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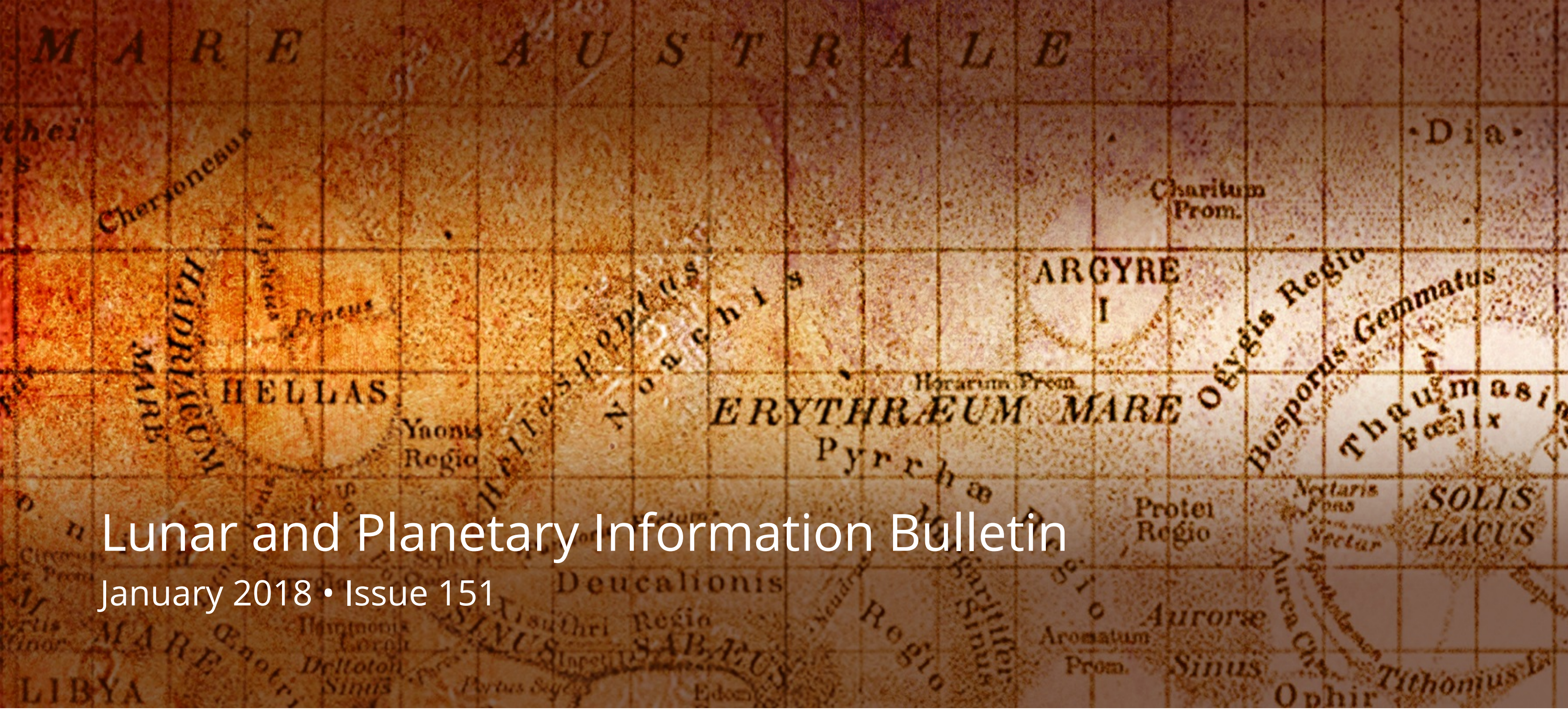

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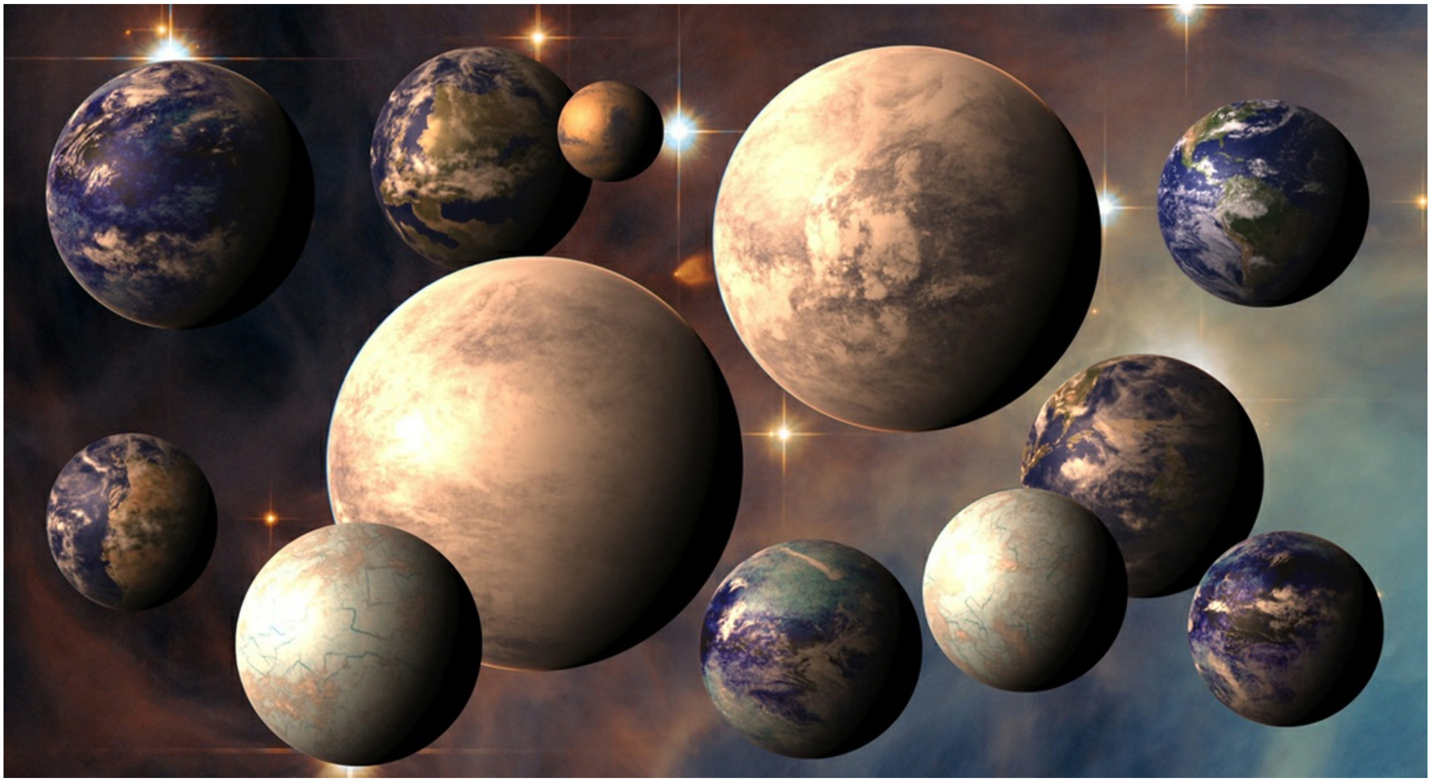


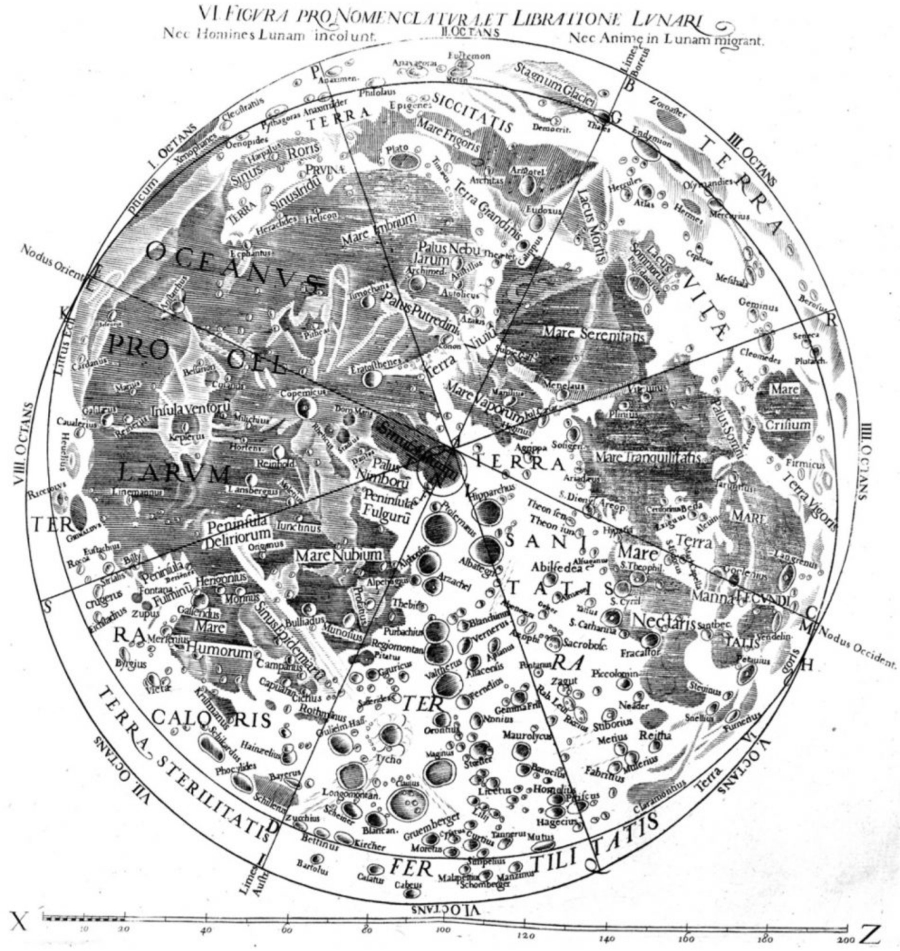
Planetary Nomenclature: A Brief History and Overview

Note from the Editors: This issue's lead article is the ninth in a series of reports describing the history and current activities of the planetary research facilities partially funded by NASA and located nationwide. This issue provides a brief history and overview of planetary nomenclature, an important activity that provides structure and coordination to NASA's planetary exploration program and the scientific analysis of planetary data. — Paul Schenk and Renée Dotson

Humans have been naming the stars and planets for thousands of years, and many of these ancient names are still in use. For example, the Romans named the planet Mars for their god of war, and the satellites Phobos and Deimos, discovered in 1877, were named for the twin sons of Ares, the Greek god of war. In this age of orbiters, rovers, and high-resolution imagery, modern planetary nomenclature is used to uniquely identify a topographical, morphological, or albedo feature on the surface of a planet or satellite so that the feature can be easily located, described, and discussed by scientists and laypeople alike.

History of Planetary Nomenclature

With the invention of the telescope in 1608, astronomers from many countries began studying the Moon and other planetary bodies. Some of these astronomers began to apply names to the features they observed, creating several different systems of nomenclature. Most of these naming systems were applied to the Moon because it was close enough for its surface features to be seen clearly. In particular, Giovanni Riccioli (Italian astronomer, 1598–1671), Johann Schröter (German astronomer, 1745–1816), and Johann Mädler (German astronomer, 1794–1874) created and distributed lunar maps showing three different sets of nomenclature. By the early 1900s, many of the prominent features on the Moon's nearside were known by at least three different names, leading to the need for a single system of lunar nomenclature.



Map of the Moon from G. B. Riccioli's 1651 Almagestum Novum, showing some of the first lunar nomenclature. Some of these names, such as Mare Frigoris, Mare Serenitatis, and Mare Tranquilitatis, are still in use today.

In 1905, British astronomer Samuel Arthur Saunder (1852–1912) drew the attention of the International Association of Academies to this unsatisfactory state of lunar nomenclature and set in motion the concept of international cooperation in the standardization of lunar nomenclature:

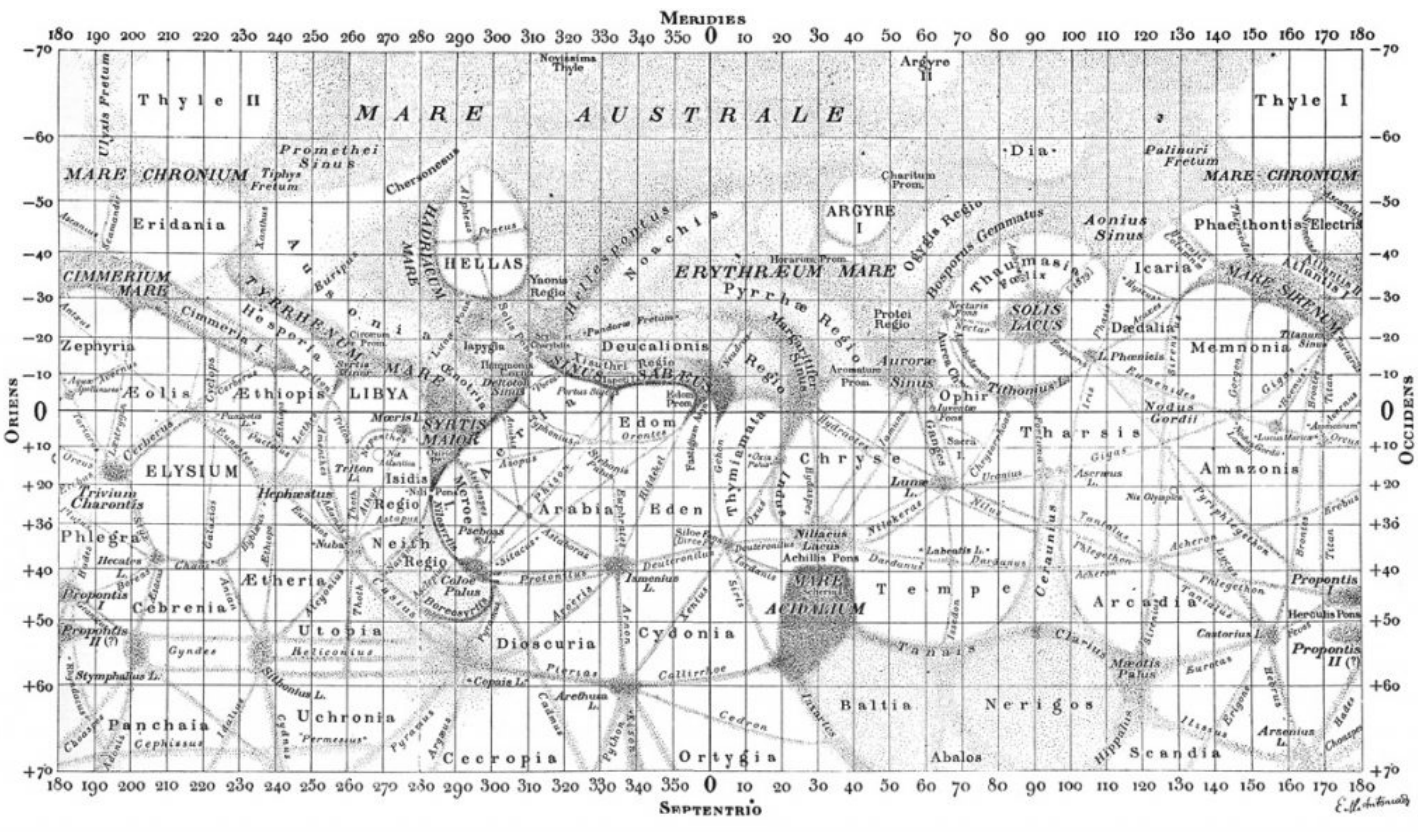
"If a remedy is to be found which will meet with universal assent — and nothing short of this would be a remedy at all — it is obvious that it must be the work of an international committee." — Monthly Notices of the Royal Astronomical Society, Vol. LXVI, No. 2

In 1907, a Committee on Lunar Nomenclature was established by the Association, and charged with the task of standardizing lunar nomenclature. Saunder enlisted the help of English astronomer Mary Blagg (1858–1944) in the task of preparing a collated list of lunar nomenclature. While a succession of deaths of committee members, including Saunder in 1912, resulted in a final Association report never being published, Blagg's collated list was published in 1913. This list included multiple discrepancies that the Association needed to resolve. When the International Astronomical Union (IAU) was founded in 1919, one of its first actions was to form a committee to regularize lunar nomenclature. The IAU appointed Blagg and several other astronomers to the newly created nomenclature committee, chaired by H. H. Turner.

The IAU nomenclature committee presented its recommendations in 1932 in the form of the classic publication *Named Lunar Formations* by Blagg and Müller (published in 1935). The IAU adopted the names included in this publication in 1935. Because this was the first systematic listing of lunar nomenclature, it set the stage for future systems that would be adopted by the IAU for names on other planets and satellites in our solar system.

Later, *The System of Lunar Craters, quadrants I, II, III, IV* was published by D. W. G. Arthur and others (1963, 1964, 1965, 1966), under the direction of Gerard P. Kuiper. These catalogues listed the names (or other designations) and coordinates of features in the current, greatly expanded lunar nomenclature; the accompanying map (also in four parts) showed their locations. These works were adopted by the IAU and became the recognized sources for lunar nomenclature.

Martian nomenclature was similarly clarified in 1958, when an ad hoc committee of the IAU chaired by Audouin Dollfus recommended for approval the names of 128 albedo features (bright, dark, or colored) observed through groundbased telescopes (IAU, 1960). These names were based on a system of nomenclature developed in the late nineteenth century by the Italian astronomer G. V. Schiaparelli (1879) and expanded in the early twentieth century by E. M. Antoniadi (1929), a Greek-born astronomer working at Meudon, France.



Albedo map of Mars, by Eugène Michel Antoniadi, 1900. Like Riccioli's lunar map, many of the names on this map are still in use today. Classical albedo names are now used, in conjunction with a descriptor term, to provide new names for morphological features identified by modern planetary scientists in spacecraft images. For example, the albedo name Argyre is used in the IAU-approved feature names Argyre Cavi, Argyre Mons, Argyre Planitia, and Argyre Rupes.

The requirements for extraterrestrial nomenclature were dramatically changed in 1957 when the age of space exploration was inaugurated by the successful flight of Sputnik and by America's consequent determination to land a man on the Moon in the 1960s. As detailed images became available for one newly discriminated extraterrestrial surface after another, the need to name features on these surfaces became evident. With each Soviet and American mission to the Moon, additional lunar features required names. As a result, the IAU was presented with several problems concerning contested and duplicated names. The international community recognized the need for an objective group to arbitrate and referee the naming process, and the Working Group for Lunar Nomenclature was established by the IAU in 1967 to serve this purpose.

In the mid to late 1960s, planetary scientists were turning their attention to Mars. As the Mariner spacecraft returned photographs of the heavily cratered martian surface, it became apparent that the existing nomenclature for Mars, based on albedo features, was inadequate for the individual topographic features (such as craters, mountains, and valleys) that now needed names. In addition, as was the case for the Moon, several systems of martian nomenclature were in use; the two systems most widely known were developed independently by Schiaparelli and Antoniadi. The IAU was asked to approve one nomenclature system for Mars. In response to this request, a Working Group for Martian Nomenclature was established in 1970, chaired by Gerard de Vaucouleurs. The group was also asked to designate names for the topographic features shown in the new spacecraft images (de Vaucouleurs and others, 1975). At about the same time, Donald H. Menzel chaired an ad hoc lunar committee that suggested names for features discriminated by the Soviet Zond and American Lunar Orbiter and Apollo cameras (IAU, 1971).

The Working Group for Martian Nomenclature presented its recommendations to the IAU at its 1973 meeting in Sydney, Australia, thus setting the stage for a single recognized system of names for Mars. At this same IAU meeting, participants recognized that the nomenclature systems for planets other than the Moon and Mars would benefit from oversight to prevent inconsistencies, contradictions, and application of inappropriate and contentious names. As a result, a new set of nomenclature committees was established to address these solar-system-wide needs. Task Groups comprising an international mix of members were created for the Moon, Venus, Mercury, Mars, and the outer solar system. A Small Bodies Task Group was formed in 1984 to name surface features on small primitive bodies (asteroids and comets).

The Task Groups were formed to conduct the preliminary work of choosing themes and proposing names for features on each newly discriminated planet and satellite. The Working Group for Planetary System Nomenclature (WGPSN), composed mainly of the chairs of the Task Groups, was also formalized at this 1973 meeting. The main functions of the WGPSN were determined to be the oversight and confirmation of the work of the Task Groups, and to set policy. The necessary governing committees were now in place. (See http://planetarynames.wr.usgs.gov/append2.html for a list of the current members of the Task Groups and the WGPSN.)

An approval process for naming features was also formalized at the 1973 meeting. New name proposals were first reviewed by the relevant Task Group, and then by the WGPSN. After the WGPSN approved the proposals, names were considered provisionally approved and could be used in publications. Names were fully approved by the IAU at their triennial General Assembly. This approval process is still in use today, except that it has been streamlined. Provisional nomenclature was abolished in 2007, and names are now considered fully approved immediately after WGPSN approval.

In 1982 at Patras, Greece, Harold Masursky of the United States became president of the WGPSN; he was succeeded in 1991 by Kaare Aksnes of Norway, and Kaare was succeeded in 2006 by Rita Schulz of Germany.

As space exploration expanded, so did the database of planetary names. It became apparent that the database needed to reside and be maintained at one location to ensure its accuracy. For many years, Masursky, president of the WGPSN and branch chief for the United States Geological Survey (USGS) Astrogeology Team (now the Astrogeology Science Center), along with his assistant, Mimi Strobell, oversaw the development of the nomenclature database and ensured the correct use of names on maps and in publications. In 1990, after Masursky became ill and could no longer attend to these duties, a meeting was held in Flagstaff during which the new president of the IAU WGPSN and Flagstaff Astrogeology representatives agreed that the maintenance of the nomenclature database should continue in Flagstaff. This decision fosters continuity and accuracy, timely responsiveness to the NASA-funded planetary science community, and the systematic advancement of planetary nomenclature with international cooperation. The IAU agreed to provide approval of names in a timeframe that meets the publication schedules of NASA-funded scientists, while the USGS agreed to adhere to IAU conventions and rules, ensuring that new names will continue to be fair and objective.

