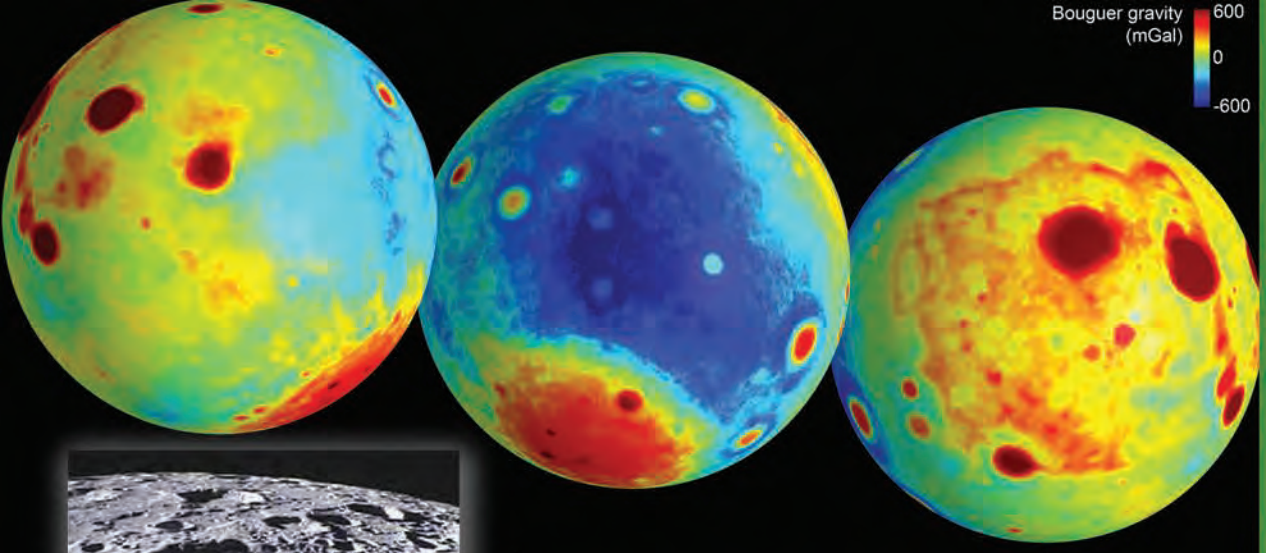
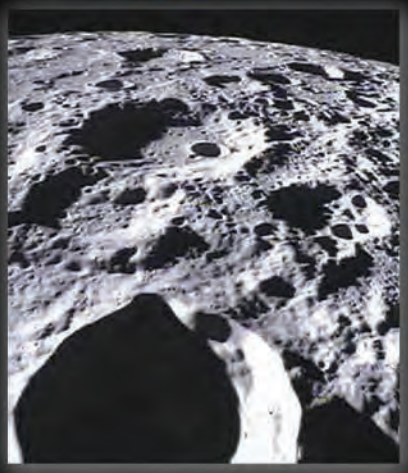
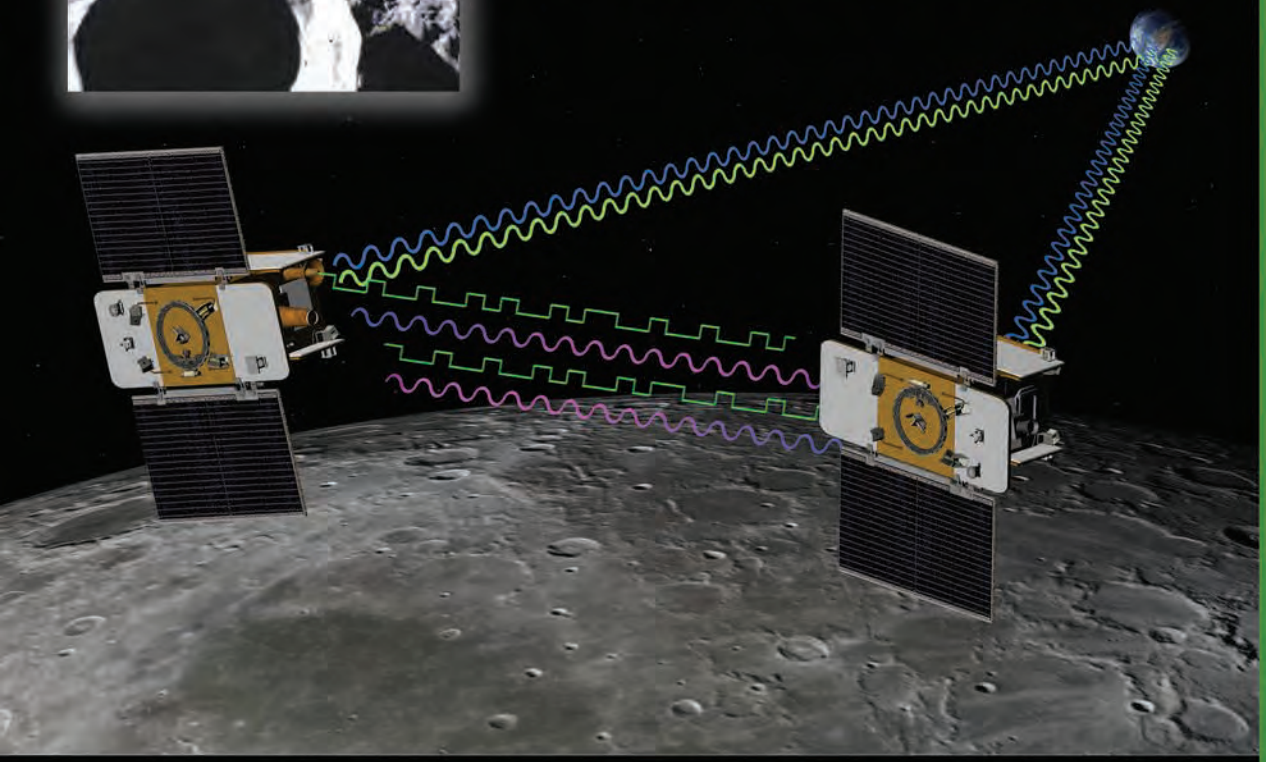




GRAIL REVEALS SECRETS OF THE LUNAR INTERIOR



CONTENTS

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GRAIL Reveals Secrets of the Lunar Interior

— Dr. Patrick J. McGovern, Lunar and Planetary Institute

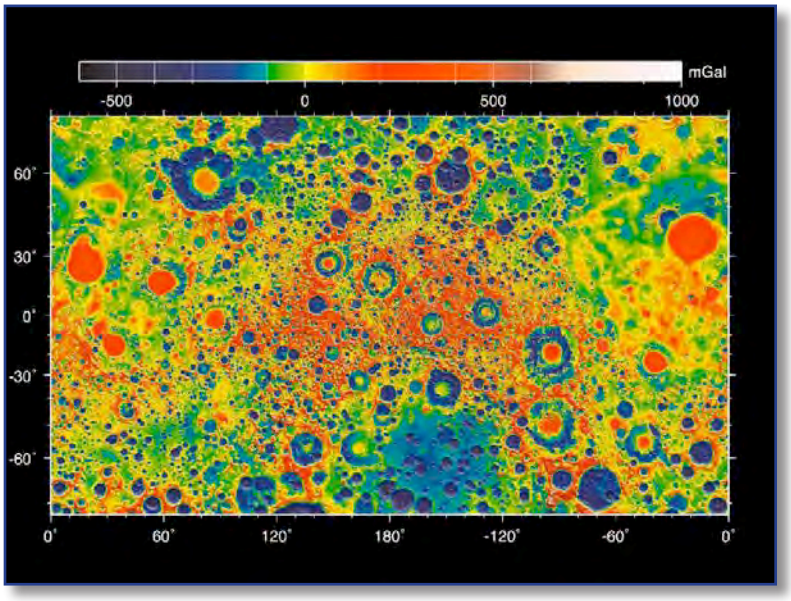
A mini-flotilla of spacecraft sent to the Moon in the past few years by several nations has revealed much about the characteristics of the lunar surface via techniques such as imaging, spectroscopy, and laser ranging. While the achievements of these missions have been impressive, only GRAIL has seen deeply enough to reveal inner secrets that the Moon holds.

Recent Lunar Missions

Country	Name	Launch Date	Status
ESA	Small Missions for Advanced Research in Technology-1 (SMART-1)	September 27, 2003	Ended with lunar surface impact on September 3, 2006
USA	Acceleration, Reconnection, Turbulence and Electrodynamics of the Moon's Interaction with the Sun (ARTEMIS)	February 27, 2007	Extension of the THEMIS mission; ended in 2012
Japan	SELENE (Kaguya)	September 14, 2007	Ended with lunar surface impact on June 10, 2009
China	Chang'e-1	October 24, 2007	Taken out of orbit on March 1, 2009
India	Chandrayaan-1	October 22, 2008	Two-year mission; ended after 315 days due to malfunction and loss of contact
USA	Lunar Reconnaissance Orbiter (LRO)	June 18, 2009	Completed one-year primary mission; now in five-year extended mission
USA	Lunar Crater Observation and Sensing Satellite (LCROSS)	June 18, 2009	Ended with lunar surface impact on October 9, 2009
China	Chang'e-2	October 1, 2010	Primary mission lasted for six months; extended mission completed flyby of asteroid 4179 Toutatis in December 2012
USA	Gravity Recovery and Interior Laboratory (GRAIL)	September 10, 2011	Ended with lunar surface impact on December 17, 2012

To probe deeper, NASA launched the Gravity Recovery and Interior Laboratory (GRAIL) mission: twin spacecraft (named "Ebb" and "Flow" by elementary school students from Montana) flying in formation over the lunar surface, tracking each other to within a sensitivity of 50 nanometers per second, or one-twenty-thousandth of the velocity that a snail moves [1], according to GRAIL Principal Investigator Maria Zuber of the Massachusetts Institute of Technology.

From repeated observations as the spacecraft orbits swept over the whole lunar surface, a map of the gravitational attraction can be constructed. Thanks to GRAIL, our knowledge of the Moon's gravity has improved by 3 to 5 orders of magnitude, and is better than that of any other solar system body, including Earth [1]. A set of three papers [2,3,4] published in the journal *Science* last month revealed the results of the GRAIL primary mission, which lasted from March to May 2012.

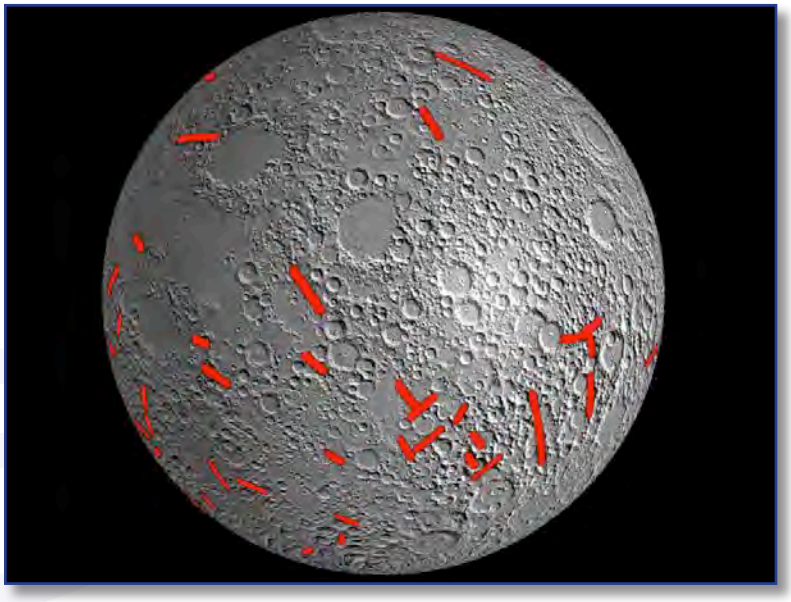


This map shows the gravity field of the Moon as measured by NASA's GRAIL mission. The viewing perspective, known as a Mercator projection, shows the farside of the Moon in the center and the nearside (as viewed from Earth) at either side. Units are milliGalileos, where 1 Galileo is 1 centimeter per second squared. Reds correspond to mass excesses, which create areas of higher local gravity, and blues correspond to mass deficits, which create areas of lower local gravity. Credit: NASA/JPL-Caltech/GSFC/MIT.

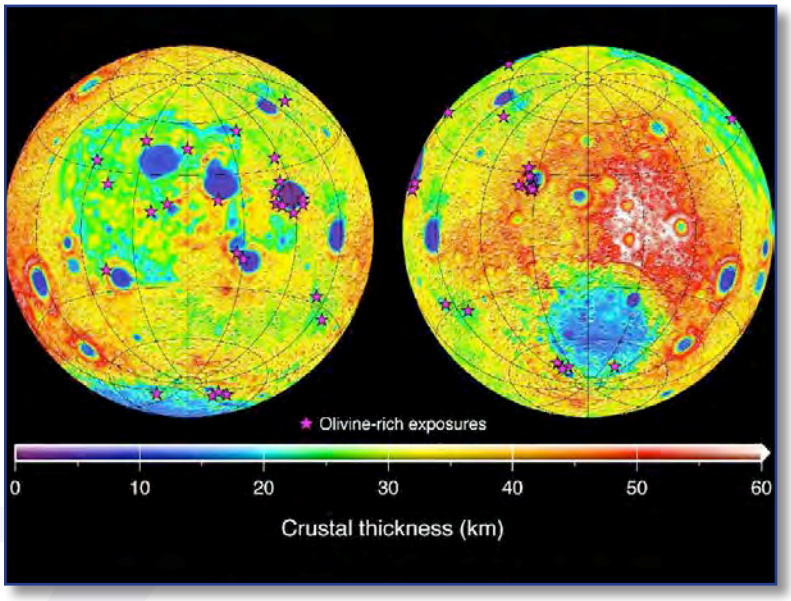
GRAIL resolved the Moon's gravity to very small scales, with an equivalent block size of 13 km^2. Surprisingly, the correlation between lunar gravity and topography at the shortest length scales is consistently greater than 98%. Such a high number indicates that anomalies resulting from subsurface processes such as intrusive volcanism are less globally prominent than previously thought. That is not to say that intrusions are absent, however; analysis of variations in GRAIL gravity using a technique called gravity gradiometry, led by GRAIL Guest Scientist Jeffrey Andrews-Hanna of the Colorado School of Mines, reveals a number of strong but narrow linear anomalies more or less randomly distributed in the lunar crust [3]. Their sizes (up to hundreds of kilometers long) and shapes (narrow) are consistent with the presence of dikes: tall tabular dense intrusive bodies created by magma upwelling into the crust. The dikes appear to have been emplaced before most impact basins, making them ancient features that reflect an early extensional (pulling-apart) stress state in the lunar crust. Such a state is predicted by models with an initially cool crust that warms with time.

The GRAIL mission also offers new insights into lunar crustal thickness and structure. GRAIL Co-Investigator Mark Wieczorek of the Institut de Physique du Globe de Paris led an effort to perform analysis of gravity, topography, and spectral remote-sensing data to elucidate the structure of the lunar crust [4]. The results show that the crust is substantially lower in density than previously estimated, with a mean density of 2550 kg/m^3. This value is in large part attributed to the very high porosity values estimated in the study, about 12% on average. This porosity likely extends to substantial depths in the lunar crust and is the result of the intense impactor bombardment that the Moon has experienced over its 4.5-billion-year history. The analysis also estimated a mean crustal thickness of 34 to 43 kilometers, somewhat lower than estimated by many geochemically and geophysically based models of the last decade or so, but consistent with values obtained via Apollo seismic experiments. These results have further implications for the chemical makeup of the crust: With a thinner crust, the amount of refractory (high melting point) elements is no longer required to be enriched relative to that of Earth, making it easier to have formed the Moon during a giant impact into the early Earth.

Ebb and Flow no longer orbit the Moon. The spacecraft were led to controlled impacts into a lunar mountain on December 17, 2012, a location that has been named the "Sally K. Ride Impact Site" after the late American astronaut who led GRAIL's MoonKAM educational outreach program. While spacecraft operations have ceased, analysis of the vast treasure trove of data collected during the GRAIL primary and extended mission phases is ongoing, with many more surprises awaiting discovery by the planetary science community!



This map of one side of the Moon shows the location of some of the giant dikes identified by the GRAIL mission. These dikes are solidified magma-filled cracks with lengths up to 300 miles (480 kilometers) and widths of up to 24 miles (40 kilometers). The formation of these dikes tells us that the Moon expanded during the first billion years of its history, with its radius increasing by as much as 3 miles (5 kilometers). This early expansion of the Moon was previously predicted by theoretical models, and is now confirmed by GRAIL gravity data. The base map consists of topographic shaded data from the Lunar Reconnaissance Orbiter's Lunar Orbiter Laser Altimeter (LOLA). Credit: NASA/ JPL-Caltech/CSM.



