Resistive MHD jet simulations with large resistivity

Miljenko Čemeljić[1](席門傑),
J. Gracia[2], N.Vlahakis[3] and K. Tsinganos[3]
[1]ASIAA (TIARA), Hsinchu, Taiwan
[2]School of Cosmic Physics, DIAS, Dublin, Ireland
[3]IASA and University of Athens, Greece

July 2008, Rodos, Greece

Outline

- Introduction
- Initial and boundary conditions
- Results
- Summary

Introduction

- Analytical solutions for radially self-similar MHD jet
- Ideal-MHD simulations, numerical resistivity
- Resistive-MHD simulations, two regimes
- Super-critical solutions
- Stability of solutions, modes of instability?

Boundary & initial conditions

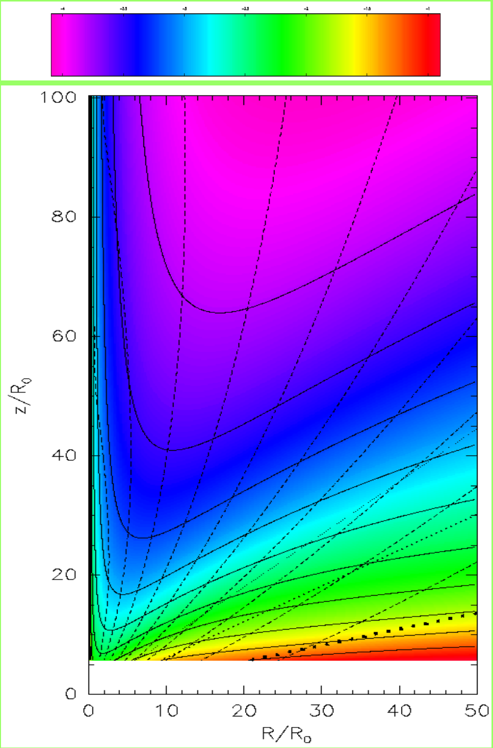
$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \boldsymbol{V}) = 0\,, \quad (1)$$

$$\rho \left[\frac{\partial \boldsymbol{V}}{\partial t} + (\boldsymbol{V} \cdot \nabla)\, \boldsymbol{V} \right] + \nabla p + \rho \nabla \Phi - \frac{\nabla \times \boldsymbol{B}}{\mu_0} \times \boldsymbol{B} = 0\,, \quad (2)$$

$$\frac{\partial \boldsymbol{B}}{\partial t} - \nabla \times (\boldsymbol{V} \times \boldsymbol{B} - \eta \nabla \times \boldsymbol{B}) = 0\,, \quad (3)$$

$$\rho \left[\frac{\partial e}{\partial t} + (\boldsymbol{V} \cdot \nabla)\, e \right] + p(\nabla \cdot \boldsymbol{V}) - \frac{\eta}{\mu_0} (\nabla \times \boldsymbol{B})^2 = 0\,, \quad (4)$$

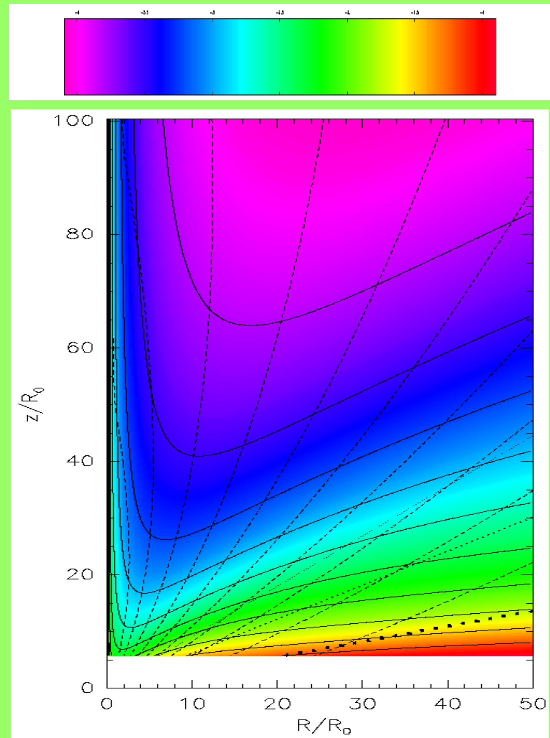
$$\nabla \cdot \boldsymbol{B} = 0\,, \quad (5)$$

