The Neutral ISM in Starburst Galaxies
ASP Conference Series, Vol. xxx, 2003
S. Aalto, S. Hüttemeister, A. Pedlar

OH Molecules and Masers in Messier 82

A. Pedlar[1], T.W,B. Muxlow, [1], R. Smith[1], H.Thrall[1], R. J. Beswick[1], M.K. Argo[1], S.Aalto[2], R.S. Booth[2], K.A. Wills[3]

1. JBO, Univ. of Manchester,Nr Macclesfield,SK11 9DL, UK

2. Onsala Space Observatory, Onsala, S-43992, Sweden

3. Dept of Physics & Astronomy, Univ. of Sheffield, S3 7RH UK

Abstract. We present VLA A-configuration observations of the 1665 and 1667 MHz transitions from hydroxyl molecules in the nearby starburst Messier 82. Both lines show extensive absorption over the central 600pc and show an approximately linear velocity gradient along the galaxy major axis. In addition we find eight new main-line OH masers. A number of the masers appear to be associated with the expanding bubble feature seen in the western part of the starburst.

1. Introduction

Messier 82 (M82) is one of the nearest, and certainly best studied, example of a starburst galaxy. Initially its intense far-infrared emission was used to infer the high starformation rate, which was confirmed by the large number (~ 50) of compact radio supernova remnants discovered in the central 600pc of the galaxy.

We have made extensive absorption studies of the atomic hydrogen associated with M82 using both MERLIN and the VLA (Wills et al 2000, 2002) and compared this with CO emission (Shen & Lo 1995) to make a preliminary comparison between the distribution and dynamics of neutral atomic and molecular gas. However as the CO data has a lower angular resolution than the atomic hydrogen, and is observed in emission rather than absorption, the validity of the comparison is open to question. Hence in order to observe molecular gas in absorption we used the VLA to observe the 1665 & 1667MHz OH transitions against the non-thermal continuum. This gives very similar angular resolution to our HI studies against essentially the same background continuum.

2. The observations

The data were observed in April 2002 using the VLA in A configuration. A total of 64 channels covering a bandwidth of 6.25MHz were used in 2-IF mode resulting in a channel separation of 98kHz ($\sim$ 17.6 km s^{-1}). Hence both F=1-1 and 2-2 transitions were observed in the same band. The data were calibrated using standard VLA methods and a 512x512x64 data cube was produced. The continuum was formed from line free parts of the cube and subtracted in order to

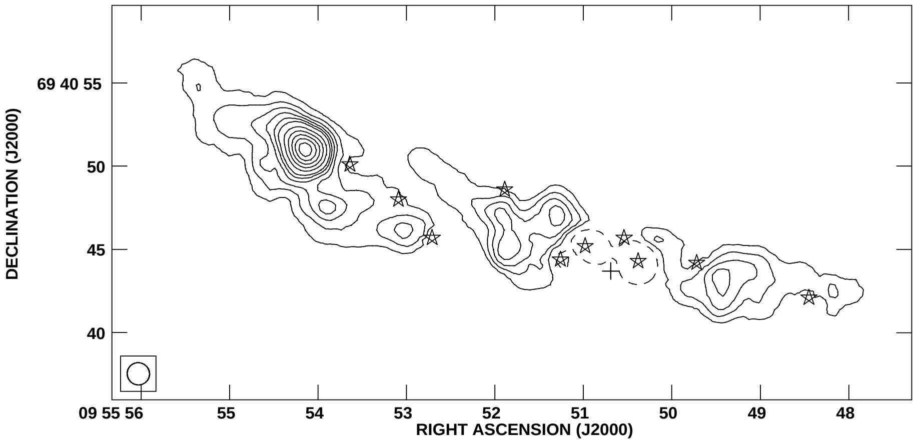

Figure 1. A contour map showing the integrated 1667MHz absorption seen against the starburst in M82. The contours of absorption are separated by units of 500 Jy beam^{-1} Hz. The stars mark the positions of the main line OH masers reported in this paper and the cross marks the position of the most luminous, compact radio source 41.95+575. The dashed contours show emission from the stronger masers.

separate the line component. The cube was then cleaned and restored with a 1.3 arcsecond beam. The resulting data-cube showed extensive absorption against the continuum, with the lines being mostly in the ratio 9:5 as expected for optically thin absorption in LTE. In addition maser emission was also detected at approximately 10 locations within the starburst. As a number of the masers were relatively intense it was necessary for some of the analysis to use hanning smoothing to remove the ringing due to Gibb's phenomenon. This resulted in a velocity resolution of 35 km s^{-1}, which was adequate for the absorption spectra, but clearly not ideal for the maser studies.

3. Results

In Fig. 1 we show the integrated 1667MHz line absorption obtained against the M82 starburst using moments analysis. There are three main areas of absorption -in qualitative agreement with the integrated CO image shown by Shen & Lo (1995). The deepest OH absorption is seen at the eastern end of the source, with an optical depth of $\sim$0.4. An example of the dynamics of the OH is shown in Figure 2 which shows a position-velocity map of the 1667MHz line absorption integrated over an 8 arcsecond wide strip along the major axis of M82.

Also in Fig.1 we show the positions of the 10 main-line masers which we detected. OH masers were first noted by Rieu et al(1976) and two masers were studied by Weliachew et al (1984). However we believe 8 of the 10 masers to be new detections. All the masers were detected at 1665MHz, and seven at 1667MHz, however in approximately half the masers the 1667MHz emission was the stronger of the two lines.

