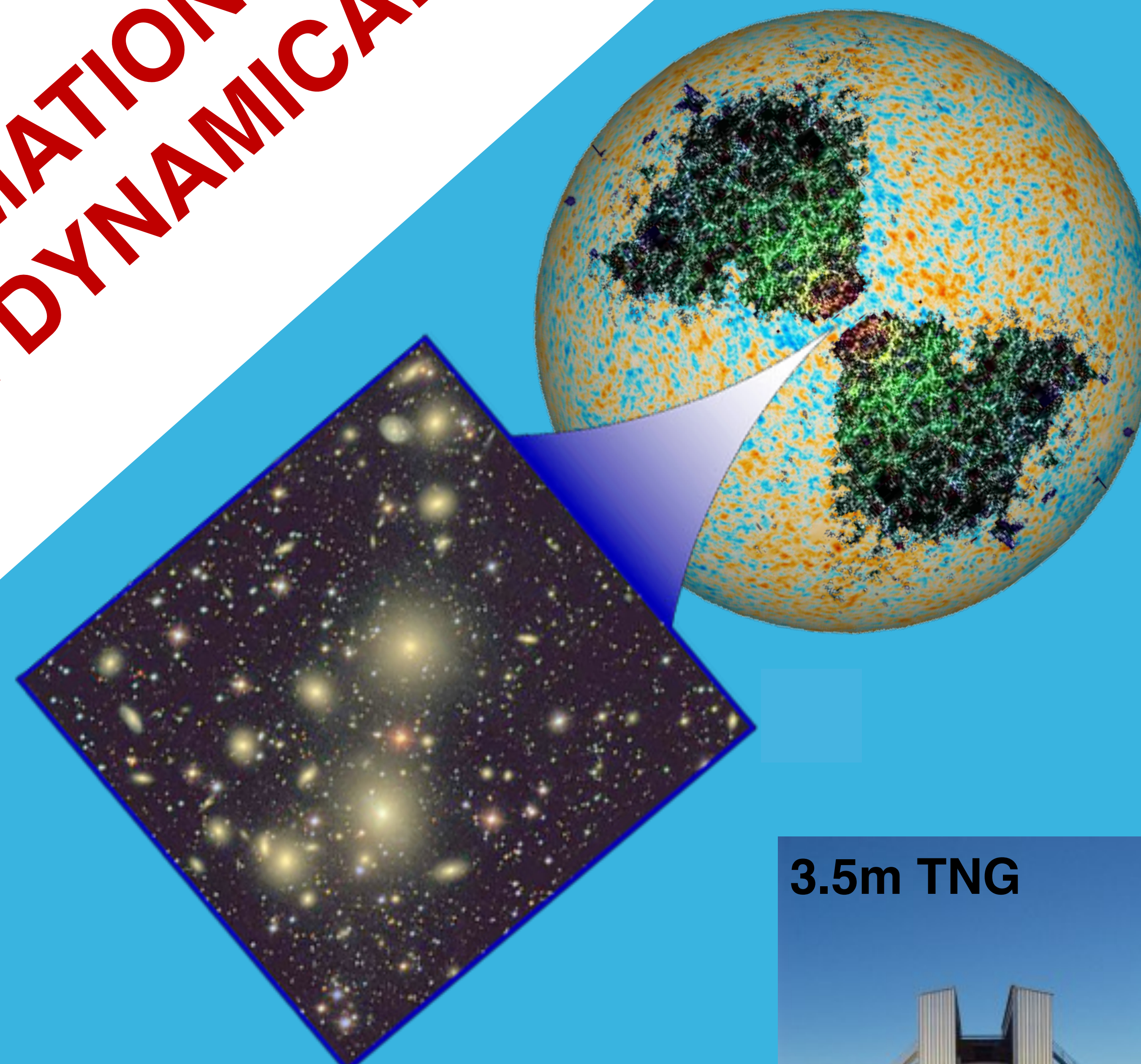
BIASES IN THE ESTIMATION OF GALAXY CLUSTER DYNAMICAL MASSES



EXCELENCIA SEVERO OCHOA

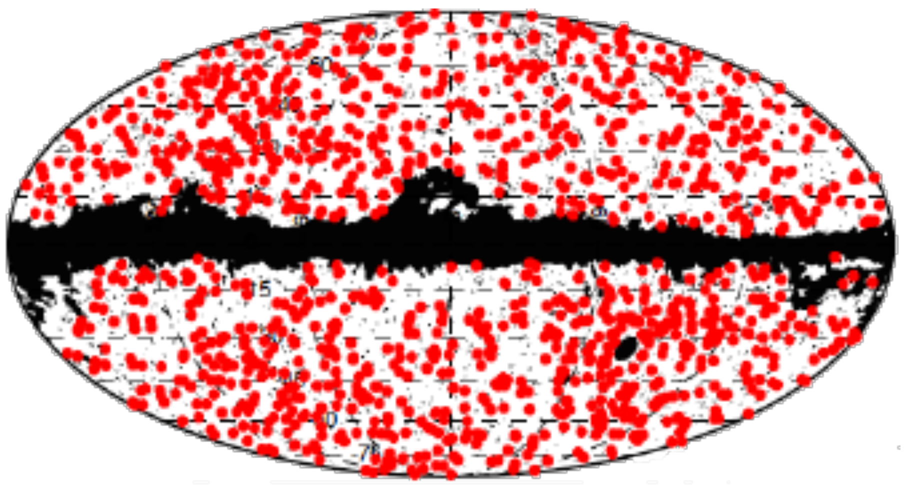
INSTITUTO DE ASTROFISICA DE CANARIAS · IAC ·

Universidad de La Laguna

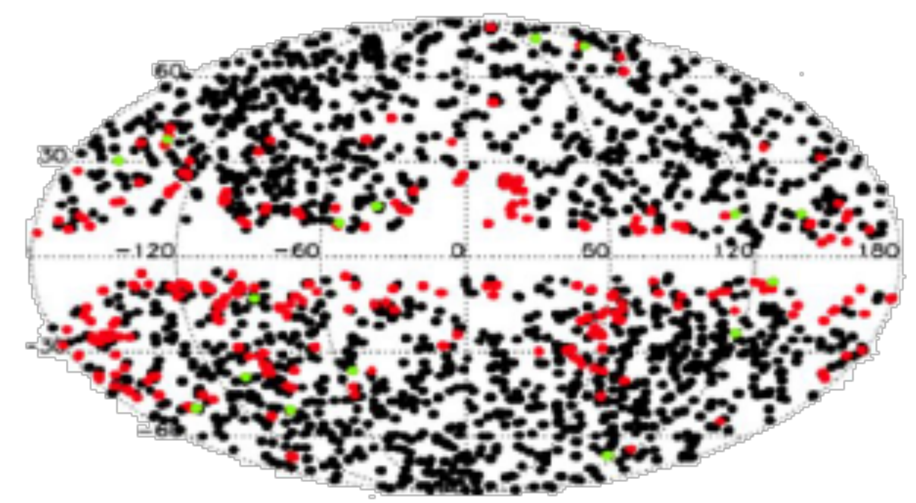
mm Universe @ NIKA2, Grenoble *03-07 June 2019*

Antonio Ferragamo

THE CONTEXT
PLANCK SZ CLUSTER CATALOGS



PSZ1



PSZ2

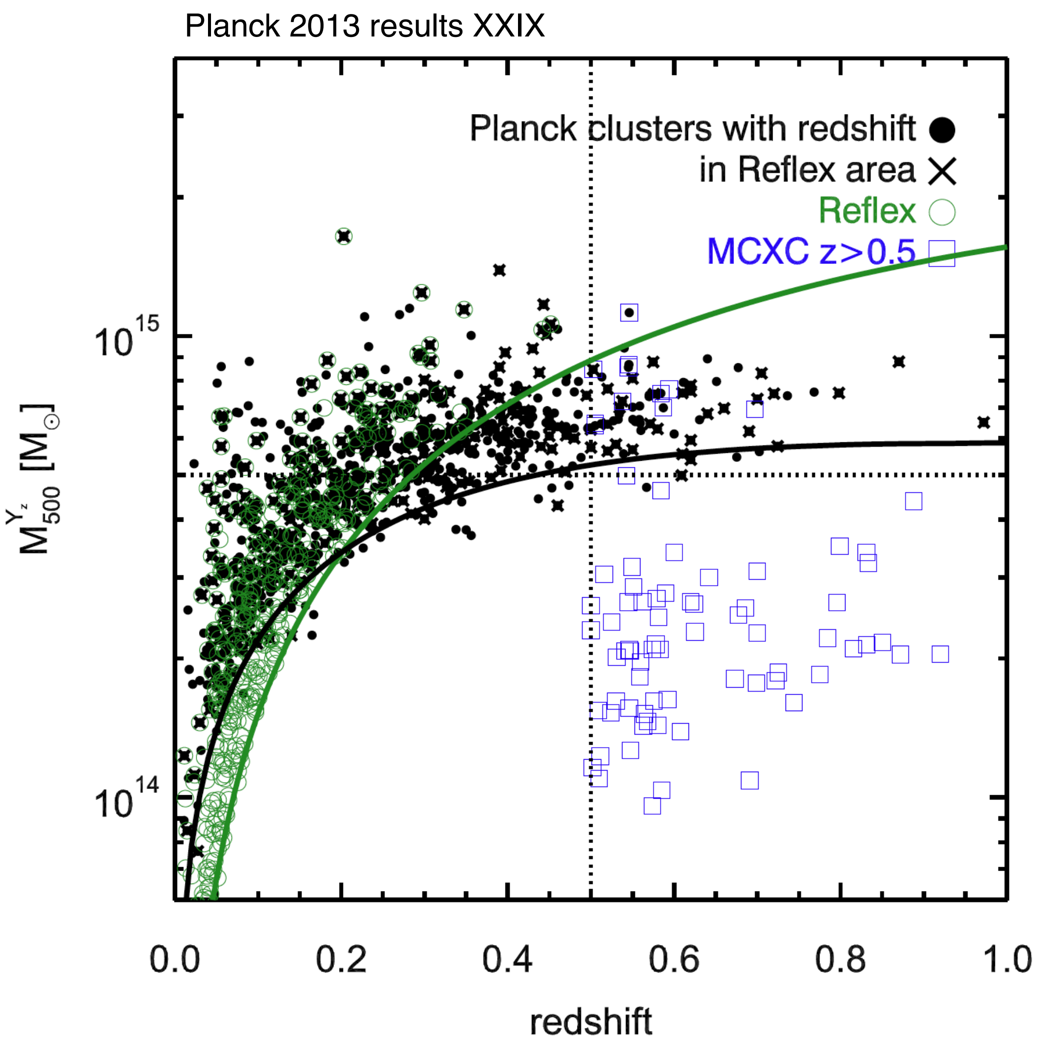
- Based on nominal mission data. Published in March 2013. (Planck Collaboration XXIX)
- New all-sky catalogue of 1227 SZ sources, the largest to date.
- Confirmed galaxy clusters: 861
- Candidate clusters: 366.

- Based on nominal mission data. Published in February 2015 (Planck Collaboration XXVII)
- New all-sky catalogue of 1653 SZ sources, the largest to date
- Confirmed galaxy clusters: 1203
- Candidate clusters: 450

Total=1943	**Confirmed=1330**	**Unknown=748**

THE CONTEXT
CLUSTER NUMBER COUNTS

The cluster number counts are very useful to estimate cosmological parameter, as σ_8 and Ω_m.



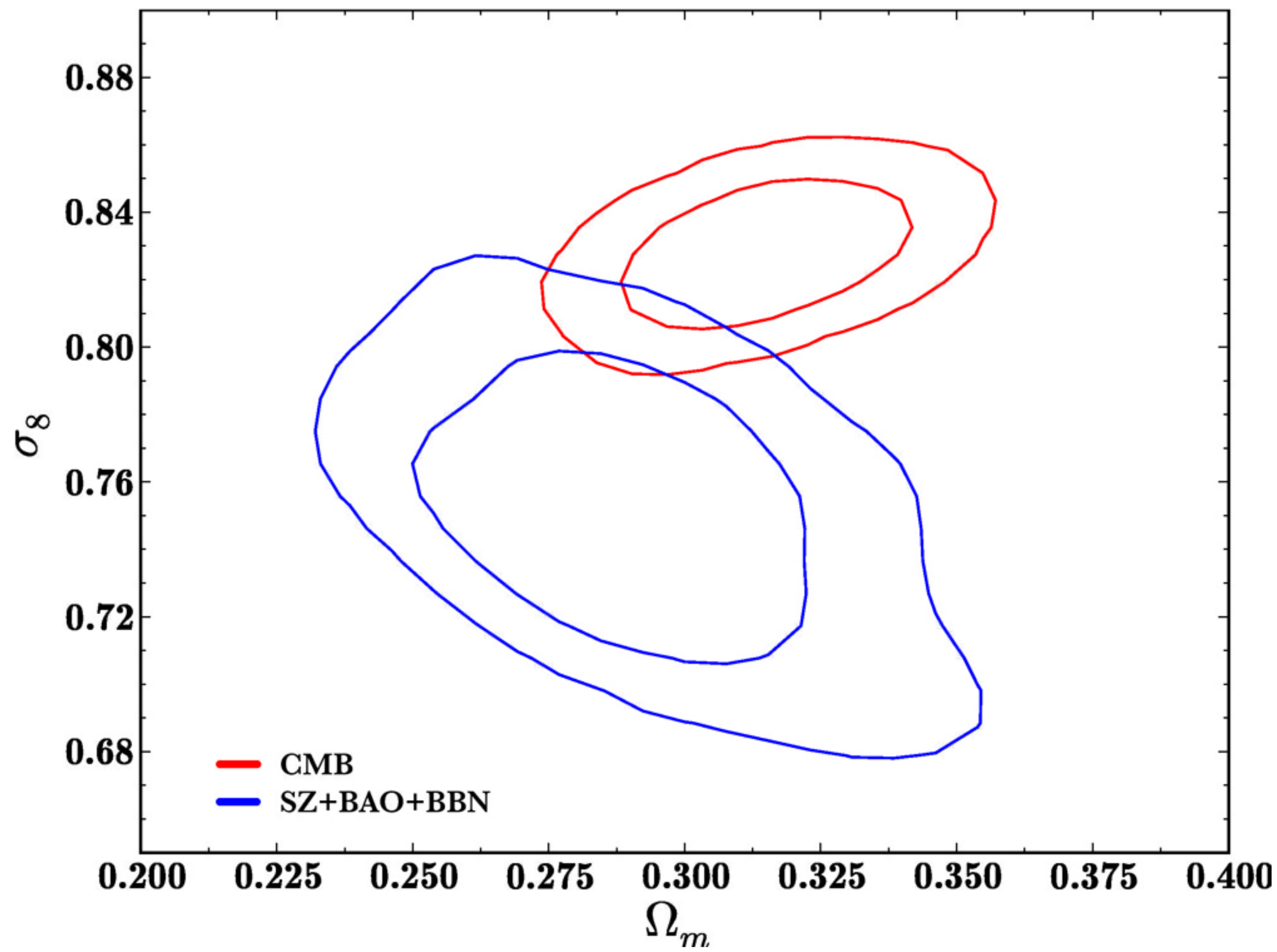
$$\frac{dN}{dz} = \int d\Omega \int dM_{500}\, \hat{\chi}(z, M_{500}, l, b)\, \frac{dN}{dz\, dM_{500}\, d\Omega}$$

