2021 Review

Introduction

Hello and welcome to the 2021 How Far Away Is It review.

Last year we covered the workings of the James Webb Space Telescope with the idea that this year's review would include pictures from Webb. Continuing delays pushed the launch out to Christmas Day. So far, telescope deployment and the journey to L2 are on schedule. But mirror calibration will take months. So, we won't be seeing images from Webb until our 2022 update. I'll have more on this in our first segment of this review.

After that we'll see an asteroid that looks like a comet. We'll take a closer look at Jupiter's great storm. Previously, we covered how the OSIRIS-REx spacecraft landed on the asteroid Bennu. In 2021 it stared its journey back to Earth carrying Bennu rocks. We'll cover new stars forming in Orion and news on the supergiant VY Canis Majoris' diming.

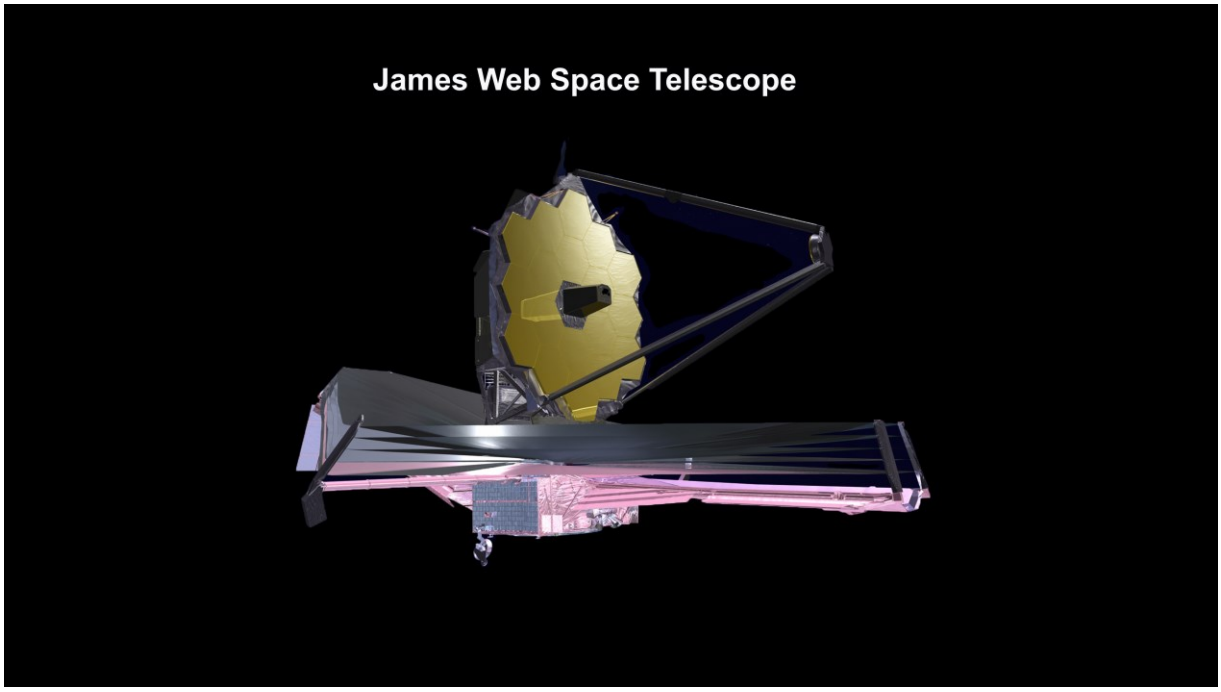
Moving out of the Milky Way, we'll see a couple of supernovae. We'll examine a diffuse galaxy without any Dark Matter. We'll see a couple of interacting galaxies, and a galaxy with a 36,000 light-years long shadow. We'll cover a gamma ray burst that may have been connect to the creation of a magnetar. I have a beautiful image of the gravitationally lensed Molten Ring Galaxy. We'll see multiple images of a supernova along with the prediction that one more image will show up in 2037. We'll take a look at a couple of double quasars. We'll finish with Hamelton's Object - 11 bly away.

For the last segment we'll do a deeper dive into three missions to Mars: One from the United Arab Emirates; one from China; and one from the US.

We'll start with a brief update on Webb. I trust you'll find it all interesting and informative. Thanks for watching.

James Webb Space Telescope (JWST) **Music –** James Horner, Legends of the Fall

Webb is currently fully deployed and in orbit around the L2 Lagrange point. It stared with 344 single points of failure when it left the Earth. Today just 49 single point failures remain. They are common to most spacecraft, such as the propulsion system, and will remain throughout the lifetime of the telescope. The current operation is adjusting the primary and secondary mirrors to provide a single, sharp image instead of 18 fuzzy ones. Each of the primary mirror's 18 gold-plated hexagons has seven actuators on its back to change the shape. The current estimate is that the process of aligning the mirrors will take three and a half months. So next year's review should have a wealth of new astronomical discoveries.

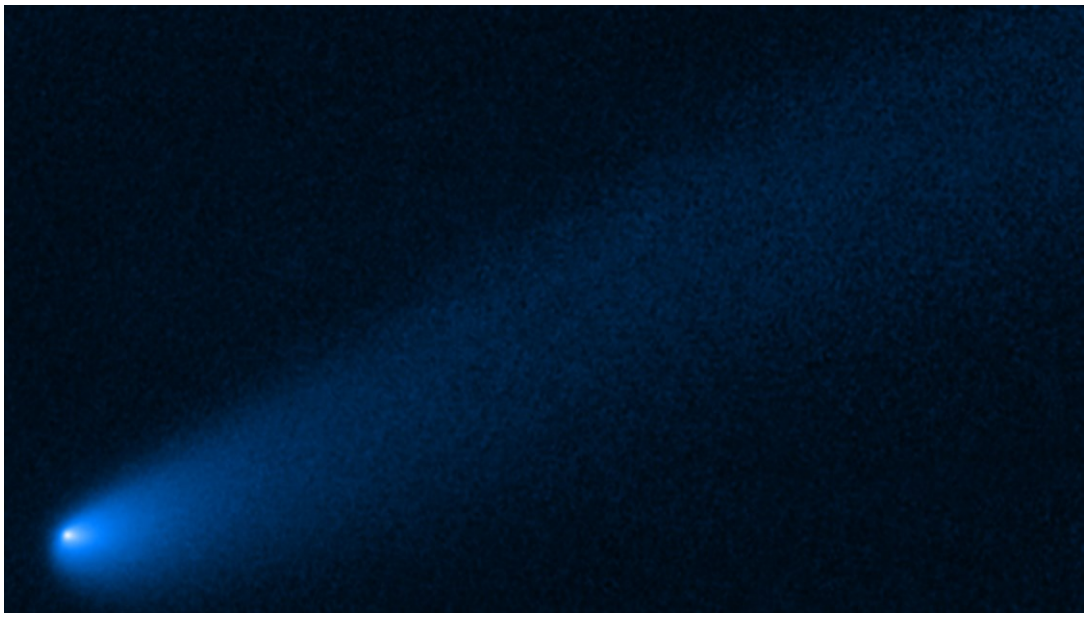


[It takes fuel for Webb to maintain its orbit. The estimate last year was that the amount of fuel available would last for 10 years. When the fuel is gone, the telescope will be lost. But the accuracy of the ESA's Ariane rocket was so good, that new estimates have extended the life of Webb to 20 years. Time will tell.]

Trojan Asteroid P/2019 LD 2

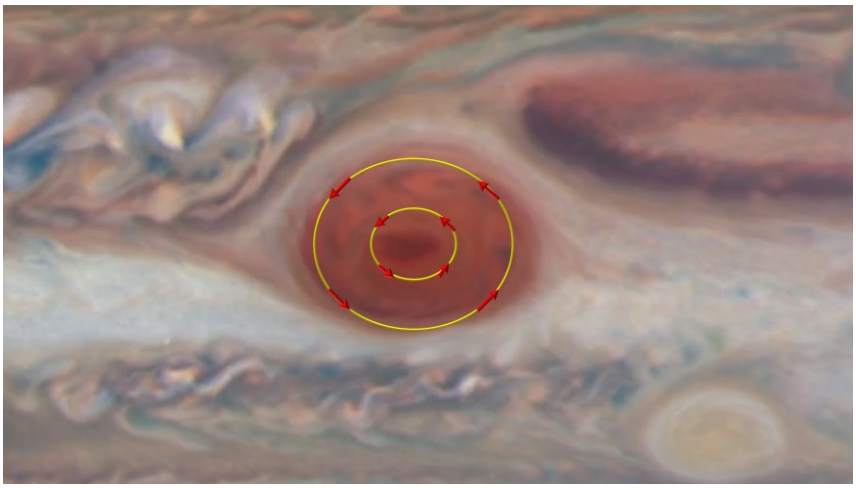
Here's an asteroid that looks like a comet. This asteroid P/2019 LD2 belongs to a class of icy bodies found between Jupiter and Neptune. Called "Centaurs". It most likely originated from the Kuiper Belt. Visible-light snapshots by Hubble reveal that the object shows signs of comet activity, such as a tail, outgassing in the form of jets, and a coma of dust and gas.

