SPECTRAL PROPERTIES OF H_2O ICE DEPENDING ON PARTICLE SIZES AND TEMPERATURES EXPECTED ON GANYMEDE AND CALLISTO. K. Stephan[1], M. Ciarniello[2], O. Poch[3], B. Schmitt[3], D. Haack[1] and A. Raponi[2], [1]Institute of Planetary Research, DLR, 12489 Berlin, Germany (Katrin.Stephan@dlr.de), [2] INAF-IAPS Via del Fosso di Cavaliere, Rome, [3]Université Grenoble Alpes, CNRS, IPAG, 38000 Grenoble, France.

Introduction: H_2O ice is one of the dominant compounds on the satellite surfaces in the outer solar system. Its varying abundance but also its physical properties such as particle size and crystallinity are important indicators to understand the geological and microphysical evolutions of the icy satellite's surface including how the surface environment influences the surface properties. As derived from reflectance spectroscopy, the surfaces of the Jovian satellites Ganymede and Callisto, the major targets of the upcoming JUICE mission, have been found to be covered by H_2O ice particles of different sizes and possibly varying crystallinity [*1,2,3*]. These properties vary on both satellites depending on geographic latitude and they point to a potential relationship with the surface temperature of these bodies and/or sputtering-induced H_2O ice enrichment [*1,2,3*]. However, major changes in the spectral signature of H_2O ice only due to temperature have also been previously reported [*4-6*], which may add up to spectral effects related to both parameters, particle size and crystallinity. In order to evaluate in detail how variations in particle size and surface temperature together influence the spectral H_2O-ice signature, we measured H_2O ice samples with particle sizes ranging between ~70 µm and ~1600 µm at temperatures between 70 and 150 K (and 220 K, for selected cases) as expected to occur on icy satellites such as Ganymede and Callisto [*7*].

Experiment procedure: Samples of five different particle sizes (70 ± 30 µm, 300 ± 100 µm, 680 ± 120 µm, 1060 ± 60 µm and 1360 ± 240 µm) were prepared by spraying spherical water droplets into liquid N_2 [*8*] or crushing and/or sieving the ice in a freezer. H_2O ice particles of ~300 µm were produced with the two methods in order to compare spectra of spherical and irregular shaped grains. In addition, three mixtures of ~70 µm and ~1060 µm particles were prepared, with mass mixing ratios of 27%/73%, 52%/48% and 77%/23% as measured during their preparation.

Measurements have been performed with the SpectropHotometer with variable INcidence and Emergence (SHINE) coupled to the CarboN-IR environmental chamber at the Cold Surfaces Spectroscopy (CSS) facility (https://cold-spectro.sshade.eu) of the Institut de Planétologie et d'Astrophysique de Grenoble (IPAG) [*9,10*]. All samples were measured at least at 8 different temperatures from 70 to 150 K. The irregular shaped ~ 300 µm particles were measured twice during a decreasing (from 150 K to 70 K) and an increasing (from 70 K to 220 K) temperature ramp with the intention of investigating possible irreversible spectral changes due to cooling and heating of the sample.

In order to provide the opportunity to directly compare the results to spectral remote sensing data sets of icy satellites, these spectra have been measured in reflectance. Spectra were acquired from 0.4 to 4.2 µm using an incidence angle of 0° and an emission angle of 30° with a spectral resolution of 0.003 µm, (0.4-0.7 µm), 0.006 µm (0.7-1.4 µm), 0.013 µm (1.4-3.0 µm), and 0.026 µm (3.0-4.2 µm). Spectralon and Infragold (Labsphere Inc.) were used as references and the non-perfect Lambertian behavior of the Spectralon was considered in the calibration [*11*]. The collected spectra were corrected for effects of transmission and multiple reflections due to the sapphire windows of the CarboN-IR chamber, as described in [*8*]. The final absolute radiometric accuracy of the laboratory measurement was better than 1 %.

Results: In order to investigate variations in the spectral signature of our samples, for each spectrum the band center (BC), band depth (BD) or strength (S) of each H_2O ice absorption and the Fresnel reflection peak at 3.1 µm, respectively, have been derived [*12,13*]. Further, as a descriptor of the shape of the individual H_2O ice absorptions we also computed the full-width at half maximum (FWHM) and the ratio between the HWHM (half-width at half maximum) derived separately for the two band wings. This latter quantity works as a potential indicator for any asymmetry (A) variation in the shape of a specific absorption band [*14*].

