XXXII Canary Islands Winter School of Astrophysics

Galaxy clusters in the local Universe

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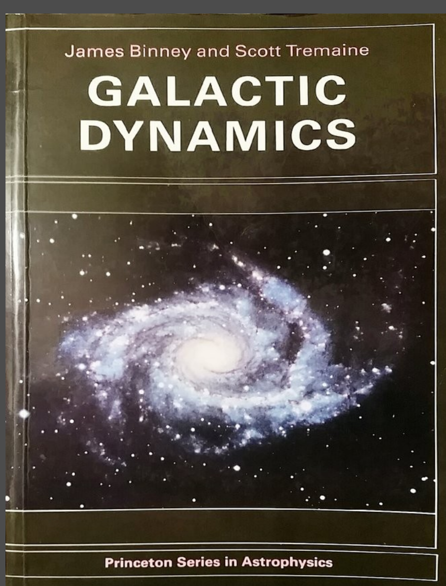
Lecture 6:

Masses & mass profiles

Based on:

Binney & Tremaine (1987),
Chapters 4.1, 4.2, 4.3



Pratt et al. (2019), Sections 2.3, 2.5, 3

Published: 28 February 2019

The Galaxy Cluster Mass Scale and Its Impact on Cosmological Constraints from the Cluster Population

G. W. Pratt, M. Arnaud, A. Biviano, D. Eckert, S. Ettori, D. Nagai, N. Okabe & T. H. Reiprich

Space Science Reviews **215**, Article number: 25 (2019) | Cite this article

Kneib (2008):

J.-P. Kneib: *Gravitational Lensing by Clusters of Galaxies*, Lect. Notes Phys. **740**, 213–253 (2008)
DOI 10.1007/978-1-4020-6941-3_7 © Springer Science+Business Media B.V. 2008

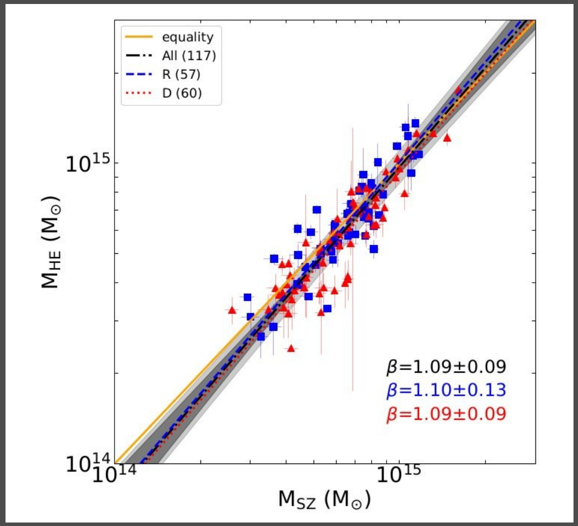
Additional readings:

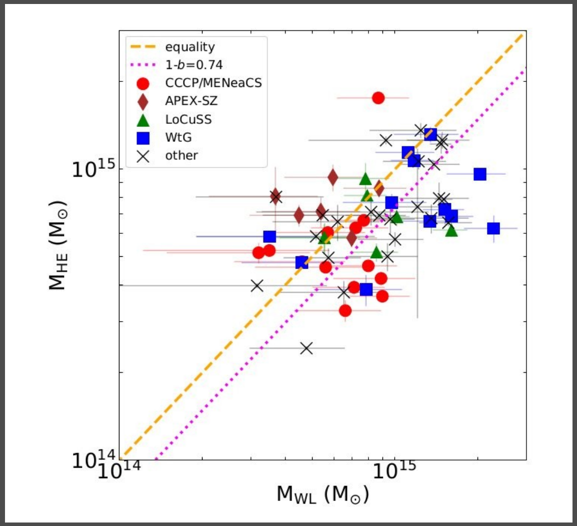
Girardi et al. (1998), ApJ, 505, 74 *(on the virial theorem)*
Mamon, AB, Boué (2013), MNRAS, 429, 3079 *(the MAMPOSSt method)*
Diaferio (1999), MNRAS, 309, 610 *(Caustic method)*
AB et al. (2013), A&A, 558, A1 *(Q(r))*

