学位報告１－１

別紙１－１

論文審査の結果の要旨および担当者

報告番号	※　甲　第　　　号

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論　文　題　目　Framework for testing the fundamental principles in gravitation and cosmology
（重力および宇宙論の基礎原理を検証する枠組み）

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論 文 審 査 の 結 果 の 要 旨

After the discovery of the expansion of the universe, the Big Bang cosmological model has been established using many astronomical observations. However, the accelerating expansion of the universe that was discovered by surveying distant supernovae approximately twenty years ago, remains one of the unsolved problems in modern cosmology.

To explain the accelerating expansion, two types of solutions have been proposed, i.e., introduction of vacuum energy with a negative pressure and modification of the Einstein gravity theory. In the latter case, various approaches exist for modifying gravity. Therefore, conventional model-specified analyses are not suitable for the investigation of all the possible theories and verifying these theories through observations.

Firstly, the candidate investigated the possibility of explaining the accelerating expansion by modifying gravitational interactions in the scalar-tensor theories including the Horndeski theory. To explore the entire parameter space in the Horndeski theory, the candidate newly developed a methodology that was based on the Monte Carlo simulation by Taylor-expanding the Lagrangian density. The candidate constructed many random models that satisfied Hubble parameter observations. However, the candidate found that these models could be considerably constrained using gravitational-wave observations and the wide range of scalar-tensor theories was rejected by the accurate measurement of the propagation speed of gravitational wave by LIGO.

Secondly, the candidate investigated the validity of Lorentz invariance in the very early universe whose violation is associated with the modification of the gravity theory in that epoch. The candidate considered the power spectra of primordial scalar and tensor perturbations with a single inflaton field in the framework of the 4d-Horava-Lifshitz gravity theory. The candidate revealed that the inflation consistency relations were in general violated in models where Lorentz invariance was explicitly broken and derived explicit conditions that indicate Lorentz violation. Therefore, the results opened a new approach to test the Lorentz invariance of the gravity sector at the inflationary energy scale by measuring Cosmic Microwave Background (CMB) B-mode polarizations for the primordial gravitational waves.

Finally, the candidate considered CMB lensing by massive radio galaxies aiming to measure the growth history of the large-scale structure at $z>1$, which could be different between various gravity theories and thus, could be used to test gravity theories at a relatively high redshift. The candidate constructed the all-sky data of radio surveys, developed a method to properly assign the number distribution and bias of radio sources, and investigated how the growth history of the large-scale structure could be extracted by future radio galaxy surveys.

In summary, the candidate established a novel numerical framework to test theories of modified gravity by pointing out the strategic importance of gravitational-wave experiments, galaxy surveys at high redshifts, and CMB polarization measurements for the primordial gravitational waves. The new framework allows to explore the vast theory space in a model-independent way. A supplement paper also showed an important relationship between CMB spectral distortion and Einstein’s equivalence principle. Therefore, we conclude that the candidate deserves to receive a Ph.D. degree.