This graphic depicting the crustal thickness of the Moon was generated using gravity data from the GRAIL mission and topography data from the Lunar Reconnaissance Orbiter. The measurements match those found via seismic data at the NASA Apollo 12 and 14 landing sites, where crustal thickness is 19 miles (30 kilometers). There is a minimum crustal thickness less than 0.6 miles (1 kilometer) within the nearside Crisium and farside Moscoviense impact basins. The average thickness of the crust is 21 miles (34 kilometers), which is almost 12 miles (20 kilometers) thinner than values from previous studies. Locations of olivine-rich materials mapped from the Japanese spacecraft Kaguya, which may represent materials excavated from the Moon's mantle, are shown as stars. The largest concentrations of olivine-rich materials are found surrounding the Crisium and Moscoviense impact basins, where the crust is nearly absent. Data are presented in two Lambert azimuthal equal-area projections centered over the near (left) and farside (right) hemispheres, with each image covering 75% of the lunar surface. Credit: NASA/ JPL-Caltech/IPGP.

References

[1] *Science* magazine press conference at the 2012 American Geophysical Union Fall Meeting, December 5, 2012.

[2] Zuber M. T., Smith D. E., Watkins M. M., Asmar S. W., Konopliv A. S., Lemoine F. G., Melosh H. J., Neumann G. A., Phillips R. J., Solomon S. C., Wieczorek M. A., Williams J. G., Goosens S. J., Kruizinga G., Mazarico E., Park R. S., and and Yuan D.-N. (2013) Gravity field of the Moon from the Gravity Recovery and Interior Laboratory (GRAIL) mission. *Science, 339(6120),* 668–671, DOI: 10.1126/science.1231507.

[3] Andrews-Hanna J. C., Asmar S. W., Head J. W. III, Kiefer W. S., Konopliv A. S., Lemoine F. G., Matsuyama I., Mazarico E., McGovern P. J., Melosh H. J., Neumann G. A., Nimmo F., Phillips R. J., Smith D. E., Solomon S. C., Taylor G. J., Wieczorek M. A., Williams J. G., and Zuber M. T. (2013) Ancient igneous intrusions and early expansion of the Moon revealed by GRAIL gravity gradiometry. *Science, 339(6120),* 675–678. DOI: 10.1126/science.1231753.

[4] Wieczorek M. A., Neumann G. A., Nimmo F., Kiefer W. S., Taylor G. J., Melosh H. J., Phillips R. J., Solomon S. C., Andrews-Hanna J. C., Asmar S. W., Konopliv A. S., Lemoine F. G., Smith D. E., Watkins M. M., Williams J. G., and Zuber M. T. (2013) The crust of the Moon as seen by GRAIL. *Science, 339(6120),* 671–675. DOI: 10.1126/science.1231530.

About the Author:

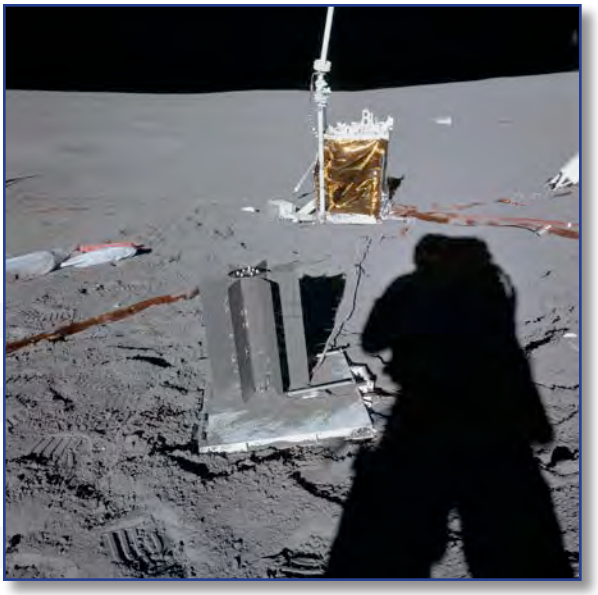
Dr. Patrick J. McGovern has been a staff scientist at the Lunar and Planetary Institute in Houston, Texas, since 1999. He received his Ph.D. in Geophysics from the Massachusetts Institute of Technology, and his research focuses on the evolution of terrestrial planet surfaces, lithospheres, and interiors, with emphasis on growth and development of large volcano-tectonic structures on the terrestrial planets. McGovern is a guest scientist on the GRAIL mission team.

Cover images:

Top:
These maps of the Moon show the "Bouguer" gravity anomalies as measured by NASA's GRAIL mission. Bouguer gravity is what remains from the gravity field when the attraction of surface topography is removed, and therefore represents mass anomalies inside the Moon due to either variations in crustal thickness or crust or mantle density. Red areas have stronger gravity, while blue areas have weaker gravity. Credit: NASA/JPL-Caltech/CSM.

Bottom:
Artist's concept of NASA's GRAIL mission. Credit: NASA/JPL-Caltech.

Inset:
This image of the lunar surface was taken by the MoonKAM system onboard the Ebb spacecraft on March 15, 2012. The 42.3-mile-wide (68-kilometer-wide) crater in the middle of the image (with the smaller crater inside) is Poinsot. Crater Poinsot, named for the French mathematician Louis Poinsot, is located on the northern part of the Moon's farside. Credit: NASA.



An Apollo 14 astronaut deploys the Apollo Lunar Surface Experiments Package's power source (foreground) and "Central Station" (background), where the Lunar Dust Detector was mounted. Credit: NASA/JSC.

Apollo's Lunar Dust Thermal Data Being Restored

Forty years after the last Apollo spacecraft launched, the science from those missions continues to shape our view of the Moon. In one of the latest developments, readings from the Apollo 14 and 15 dust detectors have been restored by scientists with the National Space Science Data Center (NSSDC) at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "This is the first look at the fully calibrated, digital dust data from the Apollo 14 and 15 missions," said David Williams, a Goddard scientist and data specialist at NSSDC, NASA's permanent archive for space science mission data.

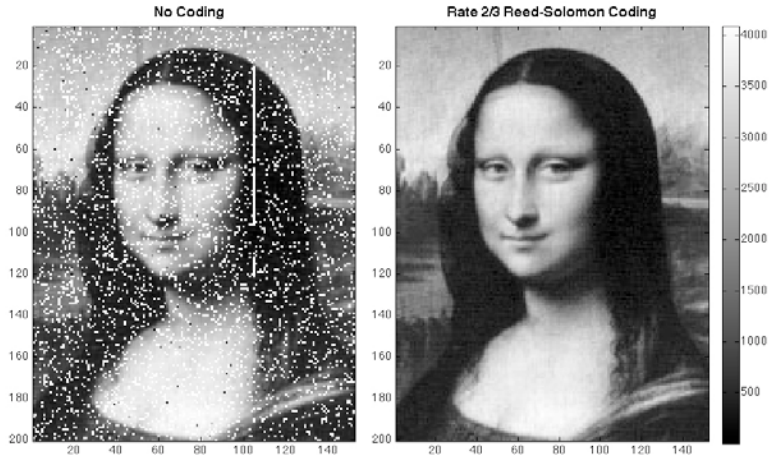
The newly available data will make long-term analysis of the Apollo dust readings possible. Digital data from these two experiments were not previously archived, and it is thought that roughly the last year-and-a-half of the data have never been studied. The work was presented on December 6 at the American Geophysical Union meeting in San Francisco, as part of a session organized in honor of the 40th anniversary of the Apollo 17 launch. Also presented in this session was a similar effort to fill in gaps in the Apollo 15 and 17 heat-flow measurements, the only such measurements ever taken on the Moon or any planetary body other than Earth. The recovery of these datasets is part of the Lunar Data Project, an ongoing NSSDC effort, drawing on researchers at multiple institutions, to make the scientific data from Apollo available in modern formats.

The Lunar Dust Detectors that were placed on the lunar surface during Apollo 14 and 15 measured dust accumulation, temperature, and damage caused by high-energy cosmic particles and the Sun's ultraviolet radiation. The same kind of instrument had flown earlier on Apollo 11 and 12 (Apollo 17 later carried a different type of dust detector). Restoring the data was a painstaking job of going through one dataset and separating the raw detector counts from temperatures and "housekeeping" information that was collected to keep an eye on how healthy the Apollo instruments were. A second, less complete dataset indicated how to convert the raw counts into usable measurements. But the second dataset had to first be converted from microfilm, which had been archived at NSSDC in the 1970s, and the two datasets had to reconciled because their time points didn't match up exactly. Most of this meticulous work was carried out by Marie McBride, an undergraduate from the Florida Institute of Technology in Melbourne who was working with Williams through a NASA internship.

Newer missions, such as NASA's Lunar Reconnaissance Orbiter (LRO), have continued to study lunar dust. "It's one of those questions that scientists keep coming back to," said McBride. "Just last week, LRO did some important measurements seeking dust profiles in the lunar atmosphere," added Richard Vondrak, the LRO deputy project scientist at NASA Goddard. LRO has been orbiting the Moon since June 2009, and the mission was recently extended through 2015. The main objective of NASA's Lunar Atmosphere and Dust Environment Explorer (LADEE), scheduled to launch in 2013, is to characterize the Moon's atmosphere and dust environment.

"This offers another example of how profoundly influential the Apollo data continues to be," observed Noah Petro, a member of the LRO project science team at NASA Goddard. "A mission ends when it ends, but the science continues forever." For more information about the NSSDC, visit *nssdc.gsfc.nasa.gov*.

NASA Beams Mona Lisa to Lunar Reconnaissance Orbiter



To clean up transmission errors introduced by Earth's atmosphere (left), Goddard scientists applied Reed-Solomon error correction (right), which is commonly used in CDs and DVDs. Typical errors include missing pixels (white) and false signals (black). The white stripe indicates a brief period when transmission was paused. Credit: Xiaoli Sun, NASA Goddard.

As part of the first demonstration of laser communication with a satellite at the Moon, scientists with NASA's Lunar Reconnaissance Orbiter (LRO) beamed an image of the Mona Lisa to the spacecraft from Earth. The iconic image traveled nearly 240,000 miles in digital form from the Next Generation Satellite Laser Ranging (NGSLR) station at NASA's Goddard Space Flight Center in Greenbelt, Maryland, to the Lunar Orbiter Laser Altimeter (LOLA) instrument on the spacecraft. By transmitting the image piggyback on laser pulses that are routinely sent to track LOLA's position, the team achieved simultaneous laser communication and tracking.

"This is the first time anyone has achieved one-way laser communication at planetary distances," says LOLA's principal investigator, David Smith of the Massachusetts Institute of Technology. "In the near future, this type of simple laser communication might serve as a backup for the radio communication that satellites use. In the more distant future, it may allow communication at higher data rates than present radio links can provide."

Typically, satellites that go beyond Earth orbit use radio waves for tracking and communication. LRO is the only satellite in orbit around a body other than Earth to be tracked by laser as well. "Because LRO is already set up to receive laser signals through the LOLA instrument, we had a unique opportunity to demonstrate one-way laser communication with a distant satellite," says Xiaoli Sun, a LOLA scientist at NASA Goddard and lead author of a paper published on January 17 in *Optics Express* that describes the work.

Precise timing was the key to transmitting the image. Sun and colleagues divided the Mona Lisa image into an array of 152 pixels by 200 pixels. Every pixel was converted into a shade of gray, represented by a number between 0 and 4095. Each pixel was transmitted by a laser pulse, with the pulse being fired in one of 4096 possible time slots during a brief time window allotted for laser tracking. The complete image was transmitted at a data rate of about 300 bits per second.

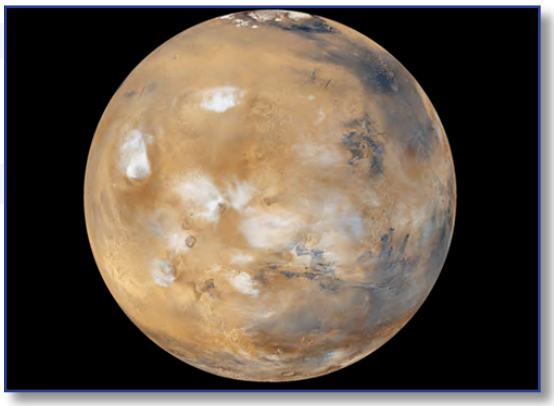
The laser pulses were received by LRO's LOLA instrument, which reconstructed the image based on the arrival times of the laser pulses from Earth. This was accomplished without interfering with LOLA's primary task of mapping the Moon's elevation and terrain and NGSLR's primary task of tracking LRO. The success of the laser transmission was verified by returning the image to Earth using the spacecraft's radio telemetry system.

Turbulence in Earth's atmosphere introduced transmission errors even when the sky was clear. To overcome these effects, Sun and colleagues employed Reed-Solomon coding, which is the same type of error-correction code commonly used in CDs and DVDs. The experiments also provided statistics on the signal fluctuations due to Earth's atmosphere. "This pathfinding achievement sets the stage for the Lunar Laser Communications Demonstration (LLCD), a high data rate laser-communication demonstration that

will be a central feature of NASA's next Moon mission, the Lunar Atmosphere and Dust Environment Explorer (LADEE)," says Goddard's Richard Vondrak, the LRO deputy project scientist.

The next step after LLCD is the Laser Communications Relay Demonstration (LCRD), NASA's first long-duration optical communications mission. LCRD will help develop concepts and deliver technologies applicable to near-Earth and deep-space communication. For more information about LCRD, visit *www.nasa.gov/mission_pages/tdm/lcrd/*.

NASA Announces Robust Multi-Year Mars Program; New Rover to Close Out Decade of New Missions



Water-ice clouds, polar ice, polar regions, and geological features can be seen in this full-disk image of Mars. Credit: NASA.

Building on the success of Curiosity's Red Planet landing, NASA has announced plans for a robust multiyear Mars program, including a new robotic science rover set to launch in 2020. This announcement affirms the agency's commitment to a bold exploration program that meets our nation's scientific and human exploration objectives. "The Obama administration is committed to a robust Mars exploration program," NASA Administrator Charles Bolden said. "With this next mission, we're ensuring America remains the world leader in the exploration of the Red Planet, while taking another significant step toward sending humans there in the 2030s."

The planned portfolio includes the Curiosity and Opportunity rovers; two NASA spacecraft and contributions to one European spacecraft currently orbiting Mars; the 2013 launch of the Mars Atmosphere and Volatile EvolutioN (MAVEN) orbiter to study the martian upper atmosphere; the Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission, which will take the first look into the deep interior of Mars; and participation in ESA's 2016 and 2018 ExoMars missions, including providing "Electra" telecommunication radios to ESA's 2016 mission and a critical element of the premier astrobiology instrument on the 2018 ExoMars rover.

The plan to design and build a new Mars robotic science rover with a launch in 2020 comes only months after the agency announced InSight, which will launch in 2016, bringing a total of seven NASA missions operating or being planned to study and explore our Earth-like neighbor. The 2020 mission will constitute another step toward being responsive to high-priority science goals and the president's challenge of sending humans to Mars orbit in the 2030s.

The future rover development and design will be based on the Mars Science Laboratory (MSL) architecture that successfully carried the Curiosity rover to the martian surface this summer. This will ensure mission costs and risks are as low as possible, while still delivering a highly capable rover with a proven landing system. The mission will constitute a vital component of a broad portfolio of Mars exploration missions in development for the coming decade.

"The challenge to restructure the Mars Exploration Program has turned from the seven minutes of terror for the Curiosity landing to the start of seven years of innovation," said John Grunsfeld, NASA's associate administrator for science. "This mission concept fits within the current and projected Mars exploration budget, builds on the exciting discoveries of Curiosity, and takes advantage of a favorable launch opportunity." The specific payload and science instruments for the 2020 mission will be openly competed, following the Science Mission Directorate's established processes for instrument selection. This process

will begin with the establishment of a science definition team that will be tasked to outline the scientific objectives for the mission. This mission fits within the five-year budget plan in the president's Fiscal Year 2013 budget request, and is contingent on future appropriations.

For information about NASA Mars activities, visit *www.nasa.gov/mars*.

NASA Mars Rover Fully Analyzes First Soil Samples

NASA's Mars Curiosity rover has used its full array of instruments to analyze martian soil for the first time, and found a complex chemistry within the martian soil. Water and sulfur and chlorine-containing substances, among other ingredients, showed up in samples Curiosity's arm delivered to an analytical laboratory inside the rover. Detection of the substances during this early phase of the mission demonstrates the laboratory's capability to analyze diverse soil and rock samples over the next two years. Scientists also have been verifying the capabilities of the rover's instruments.

View of the third (left) and fourth (right) trenches made by the 1.6-inch-wide (4-centimeter-wide) scoop on NASA's Mars rover Curiosity in October 2012. Credit: NASA/JPL-Caltech/MSSS.