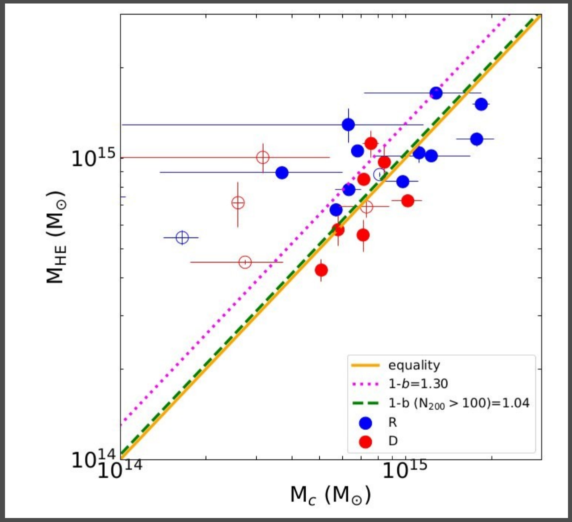
Masses & mass profiles

Galaxies, Gravitational Lensing, Intra-cluster plasma

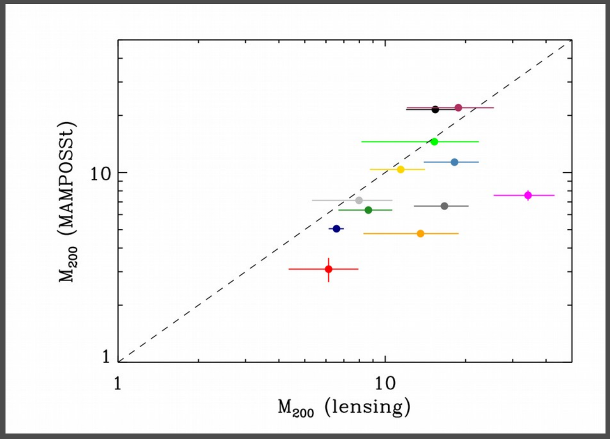
Comparing mass estimates from different methods/tracers
allows to constrain systematics and determine intrinsic scatter



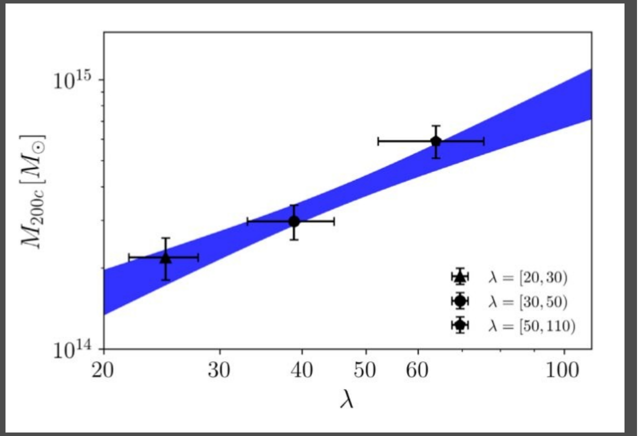




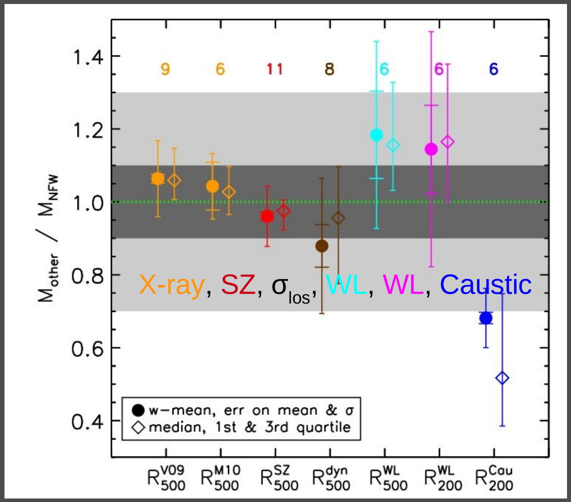
Lovisari et al. (2020): Planck ESZ, X-ray vs SZ, Weak Lensing, caustic