Planetary Nomenclature Today

Today, the six Task Groups and the WGPSN are composed of 38 volunteer members, representing 14countries: China, Finland, France, Germany, Japan, New Zealand, Norway, Russia, Spain, Switzerland, Vatican City State, Ukraine, the United Kingdom, and the United States. This international composition supports the equitable distribution of names from different ethnic groups, countries, and gender on each planetary body.

Ewen A. Whitaker, left with Gerard P. Kuiper and Raymond Heacock at the University of Arizona's Lunar and Planetary Laboratory. Whitaker was a British-born astronomer who made enormous contributions to lunar nomenclature and mapping in the Apollo era.

There are currently 15,433 IAU-approved surface feature names on 42 planetary bodies, including moons and asteroids. The Gazetteer of Planetary Nomenclature (https://planetarynames.wr.usgs.gov/) contains the database of all names of topographic and albedo features on planets and satellites (and some planetary ring and ring-gap systems) that the IAU has named and approved from its founding in 1919 through the present time.

The Gazetteer of Planetary Nomenclature database and website are maintained by the database manager at the USGS Astrogeology Science Center in Flagstaff. The database manager responds to requests from researchers for new names through the Gazetteer website, and works with researchers to refine and create their name proposals, including images and database information. The database manager tracks proposals through the IAU approval system, working with Task Group chairs and the WGPSN chair to move proposals through the system in a timely manner.

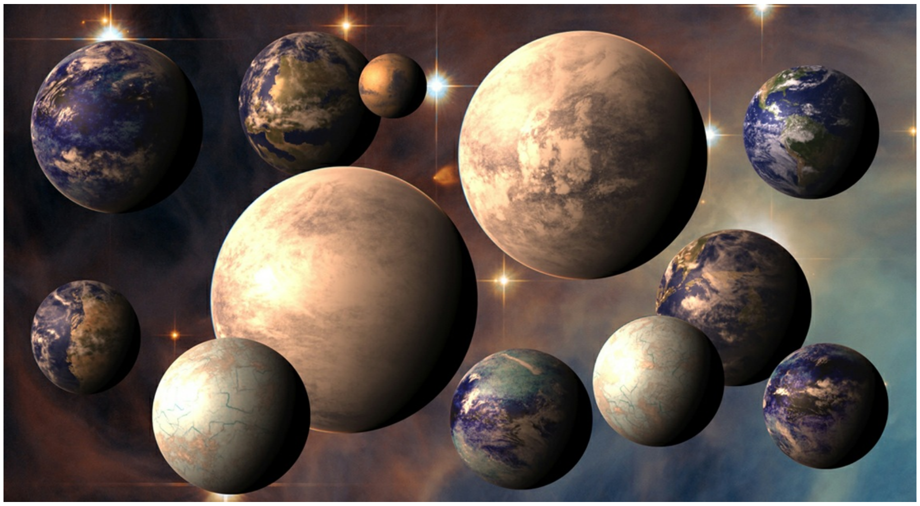
How Names Are Approved

Planetary nomenclature, like terrestrial nomenclature, is used to uniquely identify a topographical, morphological, or albedo feature — not geological features or units — on the surface of a planet or satellite, so that the feature can be easily located, described, and discussed. A distinction is made between topographical, morphological, or albedo features and geological features to avoid assigning names based on scientific interpretations, which may change over time.

When the first images of the surface of a planet or satellite are obtained, themes for naming features are chosen and names of a few important features are proposed, usually by the appropriate IAU Task Group. Recent NASA mission teams have worked with the appropriate Task Group to establish themes and compile name banks. Later, as higher-resolution images and maps become available, names for additional features may be requested by investigators mapping or describing specific surfaces or topographic formations.

Planetary scientists preparing manuscripts for peer-reviewed journal articles or maps (or students, with a letter of support from the advisor) may request a planetary feature be named. *Features are named only when they have special scientific interest, and when the naming of such features is useful to the scientific and cartographic communities at large.* Requestors submit a short justification describing why the feature needs to be named, and a timeline for publication of the work in which the name will appear. Also required are images of the feature, along with basic data about the feature (location, size, etc.). Name suggestions for specific features, submitted during the proposal process, will be considered, but final selection of the names is the responsibility of the IAU.

The request is reviewed by the appropriate Task Group. Names approved by a Task Group are then submitted by the Task Group chair to the WGPSN. Upon successful review by vote of the members of the WGPSN, names are considered approved as official IAU nomenclature, and can be used on maps and in publications. Approved names are immediately entered into the Gazetteer of Planetary Nomenclature, and posted on its website.



The Gazetteer of Planetary Nomenclature can help identify a feature on the surface of a planet or satellite so that the feature can be easily located, described, and discussed. The Gazetteer contains detailed information about all names of topographic and albedo features on planets and satellites (and some planetary ring and ring-gap systems) that the IAU has named and approved from its founding in 1919 through the present time.

The WGPSN and Task Groups follow certain established rules and conventions when approving names:

- Nomenclature is a tool and the first consideration should be to make it simple, clear, and unambiguous.
- Where appropriate, the WGPSN strongly supports an equitable selection of names from ethnic groups, countries, and gender on each map; however, a higher percentage of names from the country planning a landing is allowed on landing site maps.
- Duplication of the same surface feature name on two or more bodies, and of the same name for satellites and minor planets, is discouraged.
- No names having political, military, or religious significance may be used, except for names of political figures prior to the nineteenth century.
- Commemoration of persons on planetary bodies should not normally be a goal in itself, but may be employed in special circumstances and is reserved for persons of high and enduring international standing. Persons being so honored must have been deceased for at least three years.
- Names for all planetary features include a descriptor term, with a few exceptions. For craters, the descriptor term is implicit. Names and their descriptor terms are based solely on the morphology (shape) of a feature, and explicitly *do not* indicate geological origin.
- Additional rules and conventions are added as the IAU formulates an interesting and meaningful nomenclature for individual planetary bodies.

Descriptor Terms and Naming Categories (Themes)

The Gazetteer lists 56 descriptor terms, or feature types, that are used to describe named planetary features. Determining the most appropriate descriptor is one of the critical initial steps in the naming process, and is usually, but not always, straightforward. For example, the descriptors *vallis* (valley, canyon-like, often sinuous trough) and *fossa* (long, narrow depression; ditch; narrow, linear trench) may seem distinct, and most morphological features fit one description or the other very neatly, but some individual features may have characteristics of both descriptors. Nature does not always produce features that fit tidily into our little boxes!

Many feature types are common to several planetary bodies (such as*crater* or *mons*), and some are applied only on single bodies. For example, a flumen (plural flumina) is a channel on Titan that may carry liquid.

Once the feature has been assigned a descriptor, a name is chosen that fits the naming category (theme) assigned to that descriptor. Naming categories allow for a large number of potential names to be in reserve for future name requests. For example, small (60 kilometers or smaller) craters on Mars are named for small towns and villages of the world — no commemoration of specific modern towns or villages is intended; this category is simply a large source of international names. Likewise, craters on Mercury are named for deceased artists, musicians, painters, and authors who have made outstanding or fundamental contributions to their field, and have been recognized as historically significant figures for more than 50 years.

In Conclusion

The IAU’s WGPSN, and its Task Groups, has worked for almost a century to build and maintain a clear, simple, unambiguous system of nomenclature for our solar system. This nomenclature system aims to preserve many of the naming themes used by early astronomers, while adapting to the needs of modern planetary science and space missions. We look forward to upcoming missions that will provide high-resolution imagery of Jupiter's icy moons Ganymede, Callisto, and Europa (the JUICE and Europa Clipper missions, set to launch in 2022) and as-yet unexplored planetary bodies, such as the Lucy mission to explore six Jupiter Trojan asteroids (launch date in October 2021) and the metallic asteroid Psyche (launch date in October 2023).

About the Authors

Tenielle Gaither is a geologist at the USGS Astrogeology Science Center in Flagstaff, Arizona. She is the assistant database manager for the Gazetteer of Planetary Nomenclature and project chief for the Astrogeology Geologic Materials Collection. She received an M.S. in Geology in 2011 from Northern Arizona University for her research on silicic magma geochemistry. Gaither joined USGS Astrogeology in 2010, and works on a variety of projects including impact crater studies, planetary geologic mapping, and education and public outreach.

Rosalyn Hayward is a geologist at the USGS Astrogeology Science Center in Flagstaff, Arizona. She is the Project Chief for the Nomenclature project and the database manager for the Gazetteer of Planetary Nomenclature, helping researchers to navigate the IAU name-approval process. Hayward is also PI for a Mars analog project doing dune field research on the Navajo Nation, near Grand Falls, Arizona. Her research interests include planetary aeolian processes and she has been active in the series of International Planetary Dune Workshops that began in 2008.

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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From the Desk of Jim Green

To Explore and Name: The Solar System is Ours

"Names have power." – Rick Riordan, The Lightning Thief

What's in a name?

As humans, we're innately curious. We are born with a desire to explore our immediate surroundings, our home planet, and the planets and stars beyond our world. Exploration, naming, and mapmaking have been a fundamental part of our existence for thousands of years. If humans can see it — or find it first — we want to name it. Naming objects makes the unknown more familiar; it creates a feeling of ownership. You could say the naming process gives us a sense of control in a chaotic and ever-changing universe.

Humans are so passionate about putting our names on things that a formal process has developed over the years. In 1919, the International Astronomical Union (IAU) was recognized as the controlling body for planetary nomenclature. Names adopted by the IAU need to follow a series of rules and conventions that have evolved over the years, with the discoverer playing an important role.

The first recognized opportunity to lay claim to our place in the solar system came with the launches of Pioneer 10 and 11 in 1971 and 1972, respectively. Several reporters, including Eric Burgess of the *Christian Science Monitor*, recognized that Pioneer 10 would be mankind's first envoy beyond our solar system. Burgess wrote, "I visualized how Pioneer 10 escaping from the solar system would become mankind's first emissary to the stars . . . It should carry a message that would tell any finder of the spacecraft a million or even a billion years hence that planet Earth had evolved an intelligent species that could think beyond its own time and beyond its own solar system."

This provided an opportunity to tell any finder of the spacecraft — billions of years from now — that this corner of the galaxy was ours. Burgess pitched the idea to Carl Sagan at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California. He proposed we use the Pioneer 10 spacecraft as a courier of sorts, to carry a message that might one day be received by intelligent beings elsewhere in the universe. Sagan was immediately enthusiastic about the idea.

Sagan, along with his wife Linda, contacted Frank Drake, and the team designed a plaque to be affixed to the exterior of the spacecraft. The timing was perfect, as Sagan and Drake had both recently participated in a conference devoted to the challenge of communicating with potential extraterrestrial intelligent life. A completed plaque design was given to NASA, which accepted the idea. The plaque design was etched into a gold anodized aluminum plate. It was 6″ × 9″ in size (15 centimeters × 23 centimeters) depicting the spacecraft, a man, a woman, the solar system (with nine planets, I might add), and a hydrogen atom, along with Earth's location.

After its encounter with Jupiter, the Pioneer 10 spacecraft acquired enough energy to escape the gravity of the Sun, putting it on a trajectory never to return. In about 100,000 years from now, it will be at the distance of our nearest star in the direction of the constellation Taurus and will one day fly through another star's solar system. Pioneer 11 carried an identical plaque, and after its encounter with Saturn is also on an escape trajectory.

It wasn't long after the Pioneer missions that the next opportunity presented itself with Voyager 1 and 2. This time, Sagan was more than ready to up his game. He staked humanity's claim on this portion of the galaxy by creating a time capsule of images, songs, and greetings, all which in some way represented Earth. On August 20 and September 5, 1977, the two Voyager spacecraft each carried a gold-coated copper phonograph record as a time capsule to be received by any potential extraterrestrial civilizations that it might encounter.

More recently, a new concept has been implemented that allows the public the opportunity to become a part of a mission by submitting their name to be placed in a memory chip and affixed to the spacecraft. A chip carrying the names of 1.24 million people flew on the Curiosity mission in 2011 and is now on the surface of Mars. 1.38 million names were flown on the Orion mission in 2014, and 2.4 million will make the trek to Mars on the InSight mission in 2018. Greatly facilitated by social media, the number of submitted names at peak submission time for InSight was 5.6 per second or 17,281 per hour. Simply putting your name on the planet Mars was just too irresistible for many, thereby demonstrating the phenomenal continued interest by the public to put their name in a "bottle" headed into the solar system.

What will we think of next?

— James L. Green, Director, NASA's Planetary Science Division, January 2018

News from Space

Robot Spelunkers Go for a Dip

JPL engineer Andy Klesh lowers a robotic submersible into a moulin. Klesh and JPL's John Leichty used robots and probes to explore the Matanuska Glacier in Alaska this past July. Credit: NASA/JPL-Caltech.

NASA has changed the perspective of science, building satellites to study Earth's surface. Deep below that surface, where it's harder for satellites to see, is another story — but robotic technology might change that.

NASA roboticists are exploring moulins, places where water has punched through thousands of feet of ice to form a waterfall through a glacier. They hope to match these watery labyrinths to features that can be surveyed by satellite, such as openings in the glacier's surface. This past July, two researchers from NASA's Jet Propulsion Laboratory in Pasadena, California, traveled by plane to Alaska's Matanuska Glacier. There, they tested robotic mapping techniques while exploring these icy labyrinths.

Moulins are too small and dangerous for humans to enter, so the best way to explore them is with robotic submersibles. NASA has been interested in these flooded structures in the past because they serve as a glacier's "plumbing," carrying meltwater throughout the ice and controlling how fast a glacier moves.

In the distant future, understanding ice formations like moulins might help with deep space exploration. They could provide entrances into icy worlds like Jupiter's moon Europa.

“To get under the surface of Europa or [Saturn’s moon] Enceladus, we need to find the quickest way in,” said Andy Klesh of JPL, one of the researchers who ventured out to Matanuska Glacier. “Can we map and navigate these subglacial lakes with robots? Are there accessible passageways hidden just beneath the surface? This first foray to Alaska tested the technology to begin answering these questions.”

Klesh was joined by John Leichty, another JPL roboticist, and a guide named Keeton Kroon. They flew in a two-seater plane and backpacked to their field sites over the course of six days.

The field site was as remote as it was visually stunning, Klesh said. They were completely alone, save for a couple of bears they encountered and the occasional passing plane. At one point they came across an “ice fence” — a set of 2-meter-tall (7-foot-tall) ice pillars that included a heart-shaped hole. One of them photographed it; the next day, they passed by and the shape had completely melted away.

“The terrain changes daily,” Klesh said. “Because of the way everything melts out there, you’re the first — and maybe the last — to see it.”

At each moulin, streams of blue water emptied into pools on the surface. This liquid water is warmer than the ice, melting into it and carving different formations. Some of it melts all the way into the glacier, creating a network of underwater passages.

The team lowered a robotic submersible into these moulins, which descended to 46 meters (150 feet) at one point. Klesh said they could have descended farther, but the water became too cloudy to keep going. Underwater cameras recorded their passage; in the future, they plan to use acoustic sensors to map out surroundings when it becomes too dirty to see.

“The idea is to identify and map out these underwater channels,” Leichty said. “We want to know if they’re correlated to surface features that we can identify using satellite or overhead images.”

Understanding the relationship between the worlds above and below will let scientists guess where to lower probes to gather the best science.

Klesh and Leicty’s recent expedition relied on a commercial grade submersible and a “homemade” glacial probe. The latter was built using off-the-shelf and three-dimensional printed parts. They did all their own wiring and programming.

They said their experience with CubeSats — tiny, modular spacecraft that rely heavily on commercial parts — helped them create this probe. Both Klesh and Leichty are involved with another icy, underwater project called BRUIE (Buoyant Rover for Under-Ice Exploration). BRUIE has been tested under Alaskan ice in the past, and prepared them for the challenges of working on the Matanuska Glacier. Pro tip: Bring small handpicks to chip out ice that freezes in your robot’s bolts and prevents you from tightening them.

“We’re combining our experience with BRUIE and CubeSats and bringing that into a new area of exploration,” Klesh said. “CubeSats rely on the miniaturization of electronics to explore low-cost platforms. That allows us to explore areas that would otherwise be too risky or costly to access.”

This trial run of moulin mapping was just a start. Klesh and Leichty are roboticists, so their focus is developing the right technology. They want to partner with scientists for a more detailed exploration of moulins next summer.

For more information, visit *https://www.jpl.nasa.gov/video/details.php?id=1402*.

NASA Begins Checkout of Dellingr Spacecraft Designed to Improve Robustness of CubeSat Platforms

This image shows the release of the Dellingr spacecraft, which NASA specifically developed to provide high-quality science data on a small platform. Credits: Nanoracks/Larry Kepko.

NASA ground controllers have begun checking out and commissioning a shoebox-sized spacecraft that the agency purposely built to show that CubeSat platforms could be cost-effective, reliable, and capable of gathering highly robust science. The Dellingr spacecraft will begin science operations once ground controllers complete checkout, which began a few hours after the NanoRacks CubeSat Deployer aboard the International Space Station released the CubeSat into its low-Earth orbit November 20.

“We’re ready to start demonstrating Dellingr’s capabilities,” said Michael Johnson, chief technologist of the Applied Engineering and Technology Directorate at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. He was instrumental in pulling together a small team of scientists and engineers charged with developing the low-cost platform within a relatively short period of time, especially compared with larger, more traditional spacecraft.

“We believe Dellingr will inaugurate a new era for scientists wanting to use small, highly reliable satellites to carry out important, and in some cases, never-before-tried science,” Johnson added.

Dellingr, named after the mythological Norse god of the dawn, was designed to not only demonstrate the vigor of its design, but also gather high-quality data about the Sun’s influence on Earth’s upper atmosphere using a suite of miniaturized instruments and components.

Originally created in 1999 by the California Polytechnic State University, the CubeSat concept has grown in popularity among scientists because of its low-cost and promise to allow never-before-tried observing techniques. Constellations of many spacecraft are a mission architecture enabled by CubeSats. Instead of flying missions comprised of single spacecraft, scientists saw the potential for flying constellations of these tiny spacecraft around Earth or other solar bodies to perform simultaneous, multi-point observations — a measurement technique not financially feasible with larger, more traditional spacecraft.

“Although the platform offers great potential, historically CubeSat missions have exhibited a success rate of about 50%,” Johnson added.

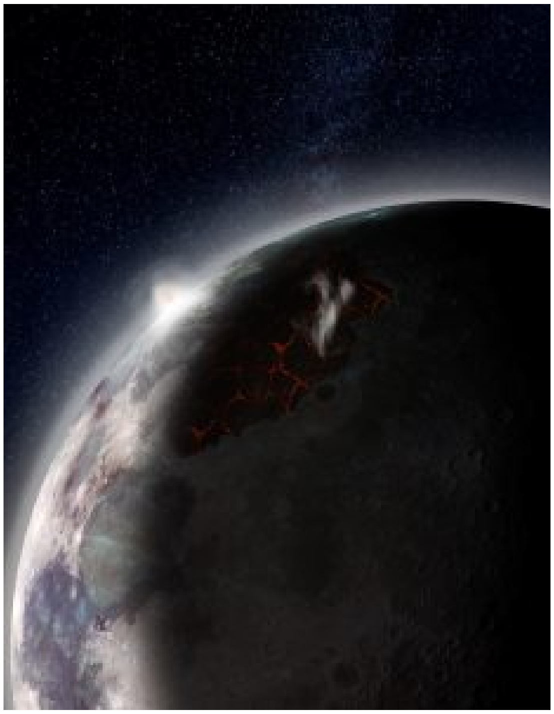
Johnson and the Dellingr team wanted to alter the perception of CubeSats as unreliable science platforms and in 2014 began their pathfinder project. The team implemented systems-development approaches that would assure a reliable, yet cost-efficient satellite that not only delivered compelling science, but also changed the CubeSat paradigm.

The spacecraft carries three heliophysics-related instruments, including the Ion-Neutral Mass Spectrometer, that will sample the densities of neutral and ionized atom species in the atmosphere, and two miniaturized magnetometer systems to measure Earth’s magnetic fields. Dellingr also carries a miniaturized device for deploying one of the magnetometers and its UHF antenna as well as a fine Sun sensor that will orient the instrument to the Sun. A new thermal-control technology used to regulate spacecraft temperatures also will be demonstrated.

“Although in orbit now for only eight days, Dellingr already is a success story,” Johnson said. The lessons learned from the Dellingr project are being infused in current and future missions, including the recently awarded PetitSat, leading to enhanced science return, and increasing the reliability of this revolutionary platform.

For more information, visit *https://www.nasa.gov/mission_pages/cubesats/index.html.*

An Atmosphere Around the Moon? NASA Research Suggests Significant Atmosphere in Lunar Past and Possible Source of Lunar Water



Artistic impression of the Moon, looking over the Imbrium Basin, with lavas erupting, venting gases, and producing a visible atmosphere. Credit: NASA MSFC.

Looking up at the Moon at night, Earth's closest neighbor appears in shades of gray and white; a dry desert in the vacuum of space, inactive and dead for billions of years. Like many things, though, with the Moon, there is so much more than what meets the eye.

Research published by NASA Marshall Space Flight Center planetary volcanologist, Debra Needham, in Huntsville, Alabama, and planetary scientist, David Kring, at the Lunar and Planetary Institute in Houston, Texas, suggests that billions of years ago, the Moon actually had an atmosphere. The ancient lunar atmosphere was thicker than the atmosphere of Mars today and was likely capable of weathering rocks and producing windstorms. Perhaps most importantly, it could be a source for some, if not all, of the water detected on the Moon.

"It just completely changes the way we think of the Moon," said Needham, a scientist in Marshall's Science and Technology Office. "It becomes a much more dynamic planetary body to explore."

Discovering the existence, thickness, and composition of the atmosphere began with understanding how much lava erupted on the Moon 3.9 to 1 billion years ago, forming the lava plains we see as the dark areas on the surface of the Moon today. Needham and Kring then used laboratory analyses of lunar basalts — iron and magnesium-rich volcanic rocks — returned to Earth by the Apollo crews to estimate the amounts and composition of gases — also called volatiles — released during those volcanic eruptions.

