Squeezed Cross-Bispectrum Correlations of Dark Energy Survey Galaxies and Shear with MeerKAT HI intensity mapping

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Level: MSc

Objectives: This project combines computer simulations with real telescope data from MeerKAT and the Dark Energy Survey to develop a new way of measuring how matter clumps together across the cosmos. The student is expected to build a simulation pipeline, test it on synthetic data, then apply it to real observations, producing the first measurement of its kind from South African radio telescopes.

Project Description: We can map the universe in two very different ways through radio waves from hydrogen gas (HI) and through the shapes of galaxies distorted by gravity (weak lensing). Each method has its own strengths and blind spots. By combining them, we get a much richer picture of how matter is distributed in the cosmos.

South Africa's MeerKAT telescope produces deep radio maps of hydrogen gas across hundreds of square degrees of sky (via the MeerKLASS survey). Meanwhile, the Dark Energy Survey (DES) has catalogued millions of galaxies and their shapes across a huge patch of the southern sky. Where these two surveys overlap, we can cross-correlate them to extract information that neither survey could reveal alone.

Standard analyses compare these maps point-by-point (two-point statistics). This project goes further; it uses a technique called the ‘squeezed bispectrum’ that asks: how does small-scale hydrogen clustering change in the presence of large-scale galaxy or shear patterns? This gives us access to new physics about galaxy formation and dark matter that two-point methods miss entirely.

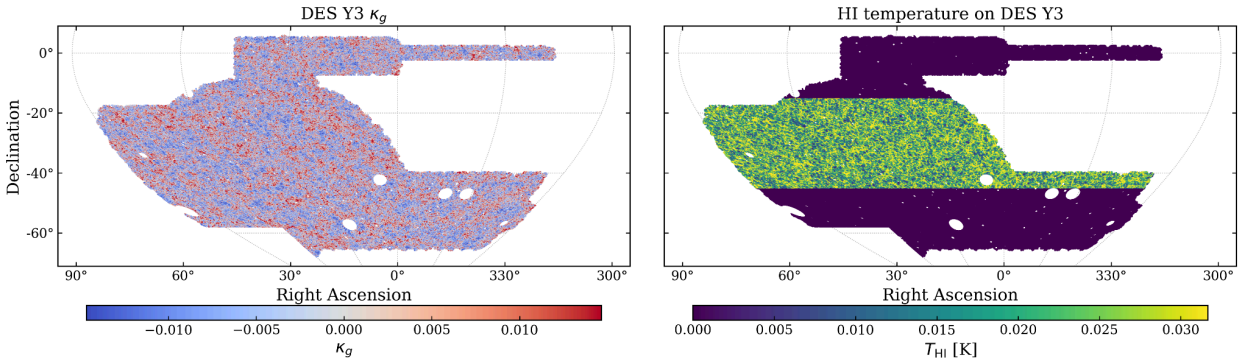

Figure: Map of the galaxy convergence field Dark Energy Survey (DES) Year 3 data release. The colour scale shows where matter is over-dense (red) or under-dense (blue) along the line of sight. The inset

highlights the sky region where DES overlaps with HI radio observations: the area where we will perform our cross-correlation measurement.

Skills & outcomes: Hands-on data skills while working with real MeerKAT radio data and DES optical catalogues, learning the full pipeline from raw observations to science results. Also, the student will learn the simulation experience, build and run cosmological simulations, a core state-of-art skill for modern astrophysics research.

Requirements: Students should have an Honours-level background in cosmology, including familiarity with basic statistics. Strong proficiency in Python is essential, and experience with handling data is desirable, but can be developed during the project.