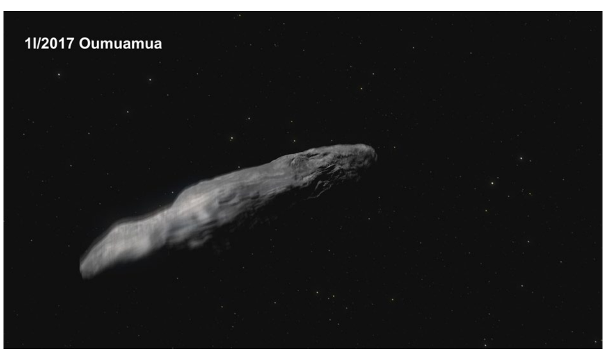
2025 Review

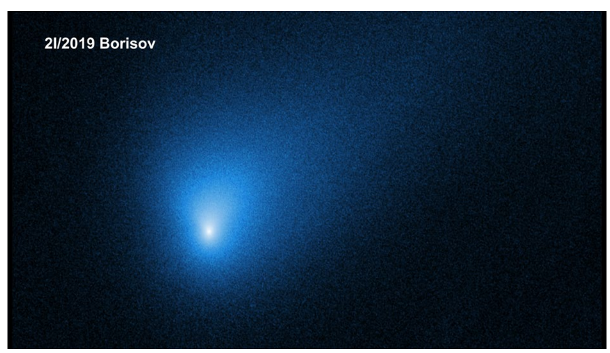
Introduction

2025 was another big year for astronomical discoveries. We have a new Interstellar Comet that's caused a stir. A study of a pair of objects in the Kuiper Belt is interesting. Next, we'll cover a number of nearby nebulas such as Cat's Paw, Flame, and the Crystal Ball. We'll examine the dust around a Wolf-Rayet star system. We'll cover a spectacular star cluster and an update on the Eagle Nebula. We'll take a close look at Cassiopeia A Light Echoes followed by a close look at our Galaxy's Center Regions. We then move out of our galaxy, starting with an examination of Andromeda's Satellites. Beyond the Local Group we'll see the Bullseye Galaxy and update Dark Matter in the Bullet Galaxy. Next, we'll cover Little Red Dots and a galaxy from the early universe. We'll end with a review of the amazing contributions made by the European Space Agency's GAIA satellite that was retired in 2025. I trust you'll find it interesting and informative.

01 - Interstellar Comet 3I/Atlas

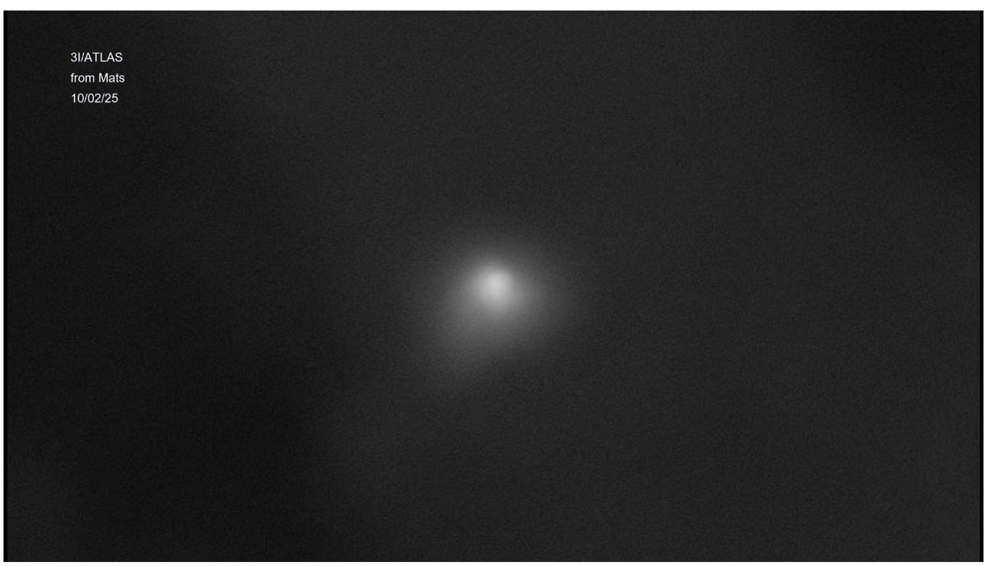
In our 2017 review, we covered 1I Oumuamua. It was the first interstellar comet ever detected. It did not have a coma. In our 2019 review, we covered 2I Borisov - the second interstellar comet detected. Its coma was very much like our normal solar system comets.



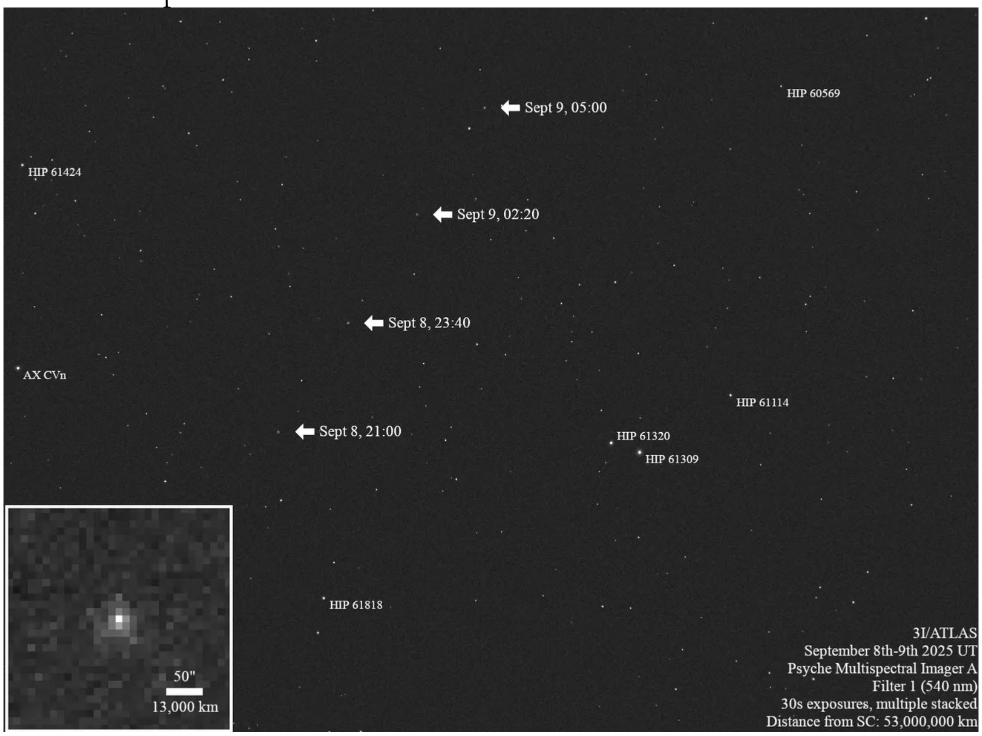


This year, we detected 3I/ATLAS. This is a July 21, 2025 Hubble Space Telescope image of the interstellar comet 3I ATLAS. Hubble photographed the comet when it was 446 million km or 277 million miles from Earth. Its velocity is 209,000 kilometers per hour or 130,000 miles per hour with respect to the Sun. That's almost twice the velocity of the Earth's orbit. The stationary background stars are streaked in the exposure. The comet follows an unbound, hyperbolic trajectory past the Sun. It will not come close to the Earth.

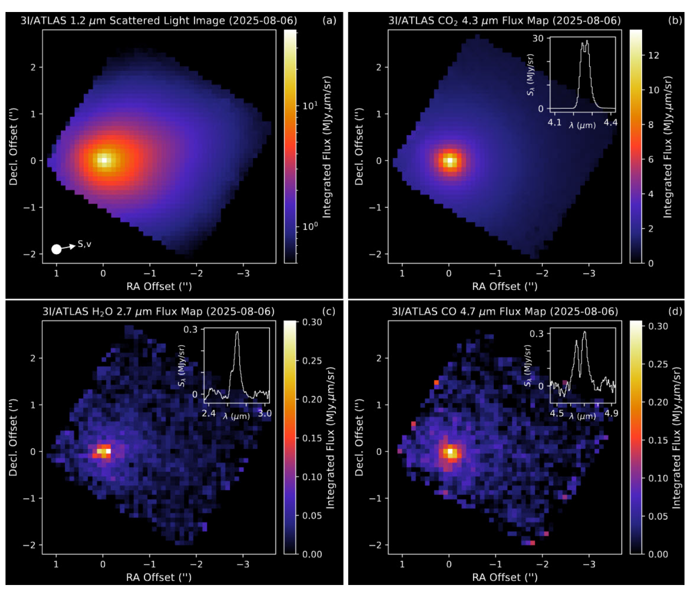
It was discovered on 1 July 2025 by the Asteroid Terrestrial-impact Last Alert System station. Observatories around the world an in space have been watching ever since. Five spacecraft, on and near Mars, zoomed in on the comet as it passed just 29 million kilometers (that's 18 million miles) from the Red Planet. A camera aboard NASA's Mars Reconnaissance Orbiter captured this image on October 2nd.



Psyche, a spacecraft named after the asteroid it will eventually reach, tracked 3I/ATLAS over the course of eight hours on September 8 and 9 when the comet was about 53 million kilometers or 33 million miles from the spacecraft.

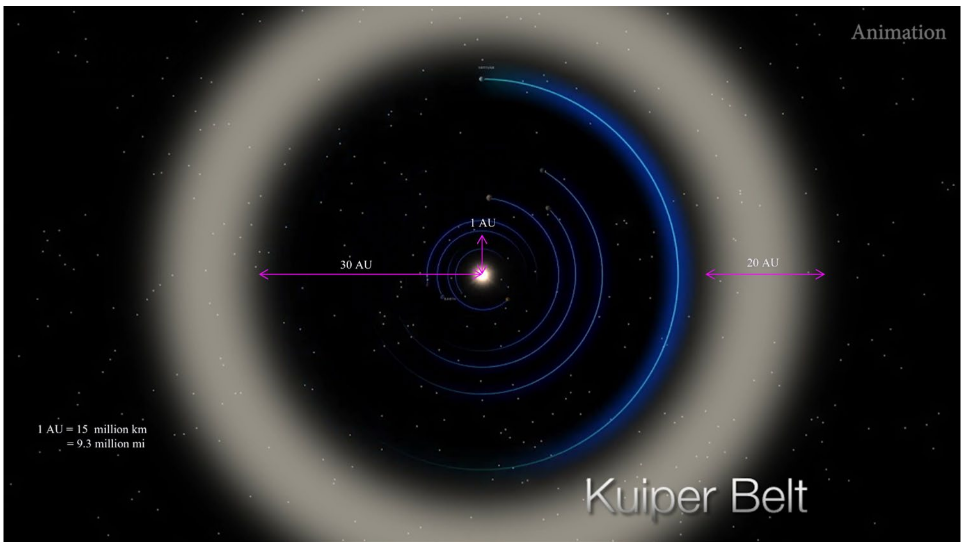


Here's Webb's Infrared spectroscopy results. The spectral images reveal a carbon dioxide dominated coma, with enhanced outgassing in the sunward direction. This is an unusual direction for solar system comets. Webb also found the presence of water and carbon monoxide as well as carbonyl sulfide (OCS) – not shown. In addition, 3I ATLAS has been releasing more carbon dioxide than water, and more nickel than iron, compared with 2I Borisov and comets that originated in our solar system.

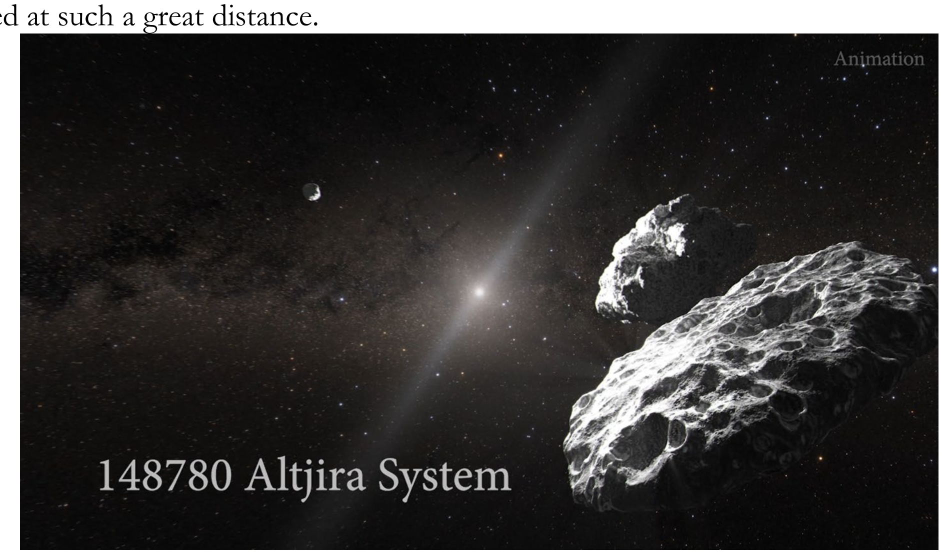


02 - Kuiper Belt – 4.5 to 7.5 billion kilometers

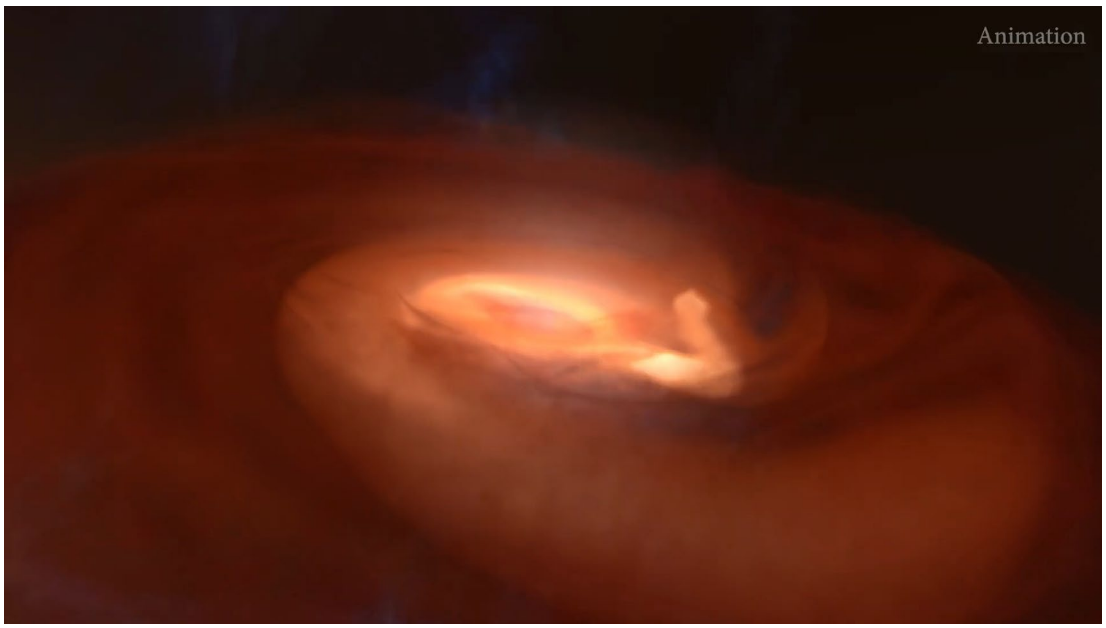
We covered the Kuiper Belt in the "Comets and the Heliosphere" chapter of the "How Far Away Is It" video book. Period comets visit the Sun so often that they quickly evaporate -- vanishing in only a few hundred thousand years. They evaporate so quickly, compared to the age of the solar system, that we shouldn't see any left at all. Yet we routinely track dozens of them every year. In 1951, Gerard Kuiper proposed that there must be a belt of icy bodies orbiting beyond Neptune that is a source for new comets. It is much further away, much larger and far less dense than the Asteroid Belt. It starts at 30 AU from the sun and is around 20 AU wide. [An Astronomical Unit is the distance from the Earth to the Sun. That's 15 million km or 9.3 million miles.]



Scientists have gathered a 17-year observational baseline of data from Hubble and the Keck Observatory, watching the orbit of an object named the Altjira system in the Kuiper Belt. It is likely a stable trio of icy space rocks. Hubble images show two objects located about 7,600 kilometers or 4,700 miles apart. In addition, researchers say that repeated observations of the objects' unique co-orbital motion indicate the inner object is actually two bodies that are so close together they can't be distinguished at such a great distance.



The finding is crucial support for a Kuiper Belt Object formation theory, in which three small rocky bodies would not be the result of collisions in a busy Kuiper Belt, but instead form as a trio directly from the gravitational collapse of matter in the disk of material surrounding the newly formed Sun. It's well known that stars form by gravitational collapse of gas, commonly as pairs or triples, but that idea that cosmic objects like those in the Kuiper Belt form in a similar way is still under investigation.



