



## Andromeda and the Local Group

**{Abstract}** – In this segment of our “How far away is it” video book, we cover the Andromeda galaxy along with our local group of galaxies, including some of the dwarf galaxies orbiting the Milky Way.

We begin with Edwin Hubble’s discovery of a Cepheid variable star in what was thought to be a Milky Way nebula. The star was V1 and it changed the history of astronomy. We also take a deep dive into the galaxy’s disk, and point out what was going on here on our planet when the light we see left Andromeda on its journey into our telescopes. We finish with a look at Andromeda’s collision course with our Milky Way.

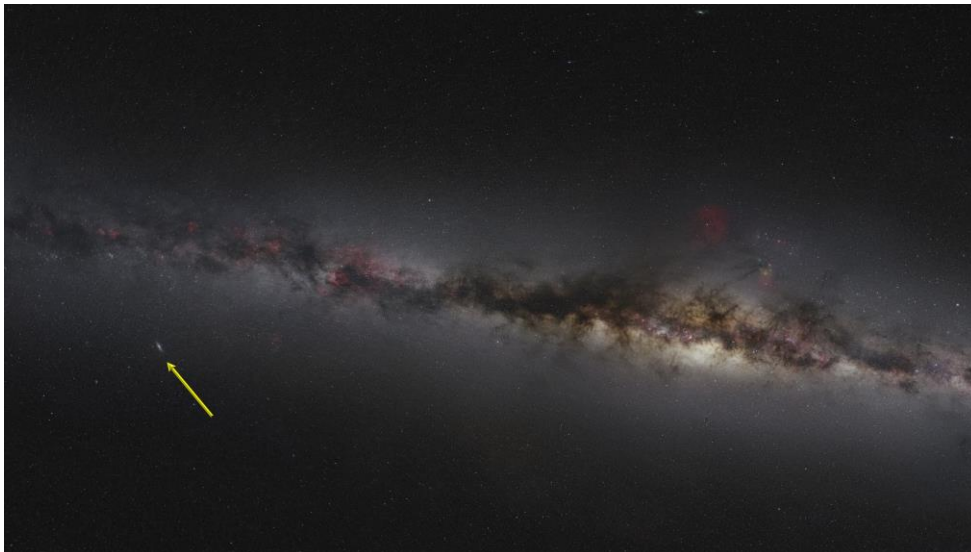
Next, we identify the local group of galaxies including: Triangulum with its great star birth H II region NGC 604; irregular galaxy NGC 6822 with its unique Hubble V H II region; the recently discovered galaxy IC 10; nearby edge on galaxy 3109; and Sextans A.

We then cover 5 of the dwarf galaxies orbiting the Milky Way including Sagittarius Dwarf, Sculptor Dwarf and Fornax Dwarf along with the Large Magellanic Cloud and the Small Magellanic Cloud. Then we examine some of the amazing nebula within these two dwarf galaxies including: Supernova Remnant N 63A, SN 0509-67.5, the Tarantula Nebula, 30 Doradus, Hodge 301, the Double Bubble, LH 95, NGC 2074, NGC 602, NGC 346 and others. We conclude with a review of the galaxies we covered marked on a map of the Local Group.}

### Introduction

[Music: @00:00 Alexander Borodin – “Nocturne” –From the album The Most Relaxing Classical Music, 2003]

Visible to the naked eye and studied by Persian astronomers around 900 AD, the Andromeda nebula was thought to be a part of the Milky Way. In fact, it was thought that all the stars in the Universe were in our Milky Way galaxy.



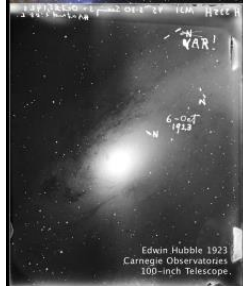
## How Far Away Is It – Andromeda and the Local Group



That changed in the early 1900s. In 1923, Edwin Hubble found a Cepheid variable in the nebula. This star altered the course of modern astronomy. The star goes by the name V1.

### Andromeda, M31 – 2.65 mly

Here's Edwin Hubble's image of Andromeda, which was made on a 4 by 5 inch glass plate and dated Oct. 6, 1923. He originally identified three stars and marked each of them with an "N" for

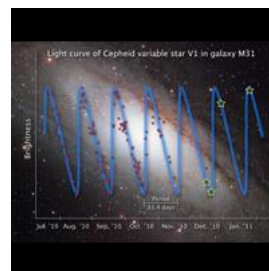


novae, a class of exploding star. Later, Hubble realized that the nova at the top right was actually a Cepheid variable. He crossed out the "N" and wrote "VAR" for variable.

He added an explanation point because he knew that this variable would allow him to calculate the distance. You may recall from our segment on distant stars, that we covered how Harriet Leavitt discovered the relationship between Cepheid variables frequency and their intrinsic luminosity. And once we know the intrinsic luminosity of a star, we can use the apparent luminosity and the inverse square law to determine how far away the star is.



And indeed, once the period was measured (at 31.4 days), he knew he had another galaxy! Before V1, distances to stars were measured in thousands of light years. After V1, the universe became a much bigger place. V1 was over two and a half million light years away.



## How Far Away Is It – Andromeda and the Local Group



Andromeda is a beautiful barred spiral galaxy with two spiral arms that glow with a massive number of new stars. This is very much like our Milky Way. But Andromeda's disk is 220,000 ly wide. That's more than twice the width of the Milky Way. But recent studies of star escape velocities indicate that both galaxies have the mass of 800 billion Suns counting stars, gas, dust and Dark matter.



Light from this magnificent galaxy left its stars just over two and a half million ~~light~~ years ago. When the light that entered Hubble's telescope left Andromeda, there were no humans on Earth. While the light traveled towards Earth: we came into being; we created and lost great civilizations; and we built the telescopes that caught that light when it finally reached our planet.

### [Andromeda's Central Black Hole]

Here we see the 100-million-solar-mass black hole at the Andromeda's core. This is the sharpest visible-light image ever made of the nucleus of an external galaxy. There is a blue glow at the center of what appears to be a double nucleus.





## How Far Away Is It – Andromeda and the Local Group



Astronomers using the Hubble Space Telescope have identified the source of the blue light surrounding this supermassive black hole in Andromeda's core.



New spectroscopic observations reveal that the blue light consists of more than 400 stars. The stars are tightly packed in a disk that is only one light-year across. The disk is nested inside an elliptical ring of older, cooler, redder stars. When the stars are at the farthest point in their orbit, they move slower and give the illusion of a second nucleus.