- survey selection function
- mass function

scaling relations

THE CONTEXT
MASS BIAS

$$E^{-\beta}(z)\left[\frac{D_{\rm A}^{2}(z)\bar{Y}_{500}}{10^{-4}{\rm Mpc}^{2}}\right]=Y_{*}\left[\frac{h}{0.7}\right]^{-2+\alpha}\left[\frac{(1-b)\,M_{500}}{6\times10^{14}{\rm M}_{\odot}}\right]^{\alpha}$$

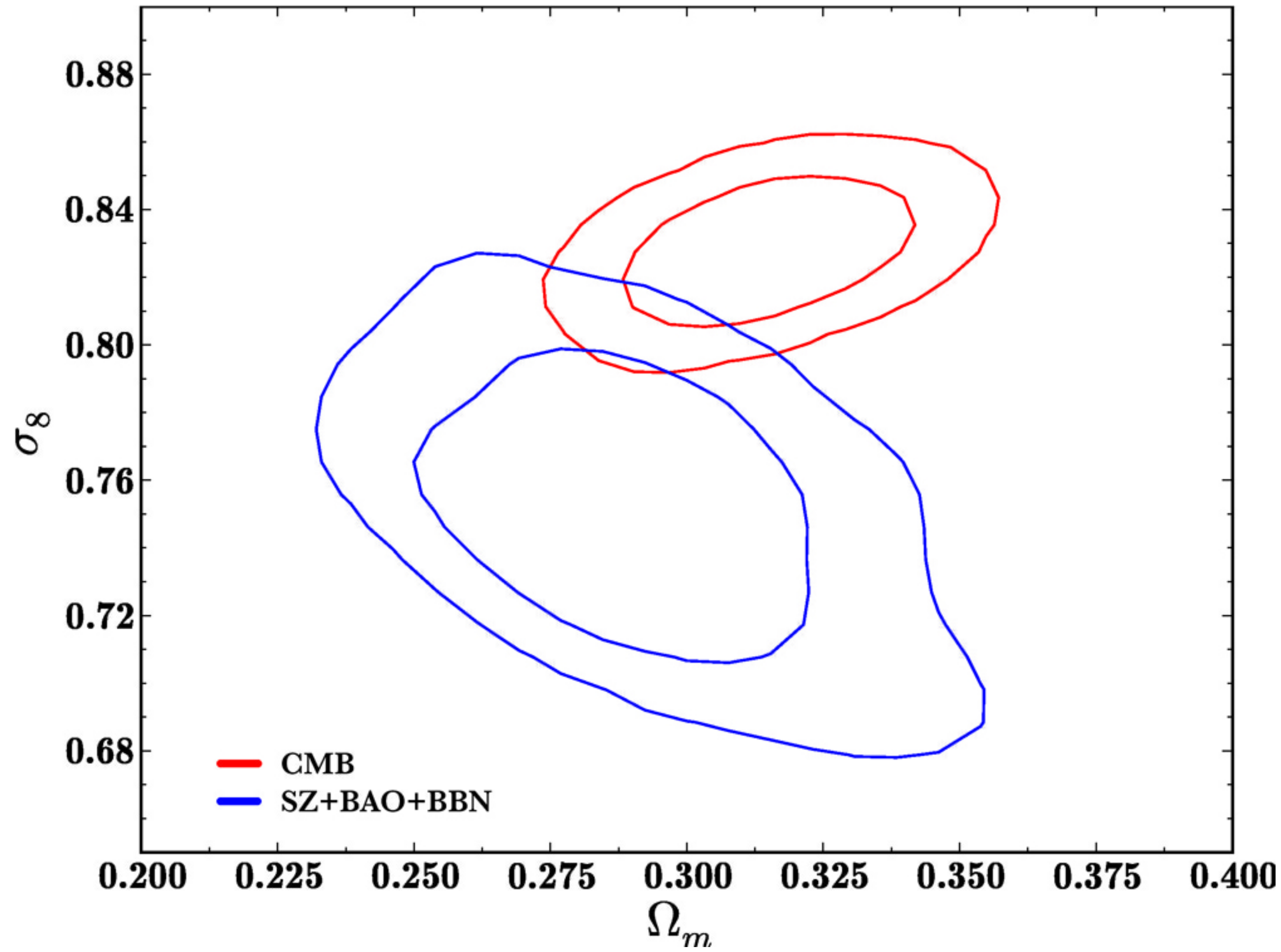


$$M_{500}^{SZ}=(1-b)M_{500}=0.8^{+0.2}_{-0.1}$$

Planck Collaboration XX

THE CONTEXT
MASS BIAS

$$E^{-\beta}(z)\left[\frac{D_{\rm A}^2(z)\bar{Y}_{500}}{10^{-4}{\rm Mpc}^2}\right] = Y_*\left[\frac{h}{0.7}\right]^{-2+\alpha}\left[\frac{(1-b)\,M_{500}}{6\times10^{14}{\rm M}_\odot}\right]^{\alpha}$$



$$M_{500}^{HE} = (1-b)M_{500} = 0.8^{+0.2}_{-0.1}$$

Planck Collaboration XX

WHAT ABOUT THE DYNAMICAL MASS?

PSZ1-PSZ2 OPTICAL FOLLOW-UP:
SUMMARY

<table>
<tr><th colspan="8">PSZ1</th></tr>
<tr><th>Telescope</th><th>Mode</th><th>Instrument</th><th># Nights</th><th colspan="3"># Clusters</th><th>Redshift range</th></tr>
<tr><td>INT</td><td rowspan="2">Imaging</td><td>WFC</td><td>21</td><td>86</td><td colspan="2" rowspan="2">204</td><td>-</td></tr>
<tr><td rowspan="2">WHT</td><td rowspan="2">ACAM</td><td>~15</td><td>118</td><td>-</td></tr>
<tr><td rowspan="2">LS</td><td>~9</td><td>37</td><td rowspan="2">87</td><td rowspan="4">187</td><td>$z < 0.3$</td></tr>
<tr><td rowspan="2">GTC</td><td rowspan="2">OSIRIS</td><td>68 hours</td><td>50</td><td>$0.1 \leq z \leq 0.85$</td></tr>
<tr><td rowspan="2">MOS</td><td>37 hours</td><td>27</td><td rowspan="2">100</td><td>$0.4 \leq z \leq 0.9$</td></tr>
<tr><td>TNG</td><td>DOLORES</td><td>26</td><td>73</td><td>$0.1 \leq z < 0.4$</td></tr>
</table>

<table>
<tr><th colspan="7">PSZ2</th></tr>
<tr><th>Telescope</th><th>Mode</th><th>Instrument</th><th># Nights</th><th colspan="2"># Clusters</th><th>Redshift range</th></tr>
<tr><td>INT</td><td>Imaging</td><td>WFC</td><td>22</td><td colspan="2">201</td><td>-</td></tr>
<tr><td>TNG</td><td rowspan="2">MOS</td><td>DOLORES</td><td>9</td><td>24</td><td rowspan="2">80</td><td>$0.1 \leq z < 0.4$</td></tr>
<tr><td>GTC</td><td>OSIRIS</td><td>70 hours</td><td>56</td><td>$0.4 \leq z \leq 0.9$</td></tr>
</table>

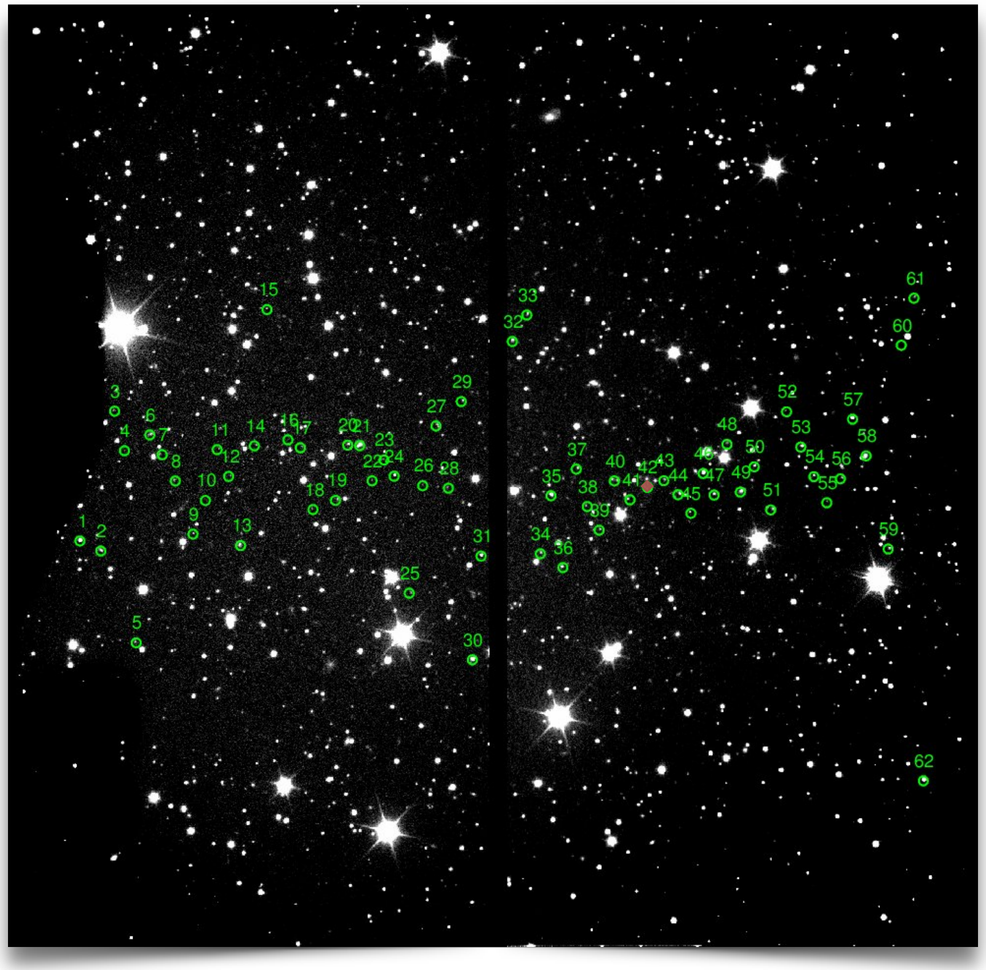
~10000 SPECTRA

DYNAMICAL MASS
CLUSTER IDENTIFICATION - SPECTROSCOPY

- Identification of possible members in the RGB images

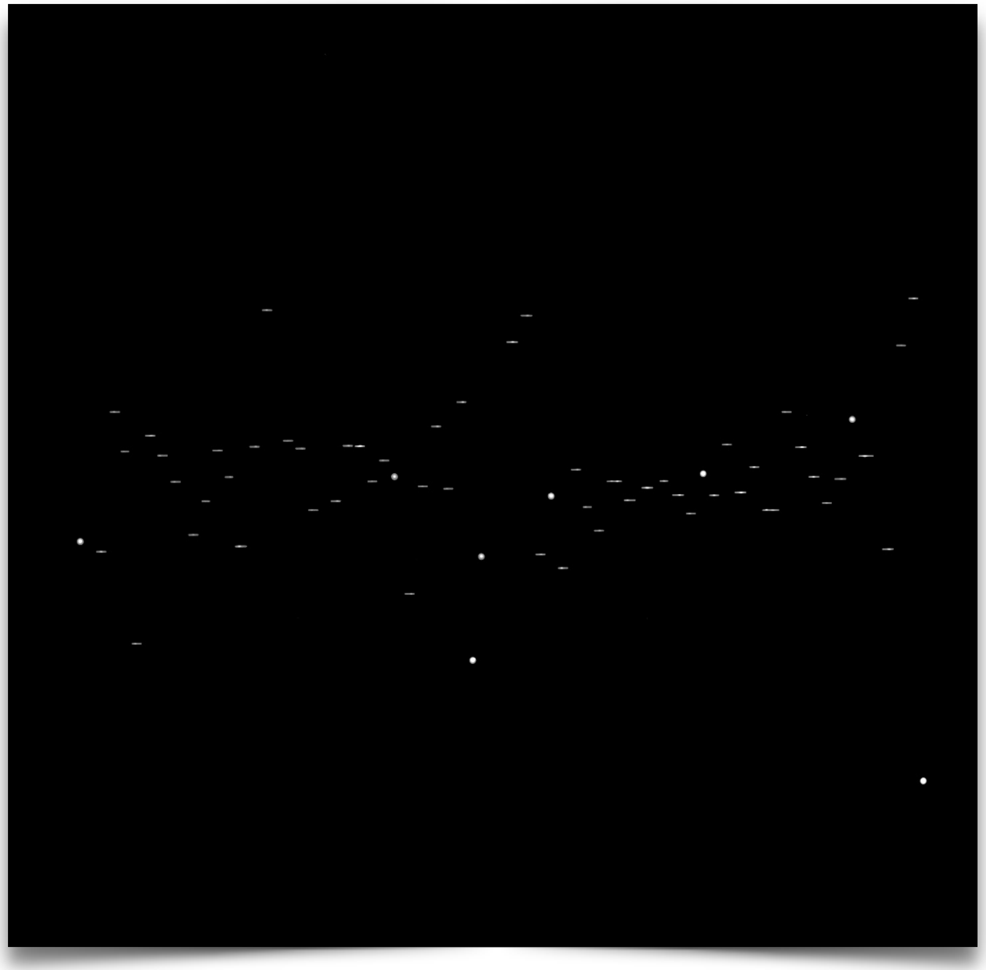
DYNAMICAL MASS
CLUSTER IDENTIFICATION - SPECTROSCOPY

- Identification of possible members in the RGB images
- Ask for preimaging



DYNAMICAL MASS
CLUSTER IDENTIFICATION - SPECTROSCOPY

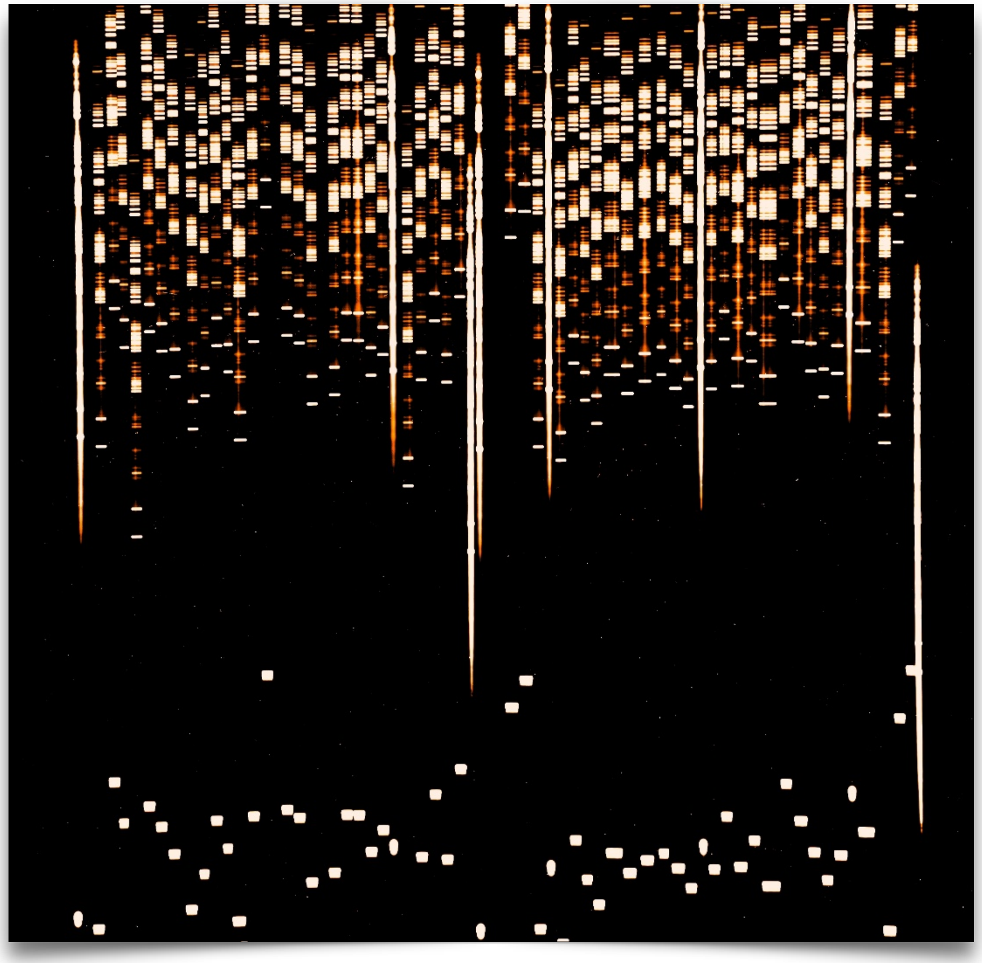
- Identification of possible members in the RGB images
- Ask for preimaging
- Design one mask per cluster based on the preimage, RGBs and CMDs



