8th Asia-Pacific Conference on Plasma Physics, 3-8 Nov, 2024 at Malacca

Multi-Wavelength Radiation Properties of Black Hole Accretion Flows and Relativistic Jets

Tomohisa Kawashima[1]
[1] Institute for Cosmic Ray Research, The University of Tokyo
e-mail (speaker): kawshm@icrr.u-tokyo.ac.jp

Astrophysical black holes are thought to be powered by accretion flows, which are plasma spirally falling onto the central object, via the gravitational energy release. As a consequence, an enormous amount of radiation will be emitted and powerful outflows (i.e., relativistic jets and mildly relativistic winds) will be also ejected.

It is widely considered that one of the most important physical parameters of black hole is the spin (i.e., the angular momentum). This is in part because it will be one of the strong proofs of the validity of Einstein's theory of gravity, and in part because it may play an essential role on the launching of relativistic jets: one of the most plausible launching mechanisms of the relativisitic jet is the "Blandford-Znajek process", i.e., the extraction of the black-hole spin energy via the magnetic field threading the region near the black holes.

Despite the importance of the black-spin mentioned above, it has not yet been strongly constrained [1-2]. Theoretical ideas to constrain the magnitude of the black-hole spin and launching mechanism of the relativistic jets are desired. We have, therefore, developed a multi-wavelength GRRT code RAIKOU[3]. The code enables us to calculate the images and multi-wavelength spectra of accretion flows and relativistic jets of supermassive black holes to reveal the black hole spacetime and the dynamics of accretion flows and relativistic jets.

For example, as a consequence of the study of multi-wavelength spectra of a phenomenological models of low-luminosity accretion flows, we have found that the photon spectra become harder when the magnitude of the black hole spin is higher. This is because the inverse-Compton scatterings producing the X-ray photons occur in the region closer to the black hole, when the black hole spin is higher. The plasma temperature is higher in the vicinity of the black holes, so that a larger amount of the X-ray photons are generated via the inverse-Compton scattering there.

On the other hand, it is meaningful to consider another direction to exploring the black-hole spin. For example, the Lense-Thirring precession is the phenomena caused by the frame-dragging effect, i.e., the effect of the black-hole spin. We carried out numerical simulations of tilted accretion flow, in which the rotation-axis of the accretion flow misaligns to the spin-axis of the black hole (Figure 1). It has been found that the timescale of the precession agrees with the observed periodic time of the oscillation of the relativistic jet in M87[]. This proposes that the black hole in M87 possess the finite magnitude of the black hole spin, and the jet launching mechanism is related to the black hole spin.

This work was supported by JSPS Grant-in-Aid for Scientific Research (C) JP23K03448, by MEXT as "Program for Promoting Researches on the Supercomputer Fugaku" (Structure and Evolution of the Universe Unraveled by Fusion of Simulation and AI; Grant Number JPMXP1020230406), by the HPCI System Research Project (Project ID: hp230116, hp240054).

References

[1] Event Horizon Telescope Collaboration, Astrophysical Journal Letters, vol. 875, L1 (2019)
[2] Event Horizon Telescope Collaboration, Astrophysical Journal Letters, vol. 930, L13 (2022)
[3] Kawashima, T., Ohsuga, K., Takahashi, H. R., Astrophysical Journal, vol. 949, 101 (2023)
[4] Cui, Y., Hada, K., Kawashima, T., et al. Nature, vol. 622, 711 (2023)

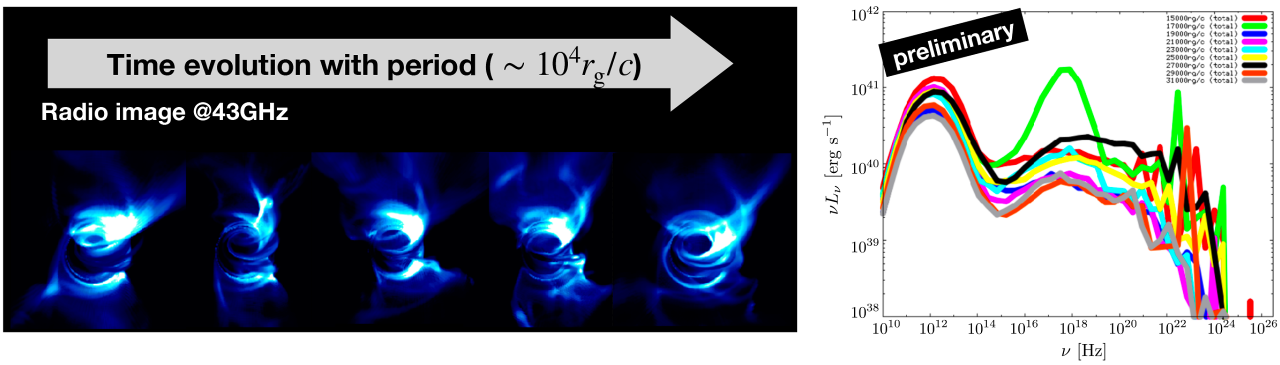

Figure 1. Left: time-series of simulated radio images of a relativistic jet and a tilted accretion flow with Lense-Thirring precession. The relativistic jets shows the precession with the timescale of ~10,000 times the light-crossing time per gravitational radius. Right: time-evolution of. multi-wavelength photon spectra.