COMPOSITIONAL GRADIENTS OF ANTI-JOVIAN SURFACE UNITS ON EUROPA FROM DESPIKED GALILEO NIMS OBSERVATIONS.
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Introduction: Knowledge of Europa's surface materials provides a window into the deep interior and informs our understanding of the subsurface ocean and its habitability. Differences in composition between surface features provide information about the crustal evolution. We report here preliminary compositional results indicating the existence of abundance gradients of hydrated sulfuric acid and hydrated salts across Europa's leading side-trailing side boundary.

Endogenic and exogenic processes: Europa's surface is bombarded by charged particles from Jupiter's magnetosphere [1]. The flux is strongest near the apex of the trailing hemisphere, and weakest on the leading hemisphere [2]. Radiolysis of surface materials and implantation of charged ions affects the surface composition. Aqueous chemistry in the ocean and interactions of fluids with the crust are expected to produce a rich, briny mixture that may have been extruded onto the surface [3]. Radiolytic processing of this material complicates investigation of endogenic materials.

Availability of "new" observations: The Galileo Near-Infrared Mapping Spectrometer (NIMS) has provided much information on the distributions of Europa's volatile ices, radiolysis products, and hydrated materials. NIMS observation 14ENSUCOMP01A covers a structurally complex portion of the anti-Jovian "wedges" region at 1.6 km resolution. We have applied a new despiking procedure to this observation. Along with extensive, diverse and geologically younger terrain, it includes older ridged plains. The study area extends from 169°-185° W longitude, sampling both the leading and trailing sides of Europa.

Despiking process: Significant levels of radiation noise in NIMS Europa observations requires averaging tens to hundreds of spatial pixels to obtain spectra with satisfactory s/n. This impedes isolation of spectral differences for diverse geologic units. We have developed a new approach to the noise removal problem, and applied the resulting algorithms to despike 14ENSUCOMP01A. We now find excellent correspondence of spectra of adjacent exposures of ridged plains materials, using 5 or fewer pixels for averaging.

The radiation noise consists of positive and negative spikes of variable amplitude. We process the raw data numbers of the NIMS observation, rather than the derived radiance or reflectance, minimizing influence of individual spikes. We compare spectra from each NIMS detector with low noise DN reference spectra of Europa obtained during E14 and E15 using a special instrument mode. Large positive spikes can be safely removed since there are no areas of enhanced emission on Europa's cold surface. We remove the obvious spikes iteratively, and produce a new fitted curve based on reference spectra. Fill values are obtained by linear interpolation between adjacent uncontaminated points, or by polynomial fits for areas of significant curvature. Spatial averaging is avoided to retain the maximum amount of recorded data. While largely automated, the process does require significant operator input.

Observational details: Geologic maps based on Galileo Solid State Imager (SSI) observations have been produced for the region, outlining major pull-apart bands, ridged plains, linea, complex ridges, and craters [5]. Europa's ubiquitous ridged plains consist of a dense network of ridges and bands striking in varied orientations with a relatively uniform, high albedo. The plains are crosscut by younger bands and ridges, overprinted by younger chaos terrains and lenticulae, indicating that they represent the oldest surface materials present. Radiation and micrometeoroid bombardment effects are presumably more advanced for ridged plains than for younger terrains. Ridged plains thus represent a baseline for spectroscopic comparisons with geologically younger mapped units, such as impact crater deposits.

Spectral modeling: In linear mixture analysis an observed spectrum is approximated by a linear combination of individual components weighted by their fractional abundances. Here the individual components included synthetic spectra of water ice of various grain sizes, and cryogenic laboratory reflectance spectra of hydrated materials. The synthetic spectra were generated for grain sizes of 5, 10, 25, 50, 75, 100, 250 500, and 750 microns; .1, .25, .5 1, 5, 10, and 50 cm using optical constants of water ice measured at 100K [6] and a radiative transfer program based on Hapke theory [7]. Laboratory spectra included the hydrated sulfate salts epsomite ($MgSO_4•7H_2O$), hexahydrite ($MgSO_4•8H_2O$), bloedite ($Na_2Mg(SO_4)_2•4H_2O$), mirabilite ($Na_2SO_4•10H_2O$), and magnesium sulfate undecahydrate ($MgSO_4•11H_2O$). The latter has received considerable attention recently and was previously believed to be a dodecahydrate [6,9,11]. Also included were spectra of $MgSO_4$, $NaHCO_3$ and Na_2SO_4 brines, and of sulfuric acid octahydrate ($H_2SO_4•8H_2O$). All were measured at either 100 or 120K [6,9] except for sulfuric acid hydrate, measured at 77K [10].

Results: Hydrated materials appear present even in the iciest ridged plains, and water ice is present in the most heavily hydrated materials. While water ice and sulfuric acid alone, or water ice and hydrated salts alone, gave approximate spectral matches, mixtures of all three classes of material always gave the best match. Water ice by itself, even in combinations of grain sizes, could not produce an exact match to any of the extracted spectra. Grain sizes of water ice tended to fall around 75 to 250 microns.