AB et al. (in prep.): CLASH, MAMPOSSt vs. Weak Lensing



Phriksee et al. (2020): CODEX, GL vs. richness

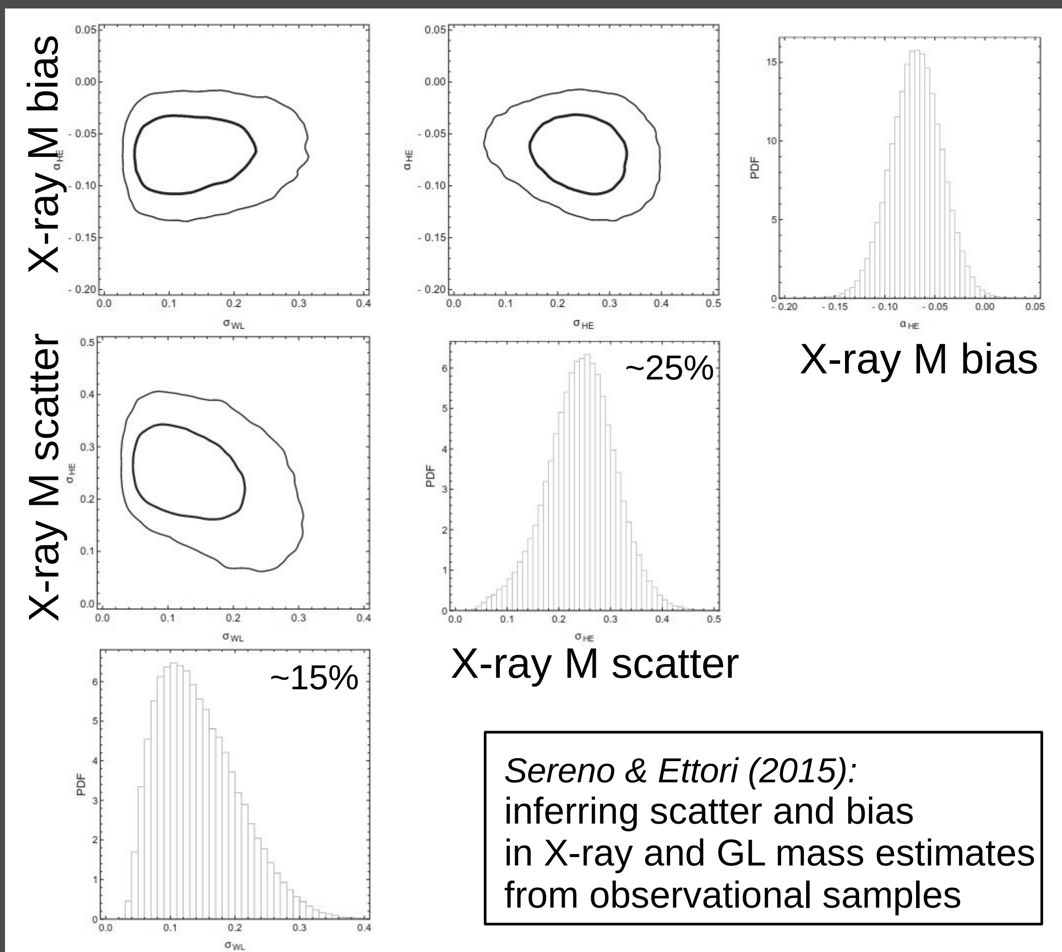


Ettori et al. (2019): XCOP, X-ray masses vs other mass estimates

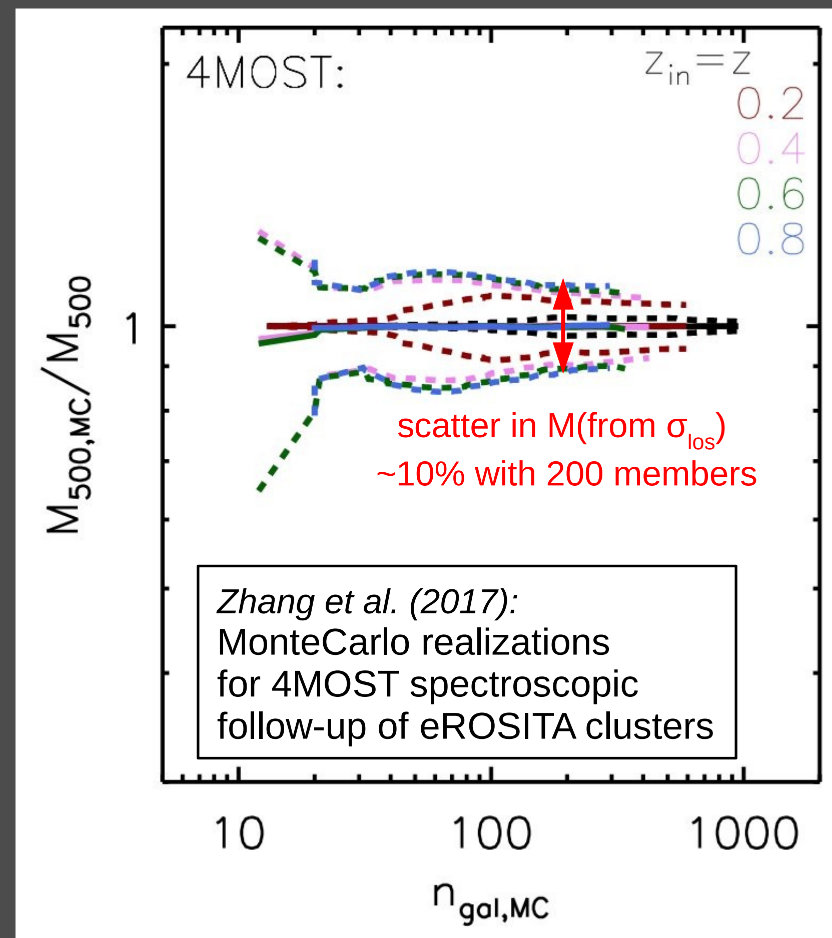
Masses & mass profiles

Galaxies, Gravitational Lensing, Intra-cluster plasma

Comparing mass estimates from different methods/tracers allows to constrain systematics and determine intrinsic scatter, also in combination with results from simulations and MonteCarlo



