INFERRING SALT COMPOSITION ON EUROPA BY CHARACTERIZING VIS-NIR SIGNATURES OF COLOR CENTERS WITH EUROPA CLIPPER EIS AND MISE INSTRUMENTS. C. A. Hibbitts[1], E. P. Turtle[1], D. L. Blaney[2], C. P. Paranicas[1], A. S. McEwen[3], J. M. Soderblom[4], D. C. Humm[1], F. P. Seelos[1], M. Hedman[5], and the EIS and MISE Europa Clipper Investigation Teams. [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD, [2]Jet Propulsion Laboratory, Pasadena, CA, [3]University of Arizona, Tucson, AZ, [4]Massachusetts Institute of Technology, Cambridge, MA., [5]University of Idaho, Moscow, ID (Contact: Karl.hibbitts@jhuapl.edu)

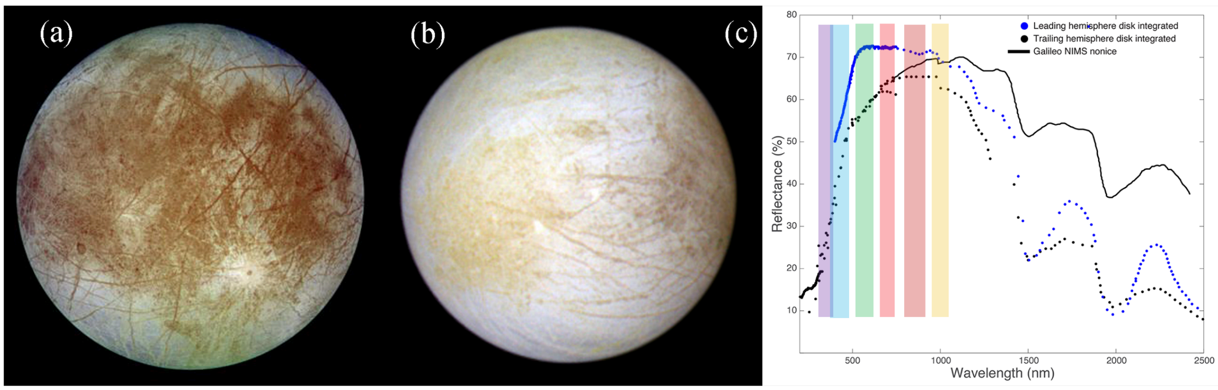

Figure 1. The ice-poor trailing hemisphere of Europa is darker and spectrally distinct from the ice rich leading hemisphere. The images are of (a) Europa's trailing hemisphere (PIA00502) and (b) leading hemisphere (PIA01295) in approximately real color with spectra shown in (c) that are representative of the leading hemisphere (blue) and trailing (black). The spectra composed of dots are disk integrated telescopic spectra from Carlson et al., 2009 and from Calvin et al.., 1995 and references therein. The solid line spectra from ~750 nm to longer wavelengths are Galileo NIMS data of ice-free material (McCord et al., 2010, Figure 2), scaled to the telescopic data of the trailing hemisphere. EIS filters are shown as color bars.

Motivation: The Europa Clipper mission will explore Europa with one objective being to understand the composition of its surface and the implications for the composition of the subsurface ocean, including its potential for sustaining life [1]. Salt minerals deposited on the surface may provide insight into the composition of this ocean [e.g., 2, 3], with the specific salt type and composition having the potential to provide significant insight into the habitability of the subsurface body of water from which it originated [4]. For instance, a surface composition dominated by sodium and other halides could indicate a chloride-rich ocean, whereas primordial sulfate hydrates could imply an ocean poor in sodium and other halides [5]. A chloride-rich ocean could indicate significant water-rock cycling at Europa's silicate seafloor [6], with potential implications for habitability. It is possible that both halides and sulfates could exist on the surface of Europa and modeling predicts that an ocean with Na, Mg, Cl, and SO_4 would tend to precipitate sodium sulfates as well as $MgCl_2$ if extruded as a solution to freeze on Europa's surface [7].

The Science: Discovered through previous missions and telescopic observations, hydrated non-ice material(s) exist on Europa's surface (Figure 1), yet much uncertainty remains about composition, origin, and evolution after emplacement. This heavily hydrated non-ice material was positively identified through the analysis of hyperspectral infrared data returned by the Galileo Near Infrared Mapping Spectrometer (NIMS), and furthermore is likely a combination of multiple materials including frozen brines [8–12] and/or hydrated sulfuric acid [13, 14, 15–17]. Since the completion of the Galileo mission, telescopic observations have refined the identity of additional components in this non-ice material. Chlorides or chlorates may be a significant component [18,19] and there is additional evidence for magnesium sulfates [12]. New telescopic observations suggest chlorides may be present in linea, yet analysis of previous telescopic measurements suggests the material dominating the trailing hemisphere is primarily $MgSO_4$ with very few halides present [20]. Both analyses may be correct given that relative proportions of these components in the non-ice material are not constant, but vary spatially over Europa's surface, especially between the leading and trailing hemispheres [16–17, 21–25].

