THE PLANETARY SOCIETY

THE PLANETARY REPORT

DECEMBER SOLSTICE 2014
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THE YEAR IN PICTURES

CELEBRATING THE EXTRAORDINARY

CLOSING IN ON CERES ✻ PLANETARY DEEP DRILL ✻ OUR VISIONARY 3-YEAR PLAN

RICHARD CHUTE *is development director of The Planetary Society.*

It's Time to Get Moving…Onward!

ABOVE *The Planetary Society's new Strategic Plan is available at* **bit.ly/1yI6aqx**.

OKAY, SPACE ENTHUSIASTS–it's time to apply your powers of deductive reasoning. What is precisely 27.94 centimeters long by 21.59 centimeters wide by 0.16 centimeters deep, weighs 73.7 grams, is flexible in two dimensions, and has the power to change the world?

If your guess is a new breakthrough in tabletop nuclear fusion or perhaps an exotic new composite material created in a high-tech laboratory, then you will have to guess again. That's because I am actually referring to The Planetary Society's new visionary Strategic Plan 2015-2017: Onward! After years of painstaking engineering and construction, the Strategic Plan is ready for launch. In fact, you may have already found that a copy of it has landed in your e-mail inbox. If you missed it, it's also available at **bit.ly/1yI6aqx**.

When you study it, as I hope you will, you will find that it lays out a clear path for advancing the mission of The Planetary Society: empowering the world's citizens to advance space science and exploration. As a member of the Society, you know that we accomplish this by engaging in three basic activities–we create, educate, and advocate. But beyond these objectives we need more tangible goals to help us focus and to guide our efforts. So, for the next three years, we will engage our members in three important initiatives. We will:

- advance the exploration of the cosmos and the search for life,
- engage the public in space exploration, and
- build a sustainable future for The Planetary Society.

In the coming months, you will hear much more about each of these critical efforts. As the new director of development of The Planetary Society, I will engage you, our members, in the third initiative–building a sustainable future for the Society. In this vein, you will find that we are beginning to put our foot forward in fresh ways, and I hope you will soon notice the difference. We will create new, more meaningful communications with you about our work and some of the exhilarating opportunities for providing philanthropic and volunteer support. Although we haven't mounted a Kickstarter campaign (but keep your eyes open for it this coming year!) you might say that the Society has always been engaged in crowdfunding because it has been you–our members–who have joined together to provide the resources to power our organization forward as we reach for the stars.

As we approach our 35th year, there is a palpable sense of excitement at The Planetary Society. Borrowing from our CEO's current attention on the theory of evolution, we see that we must continue to change and evolve, like everything in our universe, and become more "adaptively fit" as an organization. Often, evolution comes through moments of punctuated equilibrium–a period of rapid change in response to changes in the environment. This is just such a moment for The Planetary Society.

Our esteemed co-founder, Carl Sagan, said, "We have lingered long enough on the shores of the cosmic ocean. We are ready at last to set sail for the stars." These are the final words of our Strategic Plan 2015-2017. They are as much a statement about The Planetary Society itself as they are about humankind. Together, our members, our board, and our staff are poised to take that next step–no, that next leap–into the future as we advance space science and exploration. Yes, it's time to get moving … onward!

THE PLANETARY SOCIETY

ON THE COVER: India's first interplanetary mission, the *Mars Orbiter Mission*, successfully entered orbit at the Red Planet on September 24, 2014. Hours later, the spacecraft returned its first color images of Mars. This view, taken in early October, shows the volcanoes of Elysium and, toward the bottom of the disk, the dark swath of Terra Cimmeria. Above Terra Cimmeria is a small crater with a large, dark streak running down from it. That's Gale, *Curiosity*'s landing site. *Image: Indian Space Research Organization*

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

2014 WAS AN EXTRAORDINARY year for The Planetary Society. I'm honored to have been serving as your CEO for four years now. At the end of each year I like to take a moment to look back at our twelve months of work, and, each year, I'm pleased to see we've been even more active and more effective than the year before.

We just signed a lease on new space … new office space, that is. We're staying in Pasadena, California, but we're moving into a larger building that will be our home for many years to come. The space just feels like the future, which is exciting for the staff and especially for the Society. Speaking of the staff, we've expanded. There are some new faces around, thanks to your thoughtful and generous donations. Along with these changes, and unlike anything I ever expected, my book, *Undeniable: Evolution and the Science of Creation*, has become a *New York Times* bestseller. These happenings, my book, and our mission to advance space science and exploration are all extensions of the vision of our founders, Carl, Bruce, and Lou.

In 2015, The Planetary Society will celebrate its 35th anniversary! For more than a third of a century we have worked hard for space exploration and we have a great many achievements to celebrate. Even better, we have much to anticipate. We see some exciting years in space just ahead.

THE PLAN

In this issue, you'll find descriptions and references to Onward, our new three-year strategic plan. We really took our time with this plan, looking at our past and imagining our future. We reworked our mission and vision statements, and we've aligned our programs and short-term goals to move us in the right direction. We have categorized our work into three initiatives: advancing the exploration of the cosmos, engaging the public in space exploration, and building a sustainable future for The Planetary Society. We have set some ambitious goals: increased membership, even more effective political advocacy and leadership, the launch of our *LightSail* spacecraft, and development of our long-term financial security. We have turned our ship, set our course, and now we've set sail. Expect 2015 to be an even bigger year for us!

CHURYUMOV-GERASIMENKO AND YOU

As I write, the *Philae* spacecraft touched down, bounced, and touched down again on Comet Churyumov-Gerasimenko (67P), while sending us reams of data and astonishing photographs. All the while, our amazing journalist (and planetary evangelist) Emily Lakdawalla covered every breathtaking moment of the adventure from European Space Agency's Control Room in Darmstadt, Germany. Thanks to all of you, we are an international Society of explorers. The remarkable achievement of this mission bodes well for planetary exploration writ large. Space agencies around the world joined our European colleagues in celebrating the mission. Be assured they all will be sharing its data for many years to come.

Rosetta and *Philae* will do much to increase our understanding of cometary bodies. The material comprising 67P comes from the earliest epoch of our solar system. It holds keys to answering that fundamental question: Where did we come from? Life on Earth is made of the same stuff as 67P. To know it is to know ourselves.

Furthermore, as I often point out, there may come a day in the not-too-distant future (tonight or tomorrow, for example), when humankind detects an icy rock, with destruc-

tion written all over it, headed our way. We will have to muster a system to deflect such a rock from impacting our home. Understanding what's out there may be literally vital.

Speaking of our solar system's primordial material, I hope you are also looking forward to *New Horizons* flying by Pluto and continuing to a yet more distant world beyond Pluto's orbit. This coming July will bring us images from a world that humankind has, so far, only been able to imagine. As I like to say, watch this space.

DESIGN FOR DEVELOPMENT

When I started working for you–that is, for the Society–I was unfamiliar with the term "development." In the not-for-profit world, development is often seen as a synonym for fundraising, but it's so much more. Development is about developing relationships. I mention it because we have reorganized our development efforts to focus on our relationship with you. We're putting more focus on who you are and what you like, so we can develop a deeper and more meaningful relationship with you.

The interests of the Society's members are diverse. For example, for most of you, this magazine arrived in the mail. It's still very satisfying for many of us to hold the paper magazine in our hand as we read. For others among us it's equally satisfying to receive the magazine electronically. Some of us fancy ourselves as space-borne sailors. Others like to fund research such as drilling through many meters of ice on another world. Still others support finding other worlds to explore in the first place. We each have projects that are of particular interest. Of course, some of us (like me) want to support everything the Society is involved in, because everything we do these days is set up to advance space science and especially space exploration.

Along with our development reorganization, we are revamping our bookkeeping and accounting systems, to make, well ... to make our financial resource categories and allocations more meaningful and easier to understand. We are also investing in our web presence and social media outlets to provide quicker, better communication and more easily searched articles and blogs. But most important, we are investing in our people–in our members and in our staff. There is a new, wonderful spirit around the office. We are all pulling together to get people around the world excited about the prospects of discoveries in space.

WORKING FOR YOU

Meanwhile and finally, rest assured that I see that my immediate job is to support and advocate the benefits of space exploration, most especially planetary exploration. I have appeared on more than a dozen television and radio shows in connection with my new book. On each of these programs, I make a point to connect evolution to astrobiology; that is, to the scientific enterprise of exploration and discovery within the cosmos. Through these appearances and my advocacy I hope to expand our influence and extend our reach. Thanks to members like you, The Planetary Society is indeed advancing space science and exploration. We want humans everywhere to become good stewards of our world; people who find joy in knowing other worlds and who appreciate our place in space.

Bill Nye

BELOW *Using a wooden crate as a desk, Bill Nye signs the lease on the building that will become The Planetary Society's new home.*

THIS IS YOUR ORGANIZATION, AND I WANT TO HEAR FROM YOU.
E-mail me at *tellbill@planetary.org* or send a letter to Bill Nye at
The Planetary Society
85 South Grand Ave.
Pasadena, CA 91105

Also, do we have your e-mail address? To stay informed, sign up at **bit.ly/tps-email**.

