Poster contribution to IAU Symposium 170, *CO: Twenty-five Years of Millimeter-wave Spectrocopy*, 29 May – 2 June 1995, Tucson, Arizona

A Search for CO emission from HII Galaxies

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We have used the NRAO 12–m telescope to search for CO emission from a sample of HII galaxies. All targets have been previously mapped with the VLA in HI and form part of a volume limited sample of HII galaxies (see Taylor *et al.* 1995). The HI is centrally concentrated and reaches column densities well above 5×10^{20} atoms cm^{-2}, i.e., above the star formation threshold. This is confirmed by optical (CCD) imaging which shows evidence for recent star formation within the highest HI contours. Despite the fact that H_2 should be present, no CO has been detected in any of our targets. This could imply simply a lack of C and O to trace the molecular gas, or a true lack of molecular material. Combining our results with those published by Sage *et al.* (1992) who used the NRAO 12–m and IRAM 30–m telescopes, confirms the interpretation that any CO which is present, is found in highly compact clouds and that observations with large (30–m or larger) single dishes are required to detect CO routinely in HII galaxies.

INTRODUCTION

HII galaxies are actively star forming dwarf galaxies. Their optical spectra resemble those of galactic HII regions, hence their name. In the optical they are fairly compact (linear dimensions of order a few kpc) and have blue colours. This has earned them their alias Blue Compact Dwarf galaxy. Most of them have absolute B magnitudes $M_B > -19$ mag. From optical spectroscopy we know that HII galaxies have low heavy element abundances, typically down by a factor of five to ten as compared to the solar neighbourhood. The Magellanic clouds can be thought of as belonging to the high luminosity (and high mass) end of the HII galaxy population.

HII galaxies are thought to have bursts of star formation which might last some 10^8 year with the time between bursts being of order 10^9 year. This would reconcile their large current star formation rate (SFR) with the low abundance of heavy elements and the fact that the current SFR could not be sustained for a Hubble time given their limited supply of gas.

HII galaxies are relatively gas rich, their detectable mass often being dominated by their neutral gas content (Taylor *et al.* 1995). We know very little about their molecular gas content. Still, they must harbour substantial amounts of H_2 as witnessed by their star formation activity. Several authors have attempted to detect CO in dwarfs (see e.g., Sage *et al.* 1992, Israel *et al.* 1995; Brouillet, priv. comm.) mostly reporting upper limits or in some cases contradictory results, as commented upon by Sage *et al.*

WHY HAVE DWARF IRREGULARS BEEN SO ELUSIVE?

In retrospect, the difficulty in detecting molecular clouds through their tracer, ^{12}CO, is easy to understand. Because of their lower metallicity, the abundances of C and O are down by at least a factor of 5. However, Rubio *et al.* (1993) argue that in the case of the SMC this lower abundance is only part of the explanation. They note that the dust–to–gas ratio is down, by a factor of about 10, and that the interstellar radiation field is up, also by a factor of 10. Therefore, any diffuse molecular cloud is photodissociated and even dense molecular clouds are vulnerable (see e.g., Maloney & Black 1988; Elmegreen 1989). In fact, they claim that dense molecular clouds in irregular galaxies are more compact than in our Galaxy and that the CO luminosity as a whole is down by factors of at least 20. A more complete treatment on this topic was presented by Maloney (1995) during this conference.

OBSERVATIONS OF STAR FORMING DWARF GALAXIES

Not all is lost, however. Progress in receiver technology has pushed down system temperatures to levels which make a survey of HII galaxies feasible. Here we report on CO observations made with the NRAO 12–m telescope down to levels typically 3 to 5 times fainter than Sage *et al.* (1992). The sample which we observed is a subset of the objects observed in HI by Taylor *et al.* (1995) at the VLA. This is a volume limited sample ($V_\odot < 2500$ km s^{-1}) of HII galaxies with $M_B > -17$ mag which in turn was based on the work by Salzer (1989a, b). Taylor *et al.* (1994) find that the HI in HII galaxies is more centrally concentrated than is the case for low surface brightness dwarfs. Furthermore, the HII galaxies follow the finding by Skillman (1987) and Kennicutt (1989) that star formation occurs only above a threshold of $\sim 5 \times 10^{20}$ atoms cm^{-2}. Skillman favours the interpretation that this column density reflects a level above which shielding becomes efficient enough to allow for molecules to exist. In contrast, Kennicutt's interpretation is that at this level galaxy disks become unstable to large scale density perturbations, a condition conducive to cloud growth and star formation.