Normally comets create these effects via internal solid water sublimating into gas as the temperature goes up on the Sun's side of the frost line. But this asteroid is way too far away from the Sun for this to be the case. But observations by Spitzer showed the presence of carbon monoxide and carbon dioxide gas. These gasses would sublimate even at the low temperatures found at their location 750 million km or 465 million miles away from the Sun. We'll see Hydrogen-Burning White Dwarfs in M13 and cover how these stars are changing how we age globular clusters. We'll see a new image of AG Carinae one of the most massive and brightest stars known.



Jupiter's Red Spot Winds

Astronomers have studied Jupiter's Giant Red Spot storm's clouds since the 1870s. Over that time, they have noted that it is shrinking in size and becoming more circular than oval. The current diameter is 16,000 km. That's 10,000 miles. The Earth could fit inside of it. The spot's spin is counterclockwise at speeds that exceed 640 km per hour (that's 400 miles per hour). Researchers analyzing Hubble's regular "storm reports" over 11 years have found that the average wind speed just within the boundaries of the storm, known as the high-speed ring, has increased by up to 8 percent between 2009 and 2020. In contrast, the winds near the red spot's innermost region are moving significantly more slowly. Each loop in this video represents approximately 10 Earth hours or one Jupiter day.



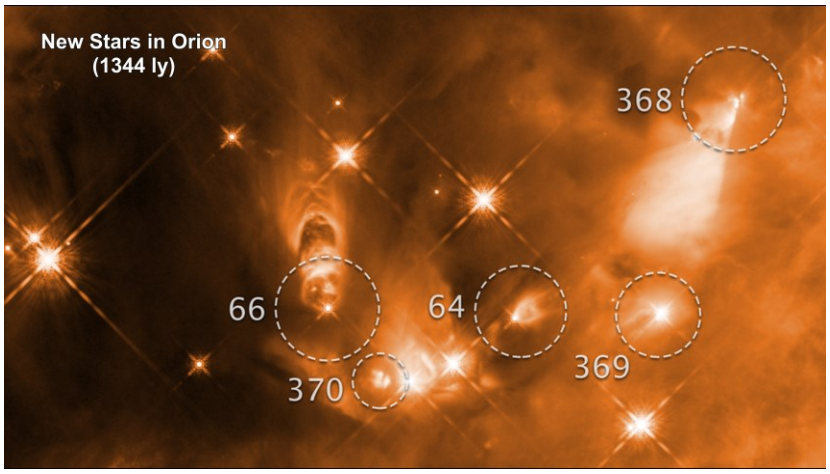
Bennu

In our 'How Far Away Is It' segment on the asteroid belt, we covered OSIRIS-REx the spacecraft that landed on the asteroid Bennu in 2018. In 2021 it began its journey back to Earth with an abundance of rocks and dust collected on the asteroid. The trip back will take 2.5 years with an expected arrival on Sept. 24, 2023. Upon return, the capsule containing pieces of Bennu will separate from the rest of the spacecraft and enter Earth's atmosphere. The capsule will parachute to the Utah Test and Training Range in Utah's West Desert, where scientists will be waiting to retrieve it. We'll cover what they found in the 2023 Review.

New Stars in Orion - 1,344 ly

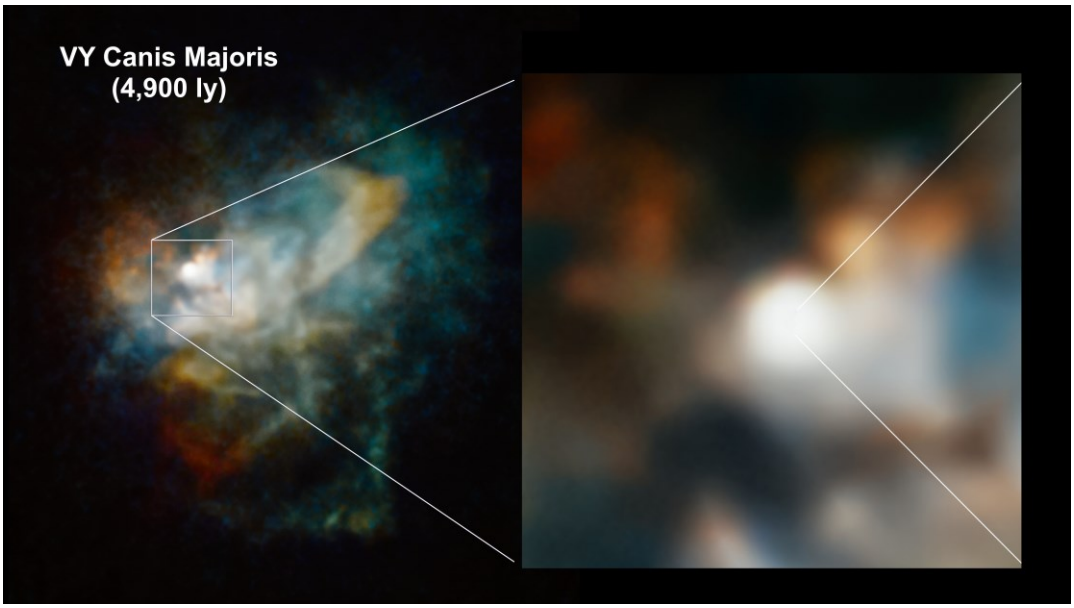
Current star forming theories predict that during a star's relatively brief protostar stage, lasting only about 500,000 years, the star rapidly accumulates mass. As the star heats up, it creates a stellar wind - outflows creating cavities in the gas and dust cloud that surrounds. These cavities grow in size until the entire gas cloud around the star is completely pushed away. At this point, the star stops accreting mass.

These four images taken by Hubble reveal the chaotic birth of stars in the Orion complex, the nearest major star-forming region to Earth. Although the stars themselves are shrouded in dust, they emit powerful radiation, which strikes the cavity walls and scatters off dust grains, illuminating, in infrared light, the gaps in the gaseous envelopes. Astronomers found that the cavities in the surrounding gas cloud sculpted by a forming star's outflow are not growing regularly as they matured, as current star forming theories propose. The James Webb Space Telescope will probe deeper into this protostar formation process find out what is really happening.



VY Canis Majoris – 4,900 LY

Last year, astronomers were puzzled when Betelgeuse dramatically faded but then recovered. The dimming lasted for weeks. Hubble found that the dimming corresponded to a gaseous outflow that formed dust, which briefly obstructed some of Betelgeuse's light from our view, creating the dimming effect. Now, astronomers have discovered that the red hypergiant VY Canis Majoris—which is far larger, more massive, and more violent than Betelgeuse—experienced much longer, dimmer periods that last for years. New findings from Hubble suggest the same processes that occurred on Betelgeuse are happening in this hypergiant, but on a much grander scale. Here we see some of the structures close to the star that are relatively compact knots. By using Hubble to determine the velocities and motions of the close-in knots of hot gas, astronomers were able to date these eruptions more accurately. They found that many of these knots link to multiple dimming episodes in the 19th and 20th centuries when VY Canis Majoris faded to one-sixth its usual brightness.

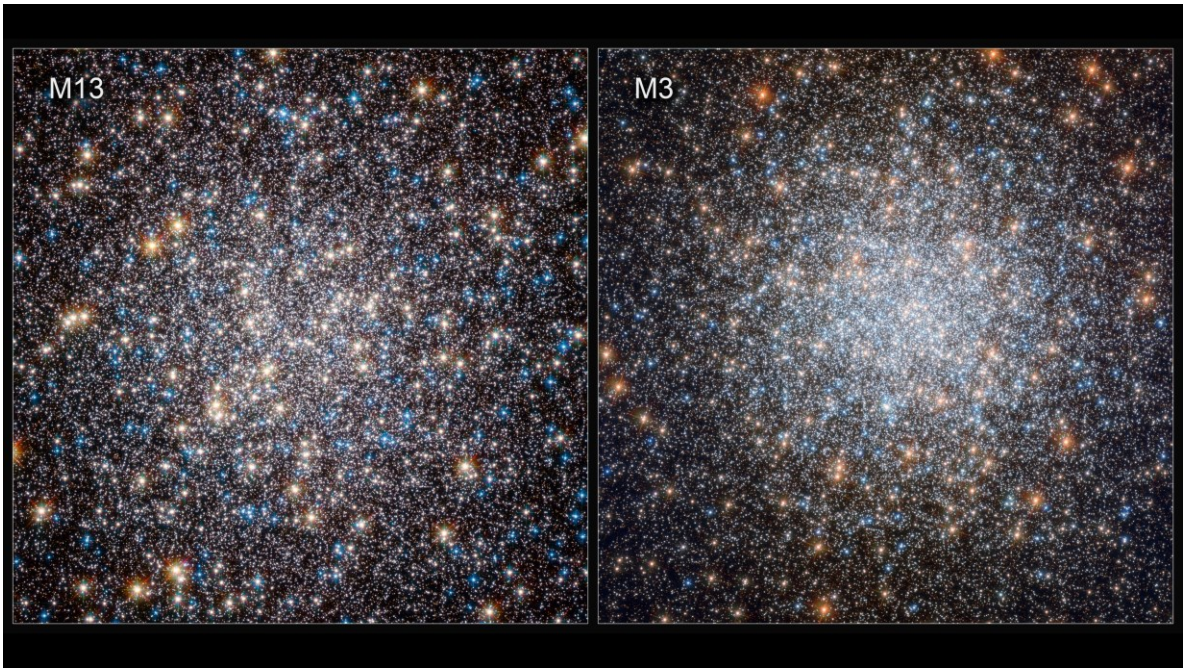


Hydrogen-Burning White Dwarfs

White dwarfs are slowly cooling stars which have cast off their outer layers during the last stages of their fusion burning phase. Roughly 98% of all the stars in the Universe will ultimately end up as white dwarfs, including our own Sun.

