Service d'Astrophysique
Laboratoire AIM

DE LA RECHERCHE À L'INDUSTRIE

Laboratoire Dynamique des Etoiles et de leur Environnement

Star-disk interaction

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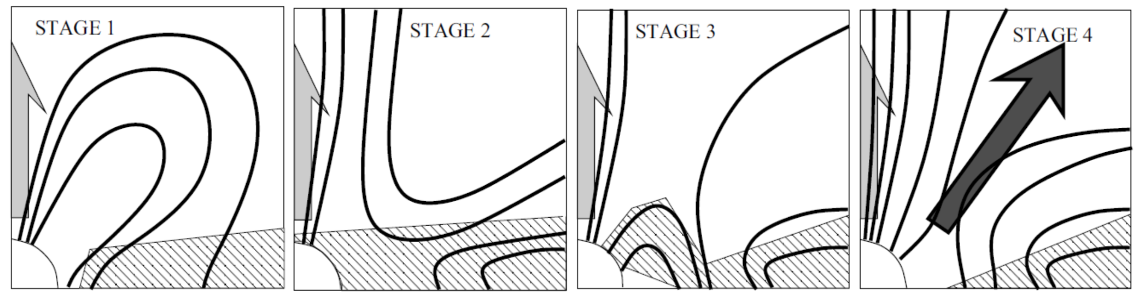
Outline

- Introduction
- Setup of (Neutron) Star-Disk
- 2D-axisymmetric simulations
  -HD
  -MHD
- Stellar surface as a boundary condition
- Summary

Introduction

- Star-disk interaction
- Tool is PLUTO code
- Viscous & Resistive MHD
- A cooling term for removal of viscous and Ohmic heating-to avoid thermal thickening of the disk, not actual radiative mechanism.

THE ASTROPHYSICAL JOURNAL, 768:5 (20pp), 2013 May 1 ČEMELJIĆ, SHANG, & CHIANG



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

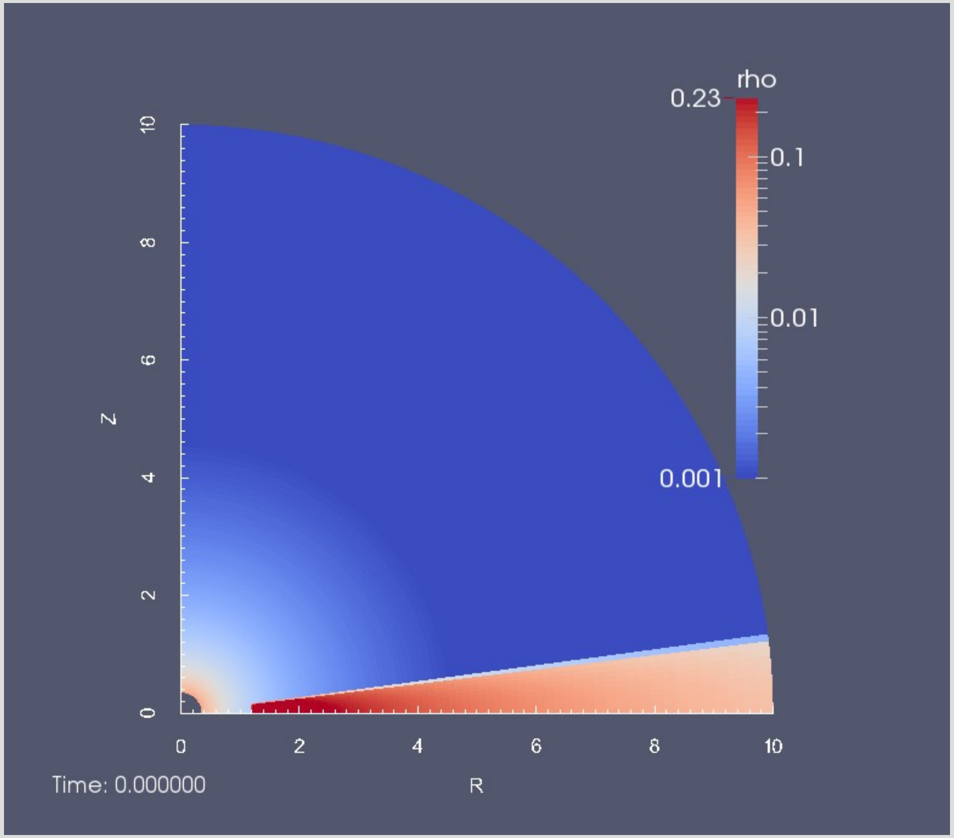
$$\frac{\partial \rho \boldsymbol{u}}{\partial t} + \nabla \cdot \left[\rho \boldsymbol{u}\boldsymbol{u} + \left(P + \frac{\boldsymbol{B}\cdot\boldsymbol{B}}{8\pi} \right) \boldsymbol{I} - \frac{\boldsymbol{B}\boldsymbol{B}}{4\pi} - \boldsymbol{\tau} \right] = \rho \boldsymbol{g}$$

