LAM
LABORATOIRE D'ASTROPHYSIQUE DE MARSEILLE

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CENTRE NATIONAL D'ÉTUDES SPATIALES

CNRS

OCEVU

GECO Circle : Galaxy Clusters

Started "*spontaneously*" Autumn 2014 (pre GECO)
[critical mass : 3PhD students]

Ana Acebron [PhD, started october 14]
Mario Bonamigo [PhD, defending september 22 !]
Giulia Despali [PhD/Postdoc, 1 year]
Carlo Giocoli [Postdoc, CNES, 2 years]
Valentina Guglielmo [PhD, 6 months]
Anna Niemec [PhD, started october 14]

+ C. Adami, C. Caretta, E. Jullo, E. Nezri, M. Limousin

Future ? [next september]

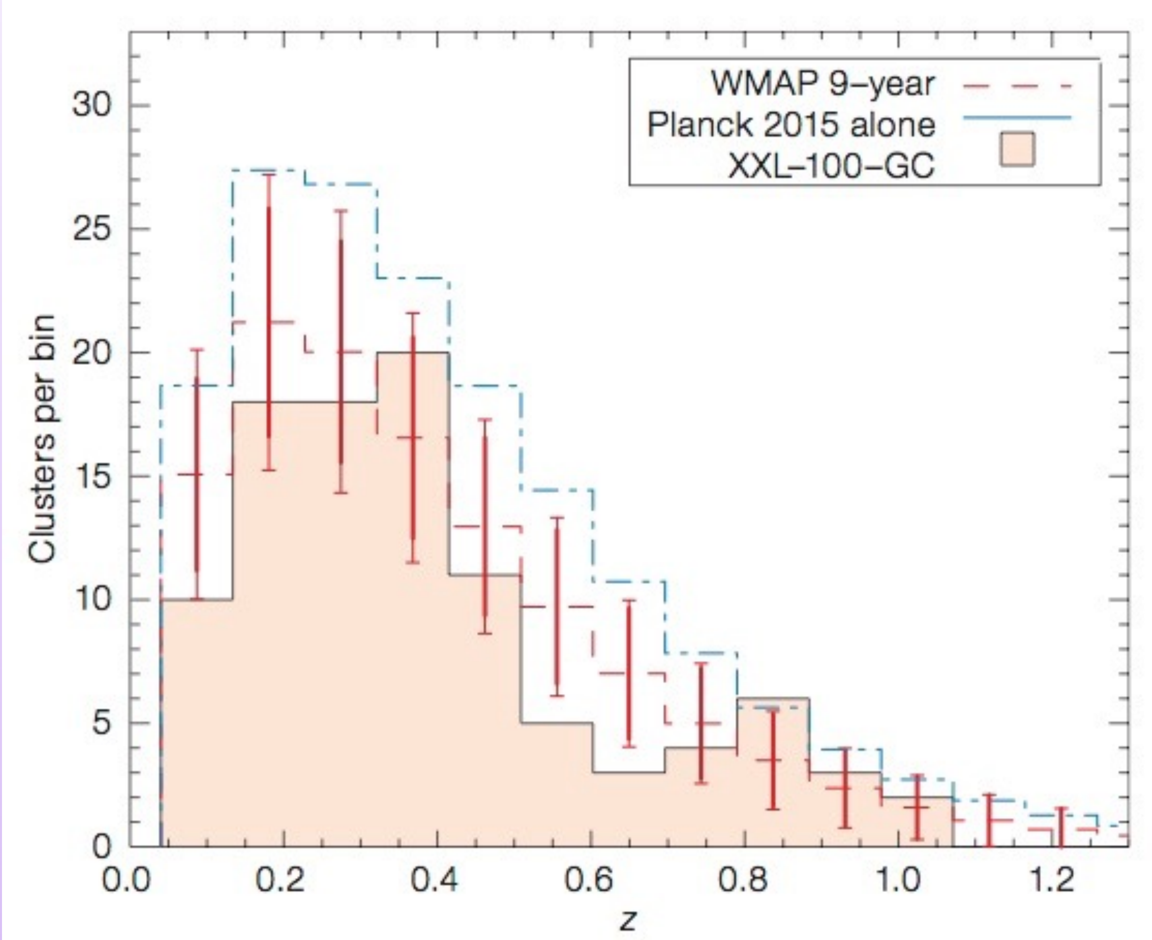
— { Bonamigo, Despali, Giocoli, Guglielmo, Jullo }
+Arturo Nunez-Castineyra (Nezri)

sub-critic ?

We might merge Cluster with DM Meeting

XXL Survey [Adami et al.]

2 x 25 sq. deg.
> 6 Ms (largest XMM project !)
450 new clusters
~15 papers

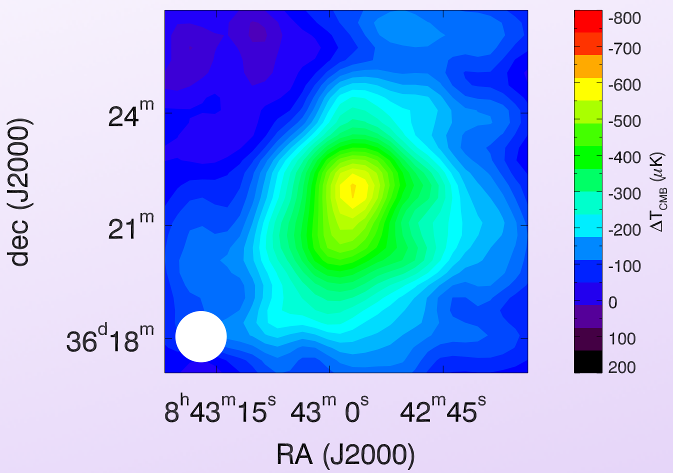


MultiLambda data
Nbody Simulations
Cosmological Parameters
Scaling Laws

Lack of Clusters compared to LCDM Predictions

Clusters are NOT Spherical [Limousin et al. 13 ScRev]

Non circular projection of various probes:



SZ [Sayers et al. 2011]

