Research plans

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○Soliton accelerations, stationary flows and plasma oscillations in a magnetic field

In [23], we have neglected the magnetic field for simplicity. In most astrophysical phenomena the magnetic field plays important roles. It would be possible to generalize the soliton acceleration mechanism in the environment of nonvanishing magnetic field. We propose an acceleration mechanism of charged particles using nonlinear density waves propagating in an ion-electron plasma in a radial magnetic field [25]. Density wave solitons whose wave front is perpendicular to the magnetic field obey the extended Korteweg-de Vries (KdV) equation and the wave height increases with power law in time as the wave shrinks to the center. The particles, which are confined between the electric potential wall, generated by the shift of the density distribution of electrons and ions, and the magnetic mirror, generated in the region where the magnetic field is large, are accelerated by collisions with the moving potential wall. It can be seen that the energy spectrum of the particles by this acceleration mechanism is power law. As a specific application, we discuss the possibility that high energy particles near compact objects are generated by the soliton acceleration mechanism. In realistic cases, the final size of the wave would be much larger than the Debye length, and the KdV description, which is obtained by the reductive perturbation method for weakly nonlinear waves, would break down due to the full nonlinearity of the waves in the final stage. We have used the solution of the KdV equation to the highly nonlinear stage in [23] in order to understand fundamental properties of the particle acceleration mechanism. One of the necessary properties for the acceleration mechanism by the waves with the electric potential is growth of the amplitude with a power law in time as the waves shrink. To explain the observations of the cosmic rays, it is important to investigate the fully nonlinear solutions for the ion-acoustic waves rather than the weakly nonlinear wave solutions described by the KdV equation. Then we investigate behaviors of such ion-acoustic solitons and shocks in plasma [26] and stationary flows, plasma oscillations, and electric fields around compact objects in two-component plasma [27].

○Verification of higher-dimensional models by squashed Kaluza-Klein solutions

The direct detection of gravitational waves generated by the coalescence of black hole binaries and the successful imaging of immediate vicinity of a supermassive black hole candidate in the center of the galaxy M87 mean that researches of black holes have entered a new stage. Motivated by these astrophysical observations, we are interested in performing in-depth studies of the microscopic features of higher-dimensional black hole solutions. Recently, verifications of extra dimensions and braneworld black holes with quantum gravity corrections by observations of black hole shadow have been studied. To the best our knowledge, effects of quantum gravity have not been discussed in asymptotically Kaluza-Klein spacetimes. Then we consider the effect of the generalized uncertainty principle on Hawking radiation from the five-dimensional charged static squashed Kaluza-Klein black holes [28].