Research results

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○Black holes in higher-dimensional spacetimes [1-22]

We consider higher-dimensional black hole spacetimes with spatial extra dimensions. Higher-dimensional black hole has attracted the attention in the field of various theoretical physics since it is expected to be a key to developing physics toward unified theory and has a central role in the progress of the holographic principle. A Kaluza-Klein type spacetime with small compact extra dimensions in higher-dimensional spacetimes is a powerful model to explain the effectively four-dimensional realistic spacetime. It is an interesting task to study what kind of black holes exist in such spacetimes and how observational verification can be done. However, since the spacetime symmetries become less, it is not easy to construct an exact solution which represents a Kaluza-Klein black hole. Introducing the twisted extra dimension, we find that an exact solution of Kaluza-Klein black hole can be constructed easily and give exact black hole solutions in the five-dimensional Einstein-Maxwell theory. In addition, by using obtained exact solutions, we study Hawking radiation from Kaluza-Klein black hole and motions of test particles around black holes to verify the extra dimension using the black hole spacetime.

○Particle acceleration by ion-acoustic solitons in plasma [23]

It is known that the energy spectrum of cosmic rays is well described by power laws over a very large energy span. It suggests a nonthermal acceleration mechanism of the high energy particles by a variety of active astrophysical objects: the solar atmosphere, supernova remnants, central region of galaxies, and so on. However, the acceleration mechanisms, which are important to understand the properties of the astrophysical objects, have not yet been elucidated. We investigate a new acceleration mechanism, soliton acceleration, for charged particles by using cylindrical or spherical nonlinear acoustic waves propagating in the plasma that consists of cold ions and warm electrons. If the density fluctuation appears in the system of cold ions and warm electrons, the extent of electron density is broader than that of ion density. This means that positive charge excess occurs in the high density region. Therefore, an electric field is produced. The inhomogeneity of density accompanied with the electric field, described by the scalar potential field, propagates as an acoustic wave. Suppose that charged test particles (protons) are confined in the electric potential wall associated with the cylindrical or spherical ion-acoustic waves; the charged particles get energy after some reflections by moving the potential wall as the waves shrink into the center. An accelerated particle escapes from the potential wall as an output when the energy of the particle exceeds the electric potential energy. We present a new mechanism for the acceleration of charged particles by using nonlinear solitonlike acoustic waves propagating in plasma described by the cylindrical or spherical Korteweg-de Vries equation. We show that the power law spectrum for accelerated output particles is obtained. As an application, we briefly discuss a possibility that high-energy particles coming from the Sun are produced by the present acceleration mechanism.