Mm and Sub-mm Wave Absorption in Low- and High-Density Amorphous Ice

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Amorphous ice is believed to be one of the principal constituents of interstellar dust with about 10% of the total oxygen in dense molecular clouds contained in H_2O ice (Pollack 1994). Although single crystal ice has been measured over part of the mm-wave spectral region, surprisingly, no data are available on the mm-wave absorption of amorphous ice even though these optical constants will certainly play an important role in modeling calculations such as for the 'MRN' dust model (Mathis 1993). The discovery of the irreversible production of the high density amorphous (HDA) phase of ice by the compression of regular ice to 10 Kbar at 77 K (Mishima 1984) makes possible the spectroscopic measurement of bulk amorphous samples at atmospheric pressure. Upon then heating this substance to ≈ 120 K it transforms to the low density amorphous (LDA) form. At still higher temperatures ≈ 145 K it transforms to the cubic crystalline phase I_c and finally at 225 K it changes to I_h the hexagonal crystalline phase. Consequently, we are able to make mm and sub-mm wave measurements on a variety of phases at low temperature in a single sample by careful temperature cycling after the initial compression. We have measured the absorption spectra of these different phases in the spectral region from 5 to 0.33 mm wavelength at temperatures ranging from 1.5 to 70 K. Significant differences are found between the spectral properties of the HDA and the LDA ice forms. The absolute absorption of the HDA ice is 3 times larger than for either the LDA or the I_c ice phases. At 10 cm^{-1} (1 mm wavelength) its mass normalized single grain absorption coefficient for spherical particles small compared to the wavelength is 0.06 ± 0.008 cm^2g^{-1}. For temperatures up to 20 K the temperature dependent part of the absorption coefficient for the HDA ice is accurately described in the mm-wave region by a near uniform spectral distribution of two level systems, a characteristic feature of other disordered solids (Phillips 1987). Interestingly, over this same low temperature interval no corresponding temperature dependence of the absorption coefficient is found for the LDA ice. For temperatures above 20 K the absorption coefficient of all the different ice phases increases with temperature in a similar way indicating that a single temperature dependent absorption mechanism dominates in this higher temperature region.

References:

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