Resistive MHD simulations of star-disk-jet system

Miljenko Cemeljic 席門傑

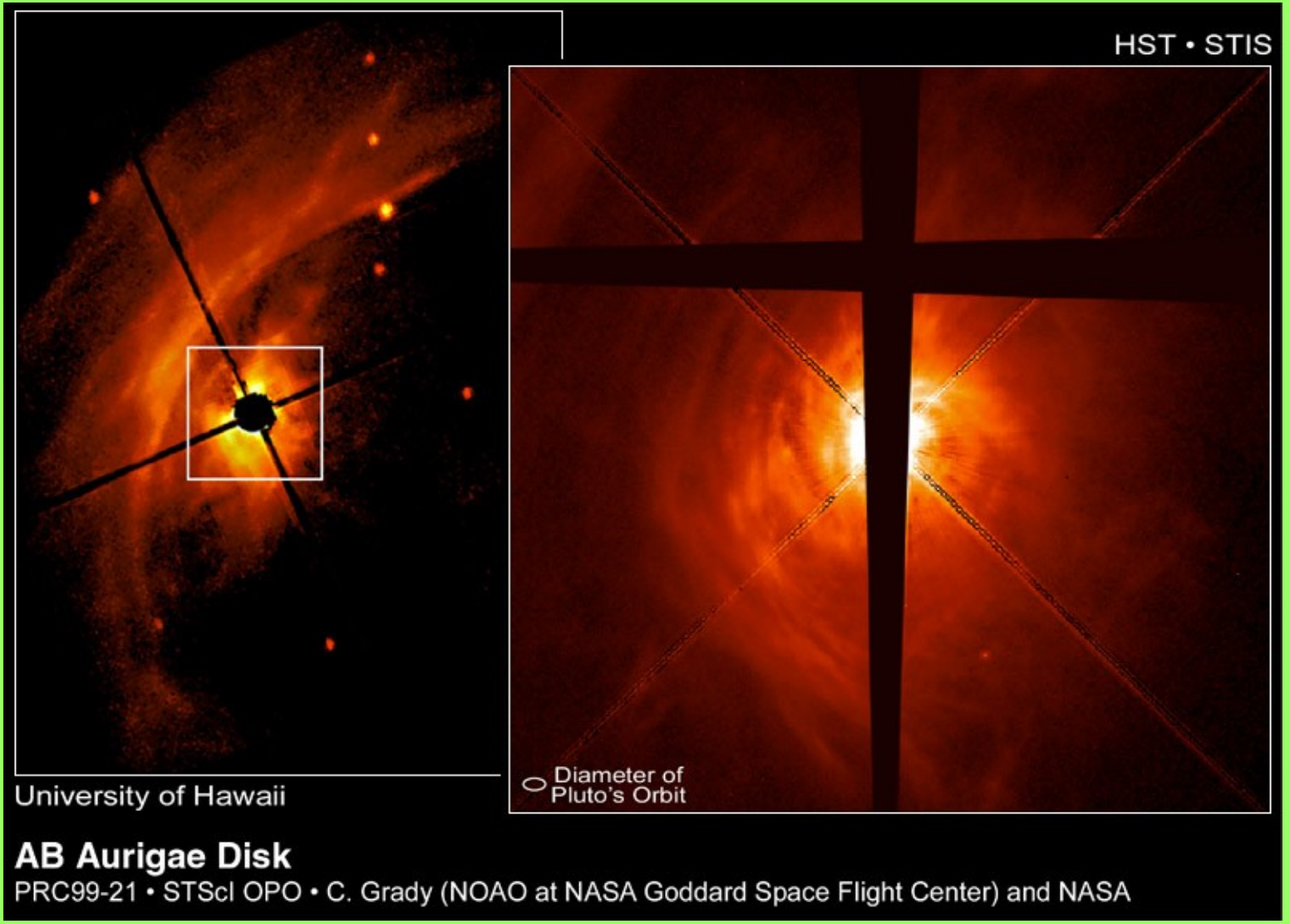
Hsien Shang & Tzu-Yang Chiang

TIARA/ASIAA, Taiwan

Outline

- Introduction
- Model
- Initial and boundary conditions
- Results
- Summary

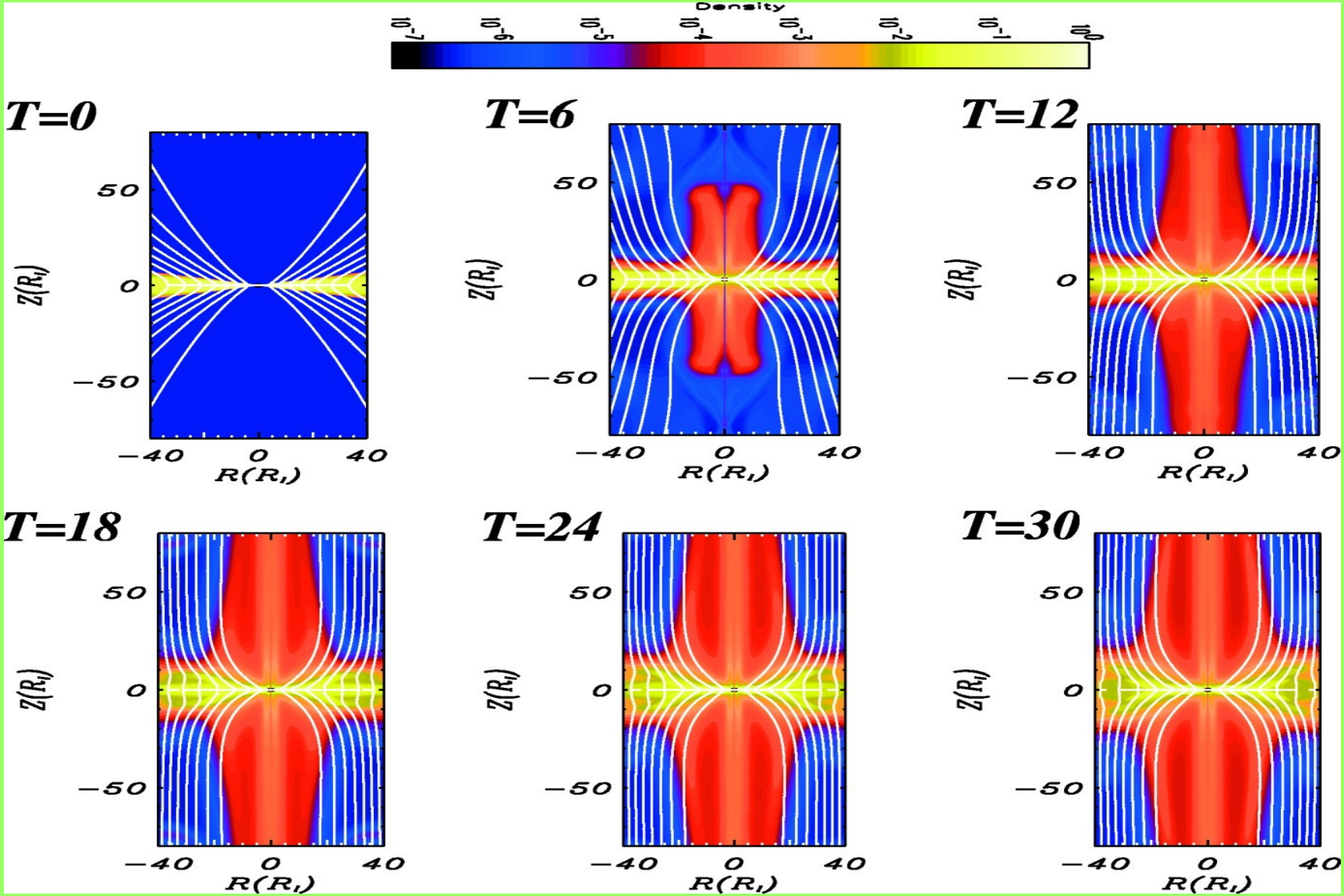
Dust disk


HST • STIS
University of Hawaii
Diameter of
Pluto's Orbit
AB Aurigae Disk
PRC99-21 • STScI OPO • C. Grady (NOAO at NASA Goddard Space Flight Center) and NASA

Introduction

- Protostellar jet launching problem
- Disk as a boundary
- Disk included in the simulations
- Resistive vs. other dissipative processes