EMILY STEWART LAKDAWALLA
blogs at planetary.org/blog

the Year in Pictures

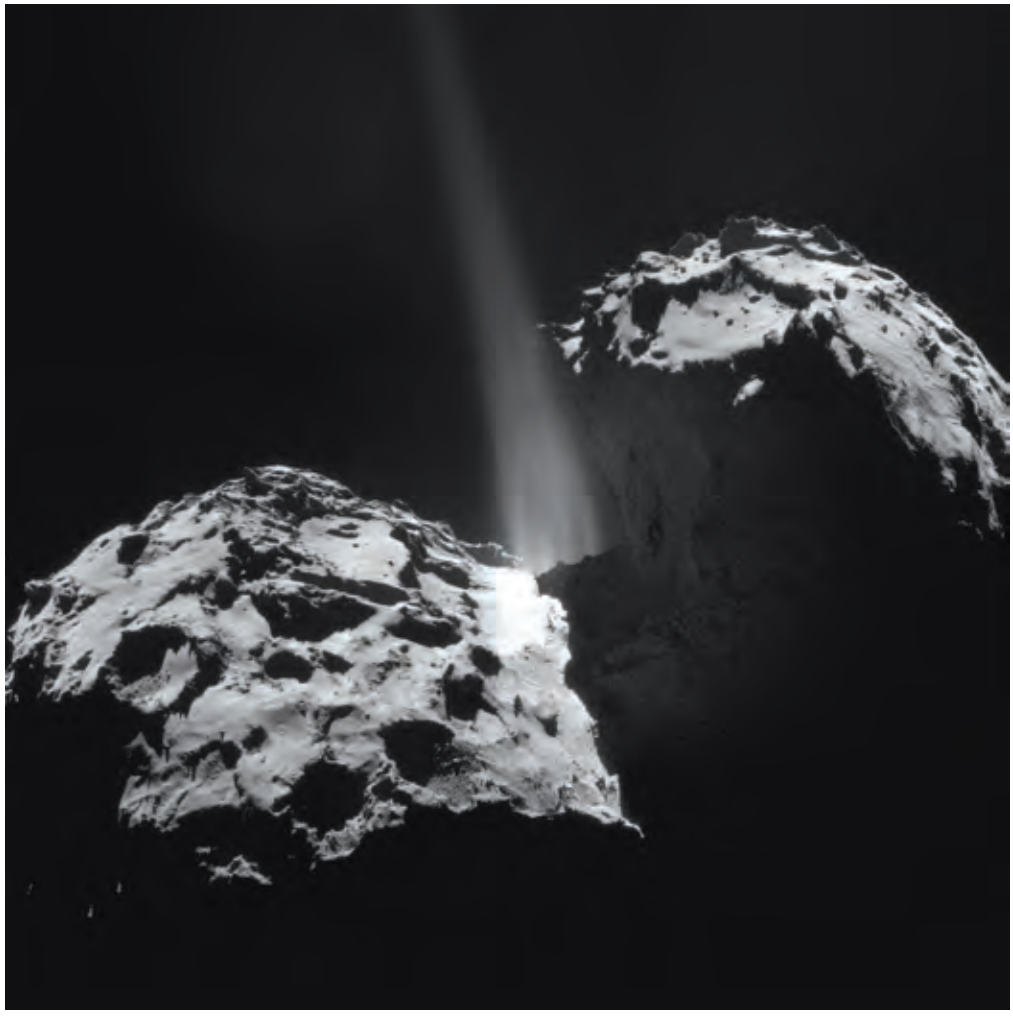
THE YEAR 2014 drew to a close with a record number of spacecraft exploring Mars. Five orbiters crisscross its skies, and two rovers ply its surface. Just after the last two of these arrived, comet Siding Spring zipped past Mars, providing an unprecedented opportunity to turn space-based instruments on a long-period comet making its first visit into the inner solar system.

Other spacecraft continue their long missions, returning science from Mercury, Venus, the Moon, Saturn, and beyond the Pluto system. *Rosetta* finally arrived at its comet, and *Dawn* and *New Horizons* are finally approaching their dwarf planet destinations.

It's an incredibly productive fleet, but it's an aging one; 2014 may represent a peak in active science missions. *MESSENGER* at Mercury and *Venus Express* at Venus will both crash in 2015, leaving the inner planets with no resident spacecraft (although *Akatsuki* might make it into Venus orbit in late 2015). At Mars, three of the orbiters and one of the rovers are showing signs of advanced age. Their survival can't be taken for granted, but while they still function, they are all highly productive science missions.

The following pages contain just a few of the images that mark significant events of 2014. They cover only January through November; please visit my Planetary Society blog for an addendum including the final weeks of the year.

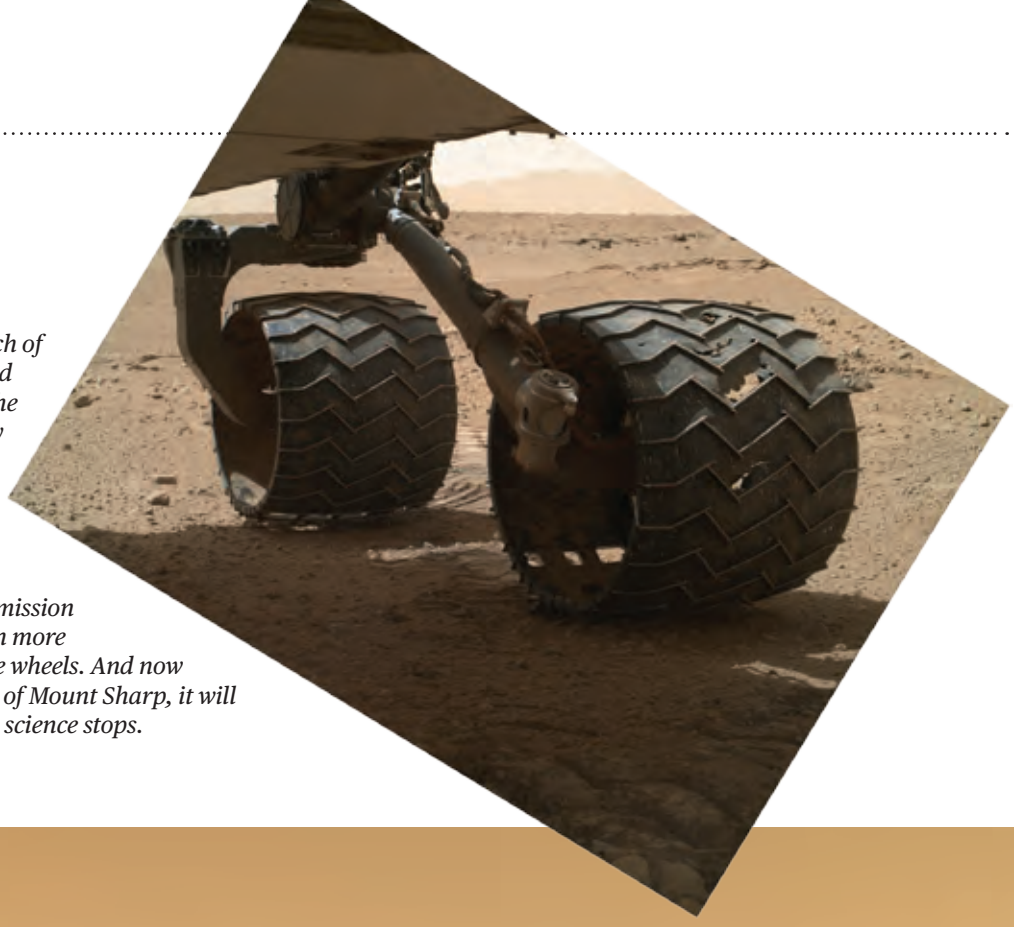
CASCADE OF LIGHT *It's safe to say that no one predicted the appearance of comet 67P/Churyumov-Gerasimenko, which* Rosetta *finally reached in 2014 after a decade-long journey. The comet is composed of two nearly separated lobes, and the comet's strongest jets emanate from the narrow neck that joins the lobes.* Rosetta *will accompany the comet as it approaches perihelion, watching how its activity and its surface change over time.*



WAITING FOR CHANGE Mars Reconnaissance Orbiter*'s scientific focus has shifted to watching for evidence of Mars' dynamic geology. By repeatedly imaging the same sites over many years, the spacecraft has seen gullies erode deeper into Martian hills, and deposits of sediment form at their mouths. Changes most often occur in winter or early spring, suggesting that seasonal deposits of carbon dioxide frost may trigger gully activity. This image covers an area about 900 meters wide.*

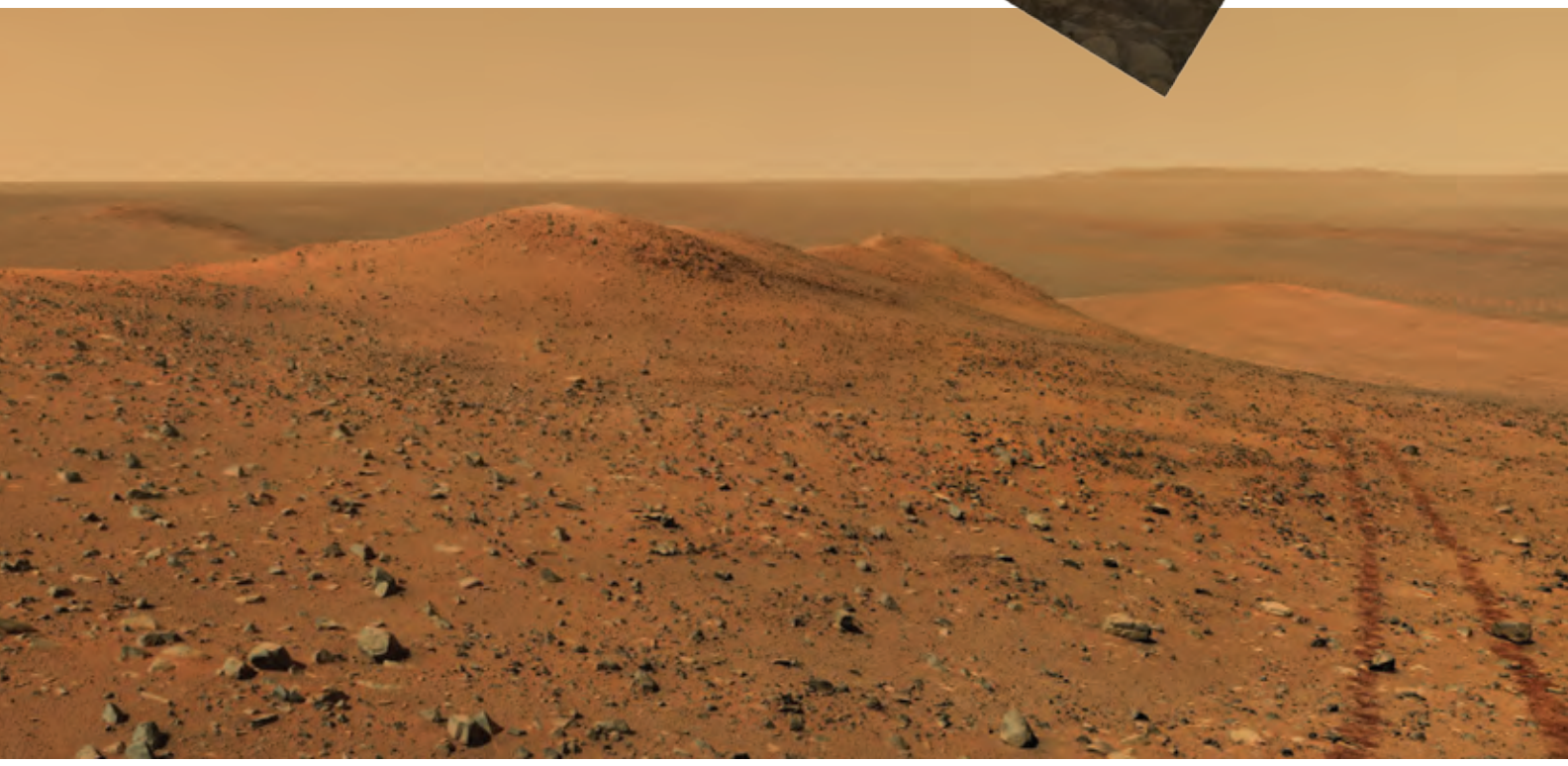
FAREWELL, *PHILAE* *After a journey of more than 10 years together, the* Rosetta *orbiter and* Philae *lander parted ways on November 12, 2014. A gentle push sent* Philae *free-falling toward comet Churyumov-Gerasimenko, where it came to a rough landing but performed its science mission well for three days before falling silent.* Rosetta*'s OSIRIS camera captured this sequence of images of the lander receding over a period of two hours.*

Images: Mars gullies: NASA/JPL/UA; Comet: ESA/Rosetta/NavCam/Mattias Malmer; Philae: ESA/Rosetta/DLR/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/ IDA



