H_2O-ICE PARTICLE SIZES OF FRESH IMPACT CRATERS IN THE JOVIAN AND SATURNIAN SYSTEM – RELATIONSHIPS TO SUBSURFACE PROPERTIES AND SURFACE TEMPERATURE.

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Introduction: Although, icy satellites are mainly composed of H_2O ice, they experienced different geological evolutions and environmental conditions, which should be mirrored by the compositional and physical structure of their surfaces. In particular, the spectral properties of subsurface material, which has been recently excavated during impact events, can deepen our knowledge about the crustal properties and how impact events and/or surface conditions at the location of the crater on the satellite's surface affect the surface properties. In this work, we use the possibility afforded by the data set acquired during the Galileo and Cassini mission to compare the spectral properties of fresh impact crater material on icy satellites of Jupiter and Saturn and their implications for the composition and the geological evolution of the specific body.

Impact crater selection: Although, measurements of the absolute crater ages are often difficult to obtain on icy satellites because of the limited availability of images with a sufficient spatial resolution, Galileo SSI and Cassini ISS images acquired during flybys at relatively low altitudes satisfactorily enable to characterize impact craters on the Jovian and Saturnian satellites as young, based on their geomorphological surface properties such as: 1) a high visible albedo, 2) a sharp crater rim, 3) a distinct ejecta blanket and 4) bright rays [1]. Numerous impact craters on Tethys, Dione and Rhea as well as on Ganymede could be selected for which also spectral information acquired by the Galileo NIMS and Cassini VIMS instrument exists at a sufficient spatial resolution. The crater dimensions range between ~2 and 135 km in diameter implying that, during the impact events, which created these craters, material from a maximum depth of few hundred meters to almost 10 km could have been excavated and distributed [1].

Data Processing: The spectral signature of H_2O ice, which dominates every VIMS and NIMS spectrum, is known to be highly dependent on the abundance as well as the size of the individual H_2O-ice particles. Usually, when only traces of an additional visually dark non-icy surface compound exist, it predominantly influences the visible portion of the VIMS and NIMS spectra. Here, H_2O ice is fully transparent making the visible albedo a good indicator for the existence of any additional dark opaque surface material [2]. In case of pure H_2O ice, the band depths (BD) of the numerous H_2O ice absorptions are simply influenced by the sizes of the individual H_2O-ice particles. Even more, band depth ratios (BDRs) of these absorptions have been found to be a good indicator for the H_2O-ice particle sizes, being rather unaffected by additional non-ice surface compounds onto the H_2O-ice signature [3]. We used H_2O-ice model spectra for particle radii between 1 µm and 1 cm calculated based on the Mie theory (model A) [4], the Skhuratov code [5] (model B) and the Hapke model [6] (model C) to compare the BDRs derived for the fresh impact craters with the properties of pure H_2O ice and to estimate ranges of H_2O ice particle sizes of the fresh crater material. Model spectra were retrieved for temperatures of 80, 130 (model A) and 120 K (model B and C), which cover the range of surface temperatures expected on the investigated satellites and therefore enable us to distinguish BDR variations due to particle size or temperature variations. Furthermore, laboratory data of pure H_2O ice samples recently produced for particle size ranges between ~70µm and ~1600µm, spherical and irregular particle shapes are available for temperatures between 70 and 150 K [7].

Results: All selected craters show a very high albedo (> ~0.85) indicating more or less pure H_2O ice dominating the uppermost crust of all satellites, which is consistent with spectral modeling results of individual impact craters indicating less than ~1% of visually dark non-ice compounds [8]. Retrieved BDR values of the selected impact craters lie relatively close to the model curves (Fig. 1 a and c). Only BDR 2/1.5µm-values start to deviate from the model curves for particle sizes larger than ~ 500 µm. However, this behavior can also be observed for the BDR values retrieved from the ice samples studied in the laboratory (Fig. 1 b and d) and thus rather implies difficulties of the models describing the probably already saturated absorption at 2 µm. Thus, BDRs of the individual H_2O-ice absorptions generally decrease mainly with increasing particle sizes [7]. This is also confirmed by the BDR values derived from the spectra of the laboratory samples, which are an even better fit to the prepared particle size range (Fig. 1). Laboratory data also show that particle shape and temperature does not significantly affect the BDRs of a specific particle size [7].

BDR values indicate that the smallest particle sizes occur in the vicinity of impact craters on the Saturnian satellites – although these particles are larger than the ones observed in the geologically old terrain on these bodies (Fig. 1 a and c). Some craters (for example impact crater Ptah) on Ganymede show similar BDR values. Most Ganymedean impact craters, however, exhibit much larger particles, almost as large as Ganymede's ancient dark terrain close to the equator.

