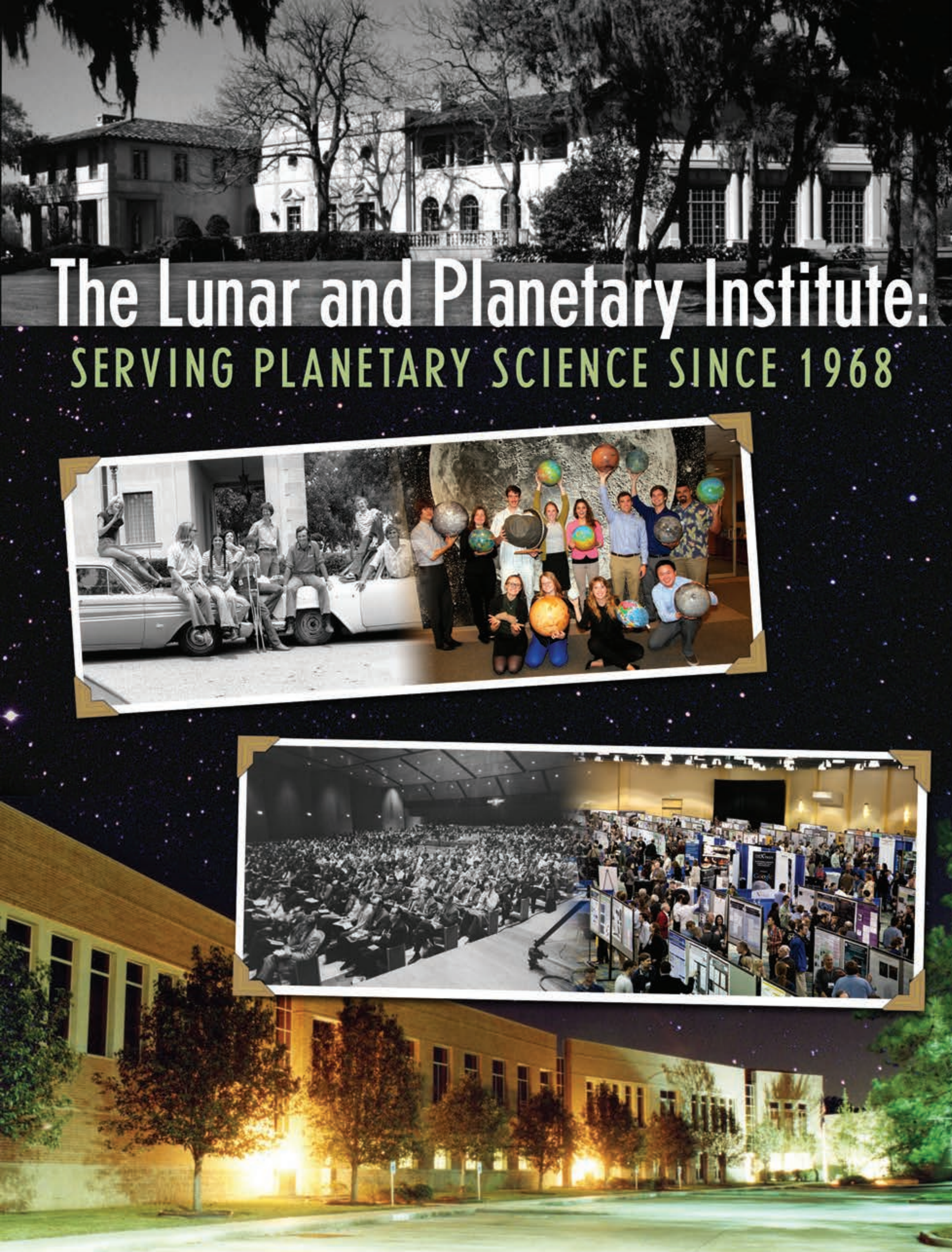

The Lunar and Planetary Institute:

SERVING PLANETARY SCIENCE SINCE 1968

Lunar and Planetary Information BULLETIN

Universities Space Research Association — Lunar and Planetary Institute

CONTENTS

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— ***Steve Mackwell, Renee Dotson, and Julie Tygielski, Lunar and Planetary Institute***

Note from the Editors: This issue's lead article is the sixth in a series of reports describing the history and current activities of the planetary research facilities funded by NASA and located nationwide. This issue features the Lunar and Planetary Institute (LPI), which was established in 1968 as "a center of research where scientists working in the sciences of space cooperate to profoundly affect the community's knowledge of the universe." — Paul Schenk and Renee Dotson

LPI History

During the mid 1960s, as NASA was aggressively working toward President John F. Kennedy's desire to land a man on the Moon, NASA administrator James Webb asked that a committee be established, to be led by Dr. Frederick Seitz, President of the National Academy of Sciences, to engage the academic community in NASA's efforts. In July 1967, the concept of a Lunar Science Institute (LSI) was born out of those discussions.


THE HOUSTON POST

HOUSTON, TEXAS, SATURDAY, MARCH 2, 1968

LBJ Visits MSC, Tells Of Lunar Institute Aims

On March 1, 1968, President Lyndon B. Johnson visited NASA's Manned Spacecraft Center (MSC) (now the Johnson Space Center, or JSC) in Houston, Texas, and made the following pronouncement:

> *"We are close to a landing on the Moon. Our space programs for the decade of the sixties are drawing to a close. Yet a mighty intellectual and technological effort, such as you are engaged in here, cannot just be turned on and off. We must stay the course. We must continue to build new strength by using the strength we have. We must continue to cross over new frontiers. This will certainly be our certain course in the next decade.*
>
> *As a further step toward joining hands with the world's scientific community, I want to announce that we will build facilities here in this great space capital of Houston to help the world's scientists work closer together more effectively on the problems of space. We are going to establish here in Houston a new Lunar Science Institute along the side of this great center which you have here.*
>
> *The new institute is a center of research designed specifically for the age of space. Here will come scientists — and their students — from all over the world. We will welcome here all who are interested in the sciences of space. We will strengthen the cooperation between NASA and*

our universities. And we will set new patterns of scientific cooperation which will have profound effects on man's knowledge of his universe.

The new Lunar Science Institute will provide new means of communication and research for the world's scientific community. It will help unite the nations for the great challenge of space. Let this great new institute stand as a symbol. Let it show the world that we do not build rockets and spacecraft to fly our flag in space, or to plan our banner on the surface on the Moon. We work to give all mankind its last great heritage. We are reaching for the stars."

On October 1, 1968, the LSI was formally established by NASA contract with the National Academy of Sciences to operate the new entity in cooperation with Rice University. The objectives of the Institute were to enhance communications among scientists, universities, and governmental organizations; to encourage use of the unique Lunar Receiving Laboratory at MSC to the common benefit of NASA and the academic community; to provide all universities with appropriate services for associate and postgraduate education at the MSC; and to provide general assistance and support for research on lunar material. Since the primary responsibility of the Institute was to develop closer working relationships among the various organizations engaged in space research, the goal of the Institute was that it should encourage scientific discussion and exchange of ideas; the convocation of seminars, workshops, symposia, and the like; accessibility of government employees and facilities such as the Lunar Receiving Laboratory (LRL) to university representatives; and the participation of interested scientists in spaceflight operations and LRL scientific activities.

Needing a more permanent entity to manage the LSI, in March 1969 the National Academy of Sciences, at the request of NASA, chartered the Universities Space Research Association (USRA), a nonprofit consortium of universities. The stated purpose of USRA was to foster cooperation among universities, other research organizations, and the U.S. government for the advancement of space research, and in December 1969 USRA assumed management of the LSI under contract to NASA.

Dr. William W. Rubey, professor of geology and geophysics at the University of California, Los Angeles, was appointed as the first Director of the Institute on October 31, 1968, and began operation in temporary offices located at MSC. Five months later the Institute moved to leased office space within close proximity to MSC. Rubey's first order of business was to find a building to house the Institute. Fortuitously, the West Mansion adjacent to the MSC had been deeded to Rice University with the stipulation that the property be used for research purposes. The Institute moved into the newly renovated West Mansion in October 1969. The dedication ceremony took place on January 4, 1970, and included remarks from NASA Administrator Thomas Paine, who concluded his speech with reading the words cast on a commemorative plaque, which still hangs outside the doors of the current building: "Dedicated to the scientists of the Earth who seek to understand the nature, origin and history of our solar system."

In keeping with the stated goals of the Institute, the scientific staff included a very small in-house staff to supply continuity and aid the orientation of visitors, with the predominant population of the staff consisting of a unique array of visiting scientists and postdoctoral fellows. In May 1969, the first visiting scientist, Dr. S. Ross Taylor, arrived; in June 1969, Dr. Friedrich Hörz was appointed as a visiting scientist; and in July 1969, Dr. Harold Urey was appointed as the first senior visiting scientist.

The Institute's primary activities in the early years focused on retaining an atmosphere conducive to research, as well as organizing and hosting a number of symposia and seminars. When the Institute began its seminar series in September 1969, Dr. Gerard P. Kuiper was the first speaker. The Institute had already begun co-sponsoring the Lunar Science Conference (LSC) (now the Lunar and Planetary Science Conference, or LPSC), and assumed many of the administrative duties for the conference when it moved to MSC from downtown Houston (where the first two conferences, known as the "Houston Rock Festivals," were held).

In 1973, NASA conducted a review of the LSI and determined continued operation of the Institute should remain under USRA management. The role of the Institute now included (1) the establishment of a lunar data center (photo, map, and document library; lunar sample information library; geophysical data files; and lunar science publication library); (2) visiting scientist program; (3) scientific symposium program; (4) publications and communications; and (5) management of the Lunar Sample Review Panel.

In December 1973, recognizing that one of the major goals of the Institute was to facilitate communication between investigators working in and beyond lunar science, the Institute announced that it would begin distributing an informal short communication to a wide audience in lunar science and related areas. The first issue of the *Lunar Science Information Bulletin* (now the *Lunar and Planetary Information Bulletin*, or LPIB) was published in February 1974. In addition to short notes about information of interest to the lunar science community, it also contained a lunar science calendar and a list of lunar articles recently received in the Institute library.

Over time, the Institute's research effort broadened to include the terrestrial planets, their satellites, the asteroids and meteorites, and the jovian and saturnian planetary systems, which prompted the LSI's name change in 1978 to the Lunar and Planetary Institute (LPI). Growth in research and the desire to establish programs to support the community led to expansion in other areas such as internships. In the summer of 1977, the Institute began the LSI Summer Undergraduate Intern Program, which continues to provide undergraduate students with the opportunity to perform experimental, theoretical, or library research under the supervision of JSC or Institute scientists.

LPI Today

Throughout its history, the LPI has made significant contributions to the understanding of lunar and planetary science. LPI staff scientists, postdoctoral fellows, and visiting scientists, whose fields of research represent much of the breadth of the planetary science community, pursue innovative research, support NASA programs, provide a connection to the university scientific community, and contribute vital science focus to all LPI activities.

The LPI remains attuned to the needs of NASA and the planetary science community, is extremely productive as a research organization, and has major involvement in current and future mission activities. LPI activities, programs, and initiatives are implemented through the interweaving of three functional components: science, service to NASA and the community, and education and public outreach (EPO). The three functional components form an integrated network of scientists, managers, educators, and support staff collaborating on LPI activities.

Science

Research pursued at the Institute is closely aligned with NASA's strategic plan. Research activities involving staff scientists, postdoctoral fellows, visiting scientists, students and interns, Heritage Fellows, and Urey Fellows include the performance and dissemination of fundamental peer-reviewed scientific research, sponsorship of topical science projects, and participation in space missions.

All activities, programs, and projects undertaken by the Institute require scientific knowledge and expertise. While most scientists work at the Institute for periods from several days up to three years, the staff scientists remain for longer periods, bringing stability to the LPI science program and connecting across the scope of the planetary community. Having resident scientists familiar with NASA and the service/EPO programs contributes efficiencies that enable the Institute to provide quality service in a timely fashion at a significantly reduced cost. Should additional expertise be required, the staff scientists are established members of the community with deep connections in their respective disciplines. These connections are exemplified by the frequent inclusion of LPI scientists on mission teams, program and panel reviews, and planning committees.

While discipline-specific research studies and programs performed by a single researcher or team remain a cornerstone of lunar and planetary science, innovative multi-disciplinary, multi-institutional programs are increasingly becoming a venue for new scientific understanding and insight. LPI has facilitated a forum for interdisciplinary activities and discussion through organization of study projects and topical initiatives throughout its history. From the Balsaltic Volcanism in the Terrestrial Planets Study Project in 1976 to Oxygen in the Solar System in 2004, the innovative concepts achieved in these topical projects result in the publishing of books based on each topical project. In response to the 2004 Presidential Vision for Space Exploration, LPI brought forth new focus on lunar science through the Lunar Science and Exploration Initiative, which involved development of a web-based information portal — the Lunar Science Exploration Portal, where the lunar science community could access Apollo-era documents to the most recent research reports. LPI also increased its lunar science cohort, leading teams for the NASA Lunar Science Institute in 2009 and Solar System Exploration Research Virtual Institute in 2013.

Services to NASA and the Planetary Community

Throughout its history, LPI has maintained an exemplary culture of service in support of NASA and the lunar and planetary science community. This component encompasses the interface with astromaterials research at NASA JSC; meetings and workshops; scientific and technical support of proposal review panels; the Regional Planetary Image Facility (RPIF); the library and resource collections; logistical, technical, and scientific support of NASA's Analysis/Assessment Groups; support of the Curation and Analysis Planning Team for Extraterrestrial Materials (CAPTEM); publication efforts; and scientific support for planning and review committees at NASA and the National Academy of Sciences.

The Institute was formed so that scientists from around the world could interact with NASA in the performance of space science. Since the early days of the space program, the Institute has facilitated access to the lunar science samples from the Apollo missions. While access to the samples has evolved over the decades, the LPI still facilitates access to the collections and to the impressive array of cutting-edge instrumentation at JSC's Astromaterials Research and Exploration Science (ARES) facility that is available for use by the scientific community and is optimally configured for extraterrestrial samples.

LPSC maintains its position as the major focal point for discussion of planetary science issues worldwide. USRA has organized the premier conference for lunar and planetary scientists in the world since the 1971 LSC in Houston during the last stages of the Apollo missions. Since that first conference, USRA has organized 44 additional LSC or LPSC meetings, with attendance growing steadily over the years. As the meeting has grown, LPSC has outgrown facilities at JSC and in the surrounding Clear Lake area, but retains a strong connection to Houston and the space program. Despite its size, LPSC remains a community-focused conference and the collegiality and open discussion of ideas is more like a meeting a fraction of its size. Students consistently comprise around 30% of attendees, making this meeting the premier opportunity for students in planetary science to make contacts and have easy access to senior colleagues.

In addition to the annual LPSC meeting, the LPI sponsors numerous conferences and workshops. Conferences organized by the Institute support mission activities as well as provide the major venue for discussion of planetary science research and analysis.

NASA's RPIFs provide convenient access to image and map data from the American lunar and planetary missions of the last 50 years as a resource to space scientists and the broader community of interested laypeople. These data include hard-copy paper and film positives, negatives, and mosaics; digital copies of select products are continually added to the collections. The LPI RPIF holds special expertise in lunar science and exploration, and data from lunar robotic and human missions (including extensive information on lunar samples) make up the bulk of the unique collections. The LPI RPIF also maintains a large collection of supporting information and study reports, including Apollo experiment reports, mission plans, transcripts, crew debriefs, and advanced studies to support future human and robotic exploration of the Moon. In the last decade, the LPI RPIF has made major progress in creating a comprehensive online digital archive of lunar maps, images, and reports. The collection includes a variety of online atlases and map collections for the Moon, as well as one of the largest lunar sample digital archives.

The LPI library organizes and maintains a collection of space science-related materials in a variety of media, including books, journals, documents, maps and images to facilitate lunar and planetary science research and disseminates information to the educational and public communities. Reference services are provided to scientists, educators, students, media representatives and the public requesting information related to lunar and planetary science.

LPI provides pre-publication services for books published in the prestigious Space Science Series of the University of Arizona Press. This series provides the planetary and space science community with a set of reference and source volumes that act as benchmarks for our current understanding of the field. Even more importantly, these volumes serve as gateways for new students and researchers to these fields. With nearly 40 volumes published over 40 years, Space Science Series books are found on the desks and shelves of virtually

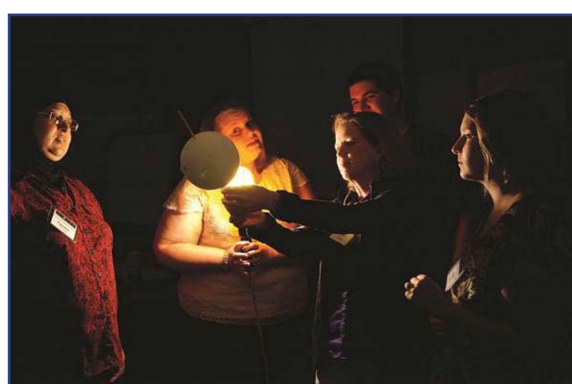
every practicing planetary scientist and in the libraries of planetary and space science institutions worldwide.

In 2013, LPI launched *Planetary News*, an informational online news service for the planetary community. News and announcements are posted rapidly on the website, which provides a searchable database with links to the original materials, aggregated once a week in an e-mail to subscribers.

The quarterly LPIB, which began in 1974, targets a diverse audience comprising scientists, educators, interested laypeople, and libraries. The LPIB is published electronically on the LPI website, and notifications of the availability of each new issue are distributed via e-mail, Facebook, Twitter, and other social media. Issues of the LPIB include articles recapping interesting mission-related science, upcoming missions, highlights of recent scientific meetings, description of new tools and resources for researchers, a spotlight on EPO, obituaries for prominent members of the community, awards and other important milestones, descriptions of new and noteworthy products, and a calendar of upcoming planetary science meetings.

The LPI website contains a vast collection of scientific and technical data, as well as substantial collections of EPO and conference resources for the scientific, technical, engineering, education, and outreach communities. The website also supports the advisory structure for NASA, acting as the primary repository for meeting information, study findings, and background resources for CAPTEM, the Lunar Exploration Analysis Group (LEAG), the Outer Planets Assessment Group (OPAG), the Small Bodies Assessment Group (SBAG), and the Venus Exploration Analysis Group (VEXAG), and as the medium for fast dissemination of presentation materials from the Planetary Science Subcommittee of the NASA Advisory Council. Periodically, new pages are established at the request of NASA to disseminate information, such as during the recent reorganization of the Planetary Research and Analysis program. Pages were also established for the collection of White Papers for the most recent Planetary Decadal Survey at the request of the U.S. National Research Council.

Education and Public Outreach



The LPI brings extensive experience and expertise in conducting a diverse portfolio of EPO activities directed at all educational levels and designed to enhance public appreciation of lunar and planetary science. EPO is an integral part of all LPI core activities, purposefully designed around LPI's scientific mission and NASA's vision of sharing planetary discoveries.

