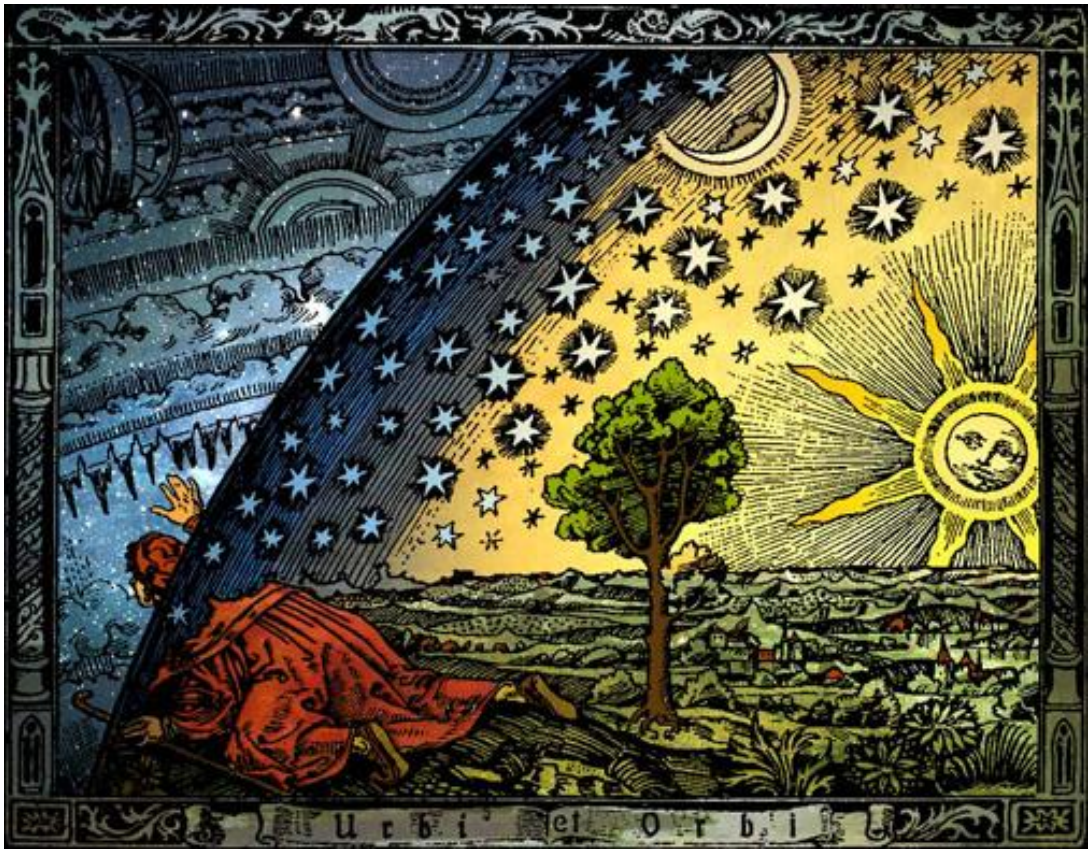
Stellar Journeys: 400 Years of Astronomical Discoveries

(An Amateur Astronomers' Anthology)



By Larry E McHenry

http://stellar-journeys.org/

Introduction:

Over the years, as part of my various astronomical visual and EAA observing projects and activities, I would spend time reading and studying the historical forefathers of today's amateur astronomers, and their solar-system and deep-sky discoveries. This 'going beyond' the catalog list of objects gave me a greater appreciation of both the object that I was trying to observe and the individual discoverer. I would then take the historical information that I learned and by adding in my personal observations, synthesize a personal perspective of their story.

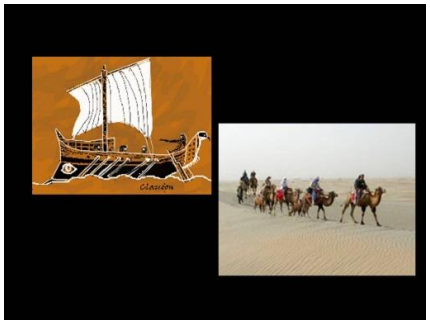
I've gathered all those various stories together below and hope you will find them as interesting to read as it was for me to write.

Contents:

Stargazing and Myths

Before we get to the astronomical discoveries from the past 400 years, I am going to introduce you to some of the ancient myths and folklore of the night-sky. Let's start off by giving you a little background about what is a 'Constellation'. Constellations are the invention of the human imagination, and are not natural. Basically, a constellation is like a 'connect-the-dots' picture, with the stars being the dots.
They are a human attempt to organize the wilderness of the Night Sky.

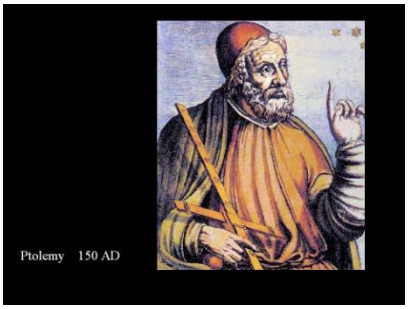
Ancient peoples had plenty of reasons for doing so: Seafarers and caravan travelers needed a way to find their destinations. Farmers and Herders needed a way to keep track of the seasons to help them figure out when to plant & harvest their crops, or move their animals from summer to winter pastures.

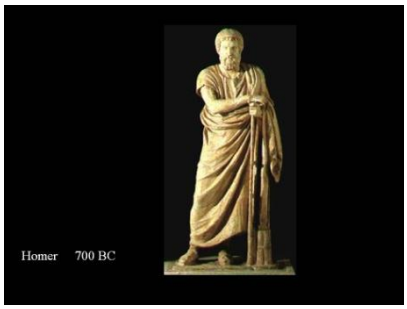


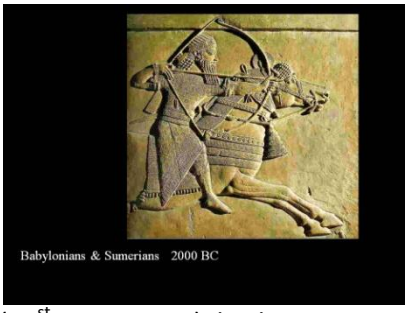
Therefore people devised 'sky pictures' or 'constellations' to help them remember these things and as an attempt to explain the natural phenomena of the night sky. The great majority of constellations have very little resemblance to the figures they're supposed to represent. They are mostly symbolic representations of the deeds, gods, sacred animals, and morality tales of the ancient peoples who invented them.

Modern astronomy currently recognizes 88 constellations that divide up the night sky.
They run thru the alphabet starting with 'A' for Andromeda thru 'V' for Vulpecula.

The constellation system we use today goes back to a list of 48 original constellations published around 150 AD in Egypt by the Greek scientist Ptolemy. Ptolemy did not invent the constellations that he listed. They are much older than his era. Some of the constellations, (the Great Bear & Orion) we can trace back to the time of Homer, around 700 BC. Others such as Taurus the Bull, we can find mentioned by the ancient Babylonians and the Sumerians around 2000 BC.

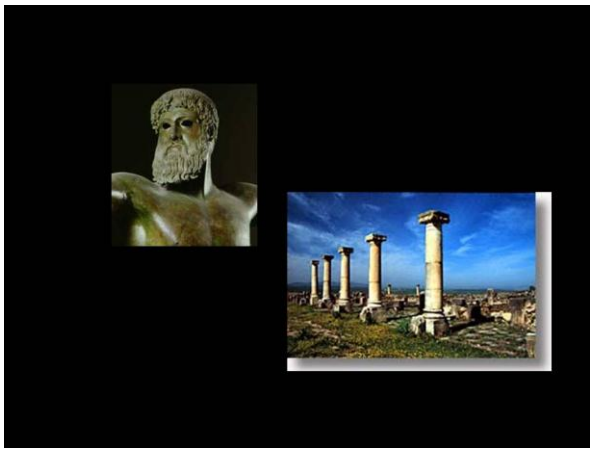
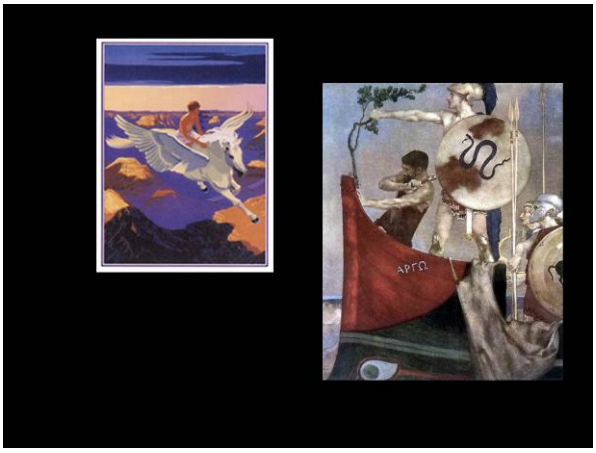




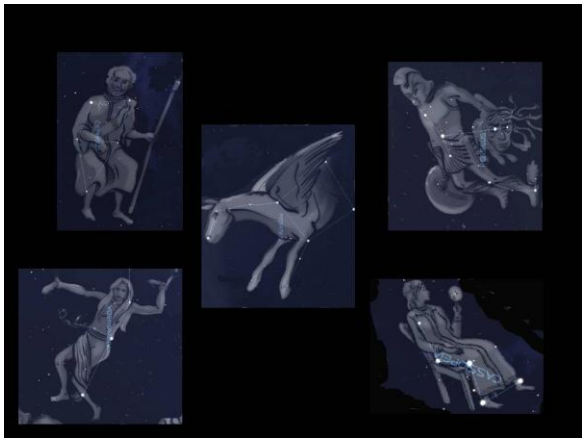


So, in a way, you can think of constellations as linking us, here in the present (21st Century AD), back in time over 4000 years to the earliest civilizations and peoples. Constellations also tell us the stories and myths of the ancient peoples who invented them.

Every Night, a parade of Greek and Roman mythology circles overhead. Perseus flies to the rescue of the princess Andromeda. Orion and his dogs are on the hunt. The ship of Jason & the Argonauts sails in search of the Golden Fleece. The Greek hero Hercules marches off to his many deeds.
Many of the great Greek and Roman heroes and their stories can be found in the night sky.

One of my favorites is that of Perseus and Andromeda! Perseus is one of the most famous Greek Heroes, and there are several myths concerning him. But the one that I am going to tell you about tonight has all of its main characters represented as constellations in the night sky.



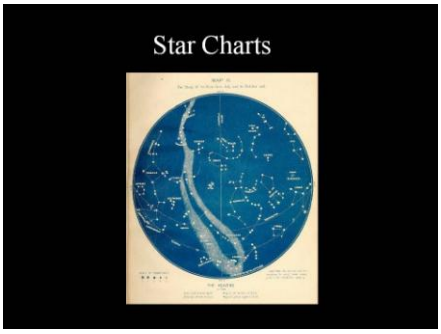
Long ago, in the ancient kingdom of Ethiopia, there lived a King and a Queen.
(King Cepheus and Queen Cassiopeia). They had a beautiful daughter named Andromeda.
Queen Cassiopeia was a very vain and boastful person, and was always getting into trouble.
One day, she went too far and dared to boast that her daughter Andromeda was more beautiful than all of the daughters of the Sea God Poseidon. The Sea God decided to punish the Queen, so he sent a sea monster

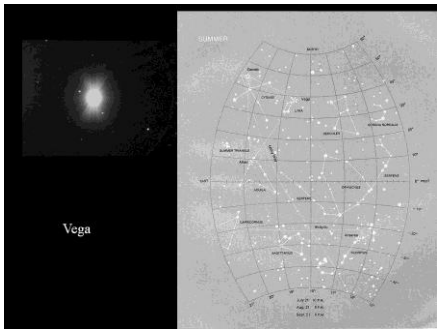
(named Cetus) to attack the coast of the King's country. The monster defeated the King's navy, sunk his ships, and destroyed his port cities. King Cepheus, not knowing what else he could do, appealed to the oracle of the gods for help. He was told that the only way to makeup for Queen Cassiopeia's insults to the Sea God's Daughters and save his people was to sacrifice his own daughter, Princess Andromeda, to the sea monster.

So Andromeda was chained to the rocks on a cliff to await the monster. About that time, the Greek hero Perseus showed up. Some say he was riding – or – flying Pegasus, the winged horse. Perseus had just gotten thru slaying another monster named Medusa, whose hair was made up of snakes, and who could turn people into stone when they looked at her. (Perseus had slain her by using a shield as a mirror, and cutting off her head with his sword). Perseus was on his way home, carrying the head of the monster in a bag.

Perseus took one look at Andromeda, and fell in love. He flew over to the King and Queen and asked to marry Andromeda. They agreed, if Perseus could save Andromeda and the kingdom from the sea monster.
When the monster Cetus appeared, Perseus swooped down on it with his sword, and began fighting it.
But he was only able to kill the monster by pulling the head of Medusa out from the bag, and turning Cetus to stone. Perseus saved Andromeda, and the King and Queen, and their country.
And they all lived happily ever after. The End.

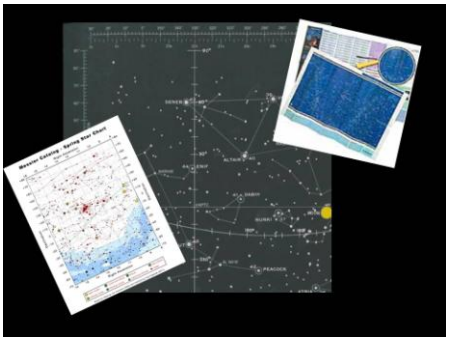
These myths are represented by some of the brighter Fall constellations. With a little practice, you can go out and locate them up in the night sky. Now that you know what Constellations are made of and what they represent, how do we go about locating them up in the night sky? By using Starcharts!





If I wanted to find out where a particular city or state was located, how would I go about doing that?
By using a road map or atlas. From the map, I would find the state, and then the city I was interested in.
Now, if I wanted to find a bright star named 'Vega', what would I do, how would I find it?
The same way that I would find a city here on the Earth. Only now, I would use a star map.
I would find that the star 'Vega' is in the constellation of 'Lyra'.

Reading and using star charts is no different than reading a road map. The symbols are a little different, but the basic concepts are the same. You figure out where you are in relation to the map. You find the object you are looking for on the map. Then you find the best way to get to that object using the map.
Like road maps, star charts can come in various sizes and the amount of detail that they can show.
They run anywhere from a few pages showing only the brightest stars to charts having hundreds of pages showing stars, galaxies, and clusters visible only with a telescope.
There's also a type of starchart called a 'Planetsphere' or 'Star Wheel' that shows the brighter stars visible above the horizon at any time of the day or year. Several examples of these are the monthly charts in 'Sky & Telescope' or 'Astronomy' magazines. So remember, one of the best tools to have in stargazing and learning the constellations is a good beginner's starchart!

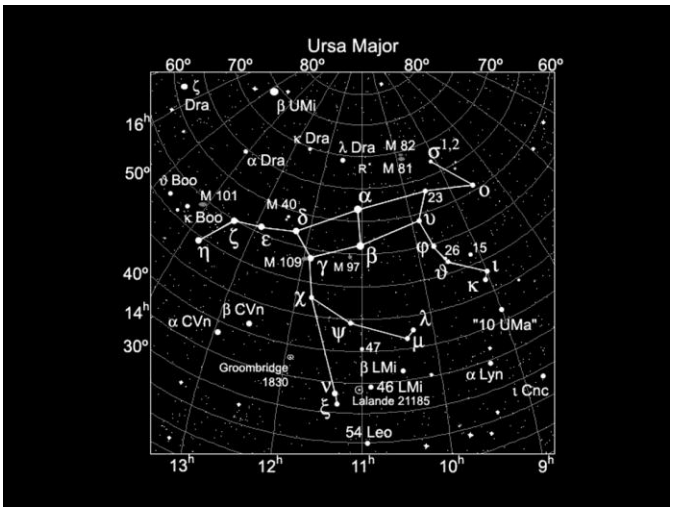


The Big Dipper!

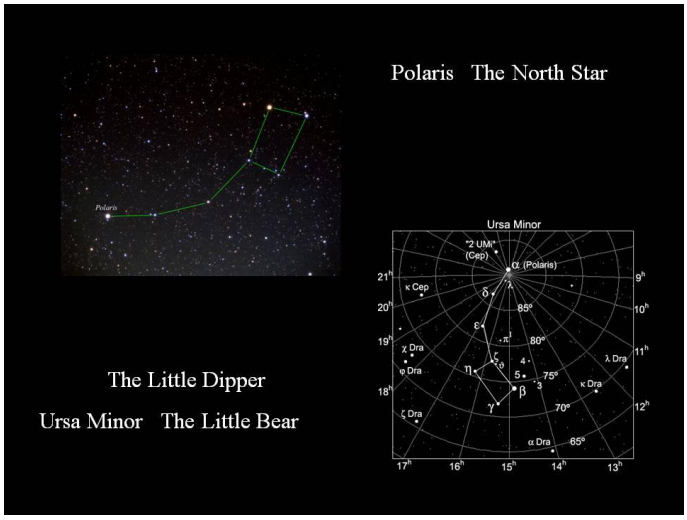
If you think of the constellations as a giant puzzle in the sky, then the 1st piece you would start with is the Big Dipper. It is the key to the puzzle. Because of its bright stars and distinctive pattern, the Big Dipper is one of the easiest constellations to find. Also, because it is located near the North Pole of the sky, it never sets, and can be found all night as it rotates around the pole. This type of constellation is called 'Circumpolar'.

The brightest stars that make up the shape of the Big Dipper are known as an 'Asterism', and are not a true constellation. There are many asterisms in the night sky, some of which you may have heard of, such as the Summer Triangle, or Northern Cross. We will talk more about those later.

The Big Dipper is part of the constellation 'Ursa Major', the Great Bear. Several ancient cultures saw the shape of a bear among these stars. However, some middle age European peoples also saw what looked like a wagon or wain, and you might see this asterism referred to as the Great Wain in old English literature.



Getting back to the puzzle, once you can find the Big Dipper, you can use it to locate other stars and nearby constellations. The first is the North Star, called 'Polaris' Polaris is the brightest star of the constellation 'Ursa Minor', or Little Bear. Because it is located at almost the exact center position of the north pole of the celestial sky, all the stars and constellations appear to rotate around it. This of course, is actually caused by the Earth rotating on its axis.



Now, the pieces of the puzzle can start to fall in place. Using the Big Dipper and Polaris, you can find the other nearby constellations. Then using these star patterns, you can star hop your way around the night sky.

Spring Constellations:

Now we are going to take a tour thru the seasons of some of my favorite, easy to find, constellations, starting with Spring. Along the way, we'll talk about some of the myths associated with the season.

Bootes: *'The Herdsman'* - from ancient Greeks. Pictured as chasing the bears away from his flock.
Star Pattern resembles a 'Kite'. Home of the bright star 'Arcturus'.

Leo: '*The Lion'* - from ancient Greeks. Represents the lion that Hercules had to fight.
Star Pattern resembles a 'Backward Question Mark'. Home of the bright star 'Regulus'

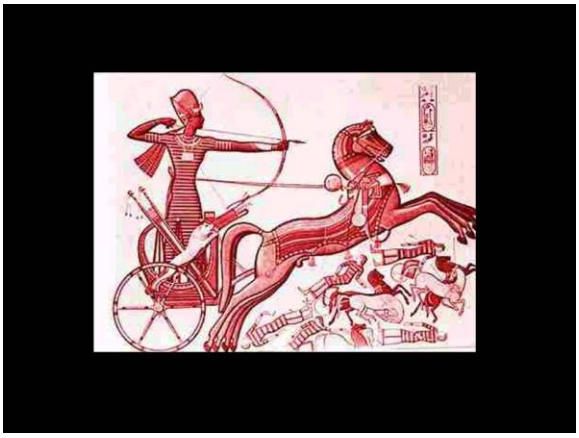
Hercules: '*The Hero'* - from ancient Greeks & Romans. Son of Zeus, known for his many 'Herculean' feats.
Star Pattern resembles a 'Keystone''.

One neat way to remember how to find the bright star Arcturus in the constellation of Bootes, and the bright star Spica, located in the constellation Virgo is the following:
"*from the handle of the Big Dipper - Arc to Arcturus, Spike to Spica*".

The Legend of Ursa Major:

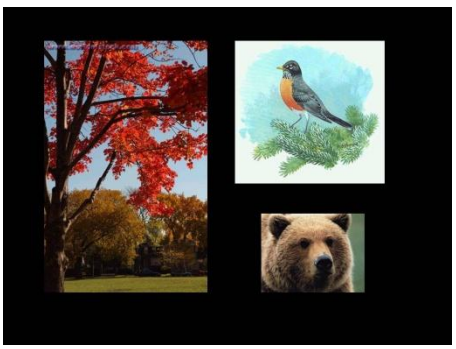
Among all the stars of the heavens, there is none so well known as this seven-starred figure. This constellation is probably the most easily recognizable star pattern in the entire sky. Almost every culture around the world throughout the ages had stories about the seven stars that we call the 'Big Dipper'.

The Sumerians thought of these stars as a ‘Celestial Wagon’ or chariot.
Across Europe, you’ll find these stars called by the old name “Charles' Wain” (wagon) and according to folktale that it was named after the great King Charlemagne. In the Northern European countries of Viking descent, it was commonly called ‘Odin's Wain’, after the Norse king of the gods.



In England and Ireland, this pattern is still commonly called ‘the Plough’ or Starry Plough referring to a farmer’s plough used to break the ground for planting crops. Today, in North America, it is universally known as the ‘Big Dipper’ because the major stars can be seen to follow the rough outline of a large ladle or dipper. This figure actually comes from Africa, where it was seen as a drinking gourd. In the pre-Civil War era, runaway slaves used the celestial ‘Drinking Gourd’ to point the way to the north and freedom.

Several Native American legends exist concerning the stars of Ursa Major as a bear. One of my favorites is from the Iroquois. The Bear is represented by the four stars of the bowl in the Big Dipper.
Bear is being hunted by three warriors named after birds, Robin, Chickadee, and Cowbird, as represented by the stars of the handle of the Big Dipper. In the early spring, Bear awakens from hibernation and leaves her Den in search of food. The Hunters spot her tracks and begin the pursuit. They stalk her all spring and summer; slowly following her northward, up into the sky country, high above the Earth.



In late autumn, the Hunters finally catch up to Bear, down near the bottom of the sky country, close to the Earth, and slay her with an arrow. Blood from Bear's wound sprinkles down on the forests of the land below and stains the leaves red. This is why tree's leaves change color in the fall. Some of the blood stains Robin's chest, and this is why these birds are red. All thru the Winter, Bear's skeleton remains in the sky low on the horizon. But, her spirit has already entered another Bear hibernating in her Den. Once again in the spring, the hunt begins anew, repeating each year for all eternity.

The Greeks also saw a shape of a bear among the stars of the Big Dipper, and another smaller bear nearby.
These bears named by the Greeks are Ursa Major and Ursa Minor.
The story of how these bears got up into the sky goes like this. Long ago, there was a beautiful daughter of the king of Arcadia named Callisto, who became the lover of the great king of the gods, Zeus.
In time, Callisto gave birth to Zeus' son Arcas. As punishment, the goddess Hera, wife of Zeus, turned Callisto into a bear and banished her to roam the wilds.

Over the years, Arcas grew into a great hunter. One day, while hunting far into the woods, he came upon an unusual bear in that it didn't turn and run from him. Seeing the bear approaching, Arcas grabbed bow to shoot it. Unknowing to him, it was his mother Callisto. To protect the son from killing his own mother, Zeus changed Arcas into a bear as well. Zeus placed both of the bears high up in the sky out of Hera's reach.
It is said that the bear's tails are longer than normal because of the fact that in order for Zeus to get them up into the sky, he grabbed them both by their tails and swung them over his head flinging them upward.
The tails stretched as the bears whirled around the great god's head.

Summer Constellations:

Lyra: '*The Lyre (or Harp)*' - from ancient Greeks. The musical instrument invented by the god Hermes
Star Pattern resembles a small 'rectangle'. Home of the bright star 'Vega'.

Scorpius: '*The Scorpion*' - from ancient Sumerians. Represents the scorpion that stung to death the great hunter Orion. Star Pattern resembles a 'Fish Hook'. Home of the bright star 'Antaries'.

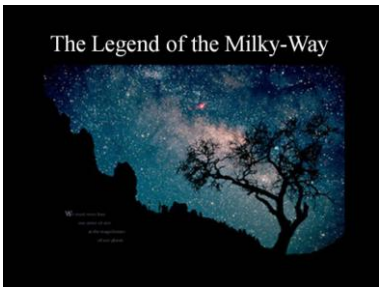
Sagittarius: '*The Archer*' - from ancient Sumerians. Represents a half man, half horse centaur.
Star Pattern resembles a 'Tea Pot'.
Home of the brightest Milky-Way star clouds and center of our galaxy.

Cygnus: '*The Swan*' - from ancient Greek. Represents the god Zeus in one of his many forms.
Star Pattern resembles a 'Cross'. (nickname is the 'Northern Cross')
Home of bright Milky-Way star clouds and the bright star 'Deneb'.

A prominent asterism of the summer sky is the 'Summer Triangle'. Three bright stars: Deneb, Vega, Altair, connects the constellations of Cygnus, Lyra, and Aquilia, and can be used as a guide in locating many nearby constellations.

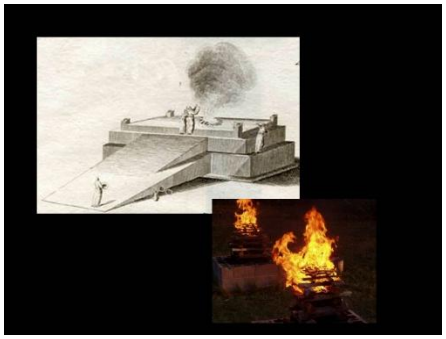
The Legend of the Milky-Way:

Living today in the 21st century's light polluted skies, we can seldom see and enjoy the beautiful splendor of the Milky Way, which can be viewed on a clear, moonless night from the countryside. The light from any nearby city will obliterate much of the faint haze like glow in the night sky that we know of today as our own home galaxy. But people living just a few hundred years ago, before the age of electricity or gas lamps had little trouble viewing the Milky Way.



Across the ages, various peoples and cultures attempted to explain what the Milky Way was.
Some thought it was a great mass of luminous vapor. Then there were those who claimed it marked the sun's path across the sky. And still others who thought it was the seam in the sky where the celestial vault didn't quite fit. Finally, there were a few who speculated that it was thousands of suns that were extremely far from the Earth and not very bright. (a pretty accurate theory!)

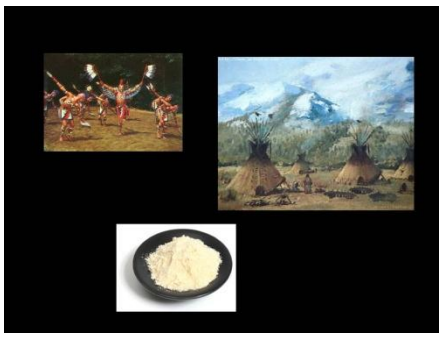
Some of the more 'non-scientific' myths of the Milky-Way:
Mesopotamian cultures thought of the Milky Way is that of smoke rising to the gods from sacrificial offerings.
The Egyptians saw it as the Great River Nile extended into heaven by the goddess Isis.
The Chinese thought of the Milky Way as the River of Heaven, where the mothers of the sun and moon bathe their children before they enter the sky.



The Norsemen saw it as the path that souls take on their way to the afterlife. A cosmic bridge linking Heaven and Earth used by the Valkries as they carried the souls of slain warriors to feast in honor in Valhalla.
They called it 'Odin's Way' or sometimes the 'Asgard Bridge'.

The Cherokee tribe saw the Milky Way as a trail of ground cornmeal scattered across the night-sky by a dog spirit that was stealing it. As the spirit was being chased away, the cornmeal spilt out of his mouth behind him, and magically rose up into the sky. The Cherokee's name for it means: 'Where the Dog Ran'.

The Navajo of the southwest desert had a similar creation story involving one of their main gods, named 'Black God' and the trickster god Coyote! On the first evening, the gods of creation met to discuss what they had made in the world that first day. Black God arrived last with a leather bag full of colorful crystals.
The other gods asked him to fill the dark sky with his crystals to make it beautiful and to provide humans with guides for living on the earth. So Black God reached into his bag and pulled out crystals of various sizes and colors. One at a time, he placed them in the sky and named them. Coyote, arriving late to the meeting, decided he too wanted to help put stars in the sky. So while Black God was busy looking up at his creations,
Coyote grabbed the bag in his mouth and ran. But his sharp teeth caused the bag to tear, spilling out thousands of tiny crystals all along the way. These tiny crystals rose up in a jumble into the sky, forming a glowing path behind Coyote, creating the Milky-Way!



Finally, classical Greek mythology describes the Milky Way in a number of colorful stories.
One story described it as mother's milk left after the infant Hercules nursed from the goddess Hera, to gain her wisdom. When Hera realized that the child was the illegitimate son of Zeus, she pushed the baby away and spilt milk across the heavens to become the 'Milky Way'

Another popular Greek explanation says the Milky Way is the burned scar across the sky formed when Phaethon, son of Apollo, tried to drive the chariot of the sun and couldn't control the horses.
The chariot weaved back and forth across the sky, sometimes coming too close to the Earth, turning the lands below into great deserts and boiling the oceans. Other times it rose too close to the dome of heaven, scorching a wide band across it. Zeus, fearing that Phaethon's uncontrolled flight would even burn up Mount Olympus, the home of the gods, took out one of his thunderbolts and zapped the chariot, killing the driver.
Apollo was able to regained control of the chariot's horses', and returns the sun chariot to its proper celestial path. Ever since, no one else other than Apollo has been allowed to ride in or drive the sun chariot!

Fall Constellations:
My four favorite are from the 'Perseus & Andromeda' myth:

Perseus: '*The Hero*' - from ancient Greek. The son of the god Zeus, slayed the monster Medusa, who turned people into stone. Star Pattern resembles the letter 'K'.

Cassiopeia: '*The Queen*' - from ancient Greek. Associated with one of the myth about Perseus.

Star Pattern resembles the letter 'W', or ‘M’.

Andromeda: '*The Princess*' - from ancient Greek. Associated with one of the myth about Perseus.
Contains the popular deep sky object M31, 'the Andromeda Galaxy'.

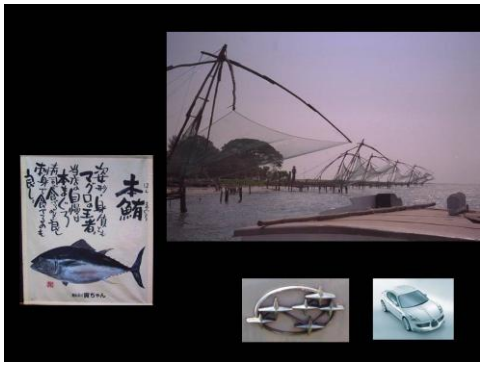
Pegasus: '*The Winged Horse*' - from ancient Greek. Associated with several myths, including Perseus.
Star Pattern resembles a square, and is often called 'the Great Square'

The Legend of the Pleiades:
Glittering like a swarm of fireflies, there is a grouping of small stars in the late fall sky that are so distinctive, that many cultures regard it as it’s own mini-constellation. The Pleiades or ‘Seven Sisters’ is actually a nearby open star cluster located within the Winter constellation of Taurus the bull.

There are ancient temples erected all over the world that are aligned with these stars. Some cultures have considered them the center of the universe or the destination of the soul when a person died.
Texts from ancient Egypt, Greece, and elsewhere link this fuzzy patch of stars to all sorts of religious matters and even more practical things such as when to plough the fields and plant crops, and when to sail on the sea.
The start of winter was marked in some cultures by the Pleiades first appearance in the evening sky.
The Celts thought this marked a period (centered on the date around November 1st) as where the boundary between the living world and that of the dead crossed. Like a doorway opening, this allowed visitors to travel to either side. In the Middle Ages, this became known as the fearsome Witch’s Sabbath, or Black Sabbath. This lead to our present day holiday of Halloween!

Within the Great Pyramid at Giza there is a tunnel directed toward the south that aligns with the meridian crossing of the Pleiades, and whose passing across that opening, at midnight, marked the beginning of the year, and renewal of the Pharaoh’s soul.
The Mayan people considered the midnight meridian crossing of the Pleiades as a very significant and dangerous time, as the world could come to an end during that crossing! In fact, their sacred history tells them that the world has already been destroyed and re-created four separate times in the past!
So to prevent this from happening, they held many great religious ceremonies involving numerous human sacrifices to appease the gods.

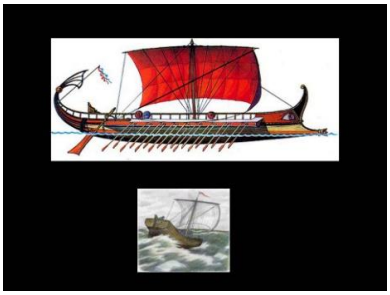
Other cultures had a more practical use for watching the celestial movements of the Pleiades.
Japanese fishermen, who called the star cluster ‘Subaru’, saw a kind of fish net made of stones and bamboo.
They used rising and setting of the bright "net" to determine when to cast their own nets into the sea.
They liked the name so much; they named a car after it!



Common European names for the Pleiades:
The Finns called it the ‘net. The Swedes had a name that translates as ‘Fur in Frost’.
The Welsh referred to it as the ‘Dog Pack’. In Germany, they were called ‘Hen and her Chicks’.
The Danes called it the ‘Eve Hen. Russian farmers named it the ‘Sitting Hen’.

The Pawnee tell a story that the stars that make up the Pleiades are six brothers who saved their little sister from an evil rolling skull. The Cherokee tell about seven boys who so loved to play a game called ‘chunky’ (involving rolling a stone with a stick), that they became so light headed from playing the game that they floated up into the sky country. The Cheyenne (have a legend that connects the Pleiades and the eroded volcanic mountain core in Wyoming called “Devil’s Tower”.
(if you ever watched ‘Close Encounters’, that’s the mountain).
According to legend, the Great Spirit raised up the mountain to protect seven Indian maidens who were being pursued by giant bears. But the bears were so persistent that the Great Spirit had to place the maidens up into the sky country to finally save them.
The marks of the giant bear’s claws can still be seen to this day on the sides of the mountain!

The Greeks referred to the Pleiades as the ‘Sailing Ones’, as they were visible all night during the sailing season. When the Pleiades disappeared from the sky, the Greeks knew it was time to beach their ships in preparation for the storm season.



In Greek mythology, the Pleiades are the seven daughters of the sea nymph Pleione, the ‘Queen of Sailing’, and the giant Atlas, who was condemned by Zeus to hold the weight of the world on his shoulders.

All seven sisters are named and each has their own stories:

- Alcyone - *`queen who wards off evil storms'*, is the brightest star of the cluster.
- Asterope - *`starry, twinkling',* one of the lovers of Zeus.
- Celæno - ‘swarthy'
- Electra - *`brightly shining'*, mother of the first king of Troy.
- Merope - *`eloquent'*, only Pleiad to marry a mortal.
- Taygete - `long-necked', mother of the founder of Sparta.
- Maia - *‘most beautiful’,* the eldest of the sisters, mother of the god Hermes.

In modern times, two fainter members of the star cluster have been given the names of Atlas & Pleione to honor their parents.

Only six stars are easily visible within the star group.
The seventh is considered the 'Lost Pleiad'. This sister is said to be Electra, who veiled her face at the sack & burning of Troy, (the great city, founded by her son)

Short version of how the Pleiades were placed up in the sky goes like this:
One day as the sisters were traveling in the countryside, they were chased by Orion, who had fallen in love with them at first sight. In their fright they prayed to Zeus to save them. In pity he turned the sisters into doves that flew up into the sky. But Orion didn't still didn't give up following them
So Zeus had to change them into stars and place them high up in the night sky where Orion could see them, but never catch them.

Winter Constellations:

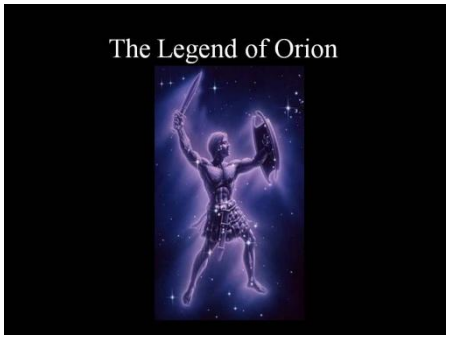
Canis Major: '*The Great Dog*' - from ancient Greek. Orion's hunting dog..
Star Pattern resembles a dog.
Home of the brightest star visible in the northern hemisphere – Sirius, 'the Dog Star'.

Taurus: '*The Bull*' - from ancient Sumerian and Greek. Several Greek myths of Taurus as the bull of King Minos of Crete. Star Pattern forms a 'V' shape.
Home of bright star Aldebaran. Contains the popular deep sky object 'the Pleiades'. ('Seven Sisters')

Orion: '*The Hunter*' - from ancient Sumerian. Represents a great hunter or warrior.
To the Greeks, he was the son of the sea god Poseidon. Star Pattern resembles a man, with the three belt stars being easy to recognize. Home of two bright stars, Rigel and Betelgeuse. Contains the popular deep sky object M42, 'the Great Orion Nebulae'.

The Legend of Orion:

After the Big Dipper, Orion is the next most commonly recognizable constellation and is visible from every part of the globe. Almost every ancient culture associated this area of the night sky with a 'star-god' or 'great warrior'. Orion marked an important position in the skies around 4000 BC. The constellation coincided with the spring equinox and marked the first day of the year for many ancient cultures.



To the Egyptians this constellation represented the solar god Horus.
In some Mesopotamian societies, Orion was considered the king of heaven.

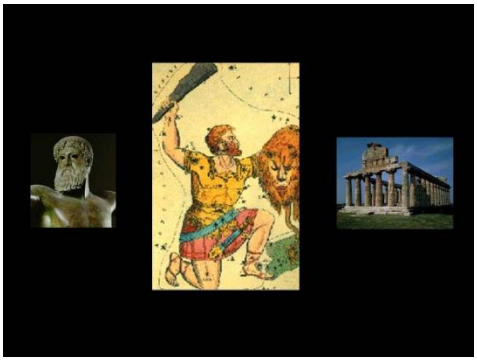
The Native American tribes of the Pacific Northwest saw in the stars of Orion a great struggle between Winter's cold and Spring's warm 'Chinook Wind' from the west. According to legend, long ago when all stars were human beings, there lived three warrior brothers, the strongest of which was named 'Chinook Wind'. During the summer, the three brothers left for a faraway journey. They were gone all summer and fall.
Late in the fall, Winter arrived from the east, and began stealing food from the brother's tribe, causing much hardship. Finally, in early spring, the three warrior brothers returned and 'Chinook Wind' began fighting with Winter, and eventually forces Winter to leave. Food once again becomes plentiful for the tribe.
To this day, every spring, Chinook Wind returns and drives off Winter. You can tell that the time is near for Chinook Wind's return when you can see him and his two brothers paddling their canoe up the celestial river.
(the stars of Orion's belt and sword!)

The ancient Sumerians saw in these stars their great hero Gilgamesh. Dating to over 4000 years ago, the epic of Gilgamesh is probably the most complete legend connected with this constellation. In the epic, Gilgamesh was noted for being a strong warrior, a great leader, and a lover of the goddess Ishtar. He slayed many monsters and went on great journeys.

The ancient Greeks named this grouping of stars after their hero Orion, where we get our classical representation of the great hunter kneeling with his raised arm holding a club, and a shield made from lion skin in his hand.

According to Greek mythology, Orion was born to a poor shepherd whose wife had died childless.
You might wonder how a man could have a child without a wife! The answer of course is the gods!
One evening the king of the gods Zeus, along with his brother Poseidon and Hermes, were traveling thru the countryside. It was getting late, and they were far from any town, so they disguised themselves and stopped for the night at a shepherd's house. Not realizing the identity of his guests, the old shepherd offered what he had, made them comfortable, and sacrificed and cooked his last cow for their dinner.

The gods, were greatly impressed by the old man's hospitality. Making polite conversation, they asked the man what one thing in the world that he wanted the most. The old shepherd replied that he wished he could have had a son. Then Zeus, Poseidon, and Hermes revealed their true selves and promised to fulfill the shepherd's wish. The gods gather around the hide of the cow that they had just eaten, performed a mystical ceremony, and bundled up the cow skin. A few months' later Orion was born! As Orion grew he became a great hunter. During his youth, he fell in love with the seven sisters of the Pleiades, pursuing them such that Zeus had to place them up in the sky out of reach of Orion's unwanted affections!



After Orion got over his love for the Pleiades, he went on to perform many deeds and feats. Thru his love of hunting, he eventually met Artemis, goddess of the hunt. They both fell in love. The god Apollo, (brother of Artemis), became jealous of Orion and killed him with a scorpion. In her sorrow Artemis begged Zeus to place Orion up in the sky among the most brilliant stars, where he could remain for all eternity with his hunting dog Canis Major, facing the snorting charge of Taurus the bull. Afterwards, Apollo insisted that the scorpion also be placed in the sky to commemorate the great hunter's downfall.
Zeus agreed, but placed the scorpion on the opposite side of the sky so as one rises, the other always sets.

Conclusion:

These myths that I've shared with you tonight are represented by some of the brighter stars and constellations. Using star charts, you can go out and locate them up in the night sky. While you're stargazing at them, think about the myths and stories behind them, and that for thousands of years, people just like ourselves have been gazing and wondering about those very same stars, and sharing the stories and myths handed down to us from our ancestors. This concludes my introduction to Star-Myths.

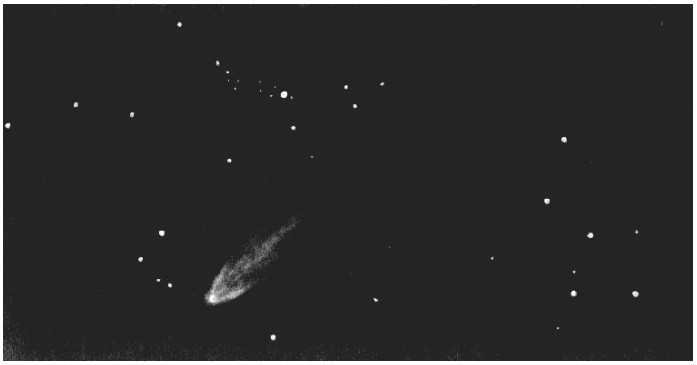
Moon Myths:

In many northern European cultures, the "Man in the Moon" was said to be a giant banished to the moon for stealing from his neighbors. But the giant would get even by pouring water down on the Earth to create floods and high tides.

Many other cultures associated a Goddess with the Moon. In China, the "Rabbit in the Moon" is said to be the companion of the moon goddess Chang'e. The Incas called their Moon goddess 'Quilla', (Kil-ya) who would cry tears of silver. They believed that lunar eclipses were caused by a serpent attacking the moon goddess and the Incas would try to scare away the serpent by making loud noises.

The ancient Greeks saw in the moon their goddess Selene, who drives a silver chariot pulled by two snow-white horses across the sky each night.

Comet Tales: The Mythology and Science of Comets (And How to Observe Them)



(LM sketch– Comet Hale-Bopp, 1997 - naked-eye)

Comets,,,,,, when I hear that phrase, I think of a type of Solar System object that's always challenging, but also interesting and fun to observe or image.

They also bring to mind their descriptions: Ephemeral ghosts, luminescent fuzzy stars with tails, unpredictable transient phenomena up in the night sky, delighting amateur astronomers using just their eyes, binoculars, or any type of telescope. They run from large, bright, easily located, showing great detail to small and faint, challenging to find. Leftover remnants, giving up secrets of the formation of our Solar System.

So today, I would like to bring these ethereal objects 'down to Earth' by discussing the ancient beliefs behind them, what they truly are both historical and modern, and how to go about observing them.
Hopefully, when we are done, some of the mystery around these objects will have been lifted, and you will find Comets as interesting to hunt as I do.

Discussion outline:

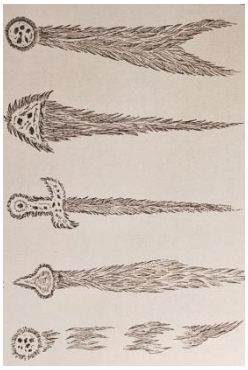
- Mythology:
- Science:
  - *Historical*
  - *Modern*
- How to Observe Them:
- When will the next Comet be Visible?
- Conclusion

Mythology:

Comets have fascinated humanity since before recorded history. From ancient texts in China going back 4,000 years, to Babylonian cuneiform records to more recent writings of the classical Greeks and Romans, it is known that comet appearances have been noticed and recorded by people for millennia. Comet symbols can be found in ancient Egyptian artwork, rock carvings in the American Southwest, and on Aztec buildings in central Mexico. But without the scientific understanding of what they are, ancient people often turned to myth and legend to explain them.

Only in the past few centuries have Comets been seriously studied as astronomical objects. Before modern times, comets were often considered to be bad omens, an ethereal weapon or message from the gods foretelling disaster, impending doom, and death to King and country. A bright comet in the sky was a sign that the Day of Judgment was at hand. That comet-related disasters would soon occur such as earthquakes, famine, floods, hail storms, drought, poor harvests, epidemics, and war. People in medieval times thought that comets were evil stars, and were so in fear of comets that they would wear charms to protect themselves from the evils that comets would bring. (the word 'disaster comes from '*dis*' meaning evil, and '*aster*', meaning star).

In his book 'Theatrum Cometrium', published in 1668, Polish Theologian Stanislaus Lubeinski, the author states: "Never had there been a disaster without a comet or a comet without a disaster."
Even in relatively recent modern times, the fear of toxic gases in the 1910 return of Halley's Comet caused panicked buying of gas masks and quack "anti-comet pills" and "anti-comet umbrellas" by the public.



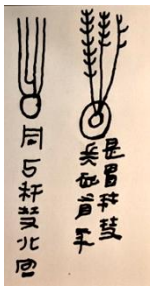
Why were ancient people so afraid of comets? Our ancestors closely followed the slow cycles of the sky as their lives depended on it to tell them when to plant crops and when to harvest them, or when it was safe to sail the sea. The stars and planets, Sun and Moon moved thru the sky in an orderly, predictable fashion. Comets didn't!

Comets would chaotically appear suddenly, some with large diffuse tails that to the overly imaginative looked like a giant dagger or sword shaped object hanging over their heads, ready to fall on them. The people felt they must have done something wrong to so displease the gods, so comets gave them a sense of impending doom.

Some of the beliefs and the historical impact of comets include:
Comets and meteors were of great importance to the Aztecs of central Mexico. Meteors were viewed as arrows of stellar gods. The arrows could hit people and were feared when walking at night. Comets were viewed as smoking stars and as bad omens, announcing the death of a ruler. A bright comet seen by the last Aztec ruler – Montezuma was said to foretell his downfall to the Spanish conquerors.

In North America around the Great Lakes region, the native Chippewa's creation myth involves a comet called "*Genondahwayanung*", (Long Tailed Heavenly Climbing Star) that flew low over the Earth, and as it went over, its long, wide tail burned-up all the land and creatures. Only the people who the Great Spirit told to take reeds to breathe thru and hide in a swamp survived the scorching heat from the comet. Thereafter, any appearances of bright comets were regarded as a serious matter requiring the attention of the tribal medicine men.

Ancient Chinese considered comets as disastrous omens, and were seen as an imbalance in nature of yin and yang that could bring on war. So as to be forewarned, Chinese emperors employed astrologers specifically to watch for comets. One emperor, Ruizong of Tang, in 712 AD actually abdicated his throne after the appearance of a comet. Chinese records of "Broom Stars" (hui-sing) as comets were called, go all the way back to 1059 BC, with the comet of 240 BC being the earliest confirmed record of Halley's Comet.



Australian Aboriginals believed that comets, which they called "star with trails", had great significance and meaning. These events were often recorded in oral tradition, but some comet inspired art has been found in rock carvings near Sydney. The appearance of a bright comet often triggered great dread among aboriginals and were associated with omens of sickness and death. Some tribes saw comets as evil spirits that drank the rain-clouds causing drought on the land below. Others thought they were spears of a celestial being named *Wurluru* who lived in the sky and would occasionally threw spears across the heavens. To drive away the comet, medicine men would throw magical stones at the comet until it faded from view.

The Greeks and Romans believed that the appearance of comets were omens from the gods. They were signs foretelling that something had happened or was about to happen, (usually something bad). In Homer's "*the Iliad*", the Greek hero Achilles said of comets: "*their flaming hair shakes down disease, pestilence, and war*".
The arrival of a comet could herald the birth of a great figure, or more likely his death or defeat in war, and conquest of a country.

For example, in Rome, soon after Julius Caesar was killed in the Senate that spring of 44 BC, a comet appeared in the skies during the funerary games held for Caesar that became so bright it was visible during the daytime. Caesar's adopted son Octavian, (soon to be the Emperor Augustus), persuaded the roman citizens that the comet's appearance was a portent of his father's deification by the gods. Once he was made emperor, Augustus had new silver coins made celebrating the comet and the deification of his father. It helped in ruling the Roman Empire to remind the people that you were the son of a god.

In another example, the Roman historians in their writing mention celestial "comet stars" occurring as among the portents witnessed after the death of the Egyptian queen Cleopatra and Egypt being fully conquered by Rome.

Comets also played a prominent role in English history. During 1066 AD, a bright comet that was seen in England was considered as a bad omen for Saxon King Harold II, and later that year he died at the Battle of Hastings, defeated by William the Conqueror during the Norman invasion. The comet, (now known as Halley's Comet), is represented as a terrifying omen on the Bayeux Tapestry and described as a star appearing to be four times the size of Venus, trailing long flaming hair, and shining brighter than the 1st Quarter Moon.

Halley's Comet is associated with a number of other historical impacts. In the year 66 AD, the comet's return was described by Jewish historians of the time as the "Sword of God", and was associated with the destruction of Jerusalem by the Romans. Another return of Halley's Comet was in 451 AD and was brightly seen at the Battle of Chalons, where Attila the Hun was finally defeated. In 684 AD, the comet was seen during an outbreak of the plague and was blamed as the cause of the sickness. And in 1456 AD, the comet was see just after the fall of Constantinople to the Turks, and was so feared that Pope Calixtrus III offered special prayers for deliverance "from the Devil, the Turk, and the Comet".

In addition to comets being blamed for crop failures, they also were thought to impact farm animals causing birth defects or death. There are several reports in Europe during bright comets in 1665 and 1680 that hens eggs were discolored by the comets passing and some hens in Warsaw and Rome had laid eggs of unusual size with flaming swords or stars on the shells. No one would eat or cook with these eggs. Around the same time, there were claims that a sneezing sickness in the cats of Westphalia was caused by an overhead comet. And some livestock were born with too many legs or heads.

Science:

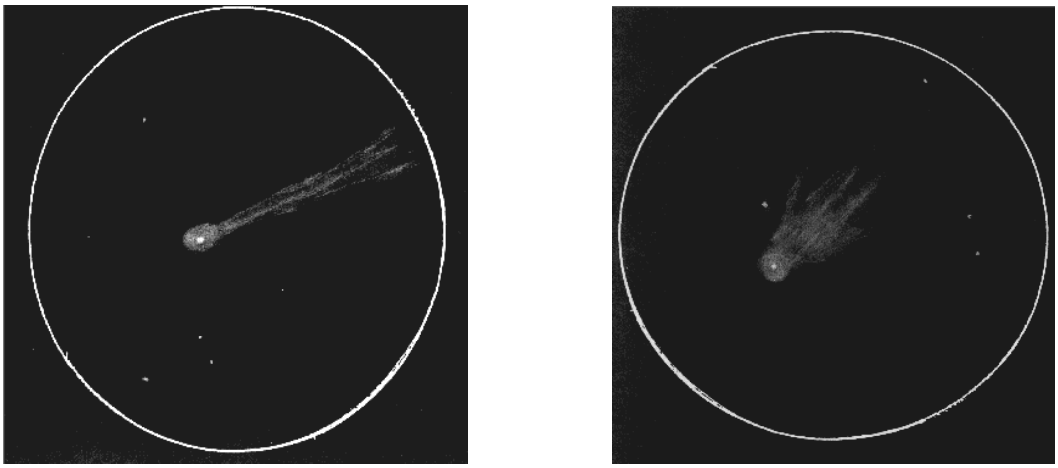
Historical:

Comets have been observed and recorded since ancient times by many cultures. Ancient philosopher's ideas as to what comets were fell into two main camps. Some ancient Greek philosopher's such as Anaxagoras believed comets to be celestial bodies, created by the conjunctions of planets, while others thought that they were meteorological in nature and occurred high in the atmosphere. The Greek philosopher Aristotle propounded the idea that comets were not the same as planets, which as heavenly bodies were pure and unchanging, but instead were phenomena of the Earth's upper atmosphere, and were hot, dry exhalations or pockets of gas gathered together that occasionally would burst into flame. Aristotle's 'view' of comets would unfortunately hold sway in

Greek, Roman, and then Western European thought for nearly two thousand years, holding back the study of comets until the mid 1500's.

The first modern attempt to understand comets came in 1577 with the appearance of a bright comet visible over Europe. Astronomer Tycho Brahe, using parallax and taking very precise measurements of the comets path, calculated the distance to this comet proving that comets were located far out in space, much more distant than the Moon, and not within the Earth's atmosphere or in orbit around the Earth.

A pivotal point in our understanding of comets and their orbits came in 1705 when English astronomer Edmond Halley, using the recently formulated laws of gravity and motion by Isaac Newton, along with twenty years of researching thru old records and manuscripts, calculated that a bright comet last seen in 1682 had the same elliptical orbital characteristics as several other prior comets and determined that all the comet appearances every 76 years were from the same comet making multiple returns in its orbit. Halley went on to calculate its future orbit and predicted the comet's return in 1759. After the comet returned as predicted, it became known as "Halley's Comet".

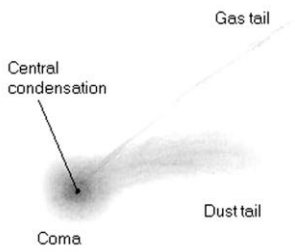


(LM sketch– Comet Halley, 1986 – 10" f5.6 reflector)

Since the confirmation of the periodicity of Halley's Comet, other historical periodic comets have been discovered through the use of telescopic observations and researching of archives, and their orbits mathematically calculated. The second comet found to have a periodic orbit observed in the past was "Encke's Comet" in 1821, just in time for a successfully predicted return in 1822. By 1900, seventeen comets had been observed through more than one return and recognized as being periodic comets. Currently, there are over 300 comets having been identified as being past historically observed periodic comets. (As of July 2019, based on modern spacecraft and automated surveys, there have now been over 6,619 known comets discovered, and constantly increasing every year. Even this is only a tiny fraction of the estimated potential of one trillion comet-like bodies in the Oort cloud reservoir of the outer Solar System)

Modern:

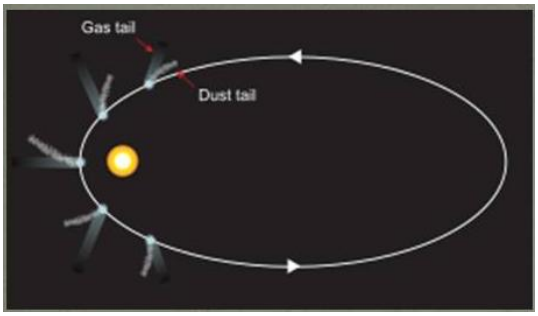
Thanks to modern science, we now know today that a comet is a small, icy member of our solar system, that when their orbits take them close to the Sun, warms up and releases gases and dust from the comet's core or "nucleus". This produces the visible head of the comet, called a "coma" and sometimes also a "tail" of gas & dust that extends from the comet.



A comet's nucleus generally runs in size from several thousand feet to several hundred miles in diameter, and is made-up of a collection of ice, dust, rocky material, and frozen gases such as carbon dioxide, carbon monoxide and hydrogen cyanide under a surface crust several feet thick. (Known as a "dirty snowball" , or if they have a higher dust content -"icy dirtballs", and have also been suggested to being like “deep fried ice-cream”)
Modern research indicates that large comets with a diameter of 30 miles and greater could contain liquid water at their cores. Because comet nuclei are not solid objects, they generally do not have enough gravity mass to become spherical, so many are irregular shaped. It been theorized that much of the water in the Earth’ oceans may have come from comet impacts bombarding the young Earth around 4 billion years ago.
With the detection of organic molecules and amino acids in comets, scientists have also speculated that comets may have brought the precursors or building-blocks of life to the Earth. Even in modern times, comets can still potentially hit the Earth. After years of research, it has been mostly determined that the June 1908 ‘explosion’ over the dense forest of the Tunguska region in Siberia that was felt for hundreds of miles and heard half-way around the world was due to a small comet disintegrating in the Earth’s atmosphere above Tunguska.

As the comet nears the Sun to within 3 to 4 AU’s, (Astronomical Unit – 1AU = about 93 million miles, the distance of the Earth’s orbit from the Sun) , depending on what elements the ice is made of, uneven heating will sublimate the ice directly into gas that will erupt from the comets surface like a geyser, carrying away with it additional ice, dust, and pebbles. These streams of gas and dust can cause the nucleus to spin, and even split apart. This material will enclose the nucleus in a bright "coma", (or cloud), upwards to 100,000 miles or larger in diameter. The force exerted by the Sun's radiation pressure and solar wind causes the coma to take on an oval shape.

As a comet approaches the inner Solar System, the increased pressure from the solar wind coming from the Sun will blow the material in the coma outward away from the comet forming a dust, and sometimes a separate gas tail, both point away from the Sun that may extend through space for many millions of miles. The dust tail, being made of heavier materials will follow the comet’s curved orbit, while the gas or ion tail being much lighter will point directly away from the Sun in the direction the magnetic field lines of the solar wind is heading.



As the comet approaches the Sun, increasing outgassing causes the coma to expand, and the intense radiation of the sunlight ionizes the gases in the coma. Interactions with strong solar winds passing thru the ionized coma can cause “bow shocks” (similar to that of a ship’s bow wave in water), to form within the coma in front of the nucleus.

Comets usually have highly elliptical orbits, with a wide range of orbital periods ranging from a few years (Short-period: 3 to 60 years) on upwards to centuries or even longer (Long-period: >100 to 1,000’s years).
Short-period comets originate in the Kuiper Belt, a circumstellar disc in the outer Solar System, beyond the orbit of Neptune that extends to about 50 AU out from the Sun. The Kuiper Belt is estimated to be about 200 times more massive than the Asteroid Belt between Mars and Jupiter, and consists mainly of small bodies or remnants from when the Solar System formed, composed largely of frozen ices such as methane, ammonia and water.
It was the recent discovery of a number of large ice worlds such as Haumea and Makemake in the Kuiper Belt that led to Pluto being reclassified as a dwarf-planet. Astronomers estimate there are over 100,000 Kuiper Belt Objects (KBO’s) with diameters greater than 50 miles. Long-period comets originate in the Oort Cloud, a vast spherical cloud of an estimated trillion icy bodies extending from outside the Kuiper belt to around one light-year.

It is thought that the gravitational nudge of nearby passing stars occasionally sends an icy member of the Oort Cloud inwards as a long-period comet. A few comets have what are called hyperbolic orbits (trajectories) with so steep of an angle that they make only one pass thru the inner Solar System before being slingshot around the Sun with enough speed to escape its gravitational pull and exits the entire Solar System into deep-space.

But not all short or long-period elliptical orbit comets make it safely thru the Solar System during a return. Close encounters with the gravity of the larger planets can alter the orbit of a comet, either ejecting it from the Solar System, or causing it to break apart, or impact another planet. In 1994, comet Shoemaker–Levy first broke apart into a string of smaller comets which then all crashed spectacularly into the planet Jupiter. The impact was visible as large smudges on the planet even in small amateur astronomer's telescopes.

Other comets, known as "Sun-Grazers" pass too close to the Sun, and the heat and solar wind causes them to break-up or completely evaporate. (both predicted bright Comets Atlas and Swan in the spring of 2020 fizzled-out). Eventually, over the course of many returns through the inner Solar System, a comet will eventually lose all of its internal gasses and ice and becomes a small inert object or rubble pile similar to an asteroid.

Whether a comets break-apart, or from just the more gradual decay over multiple returns, the comet's resulting debris field can sometimes result in spectacular meteor showers when the Earth later crosses the comet's orbital path. An example is the annual Perseid Meteor shower every mid-august that has been traced back to the debris from periodic comet Swift-Tuttle. Halley's Comet is tied to the annual Orionids Meteor shower in October.

In its 1986 return, Halley's Comet became the first comet to be observed and visited by an armada of five spacecraft from Europe, the Soviet Union, and Japan, (with the European Space Agency's Giotto probe and the Soviet Union's *Vega 1* and *Vega 2* flying through the comet coma, photographing the nucleus, and observing jets of evaporating material). The United States efforts were stymied by budget cuts and the Challenger Shuttle disaster, but several spacecraft (Pioneer 7, Pioneer Venus, and the International Cometary Explorer) launched on other missions were able to make scientifically useful observations of Halley's Comet. Additionally, there was a world-wide coordinated observational effort between amateur/professional Earth based astronomers to visually and photography observe the comet. Unfortunately for us, the 1986 return of Halley's Comet was the historically least favorable appearance on record for the past 2,000 years. During 1986, the comet and the Earth were on opposite sides of the Sun from each other, giving us the worst possible viewing angle for Earth based observers. Additionally, the comets brightest period for the northern hemisphere was in late March and early April with the comet visible only for brief periods at sunset close to the horizon. And finally, increased light pollution from across the globe prevented many people living in developed urban areas from even being able to see the comet, if the weather allowed it.

Halley was last observed in 2003 by the Very Large Array Telescope at Paranal, Chile. But, in just a few short years away, in December 2023, Halley's Comet is calculated to have reached the farthest point in its orbit from Sun, and will begin the long fall back into the inner Solar System. The Comet's next return is in July of 2061, where it will be better positioned, both orbital and seasonal, for observation, as this time it will be on the same side of the Sun as Earth, and fairly close, and it is expected to bright with a magnitude of around −1. Of course, who knows what light pollution will be like by then?

Since 1986, in addition to Comet Halley, 7 other comets have been visited by spacecraft. These were the Comets Borrelly, Giacobini–Zinner, Hartley 2, Grigg–Skjellerup, Tempel 1 (Deep Impact – first landing via impact), Wild 2 (Stardust – first sample return mission), and recently Comet Churyumov–Gerasimenko (Rosetta - with its soft lander Philae).

How to Observe Them:

So, what do we look for when observing a comet?
During its passage thru the inner Solar System around the Sun, a comet can display many interesting and dynamic features, including hood-shells, jets, and fountains in the nucleus, and streamers, kinks, and knots in the tail.

But not all these details will necessarily be visible when you observe, as these features can vary from night to night, and sometimes movement and changes in structure can be seen over a single evening.
But knowing beforehand what to look will help you to recognize and identify these features.

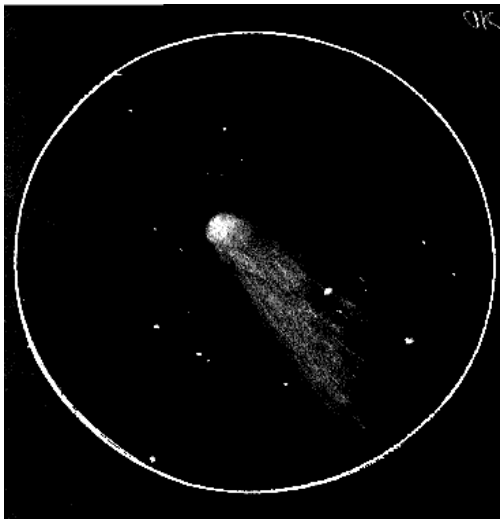
Before you begin your comet hunting, good preparation beforehand is very important, as you can waste a lot of time looking in the wrong place for a faint comet. Using a laptop or cell phone planetarium program prepare a wide field finder chart of the comet (or find and download charts from the internet.) Planetarium software can be used to zoom in/out on the fly as needed.

It is always worth the effort to find and travel to the best observing site location available that is readily accessible and has minimal light pollution. An open field with clear sightlines (no trees or buildings) in the direction of the sky where the comet will be is most desirable as comets generally tend to be low on the horizon.
If possible, plan your observing attempt when there is no bright Moon above the horizon, as it will wash-out most of the faint comet making it harder to see or image.

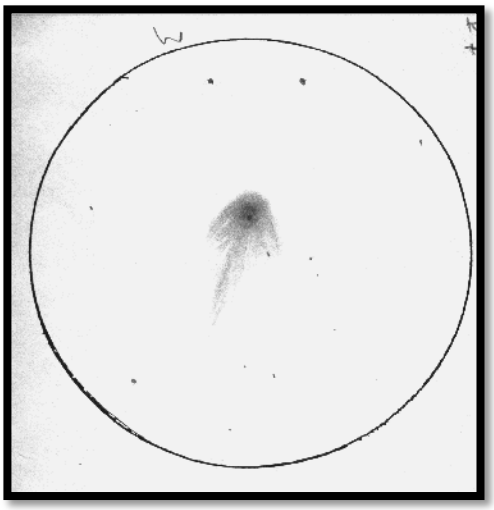
In addition to a chart showing the comets path thru the constellations and a suitable observing location, all the equipment you need to begin comet observing are your binoculars, such as a pair of handheld 7x50 or 10x50, (and larger tripod mounted 20x80 and 25x100 if you have them), or a telescope from small spotting refractors to large dobsonian reflectors with a range of eyepieces that covers low to medium to high magnifications (30mm, 16mm, 8mm, and a barlow). Additionally, if you want a visual record of your observation, you'll need a sketchpad, pencil, and red flashlight. If you wish to capture a photo, you'll need a camera, tripod, and perhaps a mount that tracks. Finally, bring along a good portable chair for taking breaks from standing.

Upon arriving at your observing location, setup your equipment and allow your eyes to dark-adapt for 20 minutes before starting your comet search. Enjoy the view of the night-sky around you. Only use your red flashlight if needed, to consult your star chart or other notes. Begin searching the sky in the general location of the comet.

So once you've located the glow of the comet with your naked-eyes or binoculars and admired the view, examine the comets diffuse coma for any bright visible details. In general, look for a star-like nucleus and specifically for bright outer hoods-shells or bow waves within the coma at the head of the comet. Within the tail, (if any), look for structure along with bright sections of the tail streaming away from the coma.



(LM sketch– Comet Bradfield, 1987 – 13" f4.5 reflector)



(LM sketch– Comet Swift-Tuttle, 1992 – 8" f4.5 reflector)

Then switch to your telescope starting with a low power eyepiece and examine the comets diffuse coma for any bright visible details that the binoculars may have missed. Take your time and look for more intricate details hidden within the coma that may not be visible at a first glance.
Specifically, try to estimate how condensed the coma is. Use the below scale in your visual description of the coma.

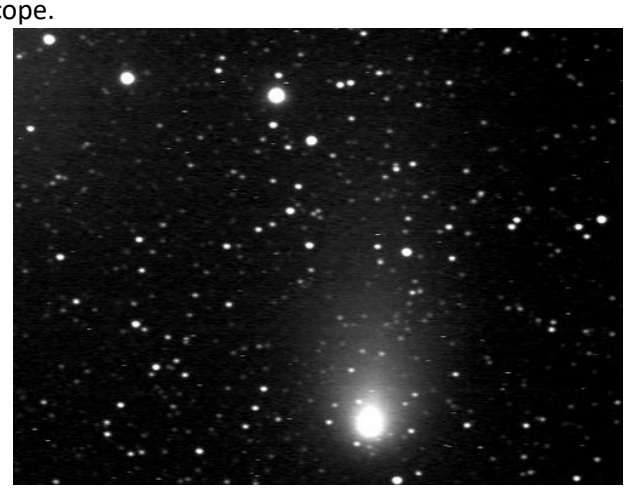
0 = Diffuse coma of uniform brightness
1 = Diffuse coma with slight brightening towards center
2 = Diffuse coma with definite brightening towards center
3 = Centre of coma much brighter than edges, though still diffuse
4 = Diffuse condensation at centre of coma
5 = Condensation appears as a diffuse spot at centre of coma – described as moderately condensed.
6 = Condensation appears as a bright diffuse spot at centre of coma
7 = Condensation appears like a star that cannot be focused – described as strongly condensed
8 = Coma virtually invisible
9 = Stellar or disk like in appearance.

Through the telescope, you may see activity within the coma such as "Jets", which can appear as a single ray or a fan of arcing rays projecting away from the central condensation either as straight lines or curved arc towards the Sun. If jets are suspected, switch to higher magnification to confirm. Long jets will show a gradual curve away from the Sun back towards the tail. Another feature to look for is "Fountains". They are diffuse features extending several degrees in angle pointing sunward and are more common than jets. Sometimes the material ejected from jets and fountains can form a series of parabolic "Hoods" or "Shells" often seen concentrically around the central condensation. Finally, look for a bright 'Spine', which is a sharp, narrow streak leading from the central coma condensation back into the tail.

The Comet's tail is generally the most distinctive feature of a comet. There are two types of tails, "Dust" and "Gas" "Dust" Tails are the most common and obviously bright type of tail for visual observers. They are made up of dust particles that reflect sunlight and curve away from the coma. Being made of heavier materials, the dust tail will flow away from behind the coma following the comet's orbital path. Dust tails can vary from faint to almost non-existent, to very bright depending on how active and dusty a comet is, its distance from the Sun at close approach, and its angle between the Earth and the Sun. Tails often appear as an off-white pastel color, or have a yellowish tinge from the reflected sunlight.

The "Gas" (sometimes called the ion or plasma) Tail being much lighter density than the dust; will point straight out from the coma, directly away from the Sun in the direction the solar wind is heading. Gas tails always display as an electric blue color. Observing gas tails requires a very transparent dark sky and are seldom seen with the naked eye so are best observed visually through binoculars or a telescope.

(LM sketch– Comet Hale-Bopp, 1997 – 80mm f3 refractor)



(LM image– Comet Giacobini-Zinner, 2018 – 8" f6.3 ACT)

Comet tails are usually uniform in brightness and structure however very active comets may exhibit what is known as 'synchronic bands'. These are bright sections of bands within the dust tail that are caused by periodic outbursts of active jets of dust from the rotating nucleus.
Tails can also be very dynamic structures and can change dramatically in a short period of time often displaying intricate detailed features such as "Kinks", "Knots", "Streamers", and "Disconnections".
Kinks are twists in the tail material that can be seen to move downwind through the tail over a period of several hours. Knots are dark patches of thicker material (gas or dust) moving downwind through the tail.
Streamers are bright but delicate thin lines, like gossamer, that radiate from the coma running straight down the tail. They can be numerous, very long and be seen superimposed on the dust tail. Disconnection Events, These are very rare to see and are caused by a change in direction of the solar wind, which temporarily severs the tail from the coma. Comet tails, like weather vanes, point in the direction that the solar wind takes them.

(LM sketch– Comet Hale-Bopp, 1997 – 80mm f3 refractor)

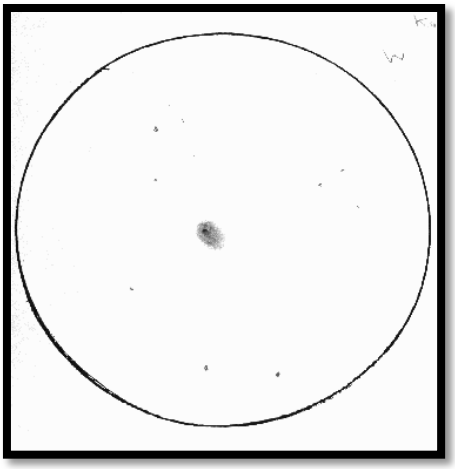
Once done with your low-power scan, then replace the low-power eyepiece with one yielding a higher power and again re-examine the comet. This will allow you to see any fine details in subtle features that may be visible in the comet's coma in and around the nucleus. Also follow the tail leading away from the coma and look for finer details along its length.

If the comet is naked-eye and has a tail, try to determine its length. Comet tail lengths are defined in degrees of arc. For a basic sky measure technique that can be used on naked eye comets, extend your arm and hand in front of you toward the comet. You can then make a rough estimate by:

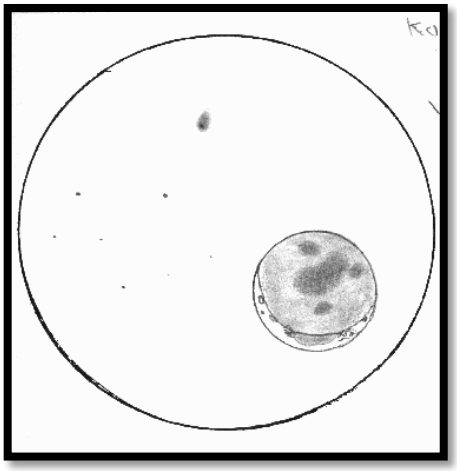
1) Tip of your little finger is about 1 degree in length.
2) Tip of your thumb is about 2 degrees long.
3) Three fingers together is about 5 degrees of length.
4) A closed fist covers about 10 degrees.
5) Your thumb and little finger on the same hand extended will cover about 20 degrees.

If using binoculars or telescope and you have a printed star atlas, you can more precisely plot the comets position and tail length using the stars on the chart. Be careful not to take too long doing this, as some comets can show rapid movement among the background stars.

Try documenting your observation by making a sketch of the comet. Drawings are a good way of training the eye to see more detail and also provide a lasting record of what you saw. It's also a good way to later share the view with family and friends. Don't forget to include information such as equipment used, and the date and time.
If you have the photographic equipment, you may also want to try and capture an image of the comet. The camera will need to expose for several seconds in order to capture the faint comet details, so you will need to use a camera tripod to hold you camera and a timed shutter release to minimize vibrations. If you are using a lens of 50mm or less, you can generally get by with a 30 second or less exposure without the stars showing trails from the Earth's rotation. Anything longer will require a polar aligned mount that will track the stars.
Many recent cell phones come with a camera 'night-mode' feature, so it never hurts to try experimenting using them for a quick comet photo.



(LM sketch– Comet Liller, 1988 – 8" f4.5 reflector)



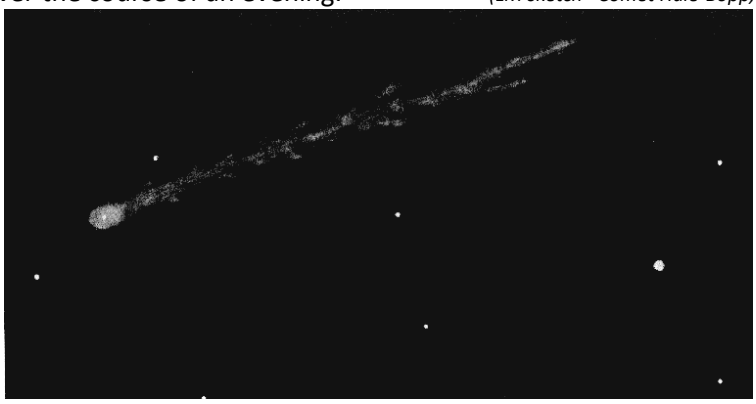
(LM sketch– Comet Okazaki-Levy-Rudenko, 1989 – 80mm f3 refractor)

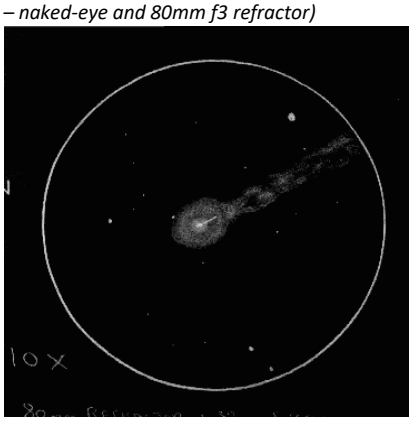
When will the Next Comet be Visible?

Generally, while up to a dozen comets may return over the course of a year, usually only one of those will become bright enough to be visible to the naked eye. Most are faint and unspectacular, requiring binoculars, telescopes, cameras, and dark country skies to be observable.

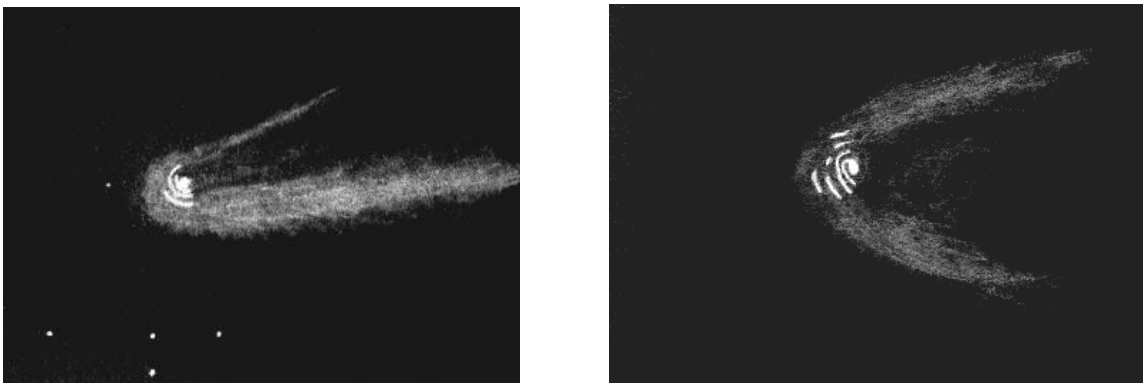
On average, a major comet arrives about every decade and becomes bright enough to be noticed by the casual observer. Particularly bright examples are called "great comets". Great comets arrive on average every 20 to 30 years. Since the year 2000, there has been one great comet, Comet McNaught in 2007, (brightest comet in over 40 years), and two major comets - Comet Lovejoy in 2011, and Comet Neowise in 2020.
But, both Comets McNaught and Lovejoy were only visible in the Southern Hemisphere. The last great comets for us here in North America was Comet Hyakutake in 1996, followed a year later by Comet Hale-Bopp in 1997. Statistically, in the northern hemisphere, we're about due for a great comet!
But for now, we'll have to get by on the memories of our last two great comets and one major comet:

The first great comet was Comet Hyakutake in the spring of 1996, which displayed an extremely long tail of ghostly pale light that extended over half the night sky. The beautiful unexpected splendor of Comet Hyakutake was a treat for the naked-eye, especially in a dark country sky. Telescopically observing Comet Hyakutake's bright coma using high magnifications observers were able to see dynamic displays of Sunward jets and a tailward spine that changed over the course of an evening. *(LM sketch– Comet Hale-Bopp, 1996 – naked-eye and 80mm f3 refractor)*





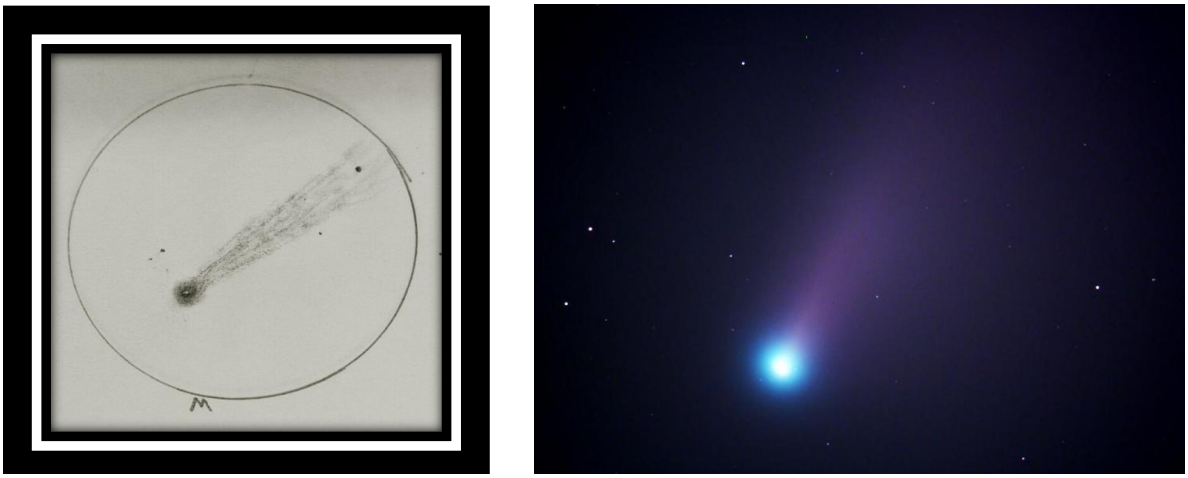
The next great comet was bright Comet Hale-Bopp, arriving a year later in 1997, and remained visible for months before and after its return. Observers using small telescopes were able to see great details in the comets coma, including jets ejecting dust and gas from the nucleus, and multiple parabolic hoods or shells surrounding the inner coma. Both the dust and gas tails were visible to the naked-eye.



(LM sketch– Comet Hale-Bopp, 1997 – 8" f4.5 reflector and 8" f10 SCT)

The summer of 2020 brought Comet Neowise, a major comet in the northern hemisphere.
The comet was just barely visible to the naked-eye, low in the NW sky, with a bright star-like nucleus surrounded by a bright coma. Observers were able to trace the comet tail for several 10's of degrees. A tailward spine and hints of streamers were visible in the tail. The view greatly benefited from a dark-sky and no nearby streetlights.

(LM image -25mm lens f5.6)



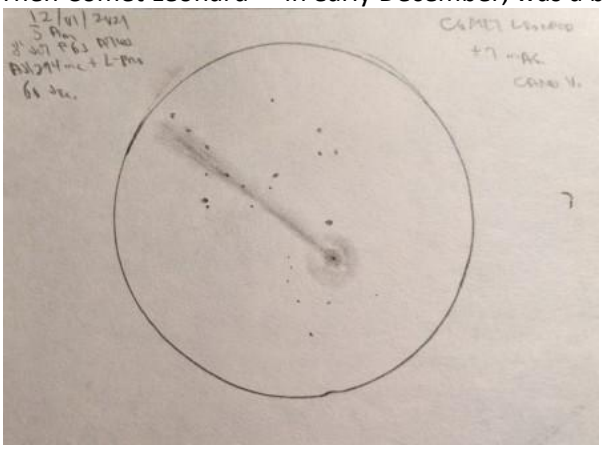
(LM sketch– Comet Neowise, 1220 – 10" f4.5 reflector and image - 8" f6.3 SCT)

Late fall of 2021, (November & December), brought us two nice comets.
First was Comet Churyumov-Gerasimenko (Rosetta mission comet) - with closest approach on November 12th, and a peak brightness of around 9th magnitude occurs in late November as the comet cruises in the evening sky thru Gemini.

Comet Churyumov-Gerasimenko

(LM image -11/30 - 8" f6.3 SCT)

Then Comet Leonard - in early December, was a bright 7th magnitude as it passed by globular cluster M3.



(LM sketch on 12/01 and image of comet & M3 on 12/03 - 8" f6.3 SCT)

And most recently, in October 2024, naked-eye Comet C/2023 A3 (Tsuchinshan-ATLAS).

(LM image -10/15 – 5mm CCTV camera lens and 10/21 - 50mm refractor)

What does the future hold?

Predicting whether a comet will become a great comet, or even visible to the naked-eye is notoriously difficult, as many factors may cause a comet's brightness to depart drastically from predictions. Over the years there have been a number of predictions that have fizzled out. (one spectacularly overhyped comet by the news media was Comet Kouhoutek in 1974, which disappointed everyone by turning out to be a dim comet).

In order for a comet to have a chance of becoming a “Great Comet”, it has to have a large, active nucleus, pass close enough to the Sun that solar radiation generates a large volume of gas and dust, (but not too close as to break-apart or evaporate), and have an orbital path that brings the comet to the same side of the Sun as the Earth so as not to be obscured by the Sun as seen from Earth when the comet is at its brightest, and it should have a higher dust content (an "icy dirtball") that will create a large, brightly visible, extended tail.

Conclusion:

Today I’ve introduced you to a special class of Solar System bodies.
We learned a little bit about the historical and modern science behind comets, their place in our mythology, and how to observe their internal features. In some ways, the more we learn about comets, the more their mysterious beauty deepens. Hopefully this little presentation has given you a taste of what comet observation is all about, and inspired you to search-out and explore these very rewarding celestial objects.

So I encourage everyone, the next time there’s a comet cruising thru the inner Solar System, to get out and try your hand at finding and observing the ghostly diffuse tails of these elusive celestial objects, the Comets!

Galileo: The First Optical Astronomer

Introduction:

A little over 410 years ago, in a time near what most historians consider to be the last days of the 'Renaissance', and just prior to start of the 'Age of Enlightenment', there was about a 150 year period, from the mid 15th to late 16th centuries, that saw a transformation of scientific ideas across the various philosophical sciences of biology, mathematics, and astronomy. This period in our history is called the 'Scientific Revolution', and came about from scholars questioning and turning away from the ancient Greek views that had dominated science for the past 1,500 years. This era was the foundation in establishing investigation and experimentation as the cornerstones of the modern sciences.

One of the major figures of that period of scientific questioning was the 16th century Italian astronomer and mathematician Galileo Galilei (1564 – 1642). Galileo straddled the old world of a natural philosopher, and mathematician, to that of the new world of modern science, and made fundamental contributions to science by his groundbreaking inventions and discoveries. He was one of the first to pioneer experimental scientific methods and in 1610 was the first astronomer to build and use a telescope and move the science of astronomy into a new age.

Through Galileo's work of studying the heavens with his new instrument, he broke new ground in our understanding of the universe, and along the way sparked a debate that challenged the ironclad rule of church doctrine over science. Today, we're going to look back on his life and accomplishments as the first optical astronomer. Along the way, we'll review Galileo's observations, along with a few of my own. *(LM)*

Discussion outline:

- **Naked-eye Astronomy before Galileo:**
- **Galileo: Childhood & Education, Professional Life, Family**
- **Invention of the Telescope:**
- **Galileo and the Telescope - 1609:**
- **Galileo's Observations and Discoveries - 1610:**
- **Revolutionary Ideas and Consequences:**
- **Galileo's Legacy & Conclusion**

Naked-eye Astronomy before Galileo:

For thousands of years, Man has studied the night sky, using just eyesight, and later a few simple measuring tools. There was the ancient Sumerians, Babylonians and Egyptians who discovered the seasonal cycles of the sky, along with determining the celestial movements of the Sun, Moon, and Planets. Then the Greek philosophers such as Aristarchus, (310-230 BC) who made the first attempt to measure the distances to the Sun and Moon, and proposed that the Earth revolved around the Sun (which even though his idea was discarded, turned out to be correct). Or Hipparchus, (~200 BC), who created the first star catalog of over 1,000 stars and developed the first model of the solar system with the Earth at the center. To Ptolemy, (~150 AD), who extended Hipparchus's star catalog and perfected the Earth centered 'geocentric' model of the universe (known as the Ptolemaic System) that lasted for over the next 1,400 years as accepted fact. (Until Copernicus published his Sun centered model in 1543).

Then more advanced visual observers such as Tycho Brahe, (1546 – 1601 AD), who built an observatory around large-scale, finely calibrated meridian transit circles to create the most accurate star positional catalog and measurements of planetary movement made by the naked-eye. This data was later used by Johannes Kepler in devising his three Laws of Planetary motion, along with proving that the Copernican (Sun-centric) System was correct.

Galileo Galilei:

Childhood & Education:

Galileo was born in Pisa, in the Duchy of Tuscany, in northwest Italy on February 15th, 1564. His father, Vincenzio, was a musician, composer, and scholar who studied ancient Greek music and stage drama, and was an early pioneer of Italian opera. Vincenzio also is known for his study of musical pitch and string tension and developed a mathematical theory of acoustics. He taught Galileo how to play the lute as a boy, and it is said that Galileo learned the importance of experimentation from his father. Galileo's mother, Giulia, was from an upper class family and she worked in the local silk trade. Galileo received his initial schooling from a private tutor, but at the age of 13 he was sent off for school to the Benedictine abbey of Vallombrosa near Florence. There he studied the usual subjects expected of a gentleman, including Greek, Latin, and the Arts, and developed a skill in drawing which was later useful in his astronomical work. After completing his school at the abbey in 1578, Galileo at first studied for the priesthood, but his father dissuaded him, so in 1580, he decided to go to the University of Pisa to study medicine. Within a few years, after becoming interested in the sweep motions of pendulums, he switched over to study mathematics and natural philosophy, graduating in 1586.

Professional Life:

Galileo's first job in 1588 was as an art instructor at the University of Florence. But he soon taught university level mathematics, first at Pisa in 1589, then taking a promotion in 1592 to the University of Padua, and then in 1610, after coming under the patronage of Cosimo II de' Medici the Grand Duke of Tuscany, as the court mathematician in Florence.

Family:

Seeing the financial and legal problems that his younger siblings encountered with not being able to pay their portion of marriage dowries, (and which Galileo being the eldest, became financially responsible for in 1591 when his father Vincenzo passed), Galileo never married. But he did fathered three children (two daughters, Virginia and Livia, and one son, Vincenzo Jr) out of wedlock with Marina Gamba who Galileo met in Venice and fell in-love with. But Marina was 14 years younger and of lower class than Galileo, and marrying her would negatively impact his career. So they lived separately from each other, he in his professor's house at the university, and she in a small house nearby. After Marina died in 1612, both of his daughters were sent to the convent of San Matteo, where his eldest, Virginia took the name Maria Celeste. Galileo kept and raised his son, who he eventually had his birth legitimated in 1619 by the Grand Duke of Tuscany. Maria (Virginia) was a devoted daughter to Galileo, and the two of them exchanged many letters over the years, with Galileo occasionally visiting her at the convent.

Invention of the Telescope:

The telescope traces its history back to the late 13th century in northern Italy with the invention of simple glass magnifying lenses and spectacles to improve eyesight. Convex glasses for those whose close-up vision was blurry, (farsighted), and concave for those who couldn't clearly see far-away, (nearsighted). But it wasn't until around 1575 that both concave and convex lenses started to be used together. In 1608, Dutch inventor Jan Lippershey combined both types of lenses into an instrument (that was called the "Dutch perspective glass") consisting of a convex objective lens and a concave eyepiece that gave an erect image of 3x magnification allowing its user to see objects at a distance. There are a number of stories about how Lippershey came up with his idea of combining lenses, with one of the more popular being that he overheard two children who were playing with lenses talking about how they could make a far-away church spire looked closer while holding the two lenses.

The first "Dutch glasses" generally had lenses of about 1" in diameter and stopped-down using aperture masks, mounted in a stiffened paper tube of about 1 foot in length and with a fixed focus. Word of the new invention quickly spread across Europe, with opticians and mathematicians in major cities soon creating their own versions. These experimenters included German astronomer Simon Marius, who later competed with Galileo in astronomical discoveries. The lack of good quality optical glass, difficulty in obtaining lens grinding tools and supplies, figuring out how to optically test the quality of the lenses, along with the lack of good material to use for tubing, made building these instruments challenging. These basic 'spyglasses' were costly and only used by the military which found them useful, or as expensive toys of the nobility. They were not yet true 'telescopes'.

Galileo and the Telescope - 1609:

In May of 1609, while on a trip to Venice from his University home in Padua, Galileo heard the news about the new optical instrument for seeing distant objects. He immediately realized the importance of this new invention, and on the next day upon returning home, he began his own experimenting with convex and concave lenses.
Ready-made quality lenses were hard to come-by, so Galileo acquired the necessary tools to grind and polish lenses himself. Galileo quickly grasped the optical refractive relationship between the lenses and how the focal point distance impacted the instruments power. Some sources indicate that it may have actually been Galileo who came up with the idea of using an aperture mask in front of the objective lens to stop it down to help eliminate optical edge curvature defects within the lens, giving a clearer view.

Galileo's efforts improved on the convex lens, and he was able to create his own perspective glass, with an objective of 1 5/8" in a 20" tube giving a magnification of around 8x. He returned to Venice in August where he demonstrated his instrument to the city nobility and gifted the instrument to the Doge of Venice.
(A politically and socially smart move). Galileo's main interest in making these instruments was at the time not using them for astronomy, but as a product to sale to the military and merchant shipping from which he hoped to make a small fortune from. Galileo actually did make a profit from selling spyglass telescopes to local merchants.

Having received a large stipend from the Venetian nobles, Galileo returned to Padua where during that fall of 1609, he proceeded to build larger telescopes with increasing magnifications and clarity. He finally produced his two finest instruments that became the first astronomical telescopes, which are still preserved today. The larger instrument having a 1 3/4" inch convex objective (stopped down to 15mm) with a focal length of 980mm in a 49" paper tube using a concave 'eyepiece' of 22mm, giving a magnification of 20x. The second glass having a 1 5/8" objective in a 37" long tube and gave a 14x magnification. While Galileo's improvements on the eyepiece convex

lens enabled it to reach focus with about 3" of eye-relief, they suffered from a narrow field-of-view (about 7.5' arcminutes or about ¼ the size of the Moon's disk) requiring the instrument to be mounted and not hand-held. Galileo called his new glass instruments a '*perspicillum*', which is Latin for "an instrument to look thru".

In April of 1611, at a dinner held in Rome to honor Galileo, a new name was given to Galileo's optical instrument by the Greek poet and mathematician Giovanni Demisiani. At the banquet, Galileo had brought one of his improved "Dutch glasses" to show the '*Medicean Stars* (moons)' of Jupiter. Demisiani felt that Galileo's invention needed a better name to differentiate it from the lesser glasses, so he came up with a new word - *teleskopos* – meaning 'far-seeing' based on the Greek words for 'far' (tele) and for 'to see' (skopein). Thus the modern word – "Telescope".

Galileo's Observations and Discoveries - 1610:

While it is not certain whether Galileo was actually the first person to use a telescope to observe the heavens, he was the first to document and publish the new discoveries of what he observed with it. As his skill in creating telescopes with better optics improved, he began to turn the new instruments towards the sky. By late November of 1609, Galileo had seen enough to convince him to begin a systematic research project of the heavens, starting with the Moon, using his best glass.

By January of 1610, the 45 year-old Galileo had made a number of spectacular discoveries in the night sky using his telescope. In addition to discerning surface features on the Moon, these discoveries included first three, then four new 'stars' that appeared to follow Jupiter and changed locations and alignments to one another each evening. He also resolved the glowing clouds of the Milky-Way into countless individual stars.

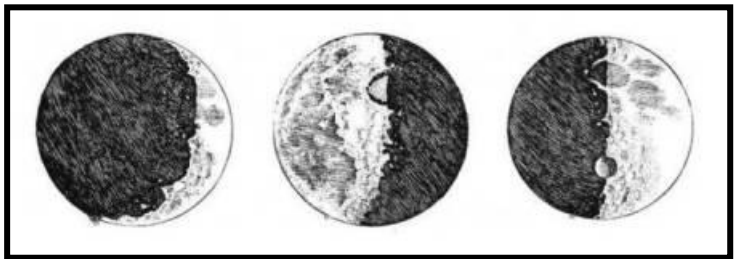
Galileo documented these discoveries and published them in a 24 page pamphlet in March 1610 titled the "*Starry Messenger*" or also called "*Sidereal Messenger*" (***Sidereus Nuncius***). This was the first scientific book based on astronomical observations made through a telescope! In some respects, the "*Starry Messenger*" really wasn't a book; it was more like an 'announcement' of newly discovered celestial phenomena that was revealed by his telescope. Galileo's style in writing it was not as dry formal textbook, but more as a conversational first-person perspective of the excitement of his discoveries.

Word of the book's contents had leaked out a few days before its release, creating a sensation, so when the book hit the streets in Venice on March 13th, the first 500 copies immediately sold out! Copies of the book were eventually sent all around Europe, but one copy was sent that very day of the 13th to the King of England by an English visitor who happened to be in Venice and hearing about the book realized its importance.

To help convince people of what he had observed, Galileo built additional telescopes as powerful as his 1 ¾" 20x instrument and sent them along with copies of his book to a number of prominent leaders who were patrons of science throughout Europe, where he knew they would be shared with various court experts that would know how to verify his results. Galileo later went on over the next several years to be the first to observe and publish additional observations on the phases of Venus, Saturn, and Sunspots which he published in 1613 in a pamphlet titled "*Letters on Sunspots*".

The Moon:

That late fall of 1609, when Galileo would complete one of his glass instruments, if the Moon was in a favorable evening position, he would point the telescope at it to try out his latest increase of magnification to see what additional details it might make visible. He was beginning to see with better clarity landscape features that encouraged him to continue building better instruments. Finally, on the night of November 30th, having completed his 1 3/4" inch objective telescope with a 22mm eyepiece giving 20x magnification, Galileo began to sketch and write down descriptions of what he observed on the Moon's surface.



(Galileo)

The first thing he noted was that the Moon did not have a smooth, celestially perfect disk as he had been taught in school. (Those with good eyesight had noticed gray patches on the Moon before, but the assumption was that these were reflections from the Earth). But now, using his improved optics, Galileo instead observed that there were mountains, valleys, and large flat plains, pockmarked with depressions (that we know today are craters).
At first Galileo wasn't sure if the 'craters' were small hills or holes. But by noting along the Moon's jagged, uneven terminator how the shadows and illumination of the crater walls and their interiors changed from where the Sun was positioned, just like watching shadows in an earthly landscape, he determined that these objects were actually holes and pits in the surface. Galileo was also able to use the same play of shadow and light to measure the angle of the mountains using simple geometry and calculate their height, finding peaks taller than any known on the Earth at that time. (His calculated results were two high, but in the ballpark). For the next month, Galileo observed the Moon for hours every clear evening, following it thru its phases and sketching what he had seen.
Taking this information, he then created rough topographical charts of the Moon. He included a number of these sketches and wash-style drawings in his book. Unfortunately, Galileo wasn't careful in accurately plotting the features as his main goal was to show that the Moon had Earth-like features. This makes his charts difficult to match with modern day photos.

(LM sketches & image – 80mm f3 Refractor)

Finally, Galileo also concurred with Kepler's belief on what was the cause of 'Earthshine' on the Moon.
The dimly illuminated areas visible on the Moon's surface right before and after its new phase are from reflected sunlight off of the Earth's oceans and clouds.

The Milky-Way:

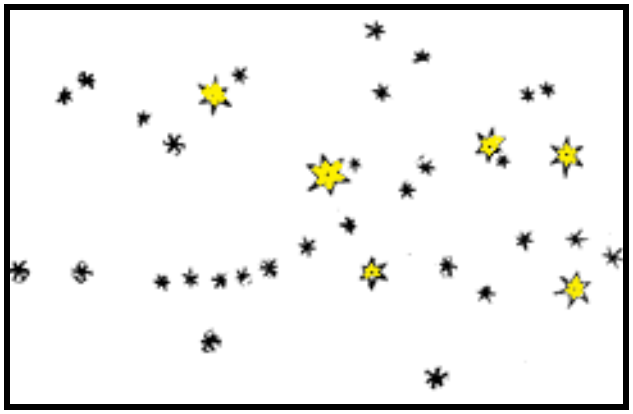
In addition to the Moon, Galileo pointed his telescope to the Milky-Way star clouds.
Throughout antiquity, people thought the Milky-Way was nebulous clouds of smoke or some other matter.
But when Galileo observed the Milky-Way, his telescope resolved the 'smoke' into a multitude of countless faint stars, so densely packed together that their combined starlight resembled glowing clouds to the naked-eye.
He found the greatest concentration of stars among the clouds in the constellations of Scorpius and Sagittarius.
In the telescope, the stars all appeared as tiny blazes of light compared to the planets which showed disks.

