EPSC Abstracts
Vol. 13, EPSC-DPS2019-996-1, 2019
EPSC-DPS Joint Meeting 2019

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

Follow the Heat: *Io Volcano Observer*

A. S. McEwen[1], E. Turtle[2], L. Kestay[3], K. Khurana[4], J. Westlake[2], P. Wurz[5], J. Helbert[6], R. Park[7], M. Bland[3], D. Breuer[6], L. Carter[1], A. G. Davies[7], C. W. Hamilton[1], S. Horst[8], X. Jia[9], L. Jozwiak[2], J. T. Keane[10], K. de Kleer[10], V. Lainey[7], K. Mandt[2], I. Matsuyama[1], O. Mousis[11], F. Nimmo[12], C. Paranicas[2], J. Perry[1], A. Pommier[13], J. Radebaugh[14], J. Spencer[15], S. Sutton[1], N. Thomas[5], A. Vorburger[5] [1]LPL, University of Arizona, [2]JHU APL, [3]USGS, [4]UCLA, [5]UBE, [6]DLR, [7]JPL, [8]JHU, [9]U.Michigan, [10]Caltech, [11]AMU, [12]UCSC, [13]UCSD, [14]BYU, [15]SwRI.

Abstract

The Io Volcano Observer (*IVO)* Discovery mission proposal [1] has been re-focused in 2019 towards understanding tidal heating as a fundamental planetary process. To “Follow the Heat”, *IVO* will determine how heat is generated in Io’s interior, transported to the surface, and how heat and mass are lost to space.

1. Tidal Heating

Tidal heating is key to the evolution and habitability of many worlds across our Solar System and beyond. However, there remain fundamental gaps in our understanding, which motivated a Keck Institute of Space Studies workshop [2]. The Laplace resonance between Jupiter’s moons, Io, Europa, and Ganymede, results in extreme tidal heating within Io [3], and this system provides the greatest potential for advances in the next few decades. The easily observed heat flow of Io, from hundreds of continually erupting volcanoes [4], makes it the ideal target for further investigation, and the missing link along with missions in development (e.g., *Europa Clipper* and *JUICE*) to understand the Laplace system.

The KISS study [2] identified five key questions to drive future research and exploration: (Q1) What do volcanic eruptions tell us about the interiors of tidally heated bodies? (Q2) How is tidal dissipation partitioned between solid and liquid materials? (Q3) Does Io have a melt-rich layer, or “magma ocean”, that mechanically decouples the lithosphere from the deeper interior? (Q4) Is the Jupiter/Laplace System in equilibrium (i.e., does the satellite’s heat output equal the rate at which energy is generated)? (Q5) Can stable isotope measurements inform long-term evolution?

A promising avenue to address these questions is a new spacecraft mission making multiple close flybys of Io, combined with research and analysis motivated by the mission. *IVO* will address all of these questions, while still within the constraints of NASA Discovery program. *IVO* will characterize volcanic processes (Q1); test interior models via a set of geophysical measurements (coupled with laboratory experiments and theory; Q2 and Q3); measure the total heat flow and orbital evolution of Io (Q4); and analyze mass loss processes (Q5). No new technologies are required for this mission, which leverages advances in radiation design and solar power realized for *Juno*, *Europa Clipper,* and *JUICE*.

2. What is the Distribution of Melt within Io?

This question must be answered to understand where and how tidal heat is generated. We plan to test four end-member models and combinations of these. The current evidence for a magma ocean in Io comes from *Galileo* magnetic induction data, which suggest at least 20% melt [5], although this has been debated [6]. *IVO* will provide a definitive result from multiple flybys with optimal geometries and plasma measurements [7]. *IVO* will also measure k_2, libration, distribution of volcanism, and lava composition and temperature to provide independent tests for the presence of a magma ocean.

3. Mission Architecture

The basic design is similar to the previous *IVO* concept [1]. The spacecraft will orbit Jupiter at an inclination of ~45°, minimizing total radiation dose to ~20 krad per flyby, and *IVO*’s total dose over 10 orbits will be less than one tenth that of *Europa Clipper*. The geometry and timing of each Io encounter (Fig. 1) has been carefully designed to accomplish the science objectives.

