Sagittarius Star Cloud
Eagle Nebula
GET OUT
LOOK UP
• When Galaxies Collide
  https://www.youtube.com/watch?v=HP3x7TgvgR8

• How Hubble Images Get Color
  https://www.youtube.com/watch?
time_continue=3&v=WSG0MnmUsEY
Experiencing Hubble

Sagittarius Star Cloud
1. 12,000 stars
2. ½ percent of full Moon area.
3. Not one star in the image can be seen by the naked eye.
4. Color of star reflects its surface temperature.

Eagle Nebula. M 16
1. Messier 16 is a conspicuous region of active star formation, appearing in the constellation Serpens Cauda. This giant cloud of interstellar gas and dust is commonly known as the Eagle Nebula, and has already created a cluster of young stars. The nebula is also referred to the Star Queen Nebula and as IC 4703; the cluster is NGC 6611.
   With an overall visual magnitude of 6.4, and an apparent diameter of 7', the Eagle Nebula's star cluster is best seen with low power telescopes. The brightest star in the cluster has an apparent magnitude of +8.24, easily visible with good binoculars. A 4" scope reveals about 20 stars in an uneven background of fainter stars and nebulosity; three nebulous concentrations can be glimpsed under good conditions. Under very good conditions, suggestions of dark obscuring matter can be seen to the north of the cluster.
   In an 8" telescope at low power, M 16 is an impressive object. The nebula extends much farther out, to a diameter of over 30'. It is filled with dark regions and globules, including a peculiar dark column and a luminous rim around the cluster. The outlines of the nebula are sometimes said to look like a three-leaf clover.
   The Eagle nebula is best seen on photographs, but larger apertures and O-III filters may help to trace some detail visually. More dark pillars, also known as "elephant trunks", can be seen in large amateur instruments (12" and larger aperture).

2. Properties and Evolution
   The Eagle Nebula lies some 7,000 light years away in the Sagittarius-Carina spiral arm of our galaxy - the next arm inward from us. At this distance, the cluster's angular diameter corresponds to a linear size of about 15 light years. The nebula extends much farther out, to dimensions of about 70 x 55 light years. M 16 might form one giant complex with M 17, the Omega Nebula, to the south in Sagittarius.
   M 16's stellar swarm is only about 5.5 million years old, with its hottest, youngest stars of spectral type O6. Excited by high-energy ultraviolet radiation from these massive stars, this great cloud of interstellar gas glows by fluorescence.

Cat’s Eye Nebula
1. The magnificent planetary nebula NGC 6543 in Draco is also known as the Cat's Eye nebula. It has a bright, bluish disk and a faint central star visible in large telescopes.
   This 8.1-magnitude planetary nebula is one of the brightest of its type. A 4" telescope will show a foggy blue-green disk about 0.3' (18 arcseconds) across, embedded in a fainter halo 5.8' across. Its resemblance to a cat's eye is due to a series of gas loops that have been ejected by the central star over the past 1,000 years or so. It is one of the most complex nebulae known, but more powerful instruments are needed to reveal its internal structure.
2. **Properties and Evolution**
   NGC 6543 is a young planetary nebula, about 3300 light years away. The great complexity of the Cat's Eye's structure - with its concentric gas shells, jets of high-speed gas, and unusual shock-induced knots of gas - suggests that the central star may be a binary system. If the companion were pulling in material from a neighboring star, jets escaping along the companion's rotation axis could be produced. The fact that the twin jets are now pointing in different directions suggests that they are wobbling, or precessing, and turning on and off periodically.

3. All stars born with less than 8 solar masses evolve into planetary nebula. This involves 99% of the stars in the sky.

4. Total mass of halo is about half that of the Sun.

5. Outer halo ejected about 25,000 years ago based on the speed we now see this outer halo spreading out.

6. Appears green in naked eye view through a telescope.

7. Cat's Eye Nebula was the first nebula to be examined with spectroscopy in 1864, The scientists did not know what the spectral lines represented, so they called it nebulium. In 1924, the spectral lines were identified as “forbidden” lines of doubly ionized oxygen.

8. The red giant the created this nebula will eventually become a white dwarf. The last phase will be a black dwarf. Our Sun will go through this same phase. The size of the white dwarf will be about the size of earth, but a teaspoon of the material will weight several tons.

