THE PLANETARY SOCIETY

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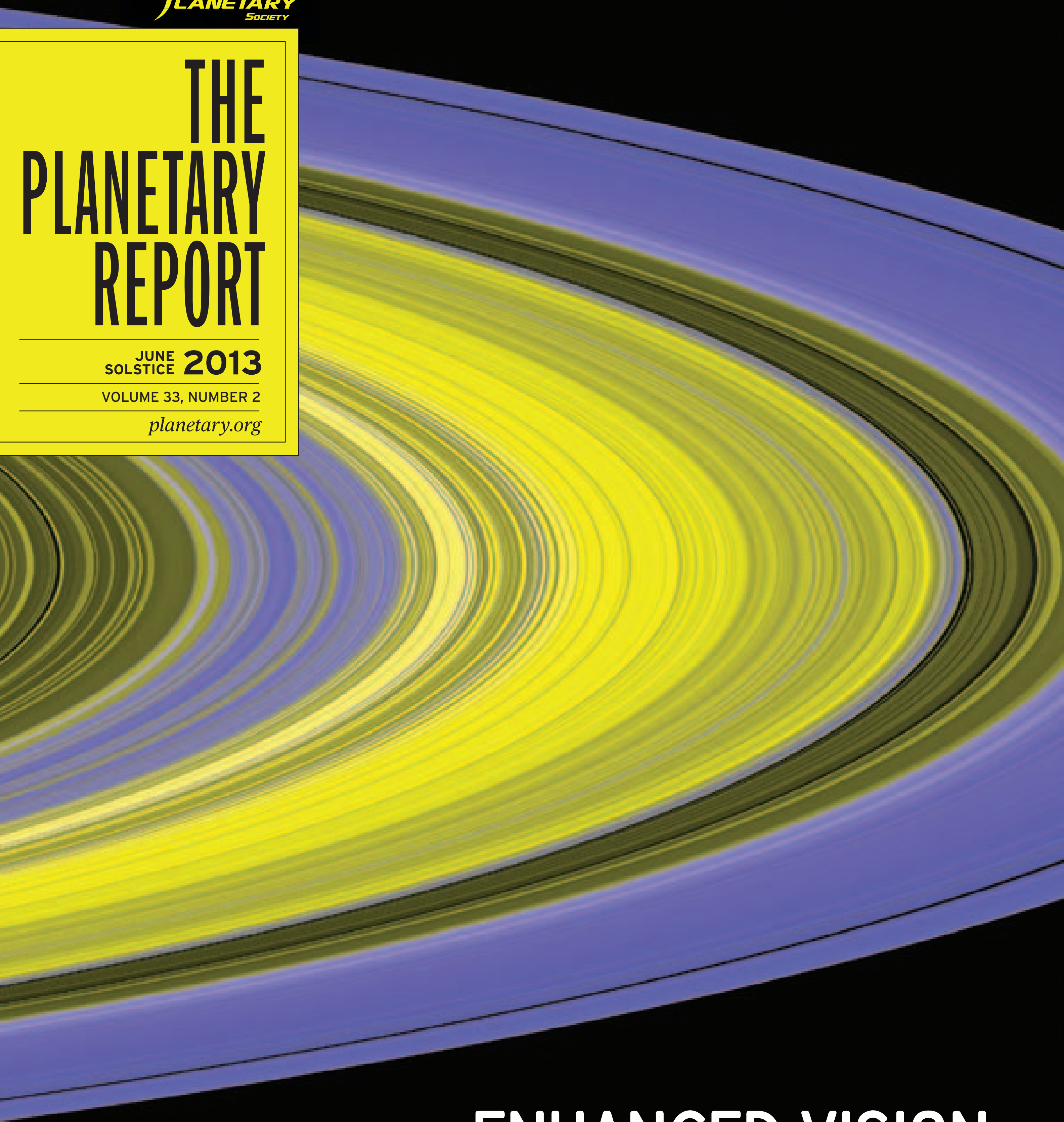


ENHANCED VISION

HOW *CASSINI* HAS DEEPENED OUR KNOWLEDGE OF SATURN'S RINGS

WATER ON THE MOON? · RIDING THE FISCAL ROLLER COASTER · NEW NEO GRANT WINNERS

EMILY STEWART LAKDAWALLA
blogs at planetary.org/blog.

Mariner 10 Data Made New Again

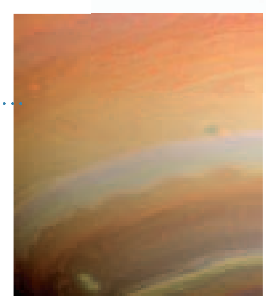
***MARINER 10* VISITED MERCURY** three times in 1974 and 1975. Global images of Mercury from *Mariner* usually look like collages of many smaller pictures–because that's what they are. Here, Ted Stryk has carefully reprocessed photos taken during *Mariner 10*'s first flyby using modern image processing methods, yielding a subtly colorful, seamless view of Mercury from data that are nearly four decades old. Just below center, near the terminator, is some strangely fractured terrain located almost exactly antipodal (that is, on the opposite side of the planet) to Mercury's giant Caloris basin.

–Emily Stewart Lakdawalla

Image: NASA/JPL/Ted Stryk

SEE MORE AMATEUR-PROCESSED SPACE IMAGES PLANETARY.ORG/AMATEUR

SEE MORE EVERY DAY! PLANETARY.ORG/BLOGS



ON THE COVER: Saturn's magnificent rings constitute one of the most beautiful features in our solar system, and *Cassini* has revolutionized our understanding of their makeup. *Cassini* data taken at stellar occultations have revealed that the rings are not clouds of uniformly distributed particles but, instead, have areas—such as the A and B rings—composed of densely packed clumps with nearly empty spaces between them. In this false-color image from 2007, the rings are represented (from left) as C, olive; B, blue and yellow; the Cassini division, olive; and A, blue. *Image: NASA/JPL/University of Colorado*

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BILL NYE *is chief executive officer of The Planetary Society.*

Trusting the Calculations

Concerned About the Number$

AS I WRITE, Mars just came back into view; not so for the path to an agreement on NASA's budget. As near as I can tell, because planetary science gets so much done for so much less money than many of NASA's other programs, people figure it can get by with less. That's just not the case, so we will continue to make known your desire for a robust program of exploration while we also continue to demonstrate the great value of planetary missions. For the latest details, see Casey Dreier's advocacy update on page 6.

DODGING AND DEFLECTING INTERPLANETARY BULLETS AND BOMBS

On February 15, Earth dodged a 143,000-ton bullet carrying the energy of a 2.4-megaton bomb—in the form of asteroid 2012 DA14. Earlier that day, Earth took a glancing blow when an 11,000-ton meteor slapped the atmosphere with a spectacular and completely unexpected encounter over Chelyabinsk, Russia. The unnamed impactor became a 440-kiloton explosion 23 kilometers (about 14 miles) above the surface—blowing out windows, doors, and roofs, while injuring more than a thousand people.

There are hundreds of thousands more such objects in the vicinity of Earth's orbit. We are the first generation of humans that could do something about an oncoming object. Impacts from asteroids are the only preventable natural disaster and, for more than 15 years, The Planetary Society has been working to find and track these objects.

In mid-April, the Society was very well represented at the Planetary Defense Conference in Flagstaff, Arizona. There, our own Mat Kaplan and Bruce Betts hosted a *Planetary Radio Live* show, which dovetailed into a panel discussion about defending Earth from hurtling rocks and chunks of ice. If you haven't done so already, you can check out the *Planetary Radio* podcast and video of the event in the Multimedia section of **planetary.org**.

Also at the conference, Alison Gibbings of the University of Strathclyde in Scotland showed remarkable Laser Bees results based on zapping suitable asteroid-simulant rocks in a laboratory vacuum chamber. For our new readers, The Planetary Society has been supporting development of a swarm of spacecraft, our Laser Bees project, that would lase the surface of an incoming asteroid using electricity generated from sunlight (read the full story in *The Planetary Report*'s June 2012 issue). The fact that the Laser Bees swarm would not need fuel could give the mission an enormous advantage over other asteroid-nudging concepts. At first, the idea might sound a bit far-fetched, like science fiction taken a bit too seriously, but this is the real deal. With your help, The Planetary Society has been funding research at Strathclyde for years. Thank you for partnering with us on this very important project.

ASTEROID RETRIEVAL MISSION: AN ARMFUL

Just before the Planetary Defense conference, NASA announced its intent to find a suitable small asteroid and tow it into a circular, so-called "halo" orbit around a gravitationally neutral Lagrange point beyond the Moon. Then, a second spacecraft, carrying astronauts, would go there, and the crew would examine the object, knock off some excellent samples, and return to Earth.

Proponents see this as a boon for space technology. The mission would include a solar electric propulsion (SEP) system that would be 10 times the size of any such motor yet built. Astronauts would take advantage

LEFT *Backstage after the public night at the 2013 Planetary Defense Conference in Flagstaff, Arizona (from left): Libby Egleson, "Meteorite Man" Geoff Notkin, Bruce Betts, Planetary Society CEO Bill Nye, Northern Arizona University Professor David Trilling, and NASA HQ NEO Program Executive Lindley Johnson.*

RIGHT *Bill Nye greets President Obama during the 2013 White House Science Fair.*

Photos: The Planetary Society

of the Space Launch System (SLS) rocket and the Orion space capsule being designed now in the United States. We'd get kilograms instead of milligrams of samples.

This is an intriguing mission. It would spur investment in technologies crucial to solar system exploration—such as very large solar electric propulsion systems and automated deep-space operations—and in enhanced and expanded ways to detect and monitor asteroids. Our support is conditional, however, because The Planetary Society is concerned that the detailed goals, costs, and implementation plan for this asteroid mission are not yet well defined. In order for this mission to succeed, the administration must plan for, and Congress must provide, long-term funding to pursue it in a timely manner without raiding funds from other high-priority scientific programs within NASA.

NATIONAL SPACE SYMPOSIUM AND THE WHITE HOUSE

For the second time, I was invited to attend the White House Science Fair, held in late April. There, I met some remarkable students who are doing fantastic new things in science. They are the future of our world, people who will be leading science and humankind in new discoveries and ways for so many of us to live on what's proving to be a small planet. I spent time with LeVar Burton, *Star Trek*'s Geordi and an influential educator, and Bill Prady, executive producer of *The Big Bang Theory*, a television show that celebrates science in a very funny way. Bobak Ferdowsi, the *Curiosity* mission's "Mohawk Guy," was there, too. The students were thrilled to meet him.