To investigate the physics underpinning white dwarf evolution, astronomers compared cooling white dwarfs in two massive collections of stars: the globular clusters M3 (with roughly half a million stars) and M13 (with several hundred thousand stars). Interestingly, their star populations which will eventually give rise to white dwarfs are different. In particular, the overall color of stars at the end of their red giant phase are bluer in M13. And Blue stars are hotter because they are burning hydrogen on their surfaces. This slows down their cooling rate.

The evolution of white dwarfs has previously been modelled as a predictable cooling process leading astronomers to use them as a natural clock to determine the ages of star clusters. However, white dwarfs burning hydrogen could cause these age estimates to be inaccurate by as much as 1 billion years.



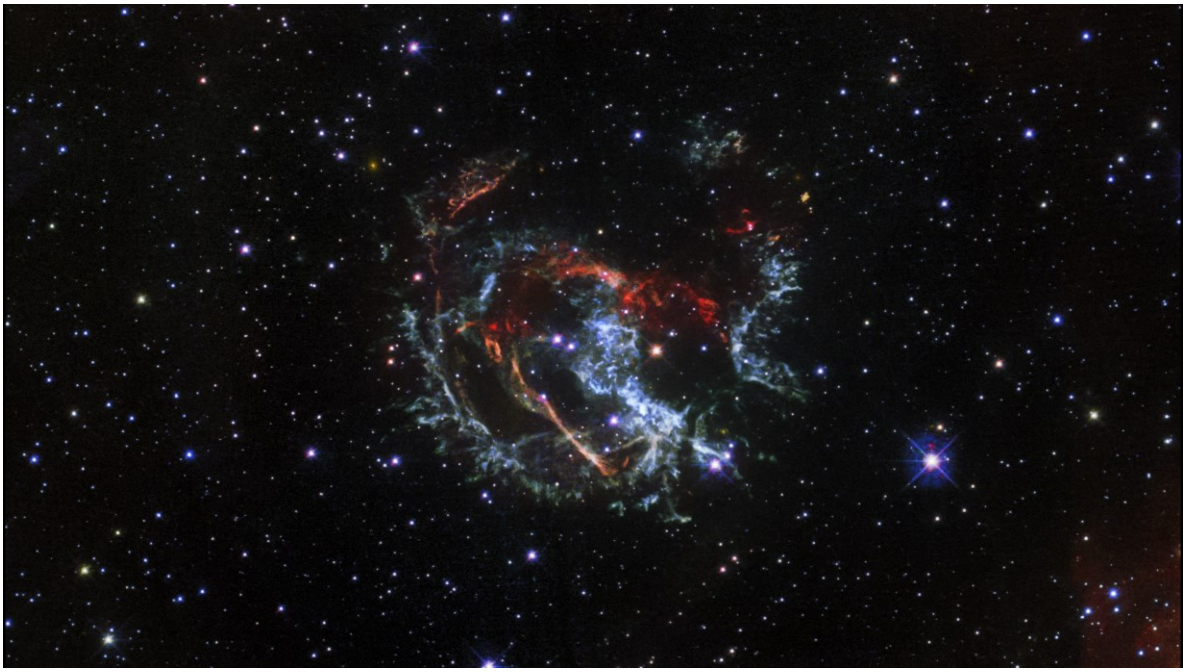
AG Carinae – 20,000 ly **Music -** Tchaikovsky: Piano Concerto 1

Here we are zooming in to take another look at AG Carinae as viewed by Hubble this past year. The expanding shell of gas and dust that surrounds the star is about five light-years wide, which equals the distance from here to Proxima Centauri - the nearest star to our Sun. The huge structure was created from one or more giant eruptions about 10,000 years ago that blew the star's outer layers into space. The expelled material amounted to roughly 10 times our Sun's mass. AG Carinae is known as a 'luminous blue variable'. These are among the most massive and brightest stars known. This one is 70 times more massive than our Sun but shines with a million times the brilliance. They only shine for a few million years, compared to the roughly 10-billion-year lifetime of our Sun. AG Carinae is estimated to be just a few million years old.

SNR 1E 0102.2-7219 – 200,000 ly

Here we are zooming into a supernova remnant in the Small Magellanic Cloud, a satellite galaxy of our Milky Way located roughly 200,000 light-years away. The gaseous knots in this supernova remnant moving toward Earth are colored blue in this composition and the ones moving away are shown in red. This new Hubble image shows these ribbons of gas speeding away from the explosion site at an average speed of 3.2 million kilometers per hour (that's 2 million mph). According to the latest estimates, light from this blast arrived at Earth 1700 years ago, during the decline of the Roman Empire. [This supernova would only have been visible to inhabitants of Earth's southern hemisphere. Unfortunately, there are no known records of this titanic event.] To pinpoint when the explosion occurred, researchers studied the oxygen-rich clumps of ejecta flung out by this supernova

blast. They traced the knots' motion backward until the ejecta coalesced at one point, identifying the explosion site. Once that was known, they could calculate how long it took the speedy knots to travel from the explosion center to their current location.

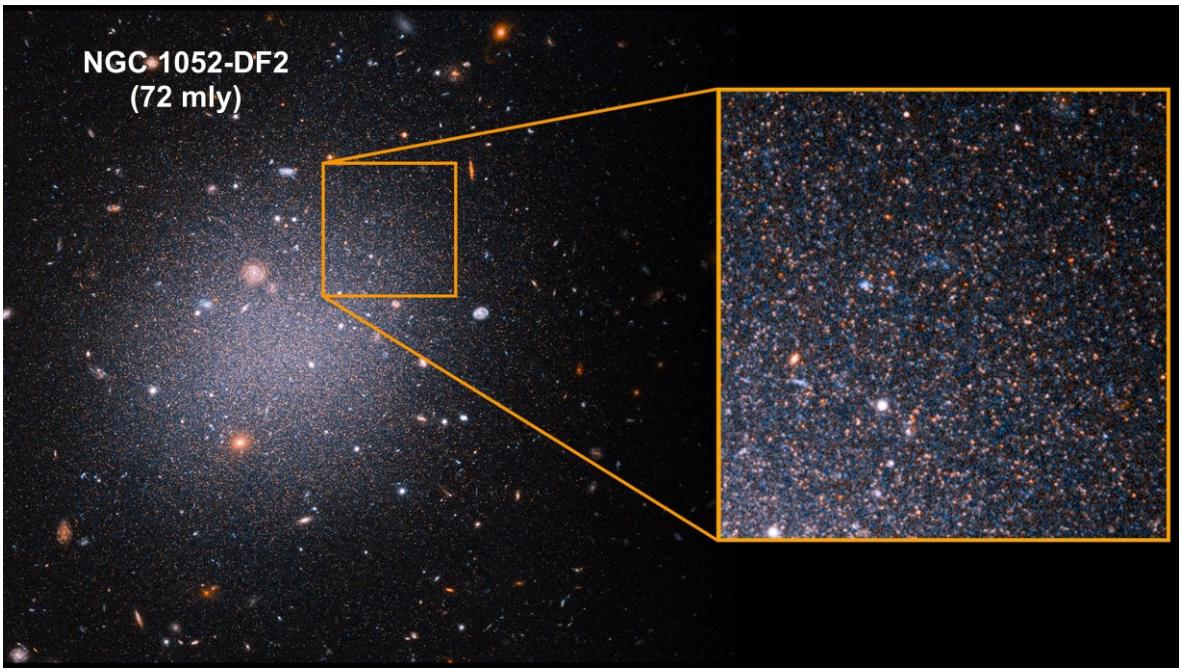


SN 2020fqv – 59 mly

Here we see interacting Butterfly Galaxies NGC 4567 and 68 located 59 million light-years away. In April 2020, the Zwicky Transient Facility at the Palomar Observatory in San Diego discovered a supernova, now called SN 2020fqv. At the same time, it turned out that the Transiting Exoplanet Survey Satellite (TESS), a NASA satellite designed primarily to discover exoplanets was looking at the same area of space. The Hubble team was alerted and within hours, it had the Hubble telescope focused on the expanding circumstellar material around the exploding star. The team looked at Hubble observations of the star going back to the 1990s. TESS provided an image of the system every 30 minutes starting several days before the explosion, through the explosion itself, and continuing for several weeks. And from studying the circumstellar material with Hubble, the scientists gained an understanding of what was happening around the star over the previous decade. By combining all of this information, the team was able to create a multi-decade look at the star's final years.

NGC 1052-DF2 – 72 MLY

NGC 1052-DF2 is a diffuse see-through galaxy. Star motion analysis in 2018 indicated that it had no detectable dark matter. In our 'Cosmos' segment of the 'How far away is it' video, we covered how these dark matter calculations done. In this case, the gravitationally calculated mass was equal to the luminosity-based calculation. This is unusual, so a deeper study was carried out in 2020 with the results published in 2021. The original estimate for DF2 had the galaxy at 65 million light-years away. If the galaxy was closer than that, say 42 mly, star motion would have needed dark matter. But a team of analysts studied data from 40 Hubble orbits studying red giant stars. They found that the distance is not closer. It is further away at 72 mly. This keeps DF2 in the category of the rare galaxies without dark matter.

