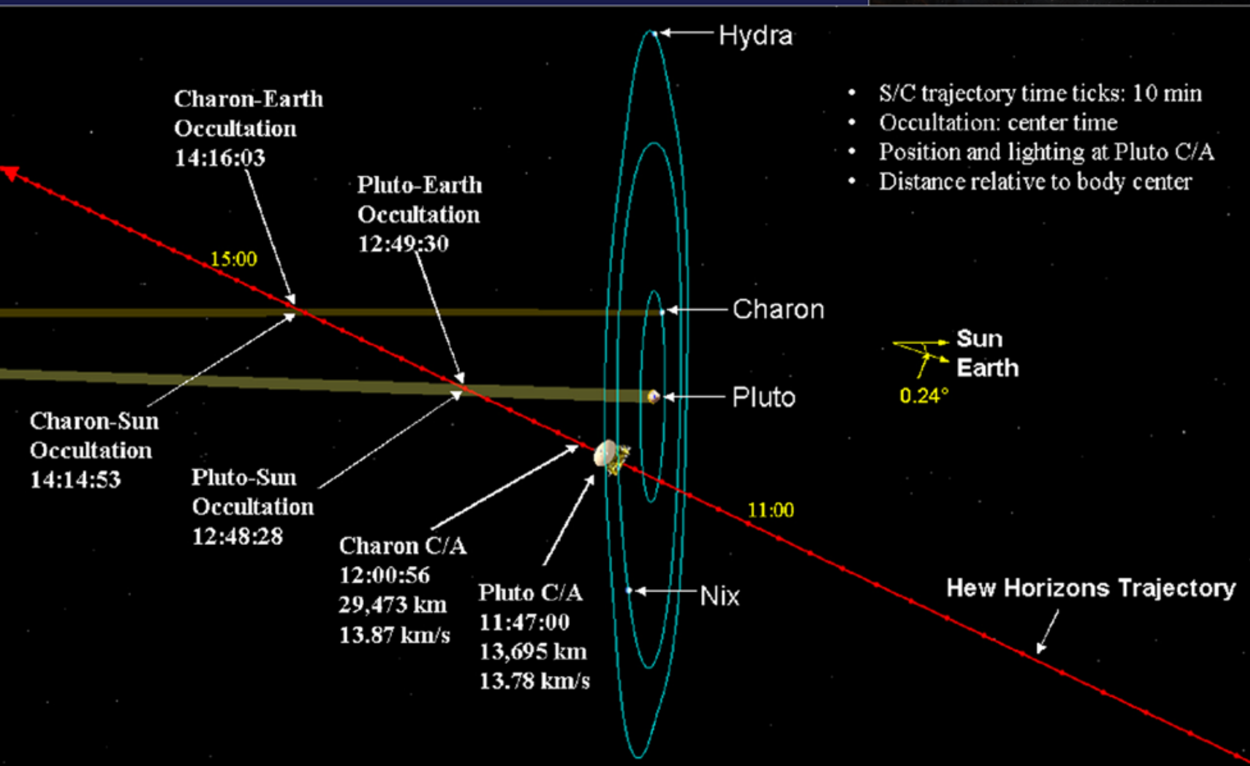
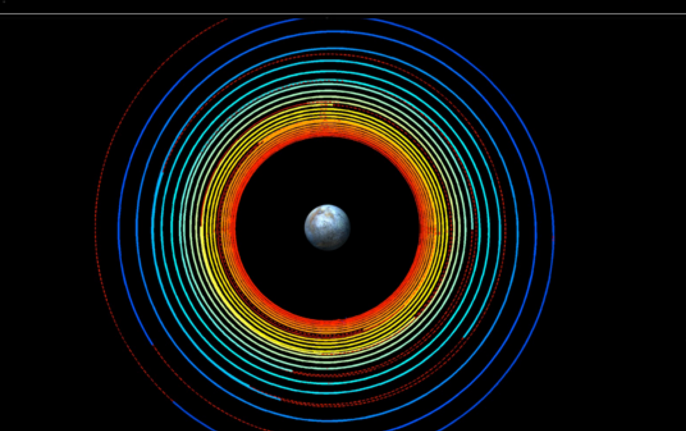
YEAR OF THE DWARVES:

CERES AND PLUTO TAKE THE STAGE





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Year of the Dwarves: Ceres and Pluto Take the Stage

— Paul Schenk, Lunar and Planetary Institute

The year 2015 is shaping up to be one of the most interesting in the short history of space exploration. Fresh on the heels of Rosetta's spectacular and revolutionary ongoing visit to a comet, and after a wait of more than half a century, we finally reach the first of the so-called dwarf planets, the last class of solar system bodies left unexplored. This year the Dawn and New Horizons missions will both reach their primary targets, Ceres and Pluto. Indeed, Dawn is on its final approach to Ceres as this is being written.

Both Ceres and Pluto are very planetary in nature. Each is the major representative of its planetary zone. Ceres holds about one-third of the total mass in the asteroid belt, and may be actively venting water vapor into space. Pluto is likely the largest Kuiper belt object (KBO), and even has a significant atmosphere and a family of at least five moons.

Our best Earth-based views of Ceres (left) and Pluto (right), both from Hubble Space Telescope images. Credit: NASA/STSci.

What will we see at Ceres and Pluto? Scientists and interested laypeople have been speculating quite a lot as we approach these two bodies. In some sense, it is an opportunity to test how well we really understand planetary bodies. Both Ceres and Pluto (and its large moon Charon) are believed to be rich in water ice. Pluto is known to have other ices on its surface, include methane, nitrogen, and carbon monoxide. We are fortunate that we have already extensively mapped comparably-sized ice-rich bodies, which serve as previews of the kinds of features we might see on Ceres and Pluto. Ceres, which is 952 kilometers in diameter, is very similar in size and overall density (ice-rock ratio) to Dione, the icy moon of Saturn, and 1208-kilometer-wide Charon is similar to Ceres as well as to Saturn's moons Rhea and Iapetus. The 2320-kilometer-wide Pluto is curiously similar to Neptune's large moon Triton.

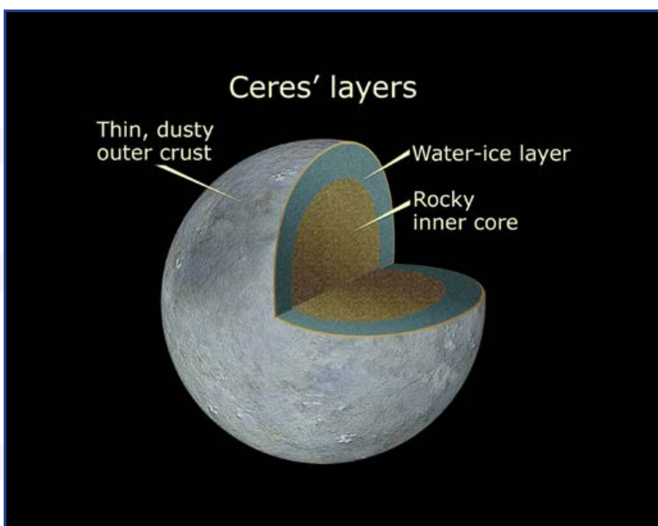
Ceres, Pluto, and Charon may (or may not!) share some features in common with these moons, but all share a critical difference. Ceres and Pluto are the first substantial icy worlds we will have visited in solitary orbit about the Sun. All the icy bodies we have visited thus far orbit close to major planets — namely Jupiter, Saturn, Uranus, and Neptune — and their geologic and atmospheric histories are strongly governed by that proximity. Gravitational tides can generate large amounts of heat within these moons. Tides power the jets of Enceladus; the tectonics and volcanism of Europa, Ganymede, Dione, Miranda, and Ariel, to name just a few; and the volcanos and perhaps even the geysers of Triton. Little of that heating presently occurs on solitary Ceres, and tides are thought to have been rather weak on Pluto or Charon. These encounters will give us our first look at icy worlds that formed and evolved on their own.

Comparison of Ceres and Dione, to scale. Dione is an icy moon orbiting Saturn, and may be the body most similar in size and internal composition to Ceres. Credit: NASA/STSci.

If there are no tides, are Ceres and Pluto cold and dead? Maybe not. All planetary bodies have within them residual heat sources: leftover heat from formation, heat from core formation, and heat from the decay of radioactive elements. These will be present in Ceres and Pluto to some degree, but will it have been enough to sustain geologic activity, or will these be bodies frozen since the solar system formed? Are there other sources of heat? Only going there will tell. As we learned from the Voyager mission, we should be prepared for anything.

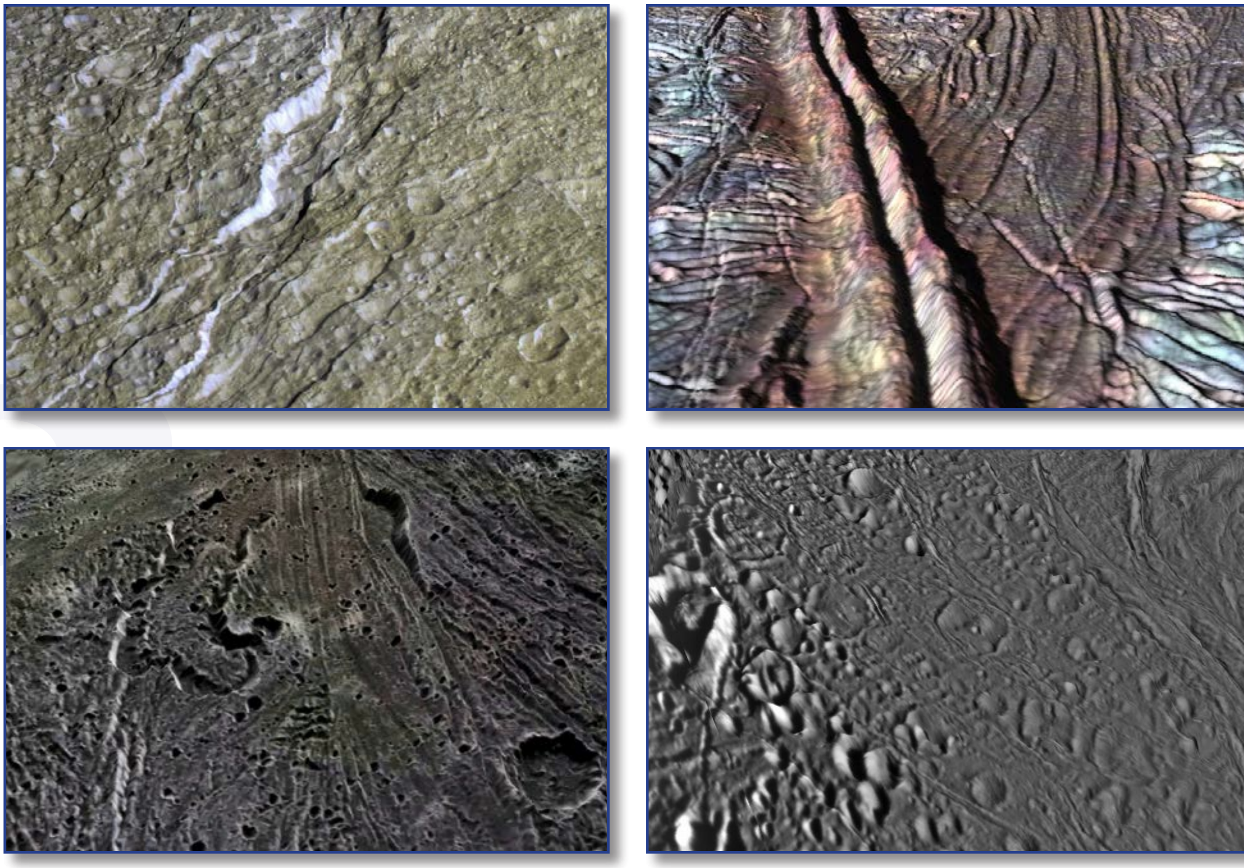
Ceres will be visited first, and we should have our first intimations of what that body looks like by the time this is published (see update at the end of this article). Although the bulk density of Ceres indicates it has an outer layer of water ice 30–100 kilometers thick, its spectral characteristics indicate a dark surface with a composition similar to that of a water-rich carbonaceous chondrite, the stuff of meteorites. Ceres has no moon and there have been no tides to heat it up, but it is the closest significant icy body to the Sun that we know of. Its surface temperature can reach almost 235 K at noon on the equator, which is rather close to the melting point of water ice (273 K) (compare this with Pluto's maximum surface temperatures of ~50 K, which is much closer to absolute zero).

The interior of Ceres is thus likely to be rather warm, and we may see flattened topography due to ice creep, signs of internal convection (perhaps similar to what we see on Europa, Triton, or Miranda), or perhaps an eroded landscape scoured of water ice by the heat of the Sun (no ice has been seen in the spectra as yet). Plus there is the evidence for venting of water vapor at Ceres, which suggests some type of internal activity or exposed water ice. It is likely that Ceres will look different from icy worlds we have seen before.



Possible internal composition of Ceres. The outer ice-rich mantle may be up to 100 kilometers thick. Model is based on studies of the shape of Ceres as derived by the Hubble Space Telescope. Dawn will test this model with detailed gravity and shape mapping. Credit: NASA, ESA, and A. Feild (STScI).

