THE UNIVERSITY OF ARIZONA

Education & Public Outreach
July 2025, Part 2b

PLANETARY SCIENCE INSTITUTE EST. 1972

VATICAN OBSERVATORY

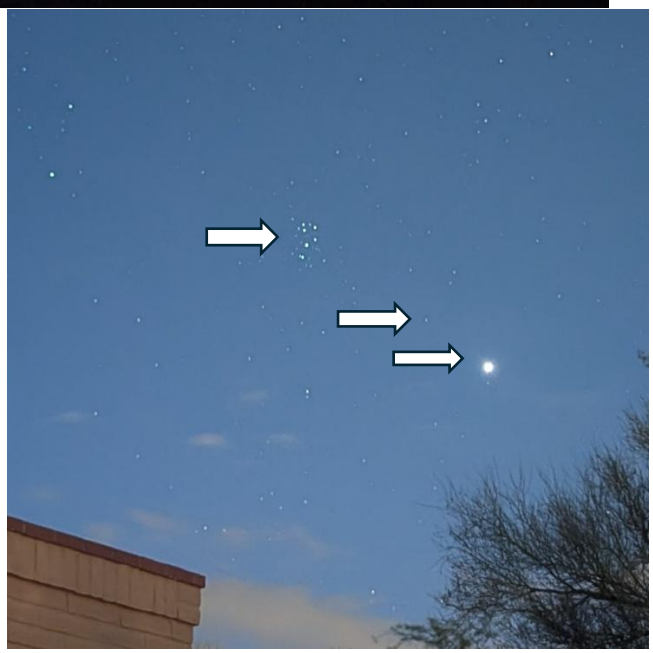
Pictures:

I hope that you and your families are having a good and safe summer season. July and August are the monsoon months in Arizona. So, most days and nights have been cloudy. We finally got some rain, 1.75 inches in a few hours. That may not sound like very much, but that is almost as much as we have gotten since November (less than 2.0 inches through the end of June). Fortunately, there have been only a few small fires in the surrounding mountains.

Pleiades

Uranus

Venus



Neptune

Saturn

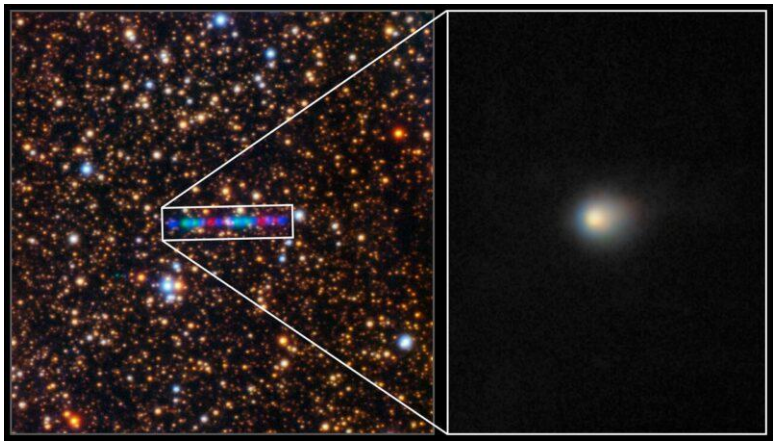
I have not taken many sky pictures recently, but I do have a few to show. Laurie Ansorge was on her way with her family to Astrocon 2025 in Bryce Canyon (there was a fire nearby). On the way, they stopped to visit Meteor Crater. She sent the picture on the upper left to me. On the upper right is a picture taken by my friend Tim Hunter on July 18 (with a 6-inch refractor). It has been processed a little by Mike Weasner. This

is Saturn, Titan, and Titan's shadow on Saturn. On the morning of July 4, it was clear (sort of) I was able to get morning images, lower left, of Venus, the Pleiades, and between them, Uranus at magnitude 5.8. It then cleared to the south, and I was able to image (lower right) Saturn and Neptune at magnitude 7.9. Both images were two-minute exposures. The Venus image is cropped from the original by a factor of 2 and the right image by a factor of 5. Uranus and Venus were about 2 degrees apart and Neptune and Saturn were less than a degree apart.

Astronomy in the News

3I/Atlas Update:

3I/Atlas was discovered on July 1, and I wrote about it on July 3. A lot has happened since then. There was confirmation that the object could be classified as an interstellar object and it has a distinctive coma, so it is cometary in nature. Even though there are some low-resolution spectra of the comet, the comet is likely too faint for the detection of expected ices such as carbon monoxide, carbon dioxide, or water. While the preliminary observations estimated the diameter of the comet to be as large as 20 km across, a recent preprint puts an upper limit of 12 km (7 miles) for its diameter. While going through its commissioning, the Vera Rubin Observatory serendipitously observed the comet from June 21 (10 days before it was discovered) to July 7. A coma was seen in the first images when the comet was at 4.8 AU from the Sun, just inside the orbit of Jupiter. During this time, no lightcurve was detected, implying that the comet is fairly spherical. A team of scientists have from the "Milky Way's thick disk, the core population of determined that the comet is likely to have originated ancient stars orbiting above and below the thin plane where the Sun and most stars reside."



"On the left, the interstellar object Comet 3I/ATLAS streaks across a dense star field as seen by the Gemini North telescope in Hawaii. The colors are courtesy of 3 filters: red, green and blue. On the right, an inset shows the comet's compact coma, or cloud of gas and dust surrounding its icy nucleus. NOIRLab released this new image on July 15, 2025. Image via International Gemini Observatory/ NOIRLab/ NSF/ AURA/ K. Meech (IfA/U. Hawaii). Image processing: Jen Miller & Mahdi Zamani (NSF NOIRLab)."

https://www.space.com/astronomy/comets/see-interstellar-comet-3i-atlas-zoom-through-solar-system-in-new-telescope-imagery-video

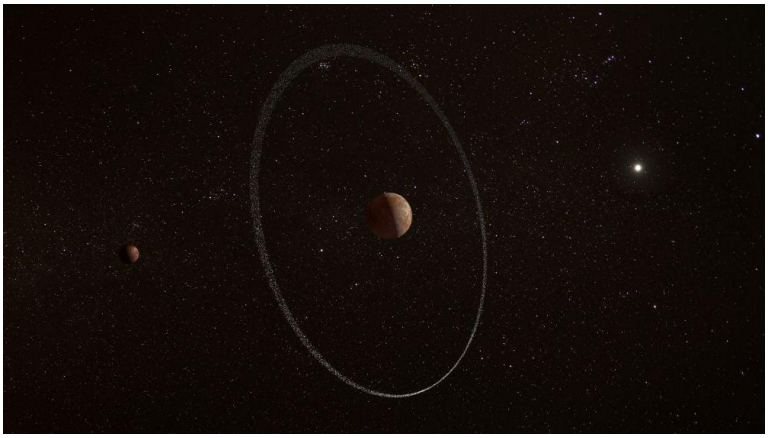
https://www.sciencealert.com/astronomers-have-traced-our-new-interstellar-comets-origin-and-its-a-first

https://earthsky.org/space/interstellar-comet-3i-atlas-oldest-comet/

https://earthsky.org/space/new-interstellar-object-candidate-heading-toward-the-sun-a11pl3z/

NASA, ESA, and Other Missions:

JWST, Quaoar's Atmosphere:

