Research results

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- **Higher-dimensional black holes with compactified extra dimensions**

Higher-dimensional theories of interactions are most promising ideas for the unification of four fundamental interactions: gravity, electromagnetism, weak interaction and strong interaction. Motivated by the idea, higher-dimensional black hole solutions are actively discussed. Since our observable world is effectively four dimensional, we can regard higher-dimensional black hole solutions with compactified extra dimensions as candidates of realistic models. We call these Kaluza-Klein black holes. The four-dimensional Schwarzschild metric uniquely describes the general relativistic gravitational field in vacuum with spherical symmetry. However, even if we impose asymptotic flatness to the four-dimensional part of the higher-dimensional spacetime model with Kaluza-Klein structure, the metric is not uniquely determined. A family of five-dimensional squashed Kaluza-Klein black hole solutions [2-4, 7, 9, 10, 12, 14-17, 20, 22] have a Hopf bundle as a subspace where the size of the base space diverges at spatial infinity while the size of the fiber has a finite limit. It means that the compactification of the extra dimension occurs at infinity and we obtain an effective four-dimensional spacetime. Then we can regard a series of squashed Kaluza-Klein black hole solutions with a twisted compactified extra dimension as one of realistic higher-dimensional black hole models. Several aspects of squashed Kaluza-Klein black holes have been discussed, for example, Hawking radiation [13, 25], regularities [18], gyroscope precession [11] and light deflection [24].

- **Five-dimensional black holes on Eguchi-Hanson space**

We construct charged rotating multi-black hole solutions on the Eguchi-Hanson space in the five-dimensional Einstein-Maxwell system with a Chern-Simons term and a positive cosmological constant [1, 6]. These solutions describe the coalescence of two rotating black holes with the horizon topologies of S^3 into a single rotating black hole with the horizon topology of the lens space S^3/Z_2. Then we analyze the appearance and disappearance process of marginal surfaces [8]. We also construct supersymmetric black ring solutions on the Eguchi-Hanson space as solutions of five-dimensional minimal supergravity [5].

- **Rotating dilatonic black holes in nonlinear electrodynamics**

The generalization of the four-dimensional Kerr-Newman black holes to include the nonlinear electrodynamics has been one of the important problems in black hole physics. We address the effects of the small rotation parameter on the exact black hole solutions of Einstein-dilaton gravity coupled to the exponential nonlinear electrodynamics [19]. Moreover, starting with an extremal Myers-Perry black hole with equal angular momenta and adding the dilaton field and the nonlinear Born-Infeld electrodynamics, we find extremal nonlinearly charged rotating black holes [21].

- **Particle acceleration by ion-acoustic solitons in plasma**

We propose a new acceleration mechanism 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 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 obtain power law spectrum of energy for accelerated particles. As an application, we discuss briefly that high energy particles coming from the Sun are produced by the present mechanism.