IAA Lunch Talk

Simulations of jets, revisited

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Outline

-Introduction

-Setup of simulations, magnetospheric interaction

-Results for various Prandtl numbers

-Problem in simulations with Pr<=1

-Recent solution: Pr~>1

Introduction

Why jets *revisited*?

-development of jet model:stellar wind, disk wind, reinstating the stellar wind in addition to disk wind.

-Main problem in simulations for years: no strong outflow

-Recent (2009) development: outflow overseen?

-Results with Pr~>1 show more possibilities

Resistive MHD equations

-in addition to physical resistivity, hydrostatic, viscous dissipation term could be added-but we investigate effects of resistivity, so we mimic viscosity with von Neumann-Richtmyer artificial viscosity, which is significant only for part of the flow with shocks-good for relaxation phase

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

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

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

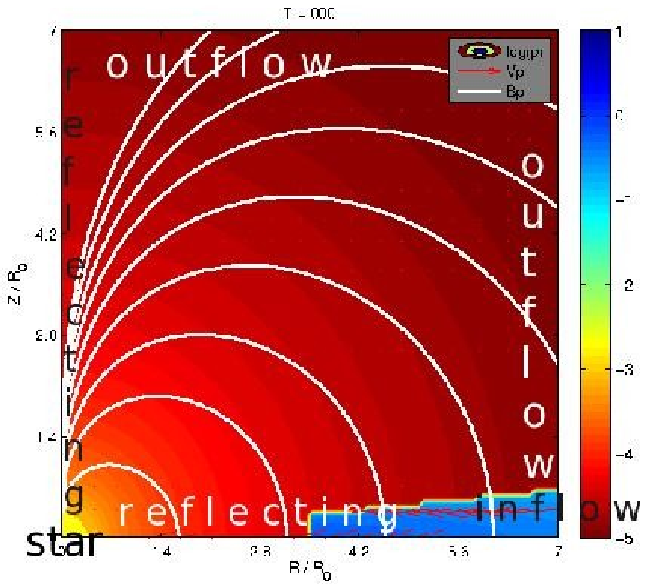
$$\rho \left[\frac{\partial e}{\partial t} + (\mathbf{v} \cdot \nabla) e \right] + p (\nabla \cdot \mathbf{v}) = 0 \quad (4)$$

$$\boldsymbol{j} = \frac{c}{4\pi} \nabla \times \boldsymbol{B} \,. \quad (5)$$

-We measure the effect by the magnetic Prandtl number,Pr=viscosity/resistivity. Two important regimes, when Pr<1 or Pr>1.

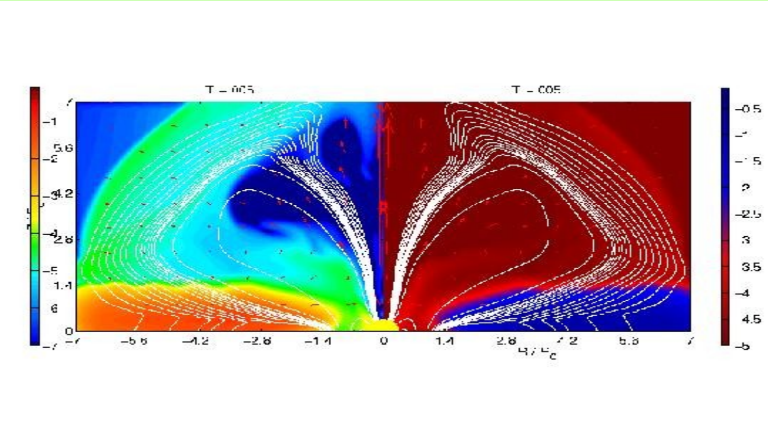
-Positioning of Rcor also important, for Rcor>Ri and Rcor<Ri results are different.