The LPI conducts trainings for formal and informal educators in the form of hour-long, day-long, and week-long professional development workshops. Trainings are designed based on audience need, and are tied to national and state science standards.

The LPI engages the local — and extended — community in lunar and planetary science and exploration. LPI holds family events several times a year by partnering with the JSC Astronomical Society to engage families in SkyFest, a celebration of celestial events or NASA milestones. Each event typically includes presentations by LPI staff scientists and postdoctoral fellows, hands-on explorations, story-time reading, and telescope viewing. The events are thematically based, with all activities tied to central learning themes and messages.

The LPI also holds an annual public lecture series designed to engage inquisitive adult members of the general public in current relevant topics in space science. The recorded presentations are archived on the LPI Education webpages for public viewing. In FY14, 780 visitors attended the Cosmic Exploration Lecture Series.

LPI also conducts student research programs, collaborates with other NASA organizations to host the International Observe the Moon Night, and shares a variety of resources with its audiences.

A Look to the Future

Over the last 47 years, the complexion of the Institute has changed as NASA and its strategic focus have grown and evolved. However, amidst the dynamic environment in which the Institute operates, its underlying mission and key objectives of scientific excellence and service have not changed. Today, the LPI is an intellectual leader in lunar and planetary science. Our mission remains: to serve as a scientific forum attracting world-class visiting scientists, postdoctoral fellows, students, and resident experts; to support and serve the research community through publications, meetings, and other activities; to collect and disseminate planetary data while facilitating the community's access to NASA science; and to engage, excite, and educate the public about space science and invest in the development of future generations of explorers.

About the Cover:

Top: The LPI's first permanent home was the West Mansion, an Italian-Renaissance-style building located on a wooded tract of land adjacent to NASA's MSC.

Inset top: Styles may have changed, but the passion for science remains the same. Many of the students who have participated in LPI's summer intern program have gone on to become prominent researchers in the field.

Inset bottom: LPSC has grown exponentially from its early years at NASA MSC (now JSC), and one of the positive results of that growth is that it has become a meeting that is both accessible and important to young scientists, as reflected by the fact that student participation makes up nearly 30% of the overall attendance.

Bottom: LPI began operations in 1992 in its new home, a 48,000-square-foot building on a 9-acre tract of land located in close proximity to JSC and adjacent to the University of Houston–Clear Lake.

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

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

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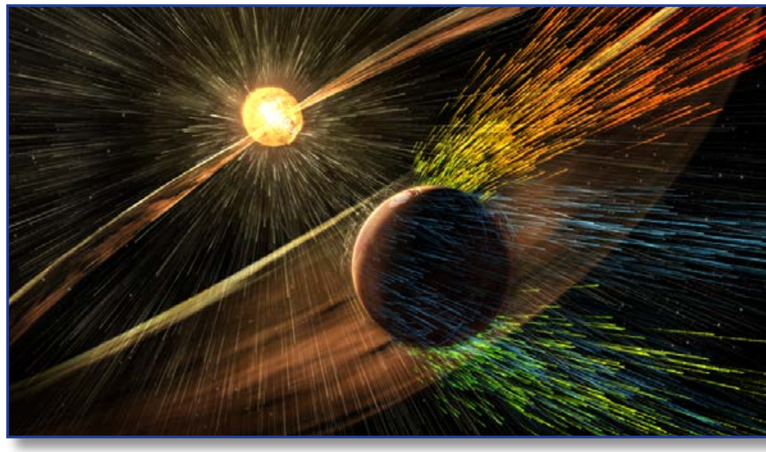
NASA Mission Reveals Speed of Solar Wind Stripping Martian Atmosphere



Artist's rendering of a solar storm hitting Mars and stripping ions from the planet's upper atmosphere. Credit: NASA/GSFC.

NASA's Mars Atmosphere and Volatile Evolution (MAVEN) mission has identified the process that appears to have played a key role in the transition of the martian climate from an early, warm and wet environment that might have supported surface life to the cold, arid planet Mars is today. MAVEN data have enabled researchers to determine the rate at which the martian atmosphere currently is losing gas to space via stripping by the solar wind. The findings reveal that the erosion of Mars' atmosphere increases significantly during solar storms. The scientific results from the mission appear in the November 5 issues of the journals *Science* and *Geophysical Research Letters*.

"Mars appears to have had a thick atmosphere warm enough to support liquid water which is a key ingredient and medium for life as we currently know it," said John Grunsfeld, administrator for the NASA Science Mission Directorate in Washington. "Understanding what happened to the Mars atmosphere will inform our knowledge of the dynamics and evolution of any planetary atmosphere. Learning what can cause changes to a planet's environment from one that could host microbes at the surface to one that doesn't is important to know, and is a key question that is being addressed in NASA's journey to Mars."

MAVEN measurements indicate that the solar wind strips away gas at a rate of about 100 grams (equivalent to roughly 0.25 pounds) every second. "Like the theft of a few coins from a cash register every day, the loss becomes significant over time," said Bruce Jakosky, MAVEN principal investigator at the University of Colorado, Boulder.

"We've seen that the atmospheric erosion increases significantly during solar storms, so we think the loss rate was much higher billions of years ago when the Sun was young and more active," continued Jakosky. A series of dramatic solar storms hit Mars' atmosphere in March 2015, and MAVEN found that the loss was accelerated. The combination of greater loss rates and increased solar storms in the past suggests that loss of atmosphere to space was likely a major process in changing the martian climate.

The solar wind is a stream of particles, mainly protons and electrons, flowing from the Sun's atmosphere at a speed of about 1.6 million kilometers (1 million miles) per hour. The magnetic field carried by the solar wind as it flows past Mars can generate an electric field, much as a turbine on Earth can be used to generate electricity. This electric field accelerates electrically charged gas atoms, called ions, in Mars' upper atmosphere and shoots them into space.

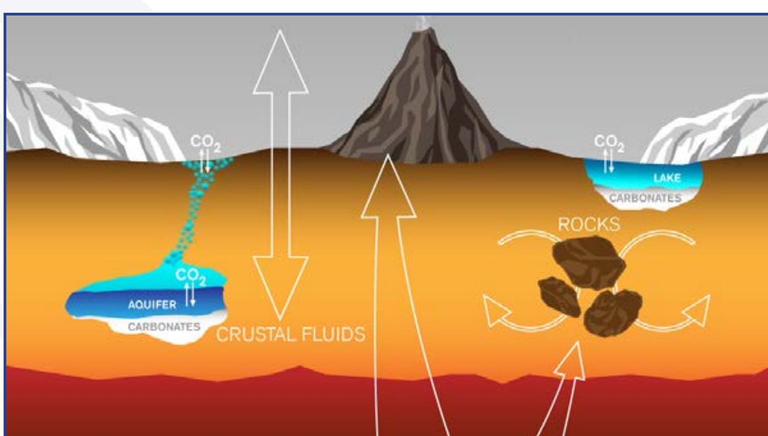
MAVEN has been examining how solar wind and ultraviolet light strip gas from of the top of the planet's atmosphere. New results indicate that the loss is experienced in three different regions of the Red Planet: Down the "tail," where the solar wind flows behind Mars; above the martian poles in a "polar plume"; and from an extended cloud of gas surrounding Mars. The science team determined that almost 75% of the escaping ions come from the tail region, and nearly 25% are from the plume region, with just a minor contribution from the extended cloud.

Ancient regions on Mars bear signs of abundant water — such as features resembling valleys carved by rivers and mineral deposits that only form in the presence of liquid water. These features have led scientists to think that billions of years ago, the atmosphere of Mars was much denser and warm enough to form rivers, lakes, and perhaps even oceans of liquid water. Recently, researchers using NASA's Mars Reconnaissance Orbiter observed the seasonal appearance of hydrated salts indicating briny liquid water on Mars. However, the current martian atmosphere is far too cold and thin to support long-lived or extensive amounts of liquid water on the planet's surface.

"Solar-wind erosion is an important mechanism for atmospheric loss, and was important enough to account for significant change in the martian climate," said Joe Grebowsky, MAVEN project scientist from NASA's Goddard Space Flight Center in Greenbelt, Maryland. "MAVEN also is studying other loss processes — such as loss due to impact of ions or escape of hydrogen atoms — and these will only increase the importance of atmospheric escape."

The goal of NASA's MAVEN mission, launched to Mars in November 2013, is to determine how much of the planet's atmosphere and water have been lost to space. It is the first such mission devoted to understanding how the Sun might have influenced atmospheric changes on the Red Planet. MAVEN has been operating at Mars for just over a year and completed its primary science mission on November 16. For more information about NASA's MAVEN mission, visit *http://www.nasa.gov/maven*.

Loss of Carbon in Martian Atmosphere Explained



This graphic depicts paths by which carbon has been exchanged among martian interior, surface rocks, polar caps, waters, and atmosphere, and also depicts a mechanism by which it is lost from the atmosphere with a strong effect on isotope ratio. Credit: Lance Hayashida/Caltech.

Mars is blanketed by a thin, mostly carbon dioxide atmosphere — one that is far too thin to keep water from freezing or quickly evaporating. However, geological evidence has led scientists to conclude that ancient Mars was once a warmer, wetter place than it is today. To produce a more temperate climate, several researchers have suggested that the planet was once shrouded in a much thicker carbon dioxide atmosphere. The question about where all the carbon went has been around for decades. The solar wind stripped away much of Mars' ancient atmosphere and is still removing tons of it every day. But scientists have been puzzled by why they haven't found more carbon — in the form of carbonate — captured into martian rocks. They have also sought to explain the ratio of heavier and lighter carbon in the modern martian atmosphere.

Now a team of scientists from the California Institute of Technology (Caltech) and NASA's Jet Propulsion Laboratory (JPL) offer an explanation of the "missing" carbon, in a paper published on November 24 by the journal *Nature Communications*. They suggest that 3.8 billion years ago, Mars might have had a moderately dense atmosphere. Such an atmosphere — with a surface pressure equal to or less than that found on Earth — could have evolved into the current thin one, not only minus the "missing" carbon, but also in a way consistent with the observed ratio of carbon-13 to carbon-12, which differ only by how many neutrons are in each nucleus.

"Our paper shows that transitioning from a moderately dense atmosphere to the current thin one is entirely possible," says Caltech postdoctoral fellow Renyu Hu, the lead author. "It is exciting that what we know about the martian atmosphere can now be pieced together into a consistent picture of its evolution — and this does not require a massive undetected carbon reservoir."

When considering how the early martian atmosphere might have transitioned to its current state, there are two possible mechanisms for the removal of the excess carbon dioxide. Either the carbon dioxide was incorporated into minerals in rocks called carbonates or it was lost to space. An August 2015 study used data from several Mars-orbiting spacecraft to inventory carbonates, showing there are nowhere near enough in the upper 1 kilometer (0.5 miles) of the crust to contain the missing carbon from a thick early atmosphere during a time when networks of ancient river channels were active, about 3.8 billion years ago.

The escaped-to-space scenario has also been problematic. Because various processes can change the relative amounts of carbon-13 to carbon-12 isotopes in the atmosphere, "we can use these measurements of the ratio at different points in time as a fingerprint to infer exactly what happened to the martian atmosphere in the past," says Hu. The first constraint is set by measurements of the ratio in meteorites that contain gases released volcanically from deep inside Mars, providing insight into the starting isotopic ratio of the original martian atmosphere. The modern ratio comes from measurements by the Sample Analysis at Mars (SAM) instrument on NASA's Curiosity rover.

One way carbon dioxide escapes to space from Mars' atmosphere is called sputtering, which involves interactions between the solar wind and the upper atmosphere. NASA's Mars Atmosphere and Volatile Evolution (MAVEN) mission has yielded recent results indicating that about 100 grams (0.25 pounds) of particles every second are stripped from today's martian atmosphere via this process, likely the main driver of atmospheric loss. Sputtering slightly favors loss of carbon-12, compared to carbon-13, but this effect is small. The Curiosity measurement shows that today's martian atmosphere is far more enriched in carbon-13 — in proportion to carbon-12 — than it should be as a result of sputtering alone, so a different process must also be at work.

Hu and his co-authors identify a mechanism that could have significantly contributed to the carbon-13 enrichment. The process begins with ultraviolet (UV) light from the Sun striking a molecule of carbon dioxide in the upper atmosphere, splitting it into carbon monoxide and oxygen. Then, UV light hits the carbon monoxide and splits it into carbon and oxygen. Some carbon atoms produced this way have enough energy to escape from the atmosphere, and the new study shows that carbon-12 is far more likely to escape than carbon-13. Modeling the long-term effects of this "ultraviolet photodissociation" mechanism, the researchers found that a small amount of escape by this process leaves a large fingerprint in the carbon isotopic ratio. That, in turn, allowed them to calculate that the atmosphere 3.8 billion years ago might have had a surface pressure a bit less thick than Earth's atmosphere today.

"This solves a long-standing paradox," said Bethany Ehlmann of Caltech and JPL, a co-author of the November publication and an August publication about carbonates. "The supposed very thick atmosphere seemed to imply that you needed this big surface carbon reservoir, but the efficiency of the UV photodissociation process means that there actually is no paradox. You can use normal loss processes as we understand them, with detected amounts of carbonate, and find an evolutionary scenario for Mars that makes sense."

For more information about Curiosity, visit *http://www.nasa.gov/msl* or *http://mars.jpl.nasa.gov/msl/*.

NASA's Curiosity Rover Team Confirms Ancient Lakes on Mars

A new study from the team behind NASA's Mars Science Laboratory/ Curiosity has confirmed that Mars was once, billions of years ago, capable of storing water in lakes over an extended period of time. Using data from the Curiosity rover, the team has determined that, long ago, water helped deposit sediment into Gale Crater, where the rover landed more than three years ago. The sediment deposited as layers that formed the foundation for Mount Sharp, the mountain found in the middle of the crater today.

A view from the "Kimberley" formation on Mars taken by NASA's Curiosity rover. Credit: NASA/JPL-Caltech/MSSS.

"Observations from the rover suggest that a series of long-lived streams and lakes existed at some point between about 3.8 to 3.3 billion years ago, delivering sediment that slowly built up the lower layers of Mount Sharp," said Ashwin Vasavada, Mars Science Laboratory project scientist at NASA's Jet Propulsion Laboratory, and co-author of the *Science* article published on October 9. The findings build upon previous work that suggested there were ancient lakes on Mars, and add to the unfolding story of a wet Mars, both past and present. In September, NASA scientists confirmed current water flows on Mars.

"What we thought we knew about water on Mars is constantly being put to the test," said Michael Meyer, lead scientist for NASA's Mars Exploration Program at NASA Headquarters in Washington. "It's clear that the Mars of billions of years ago more closely resembled Earth than it does today. Our challenge is to figure out how this more clement Mars was even possible, and what happened to that wetter Mars."

Before Curiosity landed on Mars in 2012, scientists proposed that Gale Crater had filled with layers of sediments. Some hypotheses were "dry," suggesting that sediment accumulated from wind-blown dust and sand. Others focused on the possibility that sediment layers were deposited in ancient lakes. The latest results from Curiosity indicate that these wetter scenarios were correct for the lower portions of Mount Sharp. Based on the new analysis, the filling of at least the bottom layers of the mountain occurred mostly by ancient rivers and lakes over a period of less than 500 million years.

"During the traverse of Gale, we have noticed patterns in the geology where we saw evidence of ancient fast-moving streams with coarser gravel, as well as places where streams appear to have emptied out into bodies of standing water," Vasavada said. "The prediction was that we should start seeing water-deposited, fine-grained rocks closer to Mount Sharp. Now that we've arrived, we're seeing finely laminated mudstones in abundance that look like lake deposits."

The mudstone indicates the presence of bodies of standing water in the form of lakes that remained for long periods of time, possibly repeatedly expanding and contracting during hundreds to millions of years. These lakes deposited the sediment that eventually formed the lower portion of the mountain.

"Paradoxically, where there is a mountain today there was once a basin, and it was sometimes filled with water," said John Grotzinger, the former project scientist for Mars Science Laboratory at the California Institute of Technology, and lead author of the new report. "We see evidence of about 75 meters (250 feet) of sedimentary fill, and based on mapping data from NASA's Mars Reconnaissance Orbiter and images from Curiosity's camera, it appears that the water-transported sedimentary deposition could have extended at least 150 to 200 meters (500 to 650 feet) meters above the crater floor."

Furthermore, the total thickness of sedimentary deposits in Gale Crater that indicate interaction with water could extend higher still, perhaps up to 800 meters (0.5 miles) above the crater floor. Above 800 meters, Mount Sharp shows no evidence of hydrated strata, and that is the bulk of what forms Mount Sharp. Grotzinger suggests that perhaps this later segment of the crater's history may have been dominated by dry, wind-driven deposits, as was once imagined for the lower part explored by Curiosity.

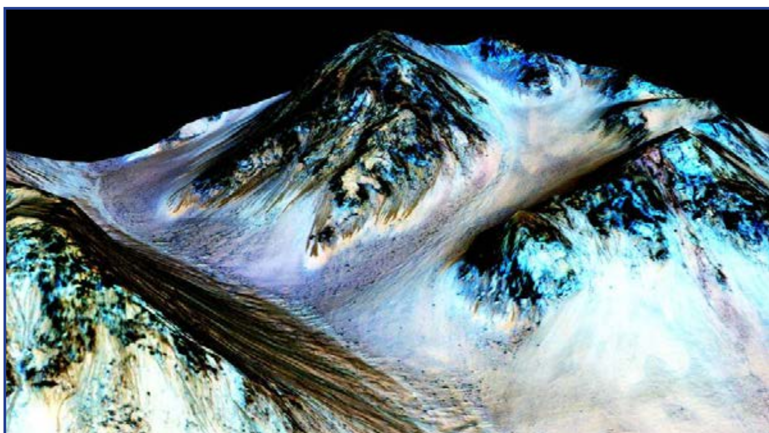
A lingering question surrounds the original source of the water that carried sediment into the crater. For flowing water to have existed on the surface, Mars must have had a thicker atmosphere and warmer climate than has been theorized for the ancient era when Gale Crater experienced the intense geological activity. However, current models of this paleoclimate have, literally, come up dry. At least some of the water may have been supplied to the lakes by snowfall and rain in the highlands of the Gale Crater rim.

Some have made the argument that there was an ocean in the plains north of the crater, but that does not explain how the water managed to exist as a liquid for extended periods of time on the surface.

"We have tended to think of Mars as being simple," Grotzinger mused. "We once thought of the Earth as being simple too. But the more you look into it, questions come up because you're beginning to fathom the real complexity of what we see on Mars. This is a good time to go back to reevaluate all our assumptions. Something is missing somewhere."

NASA Confirms Evidence that Liquid Water Flows on Today's Mars

New findings from NASA's Mars Reconnaissance Orbiter (MRO) provide the strongest evidence yet that liquid water flows intermittently on present-day Mars. Using an imaging spectrometer on MRO, researchers detected signatures of hydrated minerals on slopes where mysterious streaks are seen on the Red Planet. These darkish streaks appear to ebb and flow over time. They darken and appear to flow down steep slopes during warm seasons, and then fade in cooler seasons. They appear in several locations on Mars when temperatures are above –23°C (–10°F), and disappear at colder times.



