Part IId. HCN MASERs

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HCN(J=1-0) maser emission in the bright carbon star Y CVn

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Abstract. We present high resolution observations of HCN(J=1-0) line in the bright carbon star Y CVn. With an angular resolution of 0.5 arcsec we are able to resolve the HCN envelope around Y CVn. The HCN(J=1-0) line profile toward the central position exhibits several strong spikes having brightness temperature in excess of 1000 K. This result indicates that the J=1-0 line is masing. We also discuss the pump mechanism of this maser and the implication for the determination of the HCN abundance.

1. Introduction

The ground state HCN(J=1-0) line has been commonly observed in carbon rich circumstellar envelopes. The line is usually thought to be thermally excited by collisions with hydrogen molecules or by absorption of stellar infrared photons. However, Izumiura et al (1987) observed unusually strong HCN(J=1-0) and $H^{13}CN$(J=1-0) lines in the bright carbon star Y CVn. They suggest that these lines are in fact maser lines. Subsequent surveys by Olofsson et al. (1993) and Izumiura et al. (1995a) found several other carbon stars with strong HCN(J=1-0) emission lines. All of these objects are optically bright carbon stars having low mass loss rate, typically about a few 10^{-7} $M_{\odot}$/yr.

Izumiura et al. (1995b) attempted to map the HCN envelope of Y CVn with the Nobeyama interferometer. Due to their poor resolution the envelope of Y CVn was still unresolved and they put an upper limit of 2 arcsec to the size of the envelope. At the distance of Y CVn (218 pc) that corresponds to a linear scale of 6 × 10^{15} cm. Based on the photodissociation model of HCN, Olofsson et al. (1993) predicted that the size of HCN envelope around Y CVn is about 2× 10^{15} cm.

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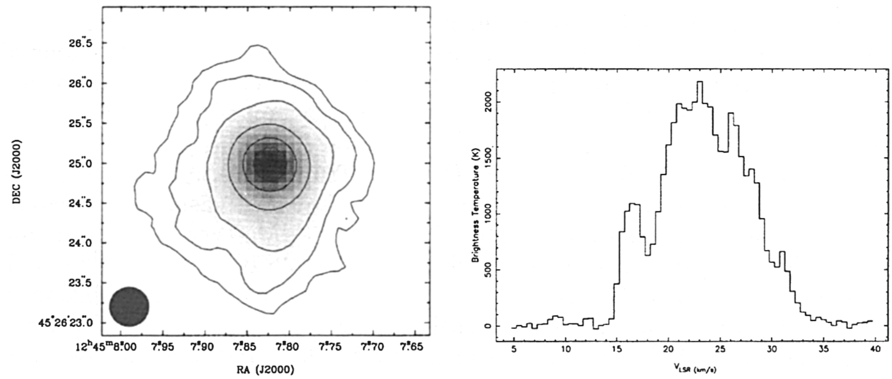

Figure 1. Left frame: contour map of the integrated intensity of HCN(J=1-0) emission. The contour levels are 2.5%, 5%, 10%, 25%, 50%, 75% and 90% of the peak value of 35.8 Jy km/s. Right frame: HCN(J=1-0) line profile toward the center position of Y CVn

By modelling the excitation of HCN molecules in the envelope of carbon rich AGB stars Dinh-V-Trung & Nguyen-Q-Rieu (2000) showed that the HCN(J=1-0) line can be inverted by the absorption of stellar photons at 3 μm. The HCN(J=1-0) line profile is predicted to contain several strong spikes resulting from the overlap of two hyperfine components F=1-1 and F=2-1.

High angular resolution observations of HCN emission will allow us to study the inner region of the envelope close to the central star which is not possible with CO observations, because CO emission is usually more extended than HCN emission and CO lines are optically thicker than HCN lines.

2. Observational results and discussion

We used the BIMA (Berkeley - Illinois - Maryland Association) interferometer in its most extended configuration to map the distribution of HCN(J=1-0) emission around Y CVn. The resulting synthesized beam is 0.5 arcsec or 1.5×10^{15} cm in linear scale. Since the line is strong we used the cleaned channel-averaged map of the emission as the starting model for self-calibration. Self-calibration on a timescale of 2 minutes improved the maps substantially by reducing phase errors caused by atmospheric delay fluctuations.

In figure 1 we show the integrated intensity map of HCN(J=1-0) emission together with the line profile toward the central position of Y CVn. The strong spikes, in particular the features at 16.5 km/s and at 24 km/s, are seen superposed on the broad profile and have brightness temperatures higher than 1000 K. Since kinetic temperature decreases rapidly with distance from the central star (Dinh-V-Trung & Nguyen-Q-Rieu 2000), a thermal line is not expected to display such high brightness temperature. Thus, these features can only be explained by maser action.

The HCN envelope is resolved with our 0.5 arcsec beam. Using gaussian fitting we can decompose the integrated intensity into two components: a bright

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and compact (0.35"×0.33") component with flux of 50 Jy km/s, and an extended component (1.8"×1.6") with flux of 80 Jy km/s. Our observations also indicate that the HCN envelope is larger than predicted by photodissociation calculations. That fact has been noted for other carbon stars (Lindqvist et al. 1995).

Using a radiative transfer model (Dinh-V-Trung & Nguyen-Q-Rieu 2000), we show that the population inversion of HCN(J=1-0) transition is created in an envelope with low mass loss rate of a few 10^{-7} $M_\odot$/yr. The inversion is strongest for the inner part of the envelope between 2×10^{14} cm to 10^{15} cm. For higher mass loss rates the inversion is quenched due to stronger collision and weaker radiative excitation. The intensity of HCN(J=1-0) line in Y CVn can be explained with HCN abundance of about 5×10^{-5} and a mass loss rate of $3\times10^{-7} M_\odot$/yr.

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