JeTSeT

JET Simulations, Experiments and Theories

Resistive MHD simulations with radially self-similar initial conditions

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MARIE CURIE ACTIONS

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Outline

- Introduction
- ZEUS347
- Ideal-MHD simulations-Zeus v. Nirvana & Pluto
- Resistive simulations, ZEUS347
- Summary

Introduction

- Radially self-similar solutions of Blandford-Payne 1982 type, but obtained as a special case of one class of solutions, systematic method of construction by N.Vlahakis et al.
- Analytical solution of the non-relativistic ideal MHD equations, under axisymmetry, steady-state and radial self-similarity assumptions, taken as initial conditions.
- Extending the analytical solution towards the axis and far away from the disk surface.
- Studying the influence of resistivity to radially self-similar solutions

Resistive MHD equations

- ZEUS347

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

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

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

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

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

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

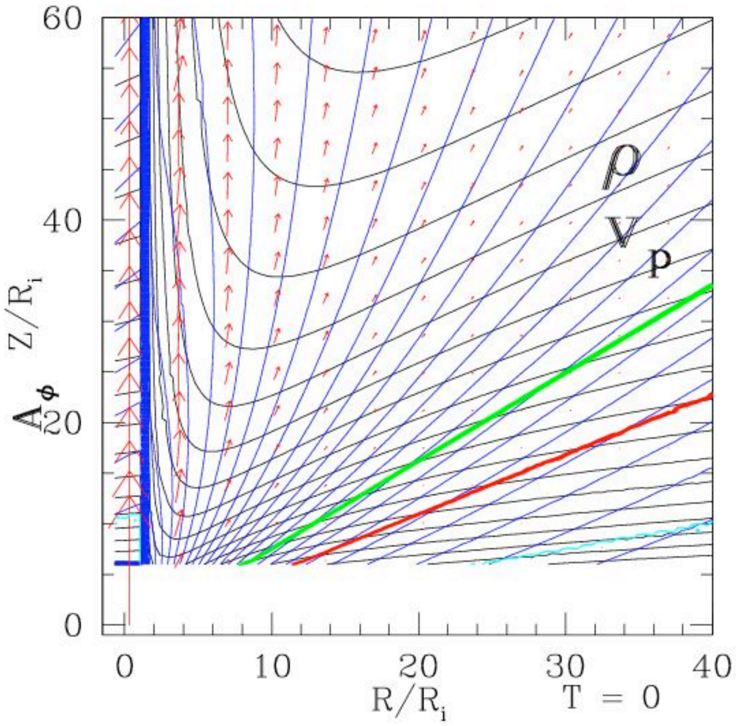
$$\frac{\partial \mathrm{B}}{\partial t} = \nabla\times(\mathbf{u}\times\mathrm{B}) + \eta\nabla^2\mathrm{B}, \quad \eta = \frac{c^2}{4\pi\sigma}$$

ZEUS-3D technical data

- fully staggered grid with scalars (d & e) zone-centered and vector components (v & B) face-centered
- derived vector components (j & emf) edge-centered
- von-Neumann Richtmyer artificial viscosity to smear shocks
- upstream-weighted, monotonic interpolation using one of donnor cell (1st order), van Leer (2nd order), or piecewise parabolic advection (3rd order) schemes
- MOCCT (Method of Characteristic-Constrained Transport) scheme for evolution of mag.fields