Our current best images, from Keck and Hubble Space Telescope (HST), don't give us many clues. Ceres is basically spherical, but could still have large impact basins. Ceres is also relatively bland, with few prominent markings except for a few pale bright and dark spots and perhaps some linear markings. The water vapor venting may correlate with surface features, but we do not yet know what those features are.

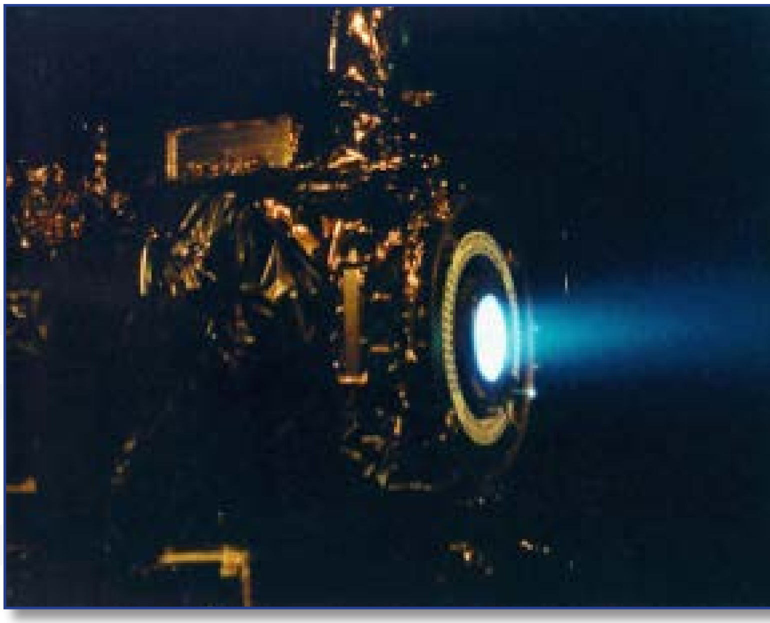


Perspective views of major features on icy satellites. Clockwise from upper left: Fractured cratered highlands on Rhea (the largest craters are ~30 kilometers across); a double ridge on Europa 3 kilometers wide and 300 meters high (these ridges may have been the sites of outgassing, similar to the "tiger stripe" double ridges on Enceladus; impactors on Enceladus flattened by high heat flow from the interior (largest craters are ~25 kilometers across); a volcanic eruption caldera on Ganymede 80 kilometers long and 35 kilometers wide.

Dawn has been slowly climbing its way toward Ceres since launch, with a yearlong stopover at asteroid Vesta in 2011–2012. Dawn has been using its ion thrusters to slowly accelerate toward Ceres, a bit like a boat uses its sails or motor to push to its island destination, and ease its way into orbit in March 2015. It will then reduce the altitude of its orbit in stages, mapping the entire surface from progressively lower altitudes over the next year or so (see the excellent blogs by Marc Rayman on the Dawn website describing the Dawn observation plans at *www.jpl.nasa.gov/blog/?search=&blog_columns=&blog_authors=Marc+Rayman*). Our final map of Ceres will be at ~35-meter resolution — better than that of Enceladus we now have from Cassini — and will make Ceres the best mapped icy world in the solar system. We should also have a global color map of Ceres at ~150-meter resolution.

Don't expect lots of images during Dawn's approach to Ceres, however. To reach orbit, the spacecraft must continue ion thrusting all the way in, and we can only point the cameras when the engines are turned off for brief intervals every 1 to 2 weeks to peek at our target. The real improvements in Ceres mapping will begin in April. Nonetheless, the science team and those watching with them will be most eager to see what those images tell us as we near our target.

While Dawn is mapping Ceres, New Horizons will complete its long-awaited visit of Pluto, providing images starting in May that are significantly improved over what we have seen from HST. The two



Dawn's ion engine undergoing testing here on Earth prior to launch in 2007. Credit: NASA.

missions are very different. New Horizons is more like a cannonball launched on a fast trajectory (with a gravity assist from Jupiter in 2007) and will zip past its "island" destination very quickly on July 14. Compared to leisurely Dawn, the Pluto encounter will occur at a blistering 14 kilometers per second. This is mostly a matter of practicality: Pluto is much further away than Ceres. New Horizons has been in high-speed flight for nine years, and its radio signal will take four hours to reach us. It was simply too expensive and would have taken far too long to send a heavy orbiter to Pluto.

The new views will come quickly as we race toward Pluto, with official encounter activities beginning this past January, and "better than Hubble" pictures throughout June. For those of us who are geologists, the real fun will begin about six days out, as we watch the final rotation of Pluto and Charon before arrival and can begin to resolve real geologic features such as craters and fractures. The high speed approach and six-day rotation periods of both Pluto and Charon mean that we will see one side of each at high resolution but will only see the other sides at resolutions from ~5 to 20 kilometers.

The highest-resolution observations will be tightly packed into a few frantic hours on July 14 when Pluto and each of its moons will all be seen at their best. In fact, New Horizons will be busy pointing at Pluto and its moons and won't communicate with Earth until after it has completed most of these observations. A full disk map of Pluto will be made at ~250-meter resolution in visible and infrared, plus a narrow strip of high-resolution pictures at 70–100-meter resolution. This will be more than twice as good as Voyager could do at Triton back in 1989. Similar maps will be made of Charon, and several looks will be made at each of the smaller moons.

New Horizons will be looking back at Pluto and Charon on departure too. It will see a slender crescent and be looking closely at the atmosphere, especially during the solar and Earth occultations when the spacecraft goes into eclipse. We may see limb hazes or even eruptions.

Neither Dawn nor New Horizons will be simple snap-and-shoot tourists! Both carry imaging spectrometers designed to identify and map the distribution of major minerals and ices on the surface. The cameras will also be used to map the topography of the surface and will supply some interesting stereo views. Dawn also has a gamma-ray spectrometer to identify elements, and New Horizons has an ultraviolet spectrometer to look at Pluto's nitrogen-rich atmosphere to determine its pressure and composition, two plasma instruments to look at the radiation environment, and a student-built dust counter. Dawn will also look into the interior of Ceres by mapping minute variations in gravity, something we won't be able to do as well for Pluto.

The New Horizons team has a special interest in Triton, which is so similar physically to Pluto but has had a very different history. Triton was likely in solar orbit like Pluto but then captured by Neptune, to catastrophic effect. As a result, Triton is one of the most geologically complex bodies in the outer solar system. In this clip from Voyager's global mosaic, cantaloupe terrain is at upper left, a volcanic province formed by icy lavas at upper right, and dark streaks formed by (non-active) gas/dust "geysers" at bottom center. The active geysers are to the south of this region. This area is 1500 kilometers across. Credit: NASA/JPL/USGS.

Dawn will take a good long look at Ceres and try to answer some fundamental questions: What has been the collisional history of the asteroid belt, as recorded in craters on the surface of Ceres? Does Ceres have an icy mantle and a rocky core? Dawn gravity and surface mapping of impact craters and other landforms should confirm this either way. How is Ceres venting water vapor into space? Is it sublimation of ice molecules from a recent impact event? Is it an active water-rich volcano? Is it like the collimated jets of Enceladus, the jets on comets, or something different?

New Horizons' visit to Pluto should answer questions as well: Will Pluto or Charon be geologically complex like Saturn's moons? How thick is Pluto's atmosphere, and how does it interact with the cold icy surface? Are there any hydrocarbon hazes in the atmosphere? What will impact craters tell us about the population of objects in the Kuiper belt that Pluto has encountered? Are there more moons or even a ring system at Pluto? Evidence is mounting that both Rhea and Iapetus had rings in the past, so maybe we will find evidence for the same at Ceres and Pluto.

Pluto is ice rich, and so is Ceres — perhaps the most ice on any body this side of Jupiter, other than Earth. Do (or did) either Ceres or Pluto have an internal liquid water ocean like those known to occur within Europa and Enceladus? Who can say what might be floating or dissolved within such oceans? Will Ceres or Pluto join the list of active icy worlds now known to be common among the giant outer planets and may well be common around other stars?

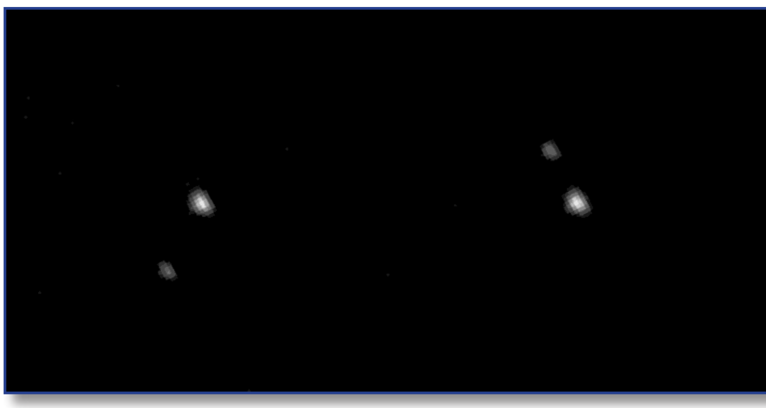
After New Horizons flashes past Pluto it may have more work to do. Hubble Space Telescope has discovered several smaller KBO's that the spacecraft can reach. All are less than 100 kilometers across and would be reached in 2019. A proposal to NASA to extend the mission and go to one of these objects will be made after the Pluto encounter. In the meantime, New Horizons will transmit its data. Most of the data will be on Earth by the end of 2015, although in compressed format; full transmission will take most of 2016. Dawn will continue mapping Ceres into early 2016. Once in its final orbit at an altitude of 375 kilometers, Dawn will remain in that orbit long after its final transmission to Earth.

So we revisit the question: What will we see? Both bodies are at present poorly resolved fuzzy tennis balls in space. Vague surface markings provide few clues; we do not even know if there are any impact craters, although it is likely we will see many (see update below). My guesses are possibly wrong, but I suspect that all these objects will be geologically complex and betray some indications of geologic activity inside.

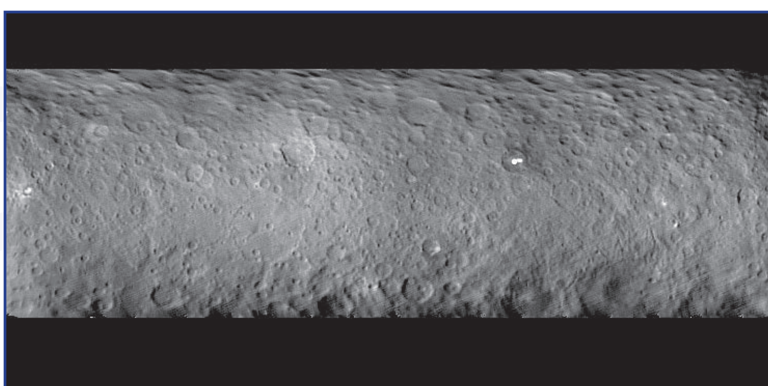
It has taken 56 years since the launch of the first Earth satellite to reach these small but fascinating objects (you could say it has taken 214 years to reach one of these objects if you count the time from the discovery of Ceres in 1801!). It has taken eight years since launch to reach Ceres and nine years — on the fastest trajectory ever — to reach cold distant Pluto. It has been a long road, but the planetary doubleheader this year should make it more than worth the wait.

Update:

Both New Horizons and Dawn have made significant process since this article was written. New Horizons has begun its formal approach phase, consisting of routine monitoring of the Pluto system. Although we must wait until May before obtaining the "Better than Hubble" images, the approach images (such as the views below obtained in late January) will allow us to search for more moons or even rings. Dawn, on the other hand, has gotten within 35,000 kilometers of Ceres on its final approach and has completed its first global map (see below)! True, the map only shows features down to 4 kilometers in size and much remains mysterious, but we now know that Ceres is cratered and has some interesting features, including several strange bright spots of mysterious origin at the bottom of a 95-kilometer-wide crater.



Credit: NASA/Johns Hopkins University Applied Physics Laboratory/ Southwest Research Institute.



Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA.

—Paul Schenk is a staff scientist at the Lunar and Planetary Institute in Houston, Texas, studying impact cratering on small bodies and plume deposition processes on Enceladus. He is a Participating Scientist on the Dawn and Cassini missions, and a Science Team member on New Horizons.

About the Cover:

Upper right: Artist's concept of the New Horizons spacecraft as it approaches Pluto and its largest moon, Charon, in July 2015. The spacecraft's most prominent design feature is a nearly 2.1-meter dish antenna, through which it will communicate with Earth from as far away as 7.5 billion kilometers. Credit: Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute (JHUAPL/SwRI).

Middle: New Horizons' trajectory takes it right through the Pluto system in just a few days. Credit: NASA/JHUAPL.

Lower left: Graphic showing Dawn's spiral descent from survey orbit to high-altitude mapping orbit (HAMO). Credit: NASA/JPL.

Lower right: Artist's concept depicting the Dawn spacecraft thrusting with its ion propulsion system as it travels from Vesta (lower right) to Ceres (upper left). Credit: NASA/JPL.

The *Lunar and Planetary Information Bulletin* collects, synthesizes, and disseminates current research and findings in the planetary sciences to the research community, science libraries, educators, students, and the public. The *Bulletin* is dedicated to engaging, exciting, and educating those with a passion for the space sciences while developing future generations of explorers.