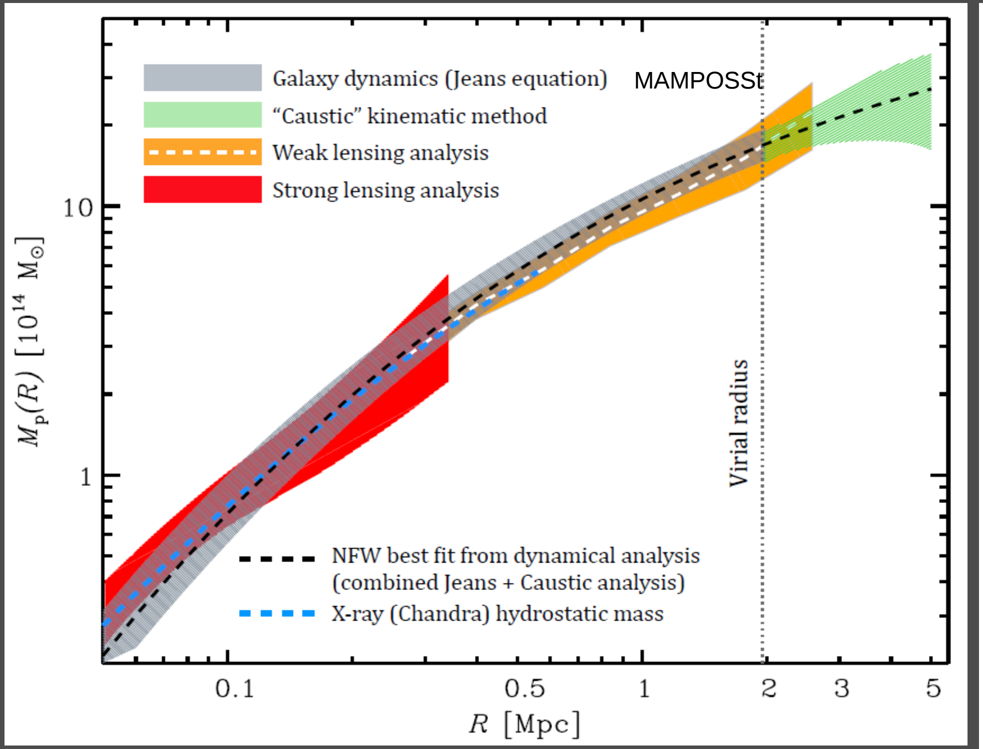
WL M scatter



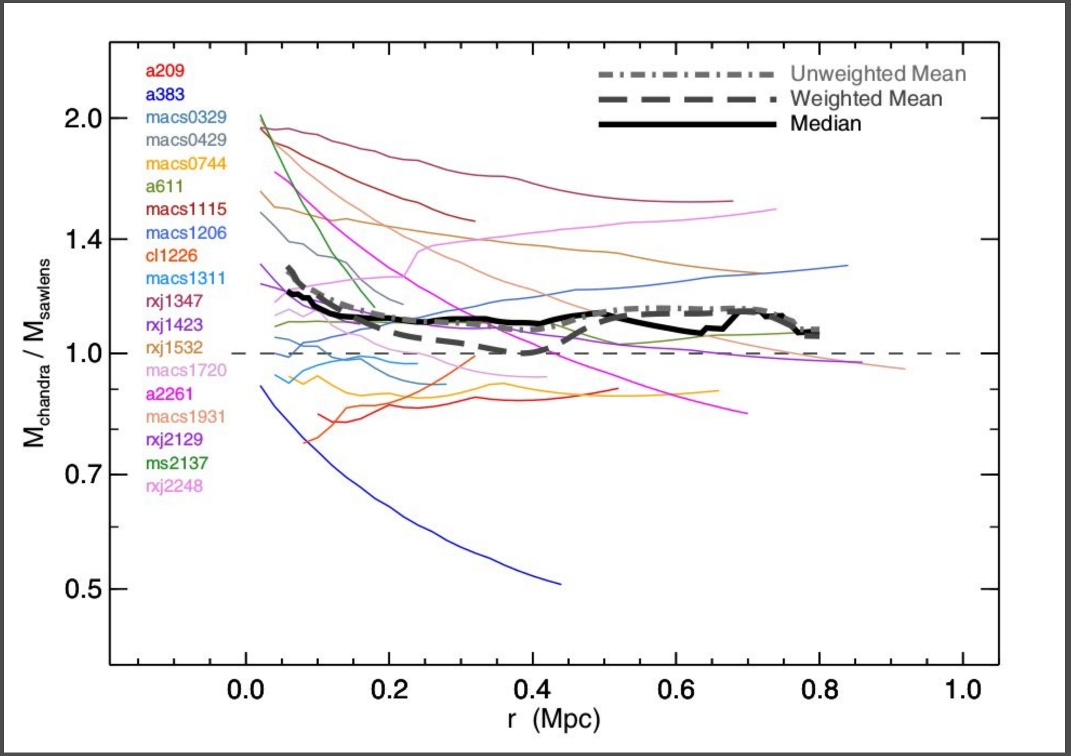
Masses & mass profiles

Galaxies, Gravitational Lensing, Intra-cluster plasma

Comparing mass **profile** estimates from different methods/tracers require excellent samples: **CLASH** (*Postman et al. 2012*), 25 clusters at 0.2<z<0.9 with excellent imaging, photometry, spectroscopy, X-ray and SZ observations



MACS1206, z=0.44, comparing MAMPOSSt, Caustic, weak and strong lensing, and X-ray M(r) (*courtesy of P. Rosati, PI of CLASH-VLT*)

