COMET HARTLEY 2 *Delights*

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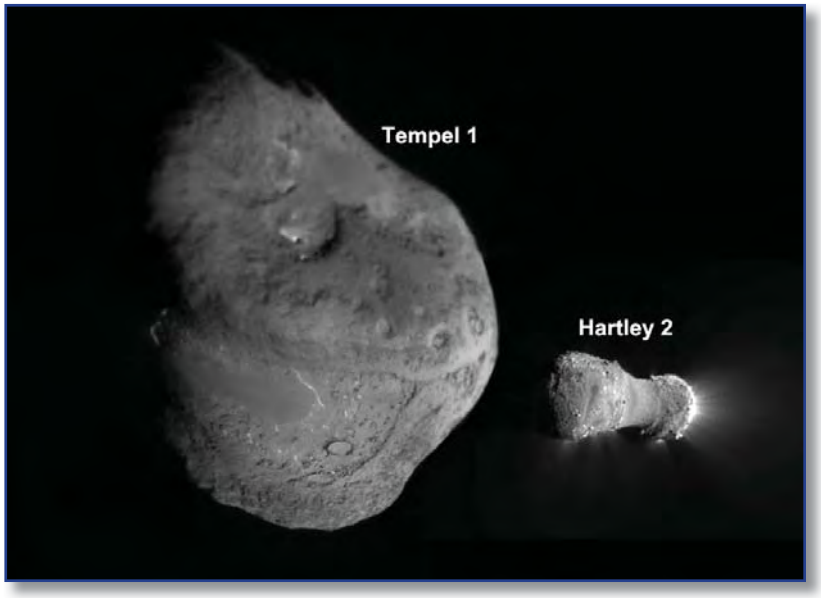
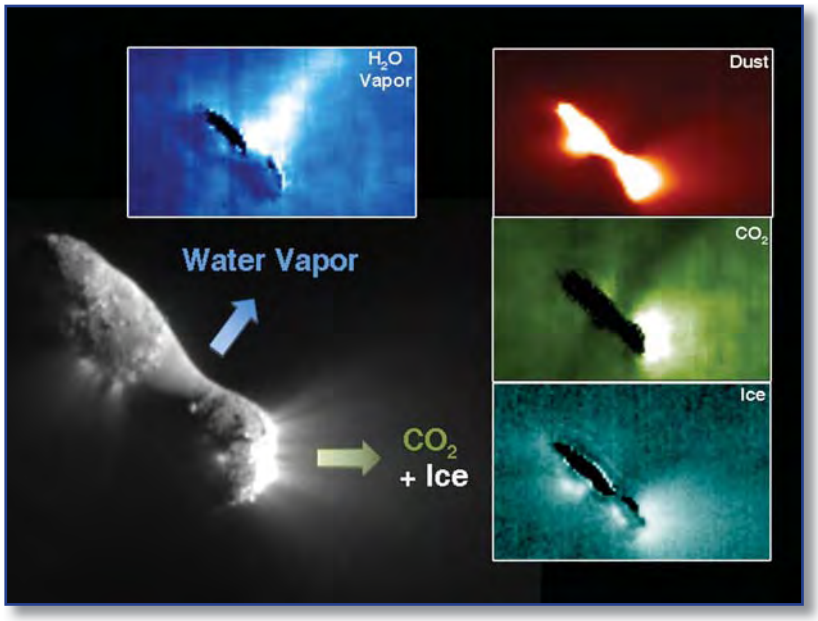
Comet Hartley 2 Delights

The past decade has seen a phenomenal change in our understanding of the true nature of comets. Comets have been a source of misconception, trepidation, and fear, sometimes lurching into hysteria for millennia (even as late as 1910, when Earth passed through the tail of Comet Halley, prompting sales of comet tonics, cure-alls, etc.). Today, comets are viewed as relicts of the formation of the solar system and possible sources for most of Earth's water.



Images of Comets Tempel 1 and Hartley 2 (to scale), which have both been visited by the Deep Impact spacecraft. Credit: NASA/JPL-Caltech/ UMD/McREL.

What we have learned from a series of spacecraft missions since 1986 that have flown past comets, returned samples of their dust, and even struck one comet is still only a start. Among the surprises: Some comets have hot and dry surfaces, others contain silicate dust normally seen in the innermost solar system, and all seem to have an endless variety of shapes, sizes, and morphologies. And the fun is only beginning: a European spacecraft, Rosetta, is on its way to orbit and land on another comet, 67P/ Churyumov-Gerasimenko, in 2014.



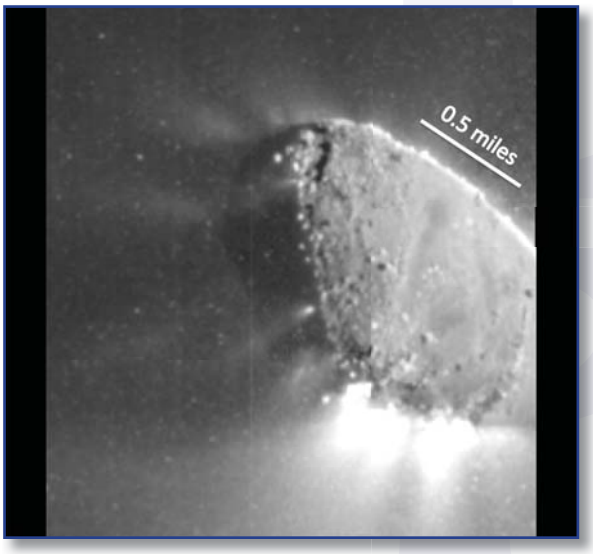
Infrared scans of Comet Hartley 2 by NASA's EPOXI mission show carbon dioxide, dust, and ice being distributed in a similar way and emanating from apparently the same locations on the nucleus. Water vapor, however, has a different distribution, implying a different source region and process. These maps were made from data obtained by the High-Resolution Instrument (HRI) on November 4, 2010.

Most comets are visitors to our section of the solar system, and don't really fit in very well. They have a lot of water ice and other volatile solids such as carbon dioxide, carbon monoxide, and hydrogen cyanide, to name just a few — materials that are common in the cold, distant outreaches of the solar system. Suprisingly, comets also have a lot of dust that most likely originated in the high-temperature environment much closer to the Sun.

Our latest visit with a comet occurred on November 4 of this year, when the Deep Impact spacecraft (now on an extended mission called EPOXI) passed within 700 kilometers (450 miles) of Hartley 2, a periodic

comet discovered in 1986. This is the same spacecraft that delivered the projectile that punched a hole in Comet Tempel 1 (which, incidentally, is going to be revisited in February by the old Stardust spacecraft that visited Wild 2 back in 2004).

A High-Resolution Instrument (HRI) image after deconvolution, a process that sharpens an out of focus image. This shows part of Hartley 2's nucleus, with the Sun illuminating it from the right. Also visible is a distinct cloud of individual particles. Credit: NASA/JPL-Caltech/UMD.



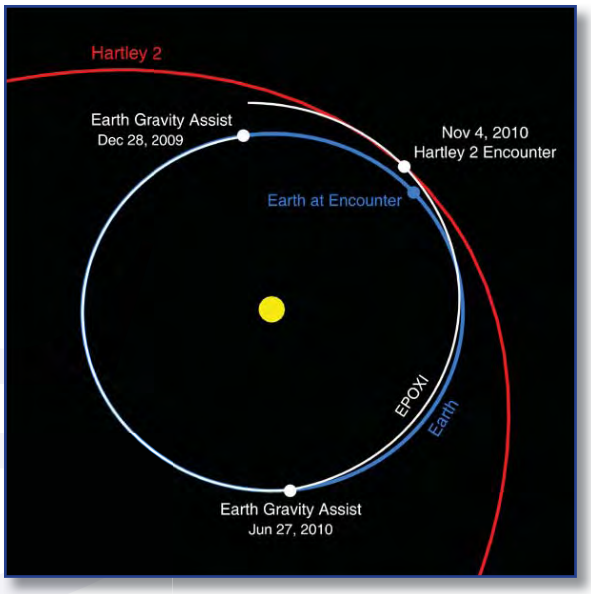
This enhanced image, one of the closest taken of Comet Hartley 2 by NASA's EPOXI mission, shows jets and where they originate from the surface. There are jets outgassing from the sunward side, the nightside, and along the terminator — the line between the two sides. The Sun is to the right. Credit: NASA/JPL-Caltech/UMD.

The name EPOXI is a combination of the names for the two extended mission components: the Extrasolar Planet Observations and Characterization (EPOCh), and the flyby of Comet Hartley 2, called the Deep Impact Extended Investigation (DIXI). The spacecraft has retained the name "Deep Impact." Its encounter phase with Hartley 2 began at 1:00 p.m. PDT on November 2, when the spacecraft began to point its two imagers at the comet's nucleus. Imaging of the nucleus began one hour later. Initial estimates indicated the spacecraft was about 700 kilometers (435 miles) from the comet at the closest-approach point, almost the exact distance that was calculated by engineers in advance of the flyby.

Images from the EPOXI mission reveal Comet Hartley 2 to have 100 times less volume than Comet Tempel 1, the first target of the Deep Impact spacecraft. The Hartley 2 images also reveal a peanut-shaped nucleus 2.25 kilometers long and 0.4 kilometers wide (the shape of the nucleus has been described as "a cross between a bowling pin and a pickle"). This makes it roughly one-third the size of Tempel 1, which had been visited in 2005. This is the smallest comet to be visited (although not as small as Itokawa, the asteroid that Hayabusa visited, returning some small samples to Earth earlier this year). Several dozen jets of gas could be clearly seen emanating from points on the rounded boulder-strewn ends of the comet. A narrow neck of smoother material connects these two larger ends of the comet.

A set of high-resolution images show several tiny jets of fine material venting from the surface of the comet, demonstrating for the first time that the jets that are the sources of the extended tail we see are driven mostly by carbon dioxide gas, which apparently sublimates from the nucleus as it approaches the hot Sun. (Most comets really have two tails, the second of which is mostly dust.) To add to the complexity, water vapor seems to be escaping from the comet's smoother central section.

The images also reveal a swarm of small particles a few meters across swirling in a "snow storm" around the nucleus of Comet Hartley 2. Despite the close passage and several hits to the spacecraft, it was not



The EPOXI mission trajectory, starting from the 2009 Earth flyby. The spacraft then had another flyby in late June 2010 before heading off to its rendezvous with Comet Hartley 2 (red arc) on November 4, 2010. On the left half of the orbit, it looks like the spacecraft was in the same orbit as Earth, but this is just because the orbits are projected onto the ecliptic. The spacecraft was actually above the ecliptic by as much as 0.11 AU. Credit: NASA/JPL-Caltech/UMD/GSFC/Tony Farnham.

More than 30 years ago, en route to the Moon in December 1972, the astronauts of Apollo 17 took an extraordinary photograph. They captured the entire Earth on one frame of film, showing it to be a lonely blue marble in empty black space, streaked by clouds and the occasional continent or smaller bit of land. We have become so used to the picture that we sometimes forget its startling message: that a world that holds life is something small and special in the vast range of space. As part of the EPOXI mission's objectives to characterize the Earth as a planet for comparison with planets around other stars, the mission captured this image of the Earth-Moon system on May 29, 2008, with the Moon beginning its transit in front of Earth. By coincidence, the Earth showed Africa as the Moon passed by, the same continent appearing in the famous Blue Marble photo from Apollo 17. Credit: NASA/JPL-Caltech/UMD/GSFC.

seriously damaged (the Giotto spacecraft was not so lucky in 1986, when a close pass of Comet Halley knocked it off its spin axis and damaged the camera).

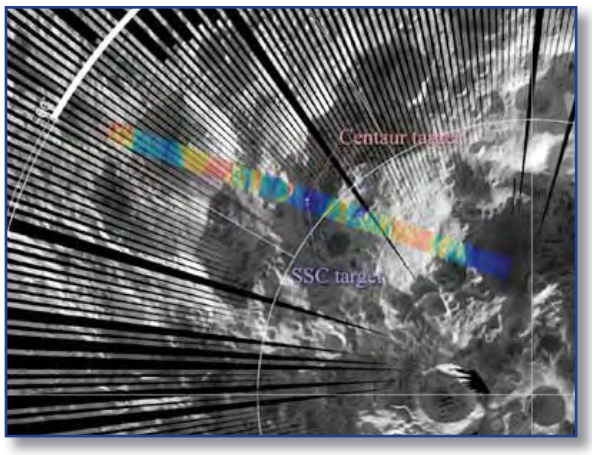
Scientists will need more detailed analysis to determine how long this snow storm has been active, and whether the differences in activity between the middle and ends of the comet are the result of how it formed some 4.5 billion years ago or are because of more recent evolutionary effects. Mission scientist Don Yeomans described Hartley 2 as "hyperactive, small, and feisty." But EPOXI principal investigator Michael A'Hearn of the University of Maryland, College Park, summarizes EPOXI's success this way: "While future generations should have the opportunity to truly explore comets, this flyby gives us an excellent preview of what they will get to enjoy. Hartley 2 exceeded all our expectations in not only scientific value but in its stark majestic beauty."

About the cover:

Spacecraft image: Artist's concept of NASA's Deep Impact/EPOXI spacecraft. Credit: NASA/JPL-Caltech.

EPOXI mission logo. Credit: NASA/JPL-tCaltech/UMD.

Comet image: This close-up view of Comet Hartley 2 was taken as NASA's EPOXI mission approached the comet at 6:59 a.m. PDT (9:59 a.m. EDT). The spacecraft's Medium-Resolution Instrument snapped the picture from a distance of 816 kilometers (507 miles). The Sun is to the right. The comet's nucleus, or main body, is approximately 2 kilometers (1.2 miles) long and 0.4 kilometers (0.25 miles) at the "neck," or most narrow portion. Jets can be seen streaming out of the nucleus. Credit: NASA/JPL-Caltech/UMD.



Diviner thermal map of the LCROSS impact sites.
Credit: NASA/GSFC/UCLA.

NASA Missions Uncover the Moon's Buried Treasures

Nearly a year after announcing the discovery of water molecules on the Moon, scientists revealed new data uncovered by NASA's Lunar CRater Observation and Sensing Satellite (LCROSS) and Lunar Reconnaissance Orbiter (LRO). The missions found evidence that the lunar soil within shadowy craters is rich in useful materials, and the Moon is chemically active and has a water cycle. Scientists also confirmed the water was in the form of mostly pure ice crystals in some places. The results were featured in six papers published in the October 22 issue of *Science*.

"NASA has convincingly confirmed the presence of water ice and characterized its patchy distribution in permanently shadowed regions of the Moon," said Michael Wargo, chief lunar scientist at NASA Headquarters in Washington. "This major undertaking is the one of many steps NASA has taken to better understand our solar system, its resources, and its origin, evolution, and future."

The twin impacts of LCROSS and a companion rocket stage in the Moon's Cabeus crater on October 9, 2009, lifted a plume of material that might not have seen direct sunlight for billions of years. As the plume traveled nearly 10 miles above the rim of Cabeus, instruments onboard LCROSS and LRO made observations of the crater and debris and vapor clouds. After the impacts, grains of mostly pure water ice were lofted into the sunlight in the vacuum of space.

"Seeing mostly pure water ice grains in the plume means water ice was somehow delivered to the Moon in the past, or chemical processes have been causing ice to accumulate in large quantities," said Anthony Colaprete, LCROSS project scientist and principal investigator at NASA's Ames Research Center. "Also, the diversity and abundance of certain materials, called volatiles, in the plume suggest a variety of sources, like comets and asteroids, and an active water cycle within the lunar shadows."

The suite of LCROSS and LRO instruments determined as much as 20% of the material kicked up by the LCROSS impact was volatiles, including methane, ammonia, hydrogen gas, carbon dioxide, and carbon monoxide. The instruments also discovered relatively large amounts of metals such as sodium, mercury, and possibly even silver. Scientists believe the water and mix of volatiles that LCROSS and LRO detected could be the remnants of a comet impact. According to scientists, these volatile chemical by-products are also evidence of a cycle through which water ice interacts with lunar soil grains.

LRO's Diviner instrument gathered data on water concentration and made temperature measurements, and LRO's Lunar Exploration Neutron Detector mapped the distribution of hydrogen. This combined data led the science team to conclude that water is not uniformly distributed within the shadowed cold traps, but rather is in pockets, which may also lie outside the shadowed regions. The proportion of volatiles to water in the lunar soil indicates a process called "cold grain chemistry" is taking place. Scientists also theorize this process could take as long as hundreds of thousands of years and may occur on other frigid, airless bodies, such as asteroids; the moons of Jupiter and Saturn, including Europa and Enceladus; Mars' moons; interstellar dust grains floating around other stars; and the polar regions of Mercury.

"The observations by the suite of LRO and LCROSS instruments demonstrate the Moon has a complex environment that experiences intriguing chemical processes," said Richard Vondrak, LRO project

scientist at NASA's Goddard Space Flight Center. "This knowledge can open doors to new areas of research and exploration."

By understanding the processes and environments that determine where water ice will be, how water was delivered to the Moon, and its active water cycle, future mission planners might be better able to determine which locations will have easily accessible water. The existence of mostly pure water ice could mean future human explorers won't have to extract the water out of the soil in order to use it for valuable life support resources. In addition, an abundant presence of hydrogen gas, ammonia, and methane could be exploited to produce fuel.

For more information about LCROSS and LRO, visit *www.nasa.gov/LCROSS* and *www.nasa.gov/LRO*.