03 - Lynds 483 – 650 ly

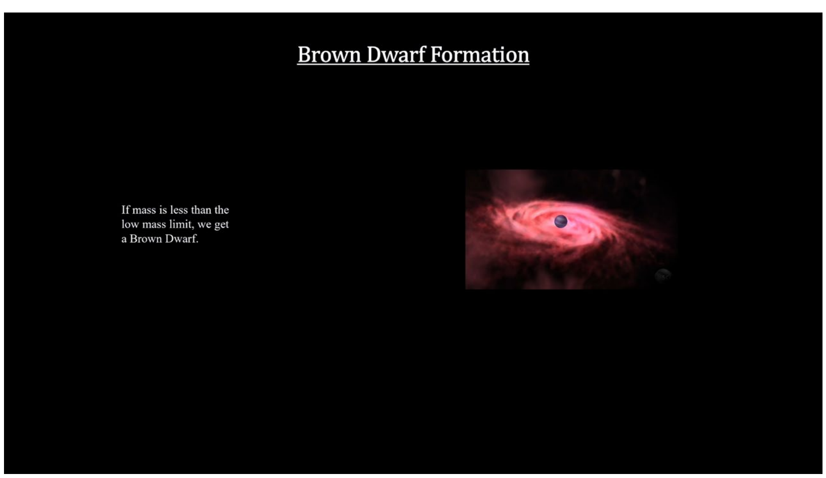
Here's a high-resolution near-infrared Webb image of Lynds 483 650 light years away. It's two actively forming stars at the center are responsible for the shimmering ejections of orange, blue, and purple gas and dust which stretches .2 lightyears in each direction.

Over tens of thousands of years, the central protostars have periodically ejected some of their gas and dust, spewing it out as tight, fast jets and slightly slower outflows. When more recent ejections hit older ones, the material can crumple and twirl based on relative velocities and the densities of what is colliding. Over time, chemical reactions within these ejections and the surrounding cloud have produced a range of molecules, like carbon monoxide, methanol, and several other organic compounds.

The bright light from the stars, shines through the gas and dust, forming large semi-transparent orange cones. Millions of years from now, when the stars are finished forming, they may each be about the mass of our Sun. Their outflows will have cleared the area. All that may remain is a tiny disk of gas and dust where planets may eventually form.

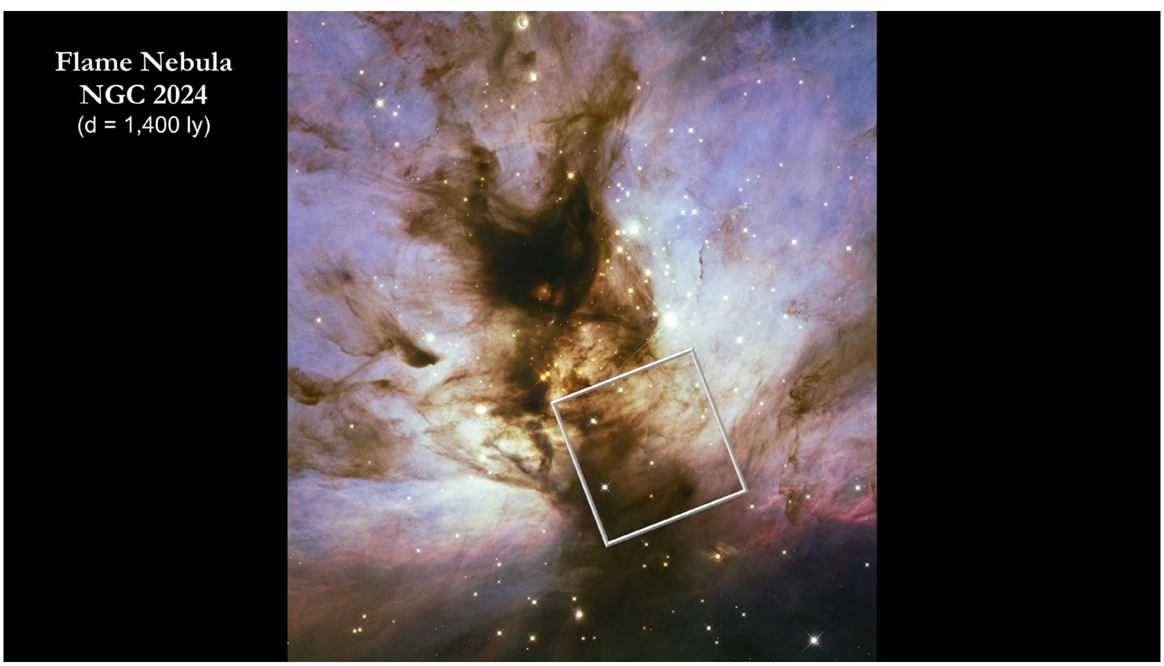
04 - Flame Nebula – 1,400 ly

We covered Brown Dwarfs in our 2018 Review. They are created by a collapsing molecular cloud just like a star. But when the mass of the collapsed gas is insufficient to trigger fusion, we get an object that glows via its heat – a brown dwarf. Astronomers search out brown dwarfs to try find the mass limit that separates them from stars. But they are dim and therefor hard to find. It's estimated that there are between 25 and 100 million in the Milky Way. But to date, less than 2000 have been discovered.



In 2015, astronomers used Webb to find brown dwarfs in the Flame Nebula - a star-forming region 1,400 light years away in the Orion Molecular Cloud Complex. It has a long history of observation from telescopes such as Hubble. The nebula is a star forming region less than 1 million years old. At that young age, we have a better chance of finding brown dwarfs, because they will be relatively hotter and brighter than the older ones scattered across the galaxy.

Here's a closer look at the nebula. We'll zoom into the box in the lower half of the image.



This is the Hubble view. The circles identify 3 low mass objects. With the Webb view, we see three 3 brown dwarfs. Webb has the sensitive to find brown dwarfs down to 0.5 times the mass of Jupiter. What they found were brown dwarfs roughly two to three times the mass of Jupiter. There were none below this presumed mass limit.

05 - Crystal Ball Nebula – 1,500 ly

Here's a ground-based view of NGC 1514 also known as the Crystal Ball Nebula around 1,500 lightyears away. It was first discovered by the astronomer William Herschel in 1790. It was the first nebula he had seen that could not be explained as a distant grouping of stars. This one was clearly a central star with a luminous atmosphere.

Here's a Webb mid-infrared view. The mid-infrared brings out the nebula's "fuzzy" dusty rings. Two central stars, which appear as one in the image, formed this nebula over four-thousand years. It will continue for thousands of years more. The stars follow a tight, elongated nine-year orbit and are located in an arc of dust represented in orange. The nebula's two rings are unevenly illuminated in Webb's observations, appearing more diffuse at the bottom left and at the top right. Scientists believe the rings are primarily made up of very small dust grains, which, when hit by ultraviolet light from the central white dwarf star, heat up enough to be detected by Webb. One of these stars, which used to be several times more massive than our Sun, took the lead role in producing this scene. Once the star's outer layers were exhausted, only its hot, compact core remained. As a white dwarf, its winds sped up and weakened, sweeping up material into these thin shells.

06 - NGC 6072 – 3,030 ly

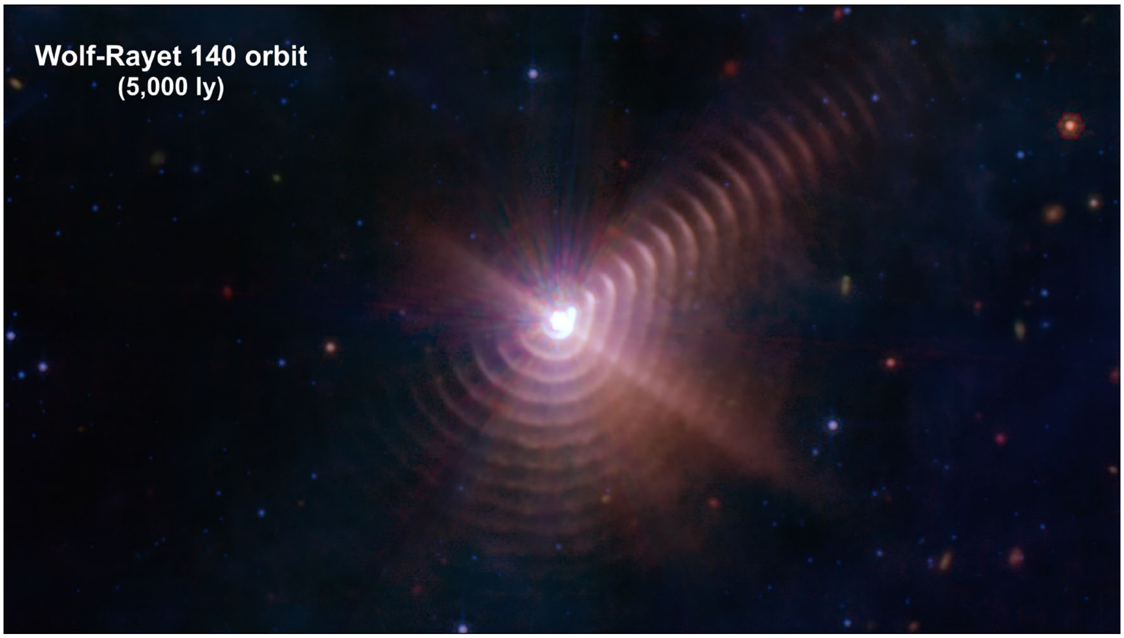
Here's a Webb image of the planetary nebula NGC 6072 a little over 3000 light years away. In Webb's Near-Infrared Camera view, the nebula is seen to be multi-polar. This means there are two different elliptical outflows jetting out in different directions from the center. These outflows compress gas towards two equatorial planes and create two discs. Astronomers say this is evidence that a companion star is interacting with an aging star that had already begun to shed some of its outer layers of gas and dust. The longer wavelengths captured by Webb's Mid-Infrared Instrument are highlighting dust, revealing the star at the center to 6072. It appears as a small pink-white dot in this image.

07 - Cat's Paw Nebula (NGC 6334) – 4,000 ly
We covered the Cat's Paw in the 'Nebula' segment of 'How Far Away Is It' video book. It is a vast 50 light-years across region of star formation 4,000 light years away. 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 started to shine in the last few million years. The region is also home to many new stars that are buried deep in the dust, making them difficult to study. In total, the Cat's Paw Nebula contains several tens of thousands of stars.

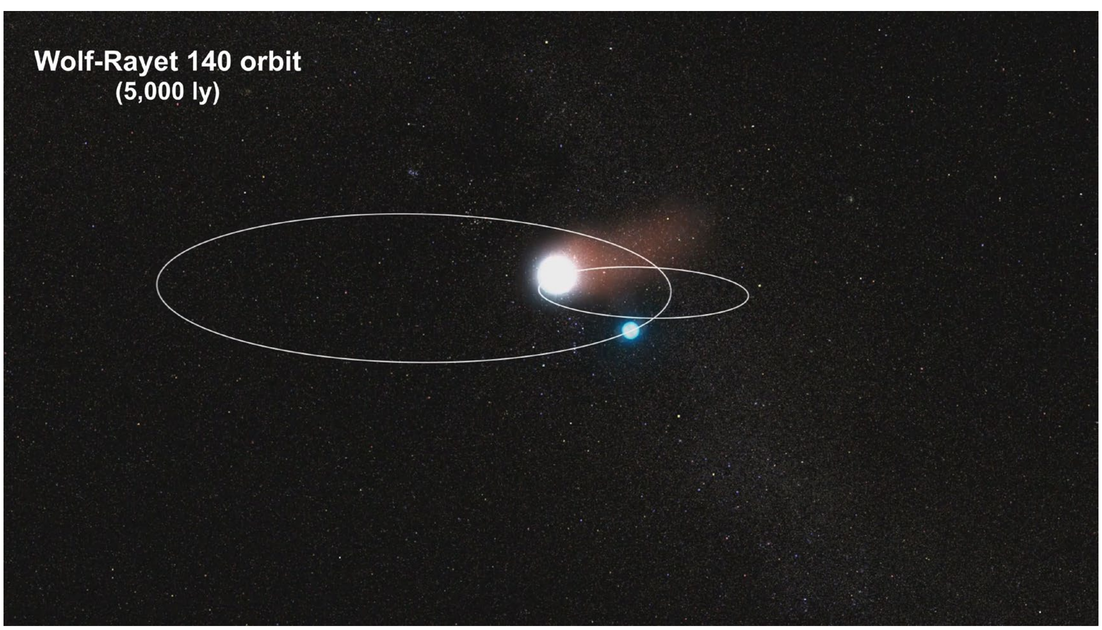
To mark Webb's third year, astronomers used its infrared capabilities to look deeper into the nebula. This star forming nebula gives us the opportunity to study how a turbulent large molecular cloud transforms into to massive stars. For example, this structure is called the "Opera House" because of its circular, tiered-like structure. The primary drivers for the area's cloudy blue glow are most likely the light from the bright yellowish stars at the bottom of the cavity. Just below the orange-brown tiers of dust is a bright yellow star with diffraction spikes. While this massive star has carved away at its immediate surroundings, it has been unable to push the gas and dust away completely, creating a compact shell of surrounding material. Note the dark tuning fork shaped area to the Opera House's immediate left. It's an area that contains very few stars. These seemingly vacant zones indicate the presence of dense foreground dust that block the light from stars behind it. Near the bottom of this region are small, dense filaments of dust. These tiny clumps of dust have managed to remain despite the intense radiation, suggesting that they could be dense enough to form protostars. One eye-catching aspect of this Webb image is the bright, red-orange oval at the top right. Its low count of background stars implies it is a dense area just beginning its star-formation process.

08 - Wolf-Rayet 140 – 5,000 ly

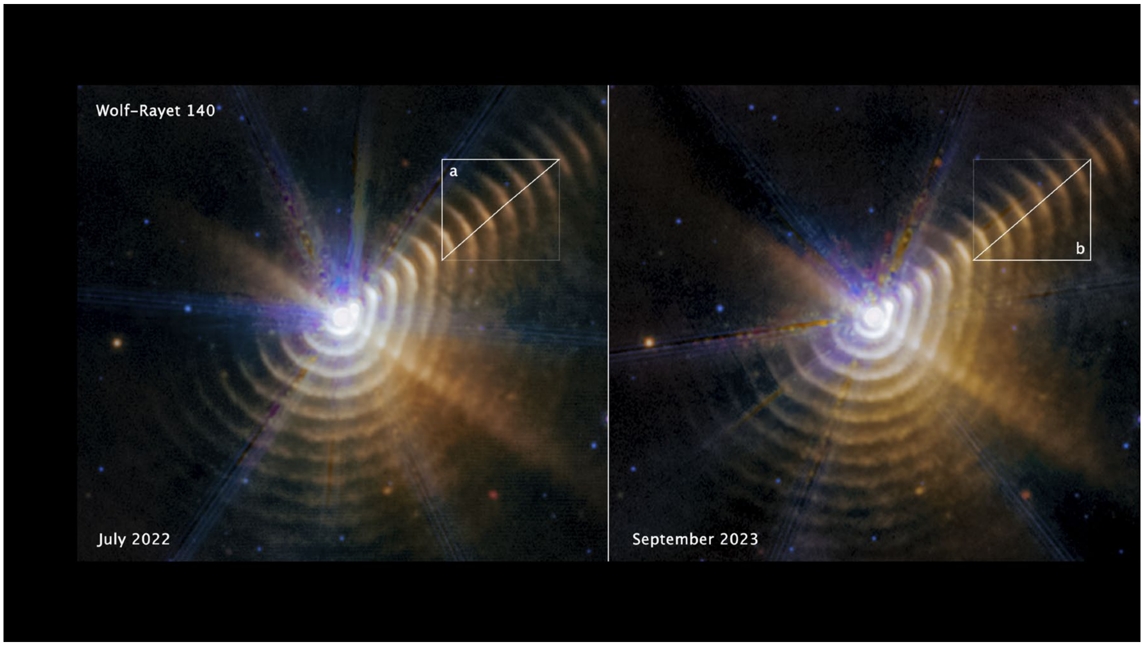
We covered Wolf-Rayet 1 4 0 in the 2023 review. In 2025 a team of astronomers examined this source of carbon-rich dust in our own Milky Way galaxy in great detail.



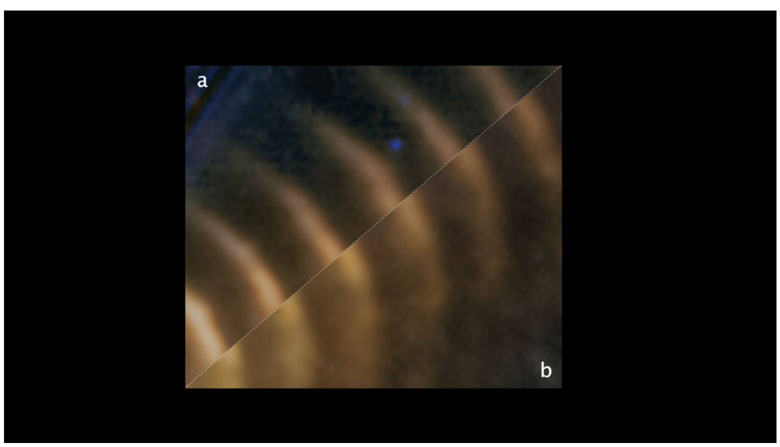
Wolf-Rayet 140 is part of a system of two massive stars that follow a tight, elongated orbit. For several months every eight years, as the pair make their closest approach, the stellar winds from each star slam together. The material is compressed, and carbon-rich dust forms.



Webb's latest observations show 17 dust shells shining in mid-infrared light that are expanding at regular intervals into the surrounding space. Every shell is racing away from the stars at more than 2600 kilometers per second or 1615 miles per second. That's almost 1% the speed of light. These shells have persisted for more than 130 years.