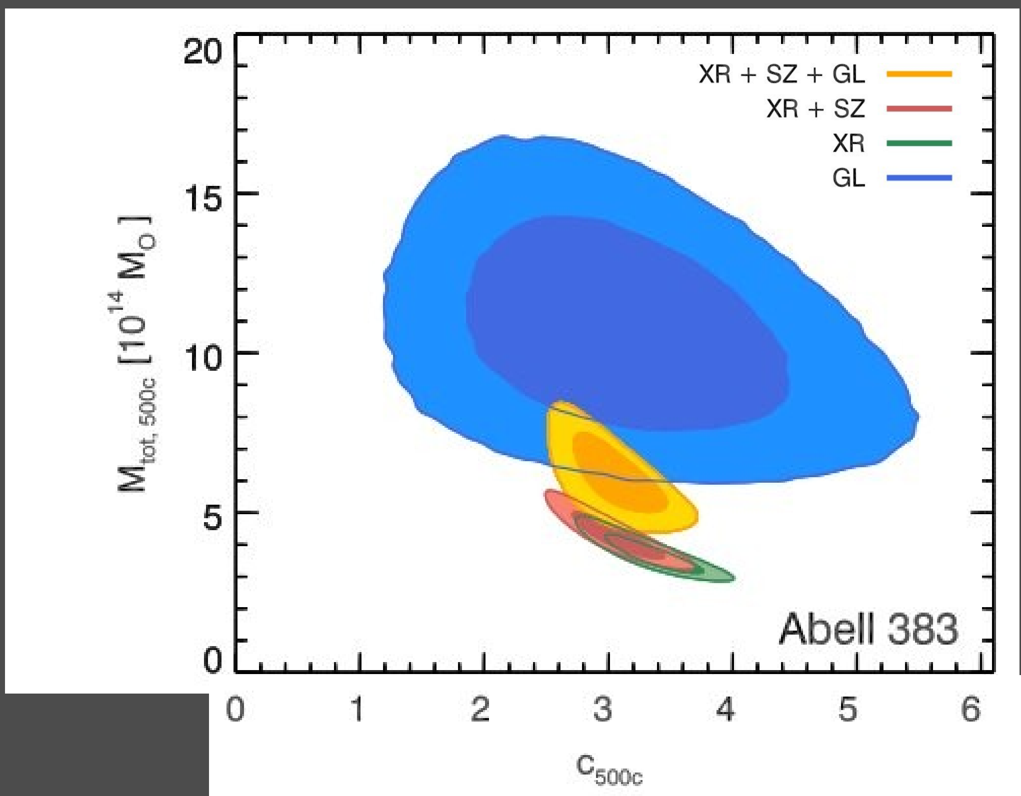


Donahue et al. (2014): X-ray vs. combined strong and weak lensing M(r) for 19 clusters *(note the Abell 383 outlier – blue curve and compare the MACS1206 curve to the left panel)*

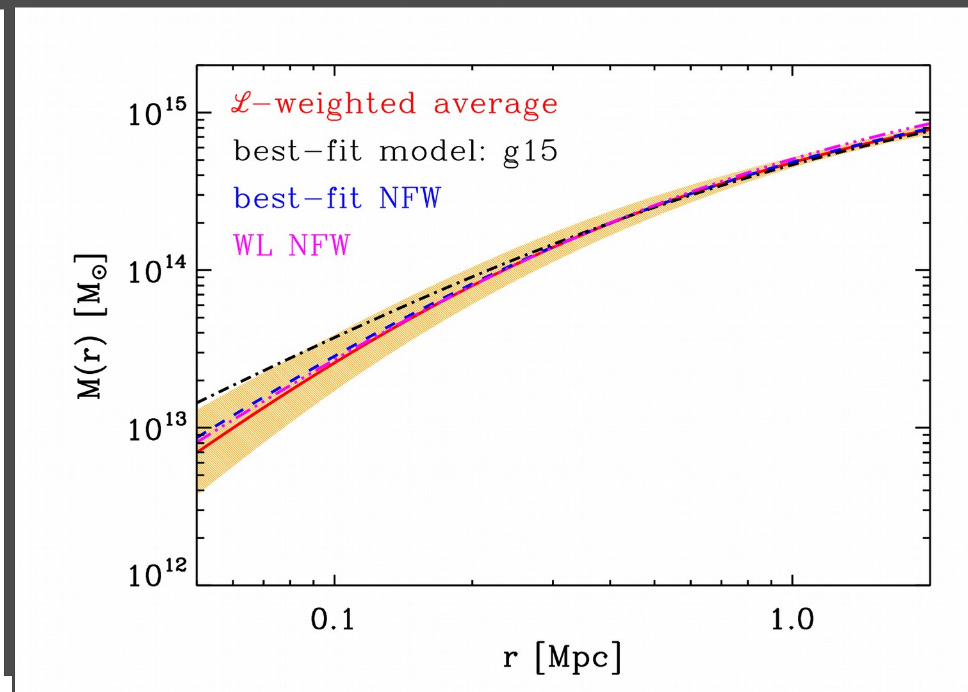
Masses & mass profiles

Galaxies, gravitational lensing, intra-cluster plasma

Comparing mass **profile** estimates from different methods/tracers require excellent samples: **CLASH** (*Postman et al. 2012*), 25 clusters at 0.2<z<0.9 with excellent imaging, photometry, spectroscopy, X-ray and SZ observations



Abell 383, z=0.19, comparing X-ray, SZ, and GL M(r) (*Siegel et al. 2018*)