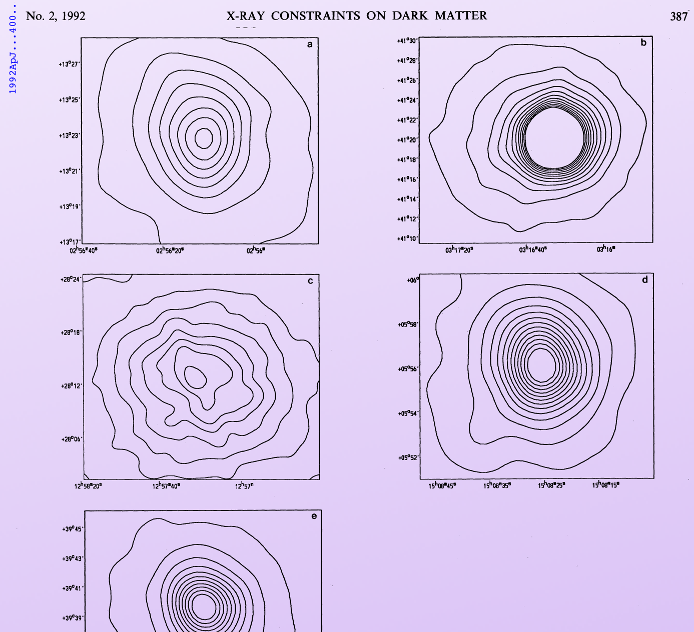


FIG. 1.—Contour maps of the X-ray surface brightness of the clusters in the energy rnge 0.2–3.5 keV; (a) = A401, (b) = A426, (c) = A1656, (d) = A2029, and (e) = A2199. The background has been subtracted and the image smoothed with a Gaussian function of 1′.76 FWHM. The effective resolution for each image is 2′.3 FWHM corresponding to 8.7 pixels. The contours for each image are separated by equal values of surface brightness, but this value differs for each image. The dimensions of each image are set so that each axis is approximately twice the value of R given in Table 2.

X-ray [Buote & Canizares 92]

Galaxies [Bingelli 1982]

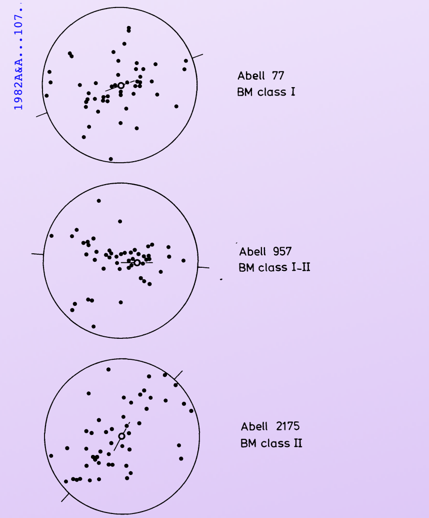
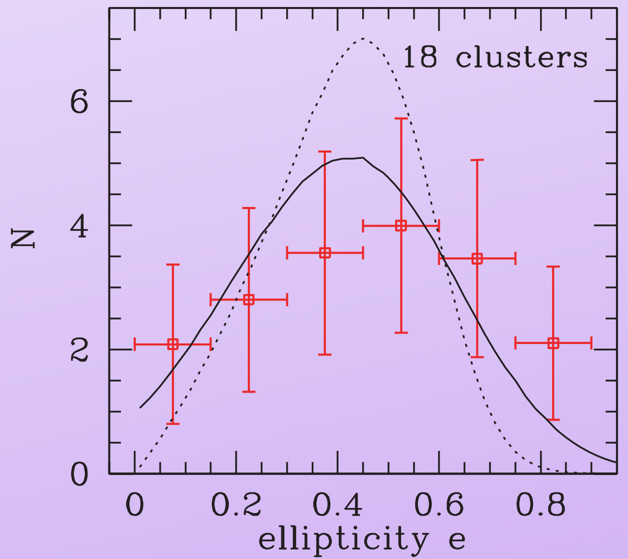
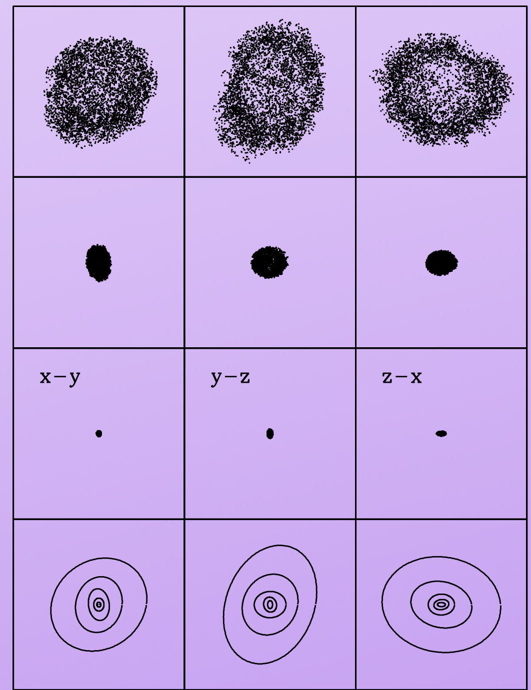


Fig. 1. Three clusters of galaxies which are strikingly elongated. For each cluster the positions of the 50 brightest galaxies within a radius of 2 Mpc are plotted; the first ranked galaxy is the small circle. Position angles are indicated by short straight lines; North is



Lensing [Oguri et al. 2010]



Numerical Simulations

[Jing & Suto 2002]

