# §39. Time Variabilities of Black Hole Accretion Disks during State Transition

Matsumoto, R. (Chiba Univ.),
Machida, M. (National Astronomical Observatory)

Magnetic fields play essential roles in time variabilities of black hole accretion disks. Mass accretion takes place by transporting the angular momentum. Efficient angular momentum transport is enabled by the magneto-rotational instability (MRI) which grows in differentially rotating weakly magnetized disks. We now can study the evolution of accretion disks without introducing the phenomenological $\alpha$-viscosity.

Multi-wavelength observations of black hole candidates revealed that relativistic jets are ejected during the transition from a spectrally hard state to a soft state. This transition takes place when the accretion rate exceeds the threshold (figure 1).

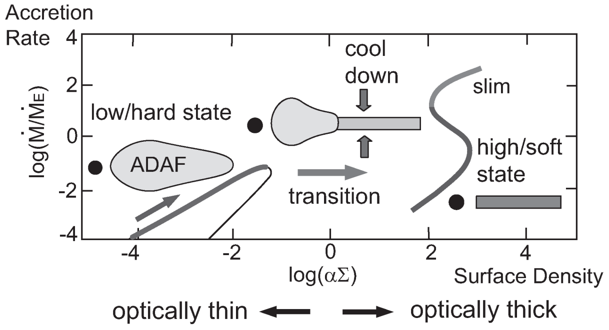

Figure 1: A schematic picture of the hard-to-soft state transition in black hole accretion disks. Solid curves show thermal equilibrium curves of conventional accretion disks obtained by assuming $\alpha$-viscosity.

Machida et al. (2006) carried out three-dimensional global magnetohydrodynamic (MHD) simulations of the hard-to-soft transition by taking into account the radiative cooling. They found that the hard state disk shrinking in the vertical direction by cooling transits to an intermediate state supported by the magnetic pressure. The magnetically supported disk is optically thin because magnetic pressure inflates the disk. Oda et al. (2007) constructed a steady model of black hole accretion disks supported by the magnetic pressure. Magnetic flux should be dissipated or buoyantly escape from the disk to complete the transition to an optically thick, soft state. Relativistic jets may be produced by the magnetic energy release.

Machida & Matsumoto (2008) carried out global 3D MHD simulations to study the dependence of time variabilities of black hole accretion flows on the temperature of the accreting gas. The initial state is an outer torus threaded by weak azimuthal magnetic fields. Figure 2 shows the density distribution for a hot disk model (left) and a cool disk model (right).

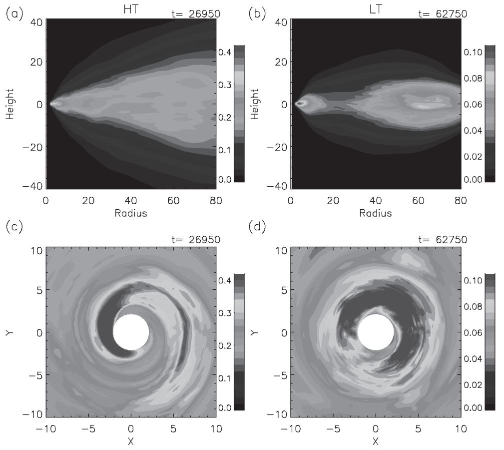

Figure 2: Density distribution for a model starting from a hot torus (left panels) and a cool torus (right panels). In the latter model, inner torus is formed. The torus deforms itself into a crescent shape.

Figure 3 shows the power spectral density (PSD) of time variations of accretion rate for a model starting from a hot torus and a cool torus. In the latter model, the width of the PSD becomes narrower because the accretion disk is separated into an inner torus and an outer torus. This result is consistent with the observation that the PSD becomes narrower during the hard-to-soft transition.

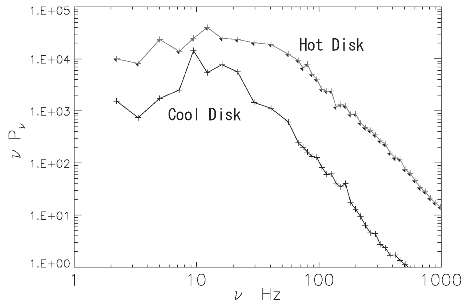

Figure 3: Power spectral density of time variabilities times frequency $\nu$ for a model starting from a hot torus (gray) and a cool torus (black). The black hole mass is $10M_\odot$.

**1)** Machida, M., Nakamura, K.E., and Matsumoto, R., Publ. Astron. Soc. Japan, **58**, (2006) 193

**2)** Machida, M., and Matsumoto, R., Publ. Astron. Soc. Japan, **60**, (2008) in press

**3)** Oda, H., Machida, M., Nakamura, K.E., and Matsumoto, R., Publ. Astron. Soc. Japan, **59**, (2007) 457