Star-disk interaction with PLUTO

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Outline

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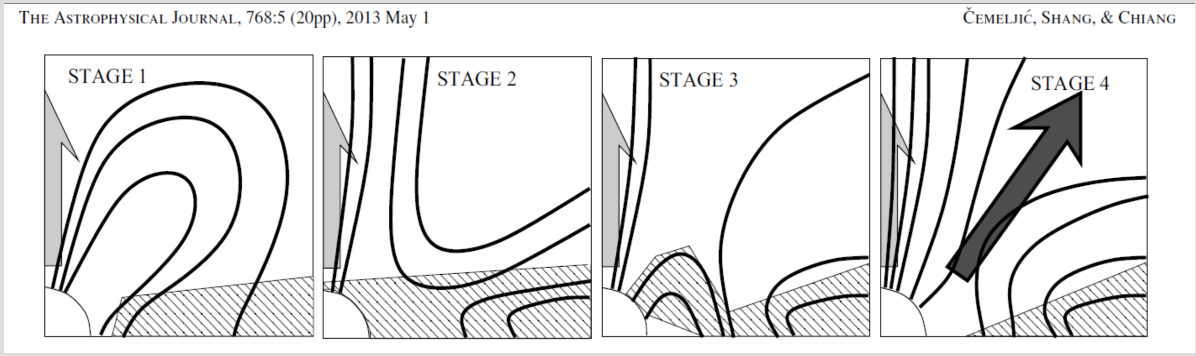
Introduction

- Star-disk problem



- Tool (PLUTO 4)

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \boldsymbol{V}) = 0 \quad (1)$$

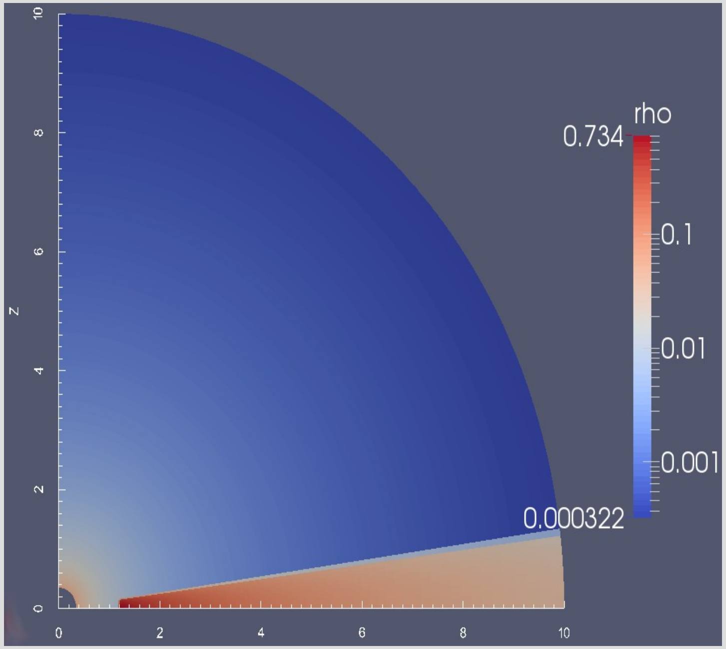
$$\rho \left[\frac{\partial \boldsymbol{V}}{\partial t} + (\boldsymbol{V} \cdot \nabla)\, \boldsymbol{V} \right] + \nabla p - \frac{\boldsymbol{j} \times \boldsymbol{B}}{c} = 0 \quad (2)$$