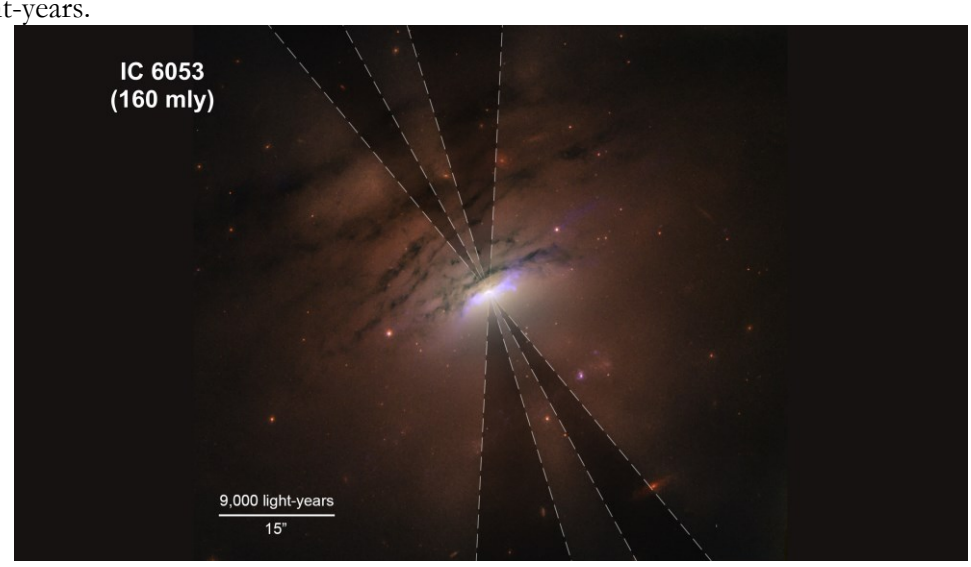


NGC 2276 - 120 mly

Here we are zooming in to the magnificent spiral galaxy NGC 2276. You can also see NGC 2300. A bright hub of older yellowish stars normally lies directly in the center of most spiral galaxies. But the bulge in NGC 2276 is offset because of an interaction with NGC 2300 which is gravitationally tugging on its disk of blue stars, pulling the stars on one side of the galaxy outward to distort the galaxy's appearance.

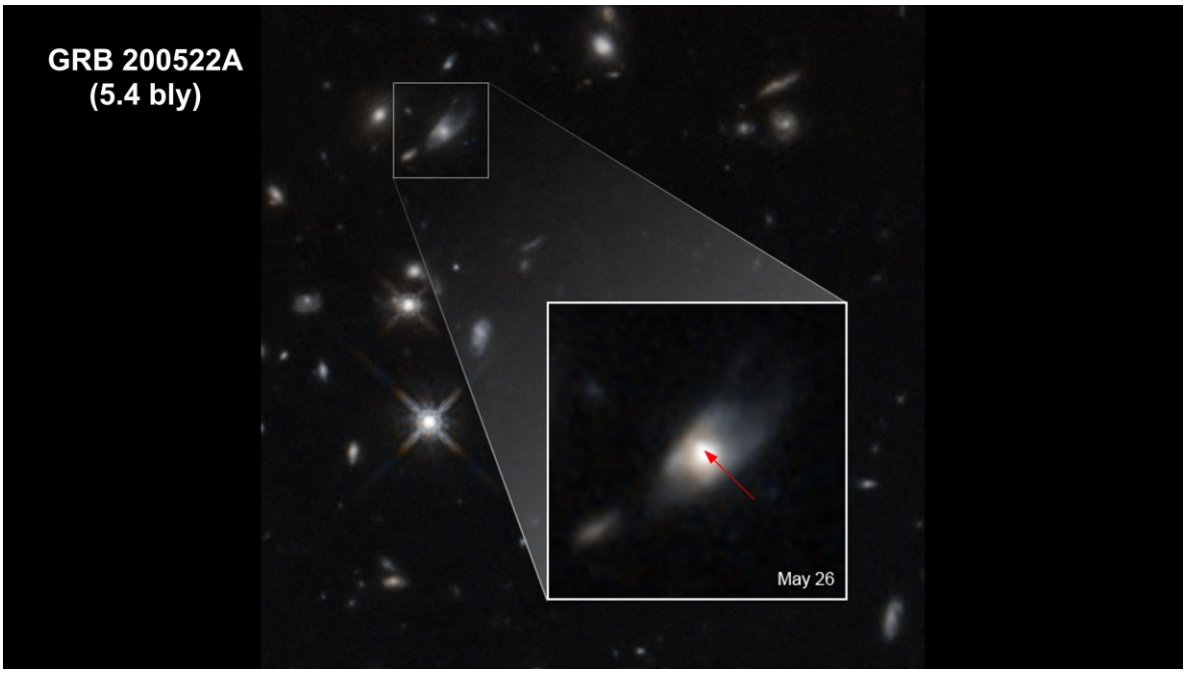
IC 5063 – 156 mly

Here's a Hubble image of the center of nearby active galaxy IC 5063. It contains a supermassive black hole. As material approaches the black hole's event horizon, massive amounts of radiation is released in all directions. But note the V shaped shadows emanating from the central core. Astronomers suggest that a ring of dusty material surrounds the black hole and may be casting its shadow into space by blocking some of this radiation. These dark shadows extend across at least 36,000 light-years.



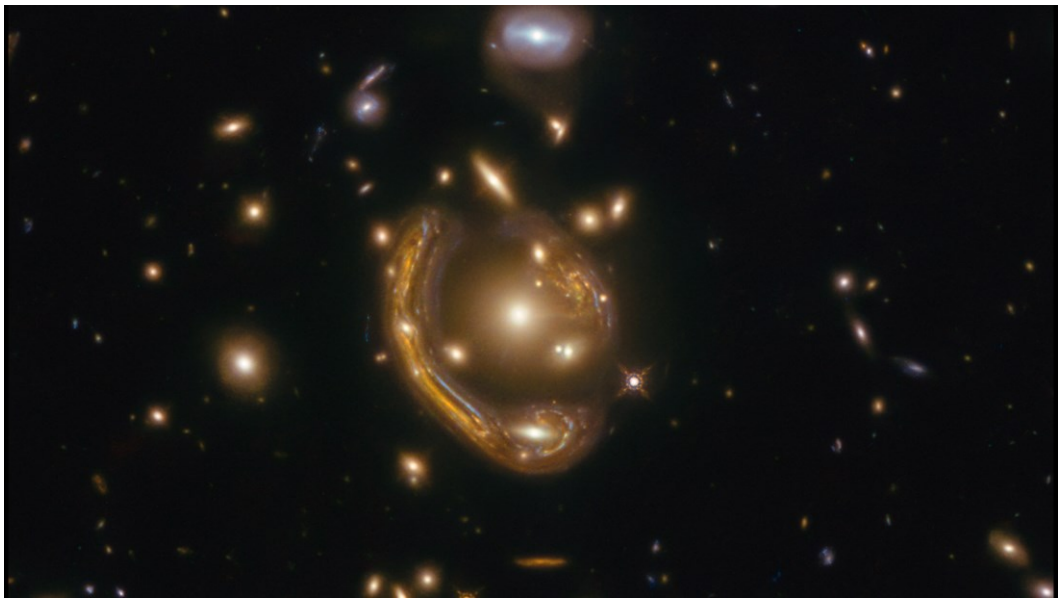
GRB 200522A – 5.4 bly

Around 5 and a half billion years ago, an enormous half a second gamma ray burst unleashed more energy than the Sun will produce over its entire 10-billion-year lifetime. In May of 2020, light from the flash reached Earth. A wide variety of telescopes turned to this event's aftermath including Hubble. The burst seemed to fit previous short GRBs thought to be caused by the merger of two neutron stars into a black hole. But this one had near-infrared emissions that were 10 times brighter than normal. One possibility is that the two neutron stars that merged in this case combined to form a magnetar, a supermassive neutron star with a very powerful magnetic field. If this is the case, the we should see light that shows up in radio wavelengths in a few years. We covered magnetars in our "How Far Away Is It" segment on Star Clusters and Supernova.



