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SWS OBSERVATION OF THE SILICATE CARBON STAR V778 CYG

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ABSTRACT

The silicate carbon star V778 Cyg was observed by the Short Wavelength Spectrometer (SWS) on board ISO. The spectrum is clearly divided into two parts; the carbon-rich part between $2.4 - 6.5\mu$m with many molecular absorption bands, and the oxygen-rich part longer than 6.5μm showing the silicate dust emission features. The shape of the silicate features has not changed since the IRAS Low Resolution Spectrometer (LRS) observations about 13 years ago, indicating that the silicate dust may be in a stable structure such as disk, although the energy distribution of the spectrum seems to be consistent with a spherical density distribution. No oxygen-rich molecules, like H_2O, were detected.

Key words: Stars: carbon – Stars: circumstellar shell – Stars: V778 Cyg – Infrared: spectroscopy

1. INTRODUCTION

Silicate carbon stars were discovered in studies with the IRAS/LRS (Willems and de Jong 1986; Little-Marenin 1986). They show silicate dust emission features at 10 and 18μm which are the characteristics of oxygen-rich circumstellar envelopes, while the central stars have properties of carbon stars. Detailed spectroscopic studies (e.g., Lloyd Evans 1990) revealed that the central stars are probably all ^{13}C rich (J-type carbon stars). Several ideas have been proposed to explain the phenomenon; a quick transition of the central star from oxygen-rich to carbon-rich (Willems and de Jong 1986), binary with an oxygen-rich giant (Little-Marenin 1986); or a disk around a dwarf companion (Lloyd Evans 1990; see also Morris 1987). In this paper we report preliminary results of an ISO/SWS study of the silicate carbon stars V778 Cyg.

2. OBSERVATION

The observation was carried out as part of the ISO GT program AGBSTARS (P.I. T. de Jong). The spectrum of V778 Cyg was taken on 1997 May 1 by the SWS AOT01, speed 3. Data were reduced with the Interactive Analysis software package developed by the SWS Instrument Dedicated Team. Data of 12 detectors in each band were rebinned with a resolution of $R = \lambda/\Delta\lambda = 500$. Discrepancies of the absolute flux between different instrumental bands in the reduced spectrum were corrected by scaling the data in each band before the rebinning. Band 1B ($2.60 - 3.02\mu$m) is assumed to be the reference.

3. RESULT

The SWS spectrum of V778 Cyg is shown in Figure 1. An oxygen-rich supergiant μ Cep and a visually bright carbon star R Scl are also plotted for comparison. They are observed with an AOT01, speed 2 and rebinned with $R = 300$. The fluxes of these two stars are arbitrarily scaled to fit in the same window. It can be seen readily that the spectrum of V778 Cyg is a combination of carbon-rich and oxygen-rich components. At short wavelengths, the spectrum of V778 Cyg is almost identical with R Scl. The features seen in two stars are mostly due to carbon-containing molecules, such as C_2H_2, HCN and C_3. Absorption bands due to H_2O and OH molecules, which are usually seen in late-type oxygen-rich stars, are not observed in V778 Cyg. This is consistent with the results of higher resolution spectroscopy by Lambert et al. (1990), and is against the idea that an oxygen-rich companion is responsible for the silicate emission. It is noticeable that the star shows a strong C_3 absorption band at 5.2μm. The strength of this feature is sensitive to the mass-loss rate of the star and weakens significantly when the mass-loss rate reaches $10^{-6}\,M_\odot\,yr^{-1}$ (Yamamura et al. 1997). Therefore, the present mass-loss rate of the star must be very small.

From about 6.5μm onwards the spectrum appears to be oxygen-rich. Strong silicate emission features at 9.7μm and 18μm dominate the spectrum, and the absorption bands of C_2H_2 and HCN at 7.5μm and 14μm which are clearly seen in R Scl are not recognizable in V778 Cyg. The shape of the silicate features is similar to those in the "template" star, μ Cep, implying the similarity in dust distribution around the stars.

