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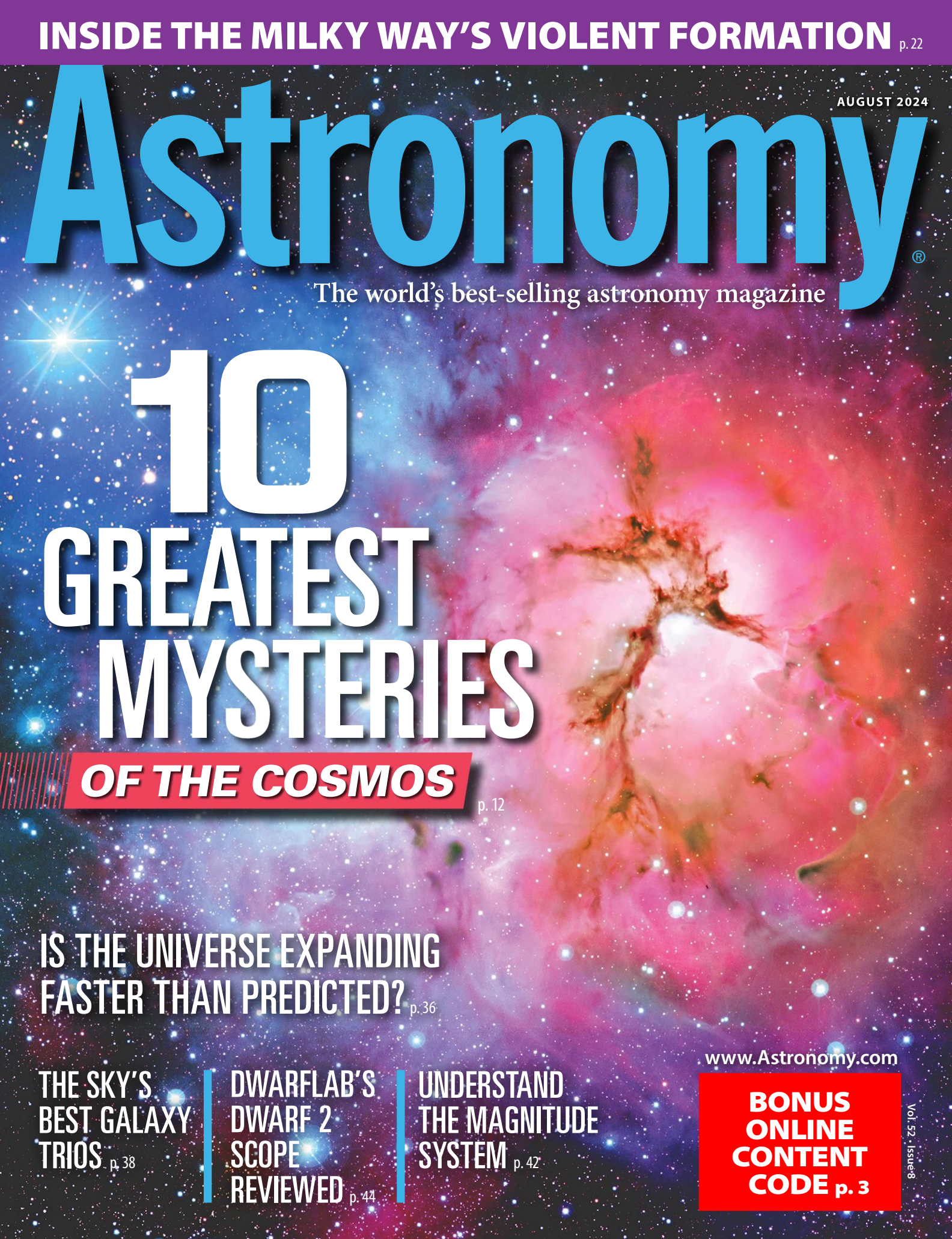

