Water ice: Experimental density and refractive index at low temperatures

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Space presents water ice signatures from objects from our solar system to the interstellar medium. Our extensive laboratory work focuses on the physical properties of thin film ices grown by vapor background deposition. We obtain the refractive index in the visible spectrum (n) using double laser interferometry, as well as the ice average density (ρ) by measuring the mass deposited on the surface of a quartz crystal microbalance. Ice is grown at constant rates (0.2 – 3 nm s^{-1}) and temperatures (33-155 K) in a high-vacuum system. Interferometry also allows us to speculate about the relation between scattering and ice structure. The n and ρ values are used to obtain the Lorenz-Lorentz factor (L), commonly used to obtain the density from experimental n values. We also estimate the ice porosity from the obtained average density and the intrinsic density from diffraction experiments in the literature. Average density measurements are also important to constrain infrared band strength values, which have become more relevant as the capabilities of observational facilities improve (VLT, JWST).

The measured solid water densities vary between 0.48 g cm^{-3} at 33 K and 0.83 g cm^{-3} at 150 K. The visible refractive index at 532 nm grows from 1.15 to 1.32 in that temperature range. Distinct reproducible regimes are observed: a step-wise growth up to 80 K; a linear slope between 80 K and 110 K; a remarkable discontinuity at 115 K, indicating the formation of cubic ice crystals; and a steeper slope up to 155 K, when hexagonal structures appear. From these observations, we discuss the validity of the L factor; study the effect of deposition rates; estimate the porosity by temperature; and present updated band strength values.