LOKI, IO: GROUNDBASED OVSERVATIONS AND A MODEL FOR PERIODIC OVERTURN. J. A. Rathbun[1] and J. R. Spencer[2], [1]University of Redlands (1200 East Colton Ave., Redlands CA 92373, USA *julie_rathbun@redlands.edu*), [2]Southwest Research Institute (1050 Walnut St., Suite 400, Boulder, CO 80302, USA).

Introduction: Io is the most volcanically active body in the solar system and Loki is the largest and most powerful volcano on Io. The Galileo spacecraft was only able to observe Loki at high resolution on a few occasions, so most of the data on Loki is from groundbased observatories. Loki's infrared brightness has been measured from the ground on approximately a monthly basis since 1989 (Spencer et al., 1990). Using that data, Rathbun et al. (2002) found that from 1989 through 2001 Loki's eruptions were periodic, not merely episodic as previously thought, with a period of 540 days (Figure 1; with more recent data added). They suggested that the periodicity could be the result of overturn of a gravitationally unstable solid crust on a liquid lava lake. If this model is correct, the 200 km diameter of Loki places it in an interesting and important size regime, bridging the gap between typical terrestrial lava lakes, that are two orders of magnitude smaller, and global asthenospheric convection, which is two orders of magnitude larger. Similarities between the behavior of lava lakes and plate tectonics are widely known, but Loki behaves differently. Plate tectonics on Earth is a continuous process. Similarly, the crust on most terrestrial lava lakes is in constant motion (while active). Loki is active for only approximately 230 days out of every 540 day cycle. This is somewhat similar to the proposed global activity on Venus, where the planet's entire surface is overturned approximately every 500 million years (Turcotte, 1993). Obviously, Loki's overturn timescale is much smaller but since it can be studied directly it may indirectly yield information about Venus.

Data: Davies (2003) found that a high resolution NIMS observation of Loki in 2002 was consistent with the model proposed by Rathbun et al. (2002). However, groundbased data taken with IRTF in 2002-2005 are not consistent with the previous periodicity (Figure 1). These data are taken by observing Io as it is occulted by Jupiter. During occultation, a series of images is taken. The brightness of Io is determined photometrically from each image after the sky and Jupiter are subtracted (Rathbun, et al., 2003). When Io's flux is plotted as a function of time, a stair-step pattern emerges, where each step gives the flux of a particular volcano. Loki is located on the Jupiter-facing hemisphere and is generally the largest step seen in the lightcurve. The height of this step, fitted with a model of Jupiter's atmosphere, gives the brightness of Loki.

Prior to 2001, measurements of Loki's brightness were generally either "high" or "low". For most of 2001 and 2002, Loki's brightness remained at a moderate value, suggesting that Loki's behavior changed. Observations taken from late 2002 through mid 2005 appear to show a return to behavior alternating between "high" and "low". Unfortunately, the sparse time resolution of these data make it difficult to detect a periodicity, so we can not tell if the same period has returned. We plan to observe Loki more often in late 2006 and early 2007 in support of New Horizons' Jupiter flyby.

Model: Loki patera is a dark, horseshoe-shaped region with an area of approximately 21,000 square kilometers and a width of 55 km across the dark portion. For simplicity, we model Loki as a rectangular region 390 km long and 55 km wide (as if the horseshoe were straightened). The length is divided into individual rafts, on order of a few meters across. Each day, some rafts sink into the liquid and the surface is renewed. The size of the rafts and rate at which they sink (propagation speed of the overturn) are the only input parameters. Each day, those areas that do not overturn, increase in age by one day. The temperature of every part of the surface is calculated from the ages using the cooling model of Davies (2005). At the end of each day, the total brightness of the lake is calculated assuming blackbody emission.

For reasonable raft sizes, the model is independent of raft size. The propagation speed affects the maximum brightness of a brightening event and the length of time it persists. The brighter the event, the shorter it lasts. The maximum brightness can be approximated, in units of GW/μm/str, as 32 multiplied by the propagation speed (in km/day). The data taken during the 1997, 1998, and 1999/2000 brightening events has the best temporal resolution. We were able to match these data (figure 2) with simple variations of velocity with time (constant and linearly changing).

This silicate model fits the data remarkably well, so we attempted to fit a sulfur model by adjusting the parameters of the cooling model. We found that the observed brightnesses can be matched by increasing the propagation speed dramatically. However, this had the effect of shortening the brightening time below what was observed, ruling out a sulfur lava lake.