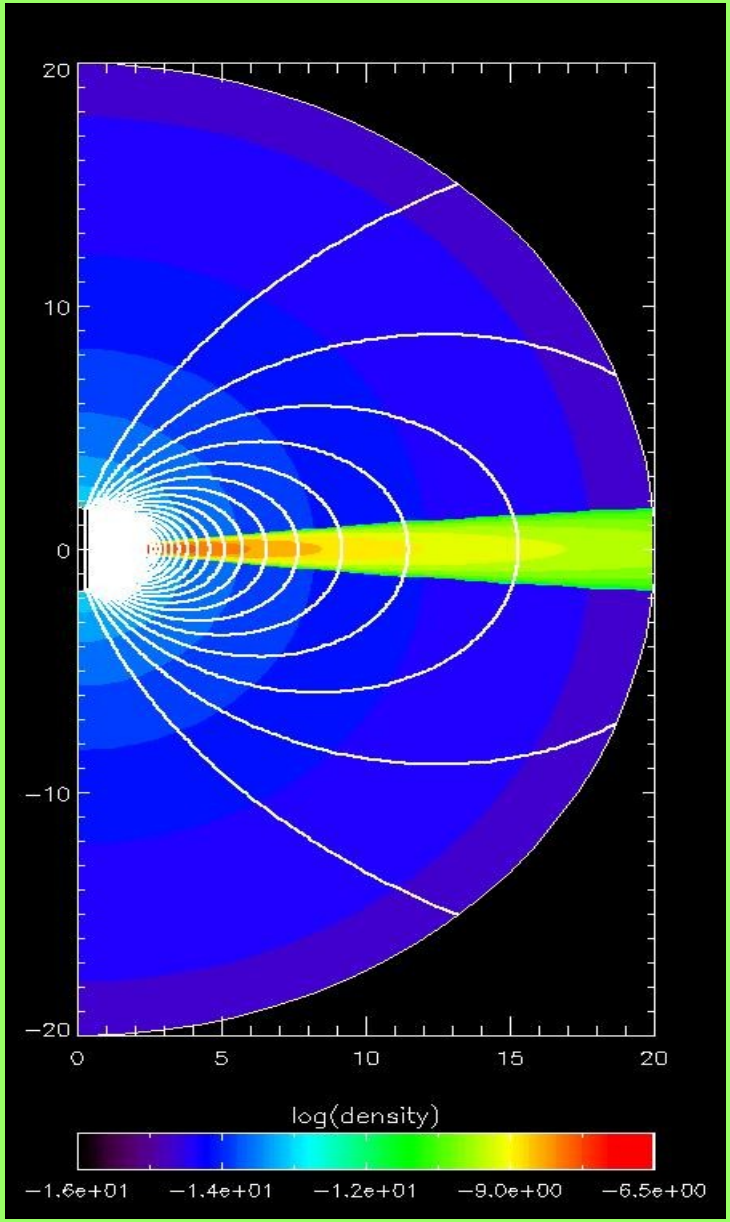
Simulations with disk open field



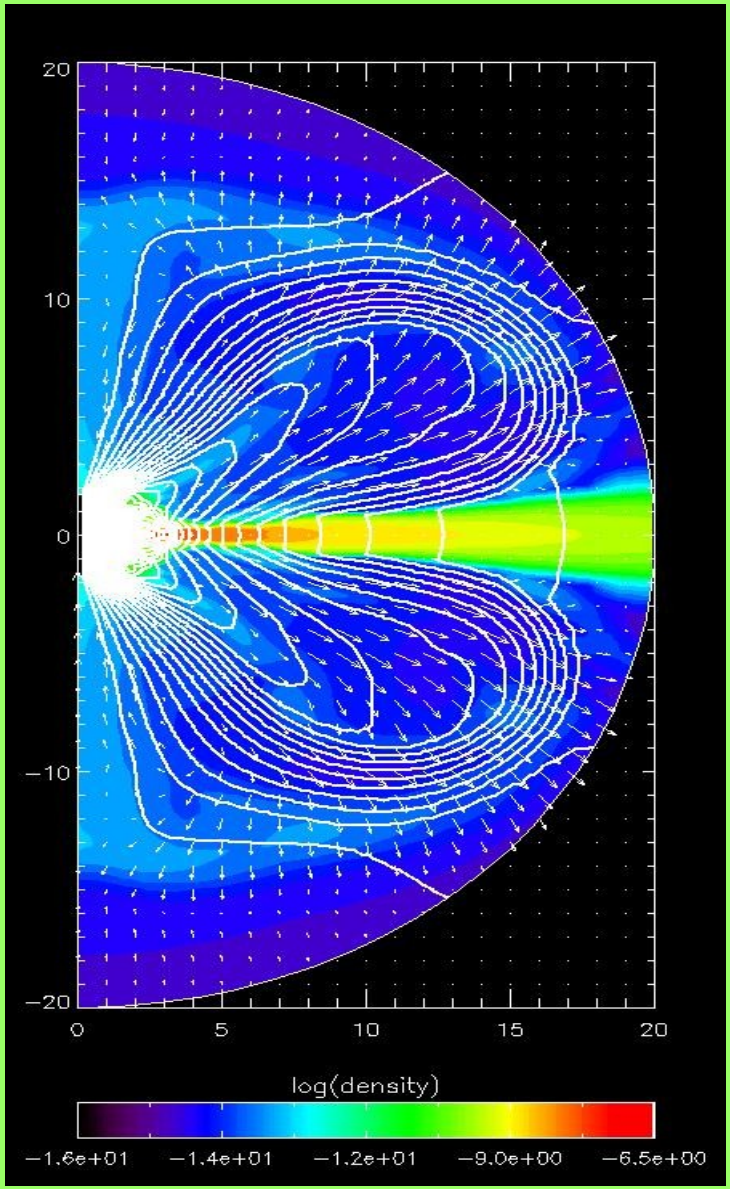
Casse & Keppens, 2002

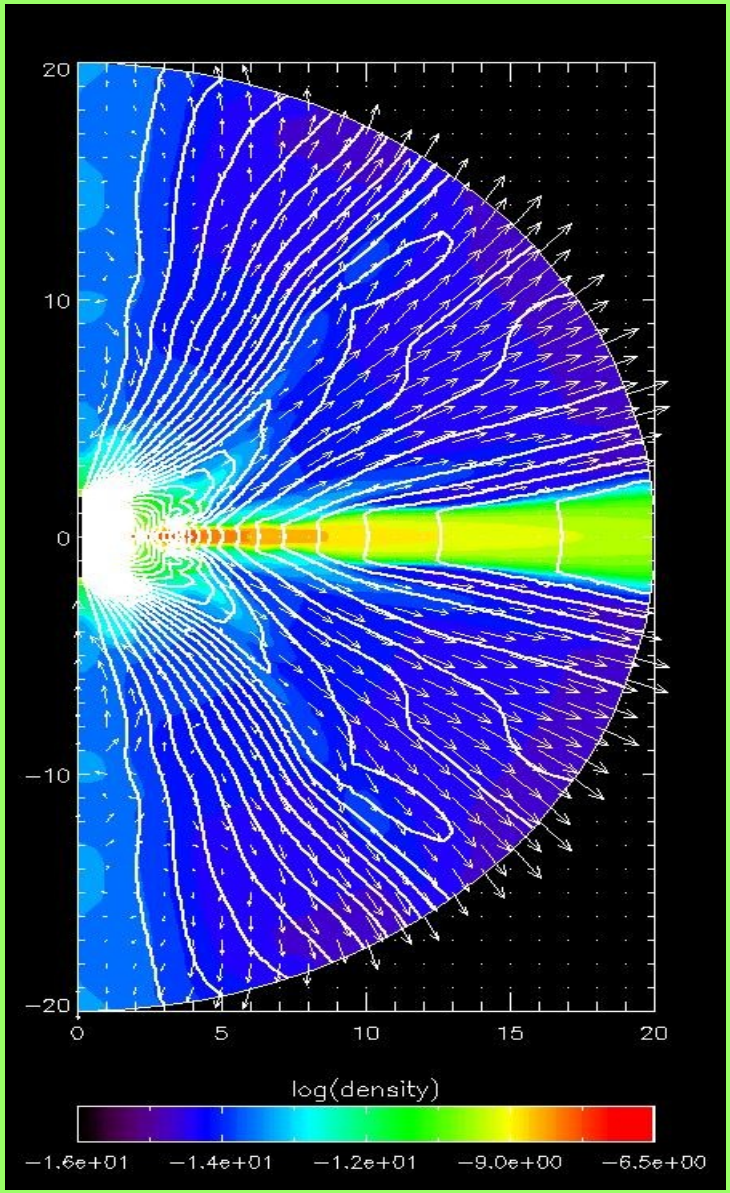
Simulations with stellar dipole field

- M. Kuker et al. 2003 – CTTS simulations, disk and disk corona included in the simulations, star as b.c.
- Magnetic field: stellar dipole field
- Density in disk ~10 000 times larger than in halo



