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On the Nature of M stars with a 60 microns Excess

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1. Introduction

Some years ago, Willems & de Jong (1988) noticed that many carbon stars display an excess of emission at $60\,\mu m$ and explained it by the presence of a fossil dust shell, containing only cold dust. This detached dust shell would be the result of an interruption of the mass loss, consequence of a thermal pulse. Detached shells around C stars have actually been mapped in the CO lines (Olofsson et al. 1992), and at $60\,\mu m$ (Waters et al. 1994). In 1992, Zijlstra et al. found about 100 M stars displaying an excess of emission at $60\,\mu m$, and proposed that interruptions of the mass loss due to thermal pulses is a general phenomenon on the AGB. This assumption is now supported by the theoretical calculations of Vassiliadis & Wood (1993). Here we present a detailed study of the 100 M stars of Zijlstra et al. in order to test the previous assumption.

2. M stars with $60\,\mu m$ excess resolved by IRAS

For these 100 M stars, we have analysed individual and averaged IRAS scans, as well as co-added maps, at $60\,\mu m$. We find that 15 sources are clearly resolved by IRAS at $60\,\mu m$, 51 objects are clean point sources, and 39 objects have an unreliable PSC $60\,\mu m$ flux. We applied maximum entropy image reconstruction techniques (Bontekoe et al. 1994) to the 15 sources resolved at $60\,\mu m$, as well as on a few point sources for comparison. 5 sources are found to be very peculiar objects. For the 10 other sources, the dust shell appears to be roughly spherical at $60\,\mu m$. These 10 stars are located in the region VIa of the IRAS two-colour diagram (van der Veen & Habing 1988) and we conclude that they have undergone a strong decrease of the mass-loss rate in the past.

3. Spectral and variability types

We performed optical spectroscopy of 29 M stars with a $60\,\mu m$ excess using the B&C spectrograph on the ESO 1.5m telescope. Spectra were taken from 3600 to 9200 Åwith a resolution of 1.9 Å. M classes were determined with an uncertainty of 0.5. For other sources we use previous determinations found in the literature. We also performed JHKL'M photometry of 30 M stars at the

ESO 1m telescope with its standard infrared photometer. M stars with a $60\,\mu m$ excess can be clearly separated in two groups : sources located in region VIa generally displaying a strong excess at $60\,\mu m$, and sources located in region VII and VIb with a small $60\,\mu m$ excess. Most M stars located in region VIa have spectral types earlier than M5 and are non or irregular variables. Conversely, most sources in region VII and VIb have spectral types later than M5 and are semi-regular or Mira variables. The energy distribution of one source located in region VIb clearly shows that the dust envelope is not spherical.

4. Discussion and conclusions

According to Vassiliadis & Wood (1993), for stars with an initial mass smaller than about $3\,M_{\odot}$, the consequences of a thermal pulse would be a strong and sudden decrease of the mass loss rate, the stellar luminosity, and the period, and a strong increase of the effective temperature. After typically 5000 years, $\dot{M}$, $L_{\star}$, and P would increase, whereas T_{eff} would decrease, regularly again, up to the occurrence of a new thermal pulse.

Under the assumption of a strong decrease of the mass loss rate, M stars with a $60\,\mu m$ excess located in region VIa should have undergone a thermal pulse a few 1000 to 10,000 years ago, while M stars located in regions VII and VIb should have undergone a thermal pulse less than a few 100 years ago (Chan & Kwok 1988). Statistically, we should then find much less sources in regions VII and VIb than in region VIa. Here we find 28 sources in region VIa and 18 in regions VII and VIb. Furthermore, following the model of Vassiliadis & Wood, M stars in regions VII and VIb should have the highest effective temperatures, while we observe the opposite.

We conclude that M stars with a $60\,\mu m$ excess located in regions VII and VIb are either stars with a slowly decreasing mass loss rate, or stars enshrouded by a non–spherical dust envelope. On the other hand, we find 28 M stars located in region VIa, of which 10 are resolved by IRAS at $60\,\mu m$, which are very good candidates to be M stars with a detached envelope. For them, our observations are in qualitative agreement with Vassiliadis & Wood concerning the behaviour of the mass loss rate and the effective temperature. However, while they predict a periodic variability for these stars, we rather find them as non or irregular variables.

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