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Hydrated minerals on Europa and Ganymede surfaces

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Introduction: We have reanalyzed some of the Near Infrared Mapping Spectrometer (NIMS) data from the Galileo mission that were recently reprocessed [1]. We concentrate here on the water spectral features in the 0.7-3-µm spectral region for Europa [2] and Ganymede.

The water-related spectral features dominate the NIMS reflectance spectra in the 1-3-µm region. Analyses of these features in hemispheric-resolution telescope observations have suggested water ice/frost of several grain sizes mixed with an unknown dark material [3, 4]. From the NIMS measurements, McCord et al., [5, 6] reported highly distorted water absorptions similar to water of hydration features that are preferentially found in disrupted regions (lineaments and chaos) on Europa and they suggested the responsible material was a mixture of heavily hydrated salt minerals such as $MgSO_4$ and Na_2SO_4, perhaps from the ocean below the surface. Carlson [7] suggested hydrated sulfuric acid (H_2SO_4) as a potential single-material explanation for the spectral features and suggested an irradiation process that might convert sulfur implanted from Io in ice on Europa's surface. McCord et al. [8] then suggested that irradiation on the surface would disrupt some Na_2SO_4 (but not $MgSO_4$) [9] and that ubiquitous H^+ in the surface from ice irradiation would substitute for the lost Na^+ and produce H_2SO_4. They suggested that the NIMS spectrum was best duplicated by a mixture of Mg^{++}, Na^+ and H^+ sulfates that are heavily hydrated, supported by Orlando et al. [10], who derived a specific mixture of these components from laboratory studies.

Hydrate Spectrum

For Europa, we first tried to derive the most pure (endmenber) spectrum for the hydrated material by averaging pixels in the center of the lineaments in a high-resolution data set, shown in Fig. 1. The hydrate spectrum in Fig. 2 shows the hydration features more clearly than earlier versions but no fine structure is evident, as might be expected for weakly hydrated but not heavily hydrated salt minerals [11]. There is a weak 1.344-µm feature in the hydrate spectrum that is missing in the ice spectrum. This feature is similar to one present in some hydrated salt spectra [12] and in published sulfuric acid spectra [13], and so may not be diagnostic of specific hydrated minerals; more investigation is needed.

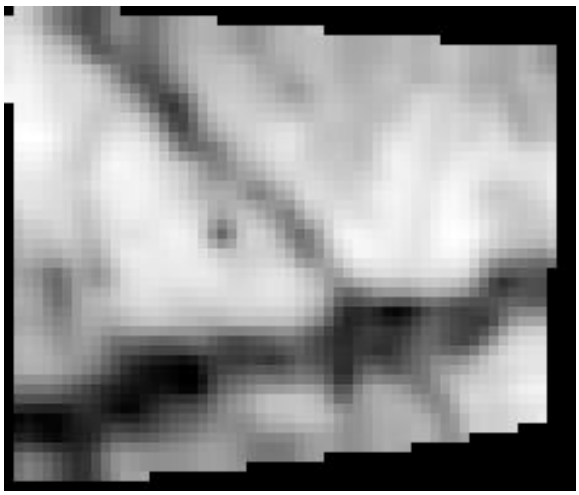

Figure 1: The 0.75-µm image from the e6ensucomp02c (high resolution) NIMS cube that was used in this analysis.

Location of Hydrated material

We also mapped the shape of the water of hydration absorption within the lineaments in the high resolution image cube. Fig. 3 shows that the shape is most hydrate-like near the center of the lineament. We show only one case and one absorption here but we attempted this for three locations and two bands with the same results.

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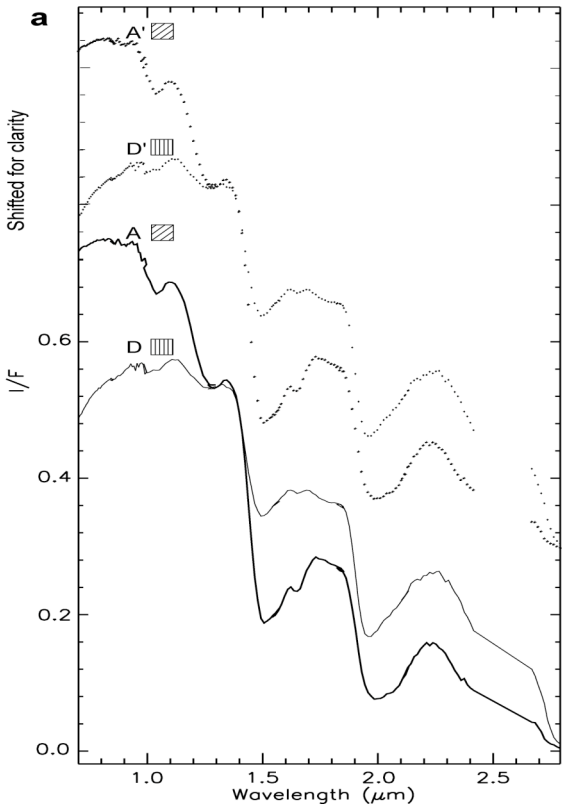

Figure 2: Shown are the endmember spectra for hydrated material and water ice derived from the high resolution NIMS data set shown here. Upper point spectra have points at the NIMS spectral channels and the lower spectra have lines connecting the upper points. A = water ice, D = hydrate material.

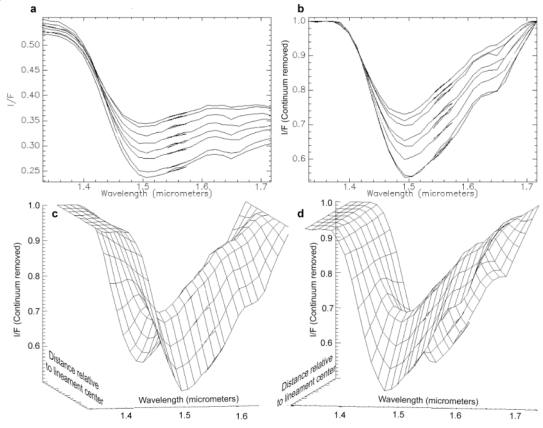

Figure 3: The change in shape of the 1.5-µm water band from ice-like to hydrate-like across the wider lineament for one transect at the lower left of Fig. 1. The spectrum in the 1.5-µm water band spectral region are shown in panel a from the reprocessed cube and in panel b with the "continuum" removed by simply fitting a straight line across the spectral region in an attempt to isolate the band shape from the overall slope of the broader spectral region. In panel c and d are three-dimensional topographic plots shown at two perspectives to illustrate the change in the 1.5-µm water band shape across the lineament. The topo plot axes are: x-wavelength, y-distance across the lineament, and z-band depth at each location across the lineament.

We also modelled both images using a spectral mixing analysis (SMA) approach [13] and found that a low resolution image could be modeled using only the two endmember spectra and their mixtures from Fig. 2, while a high resolution image required use of three additional endmember spectra. Two of these are consistent with water-frost of different grain sizes. The other endmember is found only at the dark circular spot at the left of center in Fig. 1. This suggests different composition at this spot, which might be interpreted as a dome or pit associated with upwelling material.

Following an earlier report of hydrated mineral on Ganymede with spectral signatures similar to those on Europa [14], we are using the improved NIMS spectral data to improve this analysis.

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