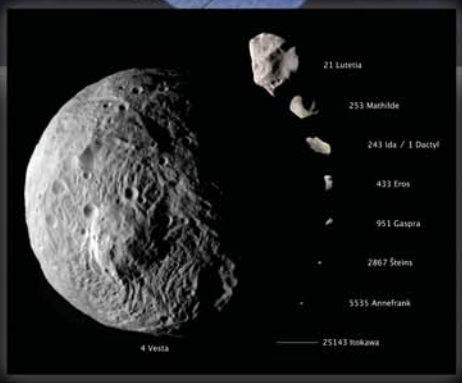
Dawn *over* Vesta



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Lunar and Planetary Information

BULLETIN

August 2011
Issue 126

Universities Space Research Association — Lunar and Planetary Institute

www.lpi.usra.edu/lpib

Dawn Over Vesta

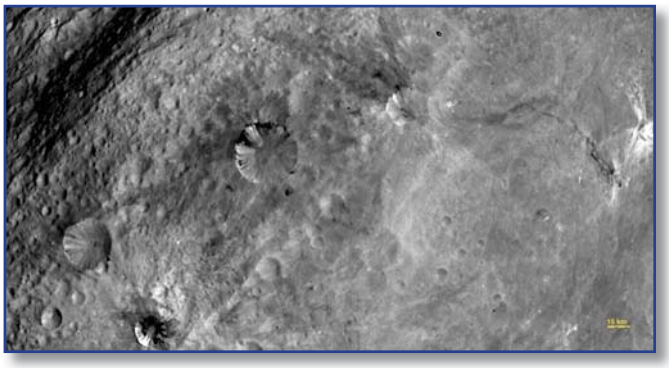
— By Dr. Paul M. Schenk, Lunar and Planetary Institute

The Dawn spacecraft, illustrated in this artist's concept, is propelled by ion engines. Credit: NASA/JPL.

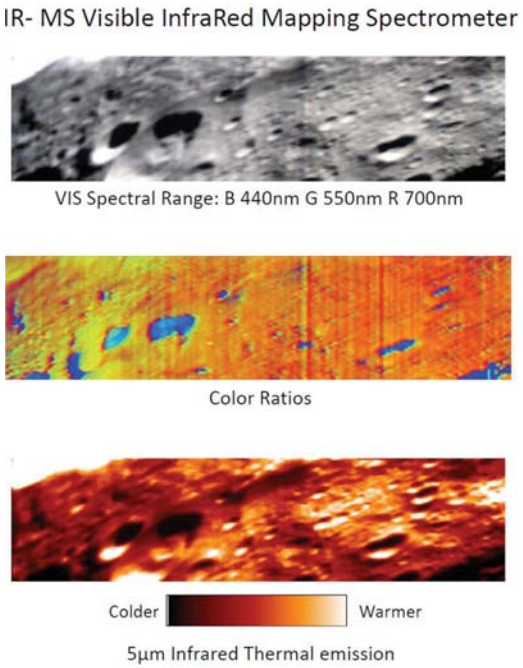
There is an unmistakable thrill in being the first humans to see a new world. European explorers in the New World 500 years ago must have felt it, despite the presence of other humans already there. The human push into space is no exception, and the Dawn spacecraft now orbiting the second most massive asteroid, Vesta, is currently doing just that. What it has revealed so far has genuinely surprised and delighted those of us on the Dawn project, many of whom have been planning for this moment for more than a decade.

The Dawn mission to Vesta and Ceres is the first targeted to visit any of the five large main-belt asteroids. Even the best Hubble Space Telescope images of Vesta showed only blurry surface markings and color variations. The Hubble images did reveal a large volume deficit or depression at the south pole. That feature alone tells us that this small world is complex, but Vesta's biggest attraction (and challenge) comes from the unusual distinction that we likely have actual rock samples from this large asteroid here on Earth. Scientists believe that Vesta is the parent body of the HED (howardite, eucrite, diogenite) basaltic meteorites, and they indicate that Vesta has experienced high enough internal heat to melt rock similar to that found on the lunar mare. Dawn will search for these melted rocks to verify this geologic connection, to determine how these rocks fit into Vesta's geologic history, and to understand how Vesta evolved over time. Because these meteorites are so old (4.4 to 4.5 billion years), we may see in Vesta a record of the earliest periods of solar system evolution.

Dawn's approach and initial survey mapping has shown us a delightfully complex geologic body worthy of the designation of (dwarf) "planet." Vesta is no simple cratered rock in space, although parts of it are indeed heavily cratered. There are numerous different color units on the surface, some linked to impact craters, others not obviously so. There are old craters and very young craters, many with peculiar dark and bright streaks down their rims. There are strange mysterious smooth patches, and an astonishing series of deep troughs girdling the equator. And there is the large south polar structure first seen by Hubble. This structure was originally thought to be a large impact crater; that may very well be true, but if so, it is one of the strangest craters seen so far anywhere in this solar system. Although there are similarities to large basins on the smaller icy satellites, including its large



In this image, various craters are visible in the southern equatorial region of Vesta. Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA.



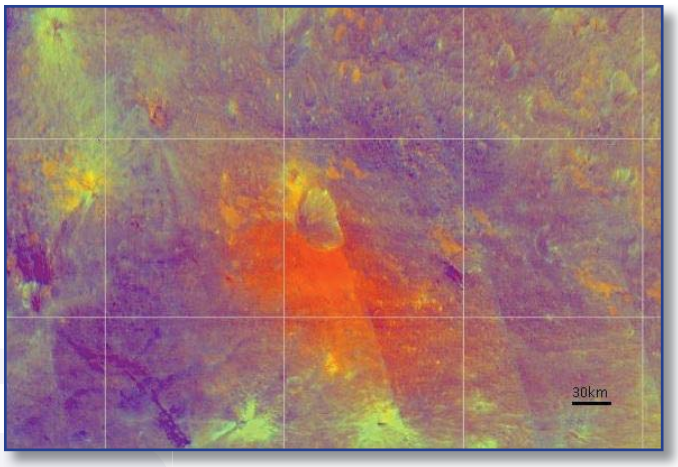
These images were obtained by the Dawn spacecraft on July 23, 2011. The bottom two images are false-color, where different colors represent visible and infrared light wavelengths. Scientists are studying these images to better understand the different materials on the surface. Blue represents wavelengths of 438 to 653 nanometers, red represents wavelengths of 438 to 750 nanometers, and green represents wavelengths of 653 to 917 nanometers. Credit: NASA/JPL-Caltech/UCLA/ASI/INAF.

central mountain and arcuate inward-facing scarps, the feature is surprisingly asymmetric and complex. Among the theories put forward so far are that the fast rotation of Vesta or internal dynamical processes (such as convection) distorted or altered the appearance of this large feature. It will require detailed geologic, topographic, compositional, and gravity mapping, as well as numerical modeling of impact processes, to understand how this large structure formed and evolved.

Despite the variety of color and albedo features, we do not as yet know the surface compositions of Vesta. The infrared and gamma-ray mapping teams will be processing their data over the next few weeks and months to determine what minerals and elements they are seeing on the surface. It takes time to properly calibrate the spectra and then compare them to the vast suite of possible minerals and rocks we have on Earth, as well as to the HED meteorites themselves, over the next weeks and months. The VIR visible and infrared mapping camera will collect detailed spectra and thermal emission from the surface and allow for comparisons and links to the Vesta-family meteorites.

Dawn won't be merely looking at the surface of Vesta. Gravity measurements in these first orbits and later at close range will be used in conjunction with high-resolution topography to determine whether Vesta has a core and how "lumpy" the interior is. The topographic mapping will be on an unprecedented scale and will use stereo and low-Sun images to map relief at scales of a few meters.

The Dawn mission plan is to map Vesta in stages. The first mapping orbit at an altitude of 2700 kilometers is going to give us a global base map at ~250-meter resolution. This phase will last just over two weeks and will provide us with compositional and topographic maps of the surface, allowing us to identify key features and Vesta's basic geologic landforms. Because of the current orientation of Vesta's rotation axis, the north polar region will remain in darkness until around the time we must depart for Ceres late next summer. At the end of this month, the ion engines will fire up again and slowly nudge the spacecraft into a closer orbit for what is called the high-altitude mapping orbit (HAMO) at 700 kilometers altitude. This will provide global imaging coverage at ~70-meter resolution, which should allow us to test hypotheses and distinguish how some of these odd geologic and color features formed. Some of the key things we will be looking for is whether there is any impact melt from the large craters, whether there are any ancient lava flows, and whether Vesta has any internal layered structure. This phase will last through most of October.



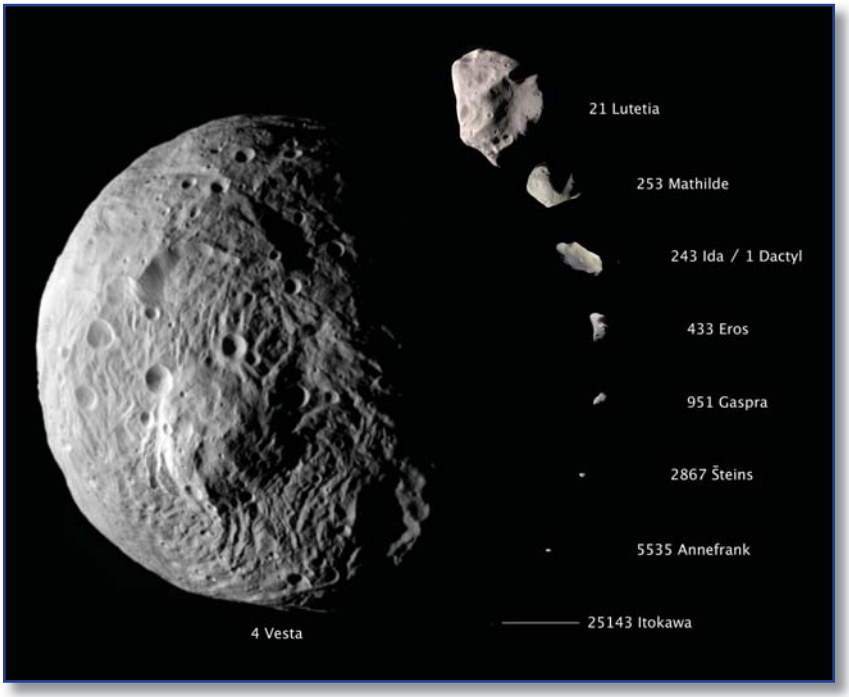
This image of the giant asteroid Vesta was taken by Dawn's framing camera on July 24, 2011. Scientists are studying images like these to better understand the different materials on the surface. Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA.

Dawn then moves down to LAMO (as you may have guessed, low-altitude mapping orbit), where we will see features as small as 25 meters across. Here we will spend another month performing detailed mapping of the surface. We may see boulders, individual rock layers, and perhaps smaller-scale tectonic features. It is at this altitude that GRaND, the gamma ray mapper, will be able to detect Vesta and map elemental composition. Finally, as Dawn prepares to leave Vesta, we will get our first good look at the northern polar region, where shock effects from the large south polar features may have disrupted the surface.

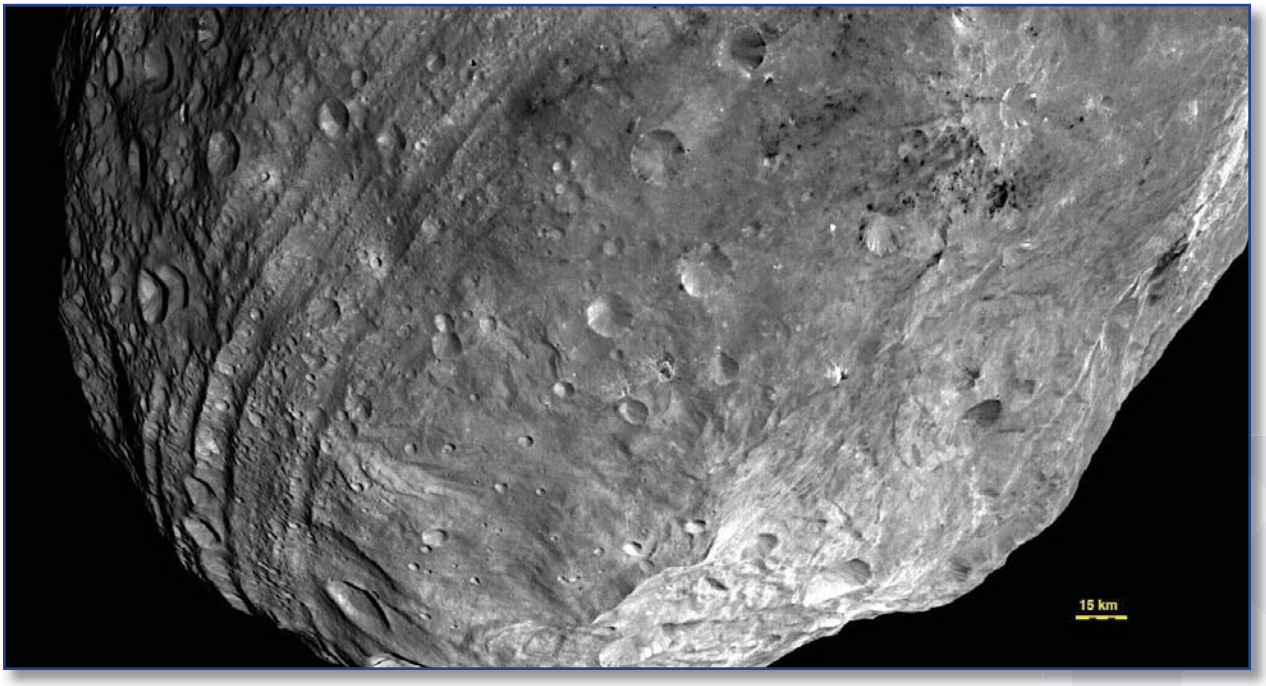
The diversity and complexity we now see on Vesta only whets our appetite for Ceres, the largest of asteroids and one that likely possesses a lot more water ice than Vesta. Ceres may well provide a link between the rocky inner solar system and the ice-rich worlds of the giant outer planets, as it has characteristics of both. Dawn won't reach Ceres until 2014, and we have another 9 months of mapping of Vesta ahead of us. It seems a good bet that we will be surprised by both of these small planetary bodies.

