PROPERTIES OF THE MOLECULAR ARMS IN THE GALAXIES M51, M101 AND IC342

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1. OBSERVATIONS AND DATA REDUCTION

M51, M101 and IC342 were all observed in the CO(1-0) line with the Onsala 20 m antenna. .The average pointing error for a 20 minute run is less than 5", usually considerably less, and the receivers are stable. The error lobe is considerable with an efficiency of about 40%. With a width of about 20' it is of little importance compared to an emission region of 2' to 3' however. Of more concern is an upper and a lower sidelobe with a combined efficiency of about 14%.
The analysis of the data has been aided by a method which we call Statistical Image Analysis (SIA). It is similar to the usual maximum entropy methods. A paper on the method is presently being prepared and will be published elsewhere. The analysis is done on the whole data cube and thus takes advantage of both spatial and spectral information. The effective resolution approaches 1/3 of the half power beamwidth, which is 33" for the Onsala telescope. The accuracy of the results is highly dependent on the reliability of both telescope pointing and receiver calibration.

2. RESULTS

2.1 THE SPIRAL ARMS

All three galaxies exhibit clear and strong molecular spiral arms (Figures 1a, 2a). A separate paper on M101 is in the poster section of these proceedings. We note in figure 2a a particularly interesting feature. M51 has what appears to be a pair of leading molecular spiral arms. Tentative traces of these arms can be seen in the less sensitive but higher resolving interferometer map of Rand and Kulkarni (1990), which in general is consistent with our SIA map. We will now discuss spiral arm related velocity structures which is the main topic of this paper.

2.2 THE ANALYSIS OF THE VELOCITY STRUCTURE

The analysis of the velocity structure from presently available molecular line data on these "small inclination angle" galaxies requires great care, mainly for the following two reasons:

i) Only one velocity component (along the line of sight) is observed. Dividing this component into one " in plane " (IVPC) and one "perpendicular to the plane" (PPVC) velocity component is model dependent. It the effective resolution is sufficiently high however, changes in the streaming, unless it is very abrupt, will be small within the resolved area, and the spectral dispersion will mainly be due to dispersion in the PPVC (since the observed IVPC is reduced by the small

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inclination). If one assumes that the PPVC is purely dispersive, i.e. it does not contain any streaming, a velocity dispersion map will mainly show PPVC dispersion, and a mean velocity map mainly the mean of the IVPC.

ii) Due to the large dynamic range in emission intensity on and off the spiral arms, (at least a factor of four in the case of M51) an off arm spectrum might pick up emission from nearby arms via beam side lobes. To avoid this effect, the dispersion was calculated on the upper 60% of the line profile, and if the lower limit got close to the noise level, the value was discarded.

2.3. STREAMING MOTION.

In all three galaxies, spiral arm related streaming motions were observed. The streaming agrees in direction with the prediction from density wave theory. The observed velocity shifts are often abrupt and large as the arms are crossed (40-80 km/s). Occasionally cloud populations with post and pre arm velocities even appear to overlap spatially (See also Rydbeck et al 1987).

2.4. VELOCITY DISPERSION PERPENDICULAR TO THE PLANE.

In both IC342 and M51, the velocity dispersion is generally lower on the spiral arms (Figure 1b and 2b). The on arm spectra in figure 1c are very narrow (5-10 KM/S), while the off arm spectra are at least three times broader. We believe that the relatively large spiral arm related IPVC shifts to some extent hides the lowered dispersion of the PPVC. The same is probably true for M101, which also has large spiral arm related velocity shifts. Although it appears to have a lowered on arm velocity dispersion thist could not be clearly determined. The analysis is in this case difficult on account of the weak signals. Preliminary analysis of M83 data (obtained with SEST) indicates a decrease in the on arm velocity dispersion. While the "leading arms" in M51 have a lowered dispersion, some of the bridges connecting the spiral arms to the bar in IC342 have increased dispersion. Spectra near the ends of the bar can be very broad approaching a width of 80 km/s.
In some positions in M51 and IC342 weak emission clouds appear to be either counter rotating or streaming perpendicular to the plane.

