SPECTRAL EFFECTS OF ELECTRON IRRADIATION OF CRYOGENIC HYDRATED MINERALS RELEVANT TO EUROPA. C. A. Hibbitts[1], K. Stockstill-Cahill[1], E. Lloyd[1], [1]Johns Hopkins Applied Physics Laboratory, 11100 Johns Hopkins Rd., Laurel, MD 20723. Karl.hibbitts@jhuapl.edu.

Introduction: The surface of Europa contains hydrated material(s) that are continually altered by bombardment with Jovian magnetospheric ions and electrons. Several candidate hydrates have bene postulated but the unequivocal signature of only sodium chloride (NaCl) has been identified through absorption bands near 460 nm 230 nm [1-6]. We explore the possibility of hydrohalite ($NaCl•2H_2O$), a flash-frozen saturated NaCl brine, magnesium sulfate dodecahydrate ($MgSO_4$ $•11H_2O$) and its related brine as explanations for the color of Europa's hemispheres.

Procedures: Frozen hydrated salts and brines were prepared and analyzed in the APL **L**aboratory for **S**pectroscopy under **P**lanetary **E**nvironmental **C**onditions (**LabSPEC**). Hydrohalite was prepared following the procedures of [7]. A frozen brine was made by dripping a 23% NaCl solution slowly using a Pasteur pipette into liquid nitrogen (LN2). Pellets were created in a cryogenic nitrogen-purged glove bagged environment by grinding the frozen material in liquid nitrogen with mortar and pestle and placing the material in a stainless steel anvil also cooled by LN2. The anvil and sample were then removed and put in a press at 15000 psi for 1 minute; returned to the glove bag, placed back into LN2 and the pellet was removed from the anvil. The pellet was then placed into the sample holder that was also cooled using LN2. Identical procedures were performed for dodecahydrate and its frozen brine, following procedures outlined in [8]. Transferal of the sample and holder from the glove bag to the pre-cooled cryostat on the UHV system required only about a second of exposure to the atmosphere resulting in little water frost build up. After attaching the Faraday cup leads (for measuring electron gun flux) and thermocouple leads (for measuring the temperature of the pellet), the chamber was then pumped to < 1e-6 torr and the sample were generally maintained between 130K and 150K during spectral collection.

Spectra were collected of the pellets from ~ 350nm to ~ 800 nm both before, intermittently during, and after irradiation with 1, 10, and 20keV electrons at a flux of a few to over 100 nanoamps/cm^2, which ranges from being similar to Europa conditions to ~ 2 orders of magnitude higher than Europa and equates to a total fluences of hours to months of exposure on Europa's surface.

Results and Discussion: Results are outline below for experiments on hydrohalite ($NaCl•2H_2O$) and magnesium sulfate dodecahydrate ($MgSO_4•12H_2O$). Cryogenic hydrohalite has a color center that matches Europa [9]. In contrast, irradiated cryogenic brine does not form an F-center (which contradicts [6] albeit their work was at a higher flux of 1 microamp), but it does darken in the UV-Vis (**Figure** 1) and reasonably matches the color of nonice material in chaos terrain on the leading hemisphere as reported by [5]. However, both the cryogenic hydrohalite and frozen brine possess infrared spectral features that were unaffected by the irradiation that also do not match the infrared spectra of Europa. Thus, neither of these hydrated NaCl materials can be considered a spectral match to Europa. Weathering, such as through ion bombardment, may sufficiently subdue the shallower features seen in the frozen brine but would not likely erase the strong features of hydrohalite. Thus, the observed color center on Europa is likely indicative of desiccated NaCl. If weathering can sufficiently subdue the infrared region, then it is possible that the shape of the visible spectrum of chaos terrain is due to irradiated cryogenic brine and that a either sputtering or thermal sublimation may desiccate the frozen brine to form NaCl.