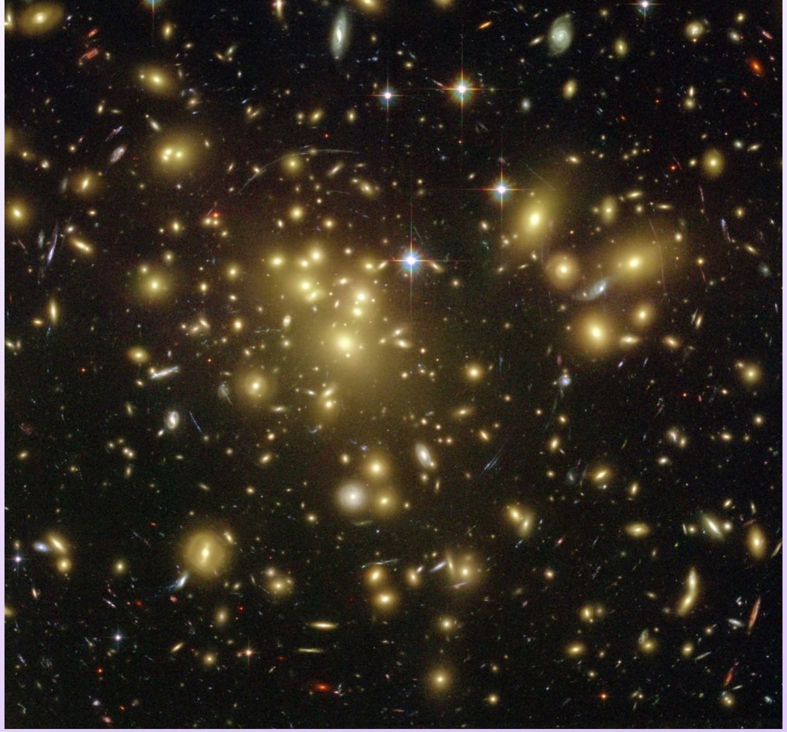
Why Bothering ??!

Solving the Abell 1689 Puzzle ?

Combining SL (HST), WL (Subaru) and

X-ray (Chandra) data within a TRIAXIAL Framework

[Morandi, Limousin et.al, 2012]



$$c_{200}^{\rm triaxial} = 5.3 \pm 0.5$$

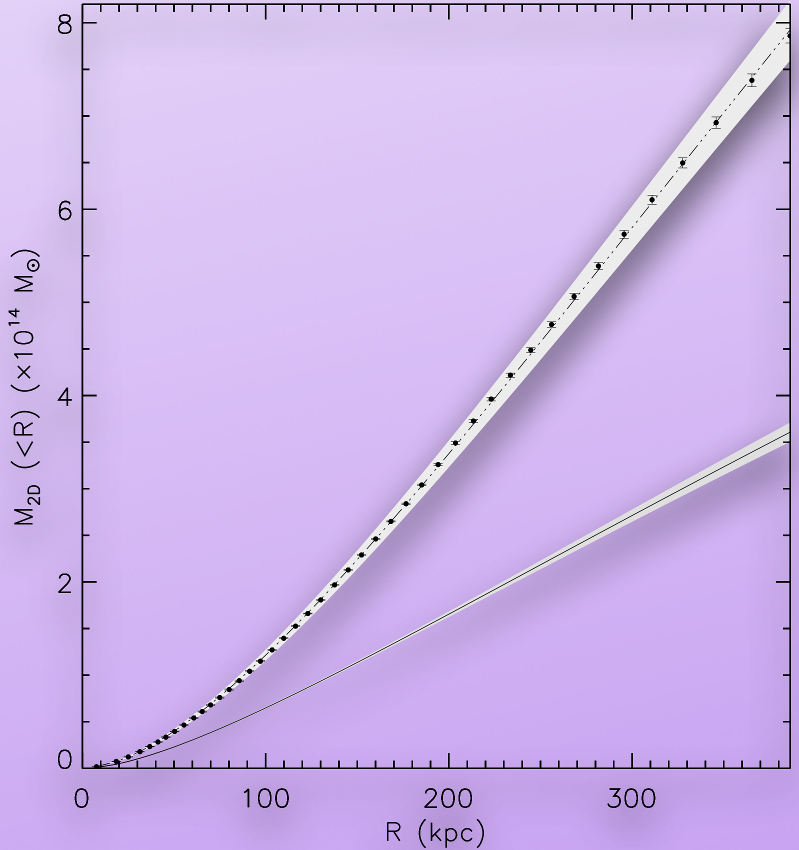
$$c/a = 0.56 \pm 0.07, \;\; b/a = 0.75 \pm 0.$$

$$\theta = 27 \, {\rm deg}$$

$$R_{\rm e} \sim 45" \;\; {\rm reproduced}$$

$$M_{2D}^{\rm lensing} = M_{2D}^{\rm X-ray}$$

$[\alpha = 1.16 \pm 0.04 \;\; {\rm instead \;\; of} \;\; \alpha = 0.92 \pm 0.07]$



Geometry Matters !

[*e.g.* Gavazzi et al. 05; Pfifaretti et al. 03; Svensmark etal. 14]

3D Shape : Insights from Simulations (MXXL + Sbarbine)

[Bonamigo, Despali, Limousin, Angulo, Giocoli, Soucail, 2015, MNRAS]

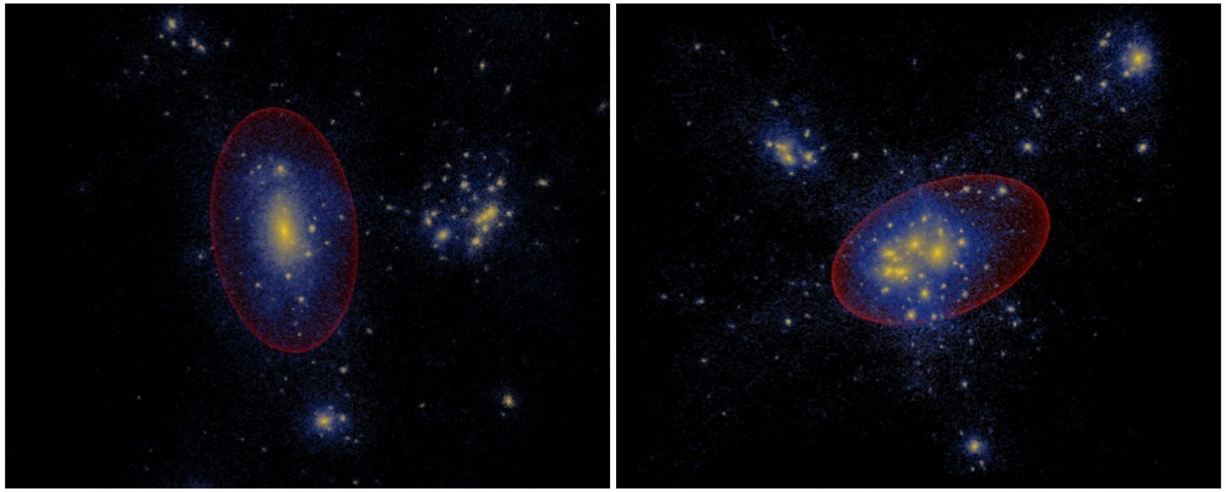


Figure 1. Density distribution (colour scale) of dark matter particles inside a 10 Mpc h^{-1} side cube centred in two different haloes and the respective computed ellipsoids (red) that approximate the mass distribution of the halo. The halo shown on the left panel has a virial mass of 5.29×10^{14} $M_{\odot} h^{-1}$, the one on the right has a mass of 6.90×10^{14} $M_{\odot} h^{-1}$. These represent two families of objects: a relaxed haloes (left) and a perturbed one (right), due to the large amount of substructures the latter has to be discarded, as it can not be well described by a triaxial approximation.