**Additional info:** Astronomers are trying to understand how apparently young stars were formed so deep inside the black hole's gravitational grip and how they survive in such an extreme environment. The fact that young stars are also closely bound to the central black hole in our Milky Way galaxy suggests this may be a common phenomenon in spiral galaxies.]

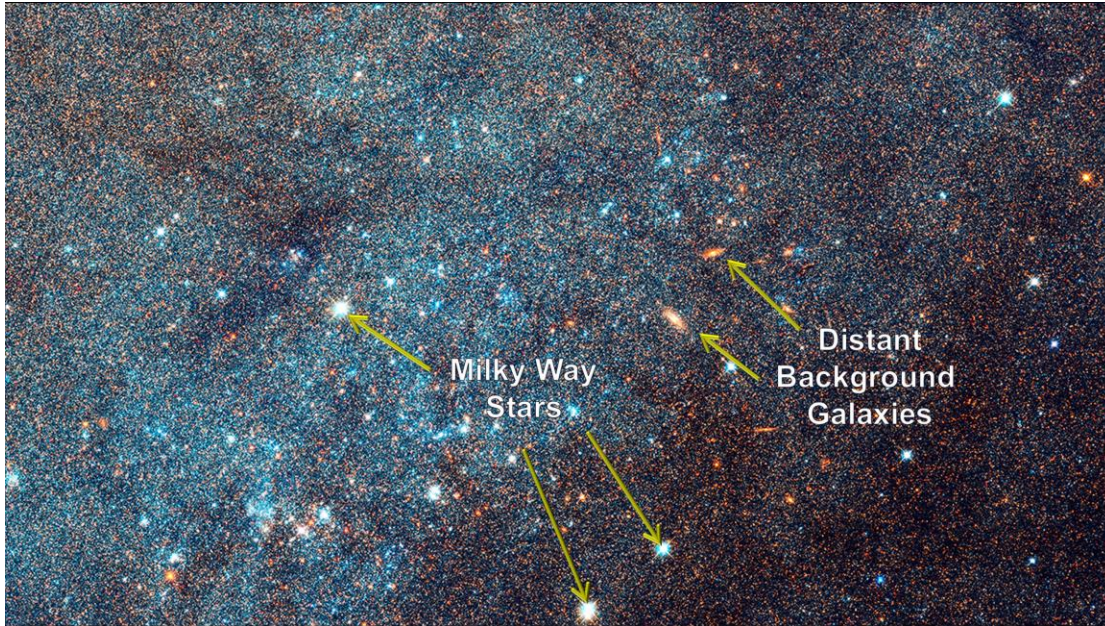
The Hubble Space Telescope has ~~now~~ captured the sharpest and most detailed image ever taken of the galaxy. It shows over 100 million stars and thousands of star clusters embedded in a section of the galaxy's disc stretching across over 48,000 light-years. It traces the galaxy from its central galactic bulge on the left, where stars are densely packed together, across lanes of stars and dust to the sparser outskirts of its outer disc on the right.



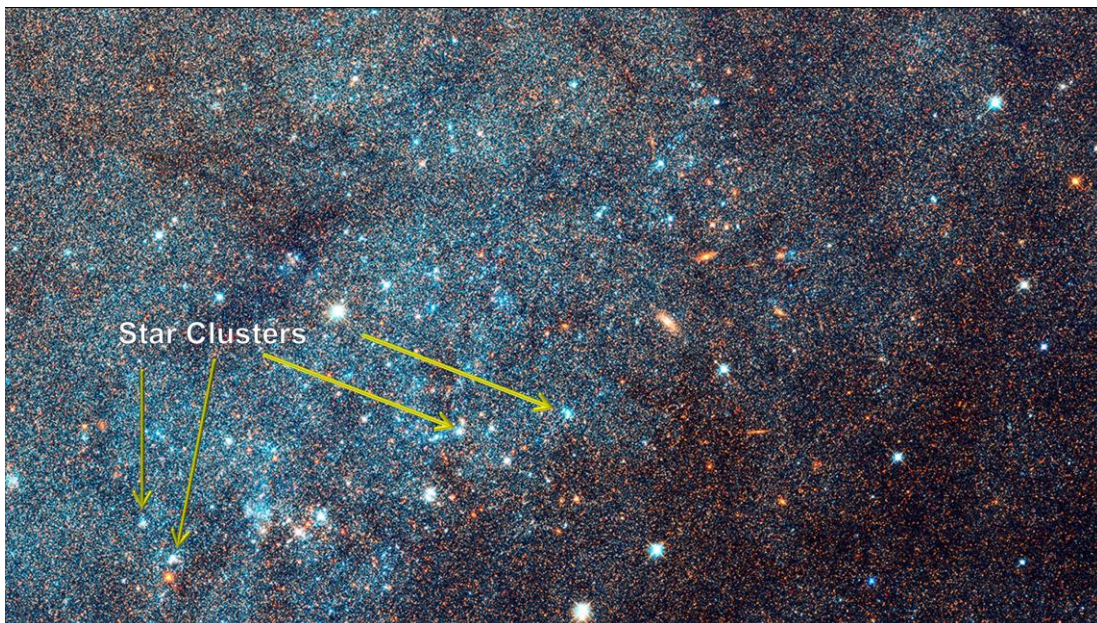




Zooming into the boxed field, we see some foreground Milky Way stars in the line of sight to Andromeda and a couple of distant spiral galaxies shining through Andromeda's disk.



A large number of star clusters can be seen in this analysis of Andromeda.