The *Bulletin* welcomes articles dealing with issues related to planetary science and exploration. Of special interest are articles describing web-based research and educational tools, meeting highlights and summaries, and descriptions of space missions. Peer-reviewed research articles, however, are not appropriate for publication in the *Bulletin*. Suggested topics can be e-mailed to the editors, who will provide guidelines for formatting and content.

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Venus Express Goes Gently Into the Night

Artist's impression of Europe's Venus Express orbiter at Venus. Credit: ESA.

ESA's Venus Express has ended its eight-year mission after far exceeding its planned life. The spacecraft exhausted its propellant during a series of thruster burns to raise its orbit following the low-altitude aerobraking earlier this year.

Since its arrival at Venus in 2006, Venus Express had been on an elliptical 24-hour orbit, travelling 66,000 kilometers (41,000 miles) above the south pole at its furthest point and to within 200 kilometers (124 miles) over the north pole on its closest approach, conducting a detailed study of the planet and its atmosphere. However, after eight years in orbit and with propellant for its propulsion system running low, Venus Express was tasked in mid-2014 with a daring aerobraking campaign, during which it dipped progressively lower into the atmosphere on its closest approaches to the planet.

Normally, the spacecraft would perform routine thruster burns to ensure that it did not come too close to Venus and risk being lost in the atmosphere. But this unique adventure was aimed at achieving the opposite, namely reducing the altitude and allowing an exploration of previously uncharted regions of the atmosphere. The campaign also provided important experience for future missions — aerobraking can be used to enter orbit around planets with atmospheres without having to carry quite so much propellant.

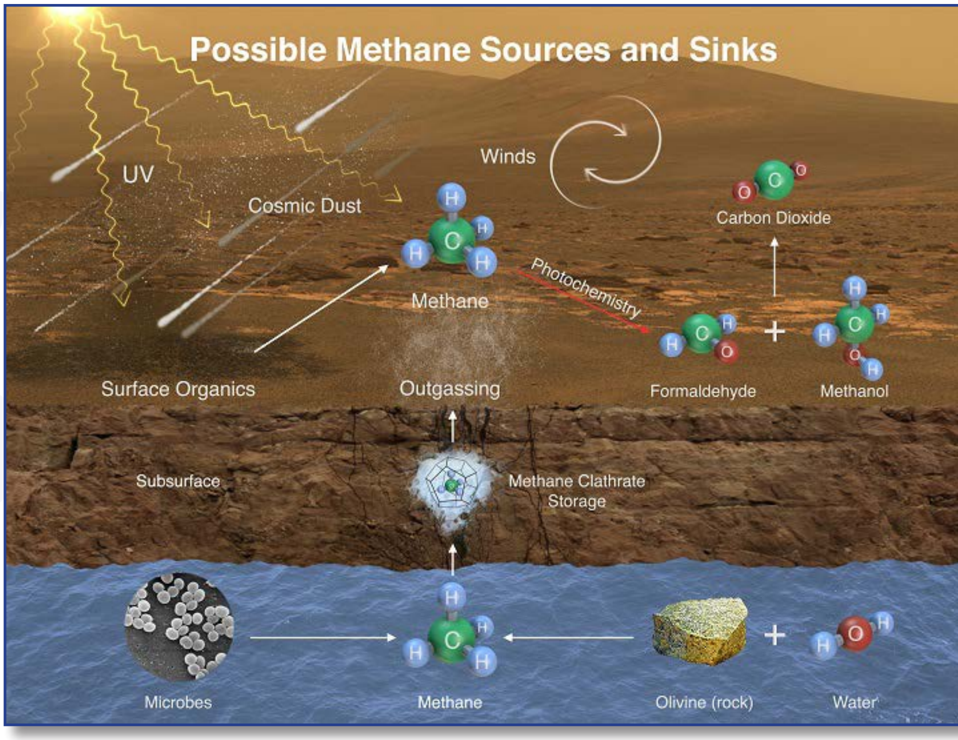
Between May and June 2014, the lowest point of the orbit was gradually reduced to about 130–135 kilometers (81–84 miles), with the core part of the aerobraking campaign lasting from June 18 to July 11. After this month of "surfing" in and out of the atmosphere at low altitudes, the lowest point of the orbit was raised again through a series of 15 small thruster burns, such that by July 26 it was back up to about 460 kilometers (286 miles), yielding an orbital period of just over 22 hours. The mission then continued in a reduced science phase, as the closest approach of the spacecraft to Venus steadily decreased again naturally under gravity.

The mission, originally planned for two-plus-two (two years nominal operation with a two-year extension) years, successfully collected critical science data from the "Morning Star" for more than eight years. For more information, visit *www.esa.int/Our_Activities/Space_Science/Venus_Express*.

NASA Rover Finds Active and Ancient Organic Chemistry on Mars

NASA's Mars Curiosity rover has measured a tenfold spike in methane, an organic chemical, in the atmosphere around it and detected other organic molecules in a rock-powder sample collected by the robotic laboratory's drill. "This temporary increase in methane — sharply up and then back down — tells us there must be some relatively localized source," said Sushil Atreya of the University of Michigan, Ann Arbor, a member of the Curiosity rover science team. "There are many possible sources, biological or non-biological, such as interaction of water and rock."

Researchers used Curiosity's onboard Sample Analysis at Mars (SAM) laboratory a dozen times in a 20-month period to sniff methane in the atmosphere. During two of those months, in late 2013 and early 2014, four measurements averaged seven parts per billion. Before and after that, readings averaged only



This image illustrates possible ways methane might be added to Mars' atmosphere (sources) and removed from the atmosphere (sinks). NASA's Curiosity Mars rover has detected fluctuations in methane concentration in the atmosphere, implying both types of activity occur on modern Mars. Credit: NASA/JPL-Caltech/SAM-GSFC/University of Michigan.

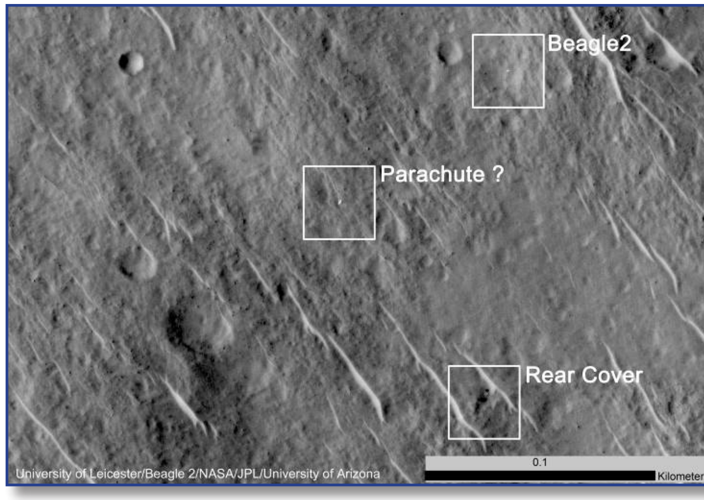
one-tenth that level. Curiosity also detected different martian organic chemicals in powder drilled from a rock dubbed Cumberland, the first definitive detection of organics in surface materials of Mars. These martian organics could either have formed on Mars or been delivered to Mars by meteorites.

Organic molecules, which contain carbon and usually hydrogen, are chemical building blocks of life, although they can exist without the presence of life. Curiosity's findings from analyzing samples of atmosphere and rock powder do not reveal whether Mars has ever harbored living microbes, but the findings do shed light on a chemically active modern Mars and on favorable conditions for life on ancient Mars. For more information, visit *mars.jpl.nasa.gov/msl*.

"Lost" 2003 Mars Lander Found by Mars Reconnaissance Orbiter

The Beagle 2 Mars Lander, built by the United Kingdom (UK), had been thought lost on Mars since 2003, but has now been found in images from NASA's Mars Reconnaissance Orbiter (MRO). A set of three observations with the orbiter's High Resolution Imaging Science Experiment (HiRISE) camera shows Beagle 2 partially deployed on the surface of the planet, ending the mystery of what happened to the mission more than a decade ago. They show that the lander survived its December 25, 2003, touchdown enough to at least partially deploy its solar arrays.

Beagle 2 hitched a ride to Mars on the European Space Agency's long-lived Mars Express mission. It was a collaboration between industry and academia designed to deliver world-class science from the surface of the Red Planet. "I am delighted that Beagle 2 has finally been found on Mars," said Mark Sims of the University of Leicester. He was an integral part of the Beagle 2 project from the start, leading the initial study phase, and was the Beagle 2 mission manager. "Every Christmas Day since 2003 I have wondered what happened to Beagle 2. My Christmas Day in 2003, alongside many others who worked on Beagle 2, was ruined by the disappointment of not receiving data from the surface of Mars. To be frank I had all but given up hope of ever knowing what happened to Beagle 2. The images show that we came so close to achieving the goal of science on Mars."



This annotated image shows where features seen in an observation by NASA's Mars Reconnaissance Orbiter have been interpreted as hardware from the December 25, 2003, arrival at Mars of the United Kingdom's Beagle 2 lander. The image was taken in 2014 by the orbiter's HiRISE camera. Credit: NASA/JPL-Caltech/Univ. of Arizona/University of Leicester.

HiRISE images initially searched by Michael Croon of Trier, Germany, a former member of the European Space Agency's Mars Express operations team, provide evidence for the lander and key descent components on the surface of Mars within the expected landing area of Isidis Planitia, an impact basin close to the equator. Subsequent reimaging and analysis by the Beagle 2 team, the HiRISE team, and NASA's Jet Propulsion Laboratory (JPL) have confirmed that the targets discovered are of the correct size, shape, color, and dispersion to be Beagle 2. JPL planetary geologist Tim Parker, who has assisted in the search and processed some of the images, said, "I've been looking over the objects in the images carefully, and I'm convinced that these are Beagle 2 hardware."

Analysis of the images indicates what appears to be a partially deployed configuration, with what is thought to be the rear cover with its pilot/drogue chute (still attached) and main parachute close by. Due to the small size of Beagle 2 (less than 2 meters, or 7 feet, across for the deployed lander) it is right at the limit of detection of HiRISE, the highest-resolution camera orbiting Mars. The targets are within the expected landing area at a distance of about 5 kilometers (3 miles) from its center.

"I can imagine the sense of closure that the Beagle 2 team must feel," said Richard Zurek of JPL, project scientist now for MRO and previously for NASA's still-missing 1998 Mars Polar Lander. "MRO has helped find safe landing sites on Mars for the Curiosity and Phoenix missions and has searched for missing craft to learn what may have gone wrong. It's an extremely difficult task, as the craft are small and the search areas are vast. It takes the best camera we have in Mars orbit and work by dedicated individuals to be successful at this."

For more information, visit *hirise.lpl.arizona.edu* and *www.nasa.gov/mro*.

This image shows asteroid 2004 BL86, which safely flew past Earth on January 26, 2015. Credit: NASA/JPL-Caltech.

Asteroid Flying Past Earth Has Moon

Scientists working with NASA's 70-meter-wide (230 feet) Deep Space Network antenna at Goldstone, California, have released the first radar images of asteroid 2004 BL86. The images show that the asteroid, which made its closest approach to Earth on January 26, 2015, at 8:19 a.m. Pacific Standard Time at a distance of about 1.2 million kilometers (745,000 miles, or 3.1 times the distance from Earth to the Moon), has its own small moon.

The images were generated from data collected at Goldstone on January 26, 2015. They show the primary body is approximately 325 meters (1100 feet) across and has a small moon approximately 70 meters (230 feet) across. In the near-Earth population, about 16% of asteroids that are about 200 meters (655 feet) or larger are a binary (the primary asteroid with a smaller asteroid moon orbiting it) or even triple systems (two moons). The resolution on the radar images is 4 meters (13 feet) per pixel.

The trajectory of asteroid 2004 BL86 is well understood. The January flyby was the closest approach the asteroid will make to Earth for at least the next two centuries. It is also the closest a known asteroid this size will come to Earth until asteroid 1999 AN10 flies past our planet in 2027.

Asteroid 2004 BL86 was discovered on January 30, 2004, by the Lincoln Near-Earth Asteroid Research (LINEAR) survey in White Sands, New Mexico. Lightcurve observations made during the days leading up to asteroid's flyby by Joseph Pollock of Appalachian State University in Boone, North Carolina, Petr Pravec of the Ondrejov Observatory in the Czech Republic, and Julian Oey of the Blue Mountains Observatory in Leura, Australia, indicated the asteroid was a binary.

NASA places a high priority on tracking asteroids and protecting our home planet from them. In fact, the U.S. has the most robust and productive survey and detection program for discovering near-Earth objects (NEOs). To date, U.S. assets have discovered over 98% of known objects.

For more information, visit *neo.jpl.nasa.gov* and *www.jpl.nasa.gov/asteroidwatch*.

JUICE Mission Gets Green Light for Next Stage of Development

The European Space Agency's JUpiter ICy moons Explorer (JUICE) mission has been given the green light to proceed to the next stage of development. This approval is a milestone for the mission, which aims to launch in 2022 to explore Jupiter and its potentially habitable icy moons. JUICE gained approval for its implementation phase from ESA's Science Programme Committee during a meeting at the European Space Astronomy Centre near Madrid, Spain, in November.