(LM image – fisheye lens)

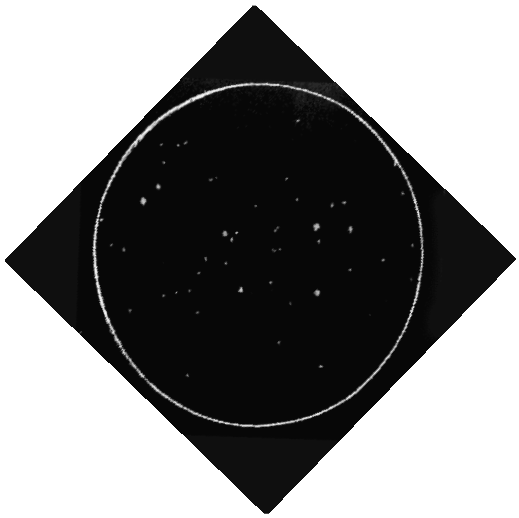
Turning to the 'Pleiades', in Taurus, Galileo found 40 more additional stars were visible other than the 6 or 7 that people had counted for centuries. Also, the Belt and Sword of Orion that normally showed only 9 stars visible to the naked-eye now showed upwards to 80 stars not visible without the telescope. (Galileo was not able to resolve the Orion Nebula, and thought he needed a bigger telescope, so he decided not to mention it)

And he viewed several of the 'nebulous clouds' mentioned in Ptolemy's catalog and was able to resolve them into swarms of tiny stars, such as the 'Praesepe Nebula', (M44), near gamma & delta Cancri in the constellation of Cancer, in which he counted 38 individual stars. He included sketches of all three of these objects in his book.
Finally, Galileo also noted that several of the known named stars that had appeared to be a single star to the naked-eye, (such as Mizar in the Great Bear) were actually revealed by his telescope to be two individual stars.

M45 – Pleiades:

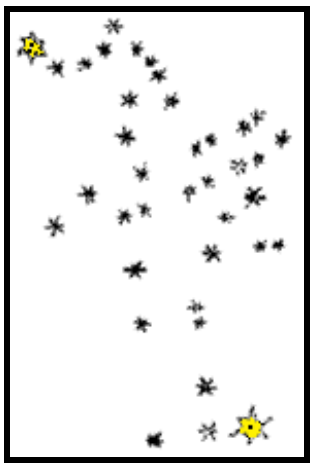


(Galileo)

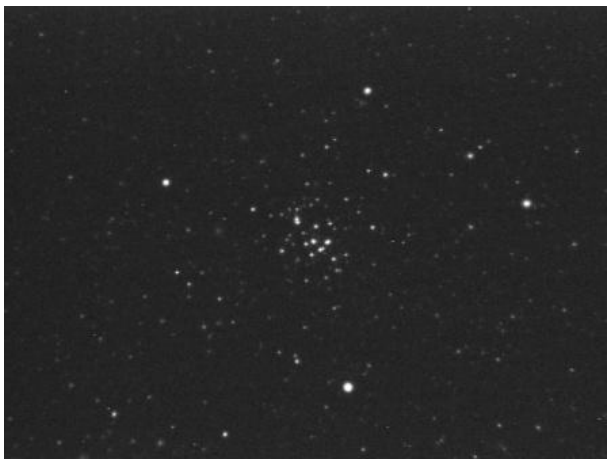


(LM sketch– 80mm f3 Refractor)

M44 – Praesepe:

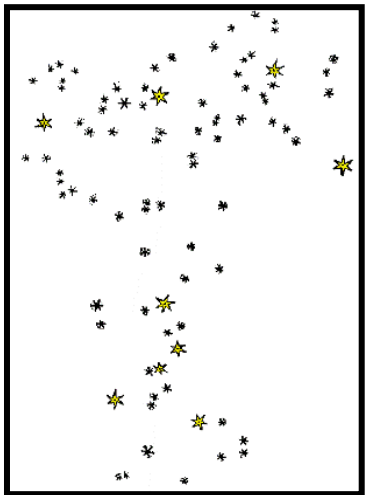


(Galileo)



(LM image – Canon 50mm lens)

Orion's Belt and Sword:



(Galileo)

(LM image – Canon 25mm lens)

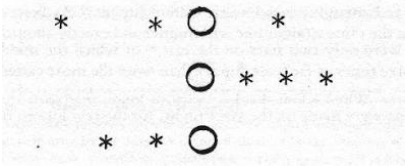
In later books, Galileo describes how he was able to measure stars by hanging a very thin string in the telescope eyepiece's line-of-sight, and using the known width of the string and the distance in which the string completely blocked the star, calculate the angle subtended by the star to give its size in arc-seconds. While Galileo's apparent sizes were greatly distorted by atmospheric diffraction, (which he was unaware of), his measurements were precise enough to add further data against the Ptolemaic System.

Jupiter & its Moons: (the Medicean Stars, later called the Galilean moons)

Having finished his observations of the Moon and the 'fixed stars', on the evening of January 7th, 1610, Galileo turned his telescope to one of the 'wondering stars', the planet Jupiter, then a brilliant object slowly gliding thru the horns of Taurus.

Immediately, Galileo noticed three small 'fixed stars', (as he called them), aligned nearly parallel with the planet, two on one side and the third on the opposite side. While these 'stars' were not visible to the naked-eye, they were very bright thru his telescope, brighter than any of the other nearby stars visible in the field. Galileo was intrigued by the view and made a descriptive note and sketch in his logbook of this observation.

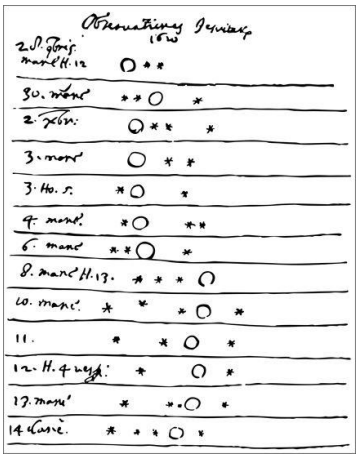
The following evening, January 8th, he pointed his telescope back to Jupiter and was surprised to find that the three 'fixed stars' from the night before were all still there near Jupiter, but now in a different formation, and had moved in the same direction of Jupiter's path thru the ecliptic, and had not fallen behind like he expected them too. When he went to view Jupiter on January 10th, (after a cloudy night on the 9th), only two of the new stars were visible, the third had disappeared. Galileo deduced that the third star must be blocked from view by Jupiter.

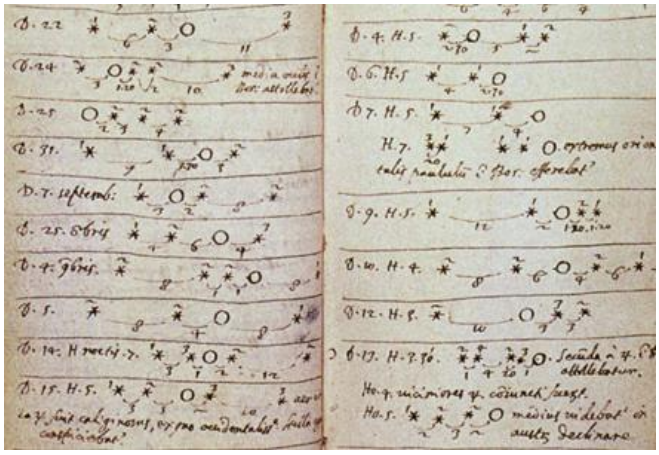


A few days later, on January 13th, he was surprised to not only find the three 'stars' that he had become accustomed to seeing, but now a fourth 'star' was visible!

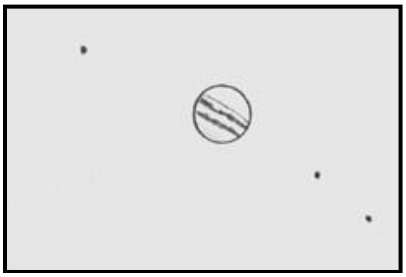
Throughout this period Galileo kept wondering what these objects were. Every night the new stars changed locations around Jupiter, sometimes leading in front of the planet, and sometimes lagging behind the planet, but always staying with the planet. As he observed these new objects over time, he realized that their slowly changing positions around Jupiter that would not be possible if they were true 'fixed stars'. Galileo finally came to the only possible conclusion, that they were new satellite 'Moons' revolving around another planet! The Earth was no longer the center of the universe. Other bodies could also be their own center with their own system of worlds in revolution around them!

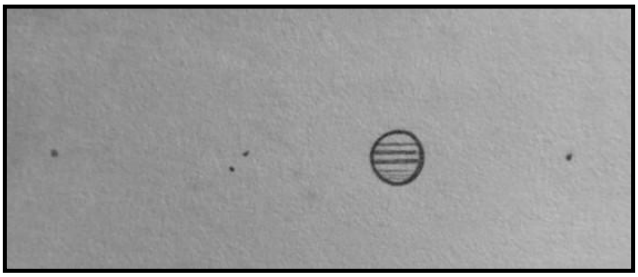
Galileo also realized the implications of his observations, and that he needed to get his book describing these new Moons into print. But, he knew that only a few days' worth of observations wouldn't be enough proof of what he was going to announce to the world. Galileo had already nearly finished writing the book's section on the Moon, and had started writing about his observations of the 'Milky Way'. But now, fearing that his discoveries might be scooped by someone else who had heard him talking about his observations, Galileo rushed thru writing the Jupiter section into the manuscript, and keeping it updated by adding in each previous night's information during the next day. He also took time to add in further details and sketches to the 'fixed stars' section.





(Galileo)





(LM sketch– 8" SCT f10)

So, for the next two months, leading right up to the last few days before publishing his observations in March, Galileo studied these four new 'Moons', and began keeping more detailed notes on their positions relative to Jupiter and one another, their movements, and brightness to each other, and including the time of night.
He even began taking multiple observations during the night, recording and sketching what he saw, and included all in his book. Today, many historians consider his observations of Jupiter's Moons to be Galileo's most important of all his discoveries and the crown jewel of the book.

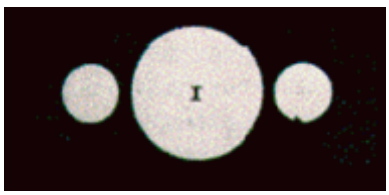
Recalling how his fortunes had increased by gifting a telescope to the Doge of Venice, Galileo shrewdly named his discovery the "Medicean Stars" in honor of Cosimo II de' Medici, the Grand Duke of Tuscany, and his brothers. (William Herschel followed Galileo's footsteps 172 years later by trying to name his new planet after King George)

But astronomers of the day soon took to calling them the "Galilean moons" for their discoverer.
Still, Galileo's play to the Grand Duke worked, and after his observations were confirmed by other astronomers, he received a hero's welcome in Rome, and secured an appointment as the Duke's court astronomer in Florence with a hefty increase in salary.

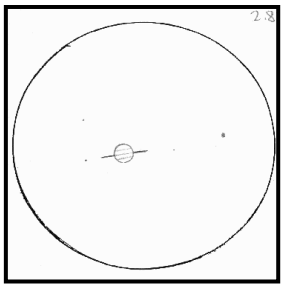
Eventually, there was some dispute as to who actually was the first to discover the moons of Jupiter.
German astronomer Simon Marius (above) published a book (*Mundus Lovialis*) in 1614 where he claimed to have independently seen the moons a day earlier than Galileo, but because Galileo was the first to publish nearly 4 years earlier and because of Galileo's more extensive descriptions; Galileo is given the principle credit for their discovery. But Marius names for the four moons, Io, Europa, Callisto, Ganymede, was eventually adopted as the official names, so he does get some credit.

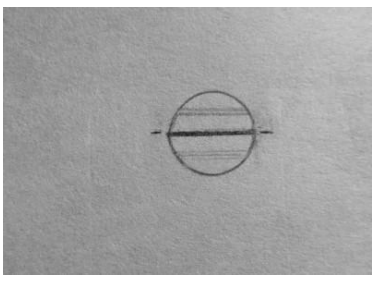
(Additional observations from 1610 in Galileo's next book "*Letters on Sunspots*", published in 1613.)

Saturn & Rings:
In July of 1610, Galileo began to observe the planet Saturn, then rising toward the meridian late evenings in the constellation of Aquarius. Turning his telescope to the bright yellow-hued star, Galileo was the first to see the planets disk. But he also noticed something strange; the planet appeared to be composed of three objects almost touching one another lined-up in parallel. Two smaller ones were on either side of the larger disk. (kind of like Mickey Mouse ears!) He thought that perhaps in this three-bodied system, the smaller two objects were moons, but unlike the Medicean Stars of Jupiter, these around Saturn did not change position over the many weeks of observations.



(Galileo)





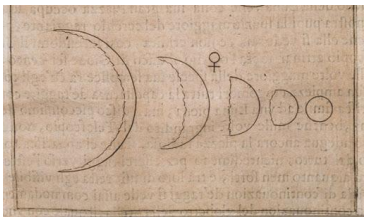
(LM sketch– 8" SCT f10)

Even using a newer telescope that gave 32x magnification, Galileo's telescopes did not have the clarity to show him that these two smaller 'objects' were actually a ring system around the central planet, with the ring nearly edge-on to the Earth, giving a narrow angle. Continuing to observe the planet over the next two years, the viewing angle got worse as Saturn's rings reached edge-on and disappeared from Galileo's limited telescopic view.

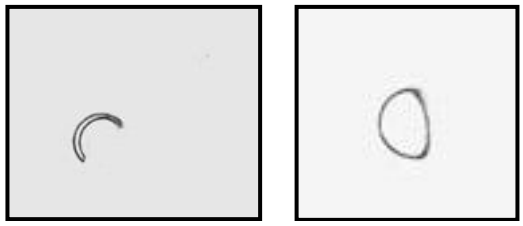
Galileo speculated that perhaps the larger disk had consumed the smaller two objects. Then a few years later, in 1616, the two small bodies reappeared on either side of the Saturn's disk. He was greatly confounded by his observations and never realized that he was looking at a ring that had turned edge-on and was now beginning to open back up. Not until 1659, did Dutch astronomer Christiaan Huygens, using a better quality telescope with a magnification of 50x solve the mystery!

The Phases of Venus:

In September of 1610, Galileo turned his telescope toward the planet Venus and immediately discovered that it was not a fully illuminated disk. He watched Venus over a period of many months, with the planet slowly going thru its crescent, gibbous and full phases and change in disk diameter. In either of Galileo's small telescopes, there were no details to be seen on Venus's brilliant white disk.



(Galileo)



(LM sketch– 8" SCT f10)

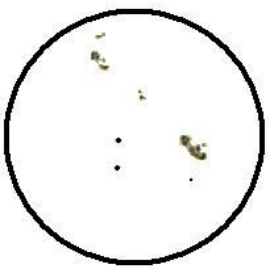
Once he reported his observations of Venus going thru phases, something that was never supposed to happen according to the Ptolemaic World view, the traditional geocentric or Earth-centered model became even more unacceptable to Galileo's contemporary astronomers.

The Sun-centered Copernican World View's acceptance was now growing among the scientist and philosophers of the time. Galileo's telescopic discovery of the phases of Venus contributed greatly to this transition.

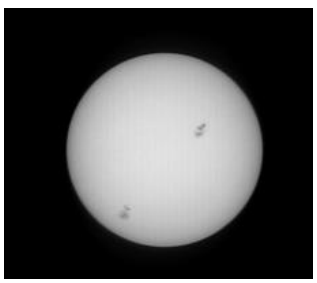
Sunspots:

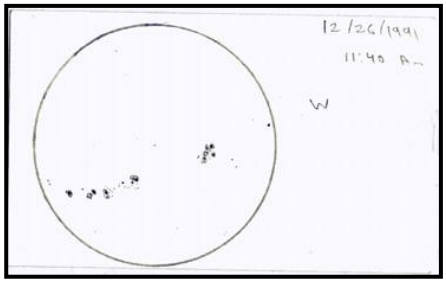
Going back for nearly 2,000 years, astronomers and other skywatchers have noticed occasional naked-eye dark blemishes on the face of the Sun, particularly at sunrise or sunset when hazy skies helped cut down on the Sun's glare. Galileo himself, pre-telescope had made these kind of observations, but again, as he had been taught in school, the Sun was a celestially perfect heavenly disk and like the Moon, these dark spots were just reflections from the Earth.

With his discovery observations of lunar terrain still fresh in his memory, and while recognizing the optical dangers of the Sun's rays, in November of 1610, Galileo devised a way to observe the Sun safely with his telescope. He would only observe the Sun by projecting the image it thru the telescope onto a flat shaded surface. He would never actually look thru his telescope at the Sun. He immediately telescopically observed various sunspot groups and determined that they were physical features on the Sun. Galileo tracked the sunspot groups on a regular basis for many weeks, watching them grow and decay. Eventually, he realized that based on his observations, the Sun had a rotation period of about one month. Galileo published his solar observations in a new book called "*Letters on Sunspots*". With this book, Galileo also firmly declared his being in favor of the Copernican System. Once again, Galileo's telescopic observations and writings were in conflict with church doctrine that the Sun as a heavenly body was supposed to be unchanging in its perfection, and was also another blow against the geo-centric Ptolemaic System.



(Galileo)





(LM image and sketch– 80mm f3 Refractor)

As with Galileo's Jupiter observations, a dispute arose over who was the first to use a telescope to 'discover' sunspots. Jesuit priest Christoph Scheiner also claimed to have observed sunspots in late 1610, and his claim led to a long and bitter feud between him and Galileo. Once again, with Galileo's detailed descriptions published before Scheiner's, Galileo was given the credit for being first. But being a Jesuit, Scheiner was in more favor with the church, and that worked against Galileo later on.

Neptune: a missed opportunity?

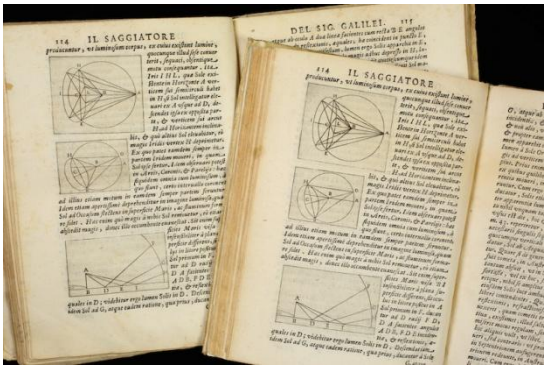
Apparently in 1612, Galileo also observed the planet Neptune without realizing what it was. He has it recorded in his notebooks as a dim star that looked to be slowly moving in relation to the other background stars.
But after only a few observations, he lost track of it. Calculating Neptune's current orbital location in reverse puts it in the location of Galileo's 1612 observation. If Galileo had stuck with following the dim moving star, he might have made another world shaking discovery! Neptune now had to wait another 234 years before German astronomer Johann Galle located it on September 23rd, 1846.

Revolutionary Ideas and Consequences:

The observations made by Galileo in 1610 quickly convinced him that the Copernican system was correct and he became an outspoken advocate for it. This, along with his observations that the Sun, Moon, and Venus were not perfect, unchanging celestial spheres of divine substance, an example of the perfection of the Heavens, but,, Were just like the rough, changeable, corruptible terrestrial things on Earth! Publishing this in the "*Starry Messenger"* put him in conflict with the religious teachings of the church. This unintended challenge to religious dogma caused such an uproar that some church officials even after hearing from others describe what they have seen visible in Galileo's telescope still refused to look themselves through it in fear that the instrument was bewitched. Galileo's response to these officials was that he hoped they would soon have a good view of the new moons while on their way up to Heaven. (Implying that he wished them dead, Galileo's outspoken quick wit probably didn't help his case).

His next published book in 1613, "*Letters on Sunspots*", where Galileo presented his observations on Sunspots, Saturn, and the phases of Venus, and again praised the Copernican System as being correct, further inflamed his critics and led to an investigation by the Inquisition. In 1616, the Papal church officially ordered him to stop teaching or writing about the Copernican system.

In 1623, Galileo published the book, '*The Assayer* ', which is considered to be one of the early pioneering works of advocating using mathematical tools and physical observations as part of the scientific method. In the book, which concerned the nature of comets, Galileo highly criticized a prominent Jesuit astronomer and permanently alienated the Roman Jesuit College who had previously been supportive of Galileo.



Galileo then published "*Dialogue Concerning the Two Chief World Systems"* in 1632 where he satirically compared the old Ptolemaic geo-centered model with the new Copernican system, arguing thru logic that the sun-centric model was correct. (This book is considered to be one of the most important scientific papers ever written). Galileo thought he had received permission to write and publish the book, from Pope Urban, as long as he didn't personally support the Copernican system. So Galileo wrote the book in which three fictional characters debated amongst themselves the merits of the two systems.

But Galileo made a huge miscalculation of unintentionally insulting the Pope by using the Pope's own arguments in support of the Ptolemaic System for a dimwitted character in the book. Galileo was literally 'playing with fire', as in living memory, philosopher and mathematician Giordano Bruno was burned at the stake (in 1600) for teaching the heretical view of the Copernican System.

This book was the last straw for Pope Urban, who summoned Galileo to Rome in 1633 to face the Inquisition. After spending two months under house arrest at the Villa Medici, Galileo was finally put on trial, where he was found to be 'vehemently suspect of heresy'. But it wasn't a unanimous decision as a number of judges voted to acquit and refused to sign the verdict. Galileo was forced to knell before the court and publicly recant his belief in the Copernican system and swear that the unmoving Earth was the center of the universe. According to some accounts, as Galileo was standing up and turning away from the judges, he whispered: "*But it does move*"!
Galileo was confined to his villa in Arcetri near Florence under house arrest for the remainder of his life.
The 69 year-old astronomer was forbidden to publish anything new, and all his older books placed on the list of church banned books which was not rescinded until 1835.

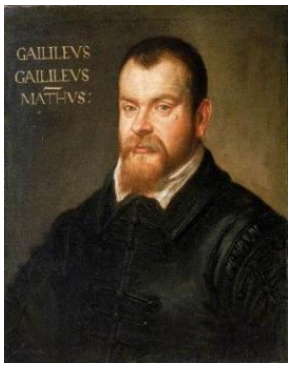
Galileo was already in poor health prior to his trial, and the pressure of the trial and house arrest left him depressed and sicker. Galileo requested several times to be allowed to travel to Florence to see a doctor, but his requests were denied by the church. His daughter Sister Maria Celeste died the following year, 1634, which left him even lonelier. During this time, Galileo's eyesight, which had given him problems for a number of years, began to fail. Over the centuries people have speculated that it was possible that Galileo had damaged his eyesight from his studying of sunspots 25 years earlier. But, it really had nothing to do with his telescopic observations of the Sun as he never directly looked at the Sun 'thru' the telescope. Eye damage from looking at the Sun damages the central fovea region of the eye, and does not cause total blindness. Galileo suffered from both glaucoma and cataracts in both eyes, which caused him to slowly lose his vision and eventually go completely bind by 1638. Galileo's friends eventually were able to get the church to ease-up on his punishment, allowing him to see a doctor, have occasional visitors and to have a personal secretary and caretaker. In late November of 1641, Galileo became very ill with a fever, and at the age of 77, on January 8th, 1642, passed away.

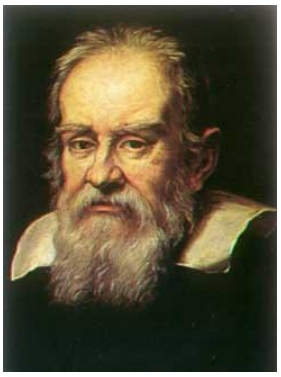
Galileo's supporters wanted him buried in the main chapel in the church of Santa Croce in Florence, but the Pope refused to allow it, so he was buried in a small side room of the church. Eventually, the church relented in 1737, allowing Galileo's body to be moved to a grand tomb in the main chapel at Santa Croce. It is said that his daughter, Sister Maria Celeste was reburied with him.
It was not until 1992 that the church finally rescinded Galileo's guilty verdict of heresy, clearing his name.

Galileo's Legacy:
Galileo and his telescopic observations made many significant contributions to astronomy. He has been referred to as the "Father of Modern Astronomy". But Galileo also made discoveries in other areas of science, among which: Galileo studied speed and velocity, gravity and free fall via his famous 'Leaning Tower of Pisa' experiments where he dropped objects (cannonballs) of different weights from the tower.
He experimented and described the properties of pendulums and "hydrostatic balances".

Galileo formulated the concept of *inertia*: an object in a state of motion remains in that state of motion unless an external force acts on it. He invented a measuring instrument called a 'Sector' or 'Military Compass', which was a calculating instrument used to solve navigation, surveying, and cannon gunnery problems in trigonometry.
He discovered the pneumatic principle in which a liquid rises and falls as the temperature changes and invented an instrument called a 'Thermoscope' that shows the change in temperature, and was a precursor to the modern thermometer. In 1619, he studied the Northern Lights and speculated that the phenomenon was caused by sunlight reflecting off of the Earth's atmosphere. (which was incorrect). But he did come up with the name that we use today, the 'Aurora Borealis'.

And, while under house arrest in 1636, he wrote his last book, "*Discourses and Mathematical Demonstrations Relating to Two New Sciences*", which summarized much of his experimental work over his last 30 years and laid the foundations of modern physics. Due to the church ban on all of his books, including anything new, Galileo had the book smuggled out of Italy a few pages at a time, and published in Holland, which was not under the Inquisition's control.





In conclusion:
The 'Scientific Revolution' is said to have begun with the Copernicus sun-centered model in 1543 and concluded with Isaac Newton publishing his 'Principia *Mathematica '* in 1687. Galileo lived and made his groundbreaking scientific contributions during this time. A late day 'Renaissance Man', who helped lead the science of astronomy into the 'Age of Enlightenment'.

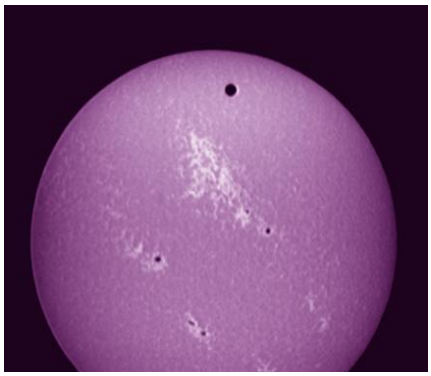
Galileo's celestial observations changed the way people thought about the universe, and our own world.
His invention of the first true "telescope" and turning it to the night sky overthrew the geocentric world-view and transformed our cosmic perspective:

- Our Moon was another feature-filled world just like the Earth, and not a celestially perfect globe.
- The Milky-Way was countless far-away stars.
- Other Moons rotated around Jupiter.
- Venus showed phases, just like our Moon.
- The Sun was pocked-marked with changing spots.

And **ALL** of it rotated around the Sun. Copernicus was correct; the Earth was not the center of all cosmic motion and itself rotates around a blemished Sun that was not a changeless orb. The Ptolemaic System was up-ended.
All these discoveries by Galileo led to a NEW 'Renaissance' in Astronomy, and a new understanding of our place in the Universe that continues to this day.

So I encourage everyone to get out tonight and try your hand at finding and observing these Galilean objects, and think about the man who was the first to observe them with a telescope. Galileo, the First Optical Astronomer!

The Venus Transit: A Historical Retrospective



Introduction:
Last June, 2012, for only the 7th time in recorded history, a rare celestial event was witnessed by millions around the world. This was the transit of the planet Venus across the face of the Sun. It is only visible from the Earth every few hundred years. Today, we are going to take a historical retrospective look at the Venus Transit.

What is a 'Venus Transit"?

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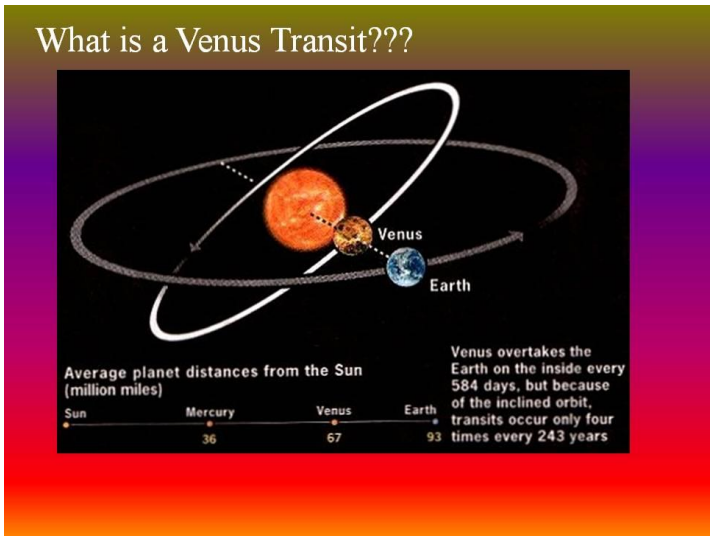
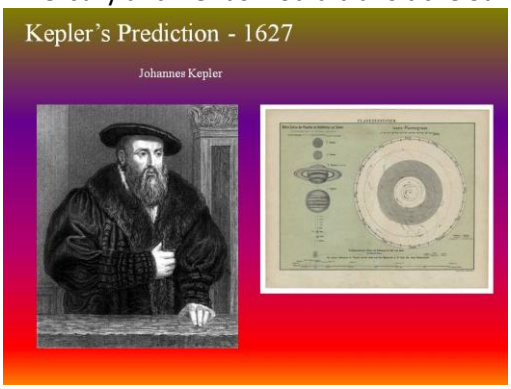
What is a 'Venus Transit"?

So, briefly, what is a Venus Transit? Basically the planet passes between the Earth and the Sun.
This occurs in a cycle of 2 every eights, then a gap of 105 years, followed by a pair of 8 year transits, followed by another gap of 121 years till the next 8 year pair.
Transits always occur either in June or December.
If you missed the June 2012 event, the next transit will not occur until December 2117.



Kepler's Prediction – 1627:
Johannes Kepler (December 27, 1571 – November 15, 1630) was a German mathematician, astronomer and astrologer. He is most famous for his laws of planetary motion. In particular, Kepler's third law, (The square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit), tells us the relationship between the distance of planets from the Sun, and their orbital periods. Using observational data and his third law, Kepler laid out a definitive model of the solar system based on what he called the 'astronomical unit' or the distance of the Earth to the Sun. Kepler gave the AU a value of '1' for his calculations. So Kepler was able to calculate that with the Earth being 1 AU from the Sun, that Venus was .7AU, and Jupiter was 5.2 AU, or Saturn was 9.5 AU. He could also calculate the AU distance between each planet; Jupiter is 4.2 AU from Earth. But Kepler did not know what the true value of '1 AU' equaled in terms of miles.

When Johannes Kepler published his last major work, the '*Rudolphine Tables*' of planetary motion in 1627, they permitted him to make detailed and fairly accurate predictions of the future positions and interesting alignments of the planets. Much to his surprise, he discovered that both Mercury and Venus would transit the Sun's disk in 1631.



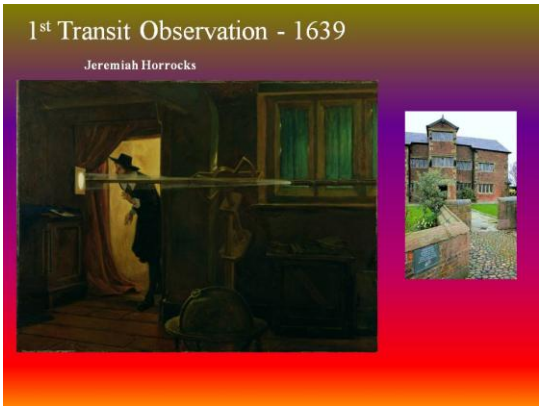
While Kepler could pinpoint the date of the transits, because of uncertainty in the exact time of the transit, he was not able to forecast from what part of the world the events would be visible. So he urged future observers to keep watch the entire day of the event. Kepler did not live long enough to attempt the observations, he died in November 1630. But French astronomer Pierre Gassendi heeded Kepler's prediction and succeeded in becoming the first to witness a transit of Mercury. Gassendi also tried to observe the transit of Venus, but it was not visible from his location.

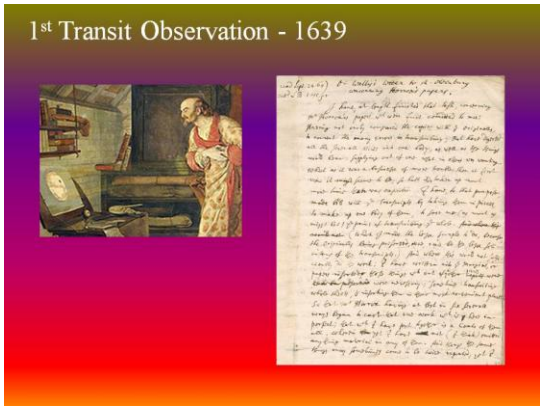
1st Transit Observation – Jeremiah Horrocks 1639

In Kepler's original predictions, the next Venus transit would not occur until the following century.
But in 1637, a young 20 year-old British amateur astronomer and minister named Jeremiah Horrocks realized that Kepler had made a mistake. Kepler had calculated the visibility of a Venus Transit using the center of the Earth as the starting point. Horrocks began the huge task of recalculating the predictions based from the Earth's surface, and completed them late in October 1639. Horrocks discovered that another transit would occur within the next month! On December 4th mid-afternoon.

He only had time to notify a couple of fellow astronomers, only one of which, William Crabtree, attempted an observation on the date, and successfully observed the transit.

As it was Horrocks nearly missed the transit himself, as being the local minister, he was called away to attend a church mass early that afternoon. Upon his return home at 3:15pm, he discovered the transit already in progress! He quickly recorded an observation and sketch of the transit before the sun set about a half-hour later.
Horrocks fast thinking allowed him to gather enough data to calculate Venus' apparent diameter to within one arcminute.





Horrocks friend William Crabtree was clouded out for the start of the transit, but the clouds lifted in time for him to also make a transit observation before sunset. After exchanging letters, that info helped to collaborate Horrick's own observation.

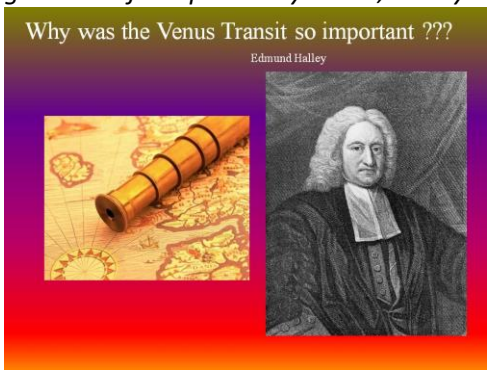
It was a good thing that the two of them exchanged their data, as before Horrocks could write up an official report of the transit, he fell ill and died suddenly. None of his records survived.

A few years later, Crabtree died fighting in the English Civil War. Crabtree's letters & records from Horrock didn't nearly survive the war either. Fortunately, enough were saved by his brother and came into the hands of German astronomer Johannes Hevelius who published them, that we even know of Horrocks and Crabtree's historic 1st observation of a Venus Transit!

Why was it so Important?
Edmund Halley's call to action in 1716
Nearly forty years after Jeremiah Horrocks, Edmond Halley observed the 1677 transit of Mercury from the island of St Helena in the South Atlantic. Halley realized that the careful timing of transits could be used to determine the Astronomical Unit (or AU), the distance of Earth from the Sun. The technique relied on observations made from the far corners of the globe. Using these observations, astronomers could use simple principles of triangulation to calculate the distance to the Sun, and from that calculate the distance to the other planets. The effect of parallax on the remote observers would allow them to derive the absolute distance scale of the entire solar system.
Once the AU was known, per Kepler's third law, all the other planet's distances from the Sun could be determined, along with their actual size and mass. This was the key to determining the true scale of our solar system.

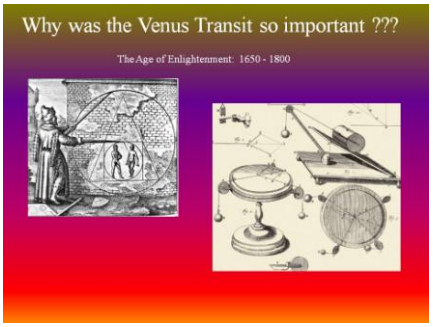
From his own experience, Halley knew that Venus transits were better suited to this goal than were Mercury transits because Venus is closer to Earth and consequently exhibits a larger parallax.
The more spread out the observers, the bigger the difference in parallax would be, allowing for more accurate calculations.

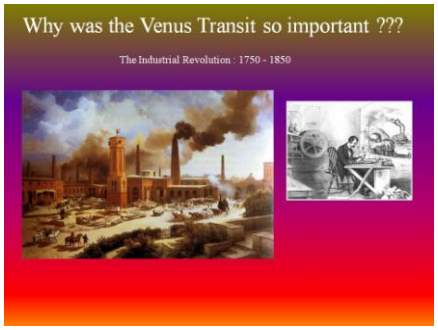
Near the end of his life, in 1716, Halley laid down a challenge to future astronomers to organize major expeditions to the ends of Earth in order to observe the transits of 1761 and 1769:
"I recommend it therefore again and again to those curious astronomers who (when I am dead) will have an opportunity of observing these things, that they remember my admonition… that having ascertained with more exactness the magnitudes of the planetary orbits, it may redound to their immortal fame and glory".



The Age of Reason (Enlightenment) and the start of the Industrial Revolution
During this time period there were several significant historical world-wide changes taking place.
The **Age of Enlightenment** (or simply the **Enlightenment** or **Age of Reason**) was a cultural movement of intellectuals in 18th century Europe and the American colonies. Its purpose was to reform society using reason and advance knowledge through science. It promoted science and intellectual thought and opposed superstition and intolerance.

The **Industrial Revolution** was a period from 1750 to 1850 where changes in agriculture, manufacturing, transportation, and technology had a profound effect on the social, economic and cultural conditions of the times. It began in England, thenspread throughout Western Europe, North America, and the rest of the world.
The Industrial Revolution impacted almost every aspect of daily life in some way.





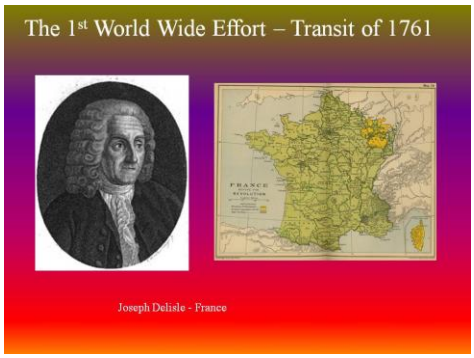
Together, the 'Enlightenment' and the 'Industrial Revolution' is sometimes referred to as the 'Age of Wonder', when modern science and its new machinery changed the world. Both of these movements lead to the rise of new nation-states and the re-birth of the old world states with a keen interest in the international prestige of competing in the new sciences and technologies being created.

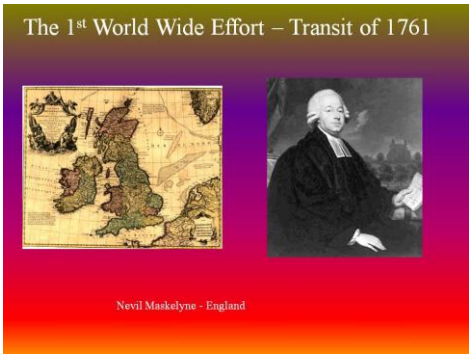
The First World Wide effort – the Transit of 1761.
Halley's challenge was the 'shot heard round the world', and launched a world-wide quest for what was considered one of the most important scientific questions of the time – the scale of the solar system! Astronomers from around the world took note of Halley's words, and when the time came in 1761 & 1769, their remembrance prompted multiple global expeditions to dangerous and exotic locations around the word, involving many of the leading explorers and scientists of the day. For 18th century astronomers, one of their most important task of their time was determining the AU.

Countries and Astronomers involved
Eight European nations sent out expeditions of the top astronomers of the day, among which were the following:

Joseph Delisle: Astronomer – France (Paris) Delisle was the organizational 'brains' behind the world-wide planning for the 1761 transit. He refined Halley's initial plans and determined where around the globe would be the best locations to positions observers, along with what data they needed to gather and what type of equipment they should use. Delisle then communicated this information to the astronomical & scientific societies and observatories of all the world powers. He would become the overall leader of the 1st international scientific endeavor in history!What makes this even more astounding was that all this international scientific cooperation occurred during the height of the 'Seven Years War' (what we call the French & Indian War), where all the major world powers were actively engaged against each other in open hostility. Because of the scope of this war, some historians actually consider it to be the first real world war.

Nevil Maskelyne: Astronomer – England (St Helena) The Royal Society selected upcoming astronomer Nevil Maskelyne to travel to the British held island of St Helena in the Atlantic.
During his voyage, he tested his new method for calculating longitude at sea, based on lunar observations.
Nevil hoped to not only succeed in observing the Venus Transit, but to also win the highly coveted Longitude Prize, a princely sum of cash from the King of England to whoever discovered a simple and practical method for the precise determination a ships location at sea.

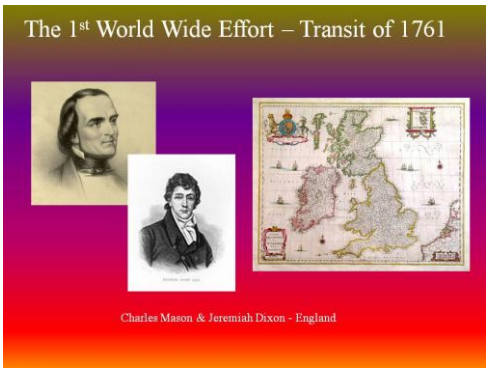


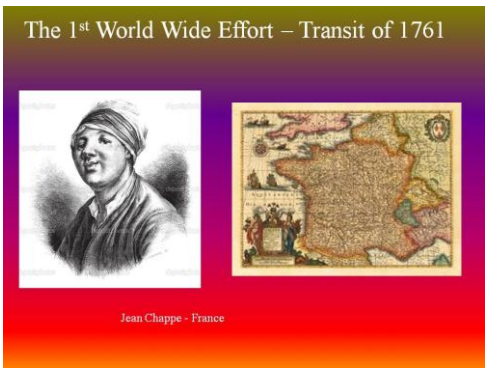


Charles Mason and Jeremiah Dixon: Astronomer/Surveyors – England (South Africa – cape)
Mason & Dixon were charted by the Royal Society to travel to Sumatra (today known as Indonesia) to observe the transit. They had barely made it out of port when their ship was attacked by a French warship and heavily damaged, with a number of sailors killed in the sea-battle. The pair survived the battle, but were quite shaken up by it and tried to back out of the trip. But they agreed to continue on, after receiving sternly worded reprimand concerning the impact of their quitting would have on the rest of their career. After the ship was repaired, they once again set out on the long voyage. Upon stopping in for supplies at Cape Town South Africa, the ship's captain

realized that there wasn't enough time to make it to Indonesia, so Mason & Dixon got permission from the Dutch running Cape Town to setup there. That ended up being a good thing, as they were the only expedition to successfully observe the transit from the Southern Hemisphere.

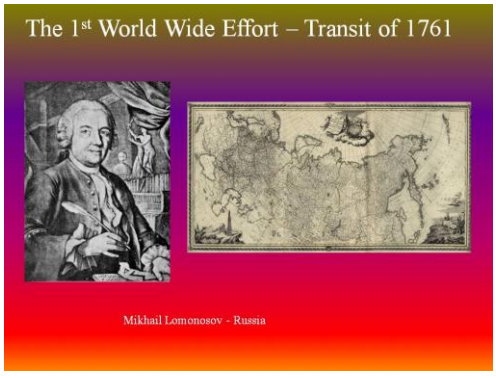
Jean Chappe: Astronomer – France (Siberia) French astronomer invited by the Russian Imperial Academy to help contribute by observing the transit from Siberia. Chappe travelled 4000 miles overland by carriage, cart, and sleds, having to ford icy rivers and sinking up to their axles on mud roads, or buried in snow drifts. After six months on the road, and suffering equipment damage from travelling over what passed as roads, He finally arrived at the location in Siberia with a little over three weeks left before the transit to prepare his observatory. But his troubles weren't over yet, as the locals accused him of being a magician and the threats to murder him or destroy his telescopes were such that he was forced to live in his observatory with a 24 hour guard.





Guillaume Le Gentil: Astronomer – France (Indian Ocean, at sea) The French sent Le Gentil to Puducherry India for his transit station. To give him plenty of time to make the journey over the war torn seas, he left for India over a year in advance. The ship arrived early to its port of call on the island of Mauritius off of Africa to resupply for the final leg of the journey. Unfortunately, Le Gentil came down with dysentery which delayed him. Once he recovered and the ship was able to sail, they hit the monsoon season, which blew the ship off course, and hit a period of calm winds with little to no travel progress. With time running out, as they were finally approaching their destination on the Indian coast, they learned that it had just fallen to British forces.
The ship captain had no choice but to turn around.

Mikhail Lomonosov: Astronomer – Russia (St Petersburg) A brilliant Russian astronomer who had a reputation of violence and was feared by his associates, having once stabbed a fellow Imperial Academy member in a drunken brawl.



What happened on Transit Day

Nevil Maskelyne: Astronomer – England (St Helena) Nevil had arrived two months before the day of transit, so he had his observatory well ordered and ready to go. The transit was already under way when the sun rose over the island. After a few initial observations, clouds quickly covered over the sun. But the overcast gradually cleared allowing Nevil to begin observing. As he prepared to time the final events, the clouds began rolling back in.
But, Nevil was really thrown off by the trembling edges of Venus's limb. He couldn't precisely determine when the planet's edge actually met the sun's limb. Between that and the thickening clouds, Nevil was unable to take any timings of the exit.

Charles Mason and Jeremiah Dixon: Astronomer/Surveyors – England (South Africa – cape)
The preceding days had been overcast, and that weather continued thru-out the transit day. Because of their location, Mason & Dixon would not see the start of the transit, as the sun was below the horizon, but once it rose, they managed to periodically glimpse views of the transit thru sucker holes. Finally with just minutes before the start of when Venus would begin exiting the sun, the sky cleared and they were able to time third and fourth contact. Shortly after Venus left the sun, clouds covered it back up.

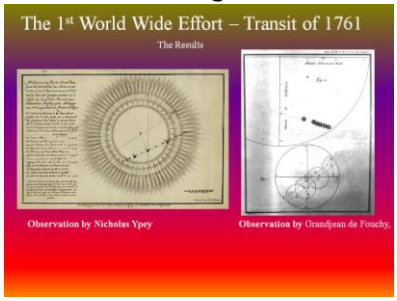
Joseph Delisle: Astronomer – France (Paris) Along with a number of other French astronomers, Delisle was able to observe the entire transit from his Paris observatory in sunny skies. But now feeling his eighty years of age and going blind, left most of the observing up to his assistants, and even turned over much of the cataloging of the worldwide observations and calculations to his trusted protégé Joseph Lalande.
A few years later he retired from astronomy to focus on religion and on the daughter of the Sultan of Constantinople.

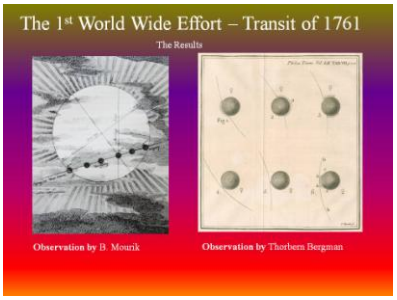
Jean Chappe: Astronomer – France (Siberia) The evening before the transit, low clouds and a thick fog had rolled that lasted thru the night and in the day of the transit, only clearing just prior to the start time. Having been up all the night before from being stressed out by the fog, Chappe hurriedly prepared his equipment, but because of a final lingering cloud missed the initial 1st contact. But he was able to accurately time second contact and the remainder of the transit.

Guillaume Le Gentil: Astronomer – France (Indian Ocean, at sea) Le Gentil had a beautiful clear view of the transit at sea with calm weather allowing him to time the whole event. But, he was unable to precisely determine his longitude location at sea, which made his observations useless.

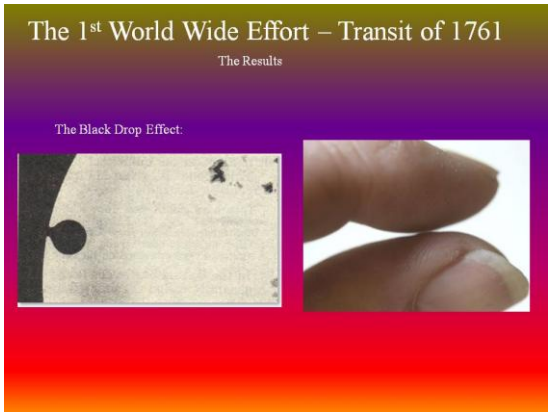
Mikhail Lomonosov: Astronomer – Russia (St Petersburg) Lomonosov was able to observe the full transit and obtain timings from his home observatory in St Petersburg. During second and third contacts, he observed a faint hazy arc of light around Venus, and was the only astronomer to realize the implications. Lomonosov was credited with the discovery of Venus having an atmosphere, and he concluded that Venus must have life on it, like the Earth. But a review of his records and recent observations from both the 2004 and 2012 transits have cast doubt that he really did see Venus's atmosphere. It looks to be based mostly on the widespread belief at that time that all worlds must have an atmosphere, even our Moon**.**

The Results
The 1761 transit was observed in part or whole from nearly 70 locations scattered around the globe.
Once all the observations were finally compiled and analyzed, the timings were so far off from one another that the calculated AU varied by nearly 25%, and fell between 77,850,000 - 96,160,000 miles.
Woefully inaccurate!!! The overall goal was deemed a failure.





This lack of accuracy in timings was the result of the '**Black Drop effect'**.
The black drop effect is an optical phenomenon visible during a transit of either Mercury or Venus across the Sun. During the transit, a small black "teardrop" appears to connect the planet's disk to the limb of the Sun, making it impossible to accurately time the exact moment of contact.



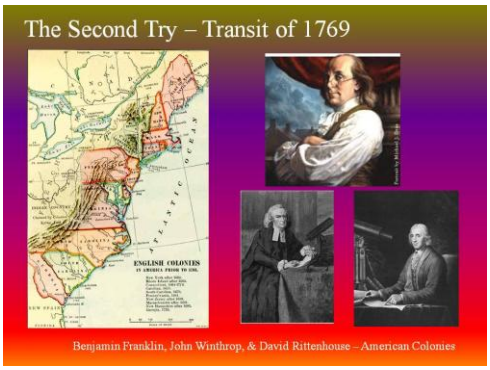
The Second Try – the Transit of 1769.
While the 1761 transit was a flop, the astronomers of the day knew they had a second chance coming up eight years later. They were determined this time to succeed, using bigger and better telescopes and timing clocks.

Countries and Astronomers involved
Now eleven European nations sent out expeditions of the top astronomers of the day to over 77 global locations. These included over 150 astronomers and their assistants, among which were the following:

Nevil Maskelyne: Astronomer Royal – England (Greenwich Observatory) Now as the head of British astronomy, Nevil took over the world-wide organizational effort that Delisle had done for the 1761 transit, sending out letters to other nations encouraging them to participate, writing transit equipment and observing instructions, and proposing expeditions to various locations around the world. All this, along with his duties as the King's Astronomer required him to stay in England and observe the transit from Greenwich. His appointment as Astronomer Royal also made Nevil the head of the 'Board of Longitude' and in charge of awarding the Longitude Prize, which put him at odds with his own longitude method contending with the other major seeker of the prize, clockmaker John Harrison. (the prize eventually went to John Harrison, but that is another story by Dava Sobel.).

James Cook: Sea Captain& Explorer (along with Charles Green : Astronomer, and Joseph Banks: Botanist) – England (Tahiti) Chosen by the Royal Navy to lead the South Seas expedition, James Cook was already known as a skilled marine surveyor, cartographer and astronomer. Along with the Royal Society astronomer Charles Green, who was in charge of the transit observation, and Joseph Banks, a wealthy gentleman botanist, Captain Cook set sailwith a crew of 94, and after nearly a year sailing on board his ship, the 'Endeavour', arrived at the island of Tahiti just in time to establish peaceful relations with the natives and setup for the transit.

John Winthrop and David Rittenhouse: Astronomers, and Benjamin Franklin – (American Colonies)
The beginning of the1769 transit would also be visible from the 13 American colonies, until sunset.
The American colonists were determined to be a part of the world-wide effort, particularly members of the American Philosophical Society (or APS), founded in Philadelphia by Benjamin Franklin for 'Promoting Useful Knowledge'. Chief among the APS was self-taught astronomer & instrument maker David Rittenhouse from the town of Norriton, located about 20 miles west of the city. Rittenhouse became the chief local organizer of the transit, in calculating and selecting the best observing locations and taking care of all advanced preparations.
From his work, the APS chose two main observing stations, one from the Philadelphia statehouse, and another from Rittenhouse's' farm. Benjamin Franklin, at the time staying in London as the unofficial ambassador of the American colonies and a leadership member of the British Royal Society, also encouraged his friend and astronomer John Winthrop in Cambridge to organize a group to observe the transit. Thru his London connections, Franklin was able to obtain new transit telescopes and timing clocks for both colonial groups.



Guillaume Le Gentil: Astronomer – France (India) Rather than head home after the Indian Ocean debacle, Le Gentil decided to stay in the region to prepare for the next transit in 8 years time. He decided that the city of Manila, Philippines, had the region's most perfect weather, and would make for a great transit site, and arrived there in 1766, well in advance, and setup an observatory. Then in late 1767, he was ordered to pull up stakes and again go to India, which was now back in French hands, for the transit. He arrived there almost a year before the 1769 transit date, and once again established an observatory.

Jean Chappe: Astronomer – France (Baja Mexico) Having successfully observed the first transit and published his three volume account of his travels in Siberia, Chappe was now assigned to travel under the Spanish to their territory in Baja Mexico, where the entire transit would be visible with the Sun high in the sky.
The King of Spain, concerned that the French had ulterior motives, greatly restricted the size and movements of the transit part and ordered the accompanying Spanish astronomers to keep a close eye on Chappe. The party endured a stormy 2 month sea crossing on a small ship, and then once in Mexico had to travel 800 miles by horse to the western coast, where they boarded another ship for another 500 mile stormy voyage along the Baja coast.
With time running out and only two weeks left before the transit, they abandon their original destination and made landfall by the small church mission community of San Jose del Cabo. A location that would prove to be fatal.

What happened on Transit Day
Nevil Maskelyne: Astronomer Royal – England (Greenwich Observatory) along with seven other astronomers at the Royal Greenwich Observatory, Nevil was able to time the start of the Transit. But the large discrepancy (53 seconds) between the seven observers made the results nearly useless. Nevil went on to lead the Royal Society's efforts in the cataloging of the worldwide observations and parallax calculations.

James Cook: Sea Captain & Explorer – England (Tahiti) after overcoming issues with the native inhabitants of the island, including their stealing and disassembling of their astronomical quadrant, without which they would not be able to calculate their exact position which would make their observation useless, Captain Cook and astronomer Charles Green successfully observed the entire transit. They distinctly noted the atmosphere around Venus, and once again all team members had difficulty with their timings, due to the Black Drop effect. They were able to get their quadrant instrument back from the natives and repaired it and determined their exact coordinates.
On the way back home, they explored the eastern coast of Australia where they collected numerous new botanical specimens and ended up running aground on the Great Barrier Reef. After making emergency repairs, they limped into port at Jakarta where Cook lost quite a few of his crew to malaria, including astronomer Charles Green.
Finally after being away for almost three years, Captain Cook and the Endeavour arrived back in London, where Cook presented Charles Greens transit notes to the Royal Society.

John Winthrop and David Rittenhouse: Astronomers, and Benjamin Franklin – (American Colonies) Franklin's new transit equipment arrived barely in time, giving the colonialist only a few days to practice using them.
The day of the transit arrived with clear skies, and the observers anxiously awaited the mid-afternoon appearance of Venus. Rittenhouse became so excited during the wait that he passed-out right before the start, missing the timing of 1st contact! After recovering, he went on to accurately record 2nd contact and continued to make observations until sunset. Winthrop's group in Cambridge MA successfully observed the transit from start to sunset. And in London, Franklin joined other members of the Royal Society in observing the transit, but the sky in their location was partly obscured by all the smoke coming up from the city!

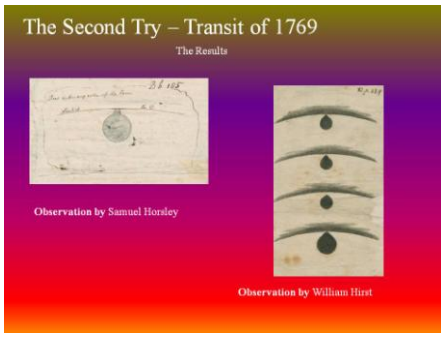
Guillaume Le Gentil: Astronomer – France (India) Le Gentil was probably the most prepared of all expeditions. He had an established observatory, all of its instruments in perfect working condition, and its location precisely calculated. But as fate would have it, shortly before the time of the transit, due to an early start of the monsoon season, the weather changed and he was clouded-out for the entire event! (he later learned that Manila had clear skies that day). Because of bad weather, Le Gentel had missed timing both the 1761 & 1769 transits! If the man could be any unluckier, during the trip home to France, he once again came down with dysentery, was almost shipped wrecked, and upon finally arrived home, discovered that he had been declared dead by his family and his estate sold off!!!

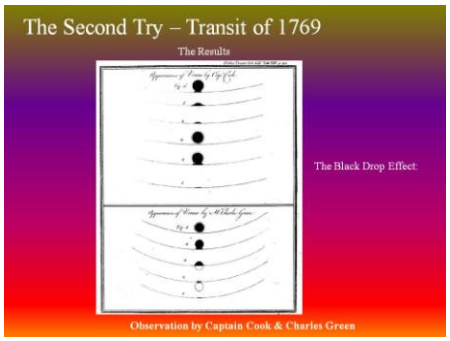
Jean Chappe: Astronomer – France (Baja Mexico) with just two weeks till the transit, Chappe converted a mission barn into a temporary observatory and prepared his telescopes and timing clocks. The transit began right at noon in a beautifully clear blue sky, and Chappe and his team were able to successfully observe and time the entire event, start to finish. Chappe couldn't believe how lucky he was, with all the trouble he had in getting to the observing location. Unfortunately for him, his luck didn't hold, as typhus was raging thru over half the local population, and eight days after his successful observation of the transit, Chappe fell sick. Over the course of a week, he forced himself out of his sickbed to complete the additional needed celestial observations of a lunar eclipse to fix his exact position coordinates so that his transit observation would not be useless. In the end, only two members of the French party survived to carry Chappe's crucial observations back to Europe. Jean Chappe, the only astronomer to successfully observe and time both the 1761 & 1769 Venus Transits in their entirety, was buried in an unmarked grave.

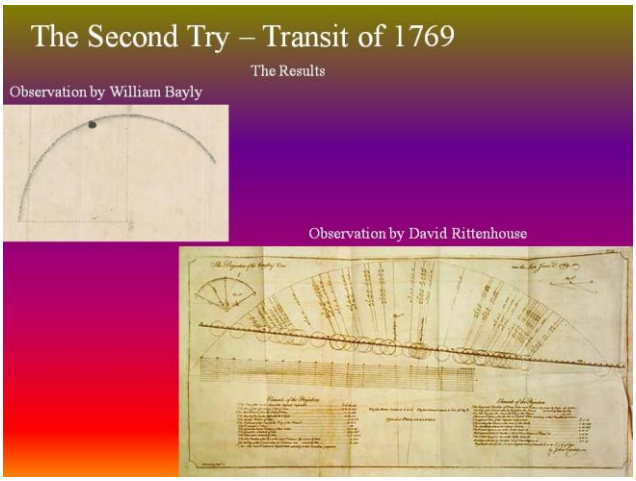
In the end, four astronomers had given their lives during overseas expeditions to observe the 1769 Transit of Venus! Charles Green, Jean Chappe, Salvador de Medina – Spanish Astronomer accompanying Chappe in Baja, and a Russian astronomer named Ochtenski on a small island in the Barents Sea.

The Results

Of the many 18th century scientific expeditions that were mounted to observe the 1769 Venus transit, all of the results, while better, were once again disappointing. The accurate parallax timings needed were still not possible due to the mysterious "black drop" effect in which the edge of Venus's disk appeared to deform and cling to the limb of the Sun. The final calculated values fell anywhere between 92 – 97 million miles, with the average being somewhere around 95 million.







So, all of the attempts during the 18th century's transits of Venus to establish a truly precise value for the Astronomical Unit, (AU), the fundamental measuring stick of the Solar System, were deemed failures. Astronomers would now have to wait 105 years for another try.

The 19th Century attempts – 1874 Transit

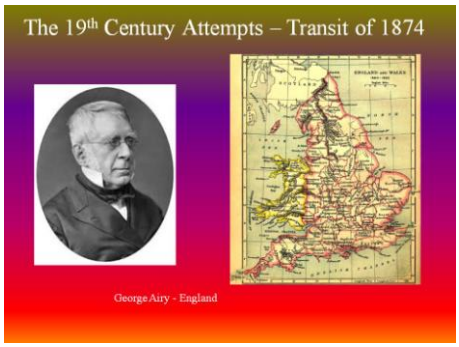
Disappointed by the results of the previous century, a new generation of 19th century astronomers, equipped with even better telescopes and new observing tools were determined to take up Halley's challenge and achieve the quest of determining the Astronomical Unit. The new astronomical tools included better refractors, new method of using silver-glass mirrors, clock-drive mounts, and the solar Heliostat. Getting around the world had also become much easier with the steamship having replaced sail. Where it use to take several months to cross the Atlantic, now it could be done in as little as eight days! Additionally, most of the major countries of the world had developed extensive railroad systems, making travel into their interior regions easy. With the invention of the telegraph and its lines weaved across the continents and oceans, planning and reporting activities could be communicated in a matter of hours throughout the world. This even allowed for accurate time signals to be transmitted from central locations, allowing the determination of a sites longitude to be much more precise.
Finally, Photography had been invented and already used by 1845 to capture images of the Sun, and a new technique of capturing multiple images, called a 'Revolver Camera' has just been invented.
This was the forerunner to the motion picture camera.

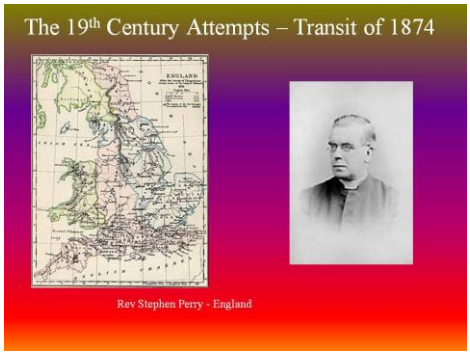
Countries and Astronomers involved

Once the transit visibility map had been calculated, it was obvious that only a few established observatories in the southern hemisphere would be able to observe the transit in its entirety – the observatories at Cape Town South Africa, Chennai India, and Adelaide, Melbourne, and Sydney in Australia. So another major overseas observing campaign was mounted by many nations to over 80 destinations for the Venus transits of 1874. These included the new counties of Germany, Italy, Mexico, Brazil, and the United States. During this transit season, there were no major ongoing wars and only a few areas of the world were considered unstable and not suitable for travel.

George Airy: Astronomer Royal – England (Greenwich Observatory) Once again, as the head of British astronomy, Airy took over the world-wide organizational effort that Nevil Maskelyne and Joseph Delisle had done for the 18th century transits, sending out letters to other nations encouraging them to participate, writing transit equipment and observing instructions, and proposing expeditions to various locations around the world. Airy was a strong advocate for transit planning, stating that finding the value of the AU is the 'noblest problem in astronomy'.
Prior to becoming the Astronomer Royal, as a relatively young astronomer, Airy was appointed head of the Cambridge Observatory where he published many scientific research papers. Once installed at Greenwich Observatory, he proceeded to organize it into the world's leading observatory in positional astronomy.
Airy was noted for his gruff personality and over the years made many critics, especially around the fiasco of his failure to use the predictive calculations of Cambridge Astronomer John Adams to search for the planet Neptune, letting that prize fall to the French.
For the 1874 Venus Transit, Airy chose 5 locations to send the British astronomers: Egypt, the Hawaiian Islands, Rodriguez Island in the western Indian Ocean, New Zealand, and Kergulelen Island in the far southern Indian Ocean.

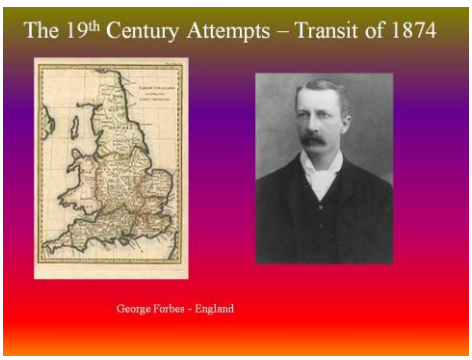
Rev Stephen Perry: Astronomer – England (Kerguelen Island – Southern Indian Ocean)
The British split into three teams on the island, as far apart as they could get. The main team was lead by Perry, who was the director of Stonyhurst Observatory, and had led the 1870 total solar eclipse expedition. Perry had a 6" refractor as their primary instrument, several 4" refractors, and transit instruments and an equatorially mounted telescopic solar camera. The secondary teams each had a 4" refractor.

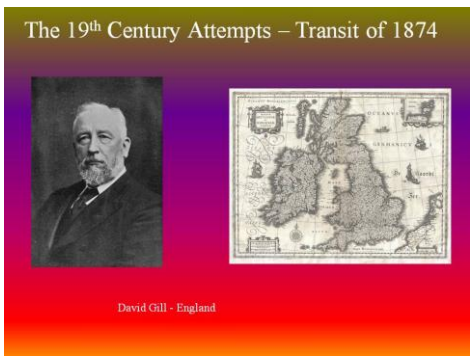




George Forbes: Astronomer – England (Kona – Big Island, Hawaii – Pacific Ocean) an astronomer from Cambridge who had written a book for the transit, Forbes was assigned to man the post on the Big Island of Hawaii.
Forbes picked a location at Kona and had a pier built on the beach for the observatory. Part of Forbes duties was to restore the monument to Captain Cook located near where he was killed. (In a dispute with the Hawaiian natives back in 1779, Captain Cook was killed, 'cooked' and eaten by the locals).

David Gill: Astronomer – England (Mauritius – Indian Ocean)
This was a private expedition funded by Lord Lindsay and was the most completely equipped.
They sailed on private 3-masted yacht, named the 'Venus' to the island arriving well in advance to setup their fully equipped transit observatory, including both visual transit refractors and solar photography equipment.

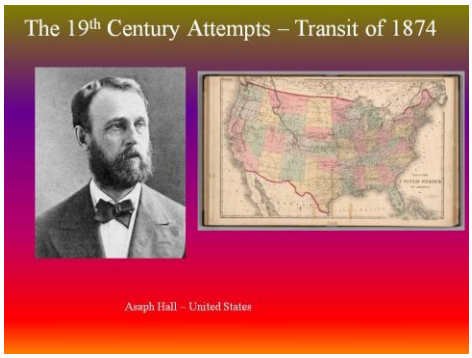




The United States Transit Commission: acquired a large fund from congress and the use of ships and assistance from the US Navy. The Americans decided to send major transit observing parties to Vladivostok Russia, Peking China, Nagasaki Japan, Kerguelen Island, Tasmania, and New Zealand.

Asaph Hall: Astronomer – USA (Vladivostok, Russia) (noted for discovering the moons of Mars in 1877) Hall, located on the coast by the Sea of Japan where he had to build his observing site over a mile from where they were staying. This made for travelling during the frigid winter weather quite uncomfortable for Hall and his team.

Comdr G.P. Ryan: USA-Navy – USA (Kerguelen Island – Southern Indian Ocean)
The Americans setup camp just across the bay from the British, close enough to signal one another.
They brought with them a 5" Alvan Clark refractor, transit instruments, and a solar camera that utilized a heliostat.

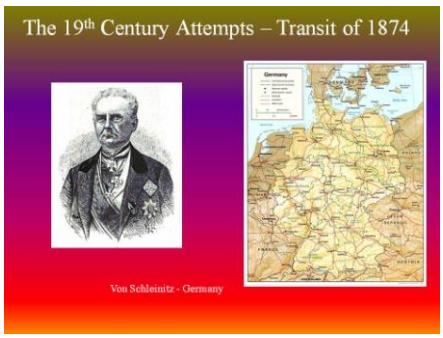


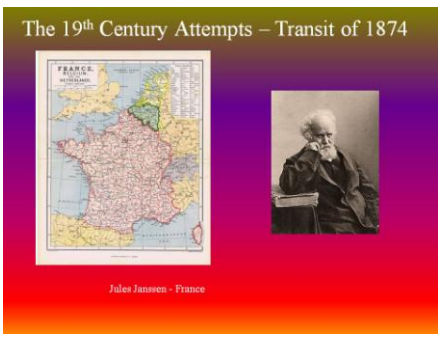
The German Transit Commission: Sent observing parties to Kerguelen Island, Mauritius Island, Auckland Islands, New Zealand, and China.

Von Schleinitz: Astronomer – Germany (Kerguelen Island – Southern Indian Ocean)
The German team setup camp on the far northern cost of the island in the flattest area they could find, which happened to be right in the middle of an old whaler's cemetery.

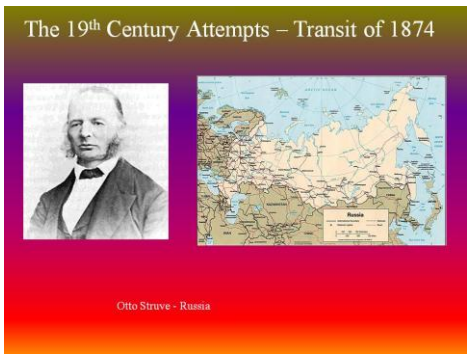
The French Transit Commission: sent astronomers to Peking China, Yokohama Japan, Saigon, and Campbell Island in the South Pacific.

Jules Janssen: Astronomer – France (Yokohama, Japan) the inventor of the Jansen 'Revolver Camera', which consisted of a rotating disk with slots in it, which projected a small window onto the photographic plate that advanced as the individual exposures were taken. This allowed 48 images to be taken in a little under 2 seconds. Even though Janssen was handicapped in his youth and was unable to walk, he was a prominent French astronomer known for his numerous solar eclipse observations. In order to observe a total eclipse in Algeria in December 1870, he rode a hot air balloon out of the city of Paris while it was under siege by the Prussians. During the trip over to Japan, his team had to ride out a typhoon off of Hong Kong. Upon arriving in Yokohama, Janssen moved his main group of observers with the Revolver Camera to Nagasaki, and sent a small detachment of visual observers to Kobe to increase his chances of clear weather.





The Russian Transit Commission: lead by Otto Struve, Sent observing parties to 32 separate locations, Stretching across the entire Russian Empire.



In addition to the above major countries, Mexico sent an expedition to Yokohama, the Italians sent one to India, and the Dutch sent one to Reunion Island

What happened on Transit Day
George Airy: Astronomer Royal – England (Greenwich Observatory) As the Astronomer Royal, Airy had to stay behind at Greenwich and await the reports to come in.

Rev Stephen Perry: Astronomer – England (Kerguelen Island – Southern Indian Ocean)
The main British team was clouded out at the start of the transit, but was able to make goodvisual timings using the 6" refractorof third & fourth contact at the end. The clouds ruined all attempts at photography.
The first 'secondary' team had good weather at the start, but was clouded out at the end, but the other secondary team, had clear weather the entire transit and had good timings of both the beginning and end of the transit. So Perry's plan of splitting the team paid off.

George Forbes: Astronomer – England (Kona – Big Island, Hawaii – Pacific Ocean) only the first two hours of the transit was visible from the Hawaiian Islands. The skies were clear at Honolulu, but on the Big Island where Forbes had setup, scattered clouds had blocked Forbes from accurately timing the first & second contact points, rendering his transit observations of little use. In addition, because of operator error in loading the plates, none of his photographic images came out. For all his troubles, Forbes almost drowned a few weeks prior to the transit, trying to save another man caught in heavy surf.

David Gill: Astronomer – England (Mauritius – Indian Ocean) Clouds blocked the initial phase of the transit, Gill was able to successfully observe egress, taking 271 photographic images and visual timings with a 6" refractor.

Asaph Hall: Astronomer – USA (Vladivostok, Russia) Hall, located on the coast by the Sea of Japan had clear skies and was able to take accurate timings of 1st and 2nd ingress contacts and third contact prior to sunset.

Comdr G.P. Ryan: USA-Navy – USA (Kerguelen Island – Southern Indian Ocean)
Being located near the primary British team on the island, the Americans suffered the same fate, clouded out except for the very end.

Von Schleinitz: Astronomer – Germany (Kerguelen Island – Southern Indian Ocean)
The German team enjoyed clear weather for the entire transit, and obtained photographic and visual contact timings of both beginning and end of the transit.

Jules Janssen: Astronomer – France (Yokohama, Japan) Janssen's team experienced perfect weather at both the main location in Nagasaki and the alternate site in Kobe, and were able to make full visual and photographic observations of both ingress and egress contacts. Using a new spectrograph, the French team also observed Venus silhouetted against the solar chromosphere. After the transit was over Janssen was able to telegraph Paris later that day with his team's success.

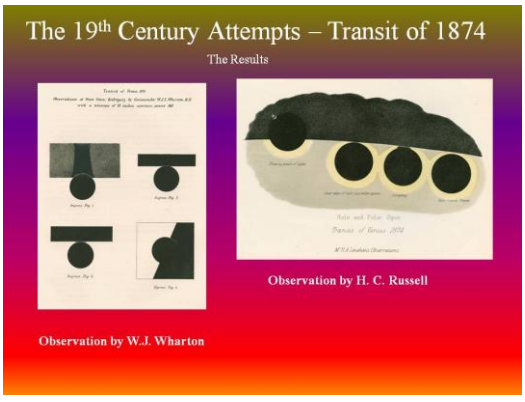
The Russian Transit Commission: lead by Otto Struve, the Russians, with their 32 observing locations, had mixed results. Only 13 stations reported any kind of observation, 10 were completely clouded out, and the rest never reported at all.

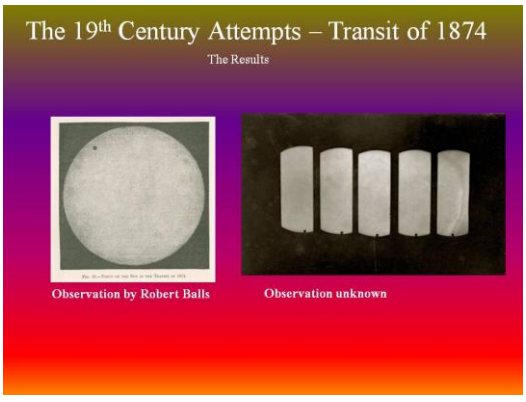
Most of the transit expeditions sent to New Zealand were clouded out.
But the Americans at Queenstown had better weather and managed to take 59 images of first and second contact.
The British were able to take a few photographs at their locations in Christchurch and Burnham.
Across the Pacific, the Germans made successful observations on Auckland Island, and the French were able to capture over 100 photographic images on Campbell Island.

In Australia, the Americans were clouded out at Hobart, but the British at the Sydney Observatory were able to take 560 photographic images using their version of the Janssen Revolver camera. Astronomer Henry Russell was also able to use the observatory's 11.5" refractor to make color drawings of the entire event.
India also enjoyed clear skies where the Italian team was successfully able to take visual timings of all four contacts, and also used a spectroscope to observe Venus against the chromosphere. The British team in India, using their revolver camera, was able to take 420 images and full visual timings of all four contacts.

The Results
The 1874 Venus Transit was successfully observed from numerous world-wide locations by both the new and old world powers, employing both the traditional visual observation utilizing 3 – 6" refractors, along with various photographic equipment, including the new Janssen Revolver camera. Within hours of their observations, preliminary reports began to come in over the telegraph to all the world's astronomical societies. Still it would take several months for the more remote island observations to make it back to civilization. Then began the calculations of adjusting the multitude of visual timings to common formats and the processing and careful measurements of all the photographic images captured.

Soon it became apparent that the curse of the 18th century had struck again!
The Black Drop effect once again allowed errors to creep into the individual astronomers visual observations.
Even worse, almost all of the photographic images suffered from fuzziness, even when magnified, and led to guesswork when trying to bisect the limb using a micrometer. Not even the motion picture Revolver cameras were able to capture enough steady single images to be conclusive. Astronomer Royal George Airy was so disappointed with the British photographic observations, that he didn't even bother to publish any of them!





As the various astronomical transit commissions from across the globe began publishing their calculated AU results in late 1875, the numbers were all over the place, depending on who did the calculations and what observations they used, with the average being somewhere around 92 million miles. In the end, there was just too much data from too many observing stations. So much, that no one ever attempted to use all of the visual timings, micrometer measurements, and photographs rolled into one definitive calculation. Once again, the attempt to use a transit of Venus to establish a truly precise value for the Astronomical Unit, (AU), was deemed a failure.
The Astronomers of the 19th century would have one more change in eight years to get it right.

The 19th Century's Last Try – 1882 Transit - Photography will save the day.
Now with the unexpected poor results of the 1874 transit behind them, a number of professional astronomers and countries around the world began to lose interest in using the Venus Transit as a method to calculate the AU. Several competing alternate methods were being advocated as replacements. That of French astronomer Leon Foucault in developing equipment to accurately measure the speed of light, which in turn using that to accurately calculate the distance to Jupiter's Moons during their eclipses, which could then be used to calculate the AU. Or the method put forward by British astronomer David Gill in using the planet Mar's changing position among background stars during a close opposition to calculate the solar parallax.

But, with the start of the 1882 transit being visible from most of Europe, and the entire event visible from the Eastern half of North American, public interest ran very high. This was fed by numerous magazine and newspaper articles, and even composer John Philip Sousa wrote an orchestral piece titled – 'Transit of Venus March'. Anyone with a telescope or even a smoked piece of glass was determined to catch a view of the transit. Everyone, Adults and children were encouraged to try and view a 'once in a lifetime' event.

Countries and Astronomers involved
This surge in public interest served to spur the professionals into taking advantage of the last Venus Transit in their lifetimes to make one more effort in determining the AU from a transit.
Most of the national 1874 transit committees were still in existence, and the professional astronomers had been honing their skills by observing the 1878 & 1881 transits of Mercury, along with a number of solar eclipses prior to 1882. Due to the failure of photography during the 1874 transit, a number of countries, including England and Germany decided to abandon photography and revert back to visual timings. Russia decided to not participate at all. But recognizing that 1882 was their last chance, a total of 45 overseas transit expeditions were organized to the areas of the Caribbean, South Africa, Australia, New Zealand, and South Georgia Island.

George Airy: Astronomer Royal – England (Greenwich Observatory) Once again, as the head of British astronomy, Airy continued his world-wide organizational efforts, but he focused on visual methods. Airy stated that the British , "due to the apparent general failure of the photographic principle, they were unwilling to spend further time on it'. While the British mounted a number of overseas expeditions to Bermuda, Jamaica, New Zealand, Australia, and several islands in the Indian Ocean, many British astronomers planned on staying in England at the major observatories where the initial contact events would be visible.

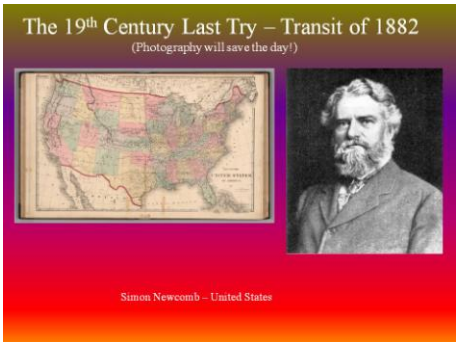
Rev Stephen Perry: Astronomer – England (small island off the coast of Madagascar) Father Perry once again led one of the two British Indian Ocean expeditions. He picked a tiny island off the southwestern coast of the main island of Madagascar.

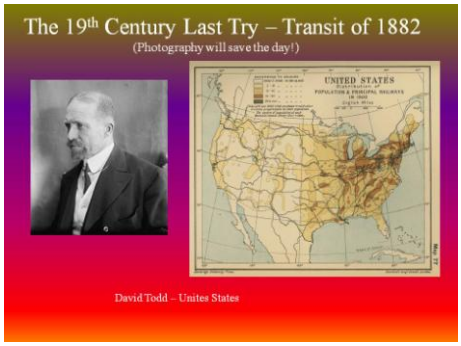
The United States Transit Commission: with the 1882 transit falling all across the east coast thru the mid-west, a number of the world's best known astronomers could easily plan on viewing the transit from among some of the foremost major observatories of the day. In fact the US would host a number of foreign transit expeditions including those from France and Germany. The Americans planned to go full-out in using photography for the transit, using the latest state-of-the-art dry plate technique, along with the older style wet plates.
The Americans decided to send major transit observing parties to San Antonio, Texas, Cedar Keys, Florida, Fort Selden, New Mexico Territory, San Francisco, Santa Barbara, and the future site of Lick Observatory on Mt Hamilton, in California. They also sent overseas expeditions to South Africa and New Zealand.

Simon Newcomb: Astronomer – USA (Cape Town, South Africa) The head of the US Naval Observatory's transit planning. While Simon was one of the professionals who no longer believed that using a Venus Transit was the best way of calculating the AU, he still would lead an overseas American expedition to Cape Town, South Africa

David Todd: Astronomer – USA (Mt Hamilton, Ca) Todd was a young upcoming astronomer employed at the Naval Observatory by Newcomb as an observer and to help with calculating the results of the 1874 Venus Transit.

While there, he assisted Asaph Hall in discovering the moons of Mars in 1877. Todd left the Naval Observatory in 1881 to head-up the small observatory at Amherst College. He was selected by Richard Floyd, president trustee of the Lick Observatory project to come to the site of the proposed observatory on Mt Hamilton, CA to operate a special horizontal photoheliograph built specifically to photograph the Venus Transit of 1882.





The German Transit Commission: In addition to home teams, they sent overseas observing parties to Argentina and the United States.

The French Transit Commission: in addition to planning observations at the major national observatories in Paris and elsewhere, they sent astronomers to Mexico, Chile, Haiti , and North Africa.

Jules Janssen: Astronomer – France (French Algeria) This time around, Janssen took his Revolver camera to French Algerian territory in Northern Africa.

In addition to the above major countries, Mexico, Brazil, and Argentina also planned transit activities at their major national observatories, and New Zealand and Australia planned to observe third and fourth contacts from their home observatories.

What happened on Transit Day

On the cold winter day of the transit, December 6th, 1882, schools along the Eastern US closed. Some rang their bells or fire alarms to signal the start of the transit. Amateurs and college observatories setup telescopes in all the large cities and some drew sizable crowds that the local police had to come to keep order in the long lines of people waiting to look thru the telescope. Even the brokers on Wall Street took a break to look thru a telescope setup near the stock exchange. (a few telescope owners made quite a killing, charging 10 cents a view).
Some of the upcoming astronomers who helped out with the public effort included E.E. Barnard at Vanderbilt University, John Rees at Columbia University, and Maria Mitchell at Vassar College. Locally, Samuel Langley at Allegheny Observatory in Pittsburgh enjoyed a view of the transit thru scattered clouds. Unfortunately, across Europe, where hundreds of astronomers scattered among the Old World's major observatories were unable to see the event due to the winter weather.

George Airy: Astronomer Royal – England (Greenwich Observatory) Airy, along with all the British astronomers who stayed home in hopes of observing the transit, were clouded, rained, or snowed out at Cambridge, Oxford, Greenwich, and elsewhere. But the British overseas teams had good success in timings at their locations in the Caribbean and New Zealand and Indian Ocean.

Rev Stephen Perry: Astronomer – England (small island off the coast of Madagascar) Perry's pick of the small island off of Madagascar in the Western Indian Ocean proved to be good, as he was able to successfully observe ingress.

The United States Transit Commission: had numerous successfully timings and photographs of the entire transit start-to-finish, from across the states, with some of the best timings made by George Davidson at Fort Selden, in

the New Mexico Territory. The overseas expedition to Auckland New Zealand led by Edwin Smith, successfully timed egress and obtained 74 photographs.

Simon Newcomb: Astronomer – USA (Cape Town, South Africa) Newcomb had setup about 40 miles out of Cape Town in a girl's school, where he had some of the best views of the Sun that he had ever seen, and made successful visual timings and photographs.

David Todd: Astronomer – USA (Mt Hamilton, Ca) As the sun rose that morning, the transit was already in progress in a perfectly cloudless sky. Todd worked the horizontal photoheliograph, while Lick Observatory trustee Richard Floyd visually observed with a 12" refractor. Todd acquired 147 plate images of the transit thru third and forth contacts. His photographs at the time were considered to have been the sharpest obtained anywhere of all the 1874 and 1882 transit expeditions, and are the best set of photographs that have survived from the 19th century transits. In later years, Todd became a prolific solar eclipse observer, going on 13 overseas expeditions across the globe.

The German Transit Commission: while the Sun was low at the start of the transit, the German home teams, had clear skies and made successful observations, including those of Herman Vogel at the Potsdam Observatory.

The French Transit Commission: the French teams that stayed in-country were also clouded out or rained on in Paris and Bordeaux, but some observers were able to make visual timings and photographs thru breaks in the clouds. All of the overseas teams were able to successfully observe the entire transit, including those in Port-au-Prince, Haiti, and Santiago, Chile.

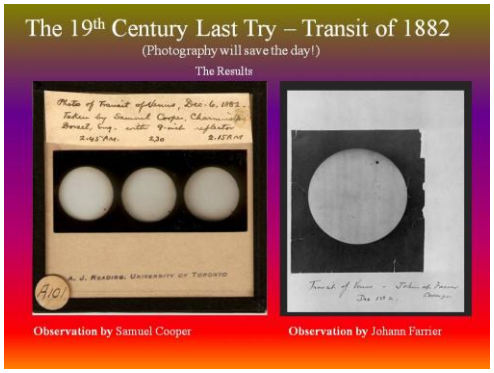
Jules Janssen: Astronomer – France (French Algeria) Janssen was once again able to successfully observe and capture multiple photographic images of the start of the transit.

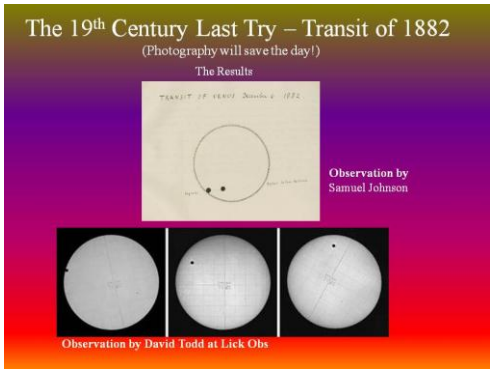
In addition to the above major countries, the start of the transit was observed throughout Italy and as far east as the Athens Observatory in Greece. The entire transit was also successfully observed by astronomers from the observatories in Central and South America, including the Brazilian emperor himself. The transit parties in New Zealand were successful in observing egress, but Australia had mixed results as Sydney and Brisbane were clouded out, but Melbourne and Hobart had clear skies.

The Results

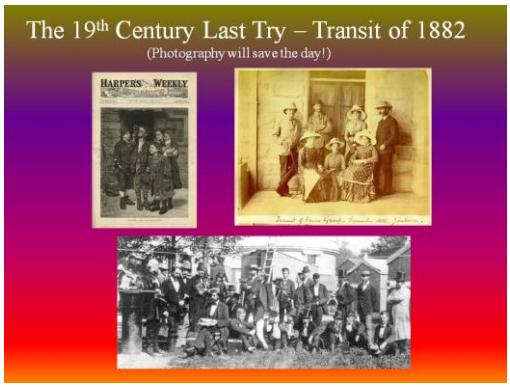
Again, the "black drop" limited the precision of the observations and the determination of the Sun's distance, even with using photography!The black drop effect was long thought to be due to Venus' thick atmosphere, and it was held to be the first real evidence that Venus had an atmosphere. Modern analyses showed that the "black drop" is really an optical effect caused by the smearing of the image of Venus by turbulence in the Earth's atmosphere or imperfections in the telescopes used in the observation. The final calculated values fell across a wide range, with the average again being somewhere around 92 million miles. (very close).

Once again, the overall astronomical goal was deemed a failure. Astronomers came to the conclusion that obtaining the AU from a Venus Transit, even using photography, would never be as precise as they wanted. Because of this, even fewer AU calculated results for 1882 were published than for the 1874 transit.

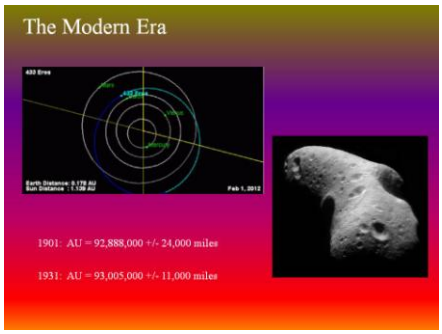




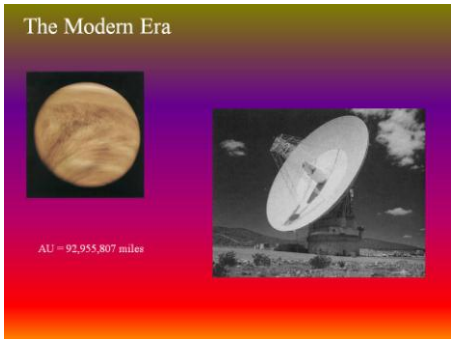
But for the first time, a Venus Transit was observed by millions of common people, and inspired many to a lifelong interest in astronomy, including a five-year-old Henry Russell from Long Island, who went on to become the leading American astrophysicist of the early 20th century.
So, in a way, the 1882 Venus Transit was a success, as it led to a higher level of public involvement in astronomy and funding of professional observatories across the US.

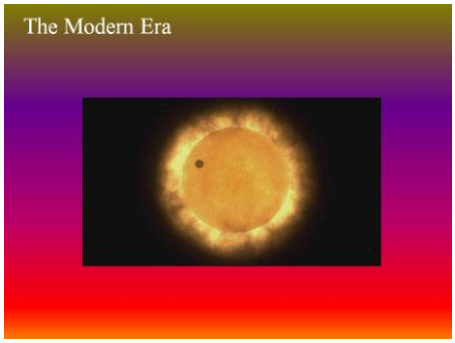


The Modern Era
Now it's just for fun: The AU has been calculated by other means.
Over the decades, since the last Venus Transit in 1882, better methods of calculating the AU were worked-out, including using the stellar parallax observations of close approach asteroids. In 1901, the asteroid Eros came within 30 million miles of Earth, and after careful visual micrometer and photographic measurements by several dozen professional observatories from around the world, the AU was calculated to equal 92,888,000 +/- 24,000 miles.
Then in 1931, Eros again made a close approach of only 26 million miles to Earth, and once again was widely observed, with almost 3,000 images taken.
Based on these observations, the Au was then calculated to equal 93,005,000 +/- 11,000 miles.



Finally, in 1958, engineers from MIT bounced radar signals off of the planet Venus. Then in 1961, astronomer Rich Goldstein from Caltech was able to accurately time the radar bounces between Venus and Earth, and using the known value for the speed of light, was able to precisely calculate the distance between the two planets, and from that definitely calculate the value of the Astronomical Unit. Today, we know that one AU is equal to 92,955,807 miles, which is Earths average distance from the Sun.

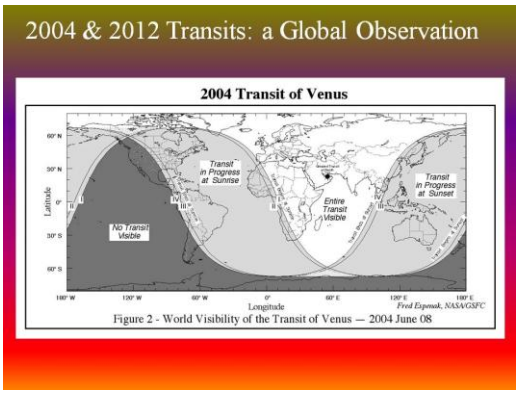




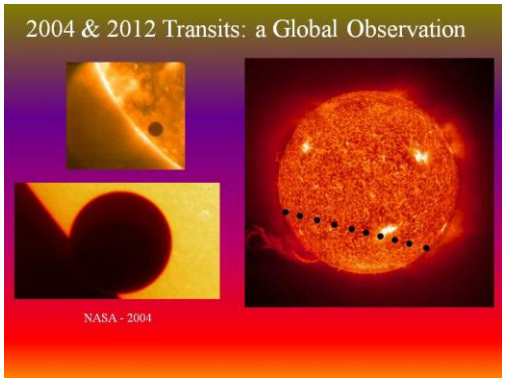
With the distance to the Sun and planets now measured extremely accurately using radar, the 21st century's round of transits lost much of its scientific importance. Still, it is a remarkably rare event which was worth observing in its own right.

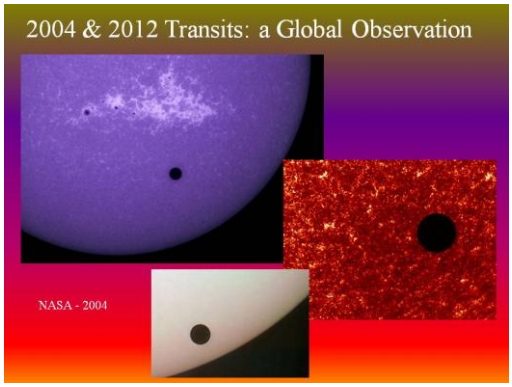
The 2004 and 2012 Transits: a Global Observation.

Over the last 25 years we've seen great advances in affordable amateur astronomy solar equipment. From 1000 Oaks optical glass WL filters, to Baader solar film, to Lumicon Prominence filters, to Daystar T-Scanner Ha filters, to Coronado PST & Cak dedicated solar telescopes, to the new line from Lunt.



There were also the corresponding advances in imaging equipment, from CCD cameras to digital SLR's, to video and webcams that gave amateurs easy-to-use tools in capturing images of the transit. Today's amateurs heading into the Venus Transits had available to them equipment that the professional astronomers over a 100 years ago couldn't even begin to dream of. In 2004, millions of people across the globe observed some portion of the transit. Here in the US, the June 8th2004 transit started in the early morning hours before sunrise, and was close to being over when the Sun finally rose on the East Coast around 7:00am. We had less than 45 minutes of transit, but still we were able to observe the egress – third & forth contact.





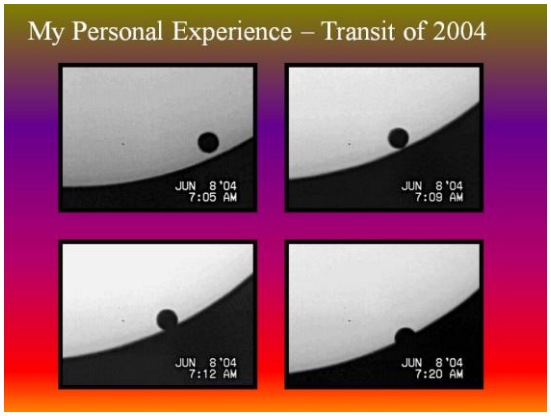
My personal experience.

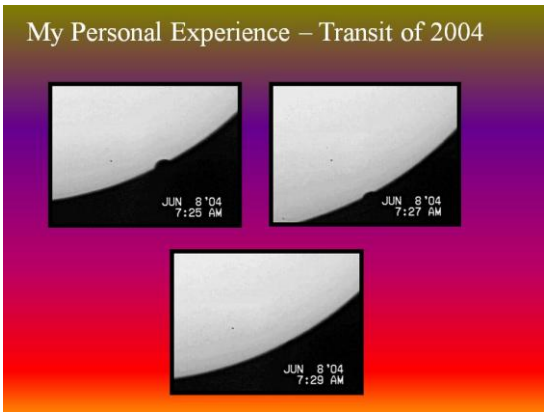
2004: *Tuesday, June 8th, 2004:*

Equipment used: 8" Celestron Ultima SCT (f10). Lumicon 1.5 A H-alpha solar filter. AstroVid StellaCam EX, 1/2" CCD with 600 line resolution.

On the early morning hours of June 8th, 2004, about 50 amateurs and public set up their solar telescopes at a local Pittsburgh area observatory to witness a rare transit of Venus. There was some concern, as the morning haze was thick on our eastern horizon, but right at 7:00am, the Sun broke out of the cloudbank it was hiding in. A big wave of excitement rolled over those gathered as they trained their telescopes on the Sun, followed by various exclamations as to how big Venus looked silhouetted against the disk of the Sun!

The joy of seeing the transit was quickly overshadowed by the realization of how close it was to the time for Venus to exit the Sun. Using my solar and video equipment, I quickly gave a 'live' video presentation for the group.
I was able to videotape the 3rd & 4th contact, and had beautiful views on the TV screens where more than one person could watch at a time.

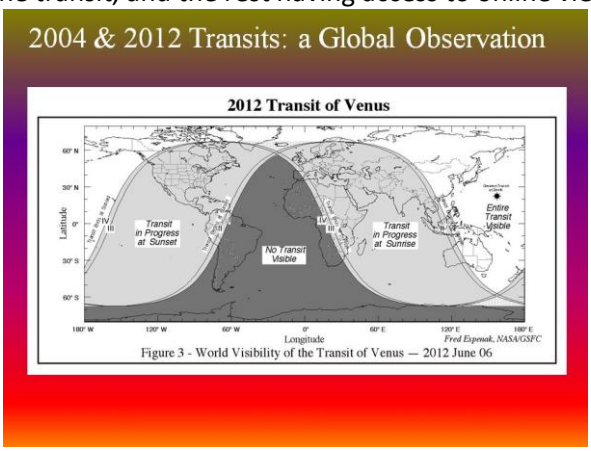




Within a half-hour, it was all over! But, we had witnessed an amazing event!
After about an hour of walking around congratulating one another, and replaying the videotape multiple times, I packed up and went home.

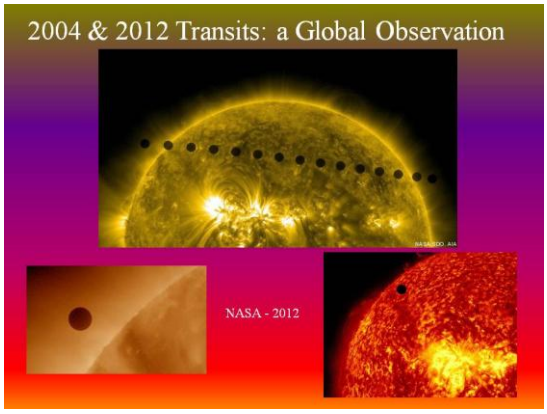
The 2004 and 2012 Transits: a Global Observation…. Cont.

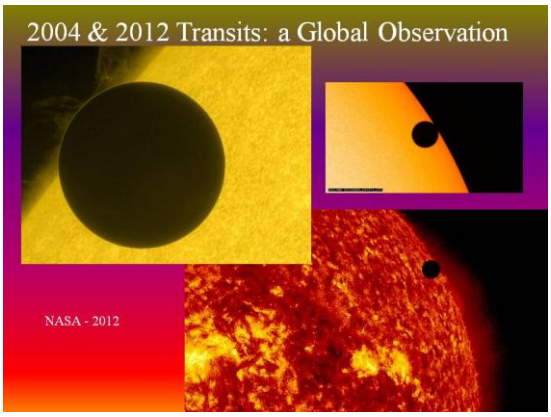
The 2012 Venus Transit was observed by an estimated 1 billion people with over half the world being able 'to directly observe some part of the transit, and the rest having access to online viewing over the internet.



For example, NASA ran a HD live video stream for the entire 6-hour 40 minute event using White-Light, H-alpha, and Calcium-K solar telescopes from the 13,800 ft summit of Mauna Kea Observatory in Hawaii. The broadcast included live interviews of solar and planetary astronomers from various agencies. The feed was even briefly carried over the major nightly broadcast news programs. The national science academies of numerous other countries, such as India, Australia, and Great Britain, also broadcast portions of the transit. Over 20,000 amateur astronomers worldwide participated by sending images.

Once again, here on the East Coast, we were only able to observe the initial stages of the transit, with Ingress – first & second contact starting a few minutes past 6:00pm and lasting till sunset at close to 8:30pm.
So even though we never got to see a transit in its entirety, those of us on the East coast did get to see the most exciting portions – ingress & egress, spanning two transits.





My personal experience….Cont.

2012: *Tuesday, June 5th, 2012:*

Equipment used: 8" Celestron Ultima SCT (f10). Daystar T-Scanner .6A H-alpha solar filter & StellaCam-3 1/2" CCD videocamera and a 40mm Coronado PST Cak with a Sony Super HAD B&W CCTV 1/3" CCD videocamera.

