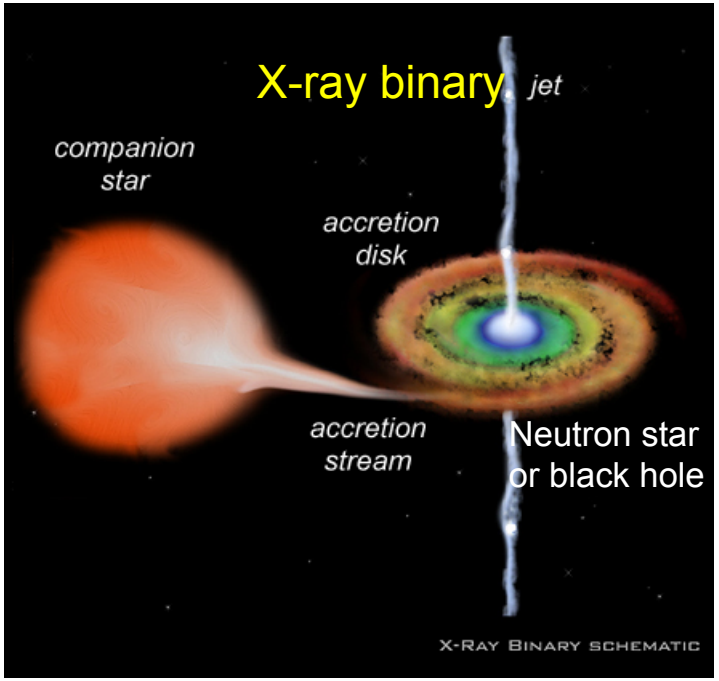
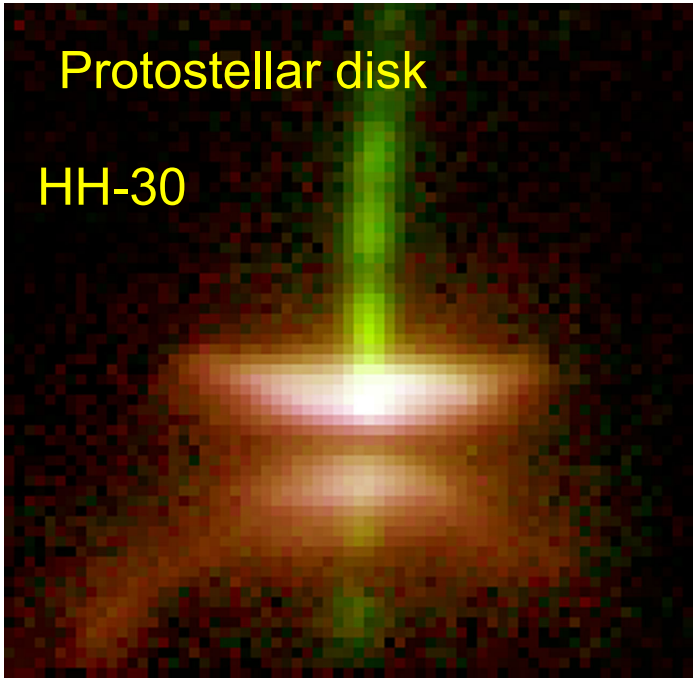
Accretion Disks