HOLEY WHEELS Curiosity *spent much of its second year on Mars roving toward the enticing rocks of Mount Sharp. The road has not been kind: unexpectedly pointy rocks, likened to sharks' teeth embedded in concrete, have punctured the thin aluminum skin of its left middle wheel, although the left rear wheel remains mostly undamaged. After much testing, the mission has determined how to choose terrain more carefully to prolong the lifetime of the wheels. And now that the rover has arrived at the base of Mount Sharp, it will have much less driving to do between science stops.*

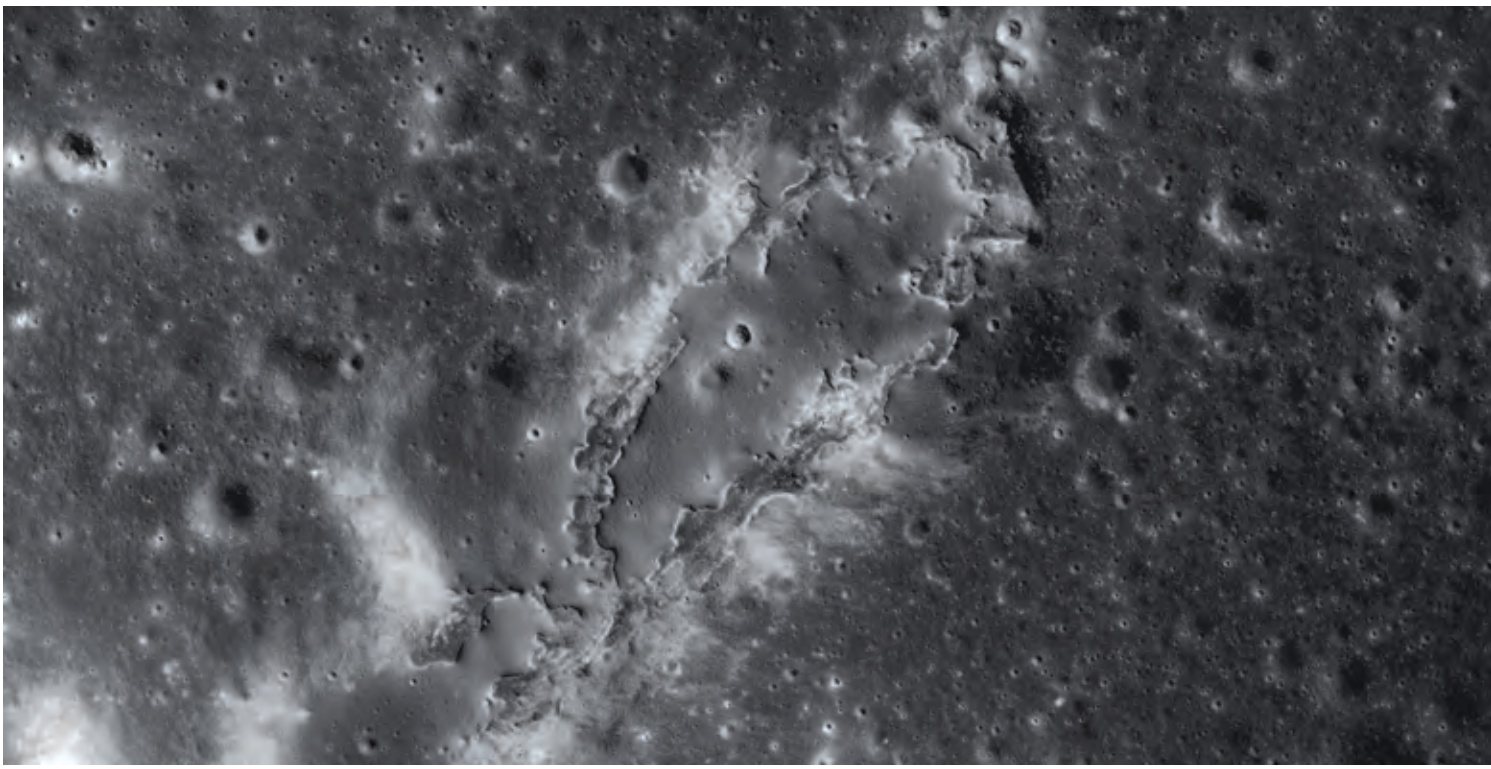
Images: Wheels: NASA/JPL/MSSS; Wdowiak Ridge: NASA/JPL/Cornell/ASU/James Sorenson

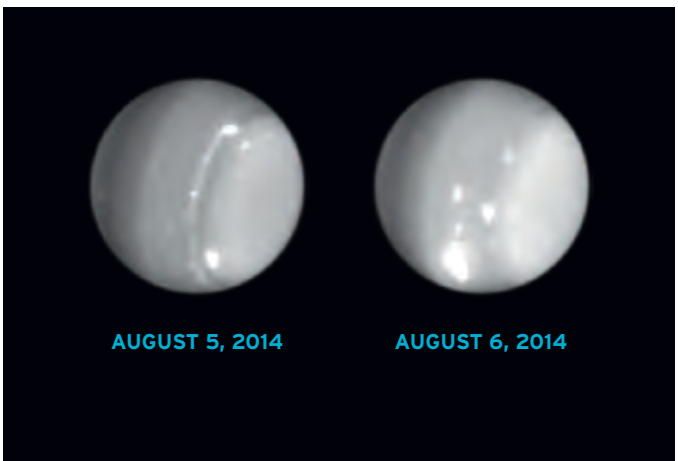


WDOWIAK RIDGE Opportunity *spent 2014 climbing mountains. In this view, captured on sol 3786 (September 17), it looks back at the path that has taken it high above the Meridiani plains, onto the rim of Endeavour crater. In the center of the image is a line of hills called Wdowiak Ridge, named for Tom Wdowiak [DOW-ee-ak], a planetary geologist and Mars Exploration Rover science team member who died in 2013.*

LUNAR ROVER STILLED *China's lunar rover,* Yutu, *rolled about 100 meters across the lunar surface before the catastrophic failure of its motor controller on January 17, which robbed it of its ability to move wheels, arm, or camera mast. Yet it remained functional and communicated with Earth through much of 2014. It returned this photo of a flat, dark plain littered with sharp, broken impact breccia around January 16.*

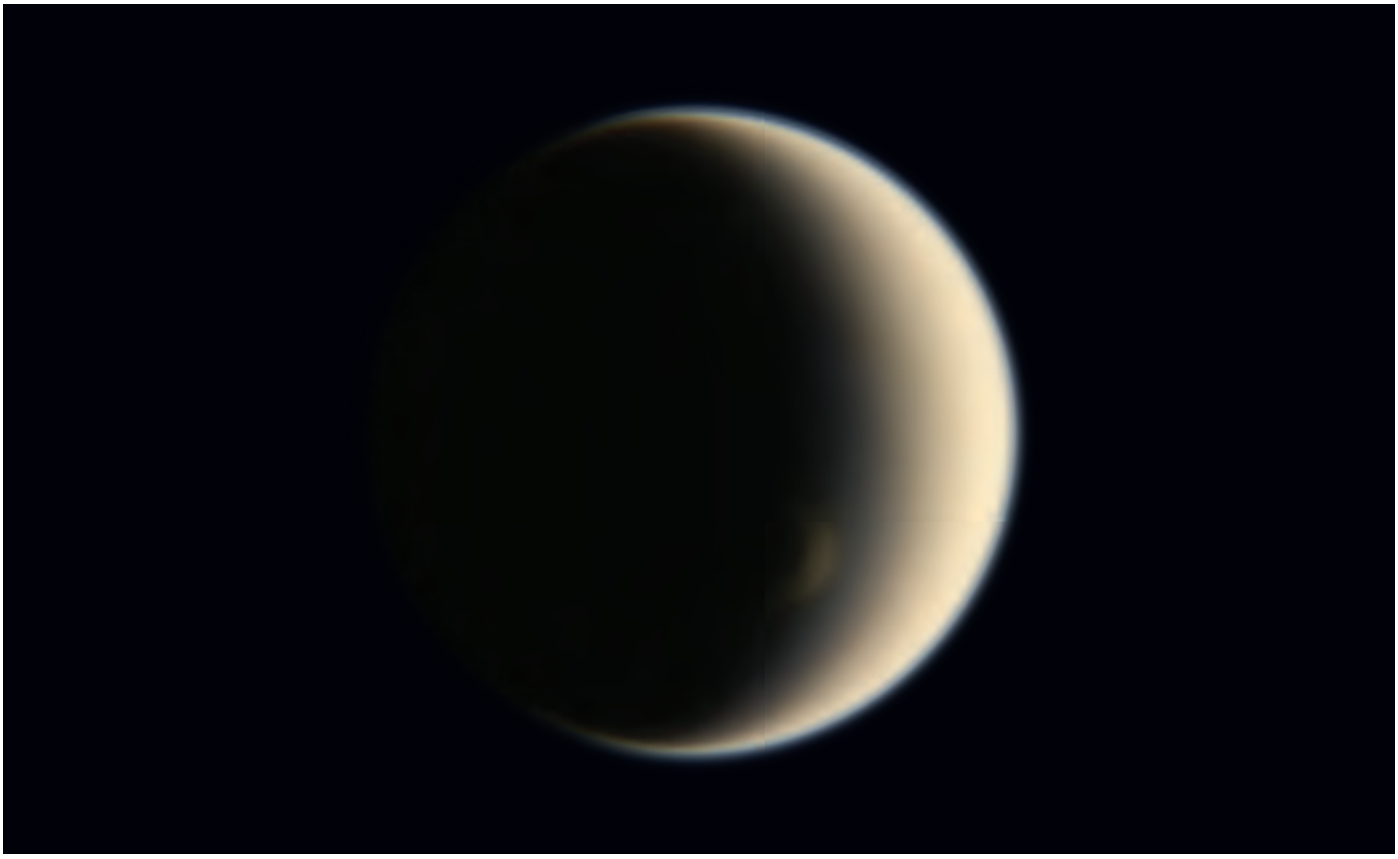
YOUNG MOON *With the benefit of the sharp eyes of* Lunar Reconnaissance Orbiter*'s camera, researchers have spotted more than 70 "irregular mare patches" like this one in Mare Nubium. The patches have sharp edges and exhibit few impact craters larger than 10 meters across. They may be evidence of recent volcanism on the Moon. "Recent" could be as old as 100 million years, but may be much younger. This image is about 3.8 kilometers (about 2.4 miles) wide.*