The day of the transit, a large cloudy weather pattern rotating in from the north-east had settled over the western PA region. The local Kiski club Transit party was soon cancelled, and I spent the early afternoon frantically looking for a break in the clouds within driving distance. Both of my alternate observing sites were engulfed in the cloud cover. I was about ready to give-up and begin unloading my car, when Gary, the organizer of the club Transit party called me. He had just gotten off the phone with Denny, another Kiski member, who noticed on the satellite images that a thin band of shoreline around Lake Erie was in the clear. It was a 'Reverse Lake Effect'! As the clouds traveled over the lake, they evaporated, but then reformed shortly after hitting land. Denny had passed that info on to Gary, who called me with a great location the he knew was right on the lake shore.

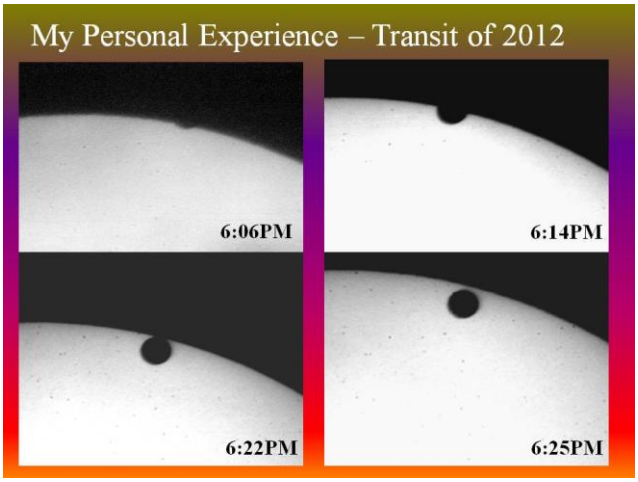
As soon as I hung up the phone with Gary, I realized that if I didn't leave 'now', I would not have enough time to make the drive. So I sent out a quick email to the club and jumped in my car and drove like a nut up I-79. I arrived at the North East Marina at 5:10pm to find mostly clear blue skies along the shore with a bit of a breeze coming in off Lake Erie. After picking out a spot in the grassy 'boat parking area', I proceeded to setup.

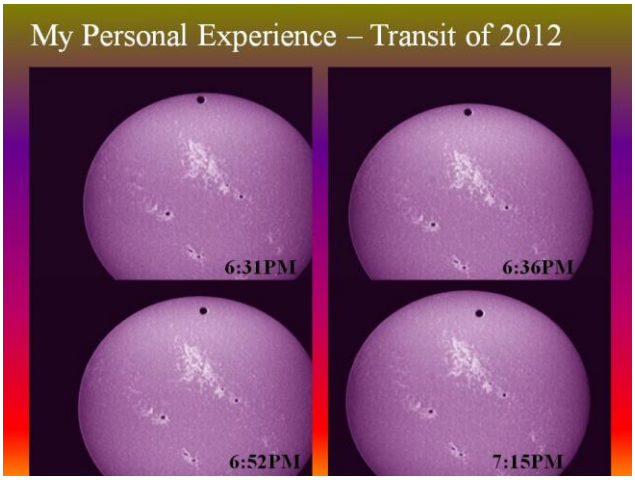
Had everything ready to go by 5:50 (except focusing the cameras) when the only grouping of clouds in the sky decided to 'park' right over-top the Sun.Finally, they thinned out enough for me to get the C8 on the Sun and the StellaCam-3 camera focused. I realized at that point I had missed 1st contact by less than two minutes.

Right about then a group of visitors stopped in, so between answering questions, starting up the camcorder to record the C8 StellaCam video feed,and getting the PST Ha scope pointed at the Sun on a separate tripod, I didn't get the PST Cak focused and video-capturing until after 2nd contact.

At that point the sky had completely cleared off, and the breeze had died down. A perfect late afternoon!
I was able to following the transit until the Sun reached the tree line, around 8:25pm.
On the drive home, was treated to a beautiful sunset over the lake.

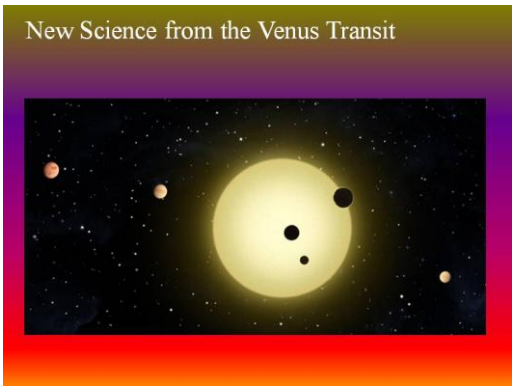
I was fortunate enough to once again witness an amazing celestial event!!!

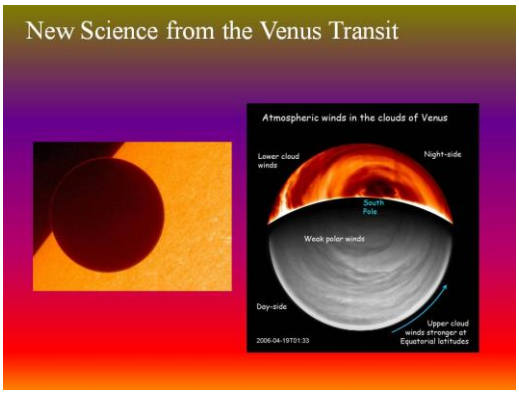




New Science from the Transit

A number of years back, scientist realized that like Venus, plants in other solar systems would also transit their own suns.From our perspective, Venus only blocks about .1% of our Sun during a transit. A similar planet orbiting another star would be much too far for us to visually observe, but sensitive instruments could be designed that could detect the miniscule drop in brightness of that distant star. This concept was proven in 1999 when a gas giant sized planet was detected transiting a G class star HD20948. Since then more than 230 exo-planets have been detected by using the transit method. Using data from the recent Venus transits, scientists are fine-tuning their detection software used by the Kepler Space Telescope, and hope to be able to detect Venus sized exo-planets sometime in the next few years.





Additionally, ground based observations of the small sliver of Venus's atmosphere visible during 2nd& 4th contacts, along with data from NASA's SDO & ESA's Venus Express orbiter was successfully used to refine wind models of Venus's upper atmospheric mesosphere layer.

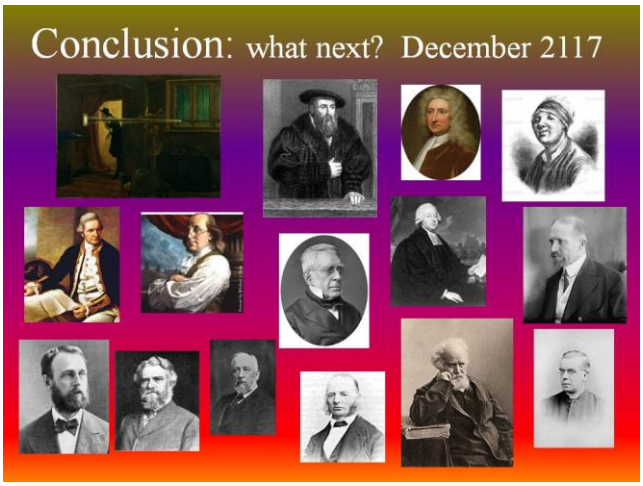
So, in a way, even after 252 years, the Transits of Venus continue to be scientifically important. Hopefully, they still will be 104 years from now, when we enter the next Venus Transit 'season'.

Conclusion – What Next – December 10th2117.

It's been years gone by now since the June 2012 Venus Transit.

The worldwide excitement of that day has started to fade, and with the realization that another transit season will not occur this century, it's become a little bittersweet thinking about the observations of 2004 & 2012.

But reading about the early astronomers involved with the Venus Transits over the centuries, and learning their adventures and stories still gives me inspiration, and leaves me with a feeling that I, as an amateur astronomer 350 years after Jeremiah Horrock's 1st brief observation, was able to stand on the shoulders of giants, and successfully observe and understand what they struggled and sacrificed to obtain.



I hope that 100 years from now, future amateur astronomers will look back to our time and our observations for a similar inspiration, and they keep the tradition alive of observing the Venus Transit!

Who knows what wonder observing tools that they will have available? X-Ray glasses with zoom lens.

Or if it's cloudy, just get in their "George Jetson" flying car with the family and head for orbit.

The Ferret of Comets

Good afternoon. Today we are going to take a short retrospective look back at the life of French astronomer Charles Messier, one of the best known astronomers and comet hunters from the 'Age of Enlightenment', which marked the birth of modern science. We'll also cover his greatest contribution – his list of deep-sky objects, to avoid while comet hunting, his '*Catalog of Nebulae and Star Clusters'.*

Outline

- Early Years:
- Equipment:
- Observations:
- Personal Life
- Legacy and Conclusion:

Early Years:

Charles Joseph Messier was born on June 26th, 1730 in the small village of Badonviller, located in the Lorraine region of France. Charles was the tenth child born, (out of twelve children) to his father Nicolas and mother Françoise Messier. At the time, the region where they lived was a semi-independent small state called the Principality of Salm. Nicolas was a court usher for the state princes, which allowed his family to live a decent well-off lifestyle in a large home. Still, six of Charles' siblings died while he was young, and at the age of 11, in 1741, his father Nicolas died. Charles also had a close brush when as a child he fell out of an upper story window and broke his leg. Due to the family's financial constraints, Charles had to leave school, and one of his older brothers finished his education and training in administrative work.

While a teenager, Charles' developed an interest in astronomy by the appearance of the six-tailed Comet of 1744, and a few years later in 1748 by an annular solar eclipse that was visible from his hometown.
From this spark, Charles began observing the stars and learning the phenomena in the night sky.

In 1751, Charles, now age 21, left home to look for work in Paris. With help from a family friend of his late father, Charles was able to get an interview with Joseph Delisle, the official astronomer of the French Navy.
Delisle found Charles fine hand-writing and drawing skills particularly useful and hired him as an assistant, at the Royal Navy observatory located on top of the Hôtel de Cluny in Paris, where he lived. Messier was given a room in the same hotel apartment wing with Delisle and his wife.

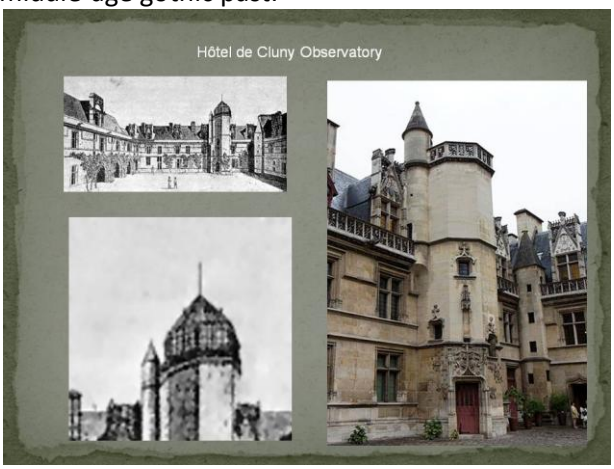
Messier's job was to keep careful records of Delisle's observations and copy maps and charts for use at the observatory. He was also to learn how the observatory functioned and instructed in using its various telescope instruments. Delisle took it upon himself to teach Charles elementary astronomy and precise record keeping and measuring exact positions of all observations. Messier excelled at the work he was given, finding it very suitable to his skills. By 1754, Charles was promoted to a clerk of the Depot of the Navy, making a tidy income and becoming involved in projects to create a new city map of Paris and a new large-scale map of France.

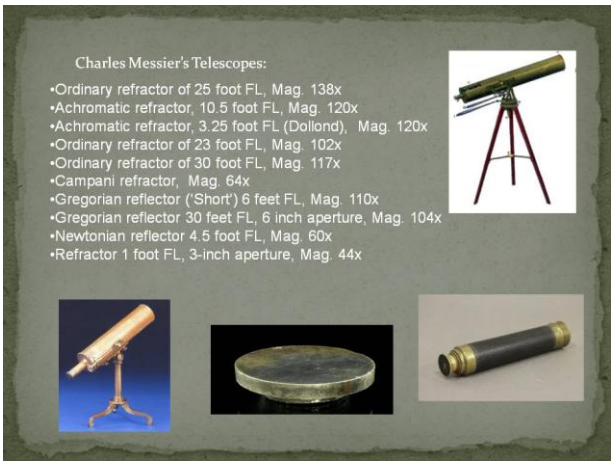
Equipment:

Observatory -

The Hôtel de Cluny was originally a medieval town house built in 1334 for the abbots of Cluny when they would visited Paris, and was constructed over the remnants of a third century Roman bath in one of the oldest districts of Paris. The townhouse and rebuilt during 1485–1510 for extended use of the local bishop, visitors from the Vatican, and the occasional royal. In the 18th century, the building was rented to the Royal Navy and the tower of the *Hôtel de Cluny* was used as an observatory by a number of French astronomers.

On the Roof of the tower was built a pyramidal structure with large side windows that could be opened. Inside was kept the portable observatory telescopes that could be positioned to point out of whichever window the observer preferred. After Messier's time, the observatory went unused, fell into disrepair, and was eventually removed from the tower. In 1843, the *Hôtel de Cluny* was made into a public museum, displaying historical objects from France's middle-age gothic past.





Telescopes -

Below is a list of telescopes that Charles Messier used at the Hôtel de Cluny observatory.

For the majority of his observing work, Messier used a small 100mm (4 inch) refractor.

The concept of interchangeable telescope eyepieces was not yet common in Messier's time; most of his telescopes have a fixed eyepiece lens and magnification. While some of Messier's reflecting telescopes had large apertures for the time, up to 8 inches, as they were made of speculum metal, which was the standard of the day, their light gathering ability was only about 70% when newly polished and generally the mirrors would tarnish quickly from the moist night air. Today's modern small refractor or reflector will easily outperform the best of Messier's telescopes.

While Messier's telescopes could be considered decisively mediocre, he always claimed to be satisfied with them as they generally worked well for what he was interested in, comet hunting.

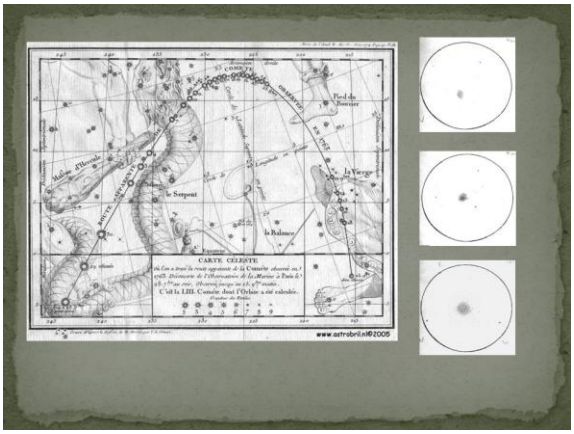
Observations:

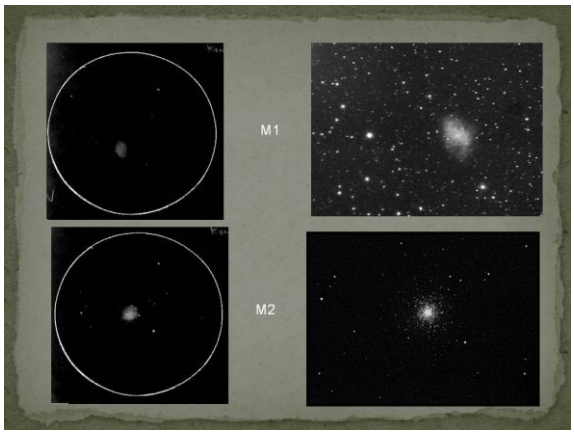
Charles Messier's first personal documented astronomical observation was that of the transit of the planet Mercury visible from Paris in May of 1753. Delisle was impressed by Messier's skill at making and recording the transit observation, along with Messier's knowledge of the observatory and it's equipment that Delisle decided to assign Messier in 1757 the task of searching early for the first predicted return of Halley's comet. Delisle drew up calculated star charts with the most probable positions of the predicted comets return for Messier to use in his nightly sweeps. Delisle instructed Messier to use the observatories 4.5 foot Newtonian reflector, specifically follow the charts, keep meticulous observation records, and not to waste time making any other observations.

During this period, Messier recovered his first returning comet in August 1758 and followed it thru early November. Finally on the night of January 21st, 1759, Messier swept up the faint glow of a comet. It was Halley's at last, appearing 52 days before reaching perihelion!

Then amazingly for some reason, Delisle decided to hold off on announcing Messier's historic recovery of the comet, and instead instructed Messier to tell no one, but to keep observing the comet until it was lost in the Sun's glare. This delay in the discovery announcement was to become the greatest disappointment in Messier's life, haunting him till the very end of his life. While waiting for the comet to rise above the Sun and become visible once again, news came that a German amateur astronomer from Dresden had actually been the first to see Halley's Comet back on December 25th of 1758. The news from Dresden had been delayed by several months and only now getting out, setting the astronomical world buzzing with the comet recovery. Messier was devastated by his lost of recognition, and it was not until early April that senior astronomer Delisle finally allowed Messier to publish his earlier observation. The lateness in releasing Messier's recovery led to skeptical criticism by other astronomers in why the observations were kept quiet, which caused more grief for Messier. In the end, Messier decided it was best to stay silent and loyal to his mentor and let it all go. This ended up working in Messier favor, as within a year of the 1761 transit of Venus, (which Messier made a successful observation of), Delisle retired and Messier was placed in charge of the observatory at Hôtel de Cluny where he could now dedicate himself to what Charles thought was his life's purpose, hunting for comets!

Before long, in late 1763, and January 1764, Charles discovered his first two comets using the observatories telescopes. He followed that up in 1766 by discovering a naked-eye comet that had been missed by all.
But, it was during his dark-of-the-Moon comet hunting that Messier began noticing a recurring problem, false comets! During his night sweeps, Charles kept finding faint dim objects that somewhat resembled comets. He would take the time to record their positions and watch for movement over several hours, sometimes for even most of an entire evening, only to finally realize he was wasting his time.
The objects weren't comets, but some faint nebula or unresolved cluster of stars.





Messier resolved in May of 1764 to keep a list of the objects as he found them so that during future comet sweeps, he could easily disregard these objects as not being the comets that he was interested in.

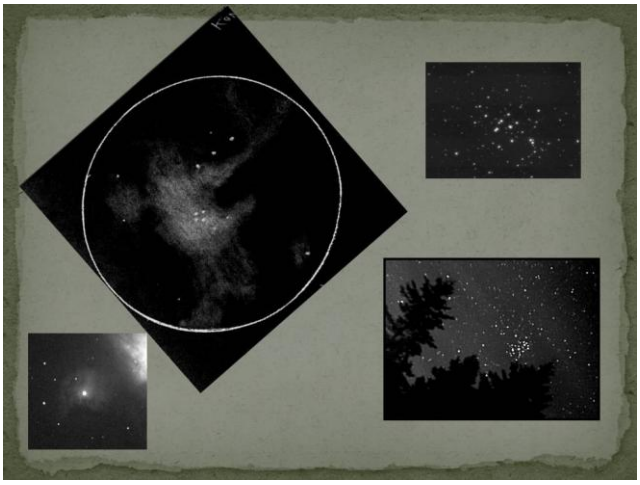
Charles decided to start making his list by re-surveying the already 16 known nebulas from antiquity.
These included the ancient hazy clouds that we know of today as the Andromeda nebula, the Double Cluster, Praesepe, the Coma Berenices cluster, and the Orion nebula.

Charles then expanded his research to more recently discovered objects by other astronomers over the last 150 years, such as Galileo, Lalande, Flamsteed, de Lacaille, and Bode who had added additional 'starry spots' such as the clusters in Scorpion's tail, in the middle of the Auriga chariot driver, and around the shoulders of Perseus, and the nebulous patches in Sagittarius the Archer and Scutum the Shield.
Before the year was out, Messier had a put together an observed list of 40 objects, 18 of which were newly discovered by him.

The first object in his list was the little nebula in Taurus that he had stumbled upon back in 1758 while searching for Halley's Comet. We know this object today as the supernova remnant M1, the 'Crab Nebula'.
The second object, M2, was a partly resolvable ball of stars in the constellation of Aquarius that we now know is a globular star clusters orbiting our home galaxy.

Within a few short months of Messier thinking he had finished his list of false comets to avoid, he stumbled on a new one, a faint cluster of stars in Canis Major, just below the bright star Sirius. Messier knew then that his search wasn't done, but other projects came up, forcing him to set aside this secondary list for the next year. One of these was a non-astronomical project involving the sea trials of a new marine chronometer used in determining longitude. Messier spent a number of months at sea, making the necessary astronomical observations needed for doing the calibrations on testing the clocks.

Once he finished that in early 1769, Messier returned to his comet hunting sweeps and decided to write-up his list of 41 'non-comet' objects, along with a description of what each one looked like and their celestial positions in the sky. But he decided to add a few more items to the list, including the already well known objects of the Pleiades and Prasepe star clusters and the Orion Nebula to round the list off at 45 objects.



But before he could publish the list, in August 1769, Charles discovered a new comet that became one of the Great Comets of the 18th century, developing a dazzling coma and a tail over 90 degrees long!.

This comet even brought royal recognition from the King of Prussia, Frederick the Great, by a written letter thanking Messier for his discovery, and for sending the king a map and description of the comet.
Charles followed this up a year later in June 1770 with another extraordinary bright comet discovery that brought worldwide recognition.

It was at this point that the King of France, Louis 15th, gave Messier the name “Ferret of Comets”.

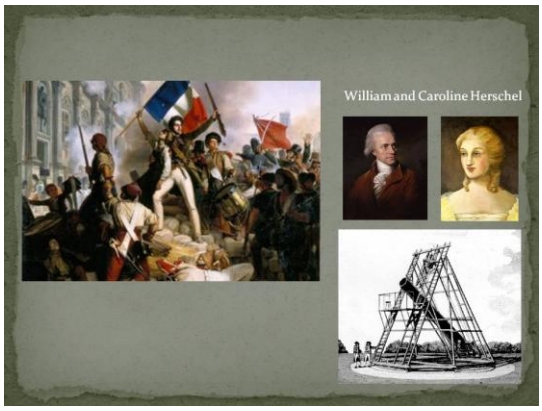
With these two great comet discoveries, Charles Messier was elected to the French Academy of Sciences. Shortly afterwards, in 1771, Charles was made the official Astronomer of the Navy, following in the footsteps of his old mentor, Joseph Delisle. And, in 1771 Messier was able to publish the first edition of his ‘*Catalog of Nebulae and Star Clusters’* in the official journal of the French Academy.
Charles Messier was now finally a world renowned astronomer!

But soon after publishing his catalog, Messier found four more objects to add to the list. He soon added a fifth in 1772, two more in 1774, and after a dry spell another in 1777. Unfortunately for whatever reason, Charles didn’t make his usual precision in recording some of the observations of these new objects, particularly M47 and 48, which led many future observers to miss-identify the objects. Messier continued to find additional new objects such that in early 1780, he published a new revised list of 68 objects in the French publication ‘Connaissance des Temps’. He then went on with help from fellow French astronomer and comet hunter Pierre Mechain to find another 32 faint ‘nebula’ by April 1781, bringing his list up to a new total of 100 ‘false-comet’ objects.

Pierre Mechain, 1744 – 1804, was gifted in physics and mathematics, and his abilities in astronomy was noticed by Joseph Lalande who had hired Pierre as a proof-reader. Lalande helped Mechain secure a post as assistant hydrographer with the Naval Depot of Maps and Charts. Through this job, he met Charles Messier and the pair became good friends, and worked together over the years as fellow astronomers. Right before Charles new list of 100 objects was to be published, Mechain sent another three objects which Messier threw in. Unfortunately, Mechain in his haste to get the new objects in time to Messier ended up duplicating the second entry, leading once again to confusing future observers.

Charles Messier went on to discover seven more comets in 1771, 1773, 1780, 1785, 1788, 1793, and 1798. Messier eventually became the discoverer or co-discoverer of 21 comets and made observations of a total of 41 individual comets, including both new discoveries and previously returning comets. Of the 45 comets discovered between 1758 and 1801, Messier accounted for almost half.
During this time, Messier had planned on revising his 103 objects catalog with additional searches. From an article in the *Connaissance des Temps* for 1801, Messier outlined plans to publish another updated version of his catalog, and that he had observed "still other" nebulous objects.

But with various distractions such as the injuries from his accident, the French Revolution, and William Herschel's deep sky searches with far superior equipment than what Messier would have, Charles never did move forward with his revisions and publishing a new list.



Over the centuries, as missing documents and manuscripts from both Messier and Mechain have been found by astronomers and historians, the case was made to expand the list to 110 objects to include those that Messier was thought to have planned on including in his final revision. Today, most sources now include those last 7 – 8 objects, though there is still some doubt as to the actual identity of several, including M102, M108 & M109. Though contested by some, M110 (satellite galaxy of M31) is generally considered to be the final object, and while Messier never listed it as an individual object, he did include it in his drawing of M31.

Out of the modern Messier catalog, Messier himself had independently found 65 of the 110 objects.
His friend and associate Pierre Mechain contributed 25 original discoveries. The remaining other 20 objects came from prior earlier sources and observers. Of the 110 objects, today we know that 40 are galaxies, 29 globular clusters, 27 open star clusters, 6 diffuse nebulae, 4 planetary nebulae, 1 supernova remnant, and 3 'misc' objects of the star cloud M24, double star M40, and the asterism of 4 stars M73.

(M51, M13, M8 M7, M57, M101 M17, M24, M27)

Personal Life:
Charles Messier married Marie-Françoise de Vermauchampt on November 26th 1770, after courting her over a fifteen year period. In the fall of 1771, the couple moved from the old Delisle apartment wing to better roomier section within the Hôtel de Cluny. There on March 15, 1772, Marie gave birth to a son, who they named Antoine-Charles. But the delivery didn't go well for either the mother or child, and Marie never recovered and passed-away on March 23rd, followed soon after by their son on March 26th.

According to popular legend, Messier's deep display of grief over his wife and son's death was as much from his missing the discovery of a new comet while attending to her on her death bed as to her actual passing away! It's been determined that this was a false story, as the actual comet in question was discovered a week before the delivery by another observer. In any event, Messier must have been devastated by the deaths of Marie and Antoine, as he went home to Badonviller in Lorraine for three months afterwards.

In November of 1782, while Charles and some friends were visiting a park owned by the royal family, he was seriously injured in an accident. Strolling along one of the many garden paths by himself, Charles noticed a small door off to one side that he thought went to another section of the park. Upon stepping into the dark interior, he fell 25 feet into what was an old ice cellar and had to be rescued by rope and ladder.
Messier received a severe bloody head wound and multiple broken bones, including several ribs, one of his wrist and arms, and his right thigh which didn't heal cleanly and had to be re-broken by his doctor.
That left him with a permanent limp that became disabling in his old age.

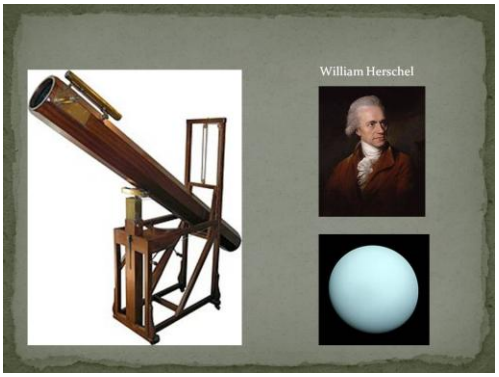
Messier was laid-up for a very long time, and it was almost a year before he could return to work at the observatory. A number of years later, one of Charles sister's, Anne, came to Paris to live with Charles for awhile, but she passed away in 1798. Thereafter, was looked after by one of his nieces.

During Charles Messier's lifetime, he gained many honors: In 1764, he was elected a fellow of the Royal Society of London. In 1769, he was elected a foreign member of both the Royal Swedish Academy of Sciences, and the Berlin Academy of Sciences. And in 1770, he was elected to the French Academy of Sciences, his most cherished membership. In 1785, he became an editor of the French science publication 'Connaissance des Temps' and served for a five year term.

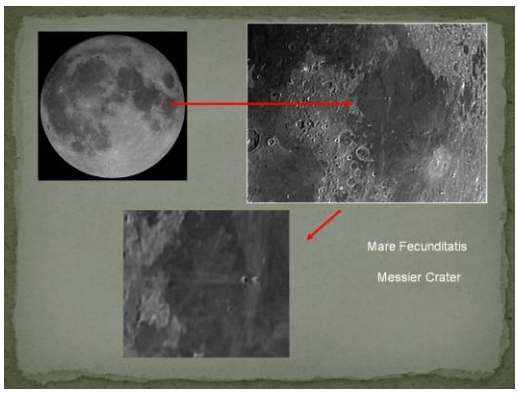
Messier lived thru the bloody French Revolution where the guillotine claimed a number of his friends and colleagues and went on to receive the 'Legion of Honour' Cross from Napoleon in 1806 for his lifetime astronomical work. Soon after this, Messier went into semi-retirement, but occasionally still used the old observatory at the Hôtel de Cluny, which had fallen into disrepair with no one to really look after it. In 1815, Messier had a stroke that partly paralyzed him. Finally in the spring of 1817, at the age of 87, Charles came down with a virus and after a few days in bed, died on April 12.

Legacy and Conclusion:
Over the course of his lifetime Charles Messier discovered 21 new comets, including the Great Comets of 1769 & 1770. Charles is also credited with the first recovery observations of many previously found comets, including being one of the first to recover Halley's Comet in 1759.
Like most astronomers, in addition to his many comet observations, Charles Messier also observed the planets Saturn, Jupiter, and Mars when they were at favorable oppositions, along with the Moon and its craters. While during the daytime, he successfully observed transits across the Sun of both Mercury in 1753 & 1782 and Venus in 1761, and tracked and recorded over 100 solar sunspot observations, and even kept records of the daily meteorological weather!

Charles Messier was also involved in 1781 with the follow-up confirmation observations of William Herschel's newly discovered object, putting his then considerable comet hunting expertise into validating that is was not some new form of comet, but instead a planet – Uranus! This led to a friendly long-term relationship between the two great observers, with Herschel actually traveling to Paris to visit Messier.



In 1775, French astronomer Jerôme de Lalande created a new constellation named after Charles Messier.
He called it '*Custos Messium*'. This constellation was located on the borders of Cepheus, Cassiopeia and Camelopardalis. It did not receive wide-spread support from the astronomical world, and was eventually dropped from usage. But Charles Messier's lifetime achievements was honored by the international astronomical community by naming a pair of Moon crater's after him, located in Mare Fecunditatis.
Also asteroid 7359, discovered on January 16, 1996, has been named "Messier" in his honor.



But none of this is what Charles Messier is known for today.
Instead, it is his list of fixed diffuse objects to avoid while comet hunting, his '*Catalog of Nebulae and Star Clusters',* that today's modern amateur astronomers seeks out as bright showcase galaxies, nebula, and star clusters of the night sky. His 100+ deep sky objects listed in hundreds of books, observing guides, magazines, and star atlases over the centuries and beloved by today's amateurs is his legacy!
That is what Charles Messier, the "Ferret of Comets", is renowned for in the 21st

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The Herschels and Their Catalog

Introduction

Good afternoon. Today we are going to take a retrospective look back at the lives of William and Caroline Herschel. Two of the greatest astronomers from the 'Age of Enlightenment', which marked the birth of modern science. We'll also cover their greatest contribution – their catalogue of deep-sky objects, and we'll discuss my personal observations of these objects.

Outline

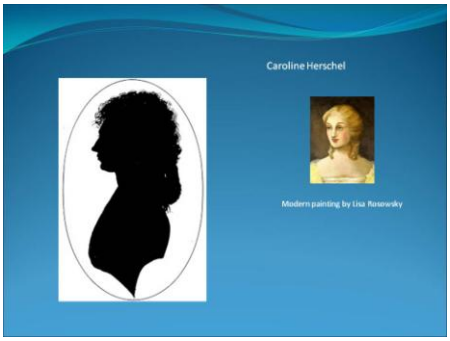
- William Herschel:
- Caroline Herschel:
- Together in England:
  - The Survey begins.
  - Dangerous work
- The Herschel Catalog – 2400+ objects:
  - Herschel's classification system: a scientific revolution.
  - My examples from all 8 Herschel classes.
- William and Caroline's lifetime achievements:

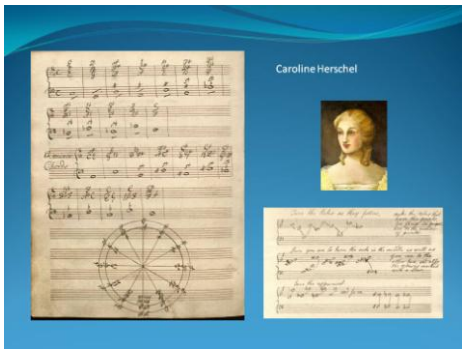
William Herschel

Friedrich Wilhelm (William) Herschel was born on November 15th 1738 in Hanover Germany.
He was the third child (out of an eventual 10), of his parents, Isaac and Anna Herschel. Isaac was a member of the Royal Hanoverian Foot Guard regimental band, where he played the oboe. Early on, Isaac taught William and his other brothers music, using various instruments as the oboe and violin. He also paid to have his sons receive extra instructions from the garrison teacher in math and French. Additionally, Isaac was a keen reader and loved to discuss philosophy at home with William and his older brothers. But, most importantly for both William and Caroline, Isaac had a personal interest in astronomy, and taught all his children the constellations and names of the stars at night. As a teenager, William joined his father as a member of the Hanoverian Guard band. At age 19, William ended up fighting with the Hanoverian regiment during the 'Seven Years War' in a disastrous battle with the French at Hastenbeck. With his regiment defeated and musket balls flying around him, William took refuge behind a hedge and made it back to Hanover.

With the fear of French invasion, and as William was just a musician and not really enlisted or trained as a full-time soldier, his father Isaac decided it would be best for William to leave Prussia and helped him to escape to England in 1757. There, William found employment as a music teacher and organist in Bath England.
In addition to the oboe, he played the violin and harpsichord and later the organ at a local chapel. Herschel quickly became a very successful musician. He composed numerous musical works, including 24 symphonies, as well as some church music, and gave many concerts. He was eventually able to fund his younger brother Alexander and sister Caroline to come join him in England in 1772. Herschel was eventually appointed director of the Bath orchestra, and his sister Caroline, who he trained, would often appear as soprano soloist.

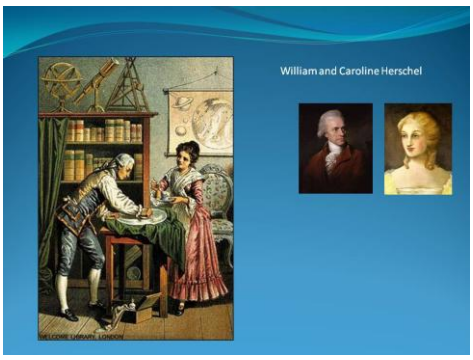
Caroline Herschel:
Caroline Herschel was born in Hanover on March 16th, 1750, 6th out of 10 siblings. Her mother Anna Herschel was illiterate and generally disapproved of education for girls. But she did allow Caroline to learn basic reading and writing, along with home skills such as knitting, washing, and cooking that would make her more eligible for marriage. Her father, Isaac, did teach Caroline how to play the violin, and William and his older brothers would sneak music lesions to Caroline as often as they could. At the age of ten, Caroline was struck with typhus, which stunted her growth and she never grew taller than four foot three inches.





As a young girl, Caroline always looked up to her older brother William, and greatly missed him when he moved to England. So she was quite excited when William came home to Hanover on a trip in 1772 and brought her back to England to live with him. On the long trip back to England William began teaching her to speak English, and at night, when their coach was traveling thru the countryside, he would point out the constellations to Caroline.
Once settled in at her new home in Bath, Caroline began taking several singing lessons a day from William.
This was in addition to also learning bookkeeping, and being put in charge of running the household for her two brothers. Soon Caroline became the principal singer at his concerts, and acquired such a reputation of her own as a vocalist that she was offered various engagements such as the annual Birmingham festival.

Together in England:
During this time, after Caroline had joined him in England, Herschel's music career led him to an interest in mathematics and lenses. This in turn, led to an interest in astronomy, and like his father, William became an avid amateur astronomer in the spring of 1773, first reading any astronomical book or list of tables he could borrow or purchase, then buying a quadrant to measure the location of stars, to renting a small reflector, and then finally proceeding to build his own 7" reflecting telescope with help from Caroline. *(aperture fever)*
He would spend up to 16 hours a day grinding and polishing the speculum metal primary mirrors, which was the standard of the day. William wouldn't even take time out to sit down for dinner, so Caroline was forced to cut up his food and feed it to him while he worked.

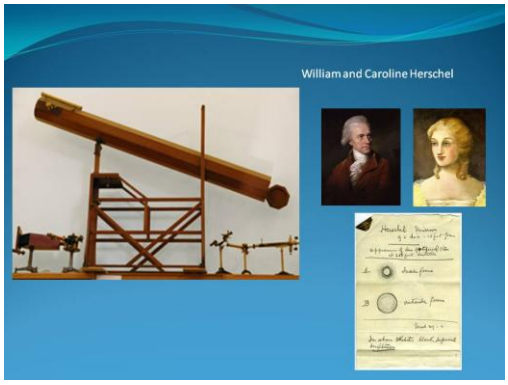


Caroline and her brother Alexander were also themselves greatly involved with the construction, working on the telescope tube and eyepieces. All this took up every free moment of time they had, as there was still music lessons, concerts, and Church performances they gave to keep the house over their heads and to pay for the workshop equipment and supplies need to construct the telescope.

Finally, in late 1773 the telescope was finished, and Herschel began observing the stars and planets.

Soon Herschel developed a reputation as a somewhat obsessed observer, going as far as when in the middle of a music lesion, William spied clearing skies out the window, he dropped his violin, and ran out to observe with his telescope, dragging the music student along. Word of his observing skills with his telescope began to spread far and wide, leading to other local astronomers stopping in to introduce themselves and to have a look thru his telescope. Thru this, William's interest in astronomy grew even stronger, especially after he made the acquaintance of the English Astronomer Royal Nevil Maskelyne, thru a mutual friend who had become impressed with Herschel's knowledge of the sky and his skill as a telescope maker and had reported such to Maskelyne.

With the Astronomer Royal's encouragement, William began sending regular letters and observing reports to him, and he in turn passed them on to others at the Royal Society, praising Herschel's observing and telescope construction skills. Herschel's early observational work focused on the search for pairs of stars that were very close together visually. In October 1779, with encouragement from the Astronomer Royal, Herschel began a systematic search for such stars among "every star in the Heavens". He soon discovered many more binary and multiple stars than expected, and compiled them with careful measurements of their relative positions in two catalogues presented to the Royal Society in London in 1782 (269 double-star systems) and 1784 (434 systems). Herschel eventually discovered over 800 confirmed double star systems, and his theoretical and observational work provided the foundation for modern binary/double-star astronomy.



But beforehand, on March 13th, 1781, at the age of 42, Herschel observed an object with an unusual disk-like shape. At first he thought it was a new comet, but after following it for several nights and calculating its orbit, he realized that it was instead a new planet with an orbit beyond Saturn. William quickly sent a report to the Astronomer Royal, who encourage Herschel to write an account of his discover and technical details of telescope used and his observing methods, and that was presented to the Royal Society on April 26th., which led to an invitation to travel to London for a formal reception. Once the new discovery had been confirmed over the summer by various observations from professional astronomers across Europe, Herschel was invited back in November to London, where he received a gold medal from the Royal Society, and inducted as a member.

Herschel wanted to name his new planet after King George III of England, but the general consensus of the worldwide astronomical community was to follow the classical Greek/Roman Gods naming of planets and Uranus was the name chosen. For his discovery, King George in 1782, knighted Herschel as the "Kings Personal Astronomer" was given an annual pension. This allowed Herschel to retire from music and devote himself fulltime to astronomy.

Like William, Caroline had always been interested in the night sky from her father teaching them the constellations, so she was a willing participant in William's new endeavor. After William began his astronomy surveys, she learned to record, reduce, and organize her brother's astronomical observations.

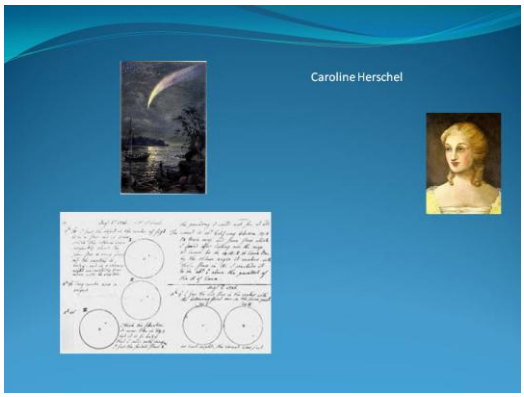
At William's insistence in 1782, Caroline even began making her own solo observations, first using a small spyglass telescope. Seeing Caroline's determination to make her own observations, in 1783 William gave Caroline a 4.2" f6 reflector telescope that he built for her, and she began to make astronomical discoveries in her own right, particularly comets.

She eventually discovered eight comets, and 10 new deep-sky objects (1 galaxy and 9 starclusters).
Caroline kept track of her deep-sky discoveries with the intention of creating her own catalog, eventually recording entries for 21 different objects. But five of the objects observed by Caroline had been previously discovered a few years prior by Charles Messier (M29, M46, M48, M93, & M110) and two by Philippe de Cheseaux (NGC6633 & IC4665), all of which Caroline had been unaware of due to their either being unpublished, reported with positional errors, or miss-identified by Caroline. Additionally, two objects were never able to be reconfirmed and are considered lost, and one object was a duplicate.

It's been suggested that William was so impressed by Caroline's deep-sky discoveries that had been missed by other astronomers, that she was what inspired him to undertake his great survey to find and observe all the possible deep-sky objects from England. William incorporated all of Caroline's discoveries into his catalog, and gave her credit for discovering them, but over the years due to clerical errors, a few of these were mistakenly attributed to William.

Caroline also updated and corrected John Flamsteed's catalog of star positions. This was published as the British Catalogue of Stars, and she was honored for this work by the recently formed Royal Astronomical Society.
Caroline also continued to serve as William's assistant at the telescope. In 1787, she became the first woman to receive a salary for services to science when she was granted an annual pension by King George III for her work as William's assistant.

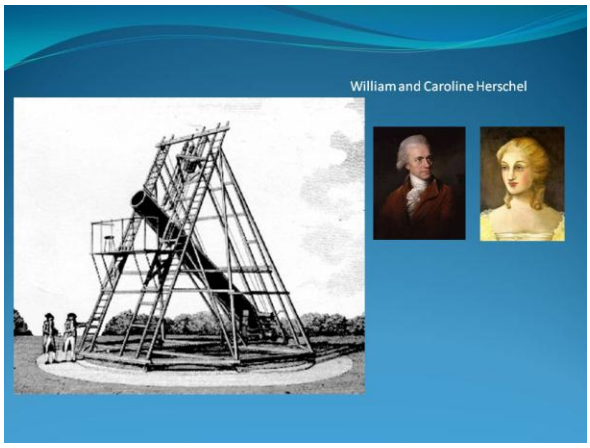
With the increasing demands on Caroline's time from assisting her brother in his own survey, to being responsible for running the Herschel household, Caroline abandoned her own catalog and focused her free time on comet sweeping.



The Survey begins.
That summer of 1782, the Herschel's quickly relocated to a small village within a mile of Windsor Castle and commenced building a new giant telescope, a permanently installed "20-foot Reflector".
For the next 20 years, from late 1782 to 1802, William and Caroline Herschel conducted systematic surveys in search of "deep sky" or non-stellar objects with his telescopes.

Herschel used two telescopes for his survey, a "20-foot Reflector", which had an 18.5" speculum-metal mirror, and later after they had relocated to a better location nearby at Slough, the great "40-foot Reflector" with a 48" mirror. Both mirrors were made by the Herschel's and had to be regularly polished, as the metal mirrors were quick to tarnish in the wet climate that England is noted for.

When he constructed the “40-foot”, Herschel actually made two sets of mirrors, one of which he kept polished and stored indoors, ready to be swapped out with the working mirror every year when it began to go bad. Then during the day, he would work on getting the swapped mirror re-polished while continuing his and Caroline’s nightly observations with the new mirror.
Most of Herschel’s recorded observations were made using the ’20-foot’ telescope, as the larger ’40-foot- was cumbersome to use and suffered from tube current distortions. (it was no modern day truss tube).
(the ’20-foot’ was the instrument that William’s son John Herschel took with him years later to Capetown South Africa to use in surveying the southern sky).



Herschel’s telescopes didn’t have clock drives to track the stars, so instead, he would point the telescope to the meridian and let the Earth’s rotation carry objects across his field of view while he was up on a latter observing. William would then call down to Caroline, at the bottom of the telescope, whenever he saw anything interesting, and she would write down his descriptions and time and where the telescope was pointing. Caroline would then quickly read this back to William and he would confirm the observation while the object was still in the eyepiece.

This method allowed them to observe and record a nightly east-west strip of sky. The next day, the two of them would use their recorded observation to calculate the objects position on a star atlas. They would then move the telescope’s elevation up or down, in preparation of the next nights survey run.
Using this method, they were eventually able to observe all of the sky visible from England. They ultimately discovered over 2400 objects defined by his unique classification system.

During this 20 year survey period, William Herschel also wrote numerous papers on varying astronomical subjects when he regularly presented to the Royal Society. He also supplemented his annual income by producing over 300 telescope mirrors sold around the world.

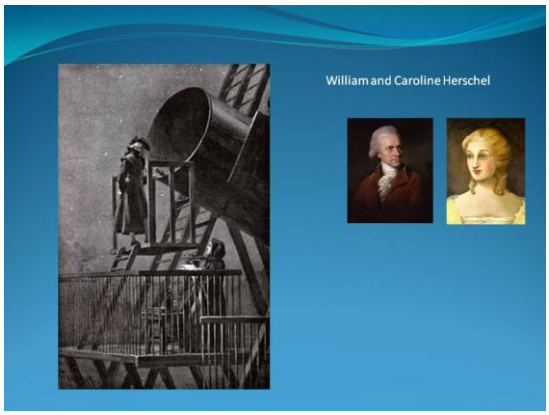
Dangerous work.
Even with a pension as the ‘Kings Personal Astronomer’ didn’t necessarily mean that the Herschel’s led a leisure free life. They still needed to build, maintain, and physically use the telescopes at night.
This sometimes led to dangerous accidents.

In the summer of 1781, William, who was always trying to make bigger mirrors, attempted to cast a 36” speculum mirror using a new metal alloy formula that he hoped would be strong enough not to sag from its own weight. William and his brother Alexander had completed the mirror mold, fired-up their furnace oven, and melted over 500 pounds of metal for casting the mirror. As they poured the molten metal into the mold, it began leaking from a crack. Before they could do anything, the metal poured out, and hit the stone floor causing it to crack and literally explode flinging chucks over their heads as they ran for the door.

Another time, late at night, William went to sharpen one of his tools, and nearly took off his fingers on the grindstone.

Caroline was William's constant companion in his nightly observations, recording at night everything William observed at the telescope, and fetching anything he might need. During one winter observation run on the "20-Foot"telescope in 1783, Caroline, coming back from an errand adjusting the telescope alignment tripped on the telescope's framework and became impaled on an iron hook used for securing the ropes that controlled where the telescope pointed. She was pinned to the sharp hook, which had gone deep into her leg, and had to call for help. After several minutes wondering where she had gone, William finally heard Caroline calling and had to run back to the house to fetch several servants to help pull her of the sharp hook. Caroline didn't come off the hook easily, and later wrote that when she was helped off "...they could not lift me without leaving nearly 2 ounces of my flesh behind". She was laid up for several weeks, recovering.

Finally, William and Alexander narrowly avoided being crushed by the 1-ton "40-Foot" mirror when swapping it out to be re-polished, the tackle-beam snapped, dropping the mirror several feet.



The Herschel Catalog – 2400+ objects:
Herschel's classification system, a scientific revolution.
William Herschel published his deep-sky discoveries as three separate catalogues:
Catalogue of One Thousand New Nebulae and Clusters of Stars (1786),
Catalogue of a Second Thousand New Nebulae and Clusters of Stars (1789),
Catalogue of 500 New Nebulae ... (1802).

Herschel classified his list into eight sub-categories:

Class I - Bright Nebulae;
Class II - Faint Nebulae;
Class III - Very Faint Nebulae;
Class IV - Planetary Nebulae;
Class V - Very Large Nebulae;
Class VI - Very Compressed and Rich Clusters of Stars;
Class VII - Compressed Clusters of Small and Large Stars;
Class VIII - Coarsely Scattered Clusters of Stars.

One of Herschel's main goals was to observe the sky systematically and map the distribution of stars, to gain a picture of where the sun stood in relation to the Milky Way. In all, Herschel catalogued close to 9,000 stars, far more than any of his predecessors, and he increased the number of known nebulae and clusters from Messiers 103 to almost 2500 objects. Herschel was the first to invent and use a method of classifying deep-sky objects.
This was a powerful tool in understanding the relationships between the different objects in the heavens, and changed the focus of astronomy. Herschel was especially interested in the classes of nebula that he discovered. Herschel theorized that the difference in various nebulas appearance was due to their distance, age, and effects of gravity. He felt these objects were evolving over time, and that the universe was in constant state of change. Herschel's theory resulted in a scientific revolution that the later Victorian and Modern day astronomers used to create our present-day understanding of our galaxy and the universe.

Each of Herschel's sub-category objects are numbered in the sequential order by when they were discovered. So unlike the Messier Objects, Herschel Object# VII-255 may have been discovered years before object# III-81. In Herschel's time, the galaxies were considered to be all just nebula, so there is no separate class for them, and they are mixed among the first five classes. Nearly three-fourths of Herschel's objects are classified as type II & III, faint and very faint. (mostly galaxies). Herschel's classes are actually useful in giving the observer an idea of what the object will look like visually at the telescope. For example, Class-I objects are bright nebulous objects, though some are actually galaxies. Class-VI objects are generally nice bright, rich open star clusters.

My examples from all 8 Herschel classes.

Ingredients to successfully observing the Herschel Objects:

Visually:

Moderate sized telescope – 10"+ or greater mirror

Dark Sky location – Cherry Springs

Electronically aided:

Deep-Sky Video Camera

CCD Camera or DSLR

Equatorially mounted Telescope 4"+ or greater

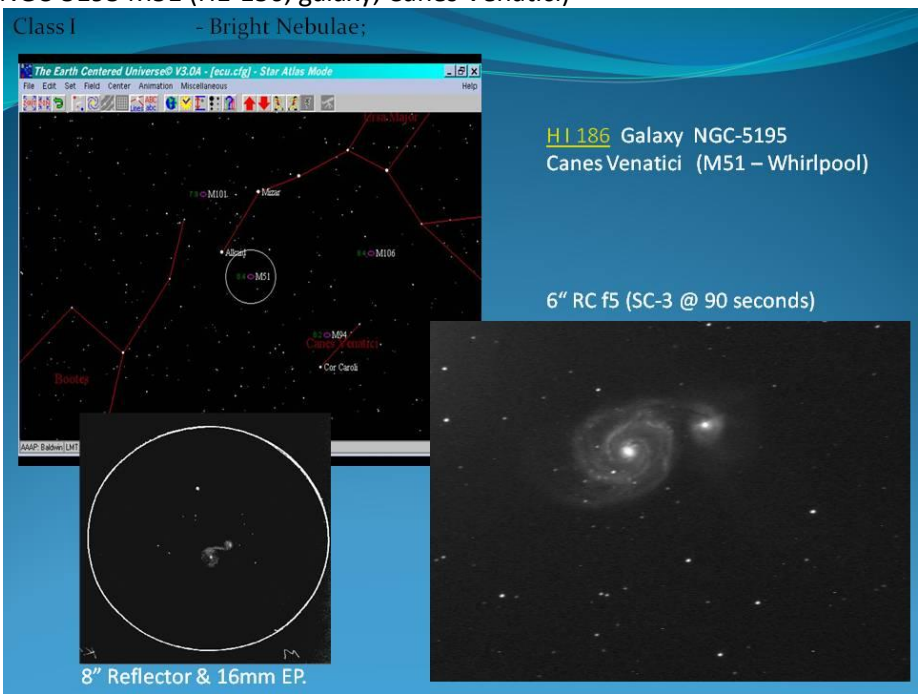
Deep Star Chart or Planetarium Software

Observing Plan

Class I - Bright Nebulae:

This Herschel class tends to be objects of various sizes and shapes, such as galaxies, clusters, and nebula. But the one thing they all have in common is that they are very bright. These are the easiest Herschel Objects to observe.

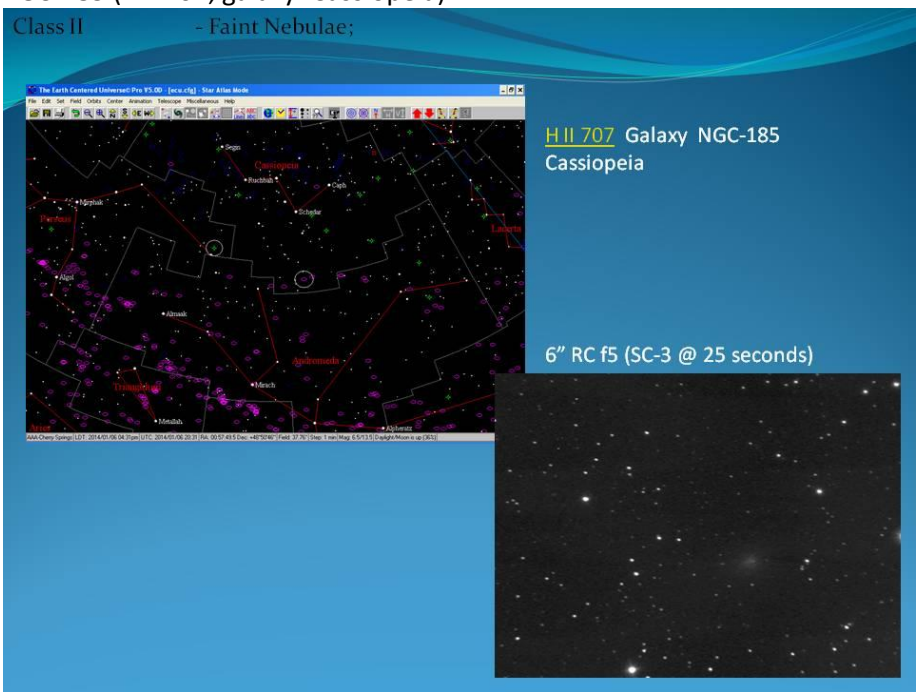
NGC-5195 M51 (H1-156, galaxy, Canes Venatici)



Class II - Faint Nebulae:

This Herschel class tends to be objects that are generally faint, such as unresolved clusters and dim galaxies. You'll need fairly dark skies and a medium to large telescope.

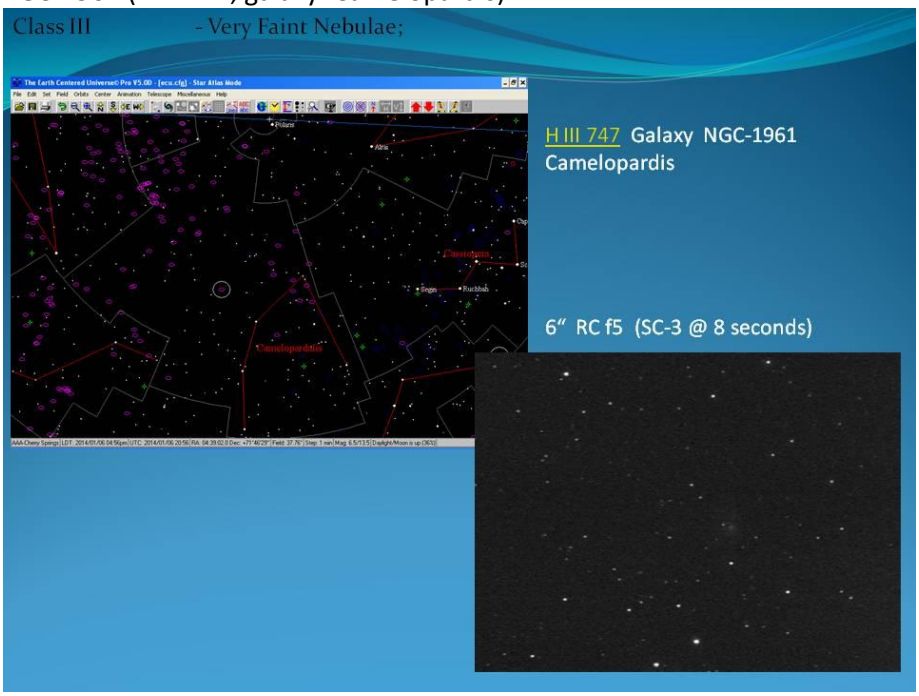
NGC-185 (HII-707, galaxy: Cassiopeia)



Class III - Very Faint Nebulae:

This Herschel class tends to be made up of very, very faint objects, mostly galaxies. This class of objects will require a dark sky location, a large telescope, or video / CCD camera, and a bit of luck.

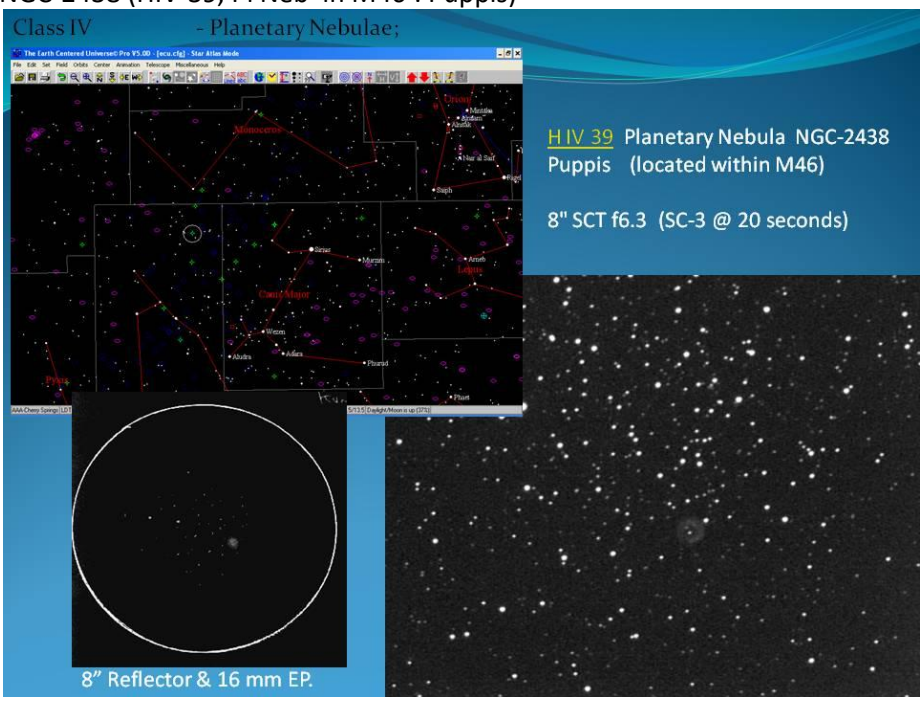
NGC-1961 (HIII-747, galaxy: Camelopardis)



Class IV - Planetary Nebulae:

This Herschel class tends to be made up of objects that are actually planetary nebula, but you can find some emission nebula and galaxies mixed in.

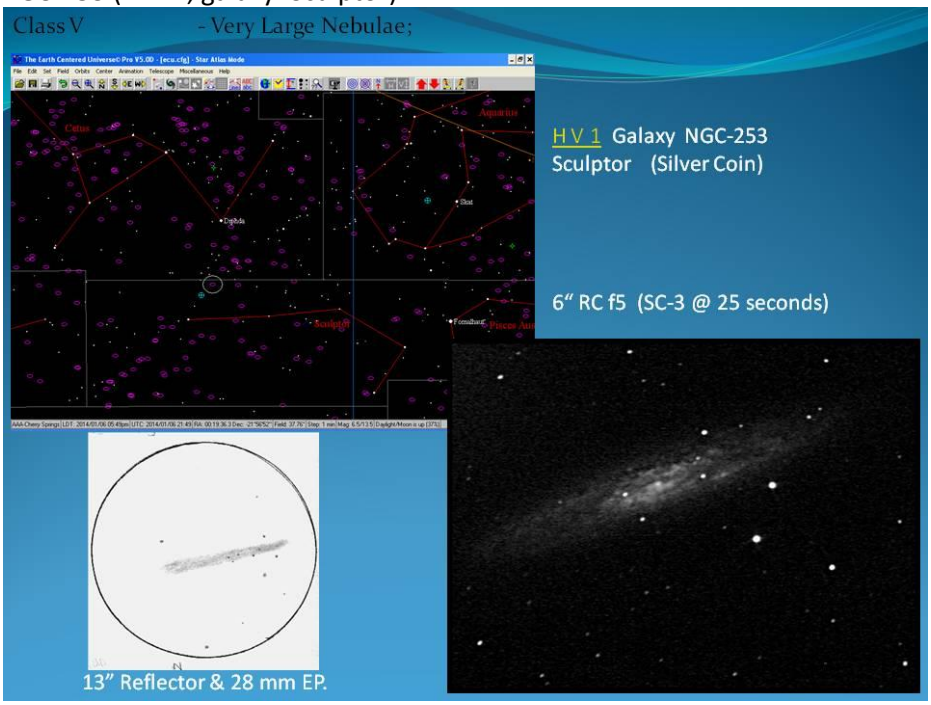
NGC-2438 (HIV-39, Pl Neb 'in M46': Puppis)



Class V - Very Large Nebulae:

This Herschel class tends to consist of very large deep-sky objects. They may not necessarily be very bright. Depending on the object, you may need a dark-sky location, and a wide-field eyepiece.

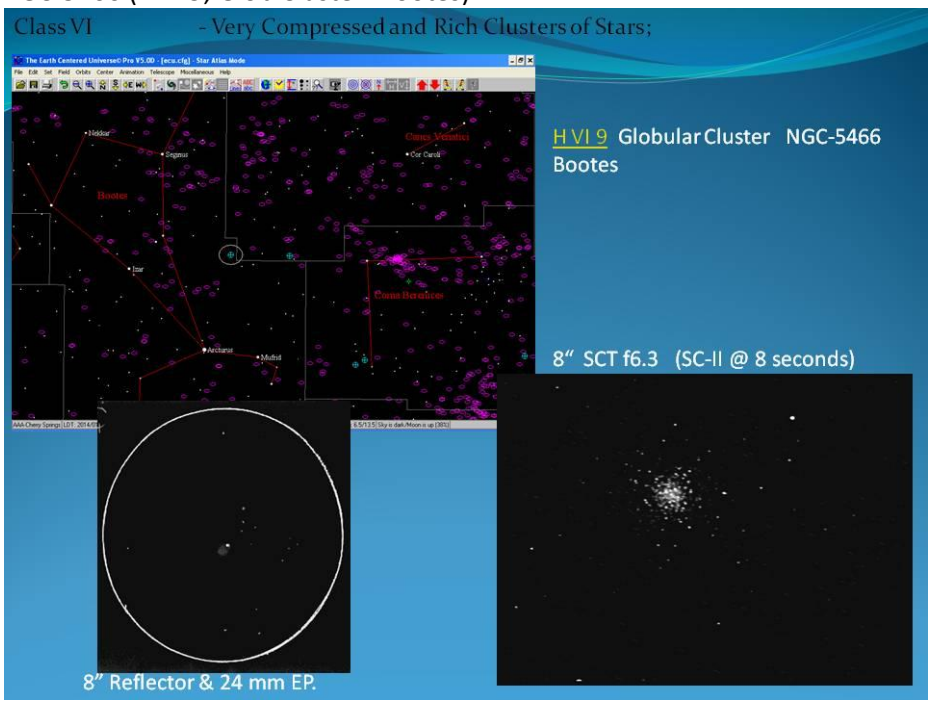
NGC-253 (HV- 1, galaxy: Sculptor)



Class VI - Very Compressed and Rich Clusters of Stars:

This Herschel class tends to be mostly bright resolvable globular clusters, and large open clusters with numerous members.

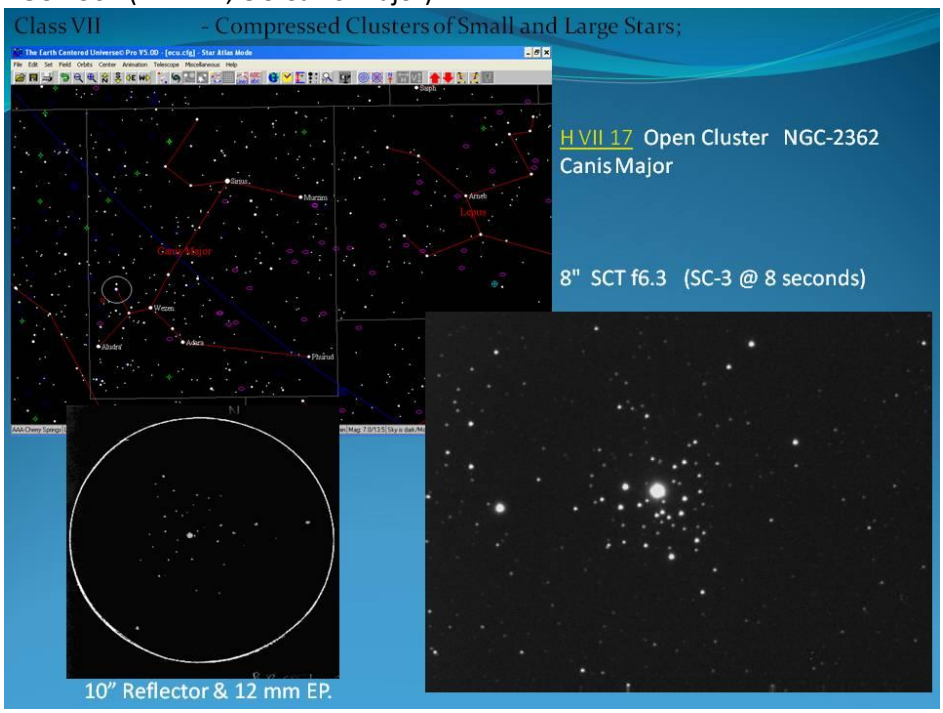
NGC-5466 (HVI-9, Glob Cluster: Bootes)



Class VII - Compressed Clusters of Small and Large Stars:

This Herschel class tends to be open clusters containing bright fore-ground stars, or cluster members with widely varying luminosities.

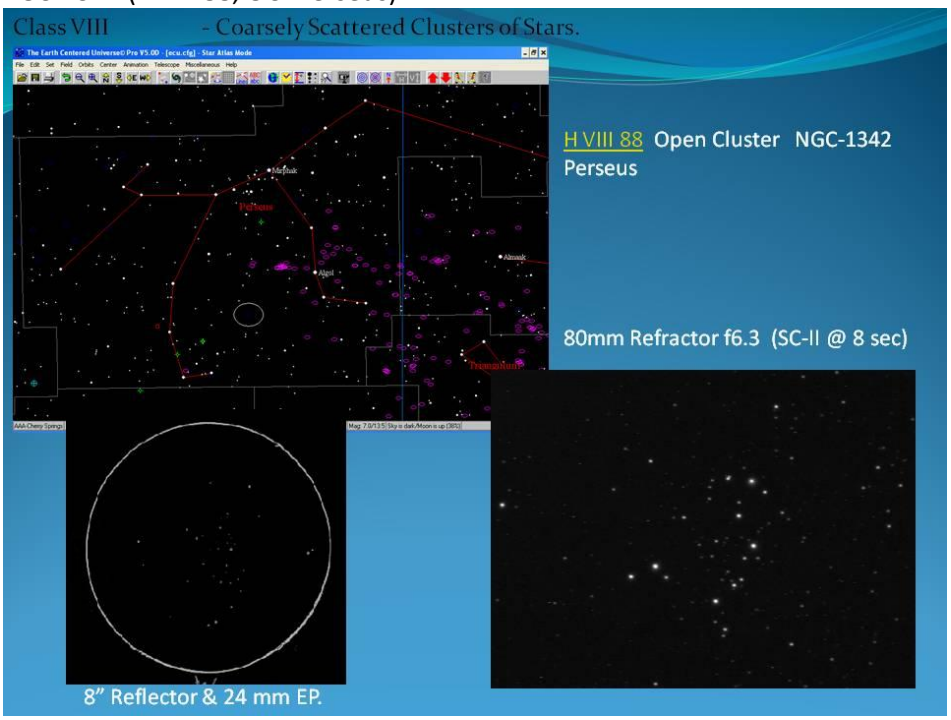
NGC-2362 (HVII-17, OC:Canis Major)



Class VIII - Coarsely Scattered Clusters of Stars:

This Herschel class tends to be loose, somewhat dim open clusters . Best suited for wide-field eyepieces.

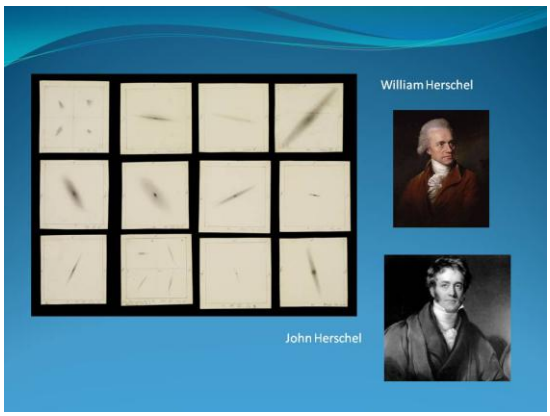
NGC-1342 (HVIII-88, OC: Perseus)



William and Caroline's lifetime achievements:

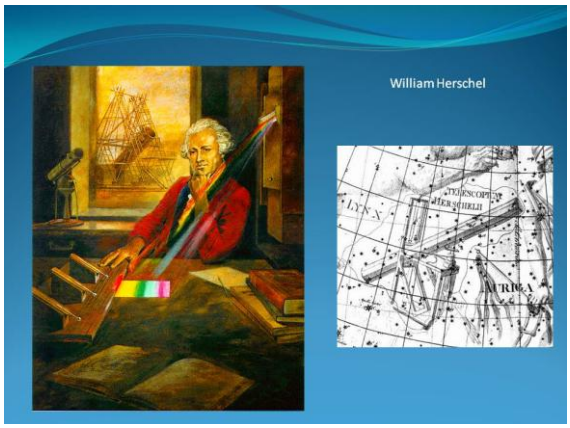
On November 30th, 1788, at the age of 50, William Herschel finally settled down to a family life by marrying a local, Mary Pitt, who he had courted for a few years. William and Mary had one child, John Herschel, born at Observatory House on March 7th, 1792. John didn't take up astronomy until after 1816, having first pursued careers as a lawyer and then a mathematics professor at Cambridge. But like his father, John soon became obsessed with all things astronomy, eventually learning how to polish the "20-Foot" speculum mirror from his father and building a new telescope framework for the mirror.

In 1821, with William at the age of 82, in declining health, he and sister Caroline made one last survey sweep of the skies, in order to train John on the proper procedures of using the '20-Foot' telescope and recording the observations in the same format they used since 1782. John then went on to expand his father's deep-sky catalog using the '20-Foot' telescope at Capetown South Africa, and became a great astronomer in his own right.

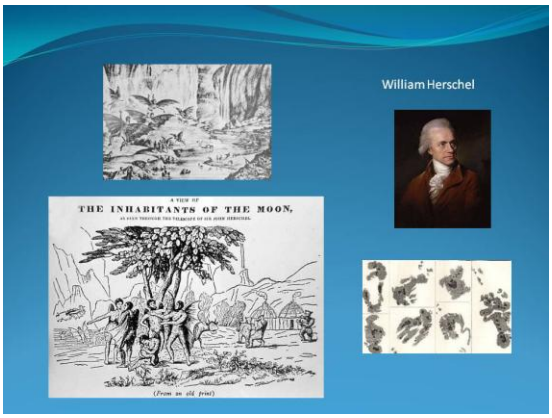


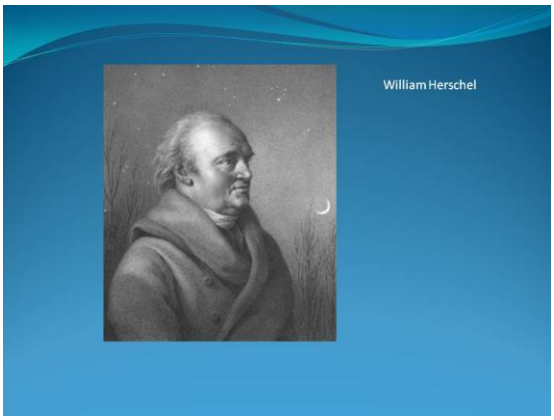
In addition to his discovery of the Planet Uranus, William Herschel also discovered two of Uranus's moons, Titania and Oberon, along with two additional moons of Jupiter, Mimas and Encleladus. Herschel was the first to measure the axial tilt of Mars, and discovered that the Martian season impacted the size of the ice-caps. He invented the word 'asteroid' (meaning 'star-like') for the class of minor planets that were being discovered during his time. Herschel also observed the Sun and tracked sunspots, and while trying to build a better solar-filter in 1800, discovered infrared radiation heating by sunlight. He did this by experimenting with passing light thru a prism and using a thermometer to measure each color spectrum's temperature. After taking the temperature of 'red', he moved the thermometer outside the 'red' range and got a higher reading than any in the visible range.

He discovered nearly 1000 double-stars and that they move around a common gravitational center, along with our solar systems direction of travel thru space. William was the first to devise the theory that our galaxy was disk-shaped, and believed that the nebulae we know today as galaxies were clusters of unresolved stars which he called "Island Nebulae".



Despite his numerous important scientific discoveries, Herschel also had a few wild ideas.
In particular, he believed every planet and moon in the solar system was inhabited. He even thought that sunspots where actually 'holes' in the Sun's luminous upper cloud atmosphere that allowed views to the Sun's surface below, which he also thought would be inhabited.





On August 25th, 1822, at age age of 83, William Herschel died at Observatory House, Windsor Road, Slough, and is buried at nearby St Laurence's Church, Upton. After William's death, his son John had the no longer used great "40-Foot" telescope dismantled and held a farewell party inside of the telescope tube.

In 1822 following her brother's death, Caroline Herschel returned to Hanover Prussia.
She had never married while living with her brother, and did not get along very well with William's wife Mary, and as the survey work had stopped, there was nothing holding her in England.
Caroline did stay in-touch with her favorite (and only) nephew John, and constantly exchanged letters.

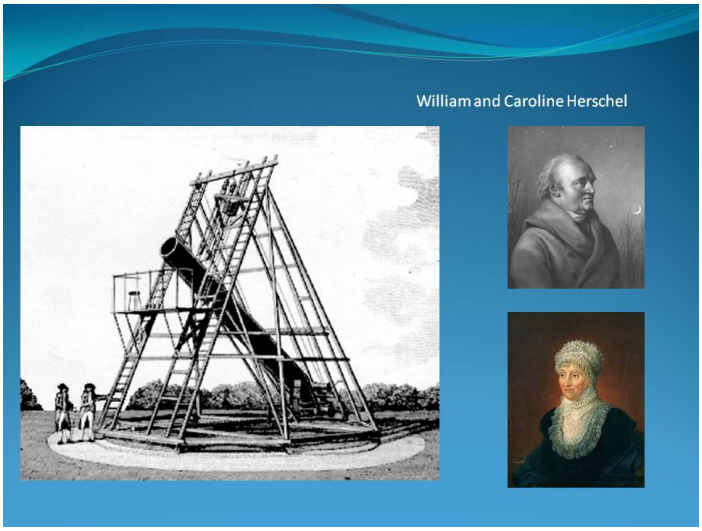
Upon John's request in 1825, she revised William's original catalog to make it easier for John to navigate.
The Royal Astronomical Society in 1828 presented her with their Gold Medal for this work.

In 1834, When John took the '20-foot' telescope to South Africa, he would send back his observing records to Caroline, who would perform the charting calculations, just as she once did for her brother William.
In 1835, she was elected to honorary membership of the Royal Astronomical Society; as the first honorary female member. In 1846, at the age of 96, she was awarded the Gold Medal for Science by the King of Prussia.
Caroline Herschel died at Hanover on January 9th, 1848, at the age of 97, and is buried there.

Conclusion :
William Herschel's discoveries of 2500 deep-sky objects were supplemented by those of Caroline Herschel (10 objects) and his son John Herschel's South African observations (1754 objects) and published by John as the *General Catalogue of Nebulae and Clusters* in 1864.
This catalogue was later edited by John Dreyer, supplemented with discoveries by many other 19th century astronomers, and published in 1888 as the *New General Catalogue* (abbreviated NGC) of 7840 deep sky objects.
Today, the NGC, along with the supplement Index Catalog (IC) is at over 13,225 objects!!

The Herschel's observing technique of surveying, cataloguing, and classifying what they found, and then using that data to try and understand the structure of the universe, has become one of the most important tools of modern astronomy.

William Herschel was one of the most notable observers in the history of astronomy, and is often referred to as the 'father of observational astronomy'. In a way, both William and Caroline are the 'mother and father' of amateur astronomy, as all of their discoveries were made with telescopes and mirrors of their own making.
And as most stargazers do today, all of their observations were made outside in the open, exposed to the elements, and not from inside an observatory building.



The Father of Amateur Astronomy

Introduction:
Today we are going to review the life of one of the greatest amateur astronomers from the 'Victorian' era, the Reverend Thomas William Webb, who lived from 1806 to 1885, and came to be known as the "the father of amateur astronomy". We'll cover his greatest astronomical contribution – Webb's handbook - *Celestial Objects for Common Telescopes*, an observing guide for which he is best known today. Along the way, we'll discuss my personal observations of objects from his handbook.

Contents:

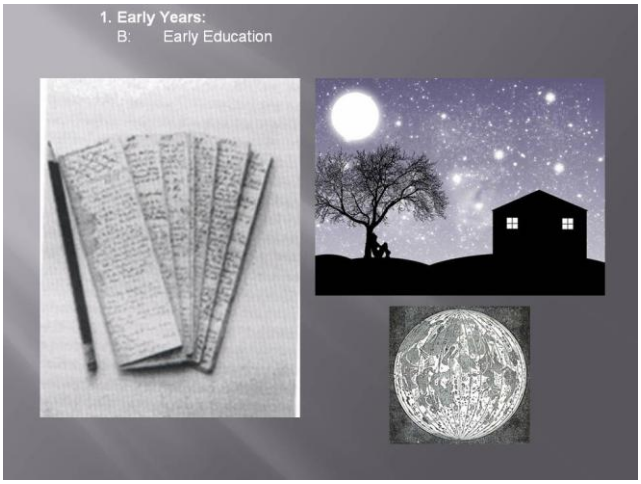
Early Years
Childhood
Thomas William Webb was born on December 14th 1806 in the county of Hereford, England in a little village called Ross-on-Wye. He was the only son to his parents Sarah and John Webb, but had an older sister named Anne born in 1801. Unfortunately, sister Anne passed-away at the age of eight, leaving her 3 year-old brother an only child. Thomas's father, John Webb came from the upper-middle-class, which gave him access to Oxford University, which he graduated from with a master degree and was ordained in the Anglican Church. His mother, Sarah Webb's family from her side was also well off, owning property in London. This allowed the Webb family to live comfortably off John's earning as an Anglican minister.

John was also well known locally as an expert authority in Norman French and a historical academic researcher of the English Civil War period, and he dabbled in music, writing several works that were performed at the Birmingham Music Festival. Finally, John kept a small home library containing his various historical research and other natural philosophy books. All this set the stage for Thomas's early home education from his parents.

Early Education.
With the educational resources available at home to the Webb family, Thomas was never sent off to a boarding school which was the 'standard' of the day, but instead was kept home, where he was educated by his father, along with a couple of other children from the local gentry. While Thomas was still a young child, his mother, Sarah, became mentally and physically frail of health, leaving his upbringing to his father who devoted himself to the boy's education. John Webb's instructions focused on classical philosophy, mathematics, and French and German languages.

Thomas became very a studious companion of his father, showing great interest in the natural world, keeping detailed notebooks with descriptions of size and shape, along with drawings, of every type of creature he would see. For the first few years he focused on earthly things, such as spiders, rabbits, and insects and other animals to be found in the country, along with seasonal changes in plants. But as Thomas grew older, he began recording daily observations of the weather such as the types of clouds, how windy it was, or the amount of precipitation in rain or snow.

Finally, Thomas began looking up at the night sky and recording observations of stars, bright meteors or naked-eye lunar surface features. In later years, he went on to record notes on speculum mirror grinding and telescope making and observations made with the telescope.



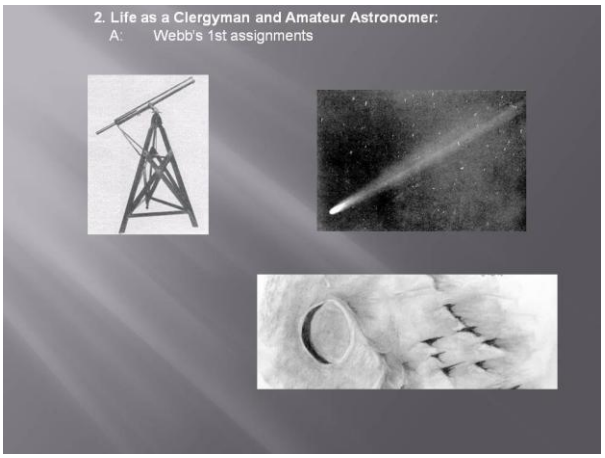
Thomas even kept a separate small personal diary where he recorded more informal activities of his daily life, such as horse riding or dinner at the neighbors. This devotion to recording life around him, along with access to his father's library helped prepare Thomas for the next phase of his life - University.

Higher Education (Oxford)
In 1826, at the age of 20, Thomas was able to enroll at Oxford University where he studied divinity, Greek Classics, and mathematics. Thomas also picked up additional course work in his favorite subject – astronomy! While there, Thomas suffered thru a number of ailments, and while not necessarily in bad health, he was never considered to be athletically strong. Partly because of this, Thomas focused on his scholarship, spending nearly every waking hour in the Oxford libraries when not in class.

But Thomas did take time out to socialize with the small group of friends in the hall where he stayed, holding the occasional tea and wine party, particularly when a 'care' package would arrive from home loaded with bottles of wine from his father's parish. Thomas would later record in his notebooks that during these parties, his university friends would have long discussions about life, death, the universe, and everything.
After three years, in 1829, he earned his degree and was ordained as a minister.

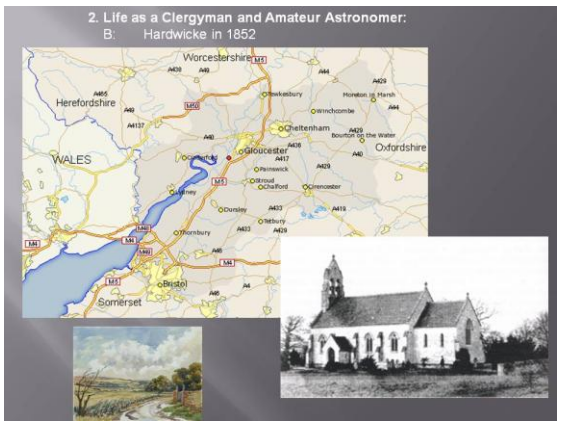
Life as a clergyman and amateur astronomer
Webb's 1st clerical assignments
After leaving Oxford, Webb's first clerical assignment was a curate at Pencoed in Wales, which lasted for two years. He then moved on in 1831 to Gloucester Cathedral where he spent the next 10 years, moving up the clerical ranks. Thomas was noted as a very caring minister, and took a keen interest in the heath of his parishioners, delivering medicines or wine to the ill or helping vaccinate local children.

During this time, in 1834, his father purchased a 3.7" refractor for Thomas, which he used in his free time and filled his notebooks with observations made with it. In 1835, he began writing astronomy oriented articles for various magazines on observing Halley's Comet or Lunar Volcanoes *(craters).*
Thomas was also invited to give lectures on comets and meteors to several local literary societies.



In 1841, Thomas was assigned back to his father's home district where he assisted John Webb for the next 20 years. While there, in 1843, he married Henrietta Montague of the local landed gentry. In 1850, Thomas was elected a Fellow of the Royal Astronomical Society, which gave him access to borrow professional books and papers from the society's library. Thomas also began sending in articles to the Society on observing comets, zodiacal light, and Lunar features.

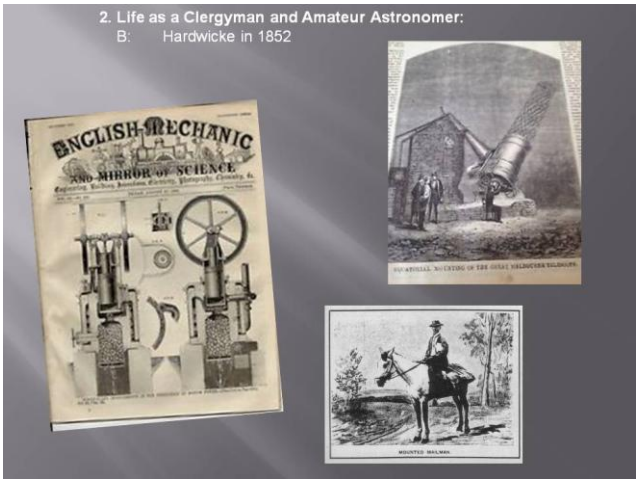
Hardwicke in 1852
Finally in 1852, Webb was assigned to head a small rural parish at Hardwick in Herefordshire, back near the border with Wales. The parish consisted of about 30 farms with around 250 people. Very rural. In addition to Sunday services, Thomas's pastoral duties consisted mainly of visiting the surrounding farms during the week and checking in on the local gentry. He would load up a knapsack with spare food and medicine from the rectory, and spend the day hiking to some distant parishioner's cottage where he would spend the afternoon with the family, handing out the small editable treats that he brought, and seeing that the children received any needed medication.
Thomas became active at the local school, encouraging the students to report to him any natural phenomena that they might have seen. He also helped set up a free soup program for the poorest children in the district.



There at Hardwicke, after a settling in period, he finally had the ability to fully focus on his personal love of astronomy. On the church grounds, just outside the minister's home, Thomas would setup his telescope in his garden and observe. Over the years, the garden was home to a number of telescopes, starting off with his small 3.7" refractor, and then to progressively larger refractors and reflectors. The largest telescope was a 9-1/3" Newtonian reflector with a silvered glass mirror on an equatorial mount inside an observatory building, used from 1866 to 1885. During this time, Thomas continued his recording nearly daily astronomical observations, including detailed sketches and specifics on using his telescope equipment and observatory.

He also continued to contribute astronomy articles to various publications and became sort of a regular columnist with one magazine titled "English Mechanic". From the publicity of these articles, Thomas began receiving correspondence from beginners and other amateur astronomers looking for help on how to use their own equipment or what telescope to buy, or what objects they should observe and how to go about doing that. Thomas would write back to each one with detailed answers to their questions, which for many would soon turn into years-long correspondences back-n-forth on such topics as how to care for eyepieces, to observations of Saturn. The volume of letters became so great that the main post-office in Hereford began delivering a private mailbag directly to the church.

Some of the amateurs who lived close enough and had the means to travel, would make the journey thru the rural countryside to visit Webb and his observatory, and would stay a few days with him to learn observing techniques. In addition to all the writing Thomas was doing, he would also travel around the region, giving lectures on astronomy and optics to local philosophical societies and colleges.

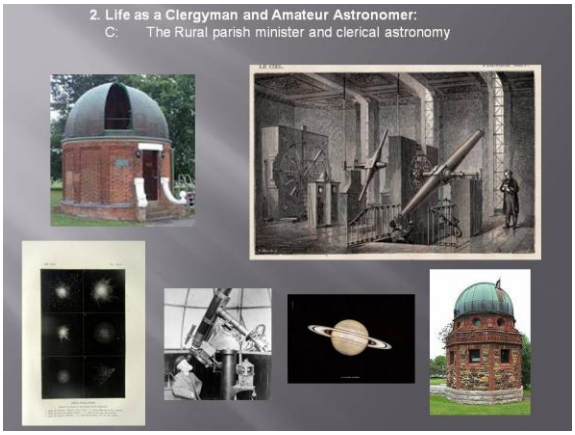


Thomas soon became widely known for his knowledge of telescopes and stargazing, and also for his charm and witty humor. An example of this was when after returning from doing a starparty at a ladies college, he remarked to a friend that the sights were very pretty and sharp. He then clarified that he was referring to the stars and planets that they observed,,,

Given his reputation and popularity Thomas could have easily moved up further within the church society, but he preferred to stay a rural minister, finding his fulfillment in tending to his parish and in astronomy.

The Rural parish minister and clerical astronomy

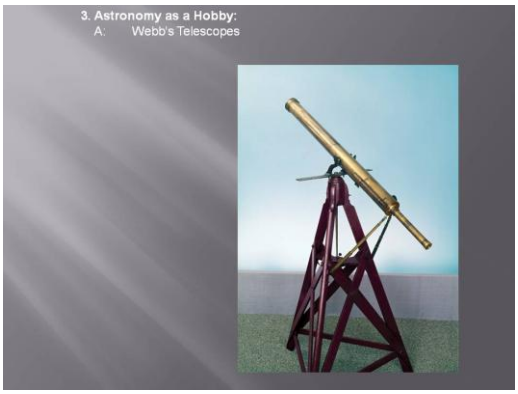
As a minister, Thomas Webb was part of a profession that contributed a good number of advanced amateur and professional astronomers during the Victorian era in England. These men were able to put aside their natural denominational rivalries to work together in promoting the science and hobby of astronomy. Some of these included Congregationalist Rev William Dawes and Rev William Lassell, Methodist Rev John Couch Adams, Scottish Presbyterian Rev Thomas Dick, Father Stephen Perry of the Jesuit run Stonyhurst College Observatory, Rev Romney Robison of the Episcopalian Armagh Observatory in Ireland, and Anglicans Rev Thomas Espin, Rev William Pearson, Rev Charles Pritchard, Rev Henry Key, and Rev Edward Berthon.



They were part of the "Grand Amateur Astronomers": a group of well-to-do gentlemen scientist, many from religious backgrounds, who took it upon themselves to help fill in the gaps from the poorly funded professional observatories of the period. They focused on either cutting-edge astronomical private research or like Thomas Webb, focused on popularizing the hobby of observational astronomy with the general public. Many of their astronomical works and publications were not only aimed toward advancing astronomy, but to also give a sense that God's glory of creation could be seen in the celestial sky, which in turn helped elevate and religiously inspire people to learn more about how God had put together his universe. Webb felt that being an amateur astronomer and studying the skies was an extension of his clerical duties on earth. The primary purpose of observing the night sky was to bring the astronomer closer to divine creation and God. His popular low-key writing style encouraged his readers to engage directly with the divine by studying the stars.

Astronomy as a Hobby
Webb's Telescopes
Thomas Webb built or purchased a number of telescopes during his life. In his younger days, when only very small expensive refractors or Gregorian reflectors were generally available, he constructed several telescopes of his own using speculum metal mirrors that were the standard of the day. (Speculum metal is an alloy of tin and copper with a reflectivity of only about 70%, and would tarnish quickly, and require frequent re-polishing).
Webb's early home-built telescopes include a 1.3" refractor and several 3" Newtonian reflectors, with his last being a 6" reflector that he finished in 1827. Webb also experimented with making his own eyepiece lenses, including using fluids such as turpentine or oil extracted from plant seeds in-between the lenses to help correct aberrations in the object glass. While Thomas was partly successful, he soon abandoned these attempts as better quality optical glass for eyepieces became more commonly available.

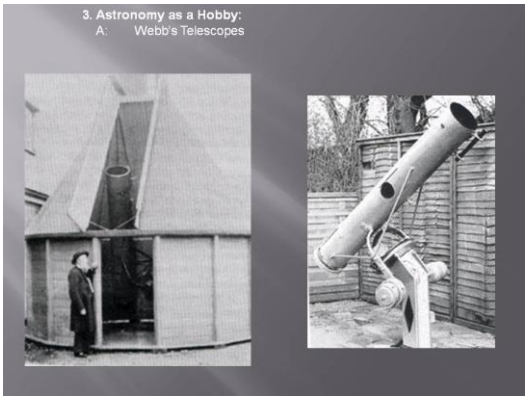
Webb lived in an era of dramatic changes in the quality, size, and design of telescopes and optical components available to the amateur astronomer. Ready-made telescopes that he could only dream of owning in his youth became more common and cheaper, allowing them to be purchased outright. The first of these was the earlier mentioned alt-az mounted 3.7" f5 Tulley refractor purchased by Thomas's father for him in 1834.
This became Thomas's primary telescope for the next 24 years, and was used by him for the majority of the observations that he eventually created his handbook with. This telescope was the actual 'common telescope' in the book's title.



Then in January 1858, with his observations for his handbook mostly completed, Thomas sold the 3.7" and purchased a high quality American made 5 ½" f7 Alvan Clark refractor objective, for which he had an optical tube and mount constructed locally. Unfortunately due to poor workmanship, he could never get the mount to work as he wanted, and even had to result to using string to help hold the mount stable. Finally Webb became so annoyed with the mount and trying to get it fixed that in 1865 he just stopped using the telescope.

By then, in 1863, Webb had moved on to another idea. The technique of silvering glass mirrors had finally been perfected during this time, allowing for cheap highly reflective larger mirrors to be made, replacing the heavy poor performing speculum metal mirrors. By 1863 there were a number of telescope makers selling silver-on-glass mirror instruments with all types of mounts, including equatorials with setting circles that were clock driven. Webb borrowed an 8" silver glass mirror telescope and used that until 1866 when Webb's 90 year old father purchased Thomas a new 9 1/3" f6 silver glass Newtonian reflector on a professionally built equatorial mount. This would become Thomas's largest telescope that he ever owned, and he used it extensively.

To house the new reflector, which was too heavy to be portable, Thomas built a small observatory on church grounds made with a wood base and canvas top. The observatory was a 'Romsey' type, which was a twelve-sided shed with a conical rotating roof made from canvas that was very popular with amateurs at the time.
For the next twenty years it was home to the large 9-1/3" Newtonian reflector, used from 1866 to 1885.



After Webb's death in 1885, the 5 ½" Clark refractor telescope was donated to Stonyhurst College where they remounted the optical tube and it became a useful instrument. The 9 1/3" reflector eventually made its way to the British Astronomical Association.

Webb's Observing log books.
Webb always encouraged amateur astronomers who he met or corresponded with to keep a written record of their observations. Webb's own log books were filled with neat even scripts of his near daily observations, including small 1.5" circle eyepiece drawings of deep-sky objects, along with larger sized sketches of comets, lunar craters, and various telescopes and equipment Webb had owned over the years. For planetary detail, Webb kept most of his drawings small; with the planetary disk generally only about ½" in diameter. Lunar craters were usually not very detailed, as Webb felt it was near impossible to accurately render them using his instruments.

These log book notes were usually transcribed the next day from rough notes that Webb took in the field during that night's observation. Using these rough notes and visual drawings, he would then sit down during the day and carefully write the full report in the log book using a fine pen. The sketches were sometimes done in pencil, colored crayons, or even as a watercolor painting. These log book records included every type of object that Webb observed either naked-eye or thru a telescope. Moon phases, meteors, naked eye comets, double stars & their colors, variables, lunar craters, star clusters and nebula. Webb recorded the state of the sky conditions during the night, what if any telescope equipment used, including the eyepieces & powers, and any useful observing technique. Webb would also include in the log books, folded up letters or newspaper articles that related to a specific object that he observed.

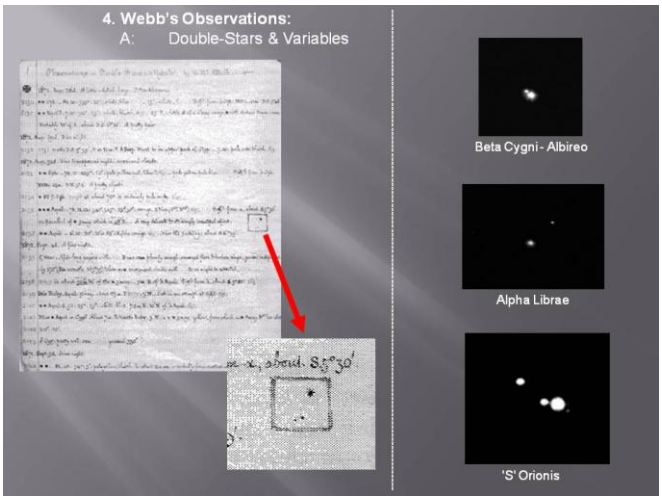
Depending on the type of observation, Webb had log books for general observations and books with sections divided between the various planets, each having their own range of pages to record observations in. Whenever Webb ran out of page space for a given object class, he would start a new log book for that planet or object, while continuing to fill the previous log book for the other objects that still had room in their sections. Webb would also keep a section at the end of the log book where he physically reversed the book to record research that he had made into other historical observations of a particular object by prior astronomers such as Herschel, Messier, Admiral Smyth, and others. He would later use all this information, his personal observations, observations from other historical observers, and his own experience with telescopes to write his handbook. Upon Thomas Webb's death in 1885, per his will, most of his log books were given to his good friend the Rev T.H. Espin, who kept them until he passed away in 1934. The log books came close to being thrown out, but for the keen eye of an assistant who saved them. They were then given to the Institute of Astronomy at Cambridge and eventually donated to the Royal Astronomical Society in 1978 where they are preserved today.

Webb's observations.

Double-Stars & Variables

Like most amateur astronomers of the Victorian era, Thomas Webb throughout his life was an enthusiastic observer of double-stars. He felt that if all an amateur astronomer ever did was to observe doubles, it would be time well spent at the telescope. Thomas's log books are filled with page after page of double and variable star observations. Along the way, Webb re-observe the 680 doubles listed in the Bedford Catalog by Admiral Smyth and many other doubles found by the other prominent double-star observers of the day that he corresponded with such as Dawes and Burnham. Thomas eventually discovered 10 new double-stars of his own, with his most favorite being the multiple variable star 'S Orionis' in 1869.

Interestingly though, Webb was not his usual precise self when it came to recording his double-star observations. Rather than use an eyepiece micrometer, which he had the funds to obtain, Webb would just give what he would call an 'eye estimate' of the double's position angle and separation. He would use various descriptions to indicate that the fainter star would be 'well separated' or 'little elongated' and its position was 'SP' (south proceeding), or 'NF' (north following) the brighter star. He also used his own unique method of identifying the location of the double, by referring it's coordinates in offsets from the RA and Dec of the nearest bright star. Webb generally used his copy of the Jamieson Star Atlas of 29 charts containing 112 constellations, (of which only 67 made it into the modern list) published in 1820. When using the atlas, Webb would sometimes make use of the various labels or titles printed on the charts, such as referring to a star's position as being to the north of the first letter 'S' in the word 'Sagittarius' on that particular chart.

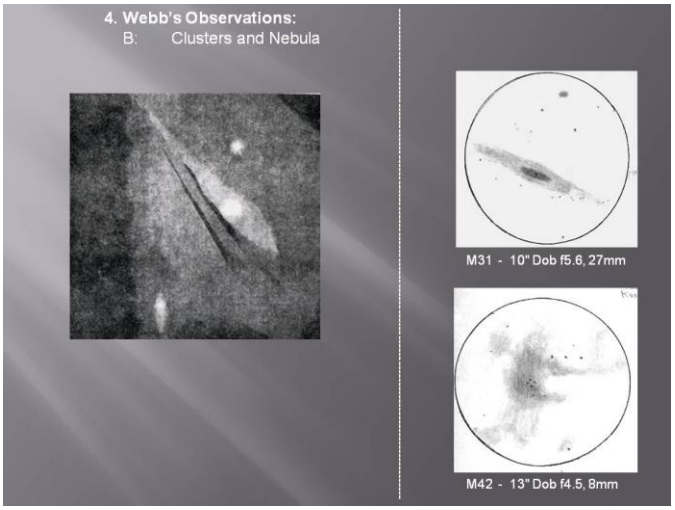


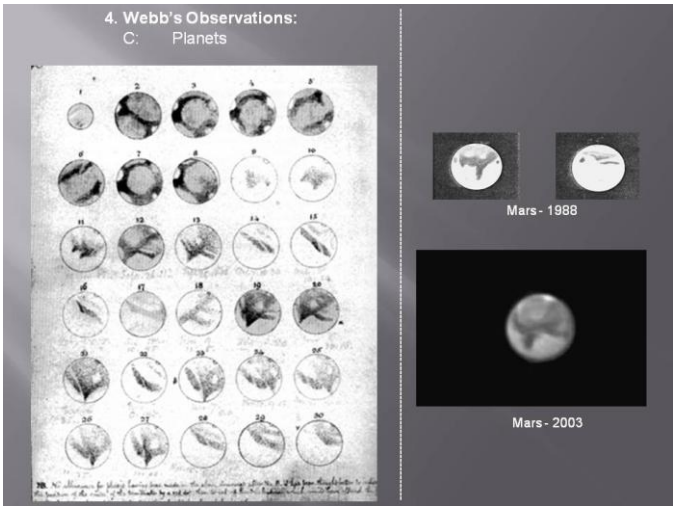
While Webb enjoyed observing double-stars, he wasn't particularly interested in variable stars, though he did record regular observations of some of the brighter long-period variables such as Mira.
But in all his observations, he liked to note the stars color. He used a shorthand notation of two to three characters to indicate color, a letter or two to indicate the primary color along with a number from 1 – 4 to indicate the shade.