The CO(1–0) observations were made on 19 to 22 January 1995. The resolution was 55″ at 115 GHz. Because any molecular gas, and thus CO, is expected to reside in the dense, 1′ central concentration we could employ beam switching, with a 2′ beam throw at 1.25 Hz. We used the 256×2 MHz filter bank, resulting in 5.2 km s^{-1} velocity resolution covering a 1300 km s^{-1} range in velocity. The system temperatures ranged from 400 to 800 K. Typically about 70 spectra were obtained per object. Bad channels were removed from each individual spectrum and each polarisation. Occasionally bad baselines forced us to reject some spectra. Eventually the remaining spectra were averaged and a linear baseline was subtracted. Two examples are shown in Figures 1 and 2.

We reach a one sigma noise level of 6 mK for UM422. Smoothing the data with a boxcar to an effective resolution of 20 km s^{-1} lowers this to 3.7 mK. For UM462 we reach (again smoothed to 20 km s^{-1}) an rms noise level of about 2.0 mK (all units are in raw telescope temperatures, T_A^*). No CO emission is seen above a level of 3σ. Integrating over the velocity range over which HI emission has been seen leads to upper limits on the integrated CO intensity of 0.59 and 0.28 K km s^{-1} for UM422 and UM462, respectively. The latter object was observed by Sage *et al.* (1992) who quoted a detection which would have easily been seen at our sensitivity levels, suggesting that their detection of UM462 is spurious.

During our run we checked on another source, Haro 2, which was observed by Sage *et al.* They detected it with high significance both in the CO(1–0) and the CO(2–1) line with the IRAM 30–m telescope. Our spectra, unfortunately, suffer from large baseline ripple and are at present inconclusive. The IRAM data seem solid, though, and show that Haro 2 is unresolved even by the 12.5″ beam of the (2–1) line.

Clearly, receiver technology has progressed to the point that intrinsically weak, extragalactic objects such as HII and other dwarf galaxies are now within reach. Observations with 30–m class telescopes will be needed to match the beamsize to the intrinsically small molecular clouds in these systems and to provide the collecting area needed to detect their signal. The benefits of detecting CO in these objects is obvious as it would allow us to determine the conversion factor, X, in potentially very low metallicity systems.

References

Elmegreen, B.G. 1989, ApJ, 340, 786

Israel, F.P., Tacconi, L.J., & Baas, F. 1995, A&A, 295, 599

Kennicutt, R.C., 1989, ApJ, 344, 685

Maloney, P. 1995, in CO: Twenty–five Years of Millimeter–wave Spectroscopy, eds. W.B. Latter, S.J.E. Radford, P.R. Jewell, J.G. Mangum, & J. Bally (Dordrecht:Kluwer), in press

Maloney, P. & Black, J.H. 1988, ApJ, 325, 389

Rubio, M, Lequeux, J. & Boulanger, F. 1993, A&A, 271, 9

Sage, L.J., Salzer, J.J., Loose, H.-H., & Henkel, C. 1992, A&A, 265, 19

Salzer, J.J., MacAlpine, G.M. & Boroson, T.A., 1989a, ApJS, 70, 447

Salzer, J.J., MacAlpine, G.M. & Boroson, T.A., 1989b, ApJS, 70, 479

Skillman, E.D. 1987, in Star Formation in Galaxies, ed. C.J. Lonsdale Persson, NASA Conf. Pub. CP-2466, p.263

