Class 15 → 3/12/20

other mechanisms for turbulence
Photoevaporation
Disk winds

What is going on in disks:

- Turbulence
- MHD winds
- Evaporation

Conclusion: we don't know
Show evidence

Work out $\beta = \frac{P_{THERMAL}}{P_{MAGNETIC}} = \frac{\rho c_s^2}{B^2/8\pi} = \frac{2 c_s^2}{B^2/4\pi\rho} = \frac{2 c_s^2}{v_A^2}$

$= \frac{nkT}{B^2/8\pi} = \frac{\rho}{m_H} \frac{kT}{B^2/8\pi} = 8\pi \frac{k}{m_H} \frac{\rho T}{B^2}$

$= \frac{8\pi \times 10^{-16}}{10^{-24}} \frac{\rho T}{B^2}$

$= 24 \times 10^{8} \frac{\rho T}{B^2}$

$\approx 5\times10^{9} \frac{\rho T}{2B^2}$ (order of mag)

Turbulence → Gravitational turbulence

at some point above, atmosphere becomes magnetically dominated. Must have $J \times B \approx 0$ so that acceleration is finite. The field becomes force-free.

$J \times B \approx 0$ as ρ decreases to keep acceleration finite

$$\frac{J \times B}{\rho c} \quad ; \quad J = \frac{c}{4\pi} \nabla \times B$$

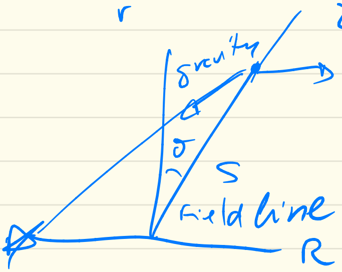
"force-free" above atm → field straight to ensure the magnetic tension is small.

$$\rho v^2 = \frac{B^2}{8\pi}$$ mag energy = kinetic energy (Alfvén surface)

Beyond Alfven surface gas inertia bends lines, rotate in spiral.

$$\Phi = -\frac{GM}{r} - \frac{\Omega^2 R^2}{2}$$ (centrifugal potential)

skip



Selfgravity

$t_{free\,fall} < \begin{cases} t_{sound} = \frac{2R}{c_s^2} \\ t_{shear} = \frac{2}{\Omega} \end{cases}$

$$t_{ff} = \sqrt{\frac{3\pi}{32G\rho}} = \sqrt{\frac{3\pi}{32 \cdot G \cdot 3M} \cdot 4\pi R^3} \approx \pi \sqrt{\frac{R^3}{8GM}}$$

$$\pi \sqrt{\frac{R^3}{8GM}} < \frac{2R}{c_s^2} \cdot \frac{2}{\Omega}$$

$$Q = \frac{c_s \Omega}{\Sigma G \pi} \lesssim 1$$

Photoevaporation