

Does Io Rotate Non-Synchronously? M.P. Milazzo, P.E. Geissler, R. Greenberg, L.P. Keszthelyi, A.S. McEwen, J. Radebaugh, E.P. Turtle. Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721. mmilazzo@pirl.lpl.arizona.edu, and the Galileo SSI Team.

Introduction:

Tidal torques due to Io's eccentric orbit would tend to drive Io's rotation rate to slightly faster than its period of rotation. Greenberg and Weidenschilling [1] suggested that Io might be rotating nonsynchronously because keeping the satellite tidally locked to Jupiter requires a mass asymmetry (mascon) that has problems being explained. Lavas of density $\sim 3000 \text{ kg m}^{-3}$, to tidally lock Io, must be $\sim 3 \text{ km}$ thick, and cover a region of $\sim 100 \text{ km}$ in radius. That is, the mass must be $\sim 3 \times 10^{17} \text{ kg}$. This is for an otherwise spherically symmetric body, so these numbers should probably be higher due to the mountains, other paterae, etc, although the exact figure is difficult to calculate.

Schenk *et al.* [2] have identified a concentration of mountains with respect to the global average at $\sim 65^\circ$ and $\sim 265^\circ$ W longitudes. These concentrations are roughly 65° and 85° off from where the required mascons for synchronous rotation should be. Also, this concentration consists of only about four mountains out of approximately 100, so it is not entirely clear that such a concentration is real or would be an effective mascon. Even if the mountains could provide the required mascon, many of the mountains are quite degraded [3], and the lifetime of the mountains may not be long enough to maintain the asymmetry. The mountains may also be created in a relatively short time, and that, too, would have the effect of re-orienting Io at irregular intervals.

If the interior of Io is molten [4] or partially molten [5] then we should expect there to be a larger amount of heating near the sub- and anti-Jovian points relative to other regions [6]. The surface expression of such heating may be a concentration of volcanic constructs such as paterae or large lava flows. Radebaugh *et al.* [7] have identified a concentration of paterae near 330° and 150° West longitude, about 30° East of the sub- and anti-Jovian points. If the paterae are genetically related to the sub- and anti-Jovian points on Io, this may be evidence for nonsynchronous rotation of Io's crust. However, it is possible that enough high density magmas come from the paterae of volcanic origin to provide the necessary mascon to lock Io into synchronous rotation. It may be that the paterae concentrated $\sim 30^\circ$ East of the sub- and anti-Jovian points were actually created near those points and rotated to the East. Such a large offset would require that Io is (or was at one time) rotating nonsynchronously [1]. This

nonsynchronous rotation may be detectable between the Voyager and Galileo observations.

Measuring Io's rotation rate from the position of the terminator

The nominal terminator on a spherical planet is a great circle, 90° from the sub-solar point. For a body with no atmospheric scattering, such as Io, the terminator marks a sharp boundary between sunrise and sunset. A constraint on the rotation rate of Io may be obtained by measuring the distances from the terminator of features in the Galileo images and comparing these with the measurements of the same features in the Voyager images. Hoppa *et al.* [8] used a pair of images from Voyager and Galileo which showed similar regions of Io, and which both contained the terminator to constrain the rotation rate of Io. They concluded that Io is rotating synchronously within $0.2 \pm 1.5^\circ$ (over 20 years). The large uncertainties arise from a number of problems, (1) the resolution of the Galileo image was only 4 km/pixel , (2) the distance of the terminator from the reference points in the Galileo image was very large, (3) Io's surface changes can be dramatic on a 20 year time scale, and (4) Io has topography that may interfere with terminator measurements. With the relatively large amount of Io data returned since the work of Hoppa *et al.* [8], it seems prudent to re-do their calculations, as well as incorporating measurements of the limb into the calculation. Images of Io at much better resolution ($.5 - 2 \text{ km/px}$), some near the same area as seen in the work by Hoppa *et al.* [8], are now available from Galileo.

Because the apparent terminator in an image may be shifted from the actual position depending on the contrast stretch of the display, an objective means of determining the terminator position was necessary. This consisted of analyzing the brightness profile across the terminator at various latitudes. The longitude of the terminator is defined by the inflection point where the darkening surface reaches a nearly flat line. The measurements of the terminator were made over a large range of latitudes. A line was fit to these points for each of the images. Nominally, the apparent terminator should be parallel to the nominal terminator.

Once the apparent terminators are determined, points which were in both images were used to measure the distances between the respective terminators. Since differences in viewing geometry, changes occurring over 20 years of activity, etc., can change the apparent

position of features, we used features which were more permanent (*e.g.* mountains, scarps, etc.) than albedo features. The distance between these points was then measured for both the Voyager and Galileo images. From the E5 ephemeris [9], the distance between the apparent terminators is the sum of these distances. The nominal terminators should be ~ 16.08 degrees (~ 511.1 km) apart, if Io were rotating synchronously. Preliminary results indicate that Io may be rotating slightly faster than synchronous. Updated work will be presented.

References:

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