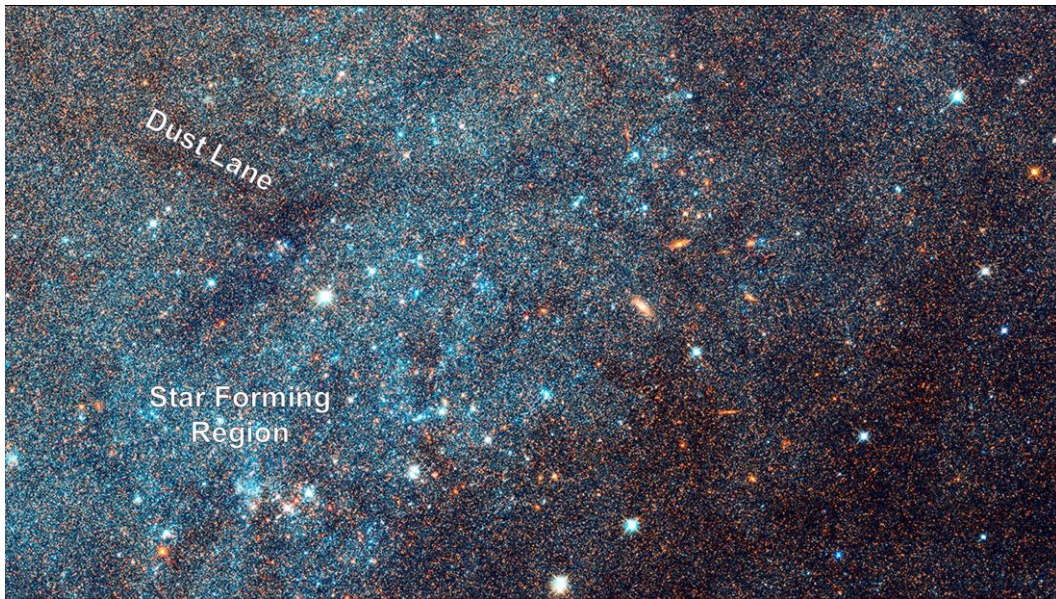
The large groups of blue stars in the galaxy indicate star-forming regions in the spiral arms, whilst the dark silhouettes of obscured regions trace out complex dust structures. Underlying



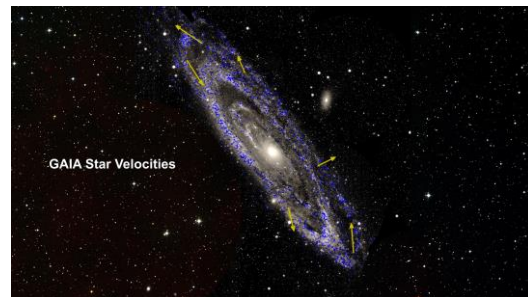
## How Far Away Is It – Andromeda and the Local Group



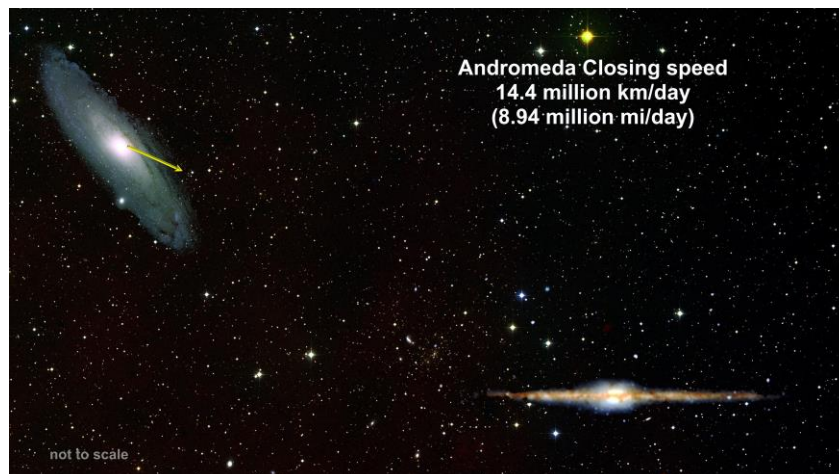
the entire galaxy is a smooth distribution of cooler red stars that trace Andromeda's evolution over billions of years.



We'll conclude our coverage of Andromeda with a look at its closing velocity. Careful analysis of Andromeda's proper and radial motion indicates that it is on a collision course with our Milky Way.



It's closing at 14.4 million km/day. That's almost 9 million miles per day. But, given the 2.5 million light years between us, it won't get here for around 4 to 4.5 billion years. We cover this in depth in a subsequent segment on colliding galaxies.



## How Far Away Is It – Andromeda and the Local Group

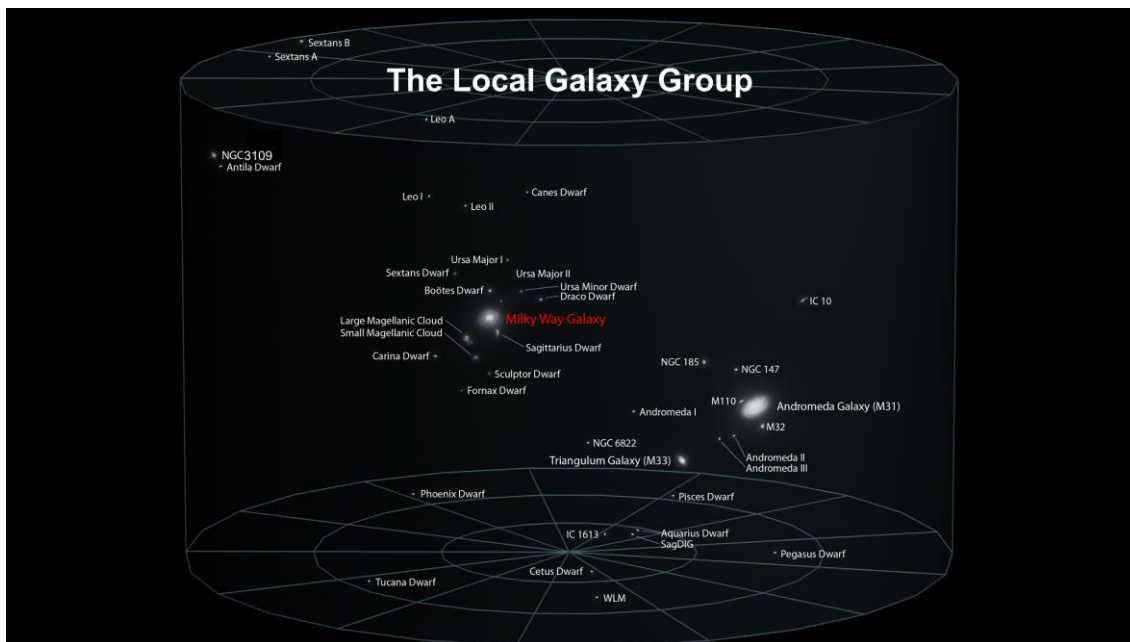


### The Local Group

[Music: @06:54 *Edward Elgar – “Enigma Variations” – from the album The Most Relaxing Classical Music, 1997.*]

There are over 30 galaxies in the local group. Andromeda is the largest. The Milky Way is second and Triangulum is third. All the rest are dwarf galaxies, and most of these are orbiting one or the other of the three big ones.