Curiosity is the first Mars rover able to scoop soil into analytical instruments. The specific soil sample came from a drift of windblown dust and sand called "Rocknest." The site lies in a relatively flat part of Gale Crater still miles away from the rover's main destination on the slope of a mountain called Mount Sharp. The rover's laboratory includes the Sample Analysis at Mars (SAM) suite and the Chemistry and Mineralogy (CheMin) instrument. SAM used three methods to analyze gases given off from the dusty sand when it was heated in a tiny oven. One class of substances SAM checks for is organic compounds — carbon-containing chemicals that can be ingredients for life. "We have no definitive detection of martian organics at this point, but we will keep looking in the diverse environments of Gale Crater," said SAM Principal Investigator Paul Mahaffy of NASA's Goddard Space Flight Center.

Curiosity's APXS instrument and the Mars Hand Lens Imager (MAHLI) camera on the rover's arm confirmed Rocknest has chemical-element composition and textural appearance similar to sites visited by earlier NASA Mars rovers Pathfinder, Spirit, and Opportunity. Curiosity's team selected Rocknest as the first scooping site because it has fine sand particles suited for scrubbing interior surfaces of the arm's sample-handling chambers. Sand was vibrated inside the chambers to remove residue from Earth. MAHLI close-up images of Rocknest show a dust-coated crust one or two sand grains thick, covering dark, finer sand.

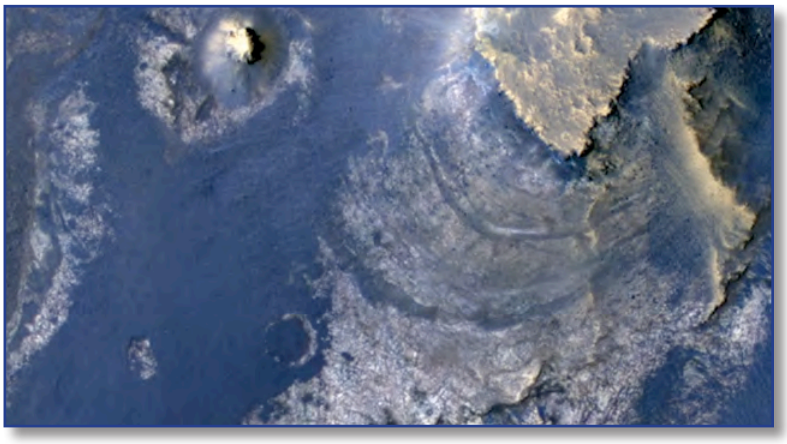
CheMin's examination of Rocknest samples found the composition is about half common volcanic minerals and half noncrystalline materials such as glass. SAM added information about ingredients present in much lower concentrations and about ratios of isotopes. Isotopes are different forms of the same element and can provide clues about environmental changes. The water seen by SAM does not mean the drift was wet. Water molecules bound to grains of sand or dust are not unusual, but the quantity seen was higher than anticipated. SAM tentatively identified the oxygen and chlorine compound perchlorate. This is a reactive chemical previously found in arctic martian soil by NASA's Phoenix Lander. Reactions with other chemicals heated in SAM formed chlorinated methane compounds — one-

carbon organics that were detected by the instrument. The chlorine is of martian origin, but it is possible the carbon may be of Earth origin, carried by Curiosity and detected by SAM's high-sensitivity design.

For more information about Curiosity and its mission, visit *www.nasa.gov/msl* or *mars.jpl.nasa.gov/msl*, or follow the mission at *www.facebook.com/marscuriosity* or *twitter.com/marscuriosity*.

Martian Crater May Once Have Held Groundwater-Fed Lake

NASA's Mars Reconnaissance Orbiter (MRO) is providing new evidence of a wet underground environment on Mars that adds to an increasingly complex picture of the Red Planet's early evolution. The new information comes from researchers analyzing spectrometer data from MRO, which looked down on the floor of McLaughlin Crater. The martian crater is 57 miles (92 kilometers) in diameter and 1.4 miles (2.2 kilometers) deep. McLaughlin's depth apparently once allowed underground water, which otherwise would have stayed hidden, to flow into the crater's interior. Layered, flat rocks at the bottom of the crater contain carbonate and clay minerals that form in the presence of water. McLaughlin lacks large inflow channels, and small channels originating within the crater wall end near a level that could have marked the surface of a lake.



This view of layered rocks on the floor of McLaughlin Crater shows sedimentary rocks that contain spectroscopic evidence for minerals formed through interaction with water. The High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter recorded the image. Credit: NASA/JPL-Caltech/Univ. of Arizona.

These new observations suggest the formation of the carbonates and clay in a groundwater-fed lake within the closed basin of the crater. Some researchers propose the crater interior catching the water and the underground zone contributing the water could have been wet environments and potential habitats. The findings were published in the January 20 online edition of *Nature Geoscience*. "Taken together, the observations in McLaughlin Crater provide the best evidence for carbonate forming within a lake environment instead of being washed into a crater from outside," said Joseph Michalski, lead author of the paper, which has five co-authors. Michalski also is affiliated with the Planetary Science Institute in Tucson, Arizona, and London's Natural History Museum. Michalski and his co-authors used the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) on the Mars Reconnaissance Orbiter (MRO) to check for minerals such as carbonates, which are best preserved under nonacidic conditions.

Launched in 2005, the Mars Reconnaissance Orbiter and its six instruments have provided more high-resolution data about the Red Planet than all other Mars orbiters combined. Data are made available for scientists worldwide to research, analyze, and report their findings. "A number of studies using CRISM data have shown rocks exhumed from the subsurface by meteor impact were altered early in martian history, most likely by hydrothermal fluids," Michalski said. "These fluids trapped in the subsurface could have periodically breached the surface in deep basins such as McLaughlin Crater, possibly carrying clues to subsurface habitability."

McLaughlin Crater sits at the low end of a regional slope several hundreds of miles, or kilometers, long on the western side of the Arabia Terra region of Mars. As on Earth, groundwater-fed lakes are expected to occur at low regional elevations. Therefore, this site would be a good candidate for such a process.

Designated Northwest Africa (NWA) 7034, and nicknamed "Black Beauty," this martian meteorite weighs approximately 11 ounces (320 grams). Credit: NASA.

Researchers Identify Water-Rich Meteorite Linked to Mars Crust

NASA-funded researchers analyzing a small meteorite that may be the first discovered from the martian surface or crust have found it contains 10 times more water than other martian meteorites from unknown origins. This new class of meteorite was found in 2011 in the Sahara Desert. Designated Northwest Africa (NWA) 7034, and nicknamed "Black Beauty," it weighs approximately 11 ounces (320 grams). After more than a year of intensive study, a team of U.S. scientists determined the meteorite formed 2.1 billion years ago during the beginning of the most recent geologic period on Mars, known as the Amazonian.

"The age of NWA 7034 is important because it is significantly older than most other martian meteorites," said Mitch Schulte, program scientist for the Mars Exploration Program at NASA Headquarters. "We now have insight into a piece of Mars' history at a critical time in its evolution."

The meteorite is an excellent match for surface rocks and outcrops NASA has studied remotely via Mars rovers and Mars-orbiting satellites. NWA 7034's composition is different from any previously studied martian meteorite. The research is published in the January 3 edition of *Science Express*.

"The contents of this meteorite may challenge many long held notions about martian geology," said John Grunsfeld, associate administrator for NASA's Science Mission Directorate. "These findings also present an important reference frame for the Curiosity rover as it searches for reduced organics in the minerals exposed in the bedrock of Gale Crater."

NWA 7034 is made of cemented fragments of basalt, rock that forms from rapidly cooled lava. The fragments are primarily feldspar and pyroxene, most likely from volcanic activity. This unusual meteorite's chemistry matches that of the martian crust as measured by NASA's Mars Exploration Rovers and Mars Odyssey Orbiter.

The research team included groups at the University of California at San Diego and the Carnegie Institution in Washington. Experiments were conducted to analyze mineral and chemical composition, age, and water content. Researchers theorize the large amount of water contained in NWA 7034 may have originated from interaction of the rocks with water present in Mars' crust. The meteorite also has a different mixture of oxygen isotopes than has been found in other martian meteorites, which could have resulted from interaction with the martian atmosphere. The full article is available online at *www.sciencemag.org/content/early/2013/01/02/science.1228858*.

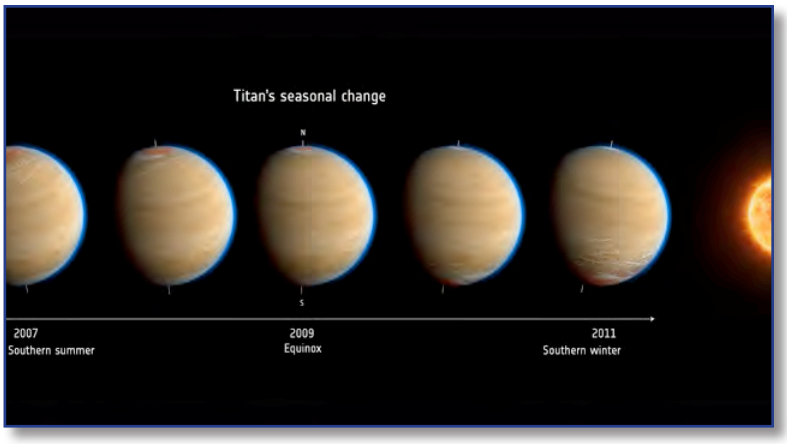
Cassini Sees Abrupt Turn in Titan's Atmosphere

Data from the Cassini spacecraft tie a shift in seasonal sunlight to a wholesale reversal, at unexpected altitudes, in the circulation of the atmosphere of Saturn's moon Titan. At the south pole, the data show definitive evidence for sinking air where it was upwelling earlier in the mission. So the key to circulation in the atmosphere of Saturn's moon Titan turned out to be a certain slant of light. The paper was published on November 28 in the journal *Nature*.

"Cassini's up-close observations are likely the only ones we'll have in our lifetime of a transition like this in action," said Nick Teanby, the study's lead author, who is based at the University of Bristol, England, and is a Cassini team associate. "It's extremely exciting to see such rapid changes on a body that usually

changes so slowly and has a 'year' that is the equivalent of nearly 30 Earth years."

In our solar system, only Earth, Venus, Mars, and Titan have both a solid surface and a substantial atmosphere — providing natural laboratories for exploring climate processes. "Understanding Titan's atmosphere gives us clues for understanding our own complex atmosphere," said Scott Edgington, Cassini deputy project scientist at NASA's Jet Propulsion Laboratory. "Some of the complexity in both places arises from the interplay of atmospheric circulation and chemistry."



This artist's impression of Saturn's moon Titan shows the change in observed atmospheric effects before, during, and after equinox in 2009. The Titan globes also provide an impression of the detached haze layer that extends all around the moon (blue). This image was inspired by data from the Cassini mission. Credit: ESA.

The pole on Titan that is experiencing winter is typically pointed away from Earth due to orbital geometry. Because Cassini has been in orbit around Saturn since 2004, it has been able to study the moon from angles impossible from Earth and watch changes develop over time. Models have predicted circulation changes for nearly 20 years, but Cassini has finally directly observed them happening — marking a major milestone in the mission.

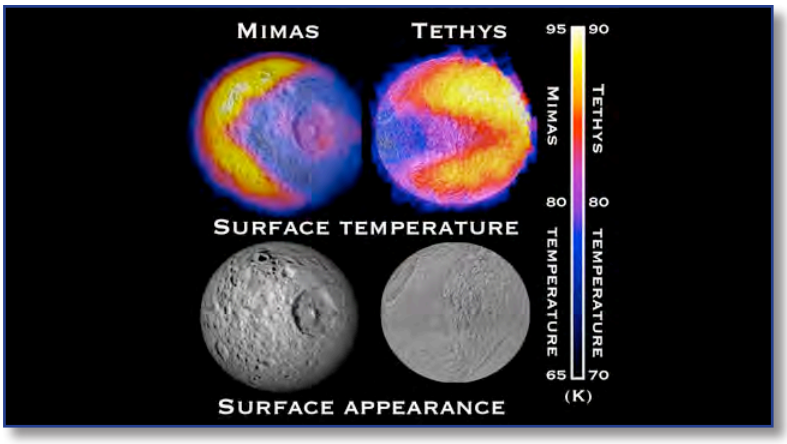
Other Cassini instruments recently obtained images of the formation of haze and a vortex over Titan's south pole, but the data from the composite infrared spectrometer (CIRS) is sensitive to much higher altitudes, provides more quantitative information, and more directly probes the circulation and chemistry. The CIRS data, which enable scientists to track changes in atmospheric temperature and the distribution of gases like benzene and hydrogen cyanide, also revealed changes in hard-to-detect vertical winds and global circulation.

Besides the evidence for sinking air, Cassini also detected complex chemical production in the atmosphere at up to 400 miles (600 kilometers) above the surface, revealing the atmospheric circulation extends about 60 miles (100 kilometers) higher than previously expected. Compression of this sinking air as it moved to lower altitudes produced a hot spot hovering high above the south pole, the first indication of big changes to come. The scientists were also able to see very rapid changes in the atmosphere and pinpoint the circulation reversal to about six months around the August 2009 equinox, when the Sun shone directly over Titan's equator. The circulation change meant that within two years of equinox, some gases had increased in abundance 100-fold — much more extreme than anything seen so far on Titan.

The results also suggest that a detached layer of haze (first detected by NASA's Voyager spacecraft) may not be so detached after all, since complex chemistry and vertical atmospheric movement is occurring above this layer. This layer may instead be the region where small haze particles combine into larger, but more transparent, clumped aggregates that eventually descend deeper into the atmosphere and give Titan its characteristic orange appearance.

"Next, we would expect to see the vortex over the south pole build up," said Mike Flasar, the CIRS principal investigator at NASA's Goddard Space Flight Center. "As that happens, one question is whether the south winter pole will be the identical twin of the north winter pole, or will it have a distinct personality? The most important thing is to be able to keep watching as these changes happen."

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



Scientists with NASA's Cassini mission have spotted two features shaped like the 1980s video game icon "Pac-Man" on moons of Saturn. One was observed on the moon Mimas in 2010 and the latest was observed on the moon Tethys. Credit: NASA/JPL-Caltech/GSFC/SWRI.

Cassini Finds a Video Gamers' Paradise at Saturn

You could call this "Pac-Man, the Sequel." Scientists with NASA's Cassini mission have spotted a second feature shaped like the 1980s video game icon in the Saturn system, this time on the moon Tethys. (The first was found on Mimas in 2010.) The pattern appears in thermal data obtained by Cassini's composite infrared spectrometer, with warmer areas making up the Pac-Man shape.

"Finding a second Pac-Man in the Saturn system tells us that the processes creating these Pac-Men are more widespread than previously thought," said Carly Howett, the lead author of a paper recently released online in the journal *Icarus*. "The Saturn system — and even the Jupiter system — could turn out to be a veritable arcade of these characters."

Scientists theorize that the Pac-Man thermal shape on the saturnian moons occurs because of the way high-energy electrons bombard low latitudes on the side of the moon that faces forward as it orbits around Saturn. The bombardment turns that part of the fluffy surface into hard-packed ice. As a result, the altered surface does not heat as rapidly in the sunshine or cool down as quickly at night as the rest of the surface, similar to how a boardwalk at the beach feels cooler during the day but warmer at night than the nearby sand. Finding another Pac-Man on Tethys confirms that high-energy electrons can dramatically alter the surface of an icy moon. Also, because the altered region on Tethys, unlike on Mimas, is also bombarded by icy particles from Enceladus' plumes, it implies the surface alteration is occurring more quickly than its recoating by plume particles.

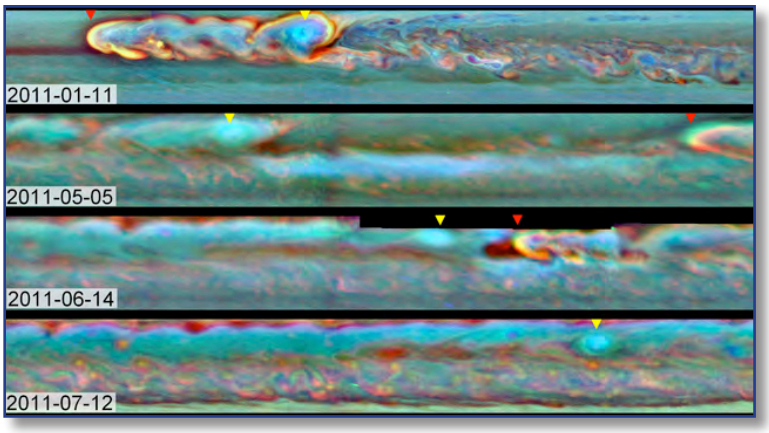
Scientists saw the new Pac-Man on Tethys in data obtained on September 14, 2011, where daytime temperatures inside the mouth of Pac-Man were seen to be cooler than their surroundings by 29°F (15 K). The warmest temperature recorded was a chilly –300°F (90 K), which is actually slightly cooler than the warmest temperature at Mimas (about –290°F, or 95 K). At Tethys, unlike Mimas, the Pac-Man pattern can also be seen subtly in visible-light images of the surface, as a dark lens-shaped region. This brightness variation was first noticed by NASA's Voyager spacecraft in 1980.