The derived BDs of the H_2O ice absorptions at 1.04, 1.25, 1.5 and 2 µm vary with particle sizes, and are more or less independent of temperature effects (Fig. 1a). Only, in case of large particles, when the absorption at 1.5 and mostly at 2 µm starts to be affected by saturation, variations in the BDs also appear with changing temperature (Fig. 1d). Furthermore, the BDs derived from the measured spectra of binary mixtures of particle sizes are relatively well in agreement with the band depths derived from linear mixtures of the spectra of the different endmembers. On the contrary, absorptions located at 1.31, 1.57 and 1.65 µm appear also related to temperature than particle size (Fig. 1b and e). They become stronger with decreasing temperature

and affect the band shape and center of the H_2O ice absorptions at 1.25 and 1.5 µm. A strengthening with decreasing temperature can also be observed for the Fresnel reflection peak at 3.1 µm (Fig. 1 c and f).

Conclusions: The collected spectra provide a useful spectral library to study icy surfaces dominated by large H_2O particles, as they accurately describe the shifts in the band center and the change of shape of the major absorptions due to saturation effects. Further, the band depths of the H_2O ice absorptions at 1.04, 1.25, 1.5 and partly 2 µm have proven to be a useful indicator for estimating particle sizes independently of temperature effects [*2*].

Since our samples are expected to be crystalline H_2O ice, the variations observed in the absorptions at 1.31, 1.57 and 1.65 µm and the Fresnel reflection peak can be interpreted to depend on temperature [*15*]. Similar variations, however, also characterize the transformation from amorphous to crystalline H_2O ice. Therefore, a combined analysis of all H_2O ice absorptions considering their mean and maximum estimated local surface temperatures might be required to disentangle their effects in the spectra of icy satellites and evaluate separately particle size, crystallinity and temperature, especially when amorphous as well as crystalline H_2O ice may occur together.

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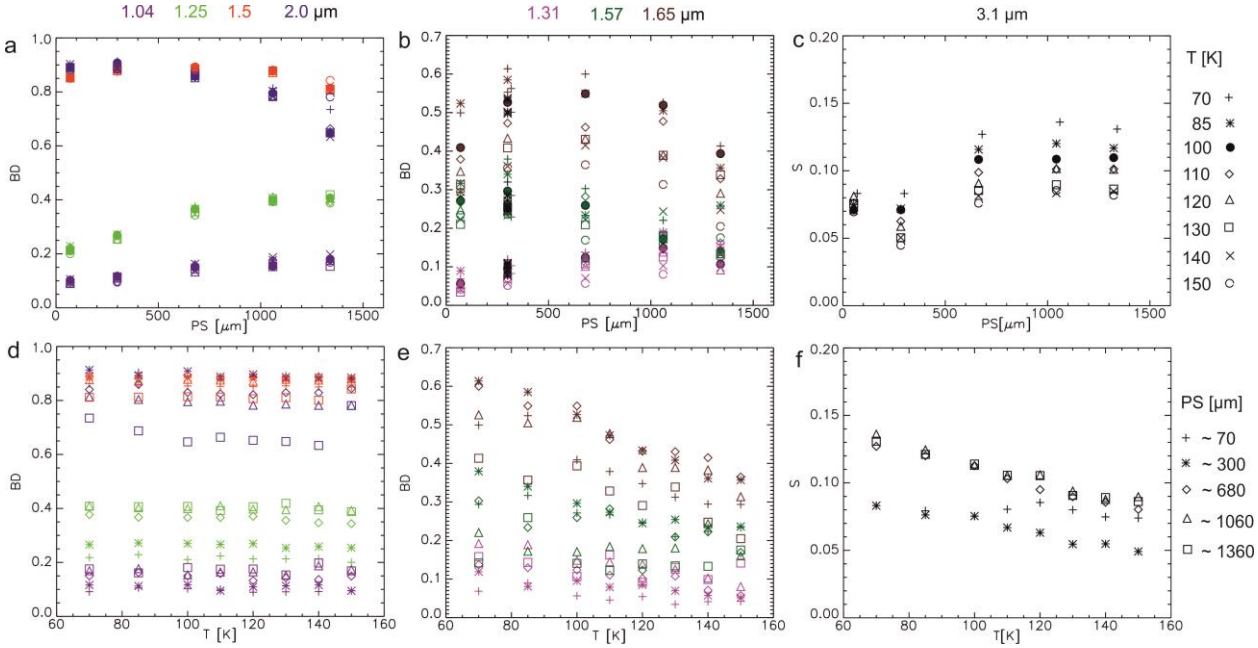

Fig. 1: Band depth (BD) variations retrieved for the H_2O-ice absorptions at 1.04, 1.25, 1.5 and 2 µm (a and d), 1.31, 1.57 and 1.65 µm (b and e) as well as the strengths (S) of the Fresnel reflection peak at 3.1 µm (c and f) in the spectra of the five samples representing different particle sizes of ~70, ~300, ~680, ~1060 and ~1360 µm depending on particle size (upper row) or on measured temperatures (lower row) with the symbols indicating different temperature (a - c) or particle sizes (d - f), respectively.