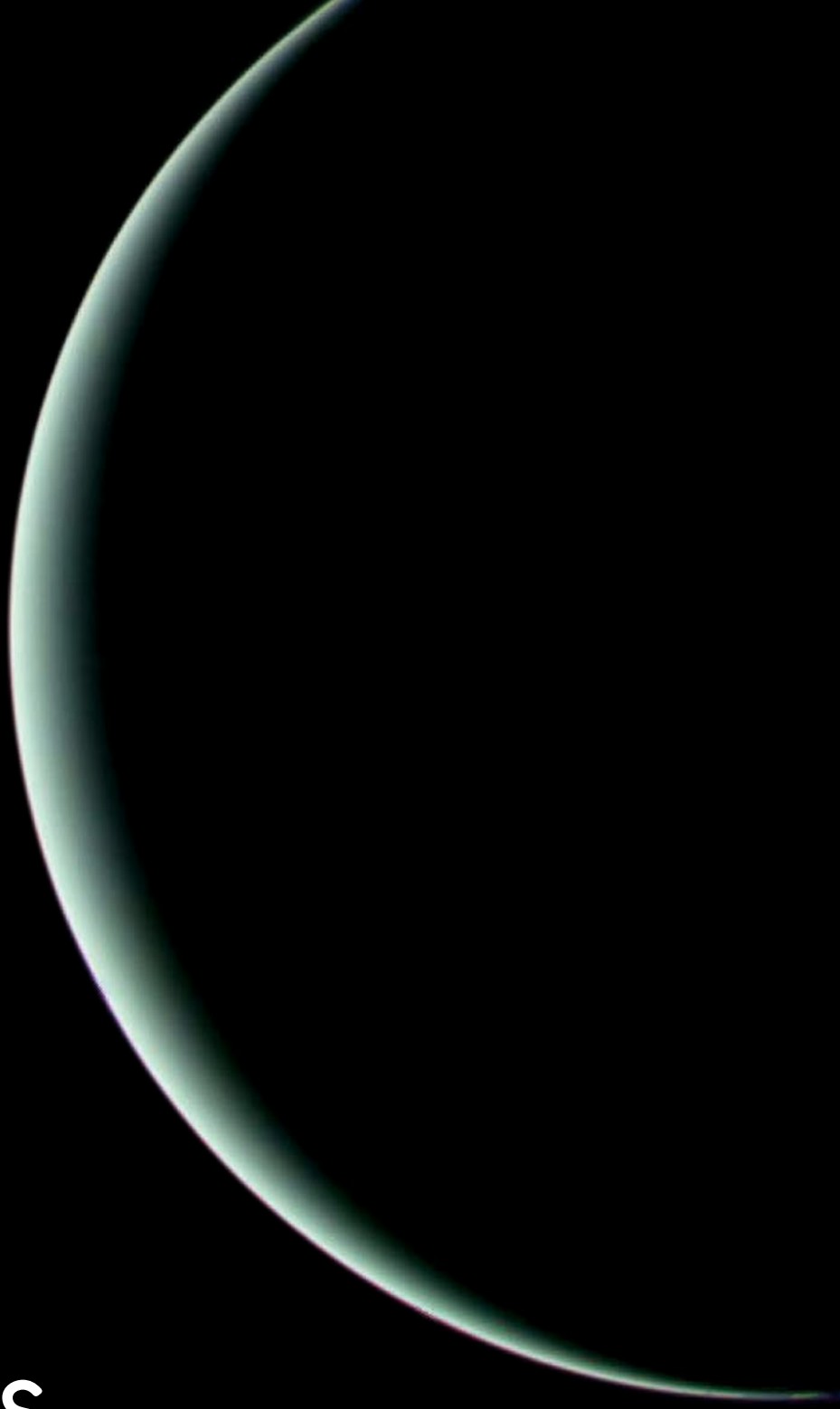
THE PLANETARY SOCIETY

THE PLANETARY REPORT

SEPTEMBER EQUINOX 2022

VOLUME 42, NUMBER 3

planetary.org



THE URANUS ISSUE

WHY THE JOURNEY WILL BE WORTH THE WAIT

AN ENTICING, ENIGMATIC DESTINATION AWAITS US

Why we'll be advocating for a mission to Uranus

by Bill Nye

EVERY 10 YEARS, the planetary science community in the United States works to identify the top exploration priorities for the coming decade. Scientists, engineers, and their organizations produce the Planetary Science Decadal Survey. This report guides NASA's decisions on which missions to fund, and in doing so, it informs many of the decisions made by other national space agencies since international cooperation is such a big part of deep space exploration. At The Planetary Society, the "decadal" is our business.

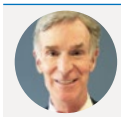
The 2022 decadal set a new destination for planetary exploration: Uranus. It's a mysterious world. Uranus and neighboring Neptune are ice giants, made mostly of materials that were ices at the time of formation. Now those materials, mostly water along with methane and ammonia, exist primarily as high-pressure, high-temperature fluids. Compared to Earth, these planets are huge. Another odd thing from an Earthling's perspective is that Uranus' north pole is sideways in its orbit. It may have wobbled over after an ancient collision. The ice giants have moons, rings, and a tumultuous past. They played a major role in the evolution of the Solar System. Using telescopes on the ground and in orbit, we've peered at these distant worlds, but there are limits to what we can learn from afar. Only one mission — Voyager 2 — has ever been out there to have a look at the ice giants up close. It flew past both in the late 1980s, not long after the Society was founded. The time has come to pay another visit to this remote part of the Solar System.

At The Planetary Society, we study the decadal survey carefully so as to guide our advocacy work to the best effect. With your help, we work to ensure that lawmakers allocate the funding that these missions need.

As a Planetary Society member, you have a key role in making sure that the planetary science community's advice is heeded by your local government. This issue of The Planetary Report will catch you up on what we've already learned about Uranus, what NASA hopes to do with the new mission to study it, and what it all means to us humans. As my grandmother always said, "An informed advocate is an effective advocate." Actually, I never heard her say that, but we at the Society say it all the time.

Watch this space because when the time comes, we'll rally members like you to make sure this mission to Uranus gets funded from the start to its launch and all the way along its 2.7-billion-kilometer (about 1.7-billion-mile) journey. The more we learn about the ice giants, the more we learn about the Cosmos and our own place in space.

Onward, Bill Nye



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

ON THE COVER: NASA's Voyager 2 spacecraft took this haunting crescent image of Uranus on Jan. 25, 1986 as it left the planet to explore Neptune. The planet's greenish glow comes from a tiny amount of methane in its atmosphere. *Image: NASA/JPL* ✳ The Planetary Report (ISSN 0736-3680) is published quarterly at the editorial offices of The Planetary Society, 60 South Los Robles Avenue, Pasadena, CA 91101-2016, 626-793-5100. It is available to members of The Planetary Society. Annual dues are $50 (U.S. dollars) for members in the United States as well as in Canada and other countries. Printed in the USA. Third-class postage at Pasadena, California and at an additional mailing office. Canada Post Agreement Number 87424. ✳ Viewpoints expressed in articles and editorials are those of the authors and do not necessarily represent positions of The Planetary Society, its officers, or its advisers.

CONTACT US: The Planetary Society, 60 South Los Robles Avenue, Pasadena, CA 91101-2016; General calls: 626-793-5100; Email: *tps@planetary.org*; Internet: *planetary.org*; *Editors* **RAE PAOLETTA** *and* **DANIELLE GUNN**; *Contributing Editor* **KATE HOWELLS**; *Science Editor* **BRUCE BETTS**; *Technical Editor* **JAMES D. BURKE**; *Copy Editor* **NICOLE YUGOVICH**; *Art Director* **LOREN A. ROBERTS for HEARKEN CREATIVE**; *Creative Services* **ANDREW PAULY**

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NASA/CXO/UNIVERSITY COLLEGE LONDON/W. DUNN ET AL.; OPTICAL: W.M. KECK OBSERVATORY

A ROSE BY ANY OTHER NAME...

How a planet got its name

by Kate Howells

THERE'S NO QUESTION that communicating to the public about the planet Uranus would be easier if it had a different name. Most people can't help but giggle when they hear one particular pronunciation of the name (you know the one). But this wasn't always the planet's name, and luckily, there are more dignified ways to pronounce it.

Most of the planets in the Solar System have names that go back thousands of years. Mercury, Venus, Mars, Jupiter, and Saturn are all visible to the naked eye, so they were given names by cultures all around the world. It wasn't until 1781 that astronomer Sir William Herschel discovered Uranus when looking for comets using a telescope. A very novel opportunity arose: naming a planet.

