DENSITY WAVE RELATED MOLECULAR CLOUD SPIRAL ARMS IN M51

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Results from a continuing study (Figure 1a) of the CO (J = 1-0) distribution in M51 are presented. The angular resolution (beam size 33" = 1.5 kpc) and pointing stability (better than 4") of the Onsala 20-m telescope have extracted a number of new features of the molecular cloud distribution and kinematics of M51 [1,2]:

i) The deconvolved radial distribution exhibits a central void (cf. ii) and a sharp peak at about 1 kpc followed by a rapid decline to a slowly diminishing disk distribution [1].

ii) The central emission contains oval shaped ridge structures probably reflecting the presence of incipient molecular cloud spiral arms.The kinematics of this region clearly deviates from circular motion and may be due to oval streaming [1].

iii) The fully sampled N-E quadrant of the galaxy shows a clearly discernible molecular cloud spiral arm structure in the disk, cf. Figure 1b. The inner side of the arm coincides with the synchrotron-continuum emission ridge revealed by aperture synthesis (at Westerbork and VLA). The observed arm-interarm brightness contrast ratio is about 2. The mass of the spiral arm "supercloud" complex is estimated to be 10^8 $M_\odot$.

iv) Streaming motions -in the sense predicted by density wave theory- are observed across the N-E spiral arm (Figure 1c) and also symmetrically in a minor axis cut across E and W arms (Figure 2). The shift in radial streaming is surprisingly large, however, at least 50 km s^{-1} [1].

v) The molecular cloud population appears to rotate systematically more slowly than the ionized gas [1].

The following statistical comments on these results may be worth-while:

1) GMC arms also have been observed in M31 (Ichikawa *et al.* 1985, Ryden and Stark 1985) and in our Galaxy arms of warmer GMC's only very recently have been discriminated from a disk distribution of colder clouds (Solomon *et al.* 1985).

2) Such streaming also has been found in CO in M31 (previous references) in our Galaxy (Clemens 1985), and in recent Onsala observa-tions of NGC 6946 and IC 342 (Winnberg *et al.*; Wiklind *et al.*), in H I in M81 (cf. Wisser 1980) and in Hα rotation curves of many spiral gal-axies (e.g. Rubin *et al.* 1980).

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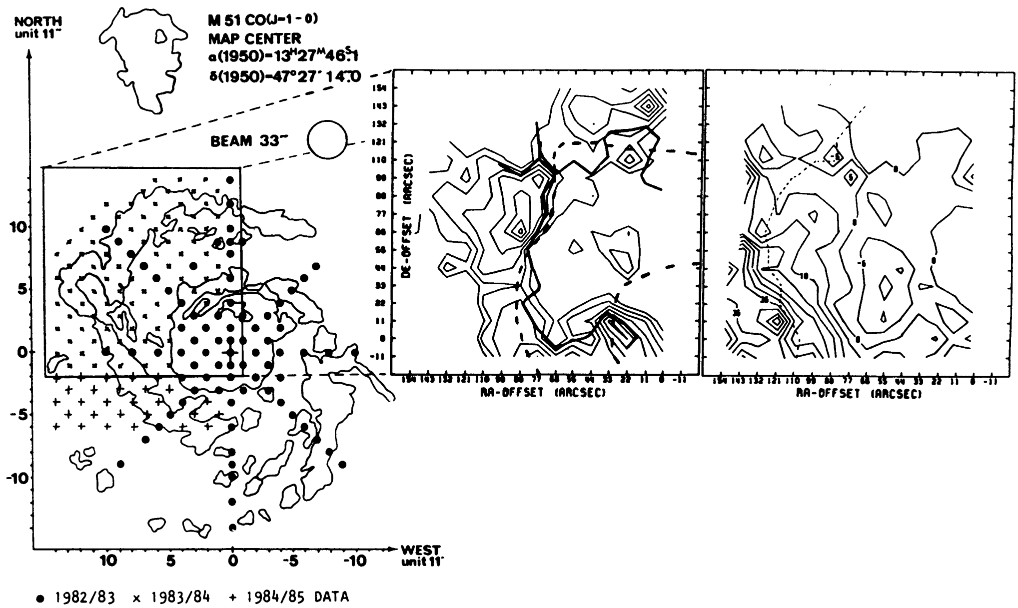

Fig. 1(a). Positions observed in the CO (J = 1-0) transition, superposed on the optical outline of M51. (b) Difference between observed integrated intensity and the average radial distribution in the N-E quadrant. ——— marks zero velocity shift with respect to circular rotation. ---- is synchrotron continuum ridge. (c) Difference between observed mean velocity and projected rotation curve.