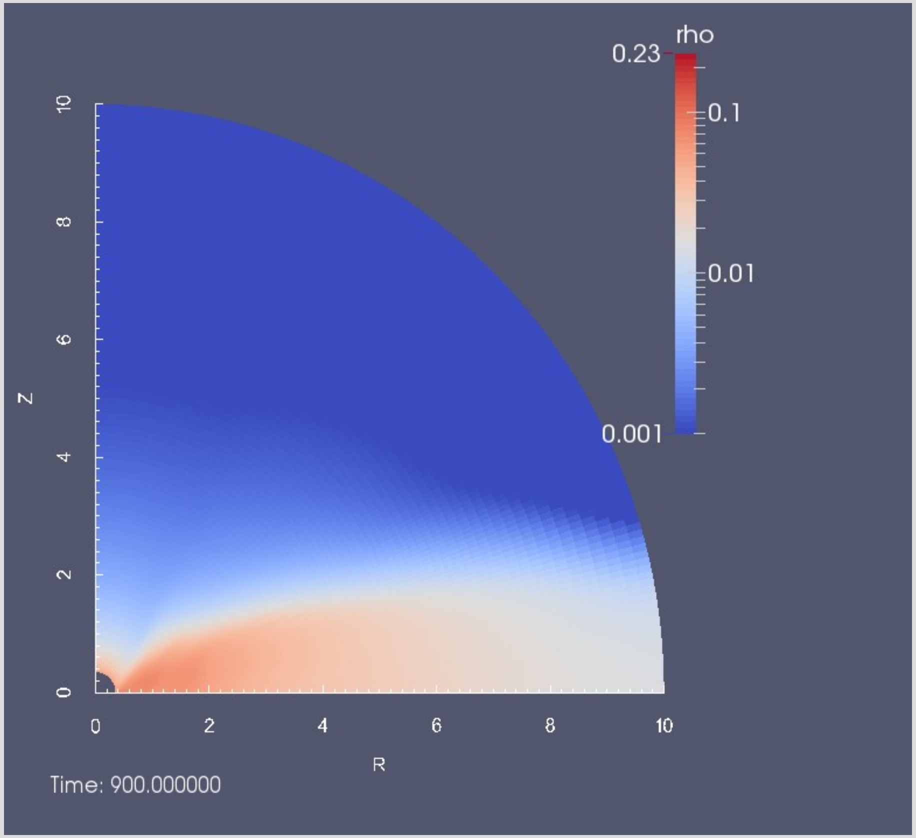
$$\frac{\partial E}{\partial t} + \nabla \cdot \left[\left(E + P + \frac{\boldsymbol{B}\cdot\boldsymbol{B}}{8\pi} \right) \boldsymbol{u} - \frac{(\boldsymbol{u}\cdot\boldsymbol{B})\,\boldsymbol{B}}{4\pi} \right] + \nabla \cdot [\eta_{\rm m} \boldsymbol{J} \times \boldsymbol{B}/4\pi - \boldsymbol{u}\cdot\boldsymbol{\tau}] = \rho \boldsymbol{g}\cdot\boldsymbol{u} - \Lambda_{\rm cool}$$

$$\frac{\partial \boldsymbol{B}}{\partial t} + \nabla \times (\boldsymbol{B} \times \boldsymbol{u} + \eta_{\rm m} \boldsymbol{J}) = 0.$$

(Neutron) Star-Disk Simulations, HD

- Collaboration with W. Kluzniak & V. Parathasarathy, CAMK Warsaw
- V.P. will focus on radiative accretion disk around a Neutron Star in HD, I will more work on magnetic field case.
- Newtonian gravity potential

