THE PLANETARY SOCIETY

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THE BLOG ISSUE

A SAMPLING FROM *PLANETARY.ORG*

EXPANDING OUTREACH ✻ VOTE FOR SPACE ✻ PICARDO'S *PLANETARY POST*

Something Special

Dear readers:

We've dedicated most of this issue of *The Planetary Report* to another of The Planetary Society's communication channels: our fascinating, informative, and all-around exceptional blog!

Many of you are frequent visitors to **planetary.org** and are already readers of the blog. But for those of you who aren't, we've selected some sample stories from the latter half of 2015 as an introduction. We've done only minor editing to fit them into our magazine's format, and, to save room, we've taken a few pictures and links out. But you'll find those in the original blogs on our website.

With such limited space, we could only pick a few, but you'll find 10 years' worth of great reading at **planetary.org/blogs**.

Here's Emily Lakdawalla to tell you how it all began.

Enjoy!
Donna Stevens, Editor

WHEN *COSMOS 1* LAUNCHED, it was my job to process the images from its camera and post them on The Planetary Society's website. The rocket failed, so I—and you—never got those photos, but *Cosmos 1* managed to launch something that's continued to this day.

Lacking image data in the days leading up to launch, I wrote short dispatches from Pasadena mission operations. In the confusion after the launch failure, with no reliable information about our spacecraft, I began to write about other spacecraft. I never stopped. And so The Planetary Society Blog was born.

The blog allowed me to write about space exploration less formally than I'd been doing in news stories for the Society's website. I could post brief updates on rapid changes in mission status, like *New Horizons*' launch, or quickly post amazing new images from *Cassini*. I could also do more public education, explaining how to find spacecraft image data and how to process it. And I could critique science results, expressing my personal opinions or doubts about them.

With the advent of the blog, The Planetary Society shifted its online news coverage. Previously, we had reported news stories in response to agency press releases. But we found that to be a crowded field, with many other sites doing the same thing. We realized we had something to offer that other news sites did not: connections with the wider community of people actually doing space exploration, and the expertise of writers like me who have actually performed scientific research on solar system objects. We don't get to every breaking news story. We go for depth, not speed, aiming to provide readers with broader context, more technical detail, and deeper understanding of the subjects we cover.

I wrote the blog on my own for a while, but soon we started inviting other experts to contribute. Just like the feature articles you read in *The Planetary Report*, the blog has scientists, engineers, and educators writing about their work, explaining the newest interpretation of data, and answering reader questions. Unlike the often-detached tone taken by some journalists, the writing on the blog features the excitement and passion of a wide variety of people involved in every aspect of space exploration. I hope you enjoy reading some of the great work that has appeared in the blog, and that you'll check out the latest posts online at **planetary.org/blogs**.

ERRATUM On page 17 of our December 2015 issue, we reported that the test landing system (Schiaparelli) on ESA's *Trace Gas Orbiter* is Russian-made. Schiaparelli is also a product of ESA.

ON THE COVER: Colorful and stunningly beautiful images of the cosmos have become a part of our everyday lives. Some viewers take them for granted as a natural outcome of our increasing technical prowess. But others ask, "Is that real?" In "Colors In Planetary Imaging," astronomer and astrophotographer Travis Rector describes the processes that lead to these breathtaking—and very real—views of our universe. This portrait of the Horsehead Nebula was taken with the National Science Foundation's 0.9-meter telescope on Arizona's Kitt Peak using the National Optical Astronomy Observatory's Mosaic CCD camera. *Image: T.A. Rector (NOAO/AURA/NSF) and Hubble Heritage Team (NASA/STScI/AURA)*

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Our Third Line of Work

The Society's Outreach Efforts Continue to Expand

CREATE. ADVOCATE. EDUCATE. That's what we do here at your Planetary Society. You've probably gotten an eyeful, and perhaps an earful, about the success of our *Lightsail-1* mission. That's a remarkable small spacecraft we created. I'm sure you've read about our Planetary Deep Drill, a project that may help us find evidence of life on Mars and Europa—another niche we seek to fill. As I write, NASA's 2016 budget will be over $19 billion, a result of a bit of legislation that you helped bring about. Thank you.

These technology and political advocacy projects have been successes. I'm proud to represent you as we work to achieve our goals. In this issue of *The Planetary Report*, though, we're homing in on our third line of work: public outreach and education.

JUNO *deputy chief engineer Tracy Drain*

I encourage you to take a few moments and read, hear, and watch the outstanding work by the people at the Society who bring the astounding new facts and developing news stories of space down to Earth. Our blogs, featured in this issue, continue to gain international attention as a go-to source for all space news. *The Planetary Report*, our first public education and outreach tool, is going strong, as is *Planetary Radio*. Our new web channel, *PlanetaryTV*, home to *Random Space Fact*, *The Space Advocate*, *The Planetary Post*, and our new *SciTech* show (pictured above), continues to amass more and more viewers each month. These outreach efforts have always been, and will always be, at the heart of our mission. Now I'm delighted that our education efforts are starting to focus on our youngest explorers as we consider what it will take to be in classrooms all over the world. For years The Planetary Society has had a presence at the annual National Science Teachers Association conference. This year, we're ramping up our involvement with a *Random Space Facts* live presentation, a booth on the exhibit floor, and the goal of engaging a network of science teachers who want to help inform our program development and ensure that we create a product they want to use.

Our education and public outreach efforts directly support our mission to empower the world's citizens to advance space science and exploration. The three founders of the Society—Carl Sagan, Bruce Murray, and Louis Friedman—very much wanted to inspire the next generation, and the generation after that, to take an interest in space. That's the easiest part of this program development: space fascinates us all, especially kids. The more we study space, the more we learn about our own world.

So it is with this history, and optimism about the future, that we at the Society are working to build an education program worthy of our founders, the space programs from around the world, and future generations. Take a look in this issue; I believe you'll get a sense of how much quality information and reportage we produce, and it's reasonable to imagine that our work with the youth of this world will be of equally high quality. Together we can engage every generation of explorers to continue making discoveries and inspiring many generations to come.

Photo: NASA/JPL

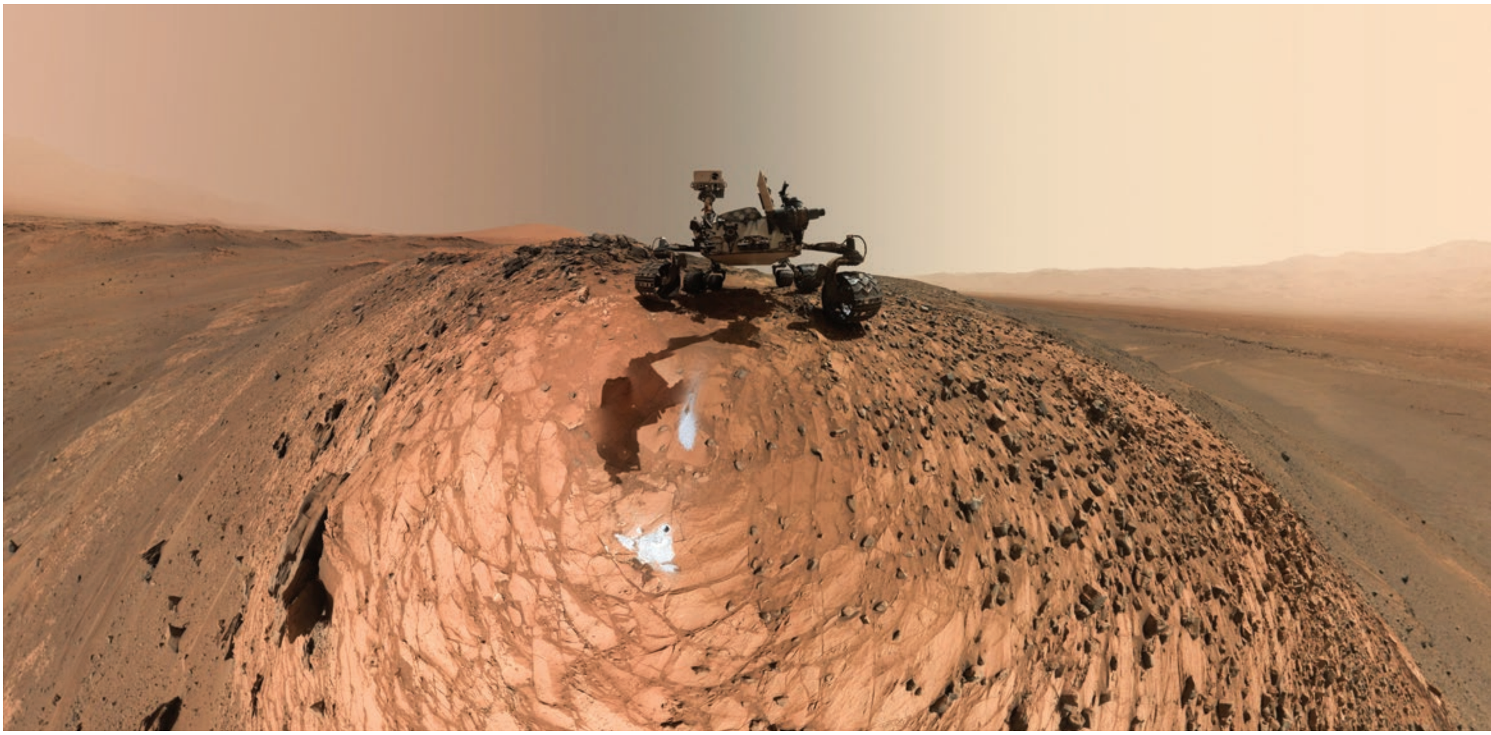


Image: NASA/JPL/MSSS

BLOG DATE 2015/12/18 23:51 UTC
AUTHOR EMILY LAKDAWALLA
ONLINE planet.ly/agu

Curiosity Stories from AGU

The Fortuitous Find of a Puzzling Mineral on Mars, and a Gap in Gale's History

YESTERDAY AT THE AMERICAN Geophysical Union (AGU) meeting, the *Curiosity* science team announced the discovery of a mineral never before found on Mars. The finding was the result of a fortuitous series of events, but as long as *Curiosity*'s instruments continue to function well, it's the kind of discovery that *Curiosity* should now be able to repeat.

