MAPS OF MILLIMETER WAVE EMISSION FROM THREE GALACTIC STAR-FORMING REGIONS

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ABSTRACT

In order to investigate the gas dynamics around young stellar objects, we have mapped three sources which exhibit supersonic velocities in the 115 GHz, J=1-0 transition of CO (Bally and Lada 1983). The maps, made with the Owens Valley Radio Observatory Millimeter Interferometer, are the highest spatial resolution (5" x 5") images currently available of millimeter-wave continuum and line emission from the sources S106, S87, and LkHα101. Observations were made in the CS (J = 2-1) and ^{13}CO (J = 1-0) transitions. In all the sources, our observations indicate that the ionized stellar wind is sweeping up ambient molecular gas. The molecular gas is found adjacent to the outer edges of the ionized winds, which originate in embedded infrared sources. From the observations presented here, we may infer that the outflowing ionized winds are channeled by the surrounding dense, neutral gas.

I. Observations

The inteferometer observations of S87 in the CS (J = 2-1) line were made with 32 channels at 3 km s^{-1} velocity resolution, while for S106 and LkHα101, the ^{13}CO maps were made at 0.14 km s^{-1} resolution. Because the interferometer resolves out 50-90% of the emission due to missing spatial sampling of large-scale (>30") features, these sources have also been mapped with the FCRAO 14-m antenna. The single-dish map of S87 in this contribution is in ^{13}CO, observed with 256 channels at 0.3 km s^{-1} per channel, sampled every 15" on a 9 x 9 element grid.

II. Results

S87 is an HII region buried in the center of a hot molecular cloud, associated with an extremely reddened IR source (Bally and Predmore 1983). It is the clearest example of a bipolar flow among the three sources discussed in this work. Figure 1 shows the single-dish map of S87 in the wings of the ^{13}CO line, while Figure 2 shows the same source as seen by the interferometer in CS. The position angles and morphologies of the emission agree over a factor of ten in length scale between the interferometer and single-dish maps, indicating that the bipolar flow is collimated within 10^{17} cm of the central star.

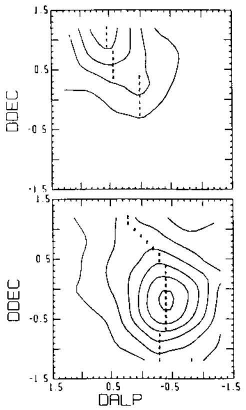

Figure 1
FCRAO 14-m map of S87 as seen in the J = 1-0 transition of ^{13}CO. Map center (1950) coordinates are α=19h 44m 13.7s, δ=24°28′05.1″. V_{LSR} = 22 km s^{-1}, so the top part of the figure is red-shifted emission (V_{LSR} = 24.5→28 km s^{-1}), while the bottom half is blue-shifted (17→21.5 km s^{-1}).

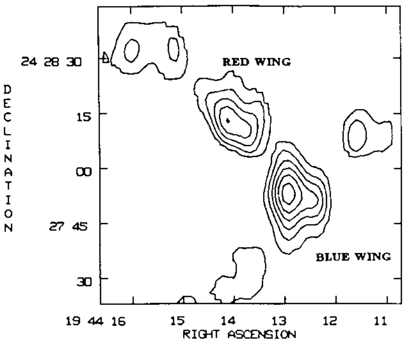

Figure 2
Same source, center coordinates, and V_{LSR} as in Figure 1, but as seen in the CS J = 2-1 transition with the OVRO interferometer. The red wing is emission integrated over V_{LSR}=19→22 km s^{-1}, while the blue wing is integrated over 22→25 km s^{-1}.

LkHα101 is a highly obscured emission line star which illuminates a roughly fan-shaped reflection nebula. In this source, there is a clear anti-correlation between the optical morphology and the molecular line emission. An unresolved 110 GHz continuum source is centered on the embedded young stellar object. Our line observations suggest that the stellar wind of LkHα101 has already cleared out most of the surrounding molecular cloud environment (Figure 3).

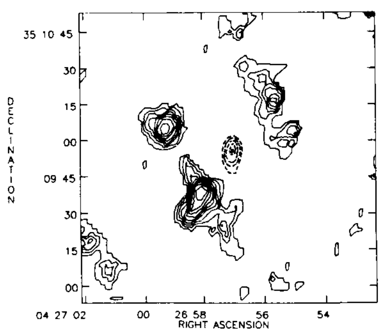

Figure 3
The ^{13}CO J = 1-0 interferometer map of the environs of LkHα101 α(1950)=04h 26m 57.23s, δ(1950)=35°09′55″, V_{LSR}=1.5 km s^{-1}. The dotted contours outline the unresolved 0.35 Jy continuum source coincident with the Hα emission line star.

