LARGE MAGNETIC FIELDS AND MOTIONS OF OH MASERS IN W75N

VINCENT L. FISH\textsuperscript{1} AND MARK J. REID\textsuperscript{2}

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ABSTRACT

We report on a second epoch of VLBA observations of the 1665 and 1667 MHz OH masers in the massive star-forming region W75N. We find evidence to confirm the existence of very strong (~40 mg) magnetic fields near source VLA 2. The masers near VLA 2 are dynamically distinct and include a very bright spot apparently moving at 50 km s\textsuperscript{-1} relative to those around VLA 1. This fast-moving spot may be an example of a rare class of OH masers seen in outflows in star-forming regions. Due to the variability of these masers and the rapidity of their motions, tracking these motions will require multiple observations over a significantly shorter time baseline than obtained here. Proper motions of the masers near VLA 1 are more suggestive of streaming along magnetized shocks rather than Keplerian rotation in a disk. The motions of the easternmost cluster of masers in W75N(B) may be tracing slow expansion around an unseen exciting source.

Subject headings: ISM: individual (W75N) — ISM: kinematics and dynamics — magnetic fields — masers — radio lines: ISM — stars: formation

1. INTRODUCTION

W75N is a complex massive star-forming region with many sites of star formation and masers (e.g., Persi et al. 2006). W75N(B) is composed of at least four continuum sources, of which VLA 1 and VLA 2 host both OH and H\textsubscript{2}O masers (Hunter et al. 1994; Torrelles et al. 1997). The H\textsubscript{2}O masers around VLA 2 appear to be located on a shell with an expansion velocity of ~28 km s\textsuperscript{-1} (Torrelles et al. 2003) and organized substructure on scales as small as 1 AU (Uschanga et al. 2005). The sources VLA 1, VLA 2, and VLA 3 are all believed to drive large-scale molecular outflows (Shepherd et al. 2003, 2004 and references therein).

The OH masers in W75N were first observed interferometrically by Harvey et al. (1974), who noted three different sites of OH maser emission. VLBI techniques were first employed in this source by Haschick et al. (1981). The full large-scale distribution of masers, including the easternmost cluster and the group near VLA 2, was detected by Baart et al. (1986). Extreme variability of OH maser features in W75N was noted by Alakoz et al. (2005), who reported that a flare up to 750 Jy was briefly the brightest OH maser in the sky. Flaring is also seen in many of the water (Lekht & Krasnov 2000 and references therein) and methanol masers in this source (Goedhart et al. 2004). The OH masers near VLA 2 appear to have a much larger velocity scatter than do the rest of the masers in W75N(B) (Fish et al. 2005). It is with the aim of exploring the kinematic differences between the masers in VLA 1 and VLA 2 that we revisit the region with VLBA observations.

2. OBSERVATIONS

The Very Long Baseline Array (VLBA) was used to observe the 1665.4018 and 1667.3590 MHz transitions of OH in W75N (G81.871+0.781) on 2000 November 22 and 2001 January 6 (data combined; hereafter epoch 1). For each frequency, dual-left and dual-right polarization observations were taken using a 125 kHz bandwidth divided into 128 spectral channels (corresponding to a velocity width of 0.176 km s\textsuperscript{-1}), centered on \( v_{\text{LSR}} = 10 \text{ km s}^{-1} \) (radio). Further details of these observations, as well as the resulting images, can be found in Fish et al. (2005). A second epoch of data was taken on 2004 September 16 and 19. Observational parameters were identical, with the exception of the bandwidth being centered at \( v_{\text{LSR}} = 7 \text{ km s}^{-1} \). The synthesized beam size was approximately 9.0 mas x 6.5 mas, with a blank-sky rms noise of 8 mJy beam\textsuperscript{-1}. In this work we report on both the second epoch of observations and the observed changes in W75N between the two epochs.

3. RESULTS

We recover a total of 123 maser features (lines), approximately the same as the 120 features detected in epoch 1 in the same amount of on-source observing time (Fish et al. 2005). Spot parameters are listed in Table 1. A map of detected maser emission is shown in Figure 1. Our velocity coverage includes most of the brightest features but is not sufficient to have seen all known maser features in this source, which range from ~4.9 km s\textsuperscript{-1} (Hutawarakorn et al. 2002) up to ~33 km s\textsuperscript{-1} (Yngvesson et al. 1975). The map is qualitatively similar to epoch 1 (Fig. 27 of Fish et al. 2005), except near VLA 2 (Fig. 2 of the present work).

