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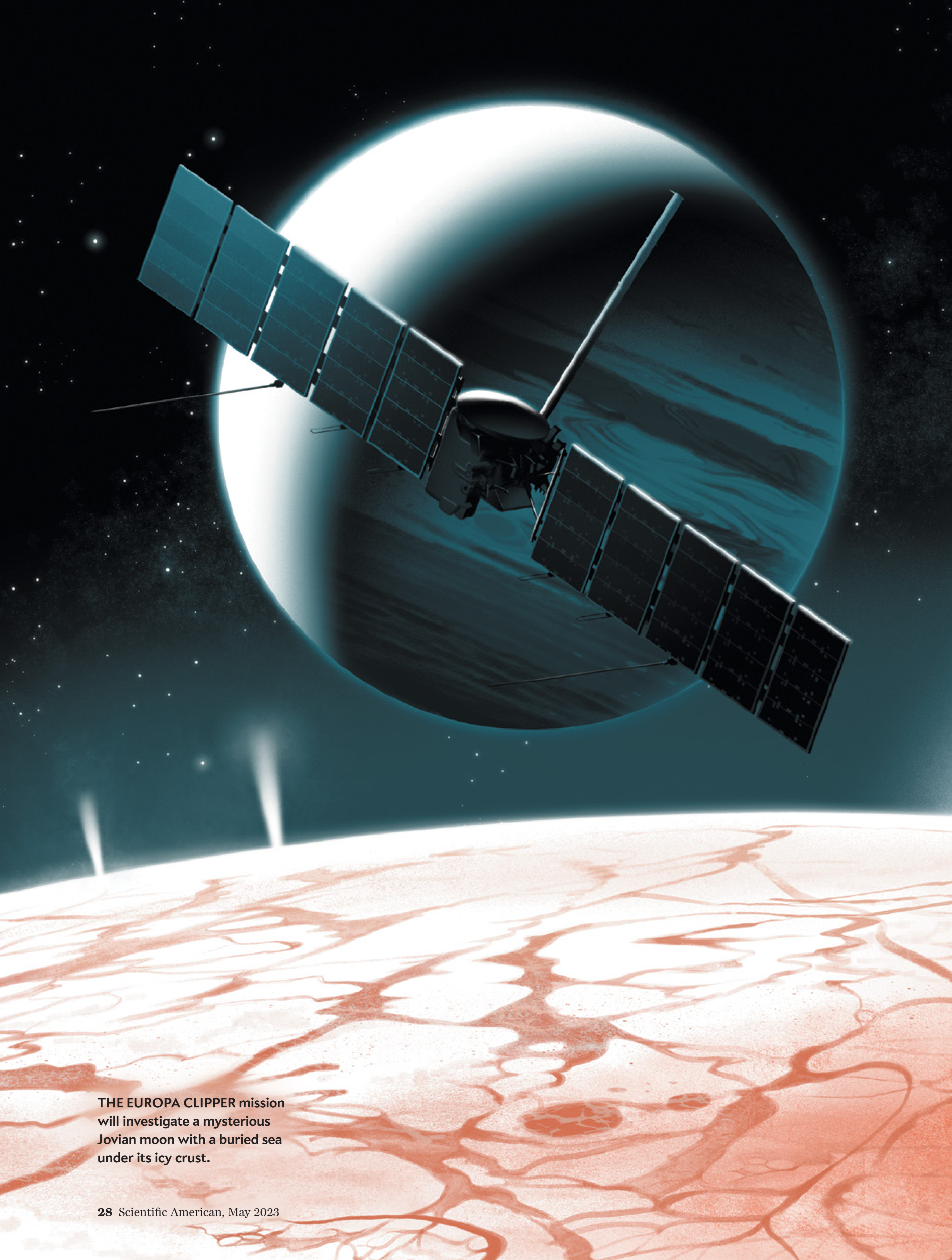
The Weight of Empty Space

Redesigning Living Matter

Understanding Witch Hunts

Destination Jupiter

New missions will explore moons with oceans that could harbor life



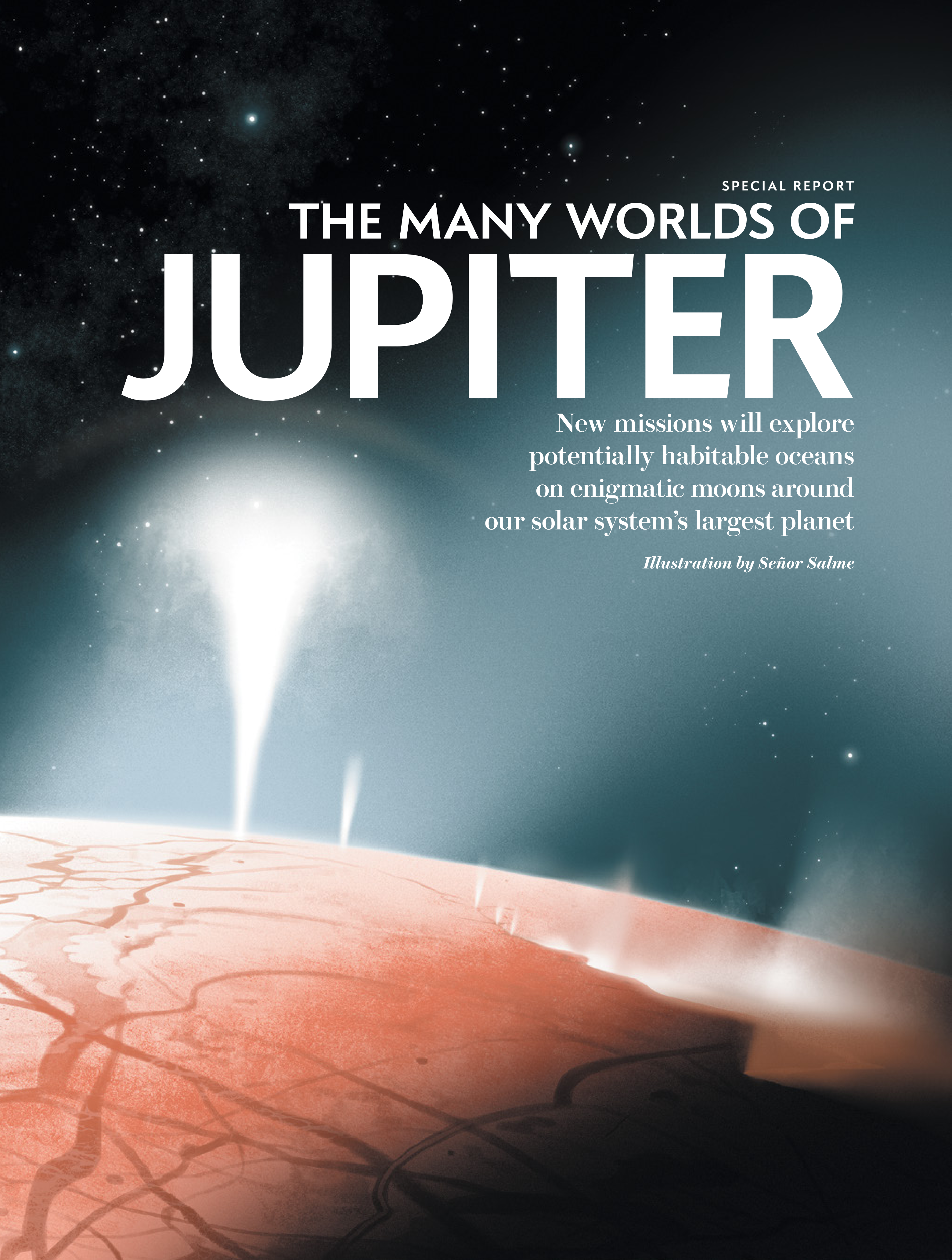
THE EUROPA CLIPPER mission will investigate a mysterious Jovian moon with a buried sea under its icy crust.