These dark, narrow, 100-meter-long (328 foot-long) streaks called recurring slope lineae flowing downhill on Mars are inferred to have been formed by contemporary flowing water. Recently, planetary scientists detected hydrated salts on these slopes at Hale crater, corroborating their original hypothesis that the streaks are indeed formed by liquid water. Credit: NASA/JPL/University of Arizona.

"Our quest on Mars has been to 'follow the water,' in our search for life in the universe, and now we have convincing science that validates what we've long suspected," said John Grunsfeld, astronaut and associate administrator of NASA's Science Mission Directorate in Washington. "This is a significant development, as it appears to confirm that water — albeit briny — is flowing today on the surface of Mars."

These downhill flows, known as recurring slope lineae (RSL), often have been described as possibly related to liquid water. The new findings of hydrated salts on the slopes point to what that relationship may be to these dark features. The hydrated salts would lower the freezing point of a liquid brine, just as salt on roads here on Earth causes ice and snow to melt more rapidly. Scientists say it's likely a shallow subsurface flow, with enough water wicking to the surface to explain the darkening.

"We found the hydrated salts only when the seasonal features were widest, which suggests that either the dark streaks themselves or a process that forms them is the source of the hydration. In either case, the detection of hydrated salts on these slopes means that water plays a vital role in the formation of these streaks," said Lujendra Ojha of the Georgia Institute of Technology (Georgia Tech) in Atlanta, lead author of a report on these findings published September 28 by *Nature Geoscience*.

Ojha first noticed these puzzling features as a University of Arizona undergraduate student in 2010, using images from the MRO's High Resolution Imaging Science Experiment (HiRISE). HiRISE observations now have documented RSL at dozens of sites on Mars. The new study pairs HiRISE observations with mineral mapping by MRO's Compact Reconnaissance Imaging Spectrometer for Mars (CRISM). The spectrometer observations show signatures of hydrated salts at multiple RSL locations, but only when the dark features were relatively wide. When the researchers looked at the same locations and RSL weren't as extensive, they detected no hydrated salt.

Ojha and his co-authors interpret the spectral signatures as caused by hydrated minerals called perchlorates. The hydrated salts most consistent with the chemical signatures are likely a mixture of magnesium perchlorate, magnesium chlorate and sodium perchlorate. Some perchlorates have been shown to keep liquids from freezing even when conditions are as cold as –70°C (–94°F). On Earth, naturally produced perchlorates are concentrated in deserts, and some types of perchlorates can be used as rocket propellant.

Perchlorates have previously been seen on Mars. NASA's Phoenix lander and Curiosity rover both found them in the planet's soil, and some scientists believe that the Viking missions in the 1970s measured signatures of these salts. However, this study of RSL detected perchlorates, now in hydrated form, in different areas than those explored by the landers. This also is the first time perchlorates have been identified from orbit. MRO has been examining Mars since 2006 with its six science instruments.

"The ability of MRO to observe for multiple Mars years with a payload able to see the fine detail of these features has enabled findings such as these: first identifying the puzzling seasonal streaks and now making a big step towards explaining what they are," said Rich Zurek, MRO project scientist at NASA's Jet Propulsion Laboratory.

For Ojha, the new findings are more proof that the mysterious lines he first saw darkening martian slopes five years ago are, indeed, present-day water. "When most people talk about water on Mars, they're usually talking about ancient water or frozen water," he said. "Now we know there's more to the story. This is the first spectral detection that unambiguously supports our liquid water-formation hypotheses for RSL."

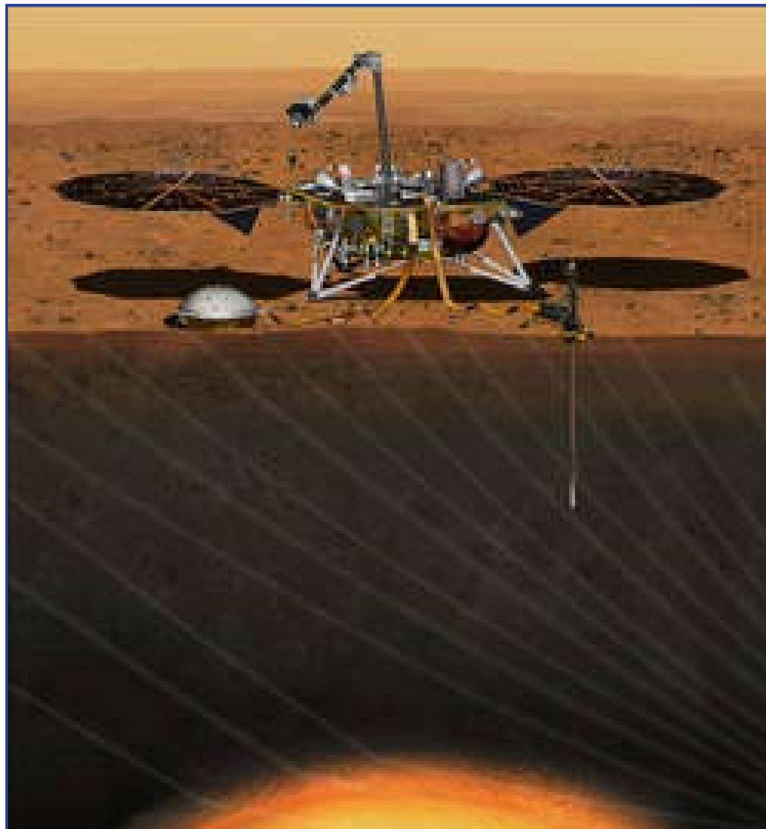
"It took multiple spacecraft over several years to solve this mystery, and now we know there is liquid water on the surface of this cold, desert planet," said Michael Meyer, lead scientist for NASA's Mars Exploration Program at the agency's headquarters in Washington. "It seems that the more we study Mars, the more we learn how life could be supported and where there are resources to support life in the future."

For more information, visit *https://www.nasa.gov/topics/journeytomars* or *http://www.nasa.gov/mro*.

Mars Mission Team Addressing Vacuum Leak on Key Science Instrument

A key science instrument that will be carried onboard NASA's Interior Exploration Using Seismic Investigations, Geodesy and Heat Transport (InSight) spacecraft being prepared for launch in March 2016 is experiencing a leak in the vacuum container carrying its main sensors. The sensors are part of an instrument called the Seismic Experiment for Interior Structure (SEIS), which is provided by the French Space Agency (CNES).

The seismometer is the prime science payload that will help answer questions about the interior structure and processes within the deep martian interior. The SEIS instrument has three high-sensitivity seismometers enclosed in a sealed sphere. The seismometers need to operate in a vacuum in order to provide exquisite sensitivity to ground motions as small as the width of an atom. After the final sealing of the sphere, a small leak was detected, which would have prevented meeting the science requirements once delivered to the surface of Mars. The CNES/JPL team is currently working to repair the leak, prior to instrument integration and final environmental tests in France before shipping to the U.S. for installation into the spacecraft and launch.



This artist's concept from August 2015 depicts NASA's InSight Mars lander fully deployed for studying the deep interior of Mars. Credit: NASA/JPL-Caltech.

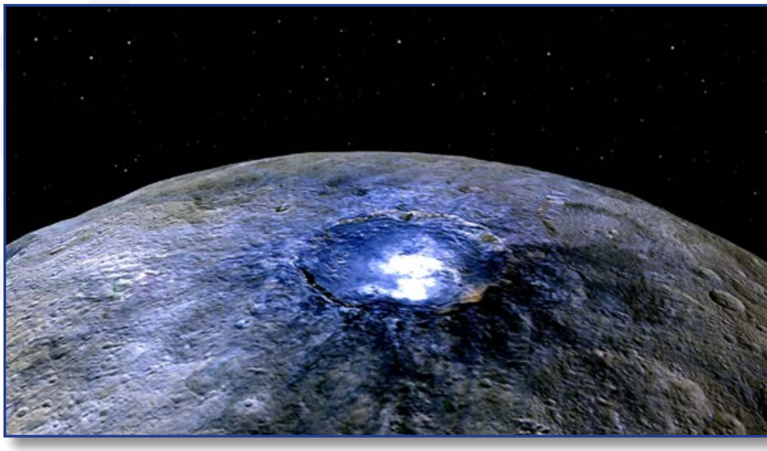
The InSight lander has completed assembly and testing at Lockheed Martin Space Systems in Colorado, and is being prepared to ship to the Vandenberg Air Force Base launch site. Installation of the seismometer is planned for early January. The Heat Flow and Physical Properties Package (HP3) from Germany and the rest of the scientific payload are already installed.

For more information, visit *http://insight.jpl.nasa.gov*.

Update of December 22: NASA managers have decided to suspend the launch of InSight following unsuccessful attempts to repair the leak in the prime instrument of the science payload.

New Clues to Ceres' Bright Spots and Origins

Ceres reveals some of its well-kept secrets in two new studies in the journal *Nature*, thanks to data from NASA's Dawn spacecraft. They include highly anticipated insights about mysterious bright features found all over the dwarf planet's surface. In one study, scientists identify this bright material as a kind of salt. The second study suggests the detection of ammonia-rich clays, raising questions about how Ceres formed.



This representation of Ceres' Occator Crater in false colors shows differences in the surface composition. Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA.

Ceres has more than 130 bright areas, and most of them are associated with impact craters. Study authors, led by Andreas Nathues at Max Planck Institute for Solar System Research, Göttingen, Germany, write that the bright material is consistent with a type of magnesium sulfate called hexahydrite. A different type of magnesium sulfate is familiar on Earth as Epsom salt. Nathues and colleagues, using images from Dawn's framing camera, suggest that these salt-rich areas were left behind when water-ice sublimated in the past. Impacts from asteroids would have unearthed the mixture of ice and salt, they say. "The global nature of Ceres' bright spots suggests that this world has a subsurface layer that contains briny water-ice," Nathues said.

The surface of Ceres, whose average diameter is 940 kilometers (584 miles), is generally dark — similar in brightness to fresh asphalt — study authors wrote. The bright patches that pepper the surface represent a large range of brightness, with the brightest areas reflecting about 50% of sunlight shining on the area. But there has not been unambiguous detection of water ice on Ceres; higher-resolution data are needed to settle this question.

The inner portion of a crater called Occator contains the brightest material on Ceres. Occator itself is 90 kilometers (60 miles) in diameter, and its central pit, covered by this bright material, measures about 10 kilometers (6 miles) wide and 0.5 kilometers (0.3 miles) deep. Dark streaks, possibly fractures, traverse the pit. Remnants of a central peak, which was up to 0.5 kilometers (0.3 miles) high, can also be seen. With its sharp rim and walls, and abundant terraces and landslide deposits, Occator appears to be among the youngest features on Ceres. Dawn mission scientists estimate its age to be about 78 million years old.

Study authors write that some views of Occator appear to show a diffuse haze near the surface that fills the floor of the crater. This may be associated with observations of water vapor at Ceres by the Herschel space observatory that were reported in 2014. The haze seems to be present in views during noon, local time, and absent at dawn and dusk, study authors write. This suggests that the phenomenon resembles the activity at the surface of a comet, with water vapor lifting tiny particles of dust and residual ice. Future data and analysis may test this hypothesis and reveal clues about the process causing this activity.

“The Dawn science team is still discussing these results and analyzing data to better understand what is happening at Occator,” said Chris Russell, principal investigator of the Dawn mission, based at the University of California, Los Angeles.

In the second *Nature* study, members of the Dawn science team examined the composition of Ceres and found evidence for ammonia-rich clays. They used data from the visible and infrared mapping spectrometer, a device that looks at how various wavelengths of light are reflected by the surface, allowing minerals to be identified. Ammonia ice by itself would evaporate on Ceres today, because the dwarf planet is too warm. However, ammonia molecules could be stable if present in combination with (i.e., chemically bonded to) other minerals.

The presence of ammoniated compounds raises the possibility that Ceres did not originate in the main asteroid belt between Mars and Jupiter, where it currently resides, but instead might have formed in the outer solar system. Another idea is that Ceres formed close to its present position, incorporating materials that drifted in from the outer solar system — near the orbit of Neptune, where nitrogen ices are thermally stable.

“The presence of ammonia-bearing species suggests that Ceres is composed of material accreted in an environment where ammonia and nitrogen were abundant. Consequently, we think that this material originated in the outer cold solar system,” said Maria Cristina De Sanctis, lead author of the study, based at the National Institute of Astrophysics, Rome.

In comparing the spectrum of reflected light from Ceres to meteorites, scientists found some similarities. Specifically, they focused on the spectra, or chemical fingerprints, of carbonaceous chondrites, a type of carbon-rich meteorite thought to be relevant analogs for the dwarf planet. But these are not good matches for all wavelengths that the instrument sampled, the team found. In particular, there were distinctive absorption bands, matching mixtures containing ammoniated minerals, associated with wavelengths that can’t be observed from Earth-based telescopes. The scientists note another difference is that these carbonaceous chondrites have bulk water contents of 15 to 20%, while Ceres’ content is as much as 30%.

“Ceres may have retained more volatiles than these meteorites, or it could have accreted the water from volatile-rich material,” De Sanctis said.

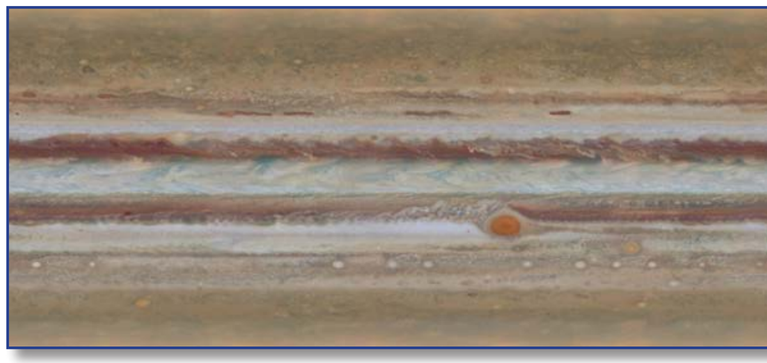
The study also shows that daytime surface temperatures on Ceres span from 180 to 240 K (–136° to –28°F). The maximum temperatures were measured in the equatorial region. The temperatures at and near the equator are generally too high to support ice at the surface for a long time, study authors say, but data from Dawn’s next orbit will reveal more details.

Dawn has reached its final orbital altitude at Ceres, about 385 kilometers (240 miles) from the surface of the dwarf planet. In mid-December, Dawn will begin taking observations from this orbit, including images at a resolution of 35 meters (120 feet) per pixel; infrared, gamma-ray, and neutron spectra; and high-resolution gravity data.

More information is available at *http://dawn.jpl.nasa.gov* and *http://www.nasa.gov/dawn*.

Hubble Maps Show Jupiter Changes and Prepare for Juno

New maps of Jupiter, produced using images from NASA's Hubble Space Telescope, provide a detailed window on the giant planet's dynamic features. The views come as the agency prepares for its Juno mission to arrive at Jupiter in a little less than a year. The maps are the first in a planned series of yearly portraits of the solar system's four giant, outer planets, and are intended help scientists monitor how these worlds change over time. The images and related findings are described in a recently published paper in the *Astrophysical Journal.*



Scientists produced new global maps of Jupiter using the Wide Field Camera 3 on NASA's Hubble Space Telescope. One color map is shown here, projected onto a globe and as a flat image. Credit: NASA/ESA/GSFC/UCBerkeley/JPL-Caltech/STScI.

The Jupiter maps are of particular interest to scientists working on Juno, which will arrive at Jupiter on July 4, 2016. "We've been coordinating with professional and amateur astronomers for several years now to collect observations that will help us plan Juno's activities once we arrive at Jupiter. The new Hubble maps are an extraordinarily valuable part of that effort," said Glenn Orton, a co-author on the paper from NASA's Jet Propulsion Laboratory.

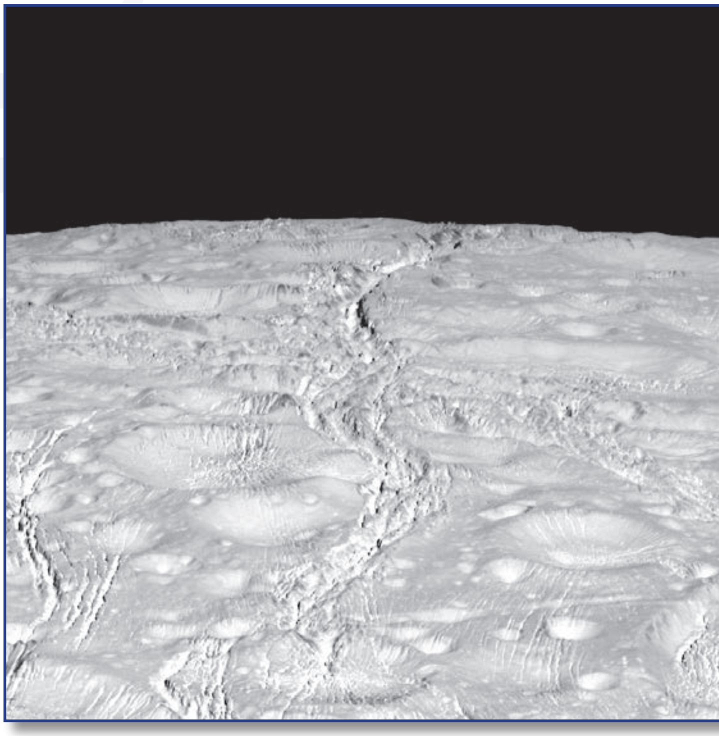
Already, the Jupiter images have revealed a rare wave just north of the planet's equator and a unique filamentary feature in the core of the Great Red Spot not seen previously. They also reveal that the red spot continues its shrinking trend of recent years, becoming more circular and changing from red to a paler orange.

The Hubble observation program, called Outer Planet Atmospheres Legacy (OPAL), is led by Amy Simon, a planetary scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

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

Closest Northern Views of Saturn's Moon Enceladus

NASA's Cassini spacecraft has begun returning its best-ever views of the northern extremes of Saturn's icy, ocean-bearing moon Enceladus. The spacecraft obtained the images during its October 14 flyby, passing 1839 kilometers (1142 miles) above the moon's surface.



NASA's Cassini spacecraft zoomed by Saturn's icy moon Enceladus on October 14, 2015, capturing this stunning image of the moon's north pole. Credit: NASA/JPL-Caltech/Space Science Institute.

Scientists expected the north polar region of Enceladus to be heavily cratered, based on low-resolution images from the Voyager mission, but the new high-resolution Cassini images show a landscape of stark contrasts. "The northern regions are crisscrossed by a spidery network of gossamer-thin cracks that slice through the craters," said Paul Helfenstein, a member of the Cassini imaging team at Cornell University in Ithaca, New York. "These thin cracks are ubiquitous on Enceladus, and now we see that they extend across the northern terrains as well."