The magnetic fields we infer from Zeeman splitting of left and right--circular polarization (LCP and RCP) components are shown in Figure 1 and listed in Table 2. The strength and line-of-sight direction of the magnetic fields are consistent with values obtained in epoch 1, except near source VLA 2. Our velocity coverage is too small to detect both Zeeman components at 1665 MHz (and at 1667 MHz, depending on the systemic velocity) when split by ~40 mg, as seen by Slysh & Migenes (2006) near VLA 2. However, we can infer magnetic field strengths where 1665 and 1667 MHz masers overlap, since the transitions undergo different Zeeman splitting for a given magnetic field strength. These values are presented in parentheses in Figure 1 and listed in Table 3. Near VLA 2 we find magnetic fields of 26.6 and 40.4 mg (Fig. 2), consistent in sign and (at least in the latter case) magnitude with values obtained by Slysh & Migenes (2006). (We note that the random error in the magnetic field strength estimate from multi-transition overlap may be somewhat larger than from traditional Zeeman pairs, since it is not known a priori that the 1665 and 1667 MHz Zeeman patterns are centered at the same systemic velocity. Nevertheless, this technique generally results in magnetic field estimates consistent with values obtained from proper Zeeman

\textsuperscript{1} Jansky Fellow, National Radio Astronomy Observatory, Socorro, NM.
\textsuperscript{2} Harvard-Smithsonian Center for Astrophysics, Cambridge, MA.
| Frequency (MHz) | Maser Feature | $\Delta$R.A. (mas) | $\Delta$Decl. (mas) | v_LSR (km s$^{-1}$) | Brightness (Jy beam$^{-1}$) | Polarization |
|----------------|---------------|--------------------|--------------------|---------------------|-----------------------------|--------------|
| 1665.............| 1             | -493.39            | 147.93             | 6.83                | 0.35                        | L            |
|                | 2             | -491.55            | -440.64            | 7.35                | 0.07                        | L            |
|                | 3             | -491.89            | -443.17            | 7.35                | 0.06                        | R            |
|                | 4             | -298.29            | 256.13             | 5.95                | 1.03                        | L            |
|                | 5             | -260.68            | -312.38            | 12.74               | 1.22                        | R            |
|                | 6             | -246.81            | -1144.76           | 9.84                | 0.25                        | R            |
|                | 7             | -249.22            | -1145.51           | 9.81                | 0.13                        | L            |
|                | 8             | -132.16            | -221.87            | 12.10               | 0.06                        | L            |
|                | 9             | -111.20            | -14.49             | 12.80               | 0.82                        | R            |
|                | 10            | -109.22            | 710.59             | 7.35                | 0.15                        | R            |
|                | 11            | -115.69            | -71.09             | 9.45                | 0.41                        | R            |
|                | 12            | 124.48             | -74.32             | 10.01               | 0.25                        | R            |
|                | 13            | 127.59             | -55.61             | 12.09               | 0.25                        | L            |
|                | 14            | 129.00             | -58.36             | 14.56               | 0.06                        | R            |
|                | 15            | 129.22             | -48.70             | 13.33               | 0.23                        | L            |
|                | 16            | 138.83             | -14.49             | 12.80               | 1.25                        | L            |
|                | 17            | 177.24             | 520.20             | 9.99                | 0.58                        | R            |
|                | 18            | 177.24             | 520.20             | 9.99                | 0.27                        | L            |
|                | 19            | 178.97             | 550.75             | 10.16               | 0.23                        | R            |
|                | 20            | 193.50             | 579.87             | 9.99                | 0.13                        | R            |
|                | 21            | 193.54             | 581.00             | 5.24                | 0.14                        | R            |
|                | 22            | 196.35             | 595.53             | 8.97                | 1.13                        | R            |
|                | 23            | 200.58             | 718.00             | 11.22               | 0.34                        | R            |
|                | 24            | 200.94             | 707.45             | 10.87               | 1.11                        | R            |
|                | 25            | 201.09             | 568.85             | 4.01                | 1.17                        | L            |
|                | 26            | 203.33             | 673.95             | 4.54                | 0.19                        | L            |
|                | 27            | 203.33             | 673.95             | 8.96                | 0.68                        | R            |
|                | 28            | 205.54             | 605.61             | 9.26                | 11.32                       | R            |