The mineral in question is tridymite, a flavor of quartz that forms under low pressures and very high temperatures. On Earth, it's found near volcanoes. *Curiosity* found it with a Chemistry and Mineralogy (CheMin) analysis of a sample drilled at a site called Buckskin.

How exactly the tridymite got there is a puzzle that is yet to be solved; as far as mineralogists know, there's no way that scientists currently know of to make it under the kinds of conditions that prevailed in the ancient lake environment in which the Murray formation was laid down. Either Mars can make tridymite in a way that Earth doesn't, or (more likely) the tridymite was carried there from some other location. But even that doesn't solve the riddle, since the kinds of environments in which tridymite gets made on Earth are not found on Mars.

The story of the silica and why it's a puzzle is well told but the story of how *Curiosity* made this discovery is a fun one, too. It happened last summer, right around sol 1000, in Marias Pass.

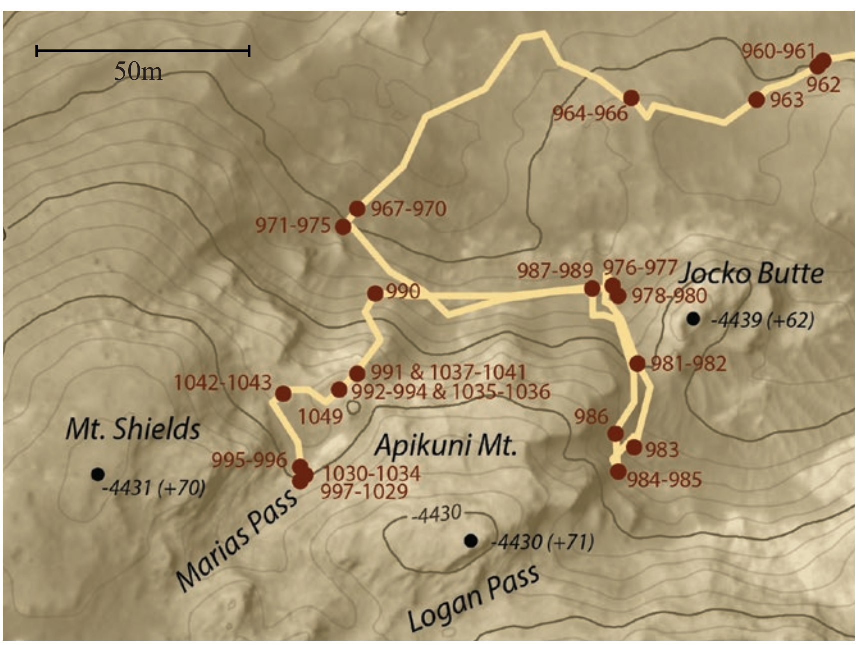
DRIVING TO THE STIMSON

At that time, *Curiosity* had driven onward from the first Mount Sharp science site (Pahrump Hills), where the rover had drilled several

ABOVE *This low-angle self-portrait of NASA's* Curiosity *Mars rover shows the vehicle above the Buckskin rock target, where the mission collected its seventh drilled sample. The site is in the Marias Pass area of lower Mount Sharp. It was taken on sol 1065 with the MAHLI camera on the end of the robotic arm.*

times into the lakebed mudstones known as the Murray formation. Having spent a long time at Pahrump Hills, the mission was eager to make driving progress toward the next-higher rock unit, called the Stimson formation. Stimson is more resistant to erosion than Murray, so it tends to cap hills, and the team was having a tough time finding a safe route up onto it. At the same time, the scientists wanted to find a good spot where they could see Murray and Stimson directly in contact, so that they could try to figure out the relationship between the two different kinds of rock. And they were under time pressure, because conjunction was approaching, when the mission would have to pause operations to wait for Mars to pass behind the Sun as viewed from Earth. Conjunction lasted from sol 1004 through sol 1026.

While all of this was happening, various science and engineering teams were getting close to solving some problems on the rover.



BELOW *Detail of a route map for* Curiosity *drawn on a base contour map derived from a* HiRISE *digital terrain model by Peter Grindrod [Birbeck U.]. Route map cartography by Phil Stooke [U. of W. Ontario].*

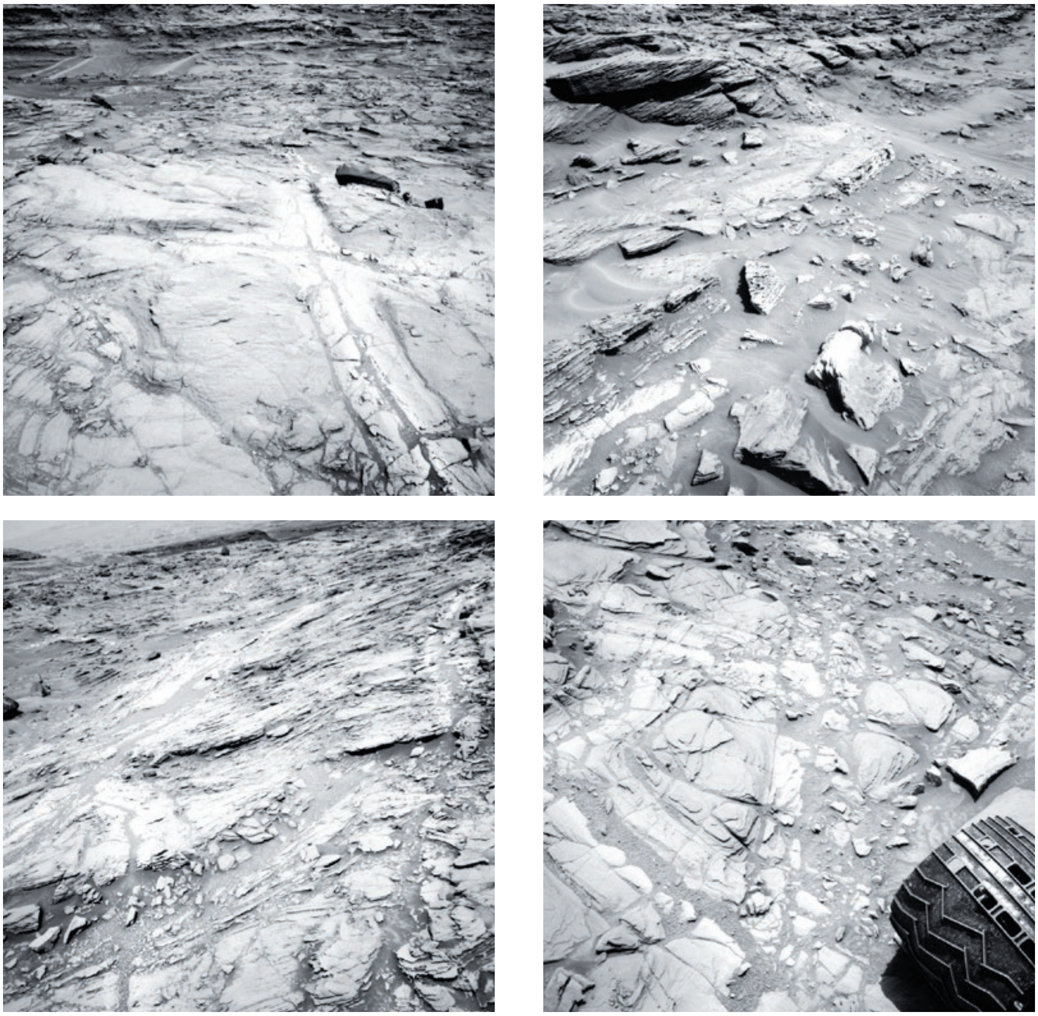
Map: Emily Lakdawalla

There had been a scary short circuit on the drill on sol 911, but the engineers were almost ready to declare it back in action. The ChemCam instrument (which uses a laser to vaporize rock and study the colors of the glowing plasma to determine rock elemental composition) had been functioning without the ability to autofocus since early on in the Pahrump Hills campaign, but they finally developed and implemented a workaround for that on sol 989.

Meanwhile, in a completely independent effort, the ChemCam team had been developing a new, more precise calibration for their instrument. ChemCam isn't a tricorder; you can't just shoot a rock with a laser and read elemental composition off a screen (unfortunately). Transforming ChemCam readings into elemental abundances requires comparing the data we get from Mars with ChemCam measurements of rock samples of known composition measured on Earth. When the rover landed on Mars, the ChemCam calibration model was based on a library of 66 rock samples that they'd shot with the actual ChemCam instrument now operating on the Martian surface. Since landing, they've built a lab containing a ChemCam copy that they can operate under Martian conditions, and they developed a new version of their model that incorporates 450 different kinds of rocks, covering a much wider range of compositions than the first 66.

Applying the new calibration to ChemCam data changes the results that they report from Mars. By email, ChemCam principal investigator Roger Wiens [LANL] told me: "These changes are relatively minor for compositions close to the average Mars crustal composition (e.g., soil, dust, Sheepbed mudstone). The largest changes are for compositions that are far from the average Mars crust (calcium sulfate veins, feldspars, etc)." (Papers have not yet been published on the new calibration, but they are forthcoming from Sam Clegg [LANL], Ryan Anderson [USGS], and Olivier Forni [IRAP].)

Right before conjunction, the team had given up on finding a way to drive through a spot called Logan Pass onto the Stimson, and had driven up into Marias Pass. Here's a map (at left) showing the rover's route as of conjunction.



LEFT *As* Curiosity *drove across the Stimson unit, the rover repeatedly encountered fractures in the rock that were surrounded by bright haloes of unknown cause. The photos were taken on sol 1083 (top left), 1087 (top right), 1093 (lower left), and 1094) lower right) by the Navcam.*

ABOVE *The Buckskin drill site on Mars. X-ray diffraction analysis of the Buckskin sample inside the rover's Chemistry and Mineralogy (CheMin) instrument revealed the presence of a silica-containing mineral named tridymite. This is the first detection of tridymite on Mars.*

Images: NASA/JPL/MSSS

SOMETHING REALLY SURPRISING

With conjunction lasting several weeks, the team took the opportunity to get together for a July science team meeting in Paris. At that meeting, one of the science instruments, Dynamic Albedo of Neutrons (DAN), reported seeing something strange: an unusually high reading of neutrons in a spot where the rover had passed over back on sol 991, several drives ago. The DAN team usually interprets high neutron counts as an indication of a high abundance of hydrogen in the soil.

