

Understanding the Nonlinear Universe

The UM/UWC Linkage Program in 2022

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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 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 data access to the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX) and officially joined in the Project Infrastructure team of the Nancy Grace Roman Space Telescope, NASA's next flagship space mission, in Fall 2023. 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 a previous UMSAEP funding in 2020-2021. 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 towards publishing these work. Instead of reporting them, however, here a surprised, new outcome from the project is described below.

Through an intense discussion during exchange visits between the two groups (see Secs. 3 and 4), the team came up with a new research idea. The basic idea comes from a sketch shown in the left panel of Fig. 1. There are two different type of functionalities of the instrument for 21cm intensity mapping experiments with radio telescopes. 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. In a paper in preparation, our preliminary 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 the right panel of Fig. 1. This project is mainly led by Dr. Karagiannis. Since this is a novel idea and impactful result, the team plans to submit our letter paper to Physical Review Letter, one of the most prestigious peer-reviewed journal in the field of physics.

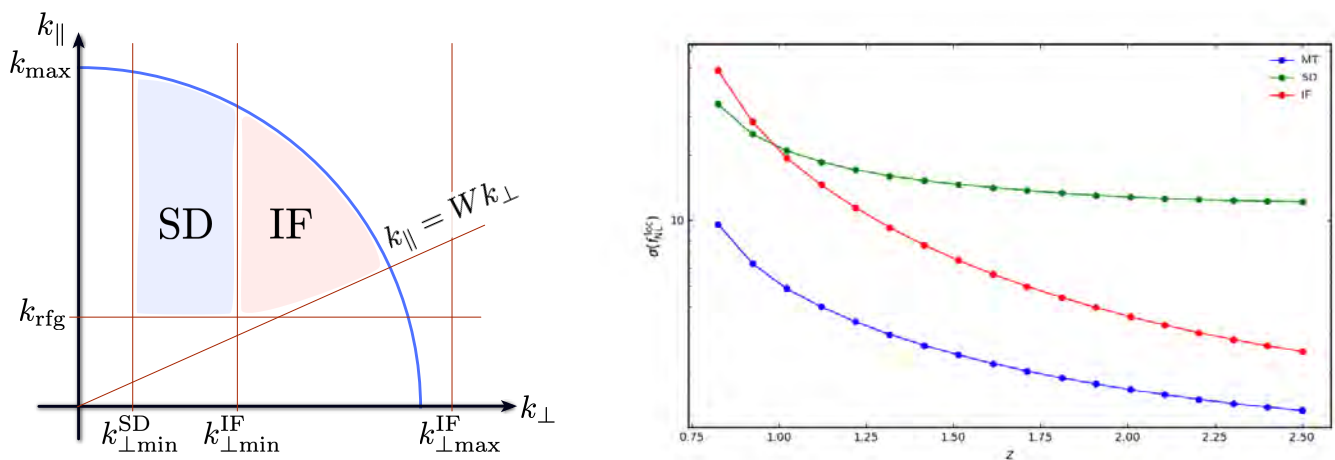


Fig. 1: (Left) A schematic picture of the scales probed by the single-dish (SD) and the interferometer (IF) mode. (Right) Expected precision level of the constraint on the non-Gaussian parameter as a function of the cosmic epoch. The combination of SD and IF (MT, blue curve) outperforms the single-use cases (SD for green curve and IF for red curve).

3. Dr. Karagiannis’s visit at S&T in January 2023

Following the proposed plan, Dr. Dionysis Karagiannis, a postdoc at UWC and a collaborator in this project, visited Saito’s group at Missouri S&T in January 2023. His visit was originally scheduled in late Fall 2022, but we had to reschedule his visit under an unexpected circumstance. It was fortunate that rescheduling his travel went smoothly thanks to Dr. Uphoff.

A positive aspect of his visit in January was that the team was able to provide him two presentation opportunities; a technical seminar talk entitled “Quasi-maximum likelihood estimation of Primordial Non-Gaussianity” at the Midwest Cosmology Network (MCN) and a more general colloquium talk entitled “A day without yesterday: Measuring the primordial Universe” at the physics department. Both talks were very well accepted by the MCN and the physics department members (about 50 people in total) and made a big

impact on them. See Fig. 2 for the photo featured in the S&T physics departmental Facebook page.

In addition, Saito and Dr. Karagiannis spent a lot of time for the proposed collaborative work. Dr. Karagiannis has a unique expertise in the bispectrum analysis to measure the primordial non-Gaussianity of the cosmic inflation, while Saito has recently developed the method and code to analyze the bispectrum from aforementioned galaxy surveys. The intense discussion during his visit led to a new idea which led to another intense discussion during Saito's visit at UWC in March as highlighted in Sec. 4.