|                | 29            | 206.33             | 1102.14            | 5.49                | 6.55                        | R            |
|                | 30            | 205.82             | 1102.49            | 5.42                | 0.91                        | L            |
|                | 31            | 211.63             | 1106.88            | 5.90                | 3.03                        | R            |
|                | 32            | 212.98             | 613.36             | 4.56                | 1.37                        | L            |
|                | 33            | 221.71             | 1104.56            | 5.95                | 0.39                        | R            |
|                | 34            | 230.48             | 581.26             | 5.41                | 4.10                        | L            |
|                | 35            | 230.63             | 581.31             | 5.48                | 0.44                        | R            |
|                | 36            | 231.83             | 581.66             | 10.15               | 0.43                        | R            |
|                | 37            | 231.93             | 549.56             | 10.11               | 3.08                        | R            |
|                | 38            | 233.01             | 558.86             | 5.55                | 11.66                       | L            |
|                | 39            | 233.29             | 559.16             | 5.53                | 2.43                        | R            |
|                | 40            | 233.47             | 1007.83            | 5.24                | 0.26                        | R            |
|                | 41            | 277.46             | 1114.03            | 6.50                | 0.45                        | R            |
|                | 42            | 277.89             | 1094.50            | 5.82                | 6.05                        | R            |
|                | 43            | 279.11             | 1097.13            | 5.59                | 0.92                        | L            |
|                | 44            | 282.51             | 1113.27            | 4.07                | 5.63                        | L            |
|                | 45            | 278.85             | 1113.22            | 4.22                | 0.28                        | R            |
|                | 46            | 297.23             | 1111.03            | 6.85                | 0.90                        | R            |
|                | 47            | 300.27             | 1178.27            | 3.21                | 0.84                        | L            |
|                | 48            | 300.94             | 1147.54            | 7.35                | 0.25                        | R            |
|                | 49            | 301.64             | 1178.27            | 5.70                | 4.93                        | R            |
|                | 50            | 301.59             | 1178.09            | 5.59                | 3.25                        | L            |
|                | 51            | 325.79             | 130.03             | 13.90               | 0.41                        | L            |
|                | 52            | 342.64             | 1177.95            | 5.51                | 15.39                       | R            |
|                | 53            | 342.01             | 1178.43            | 5.57                | 1.66                        | L            |
|                | 54            | 343.12             | 1133.25            | 6.52                | 2.57                        | R            |
|                | 55            | 342.91             | 1132.95            | 6.47                | 0.39                        | L            |
|                | 56            | 346.17             | 1180.21            | 3.48                | 0.38                        | L            |
|                | 57            | 365.98             | 1147.96            | 4.54                | 0.26                        | L            |
|                | 58            | 365.89             | 1148.01            | 4.54                | 0.08                        | R            |
|                | 59            | 367.61             | 1149.59            | 7.01                | 0.18                        | R            |
|                | 60            | 400.92             | 1229.55            | 4.71                | 0.56                        | L            |
| Frequency (MHz) | ΔR.A. (mas) | ΔDecl. (mas) | v<sub>LSR</sub> (km s<sup>-1</sup>) | Brightness (Jy beam<sup>-1</sup>) | Polarization |
|----------------|-------------|-------------|-----------------|-----------------|-------------|
| 54             | 445.02      | 1276.97     | 5.31            | 1.00            | L           |
|                | 444.40      | 1277.38     | 5.15            | 0.32            | R           |
| 55             | 457.52      | 1293.28     | 5.15            | 7.49            | L           |
|                | 457.14      | 1292.72     | 5.18            | 4.64            | R           |
| 56             | 488.92      | 1347.51     | 5.16            | 6.15            | L           |
|                | 488.92      | 1347.51     | 5.07            | 0.18            | R           |
| 57             | 489.71      | 1348.16     | 7.21            | 0.74            | R           |
| 58             | 490.24      | 1347.86     | 5.18            | 1.05            | R           |
| 59             | 533.26      | 1448.99     | 7.00            | 0.16            | R           |
| 60             | 548.23      | 1491.99     | 6.15            | 0.48            | R           |
| 61             | 550.47      | 1496.78     | 3.69            | 5.04            | L           |