UP TO 60 SLITLETS PER MASK

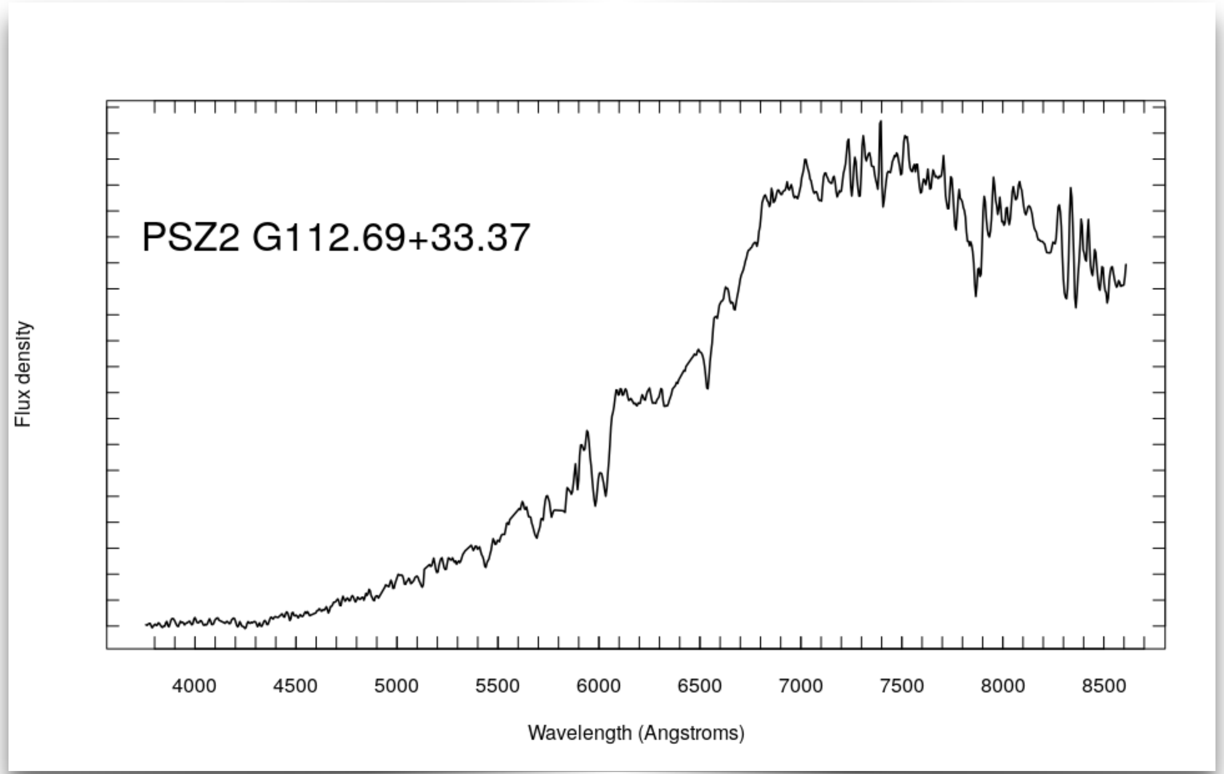
DYNAMICAL MASS
CLUSTER IDENTIFICATION - SPECTROSCOPY

- Identification of possible members in the RGB images
- Ask for preimaging
- Design one mask per cluster based on the preimage, RGBs and CMDs
- Obtain the spectra



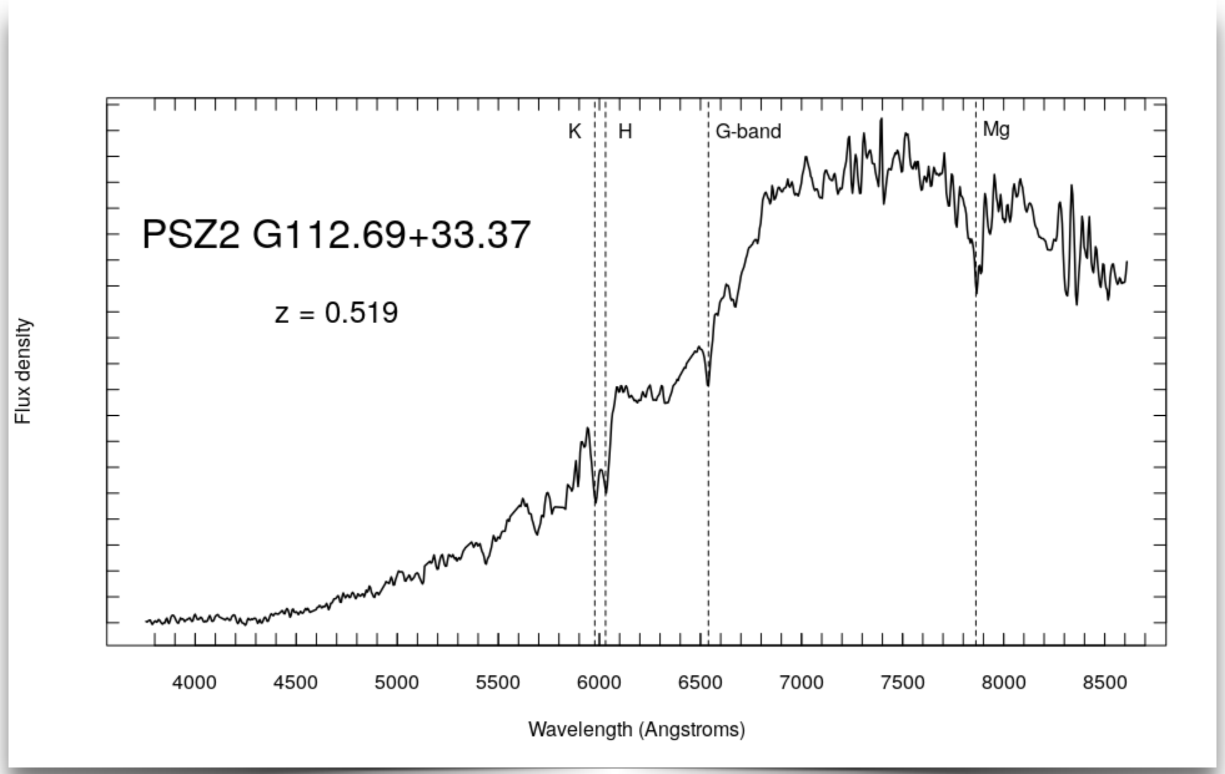
DYNAMICAL MASS
CLUSTER IDENTIFICATION - SPECTROSCOPY

- Identification of possible members in the RGB images
- Ask for preimaging
- Design one mask per cluster based on the preimage, RGBs and CMDs
- Obtain the spectra
- Reduce the spectra



DYNAMICAL MASS
CLUSTER IDENTIFICATION - SPECTROSCOPY

- Identification of possible members in the RGB images
- Ask for preimaging
- Design one mask per cluster based on the preimage, RGBs and CMDs
- Obtain the spectra
- Reduce the spectra
- Adquire radial velocity and therefore the redshift
  - Using cross-correlation (*xcsao* in IRAF) with Kennicutt (1992) templates



ΔV~150KM/S

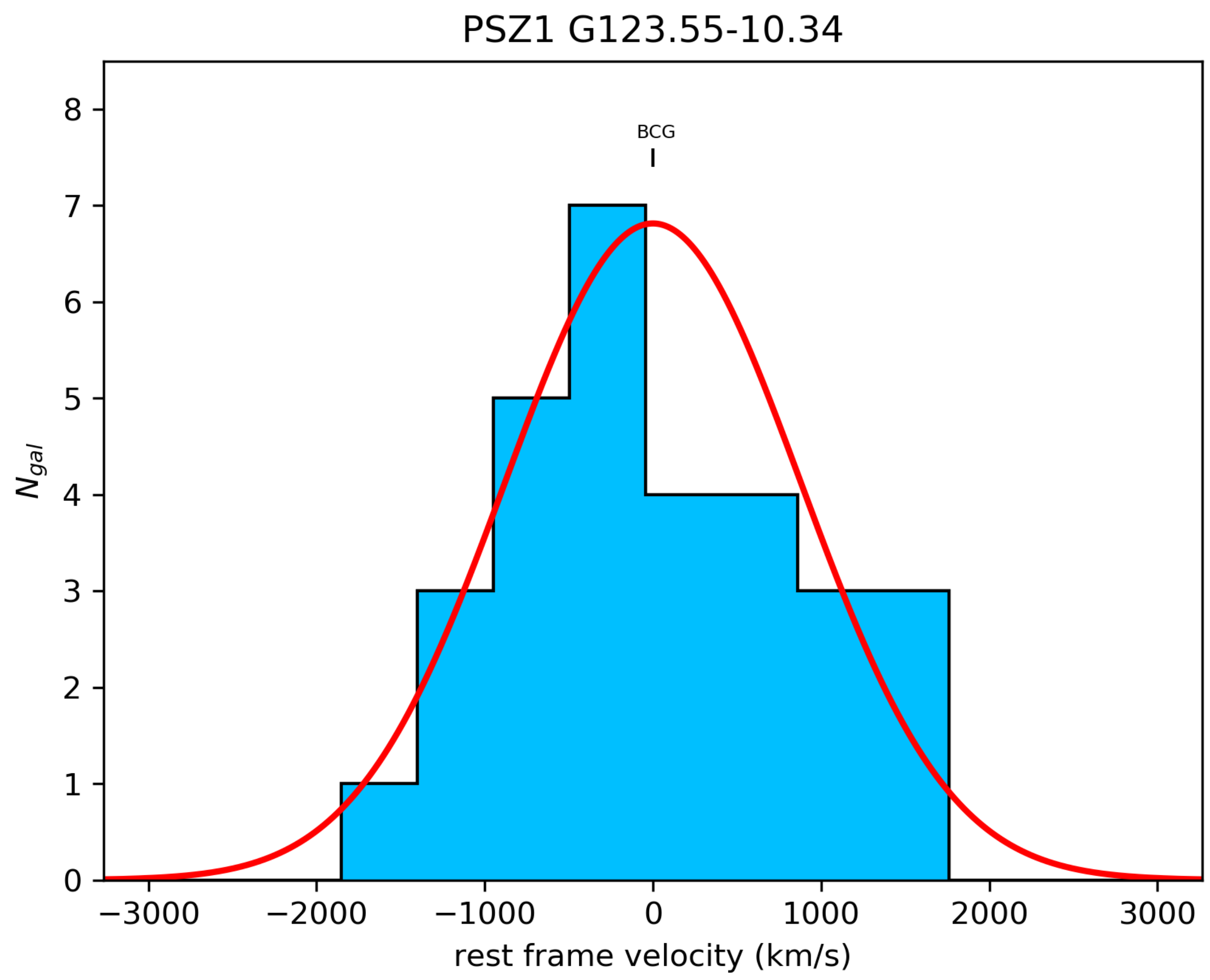
DYNAMICAL MASS ESTIMATION
VELOCITY DISPERSION

members selection and the velocity dispersion estimation:

- We make a 2.5σ clipping around the mean velocity
- To avoid the presence of interlopers are rejected all that galaxies with distance from the BCG (or mean of the members positions) is grater than 2.5 Mpc
- estimate the velocity dispersion

