COMBINING GALILEO SSI AND NIMS SPECTRA FOR EUROPA. Cynthia B. Phillips[1] and J. Brad Dalton[2], [1]Carl Sagan Center, SETI Institute, 515 N. Whisman Rd., Mountain View, CA 94043; phillips@seti.org, [2]Jet Propulsion Laboratory, MS 183-301, Pasadena, CA 91109-8001, James.B.Dalton@jpl.nasa.gov

Introduction: Prior to spacecraft exploration, ground-based observations of Jupiter's moon Europa revealed that the surface had the spectral signature of water ice [1,2]. Later observations, by the Voyager and Galileo spacecraft, have shown that the surface can be divided up into two main geological and colorimetric/spectral units [3]. Most of the surface has a bright, whitish color that is attributed to relatively pure water ice. However, various geological features such as ridges and chaotic terrain, as well as some impact craters, have a darker, reddish color associated with some non-ice component. Spectral models based on data from the Galileo spacecraft's Near-Infrared Mapping Spectrometer (NIMS) instrument suggest two primary candidates for the composition of the non-ice material: salts such as sodium and magnesium sulfate hydrates [4,5] or sulfuric acid hydrate and associated materials [6, 7]. Most models assume that the non-ice material is endogenic in origin, but some investigators have suggested that exogenic processes may also play a role [8, 9, 10], such as radiolysis of sulfur products ejected from Io and implanted on Europa's surface.

Most spectral models to date have focused either on NIMS data, or on broad conclusions from SSI color data. We are currently combining the SSI and NIMS datasets, by performing a scattered light correction to provide a quantitative calibration to the SSI color data to allow for direct comparisons with NIMS. Our preliminary work shows interesting results that can come from the broad wavelength range of the combined dataset, and also illustrates the importance of the scattered light correction.

Overlapping observations: We have begun our research by cataloguing and mapping all the Galileo SSI color observations. We have found Galileo NIMS observations that cover areas also covered by SSI. Galileo SSI filters range from 0.414 to 0.990 microns [11]. Galileo NIMS nominally provided wavelengths from 0.7 to 5.2 microns [12]. For most NIMS observations, radiation noise limits the usable range to 0.7 to 2.5 um. Detectors 3 and 8, covering respectively the 1-1.3 and the 2.4-2.7 um wavelength ranges, became inoperative during the mission but this does not limit hydrate concentration determinations [10]. Distant observations of Europa suffered less radiation noise and signals to 5.2 um are usable, but at low spatial resolution. In I24, the NIMS grating drive failed due to cumulative radiation effects. The resulting fixed-wavelength channels from NIMS's multiple detectors still permit estimation of hydrate distributions.

Galileo SSI-NIMS Synthesis and Comparison: The overlap in wavelength coverage between the Galileo NIMS and SSI observations provides additional means to verify the spliced data sets. Calibrated NIMS observations are available through the PDS. However they still require correction for detector offsets. These arise from nonlinear responses as individual detectors react to changes in light levels between portions of an observation. Some of these offsets can be as much as a few percent of the total irradiance received at the sensor. The discontinuities are more serious for distant Io measurements, for which there are much larger photometric variations. A depatterning method has been developed for use with Io measurements [13], and we are utilizing this method where necessary. For most of the NIMS Europa data we are using custom code that utilizes overlap between the detectors to derive multiplicative correction factors for these offsets. This approach preserves relative band intensities relative to the continuum levels, though slight changes in continuum slope may result.

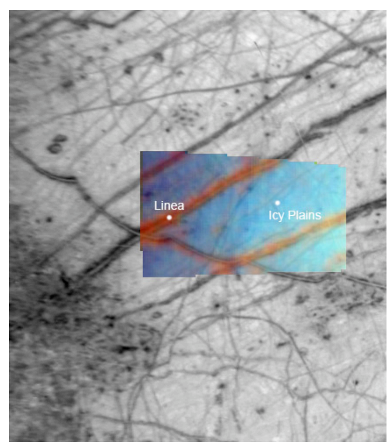

Figure 1: *Composite of Galileo NIMS and SSI data. Three bands of NIMS obs. E11ENCYCLOD01 are superimposed on green-filter data from SSI observation E14GLOCOL01. Points indicate locations where we extracted spectra from the combined dataset (Fig. 2).*

After correcting for offsets, an automated despiking algorithm is applied [14]. This replaces random spikes in the spectrum (caused by charged particle hits on the detectors) by three-dimensional interpolation, and can be set to conservatively retain spikes within 1 to 3 standard deviations from the mean value of neighboring values in both spectral and spatial domains. While this results in some spikes remaining in the final product, it prevents the loss of actual data without incurring the high labor costs associated with manual despiking approaches. Future work will incorporate such approaches as resources become available.

We plan to coregister the SSI data with the Voyager data and the newly calibrated NIMS data to build up a multispectral view of various geological features on Europa (Figure 1). We will use a combination of ISIS routines, and our own IDL algorithms [11]. Once the data have been properly coregistered and reprojected, we will perform spectral classifications using a minimum noise fraction (MNF) transformation. This variation of principal component analysis (available in ENVI, see 15) applies an estimated covariance matrix to the observation prior to the principal components transformation. This allows rapid assessment of similarities and differences between surface units while reducing the influence of random noise.