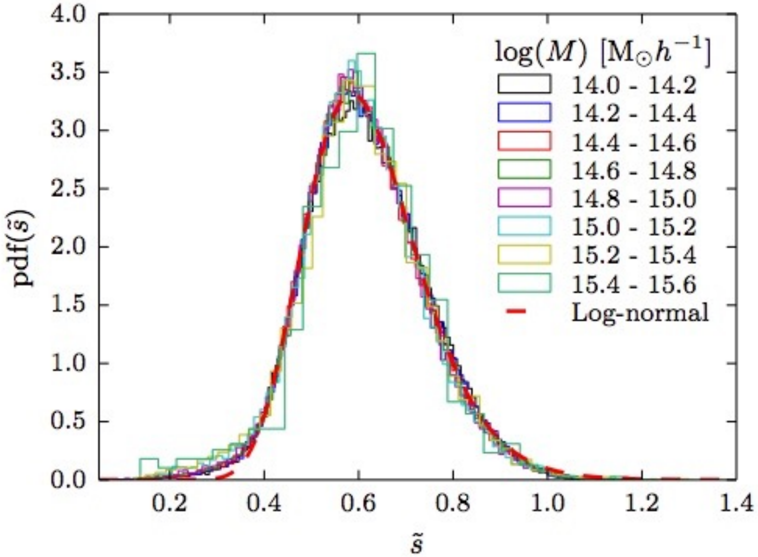


Figure 7. Distribution of the scaled axial ratio $\tilde{s}$ for masses shown in Table 2. It can be easily seen that the distributions at all masses are well represented by an unique fitting function.

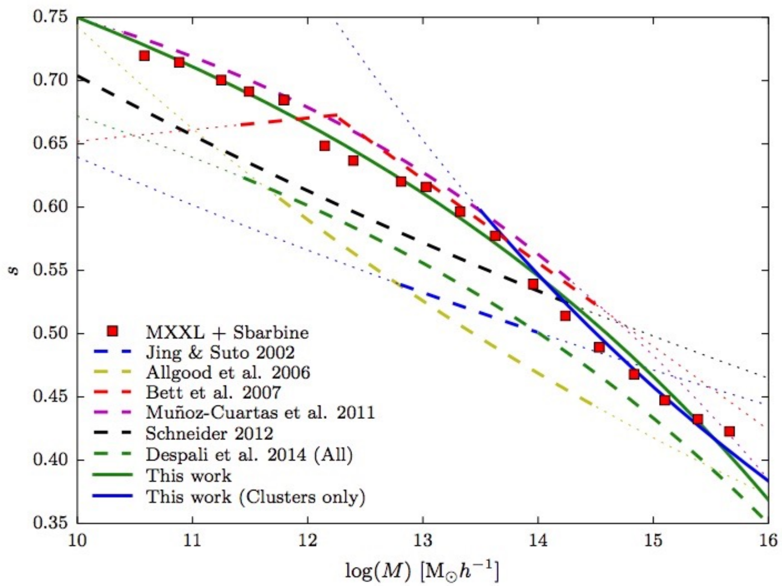


Figure 13. Comparison between previous works (dashed lines) and the results of this paper (solid lines). Red squares represent the data from both redshifts of the MXXL and the SBARBINE simulations, converted to redshift $z = 0$ for the Millennium cosmology. The blue solid line is the model for clusters shown in section 3.2; the green solid line is the fit for the entire mass interval from section 4.1. The dotted parts of the curves show the mass ranges outside where the relations have been derived from.

s = c/a
axis
ratio

Scaled Axis ratio :
Universality

First Statistically significant predictions for massive clusters

Characterizing Strong Lensing Clusters
Simulation [MXXL] + Semi-analytical [MOKA]

[Giocoli, Bonamigo, Limousin, et al. 2016, MNRAS, resub.]