| 62             | 602.08      | −97.43      | 3.11            | 2.03            | R           |
|                | 602.28      | −97.74      | 3.14            | 1.30            | L           |
| 63             | 612.70      | −91.00      | 3.13            | 0.85            | R           |
| 64             | 670.20      | −206.46     | 0.50            | 0.51            | R           |
| 65             | 673.82      | −216.53     | 4.54            | 0.23            | R           |
| 66             | 684.26      | −207.25     | 0.67            | 0.47            | R           |
| 67             | 715.54      | −221.75     | 0.67            | 0.43            | R           |
|                | 715.14      | −220.16     | 0.85            | 0.36            | L           |
| 68             | 724.38      | −233.62     | 0.60            | 0.34            | R           |
|                | 724.16      | −233.53     | 0.67            | 0.32            | L           |
| 69             | 739.42      | −173.13     | 17.40           | 0.13            | R           |
|                | 739.72      | −173.37     | 17.39           | 0.08            | L           |
| 70             | 739.60      | −145.53     | 2.00            | 408.83          | R           |
|                | 739.39      | −145.95     | 1.98            | 402.02          | L           |
| 71             | 740.07      | −150.02     | −0.12           | 51.31           | L           |
|                | 740.61      | −148.88     | −0.13           | 9.32            | R           |
| 72             | 742.92      | −130.89     | −0.77           | 52.19           | L           |
|                | 743.08      | −128.94     | −0.75           | 23.14           | R           |
| 73             | 744.08      | −134.10     | 0.09            | 134.88          | L           |
|                | 744.44      | −133.57     | 0.11            | 59.95           | R           |
| 74             | 745.71      | −148.79     | 4.26            | 0.48            | R           |
| 75             | 746.35      | −140.72     | 3.09            | 1.25            | R           |
| 76             | 746.38      | −121.79     | −3.37           | 0.73            | L           |
| 77             | 747.32      | −140.04     | 2.69            | 5.61            | L           |
|                | 747.57      | −139.85     | 2.43            | 4.58            | R           |
| 78             | 747.74      | −148.44     | 6.21            | 34.73           | R           |
|                | 747.34      | −148.90     | 6.23            | 4.89            | L           |
| 79             | 767.28      | −90.12      | 7.14            | 1.08            | L           |
|                | 767.82      | −89.66      | 7.23            | 0.32            | R           |
| 80             | 774.58      | −93.27      | 10.87           | 0.14            | L           |
| 81             | 775.76      | −132.90     | 0.85            | 0.39            | L           |
| 82             | 791.97      | −240.71     | 5.83            | 1.72            | R           |
| 83             | 817.99      | −170.32     | 17.24           | 0.57            | R           |
| 84             | 905.22      | −204.56     | −2.32           | 0.30            | L           |
| 85             | 1341.64     | 49.55       | 11.39           | 0.14            | R           |
|                | 1341.26     | 48.92       | 11.39           | 0.11            | L           |
| 86             | 1706.84     | −590.03     | 13.68           | 0.35            | R           |
| 87             | 1759.06     | −592.88     | 16.49           | 0.07            | L           |
| 88             | 1784.06     | −587.59     | 16.14           | 0.07            | L           |
| 89             | 1785.98     | −596.61     | 12.16           | 6.42            | R           |
|                | 1785.19     | −596.61     | 12.14           | 0.30            | L           |
| 90             | 1.10        | −0.61       | 11.89           | 0.76            | R           |
| 91             | 1.39        | −0.06       | 10.09           | 0.39            | L           |
| 92             | 105.78      | 211.80      | 10.19           | 1.09            | L           |
| 93             | 129.66      | −54.79      | 12.62           | 0.49            | R           |
| 94             | 129.75      | −54.81      | 12.67           | 0.45            | L           |
| 95             | 173.09      | 807.56      | 11.06           | 0.22            | R           |
| 96             | 195.97      | 575.29      | 6.47            | 0.15            | L           |
| 97             | 197.78      | 595.08      | 8.02            | 0.66            | R           |
| 98             | 198.82      | 482.75      | 9.11            | 0.54            | R           |
| 99             | 199.99      | 480.96      | 9.11            | 0.06            | L           |
| 100            | 202.42      | 708.63      | 9.98            | 1.69            | R           |
| 101            | 203.25      | 568.73      | 5.42            | 0.31            | L           |
| 102            | 203.40      | 570.11      | 5.42            | 0.10            | R           |
| 103            | 206.94      | 605.17      | 8.45            | 0.42            | R           |
| 104            | 207.18      | 674.50      | 5.42            | 5.08            | L           |
| 105            | 207.18      | 674.50      | 5.42            | 5.08            | L           |
Reanalyzing the data from epoch 1, we agree with Slysh & Migenes (2006) that spots 109 and 110 in Table 15 of Fish et al. (2005) form a 42.5 mG Zeeman pair at 1667 MHz (with multi-transition confirmation from spot 67 at 1665 MHz). Spots 112 and 113 also form a 34.5 mG Zeeman pair (approximately consistent with the $v_{\text{LSR}}$ value of nearby 1665 MHz LCP spots 69 and 70).

