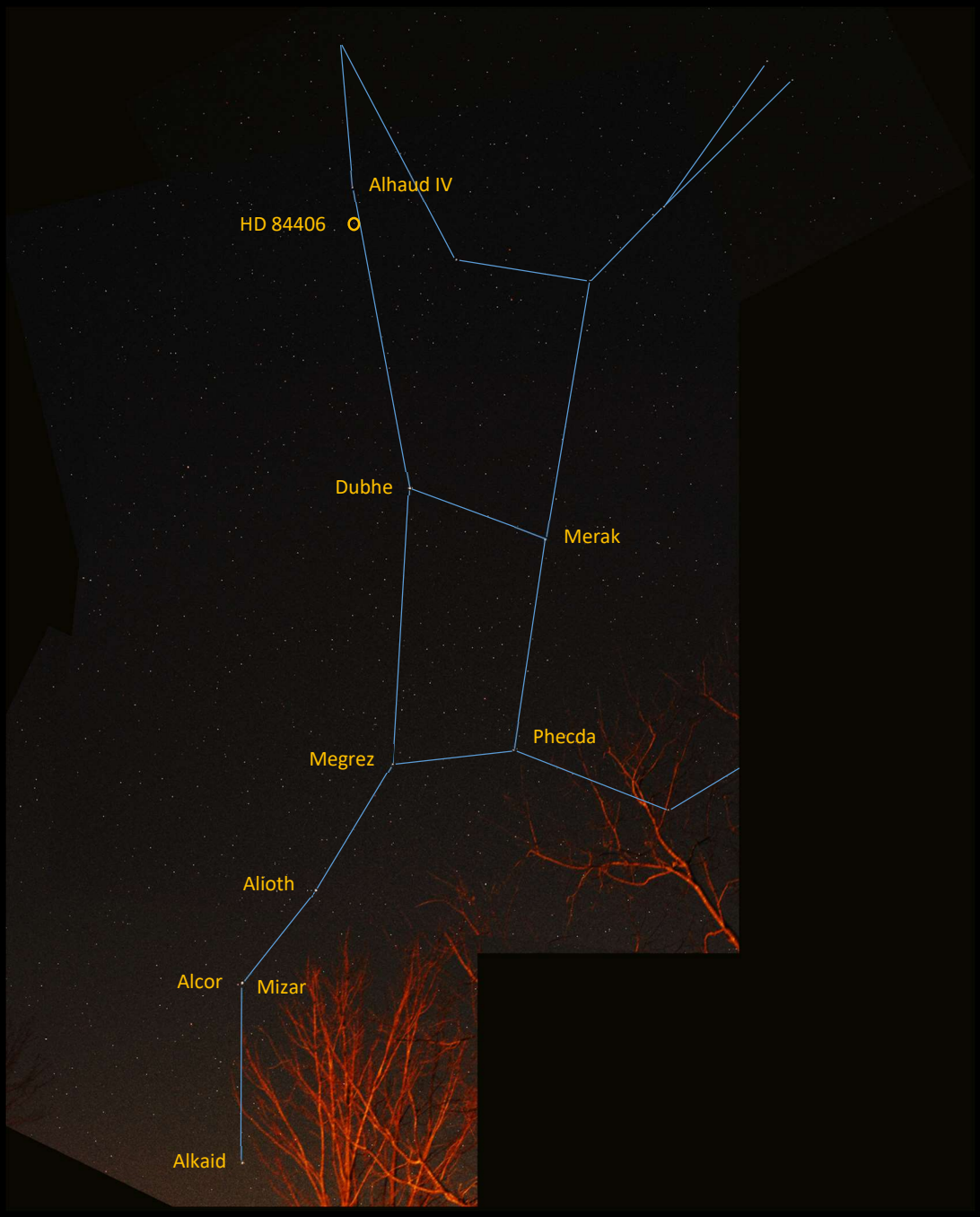
Galactic Observer

John J. McCarthy Observatory

Volume 15, No. 3 March 2022



A magnitude 6.9 star (HD 84406) in the constellation Ursa Major is being used to align the mirrors of the James Webb Space Telescope. The Webb team used the telescope's Near Infrared Camera to image the target star and were able to place the star in each of 18 mirror segments within the first six hours and 16 exposures. Over the next month or so, the team will gradually adjust the mirror segments until all 18 images become a single point of light.

March Astronomy Calendar and Space Exploration Almanac

The McMath-Pierce Solar Telescope is located on the summit of Kitt Peak in the Arizona-Sonoran Desert. The facility saw first light in 1962 and was the world's largest solar telescope for almost six decades. It was de-funded in 2017, but is being given a new life and mission (story on page 8)

Photo: Bill Cloutier

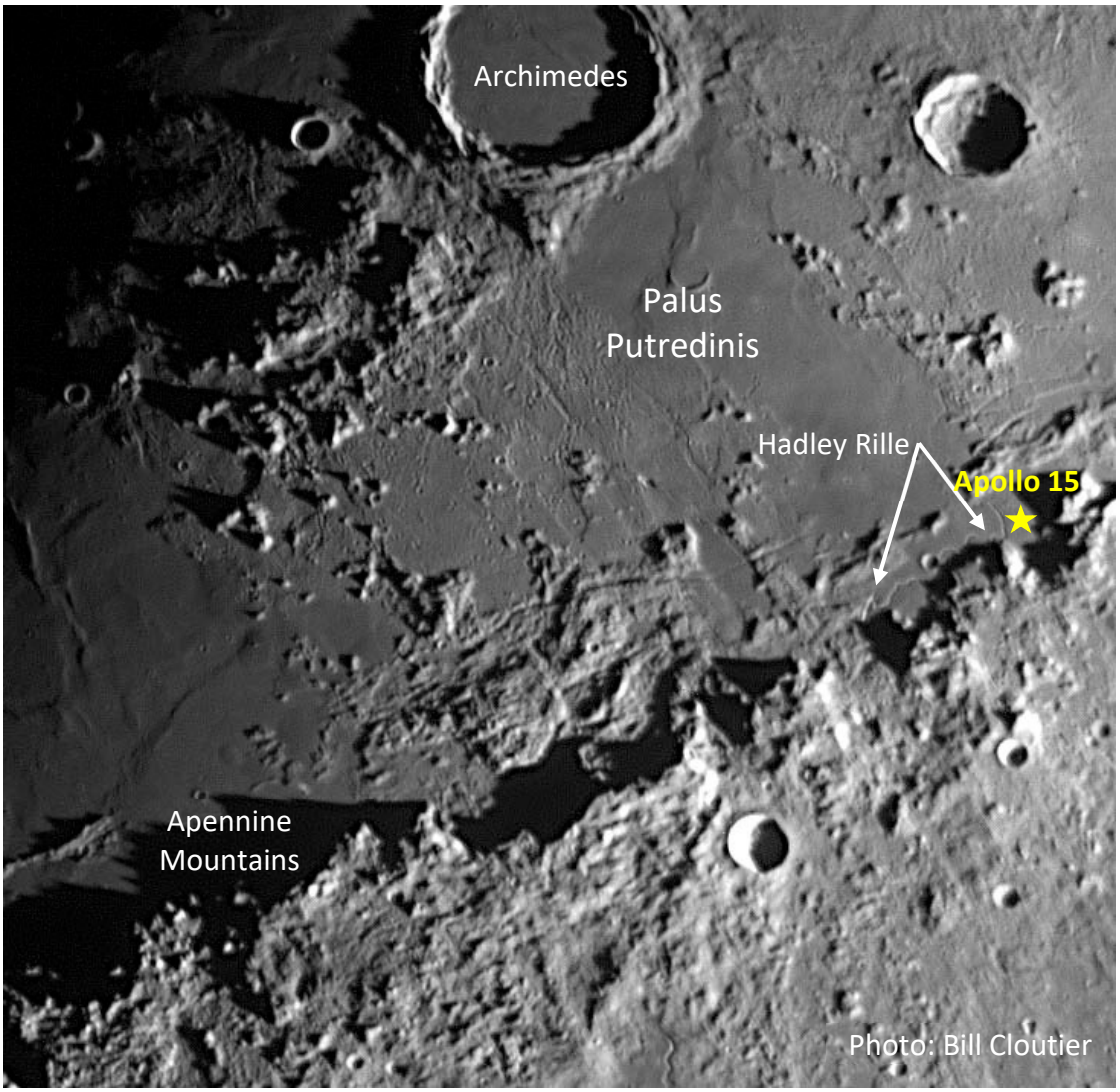
In This Issue

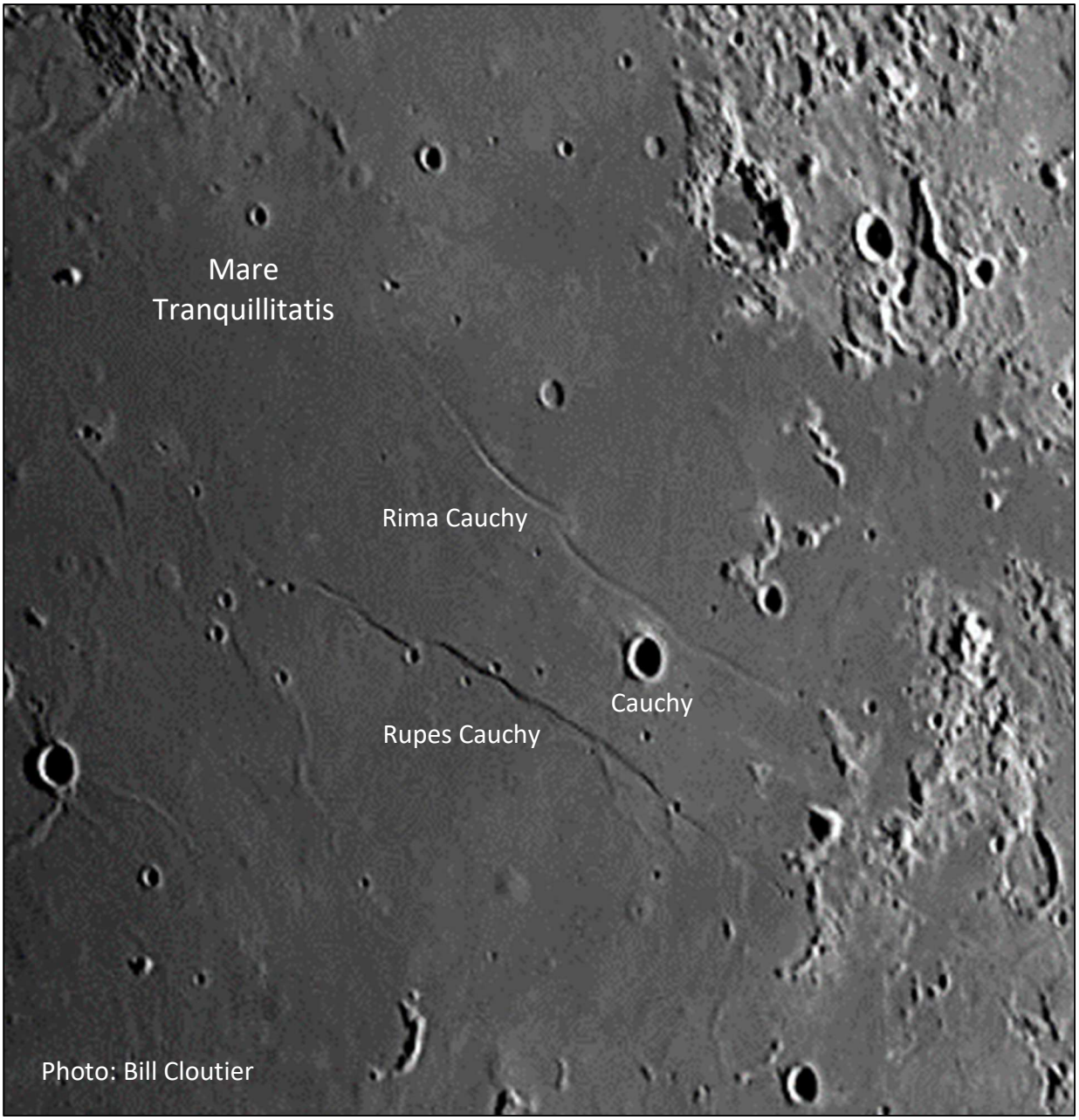
"Out the Window on Your Left"

It has been more than 52 years since Neil Armstrong first stepped onto the Moon's surface and 49 years since Gene Cernan left the last footprint. As a nation founded on exploration and the conquest of new frontiers, today's commitment to return to the Moon has been as fleeting as the funding. But what if the average citizen had the means to visit our only natural satellite; what would they see out the window of their spacecraft as they entered orbit around the Moon? This column may provide some thoughts to ponder when planning your visit (if only in your imagination).

Rilles are one of the more enigmatic lunar features. German for 'grooves,' the term is used to describe depressions in the lunar surface. There are three basic categories or types of rilles: sinuous, straight, and arcuate. With their low profile, they are best seen shortly after lunar sunrise or before sunset.