Then the ChemCam team gave a presentation on their recalibration effort. They had not been using it for operations yet, but had been beta testing it on the first ChemCam analyses that they'd done since getting autofocus back online, on sol 989. Lo and behold, a few of the spectra from their beta-testing effort showed something really surprising: a huge abundance of silica. Those ChemCam readings had been taken at the same spot where the DAN team had found the high neutron readings. Neither team had known of the other's anomalous measurements until the presentations at the Paris team meeting.

Either one of those two things—the high neutrons or high silica—wouldn't have been enough to make the team turn the rover around, but taken together, they showed that the rover had passed over a truly unusual rock. Moreover, the engineering team gave the scientists permission to use the drill again. So after conjunction was over, the team decided to command *Curiosity* to retrace its steps to the northeast, back to the high-silica, high-neutron region, looking for a spot to drill.

It was hard to find a good drill site, and the rover wound up driving back and forth a couple more times before finally locating a good spot, at a site called Buckskin. They drilled, and found the drill tailings to be brighter than anything they'd seen before or since, according to a poster presented at AGU by Mastcam team member Danika Wellington.

And the DAN team realized that the high neutron counts they'd observed weren't from hydrogen at all. The neutrons that DAN sees

ABOVE *The Big Sky [top image] and Greenhorn [bottom image] target locations. X-ray diffraction analysis of the Greenhorn sample inside the rover's CheMin instrument revealed an abundance of silica in the form of noncrystalline opal.*

are relatively slow-moving ones. Typically, the neutrons are moving slowly because they have experienced collisions with hydrogen atoms, which have very low atomic mass. But a rock that is substantially silica also has much lower atomic mass (on average) than a rock containing more ordinary Martian rock-forming minerals, and that's what DAN was seeing.

So Marias Pass was a fascinating spot, and the tridymite a cool (if very puzzling) find. They wrapped up work at Buckskin with a fun self-portrait [page 5], and drove on up into the Stimson.

HALOES IN THE ROCKS

There they were on the Stimson, with a new energy: allowed to drill again, and equipped with a ChemCam instrument that was fully operational for the first time in nearly a year—in fact, better-operating than before, thanks to the recalibration that allowed them to spot more anomalous rock compositions. Driving across the "washboard" ridges of the Stimson, they found weird haloes surrounding fractures in the rock.

Now, *Curiosity* has seen bright, white calcium sulfate veins in every kind of rock it has explored to date. But these haloes are not calcium sulfate veins. The calcium sulfate veins are places where an opening in the rock was filled by the deposition of a new mineral. The haloes seemed to be some kind of alteration of rock in place, not the deposition of something new. With the newly capable ChemCam, they were able to zap haloes all over the place, and found that the haloes marked rocks that were enriched in silica relative to the rocks away from the haloes. Huh.

The team debated what that might mean. Was the silica enrichment a result of silica-rich stuff being deposited in the rocks by groundwater? Or was it a place where the other stuff was being leached away? The latter hypothesis was favored by readings from the Alpha Particle X-Ray Spectrometer, which showed that wherever there was an enrichment in silicon, there was also an enrichment in titanium. *Spirit*'s APXS had also observed something similar in rocks near Home Plate. Titanium doesn't dissolve readily in water, so if you leached elements out of a rock, it's an element that would be left behind.

The team decided the best way to answer this question would be to drill. In fact, they needed to drill twice: once in the Stimson unit far away from a fracture, and once within a halo, close to a fracture. Comparing Big Sky (ordinary Stimson) to Greenhorn (halo Stimson), they found Greenhorn to have abundant opal, another form of silica. Unfortunately, opal can form in a wide variety of different environments, so its presence doesn't tell us anything about whether it was a hot, acid environment or a temperate, neutral one when the water was flowing through the rocks, so the jury is still out on that decision. Either way, water was required.

How does the silica in the haloes in the Stimson unit relate to the tridymite in the Murray formation that the rover saw at Marias Pass? There may or may not be any relationship. I got one *Curiosity* team geologist to speculate that the opal in the Stimson haloes was carried there in water that had flowed through the tridymite-rich Murray formation, but there's really no way that I know of to confirm or disprove that hypothesis.

THE YOUNGEST ROCK

And now for the other *Curiosity* story out of AGU. Studying the silica is not the only science experiment that *Curiosity* was conducting while passing through Marias Pass. The other reason they drove back and forth so many times was to find a location where they could see Murray and Stimson directly in contact with each other. They found that at a spot called Missoula, capturing this gorgeous MAHLI panorama.

You can see a lot of calcium sulfate veins in the lower, Murray formation rock, which is truncated by the overlying Stimson rock. That alone isn't enough to be sure that Murray and Stimson formed at very separate times; it could

Images: NASA/JPL-Caltech/MSSS

just be that the Murray formation has properties different from the Stimson that allow veins to propagate easier in it than in the Stimson. But there's something peculiar about the Stimson unit where it contacts the Murray; it's full of little rock fragments, whereas higher in the section it's a much more uniform, fine-grained sandstone. (Online you can enlarge the MAHLI photo above to spot those grains.) The newly capable ChemCam shot at the Stimson unit right above the contact, profiling the composition across matrix and grains. And when ChemCam struck a particularly bright grain, one team member told me, "Bam! Calcium sulfate."

What does it mean for tiny little grains of calcium sulfate to be incorporated into the base of the Stimson? It means that before the sands of the Stimson were laid down, the Murray formation had already been buried and turned into rock. The Murray rock had already been shot through with calcium sulfate veins. Then it had already been unburied and exposed at the surface, where the calcium sulfate veins had eroded away into calcium sulfate pebbles. When the Stimson sands blew through, the bottom-most sand layers incorporated broken up bits of Murray. In other words, a whole lot of time passed between the Murray and the Stimson. Millions of years. Maybe tens or hundreds of millions.

Kevin Lewis presented a poster at AGU that argued for the Stimson being the youngest rock encountered by *Curiosity*. As *Curiosity* has driven along, it has found the elevation of the base of the Stimson to march up the mountain; the base of the Stimson unit tilts about 4 degrees to the northwest. It's not an originally flat-lying rock that has been tilted, he argued; rather, the topography of a central mountain in Gale crater was already present when the Stimson sands were draped across its northern flanks.

They looked at the direction of the cross-beds, and determined that the flow of wind or water that laid down the Stimson sands was moving from west-southwest to east-northeast—which is to say, basically across the slope. That, in turn, means the fluid that transported the Stimson sands was almost certainly not water (at least, not most of the time); they're wind-blown sands, much like the modern Bagnold dunes. Except they don't contain olivine. And they're blowing in a different direction. And nobody knows what causes the topographic expression of east-west trending ridges in the Stimson. So perhaps they're not at all like the Bagnold dunes! As *Curiosity* keeps driving, Lewis told me, it will be able to investigate isolated outcrops of Stimson that the rover can drive around and view from all sides, which should help the team understand its depositional environment a little better.

It's a pleasure to see the rover using all its instruments together, as intended, on the rocks that the rover was sent to Mars to study. Getting ChemCam back to full function, with the new-and-improved calibration, has been particularly helpful. It took a long time to get going, but the science mission is really underway now.

ABOVE *A rock outcrop dubbed "Missoula," near Marias Pass on Mars, is seen in this image mosaic taken by* Curiosity*'s MAHLI camera on sol 1031 (July 1, 2015). The area pictured is about 40 centimeters across. Pale mudstone (bottom of outcrop) meets coarser sandstone (top) in this geological contact zone, which has piqued the interest of Mars scientists. White mineral veins that fill fractures in the lower rock unit abruptly end when they meet the upper rock unit. Such clues help scientists understand the possible timing of geological events. First, the fine sediment that now forms the lower unit would have hardened into rock. It then would have fractured, and groundwater would have deposited calcium sulfate minerals into the fractures. Next, the coarser sediment that forms the upper unit would have been deposited.*

NASA/JPL/MSSS

BLOG DATE 2015/11/23 16:36 UTC
AUTHOR JASON DAVIS
ONLINE planet.ly/surveyor

Surveyor Digitization Project

Hints at Long-Lost Lunar Treasures

BELOW *Film canisters containing images from the* Surveyor *program, stored at the University of Arizona Lunar and Planetary Laboratory.*

Jason Davis/The Planetary Society

A PROJECT TO digitize more than 90,000 images taken by NASA's five *Surveyor* spacecraft in the 1960s has revealed early hints of never-before-seen treasures captured by America's first robotic lunar landers.

Scientists at the University of Arizona Lunar and Planetary Laboratory started scanning the original *Surveyor* film reels in March 2015 and finished up in November. The *Surveyor*s were NASA's first probes to soft-land on the Moon, and only 2 percent of their images have ever been seen by the public. A set of the program's original film reels has been stored for decades at the Lunar and Planetary Laboratory.

The project team is now doing the arduous task of formatting the images for submission to NASA's Planetary Data System (PDS), the agency's master archive of space imagery. When that task is completed, anyone will be able to browse and download the pictures for free.

