様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

科学研究費助成事業　　研究成果報告書

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研究課題名（和文）Massive gravity: theory and phenomenology

研究課題名（英文）Massive gravity: theory and phenomenology

研究代表者
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交付決定額（研究期間全体）：（直接経費）　　3,500,000円

研究成果の概要（和文）：I have achieved several goals in my research during these three years of Kakenhi funding.
Lorentz breaking gravity theories can pass all the known experimental tests in cosmology and the solar system, and have an interesting phenomenology.

研究成果の学術的意義や社会的意義
With the results of my research, I was able to publish 18 papers. I have accepted one PhD student who has just started working with me.
In terms of social achievements, I have spoken several times with elementary school students about my research in a easy and funny way.

研究成果の概要（英文）：I have achieved several goals in my research during these three years of Kakenhi funding. First of all thanks to Kakenhi, and thanks to the powerful workstation I have build out of it, I was able to understand some important points in my research. 1) Lorentz breaking gravity theories can pass all the known experimental tests in cosmology and the solar system. 2) For the theories I have introduced, I have shown the existence of a non-fine-tuned parameter space in which the theories under study are stable, and do not lead to theoretical inconsistencies, such as ghost degrees of freedom. 3) One of the strongest point for these theories is their phenomenology. In fact, they predict properties which differ from General Relativity and which actually are able to give a better fit to existent cosmological data.
4) In the future, if Kakenhi will still support my research, other exiciting developments may come for these theories also in the light of new experiments.

研究分野：Cosmology

キーワード：Dark Energy　Modified gravity models　Massive gravity

１．研究開始当初の背景

At the starting point of my research project I wanted to explore new theories of massive gravity. In particular, massive gravity theories were either nonviable, as for example in de Rham-Gabadadze-Tolley (dRGT) massive gravity there is no stable Friedmann-Lemaitre-Robertson-Walker (FLRW) background. Other theories, for example bigravity, either had unstable FLRW (for a small-mass extra graviton of the size of today Hubble parameter) or had a trivial phenomenology (for a very massive extra graviton).

２．研究の目的

My goal was to try to give a non-zero interesting phenomenology to these theories. If no non-trivial phenomenology existed then there would be no use for a massive graviton in theoretical physics. To find an interesting phenomenology in massive gravity theories was something which was discussed by several authors. Since in massive gravity, the extra scalar mode was leading to the instability on cosmological backgrounds, I have searched for a modification of gravity which possessed no new scalar or vector modes, but was able to give a non-zero mass to the tensor modes of the theory. Once the cosmological background was made stable, the hope was that the new predictions of the theory for the cosmological data could be different from the standard model of cosmology.

３．研究の方法

I believed that the only way to achieve this goal for massive gravity theories was to modify the previously existing theories by allowing Lorentz violations at large scales. In order to build up a sensible theory for massive gravity, I have implemented different research methods all aimed to find the same goal, that is to find a non-trivial phenomenology for massive gravity theories. These research methods consisted of:

1. The theoretical study of the theory by using the Hamiltonian formalism in order to study the degrees of freedom present for this theory in a general background.
2. The theoretical study of the behavior of the degrees of freedom on the cosmological background in order to see the time-evolution of the observables which can be constrained by the data.

3. I have implemented a Monte Carlo code which was setting constraints on the free parameters of the theory.

４．研究成果

I succeeded to fulfill the aimed goal of building up from scratch an interesting phenomenology for the massive gravity theories I have introduced. I have found that the theory introduces, like General Relativity, only two gravitational tensor modes in any background. Then these modes, and their dynamics are able to give a new non-trivial phenomenology in the context of cosmological observables. In particular, the theory is able to set weaker gravity which seems to fit the growth of the perturbations better than the standard model of cosmology. I also found that the same model gives a result for ISW-galaxy cross correlations which makes it possible to be distinguished from the current standard model of cosmology.

５．主な発表論文等

I have prepared during the research period supported by Kakenhi, about 18 papers published in three years. All the papers have been refereed and published in journals with high impact factor, such as PRD, JCAP, PRL, Gen.Rel.Grav. My total citations added up to 6922, citations-per-paper: 80.5, and h-index: 41.

I have given 4 invited-speaker talks in conferences and institutes (1 of them in Japan, 1 in Europe, 2 in Asia).

〔雑誌論文〕（計18　　件）

〔学会発表〕（計4　　件）

〔図書〕（計0　　件）

〔産業財産権〕
○出願状況（計0　　件）

名称：
発明者：
権利者：
種類：

番号：
出願年：
国内外の別：

○取得状況（計0　　件）

名称：
発明者：
権利者：
種類：
番号：
取得年：
国内外の別：

〔その他〕
ホームページ等

６．研究組織
I was the only person which has gotten benefit from the Kakenhi support.

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