Cassini's next encounter with Enceladus occurred on October 28, when the spacecraft came within 49 kilometers (30 miles) of the moon's south polar region. During the encounter, Cassini made its deepest-ever dive through the moon's plume of icy spray, sampling the chemistry of the extraterrestrial ocean beneath the ice. Mission scientists are hopeful data from that flyby will provide evidence of how much hydrothermal activity is occurring in the moon's ocean, along with more detailed insights about the ocean's chemistry — both of which relate to the potential habitability of Enceladus.

Cassini's final close Enceladus flyby took place on December 19, when the spacecraft measured the amount of heat coming from the moon's interior. The flyby was at an altitude of 4999 kilometers (3106 miles).

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

Cassini Finds Monstrous Ice Cloud in Titan's South Polar Region

New observations made near the south pole of Titan by NASA's Cassini spacecraft add to the evidence that winter comes in like a lion on this moon of Saturn. Scientists have detected a monstrous new cloud of frozen compounds in the moon's low- to mid-stratosphere — a stable atmospheric region above the troposphere, or active weather layer.

Cassini's camera had already imaged an impressive cloud hovering over Titan's south pole at an altitude of about 300 kilometers (186 miles). However, that cloud, first seen in 2012, turned out to be just the tip of the iceberg. A much more massive ice cloud system has now been found lower in the stratosphere, peaking at an altitude of about 200 kilometers (124 miles). The new cloud was detected by Cassini's infrared instrument — the Composite Infrared Spectrometer (CIRS) — which obtains profiles of the atmosphere at invisible thermal wavelengths. The cloud has a low density, similar to Earth's fog but likely flat on top.

As winter sets in at Titan's south pole, a cloud system called the south polar vortex (small, bright "button") has been forming, as seen in this 2013 image. Credit: NASA/JPL-Caltech/Space Science Institute.

For the past few years, Cassini has been catching glimpses of the transition from fall to winter at Titan's south pole — the first time any spacecraft has seen the onset of a Titan winter. Because each Titan season lasts about 7.5 years on Earth's calendar, the south pole will still be enveloped in winter when the Cassini mission ends in 2017.

"When we looked at the infrared data, this ice cloud stood out like nothing we've ever seen before," said Carrie Anderson of NASA's Goddard Space Flight Center in Greenbelt, Maryland. "It practically smacked us in the face." Anderson presented the findings at the annual Meeting of the Division of Planetary Sciences of the American Astronomical Society at National Harbor, Maryland, on November 11.

The ice clouds at Titan's pole don't form in the same way as Earth's familiar rain clouds. For rain clouds, water evaporates from the surface and encounters cooler temperatures as it rises through the troposphere. Clouds form when the water vapor reaches an altitude where the combination of temperature and air pressure is right for condensation. The methane clouds in Titan's troposphere form in a similar way.

However, Titan's polar clouds form higher in the atmosphere by a different process. Circulation in the atmosphere transports gases from the pole in the warm hemisphere to the pole in the cold hemisphere. At the cold pole, the warm air sinks, almost like water draining out of a bathtub, in a process known as subsidence. The sinking gases — a mixture of smog-like hydrocarbons and nitrogen-bearing chemicals called nitriles — encounter colder and colder temperatures on the way down. Different gases will condense at different temperatures, resulting in a layering of clouds over a range of altitudes.

Cassini arrived at Saturn in 2004 — mid-winter at Titan's north pole. As the north pole has been transitioning into springtime, the ice clouds there have been disappearing. Meanwhile, new clouds have been forming at the south pole. The build-up of these southern clouds indicates that the direction of Titan's global circulation is changing.

"Titan's seasonal changes continue to excite and surprise," said Scott Edgington, Cassini deputy project scientist at NASA's Jet Propulsion Laboratory. "Cassini, with its very capable suite of instruments, will continue to periodically study how changes occur on Titan until its Solstice mission ends in 2017."

The size, altitude, and composition of the polar ice clouds help scientists understand the nature and severity of Titan's winter. From the ice cloud seen earlier by Cassini's camera, scientists determined that temperatures at the south pole must get down to at least –150°C (–238°F). The new cloud was found in the lower stratosphere, where temperatures are even colder. The ice particles are made up of a variety of compounds containing hydrogen, carbon, and nitrogen. Anderson and her colleagues had found the same signature in CIRS data from the north pole, but in that case, the signal was much weaker. The very strong signature of the south polar cloud supports the idea that the onset of winter is much harsher than the end.

"The opportunity to see the early stages of winter on Titan is very exciting," said Robert Samuelson, a Goddard researcher working with Anderson. "Everything we are finding at the south pole tells us that the onset of southern winter is much more severe than the late stages of Titan's northern winter."

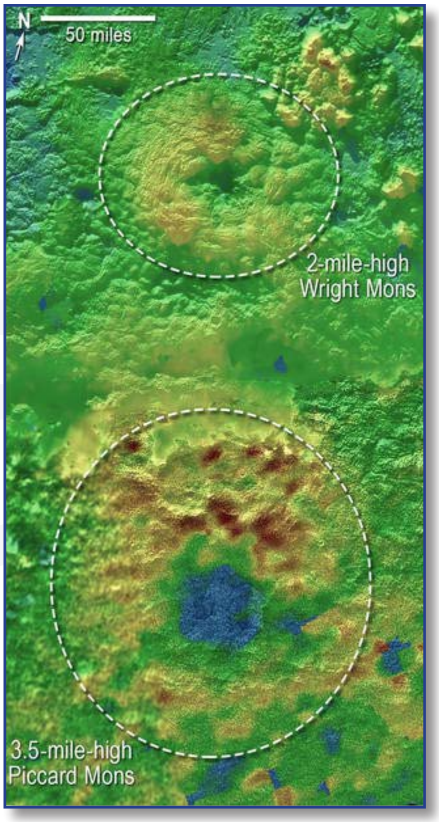
Four Months After Pluto Flyby, NASA's New Horizons Yields Wealth of Discovery

From possible ice volcanos to twirling moons, NASA's New Horizons science team presented more than 50 exciting discoveries about Pluto in November at the 47th Annual Meeting of the American Astronomical Society's Division for Planetary Sciences in National Harbor, Maryland.

"The New Horizons mission has taken what we thought we knew about Pluto and turned it upside down," said Jim Green, director of planetary science at NASA Headquarters in Washington. "It's why we explore — to satisfy our innate curiosity and answer deeper questions about how we got here and what lies beyond the next horizon."

For one such discovery, New Horizons geologists combined images of Pluto's surface to make three-dimensional maps that indicate two of Pluto's most distinctive mountains could be cryovolcanoes — ice volcanoes that may have been active in the recent geological past.

"It's hard to imagine how rapidly our view of Pluto and its moons are evolving as new data stream in each week. As the discoveries pour in from those data, Pluto is becoming a star of the solar system,"



Using New Horizons images of Pluto's surface to make three-dimensional topographic maps, scientists discovered that two of Pluto's mountains, informally named Wright Mons and Piccard Mons, could be ice volcanos. The color depicts changes in elevation, blue indicating lower terrain and brown showing higher elevation. Green terrains are at intermediate heights. Credit: NASA/JHUAPL/SwRI.

said mission Principal Investigator Alan Stern of the Southwest Research Institute in Boulder, Colorado. "Moreover, I'd wager that for most planetary scientists, any one or two of our latest major findings on one world would be considered astounding. To have them all is simply incredible."

The two cryovolcano candidates are large features measuring tens of kilometers (or miles) across and several kilometers high. "These are big mountains with a large hole in their summit, and on Earth that generally means one thing — a volcano," said Oliver White, New Horizons postdoctoral researcher at NASA's Ames Research Center in Moffett Field, California. "If they are volcanic, then the summit depression would likely have formed via collapse as material is erupted from underneath. The strange hummocky texture of the mountain flanks may represent volcanic flows of some sort that have traveled down from the summit region and onto the plains beyond, but why they are hummocky, and what they are made of, we don't yet know."

While their appearance is similar to volcanoes on Earth that spew molten rock, ice volcanoes on Pluto are expected to emit a somewhat melted slurry of substances such as water ice, nitrogen, ammonia, or methane. If Pluto proves to have volcanoes, it will provide an important new clue to its geologic and atmospheric evolution. "After all, nothing like this has been seen in the deep outer solar system," said Jeffrey Moore, New Horizons Geology, Geophysics and Imaging team leader at Ames.

Pluto's surface varies in age — from ancient, to intermediate, to relatively young — according to another new finding from New Horizons. To determine the age of a surface area of the planet, scientists count crater impacts. The more crater impacts, the older the region likely is. Crater counts of surface areas on Pluto indicate that it has surface regions dating to just after the formation of the planets of our solar system, about four billion years ago. But there also is a vast area that was, in geological terms, born yesterday — meaning it may have formed within the past 10 million years. This area, informally named Sputnik Planum, appears on the left side of Pluto's "heart" and is completely crater-free in all images received so far.

New data from crater counts reveal the presence of intermediate, or "middle-aged," terrains on Pluto as well. This suggests Sputnik Planum is not an anomaly — that Pluto has been geologically active throughout much of its more than 4-billion-year history. "We've mapped more than a thousand craters on Pluto, which vary greatly in size and appearance," said postdoctoral researcher Kelsi Singer of the Southwest Research Institute in Boulder, Colorado. "Among other things, I expect cratering studies like these to give us important new insights into how this part of the solar system formed."

Crater counts are giving the New Horizons team insight into the structure of the Kuiper belt itself. The dearth of smaller craters across Pluto and its large moon Charon indicate the Kuiper belt, which is an unexplored outer region of our solar system, likely had fewer smaller objects than some models had predicted. This leads New Horizons scientists to doubt a longstanding model that all Kuiper belt objects (KBOs) formed by accumulating much smaller objects — less than 1.6 kilometers (1 mile) wide. The absence of small craters on Pluto and Charon support other models theorizing that Kuiper belt objects tens of kilometers (miles) across may have formed directly, at their current — or close to current — size. In fact, the evidence that many Kuiper belt objects could have been "born large" has scientists excited that New Horizons' next potential target — the 40–50-kilometer-wide (30-mile-wide) KBO named 2014 MU69 — which may offer the first detailed look at just such a pristine, ancient building block of the solar system.

The New Horizons mission also is shedding new light on Pluto's fascinating system of moons, and their unusual properties. For example, nearly every other moon in the solar system — including Earth's moon — is in synchronous rotation, keeping one face toward the planet. This is not the case for Pluto's small moons. Pluto's small lunar satellites are spinning much faster, with Hydra — its most distant moon — rotating 89 times during a single lap around the planet. Scientists believe these spin rates may be variable because Charon exerts a strong torque that prevents each small moon from settling down into synchronous rotation. "Pluto's moons behave like spinning tops," said co-investigator Mark Showalter of the SETI Institute in Mountain View, California.

Images of Pluto's four smallest satellites also indicate several of them could be the results of mergers of two or more moons. "We suspect from this that Pluto had more moons in the past, in the aftermath of the big impact that also created Charon," said Showalter.

For more information on NASA's New Horizons mission, visit *http://www.nasa.gov/newhorizons*.

Rosetta and Philae: One Year Since Landing on a Comet

One year since Philae made its historic landing on a comet, mission teams remain hopeful for renewed contact with the lander, while also looking ahead to next year's grand finale: making a controlled impact of the Rosetta orbiter on the comet. Rosetta arrived at Comet 67P/Churyumov-Gerasimenko on August 6, 2014, and after an initial survey and selection of a landing site, Philae was delivered to the surface on November 12. After touching down in the Agilkia region

Artist's illustration of Europe's Philae lander touching down on Comet 67P/Churyumov-Gerasimenko in November 2014. Credit: ESA.

as planned, Philae did not secure itself to the comet, and it bounced to a new location in Abydos. Its flight across the surface has been depicted in a new animation, using data collected by Rosetta and Philae to reconstruct the lander's rotation and attitude.

In the year since landing, a thorough analysis has also now been performed on why Philae bounced. There were three methods to secure it after landing: ice screws, harpoons, and a small thruster. The ice screws were designed with relatively soft material in mind, but Agilkia turned out to be very hard and they did not penetrate the surface. The harpoons were capable of working in both softer and harder material. They were supposed to fire on contact and lock Philae to the surface, while a thruster on top of the lander was meant to push it down to counteract the recoil from the harpoon. Attempts to arm the thruster the night before failed; it is thought that a seal did not open, although a sensor failure cannot be excluded.

Then, on landing, the harpoons themselves did not fire. "It seems that the problem was either with the four 'bridge wires' taking current to ignite the explosive that triggers the harpoons, or the explosive itself, which may have degraded over time," explains Stephan Ulamec, Philae lander manager at the DLR German Aerospace Center. "In any case, if we can regain contact with Philae, we might consider an attempt to retry the firing." The reason is scientific: The harpoons contain sensors that could measure the temperature below the surface.

Despite the unplanned bouncing, Philae completed 80% of its planned first science sequence before falling into hibernation in the early hours of November 15 when the primary battery was exhausted. There was not enough sunlight in Philae's final location at Abydos to charge the secondary batteries and continue science measurements. The hope was that as the comet moved nearer to the Sun, heading toward closest approach in August, there would be enough energy to reactivate Philae. Indeed, contact was made with the lander on June 13 but only eight intermittent contacts were made up to July 9.

The problem was that the increasing sunlight also led to increased activity on the comet, forcing Rosetta to retreat to several hundred kilometers (miles) for safety, well out of range with Philae. However, over the past few weeks, with the comet's activity now subsiding, Rosetta has started to approach again. In mid-November it reached 200 kilometers (124 miles), the limit for making good contact with Philae, and on November 12 it dipped to within 170 kilometers (106 miles).

In the meantime, the lander teams have continued their analysis of the data returned during the contacts in June and July, hoping to understand the status of Philae when it first woke up from hibernation. "We had already determined that one of Philae's two receivers and one of the two transmitters were likely no longer working," says Koen Geurts, Philae's technical manager at DLR's Lander Control Centre in Cologne, Germany, "and it now seems that the other transmitter is suffering problems. Sometimes it did not switch on as expected, or it switched off too early, meaning that we likely missed possible contacts."

The team is taking this new information into account to determine the most promising strategy to regain regular contact. But it's a race against time: With the comet now heading out beyond the orbit of Mars, temperatures are falling. "We think we have until the end of January before the lander's internal temperature gets too cold to operate: It cannot work below –51°C [–60°F]," adds Koen.

Meanwhile, Rosetta continues to return unique data with its suite of instruments, analyzing changes to the comet's surface, atmosphere, and plasma environment in incredible detail. "We recently celebrated our first year at the comet and we are looking forward to the scientific discoveries the next year will bring," says Matt Taylor, ESA's Rosetta project scientist. "Next year, we plan to do another far excursion, this time through the comet's tail and out to 2000 kilometers [1243 miles]. To complement that, we hope to make some very close flybys toward the end of the mission, as we prepare to put the orbiter down on the comet."

The plan is to end the mission with a 'controlled impact' of Rosetta on the surface. This idea emerged around six months ago, when an extension of operations from December 2015 to September 2016 was announced. The solar-powered Rosetta will no longer receive enough sunlight to operate as the comet recedes from the Sun, out beyond the orbit of Jupiter on its 6.5-year circuit. It will travel even further out than during the previous 31 months of deep-space hibernation that ended in January 2014. In addition, as seen from Earth next September, Rosetta and the comet will look very close to the Sun, making the relay of both scientific data and operational commands very difficult.

The Rosetta teams are now investigating the maneuvers needed for operating close to the comet in the weeks leading up to the dramatic mission finale. "We are still discussing exactly what the final end of mission scenario will involve," says Sylvain Lodiot, ESA's Rosetta spacecraft operations manager. "It is very complex and challenging, even more so even than the lander delivery trajectory our flight dynamics teams had to plan for delivering Philae. The schedule we're looking at would first involve a move into highly elliptical orbits — perhaps as low as 1 kilometer [0.62 miles] — in August, before moving out to a more distant point for a final approach that will set Rosetta on a slow collision course with the comet at the end of September."

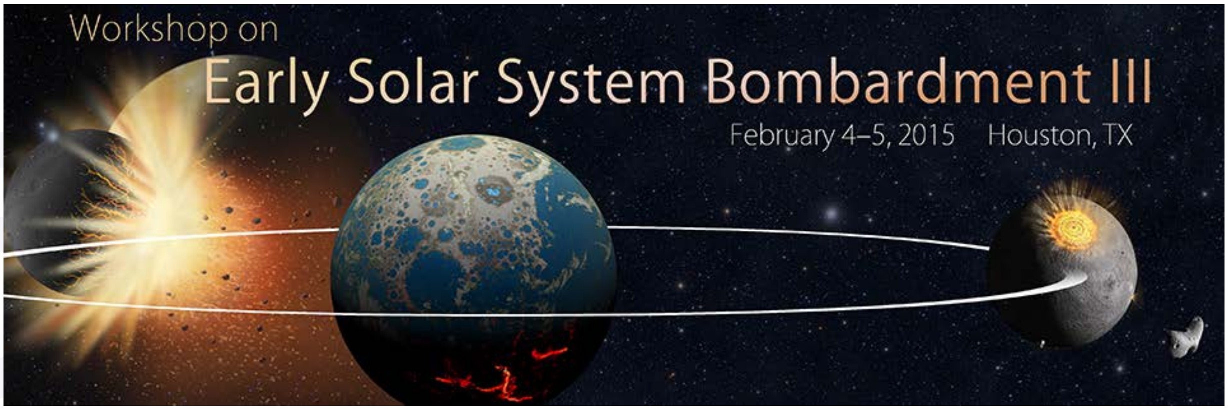
It is expected that science observations would continue throughout and up to almost the end of mission, allowing Rosetta's instruments to gather unique data at unprecedentedly close distances. "We'll control Rosetta all the way down to the end, but once on the surface it will be highly improbable that we'll be able to 'speak' to it anymore," adds Sylvain.

"Landing Rosetta on a comet will be a fitting ending to this incredible mission," says Patrick Martin, ESA's Rosetta mission manager.

For more information about Rosetta, visit *http://rosetta.jpl.nasa.gov* or *http://rosetta.esa.int*.

Workshop on Early Solar System Bombardment III

February 4–5, 2015
Houston, Texas



The third edition of an influential series of workshops was held at the Lunar and Planetary Institute in Houston, Texas, earlier this year. The scope of the meeting was to investigate a range of collisional events from the late stages of planetary accretion to the end of the basin-forming epoch on the Moon. That scope included the giant impact hypothesis for the formation of the Earth-Moon system, the lunar (or inner solar system) impact cataclysm hypothesis, and implications that these hypotheses may have for collisions elsewhere (e.g., on Mars) and the accretional and orbital evolution of the outer giant planets. In the spirit of great workshops, it provided a forum for discussion of current ideas and glimpses of new ideas that will significantly enhance our exploration of those solar system processes. The meeting included a few invited talks that were designed to identify broad issues, but it was dominated by contributed oral and poster presentations.