A few weeks earlier, Planetary Society COO Jennifer Vaughn and I attended the National Space Symposium in Colorado Springs, Colorado. This year was unusual in at least two ways. First of all, with the sequestration of funds by the U.S. government, there was no one from NASA at this event. Normally, there would be hundreds of NASA scientists, engineers, and managers. This drove home the need to allocate space resources wisely. The second unusual thing was that the National Space Foundation (organizers of the Space Symposium) presented me with the Douglas S. Morrow Award for public engagement in space science. It was an honor and a thrill.

Thanks to all of you for your support over the last two and a half years. I have done my best to engage our members, government officials, and people who aren't our members (yet) in the passion, beauty, and joy (the P, B, & J) of space exploration. Working together, we can help people everywhere know and appreciate the countless worlds of the cosmos as well as our own.

Bill Nye

PLANETARY SOCIETY KIDS

THIS IS YOUR ORGANIZATION, AND I WANT TO HEAR FROM YOU.

We are considering moving our *Planetary Society Kids* insert out of the magazine and onto our website. We will still produce a paper version and continue to provide it to schools and to members who specifically request it. We want to know what you think of this idea. Please write to us at *tellbill@planetary.org* to share your opinions.

CASEY DREIER *is advocacy and outreach strategist for The Planetary Society.*

Budgetary Whiplash

WHIPLASH—there's no better word to describe our current situation. NASA's Planetary Science Division, which manages all robotic solar system exploration, has seen its fortunes rise and fall with uncommon frequency in the past few months. Here's a quick rundown of major events.

CONGRESS COMES THROUGH IN 2013

In March, the U.S. Congress finally passed a budget for the remainder of 2013. This was a major victory for The Planetary Society (and all of humanity, really), as the legislation rejected nearly the entire proposed cut to the Planetary Science Division, providing $1.42 billion for the year. Although not the perfect number (we argue that $1.5 billion is the minimum necessary for a healthy program), no other division within NASA saw such a reversal of fortune. Congress directed these new funds to the Mars exploration program, a new mission to Europa, plutonium-238 production, and an increase in the number of small Discovery-class missions (see *The Planetary Report*, Spring Equinox 2013). The sequester, the across-the-board cuts to all federal programs, applies to this final number, but if applied evenly, the Planetary Science Division will still come out ahead. The intent from Congress was clear: planetary exploration is a priority for the United States.

ABOVE *The Planetary Society at the Capitol. From left to right: Consultant Bill Adkins, Society COO Jennifer Vaughn, Society CEO Bill Nye, and Society President Jim Bell.*

THE ADMINISTRATION CONTINUES TO CUT

Fewer than three weeks after Congress rejected cuts to planetary science in 2013, the White House released its budget proposal for the upcoming year. It ignored clear congressional support for planetary exploration and again proposed cuts to the program similar to the previous year—a level devastating to the immediate and long-term health of the program.

NASA TO RAID RESTORED PLANETARY SCIENCE FUNDING?

We've had early indications that NASA may "reprogram" nearly all of the money restored to planetary science this year for use in other programs. This is a highly unusual maneuver implemented via the operating plan, which spells out how NASA plans to use money appropriated to it by Congress. This document is not public, but an early version leaked just a few days before this article was due suggests that this may be the case. We will follow this closely at **planetary.org/SOS**.

WHAT WE'RE DOING NOW

The Planetary Society once again is mobilizing its members and supporters to action. You probably have received mail from us asking you to sign a petition and make a contribution to our advocacy efforts. Both of these actions are crucial. As we saw last year, we can make a difference if we unite to support space exploration.

We followed up on your letters and calls to your representatives by traveling to Washington, D.C. in May to talk with key congressional staffers and legislators. We heard a lot of support for planetary science and many compliments on the effectiveness of our members in communicating this issue to Congress.

We also threw a special event near Capitol Hill with Bill Nye the Science Guy; Bobak "Mohawk Guy" Ferdowsi; our president, Jim Bell; Titan Mare Explorer mission leader Ellen Stofan; and our own Planetary Evangelist, Emily Lakdawalla. We had a good crowd, including many key congressional staffers and a visit by House Science Chairman Lamar Smith (R-TX).

This is just the beginning of our yearlong effort. More trips to D.C. lie ahead, and we will continue to depend on you to stay engaged and vocal about the science budget. We did this before, and we can do it again.

Learn more and get the latest updates at **planetary.org/SOS**.

Photo: Navid Baraty

HAPPENING ON

PLANETARY RADIO

planetary.org/radio

ON THE ROAD

LIVE AT THE SPACE TECH EXPO

A conversation with enthusiastic team members at Xcor Aerospace and the Zero-G Corporation. **bit.ly/planetary-2013-05-27**

THE BASICS OF INTERPLANETARY FLIGHT

We talk with Dave Doody about what students learn in his non-technical, but eye-opening, class. **bit.ly/planetary-2013-04-08**

YURI'S NIGHT 2013 UNDER SPACE SHUTTLE *ENDEAVOUR*

Virgin Galactic and JPL's "Mohawk Guy" join us in downtown Los Angeles for a party that is out of this world. **bit.ly/planetary-2013-04-15**

PLANETARY DEFENSE CONFERENCE

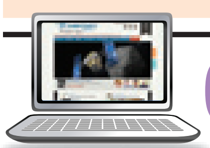
SAVING EARTH: ASTEROID EMERGENCY EXERCISE

Hundreds of attendees participate in an asteroid mitigation exercise ... and much more! **bit.ly/planetary-2013-05-06**

MUSIC OF THE SPHERES FROM THE KRONOS QUARTET

The internationally renowned string quartet talk about creating and performing Terry Riley's *Sun Rings*, which incorporates Don Gurnett's space sounds. **bit.ly/planetary-2013-05-13**

Find these shows and our entire archive of *Planetary Radio* at *planetary.org/radio*!



ON *PLANETARY.ORG*

BLOG

***OPPORTUNITY'S* FINDINGS AT ENDEAVOUR, SO FAR**

A.J.S. Rayl brings us new information on *Opportunity*'s science mission.

bit.ly/planetary-2013-05-25

MEDIA

SINGING EVERY MOON IN THE SOLAR SYSTEM Emily Lakdawalla found a student who names all of the natural satellites (moons) in our solar system using a tune based on Tom Lehrer's "The Elements Song."

bit.ly/planetary-2013-05-24

IN THE NEWS

THE SOCIETY GOES TO WASHINGTON, D.C.

Planetary science faces another round of debilitating cuts. **bit.ly/planetary-2013-05-21**

BEHIND THE SCENES

VOLUNTEER EVENTS

Special gatherings are happening all the time for our volunteers.

Check out the calendar:

bit.ly/planetary-volunteer-events

YOU CAN HAVE MORE

MORE INFORMATION...
MORE OPPORTUNITIES...
MORE FUN...

Just by giving us your e-mail address!

If we don't have your address, you are not receiving all of your Member benefits. Benefits like:

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- Opportunities to participate in contests

So visit us on the Web at **planetary.org/connect/email-update** and start getting more from your membership.

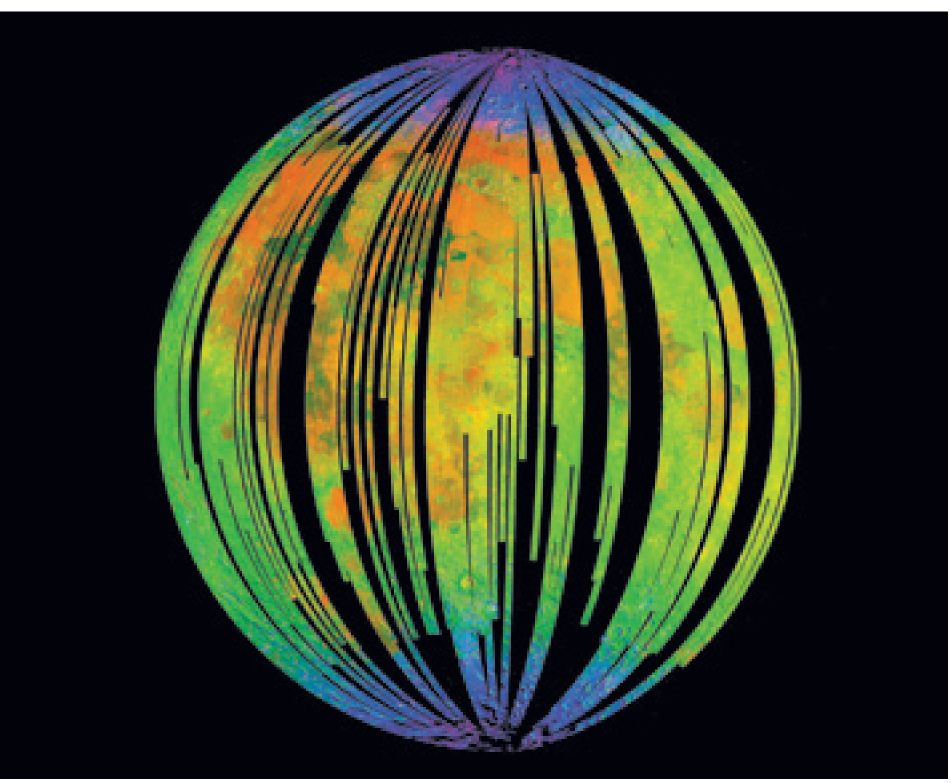
Images: NASA

AMANDA HENDRIX *is a Participating Scientist on the* Lunar Reconnaissance Orbiter *team.*

Lunar Water and Weathering

Modern Spacecraft Reshape Our View of the Moon

BELOW *Modern spacecraft agree: the Moon is not dry! In 2009, The Jet Propulsion Laboratory's Moon Mineralogy Mapper (M³) imaging spectrometer, on board India's* Chandrayaan-1, *found detectable amounts of water on the lunar surface. In this mosaic derived from M³ data, blue indicates the signature of water, green shows surface brightness, and red points out iron-bearing minerals.*



Mosaic: Indian Space Research Organization/NASA/JPL-Caltech/USGS

ALTHOUGH THE MOON IS the only body from which we have samples (at least samples that were deliberately brought to Earth—meteorites from Mars and asteroids don't count here), it has remained, oddly, rather unknown. After receiving significant focus early in the United States' space program, the Moon seemingly was forgotten as an interesting target as our sights shifted to Mars and the outer solar system. Even so, the Moon has proved itself to be a very interesting object in recent years.

We used to think the Moon was dry—"bone dry," as people used to call it. Samples taken on the *Apollo* missions hinted at some water, but it was assumed to be mostly terrestrial in source. Results have been dripping in (pun intended!) over the decades, however, providing more and more evidence of water all over the Moon. Recent results from not one but several spacecraft show that the Moon is not dry. It's not exactly soaking wet, but it's certainly not dry.