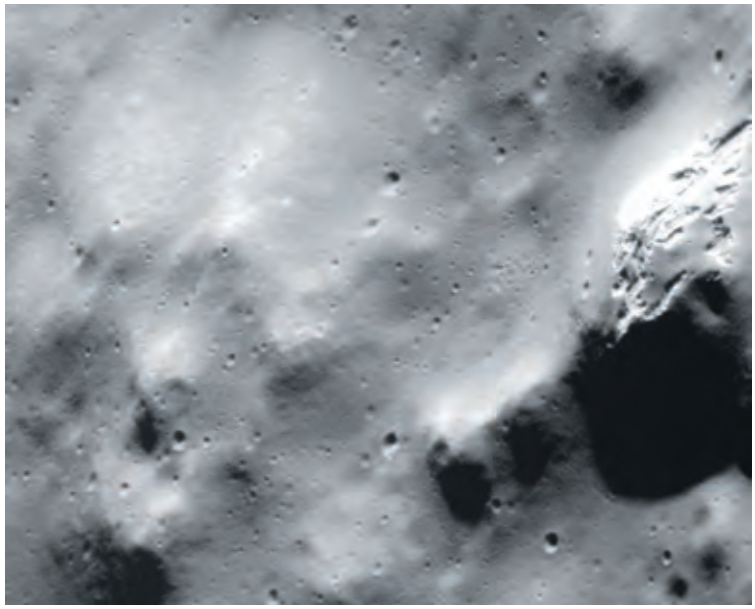


STORMY WEATHER *Uranus has a reputation as a dull planet because of its nearly featureless appearance to* Voyager 2 *during the 1986 flyby. However, as seasons come and go, Uranus develops storms that are every bit as dramatic as those on the other giant planets. Astronomers have been using the adaptive optics-equipped Keck II telescope to observe Uranus and Neptune since the system saw its first light in 2000; this summer they discovered a particularly large and bright storm.*

Images: Yutu: Chinese Academy of Sciences; Young Moon: NASA/GSFC/ASU; Uranus: Imke dePater/Keck Observatory



POLAR VORTEX Cassini *orbited far above and below the plane of Saturn's rings in 2014, allowing it to keep an eye on the seasonal changes in the atmospheres of Saturn and Titan. As winter advances at Titan's south pole, a high, swirling cloud has formed. This year,* Cassini *scientists announced that the cloud is full of toxic hydrogen cyanide and is much colder than expected, as cold as minus 148 degrees Celsius (minus 234 degrees Fahrenheit).*



DESCENT INTO MERCURY *During its second extended mission,* MESSENGER *is approaching Mercury closer than ever before, acquiring images of smaller and smaller features. This view covers an area only 7 kilometers across, within a large peak ring crater called Ahmad Baba. The soft, cratered landscape looks like the Moon until you see the hill (part of Ahmad Baba's peak ring). The pits on the mountain are some of Mercury's enigmatic hollows, places where volatile materials in Mercury's crust may have vaporized over time.*

Images: Titan: NASA/JPL/SSI/Emily Lakdawalla; Mercury: NASA/JHUAPL/CIW

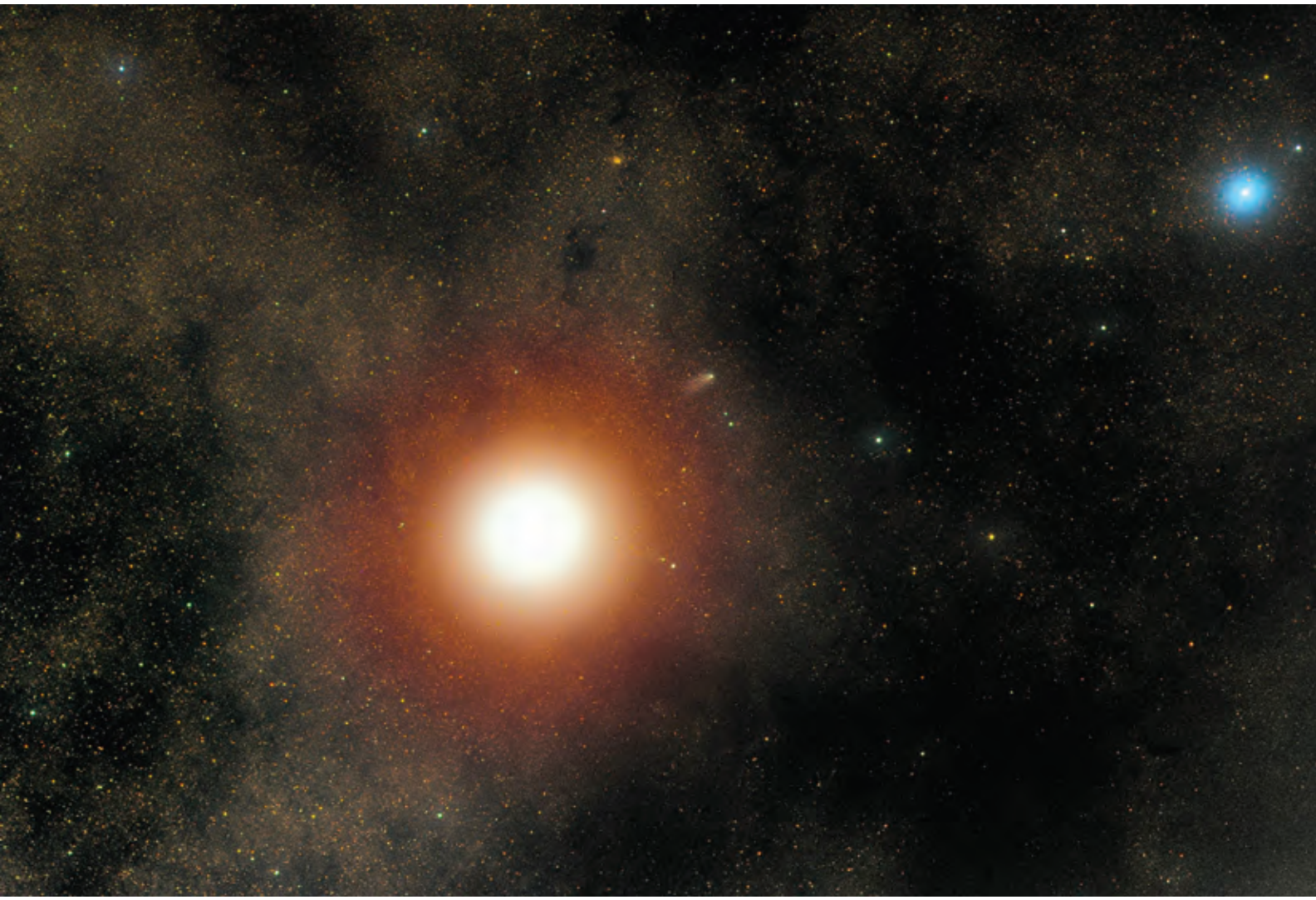
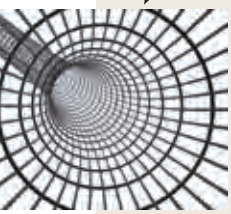


Photo: Rolando Ligustri

STARRY MESSENGER *On October 19, seven Mars spacecraft hunkered down for the historically close approach of a comet, Siding Spring, which passed by the planet at a distance of only about 134,000 kilometers (about 83,000 miles). All seven spacecraft survived and returned data on the comet and its effect on Mars' atmosphere, but the best photos came from astronomers on Earth. This one was taken by amateur astronomer Rolando Ligustri a few hours after closest approach with a telescope at Siding Spring observatory in Australia, where the comet was discovered in 2013. The comet is near the center, just above and to the right of the brilliant, bright beacon of Mars. The bright star at upper right is 51 Ophiuchi.*

HAPPENING ON
PLANETARY RADIO
planetary.org/radio



KIP THORNE AND *THE SCIENCE OF INTERSTELLAR*
Spoiler alert: Famed physicist Kip Thorne says you might be able to survive a plunge into a black hole after all! That's just one molecule of the fascinating science behind the science fiction film he helped create. We'll talk about the movie and Kip's new book, *The Science of Interstellar*. **bit.ly/1Abs9VØ**

ORION LAUNCHES INTO HISTORY
NASA's *Orion* spacecraft has taken its first step toward Mars and an asteroid mission. Jason Davis was at the Kennedy Space Center for the mission. Bill Nye believes *Orion* will bring far-reaching benefits. **bit.ly/1zoZJJ2**

SPACESHIPTWO AND ANTARES DISASTERS: SPECIAL COVERAGE
It was a terrible, tragic week for commercial space development. Historian and space policy analyst John Logsdon helps us understand the greater meaning of the SpaceShipTwo and Antares disasters on this special edition of *Planetary Radio*, with additional thoughts from Bill Nye. **bit.ly/1vEsV9E**

2014: THE YEAR WE LANDED ON A COMET
Not just landed; orbited, too. European Space Agency Senior Science Advisor Mark McCaughrean helps us celebrate the *Rosetta* orbiter and the *Philae* lander. **bit.ly/1FJkVeC**

ANCIENT WATER WAS HERE BEFORE THE SUN
Ilse Cleeves is lead author of a paper that concludes up to half of our solar system's water is older than the solar system itself. The implications for life across the galaxy are profound. **bit.ly/1z1gWt5**

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

ON *PLANETARY.ORG*

MARSWATCH

WATCHING SIDING SPRING Emily Lakdawalla has collected all pertinent information on comet Siding Spring's encounter with Mars. **bit.ly/1yL6e9Z**

COOL IMAGES

UNIQUE LUNAR ECLIPSE Have you ever seen a lunar eclipse from Mercury? **bit.ly/1qy38wL**

POLITICS

SCIENCE PLAN SLAMMED Casey Dreier reports on a NASA review panel that wasn't kind to *Curiosity*'s current science plan. **bit.ly/WcSZy1**

LOOK AT THE SKY

OCTOBER ECLIPSES Bruce Betts described in detail two October 2014 eclipses and how (and where) to see them. **bit.ly/1s6yAI8**

FILM

AMAZING NEW MOVIE Mat Kaplan is amazed by Erik Wernquist's new film *Wanderers*, which looks at how we might travel to the stars **bit.ly/1B9Va7j**

OUR SPACECRAFT

REGULAR UPDATES on The Planetary Society's *LightSail* are always available at **bit.ly/1wdOX7x**

PHOBOS IN ACTION Emily Lakdawalla put together a striking animation of Phobos zooming over Mars' surface. **bit.ly/1EYpL8t**

COOL VIDEO

PLANETVAC CLOSEUP *Fast Company* took a look at our partnership with Honeybee Robotics in this cool video short. **bit.ly/Zr2fjg**

