ACTIVE IONIAN VOLCANOES FROM NEW HORIZONS: COMBINING DATA FROM LORRI, MVIC AND LEISA. J. A. Rathbun[1], R. M. Lopes[2], R. R. Howell[3], C. C. Tsang[4], and J. R. Spencer[4], [1]Planetary Science Institute (1700 E. Fort Lowell, Tucson, AZ 85719 rathbun@psi.edu) and University of Redlands (1200 E. Colton Ave., Redlands, CA 92374), [2]Jet Propulsion Lab (4800 Oak Grove Drive, Pasadena, CA 91109), [3]University of Wyoming (1000 E. University Ave., Laramie, WY 82071), [4]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 many 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 Spectral Array (LEISA), a near-infrared imaging spectrometer, obtained 9 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 previously been performed. Here we report on the progress of the first such effort.

LORRI observations: With a wide-band filter covering approximtely 400 to 900 nm, LORRI data are most useful for detecting high-temperature eruptions, changes in brightness with time, and, due to the higher spatial resolution, precisely locating emission sources. Many of the images captured a partially daylit disk that could be used to fit Io's limb and, thus, determine locations of any hotspots with great accuracy (within 50 km in most cases).

The images obtained during the two eclipses detected the most thermal emission sources. The seven brightest volcanoes were observed multiple times at a very high temporal resolution (approximately 1 second apart): Isum, E. Girru (a new hot spot detected by New Horizons [1]), Mulungu, Riden, Pele, Marduk, and and unnamed volcano at 28 N, 192 W. No significant changes were detected on timescales of seconds to minutes. Fainter volcanoes were observed by co-adding multiple observations from the same eclipse.

Galileo SSI observed 44 emission sources over the entire globe [2]. We located 54 total hotspots in the LORRI images which covered only 60% of the surface (missing longitudes 30 to 170 W). Thus, LORRI detected twice as many emission sources as SSI. Most of the persistent Galileo spots were observed by LORRI with the exceptions of Acala and Loki, suggesting that

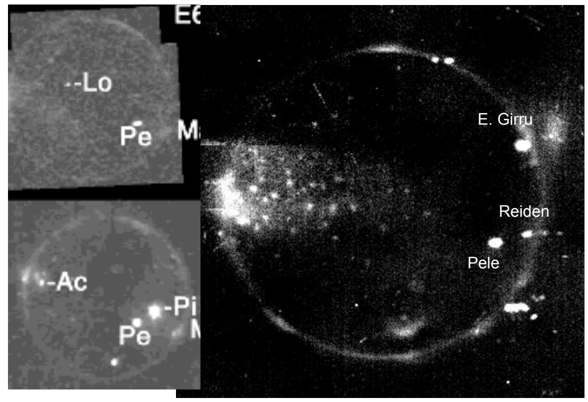

Figure 1: Eclipse images from Galileo SSI (left two) and NH LORRI (right).

these volcanoes stopped producing high-temperature eruptions. Dazhbog and Llew were observed by LORRI but not Galileo SSI, but were confirmed hotspots from other Galileo instruments, indicating that something new (perhaps a new high-temperature eruption) is occurring at these locations.

Most of the faint emission sources were located near volcanic pateras, though not necessarily dark pateras. Many of these spots were extended and located in areas of extended eclipse emission (figure 1),

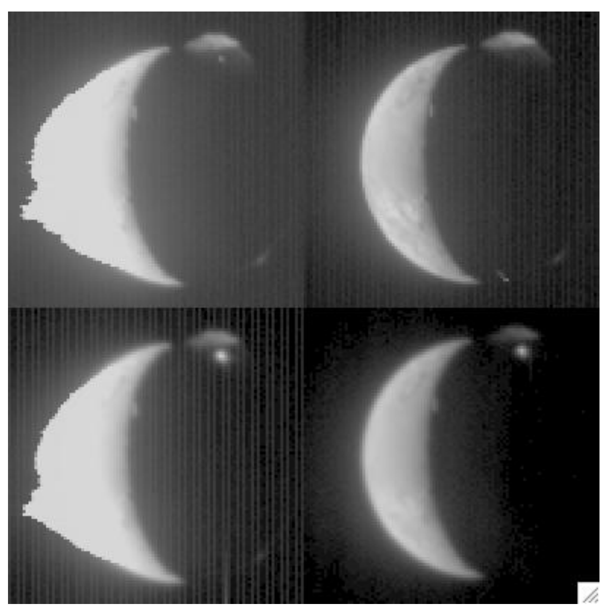

Figure 2: MVIC observation of Io showing Tvashtar hotspot and plume in the upper right of each image. The upper left image is in the red filter, upper right in blue, lower left in NIR, and lower right in methane.

suggesting an atmospheric phenomena rather than volcanic emission at these locations. Similar bright areas were observed in eclipse by both Galileo SSI and Cassini ISS.

