Angle-Resolved Autocorrelation Studies of the Magnetic Field in L1457

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We present a study of the small-scale variations in the magnetic field in the near-by molecular cloud L1457. The variations are studied by means of the Autocorrelation Function (ACF). Applied to optical polarization measurement of background star. The data set is rich enough to allow us to resolve the ACF into multiple angle sectors with respect to the direction between pairs of stars. Significant variation is found in the ACF as a function of direction. This kind of study may be extended to sightlines with higher opacity by using mid-infrared (MIR) polarization observations of emission from aligned grains. High resolution SOFIA maps of the MIR polarization thus can be used to study the influence of magnetic fields deeper into the cloud, in regions of active star formation.

The magnetic field, **B**, plays a potentially dominating role in the dynamics of the interstellar medium, with its ability to control mass flows and resist gravitational collapse. Quantitative measurements of the magnetic field are, however, notoriously difficult to make, therefore limiting our detailed understanding of cloud evolution.

Observationally, the simplest tracer of **B** is the polarization, **p**, of the light from background stars, reliably delineating the projected direction of **B**. However, due to the large number of unknowns entering into the coupling between field strength, |**B**|, and magnitude of polarization, |**B**| cannot be simply derived from polarimetric observations. One possibility for extracting information about the |**B**| from such data lies in the comparison of small scale variations in the observed polarization with theoretical predictions based e.g. on MHD simulations. For example, MHD models of a nearly incompressible medium predict that the correlation length in **B**, and thus in, **p**, the observed polarization, should be significantly larger along the field lines than across them (Goldreich & Sridhar, 1995). Here we present a preliminary study of the small scale structure of the polarization in L1457 aimed at evaluating whether this kind of information can indeed be extracted from polarimetry observations.

We have used a well-sampled map of R-band polarimetry to study the small-scale variation in the magnetic field of L1457 through a technique using Autocorrelation Functions (ACF). Here we concentrate on the ACF of the direction of polarization (θ) as a function of inter-pair distance ($|r_i-r_j|$) and inter-pair direction (ϕ). In order to minimize the effect of foreground polarization we only use those sightlines with $|p_R|\geq 0.5\%$. While the polarization map shows a generally ordered magnetic field, we here define ϕ to be the inter-pair angle relative to the average angle of polarization of the pair, in order to compensate for any large scale gradients in the field. Performing the analysis with ϕ defined in terms of angle East-of-North on the sky does not significantly change the result of the analysis.

We calculate the ACFs by averaging the pair-wise unbinned, discreet autocorrelation functions into bins of inter-pair distance and direction, using the algorithms of Edelson & Krolik (1988). For the present data set we selected 25 bins in distance and 6 bins in direction.

To study the correlation lengths in the data, we fitted the ACFs for each angle bin with a Gaussian function:

$$ACF_\theta(<|r_i-r_j|>_{bin}, \phi)=A + B \exp\{-(<|r_i-r_j|>_{bin}/\sigma_{ACF})^2\}$$

The resulting dispersions, $\sigma_{ACF}(\phi)$ were then plotted and fit to an ellipse:

$$\sigma_{ACF}(\phi)= \{(a\bullet\cos(\phi - \phi_0))^2+(b\bullet\sin(\phi- \phi_0))^2\}^{1/2}$$

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where a and b are the major and minor axes of the ellipse and ϕ_0 is the angle of the major axis w.r.t. average field. (We note that due to the nature of the ACF, the correlation length on the sky is $\sigma_{ACF}/\sqrt{2}$). In figure 1 we plot the dispersions and resulting fit in a polar plot, together with an indication of the average direction of the projected field in the cloud.

