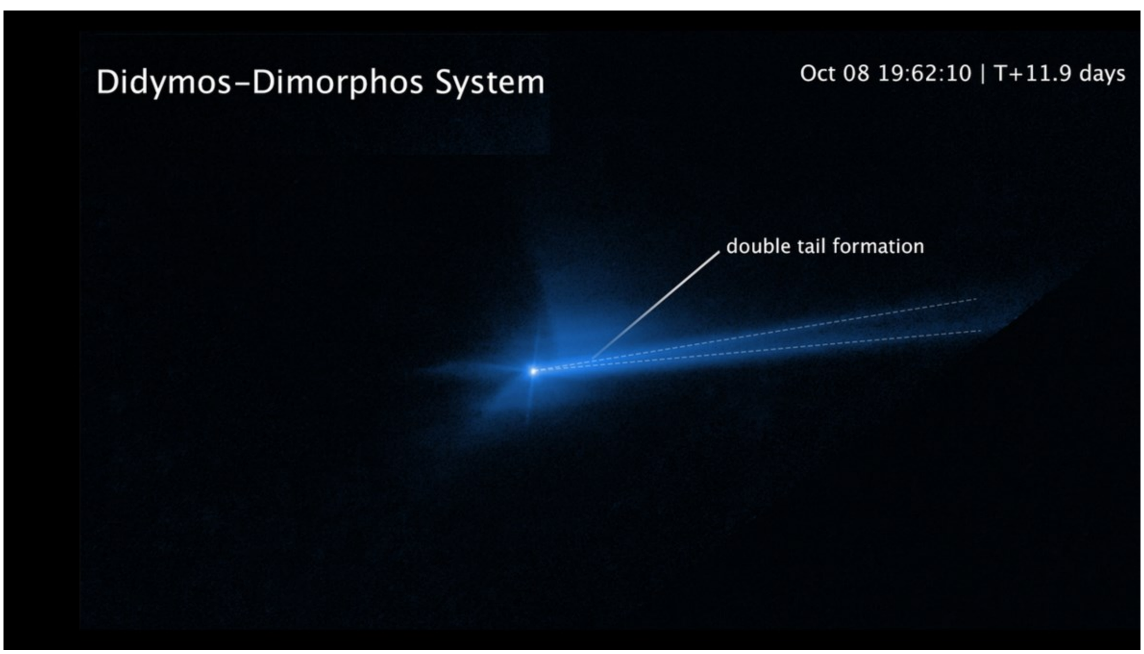
2023 Review

Introduction

2023 was a great year with both Hubble, Webb and others making new discoveries and producing amazing images. We start out with an update on the DART asteroid collision we covered last year. Staying inside the Solar System, we cover the Parker Solar Probe's journey through the Suns corona. Moving beyond the Solar System, we'll see molecular clouds, brown dwarfs, Herbig-Haro objects, and take a deeper look into the Crab and Cassiopeia nebulas. We'll then do a little astrochemistry in the Iris Nebula. Moving beyond our galaxy, we cover dwarf galaxies, a runaway black hole, a possible intermediate mass black hole, intergalactic stars, and some of the oldest galaxies ever found. We'll end with the first release images from 'Euclid," our newest space telescope.

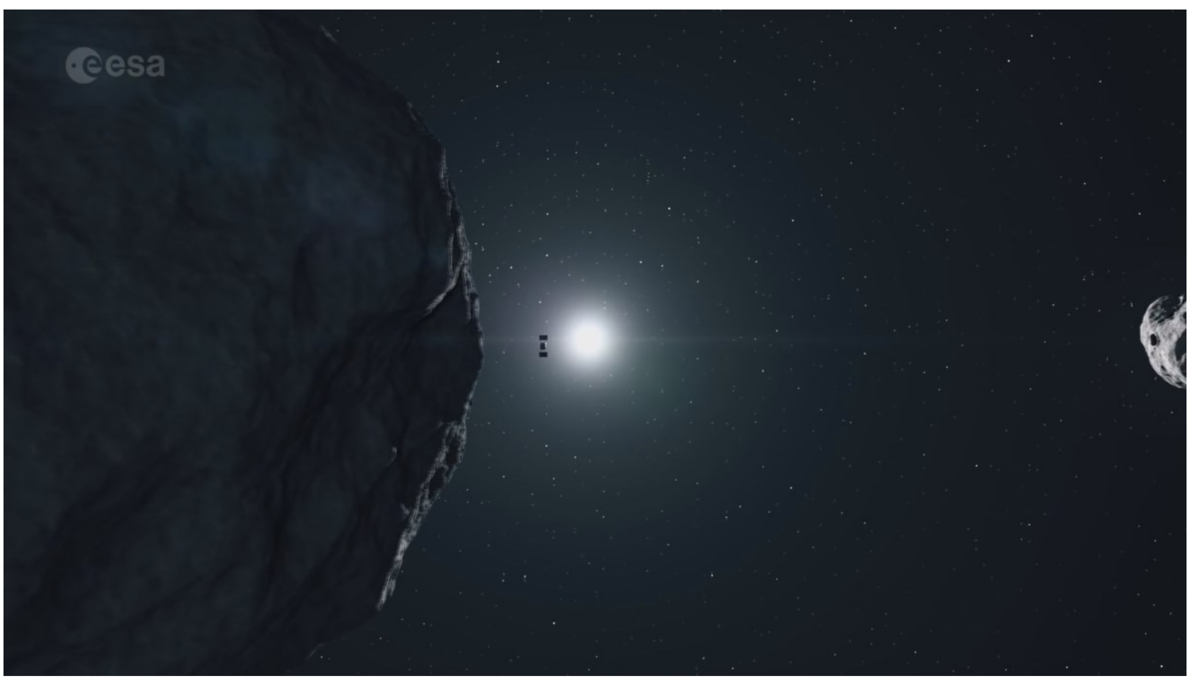
DART Update

Detailed follow-up observations on the Didymos-Dimorphos system measured the Dimorphos orbit around Didymos at once every 11 hours and 22 minutes. That's a full 33 minutes shorter than its orbital period before the collision. This dramatic increase turns out to be caused by the production at least a million kilograms (that's 1,100 U.S. tons) of material ejected by the impact.



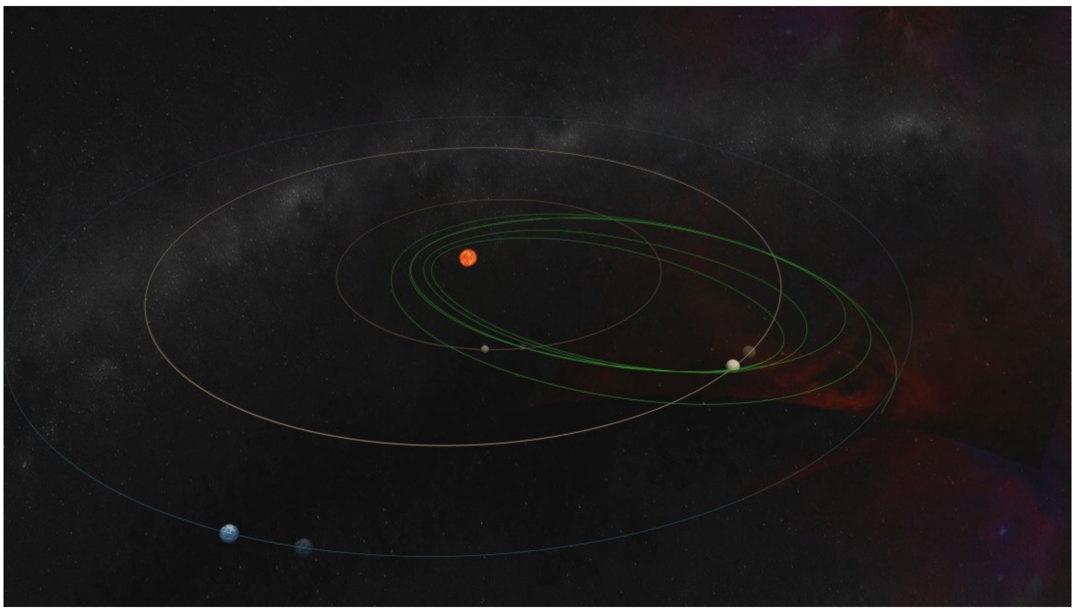
In addition, Hubble has detected 37 boulders knocked off the asteroid by the force of the collision. The total mass in these boulders is about 0.1% of the mass of Dimorphos. They are drifting away from the asteroid at around one kilometer per hour (that's .62 miles per hr).

In 2024, the European Space Agency's Hera mission plans to launch a spacecraft to the system. It will perform a detailed post-impact survey that will turn the Dart experiment into a well-understood and repeatable planetary defense technique that might one day be used for real. We'll see more on this in the 2024 Review.



Parker Solar Probe

In 2023, the Parker Solar Probe set a new speed record and entered the Sun's atmosphere - the Corona - for the second time. The Probe, launched in 2018 has an elliptical orbit around the Sun that brings it closer on every pass. In 2022, it reached 586,800 km/h (that's 364,660 mph), following a gravity assist from a Venus fly-by. It passed within 8,541,744 km (that's 5,307,594 mi) of the Sun's surface. That's inside the Sun's corona! The 2023 pass was faster and took it even closer.

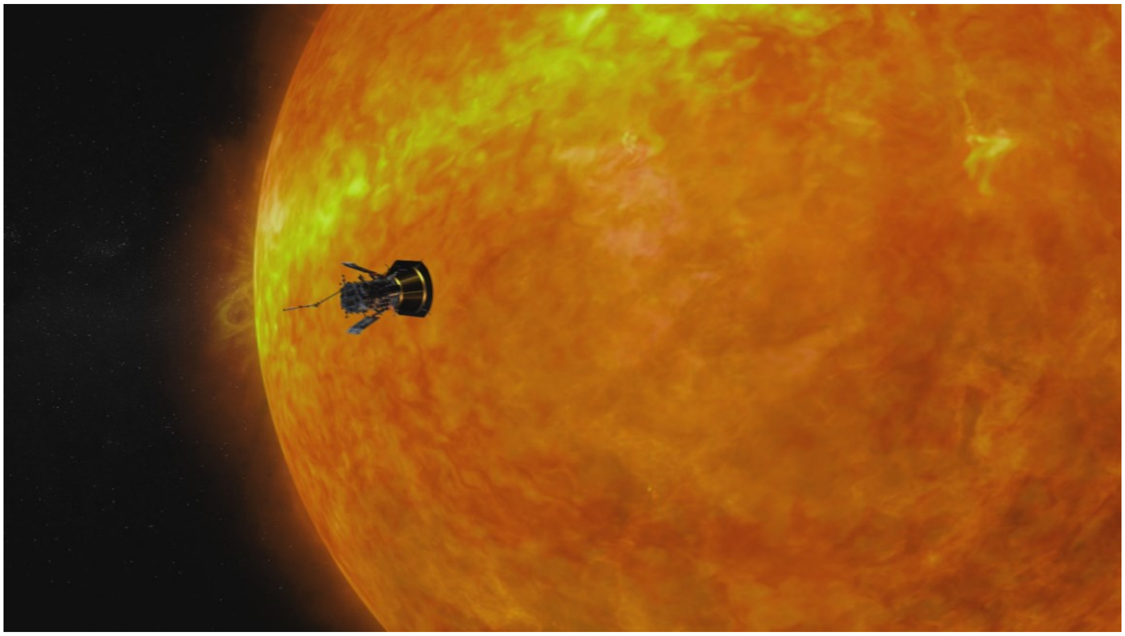


[The spacecraft is outfitted with a cutting-edge heat shield to protect the instruments from the Corona's 1,370 C temperatures (that's 2,500 F). The instruments behind it, in its shadow, will be kept at 30 C (that's 85 F).]

The Sun has a superheated atmosphere, made of solar material bound to the Sun by gravity and magnetic forces. As rising heat and pressure push that material away from the Sun, it reaches a point where gravity and magnetic fields are too weak to contain it. At that point, known as the Alfvén critical surface, the solar atmosphere ends and the solar wind begins.

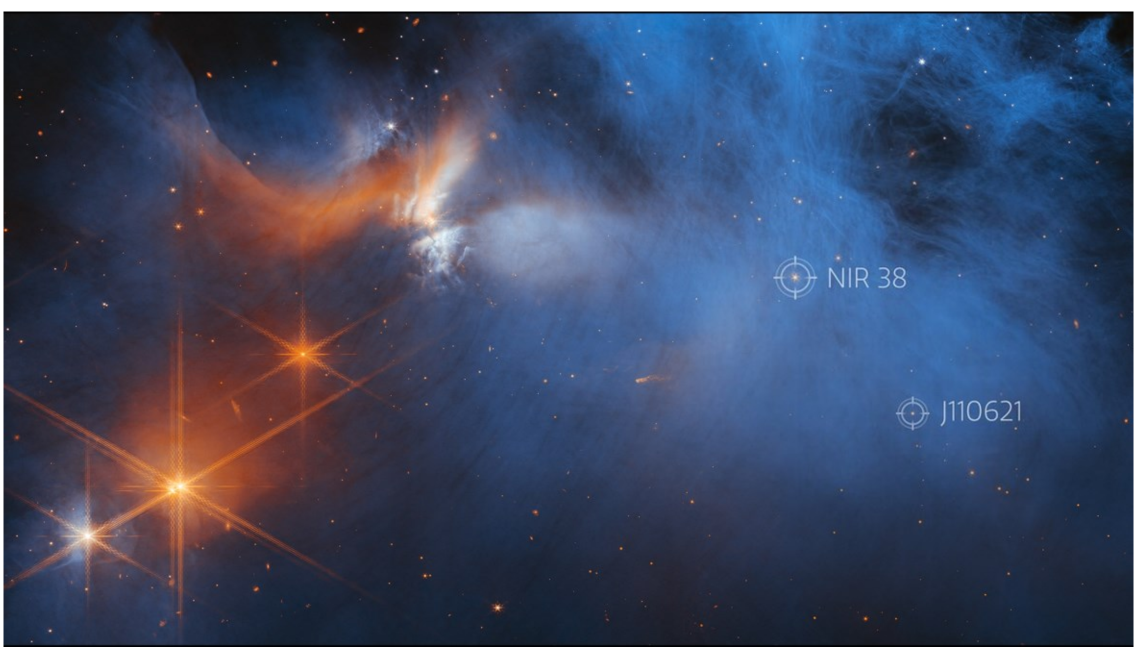
Solar material with the energy to make it across that boundary drags the magnetic field of the Sun with it as it travels across the solar system, to the Earth and beyond. During its eighth flyby of the Sun, at around 13 million km or 8.1 million miles above the solar surface, the Parker Solar Probe encountered the Sun's atmosphere magnetic and particle conditions.

