Stage 2024

Title Convergence Mass Map Emulator

Laboratory*:* IRFU/DAP/CosmoStat**,** CEA Saclay

Supervisors: Vilasini Tinnaneri Sreekanth and Jean-Luc Starck

Duration: 4-6 months

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Keywords*:* Euclid, Cosmology, cosmology, weak lensing, simulations

Subject*:*

The Euclid satellite, launched in 2023, will observe the sky in the optical and infrared, and will be able to map large scale structures and weak lensing distortions out to high redshifts. Weak gravitational lensing is thought to be one of the most promising tools of cosmology to constrain models. Weak lensing probes the evolution of dark-matter structures and can help distinguish between dark energy and models of modified gravity. Thanks to the shear measurements, we will be able to reconstruct a dark matter mass map of 15000 square degrees. Mass mapping entails the construction of two-dimensional maps using galaxy shape measurements, which represent the integrated total matter density along the line of sight. Small- field mass maps have been frequently used to study the structure and mass distribution of galaxy clusters, whereas wide-field maps have only more recently become possible given the broad observing strategies of surveys like CFHTLenS, HSC, DES, and KiDS. Mass maps contain significant non-Gaussian cosmological information and can be used to identify massive clusters as well as to cross-correlate the lensing signal with foreground structures.

The current methods of weak lensing convergence maps use the two point statistics which is limiting as it does not probe the non-Gaussianities present in the maps. Another method employed to break the degeneracies and to have a better constraints of the parameters is the higher order statistics. It was shown in [1] that the l1-norm statistics is more powerful than power spectrum and peak and void statistics combined. More recently it was shown in [2] that we can now have a theoretical prediction for the one-point Probability Distribution Function for the density maps. This work has been extended to have a theoretical prediction for the l1-norm. The goal of this project is to first verify its validity regime and then apply this to build a weak lensing map emulator.

Context:

Standard method of using the higher order statistics relies on simulations to obtain them and then use them to perform likelihood/MCMC analysis to obtain the constraints. But, this is highly resource intensive. An alternative to this is to use an emulator which drastically cuts down on the use of computational resources. There are several emulators for the weak lensing maps ex. FLASK[3], GLASS [4], but they are still limited in precision. They have the correct power spectrum but does not obey the correct higher order moments. Having an emulator with the correct maps will significantly improve the analysis, needless to say will also change the traditional methods which relies on full N-body simulations.

Goals:

This project will explore the application of the applicability and the limitations of the current l1-norm prediction and then use that to have a map emulator in place such that we now not only have an emulator with the correct 2-point statistics but also an emulator with the correct higher order moments, so that we get correct one-point Probability distribution and l1-norm.

Expected Results:

We expect breakthrough in the field of using high-order statistics in weak lensing analyses. At the end of the project, we expect to have a tool in place that is robust, accurate and also scalable to produce weak lensing convergence maps.

Candidate Profile:

Engineering school or Masters student. Advanced knowledge in statistics and signal processing. Programming in Python and knowledge in optimisation and Machine Learning are a plus.

Deadline for Application: 28/02/2024

References

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2. Barthelemy, A., Codis, S., & Bernardeau, F. (2021). Probability distribution function of the aperture mass field with large deviation theory. *Monthly Notices of the Royal Astronomical Society*, *503*(4), 5204-5222.
3. Xavier, H. S., Abdalla, F. B., & Joachimi, B. (2016). Improving lognormal models for cosmological fields. *Monthly Notices of the Royal Astronomical Society*, *459*(4), 3693-3710.
4. Tessore, N., Loureiro, A., Joachimi, B., & von Wietersheim-Kramsta, M. (2023). GLASS: Generator for Large Scale Structure. *arXiv preprint arXiv:2302.01942*.