

VOLCANIC ACTIVITY ON IO DURING 1999: THE WYOMING MONITORING PROGRAM.

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Introduction: During 1999 we obtained frequent ground-based measurements of volcanic activity on Io using the Wyoming 2.3-m telescope. These measurements, covering the 1.2 - 4.8 μm wavelength range, provide a context within which to interpret the Galileo spacecraft observations obtained during this period. Although not discussed here, additional measurements at longer wavelengths have also been obtained as part of various collaborations involving the MIRAC and MIRLIN cameras at IRTF. The ground-based measurements which are discussed here provide: 1) a detailed history of the activity at Loki which began another brightening in 1999, 2) detection of a relatively rare major outburst on August 2 for which we obtained an accurate location, and 3) time variability of the "9906A" event which was occurring at the time of the Galileo C21 flyby.

The Nature of the Data: The most detailed information regarding individual hot spots comes from occultations of Io by Jupiter while the satellite is in eclipse. Photometry of the satellite produces a lightcurve where each step corresponds to the disappearance or reappearance of a discrete hotspot -- with the magnitude of the step giving the brightness and the timing giving constraints on the location. For example Figure 1 shows such a $\approx 3.44\text{-}\mu\text{m}$ occultation lightcurve curve obtained on October 10, 1999, approximately 24 hours before the Galileo I24 flyby. The major step at 188 seconds is the disappearance of Loki while the small step at 22 seconds is Kanehekili. Other faint sources can be seen to disappear between these two times.

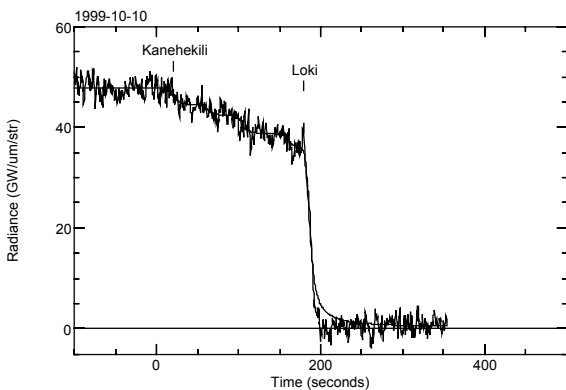


Figure 1. As the in-eclipse Io moves behind Jupiter, discrete volcanic hot spots disappear one by one.

In addition to the occultation lightcurves, general eclipse photometry and rotational lightcurves have been obtained.

The 1999 Loki Brightening: Loki is known to undergo occasional brightenings which typically last several months. One such brightening occurred in 1998 and another one began between Aug. 25 and Sept. 8 of 1999. Figure 2 shows a determination of the brightness of Loki as a function of time as measured from occultation curves like Fig. 1 then corrected to "vertical emission". (The calibrations used here are preliminary and additional data are available but not yet reduced.) At this relatively short wavelength the flux observed is a measure of the areal flow rate averaged over a few day period [1].

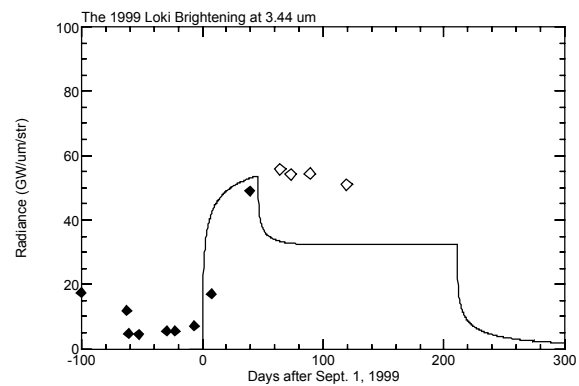


Figure 2. The 1999 Loki brightening. The closed circles are data from occultation disappearances while the open ones are occultation reappearances. The line is a model fit to the 1998 Loki brightening, as discussed in the text.

During this brightening the flux has reached a steady level by approximately October 10. The slight increase between then and November 4 may be real, but could also represent a deviation from the assumed cosine(emission angle) law combined with the geometry shift resulting from the change to observing occultation *reappearances* after Jupiter opposition. In any case the activity has been remarkably stable during November and December.

The solid line shown in Figure 2 is not a fit to *this* brightening, but rather to the one observed during 1998. Unlike that earlier one, the 1999 brightening does not show a turn-on transient then a decline to a steady level. However the 1999 activity level does match the initial 1998 value remarkably well. The *average* 1998 intensity was less than typically seen in

previous brightenings, while the 1998 duration was longer. It will be interesting to see if the more typical intensity of the 1999 brightening comes with a more typical duration. If so, it might indicate that there is a characteristic erupted *volume* for these events.