NASA'S Lunar Spacecraft Completes Exploration Mission Phase

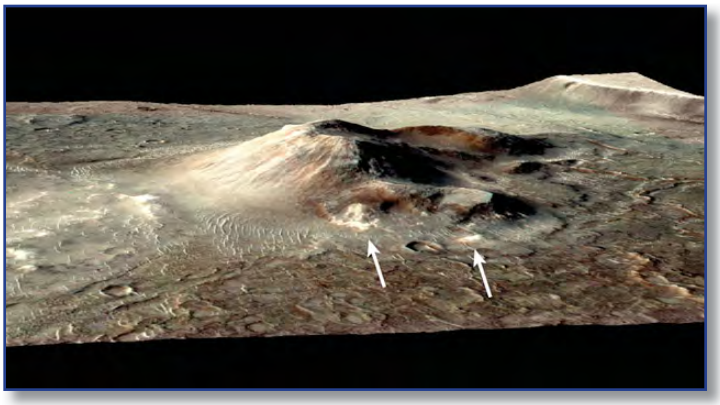
NASA's Lunar Reconnaissance Orbiter (LRO) completed the exploration phase of its mission on September 16, after a number of successes that transformed our understanding of Earth's nearest neighbor. LRO completed a one-year exploration mission in a polar orbit approximately 31 miles above the Moon's surface. It produced a comprehensive map of the lunar surface in unprecedented detail, searched for resources and safe landing sites for potential future missions to the Moon, and measured lunar temperatures and radiation levels. The mission has now turned its attention from exploration objectives to scientific research, as program management moves from NASA's Exploration Systems Mission Directorate to the Science Mission Directorate at the agency's Headquarters in Washington.

"LRO has been an outstanding success. The spacecraft has performed brilliantly," said Doug Cooke, associate administrator of the Exploration Systems Mission Directorate. "LRO's science and engineering teams achieved all of the mission's objectives, and the incredible data LRO gathered will provide discoveries about the Moon for years to come."

The LRO team will continue to send data gathered during the last year to the Planetary Data System, which archives and distributes scientific information from NASA planetary missions, astronomical observations and laboratory measurements. By the time LRO achieves full mission success in March, and its data is processed and released to the scientific community, it will have sent more information to the Planetary Data System than all other previous planetary missions combined. During its new phase of discovery, LRO will continue to map the Moon for two to four more years.

Silica on a Mars Volcano Tells of Wet and Cozy Past

Light-colored mounds of a mineral deposited on a volcanic cone more than three billion years ago may preserve evidence of one of the most recent habitable microenvironments on Mars. Observations by NASA's Mars Reconnaissance Orbiter enabled researchers to identify the mineral as hydrated silica and to see its volcanic context. The mounds' composition and their location on the flanks of a volcanic cone provide the best evidence yet found on Mars for an intact deposit from a hydrothermal environment — a steam fumarole, or hot spring. Such environments may have provided habitats for some of Earth's earliest lifeforms.



This volcanic cone in the Nili Patera caldera on Mars has hydrothermal mineral deposits on the southern flanks and nearby terrains. Two of the largest deposits are marked by arrows, and the entire field of light-toned material on the left of the cone is hydrothermal deposits. Credit: NASA/JPL-Caltech/MSSS/JHU-APL/ Brown Univ.

"The heat and water required to create this deposit probably made this a habitable zone," said J. R. Skok of Brown University, lead author of a paper about these findings published online in late October by *Nature Geoscience*. "If life did exist there, this would be a promising type of deposit to entomb evidence of it — a microbial mortuary."

No studies have yet determined whether Mars has ever supported life. The new results add to accumulating evidence that, at some times and in some places, Mars has had favorable environments for microbial life. This specific place would have been habitable when most of Mars was already dry and cold. Concentrations of hydrated silica have been identified on Mars previously, including a nearly pure patch found by NASA's Mars Exploration Rover Spirit in 2007. However, none of those earlier findings were in such an intact setting as this one, and the setting adds evidence about the origin.

Skok said, "You have spectacular context for this deposit. It's right on the flank of a volcano. The setting remains essentially the same as it was when the silica was deposited."

The small cone rises about 100 meters (100 yards) from the floor of a shallow bowl named Nili Patera. The patera, which is the floor of a volcanic caldera, spans about 50 kilometers (30 miles) in the Syrtis Major volcanic region of equatorial Mars. Before the cone formed, free-flowing lava blanketed nearby plains. The collapse of an underground magma chamber from which lava had emanated created the bowl. Subsequent lava flows, still with a runny texture, coated the floor of Nili Patera. The cone grew from even later flows, apparently after evolution of the underground magma had thickened its texture so that the erupted lava would mound up.

"We can read a series of chapters in this history book and know that the cone grew from the last gasp of a giant volcanic system," said John Mustard, Skok's thesis advisor at Brown and a co-author of the paper. "The cooling and solidification of most of the magma concentrated its silica and water content."

Silica can be dissolved, transported, and concentrated by hot water or steam. Hydrated silica identified by the spectrometer in uphill locations — confirmed by stereo imaging — indicates that hot springs or fumaroles fed by underground heating created these deposits. Silica deposits around hydrothermal vents in Iceland are among the best parallels on Earth.

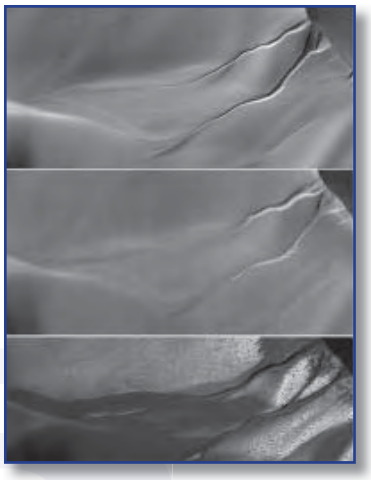
For more information about the Mars Reconnaissance Orbiter, visit *www.nasa.gov/mro*.

Study Links Fresh Mars Gullies to Carbon Dioxide

A growing bounty of images from NASA's Mars Reconnaissance Orbiter reveals that the timing of new activity in one type of the enigmatic gullies on Mars implicates carbon-dioxide frost, rather than water, as the agent causing fresh flows of sand. Researchers have tracked changes in gullies on faces of sand dunes in seven locations on southern Mars. The periods when changes occurred, as determined by comparisons of before-and-after images, overlapped in all cases with the known winter buildup of carbon-dioxide frost on the dunes. Before-and-after pairs that covered periods only in spring, summer, and autumn showed no new activity in those seasons.

"Gullies that look like this on Earth are caused by flowing water, but Mars is a different planet with its own mysteries," said Serina Diniega of the Jet Propulsion Laboratory, lead author of a report on these findings in the November issue of the journal *Geology*. She analyzed these gullies while a graduate student at the University of Arizona, Tucson. "The timing we see points to carbon dioxide, and if the mechanism is linked to carbon-dioxide frost at these dune gullies, the same could be true for other gullies on Mars."

Scientists have suggested various explanations for modern gullies on Mars since fresh-looking gullies were discovered in images from NASA's Mars Global Surveyor in 2000. Some of the proposed



The gullies on a martian sand dune in this trio of images from NASA's Mars Reconnaissance Orbiter deceptively resemble features on Earth that are carved by streams of water. However, these gullies likely owe their existence to entirely different geological processes apparently related to the winter buildup of carbon-dioxide frost. Credit: NASA/JPL-Caltech/University of Arizona.

mechanisms involve water, some carbon dioxide, and some neither. Some fresh gullies are on sand dunes, commonly starting at a crest. Others are on rockier slopes, such as the inner walls of craters, sometimes starting partway down the slope.

Diniega and co-authors at the University of Arizona and Johns Hopkins University Applied Physics Laboratory focused their study on dune gullies that are shaped like rockier slope gullies, with an alcove at the top, a channel or multiple channels in the middle, and an apron at the bottom. The 18 dune gullies in which the researchers observed new activity range in size from about 50 meters or yards long to more than 3 kilometers (2 miles) long.

"The alcove is a cutout at the top," Diniega said. "Material being removed from there ends up in a fan-shaped apron below." Because new flows in these gullies apparently occur in winter, rather than at a time when any frozen water might be most likely to melt, the new report calls for studies of how carbon dioxide, rather than water, could be involved in the flows. Some carbon dioxide from the martian atmosphere freezes on the ground during winter and sublimates back to gaseous form as spring approaches. The dunes studied are poleward of a latitude of 40°S.

"One possibility is that a pile of carbon-dioxide frost accumulating on a dune gets thick enough to avalanche down and drag other material with it," Diniega said. Other suggested mechanisms are that gas from sublimating frost could lubricate a flow of dry sand or erupt in puffs energetic enough to trigger slides. At an increasing number of sites, before-and-after images have documented changes in martian gullies. The new report uses images from the Mars Orbiter Camera on Mars Global Surveyor, which operated from 1997 to 2006, and from the High Resolution Science Imaging Experiment (HiRISE) camera and Context Camera on Mars Reconnaissance Orbiter, which has been examining Mars since 2006.

Watch Construction of NASA's New Mars Rover Live on the Web

A newly installed webcam is giving the public an opportunity to watch technicians assemble and test the next NASA Mars rover, one of the most technologically challenging interplanetary missions ever designed. NASA's Mars Science Laboratory, also known as the Curiosity rover, is in a clean room at the agency's Jet Propulsion Laboratory. The webcam, affectionately called "Curiosity Cam," provides the video feed, without audio, from a viewing gallery above the cleanroom floor. The video will be supplemented periodically by live web

The Curiosity Cam live video feed allows the public to watch technicians assemble and test NASA's next Mars rover in a clean room at the Jet Propulsion Laboratory in Pasadena, California. Credit: NASA/JPL-CalTech.

chats featuring Curiosity team members answering questions about the rover. Currently, work in the clean room begins at 8:00 a.m. PDT Monday through Friday.

Cleanroom technicians have been busy adding new avionics and instruments to the rover. Beginning October 21, viewers saw technicians carefully add the rover's suspension system and its six wheels. On October 25, the rover's 7-foot-long robotic arm was carefully lifted and attached to the front of the rover.

The camera shows a portion of the cleanroom that is typically active; but the rover, spacecraft components, and technicians may move out of view as work shifts to other areas of the room. When activity takes place in other testing facilities around JPL, the cleanroom may be empty. The camera also may be turned off periodically for maintenance or due to technical issues.

Months of assembly and testing remain before the car-sized rover is ready for launch from Cape Canaveral, Florida. The rover and spacecraft components will ship to NASA's Kennedy Space Center in Florida next spring. The launch will occur between November 25 and December 18, 2011. Curiosity will arrive on Mars in August 2012.

Curiosity is engineered to drive longer distances over rougher terrain than previous rovers with a science payload 10 times the mass of instruments on NASA's Spirit and Opportunity. The new, large rover will investigate whether the landing region has had environments favorable for supporting microbial life and for preserving evidence about whether life existed on the Red Planet.

Continuous live video of rover construction is available at *www.ustream.tv/channel/nasajpl* and *www.nasa.gov/mission_pages/msl/building_curiosity.html*. For information and news about Curiosity, visit *www.nasa.gov/msl*. Social media audiences can learn more about the mission on Twitter @MarsCuriosity or on Facebook at *www.facebook.com/MarsCuriosity*.

Saturn Then and Now: 30 Years Since Voyager Visit

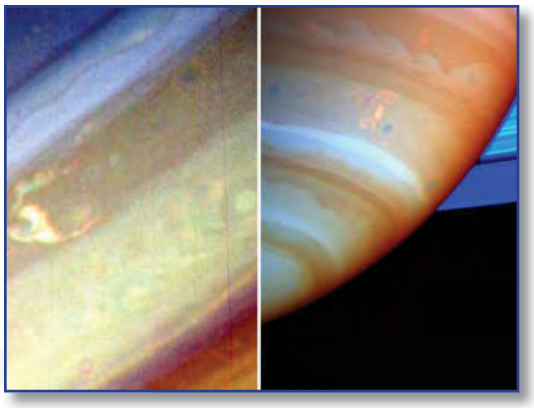
Ed Stone, project scientist for NASA's Voyager mission, remembers the first time he saw the kinks in one of Saturn's narrowest rings. It was the day the Voyager 1 spacecraft made its closest approach to the giant ringed planet, 30 years ago. Scientists were gathering in front of television monitors and in one another's offices every day during this heady period to pore over the bewildering images and other data streaming down to NASA's Jet Propulsion Laboratory in Pasadena, California.

Stone drew a crude sketch of this scalloped, multistranded ring, known as the F ring, in his notebook, but with no explanation next to it. The innumerable particles comprising the broad rings are in near-circular orbits about Saturn. So, it was a surprise to find that the F ring, discovered just a year before by NASA's Pioneer 11 spacecraft, had clumps and wayward kinks. What could have created such a pattern?

"It was clear Voyager was showing us something different at Saturn," said Stone, now based at the California Institute of Technology. "Over and over, the spacecraft revealed so many unexpected things that it often took days, months and even years to figure them out."

The F ring curiosity was only one of many strange phenomena discovered in the Voyager close encounters with Saturn, which occurred on November 12, 1980, for Voyager 1, and August 25, 1981, for Voyager 2. The Voyager encounters were responsible for finding six small moons and revealing the half-young, half-old terrain of Enceladus that had to point to some kind of geological activity.

Images from the two encounters also exposed individual storms roiling the planet's atmosphere, which did not show up at all in data from Earth-based telescopes. Scientists used Voyager data to resolve a debate about whether Titan had a thick or thin atmosphere, finding that Titan was shrouded in a thick



Data from Earth-based telescopes did not prepare scientists working with NASA's Voyager spacecraft for their first images of the individual storms roiling Saturn's upper atmosphere. The image on the left from Voyager 1 shows convective clouds in the northern hemisphere of Saturn on November 5, 1980. NASA's Cassini spacecraft was able to follow up on Voyager's discoveries. The righthand image shows the so-called "dragon storm" from September 2004. The storm was a powerful source of radio emissions detected by Cassini. The radio emissions resembled short bursts of static generated by lightning on Earth. In August 2009, Cassini was finally able to capture visible-light images of lightning flashing in Saturn's atmosphere. Credit: NASA/JPL and NASA/JPL/SSI.

haze of hydrocarbons in a nitrogen-rich atmosphere. The finding led scientists to predict there could be seas of liquid methane and ethane on Titan's surface.

"When I look back, I realize how little we actually knew about the solar system before Voyager," Stone added. "We discovered things we didn't know were there to be discovered, time after time."

In fact, the Voyager encounters sparked so many new questions that another spacecraft, NASA's Cassini, was sent to probe those mysteries. While Voyager 1 got to within about 126,000 kilometers (78,300 miles) above Saturn's cloud tops, and Voyager 2 approached as close as about 100,800 kilometers (62,600 miles), Cassini has dipped to this altitude and somewhat lower in its orbits around Saturn since 2004.

Because of Cassini's extended journey around Saturn, scientists have found explanations for many of the mysteries first seen by Voyager. Cassini has uncovered a mechanism to explain the new terrain on Enceladus — tiger stripe fissures with jets of water vapor and organic particles. It revealed that Titan indeed does have stable lakes of liquid hydrocarbons on its surface and showed just how similar to Earth that moon really is. Data from Cassini have also resolved how two small moons discovered by Voyager — Prometheus and Pandora — tug on the F ring to create its kinked shape and wakes that form snowballs.

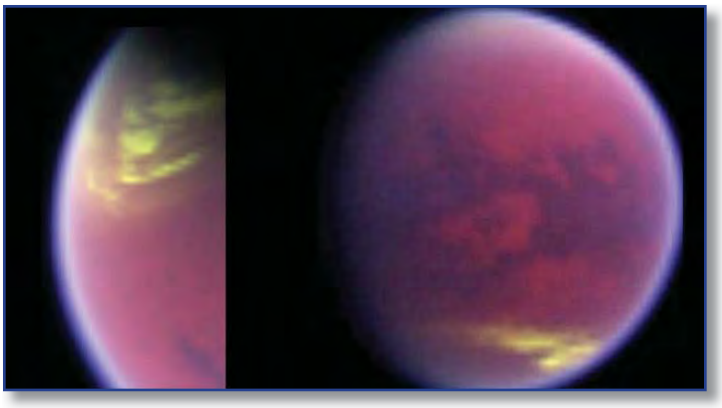
"Cassini is indebted to Voyager for its many fascinating discoveries and for paving the way for Cassini," said Linda Spilker, Cassini project scientist at JPL, who started her career working on Voyager from 1977 to 1989. "On Cassini, we still compare our data to Voyager's and proudly build on Voyager's heritage."

Voyager 1, which was launched on September 5, 1977, is currently about 17 billion kilometers (11 billion miles) away from the Sun. It is the most distant spacecraft. Voyager 2, which was launched on August 20, 1977, is currently about 14 billion kilometers (9 billion miles) away from the Sun. For more information, visit *www.nasa.gov/voyager* and *voyager.jpl.nasa.gov*.

Spring on Titan Brings Sunshine and Patchy Clouds

The northern hemisphere of Saturn's moon Titan is set for mainly fine spring weather, with polar skies clearing since the equinox in August last year. The visual and infrared mapping spectrometer (VIMS) onboard NASA's Cassini spacecraft has been monitoring clouds on Titan regularly since the spacecraft entered orbit around Saturn in 2004. Now, a group led by Sébastien Rodriguez, a Cassini VIMS team collaborator based at Université Paris Diderot, France, has analyzed more than 2000 VIMS images to create the first long-term study of Titan's weather using observational data that also includes the equinox. Equinox, when the Sun shone directly over the equator, occurred in August 2009.

Although Titan's surface is far colder and lacks liquid water, this moon is a kind of "sister world" to Earth because it has a surface covered with organic material and an atmosphere whose chemical composition harkens back to an early Earth. Titan has a hydrological cycle similar to Earth's, although Titan's cycle



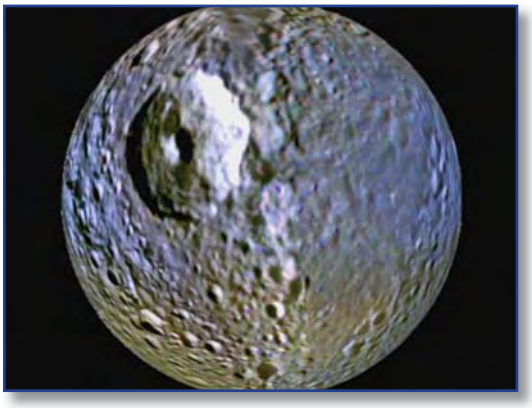
This pair of false-color images, made from data obtained by NASA's Cassini spacecraft, shows clouds covering parts of Saturn's moon Titan in yellow. Based on the way near-infrared channels of light were color-coded, cloud cover appears yellow, while Titan's hazy atmosphere appears magenta. The images show cloud cover dissolving from Titan's north polar region between May 12, 2008 (left), and December 12, 2009 (right). The clouds in the second image appear around 40°S latitude, still active late after Titan's equinox. Credit: NASA/JPL/University of Arizona/University of Nantes/University of Paris Diderot.

depends on methane and ethane rather than water.

