Monitoring Io's insane volcanic activity from the comfort of Earth

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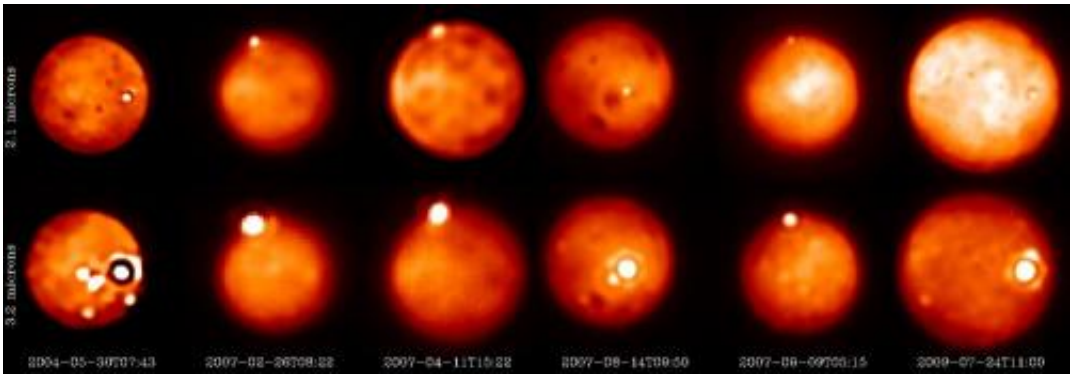

Observations of several bright & young eruptions detected at short wavelength (~ 2.1 mm) on the top and longer wavelength (~ 3.2 mm) on the bottom since 2004 using the W.M. Keck 10m telescope (May 2004, Aug 2007, Sep 2007, July 2009), the Gemini North 8m Telescope (Aug 2007) and the ESO VLT-Yepun 8m telescope (Feb 2007) and their adaptive optics systems. Credit: F. Marchis

Watching active volcanic eruptions should definitely be done from a distance, but a group of California researchers has figured out how to do it from the comfort of home. Using an ingenious combination of Earth-based telescopic surveys and archival data, they have gathered nearly 40 distinct snapshots of effusive volcanic eruptions and high temperature outbursts on Jupiter's tiny moon, Io, showing details as small as 100 km (60 miles) on the moon's surface.

Io, the innermost moon of Jupiter, is an insanely active volcanic

wonderland. Although the most detailed observations have come from spacecraft, the Galileo Jupiter orbiter mission ended in 2003 and no future mission capable of studying Io is planned until, at the earliest, 2030. However, there will be no large gap in the monitoring of Io's volcanoes, thanks to the efforts of teams like that led by Franck Marchis, a researcher at the Carl Sagan Center of the SETI Institute. Marchis will present results from ground-based telescopic monitoring of volcanic activity on Io over the past decade at the 2012 DPS Meeting in Reno, Nevada.

Erupting volcanoes on Io cannot be directly seen from the ground using classical telescopes. Io is a relatively small satellite (3,600 km diameter or 2,300 miles), almost the same size as our moon, located much further away (4.2 times the distance between Earth and the sun, so 630 million kilometers or 390 million miles away). Due to the small apparent size of Io, the observation of details on its surface has traditionally been beyond the capabilities of ground-based telescopes on Earth.

To overcome this limitation, engineers and planetary scientists designed spacecraft to visit the Jovian system, including Io. In 1979, Voyager 1 revealed Io's dynamic volcanic activity from the first close-up pictures of its surface, which captured bizarre volcanic terrains, active plumes and hot spots. The Galileo spacecraft remained in orbit in the Jovian system from 1995 to 2003 and observed more than 160 active volcanoes and a broad range of eruption styles. Several outstanding questions remained in the post-Galileo era, and the origin and long-term evolution of Io's volcanic activity is still not yet fully understood.

In the meantime, planetary astronomers have designed instruments to break the "seeing barrier" and improve the image quality of ground-based telescopes. The blurring introduced by the constant motion of the Earth's atmosphere can be corrected in real time using adaptive optics, which provides an image with a resolution close to the diffraction limit

of the telescope. Since 2001, all large 8-10m class telescopes have been equipped with this technology.

"Since our first observation of Io in 2001 using the W. M. Keck II 10m telescope from the top of Mauna Kea in Hawaii and its AO system, our group became very excited about the technology. We also began using AOs at the Very Large Telescope in Chile, and at the Gemini North telescope in Hawaii. The technology has improved over the years, and the image quality and usefulness of those complex instruments has made them part of the essential instrument suite for large telescopes", said Marchis.