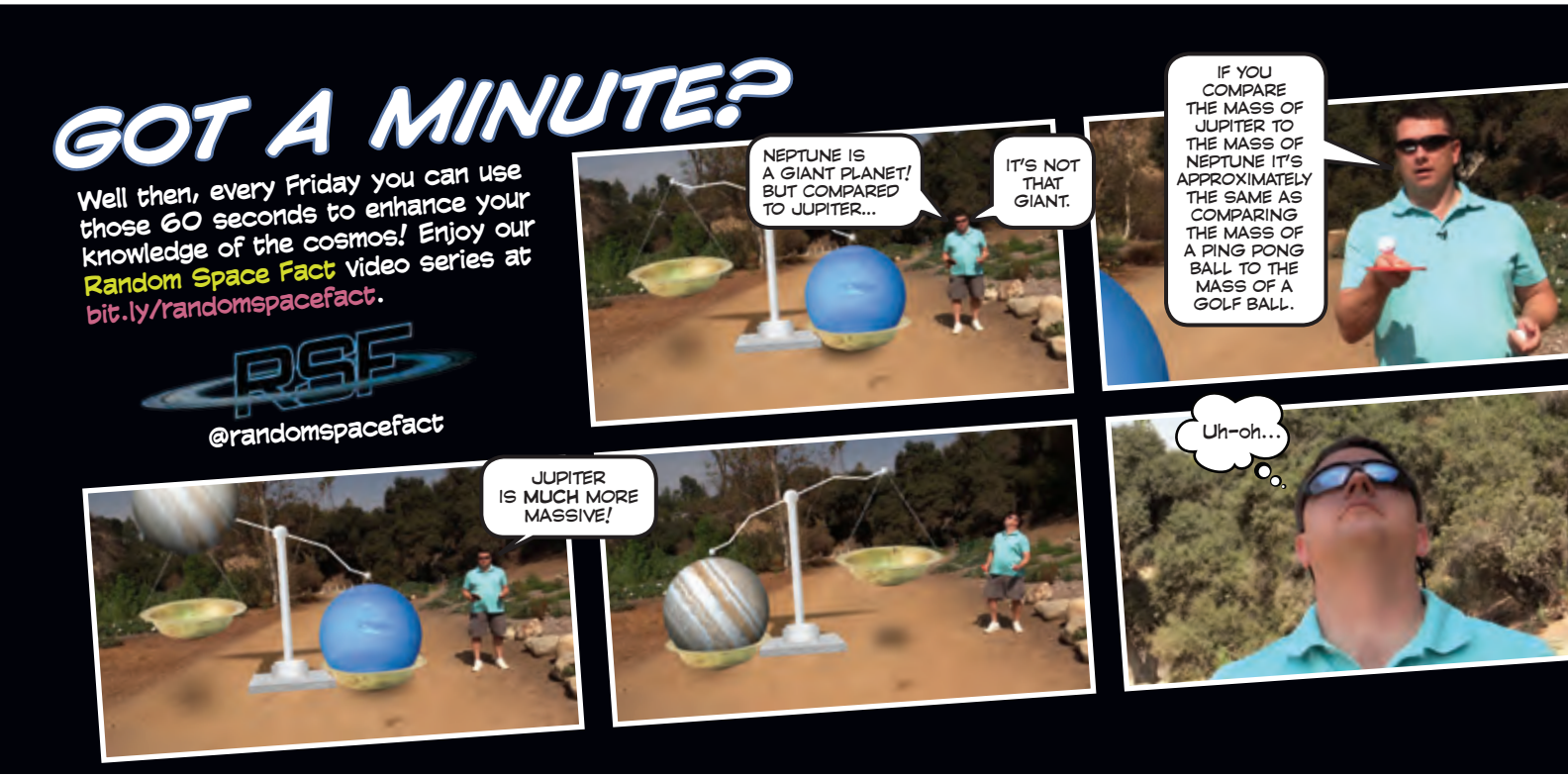
KATE HOWELLS *is The Planetary Society's Volunteer Network Manager.*

OVER THE PAST YEAR The Planetary Society's Global Volunteer Network has been growing and becoming more active than ever. I'm proud to say that we now have Outreach Coordinators working with volunteers and their local communities in more than 30 locations around the world. In this last quarter alone we formed six new outreach groups in widespread locations including New York City and Brisbane, Australia. We are reaching the public in new and unique ways, all thanks to the outstanding efforts of people who are passionate about space science, exploration, advocacy, and education.

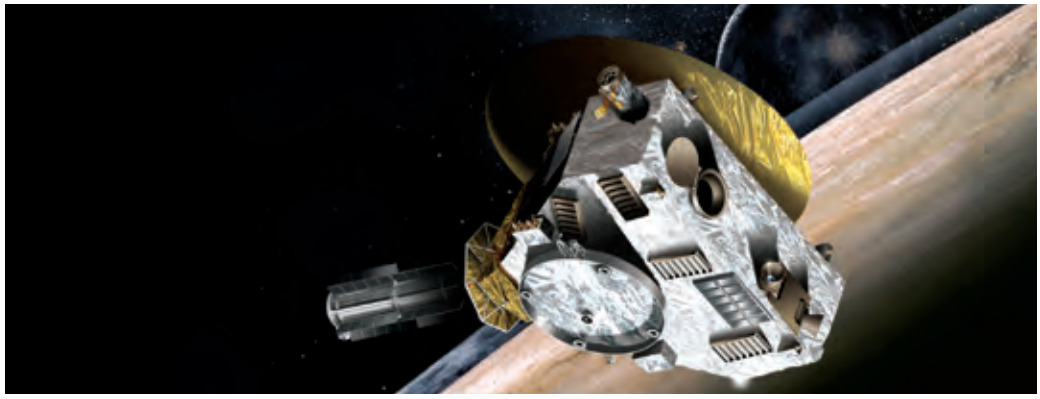
In the past three months, we and the public have benefited from some remarkable volunteer activity. Our Outreach Coordinators held meetings for local Planetary Society members, took school groups to planetariums, spoke about The Planetary Society at conferences, gave lessons on space exploration, and accomplished much more.

All our volunteers have brought stellar creativity and ingenuity to their work, embodying The Planetary Society's mission to empower the world's citizens to advance space science and education. Check out planetary.org/volunteer for more stories about The Planetary Society's Global Volunteer Network, and learn how easy it is to join in on the fun as a volunteer!

ABOVE *Outreach Coordinator Robert Amzler (center rear), a student at Arizona State University, visited a fifth grade class that is learning about the solar system and answered the students' questions about space.*



CASEY DREIER *is director of advocacy for The Planetary Society.*



The Exploration Desert

The Impact of Budget Cuts to Planetary Science

FOR THE FIRST TIME in four years, NASA didn't launch a new spacecraft this year to explore the solar system. This marks the beginning of a series of "exploration deserts"—periods of no new missions—that extend for the foreseeable future and are due to recent budget cuts. NASA won't launch a new planetary mission (*InSight*) until 2016—a bright spot, but a temporary one. After 2016, NASA enters a new planetary exploration desert lasting four years.

Other divisions within NASA are seeing a similar dearth in activity. The Astrophysics Division's James Webb Space Telescope doesn't launch until 2018. Heliophysics is working on the construction of its large Solar Probe Plus spacecraft, though its Magnetospheric Multiscale spacecraft will launch next year to study the Sun. The Human Exploration and Operations Spaceflight Directorate's Orion spacecraft just made its very first test flight on December 5, though not on a Space Launch System rocket, which won't be ready until late 2018. The Asteroid Retrieval Mission faces continued resistance from Congress and the scientific community, and NASA has yet to decide exactly how it plans to capture an asteroid (or boulder). Only the Earth Science Division saw real action this year, launching four missions into space (the division's $1.8 billion annual budget is about the same as the combined budgets of NASA's Planetary Science and Heliophysics divisions).

Budget cuts applied years ago are now beginning to be felt at a high level, particularly for planetary science. This would be much harder to manage if not for the truly exciting work done by the current fleet of planetary missions scattered throughout the solar system. Despite no new missions in 2014, there were several significant achievements: European Space Agency's *Rosetta* spacecraft completed its decade-long journey to a comet and landed a small probe on its surface, the *Curiosity* rover arrived at the foothills of Mount Sharp, *Opportunity* marked 10 years on the Martian surface, and a fleet of spacecraft watched a recently discovered comet visit the ruddy skies of Mars.

The year 2015 will bring unprecedented feats of exploration: *New Horizons* will fly by Pluto, *Dawn* will orbit Ceres, and *Cassini* will begin to modify its orbit to ultimately fly through the innermost rings of Saturn. These missions will keep the flame of exploration burning bright.

This year the fates of planetary science rose and fell, again, and the Society made an all-out effort to help stop the cuts, again. The Society had a regular presence in Washington, D.C., held two major events in the Senate and House, and promoted our advocacy work to

ADVOCATE FOR SPACE!

FEBRUARY 22-24, 2015

Join members of The Planetary Society in Washington, D.C. for the Space Exploration Alliance's Legislative Blitz on Capitol Hill. We'll set up the event; you'll meet the people in Congress. All for space.

More information and registration at:
bit.ly/tps-blitz

Illustration: Dan Durda, Southwest Research Institute

LEFT *It takes time to design and build spacecraft, and then get them to their destinations.* New Horizons *was launched in 2006 but won't reach Pluto until July 2015. The lack of new missions in development now won't be felt for a decade, but the resulting dry spell in exploration will be impossible to reverse.*

RIGHT *This evenly layered rock on Mars' Mount Sharp reveals a pattern typical of a lake floor sedimentary deposit not far from where flowing water would have entered the lake. The view here is about 1.5 meters across.*

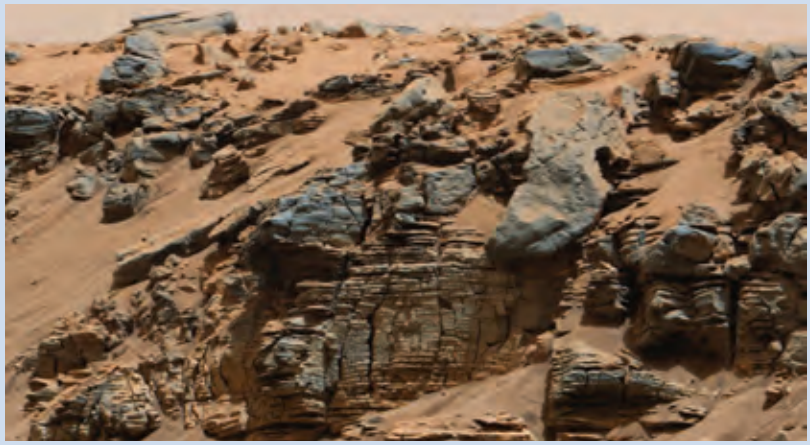
scientists throughout the country. Our president, Jim Bell, testified before the House of Representatives about the state (and fate) of planetary exploration. Bill Nye met personally with powerful lawmakers from both parties.

We also had an extraordinary year for fundraising. This allowed us to double the time of our on-the-ground D.C. consultant, Bill Adkins, and contract with a new policy advisor, Jason Callahan, who will provide crucial research and analysis to make our arguments even stronger. I was also able to devote a full 100 percent of my time to advocacy and space policy, a first for The Planetary Society. I cannot thank you enough for this support.

Transitions can be unnerving, but they are also potent times to influence the future. During this transitional period (which includes the upcoming presidential election in 2016) the Society is ready to argue that we must know the cosmos and our place within it. Let's make 2015 a historic year. Let's stay out of the desert.

BREAKING: As this issue was going to press, the U.S. Congress passed a budget deal that provides $1.44 billion for Planetary Science in 2015. This is just shy of The Society's recommended $1.5 billion and a great win for space advocates everywhere. More details online at **bit.ly/1syk1cV**.