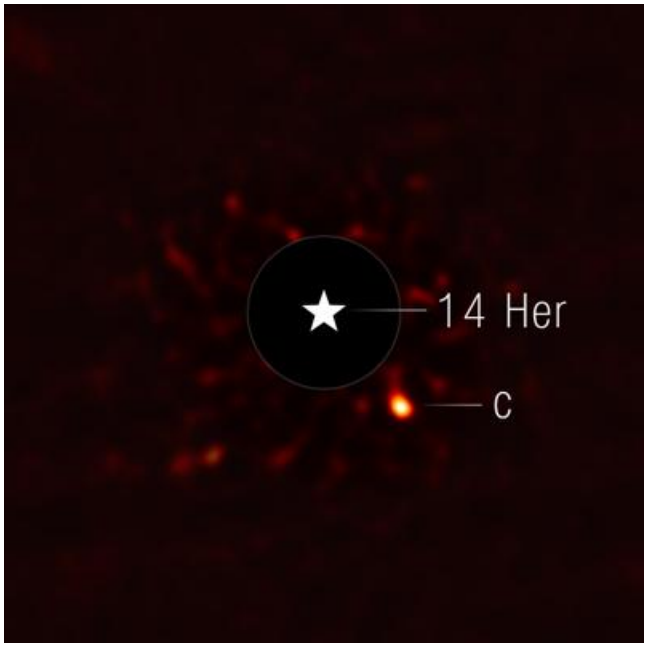


Artist's impression of Quaoar, its larger ring, and Weywot [moon]. Credit - ESA

50000 Quaoar is one of the largest Kuiper belt objects with a mean diameter of about 1,100 km (680 miles) this is less than half the diameter of Pluto and slightly less than the diameter of Pluto's moon Charon, but larger than Ceres. Previous observations of Quaoar have discovered that it has a small moon, Weywot, and two rings. Crystaline water ice and ammonia hydrate have been detected on its surface and two rings were seen in a previous stellar occultation. There were observations that also showed that Quaoar might have a thin atmosphere. The surface composition implied that the surface has to be replenished, implying there may be active cryovolcanism, ice volcanoes (seen on other icy bodies). The JWST stellar occultation reported here was able to make more detailed observations of the rings but did not detect any trace of an atmosphere. There are several unexplained mysteries.The inner ring seems to be only a partial ring implying there may be unseen shepherding moons. Also, why are there rings at all? At their present distance, rings should eventually coalesce to form moons. It is possible that there are unseen small moons or another ring. I should mention that while Quaoar is not officially a dwarf planet, it is large enough to be spherical and is one of four or five large TNOs that many planetary scientists consider to be dwarf planets. A final comment. One of the indigenous people of Southern California are the Tongva people. Quaoar is a creation deity and his son is Weywot.

https://www.universetoday.com/articles/quaoars-atmosphere-doesnt-exist-and-its-rings-shouldnt

JWST Images Unusual Exoplanet:



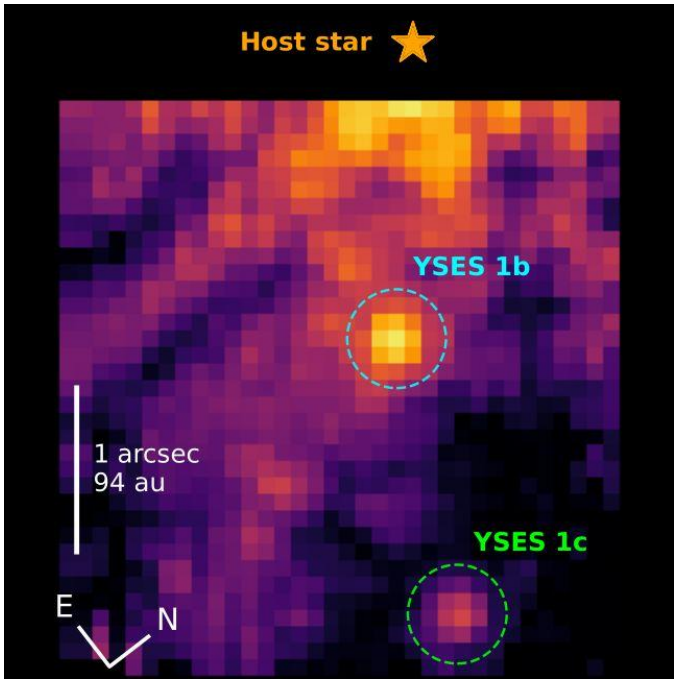
14 Hercules is a K0 (orange) star that is a little smaller and a little cooler than the Sun. It is a little less than 60 light-years from us. It is orbited by two exoplanets, 14 Her b, 9 times the mass of Jupiter and orbiting the star at a distance of 2.8 AU, and 14 Her c, 8 times the mass of Jupiter and orbiting at a distance of 20 AU (with a large uncertainty). Both were discovered by the radial velocity method (Doppler shift of spectral lines) and confirmed by astrometry (the wobble of the star as the exoplanet tugs on the star). JWST has now imaged 14 Her c (14 Her b is behind the occulting disk used to block out the light from the star). Given the age of the star system, about 4 billion years old, and the mass of the exoplanet, astronomers can estimate the temperature of the exoplanet as it cooled down from when it formed. The astronomers using NIRCam have found that the temperature is cool, cooler than predicted: 270 K (26° F). This is likely to have to do with mixing in the atmosphere. Another interesting fact about this planetary system: the two exoplanets both orbit retrograde relative to the rotation axis of the star, the orbits are both highly elliptical, and the orbits are tilted about 30 or 40 degrees relative to each other (the articles say 40 degrees, but the Catalog of Exoplanets says 30 degrees). One theory is that there was a third exoplanet that was ejected from the planetary system as the exoplanets interacted soon after formation.

https://webbtelescope.org/contents/news-releases/2025/news-2025-125.html

https://earthsky.org/space/cold-exoplanet-14-herculis-c-webb-space-telescope

JWST Images Exoplanets:

YSES 1 (Young Stars Exoplanet Survey) is a young solar-type star that is about 310 light-years from us. It is estimated to be about 27 million years old. It is orbited by two exoplanets, YSES 1b with a mass that is about 21 times that of Jupiter [could it be a brown dwarf??] and orbits at a distance of 160 AU with a period of 4,500 years and YSES 1c that has as mass that is about 7 times that of Jupiter that orbits at a distance of 320 AU with an orbital period of 5,700 years. Both of these were detected by imaging of the star in 2020. The research paper referenced in the articles below is based on JWST NIRSpec follow-up observations. The atmospheric detection method is not mentioned in the links below, but both exoplanets/brown dwarfs radiate in the infrared and molecules in the atmosphere can be detected by the thermal light as it passes through the atmosphere. Previous observations found weak evidence of the presence of water vapor and carbon monoxide in the atmospheres of both exoplanets. The new observations confirm these atmospheric components. In addition, carbon dioxide, methane, and silicate particles were detected in the atmosphere of YSES 1c. No silicate grains were found in the atmosphere of YSES, but a cloud of the mineral olivine was found in a cloud surrounding the exoplanet. It is proposed that what is seen are the remnants of an asteroid-sized body that collided with the exoplanet some time in the past few million years.



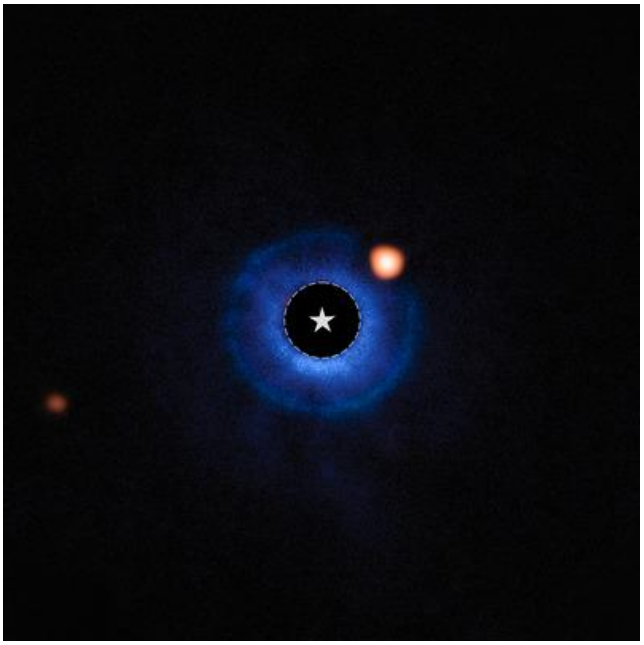
JWST NIRSpec image showing the two exoplanets. (Hoch et al., *Nature*, 2025)

https://www.sciencealert.com/stunning-direct-images-of-alien-worlds-are-detailed-enough-to-reveal-clouds

https://www.spacedaily.com/reports/Silicate_clouds_discovered_in_atmosphere_of_distant_exoplanet_999.html

JWST, New Exoplanet:

In the previous two articles, JWST observed exoplanets that were already known. The research reported here is for the first exoplanet to be discovered by JWST. CE Antliae (TWA 7) is a low mass star with a mass about 0.5 times that of the Sun. It is a M1 (red) star that is going through its T Tauri phase, stars that are still contracting and accreting dust and gas from protoplanetary disks, so they are powered by gravitational collapse, not fusion. The star is about 6.4 million years old. In 2016 reprocessed HST images (from 1998) showed that TWA 7 was surrounded by a dust disk that extended out to 35 AU. Later observations showed an outer ring and a spiral arm, plus a possible inner ring. The research paper reported here is JWST's detection of a Saturn-sized exoplanet embedded in the middle of the ring system.