9. A Neutron star, by size comparison, is about the size of a large city. Had that star been more massive initially, it would have become a black hole.

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**Crab Nebula**

1. An example of a process that seeds the the Milky Way with the elements of life and stimulates the formation of new stars.

2. Messier 1, the Crab Nebula, is the most famous and conspicuous supernova remnant in the sky. It is the centuries-old wreckage of a stellar explosion first noted by Chinese astronomers in 1054. The Crab Pulsar, a neutron star rotating 30.2 times per second, now lies the center of the nebula. The supernova that created the Crab Nebula (SN 1054, also assigned the variable star designation CM Tauri) was first noted as a "guest star" by Chinese astronomers on July 4, 1054 A.D. According to the Chinese records, it reached a peak magnitude of -6 (four times brighter than Venus!), was visible in the daylight for 23 days, and seen in the night sky for 653 days. Petroglyphs found in Navaho Canyon and White Mesa in Arizona and in the Chaco Canyon National Park in New Mexico appear to be depictions of the event by the Anasazi Indians. Spectroscopic observations in the late 19th century revealed the gaseous nature of the Crab. The first photo of M 1 was obtained in 1892 with a 20-inch telescope. The first serious investigations of its spectrum, performed in 1913-15 by Lowell Observatory astronomer Vesto Slipher, showed that its spectral emission lines were split. The reason for this was later recognized to be the Doppler shift: as parts of the nebula are approaching us, their lines are blue-shifted, and as other parts
recede from us, their lines are red-shifted. In 1921, astronomers at Lowell and Mt. Wilson Observatories compared photographs of the Crab Nebula taken years apart, and found that it was expanding at about 0.2" per year. Tracing the expansion back revealed that it must have begun about 900 years before. The same year, Knut Lundmark noted the proximity of M 1 to the 1054 supernova.

In 1949, the Crab nebula was identified as a strong source of radio radiation, listed as Taurus A. X-rays from this object were detected in 1963; the X-ray source was named Taurus X-1. Measurements during lunar occultations showed that the energy emitted by the Crab nebula in X-rays is about 100 times that emitted in visible light.

In 1968, a pulsating radio source (cataloged as NP0532 or PSR 0531+21), was detected in M 1 by astronomers using the Arecibo Observatory's 300-meter radio telescope in Puerto Rico. This pulsar was the first to be verified in the optical part of the spectrum in 1969, when astronomers of Steward Observatory in Tucson, Arizona found it flashing at the same period of 33.085 milliseconds as the radio pulsar. This optical pulsar is sometimes also referred to by the supernova's variable star designation, CM Tauri.

It came to light in 2007 that the Crab Pulsar had been found in summer 1967 - months before its detection at Arecibo - by US Air Force officer Charles Schisler on radar duty. He subsequently discovered a number of other pulsars; however, the USAF decided not to publish his findings.

3. Appearance and Occultations

The Crab Nebula can be found quite easily, about 1° NW of Zeta Tauri, the "Southern Horn" of Taurus, the Bull. It shines at magnitude 8.4, with apparent dimensions of 6 x 4 arcminutes.

The nebula can be easily seen under clear dark skies, but can just as easily get lost in the background illumination under less favorable conditions. M 1 is situated in a nice Milky Way field, and is just visible as a dim patch in 7x50 or 10x50 binoculars. With a little more magnification, it is seen as a nebulous oval patch, surrounded by haze.

Smaller instruments verify Messier's impression that M 1 looks like a faint comet without a tail. Starting in telescopes of about 4" aperture, some detail in its shape becomes apparent, with a suggestion of mottled or streaky structure in the inner parts. Only under excellent conditions, and with larger telescopes of at least 16" aperture, do the filaments and fine structure become visible.

As the Crab Nebula is situated only 1-1/2 degrees from the Ecliptic, there are occasional transits of planets, and as occultations by the Moon. These transits and occultations can be used to analyze both the nebula and the object passing in front of it. When X-rays were first observed from the Crab, a lunar occultation was used to determine the exact location of their source, and lunar transits have been used to map X-ray emissions from the nebula.