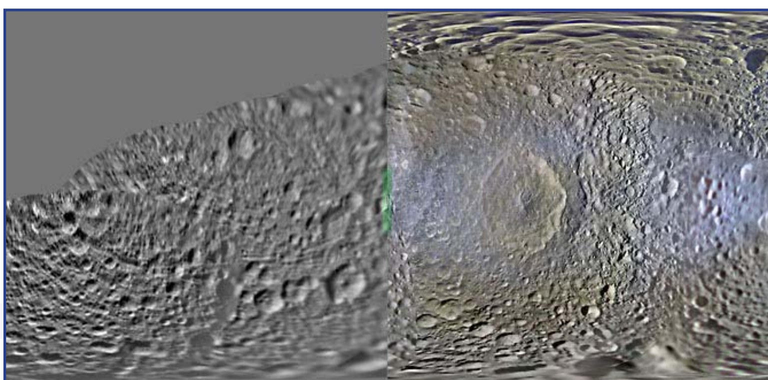
Chosen by ESA in May 2012 to be the first large mission within the Cosmic Vision Programme, JUICE is planned to be launched in 2022 and to reach Jupiter in 2030. The mission will tour the giant planet to explore its atmosphere, magnetosphere, and tenuous set of rings and will characterize the icy moons Ganymede, Europa, and Callisto. Detailed investigations of Ganymede will be performed when JUICE enters into orbit around it — the first time any icy moon has been orbited by a spacecraft. During its lifetime, the mission will give us an unrivalled and in-depth understanding of the jovian system and of these moons.

Artist's impression of the JUICE mission. Credit: ESA/AOES.

The scientific goals of the mission are enabled by its instrument suite. This includes cameras, spectrometers, a radar, an altimeter, radio science experiments, and sensors used to monitor the plasma environment in the jovian system. In February 2013, the SPC approved the payload that will be developed by scientific teams from 16 European countries, the U.S., and Japan, through corresponding national funding. For more information, visit *sci.esa.int/juice*.

Saturn's Moons: What a Difference a Decade Makes

Almost immediately after NASA's twin Voyager spacecraft made their brief visits to Saturn in the early 1980s, scientists were hungry for more. The Voyagers had offered them only a brief glimpse of a family of new worlds — Saturn's icy moons — and the researchers were eager to spend more time among those bodies.



These side-by-side images compare the saturnian moom Mimas as mapped by Voyager ten years ago (left), and as mapped using recent Cassini images (right). Credit: NASA/P. Schenk, LPI.

The successor to the Voyagers at Saturn, NASA's Cassini spacecraft, has spent the past 10 years collecting images and other data as it has toured the Ringed Planet and its family of satellites. New color maps, produced from this trove of data, show that Cassini has essentially fulfilled one of its many mission objectives: producing global maps of Saturn's six major icy moons. These are the large saturnian moons, excluding haze-covered Titan, known before the start of the Space Age: Mimas, Enceladus, Tethys, Dione, Rhea and Iapetus. Aside from a gap in the north polar region of Enceladus (to be filled in next year), and some areas of Iapetus, this objective is now more or less complete. The new maps were produced by Paul Schenk, a participating scientist with the Cassini imaging team based at the Lunar and Planetary Institute (LPI) in Houston.

These are the best global, color maps of these moons to date, and the first to show natural brightness variations and high-resolution color together. Colors in the maps represent a broader range than human vision, extending slightly into infrared and ultraviolet wavelengths. Differences in color across the moons' surfaces that are subtle in natural-color views become much easier to study in these enhanced colors.

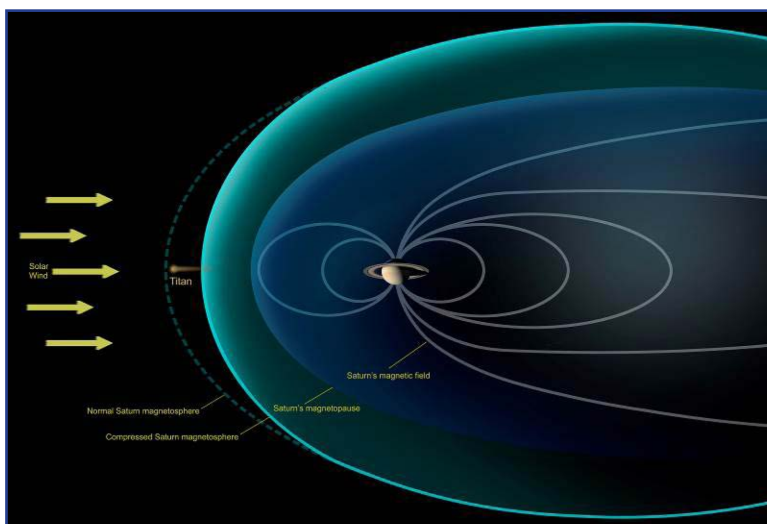
Cassini's enhanced color views have yielded several important discoveries about the icy moons. The most obvious are differences in color and brightness between the two hemispheres of Tethys, Dione, and Rhea. The dark reddish colors on the moons' trailing hemispheres are due to alteration by charged particles and radiation in Saturn's magnetosphere. Except for Mimas and Iapetus, the blander leading hemispheres of these moons — i.e., the sides that always face forward as the moons orbit Saturn — are all coated with icy dust from Saturn's E-ring, formed from tiny particles erupting from the south pole of Enceladus.

Enceladus itself displays a variety of colorful features. Some of the gas and dust being vented into space from large fractures near the moon's south pole returns to the surface and paints Enceladus with a fresh coating. The yellow and magenta tones in Cassini's color map are thought to be due to differences in the thickness of these deposits. Many of the most recently formed fractures on Enceladus, those near the south pole in particular, have a stronger ultraviolet signature, which appears bluish in these maps. Their color may be due to large-grained ice exposed on the surface, not unlike blue ice seen in some places in Earth's Arctic.

To view the maps, visit the LPI's website at *www.lpi.usra.edu/icy_moons*.

Cassini Catches Titan Naked in the Solar Wind

Researchers studying data from NASA's Cassini mission have observed that Saturn's largest moon, Titan, behaves much like Venus, Mars, or a comet when exposed to the raw power of the solar wind. The observations suggest that unmagnetized bodies like Titan might interact with the solar wind in the same basic ways, regardless of their nature or distance from the Sun.



This diagram depicts conditions observed by NASA's Cassini spacecraft during a flyby in December 2013, when Saturn's magnetosphere was highly compressed, exposing Titan to the full force of the solar wind. Credit: NASA/JPL-Caltech.

Titan is large enough that it could be considered a planet if it orbited the Sun on its own, and a flyby of the giant moon in December 2013 simulated that scenario, from Cassini's vantage point. The encounter was unique within Cassini's mission, as it was the only time the spacecraft has observed Titan in a pristine state, outside the region of space dominated by Saturn's magnetic field, called its magnetosphere. "We observed that Titan interacts with the solar wind very much like Mars, if you moved it to the distance of Saturn," said Cesar Bertucci of the Institute of Astronomy and Space Physics in Buenos Aires, who led the research with colleagues from the Cassini mission. "We thought Titan in this state would look different. We certainly were surprised," he said.

The solar wind is a fast-flowing gale of charged particles that continually streams outward from the Sun, flowing around the planets like islands in a river. Studying the effects of the solar wind at other planets helps scientists understand how the Sun's activity affects their atmospheres. These effects can include modification of an atmosphere's chemistry as well as its gradual loss to space.

Titan spends about 95% of the time within Saturn's magnetosphere. But during a Cassini flyby on December 1, 2013, the giant moon happened to be on the sunward side of Saturn when a powerful outburst of solar activity reached the planet. The strong surge in the solar wind so compressed the Sun-facing side of Saturn's magnetosphere that the bubble's outer edge was pushed inside the orbit of Titan. This left the moon exposed to, and unprotected from, the raging stream of energetic solar particles.

Using its magnetometer instrument, which is akin to an equisitely sensitive compass, Cassini has observed Titan many times during the mission's decade in the Saturn system, but always within Saturn's magnetosphere. The spacecraft has not been able to detect a magnetic field coming from Titan itself. In its usual state, Titan is cloaked in Saturn's magnetic field. This time the influence of Saturn was not present, allowing Cassini's magnetometer to observe Titan as it interacted directly with the solar wind. The special circumstance allowed Bertucci and colleagues to study the shock wave that formed around Titan where the full-force solar wind rammed into the moon's atmosphere.

At Earth, our planet's powerful magnetic field acts as a shield against the solar wind, helping to protect our atmosphere from being stripped away. In the case of Venus, Mars, and comets — none of which are protected by a global magnetic field — the solar wind drapes around the objects themselves, interacting directly with their atmospheres (or in a comet's case, its coma). Cassini saw the same thing at Titan. Researchers thought they would have to treat Titan's response to the solar wind with a unique approach because the chemistry of the hazy moon's dense atmosphere is highly complex. But Cassini's observations of a naked Titan hinted at a more elegant solution. "This could mean we can use the same tools to study how vastly different worlds, in different parts of the solar system, interact with the wind from the Sun," Bertucci said.

For more information, visit *www.nasa.gov/cassini* and *saturn.jpl.nasa.gov*.

"Astro-Archaeological" Discovery of Replica Solar System with Earth-Sized Planets from the Dawn of Time

A team of scientists led by asteroseismologists at the University of Birmingham have discovered a solar system with five Earth-sized planets dating back to the dawn of the galaxy. Observations from NASA's Kepler mission led to the discovery of a Sun-like star (Kepler-444) hosting five planets with sizes between Mercury and Venus. The results appeared in a recent issue of *The Astrophysical Journal*.

Kepler-444 was formed 11.2 billion years ago, when the universe was less than 20% of its current age. This is the oldest known system of terrestrial-sized planets in our galaxy — two-and-a-half times older than Earth.

The team carried out the research using asteroseismology — listening to the natural resonances of the host star that are caused by sound trapped within it. These oscillations lead to miniscule changes or pulses in its brightness that allow the researchers to measure its diameter, mass, and age. The planets were then detected from the dimming that occurs when the planets transited, or passed across, the stellar disk. This fractional fading in the intensity of the light received from the star enables scientists to accurately measure the size of the planets relative to the size of the star.

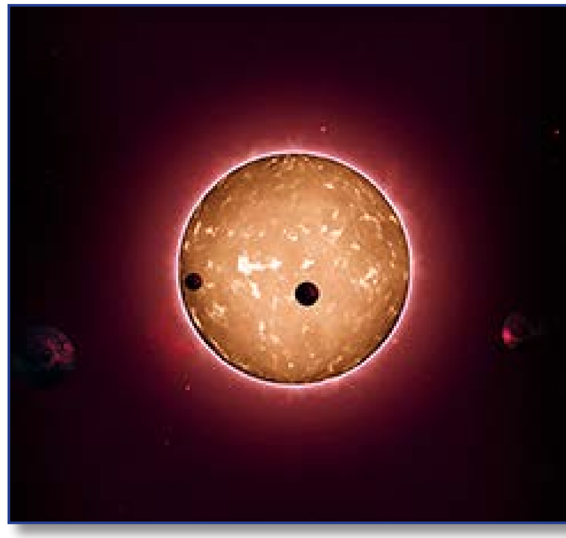


Illustration showing Kepler-444, which hosts five Earth-sized planets in very compact orbits. The planets were detected from the dimming that occurs when they transit the disk of their parent star, as shown in this artist's conception. Credit: Tiago Campante/Peter Devine.

According to research team leader Dr. Tiago Campante, of the University of Birmingham's School of Physics and Astronomy, "There are far-reaching implications for this discovery. We now know that Earth-sized planets have formed throughout most of the universe's 13.8-billion-year history, which could provide scope for the existence of ancient life in the galaxy. By the time the Earth formed, the planets in this system were already older than our planet is today. This discovery may now help to pinpoint the beginning of what we might call the 'era of planet formation'."

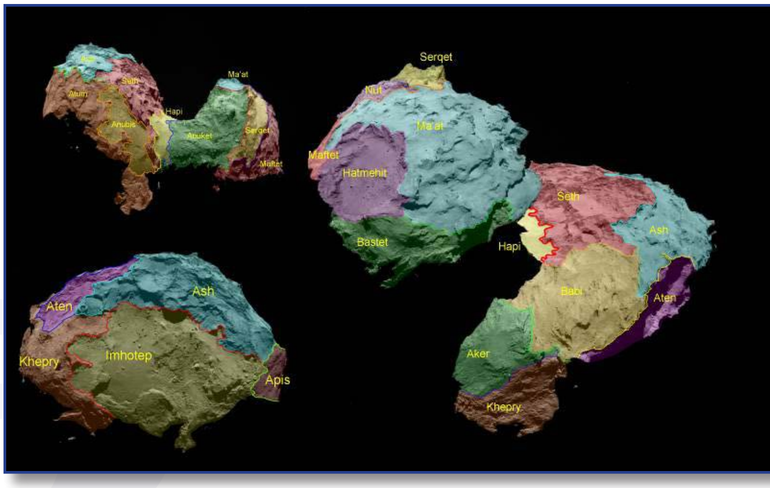
University of Birmingham professor Bill Chaplin, who has been leading the team studying solar-type stars using asteroseismology for the Kepler mission, said, "The first discoveries of exoplanets around other Sun-like stars in our galaxy have fueled efforts to find other worlds like Earth and other terrestrial planets outside our solar system. We are now getting first glimpses of the variety of galactic environments conducive to the formation of these small worlds. As a result, the path toward a more complete understanding of early planet formation in the galaxy is now unfolding before us."