A season on Titan lasts about seven Earth years. Rodriguez and colleagues observed significant atmospheric changes between July 2004 (early summer in Titan's southern hemisphere) and April 2010 (the very start of northern spring). The images showed that cloud activity has recently decreased near both of Titan's poles. These regions had been heavily overcast during the late southern summer until 2008, a few months before the equinox.

Over the past six years, the scientists found that clouds clustered in three distinct latitude regions of Titan: large clouds at the north pole, patchy clouds at the south pole and a narrow belt around 40°S. "However, we are now seeing evidence of a seasonal circulation turnover on Titan — the clouds at the south pole completely disappeared just before the equinox and the clouds in the north are thinning out," Rodriguez said. "This agrees with predictions from models and we are expecting to see cloud activity reverse from one hemisphere to another in the coming decade as southern winter approaches."

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



This enhanced color view of Saturn's moon Mimas was made from images obtained by NASA's Cassini spacecraft. Credit: NASA/JPL/SSI/LPI.

Cassini Catches Saturn Moons in Paintball Fight

Scientists using data from NASA's Cassini spacecraft have learned that distinctive, colorful bands and splotches embellish the surfaces of Saturn's inner, mid-sized moons. The reddish and bluish hues on the icy surfaces of Mimas, Enceladus, Tethys, Dione, and Rhea appear to be the aftermath of bombardments large and small.

A paper based on the findings was published online in October in the journal *Icarus*. In it, scientists describe prominent global patterns that trace the trade routes for material exchange between the moons themselves, an outer ring of Saturn known as the E ring, and the planet's magnetic environment. The finding may explain the mysterious Pac-Man thermal pattern on Mimas, found earlier this year by Cassini scientists, said lead author Paul Schenk, who was funded by a Cassini data analysis program grant and is based at the Lunar and Planetary Institute in Houston. "The beauty of it all is how the satellites behave as a family, recording similar processes and events on their surfaces, each in its own unique way," Schenk said. "I don't think anyone expected that electrons would leave such obvious fingerprints on planetary surfaces, but we see it on several moons, including Mimas, which was once thought to be rather bland."

Schenk and colleagues processed raw images obtained by Cassini's imaging cameras from 2004 to 2009 to produce new, high-resolution global color maps of these five moons. The new maps used camera frames shot through visible-light, ultraviolet, and infrared filters that were processed to enhance our views of these moons beyond what could be seen by the human eye. "The richness of the Cassini dataset — visible images, infrared images, ultraviolet images, measurements of the radiation belts — is such that we can finally 'paint a picture' as to how the satellites themselves are 'painted,' " said William B. McKinnon, one of six co-authors on the paper. McKinnon is based at Washington University in St. Louis and was also funded by the Cassini data analysis program.

Icy material sprayed by Enceladus, which makes up the misty E ring, appears to leave a brighter, blue signature. The pattern of bluish material on Enceladus, for example, indicates that the moon is covered by the fallback of its own "breath." Enceladean spray also appears to splatter the parts of Tethys, Dione, and Rhea that run into the spray head-on in their orbits around Saturn. But scientists are still puzzling over why the Enceladean frost on the leading hemisphere of these moons bears a coral-colored, rather than bluish, tint.

On Tethys, Dione, and Rhea, darker, rust-colored, reddish hues paint the entire trailing hemisphere, or the side that faces backward in the orbit around Saturn. The reddish hues are thought to be caused by tiny particle strikes from circulating plasma, a gas-like state of matter so hot that atoms split into an ion and an electron, in Saturn's magnetic environment. Tiny, iron-rich "nanoparticles" may also be involved, based on earlier analyses by the Cassini visual and infrared mapping spectrometer team.

In addition, Mimas and Tethys sport a dark, bluish band. The bands match patterns one might expect if the surface were being irradiated by high-energy electrons that drift in a direction opposite to the flow of plasma in the magnetic bubble around Saturn. Scientists are still figuring out exactly what is happening, but the electrons appear to be zapping the Mimas surface in a way that matches the Pac-Man thermal pattern detected by Cassini's composite infrared spectrometer, Schenk said.

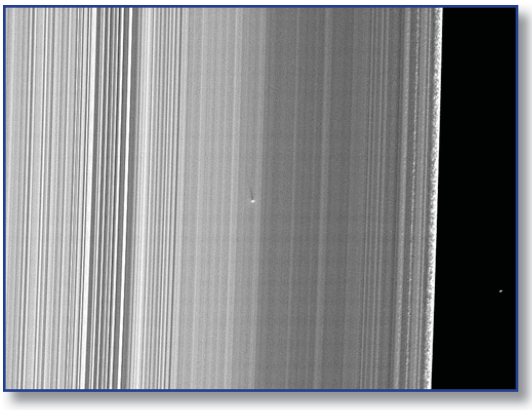
Schenk and colleagues also found a unique chain of bluish splotches along the equator of Rhea that reopen the question of whether Rhea ever had a ring around it. The splotches do not seem related to Enceladus, but rather appear where fresh, bluish ice has been exposed on older crater rims. Although Cassini imaging scientists recently reported that they did not see evidence in Cassini images of a ring around Rhea, the authors of this paper suggest the crash of orbiting material, perhaps a ring, to the surface of Rhea in the not-too-distant past could explain the bluish splotches.

"Analyzing the image color ratios is a great way to really enhance the otherwise subtle color variations and make apparent some of the processes at play in the Saturn system," said Amanda Hendrix, Cassini deputy project scientist at NASA's Jet Propulsion Laboratory. "The Cassini images highlight the importance and potential effects of so-called 'space weathering' that occurs throughout the solar system — on any surface that isn't protected by a thick atmosphere or magnetic field."

For more information, or to see the images, visit *www.nasa.gov/cassini* and *saturn.jpl.nasa.gov*.

Cassini Sees Saturn Rings Oscillate Like Mini-Galaxy

Scientists believe they finally understand why one of the most dynamic regions in Saturn's rings has such an irregular and varying shape, thanks to images captured by NASA's Cassini spacecraft. And the answer, published online in November in the *Astronomical Journal*, is this: The rings are behaving like a miniature version of our own Milky Way galaxy. This new insight, garnered from images of Saturn's most massive ring, the B ring, may answer another long-standing question: What causes the bewildering variety of structures seen throughout the very densest regions of Saturn's rings?



NASA's Cassini spacecraft captured this image of a small object in the outer portion of Saturn's B ring casting a shadow on the rings as Saturn approached its August 2009 equinox. Credit: NASA/JPL-Caltech/SSI.

Another finding from new images of the B ring's outer edge was the presence of at least two perturbed regions, including a long arc of narrow, shadow-casting peaks as high as 3.5 kilometers (2 miles) above the ring plane. The areas are likely populated with small moons that might have migrated across the outer part of the B ring in the past and got trapped in a zone affected by the moon Mimas' gravity. This process is commonly believed to have configured the present-day solar system.

"We have found what we hoped we'd find when we set out on this journey with Cassini nearly 13 years ago: visibility into the mechanisms that have sculpted not only Saturn's rings, but celestial disks of a far grander scale, from solar systems, like our own, all the way to the giant spiral galaxies," said Carolyn Porco, co-author of the paper and Cassini imaging team lead, based at the Space Science Institute in Boulder, Colorado.

Analysis of thousands of Cassini images of the B ring taken over a four-year period has revealed the source of most of the ring's complexity: at least three additional, independently rotating wave patterns, or oscillations, that distort the B ring's edge. These oscillations, with one, two, or three lobes, are not created by any moons. They have instead spontaneously arisen, in part because the ring is dense enough, and the B ring edge is sharp enough, for waves to grow on their own and then reflect at the edge.

"These oscillations exist for the same reason that guitar strings have natural modes of oscillation, which can be excited when plucked or otherwise disturbed," said Joseph Spitale, lead author of the article and an imaging team associate at the Space Science Institute. "The ring, too, has its own natural oscillation frequencies, and that's what we're observing." Astronomers believe such "self-excited" oscillations exist in other disk systems, like spiral disk galaxies and protoplanetary disks found around nearby stars, but they have not been able to directly confirm their existence. The new observations confirm the first large-scale wave oscillations of this type in a broad disk of material anywhere in nature.

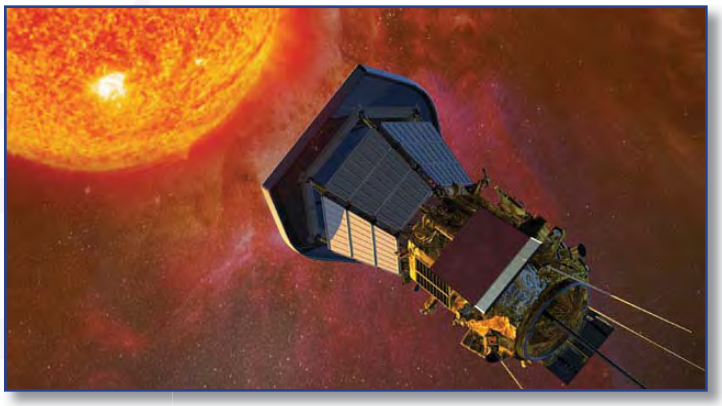
Self-excited waves on small, 100-meter (300-foot) scales have been previously observed by Cassini instruments in a few dense ring regions and have been attributed to a process called "viscous overstability." In that process, the ring particles' small, random motions feed energy into a wave and cause it to grow. The new results confirm a Voyager-era prediction that this same process can explain all the puzzling chaotic waveforms found in Saturn's densest rings, from tens of meters up to hundreds of kilometers wide.

"Normally viscosity, or resistance to flow, damps waves — the way sound waves traveling through the air would die out," said Peter Goldreich, a planetary ring theorist at the California Institute of Technology. "But the new findings show that, in the densest parts of Saturn's rings, viscosity actually amplifies waves, explaining mysterious grooves first seen in images taken by the Voyager spacecraft."

The two perturbed B ring regions found orbiting within Mimas' zone of influence stretch along arcs up to 20,000 kilometers (12,000 miles) long. The longest one was first seen last year when the Sun's low angle on the ring plane betrayed the existence of a series of tall structures through their long, spiky shadows. The small moons disturbing the material are probably hundreds of meters to possibly a kilometer or more in size. Images and movies of the outer B ring edge can be found at *www.nasa.gov/cassini*, *saturn.jpl.nasa.gov*, and *ciclops.org*.

NASA Selects Investigations for First Mission to Encounter the Sun

NASA has begun development of a mission to visit and study the Sun closer than ever before. The unprecedented project, named Solar Probe Plus, is slated to launch no later than 2018. The small car-sized spacecraft will plunge directly into the Sun's atmosphere approximately four million miles from our star's surface. It will explore a region no other spacecraft ever has encountered. NASA has selected five science investigations that will unlock the Sun's biggest mysteries.



This artist's rendition shows the Solar Probe Plus spacecraft with solar panels folded into the shadows of its protective shield, gathering data on its approach to the Sun. Credit: JHU/APL.

"The experiments selected for Solar Probe Plus are specifically designed to solve two key questions of solar physics — why is the Sun's outer atmosphere so much hotter than the Sun's visible surface, and what propels the solar wind that affects Earth and our solar system?" said Dick Fisher, director of NASA's Heliophysics Division in Washington. "We've been struggling with these questions for decades and this mission should finally provide those answers."

As the spacecraft approaches the Sun, its revolutionary carbon-composite heat shield must withstand temperatures exceeding 2550°F and blasts of intense radiation. The spacecraft will have an up close and personal view of the Sun, enabling scientists to better understand, characterize, and forecast the radiation environment for future space explorers.

NASA invited researchers in 2009 to submit science proposals. Thirteen were reviewed by a panel of NASA and outside scientists. The total dollar amount for the five selected investigations is approximately $180 million for preliminary analysis, design, development, and tests. Instruments selected include a probe of the solar wind; a wide-field three-dimensional imager; an instrument that measures electric and magnetic fields, radio emissions, and shock waves that course through the Sun'a atmospheric plasma; and a mass spectrometer to weigh and sort ions in the vicinity of the spacecraft.

"This project allows humanity's ingenuity to go where no spacecraft has ever gone before," said Lika Guhathakurta, Solar Probe Plus program scientist at NASA Headquarters. "For the very first time, we'll be able to touch, taste and smell our Sun."

The Solar Probe Plus mission is part of NASA's Living with a Star Program. The program is designed to understand aspects of the Sun and Earth's space environment that affect life and society. For more information about the Solar Probe Plus mission, visit *solarprobe.gsfc.nasa.gov*. For more information about the Living with a Star Program, visit *science.nasa.gov/about-us/smd-programs/living-with-a-star*.

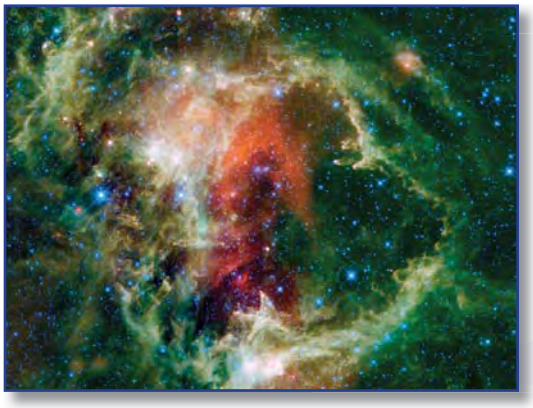
NASA's WISE Mission Warms Up but Continues with Discoveries

After completing its primary mission to map the infrared sky, NASA's Wide-field Infrared Survey Explorer (WISE) reached the expected end of its onboard supply of frozen coolant. Although WISE has 'warmed up,' NASA decided the mission will still continue. WISE is now focusing on our nearest neighbors — the asteroids and comets traveling together with our solar system's planets around the Sun.

"Two of our four infrared detectors still work even at warmer temperatures, so we can use those bands to continue our hunt for asteroids and comets," said Amy Mainzer of NASA's Jet Propulsion Laboratory. Mainzer is the principal investigator of the new phase of the mission, now known as the NEOWISE Post-

Cryogenic Mission. It takes its name from the acronym for a near-Earth object (NEO) and WISE. A cryogen is a coolant used to make the detectors more sensitive. In the case of WISE, the cryogen was frozen hydrogen.

WISE launched December 14, 2009, from Vandenberg Air Force Station in California onboard a Delta II launch vehicle. Its 40-centimeter (16-inch) infrared telescope scans the skies from an Earth-circling orbit crossing the poles. It has already snapped more than 1.8 million pictures at four infrared wavelengths. Currently, the survey has covered the sky about one-and-one-half times, producing a vast catalog containing hundreds of millions of objects, from near-Earth asteroids to cool stars called "brown dwarfs," to distant, luminous galaxies. To date, WISE has discovered 19 comets and more than 33,500 asteroids, including 120 near-Earth objects, which are those bodies with orbits that pass relatively close to Earth's path around the Sun. More discoveries regarding objects outside our solar system, such as the brown dwarfs and luminous galaxies, are expected.



This WISE mosaic is of the Soul Nebula (a.k.a. the Embryo Nebula, IC 1848, or W5). It is an open cluster of stars surrounded by a cloud of dust and gas over 150 light-years across and located about 6500 light-years from Earth in the constellation Cassiopeia, near the Heart Nebula. The cluster of stars formed about a million years ago from the material of the nebula. Credit: NASA/JPL-Caltech/UCLA.

A gallery of WISE images is available at *www.nasa.gov/mission_pages/WISE/multimedia/gallery/gallery-index.html*. More information about the mission is online at *www.nasa.gov/wise* and *wise.astro.ucla.edu*.

This image, taken by NASA's Near Earth Asteroid Rendezvous mission in 2000, shows a close-up view of Eros, an asteroid with an orbit that takes it somewhat close to Earth. NASA's Spitzer Space Telescope observed Eros and dozens of other near-Earth asteroids as part of an ongoing survey to study their sizes and compositions using infrared light. Credit: NASA/JHUAPL.

Spitzer Finds a Flavorful Mix of Asteroids

New research from NASA's Spitzer Space Telescope reveals that asteroids somewhat near Earth, termed near-Earth objects, are a mixed bunch, with a surprisingly wide array of compositions. Like a piñata filled with everything from chocolates to fruity candies, these asteroids come in assorted colors and compositions. Some are dark and dull; others are shiny and bright. The Spitzer observations of 100 known near-Earth asteroids demonstrate that the objects' diversity is greater than previously thought. The findings are helping astronomers better understand near-Earth objects as a whole — a population whose physical properties are not well known.

"These rocks are teaching us about the places they come from," said David Trilling of Northern Arizona University, Flagstaff, lead author of a paper on the research appearing in the September issue of *Astronomical Journal*. "It's like studying pebbles in a streambed to learn about the mountains they tumbled down."

After nearly six years of operation, in May 2009, Spitzer used up the liquid coolant needed to chill its infrared detectors. It is now operating in a so-called "warm" mode (the actual temperature is still quite cold at 30 Kelvin, or –406°F). Two of Spitzer's infrared channels, the shortest-wavelength detectors on the observatory, are working perfectly.

One of the mission's new "warm" programs is to survey about 700 near-Earth objects, cataloging their individual traits. By observing in infrared, Spitzer is helping to gather more accurate estimates of asteroids' compositions and sizes than what is possible with visible light alone. Visible-light observations of an asteroid won't differentiate between an asteroid that is big and dark, or small and light. Both rocks would reflect the same amount of visible sunlight. Infrared data provide a read on the object's temperature, which then tells an astronomer more about the actual size and composition. A big, dark rock has a higher temperature than a small, light one because it absorbs more sunlight.

Trilling and his team have analyzed preliminary data on 100 near-Earth asteroids so far. They plan to observe 600 more over the next year. There are roughly 7000 known near-Earth objects out of a population expected to number in the tens to hundreds of thousands. "Very little is known about the physical characteristics of the near-Earth population," said Trilling. "Our data will tell us more about the population, and how it changes from one object to the next. This information could be used to help plan possible future space missions to study a near-Earth object."