EARLY INDICATIONS

Initial hints of lunar hydration came in the 1990s, from three sources. Data from the *Galileo* spacecraft, which flew by the Moon in 1991 and 1992, showed a faint feature in the visible part of the spectrum, produced by aqueous alteration. The feature was stronger at higher latitudes than at lower latitudes. In 1994, *Clementine* bistatic radar measurements (in which radio signals from the spacecraft were reflected off the polar regions of the Moon) suggested water ice at the poles, though this was debated. Finally, in 1998, *Lunar Prospector* neutron spectrometer measurements showed evidence of excess hydrogen in the Moon's polar regions, which scientists interpreted as possibly indicating the presence of water there.

Things remained pretty quiet on the topic of lunar water during the early part of the new millennium, until India's *Chandrayaan-1* spacecraft arrived in late 2008. The spacecraft's onboard Moon Mineralogy Mapper (M³) instrument measured, for the first time, the infrared (IR) spectral signature of H_2O (or OH, which can be used as a proxy for H_2O) on the lunar surface. The IR spectrum of H_2O is well understood and is a commonly used tool for studying, for example, the surfaces of the

water ice-rich moons of the outer solar system.

The M^3 team verified these results using data from other instruments–IR data from *Cassini* (which flew by Earth in 1999) and from the *Deep Impact* spacecraft flyby of the Moon in June 2009. The spectral feature seemed to be real and to indicate that water is present on the dayside of the Moon, with greater abundances at the colder high latitudes and near the terminator (i.e., late and early in the day).

In the meantime, *Lunar Reconnaissance Orbiter (LRO)* was launched in June 2009 and entered lunar orbit in the autumn of that year. In the Lunar Crater Observation and Sensing Satellite (LCROSS) experiment, the Centaur upper-stage rocket that launched *LRO*/LCROSS was directed to impact the Moon in a south polar crater. Measurements of the plume of material created by the impact showed evidence of H_2O.

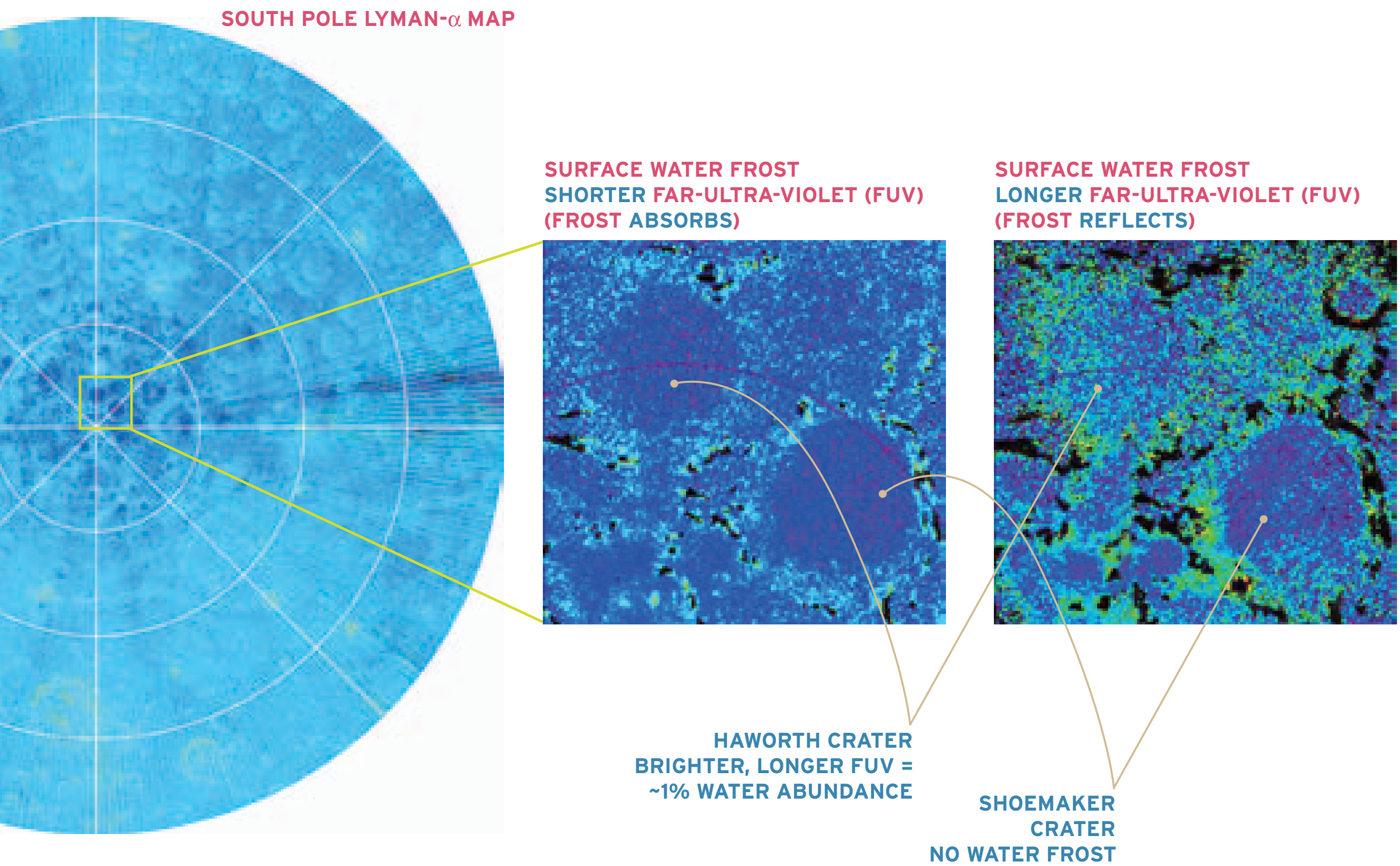
Further evidence of H_2O came from the Lyman Alpha Mapping Project (LAMP) instrument on board *LRO*. LAMP uses a tricky means of measuring *inside* the permanently shadowed regions (PSRs). These polar regions never see sunlight; as a result, the temperature in the PSRs is a constant, chilly 40 Kelvin (-233 degrees Celsius, or -387 degrees Fahrenheit)–plenty cold enough to harbor water and keep it stable. Because the traditional reflectance spectroscopy methods don't work in these constantly dark regions where no solar light is reflected, LAMP utilizes the ultraviolet (UV) illumination source from stars and interplanetary hydrogen, then measures the UV light reflected back into the instrument from the PSRs.

Using such measurements, LAMP has provided evidence of H_2O at the surface inside PSRs. LAMP measurements of the lunar dayside also indicate the presence of H_2O even at low latitudes, supporting the

ABOVE *In 1991 and 1992,* Galileo *surveyed the Moon before heading out to the Jupiter system. There, it detected faint evidence–mostly at higher latitudes–of hydration.*

Image: NASA/JPL/USGS

AMANDA HENDRIX, *a Senior Scientist with the Planetary Science Institute, is a Co-investigator on the* Cassini *Ultraviolet Imaging Spectrograph team. Her research focuses on ultraviolet spectroscopy of small bodies in the solar system.*



ABOVE *The Lyman Alpha Mapping Project (LAMP) instrument on* Lunar Reconnaissance Orbiter *(LRO) has found further evidence of water at the Moon's poles. LAMP has taken measurements inside the permanently shadowed regions there—areas dark enough to hide water and cold enough to keep it stable. The texture of the surface in the PSRs is not well understood, and it adds a layer of complexity to interpretation of the LAMP data gathered there.*

earlier results of M^3 but using an entirely different part of the spectrum to make the measurements. Even though daytime temperatures at lower latitudes on the Moon can get up to 400 Kelvin (127 degrees Celsius, or 261 degrees Fahrenheit)—much too hot for H_2O to be stable—water seems to form there and remain stable late and early in the day, when temperatures decrease.

SOURCES OF LUNAR WATER

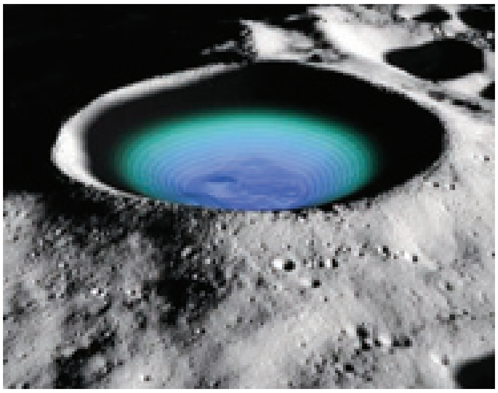
So where does all this water come from? We know that there is H_2O on the Moon that's primordial, left over from early formation processes. This has been shown from samples such as portions of primitive lunar mantle materials. There's also H_2O that was brought in by comets over the aeons. More water comes from the solar wind. Solar wind-derived water has been postulated as early as the 1950s. Hydrogen ions, carried by the solar wind, react with iron oxide in the lunar minerals and glasses to create minor amounts of water vapor and iron metal.

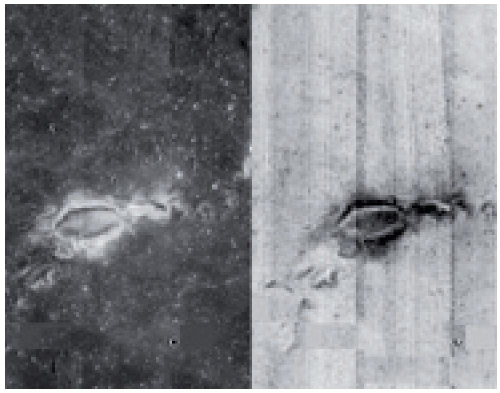
The solar wind is also known to "weather" the lunar surface. Because the Moon's surface is not protected by a thick atmosphere or magnetosphere, it becomes aged by the solar wind and micrometeoroids. This weathering darkens the Moon at visible-to-near-IR wavelengths because of the nanophase iron (which has a grain size under 100 nanometers) that is created in this process. The ultraviolet spectral range is a particularly good place to look for space weathering effects because the short wavelengths sense primarily the uppermost few microns of the grains' surfaces, where weathering rims are located. In the UV, nanophase iron is relatively bright, so fresher, less weathered regions are expected to be darker.

A good test of the link between UV brightness and weathering presents itself in lunar swirls. These regions are thought to be op-

Graphic: NASA Lunar Science Institute

Lunar water is still not fully understood. What is the distribution and abundance of the polar, surficial, and internal water?