The Sun's corona passes in front of the Crab every June, and was mapped from observations of the Crab's radio waves passing through it in the 1950s and 1960s. In 2003, the thickness of the atmosphere of Saturn's moon Titan was measured at
880 km, as it blocked out X-rays from the nebula. Saturn’s transit of M 1 in 2003 was the first since 1296; another will not occur until 2267.

4. **Properties, Pulsar, and Progenitor**

   Photographs taken decades apart show that the Crab is visibly expanding. By comparing its angular expansion with the expansion velocity determined by spectroscopy, the nebula’s distance has been well determined to be about 6,300 light years. The Crab Nebula has physical dimensions of about 13 x 11 light years, and is expanding at about 1,800 km/sec. The visual luminosity of the nebula is more than 1000 Suns. Its total luminosity in all spectral ranges is estimated at over 75,000 Suns!

5. Expanding at over 1500 times that of a rifle bullet.

6. Size is about 1/5th of full Moon.

7. Image composed of about 28 hours of RGB where R is doubly ionized oxygen, G is singly ionized sulfur, and B is oxygen. Inner blue glow is not due to atoms. It is caused by the electron synchrotron radiation from the magnetic field of the neutron star interacting with the nebula.

8. The nebular is powered by a rapidly rotating neutron star called a pulsar rotating at 30 times per second.

9. Density is about 1.5 solar masses. A teaspoon full weighs about a billion tons.

10. The first pulsar detected was labeled LGM1 where LGM stands for little green men.

**Sombrero Galaxy**

1. Messier 104 is known as the "Sombrero" galaxy. It is a spiral galaxy in the constellation Virgo, whose bright nucleus, unusually large central bulge, and prominent dust ring give it the appearance of a Mexican hat. In 1912, M 104 became the first galaxy for which a large redshift was found, by Vesto Slipher of Lowell Observatory. M 104’s redshift corresponds to a recession velocity of about 1100 km/sec - too fast for it to be an object inside our Milky Way galaxy. Slipher’s observations were among the first key pieces of evidence for the expansion of the universe and the Big Bang Theory. Slipher also observed rotation in the spectrum of the Sombrero, making it the first galaxy in which rotation was observed. It is a 9th-magnitude spiral with apparent dimensions of 8' x 4', easily visible in amateur telescopes. This galaxy's most striking feature is the massive dust band that cuts across its nucleus. Although the galaxy is visible with binoculars or a 4-inch telescope, at least an 8-inch telescope is needed to distinguish the bulge from the disk, and a 10- to 12-inch telescope is needed to see the dark dust lane. M 104 is an unbarred spiral galaxy is of type Sa-Sb, with a big bright core and well-defined spiral arms. We view it from just 6 degrees south of its equatorial plane. Very deep photographs show that the galaxy has a faint, extended halo.

2. **Physical Properties**

   At least two methods have been used to measure the distance to the Sombrero Galaxy; their results average 29.3 million light years, with an uncertainty of 1.6 million. It has a linear diameter of 130,000 light-years. The symmetric dust ring that encloses the central bulge also contains most of the galaxy’s cold hydrogen gas, and is the primary site of star formation within the galaxy.
M 104 has a mildly active nucleus, as evidenced by visible emission lines and radio emission. Based on the stellar dynamics in its core, a research group demonstrated in the 1990s that a supermassive black hole, 1 billion times the mass of the Sun, is present in the center of the Sombrero Galaxy. The Sombrero has a relatively large number of globular clusters; observations have produced population estimates in the range of 1200 to 2000. This is high compared to the Milky Way and other galaxies with small bulges, but similar to other galaxies with large bulges. The Sombrero Galaxy lies within a cloud of galaxies that extends to the south of the Virgo Cluster. Previously accepted to be a member of the Virgo-Coma Cluster, it is currently unclear as to whether the Sombrero Galaxy is part of a formal galaxy group.

3. Galaxies like this were known to astronomers long before they knew they were galaxies. Then, they were called nebulae, or nebulous objects.

**NGC 3370**

1. NGC 3370 is a 11th magnitude Spiral Galaxy appearing in the constellation Leo. It is 97 million light years from our solar system. NGC 3370 appears roughly 2.4 x 1.4 arcminutes in size, corresponding to a physical diameter of 68795 light years. It is a spiral galaxy of morphological type SABc, and is receding at 1281 kilometers per second - about 0.4% of light speed.