3. DISCUSSION

It is generally thought that the giant molecular clouds are formed as smaller clouds enter the arm, and in addition Rand and Kulkarni (1990) has suggested that the giant on arm cloud complexes (Rydbeck et al 1987, Rand and Kulkarni 1990), are gravitationally bound. One would therefore expect that the cloud velocity dispersion is decreased as the clouds enter the arm region, to allow the clouds to merge or become bound in complexes. The decrease in dispersion could possibly follow from cloud cloud interactions, combined with a decrease in the tidal shear (Elmegreen 1987), which in the interarm region, where it is larger, continously injects turbulent energy. Our results could also be explained by the possible existence of a background of high latitude clouds with a large velocity dispersion. Spiral arm forming clouds residing in the disc plane may generally have a lower velocity dispersion, and would then lower the observed on arm dispersion.

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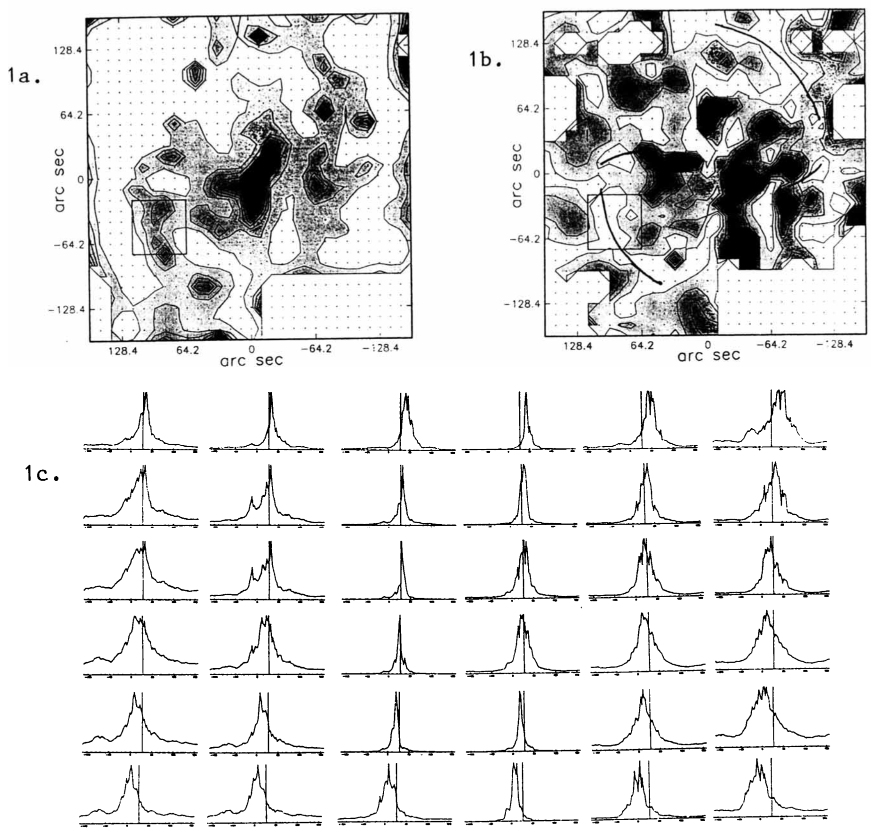

Figure 1. a, Integrated CO(1-0) emission in IC342. b) The velocity dispersion. The first contour marks 10 km/s, the increment is 5 km/s.The solid line marks the crests of the spiral arms. c) Spectra from the region within the square in a) and b). The intensity scale is floating and the velocity ticks are separated by 40km/s.

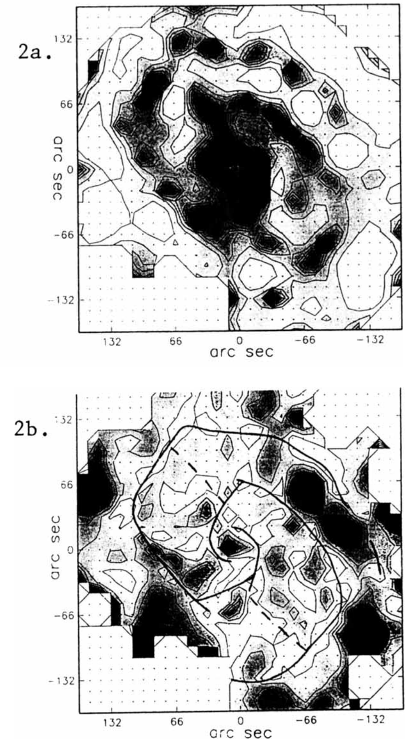

Figure 2. 2a), Integrated emission intensity in M51. 2b) The velocity dispersion. Levels as in 1b. The solid line marks the crests of the spiral arms and the dashed the crests of the "leading arms".

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