Future Research Plans

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Estimation of Dark Matter around Sgr A* from S-star Observations :

In the coming year, we will use the pericenter passage data of the S24 star, which are expected to be obtained with the Subaru Telescope, to perform a precise analysis of the gravitational potential in the vicinity of Sgr A*, including corrections from general relativity described by the post-Newtonian approximation as well as contributions from dark matter. At the same time, we will develop the underlying dark matter models required for this analysis. Specifically, we will first construct models for dark matter candidates such as axion fields and Proca fields, and derive the dark-matter-induced gravitational potential in the Galactic center region from the corresponding field equations. Next, the resulting dark matter contribution will be incorporated into the equations of motion of S stars described within the post-Newtonian approximation. By comparing the theoretical predictions with the observational data of S24, we aim to estimate the orbital elements and the parameters characterizing the dark matter distribution.

Furthermore, based on our previous investigations, we have clarified that for least-squares fitting of the post-Newtonian equations of motion of S stars, the standard fitting routines implemented in *Mathematica* cannot be used directly, and that it is necessary to construct a custom fitting code. In the coming year, we will complete this custom fitting code and obtain initial parameter estimates for the S24 data using the least-squares method. In addition to the least-squares approach, we will introduce the Hamiltonian Monte Carlo (HMC) method to perform parameter estimation. By efficiently sampling the posterior distribution in a high-dimensional parameter space, HMC will allow us to evaluate the orbital elements and dark matter parameters with high precision. Through this analysis, we expect to place more stringent constraints on the gravitational potential and the dark matter distribution around Sgr A* derived from the S24 observations.

Dynamics of Charged Particles around Dyonic Black Holes :

In parallel with the S24 analysis, we will continue our study of the dynamics of charged particles around magnetically charged (dyonic) Kerr–Newman black holes, which was originally planned in last year 's research program. These models are important for understanding energy extraction mechanisms in strong magnetic field environments, and may ultimately be connected to high-energy phenomena such as relativistic jets emitted from active galactic nuclei.

We have already analyzed the Penrose process for charged particles around a rotating magnetic monopole black hole, assuming a scenario in which particles initially at rest in the ZAMO frame undergo decay. In particular, we have investigated an electron–positron pair production scenario near the supermassive black hole at the center of the M87 galaxy. As a next step, we will study more general decay processes in which particles are not at rest in the ZAMO frame, and will also explore extended Penrose process models that incorporate decay channels other than pair production, such as β decay.