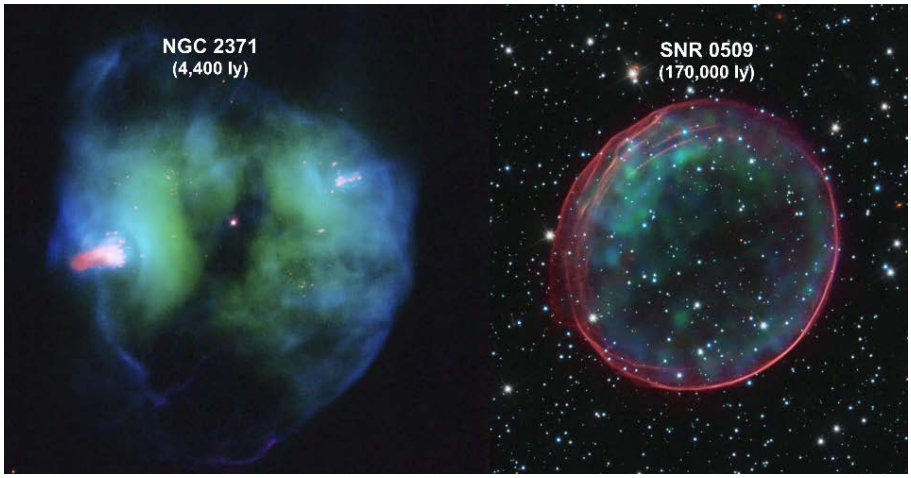
Star Birth Nebula

*{**Abstract** – Planetary nebula, such as NGC 2371, and supernova remnants, such as SN 0509, form when stars die. In this segment of our "How far away is it" video book, we'll cover the nebula associated with stars being born. We begin by showing the three kinds of nebula: Reflective like the Witch Head Nebula, emission like the Rosette Nebula NGC 2237 along with a description of H II Regions, and dark nebula like the Horsehead Nebula shown in visible and infrared light.*
We then begin a tour of some of the most spectacular star birth nebula across the Milky Way including: Rho Ophiuchi; the Blue Horsehead Nebula; R Coronae Australis, with its Herbig–Haro objects; T Tauri stars XZ and HL Tauri; the Iris Nebula, NGC 7023; the Great Orinon Molecular Cloud behind Minitaka, Alnilam, and Alnitak, with the Flame Nebula, the Horsehead Nebula, the Runing Man Nebula, and a deep look at the Orion Nebula with its Trapezian open star cluster; Young stellar objects V 633 & V376; S2-106; the Cone Nebula, NGC 2264 along with the Christmas Tree star cluster; the Lagoon Nebula, M8; the Trifid Nebula; the Cat's Paw Nebula, NGC 2237; the Omega Nebula; the Eagle Nebula, with its EGGs; a deep look at the Carina Nebula, NGC 3324, with its jets, walls, dust clouds and pillars; the Heart and Soul Nebulae; Statue of Liberty Nebula; RCW 34; NGC 2467; and NGC 3603.
We conclude by adding brightest H II Regions as a key standard candle rung on our distance ladder.}

Introduction

[Music: *Franz Liszt - Hungarian Rhapsody No. 2; Israel Philharmonic Orchestra - Zubin Mehta; from the album "Liszt: Hungarian Rhapsodies", 1989*]

Welcome to our segment on Nebulae. We'll be seeing some amazing scenes from across our galaxy. In recent segments, we've seen two types of nebula. Both have been connected with stars dying. Planetary Nebula, such as NGC 2371, are all about normal stars at the end of their hydrogen burning life. And Supernova remnants, such as SNR 0509-67.5, are the remains of giant star explosions at the end of their fusion factory life. But the most beautiful nebulae come from vast molecular hydrogen clouds were new stars are being born.



H II Regions

To understand these areas a bit better, we need to know a little more about nebulae. There are three kinds of nebulae: Reflection Nebula, Emission Nebula, and Dark Nebula.

Reflection Nebulae are clouds of interstellar dust grains that are reflecting light from a nearby bright star.

