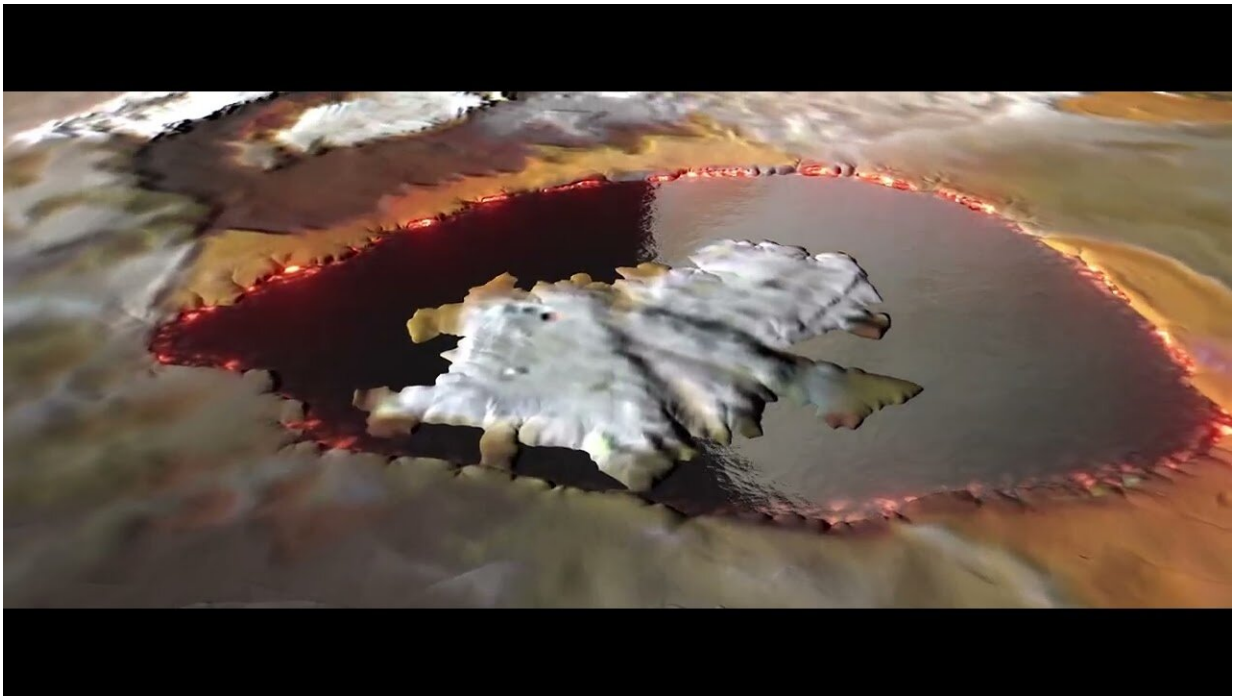
Juno reveals a giant lava lake on Io

April 22 2024, by Nancy Atkinson



An artists rendition of Loki Patera, a lava lake on Jupiter’s moon Io. Credit: NASA

NASA's Juno spacecraft came within 1,500 km (930 miles) of the surface of Jupiter's moon Io in two recent flybys. That's close enough to reveal new details on the surface of this moon, the most volcanic object in the solar system. Not only did Juno capture volcanic activity, but scientists were also able to create a visual animation from the data that shows what Io's 200-km-long lava lake Loki Patera would look like if

you could get even closer. There are islands at the center of a magma lake rimmed with hot lava. The lake's surface is smooth as glass, like obsidian.

"Io is simply littered with volcanoes, and we caught a few of them in action," said Juno principal investigator Scott Bolton during a news conference at the European Geophysical Union General Assembly in Vienna, Austria. "There is amazing detail showing these crazy islands embedded in the middle of a potentially magma lake rimmed with hot lava. The specular reflection our instruments recorded of the lake suggests parts of Io's surface are as smooth as glass, reminiscent of volcanically created obsidian glass on Earth."

Just imagine if you could stand by the shores of this lake—which would be a stunning view in itself. But then, you could look up and see the giant Jupiter looming in the skies above you.

