Black Holes from Stars to Galaxies – Across the Range of Masses
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Two-dimensional MHD simulations of accretion disk evaporation

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Abstract. We simulate the accretion disk evaporation to study the changes of accretion disk structure during the state transition from the soft state to the hard state. We performed 2 dimensional MHD simulations by including the heat conduction process. We assume the axisymmetric accretion and put a cold rotating gas torus in a hot halo in hydrostatic equilibrium initially. Weak magnetic fields are threaded vertically. Heat conduction equation and MHD equations are solved separately according to the time splitting method. We obtained the result that accretion disk is heated by the hot corona and the hot gas evaporates from the accretion disk surface. We found that magnetic fields lines bended by disk rotation restrict the energy transport vertically and make disk evaporation ineffective.

Keywords. Accretion, accretion disks – black hole physics – X-rays: binaries

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1. Introduction

The accretion disk evaporation model (Meyer-Hofmeister & Meyer 1999) is one of attractive models which can explain the state changes of black hole accretion flows. The hot corona heats the surface of cold accretion disk. The gas evaporates from the disk into the corona. Geometrically thin accretion disks change to geometrically thick hot accretion flows. The evaporation model can explain that the X-ray spectrum from accretion flows changes from the soft state to the hard state. We simulate the accretion disk evaporation by taking account of a heat conduction process to study the state transitions.

2. Numerical Models

Basic equations. We solve resistive MHD equations and heat conduction equation due to the time splitting method (Hayashi, Shibata, Matsumoto 1996, Yokoyama, Shibata 1997). We adopt the cylindrical coordinate and assume the axial symmetry.

The heat conduction equation is written as

$$\frac{1}{\gamma-1}\frac{k}{m}\rho\frac{dT}{dt} = \nabla\cdot\left(\kappa_0 T^{5/2}\frac{\boldsymbol{B}}{B^2}\left(\boldsymbol{B}\cdot\nabla\right)T\right). \tag{2.1}$$

Energy is transfered along to the magnetic fields lines. We adopt the heat conductivity, $\kappa_0 = 6.0\times10^{-6}$[g cm s^{-3} K$^{-7/2}$]. Other symbols have their usual meanings.

Conditions. An isothermal halo is in hydrostatic equilibrium initially. A rotating gas torus is dynamically balanced (Abramowicz *et al.* 1978). Magnetic fields are vertically threaded. Plasma β is 100. Black hole mass is 10 solar mass. An absorbing inner boundary condition is imposed.

Table 1. Units

Quantity	Symbol	Numerical unit
Length	r_0	3.0×10^{10}cm
Density	ρ_0	8.3×10^{-7}gcm^{-3}
Time	t_0	1.4×10^2s
Temperature	T_0	5.4×10^8K

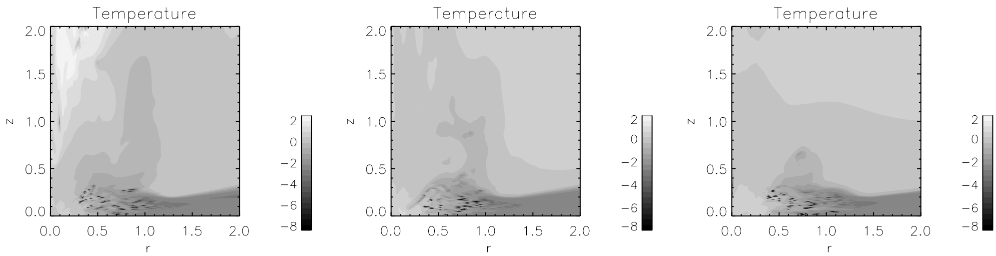

Figure 1. Temperature $\log(T/T_0)$ at $t = 8.0\ t_0$. Left: No heat conduction. Middle: Anisotropic heat conduction. Right: Isotropic heat conduction.

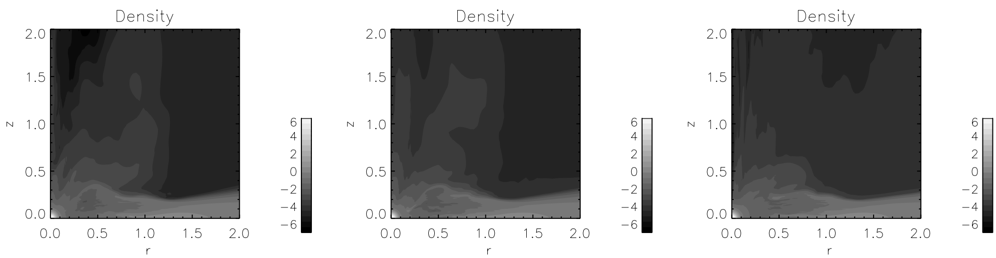

Figure 2. Density $\log(\rho/\rho_0)$ at $t = 8.0\ t_0$. Left: No heat conduction. Middle: Anisotropic heat conduction. Right: Isotropic heat conduction.

3. Results

Anisotropic conduction. Thermal energy is transfered mildly from a corona to a disk along to the magnetic field lines. The azimuthal component of magnetic fields become large by differential rotation, therefore the vertical energy transfer from a corona to a disk become inefficient due to the magnetic field line bending. The flow evolves almost same as the case of no conduction.

Isotropic conduction. Energy transfer from a hot corona to a cool disk continues regardless of the disk evolution. The structure of corona and accretion disk change wholly in short time scale. A corona become cool and dense and restrains the jet formation.

References

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