Description of the Io occultation lightcurve dataset

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1. Dataset Overview

The Io occultation lightcurve dataset consists of observations of Io while it is in eclipse and being occulted by Jupiter. The observations are obtained in the L' prime (3.5 micron) band at the InfraRed Telescope Facility (IRTF) in Mauna Kea using one of 3 instruments: NSFCam, SPEX, or iShell. For SPEX and iShell, we used the guiding camera to obtain images of Io. In-eclipse, all of the energy at near-infrared wavelengths is endogenic to Io and, therefore, originates from the surface volcanoes. As a result, the occultation lightcurves appear as step functions with each step indicating the occultation of one or more volcanoes with a total brightness equal to the height of the step. The timing of the occultation can be used to determine the location of Jupiter's limb on Io and, thus, the one-dimensional location of the active volcano being measured (Spencer et al., 1990). Figure 1 shows an example occultation disappearance curve from June 30, 1997 (Rathbun and Spencer, 2010).

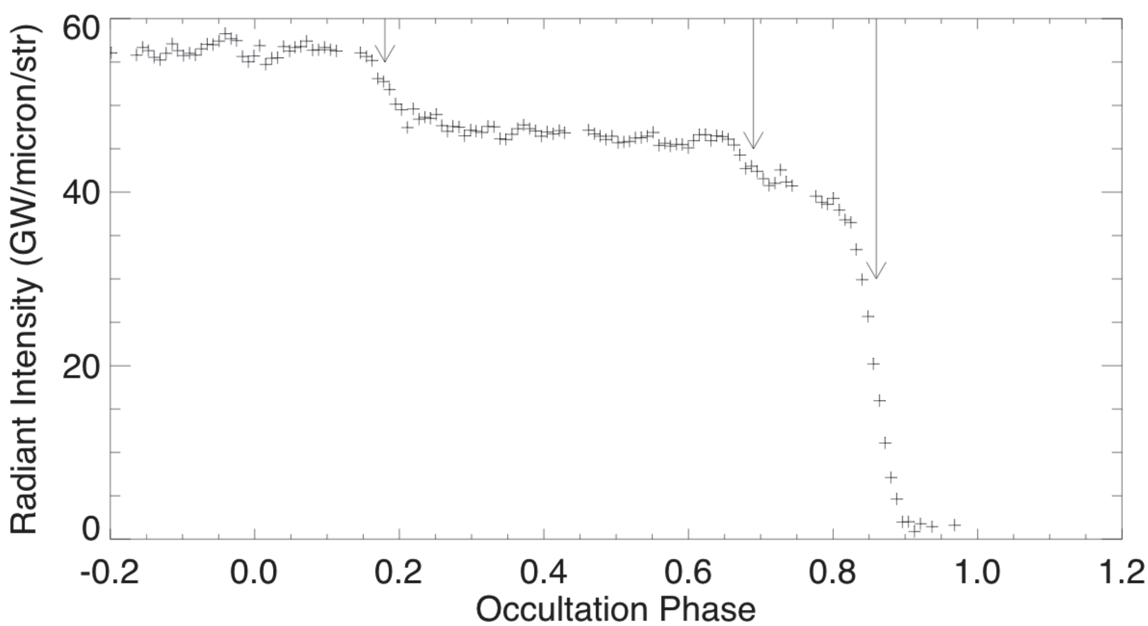

Figure 1: In-eclipse occultation disappearance lightcurve of Io obtained on June 30, 1997. Each plus sign represents the total brightness of Io from a single image. The x-axis indicates the time the image was taken relative to the occultation event. An occultation phase of 0.0 is the time at which the 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. At least three different active volcanoes can be observed in this lightcurve, as indicated by the arrows. From Rathbun and Spencer, 2010.

These data are being archived with the planetary data system (PDS) for future use in planetary volcano studies. 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. Here, the data is made available to the entire scientific community, not just those who have the specialized tools to deal with arcane photometric calibration and timing/ephemeris/location information.

This archive uses PDS4 archiving standards. An overview of PDS4 is provided in the PDS4 Concepts document (*PDS4 Concepts*, 2015) and the standards are specified in the PDS4 Standards Reference (*PDS4 Standards Reference*, 2015).

2. Data Collection

The data were collected at the IRTF in Mauna Kea. We collect images of Io as Jupiter is occulting it. Depending on the season, either the occultation disappearance or reappearance will occur while Io is in eclipse. The eclipsed occultation is the one we observe. During the approximately 5 minute occultation we collect nearly 100 images (depending on the instrument used). Our observing runs last a total of 90 minutes and include observations of Io in eclipse and relevant standard stars. We average ~10 observations per year with high variability. In 2017, for example, we successfully observed 17 Io occultations while in 2013 it was only 3.