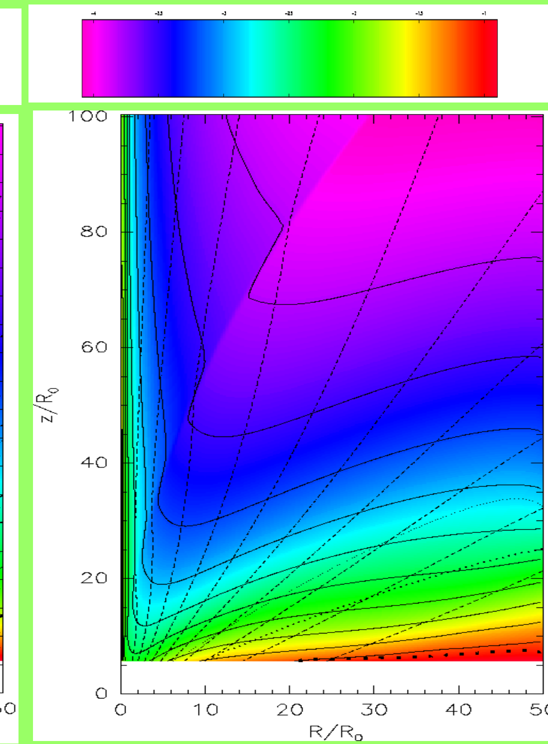


- Modified analytical solution as initial input
- Disk surface as a boundary
- Critical magnetosonic surfaces for tracking the flow evolution

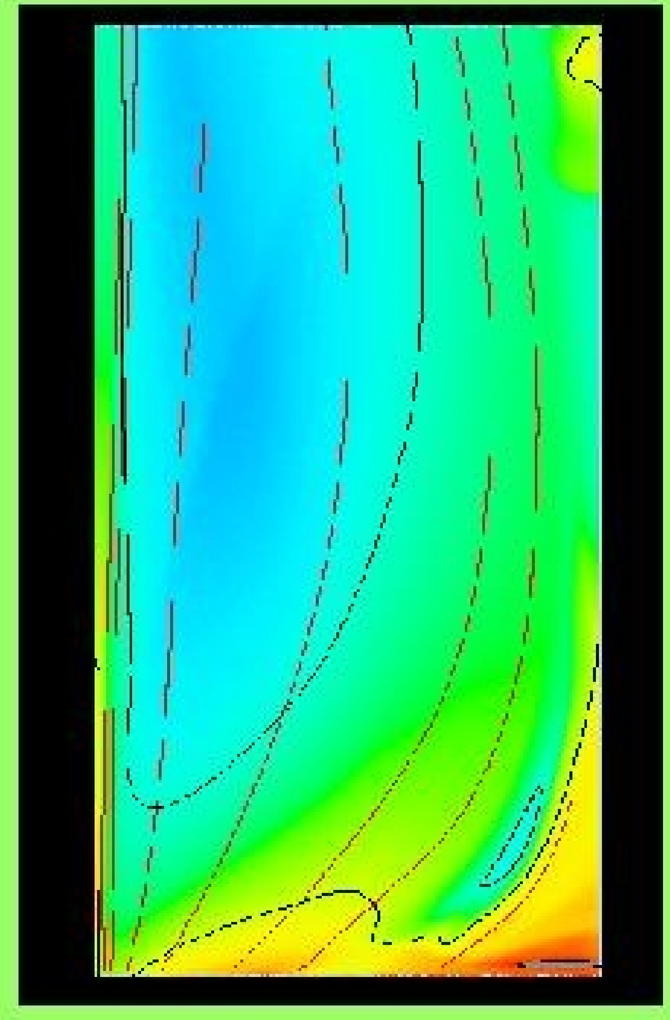
Ideal-MHD and low resistivity simulations