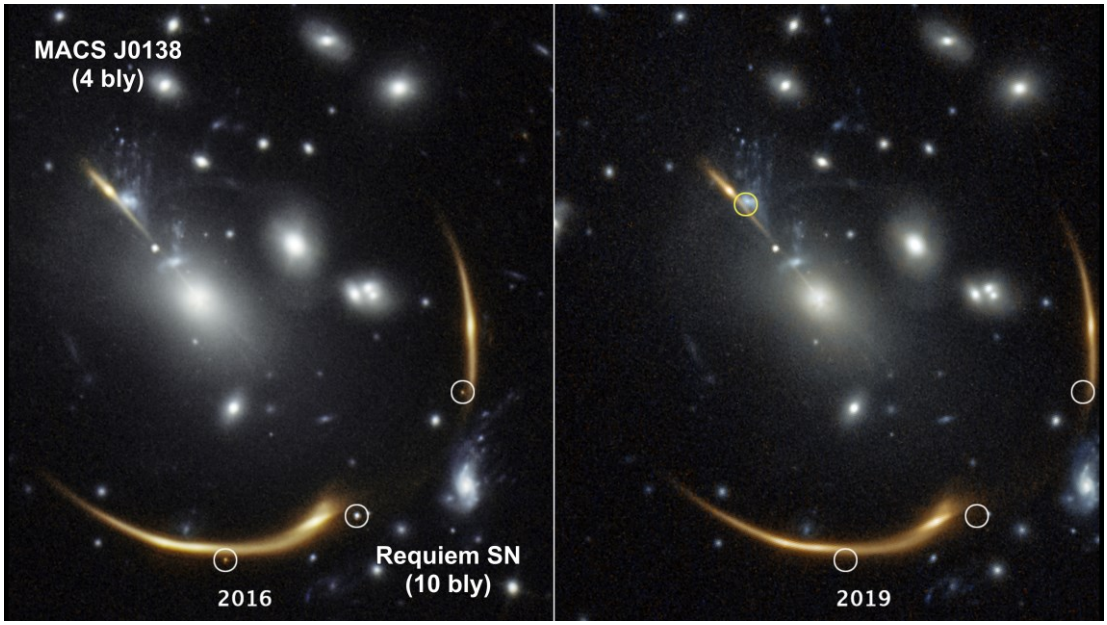
Molten Ring Galaxy – 9.4 bly **Music -** Shubert: Symphony No. 3, Allegretto

In this image, a remote galaxy is greatly magnified and distorted by gravitational lensing. The galaxy's light has also been magnified by a factor of 20. Lensing effects also created multiple apparitions around the curved arc of the single background magnified galaxy. The object, GAL-CLUS-022058s, was nicknamed the "Molten Ring" because of its appearance. After its public release in 2021, astronomers used the picture to measure the galaxy's distance of 9.4 billion light-years. At that time, there was an extremely high rate of star formation in the brightest and very dusty early galaxies. Stars were being formed at a rate a thousand times faster than occurs within our own galaxy.



Requiem SN – 10 bly

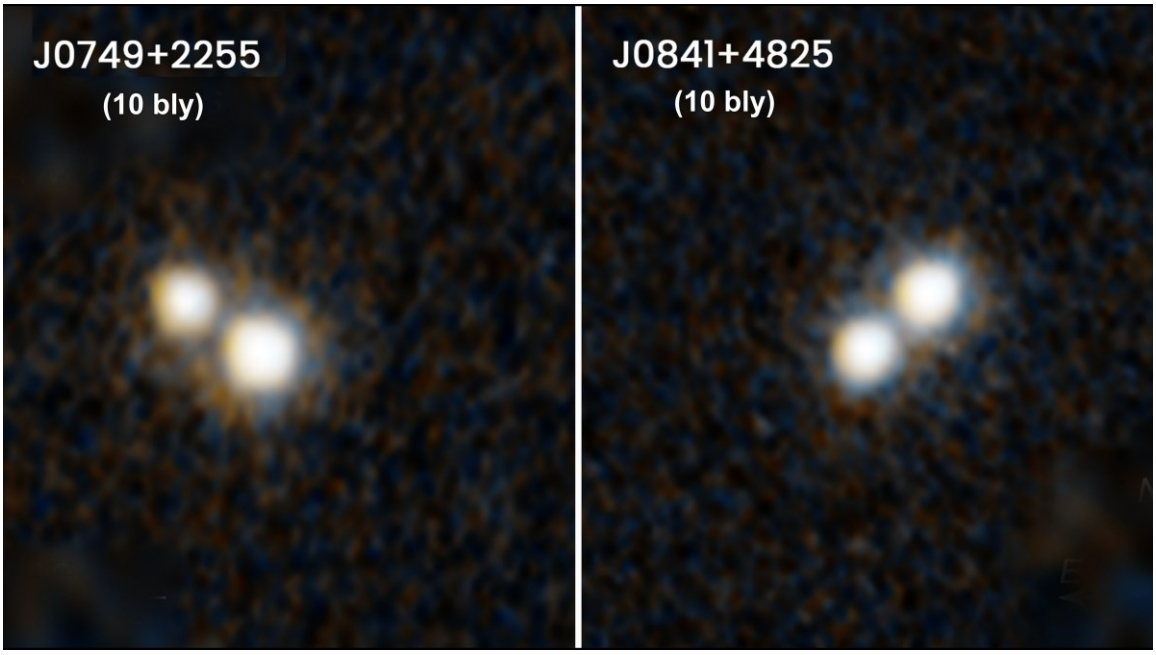
Three views of the same supernova appear in the 2016 image on the left, taken by the Hubble Space Telescope. But they're gone in the 2019 image. The distant supernova, named Requiem, is embedded in the giant galaxy cluster MACS J0138 4 bly away. The cluster gravitationally lensed the light from the supernova located in a galaxy far behind it 10 bly away. It also split the supernova's light into multiple mirror images, highlighted by the white circles in the 2016 image. Based on the foreground galaxy's dark matter distribution, researchers predict that a reappearance of the same supernova will happen in 2037. The predicted location of that fourth image is highlighted by the yellow circle at top left.



Double Quasars - 10 bly

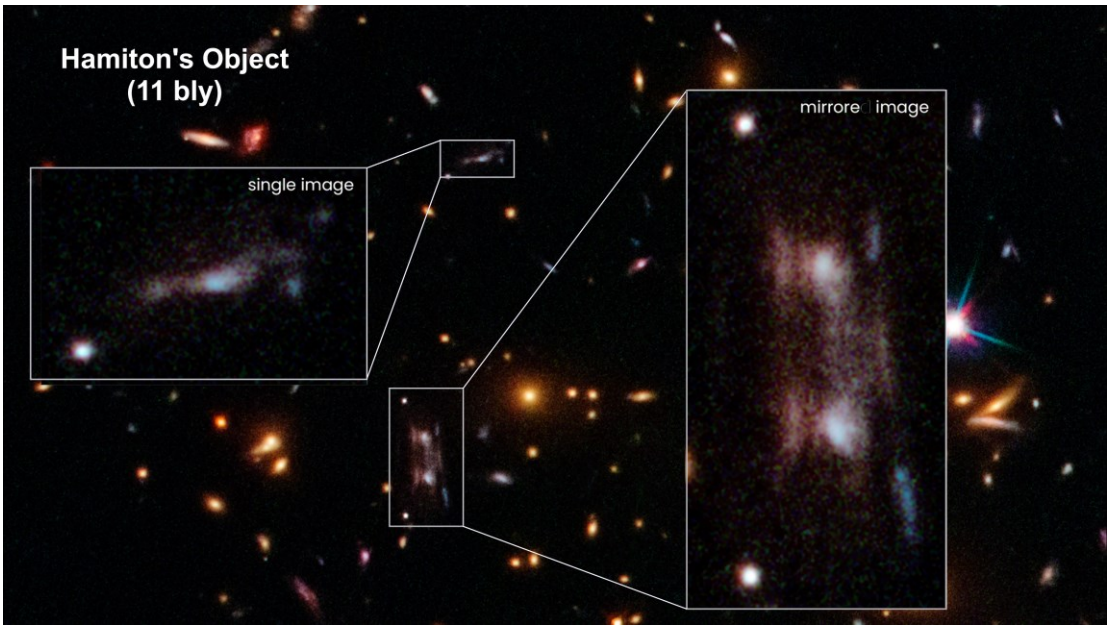
Quasars are brilliant beacons of intense light from the centers of distant galaxies. They are powered by supermassive black holes growing on infalling matter that unleashes massive amounts of radiation at the event horizon. They are scattered all across the sky and were most abundant 10 billion years ago. These Hubble images reveal two pairs of quasars that reside at the hearts of merging galaxies. These galaxies, however, cannot be seen because they are too faint, even for Hubble. We're hoping the James Web Space Telescope currently at the L2 point being calibrated will give us a good look at the galaxies around these quasars. These quasars will tighten their orbits until they eventually spiral together and coalesce, resulting in an even more massive, but solitary black hole.

[The observations are important because quasars play a critical role in galaxy formation. As two close galaxies begin to distort each other gravitationally, their interaction funnels material into their respective black holes, igniting their quasars. Over time, radiation from these quasars launch powerful galactic winds, which sweep out most of the gas from the merging galaxies. Deprived of gas, star formation ceases, and the galaxies evolve into elliptical galaxies.**]**



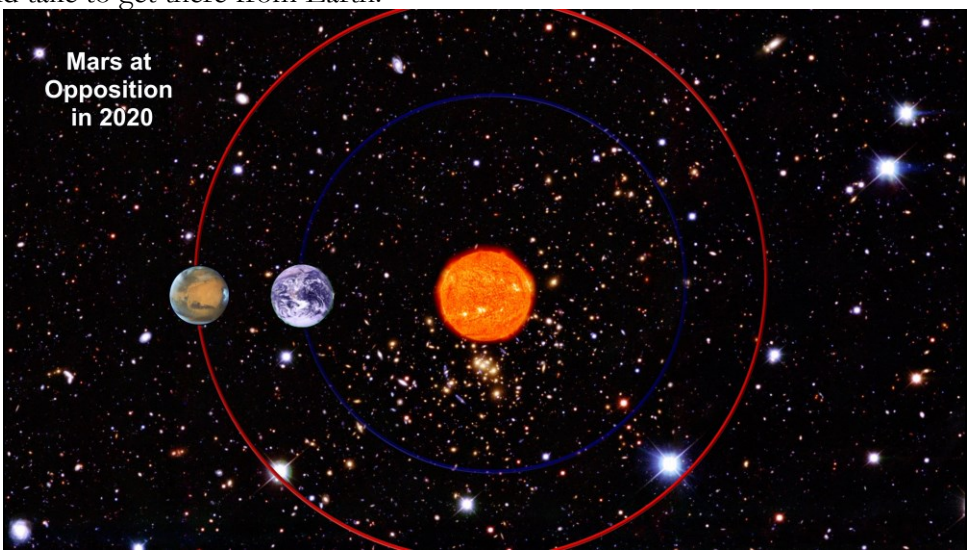
Hamelton's Object – 11 bly

Astronomer Timothy Hamilton, using the Hubble Space Telescope, discovered these unusual objects, now named after him. The objects are the stretched images of a gravitationally lensed distant galaxy, located more than 11 billion light-years away. One appears to be a mirror image. In this case, a precise alignment between a background galaxy and a foreground galaxy cluster 7 billion light-years away produced twin magnified copies of the same image of the remote galaxy. This rare phenomenon occurs because the background galaxy straddles a ripple of dark matter in the foreground galaxy. As the faraway galaxy light passes through the cluster along this ripple, two mirror images are produced, along with a third image that can be seen off to the side.