About the Author:

Dr. Paul Schenk is a staff scientist at the Lunar and Planetary Institute in Houston, and serves as the science editor for the Lunar and Planetary Information Bulletin. A space-groupie since Gemini days in the mid 1960s, Schenk's first formal introduction to planetary sciences was as a NASA Planetary Geology summer intern in 1979 at JPL during the Voyager 2 Jupiter encounter. After completing his Ph.D. at Washington University in St. Louis under advisor William B. McKinnon, Schenk came to the LPI in 1991. Since that time he has been using Voyager, Galileo, and Cassini stereo and monoscopic images to map the topography and geology of the icy outer planet satellites. Having also been a stereo image afficionado for many years, in 1997 he completed an educational CD-ROM entitled 3-D Tour of the Solar System *(see www.lpi.usra.edu/resources/stereo_atlas/SS3D.HTM), which shows the planets in 3-D. His latest publication,* Atlas of the Galilean Satellites, *was published by Cambridge University Press earlier this year. He is currently a participating scientist on the Dawn mission science team during its Vesta mapping phase.*



This composite image shows the comparative sizes of nine asteroids. Up until now, Lutetia, with a diameter of 81 miles (130 kilometers), was the largest asteroid visited by a spacecraft, which occurred during a flyby. Vesta, which is also considered a protoplanet because it is a large body that almost became a planet, dwarfs all other small bodies in this image, with its diameter of approximately 330 miles (530 kilometers). Credit: NASA/JPL-Caltech/JAXA/ESA.



In this image, obtained by Dawn's framing camera, a peak at Vesta's south pole is seen at the lower right. The grooves in the equatorial region are about 6 miles wide (10 kilometers). The image was taken on July 24, 2011, from a distance of about 3200 miles (5200 kilometers). Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA.

NASA's Juno mission lifts off from Cape Canaveral Air Force Station in Florida. Credit: NASA.

NASA's Juno Spacecraft Launches to Jupiter

NASA's solar-powered Juno spacecraft lifted off from Cape Canaveral Air Force Station in Florida at 9:25 a.m. PDT (12:25 p.m. EDT) Friday, August 5, to begin a five-year journey to Jupiter. Juno's detailed study of the largest planet in our solar system will help reveal Jupiter's origin and evolution. As the archetype of giant gas planets, Jupiter can help scientists understand the origin of our solar system and learn more about planetary systems around other stars.

Juno covered the distance from Earth to the Moon (about 250,000 miles or 402,336 kilometers) in less than one day's time. It will take another 5 years and 1740 million miles (2800 million kilometers) to complete the journey to Jupiter. The spacecraft will orbit the planet's poles 33 times and use its collection of 8 science instruments to probe beneath the gas giant's obscuring cloud cover to learn more about its origins, structure, atmosphere, and magnetosphere, and look for a potential solid planetary core.

With four large moons and many smaller moons, Jupiter forms its own miniature solar system. Its composition resembles that of a star, and if it had been about 80 times more massive, the planet could have become a star instead. "Jupiter is the Rosetta Stone of our solar system," said Scott Bolton, Juno's principal investigator from the Southwest Research Institute in San Antonio. "It is by far the oldest planet, contains more material than all the other planets, asteroids, and comets combined, and carries deep inside it the story of not only the solar system but of us. Juno is going there as our emissary — to interpret what Jupiter has to say."

Juno's name comes from Greek and Roman mythology. The god Jupiter drew a veil of clouds around himself to hide his mischief, and his wife, the goddess Juno, was able to peer through the clouds and reveal Jupiter's true nature.

For more information about Juno, visit *www.nasa.gov/juno* and *missionjuno.swri.edu*.

USRA Part of Team Selected to Manage Arecibo Observatory

The Universities Space Research Association (USRA) is part of a multi-organization team led by SRI International that has been awarded a five-year cooperative agreement by the National Science Foundation (NSF) to manage, operate, and maintain the Arecibo Observatory in Puerto Rico. The observatory, preeminent for its research in astronomy, planetary studies, and space and atmospheric sciences, is the world's largest and most sensitive single-dish radio telescope. The award, valued at approximately $42M, is scheduled to begin October 1, 2011, following a four-month transition period. "We are committed to our role in managing the astronomy and planetary studies programs, and to the entire team effort of building a great future for the observatory, in both research and education," said Dr. Fred Tarantino, USRA President.

"SRI and its partners bring extensive experience in facility management, space science, radio astronomy, and a wide range of high-power radar techniques, as well as expertise in university partnerships and community relations. Together, we will support and, more importantly, expand the observatory's cutting-edge science programs," said John Kelly, Ph.D., program director for the Center for GeoSpace Studies at SRI. "We will use our combined expertise to allow the observatory to become an ever greater resource to the astronomy, planetary science, and space science communities."

The SRI team and its on-site partners — USRA, the Universidad Metropolitana (UMET) in San Juan, Puerto Rico, and the University of Puerto Rico (UPR) — will work together under the leadership of Robert Kerr, Ph.D., SRI's director designate of the Arecibo Observatory, to forge a new future for the observatory. SRI and the USRA will leverage their science operations and management experience to enhance and develop observatory capabilities in radio astronomy (AST), planetary radar science (PRS), and space and atmospheric science (SAS). UMET, part of Puerto Rico's second largest private university system, brings expertise in education, public outreach, and facilities management, and will cover site operations and education and public outreach activities at the observatory. UPR will sponsor joint faculty appointments and will develop education and research opportunities.

To advance research and education at the observatory, SRI and its partners are working with multiple Puerto Rican government agencies and private organizations to ensure close collaboration with educational and economic development institutions in Puerto Rico.

"This is an excellent collaborative effort and will represent expanded opportunities for research and graduate studies in astronomy and atmospheric sciences at UPR," said UPR President Dr. Miguel Munoz.

USRA brings a rich history in astronomy beginning with the management of the Lunar Science Institute, now the Lunar and Planetary Institute, and including astronomy institutes at NASA's Goddard Space Flight Center, Marshall Space Flight Center, and Ames Research Center. Founded in 1969, USRA is an independent research corporation with competencies that span space-, Earth-, and life-sciences-related disciplines, which are closely aligned with the nation's science and national security agencies. As a nonprofit corporation with 105 major research university members, USRA's scientific and technical staff collaborate with over 300 universities annually. This depth of reach into the research community provides a unique platform for advancing science and technology.

For more information, visit *www.usra.edu* and *www.naic.edu*.

NASA Spacecraft Confirms Theories, Sees Surprises at Mercury

NASA scientists are making new discoveries about the planet Mercury. Data from MESSENGER, the first spacecraft to orbit Mercury, is giving scientists important clues to the origin of the planet and its geological history and helping them better understand its dynamic interior and exterior processes. NASA's MErcury Surface, Space ENvironment, GEochemistry, and Ranging spacecraft (MESSENGER) has been orbiting Mercury since March 18. To date the spacecraft has provided tens

After nearly three months in orbit about Mercury, MESSENGER's payload is providing a wealth of new information about the planet closest to the Sun. Credit: NASA.

of thousands of images showing detailed planetary features. The planet's surface previously had been seen only at comparatively low resolution but is now in sharper focus.

The spacecraft also has collected extensive measurements of the chemical composition of Mercury's surface and topography and gathered global observations of the planet's magnetic field. Data now confirm that bursts of energetic particles in Mercury's magnetosphere are a continuing product of the interaction of Mercury's magnetic field with the solar wind.

"We are assembling a global overview of the nature and workings of Mercury for the first time," said MESSENGER principal investigator Sean Solomon of the Carnegie Institution of Washington. "Many of our earlier ideas are being cast aside as new observations lead to new insights. Our primary mission has another three Mercury years to run, and we can expect more surprises as our solar system's innermost planet reveals its long-held secrets."

Flyby images of Mercury had detected bright, patchy deposits on some crater floors. Without high-resolution images to obtain a closer look, these features remained only a curiosity. Now new detailed images have revealed these patchy deposits to be clusters of rimless, irregular pits varying in size from several hundred feet to a few miles wide. These pits are often surrounded by diffuse halos of more reflective material and are found on central peaks, peak rings, and rims of craters.

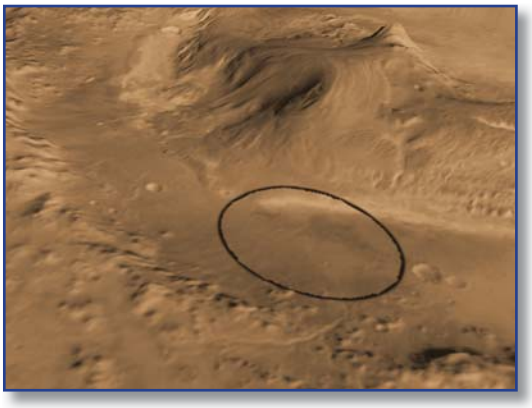
"The etched appearance of these landforms is unlike anything we've seen before on Mercury or the Moon," said Brett Denevi, a staff scientist at the Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, Maryland, and a member of the MESSENGER imaging team. "We are still debating their origin, but they appear to be relatively young and may suggest a more abundant than expected volatile component in Mercury's crust."

One of two instruments on the spacecraft designed to measure the quantity of key chemical elements on Mercury has made several important discoveries since the orbital mission began. Elemental ratios averaged over large areas of the planet's surface show that Mercury's surface differs markedly in composition from that of the Moon. Observations have revealed substantial amounts of sulfur at Mercury's surface, lending support to prior suggestions from groundbased telescopic observations that sulfide minerals are present. This discovery suggests that the original building blocks from which Mercury formed may have been less oxidized than those that formed the other terrestrial planets. The result also hints that sulfur-containing gases may have contributed to past explosive volcanic activity on Mercury. Topography data of Mercury's northern hemisphere reveal the planet's large-scale shape and profiles of geological features in high detail. The north polar region is a broad area of low elevations, whereas the overall range in topographic heights seen to date exceeds 5 miles (9 kilometers).

Two decades ago, Earth-based radar images showed deposits thought to consist of water ice and perhaps other ices near Mercury's north and south poles. These deposits are preserved on the cold, permanently shadowed floors of high-latitude impact craters. MESSENGER is testing this idea by measuring the floor depths of craters near Mercury's north pole. The craters hosting polar deposits appear to be deep enough to be consistent with the idea that those deposits are in permanently shadowed areas.

During the first of three Mercury flybys in1974, Mariner 10 discovered bursts of energetic particles in the planet's Earth-like magnetosphere. Four bursts of particles were observed on that flyby. Scientists were puzzled that no such strong events were detected by MESSENGER during any of its three flybys of the planet in 2008 and 2009. But now that the spacecraft is in near-polar orbit around Mercury, energetic events are being seen regularly.

For more information, visit *www.nasa.gov/messenger* or *messenger.jhuapl.edu*.



This computer-generated view based on multiple orbital observations shows Mars' Gale Crater as if seen from an aircraft northwest of the crater. The outlined area on the image shows the landing ellipse for the Mars Science Laboratory rover, Curiosity. Credit: NASA/JPL-Caltech/ASU/UA.

NASA's Next Mars Rover to Land at Gale Crater

NASA's next Mars rover will land at the foot of a layered mountain inside the planet's Gale Crater. The car-sized Mars Science Laboratory, or Curiosity, is scheduled to launch late this year and land in August 2012. The target crater spans 96 miles (154 kilometers) in diameter and holds a mountain rising higher from the crater floor than Mount Rainier rises above Seattle. Gale is about the combined area of Connecticut and Rhode Island. Layering in the mound suggests it is the surviving remnant of an extensive sequence of deposits. The crater is named for Australian astronomer Walter F. Gale.

During a prime mission lasting one martian year — nearly two Earth years — researchers will use the rover's tools to study whether the landing region had favorable environmental conditions for supporting microbial life and for preserving clues about whether life ever existed. "Scientists identified Gale as their top choice to pursue the ambitious goals of this new rover mission," said Jim Green, director for the Planetary Science Division at NASA Headquarters. "The site offers a visually dramatic landscape and also great potential for significant science findings."