The short-lived atmosphere — estimated to have lasted approximately 70 million years — was comprised primarily of carbon monoxide, sulfur, and water. As volcanic activity declined, the release of the gases also declined. What atmosphere existed was either lost to space or became part of the surface of the Moon.

"We're suggesting that internally-sourced volatiles might be at least contributing factors to these potential *in situ* resource utilization deposits," Needham said.

Water is one of the keys to living off of the land in space, also called*in situ* resource utilization (ISRU). Knowing where the water came from helps scientists and mission planners alike know if the resource is renewable. Ultimately, more research is needed to determine the exact sources.

The first indication of water on the Moon came in 1994 when NASA's Clementine spacecraft detected potential signatures of water-ice in the lunar poles. In 1998, NASA's Lunar Prospector mission detected enhanced hydrogen signatures but could not definitely associate them to water. Ten years later, NASA's Lunar Reconnaissance Orbiter and its partner spacecraft, the Lunar CRater Observation and Sensing Satellite (LCROSS), definitively confirmed the presence of water on the Moon. That same year, in 2008, volcanic glass beads brought back from the Moon by the Apollo 15 and 17 crews were discovered to contain volatiles, including water, leading to the research that indicates the Moon once had a significant atmosphere and was once much different than what we see today.

Casting one's eyes at the Moon or viewing it through a telescope, the surface of the Moon today gives but a glimpse into its dynamic and complex history. Recent findings that propose Earth's neighbor once had an atmosphere comparable to Mars' continue to unravel the lunar past, while prompting scientists and explorers to ask more questions about Earth's mysterious companion in the solar system.

Recurring Martian Streaks: Flowing Sand, Not Water?

This inner slope of a martian crater has several of the seasonal dark streaks called "recurrent slope lineae" (RSL) that a November 2017 report interprets as granular flows, rather than darkening due to flowing water. The image is from the HiRISE camera on NASA's Mars Reconnaissance Orbiter. Credit: NASA/JPL-Caltech/UA/USGS.

Dark features on Mars previously considered evidence for subsurface flowing of water are interpreted by new research as granular flows, where grains of sand and dust slip downhill to make dark streaks, rather than the ground being darkened by seeping water.

Continuing examination of these still-perplexing seasonal dark streaks with a powerful camera on NASA's Mars Reconnaissance Orbiter (MRO) shows they exist only on slopes steep enough for dry grains to descend the way they do on faces of active dunes.

The findings published in *Nature Geoscience* argue against the presence of enough liquid water for microbial life to thrive at these sites. However, exactly how these numerous flows begin and gradually grow has not yet been explained. Authors of the report propose possibilities that include involvement of small amounts of water, indicated by detection of hydrated salts observed at some of the flow sites.

These features have evoked fascination and controversy since their 2011 discovery, as possible markers for unexpected liquid water or brine on an otherwise dry planet. They are dark streaks that extend gradually downhill in warm seasons, then fade away in winter and reappear the next year. On Earth, only seeping water is known to have these behaviors, but how they form in the dry martian environment remains unclear.

Many thousands of these martian features, collectively called recurring slope lineae (RSL), have been identified in more than 50 rocky-slope areas, from the equator to about halfway to the poles.

"We've thought of RSL as possible liquid water flows, but the slopes are more like what we expect for dry sand," said Colin Dundas of the U.S. Geological Survey's Astrogeology Science Center in Flagstaff, Arizona. "This new understanding of RSL supports other evidence that shows that Mars today is very dry."

Dundas is lead author of the report, which is based on observations with the High Resolution Imaging Science Experiment (HiRISE) camera on MRO. The data include three-dimensional models of slope steepness using pairs of images for stereo information. Dundas and co-authors examined 151 RSL features at 10 sites.

The RSL are almost all restricted to slopes steeper than 27°. Each flow ends on a slope that matches the dynamic "angle of repose" seen in the slumping dry sand of dunes on Mars and Earth. A flow due to liquid water should readily extend to less steep slopes.

"The RSL don't flow onto shallower slopes, and the lengths of these are so closely correlated with the dynamic angle of repose, it can't be a coincidence," said HiRISE Principal Investigator Alfred McEwen at the University of Arizona, Tucson, a co-author of the new report.

The seasonal dark streaks have been thought of as possible evidence for biologically significant liquid water — sufficient water for microbial life — although explaining how so much liquid water could exist on the surface in Mars' modern environment would be challenging. A granular-flow explanation for RSL fits with the earlier understanding that the surface of modern Mars, exposed to a cold, thin atmosphere, lacks flowing water. A 2016 report also cast doubt on possible sources of underground water at RSL sites. Liquid water on today's Mars may be limited to traces of dissolved moisture from the atmosphere and thin films, which are challenging environments for life as we know it.

However, RSL remain puzzling. Traits with uncertain explanations include their gradual growth, their seasonal reappearance, their rapid fading when inactive, and the presence of hydrated salts, which have water molecules bound into their crystal structure.

The new report describes possible connections between these traits and how RSL form. For example, salts can become hydrated by pulling water vapor from the atmosphere, and this process can form drops of salty water. Seasonal changes in hydration of salt-containing grains might result in some trigger mechanism for RSL grainflows, such as expansion, contraction, or release of some water. Darkening and fading might result from changes in hydration. If atmospheric water vapor is a trigger, then a question is why the RSL appear on some slopes but not others.

"RSL probably form by some mechanism that is unique to the environment of Mars," McEwen said, "so they represent an opportunity to learn about how Mars behaves, which is important for future surface exploration."

"Full understanding of RSL is likely to depend upon on-site investigation of these features," said MRO Project Scientist Rich Zurek of NASA's Jet Propulsion Laboratory, Pasadena, California. "While the new report suggests that RSL are not wet enough to favor microbial life, it is likely that on-site investigation of these sites will still require special procedures to guard against introducing microbes from Earth, at least until they are definitively characterized. In particular, a full explanation of how these enigmatic features darken and fade still eludes us. Remote sensing at different times of day could provide important clues."

For more information, visit https://www.nasa.gov/mission_pages/MRO/main/index.html.

NASA Selects Instrument for Future International Mission to Martian Moons

Artist's concept of Japan's Mars Moons eXploration (MMX) spacecraft, carrying a NASA instrument to study the martian moons Phobos and Deimos. Credit: JAXA/NASA.

NASA has selected a science instrument for an upcoming Japan-led sample return mission to the moons of Mars planned for launch in 2024. The instrument, a sophisticated neutron and gamma-ray spectrograph, will help scientists resolve one of the most enduring mysteries of the Red Planet — when and how the small moons formed.

The Mars Moons eXploration (MMX) mission is in development by the Japan Aerospace Exploration Agency (JAXA). MMX will visit the two martian moons, Phobos and Deimos; land on the surface of Phobos; and collect a surface sample. Plans are for the sample to be returned to Earth in 2029. NASA is supporting the development of one of the spacecraft's suite of seven science instruments.

"Solving the riddle of how Mars' moons came to be will help us better understand how planets formed around our Sun and, in turn, around other stars," said Thomas Zurbuchen, associate administrator for NASA's Science Mission Directorate (SMD) at Headquarters in Washington. "International partnerships like this provide high-quality science with high-impact return."

The selected instrument, named MEGANE (pronounced *meh-gah-nay*, meaning "eyeglasses" in Japanese), will be developed by a team led by David Lawrence of the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland. MEGANE will give MMX the ability to "see" the elemental composition of Phobos, by measuring the energies of neutrons and gamma-rays emitted from the small moon. The elementary particles are emitted naturally as a result of the high-energy cosmic rays and solar energetic particles that continually strike and penetrate the surface of Phobos.

"With MMX, we hope to understand the origin of the moons of Mars," said Masaki Fujimoto, director of the department of solar system science in JAXA's Institute of Space and Aeronautical Sciences. "They may have formed as the result of a large impact on Mars, or they may be captured asteroids of a sort that may have brought a great deal of water to both Mars and Earth."

For more information about JAXA's Mars Moons eXploration mission, visithttp://mmx-news.isas.jaxa.jp/?lang=en.

Gadgets for Mars

A rover crawls over a slope in Spain's Canary Island of Lanzarote, also known as the island of a thousand volcanos. This rover is taking part in a test campaign that brings together geology, high-tech survey equipment, and space exploration. Credit: ESA–H. Stevenin.

A mini-rover, tools once used on the Moon, and lasers for three-dimensional mapping are in the backpack of the explorers of tomorrow. The terrain will be hazardous, and it will be dark in volcanic caves, but this equipment could one day help to scout other planets.

The alien-like landscapes of Lanzarote, Spain, are almost surreal, but this volcanic island is helping bring future space missions to reality. In late November, an expedition with a dozen experiments mobilized 50 people and four space agencies during five days in five different locations. This pioneering exercise is Pangaea-X, an extension of the European Space Agency's (ESA's) Pangaea geology training.

"We are supplementing the training with the latest technologies in instrumentation, navigation, remote sensing, 3D imaging, and geoscience equipment," says ESA project leader Loredana Bessone.

"Tests in a real environment with so many geological analogies to the Moon and Mars will allow us to learn much more than in any possible artificial simulation," notes geologist Francesco Sauro, scientific director.

European astronauts, scientists, and engineers work side by side to prepare for human and robotic operations away from Earth. Volcanos, caves, and underground tunnels formed by lava are included. Like on Mars, some of the caves are large enough to accommodate highways.

There is a lot to be tested, from spacewalks in rough areas to underground communications. Together with high-tech scanners, a drone, and a rover, there is sampling and *in situ* DNA analysis of microorganisms. While a set of lasers help to create spectacular three-dimensional views of the lava caves, European astronauts are wearing smartphones on their wrists displaying instructions and DNA results on the spot.

“We have to test all this technology and a full set of analysis tools in the field and learn how to best integrate it into future operations,” adds ESA astronaut Matthias Maurer.

Not everything will be state-of-the-art technology. Spacewalk experts are carrying NASA replicas of sampling tools used during Apollo missions on the Moon to assess if they are suitable for future missions.

They are encountering obstacles and mobility constraints all along the way. “It is essential to optimize the tools and equipment for exploration. Safety and efficiency will be key for the success of future spacewalks on the Moon,” says ESA spacewalk instructor Hervé Stevenin.

The organizations involved in Pangaea-X will benefit from ESA’s expertise in astronauts operations and training, as well as from the knowhow of scientists, technicians and planetary field geology instructors.

For more information, visit http://www.esa.int/Our_Activities/Human_Spaceflight/Caves/Gadgets_for_Mars.

Solar System’s First Interstellar Visitor Dazzles Scientists

Artist’s concept of interstellar asteroid 1I/2017 U1 (‘Oumuamua) as it passed through the solar system after its discovery in October 2017. The aspect ratio of up to 10:1 is unlike that of any object seen in our own solar system. Credits: European Southern Observatory/M. Kornmesser.

Astronomers recently scrambled to observe an intriguing asteroid that zipped through the solar system on a steep trajectory from interstellar space — the first confirmed object from another star. Now, new data reveal the interstellar interloper to be a rocky, cigar-shaped object with a somewhat reddish hue.

The asteroid, named ‘Oumuamua by its discoverers, is up to 400 meters (0.25 miles) long and highly-elongated — perhaps 10 times as long as it is wide. That aspect ratio is greater than that of any asteroid or comet observed in our solar system to date. While its elongated shape is quite surprising, and unlike asteroids seen in our solar system, it may provide new clues into how other solar systems formed.

The observations and analyses were funded in part by NASA and appear in the November 20 issue of the journal *Nature*. They suggest this unusual object had been wandering through the Milky Way, unattached to any star system, for hundreds of millions of years before its chance encounter with our star system.

“For decades we’ve theorized that such interstellar objects are out there, and now — for the first time — we have direct evidence they exist,” said Thomas Zurbuchen, associate administrator for NASA’s Science Mission Directorate in Washington. “This history-making discovery is opening a new window to study formation of solar systems beyond our own.”

Immediately after its discovery, telescopes around the world, including ESO’s Very Large Telescope in Chile and other observatories, were called into action to measure the object’s orbit, brightness, and color. Urgency for viewing from groundbased telescopes was vital to get the best data.

Combining the images from the FORS instrument on the ESO telescope using four different filters with those of other large telescopes, a team of astronomers led by Karen Meech of the Institute for Astronomy in Hawaii found that ‘Oumuamua varies in brightness by a factor of 10 as it spins on its axis every 7.3 hours. No known asteroid or comet from our solar system varies so widely in brightness, with such a large ratio between length and width. The most elongated objects we have seen to date are no more than three times longer than they are wide.

“This unusually big variation in brightness means that the object is highly elongated: about ten times as long as it is wide, with a complex, convoluted shape,” said Meech. We also found that it had a reddish color, similar to objects in the outer solar system, and confirmed that it is completely inert, without the faintest hint of dust around it.”

These properties suggest that ‘Oumuamua is dense, comprised of rock and possibly metals, has no water or ice, and that its surface was reddened due to the effects of irradiation from cosmic rays over hundreds of millions of years.

A few large groundbased telescopes continue to track the asteroid, although it’s rapidly fading as it recedes from our planet. As of November 20, ‘Oumuamua is travelling about 38.3 kilometers per second (85,700 miles per hour) relative to the Sun. Its location is approximately 200 million kilometers (124 million miles) from Earth — the distance between Mars and Jupiter — although its outbound path is about 20° above the plane of planets that orbit the Sun. The object passed Mars’s orbit around November 1 and will pass Jupiter’s orbit in May 2018. It will travel beyond Saturn’s orbit in January 2019; as it leaves our solar system, ‘Oumuamua will head for the constellation Pegasus.

Observations from large groundbased telescopes will continue until the object becomes too faint to be detected, sometime after mid-December. NASA’s Center for Near-Earth Object Studies (CNEOS) continues to take all available tracking measurements to refine the trajectory of 1I/2017 U1 as it exits our solar system.

This remarkable object was discovered October 19 by the University of Hawaii’s Pan-STARRS1 telescope, funded by NASA’s Near-Earth Object Observations (NEOO) Program, which finds and tracks asteroids and comets in Earth’s neighborhood. Preliminary orbital calculations suggest that the object came from the approximate direction of the bright star Vega, in the northern constellation of Lyra. However, it took so long for the interstellar object to make the journey — even at the speed of about 26.4 kilometers per second (59,000 miles per hour) — that Vega was not near that position when the asteroid was there about 300,000 years ago.

While originally classified as a comet, observations from ESO and elsewhere revealed no signs of cometary activity after it slingshotted past the Sun on September 9 at a blistering speed of 87.3 kilometers per second (196,000 miles per hour).

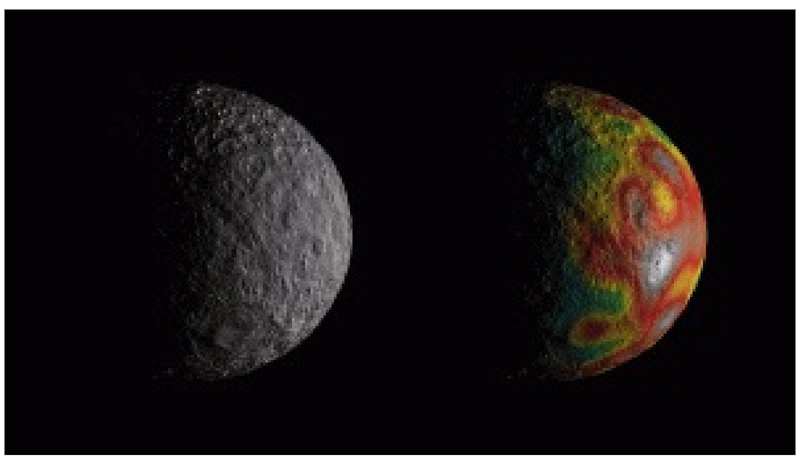
The object has since been reclassified as interstellar asteroid 1I/2017 U1 by the International Astronomical Union (IAU), which is responsible for granting official names to bodies in the solar system and beyond. In addition to the technical name, the Pan-STARRS team dubbed it ‘Oumuamua (pronounced oh MOO-uh MOO-uh), which is Hawaiian for “a messenger from afar arriving first.”

Astronomers estimate that an interstellar asteroid similar to ‘Oumuamua passes through the inner solar system about once per year, but they are faint and hard to spot and have been missed until now. It is only recently that survey telescopes, such as Pan-STARRS, are powerful enough to have a chance to discover them.

“What a fascinating discovery this is!” said Paul Chodas, manager of the Center for Near-Earth Object Studies at NASA’s Jet Propulsion Laboratory, Pasadena, California. “It’s a strange visitor from a faraway star system, shaped like nothing we’ve ever seen in our own solar system neighborhood.”

For more information, visit https://www.nasa.gov/planetarydefense.

Dawn Finds Possible Ancient Ocean Remnants at Ceres



This image shows dwarf planet Ceres as seen by NASA’s Dawn mission. The map overlaid at right shows in Ceres’ gravity field measured by Dawn. Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA.

Minerals containing water are widespread on Ceres, suggesting the dwarf planet may have had a global ocean in the past. What became of that ocean? Could Ceres still have liquid today? Two new studies from NASA’s Dawn mission shed light on these questions.

The Dawn team found that Ceres’ crust is a mixture of ice, salts, and hydrated materials that were subjected to past and possibly recent geologic activity, and that this crust represents most of that ancient ocean. The second study builds off the first and suggests there is a softer, easily deformable layer beneath Ceres’ rigid surface crust, which could be the signature of residual liquid left over from the ocean, too.

“More and more, we are learning that Ceres is a complex, dynamic world that may have hosted a lot of liquid water in the past, and may still have some underground,” said Julie Castillo-Rogez, Dawn project scientist and co-author of the studies, based at NASA’s Jet Propulsion Laboratory (JPL), Pasadena, California.

Landing on Ceres to investigate its interior would be technically challenging and would risk contaminating the dwarf planet. Instead, scientists use Dawn’s observations in orbit to measure Ceres’ gravity, in order to estimate its composition and interior structure.

The first of the two studies, led by Anton Ermakov, a postdoctoral researcher at JPL, used shape and gravity data measurements from the Dawn mission to determine the internal structure and composition of Ceres. The measurements came from observing the spacecraft’s motions with NASA’s Deep Space Network to track small changes in the spacecraft’s orbit. This study is published in the *Journal of Geophysical Research*.

Ermakov and his colleagues’ research supports the possibility that Ceres is geologically active — if not now, then it may have been in the recent past. Three craters — Occator, Kerwan, and Yalode — and Ceres’ solitary tall mountain, Ahuna Mons, are all associated with “gravity anomalies.” This means discrepancies between the scientists’ models of Ceres’ gravity and what Dawn observed in these four locations can be associated with subsurface structures.

“Ceres has an abundance of gravity anomalies associated with outstanding geologic features,” Ermakov said. In the cases of Ahuna Mons and Occator, the anomalies can be used to better understand the origin of these features, which are believed to be different expressions of cryovolcanism.

The study found the crust’s density to be relatively low, closer to that of ice than rocks. However, a study by Dawn guest investigator Michael Bland of the U.S. Geological Survey indicated that ice is too soft to be the dominant component of Ceres’ strong crust. So, how can Ceres’ crust be as light as ice in terms of density, but simultaneously much stronger? To answer this question, another team modeled how Ceres’ surface evolved with time.

The second study, led by Roger Fu at Harvard University in Cambridge, Massachusetts, investigated the strength and composition of Ceres’ crust and deeper interior by studying the dwarf planet’s topography. This study is published in the journal *Earth and Planetary Science Letters*.

By studying how topography evolves on a planetary body, scientists can understand the composition of its interior. A strong, rock-dominated crust can remain unchanged over the 4.5-billion-year-old age of the solar system, while a weak crust rich in ices and salts would deform over that time.

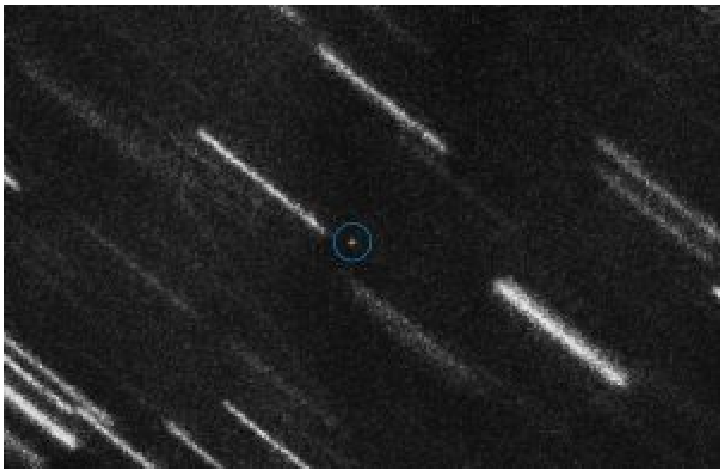
By modeling how Ceres’ crust flows, Fu and colleagues found it is likely a mixture of ice, salts, rock, and an additional component believed to be clathrate hydrate. A clathrate hydrate is a cage of water molecules surrounding a gas molecule. This structure is 100 to 1000 times stronger than water ice, despite having nearly the same density.

The researchers believe Ceres once had more pronounced surface features, but they have smoothed out over time. This type of flattening of mountains and valleys requires a high-strength crust resting on a more deformable layer, which Fu and colleagues interpret to contain a little bit of liquid.

The team thinks most of Ceres' ancient ocean is now frozen and bound up in the crust, remaining in the form of ice, clathrate hydrates and salts. It has mostly been that way for more than 4 billion years. But if there is residual liquid underneath, that ocean is not yet entirely frozen. This is consistent with several thermal evolution models of Ceres published prior to Dawn's arrival there, supporting the idea that Ceres' deeper interior contains liquid left over from its ancient ocean.

For more information, visit https://dawn.jpl.nasa.gov/mission.

Astronomers Complete First International Asteroid Tracking Exercise



Asteroid 2012 TC4 appears as a dot at the center of this composite of 37 individual 50-second exposures obtained on August 6, 2017 by the European Southern Observatory's Very Large Telescope located in the Atacama Desert region of Chile. The asteroid is marked with a circle for a better identification. The individual images have been shifted to compensate for the motion of the asteroid, so that the background stars and galaxies appear as bright trails.

An international team of astronomers led by NASA scientists successfully completed the first global exercise using a real asteroid to test global response capabilities.

