First results from long-term, hi-res tracking of eruptions on Jupiter's moon Io

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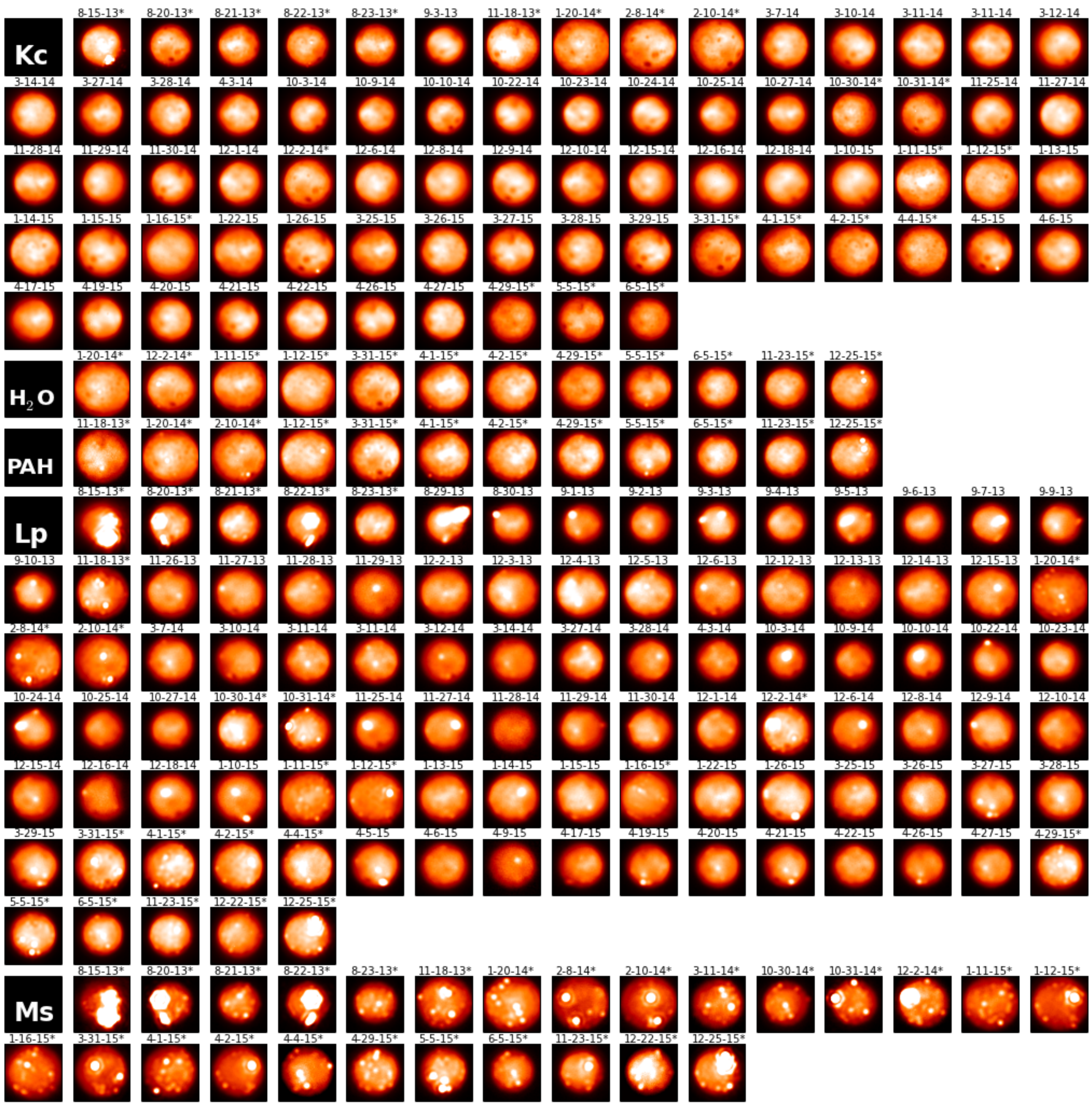


Images of Io at different near-infrared wavelengths. The name of the filter used is indicated in the black box at the start of each section. The bright spots are thermal emissions from Io's myriad volcanoes. Note the increasing number of hot spots detected at longer wavelengths, i.e. towards the bottom of the figure. Credit: Katherine de Kleer and Imke de Pater, UC Berkeley

Jupiter's moon Io continues to be the most volcanically active body in the solar system, as documented by the longest series of frequent, high-resolution observations of the moon's thermal emission ever obtained.

