3D magneto hydrodynamic jet simulations

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Universality of disk-wind jets?

- Jets are common from many systems with accretion disks + central object.
- A ”Blandford-Payne” disk wind is succesful in explaining YSO jets.
- The mass of the central object largely determines the speed of the jet.
- The magnetic field on the disk determines the overall magnetic field structures, and hence the structure of the jet.
- We are investigating the universality of this by applying the models to AGNs.
- We investigate the magnetic field structure in the jet out to scales of 0.1-1 pc, while at the same time resolving the inner edge of the disk.
- Jets are 3-dimensional structures, necessitating 3-dimensional MHD simulations.

Initial setup

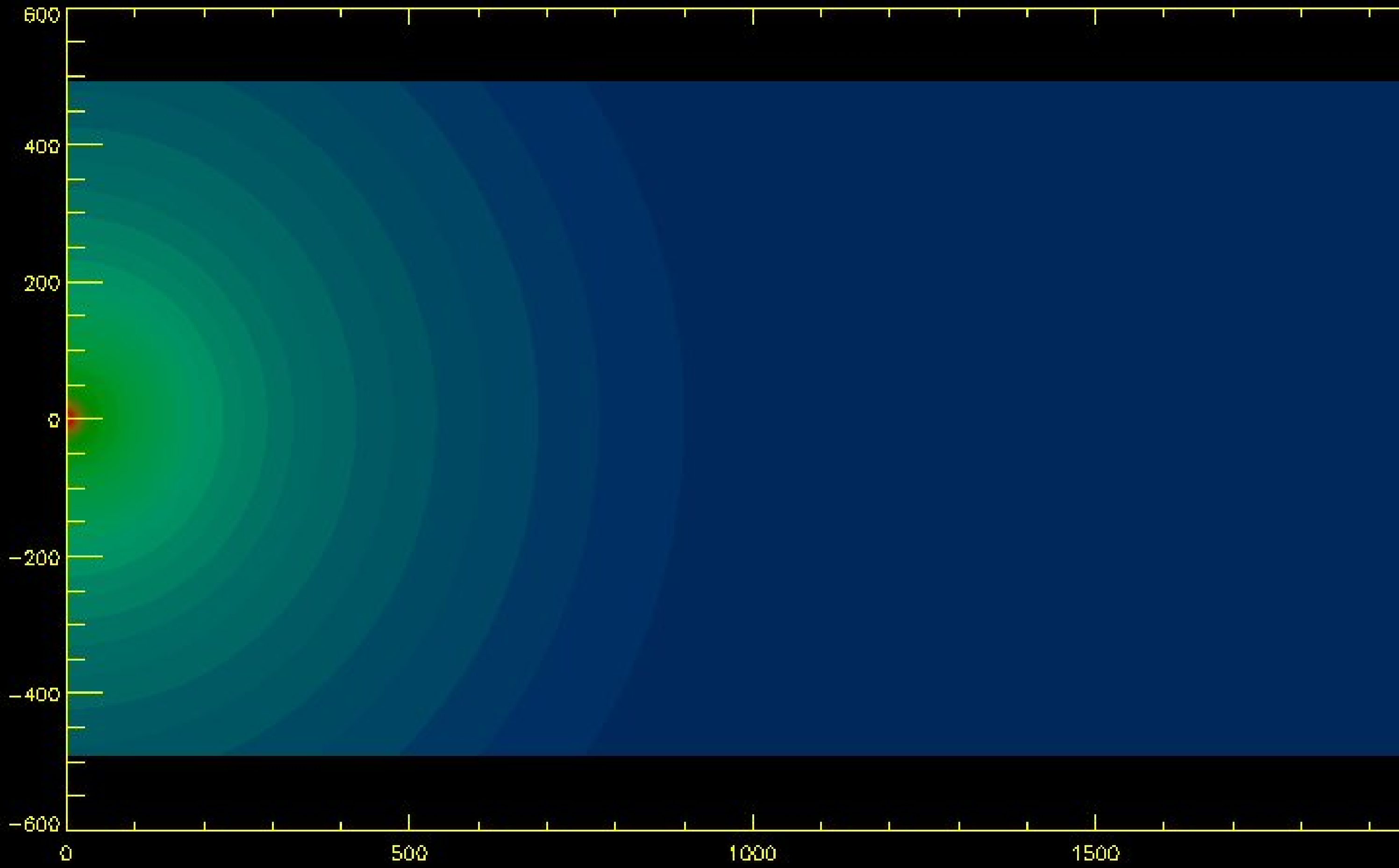
- Coronal density: $\rho \propto 1/R^{3/2}$
- Initial magnetic field is force free ($\mathbf{J}\times\mathbf{B} = \mathbf{0}$) and without a toroidal component.
- Setup is initialy in hydrostatic equilibrium.
- Disk as fixed boundary condition.