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

Cassini Watches Storm Choke on Its Own Tail

Call it a saturnian version of the Ouroboros, the mythical serpent that bites its own tail. In a new paper that provides the most detail yet about the life and death of a monstrous thunder-and-lightning storm on Saturn, scientists from NASA's Cassini mission describe how the massive storm churned around the planet until it encountered its own tail and sputtered out. It is the first time scientists have observed a storm consume itself in this way anywhere in the solar system. "This Saturn storm behaved like a terrestrial hurricane — but with a twist unique to Saturn," said Andrew Ingersoll, a Cassini imaging team member based at the California Institute of Technology, Pasadena, who is a co-author on the new

paper in the journal *Icarus*. "Even the giant storms at Jupiter don't consume themselves like this, which goes to show that nature can play many awe-inspiring variations on a theme and surprise us again and again."



This set of images from NASA's Cassini mission shows the evolution of a massive thunder-and-lightning storm that circled all the way around Saturn and fizzled when it ran into its own tail. Credit: NASA/JPL-Caltech/SSI/Hampton University.

Earth's hurricanes feed off the energy of warm water and leave a cold-water wake. This storm in Saturn's northern hemisphere also feasted off warm "air" in the gas giant's atmosphere. The storm, first detected on December 5, 2010, and tracked by Cassini's radio and plasma wave subsystem and imaging cameras, erupted around 33°N latitude. Shortly after the bright, turbulent head of the storm emerged and started moving west, it spawned a clockwise-spinning vortex that drifted much more slowly. Within months, the storm wrapped around the planet at that latitude, stretching about 190,000 miles (300,000 kilometers) in circumference, thundering and throwing lightning along the way.

Terrestrial storms have never run into their own wakes — they encounter topographic features like mountains first and expend themselves. But Saturn has no land to stop its hurricanes. The bright, turbulent storm head was able to chomp all the way around the planet. It was only when the head of the storm ran into the vortex in June 2011 that the massive, convective storm faded away. Why the encounter would shut down the storm is still a mystery.

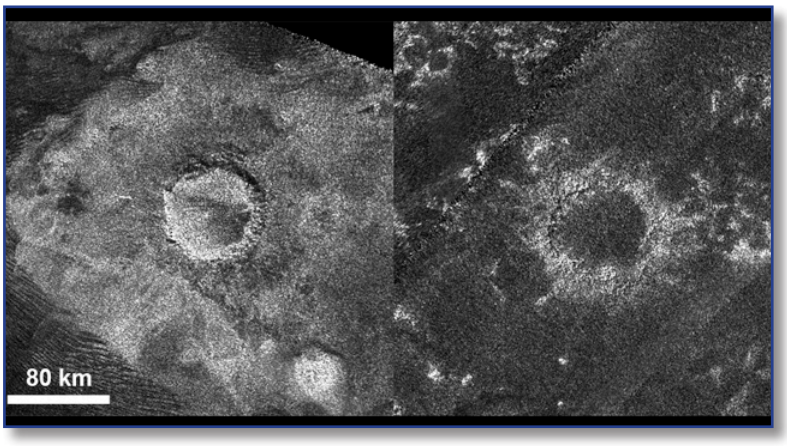
By August 28, after 267 days, the Saturn storm stopped thundering for good. While Cassini's infrared detectors continue to track some lingering effects in higher layers of Saturn's atmosphere, the troposphere — which is the weather-producing layer, lower in the atmosphere — has been quiet at that latitude. "This thunder-and-lightning storm on Saturn was a beast," said Kunio Sayanagi, the paper's lead author and a Cassini imaging team associate at Hampton University in Virginia. "The storm maintained its intensity for an unusually long time. The storm head itself thrashed for 201 days, and its updraft erupted with an intensity that would have sucked out the entire volume of Earth's atmosphere in 150 days. And it also created the largest vortex ever observed in the troposphere of Saturn, expanding up to 7500 miles [12,000 kilometers] across."

The vortex grew to be as large as the giant storm known as Oval BA on Jupiter. But Oval BA and Jupiter's more famous storm — the Great Red Spot — are not thunder-and-lightning storms. Jupiter's storms also have a quiet center, unlike the violence at the center of Saturn's storms. "Cassini's stay in the Saturn system has enabled us to marvel at the power of this storm," said Scott Edgington, Cassini's deputy project scientist at NASA's Jet Propulsion Laboratory in Pasadena, California. "We had front-row seats to a wonderful adventure movie and got to watch the whole plot from start to finish. These kinds of data help scientists compare weather patterns around our solar system and learn what sustains and extinguishes them."

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

Titan Gets a Dune "Makeover"

Titan's siblings must be jealous. While most of Saturn's moons display their ancient faces pockmarked by thousands of craters, Titan — Saturn's largest moon — may look much younger than it really is because its craters are getting erased. Dunes of exotic, hydrocarbon sand are slowly but steadily filling in its craters, according to new research using observations from NASA's Cassini spacecraft.



This set of images from the radar instrument on NASA's Cassini spacecraft shows a relatively "fresh" crater called Sinlap (left) and an extremely degraded crater called Soi (right). Sinlap has a depth-to-diameter ratio close to what we see on Jupiter's moon Ganymede. Soi has a shallow depth compared to similar craters on Ganymede. These craters are both about 50 miles (80 kilometers) in diameter. Credit: NASA/JPL-Caltech/ASI/GSFC.

"Most of the saturnian satellites — Titan's siblings — have thousands and thousands of craters on their surface. So far on Titan, of the 50% of the surface that we've seen in high resolution, we've only found about 60 craters," said Catherine Neish, a Cassini radar team associate based at NASA's Goddard Space Flight Center. "It's possible that there are many more craters on Titan, but they are not visible from space because they are so eroded. We typically estimate the age of a planet's surface by counting the number of craters on it (more craters means an older surface). But if processes like stream erosion or drifting sand dunes are filling them in, it's possible that the surface is much older that it appears." Adds Neish, "This research is the first quantitative estimate of how much the weather on Titan has modified its surface."

Titan is the only moon in the solar system with a thick atmosphere, and the only world besides Earth known to have lakes and seas on its surface. However, Titan has a frigid surface temperature of around –290°F (94 K). The rain that falls from Titan's skies is not water, but contains liquid methane and ethane, compounds that are gases at Earth's temperatures.

Neish and her team compared craters on Titan to craters on Jupiter's moon Ganymede. Ganymede is a giant moon with a water ice crust, similar to Titan, so craters on the two moons should have similar shapes. However, Ganymede has almost no atmosphere and thus no wind or rain to erode its surface.

"We found that craters on Titan were on average hundreds of yards [meters] shallower than similarly sized craters on Ganymede, suggesting that some process on Titan is filling its craters," says Neish, who is lead author of a paper about this research published online in *Icarus* on December 3, 2012.

The team used the average depth-vs.-diameter trend for craters on Ganymede derived from stereo images from NASA's Galileo spacecraft. The same trend for craters on Titan was calculated using estimates of the crater depth from images made by Cassini's radar instrument. "Since the sand appears to be produced from the atmospheric methane, Titan must have had methane in its atmosphere for at least several hundred million years in order to fill craters to the levels we are seeing," says Neish. However, researchers estimate Titan's current supply of methane should be broken down by sunlight within tens of millions of years, so Titan either had a lot more methane in the past, or it is being replenished somehow.

Team members say it's possible that other processes could be filling the craters on Titan: erosion from the flow of liquid methane and ethane, for example. Solid materials, under stress, also flow very slowly over time. This is called viscous flow, and it is like what happens when someone takes a scoop out of a

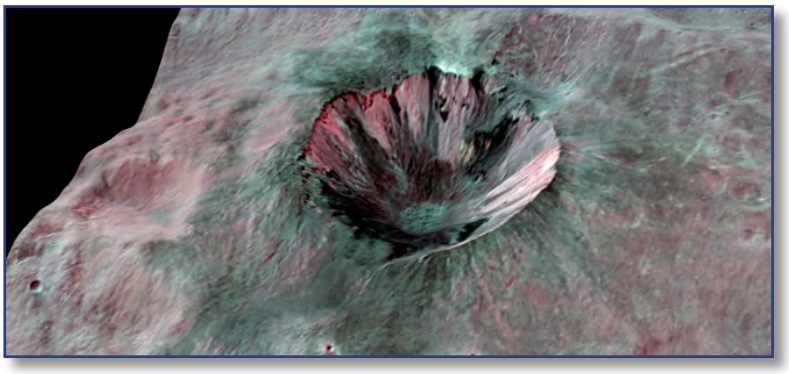
fresh tub of whipped cream — the material slowly flows in to fill the hole and flatten the surface. Craters on icy satellites tend to get shallower over time as the ice flows viscously, so it's possible that some of the shallow craters on Titan are simply much older or experienced a higher heat flow than the similarly sized, fresh craters on Ganymede studied in this work.

As Cassini flies past Titan on its multiyear tour of Saturn and its moons, its radar instrument gradually builds up a map of the surface. To date, the instrument has provided data in strips covering approximately 50% of Titan's surface. The craters measured by the team are all within about 30° of the equator, a relatively dry region on Titan.

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

Picture This: Vesta's Dark Materials in Dawn's View

A new study of images from NASA's Dawn mission examines remarkable, dark-as-coal material that speckles the surface of the giant asteroid Vesta. Scientists are using the images, taken by Dawn's framing camera, to understand the impact environment early in Vesta's evolution.



This composite-color view from NASA's Dawn mission shows Cornelia Crater, streaked with dark materials, on the giant asteroid Vesta. Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA.

In the most comprehensive analysis of the dark material to date, Dawn scientists describe how this carbon-rich material tends to appear around the edges of two giant impact basins in Vesta's southern hemisphere. The analysis suggests that the dark material was most likely delivered by the object that created the older of the two basins, known as Veneneia, about 2 to 3 billion years ago. Some of those materials were later covered up by the impact that created the younger basin, Rheasilvia. The paper, published in the November-December issue of the journal *Icarus*, was led by Vishnu Reddy of the Max Planck Institute for Solar System Research, Katlenburg-Lindau, Germany, and the University of North Dakota, Grand Forks.

The Dawn spacecraft orbited Vesta for more than a year, departing in September 2012. Dawn is now on its way to the dwarf planet Ceres, and will arrive in early 2015. For more information, visit *www.nasa.gov/dawn* or *dawn.jpl.nasa.gov*.

Chinese Spacecraft Successfully Completes Asteroid Flyby

Chang'e-2, China's second lunar orbiter, has successfully executed a close flyby of the Toutatis asteroid at a distance of approximately 7 million kilometers from Earth, making China the fourth country — after the United States, European Space Agency, and Japan — to explore asteroids. According to Chinese news sources, at 1630 on December 13, Chang'e-2 responded to commands and approached and made a close flyby of the Toutatis asteroid. Chang'e-2's relative speed at the time was 10.73 kilometers per second, and the closest distance was 3.2 kilometers from the asteroid. Chang'e-2 has a science payload that is virtually identical to that of its predecessor, Chang'e-1. Instruments include an imaging spectrometer, gamma- and X-ray spectrometers, a laser altimeter, and other instruments. Chang'e-2 used its onboard star observation cameras to capture images of the asteroid.

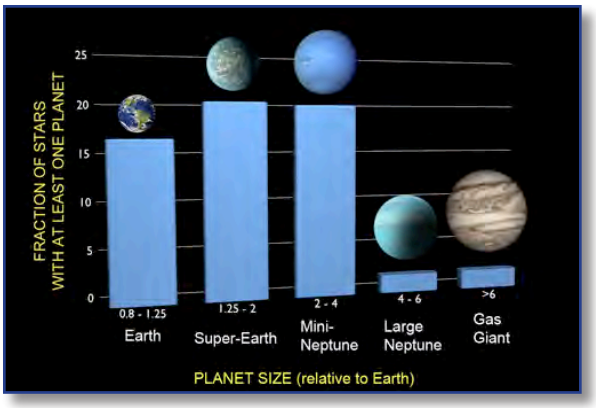
These close-ups of asteroid 4179 Toutatis, recorded from a distance of 58 to 150 miles (93 to 240 kilometers) by the Chang'e 2 spacecraft on December 13, 2012, reveal surface features down to about 35 feet (10 meters) across. Toutatis is 2.8 miles (4.5 kilometers) long. Credit: CLEP/Xinhua.

Observed chief lunar exploration engineer Wu Wei-Ren, "We completed our mission very well today; this is our first time exploring [an] asteroid. This is the world's first close-distance image capture of the Toutatis asteroid. It not only proves Chang'e-2's orbit design and navigation control, but it also realizes China's improvement in its reach for space going from 400,000 kilometers [distance to the Moon] out to 7 million kilometers from Earth."

The completion of the extended mission by Chang'e-2 means that the satelite has successfully completed its overall mission. Chang'e-2 was launched on October 1, 2010. After spending eight months orbiting the Moon, successfully completing its six planned primary engineering and four scientific missions, it flew to the L2 Lagrange point, approximately 1.5 million kilometers from Earth, then traveled on to the Toutatis asteroid.

Toutatis (formal name 4179 Toutatis) is an Apollo, Alinda, and Mars-crossing asteroid with a chaotic orbit produced by a 3:1 resonance with the planet Jupiter, a 1:4 resonance with the planet Earth, and frequent close approaches to the terrestrial planets, including Earth. It is listed as a potentially hazardous object, although the odds of a collision with the Earth are minute.

Spectral properties suggest that Toutatis is an S-type, or stony asteroid, consisting primarily of silicates. It has a moderately bright Bond albedo of 0.13. Radar imagery shows that Toutatis is a highly irregular body consisting of two distinct "lobes," with maximum widths of about 4.6 km and 2.4 km respectively. It is hypothesized that Toutatis formed from two originally separate bodies which coalesced at some point, with the resultant asteroid being compared to a "rubble pile." Views captured by Chang'e-2 seem to confirm this notion, and show that the double-lobed asteroid has a relatively smooth surface with muted craters and scattered clusters of boulders, with the surface seemingly blanketed by loose dust.



The results of a new analysis of Kepler data show that one in six stars has an Earth-sized planet in a tight orbit. About a fourth of all stars in the Milky Way have a super-Earth, and the same fraction have a mini-Neptune. Only about 3% of stars have a large Neptune, and only 5% a gas giant at the orbital distances studied. Credit: F. Fressin (CfA).

At Least One in Six Stars Has an Earth-Sized Planet

The quest to determine if planets like Earth are rare or common is taking another stride forward on the journey. Using NASA's Kepler spacecraft, astronomers are beginning to find Earth-sized planets orbiting distant stars. A new analysis of Kepler data shows that about 17% of stars have an Earth-sized planet in an orbit closer than Mercury. Since the Milky Way has about 100 billion stars, there are at least 17 billion Earth-sized worlds out there. Francois Fressin, of the Harvard-Smithsonian Center for Astrophysics (CfA), presented the analysis in January at a press conference during the American Astronomical Society meeting in Long Beach, California. A paper detailing the research has been accepted for publication in *The Astrophysical Journal.*

The research team found that 50% of all stars have a planet of Earth size or larger in a close orbit. By adding larger planets detected in wider orbits up to the orbital distance of the Earth, this number increases to 70%. Extrapolating from Kepler's currently ongoing observations and results from other detection techniques, scientists have determined that nearly all Sun-like stars have planets.

Planets closer to their stars are easier to find because they transit more frequently. As more data are gathered, planets in larger orbits will be detected. In particular, Kepler's extended mission will enable the detection of Earth-sized planets at greater distances, including Earth-like orbits in the "habitable zone," the region in a planetary system where liquid water might exist on the surface of an orbiting planet.

Kepler is the first NASA mission capable of finding Earth-sized planets orbiting in or near the habitable zone of the host star. For more information, visit *kepler.nasa.gov* or *www.nasa.gov/kepler*.

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: April 15, 2013

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

Lunar and Planetary Science Conference: Education Opportunities

The 44th Lunar and Planetary Science Conference will be held at The Woodlands Waterway Marriott Hotel and Convention Center, The Woodlands, Texas, March 18–22, 2013. There will be a variety of events and opportunities that will be of interest to the E/PO community and scientists who are involved in — or are interested in — education and outreach.

There are many E/PO opportunities to participate in at LPSC this year! Additional details are available at *www.lpi.usra.edu/meetings/lpsc2013/events/education/*.

Faculty members teaching undergraduate classes are invited to participate in the **Planetary Science Undergraduate Teaching Workshop** on Sunday, March 17, from 1:00 to 5:00 p.m. This year, we are teaming with the Center for Lunar Science and Exploration to bring together scientists and educators to talk about the latest in lunar science, lunar science education products, and tools that can be used in the undergraduate classroom. We invite you to attend the workshop! If you have a lunar-related activity that you would like to share, let us know. If you have a specific area of interest, scientific or educational, let us know and we'll try to get it included. Please RVSP to Emily CoBabe-Ammann at *ecobabe@spaceeducation.org*.

