Global MHD Simulations of Magnetic Reconnection in Accretion Disks

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We present the results of global three-dimensional magnetohydrodynamic (MHD) simulations of accretion disks initially threaded by weak toroidal magnetic fields. As the magnetorotational instability (MRI) grows, magnetic turbulence develops inside the disk. Magnetic energy released in the turbulent disk produces 1/f-like fluctuations of X-ray luminosity. We found that in the innermost region of hot black hole accretion disks, large-scale current sheets are created in regions where mass accretes along bisymmetric spiral channels. When the magnetic channel becomes rarefied as the mass accretes to the black hole, magnetic reconnection takes place in such current sheets. The magnetic reconnection produces sporadic increase of X-ray luminosity known as X-ray shots (Machida and Matsumoto 2003).

In cool accretion disks around a black hole, inner torus is created inside 10 Schwarzschild radius. We found that sawtooth like oscillation takes place in the torus. When such a torus is formed, nonaxisymmetric, $m = 1$ mode (m is the azimuthal wave number) grows. Magnetic fields are twisted by the nonaxisymmetric motion and amplified. At this stage, large-scale current sheets are formed inside the disk. When the magnetic energy becomes comparable to the thermal energy, magnetic reconnection taking place in the current sheet releases the accumulated magnetic energy. As a result of the magnetic reconnection, the disk becomes circular and becomes dominated by gas pressure (i.e., $\beta = p_{gas}/p_{mag} \gg 1$). Subsequently, the growth of the $m = 1$ mode and the amplification of magnetic fields takes place again. The magnetic energy and the mass accretion rate shows sawtooth like oscillation with frequency $5 - 10$Hz when the mass of the central black hole is 10 solar mass. This frequency is comparable to the frequency of low-frequency quasi-periodic oscillations (QPOs) observed in galactic black hole candidates. We also found that high frequency (~ 100Hz) QPOs are excited when low-frequency QPO appears.