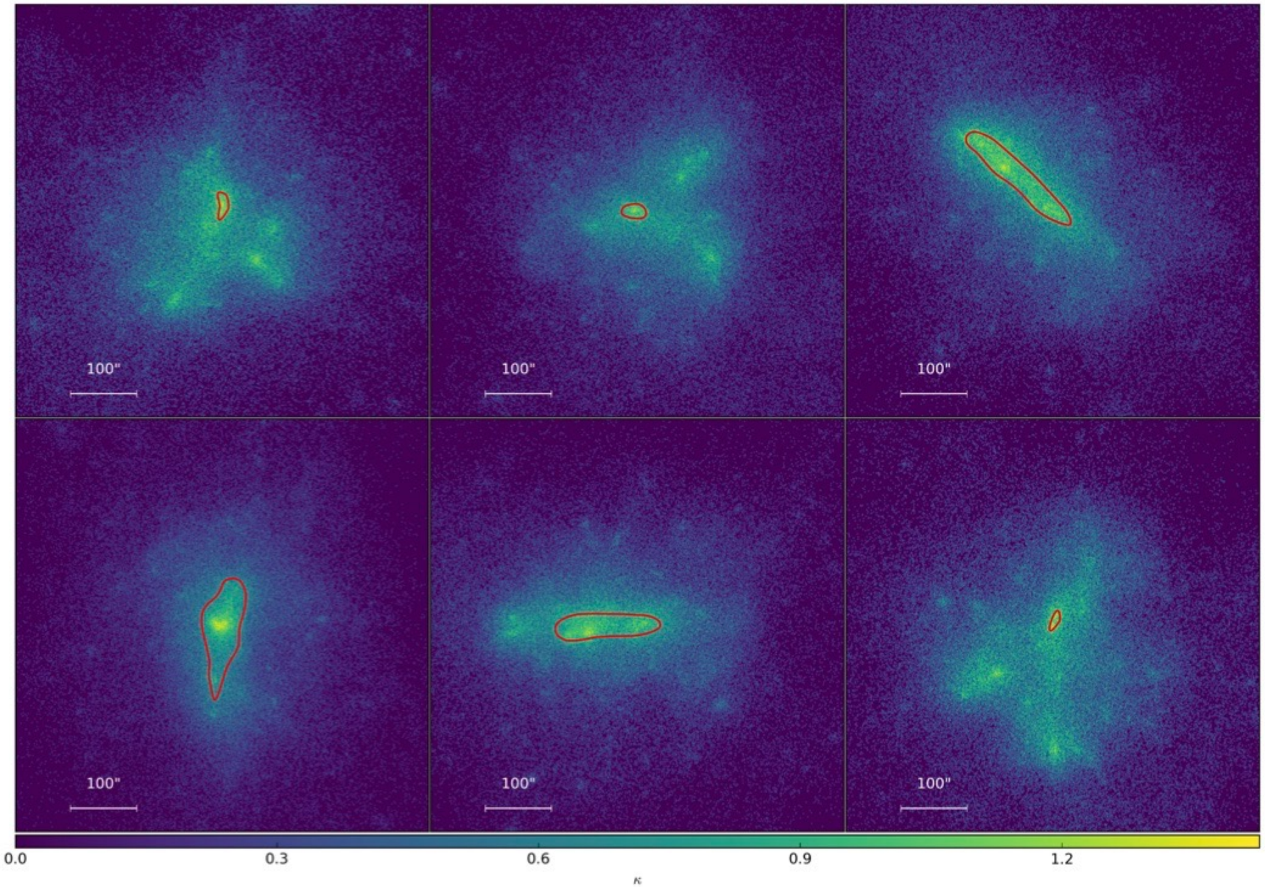
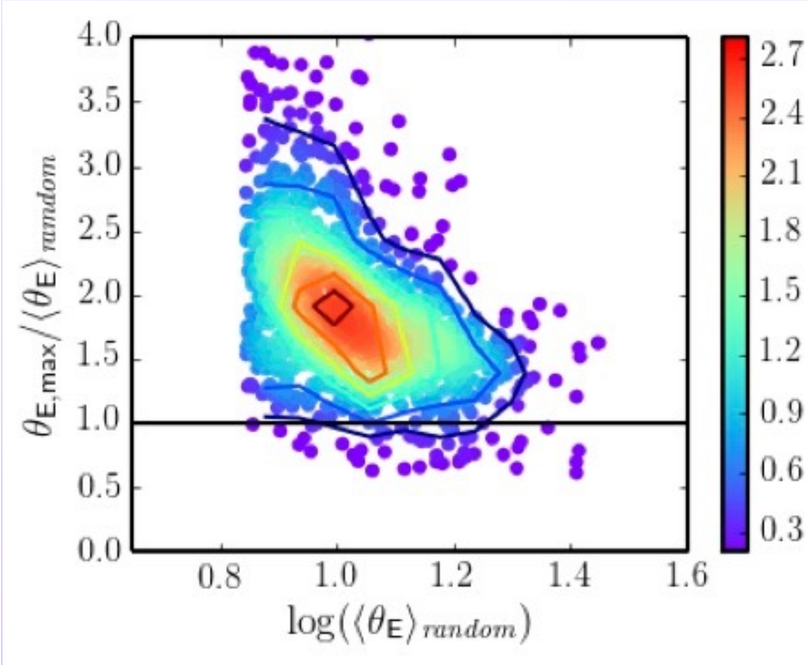


Figure 1. Convergence maps of different projections of a halo extracted from the Millennium-XXL simulation with mass $M_{200} = 1.2 \times 10^{15} M_{\odot}/h$. The red curves in each panel represent the tangential critical lines from which we compute the median Einstein radii. The top-three images show the three projections along the cartesian axes (i.e. *random* with respect to the cluster morphology), while the bottom ones from left to right, are the projections along the major, intermediate and minor axes, respectively. This particular cluster has the peculiarity of having in one projection (namely the one in the left bottom panel) the largest Einstein radius in our sample: 75 arcsec.



Relative size of the Einstein radii when the cluster major axis of the ellipsoid is oriented along the line of sight (max), compared to the average value of the three random projections

Projection effects Boost the size of the Einstein Radius ~ Projected Mass

How Does the Shape vary with Cluster Centric Distance ?

[Despali, Giocoli, Bonamigo, Limousin, Tormen, 2016, MNRAS, resub]