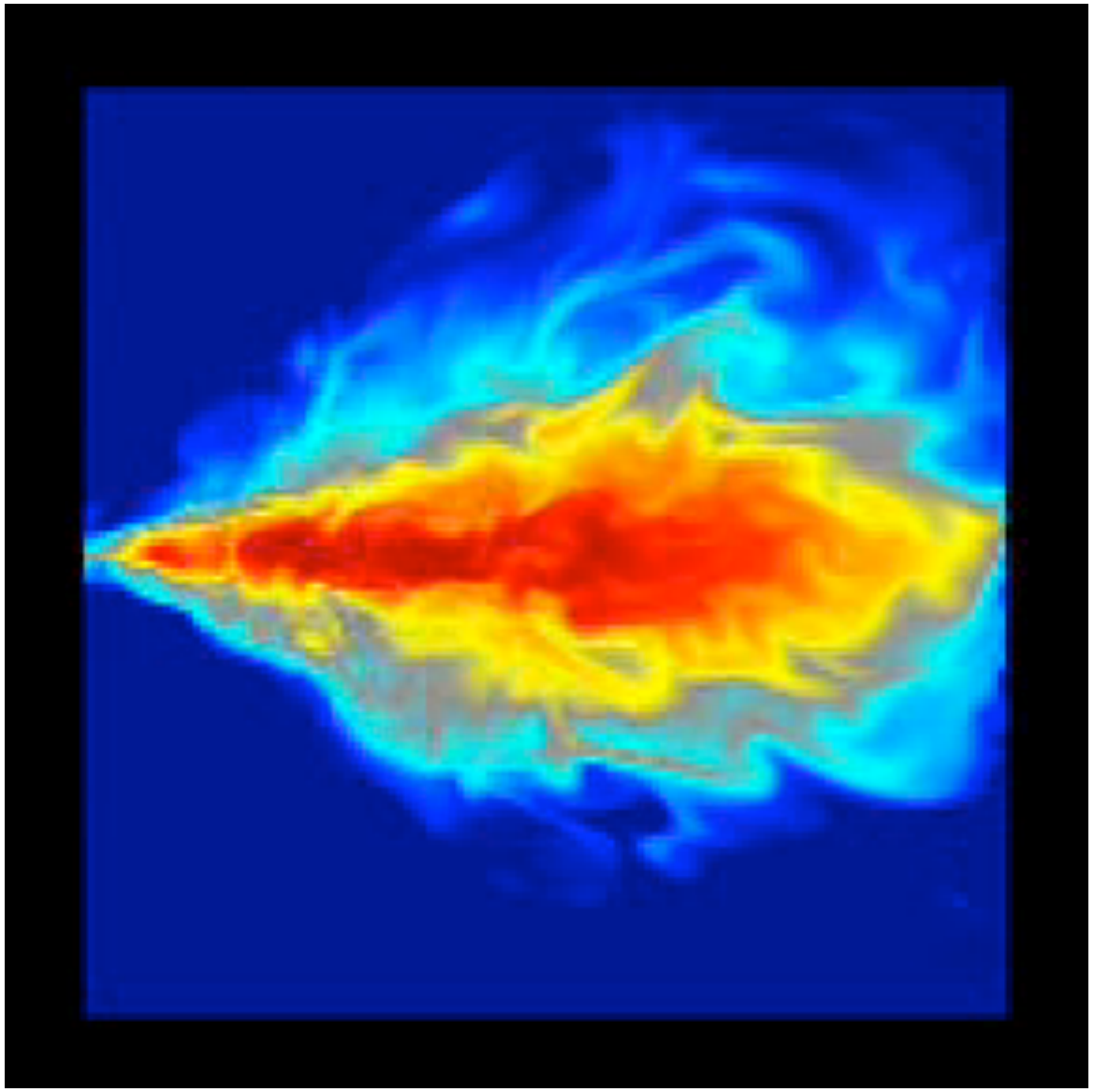




Instructor: Xuening Bai

Feb. 29, 2016

An early global MRI simulation

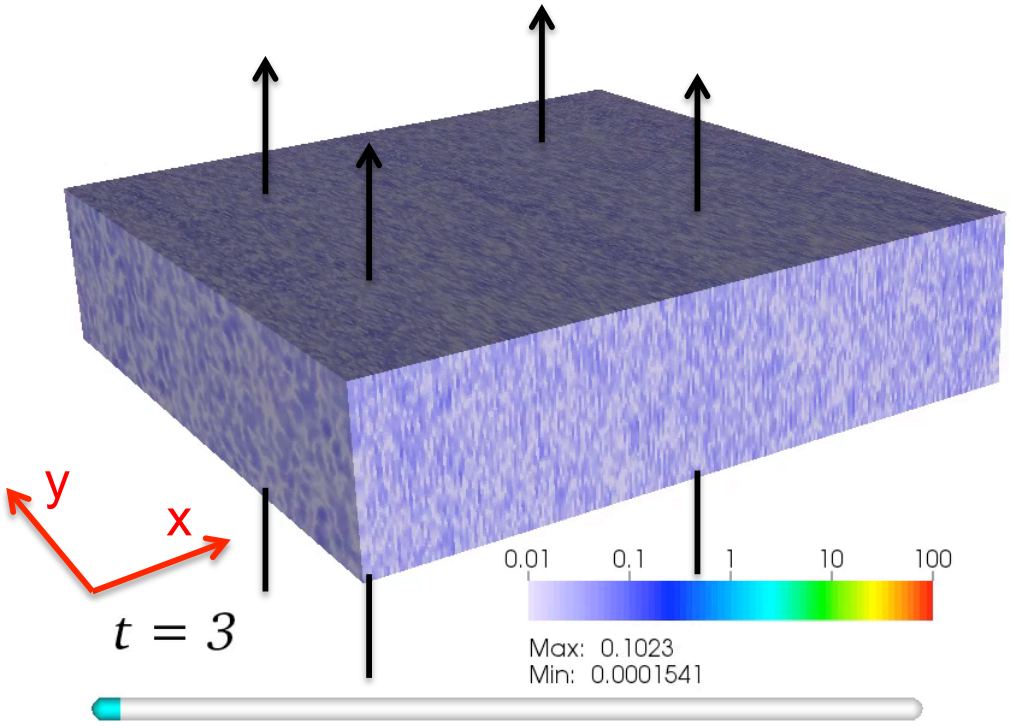


from John Hawley

Standard local shearing-box simulation

color: current density

β_{z0}=400