It had crossed the Alfvén critical surface and entered the solar atmosphere. This is quite an accomplishment. The probe will provide us with deeper insights into our Sun's evolution and its impacts on our solar system - including the solar wind and its impact on the Earth.



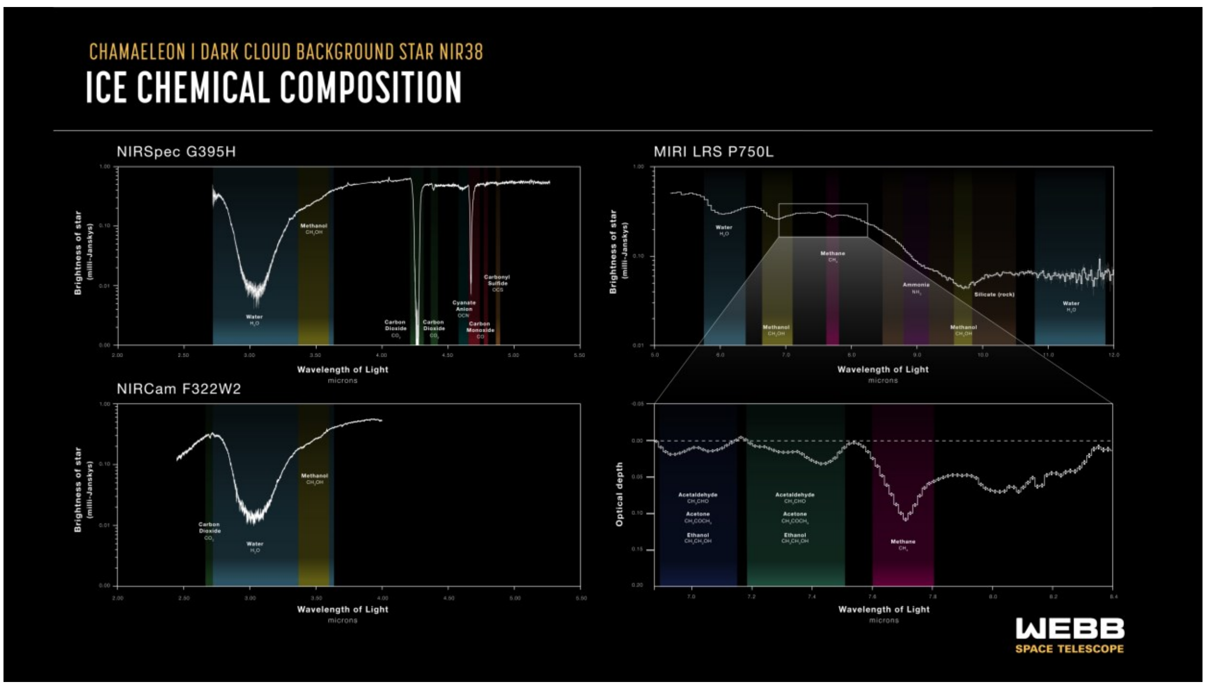
03 - Chamaeleon I molecular cloud - 630 ly

This image by NASA's James Webb Space Telescope's Near-Infrared Camera (NIRCam) features the central region of the Chamaeleon I dark molecular cloud, 630 light years away. The wispy blue cloud material in the center is illuminated in the infrared by the orange glow of the young protostar Ced 110 IRS 4 in the upper left. The light from numerous background stars, seen as orange dots behind the cloud, is used to detect molecules in ices in the cloud. The two background stars used in this study are circled.

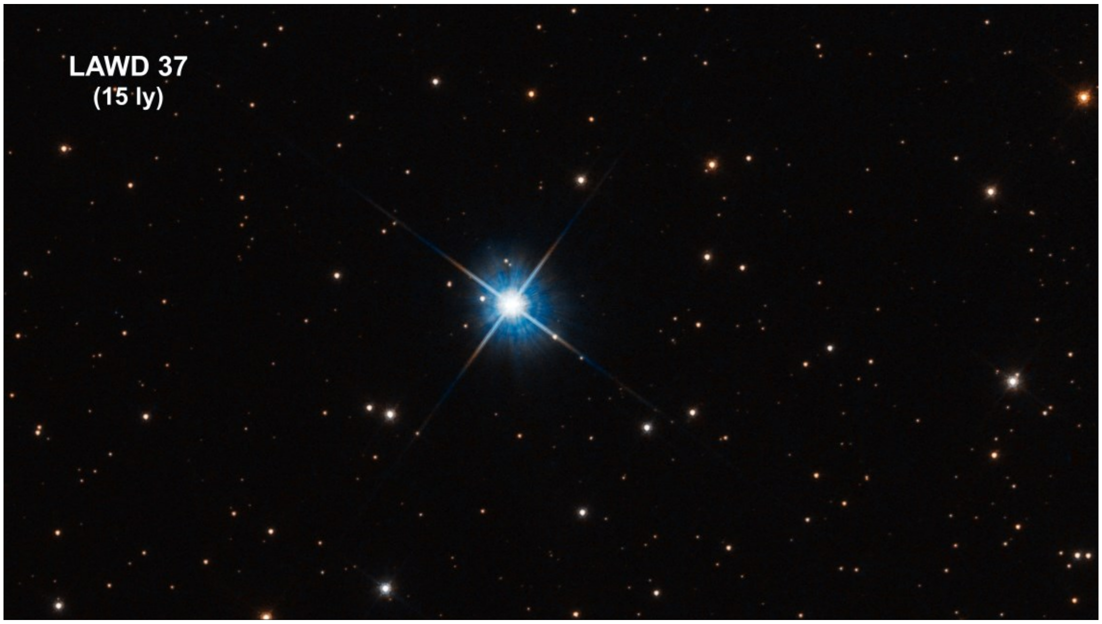


The molecules in the ices absorb the starlight passing through them. This creates a dip in the light that reaches us for each element the ice - namely carbon, hydrogen, oxygen, nitrogen, and sulfur. In addition, an international team of astronomers were able to identify frozen forms of a wide range of complex organic molecules such as ammonia, methane, and methanol. These findings provide insights into the initial dark chemistry stage of the formation of ice on the interstellar dust grains that will grow into the centimeter-sized pebbles from which planets and possibly life may form.

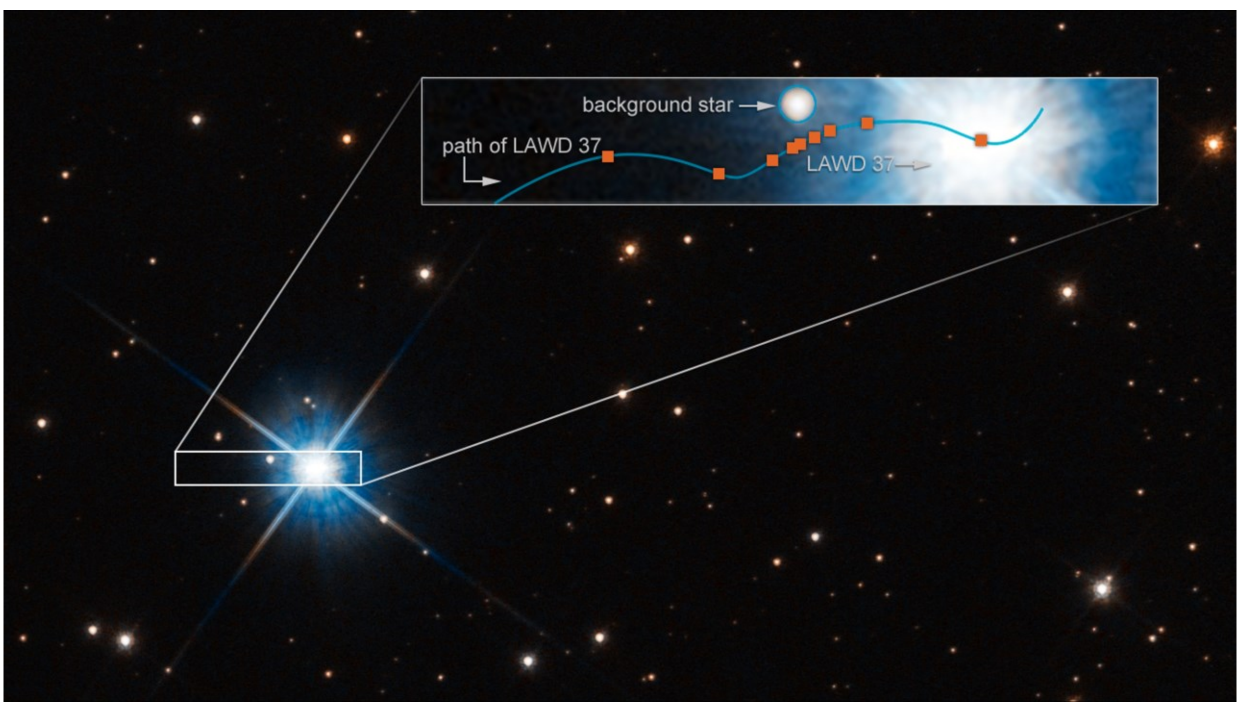
[These complex organic molecules, like methanol suggest that the many star and planetary systems developing in this particular cloud will inherit molecules in a fairly advanced chemical state. This indicates that the presence of precursors to prebiotic molecules in planetary systems may be a common result of star formation, rather than a unique feature of our own solar system.]



04 - LAWD 37 – 15 ly
Here's a Hubble image of a white dwarf star named LAWD 37, 15 ly away. Until now, white dwarf mass measurements have been determined by observing them in binary star systems. By watching the motion of two co-orbiting stars, straightforward Newtonian physics is used to measure their masses.

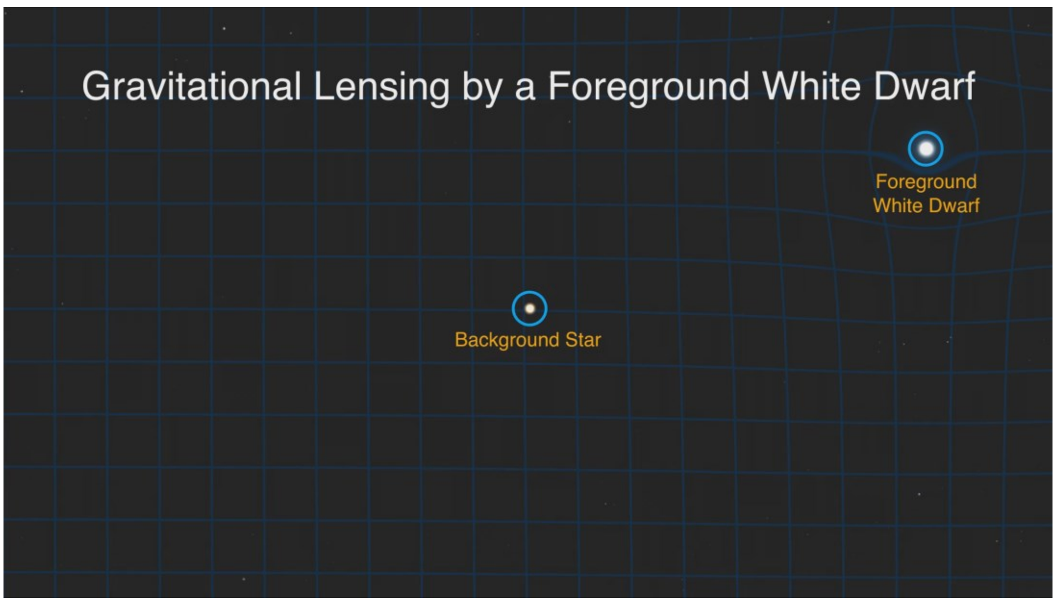


This inset box plots how the dwarf passed in front of a background star in 2019. The wavy blue line traces the dwarf's apparent motion across the sky as seen from Earth. Though the dwarf is following a straight trajectory, the motion of Earth orbiting the Sun imparts an apparent sinusoidal offset. [The star is only 15 light-years away. Therefore, it is moving at a faster rate against the stellar background.]



As the white dwarf passed in front of the background star, the star appears temporarily offset from its actual position on the sky. Given the amount of deflection, Einstein's equations give us the mass of the star. For this white dwarf, it's 56 percent of our Sun's mass.

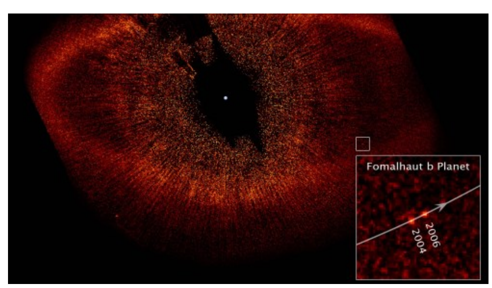
[The team zeroed in on the white dwarf thanks to ESA's Gaia space observatory, which makes extraordinarily precise measurements of nearly 2 billion star positions. Multiple Gaia observations over time are used to track a star's motion. Based on this data, astronomers were able to predict that LAWD 37 would briefly pass in front of a background star in November 2019. With this information, Hubble was used to precisely measure over several years how the background star's apparent position in the sky was temporarily deflected during the white dwarf's passage.]



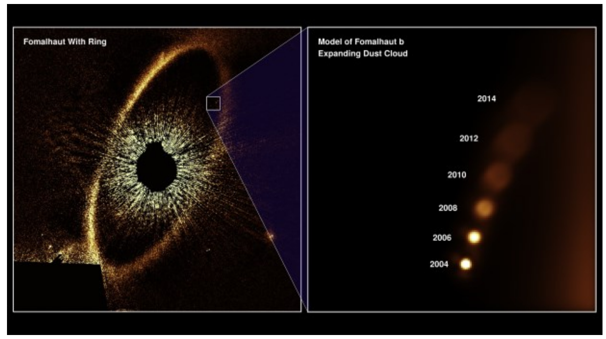
Fomalhaut - 25 ly

Here's some history of our coverage of Fomalhaut, a star 25 ly way.

