Proposition de sujet de thèse

Cross-correlations between cosmological probes from Euclid, BOSS/e-BOSS, Planck and beyond

Laboratoire : IRFU/ DAp + DPhP

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Context:

The ESA Euclid satellite, to be launched in 2022, will observe one hundred billion galaxies over a large fraction of the sky in optical and infrared wavelengths, and will be able to map large-scale structures and weak-lensing distortions out to high redshifts. Weak gravitational lensing and galaxy clustering, combined, are very promising tools to test models in cosmology, and can help to shed light on the unknown origin of the accelerated expansion of the cosmos. Whether this acceleration is due to a simple cosmological constant, a yet to be discovered "dark-energy" fluid, or indicates that gravity and Einstein's theory of General Relativity have to be modified (Modified Gravity, MG) at very large scales, is one of the most important problems of modern physics.

When considered independently, the two probes weak lensing and galaxy clustering have limited explanatory power of the acceleration: too much freedom is left to be able to pin down different theoretical models. Both probes depend on two different gravitational potentials. A very powerful test is to explore whether those potentials are equal (as in standard LCDM), or different (as modified gravity and dark energy models would typically predict). To carry out this test successfully, it is crucial to combine weak lensing and galaxy clustering.

One of the main advantages of Euclid is that it measures both probes simultaneously. Euclid will therefore provide an ideal data set to combine weak lensing and galaxy clustering, and to make significant progress towards the uncovering of the mysterious accelerated expansion of the Universe.

A simple addition of weak lensing and galaxy clustering neglects the cross-correlation between both probes. These cross-correlations are however crucial and need to be taken into account if one wants to constrain dark energy and modified gravity. In the DAp CosmoStat Lab, Martin Kilbinger has developed and tested a code (COSMOSIS) for the full cross-correlation (XC) of weak lensing and galaxy clustering; the code has been recently validated within the Euclid collaboration, in a task force led by Valeria Pettorino. So far, the code has been tested only within a LCDM scenario, and specifically when photometric galaxy clustering and weak lensing are combined. Furthermore, at DPhP, Vanina Ruhlmann-Kleider is expert on the analysis of BOSS and eBOSS, for which data will available during the PhD thesis, opening the opportunity to join efforts and work on real data.

In parallel, Planck satellite data are available and an effort is ongoing on CMB ground / balloon measurements that will provide high precision polarisation spectra at small scales, at least within the EE mode, during the years of the PhD. This also needs to be combined with Euclid data: they will allow for a better measurement in the optical depth, which in turn is degenerate with neutrino masses and Dark Energy properties.

PhD thesis:

We propose a PhD thesis which builds on the tools and expertise available within the lab, and aims at providing key tools and results that will be used for the Euclid collaboration and beyond.

The hired PhD candidate within this project will be at the interface between theory and observations to get the best scientific return out of the big investment done in space missions like Euclid, in particular in Europe and by CNES.

The main objectives are:

1) learn how to use existing XC codes (such as COSMOSIS, developed by Martin Kilbinger) and use available data (such as real or simulated data for Euclid) to test modified gravity models beyond LCDM (with supervision of Valeria Pettorino, expert in the field);
2) investigate how large the contribution of XC with spectroscopic galaxy clustering would be, potentially using 3D WL (for which a code has been validated by A. S. Mancini & V.Pettorino);
3) investigate synergies with other probes, such as data from BOSS/eBOSS (of which Vanina Rulhmann-Kleider is expert) and the Cosmic Microwave Background from Planck (of which V.Pettorino is a CORE2 team member and Planck scientist) or next to come ground space / balloon experiments which will provide (during the time of the PhD) polarisation spectra with a better resolution at small scales.

Ultimately, this will allow confirming or disproving of the standard theory of Einstein, leading to new insights in fundamental physics.

The scientific environment:

The thesis will take place within the research group CosmoStat, within the Astrophysics Department (DAp) under the supervision of Valeria Pettorino and Martin Kilbinger, and in collaboration with Vanina Ruhlmann-Kleider from DPhP for the use of BOSS/e-BOSS data. The team is strongly involved in the Euclid project and in particular in theory, weak lensing, probe combination as well as the inter science task-force to develop the Euclid Likelihood. The PhD student will be able to work at the interface between theory and observations, joining efforts from DAp and DPhP. The student will learn about Modified Gravity as well as state-of-the-art statistical methods and machine-learning applications, and investigate different data sets, also depending on the interests of the applicant, who will have the opportunity to be in contact with experts in all these fields. This will allow the student to learn a variety of different skills, both in the interpretation of data and in the analysis of the data, with a concrete impact on future surveys. The student will be in an environment which perfectly fits the topic of the thesis to facilitate the feasibility of the project. The student will be able to help in the organization of meetings and develop transferable skills, both in problem solving and in numerical analysis, that will be useful both for a future career in academia or to develop competencies used in the industrial domain.