Box size is 4*H*x4*H*x*H*, 64 cells/*H*

Impose a net vertical B field.

Initial growth: channel mode

In this case, 2 most unstable modes in the box

Turbulence is anisotropic:

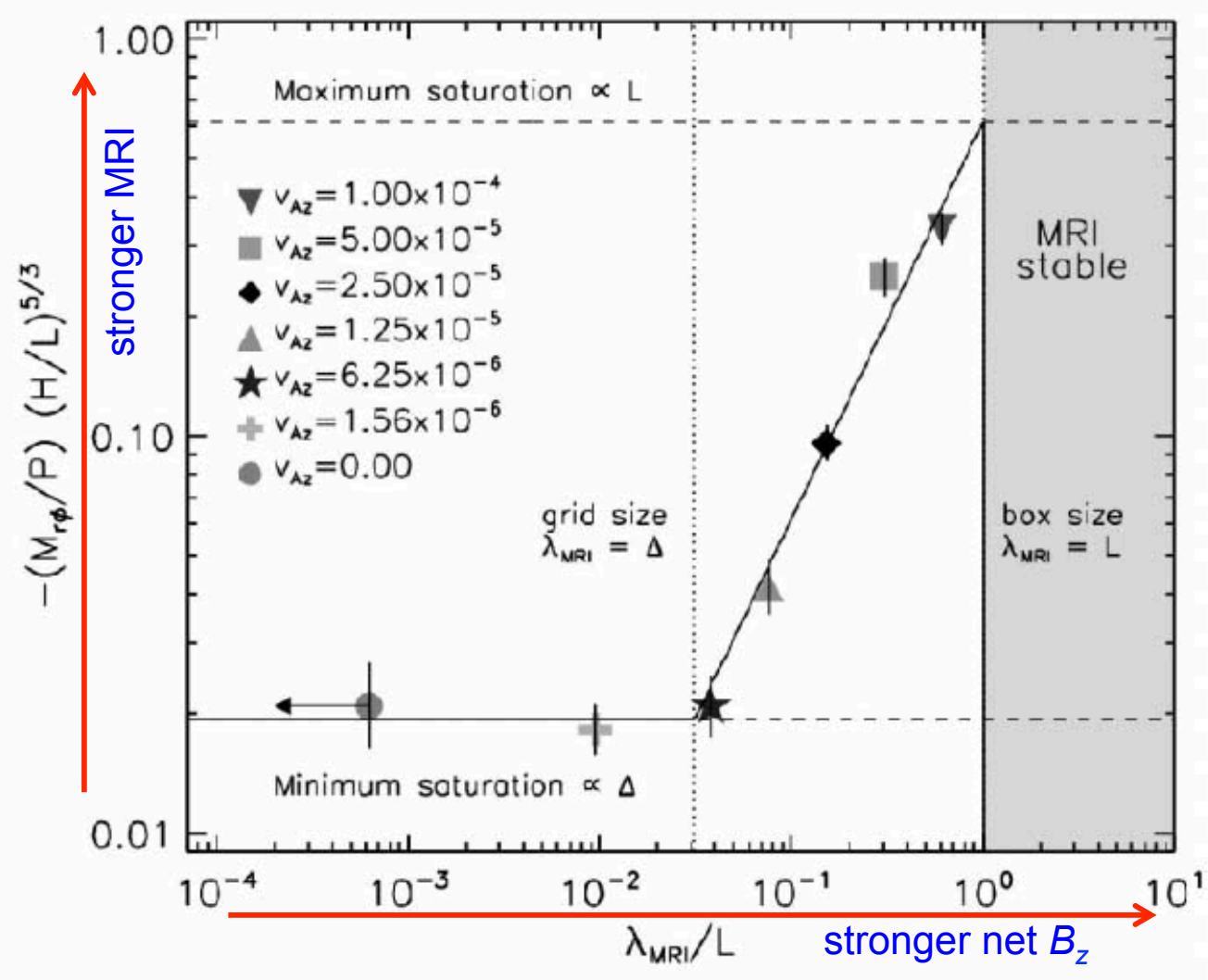
Turbulent diffusion:
azimuthal > radial > vertical

