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Magnetic Heating during State Transitions in Changing Look AGN

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Stellar mass black hole candidates show transitions between a hard X-ray dominant state and a soft X-ray dominant state. These transitions are driven by the increase or decrease of the accretion rate. In some active galactic nuclei (AGN), called changing look AGN, state tansition between a low-luminosity state without broad emission lines and a luminous state with broad emission lines are observed. Noda and Done[1] showed that in changing look AGN, hard X-ray is dominant in the low-luminosity state, while soft X-ray excess is observed in the bright state.

The soft X-ray excess in luminous AGN cannot be explained by standard accretion disks because the disk temperature of the standard disk around a supermassive black hole is the order of 10^5K. The soft X-ray excess state in changing look AGN is more like the bright hard state of stellar mass black holes. During the hard-to-soft transition in outbursts of stellar mass black holes, they stay in the bright hard state for 100days. Thus the bright hard state should be in nearly thermal equilibtium.

Machida et al.[2] reported the results of global three-dinmensional magnetohydrodynamic (MHD) simulations of black hole accretion flows during the hard-to-soft state transition. They assumed a stellar mass black hole and optically thin cooling. They found that when the surface density of the disk exceeds the upper limit for radiatively inefficient accretion flows (RIAF), the accretion flow shrinks in the vertical direction by radiative cooling. When the azimuthal magnetic flux is consdrved, since azimuthal magnetic field is amplified, the disk becomes supported by the magnetic pressure. Motivated by this result, Oda et al.[3] obtained thermal equilibrium curves of magnetically supported disks connecting the RIAF solution and the standard disk.

Igarashi et al. [4][5] extended the Machida's simulation by carrying out global 3D radiation MHD simulatios. They adopted higher accuracy CANS+ code [6] for MHD part and solved the evolution of the radiation energy density and radiative flux assuming M1 closure. Igarashi et al.[4] showed that magnetically supported Thomson thick disk is formed when the accretion rate is 10% of the Eddington accretion rate, and that radial oscillations are excited when the radiation pressure becomes dominant. However, the temperature of the magnetic pressure dominant region is the order of 10^8K, and higher than the soft X-ray emitting region.

Igarashi et al. [5] updated this simulation by considering the Compton cooling. They showed that when the accretion rate is the order of 10% of the Eddington accretion rate, hard X-ray emitting hot RIAF near the black hole co-exists with outer soft X-ray emitting magnetically supported Thomson thick disk. The radius of the interface between the hot and cool disk is around $20r_s$, where r_s is the Schwarzschild radius. The temperature of the Thomson thick region is 10^6-10^7K. Although the Compton cooling time is less than the dynamical time scale, the temprature of the region is sustained by the dissipation of the magnetic enrgy transported from the inner region. Figure 1 schematically shows the numerical result. Magnetic energy accumulated around the interfaice is transported outward as Poynting flux of counter-helicity helical flux tubes. The magnetic energy is dissipated by the merging of the flux tubes and heat the plasma. This magnetic heating sustains the temperature of the soft X-ray emitting region (see Figure 1). Results of the higher resolution RMHD simulations will be presented.

References

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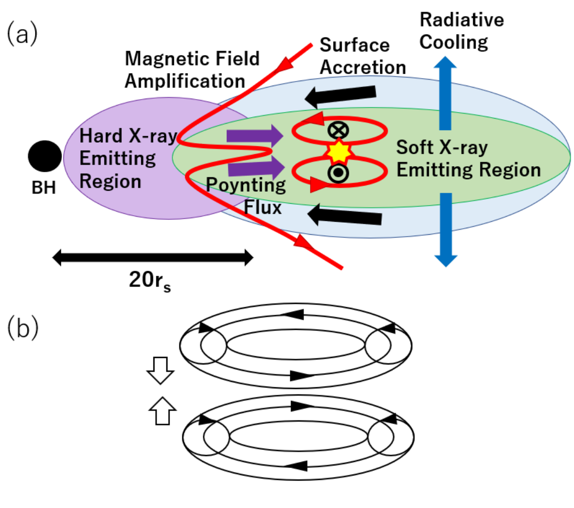

Fig. 1 (a) A schematic picture of the results of RMHD simulations by Igarashi et al.[5], (b) Merging of counter-helicity helical flux tubes.