Observations at longer wavelengths, when interpreted in terms of standard flow models [1] again indicate that this year's Loki brightening can be modeled reasonable well with steadily spreading and cooling flows.

The August 2 (9908A) Outburst: Outbursts are defined as events where the 5- μm in-sunlight flux from Io more than doubles. Several have been seen since the late 1970's, but most were observed with techniques which did not allow an unambiguous determination of location on the satellite. A major outburst observed on August 2 is readily apparent in an in-sunlight occultation reappearance on that date, and probably in the earlier in-eclipse occultation disappearance. This allows the location to be fixed. That location when combined with Galileo data should allow us to determine the nature of these dramatic but enigmatic events. The outburst may also be connected with the enhanced radiation observing during the Galileo C22 flyby 12 days later.

The outburst was bright enough that its signature was obvious even in sunlight at short wavelengths. Figure 3 shows the whole-disk brightness of Io as a function of sub-earth longitude, as the source rotates into view. The data are modeled assuming a cosine(emission angle) dependence and a source location at 71°W longitude near the equator. A blackbody fit indicates a source with diameter approximately 26 km and a temperature of 1000K.

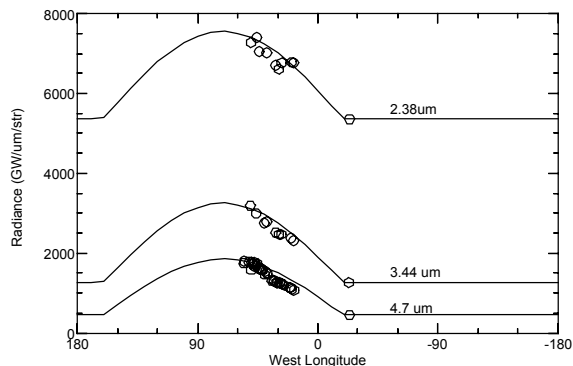


Figure 3. The August 2 outburst source rotates into view. Data are plotted versus sub-earth longitude so time increases to the left. The gap near 0° is due to the occultation by Jupiter.

Figure 4 shows the in-sunlight occultation reappearance with the very large step at the beginning being the reappearance of the outburst source and the smooth increase after that being the reappearance of the sunlit disk. If the outburst source had not been close to the limb it would have appeared even brighter. In the earlier in-eclipse disappearance it was even closer to the limb and therefore relatively faint. If the proper source in that disappearance has been identified, then the location is fixed.

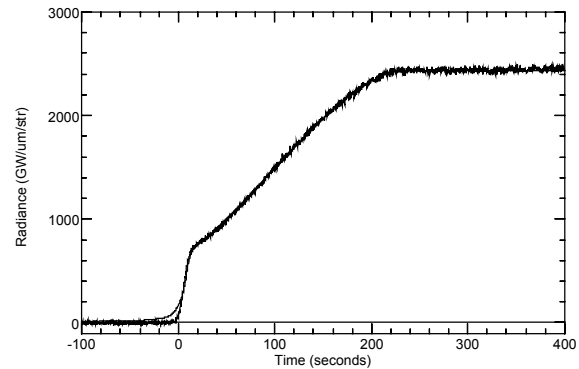


Figure 4. The August 2 in-sunlight occultation reappearance.

The well determined reappearance time gives a location which must lie between the double lines on the map in Figure 5. The less certain disappearance time gives a location along the single line. The intersections (using a somewhat preliminary ephemeris) is at (+9, 71W), with the errors less than 5° if the disappearance identification is correct.

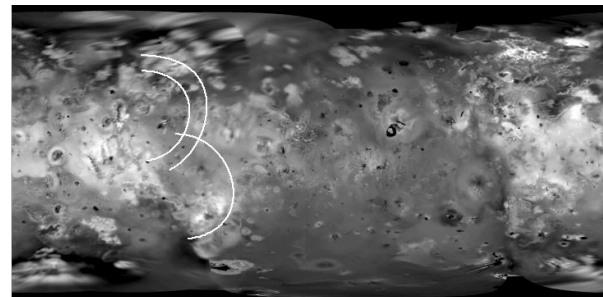


Figure 5. The location of the 9908A outburst lies between the double lines and probably along the single line, which intersect near (+9, 71W).

The 9906A event and the C22 encounter: Observations obtained on June 29 and July 1 show that the bright 9906A event originally detected on June 22 by John Spencer was still active at the time of the C21 flyby, although it had faded considerably during the intervening week.

References: [1] Howell, R. R. (1997) *Icarus*, 127, 394.