Herschel, a devoted subject of England's King George III, suggested that the new planet be named Georgium Sidus, or George's Star. This went against the naming convention that had developed in the Western world, in which planets were named after Roman deities. It was also less appealing to astronomers outside Great Britain for obvious reasons. Several alternative names were tossed around, including Herschel (after its discoverer) and Neptune. German astronomer Johann Elert Bode, whose observations helped establish the new object as a planet, suggested another possibility: Uranus.

Bode's suggestion became the most popular, and chemist Martin Klaproth even named his newly discovered element "uranium" in a show of support. Although astronomers in England continued to use Georgium Sidus until around 1850, they eventually joined the rest of the world in calling the seventh planet Uranus.

Although Uranus was a more suitable name for a planet than George, it was still an odd choice in retrospect. The existing planet names reference the Roman gods, but Uranus is a variation on the name of the Greek god Ouranos. Greek and Roman mythology share many of the same characters — just given different names — and the Roman version of Ouranos is called Caelus. Bode must have preferred the sound of Ouranos because he chose a Latinized version of the Greek name rather than the Roman name itself. Ouranos became Uranus, and the planet was officially named.

Bode probably didn't anticipate that his decision would cause headaches for scientists and science communicators more than a hundred years later. In most languages, it's not really an issue. In English, however, the popular pronunciation "your-AY-nuss" provides all-too-fertile ground for jokes and tends to distract from the majesty and dignity of the planet itself. But there is a common alternative: "YOOR-un-us." This is how you'll typically hear it pronounced by scientists, and it's the pronunciation that NASA officially endorses.

Since both pronunciations are deviations from the original Greek "OOH-ran-ohs," neither is more technically correct than the other. But as we look forward to the coming years of reporting on and advocating for the exploration of Uranus, we'll opt for "YOOR-un-us" and do our best to keep this fascinating world from becoming the butt of the joke.

KATE HOWELLS *is communications strategy and Canadian space policy adviser for The Planetary Society.*

ABOVE *This is a portrait of Johann Elert Bode, the German astronomer who first suggested the name Uranus.*

IN THE PUBLIC DOMAIN

OPPOSITE *Caroline Herschel takes notes as her brother William Herschel observes the sky on March 13, 1781, the night William discovered Uranus.*

IN THE PUBLIC DOMAIN

CHOOSING PLANETARY PRIORITIES

WHEN A MISSION to Uranus was selected as a top priority by the U.S. Planetary Science Decadal Survey, we conducted our own survey to ask our members what they thought about this news. Here is a selection of their responses.

I want to learn more about the rings of Uranus. There is much to be learned about planetary rings, and Uranus will be a comparison with all the other ringed planets. This will be a highlight of my life, and I hope I live long enough to see it. David Ogilvie, USA

There has been so little exploration of Uranus and Neptune that any missions to either of them are golden opportunities. I'd like to learn more about Uranus' moons, in large part because I'll confess near ignorance about them. Is there a potential for life on any of them? Or could we learn more about how the other planets of our Solar System were created through studying more into that frozen world? Seán Kane, USA

Excited: The ice giants have been overlooked in favour of the more impressive gas giants or the distant Plutoids, so I'm very eager to see what's found by exploration to them. Karen McLean, New Zealand

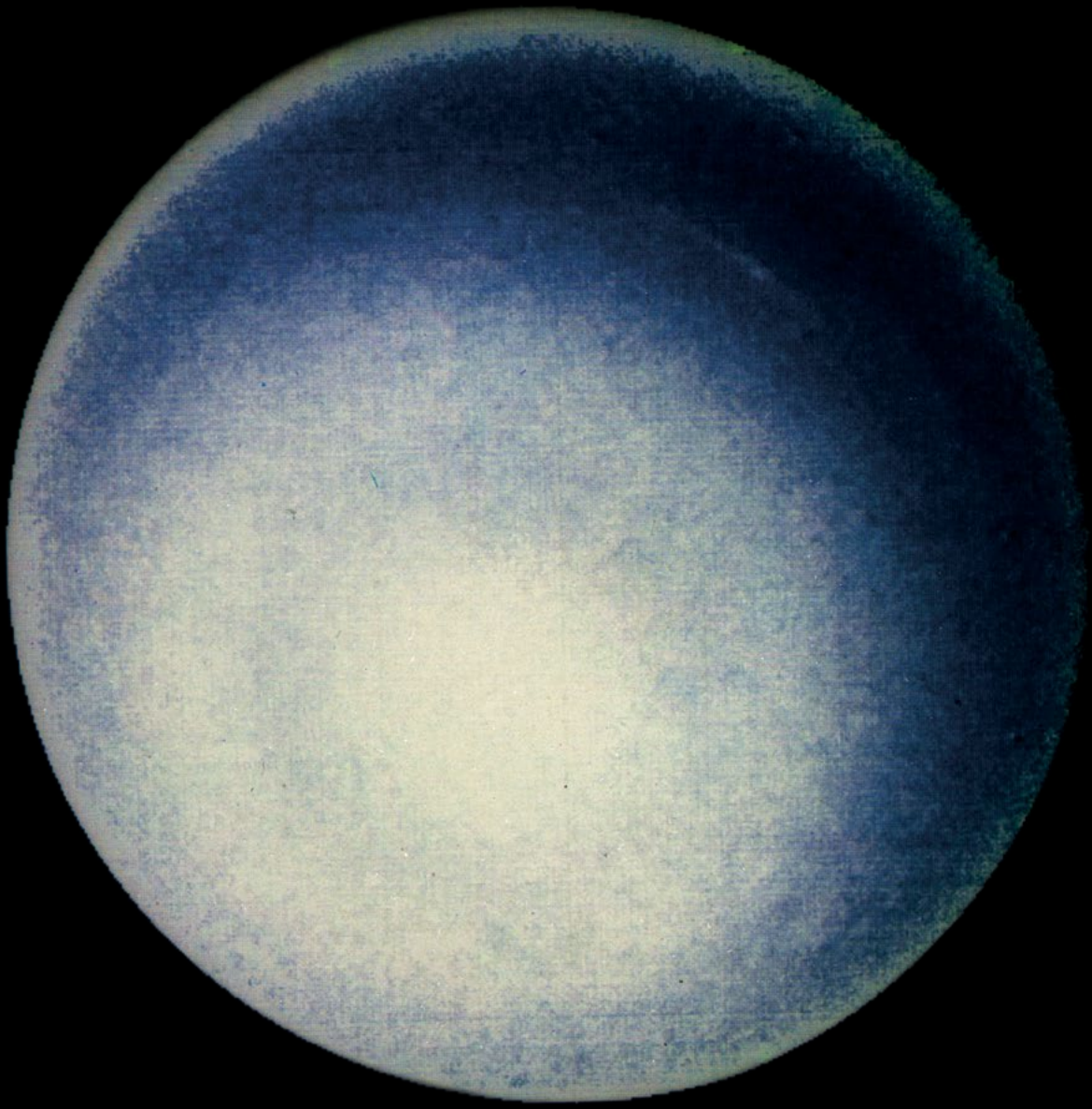
I'm stoked! Studying one of our own ice giants will allow for leaps and bounds in exoplanetary science, and Uranus' moon system is intriguing. Who knows, maybe Titania too has subsurface oceans. Ollie, United Kingdom

As an undergrad in geology with dreams of planetary science, I am very excited about the recommendation of a flagship mission to an ice giant planet. There's a lot left to learn about Mars or Jupiter, but there's even more to learn about the ice giants. I'm hoping very much that we learn more about what causes the strange tilt in Uranus' magnetic field and more about its rings. MJ, USA

Ever since Voyager 2 passed Uranus, I've wanted to know more about its moon Miranda. Its terrain is so unusual and varied, I can't help but be intrigued. How did it get that way? I'm excited that a return to Uranus is now a priority and hope to see what we might find. Myron Chaplin, USA

I have long been fascinated with Uranus. I'm old enough to remember when we knew it as little more than a bright point in the sky. Then Voyager brought Uranus to life. It showed us what a strange and intriguing planetary system it is, and my curiosity only grew. Hubble has enabled us to continue observing and learning more about Uranus, but we have reached the limit of what we can learn from so far away. The Galileo mission to Jupiter and the Cassini mission to Saturn have demonstrated that with a relatively modest investment (relative to other things we invest in as a society), we can build outer planet orbiters capable of generating decades worth of scientific discoveries that both inspire and expand our knowledge of the universe. Why wouldn't we want to send an orbiter to Uranus? We know how to do this. We know it pays off. All it takes is for us to make the commitment. Jonathan Sullivan, USA

This is a fantastic decision! With the only spacecraft to visit Uranus being Voyager 2, we definitely need more exploration of the ice giants that we still know so little about. Liz Davison, USA



ABOVE *This computer enhancement of a Voyager 2 image emphasizes the high-level haze in Uranus' upper atmosphere. Clouds are obscured by the overlying atmosphere.*
NASA/JPL/USGS

Patience for Uranus

by Jason Davis

LEFT *Voyager 2 saw Uranus as a near-featureless gray-green orb when it flew past the planet in 1986.*
NASA/JPL-CALTECH

We've only visited Uranus once.