However, not all overlaps are indicative of magnetic fields. It is

| Frequency (MHz) | Maser Feature | $\Delta$R.A. (mas) | $\Delta$Decl. (mas) | $v_{\text{LSR}}$ (km s$^{-1}$) | Brightness (Jy beam$^{-1}$) | Polarization |
|----------------|---------------|--------------------|--------------------|-----------------|-----------------|-------------|
| 102            | 207.81        | 673.79             | 8.09               | 0.94            | R               |
| 103            | 219.18        | 618.12             | 8.05               | 0.10            | R               |
| 104            | 219.78        | 617.31             | 5.24               | 0.27            | L               |
| 105            | 222.44        | 655.77             | 6.01               | 1.30            | L               |
| 106            | 233.08        | 549.21             | 9.20               | 0.32            | R               |
| 107            | 233.66        | 550.95             | 6.49               | 0.61            | L               |
| 108            | 457.98        | 1295.24            | 6.30               | 0.14            | L               |
| 109            | 465.01        | 1301.25            | 5.95               | 0.07            | L               |
| 110            | 491.50        | 1353.89            | 6.64               | 0.13            | R               |
| 111            | 491.93        | 1351.43            | 5.62               | 0.47            | L               |
| 112            | 740.70        | −146.15            | 6.79               | 0.35            | L               |
| 113            | 742.94        | −143.59            | 4.48               | 0.37            | L               |
| 114            | 744.02        | −128.38            | 4.00               | 0.47            | L               |
| 115            | 743.76        | −128.26            | 4.07               | 0.13            | R               |
| 116            | 758.52        | −90.35             | 10.17              | 0.55            | L               |
| 117            | 756.98        | −92.17             | 10.07              | 0.36            | R               |
| 118            | 776.37        | −92.64             | 14.01              | 0.11            | L               |
| 119            | 800.17        | −175.96            | 15.46              | 0.25            | L               |
| 120            | 962.06        | −207.57            | −2.53              | 0.14            | L               |
| 121            | 1784.15       | −582.29            | 15.41              | 0.21            | L               |
| 122            | 1786.02       | −584.16            | 12.94              | 0.25            | R               |
| 123            | 1833.33       | −559.66            | 14.90              | 0.12            | L               |
|               | 1833.95       | −559.60            | 12.56              | 0.79            | R               |

**Notes.**—Coordinates are position offsets from the reference feature located at the origin. Spots detected at the same location in RCP and LCP at nearly the same LSR velocity are treated as a single feature, as in Fish et al. (2005).

**Fig. 1.**—Map of detected OH maser emission in W75N (epoch 2004 Sep 16 and 19). Stars indicate 1665 MHz emission and squares indicate 1667 MHz emission. Open (filled) symbols denote emission in RCP (LCP). The LSR velocity of the peak of each maser profile is indicated by its color. Numbers indicate magnetic fields derived from Zeeman splitting, with positive values representing fields oriented in the hemisphere away from the observer. Values in parentheses are deduced from overlaps in different transitions (see Table 3). X-band (8.4 GHz) continuum emission is shown as dotted contours. The feature at the origin is the same as the reference feature of Slysh & Migenes (2006), who give its absolute position as 20$^h$38$^m$36.416$^s$, +42$^d$37′34.42″ ($\pm$ 0.01″) (J2000.0, epoch 2001 January 1).