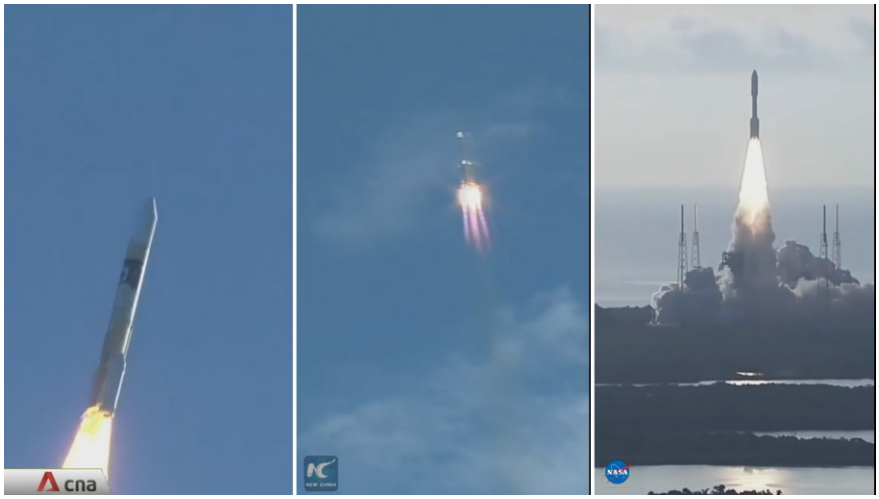


Mars

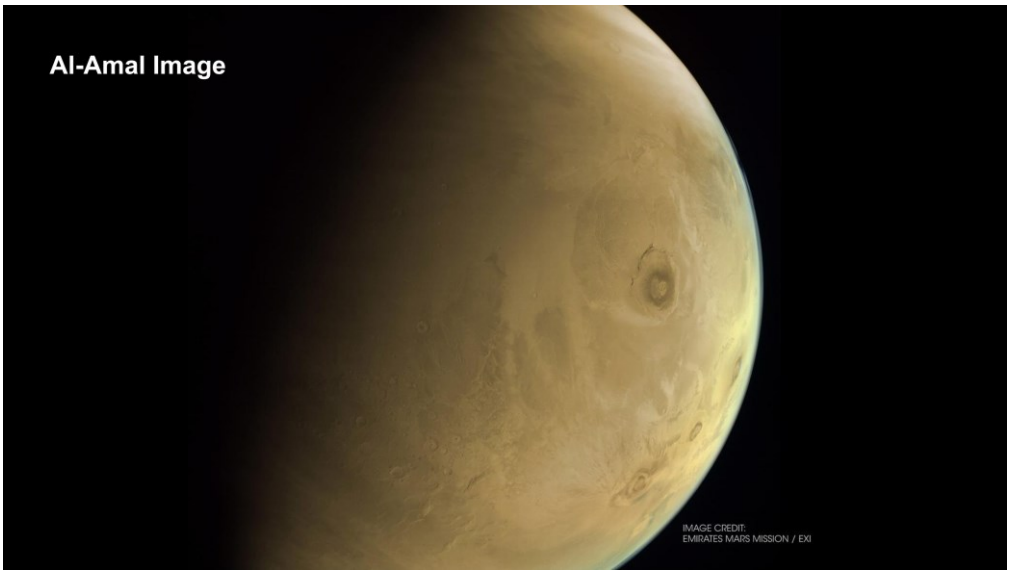
In 2020, Mars reached opposition putting it in an advantageous position for minimizing the time a probe would take to get there from Earth.



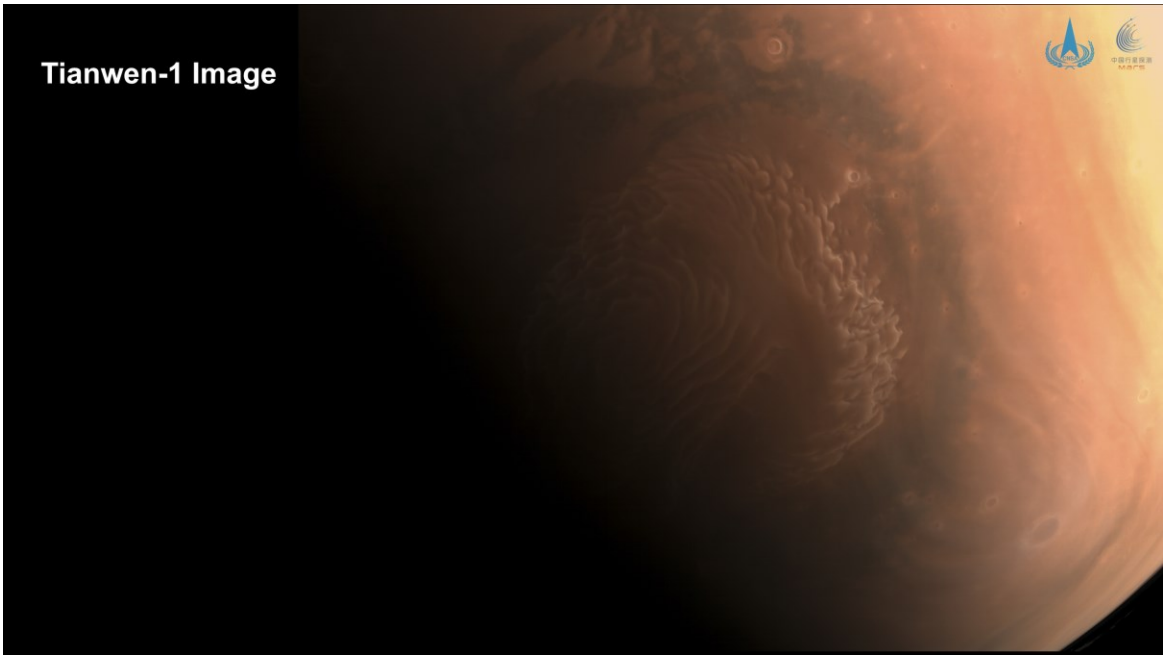
Taking advantage of the positioning, three nations launched probes to the red planet.
The United Arab Emirates launched its first space probe to Mars. Known as "Hope" or "Al-Amal" in Arabic, the probe will study Mars' weather and climate to understand how Mars lost most of its atmosphere. China launched a probe called Tianwen-1. The mission included an orbiter, two deployable cameras, a lander, a remote camera and a rover named Zhurong to both explore the surface while the orbiter analyzes the atmosphere. The United States launched its Mars 2020 mission to land a rover named Perseverance along with a helicopter named Ingenuity. Its mission is to search for signs of ancient microbial life as well as to collect Martian rocks for future pickup and delivery to Earth.



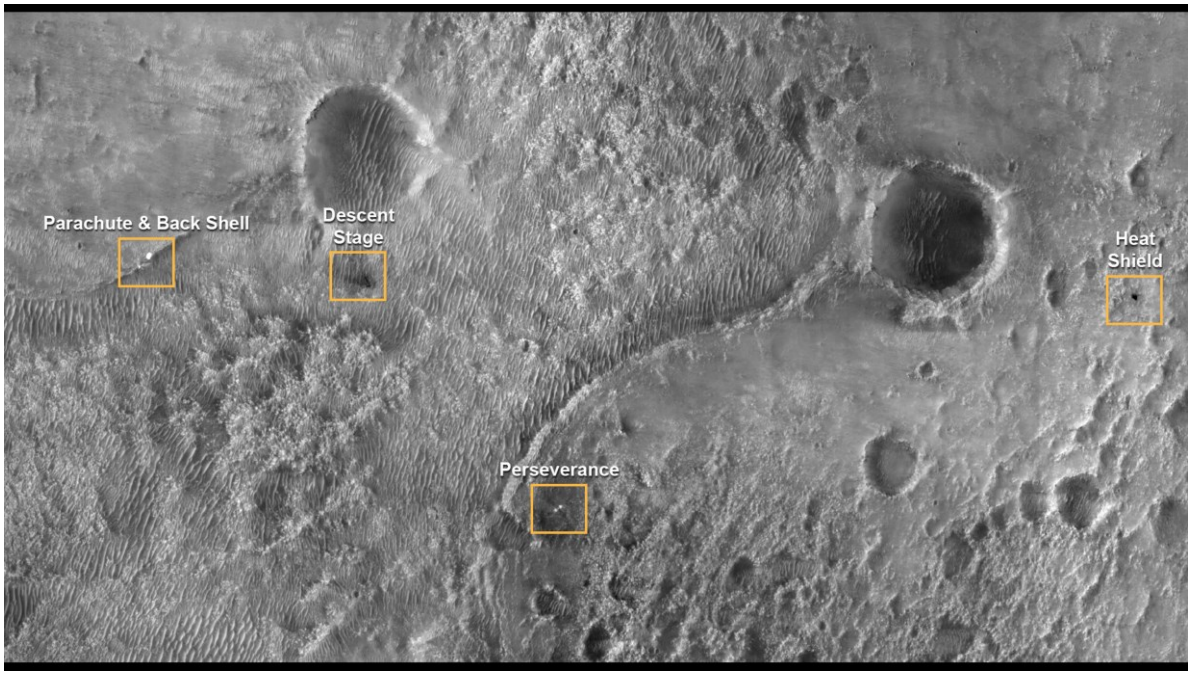
In 2021, all three probes successfully arrived at the red planet. Here's the first release image of Mars from Al-Amal. It shows Olympus Mons – the largest known volcano in our Solar System.



