Mem. S.A.It. Vol. 82, 154

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Magnetic fields along massive protostellar jets. The case of W75N & Cepheus A

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Abstract. In one of the proposed massive star-formation scenarios, core accretion, massive stars form through gravitational collapse, which involves disk-assisted accretion to overcome radiative pressure. Consequently, protostellar jets and large-scale molecular bipolar outflow originate near the protostar. However, due to the difficulties of observing magnetic fields during the protostellar phase of high-mass star-formation it is still unclear how magnetic fields influence the formation and dynamics of disks and outflows. Most current information on magnetic fields close to high-mass protostars comes from polarized maser emissions. Recently, we were able to detect an ordered magnetic field along massive protostellar jets in the massive star-forming regions W75N and Cepheus A.

Key words. Stars: formation – masers: water – polarization – magnetic fields – ISM: individual: W75N – ISM: individual: Cepheus A

1. Introduction

Magnetic fields are attributed an important role in the formation of low-mass stars. In particular in halting the collapse, transferring angular momentum, and powering the outflows (McKee & Ostriker 2007). However, this important role during the protostellar phase of high-mass star-formation is still under debate. In fact, several questions remains unanswered, e.g., how do magnetic fields influence the formation and dynamics of outflows? This question can be addressed by studying the polarized emissions of methanol (CH_3OH) and water (H_2O) masers. The bright and narrow spectral line emission of CH_3OH and H_2O masers is ideal for detecting both the Zeeman-splitting and the direction of the magnetic field near the massive protostars. In this proceeding we give a summary of the results about the orientation and the strength of the magnetic fields around the protostar VLA 1 in the star-forming region W75N (Surcis et al. 2009) and around the protostar Cepheus A HW2 (Vlemmings et al. 2010).

2. W75N

W75N is an active high-mass star-forming region in the molecular complex DR21–W75 (Dickel et al. 1978) at a distance of 2 kpc. At a resolution of $\sim 0\farcs1$ resolution, three radio sources were detected (Torrelles et al.

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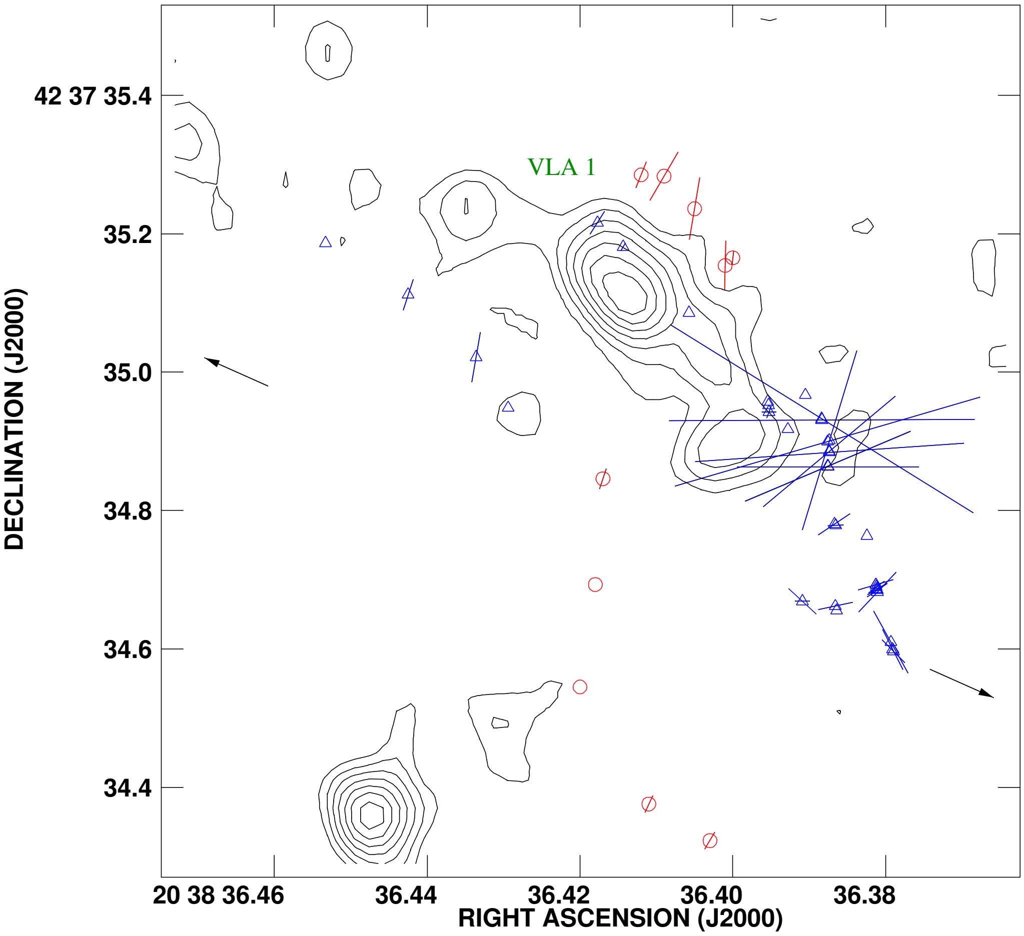

Fig. 1. Positions of methanol (red circles) and water (blue triangles) masers superimposed on 1.3 cm continuum contour map of the VLA1 thermal jet (Torrelles et al. 1997). The linear polarization vectors are also reported (20 mas correspond to a linear polarization fraction of 1%). Consider that the magnetic field direction is perpendicular to the linear polarization vectors. The two arrows indicate the direction of the large-scale molecular bipolar outflow (66°).