Taylor, C.L., Brinks, E., Pogge, R.W., and Skillman, E.D. 1994, AJ, 107, 971

Taylor, C.L., Brinks, E., Grashuis, R.M, & Skillman, E.D. 1995, ApJS, 99, 427

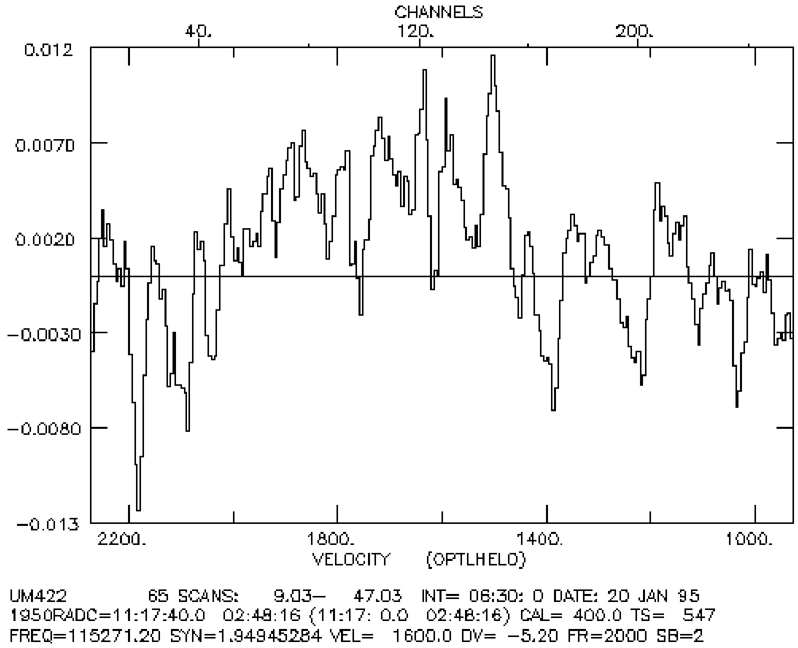

Figure 1: Spectrum of UM422 smoothed to a resolution of 20.8 $\mathrm{km\,s^{-1}}$. The one sigma noise limit is 3.7 mK in units of T_A^*.

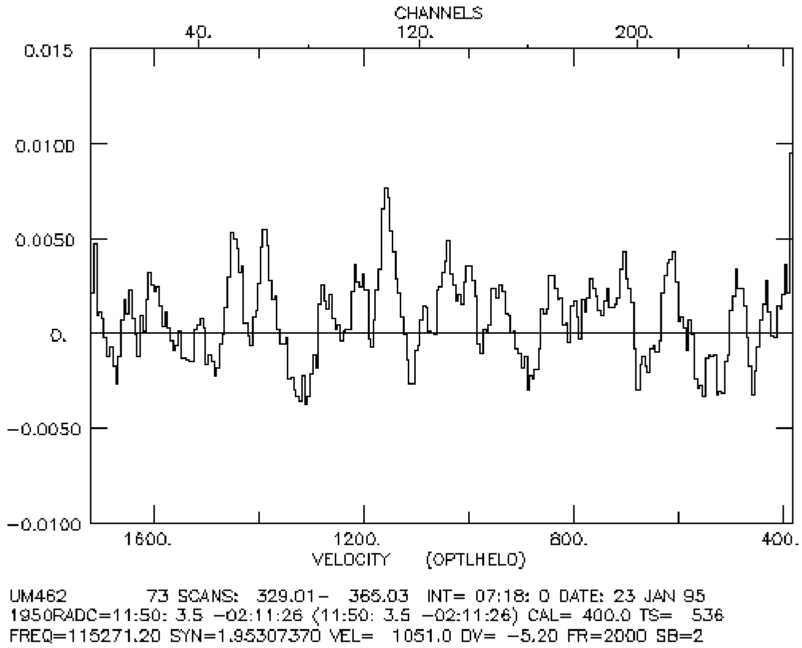

Figure 2: Spectrum of UM462 smoothed to a resolution of 20.8 $\mathrm{km\,s^{-1}}$. The one sigma noise limit is 2.0 mK in units of T_A^*.