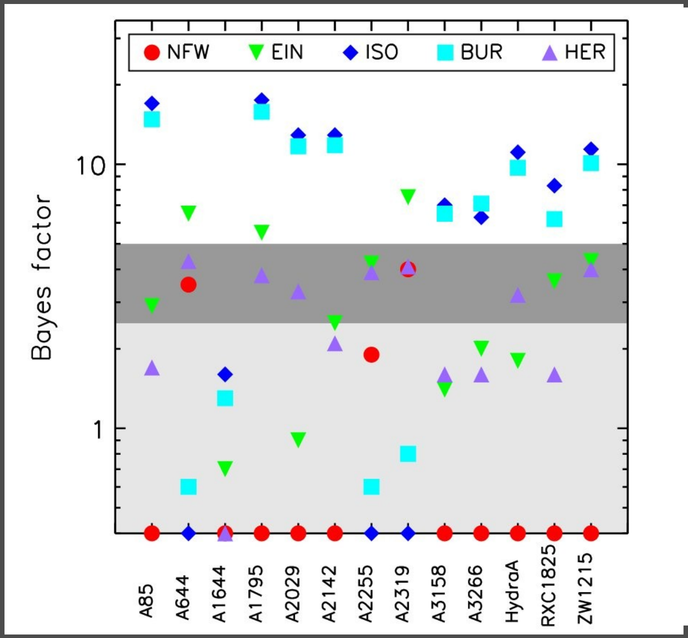


Abell 383, z=0.19, comparing MAMPOSSt and weak lensing M(r) (*AB et al. in prep.*)

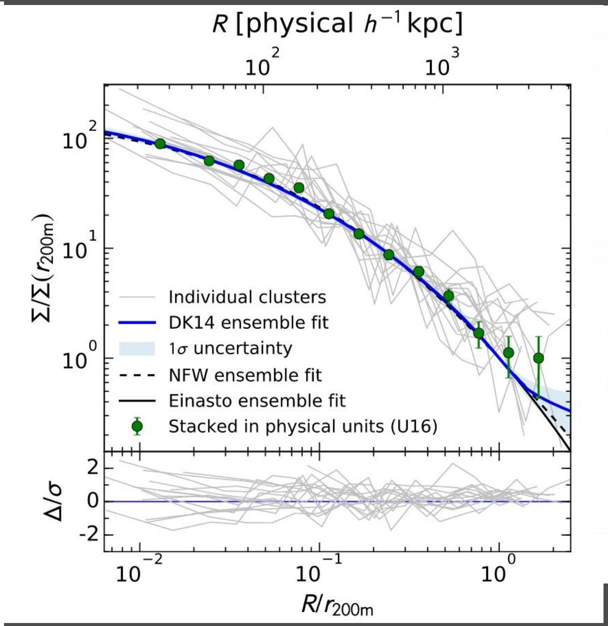
Masses & mass profiles

Redshift evolution

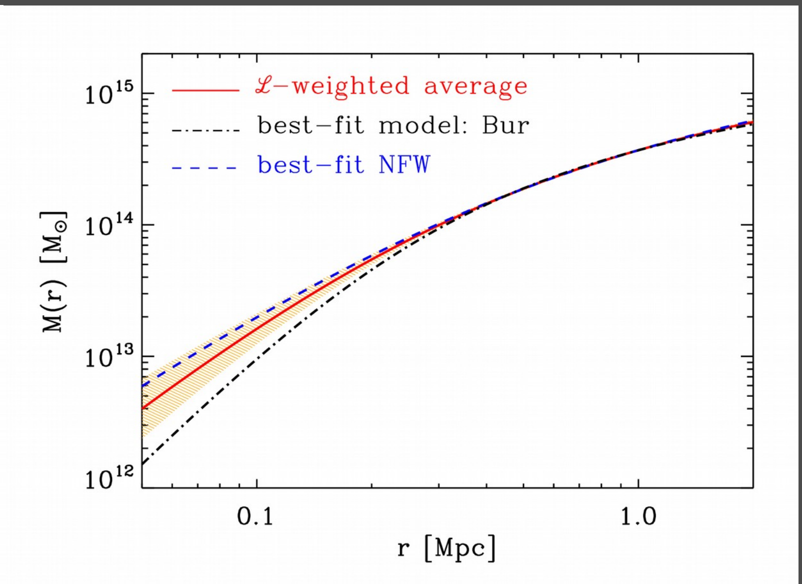
NFW is a good fit to cluster total M(r) from z≈0 to z≥1, although other models cannot be excluded – is there a central core in high-z cluster M(r)?
(*maybe the BCG is not as dominant yet in the center*)



Ettori et al. (2019):
XCOP, 12 *z*<0.1 clusters, hydrostatic M(r) from X-ray.
Model fits favor NFW.