LEFT *Shackleton, a 21-kilometer (13-mile) crater, is a permanently shadowed region at the Moon's south pole. By reflecting lasers off the lunar surface,* LRO *has enabled scientists to build 3-D models of the interiors of craters like this. The LAMP instrument uses light from other stars to illuminate the interiors.*

RIGHT *Visual evidence of weathering on the Moon's surface can be found in swirl-like features. These* LRO *camera images show a crustal magnetic anomaly called the Reiner Gamma Swirl. At left is the visible wavelength image, and ultraviolet is on the right. The spectral reversal between visible and UV is likely the result of a relative lack of nanophase iron within the swirl region, so that the swirl is bright compared to its surroundings in the visible wavelength but dark in the UV.*

Images: NASA

tically immature. They are magnetically anomalous regions that appear to be locally shielded from the solar wind flow, so that the terrain has not been exposed and aged/matured as much as surrounding regions. Indeed, such swirls have been found to be relatively dark at near-UV wavelengths (as seen in images using color data from *LRO*'s camera, LROC), consistent with a relatively younger surface.

If solar wind bombardment leads to the creation of H_2O and also creates nanophase iron, shouldn't relatively young/fresh regions also be less hydrated? Sure enough, the lunar swirls have been shown to be lower in hydration levels than the surrounding regions.

MORE TO LEARN

Lunar water is still not fully understood. What is the distribution and abundance of the polar, surficial, and internal water? There's also the question about the time scales of the production of H_2O/OH. Is it created on a daily basis? It may also be that the solar wind has been producing H_2O/OH in the lunar regolith for so many aeons that much of it is "stored" below the optical layer and "percolates" up when the temperature is right. At higher latitudes, where the temperatures are lower, H_2O could form and be stable directly on the surface.

It's important to keep in mind that we're not talking about very much water on the Moon—about 0.5 percent by weight at lower latitudes and about 1 to 2 percent by weight in PSRs. Nevertheless, it is important for understanding our Moon's history and evolution, as well as that of other bodies. For example, Mercury is now known to have polar H_2O as well.

Thus, we need to renew our resolve to study the Moon. *LRO* is still in orbit and continues to map the surface and investigate dayside, nightside, and PSR water. NASA's Lunar Atmosphere and Dust Environment Explorer (LADEE) will go into orbit later this year, to make lunar atmospheric measurements and better understand solar wind-surface interactions. Laboratory measurements of *Apollo* samples with modern instrumentation also are providing new insights, bringing us a whole new understanding of the Moon. The high-resolution views of the Moon from *LRO* (**lroc.sese.asu.edu/images**) are absolutely stunning. They are just as amazing, in their own way, as the awesome images of much more distant bodies such as Enceladus. Finally, we're getting to know our nearest neighbor. And it's about time!

FACTINOS

Gravity Map

SCIENTISTS HAVE UNCOVERED the origins of the Moon's uneven, or "lumpy," gravity–findings that will allow spacecraft to navigate more precisely during future missions to other worlds. Using data from NASA's twin *Gravity Recovery and Interior Laboratory (GRAIL)* spacecraft, they pinpointed the locations of large, dense regions they call mass concentrations, or mascons.

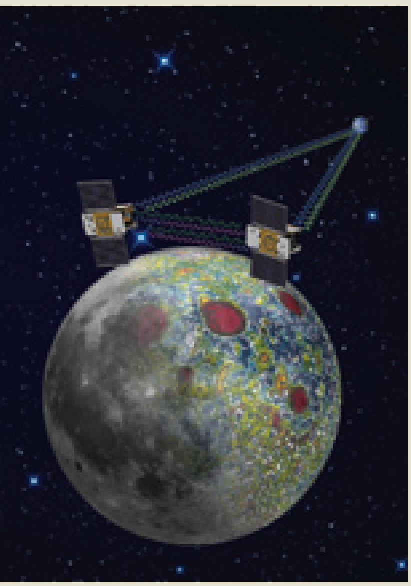
The researchers found the mascons by combining *GRAIL* gravity data with computer models of large asteroid impacts and details about the geologic evolution of the impact craters. Their findings are published in the May 30, 2013 issue of *Science*.

"*GRAIL* data confirm that lunar mascons were generated when large asteroids or comets impacted the ancient Moon, when its interior was much hotter than it is now," says Jay Melosh of Purdue University, the lead author of the article. "We believe the data from *GRAIL* show how the Moon's light crust and dense mantle combined with the shock of a large impact to create the distinctive pattern of density anomalies that we recognize as mascons."

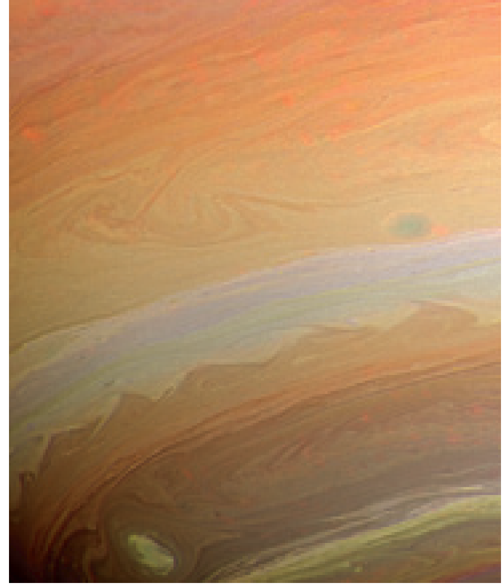
This new understanding could influence knowledge of planetary geology well beyond that of Earth and the Moon.

"Mascons also have been identified in association with impact basins on Mars and Mercury," says *GRAIL* principal investigator Maria Zuber of the Massachusetts Institute of Technology. "Understanding them on the Moon tells us how the largest impacts modified early planetary crusts." For more information, go to **bit.ly/GRAILgravity**.

–from NASA



ABOVE GRAIL*'s twin spacecraft used a precision flying technique to map the Moon's gravity field. The probes, launched in September 2011, studied the internal structure and composition of the Moon until December 2012, when mission controllers deliberately crashed them into the lunar north pole.*



Q In many cloud shots of Saturn, some of the clouds make me think of how several colors and densities of liquids would look if someone were trying to mix them. The liquids would first create swirls of different colors in various wavy patterns before becoming fully mixed. When I look at Saturn images showing giant swirls of different gases, I ask, why don't they eventually mix into one homogeneous color?

—Mike Martinez, Eagan, Minnesota

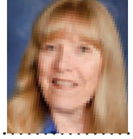
A Rarely are things truly mixed and homogeneous in nature. In the case of Saturn, turbulent heating from below and solar heating from above drive the atmospheric circulation to various degrees, depending on the location on the planet. These factors set up the wind patterns that we see in the outer, visible envelope of Saturn's atmosphere.

Air in Saturn's belts and zones (alternating bands of light and dark colors) moves in opposite directions in the alternating regions, setting up regions of turbulence. As some parcels of air move upward and some move downward, clouds form and clouds dissipate continuously. The size and exact composition of cloud particles will vary greatly as a result, thus giving a different appearance to the visible atmosphere over both time and location.

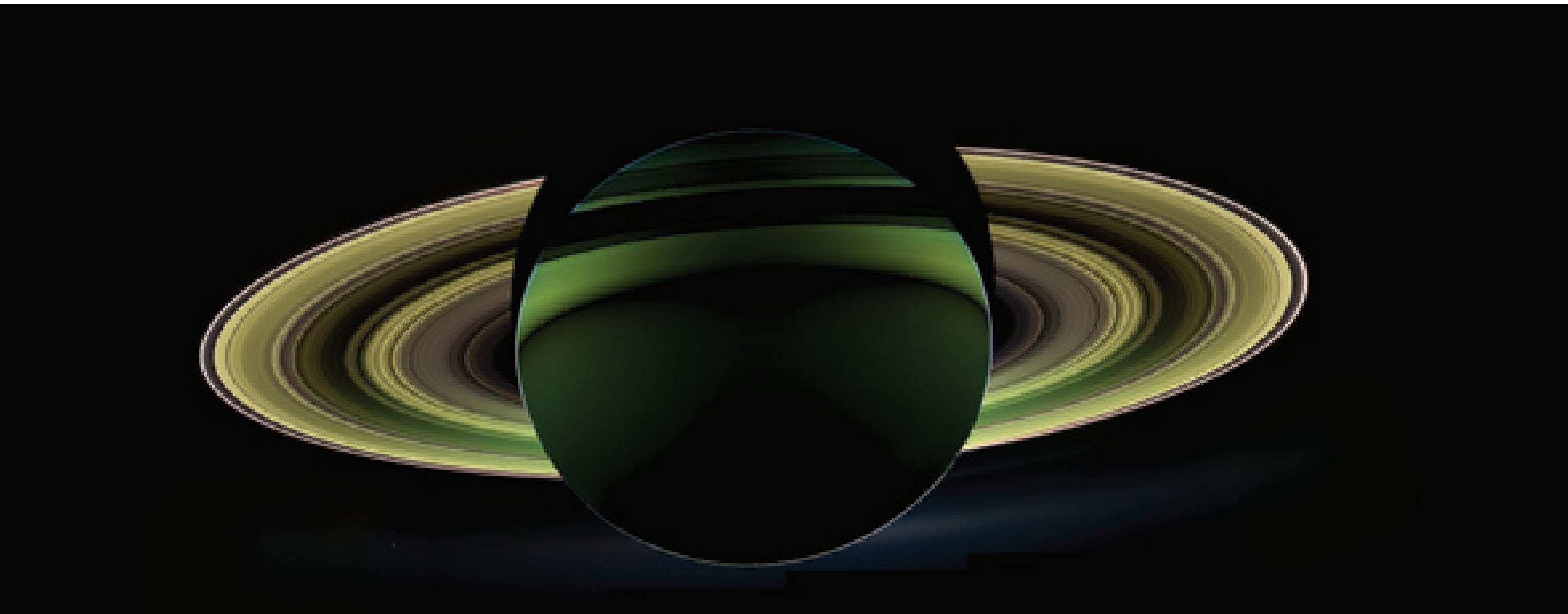
The same process applies to Jupiter. Differences in the look of the cloud structures arise from the strength of heating from the interior, the atmospheric temperature, and the exact composition of the atmospheric gases that determine what condenses and where.

–Scott G. Edgington, Jet Propulsion Laboratory

Saturn image: NASA/JPL. Illustration: NASA/JPL-Caltech



LINDA SPILKER *is the* Cassini *Project Scientist and a Co-Investigator on the* Cassini *Composite Infrared Spectrometer team.*



REWRITING THE BOOKS

Cassini's Discoveries in Saturn's Rings

***VOYAGER*'S SATURN FLYBYS** in the early 1980s left us flush with new knowledge and discoveries. The flybys found six small moons; showed that Titan was shrouded in a thick hydrocarbon haze in a nitrogen-rich atmosphere; revealed the young, uncratered terrain on Enceladus that hinted at some sort of geological activity; and discovered the Keeler gap in Saturn's A ring as well as transient clouds of tiny particles, called spokes, in the B ring. Looking from the science deck of the *Cassini* spacecraft still orbiting Saturn today, it's easy to see that, even though the *Voyagers* taught us a tremendous amount about the Saturnian system, we didn't know then how much we didn't know.