S106 is a bipolar optical nebula with a dark lane across its center, making it a prime candidate for the detection of an edge-on interstellar molecular disk. The optical emission exhibits a complicated velocity structure; however, the northern lobe is generally red-shifted, while the southern lobe is blue-shifted (Solf and Carsenty 1982). Figure 4 shows the ^{13}CO emission from S106. Figure 5 shows the CS emission from S106 superimposed on the 1.3 cm VLA map (Bally 1985). We find no evidence of the molecular disk claimed by observers at the Hat Creek Interferometer

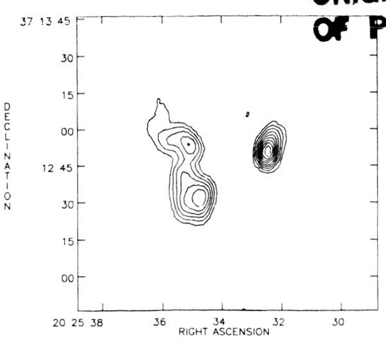

Figure 4
The interferometer map in ^{13}CO of S106. The map is centered on IRS4 (Gehrz et al. 1982) $\alpha(1950)$=20h 25m 33.8s, $\delta(1950)=37°12'48''$ V_{LSR}=-1.0 km s^{-1}. Note the similar morphologies of CS and ^{13}CO.

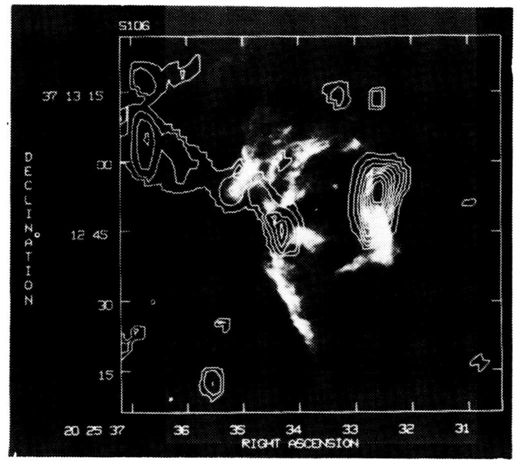

Figure 5

The interferometer map of CS emission from S106 overlaid on its 1.3 cm radio continuum emission. Note the anti-correlation of the spatial distribution of the molecular and ionized gas. There is no evidence for a disk-like structure. The white speck at map center is IRS4.

(Bieging 1984). Instead, the putative disk breaks up into two dense condensations on opposite sides of the HII region, as seen in our higher resolution observations.

III. Conclusions

High-velocity CO emission associated with active star-forming cloud cores has been interpreted as outflows from embedded young stellar objects. In some cases, these flows appear to be bipolar on arc-minute angular scales (Lada 1985). Some authors have postulated massive (100 $M_\odot$), large-scale, rotating molecular disks as the energy source and/or focussing agent for the outflows. The observations presented here show no direct evidence of the hypothesized disks. In particular, the high-resolution data for S106 (one of the sources with best prior evidence for a disk) show that the presumed disk is, in reality, two dense knots of neutral gas on opposite sides of the conical HII region. These dense concentrations of neutral gas are probably responsible for constricting the HII region's expansion along its minor axis.

A preliminary interpretation of the data presented here lends support to the idea that a hot, ionized wind sweeps out the surrounding cloud material soon after stellar formation. However, it must be noted that the three regions studied here were already known from optical and radio studies to contain ionized gas.

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References

Bally, J. 1985, private communication.

Bally, J. and Lada, C. 1983, *Ap. J.*, **265**, 824.

Bally, J. and Predmore, R. 1983, *Ap. J.*, **265**, 778.

Bieging, J. H. 1984, *Ap. J.*, **286**, 591.

Gehrz, R. D., Grasdalen, G. L., Castelaz, M., Gullixon, C., Mozurkewich, D., Hackwell, J. A. 1982, *Ap. J.*, **254**, 550.

Lada, C. 1985, *Ann. Rev. Astr. Ap.*, **23**, 267.

Solf, J. and Carsenty, U. 1982, *Astron. Ap.*, **113**, 142.