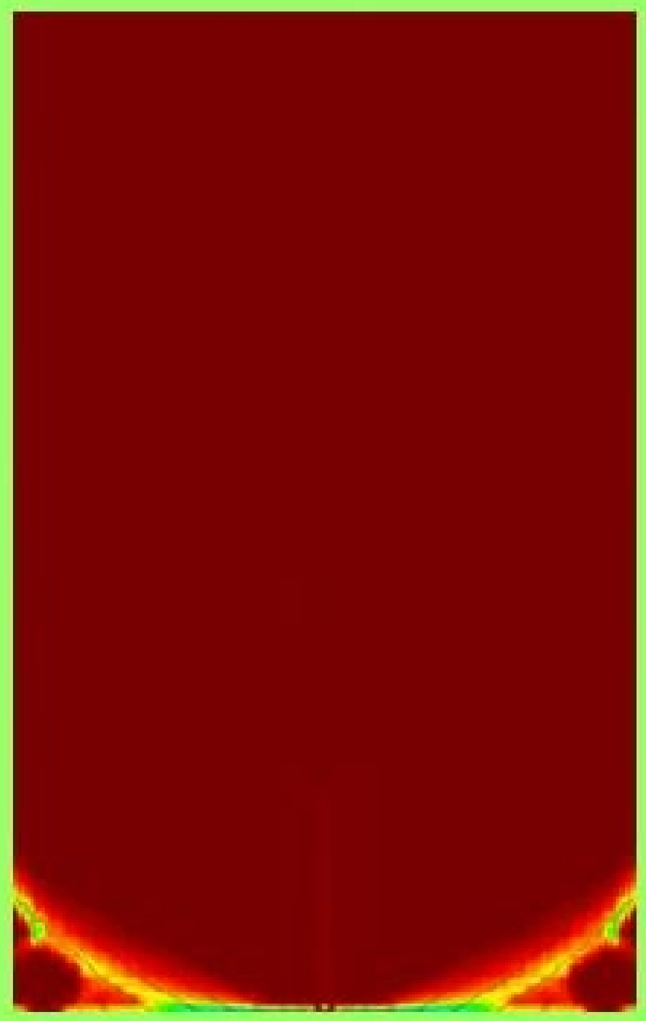
- Minor changes when compared to initial state
- **Very** well defined stationary state for final solution
- Integrals of motion **smoothly** depart from initial condition for increasing η





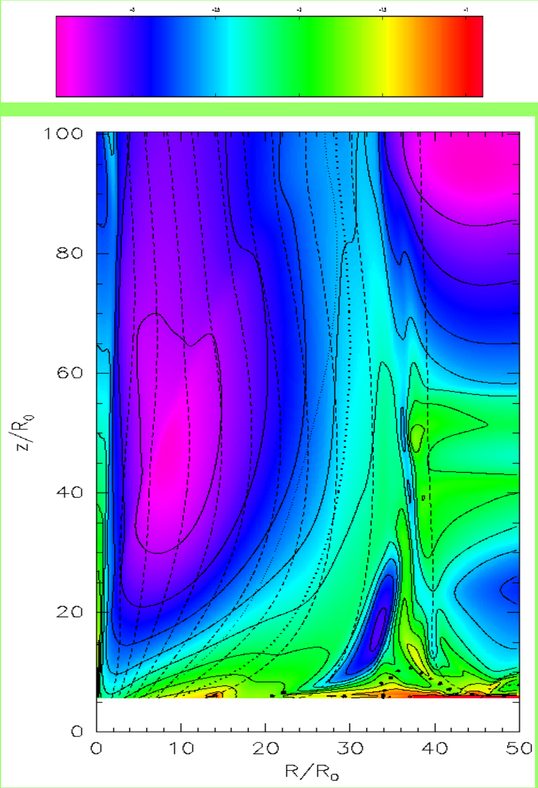
Movies: results for Blandford & Payne boundary conditions