In 2006, more than 100 scientists began to consider about 30 potential landing sites during worldwide workshops. Four candidates were selected in 2008. An abundance of targeted images enabled thorough analysis of the safety concerns and scientific attractions of each site. A team of senior NASA science officials then conducted a detailed review and unanimously agreed to move forward with the MSL science team's recommendation.

Curiosity is about twice as long and more than five times as heavy as any previous Mars rover. Its 10 science instruments include two for ingesting and analyzing samples of powdered rock that the rover's robotic arm collects. A radioisotope power source will provide heat and electric power to the rover. A rocket-powered sky crane suspending Curiosity on tethers will lower the rover directly to the martian surface. The portion of the crater where Curiosity will land has an alluvial fan likely formed by water-carried sediments. The layers at the base of the mountain contain clays and sulfates, both known to form in water.

"One fascination with Gale is that it's a huge crater sitting in a very low-elevation position on Mars, and we all know that water runs downhill," said John Grotzinger, the mission's project scientist at the California Institute of Technology. "In terms of the total vertical profile exposed and the low elevation, Gale offers attractions similar to Mars' famous Valles Marineris, the largest canyon in the solar system."

Curiosity will go beyond the "follow-the-water" strategy of recent Mars exploration. The rover's science payload can identify other ingredients of life, such as the carbon-based building blocks of biology called organic compounds. Long-term preservation of organic compounds requires special conditions. Certain minerals, including some Curiosity may find in the clay and sulfate-rich layers near the bottom of Gale's mountain, are good at latching onto organic compounds and protecting them from oxidation.

"Gale gives us attractive possibilities for finding organics, but that is still a long shot," said Michael Meyer, lead scientist for the Mars Exploration Program at NASA Headquarters. "What adds to Gale's appeal is that, organics or not, the site holds a diversity of features and layers for investigating

changing environmental conditions, some of which could inform a broader understanding of habitability on ancient Mars."

The rover and other spacecraft components are being assembled and are undergoing final testing. The mission is targeted to launch from Cape Canaveral Air Force Station in Florida between November 25 and December 18. For more information about the mission, visit *www.nasa.gov/msl and marsprogram.jpl.nasa.gov/msl/*.

NASA's Spirit Rover Completes Mission on Mars

Artist's concept of the Mars Exploration Rover. Credit: NASA/JPL-Caltech.

NASA has ended operational planning activities for the Mars rover Spirit and transitioned the Mars Exploration Rover Project to a single-rover operation focused on Spirit's still-active twin, Opportunity. This marks the completion of one of the most successful missions of interplanetary exploration ever launched.

Spirit last communicated on March 22, 2010, as martian winter approached and the rover's solar-energy supply declined. The rover operated for more than six years after landing in January 2004 for what was planned as a three-month mission. NASA checked frequently in recent months for possible reawakening of Spirit as solar energy available to the rover increased during martian spring. A series of additional re-contact attempts ended at the end of May, designed for various possible combinations of recoverable conditions. "Our job was to wear these rovers out exploring, to leave no unutilized capability on the surface of Mars, and for Spirit, we have done that," said Mars Exploration Rover Project Manager John Callas of NASA's Jet Propulsion Laboratory.

Spirit drove 4.8 miles (7.73 kilometers), more than 12 times the goal set for the mission. The drives crossed a plain to reach a distant range of hills that appeared as mere bumps on the horizon from the landing site; climbed slopes up to 30° as Spirit became the first robot to summit a hill on another planet; and covered more than half a mile (nearly a kilometer) after Spirit's right-front wheel became immobile in 2006. The rover returned more than 124,000 images. It ground the surfaces off 15 rock targets and scoured 92 targets with a brush to prepare the targets for inspection with spectrometers and a microscopic imager.

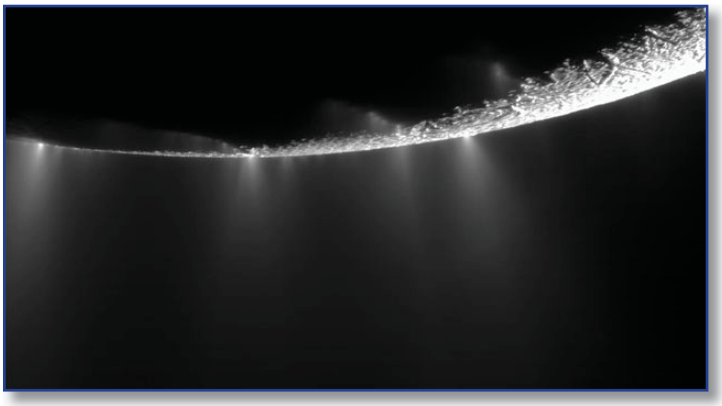
One major finding came, ironically, from dragging the inoperable right-front wheel as the rover was driving backward in 2007. That wheel plowed up bright white soil. Spirit's Alpha Particle X-ray Spectrometer and Miniature Thermal Emission Spectrometer revealed that the bright material was nearly pure silica. "Spirit's unexpected discovery of concentrated silica deposits was one of the most important findings by either rover," said Steve Squyres of Cornell University, principal investigator for Spirit and Opportunity. "It showed that there were once hot springs or steam vents at the Spirit site, which could have provided favorable conditions for microbial life."

The silica-rich soil neighbors a low plateau called Home Plate, which was Spirit's main destination after the historic climb up Husband Hill. "What Spirit showed us at Home Plate was that early Mars could be a violent place, with water and hot rock interacting to make what must have been spectacular volcanic explosions. It was a dramatically different world than the cold, dry Mars of today," said Squyres.

The trove of data from Spirit could still yield future science revelations. Years of analysis of some 2005 observations by the rover's Alpha Particle X-ray Spectrometer, Miniature Thermal Emission Spectrometer, and Mössbauer Spectrometer produced a report last year that an outcrop on Husband Hill bears a high concentration of carbonate. This is evidence of a wet, nonacidic ancient environment that may have been favorable for microbial life.

For more information about the rovers, visit *www.nasa.gov/rovers* and *marsrovers.jpl.nasa.gov*.

Cassini Captures Ocean-Like Spray at Saturn Moon



Dramatic plumes, both large and small, spray water ice out from many locations along the famed "tiger stripes" near the south pole of Saturn's moon Enceladus. The tiger stripes are fissures that spray icy particles, water vapor, and organic compounds. Credit: NASA/JPL/Space Science Institute.

NASA's Cassini spacecraft has discovered the best evidence yet for a large-scale saltwater reservoir beneath the icy crust of Saturn's moon Enceladus. The data came from the spacecraft's direct analysis of salt-rich ice grains close to the jets ejected from the moon. Data from Cassini's cosmic dust analyzer show the grains expelled from fissures, known as tiger stripes, are relatively small and predominantly low in salt far away from the moon. But closer to the moon's surface, Cassini found that relatively large grains rich with sodium and potassium dominate the plumes. The salt-rich particles have an "ocean-like" composition and indicate that most, if not all, of the expelled ice and water vapor comes from the evaporation of liquid salt water. The findings appeared recently in the journal *Nature*.

"There currently is no plausible way to produce a steady outflow of salt-rich grains from solid ice across all the tiger stripes other than salt water under Enceladus's icy surface," said Frank Postberg, a Cassini team scientist at the University of Heidelberg, Germany, and the lead author on the paper. When water freezes, the salt is squeezed out, leaving pure water ice behind. If the plumes emanated from ice, they should have very little salt in them.

The Cassini mission discovered Enceladus' water-vapor and ice jets in 2005. In 2009, scientists working with the cosmic dust analyzer examined some sodium salts found in ice grains of Saturn's E ring, the outermost ring that gets its material primarily from Enceladean jets. But the link to subsurface salt water was not definitive. The new paper analyzes three Enceladus flybys in 2008 and 2009 with the same instrument, focusing on the composition of freshly ejected plume grains. The icy particles hit the detector target at speeds between 15,000 and 39,000 mph (23,000 and 63,000 kilometers per hour), vaporizing instantly. Electrical fields inside the cosmic dust analyzer separated the various constituents of the impact cloud.

The data suggest a layer of water between the moon's rocky core and its icy mantle, possibly as deep as about 50 miles (80 kilometers) beneath the surface. As this water washes against the rocks, it dissolves salt compounds and rises through fractures in the overlying ice to form reserves nearer the surface. If the outermost layer cracks open, the decrease in pressure from these reserves to space causes a plume to shoot out. Roughly 400 pounds (200 kilograms) of water vapor is lost every second in the plumes, with smaller amounts being lost as ice grains. The team calculates the water reserves must have large evaporating surfaces, or they would freeze easily and stop the plumes. "This finding is a crucial new piece of evidence showing that environmental conditions favorable to the emergence of life can

be sustained on icy bodies orbiting gas giant planets," said Nicolas Altobelli, the European Space Agency's project scientist for Cassini.

Cassini's ultraviolet imaging spectrograph also recently obtained complementary results that support the presence of a subsurface ocean. A team of Cassini researchers led by Candice Hansen of the Planetary Science Institute in Tucson, Arizona, measured gas shooting out of distinct jets originating in the moon's south polar region at five to eight times the speed of sound, several times faster than previously measured. These observations of distinct jets, from a 2010 flyby, are consistent with results showing a difference in composition of ice grains close to the moon's surface and those that made it out to the E ring. That paper was published in the June 9 issue of *Geophysical Research Letters.*

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

An artist's interpretation of NASA's asteroid-sample mission OSIRIS-REx, which will rendezvous with the near-Earth asteroid designated 1999 RQ36 in 2020. The mission is expected to launch in 2016. Credit: NASA/Goddard/University of Arizona.

NASA to Launch New Science Mission to Asteroid in 2016

NASA will launch a spacecraft to an asteroid in 2016 and use a robotic arm to pluck samples that could better explain our solar system's formation and how life began. The mission, called Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS-REx) will be the first U.S. mission to carry samples from an asteroid back to Earth. "This is a critical step in meeting the objectives outlined by President Obama to extend our reach beyond low-Earth orbit and explore into deep space," said NASA Administrator Charlie Bolden. "It's robotic missions like these that will pave the way for future human space missions to an asteroid and other deep space destinations."

NASA selected OSIRIS-REx after reviewing three concept study reports for new scientific missions, which also included a sample return mission from the farside of the moon and a mission to the surface of Venus.

Asteroids are leftovers formed from the cloud of gas and dust — the solar nebula — that collapsed to form our Sun and the planets about 4.5 billion years ago. As such, they contain the original material from the solar nebula, which can tell us about the conditions of our solar system's birth. After traveling four years, OSIRIS-REx will approach the primitive, near-Earth asteroid designated 1999 RQ36 in 2020. Once within three miles of the asteroid, the spacecraft will begin six months of comprehensive surface mapping. The science team then will pick a location from where the spacecraft's arm will take a sample. The spacecraft gradually will move closer to the site, and the arm will extend to collect more than two ounces of material for return to Earth in 2023. The mission, excluding the launch vehicle, is expected to cost approximately $800 million.

The sample will be stored in a capsule that will land at Utah's Test and Training Range in 2023. The capsule's design will be similar to that used by NASA's Stardust spacecraft, which returned the world's first comet particles from Comet Wild 2 in 2006. The OSIRIS-REx sample capsule will be taken to NASA's Johnson Space Center in Houston. The material will be removed and delivered to a dedicated research facility following stringent planetary protection protocol. Precise analysis will be performed that cannot be duplicated by spacecraft-based instruments.

RQ36 is approximately 1900 feet in diameter or roughly the size of five football fields. The asteroid, little altered over time, is likely to represent a snapshot of our solar system's infancy. The asteroid also is likely rich in carbon, a key element in the organic molecules necessary for life. Organic molecules have been found in meteorite and comet samples, indicating some of life's ingredients can be created in space. Scientists want to see if they also are present on RQ36.

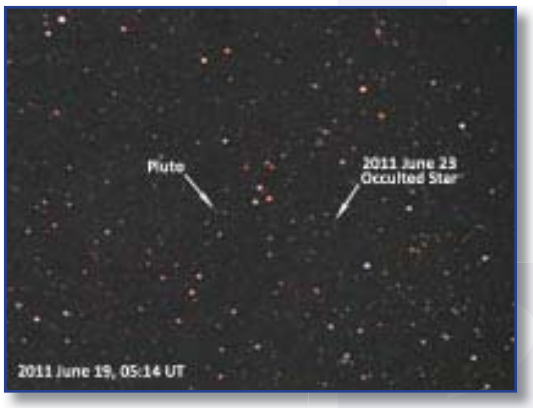
The mission will accurately measure the "Yarkovsky effect" for the first time. The effect is a small push caused by the Sun on an asteroid, as it absorbs sunlight and reemits that energy as heat. The small push adds up over time, but it is uneven due to an asteroid's shape, wobble, surface composition, and rotation. For scientists to predict an Earth-approaching asteroid's path, they must understand how the effect will change its orbit. OSIRIS-REx will help refine RQ36's orbit to ascertain its trajectory and devise future strategies to mitigate possible Earth impacts from celestial objects.

