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A COMPARISON OF THE RADIAL DISTRIBUTION OF MOLECULAR GAS AND NON-THERMAL RADIO CONTINUUM IN SPIRAL DISKS.

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1. Introduction

Recent observational results suggest a close connection between non-thermal radio continuum emission and star formation in spiral galaxies. The small dispersion in the correlations of the globally integrated 1.49 GHz radio continuum emission with both the global Hα emission (Kennicutt 1983) and thermal far infrared emission (Dickey and Salpeter 1984; Helou, Soifer and Rowan-Robinson 1985; Devereux and Eales 1989) constitute the primary evidence in support of a close correspondence between the non-thermal radio power and the intensity of star formation activity. Additionally the radial distribution of non-thermal radio emission closely traces the radial distribution of Hα and far infrared emission within the disk of the late-type spirals M 51 (Scoville and Young 1983) and NGC 6946 (Tacconi and Young 1986). On a smaller (~ 0.5 kpc) scale a close correspondence is observed between the morphology of the non-thermal radio continuum and the infrared emission in the nuclei of galaxies (Rieke et al. 1980; Becklin et al. 1980; Gehrz, Sramek and Weedman 1983; Wynn-Williams and Becklin 1985). *Thus the radial distributions of non-thermal radio continuum emission should be viewed as a potentially valuable source of information on the radial distribution of star formation in spiral galaxies.* Furthermore, the radio continuum emission does not suffer from extinction as does the Hα emission line tracer.

Since stars form in molecular clouds, the CO emission traces the sites of potential star formation. Following Israel and Rowan-Robinson (1984), it is of interest to compare the CO radial distributions measured in the course of the FCRAO Extragalactic CO Survey with the radial distributions of non-thermal radio continuum emission. Such a comparison will permit an investigation of whether the star formation rate per unit molecular gas, or equivalently, the star formation efficiency, varies with radius in spiral galaxies. A constant star formation efficiency would indicate that the star formation rate is determined by the local cloud properties; on the other hand, radial variations in the star formation efficiency may indicate that the star formation is regulated by a global process such as a spiral density wave or a galaxy-galaxy interaction.

Five College Radio Observatory Observatory (FCRAO)

2. Sample and Analysis

The present study includes 65 spiral galaxies selected from the FCRAO Extragalactic CO Survey for which the major axis distributions of CO emission and 1.49 GHz radio continuum emission are well determined. The radial distribution of the CO emission has been measured with the FCRAO at positions along the major axis that are spaced by one HPBW (45"). The radial profile of the 1.49GHz radio continuum emission was constructed by determining the radio emission at the location of the CO measurements from the 1.49 GHz maps of Condon (1987).

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3. Results and Discussion

Although the radial distributions of radio continuum and CO emission both decrease by as much as a factor of 100 with increasing radius the *ratio* of radio emission to CO emission appears rather constant. The result is quantified in Figure 1. The histogram shows the mean change in the ratio of radio continuum emission to CO intensity across the disk of 46 spirals for which the CO and radio continuum was detected at at least three independent disk locations.

The histogram is centered on zero. Thus there is no evidence for a systematic increase or decrease in the ratio of radio continuum emission to CO intensity with radius.

The narrow width of the histogram indicates that the ratio of 1.49 GHz radio emission to CO intensity does not vary by more than a factor of three for the majority of spirals in this sample. The small radial gradient is comparable to the radial change in the infrared to radio continuum ratio observed for the disks of N 6946 and M 83. The radial gradient in the infrared to radio continuum emission has been interpreted in terms of cosmic ray diffusion (Bicay, Helou and Condon 1989). The cause for the small radial change in the ratio of radio continuum to CO intensity can not be due entirely to cosmic ray diffusion, however, because the ratio does not systematically increase with radius in all spirals.

The results indicate that the star formation efficiency is not a strong function of radius for the majority of the spirals included in the present study although there are some exceptions. The ratio of radio continuum to CO intensity decreases by over an order of magnitude across the disks of M 82, NGC 488, NGC 660, NGC 2841 and NGC 6503. The radial distributions of radio continuum and CO emission suggest large radially *decreasing* gradients in the star formation efficiency. Similarly large gradients in the Hα to CO intensity ratio have been noted in M 82 and NGC 2146 (Young 1988).