Sinuous rilles have the appearance of meandering rivers and are thought to have formed from surface lava flows or collapsed lava tubes. Hadley Rille, at the base of the Apennine Mountains, was the site of the Apollo 15 mission. The V-shaped rille averages a mile in width (1.5 km), with a maximum depth of 1,300 feet (400 meters).

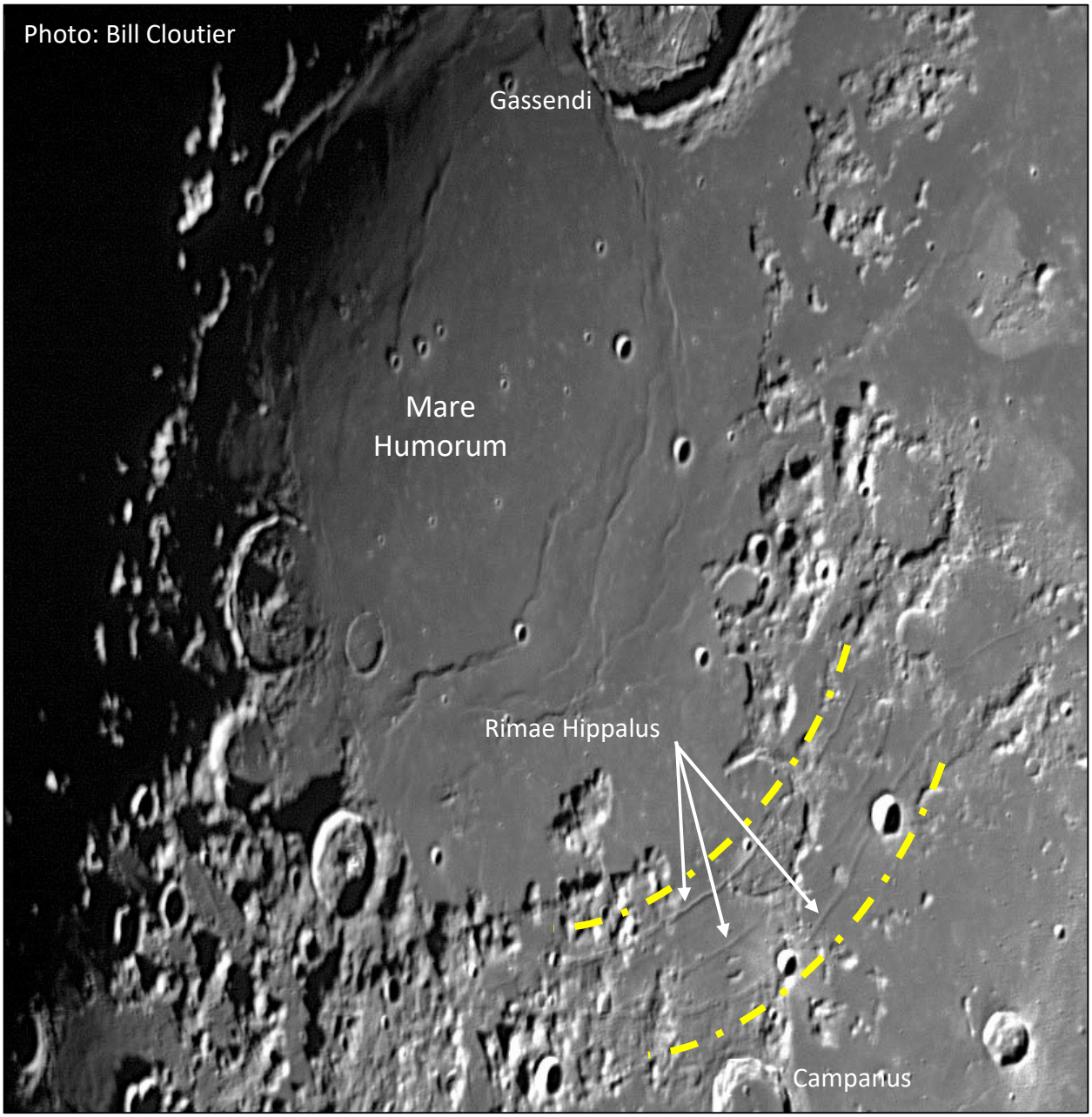




Straight rilles are believed to be caused by tectonic forces. When the crust drops down between two parallel fault lines, a narrow valley or graben is created. Those same tensional/extensional stresses can also produce a single straight fault or scarp. These lunar cliffs can cast a shadow upon the basaltic plains when the sun is low on the horizon. The International Astronomical Union uses the naming convention of 'rima' for rilles and other fissures and 'rupes' for escarpments.

Examples of both features (grabens and scarps) can be found in eastern Mare Tranquillitatis (Sea of Tranquility), near the crater Cauchy. Rima Cauchy runs across the mare to the north of the crater for more than 100 miles (about ~170 km) and is actually comprised of several segments. The valley has a nominal width of 1½ miles (2.5 km).

South of Cauchy crater is Rupes Cauchy. At almost 125 miles (200 km) in length, the 1,000-foot-high scarp (300 m) has a relatively gentle slope of 15°, although it was likely steeper in the past.



An arcuate rille is a curved feature and can be found in the lava fields along the edge of some impact basins. Concentric to the center of the impact basins, arcuate rilles likely formed as the accumulated weight of the lava on the crust caused the material inside the basin to sag inward. This compression created the serpentine wrinkle ridges that can be seen running through the mare basalt and are believed to be related to the interior, and now buried, ring structure of the basin.

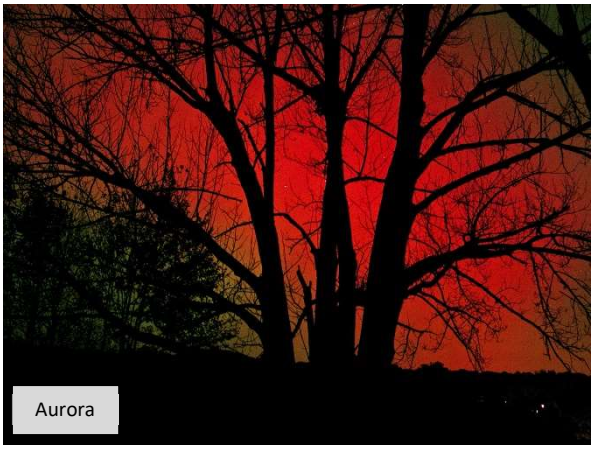
While the interior of the lava-filled basin experienced compressive forces, the outer edges were under tension, creating faults and grabens like those seen between the craters Hippalus and Campanus. These arcing rilles, called Rimae Hippalus, are each 125 miles (200 km) long and roughly 2 miles (3-3.5 km) wide.

Almost all lunar faults and grabens are associated with the deformation of the crust around impact basins.

Looking Out Your Back Door

The past two years have certainly felt at times surreal and detached, but there are still astronomical spectacles that you can enjoy while locked-down at home.

Weather permitting, the night sky can be a source of wonder and awe. Without traveling more than a few feet from my back door, I have watched the constellations advance through the seasons, meteors streak across the heavens, comets appear and then disappear like ghostly apparitions, dancing aurora, planetary conjunctions and eclipses, and rocket launches from as far away as Florida. While it may not be as exciting as traveling to exotic places, becoming, as Robert Frost described, "a watcher of the void," can be introspective and calming, particularly in these stressful and chaotic times. A few images from my backdoor over the years:


Aurora


Comet Hale-Bopp

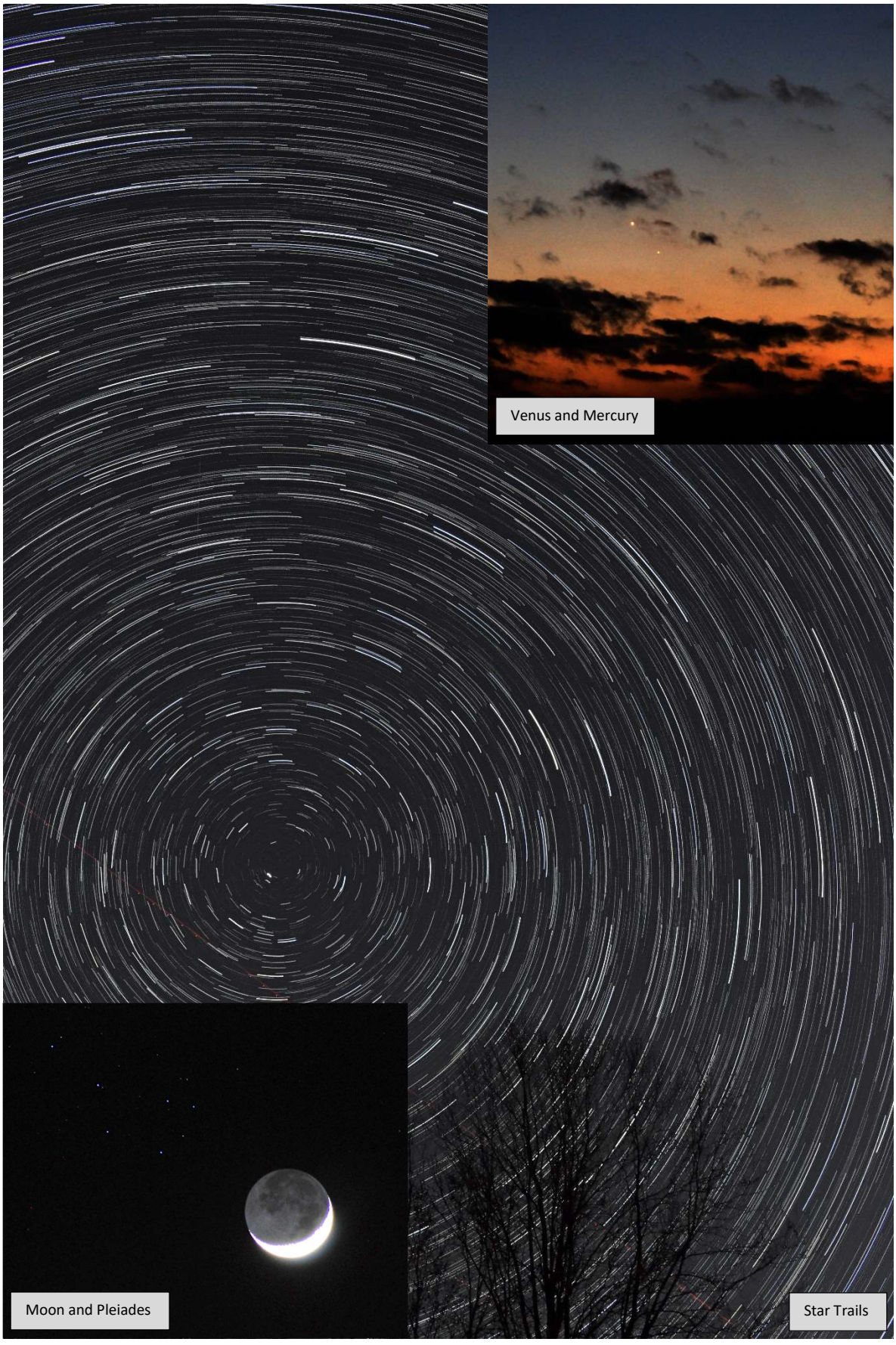
Space Shuttle
Discovery STS-119
KSC Launch


Venus Transit


Lunar Eclipse


Lunar Atmosphere and
Dust Environment Explorer
Wallops Island Launch


Space Shuttle Atlantis
Chasing the ISS


Venus and Mercury
Moon and Pleiades
Star Trails

New Mission to Enlighten

The Kitt Peak National Observatory (KPNO) is home to the world's largest collection of telescopes, including twenty-five optical and two radio telescopes. The summit, located 50 miles (about 80 km) west of Tucson, Arizona, is also home to the McMath-Pierce Solar Telescope. Dedicated in 1962, it was the world's largest solar telescope for almost 60 years.

The telescope is actually three instruments, with independent telescopes mounted on each side of the main heliostat (which follows the Sun and is used to direct sunlight down the long shaft to the primary mirror). Throughout its operational life, the facility made numerous scientific discoveries about the Sun, Moon, and planets, including detecting water vapor on the Sun.

With budget cuts and cost overruns on major projects, the National Science Foundation (NSF) announced in 2016 that they would cease funding older telescopes like the McMath-Pierce in favor of more modern and capable facilities like the Daniel K. Inouye Solar Telescope on the Hawaiian island of Maui. The McMath-Pierce telescope was subsequently closed down in 2017.

Undeterred, the operator, National Solar Observatory, began to solicit proposals for the continued use of the facility. A concept offered by KPNO's visitor center manager to convert the retired telescope into a unique outreach facility evolved into a funding proposal to the NSF. With funding approved, workers started the transformation of the facility late last year into what will become the National Optical-Infrared Astronomy Research Laboratory's "Windows on the Universe Center for Astronomy Outreach."