As of 2020, we have discovered 59 dwarf galaxies orbiting the Milky Way. Andromeda has at least 34. The Triangulum Galaxy has one. The other members of the group are gravitationally not orbiting any of these three larger galaxies. We'll take a look at some of these and then move closer to home, and have a good look at some of our orbiting dwarf galaxies.



### Triangulum M33 – 2.85 mly

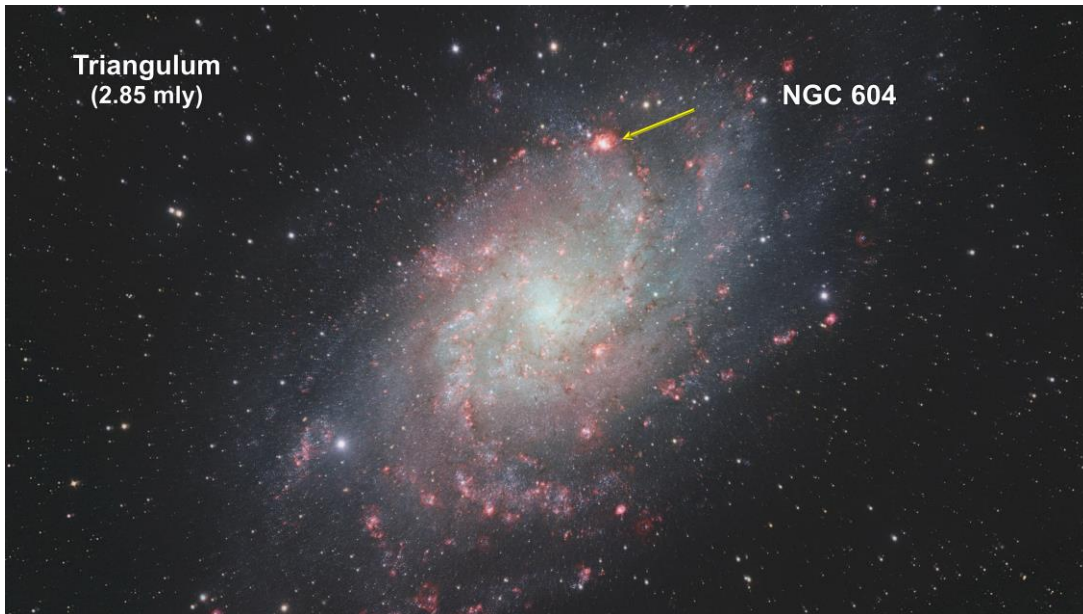
Here we are zooming into the Triangulum Galaxy. It's the third-largest member of the Local Group, with a diameter of about 60,000 light years. Triangulum is home to around 40 billion stars. That's small compared to our two to four hundred billion and Andromeda's trillion. The Galaxy doesn't have a bright bulge at its center, but it does contain a huge amount of gas and



## How Far Away Is It – Andromeda and the Local Group



dust, giving rise to rapid star formation. New stars form at a rate of approximately one every two years.



This Hubble image contains 10 to 15 million individual stars. The mosaic of the Triangulum Galaxy showcases the central region of the galaxy and its inner spiral arms. Millions of stars, hundreds of star clusters and bright nebulae are visible.







### NGC 604 in Triangulum – 2.85 mly

NGC 604 is among the largest known star formation regions in the Local Group. It lies in an outer Triangulum spiral arm. This star-birth region and contains more than 200 brilliant blue stars within a cloud of glowing gases some 1,500 light-years across. That's nearly 100 times the size of the Orion Nebula. By contrast, the Orion Nebula contains just four bright central stars. The bright stars in NGC 604 are extremely young by astronomical standards, having formed a mere 3 million years ago.



### NGC 6822 – 1.6 MLY

The small, irregular galaxy is one of the Milky Way's closest neighbors and is considered prototypical of the earliest fragmentary galaxies that inhabited the young universe. What's striking about NGC 6822 is its unusually high abundance of HII region emission nebulae. These are visible surrounding the small galaxy, particularly toward the upper right.





### Hubble V Nebula inside NGC 6822

This is one of them. The glowing gas cloud, called Hubble-V, has a diameter of about 200 light-years. A faint tail of nebulosity trailing off the top of the image sits opposite a dense cluster of bright stars at the bottom of the irregularly shaped nebula.



### IC 10 – 2.2 mly

IC 10 is another irregular galaxy. [It's the closest-known starburst galaxy. Starburst galaxies are galaxies undergoing a furious pace of star formation fueled by an ample supplies of cool hydrogen gas.] Edwin Hubble suspected it might belong to the Local Group of galaxies, but its status remained uncertain for decades. Its membership in the group was finally confirmed in 1996 by direct measurements of its distance based on observations of Cepheids. The reason it took so long is that, despite its closeness, the galaxy lies near the plane of the Milky Way and is therefore heavily obscured by our galaxy's interstellar matter.

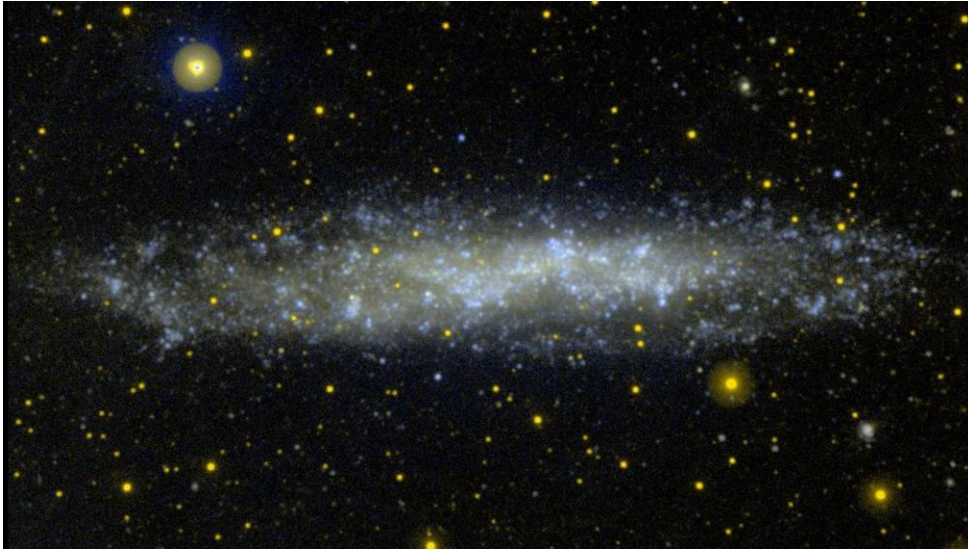






### NGC 3109 – 4.7 mly

NGC 3109 looks like a small spiral galaxy. If it is a spiral galaxy, it would be the smallest in the Local Group. It is oriented edge-on from our point of view, and may contain a disk and a halo. It does not appear to possess a galactic nucleus. But it does seem to contain an unusually large number of planetary nebulae. [The disk appears to be composed of stars of all ages, whereas the halo contains only very old stars.]



