(2) Plan of future research

Hirotaka Yoshino

I would like to contribute to progress of science, making use of numerical techniques that I acquired so far and of deep understanding on physical phenomena in strong gravity. I would choose the research issues that deepen our understanding of general relativity, and have possibility to find new physics. In the next few years, I will study the following topics.

Behavior of light around a black hole:

Currently, I have been proceeding with the research on the dynamically transversely trapping surface (DTTS) proposed in our previous paper [I-2]. The DTTS is expected to be well defined as a surface to characterize a strong gravity region, but the method of solving for this surface has been prepared only for time-symmetric initial data. In this year, we will prepare such a method on general time slices so that it can be studied in numerical relativity simulations. Furthermore, we explore the connection to a wondering set, which is proposed by Siino at Tokyo Institute of Technology as another extension of a photon sphere. I will also study whether the existence of a DTTS restricts the global properties of the spacetime and the connection to observations.

I will also proceed with further developments of the research [I-3] on the optical image of a gravitationally collapsing star. In particular, we explore the connection to neutrino observations. We are currently studying expected signals of supernova explosions that happen in the neighborhood of our solar system, and whether the general relativistic effects can be extracted from them. Also, we are studying how the collapsing star is observed by a freely falling observational instrument in the case where humans of advanced civilizations in future can arrive at the neighborhood of a black hole.

System of a black hole with axion field

I continue the research of [I-7]. I am trying to make a research with originality by including the effects of axion's self-interaction which other groups scarcely consider. After the amplification due to superradiant instability, the growth is expected to stop due to the self-interaction effects, and clarifying this final state is an important problem. There are two possibilities: The dispersion of the axion field by an explosive phenomena called "bosenova", and the saturation due to stationary emission of axion field to the distant place. Although we reported in [I-7] that both of the bosenova and the saturation happen depending on the modes of the axion cloud, the follow-up simulations with an improved boundary condition indicate that a more careful analysis is required to derive a definite conclusion on the final states.

Because the time scale of the superradiant instability is extremely long, it is difficult to solve this problem only by numerical simulations. Therefore, I am currently studying time evolutions with a simplified model by adopting an appropriate approximate method. After the completion of this issue, I will calculate gravitational waves from the axion cloud, aiming at predicting the waveform of emitted gravitational radiation that can be used as templates for analyzing observational data at the gravitational wave interferometers like the aLIGO and the KAGRA. Furthermore, I will calculate how the energy and angular momentum of the black hole change in time due to the presence of the axion cloud, and predict the distribution of mass and angular momentum of observed black holes.

Other topics:

If I have time, I would challenge other topics, such as calculation of gravitational waves emitted from merger of binary black holes/neutron stars in the Einstein-Cartan theory, where "torsion" degree of freedom is added to the theory of general relativity.

I am also interested in discussing and collaborating with group members. Other than the collaboration with Prof. Ken-ichi Nakao and his students in particle physics group, Mr. Kazuma Takahashi and Ms. Nami Fujioka, I am discussing graduate students in astrophysics group frequently. I will contribute to activity of the groups by motivating and energizing students.