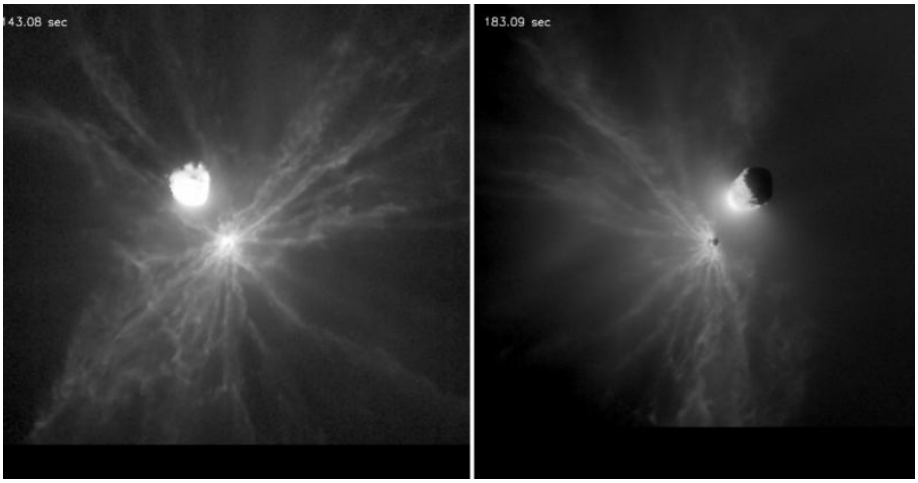
TWA 7 (MIRI and VLT image) Credit - NASA, ESA, CSA, Anne-Marie Lagrange (CNRS, UGA), Mahdi Zamani (ESA/Webb)

https://webbtelescope.org/contents/news-releases/2025/news-2025-126.html

https://www.universetoday.com/articles/webb-directly-images-a-saturn-sized-star-in-a-nearby-system

DART Update:

In September 2022 the DART (Double Asteroid Redirect Test) spacecraft crashed into Dimorphos, the small moon of the asteroid 65803 Didymos, a 765-meter (2,500 foot) Near Earth Asteroid. Dimorphos had a diameter of 160 meters (525 feet). The spacecraft was orbiting slower than the asteroid and moon, so technically the moon ran into the asteroid! The impact ultimately slowed the moon down from an orbital period of 11 hr 55 min to 11hr 23 min. This was significantly greater than had been predicted by any impact models. The DART spacecraft had a companion CubesSat, LICIACube (Light Italian CubeSat for Imaging of Asteroids), that flew by Dimorphos 165 seconds after the impact in order to record the effects of the impact. It flew by at a distance of 56.7 km (35.2 miles). The images from the CubeSat were used by scientists to monitor 104 boulders, ranging in size from 0.4 to 7.2 meters (1.3 to 23.6 feet) in diameter. It was the reaction of the launching of these boulders that gave the impact its extra boost. What was surprising and what is reported in this research, is that the ejecta did not come off the moon in uniform pattern, but in two streams. What the scientists found was that one of the solar panels (11 square meters, 120 square feet) hit the surface (hit two large boulders) just before the main body of the DART spacecraft hit. This caused the unexpected distribution of ejecta. This also means that any attempt to deflect an incoming asteroid may be more complicated than originally thought. [As a side note, it is always interesting to see how scientists name their spacecraft and instruments, often using acronyms (or technically backronyms). The LICIAcube CubeSat had two cameras, a narrow angle imager, LICIACube Explorer Imaging for Asteroid, and a wide-angle color imager, LICIACube Unit Key Explorer, LEIA and LUKE.]



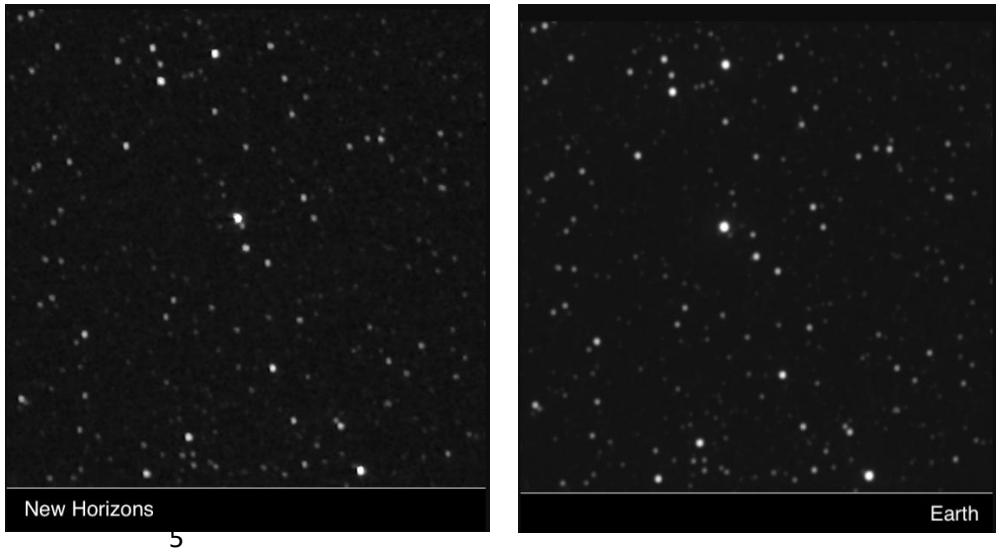
"These images, showing ejecta around the impacted near-Earth asteroid Dimorphos, were taken during the approach (with companion asteroid Didymos to the upper left) and departure (Didymos to the upper right) of DART's companion spacecraft, LICIACube, which flew past a few minutes after the DART impact and imaged the aftermath. The ejecta field consists of an asymmetric cone of dust that exhibits streamers and filaments, as well as more than 100 meter-sized (yard-sized) boulders that were ejected in preferred directions. Image via NASA/ LICIACube/ University of Maryland."

https://earthsky.org/space/dart-mission-unleashed-a-blitz-of-boulders-into-space

https://cmns.umd.edu/news-events/news/massive-boulders-ejected-during-dart-mission-complicate-future-asteroid-deflection

New Horizons: Deep Space Navigation:

Astronomers have used parallax to determine, in 3 dimensions, the location of the New Horizons spacecraft. While this is not as accurate as receiving radio signals directly from the spacecraft, it is the first time that a spacecraft with a high resolution camera has been pinpointed by comparing images from space and from the Earth. If you hold your index finger up at arm's length and blink your eyes, the finger will appear to be in a different position relative to the



distant background stars. This is an example of parallax. The New Horizons spacecraft imaged Proxima Centauri at the same time as a telescope on Earth observed the same starfield. The results are the images above. This was then repeated for another nearby star, Wolf 359, with similar results. With these sets of images, the astronomers could determine the location of the New Horizons spacecraft to within 0.2 AU at a distance of 47 AU, well beyond the orbit of Pluto. The result was limited by the resolution of the spacecraft camera but demonstrated that distances could be determined using this method.

https://earthsky.org/space/a-deep-space-navigation-first-from-new-horizons

Meteors, Meteorites, Asteroids, and Comets:

As of July 27, 2025, there are 1,456,276 known minor planets (3,990 added since June 10). Of these, 811,724 are numbered (18,486). There are 4,603 known comets (7 added). Of these, 495 are numbered. There are 38,878 (265 more) Near-Earth Objects (NEOs). There are 871 NEOs larger than a kilometer (0.6 miles) in diameter. There are 11,354 NEOs larger than 140 meters (460 ft) in diameter. [A note: there are two sources for these numbers, and they never agree exactly, even if they are updated the same day. JPL has more total asteroids by over 10 thousand and the IAU has more NEOs by a few hundred. I use JPL for total asteroids and IAU for total NEOs.] 1,416 NEOs have been discovered since the beginning of the year. A potentially hazardous asteroid is an asteroid whose orbit could bring it with 0.05 AU of Earth and is estimated to be at least 140 meters in diameter. However, many of these have orbits that are fairly-well characterized so there is little to no risk of their hitting Earth in the near future. ESA lists just those that have some potential chance of hitting Earth, usually due to orbital uncertainties. This is why my team observes them on the VATT so that we can reduce these uncertainties. ESA's "At Risk" list as of July 26, 2025, is 1,798 Near-Earth Objects (6 more).

