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Mass Loss from Carbon Stars: Circumstellar C_2 Swan Band

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Abstract. We have searched 44 optical carbon stars for circumstellar C_2 Swan (0,0) band absorption lines using the high dispersion echelle spectrograph for the 188 cm reflector at Okayama Astrophysical Observatory. We have detected the circumsteller C_2 lines definitely in 18 stars, possibly in 6 stars, and not detected in 20 stars. We discuss the observed properties of the circumstellar C_2 lines. We infer the C_2 line-forming region is located at the innermost part of the circumstellar envelope.

1. Introduction

Circumstellar C_2 absorption lines were first detected in several post-AGB stars and were used to deduce the physical conditions of their AGB remnant shells (Bakker et al. 1996; 1997). Their presence were, however, not known in currently mass-losing AGB stars except IRC+10216 (Bakker et al. 1997).

Izumiura et al. (2002) detected circumstellar C_2 Swan (0,0) band absorption lines unexpectedly in a few optical carbon stars using HIDES, a new high dispersion echelle spectrograph installed to the 188 cm reflector at Okayama Astrophysical Observatory (Izumiura 1999). This detection may lead to a new powerful tool to probe the circumstellar envelopes of optical carbon stars with relatively low mass-loss rates. For example, the expansion velocity and carbon isotopic ratio could be determined precisely for each circumstellar envelope.

2. Observations

We performed high resolution spectroscopic observations of the circumstellar C_2 Swan (0,0) band absorption lines with HIDES in 44 carbon stars during the period from December 1999 to August 2001. The resolution ($\lambda/\Delta\lambda$) was set at about 95,000 ($\sim$ 3.2km/s). We first observed the 33 stars of which chemical composition were examined in detail by Lambert et al. (1986). We added some other interesting stars such as carbon stars associated with silicate dust shells and Mira-type variables. The data were reduced in a standard manner using the echelle package of NOAO IRAF.

3. Results and Discussion

Of the 44 stars surveyed, circumstellar C_2 absorption lines were detected definitely in 18 stars, tentatively in 6 stars, and not detected in 20 stars. In one of the stars with circumstellar C_2 lines, mm-wave circumstellar CO emission has not been detected. Circumstellar C_2 detections/nondetections are clearly correlated with both photospheric effective temperature (Teff, Bergeat, Knapik, & Rutily 2001) and C/O abundance ratio (Lambert et al. 1986), that is, circumstellar C_2 is detected in stars having Teff < 2800 K and C/O > 1.1. Detections/nondetections have only a weak correlation with mass-loss rates derived from the circumstellar CO lines, but do a moderate correlation with those of circumstellar HCN emission (Olofsson et al. 1993a, 1993b). The expansion velocity of the circumstellar C_2 gas is slightly smaller than that derived from the mm-wave circumstellar CO emission lines (Olofsson et al. 1993a) by about $1 \sim 4$ km/s. Rotational excitation temperatures are found to range from about 350 to 810 K, assuming the lines being optically thin and the Boltzmann distribution for the rotational ladder.

The above results show that the C_2 lines sample a part of the circumstellar envelope that is different from one seen in the mm-wave CO emission lines. Considering that the circumstellar C_2 is seen in absorption and has a slightly smaller expansion velocity than the circumstellar CO gas, we infer the C_2 line-forming region is located at the innermost part of the circumstellar envelope, just inside the place where the outflow reaches the terminal velocity.

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