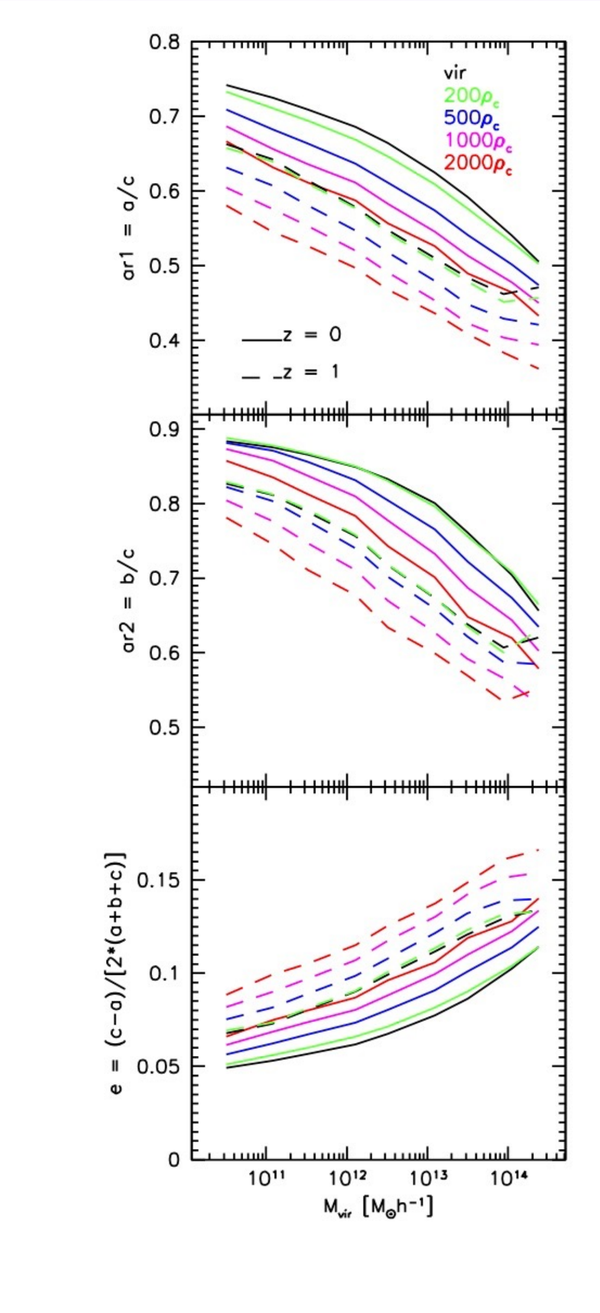
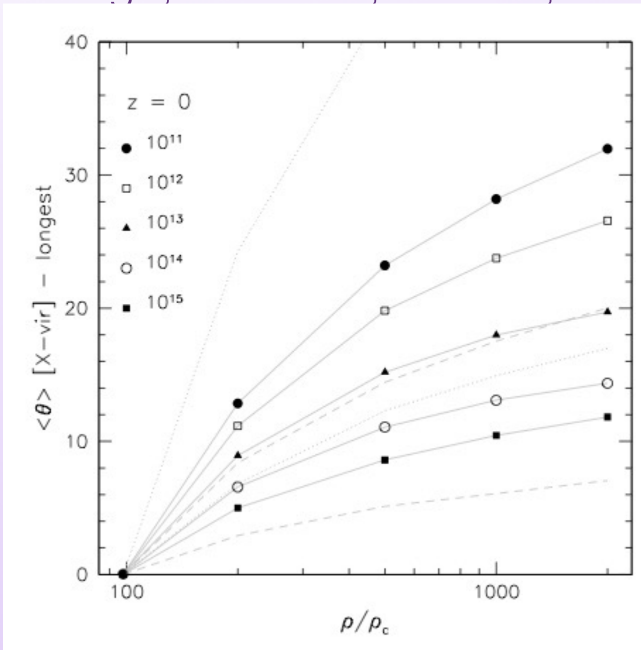


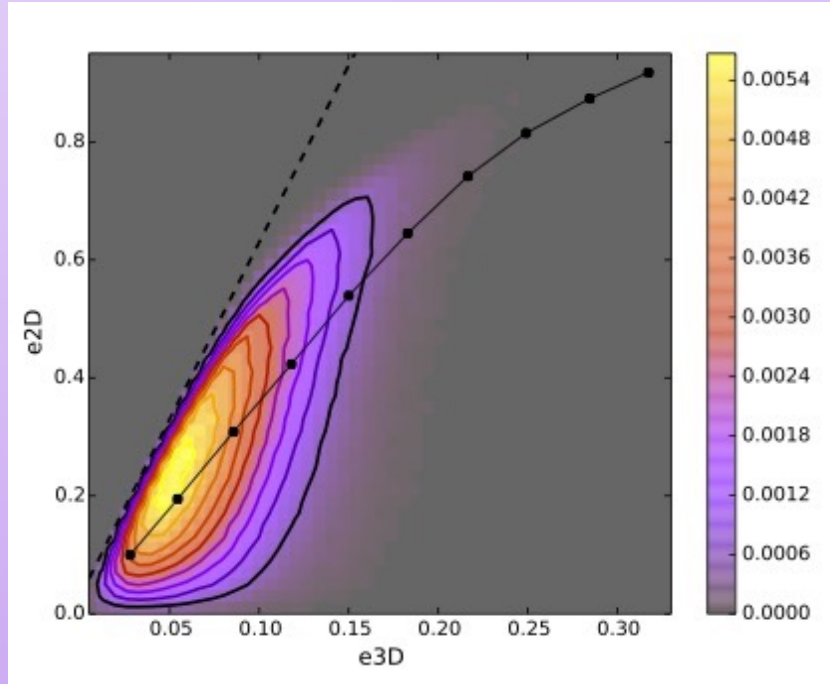
Figure 4. Axial ratios and ellipticity as a function of halo mass, for different overdensity thresholds. The lines show the median values of the distributions for $ar1 = a/c$, $ar2 = b/c$ and $e = (c-a)/[2*(a+b+c)]$) with $a \leqslant b \leqslant c$)..



