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Laboratory reflectance measurements of water ice/salt mixture irradiated by electrons

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1. Context

The Near Infrared Mapping Spectrometer (NIMS) observed Galilean moons during the Galileo mission in the nineties. Reflectance measurements revealed strong signatures of water ice almost everywhere at the surface of three of the four Galilean moons of Jupiter. The resolution of these data is sufficient to detect as well the presence of non-water ice components mostly present for example on the trailing side of Europa, or more homogeneously distributed at the surface of Ganymede. For several decades now, the exact nature of the compounds has remained unclear and is still a subject of debates in the scientific community. The non-ice components seem highly hydrated and probably contain sulphurs and chlorides [1-3].

In the case of Europa, several species in addition to water ice are proposed, such as magnesium salt epsomite ($MgSO_4.7H_2O$) or higher hydrated states, hydrated forms of sulphuric acid ($H_2SO_4.nH_2O$) or sodium chloride (NaCl). These salts are subject to intense irradiation by the electrons and ions from Jupiter's magnetosphere [4]. These irradiation processes have already been proposed as inputs for the sulphur exogeneous component of Europa [5]. They also induce chemical reactions in the ice and eject particles via sputtering, thus creating the neutral atmosphere of Europa [6]. The non-icy compounds present at the surface of Europa could differ from those at Ganymede or Callisto because the plasma flux precipitating onto the surface decreases with distance from Io [7]. Moreover, the intrinsic magnetic field of Ganymede modifies the spatial distribution of energetic particles than can reach its surface.

The MEFISTO facility at the University of Bern contains a vacuum chamber where icy surfaces can be irradiated with ions and electrons [as described by 9]. To complement this facility, a VIS-NIR hyperspectral imaging system developed by the Planetary Imaging Group (PIG) was adapted to the chamber. It consists of two cameras (visible and infrared) taking pictures of an illuminated sample. The light sent onto the sample trough an optic fibre is spectrally selected by a monochromator ranging from 0.38 to 2.4 micrometres. Hyperspectral cubes are acquired by recording images at different wavelengths. Averaged reflectance spectra are then obtained by defining Regions of Interest (ROIs) in the cubes and averaging the signal inside.

2. Measurements and first results

Here we present results of irradiation of pure and salty water ices (produced by our Setup for Production of Icy Planetary Analogs, SPIPA) by electrons at energies of 0.5 eV to 5 keV and currents from 0.5 to 5 muA. The purposes of these measurement were *i*) to know if we can detect a modification of temperature related to electron irradiations and *ii*) to extend the understanding of the process of coloration which happen during irradiation of salty ices. This irradiation has been done previously on NaCl by others [1, 10], with different energies and with UV irradiation, to mimic and explain the colored double/triple bands at the surface of Europa.

We observed the appearance of dark spots at the surface of the salty samples irradiated by electrons. The reflectance of these spots exhibits the F (460nm) and M (705nm) centers coloration of the NaCl crystal reacting to electron irradiation. The disorder induced by electrons perturbing manifests itself by visible coloration. This effect was already observed by Hand and Carlson (2015) [11] for higher energies (10keV), suggesting also the reversibility of this phenomena for lower energies (see fig.1 the difference between "fresh" and "old" samples).

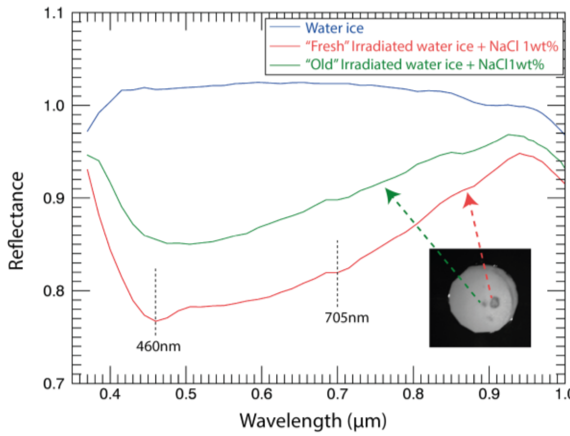

Figure 1: Reflectance measurements of pure water ice and irradiated mixture of water ice + 1wt% of NaCl. The irradiation was stopped on the "old" spot almost 1 hour before the measurements of the "fresh" spot.

We manually modified the temperature of the sample and recorded the reflectance (figure2). The depth of the absorption band at 1.65µm is highly sensitive to the temperature of the few uppermost micrometres of the sample surface, as it has already been demonstrated by Grundy et al., [12, 13]. Since it is complicated to make a direct measurement of the surface temperature of an icy sample, the possibility of doing it by remote sensing with good confidence is of major interest. We tried to fit a reflectance model on this band specifically. We will show first determinations of temperature on our samples, the quality and the potential applications of such a tool to reflectance measurements.

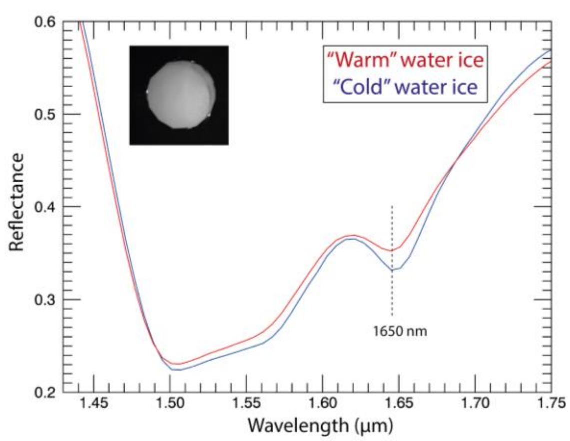

Figure 2: Reflectance measurements of warm water ice at 119K and cold-water ice at 100K. These temperatures are those of the sensors in contact with the sample holder. We expect these temperatures to be different from those of the ice's surface

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