EPSC Abstracts
Vol. 13, EPSC-DPS2019-1995-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Io as a Template for Volcanic Signatures on Exoplanets

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Abstract

Exoplanets in eccentric orbits or those orbiting very close to their host stars may host molten rock at their surfaces and silicate or sulfuric atmospheres. As the only Solar System world whose surface and atmosphere are dominated by the products of volcanic activity, Jupiter's moon Io demonstrates a range of signatures indicative of volcanism and provides a template for connecting such signatures to the volcanic activity that produces them. This presentation will review recent results from ground- and space-based observations targeting Io's volcanism and its various products and signatures, and will discuss the relevance of these results to searches for evidence of volcanism on extrasolar planets and moons.

Main Text

Volcanism is one of the central processes by which the surfaces of rocky planets are created and modified. All of the major terrestrial bodies in our Solar System appear to have undergone periods of significant volcanic activity, and host surface regions created by large-scale lava flows (Platz et al. 2015). Exoplanets whose densities point to rocky compositions and whose orbits indicate a high degree of heating are candidate volcanic planets around other stars. Such bodies may have molten surfaces due to external melting by their star (e.g. Howard et al. 2013), or may exhibit more "conventional" volcanism due to tidal heating driven by orbital eccentricities (e.g. Barr et al. 2018).

The study of volcanically active exoplanets can inform our understanding of the thermal evolution of planetary bodies and the formation of rocky crusts, and will be the first aspect of planetary geology that will be directly observable in other systems due to its prominent signatures. Although the presence of volcanism has not yet been confirmed on extrasolar planets, there are numerous markers that are conceivably detectable with the current and near-future generation of telescopes.

The jovian moon Io is our Solar System's only example of a world whose surface, atmosphere, and orbital environment are driven by volcanic activity, and provides us with a template for the set of signatures indicative of volcanism. Indicators of Io's volcanic activity cover all wavelength regimes and span large spatial scales; these include: its high and spatially/temporally variable infrared output; the dominance of sulfur-bearing species on its surface and atmospheric spectra; a torus of ionized material within the jovian system; a cloud of neutral material detected out to hundreds of jovian radii; and dust streams detected as far away $>$1 AU. Figure 1 shows the scale and spatial variation of three of these signatures.

Recent spacecraft and telescopic observations have made significant advances in our understanding of the connections between these volcanically-sourced systems. Such studies both further our knowledge of Io and the jovian system, and provide a framework for predicting and interpreting volcanic signatures from exoplanets. This presentation will review recent results from ground- and space-based studies of Io's volcanism and its products, and will discuss the relevance of this work to future studies of extrasolar planets.

References

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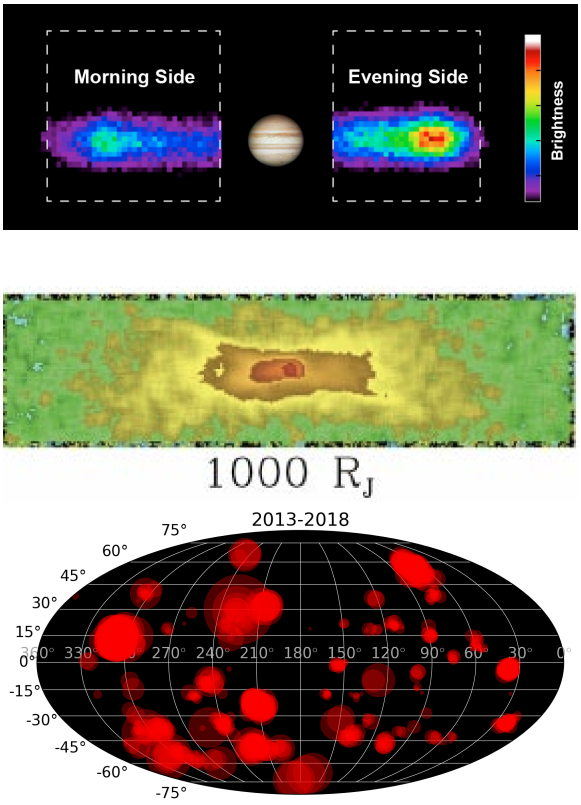

Figure 1: (top) Sulfur ion emission around Jupiter as observed by the *Hisaki* spacecraft (Murakami et al. 2016); (middle) An image of Io's extended neutral sodium cloud at a single point in time (Wilson et al. 2002); (bottom) The spatial distribution of Io's volcanic activity as observed from ground-based adaptive optics telescopes in 2013-2018 (de Kleer et al. 2019).