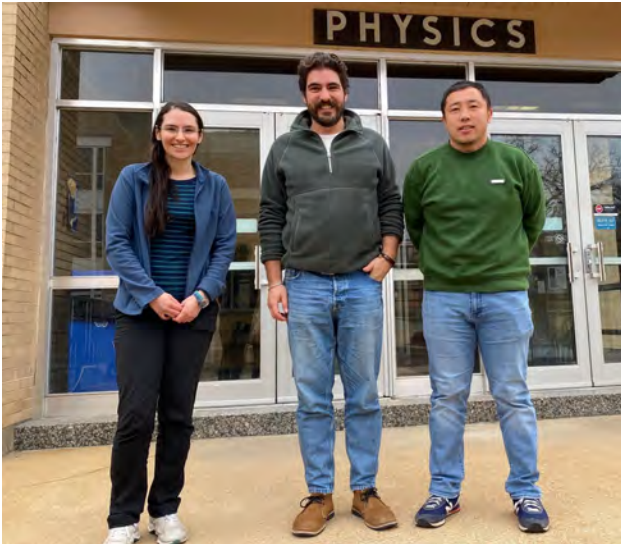


Fig.2: Dr. Karagiannis (center), a postdoc at UWC, visited Saito (right) at the physics department at S&T in January 2023. He gave a seminar talk at Saito's group and a colloquium at the physics department. He also interacted and collaborated actively with the members in Saito's group including Dr. Khoraminezhad (left).

4. Saito's visit at UWC in February-March 2023

Saito visited Maartens's group at UWC for two weeks in late February and early March. The pandemic happened right after Saito visited UWC last time in February 2020, so it was his great pleasure to come back to Cape Town. This was his second international travel after the pandemic. This was why Saito forgot how to prepare for an international trip and unsurprisingly any of his credit and ATM cards did not work. It was a terrible beginning of the trip but Dr. Uphoff and other local UMSAEP members were so kind that the problem was resolved very quickly and smoothly.

Saito gave a seminar talk entitled "A new test on the consistency relation from the anisotropic galaxy bispectrum" at Maartens's group (see the left panel of Fig. 3). The talk went very well and interactively with many questions from the audience. In particular, Maartens organized Saito's trip so that it overlaps with visit of Maartens's close collaborators including Dr. José Fonseca (University of Lisbon, Portugal), Dr. Chris Clarkson (Queen Mary University of London, UK), and their group members. In addition to

the seminar talk, Saito had a special discussion to discuss with the students at UWC and the visitors. We also hang out and went a short hiking over weekend (see the right panel of Fig. 2). Following Dr. Karagiannis's visit, we met as many times as possible and continued discussing our new idea again as highlighted in Sec. 2.

Saito's travel to UWC was overall productive and successful, although he had certain challenges to overcome. The load shedding (planned power outage) affected even at the main UWC campus. To keep connected to internet, Saito had to spend significant amount of time at the observatory or at the Starbucks in a nearby shopping mall, as he had to teach online on live. Also, Saito got infected by COVID in the last few days of his trip, which forced him to be isolated at his hotel room.

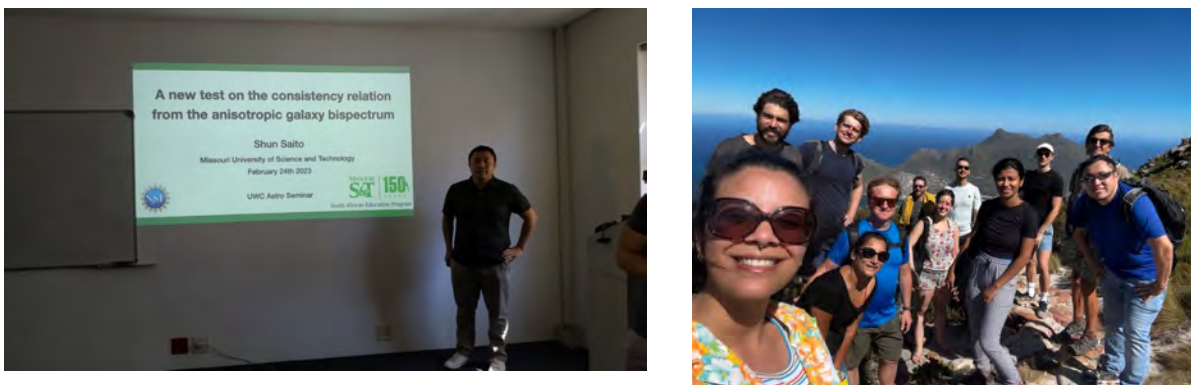


Fig. 3: (Left) Saito's seminar talk at Maartens's group. (Right) A weekend hiking trip with UWC group members and the visitors.

5. Summary and future prospects

In summary, the team made decent progresses on the proposed project with a new research idea through the exchange visits between the two groups, making every efforts to publish the collaborative project on a peer-reviewed journal as soon as possible. It is believed that the collaboration between the two groups was strengthened by this time of the linkage program support. Not only the team worked on some collaborative projects, but also the team gave their group members various opportunities to present their work and discuss interactively. A total of seven junior researchers including one undergraduate, three graduate students, and three postdocs in the two groups gave a talk at the joint UWC-S&T online zoom seminar. The team looks forward to further expanding the exciting collaboration in the future.