In our How Far Away Is It segment on nearby stars, we covered its protoplanet Fomalhaut b.

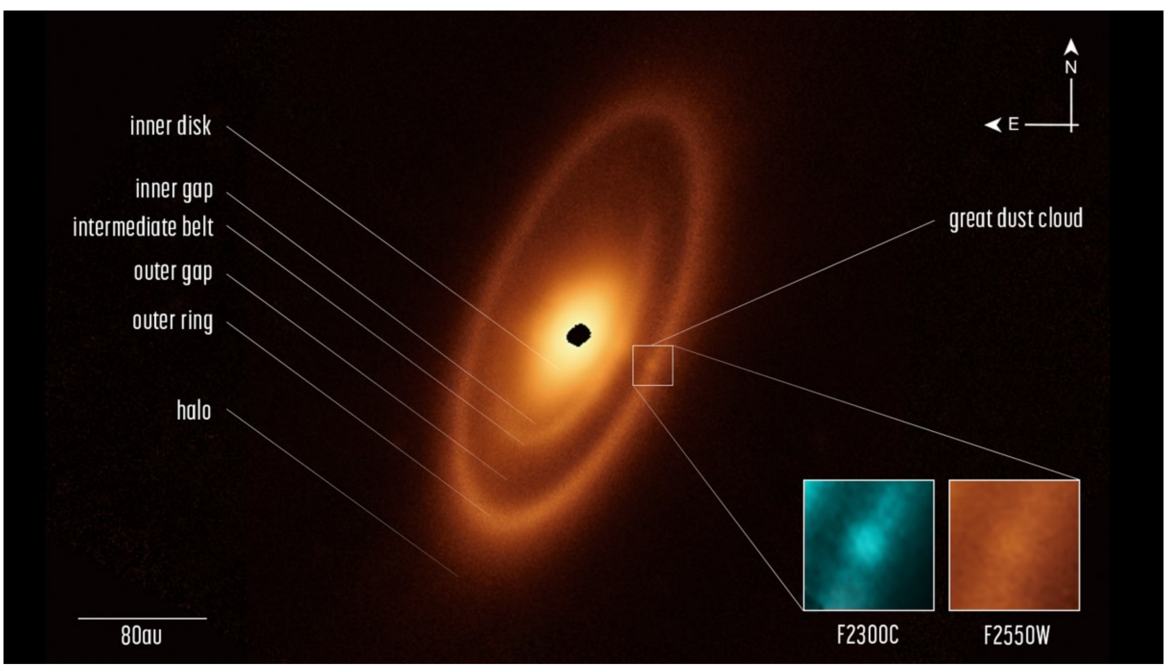


In our 2020 review we covered how this proposed planet had faded away. One analysis of all available archival Hubble data concluded that the planet-sized object never existed in the first place.



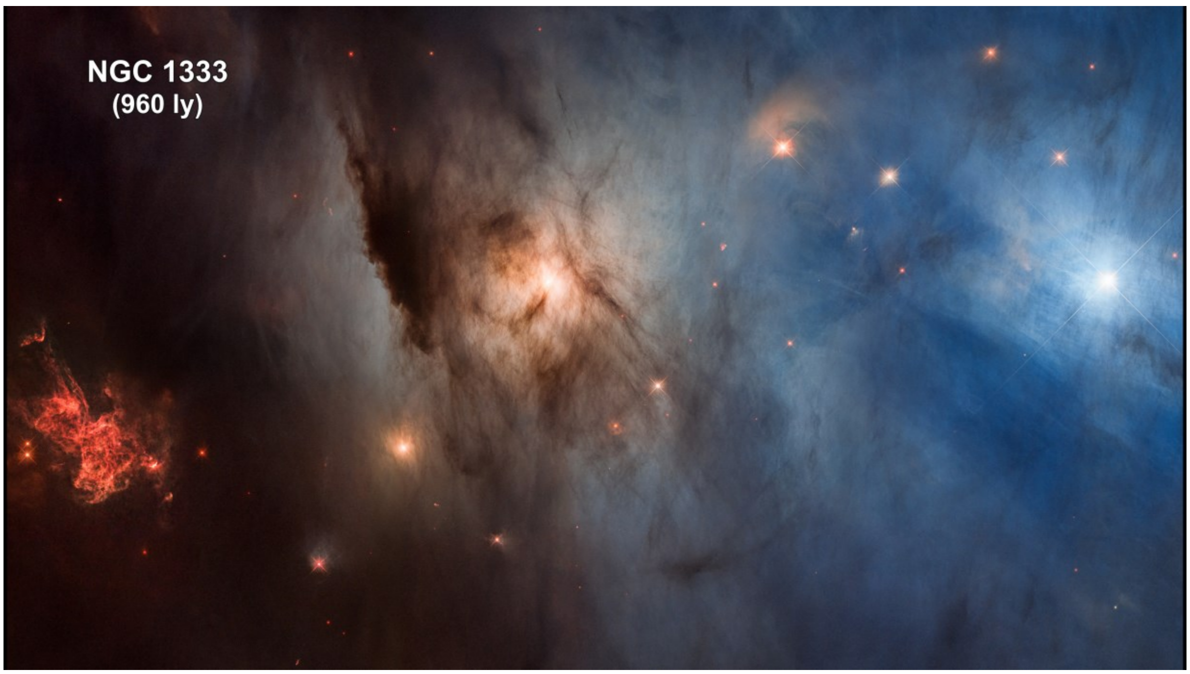
Now Webb has taken a look at this star and refers to Fomalhaut b as a previously known collisionally generated dust cloud. That would be a cloud created by a collision much like our spacecraft collision with Dimorphos created a huge dust cloud.

Webb also found that the debris disk around the star is actually multiple debris disks. Planets can clear areas between disks like our asteroid belt and the Oort cloud. But as of 2023, no Fomalhaut planet has been identified. The discovery process here is common in science. Early data produces a theory that subsequent more detailed data proves wrong. The process continues until real knowledge is produced.



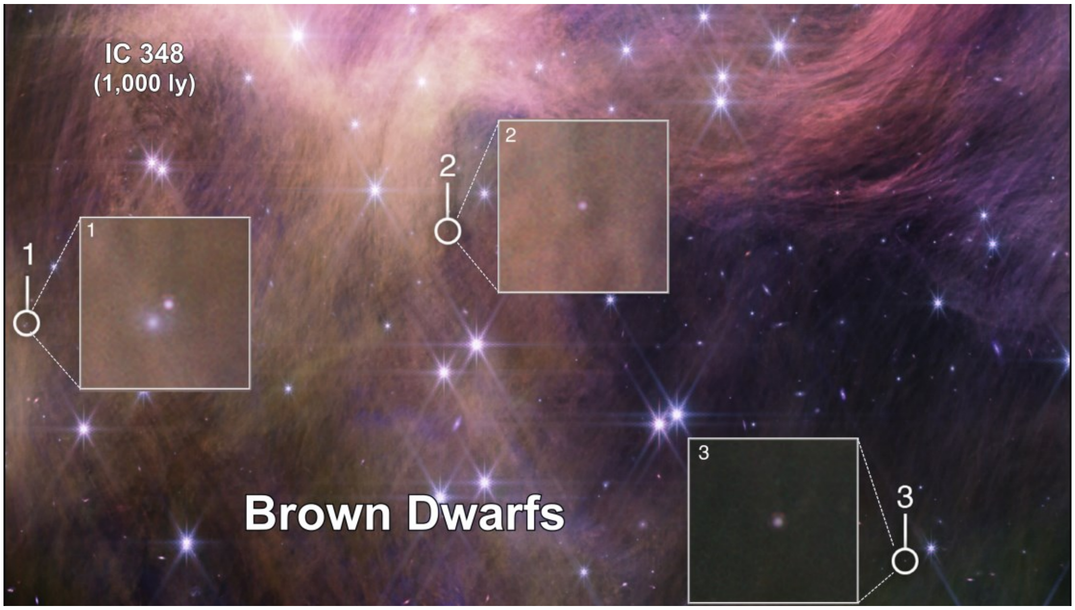
NGC 1333 – 960 ly

Here we have NGC 1333, a star forming nebula 960 light-years away. This view is a composite of light from ultraviolet to near-infrared. Most of the star-forming is hidden behind clouds of fine dust that's thicker at the bottom. On the right, a bright blue star is illuminating surrounding clouds of gas. At the center, a brighter yellow star illuminates surrounding gas. On the left, stars are surrounded by powerful magnetic fields that direct beams of hot gas deep into the hydrogen around them.



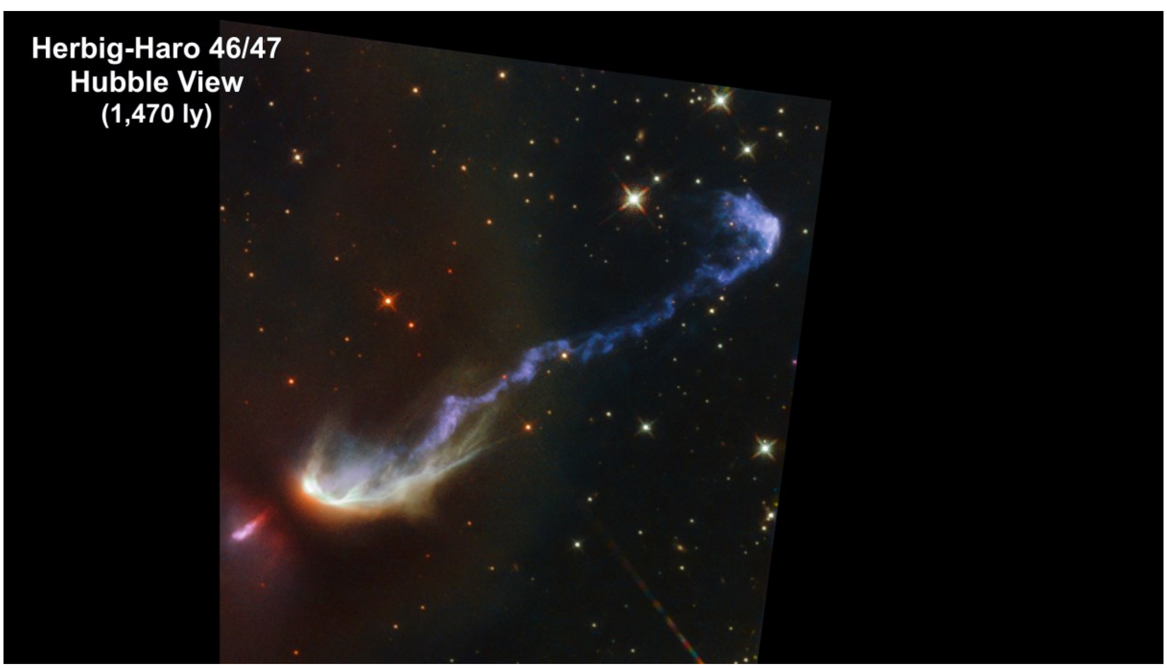
Brown Dwarfs in IC 348 – 1,000 ly

This Webb Near-Infrared Camera image shows the central portion of the star cluster IC 348. Astronomers found three brown dwarfs that are less than eight times the mass of Jupiter. Brown dwarfs are objects that straddle the dividing line between stars and planets. They form like stars, growing dense enough to collapse under their own gravity. But they never become dense and hot enough to begin fusing hydrogen and turn into a star. At the low end of the scale, some brown dwarfs are comparable with giant planets, weighing just a few times the mass of Jupiter. Here they are circled in the main image and shown in the detailed pullouts at right. The smallest weighs just three to four times Jupiter.

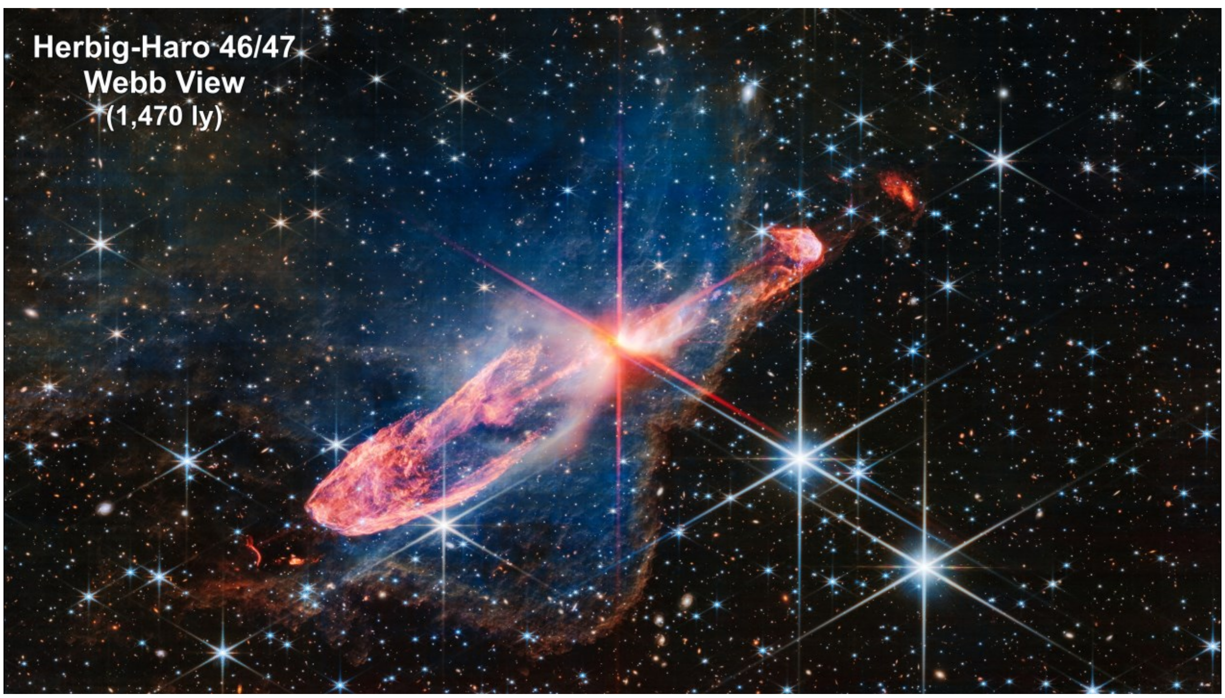


Herbig-Haro 46/47 – 1,470 ly

Herbig-Haro (HH) objects are bright, nebulous regions of gas and dust formed when material ejected from a forming protostar collides with the surrounding interstellar medium. These ejections travel in opposite directions from the star and reach velocities over 700,000 km/hr (that's 435,000 mi/hr). When this fast-moving material collides with slower-moving gas, bow shocks are created like waves are produced by the bow of a ship ploughing through water. This image of HH 46 and 47 was taken by Hubble. The protostar is not visible behind its blanket of dust.