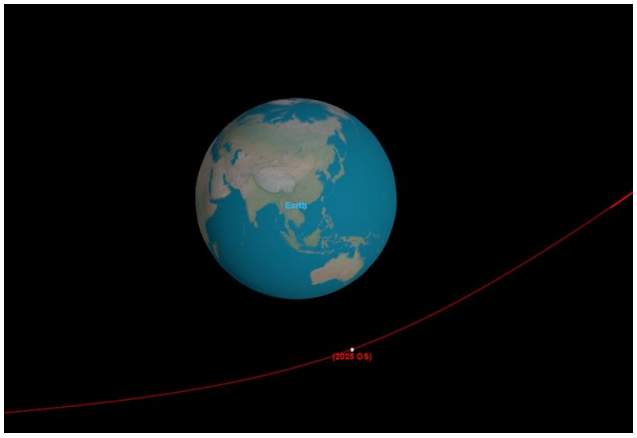
Asteroid Close Approaches:

In the last 30 days, 8 asteroids have been **observed** to have come closer to the Earth than the distance to the Moon (LD) with estimated diameters from about 1.5 meters in diameter to about 27 meters in diameter (if high or low reflectivity, respectively). There were 6 additional asteroids observed that came as close as 1.0 to 2.0 times the distance of the Moon, with estimated diameters between 8.0 and 50 meters. In the next 60 days, no asteroids are **predicted** to come closer to us than the Moon and one between 1.0 and 2.0 times the distance to the Moon with an estimated diameter between 54 and 120 meters in diameter. I have not looked all of these up to determine when they were first observed. Most were first observed within days of their closest approaches, but some were not observed until after their closest approaches, 2025 OS, for example.

Between July 10 (observed) and September 23 (predicted in the next 60 days), 10 asteroids with estimated diameters between about 70 meters and 530 meters in diameter have passed/will pass between 2.2 and 16.8 lunar distances of the Earth. Of the three large asteroids that have been **observed** to pass within 20 LD (0.05 AU) of the Earth between July 10 and July 15, one was discovered prior to this year. It was discovered in 2005. Two were discovered in 2025. Of the seven asteroids that are **predicted** to pass within 20 LD (0.05 AU) of the Earth between August 8, 2025, and September 23, 2025, five were discovered prior to 2025. One was discovered in 1997, one was discovered in 1998, one was discovered in 2009, one was discovered in 2018, and one was discovered in 2022. Of the 84 (down from 94 and 147 last two Newsletters, continued bad weather?) asteroids that were seen or are predicted to come within 20 lunar distances of the Earth (about 0.05 AU) between June 27 and August 24, we have not observed any of these, since our last two runs were in early to mid-June.

Asteroid Close Approach:

Here is an example of the collaboration between professional and amateur astronomers. On the evening of July 19, an ATLAS (Asteroid Terrestrial Impact Last Alert System) discovered a small (3 to 9 meters, 10 to 30 feet, in diameter) asteroid that had flown close to the Earth a few hours earlier, now designated as 2025 OS. Over the next 23 hours, professional and amateur astronomers made a total of 21 observations of this asteroid before it was too faint to observe. The asteroid had come within 10,500 km (6,500 miles) of the Earth. That is only 4,000 km (2,500 miles) of the surface of the Earth. Not in the article, but, while the asteroid is not predicted to make any future close approaches to the Earth, in the next 50 years, it will come within about 1.5 AU of Jupiter, close enough to be affected by Jupiter's gravity.

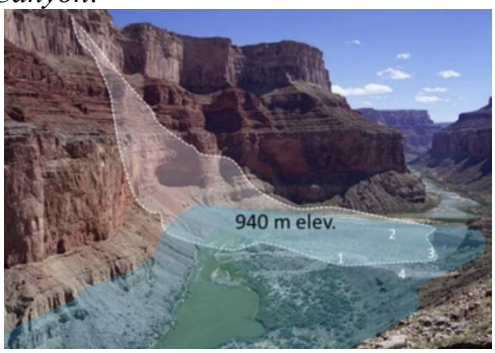


"Here's an illustration showing the path of asteroid 2025 OS that safely passed Earth on July 18. Image via NASA/ JPL."

https://earthsky.org/space/asteroid-safely-buzzed-earth-this-weekend/

Asteroid Impact and the Grand Canyon:

Geologists have been able to date driftwood in lake sediment in Stanton's Cave and one other cave along the Colorado River in the Grand Canyon. These caves are about 45 meters (150 ft) above the river level. The driftwood has been dated at about 55,600 years old. How did the driftwood get there? Downstream near Nankoweap Canyon (north of Flagstaff, AZ) there is evidence of a massive landslide more than 50,000 years ago that would have created a lake 80 km (50 miles) long and 300 feet deep, long enough and deep enough to have left the driftwood in these caves. David Kring from the Lunar and Planetary Institute is an expert on Meteor Crater. He estimates that the iron impactor that formed Meteor Crater about 50,000 years ago would have created a magnitude 6 earthquake at the crater site and would have been felt as a magnitude 3.5 to 4.1 earthquake 190 km away (118 miles) at the site of the landslide. The uncertainty in the age of Meteor Crater implies that the earthquake it created could have triggered the landslide. The authors of the paper also note that the Meteor Crater impactor came from the north, passing about 50 km (30 miles) east of the landslide and the air shockwave could have also contributed to the triggering of the landslide.



Schematic illustration outlining the locations of the dam and the ancient lake caused by blocking of the Colorado River. Image via University of Arizona.

Meteor Crater

https://www.livescience.com/planet-earth/geology/giant-meteor-impact-may-have-triggered-massive-grand-canyon-landslide-56-000-years-ago

https://earthsky.org/earth/grand-canyon-landslide-and-lake-due-to-meteor-crater-impact

Moons and Rings:

As of July 18, 2025 (last update), there are 418 moons (satellites) orbiting six planets (no change). As of July 20, 2025 (last update), there are 589 asteroids, dwarf planets, Centaurs, and Trans-Neptunian Objects with companions (7 more than the last update on May 24). There are 571 binary systems (7 more), 16 triple systems (same), 1 quadruple (130 Elektra), and 1 sextuple system (Pluto), for a total of 611 companions (7 more). To break this down, 108 Near-Earth Objects (no change) have companion moons (5 have 2 moons, same), 35 Mars-Crossing Asteroids (same) have companion moons (1 with 2 moons), 296 Main Belt

Asteroids (7 more) have companion moons (1 with 3 moons, 8 with two moons, and 1 with 1 moon and rings; 1 also has dual asteroid/comet designation), 8 Trojan Asteroids have companion moons (same), and 142 Outer Solar System Objects (dwarf planets, Centaurs, and Trans-Neptunian Objects) (same) have companion moons (2 with 2 moons, 1 with 5 moons). There are 4 TNOs and Centaurs with moons that have or are suspected to have rings (same) and 1 with rings but no moons. For those of you doing the Solar System Classification activity, this is a good example of how there is overlap among planets, dwarf planets, and asteroids as to how we classify them based on characteristics (moons and rings in this case. There are more satellites/moons of asteroids than there are of planets, 589 vs. 418. There are also more asteroids with rings than there are planets with rings, 5 vs. 4.

Active Charon:

It is hard to believe that it is exactly 10 years since the New Horizons spacecraft flew by Pluto and its five moons. The largest moon of Pluto is Charon with a diameter about half that of Pluto (pre-reclassification of Pluto, Pluto and Charon were proposed to be a binary planetary system). However, astronomers are still learning more about Charon today. In January, I reported about the "kiss and capture" model for the formation, a Kuiper belt object impacted Pluto slowly enough for the two to remain in contact for a short period of time before tidal forces separated them. What is seen in Charon's southern hemisphere is evidence of resurfacing cryovolcanism (water ice volcanoes) about 4 billion years ago. While they do not get into the details of the Pluto-proto-Charon impact, they conclude that proto-Charon was a solid icy body before the collision. The models show that within 150 million years, a subsurface ocean was formed. The length of time this ocean existed before it froze is dependent on the amount of ammonia present. With 10% ammonia in the liquid water ocean, the ocean may still exist today. None of the models were consistent with early freezing of the ocean, and so inconsistent with a 4-billion-year- old surface. Some other mechanism may be required to account for the resurfacing episode and may be dependent on the details of the original impact of proto-Charon into Pluto.

