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Polarization Structure of the Orion-KL Water Masers

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Abstract

Water masers in the star forming region Orion-KL started an outburst in 1997. Our VLBA polarimetry observations reveal that the future bursting maser spot exhibited ~70% fractional linear polarization with a modest total total flux density of ~ 30 Jy during the early stage of the burst. These results suggest that this latest bursting phenomenon has an origin similar to the super maser event of 1979.

1 Introduction

The observations of maser polarization provide information on the magnetic field direction in dense protostellar gas, which may be crucial to understanding the process of star-formation and confinement in mass outflows from protostars, but which is difficult to obtain by other means. In this paper we report our results from VLBA (Very Long Baseline Array) polarization imaging of the high-mass star-forming region Orion-KL. Information on the field structure on the scale of 10^{12}-10^{15} cm enables us to compare directly various theories of protostar formation.

2 Polarization Mapping with VLBA

The observation was made on 1 February 1997 for 8 hours with the full VLBA array. Among the spots we have identified in the velocity range $-40\,\mathrm{km\,s^{-1}}$ to $50\,\mathrm{km^{-1}}$, about half show a strong degree of linear polarization of $20\sim50\%$, with a few exceptional spots yielding linear polarizations of about 70%.

3 Super Masers and Polarization

The Orion-KL water masers are special due to their extremely strong emission. A super burst event of the masers was firstly discovered in 1979

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and lasted a few years (e.g. Garay et al. 1989). The second burst event was discovered in December 1997 and reached a peak flux of 3.5×10^6 Jy in September 1998 (Omodaka et al. 1999). Our VLBA observation was carried out about ten months before this latest burst. Space VLBI observations at the burst epoch were carried out by VSOP (Kobayashi et al. 2000) and the Japanese VLBI network (Omodaka et al. 1999). A VLBA image of this region in 1995 appears in Matveyenko et al. (1998).

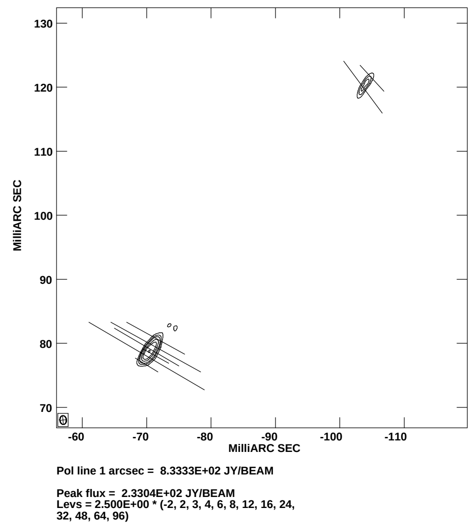

Figure 1: Linear polarization map of pre-burst spot (lower) in Orion-KL. The lines indicate the fractional polarization at this epoch (1997.09).

The highest flux peak in our map coincides with the burst spot position in the 1980's and 1990's within the accuracy of the absolute position of the VLBA of about 0.1 arcsecond. However there are several features in this region within a 100 milli-arcsecond radius. From comparison of the relative positions of several features among these maps, we found that the bursting spot is imaged in our February 1997 data and yields a 30 Jy flux and 70% fractional polarization. This flux density is consistent with the light curve of the burst event (Omodaka et al. 1999) assuming an exponential dependence in the flux density increase. The spot is not present in the 1995 map of Matveyenko et al. (1998).

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4 Discussion

Using the Mizusawa radio telescope Horiuchi and Kameya (2000) started a monitoring program of the linear polarization of the maser in December 1998, during a phase of rapid flux density decrease after the burst (Figure 2). They found that the total flux density of 2.4×10^6 Jy (December 1998) exhibited about 46% linear polarization. Over the next six months they found that the total intensity decreased by about two orders of magnitude while the fractional linear polarization gradually fell to 30%. There is also systematic variation in the polarization angle. It was 25° on 1998 December 21 and shifted almost uniformly to 40° in two months, though varied less rapidly since. These bursts with high fractional linear polarization are clearly unique events that require their own explanation, different from that of other water maser features.

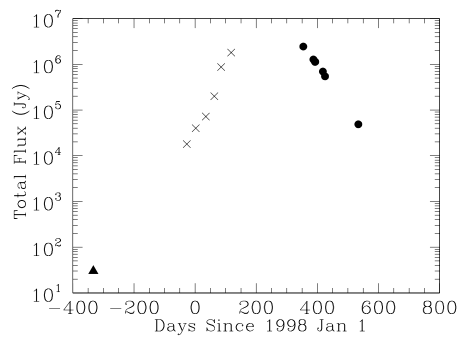

Figure 2: Total flux variation of the present burst: triangles, this work; crosses, Omodaka et al. (1998); circles, Horiuchi and Kameya (2000).

The monitoring observations of the super burst event in 1980's indicated that the time scale of such an event is ~10 years (Garay et al. 1989), while the present burst lasted only ~3 years. This suggests no periodicity in the water maser burst events of this region, although we must continue to monitor in the coming several years to confirm this. The polarization characteristics plotted as a function of total intensity are common for the two events, although the time scales of the flux variations differ. When the maser was strong (i.e., greater than 5×10^5 Jy), the degree of polarization decreased with flux density. Our results of 40% polarization at several million Jy agree well with the range measured by Garay et al. (1989). Our results for the present burst demonstrate similar variations in polarization degree and the position angle, though with

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differences in absolute position angle and time scale. The difference in the polarization angle may be accounted for by the position-angle difference of the maser elongation of the bursting spots. The present bursting maser spot has an elongated structure with aspect ratio of about 10 and position angle of -40°, as observed by VSOP in March 1998 (Kobayashi et al. 2000). Assuming that the burst spot has not changed its structure significantly, we find that the (E-vector) polarization angle is nearly perpendicular to the elongation of the bursting spots, similar to the superburst in the 1980's (Matveenko et al. 1988).

The mechanism by which we observe such extremely high brightness masers may be related to the several interacting masers located along the line of sight (Deguchi & Watson 1989). Boboltz et al. (1998) have suggested that the symmetric intensity variation of a water maser flare in W49 can be explained with two interacting maser clouds model; a system with a maser passing across the line of sight toward another background maser. From monitoring observations at Kagoshima (Omodaka et al. 1998) and from this work, we have found a symmetric variation of the total flux before and after the burst peak, which suggests that the interacting masers model is applicable (Figure 2). On the other hand, the polarization characteristics seem not to vary symmetrically in time around the peak of total intensity. Our result shows that the polarization degree decreased monotonically during the decay phase.

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