論文の内容の要旨

Systematic Construction of Healthy Gravitational Theories with Higher Derivatives (高階微分を含んだ健全な重力理論の系統的構築)

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After the discovery of the late-time cosmic acceleration, there has been a growing interest in modified theories of gravity. Today we have so many models that it is inefficient to handle them separately. This situation necessitates constructing a unified framework of gravitational theories to treat them together. In the context of scalar-tensor theories, there is a class called Horndeski theory, which is the most general scalar-tensor theory that produces second-order Euler-Lagrange equations. This second-order nature of the Horndeski theory ensures that the theory is free from the problem of Ostrogradsky ghost associated with higher-order equations of motion, and thus forms a general class of "healthy" scalar-tensor theories. Indeed, the Horndeski class encompasses many known theories and its cosmological implications have been extensively studied.

It had been believed that the Horndeski class is the most general healthy theory, but the myth was destroyed: Even if higher-order derivatives appear in Euler-Lagrange equations, there are some cases where those higher derivatives can be eliminated by algebraic manipulation to yield a set of second-order differential equations. This is possible only if higher derivative terms are contained in the action in a special combination. Several classes of healthy theories beyond Horndeski have been proposed, but the whole picture of scalar-tensor theories without Ostrogradsky ghost remains hardly understood. Some of these theories can be obtained by disformal transformation of the Horndeski class, where a disformal transformation is a redefinition of the metric that depends on the derivative of the scalar field. As such, a disformal transformation generically maps a scalar-tensor theory to another one with higher derivatives and may play a crucial role in extending the framework of healthy scalar-tensor theories.

Once a new theory without Ostrogradsky ghost is obtained, we should still investigate its theoretical viability from other perspectives, e.g., whether the theory accommodates stable cosmology or not. Regarding this point, it has been shown that all the known healthy theories

that cannot be obtained by disformal transformation from the Horndeski class are plagued with gradient instabilities in cosmological perturbations. This implies that, within known healthy scalar-tensor theories, only those connected with the Horndeski theory via disformal transformation admit viable cosmology.

In light of this situation, we propose a new methodology to construct healthy theories by means of transformation of variables. We apply the technique to the case of disformal transformation on scalar-tensor theories and yield a broad class of healthy theories beyond any existing model. We also investigate the stability of cosmological perturbations in the so-obtained theory. It is shown that perturbations about a flat, homogeneous, and isotropic cosmological background always suffer from ghost/gradient instabilities.