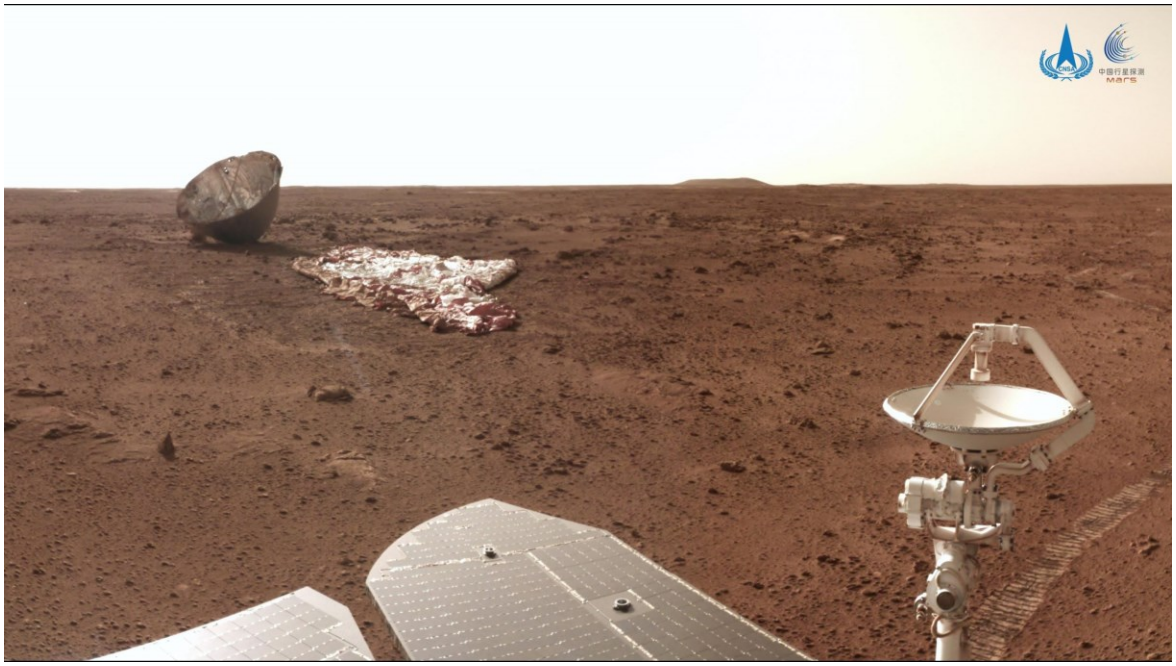
Here's an early photograph from Tianwen-1. It's a high-def image of Mars' north pole.



The American mission used the existing Reconnaissance orbiter from 2006. Here's its pictures of the Perseverance landing site.



Here are a few images from China's rover Zhurong. Since its landing, it has been traveling southward to explore and inspect the terrain and has taken daily images of rocks, sand dunes, and other features. With it various instruments it has also been collecting data on Mars' magnetic field, weather, and subsurface.

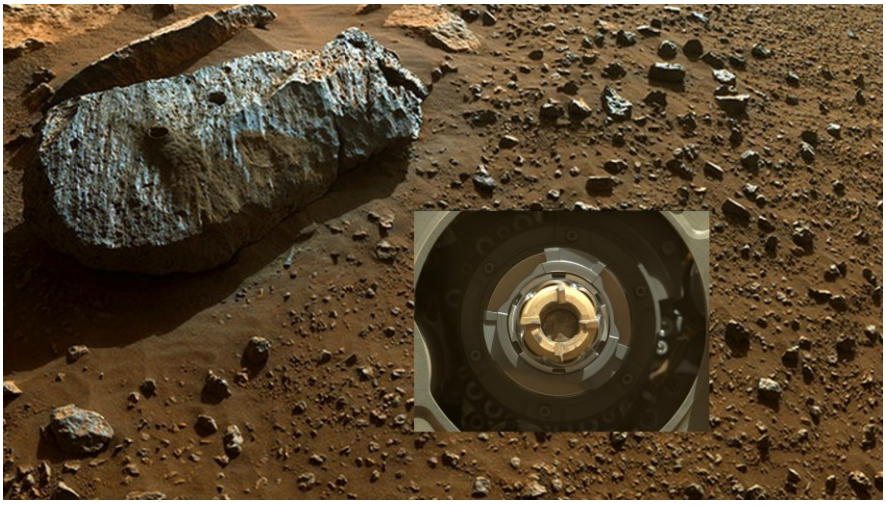


For the US, Perseverance is the 5th rover to explore Mars. In 2013, Curiosity was roaming the Marshan landscape. I put myself on one of its pictures in the 2013 edition of the How Far Away Is It chapter on the Solar System.

The rover will characterize the planet's geology and past climate, and pave the way for human exploration. But the main goal of the Mars 2020 mission is to search for signs of past life. To that end, they chose to land Perseverance in Jezero Crater. Scientists believe the area was once flooded with water and was home to an ancient river delta around 3.5 billion years ago. Conceivably, microbial life could have lived in Jezero during one or more of Mars' wet periods.

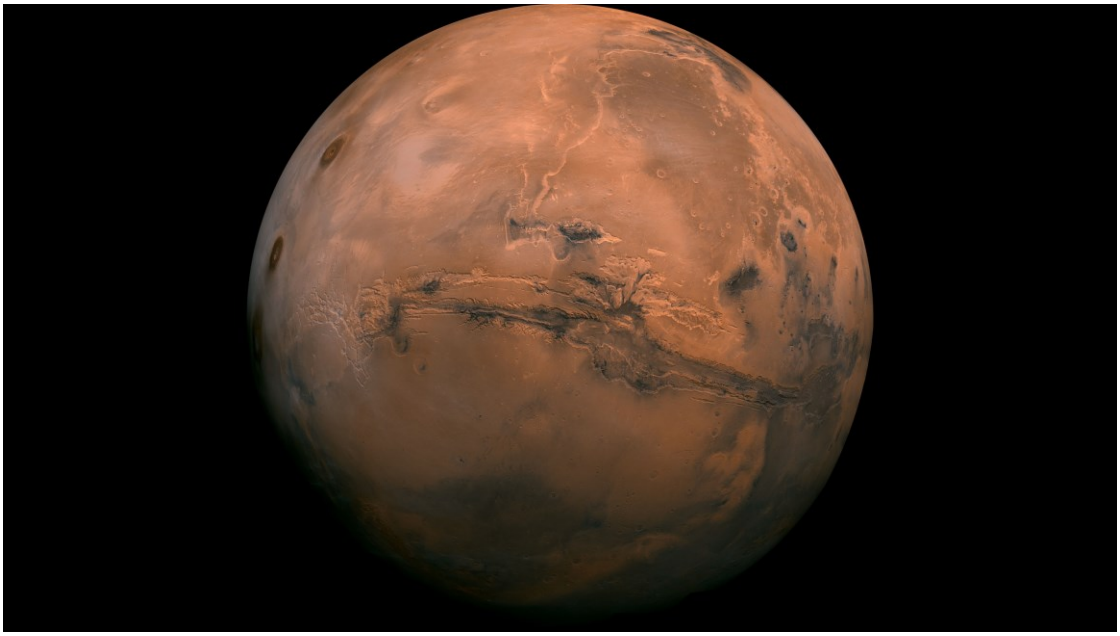
This image shows Perseverance's journey across the crater's floor since landing on Feb. 18, 2021. At an area labeled "Citadelle," it successfully collected its first two rock samples.

Here's a picture of a rock that provided core material. You can see the drill holes. Each sample is stored in a special container. You can see the material at the center inside a titanium sample collection tube. Subsequent NASA missions, in cooperation with the European Space Agency, will send spacecraft to Mars to collect these sealed samples from the surface and return them to Earth for in-depth analysis.



