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Global Radiation Magnetohydrodynamic Simulations of Precessing Disk around a Spinning Black Hole

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The rotating gas around the black holes (BH) forms the accretion disk during its accretion to the BHs. The gravitational energy of the accreting gas is released and a part of the released energy is converted to the thermal, magnetic, and radiation energy. As a result, enormous energy can be ejected as the strong radiation and/or outflows from the compact object. To research the structure and dynamics of the accretion disk, general relativistic (GR) radiation MHD simulations have been performed [1,2,3]. However, the rotation axis of the accretion disk is assumed to be aligned with the spin axis of the BH in their simulations. It is possible that the rotation axis is misaligned with the BH spin axis.

When the BH spin axis is not aligned with the rotation axis, it has been pointed out that the frame-dragging effect can cause the precession of the accretion disk around the BH (Lense-Thirring effect). In fact, GR MHD simulations reproduced the disk precession [4,5,6]. This precession might be origin of the quasi-periodic oscillation of the luminosity and the wiggling jet.

We performed GR radiation MHD simulation of the tilted accretion disk to research effects of the precession for high luminosity object. In the Figure 1, left panel shows the accretion disk (blue) and outflow (orange). The outflow is not ejected toward the BH spin axis (white arrow), but toward the rotation axis of the accretion disk. Near the BH, the accretion flow forms nonaxisymmetric structure. These features are consistent with the previous studies [4,5].

Figure 2 shows the time evolution of the polar angles (top) and azimuthal angles (bottom) of the rotation axis of the accretion disk (black), propagation direction of the radiation (red), and propagation direction of the outflow (blue). All polar angles remain almost the same as the initial tilt angle (~30 degrees). All azimuthal angles increase on average. This means the accretion disk, radiation propagation direction, and outflow propagation direction are precessing. In our simulation, the azimuthal angle becomes 20 degrees larger than the initial azimuthal angle in 0.5 second for the 10 solar mass BH. Our simulation can demonstrate not only the precession of the accretion disk and outflow but also precession of the radiation propagation direction.

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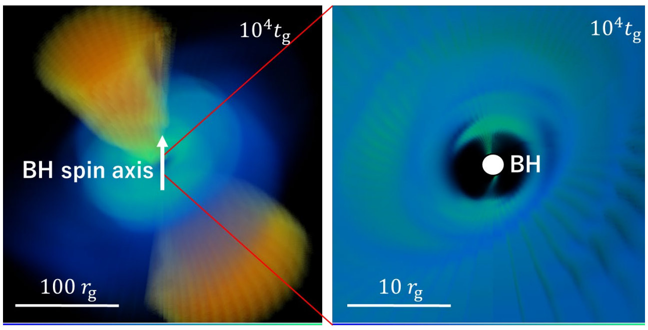

Figure 1 Left panel shows volume rendered density (blue) and lorentz factor (orange). The white arrow shows the BH spin axis. Right panel shows the density distribution near the BH (white filled circle).

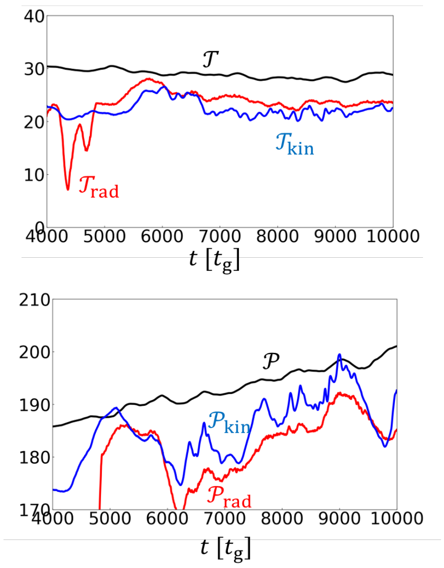

Figure 2 Time evolution of the polar angles (top) and azimuthal angles (bottom) of the rotation axis (black), radiation propagation direction (red), and outflow propagation direction (blue).