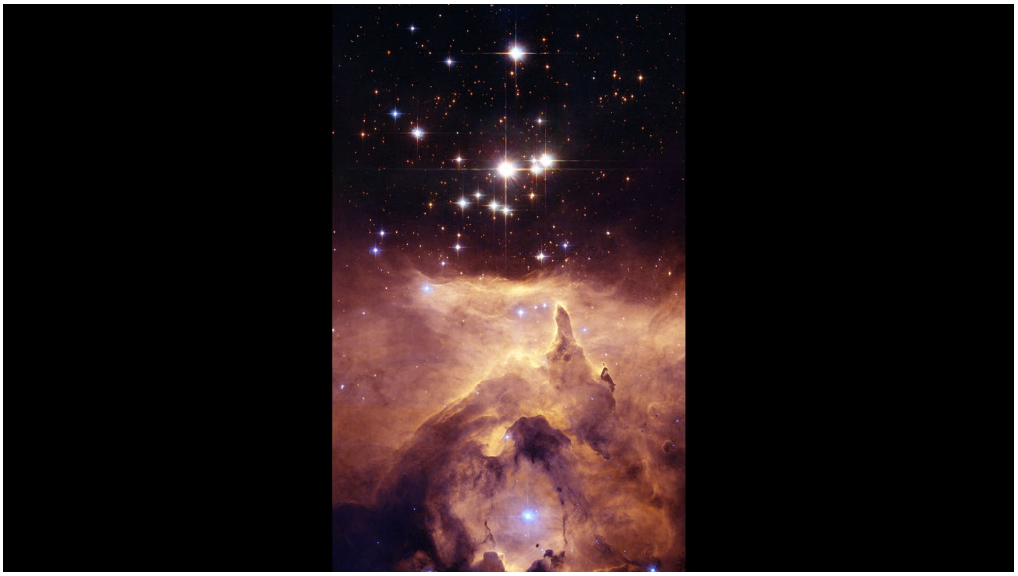


Here we compare two Webb mid-infrared images taken 14 months apart. Two triangles are matched up to show how much difference 14 months makes.



09 - Prismis 24 in NGC 6357 - 5,500 ly

Here's a Hubble image of Prismis 24 – the stars and NGC 6357 – the nebula. We covered this object in our 'How Far Away Is It' video book chapter on 'Clusters and Supernova'. This young star cluster is approximately 5,500 light-years from Earth. It's one of the closest sites where massive star formation activity is ongoing.



Here's the 2025 Webb near inferred image. At the heart of this glittering cluster is the brilliant binary star Pismis 24-1. The tallest spire is pointing directly toward it. Its two stars are 74 and 66 solar masses, respectively. They are among the most massive and luminous stars ever seen. Thousands of smaller members of the cluster appear as white, yellow, and red, depending on their stellar type and the amount of dust enshrouding them.

Super-hot, new stars (some almost 8 times the temperature of the Sun) blast out scorching radiation that is sculpting a cavity into the wall of the star-forming nebula. Dramatic spires jut from the glowing wall of gas. They are dense enough to resist the relentless radiation. The tallest spire spans about 5.4 light-years from its tip to the bottom of the image. The width of its tip is 0.14 light-years. More than 200 of our solar systems out to Neptune's orbit could fit inside of it.

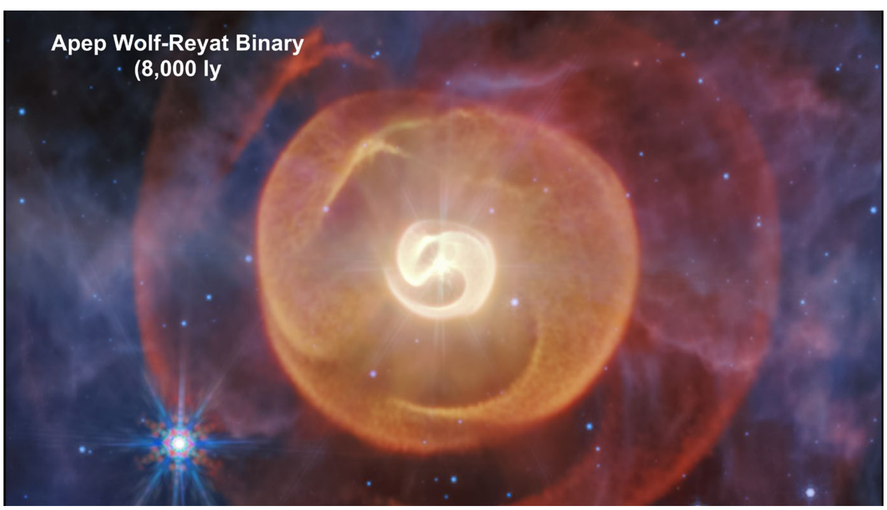
I was so impressed with this beautiful stellar object, that I ended the 'How far Away Is It' video book zooming into this image playing the end of Beethoven's Ninth.

10 - Eagle Nebula – 6,500 ly
Here's an image of the Eagle Nebula taken by Hubble in 2014. It focused on the 3 'pillars of creation' on the right. In 2025, the lone pillar on the left was revisited as part of Hubble's 35th anniversary celebrations.

This towering structure of billowing gas and dark, obscuring dust is 9.5 light-years tall. The material in the pillar is thick and opaque to light. It is highlighted at its edges by the glow of more distant gas behind it. The red colors lower down, are glowing hydrogen. The blue colors of the background are dominated by emission from ionized oxygen. Orange colors indicate starlight that has managed to break through the dust. The stars responsible for carving this particular structure out of the stellar raw material lie just out of view, at the Eagle Nebula's center. Over time, their intense radiation will totally erode the nebula.

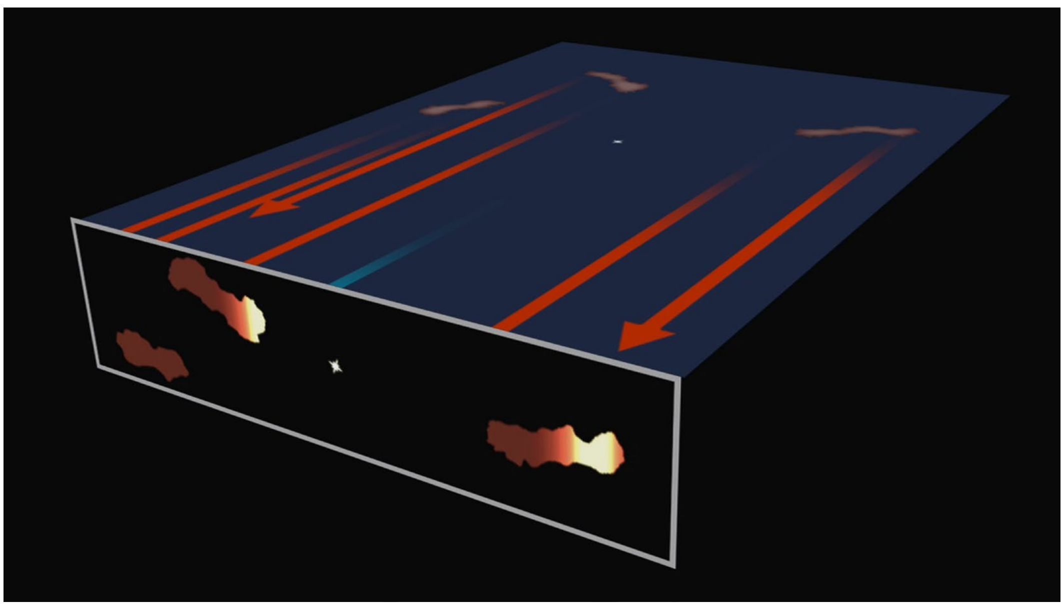
11 - Apep - A Wolf-Rayet Binary – 8,000 ly

Here's Webb's mid-infrared image of four coiled shells of dust around a pair of Wolf-Rayet stars known as Apep. Webb's data, combined with observations from the European Southern Observatory's Very Large Telescope in Chile, confirmed that the two Wolf-Rayet stars past one another every 190 years. Over each orbit, they are close for 25 years, producing and spewing amorphous carbon dust. Webb's new data also confirmed that there are three stars gravitationally bound to one another in this system. The third star is a massive supergiant. It cuts slices into these shells. To find the slices, look for the central point of light, and trace a V shape from 10 o'clock to 2 o'clock.

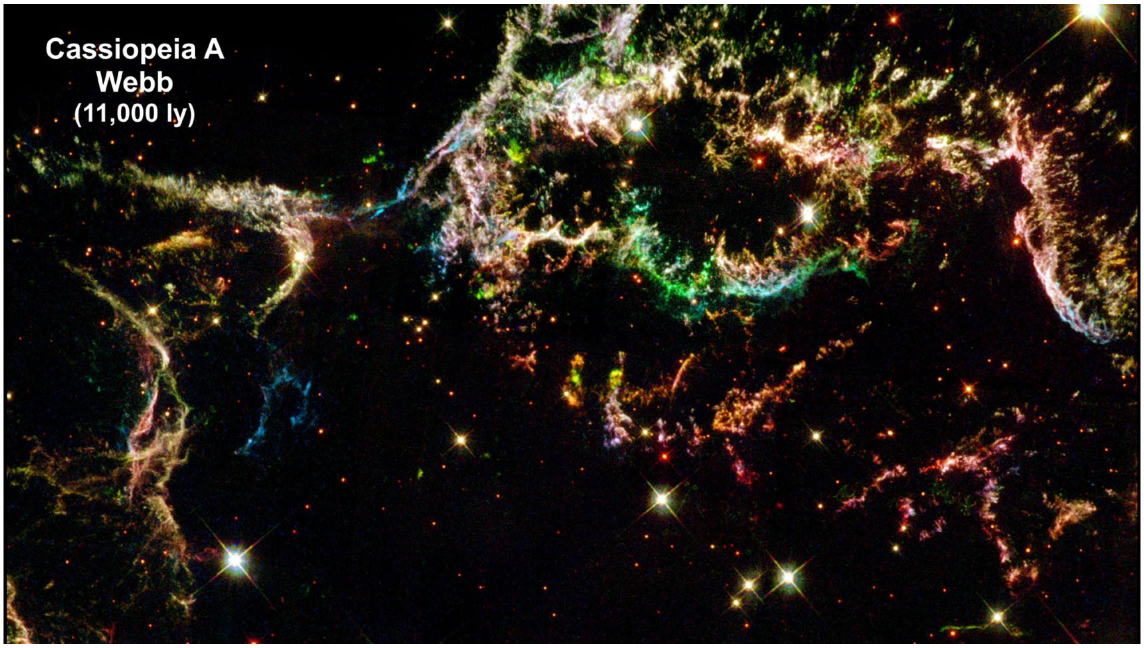


12 - Cassiopeia A Light Echo = 11,000 ly

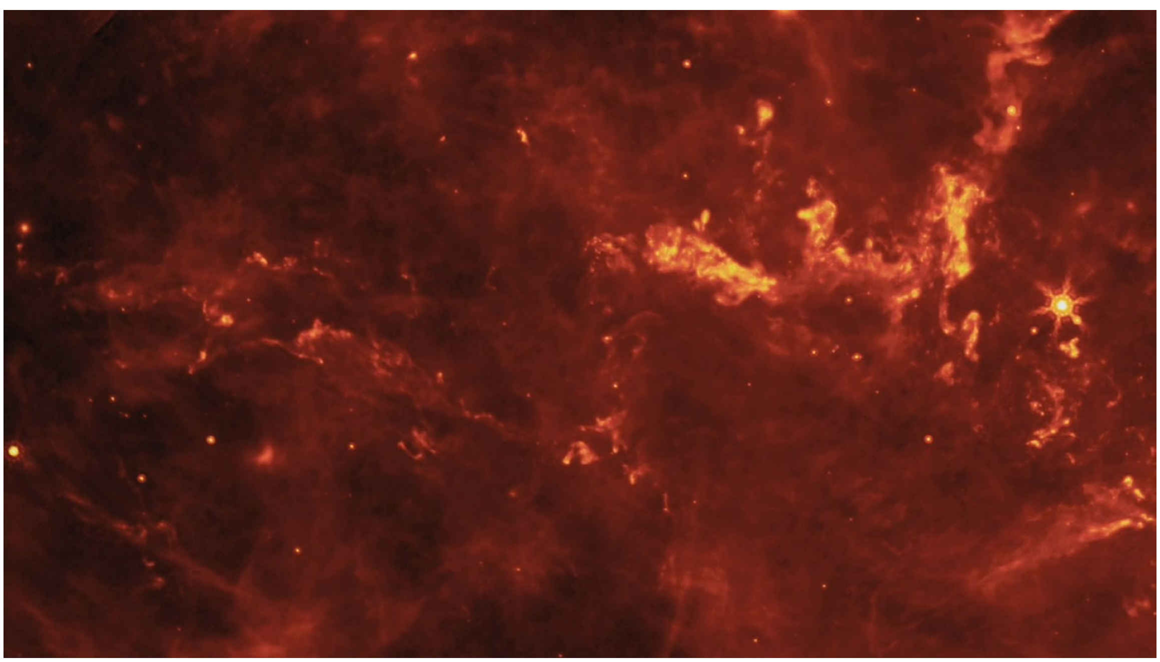
In the 'How Far Away Is It' chapter on 'Clusters and Supernova', we covered light echoes. Here's an illustration of how they work. The light from a supernova expands in all directions. One is towards us. But light not heading our way may reach dust clouds light years away in the interstellar medium (ISM for short). Light echoes at visible wavelengths are due to light reflecting off of these clouds. But light echoes at infrared wavelengths are created when the intense radiation from the supernova heats up a cloud to the point where it's radiating its own light in all directions. The frequency of this radiation puts it in the infra-red range. Following the arrows of light, it's clear that we'll see the supernova flash first. The light echoing off of the dust clouds will arrive later – at various times, delayed by up to hundreds of years from the original flash depending on how far from the supernova the clouds are.



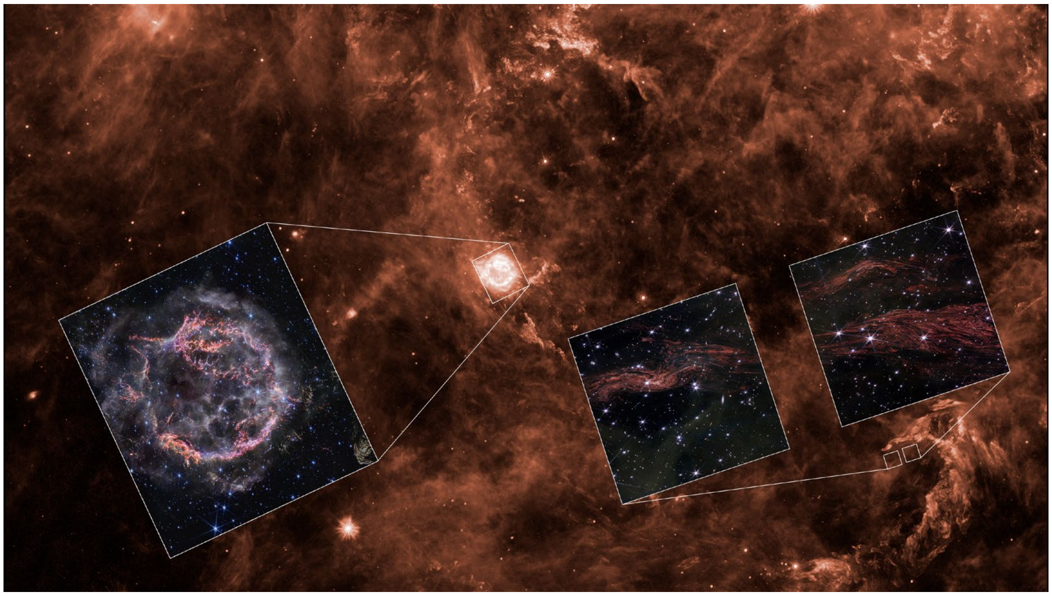
This is a Webb image of the region around supernova remnant Cassiopeia A.



Here we have images taken by the Spitzer Space Telescope in 2008. By taking multiple images of this region over three years, researchers were able to examine a number of light echoes.

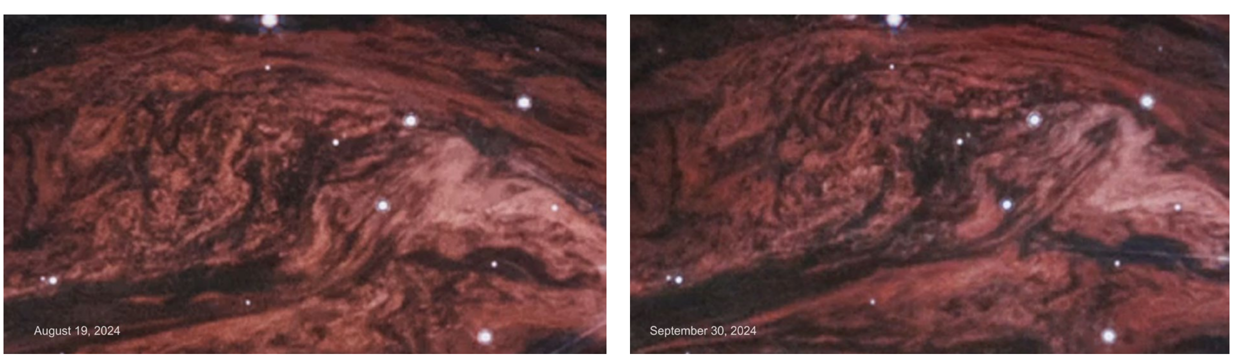


Now, Webb has imaged some of these light echoes in much greater detail. The inset shows a Webb image of the central supernova remnant released in 2023. Insets on the lower right show examples of Webb's light echo observations.