**Fig. 2.**—Enlargement of region near VLA 2. See Fig. 1 for details. The continuum contours have been suppressed.
unlikely that spots 68 and 107 arise from a 137 mG magnetic field, 
as above the maximum of detected masers in the region (Yngvesson
the maser may be nearly 100% linearly polarized.

The spectrum of recovered maser emission is shown in Figure 3. In each velocity channel, the total flux density of each (elliptical Gaussian) fitted maser spot is summed. The strongest maser we detect is located at ($\Delta$R.A., $\Delta$Decl.) = (739.60°, -145.53°), and is approximately 400 Jy in both RCP and LCP (2$kT$). The equal flux densities suggest that the maser may be nearly 100% linearly polarized, as noted by Alakoz et al. (2005). Other masers near VLA 2 also show very high linear polarization fractions (Baart et al. 1986; Slysh et al. 2001; Hutawarakorn et al. 2002; Fish et al. 2005). The strongest spot is over twice as strong as in epoch 1 (Fish et al. 2005) and is stronger than measured on 2004 October 20 by Alakoz et al. (2005). It is unclear whether the same maser spot is experiencing a second flare or a different, nearby maser spot is undergoing a flare episode.

Proper motions of the OH masers are shown in Figure 4. Since the data for both epochs were phase referenced to a maser spot rather than an external source, our data cannot distinguish between the map presented and any other frame with a single constant vector added to all motions. In Figure 4 we have chosen the frame that minimizes the total length of all arrows not associated with VLA 2. The average speed of all masers, excluding those near VLA 2, is 3.4 ± 2.1 km s⁻¹. This speed is comparable to that of OH masers around other young ultracompact HII regions, such as W3(OH) and ON1 (Bloemhof et al. 1992; V. L. Fish & M. J. Reid 2007, in preparation). The random error on the motion of an individual maser spot, given by the uncertainties in determining the position centroid in each epoch, ranges from negligible to 1.4 km s⁻¹ with a median value of 0.2 km s⁻¹.

The presence of a disk associated with VLA 1 has often been inferred from the north-south distribution of OH masers (e.g., Haschick et al. 1981; Slysh et al. 2001). Indeed, the distribution of LSR velocity increases from north to south along this structure (e.g., Fig. 1). However, the proper motions of the OH masers are less clear. Figure 4 shows the average proper motions of clusters of masers along and south of the putative disk, relative to the cluster nearest the continuum emission (velocity 0). Positive values