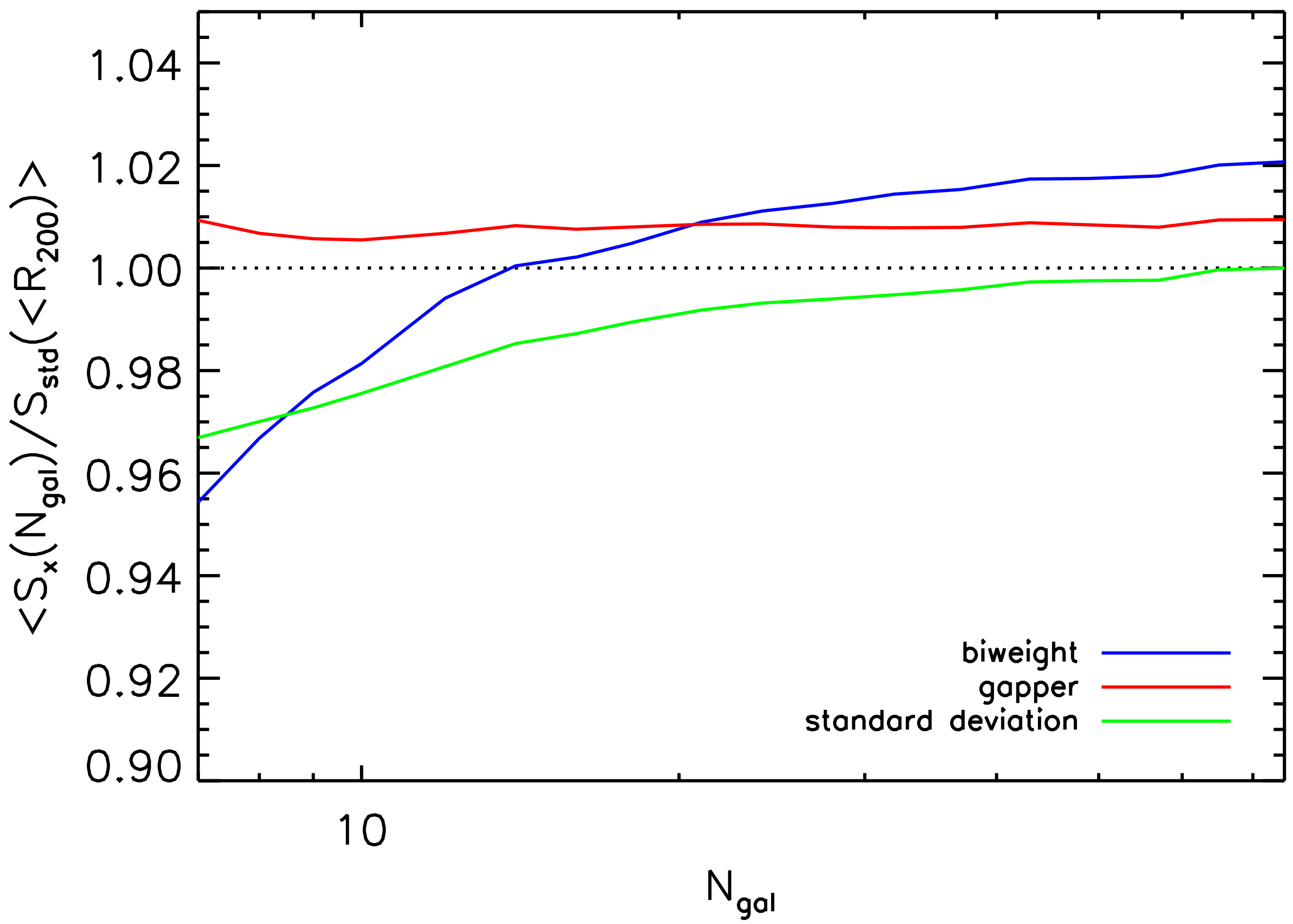
↓

BIAS



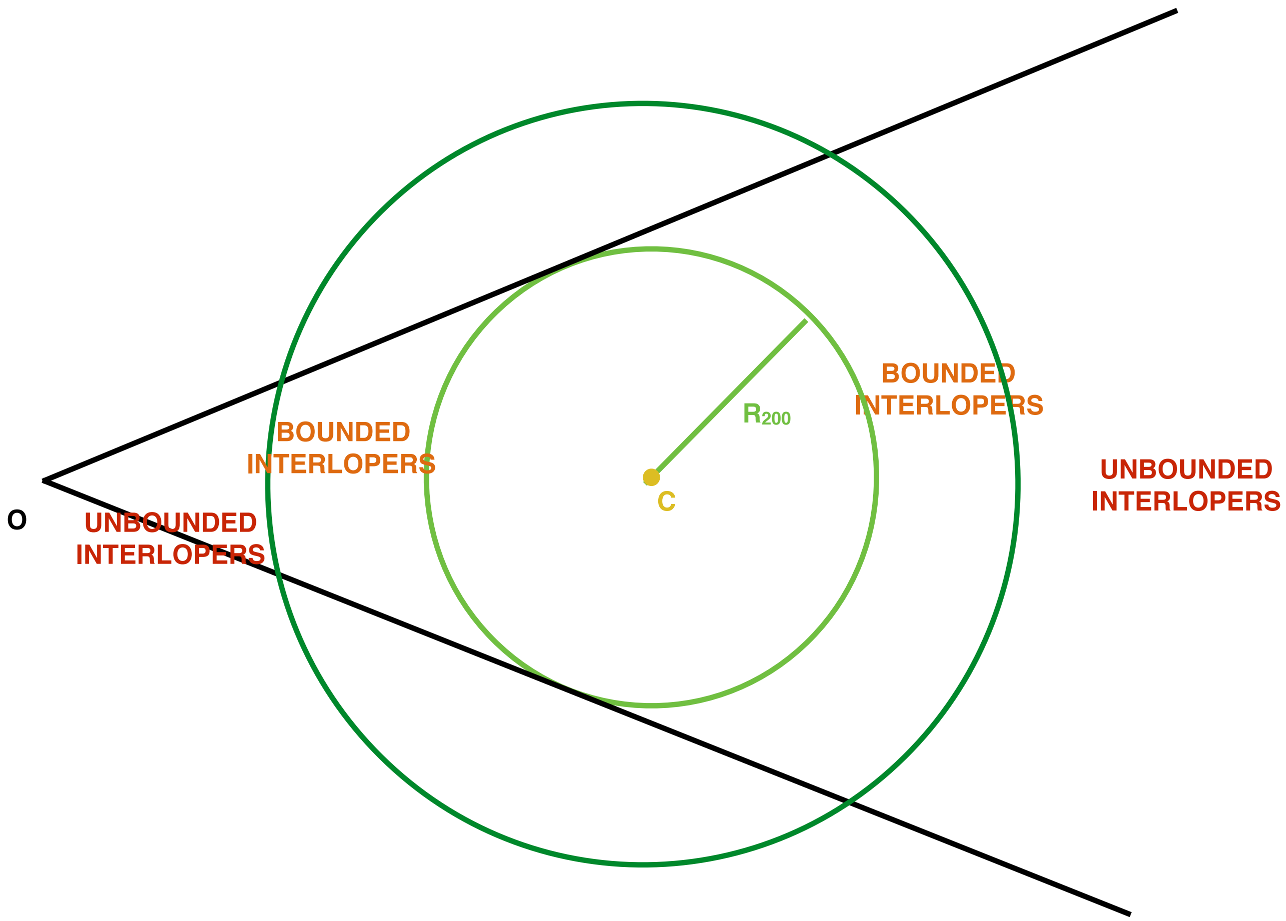
UNBIASED VELOCITY DISPERSION ESTIMATOR

In order to estimate the velocity dispersion we need to know which is the best scale estimator. We performed a statistical analysis using 73 galaxy clusters with $0.12 \leq z \leq 0.82$ and $0.2 \leq M_{200} \leq 2$ (10^{15} $M_{\odot}$) from simulations performed with TreeePM smoothed particle hydrodynamics GADGET-3 code (Springel 2005) by INAF-OA Trieste



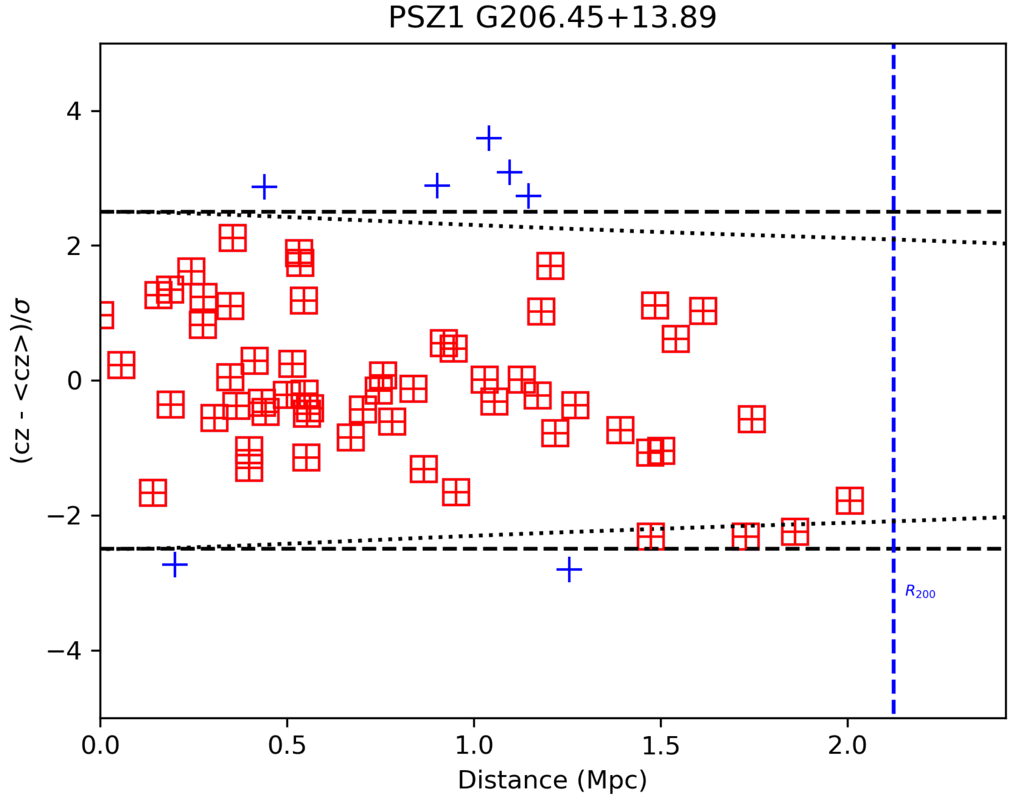
- galaxies selected within all the sample inside r_{200}
- 2250 realisations per cluster and per number of galaxies
- velocity dispersion calculated with:
  - Standard deviation
  - Biweight
  - Gapper (Beers et al. 1990)

INTERLOPERS CONTAMINATION

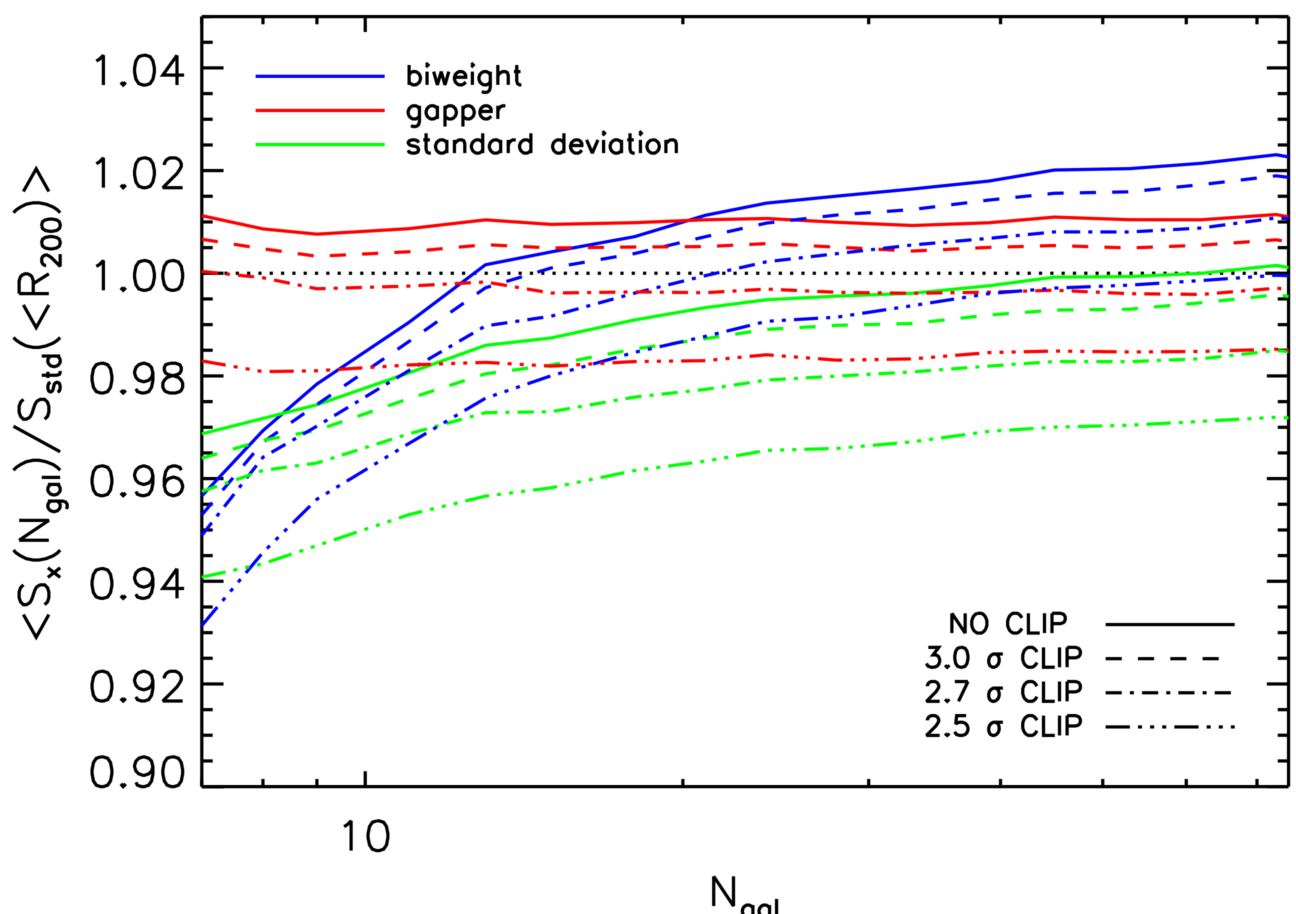


- bounded galaxies beyond $3R_{200}$
- background/foreground galaxies non gravitationally bounded to the clusters

INTERLOPERS CONTAMINATION: BOUNDED

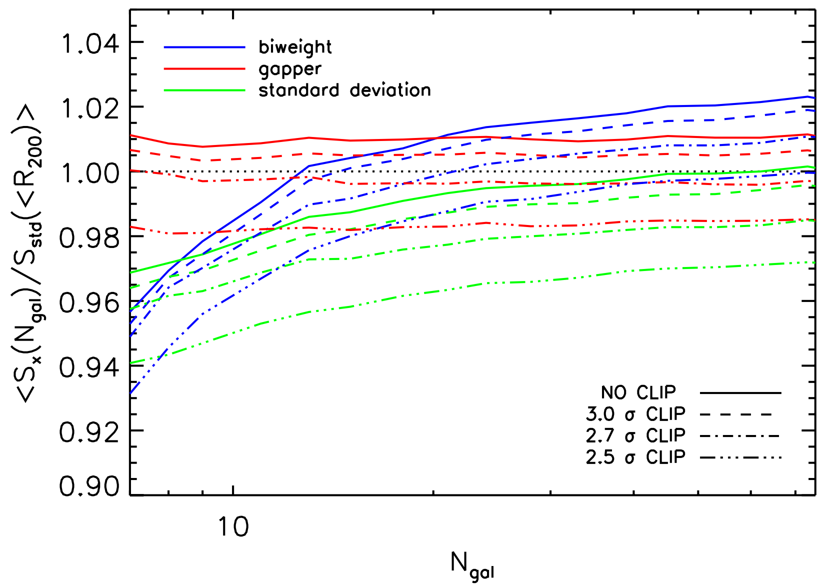


The interloper contamination is treated by clipping the tails of the members distribution in the projected phase-space

