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THE SHAPES OF THE CIRCUMSTELLAR "SILICATE" FEATURES

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Around oxygen-rich stars we find that the spectra of most long-period variables (LPV) show an excess infrared emission which is attributed to circumstellar silicate dust grains. These grains produce emission features at about 10 and 18 μm due to bending and stretching modes of SiO respectively. It has been known (Forrest, Gillett and Stein 1975) that the spectral energy distribution of the 10 μm emission shows variations from star to star. With the availability of many IRAS Low Resolution Spectra (LRS) in the 8-22 μm region of M stars, we can now study the 10 μm feature to determine its uniformity (or lack thereof). For this analysis we assume that the 8-22 μm emission from these stars is produced by a) the stellar photosphere, b) a continuum emission from the dust grains and c) a strongly wavelength dependent dust grain emission term. By representing the first two terms with blackbody energy distributions and subtracting them from the observed spectrum, we are left with a remaining strongly wavelength dependent emission feature which we call the excess silicate or 10 μm emission.

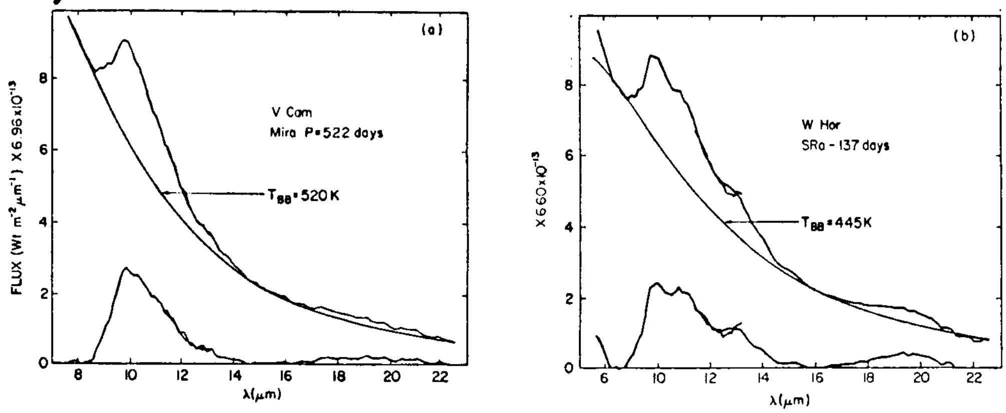

Fig. 1. Two M star LRS spectra (V Cam and W Hor) are plotted together with black body energy distributions fitted to either side of the emission feature. The 10 μm excess (observed - local black body continuum) is plotted above the wavelength axis. The difference in the shape of the excess between the two stars is obvious.

The excess silicate emissions from about 130 LPVs can be divided into three groups characterized by similiar spectral shapes. All three shapes are shown in Figure 2. The average silicate feature of semiregular (SRa,b,c) and irregular (Lb) variables is shown as a solid line. This feature extends from 8.4 to ~14.5 μm with a peak at 10±0.05 μm. The FWHM is 2.1±0.15 μm but the feature is asymmetric with the ratio of the widths of the short wavelength (rising) branch compared to the long wavelength (falling) branch of 0.6:1.5 at half intensity. The rising branch shows only minor variations in wavelength from star to star whereas the wavelength at the FWHM point of the falling branch varies by ±0.15 μm. The average silicate excess of Mira variables is shown as a dashed line in Figure 2. The average feature extends from 8 to 14.5 μm with a peak at 9.75 μm and a FWHM of 2.3 um. The feature is asymmetric but on the average has a less steeply rising branch than the other LPVs giving a ratio of the rising width to the falling width of 0.75:1.5 at half intensity. However, the spectral shape of the silicate emission feature among the Miras shows much greater variation from star to star than that of the other LPVs. The shape of the emission from Miras ranges from one identical to the SRs and Lbs to a much broader one, extending from <8 µm (the limit of the LRS detectors) to ~14.5 µm with a corresponding shift in peak emission from 10 to 9.6 µm and an increase in the FWHM from 2.1 to 2.4 µm. The long wavelength edge of the feature appears to vary very little among these Miras. Hence the difference in spectral shape between the Miras and the other LPVs is primarily due to the fact that in Miras the rising branch varies in wavelengths accompanied by a shift in the peak emission to shorter wavelengths. This shift to shorter wavelength correlates with the strength of the silicate excess. In general the greater the strength of the feature the shorter the wavelength of the rising branch. Unlike the results of DeGioia-Eastwood et al (1981), we find that the strength correlates only very weakly with period. This corroborates the conclusion reached by Vardya, De Jong and Willems (1981). At a given period the excess can vary by a factor of 4. The 18 µm emission feature is very similiar in both types of profiles and extends from about 15 to >22 µm. Both these ~10 µm and 18 µm features have been attributed to silicates.

The most interesting 10 µm emission occurs in stars which tend to show weak excesses but includes a few stars which have excesses comparable in strength to the stars with the other types of features (see Fig. 1a and 1b). There are relatively few stars in this group, but they constitute almost half of the stars with weak emission irrespective of their variability type. The feature has three components (dotted line Figure 2) with peaks at 10, 11 and 13.1 µm. The 10 µm peak is strongest in M stars and agrees in wavelength with the silicate peak of the SRs but it is narrower. The intensities of the 11 and 13.1 µm peaks vary greatly being at times quite weak. These stars show an emission excess at long wavelength which is sigificantly different from the 18 µm emission. It appears to extend from about 16 to 22 µm with a peak at about 19.5 µm. If the 3 component feature is also due to silicates is not yet known. The peak at 8 µm seen in Figure 2 appears to be an artifact of our method of analysis. It disappears if photospheric temperatures are used to fit the shortest wavelengths of the LRS. This research is supported in part by a University Resident Research Fellowship from the Air Force Office of Scientific Research to the Air Force Geophysics Laboratory.

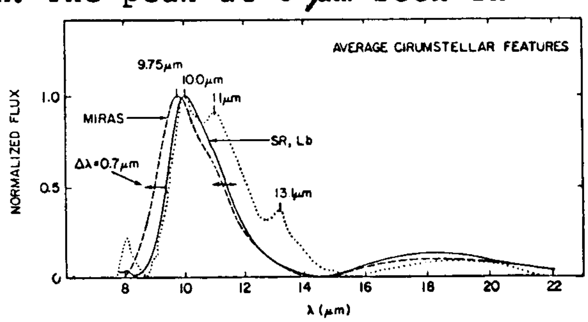

Fig 2. The three types of 10 µm excess.

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