INTERSTELLAR AND COMETARY DUST

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My talk will outline the aspects of interstellar dust which are known from direct observations. Then I will discuss several theoretical interpretations which have been advanced, highlighting first their similarities and then discussing their differences. I will mention several problems which are not understood on the basis of any present theory, and why the observations are so puzzling. I will comment on some specific difficult various theories have in explaining the observations, and in particular why it does not seem likely to me that interstellar dust grains have very important mantles of organic refractory materials or anything else. I will then discuss my own ideas about the conditions of interstellar dust throughout its life cycle, from birth to incorporation in pre-cometary ices. I will not discuss what kinds of processing might occur between the grains being incorporated into an icy matrix and the ices forming a comet.

Dust in primarily observed by its effects on the spectra of background stars, so observations at optical and ultraviolet (UV) wavelengths are confined to the diffuse interstellar medium (ISM) or to the outer regions of dense clouds. Within this somewhat limited range of environments there are very few lines of sight which show any evidence for icy mantles, but there are major variations in the wavelength dependence of the extinction. In the infrared region of the spectrum it is possible to observe a few stellar source deeply embedded within molecular clouds-- in this case, the dust clearly has accreted thick icy mantles containing a wide variety of molecules.

There are several observed facts about the interstellar extinction law, or the dependence of the extinction on wavelength, about which there is little controversy. These include:

(a) There are not many spectral features in the extinction law for the diffuse ISM, a fact has been the downfall of countless suggestions for the materials which might be present in space. The features which are present are 9.7 and 18 μm broad absorption features which are very well matched by the spectra of amorphous silicates. The same features are seen in emission in the spectra of oxygen-rich red giant stars. From these facts, it is generally accepted that silicates are present as a major constiuent of dust. **(b)** There are emission bands in the 3 - 13 μm range and associated continuum found in the spectra of a side variety of objects. The wavelengths of the bands coincide very well, but not perfectly, with the spectra of polycyclic aromatic hydrocarbons (PAHs), but other forms of hydrogenated carbon cannot be excluded. **(c)** There is a huge spectral feature at 2175 Å which has many puzzling characteristics. It is so large that it must be carried by a very abundant element or ion. It coincides with the wavelength at which graphite has a strong resonance, but there are difficulties with the graphite identification which will be mentioned. **(d)** The various extinction laws over the entire observed wavelength range, 0.1 - 5 μm, represent a regular progression with just one parameter. This parameter can be taken to be some measure of the curvature of the extinction law in either the optical or the UV part of the spectrum.

There are several theories which attempt to explain the observations. I will review those by Greenberg, Duley/Williams, Draine/"MRN", and composite grains very briefly. In general, they agree that the major constituents of dust are silicates and a form of carbon, at least some of which also contains hydrogens bonded to it. To produce the observed polarization, the grains must be nonspherical and capable of being aligned by the rather weak galactic magnetic field, even in regions of very high gas density. The theories differ considerably in the arrangement of the carbonaceous materials. Greenberg and Duley/Williams want mantles on silicate cores, while the others want bare grains in the diffuse ISM and the outer regions of dense clouds. The reasons why mantles do not seem to be important in the diffuse ISM are discussed. All of the various theories seem capable of explaining the main features of at least the average extinction law and polarization in the diffuse ISM.

The weaknesses of each theory, as I see them, are reviewed, and tests are discussed. One is the prediction of the polarization and extinction of the infrared silicate band, which is sensitive to the immediate environment of the silicates which are present in the grains-- that is, whether or not there is a surrounding mantle. Observations indicate that there is not. Another test is whether or not a given type of model can explain in a reasonable way the regular progression from the average interstellar extinction law in the diffuse ISM to that in the outer regions of dense clouds. The grains appear larger in clouds, and yet the extinction per H atom is smaller in some well-observed cases. These observations show that grains in these outer regions grow by sticking together (coagulation) rather than by accreting mantles.

A rather speculative scenario of how a given particle of refractory material cycles into and out of the diffuse ISM and dense clouds is presented. Part of the process is, indeed, related to the mantles which are known to be present deep within clouds. A possible state of the grain when it is incorporated into pre-cometary material is described. Whether or not the grain is further processed in between the dense-cloud phase and being deposited deep within a cometary nucleus is considered too speculative to discuss.