

(2) Plan of future research

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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 am proceeding with the research on the dynamically transversely trapping surface (DTTS) proposed in our previous paper [I-4]. Although the concept of the DTTS works to some extent, it is recently found that the behavior of the DTTS is unnatural in a spacetime with a rapidly spinning black hole. We examine whether this is due to a physical reason or there remains a room for improvement in the definition. Then, we develop a numerical method for solving for such surfaces and explore how this concept play an important role in various contexts. In particular, in the context of AdS/CFT correspondence, the Ryu-Takayanagi formula, the relation between the entanglement entropy on the boundary and the area of the minimal surface in the bulk of the AdS spacetime, was found and attracts a lot of attentions. We are studying to establish new correspondence between our new concepts and the CFT quantities.

I will also proceed with further developments of the research [I-5] 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-9]. 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-9] that both of the bosenova and the saturation happen depending on the configurations 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.

Because the time scale of the superradiant instability is extremely long, it is difficult to solve this problem by numerical simulations. From the fiscal year 2020, I have been studying time evolutions with a simplified model by adopting an approximate method, but the results depend on the method of the approximation and the energy is not conserved. Since other groups also consider this problem with various approaches recently, I take into account of such studies to derive a reliable conclusion.

As another topic, an astrophysical black hole often possesses magnetic field around it, which is called magnetosphere. In such an environment, the interaction between the axion and the magnetic field may affect the growth rate of the axion cloud by the superradiant instability. I examine this possibility by setting a specific model with Prof. Jiro Soda at Kobe University.

Other topics:

If time allows, I would challenge other topics, such as development gravitational theory including “torsion” (which is the extension of the Einstein-Cartan theory), and exploration of the possibility to determine whether the gravity must be quantized through experiments at low-energy scale.

I am also interested in discussing and collaborating with group members. I am currently collaborating with Prof. Ken-ichi Nakao and his student, Mr. Kazuma Takahashi. I also discuss with graduate students in astrophysics group frequently. I will contribute to activity of the groups by motivating and energizing students.