

# MERLIN 6-GHz maser emission from W3(OH)

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**Abstract.** We present the preliminary results of the first alignment to milliarcsecond accuracy of the 6-GHz maser emission in OH and methanol maser lines toward W3(OH). The identifications of Zeeman pairs allowed us to infer the actual velocity of the OH material and the magnetic field strength at the location where 6.7-GHz methanol maser emission arises.

## 1. Introduction

W3(OH) is a well-studied star forming region containing a Hot Molecular core (HMC) and an (UC)HII region (Turner & Welch 1984). The central object is thought to be a O9-O7 young star with an estimated mass of about  $30M_{\odot}$  (Dreher & Welch 1981). W3(OH) has been mapped in various maser lines: in the OH ground state lines at 18 cm and in the OH excited lines at 4.7 and 6 GHz (Moran et al. 1978; Desmurs et al. 1998; Gray et al. 2001; Palmer et al. 2003; Wright et al. 2004a,b), in the methanol lines at 6.7 GHz and 12 GHz (Menten et al. 1992; Moscadelli et al. 1999; Sutton et al. 2004). The work presented here deals with MERLIN observations in the excited OH maser lines at 6031 and 6035 MHz and in the methanol maser line at 6668 MHz internally phased allowing accurate alignment of the three datasets and therefore a precise insight into copropagation.

## 2. Observations

Observations were performed on 12th March 2001 for all the lines. In the OH excited lines, observations were obtained at a rest frequency of 6030.747 and 6035.092-MHz for the  $J=5/2, F=2-2$  and  $3-3$  transitions respectively. Both main lines were recorded with a bandwidth of 0.5 MHz, divided into 256 channels. Observations in the 6668-MHz methanol line were performed with a spectral bandwidth of 2 MHz, divided into 512 channels. The central velocity was taken to be  $V_{LSR} = -45 \text{ km.s}^{-1}$ . For all the three experiments 3C84 was used as the bandpass calibrator and 0224+671 as a phase calibrator. The initial data editing and the correction for gain-elevation effects were performed using the MERLIN dprogram packages. Further calibrations were performed within the AIPS package.

## 3. Results

Figures 1 and 2 present all the maser features detected in all the three sets of data. For the study of possible copropagation mechanisms, we determined the range for the FWHM from the spectra taken at the pixels where maser components were identified in the final images. The FWHM was found to range typically from 0.26 to 0.30 km/s.

### 3.1. Excited OH at 6035 MHz

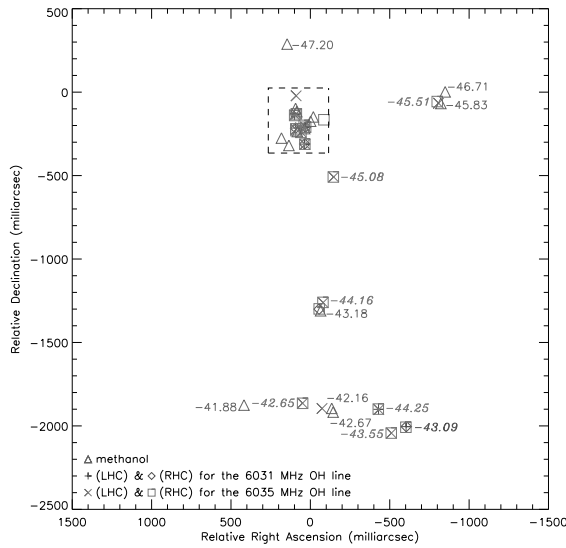
We detected 31 components (14 LHC and 17 RHC) at that frequency. Twelve possible Zeeman pairs were identified. Eleven of them are identified with a separation of less than 5 mas while one pair shows a separation of about 10 mas between the two pairs. All the pairs but one are such that  $V_{LHC} < V_{RHC}$ . One Zeeman pair is such that  $V_{LHC} \geq V_{RHC}$ . This may be due to blending of multiple components since it is known that this area contains a large number of maser spots with a wide range of velocity.

### 3.2. Excited OH at 6031 MHz

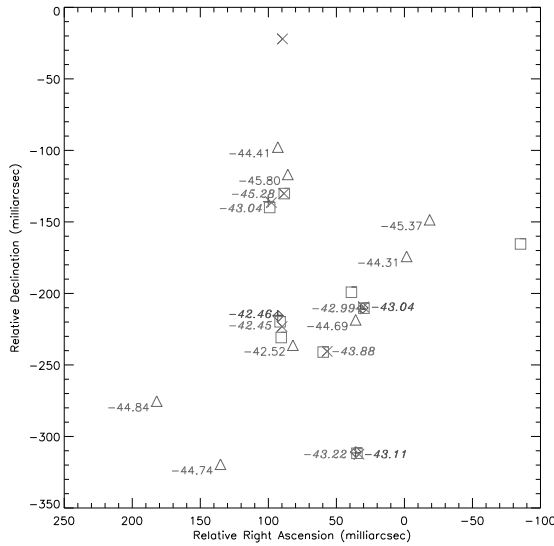
We found 11 components (6 LHC and 5 RHC) from which 4 Zeeman pairs could be identified. Three out the four Zeeman pairs observed at 6031-MHz were found coincident with 6035-MHz Zeeman pairs. The very good agreement in position ( $< 6.5$  mas) and demagnetized velocity ( $\Delta V \leq 0.11 < \text{FWHM}$ ) are such that we are fairly confident that we are observing copropagating masers. It is also noteworthy that all 6031-MHz spots coincide with 6035-MHz maser spots within 6.5 mas.