Planning for the so-called "TC4 Observation Campaign" started in April, under the sponsorship of NASA's Planetary Defense Coordination Office. The exercise commenced in earnest in late July, when the European Southern Observatory's Very Large Telescope recovered the asteroid. The finale was a close approach to Earth in mid-October. The goal: to recover, track, and characterize a real asteroid as a potential impactor — and to test the International Asteroid Warning Network for hazardous asteroid observations, modeling, prediction, and communication.

The target of the exercise was asteroid 2012 TC4 — a small asteroid originally estimated to be between 10 and 30 meters (30 and 100 feet) in size, which was known to be on a very close approach to Earth. On October 12, TC4 safely passed Earth at a distance of only about 43,780 kilometers (27,200 miles) above Earth's surface. In the months leading up to the flyby, astronomers from the U.S., Canada, Colombia, Germany, Israel, Italy, Japan, the Netherlands, Russia, and South Africa all tracked TC4 from ground- and spacebased telescopes to study its orbit, shape, rotation, and composition.

"This campaign was an excellent test of a real threat case. I learned that in many cases we are already well-prepared; communication and the openness of the community was fantastic," said Detlef Koschny, co-manager of the near-Earth object (NEO) segment in the European Space Agency's (ESA's) Space Situational Awareness program. "I personally was not prepared enough for the high response from the public and media — I was positively surprised by that! It shows that what we are doing is relevant."

"The 2012 TC4 campaign was a superb opportunity for researchers to demonstrate willingness and readiness to participate in serious international cooperation in addressing the potential hazard to Earth posed by NEOs," said Boris Shustov, science director for the Institute of Astronomy at the Russian Academy of Sciences. "I am pleased to see how scientists from different countries effectively and enthusiastically worked together toward a common goal, and that the Russian-Ukrainian observatory in Terskol was able to contribute to the effort." Shustov added, "In the future I am confident that such international observing campaigns will become common practice."

Using the observations collected during the campaign, scientists at NASA's Center for Near-Earth Object Studies (CNEOS) at the Jet Propulsion Laboratory in Pasadena, California, were able to precisely calculate TC4's orbit, predict its flyby distance on October 12, and look for any possibility of a future impact. "The high-quality observations from optical and radar telescopes have enabled us to rule out any future impacts between the Earth and 2012 TC4," said Davide Farnocchia from CNEOS, who led the orbit determination effort. "These observations also help us understand subtle effects such as solar radiation pressure that can gently nudge the orbit of small asteroids."

A network of optical telescopes also worked together to study how fast TC4 rotates. Given that TC4 is small, astronomers expected it to be rotating fast, but were surprised when they found that TC4 was not only spinning once every 12 minutes, it was also tumbling. "The rotational campaign was a true international effort. We had astronomers from several countries working together as one team to study TC4's tumbling behavior," said Eileen Ryan, director of the Magdalena Ridge Observatory. Her team tracked TC4 for about 2 months using the 2.4-meter (7.9-foot) telescope in Socorro, New Mexico.

The observations that revealed the shape and confirmed the composition of the asteroid came from astronomers using NASA's Goldstone Deep Space Network antenna in California and the National Radio Astronomy Observatory's 100-meter (330-foot) Green Bank Telescope in West Virginia. "TC4 is a very elongated asteroid that's about 15 meters (50 feet) long and roughly 8 meters (25 feet) wide," said Marina Brozovic, a member of the asteroid radar team at JPL.

Finding out what TC4 is made of turned out to be more challenging. Due to adverse weather conditions, traditional NASA assets studying asteroid composition — such as the NASA Infrared Telescope Facility (IRTF) at the Mauna Kea Observatory in Hawaii — were unable to narrow down what TC4 was made of: either dark, carbon-rich or bright igneous material.

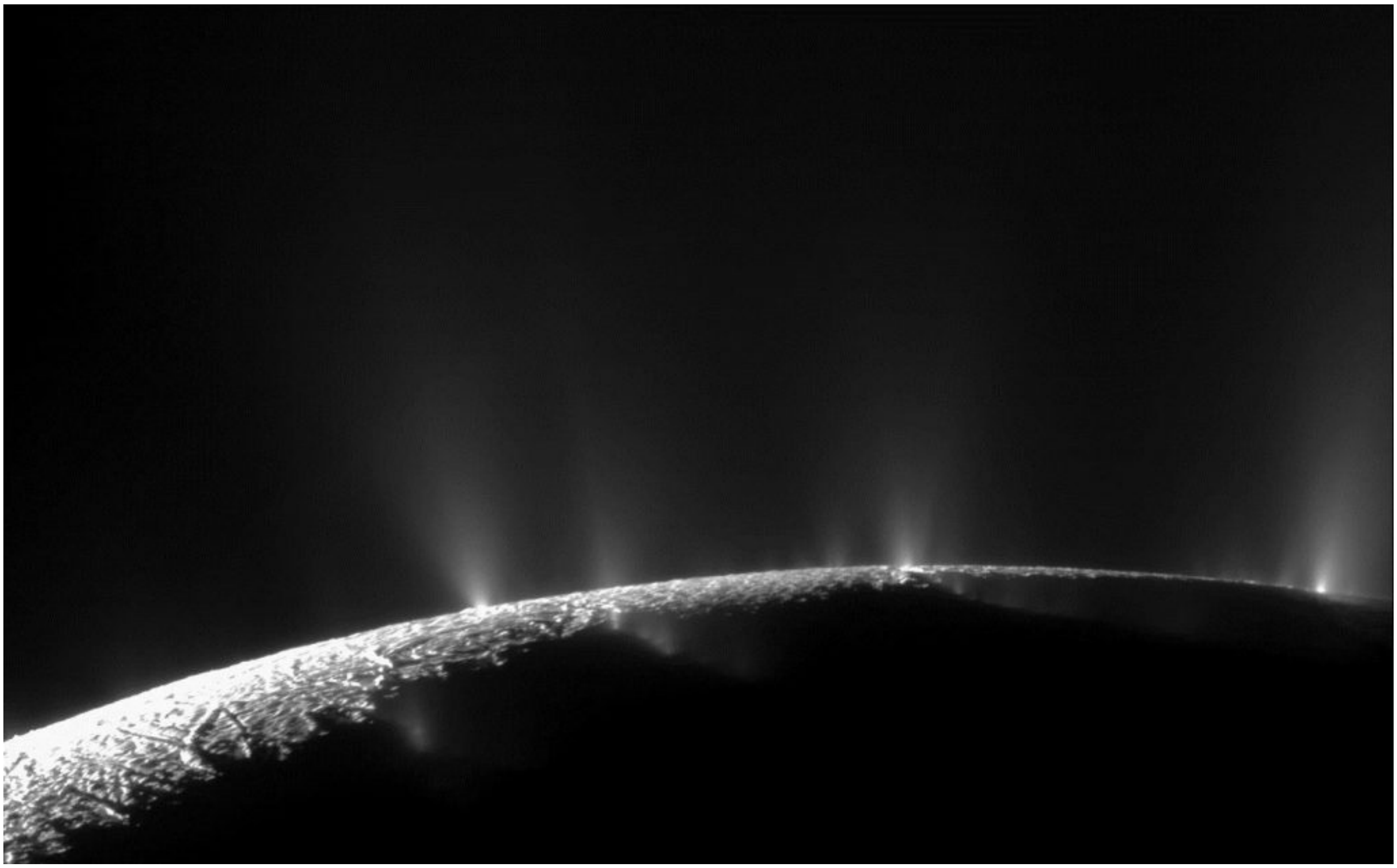
"Radar has the ability to identify asteroids with surfaces made of highly reflective rocky or metallic materials," said Lance Benner, who led the radar observations at JPL. "We were able to show that radar scattering properties are consistent with a bright rocky surface, similar to a particular class of meteorites that reflect as much as 50% of the light falling on them."

In addition to the observation campaign, NASA used this exercise to test communications between the many observers and also to test internal U.S. government messaging and communications up through the executive branch and across government agencies, as it would during an actual predicted impact emergency.

"We demonstrated that we could organize a large, worldwide observing campaign on a short timeline, and communicate results efficiently," said Vishnu Reddy of the University of Arizona's Lunar and Planetary Laboratory in Tucson, who led the observation campaign. Michael Kelley, TC4 exercise lead at NASA Headquarters in Washington, added, "We are much better prepared today to deal with the threat of a potentially hazardous asteroid than we were before the TC4 campaign."

For more information, visit https://www.nasa.gov/planetarydefense/overview.

Powering Saturn's Active Ocean Moon



A recent study has provided new insights into how the warm interior of Saturn's geologically active moon Enceladus could be sustained for billions of years. Credit: NASA/JPL-Caltech/Space Science Institute.

Heat from friction could power hydrothermal activity on Saturn's moon Enceladus for billions of years if the moon has a highly porous core, according to a new modeling study by European and U.S. researchers working on NASA's Cassini mission.

The study, published today in the journal *Nature Astronomy*, helps resolve a question scientists have grappled with for a decade: Where does the energy to power the extraordinary geologic activity on Enceladus come from?

Cassini found that Enceladus sprays towering, geyser-like jets of water vapor and icy particles, including simple organics, from warm fractures near its south pole. Additional investigation revealed the moon has a global ocean beneath its icy crust, from which the jets are venting into space. Multiple lines of evidence from Cassini indicate that hydrothermal activity — hot water interacting chemically with rock — is taking place on the seafloor.

One of those lines was the detection of tiny rock grains inferred to be the product of hydrothermal chemistry taking place at temperatures of at least 90°C (194°F). The amount of energy required to produce these temperatures is more than scientists think could be provided by decay of radioactive elements in the interior.

“Where Enceladus gets the sustained power to remain active has always been a bit of a mystery, but we’ve now considered in greater detail how the structure and composition of the moon’s rocky core could play a key role in generating the necessary energy,” said the study’s lead author, Gaël Choblet from the University of Nantes in France.

Choblet and co-authors found that a loose, rocky core with 20–30% empty space would do the trick. Their simulations show that as Enceladus orbits Saturn, rocks in the porous core flex and rub together, generating heat. The loose interior also allows water from the ocean to percolate deep down, where it heats up, then rises, interacting chemically with the rocks. The models show this activity should be at a maximum at the moon’s poles. Plumes of the warm, mineral-laden water gush from the seafloor and travel upward, thinning the moon’s ice shell from beneath to only 1 to 5 kilometers (half a mile to 3 miles) at the south pole. (The average global thickness of the ice is thought to be about 20 to 25 kilometers, or 12 to 16 miles.) This same water is then expelled into space through fractures in the ice.

The study is the first to explain several key characteristics of Enceladus observed by Cassini: the global ocean, internal heating, thinner ice at the south pole, and hydrothermal activity. It doesn’t explain why the north and south poles are so different though. Unlike the tortured, geologically fresh landscape of the south, Enceladus’ northern extremes are heavily cratered and ancient. The authors note that if the ice shell was slightly thinner in the south to begin with, it would lead to runaway heating there over time.

The researchers estimate that, over time (between 25 and 250 million years), the entire volume of Enceladus’ ocean passes through the moon’s core. This is estimated to be an amount of water equal to 2% of the volume of Earth’s oceans.

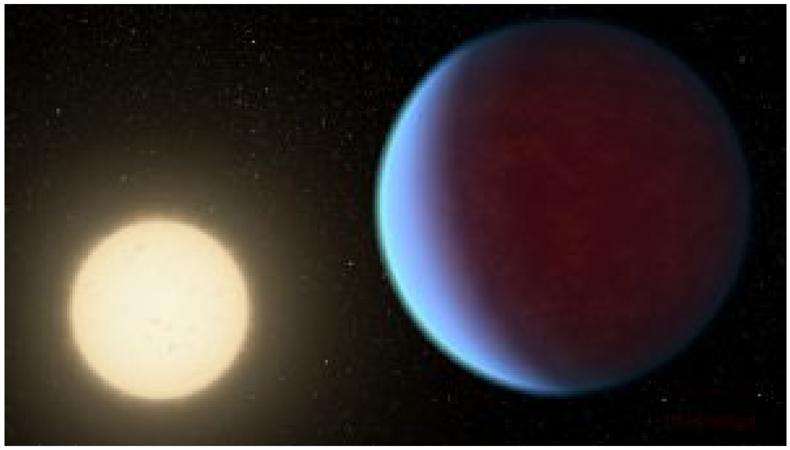
Flexing of Enceladus’ icy crust due to the tidal pull of Saturn had previously been considered as a heat source, but models showed this would not produce enough sustained power. The ocean in Enceladus would have frozen within 30 million years. Although past studies modeled how tidal friction could generate heat in the moon’s core, they made simpler assumptions or simulated the moon in only two dimensions. The new study ramped up the complexity of the model and simulated Enceladus in three dimensions.

Although the Cassini science team had suspected for years that a porous core might play an important role in the mystery of Enceladus’ warm interior, this study brings together several more recent lines of evidence in a very elegant way, according to NASA’s Cassini Project Scientist Linda Spilker at the Jet Propulsion Laboratory in Pasadena, California. “This powerful research makes use of newer details —

namely that the ocean is global and has hydrothermal activity — that we just didn't have until the past couple of years. It's an insight that the mission needed time to build, one discovery upon another," she said.

For more information, visit *https://saturn.jpl.nasa.gov/news/*.

Lava or Not, Exoplanet 55 Cancri e Likely to Have Atmosphere



The super-Earth exoplanet 55 Cancri e, depicted with its star in this artist's concept, likely has an atmosphere thicker than Earth's but with ingredients that could be similar to those of Earth's atmosphere.

Twice as big as Earth, the super-Earth 55 Cancri e was thought to have lava flows on its surface. The planet is so close to its star, the same side of the planet always faces the star, such that the planet has permanent day- and nightsides. Based on a 2016 study using data from NASA's Spitzer Space Telescope, scientists speculated that lava would flow freely in lakes on the starlit side and become hardened on the face of perpetual darkness. The lava on the dayside would reflect radiation from the star, contributing to the overall observed temperature of the planet.

Now, a deeper analysis of the same Spitzer data finds this planet likely has an atmosphere whose ingredients could be similar to those of Earth's atmosphere, but thicker. Lava lakes directly exposed to space without an atmosphere would create local hot spots of high temperatures, so they are not the best explanation for the Spitzer observations, scientists said.

"If there is lava on this planet, it would need to cover the entire surface," said Renyu Hu, astronomer at NASA's Jet Propulsion Laboratory, Pasadena, California, and co-author of a study published in *The Astronomical Journal*. "But the lava would be hidden from our view by the thick atmosphere."

Using an improved model of how energy would flow throughout the planet and radiate back into space, researchers find that the nightside of the planet is not as cool as previously thought. The "cold" side is still quite toasty by Earthly standards, with an average of 1300°C to 1400°C (2400° to 2600°F), and the hot side averages 2300°C (4200°F). The difference between the hot and cold sides would need to be more extreme if there were no atmosphere.

"Scientists have been debating whether this planet has an atmosphere like Earth and Venus, or just a rocky core and no atmosphere, like Mercury. The case for an atmosphere is now stronger than ever," Hu said.

Researchers say the atmosphere of this mysterious planet could contain nitrogen, water, and even oxygen — molecules found in our atmosphere, too — but with much higher temperatures throughout. The density of the planet is also similar to Earth, suggesting that it, too, is rocky. The intense heat from the host star would be far too great to support life, however, and could not maintain liquid water.

Hu developed a method of studying exoplanet atmospheres and surfaces, and had previously only applied it to sizzling, giant gaseous planets called hot Jupiters. Isabel Angelo, first author of the study and a senior at the University of California, Berkeley, worked on the study as part of her internship at JPL and adapted Hu's model to 55 Cancri e.

In a seminar, she heard about 55 Cancri e as a potentially carbon-rich planet, so high in temperature and pressure that its interior could contain a large amount of diamond.

"It's an exoplanet whose nature is pretty contested, which I thought was exciting," Angelo said.

Spitzer observed 55 Cancri e between June 15 and July 15, 2013, using a camera specially designed for viewing infrared light, which is invisible to human eyes. Infrared light is an indicator of heat energy. By comparing changes in brightness Spitzer observed to the energy flow models, researchers realized an atmosphere with volatile materials could best explain the temperatures.

There are many open questions about 55 Cancri e, especially: Why has the atmosphere not been stripped away from the planet, given the perilous radiation environment of the star?

"Understanding this planet will help us address larger questions about the evolution of rocky planets," Hu said.

For more information, visit http://spitzer.caltech.edu.

Giant Exoplanet Hunters Look for Debris Disks

This artist's rendering shows a large exoplanet causing small bodies to collide in a disk of dust. Credit: NASA/JPL-Caltech.

There's no map showing all the billions of exoplanets hiding in our galaxy — they're so distant and faint compared to their stars, it's hard to find them. Now, astronomers hunting for new worlds have established a possible signpost for giant exoplanets.

A new study finds that giant exoplanets that orbit far from their stars are more likely to be found around young stars that have a disk of dust and debris than those without disks. The study, published in *The Astronomical Journal*, focused on planets more than five times the mass of Jupiter. This study is the largest to date of stars with dusty debris disks, and has found the best evidence yet that giant planets are responsible for keeping that material in check.

“Our research is important for how future missions will plan which stars to observe,” said Tiffany Meshkat, lead author and assistant research scientist at the Infrared Processing and Analysis Center (IPAC)/Caltech in Pasadena, California. Meshkat worked on this study as a postdoctoral researcher at NASA’s Jet Propulsion Laboratory in Pasadena. “Many planets that have been found through direct imaging have been in systems that had debris disks, and now we know the dust could be indicators of undiscovered worlds.”

Astronomers found the likelihood of finding long-period giant planets is nine times greater for stars with debris disks than stars without disks. Caltech graduate student Marta Bryan performed the statistical analysis that determined this result.

Researchers combined data from 130 single-star systems with debris disks detected by NASA’s Spitzer Space Telescope, and compared them with 277 stars that do not appear to host disks. The two star groups were between a few million and 1 billion years old. Of the 130 stars, 100 were previously scanned for exoplanets. As part of this study, researchers followed up on the other 30 using the W. M. Keck Observatory in Hawaii and the European Southern Observatory’s Very Large Telescope in Chile. They did not detect any new planets in those 30 systems, but the additional data helped characterize the abundance of planets in systems with disks.

The research does not directly resolve why the giant exoplanets would cause debris disks to form. Study authors suggest the massive gravity of giant planets causes small bodies called planetesimals to collide violently, rather than form proper planets, and remain in orbit as part of a disk.

“It’s possible we don’t find small planets in these systems because, early on, these massive bodies destroyed the building blocks of rocky planets, sending them smashing into each other at high speeds instead of gently combining,” said co-author Dimitri Mawet, a Caltech associate professor of astronomy and a JPL senior research scientist.

On the other hand, giant exoplanets are easier to detect than rocky planets, and it is possible that there are some in these systems that have not yet been found.

Our own solar system is home to gas giants responsible for making “debris belts” — the asteroid belt between Mars and Jupiter, shaped by Jupiter, and the Kuiper belt, shaped by Neptune. Many of the systems Meshkat and Mawet studied also have two belts, but they are also much younger than ours — up to 1 billion years old, compared to our system’s present age of 4.5 billion years. The youth of these systems partly explains why they contain much more dust — resulting from the collisions of small bodies — than ours does.

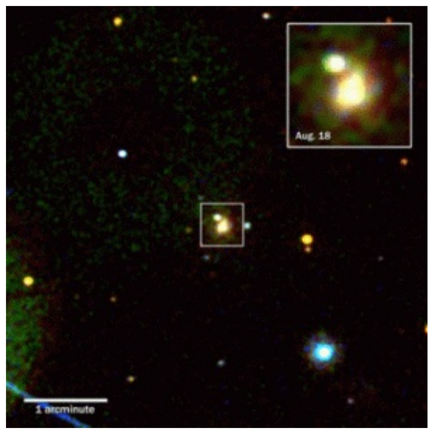
One system discussed in the study is Beta Pictoris, which has been directly imaged from groundbased telescopes. This system has a debris disk, comets, and one confirmed exoplanet. In fact, scientists predicted this planet’s existence well before it was confirmed, based on the presence and structure of the prominent disk.

In a different scenario, the presence of two dust belts in a single debris disk suggests there are likely more planets in the system whose gravity maintains these belts, as is the case in the HR8799 system of four giant planets. The gravitational forces of giant planets nudge passing comets inward toward the star, which could mimic the period of our solar system's history about 4 billion years ago known as the late heavy bombardment. Scientists think that during that period, the migration of Jupiter, Saturn, Uranus, and Neptune deflected dust and small bodies into the Kuiper and asteroid belts we see today. When the Sun was young, there would have been a lot more dust in our solar system as well.

"By showing astronomers where future missions such as NASA's James Webb Space Telescope have their best chance to find giant exoplanets, this research paves the way to future discoveries," said Karl Stapelfeldt of JPL, chief scientist of NASA's Exoplanet Exploration Program Office and study co-author.

For more information, visit https://exoplanets.nasa.gov.

NASA Missions Catch First Light from a Gravitational-Wave Event



Swift's Ultraviolet/Optical Telescope imaged the kilonova produced by merging neutron stars in the galaxy NGC 4993 (inset box) on August 18, 2017, about 15 hours after gravitational waves and the gamma-ray burst were detected. The source was unexpectedly bright in ultraviolet light. It faded rapidly and was undetectable in UV when Swift looked again on August 29. This false-color composite combines images taken through three ultraviolet filters. Inset: Magnified view of the galaxy. Credit: NASA/Swift.

For the first time, NASA scientists have detected light tied to a gravitational-wave event, thanks to two merging neutron stars in the galaxy NGC 4993, located about 130 million light-years from Earth in the constellation Hydra.

On August 17, NASA's Fermi Gamma-ray Space Telescope picked up a pulse of high-energy light from a powerful explosion, which was immediately reported to astronomers around the globe as a short gamma-ray burst. The scientists at the National Science Foundation's Laser Interferometer Gravitational-wave Observatory (LIGO) detected gravitational waves dubbed GW170817 from a pair of smashing stars tied to the gamma-ray burst, encouraging astronomers to look for the aftermath of the explosion. Shortly thereafter, the burst was detected as part of a follow-up analysis by the European Space Agency's (ESA's) INTEGRAL satellite.