Witch Head Nebula, IC 2118 – 800 light years

This Witch Head nebula is an example. It is reflecting light from the nearby star Rigel. In this photograph, the blue color of the Witch Head Nebula is caused by the dust grains scattering blue light. The same physical process causes Earth's daytime sky to appear blue.

Emission nebulae are shining their own light. In order to do that, the gas and dust needs to be excited to the point of luminesing.

This is accomplished in two primary ways:

1. By exploding stars at the end of their lives like the two we just saw
2. By new stars exciting the clouds they are born in.

Rosette Nebula – 5,500 light years

The Rosette nebula is a good example of this.This nebula is a vast cloud of dust and gas, extending over an area of almost 100 light years wide. It would cover our entire solar neighborhood. As parts of a Great Molecular Cloud condense, new stars are created. These hot new stars shine brightly in the ultraviolet. This is exactly the right wavelength for radiation to ionize hydrogen molecules and atoms by stripping away their elections. This sets off a series of quantum effects that create photons in very large numbers –

creating the light we see with our telescopes. You can see the young recently formed stars situated within this nebula. They formed from the nebula's material. These are the stars that make the nebula shine. Star formation is still in progress in this vast cloud of interstellar matter.

Areas like the one creating the Rosette stars are called **HII Regions**. There are only a few thousand of these in the Milky Way because they only last a few million years. Radiation pressure from the hot young stars drives most of the gas away.

The Pleiades are an example of a cluster which has 'boiled away' most the H II region from which it formed. Only a trace of blue reflection nebulosity remains.

Our third kind of nebulae, **Dark nebulae**, are not shining at all. They are clouds of dust and gas that are positioned in front of a bright nebula obstructing its view.

<u>Horsehead nebula – 1,600 light years</u>

The Horsehead Nebula is an excellent example of this. Rising from a sea of dust and gas like a giant seahorse, the nebula is one of the most photographed objects in the sky. It is a cold, dark cloud of gas and dust, silhouetted against a bright emission nebula.

Here's what it looks like in infrared where we can see lower wavelength light – the kind of light that can pass through the nebula's dust.

Rho Ophiuchi – 400 light years

The most interesting nebulae in the Milky Way are made up of all three types: emission, reflection, and dark. So let's take a look at some of these scattered across our galaxy.

The clouds surrounding the star system Rho Ophiuchi (oh'-fee-yu-kee) or Rho Oph for short is one of our closest star forming regions. Rho Oph itself is a binary star system visible in the light-colored region on the right side of this image. The star system is distinguished by its colorful surroundings, which include a red emission nebula and numerous light and dark brown dust lanes around 5 light years wide.

Near the image bottom lies IC 4592, the Blue Horsehead nebula. The blue glow that surrounds the Blue Horsehead's eye is a reflection nebula.

You can't see the stars behind the clouds in visible light, but x-ray and infrared brings them into view. The bright pink objects just left of center are young stellar objects. These baby stars are just now forming; many of them are still enveloped in their own tiny compact cloud called their baby blanket. There are more than 300 young stellar objects within the large central cloud. Their median age is only 300,000 years. This is very young compared to some of the universe's oldest stars, which are 12 to 13 billion years old.

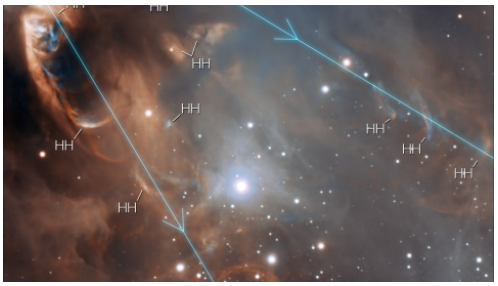
R Coronae Australis – 420 light years

This spectacular wide field image shows the area around the star R Coronae Australis. A huge dust cloud, about eight light-years long, dominates the centre of the image. At its tip (upper right) is a group of lovely reflection nebulae. It is the smaller yellowish nebula (NGC 6729) that surrounds the young variable star R Coronae Australis.