Canup opened the meeting with a discussion of the development of the giant impact model. The "canonical" model involved an oblique, low-velocity collision between the proto-Earth and a body twice the diameter of the Moon (~0.1 to 0.15 $M_{\oplus}$), producing an Fe-poor, ~1.5 to 2 lunar-mass disk, that is dominated by debris from the impactor, with a system angular momentum similar to that in the current Earth-Moon system. That model has been challenged, however, by measurements of similar O-isotope compositions on both the Earth and Moon. Because Mars and Earth have different O-isotope compositions, it is often assumed there was a gradient in O-isotope compositions for objects that formed between the Earth and Mars, which would imply the impactor, and thus Moon, had a different O-isotope composition than the proto-Earth. The O-isotope observation was compounded by a presentation by Touboul, Walker, and Puchtel. They refined techniques to measure W isotopes, knocking down the uncertainties so that a real difference has now been detected between the Earth and Moon. The offset, however, is best explained by assuming that the W-isotopic compositions of the two bodies were identical immediately following formation of the Moon, and that they then diverged as a result of disproportional late accretion to the Earth and Moon.

Dynamical solutions for the O-isotope conundrum exist in the literature, but Canup concluded those appear to have low overall probabilities (on the order of 1% or less). Jacobsen et al. then examined the accretion (or feeding zones) of the proto-Earth, Mars, and the likely impactor assuming (a) an O-isotope gradient in the solar system between the Earth and Mars and (b) the Grand Tack scenario for solar system formation (i.e., in which Jupiter and Saturn migrate inward and sculpt the inner disk). Their model suggests the impactor must have formed in the vicinity of the proto-Earth. Alternatively, it was also noted during discussion that it may be time to reexamine the assumption of an O-isotope gradient in the inner solar system. Additional dynamical and geochemical contributions to the discussion were provided by Pahlevan and Morbidelli, Quarles and Lissauer, Charnoz and Michaut, and Righter.

Workshop participants then explored the concept of collisional erosion during accretion. Bojibar et al. presented a model in which an Earth with a bulk enstatite chondrite composition is stripped of its proto-crust by impacts, followed by fractional recondensation of the ejecta; e.g., for total erosion of 15 to 45% of the Earth's mass, 100% of the Ca and Al recondenses, while only 10% of Mg and 5% of Si recondense to produce Earth's composition. Potter and Kring also examined collisional erosion during the accretion of the Earth as a possible mechanism for explaining nonchondritic geochemical signatures in the Earth. They found it can work, but only under some low-probability circumstances.

A large fraction of the meeting examined the chronology of early solar system impacts. Several papers discussing the Ar-Ar radiometric system were presented by Swindle and Kring; Norman; Zellner and Delano; Boehnke et al.; and Hartmann. Those papers were followed by others discussing the U-Pb system in zircon and other accessory phases: Crow, McKeegan, and Moser; Wielicki and Harrison; and Moser. It became clear that there are disagreements in the Ar-Ar community about how to best measure the K-Ar system and interpret the data. It also became clear that zircon U-Pb data complement the Ar-Ar data, providing an opportunity to look at (generally) older impact and magmatic events. Likewise, U-Pb analyses of lunar phosphate minerals provide complementary chronologic data. Thus, evolving tools (Ar-Ar) and new tools (U-Pb analyses of zircon and phosphate) are providing a growing dataset to test the cadence of impacts during the basin-forming epoch.

To better interpret the ages, it was generally agreed that the geologic context of existing Apollo samples needs to be clarified and that future sample sites need to be carefully selected to determine the ages of specific basins, issues that were explored by Cohen, Petro, and Lawrence, as well as Hurwitz and Kring.

A key to understanding the processes that led to bombardment is the source(s) of early solar system impactors. Walker et al. reported siderophile element and Os-isotope evidence of chondritic and iron asteroid impactors in Apollo 15 and 16 samples (i.e., in the vicinity of Nectarian and Early Imbrian basins). In contrast, Bottke et al. suggested debris left over from the Moon-forming giant impact produced the Moon's pre-Nectarian craters and, more broadly, Jackson et al. suggested that giant impacts during planetary accretion generated debris that dominated the impactor flux. In a twist of that theme, Minton et al. suggested that the proposed Borealis impact event on Mars generated the debris in the late heavy bombardment. The caveat raised during workshop discussion involved the nature of the debris ejected by giant impacts. Most large or giant impact simulations suggest the ejected debris would be melt and vapor (the protolunar disk is, for example, initially melt and vapor), but the models above require ejected debris to be solid and/or to have condensed from the melt and vapor with a fragmentation size distribution.

A presentation of potentially overlooked lunar basins was provided by Frey. That discussion of the basin-forming epoch was then amplified by a discussion of impact events on the Hadean and Archean Earth, led by Marchi et al., Lowe and Byerly, and Koeberl et al. A potential measure of even younger impact events, as deduced from Copernican craters on the Moon, was presented by Mazrouei, Ghent, and Bottke. That inner solar system record was complemented by descriptions of collisional processes that may have affected Vesta (Stickle et al.), comets (de Niem and Kührt), and the outer solar system (Movshovitz et al. and Schmedemann et al.).

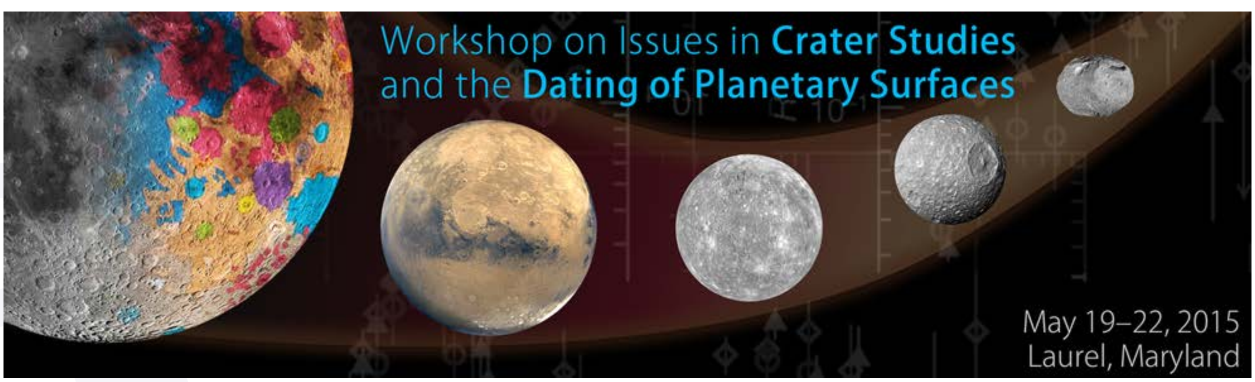
The consequences of early solar system bombardment was investigated first by Kiefer et al., who examined the density of lunar lithologies and implications a prolonged period of bombardment would have on gravity. Two papers (Kring et al. and McGovern et al.) argued that the South Pole-Aitken basin-forming impact triggered a magmatic epoch. That model was prompted, in part, by a collection of U-Pb ages derived from lunar zircon.

To capture the full scope of the workshop's science, we invite you to view the online LPI archive where all the extended abstracts are available: *http://www.hou.usra.edu/meetings/bombardment2015/pdf/program.pdf*.

— Text provided by David Kring and Robin Canup

Workshop on Issues in Crater Studies and the Dating of Planetary Surfaces

May 19–22, 2015
Laurel, Maryland



Impacts are the main exogenic process that shape the surfaces of solid bodies in the solar system. Craters are studied by observationalists, dynamicists, and experimentalists, but often in isolation from each other. Craters inform a wide variety of investigations, including modeling surface ages, understanding surface modification processes, and investigating dynamics of small bodies and the solar system as a whole, and as such they (or results from crater studies) are used by many planetary scientists.

Large advances were made in the early decades of work on and with craters, and a general consensus was developed about the impact history of the solar system and the population of bodies that created that history. However, due to the tremendous success of NASA-sponsored and other space missions in the past decade, analyses of much larger datasets available today challenge those simpler models. In addition, the best practices for how crater data should be gathered, analyzed, and presented have substantially diverged within various communities.

The Planetary Crater Consortium convened a conference, held at the Applied Physics Laboratory of The Johns Hopkins University in May 2015, with the goal of bringing together a diverse community to present on and discuss where the crater field began, where it is, and what outstanding issues remain.

The 3.5-day conference featured approximately 50 attendees and speakers from 3 continents. The talks had discussions about using craters to understand the chronology of the solar system, how impact crater statistics are abused but should be used, and what crater populations and individual craters can tell us about the planetary body and processes.

One of the themes throughout the workshop was that the crater community needs to be better at broader community education and outreach. The concept of "*we* know what we mean," but which meaning is often misinterpreted by researchers outside the field, was both an overt and covert idea throughout most of the discussion sessions. For example, if a crater-based model age is given in a paper's text, table, or figure, with an attached uncertainty, a person who studies impact craters will typically know that the quoted uncertainty in the age is only based on Poisson counting statistics, and that it is in fact much larger due to other uncertainties in the counts (e.g., choosing the count area) and the model on which the age is based (i.e., the model production function and the model chronology). But, a person outside the field may only use that apparent age and artificially small uncertainty to conclude something about an entirely different process, and make erroneous conclusions because of the appearance of a tight age constraint. In fact, even the terminology "crater-based model age" was recommended over "crater age" or the redundant "crater age date," for it conveys the idea that the derived age is based on craters and it relies on models, but it is subject to change given a different model.

Beyond this, conference attendees recognized that most planetary scientists use impact craters to derive model ages, and all model ages are based on the lunar chronology, which has substantial gaps: Ages older than 3.92 Ga, and those between 3 and 1 Ga, are unconstrained by the Apollo and Luna sample return collection. Ergo, a recommendation was that we engage in more community activism to highlight the need for more lunar sample return missions or *in situ* dating of units with crater densities between and beyond those measured at the Apollo and Luna sites to better constrain this very important tool, the lunar crater chronology.

While the above outreach should be done through conferences and white papers, 85% of conference attendees polled will be or will be considering submitting to a special issue of the journal *Meteoritics and Planetary Science* that will contain reviews, "tools," and recommendation papers about the current state of knowledge of the field. The anticipated deadline for these papers is mid- to late-2016.

One hundred percent of respondents said that that the workshop was helpful, and that they would attend a follow-up workshop if one were offered in a few years. This was the first-ever workshop of its kind, and had a good turnout and good responses from the crater community. Efforts are now being focused on following up with outreach efforts.

The full program and abstracts from the workshop are available on the meeting website at *http://www.hou.usra.edu/meetings/craterstats2015/pdf/program.pdf*.

— Text provided by Stuart Robbins

2nd International Planetary Caves Conference

October 20–23, 2015
Flagstaff, Arizona

2nd International Planetary Caves Conference

Planetary caves represent high-priority targets for future robotic and human missions. Martian and lunar caves are preexisting sheltered environments where astronaut habitation or storage facilities may be constructed. Additionally, martian caves provide access to the subsurface without a costly drilling payload (to search for evidence of life), and significant water ice deposits for human consumption and fuel. Vents associated with plumes on icy moons are considered high-priority targets for future habitability studies.

Participants at the 2nd International Planetary Caves Conference. Credit: Thomas Prettyman.

Scientists have identified more than 200 lunar and 2000 martian cave features. Vents and fissures associated with water ice plumes on saturnian, jovian, and neptunian moons have also been confirmed, and the primary vent of a possible cryovolcano was recently identified on Pluto — thus expanding the range of potential subsurface cavity-forming processes.

Nearly 40 astrophysicists, biologists, geochemists, meteorologists, roboticists, and engineers convened in October in Flagstaff, Arizona, to advance our understanding of caves in our solar system. Attendees discussed their research accomplishments and ways to heighten awareness concerning the importance of planetary caves for future robotic and human missions. This gathering also provided scientists and engineers with a rare opportunity to meet and discuss how to best further robotic planetary cave exploration capabilities.

The conference kicked off with a plenary talk by Dr. Leroy Chiao, NASA shuttle astronaut and former International Space Station Commander. He emphasized the need to return to the Moon before journeying to Mars. Chiao suggested that the establishment of a lunar base will enable us to fully develop technologies for long-duration space missions while having the luxury of being close to our home planet. Cave-exploration robotics would benefit similarly by using lunar caves as a test bed before conducting robotic missions to other planetary bodies within our solar system.

One of the most compelling results presented was the identification of subterranean voids on the Moon using gravimetric techniques. Using Gravity Recovery and Interior Laboratory (GRAIL) mission data, researchers identified subsurface anomalies associated with lunar pits. Their results suggest some pits on the Moon actually connect to large subterranean systems.

A noteworthy distinction between Earth biospheres and biospheres that may be found on desert and icy planets was provided. Type 1 is a photosynthesis-driven surface biosphere, while Type 2 is a chemosynthetically-driven subsurface biosphere. Because Earth supports rich surface and subsurface biotic communities, it represents a Type 1 and 2 hybrid. Given inhospitable surface conditions mediated by thin atmospheres, if life exists on desert and icy planetary bodies in our solar system, it would most likely occur within a Type 2 biosphere.

Additional discoveries and ideas presented during this conference included:

- The identification of regions on the surface of Titan where dissolution processes may have occurred — hinting at the possibility of dissolution caves
- The need for three-dimensional computer vision analysis of the entrance passageway and associated surface area to determine the route for entering the cave to better guide roboticists in developing appropriate rover technologies
- A payload to search for *in situ* subterranean life should include mass spectroscopy, laser-induced breakdown spectroscopy, energy dispersive spectroscopy and visible spectrum camera
- Cellular automaton algorithms for examining visible spectrum imagery (captured by a cave explorer rover) could prove quite useful in searching for biosignatures along the cave interior.

The conference included a local educational outreach component consisting of a primary school “space caves” art contest and a presentation from a local high school robotics team. Capitalizing on the “A” in STEAM (science, technology, engineering, art, and math), the art contest was held the week prior to the conference for Flagstaff-area schools (grades 6–12). Artwork ranged from alien cave life to stunning spacescapes viewed skyward through planetary cave entrances. Contest winners met Chiao, and their artwork was displayed during the conference. Currently, Lowell Observatory in Flagstaff is hosting an exhibit of the contest winners’ artwork. Another science outreach effort involved a team of “future NASA engineers” from the Coconino High School Robotics Group in Flagstaff. Approached by conference organizers, these students were asked to develop a robotic concept for planetary cave exploration. Delivering their first professional presentation, these young roboticists discussed a hybrid robotic motility consisting of traditional wheeled and climbing technologies. This technology could be used on a surface-to-cave rover on the Moon or Mars.

The conference served to bring together scientists and engineers from various disciplines, who are all passionate about planetary caves and their potential. Numerous new collaborations were forged among researchers, and participants left the conference energized about future work in this area.

— Text provided by J. Judson Wynne

LPI Summer Intern Program in Planetary Science

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

The 10-week program begins June 6, 2016, and ends on August 12, 2016. Selected students will receive a $5675 stipend; in addition, U.S. students will receive a $1000 travel stipend, and foreign nationals will receive a $1500 foreign travel reimbursement.

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

The deadline for applying for the 2016 program is **January 8, 2016**. For more information, including eligibility and selection criteria, areas of research, and an online application form, visit *http://www.lpi.usra.edu/lpiintern*.

Applications Now Being Accepted for the Exploration Science Summer Intern Program

The Lunar and Planetary Institute (LPI) and NASA Johnson Space Center (JSC) are hosting a special Exploration Science Summer Intern Program to build on the success of the former Lunar Exploration Summer Intern Program that was designed to evaluate possible landing sites on the Moon for robotic and human exploration missions. Over a five year period (2008–2012), teams of students worked with Lunar and Planetary Institute (LPI) science staff and their collaborators to produce *A Global Lunar Landing Site*

Study to Provide the Scientific Context for Exploration of the Moon. The program for 2016 is designed to have the same impact on future exploration activities, but has a broader scope that includes both the Moon and near-Earth asteroids. It is a unique opportunity to integrate scientific input with exploration activities in a way that mission architects and spacecraft engineers can use. Activities may involve assessments and traverse plans for a particular destination (e.g., on the lunar farside) or a more general assessment of a class of possible exploration targets (e.g., small near-Earth asteroids).

This program is open to graduate students in geology, planetary science, planetary astronomy, and related programs. It is also open to exceptional undergraduate students with at least 50 semester hours of credit in those fields. The 10-week program runs from May 23, 2016, through July 29, 2016. Selected interns will receive a $5675 stipend to cover the costs associated with being in Houston for the duration of the program. Additionally, U.S. citizens will receive up to $1000 in travel expense reimbursement and foreign nationals will receive up to $1500 in travel expense reimbursement.

The deadline for applying for the 2016 program is **January 15, 2016**. For more information, including eligibility and selection criteria, areas of research, and an online application form, please visit *http://www.lpi.usra.edu/exploration_intern/*.

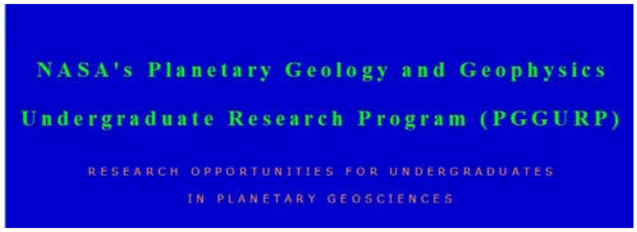
Graduate Students Eligible for the LPI Career Development Award

The Lunar and Planetary Institute (LPI) is proud to announce its ninth LPI Career Development Award, which is open to both U.S. and non-U.S. applicants. This award will be given to graduate students who have submitted a first-author abstract for presentation at the 47th Lunar and Planetary Science Conference (LPSC). A travel stipend of $1000 will be awarded to the top applicants to help cover travel expenses for attending the LPSC in March. Awards will be based on a review of the application materials by a panel of lunar and planetary scientists.

Applications must include a letter outlining why the applicant would like to participate at the LPSC and what he or she will contribute to the conference, a letter of recommendation from his or her research advisor, a copy of the first-author abstract, and a curriculum vitae for the applicant.

The deadline for application is **January 15, 2016**. Applications and all accompanying materials must be submitted electronically. All documents uploaded must be in text or PDF format. For more information and a link to the application form, visit *http://www.hou.usra.edu/meetings/lpsc2016/programAbstracts/cdaAward/*.

NASA's Planetary Geology and Geophysics Undergraduate Research Program



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

The program consists of an eight-week summer internship, in which qualified students are matched with a NASA-funded planetary scientist. Care is taken to match the skills of the student with the needs of the NASA mentor.

The application deadline is **January 29, 2016**. For more information, visit *http://www.acsu.buffalo.edu/~tgregg/pggurp.html*.