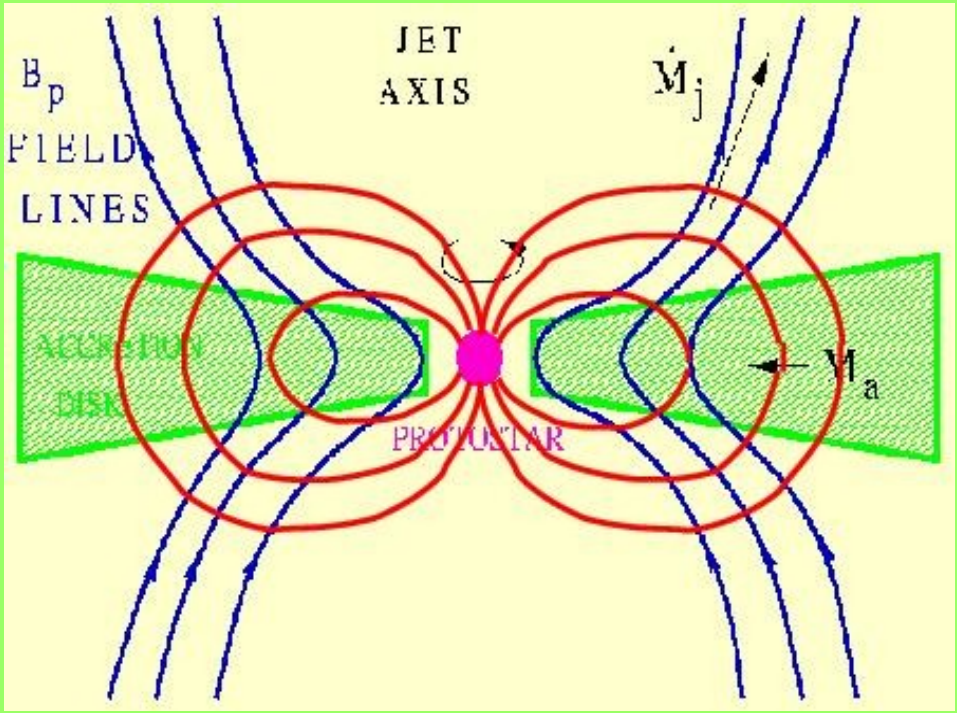
After 22 and 26 rotations





Simulations with dipole + open field

- Disk included in computational box
- Interaction of stellar magnetosphere & disk
- Stellar surface as a boundary



ZEUS-347

- Time-dependent **resistive** MHD simulations- **ZEUS347, stellar dipole +open field threading the disk**
- Setup: **RxZ=(160x250)grid cells=(12x12)R_i**

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0$$

$$\rho \left[\frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u} \cdot \nabla)\, \mathbf{u} \right] + \nabla p - \rho \nabla \left(\frac{GM}{\sqrt{r^2 + z^2}} \right) - \frac{\mathbf{j} \times \mathbf{B}}{c} = 0$$

$$\frac{\partial \mathbf{B}}{\partial t} - \nabla \times \left(\mathbf{u} \times \mathbf{B} - \frac{c\mathbf{j}}{\sigma} \right) = 0$$

$$\rho \left[\frac{\partial e}{\partial t} + (\mathbf{u} \cdot \nabla)\, e \right] + p(\nabla \cdot \mathbf{u}) - \frac{\mathbf{j}^2}{\sigma} = 0$$

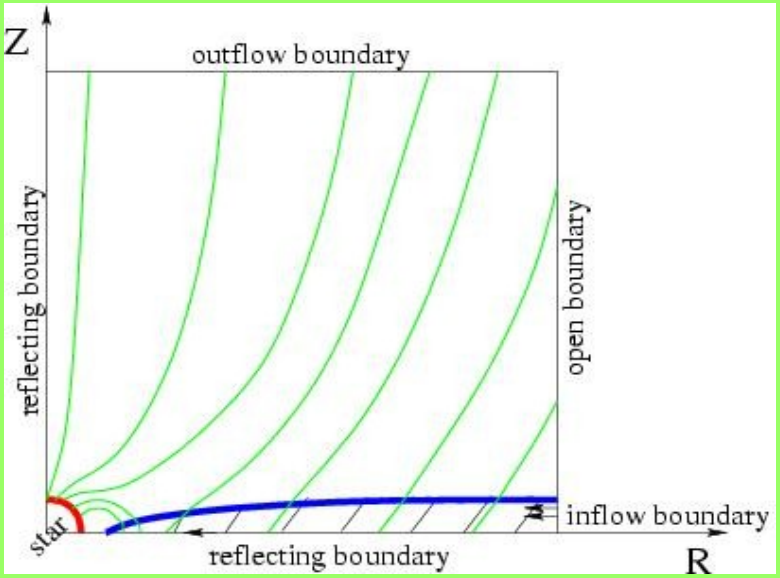
$$\nabla \cdot \mathbf{B} = 0$$

$$\frac{4\pi}{c}\mathbf{j} = \nabla \times \mathbf{B}$$

$$\frac{\partial \mathbf{B}}{\partial t} = \nabla \times (\mathbf{u} \times \mathbf{B}) + \eta \nabla^2 \mathbf{B}, \quad \eta = \frac{c^2}{4\pi\sigma}$$