False-color image of Charon using red, blue, and infrared filters to highlight specific surface features. (Credit: NASA/JPL-JHU/SWRI)

https://www.universetoday.com/articles/cryovolcanism-and-resurfacing-on-plutos-largest-moon-charon

Planets and Dwarf Planets:

Oldest Crater Revisited:

Back in March, I reported on the discovery of the oldest crater on Earth, 3.5 billion years old (older than the previous one at 2.2 billion years old) and about 100 km (60 miles) in diameter. This was based on the discovery of shatter cones, Earth rocks that have been subjected to high pressure that form the central peaks of large craters). The age estimate was based on the geologists finding shatter cones buried in sediment that was 3.5 billion years old (the shatter cones thus had to be older). In this more recent paper, a different group of geologists were also studying the same region. They found shatter cones (not seen by the previous group in volcanic rock in lavas that were only 2.77 billion years old, so the impact had to have been more recent than that, perhaps much younger. They also estimated that the crater was only about 16 km across! It will be interesting how this story/research unfolds!

https://www.sciencealert.com/scientists-just-debunked-earths-oldest-impact-crater

Oldest Rock on Earth:

The Nuvvuagittuq Greenstone Belt in Quebec, Canada has long been known to contain some of the oldest rocks on Earth. However, it has been difficult to determine their actual age. The research reported here uses zircons to determine the age of the rocks. Zircons are resistant to high temperatures. When they form, they retain uranium but reject lead. Therefore, any lead in the zircons is from the radioactive decay of the uranium. Instead of looking at the basaltic greenstone, they looked at inclusions of metagabbros, an igneous rock, gabbro, that has been metamorphosed (altered under heat and pressure) within the Earth's crust and then intruded into older basalts (the greenstone) when volcanic activity brought them back to the surface. The zircons were dated at 4.16 billion years old, implying that the gabbro was that age and the greenstone had to be at least that old.

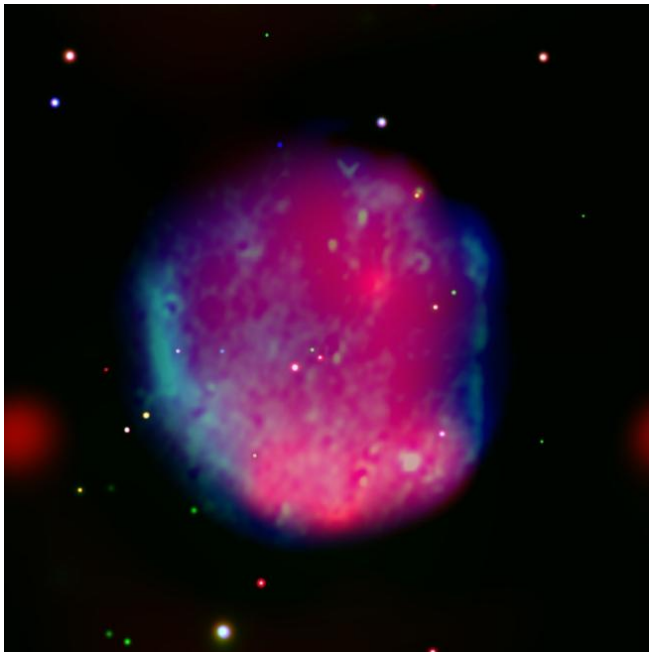
Metagabbroic rock ripples through the Nuvvuagittuq Greenstone Belt. (Jonathan O'Neil)

Metagabbroic rock from the formation gives us a new date for its age. (Jonathan O'Neil)

https://www.sciencealert.com/4-billion-year-old-stripey-rocks-in-canada-may-be-the-oldest-on-earth

Supernovae and Climate Change:

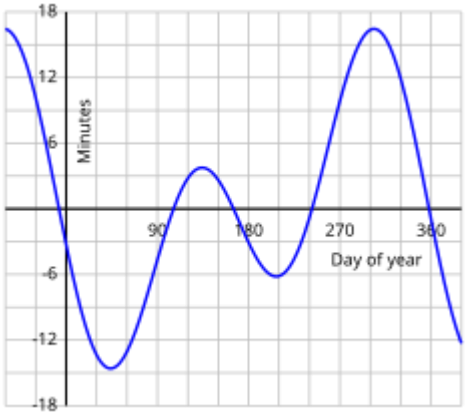
I usually do not quote the Bible, but "ask and you shall receive." Way back in June, I reported on research that found a carbon-14 excess in tree rings about 13,500 years ago that the authors proposed was due to a solar flares 500 times greater than several recent major flares. Solar storms disrupt the Earth's magnetic field and allow high energy cosmic rays to reach the Earth's upper atmosphere and create carbon-14. This carbon-14 is absorbed by trees and appears as a spike in the carbon-14. The date of such events can be determined by dendrochronologists (scientists who study tree rings, who would have thought I would have used that term twice in a month). When I reported the solar storm results, I mentioned that I was not sure how one can tell the difference between carbon-14 produced as the result of a solar flare and carbon-14 produced by X-rays from a supernova. In this new research, the author found seven carbon-14 spikes, two at 14,320 years ago and at 12,760 years ago, both very close to abrupt cooling periods on Earth. In the case of the first one, that is very close to the estimated date of a supernova explosion 1,140 light-years from us that created the Hoinga supernova remnant. The author raises the possibility that supernova events may be responsible for at least some cooling events. I should note that the author does at least acknowledge that some of the carbon-14 spikes could be do to solar storms. I should also note, that there are several other scientists who attribute the cooling events to comet impact event (for some reason they rule out asteroids). At least in the case of the earlier carbon-14 spike, a potential source (Hoinga), and a cooling event seems plausible.



"The Hoinga supernova remnant is about the size of 90 full moons, making it the largest supernova ever discovered in X-rays. It might be responsible for a cooling period on Earth more than 14,000 years ago. Image via eROSITA/ MPE (X-ray), CHIPASS/ SPASS/ N. Hurley-Walker, ICRAR-Curtin (radio)."

https://earthsky.org/earth/supernovas-linked-to-climate-change-cooling

Earth Speeding Up:



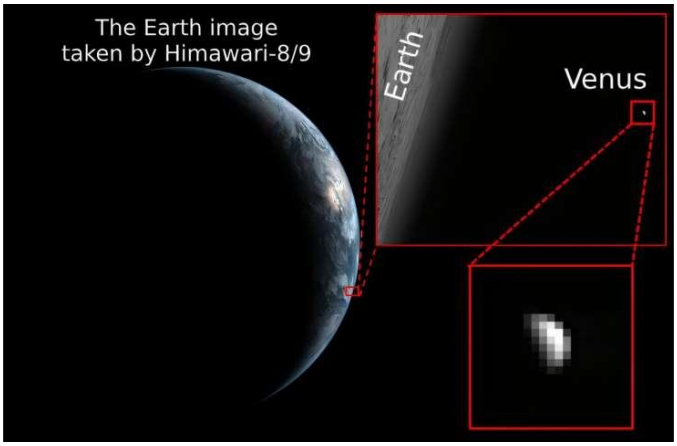
I want to try to clarify one or two things. There are two "days" that are used in astronomy, the solar day, the time from solar noon to solar noon and the sidereal day, the rotation of the Earth relative to the background stars. The mean solar day averaged over the year is 24 hours. However, the sidereal day is 23 hr 56 min 4.09054 sec. You are probably aware of this because this is why the stars rise about 4 min earlier every day and it adds up so that we have seasonal constellations. The reason for this difference is because the Earth, as it rotates on its axis, is revolving around the Sun. For those of you who were you who were in Astronomy Camp, we demonstrated this with the Orrery. As the articles explain, the rotation rate of the Earth over thousands and millions of years has been slowing down because of tidal interaction between the Earth and the Moon. However, recently the Earth's rotation rate has been speeding up. The sidereal day is getting shorter, and so the solar dayIn fact, the greatest decreases have been in previous years, according to timeanddate.com. There are some large (more than a millisecond) decreases in July and August that appear to be, in part, related to the position of the Moon relative to the equator of the Earth. Finally, as I mentioned earlier, 24 hours is the *mean* length of the solar day. It varies over the course of the year because the orbit of the Earth is elliptical, and the axis of the Earth is tilted. This gives us what is called the equation of time which I have shown above as a graph and on the sundial in our back yard. Over the course of the year, the length of the solar day is exactly 24 hours four times during the year, including July 25/26. The length of the solar day can be as much as 21.3 seconds shorter than 24 hours (September 16) or 29.9 seconds longer (December 22). The last link is to the Wikipedia page that describes the difference between sidereal and solar time.

