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The Distribution of Cold Gas in the Flocculent Spiral NGC 5055

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BIMA and FCRAO CO J=1-0 observations are used to assess the properties of the molecular gas distribution in the nearby, flocculent spiral NGC 5055 (7.2 Mpc). As the weak spiral structure in flocculent galaxies may indicate the absence of spiral density wave activity, these observations help determine the range of cloud sizes and masses that form in spiral galaxies without the influence of strong density waves. With an average surface density one-quarter that of the grand design spiral M51, NGC 5055 exhibits molecular structures with similar properties to the Giant Molecular Associations (GMA) detected in M51. The measured structures have masses between 6x10^6 and 1x$10^8 M_\odot$, and half of these have comparable virial masses. The distribution of CO cloud structures is also compared with the distribution of HI, Hα, and NIR peaks in order to examine the relationship between cold gas and star formation in NGC 5055. This comparison suggests structure organization on kiloparsec scales.

Introduction

Flocculent spiral galaxies are presumed to be unprocessed by stellar spiral density waves due to the lack of continuous spiral arm structure seen in optical bands (e.g., Elmegreen & Elmegreen 1984, 1985). This assertion is supported by theoretical modeling: numerical simulations show that models lacking density wave modes form small- and intermediate-scale structures much like those seen in flocculent spirals, but large-scale organization is absent (e.g., Elmegreen & Thomasson 1993, Roberts 1993). Thus flocculent spirals represent an important class of galaxies for studying the effects of density waves on the ISM and star formation. In order to determine the properties of cold gas and star formation in NGC 5055, we have made observations in ^{12}CO J=1-0, HI, near infrared (NIR) broadband, and Hα emission. In the following paragraphs, we address these questions:

- What is the size range of molecular cloud structures formed in flocculent galaxies?

- How are these structures correlated with recent and past star formation?

The Distribution of CO in the Inner Disk of NGC 5055

A fully sampled map of NGC 5055 was completed at the FCRAO 14m with the QUARRY 15-element array. ^{12}CO emission in the single dish map extends to a radius of $\sim$5 kpc. Assuming a CO-to-H_2 conversion factor of 3x10^{20} cm^{-2}[K km s^{-1}]$^{-1}$, the corresponding surface densities of molecular hydrogen are 6 - 50 $M_\odot$ pc^{-2} in the plane of the galaxy (PA=99°, i=55°), approximately a factor of four lower than molecular surface densities in the grand design spiral galaxy M51. To determine how the molecular gas is distributed on subkiloparsec scales, two overlapping fields in NGC 5055 have been observed with the Berkeley-Illinois-Maryland Array (BIMA), resulting in a 7″ x 5″ synthesized beam (240 pc x 175 pc).

The single dish velocity field was used as a mask in creating an integrated intensity map of the BIMA data. Detections satisfied the following criteria: (1) peak emission $> 3\sigma$, and (2) emission $> 3\sigma$ in at least three consecutive velocity channels around the expected velocity. For those cloud structures which were well separated in both space and velocity and were resolved in at least one direction, both flux-based masses and virial masses were calculated. The flux-based masses of the 12 cloud structures measured thus far range from 6x$10^6 M_\odot$to 1x$10^8 M_\odot$. Virial masses were determined using the formula M_{vir}=99(ΔV_{fwhm})^2 D_{fwhm}, where the velocity widths and diameters of the clouds were determined from Gaussian fits to the detected cloud structures. Of the twelve regions measured, six are marginally bound, their flux-based masses above or within 20% of their virial masses.

The marginally bound condensations are of similar mass to Giant Molecular Associations (GMA) seen in M51 by Rand and Kulkarni (1990). GMAs are large 10^7 - $10^8 M_\odot$ structures, and GMAs in the arms of M51 may be bound structures (Rand & Kulkarni 1990). This is the first detection of GMA-sized structures in a flocculent spiral. The existence of large, potentially bound cloud structures in NGC 5055 suggests that the formation of large molecular clouds can occur without the influence of a strong density wave such as that seen in M51.

Comparison with HI, NIR, and Hα Data

Recently obtained HI data from the VLA (Thornley & Mundy, in prep.) show multiple ridges of HI emission interior to $\sim$8 kpc, which may indicate the presence of ring or spiral arm structures. Near infrared (NIR) broadband images support this hypothesis, as they show weak, two-armed spiral structure in these same regions. By comparing the distribution of HI, NIR,and CO emission with the distribution of Hα emission, we can evaluate how well the distributions of cold gas and old stars correlate with recent star formation.

The innermost HI ridge is coincident with a NIR "arm" on the northeast side of the nucleus, and shows correlation with a ridge of HII regions seen in Hα emission. The relationship of the CO emission to the HI and NIR structures is less clear, as the northeast NIR "arm" lies outside the HPBW of the BIMA primary beam. At the present time, all detected cloud structures lie inside the NIR "arm", and the observation of adjoining fields scheduled for fall 1995 will help clarify if the CO is preferentially located interior to the NIR structure.

Summary

- BIMA interferometer observations reveal molecular gas condensations a few hundred parsecs in size, with masses between 6x10^6 and 1x$10^8 M_\odot$, similar to the masses of Giant Molecular Associations observed in the grand design spiral M51.
- Six of the GMA-like cloud structures appear to be marginally bound. This suggests that such large structures can be formed without the influence of strong density waves.
- Alignment of HI and Hα peaks with structure seen in NIR K$'$ (2.2 μm) broadband emission suggests structure organization on kiloparsec scales. An expanded interferometer map is needed to confirm that the CO condensations are found preferentially interior to the northeast NIR "arm".

References

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