For more information, visit *kepler.nasa.gov*.

Getting to Know Rosetta's Comet

Rosetta is revealing its host comet as having a remarkable array of surface features and with many processes contributing to its activity, painting a complex picture of its evolution. In a special edition of the journal *Science*, initial results are presented from 7 of Rosetta's 11 science instruments based on measurements made during the approach to and soon after arriving at Comet 67P/Churyumov-Gerasimenko in August 2014.

The familiar shape of the dual-lobed comet has now had many of its vital statistics measured: The small lobe measures 2.6 × 2.3 × 1.8 kilometers and the large lobe 4.1 × 3.3 × 1.8 kilometers. The total volume of the comet is 21.4 km^3 and the Radio Science Instrument has measured its mass to be 10 billion tonnes, yielding a density of 470 kg/m^3. By assuming an overall composition dominated by water ice and dust with a density of 1500–2000 kg/m^3, the Rosetta scientists show that the comet has a very high porosity of



The 19 regions identified on Comet 67P/Churyumov-Gerasimenko are separated by distinct geomorphological boundaries. Credit: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA.

70–80%, with the interior structure likely comprising weakly bonded ice-dust clumps with small void spaces between them.

The OSIRIS scientific camera has imaged some 70% of the surface to date; the remaining unseen area lies in the southern hemisphere, which has not yet been fully illuminated since Rosetta's arrival. The scientists have so far identified 19 regions separated by distinct boundaries and, following the ancient Egyptian theme of the Rosetta mission, these regions are named for Egyptian deities, and are grouped according to the type of terrain dominant within. Five basic — but diverse — categories of terrain type have been determined: dust-covered; brittle materials with pits and circular structures; large-scale depressions; smooth terrains; and exposed, more consolidated ("rock-like") surfaces.

Much of the northern hemisphere is covered in dust. As the comet is heated, ice turns directly into gas that escapes to form the atmosphere or coma. Dust is dragged along with the gas at slower speeds, and particles that are not traveling fast enough to overcome the weak gravity fall back to the surface. Some sources of discrete jets of activity have also been identified. While a significant proportion of activity emanates from the smooth neck region, jets have also been spotted rising from pits.

The gases that escape from the surface have also been seen to play an important role in transporting dust across the surface, producing dune-like ripples, and boulders with "wind-tails" — the boulders act as natural obstacles to the direction of the gas flow, creating streaks of material "downwind" of them.

The dusty covering of the comet may be several meters thick in places and measurements of the surface and subsurface temperature by the Microwave Instrument on the Rosetta Orbiter (MIRO) suggest that the dust plays a key role in insulating the comet interior, helping to protect the ices thought to exist below the surface.

Small patches of ice may also be present on the surface. At scales of 15–25 meters, Rosetta's Visible, InfraRed and Thermal Imaging Spectrometer (VIRTIS) finds the surface to be compositionally very homogenous and dominated by dust and carbon-rich molecules, but largely devoid of ice. But smaller, bright areas seen in images are likely to be ice-rich. Typically, they are associated with exposed surfaces or debris piles where collapse of weaker material has occurred, uncovering fresher material.

On larger scales, many of the exposed cliff walls are covered in randomly oriented fractures. Their formation is linked to the rapid heating–cooling cycles that are experienced over the course of the comet's 12.4-hour day and over its 6.5-year elliptical orbit around the Sun. One prominent and intriguing feature is a 500-meter-long crack seen roughly parallel to the neck between the two lobes, although it is not yet known if it results from stresses in this region.

Some very steep regions of the exposed cliff faces are textured on scales of roughly 3 meters with features that have been nicknamed "goosebumps." Their origin is yet to be explained, but their characteristic size may yield clues to the processes that were at work when the comet formed.

And on the very largest scale, the origin of the comet's overall double-lobed shape remains a mystery. The two parts seem very similar compositionally, potentially favoring the erosion of a larger, single body. But the current data cannot yet rule out the alternative scenario, that two separate comets formed in the same part of the solar system and then merged together at a later date. This key question will be studied further over the coming year as Rosetta accompanies the comet around the Sun.

Their closest approach to the Sun will occur on August 13 at a distance of 186 million kilometers, between the orbits of Earth and Mars. As the comet continues to move closer to the Sun, an important focus for Rosetta's instruments is to monitor the development of the comet's activity, in terms of the amount and composition of gas and dust emitted by the nucleus to form the coma.

Images from the scientific and navigation cameras have shown an increase in the amount of dust flowing away from the comet over the past six months, and MIRO showed a general rise in the comet's global water vapor production rate, from 0.3 liters per second in early June 2014 to 1.2 liters per second by late August. MIRO also found that a substantial portion of the water seen during this phase originated from the comet's neck.

Water is accompanied by other outgassing species, including carbon monoxide and carbon dioxide. The Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA) is finding large fluctuations in the composition of the coma, representing daily and perhaps seasonal variations in the major outgassing species. Water is typically the dominant outgassing molecule, but not always.

By combining measurements from MIRO, ROSINA, and Rosetta's Grain Impact Analyzer and Dust Accumulator (GIADA) taken between July and September, the Rosetta scientists have made a first estimate of the comet's dust-to-gas ratio, with around four times as much mass in dust being emitted than in gas, averaged over the sunlit nucleus surface. However, this value is expected to change once the comet warms up further and ice grains — rather than pure dust grains — are ejected from the surface.

GIADA has also been tracking the movement of dust grains around the comet, and, together with images from OSIRIS, two distinct populations of dust grains have been identified. One set is outflowing and is detected close to the spacecraft, while the other family is orbiting the comet no closer than 130 kilometers from the spacecraft. It is thought that the more distant grains are left over from the comet's last closest approach to the Sun. As the comet moved away from the Sun, the gas flow from the comet decreased and was no longer able to perturb the bound orbits. But as the gas production rate increases again over the coming months, it is expected that this bound cloud will dissipate. However, Rosetta will only be able to confirm this when it is further away from the comet again.

As the gas-dust coma continues to grow, interactions with charged particles of the solar wind and with the Sun's ultraviolet light will lead to the development of the comet's ionosphere and, eventually, its magnetosphere. The Rosetta Plasma Consortium (RPC) instruments have been studying the gradual evolution of these components close to the comet.

"Rosetta is essentially living with the comet as it moves toward the Sun along its orbit, learning how its behavior changes on a daily basis and, over longer timescales, how its activity increases, how its surface may evolve, and how it interacts with the solar wind," says Matt Taylor, ESA's Rosetta project scientist. "We have already learned a lot in the few months we have been alongside the comet, but as more and more data are collected and analyzed from this close study of the comet, we hope to answer many key questions about its origin and evolution."

For more information, visit *rosetta.jpl.nasa.gov* and *rosetta.esa.int*.

Spotlight on Education

"Spotlight on Education" highlights events and programs that provide opportunities for planetary scientists to become involved in education and public outreach and to engage science educators and the community. If you know of space science educational programs or events that should be included, please contact the Lunar and Planetary Institute's Education Department at shupla@lpi.usra.edu.

Lunar and Planetary Science Conference: Education Opportunities

The 46th Lunar and Planetary Science Conference will be held at The Woodlands Waterway Marriott Hotel and Convention Center, The Woodlands, Texas, March 16–20, 2015. There will be a variety of events and opportunities that will be of interest to the E/PO community and scientists who are involved in — or are interested in — education and outreach. Details are available at *www.hou.usra.edu/meetings/lpsc2015/events/education*.

Higher Education Faculty Workshop —

Sunday, March 15, 1:00 to 5:00 p.m., Cochran's Crossing

Higher-education faculty will engage in discussions about the use of course management systems and social media, assessment, and innovative authentic projects. Registration is free and required in order to attend; please register at *www.lpi.usra.edu/education/workshops/lpsc2015/undergraduate_teaching*. For more details, please contact Dr. Sanlyn Buxner at *buxner@psi.edu*.

Scientist and Science Educator Professional Development Workshop: Communicating with Your Audience —

Sunday, March 15, 9:00 a.m. to 5:00 p.m, College Park

Experts in communicating with the public and press will present techniques for successfully engaging a variety of audiences in different formats, including press releases, classroom presentations, and public talks. Following interactive presentations, participants will work with the presenters to apply their knowledge to their own communications products and presentations. Those wishing to attend the communications workshop in the morning and the Higher Education Faculty Workshop in the afternoon are welcome to do so! Registration is free but required in order to attend; please register at *www.lpi.usra.edu/education/workshops/lpsc2015/communication*. A 90-minute lunch break will be provided for lunch on your own. For additional information, please contact Christine Shupla at *shupla@lpi.usra.edu*.

E/PO Help Desk for Scientists Interested in Increasing Their Impact —

Monday, March 16, 2:30 to 5:00 p.m, Sterling Ridge

Wednesday, March 18, 12:00 to 1:30 p.m., Sterling Ridge

Scientists are invited to work one-on-one with Education and Public Outreach (E/PO) professionals to (1) identify paths to get involved in E/PO that match available time and resources; (2) learn about ways to achieve maximum impact in E/PO undertakings; and/or (3) understand the current E/PO landscape. Recommended resources, primers for working in different learning environments, and other materials will be available. For more information, please contact Jennifer Grier at *jgrier@psi.edu*.

Upcoming Public Event Opportunities

Upcoming opportunities exist for educator and public engagement around the broader topics of NASA planetary exploration and solar system formation. Resources for evening observing session events include the Night Sky Network's *Discover the Universe Guides* at *https://nightsky.jpl.nasa.gov/news-display.cfm?News_ID=611*. Consider getting in touch with local astronomical societies, planetariums and museums, local scientists, and NASA's Solar System Ambassadors (*http://www2.jpl.nasa.gov/ambassador/directory.htm*) — ask them to join your events and share their experiences or resources with the children.

Dawn Arrives at Ceres —

The Dawn mission left the asteroid Vesta in 2012 and is on its way to dwarf planet Ceres, the largest asteroid. It is expected to arrive in March 2015 (see the related cover story in this issue). There will be a Space Science Festival with activities and presentations on May 9, 2015; events will be occurring around the U.S., and communities are invited to host their own event. For more information, visit *dawn.jpl.nasa.gov/news/i_c_ceres.asp*.

Total Lunar Eclipse —

On April 4, 2015, a total lunar eclipse will be visible just before sunrise for western North America, and will also be visible for parts of Asia and the Pacific. The total eclipse will be at 7:00 a.m. CDT/6:00 a.m.MDT/5:00 a.m. PDT. More information is available at *earthsky.org/tonight/shortest-total-lunar-eclipse-of-the-century-on-april-4-2015*.

New Horizons Reaches Pluto —

The New Horizons mission will fly past this mysterious icy dwarf planet on July 14, 2015 (see the related cover story in this issue). Information and resources for your Pluto celebrations are available at *pluto.jhuapl.edu*.

NASA SMD Education Website

The Science Mission Directorate (SMD) Science Education and Communications Community has a public website, providing content, techniques, and strategies for formal and informal educators and the public to enhance teaching, build science literacy, and support national and local goals to improve STEM literacy and practice. On this site, you will find information about NASA SMD education resources, events and opportunities, funding opportunities, conferences and meetings, the community of SMD education and communications professionals and projects, and more! Content can be filtered and sorted by topic, audience, event type, resource type, and discipline. Go to *smdepo.org*.

Release of Final NASA SMD Education and Public Outreach CAN

On February 4, 2015, the National Aeronautics and Space Administration (NASA) Science Mission Directorate (SMD) released a Cooperative Agreement Notice (CAN) soliciting team-based proposals for SMD science education for community review and comment. The final text is downloadable from the NSPIRES web page at *https://nspires.nasaprs.com* by selecting Solicitations and searching for NASA Science Education or NNH15ZDA004C.

The goal of NASA SMD Science Education is to enable NASA scientists and engineers to engage more effectively with learners of all ages. This CAN is to meet the following NASA SMD Science Education Objectives: enabling STEM education, improving U.S. science literacy; advancing national education goals; and leveraging science education through partnerships. NASA intends to select one or more focused, science-discipline-based team(s). While it is envisioned that multiple agreements may be awarded, selection of a single award to support all of SMD science education requirements is not precluded. Awards are anticipated by September 30, 2015.

Student Opportunity: 2014 Nininger Meteorite Award

The Center for Meteorite Studies at Arizona State University is pleased to announce the application opportunity for the 2014 Nininger Meteorite Award for undergraduate and graduate students pursuing research in meteoritical sciences. The Nininger Meteorite Award recognizes outstanding student achievement in the meteoritical sciences as embodied by an original research paper. The 2014 Nininger Meteorite Award application deadline is March 31, 2015. The Nininger Award recipient receives $1000 and an engraved plaque commemorating the honor. Further information about the Nininger Award and application instructions are located at *meteorites.asu.edu/nininger*.