The data show that some of the smaller objects have surprisingly high albedos (an albedo is a measurement of how much sunlight an object reflects). Since asteroid surfaces become darker with time due to exposure to solar radiation, the presence of lighter, brighter surfaces for some asteroids may indicate that they are relatively young. This is evidence for the continuing evolution of the near-Earth object population.

In addition, the fact that the asteroids observed so far have a greater degree of diversity than expected indicates that they might have different origins. Some might come from the main belt between Mars and Jupiter, and others could come from farther out in the solar system. This diversity also suggests that the materials that went into making the asteroids — the same materials that make up our planets — were probably mixed together like a big solar-system soup very early in its history. For more information about Spitzer, visit *spitzer.caltech.edu* and *www.nasa.gov/spitzer*.

NASA's Hubble Captures First Images of Aftermath of Possible Asteroid Collision

NASA's Hubble Space Telescope has captured the first snapshots of a suspected asteroid collision. The images show a bizarre X-shaped object at the head of a comet-like trail of material. In January, astronomers began using Hubble to track the object for five months. They thought they had witnessed a fresh asteroid collision, but were surprised to learn the collision occurred in early 2009. "We expected the debris field to expand dramatically, like shrapnel flying from a hand grenade," said astronomer David Jewitt of the University of California in Los Angeles, who is a leader of the Hubble observations. "But what happened was quite the opposite. We found that the object is expanding very, very slowly."

The peculiar object, dubbed P/2010 A2, was found cruising around the asteroid belt, a reservoir of millions of rocky bodies between the orbits of Mars and Jupiter. It is estimated modest-sized asteroids smash into each other about once a year. When the objects collide, they inject dust into interplanetary space. But until now, astronomers have relied on models to make predictions about the frequency of these collisions and the amount of dust produced. Catching colliding asteroids is difficult because large impacts are rare while small ones, such as the one that produced P/2010 A2, are exceedingly faint. The two asteroids that make up P/2010 A2 were unknown before the collision because they were too faint to be noticed. The collision itself was unobservable because of the asteroids' position in relation to the Sun.

In January 2010, the Lincoln Near-Earth Research (LINEAR) Program Sky Survey spotted the comet-like tail produced by the collision. But only Hubble discerned the X pattern, offering unequivocal evidence that something stranger than a comet outgassing had occurred. "These observations are important because we need to know where the dust in the solar system comes from, and how much of it comes from colliding asteroids as opposed to 'outgassing' comets," Jewitt said. "We also can apply this knowledge to

These four Hubble Space Telescope images, taken over a five-month period, show the odd-shaped debris that likely came from a collision between two asteroids. The asteroid debris, dubbed P/2010 A2, appears to be shrinking in each successive image because Earth's faster orbit is carrying the planet away from the object. Between January and May, Earth rotated more than 100 million miles away from the debris field. The object was 102 million miles from Earth when Hubble first observed it in January 2010. The images were taken in visible light and artificially colored blue. Credit: NASA, ESA, and D. Jewitt (UCLA).

the dusty debris disks around other stars, because these are thought to be produced by collisions between unseen bodies in the disks. Knowing how the dust was produced will yield clues about those invisible bodies."

The 400-foot-wide object in the Hubble image is the remnant of a slightly larger precursor body. Astronomers think a smaller rock, perhaps 10 to 15 feet wide, slammed into the larger one. The pair probably collided at high speed, about 11,000 mph, which smashed and vaporized the small asteroid and stripped material from the larger one. Jewitt estimates that the violent encounter happened in February or March 2009 and was as powerful as the detonation of a small atomic bomb.

Sunlight radiation then swept the debris behind the remnant asteroid, forming a comet-like tail. The tail contains enough dust to make a ball 65 feet wide, most of it blown out of the bigger body by the impact-caused explosion. The science journal *Nature* published the findings in the October 14 issue.

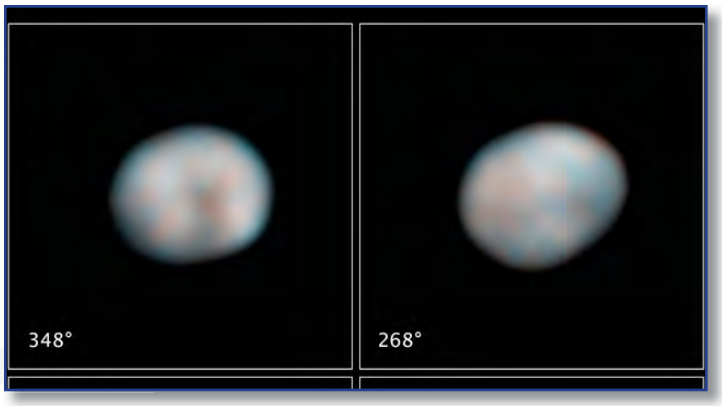
Astronomers do not have a good explanation for the X shape. The crisscrossed filaments at the head of the tail suggest that the colliding asteroids were not perfectly symmetrical. Material ejected from the impact, therefore, did not make a symmetrical pattern, a bit like the ragged splash made by throwing a rock into a lake. Larger particles in the X disperse very slowly and give this structure its longevity. Astronomers plan to use Hubble again next year to view the object. Jewitt and his colleagues hope to see how far the dust has been swept back by the Sun's radiation and how the mysterious X-shaped structure has evolved.

For images, movies, and more information about asteroid encounter P/2010 A2, visit *hubblesite.org/news/2010/34* and *www.nasa.gov/hubble*.

NASA Mission to Asteroid Gets Help From Hubble

NASA's Hubble Space Telescope has captured images of the large asteroid Vesta that will help refine plans for the Dawn spacecraft's rendezvous with Vesta in July 2011. Scientists have constructed a video from the images that will help improve pointing instructions for Dawn as it is placed in a polar orbit around Vesta. Analyses of Hubble images revealed a pole orientation, or tilt, of approximately 4° more to the asteroid's east than scientists previously thought. This means the change of seasons between the southern and northern hemispheres of Vesta may take place about a month later than previously expected while Dawn is orbiting the asteroid. The result is a change in the pattern of sunlight expected to illuminate the asteroid. Dawn needs solar illumination for imaging and some mapping activities.

"While Vesta is the brightest asteroid in the sky, its small size makes it difficult to image from Earth," said Jian-Yang Li, a scientist participating in the Dawn mission from the University of Maryland in College Park. "The new Hubble images give Dawn scientists a better sense of how Vesta is spinning, because our new views are 90° different from our previous images. It's like having a street-level view and adding a view from an airplane overhead."



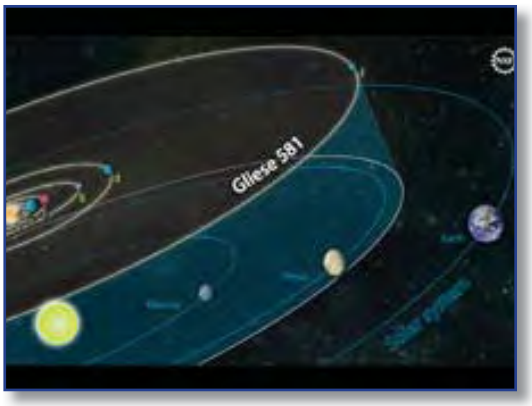
NASA's Hubble Space Telescope snapped these images of the asteroid Vesta in preparation for the Dawn spacecraft's visit in 2011. Credit: NASA/ESA/STScI/UMd.

The recent images were obtained by Hubble's Wide Field Camera 3 in February. The images complemented previous ones of Vesta taken from groundbased telescopes and Hubble's Wide Field and Planetary Camera 2 between 1983 and 2007. Li and his colleagues looked at 216 new images — and a total of 446 Hubble images overall — to clarify how Vesta was spinning. The journal *Icarus* recently published the report online.

"The new results give us food for thought as we make our way toward Vesta," said Christopher Russell, Dawn's principal investigator at the University of California, Los Angeles. "Because our goal is to take pictures of the entire surface and measure the elevation of features over most of the surface to an accuracy of about 33 feet, or the height of a three-story building, we need to pay close attention to the solar illumination. It looks as if Vesta is going to have a late northern spring next year, or at least later than we planned."

To see the Vesta images and video, visit *www.nasa.gov/mission_pages/dawn/multimedia/vestavid20101008.html*. To learn more about Dawn and its mission to the asteroid belt, visit *www.nasa.gov/dawn* or *dawn.jpl.nasa.gov*.

Research Finds First Potentially Habitable Exoplanet



The planetary orbits of the Gliese 581 system compared to those of our own solar system. Credit: National Science Foundation.

A team of planet hunters from the University of California (UC) Santa Cruz and the Carnegie Institution of Washington has announced the discovery of a planet with three times the mass of Earth orbiting a nearby star at a distance that places it squarely in the middle of the star's "habitable zone." This discovery was the result of more than a decade of observations using the W. M. Keck Observatory in Hawaii, one of the world's largest optical telescopes. The research, funded by NASA and the National Science Foundation, placed the planet in an area where liquid water could exist on the planet's surface. If confirmed, this would be the most Earth-like exoplanet yet discovered and the first strong case for a potentially habitable one. To astronomers, a "potentially habitable" planet is one that could sustain life, not necessarily one where humans would thrive. Habitability depends on many factors, but having liquid water and an atmosphere are among the most important.

The new findings are based on 11 years of observations of the nearby red dwarf star Gliese 581using the HIRES spectrometer on the Keck I Telescope. The spectrometer allows precise measurements of a star's radial velocity (its motion along the line of sight from Earth), which can reveal the presence of planets. The gravitational tug of an orbiting planet causes periodic changes in the radial velocity of the host star. Multiple planets induce complex wobbles in the star's motion, and astronomers use sophisticated analyses to detect planets and determine their orbits and masses.

"Keck's long-term observations of the wobble of nearby stars enabled the detection of this multiplanetary system," said Mario R. Perez, Keck program scientist at NASA Headquarters. "Keck is once again proving itself an amazing tool for scientific research." Steven Vogt, professor of astronomy and astrophysics at UC Santa Cruz, and Paul Butler of the Carnegie Institution lead the Lick-Carnegie Exoplanet Survey. The team's new findings were reported in a paper published in the *Astrophysical Journal.*

"Our findings offer a very compelling case for a potentially habitable planet," said Vogt. "The fact that we were able to detect this planet so quickly and so nearby tells us that planets like this must be really common."

The paper reports the discovery of two new planets around Gliese 581. This brings the total number of known planets around this star to six, the most yet discovered in a planetary system outside of our own. Like our solar system, the planets around Gliese 581 have nearly circular orbits.

The new planet designated Gliese 581g has a mass three to four times that of Earth and orbits its star in just under 37 days. Its mass indicates that it is probably a rocky planet with a definite surface and enough gravity to hold on to an atmosphere. Gliese 581, located 20 light-years away from Earth in the constellation Libra, has two previously detected planets that lie at the edges of the habitable zone, one on the hot side (planet c) and one on the cold side (planet d). While some astronomers still think planet d may be habitable if it has a thick atmosphere with a strong greenhouse effect to warm it up, others are skeptical. The newly discovered planet g, however, lies right in the middle of the habitable zone.

The planet is tidally locked to the star, meaning that one side is always facing the star and basking in perpetual daylight, while the side facing away from the star is in perpetual darkness. One effect of this is to stabilize the planet's surface climates, according to Vogt. The most habitable zone on the planet's surface would be the line between shadow and light (known as the "terminator"). For more information, visit *www.ucsc.edu/news_events*, *carnegiescience.edu*, or *www.nasa.gov/topics/universe/features/gliese_581_feature.html*.

NASA Survey Suggests Earth-Sized Planets are Common

Nearly one in four stars similar to the Sun may host planets as small as Earth, according to a new study funded by NASA and the University of California. The study is the most extensive and sensitive planetary census of its kind. Astronomers used the W. M. Keck Observatory in Hawaii for five years to search 166 Sun-like stars near our solar system for planets of various sizes, ranging from three to 1000 times the mass of Earth. All the planets in the study orbit close to their stars. The results show more small planets than large ones, indicating small planets are more prevalent in our Milky Way galaxy.

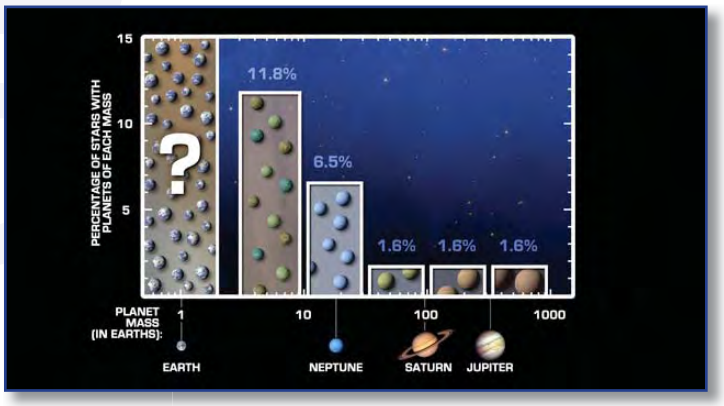
"We studied planets of many masses — like counting boulders, rocks, and pebbles in a canyon — and found more rocks than boulders, and more pebbles than rocks. Our groundbased technology can't see the grains of sand, the Earth-sized planets, but we can estimate their numbers," said Andrew Howard of the University of California, Berkeley, lead author of the new study. "Earth-sized planets in our galaxy are like grains of sand sprinkled on a beach — they are everywhere." The study appeared in the October 29 issue of the journal *Science*.

The research provides a tantalizing clue that potentially habitable planets could also be common. These hypothesized Earth-sized worlds would orbit farther away from their stars, where conditions could be favorable for life. NASA's Kepler spacecraft is also surveying Sun-like stars for planets and is expected to find the first true Earth-like planets in the next few years.

Howard and his planet-hunting team, which includes principal investigator Geoff Marcy, also of the University of California, Berkeley, looked for planets within 80 light-years of Earth, using the radial velocity, or "wobble," technique. They measured the numbers of planets falling into five groups, ranging

from 1000 times the mass of Earth, or about three times the mass of Jupiter, down to three times the mass of Earth. The search was confined to planets orbiting close to their stars — within 0.25 astronomical units (AU), or a quarter of the distance between our Sun and Earth.

A distinct trend jumped out of the data: smaller planets outnumber larger ones. Only 1.6% of stars were found to host giant planets orbiting close in. That includes the three highest-mass planet groups in the study, or planets comparable to Saturn and Jupiter. About 6.5% of stars were found to have intermediate-mass planets, with 10 to 30 times the mass of Earth — planets the size of Neptune and Uranus. And 11.8% had the so-called "super-Earths," weighing in at only three to 10 times the mass of Earth.



A new survey, funded by NASA and the University of California, reveals that small planets are more common than large ones. Credit: NASA/JPL-Caltech/UC Berkeley.

The astronomers extrapolated from these survey data to estimate that 23% of Sun-like stars in our galaxy host even smaller planets, the Earth-sized ones, orbiting in the hot zone close to a star. "This is the statistical fruit of years of planet-hunting work," said Marcy. "The data tell us that our galaxy, with its roughly 200 billion stars, has at least 46 billion Earth-size planets, and that's not counting Earth-sized planets that orbit farther away from their stars in the habitable zone."

The findings challenge a key prediction of some theories of planet formation. Models predict a planet "desert" in the hot-zone region close to stars, or a drop in the numbers of planets with masses less than 30 times that of Earth. This desert was thought to arise because most planets form in the cool, outer region of solar systems, and only the giant planets were thought to migrate in significant numbers into the hot inner region. The new study finds a surplus of close-in, small planets where theories had predicted a scarcity.

More information about exoplanets and NASA's planet-finding program is at *planetquest.jpl.nasa.gov*.

Astronomers Find Weird, Warm Spot on an Exoplanet

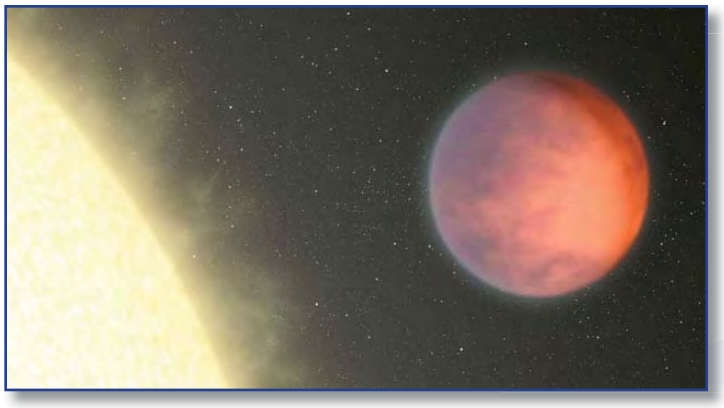
Observations from NASA's Spitzer Space Telescope reveal a distant planet with a warm spot in the wrong place. The gas-giant planet, named upsilon Andromedae b, orbits tightly around its star, with one face perpetually boiling under the star's heat. It belongs to a class of planets termed hot Jupiters, so called for their scorching temperatures and large, gaseous constitutions. One might think the hottest part of these planets would be directly under the Sun-facing side, but previous observations have shown that their hot spots may be shifted slightly away from this point. Astronomers thought that fierce winds might be pushing hot, gaseous material around.

But the new finding may throw this theory into question. Using Spitzer, an infrared observatory, astronomers found that upsilon Andromedae b's hot spot is offset by a whopping 80°. Basically, the hot spot is over to the side of the planet instead of directly under the glare of the Sun.

"We really didn't expect to find a hot spot with such a large offset," said Ian Crossfield, lead author of a new paper about the discovery appearing recently in an issue of *Astrophysical Journal*. "It's clear that we understand even less about the atmospheric energetics of hot Jupiters than we thought we did."

The results are part of a growing field of exoplanet atmospheric science, pioneered by Spitzer in 2005, when it became the first telescope to directly detect photons from an exoplanet, or a planet

orbiting a star other than our Sun. Since then, Spitzer, along with NASA's Hubble Space Telescope, has studied the atmospheres of several hot Jupiters, finding water, methane, carbon dioxide, and carbon monoxide.



