Research plans

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- **Verification of higher-dimensional spacetime models by Kaluza-Klein black hole solutions**

  We study various phenomena occurring in the vicinity of compact objects such as black holes. Recently, we discuss physical properties of particle motions and wave propagations in plasma. We focus on motions of photons and a gravitational lensing in a plasma medium in a curved spacetime. It is interesting to consider how the light trajectory and its deflection angle change in the presence of a plasma since light rays propagate through plasmas around compact objects, galaxies and galaxy clusters in the Universe. Then we have studied motions of photons in an unmagnetized cold homogeneous plasma medium in the five-dimensional charged Kaluza-Klein black hole spacetime [24]. We have considered the light deflection by the Kaluza-Klein black hole surrounded by the plasma in a weak-field limit. We have derived corrections of the deflection angle to general relativity, which are related to the size of the extra dimension, the charge of the black hole and the ratio between the plasma and the photon frequencies. The variations of these parameters provide specific signatures on the optical features of the Kaluza-Klein black hole solutions in the plasma medium which would open the possibility of testing such higher-dimensional models by using astronomical and astrophysical observations. Then we have considered the difference between angular positions of images determined by the Einstein rings in the Kaluza-Klein spacetime and in the four-dimensional Schwarzschild spacetime, and estimated its corrections by the plasma, the black hole charge and the extra dimension. We see that the correction by the plasma would be detectable in near future observations, while the other two corrections for supermassive and stellar black holes would not appear to be relevant for present and near future observations. However, it would be expected that the correction by the extra dimension might be detected in future observations of a gravitational lensing by primordial black holes. Moreover, similar to the case of the four-dimensional Schwarzschild spacetime, the squashed Kaluza-Klein black hole spacetimes admit stable circular orbits of massive test particles. Then we focus on two of the observable phenomena around the compact objects, i.e., the periapsis shift and the gravitational time delay, which are the classical tests of general relativity. We assume that the charged Kaluza-Klein black hole metric describes the geometries of the regions outside the compact objects and discuss these phenomena, including the corrections by the black hole charge and the extra dimension [26]. If future precise observations of a periapsis shift and a gravitational time delay by astrophysical compact objects agree with the expected values of general relativity, it require rigorous upper limits of the black hole charge and the size of the extra dimension, or it exclude the Kaluza-Klein metric for describing the geometries around such objects.

- **Soliton acceleration in plasma in a magnetic field**

  We study the behaviors of soliton waves propagating in plasma and the acceleration mechanism of charged particles by these waves. In the previous study [23], we have focused on the footpoint region of the flare, where the magnetic field would be negligible. However, magnetic fields play an important role in most astrophysical phenomena. Then we study the particle acceleration by the electric potential represented by soliton waves with magnetic fields. We discuss the acceleration mechanism of charged particles by soliton waves propagating in plasma with a radial magnetic field near the pole of a compact object [27]. Charged particles confined by between the contracting electric potential, where the wavefront is perpendicular to the magnetic field, and the magnetic mirror, which occurs in the region with a large magnetic field, are accelerated by repetition of reflections with the potential. Such soliton acceleration would be expected to be not only a candidate for the acceleration mechanism of high energy particles constituting cosmic rays, but also applicable to heating the atmosphere of compact objects and energy transfer through wave-particle interactions.