[Additional info: Note the globular star cluster NGC 6723 toward the upper right corner of the view. While the foreground clouds and stars are only 420 light years away, NGC 6723 lies nearly 30,000 light-years away, far beyond the Corona Australis dust clouds.**]**

NGC 6729

Here's a close up image that shows the dramatic effects of very young stars on the dust and gas from which they were born. The baby stars are invisible in this picture, being hidden behind the dust clouds at the upper left. But the material they are ejecting is crashing into the surroundings at speeds that can reach eight hundred thousand km/hr (that's a half a million miles per hour).



These shocks cause the gas to shine and create the strangely coloured glowing arcs and blobs known as Herbig–Haro or HH objects.

XZ and HL Tauri - 450 light-years

Here's a striking view of two stars called XZ Tauri and HL Tauri, and several nearby young stellar objects. XZ Tauri is blowing a hot bubble of gas into the surrounding space, which is filled with bright proto-stars that are emitting strong winds and jets, illuminating the region, and creating a number of HH objects.

Around HL Tauri, wisps of deep red seem to be streaking away from the blue-tinged clumps on the right. This star is associated with Herbig-Haro object HH 150.

These two stars are textbook examples of a class of stars known as T Tauris — young and rapidly rotating, with strong magnetic fields and powerful winds. They have yet to reach the temperatures necessary for hydrogen fusion deep in their cores. It will take around 100 million years for these stars to trigger these reactions and evolve into fully-fledged stars like the Sun.

Iris Nebula – 1,400 light years

Four light years across, this close-up of an area in the northwest region of the large Iris Nebula seems to be clogged with cosmic dust. With bright light from the nearby star HD 200775 illuminating it from above, the dust resembles thick mounds of billowing cotton. It's actually made up of tiny particles of solid matter, with sizes from ten to a hundred times smaller than a grain of dust we'd find here in our homes.

The Orion Molecular Cloud – 1,500 light years

[Music: *Eric Leslie Satie - Gymnopédie No.1 City of Birmingham Symphony Orchestra – Louis Fremaux, 1974; from the album "The most relaxing classical album in the world…ever!".****]***

This is the Giant Orion Molecular Cloud Complex. The image covers an area with objects that span about 75 light years. It holds a number of beautiful and well know nebula, including of course, the Orion Nebula itself in the upper right of this deep exposure.

The brightest three stars on the left are the three stars that make up Orion's belt. The top star is Mintaka around 900 light years way. The middle star is Alnilam. It is a blue-white supergiant around 1,300 light years way. The lowest is the star Alnitak. It is only 700 light years away. So you can see that these 3 stars are in line with the Orion cloud, but not a part of it.

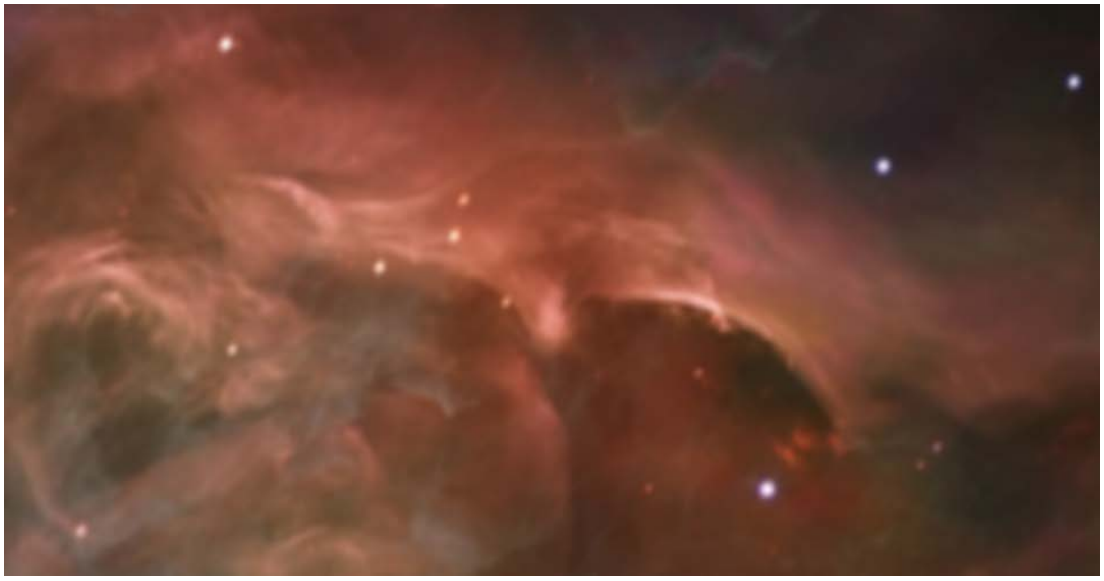
Below Alnitak is the Flame Nebula, an emission nebula in filaments of dark brown dust. Just to the right of Alnitak is the famous Horsehead Nebula. Moving over and up to the Orion nebula, we also see the Running Man nebula just to the left of Orion.