NASA's Spitzer Space Telescope has found that the hottest part of a distant planet, named upsilon Andromedae b, is not under the glare of its host star as might be expected. Credit: NASA/JPL-Caltech.

In the new study, astronomers report observations of upsilon Andromedae b taken across five days in February of 2009. This planet whips around its star every 4.6 days, as measured using the "wobble," or radial velocity, technique, with telescopes on the ground. It does not transit, or cross in front of, its star as many other hot Jupiters studied by Spitzer do. Spitzer measured the total combined light from the star and planet, as the planet orbited around. The telescope can't see the planet directly, but it can detect variations in the total infrared light from the system that arise as the hot side of the planet comes into Earth's field of view. The hottest part of the planet will give off the most infrared light.

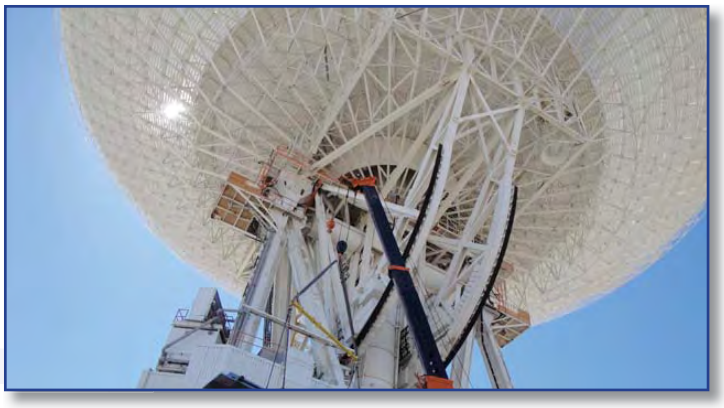
One might think the system would appear brightest when the planet was directly behind the star, thus showing its full Sun-facing side. Likewise, one might think the system would appear darkest when the planet swings around toward Earth, showing its backside. But the system was the brightest when the planet was to the side of the star, with its side facing Earth. This means that the hottest part of the planet is not under its star. It's sort of like going to the beach at sunset to feel the most heat. The researchers aren't sure how this could be. They've guessed at some possibilities, including supersonic winds triggering shock waves that heat material up, and star-planet magnetic interactions. But these are just speculation. As more hot Jupiters are examined, astronomers will test new theories.

"This is a very unexpected result," said Michael Werner, the Spitzer project scientist at NASA's Jet Propulsion Laboratory. "Spitzer is showing us that we are a long way from understanding these alien worlds." The Spitzer observations were made before it ran out of its liquid coolant in May 2009, officially beginning its warm mission. For more information about Spitzer, visit *spitzer.caltech.edu/* and *www.nasa.gov/spitzer*.

Major Surgery Complete for Deep Space Network Antenna

The seven-month upgrade to the historic "Mars antenna" at NASA's Deep Space Network site in Goldstone, California, has been completed. After a month of intensive testing, similar to the rehabilitation stage after surgery, the antenna is now ready to help maintain communication with spacecraft during the next decade of space exploration. The month of October was used as a testing period to make sure the antenna was in working order and fully functional, as scheduled, for November 1. A team of workers completed an intense series of tasks to reach its first milestone — upgrading the 70-meter-wide (230-foot-wide) antenna in time to communicate with the EPOXI mission spacecraft during its flyby of Comet Hartley 2 on November 4.

During the upgrade process, workers raised a portion of the antenna that weighs 3.2 million kilograms (7 million pounds) up from the base by 5 millimeters (0.2 inches) while they performed a precise, delicate repair. They replaced a portion of the hydrostatic bearing (enabling the antenna to rotate horizontally) and the four elevation bearings (enabling the antenna to track up and down from the horizon). Unlike the sterile confines of an operating room, this surgery took place in the middle of California's Mojave Desert,



Under the unflinching summer Sun, workers at NASA's Deep Space Network complex in Goldstone, California, use a crane to lift a runner segment that is part of major surgery on a giant, 70-meter-wide antenna. The work gives the antenna a kind of joint replacement. The antenna is officially called Deep Space Station 14, but is also known as the "Mars antenna." Credit: NASA/JPL-Caltech.

a hot oasis baked by the unforgiving desert heat. The team members were able to cheat the heat by completing a number of the 375 tasks during early morning and night shifts. The tasks required the team to analyze, load, lift, install, test, analyze again, and inspect.

The Deep Space Network consists of three deep-space communication facilities positioned approximately 120° of longitude apart. In addition to the Mojave Desert location at Goldstone, the other locations are outside of Madrid, Spain, and Canberra, Australia. Each 70-meter (230-foot) antenna is capable of tracking a spacecraft traveling more than 16 billion kilometers (10 billion miles) from Earth. The antennas are strategically situated at each location in semi-mountainous basins to reduce radio frequency interference. This careful placement helps make the Deep Space Network the largest and most sensitive science telecommunications system in the world.

In March 1966, the antenna, officially known as Deep Space Station 14, earned its nickname as the Mars antenna by receiving the first signal from NASA's Mariner 4 mission to Mars. The historic dish is now responsible for tracking an entire fleet of missions, including the rovers Spirit and Opportunity currently on the surface of Mars, the Cassini orbiter at Saturn, the twin Voyager spacecraft in the outer reaches of our solar system, and the Spitzer Space Telescope, which observes stars, galaxies, and other celestial objects. More information about the Deep Space Network is available at *deepspace.jpl.nasa.gov*.

SOFIA Observatory Completes First Science Flight

NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) completed the first of three science flights on December 1 to demonstrate the aircraft's potential to make discoveries about the infrared universe. The airborne observatory is an international collaboration between NASA and the German Aerospace Center, Deutsches Zentrum fur Luft und Raumfahrt (DLR). NASA's Ames Research Center manages the SOFIA science and mission operations in cooperation with the Universities Space Research Association (USRA) and the Deutsches SOFIA Institut at the University of Stuttgart.

SOFIA is a heavily modified Boeing 747SP that cruises at altitudes between 39,000 and 45,000 feet. It will allow researchers to better understand a wide range of astronomical phenomena including how stars and planets are born, how organic substances form in interstellar space, and how supermassive black holes feed and grow. This premiere science flight took off from an Air Force runway in Palmdale, California, on November 30, flying for approximately 10 hours.

"This major milestone marks the beginning of regular science observations with SOFIA and an exciting time for infrared astronomy," said USRA President Fred Tarantino. Adds NASA Astrophysics Division Director Jon Morse, "We anticipate a number of important discoveries from this unique observatory, as well as extended investigations of discoveries by other space telescopes."

SOFIA is fitted with a 100-inch-diameter airborne infrared telescope. It is based and managed at NASA's Dryden Aircraft Operations Facility in Palmdale. The aircraft's instruments can analyze light from a wide range of celestial objects, including warm interstellar gas and dust of bright star-forming regions, by

observing wavelengths between 0.3 and 1600 micrometers (microns). (A micrometer equals one millionth of a meter.) For comparison, the human eye sees light with wavelengths between 0.4 and 0.7 micrometers.

The first three science flights, phase one of SOFIA's early science program, will employ the Faint Object InfraRed Camera for the SOFIA Telescope (FORCAST) instrument developed by Cornell University and led by principal investigator Terry Herter. FORCAST observes the mid-infrared spectrum from 5 to 40 micrometers. Researchers used the FORCAST camera on SOFIA during a test flight two weeks ago to produce infrared images of areas within the Orion star-formation complex, a region of the sky for which more extensive data were collected during the November 30 flight.

"The early science flight program serves to validate SOFIA's capabilities and demonstrate the observatory's ability to make observations not possible from Earth-based telescopes," said Bob Meyer, NASA's SOFIA program manager. "It also marks SOFIA's transition from flying testbed to flying observatory, and it gives the international astronomical research community a new, highly versatile platform for studying the universe." In February 2011, the German Receiver for Astronomy at Terahertz Frequencies (GREAT), developed under the lead of the Max-Planck-Institut fur Radioastronomie, Bonn, Germany, will be installed in the observatory for three flights during the second phase of the program. For more information, visit *www.nasa.gov/mission_pages/SOFIA/index.html*, *www.sofia.usra.edu*, and *www.dlr.de/en/sofia*.

The Stratospheric Observatory for Infrared Astronomy (SOFIA) 747SP basks in the light of a full Moon shining over California's Mojave Desert. NASA photographer Tom Tschida shot this telephoto image on October 22, 2010. Credit: NASA/Tom Tschida.

Upcoming Spacecraft Encounters

Date	Target Body	Type of Body	Spacecraft	Website
February 14, 2011	P/Tempel 1	Comet	Stardust-NExT	*stardustnext.jpl.nasa.gov/*
July 2011	Vesta	Asteroid	Dawn	*dawn.jpl.nasa.gov/mission/*
March 18, 2011	Mercury (orbital insertion)	Planet	MESSENGER	*messenger.jhuapl.edu*
November 10, 2014	67P/ Churyumov-Gerasimenko	Comet	Rosetta	*www.esa.int/esaMI/Rosetta/index.html*

LPI Summer Intern Program in Lunar and Planetary Science

The Lunar and Planetary Institute (LPI) invites undergraduates with at least 50 semester hours of credit to experience cutting-edge research in the lunar and planetary sciences. Summer interns will work one-on-one with a scientist at the LPI or at the NASA Johnson Space Center on a research project of current interest in lunar and planetary science. Furthermore, they will participate in peer-reviewed research, learn from top-notch planetary scientists, and preview various careers in science.

The 10-week program runs from June 6, 2011, through August 12, 2011. Interns will receive a $5000.00 stipend plus a $1000.00 travel stipend for U.S. students, or a $1500.00 travel reimbursement for foreign nationals.

The LPI is located near Johnson Space Center, on the south side of Houston, Texas. The LPI provides, on NASA's behalf, leadership in the scientific community for research in lunar, planetary, and solar system sciences, and linkage with related terrestrial programs.

The deadline for applying for the 2011 program is **Friday, January 21, 2011.** For more information, including eligibility and selection criteria, areas of research, and an online application form, please visit *www.lpi.usra.edu/lpiintern*.

Lunar Exploration Summer Intern Program

The Lunar and Planetary Institute (LPI) is hosting a special lunar exploration summer intern program to evaluate possible landing sites for robotic and human exploration missions. The LPI invites applications from graduate students in geology, planetary science, and related programs. The program is also open to undergraduate students in geology, astronomy, chemistry, and physics with at least 50 semester hours of credit so that they, too, can participate in lunar exploration activities. The goal of this program is to integrate NASA's lunar science priorities with the exploration components of the Constellation program. This will be a unique team activity that should foster extensive discussions among students and senior science team members.

The 10-week program runs from May 31, 2011, through August 5, 2011. Selected interns will receive a $5000.00 stipend to cover the costs associated with being in Houston for the duration of the program. Additionally, U.S. citizens will receive up to $1000.00 in travel expense reimbursement, and foreign nationals will receive up to $1500.00 in travel expense reimbursement.

The application deadline is **Friday, January 21, 2011**. For more information, or to access the electronic application form, visit *www.lpi.usra.edu/lunar_intern*.

NASA Undergraduate Student Research Program

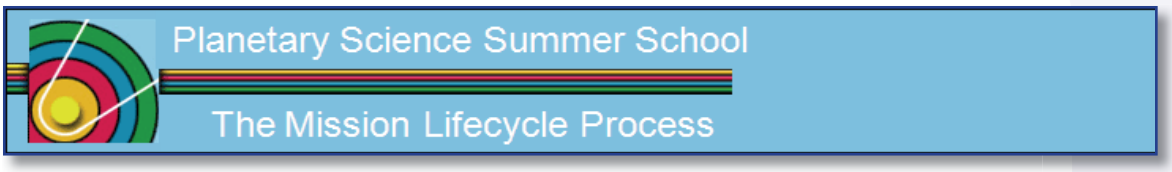
NASA's Undergraduate Student Research Program (USRP) offers undergraduates across the U.S. mentored internship experiences at NASA Centers and research support facilities. The NASA Undergraduate Student Research Program is NASA's largest nationwide internship program.

USRP is an internship program that offers NASA research and development opportunities to undergraduate students. USRP internship opportunities give students the ultimate workforce preparatory experience for careers in Science, Technology, Engineering, and Mathematics (STEM). USRP is one of most highly comprehensive internship programs for undergraduate students within the STEM majors. Students work on practical problems that will see real applications in aerospace or on future NASA missions. These immersive NASA opportunities combine scientific research with professional hands-on engineering. A USRP internship will be the first step toward a career at NASA, or within the science and engineering workforce. USRP internship opportunities are offered year round in the fall, summer, and spring.

The USRP experience is a NASA internship that places qualified undergraduates with outstanding NASA mentors in a challenging working environment. Students from around the country work on a NASA project developed to meet the needs and goals of the NASA Center and Mission Directorate. Through the USRP website students apply for the internship program and NASA mentors select students for available project positions. The USRP website is also a valuable resource of information in regard to NASA internships and NASA Centers and NASA research focus areas.

The NASA Undergraduate Student Research Program is managed for NASA by the Universities Space Research Association in Houston, Texas. The deadline for applying for the summer 2011 program is **February 1, 2011**. For more information, visit *usrp.usra.edu*.

NASA Planetary Science Summer School



NASA is accepting applications from science and engineering post-docs, recent Ph.D.s, and doctoral students for its 23rd Annual Planetary Science Summer School, which will hold two separate sessions this summer at the Jet Propulsion Laboratory in Pasadena, California. This is an intensive one-week team exercise learning the process of developing a robotic mission concept into reality through concurrent engineering. Limited funds are available to provide partial support for travel and lodging. Applications are to be submitted electronically by **April 1, 2011**. Further information is available at *pscischool.jpl.nasa.gov*.

Community College Aerospace Scholars

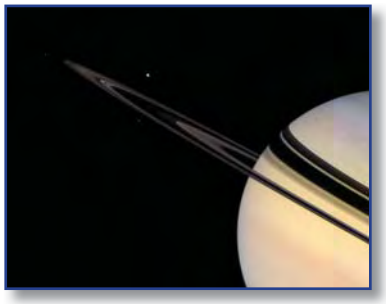
National Aeronautics and Space Administration

AEROSPACE SCHOLARS

Community College Aerospace Scholars is a pilot program funded by NASA's Exploration Systems Mission Directorate (ESMD) and administered by NASA Johnson Space Center (JSC). Community college students from across the nation who are interested in the areas of science, technology, engineering, and mathematics will apply to travel to NASA Johnson Space Center (JSC) for a three-day experience. This opportunity will provide a hands-on project featuring engineering career possibilities. Selected students will begin the semester commitment with web-based preparation prior to visiting JSC. The three-day experience at JSC will allow participants to participate in a team project directed by NASA engineers; attend engineer, scientist, and astronaut briefings; tour NASA JSC facilities; and interact with students from across the United States.

Texas residents should apply at *aerospacescholars.jsc.nasa.gov/CAS/*; the application deadline is **February 8, 2011**. (The deadline for the national program was December 9, 2010; for more information about the national program, go to *aerospacescholars.jsc.nasa.gov/NCAS/*.)

For additional information, visit the websites listed above. Questions about this opportunity should be directed to *jsc-ae-cas@mail.nasa.gov*.



NASA's Planetary Geology and Geophysics Undergraduate Research Program (PGGURP)

Through the PGGURP program qualified undergraduates are paired with NASA-funded investigators at research locations around the United States for eight weeks during the summer. PGGURP's goals are to provide incentive and development of future planetary geoscientists; broaden the base of students who participate in planetary geoscience; introduce students interested in the traditional sciences to planetary science; and give potential planetary geoscientists a chance to explore the exciting field of planetary research. Students will spend the summer at the NASA scientist's home institution, and the program will pay for housing, travel, and a cost-of-living stipend.

The program consists of an eight-week summer internship, in which qualified students are matched with a NASA-funded planetary scientist. Care is taken to match the skills of the student with the needs of the NASA mentor. Internship locations in the past have included the NASA Ames Research Center, the Jet Propulsion Laboratory, the U.S.G.S. Astrogeology Branch in Flagstaff, Arizona, and many others.

The application deadline is **January 28, 2011**. For more information, visit *www.acsu.buffalo.edu/~tgregg/pggurp.html*.

California Institute of Technology Summer Undergraduate Research Fellowships (SURF)

CALTECH

Caltech's Summer Undergraduate Research Fellowships program introduces students to research under the guidance of seasoned research mentors at Caltech and JPL. Students experience the process of research as a creative intellectual activity. SURF is modeled on the grant-seeking process: students

collaborate with potential mentors to define and develop a project; applicants write research proposals for their projects; a faculty committee reviews the proposals and recommends awards; students carry out the work over a 10-week period in the summer, mid-June to late August; and at the conclusion of the program, they submit a technical paper and give an oral presentation at SURF Seminar Day, a symposium modeled on a professional technical meeting.

The deadline for all application materials is **February 22, 2011**. For more information, visit *www.surf.caltech.edu*.

Research Experiences for Undergraduates (REU) Program, American Museum of Natural History

This program, funded by the National Science Foundation, offers the opportunity of a summer internship, complete with stipend, and additional funds for subsistence, for qualified undergraduates to pursue specific projects in conjunction with Museum scientists in the physical sciences. Included in the program are a general orientation to the Museum; a series of weekly meetings at which students will discuss their research, present informal progress reports, and participate in discussions and seminars; as well as graduate and research career opportunities. At the conclusion of the internship, students deliver oral presentations of their work, and prepare publication-quality research papers.

The application deadline is **February 1, 2011**. For more information, visit *rggs.amnh.org/pages/academics_and_research/fellowship_and_grant_opportunities#reu*.

SAO Summer Intern Program

The Smithsonian Astrophysical Observatory (SAO) Summer Intern Program is a nine- or ten-week-long program, depending on the availability of Harvard housing. In 2011 the program will run from June 5 through August 13. The program is funded by the National Science Foundation and the Smithsonian Institution. Undergraduate students interested in a career in astronomy, astrophysics, physics, or related physical sciences are encouraged to apply.

The application deadline is **February 1, 2011**. For more information, visit *hea-www.harvard.edu/REU/REU.html*.

