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Measurement of Black Hole Spin with the Event Horizon Telescope: Theory of Radiative Echoes and VLBI Observations

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Observational measurement of the black-hole spacetime is one of the essential topics in modern physics and astrophysics, since it will lead to a critical test of the theory of general relativity. In general relativity, the spacetime around is uniquely determined by its mass and spin parameter. The mass can be accurately measured by observing orbits of stars or gas dynamics inside the sphere of its gravitational influence. On the other hand, it is not easy to extract the spin information, which depends on the complexity of accretion flow properties and spacetime effects in the vicinity of the black hole.

In this presentation, we simulate Event Horizon Telescope (EHT) observations for a gas cloud intermittently falling onto a black hole and construct a method for spin measurement based on its relativistic flux variation. We investigate the spin's signature by calculating an infalling gas cloud's motion and photon trajectories in the Kerr spacetime by the general relativistic ray-tracing method. The light curve of the infalling gas cloud is composed of peaks formed by photons that directly reach a distant observer and by secondary ones reaching the observer after more than one rotation around the black hole. The time interval between the peaks is determined by a period of photon rotation near the photon circular orbit, which uniquely depends on the spin.

To optimize our new spin measurement method, we perform synthetic EHT observations for the supermassive black hole at the Galactic center (Sgr A*) under a more realistic situation by performing three-dimensional general relativistic magnetohydrodynamics simulations. Even for the realistic situation, the black hole spin's signature is detectable in correlated flux densities, which are accurately calibrated by baselines between sites with redundant stations. The synthetic observations indicate that our methodology can be applied to EHT observations of Sgr A* from April 2017-2022.*

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