\textbf{TABLE 2}

\textbf{ZEEMAN PAIRS}

| Frequency (MHz) | RCP | LCP | $B$ | Separation (mas) | Pair Number
|-----------------|-----|-----|-----|------------------|--------------|
|                 | $\Delta$R.A. (mas) | $\Delta$Decl. (mas) | $v_{LSR}$ (km s⁻¹) | $\Delta$R.A. (mas) | $\Delta$Decl. (mas) | $v_{LSR}$ (km s⁻¹) | (mG) | (mas) |
|-----------------|-----------------|-----------------|----------------|-----------------|-----------------|----------------|------|-------|
| 1665............ | 0.00            | 0.00            | 12.36          | -0.24           | -0.17           | 9.27            | 5.2  | 0.3   |      |
|                 | 99.89           | -80.27          | 9.64           | 91.69           | -70.85          | 13.68           | -6.8 | 12.5  | ... |
|                 | 129.00          | -58.36          | 14.56          | 127.59          | -55.61          | 12.09           | 4.2  | 3.1   | ... |
|                 | 193.50          | 579.87          | 9.99           | 201.09          | 568.85          | 4.01            | 10.1 | 13.4  | ... |
|                 | 203.33          | 673.95          | 8.96           | 203.33          | 673.95          | 4.54            | 7.5  | 1.4   | ... |
|                 | 231.83          | 581.66          | 10.15          | 230.48          | 581.26          | 5.41            | 8.0  | 1.4   | ... |
|                 | 231.93          | 549.56          | 10.11          | 233.01          | 558.86          | 5.55            | 7.7  | 9.4   | ... |
|                 | 277.46          | 1114.03         | 6.50           | 282.51          | 1113.27         | 4.07h           | 4.1  | 5.1   | ... |
|                 | 301.64          | 1178.27         | 5.70           | 300.27          | 1178.27         | 3.21            | 4.2  | 1.4   | ... |
|                 | 342.64          | 1177.95         | 5.51           | 346.17          | 1180.21         | 3.48            | 3.4  | 4.2   | ... |
|                 | 367.61          | 1149.59         | 7.01           | 365.98          | 1147.96         | 4.54            | 4.2  | 2.3   | ... |
|                 | 489.71          | 1348.16         | 7.21           | 488.92          | 1347.51         | 5.16            | 3.5  | 1.0   | Z3  |
|                 | 548.23          | 1491.99         | 6.15           | 550.47          | 1496.78         | 3.69            | 4.2  | 5.3   | ... |
|                 | 1785.98         | -596.61         | 12.16          | 1784.06         | -587.59         | 16.14           | -6.8 | 9.2   | ... |
| 1667............ | 1.10            | -0.61           | 11.89          | 1.39            | -0.06           | 10.09           | 5.1  | 0.6   | ... |
|                 | 207.81          | 673.79          | 8.09           | 207.18          | 674.50          | 5.42            | 7.5  | 1.0   | Z2  |
|                 | 219.18          | 618.12          | 8.05           | 219.78          | 617.31          | 5.24            | 7.9  | 1.0   | ... |
|                 | 233.08          | 549.21          | 9.20           | 233.66          | 550.95          | 6.49            | 7.7  | 1.8   | ... |
|                 | 457.98          | 1295.24         | 6.30           | 465.01          | 1301.25         | 5.95            | 1.0  | 9.3   | ... |
|                 | 491.50          | 1353.89         | 6.64           | 491.93          | 1351.43         | 5.62            | 2.9  | 2.5   | ... |
|                 | 746.10          | -142.66         | 1.02           | 742.94          | -143.59         | 4.48            | -9.8 | 3.3   | ... |
|                 | 1786.02         | -584.16         | 12.94          | 1784.15         | -582.29         | 15.41           | -7.0 | 2.6   | ... |
|                 | 1833.95         | -559.60         | 12.56          | 1833.33         | -559.66         | 14.90           | -6.6 | 0.6   | ... |

\* Pair number listed in Table 1 of Slysh & Migenes (2006).

\* Alternatively, this may form part of a loose complete 5.6 mG Zeeman pattern with spot 45 and another linearly polarized spot. See Fish & Reid (2006).
indicate net motion away from this cluster. Proper motions in the
south show clear organization away from the 0 cluster, but the motions of the northermost clusters are mixed. Alternatively,
the masers may be tracing a shocked, expanding layer (Baart et al.
1986). If so, the maser motions in the northermost cluster may
include a streaming component along an organized magnetic field (Fish & Reid 2006), with the caveat that while the field di-
rection appears to be oriented along the distribution of masers, the external Faraday rotation contribution is unknown (see also Slysh et al. 2002).

The motion of the 400 Jy maser (feature 70 in Table 1) near
VLA 2 is over 50 km s$^{-1}$. Other than this particular maser, it is
difficult to conclusively identify masers from one epoch to the next
near VLA 2 due to variability and the large number of masers in
the region. The distribution of masers near VLA 2 is also changing
rapidly, as can be seen from comparison of Figure 2 with Figure 28
of Fish et al. (2005). LSR velocity is not necessarily a reliable indi-
cator, as the masers appear to be accelerating. The brightest maser
in the region has seen a change in velocity $\Delta v_{\text{LSR}} = -0.45$ km s$^{-1}$
between the two epochs. Alakoz et al. (2005) note a similar de-
crease in $v_{\text{LSR}}$ of this feature over a 2.5 yr timescale.

The easternmost cluster of OH masers may be associated with
another exciting source not seen in the continuum maps. The ve-
locity of this cluster corrected for Zeeman splitting is $\sim 14$ km s$^{-1}$,
higher than any other cluster in W75N (except for portions of
VLA 2, which has a huge velocity scatter and no clear organi-
sation). In addition, the maser proper motions are suggestive of
slow ($\sim 5$ km s$^{-1}$) expansion from a point in the center of the cluster
(Fig. 4). This motion is likely preferentially in the plane of the
sky in light of the small LSR velocity scatter of the masers.