Orion Nebula, M42 – 1,500 light years

This Hubble mosaic of the Orion Nebula covers 24 light years across and reveals numerous features that reside within this nearby, intense star- forming region. More than 3,000 stars of various sizes appear in the image. The Trapezium open star cluster contains hundreds of brand new stars. These

new stars have cut out a cavern in the dust cloud and illuminate the nebula they were born in. The first of these were discovered by Galileo. They got their name because these first stars looked like a trapezoid.

As we scan to the outer edges of the nebula, you can see the illuminated walls of the Orion cavern along with beautiful elongated jets created by nearby stars being born.



V 633 & V376 – 1,956 ly

Here are two interesting extremely young stellar objects surrounded by the dusty material left over from their formation. These stars are firing off salvos of super-hot, super-fast gas. These expulsions can contain as much mass the entire planet Earth, and this mass is traveling at hundreds of kilometers per second. As it crashes into the interstellar material around them, they have created a number of HH Objects. (HH 161, HH 162 and HH 164).

[Music: *Jules Émile Frédéric Massenet – Meditation from 'Thais'; Hans Kalafusz (violin), Stuttgart Radio Symphony Orchestra / Sir Neville Marriner, 1987 EMI Electrola GmbH - from the album "The most relaxing classical album in the world…ever!"****]***

Sharpless 2-106 – 2,000 light years

This is one of my personal favorites. It's the bipolar star-forming region, called Sharpless 2-106. It appears in a relatively isolated region of the Milky Way galaxy and measures several light-years in length. A massive, young star, IRS 4 (Infrared Source 4), is responsible for the furious activity we see in the nebula. Twin lobes of super-hot gas, glowing blue in this image, stretch outward from the central star. A ring of dust and gas orbiting the star acts like a belt, cinching the expanding nebula into an "hourglass" shape. Hubble's sharp resolution reveals ripples and ridges in the gas as it interacts with the cooler interstellar medium. The dusky red veins that surround the blue emission area are illuminated by the central star.

Cone Nebula – 2,500 light years

This pillar of gas and dust is called the Cone Nebula. We're looking at the upper 2.5 light-years of the pillar. The entire nebula is 7 light-years long. Radiation from hot young stars, located beyond the top of the image, have slowly eroded the nebula over millions of years.

But the Cone Nebula is just a small part of an even larger nebula covering about 30 light-years. It includes the Fox Fur Nebula, whose convoluted pelt lies on the lower right and the bright variable star S Mon visible just above the Fox Fur. Given their distribution, the stars of NGC 2264 are also known as the Christmas Tree star cluster.

Lagoon Nebula, M8 – 5,000 light years

Swirling dust clouds and bright newborn stars dominate the view in this image of the Lagoon nebula. Within these clouds of dust and gas, a new generation of stars is forming. This Hubble image reveals a pair of one-half light-year long interstellar "twisters" — eerie funnels and twisted-rope structures — in the heart of the Lagoon Nebula. Analogous to Earth tornadoes, the large difference in temperature between the hot surface and cold interior of the clouds, combined with the pressure of starlight, produce strong horizontal shear to twist the clouds into their tornado-like appearance.

