Ringberg Meeting: Star Formation 2000
O. Kessel-Deynet, A. Burkert, eds.

The Structure of Magnetic Molecular Cloud Cores

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1. Implications of Recent Work

Molecular cloud cores appear to be in a curious dynamic state. On one hand, measurements of core energetics usually reveal that the magnetic and turbulent energies are comparable to the graviational binding energy, so that cores are, to zeroth order, in a state of virial equilibrium (Myers & Goodman 1988). Where measured, the mass-to-flux ratio is also typically very close to the critical value for collapse (Crutcher 1999). Virial equilibrium also appears to apply to molecular clouds as a whole, as evidenced by the well known linewidth-size relationship (Larson 1981). On the other hand, recent estimates of the star formation timescale using estimated stellar ages, by Hartmann (2000) and also Elmegreen (2000), seem to suggest that star formation may be occurring on essentially a crossing time at each scale on which we observe molecular gas. It is interesting to note that the turbulent crossing time of a cloud is typically equal to at least a few free-fall times, with some variation due to geometry.

The apparent resolution to this difficulty is likely that many cores are slightly magnetically supercritical, and undergoing magnetically diluted collapse, on a timescale of up to several free-fall times $t_{\rm ff}$. Ciolek & Basu (2000) have modeled an individual observed core, L1544, using such a magnetic model. In their model, the cloud envelope is somewhat magnetically subcritical, allowing a limited reservoir of mass in the eventually supercritical star-forming core. However, the timescale for the subcritical ambipolar diffusion phase can be significantly shorter than the often quoted $\sim 10\,t_{\rm ff}$, if the envelope is not highly subcritical (see also the analytic derivation of the duration of the subcritical phase by Ciolek & Basu 2001). Subcritical cloud fragments can be a natural product of the localized dissipation of turbulence in clouds (Basu & Pudritz 2000).

Ciolek & Basu (2000) successfully fit the observed column density and infall velocity profiles of the L1544 core, with subsequent new predictions for the magnetic field strength. Coupled with the required observing angle to match the oblate geometry of the model to the observed aspect ratio, Ciolek & Basu (2000) predicted the observable line-of-sight magnetic field in L1544, as a function of radius. Recently, Crutcher & Troland (2000) obtained a Zeeman detection in L1544; the measured field at a projected radius 0.06 pc agrees with the predicted value 16 μG within the observational uncertainties. A parallel study by Ward-Thompson et al . (2000) measured the submillimeter polarized emission from L1544. The inferred mean magnetic field direction in three observed starless cores appears to be correlated with the direction of the projected core minor axis. However, in L1544, the two directions have an offset angle $\Psi \approx 30°$. Ward-Thompson et al. (2000) wonder how this can be consistent

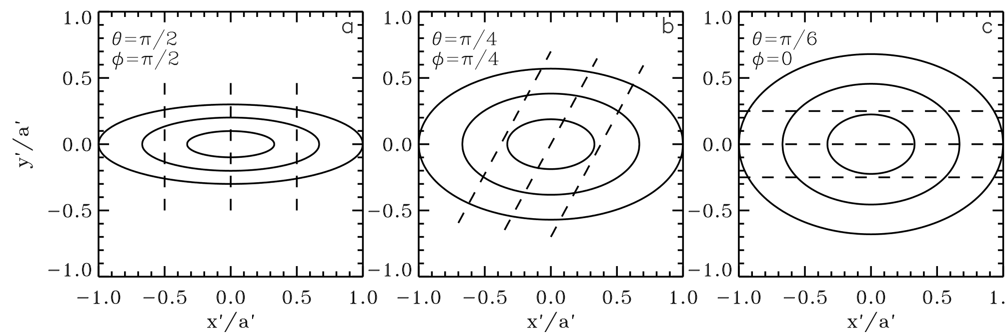

Figure 1. Simulated contours (solid lines) and projected mean magnetic field direction (dashed lines) for a triaxial body with axial ratios $\xi = c/a = 0.3$ and $\zeta = b/a = 0.6$ seen from three sets of viewing angles (θ, ϕ). The dashed lines lie along the projected direction of the shortest body axis. From Basu (2000).

with the Ciolek & Basu (2000) model. The minimum hypothesis solution to this problem is that the cores are not perfectly axisymmetric, as often modeled for convenience. Basu (2000) shows that any degree of nonaxisymmetry, introduces (unlike the perfectly oblate case) the possibility of viewing any nonzero Ψ (see Fig. 1). However, a correlation toward $\Psi = 0$ should still exist for clouds preferentially flattened along the direction of the mean magnetic field. The calculated distributions of Ψ (Basu 2000) for triaxial cores should act as a useful diagnostic to distinguish scenarios where gravity and magnetic fields primarily shape core structure, from one in which external turbulence dominates, resulting in no correlation of Ψ toward any value (Ballesteros-Paredes et al. 1999).

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