Image: NASA/JPL-Caltech/MSSS



Recent observations from *Curiosity*'s Mast Camera (Mastcam) indicate that Mars' Mount Sharp was built by sediments deposited in a large lake bed over tens of millions of years. *Curiosity*'s findings suggest that ancient Mars maintained a climate that could have produced long-lasting lakes at many locations.

"If our hypothesis for [the formation of] Mount Sharp holds up, it challenges the notion that warm and wet conditions [on Mars] were transient, local, or only underground," said Deputy Project Scientist Ashwin Vasavada of the Jet Propulsion Laboratory.

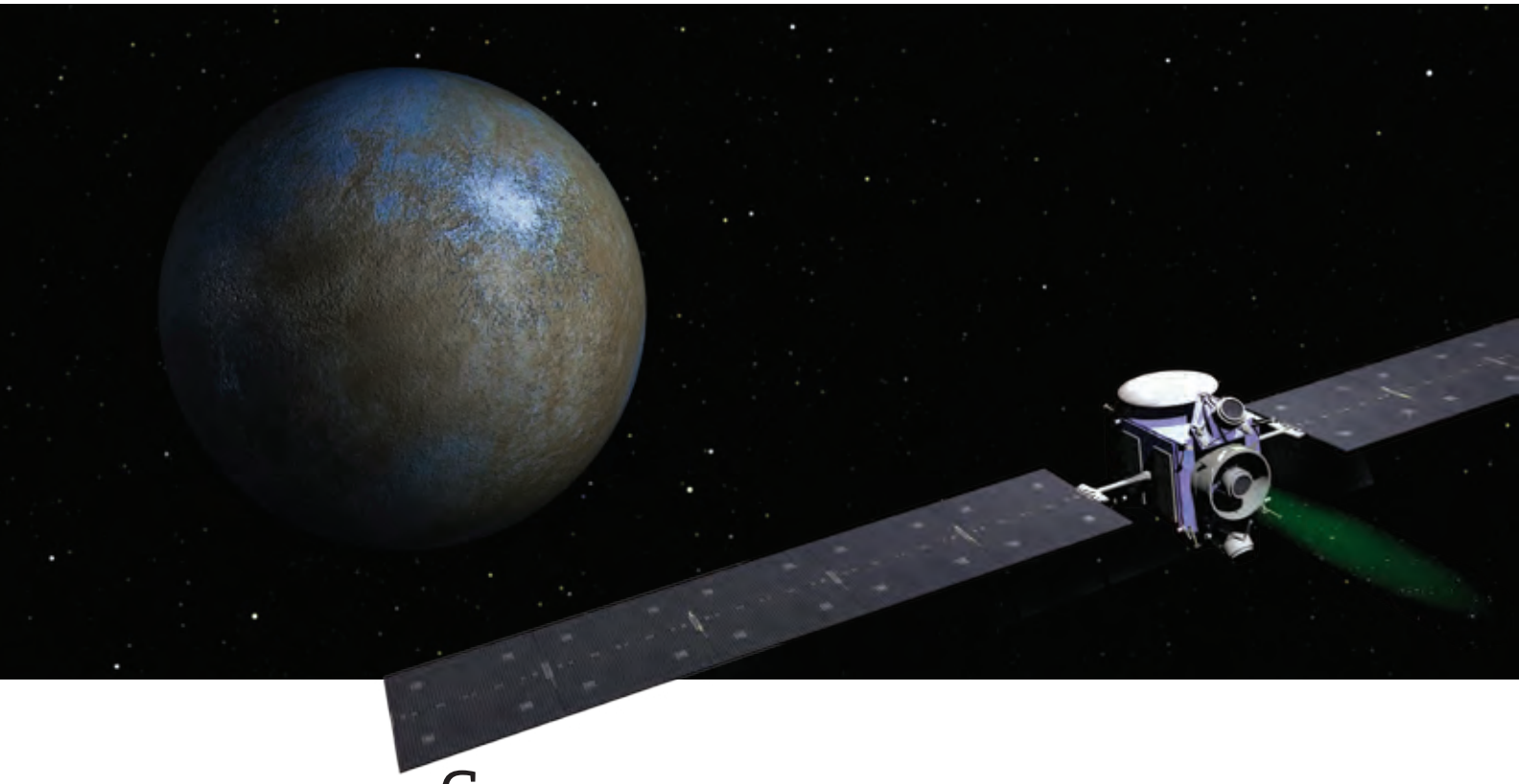
Why this layered mountain sits inside a crater (Gale) has been a challenging question for researchers. Mount Sharp stands five kilometers (about three miles) tall, its lower flanks exposing hundreds of rock layers. The layers—alternating between lake, river, and wind deposits—bear witness to the repeated filling and evaporation of a Martian lake much larger and longer-lasting than any that have previously been examined close-up. Rivers carried sand and silt to the lake, depositing the sediments at the mouth of the river to form deltas similar to those found at river mouths on Earth.

"The great thing about a lake that occurs repeatedly, over and over, is that each time it comes back it is another experiment to tell you how the environment works," said *Curiosity* Project Scientist John Grotzinger of Caltech. "As *Curiosity* climbs higher on Mount Sharp, we will have a series of experiments to show patterns in how the atmosphere, water, and sediments interact. We may see how the chemistry changed in the lakes over time. This is a hypothesis supported by what we have observed so far, providing a framework for testing in the coming year."

After the crater filled to a height of at least a few hundred meters and the sediments hardened into rock, the accumulated layers of sediment were sculpted over time into a mountainous shape by wind erosion that carved away the material between the crater's perimeter and what is now the edge of the mountain.

–from the Jet Propulsion Laboratory

ANDY RIVKIN *is a planetary astronomer specializing in asteroid studies at Johns Hopkins Applied Physics Laboratory.*



NASA/JPL-Caltech

ABOVE *This spring,* Dawn *will reach its final stop: the dwarf planet Ceres. Earth-based studies suggest Ceres is a target with an ice-rich interior, slowly leaking water vapor into space. Unlike the asteroid Vesta (*Dawn*'s first stop), we have no meteorite samples thought to come from Ceres. Given the surprises found by previous spacecraft's visits to small bodies, the largest object in the asteroid belt promises, perhaps, the biggest surprises of all.*

Ceres

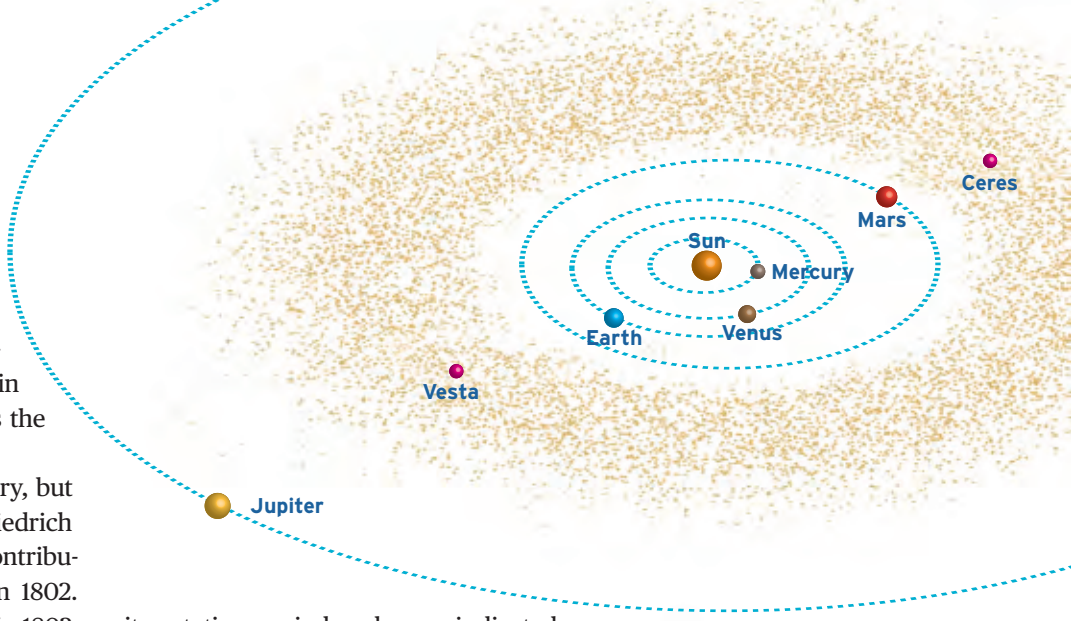
The Dwarf Planet Is Ready for Its Close-Up

SOON WE WILL ENJOY a long-awaited visit to Ceres, an object once called a planet but now known as a dwarf planet. When *Dawn*, NASA's mission to two of the most massive objects in the main asteroid belt, visits Ceres in 2015 we expect high-quality images of a small, low-albedo body spewing water vapor into space. We look forward to obtaining paradigm-busting geochemical data from an icy body that has carbon-bearing molecules on its surface, a target that some consider to be a promising site for astrobiological research. The coming year of 2015 should bring us all of these things.

While these prospects may put you in the mind of Pluto, Comet Churyumov-Gerasimenko, or Titan, all of these expectations also will be fulfilled by *Dawn*'s visit to Ceres. Astronomical, geophysical, and geochemical results indicate that Ceres is vastly more interesting than was suspected even a decade ago, and an object very different from *Dawn*'s first port of call, the asteroid Vesta.

THE "MISSING" PLANET

The story of Ceres' discovery echoes some elements of Pluto's story in that astronomers thought their discoveries validated theoretical calculations, but in retrospect they realized locations of planetary bodies were unrelated to predictions. It was known in the 1700s that the solar distances of the planets followed a progression called the Titius-Bode law, save for 2.8 astronomical units (roughly 420 million kilometers, or 260 million miles, from the Sun), where a planet would be expected but did not appear. The discovery of Uranus in 1781 in an orbit consistent with the Titius-Bode law spurred searches for a planet between Mars and Jupiter. Just



as a group of astronomers began to organize a search, Ceres was independently discovered in 1801, fitting in the missing place and being hailed as the "missing" planet.

Ceres was lost shortly after discovery, but thanks to the calculations of Carl Friedrich Gauss (in the first of his numerous contributions to science), it was recovered in 1802. Follow-up observations of Ceres later in 1802 led to the accidental discovery of Pallas in a similar orbit. By 1807, four objects orbiting between Mars and Jupiter were known. More than 30 objects were known by the time of Gauss' death in 1855, by which time these bodies were collectively known as asteroids due to their point-like appearance even in the largest telescopes.

The discovery of Neptune in an orbit far from where it would be predicted by the Titius-Bode law cast doubt on whether the "law" has any meaning; this doubt persists to this day. With logic echoed later with respect to Pluto, the realization that Ceres was much smaller than other planets and was merely the largest of a group of objects with similar orbits led to its status as a planet being revoked without fanfare. By the late 1800s studies of asteroids generally languished due to the difficulty in observing them. Because Ceres' surface is darker than Vesta's, it was not even recognized as the largest asteroid for decades. The International Astronomical Union's decision to define planets and non-planets resulted in Ceres' current classification as a dwarf planet, the only such body not orbiting beyond Neptune.

