LOKI, IO: GROUNDBASED OBSERVATIONS AND A MODEL FOR PERIODIC OVERTURN. J. A. Rathbun, *University of Redlands, 1200 East Colton Ave., Redlands CA 92373, USA*, J. R. Spencer, *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 unable to observe Loki at high resolution, except at night using the Near-Infrared Mapping Spectrometer (NIMS) and the Photopolarimeter-Radiometer (PPR) and only 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 [1]. Using that data, Rathbun et al. [2] 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 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 [3]. Obviously, Loki's overturn timescale is much smaller but since it can be studied directly it may indirectly yield information about Venus.

Data The groundbased 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 with the sky and Jupiter subtracted [4]. 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.

While in previous years measurements of Loki's brightness were generally either "high" or "low", more recent data (approximately 2001 to the present) show Loki to have a more moderate brightness. It appears that Loki's behavior changed, no longer erupting periodically. However, the average 3.5 micron power output remained unchanged. When calculating Loki's average brightness over each 540 day cycle we see that with the exception of 1992 (when few observations were made and the brightening event was appearantly missed) and 2004, the average brightness remains fairly constant, 36 $\pm$ 7 GW/str/micron. However, measurements made in October and November 2003 clearly show a much brighter Loki, signaling the beginning of a new eruption, out of phase with previous eruptions (Figure 1). The average brightness for the 2003-2004 cycle is 90 GW/str/micron, significantly higher than that in previous years. Is this merely the beginning of a new brightnening, or has Loki's behavior changed once again? More data is needed to make a determination.

Model Davies [5] found that higher resolution NIMS data taken in 2002 were consistent with the model proposed by Rathbun et al. [2], which, in turn, was based on the high resolution PPR data of Loki. The first step to understanding the change at Loki is understanding what was happening at Loki while it was behaving periodically, which we take to be the period between 1989 and 2002. The lava lake model [2] was based on the temperature variation across the patera seen in the PPR data, which was then also seen in the NIMS data. Here we expand on that model to see if it can also quantitatively match the 3.5 μm brightnesses measured from the ground.

Loki patera is a dark, horseshoe-shaped region with an area of approximately 2.1×10^4 km^2 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 temperature is assumed constant across the width and to vary linearly along the length, similar to what was seen at Loki in the high resolution PPR data [6]. The western margin has the oldest material, 540 days, and the eastern margin the youngest, 150 days. The ages come from the groundbased observations, which showed that the brightenings occur approximately every 540 days with an average of 150 days of dormancy (Rathbun et al., 2002). Using the cooling model of Howell [7], these ages are converted to lava temperatures. For each day, we determine the total brightness of Loki at 3.5 μm, simulating what would be seen from the ground. First, a random number generator determines if the oldest one kilometer long piece of solidified crust will sink that day. If it doesn't, every piece ages one day. If it does, another random number generator determines the age of that piece when it is observed (less than one day) and then ages the remaining pieces by one day. This continues for the entire 540 day period. The test for overturn is adjusted until the average velocity of the overturn wave is approximately 1 km/day. Several sample runs of this model are shown in figure 2. It is difficult to compare the model data to the observational data because of the difference in sampling timescale, but they appear qualitatively similar. The next step in the modelling is to adjust the width of the overturning chunk to see if it gives a better match to the data.

