Harnessing Neutral Hydrogen Surveys to Enhance Weak Lensing Measurements

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Level: MSc

Objective: The aim of this project is to leverage neutral hydrogen (HI) as an external spectroscopic tracer to calibrate key systematics in weak lensing surveys. A key focus here will be on intrinsic galaxy alignments (IA) that contaminate cosmic shear measurements. By utilizing precise HI redshift information and higher-order statistics between HI and optical shear, the project will:

1. Quantify the impact of IA and photometric-redshift-induced lens-source overlap on LSST-like shear observables.
2. Develop a response-based calibration framework, based on a squeezed-limit HI–shear bispectrum estimator, capable of recovering intrinsic alignment model parameters.

This work aims to provide a robust methodology for mitigating systematic biases in next-generation weak lensing surveys, improving the accuracy of cosmological inferences from cosmic shear measurements.

Project Description: Weak gravitational lensing is a powerful probe of cosmology, but its potential is limited by systematics in optical galaxy shape catalogues, particularly intrinsic galaxy alignments (IA), which can mimic true shear signals. Neutral hydrogen (HI), observed via 21-cm intensity mapping, traces the underlying matter field while being subject to very different observational systematics. This project will exploit this complementarity by using HI as an external tracer to disentangle true gravitational shear from IA in Rubin-LSST-like surveys.

Building on our existing squeezed-limit bispectrum simulation pipeline, which connects small-scale HI two-point spectra to large-scale shear, we will extend the framework to explicitly incorporate shear systematics. By studying how the HI responds to large-scale shear is modified when the shear field is contaminated by IA and related biases, we aim to quantify the impact of these systematics on the inferred response function.

In addition, the project will explore constraints on HI and galaxy parameters and assess how this technique can improve these measurements. Finally, we will forecast the improvements in cosmological parameter constraints achievable by this method, providing a robust methodology for mitigating IA contamination and enhancing the scientific output of next-generation weak lensing surveys.

Expected Outcome: This project will develop novel methods to combine HI and optical galaxy surveys to mitigate the impact of shear systematics in weak lensing measurements. We expect to demonstrate that HI-shear combinations can accurately recover intrinsic alignment model parameters, including their amplitude and redshift dependence. Additionally, we aim to quantify how these measurements can reduce uncertainties in photometric redshift surveys. Finally, we will assess the resulting improvements in cosmological parameter constraints, illustrating the potential of this approach for next-generation weak lensing surveys.

Requirements:

- A strong background in cosmology at the Honours level, including familiarity with weak gravitational lensing, large-scale structure, and basic statistical methods.
- Proficiency in programming, particularly in Python, with experience in numerical simulations or data analysis.