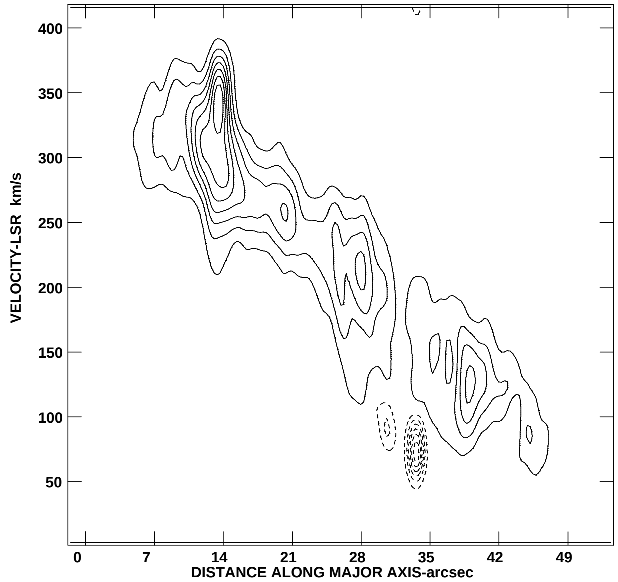

Figure 2. A position-velocity map showing the integrated absorption of the 1667MHz line observed along the major axis of M82. The solid contours are of absorption separated by 176 mJy/beam km s^{-1} and the dashed contours show regions of emission due to masers.

4. Discussion

4.1. Masers

Although the 17.6 km s^{-1} velocity resolution was well suited to the absorption studies, it clearly does not resolve the maser emission and quite possibly resulted in failure to detect weak narrow maser features. Nevertheless we can measure the positions of the masers, their line luminosity and estimate the line intensity ratio between the two lines. We find that all the masers which show both 1665 and 1667 MHz lines coincide to better than an arcsecond with the compact HII regions reported by McDonald et al (2002). In addition there is close positional agreement between the four H_2O masers reported by Baudry & Brouillet(1996) and four of these masers. None of the 'single line' 1665MHz masers appear to be associated with compact HII regions. Also we find little agreement between the positions of the 1665/7 MHz masers and the satellite line masers reported by Seaquist et al (1997).

The association of these masers with the compact HII regions confirms their being associated with regions young star-formation as seen in galactic studies. From Figure 1 it can be seen that most of the main-line masers are situated at the edges of, rather than the centres of, the OH absorbing clouds, implying that starformation in taking place at the periphery, rather than within, the molecular clouds.

4.2. Dynamics

From the position-velocity diagram shown in Fig.2 it can be seen that the dynamics of the OH are broadly consistent with those seen in atomic hydrogen absorption (Wills et al 2000) and carbon monoxide emission (Shen & Lo 1995) with an average velocity gradient of $\sim$7 km s^{-1} arcsec^{-1} over the central 40 arcsec. The gradient is much lower than that seen in ionised gas ($\sim$ 20 km s^{-1}arcsec^{-1}) from the study of [NeII] by Achtermann & Lacy 1995.

Although much of the OH velocity structure can be interpreted in terms of solid body rotation, there are clearly significant deviations from this at 350 km s^{-1} and $\sim$70 km s^{-1}. While some of this deviation may be due to non-circular motions due to a bar potential (eg Wills et al 2000), there is increasing evidence that a significant part of this motion can be attributed to expanding shells or bubbles. The 70 km s^{-1} region is particularly interesting as it coincides with a region of free-free absorption detected at 73cm (Wills et al 1997), initially interpreted as an $\sim$100pc diameter HII region. This is also the region in which Weiss et al(1999) reported a bubble of CO emission expanding at 45 km s^{-1} and Matsushita et al (2000) imaged a shell of CO emission of radius $\sim$100pc. This part of our position-velocity plot (Fig.2) is also consistent with an expanding shell, although it is the OH masers which delineate the blue-shifted part of the shell. There does not seem to be strong OH absorption at these velocities, although it is possible that the strong maser emission has masked the absorption. Nevertheless parts of an OH absorption shell can be traced, particularly along the eastern part of the CO shell.

It is tempting to associate the most luminous, compact radio source with this expanding shell as it is situated in the line of sight to the shell and appears to be situated in a cluster of the masers which define the shell dynamics (Fig.1). However both atomic hydrogen (Wills et al 2000) and the OH absorption spectra show weak red shifted absorption at $\sim$250 km s^{-1} against 41.95+575, which suggests that it is on the *far* side of the expanding shell, and hence may not be physically associated.

References

Achtermann,J.M., Lacy, J.H. 1995,ApJ, 439, 163
Baudry, A., Brouillet,N. 1996, A&A, 316, 188
Seaquist,E.R. et al 1997 ApJ487, L131
McDonald, A.R. et al. 2002, MNRAS, 334, 912
Matsushita, S. et al. 2000, ApJ, 545, L107
Rieu,N.Q. et al 1976, A&A, 52, 467
Shen, J.,Lo, K. Y. 1995, ApJ, 445, L99
Weiss,A. et al 1999, A&A, 345, 23
Weliachew, L., Fomalont, E.B, Greisen,E.W. 1984, A&A, 137, 335
Wills, K.A. et al 1997, MNRAS, 291, 517
Wills, K.A. et al 2000, MNRAS, 316, 33
Wills, K.A., Pedlar,A., Muxlow, T.W.B. 2002, MNRAS, 331, 313