Research Resume

Masroor C. Pookkillath

Personal Details

My research interest falls on *Modified Theories of Gravity*: from IR modification, understanding Dark Energy physics to UV/strong gravity modification and *Testing Gravity Theories*: from cosmology to strong gravity systems, like Black Holes. I am a postdoc fellow at the Center for Theoretical Physics and Natural Philosophy at Mahidol University, Thailand. Before joining this position, I held a short-term postdoc at Yukawa Institute for Theoretical Physics, Kyoto University, where I finished my thesis work on *Theoretical and Observational Constraints on the Cosmology of theories of gravity* under the supervision of Prof. Antonio De Felice and Prof. Shinji Mukohyama.

Contributions to the generation of new ideas, tools, methodologies or knowledge

My investigations include exploring the theoretical viability of modified gravity theories. For example, I have investigated the behaviour of the additional propagating modes in a higher derivative gravity theory called Einstein-Cubic gravity, which initially motivated explaining the strong gravity modification. However, this theory was used to describe Dark Energy physics and inflation. I showed that this theory is not viable for stable cosmology. Employing the Binachi-I metric, I exposed the strongly coupled modes in homogeneous and isotropic spacetime.

Motivated by current tensions in cosmology, I have led two projects to find how late-time modification can solve this tension. In one project, I used the Generalised Proca theory, which has additional degrees of freedom. Unfortunately, adding Baryon Acoustic Oscillation data does not solve the tension. In the other project, I used a Minimally Modified Gravity (MMG) theory called VCDM, showing that this can reduce the tension to 2σ. This result is pointed out in a significant review of the solution in Hubble tension. Due to my active involvement in the investigation of Hubble tension, I have been accepted to give oral presentations at various conferences.

I am also involved in developing a new direction in modified gravity theory called Minimally Modified Gravity and investigating its phenomenology. A different group also proposed a similar idea and introduced a theory called Cuscuton. Some characteristics of Cuscuton are identical to the VCDM, an MMG theory. After a few provocative discussions, I worked out a relationship between General Relativity, Cuscuton and VCDM theory from the Hamiltonian equations of motion. Looking at the cosmological background for the VCDM and Cuscuton, it was found that these theories are equivalent in this particular solution. This resulted in getting invited to give introductory and technical talks in different places. All these publications achieved excellent attention to the research community. Together with other publications, I have 170 citations in total.

The development of others and maintenance of effective working relationships

Currently, I am in a position at a very young research institute. I voluntarily organise activities like bimonthly cosmology research seminars to cultivate the research discussion and catalyse the research group's progress. I also run a reading club where the research group choose a book to read together with students, where I lead discussions to clarify complex parts with students. In my

previous position, also I organised the reading club (we finished reading five books), which resulted in great success. For example, a few reading club members could carry out new directions in their research based on this activity.

I also have informally supervised students in their research projects by cross-checking the results and helping them progress. For example, in the numerical part (Einstein-Boltzmann CLASS code), I have helped in a student's published work, *Linear growth of structure in projected massive gravity*. They kindly acknowledged me in their paper.

Since I have been heavily modifying the Einstein-Boltzmann code to study the phenomenology of various modified gravity theories, senior researchers have exploited my expertise to help in their projects with CLASS code. The main help I was asked for was about handling various precision and initial conditions. I have also been asked for help in modifying the code to include additional degrees of freedom. Moreover, I have given informal training to senior researchers on introducing modified gravity theories at the perturbation level.

Contributions to the wider research and innovation community

I have actively organised a workshop under the theme *Gravity: Current challenges in black hole physics and cosmology* from June 20 to July 1, 2022, by inviting experts on my research theme, the tension in cosmology, as well as actively involved in the grant application to conduct the workshop. It aimed to bring together experts working on several aspects of gravitational interaction to have intensive discussions. In addition, I am also currently organising a short, focused workshop, which includes pedagogical lectures on field theory techniques in cosmology, aiming not only to learn but also to attract young researchers to this relatively new field. I am mainly involved in the grant application for the latter activity.

In my current position, I have also been actively involved, as a Co-PI, in a grant proposal called Fundamental Fund-Basics Research Fund (FF) for improving the infrastructure of the research institute.

As a part of the peer review activity, I have been a reviewer for journals, for example, The European Physical Journal C, for a few articles.

Contributions to broader researchers and audiences and towards wider societal benefit

Giving lectures to invite young students towards research is an integral part of my interest. For example, I have given a non-technical talk titled *Understanding our Universe: Current status* to undergraduate students to attract them to pursue a research carrier in cosmology.

Additions

After my PhD, I was offered a postdoc position at the University of Science and Technology, China, starting in September 2021. Unfortunately, due to COVID-19, the employee could not support securing a visa because of border control. Even though I was given a short-term position for six months and later on a job in Thailand (the work I currently hold), I had a break for four months. Due to this break, I could not deliver the research output on time on two critical projects I was leading: 1) developing Boltzmann code for theories beyond scalar-tensor theories. 2) a project on the early dark sector to address tensions in cosmology (both H_0 and S_8 tensions).