Michael Drake of the University of Arizona in Tucson is the mission's principal investigator. NASA's Goddard Space Flight Center in Greenbelt, Maryland, will provide overall mission management, systems engineering, and safety and mission assurance. Lockheed Martin Space Systems in Denver will build the spacecraft. The OSIRIS-REx payload includes instruments from the University of Arizona, Goddard, Arizona State University in Tempe, and the Canadian Space Agency. NASA's Ames Research Center at Moffett Field, California, the Langley Research Center in Hampton, Virginia, and the Jet Propulsion Laboratory in Pasadena, California are also involved. The science team is composed of numerous researchers from universities, private, and government agencies.

This is the third mission in NASA's New Frontiers Program. The first, New Horizons, was launched in 2006. It will fly by the Pluto-Charon system in July 2015, then target another Kuiper belt object for study. The second mission, Juno, launched in August to become the first spacecraft to orbit Jupiter from pole to pole and study the giant planet's atmosphere and interior.

SOFIA Successfully Observes Challenging Pluto Occultation

On June 23, NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) observed the dwarf planet Pluto as it passed in front of a distant star. This event, known as an "occultation," allowed scientific analysis of Pluto and its atmosphere by flying SOFIA at the right moment to an exact location where Pluto's shadow fell on Earth. "This was the first demonstration in practice of one of SOFIA's major design capabilities," said Bob Meyer, SOFIA's program manager. "Pluto's shadow traveled at 53,000 mph across a mostly empty stretch of the Pacific Ocean. SOFIA flew more than 1800 miles out over the Pacific Ocean from its base in Southern California to position itself in the center of the shadow's path, and was the only observatory capable of doing so."



On June 23, SOFIA demonstrated one of its major design capabilities by capturing an image of Pluto as it passed in front of a distant star. Credit: USRA.

SOFIA is a highly modified Boeing 747SP aircraft that carries a telescope with a 100-inch (2.5-meter) reflecting mirror that conducts astronomy research not possible with groundbased telescopes. By operating in the stratosphere at altitudes up to 45,000 feet, SOFIA can make observations above the water vapor in Earth's lower atmosphere. "Occultations give us the ability to measure pressure, density, and temperature profiles of Pluto's atmosphere without leaving the Earth," said Ted Dunham of the Lowell Observatory in Flagstaff, who led the team of scientists onboard SOFIA during the Pluto observations.

"Because we were able to maneuver SOFIA so close to the center of the occultation we observed an extended, small, but distinct brightening near the middle of the occultation. This change will allow us to probe Pluto's atmosphere at lower altitudes than is usually possible with stellar occultations."

Dunham is the principal investigator for the High-Speed Imaging Photometer for Occultation (HIPO), essentially an extremely fast and accurate electronic light meter. He was a member of the group that originally discovered Pluto's atmosphere by observing a stellar occultation from SOFIA's predecessor, the Kuiper Airborne Observatory, in 1988. Pluto itself was discovered at Lowell Observatory in 1930.

A group of SOFIA German scientists and engineers were also onboard to monitor the performance of the German-built telescope and Fast Diagnostic Camera (FDC). That camera has been used on previous flights to measure the stability of SOFIA and its optical systems. On this flight, the FDC provided supplemental observations of the Pluto occultation.

There were some tense moments for SOFIA's international science team in the minutes leading up to the occultation. The precise position of Pluto in relation to Earth could not be sufficiently refined until a few hours before the event. That evening, a Lowell astronomer used facilities at the U.S. Naval Observatory in Flagstaff to take multiple photographs of Pluto and the star. Those data were passed to collaborators at the Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts, who refined their prediction of the exact position and timing of Pluto's shadow track. About two hours before the occultation, the MIT group contacted SOFIA in-flight with the news that the center of the shadow would cross 125 miles north of the position on which the airborne observatory's flight plan had been based. After recalculating and filing a revised flight plan, SOFIA's flight crew and science team had to wait an anxious 20 minutes before receiving permission from air traffic control to alter the flight path accordingly.

"We have already shown that SOFIA is a first-rank international facility for infrared astronomy research. This successful occultation observation adds substantially to SOFIA's ability to serve the world's scientific community," said Pamela Marcum, SOFIA project scientist.

For more information, visit *www.nasa.gov/sofia*, *www.sofia.usra.edu*, or *www.dlr.de/en/sofia*.

Artist's rendering of the Genesis spacecraft during the collection phase of the mission. Credit: NASA/JPL-Caltech.

NASA Mission Suggests Sun and Planets Constructed Differently

Researchers analyzing samples returned by NASA's 2004 Genesis mission have discovered that our Sun and its inner planets may have formed differently than previously thought. Data revealed differences between the Sun and planets in oxygen and nitrogen, which are two of the most abundant elements in our solar system. Although the difference is slight, the implications could help determine how our solar system evolved.

"We found that Earth, the Moon, as well as martian and other meteorites which are samples of asteroids, have a lower concentration of the oxygen-16 than does the Sun," said Kevin McKeegan, a Genesis co-investigator from UCLA, and the lead author of one of two *Science* papers published in June. "The implication is that we did not form out of the same solar nebula materials that created the Sun — just how and why remains to be discovered."

The air on Earth contains three different kinds of oxygen atoms that are differentiated by the number of neutrons they contain. Nearly 100% percent of oxygen atoms in the solar system are composed

of oxygen-16 (^{16}O), but there are also tiny amounts of more exotic oxygen isotopes called ^{17}O and ^{18}O. Researchers studying the oxygen of Genesis samples found that the percentage of ^{16}O in the Sun is slightly higher than on Earth or on other terrestrial planets. The other isotopes' percentages were slightly lower.

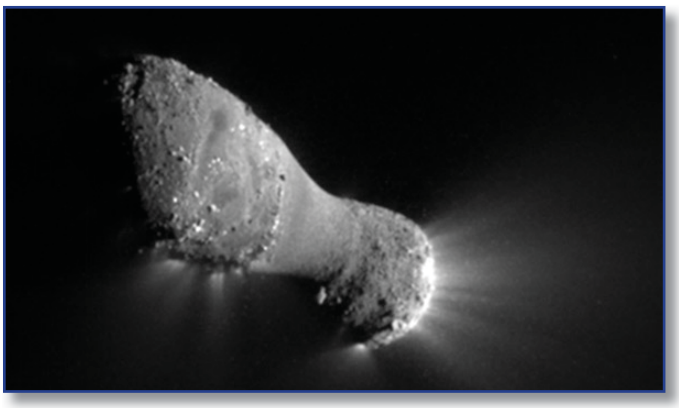
Another paper detailed differences between the Sun and planets in the element nitrogen. Like oxygen, nitrogen has one isotope, nitrogen-14 (^{14}N), that makes up nearly 100% of the atoms in the solar system, but there is also a tiny amount of ^{15}N. Researchers studying the same samples saw that when compared to Earth's atmosphere, nitrogen in the Sun and Jupiter has slightly more ^{14}N, but 40% less ^{15}N. Both the Sun and Jupiter appear to have the same nitrogen composition. As is the case for oxygen, Earth and the rest of the inner solar system are very different in nitrogen.

"These findings show that all solar system objects including the terrestrial planets, meteorites, and comets are anomalous compared to the initial composition of the nebula from which the solar system formed," said Bernard Marty, a Genesis co-investigator from Centre de Recherches Pétrographiques et Géochimiques and the lead author of the other new *Science* paper. "Understanding the cause of such a heterogeneity will impact our view on the formation of the solar system."

Data were obtained from analysis of samples Genesis collected from the solar wind, or material ejected from the outer portion of the Sun. This material can be thought of as a fossil of our nebula because the preponderance of scientific evidence suggests that the outer layer of our Sun has not changed measurably for billions of years.

Genesis launched in August 2000. The spacecraft traveled to Earth's L1 Lagrange Point about 1 million miles from Earth, where it remained for 886 days between 2001 and 2004, passively collecting solar-wind samples. On September 8, 2004, the spacecraft released a sample return capsule, which entered Earth's atmosphere. Although the capsule made a hard landing as a result of a failed parachute in the Utah Test and Training Range in Dugway, Utah, it marked NASA's first sample return since the final Apollo lunar mission in 1972, and the first material collected beyond the Moon. NASA's Johnson Space Center in Houston curates the samples and supports analysis and sample allocation.

For more information, visit *genesismission.jpl.nasa.gov*.



This image of Comet Hartley 2 was taken as NASA's EPOXI mission flew by on November 4 around 6:59 a.m. PDT (9:59 a.m. EDT), from a distance of about 435 miles (700 kilometers). Credit: NASA/JPL-Caltech/UMD.

Science Paper Details NASA EPOXI Flyby of Hyper Comet

Comet Hartley 2's hyperactive state, as studied by NASA's EPOXI mission, is detailed in a new paper published recently in the journal *Science*. After visiting a comet and imaging distant stars for hints of extrasolar planets, you could say the spacecraft used for EPOXI had seen its fair share of celestial wonders. But after about 3.2 billion miles (5.1 billion kilometers) of deep space travel, one final wonder awaited the mission's project and science teams. On November 4, 2010, the EPOXI mission spacecraft flew past a weird little comet called Hartley 2.

"From all the imaging we took during approach, we knew the comet was a

little skittish even before flyby," said EPOXI Project Manager Tim Larson of NASA's Jet Propulsion Laboratory. "It was moving around the sky like a knuckleball and gave my navigators fits, and these new results show this little comet is downright hyperactive."

The EPOXI mission found that the strong activity in water release and carbon dioxide-powered jets did not occur equally in the different regions of the comet. During the spacecraft's flyby of the comet — with closest approach of 431 miles (694 kilometers) — carbon-dioxide-driven jets were seen at the ends of the comet, with most occurring at the small end. In the middle region, or waist of the comet, water was released as vapor with very little carbon dioxide or ice. The latter findings indicate that material in the waist likely came off the ends of the comet and was redeposited.

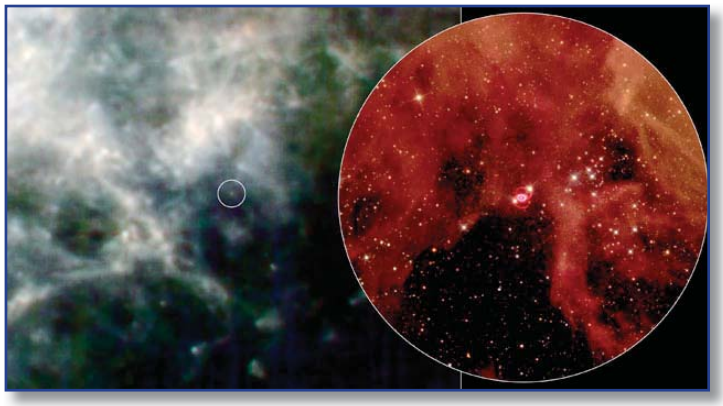
"Hartley 2 is a hyperactive little comet, spewing out more water than most other comets its size," said Mike A'Hearn, principal investigator of EPOXI from the University of Maryland, College Park. "When warmed by the Sun, dry ice — frozen carbon dioxide — deep in the comet's body turns to gas jetting off the comet and dragging water ice with it." Although Hartley 2 is the only such hyperactive comet visited by a spacecraft, scientists know of at least a dozen other comets that also are relatively high in activity for their size and that are probably driven by carbon dioxide or carbon monoxide. "These could represent a separate class of hyperactive comets," said A'Hearn. "Or they could be a continuum in comet activity extending from Hartley 2-like comets all the way to the much less active, 'normal' comets that we are more used to seeing."

The study provides several new twists in the unfolding story of this small cometary dynamo, including (1) Hartley 2 has an "excited state of rotation" because it spins around one axis, but also tumbles around a different axis; and (2) on its larger, rougher ends, the comet's surface is dotted with glittering blocks that can reach approximately 165 feet (50 meters) high and 260 feet (80 meters) wide. The block-like, shiny objects, some as big as one block long and 16 stories tall, appear to be two to three times more reflective than the surface average.

EPOXI was an extended mission that utilized the already "in-flight" Deep Impact spacecraft to explore distinct celestial targets of opportunity. The name EPOXI itself is a combination of the names for the two extended mission components: the extrasolar planet observations, called Extrasolar Planet Observations and Characterization (EPOCh), and the flyby of Comet Hartley 2, called the Deep Impact Extended Investigation (DIXI). The spacecraft retained the name "Deep Impact." During its approach, encounter and departure from Comet Hartley 2, the spacecraft beamed back more than 117,000 images and spectra.

Herschel Helps Solve Mystery of Cosmic Dust Origins

New observations from the infrared Herschel Space Observatory reveal that an exploding star expelled the equivalent of between 160,000 and 230,000 Earth masses of fresh dust. This enormous quantity suggests that exploding stars, called supernovae, are the answer to the long-standing puzzle of what supplied our early universe with dust. "This discovery illustrates the power of tackling a problem in astronomy with different wavelengths of light," said Paul Goldsmith, the NASA Herschel project



This layout compares two pictures of a supernova remnant called SN 1987A. The left image was taken by the Herschel Space Observatory, and the right image is an enlarged view of the circled region at left, taken with NASA's Hubble Space Telescope. Credit: ESA/NASA-JPL/UCL/STScI.

scientist at NASA's Jet Propulsion Laboratory, who is not a part of the current study. "Herschel's eye for longer-wavelength infrared light has given us new tools for addressing a profound cosmic mystery." Herschel is led by the European Space Agency with important contributions from NASA.