SPECIAL REPORT

THE MANY WORLDS OF JUPITER

New missions will explore potentially habitable oceans on enigmatic moons around our solar system's largest planet

Illustration by Señor Salme



PLANETARY SCIENCE

MISSIONS TO THE MOONS

A new European spacecraft is the first of two probes that will hunt for signs of habitability on Jupiter's icy satellites

By Jonathan O'Callaghan

THE MOONS Io and Europa are visible off to the right in this photograph from the Juno mission.

Jonathan O'Callaghan is a freelance journalist covering commercial spaceflight, space exploration and astrophysics.

IF THERE IS LIFE ELSEWHERE IN OUR SOLAR SYSTEM, JUPITER'S LARGE ICY MOONS ARE A PRETTY GOOD bet on where to find it.

Scientists believe vast oceans lurk within them, kept liquid by the jostling from Jupiter's immense gravitational field and protected from the planet's harsh radiation belts by thick ice sheets. "What we've learned on Earth is where you find water, you quite often find life," says Mark Fox-Powell of the Open University in England. "When we look out in the solar system, places that have [liquid] water in the present day are really restricted to Earth and the moons of Jupiter and Saturn." That last planet and its satellites, studied in detail by NASA and the European Space Agency's Cassini-Huygens mission from 2004 to 2017, still hold secrets that scientists will one day probe. For now all eyes are on Jupiter.

A new mission to visit our solar system's largest planet and investigate the habitability of its moons is now set to begin. ESA's JUICE—the Jupiter Icy Moons Explorer—was shipped to French Guiana in South America for its April launch on a European Ariane 5 rocket. The six-ton JUICE spacecraft will take eight years to reach Jupiter, saving fuel along the way by using gravitational assists from Earth, Venus and Mars. On its arrival in July 2031 the solar-powered machine will focus its 10 science instruments on three of the four largest Jovian moons—Europa, Ganymede and Callisto—all thought to harbor subsurface oceans. Ganymede, the solar system's largest moon, will receive most of JUICE's attention. After its initial reconnaissance, the spacecraft will enter orbit there in 2034. "We're trying to characterize what the habitability of Ganymede might be," says Emma Bunce of the University of Leicester in England, part of the JUICE team.

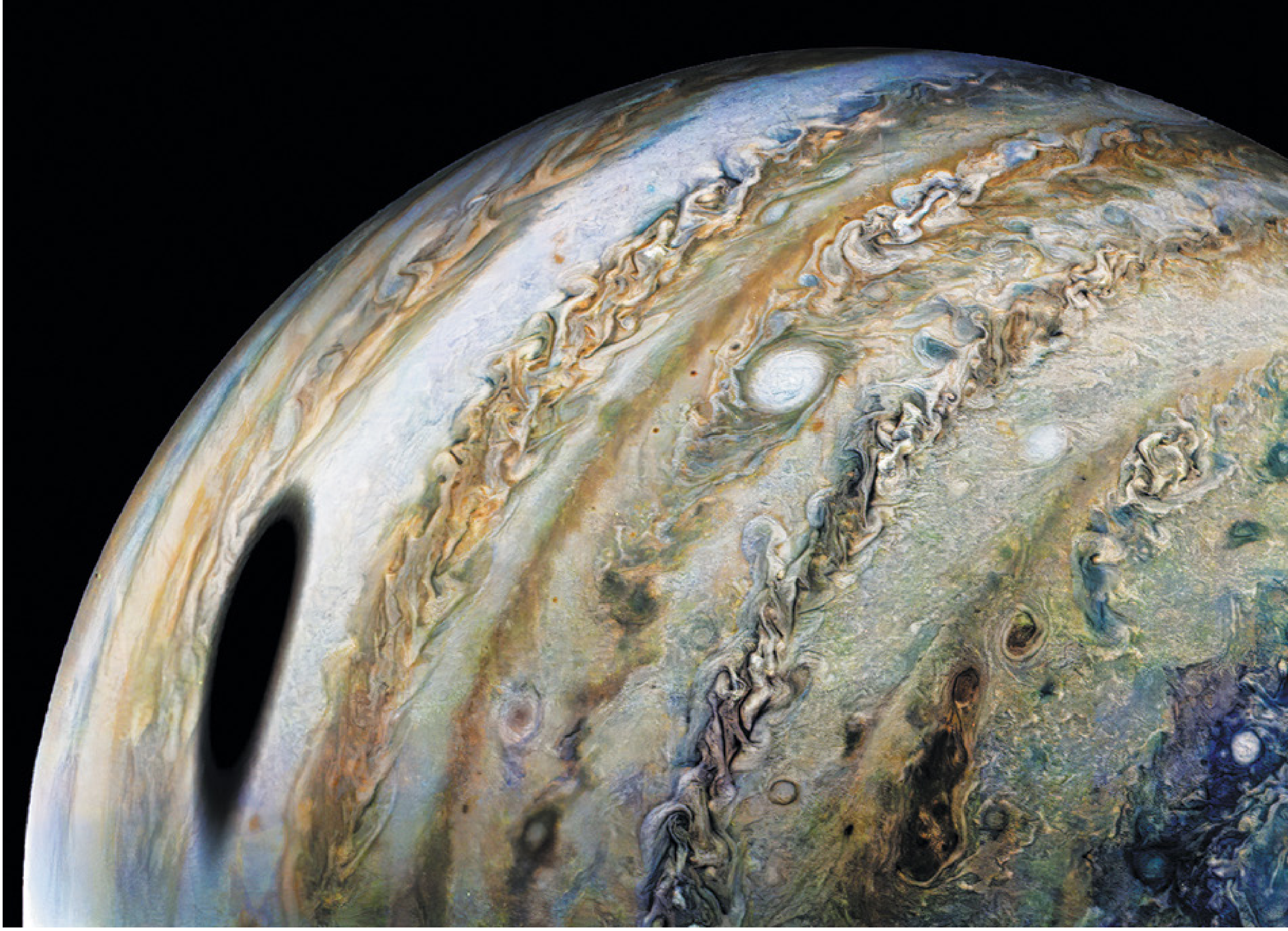
ESA isn't the only space agency with Jupiter in its sights. The concept that would ultimately become JUICE emerged in 2008 as part of the Europa Jupiter System Mission (EJSM), a joint venture with NASA. This collaborative effort called for Europe to build a Ganymede-focused spacecraft, while NASA would construct a probe for Europa. Funding issues in the U.S., however, led NASA to pull the plug on EJSM in the early 2010s, leaving Europe flying solo. "We didn't have the money," says Louise Prockter of the Johns Hopkins University Applied Physics Laboratory, part of the U.S. proposal team. "That killed the Europa part." The situation was disappointing but not wholly unexpected. "These things happen," says Michele Dougherty of Imperial College London, who worked on the European side of EJSM.

Redemption came in 2013, when NASA's efforts to explore Europa received renewed support and funding from Congress. Initially named the Europa Multiple Flyby Mission, the U.S. project eventually became Europa Clipper, after the "clipper" merchant ships of the 19th century. The international collaboration was reborn, mostly. "It's much reduced," Prockter says, although she estimates about 70 percent of the originally planned joint science will still be possible. With these two missions, our knowledge of Jupiter and its moons is set to increase substantially. The spacecraft will tell us whether life could exist in some of these worlds' bewildering subsurface oceans, laying the groundwork for later missions to look directly for evidence of such life, possibly even by diving into the oceans themselves. We can't yet travel to alien worlds around other stars, but Jupiter might offer the next best thing.