Registration Open for 2011 NASA Lunabotics Mining Competition

NASA is challenging U.S. and international undergraduate and graduate student teams to design and build a remote-controlled or autonomous excavator that could be used on the Moon. The excavator must be able to collect and deposit a minimum of 10 kilograms (22 pounds) of lunar simulant in 15 minutes.

Design teams must include one faculty advisor from a college or university and two or more undergraduate or graduate students. A group of universities may work in collaboration, and multidisciplinary teams are encouraged.

Selected teams will compete in the Lunabotics Mining Competition at NASA's Kennedy Space Center in Florida on May 23–28, 2011.

Teams must apply no later than **February 28, 2011**. A limited number of teams will be allowed to compete. For more information about the competition and to apply online, visit *www.nasa.gov/lunabotics*.

NASA Minority Innovation Challenges Institute

The mission of the Minority Innovation Challenges Institute (MICI) is to create a virtual training ground where minority undergraduate students learn how to compete in NASA technical challenges for both prestige and significant cash prizes. This NASA-funded program, which is managed by Florida Agricultural & Mechanical University (FAMU), provides a year-round virtual conference platform where students from across the country can participate in free interactive educational sessions of their choosing.

Many of the sessions will focus on competitions found within NASA's Centennial Challenges program, which provides cash prizes ranging from $50,000 to $2 million to individuals/teams that can achieve specific technical accomplishments. Centennial Challenges is modeled after numerous historic exploration contests, including the Orteig Prize won by Charles Lindbergh and the Ansari X Prize won by Burt Rutan.

In addition to Centennial Challenges, students will also learn how to compete in other NASA-sponsored competitions created specifically for universities, including the Fundamental Aeronautics Student Competition for Colleges/Universities, NASA University Student Launch Initiative, University Business Plan Contest for Engineering Technology, and Great Moonbuggy Race (see below).

The goal of MICI is to use NASA technical competitions as a way to inspire minority undergraduate students to pursue (1) an advanced degree in Science, Technology, Engineering, and Mathematics (STEM) and (2) a career in STEM-related disciplines that will ultimately contribute to NASA's future technological needs.

Registration to MICI is always open throughout the year. There are no cut-off dates because new content is being featured each month. For more information, visit *nasamici.com*.

NASA Wants Student Innovators for 2011 Great Moonbuggy Race

Four decades after the first NASA lunar rover rolled across the surface of the Moon, innovative students are preparing to design and build a new generation of wheeled wonders.

Registration is open for the 18th annual NASA Great Moonbuggy Race, set for April 1–2, 2011, in Huntsville, Alabama. Participating schools and institutions may register one or two vehicles and teams. Registration closes **February 1, 2011**.

NASA's Marshall Space Flight Center organizes the races held at the U.S. Space & Rocket Center, both in Huntsville. The event challenges high school and college students to design, build, and race lightweight, human-powered "moonbuggies."

The first rover was developed, built, and tested at Marshall in just 17 months. The rover's inaugural trip across the Moon's surface took place on July 31, 1971. It was driven by Apollo 15 astronauts David Scott and James Irwin. Two more rovers followed, enabling expanded scientific exploration during the Apollo 16 and 17 missions in 1972.

NASA Great Moonbuggy Race teams carry on the tradition of engineering ingenuity. The teams attempt to post the fastest vehicle assembly and race times in their divisions, while incurring the fewest penalties on a challenging course simulating the rocky, unforgiving surface of the Moon.

Prizes are awarded to the three teams in each division that finish with the fastest race times. NASA and industry sponsors present additional awards for team spirit, best newcomer, most memorable buggy wipeout, and other achievements.

In 2010, for the first time, the victors in the high school and college divisions were both from outside the continental United States. The International Space Education Institute of Leipzig, Germany, raced to a winning time of just 3 minutes, 37 seconds in the high school category. The University of Puerto Rico in Humacao, the only school to enter a moonbuggy every year since the races began in 1994, won the college division with a time of 4 minutes, 18 seconds.

Participation in the race has increased from just eight college teams in 1994 to more than 70 high school and college national and international teams in 2010. The high school division was added in 1996.

For complete rules, vehicle design parameters, and registration for the race, visit *moonbuggy.msfc.nasa.gov.*

2011 NASA Academies for College Students

The NASA Academies offer a ten-week summer experience for college students with emphasis on immersive and integrated multidisciplinary exposure and training. Activities include laboratory research, a group project, lectures, meetings with experts and administrators, visits to NASA centers and space-related industries, and technical presentations.

The existing NASA Academies include:

- **NASA Space Academy** at Ames Research Center, Glenn Research Center, Goddard Space Flight Center, and Marshall Space Flight Center, with emphasis on space exploration.
- **NASA Lunar and Planetary Science Academy** at Goddard Space Flight Center, with focus on lunar and planetary science mission design and operation, among others.
- **NASA Propulsion Academy** at Marshall Space Flight Center, for those with interest in propulsion careers.
- **NASA Robotics Academy** at Marshall Space Flight Center, with an emphasis on robotics.

New for the upcoming 2011 summer opportunity will be the **NASA Aeronautics Academy** at Glenn Research Center and Langley Research Center. U.S. citizens with majors in aeronautical or aerospace engineering, or related engineering and science disciplines, are eligible to apply.

To be eligible for any of the NASA Academies, students must be rising juniors or seniors at the undergraduate level or be at the early graduate level in an accredited U.S. college or university. Applications are due **January 18, 2011**. For more information and to apply online, visit *https://www.academyapp.com/*.

NASA Earth and Space Science Fellowship Program Accepting Proposals for 2011–2012 Academic Year (Deadline February 1)

This call for graduate fellowship proposals, entitled NASA Earth and Space Science Fellowship (NESSF) Program — 2011–2012 Academic Year, solicits applications from accredited U.S. universities on behalf of individuals pursuing master's or doctoral (Ph.D.) degrees in Earth and space sciences, or related disciplines. The purpose of NESSF is to ensure continued training of a highly qualified workforce in disciplines needed to achieve NASA's scientific goals. Awards resulting from the competitive selection will be training grants to the respective universities, with the advisor serving as the principal investigator. The financial support for the NESSF program comes from the Science Mission Directorate's four science divisions. Questions about this opportunity should be directed to Ming-Ying Wei (*mwei@nasa.gov*) for Earth science and to Dolores Holland (*hq-nessf-Space@nasa.gov*) for heliophysics, planetary science, and astrophysics. To view the entire solicitation, visit *http://nspires.nasaprs.com/external/solicitations/summary.do?method=init&solId=%7B6803E463-A6EF-3164-F103-A1E4178E430D%7D&path=open*.

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.

Dr. Paul Schenk,
Scientific Editor (*schenk@lpi.usra.edu*)

Renée Dotson,
Production Editor (*rdotson@hou.usra.edu*)

Copy deadline for the next issue: February 15, 2011

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NASA and Gowalla Launch Partnership with Search for Moon Rocks

NASA and Gowalla, a mobile and web service, have partnered to bring users one small step closer to the universe. The partnership populates Gowalla with NASA-related information and four virtual items — Moon rocks, a NASA patch, a spacesuit, and a space shuttle — that can be found at agency-related venues. "NASA's partnership with Gowalla is a creative way for us to reach out and share information about what the nation's space agency is doing," said Bob Jacobs, NASA's deputy associate administrator for communications at NASA Headquarters.

Gowalla users who virtually "check in" at NASA-related venues and places of discovery via their smart phone have a chance to find the four agency virtual items, which can be swapped for other items, dropped in locations, or kept in their vault. Anyone with a Gowalla account who collects three of the four items will receive a special pin in their Gowalla Passport. In addition, the first 100 people to collect three items will win the special edition NASA+Gowalla Map: Search for the Moon Rocks by JESS3, a creative agency that specializes in data visualization.

"Gowalla's mission is to inspire discovery by connecting people with the places around them," said Andy Ellwood, director of business development for Gowalla. "Space is one of the most interesting places for human exploration, and this partnership with NASA encourages our community to visit places in their world to learn more about our universe."

The partnership enables a NASA account and an account for astronaut Mike Massimino linked to the agency's primary Twitter account, @NASA, and Massimino's Twitter account, @Astro_Mike. NASA and Massimino also will drop virtual items for users to find and collect throughout the nation.

Gowalla users can find virtual Moon rocks by checking into any location where a real one is on display. The United States successfully brought lunar samples back to Earth during the Apollo 11, 12, 14, 15, 16, and 17 missions. NASA provides a number of lunar samples for display at museums, planetariums, and scientific expositions around the world. Most lunar displays are open to the public.

Gowalla users can find the virtual NASA patch, spacesuit, and space shuttles by checking in to NASA visitor centers, agency-related locations, or one of the more than 400 museums, science centers, planetariums, observatories, parks, nature centers, zoos, and aquariums that are part of NASA's Museum Alliance.

To view the map and connect with NASA and @Astro_Mike on Gowalla and other social media applications, visit ***www.nasa.gov/connect***. Gowalla is available on iPhone, Blackberry, Android, Palm, and the iPad. For more information about Gowalla, visit ***www.gowalla.com***. For information about lunar sample display locations, visit ***curator.jsc.nasa.gov/lunar/displays/displays.cfm***. For more information about NASA's Museum Alliance, visit ***https://informal.jpl.nasa.gov/museum***.

"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.

LPSC Education Oral and Poster Abstracts Due

The 42nd Lunar and Planetary Science Conference will be held at The Woodlands Waterway Marriott Hotel and Convention Center, The Woodlands, Texas, March 7–11, 2011. Planetary science E/PO specialists are invited to submit abstracts to share their innovative programs, projects, and results. *Although the submission form indicates that Education/Public Outreach topics are "Posters Only," please indicate in the comments box if you would be interested in giving an oral presentation.*

This conference brings together international specialists in petrology, geochemistry, geophysics, geology, and astronomy to present the latest results of research in planetary science. The five-day conference will be organized by topical symposia and problem-oriented sessions. The abstract deadline is **Tuesday, January 4, 2011, 5:00 p.m.** U.S. Central Standard Time (GMT-6).

For more information about the conference, visit *www.lpi.usra.edu/meetings/lpsc2011/*.

LPSC Planetary Science Education Share-a-Thon

We've all got them — content or concept challenges in our introductory or upper division planetary science courses. Maybe you have the solution? If you have a resource, demo, activity, visualization, lab, or computer interactive that you have either developed or found that solves a content or concept challenge in your classroom, share it with your community! The Planetary Science E/PO Forum is hosting a half-day workshop for undergraduate teaching faculty in planetary sciences on Sunday, March 6, 2011, at the Lunar and Planetary Science Conference.

The goals of the workshop are to:

- share resources and strategies for teaching planetary science to undergraduates
- use a new online clearinghouse tool for sharing course materials (content, syllabi, laboratories, etc.)
- continue to develop a collaborative network of undergraduate teaching faculty in planetary sciences

If you have something to share or are just interested in attending, please RVSP to Emily CoBabe-Ammann at *ecobabe@spaceeducation.org*.

YEAR OF THE
SOLAR SYSTEM

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, ice, life — weaving together activities, resources, and ideas that teachers, clubs, and organizations can use to engage audiences. Explore everything the Year of the Solar System has to offer at *solarsystem.nasa.gov/yss*.

The theme for January is *A Family Affair!* Our solar system is a family of planets, dwarf planets, comets, and asteroids orbiting our Sun. They share many common features, but each has unique personality traits.

February's theme is *Small Bodies — Big Impacts*. Some of the smallest bodies in our solar system have had the biggest impact on our understanding of how the solar system formed.

March honors Sun-Earth Day with the theme *Ancient Astronomers/Modern Tools*. Our ancestors were skywatchers, making careful observations of the Sun and Moon, making drawings and paintings and keeping count of changes on sticks and tablets. Today, our robotic bridges reach much further, giving us a better understanding of the cosmos, and of ourselves.

NEW! 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*.

Eugene M. Shoemaker Impact Cratering Award

The Vredefort structure is located near the center of the Witwatersrand Basin, about 100 kilometers from Johannesburg. Formed about 2 billion years ago, it is the oldest and largest recognized impact structure on Earth. Credit: NASA.

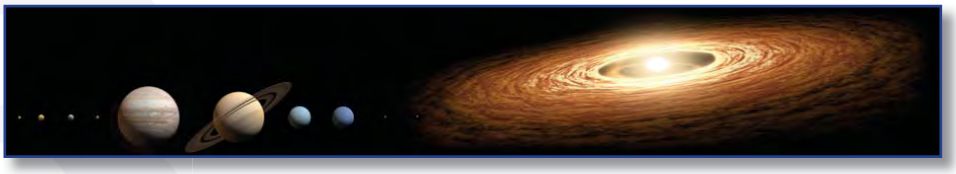
The Lunar and Planetary Institute (LPI) is pleased to announce that the 2010 recipient of the Eugene M. Shoemaker Impact Cratering Award is Timmons Erickson of the University of Puerto Rico Mayaguez. Erickson is pursuing a masters' degree and is studying the erosion of shocked minerals from the Vredefort structure and their deposition in sediments as a function of distance from the impact site. This unique sedimentary provenance study is designed to assist interpretations of shocked minerals in ancient sediments where all other remnants of the impact event have been erased from the geologic record. Erickson's thesis advisor is Aaron Cavosie, and he is working with additional collaborators at the University of Wisconsin at Madison.

The Eugene M. Shoemaker Impact Cratering Award is designed to support undergraduate and graduate students, of any nationality, working in any country, in the disciplines of geology, geophysics, geochemistry, astronomy, or biology. Grants support the study of impact cratering processes on Earth and other bodies in the solar system, including asteroids and comets that produce impacts and the geological, chemical, or biological results of impact cratering.

This award is generously provided by the Planetary Geology Division of the Geological Society of America and administered by the LPI. It commemorates the work of Eugene ("Gene") Shoemaker, who greatly influenced planetary sciences during the Apollo era and for several decades thereafter, including the discovery of Comet Shoemaker-Levy 9 with his wife Carolyn and colleague David Levy.

Proposals for next year's award will be due September 9, 2011. Application details can be found at *https://www.lpi.usra.edu/Awards/shoemaker/*.

Other Award Winners for GSA's Planetary Geology Division



Dr. Carle M. Pieters of Brown University has been selected as the 2010 winner of the *G. K. Gilbert Award*. This award is presented annually by the Planetary Geology Division of the Geological Society of America for outstanding contributions to the solution of fundamental problems in planetary geology in the broadest sense, which includes geochemistry, mineralogy, petrology, geophysics, geologic mapping, and remote sensing. Such contributions may consist either of a single outstanding publication or a series of publications that have had great influence in the field. The award is named for the pioneering geologist G. K. Gilbert.

The *Dwornik Award* was started in 1991 with a generous endowment by Dr. Stephen E. Dwornik, who wished to encourage U.S. students to become involved with NASA and planetary science. The Award consists of a plaque and a monetary award given for the best student presentations (poster and oral) or a plaque for honorable mentions (poster and oral) at the annual Lunar and Planetary Science Conference

(LPSC) hosted by the Lunar and Planetary Institute (LPI). The awards are managed and judged by the Planetary Geology Division of the Geological Society of America.

The 2010 Dwornik Award winners are:

Best Graduate Oral Presentation: Erin Shea (Massachusetts Institute of Technology)
Best Graduate Poster: Kelsi Singer (Washington University)
Best Undergraduate Oral: Jacob Richardson (Eastern Michigan University)
Best Undergraduate Poster: Cameron Mercer (Middlebury College)

Vishnu Reddy of the University of North Dakota has been named the winner of the *Pellas-Ryder Award for Best Student Paper in Planetary Sciences.* This award, which is jointly sponsored by the Meteoritical Society and the Planetary Geology Division of the Geological Society of America, is awarded to an undergraduate or graduate student who is first author of the best planetary science paper published in a peer-reviewed scientific journal during the year prior to the award. Any first author of a paper published on a topic listed on the cover of *Meteoritics & Planetary Science* who was a student when the paper was submitted is eligible for consideration for this award. The award has been given since 2001, and honors the memories of meteoriticist Paul Pellas and lunar scientist Graham Ryder.

NASA Awards Grants for High School Science Education

By a wide margin, NASA placed first in a study that ranks 100 public sector organizations in the NASA will award about $4 million in grants to public school districts, state-based education leadership, and not-for-profit education organizations to support academic excellence in science, technology, engineering, and mathematics (STEM) education. The first round of awards is valued at $3.1 million. Each award is expected to leverage NASA's unique contributions in STEM education, enhance secondary students' academic experiences, and improve educators' abilities to engage their students.

A total of eight proposals were selected for funding to school districts and organizations in California, Maine, New York (2), North Carolina, Ohio, Oklahoma, and Texas. The selected proposals illustrate innovative approaches to using NASA-themed content in support of secondary-level teaching and learning, with a particular emphasis on high school education. The proposals were selected through a two-step process, merit-based, peer-reviewed competition. The awards have a two-year period of performance, and range in value from $350,000 to $400,000.

The Summer of Innovation Capacity Building Awards are valued at $1 million. They will be shared among institutions that showed student participation in summer learning experiences helped academic performances in the following school year. The Summer of Innovation Capacity Building effort also looked for programs with the potential to be a model for middle school education. Each funding proposal leverages NASA content in STEM education to build successful programs with a special interest in reaching underserved students and strengthening the bridge between out-of-school and in-school learning programs.

There were 16 proposals selected for funding representing the District of Columbia and these 13 states: California, Connecticut, Florida, Georgia (2), Maryland, Massachusetts, Nebraska, New Mexico, Oregon, Texas, Virginia (2), Washington, and Wisconsin. For a list of selected proposals in both of these award categories, visit *nspires.nasaprs.com*. For information about the NASA Education program, visit *www.nasa.gov/education*.

NASA Funds Nationwide High School Student Robotics Program

NASA is providing up to $20 million over the next five years to support a national program to inspire student interest in science, technology and mathematics with a focus on robotic technology. The funding is part of a cooperative agreement with the Foundation for Inspiration and Recognition of Science and Technology (FIRST), a nonprofit organization in Manchester, New Hampshire. FIRST provides students the opportunity to engage with government, industry, and university experts for hands-on, realistic exposure to engineering and technical professions.