### 3.3. Methanol at 6668 MHz

We found 15 components. Five methanol maser spots (i.e., 33%) are found within 20 mas from an OH 6035-MHz maser spot. Three of these maser spots belong to the crowded area  $RA_{\text{offset}}=[+250,-100]$  mas,  $Dec_{\text{offset}}=[0,-350]$  mas, one belongs to the far West area  $RA_{\text{offset}}=[-800,-850]$  mas,  $Dec_{\text{offset}}=[0,-100]$  mas and the last one to the area  $RA_{\text{offset}}=[+100,-200]$  mas,  $Dec_{\text{offset}}=[-1200,-1400]$  mas. The maser spot belonging to the last mentioned southern area and one belonging to the crowded area  $RA_{\text{offset}}=[+250,-100]$  mas,  $Dec_{\text{offset}}=[0,-350]$  mas are such that the velocity separation between the methanol maser spot and the demagnetized velocity of the nearby OH Zeeman pair is about 1 km/s. This is far bigger than  $2 \times \text{FWHM}$ . It is therefore quite unlikely that those maser signatures actually arise from the same body of gas. On the other hand, for the three other ‘quasi coincident’ maser spots in both species the velocity difference ranges from 0.07 km/s to 0.52 km/s, that is  $\leq 2 \times \text{FWHM}$ . It is therefore quite probable that they belong to the same body of gas.



**Fig. 1.** Maser feature distribution in the 6-GHz excited OH lines and in the 6.7-GHz methanol line. Centre position (0,0) corresponds to  $RA_{J2000}=02^h27^m03^s.820$ ,  $Dec_{J2000}=61^\circ52'25''.400$ . The velocities given for the excited OH lines in italic style are ‘demagnetized’



**Fig. 2.** Magnification of the region given by the dotted box in Fig. 1

## 4. Findings

### 4.1. Magnetic field

From the Zeeman pairs identified for the excited OH 6-GHz datasets we calculated the magnetic field strength over the whole W3(OH) star forming region. This latter has been found to range from a value of 0.4 mG to 14.5 mG in agreement with the previous study of Desmurs et al. (1998). The tight associations ( $< 15$  mas) between methanol maser spots and OH maser Zeeman spots at 6-GHz, for which the velocity agree well for the 2 species to be possibly part of the same body of gas, allowed us a probe of the magnetic field strength at the location

of methanol masing regions. Interestingly, this investigation revealed a rather strong magnetic field ( $\geq 7$  mG) at such location.

### 4.2. Velocity field and density

A velocity gradient is clearly observed in what is thought to be a circumstellar disk seen edge-on delimited roughly by  $RA_{\text{offset}}=[-150;150]$  mas and  $Dec_{\text{offset}}=[+300;-1500]$  mas. The southern area at  $Dec_{\text{offset}}=[-1800,-2100]$  mas is such that the East area is red shifted while the West area is blue shifted with respect to the velocity of the southern extremity of the disk. This area is thought to be tracing a shock wave. For a better picture of the physical conditions at the various locations of maser emission found in W3(OH), we aligned our 6-7-GHz dataset to that of Wright et al. (2004a,b) presenting the OH ground state maser distribution in W3(OH). Doing so, we found that interestingly, the southern area produces methanol maser emission, both excited OH maser emission at 6031 and 6035-MHz and all the ground state OH maser lines but the 1720-MHz line. According to the models developed by Gray et al. (1992), a strong production of 6031 and 6035-MHz with a substantially fainter 1720-MHz is only achieved for relatively high densities ( $[H_2]=2.5 \cdot 10^7 \text{ cm}^{-3}$  and  $[OH]=250 \text{ cm}^{-3}$ ) and the lower end of the kinematic temperatures ( $T_k=75 \text{ K}$ ) allowing strong OH 6-GHz inversion. Also, Gray et al. mention the importance of collision in the 6035-MHz inversion. The lack of 1720-MHz with a strong production of 6-GHz OH excited maser strengthen the hypothesis of a shock wave as an explanation for the southern maser band.

## 5. Conclusion

We have presented the first alignment to milliarcsecond accuracy of the 6-GHz maser emission in OH and methanol maser lines toward W3(OH). It has been found that all 6031-MHz spots are associated with a 6035-MHz spot within less than 6.5 mas separation while only 33% of the methanol maser spots are found within 20 mas from a 6-GHz OH maser spot, none of them within less than 10 mas.

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