Disk

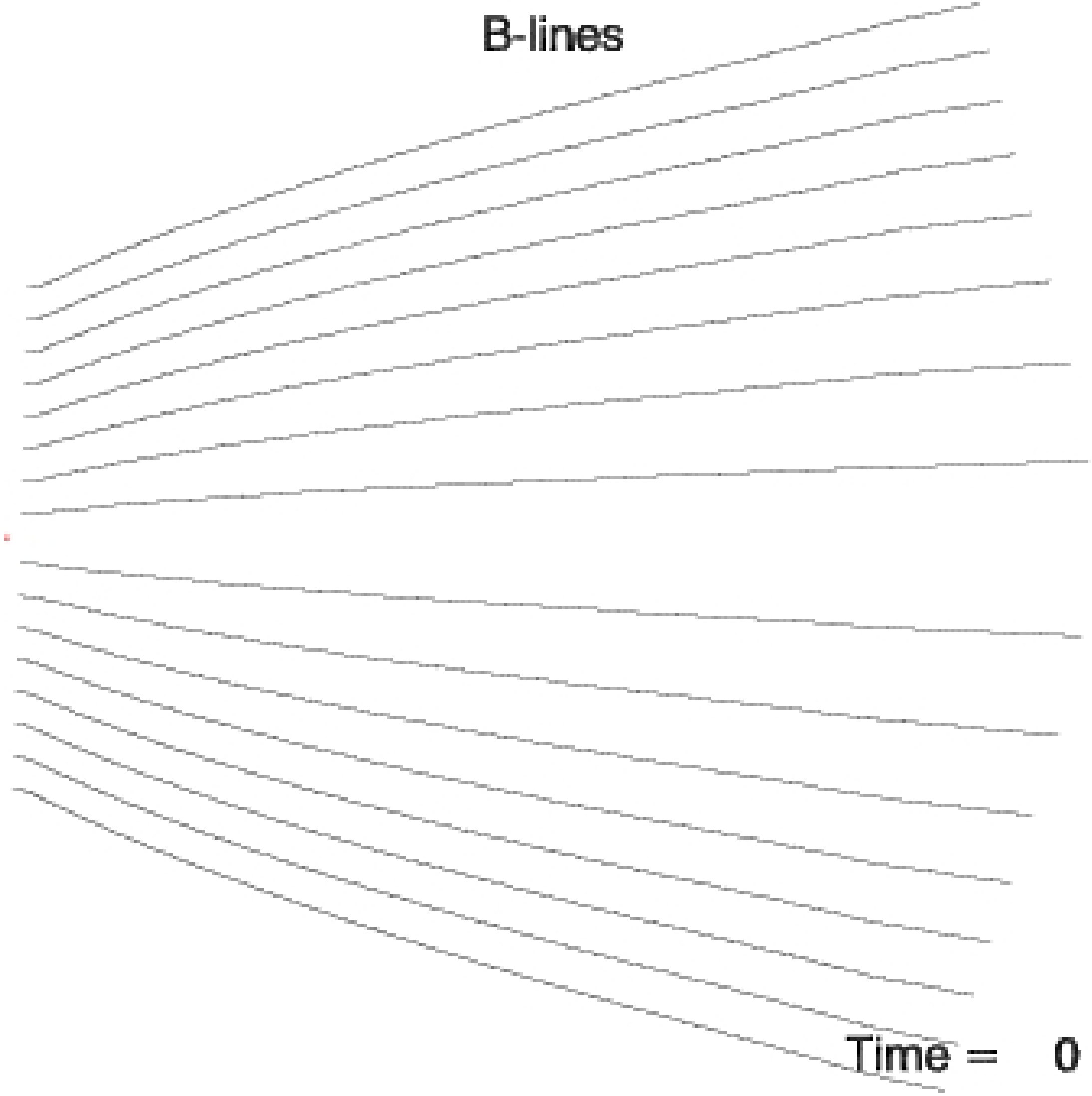
- Keplerian rotation.
- r_i is the inner disk radius ($r_i \approx 20$ M for $10^8 M_\odot$ black hole).
- Disk outer edge at $200 r_i \sim 4000$ M.
- Mass loading: mass injected from the disk with a velocity of 0.3% of the rotation-velocity in the disk.

