Bayesian Strong Lensing modelling of galaxy clusters

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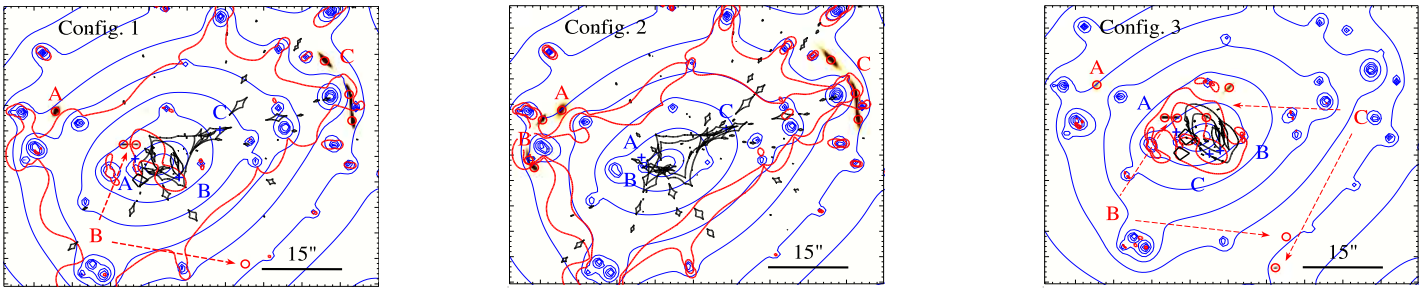
Introduction

In this study, we explore how well one can recover the mass distribution in strong lensing cluster cores where different sets of multiple images with different redshifts have been identified. To be able to quantify the uncertainty in the mass reconstruction, we have used a Bayesian Monte Carlo Markov Chain (MCMC) sampler ("Bayesys"). In particular, such optimization method allows to avoid local minima in the likelihood distributions which can be frequent in large parameter spaces modelling.

Method

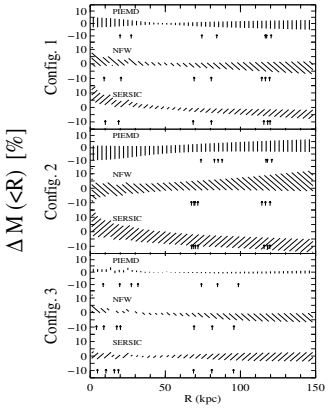
We simulate three clusters of galaxies with a set of underlying galaxy-scale subhalos and a cluster-scale halo. We model the cluster-scale halo successively with a Pseudo-Isothermal Elliptical Mass Distribution, a pseudo-elliptical Navarro, Frenk & White and a pseudo-elliptical Sérsic potential. For each of them, we study the degeneracies between the various model parameters.



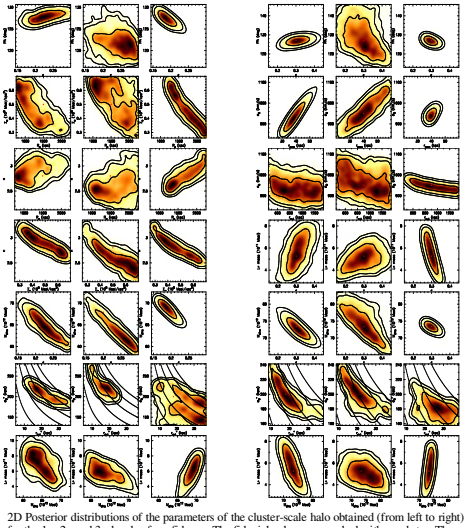
Images and sources positions of the systems A, B and C at redshifts 0.6, 1.0 and 4.0 respectively. The crosses and the circles in red mark the sources and the images centres respectively. The critical (caustics) curves of systems B and C are in red (black). The iso-density contours of the mass profile are in blue.

Results I

- The mass of the galaxies can be strongly degenerated with the cluster mass
- In our simulated clusters, the galaxy cut-off radius can only be recovered with at most a 20% error
- The mass distribution outside the region of the multiple images is very poorly constrained



Relative mass profiles recovery in the three configurations for the three potentials PIEMD, NFW and Sérsic. The arrows below each plot mark the positions of the multiple images used as constraints. The error bars are at 1σ.

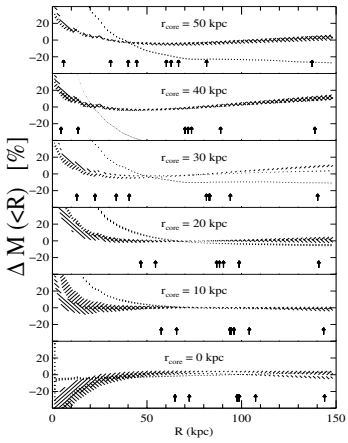


2D Posterior distributions of the parameters of the cluster-scale halo obtained (from left to right) with Config. 1, 2 and 3 for each mass profile. The 3 contours stand for the 1σ, 2σ and 3σ levels of confidence. The fiducial values are marked with a red star. The mass of a L^* galaxy is the total mass for a circular profile. The cluster mass M_{Einst} is the total enclosed mass (i.e. Galaxy subhalos and cluster-scale halo) in the Einstein radius (30"). The χ^2 was computed in the image plane.

Result II

We explore the ability of strong lensing at constraining the mass profile in the central region.

Using the Bayesian Evidence, we can successfully infer the underlying mass distribution with no manual intervention.



Mass profiles errors relative to the fiducial PIEMD mass profiles for the fitted potentials SIE (*vertically hatched region*), NFW (*-45° hatched region*) and Sérsic (*45° hatched region*) as a function of the aperture radius. The arrows mark the positions of the multiple images used as constraints. The error bars are given at 3σ.

Core radius (kpc)	E_{NFW}	$E_{Sérsic}$	E_{SIE}	E_{PIEMD}
0	-27	-25	-28	-20
10	-25	-23	-33	-19
20	-27	-24	-146	-19
30	-198	-204	-1391	-25
40	-81	-70	-2795	-19
50	-86	-73	-3260	-22

Comparison of the log (Evidence) produced by the fit of the NFW, SIE and Sérsic potentials to a core radius varying PIEMD potential. The values come from fits performed with sets of multiples images shown on the figure on the left.

Lenstool is publicly available at http://www.oamp.fr/cosmology/lenstool