Barringer Grant Applications for 2015 Now Being Accepted

This year's application deadline for grants from the Barringer Family Fund for Meteorite Impact Research is April 3, 2015. This program provides three to five competitive grants each year in the range of $2500 to $5000 USD for support of field research at known or suspected impact sites worldwide. Grant funds may be used to assist with travel and subsistence costs, as well as laboratory and computer analysis of research samples and findings. Masters, doctoral, and post-doctoral students enrolled in formal university programs are eligible. For additional details and an application, visit *www.lpi.usra.edu/science/kring/Awards/Barringer_Fund*.

Astronomy Research Experience for Undergraduates

Texas A&M University-Commerce will be hosting a summer Research Experience for Undergraduates program in physics and astronomy. This program is specifically targeted for students at junior/community colleges who are considering obtaining a four-year degree in a STEM field. Information is available at *www.tamuc.edu/academics/colleges/scienceEngineeringAgriculture/departments/physicsAstronomy/REU.aspx*; additional questions can be directed to program director Dr. Bao-An Li at *Bao-An.Li@tamuc.edu*.

Lloyd V. Berkner Space Policy Internships 2015

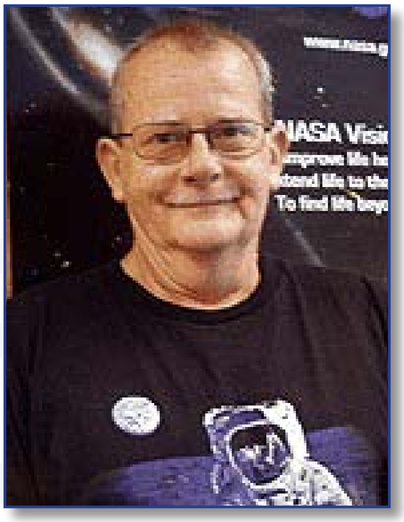
The goal of the Lloyd V. Berkner Space Policy Internship is to provide promising undergraduate and graduate students with the opportunity to work in the area of civil space research policy in the nation's capital, under the aegis of the National Research Council's Space Science Board and Aeronautics and Space Engineering Board.

The summer program is only open to undergraduates. The autumn program is open to undergraduate and graduate students. The application deadlines are February 6 and June 5 for the summer and autumn programs respectively. Candidate(s) selected for the summer and autumn programs will be contacted no later than March 6 and July 3 respectively. Additional information about the program, including the application procedure, can be found at *sites.nationalacademies.org/SSB/ssb_052239*.

NASA Office of Education Scholarship and Research Opportunities

NASA Office of Education (OE) is accepting applications for NASA Scholarship and Research Opportunities (SRO). Scholarships awards are made to individuals who are pursuing degrees in undergraduate studies leading to an associate's or bachelor's degree specifically in areas of projected deficiencies in the NASA Science, Technology, Engineering, and Mathematics (STEM) workforce. The deadline for applications is March 31, 2015. For more information, visit *https://intern.nasa.gov/* and click on "Scholarships."

Bernard Ray Hawke, 1946–2015



Dr. Bernard Ray Hawke passed away on January 24, 2015, at Straub Hospital in Honolulu, Hawaii. Hawke, known as "Ray" to family and childhood friends and "B. Ray" to most of his planetary science colleagues, was a renowned lunar scientist, valued mentor, devoted brother and uncle, and cherished friend to many.

Hawke was born on October 22, 1946, in Louisville, Kentucky, and he grew up near Elizabethtown, Kentucky, attending public schools in that area where he participated in Future Farmers of America and 4-H activities. His 4-H leader worked for the U.S. Geological Survey, which sparked an interest in geology in the young Hawke and later led to a paid internship doing field mapping in central Kentucky. Hawke was also inspired by President Kennedy's speech calling for a manned Moon landing.

Hawke earned a B.S. in geology at the University of Kentucky. He then entered the Army and served with the 173rd Airborne Brigade and N Company, 75th Rangers, in Vietnam in 1970 and 1971. After leaving the Army, he returned to the University of Kentucky where he earned his M.S. in Geology. He continued his geology studies at Brown University where he earned another M.S. and a Ph.D.

Hawke joined a small group of planetary geologists at the University of Hawaii in 1977, a group that grew and later became part of the Hawaii Institute of Geophysics and Planetology. In 1983, Hawke established the Pacific Regional Planetary Data Center, one of NASA's Regional Planetary Image Facilities, and remained Director until his death. His lunar geology interests included impact craters and volcanic deposits, and he was a pioneer in advocating the use of the resources associated with pyroclastic deposits by future inhabitants of the Moon. His scientific studies involved active collaborations with colleagues in Hawaii and around the world, and part of their success was largely due to his generous nature and willingness to share ideas and knowledge.

— Portions of text courtesy of the University of Hawaii

Owen Glenn Morris, 1927–2014

Owen Glenn Morris of Houston, Texas, passed away on December 29, 2014. He was 87 years old. Born on February 3, 1927, in Shawnee, Oklahoma, Morris was an avid model airplane builder from a young age. He attended the University of Oklahoma, completing his M.S. in Aeronautical Engineering in 1948. During college he entered the Navy Officer Training program and served briefly in the Pacific Theater.

Morris was hired by the National Advisory Committee for Aeronautics (NACA) in Langley, Virginia, to design and operate a supersonic wind tunnel. In 1958, NACA became the National

Aeronautics and Space Administration (NASA), and Morris joined the Space Task Group, focusing on the Apollo program. Morris was a pioneer throughout his life, using his positive “can do, will do” attitude to work with others on a variety of personal and professional causes and help bring many dreams to reality. Some of these include leading the team that conceptualized and developed the Lunar Module, starting the Space Center Model Airplane Club and Space Center Rotary, serving as a leader in the Rotary “End Polio Now” worldwide vaccination program, working with a group of men to build houses for their families, and planting and growing Clear Lake Presbyterian Church.

Morris always held the hard line to assure quality and safety of a space crew and payload, and he served as a consultant for the Orion Project until March 2014. He was known for his ready smile, easy laugh, and care and comfort of many. His memory lives on through the legacy of the family and community he loved and served.

LPI Announces Career Development Award Winners

The Lunar and Planetary Institute (LPI) is proud to announce the winners of the eighth LPI Career Development Award. The award is given to graduate students who submitted a first-author abstract to the 46th Lunar and Planetary Science Conference (LPSC). The awards are based on a review of the application materials by a panel of planetary scientists, and recipients will receive funds to help cover their expenses for attending the conference.

Career Development Award

The 46th LPSC will be held March 16–20, 2015, at The Woodlands Waterway Marriott Hotel & Convention Center in The Woodlands, Texas. Nearly 2000 participants from all over the world are expected to attend, and the meeting provides an invaluable opportunity for students to not only present their own research, but also to hear and see firsthand the latest-breaking results from other researchers in their field. Opportunities are also provided for students to meet and network with an international group of distinguished researchers.

Congratulations to the 2015 recipients: Jaclyn Clark (Westfälische Wilhelms-Universität Münster), Ryan N. Clegg (Washington University), R. Terik Daly (Brown University), Christopher Hamann (Museum für Naturkunde, Berlin), Patrick Hill (University of Western Ontario), Christine E. Jilly-Rehak (University of Hawaii), George D. McDonald (Georgia Tech), Nicola Potts (Open University), Adkam Sarafian (Woods Hole Oceanographic Institute), Sarah Simpson (University of Glasgow), Rebecca Thomas (Open University), Francois L. H. Tissot (University of Chicago), and Kathleen Vander Kaaden (University of New Mexico).

Pieters Awarded Medal of International Cooperation

Dr. Carle M. Pieters. Credit: Brown University.

Carle Pieters, professor in the Department of Earth, Environmental, and Planetary Sciences at Brown University, has been awarded the Medal of International Cooperation by the Committee on Space Research (COSPAR), an organization that promotes international research in space. Pieters received the medal at the biennial COSPAR Scientific Assembly in Moscow, Russia. The medal is awarded every two years to "a scientist who has made distinguished contributions to space science and whose work has contributed significantly to the promotion of international scientific cooperation." Pieters has been a member of the Brown faculty since 1980. She is a principal investigator for NASA's Moon Mineralogy Mapper, which flew onboard India's Chandryaan-1 spacecraft in 2008. She is also a co-investigator on NASA's Dawn mission exploring the asteroids Ceres and Vesta. During her career, she has assisted in planning international space exploration with Germany, England, Japan, Russia, and India. COSPAR is part of the International Council on Science, a nongovernmental organization with a mission to strengthen international scientific research.

Founding Director of Center for Meteorite Studies Inducted into Hall of Fame

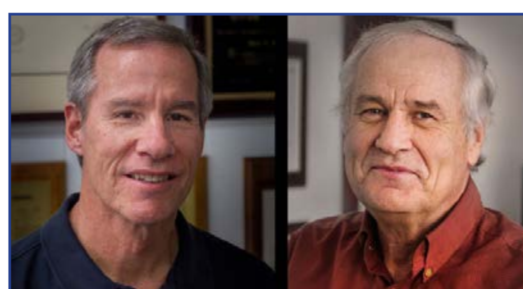
Dr. Carleton B. Moore hosts the ASU Center for Meteorite Studies booth at the Sedona Gem and Mineral Club Annual Show. Credit: ASU/CMS.

Dr. Carleton B. Moore, Founding Director of the Center for Meteorite Studies at Arizona State University, has been inducted into the Mineralogical Society of Arizona's Hall of Fame. This award recognizes, among other things, Moore's many contributions to education and public outreach through presentations to schools and clubs in Arizona.

Moore was editor of the journal *Meteoritics* for 20 years. He was a member of the Lunar Sample Preliminary Examination Team for the Apollo program, and a principal investigator for the returned lunar sample program for all the Apollo missions. Moore's research efforts have focused on the geochemistry of meteorites, lunar samples, and analytical geochemical problems. Additional research interests have taken advantage of the great statistical depth present in the Center for Meteorite Studies collections, including statistical studies of meteorite compositions and homogeneity, the origin of the low-calcium achondrites, trace elements in iron meteorites, and high- and low-temperature phases, including organic compounds, in carbonaceous chondrites.

Moore received his Ph.D. from the California Institute of Technology in 1960, and served as Founding Director of the Center for Meteorite Studies for over 40 years. In 2011, on the occasion of the Center's 50th anniversary, the ASU meteorite collection — the largest university meteorite collection in the world — was officially named the Carleton B. Moore Meteorite Collection.

National Academy of Engineering Adds Two JPL Members



Newly elected to the National Academy of Engineering are JPL's Dan Goebel (left) and Graeme Stephens (right). Credit: JPL.

Two researchers at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, have been elected to the National Academy of Engineering, the highest professional distinction for engineers. Graeme L. Stephens, the director for the Center for Climate Sciences at JPL, and Dan M. Goebel, a senior research scientist at JPL who develops technologies for deep space missions, join 65 other U.S. members and 12 foreign members as the newest additions to the organization.

The academy, which now has 2263 U.S. members and 221 foreign members, honors those who have made outstanding contributions to "engineering research, practice, or education, including, where appropriate, significant contributions to the engineering literature," and to the "pioneering of new and developing fields of technology, making major advancements in traditional fields of engineering, or developing/implementing innovative approaches to engineering education."

Stephens is being honored for his elucidation of Earth's cloud system and radiation balance. He completed his bachelor's degree in physics from the University of Melbourne in 1973 and received his doctorate in meteorology in 1977 from the same university. His research activities focus on atmospheric radiation, including the application of remote sensing to understand the role of hydrological processes in climate change. He has authored more than 240 peer-reviewed publications and a reference textbook on remote sensing of the atmosphere. He is an adjunct professor at the University of Reading in England, and a professor at Colorado State University, Fort Collins. He also serves as the principal investigator of NASA's CloudSat mission and was involved in the early development of NASA's Orbiting Carbon Observatory-2 mission, launched last year.

Goebel is being honored for his contributions to low-temperature plasma sources for thin-film manufacturing, plasma materials interactions, and electric propulsion. He received a bachelor's degree in physics, a master's degree in electrical engineering, and a doctorate in applied plasma physics from the University of California, Los Angeles, in 1977, 1978, and 1981, respectively. Goebel is responsible for the development of high-efficiency electric thrusters, advanced long-life propulsion components, and thruster-life model validation for deep space missions. He is a fellow of the American Institute of Aeronautics and Astronautics, the Institute of Electrical and Electronics Engineers and the American Physical Society; an adjunct professor at UCLA; and the author of more than 120 technical papers and one book on electric propulsion.

Indian Space Research Organization Mars Orbiter Programme Team Wins National Space Society's Space Pioneer Award for Science and Engineering

The National Space Society (NSS) has announced that its 2015 Space Pioneer Award in the Science and Engineering category has been won by the Indian Space Research Organization (ISRO) Mars Orbiter Programme Team. This award will be presented to an ISRO representative during the NSS' 2015 International Space Development Conference, to be held in Toronto, Canada, in May.

