MOLECULAR SPIRAL ARMS IN M51 AT 2.5" RESOLUTION

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ABSTRACT. We present maps of CO emission in M51 made with the Owens Valley Millimeter Interferometer. We first summarize the results from our mosaic map at 8" resolution covering the disk of M51. We then present a map of two 1' fields along the spiral arm south of the nucleus at 2.5" resolution. The Giant Molecular Associations (GMAs) seen in our 8" map are found to have substructure at the higher resolution. The interarm GMAs have a particularly patchy structure. The streaming motions found from our 8" map are confirmed at this resolution. The velocity dispersion along the arms is about 10 km s^{-1}. Possible explanations are given for the poor small-scale correlation of the Hα and CO emission.

1. Introduction

In an attempt to understand the relationship between density waves, molecular gas and star formation, a major project of mapping the grand-design spiral galaxy M51 using the Owens Valley Millimeter Interferometer has been carried out (Vogel, Kulkarni and Scoville 1988, hereafter VKS; Rand and Kulkarni 1990, hereafter RK). Thirty fields with a HPBW of about 1' have been mapped over a period of 3 years and combined into a mosaic data cube. The spatial resolution of the final map is about 8", and the velocity resolution is 5.2 km s^{-1}. Some of the results from the mosaic described below motivated us to observe two fields at 2.5" resolution. The results of those observations are also described below.

2. The Mosaic Map

In Figure 1, we show the map of total CO flux overlaid on an Hα CCD image. The region mapped is roughly delineated by the noise features around the edge. More details of the observations can be found in RK. The results from this work, including the coincidence of the molecular gas with the dust lanes, the offset of the Hα arms from the molecular arms, the existence of the streaming motions predicted by density wave theory, and the enhanced star formation efficiency on the arms, are discussed in greater detail in RK and VKS. The latter result has now been confirmed by single-dish observations (Lord and Young 1990). The concentrations of gas we have termed Giant Molecular Associations (GMAs) along the arms and between the arms have a typical mass of 3×10^7 $M_\odot$. We find that the on-arm GMAs are roughly gravitationally bound, while the interarm GMAs are unbound. The

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spectra of the GMAs show that they typically consist of one to five velocity components. They may form through collisional agglomerations of pre-existing smaller clouds or by gravitational instabilities in the molecular gas.

3. Observations at 2.5" Resolution

Motivated by our finding that the GMAs have in general a few velocity components, we decided to map two fields south of the nucleus which include on-arm and interarm GMAs at 2.5" resolution to look for smaller scale structure. The resulting contour plot of total intensity is shown in Figure 2a, while Figure 2b shows the contours overlaid on the Hα image. Once again, the noise features around the edge of the map roughly delineate the primary beams. The GMAs identified from the 8" map are labelled in Figure 2a.

The GMAs are clearly resolved at this resolution. A8 shows several peaks of emission, while A4 remains centrally concentrated, confirming our conclusion from the mosaic spectra that they consist of several components. The interarm GMAs appear as particularly loose assemblages of smaller clouds, consistent with our earlier finding that they are not gravitationally bound. The amplitude and direction of the streaming motions are confirmed at this resolution. The velocity dispersion along the arms ranges from 6 to 13 km s^{-1}, with a mean value of 10 km s^{-1}. Figure 2b shows that along the arms, the CO and Hα fluxes bear little resemblance to each other. For instance, A9 is a relatively low-mass GMA, but has a bright HII region associated with it, while A4 is a high-mass GMA with only faint Hα emission associated with it. Other HII regions appear in the gap to the west of A8 where there is no detectable CO emission. The interarm GMAs show very little associated Hα emission. We suggest three possibilities for this lack of correlation. The first is that we may simply be seeing real variations in the SFE such that A9 has a high SFE while A4 has a low SFE. The interarm GMAs would have a particularly low SFE in this case. A second possibility is that we are seeing the effects of an evolutionary sequence of star formation from GMAs. In this explanation, then, A4 is relatively young and has not formed many stars yet, while A9 is much more evolved and has formed many stars. A9 may also be significantly disrupted at this point, either by the power of star formation or the increased shear experienced as gas leaves the compressed region (RK). Finally, variable extinction along the arms may also lead to a lack of correlation.

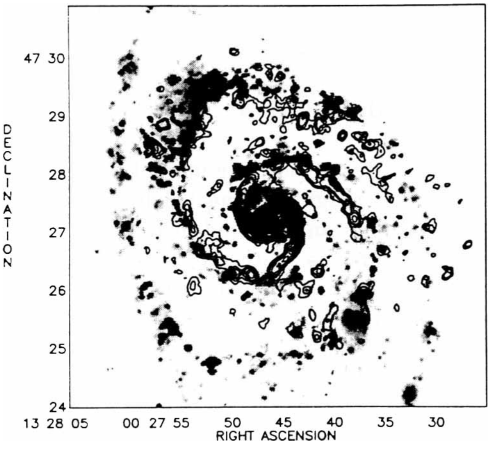

Figure 1. Contours of CO flux are overlaid on an Hα CCD image.

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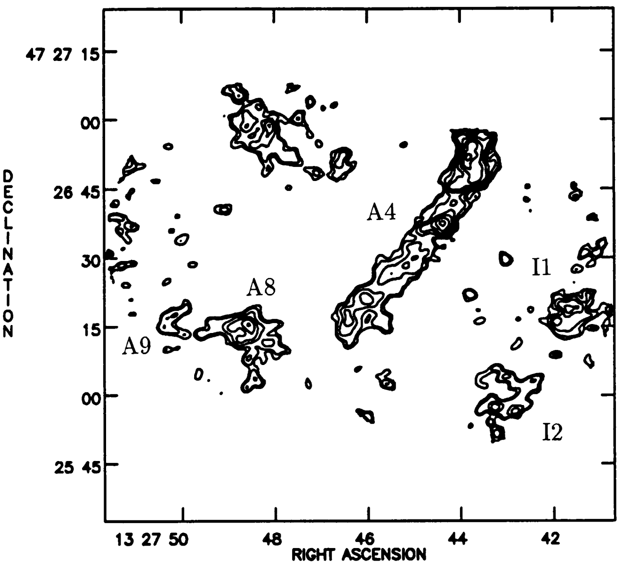

Figure 2a. Contours of CO flux at 2.5" resolution. Levels are 3, 4, 6, 8, 10, 13, 16 and 19 times the noise level of 0.7 Jy km s^{-1}.

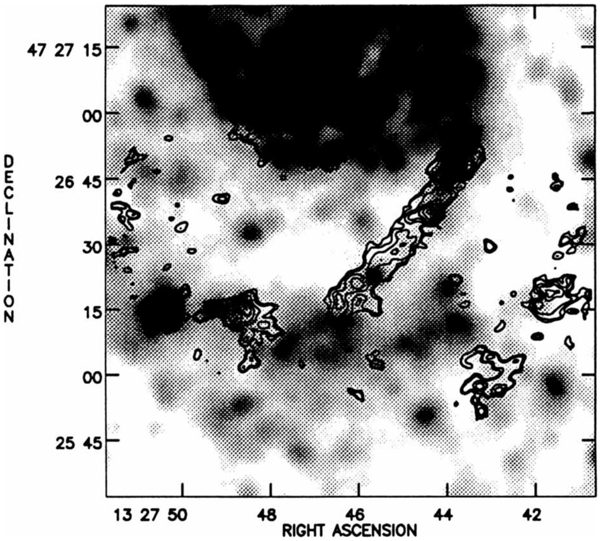

Figure 2b. Contours of CO flux overlaid on the Hα image.

4. References

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