Thus a 'Y2' would indicate a bold yellow star, with a 'Y4' indicating a pale yellow, or a 'OR4' meaning a pale orange ruby star. Thomas was particularly fond of red stars. He would make special sweeps thru the dense Milky-Way star fields looking for new red & orange stars. Webb eventually discovered 32 new 'red' stars, and is also listed as a co-discoverer of another 55 stars.

Clusters and Nebula

A fair number of deep-sky observations and sketches of star clusters and nebula can be found embedded among Webb's various other observations. (a total of 3,463 over all deep-sky observations).
All of the Messier objects and many of the brighter Herschel objects that Thomas's 3.7" refractor would show are listed. While Webb enjoyed observing the bright open clusters for their star pairings and colors, like many in his era working with small telescopes, he wasn't much interested in the generally faint, formless nebula, which included a large number of what we know today as galaxies. Thomas did keep observing the large brighter nebulas such as the Orion Nebula, also including some galaxies such as M31, in hopes of detecting changes in their shapes. Webb is credited with co-discovering the planetary nebula NGC7027 in the constellation of Cygnus, other than a couple of asterisms, his only deep-sky discovery.

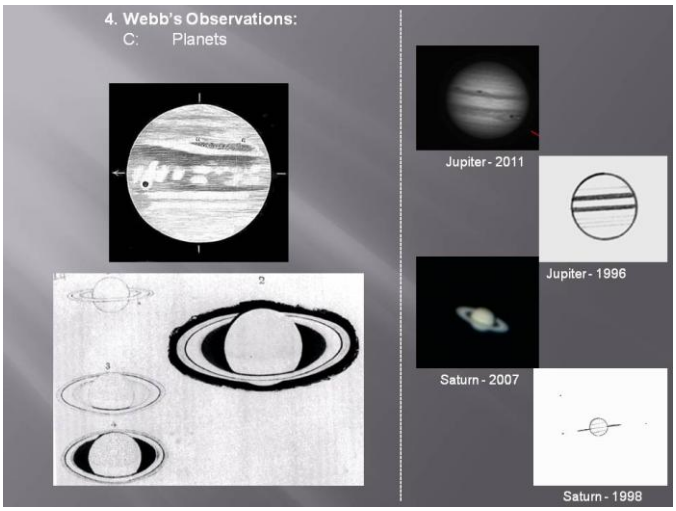


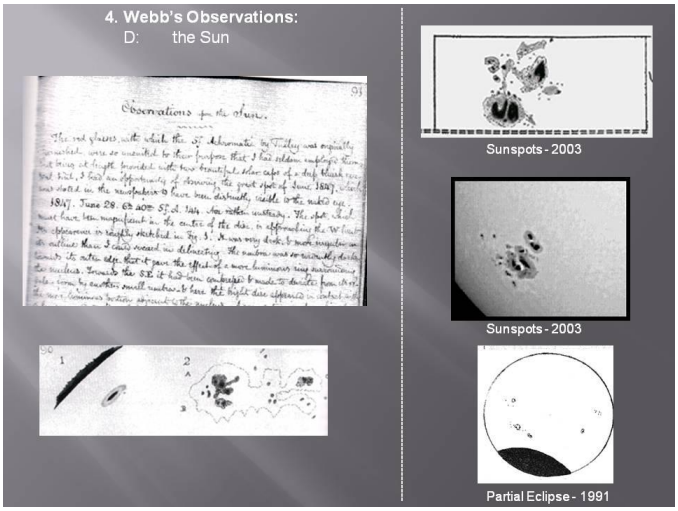


Planets

In addition to the Deep-Sky, Thomas Webb was also a dedicated observer of the solar system.
His style of sketching planets at a very small scale allowed him to accurately portray what a modest or 'Common' telescope would reasonably show to the observer. An example of this is a series of sketches he made of Mars during its opposition in 1830. The tightly drawn disks show accurately the shapes and positions of the Martian surface landscape that were visible, including features such as the dark markings of Syrtis Major, or Sinus Sabaeus, and brighter regions such as Hellas.

Webb also closely followed the gas giants Jupiter and Saturn, and especially in later years using the 9 1/3"observatory reflector, he would devote long runs of nightly observations that lasted many weeks.
One such of Jupiter went from Nov 15th 1870 thru April 15th 1871 for a total of 49 nights. Webb was one of the first to come up with the names of Jupiter's different features that we use today: bright stripes are called 'zones', the dark bands were called 'belts', further broken down into north & south 'temperate', 'torrid', and 'polar'. Web was considered one of the best amateur sketchers of planetary detail during his time.





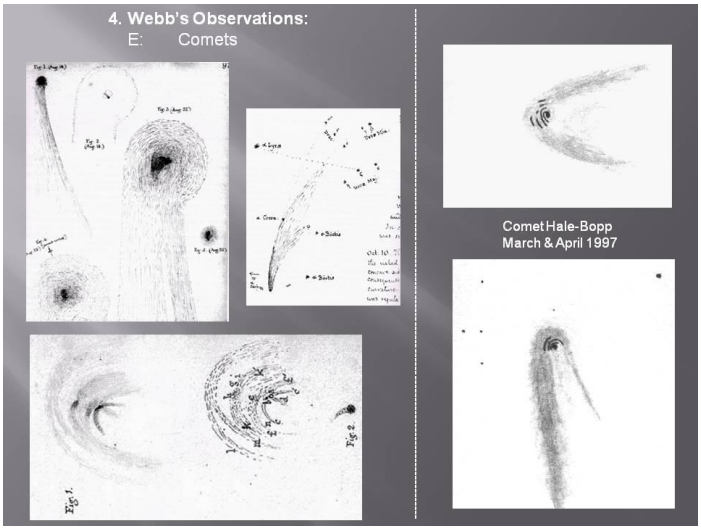
Sun

While solar observing didn't appeal much to Thomas Webb, he did spend time recording observations of the Sun, such that he ended up with a whole section regarding the Sun in his handbook, and even published a small textbook on the Sun in 1885. Like his planetary observations, Webb's solar sketches and descriptions were very precise and accurately detailed the various solar features that could be observed in white-light. He recorded a number of giant sunspots transiting the Sun, describing their large umbral structures, light bridges, and extensive branching facula.

On large sunspots near the solar limb, he would note his impression of it having a shallow depression in the surface, recording what would be known later as the Wilson Effect. Experimenting with using color filters, he also would observe that the Sun had an overall mottled or granular appearance. And like most of us modern solar observers, Webb was also frustrated by clouds on the few occasions of rare solar events such as the transit of Mercury in 1861 and a partial solar eclipse in 1870.

Comets

Webb also lived in a century that saw a number of great comets that have only been recently rivaled by comets Hale-Bopp and Hyakutake. Webb made numerous observations of these comets with both his naked-eyes and his current telescope of the time. These include the Great Comet of 1811 which Thomas remembers being shown by his father when he was a small child, to the Great Comets of 1819 and 1823 when he was a teenager, to the Great Comets of his adult life, such as Comet Halley in 1835, Comet Biela in early spring of 1845 with its double nucleus, and later in the year, the Great June Comet of 1845. There was another comet in 1847, and two in 1849, one in 1850, and Comet Biela back again in 1852. More comets in 1854, 1857, Donati's Comet in 1858, and others in 1860, and 1861, 1862, 1863, Encke's Comet in 1871, and the great comets of 1881 and 1882.

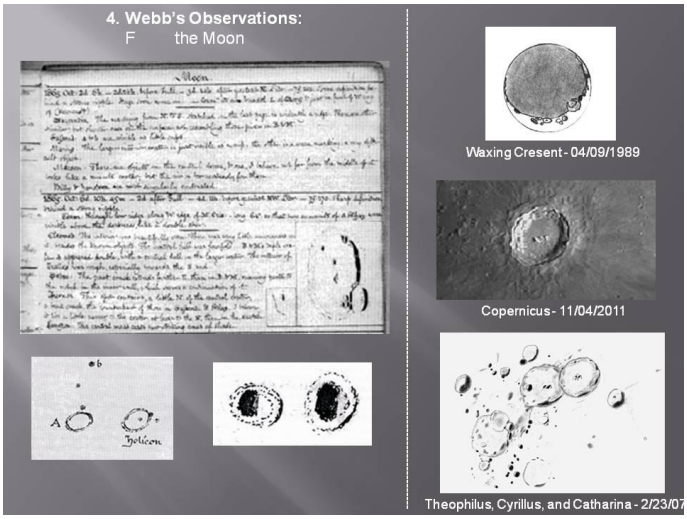


One particularly interesting entry from Webb's observing notes concerns the Great Comet of 1861, which passed close to the Earth. On the evening of June 30th, 1861, Webb was out observing the comet in his garden just after dusk. While viewing it with the naked-eye, he notice a number of faint cirrus clouds streaming across the sky. As he looked at the cirrus, he realized they converged on the visible nucleus of the comet. As he watched, the bands of cirrus slowly closed up like a fan, centered on the comet's nucleus. Webb detailed his observation and reported it to the Royal Astronomical Society. Webb's report was collaborated by several other observers, and it was determined that Webb had actually observed the passage of the Earth thru the comets tail!

Moon

While Webb's observation of the planets and comets took up a large section of his log book records, he focused even more on detailed observations of the lunar surface. Webb felt that the current theories of his day that the Moon was a geologically dead world were incorrect. That like the Earth, processes still occurred that could change the Moon. Webb considered himself a type of 'backyard prospector', a field geologist with a telescope. He felt that close, careful observational study of selected Lunar features would show changes occurring over the passage of time.

Thomas spent many evenings recording the visual details of individual craters: for example "Nov 1st, 1855 - Maginus with a very remarkable serpentine terraces in the inside of it's W. wall, and a number of craters which have reduced the E. wall to the condition of a gigantic ruin." Webb particularly thought that volcanoes were still active on the Moon, and that the craters were the remains of molten lakes. He spent many hours recording multiple observations of promising lunar locations, such as Schroter's crater, or the area around the twin Messier craters, a small pit named 'Helicon A' near Le Verrier, along with the south-eastern slopes of Copernicus.



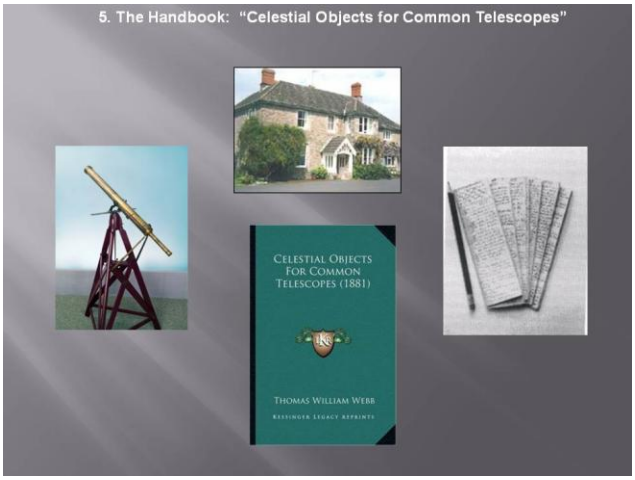
Webb even participated in the 'Committee for Mapping the Surface of the Moon', whose goal was creating a new highly detailed photographic and visual map of the lunar surface. It was sort of a Holy Grail quest for proof of the Moon's changeability. Others who participated in this great mapping project included Sir John Herschel, Warren De La Rue, and Lord Rosse. Unfortunately they never succeeded in their quest, but even today, the idea of transient lunar phenomena still keeps many amateurs interested.

The 'Handbook': Celestial Objects for Common Telescopes

In 1844, Thomas purchased a copy of Admiral W. Smyth's 'A Cycle of Celestial Objects', and decided after reading the second volume called the "Bedford Catalogue", (which was a survey of deep-sky objects made with the Admirals much larger telescope), to compile his own observations using his smaller 3.7" refractor. Small telescopes were finally becoming affordable to the educated middle-class amateur astronomer of the day, but the biggest problem they faced was their own inexperience.

Thomas resolved to create a handbook for the owners of more ordinary 'common' telescopes that would list clear basic instructions on how to use those scopes and what objects to observe with them.

So Thomas spent the next 15 years adding to his existing observations, and also putting to paper the knowledge and skills learned in using his telescope equipment, recording everything in his log books.



It was at Hardwick in 1859, that Thomas finally pulled together his observing and telescope usage notes from over the years and wrote his astronomical observing guide "*Celestial Objects for Common Telescopes* ". Within his book, Thomas broke his information into several sections, containing instructions on the use of a telescope as well as detailed descriptions of what could be observed with it. This work was written as a guide for the amateur astronomer, and became the standard worldwide observing guide, and remained so for many decades until well into the 20th Century. (*In 1917, during revisions for the sixth edition by Reverend T.E. Espin, the book was split into two separate volumes*)

The 'common telescopes' referenced in the book's title are three to four inch refractors and larger silver-glass reflectors in the six to eight inch range that were becoming popular and more commonly available to the average amateur observers of the day. Webb realized there was a need for a simple, clear guide to these telescopes, how to use them, and what to observe with them. His personal notes on observing and telescope usage went a long ways toward filling that need, and provided Webb with the core of his handbook.

How to use a telescope

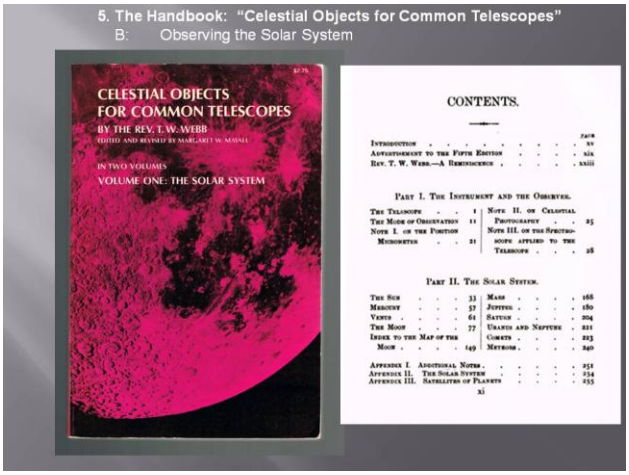
Webb's first volume covers the use of the telescope and starts off the observing with the brighter objects of the Sun, Moon and Planets. The section on equipment usage takes up about 20 pages, and while most of it is dated, there are a number of useful comments that are still valid for today.

To paraphrase a few – don't try using your telescope by pointing it out the window of a warm room, (but if you must, no fires in the fireplace), Observing on a wood floor is a bad idea as every movement by the observer will produce a tremor, and while an observatory is not essential, it has its advantages in comfort and setup time.

And remember, your telescope's brass-work should not be rubbed with polishing powder, as it might scratch the finish. ☺

Webb goes on discussing various useful accessories such as dew caps and how to make them, along with observing advice on eyepiece usage, such as don't overdo your magnification – use low powers to help find the object. He then touches on when it's best to observe certain types of objects and not to waste time trying to observe when the sky conditions don't allow. But, if you catch a really favorable night, you should really make the most of it, as you will not find too many of them.

Webb advises to try not to observe objects near the horizon, nor over a house unless you want to study the effects of a current of heated air. And he encourages you to record every observing session no matter how unimportant it may seem, and to write everything down and trust nothing to memory.



Webb offers these encouraging words from an 1828 Royal Astronomical Society report:
"Every one who possesses an instrument, whose claims rise even not above a humble mediocrity, has it in his power to chalk out for himself a useful and honourable line of occupation for leisure hours, in which his labor shall be really valuable, if duly registered,,, those who posses 'good' instruments, have a field absolutely boundless for their exertions".

Observing the Solar System
Webb starts off the section on observing the Sun by suggesting that the student had best not begin there, and they should first acquire observing experience elsewhere, if they are not careful, they could end up like Galileo and 'suffer from that piercing blaze'. Then he goes on and describes how to make various solar filters, (which I don't recommend at all trying), and the various solar features that could be observed, along with the scientific reasoning of the day. While some of the descriptions are interesting, most of this section is very, very dated, and it's best to get your information elsewhere.

Webb then has individual sections on the planets, with only a page or two on Mercury or the outer gas giants Uranus and Neptune, which he feels "may be reached (observed), but to no great purpose,,"
Webb barely gives poor Neptune a full paragraph and states: "Neptune may be found,,, but will hardly repay the search',,, and he goes on to describe the view as "but dull and ill-defined".

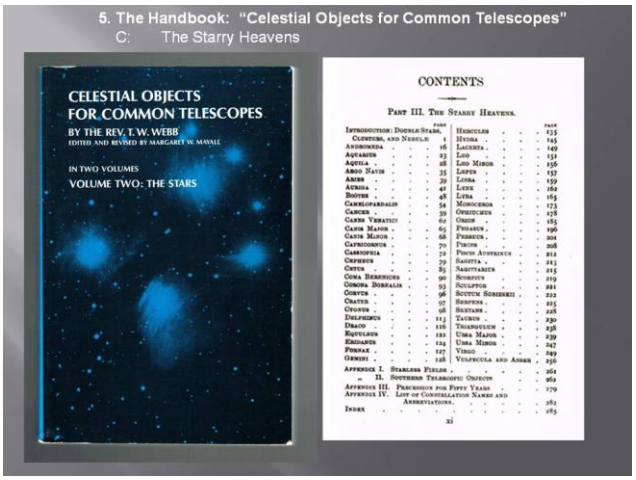
But Venus fairs better, with over 14 pages, along with Mars 12 pages on observing both planets phases and other transient surface features. With Venus, he discusses observing the 'Mountainous Surface' and the mysterious ground 'Spots', which we know today are non-existent. The section on Mars is a bit more accurate on the surface features that can be observed, including what Webb was able to see and other observers of the day such as Percival Lowell. But again the general information is a little quaintly dated.

Jupiter and Saturn each have big sections, with plenty of detail observations and sketches from Webb's contemporaries of the day and historical observers. And there are nice sections on Comets and Meteors.
Finally, as might be expected from Webb's log books, it is the Moon that takes up a good chunk of the book – 90 some pages. While the general scientific thoughts of the day regarding the Moon, and Webb's ideas of lunar volcanoes, are only interesting from a historical perspective, the bulk of the section deals with observations of the many lunar features visible with a 'common telescope', and includes a nice lunar map broken into four quadrants, along with a index to the features that can be still useful.

The Starry Heavens
The second volume is a guide to the stars, clusters, and nebulae ordered by constellation.
Webb starts off with a lofty screed to the reader that "*leaving our Sun and his attendants in the background… we are now approaching more amazing regions… with scenes of inexpressible and awful grandeur. We are now to contemplate not one Sun, but thousands and myriads… pairs, groups, galaxies of Suns – the Hosts of Heaven… in unborrowed splendor*".

After about 15 pages of additional general info on such things as determining a stars magnitude to measuring the position-angle of a double, Webb dives into the bulk of the book, individual chapters of the constellations of his era, which includes a number of outdated constellations, such as Anser 'the Goose', which is now just part of Vulpecua, or Argo Navis 'the great ship of Jason and the Argonauts', which has been broken into smaller constellations of Puppis, Vela, and Pyxis.

Here Webb focuses much more on double and variable stars which he favored, than to the nebulae. This really is not surprising given that these types of stars were the priority of astronomy at the time, and were very suitable for the 'common telescopes' available, as opposed to the deeper sky objects.
A typical constellation in Webb's handbook may list over 100 descriptions, some lengthy, of interesting double or variable stars to be found within its borders, but then only list a handful of cluster and nebulae, that we today know contains far more. His descriptions of the deep sky objects range anywhere from a terse single word 'Nebula' to poetic descriptions over a page long quoting from scripture or other prior observers descriptions, such as from William Herschel.



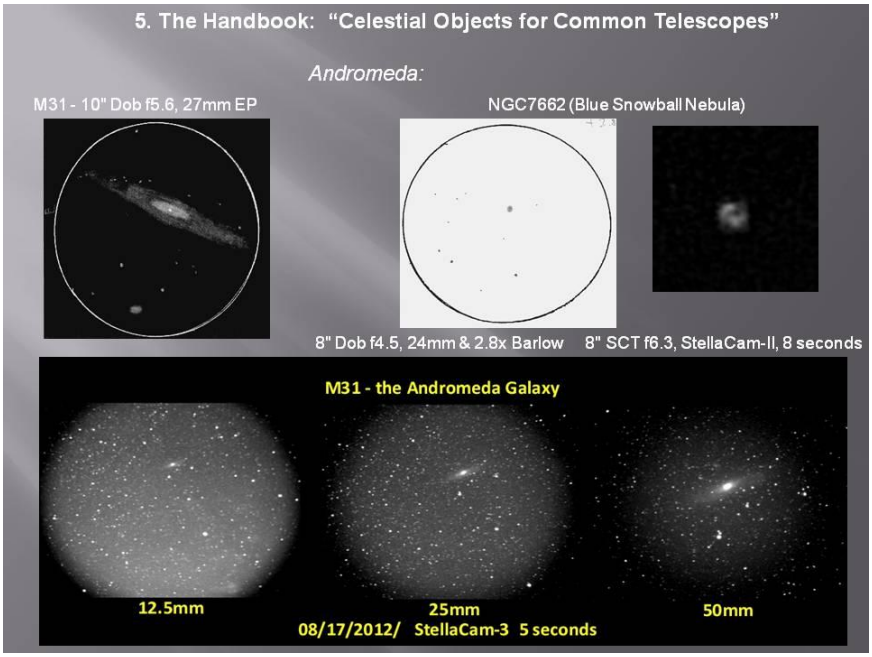
Constellation Examples:

Andromeda:

Webb starts off with the constellation of Andromeda, which he states – "is rich in interesting objects of every class". But contrary to modern observing techniques, Webb goes on to say "on the meridian, however, it is inconveniently high for an achromatic telescope, and should therefore be examined some hours E or W of it, like many other similarly situated regions.". (Apparently star-diagonals were not a common accessory during that time). Webb goes on to list 58 double-stars, 8 variable stars, and only 7 star clusters and nebula for entire constellation. The double Gamma Andromeda is described as "One of the most beautiful pairs in the heavens", and that the secondary companion star is itself a double, and is "an admirable test object".

For the deep-sky objects, M31 the Andromeda Galaxy has the longest description, with Webb calling it "one of the grandest in the heavens, long, oval or irregularly triangular, ill-bounded and brightening to the centre". He goes on to say that common telescopes will show little detail but larger telescopes may show "two curious dark streaks, like narrow clefts,,,, that forms in reality the boundary of one side of the nebula".

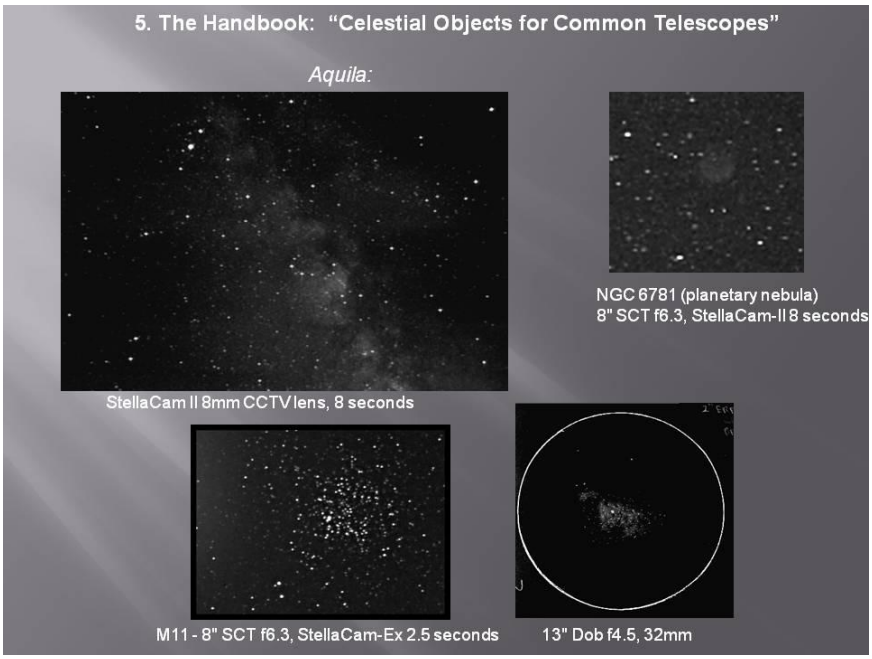
Another noteworthy object mentioned is NGC7662, the Blue Snowball planetary nebula, which Webb describes as "small, but very bright,, shows a blsh disc with wooly border and suspicion of dark centre".



<u>Aquila:</u>

In this Constellation with its bright star Altair, Webb states that it "has a very sensible p.m. (rising).
And goes on to say that "All the Galaxy here is strewed with pairs and groups of stars".
After listing 89 double and variable stars, Webb then gives a list of only 4 deep-sky objects, with the main one being the open cluster M11 which has a "Noble fan-shaped,,, at the upper edge of the broad luminous cloud which marks the shield of Sobieski,,, Ad Smyth compares it to a flight of wild ducks".
Webb also notes another observer having seen "dark structures plainly visible". While Webb includes M11 in Aquila, he does note that it is "Sometimes placed in Scutum Sobieski", which is the correct modern constellation location for the object.

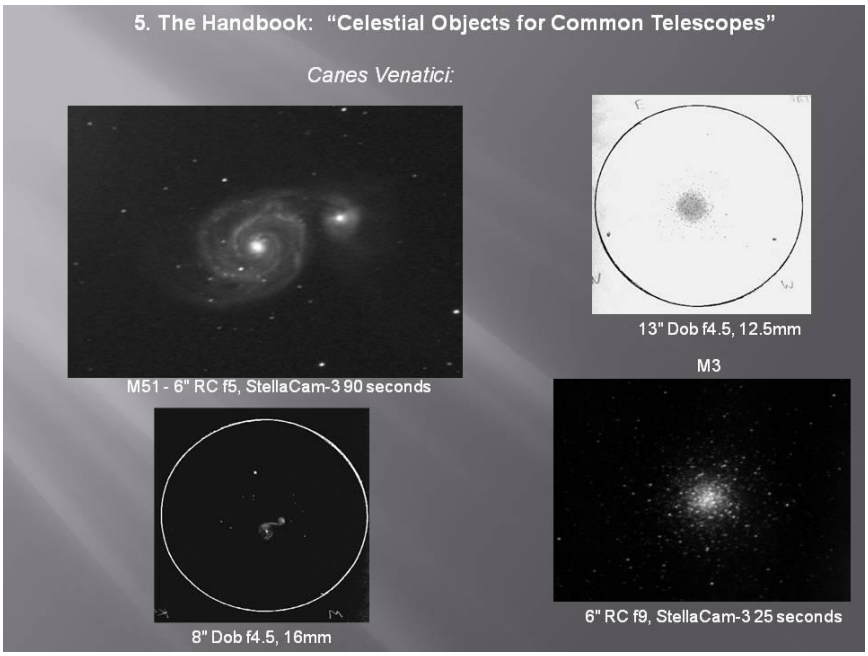
The planetary NGC6781 merits a short mention of "Large round faint neb,,, E of Rosse ring or spiral".
Also of note are several brief descriptions of other curious items, such as star chains, or wide group, (clusters), and long narrow trapezium.



Canes Venatici:

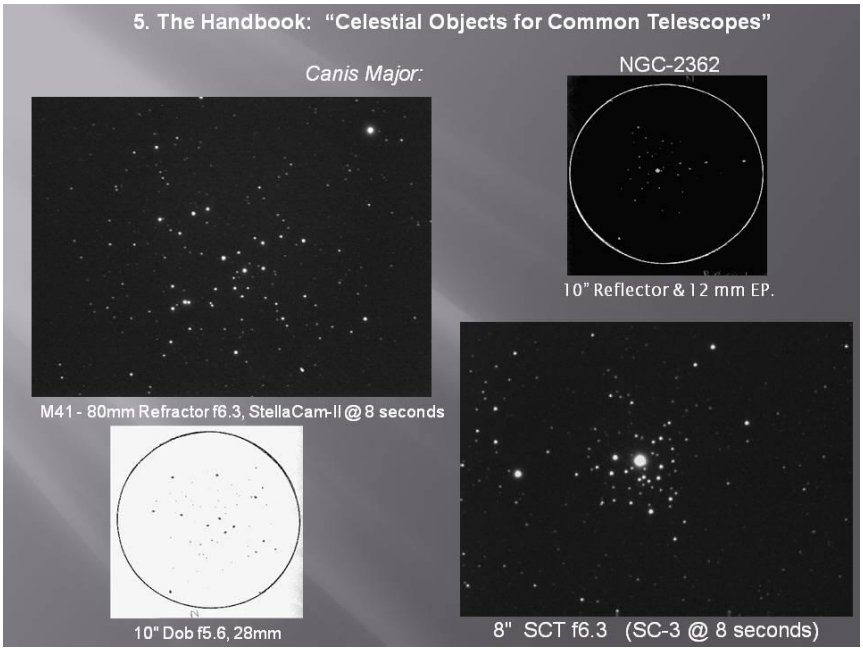
For this constellation Webb states: “The nebula here are fine”

After listing only 30 double and variables, He then lists 10 deep-sky objects of which M51, the Whirlpool Galaxy, and the globular cluster M3 are most noted. For M51 – “E of Rosse’s wonderful spiral, its wreaths are beyond all but the 1st telescopes, common ones will only show two very unequal neb nearly in contact, both brightening in the centre, traces of halo encompassing the larger may perhaps be caught,,,”. For M3, “a brilliant and beautiful globular congregation of not less than 1000 small stars, blazing splendidly,, running up into a confused brilliancy towards the centre,,’.



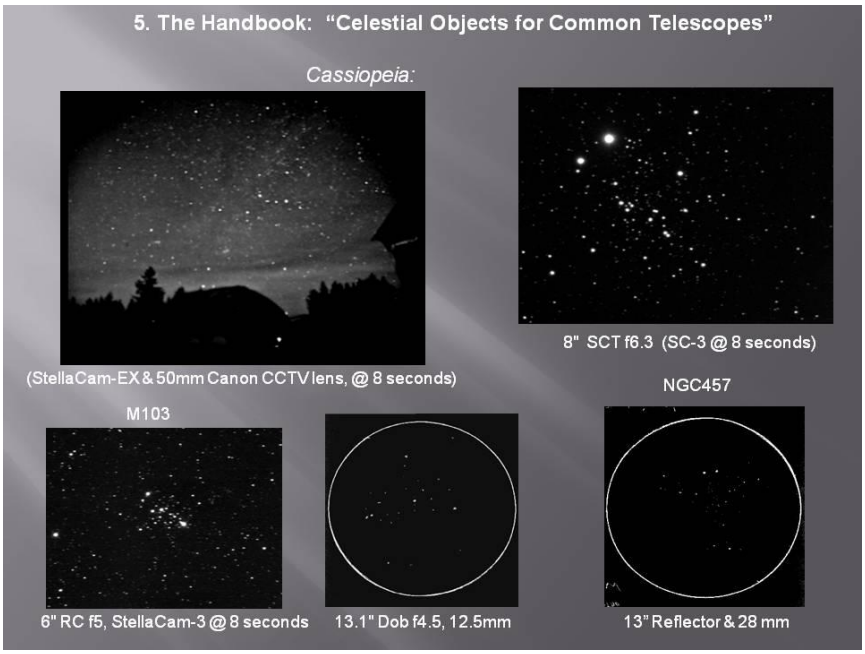
Canis Major:

For this constellation Webb declares about its bright star Sirius – “This is the leader of the host of heaven, a glorious object,,,”. Webb then goes on to mention various other historical naked-eye observations of the Dog Star, along with telescopic discovery of it being double. He then lists 36 double and variables, and two deep-sky objects, both open clusters. The first is M41, where Webb states: “Superb group, visible to the naked eye beneath ‘Alpha’,,, Larger stars in curves with ruddy star near centre”. Then for the second cluster NGC2362 – “Beautiful, melting into a very rich neighborhood, as though the Galaxy were approaching us”.



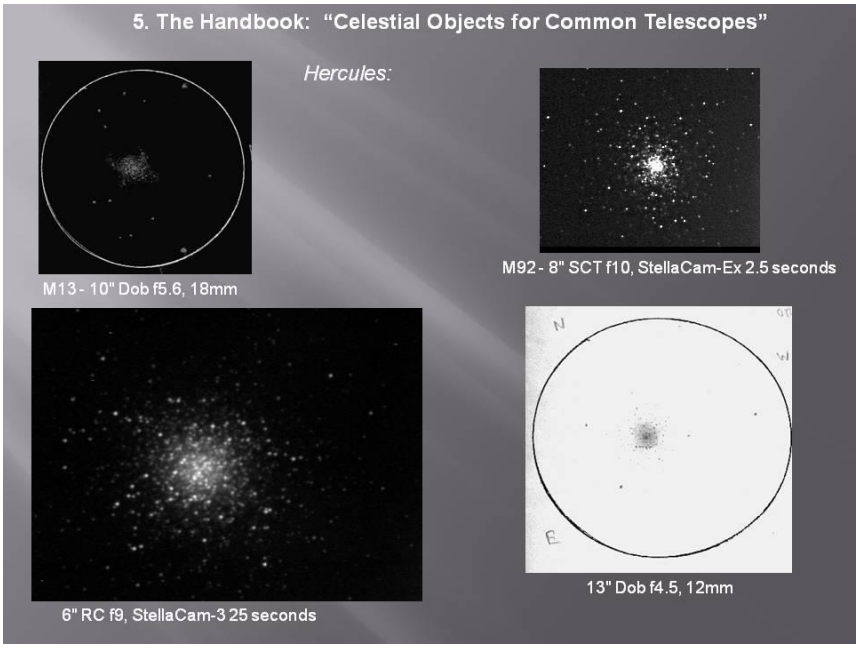
Cassiopeia:

"Here lie a multitude of superb Galaxy fields,,," starts off Webb's description of Cassiopeia.
He then lists 70 double and variable stars, and six deep-sky objects, all open clusters.
NGC457 – "a very elegant group", and NGC7789 – "Beautiful large faint cloud of minute stars,,, in a vast region of inexpressible splendor". Finally M103 – which he calls a "Beautiful field".



Hercules:

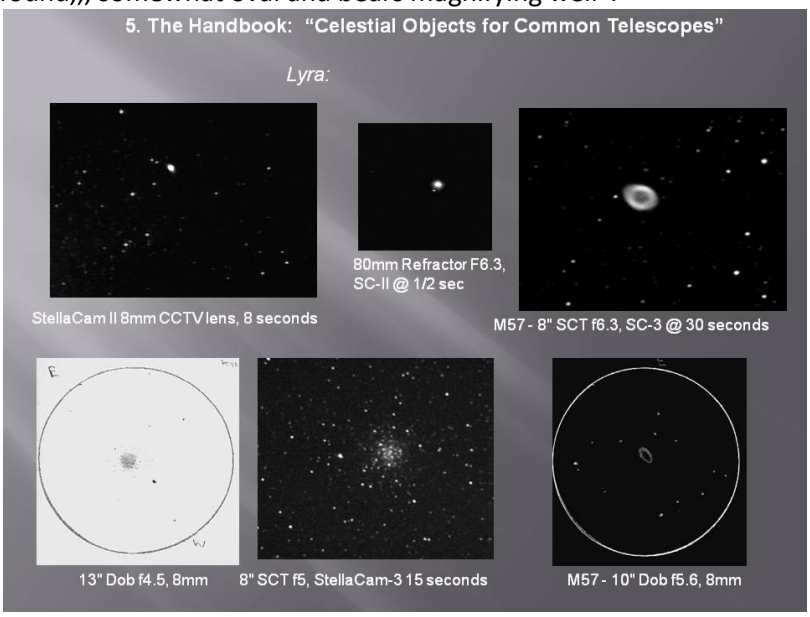
Webb notes that "Some very noteworthy telescopic objects mark this constellation, and there is very fine sweeping,,,". Webb then lists 137 double and variable stars! After that is a short list of 4 deep-sky objects, along with several interesting star-chain asterisms. The highlight of the chapter is M13 – the Great Hercules Cluster. "Superb globular cluster,,, finest of its class, just visible to the naked eye,,, spangled with glittering points,,, Ad Smyth describes it as "extensive and magnificent mass of stars with the most compressed part densely compacted and wedged together under unknown laws of aggregation,,, Herschel detected "hairy-looking curvilinear branches", also noted by E of Rosse who "noticed this spiral tendency, detected also three dark lanes or rifts in its interior". Also noted is M92 – "very fine cluster, though not the equal to M13, less resolvable, intensely bright in centre". And planetary nebula NGC6210 – "Very bright, small, not sharply defined.



Lyra:

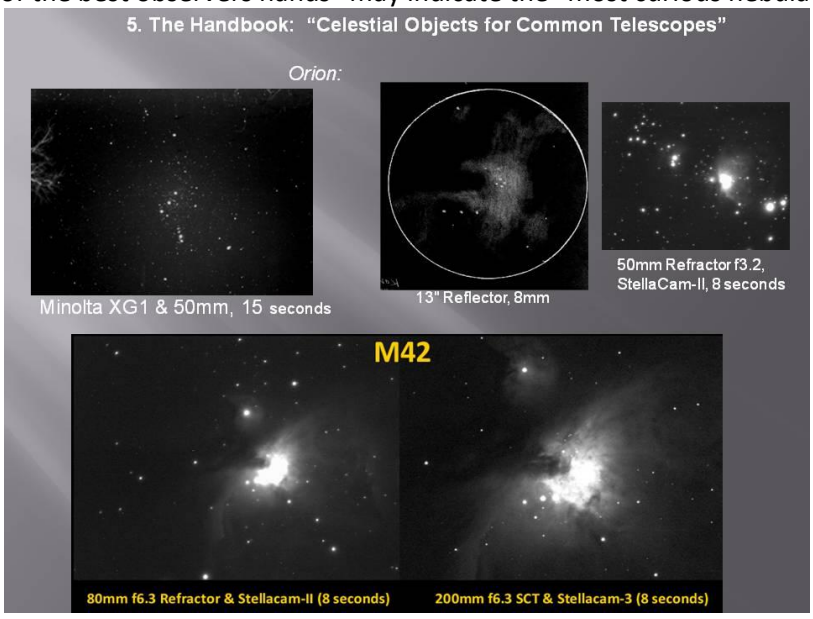
Webb calls it “one of the most remarkable constellations, full of beautiful fields adorned by one of the great leaders of the firmament”, of course referring to the star Vega, which is “inferior to Sirius only”.

Next Webb listed 61 double and variable stars, with special mention of doubles Beta Lyrae and Epsilon Lyrae the ‘Double-Double’. For nebulas and clusters, Webb states “Sweeping between Lyra and Cygnus exceedingly fine”, but then he only lists two deep-sky objects! The globular cluster M56: “Faintish, perhaps resolvable, in a fine field and rich region”. And the Ring Nebula M57: “ The only annular nebula accessible by common telescopes,,, easily found,,, somewhat oval and bears magnifying well”.



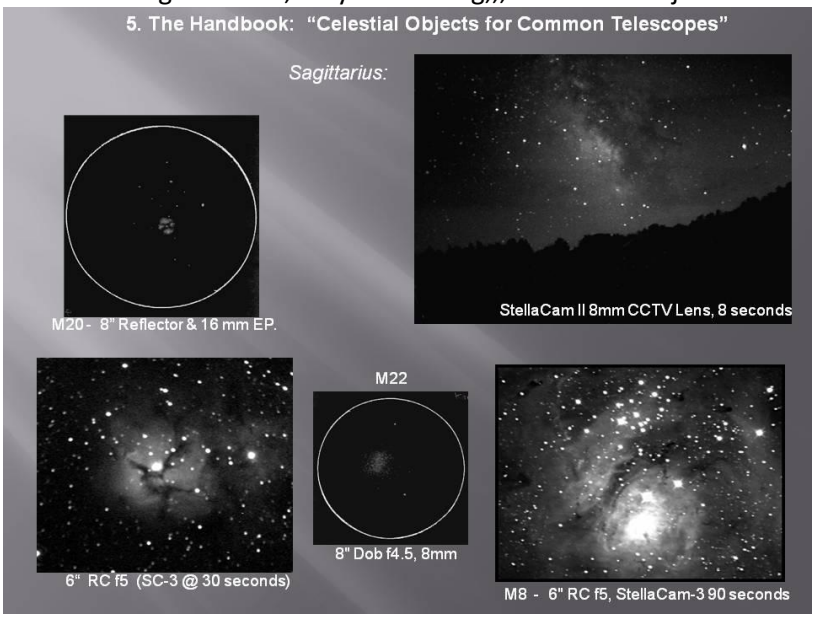
Orion:

Webb describes Orion as “The finest constellation in the heavens,,, its position is very suitable for English observers,, Sweeping in many parts most beautiful”. He notes its two bright stars Rigel and Betelgeuse, which he quotes Lassell saying “A most beautiful and brilliant gem! ,, a rich topaz,,,”. After listing 71 double and variable stars, there are 5 deep-sky objects notes, with M42, the Great Orion Nebula taking up three pages of notes. “ One of the most wonderful objects in the heavens, readily visible to the naked eye,,, The telescope shows an irregular branching mass of greenish haze, in some directions moderately well defined where the dark sky penetrates it in deep openings, in others melting imperceptibly away,,, in the densest part, four stars form a trapezium,,,”. Webb also quotes Herschel as seeing “a curdling liquid, or surface strewed over with flocks of wool, or the breaking up of a mackerel sky”. Webb goes on to discuss how all the “strange discrepancies in the drawings of the best observers hands” may indicate the “most curious nebula in the heavens” was in a state of change.



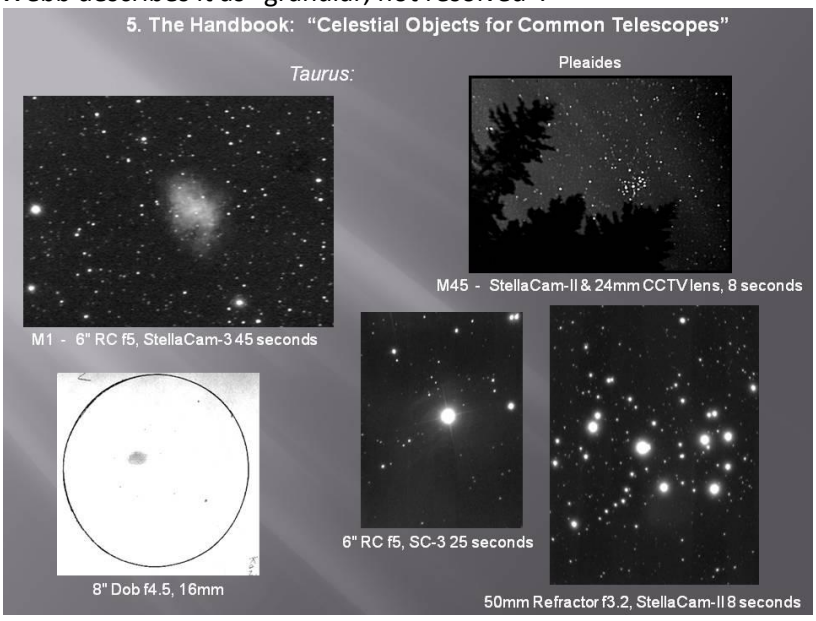
Sagittarius:

For Webb, Sagittarius was almost too low on the horizon: "The stars of this constellation have a beautiful effect about the Southern horizon near the place where the Galaxy passes from sight in our latitude, but they are apt to be obscured by haze". But even with the difficulties of observing such a low altitude constellation, Webb lists off 53 doubles and variables, along with nine deep-sky objects. There's the Trifid Nebula, M20 – "Very curious object, where three ways meet, dark rifts through nebulosity,,, a Grand region." Then the Lagoon Nebula, M8 – "Splendid Galaxy object, visible to the naked eye,,, a bright coarse triple star, followed by a resolvable luminous mass including two starry centres and a loose bright cluster, a very fine combination". Finally, the globular cluster M22 – "Beautiful bright cluster, very interesting,,, a valuable object for common telescopes".



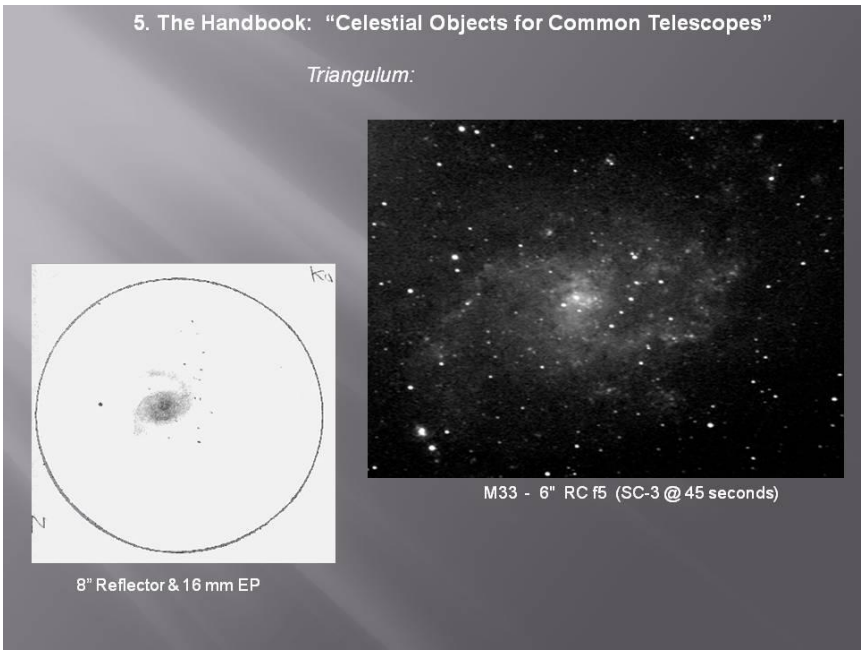
Taurus:

"An interesting constellation containing two beautiful groups familiar to the first beginner in stellar astronomy – the Pleiades and Hyades". After a discussion by Webb on how many individual stars various observers have seen in the Pleiades, he goes on to list 102 double and variable stars, including the bright gold star Aldebaran. Four deep-sky objects are listed. Webb continues the discussion on the Pleiades, M45 showing diffused nebulosity – "a faint, extended, somewhat triangular haze, involving Merope,,,", that was debated as being an illusion, but confirmed by recent photography. Also mentioned is the Crab Nebula, M1, and how "its accidental re-discovery by Messier while following a comet in 1758 led to the formation of the earliest catalogue of nebula".
Webb describes it as "granular, not resolved".



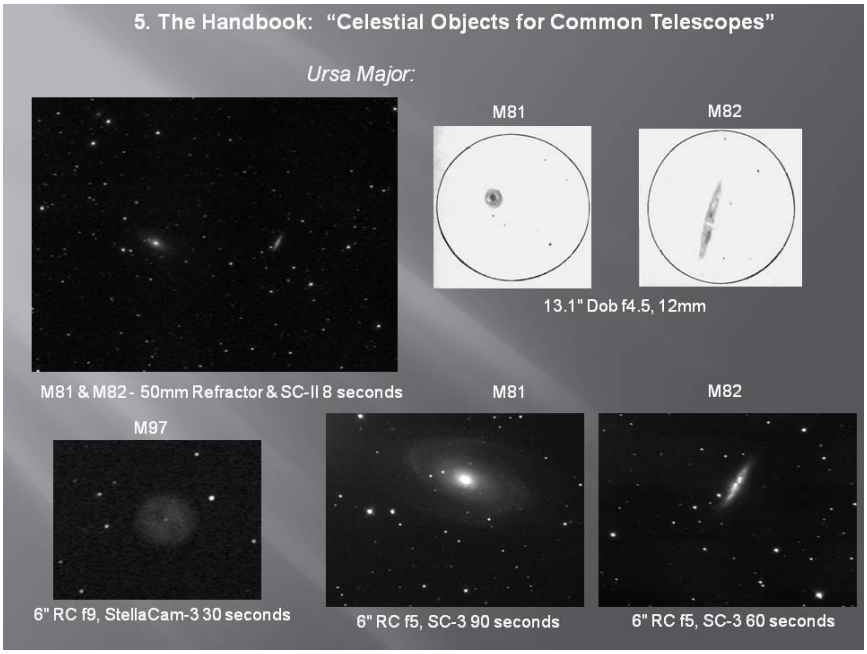
Triangulum:

Webb describes Triangulum with a single sentence – "An ancient constellation, including several good objects". After only 19 double and variable stars, Webb describes the only deep-sky object, M33, the Pinwheel Galaxy, "Very large, faint, ill-defined, visible from its great size. A very curious object, only fit for low powers, being actually imperceptible from want of contrast,,, E of Rosse saw it full of knots, found spiral arrangements,,,".



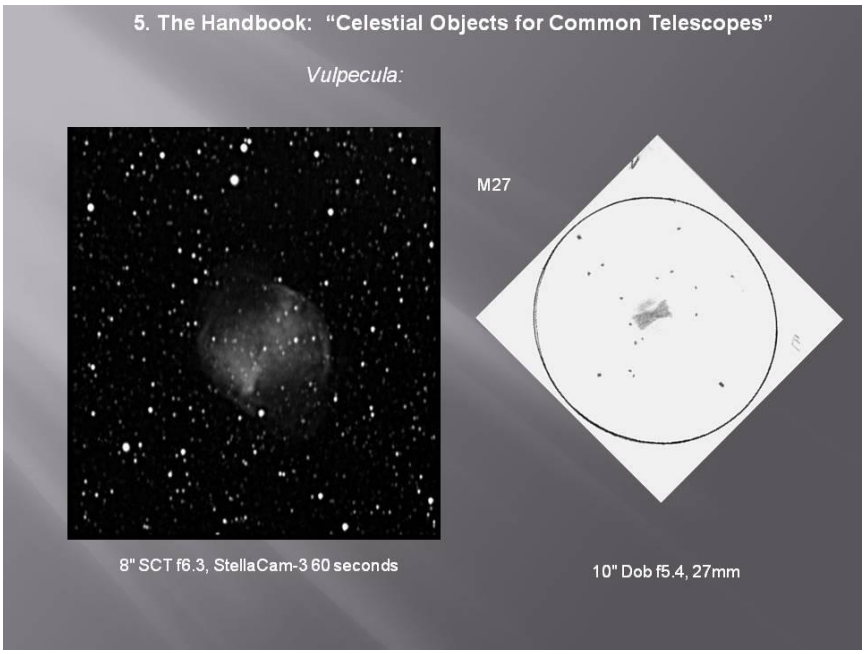
Ursa Major:

Webb notes this "familiar constellation offers a large field to the persevering observer,,, extends far beyond the region occupied by the seven stars,," Webb goes on to mention how curious it was that the North American Indians also seen a bear in these stars long before European contact. Webb then lists 62 variable and double stars, calling out the naked-eye pair of Mizor and Alcor, along with a dozen deep-sky objects. He lumps the two galaxies M81 and M82 together with "81 bright, with a vivid nucleus,,, and "82 (Bodes Nebula), a curious narrow curved ray, two nuclei and sparkling,,,". Also listed is the Owl nebula, M97 – "Large pale planetary nebula, very remarkable object,,, softened edge, faintly bicentral", and quotes the E of Rosse -"two large perforations, and an indistinct spiral structure", where the 'Owl' name comes from.



Vulpecula

Webb calls this region – "Grand sweeping". After listing 42 double and variable stars, Webb closes out his tour of the constellations with one final nebula that he feels ",,,will not be found disappointing" – the Dumbbell Nebula, M27. "in a rich field we find two oval hazy masses in contact,,," seen by Herschel containing "dark notches filled in and made protuberant by faint luminosity, converting the whole figure into an ellipse".



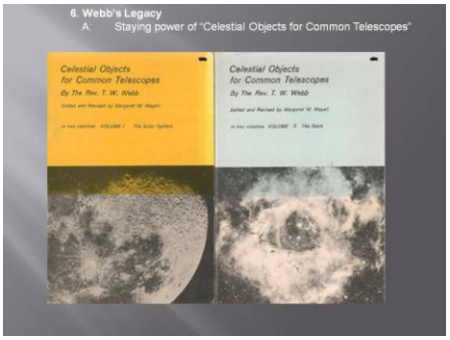
Webb's Legacy

Staying power of "Celestial Objects for Common Telescopes".

T.W. Webb's observing guide book is regarded as the first popular astronomy book of its type that was geared toward the common amateur using small telescopes of the time that were affordable. The earlier observing book that it superseded – Admiral Smyth's "Cycle of Celestial Objects " was aimed toward the more well-to-do semi-professional astronomer of the day. First published in 1859, Webb's "Celestial Objects for Common Telescopes" has gone thru six revised editions, with the last major in 1917.

Then in 1962, it was republished by Dover Publications. Volume 1 on the solar system and telescope instruments was left unchanged from the 1917 edition, (except for the inclusion of two appendices containing 1962 planetary data), and is mostly of historical interest only.

Volume 2 which focuses on the constellations listed in alphabetical order and their nearly 4000 deep-sky objects, is also mostly unchanged except for additions of new appendices for precession from 1920 to year 2000, with individual tables for double-stars, variable stars, and clusters and nebula for Epoch 2000. Also, there's a list of modern constellation names, along with new photographic illustrations from the late 1950's up to 1962.



Webb's book continued to be the 'go-to' manual for amateurs, and was only finally dethroned by Robert Burnham's three volume "Celestial Handbook" published in 1966. Burnham's guidebook focused exclusively on

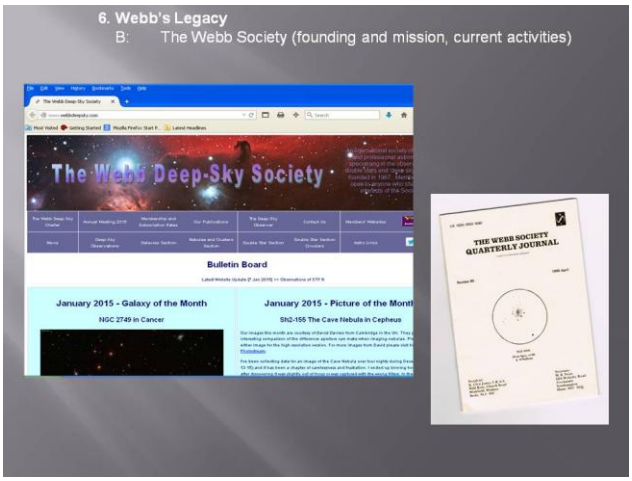
observing deep-sky objects, with the constellations listed by alphabetical order, split among the three books. Embedded within each constellation were numerous historical tidbits on its origins, along with various observational descriptions and discussions on state-of-the-art astronomical knowledge of various deep-sky objects. Burnham's, with its modern style of writing and large lists of new deep-objects to observe greatly appealed to the amateur astronomer of the early 1970's who now had much larger 'common telescopes' available to use, and it soon replaced Webb's handbook both on the bookcase and in the field. (Burnham's was later replaced in the late 1990's by the "Night Sky Observers Guide" by George Kepple and Glen Saner).

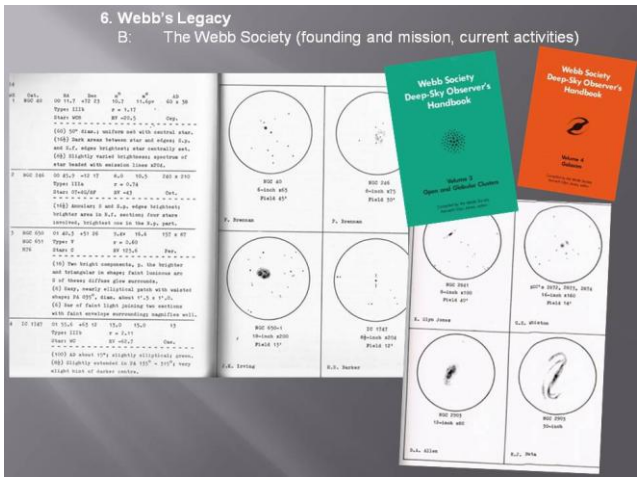
For us in the 21st century, what keeps Webb's guidebook relevant are the interesting visual observations made by Webb and various other observers of the different types of deep-sky objects.

The Webb Society (founding and mission, current activities)

The Webb Society was founded in 1967 and named in honor of the Reverend Thomas William Webb, an eminent amateur astronomer who has been an inspiration to generations of amateur astronomers. The main purpose of the Society is to advance education in the science of astronomy by encouraging amateur observations of double stars, nebulae, star clusters and other astronomical objects. And also, to provide a forum where amateur astronomers can communicate and publish the results of their work. The Society's motto is ``Caeli scrutamur plagas'' - we sweep the regions of the heavens.

Observational activities of the Society are coordinated in various sections each under the control of a director with wide experience in the particular field.
Currently the sections are:
Double Stars
Nebulae and Clusters
Galaxies
Southern Sky.
Results of the Society's work are published quarterly in the 'Deep Sky Observer/ Quarterly Journal'.
Members are encouraged to contribute to the publications and are given guidance on how to present their work.
Membership in the society is open to any person anywhere in the world.





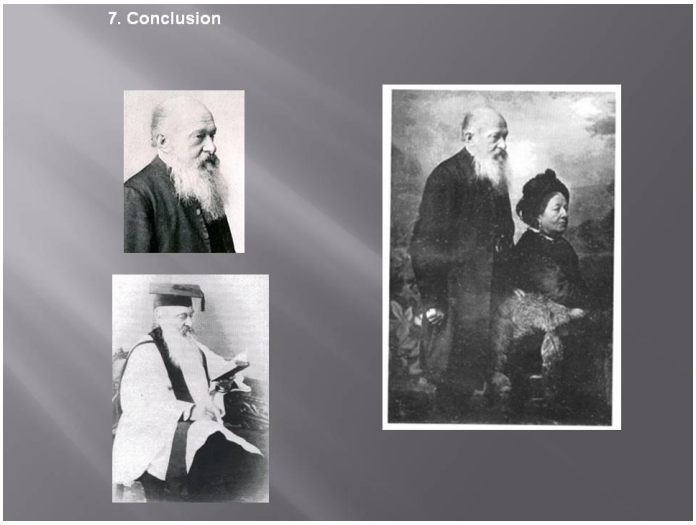
In the late 1970's, the Society began publishing a series of observer's manuals as an update and extension of Rev Webb's original work for the amateur telescope equipment that is available today.
Volume 1 - Double Stars (1975)
Volume 2 - Planetary and Gaseous Nebulae (1978)
Volume 3 - Open and Globular Clusters (1980)
Volume 4 - Galaxies (1981)
Volume 5 - Clusters of Galaxies (1982)
Volume 6 - Anonymous Galaxies (1987)
Volume 7 - The Southern Sky (1987)
Volume 8 - Variable Stars (1990)
Volume 9 - Webb Society Star Atlas

Each handbook contains observing methods and updated theoretical information on the class of objects covered by the individual handbook. The core of each handbook is a catalogue of the deep sky objects that can be observed by the amateur astronomer, which included detailed eyepiece sketches and observing descriptions that are more representative of what experienced amateurs see in their telescopes. Over the years, as newer guidebooks became available, both in print and online, the Webb Society books have joined the list of older out-of-date publications, but they are still useful to amateurs looking for new observing ideas.

Conclusion

Thomas's longtime companion and wife, Henrietta, (who he had married in 1843) passed away from a stroke on Sept 7th 1884. Eight months later, in declining health and still in grief for his wife, Thomas William Webb passed away on May 19th 1885 in Hardwick at the age of 79. He was known locally as a genial parish priest, who faithfully served the members of his church, but was also internationally acclaimed for his astronomical observing skills.

During the period of Webb's adult life in the mid-to-late nineteenth century, with the availability of inexpensive books, charts, and 'competently built' telescopes, there was an explosion of interest in popular sciences among the educated public, and Thomas Webb filled a much needed role as a promoter of astronomical observing for the serious amateur astronomers.



T.W. Webb wrote numerous astronomical articles for various magazines of the day, (around 194), which helped popularized the hobby of astronomy among the general public. He also privately corresponded with a large number of amateur astronomers, giving them advice regarding their instruments and observing techniques, with the letters frequently containing illustrated technical equipment drawings or sketches of astronomical objects.

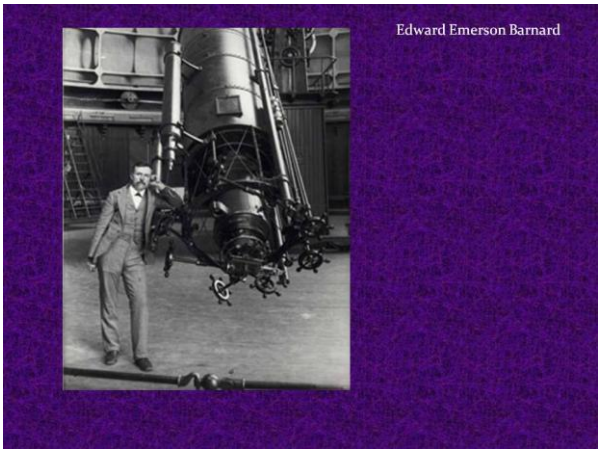
His handbook, "Celestial Objects for Common Telescopes" had become famous among multiple generations of amateur astronomers around the world in providing them with information as to what to look for with the small telescopes of the time, and how to use those telescopes to find those objects up in the 'heavens' above.

Even after 155 years, this Victorian era observational information is still enjoyable today! And the books give an interesting glimpse into the scientific understanding of the universe in the late 19th century.

It's this lasting legacy of the Rev Thomas W Webb, as to why he is known today as:
'*The Father of Amateur Astronomy*'.

E.E. Barnard and His Dark Nebula

Visible throughout our galaxy are clouds of interstellar matter, thin but widespread wisps of gas and dust that we call “nebula”. Some of the stars near nebulae are often very massive and their high-energy radiation can excite the gas of the nebula to shine; such nebula is called emission nebula. If the stars are dimmer or further away, their light is reflected by the dust in the nebula and can be seen as reflection nebula. Some nebulae are only visible by the absorption of the light from objects behind them. These are called dark nebula



Edward Emerson Barnard was a professor of astronomy at the University of Chicago Yerkes Observatory.
As a pioneer in astrophotography, he cataloged a series of dark nebula of the Milky Way. Through this work of studying the structure of the Milky Way, Barnard discovered that certain dark regions of our galaxy are actually clouds of gas and dust that obscured the more distant stars in the background. Today, we’re going to look-back on his life and accomplishments. We’ll also review several of my observations of his dark nebula.

Outline:

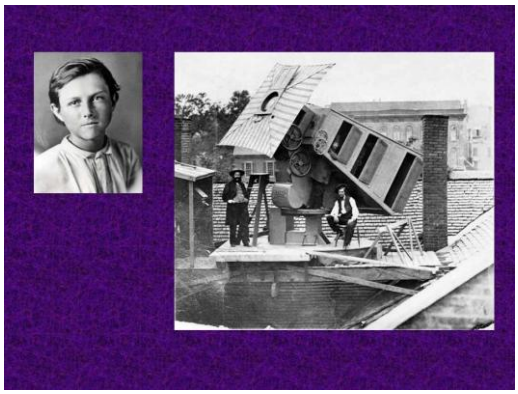
- Barnard’s Early Years:
  - Childhood, Work, and Stargazing
  - Becoming an Astronomer
- Life as an Amateur Astronomer:
  - Lick Observatory
  - Yerkes Observatory
- My Observations of Barnard’s Dark Nebula:
  - B33 – Horse head
  - B72 – The Snake
  - B86 – Ink Spot
  - B87 – Parrot Head
  - B78-Pipe neb, galactic dark horse,. Stuff in Aquila, Cygnus,,
- Barnard’s Legacy
- Conclusion

Barnard’s Early Years:

Childhood, Work, and Stargazing

Edward Emerson Barnard was born on December 16th, 1857 in Nashville Tennessee, at the cusp of the Civil War. His mother, Elizabeth, (at the age of 42), had moved the family from Cincinnati to Nashville a few months prior to Edward’s birth, when his father, Reuben Barnard had passed away. The family lived in near poverty, with Elizabeth as the sole provider working several small jobs, the most profitable being that of her making wax flowers, which she had a skill at creating.

The family moved multiple times about the city during Edward's yearly years, with several locations being near the Cumberland River where Edward would swim out into to recover supplies lost in the river by the battling upstream armies. Due to the turbulence from the war, Edward was not able to really attend a formal school setting, only getting in about two months of actual classroom time, but was homeschooled by his mother at an early age to both read and write. Besides the Bible, the family only owned a few other books, including a couple old history and science volumes, but Elizabeth had been well educated and passed on what she knew to Edward.

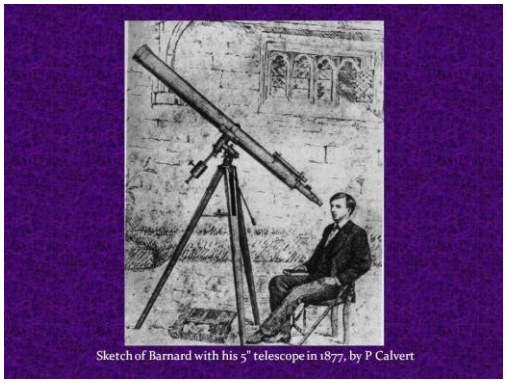


Once the war had ended and Nashville began to rebound, to help support the family as his mother's health was starting to fail, Edward at the age of nine was able to find a job in a local photography studio. The shop owner was in need of a young assistant whose primary job would be to keep a giant portrait enlarger camera located on the shop's roof pointed at the Sun in order to provide enough natural light for the photo enlargements. (the giant camera was nicknamed the "Jupiter Camera" for its kingly size and needing to follow the Sun). Having gone thru several other boys, who couldn't keep the camera drift off of tracking the Sun, when they fell asleep, Edward was given a chance at the job. Not only was Edward able to keep the camera on track throughout the day, but he was also curious in learning how it worked and developed an interest in camera lenses and learning photographic techniques. The patience and endurance skills that he learned in guiding the enlarger, along with the camera and darkroom properties that he learned over the course of 17 years that he spent working at the studio would become extremely useful to Edward in his future career as a professional astronomer.

During his tracking duties, Edward soon noticed that the Sun didn't follow the same path at the same rate every day, and 'discovered' that it varied based on the season. This was Edward's first exposure to astronomy. Walking home after dark, his interest in following the Sun's path soon led him to begin watching the stars. During the summer, once home, he would spend his free time lying in the back of an old wagon gazing at the stars overhead, and from that he became interested in the night sky. As he would lay there in the wagon, there was one particular bright white star that shone overhead which always held his attention, and he came to think of it as his special star to watch. Due to his sketchy formal education, Edward did not know that star's name was 'Vega'.

In 1870 when he was 13, Edward, through the help of one of his co-workers, acquired the parts from an old ship's spyglass, (brass tube and several lenses), and built a small altazimuth refractor with a 2" lens which Edward used to study the Moon and the planets Venus and Jupiter. Then at the age of 17, Edward got the chance to teach himself astronomy when a friend of his borrowed money from Edward and left as collateral a stack of books. One of those books was a text on astronomy and Edward was finally able to learn the names of the stars and constellations that he had been watching since he was a young boy.

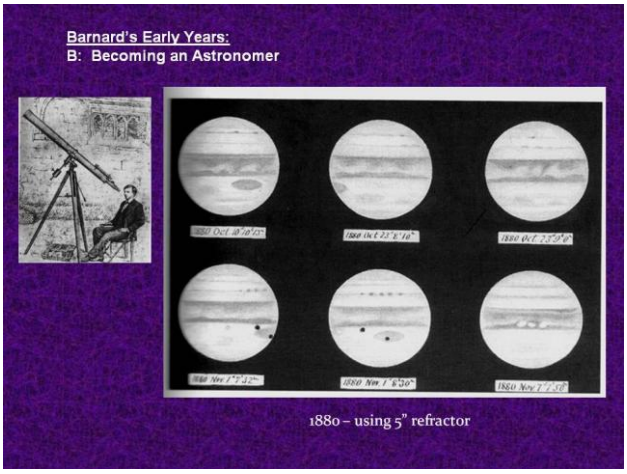
Within two years in 1876, at the age of 19, Edward had saved over a half-year worth of his salary, and used that to buy an equatorially mounted 5" refractor made in New York for $380. He used this telescope to continue observing the Moon, planets and double-stars and clusters. But he most enjoyed sweeping along the Milky-Way with it.



Sketch of Barnard with his 5" telescope in 1877, by P Calvert

The following year, in 1877, the American Association for the Advance of Science held its annual convention in Nashville at the new Vanderbilt University. Through his local connections with the photography studio, Barnard was able to meet with the association's president, prominent professional astronomer Simon Newcomb.
There, Edward asked Newcomb how to go about becoming a professional astronomer, hoping that he was already on the right track. Newcomb, after learning Barnard's background and lack of education didn't hold out much hope for Edward, as he didn't have the required mathematic knowledge. But Newcomb did suggest to Edward that he should take up comet searching as a way to perhaps become a professional observer and spent a few minutes explaining the methods of comet sweeping to him. Edward came away from that meeting feeling a little crushed, but he resolved to take Newcomb's advice and begin searching for comets.

Becoming an Astronomer
After the depressing meeting with Simon Newcomb, Barnard hired a math tutor. Edward would spend nights that were cloudy or moonlit studying and clear nights out observing. He also began to make more practical detailed observations, sketching Jupiter's bands, Great Red Spot, and the Galilean Moon's shadow transits whenever he could and even participating in recording observations of the 1878 Mercury Transit. Through these efforts, Barnard became a skilled record keeper and planetary sketcher.

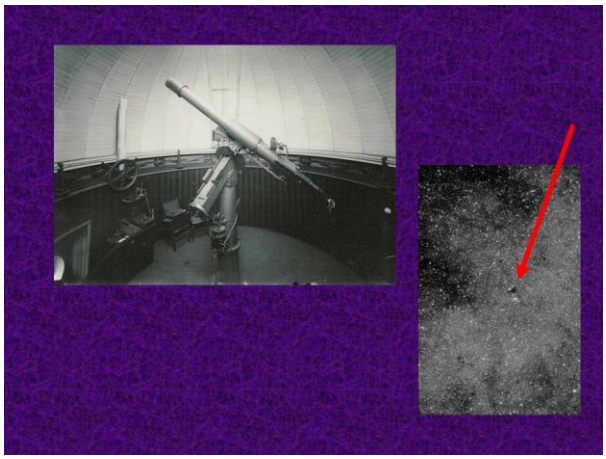


Three years later, on May 21st of 1881, Barnard's sweeping paid-off and he discovered his first comet. Unfortunately, he didn't know the proper technique to measure its position or even how to report it correctly to the professionals. Barnard realized that he needed help in learning how to make the mathematical calculations and reporting techniques, so he reached out to contacts he had made at Vanderbilt University. The university had just recently completed building a new observatory with a 6" Cooke refractor, but had no astronomer on staff to run it. The university's head of the School of Engineering, Olin Landreth, offered Edward a job as the Vanderbilt Observatory Assistant Astronomer, and enrolled Barnard as a student to acquire the necessary education in math and physics. Barnard was put in charge of the observatory which beside the 6" refractor, included a meridian circle, clocks, and several spectroscopes.

This was the break Barnard was hoping for.
He would spend the day studying mathematics and then spend the night observing the sky. Edward considered sleep a waste of time, and he soon became known as "The Man Who Never Slept"! Before long, Edward's diligence paid off again, as he discovered another comet that fall on September 17th, 1881, which became his first official find, and then a year later another new comet discovery on September 14th 1882. Edward even found time to court and marry Rhoda Calvert, the English sister of one his photography studio co-workers.

From his comet discoveries, Barnard became a sort of local Nashville celebrity. His discoveries also proved to be financially rewarding, as at the time, a wealthy American manufacturer Hulbert Warner, was offering a $200 reward to any American who discovered a new comet. Barnard used his first findings to buy land and build a house for him and his new wife, and it seem that every time a mortgage payment was due, Barnard would discover another new comet and once again collect the reward in time to pay it off. His house was known locally as "The Comet House". By 1887 Edward had went on to discover a total of 9 new comets!

In addition to comet sweeping, Barnard also spent time using the observatories 6" refractor observing the planets and other deep-sky objects such as star clusters and the various nebula scattered about the night sky.
On July 17th, 1883, while observing near M20 in Sagittarius, Barnard discovered a small triangular-shaped 'dark-hole' near a small starcluster (NGC6520). This was Edward's first telescopic discovery of what would become known decades later as Dark Nebula. It was also Edward's favorite example.



In 1884, he discovered a previously undetected faint nebulous smudge in Sagittarius known today as NGC6822 or commonly as "Barnard's Galaxy", which turned out to be a small irregular dwarf galaxy of the Milky-Way.
By the time Barnard left Vanderbilt, he had discovered 20 new nebula, including NGC2237 – a bright knot of the Rosette Nebula, in Monoceros, and NGC1499 – the California Nebula in Perseus.

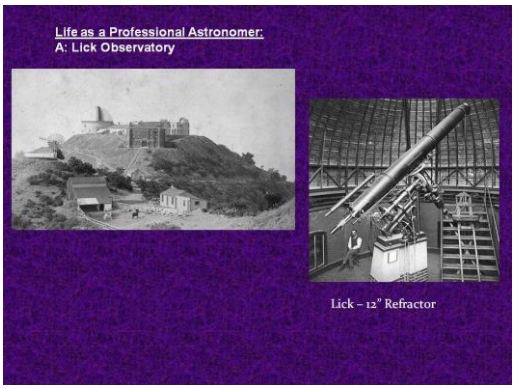
Barnard never did officially graduate from Vanderbilt University, as in 1887, Edward was offered a job as one of the initial staff astronomers at the new Lick Observatory on Mt Hamilton. Barnard jumped at the chance to use the new soon to be commissioned 36" refractor at Lick, then the world's largest telescope, and promptly quit his job at Vanderbilt, sold his home to his brother-in-law, and moved Rhoda and himself to Northern California.

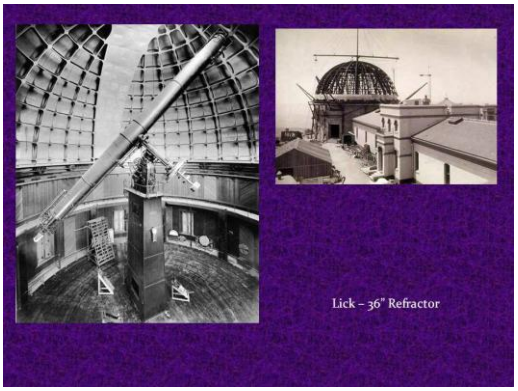
Life as a Professional Astronomer:

Lick Observatory

During the mid 1880's work on the new Lick Observatory and its 36" refractor was a hot topic of the day among the astronomical world. Edward had been following it in the news and once it was announced that Edward S Holden was named as the director of the observatory, Barnard began a letter writing campaign to him in hopes of getting a job at the new observatory, the first ever to be built on a mountain top. Thru Barnard's comet discoveries and the good reviews from other astronomers that knew of Barnard's work, Holden decided that even though Barnard didn't have a top educational background that Holden would have preferred for his staff, that Barnard's keen observing abilities was what he needed for the new observatory. So the director offered Edward a job as a junior member of the astronomy staff and was assigned time on the lesser telescopes at the observatory, such as a 12" Clark refractor and a small 6.5" equatorial refractor. Barnard was shutout of any observing time on the big 36" refractor, which eventually led to a long running feud between Barnard and Holden.

Unfortunately, for Barnard, he moved a little too soon from Tennessee, as unknown to him there were delays in building both the observatory dome and support buildings and the 36" telescope, so when the Barnard's arrived in San Francisco, the observatory hadn't yet been turned over for use. Edward had to take a job at a law office as a document copier and sale his beloved 5" refractor for enough money for them to live off of until the new observatory officially opened. Finally, in May of 1888, the observatory was finally completed and Edward was able to officially start work as a Lick Observatory Astronomer. Barnard wasted no time in sweeping up a new comet in September, and another in October.



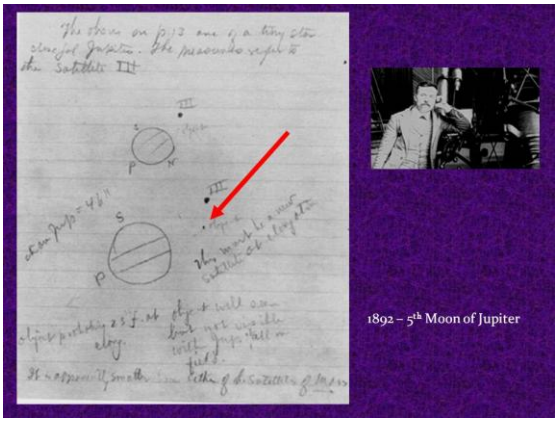


One of Barnard's early assignments was to utilize his studio photography expertise and began to systematically photograph the Milky-Way. So Barnard took a used 6" studio-portrait lens (a Petzval doublet named the Willard lens) that the observatory had acquired and mounted it in a wooden box camera back that he built by hand. Edward then piggybacked this home-made box photographic camera on the small 6.5" observatory refractor and began experimenting with guided exposures. His wide-field time exposures revealed details in the large-scale structures of bright starclouds obscured by what looked to be dark holes/voids, lanes, or spots. His photographs soon became a popular item to be passed around the observatory staff, as they showed the richness of the Milky-Way starclouds as they had never before seen. This was the start of what became Barnard's life-work, gathering evidence as to the nature of these dark features – were they really actual voids of matter in space, or were they something else.

During this period, Barnard also made some other interesting observations, such as an occultation of Saturn's moon Iapetus by Saturn's rings on November 1st 1889, in which he observed shadow bands passing over the moon. Barnard also successfully photographed the total solar eclipse of January 1st, 1889, producing at that time, the best images ever made of the solar corona. Barnard also accelerated his comet discoveries while at Lick, finding another 8 comets over the next six years. One of which, "1892 T1" was the first comet to be discovered photography.

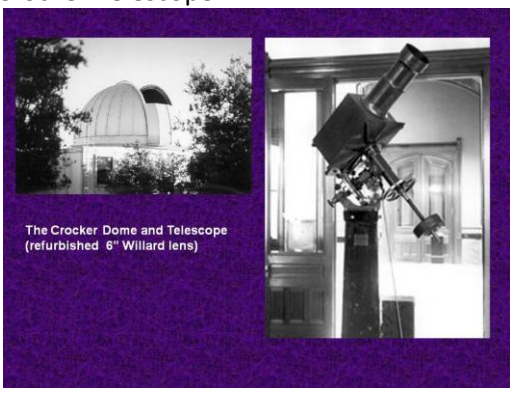
Finally in July 1892, after taking his case directly to the Cal-Tech Lick Observatory board of directors; Barnard was awarded observing time on the 36" refractor. Shortly thereafter in August of 1892, using his newly won time on the 36" refractor, Barnard was the first to visually observe gaseous emissions coming from a recent nova in Auriga, and correctly deduced that the outflow was the result of a stellar explosion. One month later, Barnard was to use the 36" to make a discovery that rocked the world and brought international fame to both Lick Observatory and Edward Emerson Barnard.

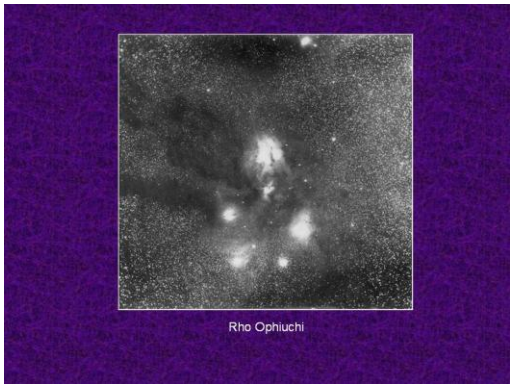
On the night of Friday September 9th, 1892, during Barnard's observing session with the 36" refractor, he pointed the great telescope to Jupiter. While observing Ganymede approaching the planets disk for a transit, he spied a faint spark of light between the two. It was a new 5th moon! The first new satellite of Jupiter to be discovered since Galileo in 1610! After a couple more nights of confirmation observations and orbital calculations, the observatory broke the news to the world.



While it was Barnard's right to name the new moon, he never could settle on what to call it.
Eventually, upon the suggestion of French astronomer Camille Flammarion, the new 5th moon of Jupiter was named Amalthea. Jupiter's new 5th moon also became the last solar-system satellite to be discovered visually, as all future discoveries have been since made only by photography.

Now, with more time allotted on the 36" refractor, Barnard tried using the old 6" Willard lens studio camera on the great telescope, but the lens had deteriorated and needed re-polished. It was sent off to John Brashear's optical shop in Pittsburgh to be refigured. A local benefactor of the observatory, Colonel C.F. Crocker donated funds to build a dedicated small dome with a dark room and equatorial mount for the new Willard lens, which was now called the Crocker Telescope.





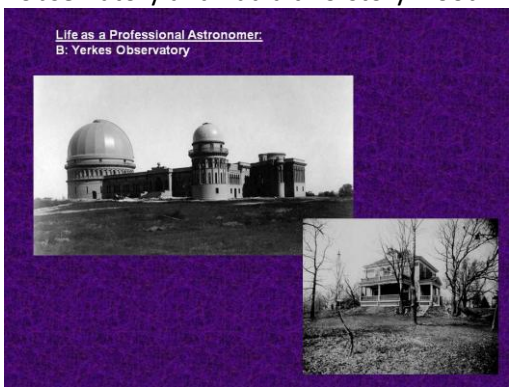
Using this Barnard went back to spending his non-36" evenings to photographing dramatic wide-field pictures of the Milky-Way, particularly the striking dark-holes in the Sagittarius region and around Rho Ophiuchi.
Barnard gave fanciful names to some of these objects, such as the 'Snake', (B72), the 'Pipe' (B78), and the 'Parrots Head' (B86). Barnard still continued to view these objects as actual voids in space, but the data was beginning to point in another direction.

Edward also took time out to use the Crocker Telescope to photograph comets. In 1893, he was the first to photographically record a tail disconnection event that occurred with Comet Brooks of that year.
During this period, Edward, on his own purchased a small cheap projecting lens of 1.5" and he made an even wider-field 'lantern' camera with it and piggybacked it on the Crocker Telescope. With this new camera he was able to photograph entire constellations, and was the first to image an enormous nebula in Orion in its entirety, now called "Barnard's Loop". This inexpensive little camera of his was also very successful in imaging the vast starclouds of the Milky-Way.

Finally by 1895, the feud between Barnard and Lick Observatory Director Edward Holden peaked, with Holden refusing to publish Barnard's wide-field and comet images.
In an opportune moment, George Hale made an offer to Edward Barnard to come work at the new Yerkes Observatory with a title of 'Professor of Practical Astronomy', where he would have full access as a staff astronomer to the new 40" Refractor being built. Barnard accepted, and was soon on his way to Williams Bay Wisconsin with his lantern camera and unpublished wide-field Milky-Way photos.

Yerkes Observatory

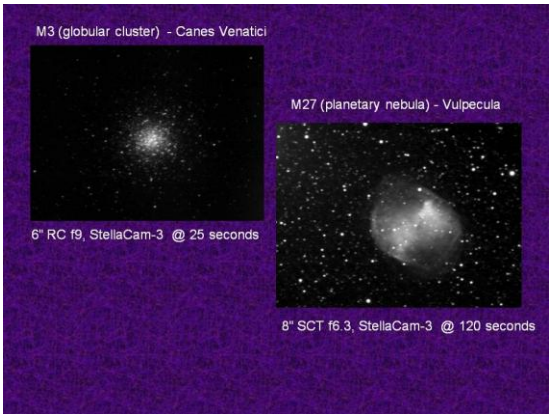
With the October 1895 offer from Hale, Barnard and Rhoda once again sold off most of their belongings and moved to the small town of Williams Bay, along the shore of Lake Geneva, Wisconsin. There they purchased land next to the new observatory and had a two-story wood-frame house built.



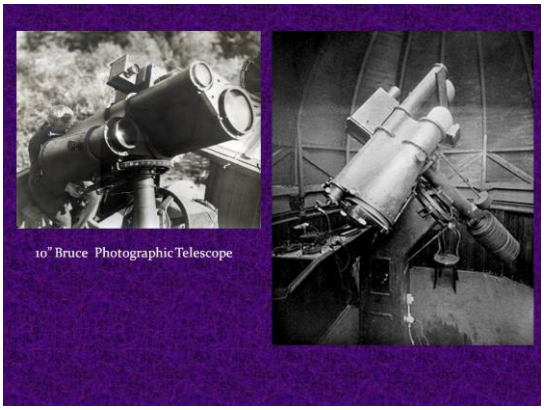
While waiting for the 40" refractor to be completed, Edward put to use George Hale's personal 12" refractor that Hale had installed in a smaller dome at Yerkes and was able to continue with visual observations. During this time in 1896, the prestigious English Royal Astronomical Society awarded its Gold Medal to Barnard for his work, and Edward spent a month over in England lecturing at Oxford and Cambridge.

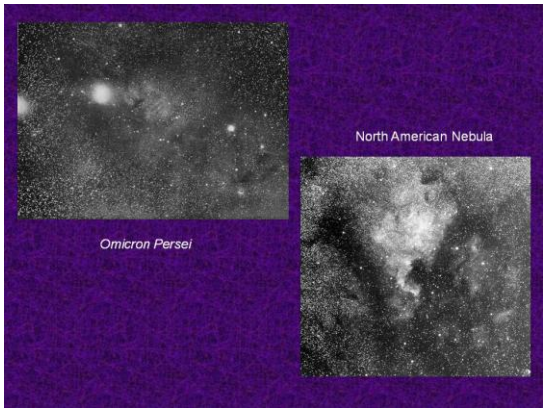
Finally in May of 1897, the 40" lens by Alvan Clark was finished, taken to Yerkes and installed in the great telescope tube. The telescope performed flawlessly, but unfortunately, less than a week later, the support system on one side of the moveable observatory floor failed, causing that side to crash down 45 feet, wrecking it.
The 40" was out of commission until the middle of August.

With the observatory officially opened, Barnard was one of the principle observers on the 40" refractor, and would never miss a clear night at the observatory. Edward used the telescope visually by taking micrometer measurements of the planets and moons, globular clusters, and planetary nebula. Barnard tracked the globulars M3, M5 and M13 in hopes of determining their distances by parallax, and planetary nebulas M27, M57, and M97 in hope of determining whether they were physically changing.



In 1897, Barnard made a successful sales pitch to the wealthy Yerkes Observatory benefactor Catherine Bruce, to fund a new wide-field 10" photographic refractor telescope for Barnard's exclusive use. This instrument became known as the "Bruce Telescope" and it's 10" doublet lens was made by John Brashear of Pittsburgh.
It was also coupled with a 6.25" German Voigtlander portrait lens. With it, once completed in September of 1900, Barnard took over 4000 images, and made a number of photographic nebula discoveries, and re-imaged the large-scale Milky-Way structures he had earlier photographed using the small lantern camera at Lick.





Using the new Bruce Telescope, it was the richness of the starclouds and outstanding Milky-Way features, showing much more fine detail in the dark regions than ever before, which became the center of Barnard's work. During this period, Barnard began to reconsider his view that these objects were actual star-less voids in space. He started to believe that what he was seeing was actual dark obscuring material, parts of what Barnard called "Dead Nebula", where he thought the nebula could no longer form stars, had burned-out, no longer emitted light and had gone dark. In March of 1907, Barnard published a research paper based on the new Bruce photos in the 'Astrophysical Journal' where he studied both the bright and dark nebula of Rho Oph in Ophiuchus (B42 & B43), and around LBN782 in Perseus (B10), and speculated that a large nebula existed in both regions, but its major portions had gone dead and was non-luminous and cutting out the light from stars behind it. Barnard stated "*I have been slow in accepting the idea of an obscuring body to account for these vacancies (voids); yet this particular case almost forces the idea upon one as fact,,, There is no question that this is real, and not a subjective effect".*

This was the evidence, from his own photographs, that convinced Barnard to finally come around to the thought that these dark voids were actually obscuring dark matter in front of and blocking the view of the more distant Milky-Way. This was considered a huge discovery among the astronomical world, as now all the various galaxy formation models would have to take into account these dark clouds of dust and gas.

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On May 28th, 1900 another total solar eclipse of about 1 minute in duration was to cross over the Eastern Seaboard, and Yerkes sent a group to Wadesboro, North Carolina to setup an observing station. Once again, Edward, tasked with photographing the solar corona, was successful. A year later, Yerkes Observatory sent Barnard and several astronomers overseas as part of a US Naval Observatory expedition to Sumatra for the 6-1/2 minute total eclipse that was to occur there on May 18th, 1901. Barnard thought the most interesting part of the trip was when they sailed past the remnants of the island of Krakatoa, which had blown its volcanic top just 8 years earlier.
Once arriving at their observing site, Barnard setup his equipment, but it was all for naught, as on the day of the eclipse, the sky was heavily clouded and the expedition was not able to observe any of it.

From the start of his time at Yerkes, first using his little 1.5" lantern camera and then once completed, the Bruce 10" photographic telescope, Barnard photographed nearly every new comet that came around, once again capturing a number of images showing comet tail structures, disconnects, and disturbances that were important in analyzing the physics of comet behavior. Using this data, in 1909 Barnard came up with the theory that these comet tail changes were caused by the effects of solar disturbances, the same that caused geomagnetic storms and auroras on Earth.

Barnard went on in May of 1916 to discover the star with the fastest proper motion of 10 arc seconds per year, since named "Barnard's Star", which is a 9th magnitude star located in the constellation of Ophiuchus.

This is also one of the closest nearby stars to our solar system at about 6 light-years.

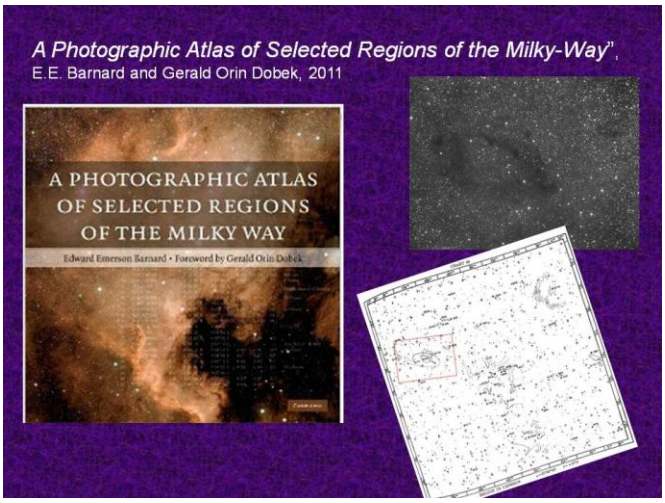
In December of 1916, Barnard using the 40" telescope was again the first to detect the expanding planetary nebula from a nova in Perseus. Edward had first observed the nova back in 1901 when it erupted, seeing nothing at the time, but kept the star in his observing plans and finally was able to visually see the forming gaseous shell.

In 1918, Barnard at age of 60, once again went on a total solar eclipse expedition, this time to Green River Wyoming for a 98 second eclipse on June 8th. Barnard was successful in recording both the inner corona and limb prominences. Arriving back at their hotel after the eclipse at dusk that evening, Barnard noticed a new naked-eye nova in Aquila, and he along with a group of astronomers rushed back to their equipment to make observations. Edward became one of the many independent observers who discovered the nova that night. Barnard followed the nova all that fall as it slowly faded.

My Observations of Barnard's Dark Nebula:

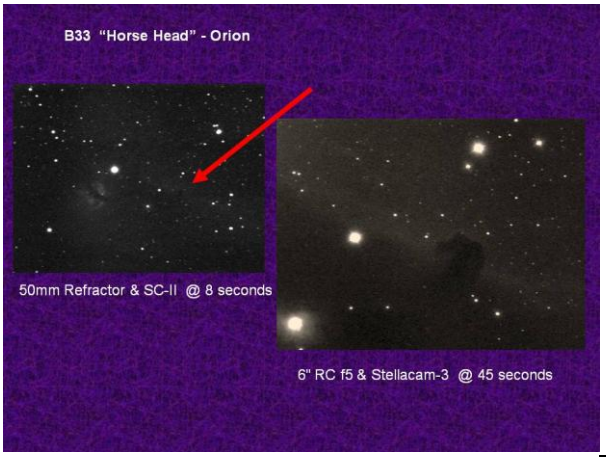
So, where can you find E.E. Barnard's Dark Nebula's?
Dark Nebula can be found all along the glowing band of light that we call the "Milky-Way", our home galaxy. Some large nebula are best suited for the naked-eye, while others are telescopic and require large apertures. Fortunately, there are many objects that display nicely using binoculars or small rich-field telescopes.
While a number of dark nebulas are fairly easy to find, most require observing from a dark-sky country location such as Cherry Springs. Observing them visually requires maintaining dark-adaptation, having good starcharts, and slow sweeping with a wide-field low-power telescope. An 80mm F6 or shorter refractor piggybacked on a larger telescope would work very well. The 80mm acts as a low-power RFT giving you a wide-field in which to find the dark-nebula and the larger telescope it is attached to allow use of higher magnifications, depending on the object. You'll need all your visual observing skills to find and bring out the subtle differences in these objects.

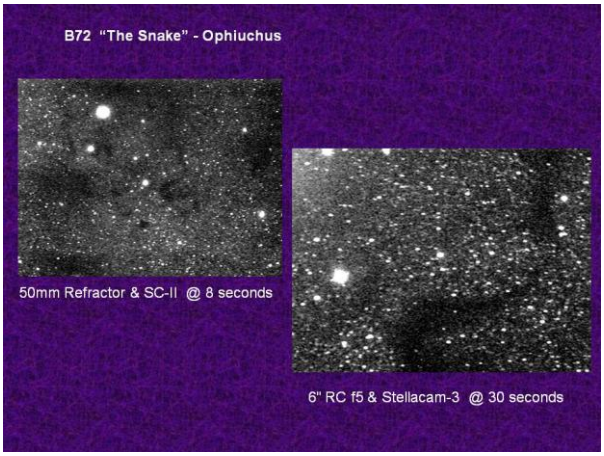
For the Imagers, dark nebula can also be challenging, in that even with an accurate GOTO mount, it may not position the telescope squarely on the object to where it's framed the way you want it. Having a photographic atlas or picture of the dark nebula will help you in both locating and identifying the most interesting sections of the nebula and framing your image.

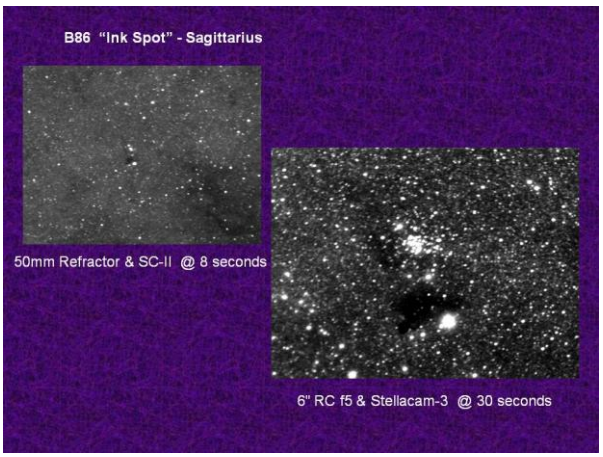


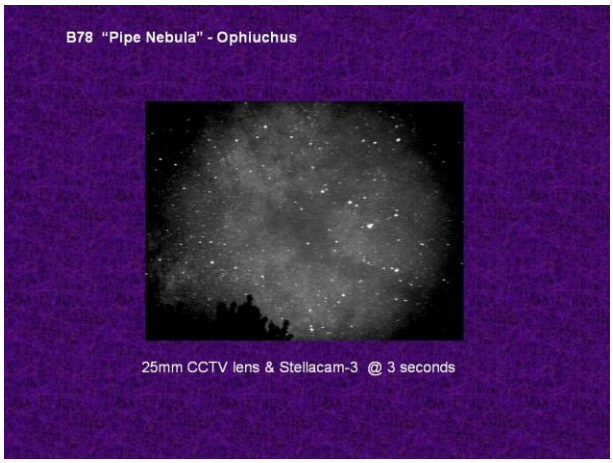
Let's run thru a few examples of Barnard's Dark Nebula:

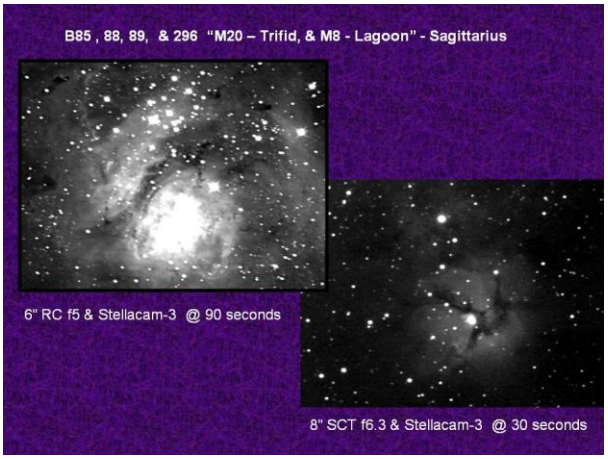
- B33 - Horse head
- B72 - The Snake
- B86 - Ink Spot
- B78 - Pipe Nebula
- B85, B88, B89, & B296 in "M20 & M8"





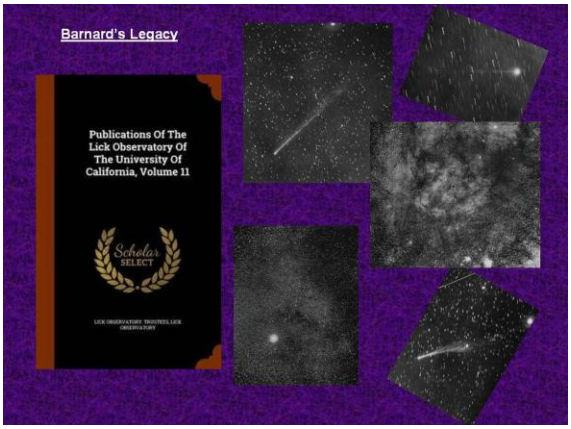






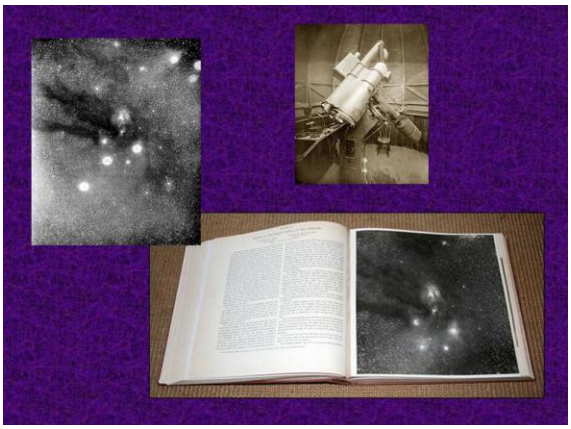
Barnard's Legacy

In 1902, after much prompting from colleagues both at Yerkes and Lick, Barnard took up the task of publishing his earlier Lick Observatory comet and Milky-Way photographs made with the 6" Willard lens/Crocker Telescope. Being the perfectionist that he was, Edward spent years experimenting with various Chicago printers using halftone processes or collotype printing, but was never happy with the quality. Finally, Edward found a printer that he was satisfied with, and his images, along with a write-up were published as volume 11 of the "Publications of the Lick Observatory" in September 1914. Even though the images were now over twenty years old, the Lick photographs were declared groundbreaking and the publication became a valuable addition to every professional observatory and astronomical institution.

