ACTIVE VOLCANOES ON IO: PUTTING GROUND-BASED OBSERVATIONS OF JUPITER OCCULTATIONS INTO THE PDS. J. A. Rathbun[1], R. R. Howell[2], and J. R. Spencer[3], [1]Planetary Science Institute (1700 E. Fort Lowell Rd., Tucson, AZ 85719, rathbun@psi.edu), [2]University of Wyoming (1000 E. University Ave. Laramie, WY 82071), [3]Southwest Research Institute (1050 Walnut St., Suite 300, Boulder, CO 80302).

Introduction: Most studies of the temporal and spatial variability of Ionian volcanoes have been forced to rely exclusively on spacecraft data, primarily Galileo [1-4], because only spacecraft data is generally available on the PDS in physical units and with relevant location information. However, ground-based observations, while at a lower spatial resolution, give the longest temporal baseline and often the highest temporal resolution of any data set. It was, for example, only the ground-based data that allowed the discovery of the semi-periodic nature of Loki, the most powerful volcano on Io [5]. Many fundamental questions about Io's volcanoes have not been addressed because the ground-based data have not been available in an accessible public archive.

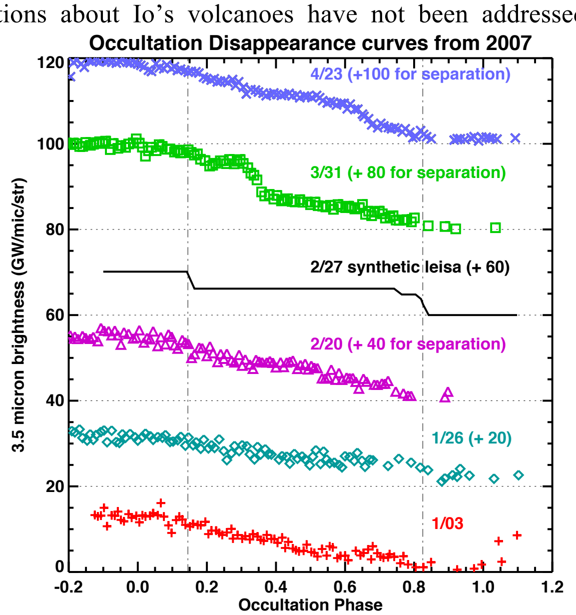

Figure 1: In-eclipse occultation disappearance lightcurves of Io obtained during the New Horizons era. Each symbol represents the total brightness of Io from a single image. Different symbols indicate different nights and are offset along the y-axis for clarity, with the relative 0-point shown as a dotted horizontal line. The x-axis indicates the time the image was taken relative to the occultation event. An occultation phase of 0.0 is the time at which the occultation begins and an occultation phase of 1.0 is the time at which the occultation ends. Each step down in the lightcurve indicates that at least one active volcano disappeared behind Jupiter at that time. The height of the step is the brightness of that volcano. The one-dimensional location of the volcano is given by the projection of Jupiter's limb on Io when the step occurs (figure 3).

Ground-based data: For more than two decades we have been observing Io from the Infrared Telescope Facility (IRTF) on Mauna Kea in Hawaii. We have observed more than one hundred occultations of Io's Jupiter-facing hemisphere, while in eclipse, at 3.5 microns. During each approximately 5 minute long occultation event, we take as many images as the instrument allows (generally into the hundreds). During the period of June 1997 through the end of 2005, ground-based data were obtained on dates clustered around Galileo flybys of Io. In late 2006 and early 2007, we resumed our observations in conjunction with the New Horizons flyby of Jupiter [6] and in 2013 in conjunction with observations of the Jupiter system by JAXA's EXCEED and NASA's Juno [7-8].

Figure 1 shows the occultation lightcurves obtained on five dates in 2007 near the time of the New Horizons flyby. Each night's occultation is shown in a different color and is offset for clarity. An occultation phase of 0.0 is the time at which the occultation begins and an occultation phase of 1.0 is the time at which the occultation ends. Each step in the lightcurve indicates a volcano or volcanoes disappearing behind Jupiter. The height of the step indicates the volcanic output and its timing gives a one-dimensional location. The solid line is a synthetic lightcurve created using observations of active volcanoes using New Horizons LEISA [9]. In the weeks leading up to and including the flyby, Io's Jupiter-facing hemisphere was particularly dim without much activity. An eruption began sometime between the flyby and the March 31st observations. The dashed vertical lines indicate the time at which two of Io's most active volcanoes would be observed: Kanehekilli/Janus and Loki [10]. Kanehekilli and Janus are close enough to each other that these observations cannot distinguish between them.

Loki: Loki is the most continuously active and powerful volcano on Io. It is observed in nearly every one of our occultation lightcurves. During most of its history, Loki has erupted periodically (figure 2) and we have developed a quantitative model of Loki as an overturning lava lake [5, 7, 11]. More recent observations suggest that the period of Loki's brightenings has shortened from 540 days to 420-470 days [12]. If this periodicity remains consistent for the next brightening, it should begin in late May 2018.