Having identified the major spectral and spatial units, we will construct spectral averages for each unit in order to maximize the spectral signal of the target materials with respect to background noise. We will then apply linear mixture analysis to determine relative proportions of surface materials such as water ice, sulfuric acid hydrates, magnesium sulfate hydrates, and other hydrated salts and brines. As candidate materials, we will use cryogenic laboratory spectra [5] to supplement existing spectral databases.

The model uses a standard representation of linear (areal) mixtures. The observed spectrum **T**[*j*] can be represented as $\mathbf{T}[j] = \sum_{i=1}^{N} w_i \mathbf{R}_i[j]$, where N is the number of reference spectra **R**[*j*] to be used, and w_i represents the weight coefficient for each of the reference spectra. The weights correspond to the abundances of the reference materials. The model is able to selectively mix the endmembers and vary their proportions, but cannot generate new endmembers. The model is also constrained to avoid unphysical combinations such as negative abundances or a mixture of abundances that sum to anything other than unity. Successive calculations are compared until χ^2 is minimized and convergence is obtained.

Initial Conclusions: An initial comparison of NIMS and SSI data [16] used data from the first few orbits of Galileo around Jupiter. We will extend this work by using the complete Europa color dataset from Galileo. Our preliminary work (Figure 2) illustrates the power of our technique. We have extracted spectra from the combined NIMS and SSI datasets shown in Figure 1. The NIMS data are shown in the curved blue and red lines, and the SSI data are the straight blue and red segments. The NIMS data has a gap in the 1-1.3 micron range due to a failed detector early in the mission, and data beyond 2.5 microns have not been included in this preliminary analysis due to noise. The SSI data has been photometrically corrected but is not yet corrected for scattered light. We have scaled the SSI data to the average NIMS values in the overlap range, and have included 10% error bars on the SSI data points in Figure 2 to indicate the expected variation due to the future scattered light correction [17], still in progress. Figure 2 also includes a laboratory spectrum for one possible hydrated salt, $MgSO_4 \cdot 11H_2O$, suggested as a non-ice component on Europa's surface [5].

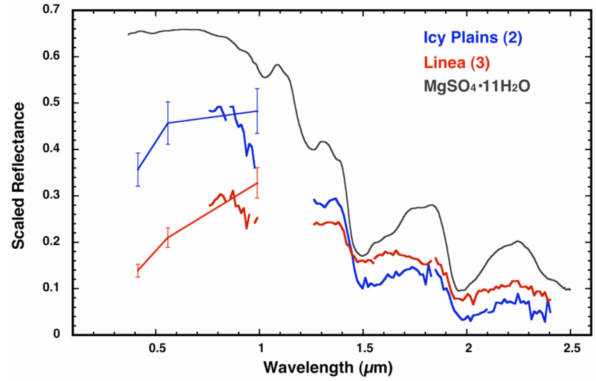

Figure 2: *Preliminary combined spectra from the E11ENCYCLOD01 and E14ESGLOCOL01 observations (Figure 1). Spectra for the icy plains and linea (points from Figure 1), and a comparison lab spectrum, are shown. SSI data is scaled to average NIMS values in the overlap region, and includes 10% error bars.*

Future work: It is clear from this preliminary analysis that the SSI data will provide a valuable addition to comparisons of Europa spectra to laboratory studies of potential surface materials. The SSI data extends the NIMS spectra into an important shorter-wavelength range that provides additional diagnostic spectral information to aid in the identification of the non-ice components of Europa's surface. The discrepancy between the laboratory spectrum and the combined SSI/NIMS spectrum in the visible/near-IR indicates the presence of additional surface components whose spectra can be further constrained by using the SSI color data. The 10% error bars show the projected improvements derived from applying the full scattered light correction on the SSI data to allow correct spectral matching. Having the ability to compare the Europa observations to lab spectra at these additional wavelengths will provide powerful constraints on surface composition, evolution and modification.

References: [1]Pilcher et al., Science 178, 1087-1089, 1972. [2] Morrison, in Satellites of Jupiter, U. Ariz. Press, 1982. [3] Greeley et al., in Jupiter, Cambridge Univ. Press, 2004. [4] McCord et al., JGR 104, 11827-11851, 1999. [5]Dalton et al., Icarus 174, 472-490, 2005. [6] Carlson et al., Science 286, 97-99, 1999. [7] Dalton, GRL 34, L21205, 2007. [8] McEwen, JGR 91, 8077-8097, 1986. [9] Phillips et al., LPSC XXVIII, abs. 1626, 1997. [10] Carlson et al., Icarus 177, 472-490, 2005. [11] Phillips et al., JGR 105, 22579-22597, 2000. [12] Smythe et al., JGR 100, 18957-18972, 1995. [13] Soderblom et al., LPSC XXX, abs. 1901, 1999. [14] Dalton, PhD Thesis, Univ. Colorado, 2000. [15] Boardman et al., 5th JPL Airborne Earth Sci. Wkshp., JPL pub 95-1, v. 1, 23-26, 1995. [16] Fanale et al., Icarus 139, 179-188, 1999. [17] Spaun and Phillips, LPSC XXXIV, abs. 1260, 2003.