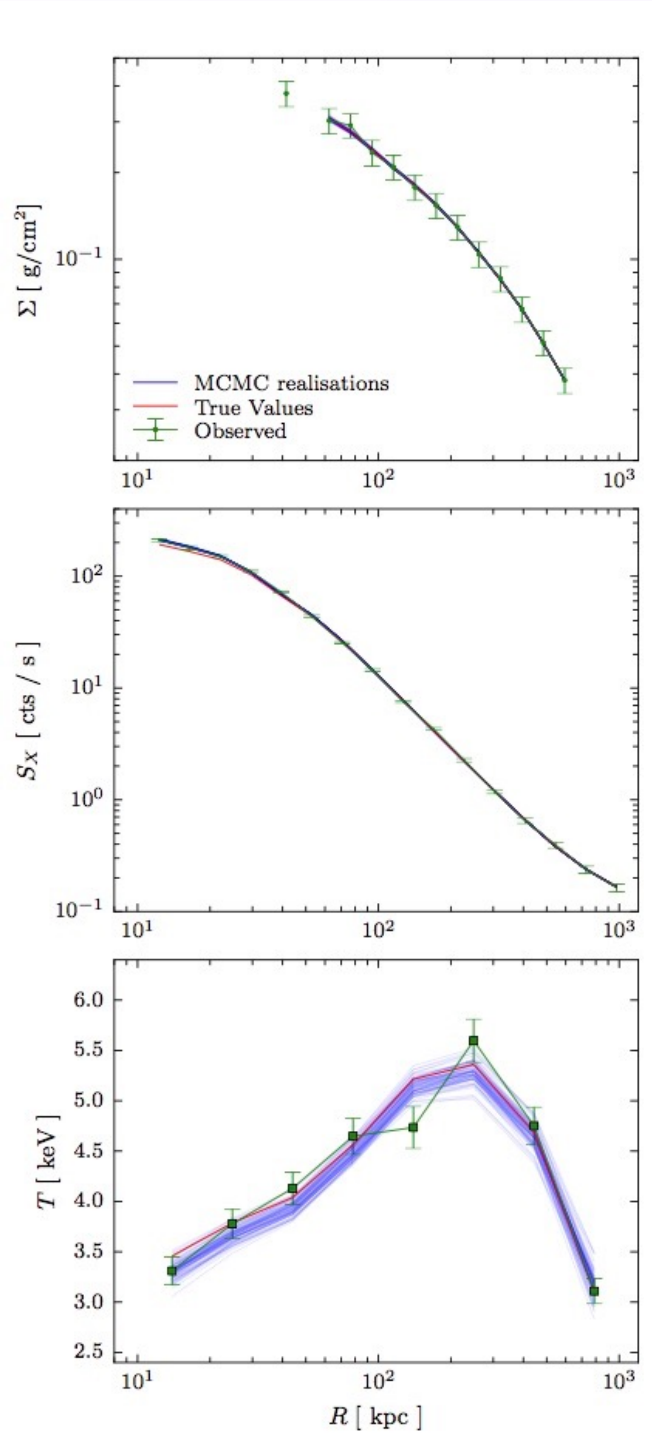
Misalignment angle of the four inner shells with respect to the viral one, as a function of halo mass

Shape is more complex than a Simple Ellipsoid !

Correlation between the 3D and 2D shapes: ellipticity Priors for the Strong Lensing Analysis most welcome



3D Shape : Combining Lensing + Xray Data: Algorithm



Red: input data
Green: including noise
Blue: MCMC chain
[Fit done in 2D, except for Temp.]

[Bonamigo et al, in prep.]

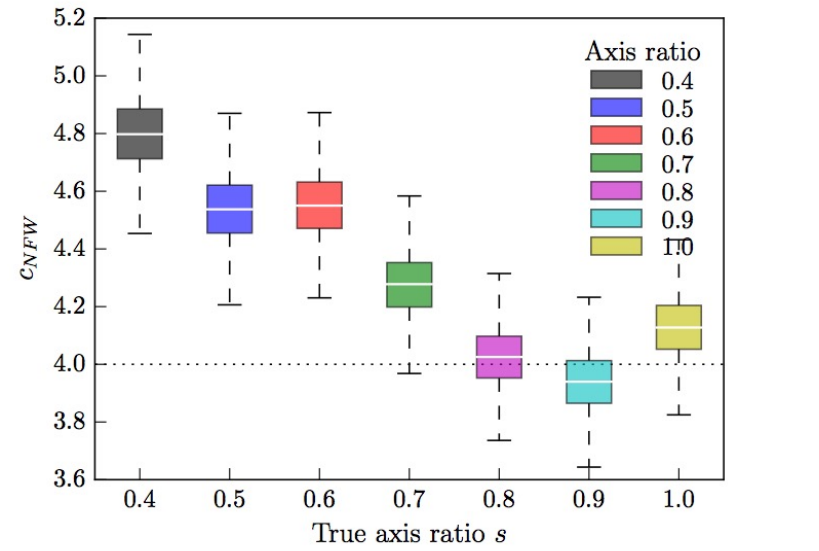
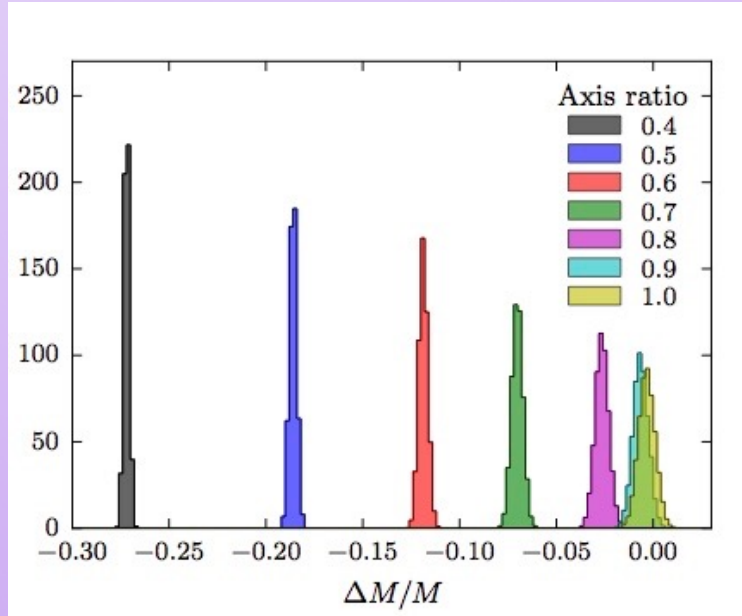