We also found that the model could match the data during the 2001 to 2004 period when Loki's behavior

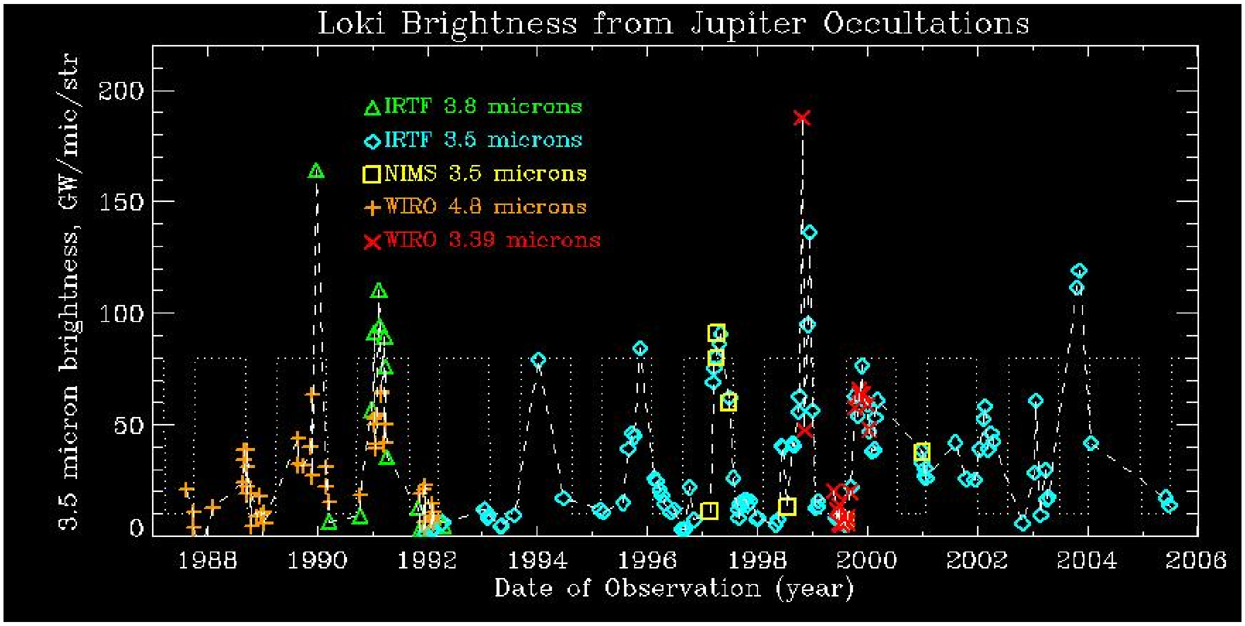

Figure 1: 3.5 µm brightness of Loki as measured primarily from Jupiter occultations. Some of the data were taken at other wavelengths (3.8, 4.8, and 3.39 µm). The 4.8 µm data were translated to 3.5 µm assuming a color temperature of 355 K (Spencer et al., 1992). The 3.39 µm data were translated to 3.5 µm using a color temperature found to be 500 K by equating data taken at both wavelengths at the same time. Similarly for the 3.5 to 3.8 µm color temperature of 500 K. Also included are 3.5 µm measurements from Galileo NIMS observations that resolve Loki. The dotted square wave has a period of 540 days to show the periodicity of Loki's brightenings through 2000, and the lack of periodic behavior in 2001 and 2002.

had changed. A speed of 0.6 km/day gives a maximum brightness of 42 GW/µm/str and a time of 650 days to overturn the entire lava lake. This time is approximately equal to the length of time Loki was observed at a brightness between 30 and 45 GW/µm/str.

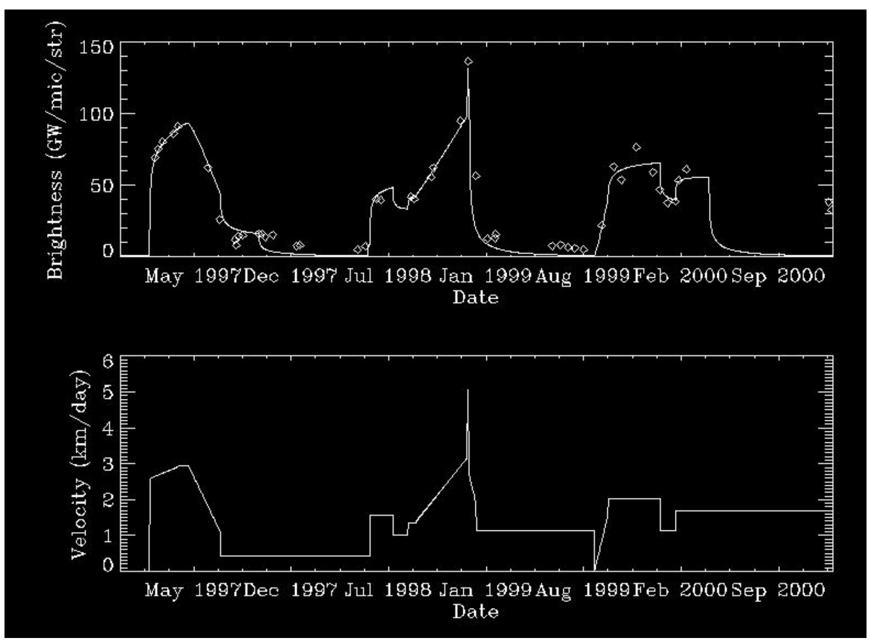

Figure 2: Top shows modeled (line) and observed (diamonds) brightness variations in Loki during the three events between 1997 and 2000. Bottom shows the imput variation of propagation speed with time.

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