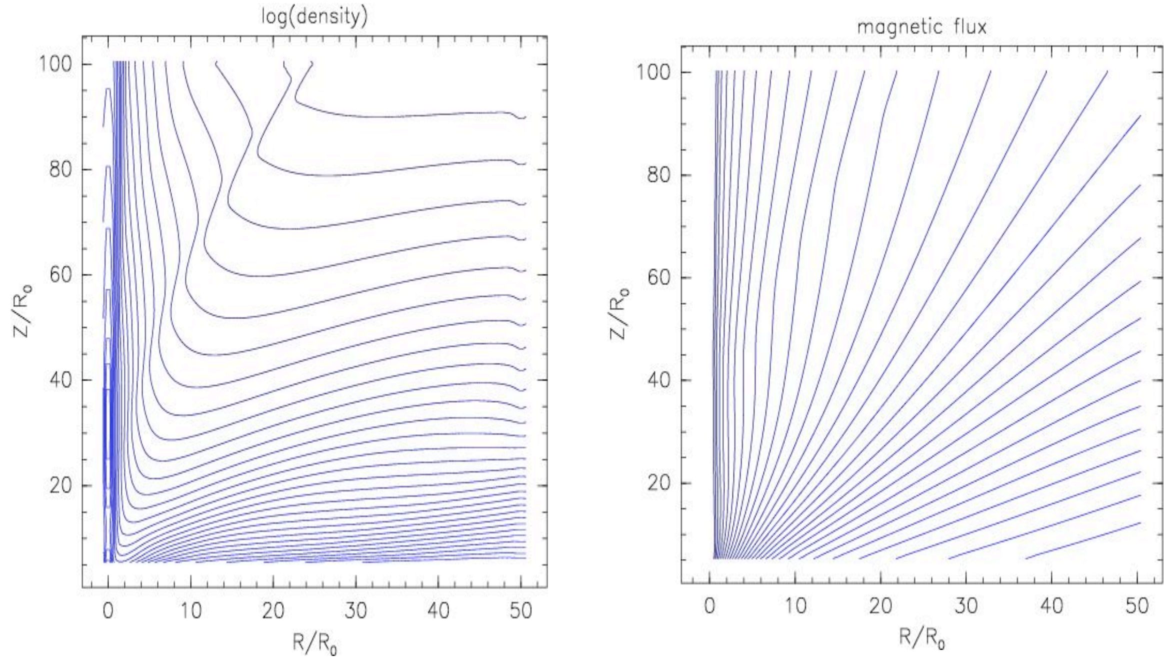
Initial conditions

- *Semi-analytical solution as a setup*
  - Semi-analytical solutions for radially self-similar outflows, N.Vlahakis et al., 2000.
  - Ideal MHD simulations, Gracia & al., 2006
  - Resistive simulations, Cemeljic & al., in prep.
  - Modified analytical solutions as initial conditions
  - RxZ=(120x180)grid cells



Nirvana&Pluto solutions

- *Nirvana & PLUTO*
  - Ideal-MHD simulations
  - J.Gracia et al., 2006
  - T.Matsakos