Space once used as offices, darkrooms and other science and engineering activities will be converted for use as interactive exhibit galleries and astronomy visualization theaters. Plumbing will be added for public restrooms along with heating, ventilation, air conditioning and internet.

When complete (likely in early 2023), visitors will be able to learn about research being carried out at NSF astronomical facilities across the globe, participate in workshops and enjoy other educational endeavors. The McMath-Pierce solar telescopes will also be preserved for the public to better understand the types of research being conducted and the methods employed.

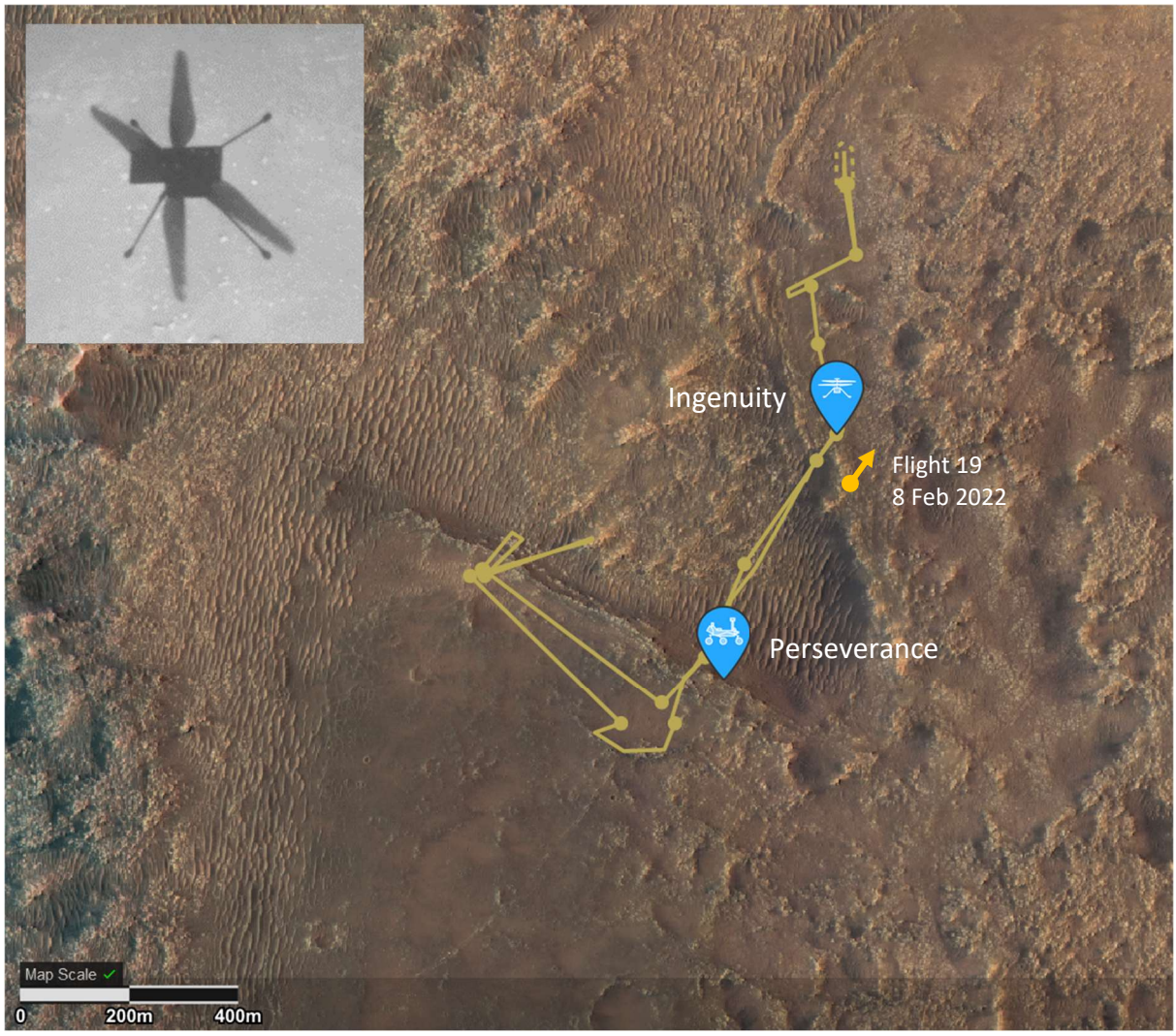
The McMath-Pierce main solar telescope is unique in that it is large enough to be used at night for bright stars, planets and the Moon. A disk of light about 32 inches in diameter, or 80 cm, can be projected onto a table in the viewing room for study and/or analysis by a suite of scientific instruments.

During the 1960s, NASA's astronauts visited the facility, accompanied by scientists, to learn about the Moon. In this 1964 photo, several astronauts can be seen studying an image of the place that they hoped to travel to, including Alan Bean (Apollo 12), Bill Anders (Apollo 8), Walt Cunningham (Apollo 7) and Rusty Schweickart (Apollo 9).

On the following page, University of Arizona professor and a world-renowned geologist, Spencer Titley worked with NASA astronauts on the geology expertise needed for their missions. He also worked with the U.S. Geological Survey (USGS) in 1964 to map the Moon for the Apollo program using the McMath-Pierce telescope. The astronauts shown with Titley, and USGS and lunar geologist Dr. Don Wilhelms, in the 1964 photo taken at Kitt Peak, are Thomas Stafford (Apollo 10), Wally Schirra (Apollo 7), Ed White (Apollo 1), Alan Shepard (Apollo 14), and Gordon Cooper (Gemini 5).


Stafford
Titley
Schirra
White
Sheppard
Cooper
Wilhelms
Tucson Daily Citizen
May 21, 1964

Back in the Air



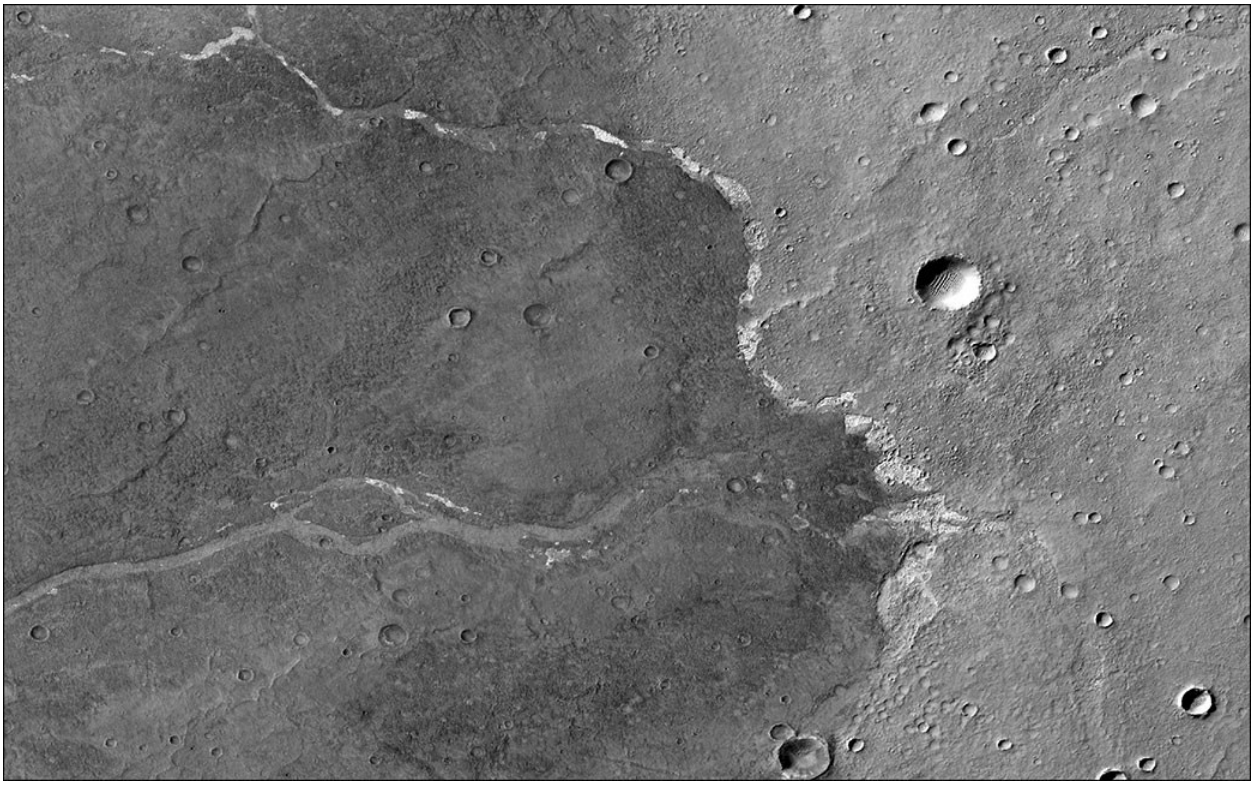
The flight path (shown in gold) and way points of the Mars helicopter, with a yellow arrow identifying the 19th flight segment on an interactive map. Ingenuity's navigation camera captured the helicopter's shadow during the flight (insert).

Image credit: NASA/JPL-Caltech

NASA's Mars helicopter 'Ingenuity' took to the rarified air after a month of being grounded by a dust storm. The flight on February 8th was the nineteenth for the little 4-pound (1.8 kgs) rotorcraft and one of its more challenging. Ingenuity's support team at the Jet Propulsion Laboratory made the decision to stand down in January over concerns that the dust storm would affect Ingenuity's ability to recharge its batteries (from the solar panel) and that dust storms warm the atmosphere which, in turn, decreases the air density, making it more difficult to fly.

The rotorcraft's 19th flight lasted 100 seconds and traversed about 205 feet (62 meters), as Ingenuity makes its way back to the landing site where it will meet up with the rover Perseverance. The flight was successful despite concerns that the sandy surface's lack of features could hamper the helicopter's navigation system (which compares sequential terrain images to assess progress).

"There Will Come Soft Rains"



White salt deposits within a dry channel, captured by NASA's Mars Reconnaissance Orbiter. The largest crater in the image is nearly 1 mile (1.5 kilometers) across.

Credits: NASA/JPL-Caltech/MSSS

Mars was once believed to be warmer and wetter, where liquid water flowed and pooled on its surface, creating shallow seas and tranquil ponds. With the loss of its magnetic field and the bulk of its atmosphere, the planet cooled and dried out. As the surface water disappeared, it left behind dry river beds, fossilized shorelines and other hints of what might have been. The timing of this transformation has been generally accepted to have occurred about 3 billion years ago.

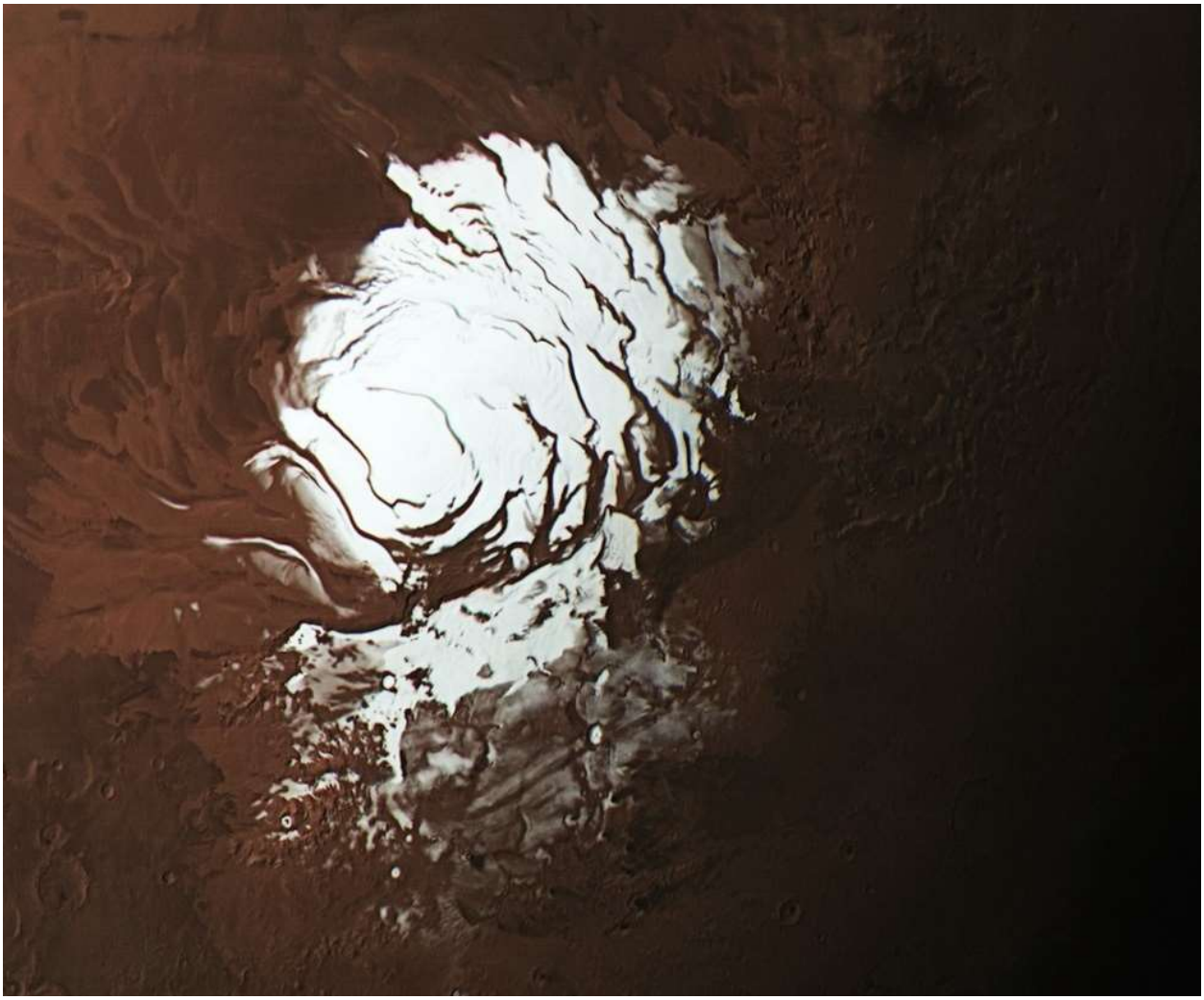
First discovered in images captured 14 years ago by NASA's Mars Odyssey orbiter, Caltech researchers have found chloride salt deposits in depressions and among features associated with surface runoff across the clay-rich highlands of Mars' southern hemisphere. Using NASA's Mars Reconnaissance Orbiter's (MRO) higher resolution cameras and imaging spectrometer, the distribution and extent of the chloride deposits have been mapped, along with the approximate age of the underlying terrain (generally based on crater counts, along with the relationship of datable surfaces).