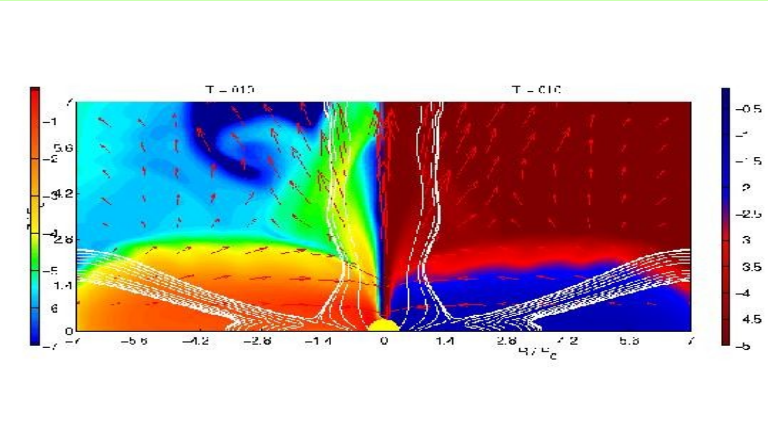
-Animation of our results for typical simulations with Pr~1 and Rcor>Ri

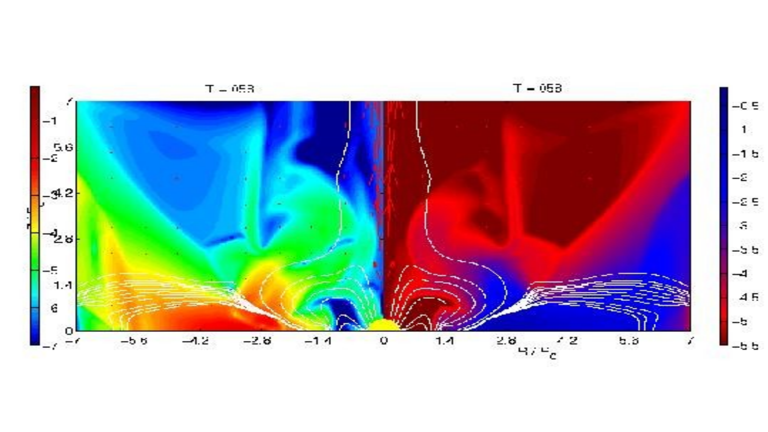


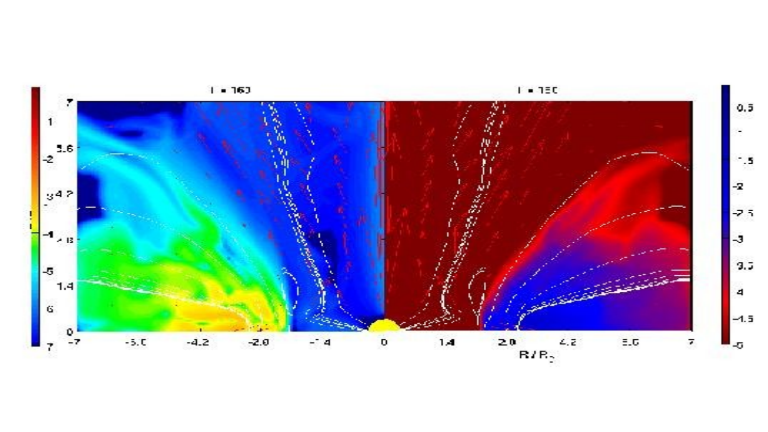
Results of our simulations

We find four characteristic stages, which appear in every (resistive) simulation-also in ideal MHD, because of numerical resistivity. 1) Initial relaxation with pinching of B, 2) Inflation & reconnection with opening of B, 3) Retraction of disk with transient flows onto central object, 4) Terminal quasi-equilibrium. These stages, all or some of them, can repeat periodically, depending on parameters.



