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Cluster cosmology with next-generation surveys.

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Abstract

The advent of next-generation surveys will provide a large number of cluster detections that will serve the basis for constraining cosmological parameters using cluster counts. The main two observational ingredients needed are the cluster selection function and the calibration of the mass-observable relation. In this talk, we present the methodology designed to obtain robust predictions of both ingredients based on realistic cosmological simulations mimicking the following next-generation surveys: J-PAS, LSST and Euclid. We display recent results on the selection functions for these mentioned surveys together with others coming from other next-generation surveys such as eROSITA, ACTpol and SPTpol. We notice that the optical and IR surveys will reach the lowest masses between $0.3 < z < 1.5$ and will be complemented by the X-rays at lower-redshift and SZ at higher redshifts. We also present results on the mass-observable relation calibrated from the simulations, obtaining similar scatter to other observational results limited to higher redshifts. Finally, we describe the technique that we are developing to perform a Fisher Matrix analysis to provide cosmological constraints for the considered next-generation surveys and introduce very preliminary results.

1 Introduction

Galaxy clusters are the largest structures bounded gravitationally. The study of the physics of these objects is very interesting since they allow us to study galaxies in similar environmental conditions and therefore, they can shed light on the main mechanisms shaping galaxy evolution in dense environments (e.g. [3, 4]).

Furthermore, galaxy clusters are very useful cosmological probes. Their simple count can be used to constraint different cosmological models (see [27] and references herein). At present, several observed cluster samples are available (e.g. [5, 6, 23, 7]) but their number, spread in redshift or in halo mass is not large enough to provide tight cosmological constraints.

Upcoming surveys observed in the optical or infrared, such as J-PAS [11], LSST [15, 18], and Euclid [16], will change this. Hundreds of thousand of these objects are expected to be found in the very large areas of the sky that these surveys will map [9]. While these samples will be extremely useful for many purposes, they will become crucial for testing cosmological models and breaking degeneracies between cosmological parameters obtained by other probes.

The structure of this proceeding is as follows. In section 2, we give a very brief description of the next-generation surveys that we will consider. Section 3 is devoted to the description of the procedure to create realistic mock catalogues, section 4 gives a brief description of the methodology to detect galaxy clusters used in this work, the Bayesian Cluster Finder (BCF, [5]), and section 5 displays recent results on selection functions, mass-observable relations and preliminary cosmological constraints for the three surveys considered.

2 Considered next-generation surveys

In this work, we have considered three of the upcoming optical and infrared photometric surveys: J-PAS, LSST and Euclid. We give a brief description of each of these surveys. For more information, please check the reference papers.

J-PAS: The Javalambre Physics of the accelerating universe Astrophysical Survey (J-PAS, [11]) will be a 56 narrow-band photometric survey in the optical mapping 8600 deg^2 of the northern sky from the 2.5 m Javalambre Survey Telescope in Teruel (Spain). The survey will start in the first half of 2017 and it will achieve a mean photometric redshift accuracy comparable to that expected from a low resolution spectroscopic survey. Further details about the survey can be found in [11, 9] and references herein.

LSST: The Large Synoptic Survey Telescope (LSST, [15, 18]) will be a 6 broad optical bands $ugrizY$ photometric survey imaging 18000 deg^2 to a depth of $r = 27.5$ mag from a dedicated 8.4 m telescope placed on Cerro Pachón (Chile). The survey will start in 2020 and it will provide the deepest images of the southern sky in the optical wavelenghts. Further details can be found in [15, 18, 10] and references herein.

Euclid: The Euclid survey [16] will be a survey that will image 15000 deg^2 of the whole sky in three IR bands YJH down to $H \sim 24$ mag, by using a dedicated satellite. The survey, starting in 2020, will consider different options for the optical counterpart. In this work, we have considered a pessimistic case, where the optical counterpart will come from DES and an optimistic case, where the optical data will come from LSST and DES. For more information, we refer the reader to [16, 10] and references herein.

3 Creation of realistic mock catalogues

In this section, we describe the methodology used to create realistic mock catalogues resembling the data of the considered survey.

We first considered the public $500\,\mathrm{deg}^2$ Euclid mock catalogue by [19], which contains dark matter halos extracted from the N-body Millenium Simulation [26] and photometric parameters for the galaxies created with the semi-analytical models of galaxy formation GALFORM [13, 12]. These mock catalogues, while having a very good performance, fail to reproduce some of the photometric properties of clusters (see [8] and references herein). For this reason, we applied `PhotReal` [8] to these mock catalogues, a technique that recomputes new photometry for different mock galaxies by employing a well-calibrated library of spectra templates.

The final mock catalogues have a much more realistic distribution of colours than the previous existing catalogues [8]. They contains new photometry mimicking the depth, photometric errors and photometric redshift distribution of these surveys. These catalogues are publicly available at http://photmocks.obspm.fr/.

4 Detection of galaxy clusters in mock data

We have detected galaxy clusters by using the Bayesian Cluster Finder (BCF, [5]) applied to the mock catalogues generated for each of the considered surveys [9, 10]. The BCF has been used to detect galaxy clusters in present optical surveys such as the CFHTLS-Archive Research Survey [5]; the Deep Lens Survey [6] and the ALHAMBRA survey [7], obtaining a >70% agreement between these detections and other works at different wavelenghts (see [5, 6, 7] for instance).