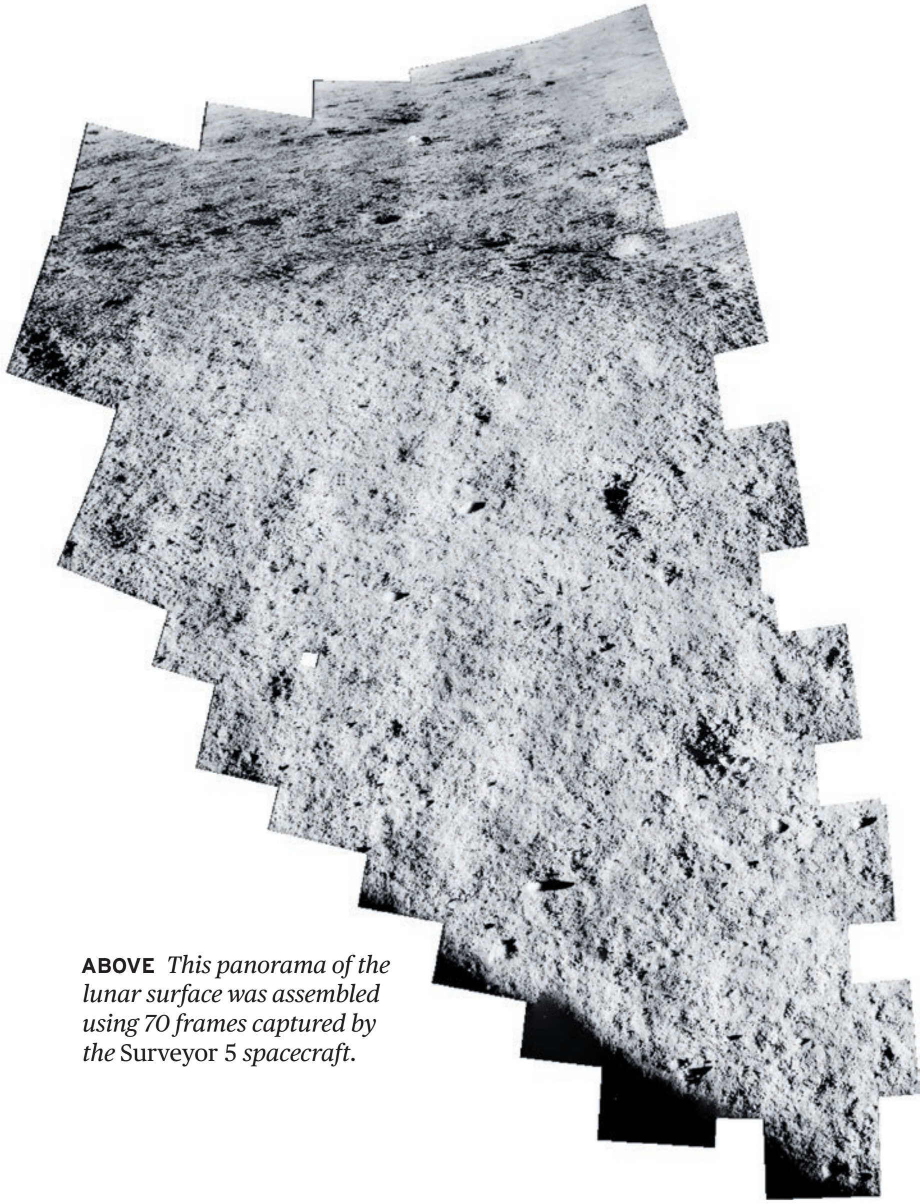
A RESCUE OPERATION

The team hasn't had much time to play with the images they've scanned during the eight-month process–the emphasis thus far has been on the tedious task of digitizing the data. Scanning took place inside a clean room built at the Lunar and Planetary Laboratory. The fifty-year-old film reels are in good shape, but Shane Byrne, the project's principal investigator, wanted to get the pictures scanned as soon as possible.

"At a fundamental level, this is like a rescue operation," Byrne said. "The most important thing is to get the frames digitized and freeze them so they don't decay any more."

Last week, John Anderson, a media technician working on the project, loaded the final reel of film onto an automated scanning machine on loan from Austin, Texas-based Stokes Imaging. The reel contained a series of calibration images taken at Cape Canaveral before one of the *Surveyor* probes launched.

"It's been in the can awhile," Anderson said, during a team meeting. "The film



ABOVE *This panorama of the lunar surface was assembled using 70 frames captured by the* Surveyor 5 *spacecraft.*

Image: NASA/JPL-Caltech/University of Arizona Lunar and Planetary Laboratory/John Anderson

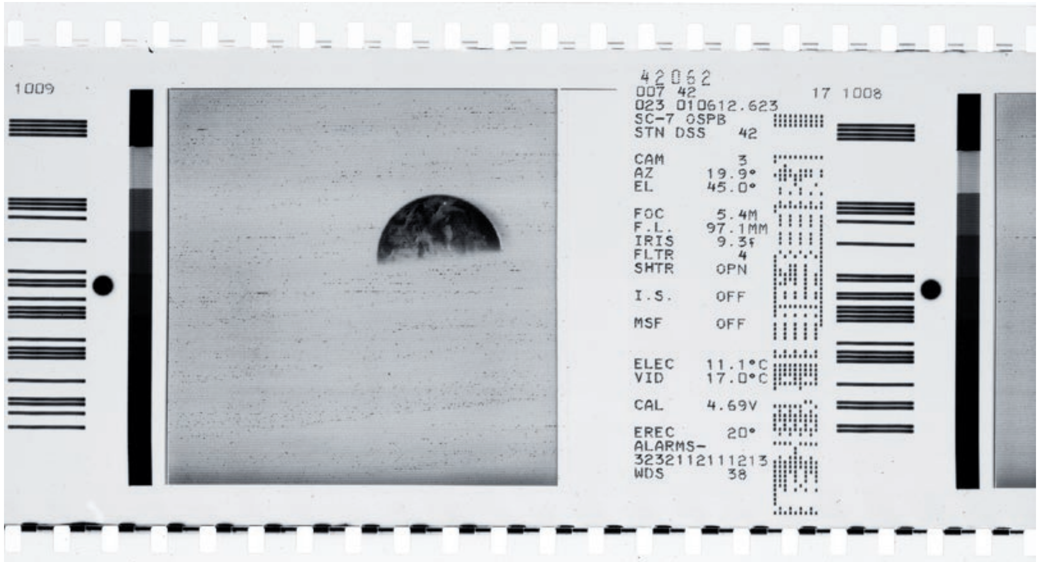
is curled as you take it off the roll." In the clean room, I watched him mount the reel onto a spindle, unroll the film between two pieces of glass, and attach it to an empty reel. A bright light was positioned under the glass, and an overhead camera snapped an image of each backlit photo as the film gently spooled through, stopping one frame at a time. Anderson observed the process carefully, occasionally fine-tuning the frame before the shutter clicked. It was a tedious process. The bulk of the scanning was done by Anderson, LPL's Maria Schuchardt, and Selina Valencia, an undergraduate student who pitched in earlier in the project. The team originally estimated there were 87,000 images, but they acquired more reels from NASA's Goddard Space Flight Center in Maryland, bringing the total up to about 93,700. Of those images, Anderson estimates 92,000 are usable, valid pictures from the lunar surface.

I asked Anderson for the size of the raw image cache. Sitting behind a dual-screen Apple computer in LPL's Space Imagery Center, he selected the project folders and tried to open a properties window to get the number. We waited for several minutes as the computer's hard drives ground away, struggling to come up with an estimate. We finally gave up. (Anderson estimates the figure is about 5 terabytes of data.)

Though the team has mostly been busy scanning, Anderson has found a few minutes here and there to play with the raw data. He created an algorithm to normalize the brightness levels across a set of frames, and has been able to stitch together part of a mosaic from *Surveyor 5* that contains 70 images thus far. Because the raw files are so big, he had to make intermediate mosaics first, and then stitch those together.

Anderson also created a composite Earthrise using 11 frames captured by *Surveyor 7*. This technique—overlaying multiple pictures of the same thing—is often used by amateur astronomers to make pretty pictures.

I asked Anderson if we could randomly browse through the archive and look for something interesting. We found a series of images showing *Surveyor 7* scooping the lunar surface, and I put those together into an animated GIF (see the animation at **planet.ly/surveyor**).



ABOVE *This image of Earth was captured by* Surveyor 7 *in 1968. The image, stored on a 70 millimeter film reel negative, also contains calibration metadata.*

RIGHT *This composite HDR image of Earth was created using 11 frames captured by the* Surveyor 7 *spacecraft.*

A METADATA PUZZLE

To submit the raw *Surveyor* images to the Planetary Data System, Byrne's team needs to convert the metadata stamped on each frame into a format that the PDS can accept. That metadata comes in three formats: human-readable text, binary coded decimal (BCD), and a barcode.

The team first focused on the text, hoping they could automate the digital conversion process through optical character recognition (OCR). But a closer look showed that the text is printed in a dot matrix–each number and letter is actually formed by a series of small dots. That tends to confuse OCR readers. One possible workaround is applying a blur to the text block to connect the dots into solid text.

Another option is creating a process to read the BCD or barcode block. But the details on how to decode these blocks have been lost over time. Justin Rennilson, a project member who was also on the spacecraft's original camera team, has been working on interpreting the BCD blocks. He discovered that the format of the blocks changed over the course of the *Surveyor* program.

Now that the scanning portion of the project is over, the team is turning its full attention to the metadata puzzle. The process they end up using to parse the 92,000-plus images needs to be nearly 100 percent accurate.

A CHALLENGE FOR ALAN SHEPARD

Back in the Space Imagery Center, Rennilson looked over a large printout of Anderson's early mosaic. I asked which part of the image was in the foreground, closer to the camera.

"Look for the fine fragments," he said. "If you can't resolve them, it's far away." Surveyor scientists used this trick to help train astronauts how to judge distances on the lunar surface.

"That was a tool we told the astronauts to use on the Moon," Rennilson said. "And it worked for most of the astronauts." One exception, he said, was Alan Shepard. America's first human in space apparently never quite got the hang of it.

Image: NASA/JPL-Caltech/University of Arizona Lunar and Planetary Laboratory/John Anderson

BLOG DATE 2015/09/25 19:27 UTC
AUTHOR EMILY LAKDAWALLA
ONLINE planet.ly/worlds1

The Solar System at 1 Kilometer per Pixel

Can You Identify These Worlds?

THIS IMAGE contains 18 samples of terrain on solid worlds across the solar system. Each square covers the same area: the squares are about 500 kilometers on a side, and the resolution of the original image data was about 1 kilometer per pixel. Can you guess which square represents which world?