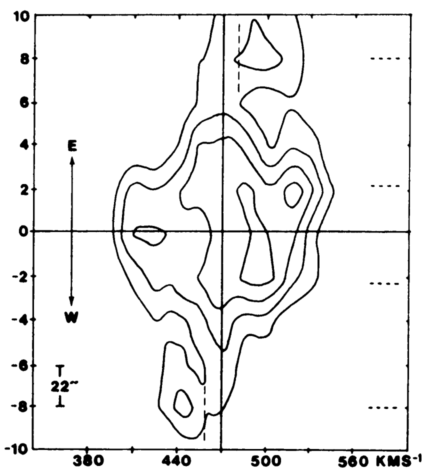

Fig. 2. Right ascension (∿ minor axis)-velocity diagram. Note velocity shifts at arm cuts.

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3) Possibly also apparent in NGC 5055 (Onsala observations by Johansson and Booth). Detailed comparisons between the molecular cloud (CO) spatial/velocity distributions with those of Hα, red and blue light may ultimately tell us whether density wave triggering is of importance only for cloud/supercloud formation in arms or if the star formation rate is also enhanced (cf. review talks at this symposium by Elmegreen and by Young).

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STARK: I very much enjoyed your talk, but I was astonished by your result that the ionized gas and the molecular gas have systematically different velocities. Would you please elaborate on how that result was obtained?

HJALMARSON: This first result was discussed in our paper in Astron. Astrophys. 144, 282. A more detailed comparison between the CO and Hα distributions in the entire galaxy probably would be helpful to understand if density wave triggering of star formation takes place, or not.

SANDERS: 1) What percentage of the total CO emission detected in your NE quadrant survey of M51 is shown in your "spiral arm" CO plot? 2) What is the maximum peak to through CO intensity ratio at a fixed radius in M51? You gave an average ratio of 2-3. And do you see any single beam region with *no* CO?

HJALMARSON: 1) Say 20%, but it could be more in terms of *mass*. 2) The peak arm/interarm contrast ratio is ∿ 3. The average is close to 2. These are "observed" ratios which will probably increase upon deconvolution. No single beam region with no CO is observed. Again, deconvolution may change this result.

KUTNER: Frances Verter and I have been using the NRAO 12-m telescope to observe CO (2→1), with 30" resolution, in the opposite corner from the one you mapped. We also find a clear arm/interarm contrast.

YOUNG: Have you tried convolving your 30" beam with the Hα velocity field to see if in fact there is a difference between the CO and Hα velocities at comparable resolution?

HJALMARSON: This has not yet been done, but clearly is an important way to proceed. This could be a way to find out whether star formation is triggered by the density wave.

A 10-GHZ RADIO CONTINUUM SURVEY OF THE GALACTIC PLANE

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A radio continuum survey of the galactic plane has been made with the 45-m telescope of the Nobeyama Radio Observatory at 10.55 GHz, which is the highest frequency among such surveys. The sensitivity of the telescope was T_b/S = 0.47 K/Jy and the HPBW was 2!6, which was a great advantage because of the same beam size of the Bonn 5-GHz survey (Altenhoff *et al.* 1978). The receiver was a cooled parametric amplifier. The instantaneous bandwidth was 500 MHz, and the system noise temperature was about 100 K. The calibration source was NGC 7027, which was assumed to be 6.6 Jy. One circular polarization component was observed. The observational parameters are summarized in Table I.

TABLE I. Observational Parameters**

Telescope	the NRO 45-m telescope
Observing date	April 1983 - June 1985
Frequency	10.55 GHz
Bandwidth	500 MHz
Half Power Beam Width	2!6
System Noise Temperature	∿ 100 K
Sensitivity of the telescope	0.47 K/Jy (T_b/S)
Observing mode	Scan along galactic latitude
Scan speed and interval	3!8/sec. and 1!2 interval
Polarization	One circular polarization
Reduction system	"CONDUCT" system at NRO* (Scan effect removed by "press" method#)
Coverage	Once or twice

* "CONDUCT" system is a radio astronomical reduction system at NRO, a part of which uses the NOD2 reduction package (Haslam 1974).
\# See Sofue and Reich 1979.
** See Sofue *et al.* 1984.

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