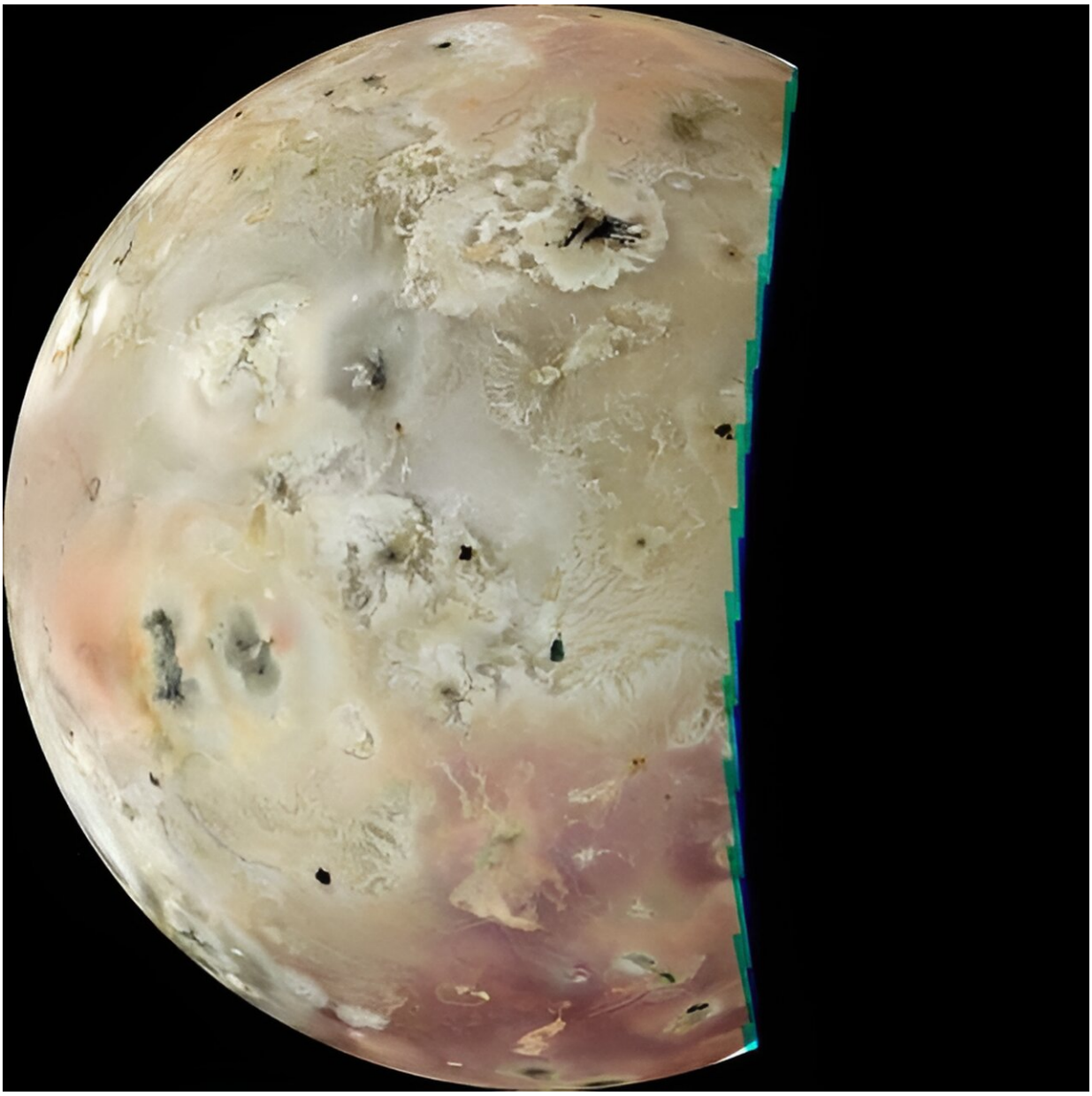
Juno made the two close flybys of Io in December 2023 and February 2024. Images from Juno's JunoCam included the first close-up images of the moon's northern latitudes. Undoubtedly, Io looks like a pizza—which has been the conclusion since our first views of this moon, when Voyager 1 flew through the Jupiter system in March 1979. The mottled and colorful surface comes from the volcanic activity, with hundreds of vents and calderas on the surface that create a variety of features. Volcanic plumes and lava flows across the surface show up in all sorts of colors, from red and yellow to orange and black. Some of the lava "rivers" stretch for hundreds of kilometers.

Juno scientists were also able to re-create a spectacular feature on Io, a spired mountain that has been nicknamed "The Steeple." This feature is between 5 and 7 kilometers (3-4.3 miles) in height. It's hard to comprehend the type of volcanic activity that could have created such a stunning landform.

Speaking of volcanic activity, two recent papers have come to a jaw-dropping conclusion about Io: this moon has been erupting since the dawn of the solar system.

All the volcanic on Io is activity is driven by tidal heating. Io is in an orbital resonance with two other large moons of Jupiter, Europa and Ganymede.

"Every time Ganymede orbits Jupiter once, Europa orbits twice, and Io orbits four times," explained the authors of a paper published in the *Journal of Geophysical Research: Planets*, led by Ery Hughes of GNS Science in New Zealand. "This situation causes tidal heating in Io (like how the moon causes ocean tides on Earth), which causes the volcanism."