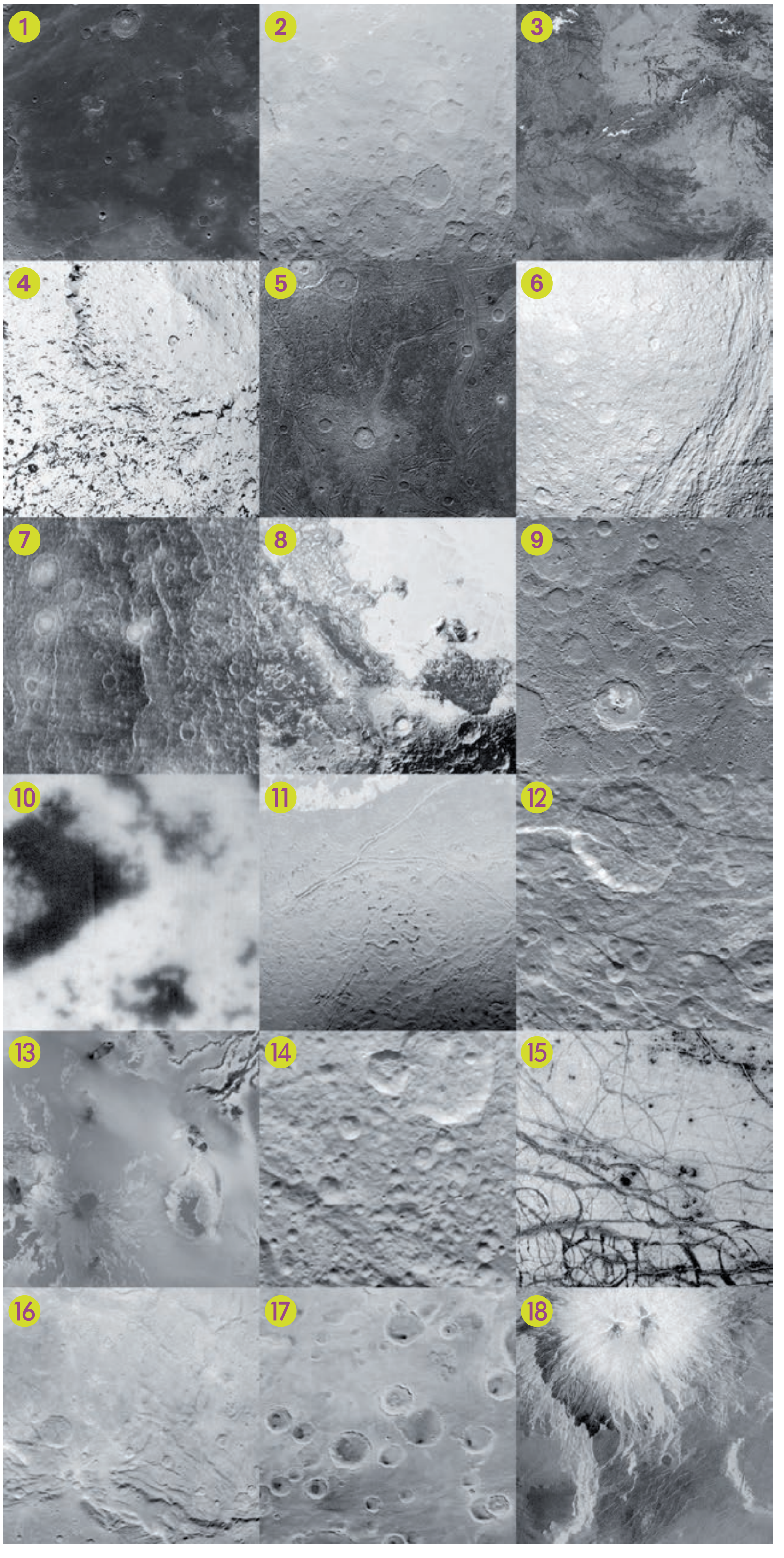
Before you even try to identify the worlds, I'd like you to just step back and appreciate the diversity of the terrains: even when things look superficially similar (i.e., lots of craters), there are major differences in the size distribution and shape of those craters. Remind yourself: all of these images have the same scale.

I've included every solid-surfaced world (a) that is large enough to completely fill the square, and (b) for which we have imagery at or very close to the target 1 kilometer-per-pixel resolution. (There are two worlds here for which the squares actually show about 430 kilometers on a side because images that have exactly the right compromise between resolution and areal coverage aren't available; I figured that was close enough for the purposes of this comparison.)

Each world is shown only once. Almost all the images were taken in visible wavelengths, but there are two worlds for which we have appropriate imagery only in infrared or radar. Sadly, none of the Uranian satellites is present, because all our images of them have a resolution too coarse for inclusion here, except for Miranda, which is too small to be included.

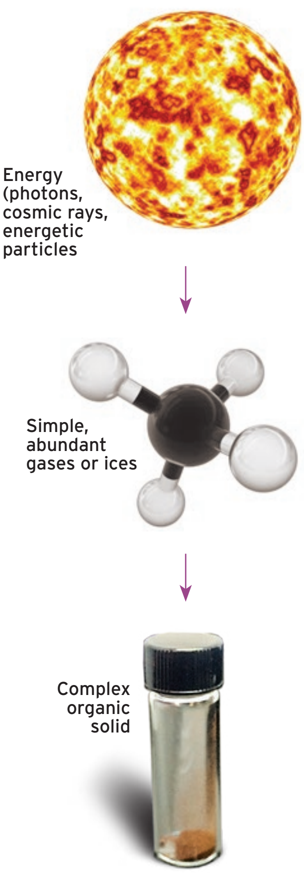
How many of these worlds can you identify? I'm not sure how I would do on this challenge—there are many I could guess right off the bat, but several that I'd have trouble telling apart.

Answers on page 21.



BLOG DATE 2015/07/23 00:00 UTC
AUTHOR SARAH HÖRST
ONLINE planet.ly/tholins

What in the World(s) are Tholins?



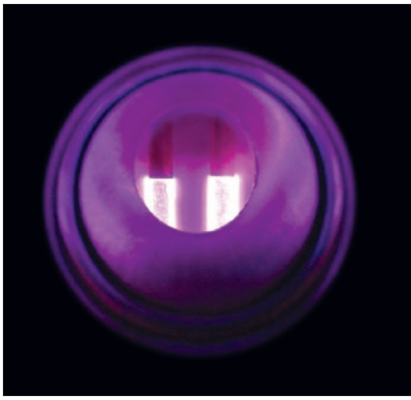
ABOVE *These steps lead to the formation of tholins, or, abiotic complex organic gunk.*

AS *NEW HORIZONS* beamed back incredible images of Pluto and Charon over the last few weeks many people learned for the first time that Pluto is red, and we discovered that Charon is strikingly red at the pole. The question, "Why is Pluto red?" has been answered with a word that most people have never heard of, and perhaps even fewer people can actually define: tholins. What in the world(s) are tholins?

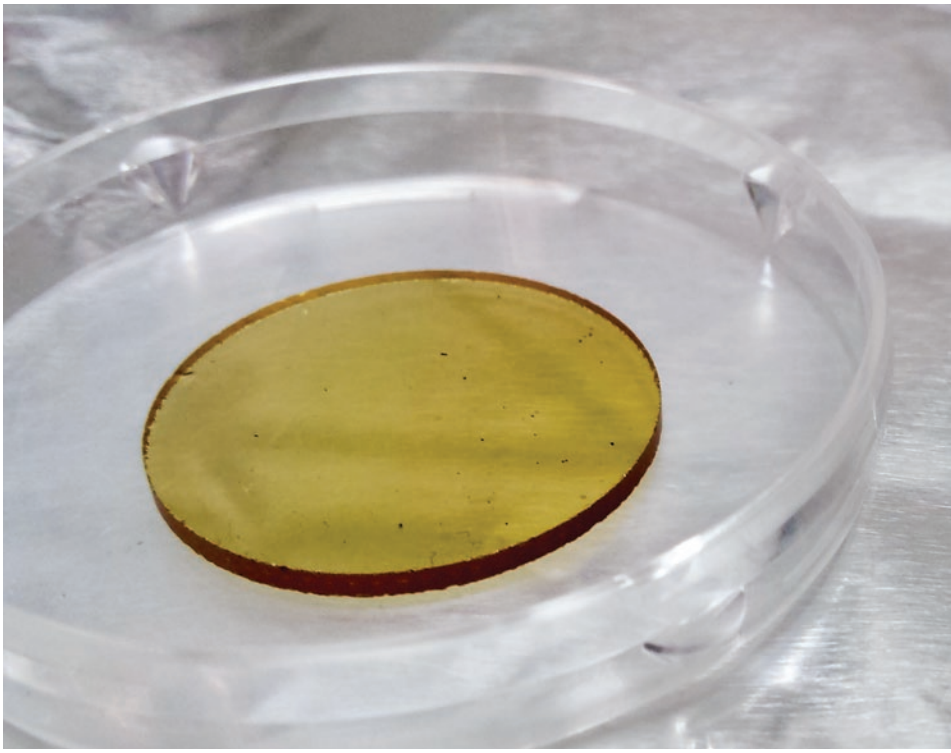
During the 1970s, Carl Sagan's laboratory at Cornell was busily taking mixtures of cosmically relevant gases and irradiating them with various energy sources. They were searching for answers to questions ranging from "Why is the Great Red Spot red?" to "How did life on Earth originate?" and in the process produced a material for which there was no name. In 1979, Carl Sagan and scientist Bishun Khare published an article titled "Tholins: organic chemistry of interstellar grains and gas" in the journal *Nature*, and the word "tholin" was born.