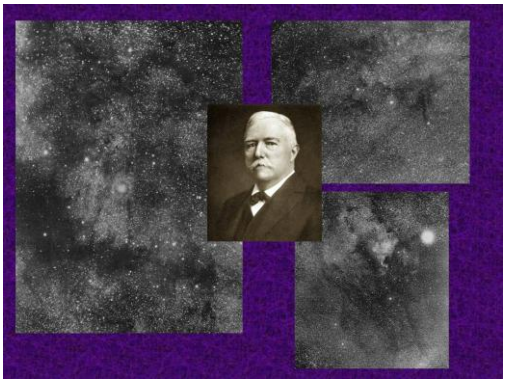


In 1907 Barnard obtained funding from the Carnegie Institution for a publication of his wide-field Milky-Way photographs made with the 10" Bruce Telescope. Using what he had learned in 1914, in trying to find the best printer for his earlier work, Edward spent the next decade continuing working with various print studios to find one that could reliably replicate his images in the best format.

After a number of false starts, Barnard finally came to the realization that none of them would ever be able to meet his high quality standard in the form of paper printed images. He decided that it would be worth the cost to have actual photographic prints made of each negative as a separate photograph that would be pasted into the pages of each individual copy of the atlas. The printer would then create photographic print batches of each individual image, and Barnard would go thru each one separately, keeping only the best quality prints and rejecting any lesser quality copies, and then sending the rejects back to be reprinted. Edward ended up sorting thru near 35,000 prints to hand-select only the finest ones of consistent uniform quality that he considered worth including.



But before he could finalize his atlas of Dark Nebula, long-standing health issues that Edward had neglected finally caught up to him. Declining in health, brought on from untreated diabetes and heart issues, Edward Emerson Barnard, at the age of 65, passed away on February 6th, 1923 at Yerkes Observatory in Williams Bay, Wisconsin. As requested, Barnard was buried in his hometown of Nashville, where he was given a heroes funeral procession fitting to a state official.



But his assistant and niece, Mary Calvert who started working for Edward in 1905, along with the current director of Yerkes Observatory, Edwin Frost, dedicated themselves to finishing Barnard's work.
So in 1927, Edward Emerson Barnard's greatest accomplishment, his photographs of the Milky-Way listing 370 of his "Barnard Objects" was published as a two-volume photographic atlas called:
"*A Photographic Atlas of Selected Regions of the Milky-Way*". Only about a 1000 copies were printed, and they soon were all taken up by the various professional observatories and universities around the world.
Today, the occasional 1st edition copy that comes available are highly sought after.

In addition to the Royal Astronomical Society's Gold Metal, Barnard also received three Gold Metals' from the French Academy of Sciences for his astronomical accomplishments. And he also received the Bruce Metal from the Astronomical Society of the Pacific. Over the years, Barnard has had a number of solar system objects named in his honor, including an asteroid, a Lunar crater, another crater on Mars, and a region on Jupiter's moon Ganymede.

Conclusion:

E.E. Barnard is considered by some to be the last great Victorian classical visual observer, living at the dawn of the age of the "New Astronomy" - astrophysics. But Barnard was also one of the first pioneers of wide-field photography, and his discoveries and studies of these 'dark voids' in space and his realization, starting in 1913, from his observations, both visual and photographic, that they were in reality foreground 'dark clouds' of interstellar gas and dust ,broke new ground in the science and changed our perception of the Milky-Way galaxy and star formation.

Edward Emerson Barnard straddled the divide between the old and new astronomy, and his work lives on today, both for the professional astrophysicist and amateur astronomer alike.

To E.E.Barnard, a clear night observing with a telescope was almost a sacred rite, to search for the truth in celestial places. So I encourage everyone to get out tonight and try your hand at finding and observing the celestial truth of these elusive deep-sky objects, the *Dark-Nebula* of Edward Emerson Barnard.

Planetary Nebula: From Messier to Abell *(What are they, and How to Observe Them)*

Introduction:

Planetary Nebula,,,,,, when I hear that phrase, I think of a specific type of deep sky object. A type of object that's always interesting and fun to observe or image. They also bring to mind their descriptions: Colorful ephemeral ghosts, luminescent wispy shells of dying stars. Little crystal ball gems in the night sky, delighting amateur astronomers using small or large telescopes. They run from large easily located extended disks showing great detail to tiny almost point-like, challenging to find. Interstellar graveyards giving up secrets of stellar evolution while spreading their wealth of star forged elements across space, swept up by gravity to enrich the next cycle of star birth. Pretty heavy stuff!!

NGC70293 ' Helix Nebula'

So today, I would like to bring these ethereal objects 'down to Earth' by discussing what they are, why we call them that, some of the people, both historical and modern, behind these objects, and how to go about observing them. Along the way, we'll also review a number of my personal observations of planetary nebula. Hopefully, when we are done, some of the mystery around these objects will have been lifted, and you will find them as interesting to hunt as I do.

Outline:

- What are Planetary Nebulae:
- Where are these Nebulae Located:
- How Planetaries got their name:
- How to Observe Planetary Nebulae:
- Historical and Modern Astronomers and their Planetary Nebula Catalogs:
    - Charles Messier:
    - William Herschel:
    - Rudolph Minkowski:
    - George Abell:
- Conclusion:

What are Planetary Nebulae?

Planetary Nebulae are clouds of interstellar matter, thin shells of ionized gas and dust. They mark where a star is slowly dying, or has ended its life in a violent explosion. These nebulae come in a wide variety of shapes and appearances. The central star that creates a planetary nebula is a red giant star in an advanced state of stellar evolution, at or just beyond, the end of its nuclear life cycle. When a star similar in size to our sun has used up all its

central nuclear fuel, it first expands into a red giant star. But eventually the force of gravity causes it to contract, and during that process it ejects a significant portion of its mass in a gaseous shell.
Ultraviolet radiation and light from the dying star then energizes the shell of expanding nebulous gas, causing it to appear as a brightly colored nebula. These shells are called ***planetary nebula,*** because they resemble a planetary disk. Most planetary nebula are just a few light-years or less in diameter, and are heated by UV radiation to temperatures of about 10,000 K. About one-fifth of all planetaries are roughly spherical, but the majority are not symmetric. Professional images show that many planetary nebulae have extremely complex and varied shapes. Planetaries are generally classified into three types: spherical, elliptical and bipolar. Some of these shapes are also due to our line-of-slight angle in how the object is projected. Magnetic fields, stellar winds, and interactions with other nearby stars can produce a wide variety of shells.

Stars which are considerably more massive than our Sun can explode violently, ejecting the greatest part of their stellar matter in a rapidly expanding shell. These are called *supernovae remnants.* Any leftover material from the exploding star may from a central compact remnant called a 'neutron star'. Supernova remnants are not considered to be Planetary Nebula. (*classical novae are considered to be mostly a type of cataclysmic variable star, caused by one star in a binary system drawing off material from the second star, leading to periodic flare-ups lasting for several weeks*).

Planetary Nebulae usually have only a few tens of thousands years before they fade and spread their matter into the interstellar environment, seeding the next round of stellar formation. On cosmic timescales, these nebulae undergo rapid changes and have comparatively short lifetimes, so that those we observe are all fairly young objects. Over a period of time, the central star cools down to a white dwarf star and the nebula will eventually fade from view.

Where are these Nebulae Located?
Planetary Nebulae can be found scattered throughout all four seasons of the night sky. There are currently about 3000 planetary nebula. Most of these nebulae that we can visually observe are located within the spiral arms of our own home galaxy, and can be found all along the glowing band of light that we call the "Milky-Way".
But some are visible thru amateur telescopes in nearby satellite galaxies, and professional observatories with large instruments have imaged planetaries in distant galaxies such as M31. Planetary Nebulae are generally among the most favorite deep-sky objects observed among amateur astronomers, and many are very interesting and worth the effort to find, regardless of the equipment that you use. While some planetary nebulae are fairly easy to find from suburban locations, most planetaries require observing from a dark-sky country location such as Cherry Springs.

How Planetaries got their name:
A lot of amateurs mistakenly credit Charles Messier for naming these types of deep sky objects. But that is not correct. Messier in 1764 discovered what would become the first planetary nebula, M27 (the Dumbbell Nebula) in the constellation of Vulpecula, and listed it in his catalogue of nebulous objects for comet hunters to avoid. Messier, with help from fellow French astronomer and comet hunter Pierre Mechain , went on to add three more of these objects to his catalog, (M57, M76, M97) but he never described them as resembling planets.

In 1779, another French astronomer Antoine Darquier, who is today co-credited with Messier for the discovery of M57, "the Ring Nebula", described his observations of it as: "...*a very dull but perfectly outlined; it is as large as Jupiter and resembles a fading planet*". But Darquier's observation of M57 wasn't widely published as Messier's and with credit for finding M57 going mostly to Messier; Darquier's description of M57 was soon forgotten.

But it wasn't until a few years later and by another astronomer that these types of objects were begun to be described as 'planetary nebula'. With the discovery in the constellation of Aquarius of what is now known as NGC7009 – (the Saturn Nebula) in 1782, William Herschel, (discover of the planet Uranus a year earlier in 1781), first used the term "planet" in his description of these objects: "*These bodies appear to have a disk that is rather like a planet, that is to say, of equal brightness all over, round or somewhat oval, and about as well defined in outline as the disk of the planets,,,,".* While it's possible that Herschel had read Darquier's previous description of M57, it could very well be that Herschel had 'planets' on his mind from his discovery of Uranus, as he always kept

an eye out for finding additional solar system members. Herschel went on to use the term "planetary" in his publications for 15 separate objects whose characteristics were a well defined round or oval shape with equal brightness across the disk. An example of which was his description of NGC7662 in Andromeda, Herschel calls it: "*a wonderful bright, round planetary, pretty well defined disk,,,"*

Herschel even named one of his deep-sky catalog classification categories (Class-IV) after these objects – "Planetary Nebula". But it wasn't until years later upon the persistence of his son John in using the term "planetary" in publications of his new discoveries from his southern sky cataloging trip to South Africa, that it really caught on and astronomers began actually calling these objects planetary nebula. John Herschel described these objects as: "*exactly the appearance of planets*", or "*perfectly round, very planetary,,, very like Uranus,,",* and "*just like a small planet*". This last quote was regarding NGC2867 in Carina, which for a few days John actually thought "*was so perfectly planetary in appearance,,"* that it took several observations over a period of days after he discovered it in 1834 before he was convinced that it wasn't moving and he didn't actually discover a new 8th planet of the solar system!

From the mid 19th century onwards, astronomers and observers now commonly described these objects as 'Planetary'. For example, the most famous discovery by 'grand amateur' Rev. T. W. Webb is the planetary nebula NGC7027 in Cygnus, which he made in November 1879. (Webb is the author of the popular Victorian era guidebook – "*Celestial Objects for Common Telescopes*"). Webb noted in his observing log that the nebula "*reminded me somewhat of the appearance of Uranus on an extremely bad night*". So the credit for popularizing the term 'planetary nebula' goes to the team of William and John Herschel.

During Herschel's time, no one understood what nebula were, so Herschel devised a theory that ran opposite of what we know today, that stars formed in isolation and were drawn together by gravity, first into loose star-cluster, then as they became more dense into globular clusters, and finally were drawn in to "*very aged*" planetary nebula. He felt that most nebulae could be resolved into stars with the right telescope. Herschel also believed that there were some types of true nebulosity, what he called an "*interstellar aether*". He came to this viewpoint from his observation of NGC1514 in 1790. This was William Herschel's first observation of a gaseous planetary shell with an obvious central star that convinced him that "*true nebulosity*" existed. Herschel went on to state in his observation of NGC1514 that it was "*A most singular phenomenon! A star of about 8th magnitude, with a faint luminous atmosphere of a circular form,,, the star is perfectly in the center,,, nor can there be a doubt of the evident connection between the atmosphere and the star*". But it wasn't until 1864 when William Huggins with his 8" Clark refractor first used a spectroscope on NGC6543 (Cats Eye Nebula) seeing a continuous monochromatic emission spectrum, that the true nature of planetary nebula was finally determined. That planetary nebula was not an irresolvable cluster of stars, but a "*luminous gas*".

How to Observe Planetary Nebulae:

Unlike the irregular shaped glow of diffuse emission nebula, planetary nebula live up to their name in that they are generally circular shaped objects somewhat resemble a planet. Some are evenly bright or illuminated across their disk, while others have a darker central region giving them a ring shape. And in some planetaries, the central star that created the nebula can still be seen. Several good examples of planetary nebula with bright prominent central stars that are easily visible are NGC40 in Cepheus, NGC1514 in Taurus, NGC6826 in Cygnus, NGC2392 in Gemini, Abell43 in Ophiuchus, and M27 in Vulpecula.

Visually, if the planetary nebula's surface brightness is high enough, you may be able to see color. While most of the dimmer planetary nebula will have a grayish color, the brighter planetaries will show variations of green and blue colors. Easiest to see colors in are M27 (Dumbbell) in Vulpecula, M57 (Ring) in Lyra, NGC7027 (Magic Carpet) in Cygnus, NGC6543 (Cats Eye) in Draco, NGC7662 (Blue Snowball) in Andromeda, NGC6905 (Blue Flash) in Delphinus, NGC6818 (Little Gem) in Sagittarius, NGC2392 (Eskimo) in Gemini, and Abell50 in Draco. Using H-a narrowband filters, Imagers will be able to pickup planetaries with reddish colors such as NGC6781 in Aquila, Abell70 (Diamond Ring) in Aquila, and the previously mentioned M57 and NGC7027. These colors are from double & triple ionized oxygen and hydrogen caused by the intense UV radiation of the central star. When these atoms drop down to a less excited state, they emit either a greenish or reddish light, depending on the wavelength. To see colors in planetary nebula, look directly at them and do not use your adverted vision.

Your eye's color receptor cones are located at the center of your eye and not on the sides.

Even though there's over 3000 planetary nebula, the majority are stellar in appearance, (especially Minkowski's), or exceedingly faint, (Abell's), needing a specialized line-filter such as an OIII filter or spectroscope to be able to even identify them. Other narrowband filters, such as Lumicon's UHC or Orion's UltraBlock will help to visually enhance viewing planetary nebulas. General broadband 'light-pollution' filters also will enhance planetary nebulas, though not as much as the others.

These filters work by blocking certain wavelengths of light and/or only transmitting certain specific angstrom lines. The idea is reject as much background skyglow as possible, while enhancing the nebula.
Planetary nebulae emit most of their light in the 4800A to 5300A range, which is the light from ionized oxygen, so a filter than passes these wavelengths work best. The OIII filter passes only the 4959A and 5007A lines, rejecting everything else, including most starlight, and leaving only the planetary nebula visible. These ionized lines are called "*Forbidden lines*" because it is not technically possible to create these types of emission lines in laboratories.

A good rule of thumb is that any planetary nebula that is identified as an NGC# are observable extended objects with disks or shell structures, while most of the IC#'s are stellar objects or have very small diameter disks, nearly indistinguishable from field stars.

The largest planetary nebula visible is NGC7293, "the Helix Nebula", in the fall constellation of Aquarius.
Due to its large dim ring-shape size, (about half the apparent diameter of the Moon), the Helix is best observed with wide-field small aperture telescopes from a dark sky. The brightest planetary is NGC7009, "the Saturn Nebula", also located in Aquarius. Due to its small size, a medium to large aperture sized telescope is required to observe any of its interior structure or the two 'ansae' that gives the nebula its Saturn appearance.

While planetaries can be classified into three generic types: spherical, elliptical and bipolar, a more detailed classification system was created by Boris Vorontsov-Velyaminov in 1934 that is still in use today.
Boris was a Russian astronomer best known for his co-discovery of the absorption of light by interstellar dust and his catalog titled: "*Atlas of Interacting Galaxies".* But he also studied planetary nebula and in 1934 devised the classification system still in use today, denoted as "VV"

Class	**Description**
I.	Stellar Image (star like) (these can be very hard to identify)
II.	Smooth disk (*a*, brighter toward center; *b*, uniform brightness; *c*, traces of a ring structure)
III.	Irregular disk (*a*, very irregular brightness distribution; *b*, traces of ring structure)
IV.	Ring or Annular structure
V.	Irregular form (similar to a diffuse nebula)

These classes will give you a good idea of what to expect from the nebula. The four Messier planetary nebulae are classified "VV" types of: "IIIa" (M27), "IV " (M57), "V" (M76), and "IIIa" (M97).
In general, for visual observers, it's best to hunt planetaries starting off with low-power, wide-field eyepieces and filters to identify the target area. Once the planetary is centered, you can then switch to higher magnifications to try and pull out details in the nebula shells, along with the central star.

Messier's four planetaries, (with the exception of M97), are high-surface brightness objects and are easily visible in most telescopes, even under suburban skies. The twenty planetary nebula from the Herschel catalog are also generally visible in medium size telescopes, though some will require larger size reflectors in the 15 to 20" range and a dark country sky. But the planetaries listed in the Abell catalog are generally very old, extended, and faint, which makes these objects very challenging to observe. The Minkowski planetary nebulae are even more difficult, most appearing star-like and embedded in crowed Milky-Way star fields, showing little to no disk nebulosity. You'll need a 17" or larger reflector or some type of imaging setup to pull these in.

Observing Guides:

There are a number of good Planetary Nebula related observing guides available to the amateur astronomer. Here's a few of my favorites:

"*The Night Sky Observers Guide – Glories of the Milky-Way*", by George Kepple:
This is the 4th in the series of handbooks written by George Kepple and Glen Sanner, each chapter covering a specific constellation, with finder charts, sketches, images, and visual descriptions of various deep sky objects. Volume 4 focuses specifically on constellations and their objects that lie along the path of our Milky-Way galaxy. Each constellation 'chapter' lists all planetary nebulae visible within its boundaries in a very convenient layout.

"*Planetary Nebulae, A Practical Guide and Handbook for Amateur Astronomers*", by Steve Hynes
Having been published in 1992, this book is a little hard to find and a bit pricy, but lists over 1,340 amateur observations of planetary nebula, including some sketches, along with 253 finder charts. Also sections on the historical discovery of, and astrophysics of planetary nebula. Well worth it if you can find one.

Another good guidebook to have is the Webb Society's Deep-Sky Observers Handbook series. With volume-two of the handbook – "*Planetary and Gaseous Nebula",* it lists a number of bright planetary nebula visible with small to medium size amateur telescopes. There are a total of 80 planetary nebula listed in the Webb Society handbook, with detailed descriptions and sketches.

Finally, on the internet, there are a number of good sites:
Amateur astronomer Alvin Huey has a number of great observing handbooks on his website: http://www.faintfuzzies.com/ The first one is called "*Planetary Nebula and Supernova Remnants*", which list over 300 planetaries with finder charts and DSS images. It's a mixture of easy and hard to find, so useful to both beginners and advanced amateurs. Alvin also has a handbook called "*The Abell Planetary Observers Guide*", also containing finder charts, DSS images, and visual eyepiece sketches made with 22" & 30" telescopes. Due to the difficulty of most of the Abell planetaries, this handbook is more for the advanced amateur looking for a visual or imaging observing project.

"*The Brightest Planetary Nebulae Observing Atlas*", by Massimo Zecchin. A downloadable PDF list of the 35 best planetaries across the sky, many that have a high surface brightness observable with small telescopes from a suburban location. Comes in either a black or white version. Includes a finder chart, object info, and a sketch by the author. http://www.pnebulae.altervista.org/contenuti/primipassi/ObservingAtlas/ObservingAtlas.html

Steve Gottlieb's Adventures In Space - http://www.astronomy-mall.com/Adventures.In.Deep.Space/abellpn.htm

Uwe Glahn http://www.deepsky-visuell.de/Projekte/AbellPN_E.htm website with visual descriptions made thru various medium and large telescopes using an OIII filter, along with DSS images.

Reiner Vogel http://www.reinervogel.net/pdf/Large_PN.pdf download observing guide - a list of 38 large planetary nebula with finder charts, DSS images and visual descriptions using a 22" reflector.

Historical and Modern Astronomers and their Planetary Nebula Catalogs:

So far we've covered what are planetary nebula, how they got named as such, and general tips on how to observe this type of deep sky objects. But who are these people that have been mentioned along the way: Messier? Herschel? Minkowski? and Abell? Let's spend some time digging a little deeper into the background of some of the historical and modern astronomers associated with catalogs of planetary nebula, and we'll look at a few examples of my observations, both visual and video capture, of their planetary nebulae.

Charles Messier:

In July of 1764, while out comet hunting with his 6" speculum mirror reflector, Charles Messier ran across a bright nebula that would become the 27th object on his list to avoid while comet hunting. Messier referred to M27 as a

"*nebula without a star,,, it appears of oval shape*". This was to become the first planetary nebula to be discovered, though it took another 20 years before it was categorized as one.

So, who was Charles Messier?

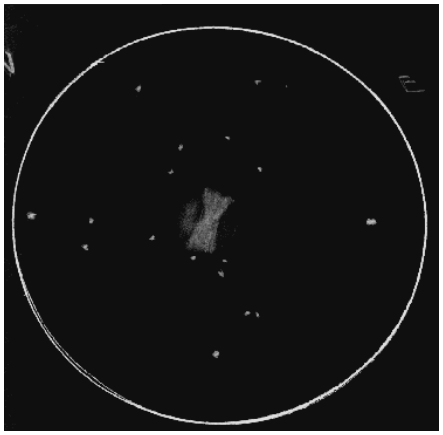
The 18th century French Astronomer Charles Messier is best known for his catalog of nebulae and star clusters, first published in 1771. This list of 110 deep-sky objects is known to today's astronomers as the 'Messier Catalog'.
As an astronomer, Messier's primary job was to hunt for comets. During his comet searches, he kept running into these diffuse non-comet objects that would frustrate him. So Messier began a list to help comet hunters avoid these false comets. Over the centuries, Messier's list became popular targets for amateurs because these 'M-objects' could be easily visually observed with small-aperture telescopes.

Messier worked as an astronomer for the French Navy. His observatory was located within the city of Paris at the Hôtel de Cluny which was originally a medieval town house built in 1334. The observatory was built on top of a tower attached to the townhouse and was a pyramidal structure with large side windows that could be opened. Inside was kept the portable observatory telescopes that could be positioned to point out of whichever window the observer preferred. For the majority of his observing work, Messier used a small 100mm (4 inch) refractor.
The concept of interchangeable telescope eyepieces was not yet common in Messier's time; most of his telescopes have a fixed eyepiece lens and magnification. While some of Messier's reflecting telescopes had large apertures for the time, up to 8 inches, as they were made of speculum metal, which was the standard of the day, their light gathering ability was only about 70% when newly polished and generally the mirrors would tarnish quickly from the moist night air. Today's modern small refractor or reflector will easily outperform the best of Messier's telescopes.

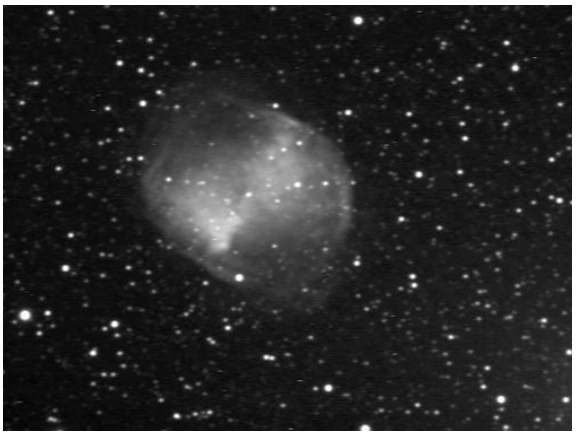
Of the 110 Messier objects, today we know that 40 are galaxies, 29 globular clusters, 27 open star clusters, 6 diffuse nebulae, 4 planetary nebulae, 1 supernova remnant, and 3 'misc' objects of the star cloud M24, double star M40, and the asterism of 4 stars M73. Over the course of his lifetime Charles Messier discovered 21 new comets, including the Great Comets of 1769 & 1770. Charles is also credited with the first recovery observations of many previously found comets, including being one of the first to recover Halley's Comet in 1759. But it is his list of fixed diffuse objects to avoid while comet hunting, his '*Catalog of Nebulae and Star Clusters',* that today's modern amateur astronomer seeks out as bright showcase galaxies, nebula, and star clusters of the night sky.
That is what Charles Messier, the "Ferret of Comets", is renowned for in the 21st century.

Messier Planetary Nebulae:

M27 known as the "Dumbbell Nebula", (also later called the "Hourglass" by John Herschel), is located in the summer constellation of Vulpecula, 'The Fox'. Discovered in 1764, it was first planetary nebula ever observed, and is one of the brightest and most impressive, easily visible in binoculars. M27 is about 1360 light years distant, and is estimated to be close to 14,600 years old, and about 3 light-years in size. On summer evenings, it is well placed, almost directly overhead, and can be naked-eye from a dark sky location. Due to its high surface brightness, M27 can even be observable thru a small telescope or binoculars during Full Moon. Its central white dwarf star shines at 12.9+ magnitude and is easily visible at the center of the dumbbell shaped nebula in small telescopes.
Distinct structural features can be observed within M27, including bright, sharply defined arcs coming off of either end of the dumbbell, along with striations between the main arcs and the center of the nebula. UHC and OIII filters will enhance the contrast of internal features of the nebula.

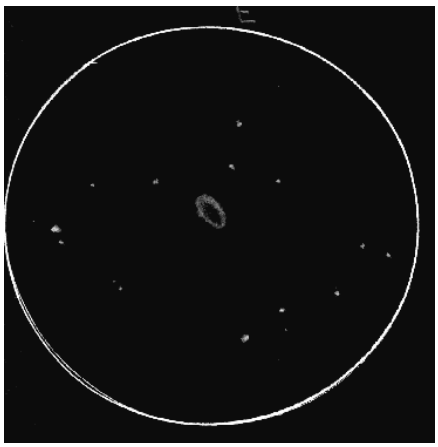


10" f5.6 Dob Reflector 27mm (52x)



8" SCT f6.3, StellaCam-3 @ 120 seconds

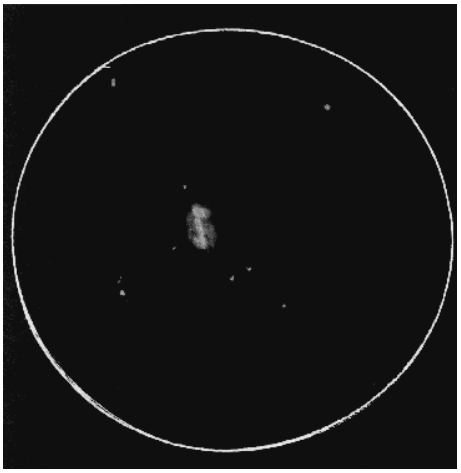
M57 Located in the summer constellation of Lyra, 'The Lyre (Harp)', and is known as the 'Ring Nebula'.
It was second planetary nebula discovered by Messier (in 1779, about 15 yrs after M27), and is easy to locate and can be observed with small telescopes, even in suburban skies. It is about 2300 light years distant, and about 6000 years old, and is estimated to have a diameter of about a half-light year, and is expanding at about 12 miles per second. With its high surface brightness, the Ring is one of the best celestial showpieces of the summer sky!
While the nebula itself is easy to observe, the central star at 15.4+ magnitude, can be quite difficult to glimpse.
Interestingly, 3-D modeling of the structure of M57 shows that it actually is similar in shape to M27.
The differences in shape are a matter of viewing angle perspective. For the Ring, we are looking down the axis of one of its ends. For M27, we are looking at it toward the side, about a 90 degrees rotation.



10" f5.6 Dob Reflector 8mm (79x)

8" SCT f6.3, StellaCam-3 @ 30 seconds

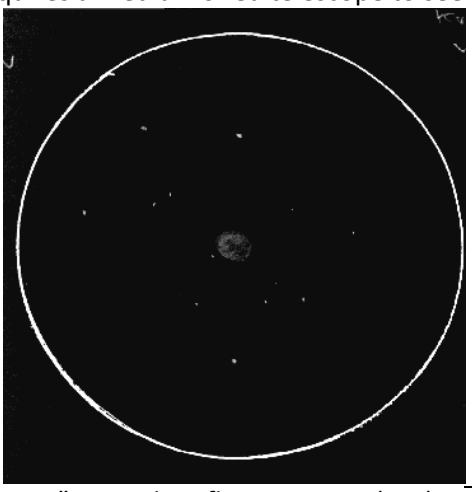
M76 Located in the fall constellation of Perseus, 'The Hero', and is known as the 'Little Dumbbell Nebula'.
Discovered in 1780 by Messier's observing partner, Pierre Mechain, it is about 2500 light years distant, and about 6000 years old, and about 1.5 light-years in size. Before it was determined that M76 was a planetary nebula (in 1918), it was once considered to be two separate emission nebula and given two NGC numbers - 650 & 651.
Visually, it is not difficult to find, and resembles its larger namesake in medium size telescopes.



8" 4.5 Dob Reflector 12.5mm (91x)

8" SCT f6.3, StellaCam-3 @ 120 seconds

M97 Located in the circumpolar constellation of Ursa Major 'The Great Bear', and is known as the 'Owl Nebula'. The last planetary nebula on Messier's "Not a Comet" list was discovered in 1781 by Pierre Mechain.
The 'Owl' got its name based on a sketch made in 1848 by the 3rd Earl of Rosse, William Parsons, using his 72" reflector. It is about 2000 light years distant, and about 8000 years old. M97 is located near the bright dipper bowel star - Merak (Beta Ursa Majoris), would normally make this planetary easy to find, but the nebula is fairly faint and requires a medium sized telescope to see visually.



8" 4.5 Dob Reflector 16mm (57x)

6" RC f5, StellaCam-3 @ 90 seconds

William Herschel:

In William Herschel's deep-sky catalog, one of the major classification categories (Class-IV) is called "Planetary Nebula". There are a total of 77 objects listed, but interestingly, only 20 of these objects are true planetary nebula. Herschel was known for dropping objects that he wasn't quite sure on how to classify into this category.
The majority are actually small galaxies (39), a dozen emission/reflection nebula, four star clusters, and several other objects that were not resolvable with Herschel's telescope.

So, who was William Herschel?
After the Messier List, the Herschel's are the next most observed deep-sky objects. Most amateur astronomers know them by their NGC, but they started out as a list created by British astronomer William Herschel and his sister Caroline. For his discovery of the planet Uranus, King George III of England in 1782, knighted Herschel as the "Kings Personal Astronomer" and gave William an annual pension. This allowed William to retire from his profession as a music teacher and devote himself fulltime to astronomy. Using his new wealth, Herschel relocated to a small village in the countryside within a mile of Windsor Castle and built a new permanently installed giant telescope, the "20-foot Reflector". (which had an 18.5" speculum-metal mirror). As the telescope stayed outdoors, unprotected from the elements, Herschel made two mirrors to use with it. When the first metal mirror would tarnish to the point of being unusable, Herschel would swap it out with the second mirror that was kept dry

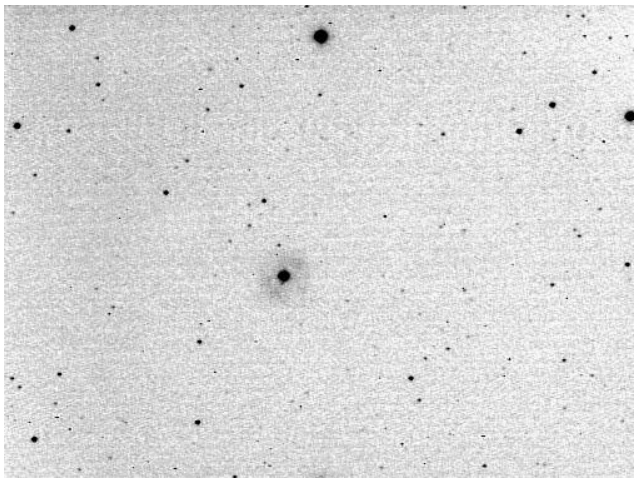
indoors, and then during the day, they would work on polishing the first mirror, readying it to be swapped back when the second mirror tarnished.

From 1782 to 1790, using the "20-foot Reflector", the Herschel's conducted systematic surveys of the night sky, in search of "deep sky" objects, and discovered over 2400. In 1834, John Herschel, (Williams son) , restored the 20-foot telescope and took it to Cape Town South Africa where he added another 1700+ entries to the list. Eventually, all of the Herschel objects, along with discoveries from other astronomers were combined and published in 1888 as the New General Catalogue (abbreviated NGC). In addition to his deep-sky surveys, William Herschel also discovered two of Uranus's moons - Titania and Oberon, along with Saturn's moons Mimas and Enceladus. He also discovered over 800 double & multiple stars. Caroline discovered 8 comets and was honored by the Royal Astronomical Society.

Herschel classified his deep-sky list into eight sub-categories or classes:
Class I - Bright Nebulae,
Class II - Faint Nebulae,
Class III - Very Faint Nebulae,
Class IV - Planetary Nebulae,
Class V - Very Large Nebulae,
Class VI - Very Compressed and Rich Clusters of Stars,
Class VII - Compressed Clusters of Small and Large Stars,
Class VIII - Coarsely Scattered Clusters of Stars.
William Herschel was one of the most notable observers in the history of astronomy, and is often referred to as the 'father of observational astronomy'. And as most stargazers do today, all of his observations were made outside in the open, exposed to the elements, and not from inside an observatory building.

Herschel Planetary Nebula Examples:

NGC1514 "Crystal Ball Nebula" **-** Located in the winter constellation of Taurus, discovered by William Herschel in 1790. This was William Herschel's first observation of a planetary gaseous shell with an obvious central star that convinced him that "true nebulosity" existed. A fairly easy 9th magnitude planetary to observe, it has a bright central star surrounded by a mottled haze. It is about 1960 light years distant.



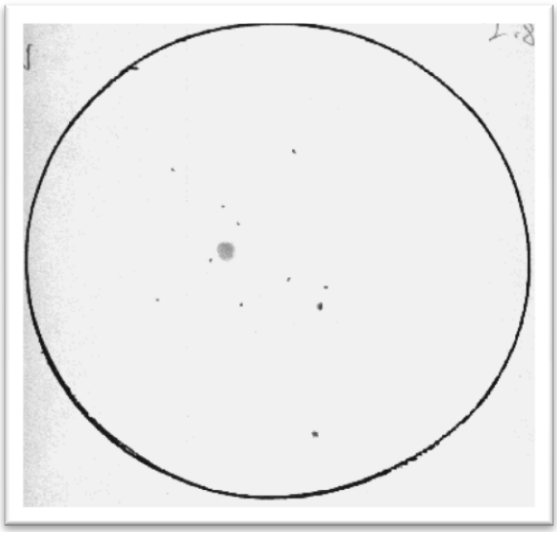
(8" SCT f6.3, StellaCam-3 @ 60 seconds)

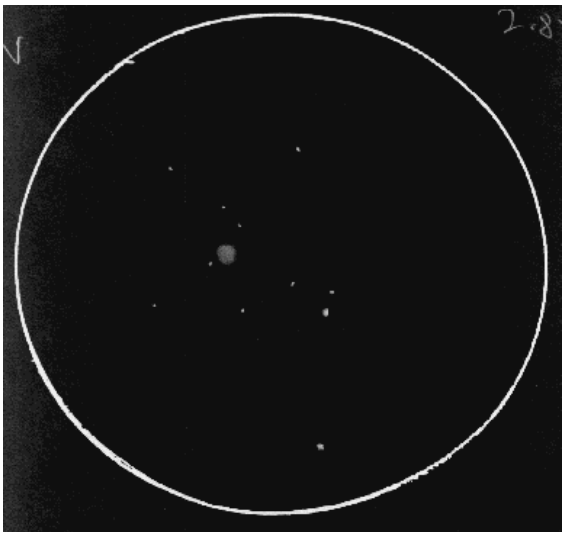
NGC2392 Located in the winter constellation of Gemini the Twins, the "Eskimo Nebula" was discovered by Herschel in 1787. It is about 2930 light years distant. NGC2362 is a bright planetary nebula, in which even small to medium size telescopes will show the 10.5th magnitude central star and multiple shells of dark and light mottled zones.

13" f4.5 Dob Reflector 28mm & 2.8x barlow (102x)

8" SCT f6.3, StellaCam-3 @ 45 seconds

NGC6445 Located in the summer constellation of Sagittarius, discovered by Herschel in 1786. Nicknamed the "Little Gem" or "Box Nebula", NGC6445 is about 3200 light years distant and a diameter of almost 4 light years across. Visually, it's a small faint nebula with a rectangular disk, best suited for medium to large aperture telescopes, and a very, very faint 19th mag+ central star visible only in the large >24" telescopes.



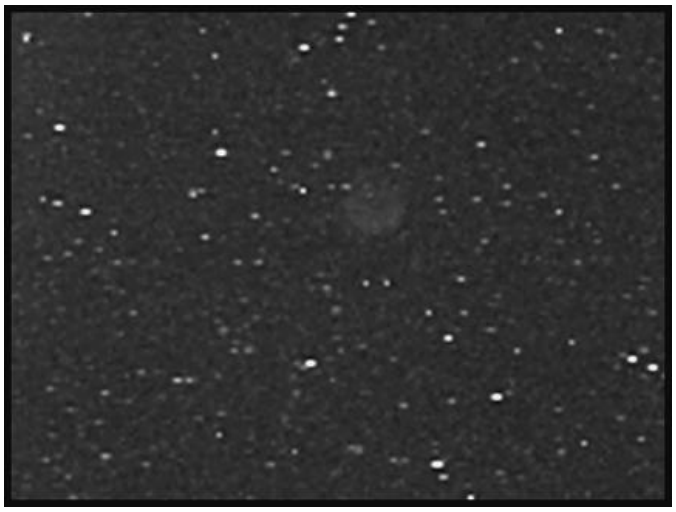


8" f4.5 Dob Reflector 16mm & 2.8x barlow (160x)

NGC6781 Located in the summer constellation of Aquila. Discovered in 1788 by John Herschel. The 10th magnitude planetary has a large somewhat faint featureless disk. NGC6781 is about 3100 light years distant with a 16th Mag+ central star.

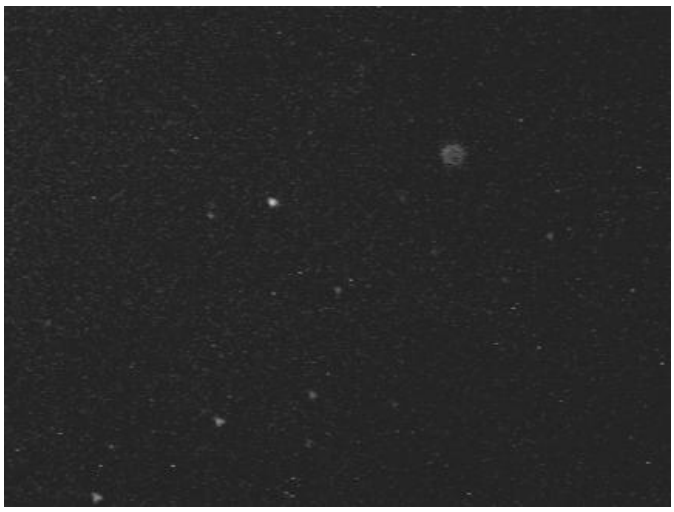
NGC6369 "Little Ghost Nebula" Located in the summer constellation of Ophiuchus, discovered in 1784 by Herschel. The planetary is ring shaped with a dark center where a 15.5th Mag+ central star is visible. In larger telescopes, the ring has an uneven bluish tint. NGC6369 is about 3900 light years distant and a diameter of about 1/3 of a light year across.

NGC6781



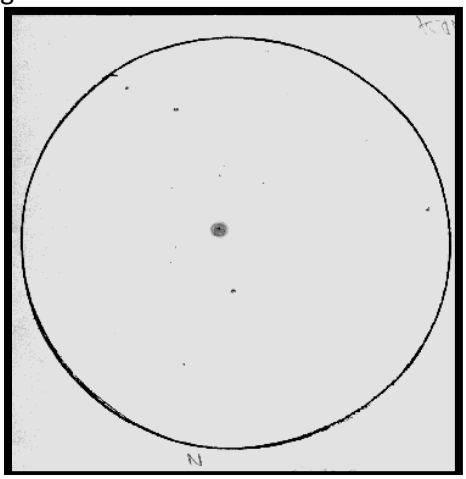
NGC6781 - 8" SCT f6.3, StellaCam-II @ 8 seconds

NGC6339



NGC6369 - 6" RC f9 StellaCam-3 @ 15 seconds

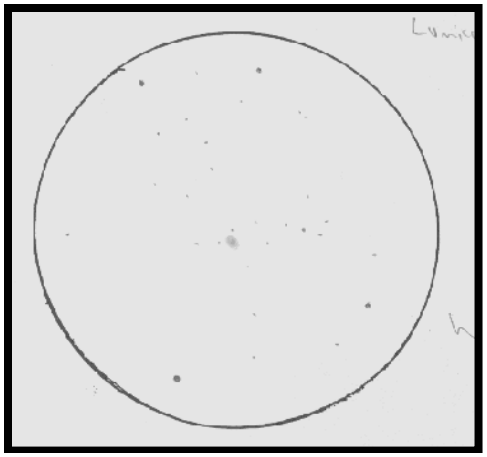
NGC6826 Located in the constellation of Cygnus, the "Blinking Planetary" was discovered by Herschel in 1793. The 10th mag+ planetary is located about 3200 light-years with a bright central star of 8.9th mag+, making it an easy target for small telescopes. Visually, when observing the bright central star directly, the nebula tend to vanish, but using averted vision causes the nebula to blink into view.



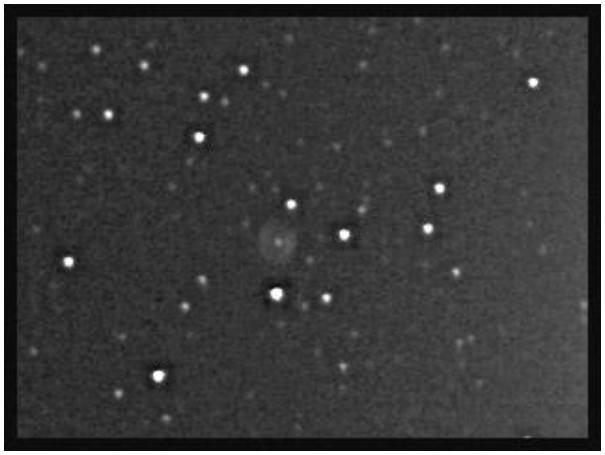
13" f4.5 Dob Reflector 8mm (143x)

8" SCT f6.3, StellaCam-3 @ 8 seconds

NGC6905 Located in the constellation of Delphinus, was discovered by Herschel in 1784. The "Blue Flash Nebula" is an oval shaped 11th mag+ planetary, with a 13.5 mag+ central star at a distance of about 4200 light-years. Visually, the planetary is fairly bright in small to medium telescopes, and shows bluish color in larger telescopes.

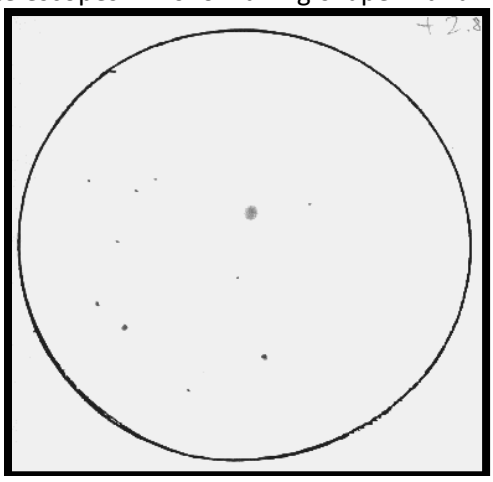


8" SCT f10, 24mm (85x)

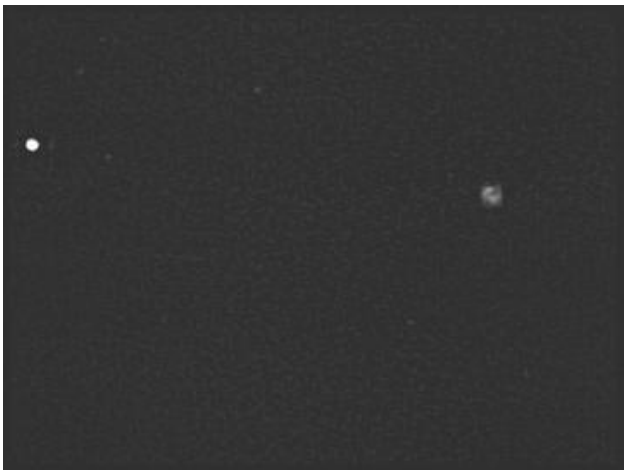


8" SCT f6.3, StellaCam-EX @ 2.5 seconds

NGC7662 Located in the fall constellation of Andromeda, was discovered by Herschel in 1784. Visually, the 8th mag+ "Blue Snowball Nebula" planetary is quite bright in small telescopes and shows a bluish-white color oval. Larger telescopes will show a ring-shape with a mottled interior. NGC7662 is about 3900 light-years distant.



8" f4.5 Dob Reflector 24mm & 2.8x barlow (106x)



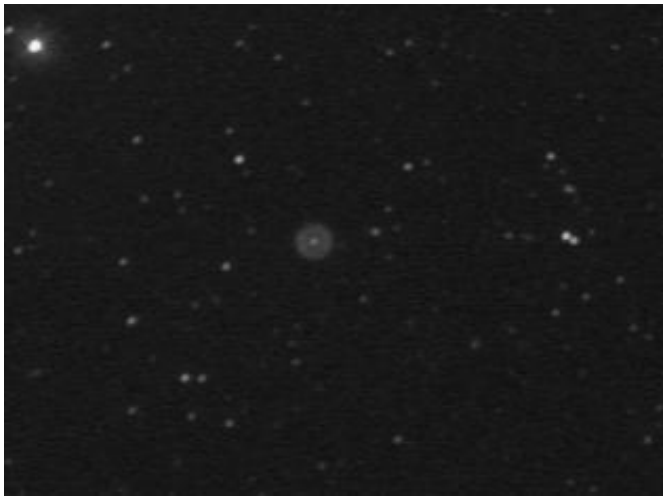
8" SCT f6.3, StellaCam-II @ 8 seconds

NGC1501 Located in the fall constellation of Camelopardalis, the Giraffe, the "Oyster Nebula" was discovered by Herschel in 1787. It is about 3600 light years distant. NGC1501 is bright ring-shaped planetary nebula, in which medium size telescopes will show the 14th magnitude central star and a mottled shell with a central dark zone.

NGC7009 Located in the fall constellation of Aquarius, the Water bearer, the "Saturn Nebula" was discovered by Herschel in 1782. It is about 3900 light years distant and about a ½ light-year in diameter. NGC7009 is bright oval-shaped 8th magnitude planetary nebula, in which medium to large size telescopes will show the two 'ansae' or handles coming off of either side which makes the object resemble the planet Saturn with its rings turned edge-on.

NGC1501

NGC7009



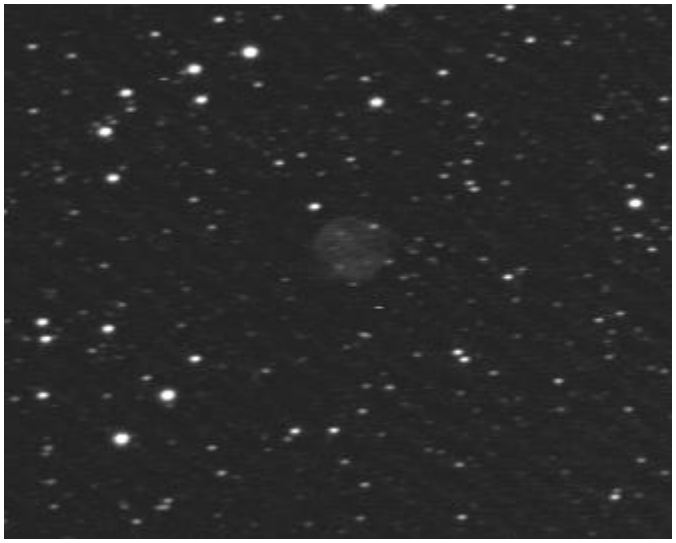
NGC1501 6" RC f5 StellaCam-3 @ 30 seconds

NGC7009 8" SCT f6.3, StellaCam-3 @ 20 seconds

NGC7139 Located in the fall constellation of Cepheus. Discovered in 1787 by Herschel. The 13th magnitude planetary has a large faint featureless disk visible in medium size telescopes from a dark sky location, with several faint embedded stars. NGC7139 is about 4300 light years distant with a 18.7th Mag+ central star.

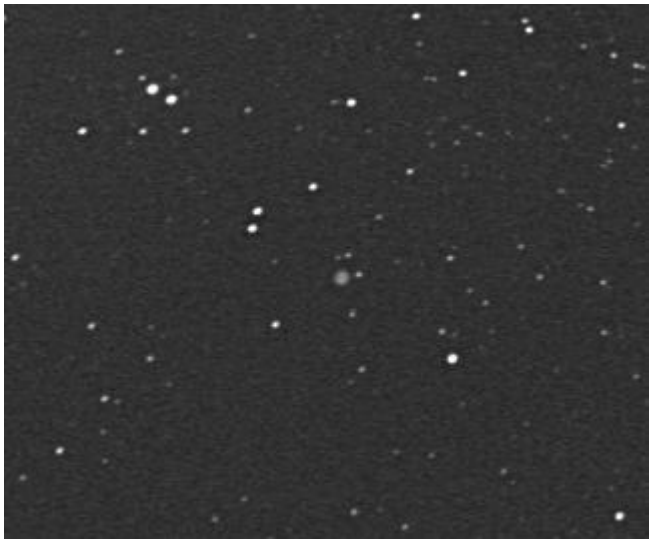
NGC7354 Located in the fall constellation of Cepheus. Discovered in 1787 by Herschel. This 13th magnitude planetary has a small circular disk visible in larger size telescopes. NGC7354 is about 4200 light years distant.

NGC7139



8" SCT f5, StellaCam-3 @ 45 seconds

NGC7354



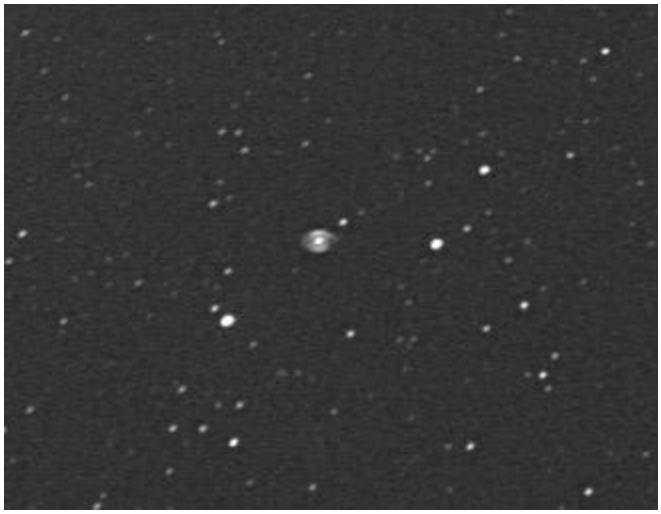
6" RC f5 StellaCam-3 @ 20 seconds

NGC40 Located in the fall constellation of Cepheus, the King, the "Bow-Tie Nebula" was discovered by Herschel in 1788. It is about 3500 light years distant and about 1 light-year in diameter. NGC40 is bright blue-green oval-shaped 10.7th mag+ planetary nebula, in which small to medium telescopes will show the 11th central star, and bright structural arcs.

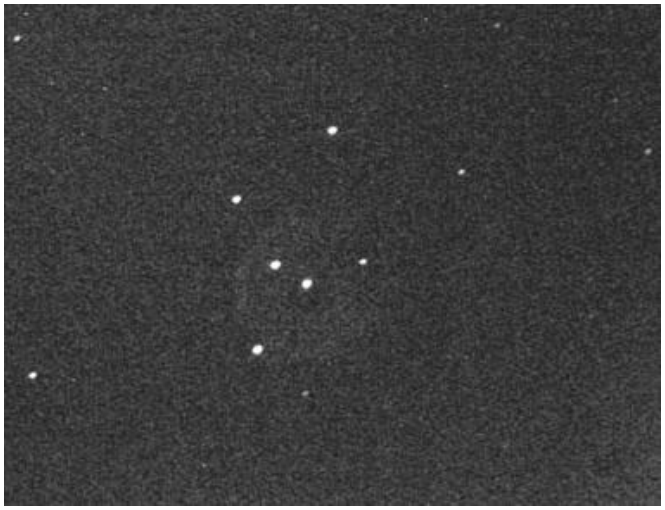
NGC246 Located in the constellation of Cetus, the "Skull or Pac-Man Nebula" was discovered by Herschel in 1785. It is about 1600 light years distant. NGC246 is a large dim mottled planetary nebula, and even though it's listed as 11th Mag+ requires a large telescope and dark skies to observe. The 12th magnitude central star is a binary system.

NGC40

NGC246



6" RC f5 StellaCam-3 @ 15 seconds

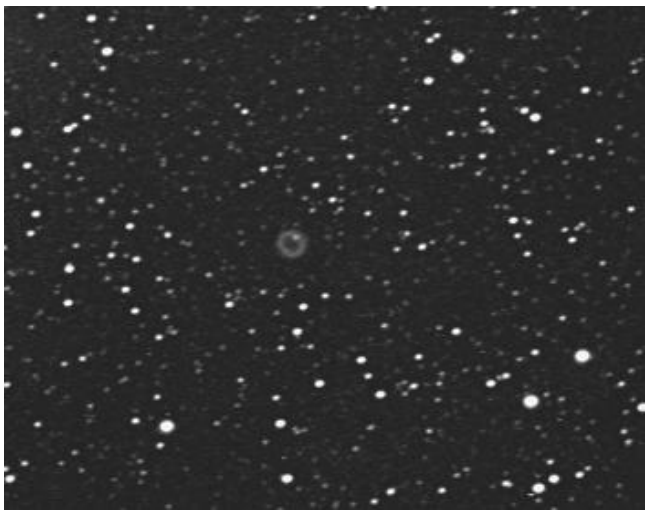


8" SCT f6.3, StellaCam-3 @ 30 seconds

NGC6894 Located in the summer constellation of Cygnus, was discovered by Herschel in 1784.
The 12th mag+ dim ring shaped planetary is located about 5000 light-years with a dim central star of 17.6th mag+.
Best visible in medium to large telescopes from a dark location.

NGC7008 Located in the summer constellation of Cygnus, the "Fetus Nebula" was discovered by Herschel in 1787.
The 10th mag+ fairly bright broken annual shaped planetary is located about 2800 light-years, with a diameter of about 1 light-year with a central star of 13.2th mag+. Visible in medium to large telescopes from a dark location.

NGC6894

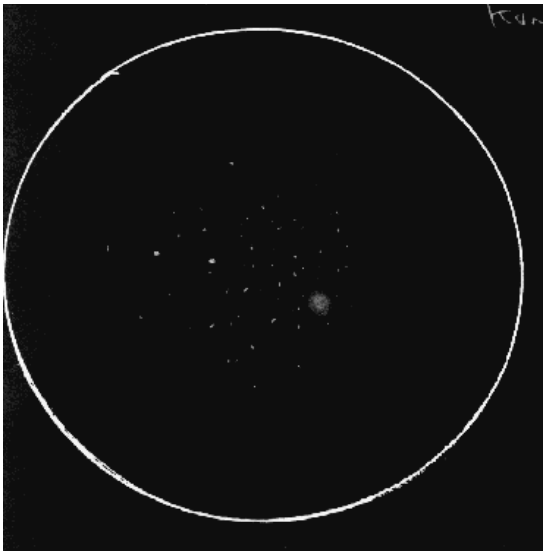


8" SCT f6.3, StellaCam-3 @ 30 seconds

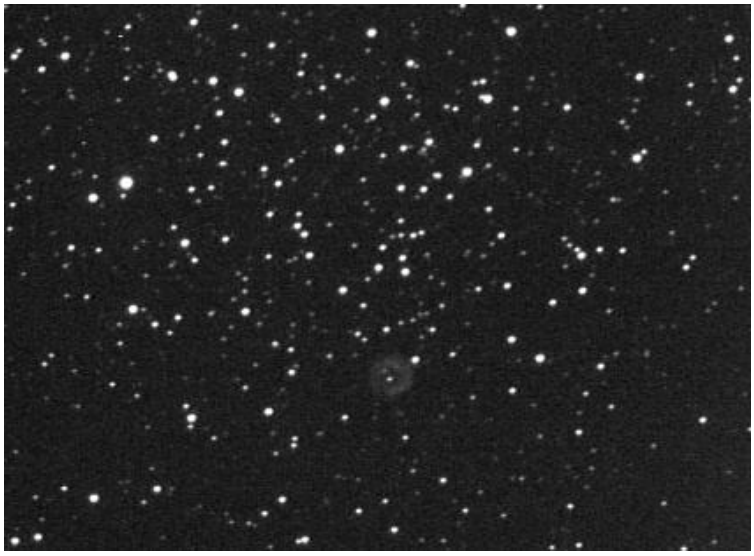
NGC7008

6" RC f5 StellaCam-3 @ 30 seconds

NGC2438 Located in the winter constellation of Puppis, was discovered by Herschel in 1786. Appears as a foreground object in fromt of the open cluster M46. The 11th mag+ ring shaped planetary is located about 2900 light-years, with a diameter of about 1 light-year with a central star of 17.5th mag+.
Visible in medium telescopes from suburban locations.



8" f4.5 Dob Reflector 16mm 57x



8" SCT f6.3, StellaCam-3 @ 20 seconds

Rudolph Minkowski:

German-American astrophysicist Rudolph Leo Minkowski was born on May 28, 1885 in Strasburg, Germany (which is now part of France), to Marie Siegel and Oskar Minkowski. In 1913, Minkowski enrolled at the University of Breslau to study physics, but was drafted into the German Army in 1914 and served thru WWI till it ended in 1918. Afterwards he returned to the university, where he earned his PhD in 1921. In 1922, he went to work for the University of Hamburg, first as an atomic physicist, then later as an observational astronomer.
In 1935, Minkowski accepted a research assistant position at Mt Wilson Observatory and immigrated to the US to escape German persecution.

Minkowski is best known for his Mt Wilson research work on supernova remnants with astrophysicist Walter Baade, in which the two of them devised the spectral grouping of 'Type-I' and 'Type-II' still used today to classify these violent explosions, and as a tool in determining cosmological distances to galaxies. In 1942, Minkowski identified the central star of M1, the 'Crab Nebula' by its unusual optical spectra.
But in the late 1940's he published three versions of a paper titled – "New Emission Nebulae" where Minkowski listed over 200 planetary nebula that he had studied for their spectra, galactic distribution, and motion. In his papers, Minkowski didn't formally label his entries, but later when they were collected into a catalog, they were given designations based on which paper they were first referenced in. An example of a Minkowski catalog object designation is: "M 2-9" (Butterfly Nebula) in the constellation Ophiuchus. (the 9th object from the second paper).

In the mid-1950's Rudolph was chosen to lead the newly commissioned 'National Geographic Society – Palomar Observatory Sky Survey', to be created using the Palomar Observatory's 48-inch Schmidt telescope. The survey was to photograph the entire northern sky down to a magnitude of +22 from Palomar. The POSS is still in use today! Minkowski was also known for designing Schmidt spectrographic cameras used on the larger telescopes, and again with Walter Baade, identified the optical counterparts to some of the early radio sources being discovered at the time, including 'Cygnus A' in 1954. Minkowski retired from his position at Mt Wilson in 1960, but remained active in the research community at the University Of California at Berkeley.

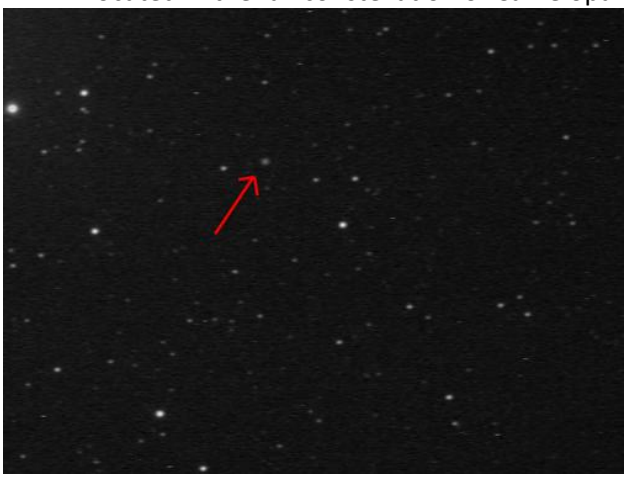
A popular story at Berkeley goes that on the night of the very last observing session that Minkowski had on the 200" Hale Reflector, before retiring the next day, he captured the spectrum of 3C-295 and determined that it was the highest redshift ever observed, at z=0.46, making it the farthest known object in the universe! (about 5 billion light-years). The astronomers on duty during the observation declared that the rest of the night was officially 'overcast', and celebrated Minkowski's discovery in the observatory's library with shots of whiskey.

At the age of 81, on January 4th, 1976, Rudolph Minkowski passed away at his home. In addition to his research legacy in supernovas, planetary nebulae, and colliding galaxies, Minkowski discovered a comet – '1950 B Minkoswki', also is credited with co-discover of NEO asteroid 1620 – 'Geographos', has a lunar created named after him along with a small planetary nebula, and was the 1961 recipient of the Astronomical Society of the Pacific's 'Bruce Medal' for research.

Minkowski Planetary Nebula Examples:

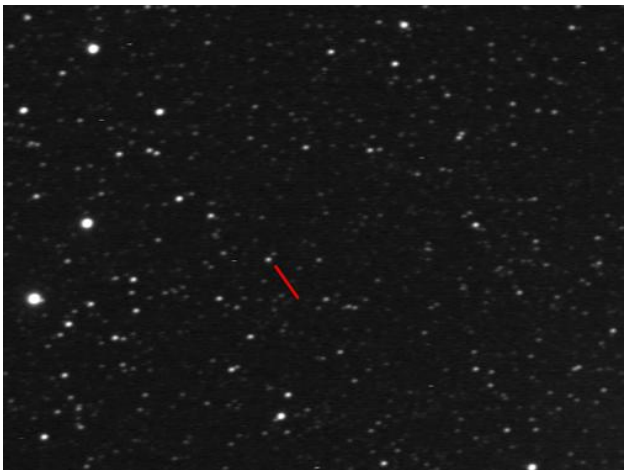
Most of Minkowski's planetary nebula are very small, star-like, (less than 10" in diameter), and very faint, (>13^{+} Mag) and are difficult visual observations. The best way to visually confirm that you have found one is to use your UHC or OIII filter and rapidly pass it back and forth between the eyepiece and you eye, causing the planetary to 'blink' in brightness from the other stars in the field of view. You can do this either by hand-holding the filter or using it in a filter slider or wheel with an open slot to one side of the filter. Imagers will need to have a very accurate polar alignment and calibrated GOTO to ensure that the planetary is centered and then afterwards will need to compare their image to a star chart or another image where the planetary is highlighted.
While most of the Minkowski's are star-like, there are a few that do show very small disks or hints of shells in medium to large telescopes under dark skies.

M 2-2 Located in the fall constellation of Camelopardalis



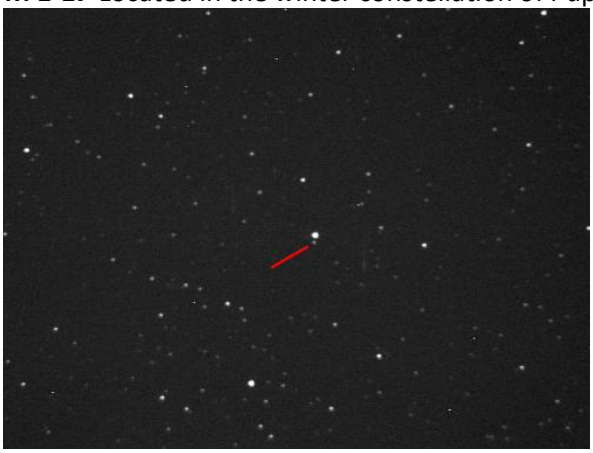
8" SCT f6.3, StellaCam-3 @ 30 seconds

M 1-74 Located in the summer constellation of Aquila



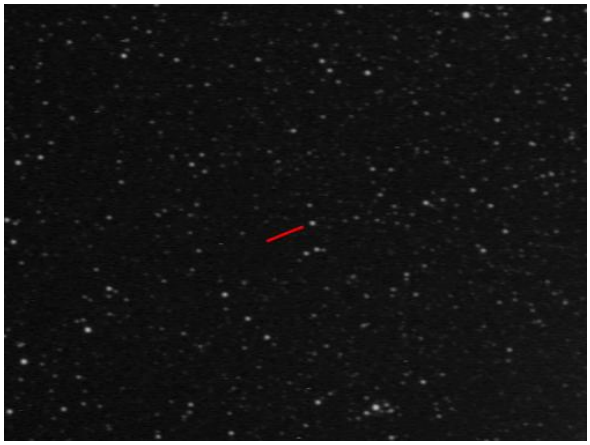
8" SCT f6.3, StellaCam-3 @ 20 seconds

M 1-17 Located in the winter constellation of Puppis



8" SCT f5, StellaCam-3 @ 20 seconds

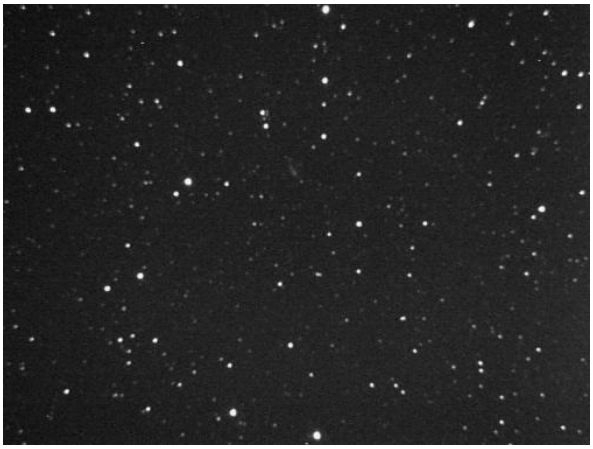
M 1-59 Located in the summer constellation of Scutum



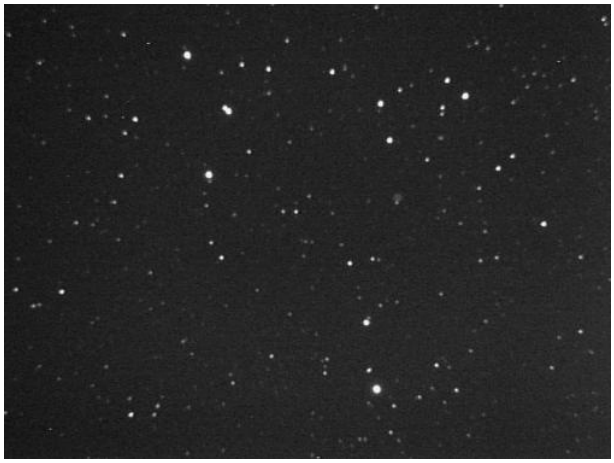
8" SCT f6.3, StellaCam-3 @ 20 seconds

M 1-68 Located in the summer constellation of Lyra

M 1-64 Located in the summer constellation of Lyra

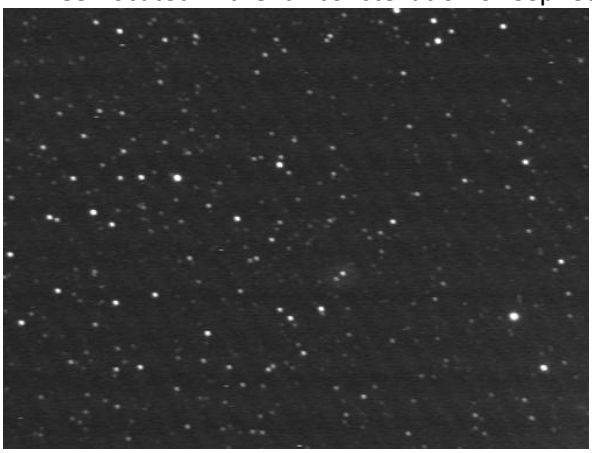


8" SCT f5, StellaCam-3 25 seconds (NGC6765)



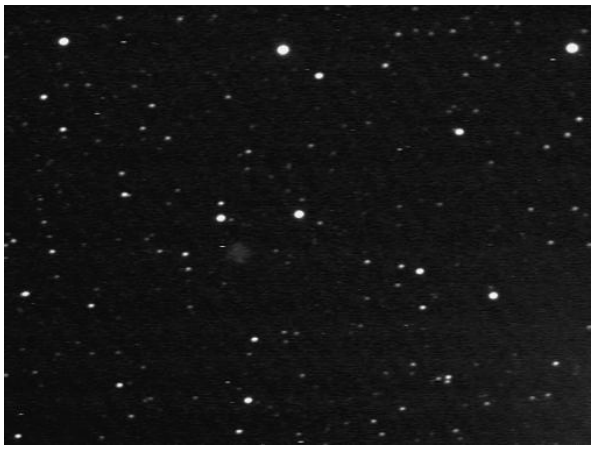
8" SCT f5, StellaCam-3 25 seconds

M 1-59 Located in the fall constellation of Cepheus



8" SCT f5, StellaCam-3 @ 25 seconds

M 2-55 Located in the fall constellation of Cepheus



8" SCT f6.3, StellaCam-3 @ 35 seconds

George Abell:

American astrophysicist George Ogden Abell was born on March 27th, 1927 in LA California to Annamarie and Theodore Abell. As a young boy growing up, George's mother, who was a librarian encouraged him in reading, while his father would take him to various Los Angeles museums, including the Griffith Observatory and Planetarium. This led to George developing an interest in science and astronomy, which he excelled at in school. After graduating from high school in 1945, Abell enlisted in the US Army Air Corps, hoping to become a pilot, but with the war winding down, he was instead sent to weather school, and was stationed over in Japan as an Air Corps weatherman. Upon discharge from the service, George enrolled at Caltech where he studied physics and astronomy. During his college years, George was active on the bowling team, drama club, and an editor for the college newspaper. Also during this time, Abell's first semi-professional astronomy related job was as a 'tour guide' at Griffith observatory, and then later as a 'lecturer'. Abell graduated in 1951 from the California Institute of Technology with a B.S. in astronomy, continued on for his masters in 1952, and then his doctorate in 1957.

Abell's first true professional job was as a Caltech astronomer was working on the National Geographic Society – Palomar Observatory Sky Survey, created using the Palomar 48-inch Schmidt telescope. Abell was one of the first to have access to the plates soon after they were taken. George's primary research was reviewing the POSS survey photographic plates looking for the formation of galaxy clusters. From this research, Abell created a catalog of 2,712 galaxy clusters that has since become a valuable tool in cosmological luminosity studies.

But while searching thru the plates for faint galaxies, he ran across a number of unreported planetary nebula.

From the new data contained on the plates, Abell compiled a list of 73 very old and faint planetary nebula, which he first published in 1955. Over the next decade, Abell expanded his list with a number of additional finds and in 1966 published his final revised catalog of 86 old and faint planetary nebula in paper titled: "Properties of Some Old Planetary Nebula". Abell, with several other astronomers, also cataloged a number of faint low-surface brightness globular star clusters from the POSS plates, which became known as the Palomar catalog.

After the POSS survey ended, Abell became a professor of astronomy at UCLA, where he spent the next 17 years, during which he became chairman of the UCLA Astronomy Department. Abell was known for his popular classroom style where he believed it was more important to teach the "how and why" of science, rather than just the facts. Abell carried this philosophy over into his working with the local LA school district's high school summer science program where he taught college level physics, astronomy, and math.

In addition to teaching at UCLA, Abell would also travel to small colleges and give public lectures on astronomy and science, calling out the difference between what is true science versus the popular pseudo-science of the day, such as the belief in the Bermuda Triangle, or ancient astronauts. He wrote a widely used college text book on astronomy titled: "*Exploration of the Universe*", and participated both in-front, and behind the camera for a number of public educational TV programs: "*Understanding Space and Time*", and "*Project Universe*".
Abell was also a founding member of the 'Committee on Scientific Investigation of Claims of the Paranormal' now known as the 'Committee for Skeptical Inquiry'.

At the age of 56, on October 7th, 1983, while at home, George O Abell died from a heart attack.
A number of astronomical 'objects' are named in Abell's honor, which includes a 17th magnitude periodic comet 52P/Harrington–Abell, with a 7 year period that he co-discovered in 1955, an asteroid (3449), and an observatory over in England.

For additional interesting information on the life of American astrophysicist George O Abell, visit the American Institute of Physics (AIP) Oral History project at:
https://www.aip.org/history-programs/niels-bohr-library/oral-histories/4475
https://www.aip.org/history-programs/niels-bohr-library/oral-histories/5193

Abell Planetary Nebula Examples:
Abell's catalog is recognized today as an excellent compilation of faint, challenging planetaries for the visual observer with access to larger telescopes and dark skies. These are also challenging to imagers using either video-astronomy or more traditional astrophotography cameras due to their large size and faintness.
Over half of the Abell planetary nebula has central stars of 17+ magnitude or fainter!!

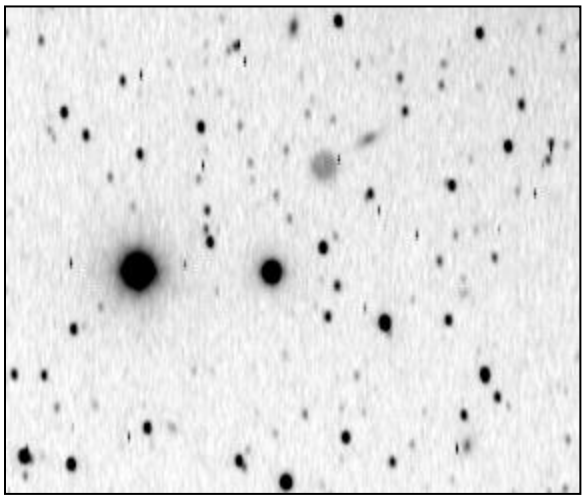
It should be noted that since being published in 1966, four of the members of Abell's catalog have since been determined to be either a faint galaxy, reflection nebula, or a non-existent photographic plate fault, bringing the corrected number of Abell planetary nebula to 82. These rejects are Abell11, 17, 32, & 76.

For the most part, due to being very old, highly evolved, large, and having a very low surface brightness, Abell's can be difficult to observe. O-III filters can be a big help, allowing the nebula to 'pop' from the dimmed field.
(Though due to the faintness of these objects, sometimes using a filter can actually make the nebula harder to see if you don't have sufficient aperture).

Interestingly, back in the early 1980's, before the Dobsonian telescope revolution took hold, which brought about large aperture reflectors becoming available to amateur astronomers, George Abell was once asked by an amateur astronomer about observing his planetaries. Being more of a theorist than an observational astronomer, Abell replied that he doubted that any would ever be visually observable, and that maybe it might be possible to photograph some. Today we know that numerous amateur astronomers, armed with either large reflectors of 20" or greater, or using state-of-the-art imaging telescopes and cameras are routinely observing and imaging his planetary nebula.

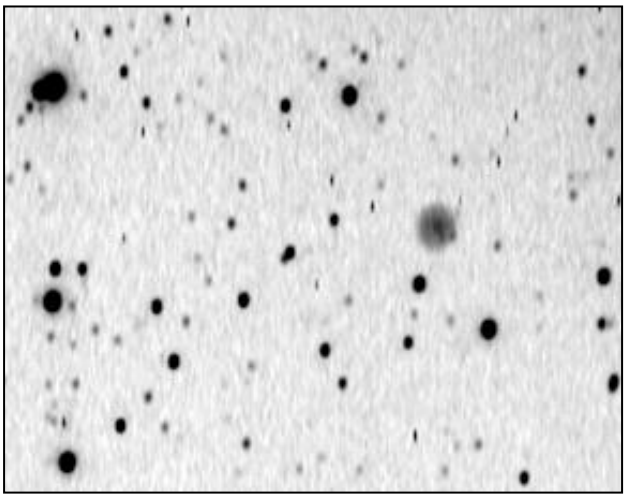
Generally it's best to save hunting for Abell Planetaries for trips to dark sky locations, and on nights of excellent transparency. Visual observers must be completely dark adapted and avoid all lights during observing.
Only use the dimmest of red lights for checking finder charts. While some Abell's can be observed using smaller telescopes in the 8 – 12" range, most of these objects will require large telescopes in the 16" or greater size.
For imagers, most of the Abell's can be captured using an 8" SCT in under 5 minutes, though there are some that will require larger optics or deep exposures.

Abell 4 Located in the fall constellation of Perseus



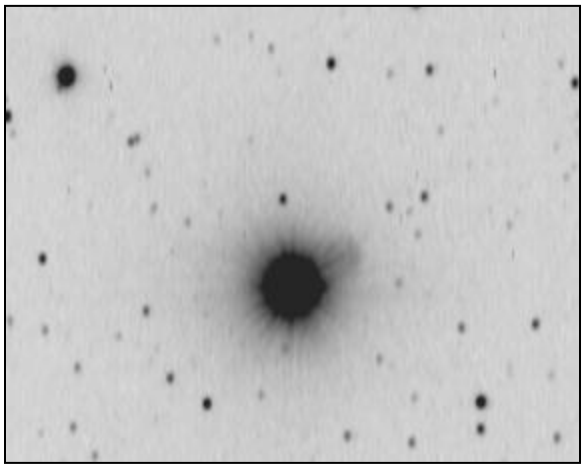
8" SCT f5, StellaCam-3 @ 3 minutes (no filter)

Abell 10 Located in the winter constellation of Orion



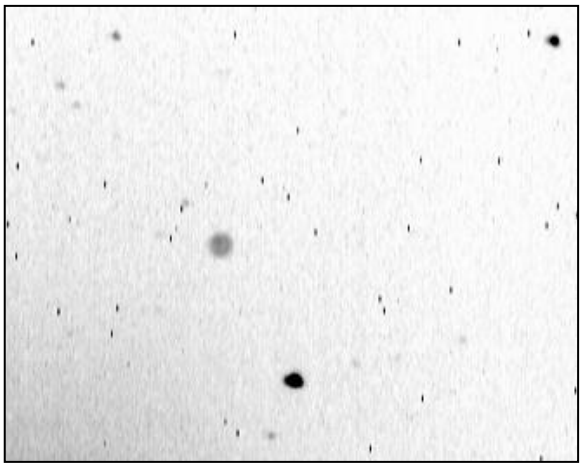
8" SCT f6.3, StellaCam-3 @ 3 minutes (no filter)

Abell 12 Located in the winter constellation of Orion



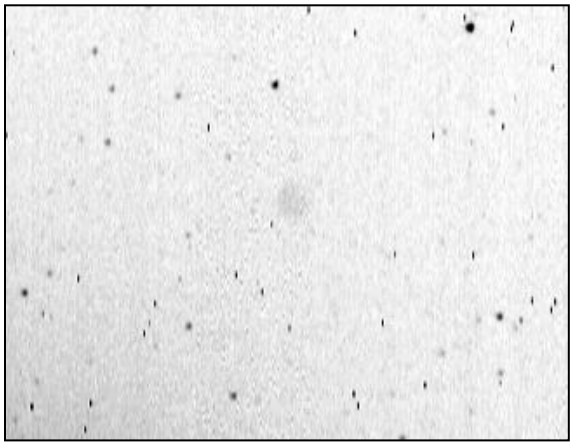
8" SCT f5, StellaCam-3 @ 3 minutes (no filter)

Abell 50 (NGC6742) Located in constellation of Draco



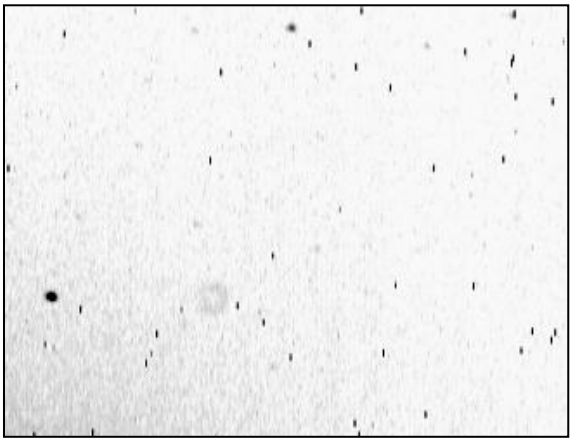
8" SCT f6.3, StellaCam-3 @ 3 minutes (OIII filter)

Abell 55 Located in summer constellation of Aquila



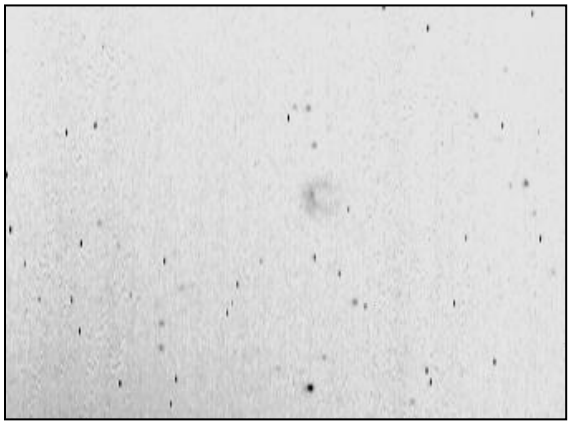
8" SCT f5, StellaCam-3 @ 3 minutes (OIII filter)

Abell 70 Located in the constellation of Aquila



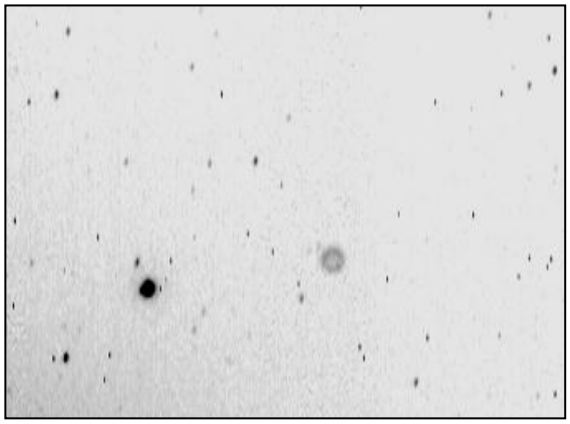
8" SCT f6.3, StellaCam-3 @ 4 minutes (OIII filter)

Abell 75 (NGC7076) Located in Cepheus



8" SCT f5, StellaCam-3 @ 3 minutes (OIII filter)

Abell 81 Located in the fall constellation of Cepheus



8" SCT f6.3, StellaCam-3 @ 3 minutes (OIII filter)

Conclusion:

So today I introduced you to a class of colorful luminescent wispy shells of deep sky objects, and some of their catalogs. We learned a little about the historical and modern individuals behind each catalog, and looked at sketches and video-capture image examples of various members of each catalog. Hopefully this little presentation has inspired you to search-out and explore these very rewarding celestial objects.

So I encourage everyone to get out tonight and try your hand at finding and observing the ghostly disks of these elusive deep-sky objects, the planetary nebula of Charles Messier, William Herschel, Rudolph Minkowski, and George Abell.

Obscure Open Star Clusters

Introduction:

Visible throughout our galaxy are one of my favorite categories of deep-sky objects: Open Star Clusters. Regardless of the type of telescope you use, Binoculars, small refractor, SCT, or large dobsonian, there are open star clusters that your equipment will give great views of. Unlike nebula and galaxies, they can be observed thru nearly any type of sky condition, such as haze, thin clouds, or light pollution.

Today, we are going to 'focus' on the more obscurely named cluster objects, and not the brighter Messier and NGC open clusters that most of us are familiar with. These are the odd sounding cluster names you run across when reading thru the pages of a book or magazine article or browsing your favorite star atlas or viewing the charts of a PC planetarium program. Trumpler, Stock, King, Berkeley, and others. Most of these clusters are faint and sparse, and not very appealing visually, but each catalog has a number of "gems" that are worth looking for.

After a good half-dozen years using either visual or videoastronomy/EAA techniques, I've completed observing cluster members from 12 major open star cluster catalogs that are visible from my Pittsburgh, Pennsylvania latitude of +40. So today, we'll discuss what I've learned during that journey among the star clusters, along with some of the people, behind these catalogs, and how to go about observing these objects. Along the way, we'll also review a number of my observations of these clusters. Hopefully, when we are done, you will find these obscure open star clusters as interesting to hunt and observe as I do.

Outline

- What are Star Clusters:
- OB Associations:
- Messier Objects:
- NGC (Herschel) Objects:
- How to Observe: Equipment and techniques:
- Examples from 12 different catalogs:
- Conclusion:

Star Clusters:

There are currently over 1,150 known open clusters in our galaxy. With more being continuously identified. Open clusters are often bright and easily observable with small telescopes and even binoculars.

What Are Star Clusters?

Open Star Clusters are physically related groups of stars held together by mutual gravitational attraction. They are loose collections of anywhere from a few dozen to several thousand stars covering large expanses of space. Having formed together from the same cloud of gas and dust, the individual stars in a cluster are all of similar age, and about the same overall cluster distance from us.

How do Star Clusters form?

They originate from large cosmic gas and dust clouds in our Milky Way galaxy that slowly collapse. Open cluster stars have evolved through many cycles of starbirth and supernovae, which enrich the heavy element concentration in star-forming clouds. Currently, in many clouds visible as bright diffuse nebulae within our galaxy, Star formation still takes place at this moment, allowing us to observe the formation of new young star clusters, in various stages.

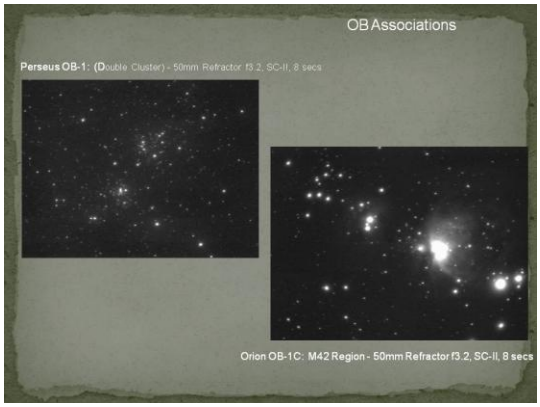
Where are Star Clusters Located?

Most of the open star clusters that we can visually observe are located within the spiral arms of our own Milky-Way galaxy. After star clusters form, they continue to orbit our galaxy scattered throughout its arms and disk. Most open clusters have only a short life as stellar swarms. As they drift along their orbits, some of their member stars

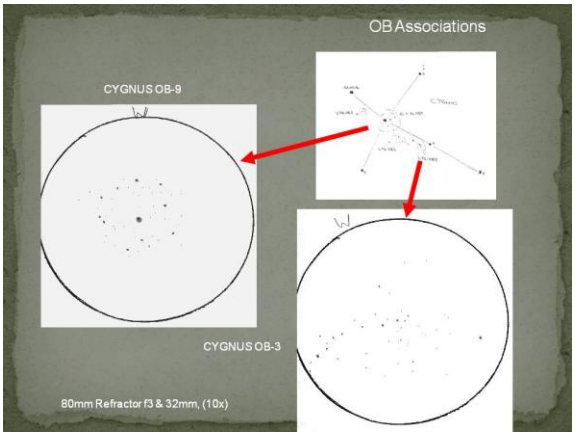
escape from the cluster by gravitational attraction from other more massive nearby objects the cluster is passing or are ejected by internal cluster interactions and become field stars within the galaxy. Eventually, all the individual cluster stars will merge into the background with the other stars within the spiral arms.

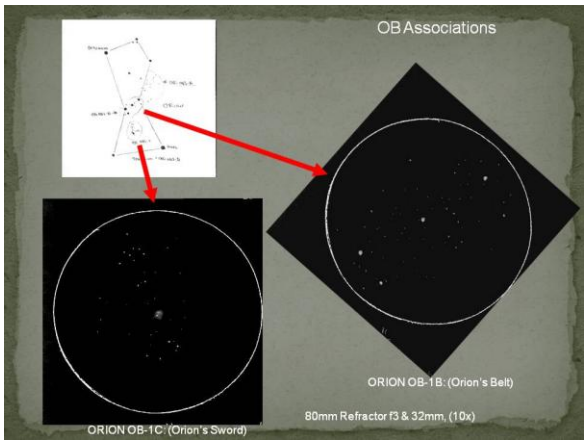
OB Associations:

There is a somewhat neglected category of Deep-Sky object that is overlooked by many amateurs.
That is the "OB Association". An OB Association is a large, very loose form of an open star cluster consisting of young spectral type "O" and "B" stars. They cover large volumes of space, generally between 30 – 100 parsecs, (1 parsec = 3.26 lightyears), are loosely held together by gravity and have very short lifetimes (a few million years) as a distinct object. They are found scattered along the Milky-Way's spiral arms. While OB Associations are considered a separate Deep-Sky category from open clusters, both types can be found together, with an open cluster forming the core region of a larger OB Association. OB Associations may also still contain clouds of interstellar gas and dust showing as bright glowing emission nebula, reflection nebula, or dark nebula.
In time, the unstable outlying OB Association will drift apart, merging with the other field stars in the region, leaving the more gravitationally bound open cluster as a still observable object. The remnants of some OB Associations, are called Stellar Streams, can still be seen. The easiest of these to find is the Ursa Major Stream, with its core consisting of the stars of the Big Dipper.



Very few star charts actually plot OB Associations as objects. But many can be found in the "SKY ATLAS 2000" and "URANOMETRIA" maps because of the number of their individual stars that are plotted.
A good example of this is "CYGNUS OB9", found around Gamma Cygni (Sadr), and nearby "CYGNUS OB3".
And "ORION OB1-B", surrounding the "Belt" stars of Orion, and "ORION OB1-C", consisting of Orion's "Sword".
Because of their large size OB Associations, are best observed with binoculars or small rich-field telescopes using low power magnifications.





There's currently about 70 known OB Associations within our Milky-Way galaxy, of which I've sketched 19.
But, you can also hunt and observe bright OB Associations in a few nearby galaxies, such as M31 and M33.

As I mentioned earlier, while we're not really going to focus on Messier and NGC (Herschel) open star clusters, I will briefly mention both:

Messier Objects:

The 18th century French Astronomer Charles Messier (the "Ferret of Comets") is best known for his catalog of nebulae and clusters, 1st published in 1771. This list of 110 deep-sky objects is known to today's astronomers as the 'Messier Catalog'. As an astronomer, Messier's primary job was to hunt for comets. During his comet searches, he kept running into these diffuse non-comet objects that would frustrate him. So Messier began a list to help comet hunters avoid these false comets. He ended up with 30 open clusters identified in his catalog. Over the centuries, Messier's list became popular targets for amateurs because these 'M-objects' could be easily visually observed with small-aperture telescopes.

NGC (Herschel) Objects:

After the Messier List, the Herschel's are the next most observed deep-sky objects.
Most amateur astronomers know them by their NGC numbers, but they started out as a list created by British astronomer William Herschel and his sister Caroline. From 1782 to 1790, the Herschel's conducted systematic surveys of the night sky, in search of "deep sky" objects, and discovered over 2400.
William's son, John, later added another 1700+ entries to the list. Eventually, all of the Herschel objects, along with discoveries from other astronomers were combined and published in 1888 as the New General Catalogue (abbreviated NGC).

How to Observe: Equipment and techniques:

So, where can you find Obscure open star clusters or OB associations?
The same place you would find Messier or NGC clusters, along the Milky-Way!
Most open star clusters form and spend their stellar lives among the spiral arms of our galaxy.
Open clusters can be found all along the glowing band of light that we call the "Milky-Way", our home galaxy.

Some large and bright clusters are best suited for the naked-eye, while others are telescopic and require large apertures. Fortunately, there are many objects that display nicely using binoculars or small rich-field telescopes. While a number of open clusters are fairly easy to find, most may require observing from a dark-sky country location such as Cherry Springs.

Observing the fainter clusters visually requires maintaining dark-adaptation, having good starcharts, and slow sweeping with a wide-field low-power telescope. An 80mm F5 or shorter refractor piggybacked on a larger telescope would work very well. The 80mm acts as a low-power RFT giving you a wide-field in which to find the location of the cluster and the larger telescope it is attached to allow use of higher magnifications, depending on the object. In general, for visual observers, it's best to hunt clusters starting off with low-power, wide-field eyepieces to identify the target area. Once the cluster is centered, you can then switch to higher magnifications and

filters to try and pull out details in the object. You'll need all your visual observing skills to find and bring out the subtle differences in these starry objects, such as various loops and chains of stars, and their individual color.

Messier's open clusters are generally large, bright objects and are easily visible in most telescopes, even under suburban skies. Most of the star clusters from the NGC (Herschel) catalog are also generally visible in small to medium size telescopes, though some will require larger size reflectors in the 10 to 15" range and a darker sky. But many of the more obscure named star clusters are generally sparse and fainter, along with being embedded in crowed Milky-Way star fields, which makes these objects challenging to find and observe.
You'll need a larger reflector or some type of imaging setup, along with a dark country sky to pull these in.

For the Imagers, open clusters can also be challenging, in that even with an accurate GOTO mount, it may not position the telescope squarely on the object to where it's framed the way you want it. Having a photographic atlas or picture of the cluster will help you in both locating and identifying the most interesting sections of the object and in framing your image. I've found that using EAA short-exposure and high gain techniques works great in positioning and identifying open star clusters.

While you don't need to use filters for observing open clusters, a general broadband 'light-pollution' filter that you can get from various astronomy equipment companies will enhance both visually viewing or imaging star clusters. Specifically for imaging, at a minimum, an "IR" filter should be used to help reduce and eliminate 'star-bloat' caused by IR light not coming to the same focus as light from the visual spectrum.

Open Star Clusters are classified into four main categories, (or classes), which are further broken down by brightness and concentration. This system, developed by Swiss-American astronomer Robert Trumpler in 1930, is known as the "Trumpler classification", and is still used today. A Roman numeral from I to IV indicates its concentration and detachment from the surrounding star field (from strongly to weakly concentrated):
class I = Detached cluster with strong central condensation.
class II = Detached cluster with little central condensation.
class III = Detached cluster with no noticeable condensation.
class IV = Appears as a star-field

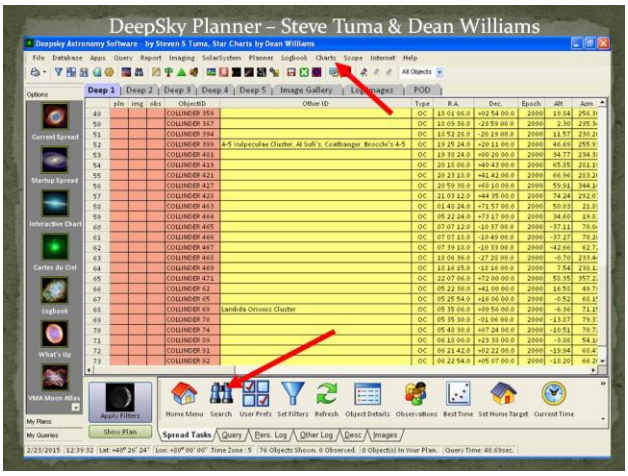
A whole number from 1 to 3 indicating the range in brightness of cluster stars (from small to large range)
1 = Small range in brightness. (most stars look about the same)
2 = Medium range in brightness. (equally bright and faint stars)
3 = Large range in brightness. (large gap between a few very bright stars and remainder of cluster stars mostly faint).

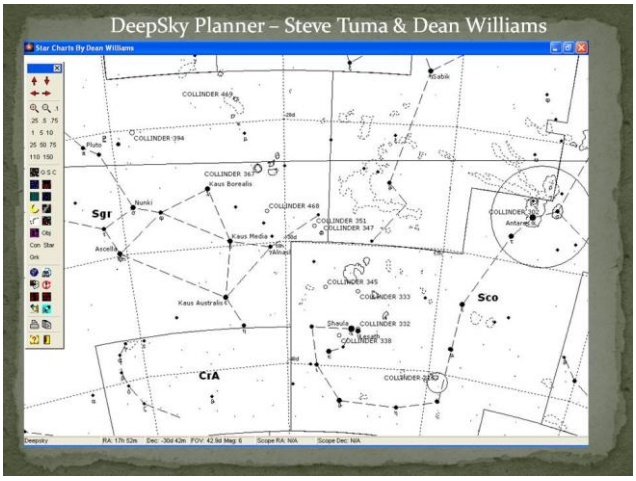
A lower-case 'p', 'm', or 'r' indicates whether the cluster is 'poor', 'medium' or 'rich' in stars.
p = Poor. (star clusters with less than 50 stars)
m = Medium. (moderately rich star clusters with 50 to 100 stars)
r = Rich. (rich star clusters with more than 100 stars)

Finally, an 'N' is appended if the star cluster lies within nebulosity.
For example the Double Cluster is classified as a "IV3r". The Pleaides is a "I3rN'.
These classes will give you a good idea of what to expect from the Star Cluster.

Observing Guides:
It helps to have a list of the cluster catalog that you want to observe. One of my favorite online resources is the website wikisky. https://wikisky.org/ The site displays a photochart of the heavens. Just type the name of the star cluster you want into the search and use the view slider to zoom in/out for the best view.

You can also get a computer software program to help: "DeepSky Planner" – Steve Tuma & Dean Williams
Do a search for your favorite catalog and generate a star chart.





Or, if you're using a planetarium program, you can utilize its settings to show the clusters that you are interested in finding. My favorite program – "Earth Centered Universe"

There are a number of good open cluster related observing guides available to the amateur astronomer. Here's a few of my favorites:

"*The Night Sky Observers Guide – Glories of the Milky-Way*", by George Kepple:
This is the 4th in the series of handbooks written by George Kepple and Glen Sanner, each chapter covering a specific constellation, with finder charts, sketches, images, and visual descriptions of various deep sky objects. New Volume 4 focuses specifically on constellations and their objects that lie along the spiral arms of our Milky-Way galaxy. Each constellation 'chapter' list all open clusters visible within its boundaries in a very convenient layout.

Another good guidebook to have, though somewhat 'dated', is the Webb Society's Deep-Sky Observers Handbook series. With volume-three of the handbook – "*Open and Globular Clusters",* it lists a number of bright clusters visible with small to medium size amateur telescopes. There are a total of 204 open clusters listed in the Webb Society handbook, with detailed descriptions and sketches.

Also, amateur astronomer Alvin Huey has a number of great observing handbooks on his website: http://www.faintfuzzies.com/ While Alvin doesn't have a specific handbook on observing open star clusters, he does have three guides on observing the Herschel Objects which includes many open clusters.
All the guides are in PDF form and contains finder charts, and sketch observations of each object, and can be downloaded and used on your favorite device or printed.

Finally, there's the book "*Star Clusters*" by Brent Archinal & Stephen Hynes that lists over 5,000 individual open clusters, globular clusters, and asterisms. A great reference book.