The findings, published in the American Geophysical Union's 'AGU Advances' in December, submit that the salts were deposited as the water evaporated as recently as 2 billion years ago. This would suggest that liquid water flowed on the surface of Mars, or at least pooled in shallow hollows, almost a billion years longer than previous estimates. If so, the window for microbial life to develop was open much longer. It might also make the task of finding evidence of past (or present) life on Mars a bit easier.

The Scientific Method – Martian Style

Discourse and debate are the cornerstones of science. Our understanding of alien worlds, probed by machines from distances of tens of millions of miles is almost always subject to the interpretation of the data transmitted, bit by bit, across the void. The question of whether water exists beneath the south polar cap of Mars is a prime example.

The European Space Agency's Mars Express Orbiter arrived at Mars in 2003 with the primary objective to scan the planet for signs of sub-surface water. Among its suite of scientific instruments is MARSIS (Mars Advanced Radar for Subsurface and Ionosphere Sounding). MARIS conducts night-time surveys of the surface by sending a stream of radio waves and collecting their echoes with the spacecraft's three antennae for analysis (at night, Mars' ionosphere doesn't interfere with MARIS' low-frequency signals). In 2018, the instrument detected a 12.5 mile-long (20 km) reflective, subsurface zone about a mile (1.5 km) under the planet's South Pole Layered Deposits.



Mars' frozen water and carbon dioxide south pole from an altitude of 6,100 miles (9,900 km) captured by the European Space Agency's Mars Express Orbiter

Image credit: ESA/DLR/FU Berlin, CC BY-SA 3.0 IGO

A team of Italian researchers reported the discovery and concluded that it was water or brine (a water/salt solution). NASA's rovers have found perchloric and chloride salts in the Martian soil that could allow a brine solution to remain liquid at temperatures as low as -103°F (-75°C), so the declaration had some merit. A 2020 study confirmed the presence of the lake and identified other buried, reflective surfaces that might also be lakes.

However, a 2021 study offered alternatives besides water for the reflective signature, including clays, some metallic minerals, and salty ice. The alternatives were dismissed by other researchers, based, in part, on laboratory experiments and simulations of the reflective properties of these materials at Martian temperatures.

The crux of the problem is that the temperature at the depths of the MARSIS' reflective zone is not truly known and it turns out that the properties of clays are temperature sensitive and that brines between grains of ice or sediments can also produce the reflections observed. To add to the debate, a paper published in January 2022 suggests that the reflections could be from a type of iron-rich volcanic rock. The belief is supported by an analysis of MARSIS reflections of volcanic plains at several locations that resembled those of liquid water.

While there is no definitive answer, the debate within the scientific community is beneficial in that it can be used to design the next generation of remote sensors and instruments – the best we may be able to do until we can put boots on the Martian soil.

Gale Crater Mysteries

Life on Earth is carbon-based, so naturally when we explore other worlds, we are biased towards the familiar. There are several forms (or isotopes) of carbon, with carbon-12 being the predominant form (>98%). A slightly heavier form of carbon, with one additional neutron (carbon-13), is the next most abundant form (~1%). On Earth, life has a preference towards the lighter carbon-12 form for metabolization or photosynthesis, which creates a distinctive signature in the environment, including what is recorded in ancient rocks.

NASA's Mars Science Laboratory, the Curiosity rover, has been exploring Gale Crater and its central peak, which rises 3.4 miles (5.5 km) above the floor of the crater, for almost ten years. While it wasn't designed to detect life, it is capable of assessing whether the planet ever had the right environmental conditions to support life. The rover's chemistry lab is equipped with a Tunable Laser Spectrometer, which is used to analyze the gases, including carbon, released from heating the samples collected by Curiosity to about 1,500°F (850°C), as it makes its way up the mountain.

An analysis of the carbon in the Martian environment, from the results published in January 2022, compared the ratio of the two carbon isotopes from 24 samples from geologically diverse locations within the crater. More than half the samples, from five different locations, had a surprisingly large amounts of carbon-12 compared to what has been measured in the atmosphere and in Martian meteorites. The carbon-rich areas appear to correspond to well-preserved ancient surfaces.

On Earth, this would be explained as a signature for life-related chemistry. On Mars, we just don't know enough about the evolution of the planet and its ability to support and sustain even the most rudimentary forms of life to make that leap. The Martian atmosphere may have started off with a

different mix of carbon isotopes than Earth and evolved differently with the planet's weaker gravity and colder temperatures.

Curiosity's view of the Stimson sandstone formation in Gale Crater and one of the sampling locations

Credits: NASA/JPL-Caltech/MSSS

Researchers have offered three possible explanations for the carbon-12 rich samples that fit the data. The biological explanation involves microorganisms that produce methane with a unique carbon signature as a metabolic byproduct. Ultraviolet sunlight would then convert the methane into other complex molecules, which would be captured and preserved in the planet's rocks and surface deposits along with the carbon signature. Non-biological explanations include that the carbon signature could have come from the interaction of the carbon dioxide in the Martian atmosphere with the ultraviolet light from the Sun or that the carbon molecules were left behind by the passing of a giant molecular cloud, hundreds of millions of years ago.

This isn't the first intriguing discovery by Curiosity. The rover has detected, what appears to be, seasonal increases in the abundance of methane in the local atmosphere, as well as sporadic plumes of gas. One of the plumes was also detected by the European Space Agency's (ESA) Mars Express orbiter in 2013.

In 2019, a dedicated survey by ESA's ExoMars Trace Gas Orbiter failed to find signs of methane in the atmosphere, even though its instruments are more sensitive to the gas than Curiosity's. The difference was eventually attributed to timing: ESA's spacecraft was analyzing the atmosphere during the day when the atmosphere was well-mixed while Curiosity was analyzing the atmosphere at night when it was cool and calm. This doesn't explain why methane isn't accumulating in the atmosphere to global levels that ESA's spacecraft could detect or what process may be accelerating the destruction of methane. Scientists are hopeful that continued exploration of Gale Crater may provide some answers.

The Atlas of 'Hope'

A team led by Dr Dimitra Atri, a research scientist at New York University's Abu Dhabi campus, has assembled an atlas of Mars using data exclusively from the Emirates Mars Mission "Hope." The spacecraft has been in orbit around the Red Planet since February 9, 2021 after a seven-month journey from Earth. The atlas, which is free to download, will be updated on a regular basis with new data. The second edition is expected to include information on auroras, changes in the cloud cover, atmospheric dust and ozone levels over time, as well as data on the polar ice caps.

The current issue includes images and descriptions of the planet's major regions and features, average daytime temperature variations over the course of a month, and other scientific data collected by the orbiter. The atlas is illustrated with photos from Hope's high-resolution camera that are not only rich in detail but visually stunning.

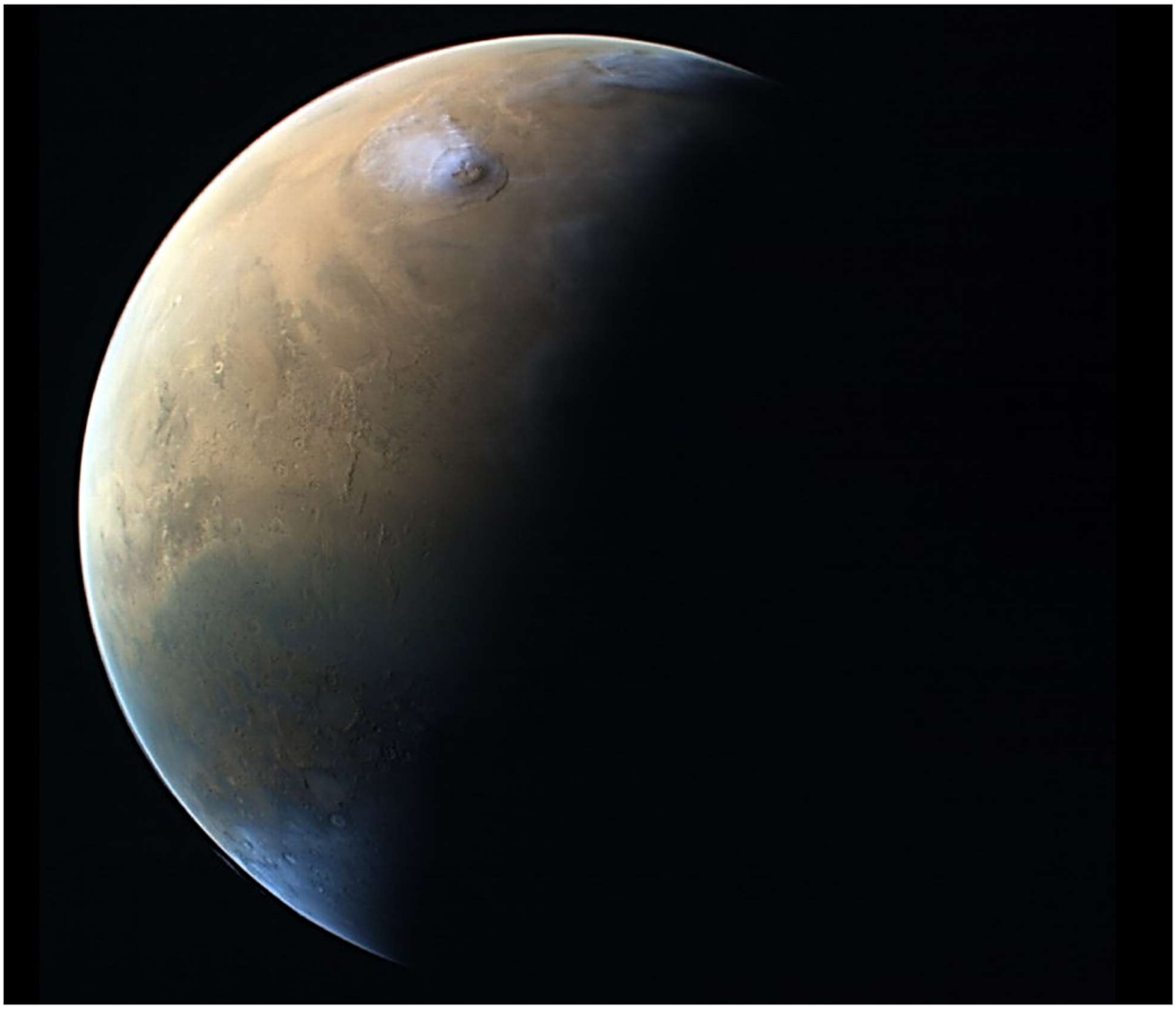


Photo from the 'Atlas of Mars' showing water-ice clouds over the summit of Olympus Mons (with an elevation of 13.6 miles or 21.9 km) on June 27, 2021 – upper left in image

Credit: UAESA/MBRSC/HopeMarsMission/EXI/AndreaLuck

Meteorite Spotlight – Park Forest

In the summer of 2018, the Observatory greatly expanded its meteorite teaching collection with the addition of a diverse and comprehensive set of meteoritic specimens from a reputable collector looking to convey his collection to someone who would maintain its integrity and capitalize on its intrinsic educational value. The collection includes whole stones, slices and fragments, numbering more than 200, from historic and scientifically-significant falls and meteorite finds dating back to 1492. From time to time, we will highlight one or more of the specimens from the collection in this newsletter.