https://www.livescience.com/planet-earth/earth-just-had-a-freakishly-short-day-but-the-fastest-day-of-the-year-is-yet-to-come

https://www.timeanddate.com/time/earth-rotation.html

https://en.wikipedia.org/wiki/Sidereal_time

Venus Weather:



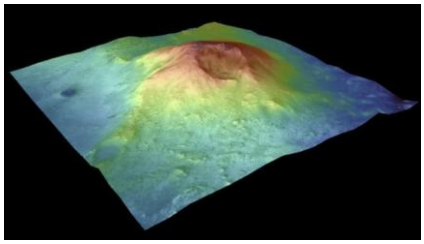
In 2014, the Japanese Space Agency launched Himawari-8 ("sunflower") into a geostationary orbit to monitor weather over Japan and the western Pacific. It later launched Himawari-9 to eventually take over from Himawari-8. These satellites are medium-resolution instruments that cover 0.5 microns (visible) to 13 microns (thermal infrared) at a resolution from 0.5 to 2 kilometers. Images are taken at 10-minute intervals The authors of this paper recently realized that, since the spacecraft's field of view was slightly larger than the Earth, they might see other Solar System objects. While the authors first looked for images of the Moon, they also found images of Mercury, Venus, Mars, and Jupiter. In this paper they report on their findings on the atmosphere of Venus, using 437 images. Over the 10 years of observations, they have found the most significant atmospheric variations around sunrise on Venus which they believe are "related to waves circulating around the planet in the atmosphere."

https://phys.org/news/2025-06-serendipitous-satellite-snapshots-venus-weather.html

https://www.space.com/astronomy/venus/2-earth-weather-satellites-accidentally-spy-on-venus

Mars Volcano Hiding in Plain Sight:
Geologists studying archived images of Jezero crater, the landing site of the Perseverance Mars rover have discovered, a previously unidentified volcanic crater. It was originally thought to be a mountain on the rim of Jezero that happened to be topped by an impact crater. Recent analysis and the discovery of basaltic material, lava flows.

The location of Jezero Mons is not far from where the Perseverance rover landed. (Cuevas-Quiñones et al., *Commun. Earth Environ*., 2025)

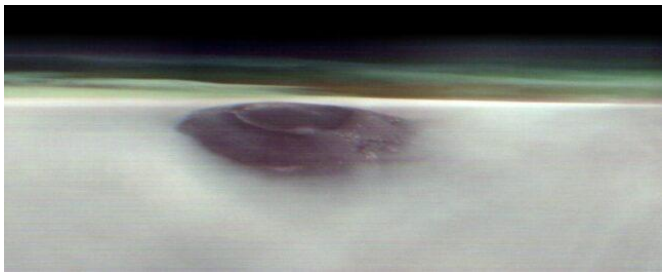


A reconstruction of the shape of Jezero Mons, colored to show elevation. (Cuevas-Quiñones et al., , 2025), height greatly enhanced

https://earthsky.org/space/hidden-mars-volcano-jezero-mons-jezero-crater-perseverance-rover

https://www.sciencealert.com/volcano-found-hiding-in-plain-sight-right-next-to-nasa-mars-rover

Cloudy Mars:
NASA's Mars Odyssey has imaged the shield volcano Arsia Mons as it peeks through the morning clouds on Mars that are not uncommon when Mars is farthest from the Sun. Arsia Mons is the tallest of the three shield volcanos known as the Tharsis Montes. It is nearly 20 km (12 miles) high. The tallest mountain on Earth (from base to peak is Mauna Kea on the Big Island of Hawaii, at 10.2 kilometers. By volume, the largest mountain on Earth is Mauna Kea's neighbor, Mauna Loa. Arsia Mons has 30 times the volume of Mauna Loa. However, the largest mountain on Mars is Olympus Mons, also on what is called the Tharsis Bulge. It is 21.9 kilometers (13.6 miles) high. I would note that, in 1879, Giovanni Schiaparelli (known for *canali,* channels, on Mars) identified a feature which he named Nix Olympica ("snow of Olympus") for the white feature that he saw on Mars. He was correct, as he saw either snow or cloud cover on what we now call Olympus Mons.

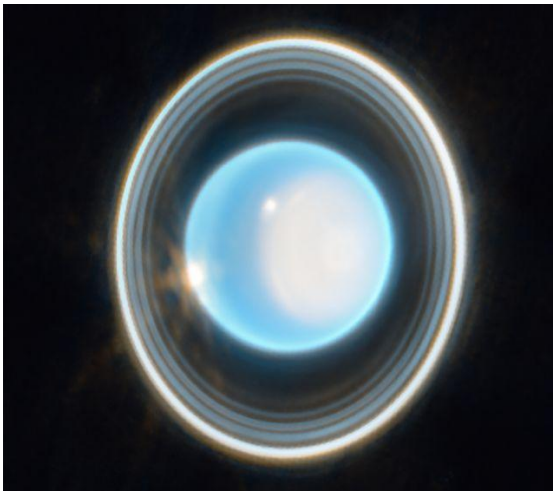


The shield volcano Arsia Mons peeks through the clouds on Mars in an image taken by the Mars Odyssey orbiter. (NASA/JPL-Caltech/ASU)

https://www.sciencealert.com/nasa-satellite-glimpses-giant-volcano-peeking-above-the-clouds-of-mars

https://www.livescience.com/space/mars/nasa-spots-martian-volcano-twice-the-height-of-mount-everest-bursting-through-the-morning-clouds-space-photo-of-the-week

Uranus is Hot:
Voyager observations (and subsequent observations from Earth) have shown that Jupiter, Saturn, and Neptune are all emitting more than twice as much energy (heat) than they receive from the Sun. This is consistent with formation and thermal models that show that they are still contracting from when they formed more than 4.5 billion years ago. However, Voyager 2 did not show any excess heat from Uranus (there was unusual solar activity that affected what was seen at Uranus). Two separate teams of scientists have reanalyzed over a decade of data and have both concluded that Uranus does emit more than it receives from the Sun. However, the excess is only 12.5%, nowhere near what the other gas and ice giants emit. Something unusual is happening with Uranus, but that will require future observations.

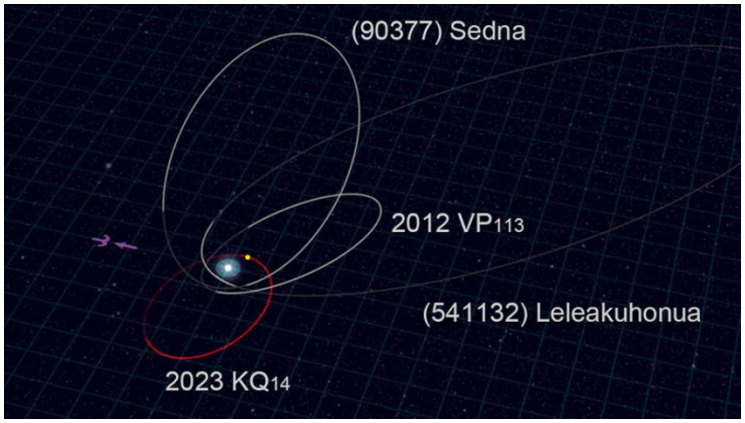


An image obtained by JWST of the rings of Uranus. (NASA, ESA, CSA, STScI, J. DePasquale)

https://www.sciencealert.com/confirmed-uranus-really-is-hotter-than-it-has-any-right-to-be

https://www.space.com/astronomy/uranus/scientists-find-uranus-is-surprisingly-warm-heating-up-the-case-for-a-new-planetary-mission

Another Potential Dwarf Planet:



In May, I reported on the possible detection of a large outer Solar System Body (Trans-Neptunian Object, TNO) that the authors claimed could be Planet Nine. However, without any follow-up observations, this cannot be confirmed. Last month, I reported on the discovery of a potential dwarf planet (or at least a large TNO). These were solid observations spanning eight years, so, follow-up observations are likely, especially with the coming online of the Rubin telescope. The observations reported here are again fairly solid, with 24 observations spanning 19 years. The TNO, 2023 KQ14, has a mean distance of 245 AU and is in an orbit that takes it from 65 AU out to 425 AU, with an orbital period of about 3,850 years. This puts it the region where it is considered to be the fifth Sednoid, named after the potential dwarf planet Sedna. These TNOs have perihelia (closes distance from the Sun of between 65 AU and 80 AU, so are far from any potential gravitational influence by any of the planets, so they most likely formed close to their present locations. Before the discovery of 2023 KQ14, the alignment of the orbital elements (primarily the direction of their closest distance to the Sun) was considered to be supportive of the idea that there is a "Planet Nine" near there. However, the orbits of both 2017 FO201 and 2023 KQ14 do not align with the other TNOs and are considered possible evidence that Planet Nine cannot exist. 2023 KQ14 has the unofficial nickname of Ammonite and is estimated to be about 250 to 350 kilometers (150 to 200 miles) in diameter.

https://www.forbes.com/sites/jamiecartereurope/2025/07/15/meet-ammonite---a-new-world-just-found-in-the-solar-system/

https://www.space.com/astronomy/solar-system/astronomers-discover-a-cosmic-fossil-at-the-edge-of-the-solar-system-is-this-bad-news-for-planet-9

Exoplanet Update:

As of July 26, 2025, there are 7,560 confirmed extra-solar planets (66 more since June 10, my last update) orbiting 5,179 stars (44 more), with 1,053 star systems (7 more) having more than one exoplanet orbiting them. In addition, there are 2,447 candidate (unconfirmed) exoplanets (10 more) orbiting 2,140 stars (3 more), with 145 stars (3 more) having more than one exoplanet orbiting them. Most of these candidate exoplanets are likely to be real but need to be confirmed by more detailed ground-based observations or other techniques. I have always used the complete list from the Catalogue of Exoplanets. This includes "exoplanets" with masses greater than 13 times the mass of Jupiter which are more likely to be brown dwarfs. If I limit my list to exoplanets having a mass less than 13 times the mass of Jupiter, the total number is obvious less. Here are the revised statistics: 6031 confirmed exoplanets orbiting 4,529 stars, with 989 star systems having more than one exoplanet orbiting it. In addition, there are 2,010 candidate (unconfirmed) orbiting 1,854 stars, with 128 having more than one exoplanet. There are 747 binary star systems with about 950 exoplanets orbiting one of the stars (9 more systems) and there are 31 star systems with 39 exoplanets orbiting both stars in the binary system (same). Three star systems have three exoplanets orbiting both stars.

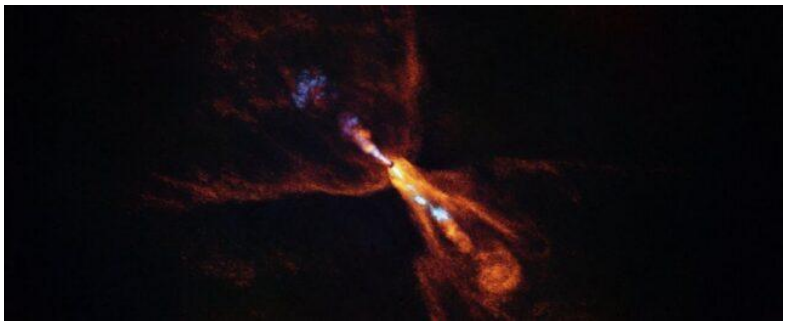
Planet-Forming Gas Disks:

Senior staff, post-doctoral fellows, and graduate students worked together, using ALMA (Atacama Large Millimeter/submillimeter Array) in Chile to map the gas and dust in 30 protoplanetary disks around Sun-like stars. These disks ranged in age from 1 million to 5 million years old. They found that as the protoplanetary disks evolved, the gas remained longer than the dust, much longer than models had predicted. This will have implications for how planets formed and how their atmospheres formed since the gas lasted longer. With their detailed observations, the team was able to detect a variety of molecules (listed in the link).

https://www.spacedaily.com/reports/ALMA_maps_evolution_of_planet_forming_gas_disks_over_millions_of_years_999.html

Birth of a Solar System:

HOPS-315 is a young star surrounded by a protoplanetary disk. The star, which is 0.6 times the mass of the Sun, is still accumulating material from the protoplanetary disk. The star is about 1,300 light-years away. Using ALMA on Earth at radio wavelengths and JWST at infrared wavelengths, astronomers have been able to pinpoint, at around 2.2 AU from the star, the region where silicon monoxide gas is condensing into grains of crystalline silicate minerals, the minerals that will accrete into larger and larger grains, the seeds of new planets.



ALMA image of HOPS-315, a baby star that is still forming. (ALMA (ESO/NAOJ/NRAO)/M. McClure et al.)

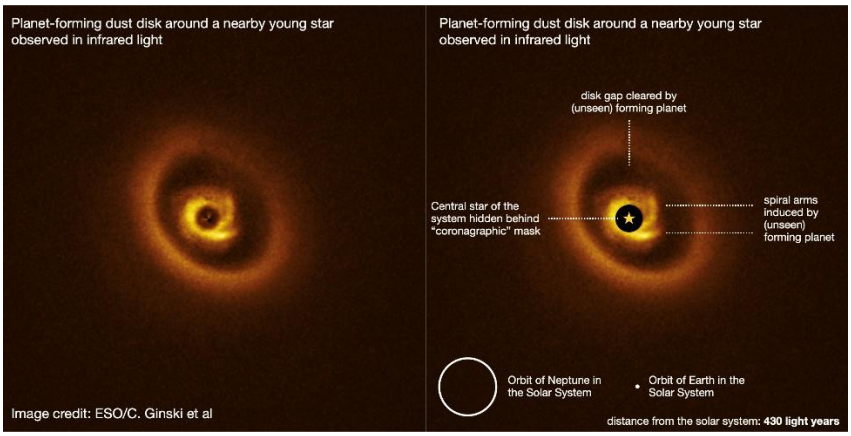
Comment: Both links below contain the image above which is the actual ALMA image and is in the published paper. However, both articles also contain two "illustrations" that is not in the published paper, showing the growing dust grains. These remind me of the asteroid field in Star Wars and is probably nothing like a true image of what you would see in the protoplanetary disk. I do not think the grains would be that close together.

https://www.sciencealert.com/birth-of-a-solar-system-witnessed-in-spectacular-scientific-first

https://www.space.com/astronomy/astronomers-witness-the-birth-of-a-planetary-system-for-the-1st-time-photo-video

A Planet is Born:

2MASSJ1612 is a young star that has a mass that is about 0.6 times the mass of the Sun and is about 430 light-years from us. It is likely that the star is still accreting material from the protoplanetary disk. The presence of a disk has been known for years and in 2024, images of the disk showed that there was a gap in the disk at a distance from the star that is a little greater than the distance of Neptune from the Sun. In the research reported here, astronomers used the Very Large Telescope in Chile to image the protoplanetary disk (I think the resolution is about 10 AU). They were able to obtain the image on the left that they interpret as the formation of a giant planet within the previously seen gap. Models for the formation of giant planets predict the presence of what appear to be spiral arms near the gap and that is what is seen in the image.

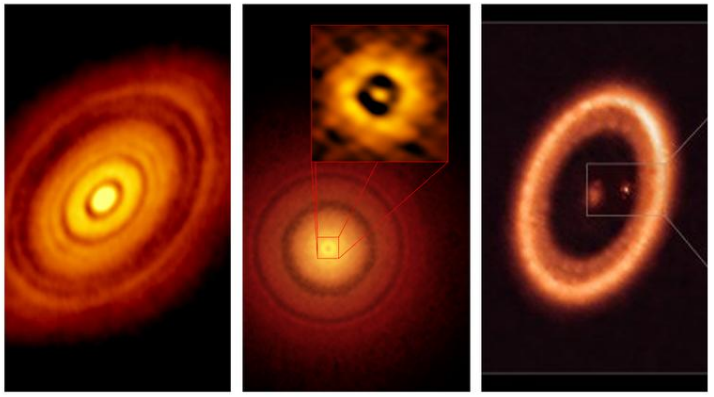


"A large forming planet would explain the structures in 2MASSJ1612's disk. (Image credit: ESO/C. Ginski et al.)"

https://www.livescience.com/space/exoplanets/see-a-young-star-potentially-giving-birth-to-a-giant-planet-in-new-image-from-very-large-telescope

Formation of Close-in Exoplanetary Systems:

The two online articles below represent two separate teams, one that developed a theoretical model for the formation of close-in, similar-sized exoplanets and the other presents the results of a study of 30 protoplanetary disks ALMA. However, the question that both teams are trying to answer is when do planets start forming? In the first paper, they are trying to understand why so many exoplanets are found close to their stars and are very similar in size. They conclude that, unlike previous models for planetary formation, planets start forming very soon after star formation, when the star is still accreting material from the young protoplanetary disk. In the second paper, their observations confirm this, as can be seen in the images above and as is implied in results presented in the first two articles above for HOPS-315 and 2MASSJ1612.



