Research plans

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○Charged particle acceleration by ion-acoustic solitons and shocks in plasma

We have proposed a new acceleration mechanism, soliton acceleration, for charged particles by using cylindrical or spherical nonlinear acoustic waves propagating in ion-electron plasma [23]. The acoustic wave, which is described by the cylindrical or spherical Kortweg-de Vries (KdV) equation, grows in its wave height as the wave shrinks to the center. Charged particles confined by the electric potential accompanied with the shrinking wave get energy by repetition of reflections. We have obtained power law spectrum of energy for accelerated particles. As an application, we have discussed briefly that high energy particles coming from the Sun are produced by the present mechanism. 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 [24]. Density wave solitons whose wave front is perpendicular to the magnetic field obey the extended Korteweg-de Vries equation and the wave height increases with power law in time as the wave shrinks toward the center. The particles confined by 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 the Sun 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 observed data 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. We investigate behaviors of such ion-acoustic solitons and shocks in plasma [25] and stationary flows, plasma oscillations, and electric fields around black holes in two-component plasma [26].

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

Five-dimensional squashed Kaluza-Klein black hole spacetimes can be regarded as realistic higher-dimensional spacetime models. We focus on light deflection and perihelion precession around a compact object. We assume that the squashed black hole solution describes the geometry around such objects, and discuss physical phenomena with higher-dimensional corrections [27]. If precise experiments of these phenomena agree with the expected values of general relativity, it requires a rigorous upper limit of the size of the extra dimension, or it excludes the squashed Kaluza-Klein metric for describing the geometry around astronomical objects. We discuss the effect of the generalized uncertainty principle on Hawking radiation from Kaluza-Klein Gödel black holes [28].