On March 26, 2003, around 11:50 p.m., a fireball appeared in the sky over parts of Illinois, Indiana, Michigan, and Missouri. The fireball produced a shower of meteorites that fell around the southern suburbs of Chicago. The center of the strewn field was Park Forest, a village about 25 miles (40 km) south of the city. Hundreds of fragments were recovered ranging from a few grams to almost 12 pounds (5.26 kgs). While the area was densely populated, there were no reports of injuries with the damage confined to roofs, windows and cars.

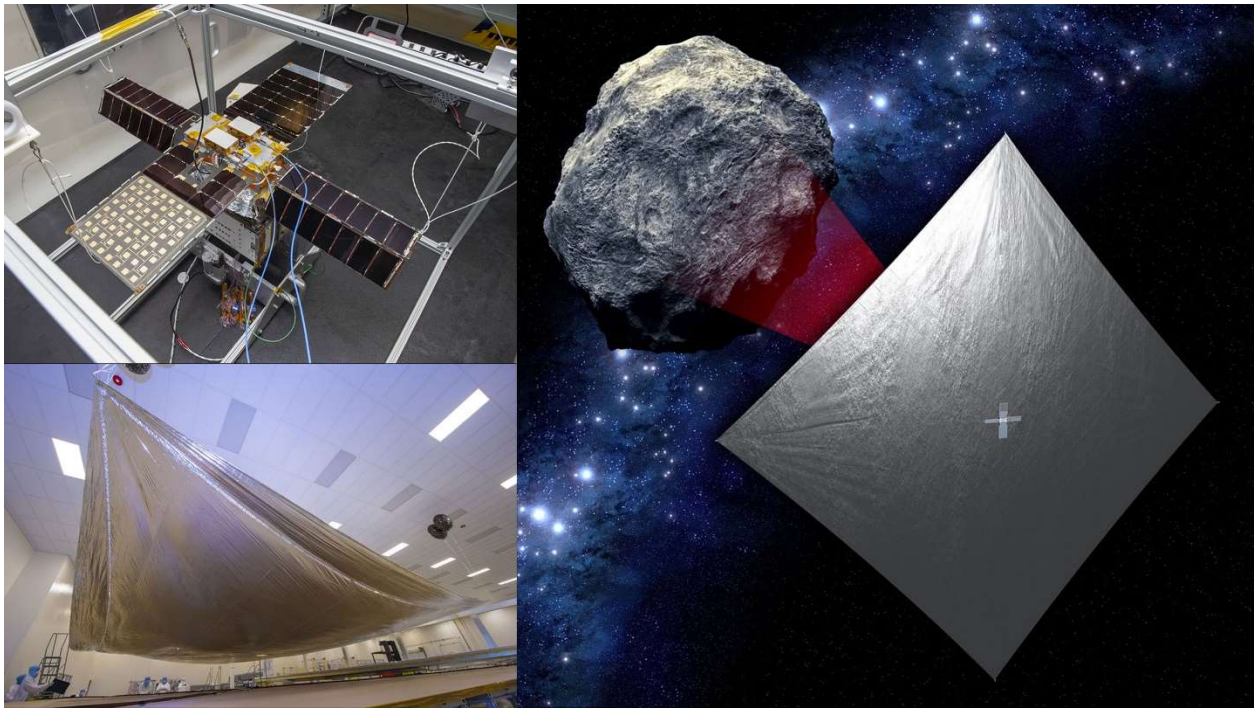
McCarthy Observatory's Park Forest sample
Image: Gerard Bianchi

The Park Forest meteorites are classified as an Ordinary chondrite (L5), one of the most primitive groups of known meteorites. They account for ~80% of all meteorite falls and the 'L' subgroup (low-iron) about 40% of the Ordinary chondrites recovered. Analysis of cosmic radionuclides in the stony material (comprised of light gray clasts in a very dark matrix) suggest that the pre-atmospheric mass was quite large, up to 7 metric tons before it broke apart. Estimates of the mass based on the energy released, are even higher.

The McCarthy Observatory's collection contains two Park Forest meteoritic fragments, a 1.6-gram piece and a 0.62-gram part slice.

NEA Scout – NASA's Solar Sail Mission

Tentatively scheduled for April, NASA plans to launch Artemis I, the first integrated test of its deep space exploration system, comprised of the Space Launch System (SLS) rocket and the Orion spacecraft. The unmanned mission, which is planned to last four to six weeks, will send the Orion spacecraft to the Moon and well beyond. The SLS's upper stage (called the interim cryogenic propulsion stage) will provide the push needed for Orion to leave Earth orbit and towards the Moon. Once expended, and Orion has separated from the upper stage, the booster will deploy a number of cubesats, as it continues along the same trajectory as Orion.



NEA Scout (top left), the aluminum-coated solar sail (bottom left) and an artist conception of the encounter with a small asteroid (right) Credits: NASA

One of the cubesats will be NASA's NEA Scout, a shoebox size mini-spacecraft powered by a racquetball court-sized solar sail (925 square feet or 86 square meters) and some small, cold-gas thrusters. Its mission is to intercept a small, near-Earth asteroid (NEA) called '2020 GE' that is less than 60 feet (18 meters) in size. The asteroid was discovered on March 12, 2020 and will make a close approach to Earth in September 2023.

If successful, this will be the smallest asteroid every studied and while the object is relatively small compared to those visited by other missions, 2020 GE is in the same class as the asteroid that produced the Chelyabinsk meteor that exploded over the west-central Russian city in 2013.

Propelled by sunlight, and a gravity assist from the Moon, mission navigators will place NEA Scout on a trajectory that will take the spacecraft within a mile of the asteroid for a slow-speed flyby (at a relative speed of less than 100 feet or 30 meters per second). This will provide several hours of close observation and imaging by the cubesat's camera, which will also be used to measure the asteroid's size, shape, rotation and surface properties.

High-Resolution Radar Imaging

A radar project by the Green Bank Observatory, the National Radio Astronomy Observatory, and Raytheon Intelligence & Space used the Green Bank Telescope and antennae in the Very Long Baseline Array to create the highest resolution, ground-based radar image of the lunar surface. The image, which includes Tycho Crater, contains 1.4 billion pixels and has a resolution close to 16 feet by 16 feet (5 meters x 5 meters). The image is the largest synthetic aperture radar image produced to date.

Tycho Crater is a 53-mile (85 km) diameter impact feature located in the southern highlands of the Moon. The complex crater with its terraced walls has a depth of 3 miles (4.8 km) and is one of the youngest, large impact features, with an age estimated at 108 million years. Its youth is manifested by the bright ray system comprised of pulverized rock ejected as a result of the impact. The bright rays can be traced across the face of the Moon and are most noticeable when the Moon is nearly full. Tycho's age was determined from a sample of ray material that happened to traverse the Apollo 17 landing site, almost 1,400 miles (2,200 km) to the northeast.

It's the Dust!

A thought-provoking article, published in the December issue of the Journal of the Geological Society, examines the correlation between where an impact occurs on Earth and whether it results in a mass extinction. The authors conclude that size of the impactor doesn't matter as much as the composition of the ground where the impact occurs.

An international team of researchers examined 33 impacts over the past 600 million years. The team included experts in mineralogy, climate, asteroid composition, and paleontology. There have been five mass extinctions over this period (a sixth is currently underway), where more than 50 percent of living creatures disappeared. The most well-known of these catastrophic events occurred 66 million years ago and resulted in the demise of the dinosaurs and the rise of the mammal. The likely cause was an asteroid, a hypothesis supported by a large crater off Mexico's Yucatan Peninsula and meteor dust in the sediment at the site and around the world.

Impacts can create a massive amount of dust which blocks out sunlight and causes a cooling effect (sometimes referred to as 'impact winter'). Typically, the cooling interval is relatively short, lasting less than a year before the Earth returns to its pre-impact equilibrium temperature.

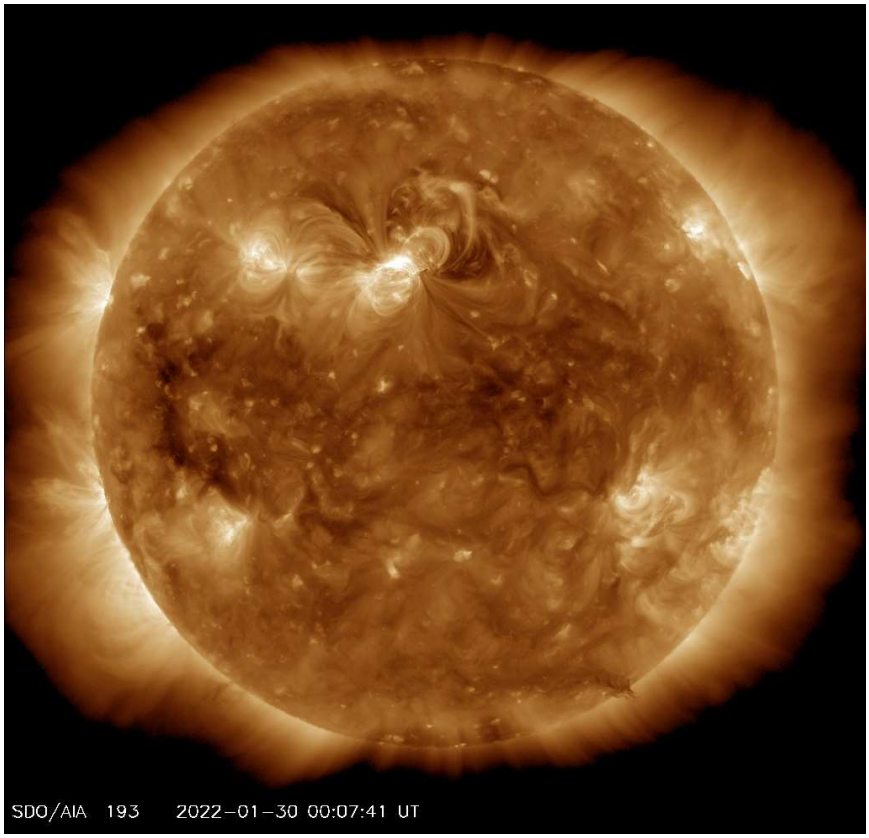
The composition of the impact dust is dominated by that of the rocks at ground zero. Researchers found a correlation between ejecta blankets rich in potassium-feldspar (Kfs) and the post-impact effect on the climate. Kfs is a major constitute in the Earth's upper crust - a common and benign mineral. It is not generally found in atmospheric dust which tends to be clay dominated.

Kfs is also a powerful ice-nucleating mineral. If Kfs is dispersed as an aerosol, it promotes the formation of ice crystals, making clouds transparent and allowing more sunlight through to warm the planet. Kfs also inhibits the melting of the ice crystals, suppressing the deglaciation of the clouds which would increase their reflectivity and restore cooling. The effect of atmospheric Kfs can last thousands of years and disrupt the planet's natural energy balance. Researchers found that smaller impactors striking Kfs-rich areas were more likely to cause an extinction than larger impacts striking Kfs-poor areas.

Solar Storms and Collateral Damage

In the early hours of January 30th, a large Earth-facing sunspot (AR2936) exploded, producing a long-duration solar flare and hurling a coronal mass ejection or CME (billions of tons of plasma with an embedded magnetic field) towards the Earth. The CME arrived two days later, hitting Earth's magnetic field, but failed to produce a geomagnetic storm. However, as the Earth passed through the CME's wake, some minor G1-class (the lowest impact level on NOAA's Space Weather Scale) geomagnetic storms developed. Geomagnetic storms heat the Earth's upper atmosphere (thermosphere), causing it to expand which, in turn, increases drag on low-Earth satellites and the International Space Station (which is why the ISS requires periodic reboosts by visiting spacecraft).

By happenstance, SpaceX had launched a Falcon 9 rocket on February 3rd, carrying 49 Starlink (internet-providing) satellites. The company deploys its satellites into a low-Earth orbit where they are checked out and allowed to disperse before using ion engines to raise their orbits into a higher, operational altitude. According to a SpaceX release, in response to the storm (and an estimated 50% increase in atmospheric drag) the company placed its satellites into a safe mode (flying edge on to minimize drag). Unfortunately, the increased drag prevented the satellites from exiting the safe mode and begin orbit raising maneuvers. As a result, SpaceX expects to lose up to 40 of the 49 Starlink satellites as they reenter the Earth's atmosphere.