MVIC observations: The MVIC camera takes 4 images sequentially in four different filters. The total spectral response for each filter is shown in figure 3. These preliminary curves include the filter response, mirror transmissivities, and CCD quantum efficiency for the camera. To use the multicolor data to determine color temperatures, for each filter we calculated the isophotal wavelength (defined as the wavelength at which the monochromatic flux is the same as the mean 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.

Due its lower sensitivity and spatial resolution, only 2 hotspots were detected by MVIC: Tvashtar (figure 2) and E. Girru. We measured the total brightness of the hotspot in each image (in DN) and converted to absolute flux, taking into account updated calibration information provided by the New Horizons team based on in flight observations of standard stars. We determined the color temperature of Tvashtar 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. E. Girru was detected in only the NIR and CH4 filters which are too similar for the ratio to yield meaningful results (figure 3). We attempted to use the measured LORRI brightness as a third constraint on surface temperature, but the filter responses are too similar to yield meaningful results.

LEISA observations: With a spectral range of 1.25 – 2.5 microns, LEISA data are most useful for measuring the power output of hotspots and determining temperature and area fits to the spectra. LEISA covers the wavelength region between 1.25 and 2.5 µm, at a resolving power of 240, with a higher resolving power segment (R=540) covering 2.1 to 2.25 µm. Both segments share the same detector array to give on a 256 x 256 pixel spectral image with a resolution of 62 µrad per pixel. Nine data cubes were obtained, three while Io was in eclipse. Spencer et al. [1] identified more than 30 individual hotspots in these data, and determined temperatures of Tvashtar, Pele, and E. Girru to be between 1287 and 1335 K.

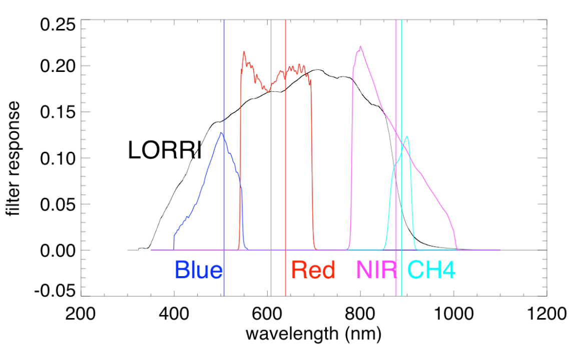

Figure 3: Response function for each filter in MVIC and LORRI. Vertical lines indicate the effective wavelength for a 1200 K blackbody corresponding to each filter.

We have completed analysis of one of the non-eclipse images (IHIRESIR04) and extracted spectra for 11 hotspots. Five of the resulting spectra had signal-to-noise too low to enable blackbody fits. The remaining 6 hotspots (Tvashtar, Amirani, Prometheus, Tupan, Malik, and Zamama) yielded preliminary fits with temperatures ranging from 700 to 1600 K.

Results: Unlike the vast majority of Ionian hotspots, the E. Girru spot does not correlate with a low albedo feature. We have analyzed the highest resolution Galileo SSI and NH LORRI images and can detect no surface changes at the location identified for the hotspot. Perhaps the eruption began recently and is too small to be identifiable in images. However, new eruptions are often accompanied by plumes and no plume was observed by NH at this location.

While no short time-scale variations in brightness were detected, most of the hotspot brightnesses did vary over the 3 days of observations. The variations in Tvashtar's brightness with emission angle were consistent with surface flows, as opposed to the fire fountains observed by Galileo [3].

Future Work: We will complete the analysis of the remaining LEISA images and obtain spectra and blackbody fits for the observed hotspots. We will use the LEISA obervations to determine which of the emission sources observed by LORRI are actually thermal hotspots. We will determine if the MVIC and LORRI brightnesses can yield further constraints on the hotspot temperatures when combined with the LEISA spectra.

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] Lopes, R.M.C. et al. (2007) Appendix 1 in *Io After Galileo*, Lopes and Spencer, eds. [3] Milazzo, M.P. et al. (2005) Volcanic Activity at Tvashtar Catena, Io, *Icarus*, **179**, 235-251.