### Sextans A – 4.3 mly

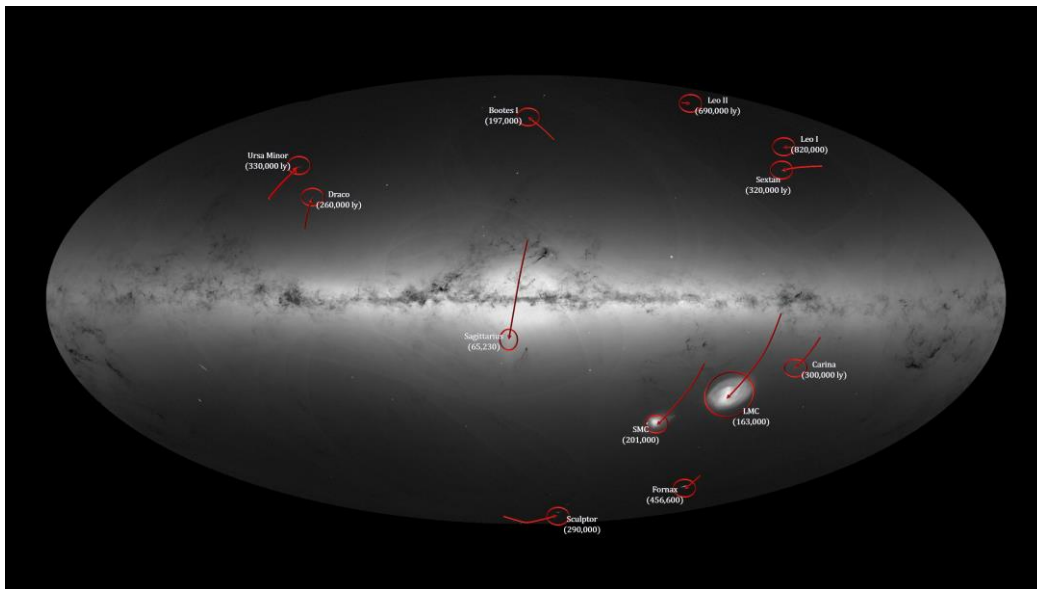
Young blue stars and older yellow and red stars shine against a dark sky in this image of Sextans A from Japan's Subaru telescope. The galaxy is a small peculiar square-shaped dwarf galaxy 5,000 light years across 4.3 million light years from Earth. The bright foreground yellowish stars are in the Milky Way.





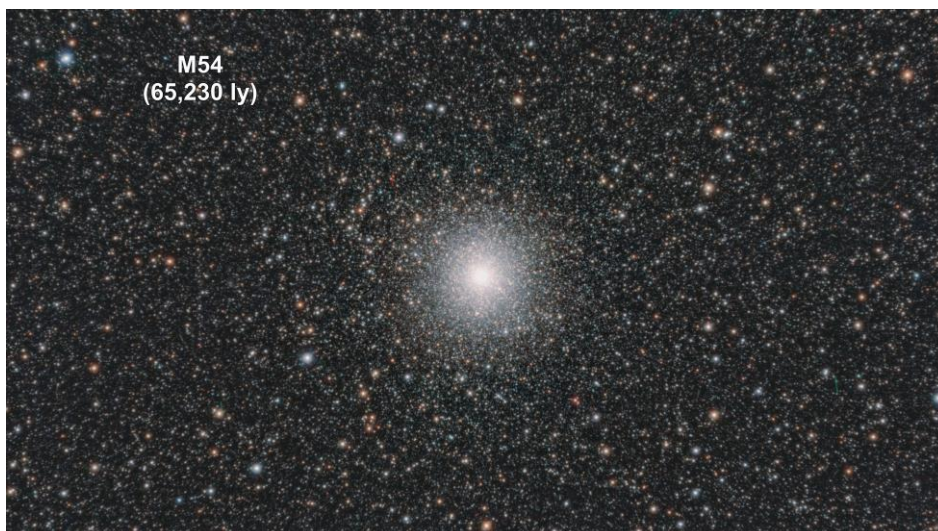
### Dwarf galaxies Orbiting the Milky Way

Here we take a look at a few of the dwarf galaxies orbiting our Milky Way. Gaia's all sky star density map picked up a few of the closer ones and calculated their orbits. The lines represent the orbital track traveled over the past few millions of years. The further away the galaxy, the longer its orbital period. It can take billions of years for the satellites further out to complete a single orbit. Compare that to the 230 million years it takes us to make one revolution.



### **Sagittarius Dwarf – 65,230 ly**

Sagittarius Dwarf is our closest orbiting galaxy. It is so close, that it is being ripped apart by the Milky Way. It will be fully integrated as part of the Milky Way within the next billion years. It can take as much as 770 million years to orbit the Milky Way. Here we are zooming into globular cluster M54 at its center.







**Sculptor Dwarf** [Music: @14:13 Tchaikovsky – “Symphony No 5” – from the album A Calendar of Classics – A 12 C ..., 2007.]

Sculptor Dwarf is a dwarf spheroidal galaxy. These are very common. They contain an old stellar population with large separations between stars. They are also devoid of gas and dust, so there is no new star formation. A team of astronomers used data from both the Hubble Space Telescope and the Gaia satellite to directly measure the 3D motions of individual stars in Sculptor. Their results show that the galaxy’s orbit is quite elongated. Currently at 290,000 ly, Sculptor Dwarf is near to its closest point to the Milky Way. But its orbit will take it as far out as 725,000 light-years.



### **Fornax Dwarf - 460,600 ly**

Fornax Dwarf is one of our furthest orbiting galaxies. It’s of interest to astronomers because its globular clusters don’t fit current globular cluster formation theory because there aren’t enough old stars in the clusters as theorized that there should be. Research continues.



