## Research plans

Ken Matsuno

### ○Particle acceleration by magnetoacoustic solitons 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 consider a new acceleration mechanism for charged particles by cylindrical magnetoacoustic solitons in plasma [24].

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 solar cosmic rays, it is important to investigate the fully nonlinear solutions for the ion-acoustic and magnetoacoustic wave rather than the weakly nonlinear wave solution described by the KdV equation. We investigate behaviors of ion-acoustic and magnetoacoustic solitons in plasma [25].

### ○Charged black holes with scalar and nonlinear 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 and the scalar fields with an astrophysical motivation. Regarding these observations, we take into account scalar and nonlinear electromagnetic fields to obtain four and higher-dimensional slowly/extremal rotating black hole solutions. 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 [26].

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 [27].