NASA's Voyager 2 spacecraft made humanity's lone visit on Jan. 24, 1986. During a six-hour period, the spacecraft captured our only up-close images of Uranus, its rings, and its large moons.

In the following 3 1/2 decades, scientists have scrutinized every scrap of data returned by Voyager's science instruments. They've also learned new things about our seventh planet using ground-based telescopes, the Hubble Space Telescope, and soon the James Webb Space Telescope (JWST). But they can only figure out so much without going back for a second up-close look.

"We've been saying for a couple of decades that getting back to the ice giants is really important scientifically," said Heidi Hammel, vice president of science for the Association of Universities for Research in Astronomy and vice president of the board of directors of The Planetary Society.

She and her colleagues may soon get their wish. A new report by the National Academy of Sciences says a Uranus orbiter and probe should be the top priority for NASA's next large-scale mission, known as a flagship. The mission could launch as soon as 2031 and would provide a comprehensive look at the entire Uranus system, from the planet's atmosphere to its exotic mantle to its diverse rings and moons.

RIGHT *Uranus has a dainty ring system. It is best seen in a wavelength of infrared light that is strongly absorbed by atmospheric methane. The methane absorption makes Uranus' atmosphere dark, so the rings and high-altitude storm clouds appear comparatively bright as in these images from the Keck Telescope.*
LAWRENCE SROMOVSKY, UNIVERSITY OF WISCONSIN-MADISON/W.W. KECK OBSERVATORY

It's an exciting prospect. But Uranus demands patience for those who study it. First, NASA must ensure two existing flagship missions, the Europa Clipper and the Mars Sample Return program, are solidly on their way to the launch pad. Depending on the positions of the planets and the available rockets at launch time, it would take a minimum of 11 years for a spacecraft to travel to Uranus. Throw in some delays typical of large-scale space projects, and you're looking at an arrival time of more than 20 years from now in the mid- to late 2040s.

Scientists supporting the mission know what they're getting into.

"I tell folks, 'This isn't going to be my mission,'" said Amy Simon, a senior scientist for planetary atmospheres research at NASA's Goddard Space Flight Center. "Just the time scales involved — I'll be the wizened elder at that point, which is fine. It's a mission for the next generation."

Richard Cartwright, a research scientist at the SETI Institute who studies icy moons, is part of that generation. But he knows much of his career will be behind him before he sees new images of Uranus' moons.

"I will be a late-career scientist at that point, as will all the other current early career scientists and engineers who are working to make this mission happen," he said.

It will be an even newer generation, then, that gets to enjoy the spoils from a Uranus mission.

"I think the future generation of planetary scientists who are currently in elementary through high school or are undergraduates are the ones who will do most of the heavy lifting when it comes to the analysis of data collected by a Uranus orbiter and probe," said Cartwright.

Twenty years is a long time to wait for a new mission to arrive at Uranus. But it will be worth it when the first images and data arrive from the outer reaches of the Solar System, giving us new insights into the planet's atmosphere, rings, and more.

VOYAGER 2 BEEFS UP URANUS EXPLORATION

Just as a new Uranus mission will shape careers, so did Voyager 2 during its long tour of the outer planets in the 1970s and '80s.

Hammel was an undergrad at the Massachusetts Institute of Technology in 1981 when Voyager 2 flew past Saturn. Some enterprising students tapped into a NASA feed so they could watch the Saturn encounter from their dorm room. Hammel recalls watching in excitement with her planetary science classmates and their professor.

After images of Saturn's twisted, braided F ring appeared, her astonished professor told his students that such ring twists should be impossible.

"That made a huge impression on me," she said. "That's the power of exploration."

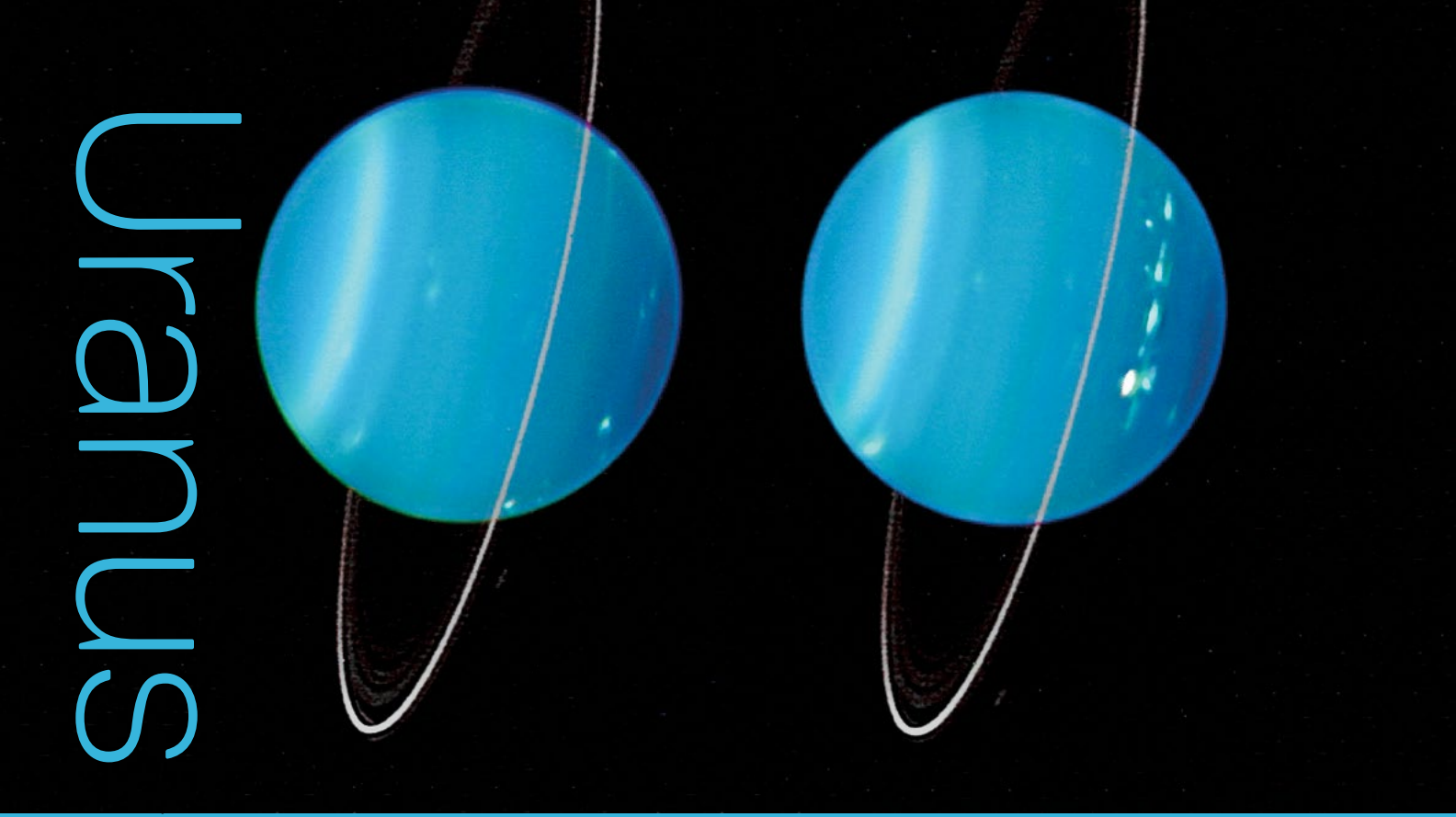
By the time Voyager 2 closed in on Uranus in 1986, Hammel was hard at work on her Ph.D. thesis, which was a study of the planet and its fraternal twin Neptune using ground-based telescopes. Her adviser arranged for her to watch the Uranus encounter from NASA's Jet Propulsion Laboratory in Pasadena, California. Her job was mostly bringing scientists coffee and computer printouts, but it was worth it to be so close to the action.

"I was just a kid in a candy store with my nose pressed to the window, watching the scientists do the work," she said.

