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HIGH RESOLUTION CO OBSERVATIONS OF THE BIPOLAR NEBULA CRL2688

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CRL2688 is suggested to be one of the proto-planetary nebulae which are probably at a stage in which the central star is evolving from the red giant phase with rapid mass loss (Zuckerman 1978). The bipolar shape in both the optical and H_2 emission indicates that a dense toroid of dust and gas obscures the star and surrounds the optical emission. The toroid is probably responsible for channelling the mass loss to the polar directions (Ney *et al.* 1975, Morris 1981, Beckwith *et al.* 1984). We present the results of mapping observations of CO (J = 1-0) emission from the expanding molecular envelope (Zuckerman *et al.* 1976, Lo *et al.* 1976, Knapp *et al.* 1982, Thronson *et al.* 1983) of the bipolar reflection

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nebula CRL2688 using the Nobeyama 45-m telescope with a 15" resolution at a 7".5 observing spacing.

The CO spectrum toward the center has line wing emission with a full width of 85 km s^{-1} (see Figure 1). On the blue-shifted wing, a narrow and deep self-absorption dip is seen at a velocity shifted by 20 km s^{-1} from the systemic velocity (see Figure 2). Figure 3 shows a series of CO maps; (a) a total integrated intensity map, (b) a map of a partially integrated intensity from V_{LSR} = -80 to -60 km s^{-1}, showing blue-shifted high velocity emission, (c) a map from V_{LSR} = -60 to -40 km s^{-1}, showing an elongated central core and a "U"-shaped structure at the north, and (d) a map of H_2 (v = 1-0) S(1) emission (Beckwith *et al.* 1984) superposed on a schematic drawing of the optical appearance of CRL2688 (Ney *et al.* 1975). In the maps, we note that the three features have symmetric structures about the bipolar axis defined by the optical bipolar nebula. The compact central core is elongated in a direction perpendicular to the bipolar axis. The size of the core is 20" -25"×15" (0.1-0.125 pc × 0.075 pc assuming a distance of 1 kpc by Crampton *et al.* 1975). The "U"-shaped structure roughly traces the outer edge of the northern optical lobe and seems to be sorrounding it. The blue-shifted high velocity emission is distributed along the optical lobes. The size is 30" × 15" (0.15 pc × 0.075 pc).

Assuming the presence of the disk of molecular gas suggested from the elongated compact core, and the fast stellar wind (Beckwith *et al.* 1984), the symmetric structures and bipolar shape of the nebula can be

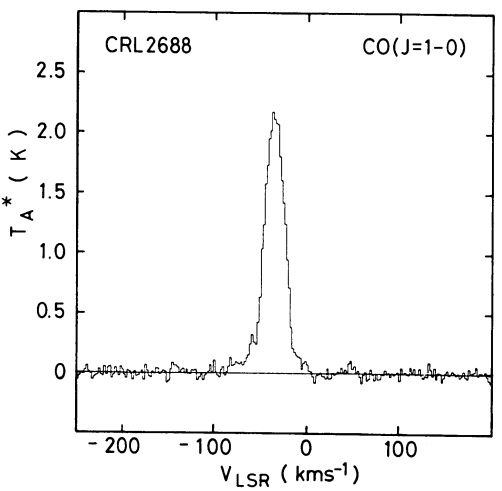

Fig. 1. A ^{12}CO (J = 1-0) spectrum obtained toward the central infrared source CRL2688. The velocity resolution is 2 km s^{-1}.

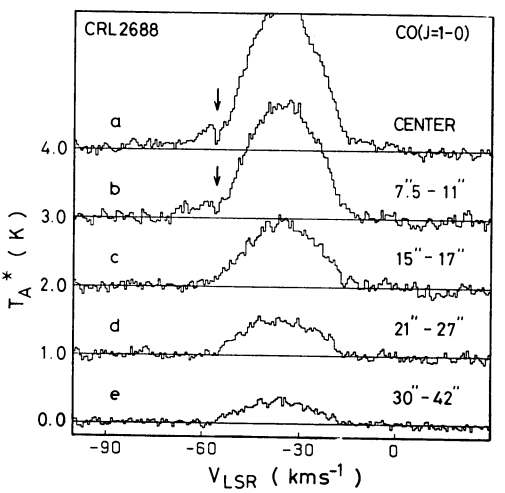

Fig. 2. Radial variation of CO spectra from the center to the outter region. From top to bottom: (a) a spectrum toward the center, and (b)-(e) four spectra averaged for four annuli indicated in the figure. The arrows indicate the position of the -55 km s^{-1} self-absorption dip.

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accounted for by a model of disk-confined stellar wind bubbles. In the model, the disk originally determines the symmetry axis. The "U"-shaped structure and the high velocity emission probably originate from the wind bubbles which expand and elongate to both polar directions of the disk.

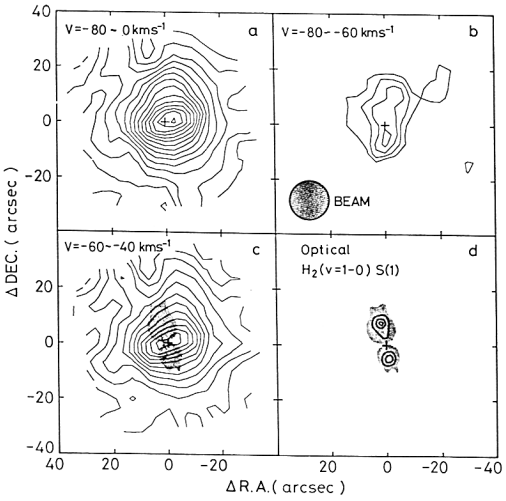

Fig. 3: (a) A map of total T_a^* (^{12}CO) integrated intensity, (b) a map of partially integrated intensity from v = -80 km s^{-1} to -60 km s^{-1}, (c) like figure 3b for v = -60 km s^{-1} to -40 km s^{-1}, and (d) a schematic drawing of the optical appearance of CRL2688 (hatched region) and H_2 (v = 1-0) S(1) emission (contours). Contour intervals and the highest contour levels are 5.0, 0.5, and 1.0 K km s^{-1} and 60.0, 2.0, 18.0 K km s^{-1} for (a), (b), and (c) respectively. The cross indicates the position of the infrared source, (R.A., Dec.) = (21^h00^m $19^s.9$, +36°29'45").

The self-absorption dip suggest that a cold absorbing envelope surrounds the relatively hot molecular envelope. The absorbing envelope has a low excitation temperature with 0.0-1.5 K excess from T_{bg} and an optical depth larger than 1.2 in the CO (J = 1-0) line, and is expanding at v = 20 km s^{-1}. The size and the mass of the absorbing envelope are estimated to be larger than 0.6 pc and 4×10^{-2} $M_\odot$, respectively.

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