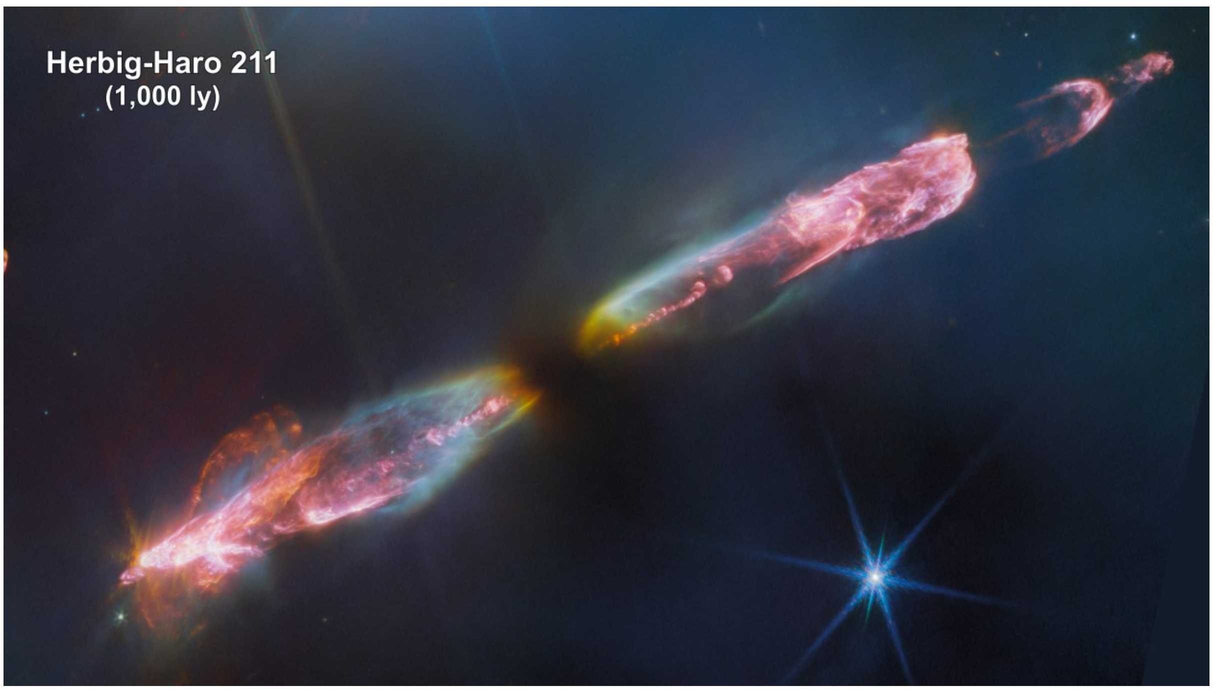
Here is the Webb image in near-infrared. At this wavelength, we can clearly see the protostar. It's actually a binary pair of protostars. They are buried deep in a disc of gas and dust that supplies the material for their ever-increasing mass. The disc is not visible, but its shadow can be seen in the two dark, conical regions surrounding the central stars. The most striking details are the two-sided lobes that fan out from the actively forming central stars, represented in orange. Much of this material has been ejected over thousands of years. The stars' more recent ejections appear in a thread-like blue. They run just below the red diagonal diffraction spike at two o'clock. They are disconnected at points, and end in a remarkable uneven light purple circle in the thickest orange area. Over millions of years, the stars in Herbig-Haro 46/47 will form fully — clearing the scene of these beautiful, multihued ejections.



Featured in this image from Webb is another Herbig-Haro object named HH 211. At roughly 1000 light-years from Earth, the object is one of the youngest and nearest protostar outflows ever observed. The image showcases a series of bow shocks to the lower-left and upper-right as well as the narrow bipolar jet that powers them in unprecedented detail — roughly 5 to 10 times higher spatial resolution than any previous images of HH 211.

Infrared imaging is needed to study new stars and their outflows, because such stars are invariably still embedded within the gas from the molecular cloud in which they formed. Molecules excited by the turbulent conditions, including molecular hydrogen, carbon monoxide and silicon monoxide, emit infrared light that Webb can collect to map out the structure of the outflows. The inner jet is seen to "wiggle" with mirror symmetry on either side of the central protostar. This may indicate that the protostar may in fact be an unresolved binary star.

[This spectacular image reveals an outflow from a Class 0 protostar, a classification that would have fit of our own Sun when it was no more than a few tens of thousands of years old and had only 8% of the present-day Sun's mass. In other words, the source for HH 21 will eventually grow into a star like the Sun.]



Crab Nebula – 6,500 ly

Here's a 2023 Webb image of the Crab Nebula. We're zooming into the pulsar at the center. A pulsar is a rapidly rotating neutron star. It produces a vast amount of synchrotron emissions. That's radiation produced from charged particles, circling magnetic field lines at relativistic speeds. The radiation appears here as light blue smoke-like material throughout the majority of the Crab Nebula's interior.

Toward the nebula's edges are cavernous filaments of dust and hot gas. It's made up of fractured material that was ejected at high speeds from the central star. Note the areas where the synchrotron emission seems to be pinched. This indicates that the pulsar is surrounded by a dense layer of gas and dust that slows down ejected matter that passes through it.

Cassiopeia A – 11,000 ly

Here we Have a visible-light Hubble image of the remnants of a supernova called Cassiopea A, 11,000 light years away. We covered it in our 'How far away is it' segment on 'Star clusters and Supernova'. It has been expanding for just 340 years and spans about 10 light-years.

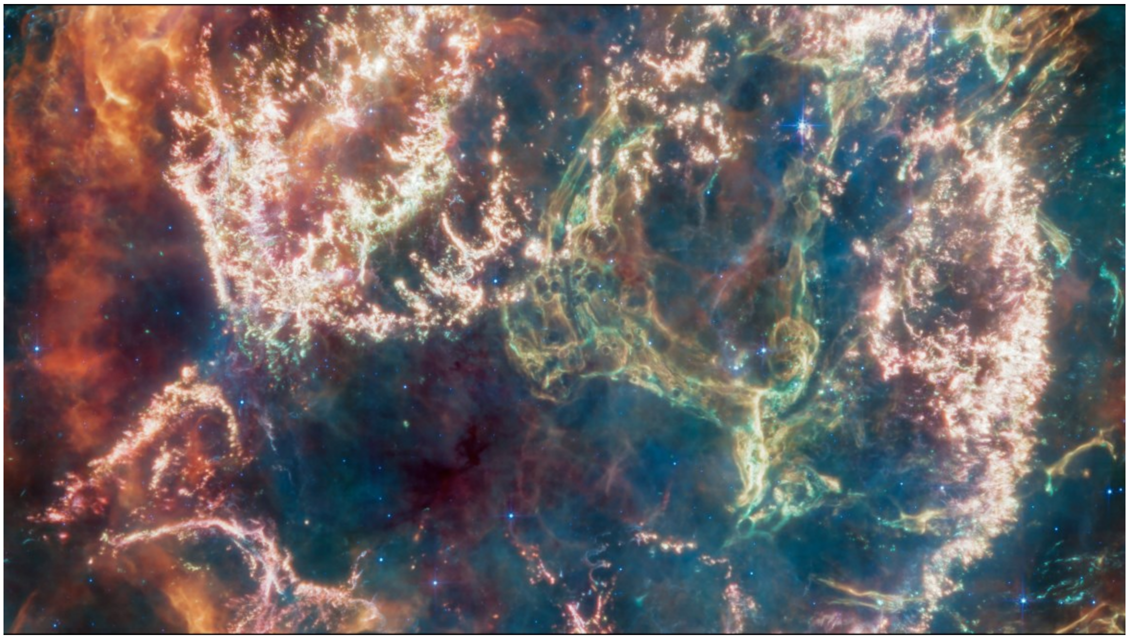
Here's a 2023 image from Webb's Near-Infrared Camera. The most noticeable colors are clumps of bright orange and light pink that make up the inner shell of the supernova remnant. These knots of gas, are composed of sulphur, oxygen, argon, and neon from the exploded star itself.

Here's a new mid-infrared image from Webb.

The striking colors, hold a wealth of scientific information that researchers are just beginning understand. On the bubble's exterior, particularly at the top and left, we see curtains of material appearing orange and red that are due to emissions from warm dust marking where ejected material from the exploded star is colliding into surrounding gas and dust.

Interior to this outer shell lie mottled filaments of bright pink studded with clumps and knots. This represents material from the star itself, including heavy elements such as oxygen, argon, and neon. The stellar material can also be seen as fainter wisps near the cavity's interior.

A loop represented in green extends across the right side of the central cavity. Its shape and complexity are unexpected and challenging for scientists to understand.

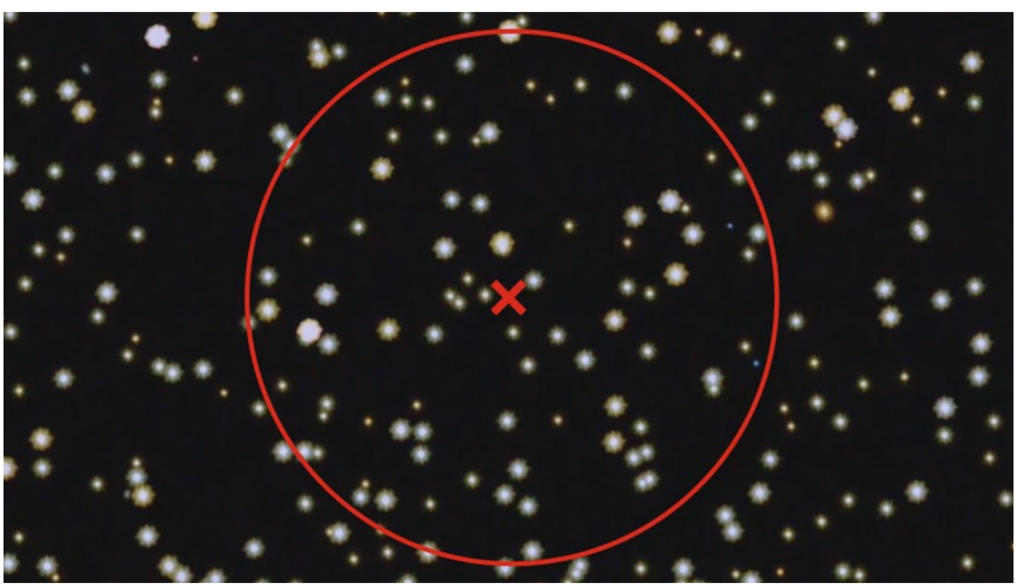


Wolf-Rayet 124 – 15,000 ly
Here we are zooming in to a Hubble image of Wolf-Rayet 124, 15,000 light years away. We covered Wolf-Rayet stars in our 2020 review. They are older, massive stars that have completely lost their outer hydrogen and are fusing helium or heavier elements in the core. This is a composite Webb image combining near-infrared and mid-infrared wavelengths of light. The nebula is 10 light-years across. A history of the star's past can be read in the nebula's structure. Rather than smooth shells, the nebula is formed from random, asymmetric mass ejections. Background stars and background galaxies populate the field of view through the nebula of gas and dust.

Finding an IMBH in M4 – 7,000 ly

In 2023, a team of astronomers detected a possible intermediate-mass black hole of roughly 800 solar masses at the center of the M4 globular star cluster. In our "How Fast Is It" video book chapter on Black Holes, we covered how no intermediate-mass black holes have been confirmed to date. But here's one that might be. They examined 12 years' worth of M4 observations from Hubble and resolved pinpoint stars. The suspected object can't be seen, but its mass is calculated by studying the motion of stars caught in its gravitational field. The black hole has an event horizon has a diameter that's a little more than half the diameter of our moon.

This is a simulation of the motions of stars around the suspected black hole. After the zoom into M4, the center of the cluster, where the suspected black hole resides, is highlighted by a red "X." The red circle has a radius of a little less than 1 light-year. It is the sphere of influence of the mass at the center.



It should be noted that although an intermediate-mass black hole can explain these star movements, other possibilities exist, such as a cluster of stellar mass black holes or neutron stars. So, by the end of 2023, there has still not been a single confirmed IMBH. In the future, the Webb Space Telescope might help resolve this question by improving the star count and velocities near the center.

NGC 346 – 200,000 ly

This is a Webb Near-Infrared image of NGC 346, a dynamic star forming region that lies within the Small Magellanic Cloud, an orbiting dwarf galaxy 200,000 light years away and 250 light years across. The region contains numerous molecular clouds packed with dust and hydrogen, the ingredients for forming new stars and planets. Large numbers of young stars are forming in these regions.

The many pillars of glowing gas throughout the area are being created by the light from these young stars. The plumes and arcs of gas in this image contain two types of hydrogen – hot (10,000 °C in pink) and cold (-200 °C in orange). The cold molecular hydrogen areas are dense and dusty.

By observing protostars still in the process of forming, researchers can learn if the star formation process in the SMC is different from what we observe in our own Milky Way. Previous infrared studies of NGC 346 have focused on protostars heavier than about 5 to 8 times the mass of our Sun. But Webb can probe down to lighter-weight protostars, as small as one tenth the mass of our Sun.