THE FIRST MOONS

THE JOVIAN ARENA is often regarded as a miniature solar system because of the complexity and variety of the planet's moons—particularly its four largest, the Galilean moons, named for Italian astronomer Galileo Galilei, who discovered them in 1610. Their identification shook people's understanding of the universe, revealing the first known objects orbiting a body that was not the sun or Earth and thereby validating the Copernican model of the cosmos, which did not have us at its center. Jupiter is now known to have 92 natural satellites. Yet even Galileo might not have appreciated how fascinating his moons would turn out to be 400 years later or how pivotal they might prove in the hunt for life elsewhere in the universe.

The first spacecraft to venture into Jupiter's realm, moons and all, was NASA's Pioneer 10 spacecraft. It flew past the planet in December 1973, providing our first close-up images of the magnificent gas giant. The flyby of NASA's Voyager 1 spacecraft in March 1979 proved even more remarkable. The spacecraft's images of the moon Europa revealed that it had a bright, icy surface devoid of



craters, hinting that some kind of resurfacing process was keeping its crust fresh and unblemished. The best bet was an unseen reservoir of liquid water below the surface, scientists surmised—an enticing option given that on Earth, life follows water.

In December 1995 NASA's Galileo mission became the first to orbit Jupiter, making numerous discoveries—for example, that the planet's third-largest moon, Io, is the most volcanically active world in the solar system. Data that Galileo took at Europa in 1996 found that something was disrupting Jupiter's magnetic field, offering stronger hints of a liquid sloshing under Europa's surface. The best evidence for a liquid ocean on Europa came two decades later, when the Hubble Space Telescope spotted plumes of water escaping from the moon's surface. The Galileo spacecraft orbited Jupiter for eight years, ending in 2003, and was "a fantastic mission," says Olivier Witasse of ESA, the project scientist for JUICE. "We are really going on the shoulders of Galileo."

No other probe would orbit Jupiter until the arrival of NASA's Juno spacecraft in 2016. Juno is still operational today, but it is focused on Jupiter itself, swinging past it in a looping orbit to probe the planet's interior, image its violent storms and monitor its immense magnetic field. The spacecraft has taken some images of Jupiter's moons, but it'll take dedicated missions to really expose their secrets. And that's where JUICE and Clipper come in.

MOON HOPPING AND PLUME SPOTTING

CLIPPER WILL LAUNCH in fall 2024 on a SpaceX Falcon Heavy rocket. Despite its later launch date, its more powerful launch vehicle

THE SHADOW of the moon Ganymede hangs over Jupiter in this image from Juno, with color enhancement by a citizen scientist.

will allow the spacecraft to reach Jupiter more than a year before JUICE, in April 2030. It will not orbit Europa like JUICE will Ganymede, because Europa's proximity to Jupiter places it perilously deep within the planet's radiation belts. Instead Clipper will perform about 50 Europa flybys as it zips around the Jovian system, allowing it to map the moon's interior and work out the extent of its subsurface ocean while also studying other targets. "Putting an orbiter around Europa, because of the radiation environment, means you're only going to survive one to three months before the radiation kills you," says Curt Niebur, Europa Clipper program scientist at NASA Headquarters in Washington, D.C. "We realized instead we could fly by, collect our data and get the heck out of town where the radiation is lower. That way we can last years, not months."

During their overlapping missions, JUICE and Clipper will perform an intricate tango as they hop between Jupiter's attractions, with copious opportunities for collaboration. "To have two spacecraft in the same system will be really fantastic," Witasse says. About 20 scientists from both missions are meeting virtually every week as part of the JUICE-Clipper Steering Committee, with the group formulating ideas for how the two spacecraft might sync up at Jupiter. "We're busy talking through the science opportunities and coming up with a plan" to present to NASA and ESA, says Bunce, who co-chairs the committee with Prockter. Whereas "some of the

IN 2021 JUNO made a close flyby of Ganymede, the solar system's largest moon.

details are a little bit different" from the initial EJSM collaboration, Bunce says, the overall dream remains alive. "The original plan was one mission focused on Ganymede and another mission focused on Europa," she says. "And that's what we've got."

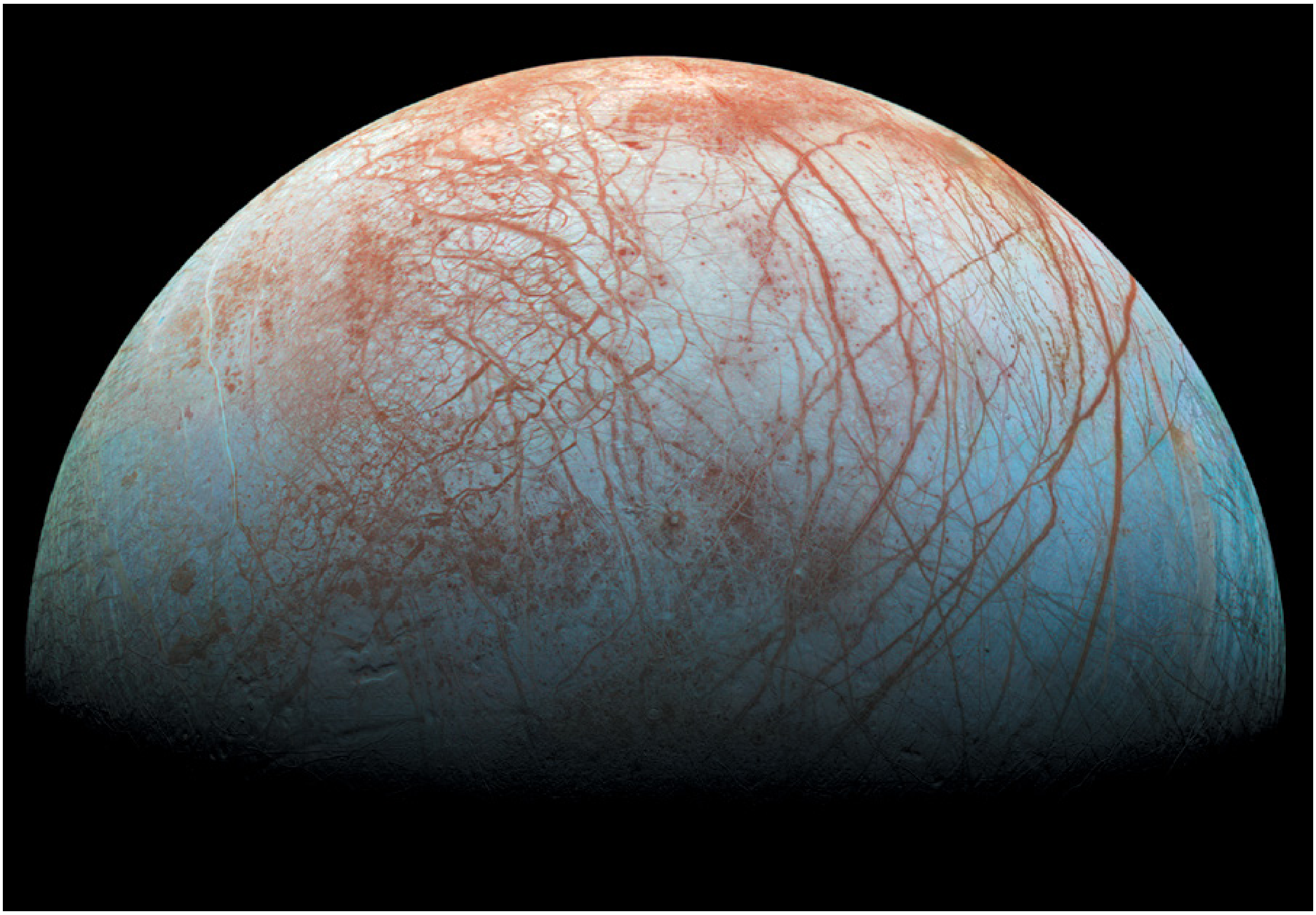
One possibility is that each spacecraft could act as a spotter for the other. JUICE, for example, could keep an eye on Europa from afar as Clipper prepares to swoop past—a valuable partnership, especially if there are indeed plumes of liquid water spouting from cracks in the overlying ice. Peering into these plumes could lead to studying oceanic ejecta that are just "minutes old," Fox-Powell says. "It really gives us an opportunity to study something that's pristine." As Clipper approaches Europa, JUICE could look for plumes erupting from the surface, allowing Clipper to train its eye in that direction. "If JUICE spotted one, that could tell us where to look," Prockter says. Clipper may even fortuitously pass through some plumes, allowing it to directly sample them and look for signs of complex molecules that might hint at signs of life in the Europan ocean.