Initial density distribution

$\rho \propto r^{-3/2}$



Initial magnetic field configuration



Simulation setup

- Using ZeusMP.
- Using Cartesian grid.
- Entire grid: 1536x500x500 zones, corresponding to 0 to 3000 r_i along the jet axis (0 to 60,000 M), and -900 to 900 r_i in each of the two directions perpendicular to the jet axis (-18,000 M to 18,000 M).

Basic equations

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

$$\frac{\partial \mathbf{B}}{\partial t} - \nabla \times (\mathbf{v} \times \mathbf{B}) = \mathbf{0}$$

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

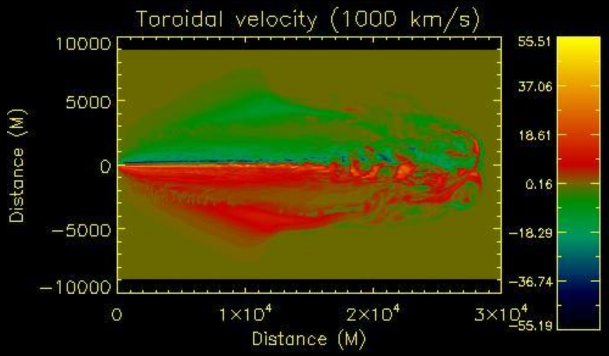
- Polytropic equation of state: $e = e(\rho)$.

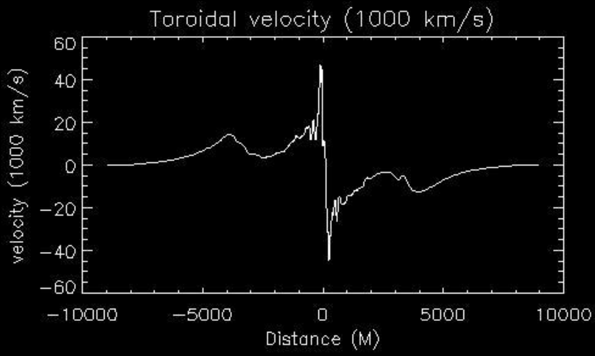
  Internal energy is a function of density only.
- We do not solve energy equation.
- $T \propto \rho^{\gamma-1}$; $\gamma = 5/3$.

Simulation results

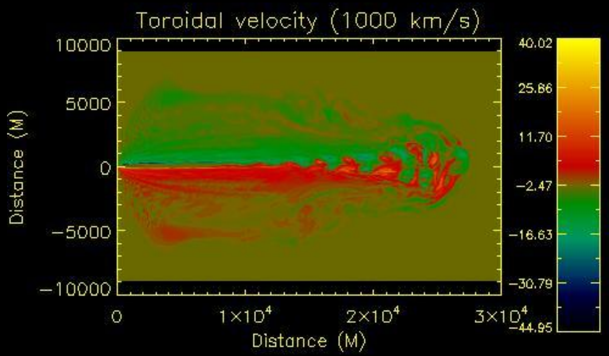
Toroidal velocity

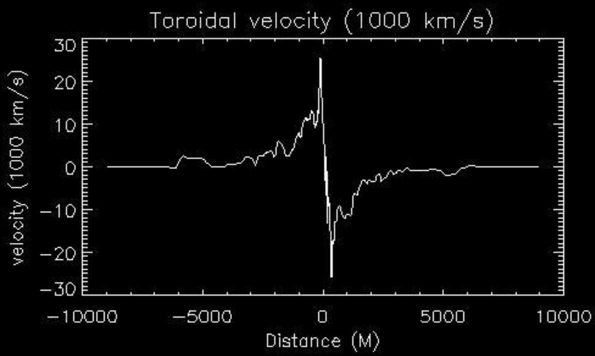
OP configuration (2 component jet):