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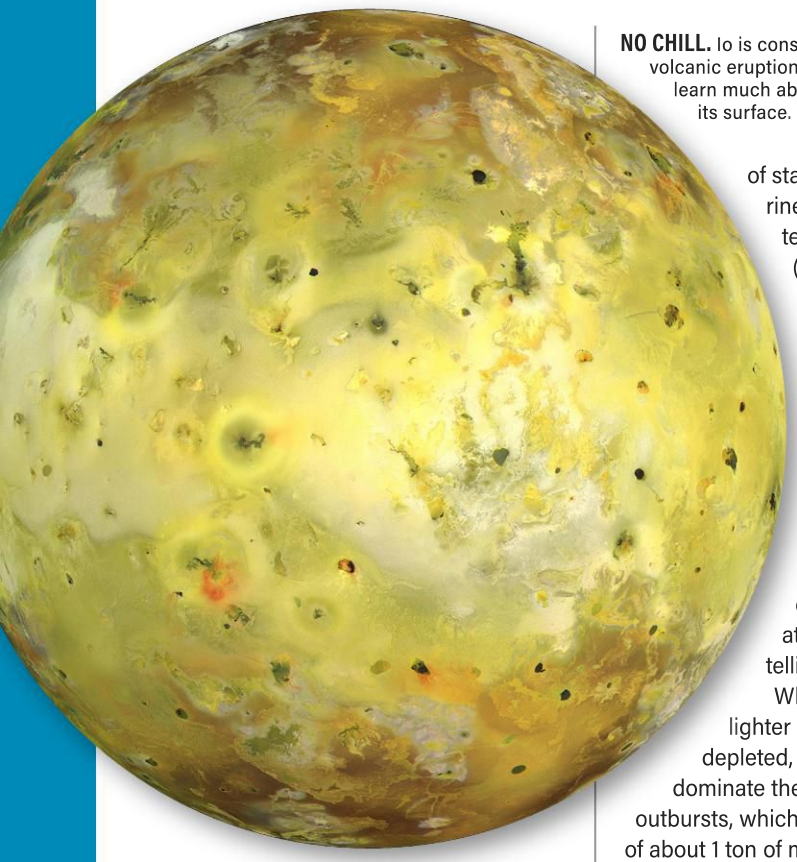
Io's long, active life



NO CHILL. Io is constantly being recoated by volcanic eruptions, erasing our ability to learn much about its past by analyzing its surface. NASA/JPL/UNIVERSITY OF ARIZONA

» Jupiter's diminutive moon Io is an infernal hellworld that constantly spits sulfurous magma into space. And a new study, published April 18 in *Science*, suggests that it's been that way for most — or possibly all — of its 4.57 billion years of existence.

As Jupiter's innermost large moon, Io is subject to an intense gravitational tug-of-war between its massive parent planet and nearby large moons Europa and Ganymede, both of which are locked in resonant orbits.

This makes Io is the most volcanic body in the solar system, and a fascinating world. But because Io is so volcanic, its surface is relatively young and can't be used to peer very far back into the moon's history. Instead, the study authors turned to radio astronomy, using the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile to look for the presence of stable sulfur and chlorine isotopes in Io's thin, tenuous atmosphere. (Isotopes are atoms of a single element that have the same number of protons but varying numbers of neutrons in their nuclei.) Sulfur dioxide and chlorine gasses are released during volcanic activity, so their presence and concentration in the atmosphere could be telling.

What they found was that lighter isotopes seem to be depleted, while heavier isotopes dominate the current volcanic outbursts, which spew an average of about 1 ton of material per second across the world. This indicates Io has already depleted about 94 to 99 percent of its available sulfur, which in turn is evidence that "Io has been losing sulfur essentially for the entire time period of its existence," says study lead author Katherine de Kleer, a planetary scientist at Caltech.

The current study also gives insight into how Jupiter's Galilean moons — Io, Europa, Ganymede, and Callisto — formed, as their orbits indicate these moons likely formed in the places they're at now. "If Io has been volcanically active for billions of years, then that means that these three moons have been in this dynamical configuration potentially for the entire age of the solar system," as well, de Kleer says.

Assuming Io initially held some 20,000,000,000,000,000,000,000 (or 20 sextillion) tons of sulfur, the amount it's lost so far leaves roughly 200 quintillion to 1.2 sextillion tons of sulfur still within the moon to drive new eruptions. That may seem like a lot, but at the rate it's going, "before the end of the solar system, before the Sun expands and swallows some of the planets and changes everything, Io will run out of [its] sulfur," de Kleer says.

What happens next is an intriguing puzzle for planetary scientists. Magma can't just make its way to the surface prior to an eruption — it needs gases to push it along. "Without the sulfur dioxide, there'd have to be something else to drive the magma to the surface," de Kleer says. "It's kind of fun to think about what Io's volcanism might look like when it doesn't have that sulfur-rich gas driving it." – J.W.

