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Relativistic dynamics in black hole systems and efforts toward the discovery of nano-Hz GWs

The study of bound particle trajectories around a rotating black hole is crucial to understanding many astrophysical phenomena. I will present a new closed-form analytic solution for the generalized non-equatorial eccentric bound particle trajectories, and their fundamental frequencies, in the Kerr spacetime using general relativity. The trajectories are expressed in the eccentricity, inverse-latus rectum, spin, and Carter's constant (e, μ, a, Q) parameter space. The generalized solutions also enabled us to obtain the necessary bound orbit conditions for (e, μ, a, Q) and novel specialized formulae for equatorial, spherical, and non-equatorial separatrix orbits. Next, I will present the Generalized Relativistic Precession Model (GRPM), which utilizes the analytic solutions of trajectories in the Kerr spacetime, to explain the origin of Quasi-periodic oscillations(QPOs) in black hole X-ray binaries (BHXRB). Our analysis of the plasma fluid flow around a Kerr black hole in the relativistic disk edge suggests that instabilities cause QPOs to originate in a torus region spanned by geodesics. The application of the GRPM will also be shown for X-ray QPOs seen in Seyferts galaxies.Toward the end, I will discuss our recent efforts for the first official data release of the Indian Pulsar Timing Array (InPTA), which will be incorporated into the global effort of the International Pulsar Timing Array (IPTA) consortium to discover nano-Hz gravitational waves emitted by the relativistic supermassive black hole binaries.

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