Soliton Stars in a Spontaneously Broken U(1) Gauge Theory

In a system that consists of a bosonic field and a gravitational field, there exist soliton like solutions, called boson stars. Though the boson stars have not been observed in the universe, they are expected as a candidate of dark matter or origin of super massive black holes. For these reasons, the boson stars are interesting exotic objects. I attempt to construct the boson stars in a system that consists of two complex scalar fields, a gauge field, and a gravitational field with the gravity.

Even if the gravity is ignored, Q-ball solutions exist as bound states of bosonic particles in the case of a class of the coupled systems. The boson stars with the gravity in the systems which admit the Q-balls are also called soliton stars. In the limit that the gravitational coupling become zero, the soliton stars approach to the Q-balls that are supported by the interaction between the matter fields. On the other hand, we expect that if the gravitational effect is larger, the gravitational collapse would happen in the cases that the mass of the soliton stars is too large. Then, an upper mass for the stable soliton stars exists. It is an interesting issue that the dependence of the upper mass and the coupling constants is classified. We study the gravitational effects of a variety of Q-balls, i.e., dust balls, shell balls, and potential balls. Since they have different equation of state inside the Q-balls, they yield different gravitational fields. Especially, for soliton stars based on the potential balls, we expect that stable solutions whose interior is filled with vacuum energy, which are called gravastar, would be obtained.

Stability for Soliton Stars by Numerical Calculations

In order to discuss a stability of the soliton stars, there are several view points. The first point is energetics. Since the soliton stars can be interpreted as a condensation of bosonic particles, we can compare the energy of the soliton star and energy of free bosonic particles of the same numbers. If the energy of soliton star is less than the one of free particles, the soliton star is stable. However, since it is not enough discussion for the stability of the soliton stars, we will try other points of view.

The next point is the linear analysis. This is achieved by solving the equations of linear perturbation for the classical fields that construct the soliton stars. The stability is characterized by the sign of energy eigenvalues of the lowest perturbed state. I learn to analyze the stability of the soliton star and maximum mass, which is especially important in a theories of the boson stars.

Furthermore, it is interesting to study time evolution of the soliton stars by numerical simulation. I want to investigate stability for nonlinear perturbations. To investigate time evolution for the Einstein equations, I decompose four dimensional spacetime to space parts and time one, and evolve the metric of the space parts. By using this method, I can observe processes of collapsing the soliton stars to black holes.