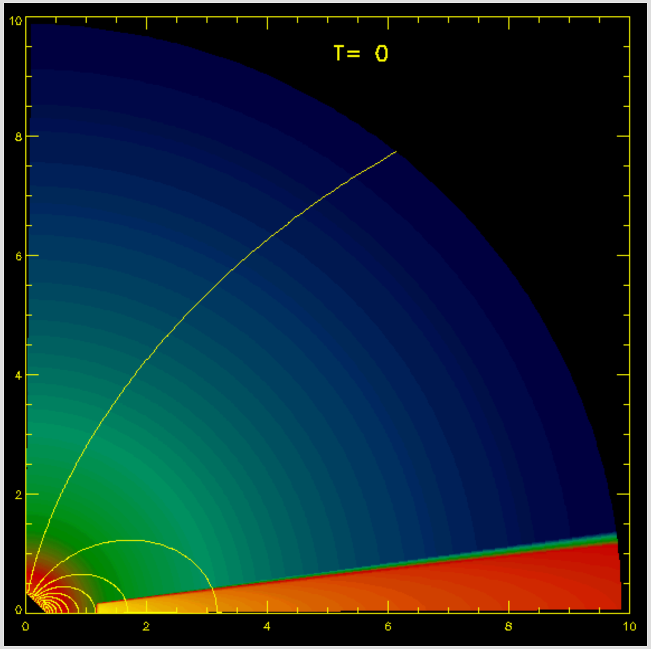
$$\frac{\partial \boldsymbol{B}}{\partial t} - \nabla \times \left(\boldsymbol{V} \times \boldsymbol{B} - \frac{4\pi}{c} \eta \boldsymbol{j} \right) = 0\,, \nabla \cdot \boldsymbol{B} = 0 \quad (3)$$

$$\rho \left[\frac{\partial e}{\partial t} + (\boldsymbol{V} \cdot \nabla)\, e \right] + p(\nabla \cdot \boldsymbol{V}) - \frac{4\pi}{c^2} \eta \boldsymbol{j}^2 = 0\,, \quad (4)$$

Setup and initial conditions

- We use stretched grid in spherical coordinates to det-up a 2D-axisymmetric star-disk simulation in (127x127) grid cells, with Rmax about 30 stellar radii. The disk velocities are set by Kluzniak & Kita (2000), and viscosity is parameterized as $\nu=\alpha\rho c^2/\Omega$. Initial magnetic field is a stelar dipole, and resistivity is set the same way as viscosity, or as $\eta=0.3\rho^{1/3}$. Initially, corona is rotating in a hydrostatic equilibrium.