> "For the past decade we have been producing in our laboratory a variety of complex organic solids from mixtures of the cosmically abundant gases CH_4, C_2H_6, NH_3, H_2O, HCHO, and H_2S [methane, ethane, ammonia, water, formaldehyde, and hydrogen sulfide]. The product, synthesized by ultraviolet (UV) light or spark discharge, is a brown, sometimes sticky, residue, which has been called, because of its resistance to conventional analytical chemistry, "intractable polymer." However, we have recently succeeded, through sequential and non-sequential pyrolysis followed by gas chromatography-mass spectrometry (GC-MS), in determining something of the composition of this material. It is clearly not a polymer–a repetition of the same monomeric unit–and some other term is needed. We have discussed this material as a constituent of the Earth's primitive oceans and therefore as relevant to the origin of life; as a component of red aerosols in the atmospheres of the outer planets and Titan; as present in comets, carbonaceous chondrites, and pre-planetary solar nebulae; and as a major constituent of the interstellar medium, which is the concept discussed here. We propose, as a model-free descriptive term, 'tholins' (Gk θὸλος, muddy; but also θολὸς, vault or dome), although we were tempted by the phrase 'star-tar.' The properties of tholins will depend on the energy source used and the initial abundances of precursors, but a general physical and chemical similarity among the various tholins is evident."
> –*Carl Sagan and Bishun Khare, 1979, "Tholins: organic chemistry of interstellar grains and gas,"* Nature, *Vol. 277, 11 January 1979.*

Although informative, the definition given in the *Nature* article is not particularly easy to repeat when people ask, "What is tholin?" I have been studying tholin for almost a decade,



RIGHT *Plasma used to generate tholin from a mixture of nitrogen and methane gases.*



ABOVE *Tholin deposited on a disk for particle size measurement.*

and in my experience the most frequently used synonyms for tholin are "gunk," "brown gunk," and "complex organic gunk." Tholin is also often described as a "tar-like" substance. Words like tar, kerogen, bitumen, petroleum, and asphalt all describe substances that may be similar to tholin in some ways. However, these materials all result from life; they are "biotic."

Since 1979, the definition of tholin has expanded and now often includes organic solids produced from irradiation of cosmically abundant ices (rather than gases), and tholin experiments now routinely include other gases like N_2, CO_2, or CO [nitrogen, carbon dioxide, or carbon monoxide].

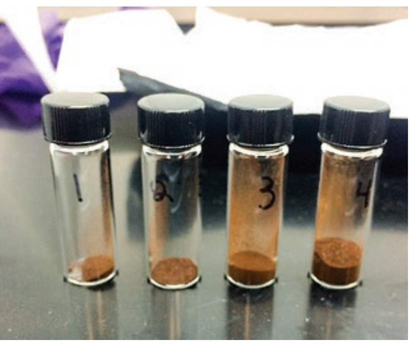
INCREDIBLY CHEMICALLY COMPLEX MATERIAL

So what do scientists mean whey they say tholin? In general, we mean an abiotic complex organic solid that is formed by chemistry from energy input into simple, cosmically relevant gases or solids. Shorter still, "abiotic complex organic gunk" works for me. You can see, perhaps, why Sagan and Khare felt the need to make up a word to capture this idea.

Indeed, tholin turns out to be incredibly chemically complex. Ultra-high-resolution mass spectrometry measurements I analyzed while in graduate school demonstrated that tholin contains at least 10,000 different molecular formulas that, once you account for different structures (isomers), could mean hundreds of thousands of different compounds! We have detected molecules in tholin with masses equivalent to about 80 carbon atoms, although we know that much heavier ions are present in Titan's atmosphere!

A final note on nomenclature: one of the biggest difficulties with the word "tholin" is that it is incredibly nonspecific. The best analogy I have been able to come up with is "salad." Salad, like tholin, is a mixture of different compounds and spans a fairly broad range of materials. Most of us would agree on a case-by-case basis whether or not something is a salad, but the definition is not at all specific

Photos: Sara Hörst and Chao He, Johns Hopkins University



ABOVE *Vials of tholin made in Johns Hopkins University's Hörst Laboratory from nitrogen and methane in the plasma.*

Photo: Xinting Yu, Johns Hopkins Universisty

and the material itself depends on the starting materials, preparation, temperature, etc. We sometimes refer to "Titan tholin" or "Triton tholin," but even then you would need to ask about factors such as temperature, energy source, precursor gas, or ice mixture to get an actual understanding of what the material is. Personally, I try to use the word "tholins" only when describing the laboratory-produced samples, in part because we do not really know yet how similar the material we produce in the lab is to the material found on places like Titan or Triton (or Pluto!). In fact, I usually call the samples produced in my laboratory "Titan aerosol analogues" rather than "tholins."

WHY DO WE CARE ABOUT THOLIN?

This is a more important question than the origin and nomenclature discussion. Here is a not-at-all-comprehensive list:

- As particles in an atmosphere, tholin affects the number and kind of photons in an atmosphere and on the surface (because particles absorb and scatter the light from a star differently than gases), which is important for temperature-dependent processes and can affect habitability. For example, a tholin haze on the early Earth may have efficiently screened UV photons, protecting early life forms before the ozone layer existed.
- Tholin is a source of organic material on a surface, which could be important for the origin or evolution of life on a world. For example, in 2012 we showed that you can produce some of the building blocks of life (amino acids–the building blocks of proteins, and nucleobases–the building blocks of DNA/RNA) in tholin experiments.
- Tholin is a source of material on a surface, period, which can participate in surface processes. For example, the extensive dune fields on Titan appear to be made of organic material like tholin.
- The presence or absence of tholin can help us figure out the age of a surface and/or composition of starting materials. For example, on a world where tholin forms efficiently, tholin-free regions would have to be relatively young or subject to some type of removal process (rain, wind, resurfacing, etc.).
- One final reason we care about tholin is that there are places we want to explore in the solar system where material similar to laboratory-produced tholin is likely present. We are working to understand tholin so that we know which instrument techniques are most useful for characterizing it, and what specifications those instruments need, and finally we can use tholin for instrument testing to ensure that it would work properly once arriving at its destination. You can imagine, for example, that one would want to test cryogenic valves designed to control the flow of Titan lake materials into an instrument with materials analogous to Titan so that your valves do not get clogged or stuck!

As for whether or not there is tholin present on Pluto or Charon, I am not on the team so I am not privy to the data they have seen. The fact that there is red material present on worlds that possess (or in Charon's case, are exposed to) some known tholin precursors (nitrogen, methane, carbon monoxide) makes a pretty compelling case for the presence of tholin. Spectrometers carried by *New Horizons* will almost certainly, if they have not already, tell us that the red material is organic and then we will all busily get to work trying to understand its formation (in the atmosphere, on the surface, or both?), composition, geographical distribution, and implications for Pluto's atmosphere and surface. I can't wait!

BLOG DATE 2015/12/08 14:26 UTC
AUTHOR TRAVIS RECTOR
ONLINE planet.ly/planetaryimagingcolors

Colors in Planetary Imaging

WHEN LOOKING AT AN image of, say, a galaxy, have you ever wondered to yourself, "Is this real?" or maybe, "Is this what it really looks like?" The first question is easy to answer. Yes, astronomy images are real. Unless it is "space art," these images are of real objects in outer space. They aren't creations of a graphic artist's imagination. But answering the second question is not as simple. How a telescope "sees" is radically different from how our eyes see. Telescopes give us super-human vision. In most cases, they literally make the invisible visible.

Let's look at an example. The picture above and (much larger) on our cover, captures the famous Horsehead Nebula, which gets its name from the distinctive dark shape at the center of the image. It is part of a large nebula in the constellation of Orion. The image was taken with an advanced digital camera from a telescope at the Kitt Peak National Observatory in southern Arizona. This is what the telescope and its camera can see. But let's pretend you had the ability to board a spaceship and fly to the Horsehead Nebula—what would you see? After a journey of more than a thousand light years, you look out of the window of your spaceship at this same scene. You're now at a distance one hundred times closer than when you were standing on Earth. Here's your view now.

ABOVE *The iconic Horsehead Nebula is part of a dense cloud of gas in front of an active star-forming region known as IC 434, a bright emission nebula in the constellation Orion.*

LEFT *The same area of the sky as shown in the first image of the Horsehead Nebula, but shown as you would see it with your naked eye.*

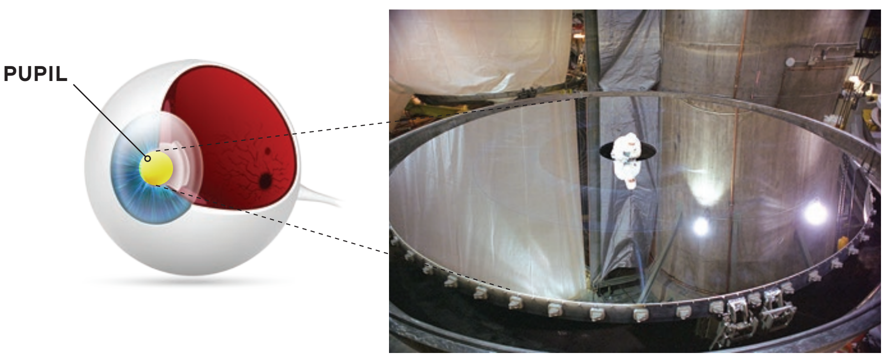
You'd see some of the brighter stars but none of the dust and gas in the nebula, including the horse head shape. Why?

Images: Horsehead Nebula: T. A. Rector (NOAO/AURA/NSF) and the Hubble Heritage Team (STScI/AURA/NASA); T. A. Rector (NOAO/AURA/NSF)

ON PLANETARY.ORG

THREE THINGS A TELESCOPE DOES

To better understand what's going on, it helps to know what a telescope does. Just as a pair of binoculars can make the upper-level seats in an arena almost as good as courtside seats, a telescope can make a distant object appear much closer. But a telescope does more than this. It doesn't just magnify an object; it also amplifies it. It makes something faint appear much brighter.



ABOVE *We can gaze at the night sky, but beyond picking out the constellations, we need specialized equipment to help us see faint objects in any detail, or to see other kinds of light beyond a small range of visible light. A specialist in a white "clean suit" sits at the center of the light-collecting mirror that was later installed in the Gemini North telescope in Hawai'i. The mirror is 27 feet (8.23 meters) wide, whereas the human pupil is only about 1.5 millimeters [bright light] to 8 millimeters [dim light] in diameter.*

NASA

Some people think the reason a telescope can see objects our eyes can't see is because it magnifies something that is too small for us to see. And this is often true. But the Horsehead Nebula is actually not that small. The fields of view of these images of the Horsehead are about twice the size of the full Moon in the sky. You can't see it because it's too faint, not because it's too small.

