Research plans

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- **Observational verifications of higher-dimensional spacetime models with charges and scalar fields by Kaluza-Klein black hole solutions**

  Higher-dimensional black holes are not only expected to be the key to developing physics toward a unified theory, but also can describe phenomena in condensed matter physics such as superconductivity and superfluidity, and atomic physics such as quark-gluon plasma, through the correspondence between the physical quantities in the anti-de Sitter spacetime and those in the conformal field theory at such a spacetime boundary. Then it would be expected that black hole physics may be able to solve problems in condensed matter physics that would be difficult to approach with quantum theory, and predict new quantum physical phenomena. In this context, higher-dimensional black holes have established an important position in modern physics. Our previous studies have shown that the black hole solutions with nontrivial electromagnetic and scalar fields and compact extra dimensions have richer features than those with ordinary fields and trivial spacetime structures. However, it has not yet been clarified how these features specifically relate to our world. Then we study the relationship between some observable physical phenomena by black holes and higher-dimensional black hole spacetime structures given by the nonlinear electromagnetic fields such as the Born-Infeld field, the scalar fields such as the dilatons and the axions, and the nontrivial compact extra dimensions, and verify those spacetime models based on the observations of some physical phenomena. We focus on some astrophysical and astronomical phenomena around compact objects, such as the propagation time delay and the gravitational lensing in the photon motions in plasmas [26], the periapsis shifts of objects [27], the innermost stable circular orbits of test particles, the cosmic ray energy emitted from accretion disks, and the black hole shadows. Assuming the black hole solutions with nonlinear electromagnetic and scalar fields and compact extra dimensions as the spacetime outside the compact object, we discuss these phenomena, including the corrections by some charges, fields, and extra dimensions. Even if future observations of these phenomena would agree with the predictions with the expected accuracy, it is expected that the accuracy of the observations would provide the upper bounds on the magnitudes of the charges and the extra dimensions, and would place the strong constraints on the higher-dimensional spacetime models.

- **Transonic steady flows and electric fields in a two-component plasma**

  In a two-component plasma consisting of ions and electrons or electrons and positrons, electron plasma waves and plasma oscillations are generated due to the differences in the mass and charge of the particles, and the temperature of each component. Focusing on the electric field in a two-component plasma, we discuss the transonic and the supersonic steady flows and the plasma oscillation in the spherically symmetric fluids in Newtonian gravity and general relativity. Especially, we consider steady flows around compact objects modified by an electric field. We assume that there is no magnetic field and no collision term. The electron flow cannot coincide with the ion flow due to the difference in particle masses. We see that in Newtonian gravity, the transonic electron flow is modified by the electric field to get close to the dust ion flow and the hot electron flow with pressure oscillates around the dust ion flow when the initial velocities are different in the supersonic region. Considering the electric field between two fluids in general relativity, we expect the transonic electron flow gets close to the ion flow and oscillates around the ion flow in the supersonic region. Then we discuss the electrification of a compact object due to the accretion of such plasma flows.