We have used NSFCAM, and the guide cameras for both SPEX and iShell. NSFCAM was our preferred instrument, since it was a camera, but has not been in operation for several years (mid-2010s). SPEX and iShell give similar results, and, by using both we increase our opportunities to be assigned telescope time. For each occultation, we determine calculate an average image of Jupiter using images where Io is completely occulted. We subtract this Jupiter image from each image obtained in order to have an image of just Io. Figure 2 shows an example image before Jupiter subtraction. We then determine the brightness of Io each of the images. We use the observed standard stars to convert from instrument data number (DN) to physical units of GW/micron/str.

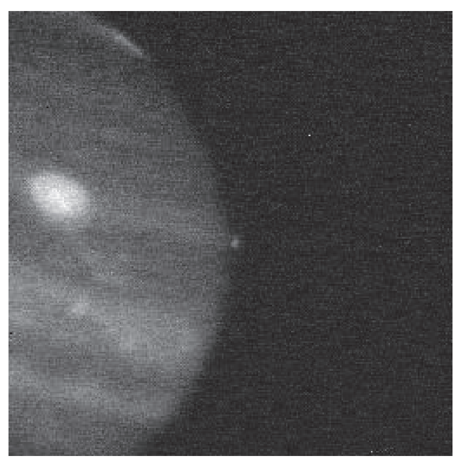

Figure 2: Image of Io and Jupiter after sky subtraction and flat fielding. Note that there is an apparent gap between Io and Jupiter due to Jupiter's terminator not being coincident with the limb.

3. Data Product Structure

The primary PDS4 product for this dataset consists of two files for each occultation observed: the PDS4 label and the data table. The PDS4 label (*.xml) is a XML file that contains metadata about how the data in the table were acquired and information on the physical structure of the table. The data table contains 3 columns of information, described below. The name of each file gives the date of the observation with the first 2 digits giving the year (anything above 85 is in the 1900s, the rest are in the 2000s), the next 2 the month and the final 2 the day of the month.

Data Table Column Descriptions

Each table contains a different number of rows, but there are generally approximately 100 rows per file. Each row describes an observation and has 3 columns with a combined total of 38-characters.

Colums:

C-1. Time of day (Characters 1-12) in decimal hours

C-2. Occultation Phase (Characters 13-24) is defined as 0 when Io's limb first touches Jupiter's limb and as 1 when the occultation has concluded. For occultation disappearances, this means that 0 indicates a fully visible Io, but touching Jupiter and 1 indicates a completely occulted Io. For a reappearance, 0 indicates a completely occulted Io just about to begin to reappear and 1 indicates a fully revealed Io.

C-3. Brightness (Characters 25-36) – the total measured brightness of Io in units of GW/micron/str

4. Archive Structure

This archive uses the PDS4 archiving standard (*PDS4 Concepts*, 2015; *PDS4 Standards Reference*, 2015) for the archive structure and product labels. In PDS4 every object in the archive is a product, meaning that it has a detached PDS4 label expressed in XML and an associated data object.

All PDS4 products are uniquely identified by a combination of a logical identifier (LID) and a version identifier (VID). The LID and VID are separate attributes in a PDS4 label. However, they can be combined together into a versioned identifier (LIDVID) to uniquely identify and locate a particular version of a particular product throughout the entire PDS inventory. The LID for this project has the form of:

urn:nasa:pds::: <bundle_id>:<collection_id>:<product_id>

where:

urn:nasa:pds notes that this is a PDS4 product
<bundle_id> is taken from the bundle LID
<collection_id> is taken from the collection LID
<product_id> is a string to uniquely identify the product within its collection.

The LID for this version of MGC3 is:
urn:nasa:pds:io_mko_irtf3m0_volcanoes_rathbun_2018:data:XXXXXXtab.txt
where:
io_mko_irtf3m0_volcanoes_rathbun_2018 is the bundle_id
data is the collection_id
XXXXXtab.txt is the product_id, where XXXXXX is a six digit number that represents the year, month, and day of the occultation

The product PDS4 label file has the same name but with XML for the file extension. The XML file contains the name of the instrument used at Mauna Kea with the tag <Observing_System_Component> with <type>Instrument.

Acknowledgements:

5. References

Planetary Data System, Standards Reference, Version 1.4.0 (2015). Available at: https://pds.nasa.gov/pds4/doc/sr/current/StdRef_1.4.0_150922.pdf

Planetary Data System, PDS4 concepts, Version 1.4.0 (2015). Available at: https://pds.nasa.gov/pds4/doc/concepts/Concepts_150909.pdf

Rathbun, J. A. and Spencer, J. R. (2010) Ground-based observations of time variability in multiple active volcanoes on Io. Icarus, 209, 625-630.

Spencer, J.R., Shure, M.A., Ressler, M.E., Goguen, J.D., Sinton, W.M., Toomey, D.W., Denault, A., Westfall, J. (1990) Discovery of hotspots on Io using disk-resolved infrared imaging. Nature 348, 618–621.