California Institute of Technology Summer Undergraduate Research Fellowships

Caltech's Summer Undergraduate Research Fellowships (SURF) program introduces students to research under the guidance of seasoned research mentors at the California Institute of Technology (Caltech) and the Jet Propulsion Laboratory (JPL). Students experience the process of research as a creative intellectual activity. SURF is modeled on the grant-seeking process: students collaborate with potential mentors to define and develop a project; applicants write research proposals for their projects; a faculty committee reviews the proposals and recommends awards; students carry out the work over a 10-week period in the summer, mid-June to late August; and at the conclusion of the program, they submit a technical paper and give an oral presentation at SURF Seminar Day, a symposium modeled on a professional technical meeting.

The deadline for all application materials is **February 22, 2016**. For more information, visit *http://sfp.caltech.edu/programs/surf*.

Internships, Scholarships, and Fellowships with NASA

NASA Internships are educational hands-on opportunities that provide unique NASA-related research and operational experiences for high school, undergraduate, and graduate students as well as educators. These internships integrate participants with career professionals emphasizing mentor-directed, degree-related, real-time world task completion. During the internship participants engage in scientific or engineering research, development, and operations activities. In addition, there are non-technical internship opportunities to engage in professional activities which support NASA business and administrative processes. Through these internships, participants leverage NASA's unique mission activities and mentorship to enhance and increase their professional capabilities and clarify their long-term career goals.

NASA Internships can be full or part-time, conducted at a NASA facility, contractor facility, or anywhere activities are ongoing to advance NASA's missions. Mentors can be civil servants, contractors, or faculty conducting activities directly related to NASA's unique assets and ongoing mission activities.

NASA internships occur within the following four sessions per year generally corresponding to the academic calendar: spring, summer, fall, and year-long (often following the academic year August–May). Applications for summer 2016 opportunities are due **March 1, 2016**. To find available opportunities and fill out an OSSI online application, visit *http://intern.nasa.gov/ossi*. Inquiries about the OSSI should be submitted via *http://intern.nasa.gov/oic*.

Postdoctoral and Graduate Fellowships at the Smithsonian

The Department of Mineral Sciences at the Smithsonian Institution–National Museum of Natural History (NMNH) invites applications for both postdoctoral and graduate fellowships. Active areas of research include volcanology, mineral spectroscopy, geomicrobiology, environmental mineralogy, geochemistry, experimental petrology, mineral physics, meteorite studies, solar system formation, and planetary formation and evolution. The department also houses the National Meteorite Collection, the National Rock and Ore Collection, the National Gem and Mineral Collection, and the Global Volcanism Program. Application deadlines vary according to the particular program. For more information, visit *http://mineralsciences.si.edu/research/fellowship.htm*.

The National Air and Space Museum offers the Verville Fellowship, which is a competitive nine- to twelve-month in-residence fellowship intended for the analysis of major trends, developments, and accomplishments in the history of aviation or space studies. The fellowship is open to interested candidates with demonstrated skills in research and writing. Publishing experience should demonstrate either a mid-level academic record of accomplishment or proven ability to reliably engage broader audiences. An advanced degree in history or a related field is preferred but not a requirement. An annual stipend of $55,000 will be awarded for a 12-month fellowship, with limited additional funds for travel and miscellaneous expenses. Applications are due by **January 15, 2016**, and the fellowship normally begins between August 15 and October 1. For more information, visit *http://airandspace.si.edu/research/fellowships/verville.cfm*.

SAO Summer Intern Program

The SAO (Smithsonian Astrophysical Observatory) Summer Intern Program is a Research Experiences for Undergraduates (REU) program where students work on astrophysics research with an SAO/Harvard scientist. In 2016 the program will run for 10 weeks from June 5 through August 13 (these dates may change depending on the availability of Harvard housing). Students are expected to be in residence at the Harvard-Smithsonian Center for Astrophysics (CfA) for the full duration of the program.

The program is funded by the National Science Foundation and the Smithsonian Institution. Undergraduate students interested in a career in astronomy, astrophysics, physics, or related physical sciences are encouraged to apply for the 2016 program. Applicants must be U.S. citizens or permanent residents ("green card" holders), and must be enrolled in a degree program leading to a bachelors degree. Seniors who will graduate in June 2016 (or before) are not eligible.

The application deadline is **February 1, 2016**. For more details, visit *http://hea-www.harvard.edu/REU/REU.html*.

NASA Minority Innovation Challenges Institute

The mission of the Minority Innovation Challenges Institute (MICI) is to create a virtual training ground where minority undergraduate students learn how to compete in NASA technical challenges for both prestige and significant cash prizes. This NASA funded program, which is managed by Florida Agricultural & Mechanical University (FAMU), provides a year-round virtual conference platform where students from across the country can participate in free interactive educational sessions of their choosing. Many of the sessions will focus on competitions found within NASA's Centennial Challenges program, which provides cash prizes ranging from $50,000 to $2 million to individuals/teams that can achieve specific technical accomplishments.

In addition to Centennial Challenges, students will also learn how to compete in other NASA-sponsored competitions created specifically for universities. The goal of MICI is to use NASA technical competitions as a way to inspire minority undergraduate students to pursue (1) an advanced degree in Science, Technology, Engineering, and Mathematics (STEM), and (2) a career in STEM-related disciplines that will ultimately contribute to NASA's future technological needs.

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

Internships Available at APL

APL offers a variety of science and engineering internships each summer. The Laboratory's internship program provides practical work experience and an introduction to APL. Students spend the summer working with APL scientists and engineers, conducting research, developing leadership skills, and growing professionally. For more information, visit *http://www.jhuapl.edu/employment/summer/*.

Lloyd V. Berkner Space Policy Internships 2016

The goal of the Lloyd V. Berkner Space Policy Internship is to provide promising undergraduate and graduate students with the opportunity to work in the area of civil space research policy in the nation's capital, under the aegis of the National Research Council's Space Studies Board and Aeronautics and Space Engineering Board. The summer program is only open to undergraduates. The autumn program is open to undergraduate and graduate students. The application deadlines are February 6 (summer) and June 3 (autumn). Additional information about the program, including the application procedure, can be found at *http://sites.nationalacademies.org/SSB/ssb_052239*.

"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 47th Lunar and Planetary Science Conference will be held at The Woodlands Waterway Marriott Hotel and Convention Center, The Woodlands, Texas, March 21–25, 2016. There will be a variety of events and opportunities that will be of interest to the science education community and scientists who are involved in — or are interested in — education and public engagement. For more information, visit *http://www.hou.usra.edu/meetings/lpsc2016*.

Submit an Education and Public Engagement Abstract

We invite all those involved with education and public engagement to submit an abstract for the poster sessions. The abstract deadline is Tuesday, January 12, 2016. To submit, follow the instructions at *http://www.hou.usra.edu/meetings/lpsc2016/programAbstracts/instructions*, and choose the topic "Education and Engagement" on the submission form.

Educator Professional Development Workshop: Exploring Planetary Science

Science educators (middle school, high school, informal educators, and college faculty) are invited to attend this free day-long workshop examining ongoing planetary science research. Meet with planetary scientists and learn about the latest discoveries, explore hands-on activities that model how planetary science exploration is conducted, and examine the big questions that drive solar system exploration.

The workshop will be held on Sunday, March 20, 2016; times and location are being finalized. Registration is free but required. For additional information, please contact Christine Shupla at *shupla@lpi.usra.edu*.

NASA Earth and Space Science Fellowships Program

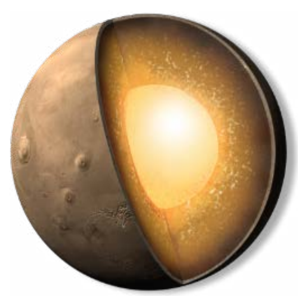
The NASA Earth and Space Science Fellowship (NESSF) program is soliciting applications from accredited U.S. universities on behalf of individuals pursuing masters or doctoral degrees in Earth and space sciences, or related disciplines, for the 2016–2017 academic year. Awards resulting from the competitive selection will be training grants to the respective universities, with the advisor serving as the principal investigator. Initially, NESSF awards are made for one year and may be renewed for up to two additional years, contingent upon satisfactory progress and the availability of funds. The maximum amount of a NESSF award is $30,000 per year. Proposals for this opportunity are due February 1, 2016. For more information about this solicitation, visit *http://go.nasa.gov/1H34oH3*.

Upcoming Public Event Opportunities

Upcoming opportunities exist for educator and public engagement around the broader topics of NASA planetary exploration. Resources for evening observing session events include the Night Sky Network's *Discover the Universe Guides* at *https://nightsky.jpl.nasa.gov/news-display.cfm?News_ID=611* and the Lunar and Planetary Institute's *Look Up* guides at *http://www.lpi.usra.edu/education/look_up/*. Consider getting in touch with local astronomical societies, planetariums and museums, local scientists, and NASA's Solar System Ambassadors (*http://solarsystem.nasa.gov/ssa/directory.cfm*) — ask them to join your events and share their experiences or resources with the children.

InSight Launches for Mars

http://insight.jpl.nasa.gov/home.cfm



The Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission will land on Mars to study its deep interior; it is scheduled to launch on March 4, 2016.

Update of December 22: The InSight mission has been postponed following unsuccessful attempts to repair a leak in one of the prime science instrumnets.

Juno Arrives at Jupiter

http://www.nasa.gov/mission_pages/juno/main/index.html

The Juno mission will improve our understanding of the solar system's beginnings by revealing the origin and evolution of Jupiter. It is scheduled to begin orbiting Jupiter around July 4, 2016.

One of Juno's engagement activities is the JunoCam — the public will be invited to act as a virtual imaging team, participating in key steps to process images. The Juno team has kicked off the first stage of JunoCam activity with the launch of a new Web platform, at *http://www.missionjuno.swri.edu/junocam*. Now and throughout the mission, amateur astronomers are invited to submit images of Jupiter from their own telescopes. These views will be the basis for online discussions about which of Jupiter's swirls, bands, and spots JunoCam should image as it makes repeated, close passes over the planet.

Astronomy Outreach Resources: MOOSE

The American Astronomical Society's "Astronomy Ambassadors" program trains early-career astronomers on how to be more effective in outreach to schools, community groups, and the public. A resource guide for doing astronomy outreach has been put together under the title Menu of Outreach Opportunities for Science Education (MOOSE). It includes exemplary programs, finding aids for organizations that need astronomers, presentation techniques, sources of activities, evaluation ideas, and more. For more information, visit *http://aas.org/outreach/moose-menu-outreach-opportunities-science-education*.

2016 Edward C. Roy, Jr. Award for Excellence in K–8 Earth Science Teaching

Each year, AGI gives this award to a full-time U.S. teacher from kindergarten to eighth grade for leadership and innovation in Earth science education. Winners receive a $2500 prize and a travel grant of $1000 to attend the National Science Teachers Association (NSTA) Annual Conference in March to accept the award. To be eligible for the 2016 competition, applications must be postmarked by January 20, 2016. More information is available at *http://www.agiweb.org/education/awards/ed-roy/*.

Nominate a Scientist or Educator for an ASP Education Award

Nomination deadline is February 15, 2016.

Richard H. Emmons Award

http://www.astrosociety.org/about-us/the-richard-h-emmons-award-for-excellence-in-college-astronomy-teaching/

The Richard A. Emmons Award of the ASP is awarded annually to an individual demonstrating outstanding achievement in the teaching of college-level introductory astronomy for non-science majors.

Klumpke-Roberts Award

http://www.astrosociety.org/about-us/klumpke-roberts-award-of-the-astronomical-society-of-the-pacific/

The ASP bestows the annual Klumpke-Roberts Award on those who have made outstanding contributions to the public understanding and appreciation of astronomy.

Thomas J. Brennan Award

http://www.astrosociety.org/about-us/thomas-brennan-award-for-outstanding-contributions-to-the-teaching-of-astronomy-in-grades-9-12

The Thomas J. Brennan Award recognizes excellence in the teaching of astronomy at the high school level in North America. The recipients have demonstrated exceptional commitment to classroom or planetarium education, as well as the training of other teachers.

Nominate a Scientist or Educator for an AGU Education Award

Nominations open January 15, 2016, and close March 15, 2016.

AGU's Spilhaus Award

http://honors.agu.org/medals-awards/athelstan-spilhaus-award/

This is awarded not more than once annually to an individual AGU member for devoting portions of their career to conveying to the general public the excitement, significance, and beauty of the Earth and space sciences.

Excellence in Geophysical Education Award

http://honors.agu.org/medals-awards/excellence-in-geophysical-education-award/

This is awarded not more than once annually to an individual, group, or team. The award is "to acknowledge a sustained commitment to excellence in geophysical education by a team, individual, or group. To educators who have had a major impact on geophysical education at any level (kindergarten through postgraduate), who have been outstanding teachers and trainers for a number of years, or who have made a long-lasting, positive impact on geophysical education through professional service."

Robert Farquhar, 1932–2015

Robert W. Farquhar, an early MESSENGER Mission Manager and a planetary trajectory pioneer who designed some of the most esoteric and complex spacecraft trajectories ever attempted, died on October 18 at the age of 83. A 50-year veteran of deep-space missions, Farquhar made pivotal contributions to the exploration of comets, asteroids, and the planets.

Farquhar was born in 1932 and raised in Chicago. He showed an interest in aviation as a child, reading about the topic and designing and building model airplanes. After serving in the Army in Japan during the Korean War, he studied aeronautical engineering at the University of Illinois and received his bachelor's degree with honors in 1959. He went on to earn a master's degree from the University of California, Los Angeles, in 1961. He worked briefly at Lockheed Missiles and Space Company in Sunnyvale, California, after which he completed a Ph.D. at Stanford University in 1969.

From 1969 to 1990, Farquhar worked at NASA's Goddard Space Flight Center in Greenbelt, Maryland, and at NASA Headquarters in Washington, DC. In 1988, as Chief of Advanced Programs with the Space Physics Division, and Program Manager for the Discovery Program with the Solar System Exploration Division, he became involved in planning spacecraft missions to Mercury and Pluto. "I was intrigued with the possibility of developing low- or moderate-cost mission and spacecraft designs that could lead to realizable flight missions with many 'firsts,' " he wrote in his memoir, *Fifty Years on the Space Frontier: Halo Orbits, Comets, Asteroids, and More*.

Farquhar commissioned a study from the Jet Propulsion Laboratory (JPL) of a Mercury orbiter mission. JPL proposed a two-spacecraft Mercury Dual Orbiter (MDO) mission that would be launched on a single launch vehicle. Although the MDO mission was never selected for flight, several aspects of its mission design and operations concepts were adopted by the MESSENGER mission. MESSENGER was selected by NASA as the seventh Discovery mission in 1999, and Farquhar — by that time at the Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, Maryland — was appointed Mission Manager during the mission's development phase. In that role, he supervised the mission design and navigation tasks, and he coordinated many activities of the science, engineering, and mission operations teams. He also worked closely with Deep Space Network (DSN) representatives at JPL to ensure that MESSENGER would have adequate DSN coverage following launch.

Farquhar retired from APL in 2007 and stepped down from his position as Mission Manager. In a new position he accepted at KinetX, Inc., he remained involved with the mission, serving as an advisor for MESSENGER's navigation team. In addition to MESSENGER, Farquhar made fundamental contributions to several other space missions, including the Comet Nucleus Tour (CONTOUR). He served as the first Mission Manager for NASA's New Horizons mission. Following a trajectory that Farquhar envisioned, that spacecraft flew past dwarf planet Pluto and its family of small moons this past July. He also conceived, and was the flight director for, the Near Earth Asteroid Rendezvous (NEAR) mission to asteroid 433 Eros— the first launch of the Discovery program and the first planetary exploration mission led by APL.

“Bob Farquhar was critical to the MESSENGER mission, from initial concept through launch and early operations,” said MESSENGER Principal Investigator Sean Solomon of Columbia University’s Lamont-Doherty Earth Observatory. “His competitive drive to achieve new firsts in space, his enthusiasm for attempting difficult tasks, and his brilliantly creative and technically thorough solutions to mission design challenges set a tone for the entire MESSENGER team. That MESSENGER was selected for flight, completed a record six planetary flybys, and became the first spacecraft to successfully orbit Mercury is in no small measure the result of Bob’s inspiration, passion, and skill at problem solving. The entire MESSENGER team will miss him.”

— Text courtesy of the MESSENGER mission website

Arlin Crotts, 1958–2015

Arlin Crotts died peacefully on November 19 after a long battle with cancer. Crotts received his A.B. in Physics from Princeton University and his Ph.D. in Physics from the University of Chicago. A member of the astronomy faculty at Columbia University since 1991, he received a Packard Fellowship for Science and Engineering and the AAS’s Newton Lacy Pierce Prize for outstanding achievement in observational astronomy.

Crott made scientific contributions in an unusually wide range of areas, addressing each topic with his characteristic daring and flare — from studying supernova light echoes in the Magellanic Clouds and nearby galaxies, to pixel-scale microlensing in Andromeda, to absorption lines in pairs and groups of quasars, to building giant liquid mirrors for telescopes, to finding water on the Moon. The review in *Nature* of his 2014 book, *The New Moon*, noted that, “Crotts mines lunar research and its implications for human colonization in staggering, often deeply engaging, detail.”

As someone who valued intellectual discourse, Crotts was a fixture at the department’s bi-weekly coffee hours, where he delighted in discussing the latest scientific discoveries with professors and students alike. Occasionally the conversation would also turn to human space exploration and the development of rockets, the history of science, his latest movie project, or the state of the world. His strong presence in the department, his sharp mind, and his quirky laugh and sense of humor will be sorely missed.

— Text courtesy of Columbia University

Heinrich Wänke, 1928–2015

Dr. Heinrich Wänke passed away on November 21 at the age of 87. Wänke was appointed Director of the Cosmochemistry Department at Max-Planck-Institut für Chemie in Mainz, Germany, in 1967. In the years that followed, he and his staff conducted studies on meteorites to help us understand the early history of our solar system, and determined how long a large number of meteorites had been in the universe and the consequences of cosmic radiation. They also began to study Mars, and were able to determine its chemical composition from meteorites originating from this planet, and subsequent space probes aided their research. The department also focused on researching Earth's crust and studying lunar rocks. Wänke retired from the department in 1996, but remained active in research for many years.

Wänke's research interests covered a wide range of topics in planetary science, including isotopic studies of meteorites and geochemistry of lunar samples. He studied isotopic compositions of cosmogenic noble gases in iron meteorites and abundances of solar-wind-implanted rare gases in meteorite breccias, argued for a martian origin of SNC meteorites, and actively participated in Mars missions. His research contributed to a better understanding of the origin of the Moon and accretion and differentiation of the terrestrial planets.

Wänke also made many contributions to The Meteoritical Society. In 1983 he organized The Society's annual meeting in Mainz, and from 1993 to 1994 served as President of The Society. He became a Fellow of The Society in 1976 and was awarded the Leonard Medal in 1980 for numerous contributions of fundamental importance to meteoritics and planetary science. He was an outstanding scientist and his death is a major loss to both The Meteoritical Society and the larger international planetary science community as a whole.