Two of the galaxies M 82 and NGC 660 are notable for the high level of star formation in the central region (Rieke et al. 1980; Young, Kleinmann and Allen 1988). The ratio of radio continuum to CO intensity in the central 45" of M 82 and NGC 660 exceeds the mean measured for spiral disks by a factor of 10 and a factor of 3 respectively. Thus in the central region of M 82 and NGC 660 gas is converted into stars at a much higher efficiency than is typically observed for the disks of late-type spirals.

On the other hand NGC 488, NGC 2841 snd NGC 6503 are distinguished by an uncharacteristically low star formation efficiency in the outer disk. The three spirals also share an unusual gas morphology in the form of a central depression in the molecular gas distribution or CO "hole". Collectively the five spirals exhibit a number of unique features although it is difficult to identify a single common property that may help explain why the radial gradient in star formation efficiency should be so much larger than that typically observed for spiral galaxies.

4. Conclusion

Large, greater than a factor of ten, radially decreasing gradients in the star formation efficiency are observed for a small percentage, ~ 10%, of the spirals in this sample. The majority of spirals, however, are associated with small gradients in the star formation efficiency that do not systematically increase or decrease with radius. That the star formation efficiency does not systematically decrease with radius tends to argue against a global dynamical mechanism, such as a spiral density wave, for being the *dominant* mechanism triggering disk star formation for the majority of spirals in this sample. The results tend to support the view that the star formation in spiral disks is dominated by a local process that depends more on the molecular cloud properties than the dynamical structure of a galaxy.

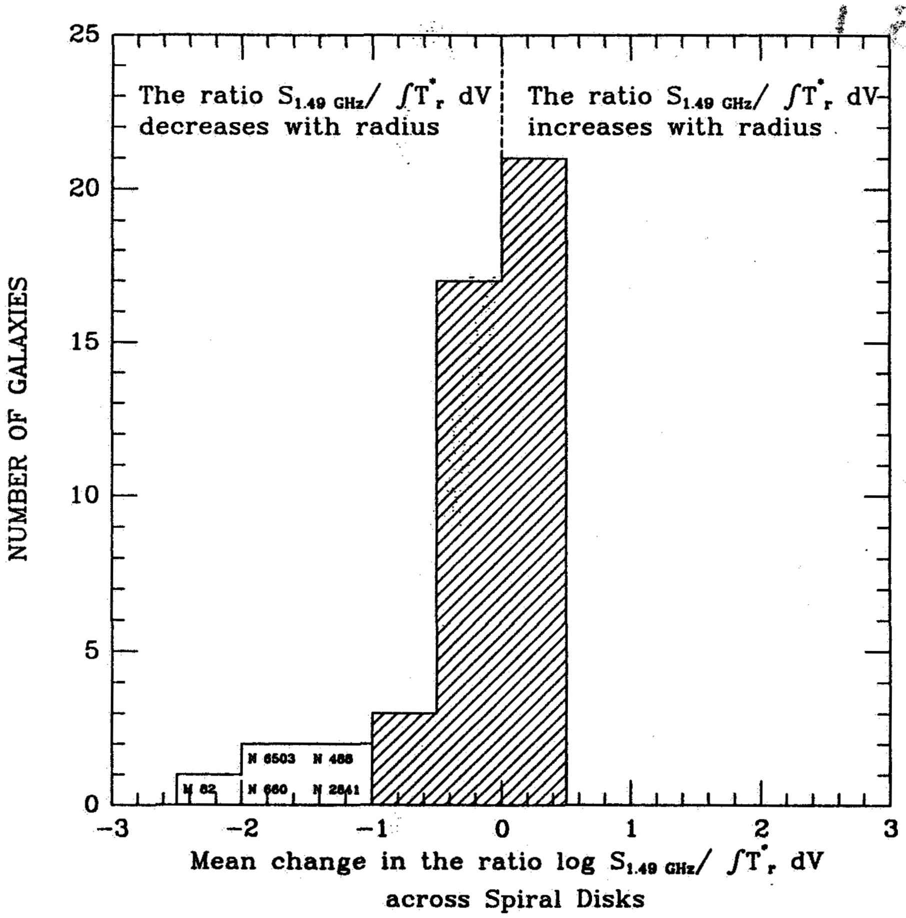

Figure 1. The histogram depicts the *mean* radial change in the ratio of 1.49 GHz radio continuum to CO line intensity across the disks of 46 spiral galaxies.

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