Umetsu & Diemer (2017):
CLASH, 16 0.2 ≤ z ≤ 0.7 clusters, weak lensing surface mass density profile.
NFW fits $M_p(r)$ well out to $\geq r_{200}$

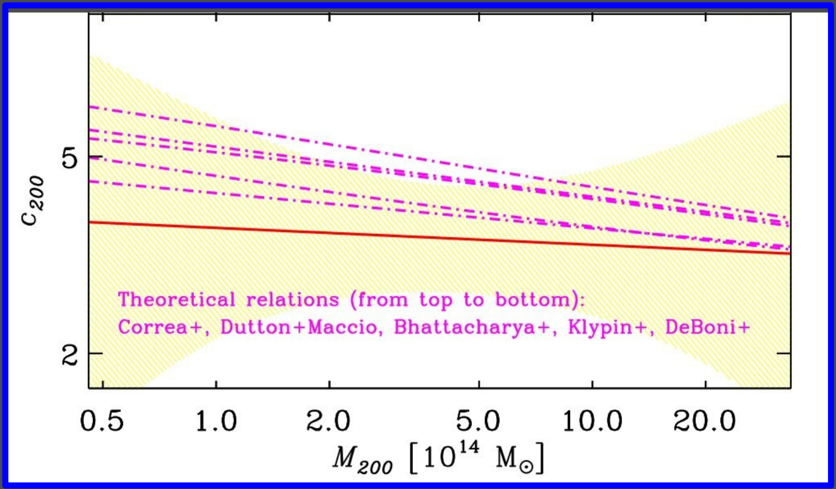


AB et al. (2021): GOGREEN, 14 0.9 ≤ z ≤ 1.4 clusters, MAMPOSSt M(r).
NFW fits well, a less centrally concentrated profile fits better

redshift

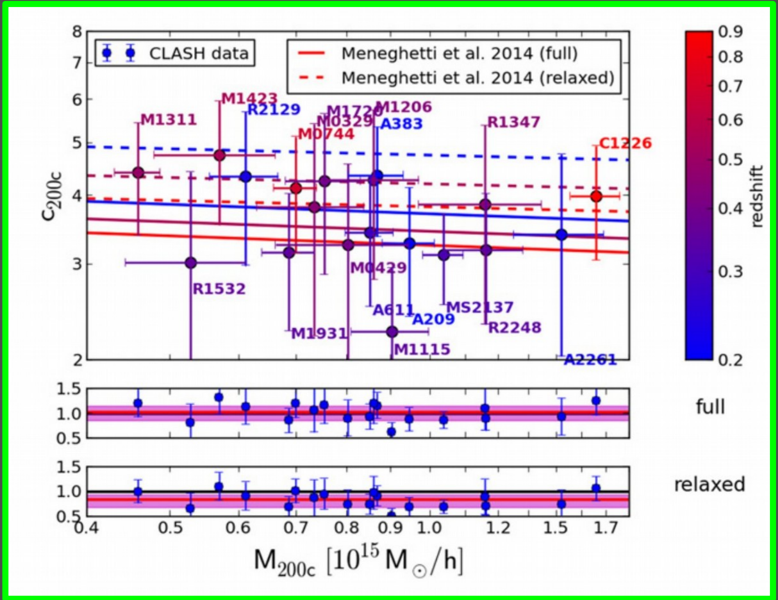
Masses & mass profiles

Redshift evolution

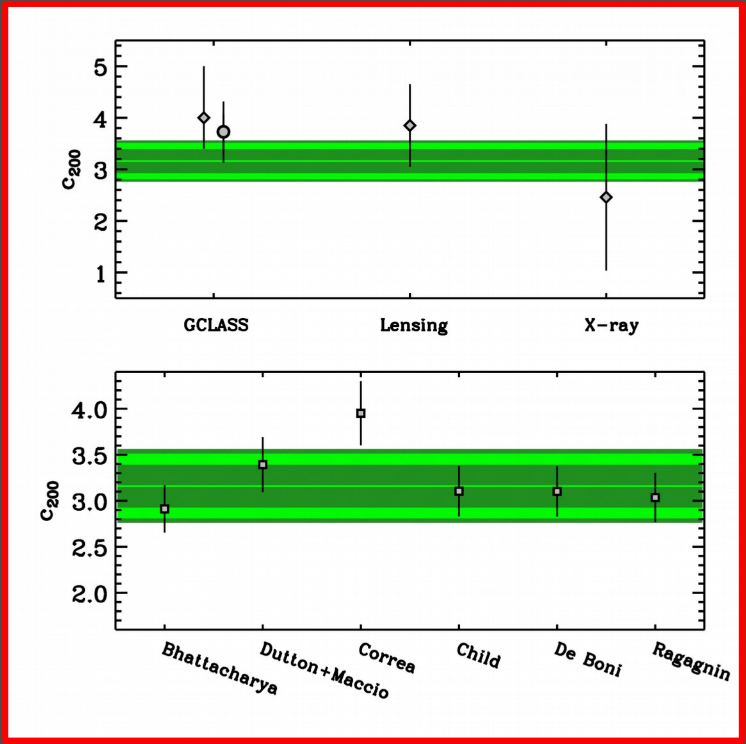


AB et al. (2017): ΩWINGS,
49 clusters
$0.04 \leq z \leq 0.07$
MAMPOSSt

The observed concentration-mass relation is in agreement with theoretical predictions at all redshifts and it is consistent across different methods, either based on dynamical equilibrium (galaxies, intra-cluster plasma) or not (gravitational lensing)