This Hubble image shows only a small part of this turbulent star-formation region, about four light-years across. The whole nebula is an incredible 55 light-years wide and 20 light-years tall.

Trifid Nebula, M20 – 5,200 light years

Three huge intersecting dark lanes of interstellar dust make the Trifid Nebula one of the most recognizable and striking star birth regions in the night sky.

The dust, silhouetted against glowing gas and illuminated by starlight, cradles the bright stars at the heart of the nebula. This image from Hubble offers a close-up view of the center of the Trifid Nebula, near the intersection of the dust bands, where a group of recently formed, massive, bright stars is easily visible.

Cat's Paw Nebula NGC 6334 – 5,500 light years

The Cat's Paw Nebula is a vast 50 light-years across region of star formation. It is one of the most active nurseries of massive stars in our galaxy and has been extensively studied by astronomers. The nebula conceals freshly minted brilliant blue stars — each nearly ten times the mass of our Sun and born in the last few million years. The region is also home to many baby stars that are buried deep in the dust, making them difficult to study. In total, the Cat's Paw Nebula could contain several tens of thousands of stars.

GGD 27 – 5,500 ly

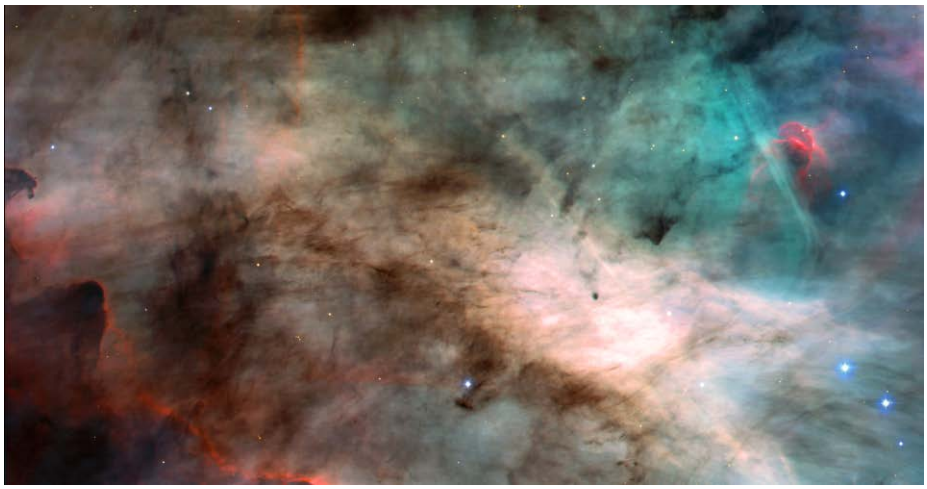
Here's a region of stellar birth known as GGD 27. At first glance it looks chaotic. However, this seemingly random cloud of gas and dust is home to several nascent stars interacting in complex, but predictable ways. Millions of years from now the prenatal cloud of gas and dust will disperse and a cluster of stars will emerge.

Monkey Head Nebula NGC 2174 – 6,400 light-years

Here's a beautiful image of the Monkey Head Nebula from the Hubble Space Telescope. This colorful H II region is filled with young stars embedded within bright wisps of cosmic gas and dust. It is the young white and pink stars sprinkled amongst the glowing clouds that are pushing away the dark stellar nurseries in which they formed.

Omega or Swan Nebula M17 – 5,500 light years

This is an image of the center of the Omega Nebula, a hotbed of newly born stars wrapped in colorful blankets of glowing gas and cradled in an enormous cold, dark hydrogen cloud 15 light years in diameter. The region of the nebula shown in this photograph is about 3,500 times wider than our solar system. The powerful radiation from its stars evaporate and erode the dense cloud of cold gas within which the stars formed. The blistered walls of the hollow cloud shine primarily in the blue, green, and red light emitted by excited atoms of hydrogen, nitrogen, oxygen, and sulphur. Particularly striking is the rose-like feature, seen to the right of center, which glows in the red light emitted by hydrogen and sulphur.



