NASSP Honours Project 2025

1. Level of the project: Honours

2. Name of the primary supervisor:
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4. Name of co-supervisor:
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7. Project title: Tomographic Mapping of Cosmic Structure Growth with HIRAX and Rubin-LSST

8. Description of project (including what will be expected of the student, the anticipated outcomes, and any special qualifications required [maximum 500 words]

Project Background:

Weak gravitational lensing, caused by the bending of light from distant galaxies by massive structures, allows us to probe dark matter and study cosmic structure evolution. HI neutral hydrogen, key in star and galaxy formation, emits a 21 cm spectral line that helps map its distribution in the universe. Intensity mapping measures the integrated emission across regions, providing a large-scale view of the cosmic web. Two-point statistics like the power spectrum and correlation function are crucial for analyzing matter distribution and galaxy clustering, helping constrain cosmological parameters. Accurate measurements of cosmic structure growth rate, quantified by $f\sigma_8$, are vital for testing General Relativity and exploring deviations from the ΛCDM model. These measurements also help to break degeneracies between key cosmological parameters such as matter density Ω_m and dark energy equation of state w, improving the precision of large-scale surveys like HIRAX and LSST.

Cross-correlation between HI intensity maps, optical surveys, and weak lensing provides a new method for studying the matter distribution and its evolution. Foreground removal is necessary to eliminate large-scale radial modes that affect 2-point statistics. The Fisher matrix formalism will be used to forecast cosmological constraints for the convergence-HI probe, while tomographic measurements will offer more precise information on cosmic structure growth over time by isolating contributions from various redshifts. Students will learn coding skills and mathematical modelling of cosmological phenomena.

Project aims:

The synergy between the Hydrogen Intensity and Real-time Analysis eXperiment (HIRAX) and the Rubin Legacy Survey of Space and Time (LSST) presents a unique opportunity to measure the growth structure of the universe with unprecedented precision. We can enhance our understanding of the large-scale structure and cosmic evolution by leveraging tomographic techniques. This project outlines a strategy to integrate tomographic analysis with HIRAX and LSST to achieve high-fidelity constraints on cosmological parameters.

In the project, we intend to perform such a tomographic analysis of the growth of structure using measurements of weak lensing. This probe is sensitive to the matter distribution projected along the line-of-sight and can be combined with 21cm surveys, which will make it possible to recover the dependence in redshift through the cross-correlation formalism. To proceed, we calculate the observable quantities, namely weak lensing convergence κ and HI temperature fluctuations ΔT_{HI}, which will then turn to the angular cross-power spectra $C^{HI-\kappa}(l)$. Using the cross-power spectrum, we use the Fisher formalism to extract constraints on the growth rate of structure.

Expected outcomes:

A. The student becomes familiar with summary statistics like 2-point correlation functions and is able to theoretically compute $C^{HI-\kappa}$ using the Limber approximation and Boltzmann solvers like CAMB or CLASS.
B. The student demonstrates how to constrain parameters using the Fisher forecast and how to interpret corner plots.
C. The student will write the code for the HIRAX × LSST cross-power spectrum analysis, enabling them to add more parameter constraints in future work.

Requirements:

Good programming skills in Python. Basic knowledge of cosmology.