Hourglass Magnetic Field of a Protostellar System [2024]

Wednesday, September 18, 2024 11:39 PM

Background

Wednesday, September 18, 2024 11:40 PM

Star-formation in general happens due to gravitational collapse of a molecular cloud with magnetic fields acting against the collapse.

Both theoretically and recently now through observations hourglass pattern were observed.

However, the hourglass pattern is a good approximation for the prestellar phase when magnetic field is almost uniform and there is a very toroidal component due to almost no rotation.

But protostellar phase brings its own complexities and the hour-glass magnetic field shall be distorted. This shall happen because of the rapid infall of material which creates strong rotational magnetic energies.

Also the magnetic field is dissipated or lost due to ohmic dissipation and ambipolar diffusion causing distortion from prestellar phases.

The paper covers a new semi-analytical model to study the magnetic fields during protostellar phases.

Introduction

Wednesday, September 18, 2024 11:57 PM

So the literature discusses about a new axisymmetric semi-analytical model that considers strong radial and toroidal magnetic field components during protostellar phase.

Previously, there was only one analytical model around protostellar cores, but the model applied to the moment where the protostar forms and doesn't consider the effects of rotation, disk and outflows which happens later after the formation.

There has been studies done to fit distributions to the polarimetry observed data or simulations data [Magnetic Field vs Density Relation in Star-Forming Clouds [2022]].

But this paper presents a new approach of using an analytical method to model Class 0 phase of protostars considering rotation, disk, outflows and Non-ideal MHD.

Analytical Method

Thursday, September 19, 2024 12:03 AM

Assumptions:

- Assuming Current Density is separable.

- Magnetic field is Bo outside the core.

Inspiration:

Follow the paper: [Magnetic Field vs Density Relation in Star-Forming Clouds [2022]] to get to know other boundary conditions and assumptions.

- In the Paper, different radial current density distributions were taken such as Gaussian, Power-Law and Bessel which all were centrally peaked.
- These were then used to get the value of coefficient in main solution and get values of magnetic field vector in z and r directions.
- However, these are good approximations for prestellar phase.

Modification:

For protostellar phase, we need radial current density distributions that can result in off-center peaks as observed in simulations (probably due to strong non-MHD affects at certain densities). We also need strong radial and toroidal components due to rapid rotating infall.

$$f(r) = A \cdot e^{-(r-r_0)^2/\sigma_0^2} + B\left[S_{10}(r) \cdot e^{-(r-r_1)^2/\sigma_1^2} + S_{01}(r) \cdot \frac{a_0^2}{a_0^2 + (r-r_1)^2}\right],$$

Modeling

Thursday, September 19, 2024 12:27 AM

Modeling Approximations:

Here, we assume the field has two peaks r0 and r1.

Before the second peak, the density curve is gaussian (r < r1).

After the second peak, the density curve goes down with the power-law scale influence. (r>r1)

As observed in Inspiration paper, a singly peaked gaussian curve results in single peak in resulting poloidal variation. Here we get two peaks current density in radial direction.

To get double peaks, A < 0 and B > 0. This is because there is more flux dissipation near the core because of opposite rotations of currents compared to outer flows.

The decrease in B after second peak is because of most material infalling and preserving flux with the fall inwards.

The second peak is what we observe as the peak of the whole radial current density distribution.

Modeling Toroidal Component:

It can be observed that the toroidal component is related to the radial component during an infall.

This is because the region of rapid infall is the region of twisting of field as well.

Hence, it is assumed that toroidal B is directly proportional to radial B.

(However in simulations region of toroidal comp is bigger than that of radial comp because of outflows twisting background magnetic fields)

Results

Thursday, September 19, 2024 12:33 AM

Discussions and Conclusion

Thursday, September 19, 2024 12:33 AM

Any Future Work?

Thursday, September 19, 2024 12:34 AM