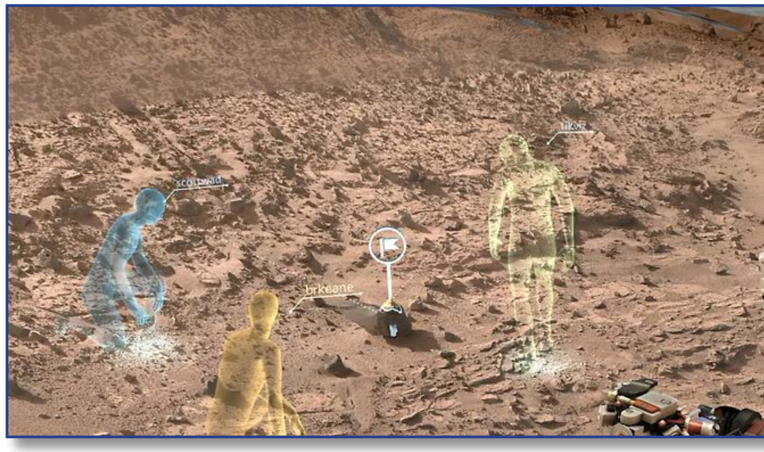
National Space Society

The Space Pioneer Award consists of a silvery pewter Moon globe cast by the Baker Art Foundry in Placerville, California, from a sculpture originally created by Don Davis, the well-known space and astronomical artist. The globe represents multiple space mission destinations and goals, and sits freely on a brass support with a wooden base and brass plaque. NSS has several different categories under which the award is presented each year, starting in 1988.

ISRO's Mars Orbiter mission was launched on November 5, 2013, and went into Mars orbit on September 24, 2014. The mission represents the first time a country has launched a spacecraft that has achieved Mars orbit on the first try. The spacecraft is also in an elliptical orbit with a high apoapsis, and its high-resolution camera is taking full-disk color images of Mars. Very few full-disk images have ever been taken in the past, mostly on approach to the planet, as most imaging is done looking straight down in mapping mode. These full-disk images will provide invaluable information for planetary scientists.

NASA, Microsoft Collaboration Will Allow Scientists to "Work on Mars"

NASA and Microsoft have teamed up to develop software called OnSight, a new technology that will enable scientists to work virtually on Mars using wearable technology called Microsoft HoloLens. Developed by NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, OnSight will give scientists a means to plan and, along with the Mars Curiosity rover, conduct science operations on the Red Planet. "OnSight gives our rover scientists the ability to walk around and explore Mars right from their offices," said Dave Lavery, program executive for the Mars Science Laboratory mission at NASA Headquarters in Washington. "It fundamentally changes our perception of Mars, and how we understand the Mars environment surrounding the rover."



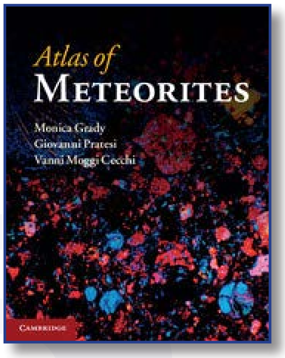
New NASA software called OnSight will use holographic computing to overlay visual information and data from the agency's Mars Curiosity Rover into the user's field of view. Holographic computing blends a view of the physical world with computer-generated imagery to create a hybrid of real and virtual. Credit: NASA.

OnSight will use real rover data and extend the Curiosity mission's existing planning tools by creating a three-dimensional (3-D) simulation of the martian environment where scientists around the world can meet. Program scientists will be able to examine the rover's worksite from a first-person perspective, plan new activities, and preview the results of their work firsthand. Until now, rover operations required scientists to examine Mars imagery on a computer screen, and make inferences about what they are seeing. But images, even 3-D stereo views, lack a natural sense of depth that human vision employs to understand spatial relationships.

The OnSight system uses holographic computing to overlay visual information and rover data into the user's field of view. Holographic computing blends a view of the physical world with computer-generated imagery to create a hybrid of real and virtual. To view this holographic realm, members of the Curiosity mission team don a Microsoft HoloLens device, which surrounds them with images from the rover's martian field site. They then can stroll around the rocky surface or crouch down to examine rocky outcrops from different angles. The tool provides access to scientists and engineers looking to interact with Mars in a more natural, human way. The OnSight tool also will be useful for planning rover operations. For example, scientists can program activities for many of the rover's science instruments by looking at a target and using gestures to select menu commands.

The joint effort to develop OnSight with Microsoft grew from an ongoing partnership to investigate advances in human-robot interaction. The JPL team responsible for OnSight specializes in systems to control robots and spacecraft. The tool will assist researchers in better understanding the environment and workspace of robotic spacecraft — something that can be quite challenging with their traditional suite of tools. JPL plans to begin testing OnSight in Curiosity mission operations later this year.

BOOKS



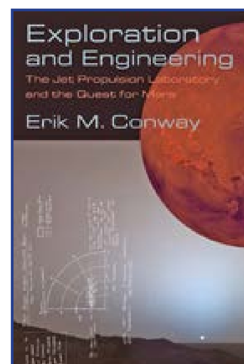
Atlas of Meteorites.

By Monica Grady, Giovanni Pratesi, and Vanni Moggi Cecchi. Cambridge University Press. 2014, 384 pp., Hardcover, $150.00. *www.cambridge.org*

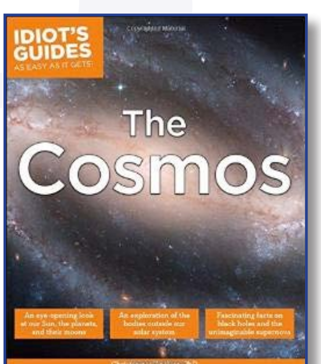
A complete visual reference for meteorite classification, this atlas combines high-resolution optical microscope images with detailed descriptions. It provides a systematic account of meteorites and their most important classification parameters, making it an essential resource for meteorite researchers. Each chapter starts with a description of the meteorite class, with a summary of the mineralogical, chemical, and isotopic characteristics of the group. The full-color images are taken in plane- and cross-polarized light and reflected light, and arranged to highlight textural variations in meteorites. Specimens are grouped to show the effects of increasing thermal alteration and shock, as well as variations in chondrule size and type. Chapters on iron meteorites, pallasites, and mesosiderites are included, photographed as mounts in reflected light, to show the range of textural variations that accompany these meteorites.

Exploration and Engineering: The Jet Propulsion Laboratory and the Quest for Mars.

By Erik M. Conway. Johns Hopkins University Press, 2015, 416 pp., Hardcover, $34.95. *jhupbooks.press.jhu.edu*



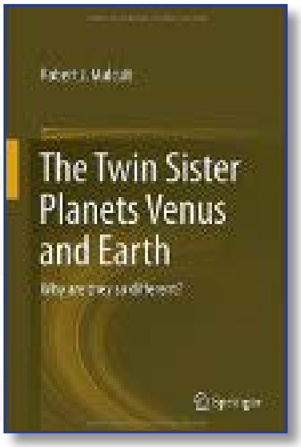
Although the Jet Propulsion Laboratory (JPL) in Pasadena, California, has become synonymous with the United States' planetary exploration during the past half century, its most recent focus has been on Mars. Beginning in the 1990s and continuing through the Mars Phoenix mission of 2007, JPL led the way in engineering an impressive, rapidly evolving succession of Mars orbiters and landers, including roving robotic vehicles whose successful deployment onto the martian surface posed some of the most complicated technical problems in space flight history. In *Exploration and Engineering,* Conway reveals how the creative technological feats of JPL engineers led to major Mars exploration breakthroughs. He takes readers into the heart of the JPL's problem-solving approach and management structure, where talented scientists grappled with technical challenges while also coping, not always successfully, with funding shortfalls, unrealistic schedules, and managerial turmoil. Conway, JPL's historian, offers an insider's perspective into the changing goals of Mars exploration, the ways in which sophisticated computer simulations drove the design process, and the remarkable evolution of landing technologies over a 30-year period.



Idiot's Guide: The Cosmos.

By Christopher De Pree. Penguin Group, 2014, Paperback, 288 pp., $21.95. *www.idiotsguidebooks.com*

Idiot's Guides are how-to and other reference books that each seek to provide a basic understanding of a complex and popular topic. As a part of this series, *The Cosmos* is a fascinating and easy-to-understand exploration of the universe. This book contains dozens of stunning, full-color photos that highlight the latest discoveries and the beauty of space, including the solar system, the Sun, the asteroid belt, the Milky Way, various star types, black holes, and more. It's everything you need to gain a better understanding of the cosmos.



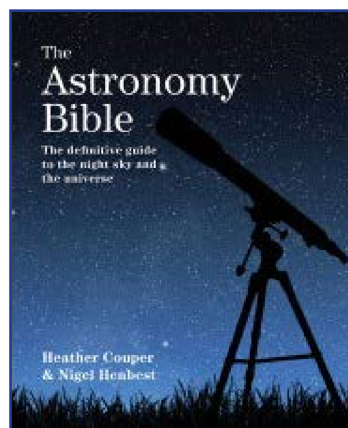
The Twin Sister Planets Venus and Earth: Why Are They So Different?

By Robert J. Malcuit. Springer, 2015, 401 pp., Hardcover, $129.00. *www.springer.com*

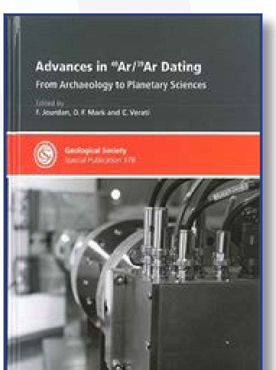
This book explains how it came to be that Venus and Earth, while very similar in chemical composition, zonation, size, and heliocentric distance from the Sun, are very different in surface environmental conditions. It is argued here that these differences can be accounted for by planetoid capture processes and the subsequent evolution of the planet-satellite system. Venus captured a one-half Moon-mass planetoid early in its history in the retrograde direction and underwent its "fatal attraction scenario" with its satellite (Adonis). Earth, on the other hand, captured a Moon-mass planetoid (Luna) early in its history in prograde orbit and underwent a benign estrangement scenario with its captured satellite. This book offers a comprehensive model for the evolution of the planet Earth and Venus over geologic time, a new approach to the intact capture model, and proposed tests of the models presented, and has many significant implications for the argument that habitable planets may be fairly rare in a large region of space.

The Astronomy Bible: The Definitive Guide to the Night Sky and the Universe.

By Heather Couper and Nigel Henbest. Firefly Books, 2015, 400 pp., Paperback, $19.95. *www.fireflybooks.com*



Interest in astronomy continues to grow stronger for readers of all ages. *The Astronomy Bible* is a comprehensive guide to the study of what lies beyond our planet and covers everything from the basic concepts of how to observe space to the current theories on everything from black holes to red giants. With this book readers can easily navigate the night sky, identify the constellations, and find planets, comets, and galaxies. Topics include the history of astronomy, how to observe the sky, the solar system, what lies beyond, Moon and planet maps, star-finder charts, and constellation maps. Informative and fully illustrated, this is a valuable companion for stargazers of all ages.

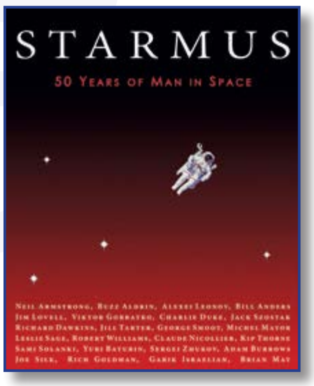


Advances in ^{40}Ar/^{39}Ar Dating: From Archaeology to Planetary Sciences.

Edited by F. Jourdan, D. F. Mark, and C. Verati. Geological Society of London Publishing House, 2014, 378 pp., Hardcover, $250.00. *www.geolsoc.org.uk*

Decoding the complete history of Earth and our solar system requires the placing of the scattered pages of Earth history in a precise chronological order, and the ^{40}Ar/^{39}Ar dating technique is one of the most trusted dating techniques to do that. The ^{40}Ar/^{39}Ar method has been in use for more than 40 years, and has constantly evolved since then. The steady improvement of the technique is largely due to a better understanding of the K/Ar system, an appreciation of the subtleties of geological material, and a continuous refinement of the analytical tools used for isotope extraction and counting. The $^{40}Ar/^{39}Ar$ method is also one of the most versatile techniques with countless applications in archaeology, tectonics, structural geology, orogenic processes and provenance studies, ore and petroleum genesis, volcanology, weathering processes and climate, and planetary geology. This volume is the first of its kind and covers methodological developments, modeling, data handling, and direct applications of the $^{40}Ar/^{39}Ar$ technique.

Starmus: 50 Years of Man in Space.