JUICE will perform two Europa flybys of its own prior to orbiting Ganymede. The one in July 2032 will be just four hours apart from a Clipper flyby. "We can make similar measurements at the same time," Witasse says. That could allow some exciting science to be done, although the exact details have yet to be determined. "We won't fly over the same location, but it will for sure be very interesting," he adds. "We could image similar surface features, or if there is a plume, we can observe it from different geometries."

The joint emphasis on Europa is partially based on scientists' suspicions that the moon's liquid-water ocean is in direct contact with a rocky core. There hydrothermal vents—openings in the seafloor where heat from deeper within can escape—could supply sufficient energy and nutrients to sustain life. "On Earth we have hydrothermal vents where there are whole communities of organisms," Fox-Powell says. "We have good reason to believe that similar kinds of chemical reactions are going on at Europa." Ganymede's much larger bulk, however, means that higher-density ice may have sunk to the bottom of its ocean, forming a vent-blocking barrier. "It could seal the rocky core away," Fox-Powell says. "Europa is not big enough to have that amount of gravity and pressure, so that high-pressure ice doesn't form."

TWO MISSIONS, ONE VISION

NONE OF THIS RULES OUT Ganymede's chances of habitability, nor does it diminish that moon's scientific interest. After entering orbit around Ganymede in December 2034, JUICE will survey the entire surface, study the moon's magnetic field and attempt to map its aquatic inner layers. For an environment to be interesting for potential habitability, it needs "a heat source, liquid water, organic material and stability," Dougherty says. "At [Saturn's moon] Enceladus we know we've got three. At Europa we've got three. And at Ganymede we're trying to find out." Although it will start in a high orbit 5,000 kilometers above Ganymede, during a nine-month period JUICE will lower its altitude to just 200 kilometers over the moon's surface. Eventually, at the mission's end in 2035, the spacecraft will be deliberately crashed into the surface to minimize the chance of any debris contaminating Europa. Ganymede is not thought to have plume activity, but if it does or if its ice crust is found to be particularly thin, this finale may have to be rethought so as not to contaminate Ganymede's liquid ocean, too. "If there is something that indicates a connection with the inner ocean and the



CRACKS AND RIDGES crisscross the surface of Europa in an image assembled from data taken by the Galileo spacecraft.

NASA/JPL-Caltech/SETI Institute

outer surface, we may need to change our orbit," says Giuseppe Sarri of ESA, project manager for JUICE.

Clipper will provide a similar level of knowledge about Europa and its ocean. It is not designed to find definitive evidence of life, however; at best, it will perhaps see the ingredients of life within the moon's plumes. Life detection may come on a later mission, such as NASA's much sought-after Europa Lander. A concept for the mission was drawn up years ago by scientists and engineers at NASA's Jet Propulsion Laboratory in California, but it awaits further funding. "Europa Lander has not been in the president's budget or the budget passed by Congress for a while," Niebur says. A road map for U.S. interplanetary exploration produced by the U.S. National Academies in late 2021, meanwhile, placed a Europa Lander mission as a lower priority for NASA than other projects.

For now the work is archived, ready and waiting to be reborn. "I'm confident that what Europa Clipper will learn will make us want to go back, and a lander of some kind is the logical next step," Niebur says. "But maybe Clipper will throw us a curveball, and a lander is not the right way to go. Maybe we'll want to hover in the plumes instead of landing."

If scientists do want to take a dip in this alien ocean, breaking through the kilometers-thick ice poses its own challenges. One possibility is that a lander could include a heat probe to melt its way through the frozen crust. Last year Paula do Vale Pereira, now at the Florida Institute of Technology, led an experiment to see how long that might take, using a two-meter-high column of cryogenic ice called the Europa Tower to simulate the Europan surface. Presenting her work at the 241st meeting of the American Astronomical Society in Seattle in early January 2023, she found the task might take anywhere between three and 13 years—long times to wait, even for multidecadal missions to the outer solar system.

Besides the ticking of the clock, other obstacles abound. "Figuring out a way to have cables transfer power and information between the lander and the probe is a big, big problem that needs to be solved in the coming years," do Vale Pereira says. The lander would have to carry perhaps several kilometers' worth of cable with it, and the cable would have to be resilient enough to endure water refreezing as ice around it during the probe's descent. The scientific value in solving such problems, however, is tremendous, not least the prospect of placing some kind of machine directly inside an alien ocean.

Such dreams are many years away. Any hope of making them a reality hinges on voyaging to Jupiter and confirming its icy moons are the attractive targets we believe them to be. Beginning with JUICE in April and Clipper next year, we are set to solve some of the most intriguing questions about Jupiter's moons that have long gone unanswered. The Galileo spacecraft "revealed to us that it's worth going back," Niebur says. Now we're doing so with not one but two spacecraft—a transatlantic partnership to significantly advance the search for habitability around our sun. There is no world in our solar system quite like Earth, but perhaps places like Europa and even Ganymede are a close second. If life can survive here, who knows where else it might thrive? SA

Rebecca Boyle is an award-winning freelance journalist in Colorado. Her forthcoming book *Our Moon: How Earth's Celestial Companion Transformed the Planet, Guided Evolution, and Made Us Who We Are* (Random House) will explore Earth's relationship with its satellite throughout history.

Juan Velasco is founder of the award-winning information design studio 5W Infographic (www.5wgraphics.com). He is a former art director of *National Geographic* and the *New York Times*.

PLANETARY SCIENCE

ALIEN OCEANS

Six moons of the outer solar system may hold vast amounts of liquid water and, with it, life

By Rebecca Boyle

Graphics by 5W Infographic

IN 2005 THE CASSINI SPACECRAFT VISITING SATURN FLEW THROUGH something engineers didn't expect—a fine water mist, spraying into space at 1,290 kilometers per hour through cracks in the surface of Saturn's tiny, ice-covered moon Enceladus. Cassini wasn't designed to sample the water, but the discovery inspired scientists to develop new missions to the outer solar system's icy moons. At least six of those worlds—two orbiting Saturn, three orbiting Jupiter and one by Neptune—might host watery oceans, sandwiched between a warm planetary core below and ice crust above.

On Earth, water is required for life "as we know it." Other than the dunes of Mars, where we have searched for half a century, astrobiologists now consider the icy moons of the outer planets some of the best places to look for life in our solar system.