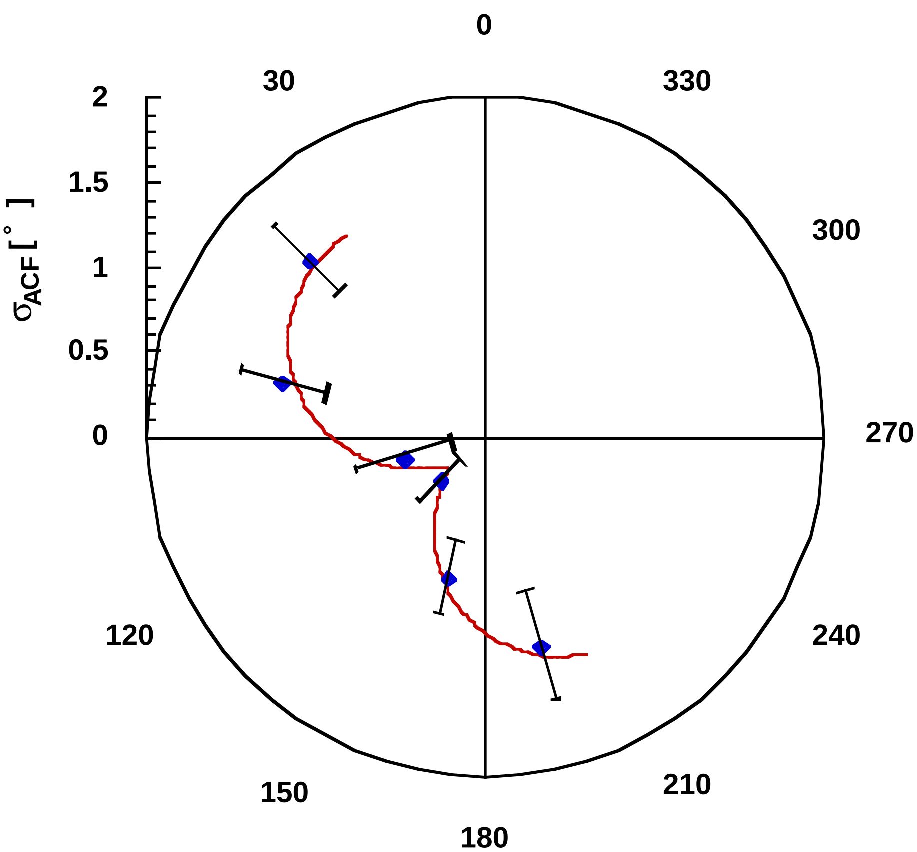

Figure 1. The fit ACF dispersions ($\sigma_{ACF}(\phi)$) for the direction of polarization (θ) are plotted as a function of ϕ, the direction between the stars in each pair (points with error bars). The best fit of these dispersions to the radius vector of an ellipse is also shown (full line). By measuring ϕ with respect to the average direction of polarization for the pair ($(\theta_i+\theta_j)/2$), we effectively measure the ACF w.r.t. the average field direction. Performing the analysis with ϕ measured w.r.t. the north direction on the sky does not change our conclusions. The fit ellipse lies with it's minor axis at 129±8˚.

Discussion and Conclusions

We have used R-band polarimetry of 240 stars in the direction of the nearby molecular cloud L1457 to study the small-scale structure of **B**. We find that the correlation length of the direction of **p**, and hence the direction of **B,** varies with direction on the sky. The correlation length has a distinct minimum and increases symmetrically away from this. Assuming a distance of 65pc to L1457 we find that the correlation length along the minimum direction is approximately 0.2pc, and about 1.2pc at maximum, based on the minor and major axes of the fit ellipse.

The minimum does not occur perpendicular to the average magnetic field direction which is surprising from a theoretical perspective. Models of MHD turbulence in the incompressible limit (e.g. Goldreich and Sridhar 1995) and simulations of compressible MHD turbulence (e.g. Stone, Ostriker, and Gammie 1998) imply that whenever the local dynamics are dominated by the magnetic field, the magnetic field direction should have a parallel correlation length which is significantly larger than its perpendicular correlation length.

By analyzing our full data set, including gas tracers with associated velocity dispersions, and refining our interpretation of the ACF results, we hope to add further constraints to the dynamics of magnetized interstellar clouds such as L1457.

References

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