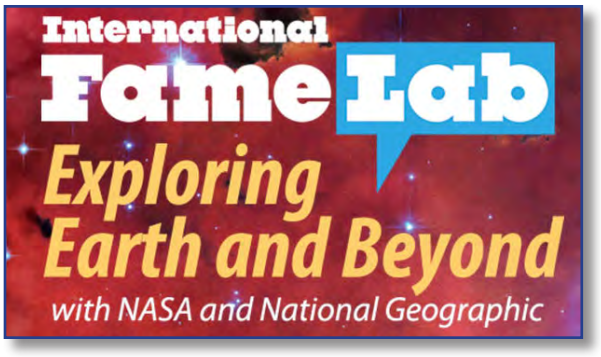
E/PO specialists and scientists who are involved in E/PO programs are invited to register for a **free workshop** that explores *First Steps in Program Evaluation* on Sunday, March 17, from 9:00 a.m. to 5:00 p.m. The workshop is designed as a starting point for learning about program evaluation, a critical component of all E/PO projects. During this workshop, you will interact with professional evaluators to create a basic evaluation plan for your project or program. You will also hear about what an external evaluator does if you are in need of one. Participants need to complete the registration form (*www.lpi.usra.edu/education/nasa_smd_pf/index.cfm*) by 5:00 p.m. Pacific time, March 8, 2013.

The **LPSC oral session,** *Rising to the Challenge: Improving the Public Understanding of Science in the Next Decade,* will explore innovative efforts that are emerging for engaging the public in science with the result of increasing science awareness, literacy, and understanding on Tuesday, March 19, from 1:30 to 5:00 p.m. in Waterway Ballroom 1. Presentations include:

- *Planetary Science: The Need and Responsibility to Engage the Public and the Challenge of Effectiveness,* Dr. Mark V. Sykes, Planetary Science Institute
- *What Does the Public Need to Know? The Nature of Science and Functioning Public Scientific Literacy,* Dr. Martin Storksdieck, Board on Science Education, National Academy of Sciences

- *Engaging the Public in Planetary Science Through Emerging Technology and New Media,* Samantha Becker, New Media Consortium
- *OSIRIS-REx Target Asteroids! Involving the Public in Asteroid Research and Scientists with the Public,* Anna Spitz, Carl Hergenrother, Dolores Hill, and Dante Lauretta
- *Ground-Based Observations of Lunar Meteoroid Phenomena in Support of the LADEE Mission,* Brian Cudnik and Brian Day
- *The Dawn Mission's Use of Google + Hangout for Professional Development and Product Assessment,* Joseph Wise, Britney Schmidt, Whitney Cobb, Judy Counley, Nicole Hess, Jennifer Scully, Pamela Gay, Scott Lewis, and Nicole Gugliccu
- *Follow Your Curiosity: A New Era of Public Participation in Discovery,* Michelle Viotti and Ken Edgett
- *Engaging the World in Dialog About Space: Humans in Space Youth Art Competition,* Jancy McPhee
- *The CosmoQuest Virtual Research Facility for the Public,* Pamela Gay, Nicole Gugliccu, Georgia Bracey, Cory Lehan, and Scott Lewis

Visit the **E/PO posters** to speak with E/PO colleagues and learn more about programs and products that bring current planetary science to a variety of audiences on Tuesday evening, March 19, beginning at 6:00 p.m. in the Town Hall Center Exhibit Area.



FameLab: Exploring Earth and Beyond... at the 44th Lunar and Planetary Science Conference!

Calling all early career scientists! Passionate about science? Love to communicate? You are wholeheartedly invited to participate in FameLab: Exploring Earth and Beyond... at the 44th Lunar and Planetary Science Conference!

FameLab is something like American Idol for scientists. Sponsored by NASA and National Geographic, it's a fun-filled day of competition, coaching, and camaraderie that's all about science communication!

At regional heats held across the U.S. over the next year, early career scientists from diverse scientific disciplines craft a three-minute, PowerPoint-free talk on their research or a related topic and deliver it in a supportive environment to judges who give only constructive feedback. No slides, no charts — just the power of words and any prop you can hold in your hands. The heart of the whole thing is a workshop conducted by communication professionals to help participants enrich their skills. So, unlike American Idol, everyone wins!

Winners from the regional competitions advance to the U.S. finals in April 2014, and the winner there goes on to compete with peers from around the world at the FameLab International Final in the UK in June 2014. It's quite the global sensation.

The competition rounds and workshop will be held on Sunday, March 17, from ~10:00 a.m. to 5:00 p.m. Ten participants will be selected to compete in a special evening event during LPSC on Wednesday,

March 20, from ~6:00 p.m. to ~10:00 p.m. There is no cost for any of the FameLab events. Space is limited, so register today at *famelab-eeb.arc.nasa.gov*.

Planetary Science E/PO Resources Sampler and Quick Start Guide

Looking for education resources connected to planetary missions and themes? The NASA SMD Education and Public Outreach Planetary Forum has created a brochure that connects the big questions and themes to existing programs and resources, along with suggestions on how to use the resources. Find it online at *smdepo.org/sites/default/files/PS_EPO_Resources_2.pdf*.

NASA SMD Scientist Speakers' Bureau

All NASA Science Mission Directorate-funded scientists interested in giving presentations are invited to join the new NASA SMD Scientist Speaker's Bureau! The intent of this new system is to enable educators and institutions to contact NASA scientists who are interested in giving presentations, based upon the topic, logistics, and audience. Aside from name, organization, location, bio, and (optional) photo and website, the information that scientists enter into this database will not be made public; instead, it will be used to help match scientists with the requests being placed.

Interested scientists can sign up at *www.lpi.usra.edu/education/speaker*.

Sun-Earth Days 2013:
Solar Max — Storm Warning: Effects on the Solar System

Join NASA in celebrating Sun-Earth Days with a series of programs and events that occur throughout the year, culminating with a final celebration. This year's theme, "Solar Max — Storm Warning: Effects on the Solar System," invites participants to explore the violent nature of our Sun at the peak of solar activity and the discoveries coming from the heliophysics and planetary missions during this exciting period. Learn about solar maximum and how it, along with other space weather, affects our daily lives. Find out why scientists and engineers find it important to track space weather, and learn about NASA Wallops Flight Facility's role in launching rockets to explore weather on Earth and in space.

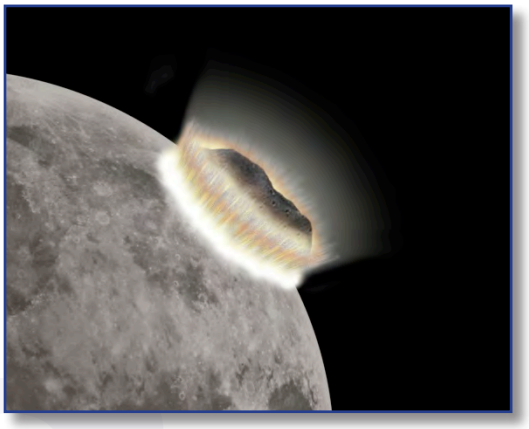
The final celebration on March 22 will feature a live Sun-Earth Day webcast. For more information, resources, and social media connections, visit *1.usa.gov/WmhWDs*.

EarthSpace

EarthSpace is a community web space for anyone to find and share about teaching space and Earth sciences in the undergraduate classroom. It includes materials for the undergraduate classroom, such as lectures, homework assignments, labs, course syllabi, and demos; news regarding the latest funding opportunities, policy news, important programs and products, workshops, and meetings; educational research — the latest innovations on teaching undergraduates; and a moderated listserv and monthly newsletter for undergraduate educators.

Not only does EarthSpace allow you to share your classroom assets with your colleagues, this new site can automatically cross-post your materials to other digital libraries and virtual higher-education clearinghouses, giving you a national platform.

EarthSpace is supported by the NASA Science Mission Directorate Education and Public Outreach Forums in Heliophysics and Planetary Science and is hosted by the Lunar and Planetary Institute. To visit EarthSpace, go to *www.lpi.usra.edu/earthspace*.



Center for Lunar Science and Exploration Releases Higher Education Lunar Resources

The Lunar and Planetary Institute (LPI) and the Center for Lunar Science and Exploration (CLSE), in collaboration with a number of higher education institutions, has announced the establishment of a Higher Education Lunar Consortium. Science faculty and CLSE researchers are working together to infuse lunar science and exploration content into undergraduate and graduate courses by developing online material that teachers anywhere in the world can access and incorporate into their classrooms.

The newly designed Higher Education Lunar Consortium webpage provides access to such resources as:

- **Classroom Illustrations:** Downloadable classroom illustrations with instructional captions for educational use
- **3D Models:** 3D models currently available include Linné Crater, Tycho Crater, and Schrödinger Basin
- **Laboratory Exercises:** Exercises that can be integrated into planetary geology courses or can stand alone as a way to illustrate planetary processes such as impact cratering
- **Lunar Sample Atlases:** Libraries of images taken in the Lunar Sample Laboratory and other research laboratories, including the Apollo Thin-Section atlas and the Virtual Microscope catalog
- **Lunar Image Atlases:** Links to a number of lunar image atlases, including Apollo surface panoramas and the Lunar Orbiter Photo Gallery

- **Video Resources:** Including flyovers, simulations, and the Moon 101 Lecture Series
- **Lunar Analogue Data Sites:** Extensive information about Barringer Meteor Crater and the Black Point Lava Flow in Arizona
- **Lunar-Related Textbooks:** Electronic versions of a number of essential books for lunar researchers, including *The Geologic History of the Moon, Planetary Science: A Lunar Perspective,* and *Lunar Sourcebook: A User's Guide to the Moon*

Other resources available include PowerPoint slide sets and PDF briefing packages; computational tools; consortium laboratory exercises; and additional classroom and laboratory props. The list of LPI/CLSE resources available to the community will continue to expand as new science and exploration concepts are developed, in an effort to provide students the latest exploration results and opportunities for research and careers in cutting-edge lunar science.

For more information and to access these resources, visit *www.lpi.usra.edu/nlsi/training/resources*.

Astronomical Society of the Pacific 125th Annual Meeting

The Astronomical Society of the Pacific (ASP) celebrates the 125th gathering of educators and public outreach professionals at the 2013 annual meeting on July 20–24, 2013. This year's meeting is hosted by San Jose State University, with a focus on STEM literacy across multiple disciplines. A Galileo Teacher Training Program will be featured, marking a Cosmos in the Classroom year. For more information and to register, visit *bit.ly/WjEGVv*.

2013 Jet Propulsion Laboratory Summer Faculty Research Program

Applications are currently being accepted for NASA's Jet Propulsion Laboratory 2013 Summer Faculty Research Program. This program provides opportunities for science, technology, engineering, and mathematics (STEM) faculty to engage in research of mutual interest to the faculty member and a JPL researcher. Non-STEM faculty will be considered based on available opportunities. To be eligible to participate in the program, a potential fellow must hold a full-time appointment at an accredited university or college in the U.S. Special requirements for foreign national faculty members may apply. Fellows are required to submit a research report and present their work at the end of the session.

The program awards $13,500 fellowships for the 10-week session. A housing allowance will be offered for awardees who live beyond a 50-mile radius of JPL. Please note that stipend payments or salaries from other federal funding sources, including research grants and contracts, may not be accepted during the 10-week tenure of a JPL faculty research appointment.

The deadline for applications is April 1, 2013. For more information about this opportunity, visit *jsfrp.jpl.nasa.gov*. Inquiries about NASA's JPL Summer Faculty Research Program should be directed to Petra Kneissl-Milanian at *Petra.A.Kneissl-Milanian@jpl.nasa.gov*.

Devendra Lal, 1929–2012

The planetary science community is mourning the loss of longtime teacher, friend, and colleague Devendra Lal, who died on December 1, 2012, at his home in San Diego, California. He was 83 years old.

Throughout his long career, Lal was known for the diversity and creativity of his research interests. His early work on the composition and energy spectrum of primary cosmic radiation and in elementary particle physics became the basis for his research on the mechanisms and rates of natural physical and chemical processes on Earth and in the solar system using radionuclides. He published extensively on cosmic-ray-produced radioisotopes in terrestrial environments, in the atmosphere, in polar ice, in the oceans and oceanic sediments, and in lakes. He also worked on nuclear tracks and radioactivity in lunar samples and meteorites. This work brought him numerous international honors, among them as a Fellow of the Royal Society, Foreign Associate of the U.S. National Academy of Sciences, Fellow of the Indian Academy of Sciences, and recipient of the V. M. Goldschmidt Medal of the Geochemical Society.

Lal was born February 14, 1929, to a large family of modest means in Varanasi, India, where he completed his bachelor's and master's education at Banaras Hindu University. His pioneering Ph.D. thesis research on cosmic-ray physics at the Tata Institute of Fundamental Research in Bombay (Mumbai) and Bombay University, completed in 1960, had its roots in the origins of modern physics in Germany and the U.S. through his thesis advisor Professor Bernard Peters, who was a refugee from both Nazism in Germany and McCarthyism in the U.S.

Lal first joined the staff of the Scripps Institution of Oceanography in San Diego, California, as a visiting researcher in 1957, and 10 years later as a professor of nuclear geophysics. Over his long career he divided his time between Scripps and appointments in India, first as a professor at the Tata Institute and then as professor and director of the Physical Research Laboratory in Ahmedabad, before making Scripps his full-time academic home in 1989. To his many friends and colleagues, Lal was best known for his insatiable curiosity, his good humor, and as a caring and demanding teacher. He was fond of asking: "What new idea did you have today?" No idea was too big or too outlandish to be considered. He loved to experiment, and if something didn't work he would try it another way. Some of his experiments were gigantic, such as dating ocean waters by submerging meter-sized frames packed with iron-impregnated sponges or fibers into the deep sea for many hours to extract minute quantities of the natural radioisotope silicon 32. He often frustrated his colleagues and students with his all-consuming pursuit of science. He was both uncompromising and patient with students, often lamenting their poor preparation, especially in mathematics, but also spending hours with them until they understood the material. Lal and his late wife Aruna were generous supporters of Scripps, notably through their endowment of the Devendra and Aruna Lal Fellowship in support of creative and exceptional Scripps graduate students. His wisdom and his good humor will be sorely missed, but his academic legacy and personal impact will remain with us for many years to come.

— Text courtesy of Scripps Institution of Oceanography

Sir Patrick Moore, 1923–2012

British astronomer and broadcaster Sir Patrick Moore has died at the age of 89. A statement issued by friends and colleagues said that Moore passed away peacefully at his home in Selsey, West Sussex, on December 9, 2012.

Moore presented the BBC programme *The Sky At Night* for more than 50 years, making him the longest-running host of the same television show ever. He wrote dozens of books on astronomy, and his research was used by the U.S. and the Russians in their space programs. Described by one of his close friends as "fearlessly eccentric," Moore was notable for his habit of wearing a monocle on screen and his idiosyncratic style. He was interred during a quiet ceremony, but a farewell event is being planned for what would have been his 90th birthday in March 2013.

Moore was born at Pinner, Middlesex, on March 4, 1923. Heart problems meant he spent much of his childhood being educated at home and he became an avid reader. His mother gave him a copy of G. F. Chambers' book, *The Story of the Solar System*, and this sparked his lifelong passion for astronomy. His was the voice of the space age; with rockets launching satellites and then astronauts above Earth and beyond, there was no greater enthusiast to chronicle and illuminate an exhilarating new era of exploration. Generations grew up with Moore as their guide and he proved hugely influential. Astronomy was no longer a niche activity, and the man with the monocle touched people who had never even thought of stargazing.

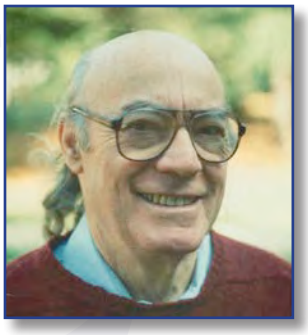
When war came, Moore turned down a place at Cambridge and lied about his age to join the Royal Air Force (RAF), serving as a navigator with Bomber Command and rising to the rank of Flight Lieutenant. But the war brought him a personal tragedy after his fiancee, Lorna, was killed when an ambulance she was driving was hit by a bomb. He never married.

During his professional career, Moore also served as the director of Ireland's Armagh Planetarium, and wrote some 70 books of popular astronomy. He was an enthusiastic amateur astronomer and contributed to mapping of the Moon before the space age (including Luna Incognita on the farside and the Orientale region during extreme librations).

Moore, who had a pacemaker fitted in 2006 and received a knighthood in 2001, won a Bafta for services to television and was a honorary fellow of the Royal Society. His other TV credits include the role of Gamesmaster in the 1990s computer games show of the same name.

"His enthusiasm was unstoppable, and on occasions he would talk at 300 words a minute," said Queen guitarist Brian May, who published a book on astronomy written with Moore, and described him as a "dear friend, and a kind of father figure to me." Added May, "Patrick will be mourned by the many to whom he was a caring uncle, and by all who loved the delightful wit and clarity of his writings, or enjoyed his fearlessly eccentric persona in public life. Patrick is irreplaceable. There will never be another Patrick Moore. But we were lucky enough to get one."