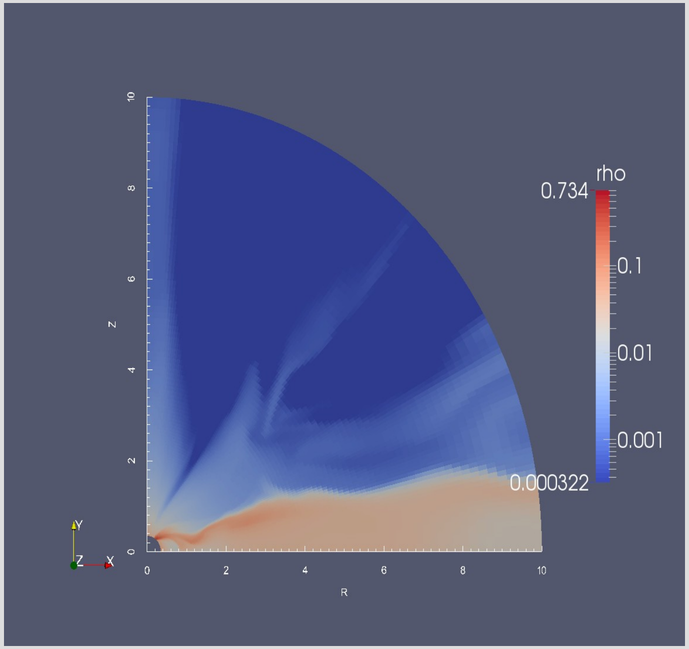


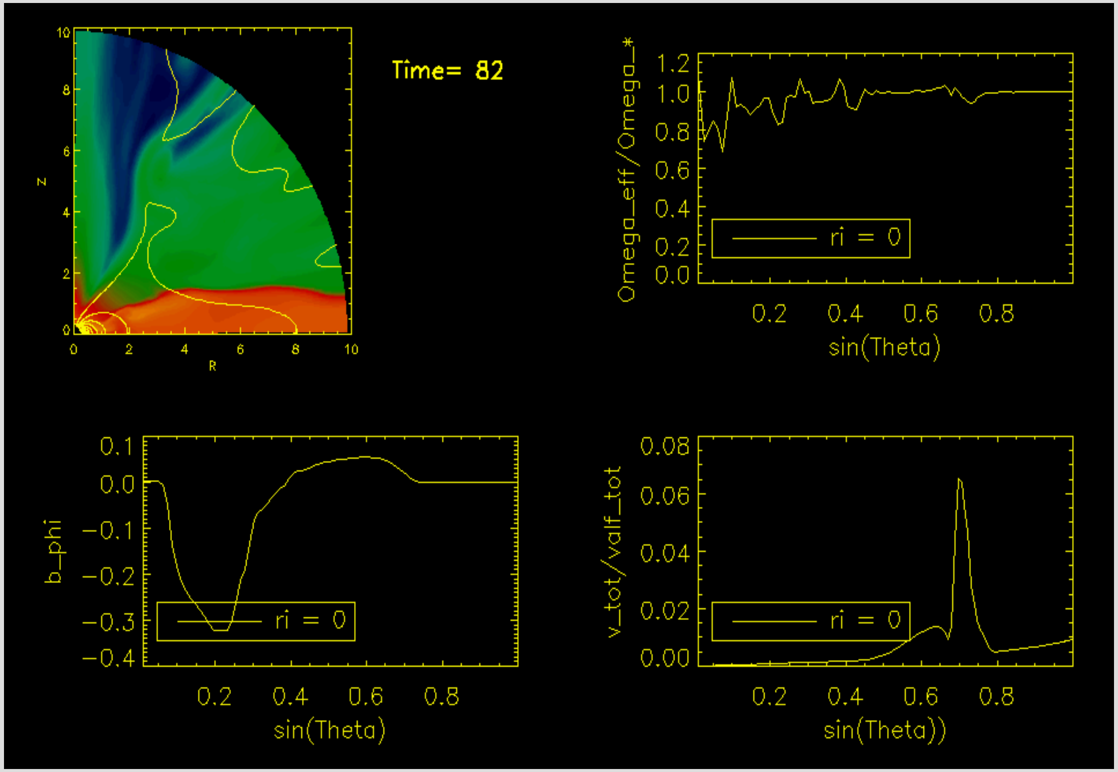


Setup-boundary conditions

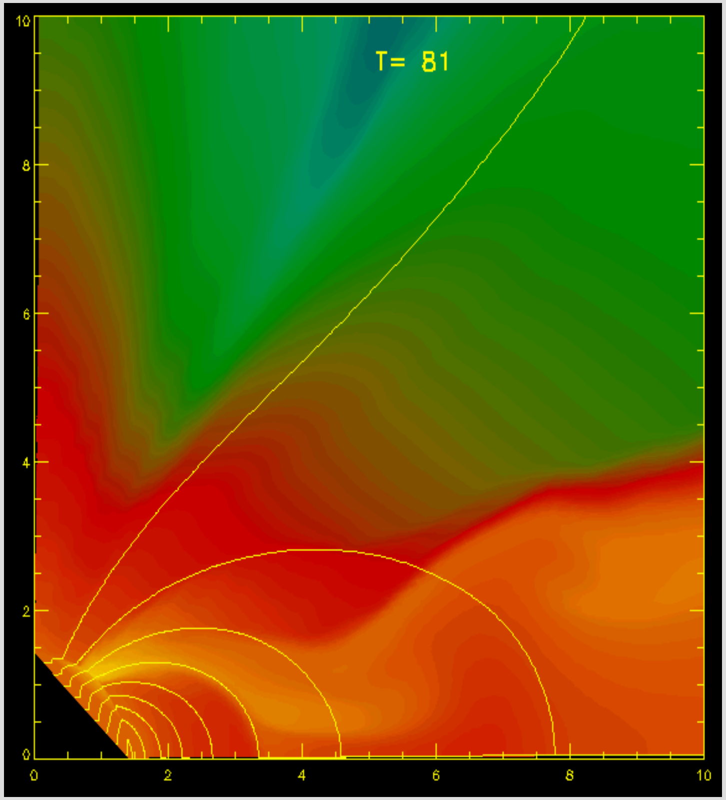
- At the corresponding boundaries, we set the axial and equatorial PLUTO setup.
- Outer radial b.c. is defined as an outflow, or modified outflow (with logarithmic extrapolation).
- Initial stellar velocity is set to 1/10 of stellar breakup rate.
- Radial inner b.c at the stellar surface is defined by a procedure developed by C. Zanni (Zanni & Ferreira 2009): A stellar surface is defined as a rotating perfect conductor, and from a condition for the electric field co-rotating with the star, derived is a b.c. for the rotation velocity of matter so that it would co-rotate with the stellar field.
