Future Research Plans

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I. ANALYSIS OF THE MAGNETOSPHERE STRUCTURE AROUND ROTATING-ALTERNATIVE BLACK HOLE

The goal of this research is to address the question in astrophysics: "Is there any possibility other than a rotating black hole for the central object of a galaxy?" by approaching the problem using "rotating boson stars." In particular, the study will explore results that connect observations with the perspective of the plasma magnetosphere surrounding such objects.

Around the central object of a galaxy, interactions with the surrounding plasma fluid lead to the formation of distinctive magnetic regions, known as magnetospheres. Within these magnetospheres, phenomena such as "accretion disks" and the "ejection of cosmic jets" are known to occur. In this research, by investigating the properties of accretion disks and cosmic jets around rotating boson stars, we aim to provide observational constraints and predictions in the case where the central object of a galaxy is a boson star.

This research considers boson star solutions in two different models. The first model is described by:

$$S = \int \sqrt{-g} d^4x \left\{ -g^{\mu\nu}(\partial_\mu \psi)^*(\partial_\nu \psi) - \frac{1}{2}m^2|\psi|^2 - \frac{\lambda}{4}|\psi|^4 \right\}$$

which is a model of a complex scalar field ψ. This is the simplest model for creating a heavy boson star solution. The second model is the one proposed by the applicants, described by:

$$S = \int \sqrt{-g} d^4x \left\{ -g^{\mu\nu}(D_\mu \phi)^*(D_\nu \phi) - g^{\mu\nu}(D_\mu \psi)^*(D_\nu \psi) - \frac{\lambda}{4}(|\phi|^2 - \eta^2)^2 - \mu\, |\phi|^2\, |\psi|^2 - \frac{1}{4}F_{\mu\nu}F^{\mu\nu} \right\}$$

In this model:

- Heavy boson star solutions that could potentially serve as the central objects of galaxies can be obtained.
- Solutions with properties similar to those of Gravitational Vacuum Stars (Gravastars), one of the black hole alternatives, can be constructed.

The specific research objectives are as follows:

1. To clarify the properties of rotating boson stars.
2. To investigate the magnetic field around rotating boson stars using magnetohydrodynamics (MHD).
3. To develop theoretical predictions for observations using gravitational waves and radio telescopes.

II. STUDY OF ALFVEN WAVES ALONG TWISTED MAGNETIC FIELDS

In recent years, phenomena such as jet ejection from black holes have been observed. To explain such high-energy phenomena, the energy extraction mechanism of rotating black holes has attracted attention. Numerical simulations using magnetohydrodynamics (MHD) suggest that Alfven waves propagating along the magnetic field in the black hole's magnetosphere play an important role in energy transport. Analyses of Alfven waves along monopole magnetic fields have been conducted in recent studies, but it is believed that the actual magnetic field lines become twisted due to the rotation of the black hole.

Based on this, the applicant will conduct an analysis of Alfven waves associated with twisted magnetic fields. In the future, the applicant hopes to propose a more efficient energy extraction mechanism through Alfven waves propagating along twisted magnetic fields in the curved black hole spacetime. The more specific research objectives are:

1. To analytically and numerically create and analyze Alfven waves along twisted magnetic fields.
2. To explore the possibilities of Alfven wave confinement phenomena and superradiance in this study.
3. To analyze the curved black hole as the background spacetime and investigate the potential energy extraction mechanisms.