So why couldn't you see the Horsehead Nebula even if you were much closer? For objects that appear to be larger than a point of light (e.g., galaxies and nebulae, but not stars), how bright it appears has little to do with how far away it is. Moving closer to it will make it bigger, but not brighter. This may seem counterintuitive, but you can try it at home. Walk toward a wall. As you approach you'll notice the wall is getting bigger, but otherwise it is the same brightness. The same is true of the Horsehead Nebula. If you can't see it with your eyes while standing on Earth, you still won't see it from your spaceship.

Why, then, can a telescope see it? A telescope offers several advantages over our eyes. As marvelous as the human eye is, it's not that well suited for nighttime observing. First, our eyes are tiny. The opening that allows light to enter our eye, known as the pupil (the black area at the center of the eye), is only about one-quarter of an inch wide when fully open.

In comparison, the mirror that collects light for the Gemini North telescope, one of the professional observatories atop Mauna Kea in Hawai'i, is over 8 meters across. What this means is that, at any given moment, this mirror is collecting more than a million times more light than your eye. The more light you collect, the fainter an object you can see.

Human eyes also don't collect light for long. Our eyes function like a video camera, taking images about 30 times every second. So the exposure time for each image captured by the human eye is only one-thirtieth of a second. With digital cameras attached to the telescope, we can collect light for as long as we like. The longer the exposure, the more light the telescope collects.

Typically, a single exposure is not more than 10 to 20 minutes, but multiple exposures can be added together to make a single image with an exposure time that is, in effect, much longer. To create the most sensitive image ever made, astronomers collected over 50 days' worth of observation time with the Hubble Space Telescope of a single portion of the sky. Known as the Hubble eXtreme Deep Field (XDF), this image represents a cumulative exposure time of about 2 million seconds!

The human eye is complex. It isn't as sensitive to faint light, and it only detects amounts of light that are above a certain threshold. To prevent confusion, our brain filters out the "noise" below that level. In comparison, modern electronics detect nearly all the light that enters a telescope's camera, even if it takes hours to collect the light. All of these factors enable telescopes to go far beyond the limits of human vision. The faintest objects in the XDF are about 10 billion times fainter than what the human eye can see.

Finally, the universe and the amazing

ABOVE LEFT *The Hubble eXtreme Deep Field (XDF) represents over fifty days' worth of observations of a single portion of the sky with a cumulative exposure time of about 2 million seconds. The faintest objects in this image are galaxies about 30 billion light years away.*

ABOVE RIGHT *Mount Everest as lit by sunset. The snow atop the mountains is intrinsically white, but it appears orange because it is reflecting light from the setting Sun.*

ESA; G. Illingworth, D. Magee, and P. Oesch, University of California, Santa Cruz; R. Bouwens, Leiden University; and the HUDF09 Team

objects in it glow in other types of light—from radio waves to gamma rays—that are impossible for our eyes to see. It's taken the ingenuity of scientists and engineers many decades to develop our abilities to capture the views of the universe that we enjoy today. Without these technical tools, many phenomena and objects simply would be entirely invisible to us.

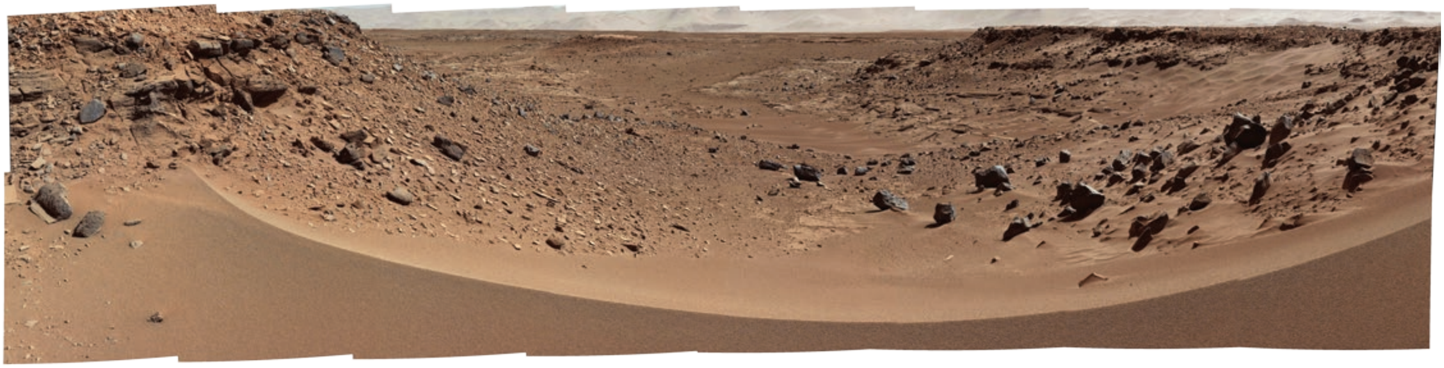
SHOW YOUR TRUE COLORS

It's no exaggeration to say that telescopes give us super-human vision. Nearly every astronomical image contains objects too small and/or too faint for us to see. And these images often show us kinds of light our eyes can't detect at all. So how do astronomers take what the telescope sees and convert it into something we can see? This is a question that has challenged astronomers and astrophotographers for decades. There's no simple answer, because it depends on the telescope and camera, the type of light, the filters used, and the object observed.

Each image is therefore made in its own way. Fortunately, professional observatories usually provide information about how an image was made. When reading the caption or background information about an image, it might be described as shown in "true color," "false color," or maybe even "pseudocolor." What do these terms mean?

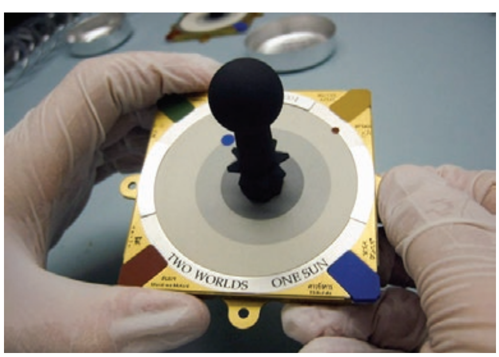
False color and pseudocolor are phrases that unfortunately have not been used consistently. What's important to know is that these terms do not mean the image is not real. They simply mean that color is used to show objects in a way that's different from what your eyes would see. On the other hand, "true color" usually means that what you're seeing is an attempt to represent how the object would look to your eyes, if they were more sensitive. Astronomers can make color images using filters that are reasonably close to the cones in our eyes. These images are often labeled as true color, even though color has an ambiguous meaning for objects too faint for our eyes to naturally see. This is the case for most objects in space.

However, true color is a realistic goal for bright, sunlit objects such as planets and their moons. Spacecraft that land on other planets often carry additional tools for color calibration to account for the effects of the atmosphere. Just as our blue skies (or orange skies at sunset) can change the apparent color of an object, the same effect occurs on other planets that have atmospheres. The thick yellow atmosphere of Venus and the dusty brown air on Mars affect



ABOVE *The top image shows a valley on Mars as you might see it if you were standing there. The dusty haze of the Martian atmosphere makes the ground appear browner than it really is. The bottom image is "white balance" color corrected to remove this effect and show the inherent colors of the rocks and sand.*

the apparent color of those planets' surfaces. To take this into account, swatches of known color are placed in the spacecraft. By taking pictures of these color swatches with the onboard cameras, the color images from those cameras can be calibrated to show what you would see if you were there. Color-corrected



RIGHT *A calibration target in the form of a sundial is mounted on the Mars* Spirit *and* Opportunity *rovers. Note the four colors in the corners. Pictures taken of the Martian landscape that have the sundial in the image are used to calibrate the color in images taken by the rover cameras. The shadow cast by the sundial also helps to measure the difference in lighting effects from the Sun and atmosphere, allowing the intrinsic color of objects to be determined.*

images can also be made to show the "intrinsic" colors of the surface–that is, as it would appear if the Sun and sky were white. Scientists use these intrinsic colors to help identify the kinds of rocks and minerals on these distant worlds.

SCIENTIFIC *AND* BEAUTIFUL

Within the confines of a blog post, I've tried to explain what a telescope does and the challenge of making astronomical images with the data they produce. It is a fundamental challenge, because our telescopes can show objects in ways that our eyes cannot see. That is, of course, the reason we build telescopes! There would be no point to building machines like Gemini, Hubble, and Chandra if they didn't expand our vision.

Astronomy images are intended to show the science that is being done with these telescopes. The reputations of the observatories, and the scientists who use them, are tied to the truth of what's in an image. No self-respecting scientist would intentionally do something to create a misleading image from his or her data. Think of a doctor who has taken an X-ray of an ailing patient. They may use techniques to enhance the picture so that more detail can be seen, but they would never add or remove a bone fracture in the picture, for example. The same is true here.

There is an artistry to making these images, but ultimately the goal is a scientific one: to share with people the discoveries astronomers are making with these fantastic machines of exploration. With advances in telescopes, cameras, and image-processing software, we continuously improve our ability to see planets, stars, and galaxies. Though each image is a representation, it offers a real view into our real and fascinating universe.

Images: NASA/JPL-Caltech/Cornell Univ/Arizona State Univ.; Sundial image: NASA/JPL-Caltech/Cornell

BLOG DATE 2015/09/30 15:00 UTC
AUTHOR EMILY LAKDAWALLA
ONLINE planet.ly/worlds2

The Solar System at 1 Kilometer per Pixel

AS A BONUS, I've included information on the instruments and missions that captured each image.

Some of the worlds' identities can be deduced from features that occur nowhere else: Europa with its bands, Ganymede with its grooved terrain, the smooth lunar maria, the funny dark splotches in Mars' flat-floored craters. You won't find rivers dammed to make reservoirs anywhere but Earth (this particular piece of Earth is entirely contained within Spain).

People who are experienced observers of spacecraft imagery might recognize the fuzziness of *Cassini*'s Titan images, and the peculiar patterns of light and dark in *Magellan* radar images of Venus. I would really like to know whether I would be able to tell Jupiter's moon Io and planet Venus apart if we were able to shoot them with the same camera.

After that, it gets a bit harder. I might possibly have recognized Ithaca Chasma on Tethys, but I don't think I would have been able to tell Dione and Rhea apart. And I think I would have been thrown by Ceres. Look how flat-floored its craters are! They look as much like Ganymede's or Mars' craters as those of Tethys or Rhea.