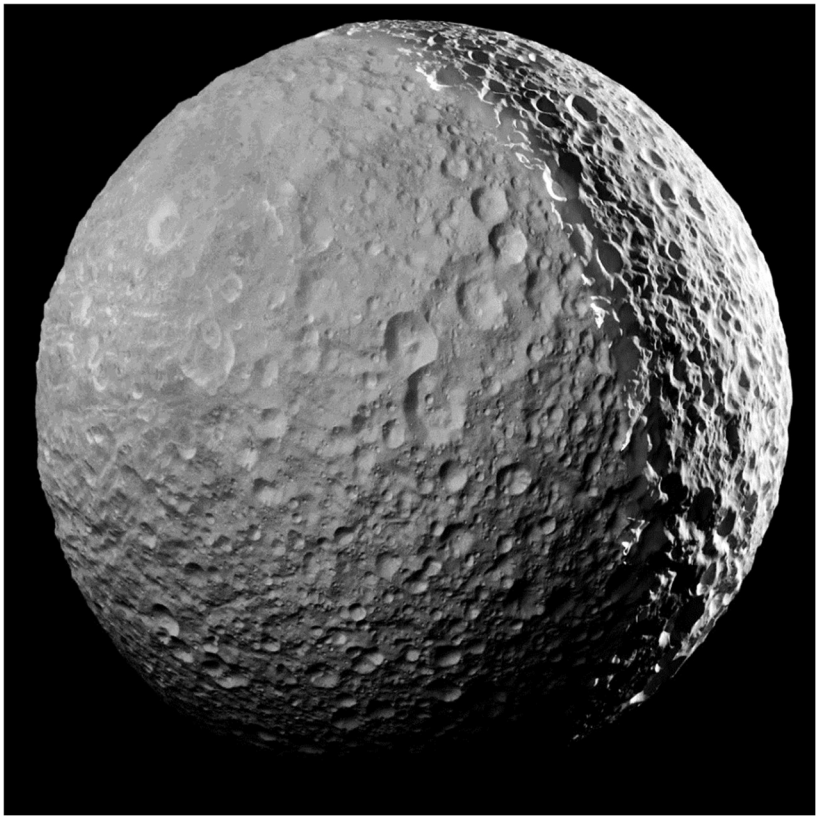


The Sun captured by the Solar Dynamics Observatory a wavelength of 193 angstroms (extreme ultraviolet) on January 30th. The bright area near the top/center is the source of the flare/coronal mass ejection.

What Lies Beneath?

In January of 2017, NASA's Cassini spacecraft made its final close approach to Saturn's moon Mimas (25,620 miles or 41,230 km). While Cassini's mission came to an end later that year, the data collected over its 13 years spent in the Saturnian system is still being mined by scientists.

A recent paper published in the journal Icarus makes the case for Mimas, one of Saturn's smallest and innermost major moons, harboring an internal ocean. Unlike Enceladus, with its fresh surface and dynamic icy geysers, the surface of Mimas is covered with craters, without any noticeable sign of geologic activity. Scientists were therefore surprised when Cassini's instruments detected an unusual libration (oscillation/ wobble) in Mimas' rotation.



Mimas illuminated on the right side by the Sun and on the left by Saturn's reflected light (enhanced to show details)

Image Credit: NASA/JPL-Caltech/Space Science Institute

There can be several explanations for the libration, including a non-spherical core (e.g., football shaped), a core and mantle of different materials and densities, or a liquid subsurface ocean. Modeling the interior of the moon with Cassini data and taking into account the moon's location within the Saturnian system (tidal heating), the authors conclude that the best fit is for a liquid water ocean beneath an icy shell 15-19 miles (24–31 km) thick.

With its proximity to Saturn, the gas giant's tidal forces would produce enough heating to keep the interior liquid. If Mimas does have a subsurface ocean, it would be the smallest of the class of moons known as Internal Water World Oceans or IWWOs (Mimas is only 246 miles or 396 km in diameter), joining larger worlds like Enceladus and Europa.

The density of the diminutive moon also suggests a rocky core. Should a subsurface ocean be confirmed, an active interface between the heated water and rock could provide the energy to support life.

Scientists expect to learn more about IWWOs from the flyby of Europa by NASA's Juno spacecraft near the end of 2022 (its microwave radiometer which will measure heat flows in this Jovian moon), and when NASA's Europa Clipper mission arrives in April 2030. The spacecraft will perform repeated flybys of the moon at a distance of about 200 miles (320 km).

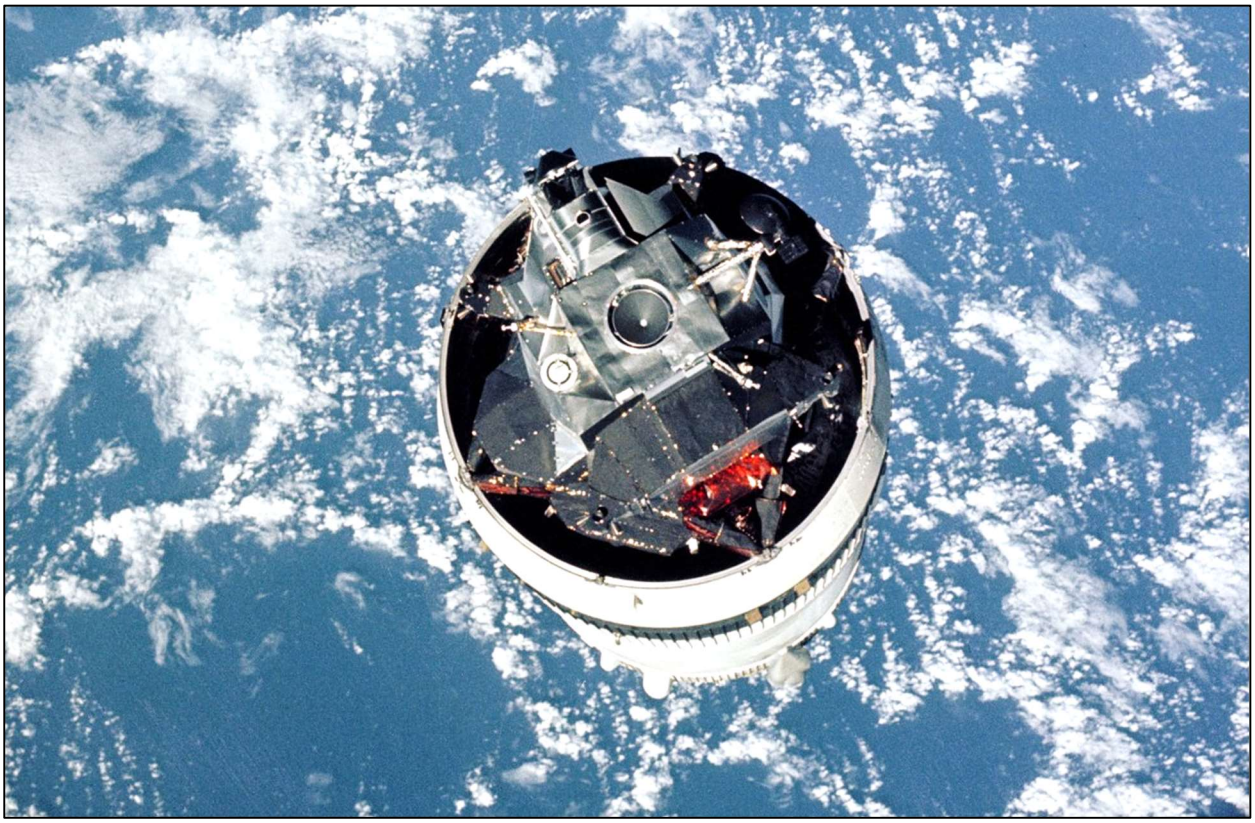
Flight of the Spider

The Apollo 9 mission was the first manned test flight of all the hardware needed for a lunar landing, including the lunar module. The Saturn V launched from the Kennedy Space Center on March 3, 1969 carried the record setting payload into low-Earth orbit. The mission was commanded by James McDivitt, with David Scott as the Command Service Module (CSM) Pilot and Russell Schweickart as the Lunar Module (LM) Pilot.

The Apollo 9 CSM taken from the window of the LM

Image: NASA

The crew would complete 152 orbits of the Earth, challenging the human physiology in ten days of weightlessness. During the first day on orbit, the CSM separated from the Saturn V's third stage. Turning around to face the rocket booster, the CSM docked with the LM nested inside. Using the CSM's thrusters, the joined pair moved a safe distance away. The third stage engine was then restarted to simulate a maneuver required for a deep space mission. It was eventually placed in a heliocentric orbit.



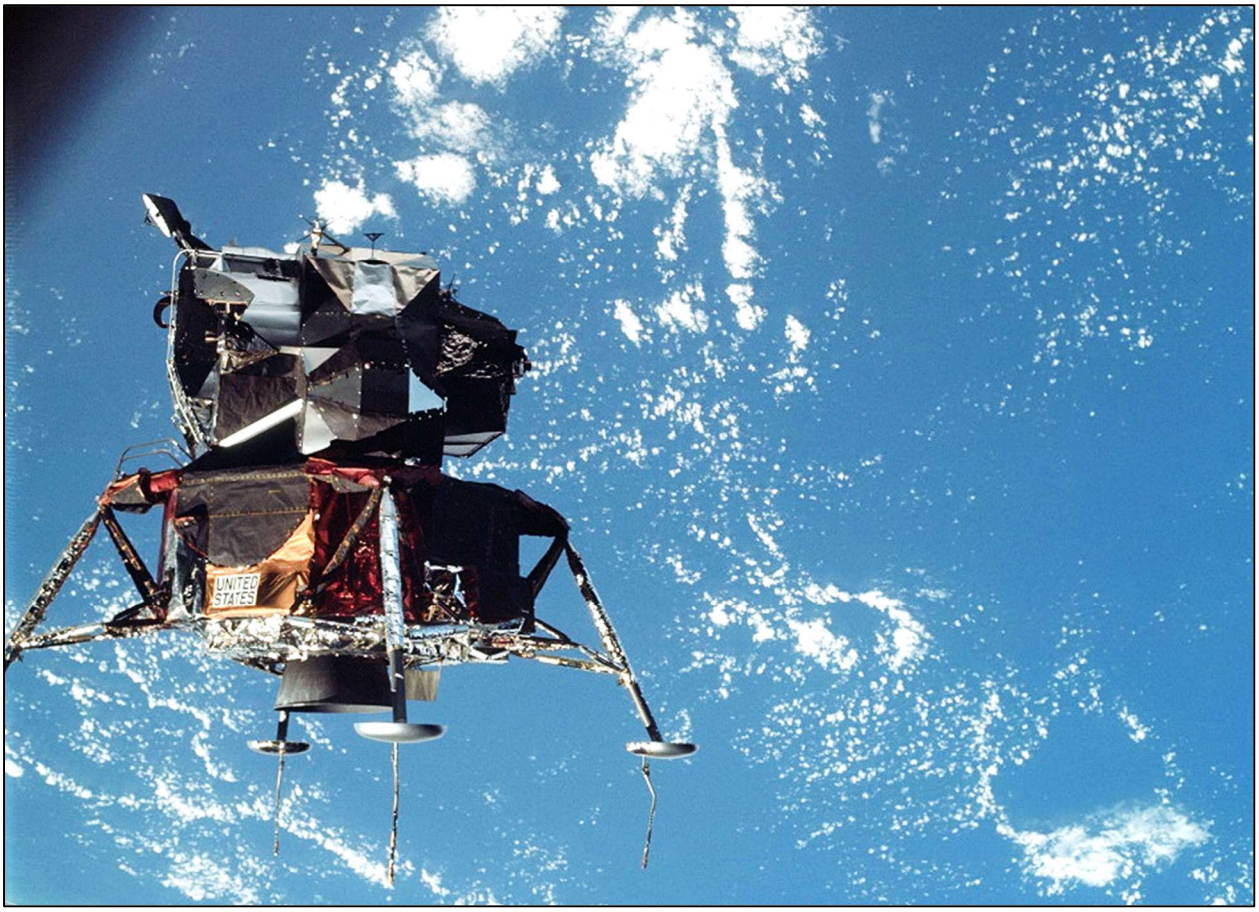
The Apollo 9 LM, nicknamed 'Spider,' shown in its launch position atop the Saturn V S-IVB third stage, its legs folded underneath. The image was taken from the CSM, nicknamed 'Gumdrop,' as it turned to face the LM. The conical drogue docking unit is visible at the top of the LM.

Image: NASA

The crew of Apollo 9 used the CSM's propulsion system to change orbit and test the structural integrity of the joined CSM and LM under load. On Flight Day 3, McDivitt and Schweickart entered the LM through a tunnel connecting the two vehicles to test fire the LM's descent engine before returning to the CSM. Schweickart's spacewalk scheduled for Flight Day 4 was cut short because of nausea. He did spend a short time outside the LM to check out the life support system backpack which the moonwalkers would use.

McDivitt and Schweickart would enter the LM again on Flight Day 5. This time the two vehicles separated, with the LM moving 113 miles away and 12 miles above the CSM. The descent stage of the LM was then jettisoned and the ascent stage engine fired for the first time. The ascent engine was used to lower the LM's altitude and rendezvous with the CSM. With docking and the transfer of McDivitt and Schweickart back into the CSM, the LM was jettisoned, its mission complete.