NASA's Swift, Hubble, Chandra, and Spitzer missions, along with dozens of groundbased observatories, including the NASA-funded Pan-STARRS survey, later captured the fading glow of the blast's expanding debris.

"This is extremely exciting science," said Paul Hertz, director of NASA's Astrophysics Division at the agency's headquarters in Washington. "Now, for the first time, we've seen light and gravitational waves produced by the same event. The detection of a gravitational-wave source's light has revealed details of the event that cannot be determined from gravitational waves alone. The multiplier effect of study with many observatories is incredible."

Neutron stars are the crushed, leftover cores of massive stars that previously exploded as supernovas long ago. The merging stars likely had masses between 10% and 60% percent greater than that of our Sun, but they were no wider than the city of Washington, DC. The pair whirled around each other hundreds of times a second, producing gravitational waves at the same frequency. As they drew closer and orbited faster, the stars eventually broke apart and merged, producing both a gamma-ray burst and a rarely seen flare-up called a "kilonova."

"This is the one we've all been waiting for," said David Reitze, executive director of the LIGO Laboratory at Caltech in Pasadena, California. "Neutron star mergers produce a wide variety of light because the objects form a maelstrom of hot debris when they collide. Merging black holes — the types of events LIGO and its European counterpart, Virgo, have previously seen — very likely consume any matter around them long before they crash, so we don't expect the same kind of light show."

"The favored explanation for short gamma-ray bursts is that they're caused by a jet of debris moving near the speed of light produced in the merger of neutron stars or a neutron star and a black hole," said Eric Burns, a member of Fermi's Gamma-ray Burst Monitor team at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "LIGO tells us there was a merger of compact objects, and Fermi tells us there was a short gamma-ray burst. Together, we know that what we observed was the merging of two neutron stars, dramatically confirming the relationship."

Within hours of the initial Fermi detection, LIGO and the Virgo detector at the European Gravitational Observatory near Pisa, Italy, greatly refined the event's position in the sky with additional analysis of gravitational wave data. Groundbased observatories then quickly located a new optical and infrared source — the kilonova — in NGC 4993.

To Fermi, this appeared to be a typical short gamma-ray burst, but it occurred less than one-tenth as far away as any other short burst with a known distance, making it among the faintest known. Astronomers are still trying to figure out why this burst is so odd, and how this event relates to the more luminous gamma-ray bursts seen at much greater distances.

NASA's Swift, Hubble, and Spitzer missions followed the evolution of the kilonova to better understand the composition of this slower-moving material, while Chandra searched for X-rays associated with the remains of the ultra-fast jet.

When Swift turned to the galaxy shortly after Fermi's gamma-ray burst detection, it found a bright and quickly fading ultraviolet (UV) source.

"We did not expect a kilonova to produce bright UV emission," said Goddard's S. Bradley Cenko, principal investigator for Swift. "We think this was produced by the short-lived disk of debris that powered the gamma-ray burst."

Over time, material hurled out by the jet slows and widens as it sweeps up and heats interstellar material, producing so-called afterglow emission that includes X-rays. But the spacecraft saw no X-rays — a surprise for an event that produced higher-energy gamma rays.

NASA's Chandra X-ray Observatory clearly detected X-rays nine days after the source was discovered. Scientists think the delay was a result of our viewing angle, and it took time for the jet directed toward Earth to expand into our line of sight.

"The detection of X-rays demonstrates that neutron star mergers can form powerful jets streaming out at near light speed," said Goddard's Eleonora Troja, who led one of the Chandra teams and found the X-ray emission. "We had to wait for nine days to detect it because we viewed it from the side, unlike anything we had seen before."

On August 22, NASA's Hubble Space Telescope began imaging the kilonova and capturing its near-infrared spectrum, which revealed the motion and chemical composition of the expanding debris.

"The spectrum looked exactly like how theoretical physicists had predicted the outcome of the merger of two neutron stars would appear," said Andrew Levan at the University of Warwick in Coventry, England, who led one of the proposals for Hubble spectral observations. "It tied this object to the gravitational wave source beyond all reasonable doubt."

Astronomers think a kilonova's visible and infrared light primarily arises through heating from the decay of radioactive elements formed in the neutron-rich debris. Crashing neutron stars may be the universe's dominant source for many of the heaviest elements, including platinum and gold.

Because of its Earth-trailing orbit, Spitzer was uniquely situated to observe the kilonova long after the Sun moved too close to the galaxy for other telescopes to see it. Spitzer's September 30 observation captured the longest-wavelength infrared light from the kilonova, which unveils the quantity of heavy elements forged.

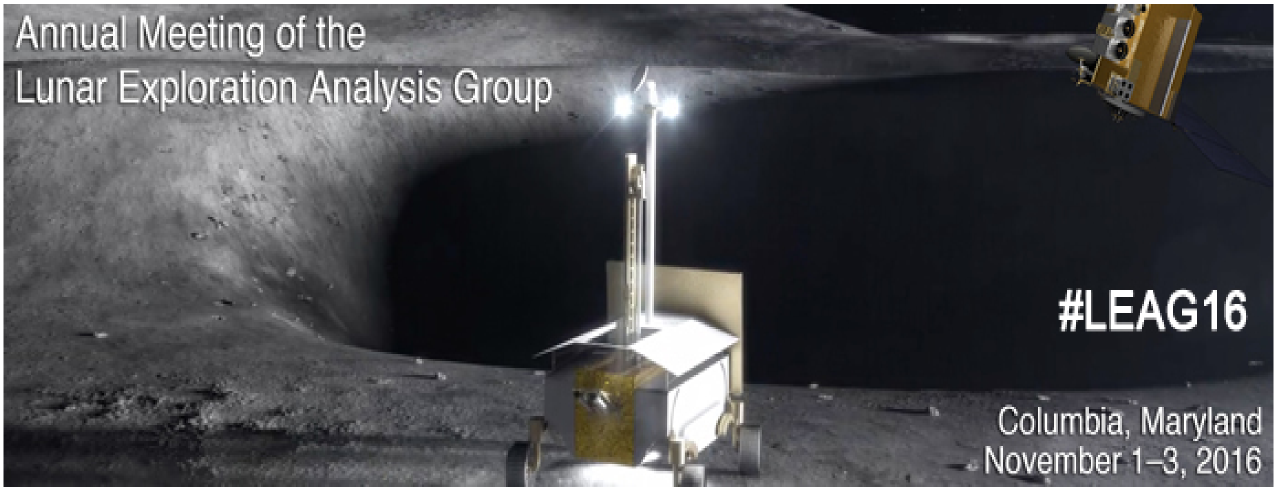
"Spitzer was the last to join the party, but it will have the final word on how much gold was forged," says Mansi Kasliwal, Caltech assistant professor and principal investigator of the Spitzer observing program.

Numerous scientific papers describing and interpreting these observations have been published in *Science*, *Nature*, *Physical Review Letters*, and *The Astrophysical Journal.*

For more information, visit https://www.nasa.gov/mission_pages/swift/main or https://www.nasa.gov/mission_pages/spitzer/main/index.html.

Annual Meeting of the Lunar Exploration Analysis Group

November 1–3, 2016
Columbia, Maryland



One hundred forty-seven people (132 professional and 15 students) attended the 2016 Lunar Exploration Analysis Group (LEAG) meeting held at the Universities Space Research Association (USRA) Headquarters in Columbia, Maryland.

LEAG is trying to grow the number of students who attend the annual LEAG meetings, and toward this end has instituted the LEAG Bernard Ray Hawke Next Lunar Generation Career Development Awards, sponsored by the NASA Solar System Exploration Research Virtual Institute (SSERVI).

The 2016 meeting was designed to address three goals:

- Integrate the perspectives and interests of the different stakeholders (science, engineering, government, and private sector) to explore common goals of lunar exploration.
- Use the results of recent and ongoing missions to examine how science enables exploration and exploration enables science.
- Provide a forum for community updates and input into the issues that affect lunar science and exploration.

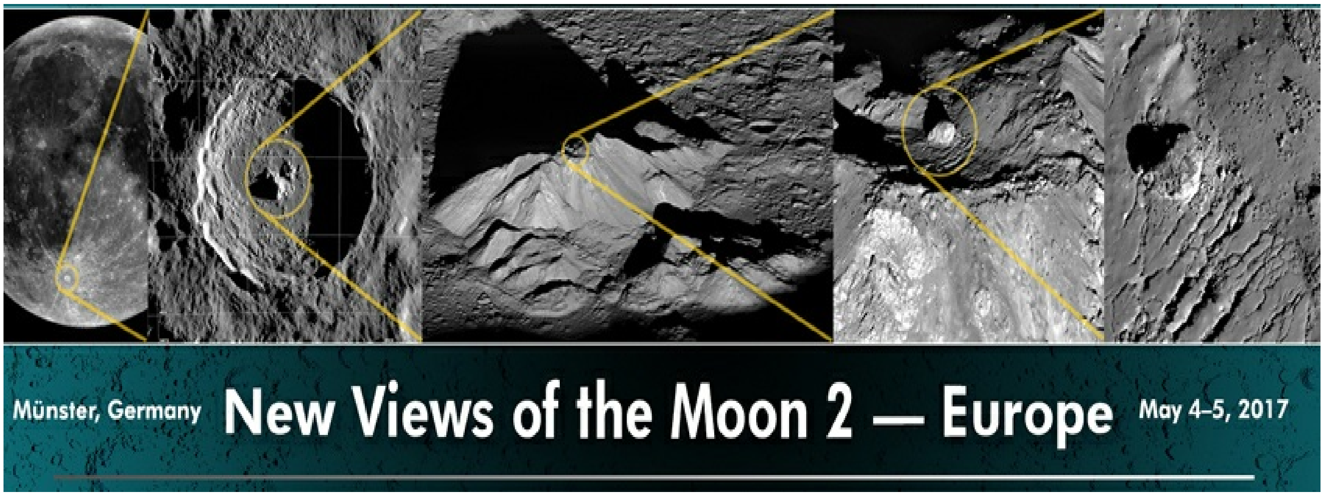
Sessions created to explore these goals were focused upon Commercial Space Opportunities (Impact on Lunar Science and Exploration), New Views of the Lunar Regolith, New Lunar Mission Concepts, the Lunar Capabilities Roadmap, and Building a Moon Village. There was strong participation from space agencies (NASA, ESA, KARI, JAXA, etc.) and from international lunar scientists. Moon Express kindly sponsored the reception and poster session on November 2, during which Congressman Jim Bridenstine (member of the House Science, Space, and Technology Subcommittee) presented a very well received talk about how the Moon could be this generation's "Sputnik moment" (*https://bridenstine.house.gov/blog/?postid=758*.

The meeting produced nine community findings (*https://www.hou.usra.edu/meetings/leag2016/Meeting-Findings.pdf*) that were forwarded to specific entities, and updates on how these have been addressed were presented at the 2017 LEAG meeting in October.

For more information about the meeting, including the complete program and abstracts, visit the meeting website at *https://www.hou.usra.edu/meetings/leag2016/*.

New Views of the Moon 2 — Europe

May 4–5, 2017
Münster, Germany



New Views of the Moon 2 — Europe (NVM2-Europe) was the second of three workshops designed to gather input to the next edition of *New Views of the Moon* (published as *Reviews in Mineralogy and Geochemistry, Vol. 60,* by the Mineralogical Society of America in 2006).

The first workshop was held at the Lunar and Planetary Institute, Houston, in 2016 (*https://www.hou.usra.edu/meetings/newviews2016/*). NVM2-Europe was graciously hosted at the University of Münster in Germany by Carolyn van der Bogert and Harry Hiesinger.

Given that missions to the Moon since 2000 have been multi-national in nature, NVM2 is an international project. This second workshop in the series immediately followed the European Lunar Symposium, which was also held at the University of Münster.

In total, 98 people attended the meeting (25 students and 73 professionals). The two-day meeting was filled with talks on new data and ideas about the Moon, and significant input to each of the chapters that will comprise the next *New Views of the Moon* book was given. This very successful meeting was a vital conduit for international participation in the NVM2 project. The third and final NVM2 workshop will be held in Japan in April 2018.

For more information about the workshop, including the complete program and abstracts, visit the workshop website at *https://www.hou.usra.edu/meetings/newviews2017/*.

Opportunities for Students

LPI Summer Intern Program in Planetary Science

The Lunar and Planetary Institute invites undergraduates with at least 50 semester hours of credit to experience cutting-edge research in the lunar and planetary sciences. As a Summer Intern, you 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, you will participate in peer-reviewed research, learn from top-notch planetary scientists, and preview various careers in science.

The 10-week program runs from June 4, 2018, to August 9, 2018. Interns will receive a $5675 stipend plus $1000 U.S. travel stipend, or $1500 foreign travel reimbursement for foreign nationals.

The LPI is located near Johnson Space Center on the south side of Houston, Texas. On NASA's behalf, the LPI provides 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 2018 program is**January 5, 2018**. For more information, including eligibility and selection criteria, areas of research, and an online application form, visit *https://www.lpi.usra.edu/lpiintern/*.

Applications Now Being Accepted for the Exploration Science Summer Intern Program

The Lunar and Planetary Institute (LPI) is hosting a special summer intern program to involve students in activities that support missions to the Moon that utilize the Orion crew vehicle, the Deep Space Gateway, and robotic assets on the lunar surface. 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 of landing sites and traverse plans for multiple destinations that are responsive to NASA objectives. The LPI invites applications from graduate students in geology, planetary science, and related programs.

The Exploration Science Summer Intern Program builds on the success of the 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 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 2018 is designed to have the same impact on future exploration activities. This will be a unique team activity that should foster extensive discussions among students and senior science team members.

The 10-week program runs from May 29, 2018, through August 3, 2018. Selected interns will receive a $5883 stipend, and up to a $1000 travel expense reimbursement for U.S. citizens, or $1500 for foreign nationals.

The deadline for applying for the 2018 program is **January 19, 2018.** For more information, including eligibility and selection criteria, areas of research, and an online application form, please visit *https://www.lpi.usra.edu/exploration_intern/*.

LPSC Student Opportunities

LPSC Student Opportunities

49th LPSC Lunar and Planetary Science Conference
March 19–23, 2018

LPI Career Development Award

The Lunar and Planetary Institute (LPI) Career Development Award, which is open to both U.S. and non-U.S. applicants, will be given to selected graduate students who have submitted a first-author abstract for presentation at the 49th Lunar and Planetary Science Conference.

The application deadline will be **Friday, January 12, 2018**.

Stephen E. Dwornik Student Awards

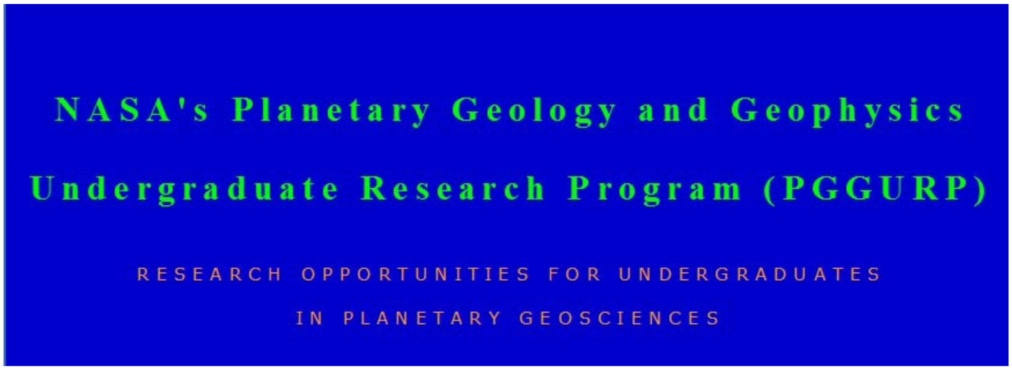
The deadline for Dwornik Award applications will be **Wednesday, January 10, 2018**.

The Dwornik Award was started in 1991 with a generous endowment by Dr. Stephen E. Dwornik, who wished to encourage U.S. students to become involved with NASA and planetary science. The Award consists of a plaque and a monetary award given for outstanding student presentations (in both poster and oral categories) or a plaque for honorable mentions (poster and oral) at the annual Lunar and Planetary Science Conference (LPSC). The awards are managed and judged by the Planetary Geology Division of the Geological Society of America.

The awards are open to students at any degree level in a field related to planetary geosciences who are either (1) U.S. citizens or non-citizens currently enrolled in a U.S. educational institution, or (2) are U.S. citizens currently enrolled in an international educational institution. Recent graduates, pre-college students, and postdoctoral fellows are not eligible. Students who have previously won a “best presentation” award as a graduate student are not eligible to compete again in either category. Students who have won a “best presentation” award as an undergraduate are not eligible to compete again in either category as an undergraduate but are eligible to compete in either category as a graduate student. Students who have won honorable mention award(s) as either a graduate or undergraduate student in either category are eligible to compete again.

For more details about either of these awards, visit *https://www.hou.usra.edu/meetings/lpsc2018/student-awards/*.

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 U.S. 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.

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 **February 21, 2018**. For more information, including eligibility requirements, visit *http://www.acsu.buffalo.edu/~tgregg/pggurp.html*.

California Institute of Technology Summer Undergraduate Research Fellowships

The Summer Undergraduate Research Fellowships (SURF) program is one of the "crown jewels" of Caltech. Since 1979, SURF students have had the opportunity to conduct research under the guidance of experienced mentors working at the frontier of their fields. Students experience the process of research as a creative intellectual activity from beginning (defining and developing a project) to end (presenting their results at SURF Seminar Day).

SURF is modeled on the grant-seeking process:

- Students collaborate with a potential mentor to define and develop a project
- Applicants write research proposals as part of the application process
- Faculty review the proposals and recommend awards
- Students carry out the work over a 10-week period during the summer
- At the conclusion of the program, students submit a technical paper and give an oral presentation at one of several SURF Seminar Days, symposia modeled on a professional technical meeting.

Fellows receive a $6275 award for the ten-week period. Award payments are distributed in equal installments in late June and late July.

The deadline for all application materials is**February 22, 2018.** For more information, visit *https://www.sfp.caltech.edu/programs/surf*.

Internships, Scholarships, and Fellowships with NASA

NASA Internships

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 2018 opportunities are due **March 1, 2018**. To find available opportunities and fill out an OSSI online application, visit *https://intern.nasa.gov/ossi*.

NASA Earth and Space Science Fellowships Program

The NASA Earth and Space Science Fellowship 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 2018–2019 academic year. Awards resulting from the competitive selection will be training grants to the respective universities, with the advisor serving as the principal investigator. Awards of $45,000 per year are made for up to three years. Proposals (new applications) are due **February 1, 2018**. More information and application instructions can be found at *http://solicitation.nasaprs.com/open* by searching for NESSF.

NASA Postdoctoral Program Fellowships

The NASA Postdoctoral Program (NPP) supports NASA's goal to expand scientific understanding of the Earth and the universe in which we live. Selected by a competitive peer-review process, NPP fellows complete one- to three-year fellowships that offer scientists and engineers unique opportunities to conduct research in fields of science relevant to NASA. These opportunities advance NASA's missions in Earth science, heliophysics, planetary science, astrophysics, space bioscience, aeronautics and engineering, human exploration and space operations, and astrobiology. Opportunities are available at

NASA centers and other NASA-approved sites. Interested applicants may apply by one of three annual application deadlines: **March 1** (current deadline), July 1, and November 1. For more information, visit *https://npp.usra.edu*.

SAO Summer Intern Program

The Smithsonian Astrophysical Observatory (SAO) is once again offering 10 exciting ten-week summer research internships through the National Science Foundation's Research Experience for Undergraduates (REU) program. SAO's REU internships bring students to Cambridge to work on the cutting edge of astrophysics, analyzing data from many of the world's foremost observatories. Research topics include but are not limited to exoplanets, stellar physics, star formation, black holes, cosmology, galaxies, galaxy evolution . . . and many others!

For more information or to apply online, go to*https://www.cfa.harvard.edu/opportunities/reu/* by January 31, 2018. Applicants must be undergraduates who are also U.S. citizens or permanent residents. We strongly encourage applications from women and members of underrepresented groups. Our interns will live rent-free in Harvard campus housing and receive a stipend of $500/week. We will also cover domestic travel expenses to attend the Seattle AAS meeting in 2019 to present your research!

Internships Available at APL

The Applied Physics Laboratory (APL) at Johns Hopkins offers 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.

The application deadline for the 2018 College Summer Internship Program is March 31, 2018. For more information, visit *http://www.jhuapl.edu/employment/summer/*.

Lloyd V. Berkner Space Policy Internships 2017

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

The application deadlines are February 2, 2018 (summer), and June 1, 2018 (autumn). Additional information about the program, including the application procedure, can be found at *http://sites.nationalacademies.org/SSB/ssb_052239*.

49th LPSC Education and Public Engagement Activities

There are a variety of education and public engagement opportunities for scientists, students, and the public at the LPSC 2018 conference.

Submit an Abstract

The LPSC abstract deadline is *Tuesday, January 9, at 5:00 p.m. U.S. Central Standard Time*. In addition to abstracts on a variety of planetary science topics, we are soliciting abstracts for Education and Public Engagement posters. College faculty are encouraged to assist their undergraduate and graduate students in submitting planetary research abstracts, and all are invited to submit abstracts sharing their education and public engagement efforts. For more information on submitting an abstract, visit https://www.hou.usra.edu/meetings/lpsc2018/abstract-submission/.

Participate as a Mentor, Reviewer, or Presenter

LPI invites planetary scientists to volunteer on Sunday afternoon, March 18, as mentors and reviewers for the *Early Career Presenters Review* and to present their science or conduct hands-on activities at *Planetary Palooza*. Volunteers are invited to mentor undergraduate students, meeting before conference presentations on Monday morning, March 19. Please e-mail education@lpi.usra.edu to volunteer as an undergraduate mentor or reviewer, or as a presenter.

Scientist and Public Engagement Sessions

The Lunar and Planetary Institute will be conducting sessions on Sunday afternoon, March 18, for planetary scientists, students, and educators.