— Text courtesy of Max-Planck-Institut für Chemie and The Meteoritical Society

USRA Announces 2015 Scholarship Award Winners

The Universities Space Research Association is proud to announce the 2015 winners of the annual USRA Scholarship Awards:

Mr. Jeremy Dietrich, a junior at the Harvard-Smithsonian Center for Astrophysics, won the James B. Willett Memorial Scholarship Award, which honors Willett's contributions to astrophysics. Dietrich has researched the habitable zones and biosignatures of exoplanets, and contributed to the search for hidden stellar companions to exoplanet host stars. He is a co-author on a paper on stellar evolution profiles and effects on variable composition on habitable systems, and is noted for his exceptional skills in computational astrophysics.

Mr. Anthony Hennig, a senior majoring in Mechanical Engineering (with aerospace option) and minoring in Physics at the Rochester Institute of Technology (RIT), has been selected to receive the John R. Sevier Memorial Scholarship Award, which honors Sevier's contributions to aerospace science. With his passion for engineering, Hennig founded a student research group at RIT, raised funds, and is working toward developing a 3U cubesat bus. During his internships at NASA's Langley Research Center he developed tools to generate better space system and architecture concepts. Hennig volunteers for FIRST Robotics-Finger Lakes Region. He is also pursuing a master's degree in technology policy, focusing on the impacts of extraterrestrial mining on commodities markets.

Ms. Elizabeth Bondi, a senior imaging science major at RIT, won the Thomas R. McGetchin Memorial Scholarship Award, which honors McGetchin's contributions to planetary science. Bondi is a highly motivated, in-depth learner, and has applied her imaging science expertise to historical documents and planetary imagery. As an intern at NASA's Jet Propulsion Laboratory, she characterized landing sites for the Insight Mars mission and also planned the test flight program for the proposed Mars Helicopter for the Mars 2020 rover. She has also presented papers at STEM education conferences on project-based learning and peer evaluations.

Ms. Namrah Habib, a junior majoring in aerospace engineering and chemical engineering at University of Arizona, won the Frederick A. Tarantino Memorial Scholarships Award, which honors Tarantino's contributions to USRA and his dedication to STEM education. Habib has worked extensively on preparations for the OSIRIS-REx mission to the asteroid Bennu. She has performed surface analog analysis of asteroids, analyzed surface features of Mercury, and adapted existing stereo-imagery software for these purposes. She also participated in engineering verification of requirements for NASA's Space Launch System and mentors high school students.

Brett Denevi Awarded Top Scientist Honor from Maryland Academy

Brett W. Denevi speaks during a briefing on the discoveries provided by NASA's MESSENGER spacecraft while in orbit around the planet Mercury in 2011. Credit: NASA/Paul E. Alers.

The Maryland Academy of Sciences presented MESSENGER Team Member Brett Denevi with their Outstanding Young Scientist award during a ceremony on November 18 at the Maryland Science Center in Baltimore. The Outstanding Young Scientist award program was established in 1959 to recognize and celebrate extraordinary contributions of young Maryland scientists.

Denevi, the Deputy Instrument Scientist for the Mercury Dual Imaging System (MDIS) on the MESSENGER spacecraft, is "an unusually accomplished young scientist who has helped to solve multiple difficult problems, the solutions to which have contributed to our basic understanding of how the solar system has evolved and the processes that drove its evolution," stated MESSENGER Co-Investigator Scott Murchie.

As a postdoctoral scientist at Arizona State University and later a planetary geologist at the Johns Hopkins University Applied Physics Laboratory (APL), Denevi was instrumental in helping to answer three of the six questions that framed the scientific objectives for the MESSENGER mission to Mercury. From multispectral images taken during MESSENGER's three flybys of Mercury, she led a paper demonstrating that much of Mercury's outer crust formed by volcanic processes. After joining APL in 2010, her maps of geological units derived from orbital images were used by the science team to address questions about Mercury's composition and the evolution of its interior. While doing this research, she served in multiple capacities on the imaging team. She was the deputy in charge of planning observations and the lead for developing the final calibration of image data. "In other words, she applied her scientific knowledge to steering MESSENGER in the best scientific direction during its limited four-year orbital lifetime," Murchie added.

Denevi is also a key participant in two other active planetary missions. She is a Co-Investigator on the Lunar Reconnaissance Orbiter Camera and a participating scientist on the Vesta phase of the Dawn mission. In her latter role, she is conducting pioneering research on optical effects of "space weathering" at ultraviolet wavelengths, a frontier area in the study of how planetary surfaces are modified by exposure to space.

LPI Announces Shoemaker Impact Cratering Award Recipient

The Lunar and Planetary Institute (LPI) is pleased to announce that the 2015 recipient of the Eugene M. Shoemaker Impact Cratering Award is James T. Keane of the University of Arizona.

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

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

Proposals for next year's award will be due in September 2016. Applications will be accepted beginning in late summer of 2016. Application details can be found at *https://www.lpi.usra.edu/Awards/shoemaker/*.

Geology Award Goes to Mars Landing Site Expert at JPL

JPL scientist Matt Golombek at launch pad for NASA's Mars Exploration Rover Spirit, at Cape Canaveral Air Force Station, Florida. Credit: NASA/JPL-Caltech.

A prestigious geology award was presented in early November to a leader in selecting landing sites on Mars: Matt Golombek of NASA's Jet Propulsion Laboratory in Pasadena, California. The Geological Society of America named Golombek to receive the 2015 G. K. Gilbert Award, which was presented during the society's annual meeting in November.

Golombek is the project scientist for NASA's Mars Exploration Rover Project, the landing site scientist for NASA's Mars Exploration Program, and co-chair of NASA's Mars Landing Site Steering Committee. He was project scientist for NASA's Mars Pathfinder Project, which successfully put the first rover on Mars in 1997. He has been a leader in evaluating and selecting sites for every NASA Mars rover mission, for the 2008 Phoenix Mars Lander, and for the upcoming InSight lander and Mars 2020 rover.

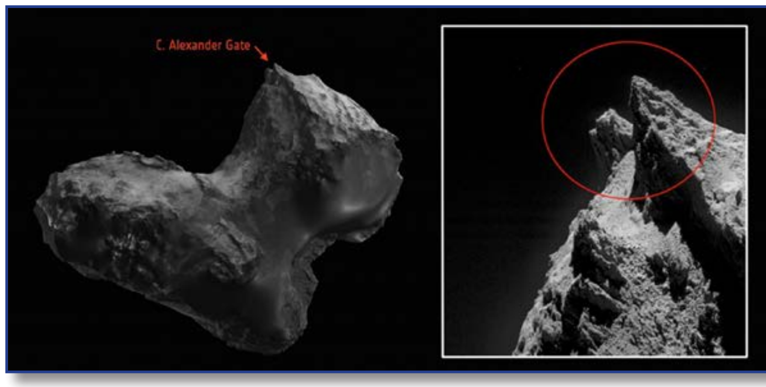
The award recognizes outstanding contributions to the solution of fundamental problems of planetary geology. It is named for Grove Karl Gilbert (1843–1918), an influential American geologist who saw the importance of a planetary perspective in solving geologic problems. Gilbert was the only person twice elected president of the Geological Society of America.

"I consider this a recognition for the kind of work JPL does at the intersection of science and engineering," Golombek said. "My work on landing site selection is right at that interface, working with the engineers who design landing systems and the scientists who study the sites."

Golombek is a New Jersey native. He holds an undergraduate degree from Rutgers University, New Brunswick, New Jersey, and masters and a doctorate in geology and geophysics from the University of Massachusetts, Amherst. In addition to assessment of landing sites on Mars before and after the landings, he has studied tectonics and erosion rates on Mars as contributors to the surface morphology and geologic evolution.

Comet Feature Named After Late NASA Scientist Claudia Alexander

Scientists from the European Space Agency's Rosetta mission are honoring their deceased colleague, Claudia Alexander of NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, by naming a feature after her on the mission's target, Comet 67P/Churyumov-Gerasimenko. Alexander, who died in July 2015 at age 56, was the project scientist for the U.S. portion of the mission. Her colleagues have named a gate-like feature on the comet "C. Alexander Gate." Another deceased colleague, Angioletta Coradini, formerly of the National Astrophysics Institute of Italy, is being honored as well, with a feature on the other lobe of the comet called "A. Coradini Gate."



Scientists from the European Space Agency's Rosetta team have honored two late team members by naming comet features after them. The feature "C. Alexander Gate" is shown on the left, with a close-up image of the same feature on the right. Credit: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA.

Alexander earned a bachelor's degree in geophysics from the University of California, Berkeley, and a master's degree in geophysics and space physics from the University of California, Los Angeles, in 1985. She earned a doctorate degree in atmospheric, oceanic, and space sciences from the University of Michigan, Ann Arbor, in 1993. Alexander began working at JPL before finishing her doctorate, nearly three decades ago, later becoming the project manager for NASA's Galileo mission in 2000 at the relatively young age of 40.

One of Alexander's passions was inspiring young people. In her spare time, she wrote two children's books on science and mentored young African-American girls. She also wrote "steampunk" science fiction short stories.

Announcing New Planetary Science Nuggets Website

A new website has been created that contains the collection of NASA Science Mission Directorate (SMD) Planetary Science Nuggets for 2015 and 2014, *http://www.lpi.usra.edu/nuggets*.

Planetary Science Nuggets are PowerPoint slides that have been provided to NASA's SMD Planetary Science Division by members of the scientific community to highlight important science results or mission activities. A subset of these submissions are selected by the Planetary Science Division to be presented to SMD leadership and potentially NASA leadership, the Office of Science and Technology Policy (OSTP), and the White House. The collection on the website represents those selected nuggets and will be updated as new nuggets are accepted. The website also includes a Powerpoint Presentation by Jim Green on how to prepare nuggets (*http://www.lpi.usra.edu/opag/meetings/aug2015/presentations/day-1/2_green.pdf*).

Anyone in the planetary science community is encouraged to submit nuggets. The nugget coordinator at JPL is Lindsay Hays (*Lindsay.E.Hays@jpl.nasa.gov*); mission nuggets should be communicated through the mission program scientist; and R&A science nuggets should be communicated through the Headquarters program scientist who funded the work.

Lunar and Planetary Institute Captivates Stargazers During White House Astronomy Night

Staff from the Lunar and Planetary Institute stand in front of the portable planetarium on the South Lawn of the White House just before events began during the White House Astronomy Night on October 19, 2015. Pictured left to right: Amanda Smith Hackler, Education and Public Engagement Manager; Andrew Shaner, Education Specialist; and Christine Shupla, Formal Education Lead Specialist.

The Lunar and Planetary Institute (LPI), a research institute managed by the Universities Space Research Association for NASA, provided a series of engaging and innovative experiences for the White House Astronomy Night on October 19, 2015. The event began in 2009, following President Barack Obama's call to action to expand access and opportunities in science, technology, engineering, and mathematics (STEM) education. Scientists, engineers, amateur astronomers, students, and teachers from across the country gathered on the South Lawn for an evening of stargazing and learning.

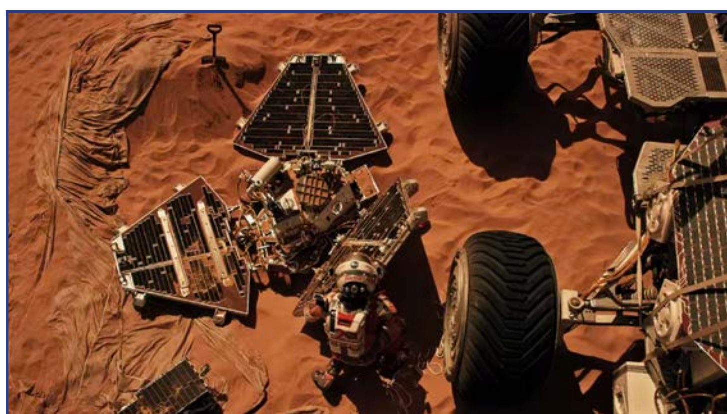
The Lunar and Planetary Institute offered participants the opportunity to immerse in a series of presentations that explore the vastness of our incredible solar system. A portable planetarium, on loan from the Houston Museum of Natural Science, presented exciting three-dimensional visualizations of space and the solar system. In a speech introducing the activities for White House Astronomy Night, LPI's planetarium exhibit was mentioned when President Obama said, "We have some incredible exhibits . . . we've got a mini planetarium." The event was broadcast live on White House LIVE, NASA TV, and other outlets.

The experience offered by LPI also included an interactive discussion of the sky and an exploration of the planets highlighting NASA's recent discoveries —particularly Mars and Pluto. Participants also listened to captivating stories, as told by Native American Master Storytellers, that examine the mysteries of our universe.

"The White House Astronomy Night provides an exceptional opportunity for students to engage in immersive STEM learning activities in a very positive environment," said Amanda Smith Hackler, USRA-LPI Education and Public Engagement Manager. "These outreach efforts are essential to stimulating interest among a new generation in STEM, and to strengthening the workforce pipeline of the future. The Lunar and Planetary Institute is pleased to support this unique effort, and offer students the opportunity to learn more about the excitement of astronomy."

JPL's Role in Making "The Martian" a Reality

When fictional astronaut Mark Watney becomes stranded alone on the Red Planet in the novel and film "The Martian," people and technology from NASA's Jet Propulsion Laboratory in Pasadena, California, played important roles in his castaway adventure. Acclaimed for its attention to scientific and technical detail, "The Martian" is steeped in decades of real-life Mars exploration that JPL has led for NASA.



People and technology from NASA's Jet Propulsion Laboratory aid fictional astronaut Mark Watney during his epic survival story in "The Martian." Credit: 20th Century Fox.

(Note: There are mild spoilers in the next section; if you haven't read or seen "The Martian," you might want to skip the rest of this article.)

Perhaps most crucial to the story of "The Martian," JPL designed, built and operated the Mars Pathfinder lander and its Sojourner rover, which landed on Mars in 1997 and operated for about three months. The hardy Pathfinder probe figures prominently into Watney's ability to communicate with Earth and survive his long ordeal. One of the technical details "The Martian" gets right is that, just as in the story, the real Pathfinder had a reprogrammable computer that an astronaut could, in principle, plug into and control.

The story also captures the famous can-do attitude of JPL engineers, who dive headlong into the challenge of helping communicate with the stranded astronaut and later, launching supplies to help keep him alive. And JPL's celebrated ingenuity is on display in the navigator who comes up with the solution for how to bring the entire Ares crew home.

Fictional JPL director Bruce Ng is a major supporting character in the story, and like the real JPL directors past and present, comes from a technical background. (The current real-life JPL director tends to dress a bit more formally, but has been known to sport a Hawaiian shirt from time to time.) However, while the heads of NASA, JPL, and the agency's Mars program are portrayed in the story as working through tough challenges on their own, their real-life counterparts rely on teams of scientists and engineers to help provide innovative solutions.

Watney finds a creative solution to stay warm on frigid Mars using a power system called a radioisotope thermoelectric generator (RTG), a "space battery" that converts heat from the natural radioactive decay of plutonium-238 into reliable electrical power. NASA's Curiosity Mars rover uses just such a power system on Mars today. JPL has for decades led the advancement of materials used to make thermocouples — the essential components of an RTG that convert heat into electricity. And JPL is currently working in partnership with the U.S. Department of Energy to develop new materials that could make the next generation of RTGs 25 percent more efficient than the generator currently being used by the Curiosity.

In creating the film version of "The Martian," producers turned to JPL for technical drawings and photos of Pathfinder, in order to accurately portray the historic spacecraft in the movie. The production team also visited JPL for research that would help them create a future version of the laboratory on film, down to the well-known informality of its culture. And cast member Jessica Chastain, who played Mars mission commander Melissa Lewis, visited JPL as part of preparation for her role.

JPL is NASA's leading center for robotic exploration of the solar system, and has provided a variety of orbiters, landers and rovers to help reveal the true nature of Mars. Similar to its efforts prior to the Apollo landings on the Moon, NASA has been sending robotic spacecraft to Mars, in part, to better characterize the environment human astronauts might face when visiting the Red Planet. Thus, as NASA studies Mars to understand its potential habitability for simple forms of life — now and in the ancient past — its fleet of Mars missions is also paving the way for human journeys.

Some of these robotic missions have found signs of water in the martian subsurface that potentially could be exploited by astronauts for life support and growing plants for food, as well as making rocket fuel. NASA's Curiosity rover has a detector, called RAD, which was designed to observe the radiation environment on the cruise to Mars and after the rover landed. These data are vital to understanding how astronauts need to be protected when they make the journey to Mars. And NASA's Mars Reconnaissance Orbiter, with its powerful imaging camera, has mapped the planet at high resolution, allowing us to see Mars on a human scale as we plan for trips by astronauts.

Looking forward, JPL is developing the technological capabilities to land payloads on the martian surface larger than the one-ton Curiosity rover. These technologies include the Low-Density Supersonic

Decelerator (LDSD) project, which is testing a mammoth parachute and a giant inflatable decelerator. LDSD is an important step toward landing payloads to support human missions, which will need a variety of massive provisions, including habitats packed with food and water, pressurized rovers, and rockets for returning to orbit from the martian surface. JPL is also advancing precision landing technologies needed to place an autonomous Mars Ascent Vehicle, as featured in "The Martian," in a desired location, years before the arrival of a human crew. The self-controlled landing of the Curiosity rover in 2012 was a major milestone on the path to this capability.

And in addition to spacecraft missions to Mars, JPL manages NASA's Deep Space Network — the vital communications link with spacecraft across the solar system, including those on Mars. The Network would also be used to keep in touch with future astronauts on deep-space voyages between Earth and Mars.

Early in the film version of "The Martian," as Watney works out how to survive on Mars, he mentions the founders of JPL, noting that they were daring students from the California Institute of Technology in Pasadena. Caltech still staffs and manages JPL for NASA. In recent years, the laboratory has adopted a quote from President Teddy Roosevelt — "Dare Mighty Things" — as its unofficial motto. That boldness lives on as JPL helps support NASA's real-life journey to Mars.

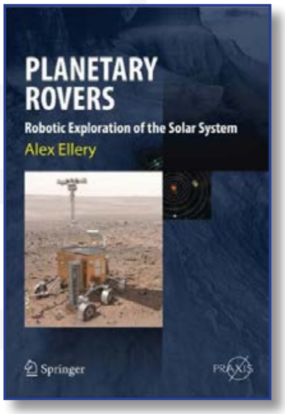
For more details about NASA's plan outlining the next steps in the journey to Mars, visit *http://go.nasa.gov/1VHDXxg*.

Note: Product descriptions are taken from the publisher's website. LPI is not responsible for factual content.

BOOKS

Planetary Rovers: Robotic Exploration of the Solar System.