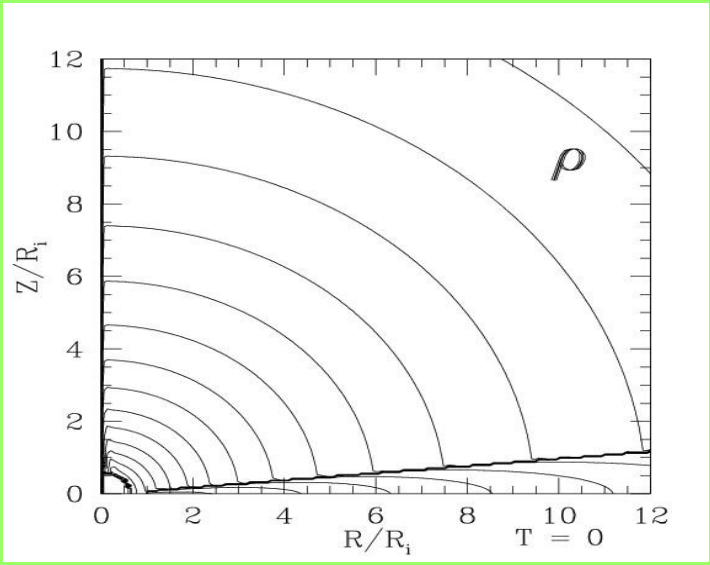
Boundary conditions

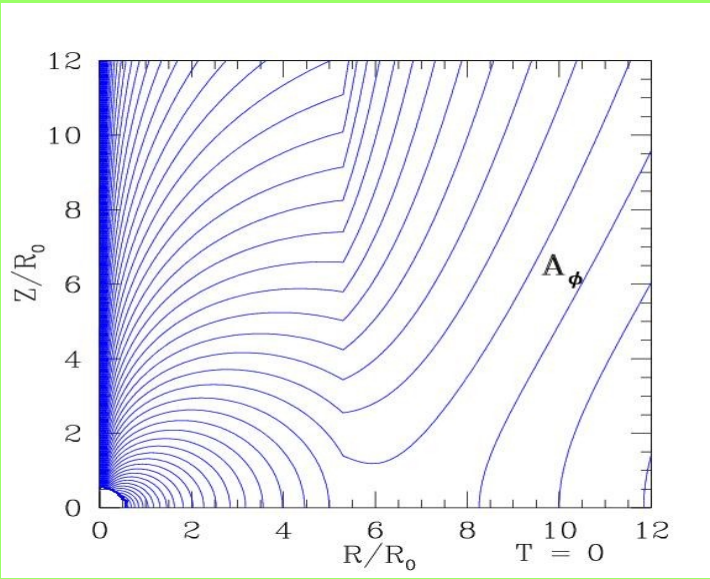
- Time-dependent **resistive** MHD simulations- **ZEUS347, stellar dipole +open field threading the disk**
- Setup: **RxZ=(160x250)grid cells=(12x12)R_i**



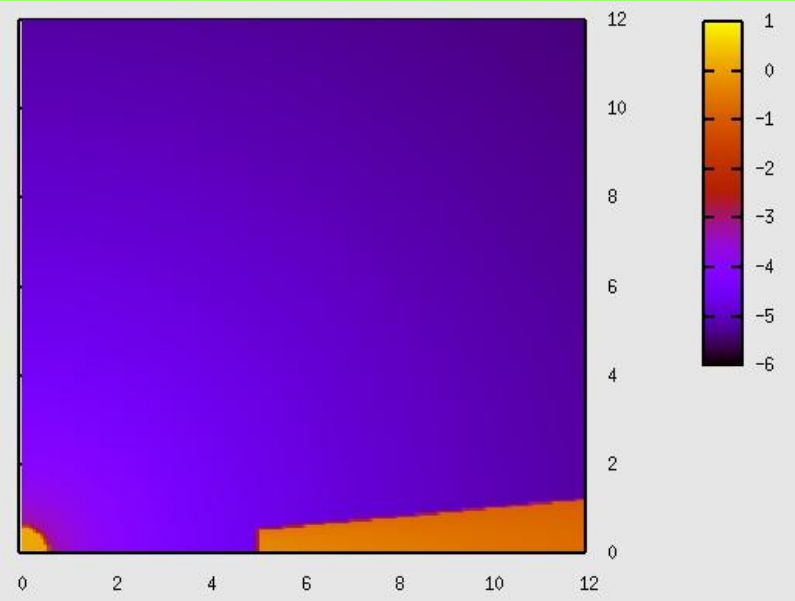
Initial conditions

- Hydrostatic co-rotating corona above the disk in hydrostatic and magnetic forces balance
- Resistive disk, corona effectively ideal-MHD
- Star as a boundary