"This is the largest NASA-funded student program geared toward robotics activities," said NASA Administrator Charles Bolden. "For the next five years, approximately 25,000 students across the country will not only learn from our nation's best and brightest, but also compete and have fun at the same time."

The centerpiece of the program is the annual FIRST Robotics Competition. During more than 45 regional competitions, teams of high school students have six weeks to build a robot using an identical kit of parts. There are dimension and weight limitations and other technical restrictions, but teams can determine the look and function of the robots. The regional competitions culminate with an international championship in April. The competition is structured like an athletic event. Teams compete in an area the size of a small basketball court. The robots must have offensive and defensive capabilities. Each team's robot works to accomplish a task, while preventing its opponent from doing the same. The robots must be sturdy because of frequent contact between the machines.

NASA's Robotics Alliance Project (RAP) solicited proposals October 4 from nonprofit and educational institutions to design and administer a robotics outreach competition. RAP, which is sponsored by NASA's Science Mission Directorate and managed from NASA's Ames Research Center, competitively selected FIRST from the candidates.

During the past 16 years, RAP has issued approximately $40 million to academic and nonprofit organizations across the nation to stimulate intellectual capability in fields tied to robotics engineering. All 10 NASA centers participate in RAP by contributing technology expertise, funding, and other resources. NASA is the largest organization involved with FIRST and has participated since 1995. In 1999, NASA and First signed a memorandum of agreement to cooperatively expand the availability of technology development, education and inspiration programs to students throughout the country.

U.S. entrepreneur Dean Kamen founded FIRST in 1989 to encourage youth to become leaders in science and technology. For more information about NASA's Robotics Alliance Project, visit *robotics.nasa.gov*.

NASA Selects Community College Students to Design Rovers and Explore Technology Careers at Field Centers

Community college students in a pilot program will take the first steps toward potential technology careers as they develop robotic explorers at NASA field centers. Ninety students from community colleges in 23 states have been selected to travel to NASA's Johnson Space Center or the Marshall Space Flight Center for hands on experience with technology development and direct interaction with NASA experts.

During the summer, students enrolled in the National Community College Aerospace Scholars pilot program completed four web-based assignments that explored topics in engineering and technology. Those whose grades on the projects averaged at least 94% qualified to participate in the NASA field

center experience, with the agency paying students' travel expenses. Students will apply what they have learned during the year to technology and design problems in consultation with NASA engineers.

"Community colleges are an important part of the academic landscape, and NASA is proud to be working with these students to continue their interest and skills in science, technology, engineering, and mathematics," said NASA Administrator Charles Bolden. "This innovative project gets students engaged in actual engineering design and production — from concept to build-out — that simulates the processes NASA uses in designing robotic explorers for solar system destinations. By letting them experience first-hand the challenges and excitement inherent in space exploration, we may be cultivating NASA's workforce of tomorrow."

While at the NASA centers, participants will form teams to establish Mars exploration "companies." Each team will develop a prototype rover, design a line drawing of their vehicle, and form a company infrastructure, including a budget and communications plan. The students also will tour center facilities and attend presentations by astronauts and other NASA technology experts about their work and careers. The National Community College Aerospace Scholars pilot program is based on the Texas Aerospace Scholars program. Both programs are designed to encourage community and junior college students to enter careers in science and engineering and join the nation's high technology workforce. For a complete list of the students selected and the community colleges they represent, visit *www.nasa.gov/offices/education/programs/descriptions/National_Community_College_Aerospace_Scholars.html*.

NASA Announces Launch of Human Health and Performance Center

NASA has established a global forum for organizations interested in advancing human health and performance innovations in space and on Earth. NASA's Human Health and Performance Center (NHHPC) will give members an opportunity to collaborate, network, and share information. NHHPC members include NASA centers and partners, industry, academic institutions, government agencies, and nonprofit organizations. Members will work together to advance human health and performance innovations for spaceflight, commercial aviation, and any challenging environment on Earth.

"The NHHPC provides a collaborative forum for many diverse organizations to develop innovative approaches to human health and performance issues in challenging environments," said Jeffrey R. Davis, M.D., director of the NHHPC and director of the Space Life Sciences Directorate at NASA's Johnson Space Center in Houston. "The NHHPC offers an opportunity to share knowledge and best practices and to develop projects so that member organizations can collaborate in addressing those issues most important to them."

NHHPC's first event will be a workshop titled "Collaborative Innovation: Strategies and Best Practices," which is scheduled for January 19 in Houston. NHHPC members and guest speakers will address how to use various innovative approaches to achieve member organizations' goals. A WebEx broadcast of keynote speakers will be available.

For more information on the NHHPC's goals and objectives, member organizations, upcoming events, and proposed themes, visit *nhhpc.nasa.gov*.

NASA Selects Astronaut Leland D. Melvin to Lead Office of Education

NASA Administrator Charles Bolden announced the selection of Leland D. Melvin as the agency's new associate administrator for education. He succeeds James L. Stofan, who had served in an acting capacity since the spring.

Since April 2010, Melvin has been assigned to the Office of Education at Headquarters leading the Education Design Team. His job was to develop a strategy to improve NASA's education offerings and to assist the agency in establishing goals, structures, processes and evaluation techniques to implement a sustainable and innovative science, technology, engineering and math (STEM) education program. He also served as the partnership development manager for the agency's new Summer of Innovation education initiative, aimed at engaging middle school students in STEM activities during the summer break.

As associate administrator, Melvin will be responsible for the development and implementation of the agency's education programs that strengthen student involvement and public awareness about NASA's scientific goals and missions. "My passion for education was inspired by my parents, who were both middle school teachers," Melvin said. "I witnessed the direct impact that educators can have in a community and on an individual's destiny. NASA's people, programs, and resources are unparalleled. Our unique assets are poised to engage students, to captivate their imagination, and to encourage their pursuit of STEM-related studies that are so vital to their future. This is an exciting challenge and I am ready to work with Administrator Bolden, my colleagues at NASA, our partners, and students across the country to usher in a new era of opportunity to inspire that next generation of explorers."

Melvin joined NASA in 1989 as an aerospace research engineer at the agency's Langley Research Center. He joined the astronaut corps in 1998 and has served as a mission specialist on two space shuttle missions, logging more than 565 hours in space. In 2003, Melvin co-managed the former Educator Astronaut Program, which recruited teachers to become fully-trained astronauts in an effort to connect space exploration with students across the country.

Credit: Harold Dorwin

Brian Marsden

Dr. Brian Geoffrey Marsden passed away Thursday, November 18, at the age of 73 following a prolonged illness. Marsden was born on August 5, 1937, in Cambridge, England. His father, Thomas, was the senior mathematics teacher at a local high school. It was his mother, Eileen (nee West), however, who introduced him to the study of astronomy, when he returned home on the Thursday during his first week in primary school in 1942 and found her sitting in the back yard watching an eclipse of the Sun. Using now-frowned-upon candle-smoked glass, they sat watching the changing bite out of the Sun. What most impressed the budding astronomer, however, was not that the eclipse could be seen, but the fact that it had been predicted in advance, and it was the idea that one could make successful predictions of events in the sky that eventually led him to his career. When, at the age of 11, he entered the Perse School in Cambridge, he was already developing primitive methods for calculating the positions of the planets. He soon realized that earlier astronomers had come up with more accurate procedures for doing this over the centuries, and during the next couple of years this led to his introduction to the library of the Cambridge University Observatories and his study of how eclipses, for example, could be precisely computed.

At the age of 16 he joined and began regularly attending the monthly London meetings of the British Astronomical Association. He quickly became involved with the Association's Computing Section, which was known specifically for making astronomical predictions other than those that were routinely being prepared by professional astronomers for publication in almanacs around the world. Under the watchful eyes of the director and assistant director of the Computing Section, this led him to prepare and publish predictions of the occasions when one of Jupiter's moons could be seen to pass directly in front of another. He also calculated the gravitational effects of the planets on the dates and sky positions of the returns of some periodic comets. He carried out these computations using seven-place logarithms. During his last year of high school he also became a junior member of the Royal Astronomical Society.

Marsden was an undergraduate at New College, University of Oxford. By the time he received his undergraduate degree, in mathematics, he had already developed somewhat of an international reputation for the computation of orbits of comets, including new discoveries, and spent part of his first two undergraduate summer vacations working at the British Nautical Almanac Office. After Oxford, he took up an invitation to cross the pond and work at the Yale University Observatory. With the ready availability of the university's IBM 650 computer in the observatory building, he had soon programmed it to compute the orbits of comets. Recalling his earlier interest in Jupiter's moons, he completed the requirements for his Ph.D. degree with a thesis on "The Motions of the Galilean Satellites of Jupiter." At the invitation of director Fred Whipple, he joined the staff of the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, in 1965. Whipple was probably best known for devising the "dirty snowball" model for the nucleus of a comet a decade and a half earlier. At that time there was only rather limited evidence that the motion of a comet was affected by forces over and above those of gravitation (limited because of the need to compute the orbit by hand), and the Whipple model had it that those forces were due to the comet's reaction to vaporization of the cometary snow or ice by solar radiation. Marsden therefore developed a way to incorporate such forces directly into the equations that governed the motion of a comet.

A series of astronomical discoveries that greatly interested Marsden were what he always called the "transneptunian objects," although many of his colleagues have insisted on calling them "objects in the Kuiper belt." When what those same colleagues considered to be the first of these was discovered in 1992, Marsden immediately remarked that this was untrue, because Pluto, discovered in 1930 and admittedly

somewhat larger in size, had to be the first. More specifically, he was the first to suggest, correctly, that three further transneptunian objects discovered in 1993 were exactly like Pluto in the sense that they all orbit the Sun twice while Neptune orbits it thrice. This particular recognition set him firmly on the quest to "demote" Pluto. Success required the discovery of transneptunian objects more comparable to Pluto in size, something that finally happened in 2005 with the discovery of the object that came to be known as Eris. At its triennial meeting in 2006 in Prague, the IAU voted to designate these objects, together with two further transneptunian objects now known as Makemake and Haumea, as well as the largest asteroid, Ceres, members of a new class of "dwarf planet." It was also at the IAU meeting in Prague that Marsden stepped down as MPC director, and he was quite entertained by the thought that both he and Pluto had been retired on the same day.

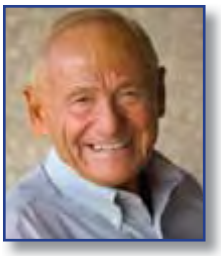
Marsden served as an associate director of the Harvard-Smithsonian Center for Astrophysics for more than 15 years; he was chair of the Division of Dynamical Astronomy of the American Astronomical Society during 1976–1978 and president of the IAU commissions that oversaw the operation of the minor Planet Center (1976–1979) and the Central Bureau for Astronomical Telegrams (2000–2003). He continued to serve subsequently on the two solar system nomenclature committees of the IAU, being the perennial secretary of the one that decides on names for asteroids. He also continued to publish a "Catalogue of Cometary Orbits," the first of these having appeared in 1972 and its successors roughly at intervals of two years. Among the various awards he received from the U.S., the U.K., and a handful of other European countries, the ones he particularly appreciated were the 1995 Dirk Brouwer Award (named for his mentor at Yale) of the AAS Division on Dynamical Astronomy and the 1989 Van Biesbroeck Award (named for an old friend and observer of comets and double stars), then presented by the University of Arizona, now by the AAS, for service to astronomy.

Credit: John Wood.

Ralph Baldwin

Dr. Ralph Belknap Baldwin died peacefully on October 23, 2010, at age 98. He was a Naples, Florida, resident since retiring in 1984 as Chairman of the Board of the Oliver Machinery Company in Grand Rapids, Michigan. Born on June 6, 1912, he graduated from the University of Michigan with a B.S. in 1934, an M.S. in 1935, and a Ph.D. in Astronomy (Physics) in 1937. He taught astronomy at the Universities of Michigan, Pennsylvania, and Northwestern. Baldwin received three honorary degrees, an LLD from Michigan in 1975, an ScD from Grand Valley State University in 1989, and an ScD from Aquinas College in 1999. During World War II he was a Senior Physicist at the Applied Physics Laboratory of Johns Hopkins University, helping develop the radio proximity fuze. After the war he returned to Grand Rapids and joined Oliver Machinery Company where he became its President in 1970.

Baldwin's most important work was in astronomy. His studies proved that the craters on the Moon were produced by the impacts of large and small asteroid-like bodies rather than volcanic in origin. Baldwin's early work culminated in his book, *The Face of the Moon* (1949), which may properly be considered the generating force behind modern research in both terrestrial impact craters and lunar surface features. He followed up his original work with a second book, *The Measure of the Moon*, in 1965. Baldwin was a Fellow in the Meteoritical Society, the American Geophysical Union, the American Association for the Advancement of Science, and the American Academy of Arts and Sciences. The Royal Astronomical Society of Canada made him an Honorary Member. He was one of only two scientists who have received both the Barringer and the Leonard Medals from the Meteoritical Society, and was the first to receive both the Leonard Medal from the Meteoritical Society and the G. K. Gilbert Award from the Geological Society of America in the same year. (That has only happened one other time since, when Michael Gaffey won both awards 20 years later, in 2006.) He also received the J. Lawrence Smith Medal from the National Academy of Sciences.



Credit: California Institute of Technology.

Thomas J. Ahrens

Thomas J. Ahrens, a geophysicist who pioneered the academic use of shock waves to study minerals under high temperatures and pressures such as those found at the center of the Earth, died on November 24 at his home in Pasadena, California. He was 74 years old.

Ahrens received his B.S. from the Massachusetts Institute of Technology in 1957, his M.S. from Caltech in 1958, and his Ph.D. from Rensselaer Polytechnic Institute in 1962. He was a geophysicist with the Pan American Petroleum Corporation from 1958 to 1959, worked as a Second Lieutenant for the U.S. Army in the Ballistics Research Laboratory from 1959 to 1960, and was the Head of the Geophysics Section in the Poulter Laboratory of the Stanford Research Institute from 1962 to 1967. He became an Associate Professor of Geophysics at the California Institute of Technology (Caltech) in 1967 and Professor of Geophysics in 1976. From 1996 to 2001 he was the W.M. Keck Professor of Earth Sciences and then Fletcher Jones Professor of Geophysics, Emeritus in 2005.

Ahrens' research encompassed a wide range of geophysical disciplines, including the dynamic properties of minerals and other materials, the effects of impacts on minerals, Earth and planetary crusts, shock temperatures and melting, planetary impacts, and the thermodynamics of Earth materials. His experiments gave a clearer picture of the Earth's core and of how cratering occurred on objects throughout the solar system.

Ahrens' measurements in the 1980s that suggested the temperature of iron in the core of the Earth were surprisingly high and very controversial, but have over time been replicated and confirmed by other laboratories. His observations on the aftereffects of impacts led to a number of influential papers. One paper, for example, questioned the prevailing theory that Earth arose from the accretion of many impacts. If that had occurred, he said, where did water and other atmospheric gases come from? Each impact would have blown those lighter elements into space. The only possible explanation, he wrote, was that icy comets must have brought water and air after the body of the Earth was formed.

Ahrens and geophysicist Manfred Lange shot steel bullets into rocks at high speeds to simulate the asteroid that researchers believe caused the extinction of dinosaurs 65 million years ago. They found that the impact on limestone released tremendous amounts of carbon dioxide that would have warmed the planet by 9° to 36°F for as long as 10,000 years, wiping the creatures out through a massive greenhouse effect.

Based on other experiments, Ahrens and geophysicist John D. O'Keefe also concluded that the object that flattened trees in a 20-mile circle in Tunguska, Russia, in 1908 was a low-density comet, not an asteroid as others had widely believed.

Ahrens was a strong believer in training the next generation, and leaves a lasting legacy with the more than 30 graduate students and more than 15 postdocs and visiting associates he supervised during his years at Caltech. He published nearly 400 papers, owns 3 U.S. Patents, and received numerous honors and awards for his research. He was a member of the U.S. National Academy of Sciences, the American Academy of Arts and Sciences, and a Foreign Associate of the Russian Academy of Sciences. He won the 1995 Arthur L. Day Medal of the Geological Society of America, the 1996 Harry H. Hess Medal of the American Geophysical Union, the 1997 Barringer Medal of the Meteoritical Society, and had an asteroid named after him.

Credit: NASA.

Clarence "Sy" Syvertson

Clarence A. "Sy" Syvertson, former Director of the NASA Ames Research Center from 1977 to 1984, died on September 13. He was 84.

Syvertson was an exemplary scientist and a dynamic and innovative leader who began his career at Ames in 1948 and matched his theoretical insights on hypersonic airflows with brilliant experimental work. He led the 3.5-foot hypersonic wind tunnel branch and developed advanced vehicles such as the XB-70 Valkyrie and the M2 lifting bodies. His fundamental work on reentry vehicles contributed to the design of the space shuttle. He served as Director of Astronautics and during the tenure of former Ames Center Director Hans Mark from 1969 to 1977 as Center Deputy Director.

Under his leadership, NASA Ames continued to blossom as a world-class research organization. Ames people did groundbreaking research on vertical-lift aircraft, built the world's largest wind tunnel, flew the Kuiper Airborne Observatory, consolidated its collaboration with NASA Dryden, and prepared the Galileo Probe for its journey to Jupiter. Syvertson was elected to the NASA Ames Hall of Fame, was a member of the National Academy of Engineering and a Fellow of the AIAA, and won many awards for his service to NASA and to space exploration.

Donald Hunten

On December 14, 2010, Don Hunten passed away after a long illness. During his last days, he was tended with loving care by his wife and colleague, Ann Sprague.

Hunten's scientific career began with the study of physics at McGill University, where he obtained a doctorate in 1950. While a faculty member at the University of Saskatchewan his research concentrated on the study of aurorae. By 1963, however, the space age was starting in earnest. At the invitation of Joe Chamberlain, he moved to Kitt Peak National Observatory in Tucson (now NOAO) to join the newly formed space research group and his main interests switched to the study of planetary atmospheres. He thus joined the first group of pioneers in the scientific exploration of the solar system and he was to be a leading figure in this community for nearly half a century.