Just a generation since the *Voyager* flybys, *Cassini*'s findings have revolutionized our understanding of Saturn's rings and fundamentally altered many of our concepts of how solar systems and planets form. We know that more discoveries are in store in the months and years ahead as we adjust the spacecraft's orbit, winding it ever closer to the rings.

I remember the tension I felt on the evening of June 30, 2004 as *Cassini* approached Saturn. For *Cassini* to be captured into Saturn's orbit, everything had to work perfectly, or it would plunge past the planet, never to return.

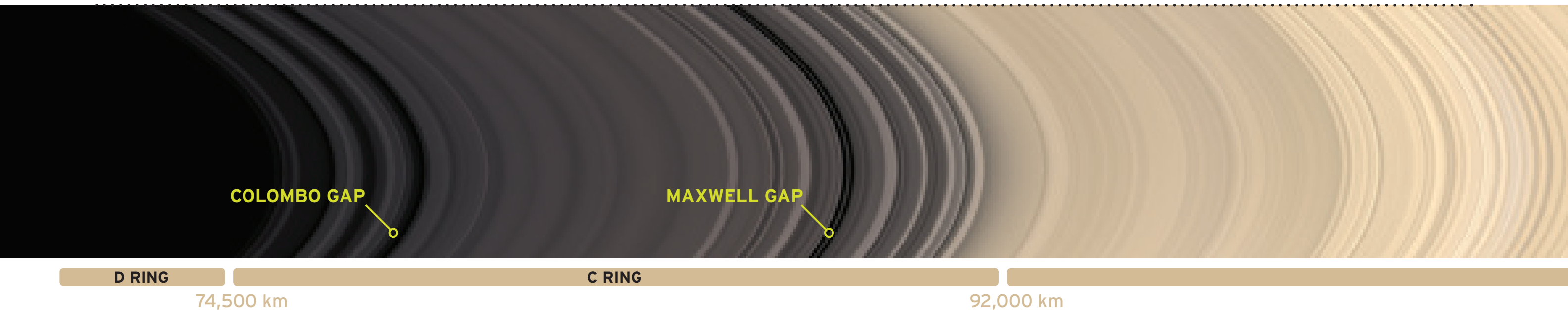
The first hold-your-breath moment that evening came as our spacecraft flew through the plane of the rings between Saturn's F and G rings. We used *Cassini*'s high-gain antenna like a giant shield, oriented in the direction of incoming ring particles, protecting the rest of

ABOVE *Whereas* Voyager *helped us to truly see Saturn for the first time,* Cassini *has dramatically sharpened our focus, gifting us with one unprecedented view after another of our solar system's bangled beauty. Here, the Sun is behind Saturn.* Cassini *captured this rare view from the planet's shadow, looking toward the non-illuminated side of the rings from about 19 degrees below the ring plane. This enhanced color portrait was created with images taken using infrared, red, and violet spectral filters. The images were obtained on October 17, 2012 with* Cassini*'s wide-angle camera from a distance of about 800,000 kilometers (500,000 miles) from the planet.*

Image: NASA/JPL-Caltech/SSI

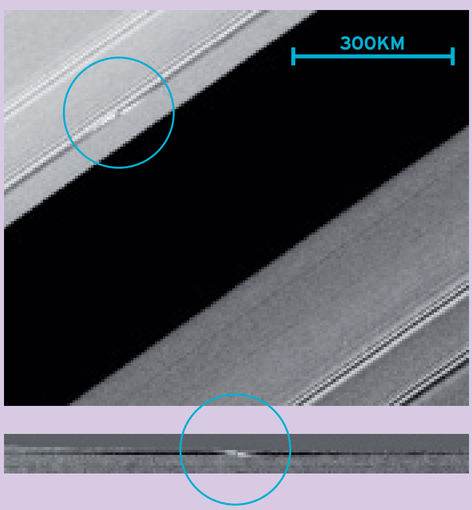
LINDA SPILKER, *a NASA principal research scientist at the Jet Propulsion Laboratory, is the* Cassini *Project Scientist and a Co-Investigator on the* Cassini *Composite Infrared Spectrometer team. She is also a scientific spokesperson for the space program, engaged in public outreach activities from K-12 to university students, as well as to the general public.*

CASSINI-HUYGENS **IS A MULTIDISCIPLINARY, INTERNATIONAL PLANETARY MISSION CONSISTING OF AN ORBITING SPACECRAFT AND A PROBE. IT IS A COOPERATIVE MISSION BY NASA, THE EUROPEAN SPACE AGENCY (ESA), AND THE ITALIAN SPACE AGENCY, WITH NASA SUPPLYING THE CASSINI ORBITER AND ESA SUPPLYING THE HUYGENS PROBE. NASA'S JET PROPULSION LABORATORY, A DIVISION OF THE CALIFORNIA INSTITUTE OF TECHNOLOGY IN PASADENA, MANAGES THE *CASSINI-HUYGENS* MISSION FOR NASA.**



the spacecraft from high-velocity impacts by tiny ring particles. After successful ring-plane crossing, *Cassini*'s signal came through loud and clear.

Next, *Cassini* had to complete its 96-minute main engine burn, slowing down by almost 1,400 miles per hour, to be captured into Saturn's orbit. *Cassini*'s engine stopped firing right on time, and our prime mission in Saturn's orbit had begun. All those years of planning and waiting since I first started working on the mission in 1988 were worth it.



RIGHT Cassini *has discovered a class of mysterious little propeller-shaped objects inside Saturn's rings—probably caused by moonlets too tiny to be seen in the images. The moonlets deflect nearby particles, creating propeller-shaped features. One of the largest propellers (top) is named after the early American aviatrix Amelia Earhart. The largest (below) is named for French aviator Louis Blériot.*

STRUCTURE OF THE RINGS

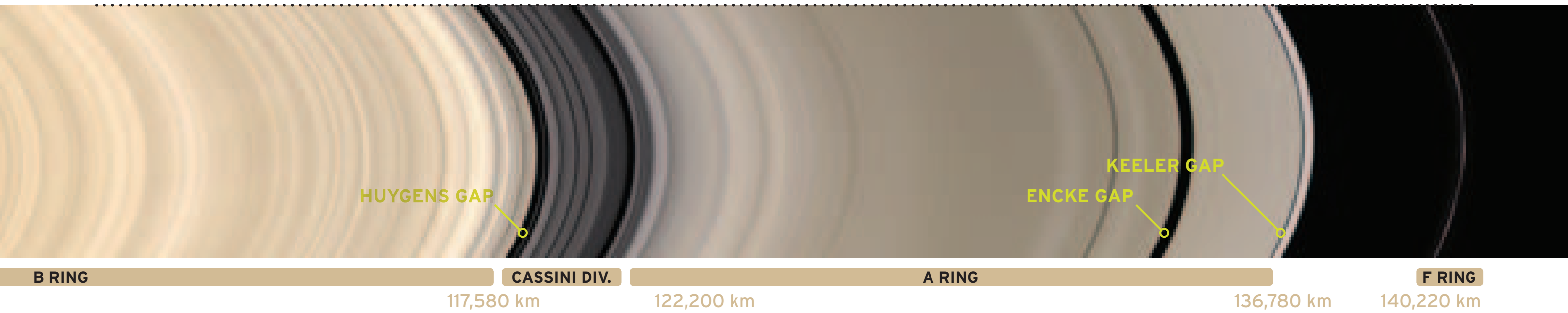
Flying just outside Saturn's ring plane, *Cassini* captured unprecedented high-resolution images and profiles of the structure of the rings in ultraviolet, near-infrared, and thermal-infrared wavelengths. For the first time, we were able to "touch" the near-ring environment as *Cassini* carried its magnetic field and dust particle sensors close to the rings. Amazing discoveries included straw-like clumps several kilometers long in the A ring, an oxygen "atmosphere" just above the rings, and fine-scale structures never seen before.

The diameter of Saturn's dense main rings (A, B, C, and D) would almost span the distance between Earth and the Moon, yet the rings are extremely thin, generally no thicker than the *Cassini* spacecraft is tall, about 10 meters. The rings are composed of countless spinning particles and clumps of particles orbiting Saturn in an intricate cosmic dance. They are made primarily of water ice mixed with a sprinkling of other materials that give parts of the rings their subtle hues. Particle sizes range from marble- to house-sized in some regions; elsewhere, they are mostly dust grains. Saturn's gravitational field keeps them narrowly confined in Saturn's equatorial plane and prevents them from combining to form moons. Each ring has its own unique characteristics.

Just outside the main rings are the twisted, forever changing F ring; the thin, faint G ring; and the dusty E ring, which extends more than three times the width of all the other rings combined. Two tiny moons, Prometheus and Pandora, orbit near the inner and outer boundaries of the F ring, gravitationally herding particles between them with intricate choreography. The G ring, which lies between the F and the inner E rings, sports an arc of debris knocked off the tiny moonlet Aegaeon, another *Cassini* discovery, which orbits in the center of the ring arc.

The E ring is created and sustained by material jetting out of Enceladus' icy plume. The jets that make up the plume were one of the *Cassini* discoveries that surprised me most. Who could have guessed that such a tiny moon, which should have frozen solid aeons ago, would have active jets of material emanating from long, tiger-stripe fractures at its south pole? One of *Voyager*'s biggest puzzles, the source of the E ring, was answered.

Images: NASA/JPL/SSI



NEW RINGS REVEALED AS SATURN COVERS THE SUN

One of my favorite pictures is the mosaic of Saturn eclipsing the Sun, with tiny Earth hanging just off the edge of Saturn. *Cassini* can be "steered" with small changes in its looping orbits around Saturn to take advantage of such unique viewing opportunities. One of the most rewarding outcomes of this capability occurred in September 2006, when we sent *Cassini* flying through Saturn's shadow for almost 12 hours. Its cameras looked in the direction of the eclipsed Sun. From this rare geometry, we detected much smaller abundances of tiny ring particles than was possible from other views. From its shadowed vantage point, *Cassini* obtained a fantastic mosaic of the planet and entire ring system, and we discovered several new rings or partial rings, called ring arcs, that co-orbit with some of Saturn's smallest moons. Micrometeoroid impacts eject dust from each of these tiny moons, forming a diffuse ring arc in the same orbit as the moon. *Cassini* achieved this viewing geometry on two more occasions, and we plan to place the spacecraft there for one last look in July 2013.

