Cosmic magnification with galaxy density and HI intensity maps

1. Level of the project, i.e. Honours or Master's: Masters
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4. Name of co-supervisor (if appropriate): Dr. Warren Naidoo
5. Institution of co-supervisor (if appropriate): University of KwaZulu-Natal
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7. Project title: Cosmic magnification with galaxy density and HI intensity maps
8. Description of project, including the aims and anticipated outcomes, what will be expected of the student, and any special qualifications required (maximum 500 words). Please also stipulate **if any specific skills** are required (eg, computational skills):

The student will require basic level python coding skills as well as basic knowledge on cosmology.

In this project, we propose using neutral hydrogen (HI) and galaxy surveys as bias tracers of the large-scale structure of the universe to probe the cosmic magnification effect. Here, we will primarily consider HI measurements from the upcoming HIRAX experiment and galaxy measurements from the Rubin-LSST telescope.

Cosmic magnification is an additional probe of weak lensing [1] that could provide useful complementary constraints for Rubin-LSST by breaking degeneracies encountered in shear measurements [2]. Magnification distortions are related to weak lensing, changing the observed size and flux of background galaxies, thereby modifying the number counts of galaxies [3, 4]. Magnification is affected by intrinsic fluctuations in the number counts of galaxies [5], to the extent that it can only be measured in cross-correlation with foreground galaxies. In some recent work, a novel estimator that used galaxy density and HI intensity maps to significantly improve the signal-to-noise on cosmic magnification measurements, taking advantage of the fact that HI intensity is not magnified to first order, has been presented [6]. In this project, we propose to extend this work to study how magnification systematics can be addressed with an HI intensity mapping survey.

We propose to study how redshift uncertainties degrade the magnification estimator and how redshift calibration can be addressed using the clustering redshifts technique described above. Photometric calibration using a HI IM spectroscopic sample will improve magnification estimates by separating the distribution of background and foreground galaxies. A complication that arises in photometric calibration is that magnification induces correlations between foreground structures and background galaxies [7]. This is an issue if we calibrate using a spectroscopic population that is lensed. Fortunately, the HI intensity is not lensed. We will study how this estimator can significantly suppress the magnification bias and thereby improve photometric redshift calibration. Finally, we will undertake a joint analysis of cosmic magnification and cosmic shear, which will help break degeneracies and address systematics in these measurements.

In this project, the student will learn theoretical computational techniques regarding the magnification effect, shear gravitational lensing effect, and cross-correlation of cosmic tracers. The student will also learn how to develop software to evaluate the results of the calculations as well as provide new results on the applications of these calculations to better understand the cosmological model.

References:

[1] B Jain. ApJL 580.1 (2002).
[2] LSST Dark Energy Science Collaboration et al. arXiv preprint arXiv:1211.0310 (2012).
[3] R Scranton et al. ApJ 633.2 (2005).
[4] C Duncan et al. MNRAS 437.3 (2014).
[5] P Schneider. Springer, 1992, pp. 196–208.
[6] M Jalilvand et al. PRL 124.3 (2020).
[7] G Bernstein and D Huterer. MNRAS 401.2 (2010).