Cosmic dust is made of various elements, such as carbon, oxygen, iron, and other atoms heavier than hydrogen and helium. It is the stuff of which planets and people are made, and it is essential for star formation. Stars like our Sun churn out flecks of dust as they age, spawning new generations of stars and their orbiting planets.

Astronomers have for decades wondered how dust was made in our early universe. Back then, Sun-like stars had not been around long enough to produce the enormous amounts of dust observed in distant, early galaxies. Supernovae, on the other hand, are the explosions of massive stars that do not live long. The new Herschel observations are the best evidence yet that supernovae are, in fact, the dust-making machines of the early cosmos.

"The Earth on which we stand is made almost entirely of material created inside a star," explained the principal investigator of the survey project, Margaret Meixner of the Space Telescope Science Institute in Baltimore, Maryland. "Now we have a direct measurement of how supernovae enrich space with the elements that condense into the dust that is needed for stars, planets, and life."

The study, appearing in the July 8 issue of the journal *Science*, focused on the remains of the most recent supernova to be witnessed with the naked eye from Earth. Called SN 1987A, this remnant is the result of a stellar blast that occurred 170,000 light-years away and was seen on Earth in 1987. As the star blew up, it brightened in the night sky and then slowly faded over the following months. Because astronomers are able to witness the phases of this star's death over time, SN 1987A is one of the most extensively studied objects in the sky.

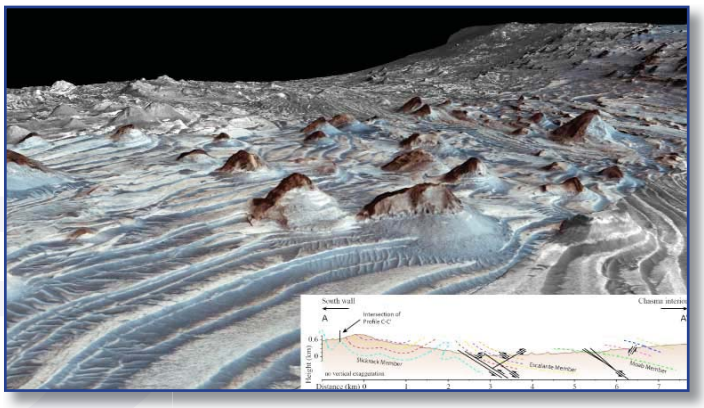
Initially, astronomers weren't sure if the Herschel telescope could even see this supernova remnant. Herschel detects the longest infrared wavelengths, which means it can see very cold objects that emit very little heat, such as dust. But it so happened that SN 1987A was imaged during a Herschel survey of the object's host galaxy — a small neighboring galaxy called the Large Magellanic Cloud (it's called large because it's bigger than its sister galaxy, the Small Magellanic Cloud).

After the scientists retrieved the images from space, they were surprised to see that SN 1987A was aglow with light. Careful calculations revealed that the glow was coming from enormous clouds of dust — consisting of 10,000 times more material than previous estimates. The dust is –429° to –416°F (about –221° to –213°C) — colder than Pluto, which is about –400°F (–204°C).

"Our Herschel discovery of dust in SN 1987A can make a significant understanding in the dust in the Large Magellanic Cloud," said Mikako Matsuura of University College London, England, the lead author of the *Science* paper. "In addition to the puzzle of how dust is made in the early universe, these results give us new clues to mysteries about how the Large Magellanic Cloud and even our own Milky Way became so dusty."

For more information, visit *www.nasa.gov/herschel* and *www.esa.int/SPECIALS/Herschel/index.html*.

High-Resolution Topographic Data Available for Research



This perspective view shows layers, knobs, and faults in Western Candor Chasma, Mars, based on a HiRISE DTM and false-color image. The three-dimensional data made it possible to reconstruct the rather complex geometry of faulting and folding as shown in the inset. From Okubo et al. (2008) *JGR, 113*. Credit: U.S. Geological Survey.

The NASA Planetary Geology and Geophysics Cartography Program would like to familiarize the planetary community with opportunities for obtaining high-resolution digital topographic data in support of geologic mapping and other research. These opportunities are of particular importance because the cartography program does not currently support the systematic production of topographic map quadrangles.

The Astrogeology Team of the U.S. Geological Survey, Flagstaff, operates a Planetary Photogrammetry Guest Facility on behalf of NASA's Planetary Geology and Geophysics program. Qualified scientists are welcome to use this facility to produce digital topographic models (DTMs) from stereo images. Training and use of the system are free but researchers are responsible for their travel expenses because the state-of-the-art hardware/software system cannot be used remotely. For more information about capabilities and how to apply, visit *astrogeology.usgs.gov/Technology/Photogrammetry*.

Cartographers of the Astrogeology Team are also available to partner with researchers to deliver DTMs via subcontract to a research proposal. The cost of DTMs depends on the volume and complexity of the image data analyzed and the ancillary products included, but is in the range of $5–10K for HiRISE and LROC-NAC DTMs with meter-scale resolution and ~10^8 height points.

For further information, visit the website above or send inquiries to Dr. Randolph Kirk at the USGS (*rkirk@usgs.gov*).

Onboard NASA's Mars Science Laboratory rover, Curiosity, the ChemCam instrument will help us understand whether rocks and "soils" on Mars have been altered by water and contain chemicals necessary for life.

Announcing the Release of the ChemCam Website

The ChemCam team, headed by principal investigator Roger Wiens of the Los Alamos National Laboratory, has recently released a website featuring this instrument. Included on the site are links to scientific publications, videos, images, resources for educators, and much more.

To check out the site, go to *www.msl-chemcam.com*.

"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.

Continuing the Year of the Solar System (YSS)

Spanning a martian year — 23 months — the Year of the Solar System celebrates the amazing discoveries of numerous NASA missions as they explore our near and distant neighbors and probe the very outer edges of our solar system. Each month, from October 2010 to August 2012, audiences explore different aspects or our solar system — its formation, volcanism, ices, and life — weaving together activities, resources, and ideas that teachers, clubs, and organizations can use to engage audiences. For more information, visit *solarsystem.nasa.gov/yss*.

The topic for August is *Windy Worlds,* as we celebrate the launch of the Juno mission to Jupiter! Check out activities about storms and weather, and examine videos and podcasts to blow some fresh air into your own programs!

September's topic is *Gravity: It's What Keeps Us Together,* as we observe GRAIL's launch to the Moon! Check out activities in Classrooms and Organizations and Clubs to explore tides, your weight on other worlds, and orbits of moons and comets. It's a weighty topic; join us to tackle it together!

The topic for October is *Moons and Rings: Our Favorite Things* as we celebrate International Observe the Moon Night.

Get Involved! Share Your YSS Events and Stories: Advertise your YSS Events on the YSS Calendar. Share your YSS stories through the YSS story space, Flickr, and YouTube. Visit *solarsystem.nasa.gov/yss/getinvolved.cfm*.

Link to YSS from Your Website: We invite you be a YSS partner during the Year of the Solar System! Post the YSS graphic element on your website and link to the YSS page. You can find YSS graphics at *solarsystem.nasa.gov//yss/display.cfm?Year=2010&Month=12&Tab=Downloads*.

Ideas? Feedback? Contact us at *planetaryforum@lpi.usra.edu*.

Earth Science Week 2011 Toolkits Available for Order

Earth Science Week 2011 will be celebrated October 9–15. The American Geological Institute is now accepting advance orders for the 2011 Earth Science Week Toolkit, which contains educational materials for all ages that correspond to this year's theme of "Our Ever-Changing Earth." The toolkit will be sent in August 2011. Visit *www.earthsciweek.org/materials/index.html*.

Ice Hunters Citizen Science Project

The world is invited to help discover a potential new, icy follow-on destination for NASA's New Horizons spacecraft. New Horizons is currently en route to make the first flyby of the Pluto system, and is then capable of making additional explorations of bodies still farther out in the Sun's Kuiper belt.

Through this citizen science project, the public can help scientists search through specially obtained deep telescopic images for currently unknown objects in the Kuiper belt. Along the way, they will also discover variable stars and asteroids. Ice Hunters is a Zooniverse citizen science project. For more information, visit *www.icehunters.org*.

International Observe the Moon Night

Celebrate the Moon! October 8, 2011, will mark the second International Observe the Moon Night! There are opportunities to host and advertise your own event as well as to connect with events within your community. Activities, information about the Moon, suggestions on hosting an event, and details about events at international partnering institutes are all available at *observethemoonnight.org*.

Education Sessions at AGU, San Francisco, California, December 5–9, 2011

Numerous education sessions have been proposed for AGU. Three that may be of particular interest to the planetary science education community are:

ED04 Best Practices in Engaging Scientists in Education and Public Outreach
Educational research and firsthand experience demonstrates that scientist participation in education and public outreach (EPO) activities increases audience interest and learning about scientific topics. Taking cues from educational research, many EPO specialists are working to increase the number of scientists who are actively engaged in EPO activities. This session will focus on best practices and lessons learned in engaging scientists in EPO activities.

ED17 Communicating Research and its Impacts: Research Geoscientists
Research geoscientists are increasingly expected to communicate the activities and outcomes of their research to students and the general public. We invite contributions from research geoscientists' perspectives that discuss the innovations, challenges, and solutions in communicating research and its significance.

ED44 Teacher Professional Development Programs Promoting Authentic Scientific Research in the Classroom
The session will focus on building a framework for successful research experiences for teachers. Papers might address new projects, roles of scientists and education specialists, the value of teams, and ways to bring research experiences back to the classroom. Other topics might include recruitment strategies, program scale-up, financial planning, internet and archival research projects, citizen science, mentoring issues, training of scientists, and evaluation.

Additional education and public outreach sessions explore citizen science, social media, attracting and retaining underrepresented racial minorities, and more! Find sessions at *www.agu.org/education/at_meetings/*.

NASA Online Videos Provide New Approach to Teach Science to Public

NASA's new video series offers the public a fast and fun way to learn about scientific discoveries and facts about Earth, the solar system, and beyond. Called "ScienceCasts," the videos are created by an astrophysicist and a team of agency narrators and videographers. The videos are posted online every Thursday afternoon at approximately 4:00 p.m. EDT. The format is designed to increase understanding of the world of science through simple, clear presentations. Future episodes will focus on citizen science research; the search for new galaxies; how to watch this summer's Perseid meteor shower; and the causes of recent wild weather events in the United States.

NASA's Science Mission Directorate seeks new knowledge and understanding of Earth, the Sun, solar system, and the universe. The directorate also constantly looks for inventive ways to reach out to the public via museums, classrooms, science centers and home schools. To view the latest videos of science online, visit *www.youtube.com/user/scienceatnasa*. For a complete list of ScienceCast episodes, visit *sciencecasts.nasa.gov*.

Barringer Fund Awardees Announced

The Lunar and Planetary Institute (LPI) is pleased to announce the names of the students whose research will be supported by The Barringer Family Fund for Meteorite Impact Research.

The 2011 awardees are Timmons Erickson (University of Puerto Rico Mayaguez, United States), Matthew Huber (University of Vienna, Austria), Chaabout Souad (Hassan II University, Morocco), and Michael Zanetti (Washington University, United States).

The Barringer Family Fund for Meteorite Impact Research was established to support field work by eligible students interested in the study of impact cratering processes. The Fund provides a small number of competitive grants each year for support of field research at known or suspected impact sites worldwide.

The Fund was established as a memorial to recognize the contributions of Brandon, Moreau, Paul, and Richard Barringer to the field of meteoritics and the Barringer family's strong interest and support over many years in research and student education. In addition to its memorial nature, the Fund also reflects the family's long-standing commitment to responsible stewardship of The Barringer Meteorite Crater and the family's steadfast resolve in maintaining the crater as a unique scientific research and education site.

For more information, visit *www.lpi.usra.edu/science/kring/Awards/Barringer_Fund/index.html*.

G. Jeffrey Taylor Receives Shoemaker Distinguished Lunar Scientist Award

G. Jeffrey Taylor received the Shoemaker Distinguished Lunar Scientist Award at the 2011 Lunar Science Forum. Taylor, a planetary science faculty member at the University of Hawaii, Honolulu, specializes in planetary volcanology, igneous processes, and extraterrestrial materials. Taylor uses a combination of petrology, geochemistry, field observations, and remote sensing and theory to address problems in planetary science.

"In view of his many fundamental and far-reaching contributions to lunar science and his leadership efforts such as serving as the founding director of the Lunar Exploration Analysis Group, Dr. Taylor is exceptionally deserving of this medal," said Yvonne Pendleton, director of the NASA Lunar Science Institute. "We are proud to present him with this honor."

The Shoemaker Distinguished Lunar Scientist Award is an annual award given to a scientist who has significantly contributed to the field of lunar science throughout the course of their scientific career. The first Distinguished Lunar Scientist Award was given posthumously to Dr. Gene Shoemaker and presented to his wife Carolyn for his many contributions to the lunar geological sciences. The award was subsequently named after Dr. Shoemaker and includes a medal with the Shakespearian quote "And he will make the face of heaven so fine, that all the world will be in love with night." Last year's Shoemaker award was presented to Don E. Wilhelms.