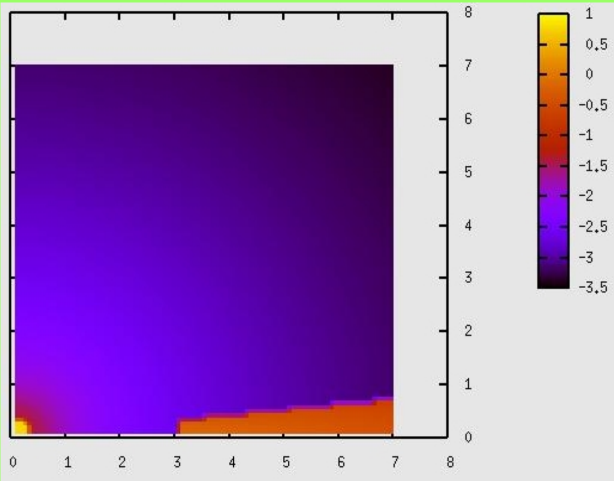


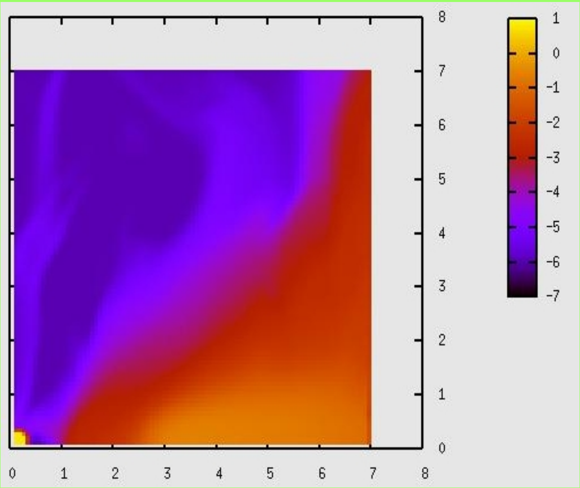
High resistivity simulations

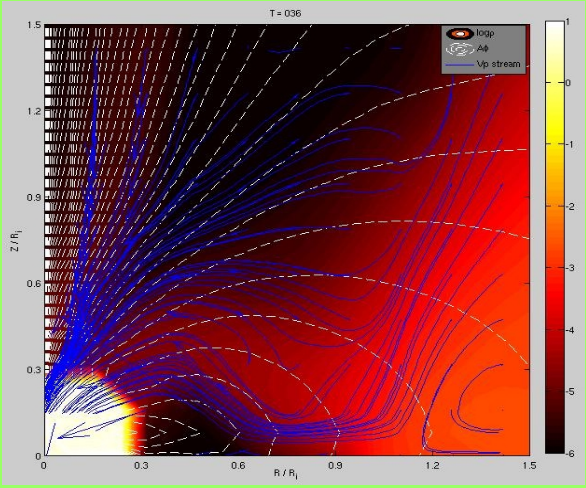
- Critical diffusivity
- Solution does not reach stationary state
- “Wing” sweeps quasi-periodically through the computational box
- New characteristic number Rb which, together with Rm, describes the influence of resistivity.

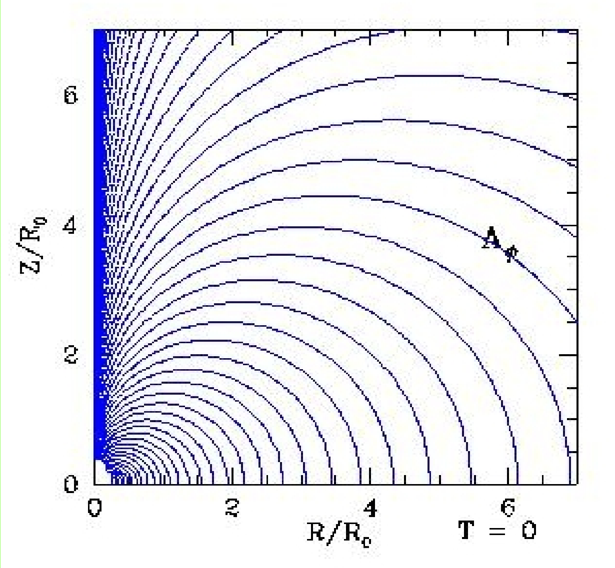


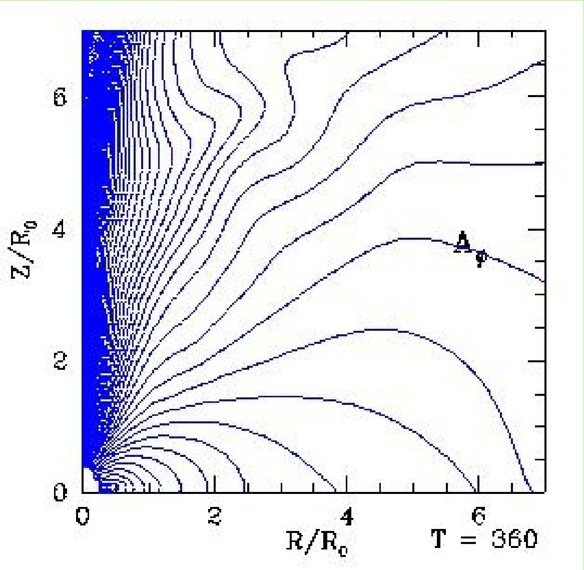
Implications for magnetospheric accretion mechanism simulations - 1