Early Career Presenters Review

All students, post-docs, and other early career scientists preparing to present research at the 49th Lunar and Planetary Science Conference are invited to present their LPSC 2018 oral or poster presentation and receive feedback from experienced scientists before presenting during the regular meeting. Details and free registration will be available mid-January. Presenters and scientists wishing to participate as reviewers are encouraged to contact Andy Shaner at shaner@lpi.usra.edu with any questions.

Planetary Scientist Workshop: Communicating Your Science

Giving presentations or conducting activities for school groups, families, or adult learners? Learn about the different needs of various audiences, identify your audience's goals, and assess your efforts in this free two-hour session on Sunday, March 18. Details and free registration will be available by mid-January. For more information, contact education@lpi.usra.edu.

Planetary Science Palooza

All members of the public, including students, educators, program leaders, amateur astronomers, and their families are invited to the LPSC Planetary Science Palooza! Explore hands-on activities and hear the latest findings from experts attending the Lunar and Planetary Science Conference! More details will be available by mid-January. For more information, contact education@lpi.usra.edu.

Upcoming Public Event Opportunities

Upcoming Public Event Opportunities

Upcoming opportunities exist for educator and public engagement around the broader topics of NASA planetary exploration. Contact 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 your audience.

60 Years of America in Space, January 29–31, 2018

Marking the launch of the U.S. satellite Explorer 1 (January 31) — and the nation's first step into space and space science.

Total Lunar Eclipse, January 31, 2018

The eclipse will be visible throughout most of western North America, eastern Asia, Australia, and the Pacific Ocean. For more information, visit *https://eclipse.gsfc.nasa.gov/LEplot/LEplot2001/LE2018Jan31T.pdf.*

Lyrids Meteor Shower, April 22–23, 2018

https://www.timeanddate.com/astronomy/meteor-shower/lyrids.html

The Lyrids Meteor Shower is produced by dust particles left behind by Comet C/1861 G1 Thatcher. The shower peaks this year on the night of April 22 and morning of April 23. Meteors will radiate from the constellation Lyra, but can appear anywhere in the sky. Meteor showers provide a great opportunity to discuss comets with your audiences!

Nominate a Scientist or Educator for an ASP Education Award

The Astronomical Society of the Pacific (ASP) bestows several awards on deserving educators. The nomination deadline for all awards is March 1, 2018.

Richard H. Emmons Award

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

Klumpke-Roberts Award

The ASP bestows the annual Klumpke-Roberts Award on those who have made outstanding contributions to the public understanding and appreciation of astronomy. More information is available at http://www.astrosociety.org/about-us/klumpke-roberts-award-of-the-astronomical-society-of-the-pacific/.

Thomas J. Brennan Award

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

Nominate a Scientist or Educator for an AGU Education Award

Nominate a Scientist or Educator for an AGU Education Award

The American Geophysical Union (AGU) presents a variety of awards, medals, and prizes to recognize individuals who have made significant contributions to the Earth and space sciences through scientific research, education, communication, outreach, and sustained impact. Each year, several exceptional individuals are honored at the annual AGU Fall Meeting. Nominations for both of the awards listed below open on January 15, 2018, and close on March 15, 2018.

AGU's Spilhaus Award

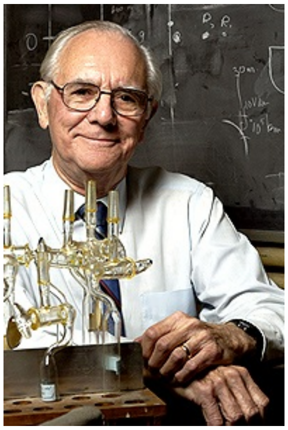
This is awarded not more than once annually to an individual AGU member for devoting portions of their career to conveying to the general public the excitement, significance, and beauty of the Earth and space sciences. More information is available at *http://honors.agu.org/medals-awards/athelstan-spilhaus-award/*.

Excellence in Earth and Space Science Education Award (formerly the 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 post-graduate), 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." For more information, visit *http://honors.agu.org/medals-awards/excellence-in-geophysical-education-award/*.

In Memoriam

Robert N. Clayton, 1930–2017



Robert N. Clayton, a Canadian-American chemist and academic, died in his sleep on December 30, 2017, after a battle with Parkinson's Disease. Clayton was the Enrico Fermi Distinguished Service Professor Emeritus of Chemistry at the University of Chicago.

Born in Hamilton, Ontario, Clayton graduated from Queen's University with undergraduate and master's degrees. He completed a Ph.D. in 1955 at the California Institute of Technology, where he was mentored by geochemist Samuel Epstein. His first academic appointment was at Penn State University. In 1958, he joined the chemistry faculty at the University of Chicago, where he took over the laboratory of Nobel Prize winner Harold Urey. From 1961 to his retirement in 2001, he held joint appointments in the chemistry and geophysical sciences departments. He directed the Enrico Fermi Institute at the university from 1998 to 2001.

Clayton pioneered the use of oxygen isotopes, chemical fingerprints found in meteorites and lunar rocks, to better understand the processes that formed the planets and asteroids early in the history of the solar system. His studies provided surprising evidence supporting the theory that the Moon was part of the Earth until a collision with another planet-sized object blasted them apart.

Most of Clayton's lunar research stemmed from his examination of approximately 300 samples collected during all six Apollo moon landings from 1969 to 1972, and those collected during the Soviet Luna 16 and 20 robotic missions. But his laboratory also became well known as a clearinghouse for the analysis of unusual meteorites.

While studying meteorites with colleagues at the Fermi Institute, Clayton discovered in 1973 that the chemistry of oxygen in the early solar system was fundamentally different from that known on Earth. This led to the recognition of the importance of photochemistry (the interaction of light and chemicals) in the formation of the planets and to a new prediction of the abundances of oxygen isotopes in the Sun.

Clayton and his colleagues identified the first lunar meteorite in 1983. And by studying martian meteorites they showed in 1992 that Mars probably once had water on its surface or in its atmosphere. He was also a member of a team that in 2000 established the Tagish Lake meteorite from Canada as perhaps the most pristine sample of the solar system ever studied.

Clayton was a member of the National Academy of Sciences and was named a fellow of several academic societies, including the Royal Society. In 1981, he received the V. M. Goldschmidt Award from the Geochemical Society. The following year, the Meteoritical Society awarded him its Leonard Medal. Clayton also won the Elliott Cresson Medal from the Franklin Institute, the William Bowie Medal from the American Geophysical Union, and the J. Lawrence Smith Medal from the National Academy of Sciences.

In 1996, Clayton was named to the National Academy of Sciences. He was also named a fellow of the

Royal Society of London and the Royal Society of Canada. In 2004, he was given the United States' highest scientific honor when he was chosen to be among the 2004 recipients of the National Medal of Science. Clayton was cited "for his leading contributions to cosmic chemistry, from pre-solar system dust to planets, and for being an exemplary role model as a mentor, teacher, and advocate for rigorous science."

Von R. Eshleman, 1924–2017

Von R. Eshleman died peacefully on September 22, 2017, five days after his 93rd birthday. Although he began his career in radar astronomy, he is best known as a pioneer in the use of spacecraft radio signals for precise measurements in planetary exploration — specifically, the radio occultation method for profiling planetary atmospheres and ionospheres, which has now been "brought home" for monitoring Earth's atmosphere using GPS satellites.

Eshleman was the youngest of four boys born in Covington, Ohio. He progressed rapidly through his early school years, then served as an electronics technician in the U.S. Navy during World War II (1943–1946). While stationed in Italy at the end of the war, he became intrigued by the possibility of bouncing radio signals from the lunar surface. Although his own ship-based experiments were unsuccessful, this curiosity guided his professional life for the next 60 years.

He attended the General Motors Institute of Technology and Ohio State University before graduating with a bachelor's degree in electrical engineering from George Washington University (GWU) in 1949. Recruited to graduate school at Stanford University by Fred Terman, he obtained an M.S. in 1950 and a Ph.D. in 1952. His doctoral research, supervised by Mike Villard and Larry Manning, was on radio reflections from ionized meteor trails in the upper Earth's atmosphere.

After serving five years as a member of Stanford's Electrical Engineering research staff, Eshleman was promoted to Assistant Professor in 1957, then Associate Professor, and finally full Professor in 1962. With colleagues Allen Peterson and Ray Leadabrand, he founded the Stanford Center for Radar Astronomy in 1962, which oversaw two-way dual-frequency radio propagation experiments between Stanford's 150-foot antenna ("The Dish") and Pioneers 6–9 in orbit around the Sun, measuring the density, velocity, and structure of the solar wind.

By the mid-1960s Eshleman's team had refocused on planets and on the telecommunications signals normally used to transmit spacecraft images and other remotely acquired data. The radio signals themselves are perturbed when a spacecraft flies behind a planet; by measuring the small changes in frequency, it is possible to determine the temperature and pressure profile of an occulting atmosphere (very similar to the results returned by a weather balloon) and the electron density of an ionosphere. The experiments were originally proposed for an "uplink" geometry (transmission from Earth to the spacecraft), but only "downlink" implementations were approved. Nonetheless, graduate students Gunnar Fjeldbo and Len Tyler (among others) perfected the technique and were rewarded with the first profiles from Mars (cold and thin) and Venus (hot and dense) in 1965 and 1967, respectively. Eshleman and his associates also demonstrated that properties of planetary surfaces could be derived from radio echoes reflected from the Moon and Mars.

Eshleman was not involved in Pioneer 10 and 11 radio occultation experiments at Jupiter until it became apparent that the radio results differed radically from results obtained by other instruments. Over several years, Eshleman and others worked out the corrections needed for analysis when planets are oblate (as the gas giants are because of their rapid rotation). Eshleman led the Radio Science Team through the very successful Voyager 1 and 2 planning, implementation, and Jupiter encounters, then handed off day-to-day operations to Tyler.

After Voyager, Eshleman focused on topics such as evolute flashes during deep radio occultations, stellar gravitational lenses and their effects on propagating radio waves, ring particle dynamics, absorption in planetary atmospheres (with students Paul Steffes and Tom Spilker), and retro-reflection from icy planetary surfaces. Although not a member of the science team, he got to see the ultimate radio occultation experiment (an uplink implementation) when New Horizons passed Pluto and signals transmitted from Earth were perturbed by its barely detectable atmosphere.

Dozens of graduate students benefited from Eshleman's direct mentoring; but he was also an innovative classroom teacher. He converted a mezzanine-level class on electromagnetics to a generalized "waves" class for a broader audience of Stanford graduate students — such as those interested in acoustics, seismology, and oceanography. For advanced undergraduates, he developed a new class called "Planetary Exploration," which was attractive to students with science, engineering, and mathematics skills but who were not majoring in astronomy.

Eshleman maintained contacts with industry, serving as a consultant for North American Rockwell and Watkins-Johnson. He advised the McGraw-Hill Book Company, the National Bureau of Standards, and (of course) NASA. He also served briefly as Deputy Director of the Office of Technology Policy and Space Affairs in the U.S. Department of State. But he always returned to the skilled and productive use of electromagnetics to explore the universe — a task that his associates recall that he not only wanted to do, but to do well.

— Text courtesy of Richard Simpson and other colleagues at Stanford University

Elmar K. Jessberger, 1943–2017

Elmar K. Jessberger passed away on November 29, 2017, at the age of 74. Jessberger was a Fellow of The Meteoritical Society since 1994 and chairman of the Leonard Medal Committee from 2001 to 2002. He was organizer of the Society's 66th annual meeting 2003 in Münster. Main belt asteroid 16231 Jessberger, discovered in 2000, was named after him in 2005.

Jessberger received his Ph.D. from Heidelberg University in 1971 with a thesis on mass spectrometric analysis of trapped gases in lunar material, meteorites, and terrestrial basalts. This study was performed with Josef Zähringer and Till Kirsten at the Max Planck Institute for Nuclear Physics in Heidelberg, where Jessberger had started working as an undergraduate in 1968 and where he stayed, ultimately as a senior scientist, until 1996. During that time, he received a National Science Foundation (NSF) fellowship and worked from 1972 to 1973 with Gerald Wasserburg at the California Institute of Technology. As a guest scientist, Jessberger visited the State University of New York in Stony Brook in 1981 and the McDonnell Center for the Space Sciences, Washington University, in St. Louis, Missouri, in 1984. From 1991 to 1992, he spent a sabbatical at the University of Vienna and the Natural History Museum in Vienna.

Most of Jessberger's early work was related to ^{40}Ar-^{39}Ar dating of lunar rocks, meteorites, and terrestrial impact crater material. Later, he started working on interplanetary dust particles using proton-induced X-ray spectroscopy (PIXE). In 1986, after the flyby of the Vega 1 and 2 and Giotto space probes at Comet 1P/Halley, Jessberger got heavily involved in the evaluation and interpretation of the data from the impact-ionization mass spectrometers onboard those missions. During his involvement in further space experiments, which ultimately led to the COSIMA instrument for the European Rosetta mission to Comet 67P/Churyumov-Gerasimenko, he promoted establishing time-of-flight secondary ion mass spectrometry (TOF-SIMS) as a new technique in cosmochemistry. His credo always was that sample analysis in space has to be complemented by state-of-the-art laboratory analysis here on Earth.

In 1996, Elmar became full professor of Analytical and Experimental Planetology at the Institute for Planetology at the University of Münster. During his time in Münster, he established a dedicated TOF-SIMS laboratory, which played an important role in the analysis of cometary samples returned by the Stardust mission. He was one of the initiators of the Mercury Radiometer and Thermal Infrared Spectrometer (MERTIS) for the BepiColombo mission and promoted GENTNER, a combined laser-induced breakdown spectroscopy (LIBS) and Raman spectroscopy instrument, for the ExoMars mission.

After his retirement in 2008, Elmar stayed involved in science, mainly as an advisor in some of the projects he initiated. He was especially pleased to see his scientific legacy live on in the work of his numerous former students. Elmar constantly promoted the careers of his students and enabled them to become successful scientists.

Those of us who had the privilege to work closely with Jessberger will miss him as a great mentor and very good friend.

— Text courtesy of Thomas Stephan and Mario Trieloff/The Meteoritical Society

LPI Announces Shoemaker Impact Cratering Award Recipient

The Lunar and Planetary Institute (LPI) is pleased to announce that the 2017 recipient of the Eugene M. Shoemaker Impact Cratering Award is Maree McGregor of the University of New Brunswick in Canada. McGregor is pursuing a Ph.D. study in geochronology and shock processes of terrestrial impact craters. She is working with Dr. John Spray at the Planetary and Space Science Centre (PASSC), University of New Brunswick. With funds provided from the award, McGregor will revisit the remote Nicholson Lake impact structure, Canada, where she will undertake a detailed mapping campaign of the crater, with sample analysis involving thermobarometric and shock attenuation analysis.

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 2018. Applications will be accepted beginning in July 2018. Application details can be found at https://www.lpi.usra.edu/science/kring/Awards/Shoemaker_Award/.

Adler Planetarium Astronomer Dr. Lucianne Walkowicz Named Chair in Astrobiology at the Library of Congress

Adler Astronomer Lucianne Walkowicz will hold the fifth Baruch S. Blumberg NASA/Library of Congress Chair in Astrobiology in the John W. Kluge Center at the Library of Congress. She will begin on October 1, 2017, and be in residence for 12 months.

Walkowicz is an astronomer at the Adler Planetarium, in Chicago, where she studies stellar magnetic activity and its influence on planetary habitability, using data from NASA's Kepler Mission. Walkowicz holds a B.S. in Physics and Astronomy from Johns Hopkins University and an M.S. and Ph.D. in Astronomy from the University of Washington. She is also a TED Senior Fellow and a practicing artist, working in a variety of media, from oil paint to sound.

At the Library of Congress, Walkowicz will work on a project titled "Fear of a Green Planet: Inclusive Systems of Thought for Human Exploration of Mars." The project is designed to create an inclusive framework for human exploration of Mars, a vision that encompasses both cutting-edge research on Mars as a place of essential astrobiological significance, and that weaves in lessons from the diverse histories of exploration on our own planet. "The Library of Congress collections include unique legislative material, which can provide primary resources on the international and domestic policies governing human exploration of space," says Walkowicz, who will also convene public meetings, bringing together the brightest, most diverse minds working at the intersections of space and society today, to explore paths toward becoming an interplanetary species that enhances access to space, rather than mirroring our Earthbound inequalities.

2017 Breakthrough Junior Challenge

Breakthrough Junior Challenge Winner Hillary Diane A. Andales attends the 2018 Breakthrough Prize at NASA Ames Research Center on December 3, 2017, in Mountain View, California. Credit: Photo by Jesse Grant/Getty Images.

The Breakthrough Junior Challenge is a global science video competition designed to inspire creative thinking about fundamental concepts in the life sciences, physics, and mathematics. In recognition of her winning submission, Hillary Diane Andales receives up to $400,000 in educational prizes, including a scholarship worth up to $250,000, another $50,000 for the science teacher who inspired her, and a state-of-the-art science lab valued at $100,000 designed by and in partnership with Cold Spring Harbor Laboratory.

This was Andales' second time in the competition, and last year, she was the Top Scorer in the Popular Vote, a segment of the contest that allows the public to vote for their favorites online. As the Top Scorer in the Popular Vote, she won a DNA molecular biology laboratory as her school recovered from damage by Typhoon Haiyan in 2013. This year, her overall victory in the competition will secure for her school a Fabrication/Physics/Design/Innovation Lab.

More than 11,000 entries from 178 countries were received in the 2017 installment of the global competition, which kicked off on September 1, 2017. The Breakthrough Junior Challenge is funded by Mark Zuckerberg and Priscilla Chan, and Yuri and Julia Milner, through the Breakthrough Prize Foundation, based on a grant from Mark Zuckerberg's fund at the Silicon Valley Community Foundation and a grant from the Milner Global Foundation.

AAS Division For Planetary Sciences Announces 2017 Prize Winners

Division for Planetary Sciences of the AMERICAN ASTRONOMICAL SOCIETY AAS

The Division for Planetary Sciences (DPS) of the American Astronomical Society (AAS) is pleased to announce its 2017 prize winners.

Gerard P. Kuiper Prize for outstanding contributions to the field of planetary science —

The Gerard P. Kuiper Prize for outstanding contributions to planetary science goes to Margaret G. Kivelson (University of California, Los Angeles, and University of Michigan) for her work studying Jupiter's magnetospheric plasmas to understand the interiors of planets and their moons. Kivelson's pioneering discoveries of an ocean inside Jupiter's moon Europa and a magnetic field generated by neighboring Ganymede showed us that these icy bodies are not inert but dynamic worlds. Her insights have spurred us to recognize that habitability need not depend on proximity to the Sun in the traditional habitable zone. As a direct result of Kivelson's advancements, we now recognize that the ocean worlds of the outer solar system may represent our best chances for discovering life beyond Earth.

Portrait painted by Pamela Davis Kivelson.

Harold C. Urey Prize for outstanding achievement in planetary research by a young scientist —

Bethany L. Ehlmann (California Institute of Technology) received the Harold C. Urey Prize for outstanding achievement in planetary research by an early-career scientist for her work using spectroscopy to determine the mineralogy of Mars' surface and the extent of the Red Planet's previous habitability. Ehlmann's discovery of carbonates, serpentines, and clay minerals in Mars' most ancient rocks shows that multiple types of clement and hospitable environments existed early in martian history, especially the most ancient groundwater-fed environments as yet unvisited by rovers. Her inspiring work has motivated the development of Mars exploration strategies and methods, has been applied to other solar system bodies, and will continue to drive planetary science forward.

Harold Masursky Award for outstanding service to planetary science and exploration —

Receiving the Harold Masursky Award for meritorious service to planetary science is Louise M. Prockter (Lunar and Planetary Institute) for her tireless participation and leadership serving on National Research Council boards and NASA committees, which has ensured that the community's voice is heard and that science priorities are established and followed. Her work with engineers has extended the scientific return of multiple NASA missions beyond their original goals. By setting up support groups and mentoring female scientists, Prockter ensured faster development of early-career researchers who have made strong contributions to the field. By choosing to serve, Prockter and the committees on which she has participated have advanced the field of planetary science and engaged more scientists successfully in discovery.

Carl Sagan Medal for outstanding communication by an active planetary scientist to the general public —

This year the DPS awarded two Carl Sagan Medals for excellence in public communication by active planetary scientists.

One medal goes to Megan E. Schwamb (Gemini Observatory) for the creation and development of new tools and venues to facilitate planetary science communication. Schwamb created the Astrotweeps project, in which a different astronomer drives the same Twitter account (@astrotweeps) each week. She started Astronomy on Tap to promote direct dissemination of planetary science in bars and restaurants. Perhaps the most valuable aspect of Schwamb's outreach work, though, revolves around creating a channel for communication in the other direction by enabling amateurs to contribute to ongoing research. The citizen science of Planet Hunters and Planet Four, facilitated by Schwamb, form the basis of this new mode of interaction.

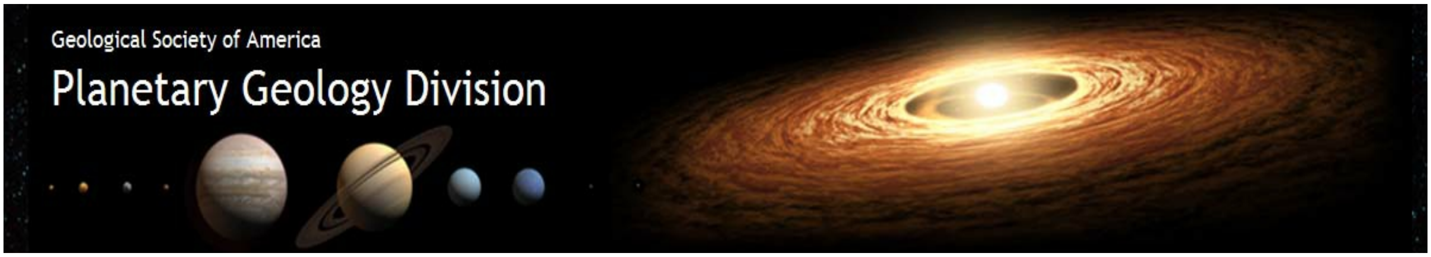
Also receiving the Carl Sagan Medal is Henry B. Throop (Planetary Science Institute) for his efforts to kindle interest in worlds beyond Earth throughout the developing world. Throop's presentations in South Africa, India, Namibia, Botswana, Nepal, and Mexico reach audiences who might otherwise not be exposed to planetary science. He closely collaborates with teachers and works with a diverse group of students and the public to stimulate their curiosity and show them how they can explore the world around them. With his engaging personality and genuine interest in interacting with students and teachers in far-flung places, Throop presents a positive face for science using planetary exploration as a driver.