Merten et al. (2015):
CLASH, 20 clusters
$0.2 \leq z \leq 0.9$
Weak Lensing

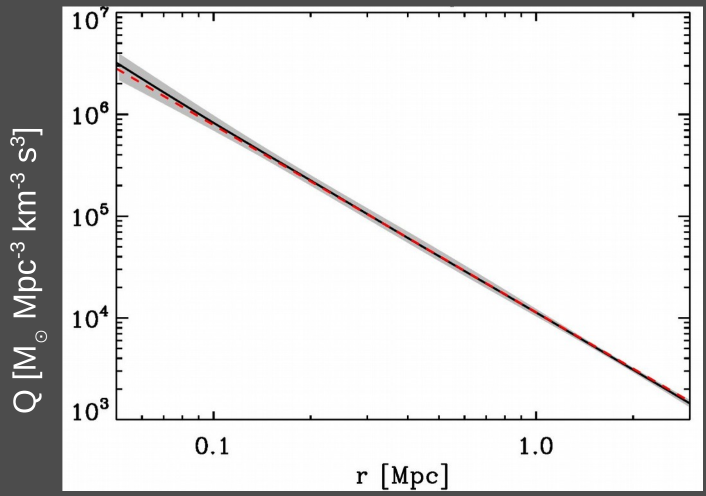


AB et al. (2021):
GOGREEN, 14 clusters
$0.9 \leq z \leq 1.4$
MAMPOSSt

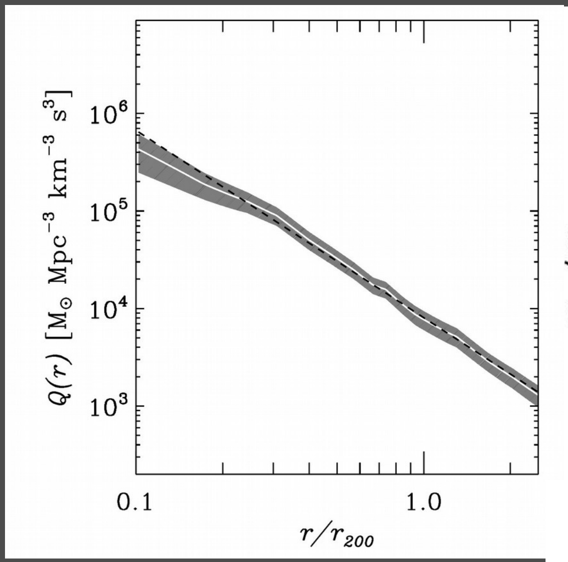
Masses & mass profiles

Redshift evolution

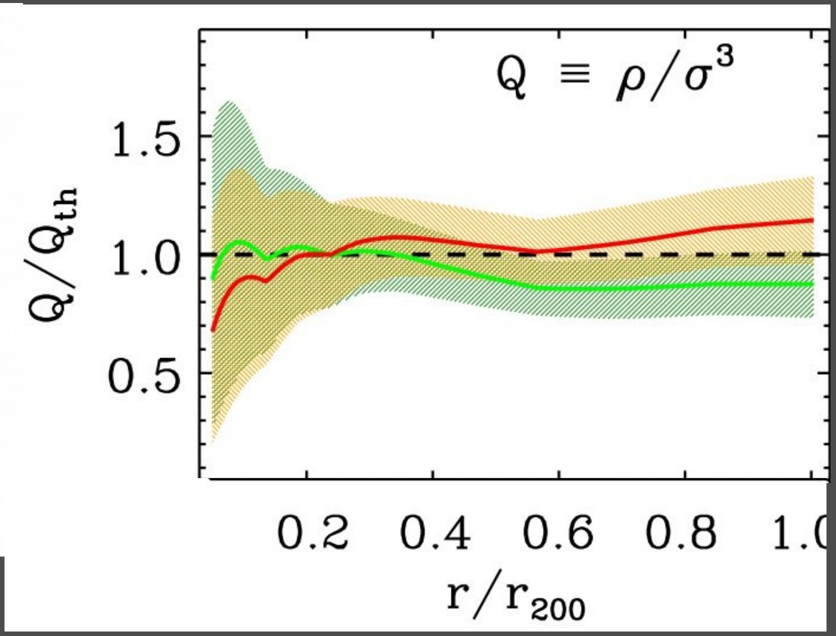
MAMPOSSt allows to estimate both M(r) and $\beta(r) \equiv 1 - (\sigma_\theta/\sigma_r)^2$, and thereby also $\sigma \equiv (\sigma_\theta^2+\sigma_r^2)^{1/2}$ and, consequently, **Q(r)** $\equiv \rho/\sigma^3$



AB, Mamon et al. (in prep.):
WINGS, 54 clusters at $0.04 \leq z \leq 0.07$



AB et al. (2013): CLASH
z=0.44 cluster MACS1206



AB et al. (2021): GOGREEN
14 clusters at $0.9 \leq z \leq 1.4$

redshift

No evolution in Q(r) from z~0 to z ≥ 1

Masses & mass profiles

Redshift evolution

z~0 and z~1 clusters have similar internal structure and dynamics.
If clusters form at z~2.5, they are already mature (dynamically speaking) when they are 1/5 of their present age, even if they will grow in mass by x4.

(Figure: young elephants look similar to old elephants, even if their tusks still have to grow)

...And so we are back where we started!

z~0 and z~1 cl … amics.
If clusters form … lly speaking)
when they are … in mass by x4.

(Figure: young elephants look similar … ephants, even if their tusks still have to grow)

Thanks for your attention!