Io's sub-Jovian hemisphere is revealed in detail for the first time since Voyager 1 flew through the Jupiter system in March 1979, during the Juno spacecraft's 58th perijove, or close pass, on February 3, 2024. This image shows Io's nightside illuminated by sunlight reflected off Jupiter's cloud tops. Several surface changes are visible include a reshaping of the compound flow field at Kanehekili (center left) and a new lava flow to the east of Kanehekili. This image has a pixel scale of 1.6 km/pixel. Credit: NASA/SwRI/JPL/MSSS/Jason Perry

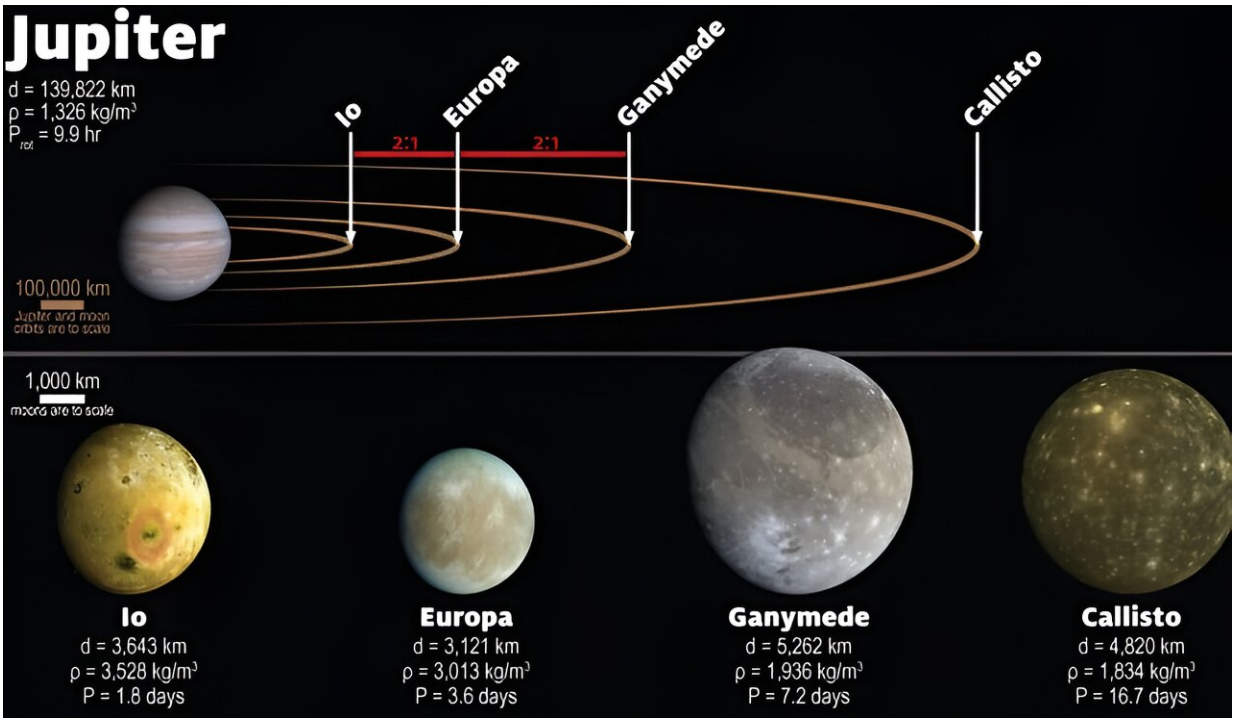
However, scientists haven't known how long this resonance has been occurring and whether what we observe today is what has always been happening in the Jupiter system. This is because volcanism renews Io's surface almost constantly, leaving little trace of the past.

The team of scientists, led by Katherine de Kleer at Caltech and Hughes at GNS Science used the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile observe the sulfur gases in Io's atmosphere. The isotopes of sulfur were used as a tracer of tidal heating on Io because sulfur is released through volcanism, processed in the atmosphere, and recycled into the mantle. Additionally, some of the sulfur is lost to space, and because of Jupiter's magnetosphere, a bunch of charged particles whirling around Jupiter that hit Io's atmosphere continuously.

It turns out that the sulfur that is lost to space on Io is a little bit isotopically lighter than the sulfur that is recycled back into Io's interior. Because of this, over time, the sulfur remaining on Io gets isotopically heavier and heavier. How much heavier depends on how long volcanism has been taking place.

What the teams found is that tidal heating on Io has been occurring for billions of years.

"The isotopic composition of Io's inventory of volatile chemical elements, including sulfur and chlorine, reflects its outgassing and mass loss history, and thus records information about its evolution," the team wrote in the paper published in *Science*. "These results indicate that Io has been volcanically active for most (or all) of its history, with potentially higher outgassing and mass-loss rates at earlier times."



Jupiter's orbital system with the host planet and orbits to scale. Credit: James Tuttle Keane / Keck Institute for Space Studies

Juno continues to makes its way through the Jupiter system. And during Juno's most recent flyby of Io, on April 9, the spacecraft came within about 16,500 kilometers (10,250 miles) of the moon's surface. It will perform its 61st flyby of Jupiter on May 12.

JunoCam is a public camera, where members of the public can choose targets for imaging, as well as process all the data. JunoCam's raw images are available here for the public to peruse and process into image products. Here you can see the most recent images that have been processed.

More information: Ery C. Hughes et al, Using Io's Sulfur Isotope Cycle to Understand the History of Tidal Heating, *Journal of Geophysical Research: Planets* (2024). DOI: 10.1029/2023JE008086

Katherine de Kleer et al, Isotopic evidence of long-lived volcanism on Io, *Science* (2024). DOI: 10.1126/science.adj0625

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