These time-lapse images highlight the evolution of one light echo in the vicinity of the supernova remnant. It took about 350 years for the light from the Cassiopeia A supernova to reach this interstellar material, illuminating it, warming it, and causing it to glow in infrared light. Webb's resolution not only shows incredible detail within these light echoes, but also shows their changes over the course of just a few weeks!

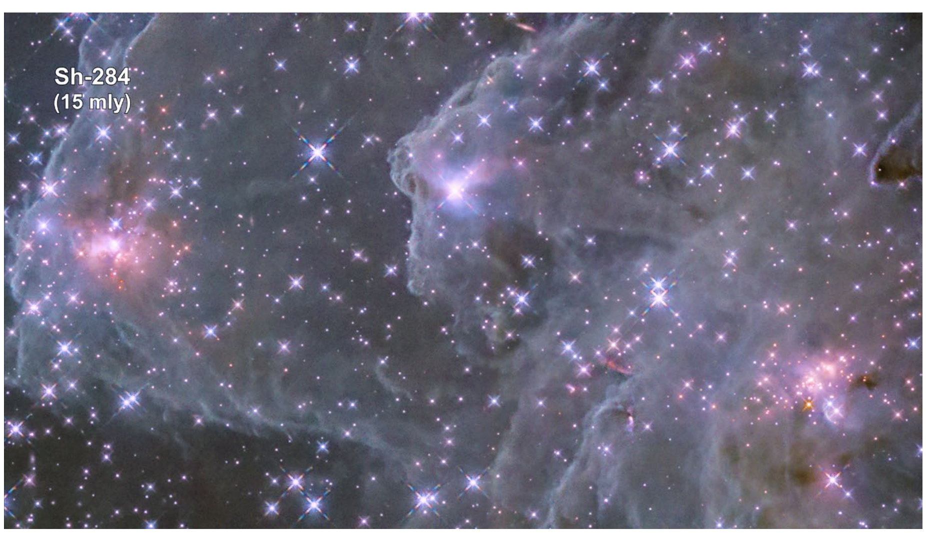
Webb's observations are allowing astronomers to map the three- dimensional structure of this interstellar dust and gas for the first time. The most obvious features in the images are tightly packed sheets or filaments. These filaments show structures on a remarkably small scale of about 400 astronomical units. That's less than one-hundredth of a light-year.



These echoes are studied to better understand the content and structure of the interstellar medium. And the interstellar medium is itself shaped by the massive stars formed out of its gas and dust and the supernovas they produce. [The ISM consists of 99% gas and 1% dust by mass.]

13 - Sh2-284 – 15,000 ly

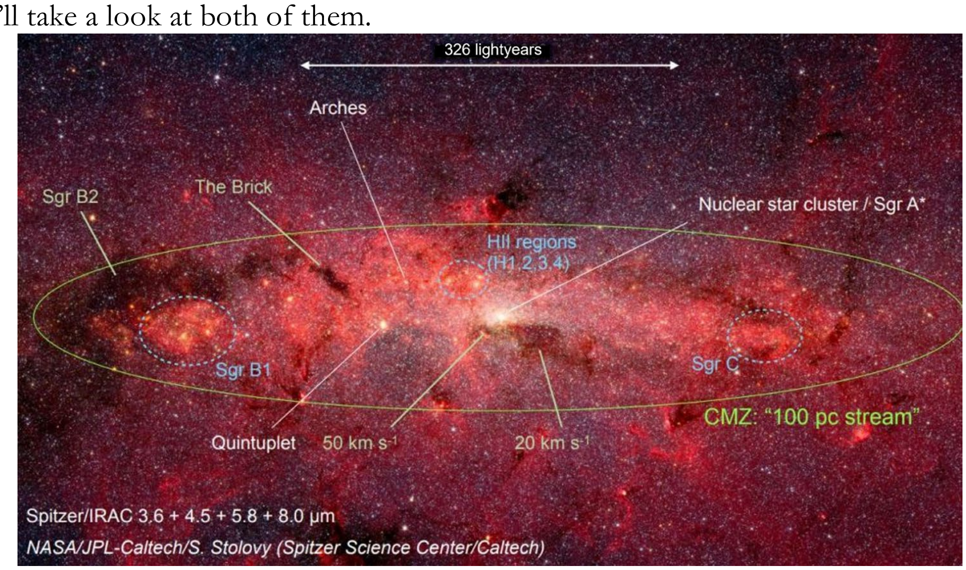
Here's Sh2-284. It's a star forming region 15,000 light years away, towards the end of an outer spiral arm of our Milky Way's disk. This Hubble near infrared image highlights its bright clusters of new stars, and clouds of gas and dust. The cloud is classification as an HII region, an emission nebula consisting primarily of ionized hydrogen. The nebula glows with its own light as stars within or nearby energize its gas with intense ultraviolet radiation.



Here's an image of an extremely large stellar jet in Sh2-284 referred to as Sh284p1. This Herbig-Haro (HH) object's, jets are 8 light-years across. This is about double the distance from our Sun to Alpha Centauri. The outflow is streaking across space at hundreds of thousands of kilometers (xxx miles) per hour. The central protostar is ten times the mass of our Sun. Its detection provides evidence that HH jets scale with the mass of their parent stars—the more massive the stellar engine driving the plasma, the larger the resulting jet.

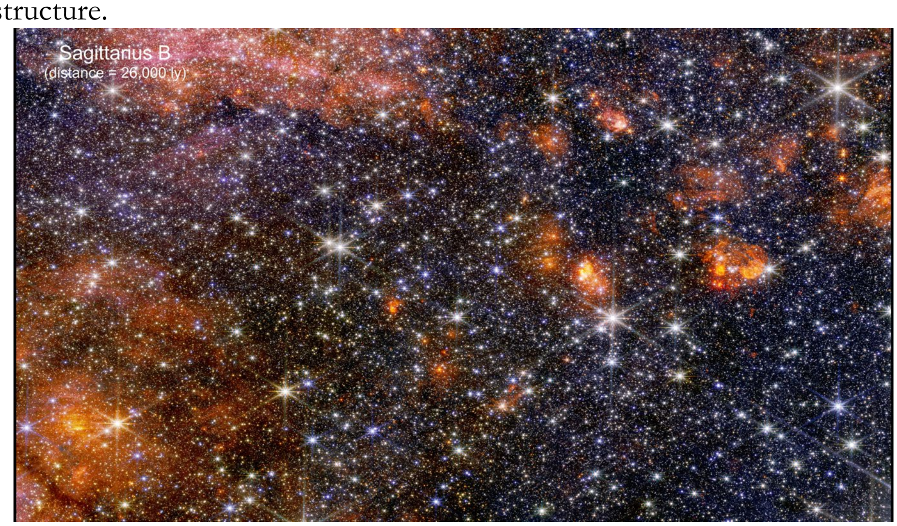
14 - Galaxy Center Regions Sagittarius B2 and C – 26,000 ly

In 2023, a team of astronomers identified a set of areas around the galactic center that they wanted the James Webb Space Telescope to investigate. In 2025, Webb released analysis for Sagittarius B2 and C. We'll take a look at both of them.



This Webb image of Sagittarius C covers 44 light-years. It shows dozens of distinctive filaments in a region of hot hydrogen plasma surrounding the main star-forming cloud. Their shape and behavior have led analysts to hypothesize that the filaments are shaped by magnetic fields. The researchers think that the magnetic forces in the galactic center may be strong enough to keep the plasma from spreading. Instead, it is confining it into the concentrated filaments seen in the image. These strong magnetic fields may also resist the gravity that would typically cause dense clouds of gas and dust to collapse and form new stars, explaining Sagittarius C's lower-than-expected star formation rate.

Here's a Webb image of Sagittarius B2, the Milky Way galaxy's most massive and active star forming cloud. It produces half of the stars created in the galactic center region despite having only 10 percent of the area's star-making material. It's a region densely packed with stars, star-forming clouds, and complex magnetic fields, and it's one of the most molecularly rich regions known. In this near-infrared light, astronomers see more of the region's diverse, colorful stars, but less of its gas and dust structure.



Here we see Webb's mid-infrared view. Only the brightest stars in this region emit mid-infrared light that can be seen. This is why the image has so many fewer visible stars. One of the most notable aspects of this image is the portions that remain dark. The black areas of space are not empty. They are actually extremely dense gas and dust clouds. Not even Webb can see through them. These thick clouds are the raw material of future stars.

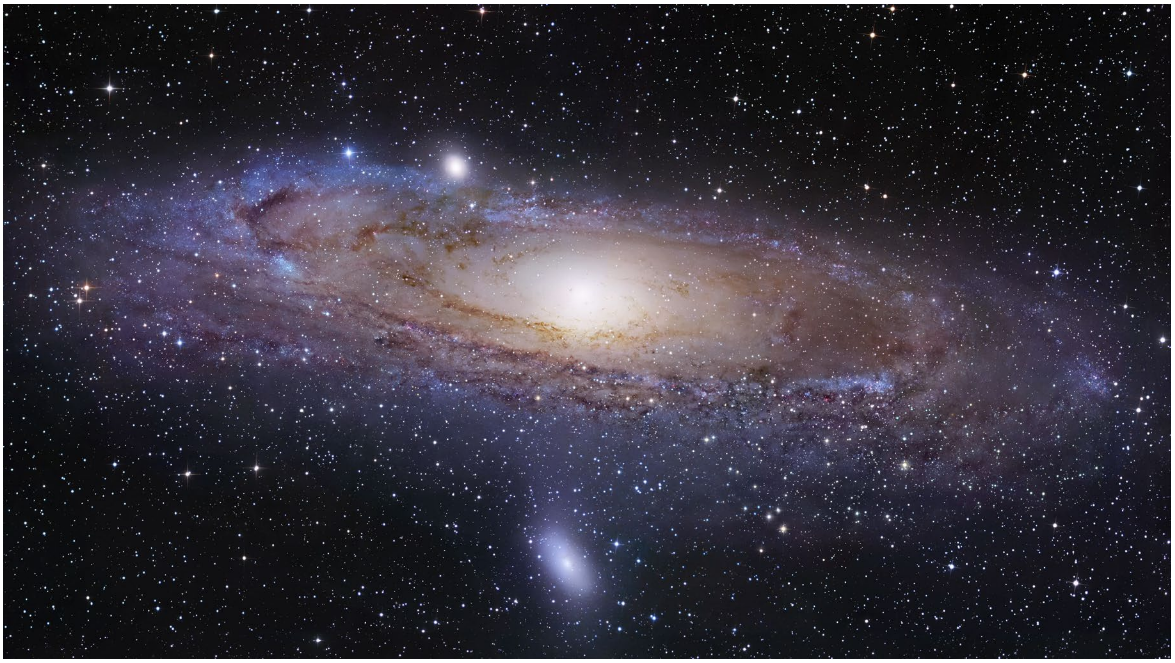
15 - NGC 346 – 200,000 ly

Here we're zooming into a new Hubble image of NGC 346, a young star cluster inside a nebula in the Small Magellanic Cloud. The cluster contains more than 2500 new hot stars. Although several images of this cluster have been released previously, this one includes new data and is the first to combine Hubble observations made at infrared, optical, and ultraviolet wavelengths. The cluster's most massive stars, which are many times more massive than our Sun, are blue in this image. The dark nebula to the left of the star cluster is named N66. It is lite by the cluster stars. It will shine only as long as the stars that light it shine. In this case, that will be around another million years of so.

16 - Andromeda and Its Satellites – 2.5 mly

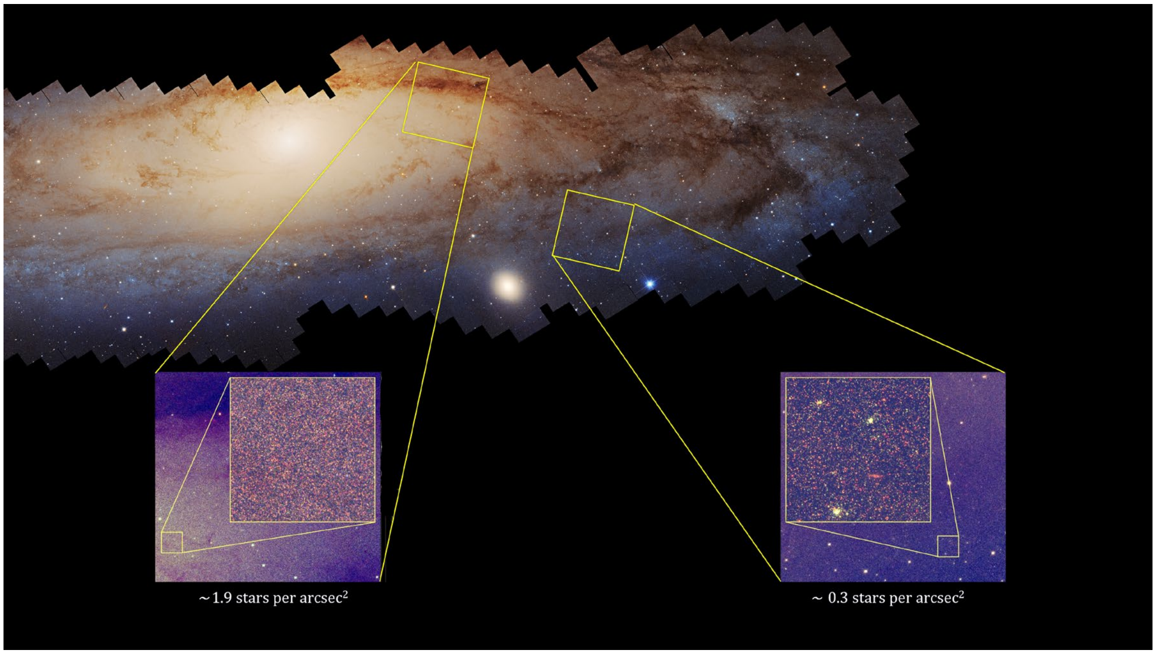
Andromeda aka M31, is the most remote celestial object normally visible to the naked eye. The earliest known reference to it is by the Iranian astronomer Sufi who called it 'the little cloud' in his Book of Fixed Stars (964 C.E.). This 2025 Hubble Space Telescope coverage of Andromeda commemorates Edwin Hubble's discovery, a thousand years later, that Andromeda is its own galaxy - 2.5 million lightyears away. That's roughly 25 Milky Way diameters. Prior to that discovery, astronomers thought that the Milky way was the entire universe. Andromeda, which is seen almost edge-on is tilted by 77 degrees relative to Earth's view. It serves as a nearby laboratory for studying the astrophysics that control the formation and evolution of galaxies such as star formation rate, stellar evolution, star chemical composition, and dust production.

Photographing Andromeda was a herculean task because the galaxy is a much bigger target on the sky than the galaxies Hubble routinely observes. The full mosaic was carried out under two Hubble programs. In total it required over 1,000 Hubble orbits, spanning more than a decade. Hubble's sharp imaging capabilities can resolve more than 200 million stars in the Andromeda galaxy, detecting only stars brighter than our Sun. But Andromeda's total population is estimated to be 1 trillion stars, with many less massive stars falling below Hubble's sensitivity limit.

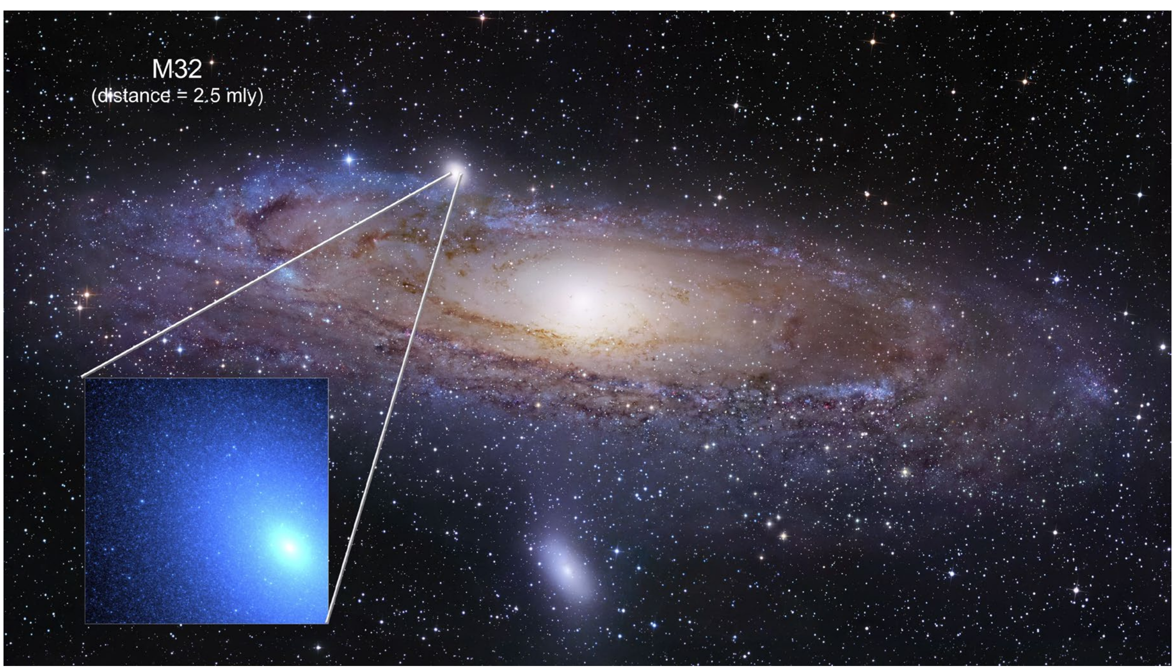


The northern half of Andromeda's disk has been successfully mapped in the Panchromatic Hubble Andromeda Treasury (PHAT for short). The program covered roughly one-third of M31's entire star-forming disk. This program was followed up by the Panchromatic Hubble Andromeda Southern Treasury (PHAST). It recently added images of approximately 100 million stars in the southern half of Andromeda.