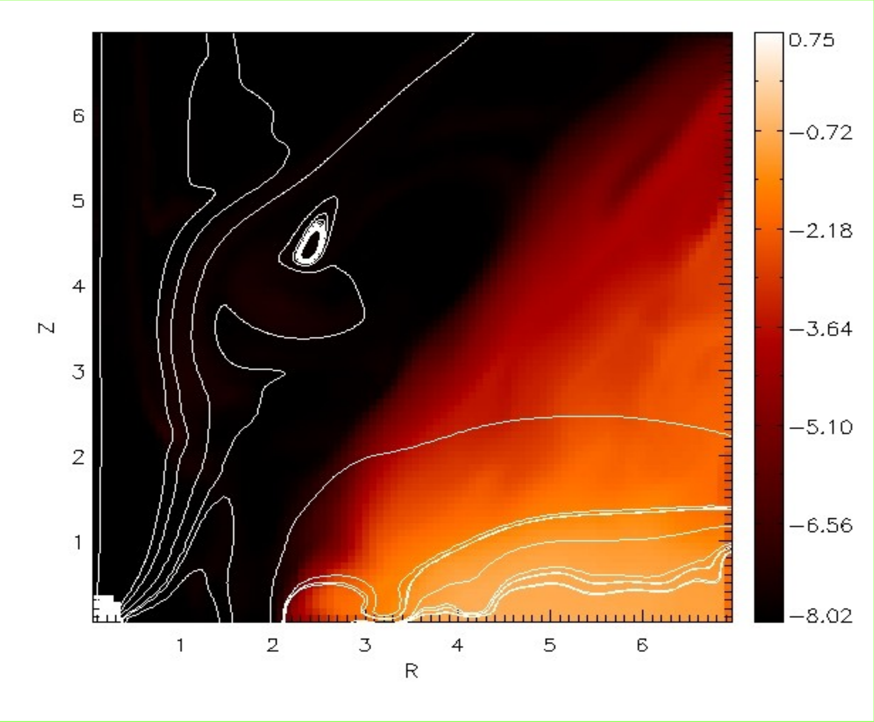






Problem: no outflows

-What are we doing here? Where is jet?



Romanova et al. last 10 years

-Weak propeller, disk accretion to a fast rotating star. Matter flow in the "propeller" regime for a star rotating at Omega_*=0.5 Omega_K* , smaller accretion rate, viscosity smaller a_vis=0.1, diffusivity a_dif<1; not enough interaction between magnetosphere & disk.

-Strong propeller regime, fast rotating star, quasi-periodic accretion and outflows in propeller regime. Larger accretion rate and viscosity: a_vis=0.3, a_dif=0.2. Color background shows density, lines are magnetic field lines. Evolution is shown for time interval from 800 to 1000 rotations. Time is measured in units of Keplerian rotation at R=1.

-Long lasting outflows in the form of conical winds. Enhanced accretion, inward transport of matter in the disk is faster than outward diffusion of magnetic flux (Pr>1, a_vis>a_dif).

