UMSAEP Activities Report 2024-2025

Decoding the Nonlinear Universe

The UM/UWC Linkage Program in 2024

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1. Background and Goals

The ultimate goal of cosmological observations is to deepen our knowledge of fundamental physics. All ongoing and future cosmological observations are designed to achieve key science goals such as revealing the origin of cosmic acceleration, weighing neutrino masses, and inferring the very early universe dubbed the cosmic inflation. The large-scale structure of the Universe is identified as a key probe to tackle these scientific questions. The cosmology groups at Missouri S&T (led by Saito) and UWC (led by Maartens) have highly complementary expertise in the large-scale structure and are heavily involved in ongoing and forthcoming experiments of the large-scale structure. Maartens's group at UWC has been leading 21cm intensity mapping experiments including MeerKat and the Square Kilometer Array (SKA). Saito's group has an official member of the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX), the Dark Energy Spectroscopic Instrument (DESI), and the Project Infrastructure team of the Nancy Grace Roman Space Telescope. The goal of this project is 1) to investigate important theoretical questions focusing on various nonlinearities in the large-scale structure of the Universe in light of these relevant experiments, and 2) to further promote and expand the collaboration between the two groups, following our successful initiation of the collaboration supported by previous UMSAEP awards. The highlight of activities and outcomes of the entire project will be given below.

2. Scientific highlight

The project members have made a steady progress on our proposed collaborative project. The team has submitted two scientific articles to a peer-reviewed journal in physics, both of which are very close to be accepted by the submitted journal.

In Karagiannis et al. (https://arxiv.org/abs/2406.00117), including Saito and Maartens, the team investigated the complementarities of two distinct modes of 21cm observations. The first is the interferometer (IF) mode which is designed to probe the range between the intermediate and very small scales (large wavenumber values) on account of their high

angular resolution, while the second is the single-dish (SD) mode which is sensitive to the large-scales (small wavenumber k-mode values). This complementary nature allows us to take the cross correlation between the IF and SD modes particularly to measure the so-called squeezed bispectrum, a key statistics to accurately measure the inflationary non-Gaussian parameter. The result shows that the combination of the IF and SD modes does lead to improve the constraint on the inflationary non-Gaussian parameter, as shown in Fig. 1. This paper was submitted to the Journal of Cosmology and Astroparticle Physics, and the revised manuscript with response to a referee has been already submitted.

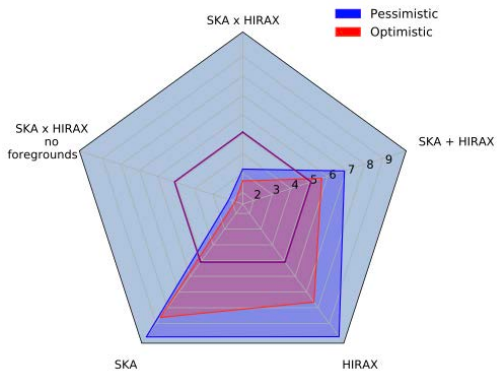

Fig. 1: Expected precision level of the constraint on the non-Gaussian parameter as a function of the cosmic epoch. The combination of SD and IF (SKA x HIRAX) outperforms the single-use cases (SKA or HIRAX only).

In Dinda et al. (https://arxiv.org/abs/2504.09681), including Saito and Maartens, the team has investigated a model independent diagnostic to perform a null test of the concordance ΛCDM model. Despite a series of successes of the ΛCDM model where the cosmic acceleration is attributed to Einstein's cosmological constant dubbed Λ, the recent DESI result showed an evidence of the deviation from Λ with a specific model being assumed. In this paper, the team proposed an improved diagnostic to test the ΛCDM model in a model-independent way, and showed that the deviation from the ΛCDM model is not statistically significant in the relevant redshift range. This paper was submitted to the Journal of Cosmology and Astroparticle Physics, and the revised manuscript with response to a referee has been also submitted.

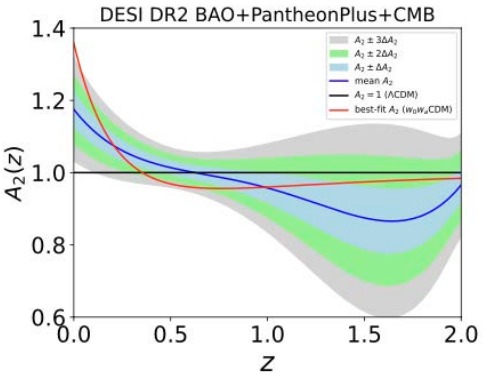

Fig. 2: An example of the diagnostic to test the ΛCDM model. The deviation from unity implies the deviation from the ΛCDM model.

3. Saito’s and Rischbieter’s visit at UWC in March 2025

PI Saito and his PhD student Rischbieter visited UWC for about two weeks in March 2025. In the first week, Maartens’s group hosted a conference to celebrate Maartens’s 70th year-old birthday, called “Cosmic Roy and and the General Roylativists.” This conference was kept secret for Maartens until the day of the conference. Saito gave a talk entitled “A positive and encouraging correlation of multi tracers Roy brought between the two towns 14,000km apart” where he highlighted the UMSAEP collaborations in the past few years. In the second week of their visit, Rischbieter gave a seminar talk on how to optimally combine multi tracers of the large-scale structure probe, which promoted further discussions among the team members. In fact, Rischbieter, Saito, Maartens, and other collaborators initiated a new research project that investigates an optimal method to measure the dipole signal in the large-scale structure probe.

Fig. 3: (Left) Rischbieter’s seminar talk at Maartens’s group. (Right) A group photo of the conference that celebrated Maartens’s 70th year-old birthday.

4. Dr. Dinda’s visit at S&T in April 2025

Following the proposed plan, Dr. Bikash Dinda, a postdoc at UWC and a collaborator in this project, visited Saito’s group at Missouri S&T in April 2025. His visit was very productive. Dinda gave an informal seminar talk at the Midwest Cosmology Network, the regional online cosmology discussion group Saito has been organizing. In addition to finalizing the project mentioned in Sec. 2, Dinda and Saito have initiated a new project regarding the anisotropic distribution of stochastic gravitational-wave background with Pulsar Timing Array and its relation the super-massive black holes in the Universe.

Fig.4: Dr. Bikash Dinda (center), a postdoc at UWC, visited Saito's group at the physics department at S&T in April 2025.

5. Summary and future prospects

In summary, the team made decent progresses on the proposed project, produced two decent scientific articles, and even came up with a few new research ideas through the exchange visits between the two groups. The collaboration between the two groups was strengthen by this time of the linkage program support. The team looks forward to further expanding the exciting collaboration in the future.