Summary of past research results

Name: Tatsuya Ogawa

In classical field theories, it is known that there are classical solutions called soliton which the fields are spatially localized. The soliton solutions are divided into two types: "topological solitons" and "nontopological solitons". We have considered natural theories in the context of gauge theory and investigated the properties of topological solitons and nontopological solitons. Up to now, the research on nontopological solitons was especially carried out. The details of the solutions are described below.

Nontopological Solitons in a Spontaneously Broken U(1) Gauge Theory

It is known that in a complex scalar field theory with global U(1) invariance, there are classical solutions called nontopological solitons which are possess conserved charge. Especially, spherically symmetric solutions are known as "Q-balls" because they have a charge Q. They are very interesting since they could be a dark matter candidate in our universe.

We generalized the model of the Q-balls by Friedberg, Lee, and Sirlin and constructed Q-ball solutions in a theory consists of a complex scalar field, a U(1) gauge field, and a complex Higgs scalar field. This model is a natural theory in a context of gauge theory. In the theory, the gauge field obtains mass through a spontaneous symmetry breaking. As a result, the influence of the gauge field remains within the scale of the Compton wavelength. As a result, it can be interpreted that the charge densities in the Q-balls are completely screened. Therefore, the Q-balls in our study can be observed as electrically neutral objects for a distance observer. It would be a desirable property as a dark matter.

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

In addition to the above model, we constructed the soliton solutions by taking the gravitational field into account. Such a solution that a gravitational field is combined to a Q-ball is called soliton stars. By numerical calculations, we show that charge screening occurs inside the soliton star like a case of the Q-balls, and that the upper limit mass appears for stable soliton stars. We also showed that the dependence of various physical quantities on the energy scale at which symmetry is broken spontaneously. As a result, it was clarified that the soliton star in this study showed a sufficient relativistic effect, and that it could have the mass of the cosmological scale.

In the model, we also constructed soliton stars whose inside is filled with the cosmological constant. They connect de-Sitter spacetime and Schwartzschild spacetime. Such solutions are called “gravastar”. In other words, we constructed gravastar solutions as soliton stars.