Global Structure of Three Distinct Accretion Flows and Outflows around Black Holes from Two-Dimensional Radiation-Magnetohydrodynamic Simulations

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With a two-dimensional global Radiation-magnetohydrodynamic (RMHD) code [1], we could reproduce three distinct inflow-outflow modes around black holes. Our three models correspond to the two-dimensional RMHD version of the slim disk (supercritical flow), the standard disk, and the RIAF, all with substantial outflows (see Figure 1) [2].

We find the supercritical disk accretion flow, of which the photon luminosity exceeds the Eddington luminosity. The vertical component of the radiation force balances that of the gravity in the disk region but it largely exceeds the gravity above the disk. Our RMHD simulations reveal a new type of jet, i.e., the radiatively driven, magnetically collimated outflow, which might account for the jets of radio-loud NLS1s and microquasars [3,4]. The disk, the temperature of which is around 10^{7-8} K, is surrounded by hot outflowing matter, $> 10^9$ K, which would induce Compton upscattering and obscuration of the inner part of the disk. Because of the mildly collimated radiative flux, the apparent (isotropic) photon luminosity is $\sim 22 L_E$, which is 1.5×10^{41} erg s^{-1} for the black hole of $50\,M_\odot$ in the face-on view. It implies that our supercritical model is able to explain the central engine of ULXs [5].

When the radiative cooling is effective, a cold ($\sim 10^6$ K) geometrically thin disk forms and enveloped by the hot rarefied atmosphere with $T_{gas} > 10^9$ K, Compton upscattering the seed photons from the cold disk. The cold thermal component and the non-thermal hard component of the spectra are observed in luminous AGNs and in the high-soft state of BHBs [6,7]. The disk wind appears above the disk, which was not predicted in the framework of the standard disk model. This result seems to be consistent with the observations of the blueshifted absorption lines [8].

The simulations with low accretion rate corresponds to the RIAF. The magnetic-pressure force, together with the gas-pressure force, drives the outflows. The flow releases the energy via jets rather than via radiation. The accretion flow as well as the outflows are hot and optically thin. Thus, the spectra would resemble those of the low-luminosity AGNs and of the BHBs in their low-hard state [9].

References

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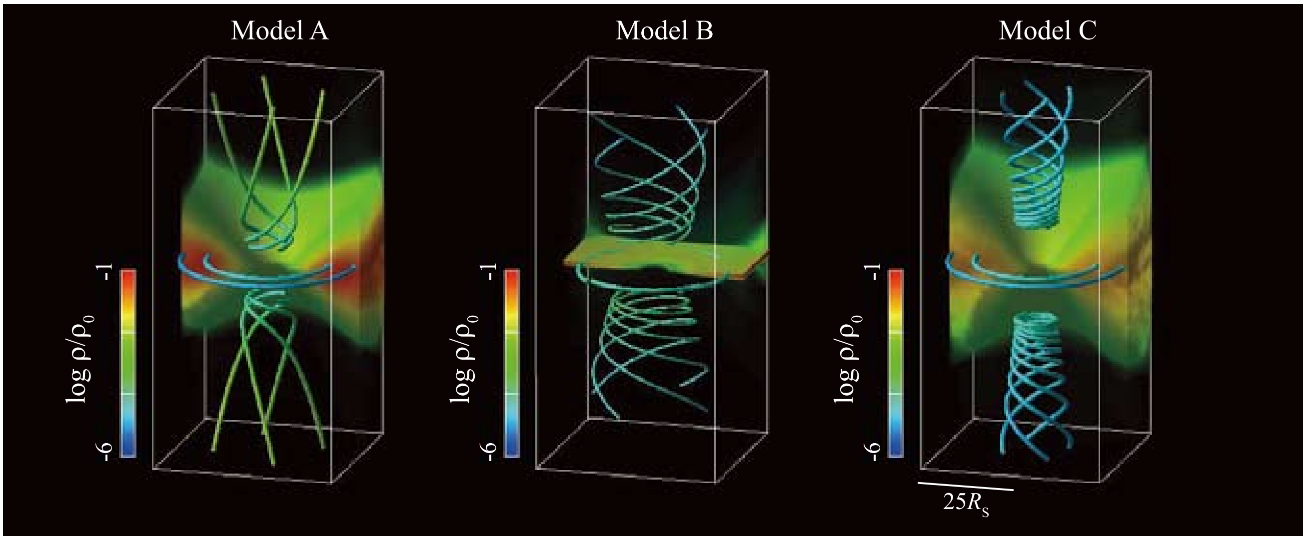

Figure 1: Simulated normalized density distributions (color) and streamlines near the black hole for three models, which correspond to the two-dimensional RMHD version of the slim disk (supercritical flow; left), the standard disk (center), and the RIAF (right).