Taylor is recognized for being both a successful researcher working at the cutting edge of planetary science and a sublime communicator in diverse professional, public, and educational forums. A faculty member at the University of Hawaii since 1990, Taylor's professional interests range from laboratory studies of rocks and meteorites to geologic field observations to remote sensing, all combined to understand planetary processes that operate on Earth, the Moon, the planets, and asteroids. He is involved in planning future missions to the Moon and Mars, in the use of robotics for field geological studies, remote sensing mapping to understand planetary composition and geologic evolution, and developing methods to prospect for resources on the Moon and Mars. In addition, Taylor serves as associate director for space science for the Hawaii Space Grant Consortium and was Director from 1998 to 2002. Taylor's achievements in scientific discoveries and publications are matched by his career-long, deep dedication to education and engaging the public in the excitement of science through workshops, public talks, and writing.

International Students Receive Hands-On Research Opportunities in Lunar Geology and Aerospace Engineering

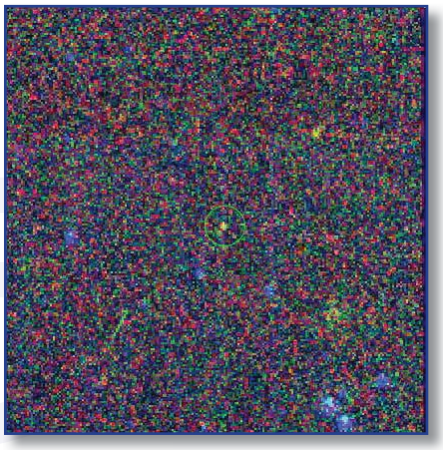
The Lunar and Planetary Institute (LPI) in Houston, Texas, and the University of Texas at Arlington recently hosted five undergraduate students from the Indian Institute of Science and Technology (IIST) in Thiravanathapuram, India. The students were accepted as part of the 2011 Universities Space Research Association (USRA) undergraduate student research program. The students participating in the program were Bhavesh Jaiswal, Apoov Mehta, Ankush Kuman, Vaibhav Dixit, and Pulkit Goyal.

Pictured from left to right: Dr. Donald Kniffen, Dr. Stephen Mackwell, Bhavesh Jaiswal, Apoov Mehta, Dr. Hussein Jirdeh, Ankush Kumar, Vaibhav Dixit, Pulkit Goyal, and Dr. Erian Armanios. Credit: USRA/LPI.

Beginning April 1, this 13-week program provided the IIST students with the unique opportunity to participate in cutting-edge research in lunar and planetary science. Three of the students worked closely with LPI scientists on research projects pertaining to lunar geology, with particular emphasis on the geology of impact craters by using recently acquired imagery from current lunar missions. The program was made possible through a Memorandum of Understanding (MOU) between USRA and IIST. The University of Texas at Arlington also participated in the program as a collaborative partner, hosting the remaining two IIST students.

The program culminated with a closing ceremony on June 23, during which the students presented the results of the research they had conducted while at the LPI and UT Arlington. Presentations were also made by LPI postdoctoral fellows Dr. Gerald Galgana and Dr. Juliane Gross. The ceremony opened with comments by Dr. Donald Kniffen, USRA Vice President for Science; Dr. Stephen Mackwell, LPI Director; and Dr. Erian Armanios, Professor and Chairperson of the Department of Mechanical and Aerospace Engineering at the University of Texas at Arlington; and it concluded with a reception honoring the students. Dr. Hussein Jirdeh, USRA Director of University Relations, also attended the ceremony.

LPI Director, Dr. Stephen Mackwell, remarked on the success of the inaugural program, stating that "the high caliber of the student participants and the results of their research will clearly have a significant impact on future collaborations within the international scientific community."



This image, from the orbiting WISE telescope, shows asteroid (15339) Pierazzo (circled). Red, green, and blue in this false-color image represent wavelengths invisible to the eye. The bluish objects are stars. Credit: NASA/JPL-Caltech/WISE team.

Asteroid Named for Elisabetta (Betty) Pierazzo

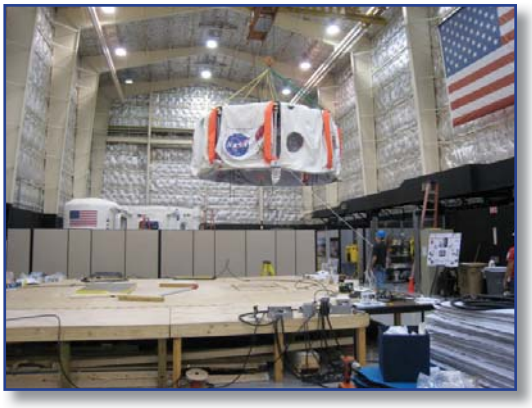
Elisabetta (Betty) Pierazzo is now memorialized in the skies as asteroid (15539) Pierazzo. The asteroid is about three times farther from the Sun than Earth is and is about 7 km in extent. It is likely related to the asteroid (243) Ida, visited by the Galileo spacecraft. (15539) Pierazzo was discovered January 8, 1994, by the Kitt Peak Observatory.

The citation, written by Jim Scotti, Don Davis, and Jay Melosh, appeared in Minor Planet Circular #75548: "Elisabetta Pierazzo (1963–2011) was an expert in impact modeling, in particular of the Chicxulub impact, as well as in modeling the effects of impacts on Earth and Mars. She was an enthusiastic communicator of science to the general public and a dedicated teacher of planetary science for students and educators."

Pierazzo passed away in May as the result of a pulmonary embolism after battling a rare form of cancer. She was only 47 years old. More information about asteroid (15539) Pierazzo is available at *ssd.jpl.nasa.gov/sbdb.cgi?sstr=15339+Pierazzo*.

University of Wisconsin Students Win Space Habitat Competition

University of Wisconsin students topped two other university teams to win the 2011 NASA eXploration Habitat (X-Hab) Academic Innovation Challenge, a competition to design and build a space habitat. The team will now take its inflatable space loft to NASA's annual Desert Research and Technology Studies (Desert RATS) field test in Arizona in September. It will be tested as part of a simulated astronaut mission to an asteroid.



The X-Hab loft built by the University of Wisconsin-Madison team is lifted and moved to the Habitat Demonstration Unit (HDU). UW-Madison, one of three finalist teams in the first annual X-Hab Academic Innovation Challenge, demonstrated their loft for judges at NASA's Johnson Space Center and was announced as the winner on July 1, 2011. Credit: NASA.

"University students are helping NASA develop potential habitats for future space missions," said Kriss Kennedy, habitat demonstration unit project manager at the NASA Johnson Space Center (JSC). "The teams collaborated to demonstrate how technology we might use in the future could actually be developed."

The three teams, totaling 135 students, each spent a week at JSC setting up and deploying their inflatable lofts for judging. Teams from Oklahoma State University, Stillwater, and the University of Maryland, College Park also competed. According to the judges, the 14-member University of Wisconsin team's design held promise for habitability and application to the

Desert RATS mission simulation and was ready for field use because it had little leakage in the inflatable systems. The loft will be part of the home for a crew of four during the field test.

In June 2010, NASA invited university teams to submit inflatable loft concepts for the X-Hab Challenge. The three competing universities received $48,000 of seed funding to assist with their projects. The winning university will receive $10,000 to offset costs associated with the desert field test.

Next year's competition, X-Hab 2012, will look at volume, geometry, and habitability of a deep space habitat and technologies for plant growth and geoscience sample handling. The competition is designed to engage and retain students in the science, technology, engineering, and math disciplines, which in turn will help develop the next generation of innovators and explorers. It also tests concepts and solutions for potential future NASA missions. The teams selected to participate in the 2012 competition are from Oklahoma State University; University of Maryland, College Park; Ohio State University; and University of Bridgeport, Connecticut.

X-Hab is sponsored by NASA's Exploration Systems Mission Directorate and the Innovative Partnerships Office in the Office of the Chief Technologist at NASA headquarters in Washington. For more information about the X-Hab competition and updates about each team's designs, visit *www.nasa.gov/exploration/analogs/xhab_challenge.html*.

NASA Announces Education Research Program Award Recipients

NASA has awarded $20 million to colleges and universities nationwide to conduct research and technology development in areas important to the agency's mission. The awards also enable faculty development and support students. The selections are part of NASA's Experimental Program to Stimulate Competitive Research (EPSCoR). The program helps develop partnerships between NASA research missions and programs, academic institutions and industry. It also helps states establish long-term academic research enterprises that will be self-sustaining and competitive and will contribute to the states' economic viability and development.

A total of 27 proposals were selected for funding in Alabama, Alaska, Arkansas, Delaware, Idaho, Kansas, Kentucky, Louisiana, Montana, Nebraska, Nevada, New Hampshire, New Mexico, North Dakota, Oklahoma, South Dakota, Tennessee, Vermont, West Virginia, and Wyoming. Winning proposals were selected through a merit-based, peer-reviewed competition.

Two proposals were selected from each of the following colleges and universities: Montana State University; South Dakota School of Mines and Technology; University of Alaska, Fairbanks; University of Delaware; University of Nebraska, Omaha; University of North Dakota; and Wichita State University. One proposal was selected from each of the following universities: Louisiana State University; New Mexico State University; University of Alabama, Huntsville; University of Arkansas, Little Rock; University of Idaho; University of Kentucky; University of Nevada, Reno; University of New Hampshire, Durham; University of Oklahoma, Norman; University of Vermont; University of Wyoming; Vanderbilt University; and West Virginia University.

For a list of selected proposals, visit *nspires.nasaprs.com*. For more information about EPSCoR, visit *education.nasa.gov/epscor*.

"Gang of Four" Receives $500,000 Gruber Cosmology Prize

Four astronomers who found a way to recreate the growth of the universe are the recipients of the 2011 Cosmology Prize of The Peter and Patricia Gruber Foundation. Marc Davis, a professor in the Departments of Astronomy and Physics at the University of California at Berkeley; George Efstathiou, the director of the Kavli Institute for Cosmology in Cambridge; Carlos Frenk, the director of the Institute for Computational Cosmology at Durham University; and Simon White, a director of the Max Planck Institute for Astrophysics in Garching, Germany, will share the $500,000 award.

The official citation recognizes the astronomers — nicknamed the "Gang of Four" by their colleagues and often collectively abbreviated as DEFW — for "their pioneering use of numerical simulations to model and interpret the large-scale distribution of matter in the universe." The Gruber Prize recognizes both the discovery method that DEFW introduced as well as the collaboration's subsequent discoveries. Davis, Efstathiou, Frenk, and White will each receive an equal share of the award, along with a gold medal, at a ceremony this fall. They will also deliver a lecture.

Astronomers have always told us what the universe looks like, and theorists have always invented ideas as to how it came to look that way. Not until the computer age, however, could scientists studying the evolution of the entire universe decisively match the gossamer of educated guesswork with the blueprint of observational evidence. The particular evidence that motivated the creation of the DEFW collaboration came in the form of a 1981 Harvard-Smithsonian Center for Astrophysics (CfA) survey of 2400 galaxies at various distances — at the time, an extraordinary census of how the heavens look on the largest scales. What the CfA survey showed was an early hint of what is today called "the cosmic web" — galaxies grouped into lengthy filaments, or superclusters, separated by vast voids.

Theorists offered two competing ideas that might explain how matter could have coalesced in such a manner. Both theories took into account the presence of dark matter, a mysterious substance that astronomers in the 1970s had come to accept as a necessary piece in the cosmic puzzle in order to explain galaxy motions that otherwise would be violating the laws of physics. One candidate theory was "hot dark matter" — "hot" because at early times the particles would travel at velocities approaching the speed of light. Such speeding particles leave behind the "regular" matter which makes up galaxies and so does not clump around them. The other candidate was "cold dark matter," relatively sluggish particles that would fall together to build galaxy halos, dragging the regular matter along for the ride. The CfA survey would allow astronomers to test these interpretations — but only if they could figure out how to model the evolution of the universe over billions of years.

Enter the Gang of Four. Although other astronomers had been working with N-body simulations — so called because they follow a number of points, N, each representing a concentration of mass — their code couldn't handle a large enough N to represent large scales in the universe. Efstathiou, however, suspected that a code used to simulate ionic microcrystals would work. He succeeded in adapting it for cosmology, and Davis, Frenk, and White then used that code to demonstrate that a simulated universe based on the hot dark matter theory didn't remotely match the CfA observations. Then, in a series of five landmark papers from 1985 to 1988, Davis, Efstathiou, Frenk, and White showed that observations of galaxies, clusters, filaments, and voids were consistent with a simulated universe that had evolved under the influence of cold dark matter.

Cold dark matter — or CDM — is today one of the two key components of the standard cosmological model. The other is the acceleration of the expansion of the universe, a discovery observers made in the late 1990s that DEFW's simulations had anticipated. Scientists designate whatever is causing the

acceleration with the mathematical symbol lambda, but it is more commonly known, in a nod to dark matter, as "dark energy." Nobody yet knows what dark matter or dark energy are. Yet as more extensive and more detailed observations of the universe have accumulated, ΛCDM has become the standard model of cosmology. Today the match between observation and theory indicates that the universe is composed of 4.6% "ordinary" matter, 23.3% dark matter, and 72.1% dark energy. Numerical simulations of the kind pioneered by DEFW show that a universe with this astonishingly precise yet remarkably strange composition does indeed develop structures that are a close match to those we see around us.