The accomplishments of these pioneers were remarkable, including the first characterizations of the atmospheres in our solar system along with development of the basic understanding of the structure and chemistry of these atmospheres and the experimental and theoretical tools used to study them. Many of the ideas developed during that time are still with us today, and Hunten's contributions were central to their development. A signature achievement during this phase of his career was an understanding of how odd hydrogen chemistry stabilized the atmosphere of Mars against destruction by photodissociation. Hunten moved to the Lunar and Planetary Laboratory of the University of Arizona in 1974, and his involvement in planetary research continued unabated. He also taught numerous students and post doctoral associates. Hunten retired in 2001, but remained active until recently. He received many honors during his career, including induction into the National Academy of Sciences, the Kuiper Prize of the Division of Planetary Sciences of the American Astronomical Society, and a Regents' Professorship at the University of Arizona. *(Text and photo courtesy of the Lunar and Planetary Laboratory, University of Arizona.)*

Books

Exoplanets.

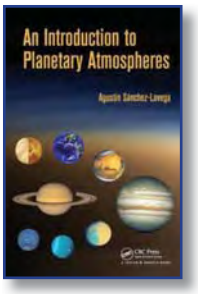
By Sara Seager. University of Arizona Press, 2010. 500 pp., Hardcover, $35.00. *www.uapress.arizona.edu*

For the first time in human history, we know for certain that planets exist around other stars. Now the fastest-growing field in space science, the time is right for this fundamental source book on the topic that will lay the foundation for its continued growth. *Exoplanets*, the latest title in the University of Arizona Press Space Science Series, serves as both an introduction for the nonspecialist and a foundation for the techniques and equations used in exoplanet observation by those dedicated to the field.

The Wright Stuff.

By Derek Webber. Apogee Books, 2010. 320 pp., Paperback, $25.95. *www.cgpublishing.com*

As the new industry of space tourism begins its rapid expansion phase with the introduction of Sir Richard Branson's Virgin Galactic spaceflights in late 2010/early 2011, the reader of this book will gain an understanding of how it reached this point. The story, told through a well-selected collection of photographs, is of a succession of developments and risk-taking that goes back a century to the almost simultaneous start of both aviation and rocketry. The key people in this story are highlighted — and are given "The Wright Stuff" Awards — for their contribution. Many of them are surprising, in that they would not previously been associated with space tourism, but the author makes their contributions clear. Readers will learn that their tickets to space have been made possible not just by the efforts of entrepreneurs and engineers, but also just as importantly by artists, regulators, politicians, and some of the earliest aviators — all of whom had *"The Wright Stuff."*



An Introduction to Planetary Atmospheres.

By Agustin Sanchez-Lavega. Taylor & Francis, 2010. 629 pp., Hardcover, $89.95. *www.taylorandfrancis.com*

Planetary atmospheres is a relatively new, interdisciplinary subject that incorporates various areas of the physical and chemical sciences, including geophysics, geophysical fluid dynamics, atmospheric science, astronomy, and astrophysics. This book presents current knowledge on atmospheres and the fundamental mechanisms operating on them, covering a panorama of solar system bodies and their relevant general properties. It explores the origin and evolution of atmospheres, along with their chemical composition and thermal structure and describes cloud formation and properties, mechanisms in thin and upper atmospheres, and meteorology and dynamics. The study of planetary atmospheres is fundamental to understanding the origin of the solar system, the formation mechanisms of planets and satellites, and the day-to-day behavior and evolution of Earth's atmosphere. With many interesting real-world examples, this book offers a unified vision of the chemical and physical processes occurring in planetary atmospheres.

Transiting Exoplanets.

By Carole A. Haswell. Cambridge University Press, 2010. 336 pp., Paperback, $60.00. *www.cambridge.org*

The methods used in the detection and characterization of exoplanets are presented through the study of transiting systems in this unique textbook for advanced undergraduates. From determining the atmospheric properties of transiting exoplanets to measuring the planetary orbit's alignment with the stellar spin, students will discover what these measurements imply for reinvigorated theories of planet formation and evolution. Worked examples and exercises with full

solutions help students to assess their understanding of concepts and results. Key points and equations are highlighted to make them easily identifiable, and there are full color illustrations throughout. Bridging the gap between introductory, nonmathematical texts and more advanced textbooks, this book is ideal for students with some background in mathematics, physics, and astronomy.

Moon: A Brief History.

By Bernd Brunner. Yale University Press, 2010. 304 pp., Hardcover, $25.00. *www.yalebooks.com*

Werewolves and Wernher von Braun, Stonehenge and the sex lives of sea corals, aboriginal myths, and an Anglican bishop: In his new book, *Moon*, Brunner weaves variegated information into an enchanting glimpse of Earth's closest celestial neighbor, whose mere presence inspires us to wonder what might be "out there." Going beyond the discoveries of contemporary science, Brunner presents an unusual cultural assessment of our complex relationship with Earth's lifeless, rocky satellite. As well as offering an engaging perspective on such age-old questions as "What would Earth be like without the Moon?," Brunner surveys the Moon's mythical and religious significance and provokes existential soul-searching through a lunar lens, inquiring, "Forty years ago, the first man put his footprint on the Moon. Will we continue to use it as the screen onto which we cast our hopes and fears?" Drawing on materials from different cultures and epochs, Brunner walks readers down a moonlit path illuminated by more than 75 vintage photographs and illustrations. From scientific discussions of the Moon's origins and its "chronobiological" effects on the mating and feeding habits of animals, to an illuminating interpretation of Bishop Francis Godwin's 1638 novel *The Man in the Moone*, Brunner's ingenious and interdisciplinary explorations recast a familiar object in an entirely original and unforgettable light and will change the way we view the nighttime sky.

Trailblazing Mars: NASA's Next Giant Leap.

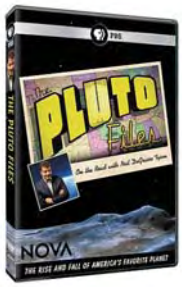
By Pat Duggins. University Press of Florida, 2010. 224 pp., Hardcover, $24.95. *www.upf.com*

Travel to and from Mars has long been a staple of science fiction. And yet the hurdles — both technological and financial — have kept human exploration of the Red Planet from becoming a reality. *Trailblazing Mars* offers an inside look at the current efforts to fulfill this dream. Award-winning journalist Pat Duggins examines the extreme new challenges that will be faced by astronauts on the journey there and back. They'll have to grow their own food, find their own water, and solve their own problems and emergencies without hope of rescue or resupply. Can the technological hurdles be cleared? Will the public accept the very real possibility of astronaut death? Should a mission be publicly or privately funded? Is the science worth the cost? These and many other questions are answered in Duggins' new book.

DVD

The Pluto Files: The Rise and Fall of America's Favorite Planet.

Produced by PBS, 2010, one disc. $24.99. *www.shoppbs.org*



Join Hayden Planetarium's director Neil deGrasse Tyson as he follows the story of Pluto's discovery and the science that surrounds this former planet, including the possibility of finding more Pluto-like planets in the mysterious Kuiper belt. From the scientists trying to classify Pluto to die-hard "Pluto-philes," Tyson meets a fascinating cast of characters with just one thing in common: strong opinions about Pluto. This disc includes a number of extra features: The Formation of the Solar System Explained Over Dinner; Two Different Ways of Looking at the Universe; Neil and Pluto the Pup Breakdown the Debate; Pluto and Partisan Politics; What Would Clyde Say —; Why Eight Planets —; and Outtakes from the Barbershop.

For Kids!

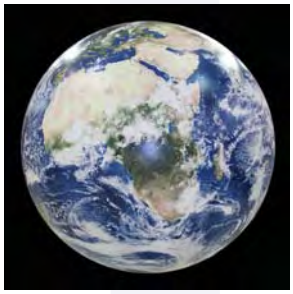
Rocket Hero Apollo Spacecraft.

By Revell. $40.95. *www.revell.com*

The Apollo Spacecraft that transported astronauts to the Moon for the first time consisted of two parts, the Command Module and the Service Module. The Command Module contained quarters for the three men, as well as extensive electronics, communications, and guidance systems. It was supplied with oxygen and electric power from the Service Module, which also contained the main propulsion engine for attaining lunar orbit and for firing into the return trip. After completing the entire mission to and around the Moon and back toward Earth together, the two modules separated just minutes before entering the atmosphere, leaving only the Command Module to return to Earth. The gold color on this model simulates the gold foil covering of the actual Command Module. Interior details such as figures of the three astronauts, instrument and control panels, structural members, parachutes, oxygen and hydrogen tanks, and fuel cells may be viewed through transparent sections. The model is 12 3/4" long (32.4 cm) and stands 8 5/8" tall (21.9 cm) on its display base. Engine nozzle extension and high-gain antenna are moveable. This 1:32-scale space model requires glue and paint to complete. Recommended for ages 10 and up.

NASA Photo Inflatable Globe.

From Space Toys. $17.95. *www.spacetoys.com*



This 16" inflatable Spaceship Earth Globe is made from thousands of NASA photos taken in 2003 that show the present view of Earth from space. It is a tool for children and adults that replicates our Earth with no boundaries, no edges, and no limitations. This globe clearly shows landforms, terrain, climate features, cloud patterns, relief contour of the oceanic floor, the reflection of coral reefs, and glow-in-the-dark cities, and serves as a useful resource at school or at home.

NASA Kids' Club.

NASA website, *www.nasa.gov/audience/forkids/kidsclub/flash/index.html*

NASA Kids' Club is an interactive educational website with games, puzzles, images, web quests, and other activities to cover K–4 students' developmental and learning abilities as addressed in national education standards in math, science, and technology. Five skill levels provide a natural progression through the site that allows users to find activities that are best suited to children's varying abilities. This website features a wealth of resources that are safe, fun, and educational and provides reliable information on a variety of space-related topics.

Space Explorer 10-Piece Backpack Space Orbiter Playset.

From In Air, $27.99. *www.amazon.com*

The young space enthusiast will love this great backpack playset loaded with high-quality diecast metal and plastic toys. This set includes a realistic playmat with educational information on the back. Not for children under age 3.

Calendar 2010 / 2011

January 2011

5–9 **Archaeoastronomy and Ethnoastronomy: Building Bridges Between Cultures,** Lima, Peru. *http://www1.archaeoastronomy.org/index.php?option=com_content&view=article&id=13&Itemid=15&lang=en*

8–14 **Colloquium of African Geology,** Johannesburg, South Africa. *http://www.cag23.co.za/*

10–14 **The Millimeter and Submillimeter Sky in the Planck Mission Era,** Paris, France. *http://www.planck2011.fr/*

10–15 **CPS 7th International School of Planetary Sciences: Theory of Stellar Evolution and Its Applications,** Kobe, Japan. *https://www.cps-jp.org/~pschool/pub/2011-01-10/index.html*

17–21 **Landing Site Characterization and Selection for Future Exploration Missions (A Europlanet JRA1 Workshop),** Leiden/Noordwijk, The Netherlands. *http://www.planetarygis.org/wiki/Workshop2011*

18–22 **The 15th International Conference on Gravitational Microlensing and School on Planetary Microlensing Events Modeling,** Salerno, Italy. *http://smc2011.physics.unisa.it/*

25–26 **Fourth Meeting of the Small Bodies Assessment Group,** Washington, DC. *http://www.lpi.usra.edu/sbag/meetings/*

29–Feb 8 **International Workshop on Extrasolar Planets,** Kish Island, Iran. *http://www.astro.ipm.ir/conferences/ESPW/*

February

7–14 **Geobiology in Space Exploration (with Field Trip),** Marrakech, Morocco. *http://www.irsps.unich.it/education/geoexp2011/*

8–11 **Fourth International Workshop on the Mars Atmosphere: Modelling and Observations,** Paris, France. *http://www-mars.lmd.jussieu.fr/paris2011/*

18–22 **IAG/AIG Regional Conference on Geomorphology,** Addis Ababa, Ethiopia. *http://www.geomorph.org/main.html*

24–25 **PLATO Science Conference,** Berlin, Germany. *http://www-astro.physik.tu-berlin.de/plato-2011/*

28–Mar 1 **Millimeter Astronomy by the Bay: CARMA Science Symposium,** Berkeley, California. *http://astro.berkeley.edu/carmaconf2011/*

28–Mar 2 **Next-Generation Suborbital Researchers Conference,** Orlando, Florida. *http://nrsc.swri.org*

March

1–3 **Astronomy with Radioactivities VII,** Phillip Island, Victoria, Australia. *http://cspa.monash.edu.au/awr7/*

5–6 **The Moon: The First Billion Years of Crustal Evolution,** The Woodlands, Texas. *http://www.planetary.brown.edu/html_pages/micro52.htm*

5–6 **The Importance of Solar System Sample Return Missions to the Future of Planetary Science,** The Woodlands, Texas. *http://www.lpi.usra.edu/meetings/sssr2011/*

7–11 **42nd Lunar and Planetary Science Conference (LPSC 2011),** The Woodlands, Texas. *http://www.lpi.usra.edu/meetings/lpsc2011/*

20–25 **Twelfth International Conference on Accelerator Mass Spectrometry,** Wellington, New Zealand. *http://www.gns.cri.nz/ams12/index.html*

28–31 **Resolving the Future of Astronomy with Long-Baseline Interferometry,** Socorro, New Mexico. *http://www.mro.nmt.edu/workshop/*

April

3–8 **European Geosciences Union General Assembly,** Vienna, Austria. *http://meetings.copernicus.org/egu2011/*

3–9 **From Planets to Life,** Villars-sur-Ollon, Switzerland. *http://www.isdc.unige.ch/sf2011/*

10–15 **MEARIM-2, The Second Middle-East and Africa IAU Regional Meeting,** Cape Town, South Africa. *http://mearim2.saao.ac.za/*

11–15 **18th IAA Humans in Space Symposium,** Houston, Texas. *http://www.dsls.usra.edu/meetings/IAA/*

11–15 **Fifth Workshop on Titan Chemistry — Observations, Experiments, Computations, and Modeling,** Poipu Koloa, Hawaii. *http://www.chem.hawaii.edu/Bil301/Titan2011.html*

12–14 **Signposts of Planets Conference,** Greenbelt, Maryland. *http://science.gsfc.nasa.gov/667/conferences/signposts.html*

12–15 **Eleventh Symposium on Advanced Space Technologies in Robotics and Automation,** Noordwijk, The Netherlands. *http://www.congrexprojects.com/11a06/*

May

2–7 **18th Young Scientists' Conference on Astronomy and Space Physics,** Kiev, Ukraine. *http://ysc.kiev.ua/*

4–6 **Solar System Science Before and After Gaia,** Pisa, Italy. *http://www.oca.eu/workshop/Pise/*

9–12 **2011 IAA Planetary Defense Conference,** Bucharest, Romania. *http://www.pdc2011.org/*

18–20 **Conference on Micro-Raman Spectroscopy and Luminescence Studies in the Earth and Planetary Sciences (CORALS II),** Madrid, Spain. *http://www.lpi.usra.edu/meetings/corals2011/*

22–26 **20th ESA Symposium on European Rocket and Balloon Programmes and Related Research,** Hyeres, France. *http://spaceflight.esa.int/pac-symposium2011/*

30–Jun 3 **The Molecular Universe,** Toledo, Spain. *http://cab.inta-csic.es/molecular_universe/*

June

5–8 **Astrobiology Graduate Student Conference (AbGradCon 2011),** Bozeman, Montana. *http://abgradcon2011.org/*

5–10 **Second Workshop on Robotic Autonomous Observatories,** Malaga, Spain. *http://arae.iaa.es:8000/malaga-2011/index.php*

6–10 **Eighth International Planetary Probe Workshop,** Portsmouth, Virginia. *http://www.planetaryprobe.org/*

6–10 **Eighth Serbian Conference on Spectral Line Shapes in Astrophysics,** Divcibare, Serbia. *http://www.scslsa.matf.bg.ac.rs/*

8–10 **International Workshop on Planning and Scheduling for Space,** Darmstadt, Germany. *http://www.congrexprojects.com/11c05/*

13–15 **A Wet vs. Dry Moon: Exploring Volatile Reservoirs and Implications for the Evolution of the Moon and Future Exploration,** Houston, Texas. *http://www.lpi.usra.edu/meetings/volatiles2011/*

18–21 **Very Wide Field Surveys in the Light of Astro2010,** Baltimore, Maryland. *http://widefield2011.pha.jhu.edu/*

20–24 **Ninth IAA Low-Cost Planetary Missions Conference,** Laurel, Maryland. *http://lcpm9.jhuapl.edu/index.php*

July

3–8 **Origins 2011: The International Astrobiology Society and Bioastronomy Joint International Conference,** Montpellier, France. *http://www.origins2011.univ-montp2.fr/*

5–8 **40th Young European Radio Astronomers Conference (YERAC),** Alcala de Henares, Spain. *http://www.yerac.org/*

11–15 **Magnetospheres of the Outer Planets 2011,** Sendai, Japan. *http://mop2011.jimdo.com/*

14–22 **Asteroids, Comets, Meteors (ACM) 2011,** Niigata, Japan. *http://chiron.mtk.nao.ac.jp/ACM2011/*

17–22 **2011 Gordon Research Conference on Origins of Solar Systems,** South Hadley, Massachusetts. *http://www.grc.org/programs.aspx?year=2011&program=origins*

18–22 **From Interacting Binaries to Exoplanets: Essential Modeling Tools,** Tatranska Lomnica, Slovakia. *http://www.astro.sk/IB2E/*

25–29 **2011 Sagan Exoplanet Summer Workshop: Exploring Exoplanets with Microlensing,** Pasadena, California. *http://nexsci.caltech.edu/workshop/2011/*

30–Aug 3 **Connecting People to Science: The 2011 Education and Public Outreach Conference of the Astronomical Society of the Pacific,** Baltimore, Maryland. *http://www.astrosociety.org/events/meeting.html*

August

2–3 **Fifth Meeting of the NASA Small Bodies Assessment Group,** Pasadena, California. *http://www.lpi.usra.edu/sbag/*

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

8–12 **74th Annual Meeting of the Meteoritical Society,** London, England, UK. *http://www.lpi.usra.edu/meetings/metsoc2011/*

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

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

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