Research Results

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I have been working on black hole physics and general relativity in higher dimensions. I summarize two main research results as follows.

1. Perturbative Analysis of Stationary Black Hole Magnetospheres

It is widely believed that there exist supermassive black holes in the center of galaxies, and these are hypothesized to be the central engines for active galactic nucleus and gamma ray bursts. The rotational energy of the black hole is one of possibilities for the energy source, and it is known that the magnetic fields can extract the energy, which is known as the Blandford-Znajek (BZ) mechanism. Therefore, magnetic fields around a black hole have gathered match attention to explain the high energy phenomena.

For rapidly rotating black holes, the amount of the rotational energy is large. Meanwhile, it is known that a magnetic field without an electric current is expelled from the event horizon of a maximally rotating black hole, which is known as the Meissner-like effect of black holes. This effect for a rapidly rotating black hole would decrease the efficiency of the BZ mechanism. In realistic astrophysical cases, there would be plasma around the black hole. We study how the Meissner-like effect is affected by the existence of plasma.

It is known that the Meissner-like effect is seen in a black hole spacetime with a degenerate horizon. Therefore, in order to see how an electric current affects the Meissner-like effect, we have studied a force-free electromagnetic system in a spherically symmetric black hole spacetime with a degenerate horizon, for simplicity. In this case, configurations of magnetic fields are determined by the Grad-Shafranov (GS) equation. Although, it is difficult to solve the GS equation by virtue of the light surfaces which are regular singular points of the GS equation, we have tried to solve the GS equation by assuming that the rotational angular velocity of the magnetic field is very small and only considering the vicinity of the black hole. As a result, we constructed a perturbative solution for the Grad-Shafranov equation. Our perturbation analysis reveals that, if an electric current exists, higher multipole components may be superposed upon the monopole component on the event horizon, even if the horizons are degenerate. This study can be seen in Takamori et al. (2010) in the list of publications.

2. Investigation of Geodesics around Black Rings

Recently, motivated by modern unified theories, gravity in higher dimensions has attracted much interest. In particular, a lot of works are devoted to higher-dimensional black holes. In 4-dimensions, there only exists black hole solutions which are topologically spherical. For 5-dimensions, not only black holes but also black ring solutions whose topology of the event horizon is $S^1 \times S^2$ are found. It is striking that the black ring solutions reveal that a black hole in vacuum is not specified only by its mass and angular momentum.

One of the important step to study those black objects is the investigation of geodesics in the black object geometry. In higher dimensions, it is known that there are not stable bound orbits in the black hole spacetime, which is quite different from the case of 4-dimensions. We have investigated geodesics around the black ring in 5-dimensions. As a result, we found that there exist stable bound orbits, which is different from the case of the black holes. Moreover, we showed that there exists chaotic motion in the bound orbits by using the Poincaré map. It implies that the absence of additional constant of motion in the black ring metric. These studies can be seen in Igata et al. (2010a) and Igata et al. (2010b) in the

list of publications.