The European Space Agency's Jupiter Icy Moons Explorer, nicknamed JUICE, was scheduled to launch in April toward the gas giant and its moons Europa, Callisto and Ganymede. JUICE and NASA's Europa Clipper mission to Jupiter and Europa, set to launch in 2024, will change our understanding of the outer solar system. The icy moons may rewrite our cosmic perspective, just as they did when astronomers discovered them in the 17th century.

"The outer solar system is probably replete with moons that could have liquid water oceans on them, and a subset could have geothermal and water-rock interactions on the bottom," says Chris German, an oceanographer at the Woods Hole Oceanographic Institution, who is co-leading a NASA-funded initiative called Network for Ocean Worlds (NOW). Why do those characteristics matter? "Everywhere that has those on our planet gets colonized by microbial life," German says.

Life could flourish in half-frozen slush on Europa and Enceladus, within the subsurface saltwater ocean of Ganymede, underneath the methane and ethane rivers of Titan, and maybe in brines in the deepest craters of the dwarf planets Ceres and Pluto. The icy shells of the ocean worlds may even contain pores filled with liquid water—and perhaps microbes, says Mike Malaska, an astrobiologist at NASA's Jet Propulsion Laboratory.

About two and a half kilometers into Greenland's ice sheet, pressure conditions mimic the top of the ice layer on moons like Europa, and microbe concentrations there are comparable to those in a spoonful of yogurt. Chemical interactions or geologic activity could provide energy for these life-forms, much as deep-sea volcanic vents like those German has discovered provide energy for extremophiles on Earth. "Pick your scenario for the origin of life on Earth, and it could have happened on Europa," says Steve Vance, an astrobiologist at JPL. Investigators might readily find organisms by using techniques for studying extreme life on our own planet.

NOW is led by scientists at Woods Hole, the Southwest Research Institute, the Desert Research Institute and Stanford University. It will host its first joint retreat in August, aiming to bring together astrobiologists and oceanographers in the search for biological beings. Co-leader Alison Murray, a microbial ecologist at the Desert Research Institute, first considered life on alien moons while studying a frozen hypersaline Antarctic lake called Lake Vida. She says that having experience in Earth's watery environments is essential to understanding those across the solar system. "We are actually going to go to places where we think life might be existing today," Murray says. "Did life evolve there? Did life *go* there?" To find out, we just need to take a deeper dive.

FROM OUR ARCHIVES

The Galileo Mission. Torrence V. Johnson; December 1995.

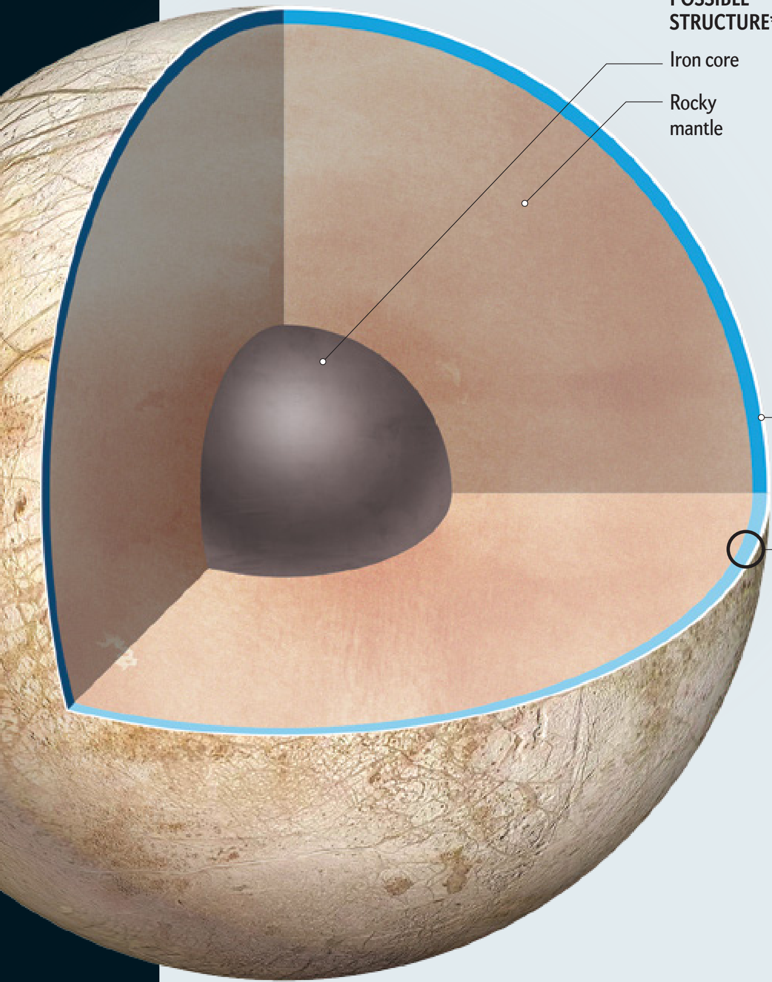
scientificamerican.com/magazine/sa

Europa

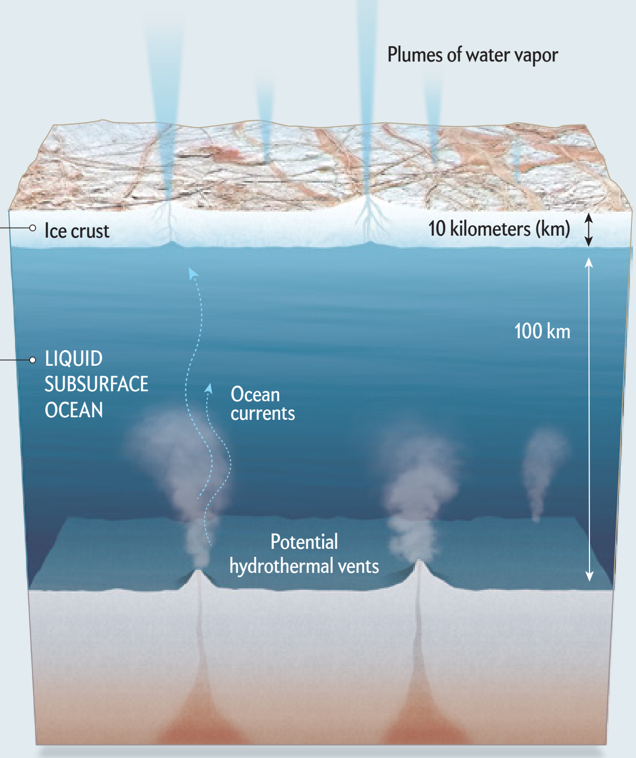
The Galileo spacecraft discovered that Europa might be venting thin plumes of water 160 kilometers into space. It also found that Jupiter's magnetic fields induced a current, indicating salty liquid water was present within the sphere. Europa is the solar system's smoothest object, suggesting its surface is remade by interior processes more frequently than most other worlds besides Earth.

STRONG EVIDENCE OF LIQUID-SALTWATER SUBSURFACE OCEAN

POSSIBLE STRUCTURE*



Blocks of ice may be rafting on top of an ocean slurry. The rocky seafloor may be covered in high-pressure ice-VII, which forms a cubic crystalline structure, unlike the hexagonal water ice on Earth. Ice-VII can efficiently transport salts, so it could support chemical interactions that could energize a web of life.



WHAT WE STILL DON'T KNOW

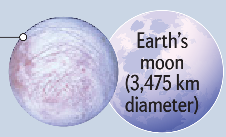
The Hubble Space Telescope saw fleeting evidence of water plumes escaping Europa through cracks in its icy shell. The upcoming Europa Clipper spacecraft has ice-penetrating radar, and its imaging spectrometer could reveal organic molecules, ammonia, high-pressure ices and even brine pools deep in the interior.