Voyager 2 skimmed the planet's cloud tops on January 24 at a distance of 81,600 kilometers (50,700 miles). Images revealed a pale green orb seemingly devoid of features and storms. The planet's magnetic field was knocked 55 degrees off axis, hinting at some strange dynamics below the atmosphere.

Because of the sideways tilt of Uranus and its rings, Voyager 2 approached the system like a dart toward a dartboard, forcing scientists to choose just one moon for a close flyby: Miranda. The small world, which is just 500 kilometers (310 miles) wide, was revealed to be scarred

Uranus



1781 Astronomer William Herschel discovered Uranus, the seventh planet from the Sun and the last to be discovered in our Solar System.

1977 Voyager 2 launched.

1986 Voyager 2 arrived at Uranus. The spacecraft came within 81,500 kilometers (50,600 miles) of the planet's cloud tops.

1997 NASA's Hubble Space Telescope detected distinct cloud formations on Uranus.

2014 Cassini took its first photo of Uranus – a pale blue dot seen through Saturn's rings.

2022 The Planetary Science Decadal Survey puts high priority on sending a new orbiter and probe to Uranus.

2031/2032 Best-case scenario for launching a Uranus probe, arriving at the ice giant 12 or 13 years later.

-195°C (-320°F)

AVERAGE TEMPERATURE, WHERE ATMOSPHERIC PRESSURE EQUALS SEA LEVEL ON EARTH

19x

FARTHER FROM THE SUN THAN EARTH

30,687 Earth days

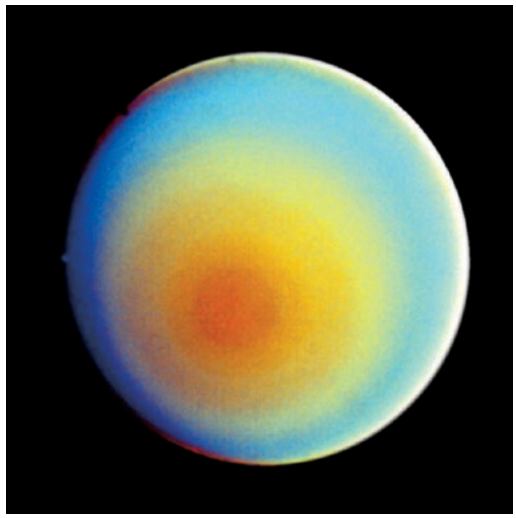
URANUS SOLAR YEAR

Oberon & Titania

MAY BE WARMED ENOUGH BY GRAVITATIONAL TUGS FROM URANUS AND OTHER MOONS TO CREATE LIQUID WATER BENEATH THEIR SURFACES

ATMOSPHERE

83%	15%	2%
HYDROGEN	**HELIUM**	**METHANE AND OTHER**



RIGHT *These two pictures of Uranus — one in true color (left) and the other in false color (right) — were compiled from images returned on Jan. 17, 1986 by the narrow-angle camera of Voyager 2. The spacecraft was 9.1 million kilometers (5.7 million miles) from the planet, several days from the closest approach. The picture at left has been processed to show Uranus as human eyes would see it from the vantage point of the spacecraft. The picture at right uses false color and extreme contrast enhancement to bring out subtle details in the polar region of Uranus.* NASA/JPL

with divots and grooves and possibly the Solar System's tallest cliff. The spacecraft also captured images of the planet's other large moons, albeit from a distance. It also discovered 10 new moons and two new rings.

By the time Voyager 2 arrived at Neptune in 1989, Hammel had joined the mission's imaging science team and was an expert on ice giants — medium-size worlds smaller than Jupiter that have a high concentration of icy materials. The Voyager mission helped launch her career, and she would continue to study Uranus and Neptune from afar using Hubble and ground-based telescopes.

THE LONG ROAD BACK TO URANUS

The road back to Uranus is paved with a complicated mix of science and politics.

Every 10 years, the National Academy of Sciences enlists committees of top planetary scientists to help create a report outlining the community's top science questions along with a prioritized list of missions to answer them. These reports are known as a decadal survey. They are used by NASA, the White House, and Congress during the budget-making process to decide which missions to fund next.

Getting a mission to Uranus or Neptune on the community's radar has been a challenge for scientists who study ice giants. In recent decades, NASA has been focused on the search for life. A flagship Uranus mission made it into the 2013 decadal survey, but it was prioritized behind Europa Clipper and Mars Sample Return.

Those missions are now under development, clearing the way for a Uranus mission to top the flagship list in the 2023 decadal survey, released in April 2022. The survey recommends starting formal work on the mission, which could have a price tag of $4.2 billion, as early as 2024.

Interest in Uranus has been bolstered by the discovery of more than 5,000 exoplanets — planets orbiting other stars. A third of these are gaseous worlds the size of Uranus or Neptune. That means studying Uranus or Neptune would give us a huge amount of insight on what is currently the most common type of exoplanet we've discovered.

Simon, the NASA planetary atmospheres expert, said that a Uranus mission designed to study all aspects of the system would reignite interest in the outer planets, which has waned since NASA's Cassini mission to Saturn ended in 2017.

"With the end of Cassini, there's not as much going on in the outer Solar System," she said. "So I think for the community, it's going to be a really good thing to have this mission that touches so many different areas."

BENEATH THE CLOUDS

As the outer planets gobbled up material in the Solar System's early days, Uranus and Neptune's positions farther from the Sun

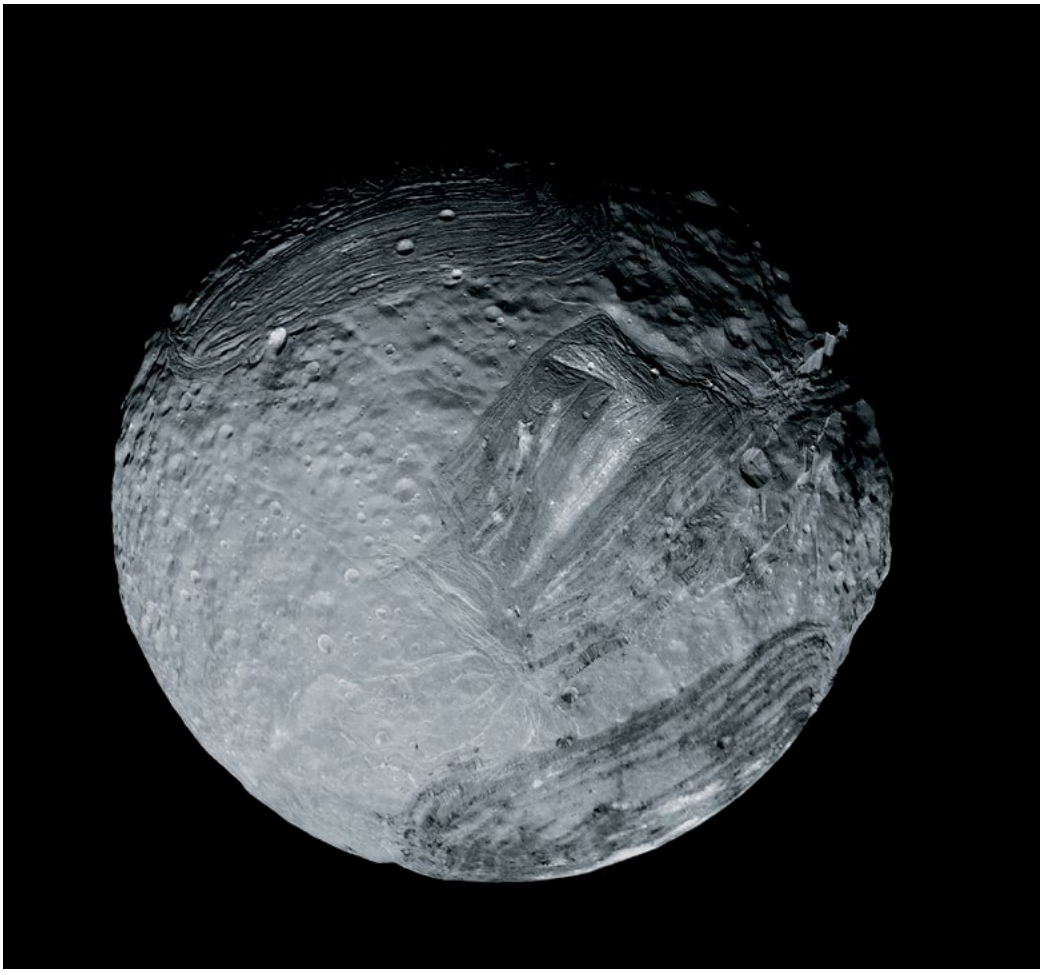
allowed them to take in extra helpings of icy water, ammonia, and methane. The methane in Uranus' atmosphere absorbs red light, giving the planet its blue-green appearance.