Ridged plains. Five spectra were extracted from icy ridged plains units spanning 15° in longitude, straddling the 180° anti-jovian meridian. All spectral models suggested 40-50% water ice of 75 to 100 microns diameter, with both sulfuric acid hydrate and hydrated salts (Figure 1). A distinct compositional gradient was observed: the amount of sulfuric acid steadily increases toward the trailing hemisphere (Figure 2). Mirabilite, in contrast, decreases towards the trailing hemisphere, suggesting destruction by radiolysis. Whether this could be a source of the sulfuric acid hydrate, as has been suggested [6,10], requires further analysis.

Crater ejecta. The modeled spectrum included both crater floor and dark ejecta. The best model contained 37% fractional abundance of water ice, with a grain size of 100 microns. The model also invoked a substantial 22% sulfuric acid hydrate, implying that the crater and ejecta have undergone radiolytic processing. The remaining 41% of the materials selected by the model were hydrated sulfate salts: 12% mirabilite; 3% hexahydrite, 19% $MgSO_4 \cdot 11H_2O$, and 6.5% $MgSO_4$ brine. This is more than twice the amount of large (≥10 H_2O) molecules in the ridged plains suggesting that it may be geologically recent. The presence of a frozen brine component is suggestive but we feel it is premature to claim detection of impact-modified materials at the present stage of this investigation.

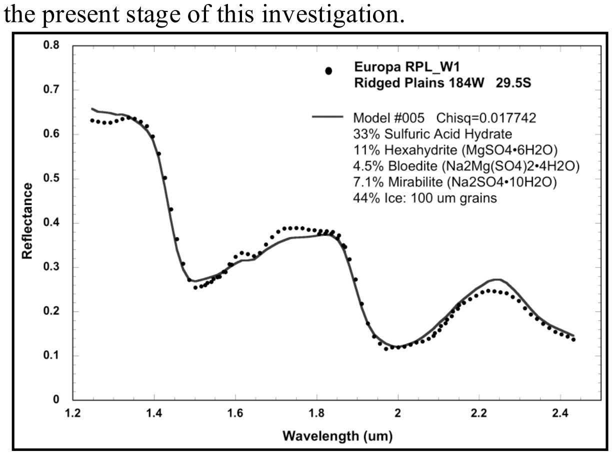

Figure 1. Spectrum of ridged plains at 184° W longitude.

Conclusions: Detection of a strong gradient of sulfuric acid hydrate concentration from east to west across the leading side-trailing side boundary is consistent with the radiolytic sulfur cycle proposed by Carlson et al. [2], while an opposite gradient in mirabilite is consistent with its susceptibility to radiation degradation, as pointed out by McCord et al. [12].

While the linear mixture modeling we have performed may not uniquely characterize the true surface composition of Europa, we are gaining confidence that its non-ice materials must include both sulfuric acid hydrate and hydrated salts; neither of these alone can adequately explain the spectral features observed.

The availability of high-quality despiked NIMS observations, combined with cryogenic laboratory reflectance spectra, permits in-depth analysis of surface composition. With this capability we can now begin to unravel the complex interplay of exogenic and endogenic processes on Europa, with the potential to develop greater understanding of the surface deposits and underlying ocean.

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References: [1] Cooper J.F. et al., (2001) *Icarus, 149*, 133-159. [2] Carlson R.W. et al., (2005) *Icarus, 177,* 461-471. [3] Kargel J.S. et al., (2000) *Icarus, 94,* 368-390. [4] Author A. B. and Author C. D. (1997) *JGR, 90,* 1151–1154. [5] Prockter L. M. et al., (1999) *JGR, 104,* 16531-16540. [6] Dalton J.B., (2007) *GRL, 34,* L21205. [8] Hapke B. (1993) *Theory of Refl. And Emitt. Spect.*, Cambridge Univ. Press, NY. [9] Dalton J.B. et al., (2005) *Icarus, 177,* 472-490. [10] Carlson R.W. et al., (1999) *Science, 283,* 2062-2064. [11] Peterson R.C. and Wang R. (2006) *Geology, 34*, 957-960. [12] McCord T.B. et al., (2001) *JGR, 106,* 3311-3320.

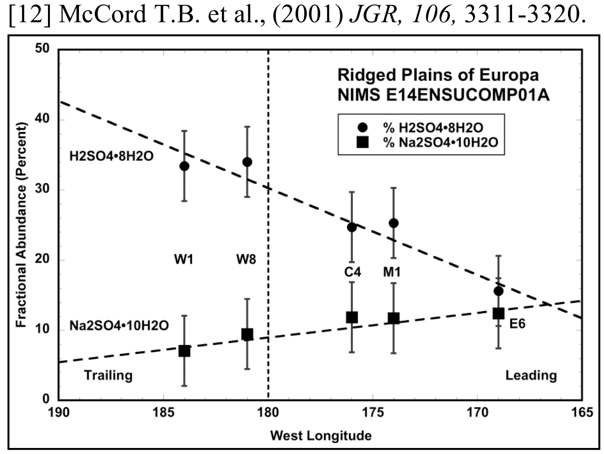

Figure 2. Fractional abundance of sulfuric acid and sodium sulfate hydrates. $H_2SO_4 \cdot 8H_2O$ increases toward the trailing hemisphere as $Na_2SO_4 \cdot 10H_2O$ decreases, implicating radiolytic processes. W1, W8, C4, M1, and E6 refer to spectra of individual ridged plains units.