After that, the detected clusters have been matched to the original halo mock catalogue in both directions by following a modification of the Friends-of-Friends (FoF, [5, 6, 7, 9]) algorithm. For space limited reasons, we refer the reader to the original publications for details on the code detector.

5 Cosmology with cluster counts

The ultimate goal of our project is forecasting a variety of cosmological parameters for future surveys by using cluster counts. In order to do this, we need two main ingredients for performing cluster cosmology (e.g. [14] and references herein): the cluster selection function and the mass-observable relation.

5.1 Selection function

In order to obtain reliable selection functions for the considered surveys, we have computed completeness and purity curves as a function of redshift and mass using the match detections in each of the mock catalogues [9, 10]. After that, we completed the minimum mass for which

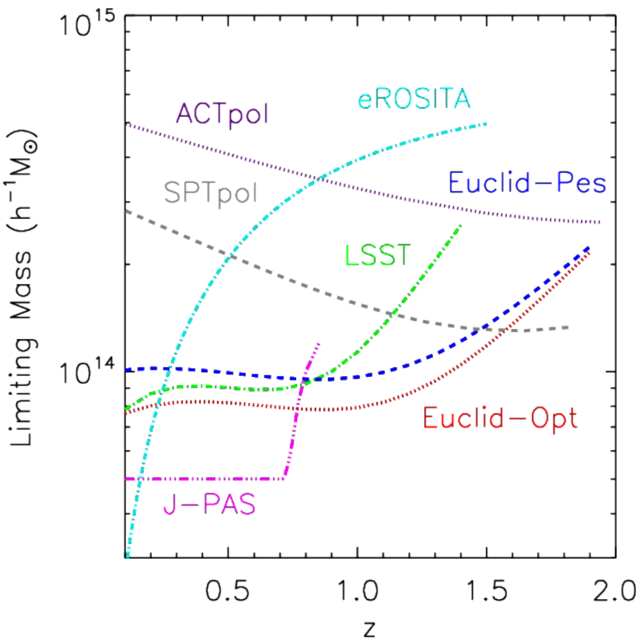

Figure 1: Selection function (minimum reachable mass as a function of redshift) for different surveys: Euclid-Opt, Euclid-Pes, LSST and J-PAS (Optical, [9, 10]; eROSITA [20]; SPTpol and ACTpol [27]). More information can be found in [10].

we were able to detect clusters with both completeness and purity $> 80\%$. The resulting selection function for Euclid, LSST and J-PAS can be seen in Fig. 1 (see also [10]). As a comparison, we display additional selection functions from other next-generation surveys in different wavelengths (X-rays; eROSITA, [20], and SZ; SPTpol and APTpol [27]).

The combination of the different selection functions highlights their complementarity. First, X-ray surveys will be able to detect galaxy clusters at $z < 0.3$ down to very low-masses ($\sim 10^{13}\mathrm{M}_\odot$). The intermediate redshift range of $0.3 < z < 1.5$ will be mapped by optical surveys down to masses ranging between $\sim 5 \times 10^{13} h^{-1}\mathrm{M}_\odot$ and $\sim 1 \times 10^{14} h^{-1}\mathrm{M}_\odot$. More specifically, J-PAS will reach these masses up to $z < 0.7$, LSST up to $z < 1.1$ and Euclid up to $z < 1.5$. Finally, higher redshift ranges ($z > 1.5$) will be mapped by SZ experiments down to similar mass thresholds.

5.2 Mass-Observable Relation

We have also calibrated our observable, the total stellar mass in the detected cluster, M^*_{CL} with respect to the halo mass from the catalogues. We have performed a fit to these date to a power law relation between the two variables and we have also included a log dependence with the redshift of the cluster [9, 10].

We obtain that the scatter in mass obtained for each of the experiments is very similar to this obtained by other works ($\sigma_{M^*_{\mathrm{CL}}|M_{\mathrm{h}}} \sim 0.12 - 0.14\,\mathrm{dex}$), with the difference that the range in redshift and mass in larger in these cases. We have also found that our fit is compatible with non-evolution of this relation, in agreement with other observational works (e.g. [17, 2, 24]).

We have also calibrated the halo mass with respect to the observable, M^*_{CL}, by performing a Monte Carlo approach to obtain the median and scatter values of the M_h for a fixed value of M^*_{CL} [9, 10]. The mean scatter found for the three surveys is $\sigma_{M_\mathrm{h}|M^*_\mathrm{CL}} \sim 0.19 - 0.25\,\mathrm{dex}$, similar to those found by other works limited to higher masses (e.g. [22, 1]).

5.3 Cosmological constraints

Both, a very well calibrated selection function and mass-observable relation, are the necessary inputs needed to perform cluster cosmology with cluster counts for a particular survey (e.g. [14]). We have developed a new package within iCOSMO [21] to obtain constraints from cluster counts using a Fisher Matrix analysis (Ascaso et al. in preparation). Preliminary results show that the constraints coming from cluster counts can help breaking degeneracies obtained by other probes, such as SN or BAOs, and therefore increase the value of the expected Figure of Merit. This result is supported by other works (e.g. [25]) and puts in evidence the importance of these objects in the understanding of the Universe with the upcoming data.

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