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Feeding IC 342: The Nuclear Spiral of a Starburst Galaxy

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ABSTRACT

IC 342 is a large nearby (1.8 Mpc, Turner and Hurt, 1991, hereafter T&H) spiral galaxy undergoing a moderate nuclear starburst. T&H have previously mapped the inner arcminute in $^{13}CO_{(1-0)}$ using the Owens Valley Millimeter Interferometer and found evidence that the nuclear molecular gas takes the form of spiral arms in a density wave pattern. They suggest that radial streaming along the arms may channel gas from the exterior of the galaxy into the nucleus, feeding the starburst.

We have mapped the $^{12}CO_{(1-0)}$ emission of the inner 2 kpc of IC 342 at 2.8" resolution using the Owens Valley Radio Observatory (OVRO) Millimeter Interferometer. The greater sensitivity of ^{12}CO observations has allowed us to trace the spiral pattern out to a total extent of >1 kpc. The ^{12}CO observations extend considerably the structure observed at ^{13}CO and offer further evidence that a spiral density wave may extend from the disk into the nucleus of IC 342.

I. OBSERVATIONS

IC 342 was observed in the 2.6 mm ^{12}CO $(J=1->0)$ transition with 3" resolution at the OVRO Millimeter Interferometer. SSB system temperatures referred to above the atmosphere ranged from 300 to 900 K. Spectral line data were collected in two filterbanks, each with 32 channels, one at 5 MHz (13.6 km/s) resolution for an overall bandwidth of 160 MHz (435 km/s) and the other at 1 MHz (2.72 km/s) resolution with an overall bandwidth of 32 MHz (87 km/s).

Five overlapping fields were observed. The phase center of the central field was at $\alpha = 03^h41^m57^s.0$, $\delta = +67^\circ 56'30"$ with the other four offset by +/-30" and +/- 60" in declination. The central velocity at channel 17 corresponds to a V_{LSR} of 28.5 km/s. The individual 5 MHz channels were deconvolved using CLEAN and mosaicked. Natural weighting produced a synthesized beam of 2.9" x 2.9" in the central frame and the frames centered 30" north and south of the nucleus. Integrated intensity and intensity-weighted velocity moment maps were produced from the channel map mosaics.

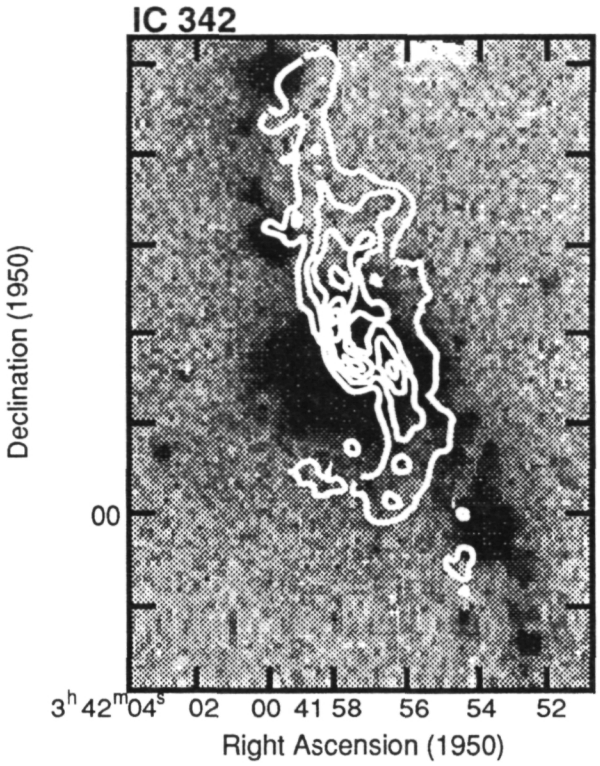
II. RESULTS

The ^{12}CO integrated intensity maps extend the nuclear molecular structure observed at ^{13}CO (T&H) . The mosaic shows that the ^{12}CO emission takes the form of a kinked bar or very open 2-arm spiral which is fairly continuous out to a distance of 800 pc (90") from the optical center. Fainter, patchy emission out to the edges of the field, where the primary beam response is low, suggests that the spiral pattern continues out to >1 kpc. Also visible in the mosaic are symmetric spurs of molecular emission suggesting more tightly wound spiral arms to the concave side of the open arms. These spurs extend about 20" (175 pc) form the optical center of the nucleus.

Figure 1 is an overlay of the integrated intensity mosaic on a gray scale plot of the Hα emission (J.Young, private communication). T&H noted that the ^{13}CO emission traced the Hα arms, offset 50-100 pc (5-10"), as would be expected if the star formation is due to compression of the molecular gas by a trailing spiral density wave. The ^{12}CO emission clearly confirms this relationship, continuing to trace the

spiral structure, offset to the concave side of the arms, out to the edge of the field as overlaid. We also note that the molecular spur running from the southern arm towards the east traces the structure of the Hα emission at the edge of the innermost nuclear region. We have also compared the ^{12}CO emission to near-IR J,H,K-band SQUIID maps (I. Gatley, private communication). The K-band map also displays faint open spiral structure, parallel to the Hα at an offset slightly less than the ^{12}CO.

The distribution of the gas in the individual channel maps is consistent with a spiral density wave. The emission shifts from the north in the most positive velocity channels to the south, indicative of rotation, but maintains a bar-like morphology over many channels. This is consistent with the ^{13}CO work by T&H. The circular velocities as measured from ^{12}CO velocity moment map compare extremely well to those determined by T&H. They are consistent with the peak velocity measured in HI of 192 km/s (Rogstad, Shostock & Rots, 1973). The isovelocity contours of the molecular gas as traced by ^{12}CO become nearly parallel to the molecular bar to the extreme north, suggesting substantial radial motion.



Overlay of the 12 CO mosaic on the Ha emission. Optical positions were determined from stellar positions on a POSS plate and are estimated to be accurate to 2"

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