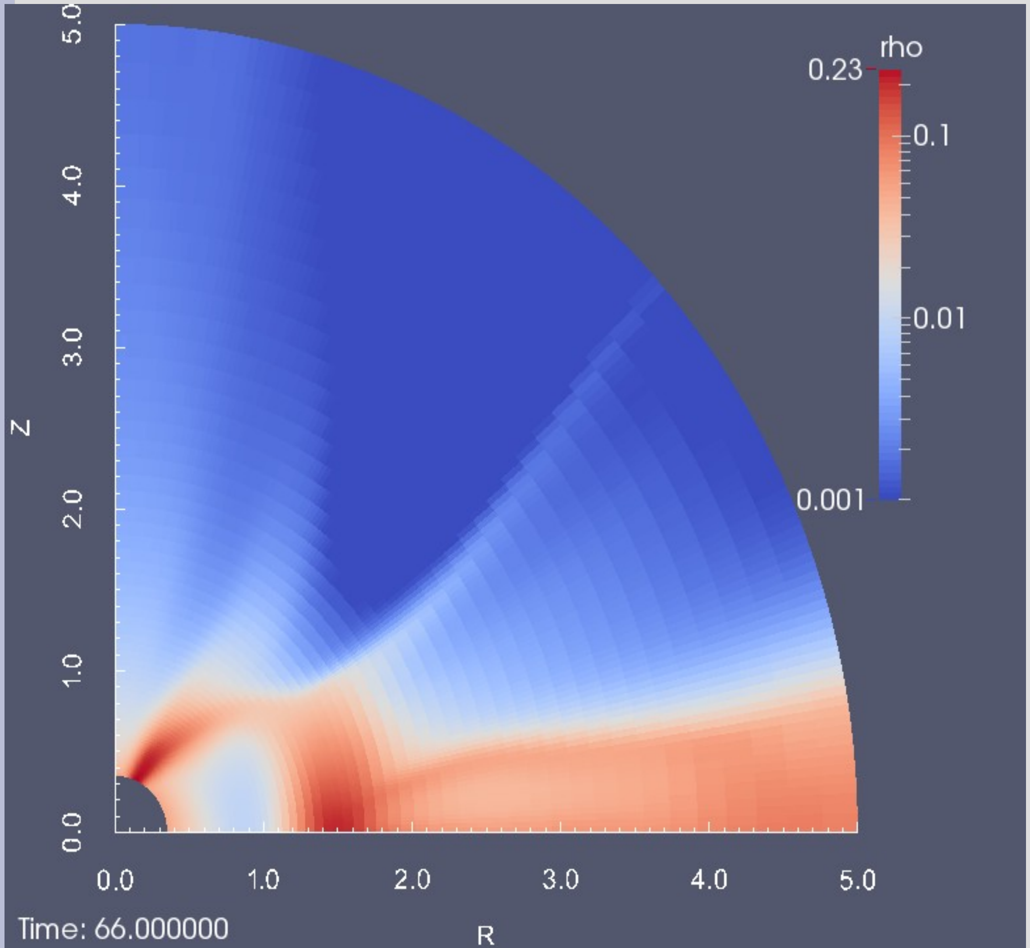




(Neutron) Star-Disk Simulations, MHD

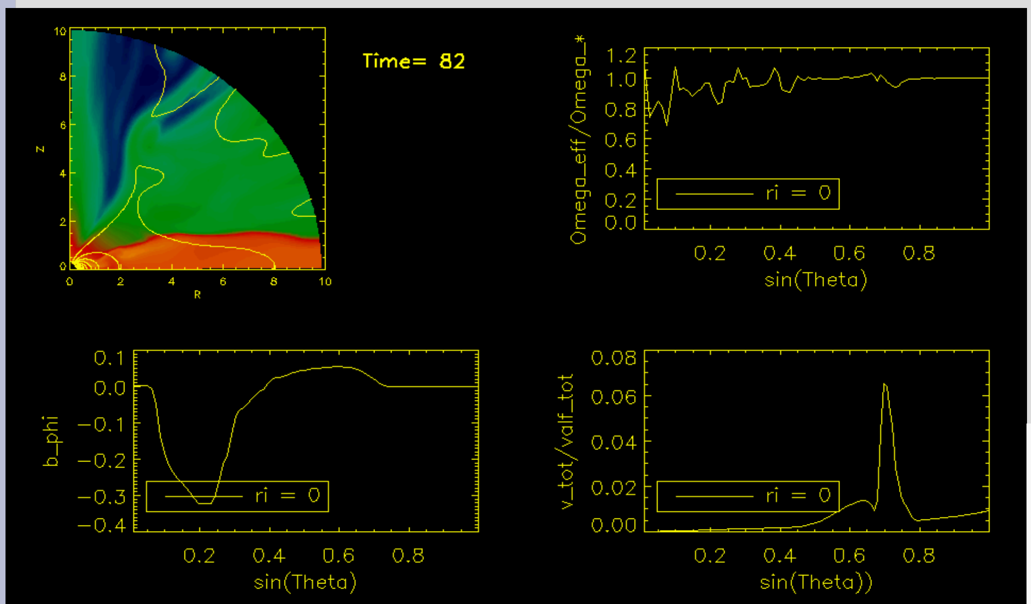
- Special care to matching of stellar and rotation of the magnetic field lines.

$$\boldsymbol{E}_{\Omega=\Omega_\star} = \boldsymbol{B} \times (\boldsymbol{u} - \boldsymbol{\Omega}_\star \times \boldsymbol{R}) = 0$$

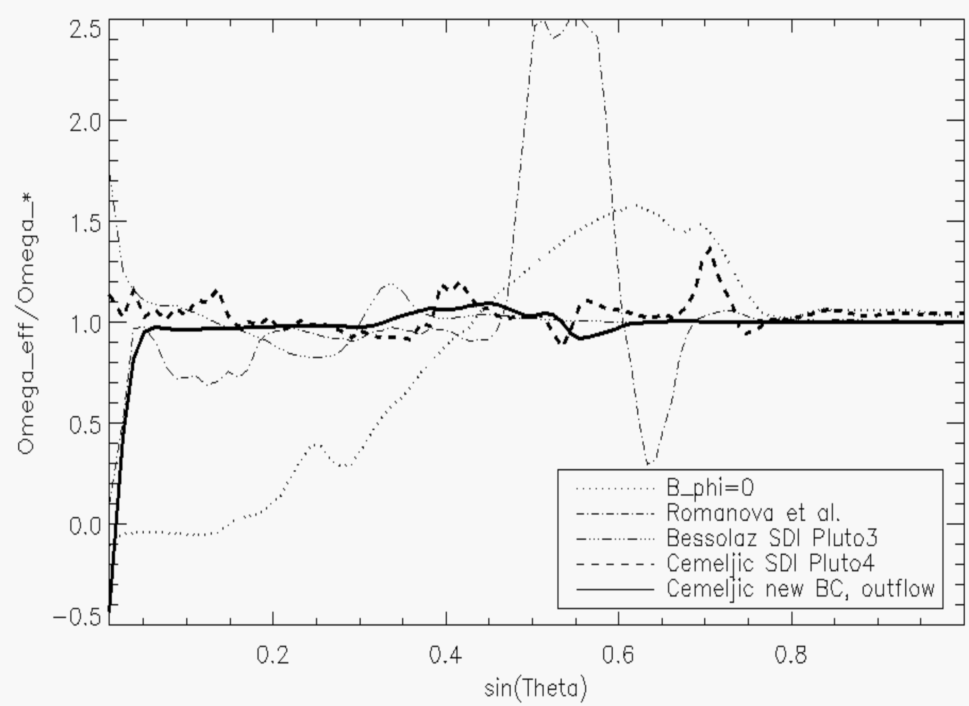


$$u_\phi = r\Omega_\star + u_{\rm p} B_\phi / B_{\rm p}$$

Stellar surface as a boundary condition



I set simulations with different choices of inner boundary conditions, and compare the matching of stellar and magnetic field rotation.



Summary

- Setup for a star-disk in 2D axisymmetric case in PLUTO 4, with viscous & resistive MHD (viscous and Ohmic heating removed).
- I will perform a parameter study, first for dipole, then quadrupole & octupole magnetic field, and combinations in more complex ones.
- Goal is to find the best torque formulation from 2D simulations for various geometries of magnetic field.
- Results are re-scalable to various objects, in Newtonian gravity potential.
- Future work: Do the same in 3D.