Results 1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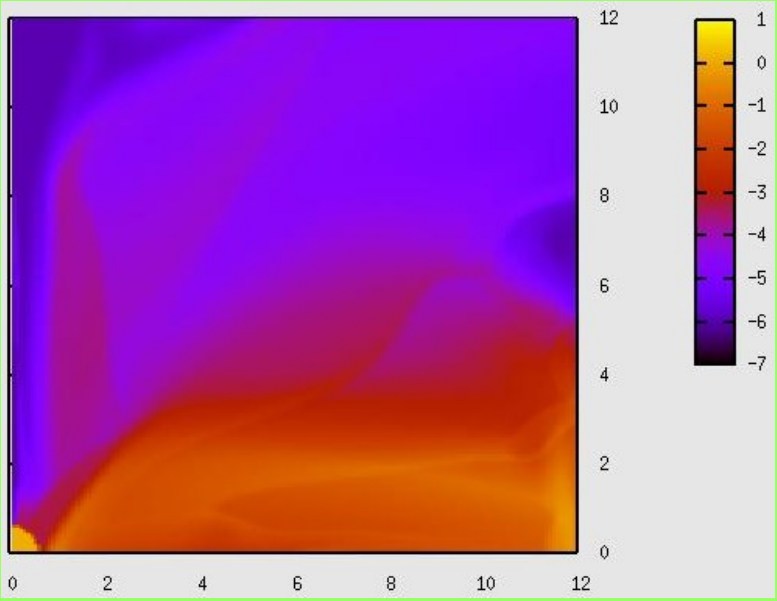
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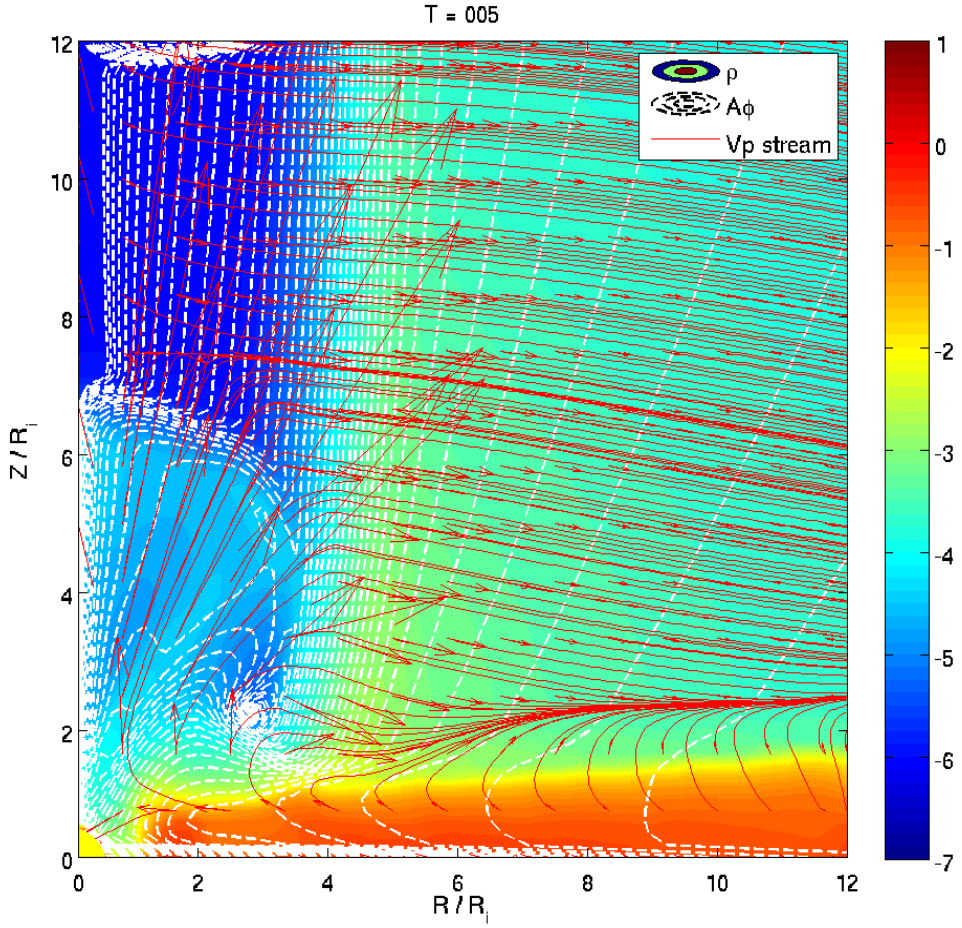
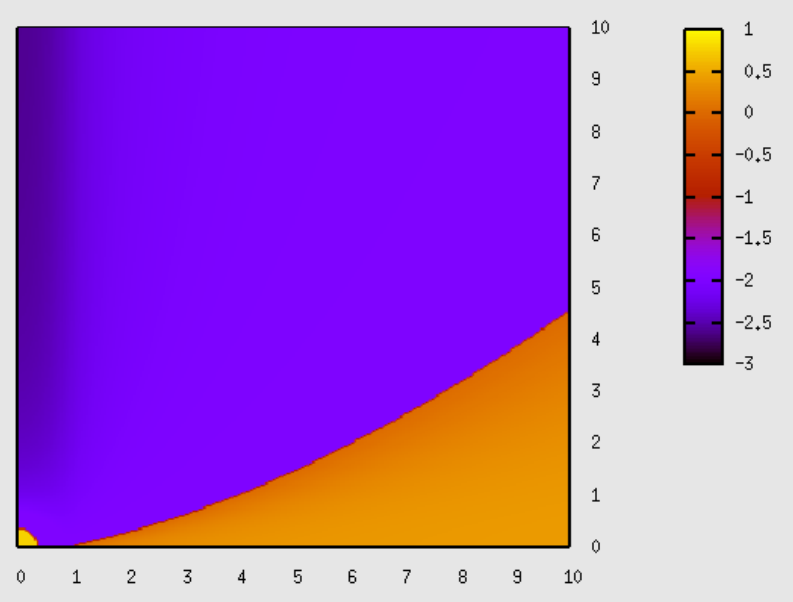
Results 2