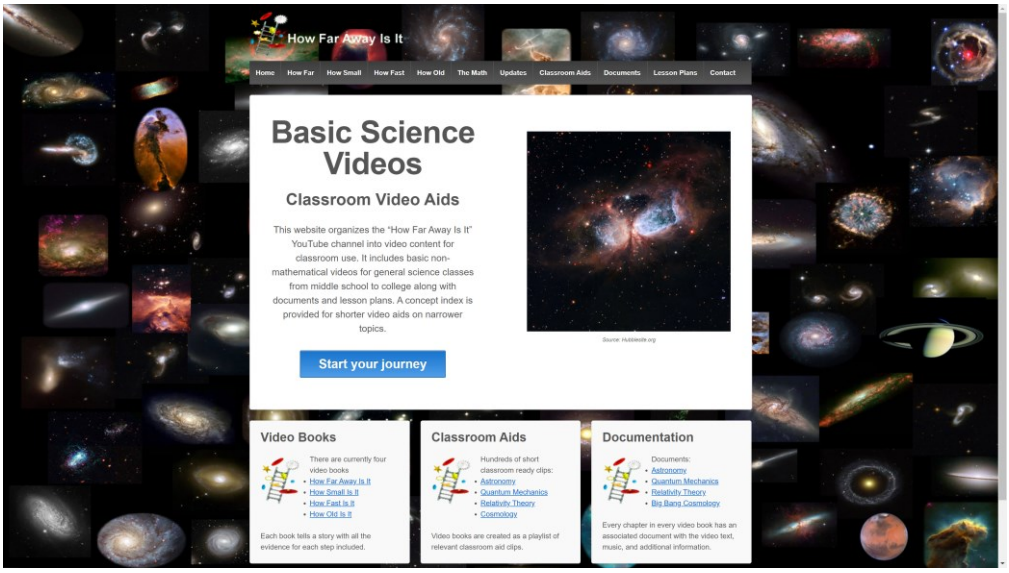
This panoramic view features several of the long, steep slopes of the river delta created by rivers that flowed into the ancient lake. The crater itself is 48 km wide. That's 30 miles.

In order to facilitate exploration and find the best places to collect rocks, the mission also include a helicopter named Ingenuity. Here's a clip of its first flight captured by Perseverance. Given Mars' thin atmosphere, the rotors need to rotate at 2,700 rotations per minute. That's more than five times the average rotor rotational speed for helicopters on Earth. Here's a picture of Perseverance's tracks captured by Ingenuity. And here we see Ingenuity's shadow captured by Ingenuity itself. I think we'll have more news on Mars over the coming years. I'm looking forward to it.



Credits

Here are the links to Hubble sites, whitepapers and other locations where I found the information contained in this 2021 review. These are also the places where you can begin to do your own research.

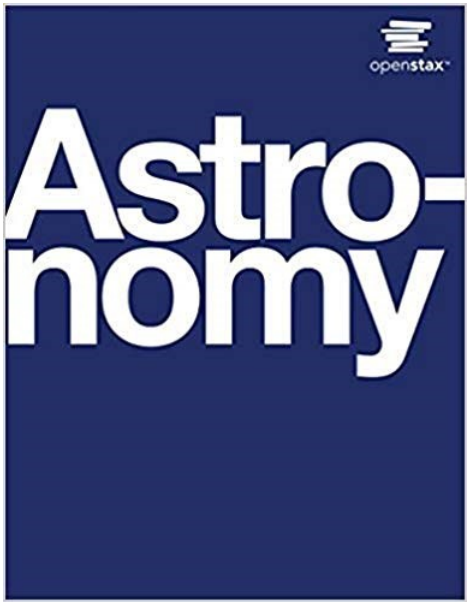


howfarawayisit.com

Also, thanks to Jonathan Onstead, there is a 'How Far Away Is It' wiki available for anyone who wants to engage in conversations about this or any channel video.

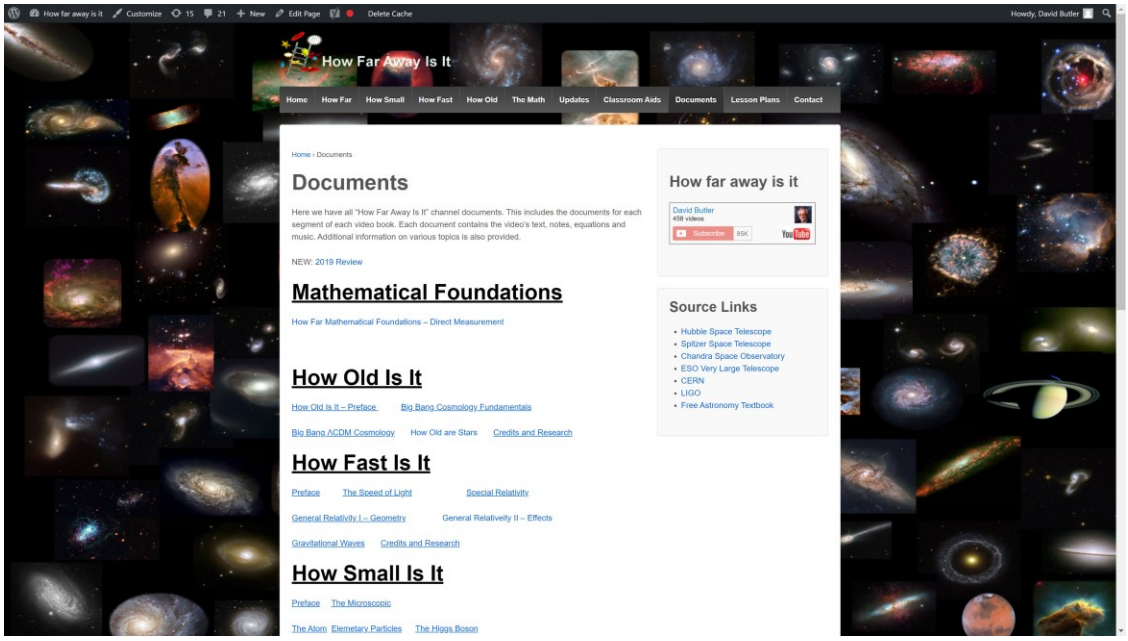
https://howfarawayisit.fandom.com/wiki/Encyclopedia_Howfarawayica

I want to call your attention to a new free online textbook called 'Astronomy" that anyone interested in astronomy can use. It is supported by OpenStax, a Rice University 501(C)(3) nonprofit charity. The book builds student understanding through the use of relevant analogies, clear and non-technical explanations, and rich illustrations. Take a look at Synchrotron radiation on page 972.



https://openstax.org/details/astronomy

And don't forget. Every video has a document on the howfarawayisit.com website containing all the text. Download and translate as needed. Thanks for watching.



http://howfarawayisit.com/documents/

Credits

James Webb Space Telescope (JWST)
https://www.nationalgeographic.com/science/article/at-long-last-the-james-webb-space-telescope-is-ready-to-launch
https://jwst.nasa.gov/content/about/orbit.html

Trojan Asteroid P/2019 LD 2
https://hubblesite.org/contents/media/images/2021/005/01EX5JYDS3224TS35BHGBS4EVX

Jupiter's Red Spot Winds
https://esahubble.org/news/heic2110/?lang

Bennu - distance
https://www.nasa.gov/press-release/nasa-s-osiris-rex-spacecraft-heads-for-earth-with-asteroid-sample

VY Canis Majoris – 4.9 LY
https://hubblesite.org/contents/news-releases/2021/news-2021-09

New Stars in Orion - 1,344 ly
https://hubblesite.org/contents/news-releases/2021/news-2021-006

Hydrogen-Burning White Dwarfs
https://esahubble.org/news/heic2108/?lang

NGC 6397 - 7,800 LY
https://hubblesite.org/contents/news-releases/2021/news-2021-08

AG Carinae – 20,000 ly
https://hubblesite.org/contents/news-releases/2021/news-2021-017

SNR 1E 0102.2-7219 – 200,000 ly
https://esahubble.org/news/heic2102/?lang

SN 2020fqv – 59 mly
https://hubblesite.org/contents/news-releases/2021/news-2021-007.html#section-id-2

NGC 1052-DF2 – 72 MLY
https://hubblesite.org/contents/news-releases/2021/news-2021-025.html#section-id-2
https://esahubble.org/news/heic2019/?lang

NGC 2276 - 120 mly
https://hubblesite.org/contents/news-releases/2021/news-2021-029.html

IC 5063 – 156 mly
https://hubblesite.org/contents/media/images/2020/58/4778-Image?news=true

GRB 200522A – 5.4 bly
https://hubblesite.org/contents/news-releases/2020/news-2020-48

Molten Ring Galaxy – 9.4 bly
https://hubblesite.org/contents/news-releases/2021/news-2021-051.html

Requiem SN – 10 bly
https://hubblesite.org/contents/media/images/2021/030/01F9KZX19D6BZJG86J3A3E8FW5?news=true

Double Quasars - 10 bly
https://hubblesite.org/contents/news-releases/2021/news-2021-014

Hamelton's Object – 11 bly
https://hubblesite.org/contents/news-releases/2021/news-2021-046.html

Mars
https://mars.nasa.gov/mars2020/multimedia/raw-images/
https://www.laprensalatina.com/chinas-tianwen-1-mission-sends-new-photos-of-mars/
https://mars.nasa.gov/news/9036/nasas-perseverance-rover-collects-puzzle-pieces-of-mars-history/

Music

@02:21 James Horner: Legends of the Fall; from the album James Horner - The Classics, 2018

@11:01 Tchaikovsky: Piano Concerto 1

@18:30 Shubert: Symphony No. 3, Allegretto: from the album Meditation: Classical Relaxation, 2010

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 ÷