EXTENSIVE CLUMPING IN THE RINGS

Cassini's detailed ring studies revealed elaborate structures and interplay between ring particles that were not fully appreciated until *Cassini*. The A and B rings, for example, are very different from what we once envisioned. At the time of the *Voyager* flybys, most people thought Saturn's main rings consisted of a fairly uniform cloud of individual, separated particles. *Cassini* data surprised all of us by showing that most A ring particles are packed into clumps, with nearly empty spaces between them. *Cassini* stellar occultations showed that in some places, the particles form long, quasi-parallel, finger-like clumps called self-gravity wakes, which have a preferred orientation in the rings. Tightly packed clumps are present in parts of the B ring as well, again separated by nearly empty gaps. Saturn's gravitational forces regularly tear all these clumps apart, only to have the particles rearrange and reassemble into new clumps.

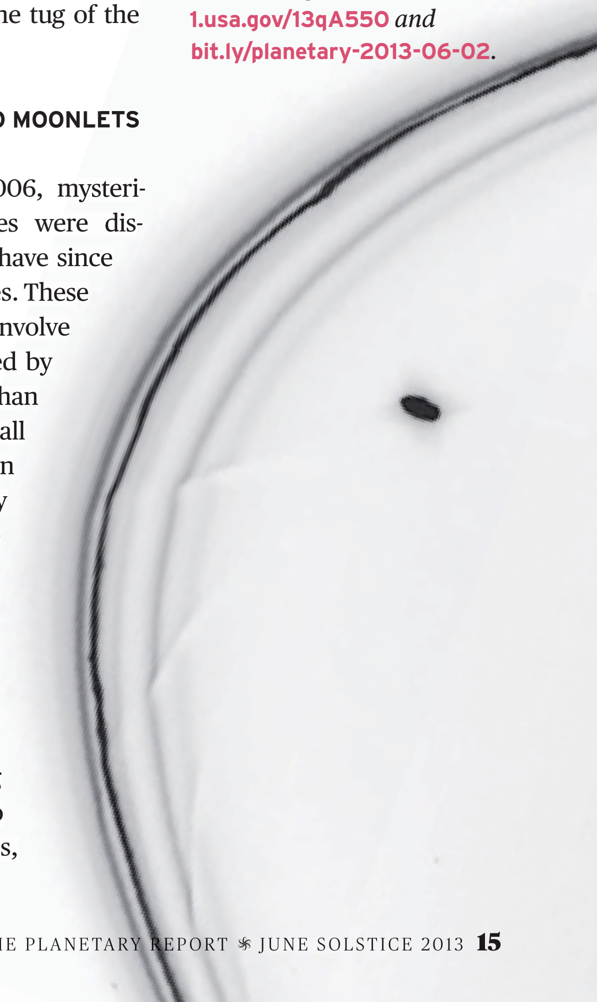
Because we now know that the ring particles are not uniformly distributed, we may have underestimated the total mass of the rings by an order of magnitude. We'll have a better answer when we make some detailed measurements of the ring mass near the end of the mission. *Cassini* will see the rings edge-on, looking outward from inside the innermost ring, and measure the tug of the rings on *Cassini*'s trajectory!

PROPELLER SHAPES POINT TO MOONLETS IN RINGS

During close ring flybys in 2006, mysterious propeller-shaped structures were discovered in Saturn's A ring and have since been monitored in *Cassini* images. These two-bladed propellers actually involve gaps in the ring material created by tiny moonlets that are larger than typical ring particles but too small to be seen in the images. They can be detected by the impact they have on their surroundings. The moonlets are large enough that their gravity deflects the trajectories of nearby particles, generating the propeller-shaped features. They are not large enough to clear their entire orbit around Saturn, as the ring moons Pan and Daphnis do to create the Encke and Keeler gaps,

ABOVE *This natural-color mosaic shows the full sweep of Saturn's rings radiating outward from the too-faint-to-see D ring at left to the thin F ring at right. Taken from the illuminated side of the rings, this view is composed of 45 narrow-angle camera images taken over the course of four hours on November 26, 2008 from a distance of 1.1 million kilometers (700,000 miles).*

BELOW *Watch moving examples of the undulations that tiny Prometheus and Pandora produce in the F ring here:* **1.usa.gov/13qA550** *and* **bit.ly/planetary-2013-06-02**.



Mosaic: NASA/JPL/SSI. F Ring (inverted) at right: NASA/JPL-Caltech/SSI/Queen Mary University of London

Cassini *returned our first edge-on views of the rings during Saturn's equinox, in August 2009. In this unique lighting, scientists were surprised to discover evidence of meteoritic impacts in the A, B, and C rings. These five images, taken between 2009 and 2012, show clouds of material ejected by small objects hitting the rings. From top are two views (taken 24.5 hours apart) of one cloud in the A ring, a cloud in the C ring, one in the B ring, and another in the C ring. The impacts' ejecta clouds were visible because they were elevated out of the ring plane and lit by the Sun.*

Images: NASA/JPL/SSI/Cornell University

respectively. These propeller-generating moonlets could number in the millions.

The propellers provide the first opportunity to track objects embedded in a disk of material and may provide insights into how planets form from a disk of material. Close monitoring with *Cassini* has revealed a number of tracked propellers that have abruptly and unexpectedly shifted orbits. The cause of these orbital changes has not yet been determined, but it may yield clues to how young planets migrate through their disks. If an object was torn apart to form Saturn's rings, these tiny objects in the A ring may represent larger shards of this material.

I especially enjoy that these ring propellers are informally named after pioneering aviators. The largest propeller is named for Louis Blériot, who piloted the first powered flight across the English Channel and had a wonderful, propeller-like handlebar mustache. Another is named for Amelia Earhart, the first woman to fly across the Atlantic Ocean.

VERTICAL STRUCTURES IN THE RINGS

Once every 15 years, at Saturn's equinox, the Sun is directly over Saturn's equator and illuminates the rings edge-on. We were fortunate to have *Cassini* there when equinox occurred in August 2009. Neither of the *Voyager* spacecraft saw this equinox geometry.

Cassini obtained the first observations from within the Saturn system under this unique lighting, then used them to search for vertical structures in the rings. Near the time of equinox, the rings are very dark, illuminated only by reflected light from Saturn, and any part of the ring sticking above or below the ring plane is bright because it catches the rays from the Sun. The biggest surprise for me was seeing so many places of vertical relief above and below the thin rings. One striking example was the mountain-high waves on the edges of the Keeler gap, created by ring particles interacting with the small, gap-orbiting Daphnis. Using the length of shadows cast by the waves, we found that these structures reach heights of about 4 kilometers (2.5 miles) above the ring plane. Daphnis probably has a slightly inclined orbit, causing these large waves.

Another unexpected equinox discovery was evidence of meteoritic impacts in the rings. Bright, elevated clouds of tiny particles

in the A, B, and C rings were seen as bright streaks up to 5,000 kilometers (3,000 miles) long. These clouds of particles are most likely ejected from the plane of the rings by impacts of meteoroids into ring particles. Orbital motion of the rings then shears the clouds into streaks. The contrast with the dark rings below made these well-lit streaks easily visible during equinox. The surface area of the rings is 100 times greater than the surface area of Earth, so the rings act as an excellent detector for these kinds of events. Pieces of interplanetary debris continually rain down on Saturn's rings, contributing to ring color, erosion, and evolution.

EVIDENCE OF A COMET STRIKE

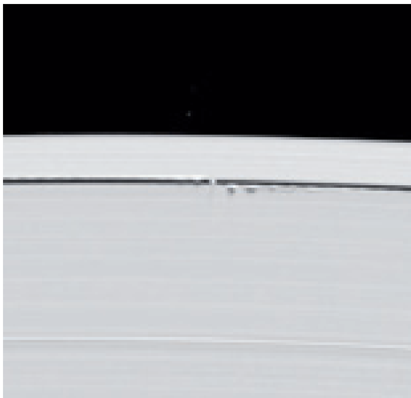
Surprising changes have occurred in the rings since the *Voyager* flybys. *Voyager 1* discovered three ringlets within the D ring, named D68, D72, and D73 based on their distance from Saturn (for example, D68 was about 68,000 kilometers, or 42,000 miles, from Saturn). Twenty-five years later, *Cassini* images showed that the D72 ringlet is now wider and more diffuse, and 200 kilometers (120 miles) closer to Saturn.

Cassini also discovered what appears to be evidence of a comet debris strike to the rings that occurred some 30 years ago, while no one was looking. *Cassini* found waves 30 kilometers (19 miles) wide, initially between D73 and the inner edge of the C ring, that were not present when the *Voyagers* flew by Saturn. At equinox in 2009, these waves were also detected throughout the C ring, extending over a radial distance of 19,000 kilometers (12,000 miles). These waves create a spiral pattern of small vertical corrugations whose wave spacing is decreasing with time. Moving backward in time by mathematically unwrapping the spiral, we think a cloud of cometary debris impacted the rings in late 1983, when Saturn was behind the Sun as viewed from Earth, causing the rings to tilt slightly relative to Saturn's equatorial plane. Since then, that tilt's interaction with Saturn's gravitational field has created the corrugated spiral. Will we be fortunate enough to witness additional impacts in Saturn's rings while *Cassini* is there to record them?

CHAOTIC F RING

From *Voyager*, we knew that the narrow, dusty F ring was different. From *Cassini*, we've learned how extreme and active it is. The F ring continues to change as we watch it, transforming on time scales from hours to years, often looking very different from the F ring imaged by *Voyager*. *Cassini* discovered that a nearby moon, tiny Prometheus, regularly steals particles from the F ring. Rapid changes in the F ring are also caused by small moonlets orbiting in, or close to, the bright core of the F ring, sometimes passing right through the F ring core. Collisions in the F ring happen almost daily, creating jets and streamers of dust. The F ring and nearby objects are being continually perturbed by close encounters with Prometheus. I was amazed to see, in a movie of an early model of the interaction, how well the model matched Prometheus' interactions as that tiny moon pulls particles away from the F ring and creates streamer

ABOVE *Wavy and ever changing, Saturn's delicate F ring lies just outside the planet's main rings. These pictures—with the planet removed from the center—look down onto the ring. (The radial distance from the center of the ring has been exaggerated by a factor of 140 to make its wiggles and other radial structures more visible.) The F ring's regular undulations are caused by the gravitational pull of moonlets Prometheus and Pandora. To read more about these images, visit* **bit.ly/planetary-13-06-01**.



ABOVE *Mountain-high waves on the edges of the rings' Keeler gap, created by the moonlet Daphnis, were another pleasant equinox surprise. This movie shows Daphnis in action:* **1.usa.gov/11KyTWQ**.