Eagle Nebula – 6,500 light years

The Eagle Nebula is 20 light years wide. Inside the Eagle, there are a number of spectacular formations. These eerie, dark pillar-like structures are columns of cool interstellar hydrogen gas and dust that are also incubators for new stars. The tallest pillar is about 4 light-years long from base to tip. In some ways, these pillars are akin to buttes in the desert, where dense rock has protected a region from erosion, while the surrounding landscape has been worn away over millennia. In this celestial case, it is especially dense clouds of molecular hydrogen gas and dust that have survived longer than their surroundings in the face of a flood of ultraviolet light from hot, massive newborn stars (located just off the top edge of the picture).

As the pillars themselves are slowly eroded away by the ultraviolet light, small globules of even denser gas buried within the pillars are uncovered. These globules have been dubbed "EGGs." EGGs is an acronym for "Evaporating Gaseous Globules," but it is also a word that describes what these objects are. Because forming inside at least some of the EGGs are embryonic stars. Eventually, the stars themselves emerge from the EGGs as the EGGs themselves evaporate.

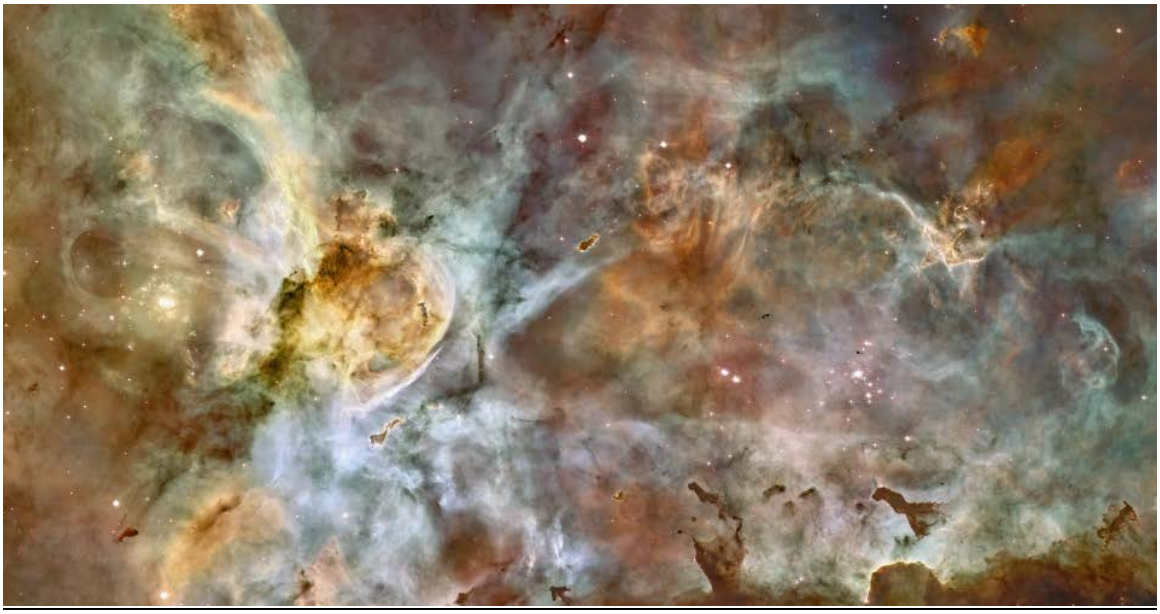
Hubble has also produced an infrared image. Infrared penetrates much of the obscuring dust and gas and unveils newborn stars, hidden in the visible-light view.

This soaring tower is 9.5 light-years high or about 90 trillion km. (That's 57 trillion miles.) The bumps and fingers of material in the center of the tower are examples of EGGs. These regions may look small but each one is roughly the size of our solar system.