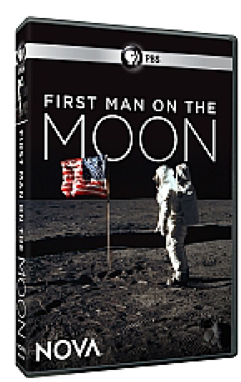
Edited by Garik Israelian and Brian May. Shelter Harbor Press, 2015, 192 pp., Hardcover, $40.00. *www.shelterharbor.com*

Never before has such an ambitious series of talks, articles, and recollections been assembled to celebrate the human exploration of space. It is the result of the unique Starmus meeting in 2011 on Tenerife, where the legendary Russian and American pioneers of the space age met up for the first time to share the moments that electrified the human race. Neil Armstrong, Buzz Aldrin, Bill Anders, Yuri Baturin, Charlie Duke, Victor Gorbatko, Alexei Leonov, Jim Lovell, Claude Nicollier, and Sergei Zhukov tell their personal stories about the first spacewalk, the lunar landing, the heroic recovery of Apollo 13, the repair of the Hubble Space Telescope, and much more. Our discovery of the universe, our place within it, and the meaning of life on Earth also forged dramatic moments at Starmus through the presentations of some of the world's leading scientists and thinkers, such as Rich Goldman, Brian May, Jack Szostak, Richard Dawkins, Jill Tarter, Joseph Silk, George Smoot, Michel Mayor, Robert Williams, Adam Burrows, Garik Israelian, Kip Thorne, Sami Solanki, and Leslie Sage. This volume was originally conceived to mark 50 years since Yuri Gagarin's first spaceflight, but is now equally dedicated to one of our greatest heroes in human history — Neil Armstrong, who passed away in 2012.

DVD

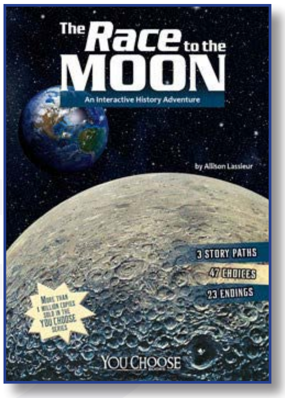
First Man on the Moon.

Produced by NOVA/PBS, 2014, one disc. $24.99. *www.shoppbs.org*



Everyone knows Neil Armstrong was the first to set foot on the Moon. But this modest and unassuming man was determined to stay out of the spotlight, so the rare combination of talent, luck, and experience that led to his successful command of Apollo 11 is not widely known. Now, for the first time, NOVA presents an intimate portrait through interviews with Armstrong's family and friends, many of whom have never spoken publicly before. Seen through the eyes of those who were close to him, the film explores the man behind the myth, and also reveals his unsung achievements as a Navy combat veteran and pioneer of high-speed flight. In its groundbreaking exploration of this quietly effective man, NOVA explores his achievements following Apollo, which included his leading role in the inquiry into the Challenger disaster and efforts to encourage young people to share his lifelong passion for flight. *First Man on the Moon* is an inspiring story of heroic risk-taking and humble dedication to advancing humanity's adventure in space.

FOR KIDS!!!



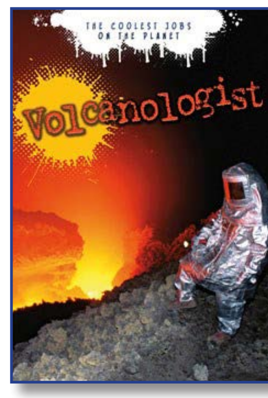
Race to the Moon: An Interactive History Adventure.

By Allison Lassieur. Capstone Press, 2014, 112 pp., $24.70. *www.capstonepub.com*

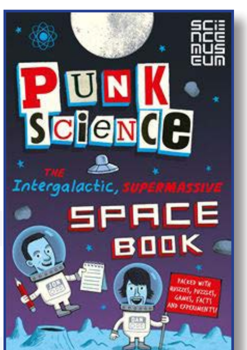
It's the 1950s and 1960s, and the United States and Soviet Union are in a race to be the first to reach the Moon. Will you participate in the space race as a young scientist working on early rocket technology? Experience the space race as a reporter following space "firsts" in both the Soviet Union and the United States? Work as a member of Mission Control during the 1969 Moon landing? Everything in this book happened to real people. And YOU CHOOSE what you do next. The choices you make could lead you to opportunity, to glory, to shattered dreams, or even to death. For grades 3–4.

Volcanologist.

By Hugh Tuffen and Melanie Waldron. Capstone Press, 2015, 48 pp., $24.00. *www.capstonepub.com*



Hugh Tuffen is a volcanologist who travels the world to study volcanos, looking at how they formed and likely they are to erupt. In this book, you'll find out all about his amazing job, including what's involved in becoming a volcanologist. You'll find out about the scientist's heroes, the equipment and skills used, and the challenges of conducting research and experiments in the shadow of erupting volcanos! For grades 5–8.



Punk Science: The Intergalactic, Supermassive Space Book.

By Punk Science. Pan Macmillan, 2014, 96 pp., Paperback, $7.99. *www.panmacmillan.com*

This fun activity and fact book about space comes from the London Science Museum and its popular Punk Science team. Each chapter in this fun and informative book is packed with puzzles, games, facts, and experiments! Find out all about spaceships and satellites, astronauts, the solar system, and the universe, and have lots of fun with the Punk Science team at the same time! Published in association with the Science Museum. For ages 7 and up.

Orion Crew Vehicle Paper Model.

Produced by NASA and Lockheed Martin. NASA SP-2008-3-004-HQ, 8 pp., free to download. *www.nasa.gov/pdf/714676main_Orion_Model.pdf*

The Orion Multi-Purpose Crew Vehicle will serve as our nation's next-generation exploration vehicle to expand human presence to asteroids, the Moon, Lagrange points, and missions to Mars. Drawing from more than 50 years of spaceflight research and experience, the Orion spacecraft design features dozens of technology innovations to support long-duration deep space missions of up to six months. This paper model of the Orion spacecraft includes both crew and service modules. For grades 6 and up.

Calendar 2015

March

2–5 **Ground and Space Observatories: A Joint Venture to Planetary Science,** Santiago, Chile. *http://www.eso.org/sci/meetings/2015/Planets2015.html*

15–18 **Ringberg Workshop on Spectroscopy with the Stratospheric Observatory for Infrared Astronomy,** Schloss Ringberg, Germany. *https://indico.mpifr-bonn.mpg.de/indico/conferenceDisplay.py?confId=93*

16–20 **46th Lunar and Planetary Science Conference,** The Woodlands, Texas. *http://www.hou.usra.edu/meetings/lpsc2015/*

22–27 **Habitability in the Universe: From the Early Earth to Exoplanets,** Porto, Portugal. *http://www.iastro.pt/research/conferences/life-origins2015/*

23–27 **Star and Planet Formation in the Southwest,** Oracle, Arizona. *https://lavinia.as.arizona.edu/~kkratter/SPF1/Home.html*

24–26 **Workshop on Planetary Protection Knowledge Gaps for Human Extraterrestrial Missions,** Moffett Field, California. *http://www.nasa.gov/ames/ppw2015workshop/*

April

7–8 **Workshop on Venus Science Priorities for Laboratory Measurements and Instrument Definition,** Hampton, Virginia. *http://www.hou.usra.edu/meetings/venustech2015/*

12–17 **European Geosciences Union General Assembly 2015,** Vienna, Austria. *http://www.egu2015.eu/home.html*

13–17 **IAA Planetary Defense Conference,** Frascati, Italy. *http://pdc2015.org/*

May

3–7 **Joint Assembly AGI, GAC, MAC, CGU,** Montreal, Canada. *http://ja.agu.org/2015/*

4–6 **Life on Earth and Beyond: The History and Philosophy of the Origin of Life,** Ven Island, Sweden. *http://www.nordicastrobiology.net/Ven2015/*

4–6 **Comparative Tectonics and Geodynamics of Venus, Earth, and Rocky Exoplanets,** Pasadena, California. *http://www.hou.usra.edu/meetings/geodyn2015/*

5–7 **Planetary GIS Workshop,** Madrid, Spain. *http://www.rssd.esa.int/index.php?project=PSA&page=gisws*

5–7 **The Humans to Mars Summit,** Washington, DC. *http://h2m.exploremars.org*

6–8 **User Training in JWST Data Analysis,** Baltimore, Maryland. *http://www.stsci.edu/institute/conference/ut_jwst_da/*

6–8 **Exoplanets in Lund 2015,** Lund, Sweden. *http://www.astro.lu.se/lundexoplanets2015/*

19–21 **Landolt Standards and 21st Century Photometry,** Baton Rouge, Louisiana. *http://www.phys.lsu.edu/landoltstandards/index.html*

19–22 **Fourth Annual International Planetary Dunes Workshop,** Boise, Idaho. *http://www.hou.usra.edu/meetings/dunes2015/*

19–22 **Workshop on Issues in Crater Studies and the Dating of Planetary Surfaces,** Laurel, Maryland. *http://www.hou.usra.edu/meetings/craterstats2015/*

25–29 **1st Advanced School on Exoplanetary Science,** Salerno, Italy. *http://www.iiassvietri.it/ases2015.html*

26–29 **Stellar and Planetary Dynamos,** Göttingen, Germany. *http://www.dynamos2015.de*

28–29 **Emerging Researchers in Exoplanet Science Symposium,** University Park, Pennsylvania. *http://eres-symposium.org*

June

2–4 **Workshop on the Formation of the Solar System II,** Bonn, Germany. *https://indico.mpifr-bonn.mpg.de/FormationOfTheSolarSystem2*

7–12 **22nd ESA Symposium on European Rocket and Balloon Programmes and Related Research,** Tromsø, Norway. *http://pac.spaceflight.esa.int*

8–11 **Autonomous Spacecraft Navigation: New Concepts, Technologies and Applications for the 21st Century,** Bonn, Germany. *http://www.mpe.mpg.de/events/593-heraeus-seminar/*

8–11 **Second Planetary Data Workshop,** Flagstaff, Arizona. *http://www.hou.usra.edu/meetings/planetdata2015/*

9–11 **The International Academy of Astronautics (IAA) LCPM-11,** Berlin, Germany. http://www.dlr.de/LCPM11

13–14 **Short Course: Radio Flyers,** Cologne, Germany. http://www.planetaryprobe.eu

14–18 **The Future and Science of Gemini Observatory,** Toronto, Canada. http://www.gemini.edu/fsg15

15–19 **Astrobiology Science Conference 2015,** Chicago, Illinois. http://www.hou.usra.edu/meetings/abscicon2015/

15–19 **12th International Planetary Probe Workshop,** Cologne, Germany. http://www.planetaryprobe.eu

22–26 **In the Spirit of Bernard Lyot 2015: Direct Detection of Exoplanets and Circumstellar Disks,** Montreal, Canada. http://craq-astro.ca/lyot2015/

28–Jul 3 **Gordon Research Conference on Origins of Solar Systems,** South Hadley, Massachusetts. http://www.grc.org/programs.aspx?id=12345

29–Jul 1 **13th Meeting of the NASA Small Bodies Assessment Group (SBAG),** Washington, DC. http://www.lpi.usra.edu/sbag/

29–Jul 3 **From Super-Earths to Brown Dwarfs: Who's Who?,** Paris, France. http://www.iap.fr/activites/colloques_ateliers/colloque_IAP/colloqueiap.php?annee=2015

July

1–13 **Nordic-Hawai'i Summer School "Water, Ice and the Origin of Life in the Universe,"** Reykjavik, Iceland. http://www.nordicastrobiology.net/Iceland2015/

6–8 **The Second Workshop on Measuring Precise Radial Velocities,** New Haven, Connecticut. http://exoplanets.astro.yale.edu/workshop/EPRV.php

19–23 **2nd International Congress on Stratigraphy,** Graz, Austria. http://strati2015.uni-graz.at/

19–25 **Planetary Systems: A Synergistic View,** Quy Nhon, Vietnam. http://rencontresduvietnam.org/conferences/2015/planetary-systems/

21–23 **NASA Exploration Science Forum,** Moffett Field, California. http://sservi.nasa.gov/ESF2015

27–31 **78th Annual Meteoritical Society Meeting,** Berkeley, California. http://metsoc2015.ssl.berkeley.edu/

August

2–7 **12th Annual Meeting of the Asia Oceania Geosciences Society (AOGS),** Singapore. http://www.asiaoceania.org/aogs2015/

3–14 **XXIX IAU General Assembly,** Honolulu, Hawaii. http://astronomy2015.org

4–6 **Second Landing Site Workshop for the Mars 2020 Rover,** Pasadena, California. http://marsnext.jpl.nasa.gov

17–21 **Cosmic Dust,** Tokyo, Japan. https://www.cps-jp.org/~dust/Welcome.html

24–27 **24th Annual Meeting on Characterization and Radiometric Calibration for Remote Sensing,** Logan, Utah. http://www.calcon.sdl.usu.edu

September

11–18 **IRAM 30m Summerschool 2015,** Pradollano, Spain. http://www.iram-institute.org/EN/content-page-308-7-67-308-0-0.html

21–26 **Bridging the Gap III: Impact Cratering in Nature, Experiements, and Modeling,** Freiburg, Germany. http://www.hou.usra.edu/meetings/gap2015/

October

9–15 **OHP 2015: Twenty Years of Giant Exoplanets,** Saint-Michel-l'Observatoire, France. http://ohp2015.sciencesconf.org

12–16 **Exploring the Universe with JSWT,** Noordwijk, The Netherlands. http://congrexprojects.com/2015-events/15a02/introduction

12–16 **Exoplanetary Atmospheres and Habitability,** Nice, France. http://exoatmo.sciencesconf.org

12–16 **66th International Astronautical Congress (IAC 2015),** Jerusalem, Israel. http://iac2015.org/

20–23 **Second International Planetary Caves Conference,** Flagstaff, Arizona. http://www.hou.usra.edu/meetings/2ndcaves2015/