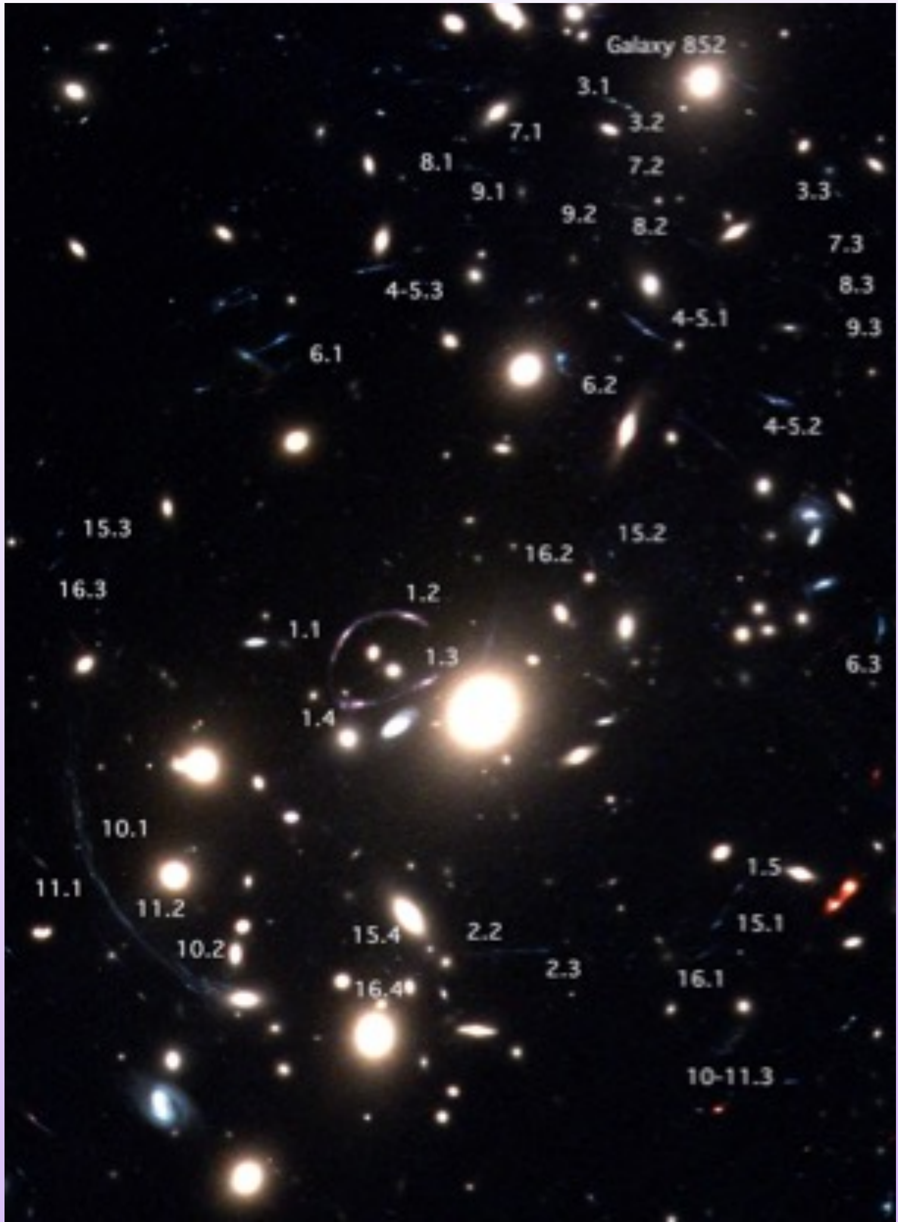
Figure 4.8.: Values of scale radius and concentration obtained with the spherical model. Each colour represents a different halo, with the minor to major axis ratio indicated in the legend and the star shows the input value of the parameters.



Spherical Assumption can induce large bias in the Mass determination and in the concentration parameter

Application: Abell 1703

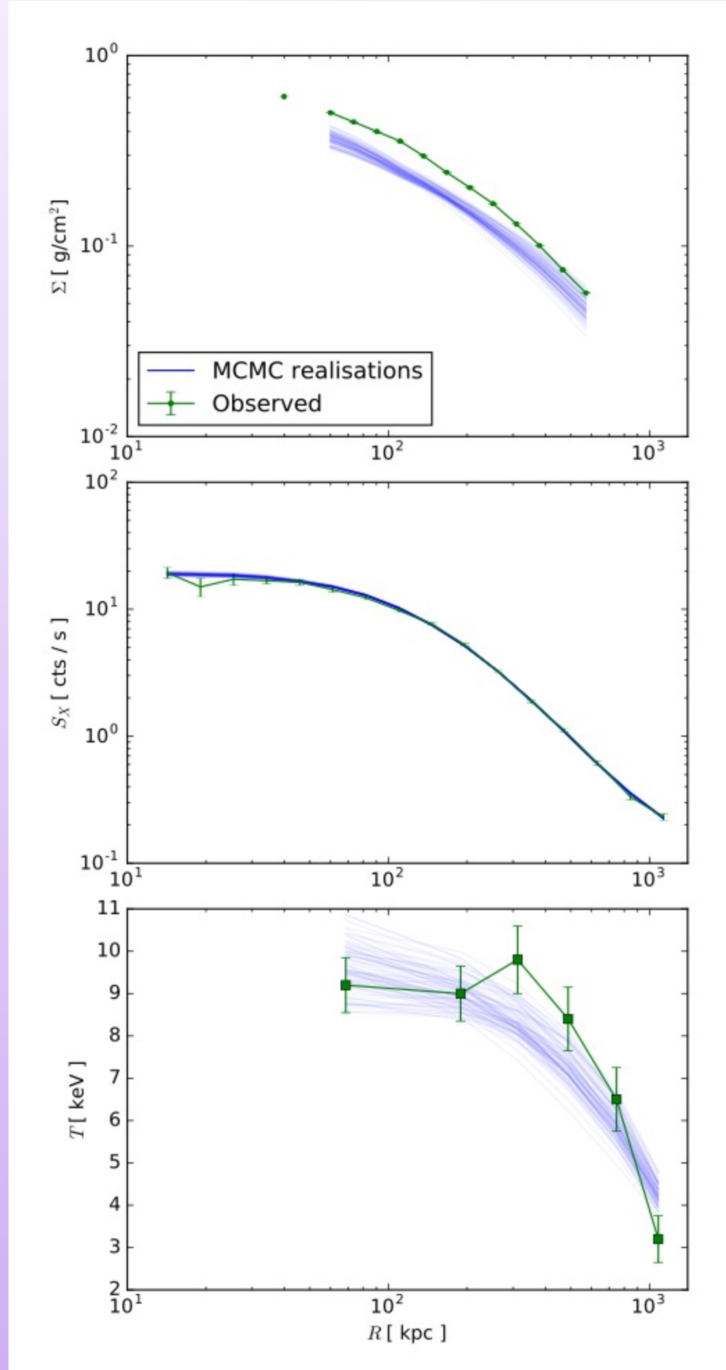
[Bonamigo, Gastaldello et al.]



Strong Lensing Analysis, ACS data

Limousin et al. 2008, A&A,

updated by M. Bonamigo et al.



Spherical Analysis of X-ray only data: Discrepancy with Lensing data : Room for improvement into a triaxial model ! [in prep…]