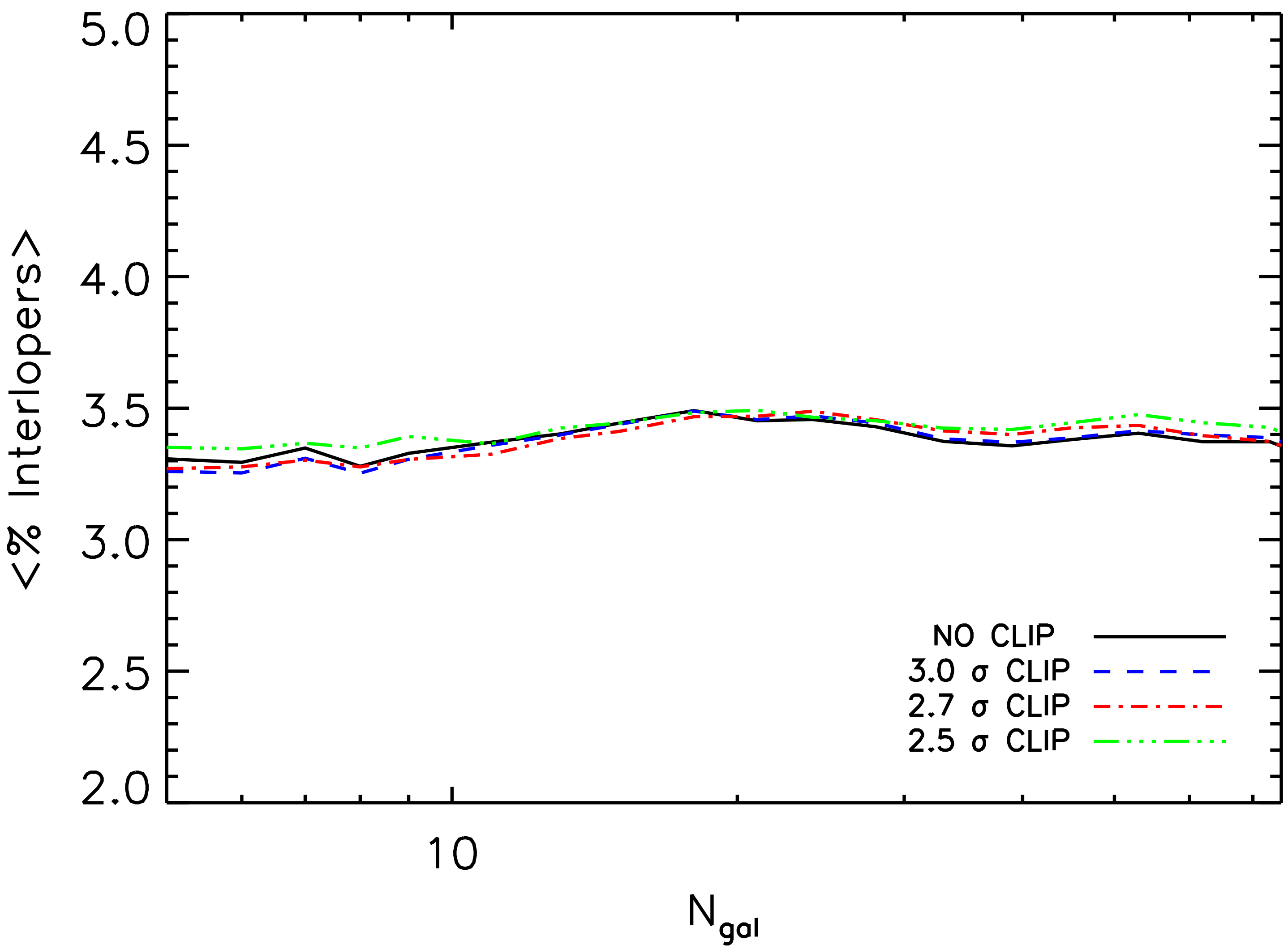


the higher the cut, the higher the bias introduced during this operation

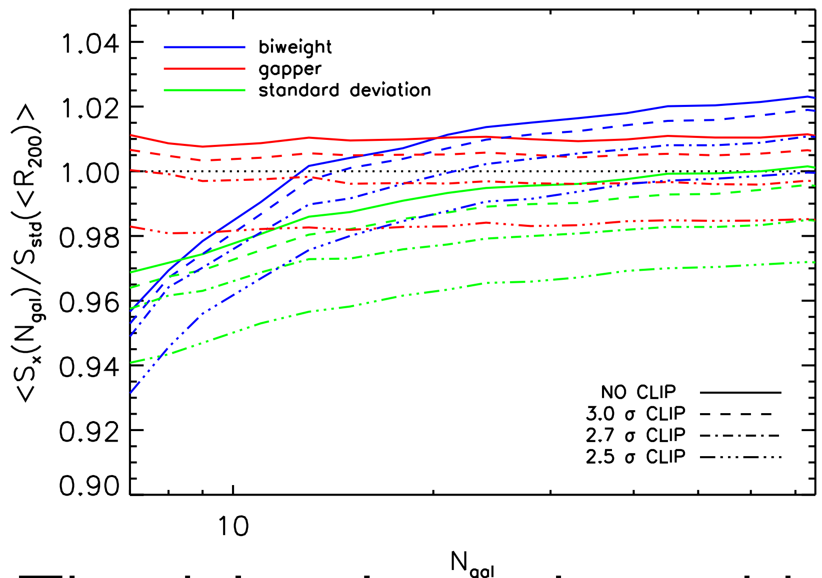
INTERLOPERS CONTAMINATION: BOUNDED



The fraction of interloper is not affected by the clipping

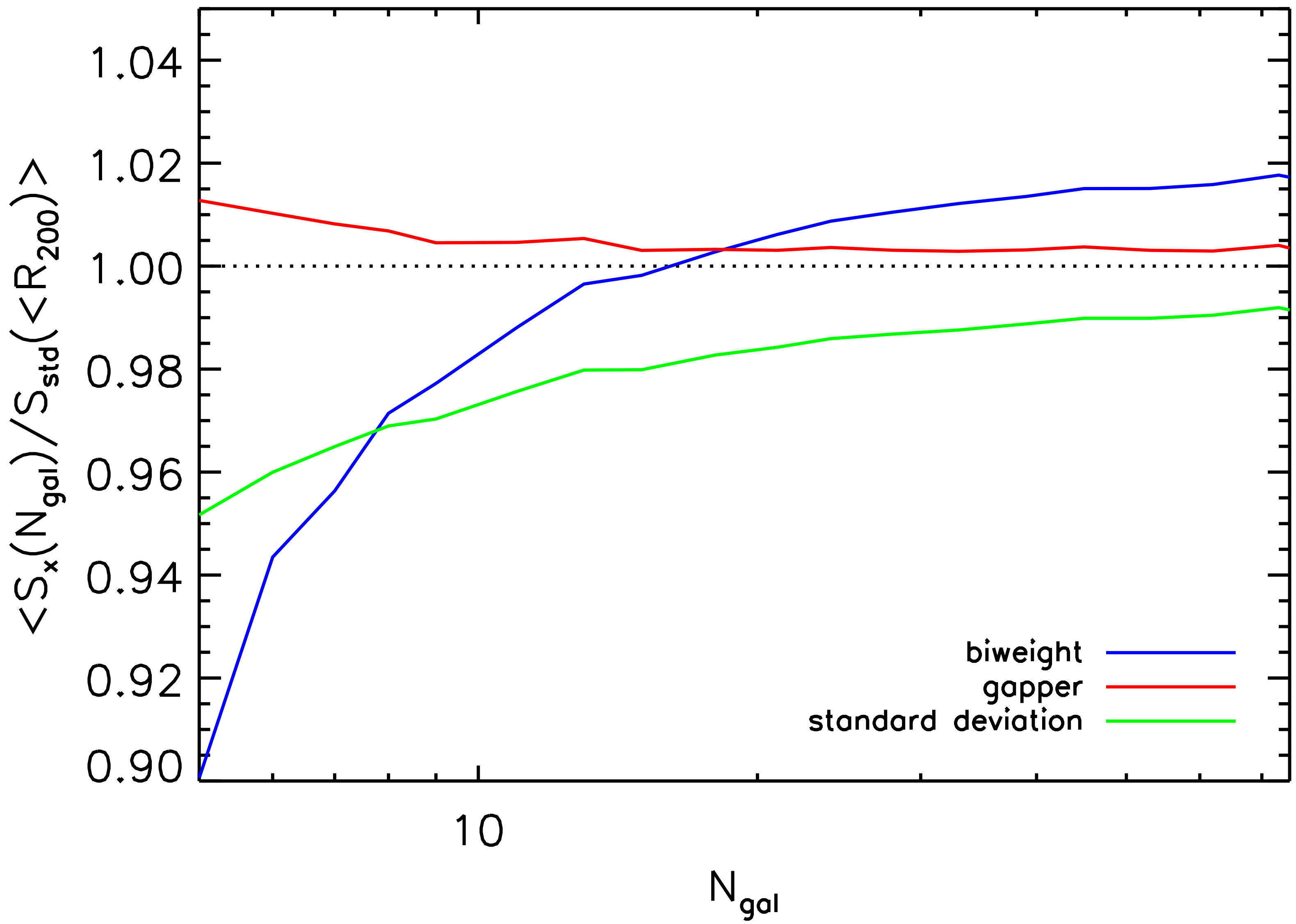


INTERLOPERS CONTAMINATION: BOUNDED

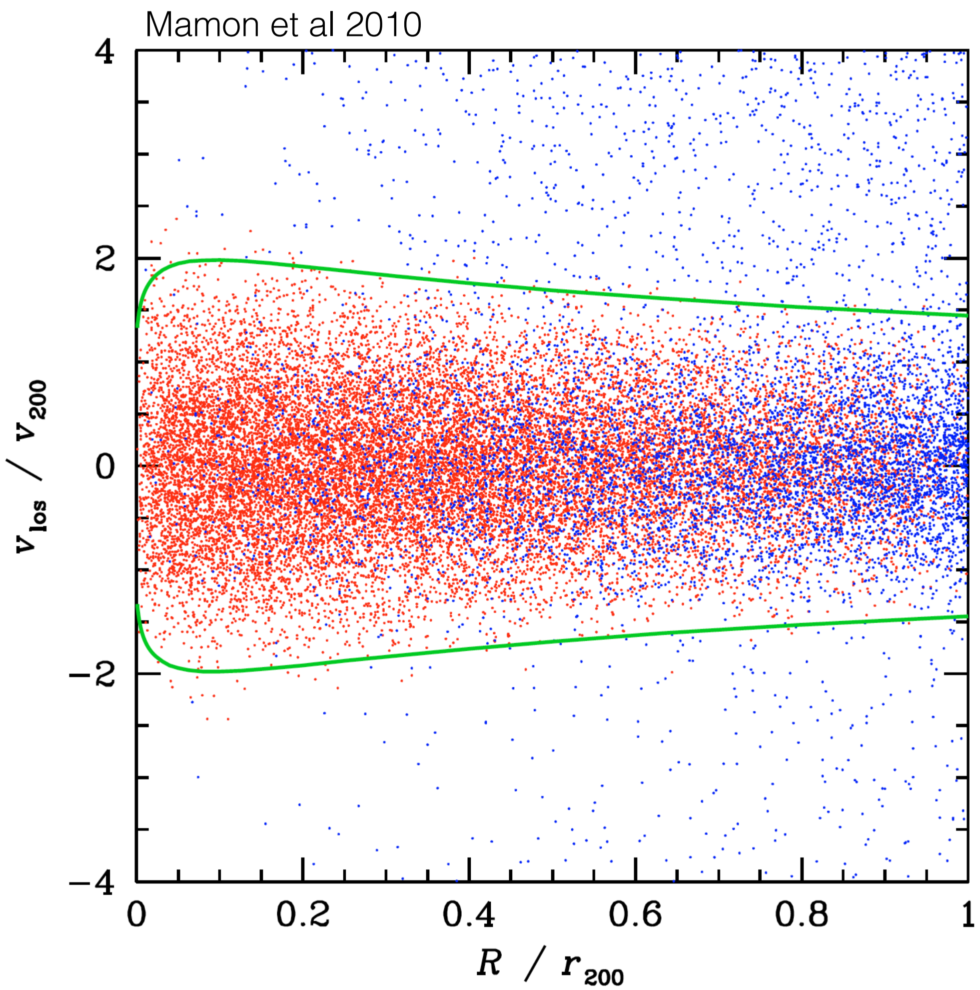


The bias introduced by the σ clipping compensates the bias due to the interlopers

Consistent with the results of Mamon et al (2010)



INTERLOPERS CONTAMINATION: UNBOUND



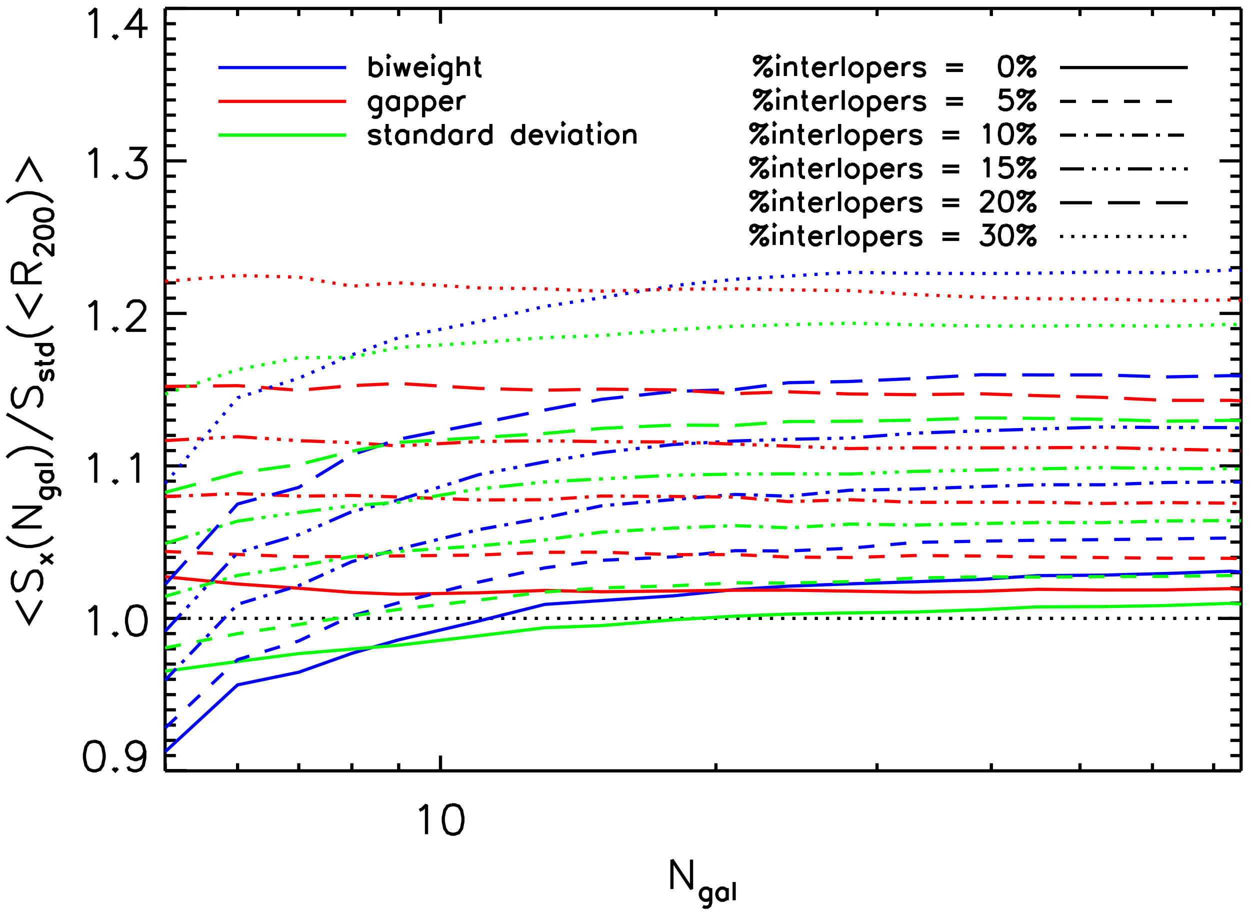
Unbounded galaxies mixed to clusters members well inside the radial 2D distribution