— Portions of text courtesy of the BBC



Bertram Donn (1919–2012)

Bertram "Bert" Donn, the first head of NASA Goddard's astrochemistry group, passed away on December 28, 2012, at age 93. Donn, a New Yorker by birth, attended Harvard University, where he was taught by such legends as Fred Whipple, Cecilia Payne, and Bart Bok. A meeting with Harold Urey in the 1950s turned Donn's attention to problems of low-temperature reactions and their connections to interstellar chemistry. A research collaboration was arranged with Urey at the University of Chicago, and several joint, influential publications resulted. Laboratory experiments followed, but were interrupted by Donn's move to NASA Goddard in 1959 to lead the newly formed astrochemistry section. He remained at Goddard for more than 30 years until his retirement.

His research at Goddard spanned theory, observation, and experiment, with connections to NASA missions such as Skylab, Apollo, and the International Ultraviolet Explorer. Almost all his research problems concerned cometary and interstellar matter in some way, and so perhaps it is not surprising that he began laboratory research in each area. Goddard's Cosmic Ice Laboratory and the Nucleation and Dust Chemistry Laboratory were established by Donn during his supervision of the Ph.D. research of Marla Moore and Joe Nuth, respectively. Donn was also an early NASA contributor to the astrobiological literature, and set in motion several astrobiology-related research projects.

A pioneer in astrochemistry and NASA research, he did much to establish NASA's strong scientific reputation among astronomers and planetary scientists around the world. Aside from his Goddard work, Donn was a well-known and honored advocate of nonviolence and peaceful conflict resolution, and was instrumental in the racial integration of Greenbelt, where he and his family lived for 50 years.

— Text courtesy of Joe Nuth and Reggie Hudson

Photo courtesy of Jim Zimbelman

Stephen Eugene Dwornik, 1926–2012

After a long and respected career, Stephen Eugene Dwornik passed away peacefully on December 17, 2012. Born on July 3, 1926, in Buffalo, New York, as a young boy he lived above, and worked at, his parents' neighborhood bar, learning from his mother a work ethic and social liveliness he never lost. He attended Buffalo's prestigious Technical High School and enlisted in the Army at age 17 (with the blessings of his mother in support of her adopted country). Dwornik fought along the front lines in Europe, participated in the Battle of the Bulge, and received the Army's Bronze Star for his service. After returning to Buffalo, he entered the State University of New York at Buffalo, where he received both a Bachelor's and a Master's degree in geology. Summer work included field work in Alaska along the Brooks Range in the late 1940s. After several years of persistent courting, he married the love of his life in 1951 and moved to Springfield, Virginia, to begin a career dedicated to scientific advancements, starting with mine detection at the U.S. Army Engineer Research and Development Laboratories and continuing with planetary geology space research at NASA.

Dwornik worked for NASA's Lunar and Planetary Programs Division of the Office of Space Science and Applications from 1965 to 1967. In 1968, he became Chief of Planetology in the Planetary Programs Division of the Office of Space Science, a position he held until 1976, when he served as Chief of Planetary Geology in the same division and office until 1979. At NASA, he was one of the first to recognize that the precision-engineered spacecraft that were being launched to the planets were nothing more than engineering experiments without scientific analysis of the returned data. That became his job — to find the best scientists to interpret the data returned from these missions and ultimately to understand the geologic development of the planets.

As Chief of Planetology and then Chief of Planetary Geology, he organized and managed a research program that lasted more than a dozen years, ensuring that NASA grants would be given to investigators who were doing interesting planetary research. The annual Planetary Geology Principal Investigators (PGPI) meeting that he organized became an early proving and training ground for planetary geology researchers and their students. His career spanned the time period from Mercury, Gemini, and Apollo to Mariner, Viking, and Voyager. Those whose careers were launched with his monetary support are now the leading figures and founding members of the field of planetary geoscience, and graduate students whose work was funded by these grants became the second generation of planetary geoscientists.

After retiring from NASA, he worked for Ball Aerospace for a number of years, and then spent a decade organizing an annual space-exploration-related elderhostel in association with William and Mary College. Dwornik was a son of Polish and Ukrainian immigrants, and that combined with his military service caused him to feel a great debt of gratitude to the U.S. As such, he was interested in encouraging more U.S. students to enter the field of planetary science. In the 1970s very few U.S. students were studying planetary science, and this concerned Dwornik. In 1991, he made an endowment to the Geological Society of America specifically to award U.S. students in planetary geoscience. The awards are managed by the Planetary Geology Division (PGD) of the Geological Society of America, and have been broadened by the PGD to include all aspects of planetary science submitted to the annual Lunar and Planetary Science Conference.

— Text courtesy of the GSA Planetary Geology Division

David S. McKay, 1936–2013

David S. McKay, Chief Scientist for Astrobiology at the NASA Johnson Space Center, passed away on February 20, 2013, at the age of 76. During the Apollo program, McKay gave the first men to walk on the Moon training in geology. In recent years, McKay was perhaps best known for being the first author of a scientific paper postulating past life on Mars on the basis of evidence in martian meteorite ALH 84001. This paper has become one of the most heavily cited papers in planetary science. The NASA Astrobiology Institute was founded partially as a result of community interest in this paper and related topics.

As a graduate student in geology at Rice University, McKay was present at John F. Kennedy's speech in 1962 announcing the goal of landing a man on the Moon within the decade. Kennedy's speech inspired his interest in helping to train the Apollo astronauts in geology. He was a chief trainer for Neil Armstrong and Buzz Aldrin during their last geology field trip in West Texas. On July 20, 1969, McKay was the only geologist present in the Apollo Mission Control Room in Houston when Armstrong and Aldrin walked on the Moon.

McKay studied lunar dust since the return of the first Apollo 11 samples in 1969, and contributed more than 200 publications on this topic. As a result of this effort, McKay contributed major discoveries, including the source of vapor deposition on lunar soil grains, the formation of nanophase iron globules on lunar soil grains, the processes on the Moon that contribute to grain size distribution, and insight into space weathering and the chemically activated nature of *in situ* lunar dust.

McKay was honored by the International Astronomical Union (IAU) by having an asteroid named after him in 2002. His IAU citation mentions his years of work on lunar samples as well as the positive effect his research on martian meteorites has had on planetary research. McKay was also a recipient of the Outstanding Graduate Student Award at Rice University, the NASA Superior Achievement Award for Lunar Science Contributions; the Laurels Award from Aviation Week and Space Technology, the NASA Exceptional Scientific Achievement Medal, and the Distinguished Texas Scientist Award from the Texas Academy of Science. McKay was with NASA for more than 47 years, and made substantial contributions to science during his career. He will be missed.

Director of NASA's Mars Exploration Program Announces Retirement

In January of this year, Doug McCuistion, Director of NASA's Mars Exploration Program, announced his retirement. Besides leading the Mars Exploration Program, McCuistion has held positions in Earth and space science at NASA Headquarters, the Goddard Space Flight Center, and the U.S. Navy. At Headquarters he was the Director of Flight Programs for NASA's Earth Science Enterprise. At Goddard, he worked on the Tracking and Data Relay Satellite (TDRS), Geosynchronous Operations Environmental Satellite (GOES), Landsat, NEXUS (a James Webb Space Telescope precursor), and as a Deputy Director in the Information Systems engineering division. Prior to his career in space, McCuistion was commissioned as an Ensign from Aviation Officer Candidate School in Pensacola and spent 13 years as an F-14 Tomcat RIO, and also worked the Navy's GEOSAT Follow-On mission. He retired from the Navy in 1998 at the rank of Commander. He has been recognized with the rank of Meritorious Senior Executive, and awarded two NASA Exceptional Achievement Medals; two Navy Commendation Medals; and various NASA, Navy, and other-Agency individual and group achievement awards.

The following is his letter to the Mars exploration community.

> "As I depart from the Program and NASA, after more than 20 years with [the] Agency and nearly 9 years leading the Mars Exploration Program, I want to thank and congratulate you all on what we have accomplished. As I look back it has truly been a remarkable decade of achievements, advancements, discovery, community convergence, and worldwide notoriety. From engineer to scientist to manager, we pulled together through some tough times, kept the program, missions and research on track, replanned as challenges were thrown our way, capitalized on the incredible successes of Odyssey, Spirit and Opportunity, MRO, Phoenix, and of course MSL/Curiosity. We have changed science and changed the text books! This community has shown incredible poise, resilience, selflessness and togetherness, and incredible foresight. You have had the vision to look past challenging times and create a bright future for Mars and solar system exploration. Our recent accomplishments with Curiosity have brought Mars and solar system exploration into many people's daily lives for the first time, and we have touched the world with this incredible feat — and there's more to come! The adventure is just beginning!
>
> While timing a retirement is always challenging, I leave encouraged and content — Curiosity safely on the surface doing incredible science (landing in a stream bed — what a start!), and a secure future for the Mars Exploration Program with a 2020 science rover mission after MAVEN and an ExoMars cooperation. In the interim, the Program is in good hands with Michael Meyer and Jim Green (acting Program Director). The Agency is well aware of the importance of Mars and will be actively pursuing a replacement.
>
> I have been honored to work with, and lead, such an extraordinary and innovative community. My years working with you, and our accomplishments, are without doubt the highlight of my career! Keep moving forward, keep innovating, keep discovering!
>
> On to Mars…
> Doug"

NASA Kepler Scientist Honored by National Academy of Sciences

William Borucki, science principal investigator for NASA's Kepler mission at the agency's Ames Research Center at Moffett Field in California, is the recipient of the 2013 Henry Draper Medal awarded by the National Academy of Sciences. Borucki is honored for his founding concept and visionary leadership during the development of Kepler, which uses transit photometry to determine the frequency and kinds of planets around other stars. "This is a commendable recognition for Bill Borucki and the Kepler mission," said John Grunsfeld, associate administrator for the Science Mission Directorate at NASA Headquarters in Washington. "It is well deserved and a tribute both to Bill's dedication and persistence and the fantastic and exciting results from Kepler."

Kepler is the first NASA mission capable of finding Earth-sized planets in or near the "habitable zone," the region in a planetary system where liquid water can exist on the surface of an orbiting planet. Kepler is detecting planets and possible candidates with a wide range of sizes and orbital distances to help scientists better understand our place in the galaxy. "It has been a privilege to participate in the initial steps in the search for life in our galaxy. I would like to thank all who have worked with me to make this possible," said Borucki.

Borucki earned a Master of Science degree in physics from the University of Wisconsin at Madison in 1962 and joined Ames as a space scientist that same year. The results of Borucki's early work developing spectroscopic instrumentation to determine the plasma properties of hypervelocity shock waves were used in the design of the heat shields for NASA's Apollo mission. In June of last year, Borucki celebrated 50 years of service at NASA.

The Henry Draper Medal is awarded every four years for an outstanding, recently published contribution to astrophysical research and carries with it an award of $15,000. The award will be presented at a ceremony April 28, during the National Academy of Sciences' 150th annual meeting in Washington.

NASA Named Best Place to Work in Government

NASA was named the best place to work in the federal government among large agencies in a survey released in December by the Partnership for Public Service, a nonprofit, non-partisan organization. This ranking, which reflects NASA's highest results since this index was developed, makes clear that the agency's work force is focused on carrying out the nation's new and ambitious space program.

"The best workforce in the nation has made NASA the best place to work in federal government," said NASA Deputy Administrator Lori Garver, who accepted the award at a ceremony in Washington, DC. "Our employees are carrying out the nation's new strategic missions in space with heart-stopping landings on Mars, cutting-edge science, and ground-breaking partnerships with American companies to resupplying the space station. They are truly leading in the innovation economy."

The rankings are based on responses from nearly 700,000 federal workers. The Best Places to Work rankings are based on data from the Office of Personnel Management's annual Federal Employee Viewpoint Survey conducted from April through June 2012 and additional survey data from nine agencies plus the Intelligence Community. This is the seventh edition of the Best Places to Work rankings since the first in 2003. NASA's Stennis Space Center was ranked second in the subagency component category.

NASA Selects High-Performing Interns as Student Ambassadors

NASA has inducted 86 top-performing interns into the 2013 NASA Student Ambassadors Virtual Community, a vital component of the agency's ongoing effort to engage undergraduate and graduate students in science, engineering, mathematics, and technology (STEM) research and interactive opportunities. This fifth group of student ambassadors, Cohort V, includes interns from 32 states and 70 different universities. NASA managers and mentors nominated the recipients from the hundreds of current interns and fellows across the agency. NASA's goal is to provide internships that are among the most exciting research and education opportunities available to college students. This online initiative further recognizes exceptional students. The NASA Student Ambassadors Virtual Community aims to elevate the experiences, visibility, and contribution of these students; leverage their presence and input for recruitment; and provide increased involvement with the agency's exploration and STEM education missions.

"The NASA Student Ambassadors Virtual Community will serve as an outreach vehicle to the nation's students as well as a way to engage exceptional NASA interns, fellows, and scholars," said Mabel Jones Matthews, director of the Infrastructure Division in NASA's Office of Education. "This innovative activity is a leading effort to help NASA attract, engage, educate, and employ the dynamic next generation."

Members of this virtual community will interact with NASA, share information, make professional connections, collaborate with peers, represent NASA in a variety of venues, and help inspire and engage future interns. Through the community's website, participants will have access to tools needed to serve as a NASA Student Ambassador, as well as the latest NASA news, blogs, and announcements; member profiles; forums, polls, and NASA contact information; and links to cutting-edge research and career resources. For more information about the NASA Student Ambassadors Virtual Community 2013 Cohort V participants, visit *intern.nasa.gov*.

Ms. Curiosity Goes to Washington

It's an all-American, once-every-four-years tradition: the inauguration of a president. On January 21, the Red Planet joined the traditional red-white-and-blue pageantry when a life-sized model of NASA's Mars rover Curiosity appeared in the inaugural parade after President Barack Obama took the oath of office.

The rover model was accompanied by engineers and scientists from NASA and the Jet Propulsion Laboratory representing Curiosity and the Mars Science Laboratory, the spacecraft that transported the rover to a safe landing on the martian surface last August: Richard Cook, Project Manager (JPL); Bobak Ferdowsi, Flight Director (JPL); Dave Lavery, Program Executive (NASA Headquarters); Michael Meyer, Program Scientist (NASA HQ); Jennifer Trosper, Mission Manager (JPL); and Ashwin Vasavada, Deputy Project Scientist (JPL). In addition, current and former NASA astronauts appeared in the parade, along with a model of Orion, the multipurpose capsue that will take astronauts farther into space than ever before.

Mars Rover Curiosity's Team to Receive Space Foundation Award

The NASA mission that had the nation holding its breath as it tested an ingenious but never-before-used landing technique, and continues to amaze with new discoveries about Mars, has been selected as the 2013 recipient of the Space Foundation's John L. "Jack" Swigert Jr. Award for Space Exploration. NASA's Mars Science Laboratory project is using the rover Curiosity to investigate whether the study

area within Gale Crater has offered environmental conditions favorable for microbial life. “We are recognizing the NASA Mars Science Laboratory mission team for its aggressive and technologically advanced exploration of another planet,” said Space Foundation Chief Executive Officer Elliot Pulham. “This incredible mission will yield valuable science about conditions on Mars and enable critical technologies for future missions.”

The award is given annually to the person or organization that has made the most significant accomplishment in advancing the exploration of space during the previous year. It will be presented April 8 during the opening ceremony of the 29th National Space Symposium at The Broadmoor Hotel in Colorado Springs, Colorado.

The John L. “Jack” Swigert Jr. Award for Space Exploration honors NASA Apollo astronaut Jack Swigert. The Space Foundation, founded in 1983 in part to honor Swigert’s memory, created the Swigert Award in 2004 in tribute to his lasting legacy of space exploration. Previous recipients include NASA’s Phoenix Mars Lander Team, the Japan Aerospace Exploration Agency, the California Institute of Technology, NASA’s Jet Propulsion Laboratory, NASA’s Mars Exploration Rover team from JPL, President George W. Bush, the LCROSS mission, and, in 2012, NASA’s Kepler mission.

On January 27, 1967, veteran astronaut Gus Grissom, first American spacewalker Ed White, and rookie Roger Chaffee were sitting atop the launch pad for a pre-launch test for Apollo 1 when a fire broke out in their capsule. The investigation into the fatal accident led to major design and engineering changes, making the Apollo spacecraft safe for the coming journeys to the Moon.

NASA Observes Day of Remembrance

NASA paid tribute to the crews of Apollo 1 and space shuttles Challenger and Columbia, as well as other NASA colleagues, during the agency’s Day of Remembrance on Friday, February 1, the 10th anniversary of the Columbia accident. NASA’s Day of Remembrance honors members of the NASA family who lost their lives while furthering the cause of exploration and discovery. Flags across the agency were flown at half-staff in their memory.