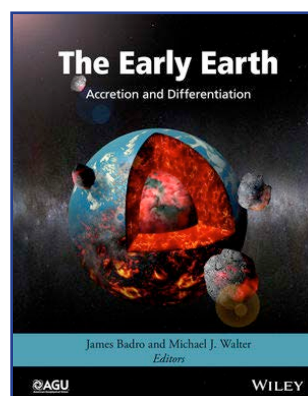
By Alex Ellery. Springer. 2015, 700 pp., Hardcover. $159.00. *www.springer.com*



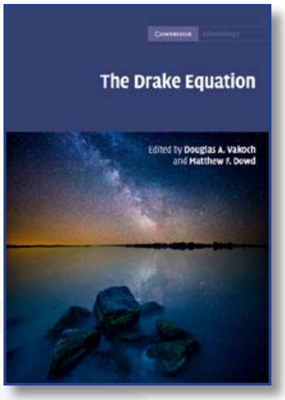
With the recent declarations of intent by spacefaring nations to return to the Moon and to send sample return missions to Mars, this self-contained and comprehensive book is timely. To the author's knowledge, this unique book is the only one that covers the space, automotive, and robotics technologies specifically geared to the development and design of planetary rovers and the associated problems of locomotion and navigation. The book opens with an introduction to the use of robotic rovers for planetary exploration and their relationship to other terrestrial applications, including oceanography. In a planetary environment, the terrain in particular is a major design driver for the planetary rover, and a review of each planet and small bodies of the solar system and their impact on rover design is provided. Planetary missions are designed with a different engineering philosophy than Earth-orbiting missions. There are great uncertainties about the operational environment, new scientific instruments, and the requirement for new spacecraft and robotic technologies to make them economically feasible. These include rover design, locomotion, autonomous navigation, rover avionics, mission communications' architecture, and power generation and thermal control. The author concludes by speculating on the need for the manned astrobiological investigation of Mars in terms of near-term evolution of robotic terminology and how robotic rovers can support manned missions by relieving the astronaut/cosmonaut workload. The future of robotic astrobiology missions will be explored with the implementation of biomimetic robots that attempt to utilize biological solutions to engineering problems. Nanotechnology and its limitations in the miniaturization of actuation systems will be covered.

The Early Earth: Accretion and Differentiation (AGU Geophysical Monograph Series Volume 212).

Edited by James Badro and Michael J. Walter. Wiley. 2015, 198 pp., Hardcover, $149.95. *www.wiley.com*



The Early Earth: Accretion and Differentiation provides a multidisciplinary overview of the state of the art in understanding the formation and primordial evolution of the Earth. The fundamental structure of Earth as we know it today was inherited from the initial conditions 4.56 billion years ago as a consequence of planetesimal accretion, large impacts among planetary objects, and planetary-scale differentiation. The evolution of Earth from a molten ball of metal and magma to the tectonically active, dynamic, habitable planet that we know today is unique among the terrestrial planets, and understanding the earliest processes that led to Earth's current state is the essence of this volume. Important results have emerged from a wide range of disciplines, including cosmochemistry, geochemistry, experimental petrology, experimental and theoretical mineral physics, and geodynamics.



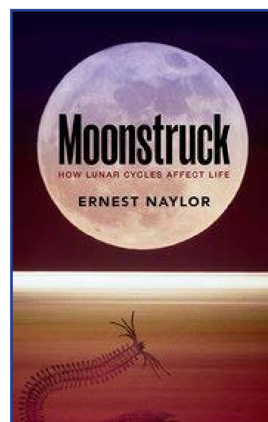
The Drake Equation.

Edited by Douglas A. Vakoch and Matthew F. Dowd. Cambridge University Press, 2015, 340 pp., Hardcover, $155.00. *www.cambridge.org*

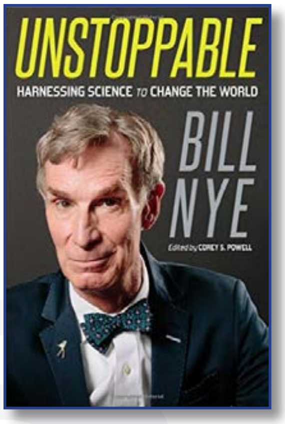
In this compelling book, leading scientists and historians explore the Drake Equation, which guides modern astrobiology's search for life beyond Earth. First used in 1961 as the organizing framework for a conference in Green Bank, West Virginia, it uses seven factors to estimate the number of extraterrestrial civilizations in our galaxy. Using the equation primarily as a heuristic device, this engaging text examines the astronomical, biological, and cultural factors that determine the abundance or rarity of life beyond Earth and provides a thematic history of the search for extraterrestrial life. Logically structured to analyze each of the factors in turn, and offering commentary and critique of the equation as a whole, contemporary astrobiological research is placed in a historical context. Each factor is explored over two chapters, discussing the preconference thinking and a modern analysis, to enable postgraduates and researchers to better assess the assumptions that guide their research.

Moonstruck: How Lunar Cycles Affect Life.

By Ernest Naylor. Oxford University Press, 2015, 256 pp., Hardcover, $29.95. *global.oup.com*



Throughout history, the influence of the full Moon on humans and animals has been featured in folklore and myths. Yet it has become increasingly apparent that many organisms really are influenced indirectly, and in some cases directly, by the lunar cycle. Breeding behavior among some marine animals has been demonstrated to be controlled by internal circalunar biological clocks, to the point where lunar-daily and lunar-monthly patterns of Moon-generated tides are embedded in their genes. Yet, intriguingly, Moon-related behaviors are also found in dry land and fresh water species living far beyond the influence of any tides. In *Moonstruck*, the author dismisses the myths concerning the influence of the Moon, but shows through a range of fascinating examples the remarkable real effects that we are now finding through science. He suggests that since the advent of evolution on Earth, which occurred shortly after the formation of the Moon, animals evolved adaptations to the lunar cycle, and considers whether, if Moon-clock genes occur in other animals, might they also exist in us?



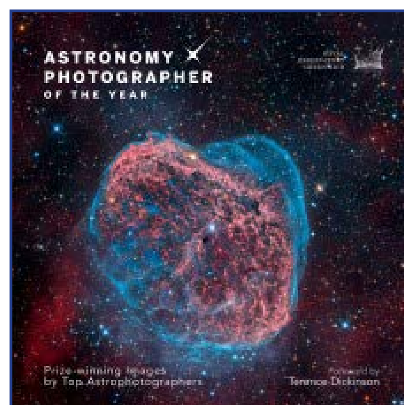
Unstoppable: Harnessing Science to Change the World.

By Bill Nye and Corey S. Powell. St. Martin's Press, 2015, 352 pp., Hardcover, $26.99. *us.macmillan.com*

Just as World War II called an earlier generation to greatness, so the climate crisis is calling today's rising youth to action: to create a better future. In *Unstoppable*, Nye crystallizes and expands the message for which he is best known and beloved. That message is that with a combination of optimism and scientific curiosity, all obstacles become opportunities, and the possibilities of our world become limitless. With a scientist's thirst for knowledge and an engineer's vision of what can be, Nye sees today's environmental issues not as insurmountable, depressing problems but rather as chances for our society to rise to the challenge and create a cleaner, healthier, smarter world. We need not accept that transportation consumes half our energy, and that two-thirds of the energy we put into our cars is immediately thrown away out of the tailpipe. We need not accept that dangerous emissions are the price we must pay for a vibrant economy and a comfortable life. Above all, we need not accept that we will leave our children a planet that is dirty, overheated, and depleted of resources. As Nye shares his vision, he debunks some of the most persistent myths and misunderstandings about global warming. When you are done reading, you'll be enlightened and empowered. Chances are, you'll be smiling too, ready to join Nye and change the world.

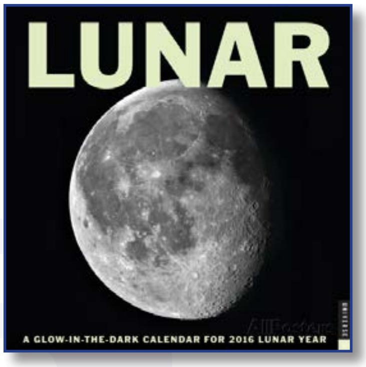
Astronomy Photographer of the Year: Prize-Winning Images by Top Astrophotographers.

By The Royal Observatory, Greenwich UK. Firefly Books, 2015, 288 pp., Hardcover, $39.95. *www.fireflybooks.com*



This stunning collection of images from the Astronomy Photographer of the Year competition assembles the very best astrophotography from around the world. Organized by the Royal Observatory, the photographs capture an astounding range of astronomical phenomena both within our solar system and far into deep space. The book features four sections: Earth and Space, Our Solar System, Deep Space, and Overall Winners. The images are from the first six years of the competition (2009–2014), and include all the winners from each year along with a carefully curated selection from the short lists. They are accompanied by notes from the judges and photographer, with background information and camera specifications. From giant storm systems in Jupiter's atmosphere to the colorful, wispy remnants of a supernova explosion and the dazzling green curtain of the Northern Lights, *Astronomy Photographer of the Year* will appeal to both astrophotographers and beginners who simply enjoy gazing at the night sky.

CALENDAR



Lunar 2016 Wall Calendar.

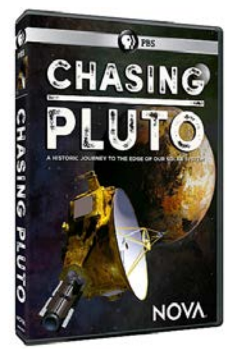
Produced by Universe Publishing. 2016, $14.99. *www.rizzoliusa.com/calendars*

A perfect gift for Moon-watchers, stargazers, and weekend astronomers of all ages, this stunning lunar glow-in-the-dark wall calendar brings the wonder of the night sky indoors. Each page of this calendar illuminates the nightly phases of the Moon and showcases extraordinary photographs of the lunar surface, lunar phenomena, and the Moon against spectacular Earthly landscapes.

DVD

Chasing Pluto: A Historic Journey to the Edge of Our Solar System.

Produced by NOVA/PBS, 2015, one disk. $24.99. *www.shoppbs.org*



NOVA captures New Horizons' historic flyby of Pluto, the culmination of the spacecraft's nine-year, three-billion-mile journey, to reveal the first ever detailed images of this strange, icy world at the very edge of our solar system.

FOR KIDS!!!

The Astronaut Instruction Manual: Practical Skills for Future Space Explorers.

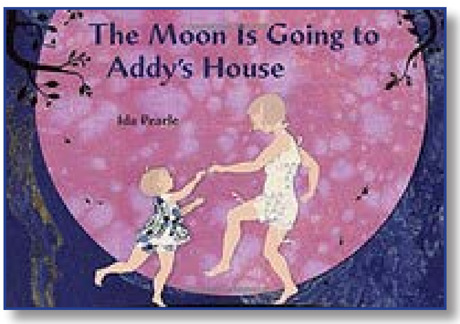
By Mike Mongo. Inkshares, Inc., 2015, 98 pp., Paperback. $12.99. *www.inkshares.com*

This book is a functioning, first-step instruction manual for future astronauts designed to inspire today's students to prepare for their own careers in space. With excitement and honesty, the author encourages his readers to articulate and personalize their own vision of next-generation space travel. For ages 9 to 12.

Dig Your Own Meteorites.

Produced by Gem Center USA. $29.95. *www.gemcenterusa.com*

The best way to collect meteorites is to dig them up yourself. Most people don't know how to determine if they have found a genuine meteorite. This geology kit will guide you in the right direction to learn how to identify real meteorites. It includes three naturally occurring meteorites, three tektites, and two pseudo-meteorites (lookalikes) that are buried inside an easy to dig 13 × 18-centimeter (5 × 7-inch) plaster block. The kit also includes a digging tool, magnifying glass, and small brush. The guide explains how meteorites fall to Earth's surface, how tektites are formed, and how to test pseudo-meteorites to see whether they really are space rocks or not. Get ready to embark on an ancient treasure adventure! For ages 8 and up.



The Moon is Going to Addy's House.

By Ida Pearle. Dial Books, 2015, 32 pp., Hardcover, $17.99. *www.penguin.com*

After a play date in the city, Addy heads home to the country with her family. And throughout the long drive, the Moon seems to be following them closely — Addy's faithful guardian and friend. The comforting sense that the Moon is your own personal companion is universal to childhood, and Pearle has depicted it beautifully through her lyrical text and soft, sleepy cut-paper collage illustrations. This is a book that children will ask to hear every night at bedtime. For ages 3 to 5.

Planets.

By Thomas K. Adamson, Kassandra Radomski,and Emma Carlson Berne. Capstone Press, 2016, set of eight books, 32 pp. each, Hardcover, $250.56. *www.capstonepub.com*

This series of eight books introduces young readers to the planets in our solar system. From early human observations of lights in the sky, to past and future research missions, they'll uncover many secrets about our celestial neighborhood. Comparisons to Earth, fact boxes, maps, and captions all combine to aid understanding. These books support Next Generation science standards, and the Smithsonian's seal of approval guarantees the excellence of this nonfiction set. The books are also sold separately. For grades 2 to 4.

Calendar 2016

For the latest version of the meeting calendar, visit http://www.hou.usra.edu/meetings/calendar.

January

4–8 **American Astronomical Society 227th Meeting,** Kissimmee, Florida. *http://aas.org/meetings/aas227*

12–15 **4th ELSI Symposium: Three Experiments in Biological Origins,** Tokyo, Japan. *http://www.elsi.jp/en/research/activities/symposium/2016/01/sympo-04.html*

17–22 **Bridging Disciplinary Perspectives to See Further Into Life's Origins,** Galveston, Texas. *http://www.grc.org/programs.aspx?id=14007*

27–29 **14th Meeting of the NASA Small Bodies Assessment Group (SBAG),** Pasadena, California. *http://www.lpi.usra.edu/sbag/*

February

8–12 **The Astrophysics of Planetary Habitability,** Vienna, Austria. *http://habitability.univie.ac.at*

17–19 **Solar-System Symposium in Sapporo 2016,** Hokkaido, Japan. *http://ws2016.webnode.jp/*

22–25 **Nuclear and Emerging Technologies for Space (NETS) 2016,** Huntsville, Alabama. *http://anstd.ans.org/nets-2016/*

28–Mar 1 **The 2nd Conference on Astrophysics and Space Science (APSS 2016),** Beijing, China. *http://www.engii.org/ws2016/Home.aspx?id=686*

March

7–11 **Protoplanetary Discussions,** Edinburgh, United Kingdom. *http://www-star.st-and.ac.uk/ppdiscs/index.html*

19–20 **Microsymposium 57 — Polar Volatiles on the Moon and Mercury: Nature, Evolution, and Future Exploration,** The Woodlands, Texas. *http://www.planetary.brown.edu/html_pages/micro57.htm*

21–25 **47th Lunar and Planetary Science Conference,** The Woodlands, Texas. *http://www.hou.usra.edu/meetings/lpsc2016/*

31–Apr 1 **The Asteroid-Meteorite Connection,** Los Angeles, California. *http://planets.ucla.edu/meetings/upcoming-meetings/amcw2016/*

April

4–8 **International Venus Conference 2016,** Oxford, United Kingdom. *http://venus2016.uk/*

8 **Royal Astronomical Society Meeting on Space Resources,** Burlington House, Piccadilly, London. *https://www.ras.org.uk/component/gem/?id=375*

11–15 **15th Biennial ASCE International Conference in Engineering, Science, Construction and Operations in Challenging Environments,** Orlando, Florida. *http://earthspaceconf.mst.edu/*

May

18–19 **4th European Lunar Symposium, Trippenhuis (Dutch Royal Academy of Arts and Sciences),** Amsterdam, The Netherlands. *http://sservi.nasa.gov/els2016/*

24–25 **5th Interplanetary CubeSat Workshop,** Oxford, United Kingdom. *http://icubesat.org/*

27–30 **Fourth Beijing Earth and Planetary Interior Symposium,** Beijing, China. *http://bepis2016.csp.escience.cn*

29–Jun 24 **Water in the Solar System and Beyond,** Rome, Italy. *http://www.vaticanobservatory.va/content/specolavaticana/en/summer-schools--voss-/voss2016.html*

June

1–3 **2nd Asteroid Impact Deflection Assessment (AIDA) International Workshop 2016,** Nice, France. *https://www-n.oca.eu/michel/AIDAWorkshop2016/*

2–4 **Next-Generation Suborbital Researchers Conference,** Broomfield, Colorado. *http://nsrc.swri.org*

11–12 **International Planetary Probe Short Course,** Laurel, Maryland. *http://ippw2016.jhuapl.edu/*

13–17 **International Planetary Probe Workshop (IPPW-13),** Laurel, Maryland. *http://ippw2016.jhuapl.edu/*

20–21 **Martian Gullies and Their Earth Analogues,** London, England. *http://www.geolsoc.org.uk/martiangullies*

21–23 **Binaries in the Solar System IV,** Prague, Czech Republic. *http://www.boulder.swri.edu/binaries4-mtg/*

28–30 **15th Meeting of the NASA Small Bodies Assessment Group (SBAG),** Washington, DC. *http://www.lpi.usra.edu/sbag/*

July

3–8 **Exoplanets Conference,** Davos, Switzerland. *http://www.exoplanetscience.org/*

3–8 **International Symposium and Workshop on Astrochemistry,** Campinas, Brazil. *http://www1.univap.br/gaa/iswa/*

10–12 **Astrobiology Australasia Meeting 2016,** Perth, Australia. *http://www.aa-meeting2016.com*

11–15 **4th International HSE Geochemistry Workshop,** Durham, United Kingdom. *http://www.hseworkshop.co.uk/*

25–29 **2016 Sagan Exoplanet Summer Workshop,** Pasadena, California. *http://nexsci.caltech.edu/workshop/index.shtml*

26–29 **Enceladus and the Icy Moons of Saturn,** Boulder, Colorado. *http://www.hou.usra.edu/meetings/enceladus2016/*

30–Aug 7 **41st Scientific Assembly of the Committee on Space Research (COSPAR 2016),** Istanbul, Turkey. *http://www.cospar-assembly.org*

August

1–4 **The Diversity of Planetary Atmospheres (IV),** Squamish, Canada. *http://www.exoclimes.org*

7–12 **79th Meeting of the Meteoritical Society,** Berlin, Germany. *http://www.metsoc-berlin.de/*

15–19 **The 9th Meeting on Cosmic Dust,** Sendai, Japan. *http://www.cps-jp.org/~dust/Welcome.html*

23–Sep 11 **Summer School "Volcanism, Plate Tectonics, Hydrothermal Vents and Life," Angra Do Heroísmo,** Azores, Portugal. *http://www.nordicastrobiology.net/Azores2016*

27–Sep 4 **35th International Geological Congress,** Cape Town, South Africa. *http://www.35igc.org/*

September

5–9 **6th International Conference on Mars Polar Science and Exploration,** Reykjavik, Iceland. *http://www.hou.usra.edu/meetings/marspolar2016/*

October

24–26 **Global Congress and Expo on Materials Science and Nanoscience,** Dubai, UAE. *http://scientificfederation.com/materialsscience-congress/*

24–27 **3rd International Workshop on Instrumentation for Planetary Missions,** Pasadena, California. *http://www.hou.usra.edu/meetings/ipm2016/*

November

15–17 **14th Meeting of the Venus Exploration Analysis Group (VEXAG),** Location to be announced. *http://www.lpi.usra.edu/vexag/*

December

12–16 **2016 AGU Fall Meeting,** San Francisco, California. *http://agu.org*