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A new method of measuring magnetic field strength in the highly structured protostellar envelopes

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Magnetic fields are believed to play a crucial role in star formation and have been detected across all evolutionary stages. Their strengths have been measured in both the early, pre-stellar core stage and the later, well-formed protostellar and disk stages. However, during the intermediate stage—when the envelope is rapidly infalling and assembling the star–disk system—no robust method exists to measure the magnetic field strength. We propose a new technique to infer the field strength using kinematic and gravitational information during this intermediate phase, and validate it using non-ideal magnetohydrodynamic (MHD) simulations performed with Athena++. In simulations of the collapse of a non-turbulent protostellar core, we recover the classical pseudodisk: a flattened, rapidly infalling structure formed on the equatorial plane. When turbulence is included, the pseudodisk becomes warped into individual "sheets," forming a highly perturbed three-dimensional structure that we term "gravo-magneto sheetlets", reflecting their coupled gravitational and magnetic origins. These sheetlets dominate the envelope evolution, channeling most of the mass, magnetic flux, and angular momentum toward the disk. We find that the dominant forces acting on the sheetlets are gravity, gas inertia, and magnetic tension. Because the magnetic contribution can be inferred from the balance of the first two—both of which are observable—our method provides a new way to estimate the magnetic field force in protostellar envelopes. Given that magnetic tension depends only on the field's strength and geometry, incorporating independent constraints on field morphology (e.g., from dust polarization) enables an indirect measurement of the magnetic field strength during this critical, rapidly evolving, stage of star formation.

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