A Uranus mission would carry a probe to plunge into the planet's atmosphere and measure its composition, including the specific isotopes of each element. Isotopes, which are variations in the number of neutrons amongst the same element, act like fingerprints that would allow scientists to figure out where Uranus formed and what conditions were like in the Solar System's early days, long before life arose on Earth.

Jupiter and Saturn may have originally formed farther from the Sun than their current locations, while Uranus and Neptune may have formed closer to the Sun. About 4 billion years ago, the giant planets began jostling for position, pushing Uranus and Neptune out to their current locations.

At some point, Uranus ended up on its side. Whereas Earth has a modest 23-degree tilt that gives us our seasons, Uranus' rotation axis is tilted by a huge 98 degrees. Essentially, the planet rolls around the Solar System on its side.

It's not clear what caused this. Gravitational resonances between Uranus and Saturn may have made Uranus wobble until it fell over. Another popular theory is that a giant proto-world slammed into the planet. A new Uranus mission will look for evidence of what happened deep below the planet's icy clouds, where its magnetic field is generated.



LEFT *Voyager 2's images of Miranda were the highest-resolution images of any of Uranus' moons. Voyager 2 spent 17 minutes capturing numerous photos to make this high-resolution portrait.*
NASA/JPL/TED STRYK

Uranus has no crust to stand on; the planet's gaseous atmosphere of mostly hydrogen and helium transitions directly to a mantle composed of water, ammonia, and methane as high-pressure fluids that reach 5,000 degrees Celsius (9,000 degrees Fahrenheit). Deep below the mantle sits what is probably a core of rock and materials like water and methane.

ABOVE *This collage shows the major moons of Uranus to scale. These images were taken on Jan. 24, 1986. The geologic diversity these moons show begs for another mission to explore them thoroughly. Sadly, we have never been back, but that could change now that the newest Planetary Science Decadal Survey recommends a Uranus orbiter and probe mission as one of NASA's next priorities. From left: Titania, Oberon, Umbriel, Ariel, Miranda, and Puck.* NASA/JPL/TED STRYK

As the mantle churns, it creates electrical currents, which in turn generate Uranus' magnetic field. The process is similar to how swirling molten rock makes Earth's magnetic field. But whereas Earth and many other planets have a tidy magnetic field roughly aligned with their north-south axes, Uranus' field is 59 degrees off center and 8,000 kilometers (5,000 miles) from the core. Mapping this field may offer clues as to whether or not an ancient impact knocked over the planet.

Just like on other planets, charged particles from the Sun get caught in Uranus' magnetic field, creating aurorae. But because of the field's tilt, the aurorae pop up in unexpected places, said Henrik Melin, a planetary scientist at the University of Leicester.

"The northern and southern aurorae appear close to the equator, a scenario very unfamiliar to us," he said. "The mechanisms that drive them remain largely unclear."

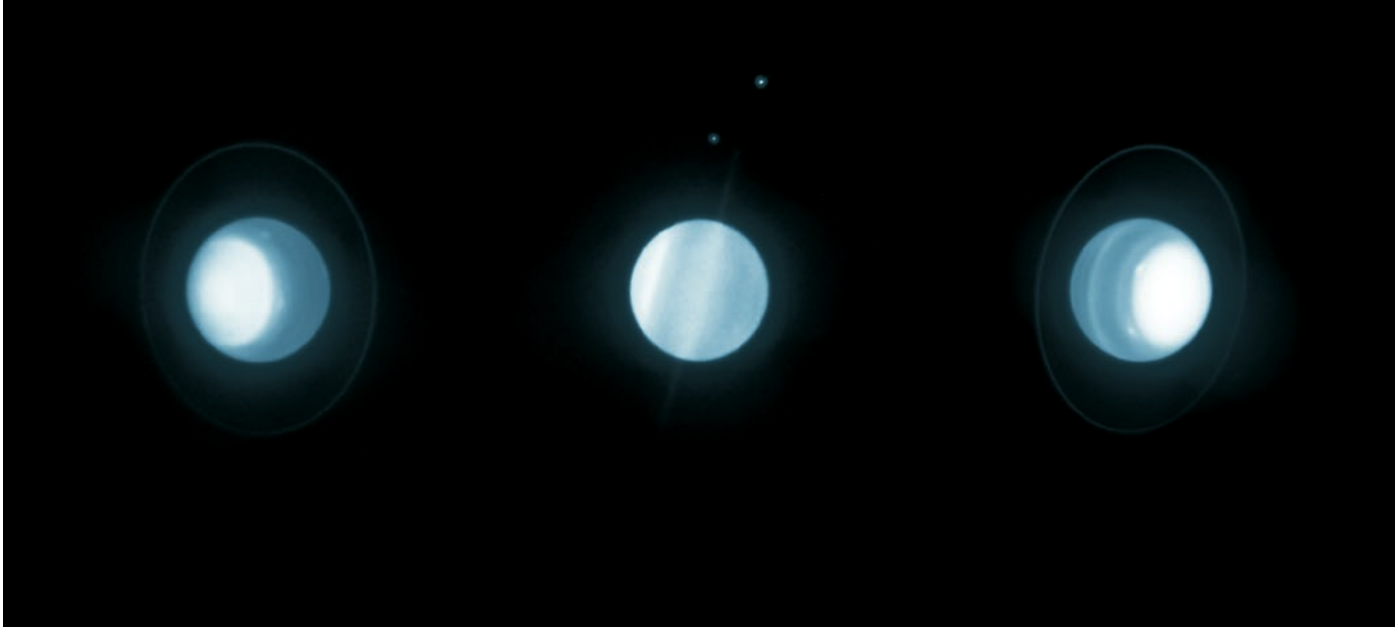
Long before a new mission arrives at Uranus, Melin will use JWST to study the aurorae and characterize the planet's atmosphere. "I fully expect that the new questions that will be raised by the JWST observations will add to the very strong science case that motivates us to visit Uranus with a full-on flagship orbital mission."

RINGS AND MOONS

During its 13-year tour of Saturn, Cassini snapped thousands of images of the planet's enigmatic rings and moons. A Uranus mission would send home similarly astonishing images.

The planet's rings are clumpy, thin, and faint. The innermost rings may be continually raining material onto Uranus. The outermost ring is home to a small moon named Mab, which may be feeding the ring with dust.

As of today, Uranus has 27 known moons; the five largest are Miranda, Ariel, Umbriel,



ABOVE *Three seasons are shown in images of Uranus taken by the Hubble Space Telescope in 1995, 2007, and 2019.*
NASA/ESA/P. KENNETH SEIDELMANN, KATHY RAGES, AND AMY SIMON/OPAL/JUDY SCHMIDT

Oberon, and Titania. Cartwright, the icy moons expert, says that Voyager 2 wasn't equipped with the right tools to study their surface compositions. Like Uranus itself, the spacecraft only saw the moons' Southern Hemispheres when it flew by.

A Uranus mission arriving in the mid-2040s would allow scientists to get a peek at the moons' Northern Hemispheres via close flybys. The fleeting glimpses Voyager 2 got offered some intriguing possibilities, including the possibility that some of the moons leak materials from their interiors onto their surfaces.

Could one or more moons harbor an underground liquid water ocean? Such an ocean would require heat, either left over from the moons' formations or from gravitational squeezing by other moons and Uranus itself. Only a new mission would be able to say for sure.

SEASONAL CHANGES

It takes 84 years for Uranus to orbit the Sun once and progress through its seasons. Because of the planet's extreme tilt, one pole can bathe in sunlight for decades as the other pole languishes in darkness. At other times, Uranus turns broadside to Earth so that its rings nearly disappear into a thin sliver, allowing the whole atmosphere to experience the light of the Sun.

How do these seasons affect Uranus' atmosphere? When Voyager 2 flew by in 1986, the planet was at southern summer solstice, with its south pole fully lit. Very few atmospheric features were visible. But by 2007, Uranus was turned sideways to Earth, and ground-based telescopes saw myriad clouds and storms, hinting at a dynamic, seasonal world.

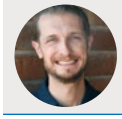
"We saw the polar regions change pretty dramatically and really fast," said Simon.

In 2028, the planet will be at northern summer solstice, with its north pole lit and rings face-on — the opposite view from what Voyager 2 got. Will the atmosphere be quiet once more?