ZEUS ideal-MHD solutions-1

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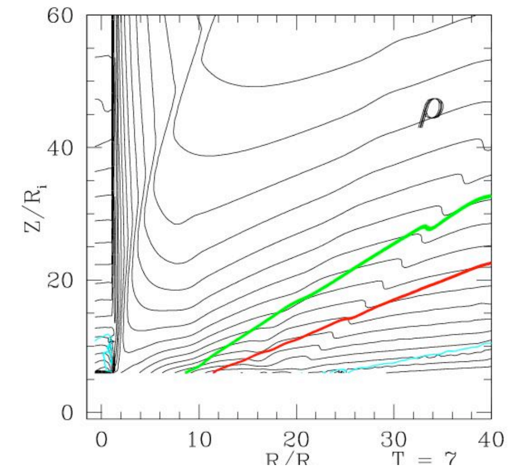
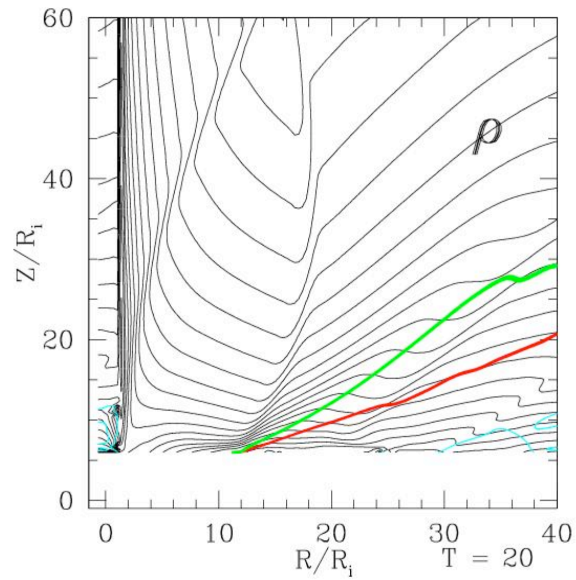
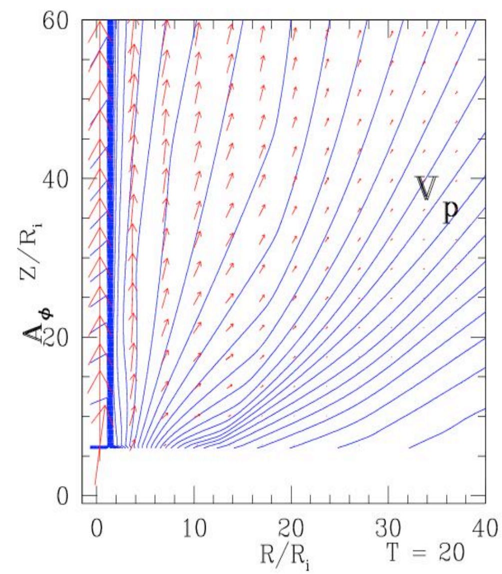
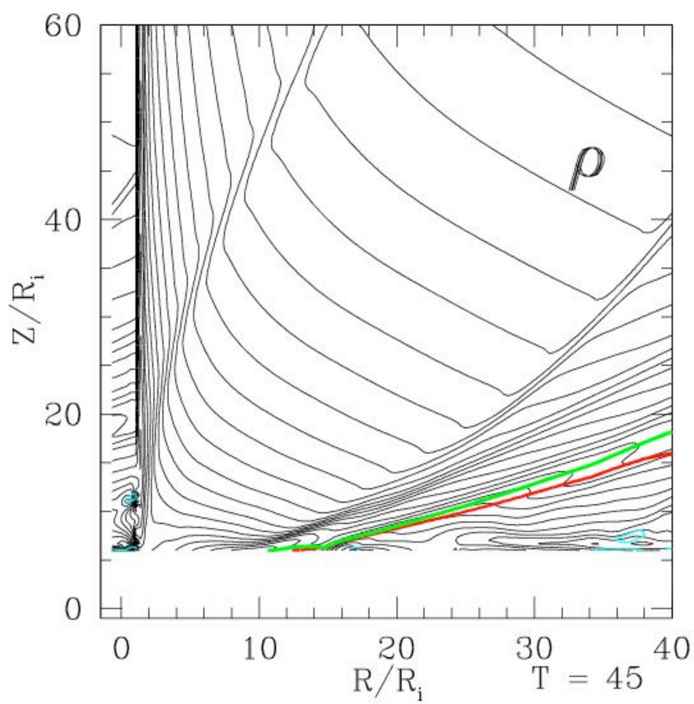
- *intermediate state*
  - Similar to Gracia et al. 2006 and initial conditions
  - BUT: simulations continue to evolve, in difference to Nirvana and Pluto