The crew of Apollo 9 accomplished all of the primary mission objectives, including rendezvous and docking of the two spacecraft, LM operations as a separate and independent spacecraft, transfer of the crew between the two spacecraft, a simulated rescue operation assuming a lunar landing abort, multiple restarts of the CSM's propulsion system (seven burns), and a full checkout of the CSM and LM systems. On Flight Day 10, the Command Module separated from the Service



A view of the free flying LM with its landing legs extended captured by David Scott who remained in the CSM while McDivitt and Schweickart checked out the LM. The Apollo 9 mission was the only time the LM flew in Earth orbit and would be photographed against a vibrant and colorful background rather than the stark lunar landscape.

Image: NASA

Module and reentered the Earth's atmosphere, splashing down in the Atlantic Ocean within three miles of the recovery ship, the USS Guadalcanal.

The near-Earth success of Apollo 9 would be repeated in lunar orbit by Apollo 10 in May of 1969, the precursor to the first Moon landing by the crew of Apollo 11 in July. Apollo 9 would also play a role in determining which astronaut would take that first step on Moon. McDivitt was originally selected to command Apollo 8, with the same mission objectives (full check out of the CSM and LM). However, the LM was behind schedule and wouldn't be ready, so NASA decided to send the Apollo 8 CM to the Moon without the LM.

McDivitt declined the command of Apollo 8's new mission (believing it was a publicity stunt), electing to trade places with the Apollo 9 crew, commanded by Frank Borman, in anticipation that the LM would be available for that flight. McDivitt's decision resulted in the swap of the backup crews for the two missions with Pete Conrad moving to command Apollo 12 rather than 11. Had McDivitt agreed to remain with Apollo 8, it's likely that Conrad would have taken the first step.

"The Times regrets the error"

On March 16, 1926, in Auburn, Massachusetts, Robert Goddard launched the first liquid-fueled rocket on a flight that would last only 2½ seconds. A graduate of Worcester Polytechnic Institute, despite discharging a powder rocket from the basement of the physics building, the significance of Goddard's feat is compared by space flight historians to the first aircraft flight at Kitty Hawk. Among his achievements, Goddard was first to prove that rockets would work in a vacuum and to mathematically explore the practicality of using rocket propulsion to reach high altitudes and even the Moon (1912).

Dr. Goddard with his liquid oxygen-gasoline rocket "Nell" in its launching frame on his aunt's farm in Auburn, MA NASA photo

His revolutionary ideas on spaceflight were treated harshly by the press (a New York Times 1920 editorial suggested that "he only seems to lack the knowledge ladled out daily in high schools."). As such, Goddard retreated from the public eye, eventually moving his research on rockets to the New Mexico desert (he had been banished in 1929 from the farm fields of Auburn by the local fire marshal).

Between 1926 and 1941, Goddard and his team, launched 34 rockets, achieving altitudes as high as 1.6 miles (2.6 km). He developed methods to control a rocket in flight using gyroscopes and steerable thrust. His patented inventions on multi-stage rockets and a liquid-fuel rocket in 1914 (Goddard is credited with 214 inventions) and his work as a theorist and engineer are considered significant to the advancement of spaceflight and Goddard is counted one of the founding fathers of modern rocketry. Before his death in 1945, he worked for the U.S. government on rocket research. NASA's Goddard Space Flight Center was named in his honor in 1959.

The location of the first liquid-fueled rocket flight is commemorated by granite markers erected on, what is now the Pakachoag Golf Course, not far from where the Massachusetts Turnpike passes by the Auburn Mall heading east.

Forty-nine years after their mocking editorial, on July 17, 1969, the day after the launch of Apollo 11, the New York Times issued a correction stating that "Further investigation and experimentation have confirmed …it is now definitely established that a rocket can function in a vacuum as well as in an atmosphere," adding "The Times regrets the error."

Zodiacal Light

The solar system is a dusty place – the source of the dust was thought to be from passing comets and collisions of asteroids. However, an accidental discovery by the Juno spacecraft on its journey to Jupiter suggests that Mars may be the source of the interplanetary dust in the orbital plane, although a clear mechanism for the dust escaping the Red Planet hasn't been identified.

Shortly before sunrise and just after sunset, sunlight can be seen reflecting off this disk of debris. Called the zodiacal light, it is best observed when the ecliptic (the apparent path of the Sun and planets) is nearly perpendicular to the horizon (on spring evenings and autumn mornings). The best time to glimpse the zodiacal light is when the Moon is absent from the evening sky (for example, during the last week of March and around the New Moon on the 2nd).

Sunrise and Sunset (New Milford, CT)

March, the month named for the planet Mars, denotes the end of the long winter nights. The Sun crosses the celestial equator at 11:33 AM (EDT) on the 20th marking the Vernal Equinox and the beginning of the spring season in the northern hemisphere.

Sun	Sunrise	Sunset
March 1st (EST)	06:28	17:44
March 15th (EDT)	07:05	19:00
March 31st (EDT)	06:38	19:17

Astronomical and Historical Events

1st Amor Asteroid 153591 (2001 SN263) (2 moons) closest approach to Earth (0.101 AU)
1st Atira Asteroid 2018 JB3 closest approach to Earth (0.611 AU)
1st History: Launch of the space shuttle Columbia (STS-109) on an eleven-day mission to service the Hubble Space Telescope (4th servicing mission) (2002)
1st History: U.S. astronaut Scott Kelly and Russian cosmonaut Mikhail Kornienko return to Earth after a one-year stay on the International Space Station (2016)
1st History: Soviet spacecraft Venera 13 lands on Venus and records first color panoramic views of the surface (1982)
1st History: discovery of Saturn's moon *Helene* by Pierre Laques and Jean Lecacheux from the Pic du Midi Observatory in the French Pyrenees; named after Helen of Troy (1980)
1st History: Soviet spacecraft Venera 3 lands (crashes) on Venus, becoming first spacecraft to impact the surface of another planet (1966)
2nd New Moon
2nd Asteroid *16 Psyche* closest approach to Earth (2.226 AU)
2nd Centaur Object *121725 Aphidas* at Opposition (23.800 AU)
2nd History: launch of an unmanned SpaceX Crew Dragon spacecraft. First American spacecraft to autonomously dock with the International Space Station (2019)
2nd History: launch of the Rosetta spacecraft (2004); rendezvoused with *Comet 67 P/Churyumov-Gerasimenko* in May 2014, sending a lander to its surface in November 2014
2nd History: launch of Pioneer 10, a Jupiter flyby mission (1972)

Astronomical and Historical Events (continued)

3rd History: Chinese National Space Agency announces the Chang'e lunar exploration program (2003)
3rd History: launch of Apollo 9 with astronauts James McDivitt, David Scott and Russell Schweickart in the first manned flight test of the lunar module (1969)
3rd History: launch of the Pioneer 4 spacecraft towards the Moon; first U.S. spacecraft to escape the Earth's gravity (1959)
4th Apollo Asteroid 2021 UL7 Near-Earth flyby (0.030 AU)
4th Apollo 138971 (2001 CB21) Near-Earth flyby (0.033 AU)
4th Plutino *90482 Orcus* at Opposition (47.121 AU)
4th History: discovery of Jupiter's rings by the Voyager 1 spacecraft (1979)
5th Comet *9P/Tempel* Perihelion (1.544 AU)
5th Aten Asteroid *3554 Amun* closest approach to Earth (1.632 AU)
5th History: discovery of Jupiter moon *Thebe* by Steve Synnott (1979)
5th History: Soviet spacecraft Venera 14 lands on Venus and uses a screw drill to obtain a surface sample that was determined to be similar to oceanic basalts on Earth (1982)
5th History: flyby of Jupiter by the Voyager 1 spacecraft (1979)
6th Apollo 2020 DC Near-Earth flyby (0.010 AU)
6th History: Valentina Tereshkova's birthday (1937), Soviet cosmonaut became the first woman to fly to space in 1963
6th History: Dawn spacecraft enters orbit around the dwarf planet *Ceres* (2015)
6th History: launch of the Kepler telescope from Cape Canaveral Air Force Station aboard a Delta II rocket (2009); designed to survey nearby stars for Earth-size and smaller planets; as of February 2019, Kepler discovered 2,414 confirmed planets with just as many yet to be confirmed3,255
6th History: flyby of Comet Halley by Vega 1, a Soviet spacecraft (1986)
7th Apollo Asteroid *314082 Dryope* closest approach to Earth (0.916 AU)
7th Kuiper Belt Object 2017 FO161 at Opposition (76.963 AU)
7th History: John Herschel born, first astronomer to survey the southern hemisphere (1792)
8th Atira Asteroid 1998 DK36 closest approach to Earth (0.994 AU)
8th Kuiper Belt Object 523671 (2013 FZ27) at Opposition (46.573 AU)
8th Kuiper Belt Object 532037 (2013 FY27) at Opposition (78.693 AU)
8th History: maiden voyage of Europe's first unmanned cargo ship to the International Space Station; the Jules Verne was launched from Kourou, French Guiana aboard an Ariane 5 rocket; in addition to delivering supplies to the ISS, the cargo ship contained a manuscript by the 19th century French author and science fiction pioneer with computations of distances from Earth to several astronomical destinations, as well as to the center of the planet (2008)
8th History: flyby of *Comet Halley* by Susei, a Japanese spacecraft (1986)
8th History: discovery of rings around Uranus by NASA's airborne observatory (1977)
9th Kuiper Belt Object *88611 Teharonhiawako* at Opposition (46.196)
9th History: launch of Ivan Ivanovich on Sputnik 9, a mannequin used to test the Russian Vostok spacecraft in preparation for its crewed missions (1961)
9th History: Space Shuttle Discovery (STS-133) makes its final landing (2011)
9th History: flyby of *Comet Halley* by Vega 2, a Soviet spacecraft (1986)
9th History: launch of the Soviet spacecraft Sputnik 9, with dog Chernushka (1961)
9th History: Yuri Gagarin born; first person to orbit the Earth in 1961 (1934)

Astronomical and Historical Events (continued)

10th First Quarter Moon
10th Moon at apogee (furthest distance from Earth)
10th Amor Asteroid *2368 Beltrovata* closest approach to Earth (1.926 AU)
10th History: Mars Reconnaissance Orbiter arrives at Mars (2006)
10th History: flyby of *Comet Halley* by Sakigake, a Japanese spacecraft (1986)
10th History: Uranus' rings discovered by astronomers James Elliot, Edward Dunham, and Jessica Mink using the Kuiper Airborne Observatory while observing a stellar occultation (1977)
11th Atira Asteroid 2015 DR215 Near-Earth flyby (0.045 AU)
11th History: launch of Pioneer 5 into solar orbit between the Earth and Venus; confirmed the existence of interplanetary magnetic fields (1965)
11th History: Urbain Leverrier born, mathematician and astronomer, predicted existence of Neptune (1811)
12th **Second Saturday Stars - Open House at McCarthy Observatory**
13th Daylight Saving - Set Clock Ahead 1 Hour (United States)
13th Aten Asteroid 2018 GY Near-Earth flyby (0.030 AU)
13th History: flyby of *Comet Halley* by Giotto, a European Space Agency spacecraft (1986)
13th History: discovery of Saturn's moon *Calypso* by Dan Pascu, P.K. Seidelmann, William Baum and D. Currie (1980)
13th History: Percival Lowell born, established observatory in Flagstaff, AZ to observe Schiaparelli's Martian "canali" and look for other signs of life (1855)
13th History: William Herschel discovers the planet Uranus; originally named Georgium Sidus by Herschel in honor of his patron, King George III of England (1781)
13th History: Galileo Galilei publishes "Sidereus Nuncius" (Starry Messenger), the first scientific treatise based on observations made through a telescope; it described Galileo's early observations of the Moon, the stars, and the moons of Jupiter (1610)
14th Pi Day
14th History: launch of ESA's ExoMars Trace Gas Orbiter and Schiaparelli lander aboard a Russian Proton rocket from the Baikonur Cosmodrome in Kazakhstan (2016)
14th History: Stardust passes within 112 miles (181 km) of the nucleus of *Comet Tempel 1* (2011)
14th History: John J. McCarthy Observatory issued Observatory Code Number 932 by the Minor Planet Center of the International Astronomical Union (2001)
14th History: first European launch of a liquid-fueled rocket by Johannes Winkler (1931)
14th History: Albert Einstein born, developed theories of mass to energy conversion and the curvature of space and time in large gravitational fields (1879)
14th History: Giovanni Schiaparelli born, director of the Milan Observatory and first to describe faint features on Mars as "canali" (1835)
15th History: dedication of the Kitt Peak National Observatory (1960)
15th History: Alan Bean born; astronaut, moonwalker and artist (1932)
16th Apollo Asteroid 2009 BD closest approach to Earth (0.361 AU)
16th History: third and final flyby of Mercury by the Mariner 10 spacecraft (the last of the Mariner probes); Mariner 10 was also the first spacecraft to use solar radiation pressure on its solar panels and the antenna for attitude control during flight (1975)
16th History: launch of Gemini 8 with astronauts Neil Armstrong and David Scott; first docking with another space vehicle, an unmanned Agena stage (1966)