The Carina Nebula – 7,500 light years

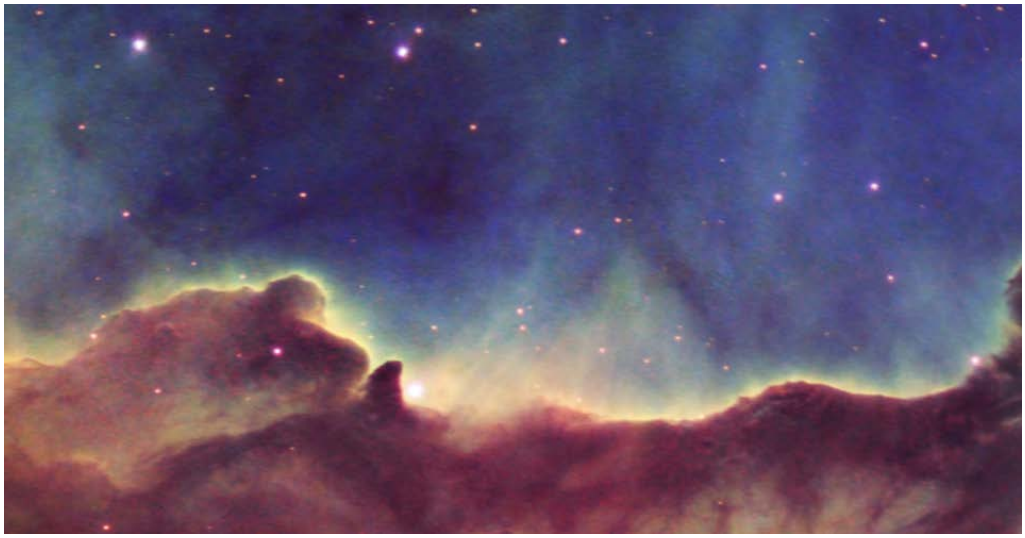
> ***[Music:*** *Puccini - Manon Lescaut, Act II Intermezzo; Belgian Radio and Television Philharmonic Orchestra; Miriam Gauci; from the album "Puccini: The Best of Puccini", 1993****]***

Here we are zooming into the giant Carina Nebula. It is a very large bright nebula that surrounds several clusters of stars. The nebula itself measures some 260 light years across, - that's about 7 times the size of the Orion Nebula! Let's take a look at some of the amazing structures contained in Carina.



NGC 3324 – 7,200 light years

NGC 3324 is located at the northwest corner of the Carina Nebula. The glowing nebula has been carved out by intense ultraviolet radiation and stellar winds from several hot, young stars. The image also reveals dramatic dark towers of cool gas and dust that rise above the glowing wall.

