Thesis subject

Laboratory : Laboratoire d'Astrophysique de Marseille

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Title of the thesis subject :
Tomography of the dust-obscured build-up of cosmic structure with NIKA2 and Euclid

Description of the thesis subject :

A complete understanding of how cosmic structures form and evolve requires probing the history of star formation across the full electromagnetic spectrum. A major fraction of star formation activity, particularly at high redshif, is obscured by dust, and therefore invisible to optical surveys. Millimetre observations are essential for accessing this hidden component. The launch of Euclid and the forthcoming deep millimetre observations with NIKA2 offer a unique opportunity to construct a tomographic view of the dust-obscured Universe, linking the evolution of dusty galaxies, the Cosmic Infrared Background (CIB), and the growth of dark-matter structures across cosmic time.
In Fall 2026, the NIKA2 camera on the IRAM 30-m telescope will begin a dedicated deep programme on the Euclid Ultra-Deep Field (UDF). This unique dataset will combine Euclid's exquisite near-infrared imaging, photometry, and spectroscopy with some of the highest-quality millimetre datasets achievable from the ground. The synergy between these two major international projects, both with strong involvement from LAM, provides the core scientific framework of this PhD thesis.

Scientific objectives: The aim is to reconstruct the dust-obscured build-up of cosmic structure by combining resolved and unresolved millimetre emission from NIKA2 with Euclid galaxy and lensing data. The student will address the following questions:

1. **What is the redshift distribution and evolution of dust-obscured star formation?** NIKA2 observations will provide direct detections of dusty star-forming galaxies and constraints on the CIB fluctuations. Euclid will supply accurate redshifts, stellar masses, morphologies, and weak-lensing maps.
2. **How does dust-obscured star formation trace the underlying dark-matter distribution?**
   By correlating NIKA2 detections and CIB fluctuations with Euclid weak-lensing maps, the project will measure the halo masses hosting dusty star-forming galaxies and test the galaxy–halo connection across cosmic time.

3. **How does obscured star formation contribute to the assembly of large-scale structure?**
   The combination of clustering, cross-correlation tomography, and comparison with simulations (e.g. SIDES) will reveal how dusty star formation traces cosmic filaments, early massive halos, and forming protoclusters.
4. **Can NIKA2 + Euclid uncover rare, massive structures at high redshift?**
   The project will also search for the most extreme peaks of large-scale structure, protoclusters and overdensities, similar to the prominent case of massive structures recently identified in the literature at z>3.

Together, these aims will produce the first tomographic map of dust-obscured cosmic evolution in the Euclid Ultra-Deep Field.

Methodology: The PhD project will combine observational work, data processing, the use of realistic simulations, advanced statistical analysis, and astrophysical interpretation. The timeline follows the arrival of NIKA2 and Euclid data:

- **Observations with NIKA2:** The student will participate in several observing runs at the IRAM 30-m telescope in the Sierra Nevada, as part of the scheduled NIKA2 EUDF programme. This early involvement ensures deep understanding of the data characteristics, calibration procedure and systematic effects.
- **Data Reduction and Pipeline Development:** The observational data will be processed using PIIC, the official NIKA2 data reduction pipeline. The student will perform full reduction of the UDF dataset, develop the end-to-end calibration pipeline required for both point-source extraction and CIB fluctuation analysis. This involves dedicated simulations inserted directly into PIIC, enabling the characterisation of the transfer function for both compact sources and extended fluctuations.
- **Advanced Source Extraction:** To improve deblending and identify Euclid counterparts, the student will explore innovative approaches based on machine learning and inference algorithms (IA). These methods will help disentangle blended NIKA2 sources and enhance the reliability of cross-identifications between the millimetre and near-infrared datasets.
- **Follow-up Observations:** Based on early results, the student may propose follow-up observations with NOEMA interferometer or other facilities to confirm high-redshift candidates or validate protocluster memberships.
- **Clustering, Lensing, and Tomographic Analyses:** This is the core scientific analysis of the thesis. For resolved galaxies: measurement of their angular two-point correlation function, cross-correlation with Euclid weak-lensing maps, estimation of typical halo masses and bias, redshift tomography using Euclid photometric and spectroscopic data. For CIB fluctuations: cross-power with Euclid galaxy density and lensing, reconstruction of the redshift distribution of the CIB, measurement of dusty galaxy bias. This combination will directly probe how dusty star formation maps onto the dark-matter scaffolding of the Universe.
- **Comparison with models and simulations:** comparison with the SIDES simulation suite and other theoretical models of the dusty universe, quantification of the dust-mass

and star-formation evolution, identification of massive structures and protoclusters in formation.

By combining NIKA2 millimetre data with Euclid photometry, spectrocopy and lensing, the PhD will deliver one of the most complete views of dust-obscured star formation in the Euclid Ultra-Deep Field. The project will:

- produce a first tomographic reconstruction of obscured star formation across cosmic time,
- provide new constraints on the galaxy–halo connection for dusty galaxies,
- map how dust-obscured activity traces the underlying dark-matter distribution and cosmic web,
- distribute validated catalogues and data products to the NIKA2 and Euclid teams,
- and strengthen the scientific return of two major observational programmes in which the LAM is involved.

References :

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