**Antennae Galaxies**

1. In small telescopes, the pair have a high surface brightness, and appear slightly blue. NGC 4038 and 4039 have a visual magnitude of 10.5 and 10.3, respectively, and their cores appear both 5.4 arc minutes across. The nuclei of the two galaxies are joining to become one giant galaxy; two long streamers of ejected stars, gas and dust extend outward from their centers, making two long tails which resemble the antennae of an insect.

2. **Properties and Evolution**
   
   Detailed images captured by the Hubble Space Telescope show over a thousand bright young star clusters in the cores of Antennae, the result of a burst of star formation triggered by their collision. These bright knots are infant globular clusters, newly born out of collisions between giant hydrogen clouds in the two galaxies. At the other end of the stellar evolutionary spectrum, images taken by the Chandra X-ray Observatory have revealed dozens of bright point X-ray sources that are probably neutron stars or black holes tearing gas off nearby stars. These collapsed objects are the remains of large stars that formed earlier in the burst of star formation triggered by the collision, and have already died. Two supernovae have been discovered in these galaxies: SN 2004GT and SN 2007sr.

3. The Antennae lie about 63 million light-years away, in the NGC 4038 Group of galaxies in the constellations Corvus and Crater. The group's best known galaxies are NGC 4038 and 4039; but NGC 3956, 3957, 3981, 4024, 4027, 4033, and 4050
have also been consistently identified as group members. The group may contain between 13 and 27 galaxies. A recent study finds that these interacting galaxies may closer than previously thought, at 45 million light-years.

4. In any case, the Antennae are the nearest and youngest example of a pair of colliding galaxies. About 1.2 billion years ago, the Antennae were two separate galaxies; NGC 4038 was a spiral, and NGC 4039 was a barred spiral. Before the galaxies collided, NGC 4039 was probably larger than NGC 4038. 900 million years ago, the Antennae began to approach one another, appearing similar to NGC 2207 and IC 2163. 600 million years ago, the Antennae passed through each other, like the Mice Galaxies (NGC 4676 in Coma Berenices). 300 million years ago, the collision began to release the Antennae's stars, as each galaxy's gravitation has drawn out a curved tail of stars from the other. Today the two streamers of ejected stars extend far beyond the original galaxies, spanning a total of some 360,000 light-years.

5. Within 400 million years, the Antennae's nuclei will collide and become a single core with stars, gas, and dust around it. Observations and simulations of colliding galaxies suggest that the Antennae will eventually form a single elliptical galaxy. This is likely the future of our Milky Way when it collides with the Andromeda Galaxy; most galaxies probably undergo at least one significant collision in their lifetimes.

**Abell 2218**

1. Exemplifies gravitational lensing.
2. Implications of dark matter
3. Not the only cluster showing GL.
4. In the constellation Draco.
5. Approximately 10,000 galaxies in the cluster.
6. Abell 2218 is a rich galaxy cluster composed of thousands of individual galaxies. It sits about 2.1 billion light-years from the Earth (redshift 0.17) in the northern constellation of Draco. When used by astronomers as a powerful gravitational lens to magnify distant galaxies, the cluster allows them to peer far into the Universe. However, it not only magnifies the images of hidden galaxies, but also distorts them into long, thin arcs.
   Several arcs in the image can be studied in detail thanks to Hubble's sharp vision. Multiple distorted images of the same galaxies can be identified by comparing the shape of the galaxies and their color. In addition to the giant arcs, many smaller arclets have been identified.

**Hubble Ultra Deep Field**

1. 1996: Deep Field image 50 orbits (97 minutes each, telescope time for an object is anywhere from 50 to 97 minutes)
2. FOV: A grain of sand at arm's length near Big Dipper.
3. 98 hour composite of 276 wide field planetary camera 2 images
5. Over 3,000 galaxies
6. 2004: Ultra Deep Field image in Fornax, over 10,000 galaxies
7. Over 11 days and 400 complete orbits.
8. Advanced camera for surveys.
9. Over four times deeper than Deep Field.

When Galaxies collide:
https://www.youtube.com/watch?v=HP3x7TgvgR8

How Hubble images get color:
https://www.youtube.com/watch?time_continue=3&v=WSG0MnmUsEY