Io close to thermal equilibrium

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Is Io in thermal equilibrium? Using a set of astrometric observations of the four Galilean moons of Jupiter (Io, Europa, Ganymede, and Callisto) covering the years 1891-2007, astronomers of the Paris Observatory and the Royal Observatory of Belgium have shown that the heat produced by tides deep inside Io compensates for the heat loss at its surface. Tidal dissipation in Jupiter induced by Io's gravitational pull has also been found close to its expected higher limit. This is the first time that tidal dissipation in a giant planet is reliably quantified from astrometry. These results are published in the journal Nature on June 18.

Observed for the first time by Voyager 1 in 1979, Io's strong volcanic activity is most likely a consequence of tides on Io raised by Jupiter, since periodic tidal deformations generate large amounts of heat by friction inside the satellite. A large surface heat flow associated with this geological activity was derived from observations of Io's infrared emission, but it was unknown whether the tidal heat production in the interior is sufficient to explain the energy loss at the surface.

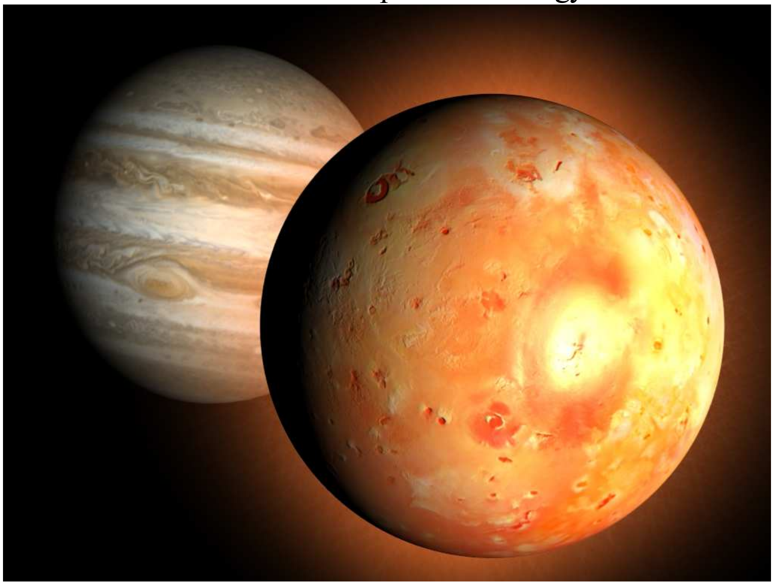

Figure 1: *Artist view of Io's heat loss induced by Jupiter's tides (V.Lainey, copyright: IMCCE-Paris Observatory, CNRS).*

To quantify Io's tidal heat production rate, a team led by V.Lainey and involving astronomers of the Paris Observatory and the Royal Observatory of Belgium has studied Io's orbital energy loss. When tidal heat is produced inside the satellite, Io loses orbital energy and moves deeper into Jupiter's gravitational well. In addition, tidal dissipation in Jupiter tends to move Io outward and to decelerate the orbital motion while the spin of Jupiter decreases, similar to the Earth-Moon system. Therefore, Io's change in orbital motion is the sum of two opposite effects: a deceleration due to dissipation in Jupiter and an acceleration due to dissipation in Io.

The idea that the tidally dissipated energy of Io can be determined from its orbital evolution has been recognized long time ago. Former studies, however, failed to develop a dynamical model of all four orbital Galilean moons accurate enough to reveal tidal accelerations. Using a new dynamical model of the Galilean system and considering astrometric observations (observations of the positions of celestial objects) covering more than a century and including new types of observations of high accuracy such as the mutual occultations and eclipses between the satellites, the team has succeeded to quantify Io's and Jupiter's tidal dissipation from Io's orbital acceleration. They deduced that Io is close to thermal equilibrium. This has significant consequences for interior modeling and, in particular, for the heat transport mechanism. Jupiter's tidal dissipation has also been quantified and found close to the higher limit expected from the long-term evolution of the system. It is the first time that tidal dissipation in a giant planet is derived from astrometry. It demonstrates that strong dissipation can occur in giant planets (that are essentially gaseous), which is a key point to long term evolution of satellite orbits and may have consequences for the study of extra-solar planets.

Figure 2: *(V.Lainey, copyright:*

IMCCE-Paris Observatory, CNRS) Monitoring the Galilean moon orbits has allowed astronomers to obtain significant informations on tidal dissipation in Io and Jupiter.

Reference

Strong tidal dissipation in Io and Jupiter from astrometric observations, V. Lainey, J.-E. Arlot, Ö. Karatekin & T. Van Hoolst, Nature, 18/06/2009.

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