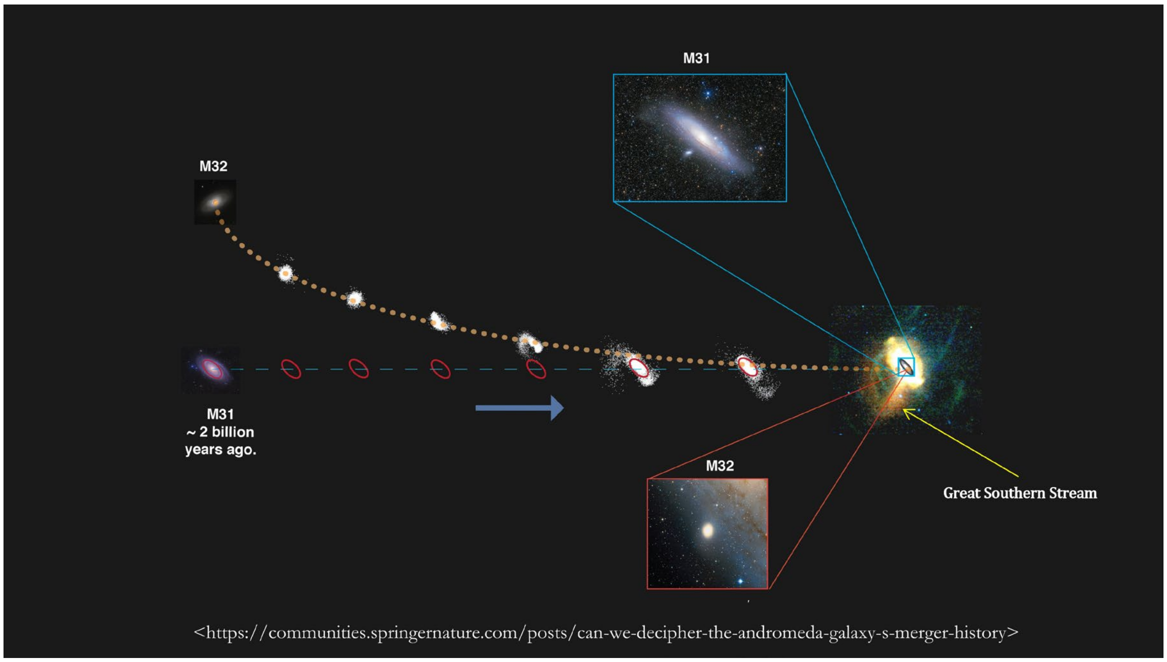
This sweeping view shows one third of the Andromeda Galaxy. It traces the galaxy from its central galactic bulge on the left, where stars are densely packed together, across lanes of stars and dust to the sparser outskirts of its outer disc on the right.



The galaxy's southern half appears fundamentally different from the north. Its features suggest that it has been more affected by the collision with M32, a compact dwarf elliptical satellite galaxy that's, just 16,300 light years from Andromeda's center.

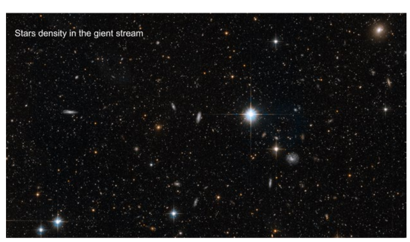


It is thought that the collision caused the formation of the giant southern stream of stars in Andromeda's halo - spanning approximately 490,000 light years, extending outwards from the southern half of the disk. This would be consistent with the simultaneous burst of star formation seen in both M32 and M31.



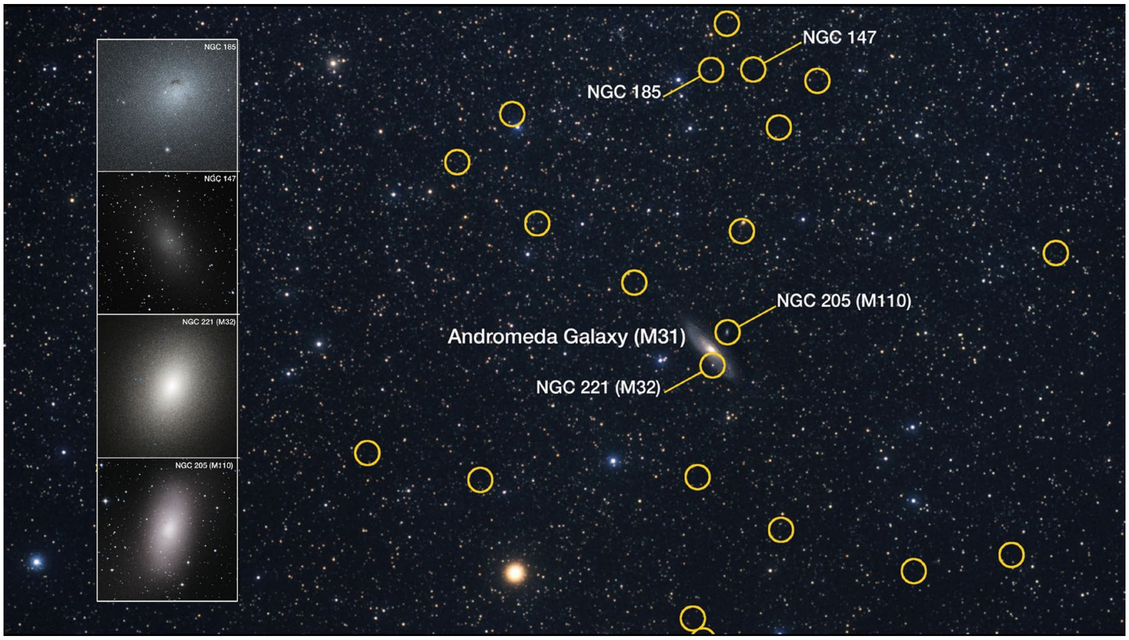
<https://communities.springernature.com/posts/can-we-decipher-the-andromeda-galaxy-s-merger-history>

Here's a look at the star densities in the disk, the Giant Southern Stream, and the galaxy's halo. In commemoration of Edwin Hubble's discovery of the Cepheid variable class star V1, in Andromeda 100 years ago, astronomers partnered with the American Association of Variable Star Observers (AAVSO) to study the star. Based on their data, the Hubble Space Telescope was used to capture the star at its dimmest and brightest light.



In addition to M32, Andromeda has 35 additional satellite galaxies. Here's an image from data collected by 1,000 Hubble orbits. This work built a precise 3D mapping of all the dwarf galaxies, and reconstructed how efficiently they formed new stars over nearly 14 billion years. Interestingly, half of the Andromeda satellite galaxies seem to be confined to a plane, all orbiting in the same direction. It is not yet understood why they appear that way.

Here's a view of a few of them.



17 - Leo P dwarf galaxy – 5.3 mly

Over cosmic time, galaxies start small and grow larger by accumulating gas and merging with each other. Many small "seed" galaxies persist into the present day, and astronomers study these dwarf galaxies to learn how they have evolved over time. Isolated dwarf galaxies that have been unaffected by mergers are of particular interest, because they can provide a window into processes that played out on a cosmic scale.

In 2013, a team of researchers found an isolated dwarf galaxy 5.3 million light years away. They named it Leo P. A star with high metallicity means it has a relatively high abundance of elements heavier than helium. The "P" in the galaxy's name refers to "pristine" because the galaxy is metal-poor, possessing only 3% of the Sun's heavy elements (which astronomers call metals). This makes Leo P similar to the primordial galaxies of the early universe.

Generally, older stars have lower metallicity compared to younger stars, meaning that a star's metallicity is directly correlated with its age - older stars tend to have lower metallicity because the heavier elements were not as prevalent when they formed, while younger stars formed in an environment enriched by supernovae that created these heavier elements; this relationship is known as the "age-metallicity relation".

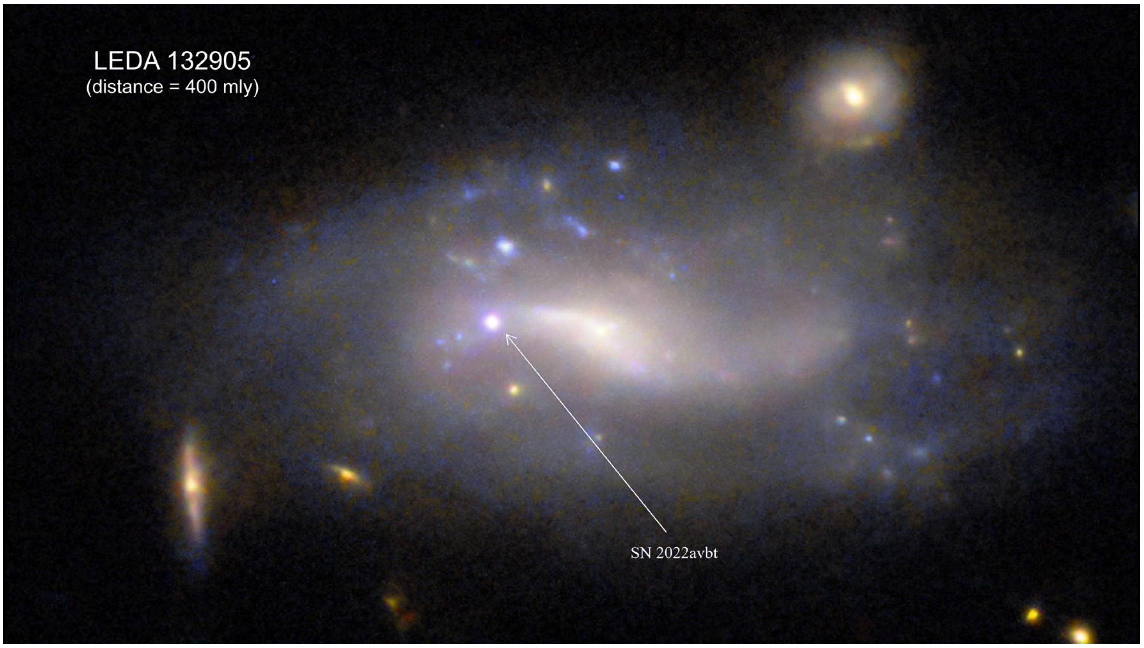
Using the metallicity data, the team found that Leo P formed stars early on but then stopped making them shortly after the "Epoch of Reionization". We covered this significant period in the early history of the universe in the "How Old Is It" video book. After a few billion years the galaxy reignited and started forming new stars again. Astronomers have measured a similar pattern for only three other galaxies within the Local Group that were all isolated from the Milky Way, but they never resumed star production.

[The contrast between the star production of isolated dwarf galaxies versus those in the Local Group provides compelling evidence that it isn't just the mass of a galaxy at the time of reionization that determines whether its star formation will be shut down. Its environment is an important factor.]

The stars in Leo P appear blue in comparison to the background galaxies for several reasons. Young, massive stars that are common in star-forming galaxies are predominantly blue. Leo P also is extremely lacking in elements heavier than hydrogen and helium, and the resulting "metal-poor" stars tend to be bluer than Sun-like stars. A bubble-like structure at bottom center is a region of ionized hydrogen surrounding a hot, massive star.

18 - LEDA 132905 – 400 MLY

Here's a Hubble image of galaxy LEDA 132905. Even though the galaxy is 400 million light-years away, you can see its faint spiral structure. Patches of bright blue stars are also discernable. The supernova SN 2022abvt can also be seen. It's a type 1a – the kind that we use to calibrate the 'redshift' rung on the 'Cosmic Distance Ladder'. It was discovered in late 2022 by the Asteroid Terrestrial-impact Last Alert System (ATLAS). Hubble observed the explosion about two months after its discovery.

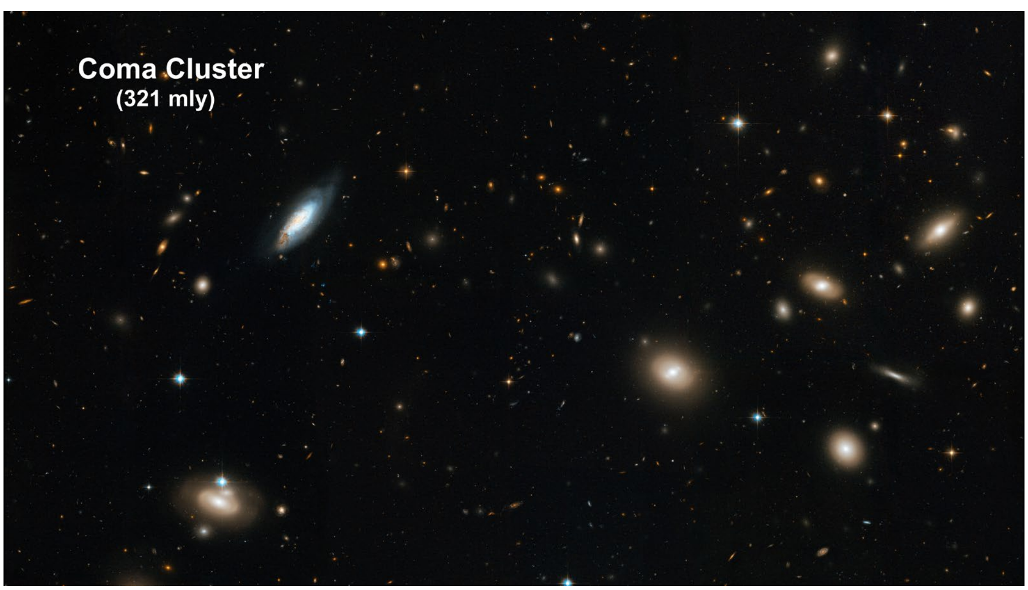


19 - Bullseye Galaxy – 567 mly

The Bullseye Galaxy, also known as LEDA 1313424, is located approximately 567 million light-years away. It is two and a half times the size of our Milky Way and has nine rings — six more than any other known galaxy. Hubble has confirmed eight rings, and data from the W. M. Keck Observatory in Hawaii confirmed a ninth. Hubble and Keck also confirmed which galaxy traveled through the Bullseye, creating these rings. It's the blue dwarf galaxy that sits to its immediate center-left. This relatively small galaxy tiny went through the core of the Bullseye about 50 million years ago, leaving rings in its wake like ripples in a pond. A thin trail of gas now links the pair, though they are currently separated by 130,000 light-years.

20 - Dark Matter Update - Bullet Galaxy Cluster – 3.7 bly

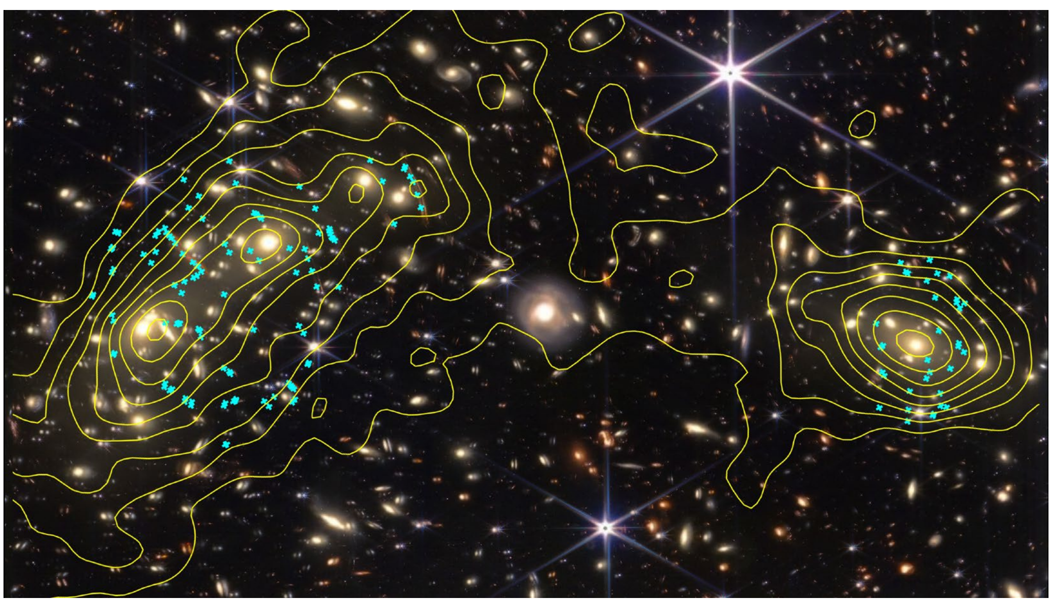
We covered Dark Matter in the in 'Cosmos' chapter of the 'How Far Away Is It' video book. In the early 1930s the astronomer Fritz Zwicky studied star motion in the Coma galaxy cluster and concluded that most of the mass must be dark – Dark Matter. He deduced that dark matter particles do not interact with ordinary baryonic matter. Their only interaction is gravitational. That is, because they are matter, and matter bends spacetime, they bend spacetime. This in turn causes all other particles trajectories to bend.