1997): VLA 1, VLA 2 and VLA 3. A large scale high-velocity outflow, with an extension greater than 3 pc and a total molecular mass greater than 255 $M_\odot$, was also detected from W75N (B) (Shepherd et al. 2003). So far, it has been impossible to determine which is the main powering source of this outflow. We observed W75N at 6.7 GHz (EVN) and 22 GHz (VLBA) in order to detect linear and circular polarized emissions of methanol and water masers, respectively. The CH_3OH and the H_2O masers showed a magnetic field orientation (NE-SW) around the source VLA 1 of about 73° and 71°(Fig.1), respectively, in the plane of the sky. The magnetic field is thus almost perfectly aligned with the jet and outflow, which has a position angle of 66°(Hunter et al. 1994). From the circular polarization we measured a magnetic field strength of about 50 mG (CH_3OH) and 670 mG (H_2O) depending on the density of the gas. We suggest VLA 1 as the driving source of the large-scale molecular

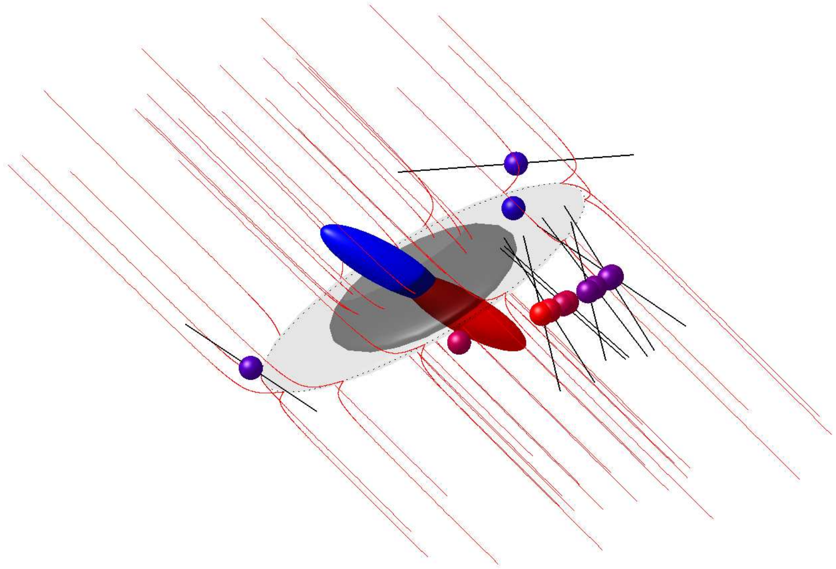

Fig. 2. The three dimensional magnetic field structure around the massive protostar Cepheus HW2. This image correspond to a viewing angle close to the observations. Spheres indicate the masers, with the black vectors indicating the true magentic field direction. The masers are colour coded according to their velocity. The molecular disk is indicated by the dashed line and light-grey structure while the dust disk corresponds to the dark-grey ellipse. The blue- and redshiftef lobes of the collimated radio outflow are also shown. The red line indicate the proposed magnetic field morphology.

bipolar outflow. For more details see Surcis et al. (2009) and Surcis et al. (2010, *in prep.*).

3. Cepheus A

Cepheus A at a distance of 700 pc (Moscadelli et al. 2009) is one of the closest regions of active massive star formation. Located in the Cepheus OB3 complex, it hosts a powerful extended bipolar molecular outflow that likely originates from HW2, the brightest high-mass protostar (type B0.5) in the region (Hughes & Wouterloot 1984). The extended outflow appears to be driven by a small-scale (∼700 au) thermal jet. In addition to the bipolar outflow, Cepheus A HW2 is surrounded by a rotating disk of dust and molecular gas oriented perpendicular to the jet (Patel et al. 2005) (Jiménez-Serra et al. 2007). We observed Cepheus A HW2 at 6.7 GHz with the MERLIN in order to detect linear and circular polarized emissions of CH_3OH masers. The CH_3OH masers detected by us are not part of the molecular disk itself but trace molecular infalling on the disk at about 1.7km s^{-1}. Using the maser radiative transfer method (Vlemmings et al. 2010) we are able to infer, for the first time, the three-dimensional magnetic field orientation ($\phi_{\rm B}$=26° in the plane of the sky) parallel to the outflow (Fig.2). We measured a magnetic field strength of the order of 23 mG which plays a crucial role in regulating the final stages of the formation of the massive protostar Cepheus A HW2, as is commonly expected during low-mass star formation. For more details see Vlemmings et al. (2010).

4. Conclusions

We have demonstrated the power of methanol maser polarization observations in deducing the full three-dimensional strength and structure of the magnetic field around massive protostars. In both cases, W75N VLA 1 and Cepheus A HW2, the magnetic field is parallel to the molecular outflow at small scales. More sources are under investigation in order to improve the statistics and to give a larger picture of the crucial role of the magnetic field in powering the molecular outflows in high-mass star formation.

Acknowledgements. GS and WHTV acknowledge support by the Deutsche Forschungsgemeinschaft (DFG) through the Emmy Noether Reseach grant VL 61/3-1. GS thanks S. Curiel, R. Dodson, B. Hutawarakorn Kramer, H.J. van Langevelde, A.P. Sarma, J.M. Torrelles and K.J.E. Torstensson for their contributions.

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