NASA Administrator Charles Bolden and other NASA senior officials held an observance at the astronaut memorial at Arlington National Cemetery. A wreath-laying ceremony was also held at the Space Mirror Memorial located in the Kennedy Space Center Visitor Complex in Florida. The observance is hosted by the Astronauts Memorial Foundation.

Ceremony speakers included NASA Associate Administrator Robert Lightfoot; William Gerstenmaier, NASA’s associate administrator for human exploration and operations; Robert Cabana, director of NASA’s Kennedy Space Center; Thad Altman, president and chief executive officer of the Astronauts Memorial Foundation; Jon McBride, chairman of the board of directors of the Astronauts Memorial Foundation; Mick Ukleja, chairman of the board of trustees of the Astronauts Memorial Foundation; Evelyn Husband-Thompson, widow of Col. Rick Husband, who was commander of space shuttle Columbia’s final mission, STS-107, in 2003; and Eileen Collins, commander of shuttle Discovery for the mission in 2005 that returned shuttles to flight after the Columbia accident. NASA has also paid tribute to the agency’s fallen astronauts with special online content available at *go.nasa.gov/XNe5MU*.

The Astronauts Memorial Foundation is a private, not-for-profit organization that built and maintains the Space Mirror Memorial. The mirror was dedicated in 1991 to honor all astronauts who lost their lives on missions or during training. It has been designated a National Memorial by Congress.

NASA's PhoneSat Wins 2012 *Popular Science* Best of What's New Award

NASA's PhoneSat project has won *Popular Science*'s 2012 Best of What's New Award for innovation in aerospace. PhoneSat will demonstrate the ability to launch one of the lowest-cost, easiest-to-build satellites ever flown in space — capabilities enabled by using off-the-shelf consumer smartphones.

Each year, *Popular Science* reviews thousands of new products and innovations, and chooses the top 100 winners across 12 categories for its annual "Best of What's New" issue. To win, a product or technology must represent a significant step forward in its category. All the winners were featured in the December special issue of the magazine.

"NASA's PhoneSat mission will demonstrate use of small satellites for space commerce, educational activities, and citizen-exploration are well within the reach of ordinary Americans because of lower cost, commercially available components," said Michael Gazarik, director of NASA's Space Technology Program at NASA Headquarters in Washington. "Thanks to America's continuing investment in space technology to enable NASA missions, we've seen space tech brought down and into our lives here on Earth. With PhoneSat, we're doubling up, and taking those same great technologies back to space."

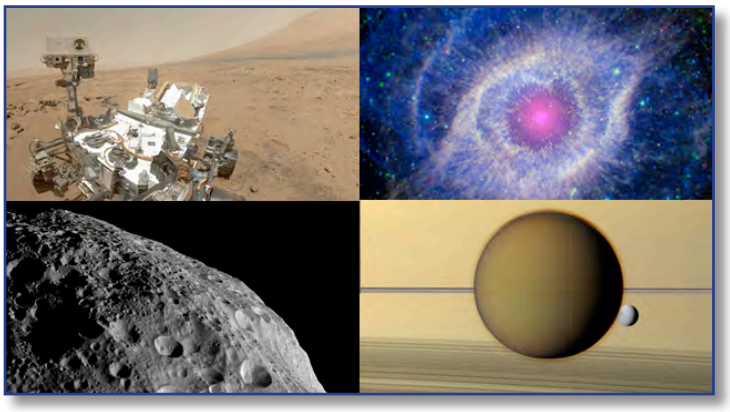
NASA's PhoneSat 1.0 satellite has a basic mission goal — to function in space for a short period of time, sending back digital imagery of Earth and space via its camera, while also sending back information about the satellite's health. NASA engineers kept the total cost of the components to build each of the three prototype satellites in the PhoneSat project to $3500 by using only commercial-off-the-shelf hardware and establishing minimum design and mission objectives for the first flight.

Each NASA PhoneSat "nanosatellite" is a 4-inch cube and weighs three pounds. NASA's PhoneSat design makes extensive use of an unmodified, consumer-grade smartphone. Out-of-the-box smartphones offer capabilities needed for satellites, including fast processors, versatile operating systems, multiple miniature sensors, high-resolution cameras, GPS receivers, and several radios. "NASA PhoneSat engineers are changing the way missions are designed by rapidly prototyping and incorporating existing commercial technologies and hardware," said S. Pete Worden, director of NASA's Ames Research Center at Moffett Field, California, where a small team of engineers developed and built PhoneSat. "This approach allows engineers to see what capabilities commercial technologies can provide, rather than trying to custom-design technology solutions to meet set requirements."

NASA's prototype smartphone satellite, known as PhoneSat 1.0, is built around the Nexus One smartphone made by HTC Corp., which runs Google's Android operating system. The Nexus One acts as the spacecraft's onboard computer. Commercial-off-the-shelf parts include an open-source, micro controller adapted as a watchdog circuit that monitors the systems and reboots the phone if it stops sending radio signals.

NASA's PhoneSat 2.0 will lay the foundation for new capabilities for small-sized satellites, while advancing breakthrough technologies and decreasing costs of future small spacecraft. PhoneSat 2.0 will be equipped with an updated Nexus S smartphone made by Samsung Electronics, which runs Google's Android operating system, to provide a faster core processor, avionics, and gyroscopes. PhoneSat 2.0 will supplement the capabilities of PhoneSat 1.0 by adding solar panels to enable longer-duration missions and a GPS receiver. In addition, PhoneSat 2.0 also will add magnetorquer coils — electromagnets that interact with Earth's magnetic field — as well as reaction wheels to actively control the satellite's orientation in space.

The PhoneSat project is a technology demonstration mission funded by NASA's Small Spacecraft Technology Program, which is managed by NASA's Space Technology Program. NASA's Space Technology Program is innovating, developing, testing, and flying technology for use in NASA's future missions and by the greater aerospace community. For more information about PhoneSat, visit *go.nasa.gov/ZoNxpg*.



One Million Downloads for JPL Space Images App

Space Images, the mobile image application from NASA's Jet Propulsion Laboratory that puts visuals direct from space missions at users' fingertips, has reached 1 million downloads. The app recently amassed a cadre of exciting images from many of the laboratory's missions, including the Mars Curiosity rover, which made a dramatic landing on Mars in August and has sent back many novel views of the Red Planet. Vibrant explosions from dying stars, the elegant choreography of Saturn's moons, and the scarred and cratered surface of a giant asteroid are just a few of the other scenes users can discover by downloading the app.

Chosen as a Staff Favorite in the Apple App Store shortly after its release in 2010, Space Images is now in Version 2, featuring videos and 3-D image collections and more extensive sharing options. The app is available free on both Android and Apple devices as well as online on the Space Images website at *www.jpl.nasa.gov/spaceimages*. To download Space Images for Apple device, visit *bit.ly/Ym9ir1* and for Android devices, visit *bit.ly/T85EfG*. Explore more mobile offerings from JPL at *www.jpl.nasa.gov/apps*.

NASA Launches Second International Space Apps Challenge

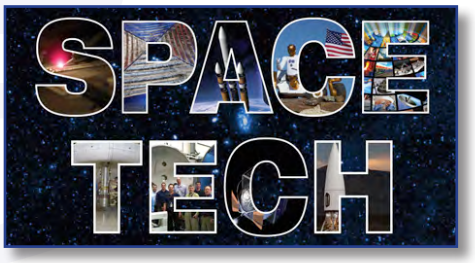
NASA and government agencies worldwide will host the second International Space Apps Challenge April 20–21, with events across all seven continents and in space. Participants are encouraged to develop mobile applications, software, hardware, data visualization, and platform solutions that could contribute to space exploration missions and help improve life on Earth. The two-day event will provide an opportunity for government to harness the expertise and entrepreneurial spirit of citizen explorers to help address global challenges. During the event, representatives of NASA and other international space agencies will gather with scientists and participants to use publicly released open data to create solutions for 50 software, hardware, and visualization challenges, including robotics, citizen science platforms, and applications of remote sensing data. Challenges selected to be worked on during the event will be published online prior to the event.

The 2012 challenge engaged more than 2000 participants who collaborated on more than 100 open source solutions to 71 featured challenges. "What sets apart the International Space Apps Challenge from other events is that this is a collaborative opportunity to engage people from all over the world to participate in space exploration and develop state-of-the-art technology to improve life on Earth and in space," said Nick Skytland, program manager of NASA's Open Innovation Program.

Twelve locations in the United States will host an International Space Apps Challenge event: Atlanta, Georgia; Austin, Texas; Cape Canaveral, Florida; Cleveland, Ohio; Detroit, Michigan; Easton, Maryland; New York, New York; Philadelphia, Pennsylvania; Reno, Nevada; Rochester, New York; San Francisco, California; and Syracuse, New York. Thirty-eight other events will be held in 30 other countries:

Australia, Bolivia, Brazil, Bulgaria, Canada, Chile, Colombia, Dominican Republic, Ecuador, France, Finland, Germany, Greece, Guatemala, India, Indonesia, Italy, Japan, Poland, Macedonia, Mexico, Nepal, New Zealand, South Africa, Spain, Sweden, Switzerland, Turkey, Uganda, and the United Kingdom. Also participating will be McMurdo Station in Antarctica and astronauts onboard the International Space Station.

Registration for citizen participation opened on March 1. To learn more about the International Space Apps Challenge, *visit spaceappschallenge.org*.



Investing in Technology to Enable the Future: NASA Creates Space Technology Mission Directorate

As part of the Obama Administration's recognition of the critical role that space technology and innovation will play in enabling both future space missions and bettering life here on Earth, NASA Administrator Charles Bolden has announced the creation of the Space Technology Mission Directorate. The directorate will be a catalyst for the creation of technologies and innovation needed to maintain NASA leadership in space while also benefiting America's economy. The Space Technology Mission Directorate will develop the cross-cutting, advanced, and pioneering new technologies needed for NASA's current and future missions, many of which also benefit America's aerospace industries, other government agencies, and address national needs. NASA will focus leadership responsibility for the existing Space Technology Program in the mission directorate, improving communication, management and accountability of critical technology investment activities across the agency.

"A robust technology development program is vital to reaching new heights in space — and sending American astronauts to new destinations like an asteroid and Mars," NASA Administrator Charles Bolden said. "A top priority of NASA is to invest in cross-cutting, transformational technologies. We focus on collaboration with industry and academia that advances our nation's space exploration and science goals while maintaining America's competitive edge in the new innovation economy."

Associate Administrator Michael Gazarik will head the organization. He previously served as the director of the Space Technology Program within the Office of the Chief Technologist. Serving as the Deputy Associate Administrator for Programs, James Reuther brings years of expertise in technology development, research, and project management to oversee the nine programs within the mission directorate. Reuther previously served as deputy director of the Space Technology Program within the Office of the Chief Technologist. Dorothy Rasco, formerly the business manager of the Space Shuttle Program and the manager of the Space Shuttle Program Transition and Retirement, will join the directorate as the Deputy Associate Administrator for Management, assisting with the organizations strategic planning and management.

The Space Technology Mission Directorate will employ a portfolio approach, spanning a range of discipline areas and technology readiness levels. Research and technology development will take place within NASA centers, in academia, and industry, and leverage collaboration with other government and international partners. NASA's Chief Technologist Mason Peck serves as the NASA administrator's principal advisor and advocate on matters concerning agencywide technology policy and programs. Peck's office will lead NASA's technology transfer and commercialization efforts, integrating, tracking, and coordinating all of NASA's technology investments across the agency. The Office of the Chief

Technologist also will continue to develop strategic innovative partnerships, manage agency-level competitions and prize activities, as well as document and communicate the societal impacts of the agency's technology efforts.

For more information about NASA's Space Technology Mission Directorate, visit *www.nasa.gov/spacetech*.

The BBC's *Sky At Night* Unveils the Sir Patrick Moore Observatory at the Kielder Observatory

Presenters from the legendary BBC science program, *The Sky at Night*, along with members of the Kielder Observatory Astronomical Society, have named the largest facility at The Kielder Observatory "The Sir Patrick Moore Observatory," in honour of Sir Patrick Moore, who died on December 9, 2012 (see related story in the "In Memoriam" section of this issue).

The dedication ceremony at the United Kingdom's leading public observatory was conducted as filming of a new episode of the program began at Kielder Observatory. Jon Culshaw, the famous UK comedian and impressionist who has appeared on many *Sky At Night* episodes and is a keen amateur astronomer, unveiled a plaque with founder director Gary Fildes. Many of the *Sky at Night*'s presenters, including Chris Lintott and the full production team, were on hand to witness the ceremony before filming began.

Chris Lintott, lead presenter on the *Sky at Night* and an Oxford University cosmologist, said "It's wonderful to have a chance to visit the Kielder Observatory. It's a much loved and important facility, and I know that Patrick would have loved to have visited himself."

Kielder Observatory has dedicated its largest "turret," home of one of the largest public telescopes in the UK (a 0.5-m Newtonian reflecting telescope), to Moore. It is one of two permanently mounted telescopes at Kielder, each housed in separate facilities at the Observatory, and part of its large telescope collection, which is regularly used by the public.

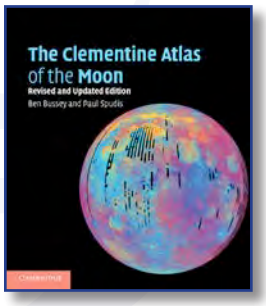
The Sky At Night recorded its March episode at Kielder, which will feature observations of the large asteroid DA14 as it traveled, closely but safely, past Earth. DA14 is 45 m across and passed closer to Earth than the Moon, and closer than some satellites orbit. The main part of the program will be about "The Moore Winter Marathon," a challenge devised by Moore to see 50 of the winter sky's most striking objects. Objects that will be observed by telescope, binoculars, and the naked eye include supernova remnants, areas of star formation, star clusters, distant galaxies, and Jupiter, the largest planet in the solar system.

The Kielder Observatory was built in cooperation with the Kielder Partnership and Forestry Commission. For more information, visit *www.kielderobservatory.org*.

BOOKS

The Clementine Atlas of the Moon, Revised and Updated Edition.

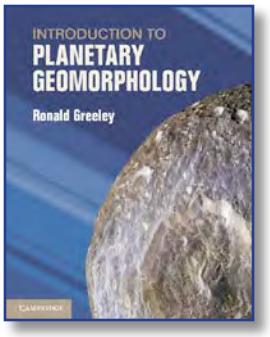
By Ben Bussey and Paul D. Spudis. Cambridge University Press, 2012. 380 pp., Paperback, $50.00. *www.cambridge.org*



The highly successful Clementine mission gave scientists their first global look at the Moon. Based on information gathered from this mission combined with data from recent missions, this unique atlas contains 144 maps covering the entire lunar surface, along with color plates showing the Moon's composition and physical properties. The first part of the atlas describes the origin and geological evolution of the Moon and gives a brief history of lunar science and exploration, while the second features double-page spreads consisting of Clementine images paired with newly created shaded-relief maps generated from LROC topography data. This edition has been fully revised and extended to cover the armada of new missions that have launched since 2004. With one of the most complete and up-to-date lunar nomenclature databases, this is an indispensable reference for professional planetary and space scientists, amateur astronomers, and lunar enthusiasts.

Introduction to Planetary Geomorphology.

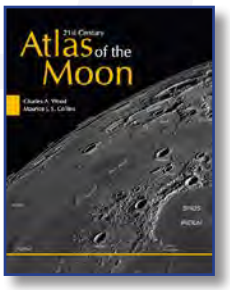
By Ronald Greeley. Cambridge University Press, 2013. 240 pp., Hardcover, $85.00. *www.cambridge.org*



Nearly all major planets and moons in our solar system have been visited by spacecraft and the data they have returned has revealed the incredible diversity of planetary surfaces. Featuring a wealth of images, this textbook explores the geological evolution of the planets and moons. Introductory chapters discuss how information gathered from spacecraft is used to unravel the geological complexities of our solar system. Subsequent chapters focus on current understandings of planetary systems. The textbook shows how planetary images and remote sensing data are analyzed through the application of fundamental geological principles. It draws on results from spacecraft sent throughout the solar system by NASA and other space agencies. Aimed at undergraduate students in planetary geology, geoscience, astronomy, and solar system science, it highlights the differences and similarities of the surfaces at a level that can be readily understood by nonspecialists.

21st Century Atlas of the Moon.

By Charles A. Wood and Maurice S. J. Collins. Lunar Publishing, UAI Inc., 2012. 111 pp., Paperback, $29.95.
lpod.wikispaces.com/21st+Century+Atlas+of+the+Moon



Introducing a new atlas of the Moon created by lunar scientist Charles Wood and amateur astronomer Maurice Collins. This atlas is based on mosaics from the Lunar Reconnaissance Orbiter (LRO), the amazingly successful spacecraft that, along with Kaguya, is finally taking the understanding of the Moon significantly beyond Apollo-era data. This atlas uses LRO Wide Angle Camera (WAC) images, giving uniformly high resolution for the nearside. Special charts provide rectified views of the limbs, low-illumination depictions of major lunar basins and their ridge systems, and synoptic high-Sun views of the nearside and LRO quadrants of the lunar farside.

