East-Asia School and Workshop on Laboratory, Space, and Astrophysical Plasmas, Tsukuba, Japan, Jul. 11 - Jul. 16, 2016

Plasma Dynamics in Accretion Disks

R. Matsumoto

Department of Physics, Graduate School of Science, Chiba University,
1-33 Yayoi-cho, Inage-ku, Chiba 263-8522, Japan
matsumoto.ryoji@faculty.chiba-u.jp

Abstract

We review results of global magnetohydrodynamic (MHD) simulations of black hole accretion flows carried out by taking into account the radiative cooling. In differentially rotating, weakly magnetized disks, the magnetic field amplification by magneto-rotational instability (MRI) and the buoyant escape of the magnetic flux drive quasi-periodic dynamo, in which the direction of mean azimuthal magnetic fields reverses quasi-periodically. The buoyantly rising magnetic loops twisted by the rotation of the disk form current sheets inside the expanding magnetic loops. Magnetic reconnection taking place in the current sheet produce plasmoids and outflows. When the accretion rate is smaller than the threshold for the onset of the cooling instability, radiatively inefficient, optically thin, hot accretion flow is formed. This state corresponds to the X-ray hard state observed in galactic black hole candidates and in low luminosity active galactic nuclei (AGNs).

When the accretion rate exceeds the upper limit for the existence of radiatively inefficient accretion flow (RIAF), the disk shrinks in the vertical direction because the radiative cooling rate exceeds the heating rate. This transition corresponds to the hard-to-soft transition observed in black hole candidates. Machida et al. (2006) showed by three-dimensional global MHD simulations that magnetically supported disk is formed during the vertical contraction of the disk because the total azimuthal magnetic flux should be conserved. Since the magnetic pressure supports the disk, the disk stays in optically thin state. This state corresponds to the luminous hard state observed during the hard-to-soft transition. Machida et al. (2006), however, could not carry out longer time scale simulations because numerical oscillations appeared in magnetically supported region.

Here, we present numerical results of the hard-to-soft state transition obtained by applying CANS+ code, in which HLLD scheme (Miyoshi and Kusano 2005) is applied for MHD equations. In CANS+, 5th order accuracy in space is achieved by applying MP5 scheme. We confirmed that magnetically supported disk is formed during the transition. We found that magnetic reconnection taking place in the interface between the magnetically supported, cool disk and ambient RIAF heats the cool disk and drive outflows. We discuss the observational signatures of the co-existence of the magnetically supported cool disk and hot RIAF. We also present preliminary results of MHD simulations taking into account the evaporation of the cool disk by thermal conduction.