VLA MAPPING OF MAGNETIC FIELDS IN W 3 AND S 106

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1. INTRODUCTION

The importance of magnetic fields to the evolution of dense interstellar clouds and to the star formation process is now widely appreciated. Troland (this volume) has reviewed work to measure strengths of interstellar magnetic fields by observation of the Zeeman effect in radio frequency spectral lines. The next step is to map magnetic fields with radio synthesis arrays in order to obtain high spatial resolution. This abstract is a preliminary report of VLA results for two clouds - the W 3 region of massive star formation (to be published by Troland, Crutcher, Goss, and Heiles) and S 106, a biconical H II region with a confining molecular disk (to be published by Loushin, Crutcher, and Troland).

2. OBSERVATIONS

Observations of Stokes' parameter I and V spectra were made with the VLA. The 1420 MHz H I absorption line toward the W 3 core was mapped with ~1' resolution between -51 km s^{-1} $< V_{LSR} <$ -31 km s^{-1}. For S 106 the 1665 MHz OH absorption line toward the H II region was mapped with ~10" resolution between -23 km s^{-1} $< V_{LSR} <$ $+9$ km s^{-1}; also, the positions of the circularly polarized 1720 MHz maser lines were measured.

3. W 3 RESULTS

Sufficient sensitivity to detect the Zeeman effect was achieved only over about a 3' x 2' area centered at $\alpha_{1950} = 02^h21^m50^s$, $\delta_{1950} = 61°50'$, which is the core of the molecular cloud/H II region complex. The only significant signal in the V spectrum was near -33.5 km s^{-1}, at the most positive velocity side of the heavily saturated H I absorption line. Goss *et al.* (1983) have found that the H I absorption is made up of velocity components at $V_{LSR} \approx$ -38.5, -43.5, and -48.0 km s^{-1}. We interpret the feature in the V spectrum at -33.5 km s^{-1} as a Zeeman signal due to a magnetic field in the -38.5 km s^{-1} cloud, with the expected feature on the other side of this line at -43.5 km s^{-1} being

R. Beck et al. (eds.), Galactic and Intergalactic Magnetic Fields, 315–317.

suppressed by the very optically thick line at -43.5 km s^{-1}. The maximum magnitude of the field is about 100 μG. Remarkably, the line-of-sight component of the magnetic field reverses direction from the northeast to the southwest, with the locus of zero line-of-sight field passing through the position of IRS 5, a H_2O maser and infrared point source. There are two possible explanations for this reversal. When a dense cloud collapses to form stars, so long as the field remains frozen into the matter, the field morphology will assume an hourglass shape, with the dense core at the "neck" of the hourglass. Since we observe the Zeeman effect in H I absorption against the H II regions in the cloud core, we measure only the line-of-sight component of the field on the near side of the core. Hence, one expects the line-of-sight component to reverse direction from one side of the core to the other. Another possibility is that the enhanced pressure of the H II regions produced by star formation activity has significantly modified the field morphology. Region A, which occupies the eastern half of the core region, appears now to be in a champagne flow toward the sun. This flow could have carried with it the H I gas at the interface between the ionized gas and the surrounding molecular cloud. Hence, the field in the northeast could have been reversed from its original direction.

4. S 106 RESULTS

Kazès *et al.* (1987) originally detected the Zeeman effect in the main OH absorption lines toward S 106 and discussed the apparent Zeeman splitting of the 1720 MHz maser line. We find the oppositely circularly polarized masers to agree in position within 1"; the maser is not located at IRS 4, the central star of the bipolar H II region, but near the northeast edge of the northern H II lobe. The 1665 MHz OH absorption line is distributed in two distinct components: a narrow component near 0 km s^{-1} which is associated with the toroidal molecular cloud surrounding the H II region, and a clumpy component at more negative velocities associated with the interface between the H II region and the surrounding molecular cloud. The line-of-sight magnetic field in the first component does not appear to show spatial structure; this component is the one in which the Zeeman effect was measured by Kazès *et al.* to be about 140 μG. The field in the other component reverses direction between the northern and southern lobes of the H II region, with strengths of about 0.5 mG and 1 mG in the southern and northern lobes, respectively. This field is probably the hourglass morphology expected for a region of recent star formation with the magnitude enhanced by compression of the interface region between the surrounding molecular cloud and the bipolar H II region.

5. REFERENCES

Goss, W.M., Retallack, D.S., Felli, M., and Shaver, P.A. 1983, *Astr. Ap.*, **117**, 115.

Kazès, I., Troland, T.H., Crutcher, R.M., and Heiles, C. 1987, *Ap. J.*, **335**, 263.

PUDRITZ: S106 is a well-known bipolar outflow. Any MHD wind theory predicts the presence of toroidal field in the outflow. Your "reversal" regions may be such a toroidal component superimposed on a poloidal component you deduce. Is this interpretation compatible with your data? In centrifugal winds, B_ϕ is weak at source and increases with distance. Do you have the sensitivity to check $B_\phi/B_{poloidal}$ ratios to ±10 factors? Your results are very exciting.

CRUTCHER: The magnetic field map of S106 was only produced last week, and a proper error analysis has not yet been carried out. There should be sufficient sensitivity to check $B_\phi/B_{poloidal}$ to 1st order, and a more sensitive VLA experiment is planned for the future.

SHUKUROV: The picture which you just have described resembles the magnetic field distribution produced by the fluctuation dynamo with strongly concentrated magnetic ropes and field reversals at small scales (see the report of Sokoloff et al., this volume). Comparison of the theory with observations necessitates determination of observed two- point, three-point and higher correlation functions of the magnetic field. Have you attempted to do this?

CRUTCHER: We have not attempted such an analysis, but can certainly do so.

VERSCHUUR: I was extremely impressed by the 5 contributions on Zeeman effect measurements today, as well as that by Carl Heiles earlier in the meeting. In her opening review, Virginia Trimble pointed out that the Galactic magnetic field is 40 years old! Since the Cas A Zeeman effect signal first appeared out of the noise, 21 years have passed. In fact just 13 days and 4 1/2 hours less than 21 years. These impressive contributions are a dramatic illustration that our ability to measure the interstellar magnetic field has indeed come of age. Personally, I find this extremely heartening and exciting.

https://doi.org/10.1017/S0074180900190321 Published online by Cambridge University Press