OCEAN VOLUME (billions of km^3): 1.8 Earth; 2.6 Europa

DISCOVERED
1610
by Galileo Galilei

DIAMETER
3,130 KM

SURFACE TEMPERATURE
–225 °F



EXPLORED BY
1970s: Flybys of Pioneer 10, Pioneer 11, Voyager 1, Voyager 2
1996: Galileo

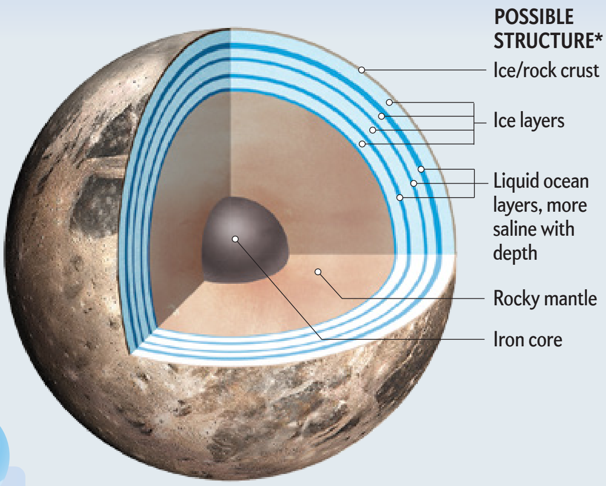
PLANNED MISSIONS
April 2023: European Space Agency's JUICE
2024: NASA's Europa Clipper

**Layers are not drawn to scale*

NASA Visualization Technology Applications and Development (VTAD) (*Europa and Ganymede exteriors*), NASA/JPL-Caltech/SETI Institute (*Europa surface texture*), NASA/JPL/DLR (*Callisto exterior*)

Ganymede

The largest moon in our solar system might contain several layers of rock, water and exotic high-pressure ices. Interactions between rock and water are fundamental to microbial diversity on Earth. Ganymede is the only known moon with its own magnetic field, which causes auroras akin to those on Earth. The auroras sway when Jupiter's magnetic field fluctuates, partial evidence for a large saltwater ocean.



STRONG EVIDENCE OF LIQUID-SALTWATER SUBSURFACE OCEAN

OCEAN VOLUME (billions of km³)

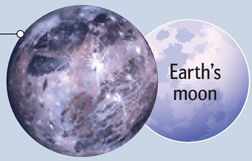
WHAT WE STILL DON'T KNOW

Ganymede is the JUICE mission's primary target. Scientists will use the spacecraft to try to determine the source of the moon's magnetic field and to study details about its auroras.

- **DISCOVERED**
  1610
  by Galileo Galilei

- **DIAMETER**
  5,262 KM

- **SURFACE TEMPERATURE**
  −297 °F TO −171 °F

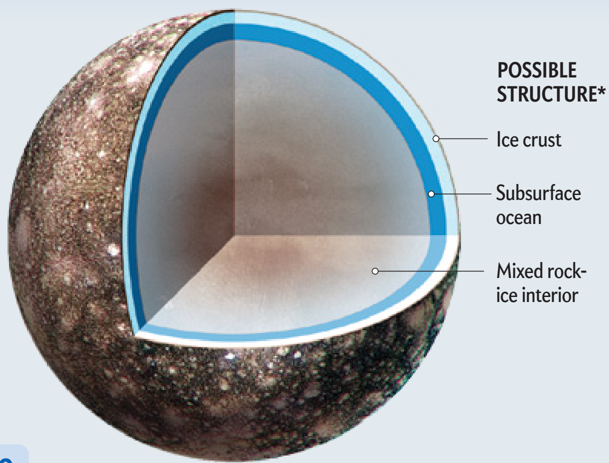


- **EXPLORED BY**
  1970s: Flybys of Pioneer 10, Pioneer 11, Voyager 1 and Voyager 2
  1996: Galileo **2000:** Cassini **2021:** Juno

- **PLANNED MISSIONS**
  April 2023: European Space Agency's JUICE

Callisto

Callisto is the least dense of Jupiter's moons. It has the good fortune of orbiting 1.8 million kilometers from the planet, beyond Jupiter's intense radiation belts. Because Jupiter's gravitational field is weaker at this distance, Callisto also experiences less tidal friction than its companion moons. The moon's heavily cratered surface suggests it has not been geologically active since its formation, so it might preserve a record of the primordial solar system.



POTENTIAL LIQUID SUBSURFACE OCEAN

OCEAN VOLUME (billions of km³)

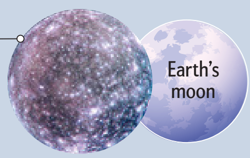
WHAT WE STILL DON'T KNOW

Scientists are split on whether Callisto hosts an underground saltwater ocean and how deep it would be. By using JUICE to study the moon's shape and its gravity field, scientists hope to settle this debate.

- **DISCOVERED**
  1610
  by Galileo Galilei

- **DIAMETER**
  4,820 KM

- **SURFACE TEMPERATURE**
  −218 °F



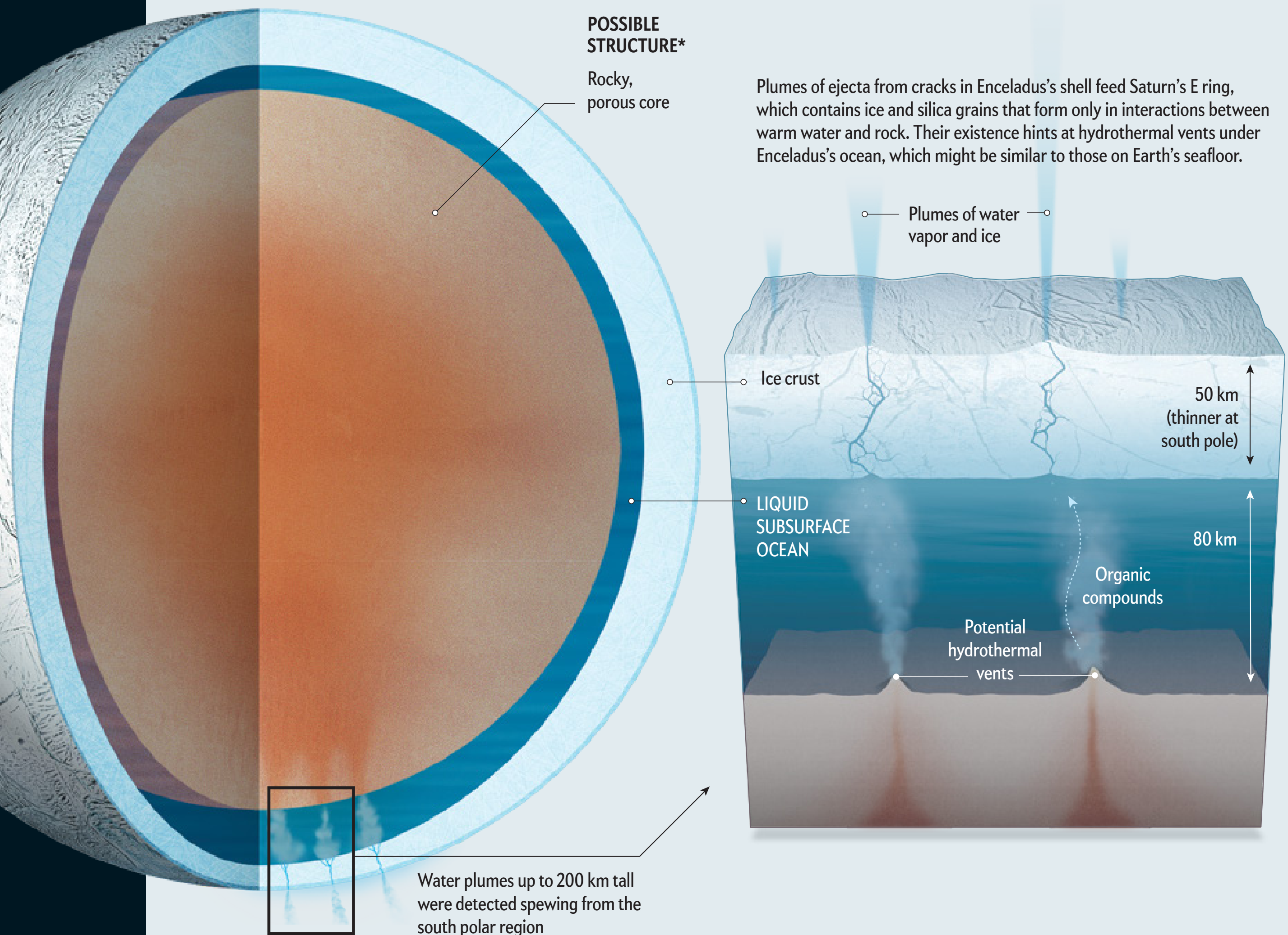
- **EXPLORED BY**
  1970s: Flybys of Pioneer 10, Pioneer 11, Voyager 1 and Voyager 2
  1996: Galileo

