Mean Field MHD of (Magnetized Circumstellar) Accretion Disks

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Ap.J. 665 535 (2007)

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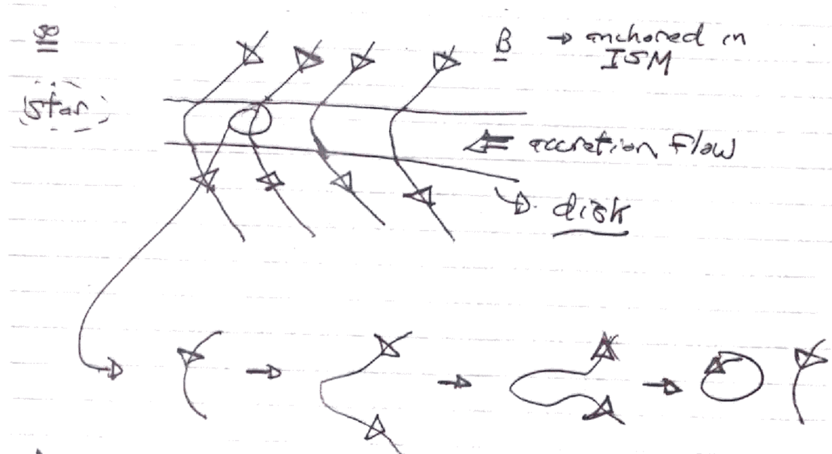
Good News: $\alpha = \alpha_{ss}$, only.

Bad News: B has 2 meanings $\Rightarrow \eta_T$

① → The Point:

- YSO's accumulate mass from cloud cores, via disk accretion
- ISM B-fields dragged along



→

- physical accretion scenario requires slip of fluid and field

∴ ↓

- reconnection, η_T required
- steady accretion $\Rightarrow v_r, \eta_T$ relation

② → Steady Accretion – Macroscopics
(cf.; Lubow, et al. '94)

– 1D, local transport

$(r \equiv \varpi)$

$$r \Sigma u = -\dot{M}/2\pi$$

$$\dot{M} r^2 \Omega = -2\pi r^3 \Sigma \nu_T (d\Omega/dr)$$

$\updownarrow$

$$B_z u = -B_z \frac{\dot{M}}{2\pi r \Sigma} = -\eta_T \frac{B_r^+}{z_0}$$

where:

→ $B_r^+ = \int_0^\infty k_0 (R/r)\, B_z(R,t)\, \frac{R\,dR}{r^3}$

$\eta_T\, \partial B_r/\partial z \rightarrow \eta\, B_r^+/z_0$

$K_0 = \frac{1}{2\pi} \oint \frac{(1-\varepsilon\cos\phi)\,?}{(1+\varepsilon^2-2\varepsilon\cos\phi)}$

→ deviation from Kepler retained
(magnetic stress, self-gravity)

so . . . .

→ Typically:

$$\boxed{\eta_T/\nu_T \sim z_0/r \ll 1}$$

– why? ⇒ ν_T → radial transport

η_T → vertical diffusion of $\underline{B}$
(incl. ambipolar)

which begs the questions:

– how?

→ likely $\begin{cases} \eta_T/\nu_T = F(P_m) \\ < 1 \text{ for } P_m < 1 \end{cases}$

but

→ dynamics intrinsically prefer $\eta_T/\nu_T = z_0/r$?

→ more generally, why should microphysics conform to macroscopic constraint ?

⇔ stationarity ?

③ → Estimating ν_T a/a' Prandtl

– for MRI, magnetic stress dominant

⇒ seek $\langle B_r B_\phi \rangle / 4\pi$

– have:

$$B_\phi \, \delta u \sim B_r \, r \frac{d\Omega}{dr} \, \delta r$$

(element velocity, mixing length)

$$\delta u \sim \Omega \, \delta r \quad \text{(assumed)}$$

⇒ $$\frac{\langle B_r B_\phi \rangle}{4\pi} \sim \mathcal{F} \frac{(B_r^+)^2}{2\pi} \frac{r}{\Omega} \frac{d\Omega}{dr} z_0$$

(form factor)

$$\nu_T \sim \mathcal{F} \frac{(B_r^+)^2 z_0}{2\pi \Sigma \Omega}$$

⇝ $$\nu = \Delta \, B_z^2 z_0 / 2\pi \Sigma \Omega$$

(vertical field; Δ ↑ complicated)

$(\alpha_{SS} \sim 1/\beta)$

④ Discussion Issues

→ What can be said re: $\left\{ \begin{array}{l} \mathcal{I}, \nu_T \\ \eta_T \end{array} \right.$.
from mean field theory, simulation?
Exploit $P_m < 1$?

→ Why should microscopics vindicate microscopic
Is stationarity viable?

→ Are high//low accretion states a manifestation of "layering"?

→ dead zone → uncoupled

surface layer → MRI ?, η_T ?

→ What triggers high↔low transitions ?

collisions + coupled/uncoupled slipping → E-fields → suprathermals

→ ionization → ?

6.

→ How might an MRI dynamo interact with ambient magnetization ?