Gravitation theory and its applications

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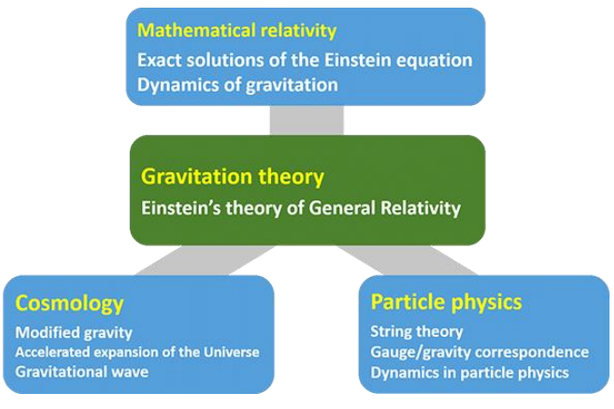
General relativity, the theory that governs gravitational physics, has been playing a key role in theoretical physics since the theory was established by Einstein 100 years ago. This theory describes time evolution of the curvature of spacetime, and it is intimately related to mathematical theories such as geometry and analysis. This theory also provides basis for astrophysics and cosmology that describe our universe. For example, this theory predicted existence of the gravitational wave, and it was confirmed recently by direct observations to which Nobel Prize was awarded in 2017. Nowadays the gravitation theory is applied also to high energy physics and have been attracting wide academic interest.

I have been engaged in theoretical and mathematical research on gravitation theory and its applications to other research fields. The main topics are (1) Mathematical aspects of general relativity, (2) modified gravity theories and cosmology, and (3) applications to dynamical phenomena in elementary particle physics.



(1) Mathematical aspects of general relativity

General relativity is the theory that governs the dynamics of spacetime curvature. The basic equation of this theory is the Einstein equation, which is the set of partial differential equations for the spacetime metric. To elucidate mathematical properties of this equation, I studied construction methods of exact and numerical solutions for this equation, and also examined properties of those solutions. One typical solution of the Einstein equation is the black hole solution that describes a stellar body from which even light cannot escape due to extremely strong gravity. In my past works I examined basic properties of such black hole solutions including stability for linear and nonlinear perturbations.

(2) Modified gravity theories and cosmology

Theories of gravitation that are modified from the general relativity are called modified gravity theories, and phenomena caused by such modifications are attracting wide interest in cosmology and astrophysics. One topic in this context is the accelerated expansion of the universe. By means of cosmological observations it is confirmed that our universe is expanding and also the speed of the expansion is growing in time, although the origin of this phenomenon is still unknown. In my past works I examined how to realize this phenomenon based on the modifications introduced to the gravitation theory, and also studied influences to the gravitational wave propagation and the shock formation caused by the modifications.

(3) Applications to dynamical phenomena in elementary particle physics

The string theory, a candidate of the theory that unites the elementary particle theory and the gravitation theory, predicts that these two different theories are connected by a duality relation. Based on this duality, we can study phenomena in one theory by studying corresponding phenomena in the other theory. Using this property I studied dynamical phenomena and chaos in elementary particle physics setup employing techniques to study the dynamics of gravitation theory.

The above studies are intimately related to studies on mathematical analysis, geometry, fluid dynamics, dynamical system and chaos. Combining mathematical techniques in these research fields and my experiences in the past studies, I will tackle more challenging problems in theoretical/mathematical physics, and also try to apply my research techniques to problems in other research fields.