TVASHTAR AND OTHER ACTIVE IONIAN VOLCANOES FROM NEW HORIZONS MVIC AND LORRI DATA . J. A. Rathbun[1], L.W. Kamp[2] , R. M. Lopes[2] and J. R. Spencer[3], [1]Planetary Science Institute (1700 E. Fort Lowell, Tucson, AZ 85719 *rathbun@psi.edu*), [2]Jet Propulsion Lab (4800 Oak Grove Drive, Pasadena, CA 91109), [3]Southwest Research Institute (1050 Walnut St., Suite 300, Boulder, CO 80302).

Introduction: The New Horizons spacecraft flew by the Jupiter system on its way to Pluto. Its closest approach to Io occurred on February 28th, 2007 at a range of 2.24 million km. For more than 3 days, the spacecraft was within 3.5 million km, close enough to obtain high quality observations covering all longitudes of Io.

Three data sets obtained at Io are particularly useful for studying active volcanoes. The Long-Range Reconnaissance Imager (LORRI), a high-resolution black and white camera, obtained 190 images, including several of an eclipsed Io. The Multicolor Visible Imaging Camera (MVIC), a four-color (visible to near infrared) camera, obtained 17 sets of images. The Linear Etalon Imaging Sprectral Array (LEISA), a near-infrared imaging spectrometer, obtained 7 image cubes. Spencer et al. [1] already searched the data for plumes and surface changes. However, no complete search and analysis of active volcanic hotspots has been performed.

One obvious source of activity during the New Horizons flyby was at Tvashtar [1] where a large plume is seen in many of the images. The hotspot at the source of the plume is also visible. Spencer et al. [1] used the LEISA instrument to measure a temperature of 1160-1200 K and and area of 40-80 km^2 for the hotspot. Milazzo et al. [2] summarized Galileo-era observations of Tvashtar. High-resolution images in November 1999 showed active fountains and flows with a brightness temperature of 1300-1400K over an area of 25 km^2 based on fire fountain extent. February 2000 observations measured brightness temperatures of 1220-1240 K in small areas (~0.1 km^2) at the end of a flow and 1300 K in the larger (~6.3 km^2) flow area. Fire fountains were not observed in February 2000.

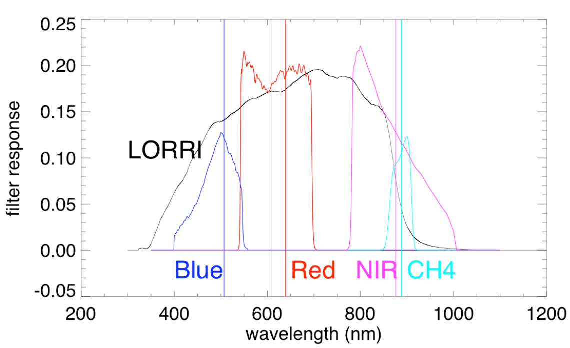

Figure 1: Response function for each filter in MVIC and LORRI. Vertical lines indicate the effective wavelength for a 1200 K blackbody corresponding to each filter.

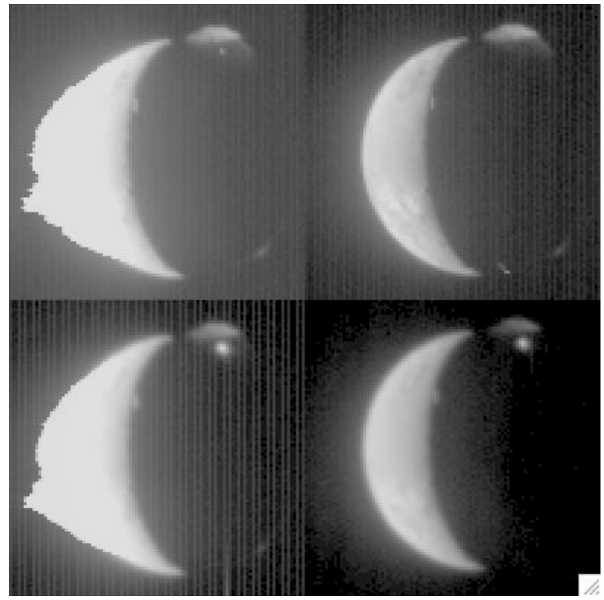

Figure 2: MVIC observation of Io showing Tvashtar hotspot and plume in the upper right of each image. The upper left image is in the red filter, upper right in blue, lower left in NIR, and lower right in methane.

MVIC observations: The MVIC camera takes 4 images sequentially in four different filters. The Total spectral response for each filter is shown in figure 1. This preliminary curve includes the filter response, mirror transmissivities, and CCD quantum efficiency for the camera. For each filter we calculated the isophotal wavelength (defined as the wavelength at which the monochromatic flux is the same as the total flux through the filter) for a 1200 K blackbody (vertical lines in figure 1). The band passes of the near infrared (NIR) and methane (CH4) filters are too similar to yield meaningful color temperatures.