A Uranus mission arriving in the mid-2040s would be able to observe both the planet's north pole and its equator. That's more than 20 years from now, but Melin, who started his career on the Cassini mission and will soon observe with JWST, knows that the payoff from large-scale missions is huge.

That payoff includes studying Uranus' atmosphere, mantle, and magnetic field to determine where it formed and how it got knocked on its side, investigating the planet's moons for signs of oceans leaking onto their surfaces and seeing firsthand how Uranus' atmosphere changes with the planet's seasons.

"Starting out as young planetary scientists, we drink from wells that we did not dig," Melin said. "So, it is my sincere hope that I could be a part of developing this new mission to Uranus, to dig new wells for the future generation of scientists."



JASON DAVIS *is the senior editor for The Planetary Society.*

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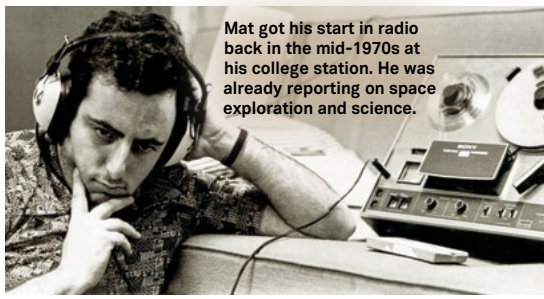
- **Reach: every major podcast streaming platform and more than 100 radio stations around the world**
- **Audience: listeners hail from more than 40 countries**
- **Honors: Planetary Radio is among the top 0.5% most popular shows out of 2.8 million podcasts globally* and is one of Apple's top five space exploration podcasts**
- **Notable guests: Sir Arthur C. Clarke, Ray Bradbury, Buzz Aldrin, Sally Ride, Mae Jemison, Poppy Northcutt, Brian May, Ann Druyan, Jill Tarter, Elon Musk, Neil deGrasse Tyson, and, of course, our CEO, Bill Nye**

Listen for free at planetary.org/radio!

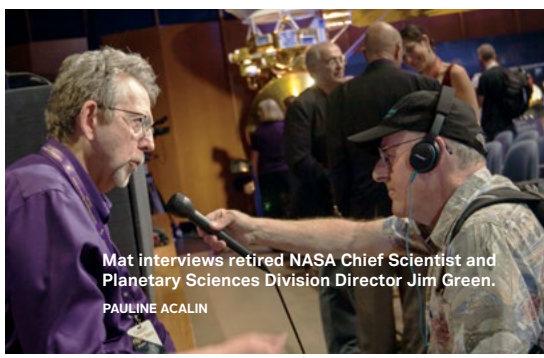
*Source: Listen Notes



Mat got his start in radio back in the mid-1970s at his college station. He was already reporting on space exploration and science.

Mat Kaplan receives the 2022 Mars Horizon award.

Mat interviews Psyche principal investigator Lindy Elkins-Tanton beside the spacecraft in the JPL clean room.



Mat interviews retired NASA Chief Scientist and Planetary Sciences Division Director Jim Green.

PAULINE ACALIN

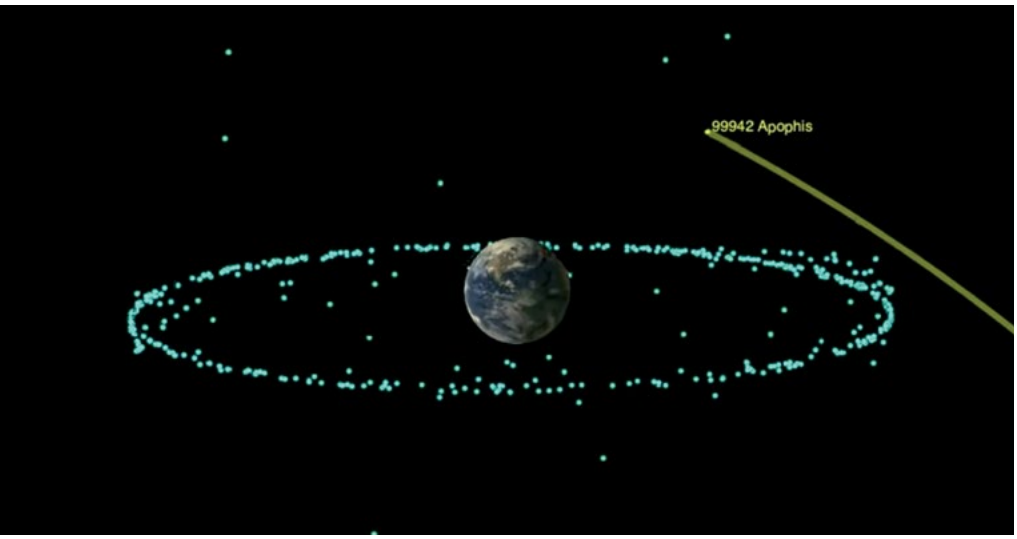
The Planetary Society's podcast and radio show, *Planetary Radio*, is celebrating its 20th anniversary this year. To mark this milestone, take a look [above] at some of the highlights of the program that your membership makes possible.

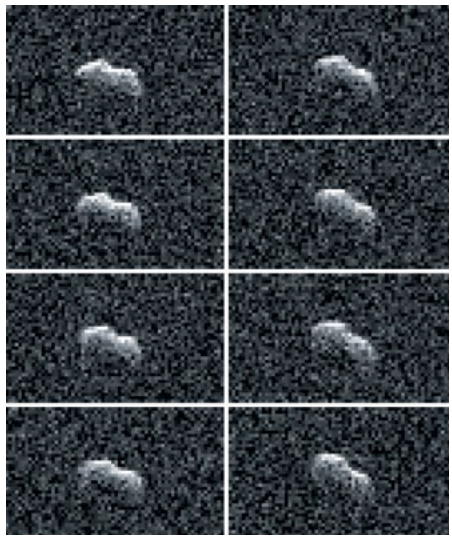
THE HOST WITH THE MOST

Planetary Radio's founding host and producer Mat Kaplan has been at the show's helm since its very beginning. For 20 years, Mat has done it all: conducting research; finding and interviewing guests; traveling to NASA facilities, science conferences, clean rooms, launches, and much more; recording, editing, and producing every episode; and hosting live events (including a recent *Planetary Radio* Live show in London, United Kingdom).

Mat was recently honored with the Mars Horizon award at this year's Humans to Mars Summit in Washington, D.C. This award recognizes his decades of work educating the public about Mars science, exploration, and so much more through his work with *Planetary Radio* as well as his many contributions to the Humans to Mars Summit over the years.

After 20 years of dedicated service to public education about space science and exploration, Mat Kaplan has decided to retire as host later this year. The Planetary Society is truly grateful for the outstanding work he has done over the years and the huge impact he has had on this world. We're also very happy to know that Mat will continue to be an important contributor to our work. *Planetary Radio* will continue with a new host who will be announced in the coming months.





LEFT *This illustration depicts the orbital trajectory of asteroid 99942 Apophis as it zooms safely past Earth on April 13, 2029. Earth's gravity will slightly deflect the trajectory as the 340-meter-wide (1,100-foot-wide) near-Earth object comes within 32,000 kilometers (20,000 miles) of our planet's surface. The blue dots depict geostationary and geosynchronous satellites.*
NASA/JPL-CALTECH

ABOVE RIGHT *On March 21, 2021, the large asteroid 2001 FO32 made a close approach with our planet, passing at a distance of about 2 million kilometers (1.25 million miles), or 5¼ times the distance from Earth to the Moon. While there was no risk of the near-Earth asteroid colliding with Earth since its orbit is very well known, scientists at NASA's Jet Propulsion Laboratory in Southern California took the opportunity to capture these radar images of the asteroid as it tumbled past.*
NASA/JPL-CALTECH AND NSF/AUI/GBO

DEFENDING EARTH

One of The Planetary Society's core enterprises is planetary defense against asteroid impacts. Your support keeps this essential work going strong.

PREPARING FOR ASTEROID APOPHIS

In May, Society leaders participated in an international conference titled "Apophis T-7 Years: Knowledge Opportunities for the Science of Planetary Defense," which dealt with preparations for the close approach of asteroid Apophis in 2029. Chief Communications Officer Danielle Gunn led a presentation about communications best practices to help asteroid researchers better convey their work and its importance to the public and to decision-makers in government. The Planetary Society will continue to contribute to the global effort to make the most of the opportunities the Apophis approach will offer, both for asteroid research and for public education about the asteroid threat.