Turbulent stress:

$$\alpha_{\rm Rey} = \frac{\overline{\rho v_x v_y'}}{\rho_0 c_s^2} \qquad \alpha_{\rm Max} = -\frac{\overline{B_x B_y}}{\rho_0 c_s^2}$$

$\alpha_{\rm Max}$ generally dominates $\alpha_{\rm Rey}$.

Scaling relation

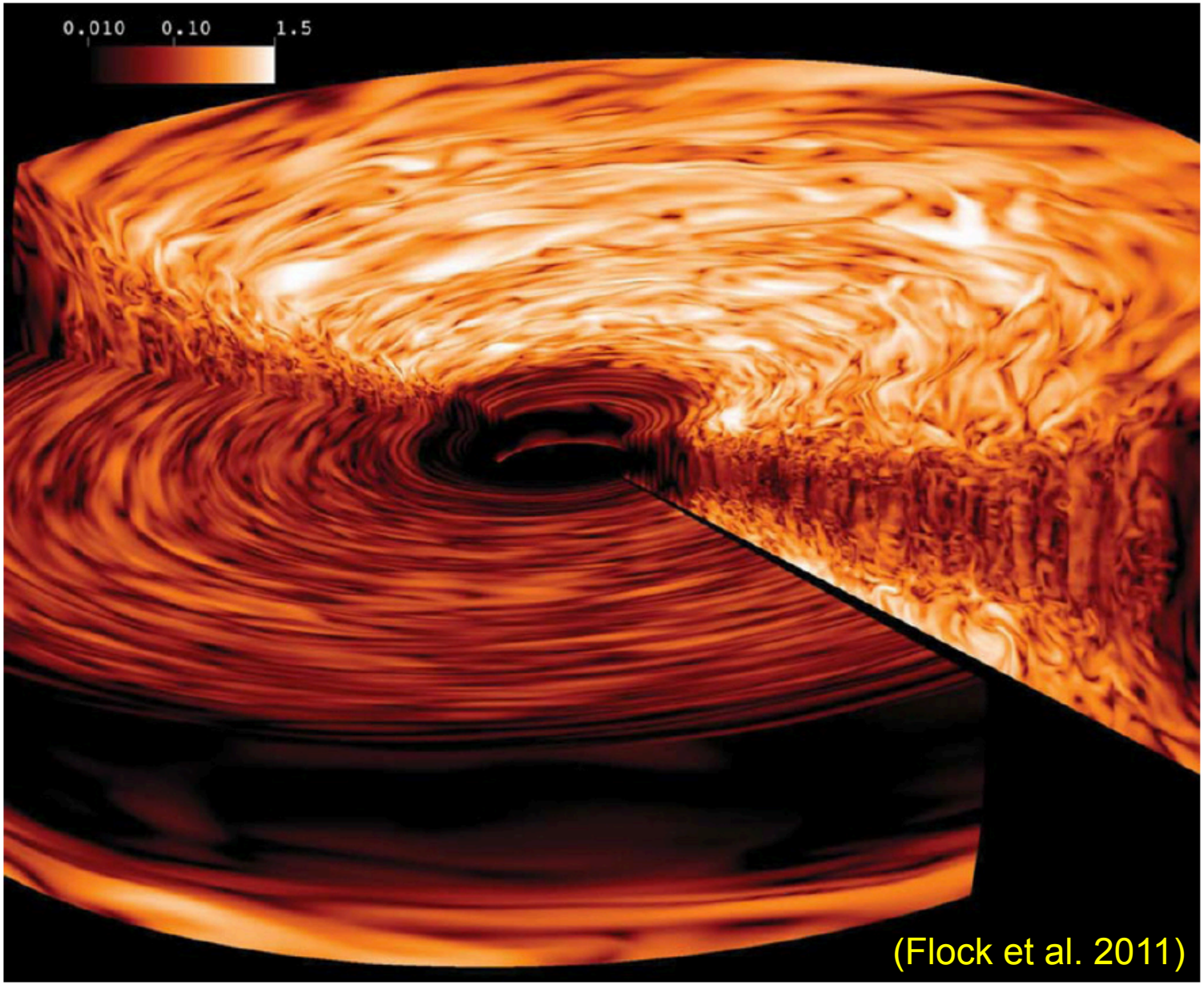


(Sano et al. 2004, Pessah, Chan & Psaltis. 2007)

