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Strong Lensing Cosmography in the Frontier Fields

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Abstract. The wealth of strong lensing features observed in the Frontier Fields clusters offers insights on the nature of dark energy. The large number of multiple-images systems with redshifts allows to simultaneously estimate the lens model parameters and the cosmological parameters involved in the distances calculations. In particular for the ΛCDM model, it is possible to estimate the matter density Ω_m and the dark energy equations parameters w_X. In this talk, I will present recent analyses of systematic errors based on Frontier Fields observed and simulated data.

Keywords. cosmological parameters, cosmology: observations, gravitational lensing, galaxy clusters

1. Introduction

In Jullo *et al.* (2010), we presented a method to estimate w_X using strong lensing in massive galaxy clusters. Strong lensing tells us about the mass distribution in the lens, but also about the distances to the background lensed objects. With a sufficient number of multiply-imaged background objects located at different redshifts, we can sample the growth of the Universe, and put constraints on the cosmological parameters. However, this method is affected by different sources of systematic errors. In particular, D'Aloisio & Natarajan (2011) studied the impact of line of sight structures and scatter in the cluster-galaxy scaling relations.

2. Method

The Frontier Field ARES cluster was specifically simulated to test modelling methods. With 242 multiple images and a bimodal mass distribution with 2 BCGs, this cluster is representative of the clusters observed in the HST FF program. From the simulators, we were given the catalogs of multiple images, of shear, of cluster-galaxies with magnitudes in 7 HST-bands from UV to NIR, and the maps of shear and convergence at redshift $z = 9$.

We used the LENSTOOL package(Jullo *et al.*, 2007) to model the clusters, adjust the parameters to the observational constraints, and produce the predicted mass maps, amplifications and sub-halo tidal masses. In our models, the mass distribution is decomposed into a sum of halos with PIEMD profiles (Elíasdóttir *et al.*, 2007), either of cluster-scale size, and allowed to float within 10" from the BCGs, or of galaxy-scale size, and centred at the location of the cluster-galaxies, and with density profile scaled with the magnitudes in F160w band, as described in Jullo *et al.*, 2007.

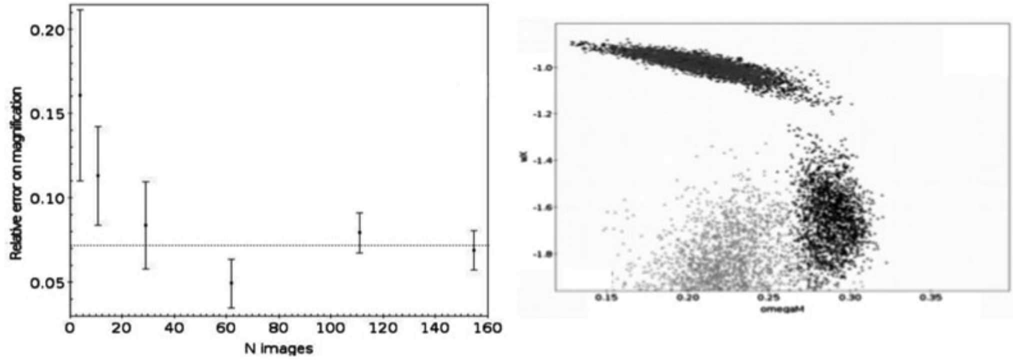

Figure 1. (Left) Relative error on amplification as a function of number of multiple images considered in the modelling. (Right) Impact of redshift binning of sources on the estimation of the cosmological parameters. Points are MCMC samples for sources with spectroscopic redshift in the range $2 < z < 3$ (gray), with the addition of photometric redshifts with 2% (black points at $w_X < 1.4$), 0.2% (back points around $w_X = -1$).

