New Horizons/LEISA Observations of the Icy Galilean Satellites. J.P. Emery[1], W.M. Grundy[2], A. Lunsford[3], C.A. Hibbitts[4], C.B. Phillips[5], R.M.E. Mastrapa[5] [1]University of Tennessee (jemery2@utk.edu), [2]Lowell Observatory, [3]The Catholic University of America, [4]Johns Hopkins University/Applied Physics Lab, [5]SETI Institute.

Introduction: The icy Galilean satellites of Jupiter – Europa, Ganymede, and Callisto – rank among the highest priority targets for planetary exploration. Such a high level of interest is evidenced in the selection by both NASA and ESA of these moons as targets of upcoming flagship-class missions. The surfaces of these three large moons are fascinating laboratories of planetary evolution, having arisen in the same circumplanetary accretion disk but under slightly different conditions. Each is also scientifically intriguing in its own right. Europa, in particular, receives a lot of attention because its subsurface ocean may be the most likely extraterrestrial habitable environment in the Solar System [e.g., 1].

Years of observations with Earth-based telescopes and spacecraft remote sensing have provided a vast amount of information about the icy Galilean satellites. Yet, many gaps remain in our knowledge. These include issues relating to the communication between the surface and subsurface, the source, distribution, and composition of the low albedo material, and the effects of the different radiation environments. These issues in turn have direct implications for the accessibility and potential habitability of subsurface liquid environments. We present compositional characterization of the surfaces of Europa, Ganymede, and Callisto using data from the Linear Etalon Imaging Spectral Array (LEISA) on the New Horizons spececraft, which flew through the Jupiter system in early 2007.

Background: Early ground-based disk-integrated photometry and spectroscopy indicated that the surfaces of Europa, Ganymede, and Callisto were covered in H_2O ice [e.g., 2,3,4]. Decreasing albedos from Europa to Callisto suggested an increasing abundance of low albedo material. The 3-μm band on Callisto is distinct in that it is narrower than on the other two moons, perhaps due to very fine grains or coatings scattering a significant fraction of sunlight before it can be absorbed, or to a hydrated or organic component of the low albedo material. Phase curves of the satellites from ground-based and Voyager data revealed macroscopic roughnesses for Ganymede and Callisto similar to that of the Moon, a more compacted surface on Europa, and textural difference between the leading and trailing sides of the satellites [5].

NIMS on the Galileo spacecraft revealed that the 1.5- and 2.0-μm H_2O band shapes on Europa were distorted for some regions of the surface, particularly the trailing side [6]. Two main hypotheses have arisen to explain the distorted bands. The first attributes the band shapes to hydrated salts, the source of which may be a subsurface ocean [6,7]. This endogenic hypothesis is exciting for the astrobiological implications of a salty ocean and communication between that ocean and the surface. The second hypothesis attributes the band shapes to hydrated sulfuric acid, which is suggested to form as a result of irradiation of a surface containing sulfur delivered from Io [8,9]. Complicating matters, mixtures of amorphous and crystalline ice can mimic some of the band-shape distortion [10]. The spectral resolution of NIMS was insufficient for a detailed examination of the narrow 1.65-μm band, which is particularly sensitive to amorphous/crystalline variations.

Though far less prevalent than on Europa, distorted H_2O bands were also identified on Ganymede [11]. The distribution of the distorted band material is not clear, partly because a large region of Ganymede's surface (~330 to 100^o W longitude) was not observed by NIMS. Several other minor bands detected in NIMS data are attributed to C-H (3.4 μm), C≡N (4.57 μm), and S-H (3.88 μm) [12], suggesting an organic component to the low albedo material.

None of the material that distorts the H_2O bands appears to be present on Callisto. The surface is dominated by low albedo material and water ice. A ~4.26 μm CO_2 band that was detected on Europa and Ganymede is both stronger and more widespread on Callisto [13]. The C-H, C≡N, and S-H features seen on Ganymede are even stronger in spectra of Callisto [12].