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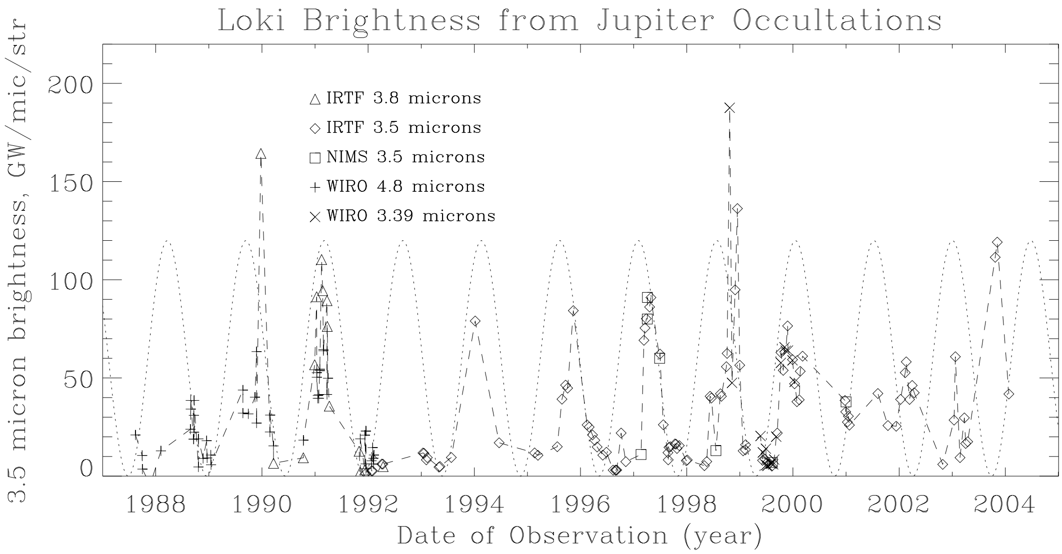

Figure 1: *3.5 μm brightness of Loki as measured primarily from Jupiter occultations. Some of the data were taken at other wavelengths (3.8, 4.8, and 3.39 μm). The 4.8 μm data were translated to 3.5 μm assuming a color temperature of 355 K. The 3.39 μm data were translated to 3.5 μm using a color temperature 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 sine wave has a period of 540 days to show the periodicity of Loki's brightenings through 2000, and the lack of periodic behavior since then.*

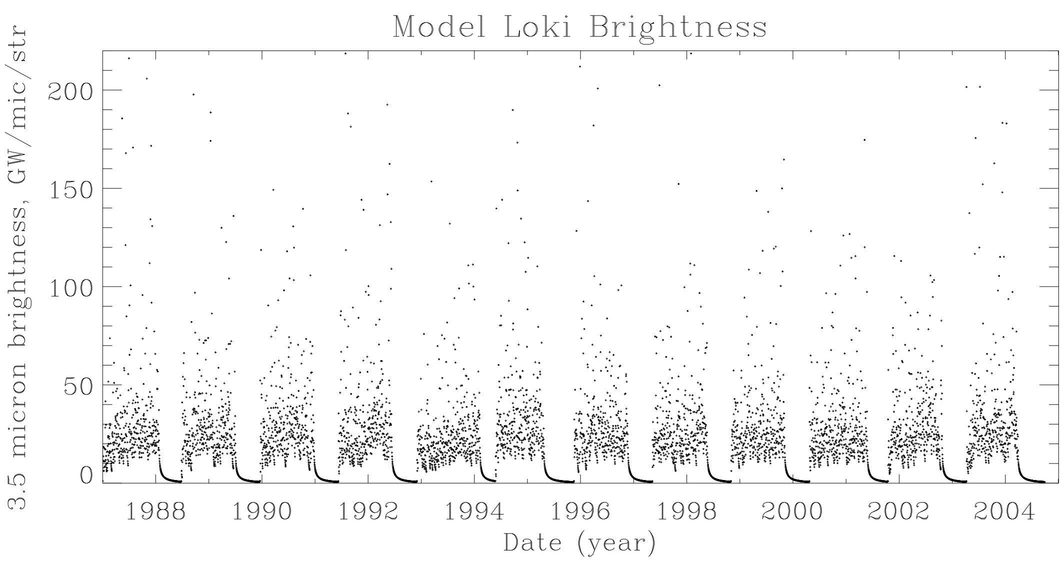

Figure 2: Modelled brightnesses during twelve 540 day periods (+) for comparison to observed brightnesses. Each period shows a different model run.