ABOVE *The space between Mars and Jupiter is the realm of the asteroids. Roughly a million objects larger than one kilometer in diameter can be found there.* Dawn*'s two targets, Ceres and Vesta, are the most massive among them and account for nearly half of the belt's total mass.*

Illustration: Loren A. Roberts for The Planetary Society

CERES' ROCKY, ICY INTERIOR

The most recent round of interest in Ceres was kicked off by observations by the Hubble Space Telescope (HST) in 2003 and 2004. A close look at Ceres' shape combined with its rotation period and mass indicated that, rather than being a homogeneous body like those from which most meteorites are derived, Ceres has an interior that's differentiated, or separated into a core, mantle, and crust. Given Ceres' mass and volume, it has a density roughly twice that of water, much too low for it to be entirely rock. Given Ceres' size we don't expect significant interior void space to be present, unlike what is found for smaller objects like Mathilde, Deimos, or Bennu. The best explanation for Ceres' low density is a significant ice fraction which, in combination with the shape and rotation data, suggests its mantle is icy and its core is rocky. This is in contrast with Vesta, which has a much higher density and an interior we think is like Earth's, with a rocky mantle over a metallic core.

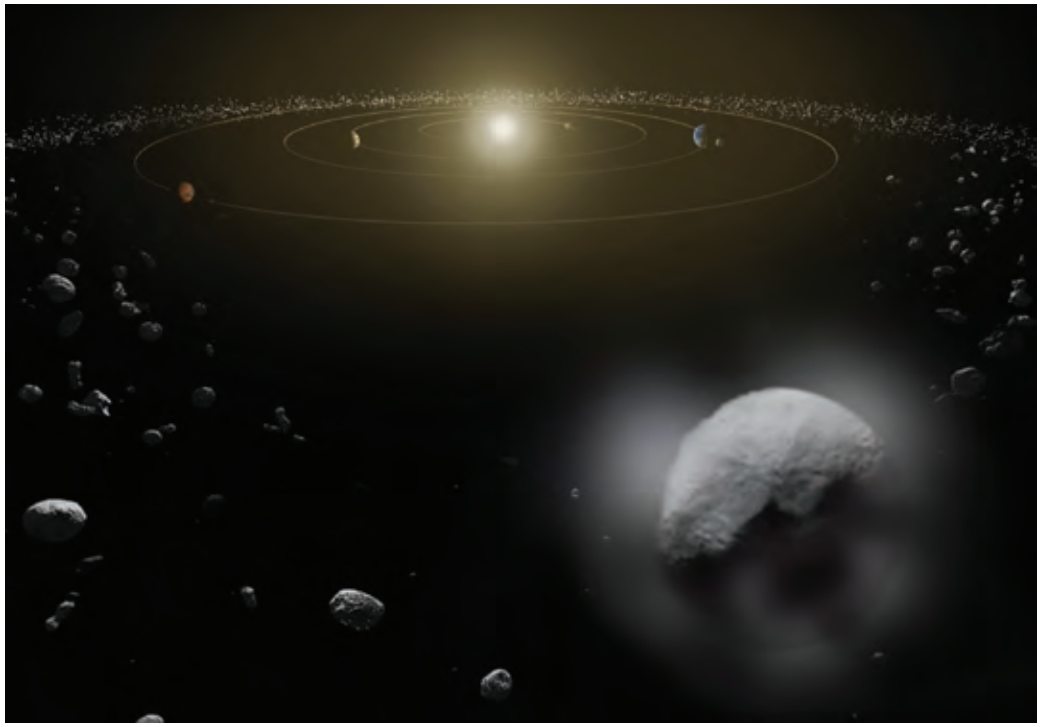
These results were anticipated by models developed by workers who were studying Ceres' earliest history. Beginning with a homogeneous object the size and mass of Ceres, and a composition similar to what we find in the most common meteorites, heat due to the decay of radioactive elements inevitably raises the interior temperature to the point where ice melts and reactions can begin. Careful accounting of the interior heat transfer and chemical reactions leads to the conclusion that Ceres should have a rocky core and an icy mantle, predicting the HST observations. Some models suggest there may still be a very salty layer of liquid water separating the ice

ANDY RIVKIN *studies the composition of small bodies, and has a long-standing interest in Ceres. He is also involved in efforts to characterize and understand how to deflect threatening near-Earth asteroids. When not at the telescope, Andy dabbles in music and poetry.*

and rock today. Some models even include the possibility that Ceres may be an active body, with the transfer of heat leading to icy volcanoes spewing material onto Ceres' surface. Unfortunately, the kinds of instruments best suited to answering some of these questions aren't on board *Dawn*, but a precise measure of Ceres' gravitational field will help our understanding of its interior structure.

ABOVE *Land ho!* Dawn's *final science camera calibration image of Ceres, taken December 1, 2014, may not look impressive, but it is a harbinger of images that will match, then far exceed, the best available views of this small world.*

RIGHT *The distinctive appearances of comets result from the rapid loss of tons of water vapor and dust as they are heated above the stability temperature of ice during part of their eccentric orbits. Ceres experiences similar water vapor loss, though much more slowly due to its circular orbit. Scientists think ice is absent from most of Ceres' surface, but it is probably abundant at shallow depths and may be present at the surface near the poles.*



Ceres image: NASA/JPL/UCLA/MPS/DLR/IDA; Asteroid belt illustration: ESA/ATG medialab

MYSTERIES OF CERES' SURFACE

Ironically, despite all of the evidence that Ceres has an icy interior, we do not know whether ice is present anywhere at its surface. The interior models that predict an icy mantle over a rocky core also predict a thin crust should remain, unaltered by all the activity below. However, such a crust would be of a higher density than the ice below, an unstable situation. Given enough time it is thought such a crust would founder, leaving ice at Ceres' surface.

On the other hand, while conditions in Ceres' interior favor ice, surface conditions are generally much too warm for ice. Temperatures at very high latitudes may be suitable for ice, but over most of its surface they are high enough that any ice present will quickly sublime (vaporize) away until it reaches a depth of a few meters to a few hundred meters below the surface, leaving behind only whatever material was carried by or dissolved in the ice. The predicted depth of ice stability is sufficiently shallow that relatively frequent impacts could excavate ice, leading to enhanced sublimation until the ice again recedes below the surface. This may be the origin of the water vapor from Ceres detected by European Space Agency's *Herschel* spacecraft. Even in its interior where it is stable, Ceres' ice is warm enough that it flows over long timescales. According to some studies, this happens so rapidly that it might destroy most of Ceres' topography and craters. This fits well with the measurement, also from the HST data, that the highest peak on Ceres must have an altitude of less than a few kilometers.

Compositional studies of Ceres show evidence of minerals that were altered in an aqueous environment: brucite (a magne-

sium hydroxide) and carbonates. It has been proposed that these minerals resulted from reactions between common silicate minerals, water, and carbon dioxide. Other interpretations exist, however, and some scientists suspect Ceres' composition includes ammonium-bearing clays, intriguingly consistent with an outer solar system origin.

Whichever interpretation is correct, the composition of Ceres' surface is surprisingly uniform: subtle variations in Ceres' spectral properties are seen, but they are far less than the variations found on Vesta or similarly sized planetary satellites. What is not seen, however, is water ice. As noted, this is consistent with our understanding of Ceres' warm surface temperature. Intriguingly, the amount of water vapor detected by *Herschel* seems to be correlated to surface features visible in HST and other Earth-based imagery, and also to the subtle spectral variation. Perhaps these features represent relatively recent impact sites, a possibility that *Dawn* should be able to confirm.

COMPARISONS WITH VESTA

Another major difference between Ceres and Vesta is the lack of meteorites known or suspected to have come from Ceres; the carbonaceous chondrites are similar in some ways to what we see on Ceres' surface, but their composition differs in important ways. Also unlike Vesta and most other large asteroids, Ceres does not have a dynamical family of smaller asteroids. Such families originate via collisions that are large enough to eject material from the target surface. Because the speed needed for material to escape from Ceres' surface (about 500 meters per second) is much slower than Ceres' speed in its orbit around the Sun (nearly 18 kilometers, or about 11 miles, per second), we would expect debris from large collisions to remain in heliocentric orbits that are similar to Ceres' orbit.

The analytical and observational tools available to the community would be able to detect even a small Ceres family, let alone one as large and numerous as Vesta's, and the odds are excellent that Ceres has suffered impacts of sufficient size to create such a family. Why don't we see it? The answer may relate again to a near-surface icy layer on Ceres: impacts that would dig up rock and form families may have dug up ice on Ceres. Since the temperature is too high for ice and these bodies are much smaller than Ceres, members of a Ceres family may simply have sublimed away like dry ice left out here on Earth. A similar argument can be used to suggest Ceres should have no satellites–we do not know of any, but much better data will be obtained from *Dawn*.

FROM INDIFFERENCE TO INTRIGUE

A combination of the factors above–the abundance of ice and possible liquid water, present-day minerals that suggest reactions with water and the presence of carbon, and the possibility of interior heat persisting to the present day–make Ceres increasingly interesting to the astrobiological community. While the science of astrobiology is still in its infancy, Ceres can serve as an interesting addition to better-known targets, such as Europa or Titan, in the search for life. Even if it is not found to be as habitable as some of the other suspects, Ceres can be considered in some ways a "free range icy satellite," roughly the size of Tethys and twice the size of Enceladus, a point of comparison to help understand icy bodies and how they change when they orbit a planet in terms of surface stresses and tectonic features, although Ceres' warmer environment provides an extra factor to be accounted for.

After billions of years circling the Sun and centuries of indifference from the scientific community, it is only in the very recent past that we have come to understand Ceres' scientific bounty. As it gets ready for its close-up in 2015, many of us hope that *Dawn* is merely its first visitor and that we can all look forward to additional missions to land on and rove its surface, and perhaps serve as the next goal for astronauts, after Mars!

ABOVE *The few asteroids that have been explored by spacecraft show remarkable diversity.* Galileo*'s visit to Ida found it to have a satellite (Dactyl), the first one ever detected for an asteroid. Eros was studied by the* NEAR Shoemaker *spacecraft, which discovered a geologically and geophysically varied world.* Dawn *has already delivered several surprises from its study of Vesta, including water on its surface. We anticipate further surprises from Ceres!*

Images: NASA/ESA/J. Parker/L. McFadden/JPL-Caltech/UCLA/MPS/DLR/IDA

BRUCE BETTS *is director of science and technology for The Planetary Society.*

The Planetary Deep Drill

A New, Exciting Project From a Longtime Partner

ABOVE *Made of tungsten carbide, the Planetary Deep Drill bit is several times stronger than steel.*

BELOW *Kris Zacny, vice president and director of exploration technology for Honeybee Robotics, holds part of the instrument package for the Planetary Deep Drill, which contains a microscope capable of resolving particles that are only 0.5 microns across.*

I AM VERY EXCITED to announce The Planetary Society's futuristic new project: the Planetary Deep Drill with Honeybee Robotics, which will develop a prototype of a drill that could allow drilling through planetary ices to unprecedented depths of hundreds of meters, even kilometers. The ability to drill much deeper into planetary ices would be a revolutionary step in planetary exploration. It would allow us to look back in time by drilling through the layers of the Martian polar caps, for example, or learn more about the possible subsurface oceans on Europa and Enceladus.