Using near-infrared adaptive optics on two of the world's largest telescopes - the 10-meter Keck II and the 8-meter Gemini North, both located near the summit of the dormant volcano Maunakea in Hawaii - University of California, Berkeley astronomers tracked 48 volcanic hot spots on the surface over a period of 29 months from August 2013 through the end of 2015.

Without adaptive optics - a technique that removes the atmospheric blur to sharpen the image - Io is merely a fuzzy ball. Adaptive optics can separate features just a few hundred kilometers apart on Io's 3,600-kilometer-diameter surface.

"On a given night, we may see half a dozen or more different hot spots," said Katherine de Kleer, a UC Berkeley graduate student who led the observations. "Of Io's hundreds of active volcanoes, we have been able to track the 50 that were the most powerful over the past few years."

She and Imke de Pater, a UC Berkeley professor of astronomy and of earth and planetary science, observed the heat coming off of active eruptions as well as cooling lava flows and were able to determine the temperature and total power output of individual volcanic eruptions.They tracked their evolution over days, weeks and sometimes even years.

Interestingly, some of the eruptions appeared to progress across the surface over time, as if one triggered another 500 kilometers away.

"While it stretches the imagination to devise a mechanism that could operate over distances of 500 kilometers, Io's volcanism is far more extreme than anything we have on Earth and continues to amaze and baffle us," de Kleer said.

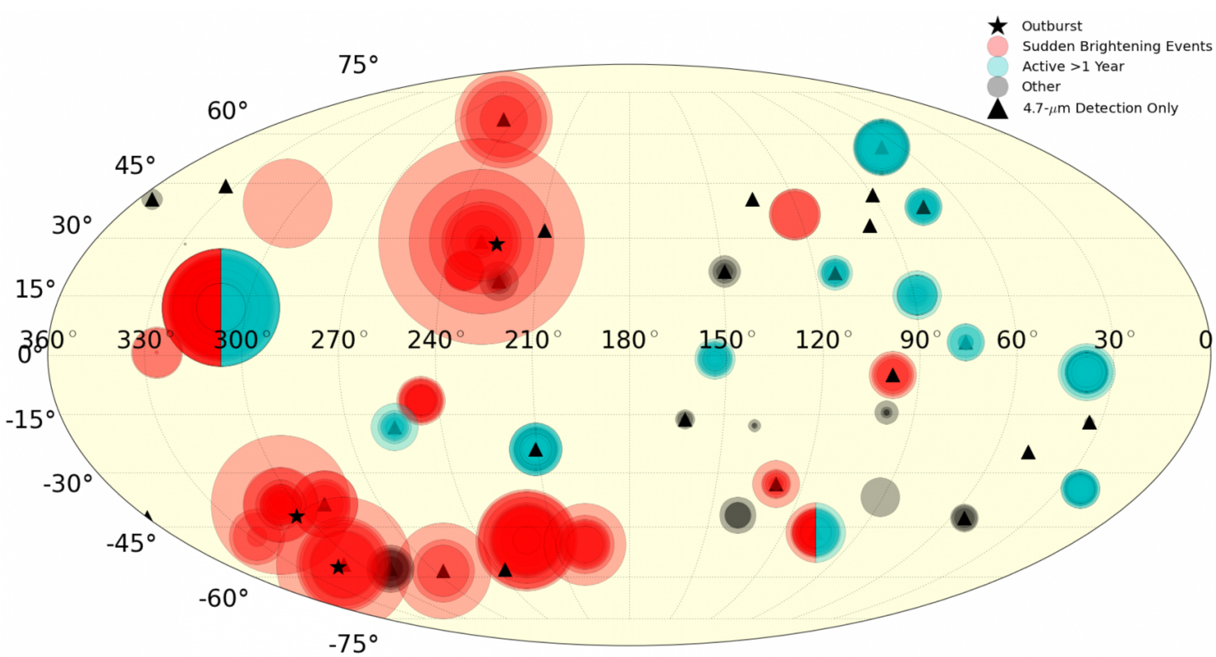
De Kleer and de Pater will discuss their observations at a media briefing on Oct. 20 during a joint meeting of the American Astronomical Society's Division for Planetary Sciences and the European Planetary Science Congress in Pasadena, California. Papers describing the observations have been accepted for future publication by the journal *Icarus*.