3. Results

For ARES, we investigated 2 quality estimators: (i) we compared our predicted amplifications to the true ones, and found that our predictions were dominated by systematic errors beyond 50 multiple images used as constraints (see Fig. 1), (ii) we extracted the radial evolution of the iso-density contours ellipticity from the mass maps, and found a good agreement with the true radial evolution. Also, we also obtained better adjustments with individually-modelled BCGs and with Navarro, Frenk & White (1997) density profiles for the cluster-scale halos. We also found that by including in our models 2 massive structures located 125" outside of the strong lensing region, we improved our χ^2 by a factor of 2.

Regarding the estimation of w_X, we found that strong biases could happen if the multiple images were strongly segregated in redshift bins (see Fig. 1). Photometric redshifts help, provided they are unbiased and estimated with currently unreachable precision ($\sigma_z/(1+z) < 0.2\%$).

For MACSJ0717, we compared the tidal mass histograms obtained with 2 different priors on the model. The reconstruction was performed with 165 multiple images discovered in the new HST FF images (Limousin *et al.*, in prep.). We computed the tidal radius and tidal mass of the cluster-galaxy halos assuming that the tidal radius is the radius at which the mean density inside the sub-halo was equal to the density of the cluster-scale components. Assuming an analytical expression for the sub-halo mass loss in clusters (Giocoli *et al.*, 2012), we estimated the cluster formation redshift to $z_m = 1.97$ or $z_m = 3.41$ (see Fig. 2). This result therefore likely discards the second model.

4. Conclusion

Current lensing models are too simplistic to reliably reproduce the large amount of multiple images found in the HST FF clusters. In this talk, we presented several estimators to assess the quality of the reconstruction. We compared to the true inputs of the simulated clusters, and to analytic predictions derived from numerical simulations. This work demonstrates that numerical simulations help on improving lensing models, and conversely with observational constraints these models give us more insights into the physical processes at play in galaxy clusters.

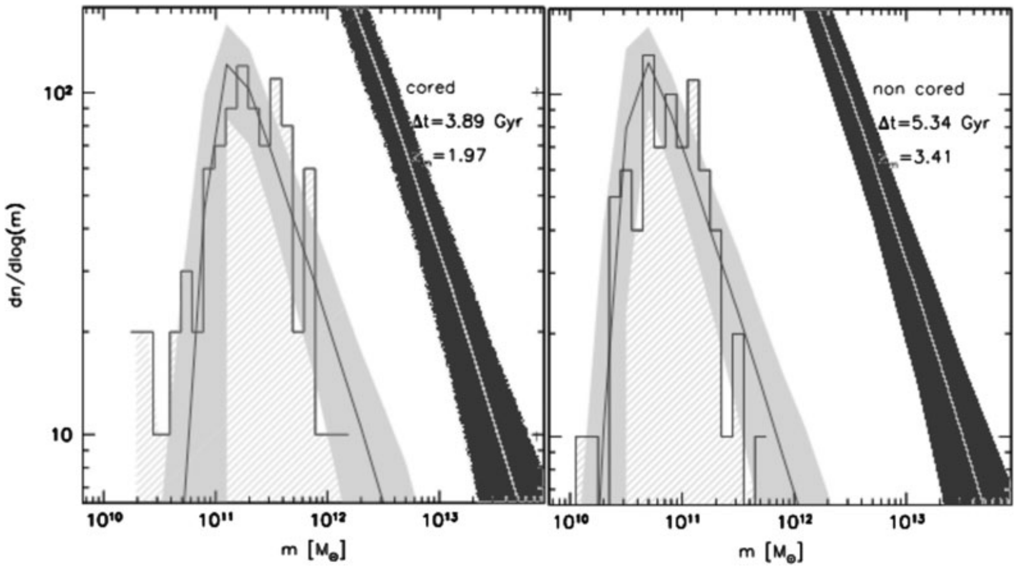

Figure 2. Sub-halo mass function (SHMF) of the cluster-galaxies in the cored (left) and non-cored (right) models of MACSJ0717+3745 described in Limousin *et al.* in prep. The histogram corresponds to the estimated SHMF, whereas the curves show the predicted SHMF before collapse (black) and at the cluster redshift (gray).

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