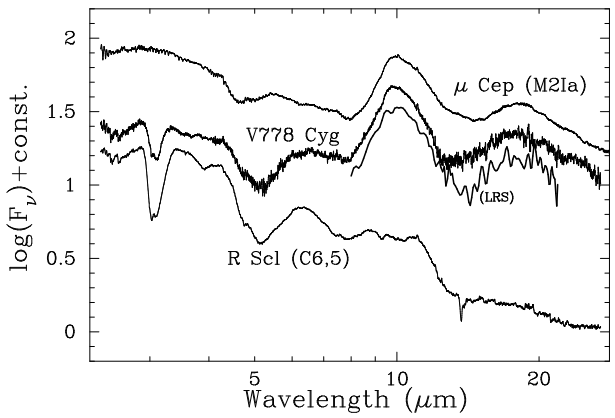

Figure 1. ISO/SWS spectrum of V778 Cyg, μ Cep, and R Scl between 2.38 and 27μm. The IRAS LRS spectrum of V778 Cyg is also plotted by thick line. The flux scale (Jy) is correct only for V778 Cyg. Note that small peaks at 10, 11, and 19μm are instrumental spurious.

4. DISCUSSION

If the silicate carbon star is a result of transition from an oxygen-rich star to a carbon star in a very short time (Willems and de Jong 1986), we could expect a change in shape of the silicate features with the time, because the inner boundary of the silicate shell moves outward. The IRAS/LRS spectrum of V778 Cyg is presented in Figure 1. The spectrum is obtained from the IRAS data server at SRON-Groningen and reduced with the GIPSY software package. The SWS spectrum and the LRS spectrum are quite similar. No appreciable variation in shape of the silicate features is found except a small difference in the flux level which may be due to the variation of the central star. This fact suggests that the silicate dust is not in an expanding shell detached from the central star, but in rather a stable structure. The disk model is preferable in this context.

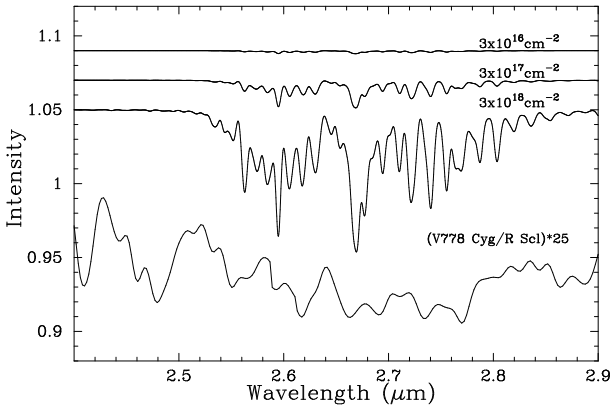

Figure 2. H_2O *model spectra calculated for* $T_{ex} = 300K$ *and three different column densities. The V778 Cyg spectrum is divided by the R Scl spectrum in order to cancel the carbon-rich features.*

If the star is surrounded by an oxygen-rich circumstellar shell, absorption features due to cool oxygen-rich molecules in the shell could be observed. Figure 2 shows model spectra of the H_2O molecule in the 2.7μm region with three different column densities. The molecule is assumed to be in LTE state with an excitation temperature of 300K. The spectrum of V778 Cyg is divided by R Scl's spectrum after scaling to the same flux level and smoothed to the same resolution. Features of C_2H_2 and HCN, present in the both stars should be canceled by this process. No clear indication of the H_2O features is seen in the residual spectrum. An upper limit to the column density of H_2O estimated from this is 3×10^{17}cm^{-2}. If we assume an inner radius of the circumstellar shell of 3×10^{14}cm, an expansion velocity of 5km s^{-1} (Engels and Leinert 1994), and an abundance of H_2O of $3 \times 10^{-4}/H_2$, we obtain an upper limit to the mass-loss rate of about $1 \times 10^{-7}\,M_\odot\,yr^{-1}$. This is almost consistent with the mass-loss rate expected for stars with silicate emission features like V778 Cyg (e.g. Bedijn 1987).

In conclusion, it is not yet clear how the material is distributed around V778 Cyg. The lack of change in the silicate emission features since the IRAS observation indicates that the silicate dust is not in a detached shell. On the other hand, the presence of oxygen-rich molecules in the circumstellar shell cannot be completely ruled out. Both disk and shell models need to be tested further in detail with respect to the dust features as well as intensities of molecular absorption features in different wavelengths.

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