In 2006, the Bullet Galaxy Cluster was used to provide additional evidence for dark matter. Specifically, data from the Chandra X-ray Observatory and the Hubble Space Telescope, were analyzed to show that the hot gas in the cluster, detected by Chandra, was separated from the mass distribution inferred from gravitational lensing. When we superimpose the dark matter shown in blue, and the gas shown in pink over the visible components of the cluster's mass we get the full picture. The galaxies and the dark matter have traveled a great deal further than the gas. This indicates that the galaxies and dark matter in the two colliding clusters did not interfere with each other. On the other hand, the gas clouds were slowed by a drag force. Unfortunately, measurements were not detailed enough to determine whether dark matter particles interacted with themselves. It was still possible that they might - to some degree.

Here we have the cluster as seen by Webb. The two massive galaxy clusters that exist on either side of the large, light blue spiral galaxy at the center are circled. Webb's extremely precise images revealed many more galaxies and faint objects. This enabled significantly better gravitational lensing accuracy. This in turn enabled astronomers to refine the amount of mass and its location in the two galaxy clusters.

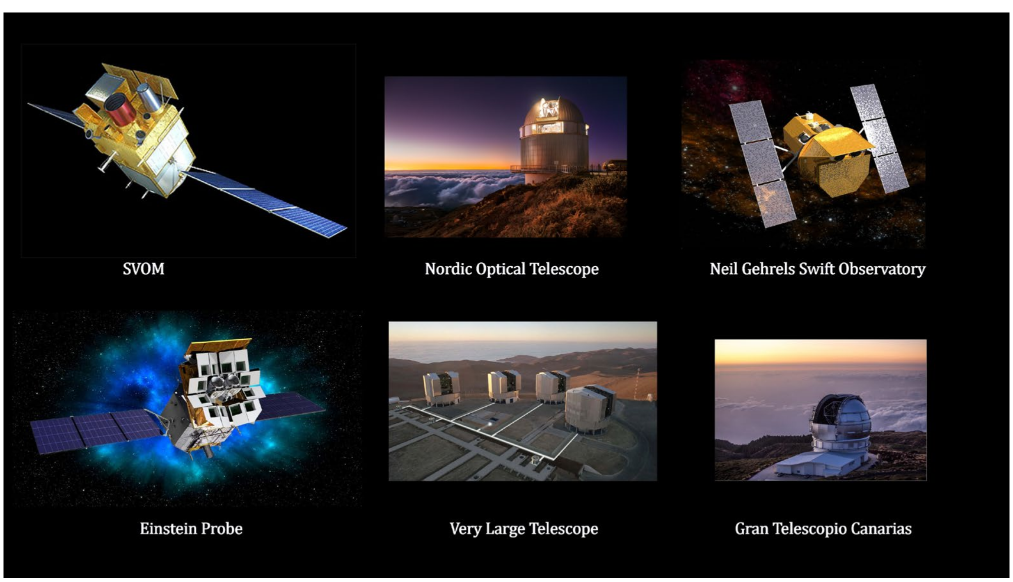
Here are the gravitational lensing lines. They are used for the mass reconstruction based on the new Webb data.



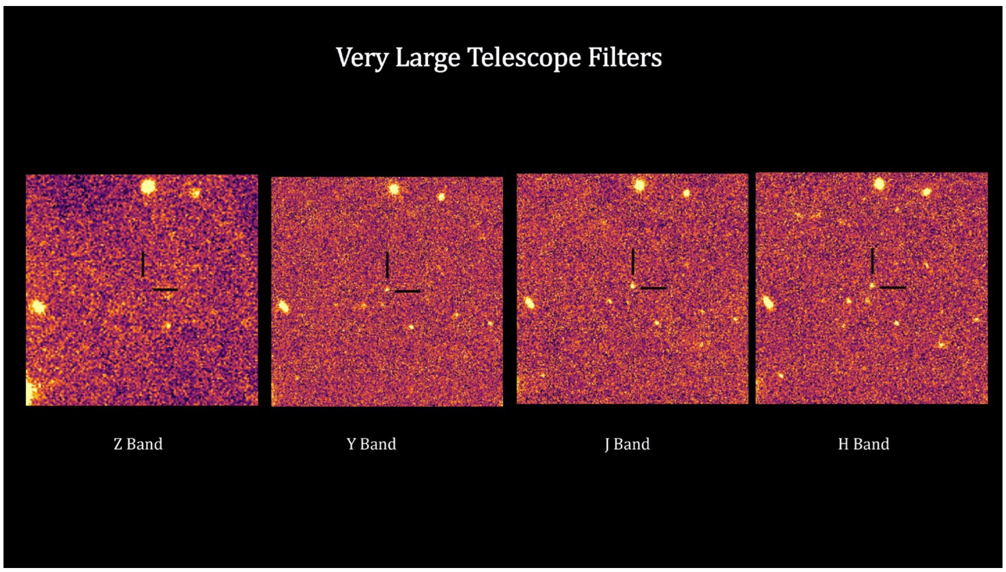
The revised map of the Bullet Cluster is shown in this new image. Chandra data shows the hot gas in pink. Refined measurements of the dark matter, calculated by the Webb team are represented in blue. Dark matter does not emit, reflect, or absorb light, and the team's findings indicate that dark matter shows no signs of significant self-interaction. If dark matter did self-interact in Webb's observations, the team would have seen an offset between the galaxies and their respective dark matter. They did not find any offset.

20a – GRB 250314A – z=7.3

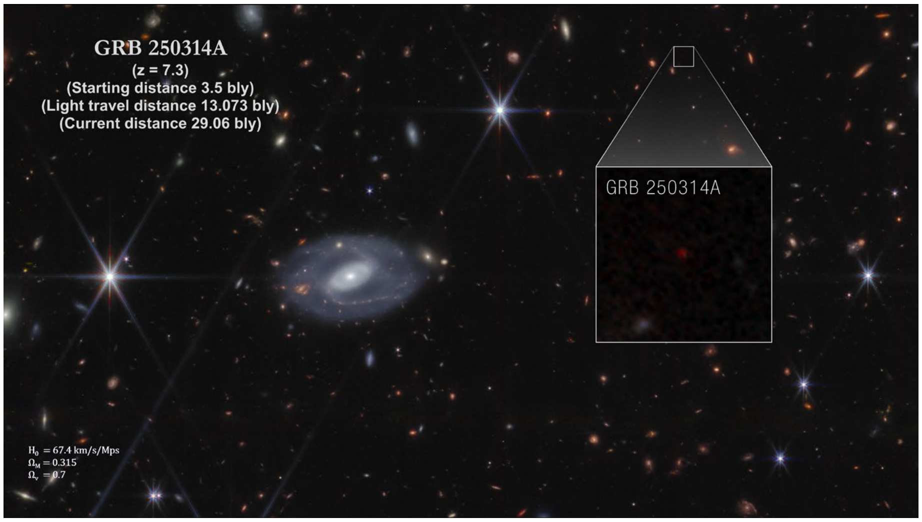
Around 13 billion years ago, one of the first stars in the Universe collapses into a black hole, releasing a flash of light of unprecedented power. This light travelled through the expanding Universe, past the first galaxies, then drifted through the ages… all the way to us. And on the 14th of March 2025, the Space-based multi-band astronomical Variable Objects Monitor SVOM satellite captured it. The Nordic Optical Telescope, as well as the Neil Gehrels Swift Observatory and the Einstein Probe satellite, pointed their instruments at the source and pinpointed its location. Einstein Probe's observations even confirm the transient nature of the optical counterpart, a key clue in favor of a gamma-ray burst. Around 17 hours after the SVOM alert, the spectrum was acquired by the Very Large Telescope VLT, and the Gran Telescopio Canarias.



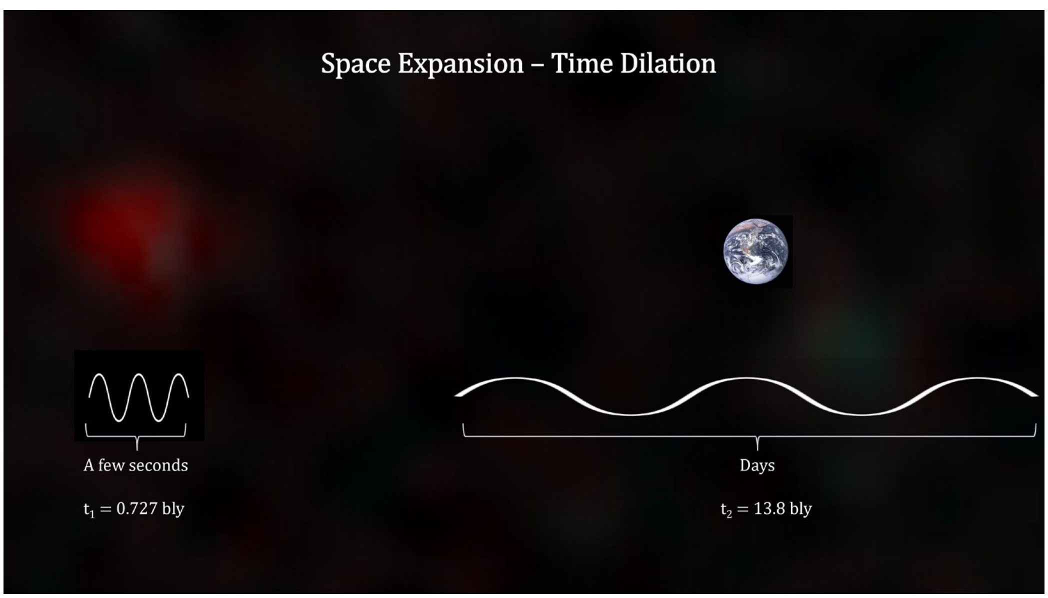
Here's the sequence of near-infrared images acquired in different filters, from short to long wavelength. Focusing on the center of each image it is evident how the optical counterpart is absent in the z band while flux arises in the other three bands. Distant objects have their short-wavelength light absorbed, while the ones at longer wavelengths survive. This was a sign that the gamma-ray burst could be one of the very first stars in the Universe to collapse into a black hole.



The James Webb Telescope confirmed that the gamma-ray burst was indeed generated by a supernova. It was a Type 1c core collapse supernova. Its redshift is 7.3. This means that the light travel distance was 13.073 billion light years. The light from this gamma-ray burst was emitted when the Universe was only 727 million years old, compared with the 13.8 billion years old it is now. This was the fifth most distant gamma-ray burst ever detected and the furthest ever supernova. Since this is the earliest, farthest supernova to be detected to date, researchers compared it to what they know about modern, nearby supernovae. They found them to be quite similar. Thus, it may well be that the mechanisms and stars that give rise to gamma ray bursts now, are the same as those created way back at the beginning.

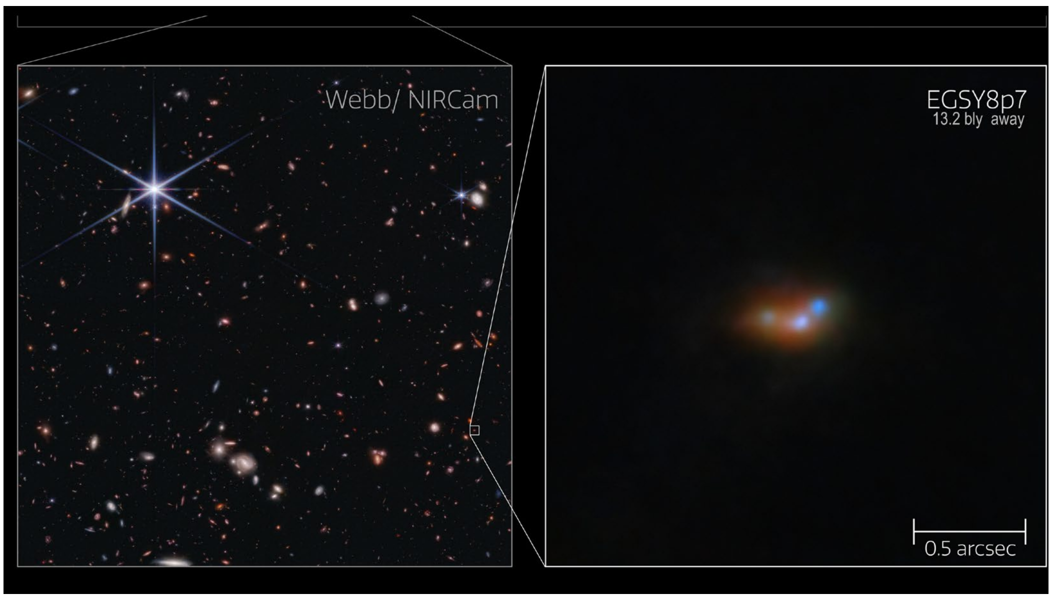


While a gamma-ray burst typically lasts for seconds to minutes, a supernova rapidly brightens over several weeks before it slowly dims. In contrast, this supernova brightened over months because its light was stretched as the cosmos expanded over 13 billion years. As light is stretched, so is the time it takes for events to unfold. Webb's observations were intentionally taken three and a half months after the gamma-ray burst ended, since the underlying supernova was expected to be brightest at that time.



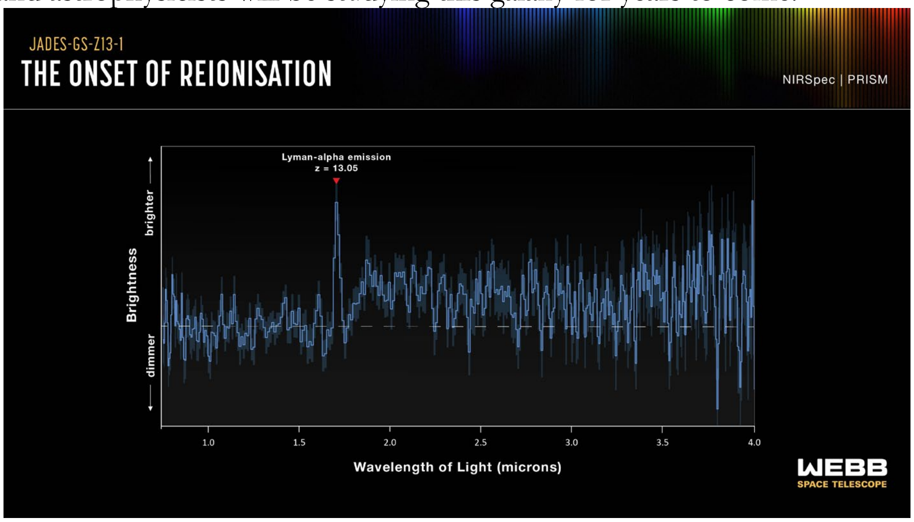
22 - JADES-GS-z13-1 – z = 13.05

We covered the epoch of Reionization in Chapter 3 of the How Old Is It video book. It went from the first stars, when the universe was filled with molecular hydrogen, to the ionized hydrogen we see today. We saw how early galaxies like EGSY8p7, helped astronomers figure out how Lyman-Alpha photons - created when an electron falls from a hydrogen atom's second energy level to the first - made it through the molecular hydrogen to reach Earth.



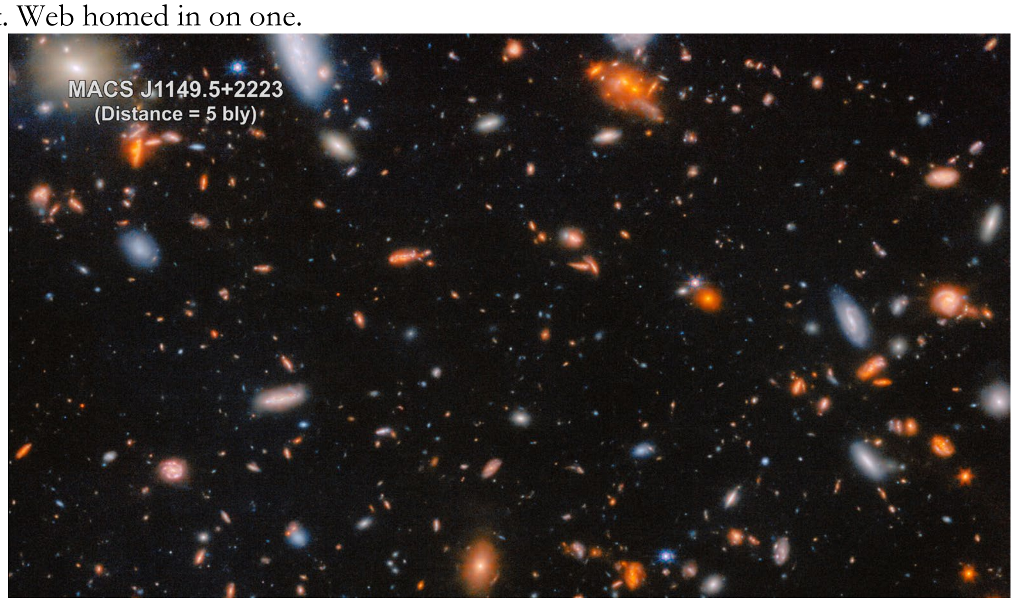
In 2025, an international team of astronomers used Webb to study light from the distant galaxy Jades GS-z13-1. It's the red dot at the center of the view on the right. The light from the galaxy took 13.465 billion years to reach us. This equates to a galaxy as it looked just 335 million years after the Big Bang. We could be seeing one of the first stars to ever exist.