Examples from 12 different catalogs:
Now let's run thru the dozen most common 'obscure' star cluster catalogs:

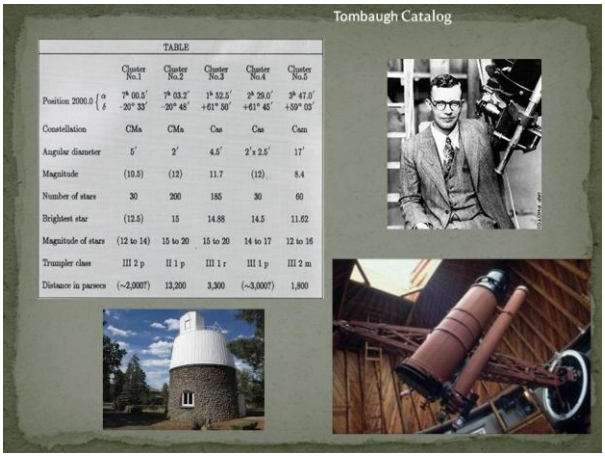
Tombaugh Cluster Catalog
Collinder Cluster Catalog
Trumpler Cluster Catalog
Haffner Cluster Catalog
Stock Cluster Catalog
Harvard Cluster Catalog
King Cluster Catalog

Dolidze Cluster Catalog
Berkeley Cluster Catalog
Ruprecht Cluster Catalog
Czernik Cluster Catalog
Melotte Cluster Catalog

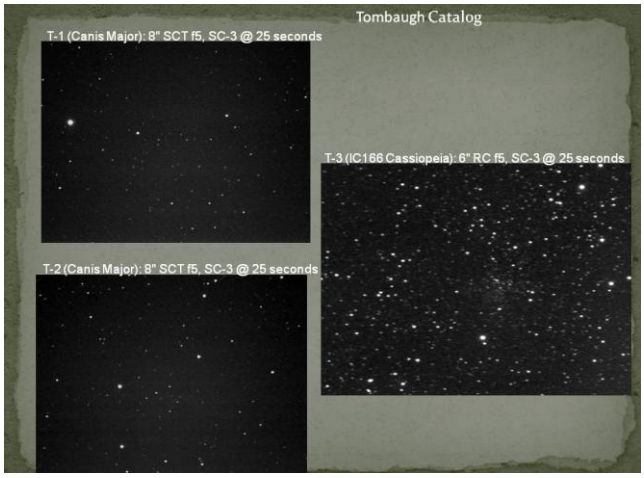
Tombaugh Cluster Catalog

American astronomer Clyde Tombaugh (1907 – 1997), is best known for his discovery of the plant Pluto while working at Lowell Observatory in Flagstaff Arizona. But, during Tombaugh's search for trans-Neptunian planets, he ran across a number of unknown open star clusters. Of the five clusters 'discovered' by Tombaugh, four were first observed by him, with a fifth star cluster, Tombaugh-3, being a re-observation of little-known cluster IC166, which at that time, was not included on any of the usual catalogs.

Tombaugh didn't directly discover his clusters visually thru the telescope, but by examining negative photographic plates taken by him between 1938 - 1941, using a 13" astrograph located at Lowell Observatory in Arizona. (The 13" Lawrence Lowell Telescope).



	Cluster No.1	Cluster No.2	Cluster No.3	Cluster No.4	Cluster No.5
Position 2000.0 α	7h 00.5'	7h 03.2'	1h 52.5'	2h 29.0'	3h 47.0'
Position 2000.0 δ	-20° 33'	-20° 48'	+61° 50'	+61° 45'	+59° 05'
Constellation	CMa	CMa	Cas	Cas	Cam
Angular diameter	5'	2'	4.5'	2'x 2.5'	17'
Magnitude	(10.5)	(12)	11.7	(12)	8.4
Number of stars	30	200	185	30	60
Brightest star	(12.5)	15	14.88	14.5	11.62
Magnitude of stars	(12 to 14)	15 to 20	15 to 20	14 to 17	12 to 16
Trumpler class	III 2 p	II 1 p	III 1 r	III 1 p	III 2 m
Distance in parsecs	(~2,000?)	13,200	3,300	(~3,000?)	1,800



With the exception of Tombaugh-5, the 1st-four star clusters are small, faint, and can be difficult to find. Three are located by Cassiopeia, and the last two in Canis Major. A visual observer will need a moderate size telescope with a mirror 10" or greater, and a dark-sky location. EAA-observers and CCD imagers will be able to use smaller scopes with exposures of 20 seconds or more. I currently have observed all 5 Tombaugh clusters.

Collinder Cluster Catalog

In 1931, Swedish astronomer Per Collinder (1890 - 1974, born in Sundsvall, Sweden), created a catalog of the known galactic open star clusters as part of his graduate student thesis: "*On structural properties of open galactic clusters and their spatial distribution*". His list contains 471 entries, of which a large number are already cataloged Messier and NGC objects. Most, of his work was based on using photographic plates taken from a variety of observatories, and Collinder actually observed very few of the objects himself.

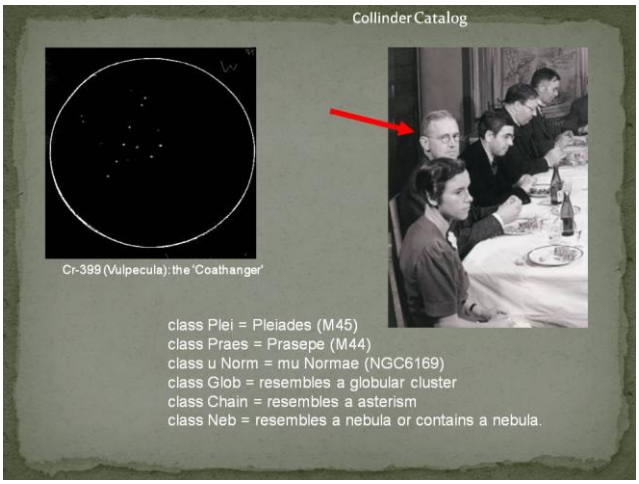
This graduate survey work of Collinder's appears to be the highlight of his astronomical career, as he is more noted for his work in navigation.

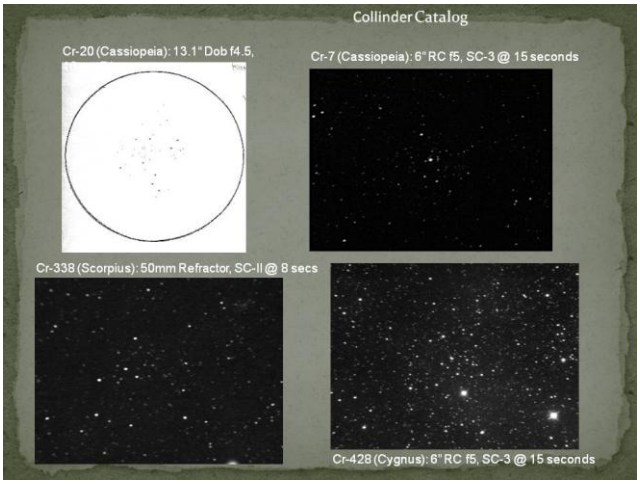
The amateur astronomer will find many of his 'Cr' objects listed on star atlases and observing guides.

While some of the 'CR' objects are asterisms or even globular cluster, the majority of objects are open star clusters. A fair number are unique objects, not listed in any other prior catalog.

Per Collinder classified his list into six unique sub-categories based on using three known star-clusters as class types, along with three additional general descriptive classes:
class Plei = Pleiades (M45)
class Praes = Prasepe (M44)
class u Norm = mu Normae (NGC6169)
class Glob = resembles a globular cluster
class Chain = resembles a asterism
class Neb = resembles a nebula or contains a nebula.

Collinder's classification system didn't catch-on with the astronomical world and quickly fell out of use.



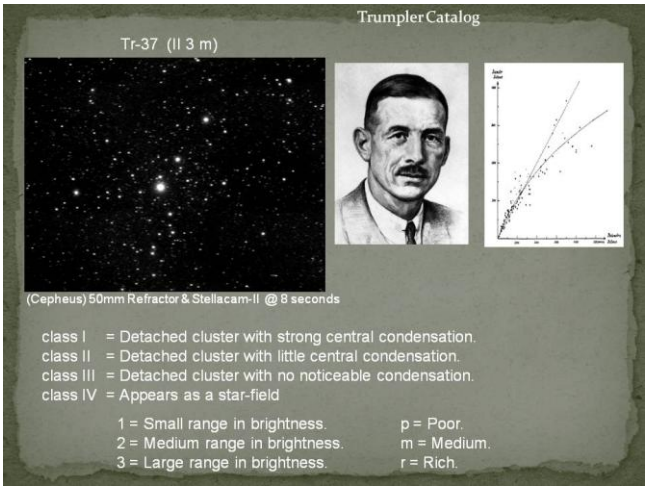


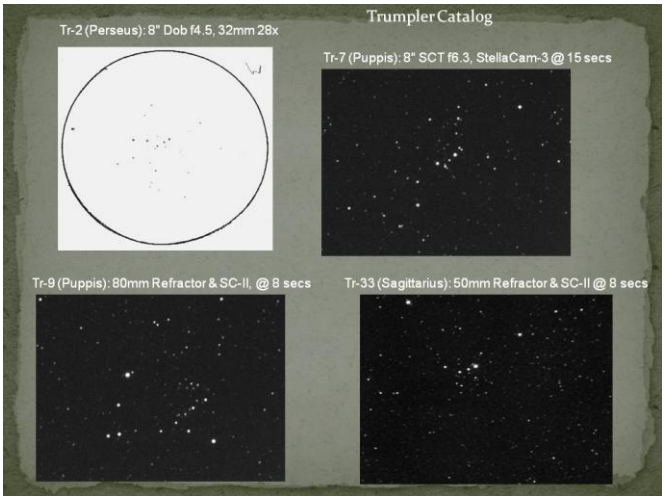
Visually, the Collinder catalog clusters cover a wide range, from naked-eye objects to those requiring binoculars or a small rich-field telescope, all the way up to needing a 20" or larger telescope.
Collinder clusters can be found along the entire length of the Milky-Way, with one of the easiest to find, requiring only binoculars, is Cr399, the "Coathanger", in Sagitta.

I currently have observed 348 Collinder objects visible from my Pittsburgh, PA latitude of +40.
(123 of the 'Cr' objects are located too far south and not observable from my region).

Trumpler Cluster Catalog
Robert Trumpler, (1886 - 1956), was born in Zurich Switzerland. He received his PH.D. in astronomy in 1910.
In 1915, he took a position at Allegheny Observatory, and later in 1918 went to Lick Observatory.
Trumpler studied the brightness of distant open star clusters in order to determine the size of the Milky Way galaxy. In 1930, he published a catalogue of open clusters titled: "Preliminary results on the distances, dimensions and space distribution of open star clusters". His investigation of distances, dimensions, and space distribution of galactic open star clusters was a significant contribution to astronomy.
Trumpler's work contains a table of 37 new open star clusters, now known as the Trumpler catalog.
The amateur astronomer will find many of his 'Tr' objects listed on star atlases and in observing guides.

While cataloguing open clusters, Trumpler also devised a classification system in 1930 according to the number of stars observed within them, how concentrated these stars are in the center of the cluster and the range of their apparent brightness. As previously mentioned, this system, known as the "Trumpler classification", is still used today. While some of the 'Tr' objects are already listed under other catalog designations such as 'NGC', the majority are unique objects, not listed in any other prior catalog.

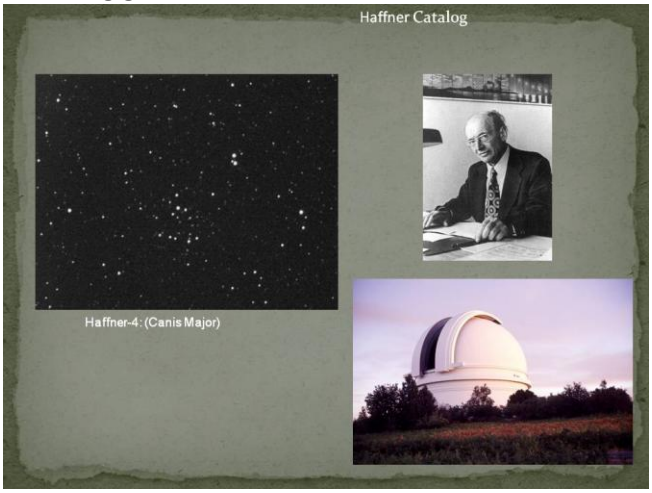


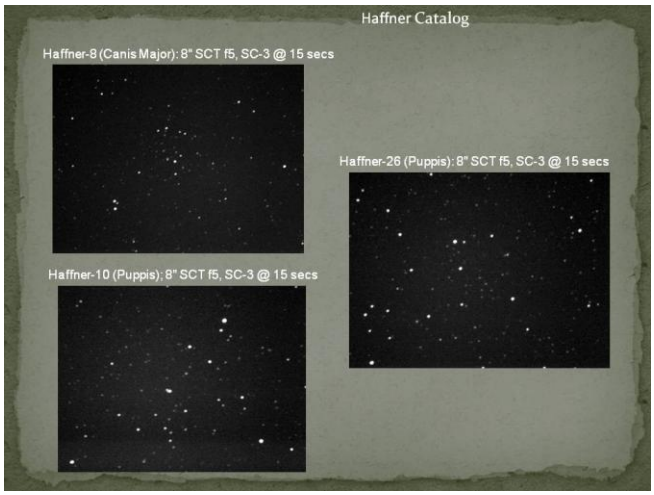


Trumpler clusters cover a wide range in brightness, and can be found along sections of the Milky-Way, with several nice ones laying between Scutum, Sagittarius, and Scorpius. Of the 37 Trumpler open clusters, I have observed all 23 objects visible from my Pittsburgh, PA latitude of around +40.
(14 of the 'Trumpler' objects are not observable from my region).

Haffner Cluster Catalog

In 1957, German astronomer Hans Haffner (1912 - 1977), working at Boyden Observatory in South Africa, (which he later became the Director of), created a catalog of "New Galactic Star Clusters in the Southern Milky Way", containing 26 open clusters. Additionally, during the 1960's, Haffner served as chairman of the open clusters section of the IAU. The amateur astronomer will find many of his 'Haffner' cluster objects listed on star atlases and observing guides.



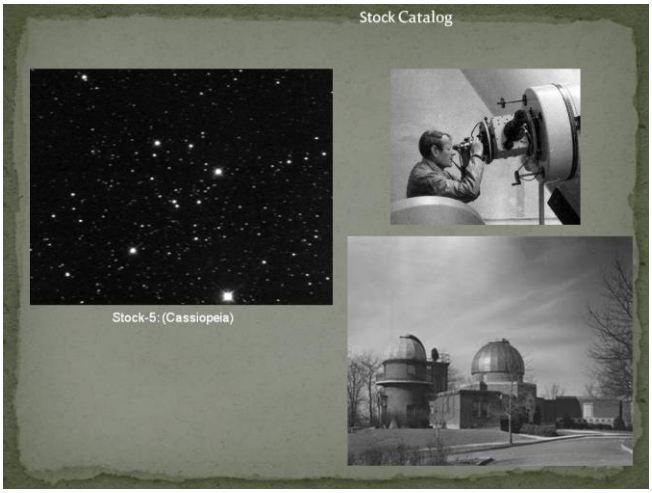


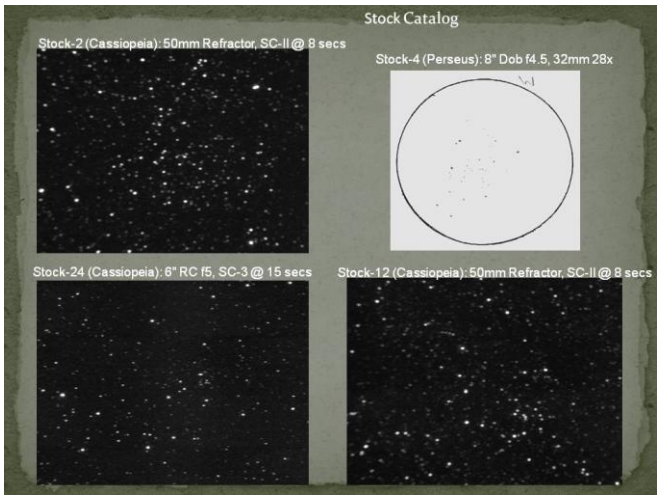
While some of the 'Haffner' objects are already cataloged under other designations such as 'NGC', the majority are unique objects, not listed in any other prior catalog.
Haffner clusters can be found along the Winter Milky-Way in Canis Major and Puppis.
I currently have observed all 26 objects visible from my Pittsburgh, PA latitude of around +40.

Stock Cluster Catalog

Jurgen Stock, (1923 - 2004), was born in Hamburg, Germany, where he received his PH.D. in astronomy in 1951 from Hamburg University. In the early 1950's, Stock, worked at Case Western Reserve University in Cleveland, OH, at the Warner and Swasey Observatory. While there he conducted a photographic photometry study of open

clusters, which led to the discovery of two dozen previously unknown sparse clusters in the northern Milky-Way. Stock was the first director of the Cerro Tololo Inter-American Observatory in Chile.
He was instrumental in selecting the observatory site, spending nearly three years in the region, exploring and surveying the nearby mountains, accessible only by horseback. After finally selecting Cerro Tololo, Stock overseen construction of the road to the sumit and the first installations of the observatory itself.
His contributions to many areas of astronomy and other sciences played a key role in the development of astronomy in Latin America.





The amateur astronomer will find a number of his 'Stock' Star Clusters listed on star atlases and observing guides. While some of the 'Stock' objects are already listed under other catalog designations such as 'NGC', the majority are unique objects, not listed in any other prior catalog. Stock clusters are generally large, sparse, and very faint. Many are not plotted on star atlases. But, they can be found along the Fall Milky-Way in Cassiopeia, Perseus, and Auriga. I currently have observed all 20clusters (from the list of 24) visible from my Pittsburgh, PA latitude of around +40. (4 of the 'Stock' objects are located too far south in latitude for me to observe: Stock13, 14, 15 & 16).

Harvard Cluster Catalog

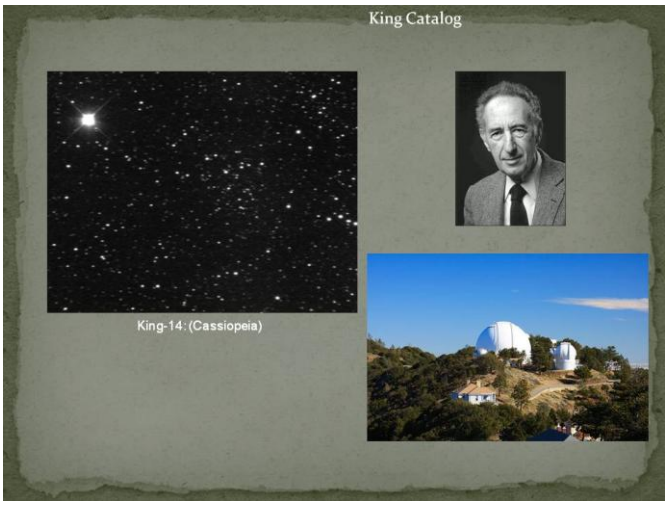
American astronomer Harlow Shapely, (1885 - 1972), born in the small town of Nashville Missouri, studied astronomy at the University of Missouri, and earned his PH.D from Princeton University.
One of the lesser known catalogs of open star clusters is the Harvard catalogue, of 21 open clusters.
It was compiled in 1930 by Shapely, whose many accomplishments include correctly estimating the size of the Milky-Way Galaxy and the sun's position within it. Shapley also served as director of the Harvard College Observatory from 1921 to 1952, and published a number of books on astronomy. In 1953, he came up with the “Liquid Water Belt” habitable zone theory of planetary formation around stars.

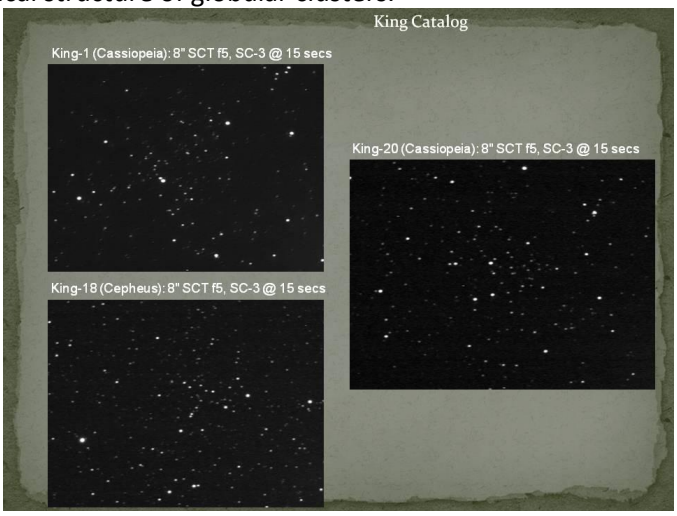
While a number of the 'Harvard' objects are already listed under other catalog designations such as 'Trumpler', or 'NGC', about half are unique objects, not listed in any other prior catalog. These clusters are generally faint and sparse, and are sporadically listed in star charts & in observing guides. A number of these faint clusters can be found in Scorpius, but an interesting one, H20, can be found in the Sagitta.

I currently have observed 11 Harvard clusters that are visible from my Pittsburgh, PA latitude of around +40. (9 of the 'Harvard' objects are not observable from latitude +40. Also, one cluster: Harvard-3 has gone missing and is probably a false observation mistakenly included by Shapely).

King Cluster Catalog

American astronomer Ivan R. King, (1927 - 2021), graduated from Hamilton College in 1947 and received his doctorate from Harvard University in 1952. Starting in 1949, while at Harvard, and later in 1966, at the University of California, Berkeley, King created a catalog of 27 open star clusters, based on his study involving the dynamical modeling of star clusters (referred to as the "King model").
King's most recent research involved studies of the dynamical structure of globular clusters.



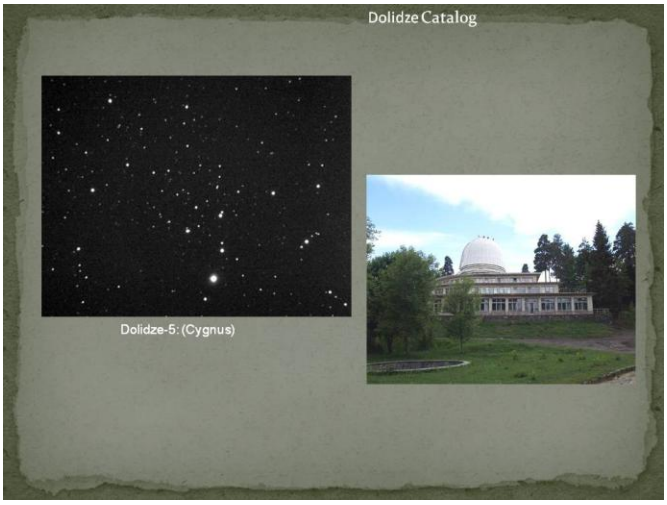


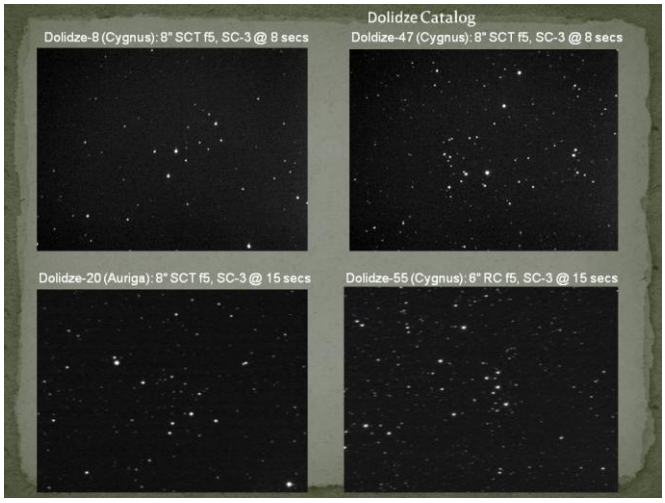
The amateur astronomer will find many of his 'King' cluster objects listed on star atlases and observing guides. While a few of the 'King' objects are already listed under other catalog designations such as 'NGC', the majority are unique objects, not listed in any other prior catalog. The majority of King clusters can be found in the Fall Milky-Way region of Cassiopeia and Cepheus. I currently have observed all 27 King objects.

Dolidze Cluster Catalog

In 1966, Russian astronomer Madona V. Dolidze at the Abastumani Astrophysical Observatory located in Georgia, created a catalog of 57 open star clusters based on his emission-line spectral surveys done with the observatory's 70cm f/3 Maksutov astrograph. Later, he was joined by astronomer G. N. Dzimselejsvili and together the two astronomers published a follow-up list of 11 additional clusters. (Do-DZ)

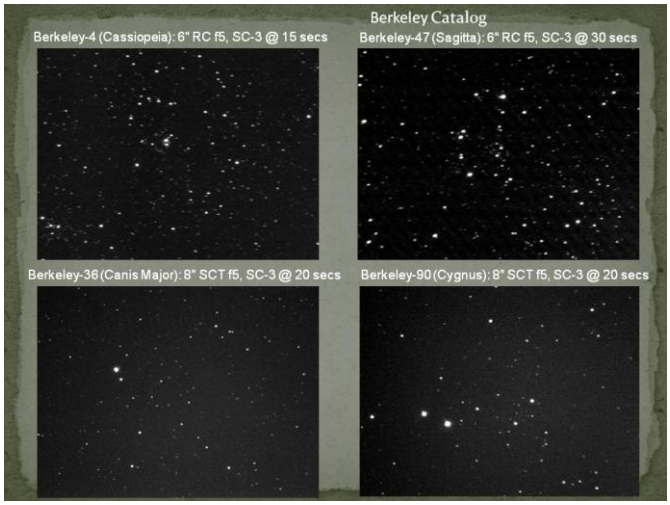
The amateur astronomer will find many of the 'Dolidze' cluster objects listed on star atlases and in observing guides. While a very few of the 'Dolidze' objects are already listed under other catalog designations such as 'NGC', the vast majority are unique objects, not listed in any other prior catalog. These clusters generally consist of very loose and sparse stars. Most lie within the more rich areas of the Milky-Way, which tends to make them difficult to find and identify from the surrounding field stars. Only a few of the Dolidze/Dzimshelishvili (Do-DZ) clusters are true physical clusters. One good area to search for these clusters is in the central portion of Cygnus. I currently have observed all 57 Dolidze objects, along with all 11 of the Dolidze-Dzimselejsvili objects.





Berkeley Cluster Catalog

In 1958, Berkeley astronomers Gosta Lynga (Sweden, 1930 -), and Jiri Alter (Czechoslovakia, 1891 – 1972) published a catalog of Star Clusters and Associations, compiled in CCD photometry studies by various astronomers at the University of California at Berkeley. The catalog is a collection of 104 extremely old open star clusters identified from the Palomar Observatory Sky Survey (POSS) plates. It includes the currently oldest known open star cluster in the Milky-Way, Berkeley-17, estimated at around 10.7 billion years old. Lynga went on to the Mt Stromlo Observatory in Australia to research star formation in the southern Milky-Way.

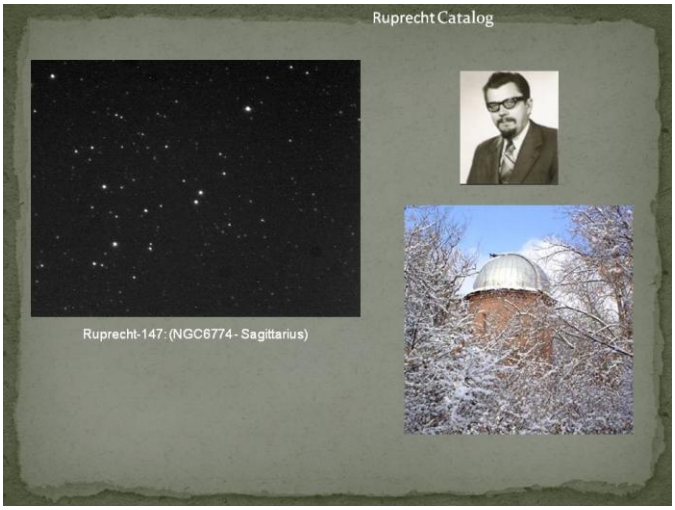


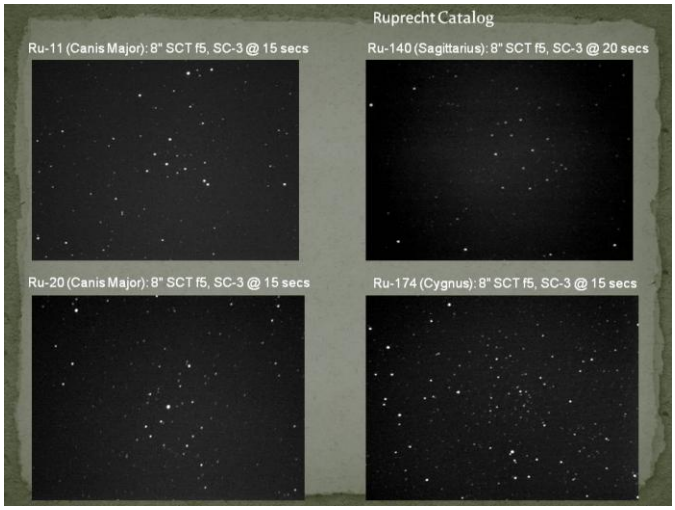
The amateur astronomer will find many of the 'Berkeley' objects listed on star atlases and observing guides. While some of the 'Berkeley' objects are already listed under other catalog designations such as 'NGC', the majority are unique objects, not listed in any other prior catalog. Berkeley clusters can be found along the entire length of the Milky-Way, with a number of nice ones located in Cygnus and Sagitta.
I currently have observed all 104 objects visible from my Pittsburgh, PA latitude of around +40.

Ruprecht Cluster Catalog

In 1958, Czech astronomer Jaroslav Ruprecht, (1931 - 2011), published a paper, (of which he was one of the main compilers), of all known stellar associations, open star clusters, and globular clusters called "Catalogue of Star Clusters and Associations". Within this catalog, there are a total of 176 new open clusters.
Ruprecht 147 (NGC 6774), is particularly interesting in that it is only 800 to 1,000 light-years from Earth, and it's component stars, which were born out of the same cloud of gas and dust, are approximately 2-billion years old,

making it the closest star cluster to Earth that have member stars similar to the Sun's mass and age than those in all the other nearby clusters. Astronomers have identified this cluster as a potentially important new reference gauge for fundamental stellar astrophysics, and will become very useful in understanding the evolution of stars like the Sun, and in the search for Earth-like planets orbiting around Sun-like stars.



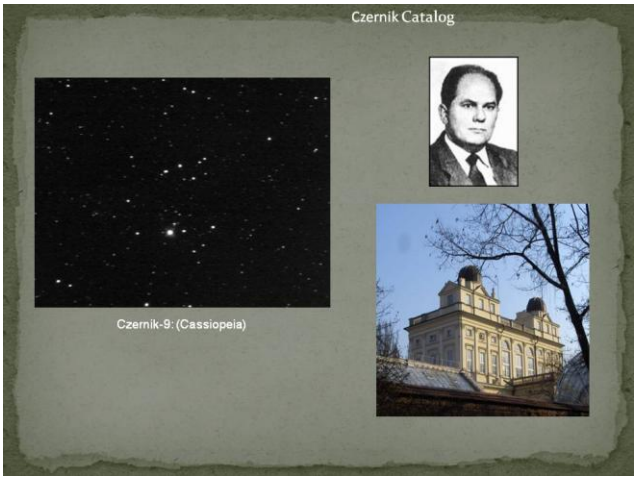


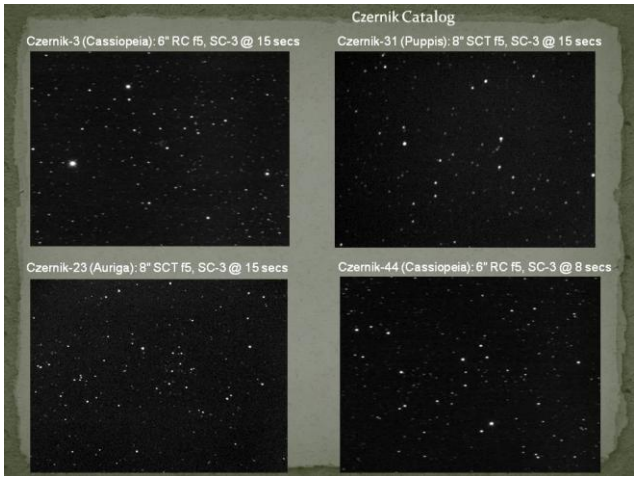
The amateur astronomer will find many of his 'Ruprecht' objects listed on star atlases and observing guides. While a very few of the 'Ruprecht' objects are already listed under other catalog designations such as 'NGC', the majority are unique objects, not listed in any other prior catalog. Ruprecht clusters can be found along the entire length of the Milky-Way, but there's a nice 'clustering' of them along the Winter Milky-Way in Canis Major and Puppis.
I have currently observed the possible 92 cluster objects visible from my Pittsburgh, PA latitude of around +40. (84 of the '176' total objects are not observable from my regions lattitude).

Czernik Cluster Catalog

In 1966, Polish astronomer Mieczyslaw Czernik, (1933 - 1991), of the Warsaw University Observatory and Astronomical Institute created a catalog of 45 open star clusters based on a study of the images of the Palomar Sky Atlas.

The amateur astronomer will find many of his 'Czernik' objects listed on star atlases and observing guides. While a very few of the 'Czernik' objects are already listed under other catalog designations such as 'Basel' or 'King', the majority are unique objects, not listed in any other prior catalog. Czernik clusters can be found along the entire length of the Milky-Way, but a large number can be found mostly along the Fall Milky-Way in Cassiopeia and Auriga. I currently have observed 38 out of a possible 41 objects visible from my Pittsburgh, PA latitude. (Clusters #33, 35, 36, & 37 are missing, and #34 is a galaxy).





Melotte Cluster Catalog

In 1915, British astronomer Philbert Jacques Melotte, (1880-1961), at the Royal Greenwich Observatory, created a catalog of 245 deep sky clusters as part of a astrographic study of a early photographic atlas of the sky (called the Franklin-Adams) based on plates taken at Johannesburg, South Africa, and Godalming, England.
Mellotte also discovered in 1908 the 8th moon of Jupiter, today known as Pasiphae, and also asteroid 676 Melitta in 1909. The Melotte catalogue contains both open and globular clusters.
The distribution of these clusters around the sky was used in determining the overall structure of our Milky-Way galaxy.

The amateur astronomer will find many of his 'Melotte' objects listed on star atlases and observing guides. While some of the 'Melotte' objects are unique objects, such as Mel111 - the Coma Berenices cluster, the majority are already listed under other prior catalog designations such as 'M', 'NGC', or 'IC', Melotte clusters also cover a wide range in brightness and size, and can be found all along the Milky-Way,
with several large bright members located in Perseus (Melotte-20, Alpha Persei OB Association), and Taurus (Melotte-22, Pleiades, and Melotte-25, Hyades).

I currently have observed all 182 clusters that are visible from my Pittsburgh, PA latitude of around +40.
(63 objects are not observable from latitude +40).

I've also observed four additional cluster catalogs: Basel, Biurakan, Bochum, and Roslund, and these can be found on my website. http://stellar-journeys.org/

Conclusion:

So today I introduced you to some of the more obscurely named open star cluster catalogs.
We learned a little about the individuals behind each catalog, and reviewed both visual sketches and EAA capture image examples of various members from each catalog.
Hopefully this little presentation has inspired you to search-out and explore these often missed, but very rewarding celestial objects.

So I encourage everyone to get out the next clear night and try your hand at finding and observing these elusive deep-sky gems, the obscure open star clusters of Per Collinder, Clyde Tombaugh, Ivan King, Robert Trumpler, Jurgen Stock, Philbert Melotte, and many others.

Thank you.
Larry McHenry

Edwin Hubble: The Surveyor of the Universe

One hundred years ago, on the night of October 5th, 1923, a discovery was made that changed our understanding of the cosmos. American astronomer Edwin Hubble, using the new 100" Hooker reflector telescope at Mt Wilson Observatory, identified within the Andromeda Nebula what was to become the first extragalactic variable star. This led to astronomers adopting the expanding universe theory! Some historians consider Hubble's discovery to be one of the greatest in astronomy since Galileo's time.

Through his work of studying variable stars in galaxies, Hubble broke new ground in our understanding the universe, and along the way sparked the basics of the Big Bang Theory. Today, we're going to look-back on his life and accomplishments, and talk a little bit about his discoveries. We'll also review a number of my observations of Hubble's objects and how you can observe them too.

Discussion outline:

- **Galaxies – What are they:**
  - Classic Morphology
  - Local Group
- **Island Universes - The Nebula Controversy:**
  - Historical & Modern Astronomers
  - The Great Debate
- **Edwin Hubble:**
  - Childhood & Education
  - Service in WWI
  - Family Life
  - Service in WWII
- **Life as an Astronomer:**
  - Yerkes Observatory
  - Mt Wilson Observatory
  - Palomar Observatory
- **Hubble's Discoveries:**
  - What are Cepheid Variables
  - Distance to M31 using Cepheid variables
  - Red shift and the expanding universe – Hubble's Law
  - The Big Bang - the Hubble Constant
  - Hubble Sequence - Galaxy Classification – Tuning Fork
- **Amateur Observations of Hubble's Galaxies:**
  - How to observe galaxies
  - Andromeda and V1
  - M33
  - Other
- **Hubble's Legacy & Conclusion:**

Galaxies – What are they:

Galaxies are large systems of stars and interstellar matter, typically containing from several million to several trillion stars. They run in size from a few 10's of thousands to several 100,000 light years in size, and are separated from other galaxies by millions of light years.



How do Galaxies form?

They originate from large cosmic primordial clouds of gaseous matter (hydrogen and helium) in our Universe that slowly collapsed. Most galaxies have formed at about the same time, within the first billion years after the universe started to expand, from an initial hot state.

Thus, they are all almost as old as the universe itself, currently thought to be about 14 billion years.

Where are Galaxies Located?

Galaxies are scattered throughout the visible universe. We live inside a giant spiral galaxy, called the Milky-Way Galaxy. The Milky-Way is about 100,000 light years in diameter and contains a mass equal to about a trillion stars. Our galaxy has several small dwarf galaxies orbiting around it that are only a few 100,000 light years distant.

The nearest giant galactic neighbor, the Andromeda Galaxy, also a spiral, is about 2-3 million light years distant.

Some galaxies are isolated "island universes" which float lonely through an otherwise empty region of the universe. But the distribution of matter in the Universe is not uniform. That causes groups of galaxies, running to few dozens of galaxies, or even large clusters of up to several thousands of galaxies, to form. The galaxies of these groups are in mutual gravitational interaction, which may have significant influence on their appearance.

Galaxy Morphology

Galaxies come in several types, a wide variety of shapes and appearances, and have many common features. From their appearance, galaxies are classified as spiral, lenticular, elliptical, and irregular

Elliptical

Elliptical galaxies are shaped like giant luminous cosmic balls, and have no spiral or disk components.

They have little or no rotation as a whole. Normally, elliptical galaxies contain very little or no interstellar matter, and consist of older population stars only:

Lenticular

Lenticular galaxies are shaped like spiral galaxies without a spiral structure. They are smooth disk galaxies, where stellar formation has stopped long ago, because the interstellar matter was used up. They consist of mostly older population stars only. From their appearance and stellar contents, they can often be observationally confused with ellipticals.

Spiral

Spiral galaxies usually consist of three major components: A flat, large disk which often contains interstellar matter visible as diffuse glowing emission nebulae or as dark dust clouds. Young open star clusters, associations, and random stars arranged in conspicuous and striking spiral patterns and / or bar structures. Finally, a central bulge or core, consisting of older stellar populations with little interstellar matter, and often surrounded by a halo of older globular star clusters.

Irregular

Irregular galaxies have many different shapes and sizes due to distortions caused by their intergalactic neighbors. These galaxies do not fit into the normal scheme and exhibit no particular shape.

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The "Local Group"

The "Local Group" is the group of galaxies that includes our home galaxy, the Milky Way, among others. It comprises more than 54 galaxies, counting low surface brightness dwarf galaxies, divided into three main sub-groups. The most massive member of the group is M31, the Andromeda Galaxy, followed next by the Milky Way, with the third being M33, the Triangulum Galaxy. Both the Milky Way and Andromeda galaxies each have a system of satellite dwarf galaxies. The gravitational center of the Local Group is located between the Milky Way and the Andromeda Galaxy. Overall, the Local Group has a rough diameter of around 10 million light-years, and contains three spirals, two elliptical, nine irregulars, and forty dwarf galaxies.

The Milky Way's satellite system consists of the Large Magellanic Cloud, Small Magellanic Cloud, and about a dozen dwarf galaxies. The much larger Milky Way is cannibalizing several of its smaller dwarf galaxies such as the Sagittarius and Canis Major dwarfs, which are in the process of being stretched into remnant stellar steams.

Andromeda's satellite system consists of the brighter members M32, M110, NGC 147, NGC 185, along with another 10 dwarf galaxies. The Andromeda galaxy is also in the process of gobbling-up several of its own smaller satellite galaxies.

The third sub-group is the Triangulum Galaxy, M33, which is the only unbarred spiral galaxy in the Local Group. M33 currently does not have any known satellite system of smaller galaxies.

Finally, there are a number of small dwarf galaxies in the Local Group that are not bound to any of the three main galaxies.

While there's currently 54 individual galaxies identified as members of the Local Group, with the Milky Way blocking a large band of the sky, new discoveries of galaxies with extremely low surface brightness, obscured by our galaxies dust are still being discovered, so the group membership will rise as we develop better instruments.

Island Universes - The Nebula Controversy:

In addition to the glowing cloud band of light known as the Milky Way, Ancient people also noticed other smaller patches of unmoving 'little clouds' up in the night sky, one in the constellation of Andromeda, and another in the stars of the triangle. Having only their naked-eyes, most people could only speculate as to what these night-time clouds were.

With modern science, we now understand what the Milky Way and the Andromeda and Triangulum galaxies are. We can trace the beginnings of scientific observations of the galaxies back through history over the last four centuries.

Galileo:

After the invention of the telescope, Italian astronomer Galileo Galilei was the first to use one to observe the Milky Way. Galileo reported in his book "The Starry Messenger" published in 1610, that he was able to resolve the nebulous glowing band into a multitude of individual stars so densely packed that without a telescope they appeared as clouds to the naked-eye. During this period, German astronomer Simon Marius used his own telescope in 1612 to observe the Andromeda nebula which he described as a dull, pale light, "like a candle shining thru horn", but was not able to resolve it into stars.

Immanuel Kant:

In 1755, German Enlightenment philosopher Immanuel Kant in a paper titled "*Universal Natural History and Theory of the Heavens*" theorized that the stars of the Milky Way, like the sun and planets of the solar system, formed from a large spinning disk of gas and was held together by gravitational forces. This was known as his "Nebular Hypothesis". The reason that the Milky Way galaxy looked like a band was due to our being inside the disk. Kant also thought that other distant "nebulae", which he called 'Island Universes', might be other separate galaxies located outside the Milky Way.

Charles Messier:

While both the Andromeda and Triangulum nebula were well known in Charles Messier's time, in 1764 he still went ahead and listed both small clouds as the 31st and 33rd entry on his list of objects to avoid while comet hunting. Messier used various small telescopes from his observatory in Paris to view both nebulas describing M31 as "Beautiful nebula, shaped like a spindle, center appears clear without any stars appearing, and the light gradually diminishes until extinguished". And for M33 – "of a whitish light of almost even density and contains no stars".

William Herschel:

In 1785, As the 'Kings Personal Astronomer' to England's King George III, as part of his work to study everything about the night sky, William Herschel made the first attempt to define the actual shape of the Milky Way from observation and measurement by carefully counting the number of stars in different regions of the sky. From his observations, William created a diagram of the Milky Way, placing the solar system at its center, and devised his own theory that our galaxy was disk-shaped.

Herschel also used his "20 foot" reflector to observe both the M31 and M33 nebulas, resolving some features of each and giving them their own designations, such as NGC206 which is a bright section of spiral arm in M31, and NGC604 which is a bright HII region within M33. Additionally, Williams sister, Caroline, discovered the second satellite galaxy to M31, NGC205, also known in modern times as M110. Herschel described M31 as "brightest part approaches resolvable nebulosity, faint reddish hue to its core", and M33 as "Milky nebulosity, and has a mottled aspect". Herschel believed that both nebulae we know today as galaxies were clusters of unresolved stars which he called "Island Nebulae" to distinguish them from Kant.

Lord Rosse:

Using his 72" reflector, in 1850, Anglo-Irish astronomer William Parsons, the 3rd Earl of Rosse reported that the disks of both M31 and M33, along with a number of other nebula, (particularly M51 which he nicknamed the "Whirlpool'), exhibited a spiral shape, and he began referring to these as 'spiral nebula' to distinguish them from the various other nebula. Parsons was also able to visually resolve some individual stars in the spiral nebula that he observed.

William Huggins:

English astronomer William Huggins, and later, along with his wife Margaret, pioneered the new field of astronomical spectroscopy during the latter half of the 19th century. In 1864, he was the first to successfully capture the spectrum of the planetary nebula NGC6543 in Draco. That planetary and other nebula that Huggins took displayed a pure emission spectra characteristic of a gas. But some 'nebula', such as M31, was different, and displayed the spectral characteristics of stars, rather than a gas. From this discovery, astronomers determined that the Andromeda nebula and other similar spirals were stellar in nature.

Herber Curtis:

American astronomer Herber Curtis (1872 – 1942), born in Muskegon, Michigan and after attending the University of Michigan, earned his PHD in Astronomy in 1902 from the University of Virginia. Herber was known for his studies of solar eclipses, having participated in 11 eclipse expeditions. During his professional career, Curtis worked at Lick Observatory and served as president of the Astronomical Society of the Pacific. In 1918, he was the first astronomer to observe the jet coming out of the core of M87. He later was appointed in 1920 as director of the Allegheny Observatory in Pittsburgh. In 1930, Curtis accepted a position as director of the University of Michigan's astronomical observatories where he finished his career.

While at Lick Observatory in 1917, researching the spectrum of a prior nova, (1885A, S Andromedae), that appeared to be from within the Andromeda Nebula, Curtis uncovered 11 more examples of nova from within the nebula. Curtis determined all 12 of the 'Andromeda' nova had similar magnitudes that were at least 10 times fainter than similar nova from within the Milky Way. Taking into account the differences in nova magnitudes, Herber calculated that the Andromeda Nebula must be at least 490,000 light-years distance, well outside of the Milky Way galaxy. From this, Curtis became a leading proponent of Kant's 'Island Universe' hypothesis that spiral nebula were all external from the Milky Way.

Harlow Shapley:

American astronomer Harlow Shapley, (1885 - 1972), born in the small town of Nashville Missouri, studied astronomy at the University of Missouri starting in 1907, and later earned his PH.D from Princeton University. After graduating, Shapley was hired by George Hale to work at Mt Wilson Observatory with the 60" reflector, at the time, the largest telescope in the world.

Shapley served as director of the Harvard College Observatory from 1921–1952, and published a number of books on astronomy. One of the lesser known catalogs of open star clusters is the Harvard catalogue, of 21 open clusters and was compiled in 1930 by Shapely. His other major accomplishments include correctly estimating the size of the Milky-Way galaxy using RR Lyrae and Cepheid variable stars and their Period-Luminosity Relationship, and the sun's position within the Milky Way of being two-thirds toward the outer edge rather than in the center of the galaxy. Shapley was elected president of the American Association for the Advancement of Science in 1947.
In 1953, he came up with the "Liquid Water Belt" habitable zone theory of planetary formation around stars.

During his early career, Shapley as an avid supporter of the Milky Way being the entire universe, with spiral nebula as just another type of nebulous gas object within the Milky Way. (his "Big Galaxy" model).

While initially criticizing and opposing astronomer Edwin Hubble's galaxy distance observations, after seeing and analyzing Hubble's data, Shapley realized that Hubble was fundamentally correct, and became a supporter of Hubble's theory. Shapley went on to make significant contributions in the research of galaxy distribution, mapping over 76,000 galaxies. He was one of the first astronomers to support the theory of galaxy superclusters.

The Great Debate - external galaxies vs. internal nebula:

At the turn of the 20th century, one of the major questions that professional astronomers were trying to answer was "how far away are the galaxies?" Does the Milky Way represent the extent of the entire known Universe, or was it just one of many galaxies in a much larger Universe?

In April of 1920, the question of what were spiral nebulae and the size of the universe came to a head.
The National Academy of Sciences hosted a public lecture at the Smithsonian Museum between astronomers Curtis and Shapley who both presented opposing papers. Shapley defended that spiral nebulae were all small objects located inside the Milky Way, and Curtis argued that the spiral nebulae are large 'island universes' that were located far outside the Milky Way.

Shapley's main line of argument was that as the overall luminosity of the Andromeda nova generally matched nova elsewhere in the Milky Way so that the nova observed in M31 must also be nearby. But his key supporting fact was based on observations from another astronomer (Adriaan Van Maanen) that rotation had been observed in M101, 'Pinwheel' Galaxy'. If the M101 spiral nebula was external to the Milky Way, this visible rotation would be a violation of the speed of light!

Curtis used his Andromeda nova magnitude research as his key evidence in arguing for galaxies being much further away external objects. He also used the measurable Doppler Redshift and the dark dust lanes visible in the spiral nebula arms that resembled the Milky Way's as additional proof that spiral nebulae were independent external galaxies.

The general consensus of the astronomical world after the debate was it was mostly a draw, with Shapley having the edge in being a stronger debater than Curtis. But, it soon turned-out that Curtis had the better observational facts, as Shapley's key supporting argument that rotation had been observed in M101 was based on Van Maanen's using an old optically defective blink-comparator machine and his observations were disproven. The answer to the question on spiral nebulae would have to wait until another astronomer could more accurately measure the distance to the galaxies.

Edwin Hubble:

Childhood:

American astronomer Edwin Hubble, (1889 – 1953), was born at his grandparents dairy farm home in Marshfield, Missouri on November 20th, 1889. The single story house was heated by only one fireplace, located in the living room, and lighted at night by kerosene lamps. Edwin's father, John, was a salesman in the insurance business, while his mother, Virginia, managed the Hubble household, which included raising seven other children in addition to Edwin. (Edwin was the third oldest). Edwin's father enjoyed good success as a salesman, and was able to give Edwin and his siblings a normal childhood growing up in a middle-class family. In late 1899, the Hubble's moved first to Evanston, Illinois, before finally settling in nearby Wheaton.

As a young boy, Edwin learned to play the mandolin, and loved to read books, especially the stories of Jules Verne. For his eight birthday, Edwin's grandfather built a basic telescope for Edwin as a gift.
Edwin stayed up all night looking thru the telescope. That is where Edwin developed a passion for astronomy, and loved to watch meteor showers from his yard. Two years later, in June of 1899, Edwin camped out all night with friends to view a total lunar eclipse. It was said by Edwin's friends that this eclipse may have been what sparked Edwin wanting to be an astronomer. By age twelve, Edwin was knowledgeable in astronomy, such that a letter that he wrote to his grandfather about the planet Mars was published in the local paper.

Edwin was a tall athletic boy, and eventually reached the height of 6' 3" in high school, where he excelled at the sport of track and field and broke the state record for the high jump. Hubble also excelled at his school studies in the sciences, algebra, and Latin, such that the school principle said of Hubble at his graduation – "*I have watched you for four years and never seen you study for ten minutes*". During the summer, Edwin would return to his grandparent's home in Marshfield where he worked on their dairy farm. Later, during Edwin's college years in Chicago, his father, John, moved the family to Shelbyville Kentucky, near Louisville, for a job promotion.

Education:

Upon graduating from high school at the age of 16 in 1906, Edwin received a scholarship to the University of Chicago where he studied mathematics, astronomy, and natural sciences, and spent a year working as a lab assistant for the university's famous physicist Robert Millikan. Edwin also continued in sports, helping the men's basketball team win the Big Ten basketball championship in 1910. Edwin graduated from the University of Chicago in 1910 with a degree in mathematics. He then spent the next three years over in England as one of the first Rhodes Scholars at Queens College, in Oxford England where he studied law and graduated from in 1913 with a master's degree. During the winter and summer breaks from class, Edwin would take long trips across the channel to the European continent where he traveled throughout Spain and Germany. While at Oxford, Edwin became immersed in the traditions of the English gentleman society in dress and manors, which he adopted and continued with those mannerisms once he was back in America. Edwin also took up the English sport of rowing, though he never competed, and also participated on Oxfords track team until he twisted an ankle in the high jump. Hubble also helped form an American baseball team at Oxford who played against other local teams. And Edwin learned how to smoke a pipe while at Oxford, which later became his signature look at Mt Wilson.

The summer of 1913, while Edwin was still staying in England, his father John passed away, and Edwin returned home to Kentucky to care for his mother and younger siblings and help them financially. After spending one year teaching high-school physics and coaching the basketball team at a school across the river in New Albany, Indiana to its first undefeated season, Hubble re-enrolled back at the University of Chicago to study for a doctorate in astronomy. For Hubble, astronomy was his calling.

Hubble obtained a small scholarship, from Professor Edwin Frost the Director of the Yerkes Observatory at Williams Bay Wisconsin, allowing Hubble to use the observatory's 40" refractor, the largest in the world, in addition to a 24" reflector. While as a student at the observatory, Edwin had the opportunity to attend a conference of the American Astronomical Society where he was able to meet a number of the top astronomers from around the country, including V.M. Slipher from Lowell Observatory who was working on obtaining spectrographs and radial velocities of spiral nebula.

This presentation inspired Edwin to devote himself to studying these spiral nebulas. After a rushed thesis, Hubble graduated with his PhD in astronomy in 1917. (We'll talk more about Hubble's work at Yerkes further below). And, while still a student at Yerkes, Hubble met George Hale, the director of Mt Wilson Observatory who offered Hubble a job once he graduated. The day after Edwin passed his PhD exams, he wrote to Hale on the job offer: "*Regret cannot accept your invitation. I am off to the war*".

Service in WWI:

After graduating from the University of Chicago in 1917, the 28 year-old Hubble enlisted with the US Army to fight in WWI. The United States had entered the war on the side of England that spring, and Hubble with his ties to Oxford felt obligated to serve. Hubble quickly rose thru the ranks, promoted to a Captain and put in charge of training new recruits at an army camp in Rockford, Illinois. One of his duties was to train the recruits in how to navigate cross-country at night by using the stars. Hubble also became known as an expert sharpshooter on the riffle range, and it was said that crowds would gather to watch him target practice. Within a year, he was made a Major and placed in charge of the 2nd Battalion of the 343rd infantry of the American Expeditionary Forces.
In September of 1918, Hubble and his troops shipped off overseas to England, and then on to France. While at the expeditionary camp in England, the Spanish Flu pandemic swept thru the ranks, taking several of Hubble's friends, including his favorite sergeant. Edwin appears to have avoided catching the illness.

But before Hubble could make it over to the battlefront near Bordeaux, the war ended. In a letter back to Edwin Frost at Yerkes, Hubble wrote sadly that "*I barely got under fire and altogether I am disappointed in the matter of war*". Hubble was then transferred back to Cambridge, England where he was assigned to work as a judge in court-martials and war reparations claims. During this assignment, Hubble attended meetings of the Royal Astronomical Society in London, and met there visiting astronomers from Mt Wilson Observatory that he would soon be working with. The now 30 year-old Hubble was finally discharged from military service in the summer of 1919, and returned to the US to take up the position offered by George Hale at Mt Wilson.

Family Life:

During his high school and college years, Edwin had very few romantic attachments, except for during the summer vacation before his junior year of college at the University of Chicago, where he fell in love with a local Marshfield girl named Elizabeth. But she eventually broke off the relationship as she realized that she could 'never hope to rival Edwin's love of Mars and the stars'. While at Oxford, and later during his years of graduate work at Yerkes, and then in the military, Edwin didn't have the time to spare. But, once he was settled in at Mt Wilson, the pace of Hubble's live slowed.

In late 1923, Edwin Hubble began dating Grace (Burke) Leib from Pasadena that he had met a few years before during a visitor's tour of the Mt Wilson Observatory. Edwin had also previously spent time with Grace during an expedition for a total solar eclipse that just grazed the southwestern corner of California in September of 1923. (She was part of a group from Lick Observatory with her uncle astronomer Fred Wright). Grace came from a wealthy, socially connected family, was a graduate from Stanford University, and found Hubble's work interesting. Grace was very knowledgeable in art, music, and architecture. Like Edwin, she was also athletic and active in sports, and the pair enjoyed going on long hikes and other outdoor activities in the California Mountains. In February of 1924, the couple married.

The Hubble's purchased a two-story stone house in a quiet neighborhood of San Marino, about a three mile commute from the observatory office in Pasadena. The Spanish-style medium-size house wasn't considered to be very spacious, but the Hubble's found it fine for entertaining guests. It was said by their visitors that the Hubble's were a happy couple, devoted to each other.

When Edwin was not tied-up with an observing run on Mt Wilson, usually for about one week a month, he spent time either at the Pasadena office or working from his home study. This gave him enough free time that the couple was active in southern California social events, and became friends with a number of Hollywood stars, wealthy philanthropist, and California intellectuals including Frank Capra, Clark Gable, Charlie Chaplin, the Marx brothers,

Howard Hughes, Randolph Hearst, and Walt Disney. They also maintained friendships from Edwin's days over in Europe, with a number of famous British astronomers, novelist and playwrights, including Arthur Eddington, Fred Hoyle, H.G. Wells, and Aldous Huxley who visited the Hubble's in Pasadena. During Albert Einstein's visit to Mt Wilson, the famous physicist and his wife spent time at the Hubble's home, with Grace chauffeuring Einstein around Pasadena to various events. Einstein is quoted as saying to Grace – "*Your Husbands work is beautiful'*. Edwin also found time to participle in local civic activities, including being on the board of trustees of the Huntington Library and Art Gallery of San Marino, and to be elected vice-president of the American Astronomical Society.

A few years after their marriage, Grace became pregnant. While Edwin was away on Mt Wilson for an observing run, Grace had a miscarriage and lost the baby. Afterwards, Grace and Edwin decided to never had any additional children, being content with their lives together as a childless couple.

Service in WWII:

With the United States entering World War II after the bombing of Pearl Harbor, early in 1942, Edwin Hubble was asked to head-up the ballistics department at the Army's Aberdeen Proving Grounds in Maryland. (Edwin at first had tried to re-enlist in the army in December 1941, but was not accepted). After the war, Hubble mentioned in a talk that his name was at the top of the list of scientist the army was interested in recruiting for Aberdeen, as it was the army's view that Hubble being an officer in the last war would better appreciate the gunnery/ballistics problems as anyone else.

The Hubble's closed up their house in Pasadena and moved to Maryland, along the Chesapeake Bay where Grace ran the Hubble household until after the war ended and they were able to move back in 1946 to California.
At first the Hubble's lived out of a local Aberdeen hotel, but eventually Edwin was able to arrange for them to live in a small cottage on a nearby island that was leased by the military for as additional testing grounds.
That might have been a bad choice as the cottage's windows were constantly being cracked by test explosions from the other end of the island, and one morning, a particularly large detonation blew the house door off its hinges.
From the Hubble's house in the later days of the war, Grace could watch troops practicing amphibious landing maneuvers at the local beach.

At the proving grounds, Hubble was put in charge and responsible for the ballistics testing of new artillery shells and bombs, and developing and calculating firing and bombing tables for each type of shell, bomb, and rocket. Part of the work on the firing range involved high-speed photography of projectiles in flight and then careful measuring of the photographic plates. Hubble accomplished this by utilizing astronomical photographic techniques that he was very experienced with. Hubble's department eventually grew to 280 people, both civilian scientist and military personnel, and included two of the four existing early IBM mainframe computers.

Hubble also personally troubleshooted an issue with a new anti-tank weapon called the "Bazooka". The gun tended to malfunction and injure the solder operating it. Edwin used one repeatedly on the firing range, finally determining what was causing the issue which led to a design change to correct it. Hubble's unit was also responsible for the design and development of accurate bombsights used by American bombers in the war.

The war efforts by Edwin Hubble had not gone unnoticed by the enemies of the United States. According to Grace, a military source told her years afterwards that a German U-boat had been intercepted and captured in Chesapeake Bay that contained written personal orders from Hitler to blow-up the Aberdeen Proving Grounds, along with "Dr Hubble".

While Hubble was away, the Mt Wilson observatory was closed to the public, observational work at the observatory slowed from lack of employees, most of who had left for service in the war, Once the war ended in May of 1945, Edwin wrapped up his tenure at Aberdeen, turning his department back over to a military lead, and he and Grace closed up their Maryland house. By December of 1945, Edwin was back to work at Mt Wilson Observatory. In 1946, Hubble was awarded the Medal of Merit by President Harry Truman for his service at Aberdeen.

Life as an Astronomer:

Yerkes Observatory:

While studying astronomy at the University of Chicago, at the Yerkes Observatory, Hubble worked under the direction of observatory director Edwin Frost and E.E. Barnard using the observatory's 24" reflector and 40" refractor to photograph nebula. Hubble based his PhD thesis "*Photographic Investigations of Faint Nebulae*" on this work. Hubble made his very first discovery from this project, using the 24" reflector, that the brightness of reflection nebula NGC2261 in Monoceros was variable. This nebula has since become known as "Hubble's Variable Nebula'. The comet shaped nebula is illuminated by the nearby bright variable star R Monocerotis. It is thought that the nebula's variability is caused by shadows cast by dense dust clouds that lay between the star and nebula.

As part of his thesis work, Hubble also studied nebula located far from the glowing band of the Milky Way, using the 24" reflector to photograph seven regions and discovered 512 new small nebulas. Hubble measured their individual positions, along with describing their shape, size, and brightness. In several of the regions Hubble studied, a number of small spiral nebulas grouped close together, prompting Hubble to speculate in his paper: "*Suppose them to be extra-sidereal and perhaps we see clusters of galaxies; suppose them within our system, their nature becomes a mystery*". Hubble was beginning to conclude that spiral nebula were distant stellar systems at great distances. Hubble's work at Yerkes was interrupted by the United States entering WWI.

Mt Wilson Observatory:

Once back from his WWI military service, Hubble went to work for George Hale in Pasadena, CA. at the Mt Wilson Observatory in 1919 and was one of the first groups of astronomers to utilize the new 100" Hooker reflector in studying spiral nebula. Hubble was interested in resuming his research started at Yerkes in determining whether spiral nebula were just distant unresolvable gas and stars within our own galaxy, or if they were external systems to the Milky Way. Edwin would observe these nebula with the 100" every clear night that he could, and then use the smaller 60" reflector when the 100" was taken by other researchers. As part of this work, Hubble also began to develop a classification system for the nebula he was studying.

Hubble became friends with Mt Wilson night assistant and observer Milton Humason, and the two collaborated on a number of projects together. Humason once described Hubble's approach to his research work: "*He was sure of himself – of what he wanted to do, and how to do it*". Hubble also became quickly known for his knowledge of the night sky and could describe the shape and location of hundreds of deep sky objects from memory.

While at Mt Wilson, Hubble developed a bit of a rivalry with astronomer Harlow Shapley, who also worked at that time at Mt Wilson studying Cepheid variables to determine whether they could be used as distance indicators within the Milky Way. Both men were interested in solving the mystery of spiral nebulae, with Shapley championing their being internal to the Milky Way, (his "Big Galaxy" as the universe model), while Hubble was in the camp of their being external objects. Hubble, being aware of the distance relationship of Cepheid's hoped to be able to discover these stars within the Andromeda and Triangulum nebula and searched for them using the 100" Hooker Reflector. We'll talk more about how the rivalry ended in another section below.

Hubble also continued to make occasional observations of his variable nebula NGC2261 in Monoceros, and while these are listed in the observatory logbooks, Hubble but never formally published any additional research results on the nebula. Other than a four year period during WWII, when Edwin took a position with the army in Maryland to help with the WWII war effort, Hubble remained at Mount Wilson for the remainder of his career.

Palomar Observatory:

While still based out of Mt Wilson, Hubble became one of the first astronomers to use the completed 200" Hale reflector at Mt Palomar Observatory. As part of the grand opening on January 26th, 1949 of the new 200" Hale Reflector Telescope on Mt Palomar, Edwin Hubble was chosen to lead the first night of observing. Hubble selected the reflection nebula NGC 2261 "Hubble's Variable Nebula" as the first object to be imaged as the 200" telescope's first light. After a 15 minute exposure, the first astronomical photograph taken with the 200" was done.

The plate was labeled: “PH-1-H” (Palomar, Hale telescope, negative No.1, observer Hubble). Hubble then took four additional images, including M87. Afterwards, Hubble submitted a paper to “Scientific American” on the first five historic photographs from Palomar.

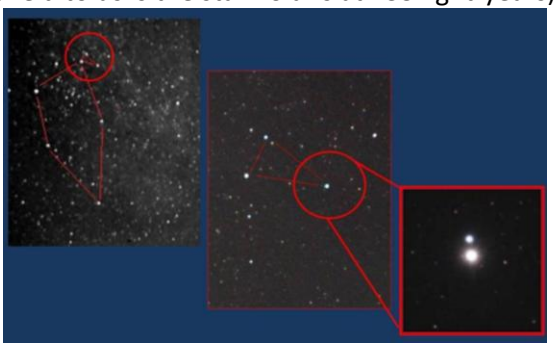
In addition to the 200” reflector, also in early 1949, the new 48” Schmidt telescope/camera was completed, and Hubble, along with his graduate associate observers Allan Sandage and Halton Arp, used the telescope’s wide-field to image and study faint galaxy groups.

Hubble had only completed four observing runs with the new telescopes when health issues got in the way. After recovering from his illness in late 1950, Hubble only made it back to Palomar twice more. In one of those sessions, Edwin successfully imaged a number of Cepheid’s and several bright novas in both spiral galaxies M81 and M101. Hubble continued working with Milton Humason, and his new assistant Allan Sandage on further refining his redshift theory. On the evening of September 3rd, 1953, Edwin Hubble made his last observation using the Palomar 200” of the pair of interacting galaxies NGC520 (Arp157) in Pisces.

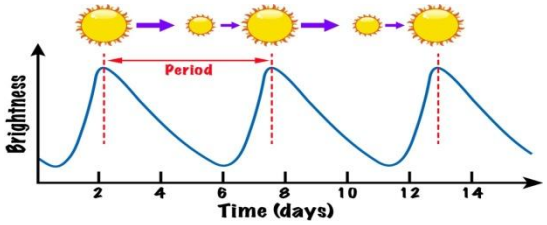
Hubble’s Discoveries:

What are Cepheid Variables:

Cepheid variables are stars that vary their brightness by a specific range and timeframe.
(Generally 1 to 2 magnitudes with a typical period of 1 to 5 days).
The very first star of this type to be identified was +4 mag Delta Cephei in the constellation of Cepheus.
Delta Cephei has a period of 5.37 days and varies in magnification from a +3.5 to a +4.4 with a slow decline to minimum, then a rapid rise to maximum. At 890 light-years distant, Delta is the second nearest Cepheid variable to the Sun. (the closest Cepheid to us is the star Polaris at 433 light-years).



The reason Cepheid stars vary in brightness is due to instabilities in their nuclear fusion core.
As stars similar in size to our own Sun burn thru all of their hydrogen gas and contract in size and begin to burn ionized helium, the initial heat energy doubly ionizes the helium gas, which causes it to absorb light energy, making the star dim. But as the light energy is absorbed by helium, the star becomes hotter causing its outer layers to expand outwards, which then cools the star causing the helium to drop back down to only a single ionized state, making the star more light transparent, causing it to brighten.
As the star cools, it begins to once again contract, causing helium to once again doubly ionize and diming the star. These pulsations continue to repeat back and forth until eventually the star burns thru all its helium gas and contacts to become a white dwarf star.



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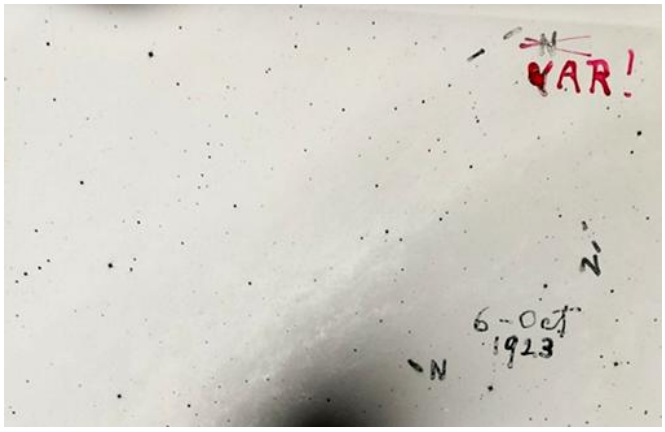
This relationship between the star’s luminosity and period of change allows astronomers to determine what the stars true brightness is, and in turn, lets them determine the star’s distance.
This characteristic was discovered in 1908 by Henrietta Leavitt, working at the Harvard Observatory.

This fundamental characteristic of cosmology is known today as “Leavitt’s Law”. Using this relationship, astronomers were able to accurately calculate distances to Cepheid’s in our Milky-Way galaxy using the inverse square law of light (a luminous body appears to dim by its distance squared. An analogy of the inverse square law would be like turning down a volume knob on a stereo system, the loudness intensity is turned down, but without affecting the pitch of the music).

Distance to M31 using Cepheid variables:

In the early 1920’s, American astronomer Edwin Hubble, was one of the first astronomers to utilize the new 100” Hooker reflector telescope at Mt Wilson Observatory in California.

On the night of October 5th, 1923, Hubble was making a photographic observation of the Andromeda Nebula, also known as M31, using the 100” telescope. Hubble was studying the spiral nebula looking for changes, doing this by taking photographs of the nebula and comparing that evening’s image with a previous nights photo plates.
On one 45 minute exposure plate of a region near the core of the Andromeda Nebula, Hubble discovered a faint star that was brighter than its image on the prior plate. Hubble at first thought the star was a new nova, as he had already found several that night within the nebula. But, after continuing observations over several nights, and reviewing additional past plates going back to 1909, Hubble realized that this particular star which had started to dim, had now begun to re-brighten, which was not the known behavior of a nova. The star was pulsating in brightness, which meant it was a variable star! Hubble relabeled the star as “V1” on the discovery photographic plate. This was the first variable star ever confirmed in a spiral nebula!



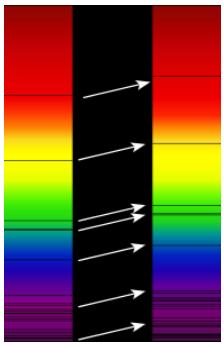
Once Hubble was able to plot the stars light-curve and identify the variable star as a Cepheid, he was able to calculate the star’s distance of 1 million light-years, finding that the star was many times further away than what was considered to be the boundaries of the Milky Way, making both the star and the Andromeda Nebula extragalactic. The universe has suddenly expanded.

Hubble went on to discover several dozen other Cepheid variables within the Andromeda spiral nebula, along with 35 variables in the Triangulum spiral - M33 and another 11 in “Barnard’s Galaxy” - NGC6822.
Using Harlow Shapley’s own Cepheid based calibrated Milky Way distance calculations; Hubble was able to determine that all of these other spiral nebula variable star distances, like that of V1, to be much greater than Shapley’s own accepted “Big Galaxy” size of the Milky Way of 300,000 light-years. (Current, modern calculations have now revised the size of the Milky Way to about 100,000 light-years in size, and the distance to the Andromeda galaxy to about 2.5 million light-years).
Prior to his announcement being published in 1925, Hubble sent a letter describing the discovery to his old rival Harlow Shapley, who had since become the director of the Harvard Observatory.
Upon reading the letter, Shapley said to Harvard astronomer Cecilia Payne, “Here is the letter that destroyed my universe”. Hubble’s observations of additional Cepheid’s in the Andromeda and Triangulum nebulas proved conclusively that they were too distant to be located inside of the Milky Way and that spiral nebula were in fact external to the Milky Way. The first accurate distances to galaxies had finally been determined by Edwin Hubble using Cepheid variables.
Hubble had finally answered the old question of external galaxies vs. internal nebula and settled the Great Debate in favor of Immanuel Kant’s 1755 'island universes'!

Red shift and the expanding universe – Hubble's Law:

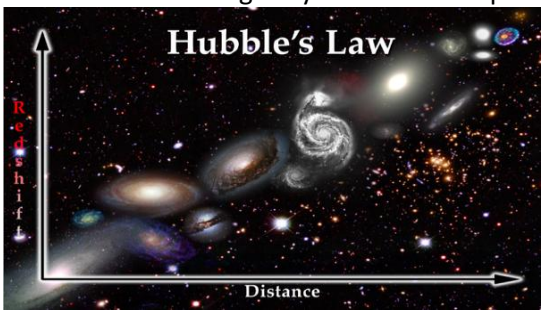
With Hubble's discovery of Cepheid's in the nearby galaxies, such as M31 the Andromeda Galaxy, this allowed astronomers to extend accurate distances throughout the Local Group of galaxies. But in galaxies further away, Cepheid's were not identifiable, so astronomers turned to another celestial yardstick, supernovas.
Extra-galactic supernovas are similar to Cepheid's in that their intrinsic brightness could be compared against these stellar explosions that have occurred within our own galaxy. This allowed us to measure distances out into our nearby supercluster of galaxies, such as the Virgo and Coma Clusters.

To go even further out into the universe, Hubble realized that there was a relationship between a galaxy's determined distance, its faintness, and its spectroscopic radical velocity. Working with astronomers Vesto Slipher from Lowell Observatory and Milton Humason, also at Mt Wilson, Hubble discovered in 1929 that every galaxy has a measurable redshift that could be utilized for calculating its distance.



Every star gives off a spectrum of bright and dark emission and absorption lines, when viewed thru a spectrograph prism, made up of the various atomic elements within the star. Hydrogen and helium being the primary elements, along with oxygen, carbon, neon and nitrogen. Depending on the direction that the star is moving, either toward us or away from us, the star's spectrum exhibits a light wave Doppler shift, similar to the sound wave Doppler effect, such as from a passing train. If the object is approaching us, it is blueshifted, if it is receding from us, the spectrum is redshifted. The greater the spectral lines of an object are shifted towards the red end of the spectrum, the greater its distance is from us.
The symbol for redshift, expressed as a fractional displacement of wavelength is 'z'.
An object with z=0.0 or smaller has a low redshift and is nearby.
A redshift greater than z=0.0 is a high redshift and represents an object very far away. The bigger the number, the father away it is.

A central part of today's 'Big Bang' cosmology this key tenet is named Hubble's Law.
Basically stated, Hubble's Law is that the larger an objects redshift, the farther away it is and the faster it is receding from us. All astronomers had to do was measure the redshift of a galaxy and then it was just a matter of computing the distance of that galaxy. It is a critical piece of the expanding universe theory.



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Using Slipher's pioneering spectrographic work, Humason was able to take a multi night 45 hour long spectrum of elliptical galaxy NGC7619 in Pegasus resulting in a redshift of z=0.01234 and a receding radical velocity of 2400 miles per second. Based on the distance-velocity relationship law that Hubble has devised, he predicted that it would be around 24 million light-years distant, which Hubble then confirmed as correct after calculating its distance using Cepheid variables that he observed.

The Big Bang- the Hubble Constant:

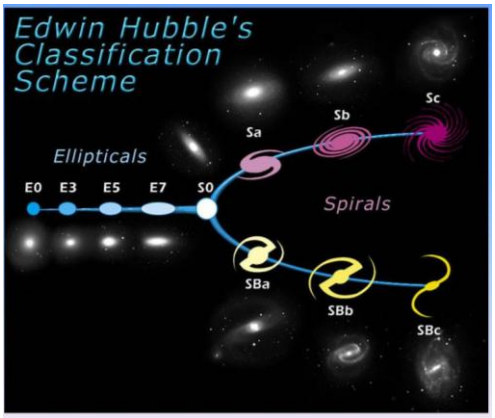
Hubble's discovery of the velocity-distance law, is considered to be the first observational evidence for the expansion of the universe, and most often cited in support of the Big Bang model. Hubble's findings established that galaxies were not fixed in their positions, but most were moving outwards, away from the Milky Way at a rapid rate. Part of the equation that describes Hubble's law is the Hubble Constant, which can be interpreted as the relative rate of the expansion of the universe. The current value is about 70 (69.8) (km/s)/Mpc. (a mega parsec (Mpc) is equal to one million parsecs, or about 3,260,000 light years).

A small value, fewer than 100, means that the universe is expanding at a slow rate and is older. A higher Hubble Constant value, over 400 – 500, means that the universe is expanding rapidly and was much younger.
The current value of 70 gives us a universe that is about 14 billion years old.

The discovery of the Hubble Constant and along with it the expansion of the universe, led Albert Einstein to abandon his attempts to integrate a cosmological constant into his field equations of general relativity that would have made the universe static and not expanding. Einstein later referred to his cosmological constant as his biggest mistake. In 1931, Einstein made a special trip to Mount Wilson Observatory just to thank Edwin Hubble for his observational discovery that became the basis for modern cosmology and the Big Bang.

In Hubble's book "Realm of the Nebula", published in 1936, while commenting on his velocity law and the vast distances to the galaxies and age of the universe, Hubble states "*the history of astronomy is a history of receding horizons. ,,,, we know our immediate neighborhood rather intimately. Eventually, we reach the dim boundary – the utmost limits of our telescopes. There, we measure shadows, and we search among ghostly errors of measurement for landmarks that are scarcely more substantial*".

Hubble Sequence - Galaxy Classification – Tuning Fork:
As mentioned earlier, galaxies come in several types, and a wide variety of shapes and appearances.
In 1926, astronomer Edwin Hubble devised a galaxy classification diagram based on their visual appearance – elliptical, lenticular, spiral, or irregular. He organized these shapes into a sequence of morphological classifications that he invented to help astronomers determine the type of galaxy that they were studying.
This classification sequence system is commonly called the: Hubble Tuning Fork diagram. Hubble divided the galaxies into three simple, broad classes: spirals, elliptical, and lenticulars, along with a fourth class of irregulars.



https://en.wikipedia.org/wiki/Hubble_sequence

All the main types have sub-category classifications, and we still use a modified version of this today.
Elliptical 'E' galaxies are smooth, nearly featureless objects running from near-circular to an ellipsoidal shape.
Lenticular "S0" galaxies have a bright central core surrounded by an extended, flattened disk with no visible spiral arm structure. Spiral "S" galaxies have a flattened disk with a central bulge, and multiple spiral arm structures. Roughly half of all spirals also have a bar-like structure, extending from the central bulge. These barred spirals are identified with the symbol "SB". The last type is Irregular "Irr" galaxies that do not have a distinct shape that fits into the first three categories. A lowercase 'd' appended in front of 'Irr' indicates a dwarf galaxy.

Additional Discoveries:
The first astronomer to identify our local grouping of galaxies as the "Local Group" was Edwin Hubble.
Hubble gave these galaxies this name in his 1936 book, *The Realm of Nebulae*, where he referred to the initial 12 galactic members as "a typical small group of nebulae".

Also, in early 1942, right before leaving to serve at the Aberdeen Proving grounds during WWII, Hubble solved the question of which direction did a galaxies spiral arms rotate. Did the arms trail the rotation of a galaxies' core? Did the arms lead the rotation? Or was it both? From a series of spiral galaxy images taken that February, Hubble determined that the arms trailed behind the core's rotation.

Amateur Observations of Hubble's Galaxies:
How to observe galaxies:
So, where can you find the galaxies that Hubble studied and how do you observe them?
Galaxies in general can be found opposite the glowing band of light that we call the "Milky-Way", our home galaxy. Usually, when we want to observe bright or dark nebula and star clusters, the Milky-Way is exactly where we want to look, but for galaxies, this is the "Zone of Avoidance', as all the gas and dust nebula and stars of the spiral arms of our galaxy tend to obscure all the faint extra-galactic 'nebula' that we want to observe. Generally, galaxies come in all shapes, sizes, and brightness, and many are very interesting and worth the effort to find, regardless of the equipment that you use. With the exception of M31 & M33 and a few other brighter galaxies, most are small faint, and will require large aperture telescopes or imaging setups, along with a dark-sky location such as Cherry Springs.

There are a number of good 'galaxy' related observing guides available to the amateur astronomer.
One of my favorites is "*The Night Sky Observers Guide – Volumes 1 & 2.* These handbooks were written by George Kepple and Glen Sanner, each chapter covering a specific constellation, along with finder charts, sketches, images, and visual descriptions of various deep sky objects, including various galaxies.

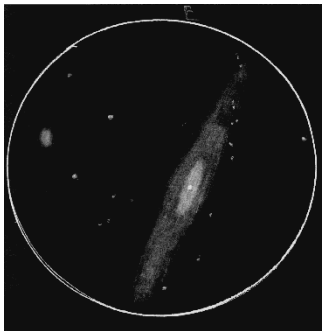
Amateur astronomer Alvin Huey has a great observing book on his website www.faintfuzzies.com
Called "Observing Local Group Members" devoted specifically to the Local Group of galaxies.
It contains finder charts, and DSS images for Local Group members.

Ingredients to successfully observe Galaxies:
While most galaxies can be challenging, this is what makes them interesting to find and attempt to visually see or capture an image of. Observing them visually requires maintaining dark-adaptation, good starcharts, and slow sweeping with a wide-field low-power eyepiece and a fast low focal-length telescope. An 80mm F6 or shorter refractor piggybacked on a 10" or greater telescope would work very well. The 80mm acts as a low-power RFT giving you a wide-field in which to find the galaxy and the larger telescope it is attached to allows use of higher magnifications, depending on the object. You'll need all your visual observing skills to find and bring out these subtle objects.
Many galaxies are very faint, and depending on what size telescope you are using, may not be visible.
But like any deep-sky object, half the fun is just successfully finding it and knowing what it is that you are observing.

For the Imagers, galaxies can also be challenging due to their faintest, in that even with an accurate GOTO mount, it may not position the telescope squarely on the object to where it's framed the way you want it.
Having a photographic atlas or picture of the galaxy will help you in both locating and identifying the object and in framing your image. I've found that using short-exposure video-astronomy cameras works great in positioning and identifying galaxies.

Andromeda and V1:
The Andromeda Galaxy, is the largest member of the Local Group, is also a barred-spiral galaxy with the bar oriented along the length of the galaxy, and including at least two tightly-wound spiral arms has a diameter of around 220,000 light-years with about one trillion stars. Andromeda's galactic core contains a radio source called 2C 56, with a supermassive black hole of 3 to 5 million solar masses, and a possible double nucleus.

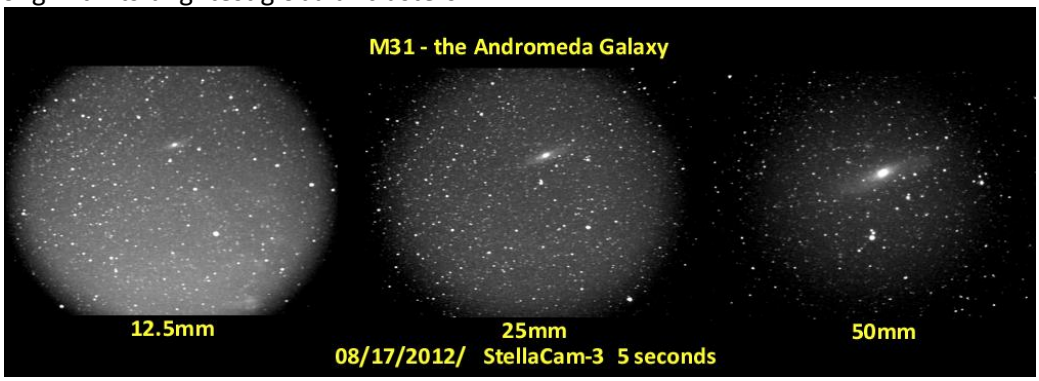
The Andromeda galaxy is the nearest major galaxy to the Milky Way at about 2.5 million light-years distant, and is moving at around 110 km per second in the direction of the Milky Way, which it will collide with in about 4.5 billion years.



The compact 8.7 magnitude elliptical satellite galaxy **M32** (with a diameter of about 6500 light-years) is thought to have once been a small spiral galaxy that had a close interaction with M31 around a billion years ago, which stripped away most of M32's arms and disk, leaving only the core which then underwent renewed star formation from infalling gas and dust, and partly regenerated the small galaxy. M32 contains a massive central black hole of between 1.5 to 5 million solar masses and is a faint radio and x-ray source.

Andromeda's second satellite galaxy, NGC205 (or **M110**) at 8.5 magnitude, is a dwarf elliptical, (about 12,000 light-years across), and also shows signs of recently interacting with M31 from a stream of stars and gas stretching between the two. It is classified as being a 'peculiar' galaxy in that unlike most ellipticals, M110 has dust clouds and younger stars near its core. Astronomers have not observed any signs of M110 having a black hole in its galactic center.

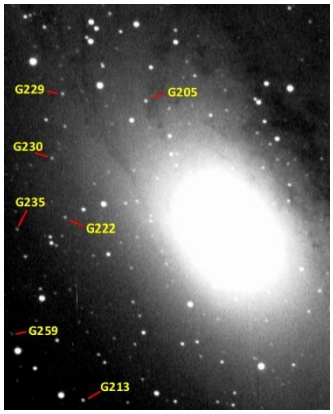
At a magnitude of 3.4, the Andromeda Galaxy is visible to the unaided-eye as a bright patch even from suburban areas on moonless nights. On fall nights, it is well-placed almost directly overhead for observing with binoculars or small to medium size telescopes which under good seeing conditions can reveal the galaxy's extended disk and dust lanes, along with its brightest globular clusters.



Also visible is the large starcloud **NGC206**, along with two small satellite galaxies M32 and NGC205 (M110) and several of their globular clusters. Larger size telescopes of 18" or greater will allow the observer to see additional internal structures within the spiral arms including clusters of OB associations and HII star forming regions. Andromeda's galactic plane is highly inclined to our point-of-view, around 77%, giving it a near edge-on look, making it difficult to observe its spiral arms.

Observing Andromeda Globular Clusters:

The Andromeda galaxy has over 450 globular clusters, a number of which are observable by amateur astronomers. These include the most massive cluster of the entire Local Group, named **Mayall-II**, which may actually be the remnant core of a small galaxy that was cannibalized by Andromeda.



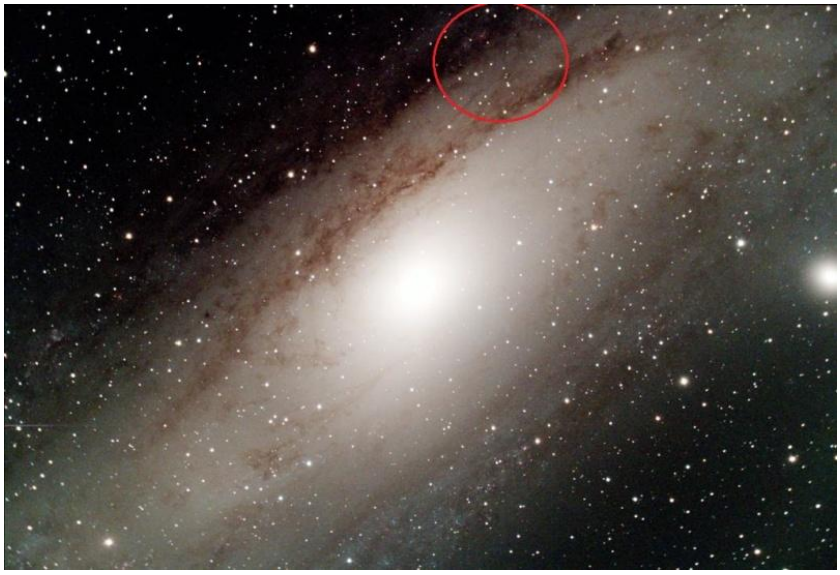
Observing V1:

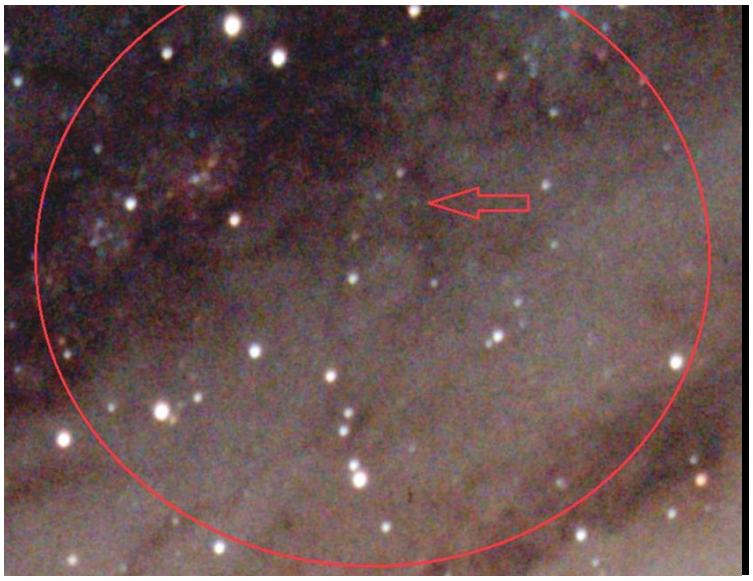
Located near the busy core of the galaxy is the dim Cepheid variable whose discovery by Hubble in 1923 led to the confirmation that the Andromeda Nebula was actually an external galaxy to the Milky Way, leading to the expanding universe of the Big Bang.

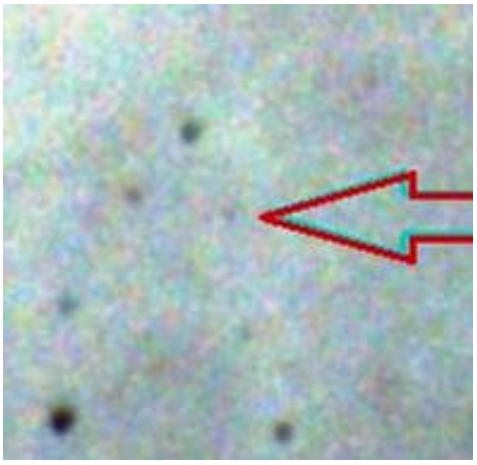
Can this star be observed visually or imaged by amateur astronomers? **Yes!**
In fact, back in 2010, over a six month period, a number of amateurs from the AAVSO, as part of a project coordinating with NASA and the Hubble Space Telescope, actually observed the star for enough observations (214) to plot a light-curve of 31.39 days for the variable. Other amateur astronomers have reported successfully visually observing and imaging VI in various magazines and the CloudyNights forum.

With the variable star, (V1), having a magnitude range of +18.5 to +19.8, to observe it visually, you will need a very large reflector – in the 30" mirror size category and use a high magnification eyepiece, along with attempting the observation from a very dark sky location. You will also need a detailed finder chart, such as one from the AAVSO, or a photo of the star's location. These can be found online.

The best time to attempt the observations is during late fall, when M31 is high overhead near the zenith, and on nights of excellent transparency. Start by centering on Andromeda's core, then moving to its northeast side, opposite M32. Look for a small faint arrow-head asterism of stars that point away from the core.
There is a much smaller equilateral triangle just off the tip of the arrow with V1 being one of those stars.







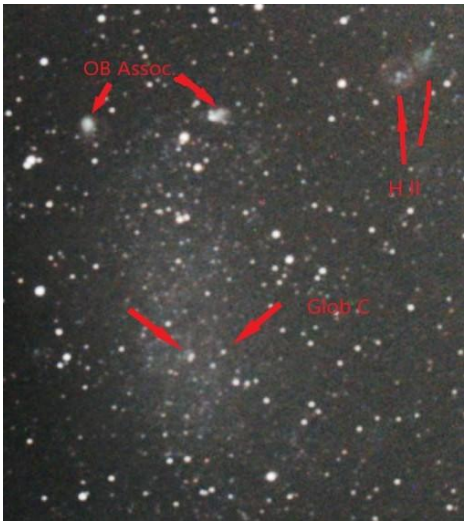
M33:

The Triangulum Galaxy, while it is the third largest member of the Local Group, is only about one-tenth the size of the Milky Way, but it is the only classic shaped spiral galaxy of the Local Group. It has two bright, loosely wound spiral arms, along with multiple connecting spurs, giving the galaxy an overall diameter of around 60,000 light-years with about 40 billion stars. Triangulum's galactic core does not contain either a radio source or a black hole, just a large HII nucleus. The galaxy has over 54 globular clusters identified, along with a number of OB associations. Triangulum does not have any satellite companions, though the Pisces Dwarf galaxy could possibly be in a very distant orbit around M33. The Triangulum Galaxy is about 2.7 million light-years distant, and is moving at around 190 km per second in the direction of the Andromeda galaxy. M33 may be gravitationally bound to the larger Andromeda galaxy. Depending on modeling, the Milky Way may actually collide with M33 just prior to colliding with M31. A three galaxy interstellar pileup!!!

At magnitude of 5.7, the Triangulum Galaxy (also called the Pinwheel), may be visible to the naked-eye from a dark-sky country location on moonless nights. M33's galactic plane has an inclination of about 54° to us, allowing its spiral arms to be viewed without significant obstruction by gas and dust. There is no central bulge visible at the nucleus. On fall nights, like M31,it is well-placed overhead for observing with small to medium size telescopes which under good seeing conditions can reveal the galaxy's extended spiral arms, dust lanes, bright globular clusters, and HII star forming regions such as NGC588, 592, 595, IC132, IC133, with the largest and brightest being **NGC604**. With a diameter of around 1500 light-years, NGC604 is one of the largest and brightest known HII emission nebula in all of the galaxies of the Local Group. It, along with three other HII regions is located in the northern spiral arm, to the northeast of the central core. The southern arm of M33 has been a major source of extra-galactic supernova, with at least 100 supernova remnants having been identified.

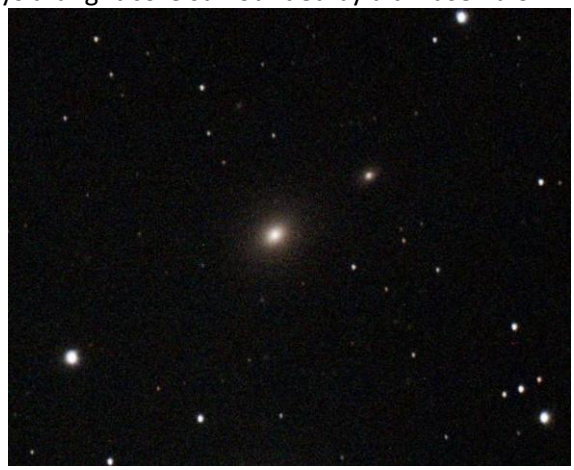
NGC6822:

NGC6822, known as "Barnard's Galaxy" is a +8.5 magnitude Irregular barred-dwarf galaxy about 1.5 million light-years distant from the Milky Way, and is located in the constellation of Sagittarius and heavily obscured by the Milky Way. It has a diameter of about 7,000 light-years, and shows active star formation. After the Magellanic Clouds and the Sagittarius Dwarf galaxies, NGC6822 is the fourth closet galaxy to the Milky Way. Visibly, NGC6822 is highly inclined to our view point, with several HII star forming regions and large OB associations being observable in medium to large size telescopes.



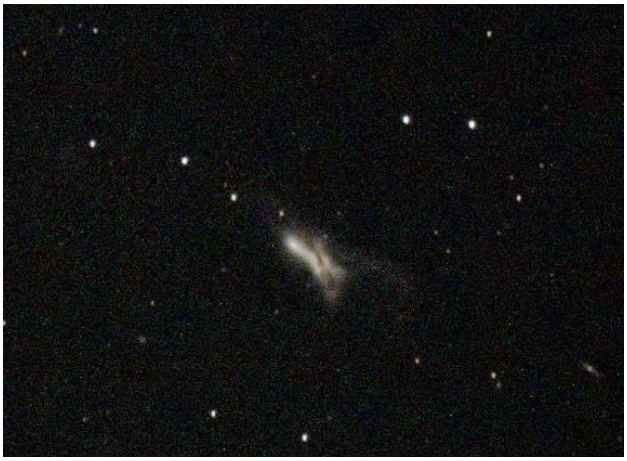
NGC7619:

NGC7619 is a +12.7 mag elliptical galaxy in the constellation of Pegasus. The bright oval-shaped galaxy is embedded near the middle of the Pegasus-I galaxy cluster. The galaxy displays a bright core surrounded by a diffuse halo.



NGC520 (Arp157):

NGC520 is a +12.2 mag pair of edge-on interacting spiral galaxies in the constellation of Pisces.
The close bright pair is a peanut-shaped oval, with a dark lane separating the two objects. A very faint plume extends off of either end of the pair.



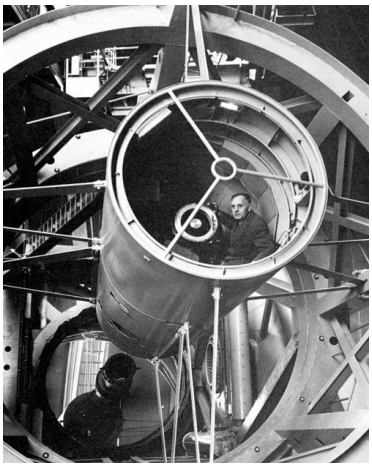
NGC2261 – Hubble's Variable Nebula:

NGC2261 is a +9 mag reflection nebula in the constellation of Monoceros, located next to the variable star R Monocerotis. The nebula has a comet-shaped appearance, with the bright star appearing as the head of the comet.

Hubble's Legacy & Conclusion:

Over the years, Edwin Hubble received various awards and metals for his work.
These include the Newcomb Cleveland Prize in 1924, the Barnard Metal in 1935, the Bruce Metal in 1938, the Franklin Medal in 1939, and the Gold Metal of the Royal Astronomical Society in 1940. In 1927, Hubble was elected to the National Academy of Science of the USA; in 1928 he was elected to the Royal Astronomical Society of Great Britain, Elected to the Vienna Academy of Science in 1947, and elected to the French Academy of Science in 1949. Oxford University in 1934 also awarded Hubble an honorary degree of Doctor of Science.

Hubble was the first astronomer, in 1948, to have his portrait appear on the cover of Time magazine. Hubble also gave numerous public lectures at universities and scientific institutions around the country and over in Europe, and gave a series of talks over the radio, discussing the new 200" Palomar reflector, always stressing that the study of the universe must be pushed to even greater cosmological distances.



Throughout their marriage, both Edwin and Grace continued with athletic outdoor activities such as tennis, swimming, horseback riding, hiking and fishing. They enjoyed traveling to remote areas of the country for the scenic wilderness vacations. Hubble was an avid fly fisherman.

During the summer of 1949, after a successful observing run at Palomar, while vacationing on a fishing trip near Grand Junction Colorado, the 59 year-old Edwin suffered a sudden heart attack.
It took several hours to get Hubble down off the remote mountain and make the 100 mile drive to a local hospital. While recovering there he suffered a second more serious heart attack and lost part of his heart function.

The local doctors at the time didn't think he would survive, but Hubble pulled thru and after a month was able to return to Pasadena where he spent the next several years regaining his strength. Edwin was able to return to work part-time at the Pasadena office, but could no longer work long multiple nights in a row in the cold, high-altitude at either Mt Wilson or Mt Palomar. The few trips that Edwin was able to make to the observatories, Grace would accompany him and stay overnight, along with Edwin's observing assistant Allan Sandage.

Then, on September 28th, 1953, while being driven home from the office by Grace to have lunch at home, just as they were pulling into the driveway, the 64 year-old Edwin suffered a stroke and died there in the car from a cerebral thrombosis.

Years earlier, Edwin had told Grace that when he died, that he wanted to "*disappear quietly*". Honoring his wishes, Grace had Edwin cremated, and there was no funeral or memorial service, and Hubble's ashes was buried in an unmarked location known only to Grace and four other people.
It is said that when Grace finally passed, in 1980 at the age of 90, that her cremated ashes were placed with Edwin's. As of this date, the four remaining people have all themselves passed on, leaving no information as to where the Hubble's final resting place is located. There is no cemetery monument honoring the greatest observer since William Herschel, but his discoveries still live on today.

Within a year of his death, Edwin Hubble was nominated for the Nobel Prize, but the selection committee had to reject his nomination, as per the Nobel award rules, the prize could not be awarded posthumously.
But, in addition to the metals and awards that Hubble received while he was alive, he has since been further honored by the Hubble Space Telescope being named after him, the 25 mile diameter main-belt asteroid (2069), discovered in 1955 named 'Hubble', the crater 'Hubble' on the Moon, and a series of USPS Hubble stamps issued in 2000 and 2008 that honors both Edwin Hubble and the space telescope.