Irradiated frozen magnesium sulfate dodecahydrate and its frozen brine also browns but do not form color centers after similar irradiation (Figure 2). Its color is similar to room temperature, less-hydrated $MgSO_4$ irradiated with 40keV electrons equivalent to about 20000 years on Europa's surface. There are temperature dependent spectral features in the infrared but irradiation by electrons does not alter its infrared spectrum. Hibbitts et al., [2019] noted the similarity between the color of irradiated $MgSO_4$ hydrate and the trailing hemisphere of Europa; thus, it is conceivable the irradiated dodecahydrate may be responsible for the color of Europa's trailing hemisphere. However, spectra of irradiated acid hydrate should be obtained to explore that alternative hypothesis.

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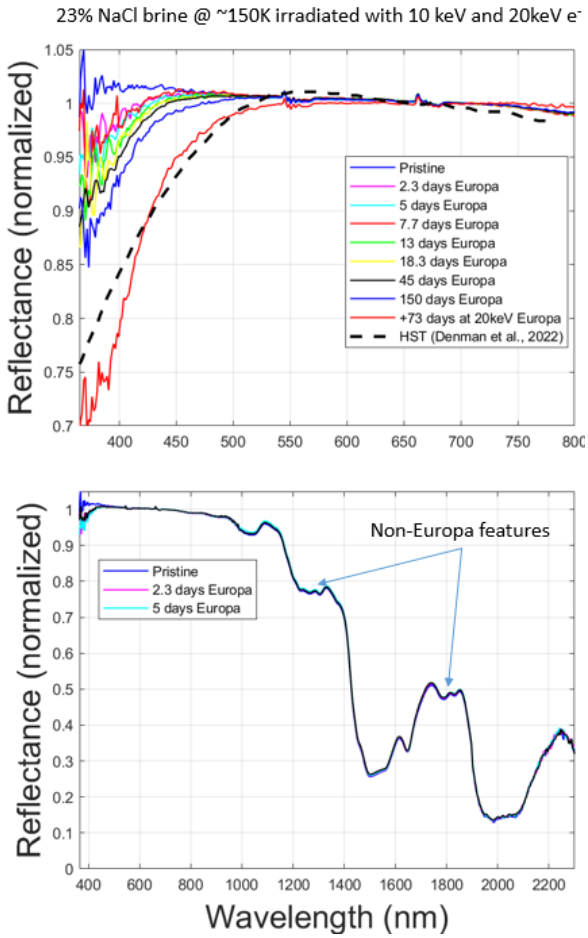

Figure 1. Irradiated frozen NaCl brine is colored similarly to Europa's leading hemisphere but its infrared spectrum has spectral features not present on Europa.

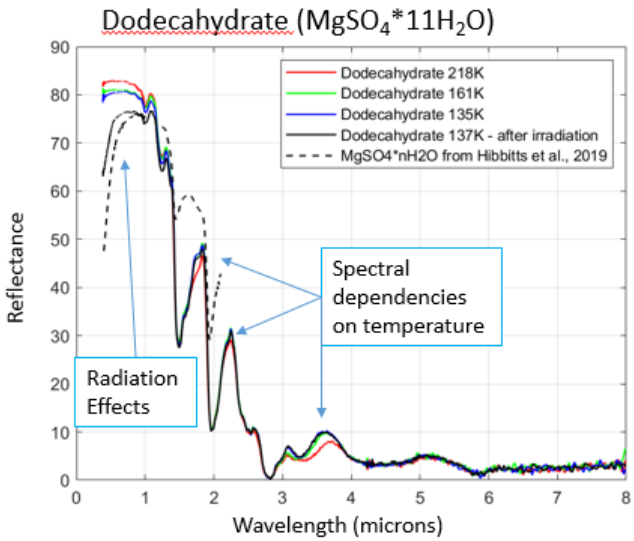

Figure 2. Irradiated frozen dodecahydrate color is similar to irradiated room temperature $MgSO_4$ hydrate. Both are dissimilar in color from the leading hemisphere of Europa.