The team also found a strong presence of Lyman-α emissions. Note the distinctly bright wavelength of light. This emission was far stronger than astronomers thought possible at this early stage in the Universe's development. The source of the Lyman-α radiation from this galaxy is not yet known, but it is may include the first light from the earliest generation of stars to form in the Universe, or from a powerful active galactic nucleus driven by one of the first supermassive black holes. In any case, astronomers and astrophysicists will be studying this galaxy for years to come.

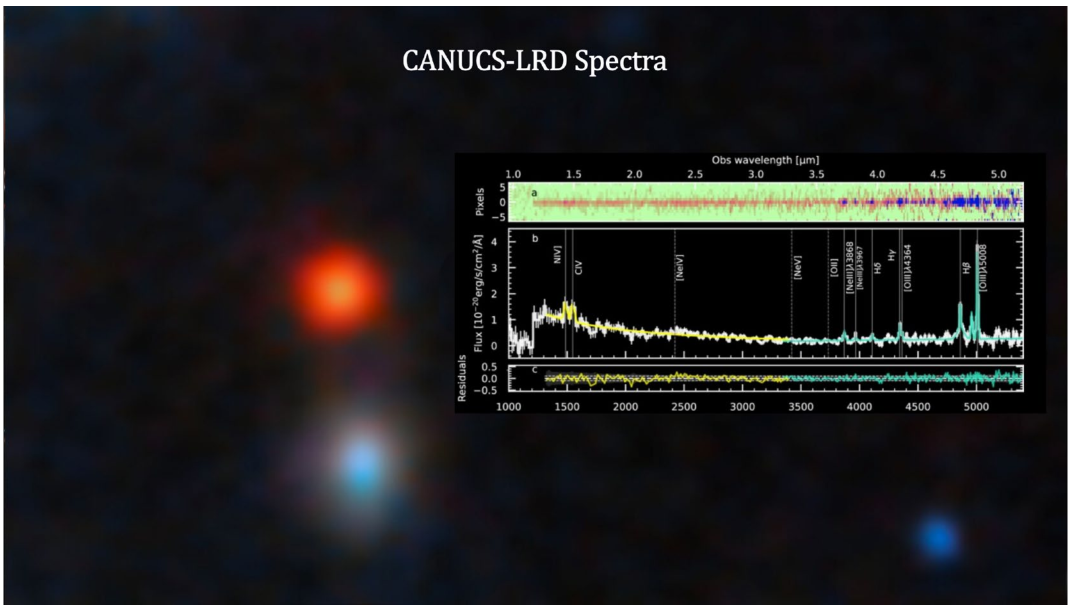


21 - CANUCS-LRD-z8.6

Over its early years, Webb surveys of the Universe turned up an increasing number of small, extremely distant, and strikingly red objects. These so-called "Little Red Dots" remain a mystery, despite their unexpected abundance. From samples, researchers found that these objects emerged in large numbers around 600 million years after the big bang and underwent a rapid decline in quantity around 1.5 billion years after the big bang. This Webb Near-Infrared image shows a portion of a galaxy cluster (MACS J1149.5+2223), 5 billion light years away. Lots of distant "Little Red Dots" stand out. Web homed in on one.

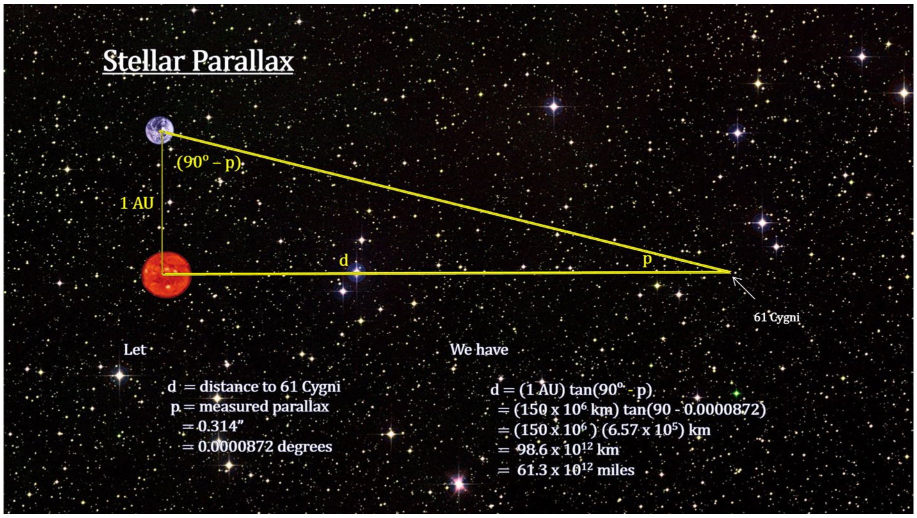


This is CANUCS-LRD. The light we see took 13.214 billion years to reach us. It left the object just 586 million years after the Big Bang. Webb found gas that had been highly ionized by energetic radiation. This suggested it was rotating rapidly around a central source. Additionally, Webb spectroscopy allowed the team to measure how much energy is emitted at different wavelengths. With this, they were able to characterize the galaxy's physical properties. This in turn enabled them to calculate the mass of the galaxy's stars and compare it with the black hole's mass. It turns out that this little red dot is the most massive host galaxy known at such an early time, yet its central black hole is even more massive for such an early stage in the Universe. The result suggests that black holes may have formed and started growing at an accelerated pace in the early Universe, even in relatively small galaxies.

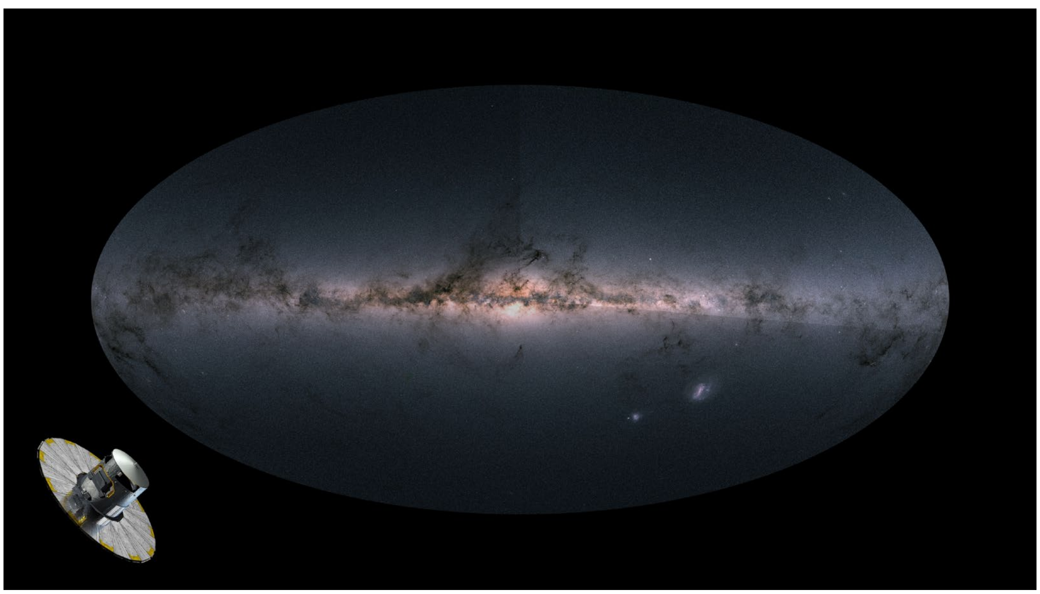


23 - GAIA

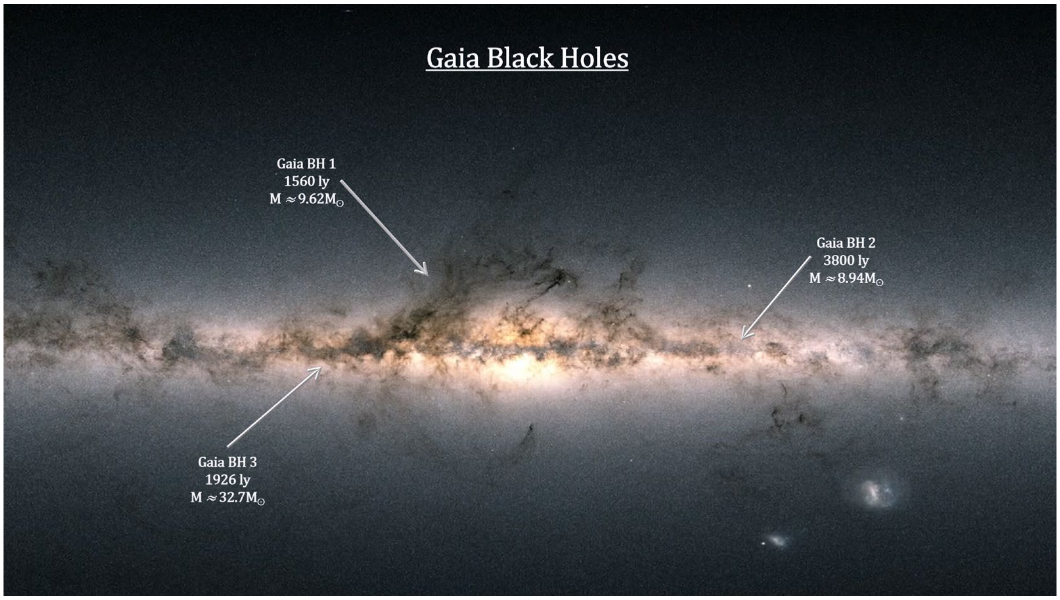
In the 'How Far Away Is It' video book chapter on Nearby Stars, we covered the 1830s race to see who could find the first real stellar parallax. The astronomer Fredrich Bessel won. He mapped the star 61 Cygni against a distant star background for 28 years observing the star's ellipses that followed the earth's orbit. In 1838, after thousands of measurements and calculations, he made scientific headlines by announcing that the parallax of 61 Cygni was 0.314 arcseconds. That gives us a distance of 98 trillion km – that's 61 trillion miles. That's over 6 hundred thousand times further from the sun than we are. That's too far to be reflecting the Sun's light. This is how, in the middle of the 19th century, we discovered that stars burned with their own light.



A 175 years later, Gaia, a European Space Agency mission started making precise parallax distance measurements. This view shows the density of stars observed by Gaia in each portion of the sky. Brighter regions indicate denser concentrations of stars, while darker regions correspond to patches of the sky where fewer stars are observed.

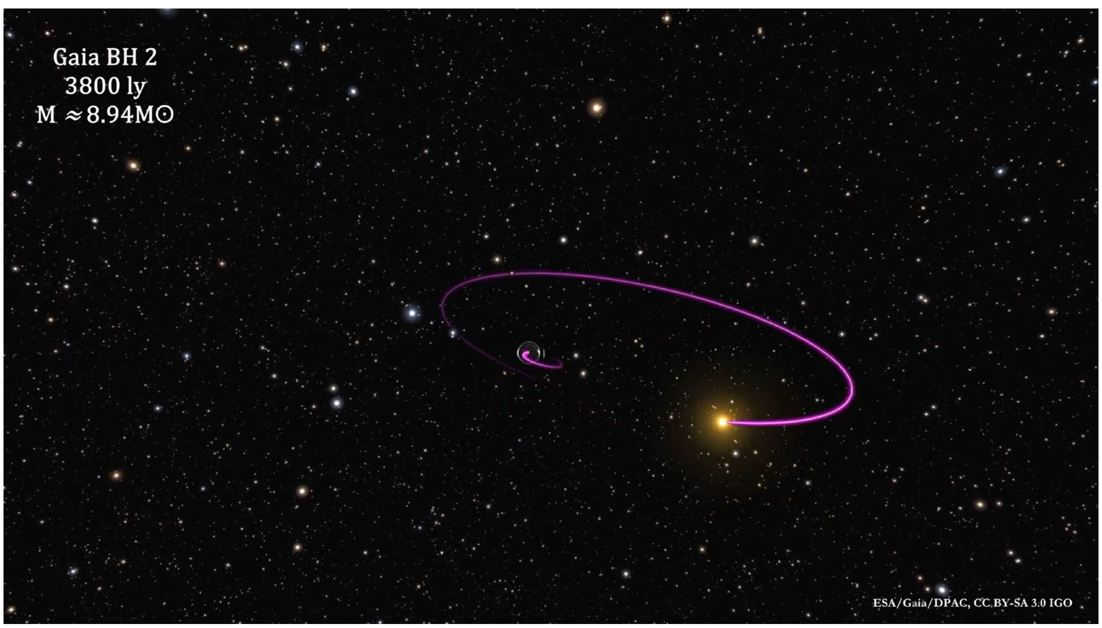


In the process of scanning the stars in our own galaxy, Gaia has also spotted other objects, from asteroids in our Solar System to quasars outside the Milky Way. It also found three stellar mass black holes including one less than 2000 light-years from Earth. They were discovered by studying ultra-precise measurements of stellar positions and motions. A 'wobble' in the movement of stars on the sky indicated that they are orbiting a very massive object. The objects are approximately ten times more massive than our Sun.



Credit: ESA/Gaia/DPAC, CC BY-SA 3.0 IGO

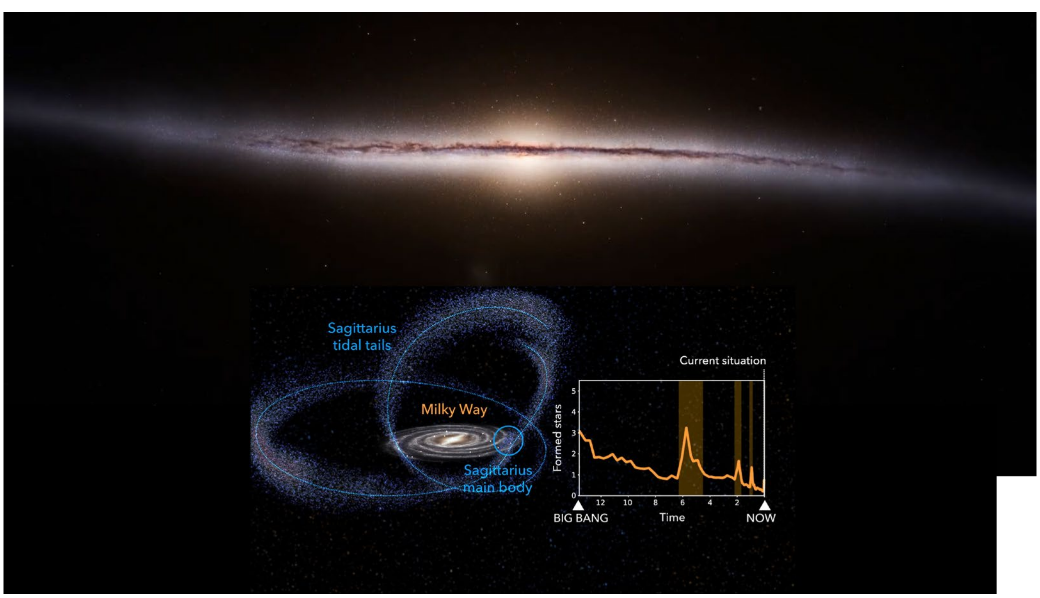
Gaia's second black hole, BH2, is located 3800 light-years away from Earth. It is a binary system consisting of a red giant star and a black hole. In this animation of Gaia BH2, the orbits are accurately sized, but the back hole diameter is not to scale.



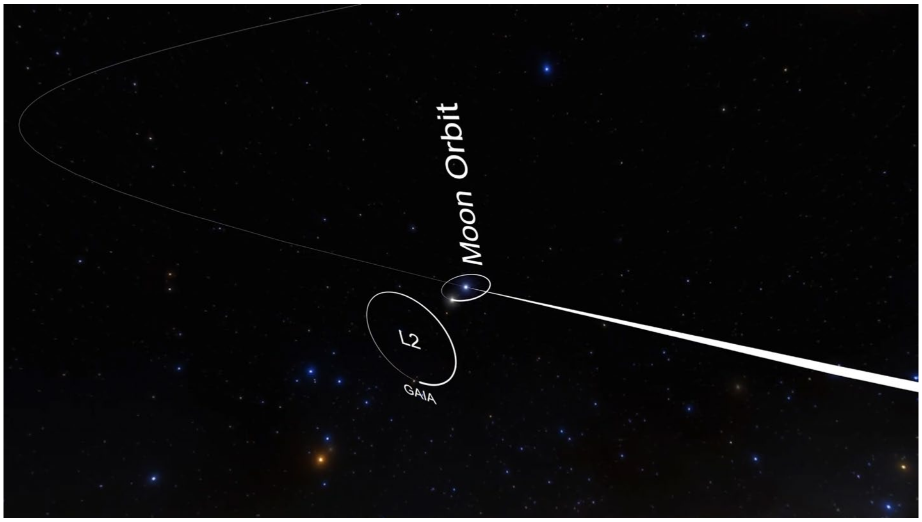
Here's a Milky Way map, built with Gaia's data. You can see the central bar, and the detailed structure of spiral arms. Here's what it looks like edge-on. You can see the central bulge and the warped disk.

