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PROPERTIES OF INTERSTELLAR DUST IN REFLECTION NEBULAE

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Observations of interstellar dust in reflection nebulae are the closest analog in the interstellar medium to studies of cometary dust in our solar system. The presence of a bright star near the reflection nebula dust provides the opportunity to study both the reflection and emission characteristics of interstellar dust. At 0.1-1μm, the reflection nebula emission is due to starlight scattered by dust. The albedo and scattering phase function of the dust is determined from observations of the scattered light. At 50- 200μm, thermal emission from the dust in equilibrium with the stellar radiation field is observed. The derived dust temperature determines the relative values of the absorption coefficient of the dust at ultraviolet wavelengths where the stellar energy is absorbed and at far infrared wavelengths where the absorbed energy is reradiated. These emission mechanisms directly relate to those seen in the near- and mid-infrared spectra of comets. In a reflection nebula, however, the dust is observed at much larger distances (0.1 pc) from the star than in our solar system (1 AU), so that the equilibrium dust temperature is 50 K rather than 300 K. Thus, in reflection nebulae, thermal emission from dust is emitted at 50-200μm.

At 1-25μm in reflection nebulae, non-equilibrium emission from small particles (a$\sim$10Å) is observed in excess over scattered light and equilibrium thermal emission from dust. These small particles, which may be either small grains or large molecules such as polycyclic aromatic hydrocarbons, have low enough heat capacity that when they absorb a single ultraviolet photon, they are temporarily heated to high temperatures ($\sim$1000 K). This theory has been proposed to explain the 1-25μm continuum and unidentified emission features (at 3.3, 3.4, 6.2, 7.7, 8.6, and 11.3μm) observed in reflection nebulae and elsewhere in the interstellar medium.

The IRAS survey is ideal for studying the excitation of these small particles, as it is very sensitive to low-surface brightness emission and its 12μm band in reflection nebulae is dominated by small particle emission. Detailed spatial studies of the Pleiades reflection nebulae, illuminated by B stars, show that the 12 and 25μm emission is mostly non-equilibrium emission, while the 60 and 100μm emission is mostly equilibrium thermal emission from dust. The 12/25μm color temperature is independent of distance from the star, as predicted by non-equilibrium emission models, while the 60/100μm color temperature decreases with distance from the star, as expected for equilibrium thermal emission. The 60/100μm color temperature observed in other reflection nebulae, whose stars range in temperature from 3,000 to 21,000 K, implies that 60 and 100μm emission from these reflection nebulae is also primarily due to equilibrium thermal emission. The 12/100μm ratio should therefore be a measure of the relative amount of non-equilibrium and equilibrium thermal emission from dust in reflection nebulae. We have observed the 12/100μm ratio to be roughly constant for stellar temperatures of 5,000 to 21,000 K. This implies that the excitation of the small grain emission must occur over a broad range of visual and ultraviolet wavelengths, rather than at a specific visual or ultraviolet wavelength. The 12μm emission also accounts for a large fraction ($\sim$25-40%) of the total infrared emission from dust. Because it radiates such a large fraction of the total reradiated stellar energy, it therefore must contribute a similarly large fraction of the visual and ultraviolet absorption from dust. This again suggests a broad band absorption, as there are few or no visual or ultraviolet absorption features capable of accounting for such a large fraction of the total absorption by dust.