Tidal heating

Io's intense volcanic activity is powered by tidal heating—heating from friction generated in Io's interior as Jupiter's intense gravitational pull changes by small amounts along Io's orbit. Models for how this heating occurs predict that most of Io's total volcanic power should be emitted either near the poles or near the equator, depending on the model, and that the pattern should be symmetric between the forward- and backward-facing hemispheres in Io's orbit (that is, at longitudes 0-180 degrees versus 180-360 degrees).

That's not what they saw. Over the observational period, August 2013 through December 2015, the team obtained images of Io on 100 nights. Though they saw a surprising number of short-lived but intense eruptions that appeared suddenly and subsided in a matter of days, every single one took place on the trailing face of Io (180-360 degrees longitude) rather than the leading face, and at higher latitudes than more typical eruptions.

"The distribution of the eruptions is a poor match to the model predictions," de Kleer said, "but future observations will tell us whether this is just because the sample size is too small, or because the models are too simplified. Or perhaps we'll learn that local geological factors play a much greater role in determining where and when the volcanoes erupt than the physics of tidal heating do."



All hot spot detections from August 2013 through December 2015 shown on a full map of Io. Each circle represents a new detection; the size of the circle corresponds logarithmically to the intensity, and more opaque regions are where a hot spot was detected multiple times. The color and symbol indicate the type of eruption, following the legend. Loki Patera is at 310 West, 10 North and Kurdalagon Patera is at 220 West, 50 South. Credit: Katherine de Kleer and

Imke de Pater, UC Berkeley

One key target of interest was Io's most powerful persistent volcano, Loki Patera, which brightens by more than a factor of 10 every 1-2 years. A patera is an irregular crater, usually volcanic.

Many scientists believe that Loki Patera is a massive lava lake, and that these bright episodes represent its overturning crust, like that seen in lava lakes on Earth. In fact, the heat emissions from Loki Patera appear to travel around the lake during each event, as if from a wave moving around a lake triggering the destabilization and sinking of portions of crust. Prior to 2002, this front seemed to travel around the cool island in the center of the lake in a counter-clockwise direction.

After an apparent cessation of brightening events after 2002, de Pater observed renewed activity in 2009.

"With the renewed activity, the waves traveled clockwise around the lava lake," she noted.

Another volcano, Kurdalagon Patera, produced unusually hot eruptions twice in the spring of 2015, coinciding with the brightening of an extended cloud of neutral material that orbits Jupiter. This provides circumstantial evidence that eruptions on the surface are the source of variability in this neutral cloud, though it's unclear why other eruptions were not also associated with brightening, de Kleer said.

De Kleer noted that the Keck and Gemini telescopes, both atop the dormant volcano Maunakea, complement one another. Gemini North's queue scheduling allowed more frequent observations - often several a week - while Keck's instruments are sensitive also to longer wavelengths

(5 microns), showing cooler features such as older lava flows that are invisible in the Gemini observations.

The astronomers are continuing their frequent observations of Io, providing a long-term database of high spatial resolution images that not even Galileo, which orbited Jupiter for eight years, was able to achieve.

Provided by University of California - Berkeley

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