12a - Dwarf Galaxy UGC 8091 – 7.9 mly
The dwarf galaxy UGC 8091 is approximately 8 million light-years from Earth and contains a billion stars. It's considered an "irregular galaxy" because it does not have an orderly spiral or elliptical appearance. Some irregular galaxies may have become tangled by tumultuous internal activity, while others have formed by interactions with neighboring galaxies. The result is a class of galaxies with a diverse array of sizes and shapes, including the diffuse scatter of stars like we see in this galaxy. The red patches are likely interstellar hydrogen molecules that are glowing because they have been excited by the light from hot, energetic stars.

Astrochemistry in the Iris Nebula

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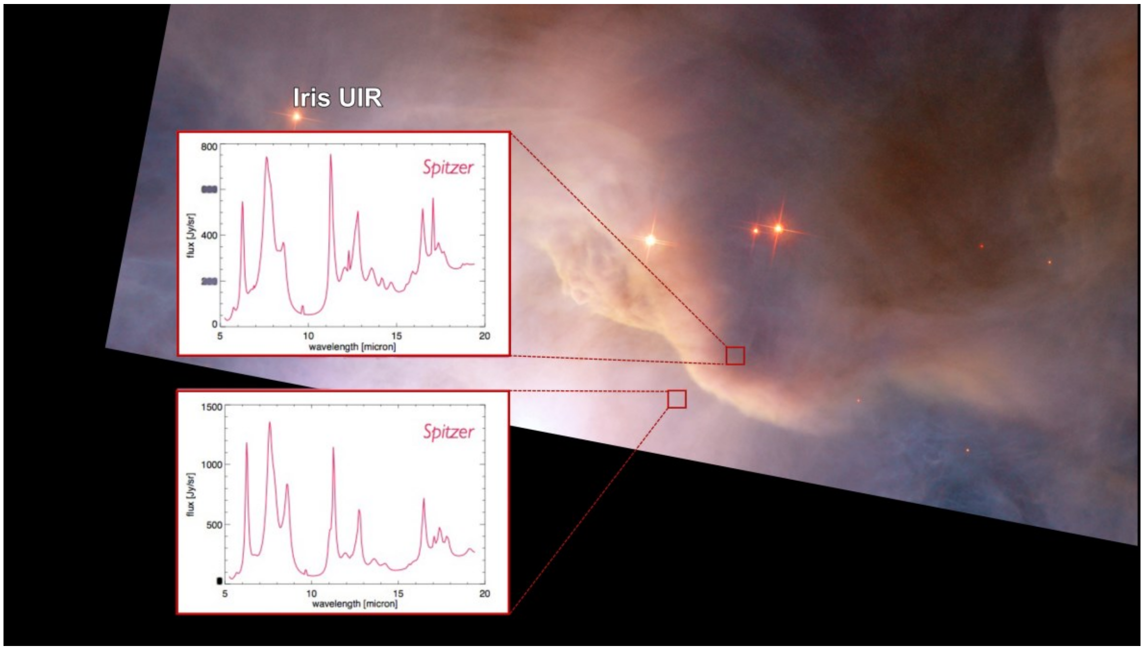
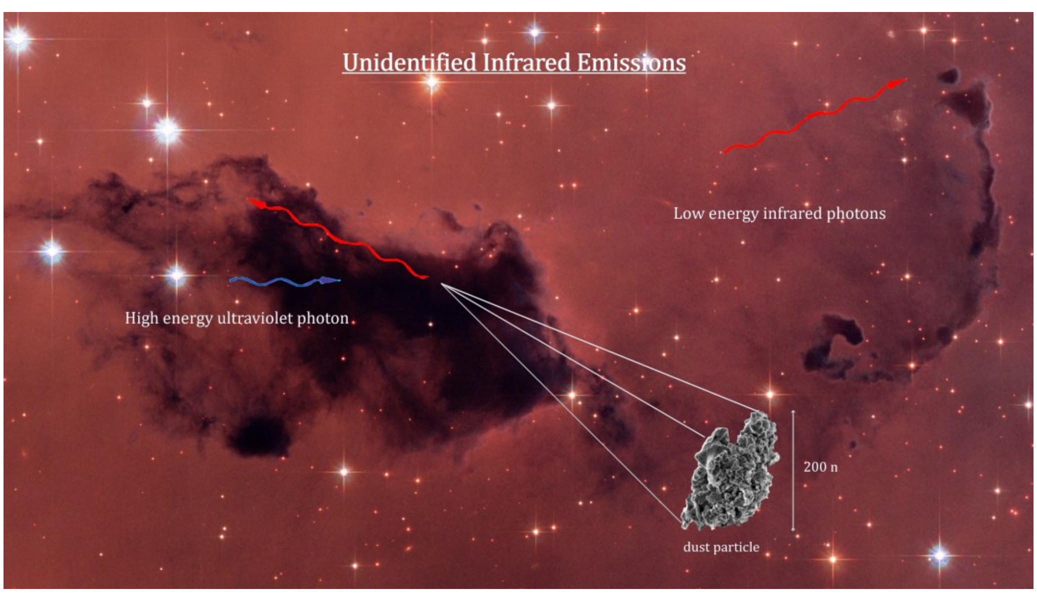
https://webbtelescope.org/contents/media/images/2023/104/01GS812G7AGRG6D1WCXPS3EYZ5?news=true

Here's an interesting story about unidentified infrared emission bands discovered in the early 1970s. Called UIR bands, they are found in a wide variety of celestial objects from planetary disks to starburst galaxies. And they have been observed as far back in time as when the universe was a mere 3.3 billion years old. This makes them very important for astronomers to understand. Here's a spectrum of the Iris Nebula taken by Spitzer, showing the UIR Bands. Just what could be causing these emissions was a mystery.

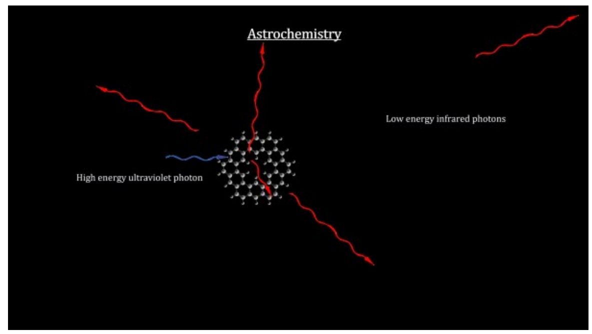


Astronomer Kris Sellgren, while working on her Ph.D. at Caltech, made a discovery that turned out to be the key in unravelling the mystery. She found that sources of the unidentified infrared radiation also emitted continuously in the near-infrared from dust grains heated to 1000 K. This temperature was too hot to be from a large number of dust grains. So, she hypothesized that while most of the grains were far cooler than this, some would be heated for very short periods of time to 1000 K by the absorption of a high energy UV photon. These would then quickly cool to much lower temperatures creating the unidentified near-infrared emissions. The most likely source for the unidentified infrared radiation had to be a carbon-based dust grain, because they are the only material able to withstand the harsh environments where this radiation is observed.



Sellgren's discovery led the astrochemists at NASA and a competing group in France to investigate carbon-based soot particles in the laboratory. They found that the emission spectra from the soot produced a good match to the UIR spectrum. The molecules involved are called "Polycyclic aromatic hydrocarbon" molecules or PAHs for short. (They're called 'aromatic' because they actually smell bad in the labs.)

When a high energy ultraviolet photon hits the molecule, it is absorbed creating a characteristic absorption line, heating the molecule to 1000 K, and kicking it into its natural vibration modes. These vibrations accelerate electrons and produce infrared photons ejected in all directions driving the molecule's temperature back down to normal. Today, it is understood that this class of molecule is almost certainly responsible for the unidentified infrared emission (UIR) bands discovered in the early 1970s.



Research into this kind of radiation continues with new images from Webb adding significant additional data. In these three Webb mid-infrared images, the polycyclic aromatic hydrocarbons are found mostly within the main dust lanes in the spiral arms. These images are providing insights into how PAH molecular dust depends on local interstellar medium conditions. This research is important because these particles account for up to 15% of the carbon in galaxies, play a critical role in the formation of stars and planets, and are thought to be the starting material for the earliest life forms. In fact, they may have been vital in the formation of life here on Earth.

Arp 220 – 250 mly
Here's Webb's near and mid infrared view of Arp 220 – an ultra-luminous infrared galaxy with a luminosity of more than a trillion suns. It's 250 million light-years away. It is actually the merging of the two spiral galaxies that began their collision about 700 million years ago, sparking an enormous burst of star formation. The cores of the parent galaxies are 1,200 light-years apart. Near the center, around 200 huge star clusters are packed into a dusty region about 5,000 light-years across. The

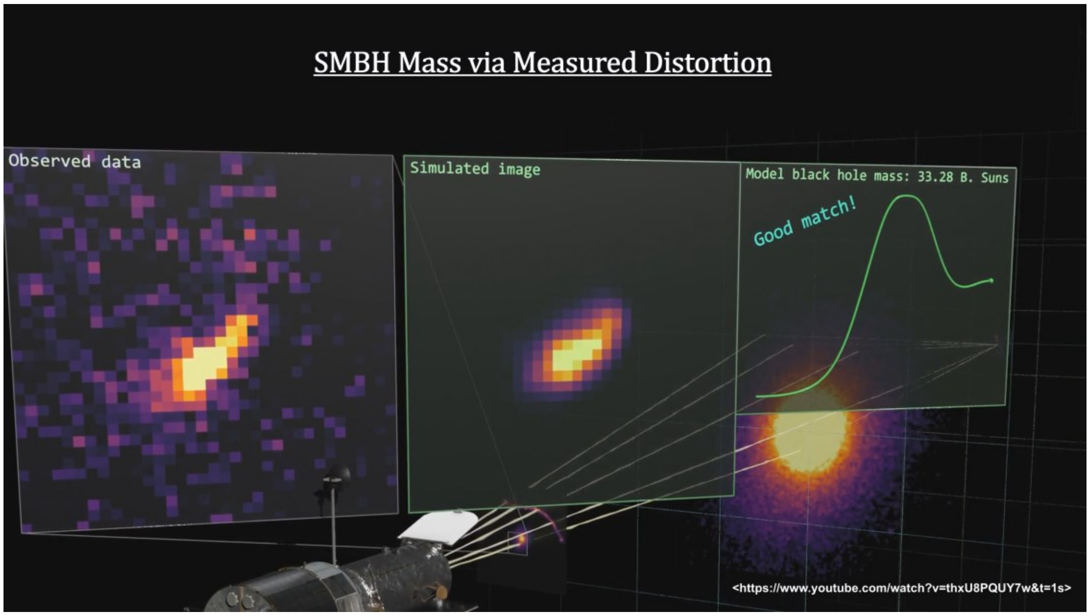
amount of gas in this tiny region is equal to all of the gas in the entire Milky Way galaxy. The light is so bright that it creates diffraction spikes.

Finding a Black Hole's Mass by the Distortions it Creates - 4.7 bly

Here's a unique way to detect the mass of a black hole. It uses the distortions the black hole creates in background images. Here's an illustration from Durham University. It highlights how the distortions created by using a black hole as a lens can determine the black hole's mass. We start with the distant galaxy 4.7 bly away. The light from this object passes through the galaxy Abell 1201, 2.1 bly away. The light passes within 3000 ly of the SMBH at the center of this lensing galaxy.

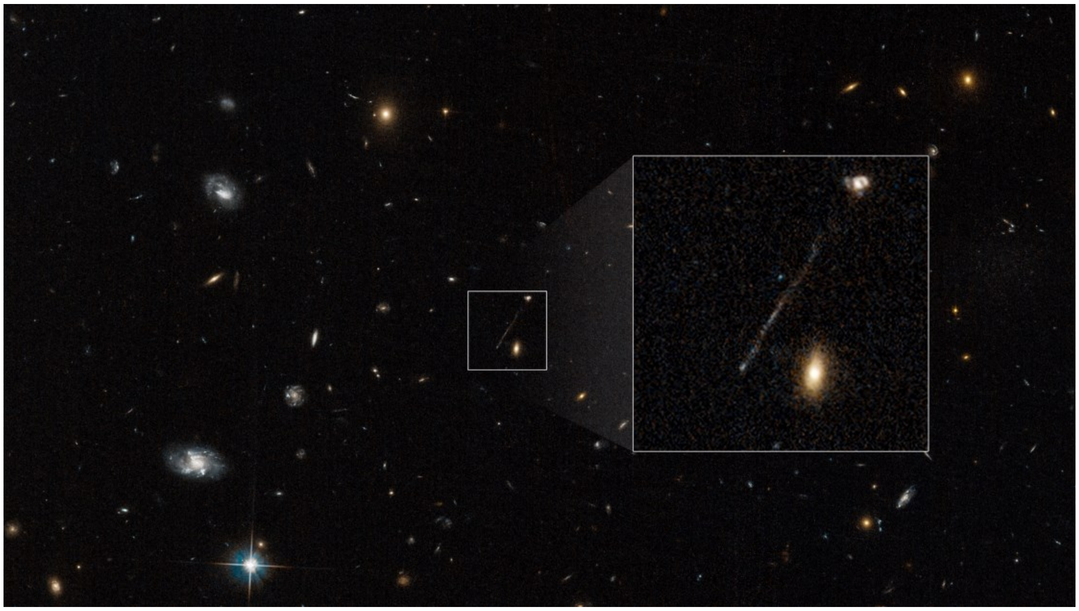
We can't see the black hole, but we can see the distortions it creates. In this example, the lensing galaxy distorts the distant galaxy image into a wide arc. In addition, some of the light passes near to the central black hole. The black hole acts as a lens and forms a duplicate image of the distant galaxy. To find the mass of this black hole, astronomers, with the help of large computer models, simulated an image that a black hole would create.

The output image depends on the mass of the black hole. Mass is an input to the algorithm. Masses too low or too high, would not create the image observed. But the correct mass would. The best fit came when a mass of 33 billion suns was input. This mass makes it one of the most massive black holes ever detected.