Numerical convergence can be achieved once the most unstable mode is resolved and fits into the box.

Strength of turbulence increases linearly with net vertical magnetic flux.

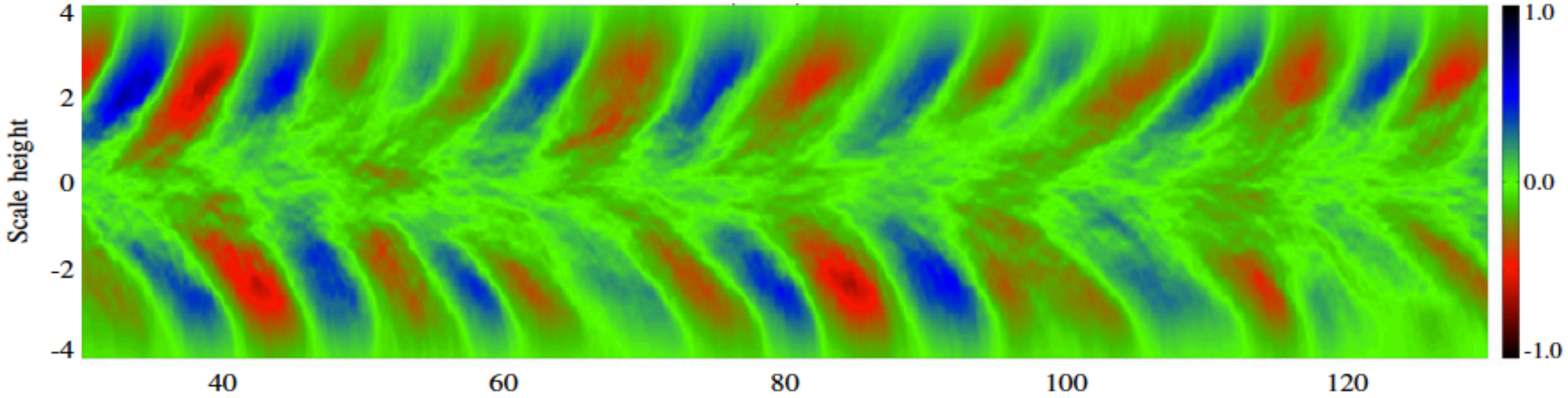
A high-resolution global simulation



No net vertical field, with α~0.01-0.02.

