Low Temperature Mm-wave Properties of Model Celestial Grains

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Interstellar and interplanetary dust consists mainly of silicates, organics, iron compounds and ices, the exact mix depending on the local environment. The observations of thermal radiation from these particles are often converted to total particle mass by using the theoretical absorptivity of these constituents. This method has been particularly important in the mm-wave region where it is used for mass estimates of particles orbiting stars, of molecular cloud complexes and of distant galaxies. The best estimates for silicates generally predict values for isolated grain mass opacity coefficient of interstellar particles: $\kappa_\nu \approx A\,(\tilde{\nu}/10cm^{-1})^\beta$ cm^2g^{-1} where $\tilde{\nu} = 1/\lambda$, $A = 0.3$ and $\beta = 2$ (Draine & Lee 1984). Although current theories of interstellar dust agree that the grains are probably porous and amorphous (Mathis 1993), the effect of porosity and structure on the strength and temperature dependent mm-wave optical constants of model interstellar dust still needs to be explored experimentally. The first low temperature measurements on realistic analogs of silicate grain materials (Agladze 1996) showed that the millimeter-wave mass opacity coefficient at 1 mm wavelength ranged up to $A = 1.6$ at a temperature of 1.2 K and decreased with increas ing temperature to $A = 1.0$ at 20 K. The decrease in the opacity coefficient with increasing temperature has been identified with resonant absorption by a continuous distribution of two level systems (TLS) associated with amorphous solids (Agladze 1996). To examine the influence of porosity we compare our findings for amorphous silicate grains synthesized by sol-gel reaction with those measured for SiO_2 aerogel which has an extremely open structure. For samples of aerogel with a volume fill fraction of 5% SiO_2 at 1.5 K we find in the region between 0.7 and 2.9 mm wavelength (3.5 - 15 cm^{-1}) that $A = 1.3$ and $\beta = 1.2$. Temperature dependences are found for both coefficients: by 16 K the coefficient A decreased to 0.8 and β increased to 1.6. The large change in the coefficients with increasing temperature, which corresponds to a 50% bleaching effect in absorption, occurs because the TLSs have large dipole moments and extend to much larger frequencies, consequently, for open grain structures the mm and sub-mm wave absorption produced by TLS represents a more significant contribution than for bulk amorphous solids.

References:

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