The particle size ranges estimated based on the BDR models and/or laboratory values imply a surprisingly large deviation in the particle sizes of the selected fresh impact craters. Although the estimated particle size ranges differs slightly depending on the used model BDR values, the direct correlation between the particle size and the local surface temperature derived from Voyager images, VIMS and CIRS data [9 - 11] is always evident, with the particle size increasing for increasing surface temperature (Fig. 2).

Implications: All satellites exhibit an uppermost crust dominated by H_2O ice. The particle sizes of the shocked impact ice apparently easily adapt to environmental conditions i.e. surface temperature. On the Saturnian satellites the particles stay small because of the low surface temperature, with the size decreasing due to sputtering and/or deposition of E-ring material [12].

On Ganymede, only the small craters on Ganymede – probably the youngest in our study – and impact craters in colder regions exhibit small particles similar to impact craters on the Saturnian satellites. Sizes increase and become more similar to the ancient dark terrain close to the equator. Either the particles recrystallize in relation to the temperature subsequently after deposited as shocked material on the surface or experience a fast growing in particle size (particle welding) due to sublimation and/or sintering during the diurnal temperature variations on Ganymede's surface. More high-resolution spectral and imaging data are necessary to distinguish between these two effects and to further our knowledge about the crustal composition and the thermal evolution of the surface ice, which hopefully can be achieved during the coming ESA JUICE mission [13].

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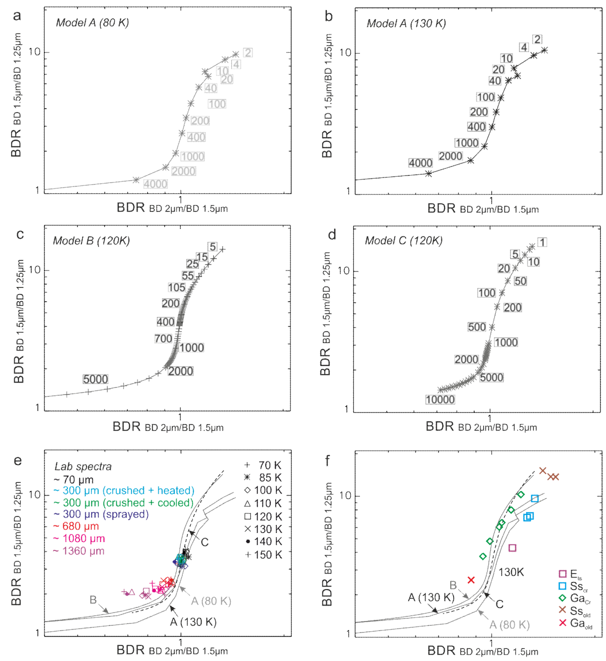

Fig. 1: BDR values of theoretical H_2O ice model spectra (a – d) to BDR values of laboratory data (e) and (f) fresh impact craters on Ganymede (Ga cr) and the Saturnian satellites (Ss cr), geologically ancient regions on these bodies (Ga old and Ss old) and tigerstripes of Enceladus (E ts).

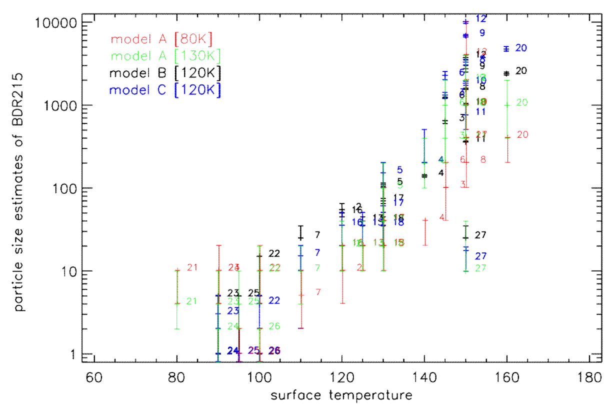

Fig. 2: H_2O-ice particle size range estimates based on the BDR 215 (BD 2µm/BD 1.5µm) values derived for the four different ice models compared to local surface temperatures derived from [9], VIMS [10] and CIRS data [11] (Ganymede craters ID 1 – 19; Ganymede ancient dark terrain ID 20; impact craters on the Saturnian satellites ID 21 – 23; ancient terrain on the Saturnian satellites ID 24 – 26; Enceladus tiger stripes ID 27).