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MHD Simulations of Jets from Magnetized Accretion Disk

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In the last 10 years, magnetohydrodynamic (MHD) simulations of jets ejected from magnetized accretion disks, such as that shown in Color Figure 7, have developed significantly through the rapid development of supercomputers:

1. It has been found that the terminal velocity and mass flux of jets in nonsteady MHD models show basically the same scaling laws as those found for steady MHD models (Kudoh and Shibata 1995, 1997; Kudoh et al. 1998).

2. Nevertheless, magnetized accretion disks and jets never reach steady state because of magneto-rotational instability occurring in magnetized accretion disks (Kudoh et al. 1998). Disks are full of flares and bursts, and very energetic jets are intermittently produced in association with them (Hayashi et al. 1996; Kuwabara et al. 2000).

3. 3D simulations of MHD jets from accretion disks have started to be performed, which show that the MHD jet is dynamically stable for the kink instability at least for several Keplerian orbits even if the magnetic field in the jet is highly twisted (Matsumoto and Shibata 1997).

4. Self-consistent general relativistic MHD simulations have been performed for the first time on jets from disks around a black hole, which revealed the formation of shock waves and ejection of jets from near to the hole inside $3r_s$, where r_s is the Schwarzchild radius. At present, the maximum Lorentz factor of jets found in these nonsteady simulations is about 2, though this limit is basically due to difficulty of simulations of high Lorentz factor MHD plasmas (Koide et al. 1998, 1999, 2000).

Although these are remarkable achievements, it is still difficult to construct self-consistent time-dependent MHD models of jets from near to the black hole to the scale of VSOP jets. The reader is referred to Shibata and Kudoh (1999) for a review of recent studies on time-dependent MHD simulations of jets from accretion disks.

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