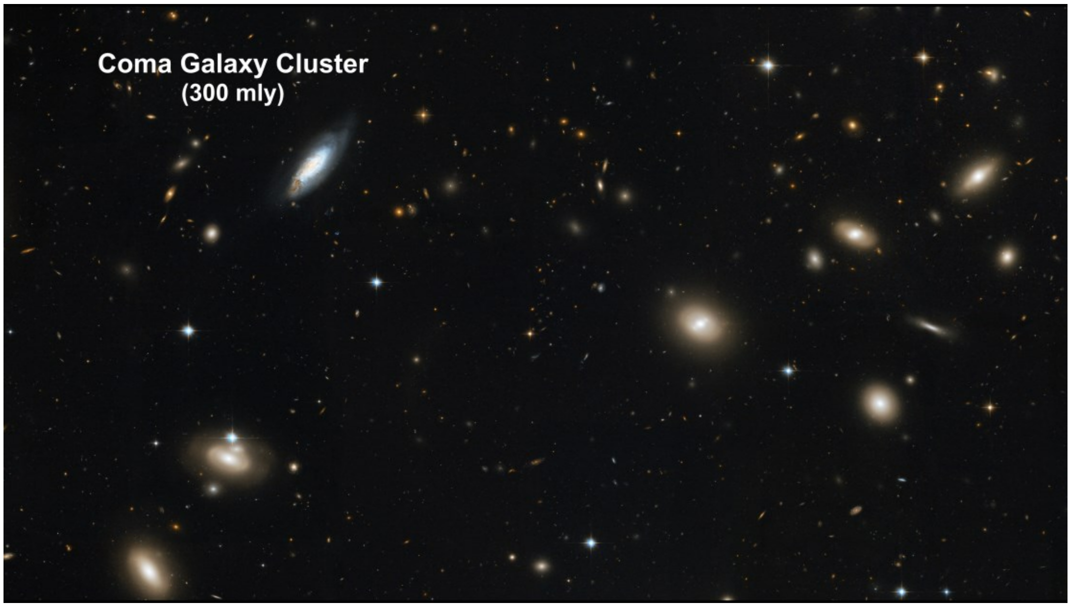
Runaway Black Hole – 7.7 bly

This Hubble Space Telescope archival photo captures a curious linear feature that is so unusual it was first dismissed as an imaging artifact from Hubble's cameras. But follow-up spectroscopic observations reveal it is a 200,000-light-year-long chain of young blue stars. A supermassive black hole lies at the tip of the bridge at lower left. The black hole was ejected from the galaxy at upper right. It compressed gas in its wake to leave a long trail of young blue stars. Nothing like this has ever been seen before in the universe. This unusual event happened when the universe was approximately half its current age.

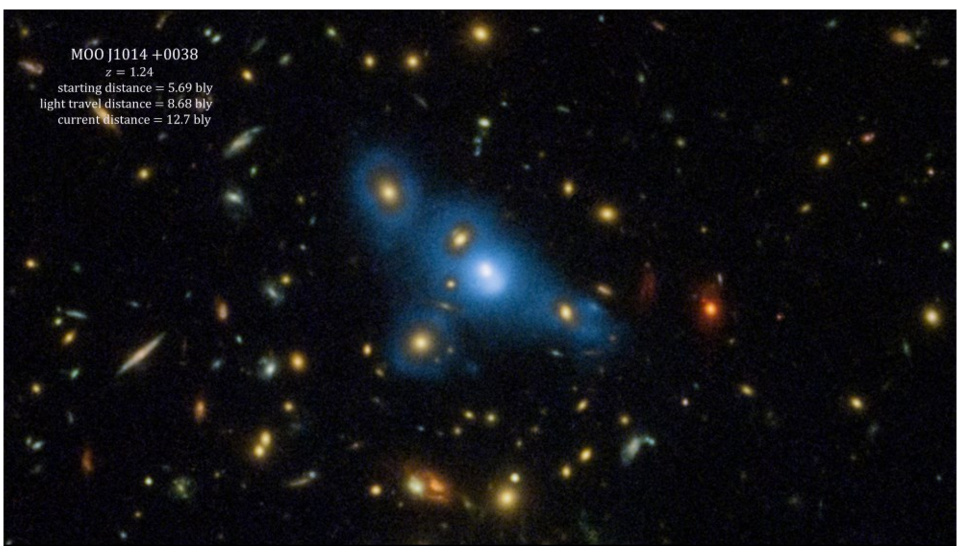


Zwicky Intergalactic Stars – 8 bly

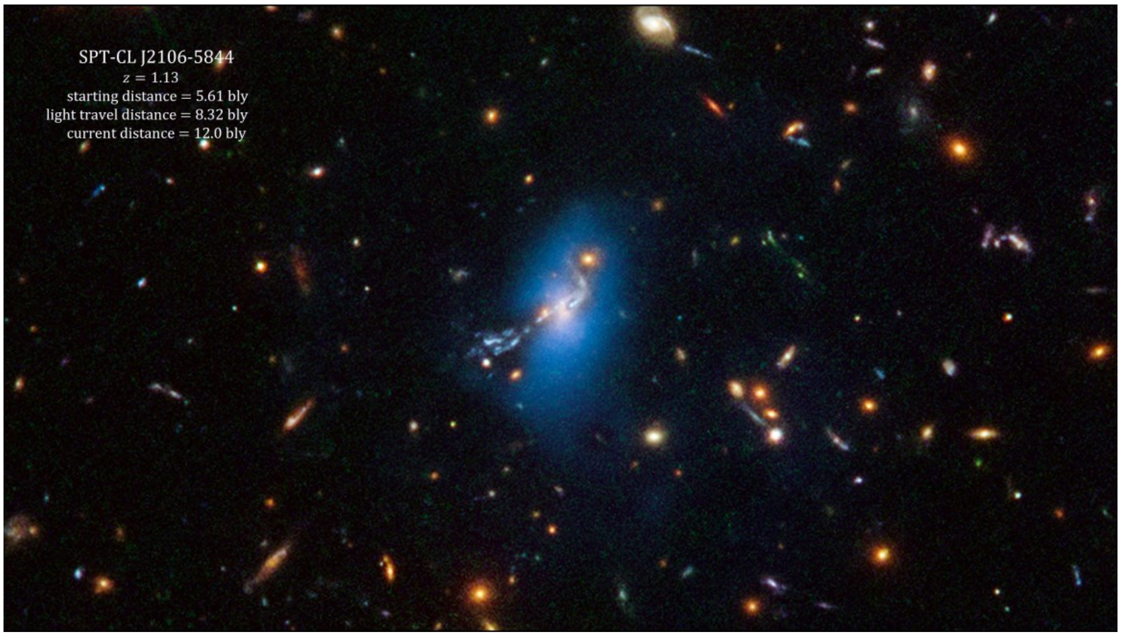
Intergalactic light (also known as Intra-Cluster-Light or ICL for short) is the light from stars that exist outside of galaxies - in the space between galaxies in a galaxy cluster. These stars are not gravitationally bound to any one particular galaxy in their cluster. They were first detected in the Coma cluster of galaxies in 1951 by Fritz Zwicky, who reported that one of his most interesting discoveries was observing luminous, faint intergalactic matter in the cluster. [Because the Coma cluster, containing at least 1000 galaxies, is one of the nearest clusters to Earth (330 million light-years), Zwicky was able to detect the ghost light even with a modest 18-inch telescope.]



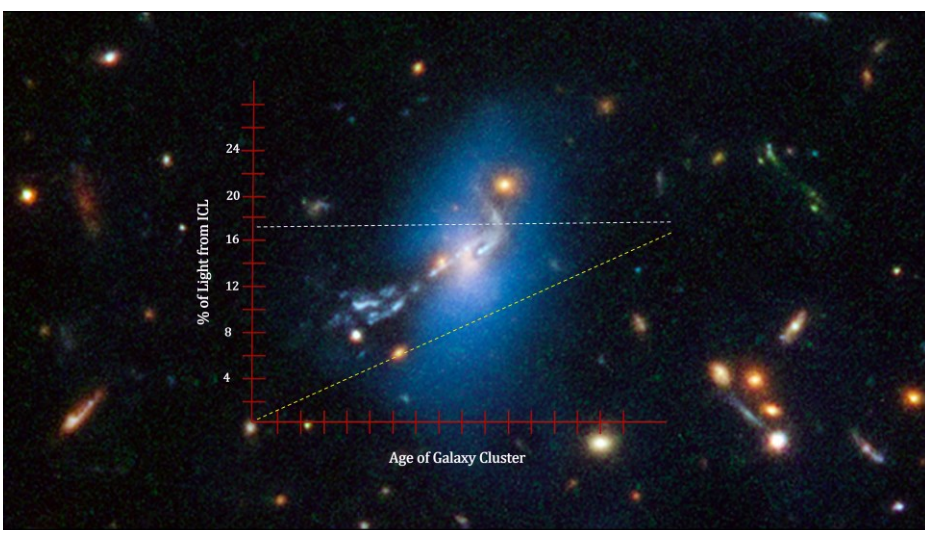
Here's a Hubble image. The artificially added blue color is where Hubble data found this intracluster light. The extremely faint glow traces a smooth distribution of light from stars scattered across the cluster.



Astronomers are trying to find out how these stars came to be where they are. There are two competing theories. One is that the stars formed inside galaxies and were stripped away by galaxy cluster gas, or by galaxy collisions. The competing theory is that these stars actually formed outside of any galaxy at all. Here's a second galaxy out of the 10 studied for this project.

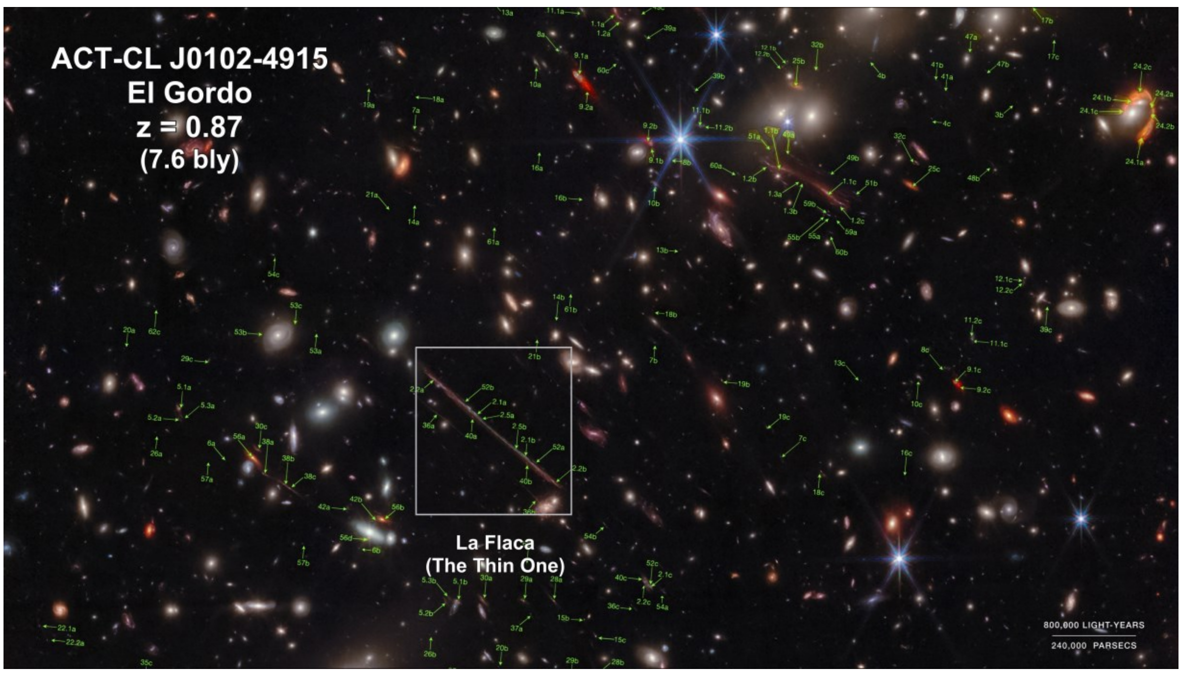


If the first theory is correct, we would expect the percentage of light coming from these galaxy clusters generated by intergalactic stars to grow over time as more and more of the stars are produced. But this Hubble survey shows that intergalactic light accounts for around 17% of a cluster's light no matter how old the cluster is. This suggest that these stars formed at the same time as their galaxy clusters formed! These findings have significant implications for dark matter distribution analysis and the calculations for gravitational lensing so critical for studies of the early universe.