In conclusion,
Edwin Hubble is considered by some to be one of the great American observational astronomers of the 20th century, whose discovery of extragalactic variable stars led to a deeper understanding of our expanding universe. In just a ten-year period, from 1923 to 1933, Hubble confirmed that spiral nebulae were actually external galaxies, he developed a general classification of galaxies, and he discovered the expansion of the universe and confirmed the redshift theory leading to today's Big Bang cosmology! Few other astronomers, besides Copernicus or Galileo, have had such a revolutionary affect on our knowledge of the universe.

So I encourage everyone to get out tonight and try your hand at finding and observing the Island Universes of the Andromeda and Triangulum galaxies. And while doing so, think about the man whose observation that October night, just one hundred years ago, led to the Big Bang Theory.
Edwin Hubble, the Surveyor of the Universe!

Halton Arp and his Peculiar Galaxies

In 1966 American astrophysicist Halton Arp published a paper titled "Atlas of Peculiar Galaxies", which list 338 'interesting' photographs of galaxies that didn't fit into the normal Hubble classification scheme. Arp was a professor of astronomy at the California Institute of Technology and staff observer at Palomar Observatory. His paper cataloged a series of peculiar galaxies, giving them numerical designations, using the Palomar 48" and 200" telescopes. Through his work of studying these types of unusual galaxies, Arp broke new ground in our understanding the universe, and along the way sparked a debate that challenged the basics of the Big Band Theory. Today, we're going to look-back on his life and accomplishments, talk a little bit about the redshift controversy, and his Atlas. We'll also review a number of my observations of his peculiar galaxies.

- **Discussion outline:**
- **Galaxies – What are they?**
  - **Classic Morphology**
  - **Peculiar Galaxies**
- **Halton C Arp:**
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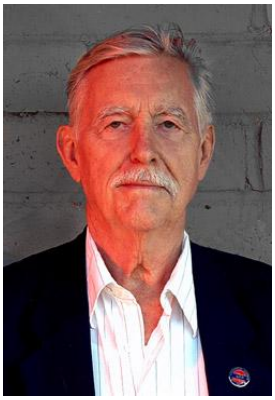
- **Galaxies – What are they?**

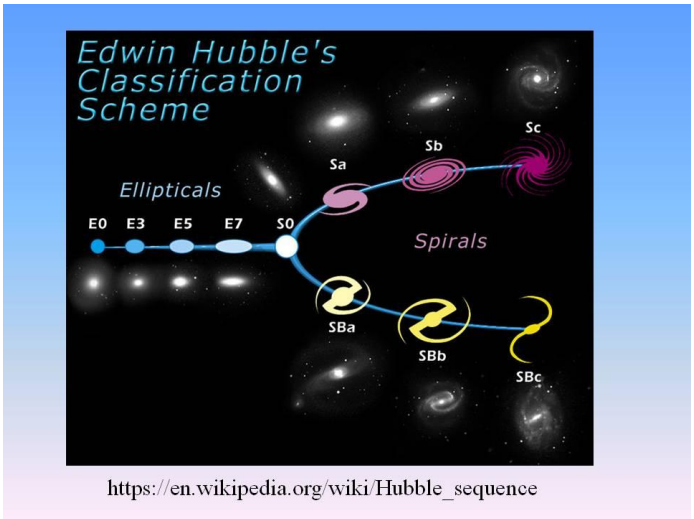


Galaxies are large systems of stars and interstellar matter, typically containing from several million to several trillion stars. They run in size from a few 10's of thousands to several 100,000 light years in size, and are separated from other galaxies by millions of light years.

How do Galaxies form?
They originate from large cosmic primordial clouds of gaseous matter (hydrogen and helium) in our Universe that slowly collapsed. Most galaxies have formed at about the same time, within the first billion years after the universe started to expand, from an initial hot state.
Thus, they are all almost as old as the universe itself, currently thought to be about 14 billion years.

Where are Galaxies Located?
Galaxies are scattered throughout the visible universe. We live inside a giant spiral galaxy, called the Milky-Way Galaxy. The Milky-Way is about 100,000 light years in diameter and contains a mass equal to about a trillion stars. Our galaxy has several small dwarf galaxies orbiting around it that are only a few 100,000 light years distant. The nearest giant galactic neighbor, the Andromeda Galaxy, also a spiral, is about 2-3 million light years distant. Some galaxies are isolated "island universes" which float lonely through an otherwise empty region of the universe. But the distribution of matter in the Universe is not uniform. That causes groups of galaxies, running to few dozens of galaxies, or even large clusters of up to several thousands of galaxies, to form. The galaxies of these groups are in mutual gravitational interaction, which may have significant influence on their appearance.

Classic Morphology
Galaxies come in several types, and though of a wide variety of shapes and appearances, have many basic common features. They are huge conglomerations of stars like our Sun. From their appearance, galaxies are classified as spiral, lenticular, elliptical, and irregular. In the early 20th century, astronomer Edwin Hubble devised a galaxy classification diagram based on their visual appearance.
This classification is commonly called the: Hubble Tuning Fork diagram. Hubble divided the galaxies into three broad classes: spirals, elliptical, and lenticulars, along with a fourth class of irregulars.
All the main types have sub-category classifications, and we still use a modified version of this today.



https://en.wikipedia.org/wiki/Hubble_sequence

Elliptical

Elliptical galaxies are shaped like giant luminous cosmic balls, and have no spiral or disk components. They have little or no rotation as a whole. Normally, elliptical galaxies contain very little or no interstellar matter, and consist of older population stars only:

Lenticular

Lenticular galaxies are shaped like spiral galaxies without a spiral structure.
They are smooth disk galaxies, where stellar formation has stopped long ago, because the interstellar matter was used up. They consist of mostly older population stars only. From their appearance and stellar contents, they can often be observationally confused with ellipticals.

Spiral

Spiral galaxies usually consist of three major components:
A flat, large disk which often contains interstellar matter visible as glowing emission nebulae or as dust clouds. Young open star clusters, associations, and random stars arranged in conspicuous and striking spiral patterns and or bar structures. Finally, a central bulge or core, consisting of older stellar populations with little interstellar matter, and often surrounded by a halo of older globular star clusters.

Irregular

Irregular galaxies have many different shapes and sizes due to distortion by the gravitational pull of their intergalactic neighbors. These galaxies do not fit into the scheme of spirals, disks and ellipsoids, and exhibit no particular shape.

Peculiar Galaxies

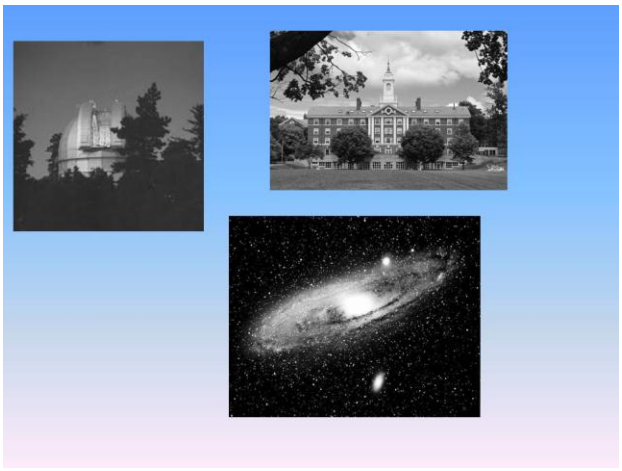
Peculiar galaxies come in various types, those with jets, split arms, diffuse tails, filaments and ejected material, and for the most part, peculiar galaxies can be found anywhere along the Hubble classifications system. But a large number can be found along the 'spiral' sections of Hubble's Tuning Fork, such as interacting galaxies (colliding galaxies being the most interesting), whose gravitational fields result in a disturbance of one another.
An example of a minor interaction is a small satellite galaxy's disturbing the primary galaxy's spiral arms.
Or it could be a major interaction, such as a galactic collision of two large galaxies, with one diving into the core of the other, shredding both in the process. Because of the tenuous distribution of matter in most galaxies, these collisions are not like a head-on car wreck, but more of a gravitational interaction that eventually combines two or more individuals into one large galaxy. The significance of peculiar galaxies is that from studying the Hubble Space Telescope deep-field images, close to 30% of all galaxies exhibit some type of disturbance or distortion, and the deeper the images go, the higher the number of galaxies that don't cleanly fit within the Hubble classifications. More research needs to be done on these galaxies and what it means for cosmology.

Halton C Arp:

Childhood & Education

Halton Christian Arp was born on March 21st, 1927 in New York City to August and Anita Arp.
Arp's parents were both artists and he was a distant cousin to the French abstract sculptor and painter Jean 'Hans' Arp. Halton grew up in the Greenwich Village area of Manhattan and also spent time with his parents travelling to Woodstock, New York for seasonal art fairs. They gave him the nickname "Chippy", which Halton later shortened to "Chip" and was called that by his friends.

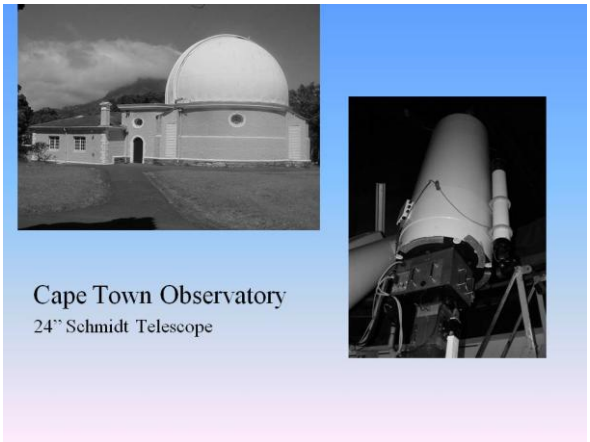
Arp did not attend formal public school until he was almost 10 years old, being self-taught at home by his parents and others from the local artist community, where he was exposed to the roots of the bohemian counterculture movement that arose there in the late 1950's. When he was older, Arp was sent to a US Naval Academy prep school in Buzzards Bay, Massachusetts, where after he graduated with his high school diploma, he spent two years in the Navy before enrolling at Harvard. Arp graduated from Harvard College in 1949 with a major in astronomy and received his doctorate from Caltech in 1953. While a student at Caltech, he worked under Edwin Hubble at Mt Wilson assisting Hubble with his search for nova's in the Andromeda Galaxy, and specialized in study of galaxies.



As a student at Harvard, Arp was a champion fencer and participated in national matches. During one practice session his career almost came to a short end, as during a match, his opponent's blade snapped and Arp was impaled by the broken tip. He was hospitalized for a week in serious condition, but eventually recovered. He kept up with his sport while at Caltech and afterwards while working as an astronomer. In 1965, he joined the US men's fencing team and competed in the Paris world fencing championship. Arp's love of the sport of Fencing and its techniques became useful later in professional life as he used the concept of thrust and parry verbally when participating in debates, making for lively discussions.
Over the years, Arp married three times and has four daughters and five grandchildren.

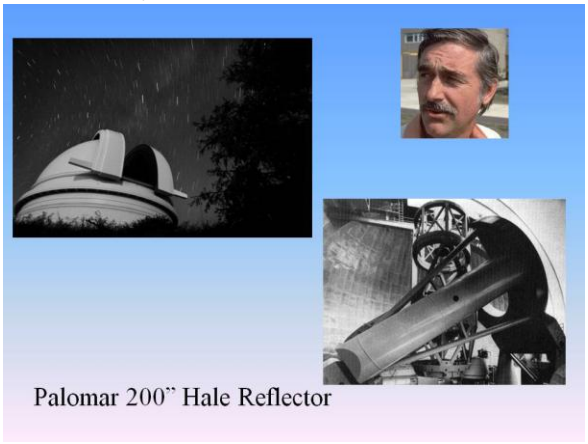
Life as an Astronomer

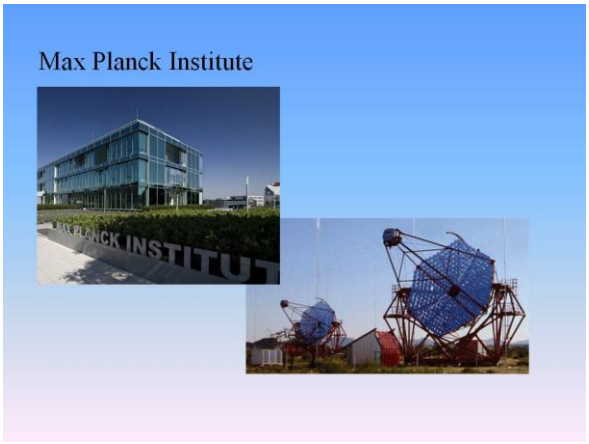
Arp's first professional job as an astronomer was after graduating from Harvard in 1949, when he was employed as a 'computer' at Mt Wilson observatory as a summer intern. Upon graduating from Caltech in 1953, Hubble offered Arp a job once again at Mt Wilson, and Arp worked directly with Hubble, using the 60" reflector to gather the nova data that Hubble required for his distance scale research. After Hubble passed away from a sudden stroke in the fall of 1953, the observatory director kept Arp on staff for the next two years to finish Hubble's last project. Afterwards, Arp's next job was in 1955 for the University of Indiana as a Research Assistant on assignment to South Africa to use the 24" Schmidt telescope at the observatory in Cape Town to study Cepheid variables in the Small Magellanic Cloud.



Upon completing that work in 1957, Arp then became a Fellow of the Carnegie Institution and a full staff astronomer at Palomar Observatory, and worked there for the next 29 years. While there, he had frequent access to the 200" Hale reflector where he pursued observations of galaxies. Arp was considered a master of astronomical photographic techniques with the 200" telescope.

As a staff astronomer at Palomar Observatory with observational use of the 200" Hale Reflector, along with degrees from Harvard and Caltech, Halton Arp wasn't your average astrophysicist. Over the years, he earned a number of professional awards, including the American Astronomical Society's Helen B. Warner prize for research and the American Association for the Advancement of Science's Newcomb Cleveland award for published research, both in 1960. From 1981 to 1983, Arp served as President of the Astronomical Society of the Pacific.
And in 1984, he received the Alexander von Humboldt Senior Scientist award for research.

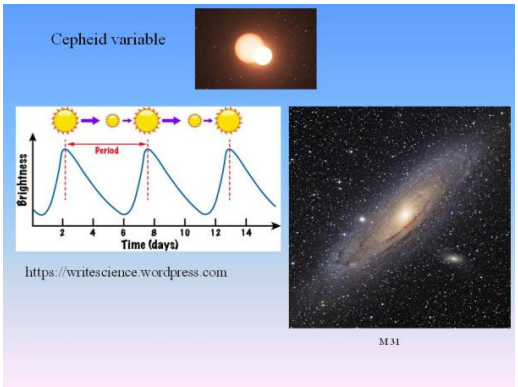


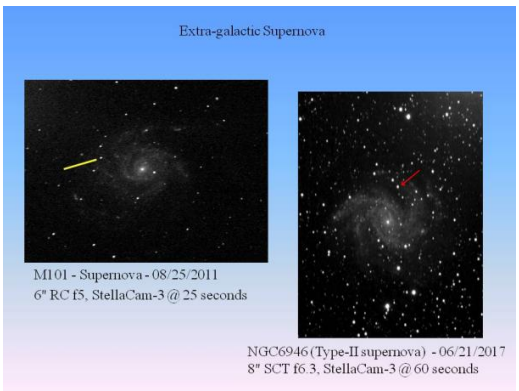


In 1983 Arp retired from Caltech and joined the staff of the Max Planck Institute for Astrophysics near Munich, Germany. While he no longer had personal observing access to large observatory telescope, Arp did have access to data in multiple wavelengths from European observatories around the world and was able to continue his research.

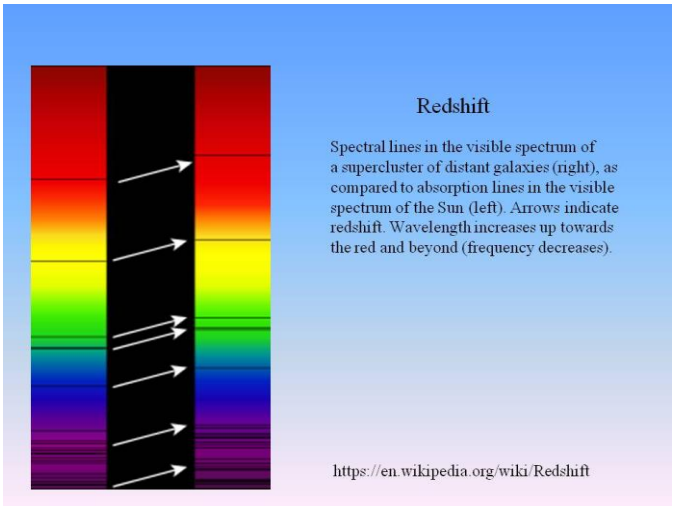
Redshift Controversy:

At the turn of the 20th century, one of the major questions that professional astronomers were trying to answer was "how far away are the galaxies?" The first accurate distances to galaxies were determined by Edwin Hubble in the 1920's by using Cepheid variables. Cepheid variables are stars that vary their brightness by a specific range and timeframe. This relationship between the star's luminosity and period of change allows astronomers to determine what its true brightness is and allows them to determine the star's distance. Using this relationship, astronomers were able to accurately calculate distances to Cepheid's in our Milky-Way galaxy. Then the discovery of Cepheid's in the nearby galaxies, such as M31 the Andromeda Galaxy, allowed astronomers to extend accurate distances throughout the Local Group of galaxies. But in galaxies much further away, Cepheid's were not identifiable, so astronomers turned to another celestial yardstick, supernovas. Extra-galactic nova's and supernova's are similar to Cepheid's in that their intrinsic brightness could be compared against these stellar explosions that have occurred within our own galaxy. This allowed us to measure distances out into our nearby supercluster of galaxies, (Virgo and Coma Clusters). To go even further out into the universe, astronomers discovered that every galaxy has a measurable redshift that could be utilized.



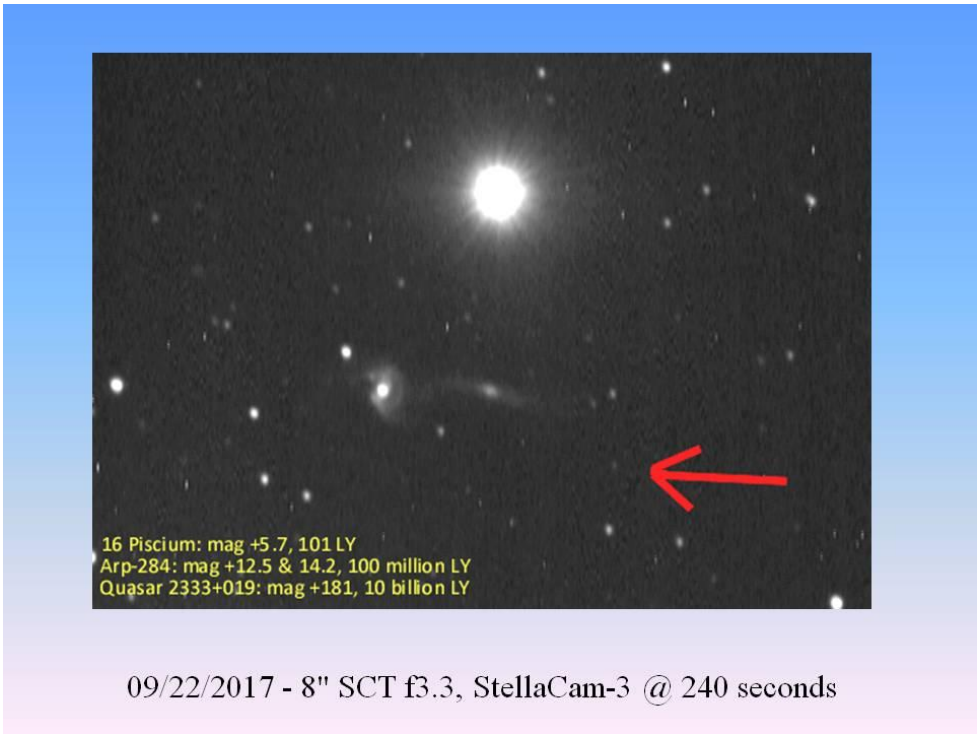


Every star gives off a spectrum of bright and dark emission and absorption lines, when viewed thru a spectrograph prism, made up of the various atomic elements within the star. Hydrogen and helium being the primary elements, along with oxygen, carbon, neon and nitrogen. Depending on the direction that the star is moving, either toward us or away from us, the star's spectrum exhibits a lightwave Doppler shift, similar to the soundwave Doppler effect, such as from a passing train. If the object is approaching us, it is blueshifted, if it is receding from us, the spectrum is redshifted.

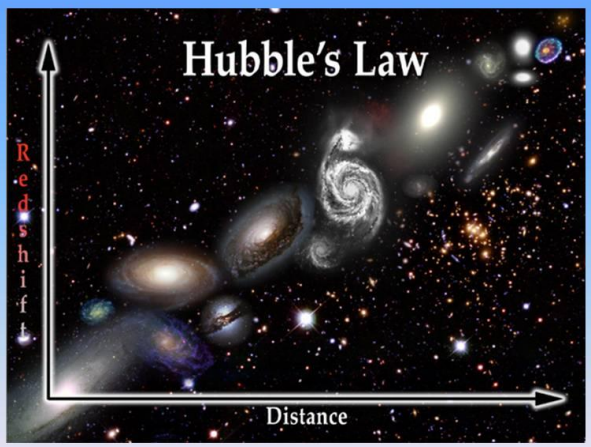


The greater the spectral lines of an object are shifted towards the red end of the spectrum, the greater its distance is from us.
The symbol for redshift, expressed as a fractional displacement of wavelength is 'z'.
An object with z=0.00 or smaller has a low redshift and is nearby. A redshift greater than z=0.0 is a high redshift and represents an object very far away.
(The bigger the number, the father away it is).

An example of using redshift to measure cosmological distances is Arp284: interacting galaxies NGC7714 & 7715 and the Quasar 2333+019, mentioned in the October 2017 issue of 'Sky & Telescope' magazine, located near the 5th magnitude star 16 Piscium. The authors of the article had used a 48" reflector visually to make the observation. The bright +5.7 star is about 101 light-years away, the pair of +12.5 & +14.2 galaxies at z=0.0093 or about 100 million light-years, and the +18th magnitude Quasar at z=1.871 or about 10 billion light-years, nearly 2/3 the age of the universe! (Here's a 3 minute video-capture taken with a Celestron 8" SCT @ f6.3 and StellaCam-3 video-cam)



A central part of today's 'Big Bang' cosmology this key tenet is named Hubble's Law. Basically stated, Hubble's Law is that the larger an objects redshift, the farther away it is and the faster it is receding from us. All astronomers had to do was measure the redshift of a galaxy and then it was just a matter of computing the distance of that galaxy. It is a critical piece of the expanding universe theory.

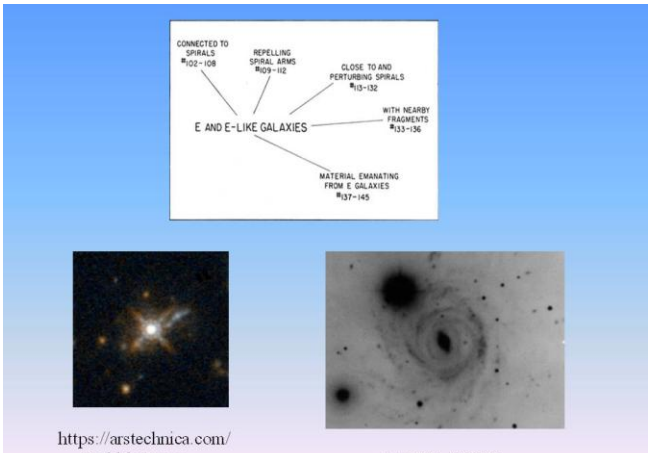


https://www.quora.com/

While at Palomar, Arp began 'collecting' unusual galaxies that other researchers would drop from their studies as being too unusual or peculiar. Using his artist 'eye', Arp realized that these odd galaxies represented different stages in galaxy evolution, and devoted his career to studying them utilizing the 200-inch Hale telescope. His research goal was to produce a catalog that other cosmologist could use to model and test the Hubble theory of galaxy formation.

From his catalog, Arp noticed that some of his elliptical galaxies associated with disturbed spirals (Arp#100 thru #150) seemed to have relationships with nearby quasi-stellar objects (QSOs), or quasar radio sources - which in the mid-1960's had recently been discovered having high redshifts, indicating great distances. Quasars were considered to be 'left-over's' from the creation of the early universe, and their great distance indicated their extreme age. But from Arp's Palomar observational evidence from the 200" Hale telescope, it appeared that some high velocity quasars were physically connected to bright, nearby galaxies with a much lower redshift. A theoretical impossibility! Arp coined a new phrase to describe what he was seeing – 'discordant redshift'.
He came to believe that an objects redshift may not be solely explained by its distance and velocity, and there may be some other cosmological mechanism at work. Thus, not all redshifts can be attributed to the expansion of the universe.

This eventually led to his challenging the current interpretation of these highly red-shifted sources, even calling into question the Big Bang theory, and that the universe may not actually be expanding.
This became a long running controversy between the majority of the traditional astronomical world that supports Big Bang cosmology and a small band of challengers led by Arp and a few other prominent astronomers that still hasn't quite died down even today.



https://arstechnica.com/
HubbleImage

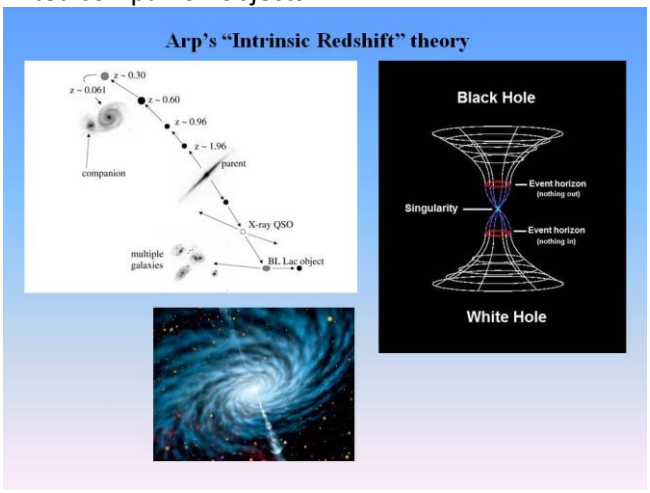
Arp117 - IC950

The debate over whether redshifts were cosmological or something else came to a head in December 1972, as at a symposium on December 30th, Arp and Princeton astronomer John Bachall held a debate to a packed audience of astronomers and cosmologist. Arp's main argument was that something unexplained was happening with the examples that he had brought with him. Bachall's rebuttal was that Arp didn't have any explanation to his observations; therefore they must be observational errors.

The back and forth was intense with both sides eventually claiming victory, but the general consensus of the astronomy community was that Arp lost the debate due to his not yet having developed a theory to support his observations.

Arp's willingness as a scientist to stand behind his data in challenging the Big Bang model eventually cost him his observing privileges at Palomar in 1983, and many astrophysics journals began rejecting the research papers that he would submit. This led Arp to retire from Caltech and move to Germany where he could continue his research work at the Max Planck Institute for Astrophysics.

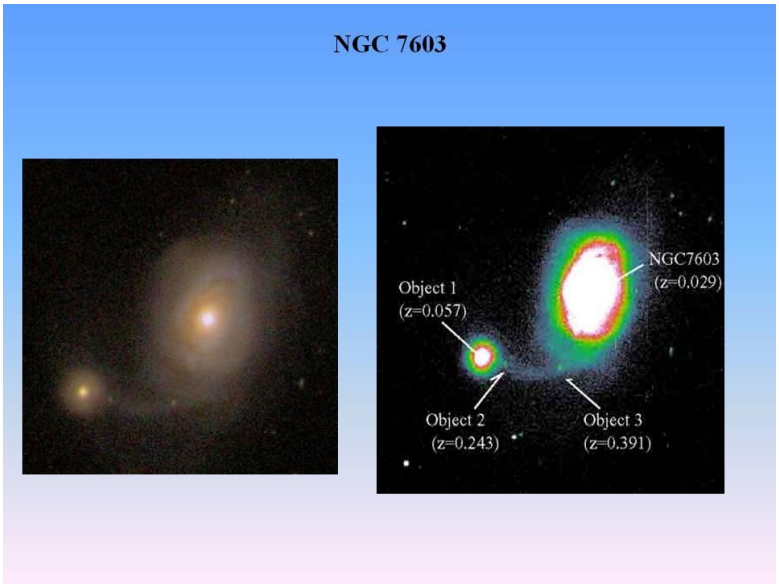
From his research, Arp eventually developed a theory which he called “intrinsic redshift”, that in the core of active galaxies, new matter is created from a whitehole singularity, with the new matter having zero to low mass and is ejected as a quasar from the parent galaxy with a high velocity redshift. During the ejection process, the new material interacts with the older galactic material of the host galaxy, causing the new material to increase in mass, which in turn causes its high redshift to slow down as it moves away from the host galaxy and evolves into the more traditional redshifted companion objects.



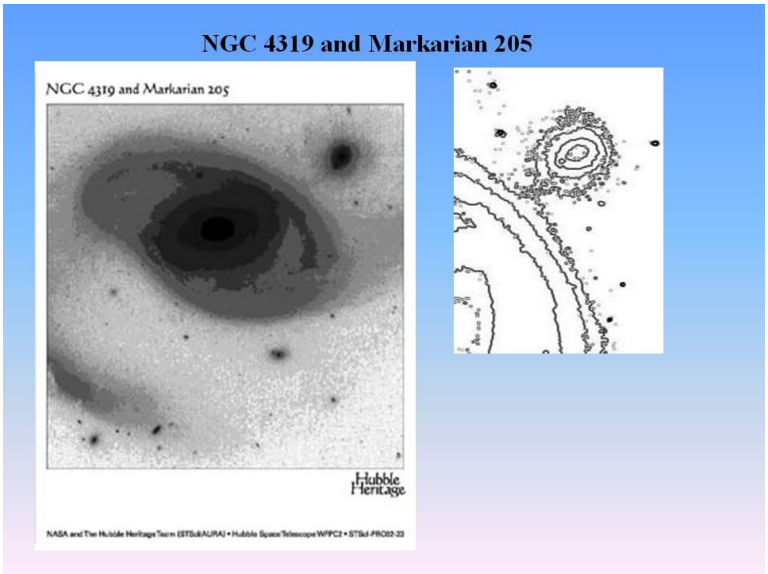
As it was difficult to get published in scientific journals, Arp wrote and published two books documenting his discordant redshift observations and cosmological theories: “*Quasars, Redshifts and Controversies*” and “*Seeing Red*”. Supporters of Arp’s alternate theories are still gathering observational research and studying whether everything seen in peculiar galaxies can be explained by conventional astrophysics, or if some new physical mechanism exists that we are still unaware of. A few examples of these ongoing studies are NGC7603 (Arp92) in Pisces and NGC4319 & Markarian205 in Draco.

<u>NGC7603 (Arp92) in Pisces:</u>

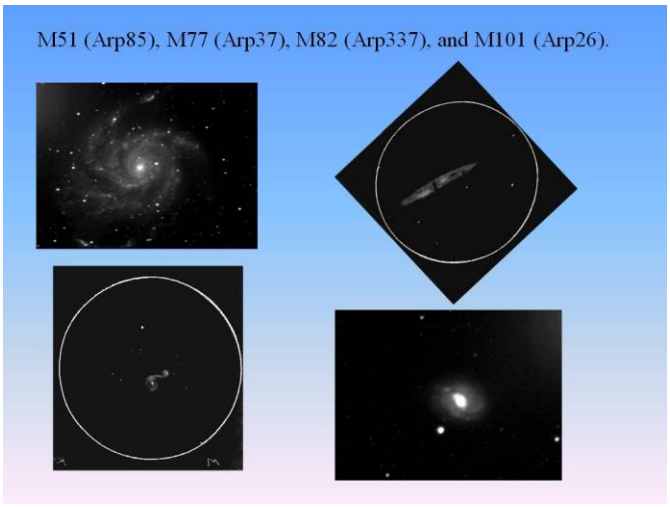
NGC7603 is a Seyfert type spiral galaxy with an active galactic nucleus and a redshift of z=0.029. It has a small elliptical companion at the end of one arm with double the redshift of the parent galaxy, z=0.057.
Additionally, along the arm connecting the elliptical are several small knots of material with very high redshifts, z=0.243 & z=0.391. Arp believed that all three high redshift objects were ejected from the core of NGC7601, with the elliptical being the oldest and furthest object with its redshift having slowed.
Most other astronomers believe this is just a chance alignment between NGC7603’s spiral arms, and a further out in the distance elliptical galaxy, and several cosmologically distant quasars.



NGC4319 & Markarian205 in Draco:
NGC4319 is a typical 'Barred Spiral' galaxy with an internal bar structure with spiral arms coming off of.
It has a redshift of z=0.0046 making it relatively nearby in cosmological distances.
Markarian205 is a low-luminosity active quasar at a redshift of z=0.071 making it about 15 times more distant than NGC4319. What makes these two 'peculiar' is what appears to be a very faint filament bridge that connects the two. This would not be possible given the difference in redshifts.
Arp believed that this is a true connection, as Mrk205 must have been ejected by NGC4319 and is trailing material. But the conclusion of the majority of astronomers is that this bridge is just some irregularity in the spiral arm structure of NGC4319 and a chance alignment or optical illusion of material projected in front of Mrk205.



My Observations of Arp's Peculiar Galaxies:
So, where can you find Arp's Peculiar Galaxies? Galaxies in general can be found opposite the glowing band of light that we call the "Milky-Way", our home galaxy. Usually, when we want to observe bright or dark nebula and star clusters, the Milky-Way is exactly where we want to look, but for galaxies, this is the "Zone of Avoidance', as all the gas and dust nebula and stars of the spiral arms of our galaxy tend to obscure all the faint extra-galactic 'nebula' that we want to observe. Among galaxies, peculiar Galaxies come in all shapes, sizes, and brightness, and many are very interesting and worth the effort to find, regardless of the equipment that you use. Some large bright galaxies are best suited for medium-size telescopes, while others are very faint and require large apertures.

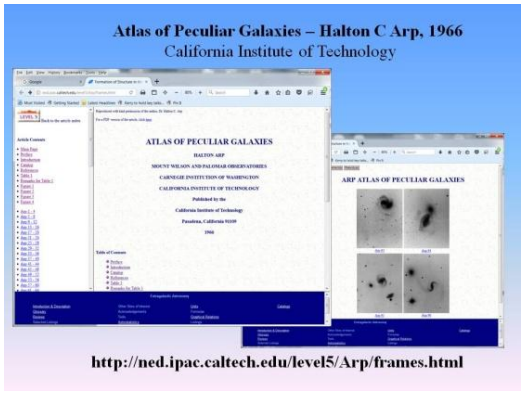


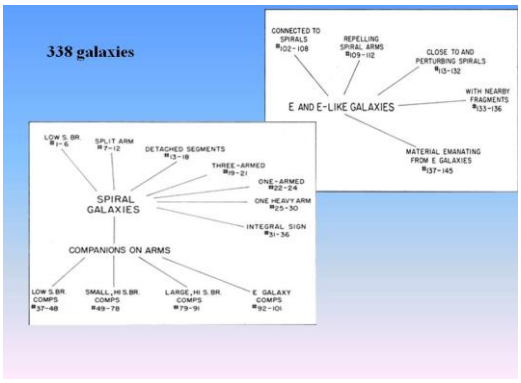
There are even some galaxies that display nicely using binoculars or small telescopes. A number of Messier Objects are Also Arp galaxies, and observing these are a good way to get started, even using smaller 8 – 10" telescopes. These include M51 (Arp85), M77 (Arp37), M82 (Arp337), and M101 (Arp26).

It helps to have a list of the Arp catalog. There's a number of ways to find these peculiar galaxies. You can get a computer software program to help: "Deep Sky Planner" – Steve Tuma & Dean Williams Do a search for Arp's catalog, and generate a star chart.
Or, if you're using a planetarium program, you can utilize its settings to show the galaxies that you are interested in finding. This example is from my favorite program – "Earth Centered Universe"
You can also download a PDF copy of Arp's original atlas to your computer, tablet, or smart phone.

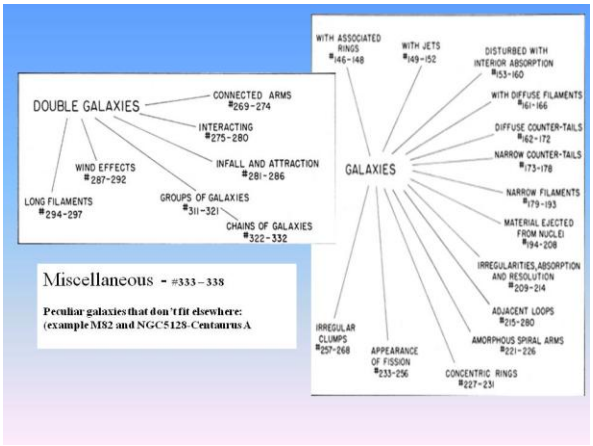
The catalog is organized into 5 main areas or classes with each having many sub-classifications.
There are 338 galaxies with some type of irregularity or odd features.

Spiral Galaxies: Arp1 – 101 are spiral galaxies that have various types & shaped arms, along with detached segments, and faint companion galaxies.
Elliptical and Elliptical-Like: Arp102 – 145 are elliptical galaxies with associated fragments or ejected material, and connected to or disturbing close spirals.

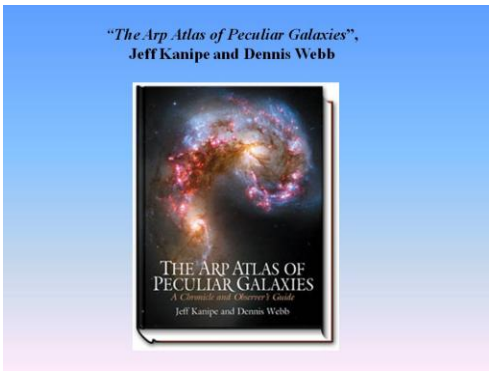


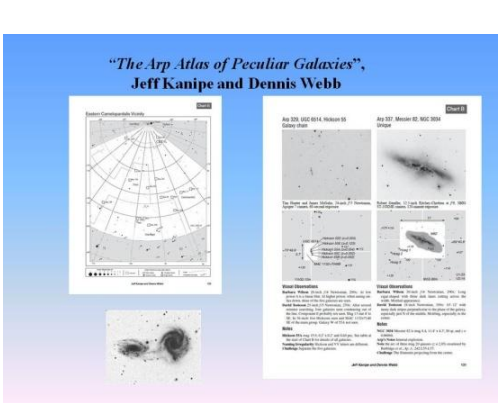


Galaxies: Arp146 – 268 are spirals and elliptical not included with the first two classes that have filaments, rings, tails, jets, loops, and other nearby features.
Double Galaxies: Arp269 – 332 are multiple galaxies or groups that are connected by long filaments, bridges, or aligned in a chain.
And **Miscellaneous:** Arp 333 – 338 are really unusual galaxies that don't fit anywhere else, such as M82 or NGC5128-Centaurus A.

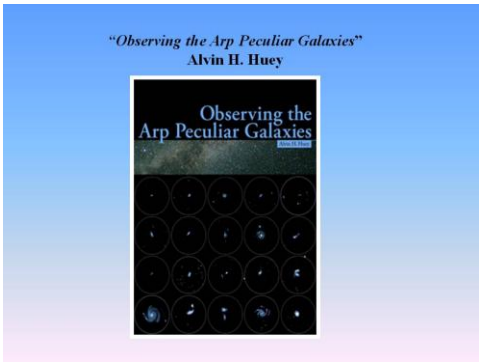


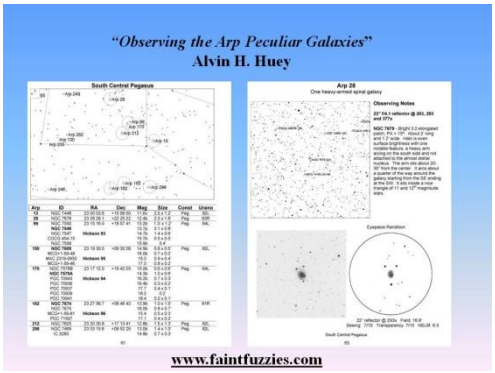
In 2006 Amateur Astronomers Jeff Kanipe and Dennis Webb expanded Arp's atlas into an observers guide, complete with Arp's original images, along with finder charts and CCD images and visual observations from other participating amateurs. It's a great book to use in the field!!





Also, amateur astronomer Alvin Huey has a great observing book on his website www.faintfuzzies.com
It too contains finder charts, DSS images, and eyepiece sketches.





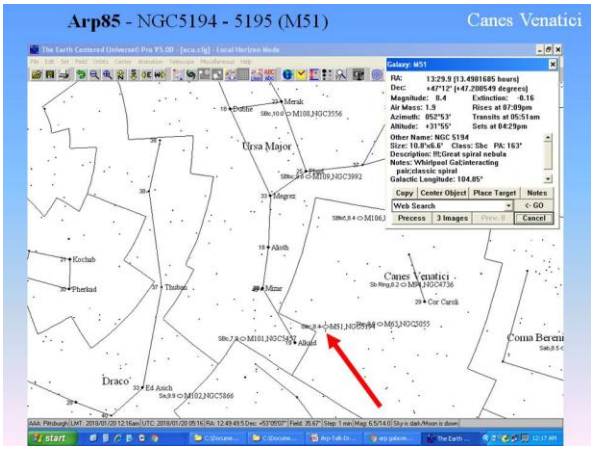
Ingredients to successfully observe Peculiar Galaxies:
All of Arp's galaxies exhibit some form of abnormality, whether they're multiple interacting or just have oddball shapes or features. This is what makes them interesting to find and attempt to visually see or capture an image of.

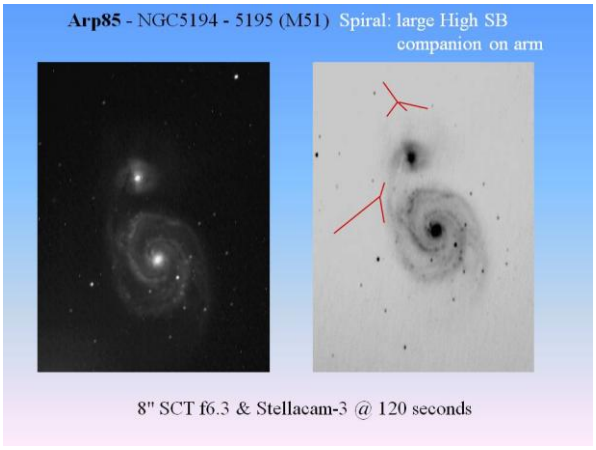
Observing them visually requires maintaining dark-adaptation, good starcharts, and slow sweeping with a wide-field low-power eyepiece and a fast low focal-length telescope. A nice 80mm F6 or shorter refractor piggybacked on a 10" or greater telescope would work very well. The 80mm acts as a low-power RFT giving you a wide-field in which to find the galaxy and the larger telescope it is attached to allows use of higher magnifications, depending on the object. You'll need all your visual observing skills to find and bring out the subtle differences in these objects. Many of Arp's features are very faint, and depending on what size telescope you are using, may not be visible. But like any deep-sky object, half the fun is just successfully finding it and knowing what it is that you are observing.

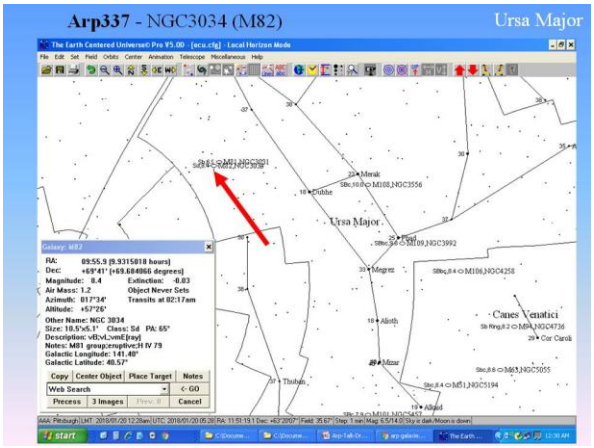
For the Imagers, Peculiar Galaxies can also be challenging, in that even with an accurate GOTO mount, it may not position the telescope squarely on the object to where it's framed the way you want it.
Having a photographic atlas or picture of the galaxy will help you in both locating and identifying the most interesting sections of the object and in framing your image. I've found that using short-exposure video-astronomy cameras works great in positioning and identifying Peculiar Galaxies.

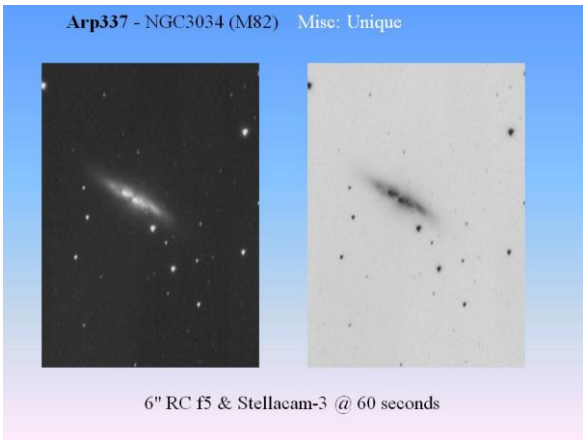
My Observations of Arp's Peculiar Galaxies:

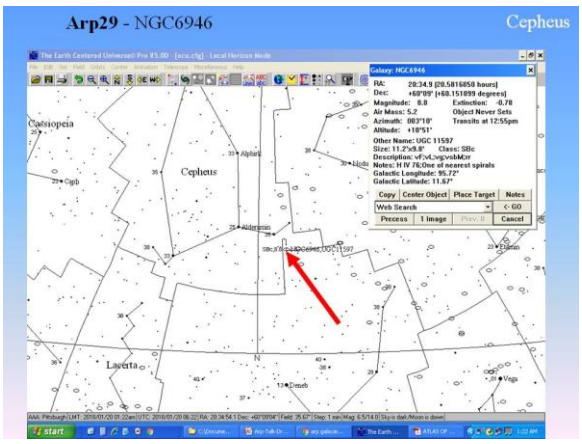
Arp85 - NGC5194-5195 (M51)	*Spiral: large High Surface Brightness companion on arm*
Arp337 - NGC3034 (M82)	*Misc: Unique*
Arp29 - NGC6946	*Spiral: one heavy arm*
Arp310 - NGC7317, 18A, 18B, 19, 20 (Stephan's Quintet) Galaxy	*Group*
Arp284 - NGC7714 & 7715	*Double Galaxies*
Arp13 - NGC 7448	*Spiral: detached segments*
Arp30 - NGC6365A & B	*Spiral: one heavy arm*
Arp38 - NGC6412	*Spiral: Low SB companion on arm*
Arp78 - NGC770 & 772	*Spiral: Small High SB on arm*
Arp84 - NGC5394 & 5395	*Spiral: large High SB on arm*
Arp273 - UGC1810-1813	*Galaxies: With Connected Arms*
Arp185 - NGC6217	*Spiral: Narrow filaments*
Arp92 - NGC7603	*Spiral: elliptical companion on arm*
NGC 4319 and Markarian 205	

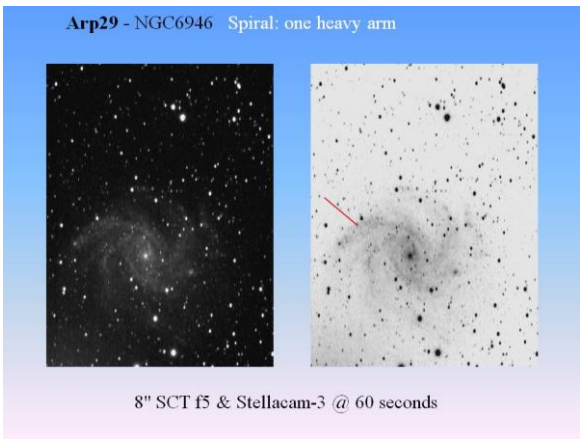

Arp85 - NGC5194 - 5195 (M51)
Canes Venatici
Ursa Major
Canes Venatici
Coma Berenices
Draco

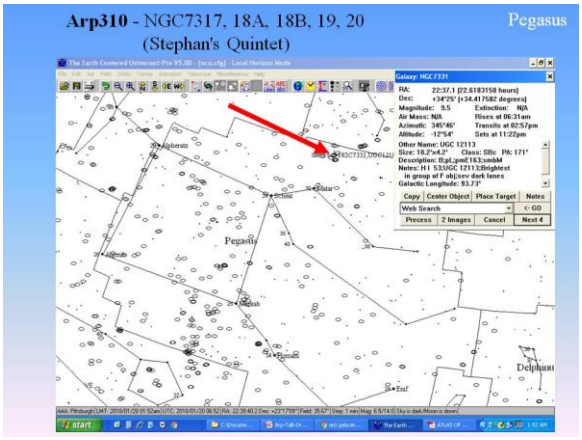

Arp85 - NGC5194 - 5195 (M51) Spiral: large High SB companion on arm
8" SCT f6.3 & Stellacam-3 @ 120 seconds

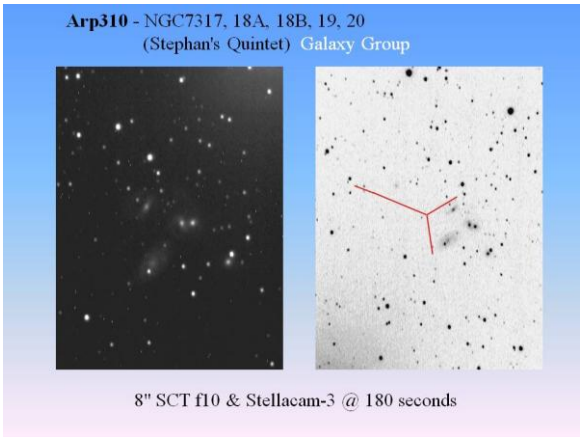

Arp337 - NGC3034 (M82)
Ursa Major
Canes Venatici

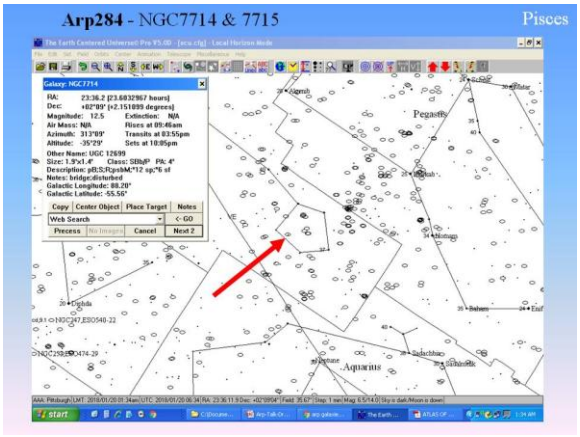

Arp337 - NGC3034 (M82) Misc: Unique
6" RC f5 & Stellacam-3 @ 60 seconds

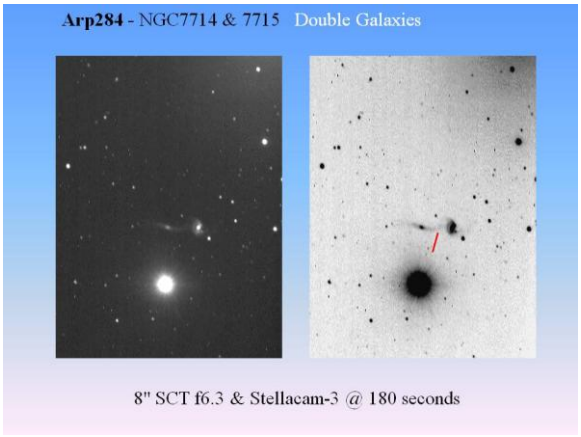

Arp29 - NGC6946
Cepheus
Cassiopeia
Cepheus
Lacerta

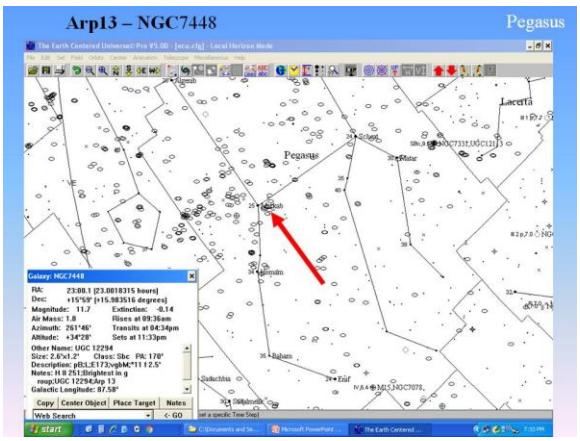

Arp29 - NGC6946 Spiral: one heavy arm
8" SCT f5 & Stellacam-3 @ 60 seconds

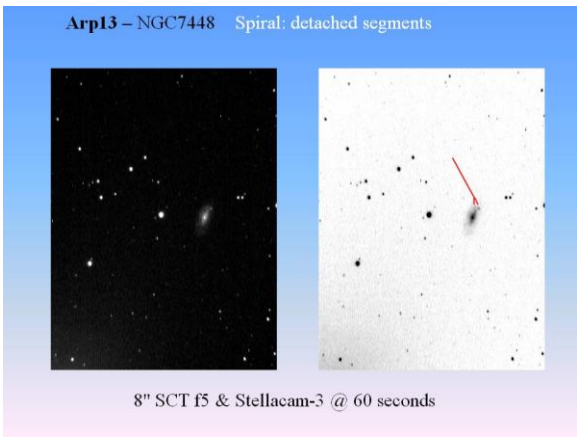

Arp310 - NGC7317, 18A, 18B, 19, 20
(Stephan's Quintet)
Pegasus

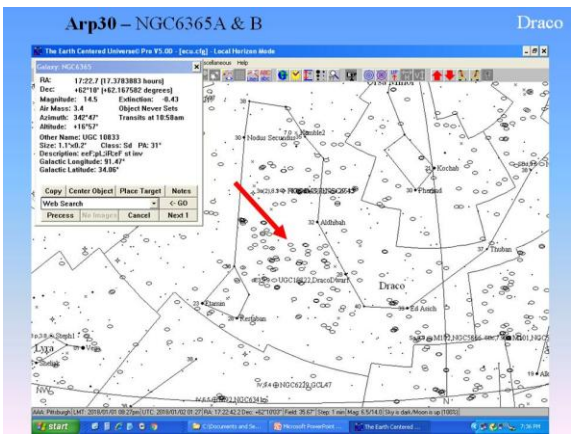

Arp310 - NGC7317, 18A, 18B, 19, 20
(Stephan's Quintet) Galaxy Group
8" SCT f10 & Stellacam-3 @ 180 seconds

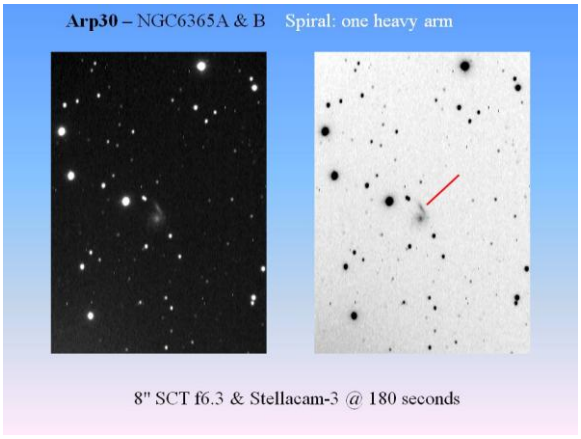

Arp284 - NGC7714 & 7715
Pisces
Pegasus
Aquarius

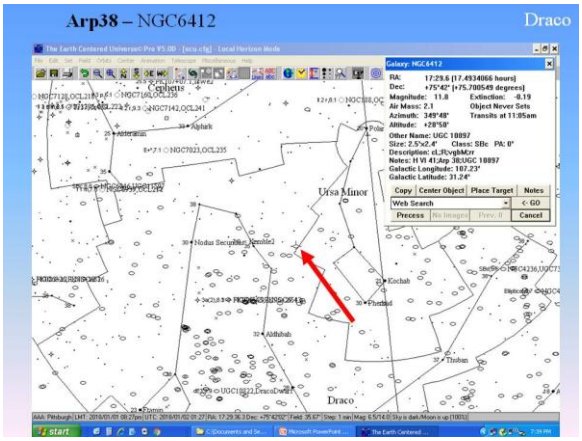

Arp284 - NGC7714 & 7715 Double Galaxies
8" SCT f6.3 & Stellacam-3 @ 180 seconds

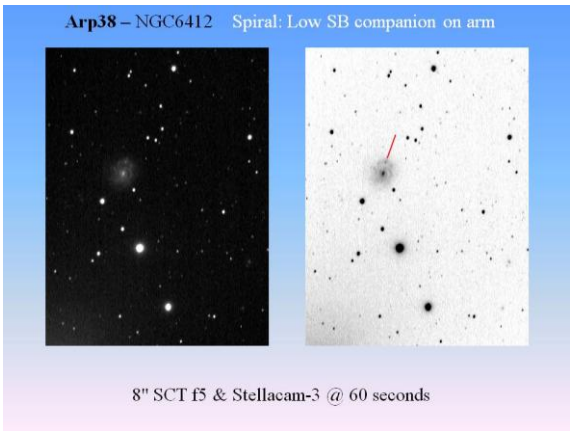

Arp13 – NGC7448
Pegasus
Lacerta
Pegasus

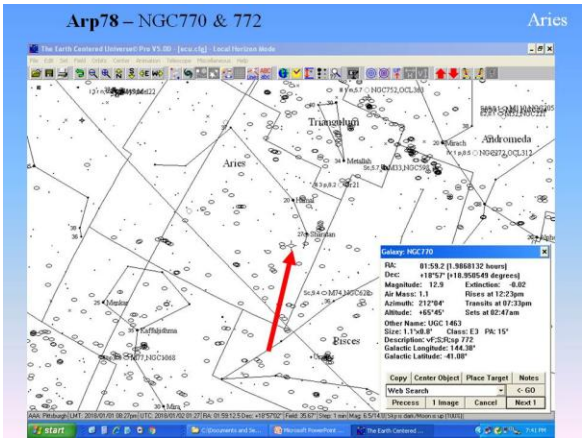

Arp13 – NGC7448 Spiral: detached segments
8" SCT f5 & Stellacam-3 @ 60 seconds

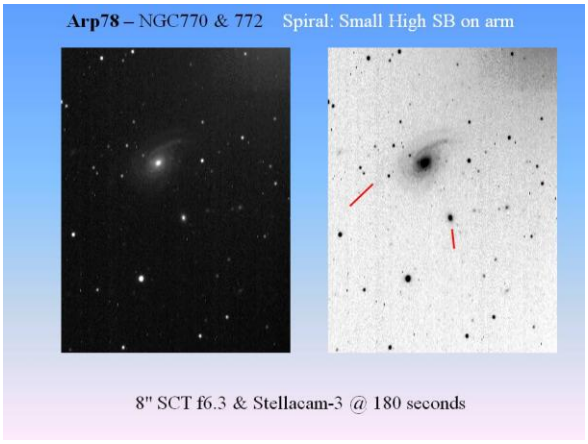

Arp30 – NGC6365A & B
Draco
Draco

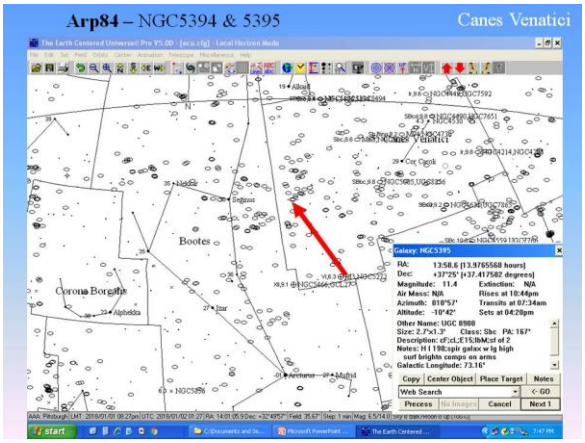

Arp30 – NGC6365A & B Spiral: one heavy arm
8" SCT f6.3 & Stellacam-3 @ 180 seconds

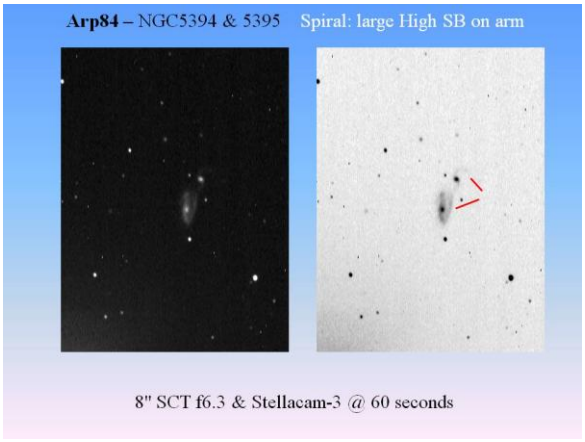

Arp38 – NGC6412
Draco
Ursa Minor
Draco

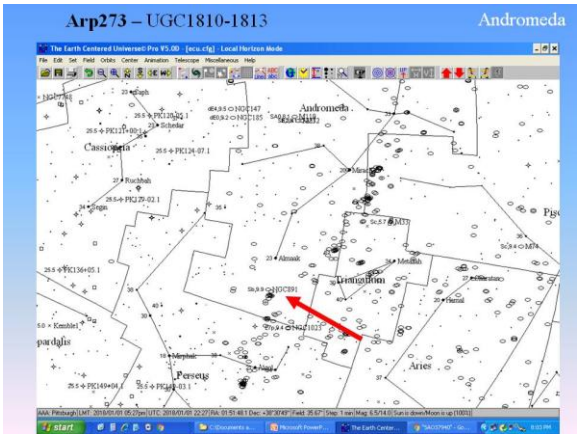

Arp38 – NGC6412 Spiral: Low SB companion on arm
8" SCT f5 & Stellacam-3 @ 60 seconds

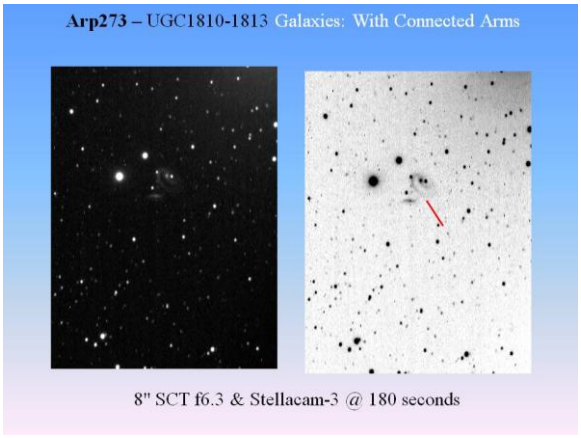

Arp78 – NGC770 & 772
Aries
Triangulum
Andromeda
Aries
Pisces

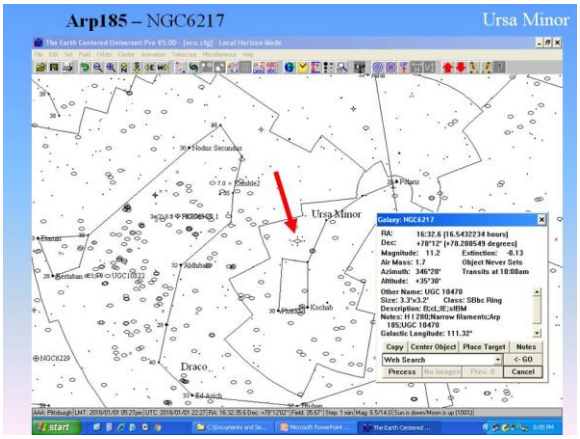

Arp78 – NGC770 & 772 Spiral: Small High SB on arm
8" SCT f6.3 & Stellacam-3 @ 180 seconds

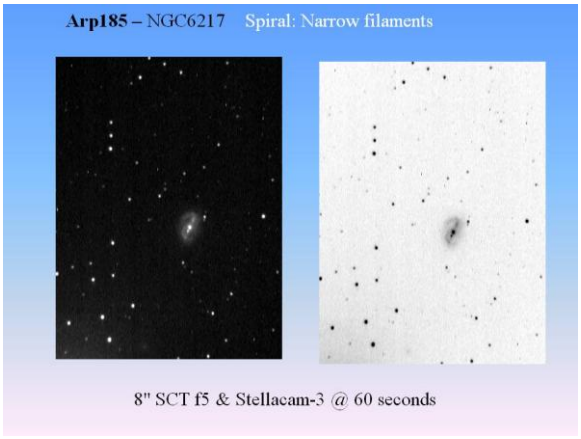

Arp84 – NGC5394 & 5395
Canes Venatici
Bootes
Corona Borealis

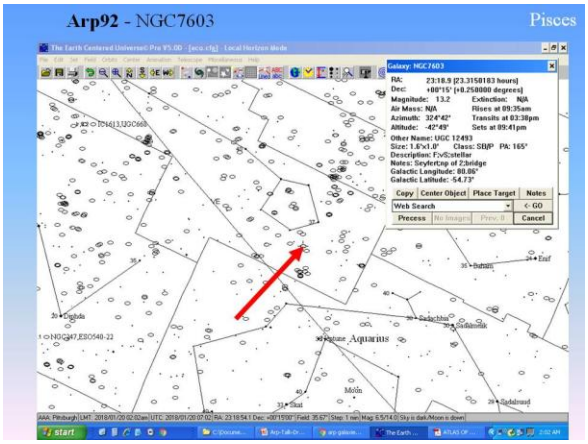

Arp84 – NGC5394 & 5395 Spiral: large High SB on arm
8" SCT f6.3 & Stellacam-3 @ 60 seconds

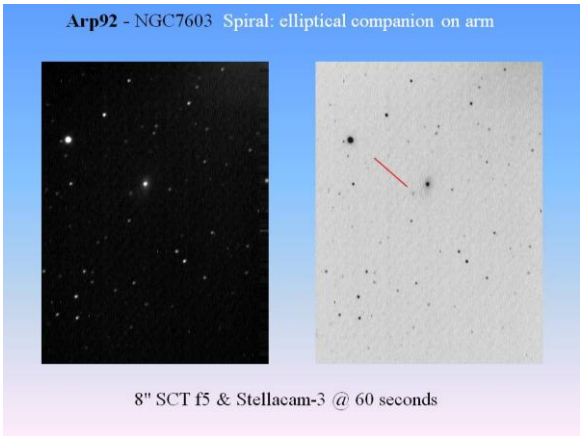

Arp273 – UGC1810-1813
Andromeda
Cassiopeia
Perseus
Aries

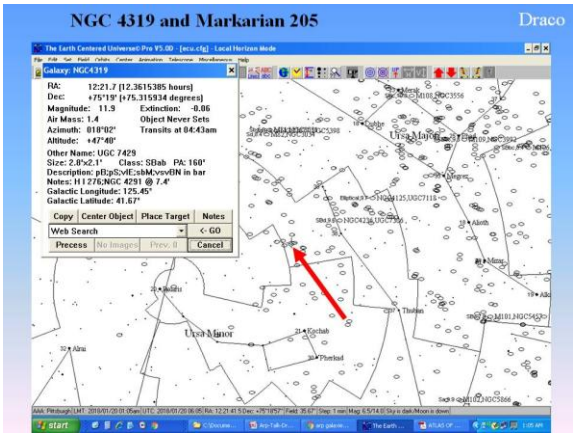

Arp273 – UGC1810-1813 Galaxies: With Connected Arms
8" SCT f6.3 & Stellacam-3 @ 180 seconds

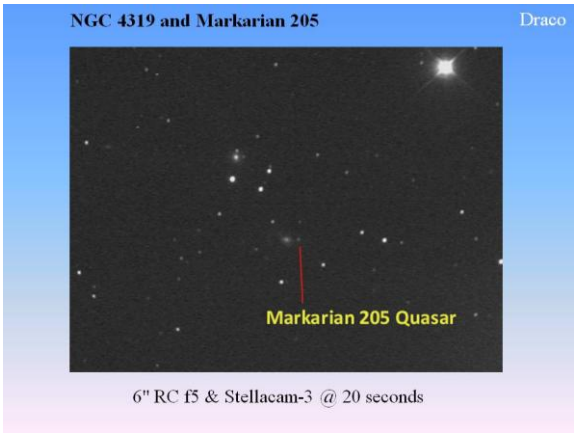

Arp185 – NGC6217
Ursa Minor
Draco


Arp185 – NGC6217 Spiral: Narrow filaments
8" SCT f5 & Stellacam-3 @ 60 seconds









Arp's Legacy & Conclusion

Until his death at the age of 86 on December 28th, 2013, in Munich Germany, Arp continued to hold his contrary view of the Big Bang and published his research in both popular and scientific literature.
Today, with modern observatories such as the Keck's and VLT, along with new CCD cameras and space telescopes available, new data such as the Sloan Digital Sky Survey and the Hubble Deep Field across multiple bandwidths of the observable spectrum with higher resolution and dynamic range, along with conclusive research has proven Arp's "counter-theories" of intrinsic redshift to be incorrect.

But, even though he was eventually proven to be wrong, Halton Arp made significant contributions to astrophysics by his strong challenges to accepted theory, based on observations, forcing other astronomers to re-validate their assumptions about galaxy formation and cosmology.

Halton C Arp's Atlas of Peculiar Galaxies is not just a neat list of interesting looking galaxies, but also has become a useful tool for the advanced amateur astronomer looking for deep-sky observing/imaging projects. Professionally, Arp's atlas is recognized as an excellent compilation of interacting and merging galaxies that provides a useful benchmark of local peculiar galaxies to compare against more distant objects being discovered in deep HST images.

Halton Arp is considered by some to be one of the great American observational astronomers of the latter half of the 20th century, living at the dawn of the age of the "Quasar" – which discovery of led to a deeper understanding of our expanding universe. His willingness to follow the observational data, even if it didn't fit into accepted theory, to wherever it led, is a hallmark of the scientific method.
Arp's work lives on today, both for the professional astrophysicist and amateur astronomer alike.

So I encourage everyone to get out tonight and try your hand at finding and observing these strange and elusive deep-sky objects, the *Peculiar Galaxies* of Halton C Arp.

The Local Group of Galaxies

The Local Group,,,,,
Over the years, I've clipped and saved interesting articles from the various astronomy related magazines that have come and gone, and some that are still with us. One of my favorite 'observing' oriented publications was the old 'Deep Sky' magazine. In their fall 1984 issue there was a detailed article titled "*All About M31*", which was about observing the Great Andromeda Galaxy's internal open and globular clusters and M31's attendant satellite galaxies. They followed that up a few years later in the autumn of 1991 with an article on "*Observing the Local Group*".
I've held on to those issues over the years, wanting someday to do an observing project based on them. Then more recently both 'Astronomy' magazine 'Sky and Telescope' came out with a number of great observing articles on other 'Local Group' themed topics such as the December 2013 Sky & Telescope issue - "*Exploring the Triangulum Galaxy*", and "*Local Group Dwarf Galaxies*" , and the entire March 2019 issue of 'Astronomy' about galaxies.

It was that December 2013 Sky& Tel issue that inspired me to finally start an observing project in the spring of 2014 to explore our Local Group of galaxies. So I started diving into these articles with their photographs and finder charts, comparing with what I've observed or video-captured over the years. I was able to identify a number of extra-galactic globular clusters and H-II regions in M31 & M33, along with already having several additional Local Group members video-imaged. Then I learned of Alvin Huey's downloadable observing book - "*The Local Group*", from his website www.faintfuzzies.com, and my journey into the Local Group began in earnest.

So today, we'll discuss what I've learned during that journey among the Local Group, along with some of the people, both historical and modern, behind these objects, and how to go about observing them.
Along the way, we'll also review a number of my personal observations of Local Group members.
Hopefully, when we are done, you will find them as interesting to hunt as I do.

Discussion outline:

- **Galaxies – What are they:**
- **What is the "Local Group":**
- **Historical and Modern Astronomers associated with the Local Group:**
- **How to Observe the Local Group:**
- **Observations of the Local Group Galaxies:**
- **Conclusion**

Galaxies – What are they?
Galaxies are large systems of stars and interstellar matter, typically containing from several million to several trillion stars. They run in size from a few 10's of thousands to several 100,000 light years in size, and are separated from other galaxies by millions of light years.

How do Galaxies form?
They originate from large cosmic primordial clouds of gaseous matter (hydrogen and helium) in our Universe that slowly collapsed. Most galaxies have formed at about the same time, within the first billion years after the universe started to expand, from an initial hot state.
Thus, they are all almost as old as the universe itself, currently thought to be about 14 billion years.

Where are Galaxies Located?

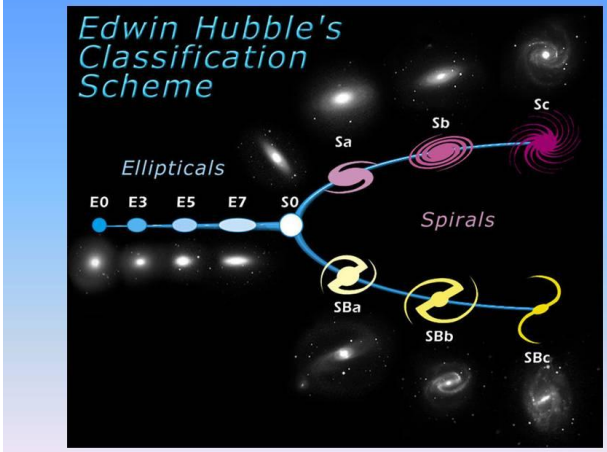
Galaxies are scattered throughout the visible universe. We live inside a giant spiral galaxy, called the Milky-Way Galaxy. The Milky-Way is about 100,000 light years in diameter and contains a mass equal to about a trillion stars. Our galaxy has several small dwarf galaxies orbiting around it that are only a few 100,000 light years distant. The nearest giant galactic neighbor, the Andromeda Galaxy, also a spiral, is about 2-3 million light years distant. Some galaxies are isolated "island universes" which float lonely through an otherwise empty region of the universe. But the distribution of matter in the Universe is not uniform. That causes groups of galaxies, running to few dozens of galaxies, or even large clusters of up to several thousands of galaxies, to form. The galaxies of these groups are in mutual gravitational interaction, which may have significant influence on their appearance.

Classic Morphology

Galaxies come in several types, and though of a wide variety of shapes and appearances, have many basic common features. They are huge conglomerations of stars like our Sun. From their appearance, galaxies are classified as spiral, lenticular, elliptical, and irregular. In the early 20th century, astronomer Edwin Hubble devised a galaxy classification diagram based on their visual appearance.

This classification is commonly called the: Hubble Tuning Fork diagram. Hubble divided the galaxies into three broad classes: spirals, elliptical, and lenticulars, along with a fourth class of irregulars.

All the main types have sub-category classifications, and we still use a modified version of this today.



https://en.wikipedia.org/wiki/Hubble_sequence

Elliptical

Elliptical galaxies are shaped like giant luminous cosmic balls, and have no spiral or disk components. They have little or no rotation as a whole. Normally, elliptical galaxies contain very little or no interstellar matter, and consist of older population stars only:

Lenticular

Lenticular galaxies are shaped like spiral galaxies without a spiral structure.

They are smooth disk galaxies, where stellar formation has stopped long ago, because the interstellar matter was used up. They consist of mostly older population stars only. From their appearance and stellar contents, they can often be observationally confused with ellipticals.

Spiral

Spiral galaxies usually consist of three major components:

A flat, large disk which often contains interstellar matter visible as diffuse glowing emission nebulae or as dark dust clouds. Young open star clusters, associations, and random stars arranged in conspicuous and striking spiral patterns and / or bar structures.

Finally, a central bulge or core, consisting of older stellar populations with little interstellar matter, and often surrounded by a halo of older globular star clusters.

Irregular

Irregular galaxies have many different shapes and sizes due to distortion by the gravitational pull of their intergalactic neighbors. These galaxies do not fit into the scheme of spirals, disks and ellipsoids, and exhibit no particular shape.

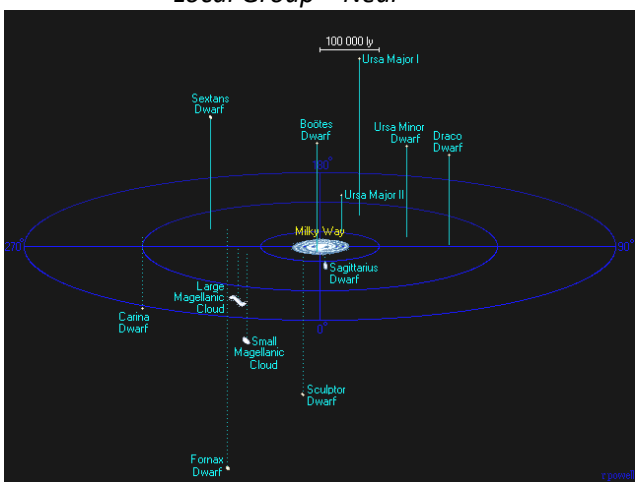
Peculiar Galaxies

Peculiar galaxies come in various types, those with jets, split arms, diffuse tails, filaments and ejected material, and for the most part, peculiar galaxies can be found anywhere along the Hubble classifications system. But a large number can be found along the 'spiral' sections of Hubble's Tuning Fork, such as interacting galaxies (colliding galaxies being the most interesting), whose gravitational fields result in a disturbance of one another.

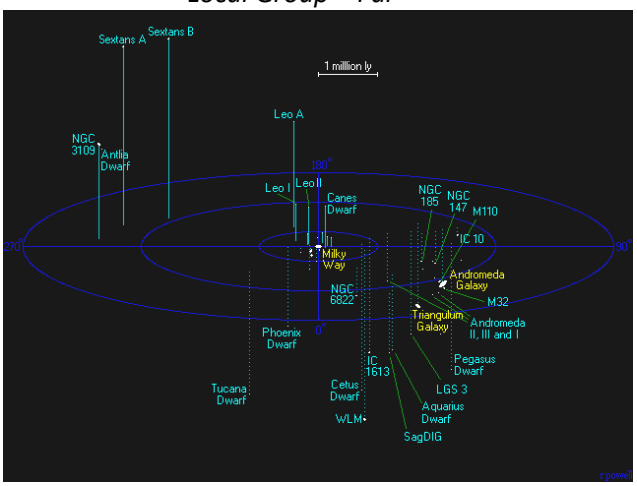
What is the "Local Group"?

The "Local Group" is the group of galaxies that includes our home galaxy, the Milky Way, among others. It comprises more than 54 galaxies, counting low surface brightness dwarf galaxies, divided into three main sub-groups. The most massive member of the group is M31, the Andromeda Galaxy, followed next by the Milky Way, with the third being M33, the Triangulum Galaxy. Both the Milky Way and Andromeda galaxies each have a system of satellite dwarf galaxies. The gravitational center of the Local Group is located between the Milky Way and the Andromeda Galaxy. Overall, the Local Group has a rough diameter of around 10 million light-years, and contains three spirals, two elliptical, nine irregulars, and forty dwarf galaxies.

Local Group – Near



Local Group – Far



Charts by Richard Powell: http://www.atlasoftheuniverse.com/localgr.html

The Local Group is near the outer edge and part of the larger Virgo Cluster.
The Virgo Cluster is a grouping of over 1500 galaxies with a cluster diameter of around 54 million light-years centered on M84, M86, and M87. Other nearby galaxy groups within the Virgo Cluster in our neighborhood includes Maffei-1, NGC253 and M81 groups. Moving up in scale, the Virgo Cluster is part of the Coma-Virgo Supercluster, (also called the Local Supercluster), a giant grouping of around 100 galaxy groups with a total of over 20,000 galaxies, and a diameter of over 110 million light-years centered on the Virgo Cluster.

The Coma-Virgo Supercluster is itself part of an even larger structure called the Laniakea Supercluster, (Hawaiian for "immense heaven'), made up of at least four smaller superclusters totaling over 100,000 galaxies stretched over 520 million light-years. And Laniakea in turn may be part of an even greater structure!
The Universe is a big place!!

Getting back to the smaller scale "Local Group" and its three sub-groups:
The Milky Way's satellite system consists of the Large Magellanic Cloud, Small Magellanic Cloud, Sagittarius Dwarf Galaxy, Canis Major Dwarf, Ursa Minor Dwarf, Draco Dwarf, Carina Dwarf, Sextans Dwarf, Sculptor Dwarf, Fornax Dwarf, Leo I, Leo II, and Ursa Major I Dwarf and the Ursa Major II Dwarf.

The much larger Milky Way is cannibalizing several of its smaller dwarf galaxies such as the Sagittarius and Canis Major dwarfs, which are in the process of being stretched into remnant stellar steams.

Andromeda's satellite system consists of the brighter members M32, M110, NGC 147, NGC 185, along with much fainter Pegasus Dwarf, Cassiopeia Dwarf, And I, And II, And III, And IV, And V, And VIII, And IX, and And X.
The Andromeda galaxy is also in the process of gobbling-up several of its own smaller satellite galaxies.

The third sub-group is the Triangulum Galaxy, M33, which is the only unbarred spiral galaxy in the Local Group.
M33 currently does not have any know satellite system of smaller galaxies.

Finally, there are a number of small dwarf galaxies that are not bound to any of the three main galaxies.
These include Sextans-A and the Antlia Dwarf, IC 10, Leo A, Cetus Dwarf, Pegasus Dwarf Irregular, Aquarius Dwarf, and the Sagittarius Dwarf Irregular.

While there's currently 54 individual galaxies identified as members of the Local Group, with the Milky Way blocking a large band of the sky, new discoveries of galaxies with extremely low surface brightness, obscured by our galaxies dust are still being discovered, so the group membership will rise as we develop better instruments.

The first astronomer to identify our local grouping of galaxies as the "Local Group" was Edwin Hubble.
Hubble gave these galaxies this name in his 1936 book, *The Realm of Nebulae*, where he referred to the initial 12 galactic members as "a typical small group of nebulae".

Historical and Modern Astronomers associated with the Local Group:

In addition to the glowing cloud band of light known as the Milky Way, Ancient people also noticed other smaller patches of unmoving 'little clouds' up in the night sky, one in the constellation of Andromeda, and another in the stars of the triangle. Having only their naked-eyes, most people could only speculate as to what these night-time clouds were. Across the ages, people attempted to explain what the Milky Way was. Some thought it was a great mass of luminous vapor. Then there were those who claimed it marked the sun's path across the sky. And still others who thought it was the seam in the sky where the celestial vault didn't quite fit, and was pulling apart.
But there were a few ancient Greek philosophers, such as Aristotle, who speculated that these clouds were made of faint groupings of stars too distant to see individually.

With modern science, we now understand what the Milky Way and the Andromeda and Triangulum galaxies are.
While Hubble was the first to coin the phase "Local Group", we can trace the beginnings of scientific observations of the Local Group members back through history over the last four centuries.

Galileo:

After the invention of the telescope, Italian astronomer Galileo Galilei was the first to use one to observe the Milky Way. Galileo reported in his book "The Starry Messenger" published in 1610, that he was able to resolve the nebulous glowing band into a multitude of individual stars so densely packed that without a telescope they appeared as clouds to the naked-eye.
During this period, German astronomer Simon Marius used his own telescope in 1612 to observe the Andromeda nebula which he described as a dull, pale light, "like a candle shining thru horn", but was not able to resolve it into stars.

Immanuel Kant:

In 1755, German Enlightenment philosopher Immanuel Kant in a paper titled "*Universal Natural History and Theory of the Heavens*" theorized that the stars of the Milky Way, like the sun and planets of the solar system, formed from a large spinning disk of gas and was held together by gravitational forces. This was known as his "Nebular Hypothesis". The reason that the Milky Way galaxy looked like a band was due to our being inside the disk. Kant also thought that other distant "nebulae", which he called 'Island Universes', might be other separate galaxies located outside the Milky Way.

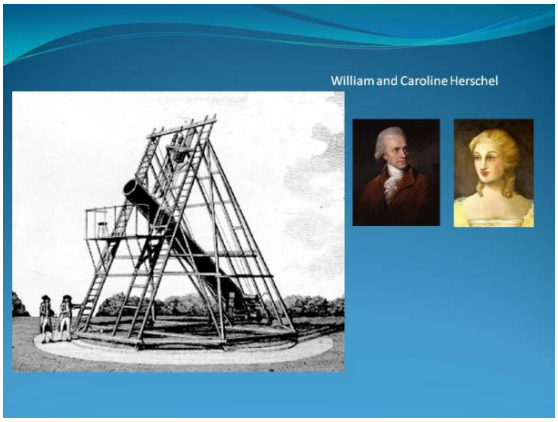
Charles Messier:

While both the Andromeda and Triangulum nebula were well known in Charles Messier's time, in 1764 he still went ahead and listed both small clouds as the 31st and 33rd entry on his list of objects to avoid while comet hunting. Messier used various small telescopes from his observatory in Paris to view both nebulas describing M31 as "Beautiful nebula, shaped like a spindle, center appears clear without any stars appearing, and the light gradually diminishes until extinguished".
And for M33 – "of a whitish light of almost even density and contains no stars".

William Herschel:

In 1785, As the 'Kings Personal Astronomer' to England's King George III, as part of his work to study everything about the night sky, William Herschel made the first attempt to define the actual shape of the Milky Way from observation and measurement by carefully counting the number of stars in different regions of the sky. From his observations, William created a diagram of the Milky Way, placing the solar system at its center, and devised his own theory that our galaxy was disk-shaped.

Herschel also used his "20 foot" reflector to observe both the M31 and M33 nebulas, resolving some features of each and giving them their own designations, such as NGC206 which is a bright section of spiral arm in M31, and NGC604 which is a bright HII region within M33.
Additionally, Williams sister, Caroline, discovered the second satellite galaxy to M31, NGC205, also known in modern times as M110. Herschel described M31 as "brightest part approaches resolvable nebulosity, faint reddish hue to its core", and M33 as "Milky nebulosity, and has a mottled aspect". Herschel believed that both nebulae we know today as galaxies were clusters of unresolved stars which he called "Island Nebulae" to distinguish them from Kant.



Lord Rosse:

Using his 72" reflector, in 1850, Anglo-Irish astronomer William Parsons, the 3rd Earl of Rosse reported that the disks of both M31 and M33, along with a number of other nebula, (particularly M51 which he nicknamed the "Whirlpool Galaxy'), exhibited a spiral shape, and he began referring to these as 'spiral nebula' to distinguish them from the various other nebula. Parsons was also able to visually resolve some individual stars in the spiral nebula that he observed.

Herber Curtis:

American astronomer Herber Curtis (1872 – 1942), born in Muskegon, Michigan and after attending the University of Michigan, earned his PHD in Astronomy in 1902 from the University of Virginia.
Herber was known for his studies of solar eclipses, having participated in 11 eclipse expeditions.
During his professional career, Curtis worked at Lick Observatory and served as president of the Astronomical Society of the Pacific. In 1918, he was the first astronomer to observe the jet coming out of the core of M87.
He later was appointed in 1920 as director of the Allegheny Observatory in Pittsburgh. In 1930, Curtis accepted a position as director of the University of Michigan's astronomical observatories where he finished his career.

While at Lick Observatory in 1917, researching the spectrum of a prior nova, (1885A, S Andromedae), that appeared to be from within the Andromeda Nebula, Curtis uncovered 11 more examples of nova from within the nebula. Curtis determined all 12 of the 'Andromeda' nova had similar magnitudes that were at least 10 times fainter than similar nova from within the Milky Way. Taking into account the differences in nova magnitudes, Herber calculated that the Andromeda Nebula must be at least 490,000 light-years distance, well outside of the

Milky Way galaxy. From this, Curtis became a leading proponent of Kant's 'Island Universe' hypothesis that spiral nebula were all external from the Milky Way.

Harlow Shapley:

American astronomer Harlow Shapley, (1885 - 1972), born in the small town of Nashville Missouri, studied astronomy at the University of Missouri starting in 1907, and later earned his PH.D from Princeton University. After graduating, Shapley was hired by George Hale to work at Mt Wilson Observatory with the 60" reflector, at the time, the largest telescope in the world.

Shapley served as director of the Harvard College Observatory from 1921–1952, and published a number of books on astronomy. One of the lesser known catalogs of open star clusters is the Harvard catalogue, of 21 open clusters and was compiled in 1930 by Shapely. His other major accomplishments include correctly estimating the size of the Milky-Way galaxy using RR Lyrae stars and their Period-Luminosity Relationship, and the sun's position within the Milky Way of being two-thirds toward the outer edge rather than in the center of the galaxy. Shapley was elected president of the American Association for the Advancement of Science in 1947. In 1953, he came up with the "Liquid Water Belt" habitable zone theory of planetary formation around stars.

During his early career, Shapley as an avid supporter of the Milky Way being the entire universe, with spiral nebula as just another type of nebulous gas object within the Milky Way.

While initially criticizing and opposing astronomer Edwin Hubble's galaxy distance observations, after seeing and analyzing Hubble's data, Shapley realized that Hubble was fundamentally correct, and became a supporter of Hubble's theory. Shapley went on to make significant contributions in the research of galaxy distribution, mapping over 76,000 galaxies. He was one of the first astronomers to support the theory of galaxy superclusters.

The Great Debate - external galaxies vs. internal nebula:

At the turn of the 20th century, one of the major questions that professional astronomers were trying to answer was "how far away are the galaxies?" In April of 1920, the question of what were spiral nebulae and the size of the universe came to a head. The National Academy of Sciences hosted a public lecture at the Smithsonian Museum between astronomers Curtis and Shapley who both presented opposing papers.
Shapley defended that spiral nebulae were all small objects located inside the Milky Way, and Curtis argued that the spiral nebulae are large 'island universes' that were located far outside the Milky Way.

Shapley's main line of argument was that as the overall luminosity of the Andromeda nova generally matched nova elsewhere in the Milky Way so that the nova observed in M31 must also be nearby. But his key supporting fact was based on observations from another astronomer (Adriaan Van Maanen) that rotation had been observed in M101, 'Pinwheel' Galaxy'. If the M101 spiral nebula was external to the Milky Way, this visible rotation would be a violation of the speed of light!

Curtis used his Andromeda nova magnitude research as his key evidence in arguing for galaxies being much further away external objects. He also used the measurable Doppler Redshift and the dark dust lanes visible in the spiral nebula arms that resembled the Milky Way's as additional proof that spiral nebulae were independent external galaxies.

The general consensus of the astronomical world after the debate was it was mostly a draw, with Shapley having the edge in being a stronger debater than Curtis. But, it soon turned-out that Curtis had the better observational facts, as Shapley's key supporting argument that rotation had been observed in M101 was based on Van Maanen's using an old optically defective blink-comparator machine and his observations were disproven.
The answer to the question on spiral nebulae would have to wait until another astronomer could more accurately measure the distance to the galaxies.

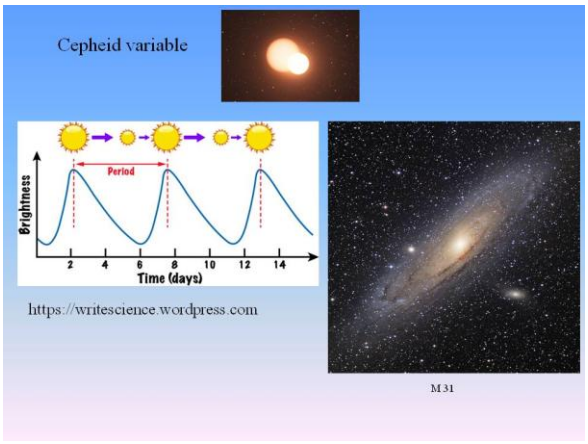
Edwin Hubble:

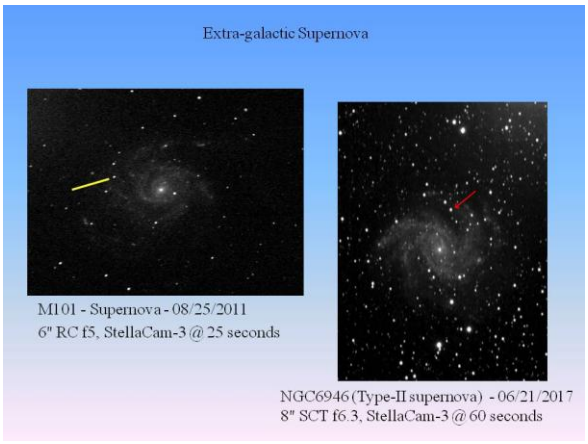
American astronomer Edwin Hubble, (1889 – 1953), was born in Marshfield, Missouri but grew up in Wheaton, Illinois where he developed a passion for astronomy. Hubble attended the University of Chicago, where he studied law and graduated with a BS in 1910, and spent three years as one of the first Rhoades Scholars at Queens College, Oxford England which he graduated from in 1913 with a master's degree. After spending several years teaching high-school physics in Indiana, Hubble re-enrolled back at the University of Chicago to study astronomy, and while there worked at the Yerkes Observatory using its 40" refractor. Hubble graduated with his PHD in astronomy in 1917 and enlisted with the US Army to fight in WWI. Before Hubble could make it over to the European battlefront, the war ended. Hubble then went to work for George Hale at the Mt Wilson Observatory in 1919 and was one of the first groups of astronomers to utilize the new 100" Hooker reflector in studying Cepheid variables. Hubble remained at Mount Wilson for the remainder of his career and became the first astronomer to use the completed 200" Hale reflector.

While using the 100" Hooker telescope in 1923 for a photographic study of the Andromeda nebula, Hubble discovered a number of Cepheid variables within the spiral nebula. Using Shapley's own RR Lyrae based Period-Luminosity Relationship theory; Hubble was able to determine their distance to be greater than the accepted size of the Milky Way.

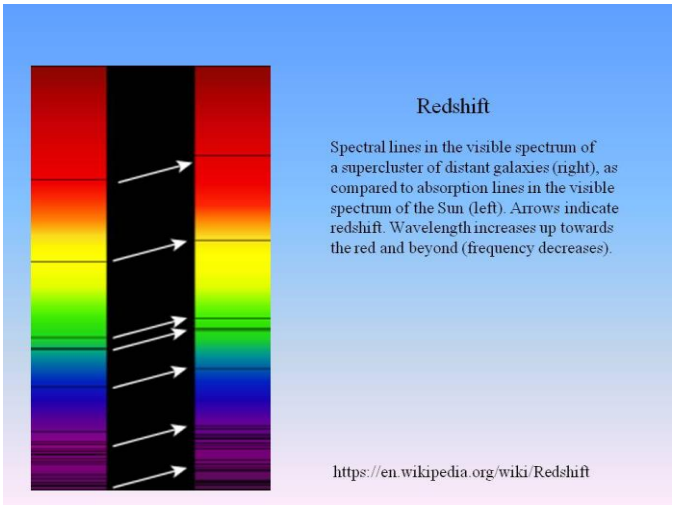
By 1925, Hubble's observations of additional Cepheid's in the Andromeda and Triangulum nebulas proved conclusively that they were too distant to be located inside of the Milky Way and that spiral nebula were in fact external to the Milky Way. The first accurate distances to galaxies had finally been determined by Edwin Hubble using Cepheid variables. Hubble had finally answered the old question of external galaxies vs. internal nebula and settled the Great Debate in favor of Immanuel Kant's 1755 'island universes'!

Cepheid variables are stars that vary their brightness by a specific range and timeframe.
This relationship between the star's luminosity and period of change allows astronomers to determine what its true brightness is and allows them to determine the star's distance. Using this relationship, astronomers were able to accurately calculate distances to Cepheid's in our Milky-Way galaxy. With the discovery of Cepheid's in the nearby galaxies, such as M31 the Andromeda Galaxy, this allowed astronomers to extend accurate distances throughout the Local Group of galaxies.





But in galaxies much further away, Cepheid's were not identifiable, so astronomers turned to another celestial yardstick, supernovas. Extra-galactic nova's and supernova's are similar to Cepheid's in that their intrinsic brightness could be compared against these stellar explosions that have occurred within our own galaxy.
This allowed us to measure distances out into our nearby supercluster of galaxies, (Virgo and Coma Clusters).
To go even further out into the universe, Hubble, working with astronomers Vesto Slipher and Milton Humason in 1929, discovered that every galaxy has a measurable redshift that could be utilized. The greater the spectral lines of an object are shifted towards the red end of the spectrum, the greater its distance is from us. The symbol for redshift, expressed as a fractional displacement of wavelength is 'z'. An object with z=0.0 or smaller has a low redshift and is nearby.



A redshift greater than z=0.0 is a high redshift and represents an object very far away. The bigger the number, the father away it is. A central part of today's 'Big Bang' cosmology this key tenet is named Hubble's Law. Basically stated, Hubble's Law is that the larger an objects redshift, the farther away it is and the faster it is receding from us. It is a critical piece of the expanding universe theory.

How to Observe the Local Group:

So, where can you find the Local Group Galaxies? Galaxies in general can be found opposite the glowing band of light that we call the "Milky-Way", our home galaxy. Usually, when we want to observe bright or dark nebula and star clusters, the Milky-Way is exactly where we want to look, but for galaxies, this is the "Zone of Avoidance', as all the gas and dust nebula and stars of the spiral arms of our galaxy tend to obscure all the faint extra-galactic 'nebula' that we want to observe. Generally, galaxies come in all shapes, sizes, and brightness, and many are very interesting and worth the effort to find, regardless of the equipment that you use. With the exception of M31 & M33 and a few other brighter members, most of the galaxies of the Local Group are small faint, and will require large aperture telescopes or imaging setups, along with a dark-sky location such as Cherry Springs.

It helps to have a list of the Local Group catalog. There are a number of good observing guides available to the amateur astronomer that includes a list of Local Group members. One of my favorites is "*The Night Sky Observers Guide – Volumes 1 & 2.* These handbooks were written by George Kepple and Glen Sanner, each chapter covering a specific constellation, along with finder charts, sketches, images, and visual descriptions of various deep sky objects, including the Local Group galaxies.

Amateur astronomer Alvin Huey has a great observing book on his website www.faintfuzzies.com
Called "Observing Local Group Members" devoted specifically to the Local Group. It contains finder charts, and DSS images for Local Group members.

Ingredients to successfully observe Local Group Galaxies:

While most Local Group galaxies can be challenging, this is what makes them interesting to find and attempt to visually see or capture an image of.

Observing them visually requires maintaining dark-adaptation, good starcharts, and slow sweeping with a wide-field low-power eyepiece and a fast low focal-length telescope. A nice 80mm F6 or shorter refractor piggybacked on a 10" or greater telescope would work very well. The 80mm acts as a low-power RFT giving you a wide-field in which to find the galaxy and the larger telescope it is attached to allows use of higher magnifications, depending on the object. You'll need all your visual observing skills to find and bring out these subtle objects. Many Local Group galaxies are very faint, and depending on what size telescope you are using, may not be visible. But like any deep-sky object, half the fun is just successfully finding it and knowing what it is that you are observing.

For the Imagers, Local Group galaxies can also be challenging due to their faintest, in that even with an accurate GOTO mount, it may not position the telescope squarely on the object to where it's framed the way you want it. Having a photographic atlas or picture of the galaxy will help you in both locating and identifying the object and in framing your image. I've found that using short-exposure video-astronomy cameras works great in positioning and identifying Local Group galaxies.

Observations of the Local Group Galaxies:

The Milky-Way

The Milky Way, second largest galaxy of the Local Group, is a barred-spiral galaxy (type Sbc) with spiral arms radiating off of either end of the bar and has a diameter between 150,000 and 200,000 light-years and about a 1,000 light-years thick. An example of what the Milky Way may look like is NGC3953, a barred-spiral in the constellation of Ursa Major. Recent studies have indicated that the Milky Way has a bit of a warp to its shape from interacting with its satellite galaxies. With the overall shape of the Milky Way still being a little uncertain, the disk of the Milky Way is believed to be organized into four major spiral arms with several minor arms and spurs.
It is estimated to contain close to 400 billion stars and 10's of billions of planets. The Milky Way's galactic core, located just to the west of the Large Sagittarius Starcloud, contains an intense radio source, Sagittarius A*, which is a supermassive black hole of around 4 million solar masses. The Solar System is located about 27,000 light-years from the galactic core, on a spur along the inner edge of the Orion Spiral Arm. (more recently, astronomers have begun referring to the Orion Arm as the "Local Arm"). The Orion/Local Arm is located between the inner Sagittarius Arm and the outer Perseus Arm. It's estimated to be about 16,000 to 20,000 light-years long and includes nearly all the naked-eye stars. The Sun rotates around the Milky Way about every 220 million years.
The Milky Way galaxy itself is moving at around 600 km per second in the direction of the Andromeda Galaxy.