Although halides, including chlorides, are spectrally bland in the NUV through IR, except for non-diagnostic water absorption features if hydrated, halides, as well as other salts, can develop defect centers optically active in the UV through NIR [e.g. 26]. These centers have been proposed as a means for halide identification on ocean worlds embedded in a high radiation environment like Europa is [e.g. 4, 27]. However, the spectral signature of the halide defect center is sufficiently strong that the fact that it does not stand out in Europan spectra indicates halides are probably not a widespread abundant component of the non-ice material [20].

The Europa Clipper Measurements: Two investigations on Europa Clipper have the potential to acquire spectral reflectance measurements to positively idenfity specific salt minerals via the spectral characteristics of color centers: the Europa Imaging System (EIS) and the Mapping Imaging Spectrometer for Europa (MISE). Color centers in halides, sulfates, and carbonates are spectrally active from the UV through the NIR and thus can be detected by EIS and MISE (Figure 2). Mapping those salts at high spatial resolution would have the potential to link deposit composition, non-ice abundance, and relative age to geologic features to understand origin and accurately infer subsurface ocean composition.

EIS consists of a narrow-angle camera (NAC) and wide-angle camera (WAC), both of which have filters that span from 350 nm to almost 1050 nm, although the short-wavelength sensitivity of the WAC is more limited by the optical design for the high-radiation environment. The NAC has a 2.3° cross-track x 1.2° along-track FOV with 10-μrad IFOV, to perform color imaging at better than 10 m pixel scale. The WAC FOV is 48° cross-track x 24° along-track, and with a 218-μrad IFOV will achieve 11-m pixel-scale color imaging over a 44-km-wide swath from 50-km altitude.

MISE is a hyperspectral imager with 421 wavelengths for continuous spectral coverage from 800 nm to 5000 nm at 10 nm resolution. It has a 250 μrad IFOV and 4.3° wide FOV, providing 12.5-m pixle-scale data over a 3.75-km wide swath from 50-km altitude. Specific color centers can be discerned from the EIS multispectral sampling of surface reflectance, and MISE will provide additional spectral and color information for any portions of the surface that might be saturated with

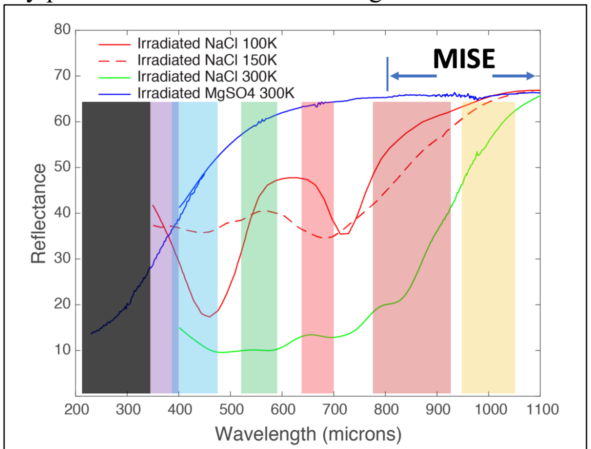

Figure 2. Spectra of hydrated $MgSO_4$ and anhydrous NaCl are readily distinguishable in the NUV – NIR.. The color bars correspond to the locations and widths of the EIS filters.

color centers or appear bland at EIS wavelengths (Figure 3). Together these two instruments can positively identify halides and other salts through the spectral nature of their color centers thereby providing a previously unexpected capability for determining surface composition in a manner that has great significance for our understanding of the composition of Europa's subsurface ocean and its potential for harboring life.

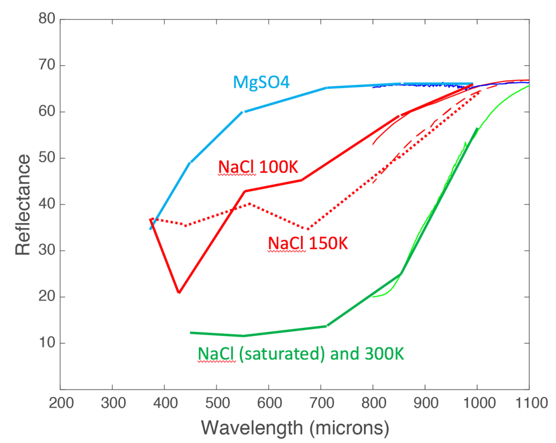

Figure 3. Spectra of irradiated salts shown in Figure 2 retain their diagnostic shapes when sampled in EIS filters and MISE spectral resolution.

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