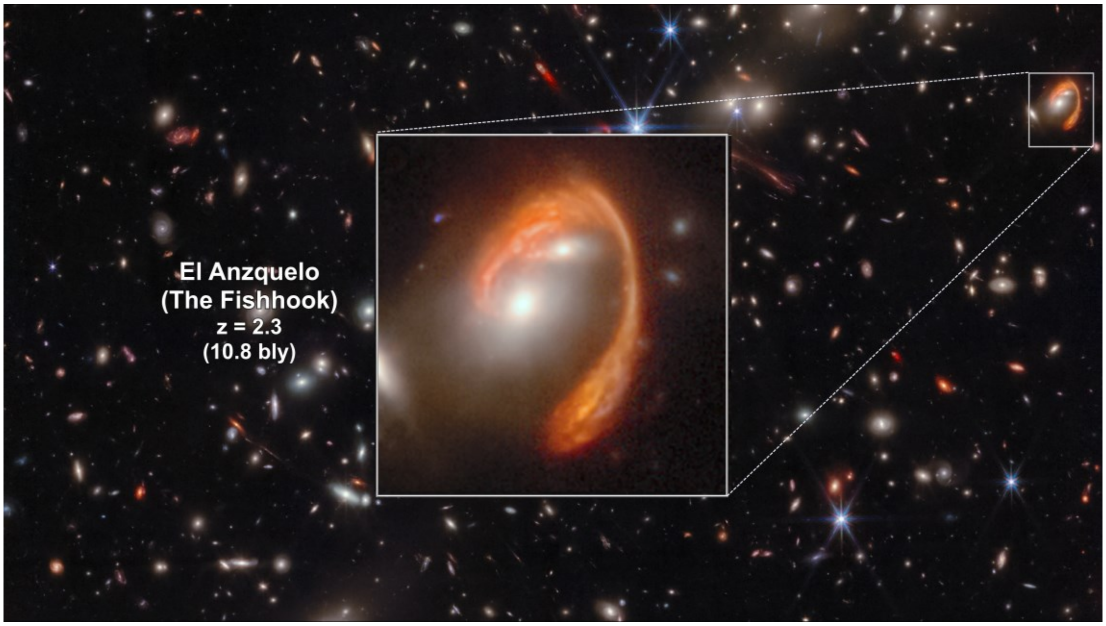


The Fishhook and Quyllur through El Gordo's Gravitational Lense - 10.8 bly

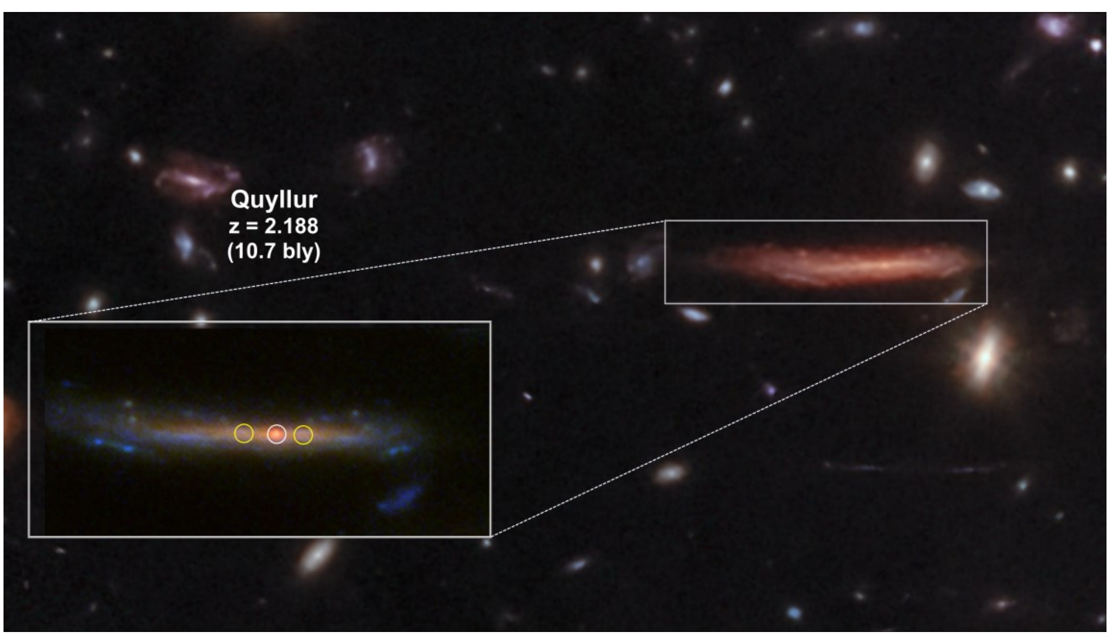
El Gordo is a cluster of hundreds of galaxies that existed when the universe was 6.2 billion years old. It's the most massive cluster known to exist at that time. This image was produced by a combination of Hubble and Webb data. It contains 60 lensed arcs of galaxies billions of light years further away than El Gordo. Here's a sample of the numbering system used to identify each object studied. There are over 180 points of interest. Note the long, pencil-thin line below and left of center. Known as "La Flaca" (the Thin One), it is extremely thin and one of the longest arcs known.



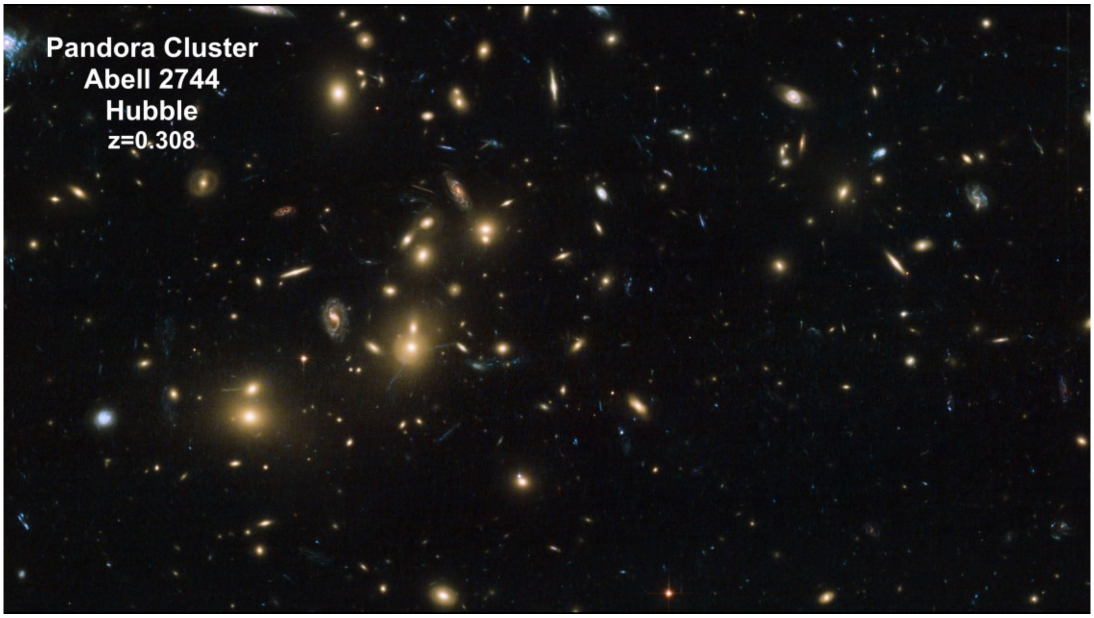
One of the most striking features is the bright red arc at the upper right. It's called "The Fish Hook". The light from this galaxy took 10.8 billion years to reach Earth. Its distinctive red color is due to a combination of reddening from dust within the galaxy itself and cosmological redshift due to space expansion. In our "Gravitational Lensing" segment of the "How Fast Is It" video book, we covered how knowledge of the lens properties and critical curves of the foreground cluster enables astronomers to reconstruct the source galaxy's size and shape. Using these techniques, astronomers were able to determine that the background galaxy is disk-shaped and 26,000 light-years in diameter. That's about one-fourth the size of the Milky Way.



Another fascinating find in El Gordo is the first individual red supergiant star beyond 1 bly from Earth. Until now, all previous stars discovered at high redshifts have been hot blue stars. Red supergiants are stars in their final stage with initial masses between 7 and 40 times the mass of the Sun. These stars have the largest radius of all known stars, although they are not the most massive or luminous. Betelgeuse and Antares are the brightest and best-known red supergiants in our Milky Way Galaxy. This star is named Quyllur. Such stars at high redshift are only detectable using the infrared filters and sensitivity of Webb. The outer, yellow circles mark the positions of two counterimages of a source that brackets the position of the critical curve. The white, central circle marks Quyllur.

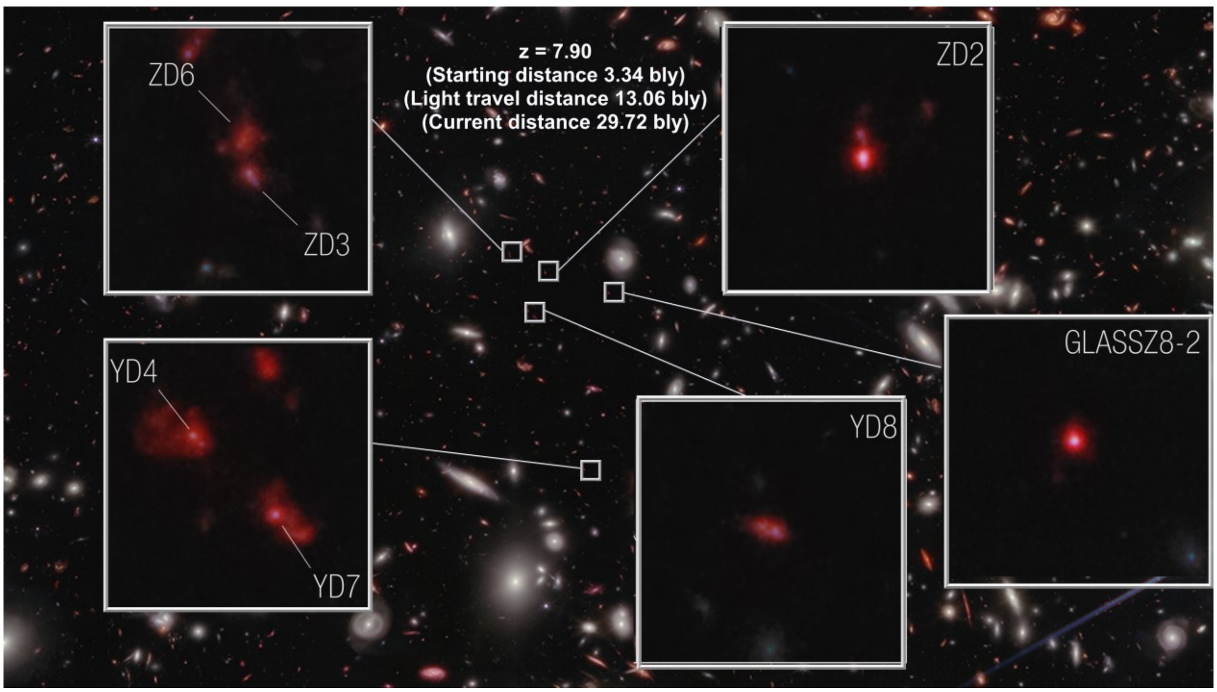


Early Galaxy Protocluster – 13 bly
Here's a Hubble image of Abell 2744, 4.2 bly away. It's named Pandora's galaxy cluster. It acts as a gravitational lens into even more distant galaxies seen as blueish distorted lines across the cluster.



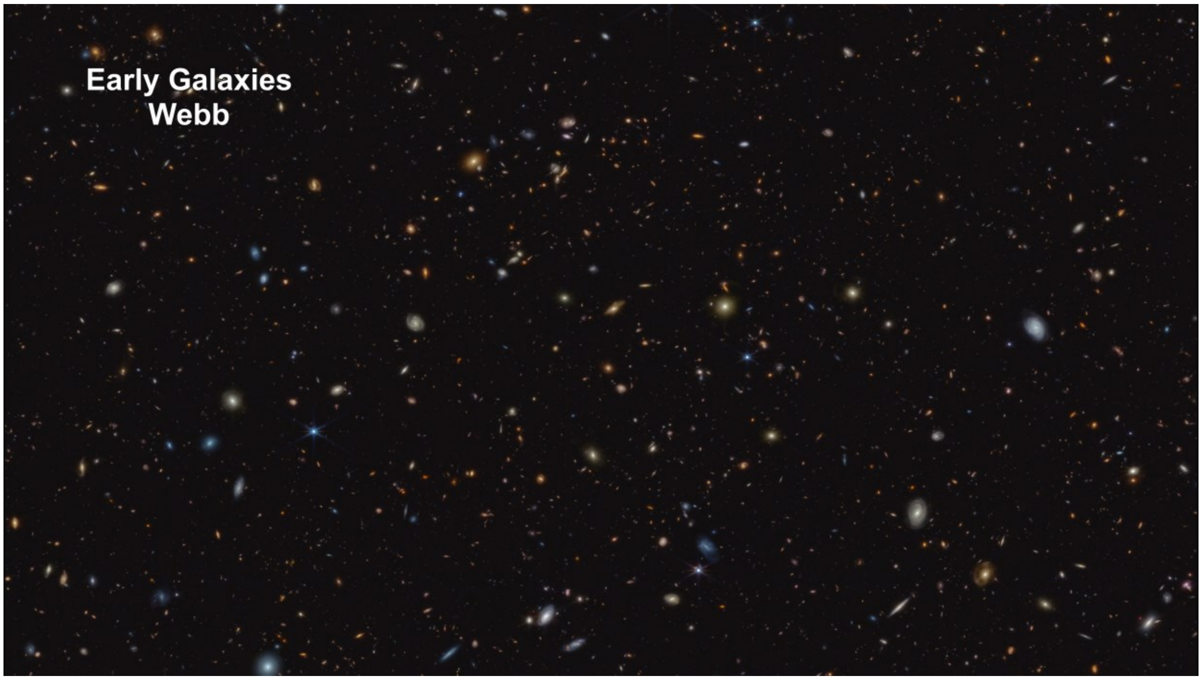
Here's the view from Webb. You'll note that the distorted images of the more distant galaxies are now reddish. That's because this is seen through Webb's near infrared camera. Zooming out, we see areas that have never been imaged by Hubble. Astronomers estimate that there around 50,000 sources of near-infrared light in this image. Bright white sources surrounded by a hazy glow are the galaxies of Pandora's Cluster, a conglomeration of already-massive galaxy clusters coming together to form a megacluster. The concentration of mass is so great that it produces one of the strongest gravitational lenses known. The lensed galaxies themselves are the object of this study.

Astronomers used a process called photometry to estimate the distances to the many warped background galaxies. The technique measures light intensity through various filters and compares the results to a database of model galaxies. Results showed that 6 of these 7 galaxies that are close together on the sky are also at the same distance behind Pandora. Later, Spectroscopic analysis, which takes a good deal longer to collect, determined conclusively that all 7 were at the same distance with a redshift of 7.9. This would make them all members of an early galaxy protocluster that formed just 650 million years after the big bang.