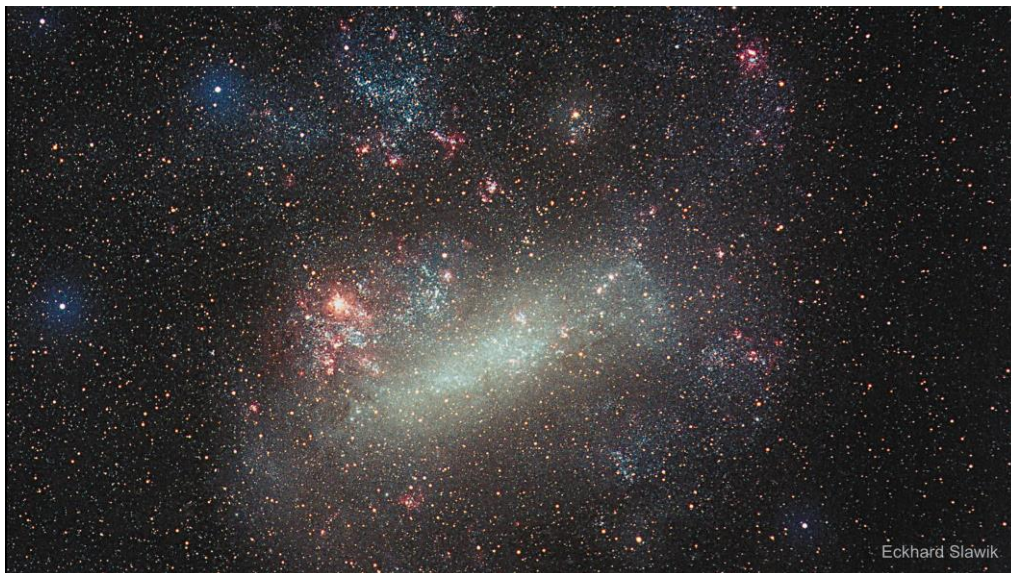


### Large and Small Magellanic Clouds

But the two dwarfs of the most interest can be seen in the southern night sky. They are the Large Magellanic Cloud 160 to 170 thousand light years away and the Small Magellanic Cloud a bit further at 200,000 light years from us. These companion galaxies were named for the Portuguese navigator Ferdinand Magellan, whose crew discovered them during the first voyage around the world (1519 to 1522).



The Large Magellanic Cloud or LMC for short is the brightest galaxy in the sky. It contains several billion stars and many stars are still forming in it.







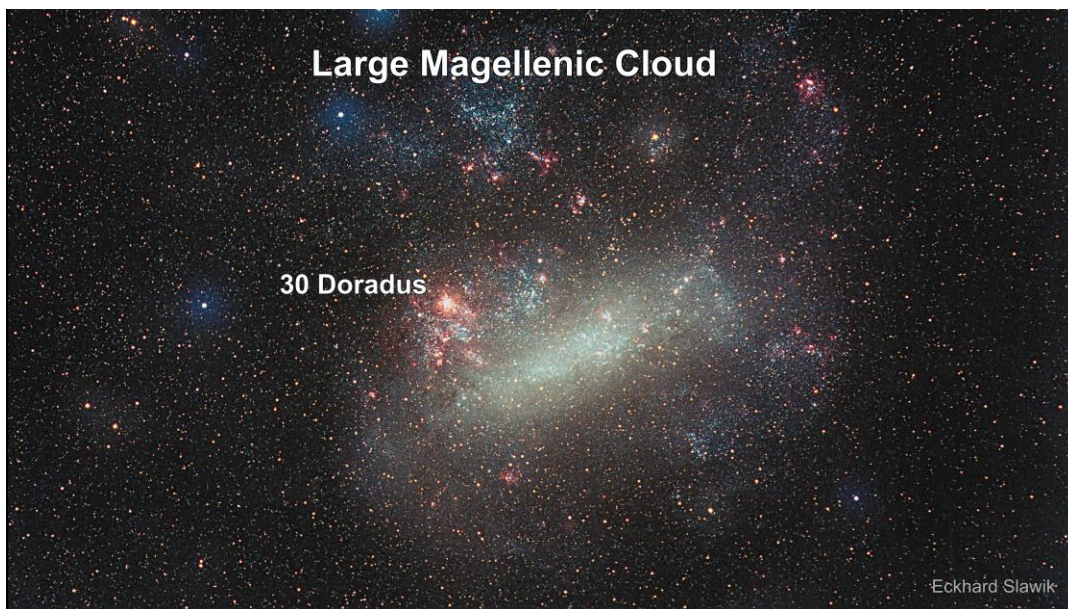
The Small Magellanic Cloud or SMC for short contains at least several hundred million stars. Like the LMC, there is still a lot star formation taking place within it.



[**Music:** *We return to and conclude with the exotic and lush melodies in Alexander Borodin's "Nocturne".*]

### 30 Doradus

Here we'll take a look at some of the amazing nebula in the LMC. This stellar region is called 30 Doradus. It contains millions of young stars including the most massive stars ever seen, weighing more than 100 times the mass of our Sun. No known star-forming region in our galaxy is as large or as prolific as 30 Doradus.







### Tarantula Nebula

With this closer look, we see the Tarantula Nebula. Early astronomers nicknamed the nebula because its glowing filaments resemble spider legs. The image reveals the stages of star birth, from embryonic stars a few thousand years old still wrapped in their eggs to behemoths that die young in supernova explosions.



### **R136 – 170,000 ly**

Astronomers using the unique ultraviolet capabilities of the Hubble Space Telescope have identified nine monster stars with masses over 100 times the mass of the Sun in the star cluster R136. This makes it the largest sample of very massive stars identified to date. The detected stars are not only extremely massive, but also extremely bright. Together these nine stars outshine the Sun by a factor of 30 million.







