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LABORATORY STUDIES OF THE INFRARED SMALL-PARTICLE EXTINCTION OF AMORPHOUS SILICATES

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The broad interstellar IR extinction features located at 9.7 and 18 um wavelength are believed to originate from silicate dust grains. Cosmic abundances suggest that the silicate should have a chemical composition similar to that of olivine, i.e. $(Mg,Fe)_2 SiO_4$. Olivine is a very common terrestrial silicate mineral of crystalline structure. However, crystalline olivine grains do not fit the interstellar features well. Based on spectroscopic data obtained in laboratory studies and astronomical observations it has been concluded that the interstellar silicate grains consist of a material with amorphous rather than crystalline structure (see e.g. Aitken, 1981, and the references therein). In the following, I want to review briefly the astronomical arguments and the results obtained in our laboratory experiments which support this view.

To appreciate the significant difference between the small particle extinctions of a crystalline and an amorphous silicate, fig. 1 shows both kinds of extinction spectra for a silicate of the composition $Mg_{1.9} Fe_{0.1} SiO_4$. Notice that the extinction is plotted on a logarithmic scale. The spectra were calculated using the published optical constants of both kinds of silicates (Huffman, 1977; Krätschmer, 1980), assuming that the dust grains are spherical in shape and of sizes small compared to the wavelength. The extinction of the amorphous silicate is characterized by (a) loss of structure within the peaks and broadening of the peaks, (b) decrease of strength in the extinction peak maxima, and (c) shifts of the peak centers to slightly shorter wavelength. All these characteristics also seem to be exhibited by interstellar silicates. The wavelength positions of the extinction maxima of the amorphous silicate (9.7 and 17 um) compare favourably with that of the interstellar features. The strength of the interstellar extinction at 9.7 um has been estimated to about 3000 cm^{-1} which, as a peak absorption, is unusually small for crystalline silicates (see e.g. Capps and Knacke, 1976), and is even lower than that of our amorphous olivine. The most powerful argument in favour of amorphous interstellar silicates is based on the apparent absence of any sub-structure within the interstellar 9.7 um band. The sub-features originate from the optical anisotropy of the silicates and are tied to the crystalline structure.

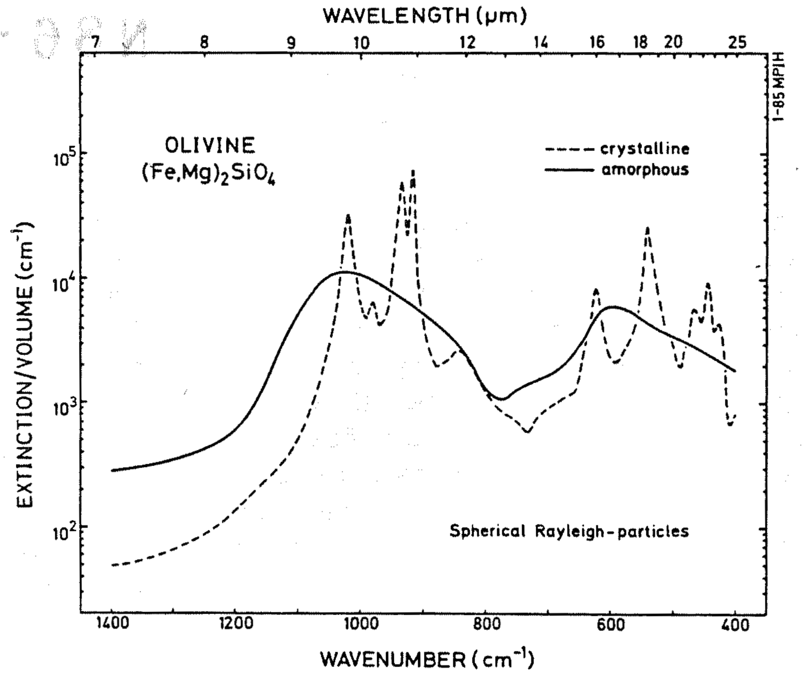

Fig.1: The extinction of the magnesium-iron-silicate called olivine in the crystalline and in the amorphous state. The Fe/Mg ratio of this particualar silicate is about 10% by atom. The amorphous silicate was produced by ion-sputtering of crystalline olivine (for details, see Krätschmer, 1980).

Since, in the case of a crystalline structure, the detailed positions and strengths of the sub-structures depend on the chemical composition of the silicate, one may argue that a suitable mixture of a variety of crystalline silicates with all their different extinction sub-structures superimposed could mimic the interstellar extinction as well. I regard this case as unlikely. The absence of wiggles in the shape of the 9.7 um feature, the wavelength positions of the extinction peaks, the comparatively weak strengths of the interstellar silicate absorptions, all this together can be much more coherently explained by silicates with amorphous structure.

The amorphous state of a solid usually is thermodynamically metastable, i.e. the solid tends to re-crystallise at a rate which strongly increases with increasing temperature. Thus the interstellar grains possess an internal memory of their thermal history to which an observer has access via IR-spectroscopy. The temperature regime at which recrystallisation takes place and in which the silicate grains may be used as temperature probes amounts to several 100 K. This seems to be quite high compared to average interstellar conditions. The amorphous structure of the so far observed interstellar silicates in fact suggests that they never were appreciably heated. In this context it may be noted that interstellar H_2O ice in dense clouds seems to exist in an amorphous structure as well (see e.g. Kitta and Krätschmer, 1983). Phase transitions of this material, detectable by IR spectroscopy, occur at much lower temperatures (several 10 K). It thus may be useful to exploit the thermal memory of the amorphous interstellar grain materials in future IR-astronomical studies to investigate the thermal conditions within various interstellar environments.

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