Results 3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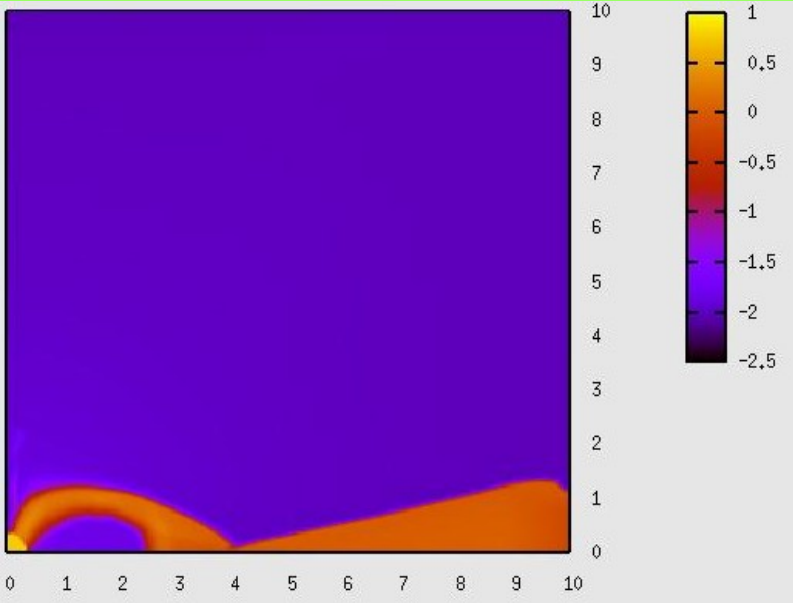
0 1 2 3 4 5 6 7 8 9 10
1 0.5 0 -0.5 -1 -1.5 -2 -2.5 -3


0 1 2 3 4 5 6 7 8 9 10
0 1 2 3 4 5 6 7 8 9 10
1 0.5 0 -0.5 -1 -1.5 -2 -2.5

Summary

- Numerical simulations in various geometrical setups
- Magnetic fields from simpler to more complicated
- Close vicinity of the star
- Prospects:Accretion disk & Full 3D simulations