4. DISCUSSION

It is difficult to track OH motions from the first epoch to the
second epoch near VLA 2, both due to variability and the fast
motions involved. These properties may be interrelated. It is prob-
ably not a coincidence that the two strongest (>100 Jy) masers in
W75N (features 70 and 73) both appear in the complicated clus-
ter around VLA 2. While a connection between kinetic energy and
H$_2$O maser flux density has been clearly established (Anglada
et al. 1996), such a correlation is far less clear for OH, which is
believed to be predominantly radiatively pumped. Nevertheless,
regions with energetic motions may change the balance of pump-
ing routes in favor of those with collisional components, possibly
increasing the net pump rates in certain ground-state lines. (For a
d fuller discussion in a different context, see Gray et al. 2005.)
We speculate that the energy source powering the VLA 2 outflow also
helps to produce one of the strongest OH masers in the sky.

In most OH maser sources, it is fairly well established that the
observed proper motions of the masers correspond to motions of
physical clumps of material (see Bloemhof et al. 1996; V. L. Fish
& M. J. Reid 2007, in preparation). But it is perhaps possible that
the apparent motion of the brightest maser in VLA 2 is due to the
passage of a fast-moving shock front through different portions
of a cloud of OH rather than the ballistic motion of a single high-
velocity clump of material. In any event, it appears that most in-
dividual maser spots near VLA 2 do not persist over timescales of
years or longer. Multipech phase-referenced VLBI observations
spaced several months apart will be essential in tracking the
motions of the OH masers around VLA 2. Phase referencing to
a nearby bright calibrator would eliminate the ambiguity of the ab-
solute position of the reference spot in each epoch. Despite this
ambiguity in our data, it is clear that the 50 km s$^{-1}$ motion of
feature 70 in Table 1 with respect to the other masers in W75N
is due to a large intrinsic motion of feature 70 itself, since the
velocity scatter (both from proper motions and radial velocities)
of the rest of the W75N masers is small.

Argon et al. (2003) report on a class of OH masers associated
with outflows. For an OH maser in the Turner-Welch (TW) ob-
ject near W3(OH), they obtain a (projected) proper motion of
66 km s$^{-1}$ with $\Delta v_{\text{LSR}} = 0.5$ km s$^{-1}$ over a period of 8 yr. This
is remarkably similar to what is seen near VLA 2. A key difference,
however, is that the water masers in the TW object span a range
in $v_{\text{LSR}}$ of about 100 km s$^{-1}$ (Cohen 1979; K. Hachisuka et al.
2007, in preparation) with proper motions of several tens of km s$^{-1}$.
In comparison, the water masers in VLA 2 span a range of about 25 km s\(^{-1}\), are arranged in a fairly organized circular pattern, and appear to be expanding at \(\sim 28\) km s\(^{-1}\) (Torrelles et al. 2003), slower than the OH masers.

The magnetic field near VLA 2 appears to undergo a line-of-sight reversal across this very compact source. (We note the caveat, however, that three of the four magnetic field measurements are inferred from multitransition overlap rather than single-transition Zeeman splitting.) Given the rapidly changing nature of this source, it would be fruitful to attempt confirmation of the magnetic field at another epoch, especially since new masers that appear may provide magnetic field information in regions presently unprobed by Zeeman splitting. The polarity of the field may be important if, for instance, the masers trace a magnetically collimated outflow (Cunningham et al. 2005). While the exact relation between magnetic field strength (\(B\)) and density (\(\rho\)) may depend on the particular model (e.g., Pudritz et al. 2006), it is possible that 40 mG magnetic fields do not necessarily imply the extremely large densities that would be obtained from collapse models, where \(B \propto \rho^\kappa\), \(\kappa \approx 0.5\) (Crutcher 1999). Possibly, these masers are from material being ejected from a protostellar disk, which may involve strong magnetic fields originating in the disk. Future observations may also be able to determine whether the unusually strong magnetic field at the OH masers in VLA 2 is decaying as in Cep A (Cohen et al. 1990; Bartkiewicz et al. 2005).

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