- **PLANNED MISSIONS**
  April 2023: European Space Agency's JUICE

Enceladus

Tiny Enceladus is the most reflective object in the solar system. Plumes of mist emanating from the outer shell freeze and fall back to the surface, keeping it snowy white. It is smooth like Europa, further evidence that it is geologically active today. Because the mist generates Saturn's second-outermost band—the E ring—sampling the band is a way to sample Enceladus's putative ocean and to search for organic molecules, amino acids or other ingredients for life.

STRONG EVIDENCE OF LIQUID-SALTWATER SUBSURFACE OCEAN



WHAT WE STILL DON'T KNOW

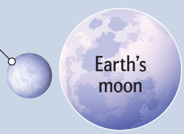
Scientists don't know the size of Enceladus's ocean, but the moon may be one of the easiest to investigate because spacecraft can detect elements in its plumes as well as in Saturn's E ring.

OCEAN VOLUME (billions of km³)

1.8	0.01
Earth	Enceladus

- **DISCOVERED**
  1789
  by William Herschel

- **DIAMETER**
  504 KM



- **SURFACE TEMPERATURE**
  –330 °F

- **EXPLORED BY**
  1980–81: Flybys by Voyager 1 and Voyager 2
  2005: Cassini

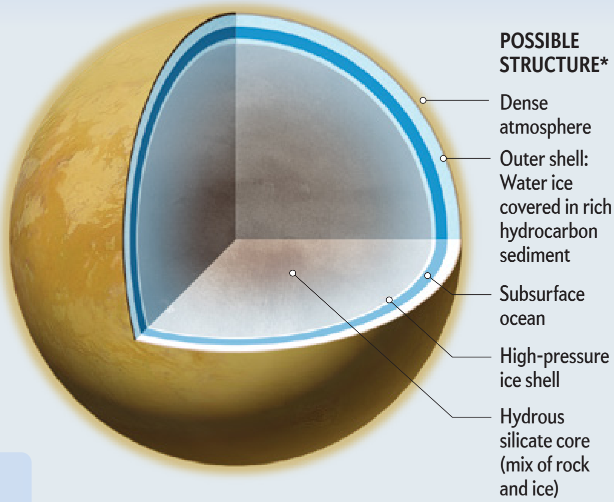
- **PLANNED MISSIONS**
  Enceladus Orbilander concept by Johns Hopkins Applied Physics Laboratory would orbit and then land in search for potential life

**Layers are not drawn to scale*

NASA/JPL-Caltech (*Enceladus exterior*), NASA/JPL-Caltech/University of Nantes/University of Arizona (*Titan exterior*), NASA Visualization Technology Applications and Development (VTAD) (*Triton exterior*)

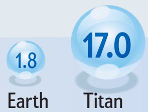
Titan

Cassini dropped a lander on Titan, the alien world most like Earth, with vast plains and canyonlands. It settled on a plain made of ice grains and found evidence for great hydrocarbon lakes. Titan's dense atmosphere is mostly nitrogen, like Earth's, but lacks oxygen. It has abundant liquid methane and ethane, which create the moon's hazy orange cast. The compounds have a circulation cycle like water does on Earth that could support methane-based life.



STRONG EVIDENCE OF LIQUID SUBSURFACE OCEAN

OCEAN VOLUME (billions of km³)

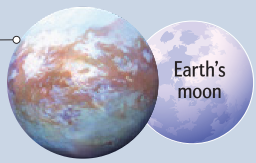


WHAT WE STILL DON'T KNOW

One theory for why Titan hosts so much methane—which continually breaks down in sunlight—is that methane might erupt from cryovolcanoes that ooze chilled water instead of molten rock.

- **DISCOVERED**
  1655
  by Christiaan Huygens

- **DIAMETER**
  5,152 KM
- **SURFACE TEMPERATURE**
  −290 °F



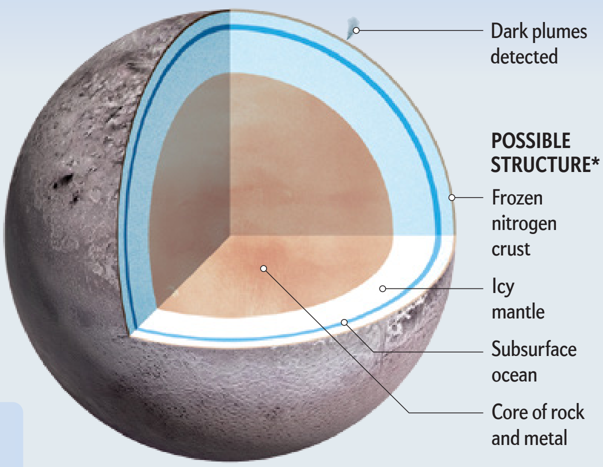
- **EXPLORED BY**
  1980–81: Flybys by Voyager 1 and 2
  2005: Cassini-Huygens (Cassini flybys and Huygens probe landing)

- **PLANNED MISSIONS**
  Mid-2030s: Dragonfly is set to launch in 2027 and arrive in 2034

MOON OF NEPTUNE

Triton

The largest Neptunian moon orbits in a retrograde motion and was most likely captured from the icy Kuiper belt, a distant asteroid ring. The wrenching change in the moon's trajectory probably heated it up, perhaps enough to warm a global ocean below the crust. Seasonal heating from the sun also warms the moon ever so slightly, even at 4.5 billion kilometers.



HYPOTHESIZED LIQUID SUBSURFACE OCEAN

OCEAN VOLUME (billions of km³)

WHAT WE STILL DON'T KNOW

Voyager 2 glimpsed evidence of geysers and lavalike flows above Triton's surface, suggesting the presence of an ocean under a geologically active, icy crust. A closer look would help explain what is going on.

