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A SILICATE CARBON STAR AS SEEN BY ISO*

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ABSTRACT

We report the result of the SWS observations of a silicate carbon star, V778 Cyg. This is the only 'IRAS-discovered' silicate carbon star observed by ISO. The profile of the silicate dust feature in the star does not show any changes since the IRAS LRS observation in 1983. The silicate feature is dominated by the amorphous component, and crystalline silicate bands are not noticeable, indicating that the dust is recently formed. We discuss the possibility of steady formation of the silicate dust in the stellar wind.

Key words: stars: carbon – circumstellar matter – stars: individual: V778 Cyg – stars: mass-loss

1. Introduction

The silicate carbon stars are a group of carbon stars which show prominent silicate emission features. Because silicate dust is normally formed and observed in the oxygen-rich environment, the origin of the silicate emission in these stars has been a big puzzle as well as the evolution of these stars, since their first discovery by the IRAS Low-Resolution Spectrometer (LRS; Willems & de Jong 1986; Little-Marenin 1986). The central stars are probably all ^{13}C rich (i.e. J-type carbon stars; Willems & de Jong 1986, Lloyd Evans 1990), suggesting an unique evolutionary scenario of the stars. The nature of the silicate carbon stars is still unknown. The most widely accepted formation scenario of a silicate carbon star is that the oxygen-rich material is stored in a disk surrounding a companion, or surrounding the binary system. The O-rich dust is thus a remnant of a previous phase of mass loss when the star was oxygen-rich (Morris 1987, Lloyd Evans 1990).

V778 Cyg is a carbon star with spectral type C4,5J (Yamashita 1975) and variable type Lb. The IRAS / LRS spectrum shows prominent silicate emission features (LRS class = 29). H_2O and OH masers are detected (Nakada et al. 1987, Little-Marenin et al. 1988). No clear evidence of binarity has been found by radial velocity measurement (Barnbaum et al. 1991).

2. Observation and Results

The observation of V778 Cyg was carried out as part of the ISO guaranteed time program AGBSTARS (P.I. T. de Jong), on 1997 May 1. The SWS AOT01 (speed 3) mode was used, which covers $\lambda = 2.38-45.2$ μm with a resolution ≈ 500.

The SWS spectrum (Figure 1) reveals again the coexistence of C-rich and O-rich chemistry in the object with a rather clear transition at ~ 6.5 μm. The short wavelength part of the spectrum shows strong molecular absorption features of C_2H_2, HCN, and C_3, which confirms that the central star is a low mass-loss carbon-rich star (Yamamura et al. 1998). No oxygen-rich molecular feature is detected up to the level of a few % of the flux (Yamamura et al. 1997). This is consistent with previous ground-base observations (Lambert et al. 1990). The long wavelength region is dominated by the silicate features peaked at 9.7 and 18 μm. The 14 μm C_2H_2 band is hardly recognized. This can be explained if the strong silicate dust emission veils the feature arising in the photosphere, and if there is no C-rich gas in the circumstellar envelope.

The most remarkable point of the SWS spectrum of V778 Cyg is that the profiles of the silicate features in the spectrum is perfectly consistent with the IRAS LRS spectrum; i.e., there is no change in the silicate feature in 14 years between the two observations. Also, the fluxes corresponding to the IRAS 12 and 25 μm broad-band photometry fluxes measured from the SWS spectrum agree with the IRAS measurement. These results suggests that the dust is either in a steady outflow, or stored in a disk near the star, and not in a detached expanding shell.

3. Discussion

The large 10 μm / 20 μm intensity ratio suggests a very high dust temperature. A simple modeling of

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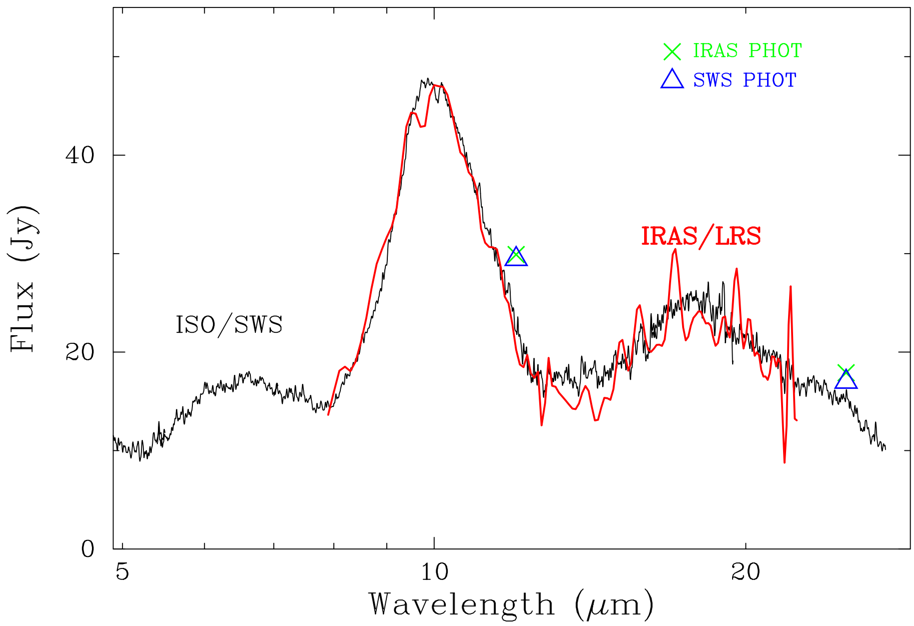

Figure 1. Comparison of the SWS spectrum with the IRAS/LRS shows that there is no change in the profile of the silicate feature in 14 years (the LRS spectrum is scaled at 10 μm). The IRAS 12 and 25 μm broad-band photometry fluxes measured on the SWS data match with the IRAS measurement within 1 Jy, indicating that the absolute flux level also did not change.

the dust feature indicates that the dust is at $\sim 13\ R_\star$ with a temperature ~ 560 K. If this is the case, the dust is exposed to the radiation from the central star, and must be pushed out by its radiation pressure. This effect cannot be avoided even if the dust is in a disk-like structure.

It is noticeable that we do not find strong evidence for crystalline silicates in V778 Cyg, even when we consider that crystalline silicates are usually cooler than amorphous ones due to differences in the Fe content. In other stars with *stationary*, long-lived circumstellar disks, such as AC Her (van Winckel et al. 1998) and the Red Rectangle (RR) (Waters et al. 1998), crystalline dust is very abundant. Since crystallization requires high temperatures, and since the dust in V778 Cyg is much hotter than the O-rich dust in cases as AC Her and the RR, the difference in composition is remarkable. It is possible that the abundance of crystalline silicates in stationary disks increases with time. This would imply that the dust in V778 Cyg is young.

One possible explanation for these observational results is that the oxygen-rich dust is continuously formed in the system presently. The C / O ratio in the surface of many carbon stars is ~ 1.1 (Lambert et al. 1986), while that of solar abundance is ~ 0.5. If the star has a binary companion (possibly a main-sequence star), and the companion provides some oxygen-rich material to the stellar wind, the wind can be turned to oxygen-rich. The required amount of mass provided from the secondary is ~ 13 % of the total wind mass. It can be even smaller if the C / O ratio of the primary is closer to 1, or if only part of the wind is turned to oxygen-rich.

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