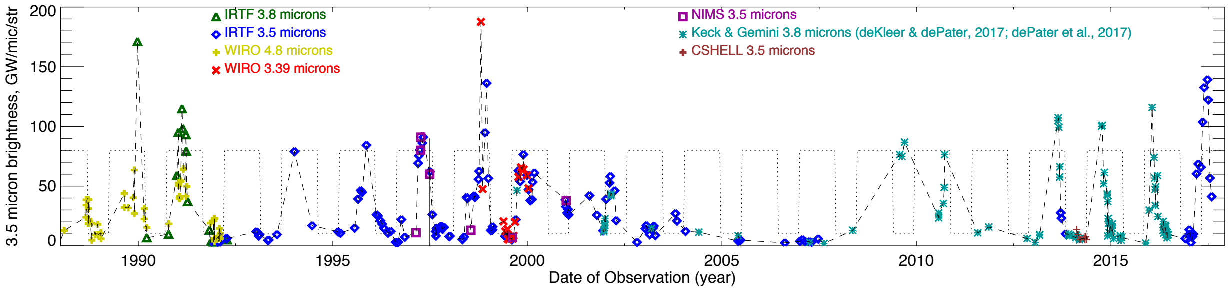

Figure 2: Measured brightnesses of the Loki volcano. Each point on this plot comes from a single observation of a Jupiter occultation.

Other volcanoes: In addition to the persistently observable volcanoes, the past twenty years of observations have yielded more than 40 measurements of the brightness of "short-lived" volcanic events. Locations and brightnesses for 28 of these events, which occurred between 1996 and 2002, have been published [10]. Based on these measurements, we have determined that most volcanoes vary by a factor of only 2 to 3 [10]. Figure 3 shows the one-dimensional locations of three volcanoes observed just after the New Horizons flyby. Also shown are volcanoes observed by the New Horizons LEISA instrument, with the size of the red circle indicating the brightness measured [9]. Since these volcanoes were observed by ground-based observations only after the flyby, it is unclear if they were also observed by LEISA.

PDS: We will create an ASCII file for each lightcurve, with standardized filenames and formatting, in order to post on the Planetary Data System (PDS) so that others can use these data. Each text file will consist of 3 columns: time, occultation phase, and brightness of Io (in W/micron/str). We will also share programs for plotting the location of Jupiter's limb at any given time onto a map of Io (as in figure 3) and for determining the occultation phase of a volcano at any latitude and longitude.

Besides occultations of Io by Jupiter, occultations by other Galilean satellites (mutual events) occur every six years and the spatial resolution these provide is not degraded by the presence of the fuzzy Jupiter atmosphere. We will also be placing in the PDS our observations of mutual events from 1985 through 2015.

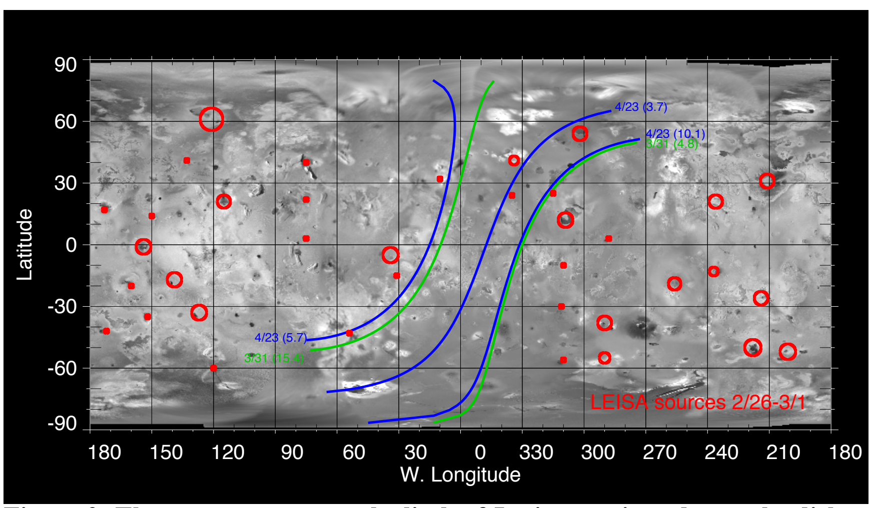

Figure 3: The curves represent the limb of Jupiter projected onto the disk of Io at the time of volcano disappearances in the occultation lightcurves obtained during the New Horizons era (besides Loki and Kanehekili/Janus). Each line corresponds to a step measured in an occultation curve in figure 1. The green line shows volcanoes observed on 3/31 while the blue line shows volcanoes observed on 4/23. The number in parentheses indicates the 3.5-micron brightness of the volcano.

References:

[1] Davies, A. G. et al. (2012) *Icarus*, **221**, 466-470. [2] Davies, A. G. et al. (2012) *GRL*, **39**, doi:10.1029/2011GL049999. [3] Veeder, G. J. et al. (2012) *Icarus*, **219**, 701-722. [4] Hamilton, C. W. et al. (2013) *EPSL*, **361**, 272-286. [5] Rathbun, J. A. et al. (2002), GRL, 29, 84-1 to 84-4. [6] Rathbun, J. A. and Spencer, J. R. (2009) LPS XXXX, Abs. #2177. [7] Rathbun, J. A. et al. (2014) *Icarus*, **231**, 261-272. [8] Rathbun, J. A. and Spencer, J. R. (2017) DPS 49, abstract #407.01 [9] Tsang, C. C. C. et al. (2014) *JGR*, **119**, 2222-2238. [10] Rathbun, J. A. and Spencer, J. R. (2010) *Icarus*, 209, 625-630. [11] Rathbun, J. A. and Spencer, J. R. (2006) GRL, 33, doi:10.1029/2006GL026844. [12] Rathbun, J. A. and Spencer, J. R. (2017) DPS, id#407.01.