The Peter and Patricia Gruber Foundation honors and encourages educational excellence, social justice, and scientific achievements that better the human condition. For more information, visit *www.gruberprizes.org*.

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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Copy deadline for the next issue: October 15, 2011

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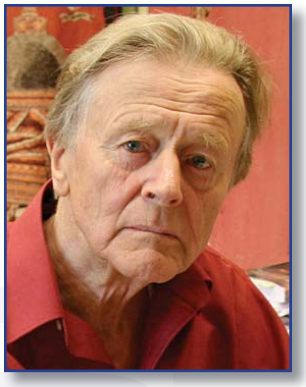
The *Bulletin* is published quarterly by the Lunar and Planetary Institute (LPI), 3600 Bay Area Boulevard, Houston TX 77058. Material in this issue may be copied without restraint for library, abstract service, education, or personal research purposes.

ISSN 1534-6587

The LPI is operated by the Universities Space Research Association under a cooperative agreement with the Science Mission Directorate of the National Aeronautics and Space Administration. Any opinions, findings, and conclusions or recommendations expressed in this issue are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration.

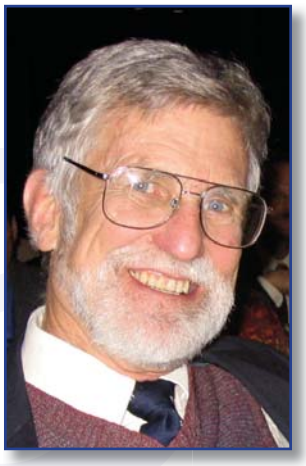


Tom Gehrels, 1925–2011

Tom Gehrels joined the University of Arizona's Lunar and Planetary Laboratory (LPL) in 1961 as an Associate Professor. He earned his B.S. in Physics and Astronomy from Leiden University in The Netherlands in 1951, and his Ph.D. in Astronomy and Astrophysics from the University of Chicago in 1956. While at Chicago, he worked with Subrahmanyan Chandrasekhar and Gerard P. Kuiper (who founded LPL in 1960). Gehrels' distinguished science career featured many highlights. During the 1950s, he pioneered the first photometric system of asteroids and discovered the opposition effect in the brightness of asteroids. In the 1960s, he pioneered wavelength dependence of polarization of stars and planets. His research interests then migrated to imaging photopolarimetry of Jupiter and Saturn, and he was named principal investigator for the Pioneer 10 and 11 Imaging Photopolarimeters, which discovered Saturn's F ring.

In 1980, Gehrels founded the Spacewatch Project, which uses telescopes on Kitt Peak to survey the sky for dangerous asteroids; he led the project until 1997. Gehrels also founded the well-known and well-respected Space Science Series, still published by the University of Arizona Press (now published in collaboration with the Lunar and Planetary Institute in Houston). He served as general editor for the first 30 volumes of the series. At its start in the 1980s, the Space Science Series represented a new way of producing research textbooks. In 2007, Gehrels was the recipient of the Harold Masursky Award, presented by the American Astronomical Society's Division for Planetary Sciences in recognition of meritorious service to planetary science.

Gehrels' recent research interests were in universal evolution. Each fall, he taught an undergraduate course for non-science majors at the University of Arizona and each spring, he presented a brief version of that course at the Physical Research Laboratory in Ahmedabad, India, where he was a lifetime Fellow.



Conway B. Leovy, 1933–2011

Conway Leovy was a professor in Atmospheric Sciences and Geophysics at the University of Washington, Seattle, whose contributions to planetary science spanned over forty years. He made major contributions to our understanding of planetary atmospheres, including those of Earth, Mars, Venus, Jupiter, and Titan. His work was recognized by a NASA Exceptional Scientific Achievement Medal in 1973 and the Kuiper Prize of the American Astronomical Society's Division of Planetary Science in 2000.

In Mars exploration, Conway participated in imaging experiments on the Mariner 6 and 7 flyby missions in the 1960s, while in the 1970s, he was part of the teams for the imaging experiment of Mariner 9 and the Meteorology Experiment on the Viking Landers. Conway was also a Co-Investigator for the Mars Climate Sounder instrument on Mars Reconnaissance Orbiter.

Conway remained engaged with friends, colleagues and family up until a couple of weeks before he died of cancer on July 9, 2011. His sharp mind, modesty, and generosity will be much missed by everyone. Memorial information and a more detailed tribute to Conway's career can be found at *www.atmos.washington.edu/people/leovy*.

Nicholas M. Short, 1927–2011

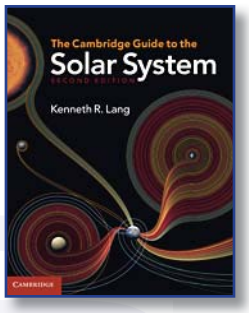
Nicholas M. Short, a geologist who helped establish the fields of shock metamorphism and meteorite impact crater studies, and who made later contributions to lunar sample investigations and the use of remote sensing in terrestrial geology, died on June 12 in Bowie, Maryland, after a long battle with cancer.

Short received his Ph.D. in geochemistry in 1958 from the Massachusetts Institute of Technology and worked in the early 1960s with the Lawrence Livermore Laboratory, studying the unique deformation effects created in rocks and minerals by the intense shock waves produced by nuclear and chemical explosions. His petrographic and mineralogical observations helped establish that the extreme environments of nuclear explosions were closely similar to those of natural meteorite impact events, and that both processes produced identical and unique geological and petrographic effects in their target rocks. His work was a major contribution to the now-widespread use of planar deformation features (PDFs) in quartz, as well as other shock-produced effects, as unique indicators of ancient meteorite impact events. Later, as a professor at the University of Houston, he helped organize the benchmark NASA Conference on Shock Metamorphism of Natural Materials (1966) and co-edited (with Bevan French) the resulting book, *Shock Metamorphism of Natural Materials* (1968) (aka "The Green Bible"), which became, and still remains, a fundamental text for the field. During the Apollo program, at the NASA Goddard Space Flight Center, he studied the returned lunar samples and the impact-produced shock effects in them. In the 1970s, he became involved in using remote-sensing data for terrestrial geological and environmental studies and developed the still-active NASA Remote Sensing Tutorial website (*rst.gsfc.nasa.gov*). Retiring from Goddard in 1988 to still another career as a professor at Bloomsburg University, Pennsylvania, Short continued his work on remote sensing, and, even after being diagnosed with cancer several years ago, remained actively involved in expanding and updating the Tutorial until just shortly before his death.

Short is survived by his wife, son and daughter-in-law, two grandchildren, and many friends and colleagues who will miss his enthusiasm, his keenly inquiring mind, his wide range of interests, his fondness for birdwatching and Mahler, his love of puns, and his great dedication, not only to research, but to the teaching of others.

—Text courtesy of Bevan M. French, Smithsonian Institution

Books



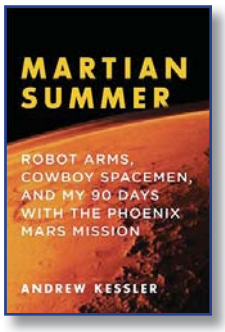
The Cambridge Guide to the Solar System, Second Edition.

By Kenneth R. Lang. Cambridge University Press, 2011. 502 pp., Hardcover, $58.00. *www.cambridge.org/us*

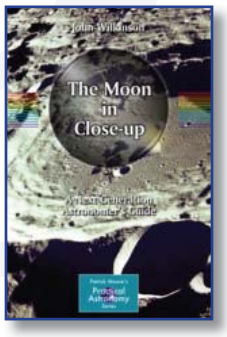
Richly illustrated with full-color images, this book is a comprehensive, up-to-date description of the planets, their moons, and recent exoplanet discoveries. This second edition of a now classic reference is brought up to date with fascinating new discoveries from 12 recent solar system missions. Examples include water on the Moon, volcanism on Mercury's previously unseen half, vast buried glaciers on Mars, geysers on Saturn's moon Enceladus, lakes of hydrocarbons on Titan, encounter with asteroid Itokawa, and sample return from Comet Wild 2. The book is further enhanced by hundreds of striking new images of the planets and moons. Written at an introductory level appropriate for undergraduate and high-school students, it provides fresh insights that appeal to anyone with an interest in planetary science.

Martian Summer: Robot Arms, Cowboy Spacemen, and My 90 Days with the Phoenix Mars Mission.

By Andrew Kessler. Pegasus Books, 2011. 352 pp., Hardcover, $27.95. *www.pegasusbooks.us*



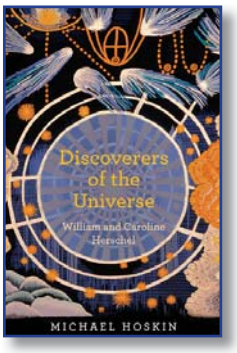
In the summer of 2008, author Andrew Kessler spent three months in mission control of the Phoenix expedition with 130 top NASA scientists and engineers as they explored Mars. This story is a human drama about modern-day Magellans battling NASA politics — you haven't lived until you've seen this miracle of birth from the inside — and the bizarre world of daily life in mission control. Kessler was the first outsider ever granted unfettered access to such an event, giving us a true Mars exclusive. The Phoenix mission was the first man-made probe ever sent to the martian arctic. They planned to find out how climate change can turn a warm wet planet (read: Earth) into a cold barren desert (read: Mars). That might seem like a trivial pursuit, but it's probably the most impressive feat we humans can achieve. This is only the sixth landing on Mars. Along the way, Phoenix discovered a giant frozen ocean trapped beneath the north pole of Mars, exotic food for aliens, and liquid water. This is not science fiction. It's fact. Not bad for a summer holiday.



The Moon in Close-Up.

By John Wilkinson. Springer, 2011. 310 pp., Paperback, $39.95. *www.springer.com*

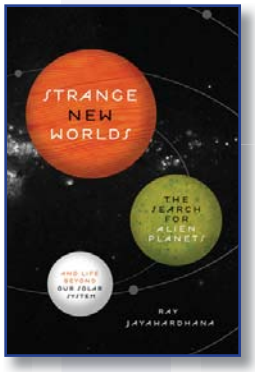
Information collected by recent space probes sent to explore the Moon by the United States, the European Space Agency, Japan, China, and India has changed our knowledge and understanding of the Moon, particularly its geology, since the Apollo missions. This book presents those findings in a way that will be welcomed by amateur astronomers, students, educators, and anyone interested in the Moon. Enhanced by many color photos, it combines newly acquired scientific understanding with detailed descriptions and labeled photographic maps of the lunar surface. Guided by observation methods explained in the book and 17 study areas presented and carefully explained in the last chapter, amateur astronomers can observe these features from Earth using telescopes and binoculars. Readers who consult the photographic maps will gain a better understanding about the Moon's topography and geology. The book is rounded out by a helpful glossary.



Discoverers of the Universe: William and Caroline Herschel.

By Michael Hoskin. Princeton University Press, 2011. 237 pp., Hardcover, $29.95.
www.press.princeton.edu

Discoverers of the Universe tells the gripping story of William Herschel, the brilliant, fiercely ambitious, emotionally complex musician and composer who became court astronomer to Britain's King George III, and of William's sister, Caroline, who assisted him in his observations of the night sky and became an accomplished astronomer in her own right. Together, they transformed our view of the universe from the unchanging, mechanical creation of Newton's clockmaker god to the ever-evolving, incredibly dynamic cosmos that it truly is. Written by the world's premier expert on the Herschels, this book traces William and Caroline's many extraordinary contributions to astronomy, shedding new light on their productive but complicated relationship, and setting their scientific achievements in the context of their personal struggles, larger-than-life ambitions, bitter disappointments, and astonishing triumphs.



Strange New Worlds: The Search for Alien Planets and Life Beyond Our Solar System.

By Ray Jayawardhana. Princeton University Press, 2011. 254 pp., Hardcover, $24.95.
www.press.princeton.edu

Astronomer Ray Jayawardhana brings news from the front lines of the epic quest to find planets — and alien life — beyond our solar system. Only in the past 15 years, after millennia of speculation, have astronomers begun to discover planets around other stars — hundreds in fact. But the hunt to find a true Earth-like world goes on. The author recounts the stories of the scientists and the remarkable breakthroughs that have ushered in this extraordinary age of exploration. He describes the latest findings — including his own — that are challenging our view of the cosmos and casting new light on the origins and evolution of planets and planetary systems. He reveals how technology is rapidly advancing to support direct observations of Jupiter-like gas giants and super-Earths — rocky planets with several times the mass of our own planet — and how astronomers use biomarkers to seek possible life on other worlds. *Strange New Worlds* provides an insider's look at the cutting-edge science of today's planet hunters, our prospects for discovering alien life, and the debates and controversies at the forefront of extrasolar-planet research.

Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies.