- It is then needed to correctly account for rotation of the matter accreting along the accretion funnels with velocity slower or faster than the stellar surface. For this purpose, a gradient of the toroidal magnetic field is estimated to determine the poloidal electric current.

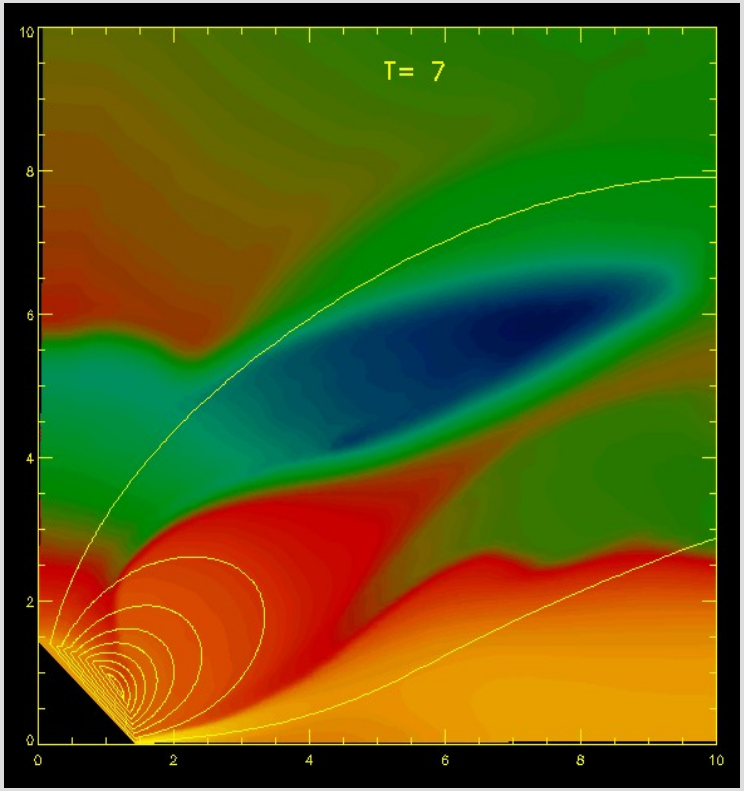
2D axisymmetric runs





2D axisymmetric runs-dipole versus quadrupole





Conclusions, future work

- We have a working setup for a star-disk in 2D axisymmetric case in PLUTO
- Boundary conditions seem to work well.
- Stability of the simulation after T=100 still an issue.
- Quadrupole magnetic field also set, but needs more work on B.C.
- When we obtain satisfying setups we will perform parameter study, first for dipole, then quadrupole and octupole.
- Goal is to find the best torque formulation from 2D simulations.