ASTEROID DAY

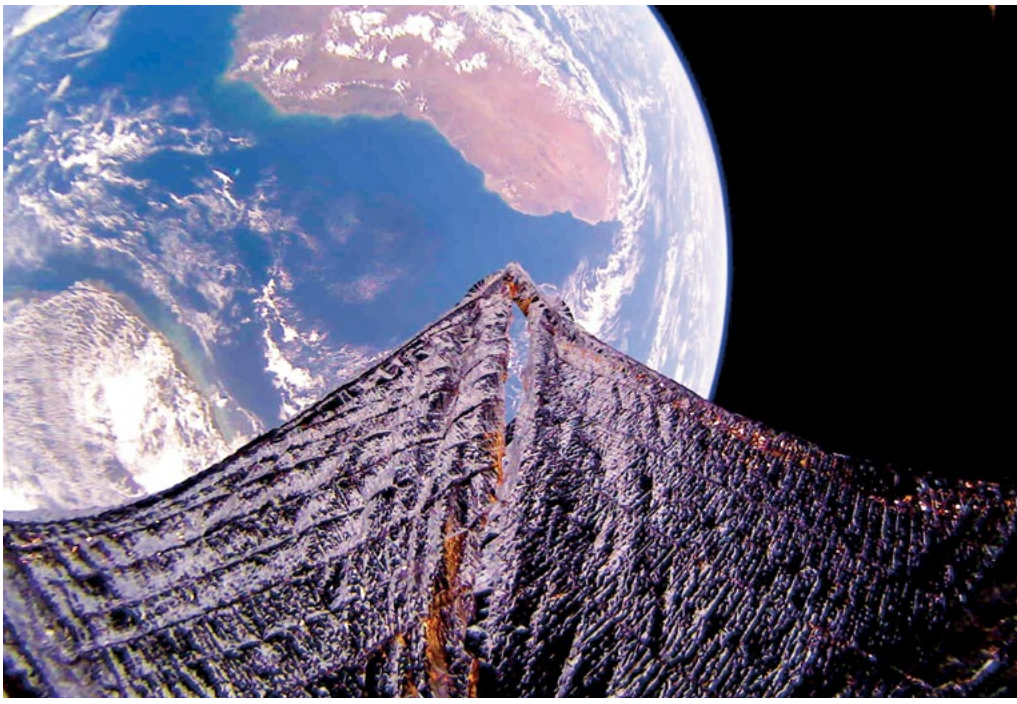
The Planetary Society has long been a partner of Asteroid Day, a global series of events celebrating asteroid research and raising public awareness of the asteroid threat. This year's event involved in-person activities as well as a live-streamed video event for audiences around the world. To celebrate, The Planetary Society hosted a webinar for our members called "Defending Earth! A Planetary Society Planetary Defense Update" with guests Bruce Betts, our chief scientist, and Nancy Chabot, planetary chief scientist at the Johns Hopkins University Applied Physics Laboratory. We also released a new educational video all about planetary defense. Watch it at **planetary.org/asteroid-video**.

FUNDING SUCCESS

In June, our members raised a whopping $80,000 to support further planetary defense work. This will ensure that The Planetary Society can continue our efforts to find, track, characterize, and deflect potentially dangerous near-Earth objects as well as educate the public and government leaders about the importance of investing in planetary defense.

MAINTAINING LEADERSHIP IN SPACE POLICY

The Planetary Society's board of directors and staff came together this year to establish a new set of space policy principles in response to a growing sector of the space industry: commercial spaceflight. This sector involves all companies that engage in space activities for profit as opposed to government bodies. It includes companies like SpaceX that provide launch services and vehicles for NASA and others, businesses like Blue Origin and Virgin Galactic that offer spaceflight experiences for private clients, and many others. The Planetary Society has outlined a set of principles that will guide our engagement to the activities of these companies, focusing on the potential benefits and risks that such activities could yield for scientific exploration of the Cosmos. Learn more at **planetary.org/commercial-principles**. Planetary Society Senior Space Policy Adviser and Chief Advocate Casey Dreier also recently published a paper in the peer-reviewed journal Space Policy titled "An Improved Cost Analysis of the Apollo Program." This in-depth analysis of the total costs of NASA's program to send humans to the Moon provides an invaluable resource for space historians, policy analysts, and those working on current efforts to return humans to the lunar surface. At our upcoming member-exclusive webinar, you can learn more about The Planetary Society's space policy work and how your membership makes it possible. We'll be emailing all our members with details once the date is set, so stay tuned for more information.



THREE YEARS STRONG AND SAILING ON: LIGHTSAIL 2 CELEBRATES ANOTHER ANNIVERSARY

When the LightSail 2 spacecraft launched in 2019, nobody expected that this crowdfunded, low-cost, experimental solar sailing spacecraft would outlive its one-year mission by very much. But here we are three years later, and this marvel of innovation continues to orbit Earth and teach us about the science of solar sailing. And in those three years, LightSail 2 has already had a huge impact on space exploration. NASA is now developing its own solar sailing missions building on what we've learned from LightSail 2. Earlier this year, the public had an unprecedented opportunity to learn about this fascinating method of spacecraft propulsion through the FUTURES exhibition at the Smithsonian Institution in Washington, D.C. To catch up on all things LightSail, check out the video recording of our recent member-exclusive webinar with mission leaders at **planetary.org/ls2anniversary**.

TOP *This image taken by The Planetary Society's LightSail 2 spacecraft on June 11, 2022 shows Madagascar and a portion of Mozambique. North is approximately at top left. A piece of material similar to fishing line called Spectraline that held the spacecraft's solar panels closed prior to sail deployment can be seen in the upper right and upper left.*
THE PLANETARY SOCIETY

BOTTOM *Planetary Society CEO Bill Nye poses with the LightSail display at the Smithsonian Institution's FUTURES exhibition in November 2021.*
JASON DIXSON FOR THE PLANETARY SOCIETY

DEIA at TPS

Over the past two years, The Planetary Society has taken on a course of internal work to improve our diversity, equity, inclusion, and accessibility (DEIA) practices. This summer, we concluded a six-month-long project with a DEIA expert who helped assess the organization as it is now, provided training and guidance, and set out a roadmap for improvement. We are committed to working hard to ensure that everyone is welcome in our organization at every level, from members and supporters to staff, volunteers, and board members. This is ongoing work, and we appreciate the support of our members as we all learn and grow as individuals, a team, and a global community.

To reflect this commitment, we have added inclusion to our organizational core values:

PASSION
We are fervent supporters of space exploration. We deliver our very best in all we do to advance our mission, and we hold ourselves accountable for results.

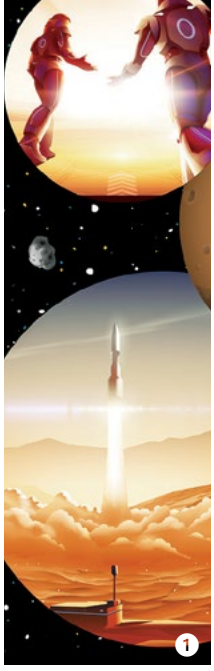
CREDIBILITY
We are an honest broker of information and a trusted steward of resources. Our stakeholders trust us.

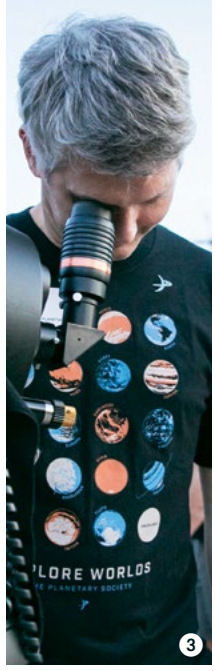
OPTIMISM
We bring a positive outlook and attitude to all that we do. Our work is visionary, solution-seeking, and empowering.

INTEGRITY
We conduct our work in accordance with the highest standards of professional behavior and scientific principles.

EFFECTIVENESS
Our work produces intended results. We know our strengths and how to leverage them.

INCLUSION
Our community is strengthened by its diversity of talents and perspectives. We foster mutual respect and a sense of belonging for all people in our work.