Jonathan Eberhart Planetary Sciences Journalism Award to recognize and stimulate distinguished popular writing on planetary sciences —

The Jonathan Eberhart Planetary Sciences Journalism Award for distinguished popular writing goes to Cambridge, Massachusetts-based science writer Joshua Sokol for his article "Hidden Depths" in the August 13, 2016, issue of *New Scientist.* In his thoroughly researched and beautifully written story, Sokol explains how icy worlds far from the Sun's warmth, such as Jupiter's moon Europa and Saturn's moon Enceladus, can maintain subsurface oceans. After describing the otherworldly environment of our own planet's deep seafloor and the creatures that dwell there, he explores how hydrothermal and chemical processes within extraterrestrial oceans might support microbes or other forms of life. Sokol's article ends with the compelling and provocative suggestion that ice worlds with concealed oceans may be the norm, making Earth — with its exposed oceans — an outlier.

The 2017 DPS prizes were presented at the 49th annual DPS meeting, which was held in Provo, Utah, in October.

GSA's Planetary Geology Division Announces 2017 Award Winners



2017 Dwornik Award

The Dwornik Award was endowed by Stephen E. Dwornik in 1991 to encourage students in the field of planetary science. The Dwornik Award originally acknowledged the best oral presentation at both LPSC and GSA, with the winners traveling to Washington, DC, to accept their award. Due to the overwhelming number of planetary-related presentations at LPSC relative to GSA, the award later became a LPSC-only competition but expanded to include honorable mentions and poster presentations. A brief biography of Stephen Dwornik's influential career can be found on the Dwornik Award webpage: http://rock.geosociety.org/pgd/dwornik.html.

The 2017 Dwornik winners are:

Best Graduate Oral Presentation: R. Terik Daly, Brown University, "Projectile preservation during oblique hypervelocity impacts"

Honorable Mention — Graduate Oral: Kevin M. Cannon, Brown University, "Primordial clays on Mars formed beneath a steam or supercritical atmosphere"

Graduate Poster: Tess E. Caswell, Brown University, "Grain size evolution in icy satellites: New experimental constraints"

Honorable Mention — Graduate Poster: Hannah H. Kaplan, Brown University, "Reflectance spectrosocopy of meteorite insoluble organic matter (IOM)"

Undergraduate Oral: Allison M. McGraw, University of Arizona, "Do L-chondrites come from the Gefion asteroid family?"

Honorable Mention — Undergraduate Oral: Carol B. Hundal, Wellesley College, "Chronology of fresh rayed craters in Elysium Planitia, Mars"

Undergraduate Poster: Emma S. Sosa, "Constraining the petrogenesis of the paired achondrites GRA 06128/9 through partial melting of an oxidized chondrite"

Honorable Mention — Undergraduate Poster: Isabel R. King, Harvey Mudd College, "Evolution of circular polarization ratio (CPR) profiles of kilometer-scale craters on the lunar maria"

2017 Pellas-Ryder Award

The Pellas-Ryder award is given to the Planetary Science Best Student Paper published during the preceding year. The award is jointly given by the Meteoritical Society and the Planetary Geology Division of the Geological Society of America and includes a $500 award from the Meteoritical Society and a plaque awarded by the PGD. This year's Pellas-Ryder award was jointly awarded to Gerrit Budde of Wilhelms- Universität Münster Germany and James Keane of the University of Arizona.

Budde's paper was "Tungsten isotopic constraints on the age and origin of chondrules" in*Proceedings of the National Academy of Sciences, 113,* 2886–2891.

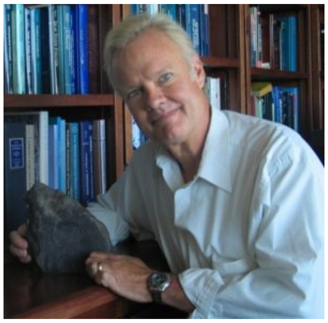
Keane's paper was "Reorientation and faulting of Pluto due to volatile loading within Sputnik Planitia" in *Nature*, *540(7631),* 90–93.

Congratulations to all these winners!

Meteoritical Society Awards

THE METEORITICAL SOCIETY
International Society for Meteoritics and Planetary Science

2017 Leonard Medal —



This is the society's highest and oldest award and is given to individuals who have made outstanding original contributions to the science of meteoritics or closely allied fields. It is named for Frederick C. Leonard, who was a founder of the Meteoritical Society and its first president. This year the award was presented to Mark Thiemens (University of California, San Diego, USA), for the fundamental insight that local chemical fractionation processes can explain oxygen isotope systematics in the early solar system, a seminal breakthrough in understanding one of the most important observations in meteoritics.

2017 Barringer Medal and Award —

Both the medal and the award are sponsored by the Barringer Crater Company and were created in memory of D. Moreau Barringer Sr. and his son D. Moreau Barringer Jr. The award is given for outstanding work in the field of impact cratering. This year, the Barringer Award is given to Akira Fujiwara (Institute of Space and Astronautical Science, and the Japan Aerospace Exploration Agency) for his pioneering work in the investigation of the collisional disruption of small bodies in the solar system. The citation was given by Masanao Abe.

2017 Nier Prize —

This prize is awarded to a young scientist in the field of meteoritics, and the 2017 winner is Francis McCubbin of the NASA Johnson Space Center (Houston, Texas, USA). McCubbin receives this award for his significant contributions to our understanding of lunar volatiles, and the cosmochemical implications for both lunar and solar system evolution. The citation was given by Carl Agee.

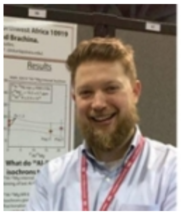
2017 Service Award —

Cecilia Satterwhite of Jacobs, Inc. (at NASA Johnson Space Center), in Houston, Texas, is the winner of the 2017 Meteoritical Society Service Award. Satterwhite receives this award for her effort in curatorial work that is critical to implementation of essentially all research on the U.S. Antarctic meteorite (ANSMET) collections. The citation was given by Kevin Righter. This award honors members who have advanced the goals of the Society to promote research and education in meteoritics and planetary science in ways other than by conducting scientific research.

2017 Gordon A. McKay Award —

This award is given for the best oral presentation by a student at the annual meeting of the 80th Annual Meeting of the Meteoritical Society. The 2017 award goes to Jennika Greer of the University of Chicago (Illinois, USA) for her talk entitled “Atom Probe Tomography of Lunar Regolith Ilmenite Grain Surfaces.” The McKay Award honors the memory of Gordon A. McKay and is supported by the McKay Fund, established in 2008 as a part of the society’s endowment.

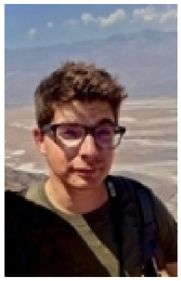
The Wiley Award —



Daniel R. Dunlap

Maximilien J. Verdier

Jonas Pape



Lionel G. Vacher

Sponsored by the publisher of *Meteoritics and Planetary Science*, four Wiley Awards are given each year for outstanding oral presentations by students at the annual meeting. For this year's meeting in Santa Fe, the awardees are Daniel R. Dunlap (Arizona State University) for the presentation "^{26}Al-^{26}Mg Systematics of the Ungrouped Achondrite Northwest Africa 11119: Timing of Extraterrestrial Silica-Rich Magmatism," Maximilien J. Verdier (Muséum National d'Histoire Naturelle, Paris) for the presentation "Temperature Precipitation of Ca-Carbonates in CM Chondrites Inferred from In-Situ Oxygen Isotopes," Jonas Pape (University of Bern) for the presentation "In-Situ ^{26}Al-^{26}Mg Dating of Single Chondrules by Secondary Ion Mass Spectrometry," and Lionel G. Vacher (Université de Lorraine, France) for the presentation "Petrographic and Isotopic C and O Survey of the Earliest Stages of Aqueous Alteration of CM Chondrites."

New Space Policy Directive Calls for Human Expansion Across Solar System

President Donald Trump is sending astronauts back to the Moon.

On December 11, 2017, the president signed at the White House Space Policy Directive 1, a change in national space policy that provides for a U.S.-led, integrated program with private sector partners for a human return to the Moon, followed by missions to Mars and beyond.

The policy calls for the NASA administrator to "lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities." The effort will more effectively organize government, private industry, and international efforts toward returning humans on the Moon, and will lay the foundation that will eventually enable human exploration of Mars.

Representatives of Congress and the National Space Council joined President Donald J. Trump, Apollo astronaut Jack Schmitt, and current NASA astronaut Peggy Whitson on Monday, December 11, 2017, for the president's signing of Space Policy Directive 1, a change in national space policy that provides for a U.S.-led, integrated program with private sector partners for a human return to the Moon, followed by missions to Mars and beyond. Credits: WhiteHouse.gov.

The policy grew from a unanimous recommendation by the new National Space Council, chaired by Vice President Mike Pence, after its first meeting on October 5, 2017. In addition to the direction to plan for human return to the Moon, the policy also ends NASA's existing effort to send humans to an asteroid. The president revived the National Space Council in July to advise and help implement his space policy with exploration as a national priority.

Among other dignitaries on hand for the signing were NASA astronauts Senator Harrison "Jack" Schmitt, Buzz Aldrin, Peggy Whitson, and Christina Koch. Schmitt landed on the Moon 45 years to the minute that the policy directive was signed as part of NASA's Apollo 17 mission, and is the most recent living person to have set foot on our lunar neighbor. Aldrin was the second person to walk on the Moon during the Apollo 11 mission. Whitson spoke to the president from space in April onboard the International Space Station and while flying back home after breaking the record for most time in space by a U.S. astronaut in September. Koch is a member of NASA's astronaut class of 2013.

Work toward the new directive will be reflected in NASA's Fiscal Year 2019 budget request next year.

NASA Establishes Advisory Group for National Space Council

NASA has established a new advisory group on behalf of the National Space Council that will represent the expertise, interests, and perspectives of non-federal aerospace organizations to the National Space Council.

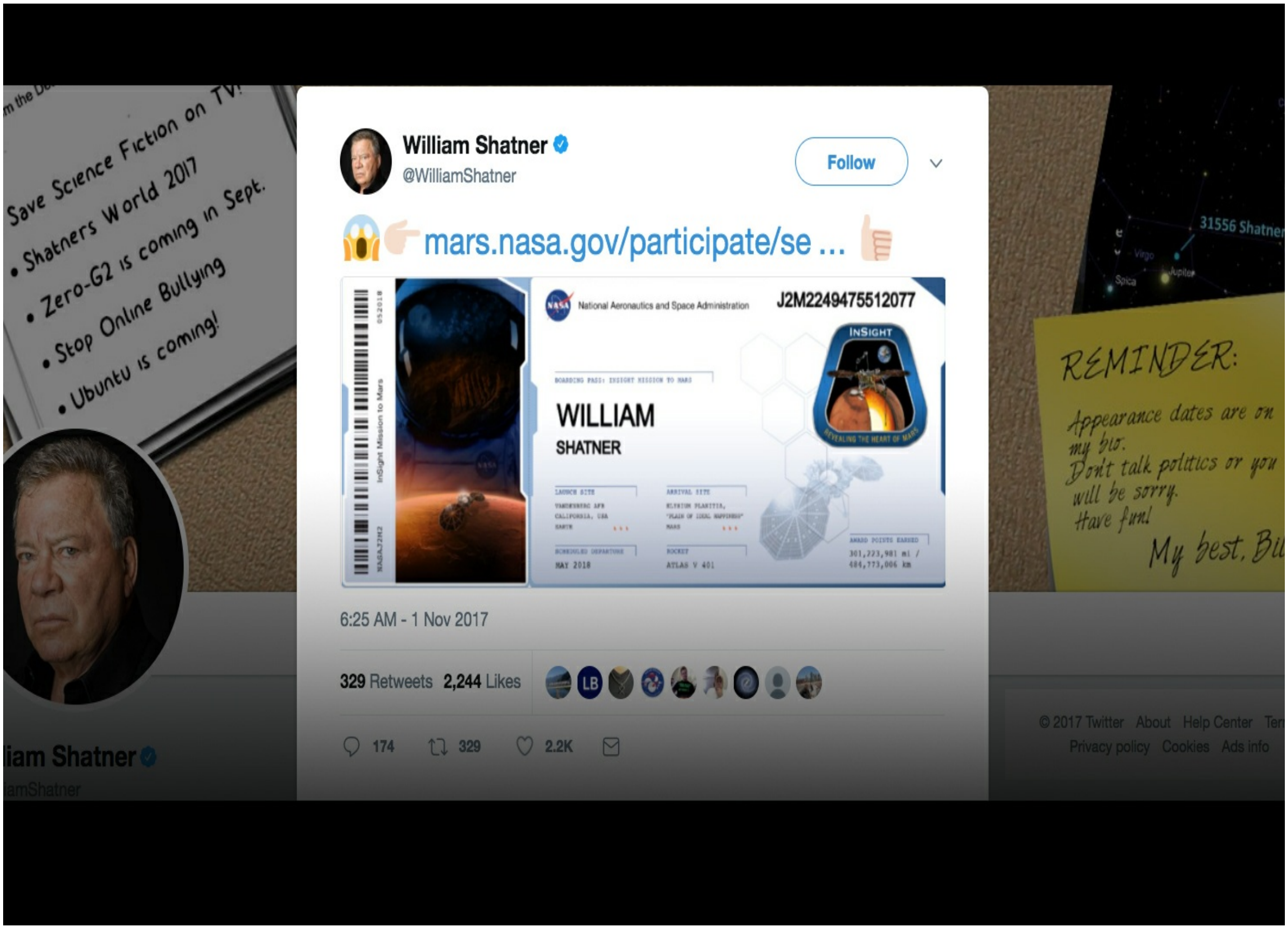
The official charter for the Users' Advisory Group (UAG) was signed by acting NASA Administrator Robert Lightfoot on December 6, 2017, and subsequently announced in the Federal Register. It explains in detail the role, responsibilities, and operation of the advisory group. The UAG will advise and inform the National Space Council on a broad range of aerospace topics, including the impacts of U.S. and international laws and regulations, national security space priorities relating to the civil and commercial space sectors, scientific and human space exploration priorities, and ways to bolster support for U.S. space priorities and leadership in space.

The UAG will consist of between 15 and 30 members selected to serve in the capacity of either a representative or a special government employee (SGE). Representatives will come from non-federal aerospace organizations, such as private industry, and act as advocates for their sector. SGEs will be selected for their expertise in their particular aerospace field to provide objective advice. More information on the member nomination process will be made available later.

The charter is available on NASA's website at *https://oiir.hq.nasa.gov/acmd.html*.

Vice President Mike Pence delivers opening remarks during the National Space Council's first meeting, Thursday, October 5, 2017, at the Smithsonian National Air and Space Museum's Steven F. Udvar-Hazy Center in Chantilly, Virginia. The National Space Council, chaired by Vice President Mike Pence, heard testimony from representatives from civil space, commercial space, and national security space industry representatives. Credit: NASA/Joel Kowsky.

More Than 2.4 Million Names are Going to Mars



NASA invited members of the public to send their names to Mars. And the public responded loud and clear.

More than 1.6 million people signed up to have their names etched on a microchip that will be carried on NASA's upcoming InSight mission, which launches in May of 2018.

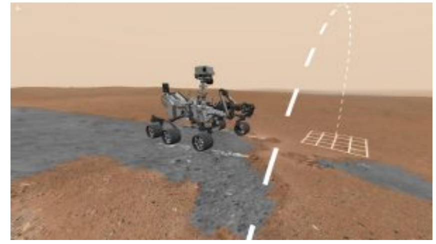
NASA's Jet Propulsion Laboratory in Pasadena, California, reopened the opportunity after it proved successful in 2015. During that open call, nearly 827,000 names were collected for a microchip that now sits on top of the robotic InSight lander.

The grand total once a second microchip is added in early 2018 will be 2,429,807 names. Space enthusiasts who signed up this last round shared their downloadable "boarding passes" on social media, complete with the total number of flight miles they've collected by participating in engagement initiatives for other Mars missions.

InSight will be the first mission to look deep beneath the martian surface, studying the planet's interior by listening for marsquakes. These quakes travel through geologic material at different speeds and give scientists a glimpse of the composition and structure of the planet's insides. The insights into how Mars formed will help us better understand how other rocky planets are created.

Take a Walk on Mars with Access Mars Experience

When NASA scientists want to follow the path of the Curiosity rover on Mars, they can don a mixed-reality headset and virtually explore the martian landscape.



Access Mars allows any member of the public to explore the discoveries of NASA's Curiosity rover. Credit: NASA/JPL-Caltech.

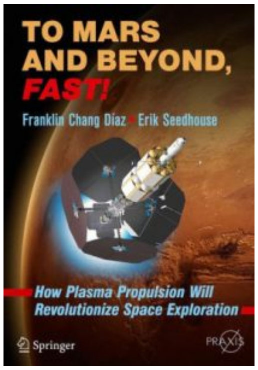
Now everyone can get a taste of what that feels like. NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, collaborated with Google to produce Access Mars, a free immersive experience. It's available for use on all desktop and mobile devices and virtual reality/augmented reality (VR/AR) headsets. That includes mobile-based virtual reality devices on Apple and Android.

Access Mars lets anyone with an Internet connection take a guided tour of what those scientists experience. A simple walkthrough explains what the Curiosity rover does and details its dramatic landing in 2012. Users also can visit four sites that have been critical to NASA's Mars Science Laboratory mission: Curiosity's landing site, Murray Buttes, Marias Pass, and Pahrump Hills. Additionally, the rover's latest location on lower Mt. Sharp will be periodically updated to reflect the mission's ongoing progress.

Access Mars was created using data collected by JPL and built on WebVR, an open-source standard, in an effort to expand access to immersive experiences. Google's Creative Labs team was looking for novel uses for VR and encouraged developers to experiment using its tools.

To experience Access Mars, visit *http://g.co/accessmars.*

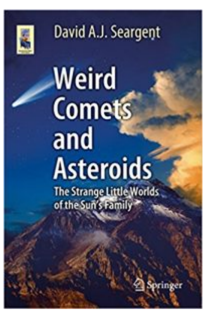
To Mars and Beyond, Fast! How Plasma Propulsion Will Revolutionize Space Exploration



Springer, 2017, 201 pp., Paperback, $34.99.www.springer.com

As advanced in-space propulsion moves from science fiction to reality, the Variable Specific Impulse Magnetoplasma Rocket (VASIMR®) engine, is a leading contender for making "Mars in a month" a possibility. A paradigm shift in space transportation, this book is an in-depth and compelling story co-written by its inventor. It traces the riveting history of the development of the VASIMR® engine. This landmark technology is grounded in concepts of advanced plasma physics. It cross-pollinates ideas and disciplines to offer a new, practical, and sustainable solution for in-space transportation beyond low-Earth orbit in the decades to come. Invented by the co-holder of the world's spaceflight record, astronaut Franklin Chang Díaz, the VASIMR® engine is developed by Ad Astra Rocket Company in its Texas facilities with NASA as part of the NextSTEP VASIMR® partnership. With adequate funding, the first spaceflight of the VASIMR® engine is imminent. Plasma rockets feature exhaust velocities far above those achievable by conventional chemical rockets. The VASIMR® engine is the most advanced high-power plasma propulsion system operating in the world today and it may place long, fast interplanetary journeys within our reach in the near future.

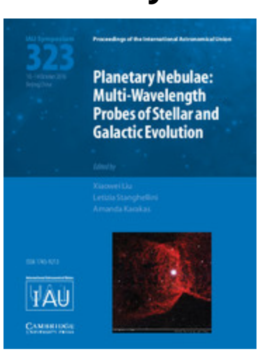
Weird Comets and Asteroids: The Strange Little Worlds of the Sun's Family



Springer, 2017, 279 pp., Paperback, $34.99.www.springer.com

This book concentrates on some of the odd aspects of comets and asteroids. Strange behavior of comets, such as outbursts and schisms, and how asteroids can temporally act as comets are discussed, together with the possible threat of Centaur-class objects like the Taurid complex. Recent years have seen the distinction between comets and asteroids become less prominent. Comets in "asteroid" orbits and vice versa have become almost commonplace, and a clearer view of the role of small bodies in the formation of the solar system and their effect on Earth has become apparent. The author covers this development in detail by including new data and information from space probes.

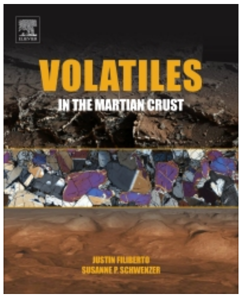
Planetary Nebulae: Multi-Wavelength Probes of Stellar and Galactic Evolution



Cambridge University Press. 2017, 500 pp., Hardcover, $125.00. www.cambridge.org

Planetary nebulae, glowing shells of ionized gas, are the spectacular products of the evolution of low- and intermediate-mass stars. For astrophysicists, they are important laboratories for the understanding of atomic, molecular, dust, and plasma processes in different cosmic environments; they enable the exploration of the fundamental physics of single and binary star evolution including nucleosynthesis, rotation, mass transfer and loss, and magnetic fields; and they help trace stellar populations, the kinematics, and chemistry of galaxies including our own galaxy, the Milky Way. This volume reviews the current status of this vibrant research field in the form of invited reviews, contributed talks, and posters presented at International Astronomical Union (IAU) Symposium 323. This book will be of interest to researchers and advanced students interested in this field and in related fields, including stellar physics, the interstellar medium, and galactic and extragalactic astronomy.