MRI dynamo (no net Bz)

Color: azimuthally averaged B_ϕ



(Flock et al. 2012)

Periodic generation of large-scale toroidal field, which then buoyantly escape.

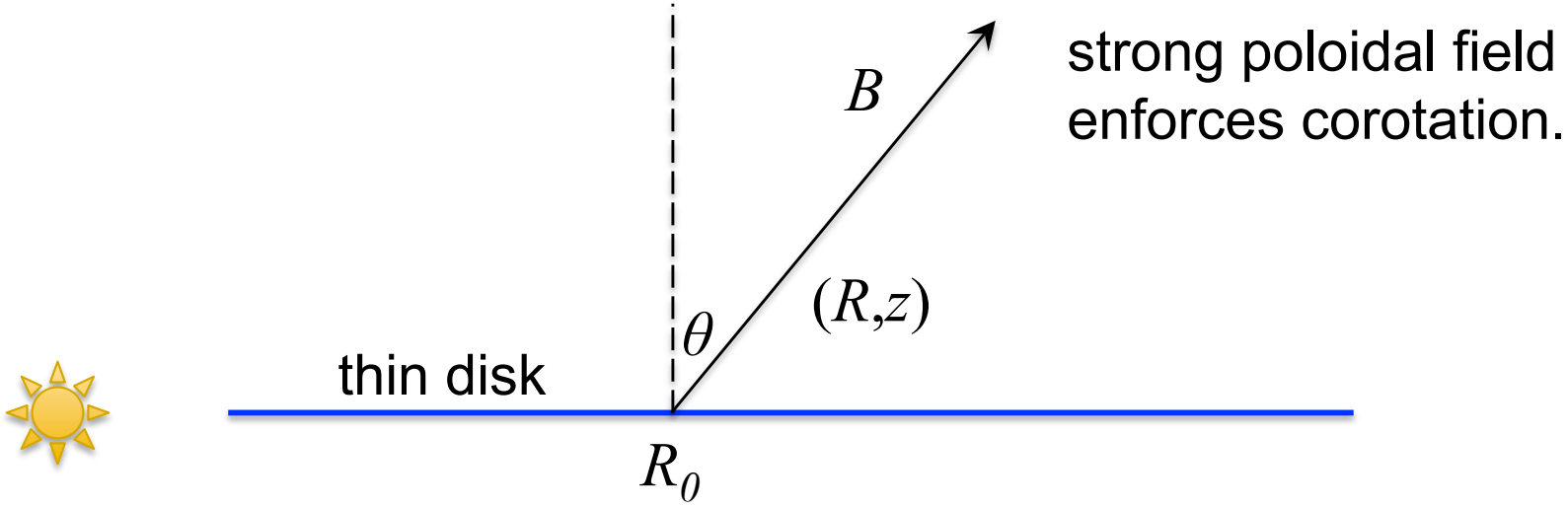
MRI research: frontiers

- Microphysics of the MRI (saturation mechanism, dynamo, turbulence properties, Prandtl # dependence)
- Role of external magnetic flux, interplay between the MRI and MHD winds
- MRI in weakly ionized gas (e.g., protostellar disks)
- MRI with realistic thermodynamics, and in radiation dominated regime (i.e., black hole accretion disks)
- MRI in the weak collisional regime (i.e., radiatively inefficient accretion flow)
- Role of the MRI in other astrophysical systems (e.g., supernovae, gamma-ray burst)
- Laboratory experiments of the MRI