- **DISCOVERED**
  1846
  by William Lassell

- **DIAMETER**
  2,704 KM
- **SURFACE TEMPERATURE**
  −391 °F

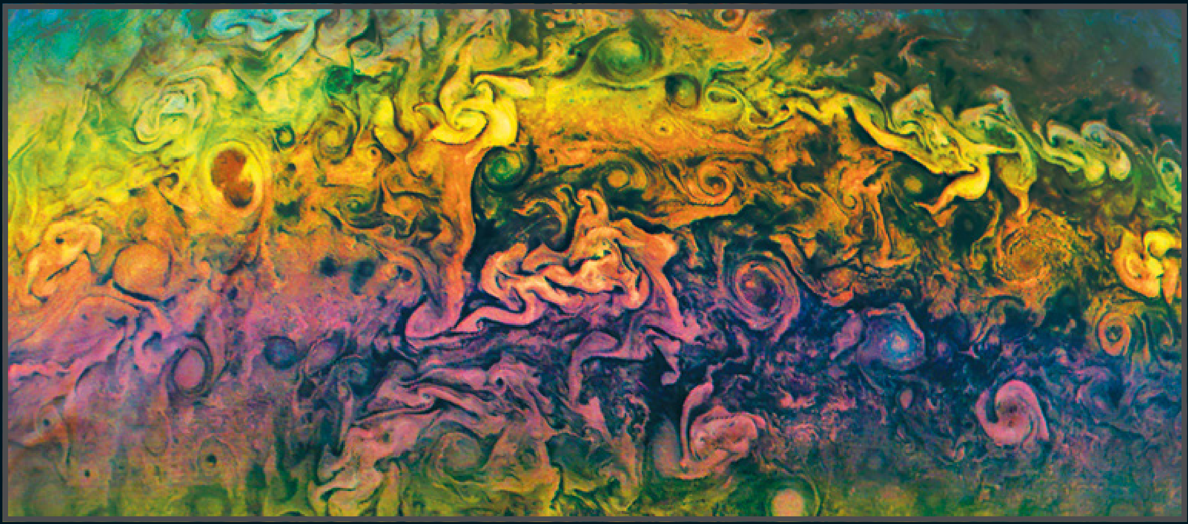
- **EXPLORED BY**
  1989: Flyby by Voyager 2

- **PLANNED MISSIONS**
  None planned so far

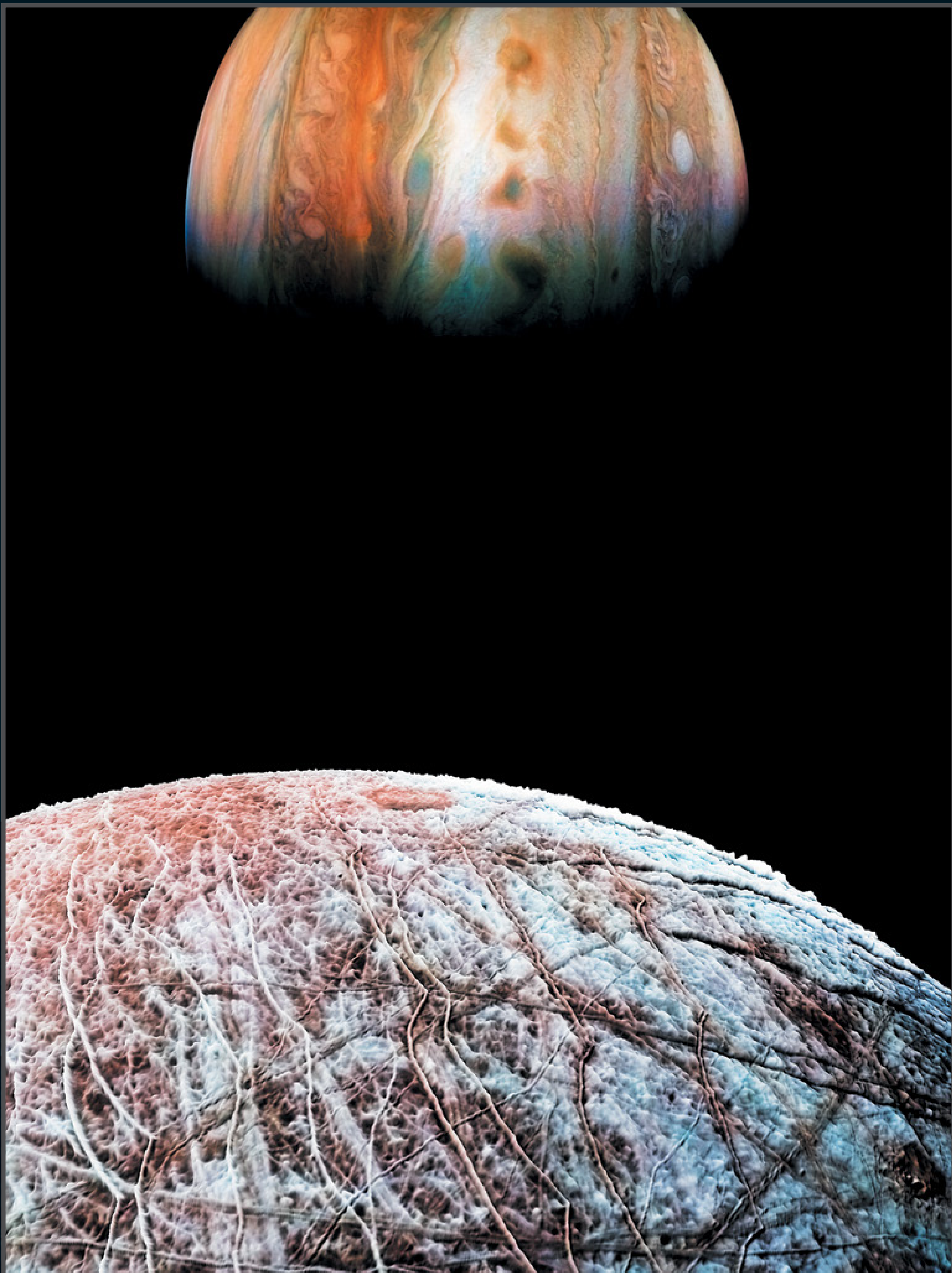
PLANETARY ART

Citizen scientists blend creativity and research using data from a dedicated camera on NASA's Juno probe

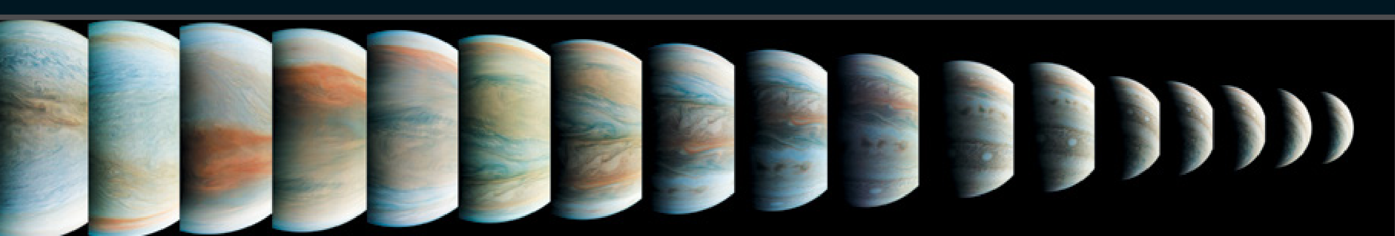
JUPITER'S STORMS recall Vincent van Gogh's *The Starry Night* in a processed image.



ADDED COLOR and effects highlight cyclones at Jupiter's northern pole.



AN EXAGGERATED elevation model shows, in a composite image, what the moon Europa might look like to a nearby visitor.



A MONTAGE shows the changing faces of Jupiter's atmosphere over time.

Clockwise from top left: NASA/JPL-Caltech/SwRI/MSSS/Kevin M. Gills; NASA/JPL-Caltech/SwRI/MSSS (*image data*), Gerald Eichstädt (*image processing*); NASA/JPL-Caltech/SwRI/MSSS/Kevin M. Gill; NASA/JPL-Caltech/SwRI/MSSS/Abastumani-63