Research plans

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○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. Then we propose a charged particle acceleration process by density wave solitons in electron-ion plasmas. We focus on charged particles inside electric potential represented by cylindrical and spherical soliton solutions where potential moves inward as time elapses. We study energy spectrum in elastic reflection of charged particles by electric potential [23].

○Black hole solutions with scalar and extended electromagnetic fields

In the context of low-energy limit of heterotic string theory or as an effective action for the consideration of effects of loop corrections in quantum electrodynamics, considering strong electromagnetic fields in the regions near to pointlike charges, it was suggested that one may have to 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, the exponential and the 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 the physical quantities such as the mass, the charge, the angular momentum, and the gyromagnetic ratio 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].

○Spacetimes with asymptotic Killing horizons

We have investigated charged black string solutions residing in a five-dimensional Kasner universe [22]. Although there is no exact timelike Killing vector in the spacetime, the geometry is approximately static near the horizon. In fact, the spacetime admits a unique second order asymptotic Killing generator which satisfies an approximate Killing equation. To discuss physical properties of asymptotic Killing horizons, as a first step, 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].