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Projection Bias in galaxy cluster weak-lensing for Euclid Survey

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Galaxy clusters are the most massive gravitationally bound objects in the Universe. Their number density offers a sensitive probe for the growth rate of large scale structure and the underlying cosmology. A way to produce this type of analysis is relying on wide-field optical imaging and photometric surveys, since they are capable of providing both large cluster samples and weak gravitational lensing mass calibration. The combination of information from three cosmological observables such as cluster counts, clustering (i.e. 2-point correlation function) of clusters and weak lensing mass makes it possible to break some degeneracies between cosmological parameters and parameters defining scaling relations between lensing masses and richness, allowing for much more refined constraints on them via Bayesian inference techniques. In this scenario the photometric survey of galaxy clusters that is being carried out by the Euclid space telescope [Laureijs et al., 2011], will reach unprecedented sensitivity and, in turn, unprecedented precision on the expected constraints on cosmological parameters. In order to harvest the full potential of Euclid's data a good understanding of systematics is mandatory.

In this perspective, my PhD project will concentrate on the characterisation of the systematics related to projection effects and their impact on the scaling relation between weak lensing masses and observed richness of galaxy clusters to be identified in the Euclid wide survey. As already discussed in the literature [e.g. Fumagalli et al., 2023, and references therein], projection effects occur when multiple foreground and background objects along the same line of sight are mistakenly associated with a galaxy cluster, increasing the apparent richness of the cluster. While this effect is arguably of relative importance in the SDSS cluster survey, it has been shown to produce a significant effect on the cosmological posteriors derived from the Dark Energy Survey (Costanzi et al. [2019, 2021], Salcedo et al. [2023]). We then expect that, if not accurately characterised, projection effects should have an even stronger impact in severely limiting the cosmological constraining power of the Euclid photometric cluster survey.

Different methods to estimate and mitigate the projection effect have been recently proposed (e.g. Sunayama [2023], Wu et al. [2022]). The common approach these method shares, is to find a suitable estimator for the boost in observed lensing signal induced by the bias (e.g the ratio between the observed signal from a richness-selected sample and the signal expected from the underlying halo mass PDF). Once this estimator has been properly crafted, one can think of applying some mitigation methods that can range from simulating different galaxy models to apply multi-wavelength or multi-tracers techniques. The end result for all these methodologies should be a model capable of removing the bias effect from the cosmological parameters inference.

Starting from the work done in the above papers, my PhD project, that will develop within the activities of the Science Working Group of Galaxy Clusters (SWG-CL) of the Euclid Consortium (EC) will consist in finding efficient way (exploring some of the different approaches mentioned above) to quantify projection effects by using suitably designed mocks Euclid photometric galaxy surveys. These synthetic Euclid mock cluster surveys will be generated using a large set of in-house cosmological N-body simulations and populating them with galaxies. In this way, I will aim at quantifying the impact of projection effects on cosmological posteriors, and to define a model to correct for them.

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