Astronomical and Historical Events (continued)

16th History: launch of the first Titan II Intercontinental Ballistic Missile, also used as the launch vehicle for the manned Gemini spacecraft in the early 1960's (1962)
16th History: Robert Goddard launches first liquid-fuel rocket in Auburn, MA (1926)
16th History: Caroline Herschel born (1750)
17th Apollo Asteroid *1864 Daedalus* closest approach to Earth (1.278 AU)
17th History: discovery of Asteroid 16 *Psyche* by Annibale de Gasparis (1852)
17th History: launch of the Gravity Recovery And Climate Experiment (GRACE) spacecraft (2002)
17th History: launch of Vanguard 1, 4th artificial satellite and oldest still orbiting Earth (1958)
17th History: discovery of Saturn's moon *Phoebe* by William Pickering (1899)
18th Full Moon (Full Worm Moon)
18th Scheduled launch of a Russian Soyuz spacecraft from the Baikonur Cosmodrome, Kazakhstan, to the International Space Station with the next team of cosmonauts
18th Atira Asteroid 434326 (2004 JG6) closest approach to Earth (1.169 AU)
18th History: MESSENGER enters orbit around Mercury (2011)
18th History: New Horizons spacecraft (on its way to Pluto) crosses the orbit of Uranus (2011)
18th History: explosion during launch of a Vostok rocket carrying a military spy satellite kills 48 members of the Soviet Missile Troop; likely cause of explosion was an oxygen peroxide leak caused by the poor quality of the rocket's fuel filters (1980)
18th History: Alexei Leonov performs first spacewalk from Soviet Voskhod spacecraft (1965)
19th Apollo Asteroid 2016 FZ12 Near-Earth flyby (0.005 AU)
19th History: Tenham meteorite fall; fragments of a large meteor rain down on a remote area of western Queensland, Australia (1879)
19th History: Moon flyby by the Hiten spacecraft; Japan's first lunar flyby, orbiter and surface impactor (1990)
20th Vernal Equinox (beginning of the Spring season in the northern hemisphere) at 11:33 AM EDT (15:33 UT)
20th Vatira Asteroid *594913 'Aylo'chaxnim* closest approach to Earth (0.537 AU)
20th Apollo Asteroid *343158 Marsyas* closest approach to Earth (3.323 AU)
20th Kuiper Object 145480 (2005 TB190) at Opposition (47.306 AU)
21st Apollo Asteroid 2020 SQ Near-Earth flyby (0.007 AU)
21st Centaur Object *346889 Rhiphonos* at Opposition (13.401 AU)
21st Binary Kuiper Belt Object *385446 Manwe* at Opposition (44.079 AU)
21st History: launch of Ranger 9, Moon impact mission; transmitted the highest resolution imagery obtained to that date before impacting the floor of Alphonsus crater on the 24th (1965)
21st History: discovery of Saturn's moons *Tethys* and *Dione* by Giovanni Cassini (1684)
22nd Apollo Asteroid *1866 Sisyphus* closest approach to Earth (1.729 AU)
22nd Kuiper Belt Object 2014 YA50 at Opposition (40.787 AU)
22nd History: launch of space shuttle Atlantis (STS-76), third mission to Russian space station Mir and transfer of the first American woman, Shannon Lucid, to the station (1996)
23rd Moon at perigee (closest distance from Earth)
23rd History: launch of Gemini 3 with astronauts Virgil Grissom and John Young, first manned Gemini flight (1965)
23rd History: Wernher von Braun born, German rocket scientist and leader of the U.S. moon program (1912)

Astronomical and Historical Events (continued)

24th Apollo Asteroid 2013 BO76 Near-Earth flyby (0.034 AU)
24th History: discovery of Comet Shoemaker-Levy 9 (1993)
25th Last Quarter Moon
25th Aten Asteroid 2011 GE3 Near-Earth flyby (0.020 AU)
25th History: launch of the IMAGE spacecraft, first mission dedicated to mapping the Earth's magnetosphere (2000)
25th History: close approach of Comet *Hyakutake* (0.10 AU) to Earth (1996)
25th History: launch of Soviet spacecraft Sputnik 10 with dog Zvezdochka (1961)
25th History: Christiaan Huygens discovers *Titan*, Saturn's largest moon (1655)
26th Apollo Asteroid 2012 FX35 Near-Earth flyby (0.036 AU)
26th Amor Asteroid *8709 Kadlu* closest approach to Earth (1.260 AU)
26th History: American astronomer J.W. Draper takes first photograph of the Moon (1840)
27th Amor Asteroid *5324 Lyapunov* closest approach to Earth (2.632 AU)
27th History: U.S. astronaut Scott Kelly and Russian cosmonaut Mikhail Kornienko arrive at the International Space Station for a year-long mission (2015)
27th History: launch of the Soviet atmospheric probe and lander Venera 8 to Venus (1972)
27th History: launch of Mariner 7, Mars flyby mission (1969)
27th History: President Eisenhower approves the military lunar program to be managed by the Advanced Research Projects Agency (1958)
28th Atira Asteroid 2019 LF6 closest approach to Earth (0.264 AU)
28th Amor Asteroid *4055 Magellan* closest approach to Earth (1.173 AU)
28th Atira Asteroid 2021 LJ4 closest approach to Earth (1.274 AU)
28th Dwarf Planet *136472 Makemake* at Opposition (51.751 AU)
28th History: flyby of Comet Halley by the ICE spacecraft (1986)
28th History: Heinrich Olbers discovers the asteroid 2 *Pallas* (1802)
29th Aten Asteroid 2010 GD35 Near-Earth flyby (0.045 AU)
29th Aten Asteroid *99942 Apophis* closest approach to Earth (0.528 AU)
29th Asteroid *3530 Hammel* closest approach to Earth (1.866 AU)
29th History: First flyby of Mercury by the Mariner 10 spacecraft (1974)
29th History: Heinrich Olbers discovers the asteroid 4 *Vesta* (1807)
30th Apollo Asteroid 2020 FW5 Near-Earth flyby (0.023 AU)
30th Binary Kuiper Belt Object *58534 Logos* at Opposition (42.658 AU)
30th Scheduled launch of the Axiom Mission 1 from the Kennedy Space Center to the International Space Station for a 10-day stay
31st Aten Asteroid *398188 Agni* closest approach to Earth (0.271 AU)
31st Amor Asteroid *164215 Doloreshill* closest approach to Earth (1.478 AU)
31st Apollo Asteroid *24761 Ahau* closest approach to Earth (1.650 AU)
31st History: discovery of Dwarf Planet *Makemake* by Mike Brown, et al's (2005)
31st History: launch of Soviet spacecraft Luna 10, first man-made object to go into orbit around another planetary body; detected evidence of mass concentrations on the Moon called "mascons" (1966)

Commonly Used Terms

- Apollo: a group of near-Earth asteroids whose orbits also cross Earth's orbit; Apollo asteroids spend most of their time outside Earth orbit.
- Aten: a group of near-Earth asteroids whose orbits also cross Earth's orbit, but unlike Apollos, Atens spend most of their time inside Earth orbit.
- Atira: a group of near-Earth asteroids whose orbits are entirely within Earth's orbit
- Centaur: icy planetesimals with characteristics of both asteroids and comets
- Kuiper Belt: region of the solar system beyond the orbit of Neptune (30 AUs to 50 AUs) with a vast population of small bodies orbiting the Sun
- Opposition: celestial bodies on opposite sides of the sky, typically as viewed from Earth
- Plutino: an asteroid-sized body that orbits the Sun in a 2:3 resonance with Neptune
- Trojan: asteroids orbiting in the 4^{th} and 5^{th} Lagrange points (leading and trailing) of major planets in the Solar System

References on Distances

- the apparent width of the Moon (and Sun) is approximately one-half a degree (½°), less than the width of your little finger at arm's length which covers approximately one degree (1°); three fingers span approximately five degrees (5°)
- 1 astronomical unit (AU) is the distance from the Sun to the Earth or approximately 93 million miles

International Space Station and Starlink Satellites

- www.heavens-above.com for the times of visibility and detailed star charts for viewing the International Space Station and the bright flares from Iridium satellites.

Solar Activity

- For the latest on what's happening on the Sun and the current forecast for flares and aurora, check out www.spaceweather.com

NASA's Global Climate Change Resource

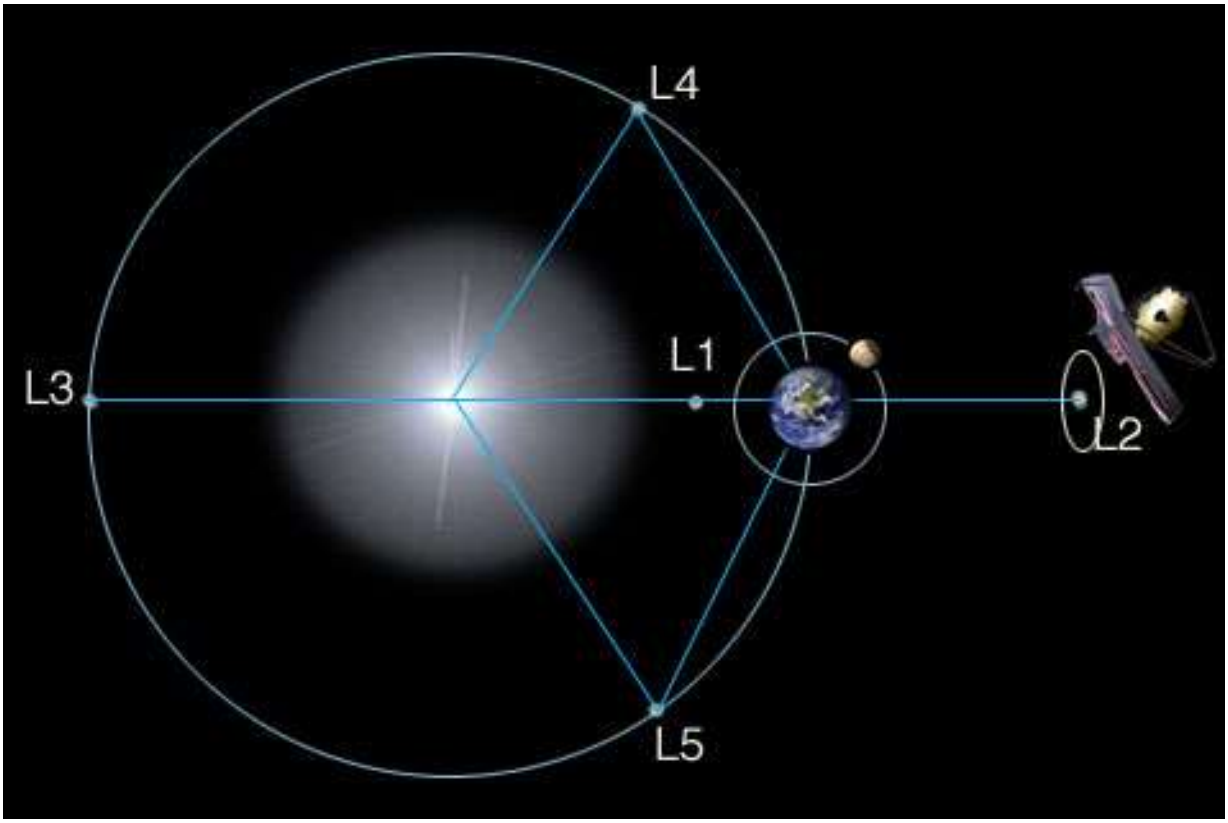
- Vital Signs of the Planet: https://climate.nasa.gov/

Mars – Mission Websites

- Mars 2020 (Perseverance rover): https://mars.nasa.gov/mars2020/
- Mars Helicopter (Ingenuity): https://mars.nasa.gov/technology/helicopter/
- Mars Science Laboratory (Curiosity rover): https://mars.nasa.gov/msl/home/
- Mars InSight (lander): https://mars.nasa.gov/insight/

Lagrange Points

Five locations discovered by mathematician Joseph Lagrange where the gravitational forces of the Sun and Earth (or other large body) and the orbital motion of the spacecraft are balanced, allowing the spacecraft to hover or orbit around the point with minimal expenditure of energy. The L2 point (and location of the Webb telescope) is located 1 million miles (1.5 million km) beyond the Earth (as viewed from the Sun).



James Webb Space Telescope

- https://webb.nasa.gov/index.html

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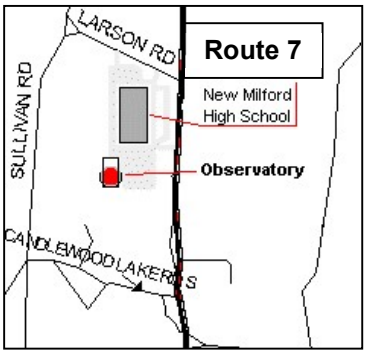

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