Since 2003, using their own observing programs and archival data, the team led by Marchis has gathered approximately 40 epochs of observations of Io in the near-infrared. These images show details as small as 100 km (60 miles) on the surface of the satellite.

Their observations have revealed young and energetic eruptions called outbursts. These are easily detectable from their immense thermal emission at shorter wavelengths, implying a high eruption temperature. The team observed the awakening of the volcano Tvashtar simultaneously with the New Horizons spacecraft, which flew past Jupiter on its way to Pluto. From a combined survey based on three large telescopes, they report that the eruption was detectable from April 2006 to September 2007. Older observations from the Galileo spacecraft and the W.M. Keck observatory show that this volcano previously displayed a similar fire fountain eruptive style which started in November 1999 and lasted for 15 months. Similarly, Pillan, an energetic eruption detected with the Galileo spacecraft from 1996 to 1999, had sporadic activity again in August 2007 which was reported by the team using the W.M. Keck telescope.

"The episodicity of these volcanoes points to a regular recharge of

magma storage chambers" said Ashley Davies a volcanologist at the Jet Propulsion Laboratory, California Institute of Technology, and a member of the study. "This will allow us to model the eruption process and understand the how heat is removed from Io's deep interior by this particular style of volcanic activity".

Four additional young eruptions were detected during this survey including an extremely active volcano located at a region which had never showed activity in the past (planetocentric coordinates 17S, 5W) in May 2004. This new and sporadic outburst had a total output of 10% the average Io thermal output, so it was more energetic than Tvashtar in 2001, implying a fire fountain style eruption. Interestingly, the team did not observe any "mega-outburst" during this survey, with an energetic output similar to the eruption on Surt in 2001, the most energetic eruption ever witnessed in the solar system. They conclude that those outbursts should be extremely rare or very sporadic, lasting for a few days.

The team and several others groups are still monitoring Io's volcanic activity. They noticed that since September 2010, Io's volcanic activity has been globally quiescent. A dozen permanent, low temperature eruptions, which represent effusive activity, are still detected across the surface of Io, but recent observations of the satellite reveal the absence of young bright eruptions and outbursts. The last one seen from the survey was the detection the Loki Patera eruption on July 24 2009, an active lava lake known for its episodic activity.

"Spacecraft have only been able to capture fleeting glimpses of Io's volcanoes, Voyager for a few months, Galileo a few years, and New Horizons a few days. Ground-based observations, on the other hand, can continue to monitor Io's volcanoes over long time-scales. The more telescopes looking at Io, the better time coverage we can obtain." Said Julie Rathbun from Redlands University, a planetary scientist not

directly involved in this study but who has conducted monitoring of Io with IRTF-3m telescope for more than 15 years. "AO observations from 8-10m class telescopes are a dramatic improvement in spatial resolution over previous ground-based observations. Soon they will not only be our only way to monitor Io's volcanoes, but the best way. We should be making these observations more often."

The monitoring of Io's volcanic activity will continue to build a timeline of volcanic activity and thermal emission variability, which will be further complemented by data obtained by other missions to the Jupiter system (such as the ESA mission JUICE, or a future dedicated Europa or Io mission). Until these missions, however, the task of monitoring Io's volcanic activity will be from large, AO-enabled ground-based telescopes.

The next generation of AO systems will provide a better image quality and open the visible wavelength range to planetary astronomers. These systems are currently under development and will have their first light in the coming years. Colorful surface changes due to volcanic activity, such as plume deposits or lava flow fields, will be detectable from the ground.

"The next giant leap in the field of planetary astronomy is the arrival of Giant Segmented Mirror Telescopes, such as the Thirty Meter Telescope expected to be available in 2021. It will provide a spatial resolution of 35 km in the near-infrared, equivalent to the spatial resolution of global observations taken by the Galileo spacecraft. When pointed at Io, these telescopes will offer the equivalent of a spacecraft flyby of the satellite", Marchis said.

Io was discovered by Galileo Galilei in January 1610, and the discovery announced in Sidereus Nuncius published in March 1610. Simon Marius claimed to have discovered Io and the other Galilean satellites (Europa, Ganymede, Callisto) independently and at the same time in Mundus

Iovalis, published in 1614. The names of the moons of Jupiter, several lovers of the god Jupiter, were suggested by Johannes Kepler and proposed by S. Marius. The eruptive center detected in May 2004 has not yet received an official name.

Provided by SETI Institute