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Ice particle size variations and candidate non-ice materials on Ganymede and Callisto

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1. Introduction

Band depth ratios (*BDR*s) of the major H_2O-ice absorptions in the spectra of the Jovian satellites Ganymede and Callisto acquired by the NIMS spectrometer onboard the Galileo spacecraft [1] have been found to be semi-quantitative indicators of changes in the ice particle sizes across its surface allowing their detailed mapping across the satellites' surfaces without extensive modeling [2]. Based on the achieved results, processes responsible for these variations as well as the implications for the nature and composition of the dark non-ice materials on both satellites have been investigated.

2. Ice particle size variations

Intriguingly, the general H_2O-ice particle size variations show almost no correlation with the surface geology but change continuously with geographic latitude on both satellites. On Ganymede, sizes reach from 1 µm near the poles to > 100 µm up to 1 mm near the equator [2, 3]. Smallest particles occur at latitudes higher than ±30° where the closed magnetic field lines of Ganymede's magnetic field change into open ones and Ganymede's polar caps become apparent. On Callisto, which does not exhibit an intrinsic magnetic field, however, *BDR*s show a similar trend. Ice particles appear slightly larger at low and mid latitude than observed on Ganymede, whereas the ratio values converge toward the poles indicating similarly small ice particle sizes.

Similar trends in the particle size variations on Callisto as well as on Ganymede imply that these variations are caused by similar surface processes. The formation of Ganymede's polar caps has often been attributed to brightening effects due to sputtering of ice by plasma bombardment with local and regional redeposition as finer grained ice [4, 5]. Our measurements rather point to a continuous decreasing of ice particle sizes toward the poles on both satellites. This smooth latitudinal trend may be related to the surface temperatures and possible thermal migration of water vapor to higher latitudes [6] and grain welding at lower latitudes. Maximum temperatures during the day reach 150 K and 165 K near the equator of Ganymede and Callisto [7, 8], respectively. At these temperatures, ice sublimation and crystal growth [9], whose rates are exponentially dependent on temperature, will be processes that occur rapidly compared to impact processes. In contrast, polar temperatures do not exceed 80 ± 5 K [10, 7] and ice will be immobile. Larger particles in the equatorial region of Callisto than on Ganymede could be explained due to the slight higher maximum temperature but also a longer Callistoan day (Callisto: ~ 17 Earth days; Ganymede: ~ 7 Earth days) [8].

3. Implications for the dark non-icy material

The specific composition of Ganymede's and Callisto's non-ice material is still not fully solved. However, it is not expected that the observed relationship between the H_2O-ice absorptions occurs for every non-ice material and thus might help to restrict the variety of considered materials such as carbon-rich materials, phyllosilicates and H_2O-bearing salts [7, 8, 11, 12].

Areal mixtures of H_2O ice with possible dark non-ice candidates such as carbon-rich material, hydroxylated and hydrated phyllosilicates [7, 8] have been calculated depending on different abundance and H_2O-ice particle sizes. The relationship between the H_2O-ice particle sizes and the *BDR*s is valid for most materials if the amount in the mixture does not exceed 10%. Best results across the full range of percentage could be achieved for carbon-rich material and hydroxylated phyllosilicates as expected in carbonaceous chondrites [11]. In contrast, significant amounts of hydrated material as identified on Ganymede and Europa [12] significantly changes the *BDR*s and cannot fully explain the global trend.

References

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