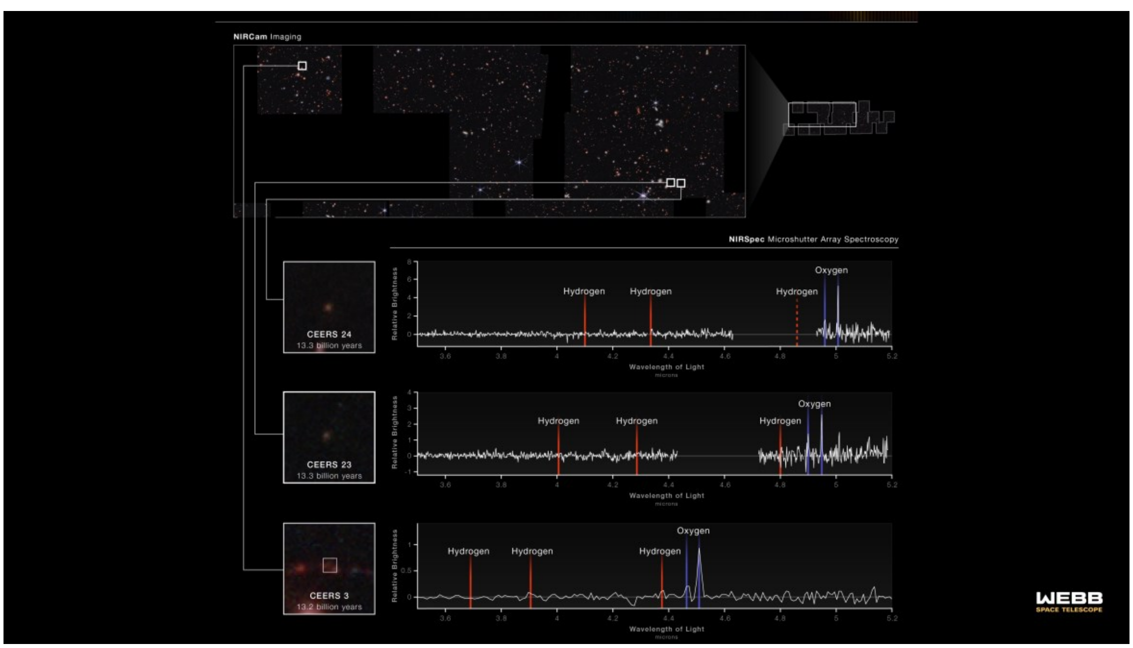


Early and Oldest Galaxies

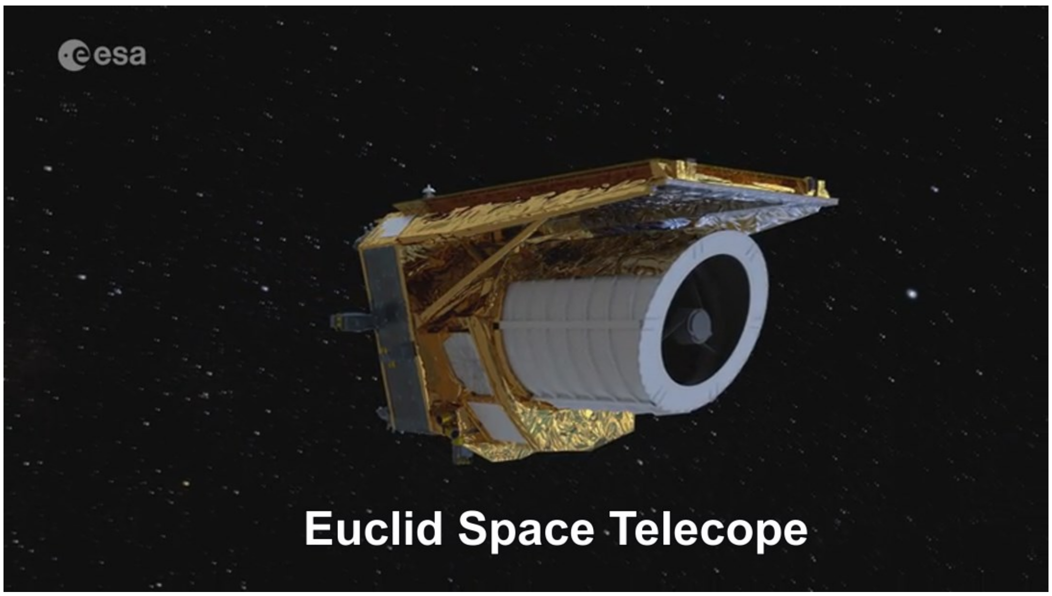
One of the largest programs in Webb's first year of science was the Advanced Deep Extragalactic Survey. The object of the study is to learn how the earliest galaxies assembled themselves and how fast they formed stars. This Webb image shows a portion of an area of the sky known as GOODS-South. Over 45,000 galaxies are visible in this image. Before Webb, there were only a few dozen galaxies observed above a redshift of 8 when the universe was less than 650 million years old. Webb has identified more than 700 candidate galaxies that existed before that. This was far beyond predictions from observations made before Webb's launch.



A team named the Cosmic Evolution Early Release Science (CEERS) Survey produced this image. It includes over 100,000 galaxies. Spectroscopy has identified three of the oldest galaxies. Three lines appear in the same order – one hydrogen line followed by two ionized oxygen lines in each spectrum. The further to the right this pattern falls, the older the light source. CEERS 3 emitted its light 13.2 billion years ago. CEERS 24 and CEERS 23 emitted their light 13.3 billion years ago.



Euclid Space Telescope
On July 1st, 2023, the European Space Agency launched a new space telescope named Euclid. Its mission is to explore the composition and evolution of the dark Universe. Euclid will explore how the Universe has expanded and how structure has formed over cosmic history, revealing more about the role of gravity and the nature of dark energy and dark matter. We'll close our 2023 Review with its first 5 images.



This image shows 1000 galaxies belonging to the Perseus Cluster, and more than 100 000 additional galaxies further away in the background, each containing up to hundreds of billions of stars.

At approximately 1375 light-years away in the vast Orion molecular cloud, the Horsehead nebula is the closest giant star-forming region to Earth.

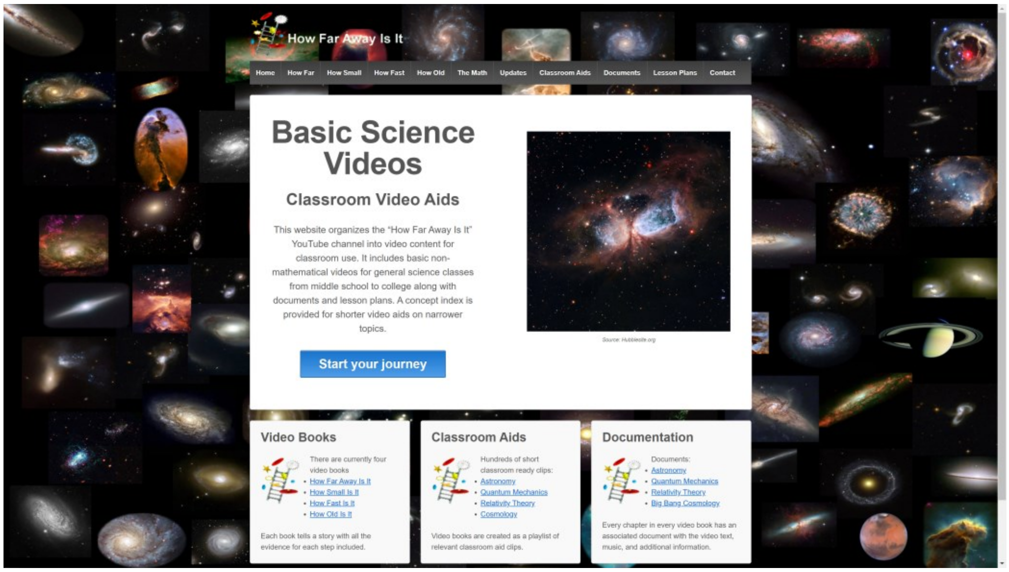
The galaxy IC 342 is nicknamed the 'Hidden Galaxy' because it's difficult to observe due to the fact that it lies behind the dusty disc of our Milky Way. The dust, gas and stars obscure our view.

NGC 6822 is an irregular dwarf galaxy located close by. It's just 1.6 million light-years from Earth.

Here's globular cluster NGC 6397. It's a collection of hundreds of thousands of stars held together by gravity. Located about 7800 light-years from Earth, it is the second-closest globular cluster to us.

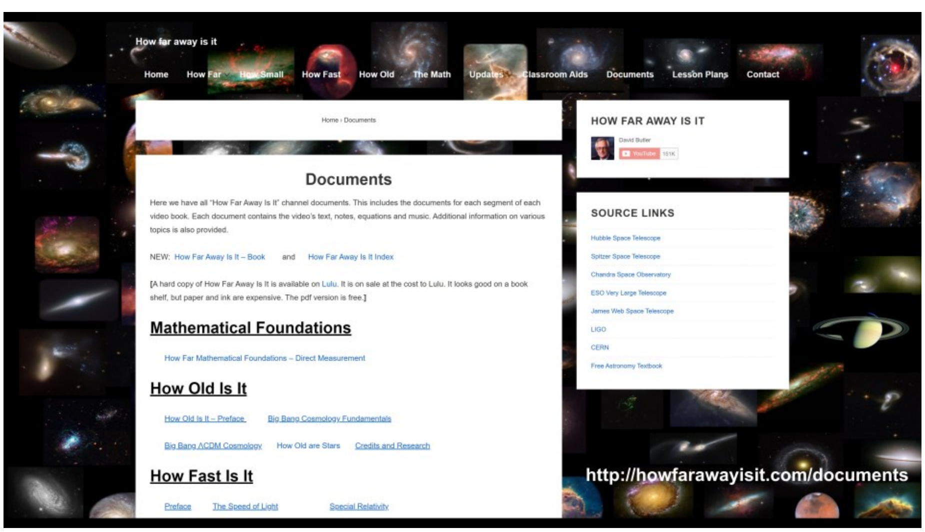
I expect that the 2024 review will contain a number of Euclid's finding.

Credits and Research
Here are the links to Hubble and Webb sites, whitepapers, and other locations where I found the information contained in this 2023 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/

Credits

DART Update

https://eos.org/articles/nasas-double-asteroid-redirection-test-is-a-smashing-success
https://www.nasa.gov/feature/goddard/2023/hubble-captures-movie-of-dart-asteroid-impact-debris
https://esahubble.org/images/heic2307a/
https://www.heramission.space/
https://heramission.squarespace.com/presention-gallery/yr59obe9tofmlr4e7rq93b3j1obofy

02 - Parker Solar Probe

https://www.nasa.gov/feature/goddard/2021/nasa-enters-the-solar-atmosphere-for-the-first-time-bringing-new-discoveries
https://www.guinnessworldrecords.com/world-records/66135-fastest-spacecraft-speed#:~:text=The%20fastest%20speed%20by%20a,UTC%20on%2020%20November%202021
https://www.nasa.gov/feature/goddard/2021/nasa-enters-the-solar-atmosphere-for-the-first-time-bringing-new-discoveries
https://svs.gsfc.nasa.gov/14045

03 - Chamaeleon I molecular cloud - 630 ly

https://webbtelescope.org/contents/news-releases/2023/news-2023-106.html
https://esawebb.org/images/weic2303a/

04 - LAWD 37 – 15 ly

https://hubblesite.org/contents/news-releases/2023/news-2023-004.html

06 - NGC 1333 – 960 ly

https://esahubble.org/images/heic2304a/

07 - Brown Dwarfs in IC 348 – 1,000 ly

https://webbtelescope.org/contents/news-releases/2023/news-2023-151?news=true

08 - Herbig-Haro 46/47 – 1,470 ly

https://esawebb.org/news/weic2312/?lang
https://www.jpl.nasa.gov/images/pia04939-embedded-outflows-from-herbig-haro-4647
https://esawebb.org/news/weic2319/?lang

09 - Crab Nebula – 6,500 ly

https://webbtelescope.org/contents/news-releases/2023/news-2023-137.html

10 - Cassiopeia A – 11,000 ly

https://esawebb.org/news/weic2311/?lang

11 - Wolf-Rayet 124 – 15,000 ly

https://webbtelescope.org/contents/media/images/2023/111/01GTWASGERK0M8G86WZZSRC1ZX

12 - NGC 346 – 200,000 ly

https://webbtelescope.org/contents/news-releases/2023/news-2023-101.html

12a - Dwarf Galaxy UGC 8091 – 7.9 mly

https://hubblesite.org/contents/media/images/2023/020/01HHDA65V5DSVNAAWE6QW90KDQ?news=true

13 - Arp 220 – 250 mly

https://webbtelescope.org/contents/media/images/2023/116/01GXS09CCZWBFQKNHCG360W6F1

13 - Finding a Black Hole's Mass by the Distortions it Creates

https://www.youtube.com/watch?v=thxU8PQUY7w&t=1s

https://academic.oup.com/mnras/article/521/3/3298/7085506?login=false

14 - Runaway Black Hole – 7.7 bly

https://hubblesite.org/contents/media/images/2023/010/01GWQ1F36Y4JK6Y4K8AWMZ86AF?news=true

15 - Zwicky Intergalactic Stars – 8 bly

https://hubblesite.org/contents/news-releases/2023/news-2023-003.html
https://www.nature.com/articles/s41586-022-05396-4

16 - The Fishhook and Quyllur through El Gordo's Gravitational Lense - 10.8 bly

https://webbtelescope.org/contents/news-releases/2023/news-2023-119.html#section-id-2
https://www.youtube.com/watch?v=k6kMKmpveyo&t=125s

18 - Early and Oldest Galaxies

https://webbtelescope.org/contents/news-releases/2023/news-2023-127.html
https://webbtelescope.org/contents/news-releases/2023/news-2023-122?news=true

https://webbtelescope.org/contents/news-releases/2023/news-2023-114.html

Euclid Space Telescope

https://www.esa.int/Science_Exploration/Space_Science/Euclid/Euclid_s_first_images_the_dazzling_edge_of_darkness

Finding an IMBH in M4 – 7,000 ly

https://hubblesite.org/contents/news-releases/2023/news-2023-016.html
https://stsci-opo.org/STScI-01H13881ME86SD2QE33R2RJB09.pdf

Astrochemistry in the Iris Nebula

https://users.physics.unc.edu/~gcsloan/research/pah_info.html
https://sab-astro.org.br/wp-content/uploads/2023/04/williamchaves.pdf
https://www.universiteitleiden.nl/en/news/2009/11/what-do-pahs-do-in-space
https://www.nasa.gov/multimedia/imagegallery/image_feature_398.html
https://webbtelescope.org/contents/media/images/2023/104/01GS812G7AGRG6D1WCXPS3EYZ5?news=true

Music

Mendelssohn - Concerto for Piano, Violin and String Orchestra: Bulgarian Symphony Orchestra; from the album "50 Must-Have Adagio Masterpieces" 2013

Mendelssohn - Violin Concerto in E Minor Op.64 – Andante: from the album "The Most Relaxing Classical Music" 1997

Mendelssohn - Symphony No 3 Scottish IV Adagio: Philharmonia Orchestra; from the album "50 Must-Have Adagio Masterpieces" 2013

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 ÷