Illustration: Michael Carroll; Saturn image: NASA/JPL/SSI/color composite by Ian Regan

ABOVE LEFT *This false-color close-up of Pandora is composed of infrared, green, and ultraviolet images taken by* Cassini's *narrow-angle camera on September 5, 2005, from a distance of about 52,000 kilometers (32,000 miles). To enhance visibility, this image is magnified by a factor of two.*

ABOVE RIGHT *This portrait of Saturn, lit from behind by the Sun, is one of the most beloved space images of all time. This marvelous view, adjusted to resemble natural color, was created from 165 wide-angle camera images taken by* Cassini *over nearly three hours on September 15, 2006. To see and read more, go to* http://1.usa.gov/11xPPnM.

channels in the F ring material. Understanding these processes will help us understand the early, chaotic phases of planet formation.

CASSINI DUE TO IMPACT SATURN IN 2017

The final chapter of the *Cassini* mission, from November 2016 to September 2017, will end with a set of "proximal orbits" eagerly anticipated by the planetary science community. Close passes to Saturn's dynamic F ring in November 2016 will lead to a close flyby of Titan, whose gravity will allow *Cassini* to jump over the main rings to the near polar proximal, or close, orbits. During the closest approach (periapse) of each orbit, *Cassini* will make repeated daredevil dives through the clear region, about 2,000 kilometers (1,200 miles) wide, between the inner edge of the D ring and Saturn's upper atmosphere, repeating this orbit 22 times. No spacecraft has ever explored this region so close to Saturn. These proximal orbits represent a completely new type of science mission for *Cassini*.

Much like the rocket firing that slowed *Cassini* enough to be captured into Saturn's orbit, the proximal orbits involve risks of their own, especially the closest approach of the very first proximal orbit. Is this region truly empty of ring particles, or at least safe enough to traverse? What is the radiation environment like? Current models indicate that this region is safe for *Cassini*, but the only way to find out is to go there.

These exciting orbits will give us new, breathtaking views of Saturn and its rings and provide numerous unique opportunities for fresh discoveries and groundbreaking science. Fundamental observations made from these orbits will provide a much better understanding of Saturn's formation and evolution, as well as that of the early solar system. We intend to augment earlier measurements and address unanswered questions. Among our goals are (1) detailed measurements of both the gravity and magnetic fields, to determine Saturn's internal structure and possibly its internal rotation rate; (2) measurement of the mass of Saturn's rings, currently uncertain by at least an order of magnitude; (3) measurements from within Saturn's ionosphere, innermost radiation belts, and D ring; (4) the highest resolution studies ever of the main rings; and (5) high-resolution Saturn atmospheric studies.

The proximal orbits were specifically designed to achieve "*Juno*-like" end-of-mission science, providing observations of Saturn that complement those that the *Juno* spacecraft will make of Jupiter in 2016 so that we can understand what makes these gas giants similar or different. The *Cassini* mission will end in September 2017 as the final orbit puts *Cassini* on an irrevocable path into Saturn's atmosphere.

Our spacecraft has been a marvel of engineering in the service of planetary science and promises more spectacular images and scientific data through the end of its mission. In the meantime, I look forward to the continuing chapters in the *Cassini* story.

Images: NASA/JPL/SSI

Astrophotography is my passion. I have been interested in optics and have loved astronomy, photography, and the study of weather since I was a kid. I am lucky to live in an area with some decent dark skies, but we are losing out to light pollution.

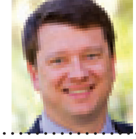
One of the highlights of my hobby was the early morning of November 17, 2001 during the "Great Leonid Meteor Storm of 2001." I braved temperatures of 20 degrees Fahrenheit (–17 degrees Celsius) for several hours while observing and experiencing the swarm of meteors, many of which were bright fireballs, around me. This image captures the most intense fireball slicing through the Orion constellation. What a catch!

I am honored to be a member of The Planetary Society and to know that I am supporting space travel and exploration. —*Ronald Zincone, Richmond, Rhode Island*

Planetary Society Members are united in their love of space exploration—which has its origins in Earth's skies. Thank you for sharing your views with us! To see more, go to **MYSKY.PLANETARY.ORG**.

WANT TO SHARE YOUR SPACE IMAGE? Send us an e-mail with a jpeg (less than 5 MB) attachment of your image to *planetaryreport@planetary.org*. Please use the subject line "MySky" and include a short caption (such as where you took the image and, if appropriate, with what equipment) and credit line for the image. Please include just one MySky image per submission. Also, be sure to include your name, contact information, and membership number (it's on your membership card and on the mailing label of your magazine). We'd also love to receive a picture of you and to learn more about what is most important to you about being a Planetary Society Member. Questions? E-mail *planetaryreport@planetary.org* or call (626) 793-5100, extension 218.

Answers to *Planetary Society Kids* "Elementary, My Dear...": O: Oxygen; Ne: Neon; H: Hydrogen; C: Carbon; He: Helium; Mg: Magnesium; Au: Gold; N: Nitrogen. BONUS: All but one of these elements occur abundantly in the solar system. Can you guess which one? Answer: Gold. DOUBLE BONUS: 99% of the mass of the solar system is made up of which two elements above? Answer: Hydrogen and helium. Triple bonus if you also discovered that over 99% of the mass of our solar system is contained in our star—the Sun!



BRUCE BETTS *is director of projects for The Planetary Society.*

Near-Earth Asteroids

Saving Our World and Naming Another

SAVING THE WORLD: 2013 SHOEMAKER NEO GRANT WINNERS ANNOUNCED

What do the discovery of close flyby asteroid 2012 DA14 and the world's most productive near-Earth object (NEO) follow-up tracking program have in common? They were both made possible by you through The Planetary Society's Shoemaker NEO Grants.

I am very excited to tell you that we have chosen the winners of the 2013 Shoemaker NEO Grants. These winners were announced at the International Academy of Astronautics' Planetary Defense Conference, which took place in mid-April in Flagstaff, Arizona.

Now in its 16th year, the Shoemaker NEO Grants program provides funding—primarily for extremely advanced amateurs but also for underfunded professionals—to take their asteroid observational programs to the next level. A string of success stories shows that our grants have made real differences in facilitating improved tracking observations, physical characterization, and even, in this age of professional surveys, some key discoveries of near-Earth asteroids by amateurs.

Thank you, members of The Planetary Society who generously make this program possible! Over the program's 16 years, we have presented 43 awards, totaling more than $270,000, to observers in 16 countries on five continents. The Planetary Society also sincerely thanks our expert international advisory and review panel members: Planetary Society NEO Grant Coordinator Timothy Spahr, Director of the Minor Planet Center, Smithsonian Astrophysical Observatory, USA; Alan Harris, MoreData!, USA; Carl Hergenrother, University of Arizona, USA; Petr Pravec, Ondrejov Observatory, Czech Republic; and Duncan Steel, University of Canterbury, New Zealand.

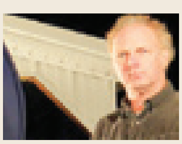
Sixteen people submitted proposals for this year's round of grants. Based on recommendations of the review panel and the resources available, five grants were awarded, for a total of $34,307.

Thanks!

Planetary Society Members have helped make these and other planetary defense programs possible. Thank you.

2013 SHOEMAKER NEO GRANT WINNERS

ALBINO CARBOGNANI, Astronomical Observatory of the Autonomous Region of the Aosta Valley in the Italian Alps, is awarded $9,120 for improvements to the observatory's 0.81-meter telescope.



ROBERT HOLMES, Astronomical Research Institute (ARI) in Westfield, Illinois, USA, is awarded $6,662 for purchase of a CCD camera for the institute's recommissioned 0.76-meter telescope. ARI will contribute $3,333 toward the camera. Holmes is the only four-time winner of a Shoemaker NEO Grant. In 2012, he recorded 14,518 NEO observations—a world record for the most NEO observations in a single year.

GARY HUG, Sandlot Observatory, Scranton, Kansas, USA, is awarded $2,390 for two computers, upgraded software, and peripheral equipment that will allow more observations and increased reliability with his 0.56-meter telescope.

DONALD PRAY, Sugarloaf Mountain Observatory, South Deerfield, Massachusetts, USA, is awarded $8,070 for the mirror, structure, and focuser for a new 0.5-meter telescope. Sugarloaf Mountain Observatory will contribute the camera and mount for the new telescope.

ROBERT STEPHENS, Center for Solar System Studies (CS3) in Landers, California, USA, in the Southern California desert, is awarded $8,065 for purchase of a dedicated CCD camera for a 0.4-meter telescope.

For more information on the winners, including their plans for use of their new hardware and software, see planetary.org/neogrants.

PLANETARY DEFENSE CONFERENCE

Every two years, The Planetary Society co-sponsors the International Academy of Astronautics Planetary Defense Conference. This conference brings together the world's experts in all aspects of defending the world from asteroid and comet impacts. This April, the conference was held in Flagstaff, Arizona, near the world's best-preserved large impact crater, Meteor Crater. Several of our staff attended, and we hosted a public evening (see page 4).

We also visited with some of our past Shoemaker NEO Grant winners, including Jaime Nomen from Spain, who discovered close flyby asteroid 2012 DA14 thanks to one of our grants, and Alison Gibbings, a graduate student at the University of Strathclyde in Scotland, who is carrying out the Planetary Society-sponsored Laser Bees project, conducting lab experiments to study the viability of using spacecraft-based lasers to deflect asteroids. Alison took second place for Best Student Paper at the conference, where she presented results from her work using a laser to zap asteroid simulant rocks in a laboratory vacuum chamber.

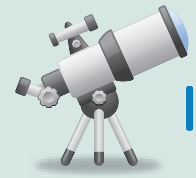
More information about the Laser Bees project and the entire conference can be found on our website. We've posted a video of the public evening and *Planetary Radio* shows from the conference.

NEW NAME FOR OSIRIS-REX TARGET ASTEROID

Asteroid (101955) 1999 RQ36 now has the much friendlier name Bennu, thanks to third-grade student Michael Puzio from North Carolina. NASA's Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS-REx) spacecraft is scheduled to launch in 2016, visit Bennu in 2018, and return a sample of the asteroid to Earth in 2023.

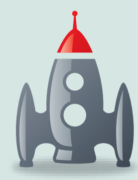
More than 8,000 students from dozens of countries around the world entered the *Name That Asteroid!* competition. The contest was a partnership among the University of Arizona, The Planetary Society, and the Lincoln Near Earth Asteroid Research (LINEAR) survey at the Massachusetts Institute of Technology's Lincoln Laboratory. Learn more about the contest, its finalists and semifinalists, entries, and the OSIRIS-REx mission at **planetary.org/name**.

WHAT'S UP? *by Bruce Betts*



IN THE SKY

Venus is very low, but very bright, in the west after sunset throughout the summer. Yellowish Saturn is above Venus, growing closer as the months pass. On September 8, the Moon will be between them. In July, bright Jupiter and much dimmer, reddish Mars are low in the pre-dawn east; both will get higher as the weeks pass. In late July and early August, Mercury will be below them. On August 4, the Moon joins the planetary trio. The Perseid meteor shower peaks August 12/13, with little interference from the Moon. Increased activity will be seen from several days before to several days after the peak. The Perseids typically are one of the best showers of the year, with an average of 60 meteors per hour visible from a dark site.