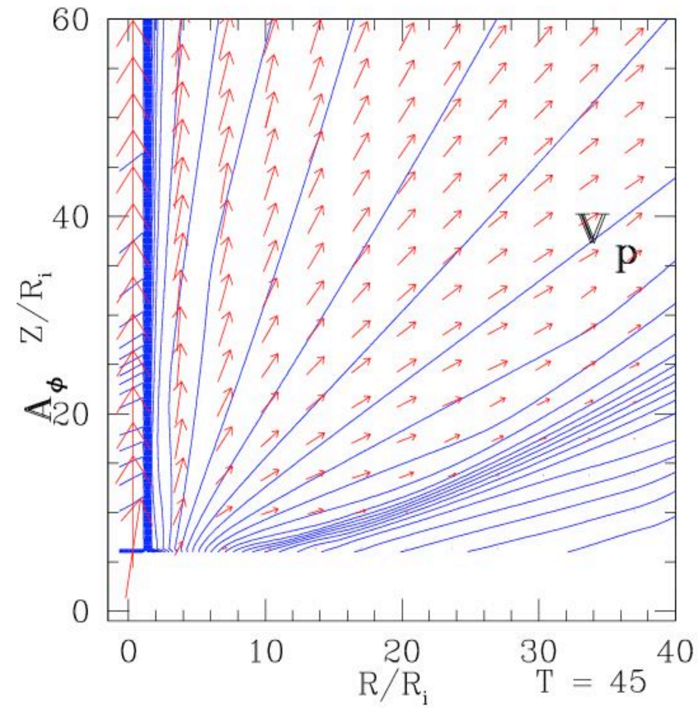






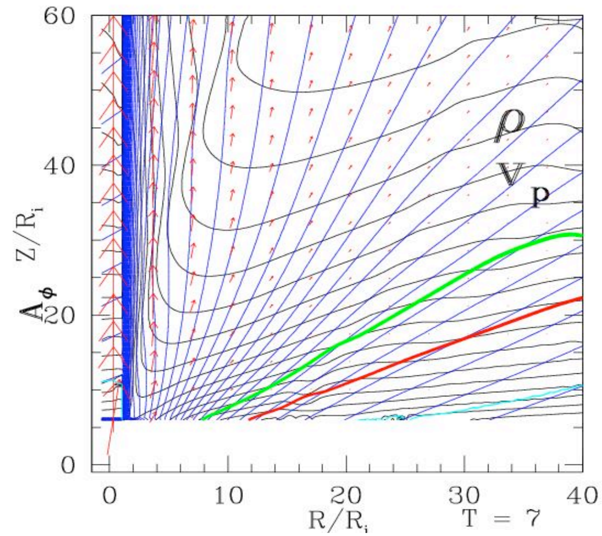
- *Quasi-stationary state*
  - different than one in Nirvana & Pluto simulations
  - robust

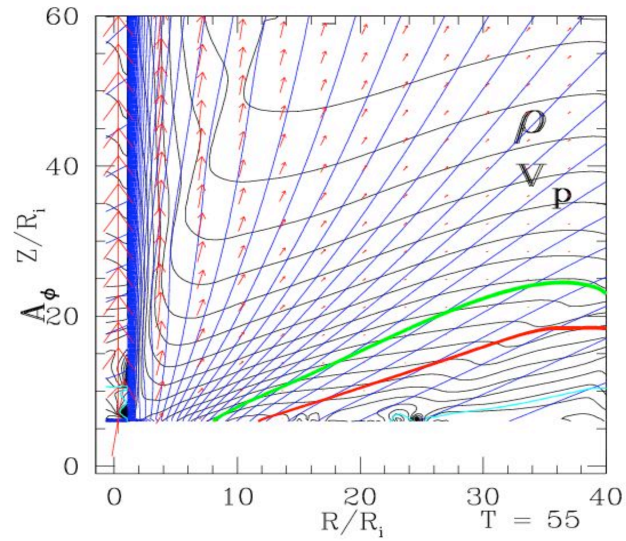




ZEUS347 resistive solutions

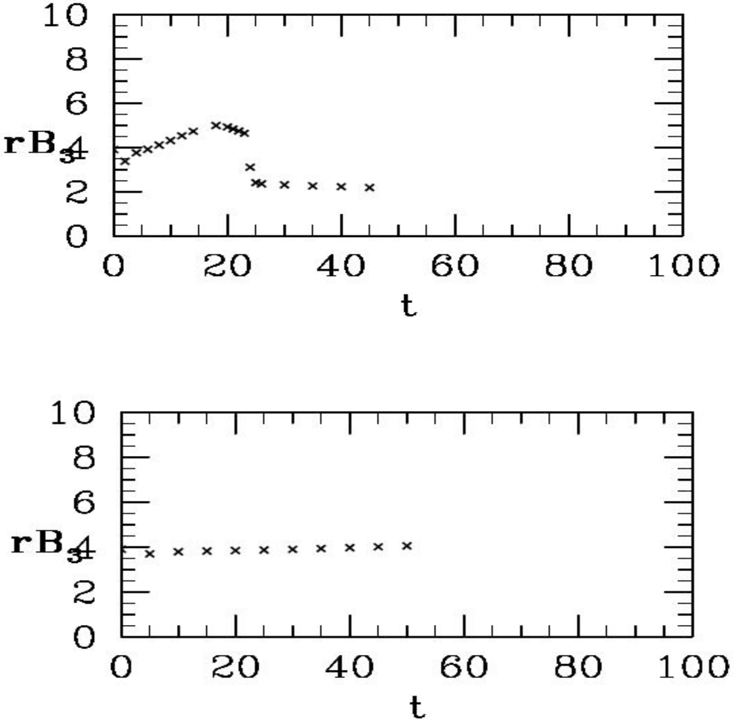
- **Disk as a boundary condition**
  - Ideal MHD, Ouyed & Pudritz, 1997, Zeus-2D
  - Resistive MHD, Cemeljic & Fendt, 2002, Zeus-3D
  - Similar setup, other i.c.
  - Diffusivity as a free parameter
  - Numerical diffusivity???





Comparison

- *Currents in time*
  - current in center of the computational box



Summary

- The same setup for disk as a b.c. as in previous works
- Different time-evolution than in Nirvana and Pluto
- Robust quasi-stationary state reached
- need for a measure of the numerical resistivity of different codes