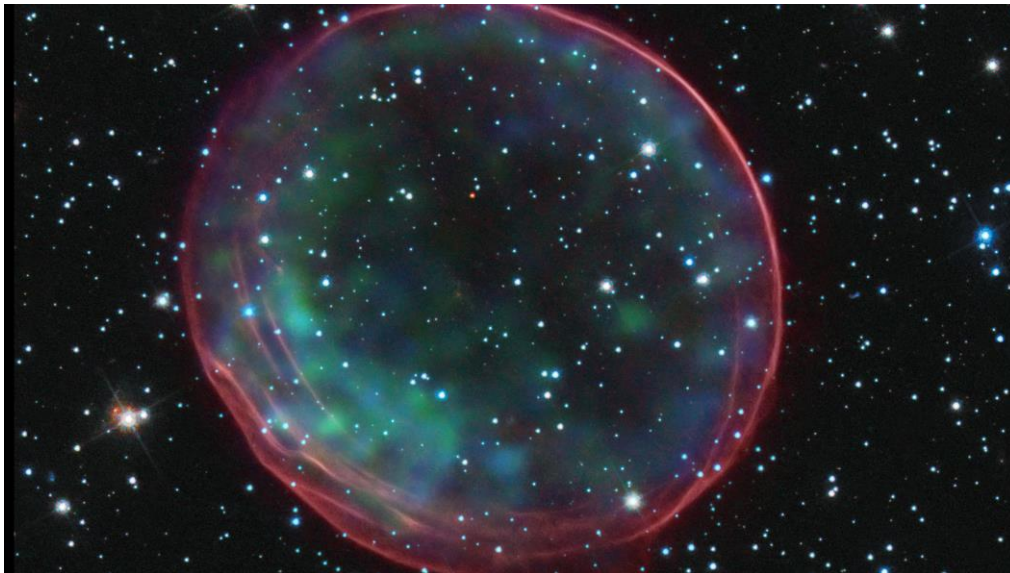
### **Hodge 301**

Hodge 301, seen in the lower right-hand corner of this image, lives inside the Tarantula Nebula. Many of the stars in Hodge 301 are so old that they have exploded as supernovae. These exploded stars are blasting material into the surrounding region at speeds of almost 320 km/s (that's 200 miles per second). The high-speed matter is plowing into the surrounding Tarantula Nebula, shocking and compressing the gas into a multitude of sheets and filaments, seen in the upper left portion of the picture.



### **SNR 0509-67.5 – 170,000 light years**

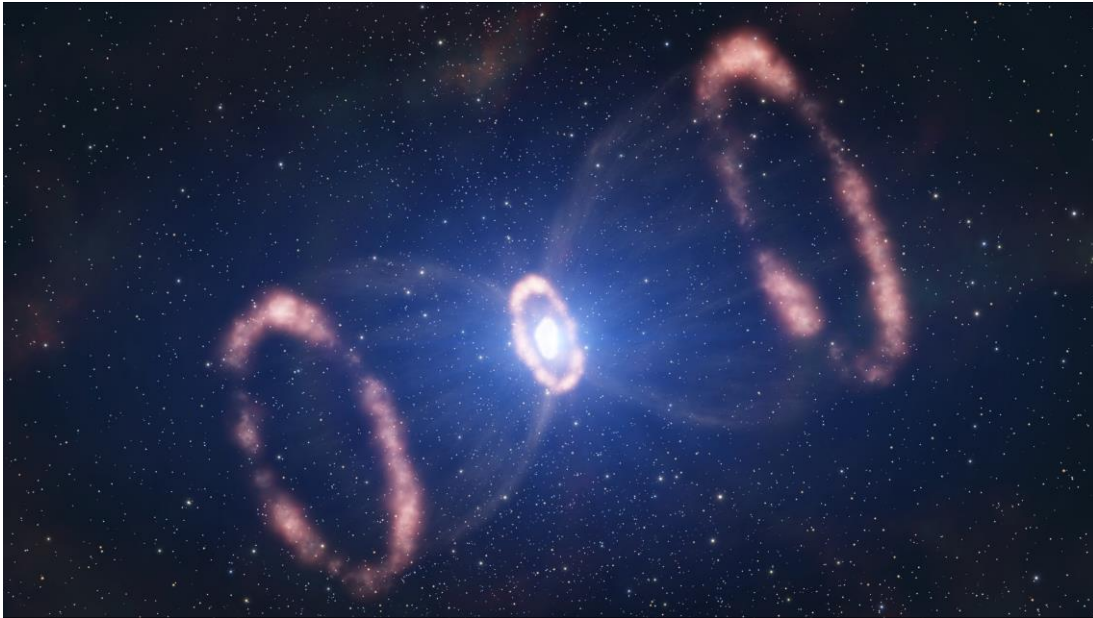
This image of supernova remnant 0509-67.5 was made by combining data from two of NASA's Great Observatories: Hubble and the Chandra X-ray Observatory. The result shows soft green and blue hues of heated material from the X-ray data surrounded by the glowing pink optical shell, which shows the ambient gas being shocked by the expanding blast wave from the supernova.





### SN 1987A – 163,000

Three decades ago, astronomers spotted one of the brightest exploding stars in more than 400 years. The titanic supernova, called 1987A (SN 1987A) in the Large Magellanic Cloud, blazed with the power of 100 million Suns for several months following its discovery [on Feb. 23, 1987]. A dense ring of gas around the supernova is glowing in optical light, and has a diameter of about one light-year. A flash of ultraviolet light from the explosion energized the gas in the ring, making it glow for decades. [The ring was created when the star was a red giant - around 20,000 years before the star exploded.]



This time-lapse video sequence of Hubble images shows the effects of the shock wave from the supernova blast smashing into the ring. The ring begins to brighten as the shock wave hits it. [The ring is about one light-year across.] In the past few years, the ring's X-ray light has stopped getting brighter. And, the bottom left part of the ring has started to fade. These changes provide evidence that the explosion's blast wave has moved into the region beyond the ring. This represents the end of an era for this supernova. We expect to learn more about this new region as the blast wave impacts its contents.







### Double Bubble DEM L 106 and N30B – 160,000 light years

A unique peanut-shaped reflection nebula surrounds a cluster of young, hot stars in this view from Hubble. The "double bubble - N30B" is inside a larger nebula. The very bright star at the top of the picture, called Henize S22, illuminates the dusty cocoon like a flashlight shining on smoke particles. This searing supergiant star is only 25 light-years from the N30B nebula.



### LH -95

Swirls of gas and dust reside in this ethereal-looking region of star formation. It reveals a region where low-mass, infant stars and their much more massive stellar neighbors reside. This is just one of the hundreds of star-forming systems, located in the LMC.