~27% is the fraction of interlopers before the velocity cut
~23% of interlopers remains after the 2.7σ clipping (Mamon et al.2010)

none algorithm can remove completely the interlopers

THE CLIPPING AFFECT VERY SLIGHTLY THE FRACTION OF INTERLOPERS

INTERLOPERS CONTAMINATION: UNBOUND



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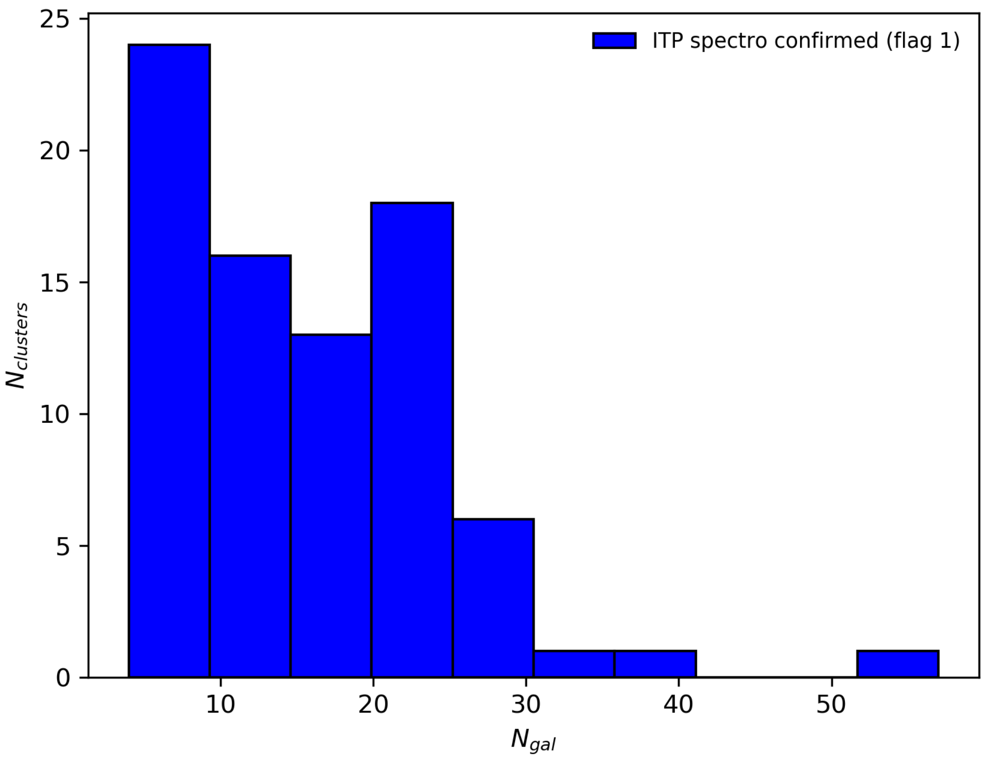
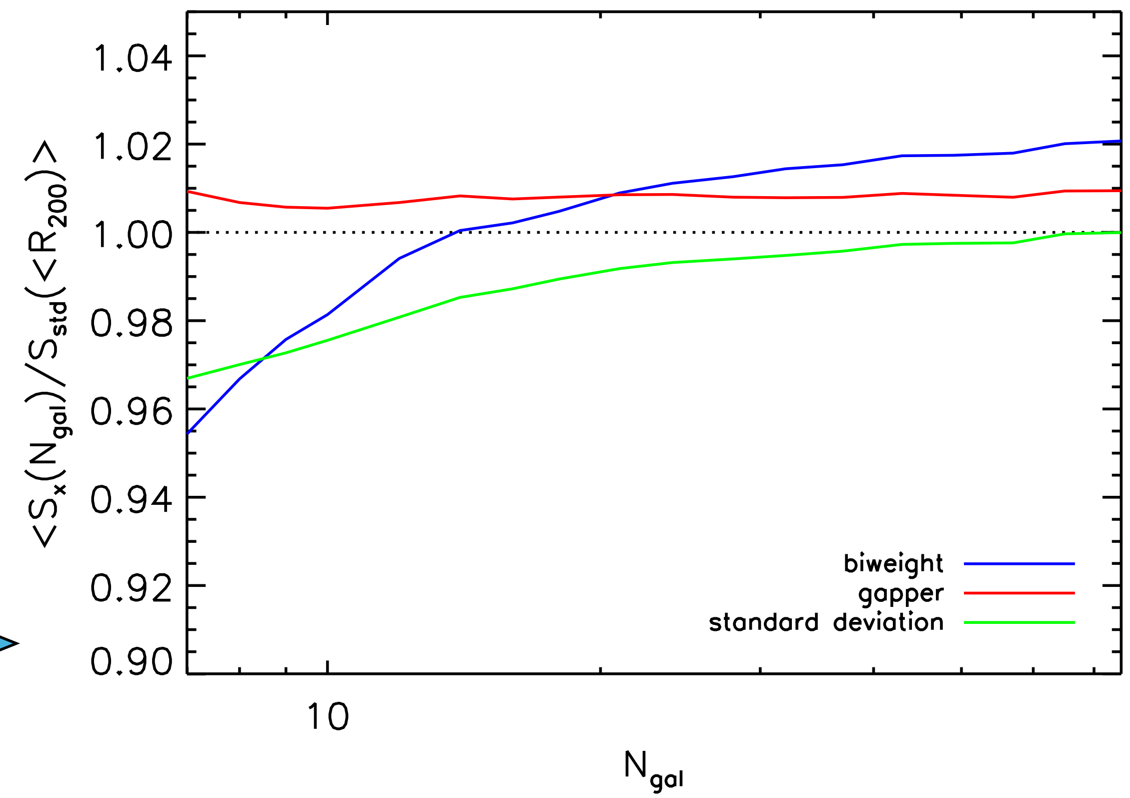
THE CLIPPING AFFECT VERY SLIGHTLY THE FRACTION OF INTERLOPERS

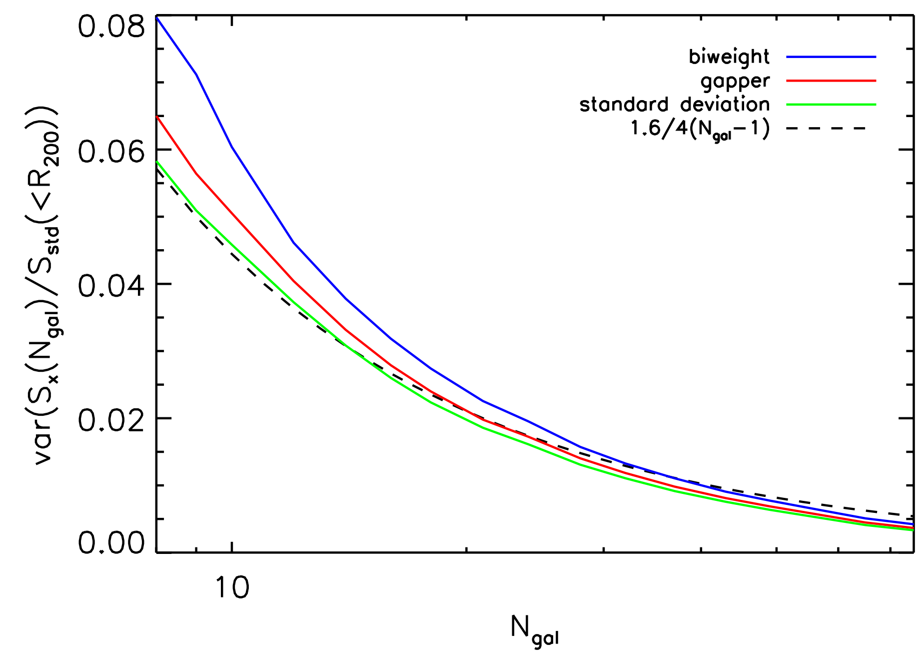
non algorithm can remove completely the interlopers

UNBIASED VELOCITY DISPERSION ESTIMATOR IN THE SMALL NUMBER OF GALAXIES REGIME

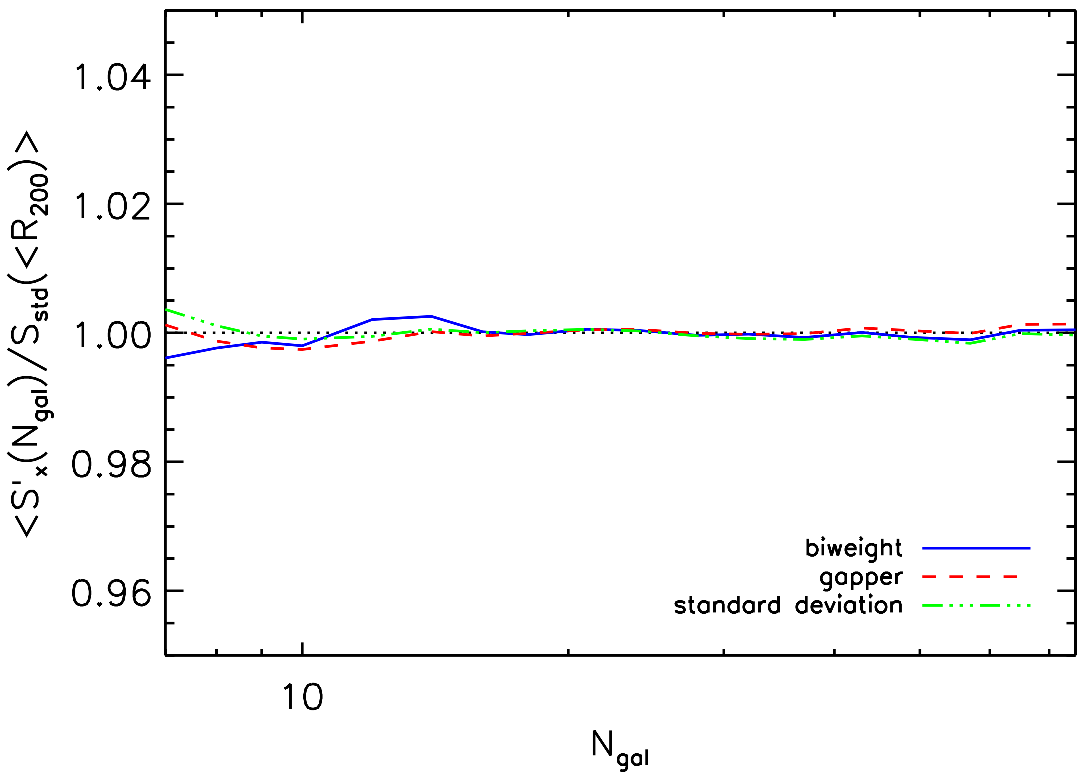
ITP median N_{gal} ~ 14

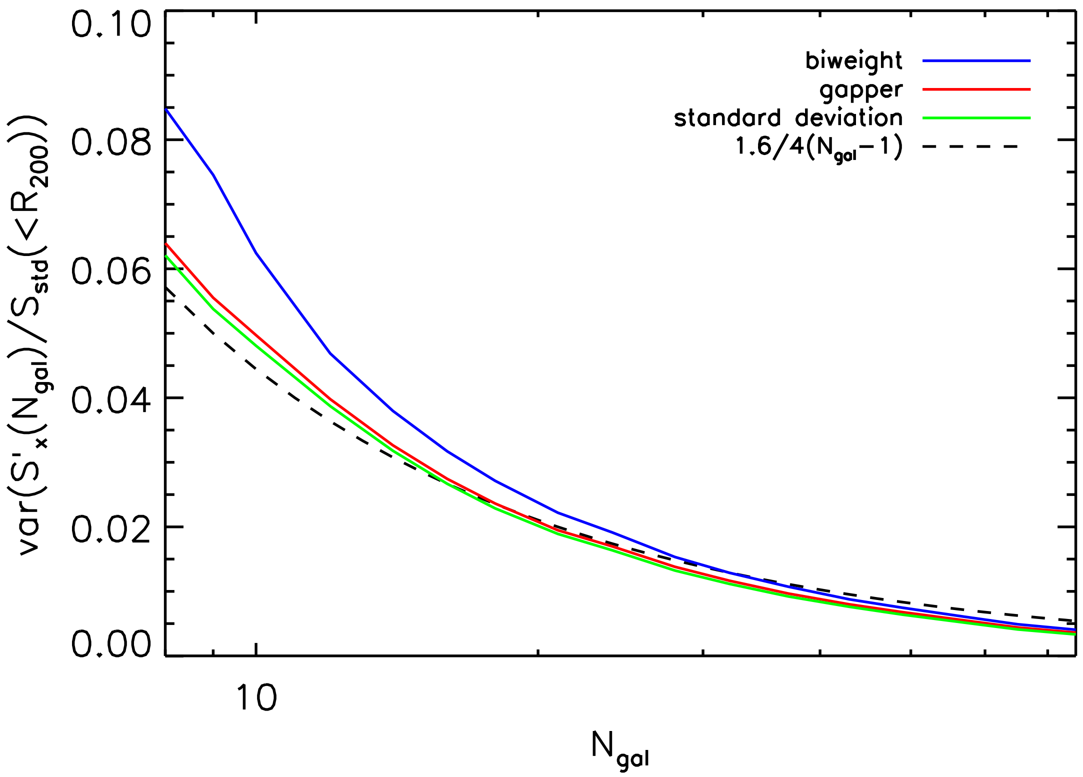






UNBIASED VELOCITY DISPERSION ESTIMATOR IN THE SMALL NUMBER OF GALAXIES REGIME





statistically unbiased velocity dispersion estimators

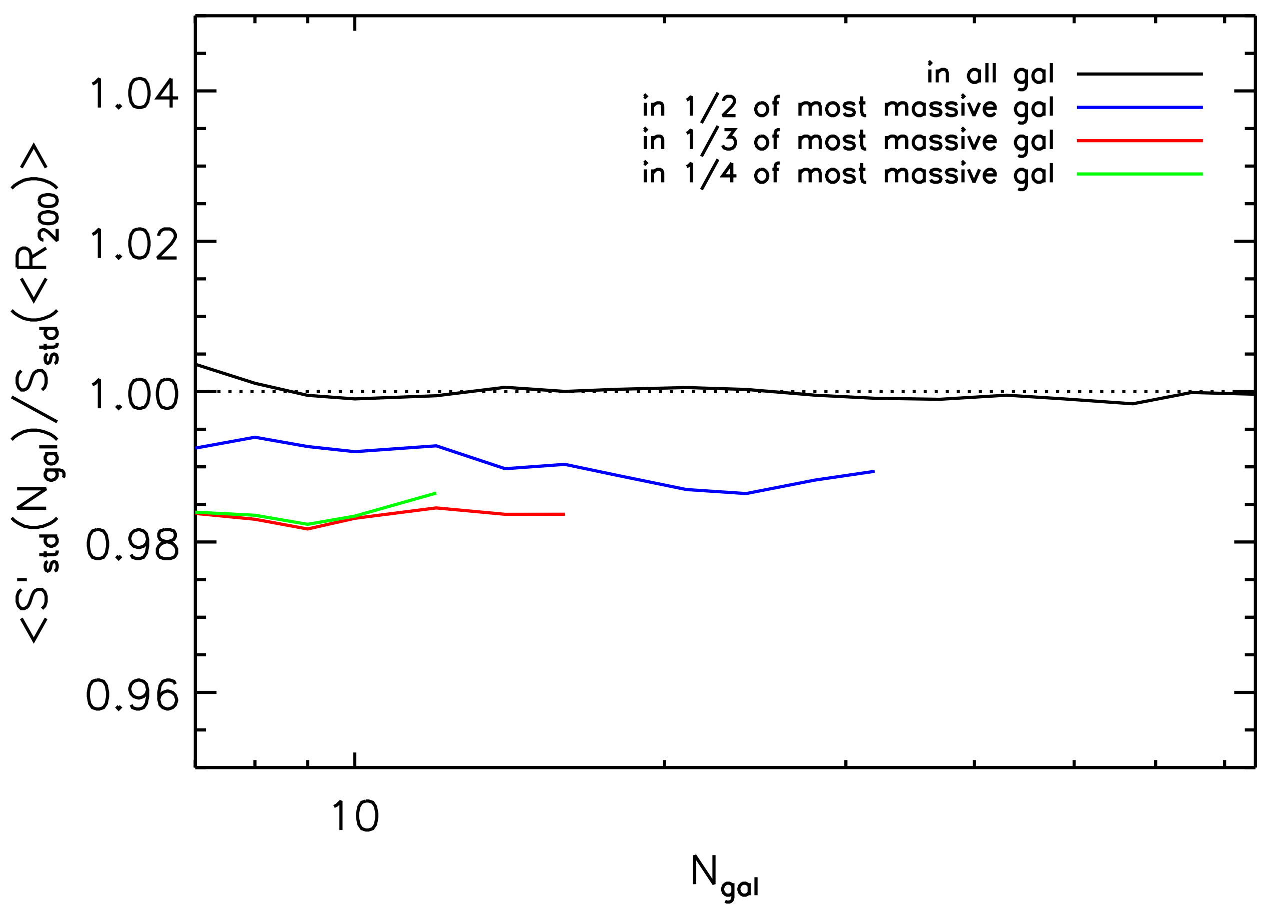
$$S'_{\rm x} = S_{\rm x}\left(1 + \left(\left(\frac{A}{(N_{\rm gal}-1)}\right)^{C} + B\right)\right)$$