RANDOM SPACE FACT

The gravity at the surface of a neutron star is more than 100 billion times the gravity at the surface of the Earth.

TRIVIA CONTEST

Our December Solstice contest winner is Cheryl Dodes from Boca Raton, Florida. Congratulations! **THE QUESTION WAS**: In what constellation is the Crab nebula, which is a remnant of a supernova observed in 1054 by astronomers around the world? **THE ANSWER**: Taurus.

Try to win a free year's Planetary Society membership and a *Planetary Radio* T-shirt by answering this question:

What are the only planets that have been visited (in flybys or by orbiters) by one and only one spacecraft, as of 2013?

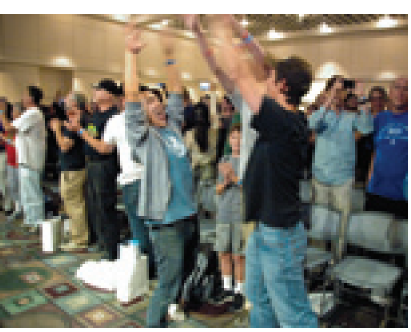
E-mail your answer to *planetaryreport@planetary.org* or mail your answer to *The Planetary Report*, 85 South Grand Avenue, Pasadena, CA 91105. Make sure you include the answer and your name, mailing address, and e-mail address (if you have one). By entering this contest, you are authorizing *The Planetary Report* to publish your name and hometown. Submissions must be received by August 1, 2013. The winner will be chosen by a random drawing from among all the correct entries received.

For a weekly dose of "What's Up?" complete with humor, a weekly trivia contest, and a range of significant space and science fiction guests, listen to *Planetary Radio* at *planetary.org/radio*.

Annual Report to Our Members

ABOVE *The Society's new website is home to myriad images, stories, and updates of science, advocacy, and events.*

BELOW *In the ballroom at* Planetfest, *cheers broke out once* Curiosity *let Earth know it was safe on Mars.*



Dear Planetary Society Members, Donors, and Friends,

CONGRATULATIONS, and thank you!

As I look back at fiscal year 2012 (October 1, 2011 through September 30, 2012), I'm filled with pride, optimism, and determination—the same feelings so many of you share about The Planetary Society.

I'm pleased to share a few highlights from our year of accomplishments.

PLANETARY.ORG

Our new website brings you new discoveries, beautiful images, and cutting-edge insights, and it involves you in shaping space science and exploration.

- CEO Bill Nye, our own Emily Lakdawalla, Casey Dreier, and other stellar educators and scientists host Google hangouts, post video updates, and involve you in projects and advocacy.
- You can share your own space images and stories via the MySky and MyStory sections of our website.

EXPLORING OTHER WORLDS

NASA's *Curiosity* rover, carrying The Planetary Society's third MarsDial, along with every Society Member's name, made headlines with its dramatic landing on Mars. Thousands joined our *Planetfest: Curiosity Knows No Bounds* celebration in Pasadena and at satellite events, including a Jumbotron shout-out at New York's Times Square (courtesy of Toshiba) and lectures and landing parties at science centers and museums in both hemispheres.

Visitors to our Pasadena *Planetfest* were greeted by a towering SpaceX *Dragon* crewed capsule, and inside the building, they posed for photos in the cockpit of a full-scale XCOR *Lynx* suborbital spacecraft and also next to a full-scale model of *Curiosity*. A packed schedule of appearances by leading scientists, engineers, and celebrities kept festival-goers enlightened and entertained. Our live video feed from JPL's mission control sent attendees home with the knowledge that they'd watched history being made.

The Planetary Society community reveled in another spectacular event—we helped solve the *Pioneer* Anomaly! Your donations saved the data, got the analysis started, and gave an emphatic "yes" to solving the anomaly.

With partner Honeybee Robotics, we announced a bold new project—PlanetVac, an innovative system for gathering regolith from another planet, the Moon, or an asteroid.

Also, with your support:

- The planet-hunting team of Yale's Debra Fischer is looking for Earth-like worlds around Alpha Centauri as part of FINDS (Fiberoptic Improved Next-generation Doppler Search) for Exo-Earths.
- The Planetary Society's Optical Search for Extraterrestrial Intelligence (SETI) Telescope search, led by Harvard's Paul Horowitz and his team, was upgraded to the latest technology.
- Our solar sail space mission, *LightSail*, is awaiting launch and the chance to test a technology that will one day take us to the stars. Like you, I can hardly wait.

UNDERSTANDING OUR OWN WORLD

The Society's mantra, "Know your place in space," guided initiatives to educate Members of all ages and to reach new audiences:

- Bill Nye leveraged his international acclaim as a science educator by speaking to audiences at the International Astronautical Congress; USA Science and Engineering Festival; Homestead National Monument; Arecibo Radio Observatory; White House Science Fair; and TED (Technology, Education, Design) conference;

and talking with astronaut Sunita Williams in the International Space Station.

- Planetary Society volunteers held lectures, hosted star parties, and spoke to school groups and at libraries to bring the passion, beauty, and joy of space to their communities.
- *The Planetary Report*'s new "Planetary Society Kids" insert entertained and educated younger readers. Thank you to the Clarence Foster Stanback Donor Advised Fund of Foundation For The Carolinas for its support.
- *Planetary Radio* marked its 10-year anniversary. Generous Member support, in-kind gifts from Celestron, and a grant from the Kenneth T. and Eileen L. Norris Foundation made this possible.
- Thanks to funds from the Gene Shoemaker Near Earth Object Grant Fund, astronomers at Spain's La Sagra Observatory discovered asteroid 2012 DA14, which this year made the closest known approach to Earth ever.
- Member funding also launched a study of "Laser Bees," a technique using concentrated light to deflect an asteroid from a collision course with Earth.

Projects, education, and advocacy go hand in hand. Last year, you and your fellow space advocates worked tirelessly to Save Our Science, and you helped to restore funding to NASA's FY13 space science budget. That success will fuel this year's fight to save FY14's funds.

OUR FINANCIAL PICTURE

Your generous donations and planned gifts make an impact. Your Membership matters–as a New Millennium Committee Member, a Charter Member, an Annual Supporter, or a Discovery Team Member.

We're pleased to reignite the Carl Sagan Fund for the Future with a challenge grant from the M.R. and Evelyn Hudson Foundation. I invite you to be a part of that.

I would be remiss if I didn't make my annual plea for you to bring The Planetary Society and the thrill of space exploration to the young people in your life–as I often do–with the gift of a Student Membership. We need to get our youth interested in science and math, preparing them for what will be a scientifically rich and exciting future.

You are creating a better future by joining us as we explore other worlds and understand our own. Thank you.

Sincerely yours,

Dan Geraci

Financial Statement

For the fiscal years ended September 30, 2009, 2010, 2011, and 2012 in thousands of dollars

Total All Funds:	FY2012	FY2011	FY2010	FY2009
Assets				
Current Assets				
Cash and Cash Equivalents and Investments	2,132	2,693	2,984	2,636
Membership Dues and Misc. Receivables	34	35	32	41
Inventories	0	0	0	28
Prepaid Expenses	37	90	51	64
Total Current Assets	**2,203**	**2,818**	**3,067**	**2,769**
Land, Building, and Equipment	**106**	**49**	**61**	**583**
Total Assets	**2,309**	**2,867**	**3,128**	**3,352**
Liabilities	FY2012	FY2011	FY2010	FY2009
Accounts Payable and Accrued Expenses	136	92	232	141
Deferred Dues and Grant Revenue*	1,026	1,036	1,330	1,606
Total Liabilities	**1,162**	**1,128**	**1,562**	**1,747**
Net Assets (Deficits)	FY2012	FY2011	FY2010	FY2009
Unrestricted	587	1,249	876	226
Temporarily Restricted	558	488	688	1,377
Permanently Restricted	2	2	2	2
Total Net Assets	**1,147**	**1,739**	**1,566**	**1,605**
Total Liabilities and Net Assets (Fund Balances)	**2,309**	**2,867**	**3,128**	**3,352**
Revenues	FY2012	FY2011	FY2010	FY2009
Membership Dues	1,166	1,319	1,110	1,101
Donations/Grants	1,435	1,949	1,446	2,208
Bequests	143	286	210	277
Other**	166	174	1,206	144
Total	**2,910**	**3,728**	**3,972**	**3,730**
Expenses	FY2012	FY2011	FY2010	FY2009
Member Development and Fund-raising	487	453	492	488
Communications: Print/Web/Radio	639	588	583	621
Education & Information	69	49	110	81
Programs***	546	265	298	172
Member Services	374	228	345	371
Administration	359	412	325	318
Projects	619	537	438	616
Solar Sail	409	1,023	1,420	230
Total	**3,502**	**3,555**	**4,011**	**2,897**

* Income received but not yet recognized
** Admissions, events, interest, net sales, royalties, etc.
*** Events, lectures, tours, and expeditions
Note: In FY2011 Publications Department changed to Communications and added Radio to new department

A copy of The Planetary Society's latest audited statement can be obtained by contacting:

LU COFFING
Chief Financial Officer
85 S. Grand Avenue
Pasadena, CA 91105
(626) 793-5100 x234
lu.coffing@planetary.org

THE PLANETARY SOCIETY
85 SOUTH GRAND AVENUE
PASADENA CA 91105-1602 USA

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You are standing on the shoulders of a giant.

Carl Sagan founded The Planetary Society with the belief that space exploration brings out the best in humanity.

You can help guarantee that we never back off from the enterprise of the planets—and ensure a strong long-term future for The Planetary Society.

Invest in our reserve fund, the **CARL SAGAN FUND FOR THE FUTURE**.

The M.R. & Evelyn Hudson Foundation will match your gift of any amount, dollar for dollar, until we raise $100,000. It will double and even triple larger gifts, so your donation will make an even greater impact.

The **CARL SAGAN FUND FOR THE FUTURE** will give us the long-term stability we need to expand our advocacy work and pursue exciting projects to advance us farther, faster, and more creatively into space.

Carl intended that The Planetary Society would flourish long after we're gone.

You can help make his dream a reality. We can stand even taller.

"If we back off from the enterprise of the planets, we will be losing on many different levels…"

—CARL SAGAN, FROM THE FIRST ISSUE OF *THE PLANETARY REPORT*, DECEMBER 1980

Painting: K. Johnson from a photo by Andy Levin

Invest in the Future of Space Exploration at

planetary.org/futurefund