The choice of 1 kilometer per pixel and 500-kilometer squares was not made at random. It was a deliberate choice based on my knowledge of what imagery is available and the sizes of solar system worlds, including the very new additions of photos from *New Horizons* at Pluto and Charon. The vast majority of cameras that have been sent to other worlds have detectors that are square and have 800 or 1,024 pixels on a side. I needed to pick a square smaller than that, so that I could have some flexibility in resizing images to match their scales. There's also a limitation imposed by the solar system, a break in the size distribution below a diameter of about 1,000 kilometers. The next-largest object in the solar system after Ceres that we have visited with a spacecraft is Vesta, which is barely more than half the size of Ceres. You can comfortably fit a 500-kilometer square with room to spare on a 1,000-kilometer circle, so the choice of scale was basically made for me.

In the future I may well do another of these comparisons looking at a much smaller scale, but I'll be limited by the availability of high-resolution images for many of these worlds; it will take some work to identify the resolution that will allow me to include the highest possible number of places.

To locate these images, I went to a variety of sources. For Mercury, I began with the global mosaic from the *MESSENGER* website; this mosaic is available for download at a variety of resolutions. For Venus, I turned to some of the *Magellan* images that I had already processed for The Planetary Society. For Earth, I went to NASA's Visible Earth image gallery and filtered it by MODIS. For the Moon, I knew I could find the right resolution of imagery from *Lunar Reconnaissance Orbiter*'s Wide-angle Camera global lunar mosaics. For Mars, 1 kilometer per pixel is a kind of tricky in-between resolution that we haven't seen much of since early days, but I remembered that *Mars Express* had recently released an unusually wide-angle view of Mars that I could grab a crop from. For Ceres, there's no formally released data yet, so the best source was JPL's Planetary Photojournal for press-released *Dawn* Ceres images. For the moons of Jupiter, Saturn, and Neptune, I turned to the trusty Outer Planets Unified Search tool hosted by the Rings Node of the Planetary Data System. They have a relatively new feature that dramatically eases the search among *Cassini* images: if you click on "*Cassini* Surface Geometry" at the left, and click on "*Cassini* Target Name" and then select a target, you can specify a minimum and maximum pixel resolution to refine your search. And for Pluto and Charon, I went to my own index of publicly released *New Horizons* images.

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13	14	15
16	17	18

Images appear on page 13.

1. **The Moon**
Lunar Reconnaissance Orbiter Camera Wide-Angle Camera
NASA/GSFC/ASU

2. **Ceres**
Dawn Framing Camera
NASA/JPL/UCLA/MPS/DLR/IDA

3. **Earth**
Terra Moderate Resolution Imaging Spectroradiometer
NASA/GSFC

4. **Iapetus**
Cassini Imaging Science Subsystem
NASA/JPL/SSI

5. **Ganymede**
Voyager Imaging Science Subsystem
NASA/JPL

6. **Tethys**
Cassini Imaging Science Subsystem
NASA/JPL/SSI

7. **Callisto**
Voyager Imaging Science Subsystem
NASA/JPL

8. **Pluto**
New Horizons Long-Range Reconnaissance Imager
NASA/JHUAPL/SwRI

9. **Mercury**
MESSENGER Mercury Dual Imaging System
NASA/JHUAPL/SwRI

10. **Titan**
Cassini Imaging Science Subsystem
NASA/JPL/SSI

11. **Triton**
Voyager Imaging Science Subsystem
NASA/JPL

12. **Rhea**
Cassini Imaging Science Subsystem
NASA/JPL/SSI

13. **Io**
Voyager Imaging Science Subsystem
NASA/JPL

14. **Dione**
Cassini Imaging Science Subsystem
NASA/JPL/SSI

15. **Europa**
Galileo Solid State Imaging
NASA/JPL/UA

16. **Charon**
New Horizons Long-Range Reconnaissance Imager
NASA/JHUAPL/SwRI

17. **Mars**
Mars Express High-Resolution Stereo Camera
ESA/DLR/FU Berlin (G. Neukum)

18. **Venus**
Magellan Synthetic Aperture Radar
NASA/JPL

WHAT'S UP? *by Bruce Betts*

IN THE SKY

In April, Mercury is low in the West after sunset. On May 9, Mercury transits in front of the Sun. Over several hours, Mercury will appear as a small dot moving across the Sun. The best way to observe it is with a telescope with proper safety filters. You can also find sites that will cover it live online. The last Mercury transit was in 2006, and the next one will be in 2019. Jupiter is the brightest star-like object in the evening sky, appearing in the East and South. Mars reaches opposition (the opposite side of the Earth from the Sun) on May 22, when it will be rising around sunset and setting around sunrise. Saturn rises about an hour after Mars.

RANDOM SPACE FACT

If you were standing on the surface of Mercury when it was at the closest point in its orbit to the Sun, the Sun would appear about three times bigger in diameter than it appears from Earth.

TRIVIA CONTEST

Our September Equinox contest winner is Gill Cooper of Wainfleet All Saints, United Kingdom. Congratulations! **THE QUESTION WAS:** What is the ninth-largest object (in diameter) in our solar system? **THE ANSWER:** Ganymede, moon of Jupiter. The largest objects in our solar system, ranked by size are: the Sun, the seven planets, Ganymede, and then Mercury.

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

Who was the first person to fly on two different orbital spaceflights?

E-mail your answer to *planetaryreport@planetary.org* or mail your answer to *The Planetary Report*, 60 S. Los Robles Ave., Pasadena, CA 91101. 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 May 1, 2016. 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.*

SOCIETY TRAVEL

SAN RAFAEL GLACIER, CHILE

EASTER ISLAND

ALASKA

AT TOP *This photo of the total solar eclipse was taken by David Morrison on March 9, 2016 during Betchart's recent Indonesia Total Solar Eclipse Expedition.*

Amazing Eclipse & Aurora Adventures for Our Members!

CHILE ANNULAR ECLIPSE EXPEDITION

FEBRUARY 22 - MARCH 4, 2017
With optional Easter Island extension March 4–7, 2017

ANTARCTICA ANNULAR ECLIPSE EXPEDITION

FEBRUARY 23 - MARCH 9, 2017
Including the Annular Solar Eclipse over southern Argentina!

ALASKA AURORA BOREALIS EXPEDITION

MARCH 2 - 8, 2017
Watch "The Greatest Light Show on Earth!" See the Aurora Borealis dance across the night sky! Take the Alaska Railroad from Talkeetna (past Denali, the highest peak in North America) to Fairbanks, where you'll delight in the Fairbanks Ice Festival!

Join fellow Planetary Society members on these terrific adventures! To learn more, call Betchart Expeditions at 800-252-4910, or visit *betchartexpeditions.com.*

CASEY DREIER *is director of space policy for The Planetary Society.*

Do You Vote For Space?

Make Your Vote Count for the Future of Space Exploration

THERE IS A scientific revolution waiting to happen. We have the technological ability to actively search for life beyond Earth. This discovery would have unknowable but immense significance to chemistry, biology, and philosophy. Even a negative result—not finding life in the most promising locales in our solar system—would be an important discovery with major implications. We can go look. The question is: will we?

We are asking all our members—particularly our members in the United States—to think about this as they select their political representatives this year. Do you desire an increased priority on NASA and other space endeavors? Then consider telling your representatives that you vote for space.

This is all the more important now, in the context of NASA's biggest transition period since the 1970s. Major new human spaceflight hardware is under development, both by NASA and new commercial partners. How we use this hardware, where we choose to go, and when, is a story not yet written. But it will be soon, and I'd rather we be a contributing author and not mere observers.

The search for life isn't the only reason to explore. Knowledge of our solar system's origins and evolution is revealed through the information returned by robotic spacecraft, and future human endeavors to Mars will amplify that knowledge. The extreme climates of sweltering Venus and frozen Mars help us understand changes in Earth's own climate. The very act of space exploration itself reflects the health of our culture, indicating that we are open, curious, and committed to the pursuit of knowledge.

Those we elect to represent us will be critical in carrying NASA through this major transition. We should keep alive the high priority of exploration and the search for life, not just in our own solar system, but in the other solar systems that fill the galaxy.

We must also ensure that space infrastructure here on Earth—like the Deep Space Network that communicates with our spacecraft, and the Plutonium-238 that powers them—is maintained.

The Planetary Society is the leading independent space organization working to promote space science and exploration. Our achievements of the past few years—record numbers of letters to Congress and the White House, hundreds of millions of additional dollars for NASA planetary science, the start of a mission to explore Europa—were made possible because

Darren Hauck/Getty Images

of you and your fellow members. Our success is your success, and we're just getting started. Growth is our goal, and, as they say, even the sky is not the limit.

The next few years will be critical to defining NASA exploration for the coming decades. And the legacy we leave for the world's future generations is up to us. Will our legacy be the discovery of biology beyond Earth? Humanity's first journey to Mars? Or will we bequeath to them a bitter regret about what could have been, but wasn't?

U.S. and International members can take action here: **planetary.org/vote4space**

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Picardo's Pithy *Planetary Post*

Our newest board member, Robert Picardo, has created the perfect outlet for his passion for space with our new, monthly e-Newsletter, *The Planetary Post*. Did you catch Issues 1 and 2 in your inbox?

You might recognize Bob from his role as the holographic doctor on the TV series, *Star Trek Voyager*. A long-time member of our advisory council, Bob stepped up this past December to join our board of directors. We are excited to add Bob's unique talents to our board, and he wasted no time in putting them to use by working with Creative Director Merc Boyan to create *The Planetary Post* for our members.

Going live around the middle of each month, *The Planetary Post* will feature a video starring Bob and will mix humor and (occasionally) more serious commentary to cover news and events connected with space, planetary science, and The Planetary Society. As a bonus, Bob will give us "Picardo's Pic"—his personal choice of a beautiful, high-resolution space image that members can download and share.

We hope you enjoy *The Planetary Post*. Even better, share it with a friend as a natural extension of The Planetary Society's expanding public outreach and education projects.

Onward,

Richard

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