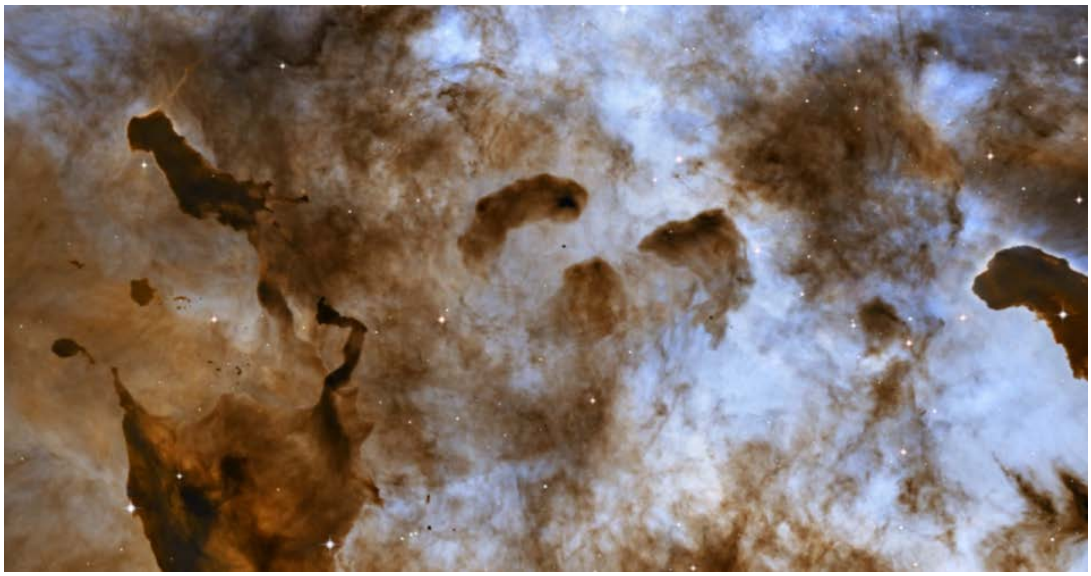


Jet in the Carina Nebula – 7,500 light years

This image from Hubble shows the tip of a 3-light-year-long pillar, bathed in the glow of light from hot, massive stars off the top of the image. Scorching radiation and fast stellar winds are sculpting the pillar and causing new stars to form within it. Although the stars themselves are invisible, one of them is providing evidence of its existence. Thin jets of material can be seen traveling to the left and to the right of a dark notch in the center of the pillar. Astronomers estimate that the jets are moving at speeds of up to 1.4 million km/hr (that's 850,000 miles per hour).

Carina Nebula dust clouds – 7,500 light years

These one-light-year-tall pillars of cold hydrogen and dust are created by violent stellar winds and powerful radiation from massive stars.



Carina Nebula pillars – 7,500 light years

Here's a three-light-year-tall pillar of gas and dust that is being eaten away by the brilliant light from nearby bright stars. The pillar is also being assaulted from within, as infant stars buried inside it fire off jets of gas that can be seen streaming from towering peaks.

Heart Nebula, IC 1805 and Soul Nebula IC 1848 – 7,500 light years

The Heart nebula's intense red output and its configuration are driven by the radiation emanating from a small group of stars near the nebula's center. The Soul nebula is the eastern neighbor of the Heart Nebula and the two are often mentioned together as the "Heart and Soul".

The Statue of Liberty Nebula – 9,000 ly

Here are two nebulae drifting through the Sagittarius arm of our Milky Way Galaxy. The nebula on the right is called the Statue of Liberty, or Torch Bearer. It's 9,000 light years away.

The nebula on the left, NGC 3603, is actually 11,000 light years further away than that. It is classified as a giant HII Region. In fact, it's the largest nebula in the Milky Way! We'll cover it in more detail at the end of this segment.

NGC 3576's delicate loops around the statue are approximately 100 light years wide and are caused by material being blown outwards by the intense radiation pressure from young stars in the center of the nebula. Most of these stars are hidden from our view in the bright area at the base of the loops.

RCW 34 – 10,100 light years

Here we are zooming into the glowing nebula called RCW 34. Its central gas is heated dramatically by young stars and expands through the surrounding cooler gas. Once the heated hydrogen reaches the borders of the gas cloud, it bursts outwards into the vacuum like the contents of an uncorked champagne bottle — this process is referred to as champagne flow.

NGC 2467 – 13,000 light years

Like the familiar Orion Nebula, NGC 2467 is a huge cloud of gas — mostly hydrogen — that serves as an incubator for new stars. The huge clouds of gas and dust are sprinkled with bright blue, hot young stars.

NGC 3603 – 20,000 light years

Here we're zooming into the giant nebula NGC 3603 - a prominent star-forming region, about 20,000 light-years away. As we said earlier, it is the largest H II Region in the galaxy, and it's the last H II reagion we'll cover in this segment.

The star cluster HD 97950 is nestled within the nebula. It contains three of the most massive and luminous stars known. Ultraviolet radiation and violent stellar winds from these stars have blown

out an enormous cavity in NGC 3603's gas and dust enveloping the cluster. These winds have created the unobstructed view we see here.

Distance Ladder

Like Globular Star Clusters, HII regions come in a wide variety of sizes and luminosities, but, just like with globular clusters, observations have shown that the brightest HII regions all have a common luminosity. This makes them an important standard candle because, just like the brightest globular clusters, they are bright enough to be seen out to great distances. So we can add them to our distance ladder.