Because the instruments were optimized to work at Pluto, many images of Io are overexposed in some places. Figure 2 shows the best set of images of Tvashtar with a logarithmic stretch. Note that the hotspot cannot be seen in the blue filter (upper right). We measured the total brightness of the hotspot in each image (in DN) and determined the color temperature based on the ratio of observed brightnesses to be 1160 +/- 60 K for the Red/NIR ratio and 1200 +/- 100 K for the Red/CH4 ratio. We also took into account updated calibration information provided by the New Horizons team based on in flight observations of standard stars. Tvashtar appears in a second set of images (NIR and CH4 filters only), but is located very close to the limb

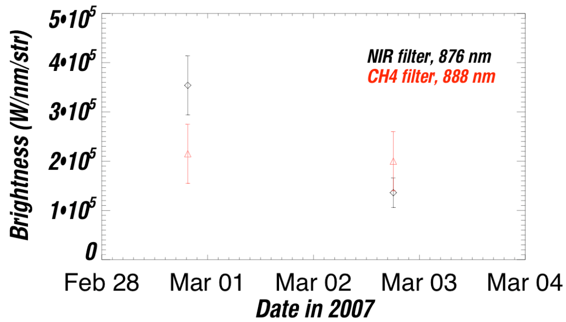

Figure 3: Brightness of East Girru hotspot from MVIC images.

of Io, making measurements of the brightness substantially lower precision due to the hot spot's faintness.

After examining LORRI and LEISA data sets, Spencer et al. [1] found a new bright hotspot at 22 N 245 W that they call East Girru. We identified this hotspot in two sets of MVIC images, but only in the NIR and CH4 filters. Since the filters are too similar for the ratio to yield meaningful results, we took the measured total brightnesses and transformed them to physical units. Figure 3 shows the resulting brightnesses as a function of time for each of the observations. No meaningful changes were detected over the 2 day observing period.

LORRI observations of Tvashtar: Nine images obtained over 2 days clearly showed the Tvashtar Plume and hotspot, thus making identification of the hotspot trivial. We again measured the total brightness of the hotspot in each image. Next, we coverted these brightnesses into physical units, and, assuming a temperature, were able to calculate the area of the hotspot. The observations were obtained at different emission angles (figure 4). Fire fountains were previously observed at Tvashtar. However, the brightness of fire fountains, with their considerable vertical extent, should not vary dramatically with emission angle. As long as it is not being occulted (by, for example, patera walls, or the sides of cracks), the brightness of surface flows should vary as the cosine of the emission angle. The data (figure 4) show a roughly cosine dependence and are thus most consistent with surface flows. Assuming a temperature of 1200 K, a flow of 40 km^2 at 1200 K best matches these data.

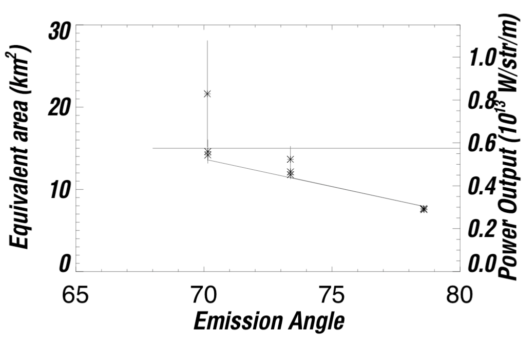

Figure 4: Brightness of Tvashtar as measured in LORRI observations as a function of emission angle. The horizontal line indicates behavior expected for a fire fountain while the curve segment shows the cosine dpendence expected for surface flows.

Combining LORRI and MVIC observations of Tvashtar. Figure 5 shows the total brightness of Tvashtar (in physical units), corrected for emission angle, from the MVIC observation and the LORRI observation obtained 10 minutes later. Two blackbody fits are shown. Blackbodies with widely varying temperatures (200 K) and areas (100 km^2) can be fit to the data, within the errors.

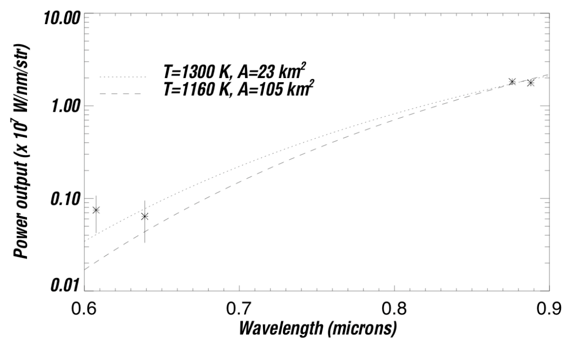

Figure 5: Brightness of Tvashtar as a function of effective wavelength as measured from LORRI and MVIC observations. Two blackbody curves are also shown.

Conclusions: The MVIC data show that neither the East Girru nor the Tvashtar eruption varied dramatically in two days. Furthermore, the emitting surface at Tvashtar appears to be horizontal (ie., not a fire fountain) and away from the patera walls. The Tvashtar eruption was similar in temperature to earlier eruptions of Tvashtar, yet the areal extent is much larger than previous surface flows and only slightly larger than the earlier fire fountain eruption.

Future Work: The spatial resolution of the LORRI observations is high enough that the location of the Tvashtar eruption can be measured and tracked over 2 days. We plan to do this, accounting for the non-spherical shape of Io for maximum precision. We will examine the LORRI observations, especially the eclipse observations, and identify other active volcanoes, determine their location and measure their brightness. Finally, we will measure temperatures of hotspots by combining data from all 3 instruments: MVIC, LORRI, and LEISA.

References: [1] Spencer, J.R. et al. (2007) Io Volcanism Seen by New Horizons: A Major Eruption of the Tvashtar Volcano, *Science*, **318**, 240-243. [2] Milazzo, M.P. et al. (2005) Volcanic Activity at Tvashtar Catena, Io, *Icarus*, **179**, 235-251.