By the Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies, National Research Council. National Academies Press, 2010, 152 pp. Paperback, $36.50. *www.nap.edu*

The United States spends approximately $4 million each year searching for near-Earth objects (NEOs). The objective is to detect those that may collide with Earth. The majority of this funding supports the operation of several observatories that scan the sky searching for NEOs. This, however, is insufficient in detecting the majority of NEOs that may present a tangible threat to humanity. A significantly smaller amount of funding supports ways to protect the Earth from such a potential collision or "mitigation." In 2005, a Congressional mandate called for NASA to detect 90% of NEOs with diameters of 140 meters of greater by 2020. This book identifies the need for detection of objects as small as 30 to 50 meters, as these can be highly destructive. The book explores four main types of mitigation including civil defense, "slow push" or "pull" methods, kinetic impactors,

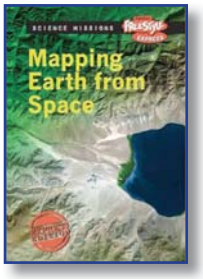
and nuclear explosions. It also asserts that responding effectively to hazards posed by NEOs requires national and international cooperation. It is a useful guide for scientists, astronomers, policy makers, and engineers.

Observing Tool

Moon Gazer's Wheel. By Bob Crelin.
Celestial Products. $5.95. *www.celestialproducts.com*

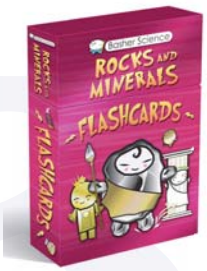
This is the perfect item to help anyone get started in astronomy — no telescope required! The Moon Gazers' Wheel is a unique, new interactive guide to the Moon, sure to make Moon gazing fun, informative and easy for anyone to do. Just rotate the chart to match the Moon in the sky with the phase illustrations shown in the cutout. When the phases match, it tells you the name of the phase, the Moon's position in orbit, the day of the lunar month, the Moon's rise and set time, and the time of day or night that this phase is visible in the sky. The wheel measures 6.5" × 8" with instructions on the back.

For Kids!



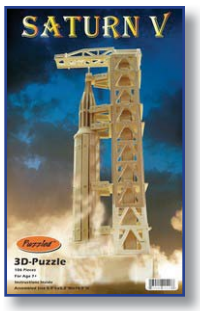
Mapping Earth from Space.
By Robert Sneddon. Heinemann Raintree, 2011. 56 pp., Hardcover, $33.50.
www.heinemannlibrary.com

Satellites can now map 99% of Earth's surface. What can scientists learn from these images? Find out in this fascinating book. For ages 11 to 14.



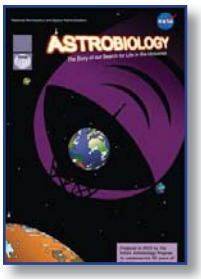
Rocks and Minerals Flashcards.
By Dan Green and Simon Basher. Kingfisher, 2011. Set of 104 cards. $12.99.
us.macmillan.com

The perfect companion to any study of Earth science, the best-selling *Rocks and Minerals: A Gem of a Book!* is now available as a card deck. The rocks and minerals are grouped into families, and each is presented with key facts and metrics such as hardness, color, origin, and components. Simon Basher's iconic character-driven artwork gives each rock or mineral a friendly face to go with all the scientific detail. These cards make a handy study aid, quiz tool, or rock-hunting companion. For ages 8 to 12.



3-D Wooden Saturn V Rocket Puzzle.
Available from Puzzled, Inc. 106 pieces, $12.95. *www.puzzledinc.com*

This high-grade three-dimensional wooden puzzle comes individually shrink-wrapped with instructions and sandpaper included. Pop out the pieces and go! Painted or left as natural wood, it's a challenging, educational, and creative activity for ages 7 and up.



Astrobiology: The Story of Our Search for Life in the Universe Graphic Novel.

Produced by the NASA Astrobiology Program. *astrobiology.nasa.gov/nai/education-and-outreach/products-and-resources/astrobiology-graphic-novel*

Through original artwork and a compelling storyline, this graphic novel chronicles the origin and evolution of astrobiology itself, tracing its roots from early cave paintings, through speculations of ancient Greek philosophers on the existence of other worlds, to contributions from more modern scientists such as Huygens, Galileo, Oparin, Haldane, Miller, Urey, Franklin, Watson, Crick, and Sagan. It goes on to explain how shortly after NASA was created in 1958, the NASA Exobiology Program, a research program supporting the search for life beyond Earth, came along. It would eventually become the Astrobiology Program in the mid-1990s. This graphic novel was produced by the NASA Astrobiology Program to celebrate the 50th anniversary of astrobiology. Issues 1 and 2 have been published.

Constellation Connect Card Game.

From Evolving Toys. $10.99. *evolvingtoys.com*

Can you group the constellations into star families? This stellar game is like "Go Fish" in outer space! Night Sky cards change the game play up in lots of fun and spacy ways. Gather around for a neat way to learn the beauty of the night sky while spending quality time with friends or family! For ages 8 and up.

Calendar 2011–2012

August

1–5 **6th Heidelberg Summer School: Characterizing Exoplanets — From Formation to Atmospheres,** Heidelberg, Germany. *http://www.mpia.de/imprs-hd/SummerSchools/2011/*

7–12 **12th Annual Summer School on Adaptive Optics,** Santa Cruz, California. *http://www.cfao.ucolick.org/aosummer/2011/index.php*

8–11 **AOGS2011 — Asia Oceania Geosciences Society,** Taipei, Taiwan. *http://www.asiaoceania.org/aogs2011/public.asp?page=home.htm*

8–11 **Small Sat Conference,** Logan, Utah. *http://www.smallsat.org/*

8–12 **74th Annual Meeting of the Meteoritical Society,** London, England, UK. *http://www.metsoc2011.org/London_Met_Soc_2011/Welcome.html*

10–12 **Stars, Companions, and Their Interactions: A Memorial to Robert H. Koch,** Villanova, Pennsylvania. *https://sites.google.com/site/rhkochconference/home*

14–19 **Goldschmidt 2011,** Prague, Czech Republic. *http://www.goldschmidt2011.org/*

20–31 **Formation, Detection, and Characterization of Extrasolar Habitable Planets,** Beijing, China. *http://www.iau.org/science/meetings/future/symposia/1030/*

22–25 **Magnetic Fields in Stars and Exoplanets,** Potsdam, Germany. *http://www.aip.de/thinkshop7/*

23 **Building Bridges: Cooperation of UK and Iranian Astronomers,** Keele, United Kingdom. *http://www.astro.keele.ac.uk/iran*

25–26 **Fifth Meeting of the NASA Small Bodies Assessment Group,** Pasadena, California. *http://www.lpi.usra.edu/sbag/*

29–Sep 1 **Conference on Characterization and Radiometric Calibration for Remote Sensing (CALCON),** Logan, Utah. *http://www.spacedynamics.org/conferences/calcon/*

30–31 **New Horizons Workshop on Icy Surface Processes,** Flagstaff, Arizona. *carrie.l.chavez@nasa.gov*

30–Sep 1 **Ninth VEXAG Meeting and Venus Science Conference,** Washington, DC. *http://www.lpi.usra.edu/vexag/*

September

5–9 **Summer School on Astronometry,** Antalya, Turkey. *http://www.tug.tubitak.gov.tr/aass/*

7 **Online Workshop on Lunar Swirls.** *http://sites.google.com/site/lunarswirls/*

11–17 **Extreme Solar Systems II,** Moran, Wyoming. *http://ciera.northwestern.edu/Jackson2011/*

12–16 **Fifth International Conference on Mars Polar Science and Exploration,** Fairbanks, Alaska. *http://www.lpi.usra.edu/meetings/polar2011/*

14–16 **Second Planetary Consortium Meeting,** Flagstaff, Arizona. *http://www.planetarycraterconsortium.nau.edu/PCCMeeting.htm*

19–21 **Journees 2011: Systemes de reference spatio-temporels,** Vienna, Austria. *http://info.tuwien.ac.at/hg/meetings/journees11/index.html*

19–23 **New Horizons in Time Domain Astronomy,** Oxford, United Kingdom. *http://www.physics.ox.ac.uk/IAUS285/*

21–23 **Nitrogen in Planetary Systems: The Early Evolution of the Atmospheres of Terrestrial Planets (COST CM-0805),** Barcelona, Spain. *http://ulisse.busoc.be/cost/barcelona-meeting.php*

25–Oct 1 **Field Training and Research Program at Meteor Crater,** Winslow, Arizona. *http://www.lpi.usra.edu/nlsi/mcFieldCamp/?view=program*

26–Oct 1 **Joint Assembly: CPS 8th International School of Planetary Sciences,** Hyogo, Japan. *https://www.cps-jp.org/~pschool/pub/2011-09-26/index.html*

October

3–7 **EPSC-DPS 2011: A Joint Meeting of the European Planetary Science Congress and the American Astronomical Society Division for Planetary Sciences,** Nantes, France. *http://meetings.copernicus.org/epsc-dps2011/*

9–12 **Geological Society of America Annual Meeting,** Minneapolis, Minnesota. *http://www.geosociety.org/meetings/2011/*

10–12 **Orbital Couples: 'Pas de Deux' in the Solar System and the Milky Way,** Paris, France. *http://wwwhip.obspm.fr/PasDeDeux*

10–12 **Following the Photons: Astronomical Simulations for Instruments and Telescopes,** Edinburgh, United Kingdom. *http://www.roe.ac.uk/roe/workshop/2011/*

10–13 **Large Optical Telescopes,** Nizhnii Arkhyz, Russia. *http://agora.guru.ru/display.php?conf=lot&l=1*

11–12 **XVI National Conference of Astronomers of Serbia,** Belgrade, Serbia. *http://nkas.aob.rs/*

14–16 **Heavenly Discourses: Myth, Astronomy, and Culture,** Bristol, United Kingdom. *http://heavenlydiscourses.org/*

16–20 **Third International Conference on Biosphere Origin and Evolution,** Rethymno, Crete, Greece. *http://conf.nsc.ru//BOE-2011*

23–28 **Special Session on Planetary Dunes at Minerva Gentner Symposium on Aeolian Processes,** Eilat, Israel. *http://cmsprod.bgu.ac.il/Eng/humsos/departments/geog/Aproc*

25–28 **First International Planetary Cave Research Workshop: Implications for Astrobiology, Climate, Detection, and Exploration,** Carlsbad, New Mexico. *http://www.lpi.usra.edu/meetings/caves2011/*

November

2–4 **6th Biennal Geochemical SIMS Workshop (BGSW6),** Honolulu, Hawaii. *http://www.higp.hawaii.edu/bgsw6.html*

5–6 **2011 PERC Planetary Geology Field Symposium,** Kitakyushu City, Japan. *http://www.perc.it-chiba.ac.jp/meetings/pgfs2011/*

6–10 **Astronomical Data Analysis Software & Systems (ADASS XXI),** Paris, France. *http://adass.org/*

7–9 **Annual Meeting of the Lunar Exploration Analysis Group (LEAG 2011),** Houston, Texas. *http://www.lpi.usra.edu/meetings/leag2011/*

7–9 **Workshop on Formation of the First Solids in the Solar System (Solids 2011),** Kauai, Hawaii. *http://www.lpi.usra.edu/meetings/solids2011/*

13–20 **Second Arab Impact Cratering and Astrogeology Conference (AICAC II),** Casablanca, Morocco. *http://www.fsac.ac.ma/aicaii/index.html*

23–25 **Canadian Space Summit,** Calgary, Canada. *http://www.css.ca/index.php?option=com_content&view=article&id=427&Itemid=57*

December

5–9 **The First Kepler Science Conference,** Moffett Field, California. *http://kepler.nasa.gov/Science/keplerconference/*

5–9 **AGU Fall Meeting,** San Francisco, California. *http://www.agu.org/meetings/*

January

23–27 **Planets Around Stellar Remnants,** Arecibo, Puerto Rico. *http://www.mpia-hd.mpg.de/PLANETS2012/index.html*

February

1–3 **Workshop on the Early Solar System Bombardment II,** Houston, Texas. *http://www.lpi.usra.edu/meetings/bombardment2012/*

13–15 **Conference on Life Detection in Extraterrestrial Samples,** San Diego, California. *http://www.lpi.usra.edu/meetings/lifedetection2012/*

March

5–8 **Observing Planetary Systems II,** Santiago, Chile. *http://www.sc.eso.org/~cdumas/OPSII.html*

12–16 **STFC Graduate Course: Exoplanets and Their Host Stars,** Oxford, United Kingdom. *http://www.physics.ox.ac.uk/EAHS12/home.html*

15–17 **Second International Lunar Superconductor Applications Workshop,** Houston, Texas. *http://lsa2012.com*

19–23 **43rd Lunar and Planetary Science Conference (LPSC 2012),** The Woodlands, Texas. *http://www.lpi.usra.edu/meetings/lpsc2012/*

21–23 **NETS 2012: Nuclear and Emerging Technologies for Space,** The Woodlands, Texas. *http://anstd.ans.org/NETS2012/NETS2012Home.html*

20–23 **From Atoms to Pebbles: Herschel's View of Star and Planet Formation**, Grenoble, France. *http://www.herschel2012.com/information/*

April

15–18 **Earth and Space Conference 2012: Engineering for Extreme Environments,** Pasadena, California. *http://content.asce.org/conferences/earthspace2012/index.html*

23–25 **Facets of Professional Astronomy,** Paris, France. *http://astro.u-strasbg.fr/~heck/fopa2012.htm*