Two flavors of MHD winds

Magneto-centrifugal wind:

(Blandford & Payne 82)

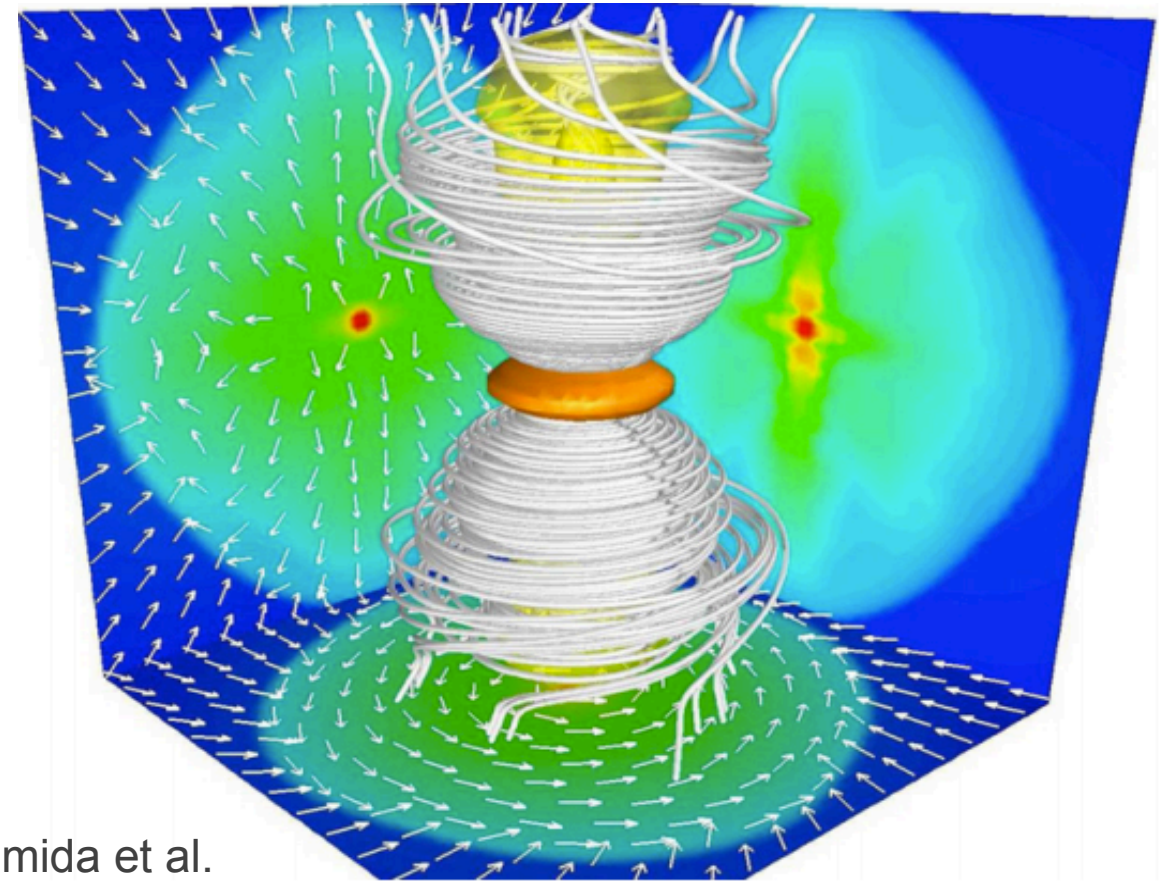


Fluid particles loaded to the wind field are centrifugally accelerated like “beads on a wire” when θ>30°.