Credit: ESA/Gaia/DPAC, Stefan Payne-Wardenaar

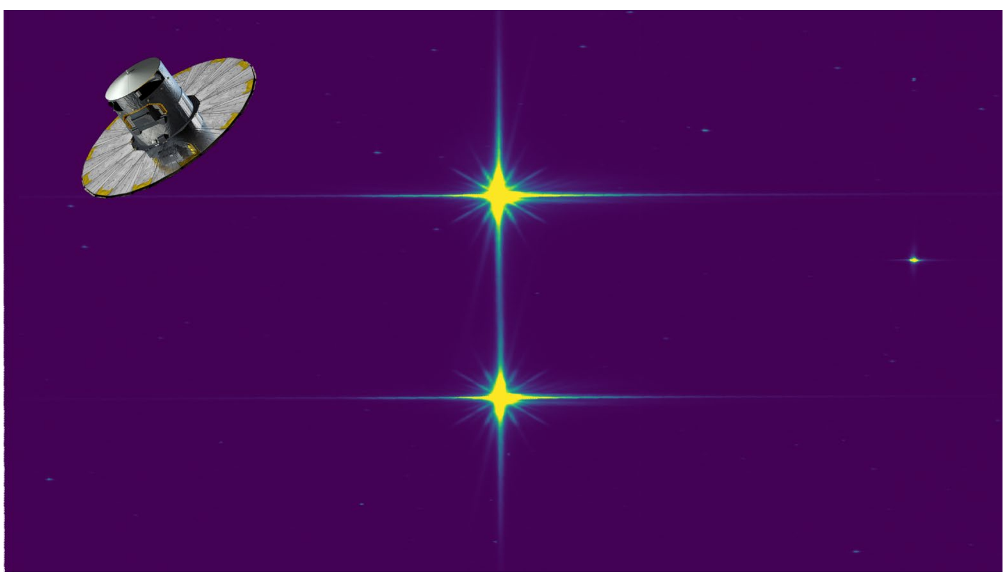
Gaia's detailed star locations show that the disk wobbles. A new study, revealed that the influence of the orbiting dwarf galaxy Sagittarius may be partly responsible for the wobble. It is known from existing models that Sagittarius fell into the Milky Way three times – first about five or six billion years ago, then about two billion years ago, and finally one billion years ago. Gaia also found three periods of increased star formation in our galaxy that peaked around the same times that Sagittarius is believed to have passed through the disc. This would have caused previously still gas and dust inside the Milky Way to slosh around like ripples on water. In some areas, these ripples would lead to higher concentrations of dust and gas, triggering the formation of new stars. It's possible that Sagittarius's first pass may have started the formation of the Sun and its planets.



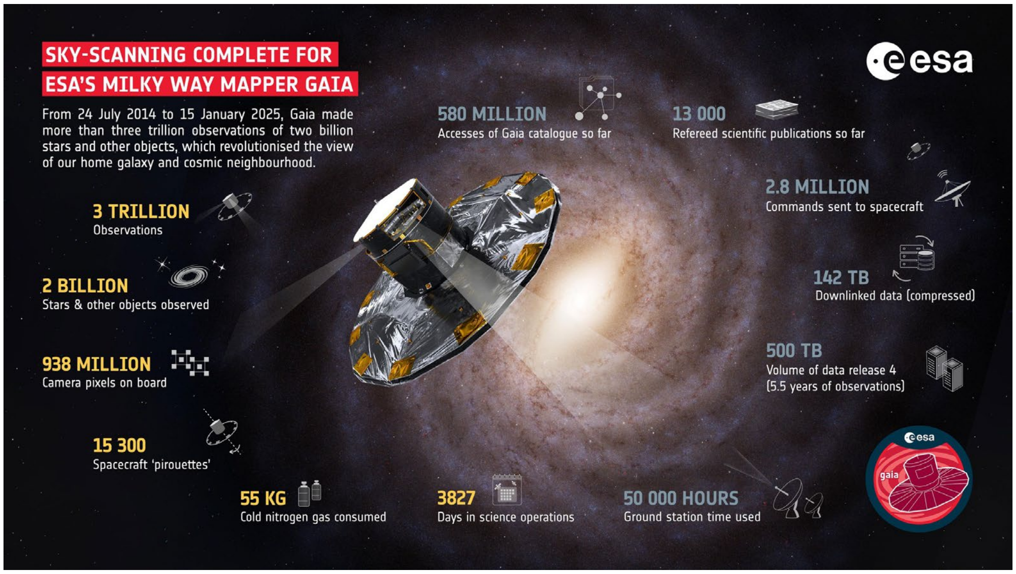
After 3827 days of amazing science operations, Gaia ran out of fuel. It could no longer maintain its position at the L2 Lagrange point. Its science observations were complete.



Its last targeted observation, on January 10 2025, was of binary pair 61 Cygni. This is Gaia's final view. The brightest component, 61 Cygni A, is seen North of its companion, 61 Cygni B. A few background stars are visible as well. Fredrich Bessel would be pleased.



Over the past decade, Gaia has made more than three trillion observations of around two billion stars and other celestial objects. It has pinned down the brightness and position on the sky of 2 billion stars. It has also cataloged the parallax, proper motion, and color for 1.3 billion stars, and it has accurate distance information on 96 million stars. All in all, it has accumulated 500 terabytes of data, transforming our understanding of the galaxy.



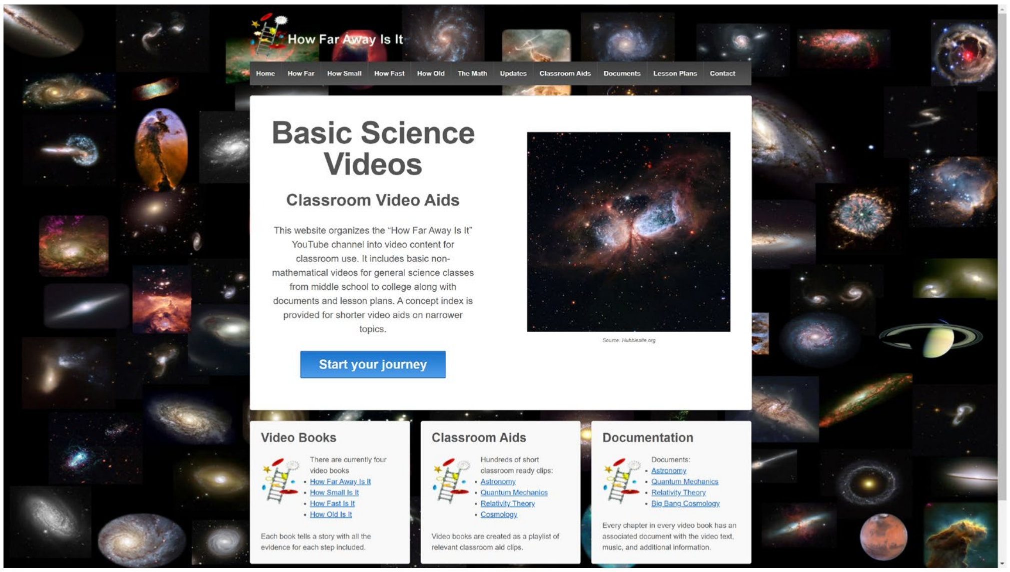
Credit: ESA/Gaia/DPAC, Milky Way impression by Stefan Payne-Wardenaar

On March 27, 2025, Gaia went into its final orbit around the Sun, far away from Earth's sphere of influence. It was passivated, to avoid any harm or interference with other spacecraft. The term "passivation" refers to the process of removing stored energy from a space vehicle to reduce the risk of explosions that would produce dangerous debris.

Gaia is gone. But the hundreds of thousands of bytes of data collected and released in its Data Release 4 will keep astronomers busy for decades to come.

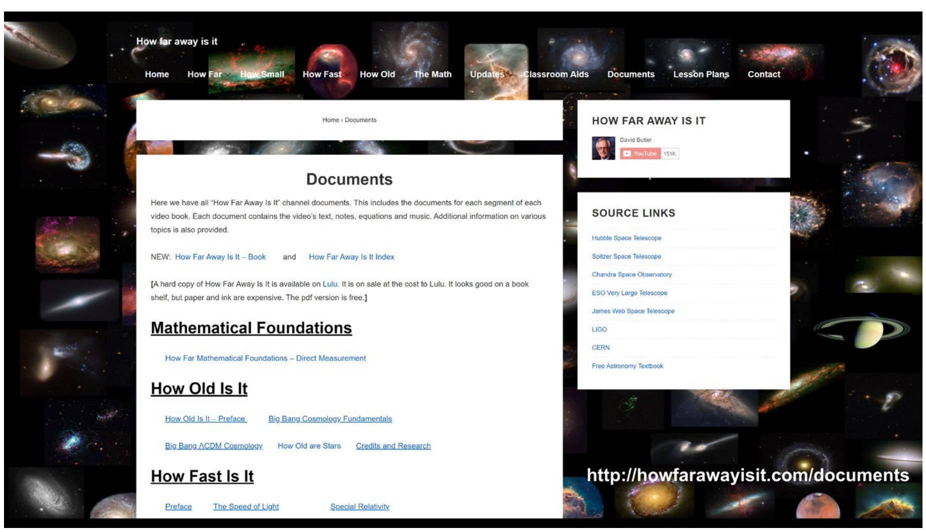
Credits and Research

Here are the links to Webb, Hubble and other locations where I found the information contained in this 2025 review. These are also the places where you can begin to do your own research.



https://howfarawayisit.com/

And don't forget. Every video has a document on the howfarawayisit.com website containing all the text and pictures. Download and translate as needed. In closing, I want to thank Jonathan Onstead for his excellent editing. And I want to thank everyone for all the great comments and questions posted on my videos. I read them all. Keep them coming, and thanks for watching.



http://howfarawayisit.com/documents/

Interstellar Comet 3I/Atlas

https://science.nasa.gov/missions/hubble/as-nasa-missions-study-interstellar-comet-hubble-makes-size-estimate/
https://zenodo.org/records/16941949?token=eyJhbGciOiJIUzUxMiJ9.eyJpZCI6IjJlMzIzZWNlLTE2NmMtNDVlYi1hNjQ1LWY0NWYzNjNkOTQwNyIsImRhdGEiOnt9LCJyYW5kb20iOiJkOGEyYjcxNmQ0NjFhZmM5MGRlMWM3NjU2NTY4Nzg3MiJ9.ydkIUd_88sI0zsbhRzfUBANVpxZt1dRH7alRn-bhh4EAd8R07WGFzTW6yGkQgdOyKr_1vz1dzOe8zNsr4bK04A
https://www.youtube.com/watch?v=bwJgcflf0lM&t=402s
https://www.pbs.org/newshour/science/nasa-releases-close-up-pictures-of-interstellar-comet-3i-atlas

Kuiper Belt – 3.7 billion miles
https://www.stsci.edu/contents/news-releases/2025/news-2025-007.html
https://keckobservatory.org/kuiper-trio/
https://www.tigoenergy.com/monitoring
https://ei.tigoenergy.com/site/forgot-password
https://ei.tigoenergy.com/fleet/system/status/index?sysid=450
https://link.springer.com/article/10.1007/s11229-020-02801-1

Lynds 483 – 650 ly

https://webbtelescope.org/contents/news-releases/2025/news-2025-111.html

Flame Nebula – 1,400 ly

https://webbtelescope.org/contents/news-releases/2025/news-2025-105.html
https://iopscience.iop.org/article/10.3847/2041-8213/adb96a

Crystal Ball Nebula – 1,500 ly

https://esawebb.org/news/weic2508/?lang
https://en.wikipedia.org/wiki/NGC_1514

NGC 6072 – 3,030 ly

https://esawebb.org/news/weic2514/?lang
https://www.astroexplorer.org/details/apj322067f9

Cat's Paw Nebula (NGC 6334) – 4,000 ly

https://esawebb.org/images/weic2513a/

Wolf-Rayet 140 – 5,000 ly

https://esawebb.org/news/weic2501/?lang

Prismis 24 in NGC 6357 - 5,500 ly

https://esawebb.org/images/weic2518a/

Eagle Nebula – 6,500 ly
https://esahubble.org/images/heic2507a/

Apep - A Wolf-Rayet Binary – 8,000 ly
https://science.nasa.gov/asset/webb/wolf-rayet-apep-miri-image/

Cassiopeia A Light Echo = 11,000 ly
https://webbtelescope.org/contents/news-releases/2025/news-2025-102.html
chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.stsci.edu/jwst-program-info/download/jwst/pdf/5451/

Sh2-284 – 15,000 ly
https://esawebb.org/images/weic2519a/
https://science.nasa.gov/missions/hubble/hubble-unveils-a-glittering-view-of-sh2-284/

Galaxy Center Regions Sagittarius B2 and C – 26,000 ly
https://www.eso.org/public/images/eso0924e/
https://esawebb.org/news/weic2520/?lang
https://arxiv.org/abs/2509.11771

NGC 346 – 200,000 ly
https://esahubble.org/news/heic2502/?lang

Andromeda and Its Satellites– 2.5 mly
https://hubblesite.org/contents/news-releases/2025/news-2025-001.html
https://hubblesite.org/contents/news-releases/2025/news-2025-005.html
https://carnegiescience.edu/news/carnegie-science-celebrates-edwin-hubbles-discovery-universe
https://www.youtube.com/watch?v=udAL48P5NJU&t=207s
chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://stsci-opo.org/STScI-01JHRD6B0ANRZ7ZTG4KZ7KR9ZN.pdf
http://www.messier.seds.org/Pics/Hi-res/m32_9940y.jpg
https://communities.springernature.com/posts/can-we-decipher-the-andromeda-galaxy-s-merger-history
https://esahubble.org/images/heic1112a/
https://www.stsci.edu/contents/news-releases/2025/news-2025-009.html

Leo P dwarf galaxy – 5.3 mly
https://www.stsci.edu/contents/news-releases/2025/news-2025-401.html
chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://iopscience.iop.org/article/10.3847/1538-4357/ad8158/pdf
https://iopscience.iop.org/article/10.1088/0004-637X/812/2/158

LEDA 132905 – 400 MLY
https://esahubble.org/images/potw2505a/

Bullseye Galaxy – 567 mly
https://www.stsci.edu/contents/news-releases/2025/news-2025-006.html#heading-full-article
https://iopscience.iop.org/article/10.3847/2041-8213/ad9f5c

Dark Matter Update - Bullet Galaxy Cluster – 3.7 bly
https://webbtelescope.org/contents/news-releases/2025/news-2025-128.html?utm_source=webb&utm_campaign=inbox_astronomy&utm_id=2025-128
https://iopscience.iop.org/article/10.3847/2041-8213/add2f0
A High-Caliber View of the Bullet Cluster through JWST Strong and Weak Lensing Analyses

CANUCS-LRD-z8.6
https://esawebb.org/images/weic2522a/
https://science.nasa.gov/missions/webb/newfound-galaxy-class-may-indicate-early-black-hole-growth-webb-finds/
https://www.nature.com/articles/s41467-025-65070-x

JADES-GS-z13-1
https://esawebb.org/images/weic2505d/
https://www.nature.com/articles/s41586-025-08779-5
https://esawebb.org/images/jades5/

GAIA
https://scitechdaily.com/gaia-discovers-a-mysterious-new-type-of-black-hole-and-two-are-lurking-in-earths-cosmic-backyard/
https://www.cosmos.esa.int/en/web/gaia/iow_20250115
https://scitechdaily.com/gaia-completes-its-stellar-odyssey-leaving-a-cosmic-legacy/
https://www.youtube.com/watch?v=MKirPGFJvdU&t=3s Non-accreting
https://www.youtube.com/watch?v=f3uU7lpmcN4&t=119s
https://sci.esa.int/web/gaia/-/galactic-crash-may-have-triggered-solar-system-formation
https://www.nature.com/articles/s41550-020-1097-0
https://www.youtube.com/watch?v=Bm_29I9NJjI&t=30s

GRB 250314A
https://www.svom.eu/en/grb-250314a-a-message-from-the-depths-of-time/
https://www.aanda.org/component/article?access=doi&doi=10.1051/0004-6361/202556581
chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/file:///C:/Users/david/Downloads/JWST_reveals_a_supernova_following_a_gamma-ray_bur%20(1).pdf
https://www.svom.eu/en/grb-250314a-a-message-from-the-depths-of-time/
https://esawebb.org/news/weic2523/

Music

Puccini: Caro Mio Ben; from the album Meditation: Classical Relaxation 2010

Mendelson violin concerto from the album Most Relaxing Classical Music 1997

Chopin, Frédéric: Prelude from Les Sylphides; from the album “A Calendar of Classics - A 12 CD set of Romantic Classics for every Month of the Year”, 2007

Puccini, Giacomo: Crisantemi; Radio Symphonie Orchester Berlin and Riccar-do Chailly; from the album “Puccini without Words”, 2006

Mozart: Sinfonia concertante for violin, viola & orchestra in E flat from the album Amadeus

Greek letters:
- α β γ δ ε ζ η θ ι κ λ μ ν ξ ο π ρ σ τ υ φ χ ψ ω
- Α Β Γ Δ Ε Ζ Η Θ Ι Κ Λ Μ Ν Ξ Ο Π Ρ Σ Τ Υ Φ Χ Ψ Ω

⇒ → ± ⊙ ∞ ↛ ∃ ∄ ∈ ∉ ∬ ∫ ≅ ≥ ≤ ≈ ≠ ≡ √ ∛ ~ ∝ ħ ÷