The Milky Way's two main satellite galaxies are the Large and Small Magellanic Clouds, with the LMC being the fourth largest member of the Local Group, but only about one-hundredth the size of the MW.
The LMC is about 163,000 light-years distant and around 14,000 light-years in diameter. The SMC is around 200,000 light-years away and about 7,000 in diameter. Both the LMC and SMC are classified as spiral galaxies with a central bar structure and both may have once been barred-spirals that have been disrupted by interactions with the much larger Milky Way. The LMC still has at least one spiral arm and is home to the Tarantula Nebula (30 Doradus), one of the largest HII star forming regions in the Local Group. While both satellite galaxies are naked-eye patches comparable to bright Milky Way starclouds, neither the LMC nor SMC are visible for the majority of the Earth's northern hemisphere observers, being only above the horizon for people living no greater than 15 degrees north.

The Milky Way is a low-surface brightness hazy band of light formed from stars that cannot be individually seen by the naked-eye. It appears as a band because we are viewing its disk-shaped structure from within. Any kind of stray light such as from a natural source like the Moon or man-made sources such as light pollution from cities will wash-out most of its faint detail, and can make it difficult to even see from brightly lit urban or suburban areas. Living today in the 21st century's light polluted skies, we can seldom see and enjoy the beautiful splendor of the Milky Way, which can be viewed on a clear, moonless night from the countryside. The light from any nearby city will obliterate much of the faint haze like glow in the night sky that we know of today as our own home galaxy. It is estimated that close to half the world's population can no longer see the Milky Way from where they live, and must travel to a dark-sky park, such as Cherry Springs, where on good nights it can still be bright enough to cast shadows on the ground.

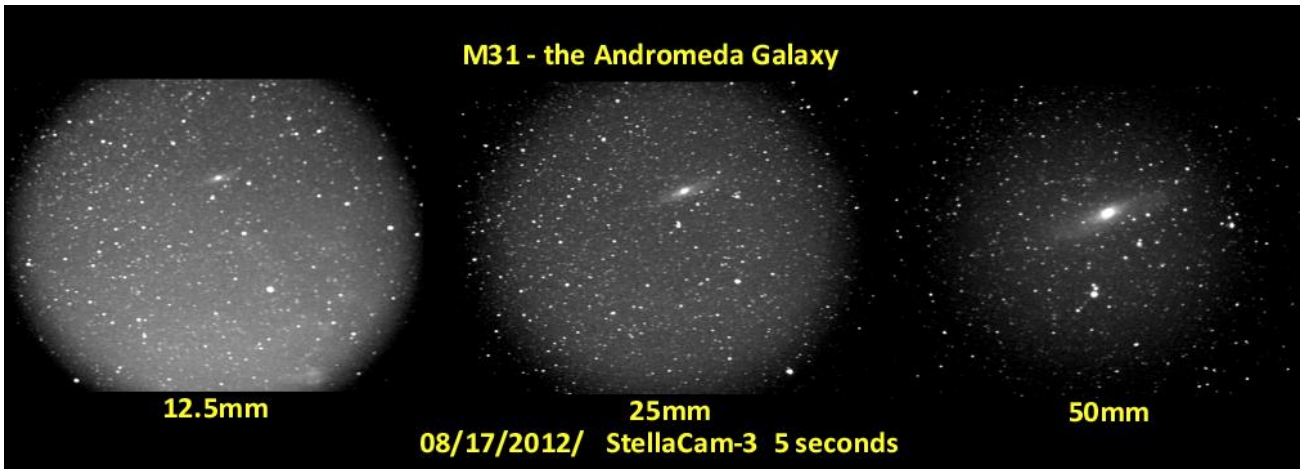
Visually, the Milky Way is made-up of bright knots and star clouds intertwined with dark regions of interstellar gas and dust that blocks the background stars giving the appearance of rifts and holes in the overall shape.

Generally the Milky Way is around 30 degrees in width, with the widest and brightest section located in the region around the constellations of Sagittarius and Scorpius which lay in the direction of the galactic center of our galaxy. Other bright sections that are visible from our northern hemisphere can be found running from nearby constellations of Scutum up thru Aquila into Cygnus where it is bisected by the Great Rift. The stars of the Summer Triangle, (Vega in Lyra, Deneb in Cygnus, and Altair in Aquila), can be used as a guide to find the Milky Way as it passes thru the triangle. The narrowest section is centered on the constellations of Auriga, Gemini, and Orion.

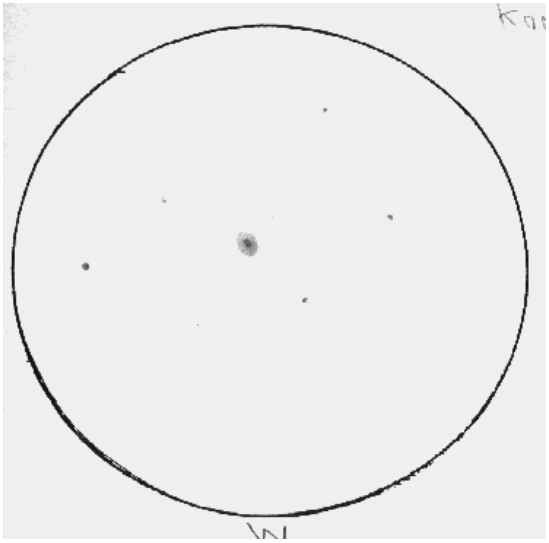
Overall, the band of the Milky Way can be found running thru 30 out of the 88 constellations of the night sky. Because of the high inclination difference in the plane of our solar system and the Milky Way, (about 60 degrees), depending on the observer's location and the time of year, the band of the Milky Way can be seen to arch from the Northeast, high overhead, and down to the Southwest. The late summer, fall season is the best time for this at Cherry Springs. During our northern winter and into spring, the Milky Way occupies lower latitude constellations which further dim its appearance as we're looking thru more of an angle towards the horizon, and thru more of Earth's atmosphere.

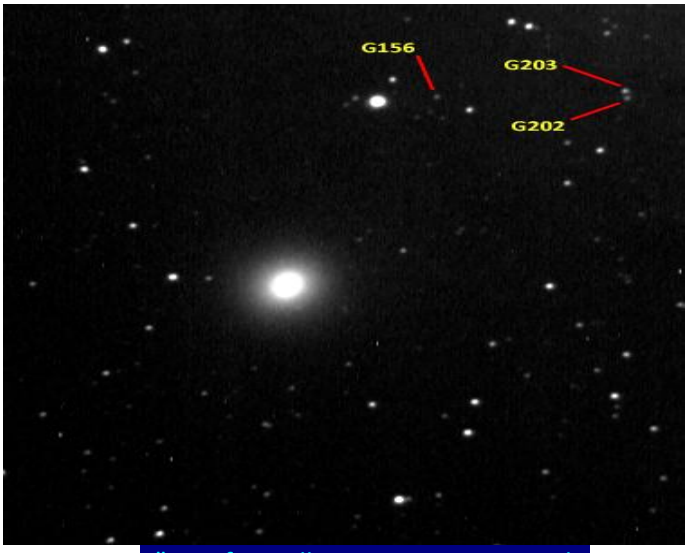
The Milky Way is best observed with your naked-eyes or low power binoculars or a spotting scope.
You'll want to be dark adapted and at a dark-sky location. A planetsphere will help you identify which constellations are best suited for viewing the Milky Way depending on the date and time.

M31 – The Andromeda Galaxy: (including M32 & M110, associations & globular clusters)
The Andromeda Galaxy, is the largest member of the Local Group, is also a barred-spiral galaxy with the bar oriented along the length of the galaxy, and including at least two tightly-wound spiral arms has a diameter of around 220,000 light-years with about one trillion stars. Andromeda's galactic core contains a radio source called 2C 56, with a supermassive black hole of 3 to 5 million solar masses, and a possible double nucleus. The galaxy has over 450 globular clusters, including the most massive cluster of the entire Local Group named Mayall-II, and may be the remnant core of a small galaxy that merged with Andromeda. The Andromeda galaxy is the nearest major galaxy to the Milky Way at about 2.5 million light-years distant, and is moving at around 110 km per second in the direction of the Milky Way, which it will collide with in about 4.5 billion years.



The compact 8.7 magnitude elliptical satellite galaxy M32 (with a diameter of about 6500 light-years) is thought to have once been a small spiral galaxy that had a close interaction with M31 around a billion years ago, which stripped away most of M32's arms and disk, leaving only the core which then underwent renewed star formation from infalling gas and dust, and partly regenerated the small galaxy. M32 contains a massive central black hole of between 1.5 to 5 million solar masses and is a faint radio and x-ray source.

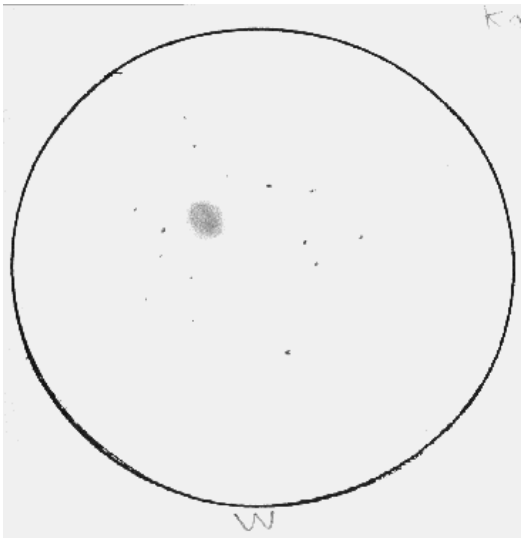


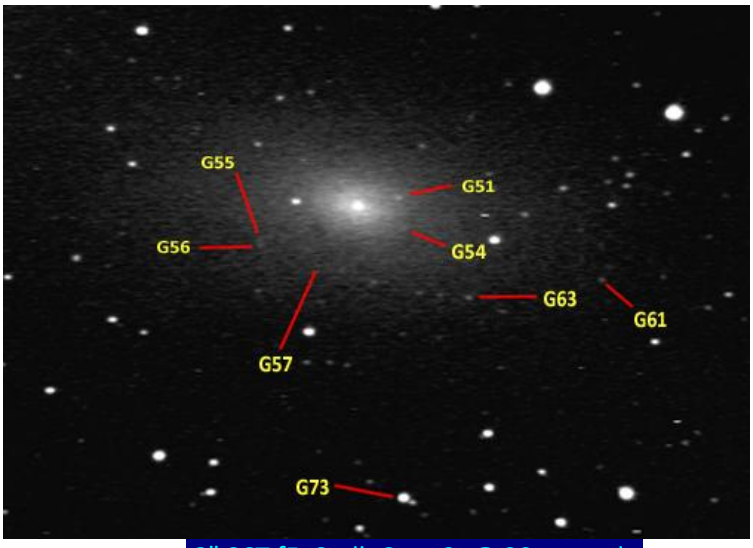


8" SCT f5, StellaCam-3, @ 30 seconds

LM – 09/25/1989, 8" Dob f4.5, 8mm EP 143x: @ suburban backyard
Object: M32 *"Small, round shape, with bright nucleus".*

Andromeda's second satellite galaxy, NGC205 (or M110) at 8.5 magnitude, is a dwarf elliptical, (about 12,000 light-years across), and also shows signs of recently interacting with M31 from a stream of stars and gas stretching between the two. It is classified as being a 'peculiar' galaxy in that unlike most ellipticals, M110 has dust clouds and younger stars near its core. Astronomers have not observed any signs of M110 having a black hole in its galactic center.



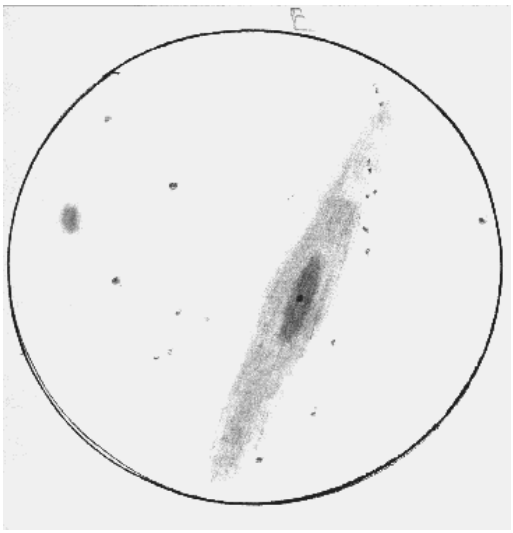


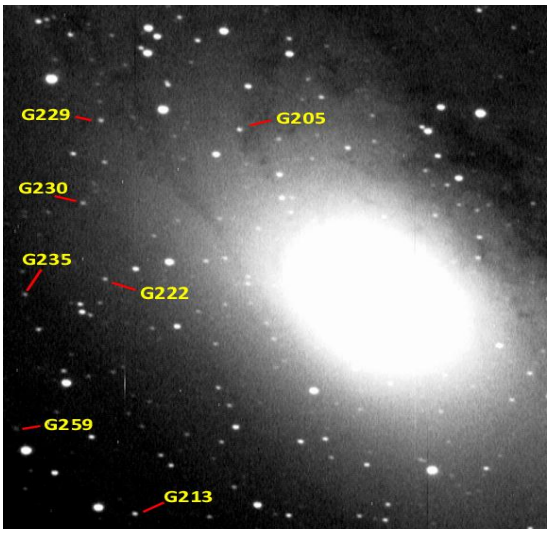
8" SCT f5, StellaCam-3, @ 30 seconds

LM – 09/25/1989, 8" Dob f4.5, 16mm EP 57x: @ suburban county park
Object: M110 *"Moderate size, but very faint. No central bright core".*

At a magnitude of 3.4, the Andromeda Galaxy is visible to the unaided-eye as a bright patch even from suburban areas on moonless nights. On fall nights, it is well-placed almost directly overhead for observing with binoculars or small to medium size telescopes which under good seeing conditions can reveal the galaxy's extended disk and dust lanes, along with its brightest globular clusters. Also visible is the large starcloud NGC206, along with two small satellite galaxies M32 and NGC205 (M110) and several of their globular clusters.
Larger size telescopes of 18" or greater will allow the observer to see additional internal structures within the spiral arms including clusters of OB associations and HII star forming regions.

Andromeda's galactic plane is highly inclined to our point-of-view, around 77%, giving it a near edge-on look, making it difficult to observe its spiral arms.





8" SCT f6.3, StellaCam-3, @ 45 seconds

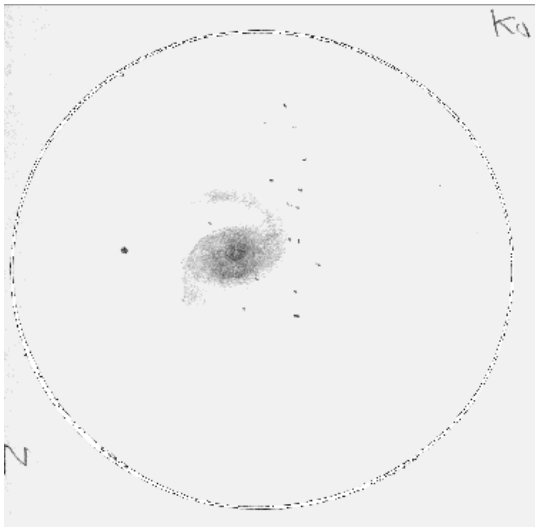
LM – 08/31/1984, 10" Dob f5.6, 27mm EP 52x: @ suburban county park
Object: M31 *"Galaxy extends to either side of the eyepiece. Central core has a star-like point".*

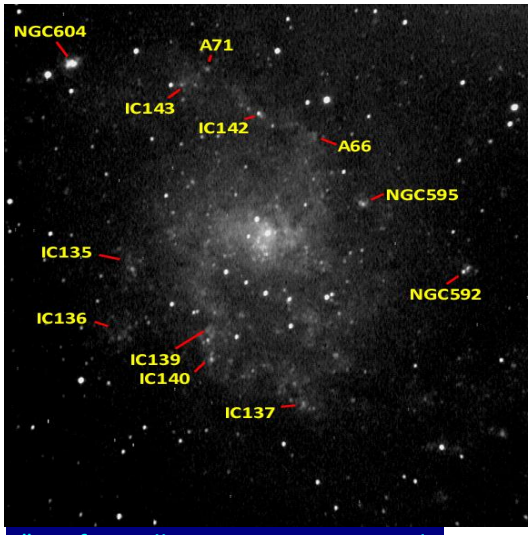
M33 – The Pinwheel Galaxy: (associations & globular clusters)

The Triangulum Galaxy, while it is the third largest member of the Local Group, is only about one-tenth the size of the Milky Way, but it is the only classic shaped spiral galaxy of the Local Group. It has two bright, loosely wound spiral arms, along with multiple connecting spurs, giving the galaxy an overall diameter of around 60,000 light-years with about 40 billion stars. Triangulum's galactic core does not contain either a radio source or a black hole, just a large HII nucleus. The galaxy has over 54 globular clusters identified, along with a number of OB associations. Triangulum does not have any satellite companions, though the Pisces Dwarf galaxy could possibly be in a very distant orbit around M33. The Triangulum Galaxy is about 2.7 million light-years distant, and is moving at around 190 km per second in the direction of the Andromeda galaxy. M33 may be gravitationally bound to the larger Andromeda galaxy. Depending on modeling, the Milky Way may actually collide with M33 just prior to colliding with M31. A three galaxy interstellar pileup!!!

At magnitude of 5.7, the Triangulum Galaxy (also called the Pinwheel), may be visible to the naked-eye from a dark-sky country location on moonless nights. M33's galactic plane has an inclination of about 54° to us, allowing its spiral arms to be viewed without significant obstruction by gas and dust. There is no central bulge visible at the nucleus. On fall nights, like M31,it is well-placed overhead for observing with small to medium size telescopes which under good seeing conditions can reveal the galaxy's extended spiral arms, dust lanes, bright globular clusters, and HII star forming regions such as NGC588, 592, 595, IC132, IC133, with the largest and brightest being

NGC604. With a diameter of around 1500 light-years, NGC604 is one of the largest and brightest known HII emission nebula in all of the galaxies of the Local Group. It, along with three other HII regions is located in the northern spiral arm, to the northeast of the central core. The southern arm of M33 has been a major source of extra-galactic supernova, with at least 100 supernova remnants having been identified.





6" RC f5, StellaCam-3, @ 45 seconds

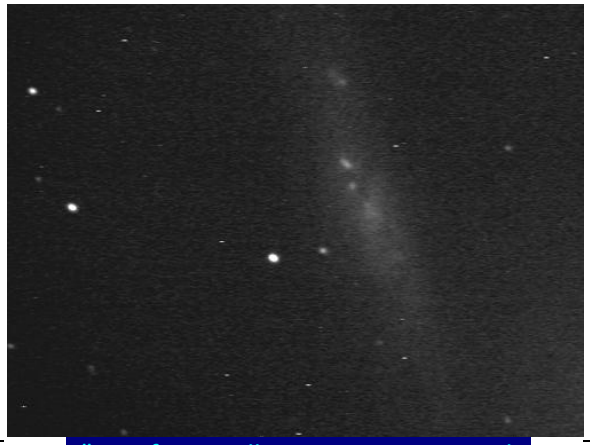
LM – 10/22/1989, 8" Dob f4.5, 16mm EP 57x: @ suburban county park
Object: M33 *"Very large, but dim. Two faint arms visible aligned north & south. Also faint knots".*

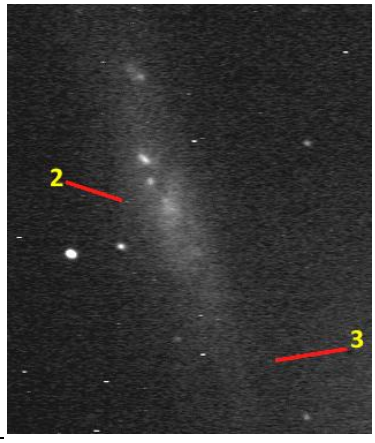
Other bright local members

NGC55

The 8.4 magnitude small Irregular barred-galaxy NGC55 is located about 5.8 million light-years distant from the Milky Way, and is located in the constellation of Sculptor. (it is probably actually a member of the Sculptor Galaxy Group instead of the Local Group) It has a diameter of about 50,000 light-years, and has active star formation ongoing in its central region.

Visibly, NGC55 is oriented nearly edge-on to our view point. It has a bright core, with dust clouds and knots of HII star forming regions, along with several globular clusters visible in medium to large telescopes.



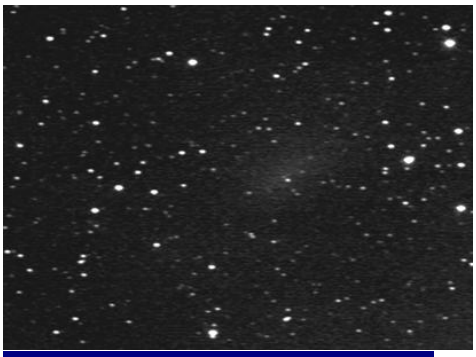


8" SCT f6.3, StellaCam-3 @ 30 seconds

NGC147

The 10.4 magnitude dwarf Elliptical galaxy NGC147 is located about 2.6 million light-years distant from the Milky Way, and located in the constellation of Cassiopeia. It has a diameter of about 4,500 light-years across.

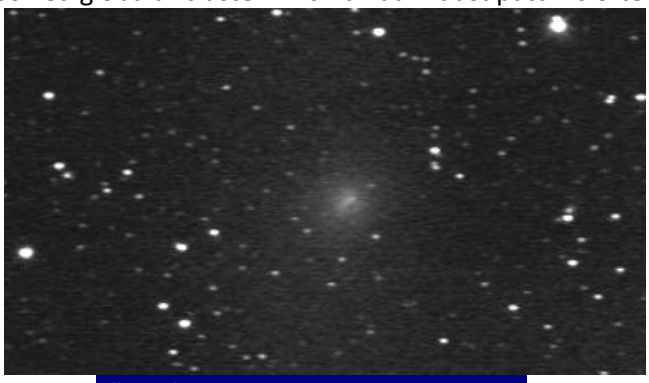
Visibly, NGC147 has a faint, low-surface brightness, and has an elongated lenticular shape.



6" RC f5, StellaCam-3 @ 20 seconds

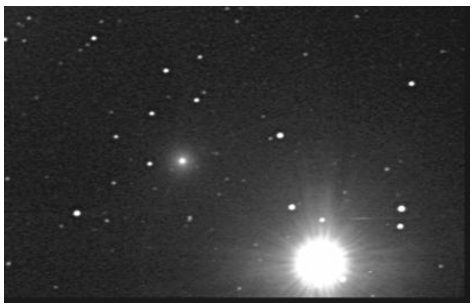
NGC185

The 9.2 magnitude dwarf Elliptical galaxy NGC185 is located about 2.2 million light-years distant from the Milky Way, and located in the constellation of Cassiopeia. It has a diameter of about 2,300 light-years, and shows active star formation. NGC185 is classified as a quasar-like Seyfert galaxy with an Active Galactic Nucleus (AGN), and is the closet known Seyfert galaxy to the Milky Way. Both NGC185 and NGC147 lay about seven degrees to the north of are gravitationally bound to M31 and are considered to be satellites of the giant spiral, with NGC185 being the brighter of the pair. Visibly, NGC185 is a moderately faint low-surface brightness galaxy that somewhat resembles an unresolved globular cluster. A small dark dust patch is often visible in larger telescopes.



6" RC f5, StellaCam-3 @ 20 seconds

NGC404 (Mirach's Ghost)



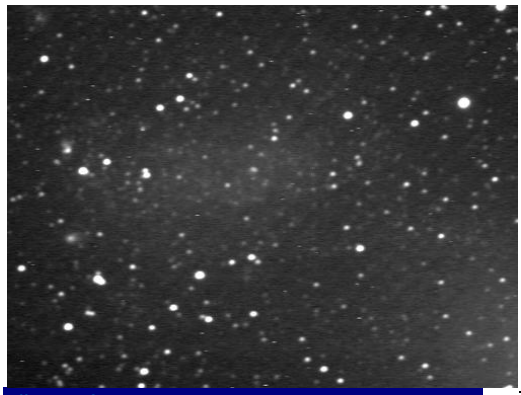
The 10.1 magnitude dwarf Lenticular galaxy NGC404 is located about 10 million light-years distant from the Milky Way, just beyond the edge of the Local Group boundary, and today is technically considered to be no longer a member of the Local Group. NGC404 is located in the constellation of Andromeda. The galaxy has a diameter of about 65,000 light-years, and contains a likely small central black hole of less than 50,000 solar masses. Visibly, NGC404 can be difficult to observe, as it lays just seven degrees away from the 2nd magnitude bright star of Beta Andromedae (Mirach). It has a bright round central core that gradually decreases in brightness. This deep-sky object and star is a good example of line-of-sight distances as the star is only 200 light-years away, while the galaxy is 10 million light-years from us.

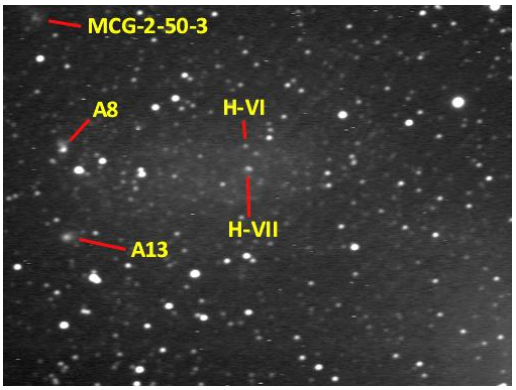
8" SCT f6.3, StellaCam-3, 45 seconds

NGC6822 (Barnards Galaxy)

The 8.5 magnitude Irregular barred-dwarf galaxy NGC6822 is located about 1.5 million light-years distant from the Milky Way, and is located in the constellation of Sagittarius and heavily obscured by the Milky Way. It has a diameter of about 7,000 light-years, and shows active star formation. After the Magellanic Clouds and the Sagittarius Dwarf galaxies, NGC6822 is the fourth closet galaxy to the Milky Way.

Visibly, NGC6822 is highly inclined to our view point, with several HII star forming regions and large OB associations being observable in medium to large size telescopes.

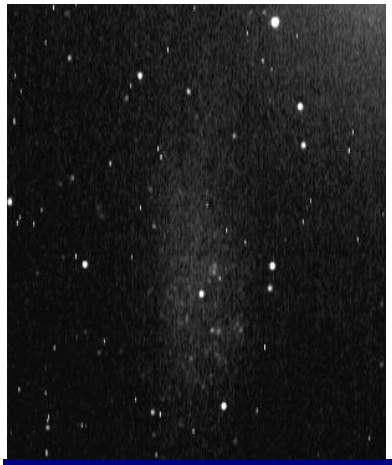


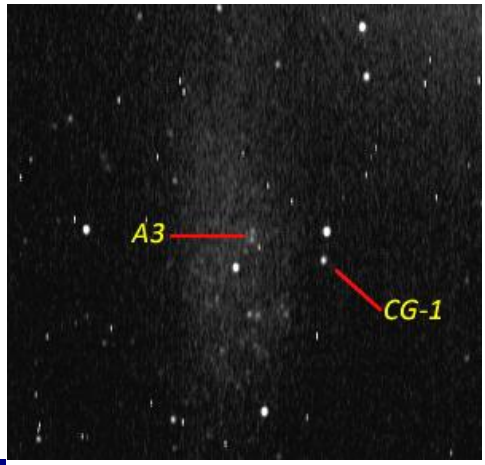


8" SCT f6.3, StellaCam-3 @ 180 seconds

WLM (MCG-3-1-15) (Wolf-Lundmark-Melotte)

The 10.9 magnitude Irregular dwarf galaxy WLM is about 3.4 million light-years distant from the Milky Way, one of the most remote members of the Local Group, in the constellation of Cetus. It has a diameter of about 8,000 light-years, and shows active star formation. Visibly, WLM is large diffuse low-surface brightness galaxy with an elongated oval shape. It has no defined core, but shows visible mottling all along its length, along with several OB associations and globular clusters in large telescopes.





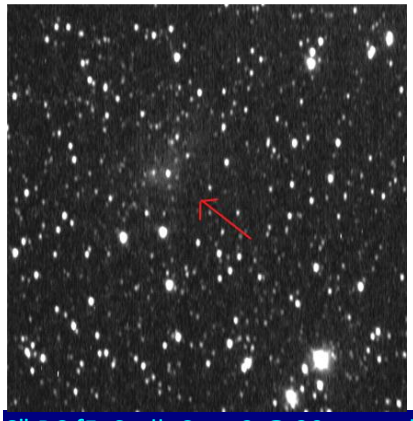
8" SCT f6.3, StellaCam-3 @ 120 seconds

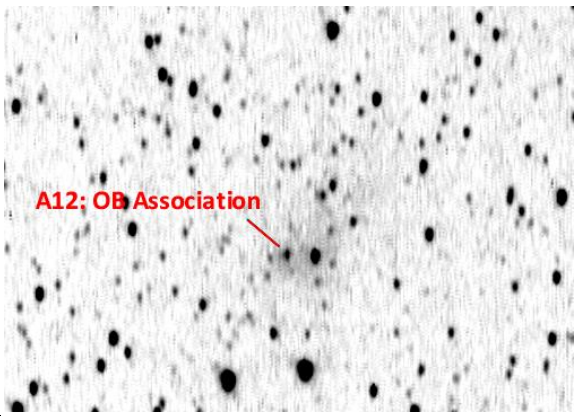
The really faint stuff

IC10

The 10.4 magnitude Irregular dwarf galaxy IC10 is located about 2.3 million light-years distant from the Milky Way, and located in the constellation of Cassiopeia. It has a diameter of about 5,000 light-years, and shows active star formation as a starburst galaxy with an HII nucleus. IC10 is one of the few galaxies that exhibit a blueshift as it is moving toward the Milky Way at 350km/s.

Visibly, IC10 is difficult to observe as it is heavily obscured by the Milky Way, and has a small faint irregular shape. Through a large telescope at a dark sky site, several knots of knots of HII star forming regions are visible.

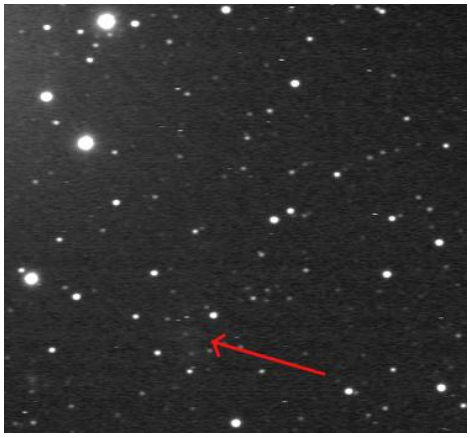




6" RC f5, StellaCam-3 @ 30 seconds

Aquarius Dwarf (MCG-2-53-3)

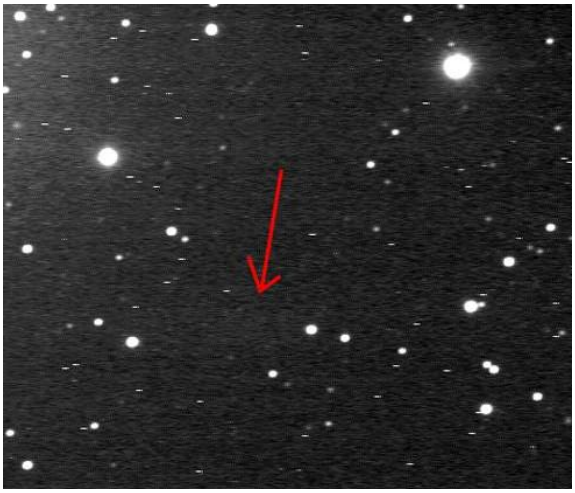
The 13.9 magnitude Irregular dwarf galaxy Aquarius Dwarf is located about 3.4 million light-years distant from the Milky Way, and located in the constellation of Aquarius. The Aquarius Dwarf is one of the youngest galaxies in the local group at about 6.8 billion years, not much older than our solar system. It is one of the dimmest members of the Local Group with a very low level of star formation and contains a large amount of neutral hydrogen. Visibly, the Aquarius Dwarf is extremely faint irregular patch, requiring a larger 20" or greater telescope.



8" SCT f6.3, StellaCam-3, @ 120 seconds

Pisces Dwarf

The 15.4 magnitude Irregular dwarf galaxy Pisces Dwarf is located about 3 million light-years distant from the Milky Way, and located in the constellation of Pisces.
The galaxy shows little active star formation.
Visibly, the Pisces Dwarf is another extremely faint elongated smudge that will be barely visible in 25" telescopes and requiring deep exposures from imaging setups.



8" SCT f6.3, StellaCam-3 @ 300 seconds

UGCA-86 (PGC14241)

The 15.2 magnitude Irregular galaxy UGCA-86 is located about 6.2 million light-years distant from the Milky Way, and can be found in the constellation of Camelopardalis. As UGCA-86 lies close to the Local Group boundary, there is some question as to whether it is an actual member.

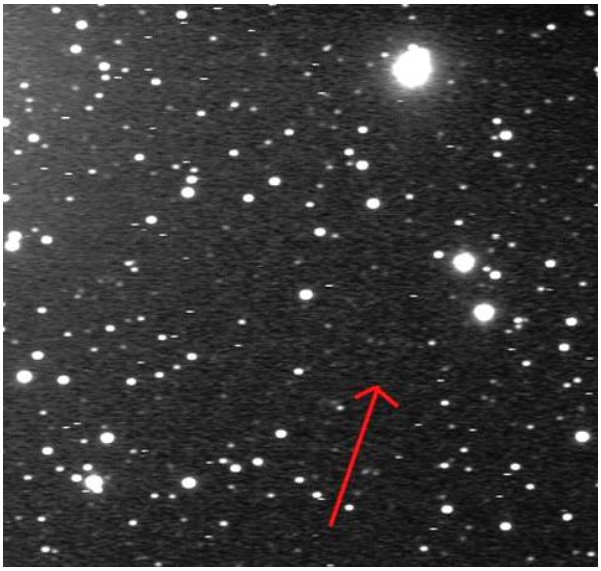
Visibly, UGCA-86 is heavily obscured by the Milky Way and is quite faint! Fortunately a number of bright stars help to identify the galaxy's location in the field-of-view. Still, you'll need a large telescope or imaging rig to pull this one in.

8" SCT f6.3, StellaCam-3 @ 180 seconds

Andromeda-I thru X (forget about it!,,, seriously,, just don't!)

The 16.1 magnitude dwarf Elliptical galaxy Andromeda-X is located about 2.4 million light-years distant from the Milky Way, and located in the constellation of Andromeda.

Visibly, Andromeda-X is probably impossible, unless you have a 30" or greater telescope. It is considered to be the dimmest Local Group member, and will even drive imagers to pull out their hair.



8" SCT f6.3, StellaCam-3 @ 180 seconds

Conclusion

So today, we've learned what the "Local Group" is, some of the people, both historical and modern, behind these objects, and how to go about observing them. We've also reviewed observations of the more prominent members of the Local Group, along with a number of the fainter ones.

Hopefully, you now find them as interesting to hunt as I do.

So I encourage everyone to get out tonight and try your hand at finding and observing our neighborhood of galaxies known as the "Local Group"!

Galaxy Clusters: Abell's, Hickson's, and Palomar's

I love EAA observing galaxies!
Especially the large, bright showcase Messier and the NGC galaxies that show plenty of spiral arm details or interactions with other nearby galaxies. But Galaxy Clusters,,,,, What are they? And how do the bright galaxies that we like to observe fit in with these clusters.

A few years back, I became interested in observing Hickson Compact Galaxy Clusters. That prompted me to also begin a detailed examination of the larger scale Abell clusters and the much smaller, more fainter & compact, Palomar clusters.It's been an interesting observational journey into the 'universe' of galaxy clusters, macro to micro. Most galaxy clusters are faint and / or sparse, and not very appealing visually, but each catalog has a number clusters that are worth looking for.

So today, we'll discuss what I've learned during that journey among the galaxy clusters, along with some of the people, behind these catalogs, and how to go about observing these objects. Along the way, we'll also review a number of my personal EAA observations of galaxy clusters. Hopefully, when we are done, you will find them as interesting to hunt and observe as I do.

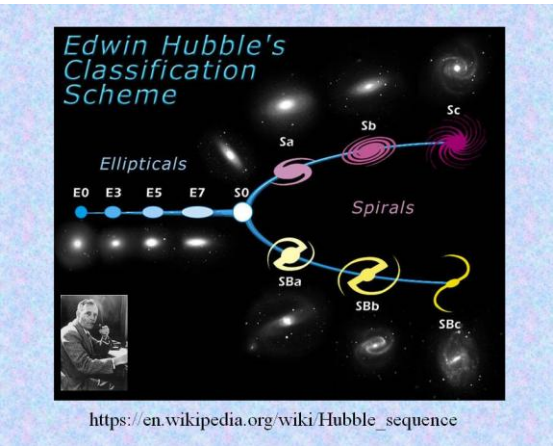
Outline:

Galaxies – What are they?

Galaxies are large systems of stars and interstellar clouds of matter, typically containing from several hundred million to several trillion stars. They originate from large cosmic primordial clouds of hydrogen and helium gas through-out the universe that slowly collapsed. Most galaxies formed at about the same time, within the first few billion years after the universe started to expand. They run in size from a few 10's of thousands to several 100,000 light years in size, and are separated from other galaxies by millions of light years.

Classic Galaxy Morphology:

Galaxies come in several types, and though of a wide variety of shapes and appearances, have many basic common features. From their appearance, galaxies are classified as spiral, lenticular, and elliptical.
In the early 20th century, astronomer Edwin Hubble devised a galaxy classification diagram based on their visual appearance. This classification is commonly called the "Hubble Tuning Fork diagram". Hubble divided the galaxies into three broad classes: spiral, elliptical, and lenticular. All the main types have sub-category classifications, and we still use a modified version of this today.



Elliptical **-** Elliptical galaxies are shaped like giant luminous cotton balls, and have no spiral or disk components. They have little or no rotation as a whole. Normally, elliptical galaxies contain very little or no interstellar matter, and consist of older population stars only:

Lenticular **-** Lenticular galaxies are shaped like spiral galaxies without a spiral structure. They are smooth disk galaxies, where stellar formation has stopped long ago, because the interstellar matter was used up. They consist of mostly older population stars only. From their appearance and stellar contents, they can often be observationally confused with ellipticals.

Spiral **-** Spiral galaxies usually consist of three major components: A flat, large disk which often contains interstellar matter visible as diffuse glowing emission nebulae or as dark dust clouds.
Young open star clusters, associations, and random stars arranged in conspicuous and striking spiral patterns and or bar structures. Finally, a central bulge or core, consisting of older stellar populations with little interstellar matter, and often surrounded by a halo of older globular star clusters.

Irregular **-** Irregular galaxies have many different shapes and sizes due to distortion by the gravitational pull of their intergalactic neighbors. These galaxies do not fit into the scheme of spirals, disks and ellipsoids, and exhibit no particular shape.

Galaxy Groups & Clusters:
Galaxies are scattered throughout the visible universe. Some galaxies are isolated "island universes" which float lonely through an otherwise empty region of space. But the distribution of matter in the universe is not uniform.

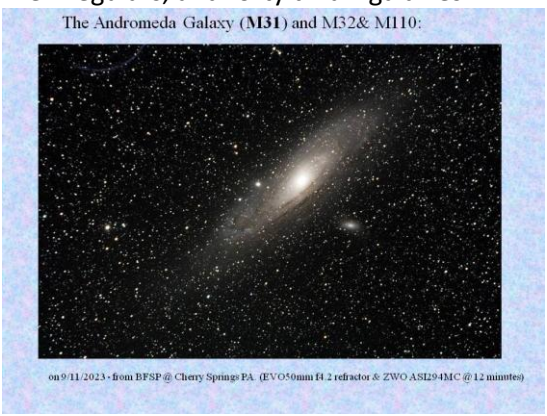
The majority of galaxies are gravitationally clumped together in groups, running from a handful to a few dozens of galaxies, such as our “Local Group”, to large clusters of hundreds of galaxies such as the Virgo galaxy cluster, to the larger Abell galaxy clusters of upwards to several thousands of galaxies, which in turn are bound into giant superclusters of 10’s of thousands of galaxies. These huge structures are the fundamental building blocks of the universe!

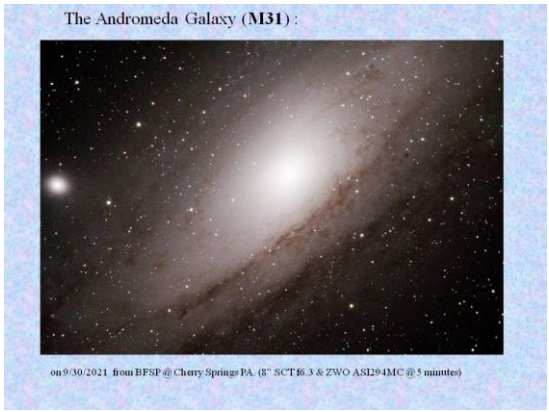
These groups are generally scattered across vast distances, but some are compact due to mutual gravitational interaction, which may have significant influence on their appearance. The individual galaxies of these groups vary in size and type classification, but most of the larger clusters contain one or more giant elliptical galaxies at their core.

What is the "Local Group":

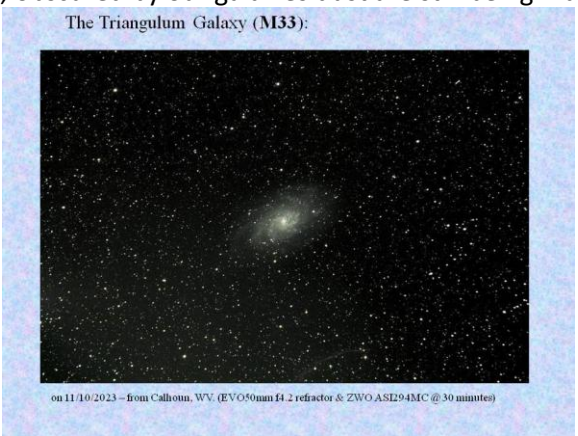
The "Local Group" is the group of galaxies that includes our home galaxy, the Milky Way, and its neighbors. (Named as such by Edwin Hubble in 1936). It comprises more than 54 galaxies, the majority of which are low surface brightness dwarf. The most massive member of the group is M31, the Andromeda Galaxy, followed next by the Milky Way, with the third being M33, the Triangulum Galaxy. Both M31 and the Milky Way each have a system of satellite dwarf galaxies. http://stellar-journeys.org/LocalGroupTour.htm

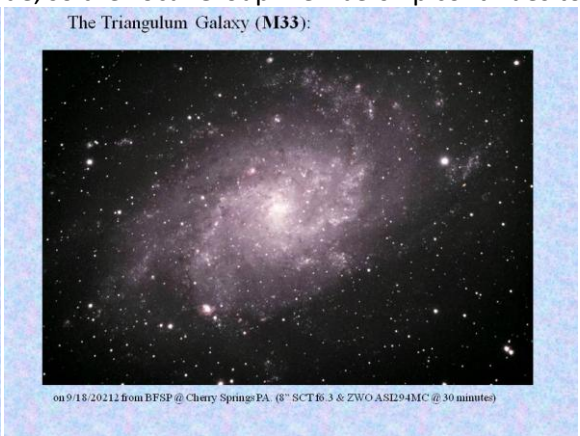
The gravitational center of the Local Group is located between the Milky Way and the Andromeda Galaxy. Overall, the Local Group has a rough diameter of around 10 million light-years, and contains three spirals, two elliptical, nine irregulars, and forty dwarf galaxies.





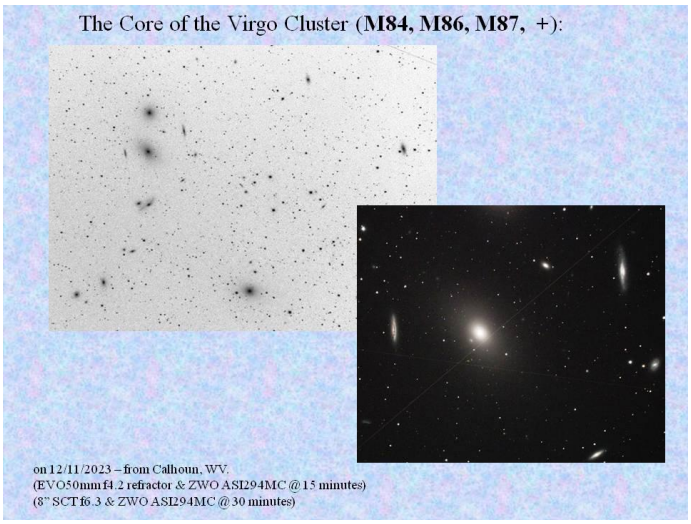
While there's currently 54 individual galaxies identified as members of the Local Group, with the Milky Way blocking a large band of the sky, new discoveries of small dwarf galaxy members with extremely low surface brightness, obscured by our galaxies dust are still being made, so the Local Group membership continues to rise.





What is the Virgo Cluster:

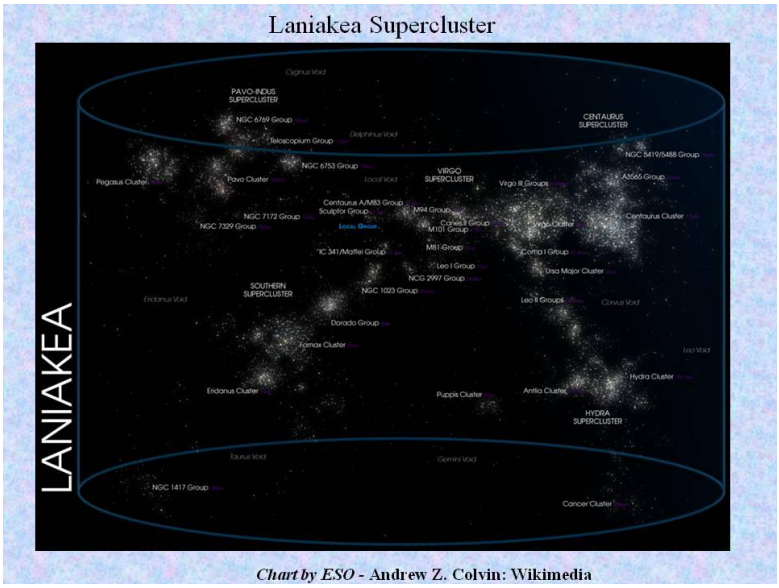
The Virgo Cluster is a grouping of over 1500 galaxies with a cluster diameter of around 54 million light-years centered on the giant ellipticals M84, M86, and M87. (The Local Group is near the outer edge and part of the larger Virgo Cluster). The Virgo cluster can be traced thru the sky starting in southern Virgo to Coma Berenices to Canes Venatici into Ursa Major. Edwin Hubble referred to this region of the sky as the "Realm of the Nebulae".



Cluster Members: M86, M84, NGC438, NGC4388, NGC4402, NGC4413, NGC4425, and IC3303, IC3355, IC3363, and PGC40534, PGC40548, PGC40598, PGC40636, and many, many, more Messier, NGC, etc.

Other nearby galaxy groups within the Virgo Cluster in our neighborhood includes the Sculptor Galaxy Group (which includes NGC253), at about 8 million light years, the Ursa Major Galaxy Group (which includes M81 & M82) at about 10 million light years away, and the Centaurus Galaxy Group (NGC5128) at about 22 million light years.

Moving up in scale, the Virgo Cluster in combination with the Coma Galaxy Cluster (which contains over 1,000 member galaxies centered on the two giant ellipticals galaxies NGC4874 & NGC4889), is part of the Coma-Virgo Supercluster, (also called the Local Supercluster), a giant grouping of around 100 galaxy groups centered on the Virgo Cluster, with a total of over 20,000 galaxies, and a diameter of over 110 million light-years, that stretches across the sky from the constellations of Ursa Major thru Canes Venatici, Coma Berenices, Virgo, to Centaurus. The Coma-Virgo Supercluster is itself part of an even larger structure, called the Laniakea Supercluster, (Hawaiian for "immense heaven'), and made up of at least four separate superclusters totaling over 100,000 galaxies stretched over 520 million light-years. And Laniakea in turn may be part of an even greater structure!
The Universe is a big place!!



What are Abell Galaxy Clusters:

American astrophysicist George Abell was born on March 27th, 1927 in Los Angeles California. (Died from a heart attack at the age of 56, on October 7th, 1983). After graduating from High School in 1945, Abell joined the US Army Air Corps, hoping to become a pilot, but he was instead stationed over in Japan as an Air Corps weatherman. Upon discharge from the service, George enrolled at Caltech where he studied physics and astronomy.

During this time, Abell worked as a 'tour guide' and as a 'lecturer' at the Griffith observatory. Abell graduated in 1951 from the California Institute of Technology with a B.S. in astronomy, continued on for his masters in 1952, and then his doctorate in 1957. Abell's first professional job as a Caltech astronomer was working on the National Geographic Society Palomar Observatory Sky Survey, created using the Palomar 48-inch Schmidt telescope. George's primary research was reviewing the POSS survey photographic plates looking for the formation of galaxy clusters.

Using the Palomar 48-inch Schmidt telescope, Abell compiled a catalog of clusters of galaxies, (2,712), which was first published in 1958 titled "*The Distribution of Rich Clusters of Galaxies*". (Also later called the "*Northern Survey*"). An expanded version, published in 1989, of an additional 1,361 galaxy clusters, (in collaboration with astronomers Harold Corwin and Ronald Olowin), covering the southern hemisphere, brought the catalog up to 4,073 total galaxy clusters. (Often referred to as the "*Southern Survey*").

Abell's qualifications for a galaxy cluster to be included in the catalog were the following four criteria:
(1) A galaxy cluster must have a minimum population of 50 members within a two magnitude range of the 3rd-brightest galaxy cluster member.
These are then divided into six "richness groups" based on the number of galaxies their contained:
Group 0: 30 to 49 galaxies
Group 1: 50 to 79 galaxies
Group 2: 80 to 129 galaxies
Group 3: 130 to 199 galaxies
Group 4: 200 to 299 galaxies
Group 5: greater than 299 galaxies


Abell 2744 – Hubble Space Telescope Frontier Fields observing program.

(The average Abell galaxy cluster contains 64 individual members, falling under the Group 1 classification)
(2) A cluster must be sufficiently compact that at least fifty or more of the cluster members must lie within a radius of about 2 mega parsecs from the clusters center.

(3) A catalog member cluster should have a redshift of between 0.02 and 0.2, corresponding to distances of between 85 and 850 Mega parsec (Mpc). As redshift distance calculation improved over time, Abell divided the galaxy clusters into seven "distance groups" according to the magnitudes of their tenth-brightest galaxy member:
Group 1: mag 13.3 to 14.0
Group 2: mag 14.1 to 14.8
Group 3: mag 14.9 to 15.6
Group 4: mag 15.7 to 16.4
Group 5: mag 16.5 to 17.2
Group 6: mag 17.3 to 18.0
Group 7: mag > 18.0

(4) In general, regions close to the galactic plane of the Milky Way were to be excluded from the study due to the interstellar obscuration by the Milky Way's spiral arms made it difficult to positively identify galaxy clusters.

Abell's catalog continues to be relevant to today's professional astronomers and cosmologist in studies of large-scale three-dimensional structures across the universe. His work is considered to be the first steps in leading to our understanding of the clustering of galaxies into filaments and voids.

What Are Hickson Compact Galaxy Clusters:

Canadian astrophysicist Paul Hickson graduated from the California Institute of Technology with a doctorate in astrophysics in 1976. A few years after, he became a professor at the University of British Columbia their Department of Physics and Astronomy. Using the Palomar Observatory Sky Survey (POSS), Hickson compiled a catalog of 100 faint, compact galaxy clusters which was he published in 1982.

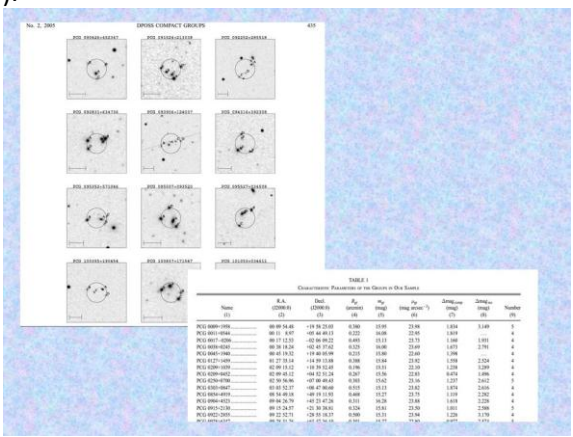
His criteria for inclusion in the catalog was:
(1) Small, relatively isolated, system of typically 4 to 8 galaxies in close proximity to one another.
(2) Specifically, each galaxy cluster had to contain at least 4 members, not be part of a larger cluster of galaxies.
(3) The difference in magnitude between the brightest and faintest cluster member not be more than +3 magnitudes.
(4) Had to be a compact group, and cluster members must have a similar radius of spacing.

Hickson's research goal in creating his catalog was to develop a uniform statistically significant sample to aid in studying galaxy evolution and any discordant red shifts between the individual members of these compact groups.

What are Palomar Compact Galaxy Clusters:

Using the Palomar Observatory Sky Survey, in 2003, Italian astronomer Angela Iovino, of the Brera Astronomical Observatory in Milan Italy, published a research catalog of compact galaxy clusters using tighter selection criteria than what has been used in previous catalogs such as the Hickson Catalog.

Her criteria for inclusion in the catalog was:
(1) Galactic Latitude: Regions close to the galactic plane (+/- 40 deg) of the Milky Way were to be excluded from the study as the Milky Way's spiral arms made it difficult to positively identify faint galaxy clusters.
(2) Richness: A galaxy cluster must have a minimum population of 4 members with only a two magnitude range between the brightest and dimmest galaxy cluster member.
(3) Compactness: The apparent size of a cluster must be less than one arc minute in size. (Smaller than the visual size of the planet Jupiter's disk!)
(4) Isolation: A catalog member cluster must be at least three group size diameters away from any nearest galaxy (3 arc minutes or greater).



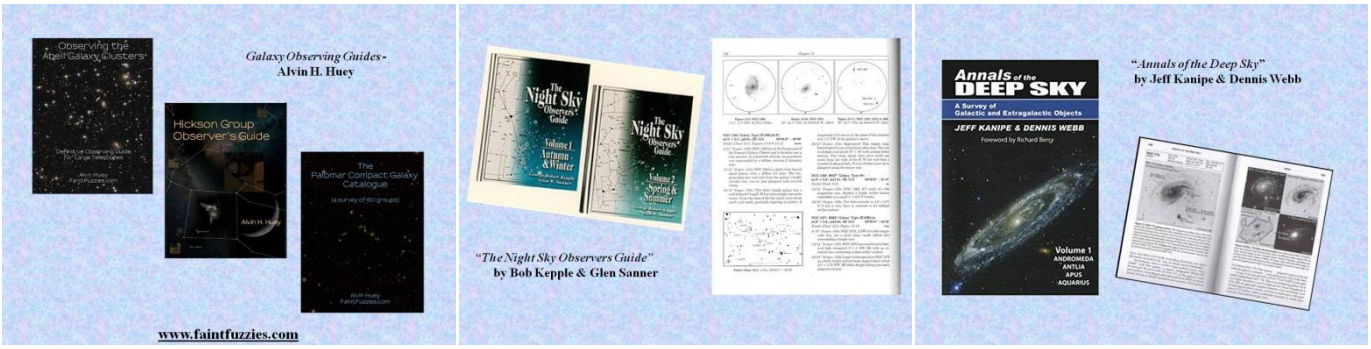
In her paper – "*A New Sample of Distant Compact Groups from the Digitized Second Palomar Observatory Sky Survey*", Dr Iovino identified 459 compact galaxy groups using her selection criteria covering both the northern and southern hemisphere:

How to Observe Galaxy Clusters:

So, where can you find Abell, Hickson, and Palomar galaxy clusters and how do you observe them?
Galaxies in general can be found opposite the glowing band of light that we call the "Milky-Way", our home galaxy. Usually, when we want to observe bright or dark nebula and star clusters, the Milky-Way is exactly where we want to look, but for galaxies, this is the "Zone of Avoidance', as all the gas and dust nebula and stars of the spiral arms of our galaxy tend to obscure all the faint extra-galactic 'nebula' that we want to observe. Generally, galaxies come in all shapes, sizes, and brightness, and many are very interesting and worth the effort to find, regardless of the equipment that you use. With a few exceptions most galaxy clusters are small faint, and will require large aperture telescopes or imaging setups, along with a dark-sky location such as Cherry Springs.

There are a number of good 'galaxy cluster' related observing guides available to the amateur astronomer.
One of my favorites is "*The Night Sky Observers Guide – Volumes 1 & 2.* These handbooks were written by George Kepple and Glen Sanner, each chapter covering a specific constellation, along with finder charts, sketches, images, and visual descriptions of various deep sky objects, including various galaxy clusters.

Amateur astronomer Alvin Huey has a great observing book on his website www.faintfuzzies.com devoted specifically to observing galaxy clusters. They contain finder charts, and DSS images for catalog members.



And "Annals of the Deep Sky!" – goes into deep details on all the current astrophysical characteristics of galaxy clusters.

Ingredients to successfully observe Galaxies:

While most galaxy clusters can be challenging, this is what makes them interesting to find and attempt to visually see or capture an image of. Observing them visually requires maintaining dark-adaptation, good starcharts, and slow sweeping with a wide-field low-power eyepiece and a fast low focal-length telescope. An 80mm F6 or shorter refractor piggybacked on a 10" or greater telescope would work very well. The 80mm acts as a low-power RFT giving you a wide-field in which to find the galaxy cluster and the larger telescope it is attached to allow use of higher magnification.

You'll need all your visual observing skills to find and bring out these subtle clusters.
Many galaxy clusters are very faint, and depending on what size telescope you are using, most of their member galaxies may not be visible. The observer is much more likely to only see the higher contrast elliptical and lenticular galaxies, and edge-on spirals than any face-on low-surface brightness spirals. But like any deep-sky object, half the fun is just successfully finding the galaxy cluster and knowing what it is that you are observing.

For the Imagers, galaxy clusters can also be challenging due to their faintest or large scale, in that even with an accurate GOTO mount, it may not position the telescope squarely on the cluster to where it's framed the way you want it. Having a photographic atlas or picture of the galaxy cluster will help you in both locating and identifying the object and in framing your image. I've found that using short-exposure EAA camera techniques works great in positioning and identifying galaxies.

My Observations of Galaxy Clusters:

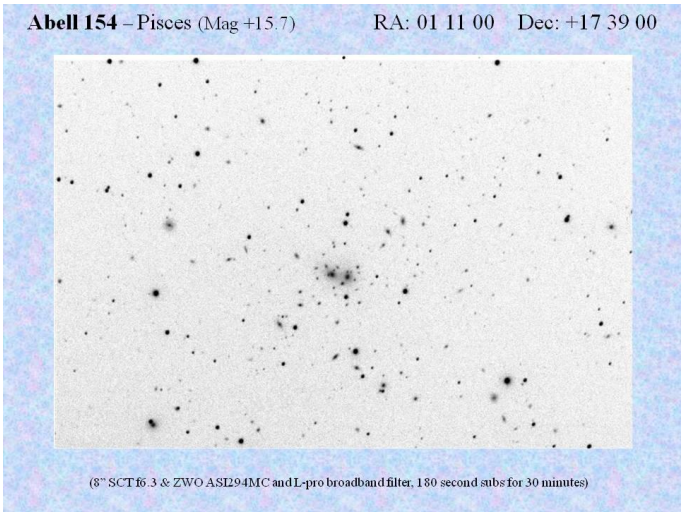
As I mentioned earlier, it's been an interesting observational journey among the 'universe' of galaxy clusters.
The Abell clusters – where the FOV overflows with numerous relatively nearby galaxies.
To the intermediate size, & distance Hickson clusters of compact groups of galaxies.
To the tiny, faint, and very distant Palomar compact clusters where the galaxies look like a few little grains of sand.

Abell Galaxy Clusters:

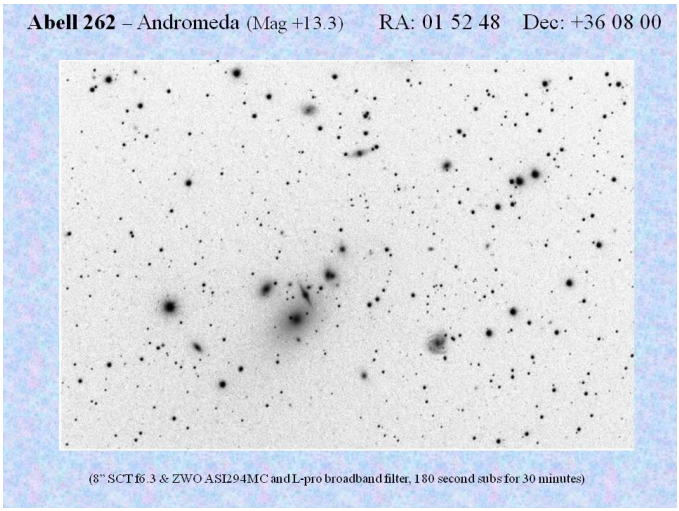
Abell's catalog is recognized as an excellent compilation of galaxy clusters for the observer with access to medium to large telescopes and dark skies. While several of the clusters contain one or more relatively bright NGC or IC galaxies, the majority of the catalog is galaxy clusters of faint PGC, UGC, or MCG galaxies. (+12th mag or fainter). Many of the groups, (officially designated as 'ACO'), have at least one member plotted in several popular printed star atlases such as 'Uranometra 2000' or the 'Millennium Star Atlas". For the most part, they can be difficult to observe, but broadband light-pollution filters, such as the L-Pro, can be a big help, allowing the galaxies to 'pop' from the star field. http://stellar-journeys.org/AbellGalaxyTour.htm

Abell Galaxy Cluster Exmples:

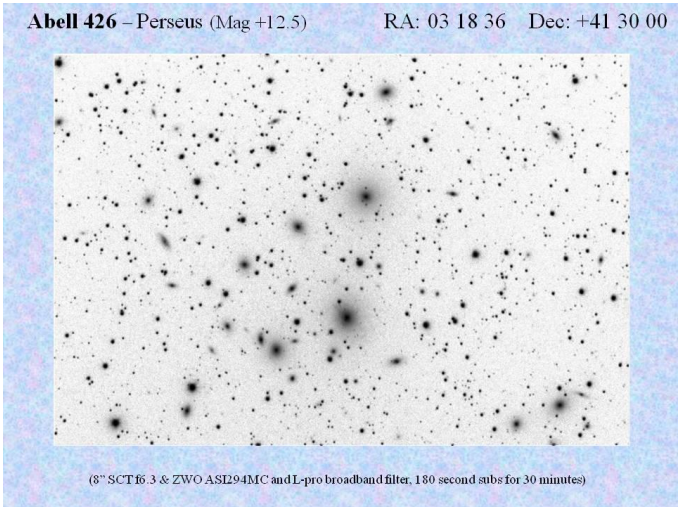
Abell 154 - Pisces (image scale = 24' x 16' arc minutes) (cluster mag +15.7 – mag of the 10th brightest galaxy in the cluster), #members=35,
Abell class richness / distance: '0/3'. Located about 815 million light-years distant.
Core Cluster Members: IC1634 (brightest member +15.6 - elliptical), IC1635, PGC4253, PGC4193, PGC4209, PGC73760, PGC73748, PGC73743, PGC73761, PGC73764, PGC73766, PGC1535574, PGC1539023, MAC0110+1745A, MAC0110+1745B, MAC0110+1736, MAC0111+1738B, MAC0111+1741B
8" SCT optical tube @ f6.3, Atlas Gem mount, ASI294MC & L-Pro filter @ 180 seconds livestacked for 30 minutes.



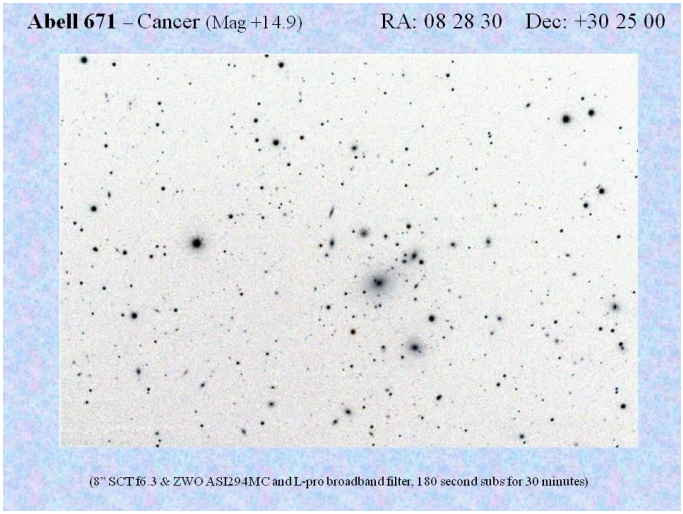
Abell 262 - Andromeda (image scale = 24' x 16' arc minutes) (near open cluster NGC752)
(cluster mag +13.3 – 10th brightest galaxy in cluster), #members=40, Abell class richness / distance: '0/1'. Located about 224 million light-years distant, most of its members are spirals, which is unusual for Abell galaxy clusters.
Core Cluster Members: NGC708 (brightest member +12.7 - elliptical), NGC700, NGC703, NGC704, NGC705, NGC709, NGC710, PGC6974, UGC1319, CGCG522-30, MCG+6-5-24
8" SCT optical tube @ f6.3, Atlas Gem mount, ASI294MC & L-Pro filter @ 180 seconds livestacked for 30 minutes.



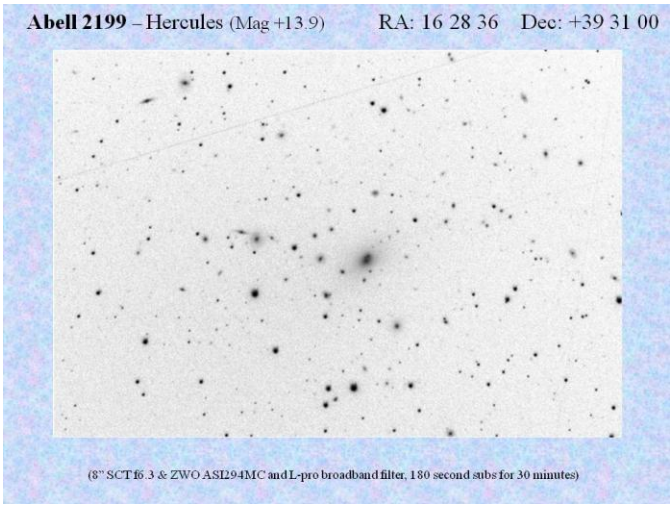
Abell 426 – Perseus known as the "Perseus Galaxy Cluster" (image scale = 9' x 9' arc minutes) (near open cluster M34)
(cluster mag +12.5 – 10th brightest galaxy in cluster), #members=88, Abell class richness / distance: '2/0'. Located about 230 million light-years distant, the closest of the nearby rich Abell galaxy clusters.
Core Cluster Members: NCG1275 (brightest member +11.9 – lenticular, X-ray & radio source 3C84 known as Perseus A, which is a Seyfert galaxy with a quasar like core containing a supermassive blackhole), NGC1270, NGC1271, NGC1272, NGC1273, NGC1277, NGC1278, NGC1281, NGC1282, NGC1283, IC1907
8" SCT optical tube @ f6.3, Atlas Gem mount, ASI294MC & L-Pro filter @ 180 seconds livestacked for 30 minutes.



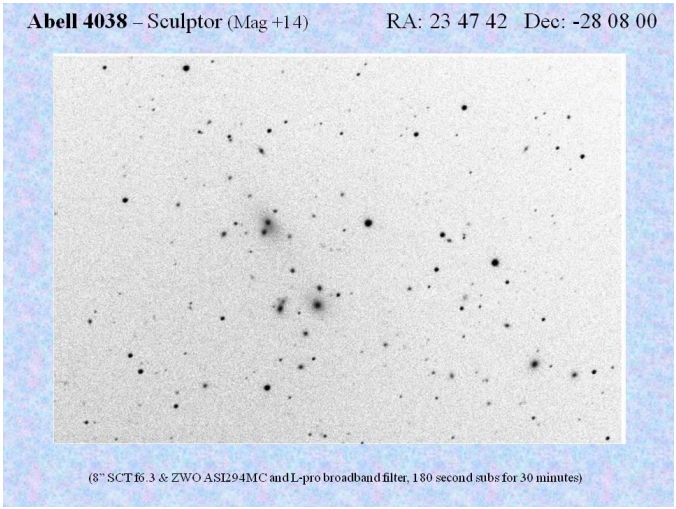
Abell 671 - Cancer (image scale = 24' x 16' arc minutes) (cluster mag +14.9 – 10th brightest galaxy in cluster), #members=38, Abell class richness / distance: '0/3'. Located about 600 million light-years distant.
Core Cluster Members: IC2380 (brightest member +11.1 - lenticular), IC2378, MAC0828+3024A, MAC0828+3024B, MAC0828+3026, CGCG149-35, CGCG149-27, CGCG149-28
8" SCT optical tube @ f6.3, Atlas Gem mount, ASI294MC & L-Pro filter @ 180 seconds livestacked for 30 minutes.



Abell 2199 - Hercules (image scale = 24' x 16' arc minutes) (near globular cluster M13)
(cluster mag +13.9 – 10th brightest galaxy in cluster), #members=88, Abell class richness / distance: '2/1'. Located about 417 million light-years distant.
Core Cluster Members: NGC6166 (brightest member +12.8 - elliptical), NGC6166C, MCG+7-34-50, MCG+7-34-48, PGC58277, PGC58278, PGC58279, PGC 58325, PGC58262, PGC2149914, PGC2153801, PGC2154233
8" SCT optical tube @ f6.3, Atlas Gem mount, ASI294MC & L-Pro filter @ 180 seconds livestacked for 30 minutes.



Abell 4038 - Sculptor (image scale = 24' x 16' arc minutes)
(cluster mag +14.7 – 10th brightest galaxy in cluster), #members=117, Abell class richness / distance: '2/2'.
Located about 430 million light-years distant.
Core Cluster Members: IC5358 (brightest member +13.4 - elliptical), IC5353, IC5354, PGC85756, PGC85759, PGC72451, PGC72436, PGC72393, PGC85750, PGC85758, PGC72403, PGC747116
8" SCT optical tube @ f6.3, Atlas Gem mount, ASI294MC & L-Pro filter @ 180 seconds livestacked for 15 minutes.

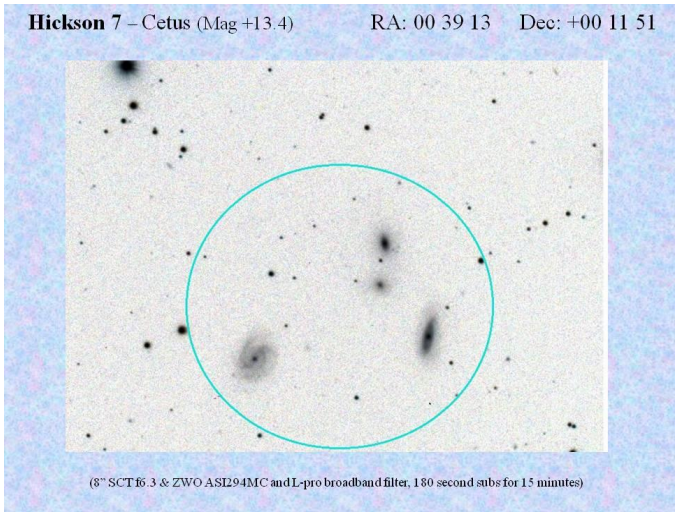


Hickson Compact Galaxy Clusters:
Hickson's catalog is recognized as an excellent compilation of challenging galaxy clusters for the observer with access to medium to large telescopes and dark skies. While several of the clusters contain one or more relatively bright NGC or IC galaxies, the majority of the catalog consists of faint galaxy clusters of PGC, UGC, or MCG galaxies. (The average galaxy member magnitude is around +14. The faintest is HCG20 in Aries at +17.2).

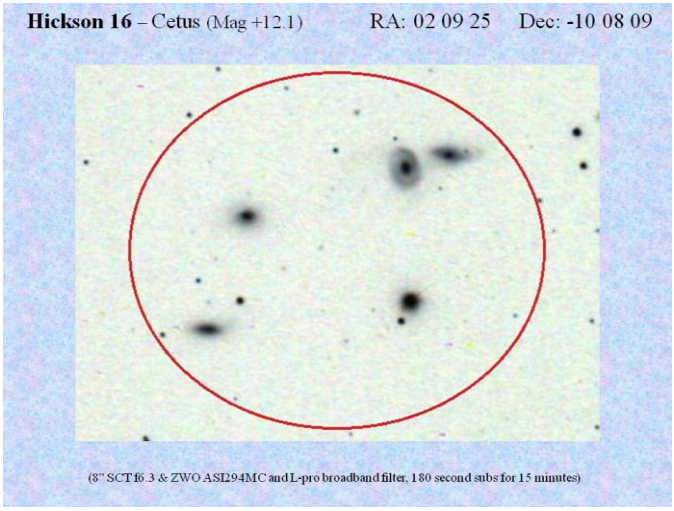
Many of the groups have at least one member plotted in several popular printed star atlases such as 'Uranometra 2000' or the 'Millennium Star Atlas", and can also be found in various planetarium programs. You can also find 18 HCG's included within Halton Arp's 'Atlas of Peculiar Galaxies'. All 100 catalog members have high enough declinations to be viewable by northern hemisphere observers. http://stellar-journeys.org/HicksonGalaxy.htm

Hickson Galaxy Cluster Exmples:

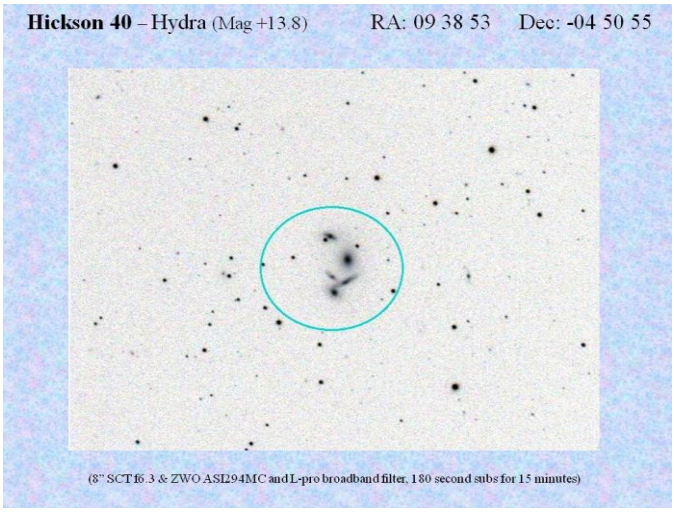
HCG-7 - Cetus (image scale = 16.5' x 12' arc minutes)
(Cluster mag +13.4 = brightest member), #members=4, Located about 189 million light-years distant.
Cluster Members: NGC192 (brightest - spiral), NGC196, NGC197, and NGC201
8" SCT optical tube @ f6.3, Atlas Gem mount, ASI294MC & L-Pro filter @ 180 seconds livestacked for 15 minutes.



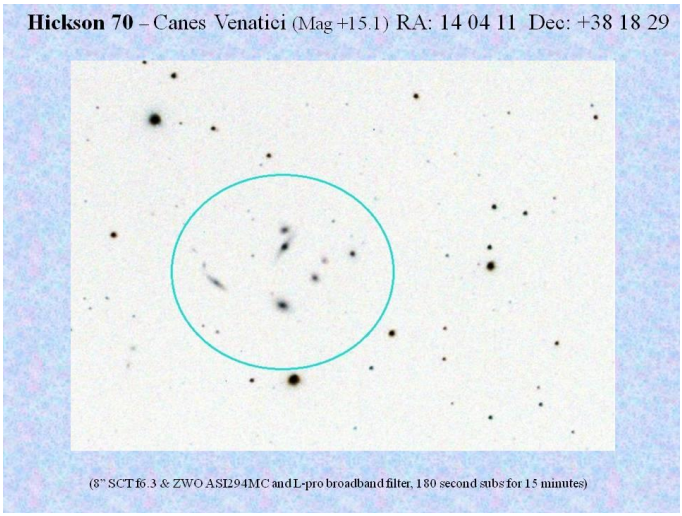
HCG-16 - Cetus (image scale = 11’ x 8’ arc minutes) Arp318
(Cluster mag +12.1 = brightest member), #members=4, Located about 110 million light-years distant.
Cluster Members: NGC835 (brightest - spiral), NGC833, NGC838, and NGC839
8" SCT optical tube @ f6.3, Atlas Gem mount, ASI294MC & L-Pro filter @ 180 seconds livestacked for 15 minutes.



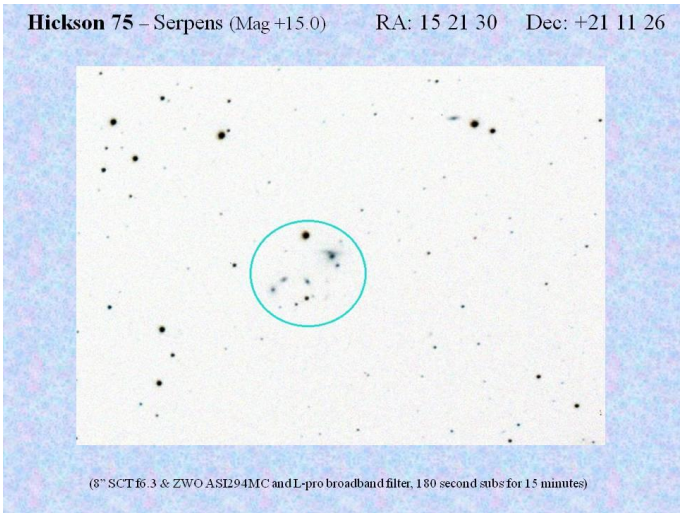
HCG-40 - Hydra (image scale = 16.5’ x 12’ arc minutes) Arp321
(Cluster mag +13.8 = brightest member), #members=5, Located about 280 million light-years distant.
Cluster Members: MCG-1-25-9 (brightest - elliptical), MCG-1-25-8, MCG-1-25-10, MCG-1-25-11, MCG-1-25-12
8" SCT optical tube @ f6.3, Atlas Gem mount, ASI294MC & L-Pro filter @ 180 seconds livestacked for 15 minutes.



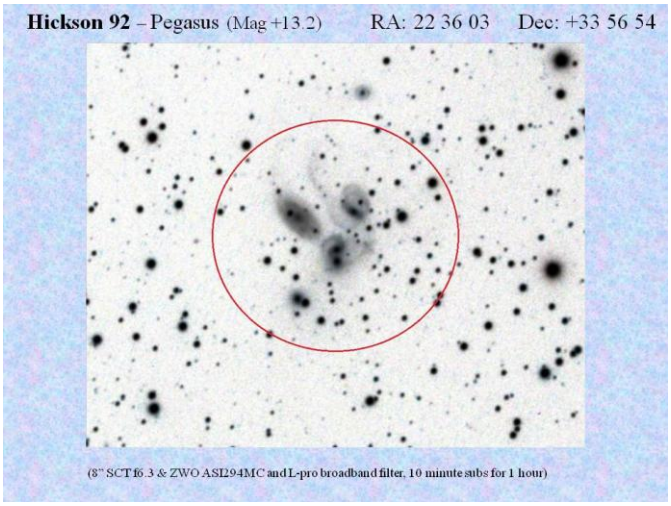
HCG-70 – Canes Venatici (image scale = 16.5’ x 12’ arc minutes)
(Cluster mag +15.1 = brightest member), #members=7, Located about 375 million light-years distant.
Cluster Members: IC4370 (brightest - spiral), IC4371, IC4369, PGC50123, MCG+6-31-65, MCG+6-31-60, and MCG+6-31-57
8" SCT optical tube @ f6.3, Atlas Gem mount, ASI294MC & L-Pro filter @ 180 seconds livestacked for 15 minutes.



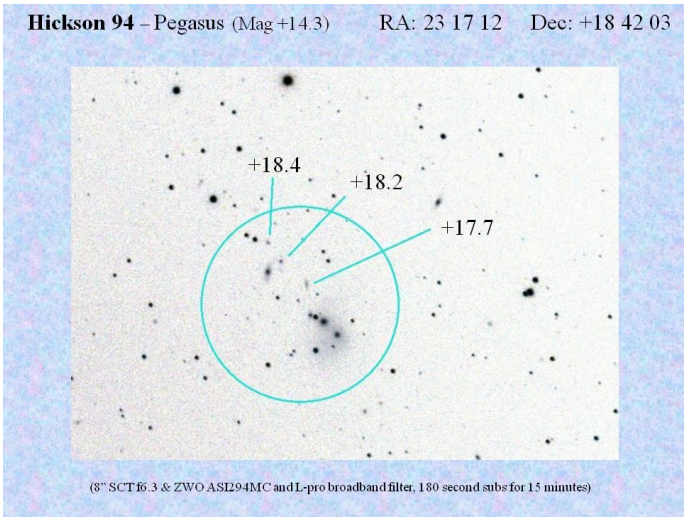
HCG-75 – Serpens (image scale = 16.5’ x 12’ arc minutes)
(Cluster mag +15.0 = brightest member), #members=6, Located about 596 million light-years distant.
Cluster Members: CGCG135-50 (brightest - elliptical), PGC54802, PGC54803, PGC54818, PGC54824, and PGC54827. Nearby Galaxies: PGC1646140
8" SCT optical tube @ f6.3, Atlas Gem mount, ASI294MC & L-Pro filter @ 180 seconds livestacked for 15 minutes.



HCG-92 - Pegasus (image scale = 14.5’ x 12’ arc minutes) Arp 319 - “Stephans Quintet”
(Cluster mag +13.2 = brightest member), #members=5, Located about 280 million light-years distant.
Cluster Members: NGC7320 (brightest - spiral), NGC7318B, NGC7319, NGC7318A, and NGC7317
8" SCT optical tube @ f6.3, Atlas Gem mount, ASI294MC & L-Pro filter @ 10 minute subs livestacked for 1 hour.



HCG-94 – Pegasus (image scale = 16.5’ x 12’ arc minutes)
(Cluster mag +14.3 = brightest member), #members=7, Located about 564 million light-years distant.
Cluster Members: NGC7578A (brightest - elliptical), NGC7578B, PGC70936, PGC70937 (+17.7), PGC70939 (+18.2), PGC70941 (+18.4), PGC70943 Nearby Galaxies: MAC 2316+1845
8" SCT optical tube @ f6.3, Atlas Gem mount, ASI294MC & L-Pro filter @ 180 seconds livestacked for 15 minutes.



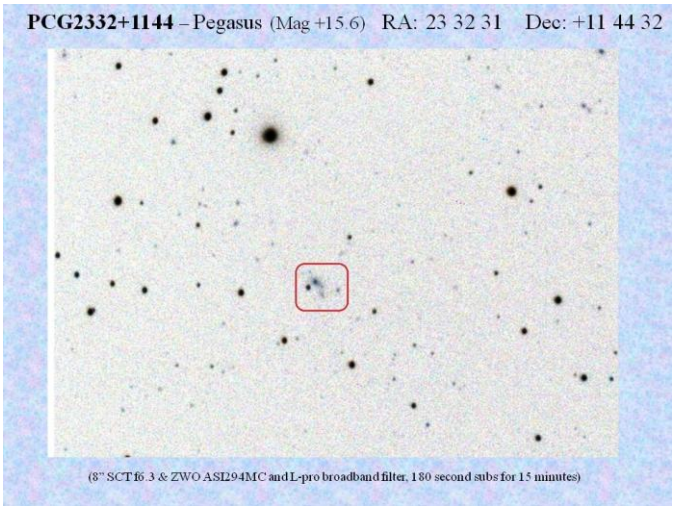
Palomar Compact Galaxy Clusters:

The Palomar catalog is recognized as an excellent compilation of very challenging galaxy clusters for the observer with access to large telescopes or imaging kits, and dark skies. Due to their great distance, the majority of the catalog members are very faint galaxy clusters, (+15th Mag and fainter), and generally not plotted on star atlases or listed in planetarium programs. You will need to utilize the cluster's RA & Dec to find the object. For the most part, Palomar clusters can be very difficult to observe visually, requiring large 24" and greater telescopes, along with dark skies. For imagers, 6" to 8" size optics will be required, and once again, broadband filters, such as the L-Pro, can be a big help.

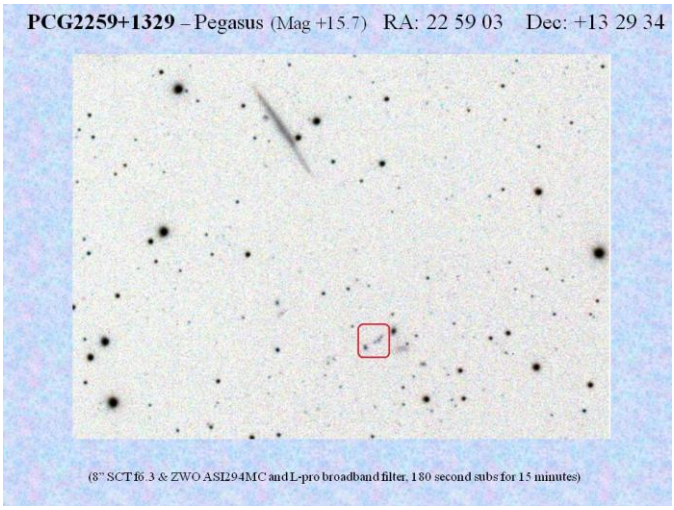
http://stellar-journeys.org/PalomarGalaxyTour.htm

PalomaGalaxy Cluster Exmples:

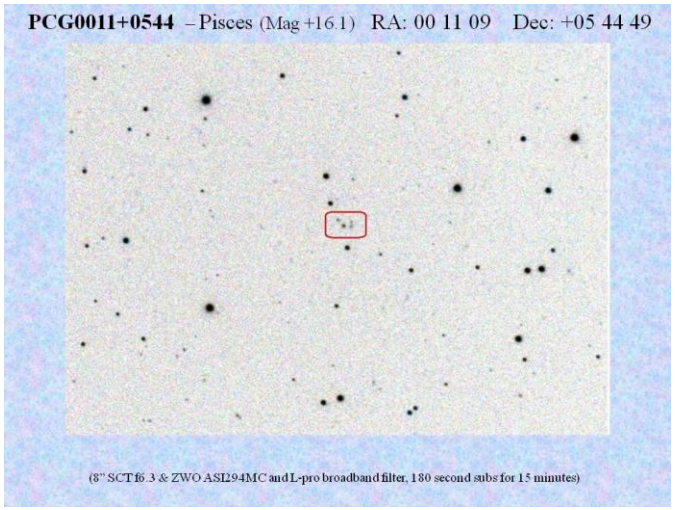
PCG2332+1144 – Pegasus (image scale = 16.5' x 12' arc minutes)
(galaxy cluster mag +15.6), #members=4, Located about ??? billion light-years distant.
8" SCT optical tube @ f6.3, Atlas Gem mount, ASI294MC & L-Pro filter @ 180 seconds livestacked for 15 minutes.



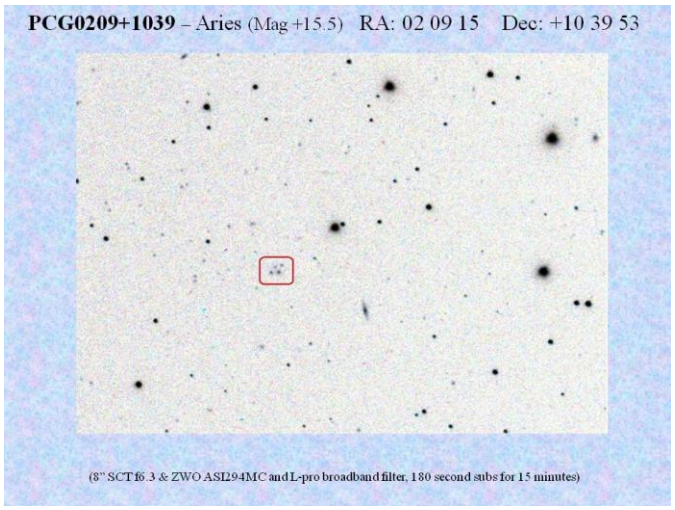
PCG2259+1329 - Pegasus (image scale = 16.5' x 12' arc minutes)
(galaxy cluster mag +15.7), #members=4, Located about 1.8 billion light-years distant. Nearby Galaxies: UGC12281



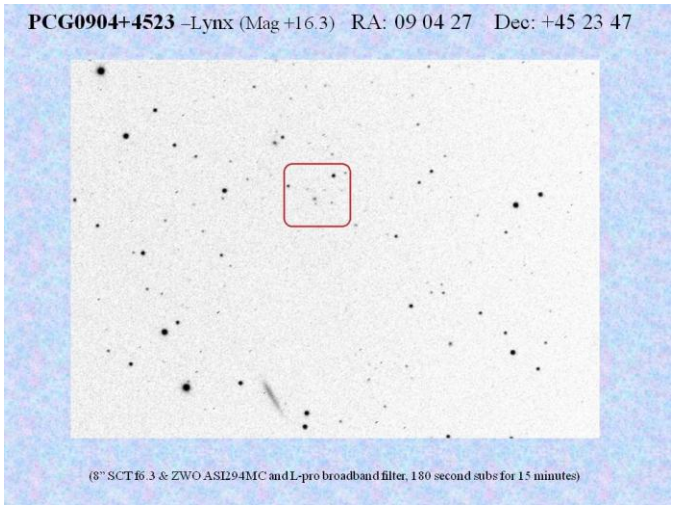
PCG0011+0544 - Pisces (image scale = 16.5’ x 12’ arc minutes)
(galaxy cluster mag +16.1), #members=4, Located about 2.1 billion light-years distant.
8" SCT optical tube @ f6.3, Atlas Gem mount, ASI294MC & L-Pro filter @ 180 seconds livestacked for 15 minutes.



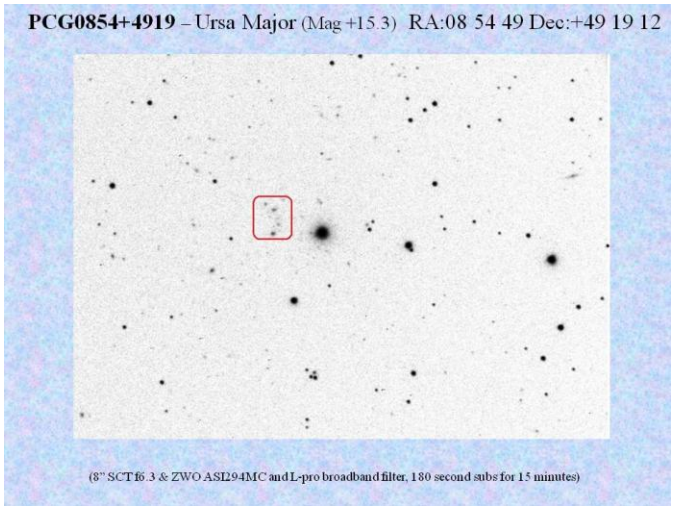
PCG0209+1039 - Aries (image scale = 16.5’ x 12’ arc minutes)
(galaxy cluster mag +15.5), #members=4, Located about ??? billion light-years distant.
8" SCT optical tube @ f6.3, Atlas Gem mount, ASI294MC & L-Pro filter @ 180 seconds livestacked for 15 minutes.



PCG0904+4523 - Lynx (image scale = 16.5’ x 12’ arc minutes)
(galaxy cluster mag +16.3), #members=4, Located about 2.9 billion light-years distant.
Nearby Bright Galaxies: PGC25472
8" SCT optical tube @ f6.3, Atlas Gem mount, ASI294MC & L-Pro filter @ 180 seconds livestacked for 15 minutes.



PCG0854+4919 - Ursa Major (image scale = 16.5' x 12' arc minutes)
(galaxy cluster mag +15.3), #members=4, Located about 2.7 billion light-years distant.
Nearby Bright Galaxies: PGC90877
8" SCT optical tube @ f6.3, Atlas Gem mount, ASI294MC & L-Pro filter @ 180 seconds livestacked for 15 minutes.



Conclusion :
So today I introduced you to a class of large scale deep sky objects – galaxy clusters, and some of their catalogs. We learned a little about the individuals behind each catalog, and reviewed EAA capture image examples of various members of each catalog. Hopefully this little presentation has inspired you to search-out and explore these very rewarding celestial objects. These huge three-dimensional structures that are the fundamental building blocks of the universe!

So I encourage everyone to get out tonight and try your hand at finding and observing these elusive deep-sky objects, the galaxy clusters of George Abell, Paul Hickson, and Angela Iovino.

Closing Thoughts:

I hope you enjoyed reading this amateur astronomer's anthology, and that it may add to your astronomical observing experience. As I've stated throughout these stories, I encourage everyone to get outside the next clear evening and try your hand at finding and observing these various objects and think about and remember the people behind them: Galileo, Messier, Herschel, Barnard, Hubble, Arp, Abell, Hickson, and all the others who came before us over the past 400 years of astronomical discoveries.
It is up to us in the present to keep their historical perspective alive.

Thank you! *Larry E McHenry*

Credits:

Stargazing and Myths

Books:

"*Star Tales*" by Ian Ridpath

"They Dance in the Sky – Native American Star Myths" by Jean Monroe and Ray Williamson

"*Burnham's Celestial Handbook*" by Robert Burnham Jr.

"*The Glorious Constellations: History and Mythology*" by Giuseppe Sesti

Magazines:

"Scientific American" Nov 2006 – '*Origin of the Greek Constellations*' by Bradley Schaefer

Internet:

"*The Stories in the Night Sky*" website: http://www.ufrsd.net/StaffWWW/Stefanl/myths/index.htm

"*The Constellations*" website: http://www.dibonsmith.com/stars.htm

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Comet Tales

Books:

"*A Complete Manual of Amateur Astronomy*", by P. Clay Sherrod, 1981.
"*The First Stargazers*", by James Cornell, 1981.
"*Introduction to Comets*" by John Brandt and Robert Chapman, 1982
"*The Atlas of the Solar System*", by Patrick Moore & Garry Hunt , 1983.
"International Halley Watch Amateurs Observers Manual", by Stephen Edberg, 1983.
"*Comets*", by Martyn Hamer, 1984.
"*Astronomy with a Small Telescope*", by James Muirden, 1985.
"*The Arrival of Halley's Comet*", by Paul Doherty, 1985.
"*Halley's Comet!*", by Francis Reddy, 1985.
"*Comets*", by David C Knight, 1986.
"*Beyond the Blue Horizon*", by E.C. Krupp, 1991.
"*Comets: A Chronological History of Observation, Science, Myth, and Folklore*", by Donald Yeomans, 1991.
"*Earth & Sky – Visions of the Cosmos in Native American Folklore*", by Ray Williamson & Claire Farrer , 1992.
"*Comets, Popular Culture, and the Birth of Modern Cosmology*" by Sara Genuth, 1997
"*Comets in Australian Aboriginal Astronomy*", by Duane W. Hamacher and Ray P. Norris, 2011.

Magazines:

Sky & Telescope
Astronomy
National Geographic

Internet:

Google, Wikipedia & Wikimedia

Galileo: The First Optical Astronomer

Books:

"*The Telescope*", by Louis Bell, 1981.
"*The Atlas of the Solar System*", by Patrick Moore & Garry Hunt, 1983.
"*Seeing and Believing*", by Richard Pane, 1998.
"*Astronomical Scrapbook*", by Joseph Ashbrook , 1984.
"*The Clockwork Universe*", by Edward Dolnick, 2011.
"*Boltzmann's Tomb*", by Bill Green , 2011.
"Galileo's Daughter", by Dava Sobel, 1999.

"*The Starry Messenger*", by Galileo, 1610.

Magazines:

"*Galileo's New Universe*", Sky & Telescope, February 2009

"*Celebrate Galileo's 455th Birthday*", Astronomy, May 2009

"*Who Invented the Telescope*", Sky & Telescope, July 2009

"*Galileo – The Genus Who Charted the Universe*", National Geographic, 2005

Internet:

Wikipedia & Wikimedia

seds.org

"Earth Centered Universe" by David Lane http://www.nova-astro.com/

Astronomical League – Galileo Club: https://www.astroleague.org/al/obsclub/galileo_club/galileo_club.html

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The Venus Transit: A Historical Retrospective

Books:

"Chasing Venus – The Race to Measure the Heavens" by Andrea Wulf

"Transit of Venus – 1631 to the Present" by Nick Lomb

"The Transit of Venus"by William Sheehan and John Westfall

"The Suns Heartbeat" by Bob Berman

"The Astronomical Scrapbook" by Joseph Ashbrook

"A short History of Nearly Everything" by Bill Bryson

Magazines:

"Sky & Telescope" magazine – January 2012, June 2012, October 2012

"Astronomy" magazine – June 2012

"Astronomy Technology Today" magazine – March-April 2012

"Reflector" magazine – September 2012

Internet:

Wikipedia.org

transitofvenus.org

NASA

Google

The Ferret of Comets

Books:

"Messier's Nebulae and Star Clusters", by Kenneth Glyn Jones:

"*The Complete Guide to the Herschel Objects*", by Mark Bratton

Internet:

Wikipedia.org

SEDS (Students for the Exploration and Development of Space): SEDS Messier Database

Google

The Herschels and Their Catalog

Books:

"The Georgian Star" by Michael Lemonick

"The Comet Sweeper" by Clare Brock

"The Age of Wonder" by Richard Holmes

"Observe the Herschel Objects" by Astronomical League & Ancient City astronomy club

Magazines:

"Exploring the Herschel Catalog" – Dennis di Cicco , Sky & Telescope, Sept 1992

"In Caroline Herschel's Footsteps" – Michael Hoskin , Sky & Telescope, Aug 2007

"The Herschel Project" – Rod Mollise, Sky & Telescope, August 2012

"Explore Caroline Herschel's Celestial Showpieces" – Bob King , Sky & Tel website, Sep 23 2021

Internet:

Wikipedia.org
Google
SEDS http://www.messier.seds.org/xtra/similar/cher.html Michael Hoskin's recent work

Software:

"Earth Centered Universe" planetarium software by David Lane http://www.nova-astro.com/

The Father of Amateur Astronomy

Books:

"Celestial Objects for Common Telescopes" by Rev Thomas W Webb.
"The Stargazer of Hardwicke" by Janet & Mark Robinson.
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About the Author:

I have been active in amateur astronomy as a hobby for over 45 years. My interest in astronomy developed from reading science fiction as a child, but what really got me 'looking up' were the Apollo Moon landings.

Currently, I live and observe in the Western Pennsylvania area. I am now officially retired, but prior to that I worked for many years in downtown Pittsburgh as an IT systems project manager with programming experience in both mainframe and desktop systems. I've designed my own personal website on astronomical observing.
Over the years, I have participated as a member and officer in several Pittsburgh area astronomy clubs and assisted with the building of regional amateur observatories.

I am an experienced amateur astronomer presenter, having created and delivered astronomy presentations and public observing sessions to diverse audiences, including libraries, schools, science centers, astronomy clubs and amateur conventions.

In 1996, I built my home backyard observatory with a pier mounted 8" SCT, which I use primarily for Lunar/Planetary/solar observing during the winter season. During the summer, I can be found at Cherry Springs State Park in Pennsylvania or at the Calhoun County Park in West Virginia, with my teardrop camper and telescope, observing deep-sky objects.

Larry McHenry, Pittsburgh, PA. USA
http://stellar-journeys.org/

Backyard Observatory – Big Woodchuck Observatory

Mobile Observatory – Tab Clamshell Camper