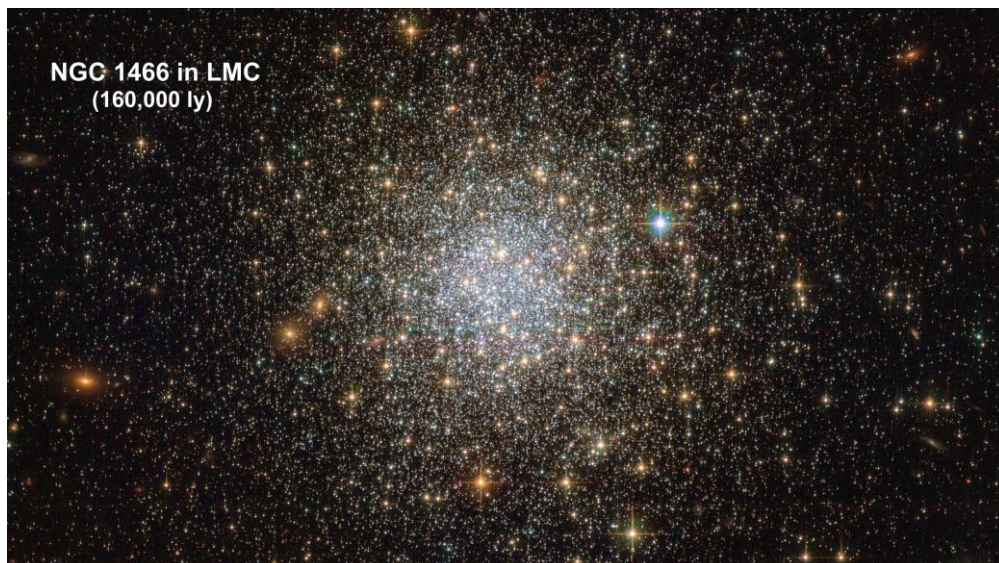
### Star Cluster NGC 2074 – 170,000 light years

This region is a firestorm of raw stellar creation, perhaps triggered by a nearby supernova explosion. The three-dimensional-looking image reveals dramatic ridges and valleys of dust, serpent-head "pillars of creation," and gaseous filaments glowing fiercely under torrential ultraviolet radiation. The region is on the edge of a dark molecular cloud that is an incubator for the birth of new stars.



### **NGC 1466 - 160,000 ly**

In 2019 I released the "How Old are Stars" video where we covered HR Diagram turnoff points to find the age of star clusters. Here's NGC 1466, a very old globular cluster in the Large Magellanic Cloud (LMC) 160,000 ly away. It has a mass equivalent to roughly 140,000 Suns and a turnoff point that indicates its age as around 13.1 billion years - making it almost as old as the Universe itself.

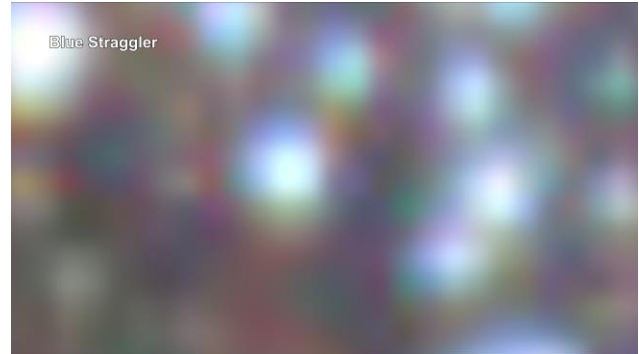






[All high mass blue stars would have moved into their Giant and Super Giant phases by now. But we do see blue stars in this and many other clusters of similar age.

These massive hot blue stars are a special type of re-invigorated stars called blue stragglers. Under certain circumstances, stars receive extra fuel that bulks them up and substantially brightens them. This can happen if one star pulls matter from a neighbor, or if two stars collide. Blue stragglers are so called because of their blue color, and the fact that their evolution lags behind that of the rest of the stars in the cluster.



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### NGC 602

Now let's take a look at a couple of objects in the Small Magellanic Cloud.

At the heart of the SMC, lies star cluster NGC 602. The high-energy radiation blazing out from the hot young stars is sculpting the inner edge of the outer portions of the nebula, slowly eroding it away and eating into the material beyond. Elephant trunk-like dust pillars point towards the hot blue stars and are tell-tale signs of their eroding effect.





### NGC 346

The NGC 346 cluster, at the center of this Hubble image, is resolved into at least three sub-clusters and collectively contains dozens of hot, blue, high-mass stars, more than half of the known high-mass stars in the entire SMC galaxy. A myriad of smaller, compact clusters is also visible throughout the region.



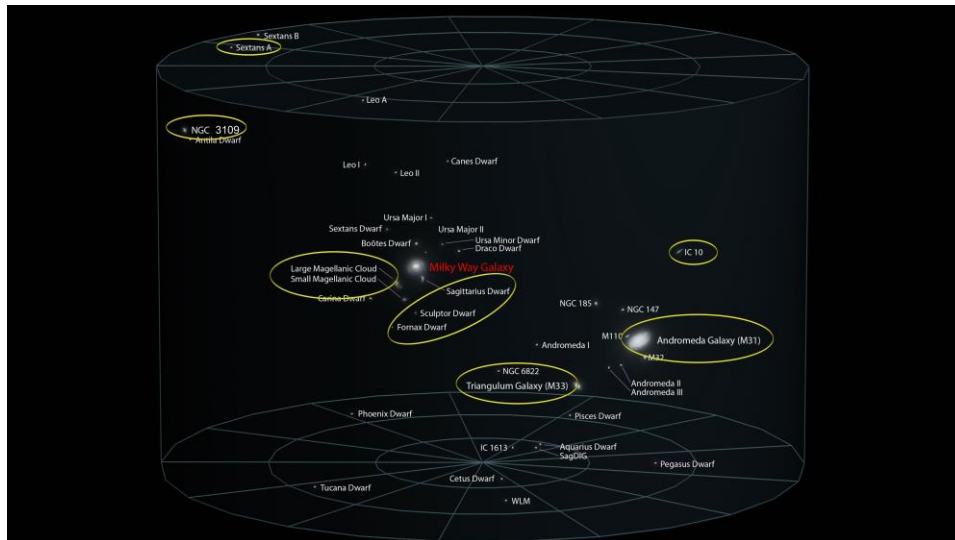
### NGC 248 – 200,000 ly

Hubble captured two nebulae inside the Small Magellanic Cloud, situated so as to appear as one. Intense radiation from the brilliant central stars is heating hydrogen in each of the nebulae, causing them to glow red. This is part of a study to understand how interstellar dust is different in galaxies that have a far lower supply of heavy elements. The Small Magellanic Cloud has between a fifth and a tenth of the amount of heavy elements that the Milky Way does. Because it is so close, astronomers can study its dust in great detail, and learn about what dust was like earlier in the universes' history.





Here are the Local Group galaxies we saw in this segment. The Local Group is part of a larger structure known as the Local Volume. We'll explore this Local Volume in our next segment.



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23