Two flavors of MHD winds

Magnetic pressure gradient driven wind (or “magnetic tower”)

(e.g. Lynden-Bell 03)



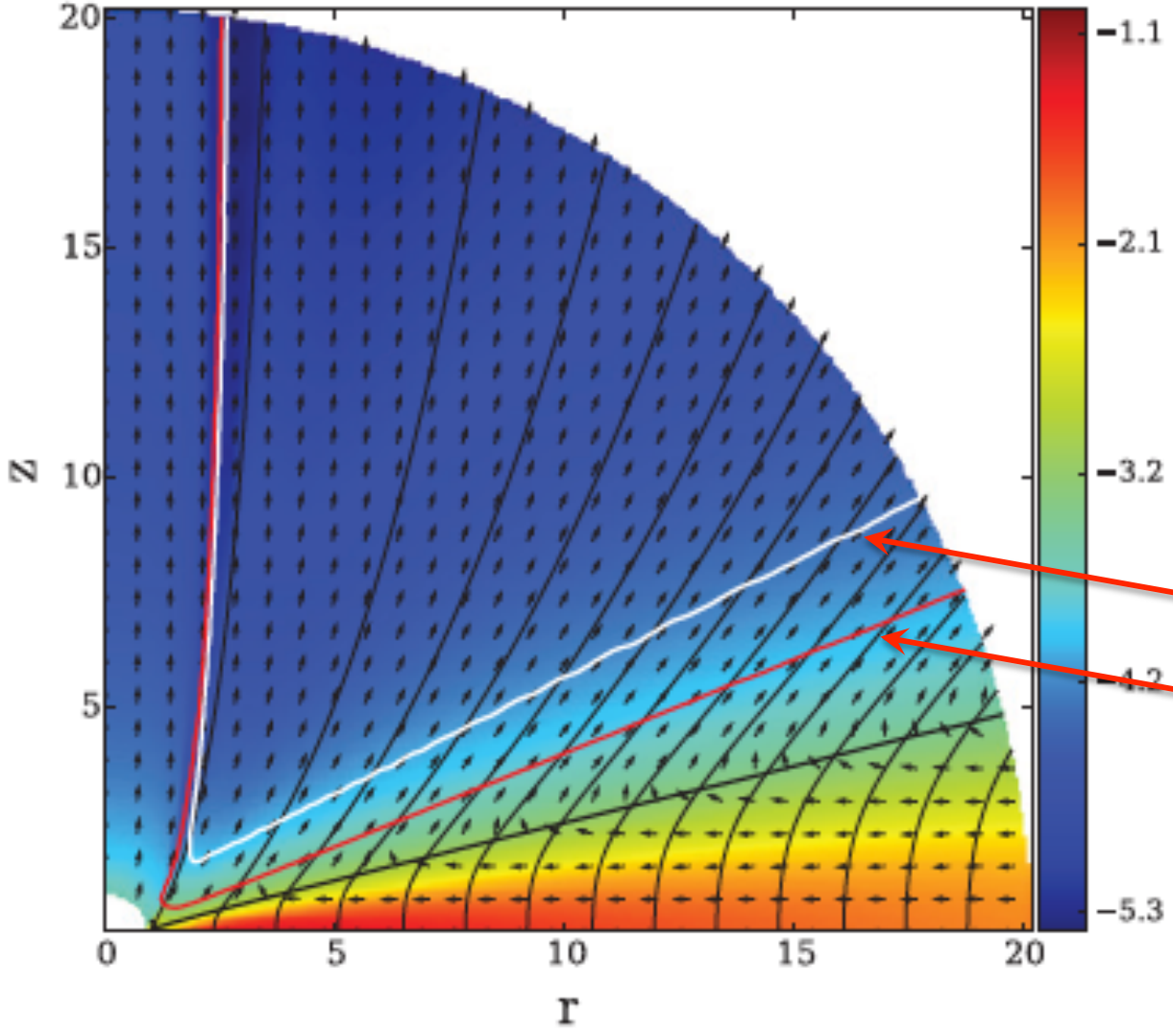
Tomida et al. 2013

Weak poloidal field shear-amplified & twisted ->

Build up strong B_ϕ ->

Outflow driven by the pressure gradient of B_ϕ

Wind structure



Caveat: these wind simulations don't resolve disk physics.

Alfvén point

Sonic point

Back to board.

Stepanovs & Fendt, 2014