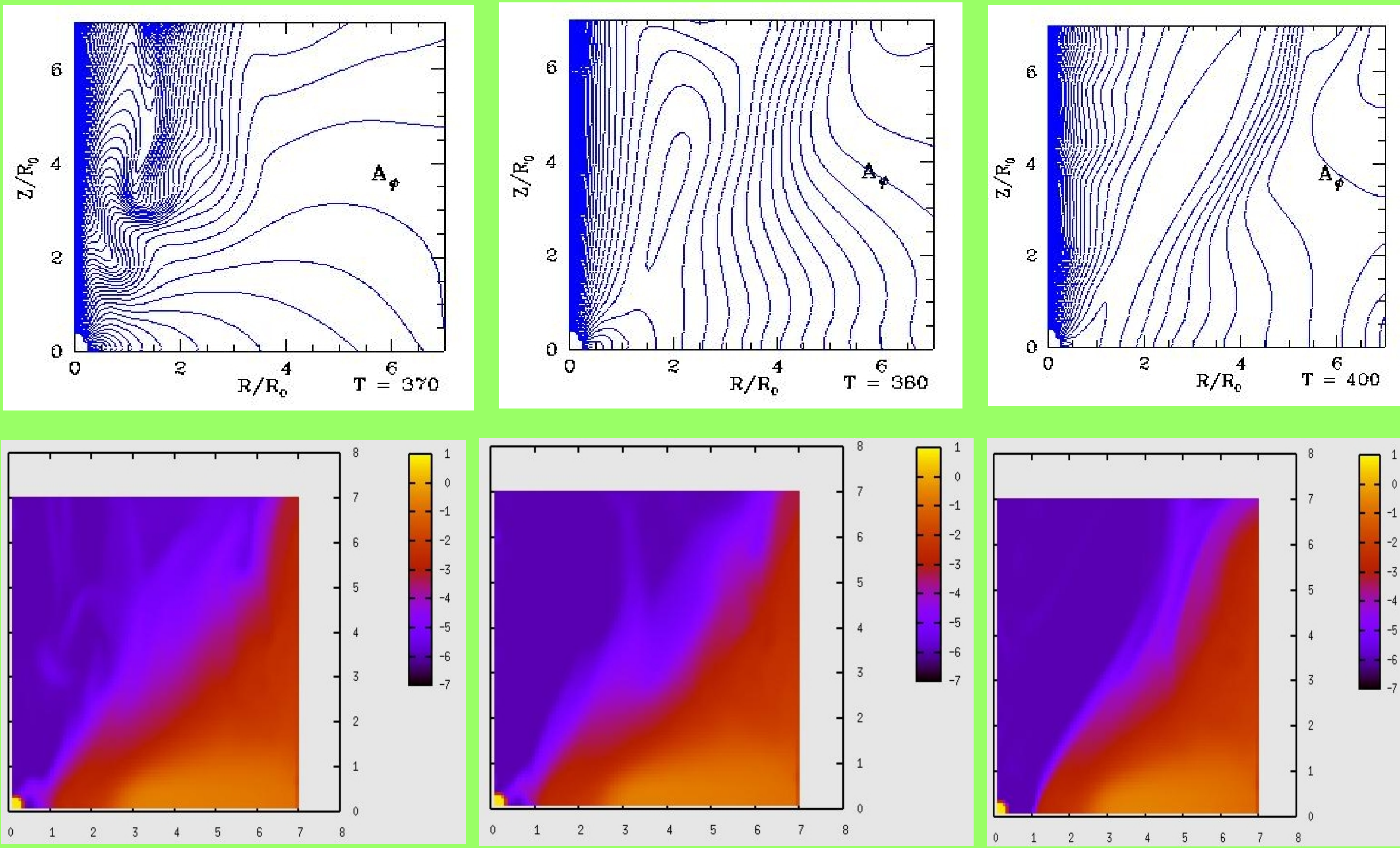






- star+disk, disk included
- stellar dipole magnetic field
- With lower diffusivity-reconnection does not occur-no funnel onto the star for 0.5 kGauss stellar field

Implications for magnetospheric accretion mechanism simulations - 2



- Cemeljic, Shang & Chiang, 2008, in preparation

Summary

- Self-similar analytical solutions modified and used as initial condition
- Two regimes of solution recognised: low and high resistivity case
- Low resistivity: stationary solution
- Super-critical solution: periodical?
- Prospects: astrophysical implications?