	BWT	*GAP*	*STD*
A	0.72 ± 0.03	0	0.25
B	−0.007 ± 0.001	0.0007 ± 0.0002	0
C	1.28 ± 0.03	1	1

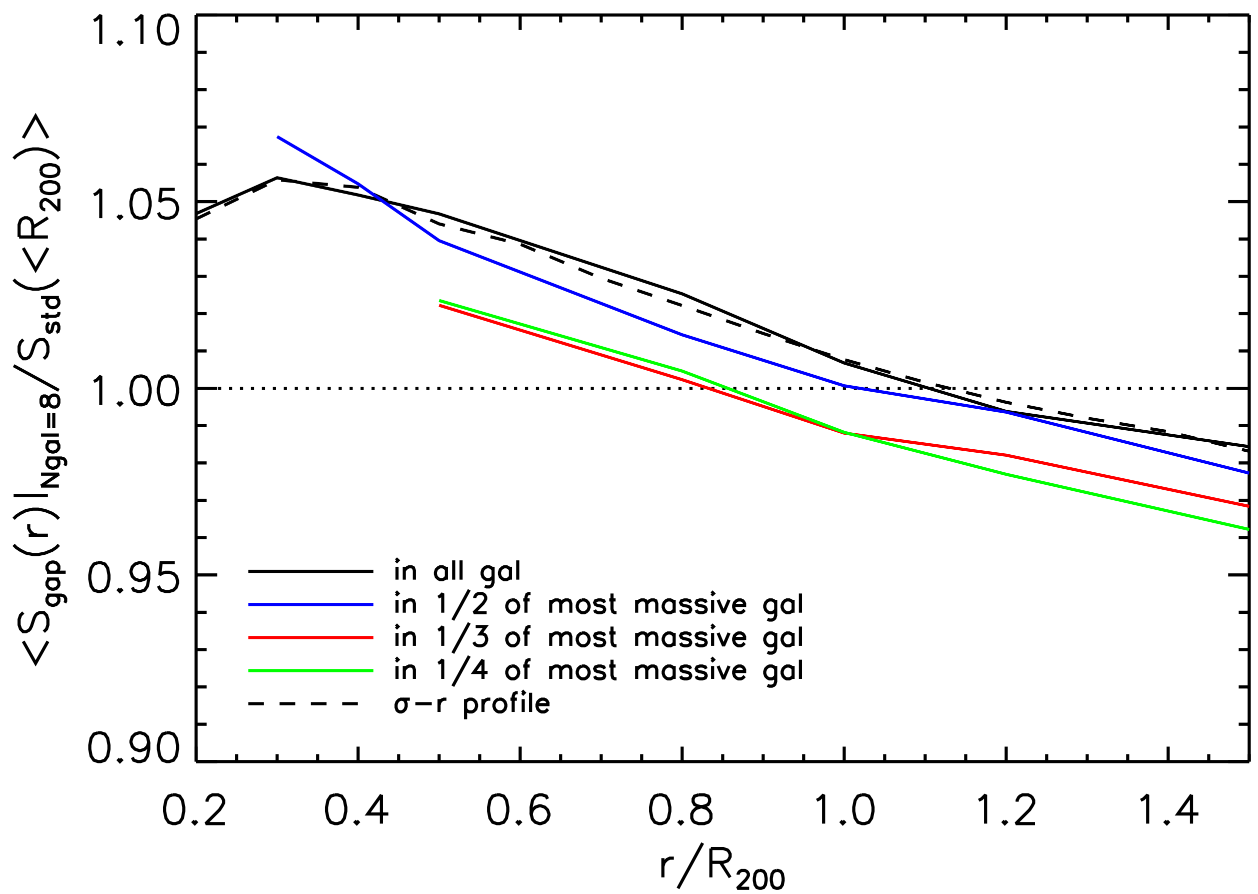
UNBIASED VELOCITY DISPERSION ESTIMATOR IN THE SMALL NUMBER OF GALAXIES REGIME

The new estimators avoid biased in velocity dispersion estimate. However, observational limits could be source of additional biases.

MASS FRACTION BIAS

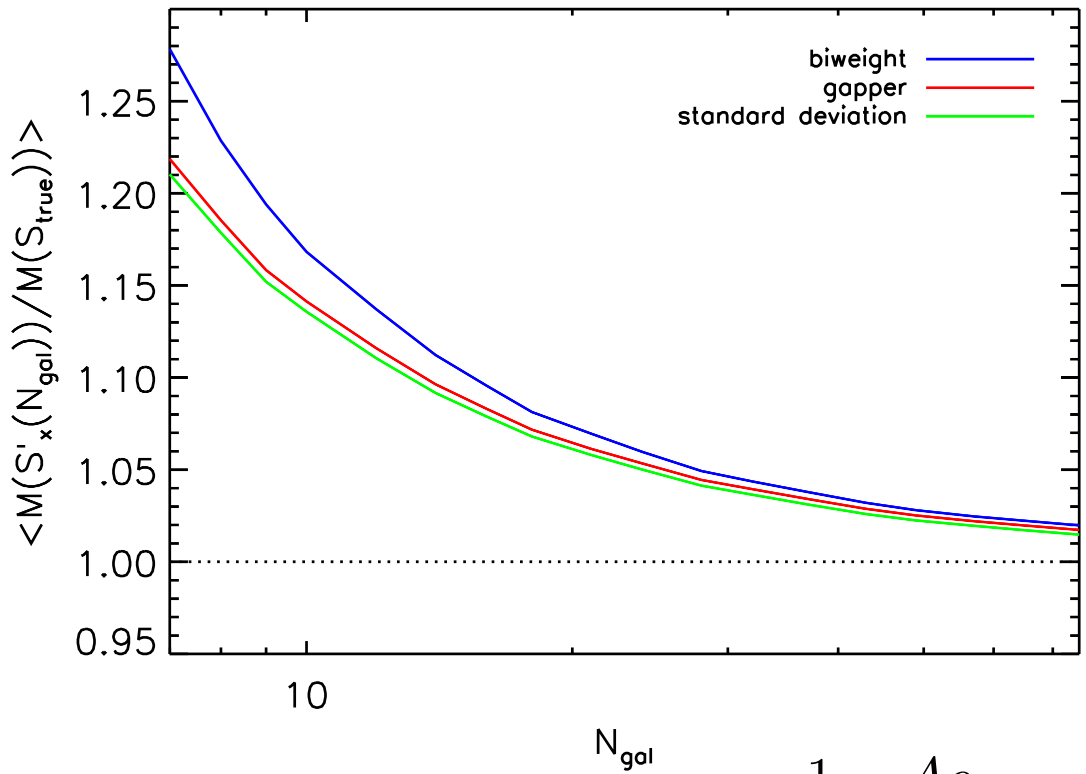


APERTURE BIAS



UNBIASED MASS ESTIMATOR IN THE SMALL NUMBER OF GALAXIES REGIME

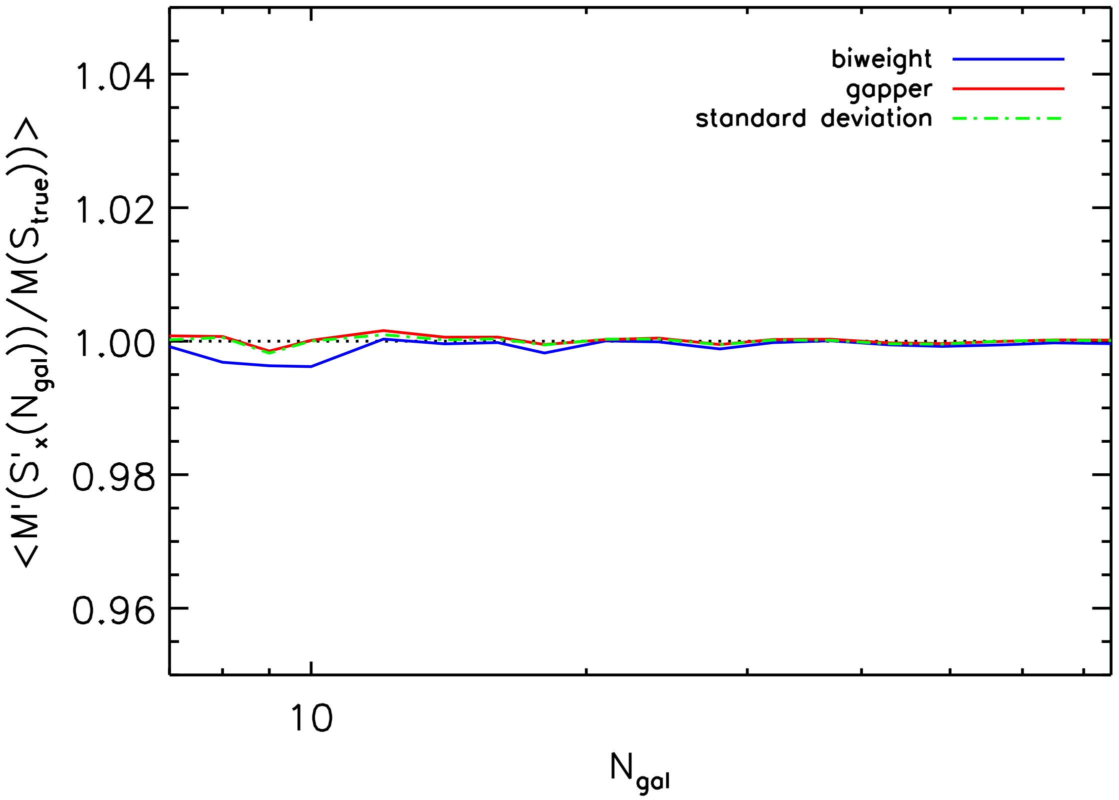
Simulated Cluster masses are calculated using the Munari el al. (2013) relation with the galaxy fit parameter A=1177 and α=0.364



$$\frac{M(S_X)}{10^{15}\ \mathrm{M_\odot}} = h(z)^{-1}\left(\frac{S_X}{A\ \mathrm{km\ s^{-1}}}\right)^{1/\alpha}$$

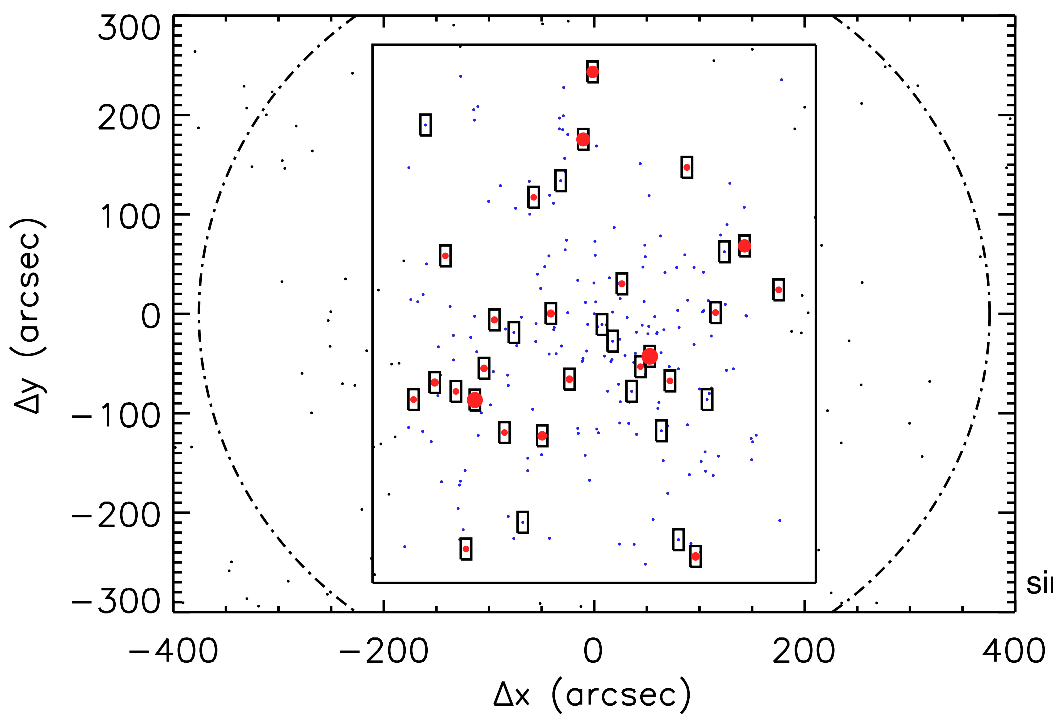
$$M'(S'_X) = M(S_X(N_{gal})\,\frac{1-A\alpha}{(A\alpha)^2(N_{gal}-1)^C} + B$$

	BWT	*GAP*	*STD*
A	1.31 ± 0.03	1.50 ± 0.03	1.53 ± 0.03
B	0	0	0
C	1.24 ± 0.03	1.17 ± 0.04	1.11 ± 0.04



DYNAMICAL MASS ESTIMATION

To test this corrections we simulated our mask and our members selections.
We perform 300 different configurations for each cluster changing, orientation, line of sight and clusters members.