Use of Extraterrestrial Resources for Human Space Missions to Moon or Mars.

By Donald Rapp. Springer, 2013, 209 pp., Hardcover, $129.00. *www.springer.com*

This book carries out approximate estimates of the costs of implementing *in situ* resource utilization (ISRU) on the Moon and Mars. In addition, this book provides a detailed review of various ISRU technologies. This includes three approaches for Mars ISRU based on processing only the atmosphere: solid oxide electrolysis, reverse water gas shift reaction (RWGS), and absorbing water vapor directly from the atmosphere. Technologies for lunar ISRU are also reviewed, even though none of them provide significant benefits to near-term lunar missions. These include oxygen from lunar regolith, solar wind volatiles from regolith, and extraction of polar ice from permanently shaded craters.

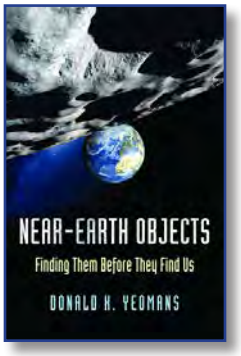
Coming Home: Reentry and Recovery from Space.

By Roger D. Launius and Dennis R. Jenkins. NASA History Office, 2012. 337 pp., Hardcover, $41.00. *bookstore.gpo.gov*

The technologies for the reentry and recovery from space might change over time, but the challenge remains one of the most important and vexing in the rigorous efforts to bring spacecraft and their crews and cargo home successfully. Returning to Earth after a flight into space is a fundamental challenge, and contributions from the NASA Aeronautics Research Mission Directorate in aerodynamics, thermal protection, guidance and control, stability, propulsion, and landing systems have proven critical to the success of the human space flight and other space programs. Without this base of fundamental and applied research, the capability to fly into space would not exist. (Also available as an e-book at *www.nasa.gov/connect/ebooks/coming_home_detail.html*.)

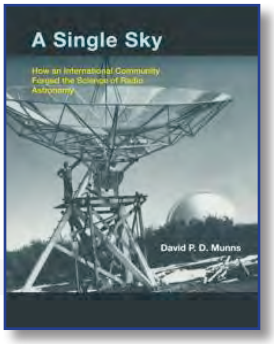
Near-Earth Objects: Finding Them Before They Find Us.

By Donald K. Yeomans. Princeton University Press, 2013. 192 pp., Hardcover, $24.95. *press.princeton.edu*



In this book, author Donald Yeomans introduces readers to the science of near-Earth objects — its history, applications, and the ongoing quest to find near-Earth objects before they find us. In its course around the Sun, Earth passes through a veritable shooting gallery of millions of nearby comets and asteroids. One such asteroid is thought to have plunged into our planet 65 million years ago, triggering a global catastrophe that killed off the dinosaurs. This book is an up-to-date and accessible guide for understanding the threats posed by near-Earth objects, and also explains how early collisions with them delivered the ingredients that made life on Earth possible. He shows how later impacts spurred evolution, allowing only the most adaptable species to thrive — in fact, we humans may owe our very existence to objects that struck our planet. Today's efforts to find, track, and study near-Earth objects are covered, and the possibility of mining comets and asteroids for precious natural resources like water and oxygen and using them as watering holes and fueling stations for expeditions to Mars and the outermost reaches of our solar system is discussed.

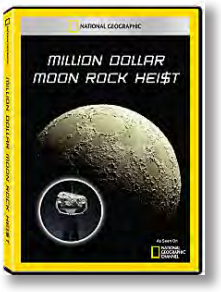
A Single Sky: How an International Community Forged the Science of Radio Astronomy.
By David P. D. Munns. MIT Press, 2013. 256 pp., Hardcover, $34.00. *mitpress.mit.edu*



For more than 3000 years, the science of astronomy depended on visible light. In just the last 60 years, radio technology has fundamentally altered how astronomers see the universe. Combining the wartime innovation of radar and the established standards of traditional optical telescopes, the "radio telescope" offered humanity a new vision of the universe. Author David Munns explains how the idea of the radio telescope emerged from a new scientific community uniting the power of radio with the international aspirations of the discipline of astronomy. The radio astronomers challenged Cold War-era rivalries by forging a united scientific community looking at a single sky. Munns tells the interconnecting stories of Australian, British, Dutch, and American radio astronomers, all seeking to learn how to see the universe by means of radio. Jointly, this international array of radio astronomers built a new "community" style of science opposing the "glamour" of nuclear physics. *A Single Sky* describes a communitarian style of science, a culture of interdisciplinary and international integration and cooperation, and counters the notion that recent science has been driven by competition. Collaboration rather than competition produced a science as revolutionary as Galileo's first observations with a telescope. Working together, the community of radio astronomers revealed the structure of the galaxy.

DVD

Million Dollar Moon Rock Hei$t.
Produced by National Geographic, 2012, one disc. $19.95. *shop.nationalgeographic.com*



It was a headline-grabbing heist of NASA proportions. Each year, hundreds of students apply to NASA's prestigious Co-Operative Education Program, but only a handful are accepted — allowing them to work alongside NASA's top scientists and go on to careers at NASA and elsewhere. In 2000, one co-op student showed an inordinate interest in the cache of Moon rocks kept at the Johnson Space Center in Houston, Texas, repeatedly visiting the lab to examine them. Then the Moon rocks mysteriously disappeared. *Moon Rock Hei$t* follows the trail of international intrigue surrounding the recovery of the rocks and reveals how law enforcement finally tracked down the thieves.

FOR KIDS!!!

Mars Science Laboratory Lunch Box.
Available from the JPL store. $20.00. *bookstore.caltech.edu/JPLLAB/*

This metal lunch box has the Curiosity rover and the Mars Science Laboratory (MSL) logo on the front, and the back boasts a progression of landing drawings. Inside there is an MSL payload decal.

Are There Other Earths?

By Michael Portman. Gareth Stevens Publishing, 2013, 32 pp., Hardcover, $25.25. *www.garethstevens.com*

The question of other planets sustaining life, as it is on Earth, has been plaguing scientists and curious minds for some time. Through accessible text, fun fact boxes, and amazing photographs, this book discusses other planets that scientists have discovered. Children will be introduced to amazing scientific tools, such as the Kepler telescope, that have assisted in locating many planets outside our solar system. Are there habitable planets, and if so, could people move to them? For grades 2–3.

High Frontier Game, Second Edition.

Produced by Sierra Madre Games. $44.00. *www.sierra-madre-games.com*

This may be the most scientific sci-fi game ever produced! High Frontier has players designing space missions to explore and industrialize the solar system. Players need to find water out there as reaction mass for their rockets, and points are awarded according to the scarcity of the space products produced, colonies, and mega-engineering projects. This game includes rocket, freighter, and factory pieces, along with rules, patent cards, rocket diagrams, and a unique mounted "delta-v" map of the inner solar system. For two to five players, ages 12 and up.

Break Your Own Geodes Kit.

Produced by Ancient Treasure Adventures. $19.95. *ancienttreasureadventures.com*

This geode kit offers six whole specially selected geodes ranging from large marble- to golf-ball-sized. These geodes have incredible crystal formations. Each kit comes with a geode guide that explains how geodes are formed. For ages 8 and up.

Sponge in Space!

By Golden Books, illustrated by Heather Martinez. Golden Books, 2012. 24 pp., Hardcover, $3.99. *www.randomhouse.com/golden/*

For 65 years, Little Golden Books has published high-quality, low-cost books for children featuring favorite characters mirroring popular culture over the years. *Sponge in Space!* continues that tradition. Deep space explorer SpongeBob SquarePants blasts off from Bikini Bottom and discovers there's no place like home. This Little Golden Book is a close encounter of the silly kind that's sure to thrill little astronauts who love Nickelodeon. For ages 2–5.

Calendar 2013

March

6–8 **Committee on Astrobiology and Planetary Science,** Washington, DC. *http://sites.nationalacademies.org/ssb/SSB_067577.htm*

11–12 **Characterising Exoplanets: Detection, Formation, Interiors, Atmospheres and Habitability,** London, United Kingdom. *http://royalsociety.org/events/2013/exoplanets/*

16–17 **Microsymposium 54, Lunar Farside and Poles: New Destinations for Exploration,** The Woodlands, Texas. *http://lunarscience.nasa.gov/articles/microsymposium-54-lunar-farside-and-poles-new-destinations-for-exploration/*

18–22 **44th Lunar and Planetary Science Conference (LPSC 2013),** The Woodlands, Texas. *http://www.lpi.usra.edu/meetings/lpsc2013/*

25–27 **Herschel Calibration Workshop: Only the Best Data Products for the Legacy Archive,** Madrid, Spain. *http://herschel.esac.esa.int/CalibrationWorkshop5.shtml*

April

3–6 **From Stars to Life — Connecting our Understanding of Star Formation, Planet Formation, Astrochemistry and Astrobiology,** Gainesville, Florida. *http://conference.astro.ufl.edu/STARSTOLIFE/*

7–12 **European Geosciences Union General Assembly 2013,** Vienna, Austria. *http://www.egu2013.eu/*

8–12 **Transformational Science with ALMA: From Dust to Rocks to Planets Formation and Evolution of Planetary Systems,** Waikoloa, Hawaii. *http://www.cv.nrao.edu/rocks/index.html*

9–10 **Third International Workshop on Lunar Superconductor Applications,** Cocoa Beach, Florida. *http://www.lsa2013.com*

11 **LunarCubes Missions Briefing,** Cocoa Beach, Florida. *http://www.lunar-cubes.com/*

15–19 **2013 IAA Planetary Defense Conference,** Flagstaff, Arizona. *http://iaaweb.org/content/view/492/661/*

17–19 **UK Astrobiology Conference,** Edinburgh, Scotland. *http://www.astrobiology.ac.uk/astrobiology-conference-2013*

22–24 **Workshop on the Evolution and Constitution of Mercury's Interior,** Chicago, Illinois. *http://bit.ly/mercuryinterior*

22–27 **20th Young Scientists' Conference on Astronomy and Space Physics,** Kyiv, Ukraine. *http://ysc.kiev.ua/*

23–25 **SPICE Domestic Training Class for 2013,** Monrovia, California. *http://naif.jpl.nasa.gov/naif/announcement_SPICE-2013*

29–May 2 **Habitable Worlds Across Time and Space,** Baltimore, Maryland. *http://www.stsci.edu/institute/conference/habitable-worlds*

May

5–9 **43rd Annual Meeting of the American Astronomical Society Division on Dynamical Astronomy,** Paraty, Brazil. *http://dda.harvard.edu/meetings/2013/*

6–7 **First Annual International Conference on Space Environment & Aviation Technology (SEAT 2013),** Singapore. *http://www.space-aviation.org/index.html*

6–8 **Humans to Mars Summit (H2M),** Washington, DC. *http://www.exploremars.org*

10 **RAS Specialist Discussion Meeting: Observation, Evolution and Origin of Planetary Satellites,** London, United Kingdom. *http://www.ras.org.uk/events-and-meetings/ras-meetings*

15–17 **Ice and Planet Formation,** Lund, Sweden. *http://www.astro.lu.se/~anders/IPF2013/*

24–27 **Spacefest V,** Tucson, Arizona. *http://www.spacefest.info/V/*

28–29 **iCubeSat 2013 — The 2nd Interplanetary CubeSat Workshop,** Ithaca, New York. *http://iCubeSat.org*

28–30 **Annual Meeting of the Canadian Astronomical Society (CASCA),** Vancouver, Canada. *http://casca2013.phas.ubc.ca*

29-31 **Third Meeting of the International Primitive Body Exploration Working Group (IPEWG),** Nice, France. *http://www.oca.eu/michel/IPEWG2013/*

June

2–6 **222nd Meeting of the American Astronomical Society,** Indianapolis, Indiana. *https://aas.org/meetings/aas222*

2–7 **Exploring the Formation and Evolution of Planetary Systems,** Victoria, Canada. *http://www.iau.org/science/meetings/future/symposia/1064/*

3–4 **1st Annual International Conference on Astronomy and Astrophysics (Astro 2013),** Singapore. *http://www.astro-conf.org/*

3–5 **Next-Generation Suborbital Researchers Conference 2013,** Broomfield, Colorado. *http://nsrc.swri.org*

6–9 **1st International Workshop on Education in Astrobiology,** Hoor, Sweden. *http://www.nordicastrobiology.net/IWEA/*

10–14 **International Venus Workshop,** Catania, Italy. *http://www.iaps.inaf.it/Venus2013/*

10–14 **AbGradCon 2013,** Montreal, Canada. *http://www.abgradcon.org*

11–14 **Isotopes as Diagnostic Tools in Astronomy, Geology and Biology,** Hoor, Sweden. *http://www.nordicastrobiology.net/Isotopes2013/*

15–16 **IPPW-10 Short Course on Entry, Descent, and Landing Systems,** San Jose, California. *http://www.ippw10.com/index.php/program/short*

17–21 **10th International Planetary Probe Workshop (IPPW-10),** San Jose, California. *http://ippw10.com/*

17–21 **14th International Conference on Electromagnetic and Light Scattering (ELS-XIV),** Lille, France. *http://www-loa.univ-lille1.fr/ELS-XIV*

18–20 **10th IAA Low-Cost Planetary Missions Conference (LCPM-10),** Pasadena, California. *http://lcpm10.caltech.edu/*

18–21 **From Exoplanets to Distant Galaxies: SPICA's New Window on the Cool Universe,** Kanagawa, Japan. *http://www.ir.isas.jaxa.jp/SPICA/spica2013/*

23–25 **2013 Space Cryogenics Workshop,** Girdwood, Alaska. *www.spacecryogenicsworkshop.org*

23–28 **Gordon Conference on Origins of Solar Systems,** South Hadley, Massachusetts. *http://www.grc.org/programs.aspx?year=2013&program=origins*

24–27 **8th Workshop on Catastrophic Disruption in the Solar System (CD8),** Hapuna Beach, Hawaii. *http://www.cd8.hawaii-conference.com/*

24–28 **10th Annual Meeting of the Asia Oceania Geosciences Society (AOGS),** Brisbane, Australia. *http://www.asiaoceania.org/aogs2013/public.asp?page=home.htm*

24–28 **Crossing the Boundaries in Planetary Atmospheres: From Earth to Exoplanets,** Annapolis, Maryland. *http://chapman.agu.org/planetaryatmospheres/*

25–28 **5th Workshop on Hyperspectral Image and Signal Processing: Evolution in Remote Sensing (WHISPERS),** Gainesville, Florida. *http://core.ieee-whispers.com/index.php?option=com_content&view=article&id=211&Itemid=55*

30–Jul 2 **Australian Astrobiology Meeting,** Sydney, Australia. *http://astrobiologyaustralia.com.au*

July

1–4 **International Symposium on Planetary Sciences (IAPS2013),** Shanghai, China. *http://202.127.29.4/meetings/iaps2013*

8–12 **Magnetospheres of the Outer Planets 2013,** Athens, Greece. *http://space.academyofathens.gr/mop2013/*

9–11 **Ninth Meeting of the NASA Small Bodies Assessment Group,** Pasadena, California. *http://www.lpi.usra.edu/sbag/meetings/*

9–11 **Comets as Tracers of Solar System Formation and Evolution,** Toulouse, France. *http://icw.space.swri.edu/index.htm*

12 **Rocks in our Solar System — Bridging the Gap Between Meteor, Meteorite and Asteroid Studies,** Turku, Finland. *http://www.physics.helsinki.fi/conf/EWASS2013*

15–19 **Eighth International Mars Conference,** Pasadena, California. *http://www.lpi.usra.edu/meetings/8thmars2013/*

15–20 **Protostars and Planets VI,** Heidelberg, Germany. *http://www.ppvi.org*

22–26 **The Pluto System on the Eve of Exploration by New Horizons: Perspectives and Predictions,** Columbia, Maryland. *https://dnnpro.outer.jhuapl.edu/plutoscience/Home.aspx*

16–18 **NASA Lunar Science Forum,** Moffett Field, California. *http://lunarscience.nasa.gov/lsf2013*

17–19 **Dusty Visions 2013,** Stuttgart, Germany. *http://www.dsi.uni-stuttgart.de/cosmicdust/news/dustyvisions2013.html*

22–26 **The Pluto System on the Eve of Exploration by New Horizons: Perspectives and Predictions,** Columbia, Maryland. *https://dnnpro.outer.jhuapl.edu/plutoscience/Home.aspx*

29–Aug 2 **2013 Sagan Exoplanet Summer Workshop,** Pasadena, California. *http://nexsci.caltech.edu/workshop/2013/*

29–Aug 2 **76th Annual Meeting of the Meteoritical Society,** Edmonton, Canada. *http://metsoc2013edmonton.org/*