Research plans

Ken Matsuno

○Charged particle acceleration by density wave solitons in plasmas

The generation of nonthermal high energy particles is observed not only in the near universe such as the interplanetary space and the Earth's magnetosphere but also in distant objects such as supernova remnants and pulsar magnetosphere. Then such generation is a universal phenomenon in astrophysical plasmas. For example, it is revealed by observations that nonthermal high energy particles such as electrons of about 10 MeV and ions of about 1 GeV are generated with the solar flare. However, the generation mechanism of these high energy particles is unknown in many parts, and it is an important astrophysical problem. For example, Fermi accelerations by astrophysical shocks, magnetic reconnections in the solar corona and the Earth's magnetosphere plasma sheet, electrostatic double layers in the upper atmosphere of the Earth polar region, unipolar electromagnetic inductions in neutron stars, and surfatron accelerations in shocks have been proposed as acceleration mechanisms of high energy electrons and ions in cosmic rays. Then, as a new acceleration mechanism of charged particles, we propose particle acceleration by time-varying electric fields represented by density wave solitons in ion-electron plasmas. Unlike planar solitons, amplitudes of cylindrical and spherical solitons of this system increase with the power-law of time as solitons move to the center. Then energy spectra of particles after elastic reflections with electric scalar potentials described by cylindrical and spherical solitons are power-law. Therefore, focusing on systems such as solar flares, we study the energy spectrum of charged particles accelerated by solitons quantitatively [23].

○Charged black holes with scalar and extended electromagnetic fields

In the context of low-energy limit of heterotic string theory or as an effective action with loop corrections in quantum electrodynamics, considering strong electromagnetic fields in the regions near to pointlike charges, it was suggested that one may use generalized nonlinear Maxwell theory with quartic corrections of Maxwell field strength in those regions. Similar behavior may occur in the vicinity of compact objects and therefore it is reasonable to consider the nonlinear electrodynamics with an astrophysical motivation. Regarding these observations, we take into account scalar and electromagnetic fields such as the dilaton field, the Born-Infeld field, the power-law Maxwell field, and the exponential and logarithmic forms of nonlinear electrodynamics to obtain four and higher-dimensional rotating black hole solutions. An exact charged rotating black hole solution in higher-dimensional Einstein-Maxwell theory has not been obtained. Then, as a first step, we perturbatively construct charged slowly/extremal rotating black hole solutions with scalar fields, nonlinear electromagnetic fields, and a compact extra dimension. We investigate its geometries and physical quantities such as masses, charges, angular momenta, and gyromagnetic ratios with corrections. We also study the motion of test particles around the black hole and the existence of stable circular orbits. Then we discuss the verification of these black hole models by observations [24,25]. Further, related to charged black string solutions with the asymptotic Killing horizons [22], we consider the confinement of the metric by assuming the existence of the n-th order asymptotic Killing generator in the spacetime. For example, in Einstein-Maxwell theory, if we specify the asymptotic structure and the physical quantities defined by the asymptotic Killing generator, we expect that the spacetime with the asymptotic Killing horizon is uniquely determined [26].