Outstanding Questions: The brief summary above gives rise to several outstanding questions concerning these bodies:

1. *What is the composition and origin of the material that is responsible for the distorted H_2O bands?*
2. *What is the composition of the low albedo material(s)? Is there a single low albedo material throughout the Jovian system, or is it unique in each environment?*
3. *How are the main compositional units (crystalline and amorphous H_2O ice, distorted band material, low albedo material) and minor species affected or controlled by the geology and irradiation patterns?*
4. *What is the structure of the upper few millimeters of the surfaces of these icy bodies?*
5. *What is the timescale of spectroscopic change (due to textural or composition changes) on each satellite?*

Table 1. *Geometry of LEISA observations of Europa, Ganymede, and Callisto*

Target Sequence name	2007 UT date/time (m/d h:m)	Target range (10^6 km)	Sub-spacecraft Lon. (deg.)	Sub-spacecraft Lat. (deg.)	Pixel scale (km)	N_{spec} (on-targ)	Phase angle (deg.)
Europa							
Ecomp01	2/25 18:52	4.1	168 W	8 S	251	120	20
Ecomp02	2/26 19:13	3.3	91 E	8 S	200	180	22
Ebest01	2/28 01:28	3.0	13 E	6 S	180	230	71
Ganymede							
Gcomp02	2/26 08:25	5.0	19 W	6 S	303	220	29
Gbest01	2/27 11:15	3.5	39 W	6 S	212	470	65
Callisto							
Ccomp01	2/25 17:48	6.7	3 W	5 S	409	100	18
Ccomp02	2/27 05:03	4.8	5 W	5 S	290	210	46
Cbest01	2/28 03:25	4.2	4 E	4 S	254	270	76

The New Horizons Jupiter flyby data are well-suited for addressing these questions.

LEISA data from the Jupiter flyby: The New Horizons spacecraft is racing toward a 2015 rendezvous with Pluto. During a flyby of Jupiter in February 2007, imaging and spectral observations were made of the Jupiter system, including the icy satellites. LEISA is a spectral imager that covers 1.25 to 2.5 μm at a spectral resolution (R=λ/Δλ) of ~240, with a second segment covering 2.1 to 2.25 μm at R~560. These are higher R than obtained with NIMS, particularly at Europa where increased radiation noise necessitated effectively smoothing the data in both spectral and spatial dimensions [e.g., 14], and are ideally suited for the compositional characterizations described above.

During the Jupiter flyby, three global observations of Europa were conducted with LEISA. The sub-spacecraft pixel scales were 251, 200, and 180 km, respectively, resulting in ~120, ~180, and ~230 individual on-target spectra. The three observations obtained broad surface coverage, including portions of the leading and Jupiter-facing hemispheres that were not well mapped by Galileo/NIMS. LEISA performed two scans of Ganymede during the flyby, with sub-spacecraft pixel scales of 212 and 303 km, obtaining ~470 and ~220 individual on-target spectra. Surface coverage is not as extensive as for Europa, but the observations are centered on a region that was not observed by NIMS. Three scans of Callisto all observed the Jupiter facing hemisphere at different times of day and different phase angles. The sub-spacecraft pixel scales of 409, 290, and 254 km resulted in ~100, 210, and 270 on-target spectra. The highest spatial resolution scans of each satellite were made near quarter phase, so only ~2/3 of the on-target spectra are of the sunlit side. Four LEISA scans of Io serve to check that any newly detected icy satellite features are not instrumental artifacts. Several LEISA eclipse scans were also made, but those data will not return useful surface spectra, so will not be used in this study. Each LEISA scan was accompanied by a LORRI frame to capture an image of the target at the same geometry.

Initial Results: LEISA has a different design than other previous or current imagin spectrometers [15]. Two-dimensional images are taken through a linearly varying filter, such that each row of the image has a different wavelength. A spectral cube is built up by using spacecraft motion to scan the FOV over the target. This procedure creates several processing challenges that must be dealt with. Our main focus to date has been addressing these processing challenges. Nevertheless, some initial science has begun to emerge.

The LEISA spectra of Europa are dominated by broad absorptions at ~1.5 and 2.0 μm and a smaller band at 1.65 μm, all of which vary dramatically across surface. A map of distortion of the 1.5 and 2.0 μm bands shows band distortion centered on the trailing side, as also seen in previous such maps. On Ganymede, in a region not mapped by Galileo/NIMS, New Horizons identifies distorted bands that appear to be correlated with low-albedo material in this sub-jovian region of the surface.

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