"ALMA images of a dusty disk around the star HL Tau, showing ringed structure and a gap at 1 AU from the forming star. The structure is likely being created by gravitational interactions with a possible planet in the disk. Our own Solar System might have looked like this some 4.5 billion years ago. Credit: ALMA/ESO.org"

https://www.universetoday.com/articles/new-theory-explains-why-so-many-exoplanets-crowd-close-to-their-stars

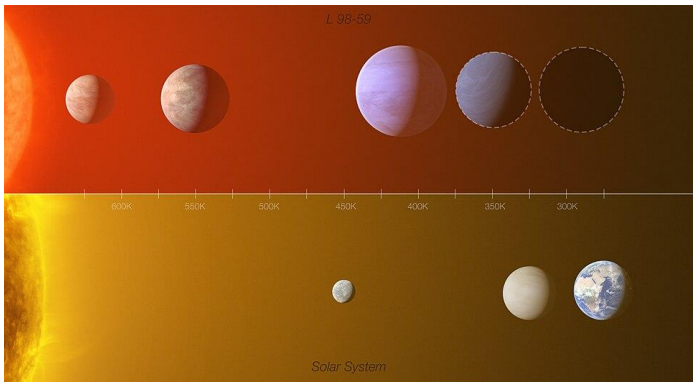
https://www.universetoday.com/articles/planets-form-earlier-than-thought-around-baby-

Exoplanet Discovery:

A few months ago, I wrote about the activities we did at the Tucson Festival of Books. One of the ways for discovering exoplanets is by what is called microlensing. I have written many times about HST and JWST using gravitational lensing to see distant faint galaxies that lie behind closer galaxy clusters. If a faint (invisible) star and its exoplanet(s) pass in front of a more distant visible star, the light from that star increases due to gravitational microlensing. Microlensing events can last for days, weeks, or months, depending on how fast the nearby star (and exoplanet) is moving relative to the more distant star. Since the events last so long, they can be monitored by multiple telescopes. Using microlensing, astronomers discovered a star and its exoplanet AT20021uey b. The star and exoplanet were first seen by the Gaia spacecraft and then were tracked by other telescopes. The entire microlensing event lasted more than 60 days and increased the light from the distant star by more than a magnitude. The results show that star is an M dwarf star with a mass about 0.5 times that of the Sun and the exoplanet has a mass of about 1.3 times that of Jupiter. The exoplanet orbits about 4 AU from the star with an orbital period of about 4,000 days. What is highlighted in the article is that the star and exoplanet are 3,200 light-years away in "the outskirts of our galaxy's dense central bulge." This is only the third planetary system that has been found in that region of the Milky Way, a region with older, metal-poor stars (thought to make it more difficult to form exoplanets). I should note that online articles seem to leave out the uncertainties in the reported measurements. For example, online article gives the orbital period as 4,170 days, but what is reported in the research paper is 4,170+/-1,700 days, and the distance is known to only about +/-1,000 light-years. As a final note, to date, 329 exoplanets have been found orbiting 282 planetary systems, with 12 multiple exoplanet systems

https://www.livescience.com/space/scientists-discover-rare-planet-at-the-edge-of-the-milky-way-using-space-time-phenomenon-predicted-by-einsteincan

Exoplanet in Habitable Zone:



Artist's impression of the L 98-59 system, compared to the inner Solar System. Distances are not to scale. **[This is from Wikipedia. It must be noted that this is a temperature comparison, not a distance comparison. I may eventually create a size and distance comparison that includes one other exoplanet, L 98-59 g, that is smaller than L98-59 b and inside its orbit]**

First, a little bit of background to put the research reported here into context. L 98-59 is an M-type (red dwarf) star that is 34.6 light-years from us. Because it is so cool (visible surface temperature of 3,400 K), it is only 0.01 times as luminous as the Sun and its habitable zone is estimated to be 0.09 to 0.24 AU from the star. That is within the orbit of Mercury. The link to the research paper mentions five exoplanets orbiting the star, but the Catalogue of Exoplanets lists six confirmed exoplanets (see below). Three exoplanets were discovered in 2018. They all transit the star. One is smaller than the Earth and two are larger than the Earth (image on the right). Transits give diameters and all three were confirmed and their masses determined by radial velocity measurements in 2021. At that time, two additional exoplanets were discovered. One of these was soon confirmed, but one, L 98-59 f, was a tentative discovery until the new observations reported here. Along with the radial velocity measurement, there have been transit observations of L 98-59 b-d by HST and JWST, so that gravitational interactions can be used to refine the masses of L 98-59 e and f. The major discovery as reported is that L 98-59 f is within the star's habitable zone. It is about 2.8 times the mass of the Earth. While the exact inclination of the orbit of L 98-59 f is not known, the authors appear to assume that L 98-59 f is in the same plane as b-e. It is about 0.11 AU from the star and has an orbital period of 23 days. This puts it well within the habitable zone of the star. In the same research paper, the authors mention the tentative discovery of another exoplanet, L 98-59 g, that appears to have been confirmed (according to the Catalogue of Exoplanets). L 98-59 g is the closest of the exoplanets to the star at 0.018 AU from the star with an orbital period of 1.7 days. Since it does not appear to transit the star, I assume that it orbit is tilted relative to the other exoplanets.

https://www.spacedaily.com/reports/Diverse_rocky_planets_found_around_nearby_red_dwarf_including_one_in_the_habitable_zone_999.html

Citizen Science, an Exoplanet Transit:

TOI-4465 is a solar-type star that is about 400 light-years from us. It is orbited by one known gas giant that is about 6 times the mass of Jupiter and 1.3 times the diameter of Jupiter. It orbits at a distance of 0.4 AU with an orbital period of 102 days. The exact orbital period was not known until the observations reported here. The problem was that its transits last about 12 hours, very difficult to measure at any one location. Therefore, the authors brought together a team of professionals and amateurs (citizen scientists) from around the world to observe, individually, segments of the transit that could be combined to give a full transit timing.

https://www.universetoday.com/articles/worldwide-team-of-citizen-scientists-help-confirm-a-tricky-exoplanet

Exoplanet Death Wish:

HIP 67522 is a solar-type star that is a little more massive and a little larger in diameter than the Sun. It is a little cooler than the Sun, but about 1.8 times as luminous as the Sun. However, it is only 17 million years old and its rotational period is 1.7 days (the Sun is 25 days). HIP 67522 is about 407 light-years from us. HIP 67522 has two known exoplanets. HIP 67522 b orbits at a distance of 0.07 AU with an orbital period of 6.96 days and HIP 67522 c orbits at a distance of 0.12 AU with an orbital period of 14.3 days (Mercury's mean distance from the Sun is 0.39 AU and has an orbital period of 88 days). The exoplanet that is reported on in the research paper is HIP 67522 b. While it has a diameter that is 0.9 times that of Jupiter, its mass is only 0.04 times the mass of Jupiter, about 15 times the mass of the Earth [the mass was determined based on its size, age, and atmospheric models]. This implies that it has a density of only about 0.1 times that of

water, one of the “cotton candy” exoplanets. Because of its mass (a little less than the mass of Neptune), it is considered to be a hot Neptune rather than a hot Jupiter. What is interesting about this exoplanet is that the star is a flare star. However, the flares seem to be triggered by the interaction between the star’s magnetic field and the exoplanet’s magnetic field. The exoplanet is receiving six times as much solar radiation as would be expected without the flares. This flaring is eroding the exoplanet's atmosphere, losing about 0.01 to 0.03 Earth masses every million years. In about 100 million years, it will be smaller than Neptune and half the mass of Neptune.

https://earthsky.org/space/planet-with-a-death-wish-triggers-solar-flare-doom

https://www.sciencealert.com/alien-world-discovered-provoking-its-own-hellish-apocalypse