NASA'S SLITHERING ROVER

A NEW SNAKELIKE ROBOT being developed at NASA's Jet Propulsion Laboratory (JPL) could someday help scientists explore icy moons like Saturn's Enceladus and Jupiter's Europa — tantalizing places to search for alien life, thanks to liquid oceans sloshing beneath their frozen surfaces.

The 13-foot-long (4 meters) robot, named Exobiology Extant Life Surveyor (EELS), is currently in its third year of development and is designed to autonomously navigate icy surfaces and explore areas that are otherwise inaccessible to conventional four-wheeled rovers. The serpent-shaped robot has a "head" infused with cameras and sensors, including a laser-based system that creates maps of its environment, similar to an

SLITHERING SPEARHEAD. JPL's EELS robot snakes across Athabasca Glacier in Alberta during field testing in September 2023. NASA/JPL-CALTECH

autonomous car. The bot's "body" comprises individual modules linked together that can host science instruments. It also has spiral connectors throughout the body to propel the robot forward.

This technology, described in a paper published March 13 in *Science Robotics*, allows EELS to traverse flat ground, wrap itself around an object to inch ahead, and tunnel through narrow passages by changing its shape to get in and out of spaces where a conventional rover is too big to fit. The sleek design is inspired by the desire to wiggle through narrow plume-blasting vents on Enceladus. So far, the team has tested it at JPL's Mars Yard — plus a Canadian glacier, a snowy California ski resort, and a local ice rink.

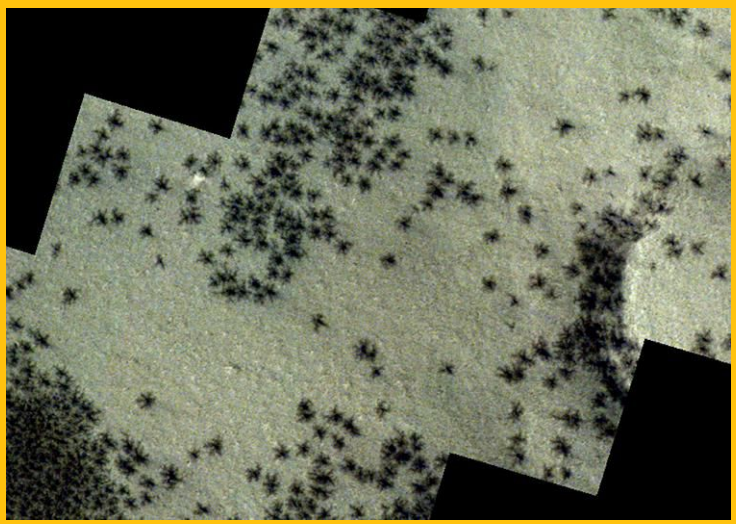
When EELS finds itself in dimly lit terrain where the robot's cameras cannot create a good map of its surroundings, it relies on a sense of touch, courtesy of sensors that measure how much it is pushing against its environment, says EELS project manager Matt Robinson of JPL. On destinations like Enceladus or Europa, which are nearly a billion miles (1.6 billion kilometers) from Earth, the engineers can't "joystick the robot" in real time, says Robinson, because it would take up to an hour to send a command and another hour to get a response. Hence, the necessity of autonomy.

"It represents very impressive state-of-the-art engineering," says Manasvi Lingam, an astrobiologist at the Florida Institute of Technology.

The robot is still in the early stages of development and is currently not part of any NASA mission. If it were to be sent to explore Enceladus, however, it would need to tunnel through several miles of ice to reach the moon's subsurface ocean — a challenging task, Lingam says, but "it might be able to search for biosignatures frozen in the surface ice."

EELS' engineers also envision versions of the robot that could scope out cavelike structures on the Moon where astronauts may find shelter, or explore hard-to-reach areas on Earth itself. –SHARMILA KUTHUNUR

'SPIDERS' ON MARS



ESA/TGO/CASSIS

ESA's ExoMars Trace Gas Orbiter (TGO) normally studies the martian atmosphere — but recently, it added spiders to its research agenda. These creepy-crawly topographical features are found during spring near the southern polar region of Mars. As temperatures rise and rays of sunlight touch the carbon dioxide ice that built up during winter, the accumulated warmth at the bottom of the layer causes the carbon dioxide to turn into gas. The gas eventually escapes by cracking and bursting through the slabs of ice as a fountain or geyser, mixing with dark dust. This mixture then falls back to the surface and settles in a spindly shape. –ELIZABETH GAMILLO