Honeybee Robotics was our partner on another project, PlanetVac, which created and tested a prototype for rapid, reliable planetary surface sampling (see the December 2013 issue of *The Planetary Report*). Planetary Deep Drill will take us to the other end of the sampling spectrum: drilling to obtain deep samples, in this case from ice. Honeybee has extensive experience with drilling projects and has provided sampling-related hardware to the last four NASA landers, including the rock abrasion tool on the Mars Exploration Rovers.

Thus far, planetary drilling has been measured in centimeters. The goal of the new Planetary Deep Drill project is to build and field-test the first prototype of a "wire-line" drill system that could robotically drill to hundreds of meters or even kilometers. Planetary Deep Drill is designed for deployment from a planetary lander. Unlike previous planetary drills, the drilling depth of the Planetary Deep Drill will be limited only by the length of a suspension tether rather than by the length of the drill pipe (as in oil and gas drilling). The drill assembly contains all of the motors, electronics, and sensors required to operate the drill, and it uses a highly efficient rotary percussive drilling technology, which makes for a relatively low-power drill, critical on a planetary spacecraft mission.

The 4-meter drill assembly will be lowered on a wire/tether as it drills. The tether is actually a collection of Kevlar wire, electrical cabling that takes power from the surface, electrical cabling that returns data to the surface, and pressurized gas that clears the view of the camera mounted on the drill assembly. Visible and UV LED lights will illuminate the bore hole for the camera, enabling real-time science. As the drill bit rotates, drill cuttings will be collected in the hollow auger. When the augur becomes full, the drill will be retracted to the surface, where the cuttings could undergo detailed analyses. Then, the assembly will be lowered into the hole

Illustration: Honeybee Robotics; photo: The Planetary Society

again. Each time the drill assembly is ready to drill, three "shoes" will hold the top of the drill assembly in the hole as the lower portion of the drill assembly does the actual drilling.

The Planetary Society is supporting field tests of the drill at a gypsum mine near the Salton Sea in Southern California. Gypsum has strength properties that are similar to those of extremely cold water ice found on other planetary bodies, so it is a good first-step test for the prototype. The tests will likely occur in March 2015.

Learn more cool details and background about our new project on its project page on our web site at bit.ly/planetarydeepdrill.

CALLING SERIOUS ASTEROID HUNTERS

I am happy to announce a new call for proposals for The Planetary Society's Gene Shoemaker Near Earth Object (NEO) Grant Program. Proposals are due February 2, 2015.

The Shoemaker NEO grants are designed to assist serious asteroid hunters—amateur observers, observers in developing countries, and under-funded professional observers—in contributing to vital NEO research. The winning proposers typically have existing track records and facilities, and are looking for a boost to take their work to the next level.

Past Shoemaker grant winners have made tremendous contributions to the discovery, follow-up, and characterization of potentially dangerous near-Earth asteroids using the upgrades facilitated by the grants. We are very proud of our program, now in its 17th year, and the contributions it has made to NEO research. Timothy Spahr, director of the Minor Planet Center (MPC), has again agreed to be our Shoemaker NEO Grant coordinator. Tim will guide the direction of the program and coordinate the review panel that will make recommendations for funding.

This round of grants will continue to focus on improving capabilities for characterizing the physical properties of near-Earth asteroids (important for deflecting dangerous asteroids), and also on NEO follow-up observations. See our Shoemaker NEO Grant page at bit.ly/shoemakergrants to find the Call for Proposals and related information, as well as to read updates on past grant winners.

ABOVE *Donald Pray studies asteroid pairs with the new 0.5-meter telescope at Sugarloaf Mountain Observatory in Massachusetts. The mirror, structure, and focuser were purchased with a 2013 Shoemaker NEO Grant.*

Photo: Courtesy of Donald Pray

Planetary Society members have helped make these projects—and many others—possible! Thank you. *Thanks!*

Member Receives NASA Award

ABOVE *Patrick Wiggins poses with his hardbound collection of* The Planetary Report*–an archive that dates back to The Planetary Society's formation in 1980.*

ABOVE RIGHT *Robert M. Lightfoot, Jr. (left) and NASA Administrator Charles F. Bolden, Jr. present the NASA Distinguished Public Service Medal to Patrick Wiggins in Washington, D.C.*

IN AUGUST 2014, Patrick Wiggins, a Planetary Society member since 1980, was awarded NASA's Distinguished Public Service Medal in a ceremony held at NASA Headquarters in Washington, D.C.

Patrick received this honor for serving the people of his home state of Utah as a NASA Solar System Ambassador (SSA). This public outreach program is designed to work with volunteers across the nation to communicate the excitement of space exploration and recent discoveries to people in their local communities. While the SSA program asks that Ambassadors donate their time to lead at least four events a year, Patrick's efforts have far exceeded that minimum as he travels tirelessly across Utah giving talks in schools, libraries, and museums. A large percentage of his SSA outreach work is achieved by sending frequent news releases to local media, alerting them to exciting news from the world of space exploration. Patrick describes himself as "an equal opportunity speaker" in that he makes it a point to educate the public about the efforts and discoveries of "every spacefaring nation on the planet."

This work comes naturally to Patrick partly because, for 26 years, he worked at Utah's Hansen Planetarium. He joined the SSA program shortly before retiring from Hansen in 2002. But more than that, it's his passion for spreading the excitement of science that fuels his prolific activity. When he's not speaking or writing about science and space exploration, Patrick, a retired United States Air Force Master Sergeant, can be found enjoying Earth's skies in freefall as a skydiver and as a pilot in his Cessna. "You gotta have fun with it," he says about everything he does.

When asked about his long-time membership in our organization, he said he credits The Planetary Society for being a valuable source of space exploration information, citing in particular our blogs, *Planetary Radio*, and *The Planetary Report*, which he described as "one piece of mail that I actually look forward to."

Patrick is the first Solar System Ambassador to receive the Distinguished Public Service Medal, the highest civilian honor bestowed by NASA. Past recipients of the award include Carl Sagan, Neil DeGrasse Tyson, Lyman Spitzer, and Ed Stone. NASA accepts applications for the SSA program every year, during the month of September. For more information, visit solarsystem.nasa.gov/ssa.

–Donna Stevens, Editor

Collection photo courtesy of Patrick Wiggins; award photo: NASA

SOCIETY TRAVEL

Alaska Aurora Borealis

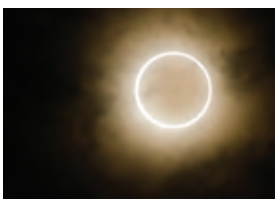
MARCH 26-APRIL 1, 2015
MARCH 3-9, 2016

Explore the wonderland of Alaska in winter and watch the Aurora Borealis dance across the night skies! See breathtaking snow-capped peaks, including Denali, the highest mountain in North America. Enjoy fascinating lectures, meet sled dog teams, and experience the Ice Festival in Fairbanks. *$2,795 plus air.*

Madagascar Annular Solar Eclipse

AUGUST 20-SEPTEMBER 4, 2016

Discover the fascinating natural world of Madagascar and watch the Annular Solar Eclipse on September 1, 2016 as it crosses the sky from Africa. This unique island nation has a profusion of species only found here. Delight in the antics of ring-tailed lemurs cavorting down the trail, large white Indri lemurs, flying foxes, and mouse lemurs in the forests, and enjoy many rare plants and birds. An amazing opportunity! *$4,995 plus air.*



Antarctica Annular Solar Eclipse

FEBRUARY 23-MARCH 9, 2017

This is a rare opportunity to both explore Antarctica and view a Solar Eclipse! Discover the massive glaciers and stunning peaks of Antarctica and learn about the unique role that Antarctica plays in the world's climatic balance, ocean temperatures, and weather. See a profusion of wildlife throughout and watch the Annular Eclipse south of Trelew, Argentina. *From $8,695 plus air.*

To get started on your adventure, go to **planetary.org/expedition** to download more information.

You can also contact Taunya at Betchart Expeditions to learn more:
Taunya@betchartexpeditions.com
408-252-4910 (International)
800-252-4910 (USA only)
408-252-1444 (Fax)

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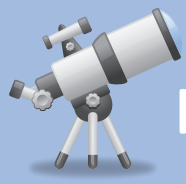
WHAT'S UP? *by Bruce Betts*



IN THE SKY

A total lunar eclipse is visible April 4 from most of North America, South America, eastern Asia, and Australia. A total solar eclipse occurs March 20 with totality crossing Greenland and parts of Siberia. Very bright Venus is low in the southwest in the early evening, as is much dimmer Mars. They grow closer through January and February, and are very close together and joined by the Moon on February 20. Saturn is in the pre-dawn East, and bright Jupiter is in the East in the evening.

RANDOM SPACE FACT

The rings of Saturn are extremely thin compared to their diameters. If the main rings (rings A through D) had an average thickness of a DVD, that DVD would have a diameter of more than 33 kilometers (21 miles).

TRIVIA CONTEST

Our June Solstice contest winner is Nick Green of Waterloo, Iowa. Congratulations! **THE QUESTION WAS:** What is the name of the set of buttes on Mars that the *Curiosity* rover will pass by on its way to Mount Sharp? **THE ANSWER:** The Murray Buttes, named after Planetary Society Co-founder Bruce Murray.

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

In November 2014, ESA's* Rosetta Philae *lander became the first to soft-land on a comet. On what spacecraft mission did a human-made object slam into a comet in 2005?

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 March 1, 2015. 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.*

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

Your Legacy: The Past Meets the Future

What do you think of when you read the word, "legacy?"

As we mark our 35th anniversary, it seems appropriate to reflect on the meaning of this word. Our good friends at Merriam-Webster define "legacy" as "something that happened in the past or that comes from someone in the past." Often, this can mean a special gift, such as a bequest, that is passed on after we are gone.

For me, the word legacy invokes thoughts of the future instead of the past. What will we accomplish? What kind of world will we create for future generations? Where are we headed—literally—to other planets, and then to the stars?

Your legacy can certainly be a gift to the Society through your will or estate plan—a growing number of members have done just that! Just as important, however, are those actions and choices that we make right now to shape our future. When you support the Society with your annual membership or give to a special appeal for planetary research, you are creating a legacy.

The inspiring mission of The Planetary Society is to empower the world's citizens to advance space science and exploration. Through this effort, we will expand education and science literacy, we will undertake select projects and missions that lead to innovation, and we will advocate for the critical role of space exploration in lifting our sights to the skies and beyond.

What legacy will we create over the next 35 years? Our goal is nothing less than to transform the world. We are glad to be sharing this journey with you.

Regards,

Richard

Richard Chute
Director of Development
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