Mass fluxes for different Rcor and Pr

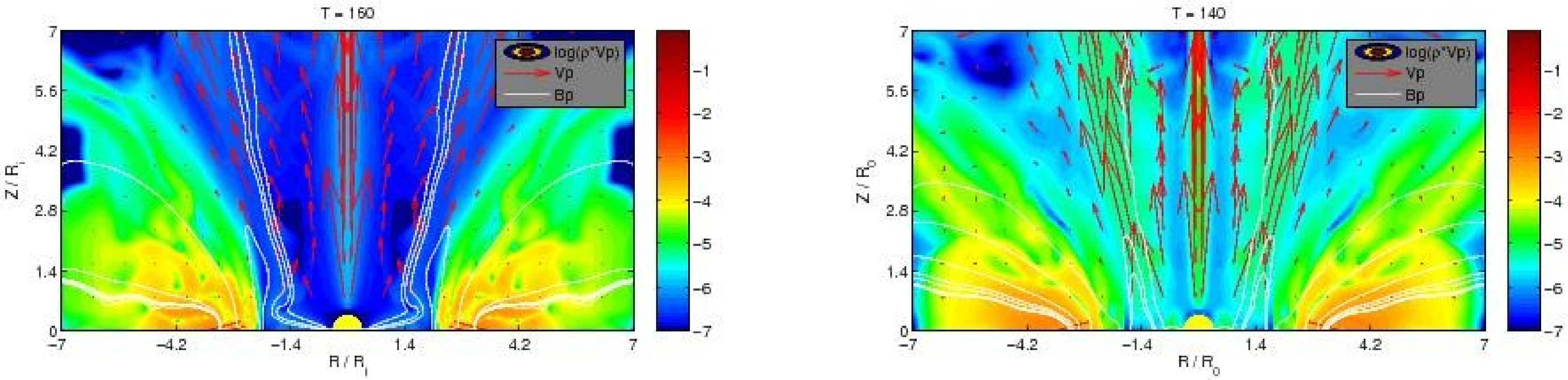


Fig. 4.— In snapshots at T=160 and T=140 shown is the mass flux ρ_v in logarithmic color grading for our typical case with $R_{cor} > R_i$ in the *left* panel, and for the case with $R_{cor} < R_i$ in the *right* panel.

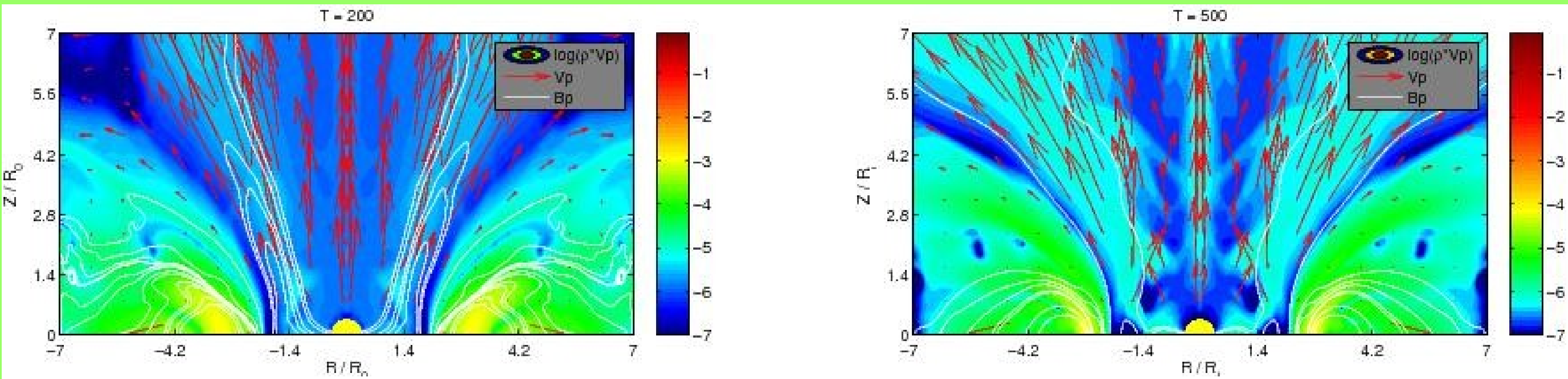


Fig. 11.— The mass flux ρv in logarithmic color grading for cases with Pr$>$ 1, with $R_{cor} > R_i$ in the *left* panel, and for the case with $R_{cor} < R_i$ and $B_* =$ 50 Gauss in the *right* panel. The axial outflow vanishes for slow rotating star, and for faster rotating star it is present.

Summary

-Numerical simulations of magnetospheric outflows

-Ideal MHD ver. resistive and viscous MHD

-Importance of magnetic Prandtl number Pr

-Problem in simulations with Pr<=1, no outflows

-For Pr~1 or Pr>1 magnetospheric outflows present