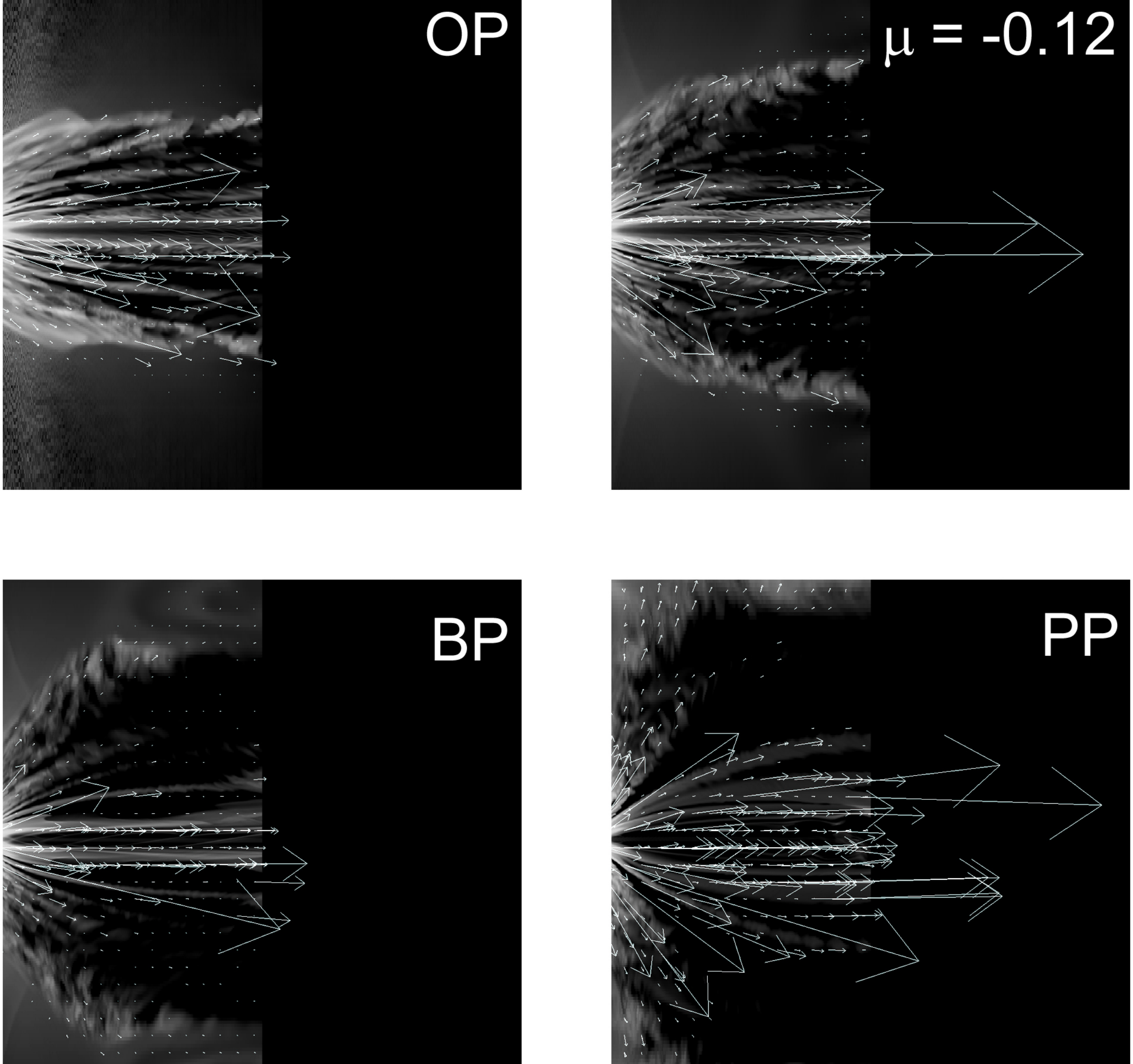




BP configuration (1 component jet):






OP
μ = -0.12
BP
PP

Summary

- More open field configurations lead to somewhat slower jets.
- A two component jet structure (thin inner jet surrounded by a cylindrical shaped outer jet) occurs in initially more collimated magnetic field configurations.
- More open magnetic field configurations lead to only one jet component

Thank you!