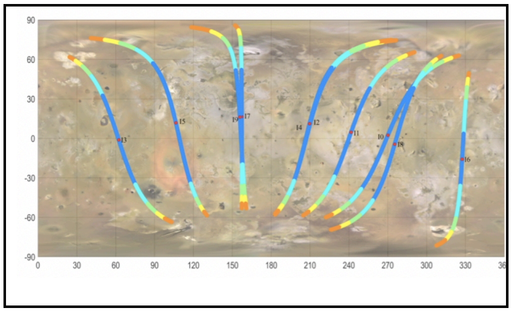

Fig. 1 Plot of groundtracks over Io during closest approach, color-code by range (blue indicates <1000 km).

Science instruments will include a narrow-angle camera nearly identical to that of the Europa Imaging System [8], the Plasma Instrument for Magnetic Sounding [9], dual fluxgate magnetometers from multi-mission heritage at UCLA, a thermal mapper with heritage from *Bepi-Colombo* [10], and a neutral mass spectrometer in development for *JUICE* [11].

4. Science Questions

Key science questions IVO will address are: (A) How and where is tidal heat generated within Io? (B) How is tidal heat transported to the surface, and how is it lost at the surface? (C) How is Io evolving: Are the orbit, volatiles, lithosphere, and interior in a steady state? IVO will test the volcanic heat-pipe model, a fundamental end-member, along with conduction and plate tectonics, for how planets lose heat.

5. Key Measurements

1. Astrometry of Io's orbit: This is a fundamental constraint on tidal heating of the total system along with comparable measurements of Ganymede and Europa [12].

2. Measure tidal amplitude: The tidal k_2 Love number will be much larger if Io has a liquid magma ocean, decoupling the lithosphere [13].

3. Measure Io's libration: The libration amplitude will be much larger if a magma ocean detaches a rigid lithosphere [14].

4. Multi-frequency magnetic induction: measure the global average lithospheric thickness and global conductivity (from inter-connected melt) of Io's mantle [7]. Plasma measurements [9] and orbits emphasizing high and low magnetic latitudes will provide definitive results. Global conductivity will need to be combined with electrical experiments in the lab to be interpreted in terms of melt fraction [15].

5. Near-global mapping of volcanic and tectonic landforms (<300 m/pixel), hot spots, plumes, and heat flow.

6. Compositional constraints: The lava compositions might be ultramafic [16], which implies a large degree of mantle melting [17].

7. Volcanic eruption style: How lava erupts and cools is key to understanding how Io loses heat. Very high eruption rates are inferred for past eruptions on Earth, Moon, Mercury, and Mars, but only on Io can we observe such eruptions today.

References:

[1] McEwen, A.S. et al. (2014) Acta Astron. 93, 539. [2] http://kiss.caltech.edu/workshops/tidal_heating. [3] Peale, S.J. et al. (1979) Science 203, 892–894. [4] Veeder, G.J. et al. (2012) Icarus 219, 701–722. [5] Khurana, K.K. et al. (2011) Science 332, 1186–1189. [6] Blöcker, A. et al. (2018) JGR SP, 9286–9311. [7] Khurana, K.K. et al. (2009) in Europa, UA press, 571–586. [8] Turtle, E.P. (2016) 3rd Int. Workshop Instr. Planet. Mission., LPI Contr. 1980, 4091. [9] Westlake, J.H. et al. (2016) 3rd Int. Workshop Instr. Planet. Mission., LPI Contr. 1980, 4037. [10] Hiesinger, H. et al. (2007), PSS 58, 144–165. [11] Wurz, P. et al. (2018) EGU2018, 10091. [12] Dirkx, D. et al. (2016) PSS 134, 82–95. [13] Bierson, C.J. and F. Nimmo (2016) JGR Planets 121, 2211–2224. [14] Van Hoolst, T. et al. (2018) Fall AGU abstract P51E-2929. [15] Pommier, A. (2014) Surv Geophys 35, 41-84. [16] McEwen, A.S. et al. (1998) Science 281, 87. [17] Keszthelyi, L. et al. (2007) Icarus 192, 491–503.

IO VOLCANO
IVO
OBSERVER