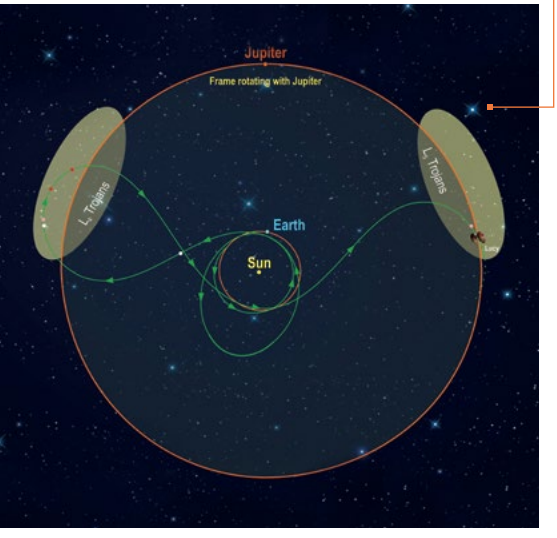


SHARING SPACE IN THE COMMUNITY

With the gradual return of in-person events, The Planetary Society was able to share the passion, beauty, and joy of space with people face to face. In May, Planetary Radio host Mat Kaplan took part in the Humans to Mars Summit in Washington, D.C. ❶, which brought together Mars exploration researchers from around the world to share updates on their work. He then traveled to London, United Kingdom to host a Planetary Radio event with a live public audience. Also in May, Planetary Society leaders participated in AbSciCon, a conference organized by NASA and the American Geophysical Union to bring together the astrobiology community to share research, collaborate, and plan for the future of exploration. We also participated in two major public events this summer, reaching thousands of people and inspiring an interest in space among many of them. In June, we were right near our headquarters in Pasadena, California at AstroFest 2022 ❷, held in conjunction with the 240th meeting of the American Astronomical Society. And in July, we participated in the Astronomy Festival on the National Mall in Washington, D.C. ❸

OUR NEXT BIG STEP

The Planetary Society's STEP (Science and Technology Empowered by the Public) Grant program is once again reviewing a round of pre-proposals. These crowdfunded grants support innovative science and technology projects that will help explore worlds, find life, or defend Earth from impacts. Our first grant winners are already hard at work expanding the frontiers of exploration through two projects: using citizen science contributions in the search for extraterrestrial intelligence (SETI) and developing a new way of studying asteroid physical characteristics using orbit data. The latest round of pre-proposals closed in August, so keep your eyes peeled in the coming months for the announcement of the next round of winners.



MAKE SPACE FOR SPACE!

There's a lot to look forward to in the coming months, especially in October! Here are some highlights.

INTERNATIONAL OBSERVE THE MOON NIGHT OCT. 1, 2022
Join NASA and its global partners in celebrating lunar science, exploration, and observation. Whether you're just stepping outside to gaze up at our planet's natural satellite or are diving into some of NASA's online resources, there are many ways you can join the fun and learn a thing or two about the Moon.

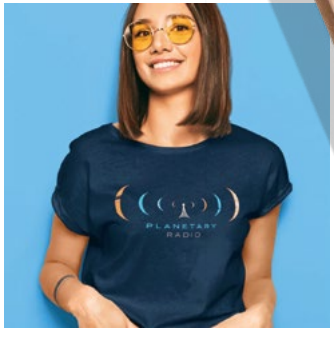
WORLD SPACE WEEK OCT. 4–10, 2022
With the theme of "space and sustainability," this year's World Space Week will include virtual and in-person events with thousands of participants in over 90 countries celebrating sustainability in space and sustainability on Earth thanks to things we do in space.

LUCY EARTH FLYBY OCT. 16, 2022
NASA's Lucy mission is on its way to study the Jupiter Trojan asteroids, but first, it's making a quick swing by Earth. Missions with far-away destinations often have to perform flybys of other planets on their way to either slow down or, in Lucy's case, pick up speed. The spacecraft should snap some great pictures of our home planet on its way past it, so keep an eye out for those!

Learn more about all these events by subscribing to The Planetary Society's weekly email newsletter, the Downlink, at planetary.org/connect.

JASON DIXSON FOR THE PLANETARY SOCIETY

YOUR GUIDE TO THE NIGHT SKY
Want to know what to look for in the night sky? We've got you covered! Check out The Planetary Society's new monthly series of night sky guides, which tell you what you can expect to see throughout the month regardless of where on the planet you live. Each guide is written by our chief scientist, Bruce Betts, who also writes the What's Up section at the end of each issue of this magazine. Find each month's night sky guide as well as lots of other great resources at planetary.org/night-sky.



SHOP TO SUPPORT SPACE EXPLORATION

Your membership already does so much to enable The Planetary Society to do our work advancing space science and exploration, and when you shop with us and our partners, you can do even more! We have some great opportunities for you to get cool space gear that supports our mission.

The Planetary Society offers an online store in partnership with Chop Shop. It's full of exclusive Planetary Society clothing, accessories, stickers, gifts, and more. Explore it all at **planetary.org/store**.

Plus, right now we're partnering with Conscious Step to offer a series of space-themed socks featuring rockets, constellations, and galaxies. Every purchase supports The Planetary Society. Check it out at **consciousstep.com/collections/support-space-exploration**.

And if you know someone who loves space and isn't yet a Planetary Society member, you can always buy them a gift membership. It's a great way to help them level up as a space enthusiast, all while helping to advance our mission. Learn more at **planetary.org/gift**.

LEFT *During a total lunar eclipse, some sunlight still reaches the Moon's surface after bouncing through the edges of Earth's atmosphere. Because our atmosphere scatters blue light, the light that reaches the Moon takes on a reddish hue.*
NASA

LUNAR ECLIPSE, METEORS, AND BRIGHT MARS

IN THE SKY

In September, very bright Jupiter and yellowish Saturn are rising in the east around sunset with reddish Mars rising later in the evening. All rise earlier as the months pass. Mars and Earth grow closer during this period, causing Mars to become brighter than the brightest nighttime star as Mars approaches opposition (the opposite side of Earth from the Sun) on Dec. 8. On Dec. 7, bright Mars will appear less than one lunar diameter from the almost full Moon. A total lunar eclipse occurs Nov. 8, visible from Asia, Australia, the Pacific, and the Americas. The Geminids meteor shower peaks Dec. 13/14. The Geminids are usually the best shower of the year, with 100+ meteors per hour from a dark site, but a gibbous Moon will wash out dimmer meteors this year. For more night sky tips, you can always check out planetary.org/night-sky.

RANDOM SPACE FACT

Uranus' moons are named after characters from the plays of William Shakespeare and Alexander Pope.

TRIVIA CONTEST

Our March equinox contest winner is Karina Parra of El Paso, Texas, USA. Congratulations! The question was: ***What chemical element is named after the Sun, and which is named after the Moon?*** The answer: ***Helium, from the Greek word "helios," meaning "Sun," and selenium, from the Greek word "selene," meaning "Moon."***

Try to win a copy of the new book "Solar System Reference for Teens" by Bruce Betts and a Planetary Radio T-shirt by answering this question: ***Who made the first discovery of a moon of Uranus?***

Email 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 email 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 Dec. 1, 2022. One entry per person. The winner will be chosen in 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.

Please contact Terri or Taunya at Betchart Expeditions for brochures and updated information on COVID and travel. Call 1-800-252-4910 or go to betchartexpeditions.com.

We invite you to join other members of The Planetary Society to discover the world on Betchart Adventures!

HAWAII TOTAL LUNAR ECLIPSE
NOVEMBER 6-14, 2022
See the total lunar eclipse on the Big Island of Hawaii with astronomer Dr. Tyler Nordgren. Also visit Hawaii Volcano National Park and astronomical observatories that explore our Solar System, galaxies, black holes, and more!

ALASKA AURORA BOREALIS
MARCH 16-22, 2023
Discover magnificent Denali and the northern lights in the pristine splendor of Alaska in winter.

BALI AND EAST TIMOR
TOTAL SOLAR ECLIPSE
APRIL 9-23, 2023 or APRIL 14-29, 2023
Enjoy the enchantment of Bali and see the Komodo dragons on Flores. Then, fly to East Timor to see the total solar eclipse.

WESTERN AUSTRALIA
TOTAL SOLAR ECLIPSE
APRIL 13-24, 2023
Delight in the magnificent natural world of Western Australia. Stay on a quarter-million-acre cattle station near Exmouth in glamping tents for the time of your life! Swim with manta rays and whale sharks in the Indian Ocean.

THE PLANETARY SOCIETY
60 SOUTH LOS ROBLES AVENUE
PASADENA CA 91101-2016 USA

Pavel Gabzdyl: View of planet Uranus from a hypothetical cometary nucleus with an extremely thin atmosphere

Planetary Society member Pavel Gabzdyl created this depiction of Uranus as seen from the vantage point of the surface of a passing comet. Gabzdyl chose this angle because it shows Uranus' rings, which are much less noticeable when seen from the side. The artwork also emphasizes the darkness of these far reaches of the Solar System, with only the faintest blue-green coloring visible on the ice giant.

Do you want to see your artwork here? We love to feature our members throughout this magazine. Send your original, space-related artwork to *connect@planetary.org*.