TNG
simulated mask

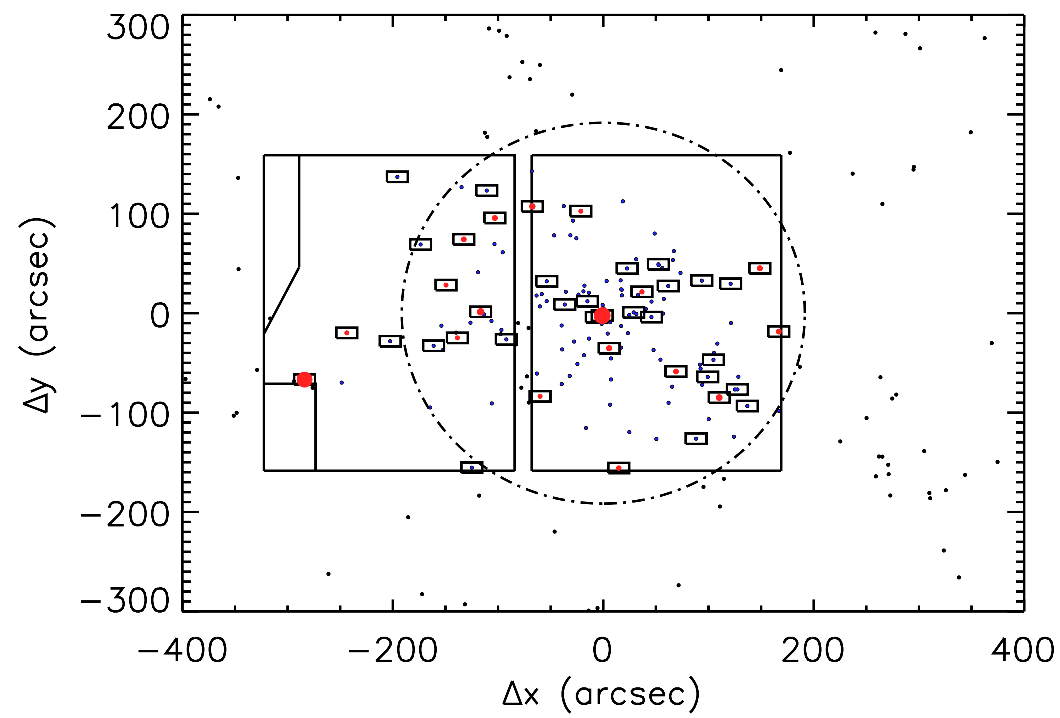
before correction

$$\left\langle \frac{S_{\rm std}}{S_{\rm bwt}} \right\rangle = 0.96 \pm 0.02$$

after correction

$$\left\langle \frac{S'_{\rm std}}{S_{\rm bwt}} \right\rangle = 1.00 \pm 0.02$$

GTC
simulated mask



before correction

$$\left\langle \frac{M(S'_{\rm std})}{M(S_{\rm bwt})} \right\rangle = 1.13 \pm 0.07$$

after correction

$$\left\langle \frac{M'(S'_{\rm std})}{M(S_{\rm bwt})} \right\rangle = 0.99 \pm 0.06$$

M_{SZ} - M_{DYN} SCALING RELATION:

$$M_{500}^{SZ} = (1 - B) M_{500}^{dyn}$$

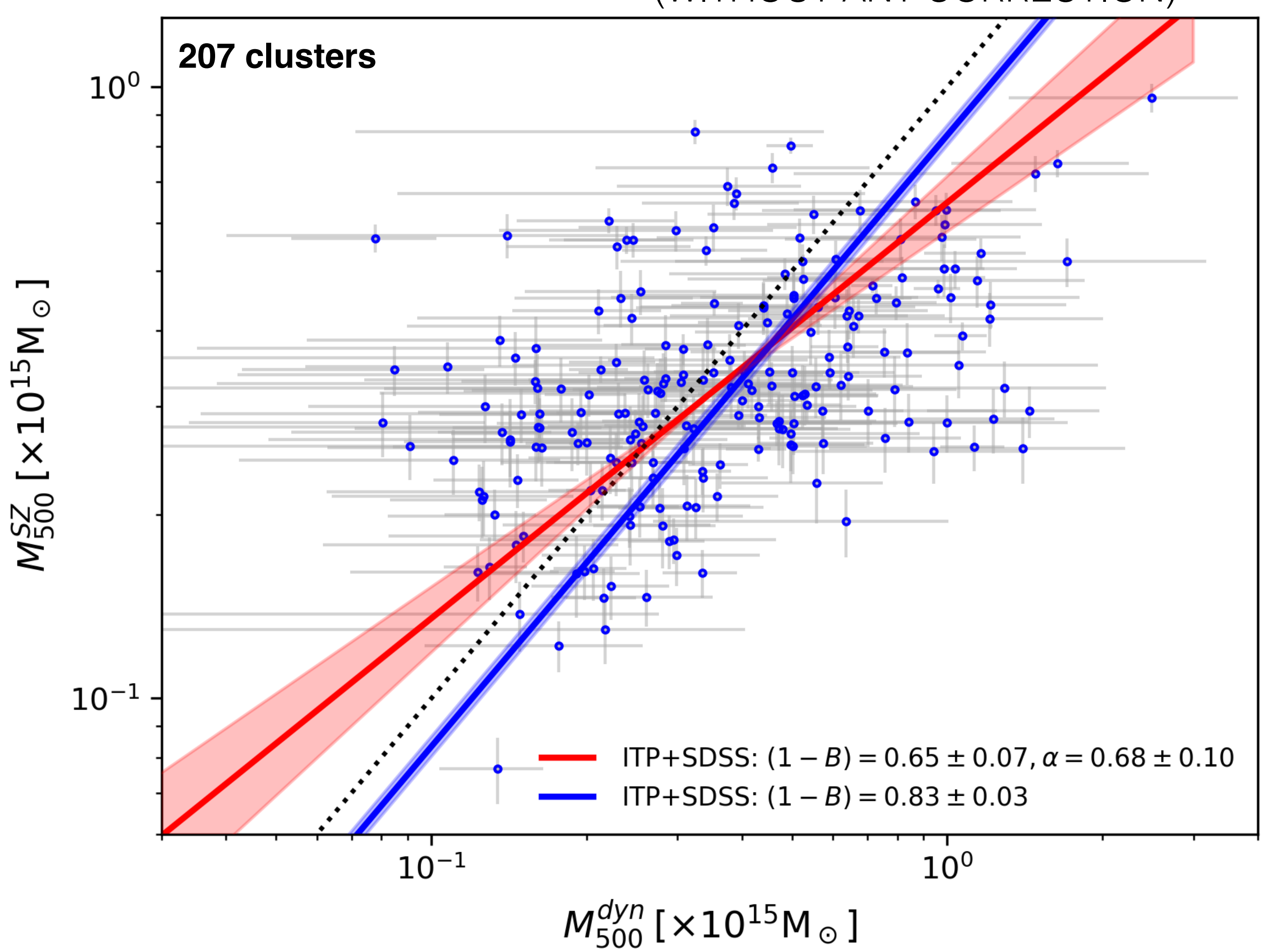
PRELIMINARY

(WITHOUT ANY CORRECTION)

$$(1 - B) \equiv \frac{(1 - b_{SZ})}{\beta}$$

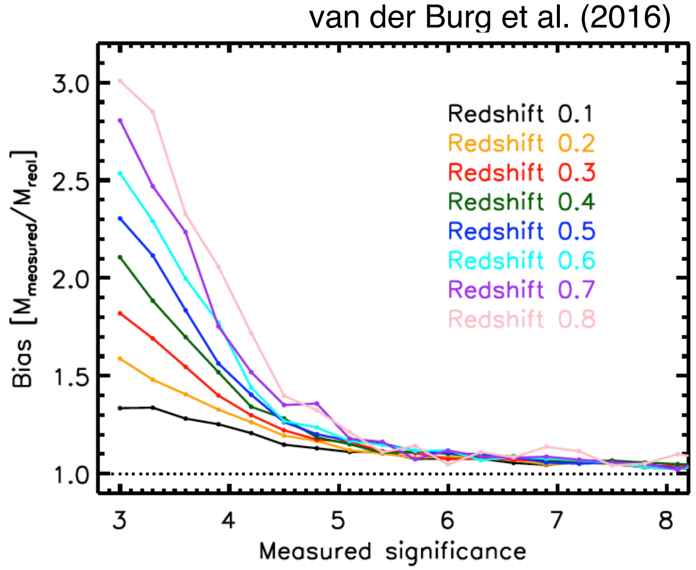
$$M_{500}^{SZ} = (1 - b_{sz}) M_{500}$$

$$M_{500}^{dyn} = \beta M_{500}$$



Eddington Bias Correction

van der Burg et al. (2016)



$$(1 - B) = 0.83 \pm 0.03$$

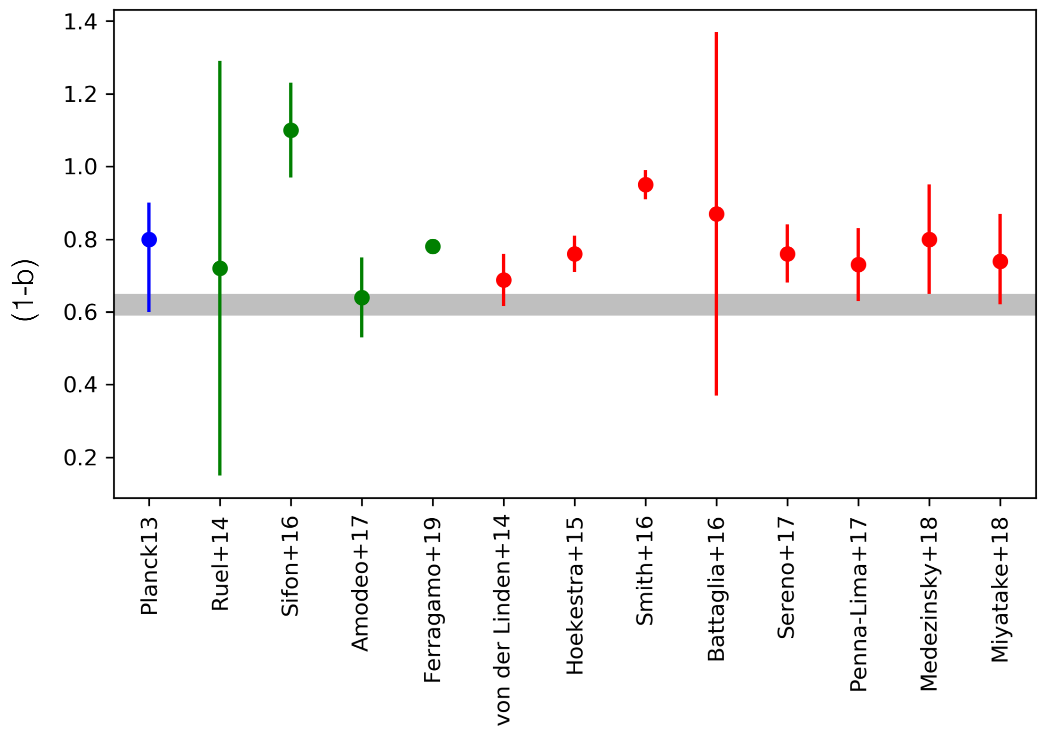
$$\alpha = 0.68 \pm 0.10; (1 - B) = 0.65 \pm 0.07$$

M_{SZ} - M_{DYN} SCALING RELATION:

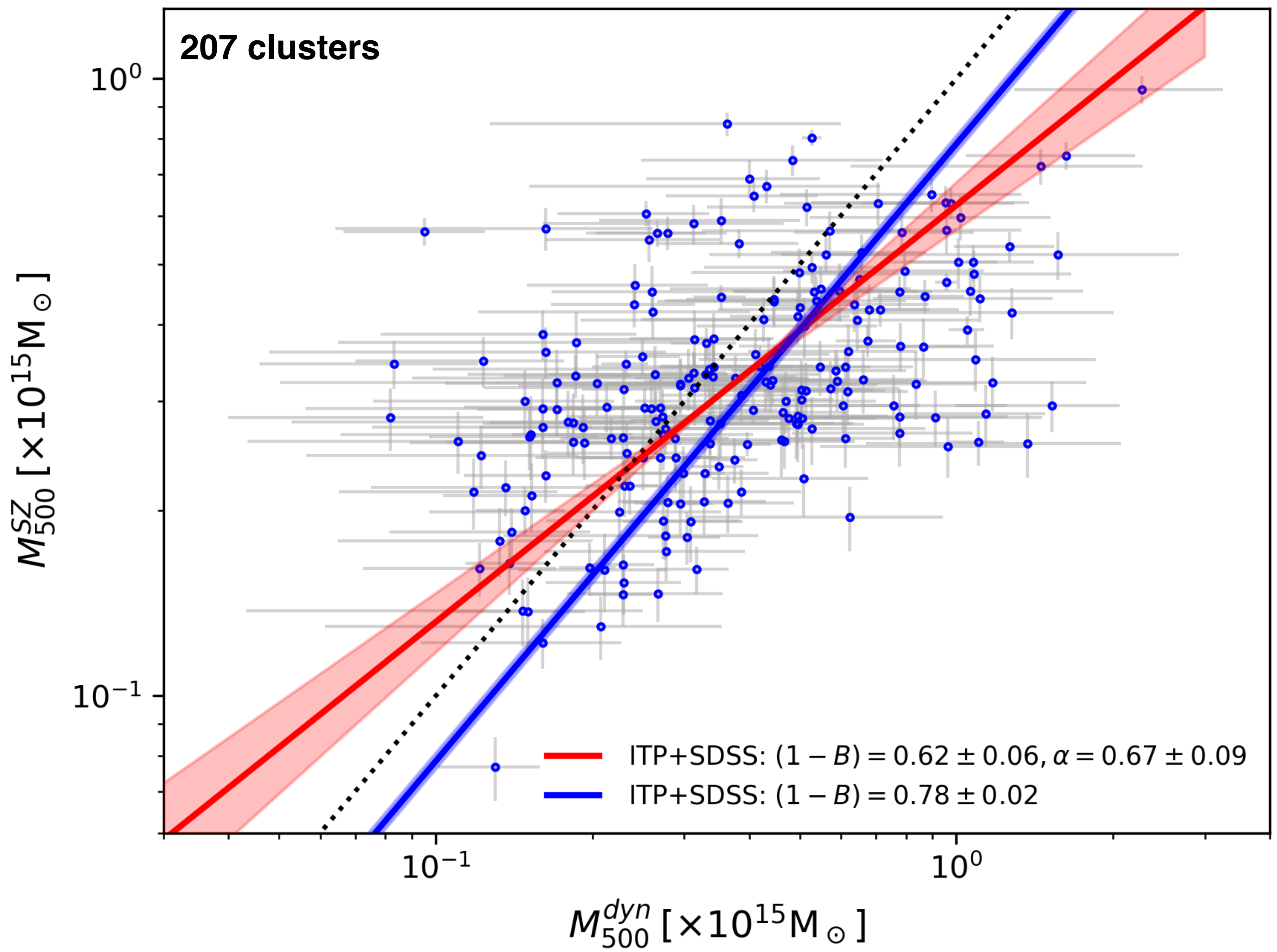
PRELIMINARY

$$M_{500}^{SZ} = (1-B)M_{500}^{dyn}$$

COMPARISON WITH LITERATURE



(WITHOUT INTERLOPERS CORRECTION)



$$(1-B) = 0.78 \pm 0.02$$

$$\alpha = 0.67 \pm 0.09; (1-B) = 0.62 \pm 0.06$$