In the area of cosmology, I am interested both in high energy regime, where inflation occurs, and in low energy regime, where dark energy and dark matter are effective. I would like to challenge them through the following approaches.

General interaction between bosons and fermions Though generic picture of inflation has been well-established, we know very few about the following reheating era, where inflaton still plays a roll. To discuss reheating, we need to know how the inflaton is coupled to the Standard Model particles, but we have not succeeded in it yet. Once we find what kinds of interactions between inflaton (boson) and SM particles (bosons and fermions) are allowed in principle, it seems to become much easier to identify the actual set of interactions by the comparison between their predictions and observations. What we would like to find is general boson-fermion interactions, which seem not to be discussed up to now in contrast with boson-boson interactions. Even during inflation, the boson-fermion interactions may affect inflaton dynamics through loop corrections with the virtual propagation of fermions in SM, which might contribute to observables, e.g., non-Gaussianity. At least, interactions should avoid so-called Ostrogradsky's ghost instability, which is carried by extra degrees of freedom coming from higher derivatives. As a first step, we are now working on finding general (Ostrogradsky's) ghost-free interactions between bosons and fermions. We found a (sufficient) condition for the absence of the instability in the point-particle system with interactions between regular bosons (w/o higher derivatives) and extended fermions, where the Lagrangian includes even non-linear terms of first time derivatives of fermions, corresponding to second derivatives in bosonic case. What we would like to do next is the inclusion of higher time derivatives of fermions (e.g. the second derivatives) and the covariantization, where we anticipate that much effort is needed, to promote the point particle theory to the field theory. Then, for applying them to cosmology, we will include gravity to find gravity-boson-fermion system. Another possible application of such general interactions is proposing new dark matter models.

Vainshtein mechanism in bigravity We have confirmed that bigravity is consistent with inflation, but we have another observational constraint from solar system experiments. Since bigravity has massive helicity-0 modes, Vainshtein mechanism is necessary to reproduce GR in the region near sources. We would like to examine if the mechanism works enough even in bigravity models with large difference between the coupling constant of metrics and the graviton's mass, which is required in order that the stability of FLRW solutions is compatible with IR modification of gravity [1], which is an original motivation to introduce bigravity.

In addition, as future projects, I would like to discuss the cosmological constant problem (There may be some ways to challenge the problem from the gravity side, such as "degravitation", a screening mechanism of large vacuum energy. I am also interested in particle physics, needed for the calculation of vacuum energy, in the context of the CC problem.), the origin of dark matter and dark energy (not only in bigravity) and the classicalization of the quantum fluctuations generated during inflation.

[1] A. de Felice et. al., JCAP 1406 (2014) 037.