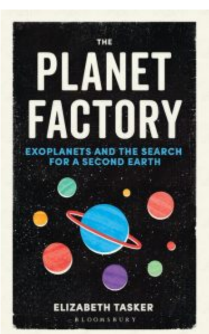
Volatiles in the Martian Crust



Elsevier, 2017, 432 pp., Paperback, $99.95. www.elsevier.com

Volatiles in the Martian Crust is a vital reference for future missions — including ESA's EXO Mars and NASA's Mars2020 rover — looking for evidence of life on Mars and the potential for habitability and human exploration of the martian crust. Mars science is a rapidly evolving topic with new data returned from the planet on a daily basis. The book presents chapters written by well-established experts who currently focus on the topic, providing the reader with a fresh, up-to-date, and accurate view. Organized into two main sections, the first half of the book focuses on the martian meteorites and specific volatile elements. The second half of the book explores processes and locations on the crust, including what we have learned about volatile mobility in the martian crust. Coverage includes data from orbiter and *in situ* rovers and landers, geochemical and geophysical modeling, and combined data from the SNC meteorites.

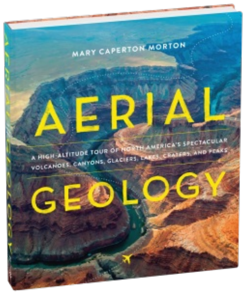
The Planet Factory: Exoplanets and the Search for a Second Earth



Bloomsbury Sigma, 2017, 336 pp., Hardcover, $27.00. www.bloomsbury.com

The search for planets — and life — outside the solar system is one of the most rapidly growing fields in astronomy, with thousands of these "exoplanets" discovered so far. The detection of these worlds has only been possible in the last decade, with the number of discoveries increasing enormously over the last year following the findings of the Kepler Space Telescope. These new worlds are more alien than anything in fiction. Planets larger than Jupiter with years lasting one week, planets circling the dead remains of stars, and others with two suns lighting their skies or with no sun at all. These locations hint at Earth-sized worlds but with split hemispheres of perpetual day and night, water worlds drowning under global oceans, and volcanic lava planets spewing seas of magma. *The Planet Factory* tells the story of exoplanets, planets orbiting stars outside of our solar system. Discover the specks of dust that circle a young star come together in a violent building project that can form colossal worlds hundreds of times the size of the Earth; the changing orbits of young planets that risk dooming the life forming on neighboring worlds or, alternatively, that can deliver the key ingredients needed to seed its beginnings. Exoplanets are one of the greatest construction schemes in the universe and they occur around nearly every star you see. Each result is an alien landscape, but is it possible that one of these could be like our own home? *The Planet Factory* discusses the way these planets form, their structure and features, and describes in detail the detection techniques used (there are many) before looking at what we can learn about the surface environments and planetary atmospheres, and whether this hints at the tantalizing possibility of life.

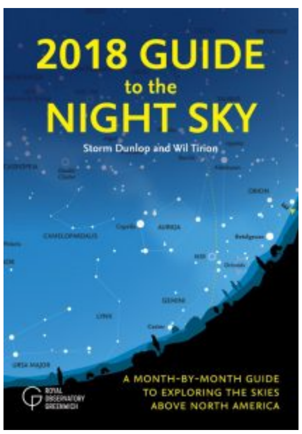
Aerial Geology: A High-Altitude Tour of North America's Spectacular Volcanoes, Canyons, Glaciers, Lakes, Craters, and Peaks



Workman Press. 2017, 308 pp., Hardcover, $29.95.www.workman.com

Sit back and enjoy a new view.*Aerial Geology* is an up-in-the-sky exploration of North America's 100 most spectacular geological formations. Crisscrossing the continent from the Aleutian Islands in Alaska to the Great Salt Lake in Utah and to the Chicxulub Crater in Mexico, author Mary Caperton Morton takes you on a tour, sharing aerial and satellite photography, and providing explanations on how each site was formed and details on what makes each landform noteworthy. Maps and diagrams help illustrate the geological processes and clarify scientific concepts. Fact-filled, curious, and way more fun than the geology you remember from grade school, *Aerial Geology* is a must-have for insatiably curious armchair geologists, million-mile travelers, and anyone who has stared out the window of a plane and wondered what was below.

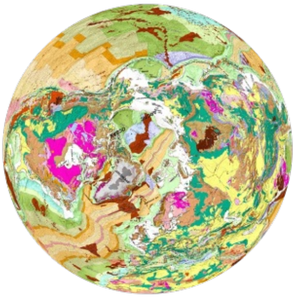
2018 Guide to the Night Sky: A Month-by-Month Guide to Exploring the Skies Above North America



Firefly Books, 2017, 96 pp., Paperback, $14.95.www.fireflybooks.com

The night sky is always an amazing sight, but it's a thrill when you can locate stars or catch sight of a meteor. With *2018 Guide to the Night Sky,* amateur astronomers can view the sky over the course of the year and not miss a thing. It is also a compact and comprehensive introduction to astronomy. Using the guide's charts and maps and following the text, sky watchers can enjoy viewing the night sky with nothing more complicated than a pair of binoculars or the naked eye. With its maps centered on latitude 40° north, this guide will help backyard astronomers in the United States and Canada see how the visible stars change over the year, and ensure that they catch the exciting sky events that occur. In addition to the month-by-month guides, the guide includes an introduction to the planets, sky and constellation maps, moon and meteor calendars, and ecliptic charts. An appendix includes a glossary, the Greek alphabet, the constellation genitives, common asterisms, software and Internet sources, and much more. The small and light format makes this book the ideal portable reference. This book provides a good introduction for new astronomers, helping them enjoy the thrill of seeing one-time sky events, follow the changes in the night sky, and learn about the Milky Way and its resident stars. The background and technical information will serve beginning astronomers well as they develop their skills for a lifetime of sky watching.

Geological Globe of the World



10-inch (25-centimeter) assembled globe, $250.00; 18-inch (46-centimeter) assembled globe, $450.00; and 30-inch (76-centimeter) assembled globe, $3000.00. www.realworldglobes.com

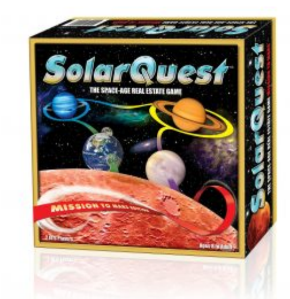
This unique Geological Globe of the World features rich geological information content about Earth compiled from geological maps of hundreds of countries from both national and international organizations. This is a comprehensive and undistorted view of Earth's global geology. Experience for the first time an accurate depiction of the geological features of the world without map projection distortions. Both the size and shape of geological features are accurately represented. This globe is available in three sizes: small (10-inch diameter, or 25 centimeters), large (18-inch diameter, or 46 centimeters), and colossal (30-inch diameter, or 76 centimeters). It can be ordered as a build-it-yourself kit or assembled. It is lightweight and has a protective dry-erase and wet-erase surface. A ring stand for displaying the globe is included.

Space Machines

QEB Publishing, 2017, 24 pp., Hardcover. $17.95. www.quartoknows.com

Discover all there is to know about the machines used in space by building them with this interactive guide! *Space Machines* includes everything you will need and full, step-by-step instructions to build nine different space machines with working parts. With a pegboard and 40 sturdy, colorful machine pieces, plus plastic nuts and bolts, this is the perfect, hands-on introduction for budding engineers and sci-fi fans everywhere. For ages 5–8.

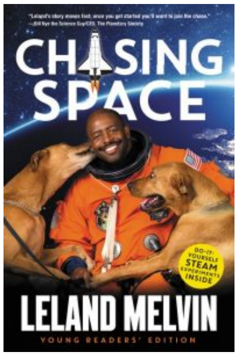
SolarQuest, The Space-Age Real Estate Game: Mission to Mars Edition



$39.00.

This special edition of the classic board game SolarQuest includes enhanced graphics, the major dwarf planets, magnets on the Fuel Card and game board to hold the Fuel Stations in place, two levels of game play including an easy version that does not require fuel monitoring for younger players, and special rules that make the planet Mars the coveted "Boardwalk" of the solar system. This game is designed to be played by two to six players. For ages 8 and up.

Chasing Space



Harper Collins, 2017, 240 pp., Hardcover. $17.99. www.harpercollins.com

In this inspiring memoir, young readers will get to learn about Leland Melvin's remarkable life story, from being drafted by the Detroit Lions; to bravely orbiting our planet in the International Space Station; to writing songs with will.i.am, working with Serena Williams, and starring in top-rated television shows like *The Dog Whisperer*, *Top Chef*, and *Child Genius*. When the former Detroit Lion's football career was cut short by an injury, Leland didn't waste time mourning his broken dream. Instead, he found a new one — something that was completely out of this world. He joined NASA, braved an injury that nearly left him permanently deaf, and still managed to muster the courage and resolve to travel to space on the shuttle Atlantis to help build the International Space Station. Leland's problem-solving methods and can-do attitude turned his impossible-seeming dream into reality. His story introduces readers to the fascinating creative and scientific challenges he had to deal with in space and will encourage the next generation of can-do scientists to dare to follow their dreams. With do-it-yourself experiments in the back of the book and 16 pages of striking full-color photographs, this is the perfect book for young readers looking to be inspired. For ages 8–12.

Sums in Space: An Addition and Subtraction Board Game Adventure

$19.95. www.davincisroom.com

On a deep space mission, your crew is stranded on a planet that's headed toward a black hole. Your only hope of escape is to race back to your rocket ship to escape in time. This game allows kids to practice early math skills — for example, adding and subtracting 0–9, comparing numbers (greater than, less than, equal to), and practicing odds and evens. The game has both cooperative and competitive rules so kids can work together toward a common goal or race each other to the finish. For ages 5 and up and for two to four players.

Space Playing Cards

54 cards. $6.99. www.peaceablekingdom.com

Here's a deck of classic playing cards with a twist: These cards feature planetary artwork by illustrator, author, and computer animator Mark Garlick. For ages 3 and up and for one to several players.

NASA Space Travel Poster Jigsaw Puzzles

500- and 1000-piece puzzles. $16.00 and $18.00. www.newyorkpuzzlecompany.com

The NASA JPL Visions of the Future Poster series features images of imaginative travel destinations. The New York Puzzle Company has created jigsaw puzzles from some of these posters. These 500- and 1000-piece puzzles have a linen-style finish designed to reduce glare and are made in the USA. For ages 7 and up.

Calendar

2018 Upcoming Events

January

Building Bridges from Earth to Life: From Chemical Mechanism to Ancient Biology

- January 9-11
- Tokyo, Japan
- https://elsi6sympo.com/

Lunar Science for Landed Missions Workshop

- January 10-12
- Moffett Field, California
- https://lunar-landing.arc.nasa.gov/

The Prebiotic Milieu Building the Evolution of Early Life

- January 14-19
- Galveston, Texas
- https://www.grc.org/origins-of-life-conference/2018/

18th Small Bodies Assessment Group Meeting

- January 17-18
- Moffett Field, California
- https://www.lpi.usra.edu/sbag/meetings/

2018 EON/ELSI Winter School on Earth-Life Science

- January 22-2
- Tokyo, Japan
- https://elsischool.com/

22nd International Microlensing Conference

- January 25-28
- Auckland, New Zealand
- https://www.physics.auckland.ac.nz/en/about/international-microlensing-conference.html

February

Magnetic Fields or Turbulence: Which is the Critical Factor for the Formation of Stars and Planetary Disks?

- February 6-9
- Hsinchu, Taiwan
- http://events.asiaa.sinica.edu.tw/workshop/20180206/index.php

NASA IRTF Future Directions Workshop

- February 12-14
- Tucson, Arizona
- http://irtfweb.ifa.hawaii.edu/meetings/irtf_future_2018/

Water During Planet Formation and Evolution

- February 12-16
- Zurich, Switzerland
- https://waterzurich.github.io/

Women in Planetary Science and Exploration

- February 17-18
- Toronto, Canada
- http://wpse2018.ca

The 2nd Rencontres du Vietnam on Exoplanetary Science

- February 25-2
- Quy Nhon, Vietnam
- http://rencontresduvietnam.org/conferences/2018/exoplanetary_science/

PERC International Symposium on Dust and Parent Bodies (IDP2018)

- February 26-28
- Chiba, Japan
- http://www.perc.it-chiba.ac.jp/meetings/IDP2018

IX Taller de Ciencias Planetaries (IX Planetary Science Workshop)

- February 26-2
- La Plata, Argentina
- http://tcp2018.fcaglp.unlp.edu.ar/

From Mars Express to Exomars

- February 27-28
- Madrid, Spain
- http://upwards.iaa.es/content/mars-express-exomars

Human Missions and Planetary Protection

- February 27-28
- Houston, Texas
- https://planetaryprotection.nasa.gov/COSPARHumans2018

Deep Space Gateway Science Workshop (#deepspace2018)

- February 27-1
- Denver, Colorado
- https://www.hou.usra.edu/meetings/deepspace2018/

March

International Workshop on Occultation and Eclipse

- March 1-2
- Istanbul, Turkey
- http://iota-me.com/oe.php

IEEE Aerospace Conference

- March 3-10
- Big Sky, Montana
- https://aeroconf.org/

Diversi Mundi (OPS-III): The Solar System in an Exoplanetary Context

- March 5-9
- Santiago, Chile
- http://www.eso.org/sci/meetings/2018/ops2018.html

Merging Giant-Star Asteroseismology with the Fate of Extrasolar Planetary Systems

- March 9
- London, United Kingdom
- https://sites.google.com/view/ras-evolsystems/home

Science with the Atacama Pathfinder Experiment (APEX2018)

- March 11-14
- Tegernsee, Germany
- https://events.mpifr-bonn.mpg.de/indico/event/58/

Planetary Science Deep Space SmallSat Studies

- March 18
- The Woodlands, Texas
- https://www.hou.usra.edu/meetings/smallsat2018/

49th Lunar and Planetary Science Conference (#lpsc2018)

- March 19-23
- The Woodlands, Texas
- https://www.hou.usra.edu/meetings/lpsc2018/

Life on Earth and Beyond: Emergence, Survivability, and Impact on the Environment

- March 19-24
- Bertinoro, Italy
- http://www.arcetri.astro.it/~bertinoro/

UK Exoplanet Community Meeting 2018

- March 21-23
- Oxford, United Kingdom
- https://users.physics.ox.ac.uk/~pierrehumbert/ukexom2018/

Communicating Astronomy with the Public (CAP 2018)

- March 24-28
- Fukuoka, Japan
- https://www.communicatingastronomy.org/cap2018/

The Transneptunian Solar System

- March 26-29
- Coimbra, Portugal
- http://www2.mps.mpg.de/services/coimbra/

Circumplanetary Disks and Satellite Formation

- March 26-30
- Nagoya, Japan
- https://cpdsf2018.wixsite.com/home

SSB Committee on Astrobiology and Planetary Science

- March 27-28
- Washington, D.C.
- http://sites.nationalacademies.org/SSB/SSB_067577#Meetings_and_Events

April

MEPAG Meeting

April 3-5
Washington, DC Area
https://mepag.jpl.nasa.gov/

European Geosciences Union General Assembly 2018

April 8-13
Vienna, Austria
https://www.egu2018.eu/

16th Biennial ASCE International Conference on Engineering, Science, Construction and Operations in Challenging Environments

April 9-12
Cleveland, Ohio
https://earthspaceconf.mst.edu/

2018 Southeastern Sectional Meeting of the Geological Society of America

April 12-13
Knoxville, Tennessee
https://www.geosociety.org/se-mtg

International Conference on Nanoscience and Nanoengineering

April 18-19
Las Vegas, Nevada
https://nanotech.conferenceseries.com/

New Views of the Moon 2 Asia

April 18-20
Fukushima, Japan
https://www.hou.usra.edu/meetings/newviews2018/

Planetary Science Informatics and Data Analytics Conference

April 24-26
St. Louis, Missouri
https://psida.rsl.wustl.edu/

Second International Mars Sample Return Conference

April 25-27
Berlin, Germany
https://atpi.eventsair.com/QuickEventWebsitePortal/2nd-international-conference-on-mars-sample-return/home

May

Mercury: Current and Future Science of the Innermost Planet (#mercury2018)

May 1-3
Columbia, Maryland
https://www.hou.usra.edu/meetings/mercury2018/

Differentiation: Building the Internal Architecture of Planets (#1st1e9)

May 7-11
Pasadena, California
https://www.hou.usra.edu/meetings/differentiation2018/

Sixth European Lunar Symposium

- May 13-16
- Tolouse, France
- https://els2018.arc.nasa.gov/

9th Workshop on Catastrophic Disruption in the Solar System (CD9)

- May 14-17
- Kobe, Japan
- http://www.impact-res.org/CD2018/Catastrophic_Disruption_2018/Welcome.html

MIAPP 2018 Workshop Near Earth Objects: Properties, Detection, Resources, Impacts and Defending Earth

- May 14-8
- Munich, Germany
- http://www.munich-iapp.de/programmes-topical-workshops/2018/near-earth-objects-properties-detection-resources-impacts-and-defending-earth/

Ocean Worlds 3: Water-Silicate Interactions (#oceanworlds2018)

- May 21-24
- Houston, Texas
- https://www.hou.usra.edu/meetings/oceanworlds2018/

iCubeSat 2018 The 7th Interplanetary CubeSat Workshop

- May 29-30
- Paris, France
- https://icubesat.org/

June

15th Annual Meeting, Asia Oceania Geosciences Society

- June 3-8
- Honolulu, Hawaii
- http://www.asiaoceania.org/aogs2018/public.asp?page=home.htm

Cryovolcanism in the Solar System Workshop (#cryovolcanism2018)

- June 5-7
- Houston, Texas
- https://www.hou.usra.edu/meetings/cryovolcanism2018/

Meteorites Understanding the Origin of Planetodiversity

- June 6-8
- Paris, France
- https://meteorites2018.sciencesconf.org/

15th Annual International Planetary Probe Workshop (IPPW-15)

- June 11-15
- Boulder, Colorado
- https://www.colorado.edu/event/ippw2018/

Planetary Geologic Mappers Annual Meeting (#pgm2018)

- June 12-14
- Knoxville, Tennessee
- https://www.hou.usra.edu/meetings/pgm2018/

Geobiology 2018: An International Training Course in a Rapidly Evolving Field

- June 12-15
- Pasadena, California
- http://web.gps.caltech.edu/GBcourse/

Mars Workshop on Amazonian and Present Day Climate (#amazonianmars2018)

- June 18-22
- Lakewood, Colorado
- https://www.hou.usra.edu/meetings/amazonian2018/

Atmosphereless Solar System Bodies in the Space Exploration Era

- June 19-22
- Kharkiv, Ukraine
- http://www.astron.kharkov.ua/conference/ssb/18/index.php

Workshop in Geology and Geophysics of the Solar System

- June 23-1
- Petnic, Serbia
- http://petnica.rs/planetary2017/

EUCOP 2018: 5th European Conference on Permafrost

- June 23-1
- Chamonix, France
- https://eucop2018.sciencesconf.org/

Astrobiology Australasia Meeting

- June 24-29
- Rotorua, New Zealand
- https://www.aca.unsw.edu.au/content/astrobiology-australasia-conference-2018

Exploration Science Forum

- June 26-28
- Moffett Field, California
- https://nesf2018.arc.nasa.gov/

Astrophysical Frontiers in the Next Decade and Beyond: Planets, Galaxies, Black Holes, and the Transient Universe

- June 26-29
- Boulder, Colorado
- http://go.nrao.edu/ngVLA18

July

Astrobiology Grand Tour 2018

- July 1-9
- Denham, Australia
- https://astrobiology.nasa.gov/events/astrobiology-grand-tour-2018/

Exoplanets II

- July 2-6
- Cambridge, United Kingdom
- http://exoplanets.phy.cam.ac.uk/Meetings/exoplanets2

Conference on Magnetospheres of the Outer Planets

- July 9-13
- Boulder, Colorado
- http://lasp.colorado.edu/home/mop/mop2018/

Astrochemistry: Past, Present, and Future

- July 10-13
- Pasadena, California
- https://www.cfa.harvard.edu/events/2018/astrochem18/

42nd COSPAR Scientific Assembly

- July 14-22
- Pasadena, California
- http://cospar2018.org/

81st Annual Meeting of The Meteoritical Society

- July 22-27
- Moscow, Russia
- http://metsoc81-moscow.ru/

Robotic Telescopes, Student Research and Education (RTSRE) and InterNational Astronomy Teaching Summit (iNATS)

- July 23-27
- Hilo, Hawaii
- http://rtsre.net

August

Lunar Polar Volatiles (#LPV2018)

- August 7-9
- Laurel, Maryland
- http://www.hou.usra.edu/meetings/lunarvolatiles2018

LSST 2018 Project and Community Workshop

- August 13-17
- Tucson, Arizona
- https://project.lsst.org/meetings/lsst2018/

The 11th Meeting on Cosmic Dust

- August 13-27
- Sagamihara, Japan
- https://www.cps-jp.org/~dust/Welcome.html

XXXth General Assembly of the International Astronomical Union

- August 20-31
- Vienna, Austria
- http://astronomy2018.univie.ac.at/

Comparative Climatology of Terrestrial Planets III (#CCTP3)

- August 27-30
- Houston, Texas
- https://www.hou.usra.edu/meetings/climatology2018/

A Century of Asteroid Families

- August 28-30
- Vienna, Austria
- http://asteroidfamilies.net/IAU2018/

September

International Venus Conference 2018

- September 11-14
- Niseko, Japan
- https://www.cps-jp.org/~akatsuki/venus2018/

SSB Committee on Astrobiology and Planetary Science

- September 12-13
- Irvine, California
- http://sites.nationalacademies.org/SSB/SSB_067577#Meetings_and_Events http://sites.nationalacademies.org/SSB/SSB_067577#Meetings_and_Events

Extrasolar Cloud Academy: Cloud Formation and Properties in Extrasolar Planets

- September 23-28
- Grenoble, France
- http://eos-nexus.org/clouds/

Bombardment: Shaping Planetary Surfaces and Their Environments

- September 30-3
- Flagstaff, Arizona
- https://www.lpi.usra.edu/first-billion-years/

October

Late Mars Workshop (#Latemars)

- October 1-3
- Houston, Texas
- https://www.hou.usra.edu/meetings/latemars2018/

November

2018 Geological Society of America Annual Meeting

- November 4-7
- Indianapolis, Indiana
- https://www.geosociety.org/GSA/Events/Annual_Meeting/GSA/Events/gsa2018.aspx

December

2018 AGU Fall Meeting

- December 10-14
- Washington, DC
- http://fallmeeting.agu.org