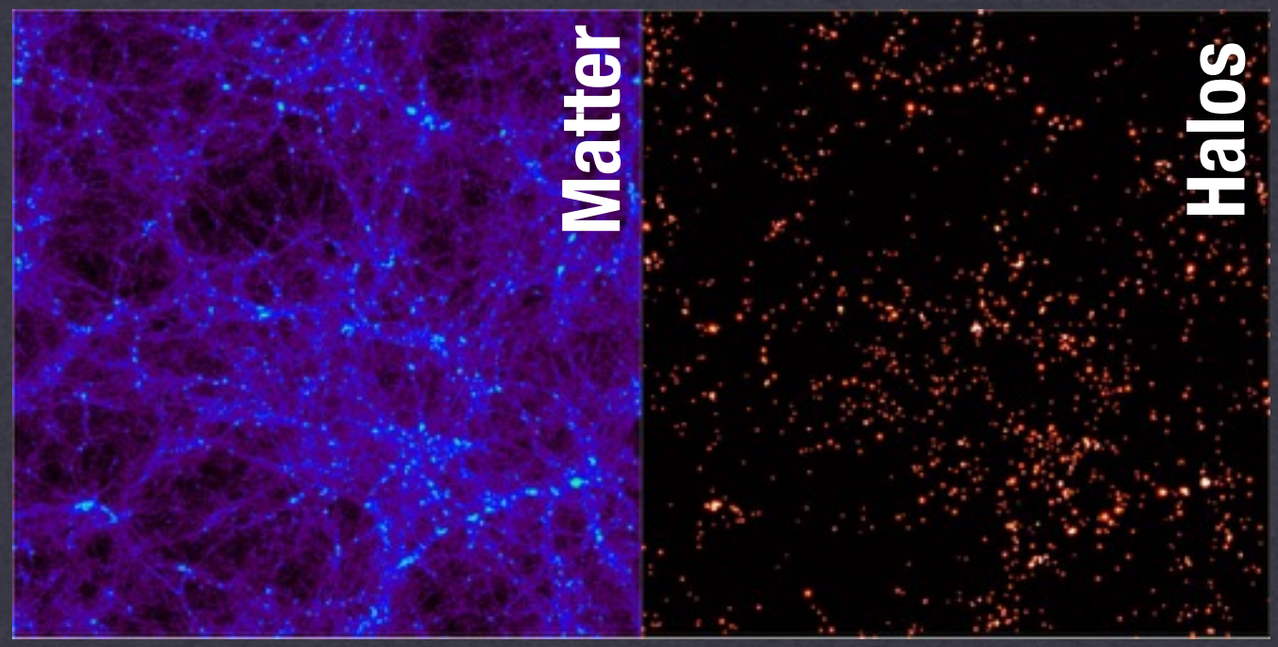
Halo assembly bias on cluster scales

Surhud More (Kavli-IPMU)

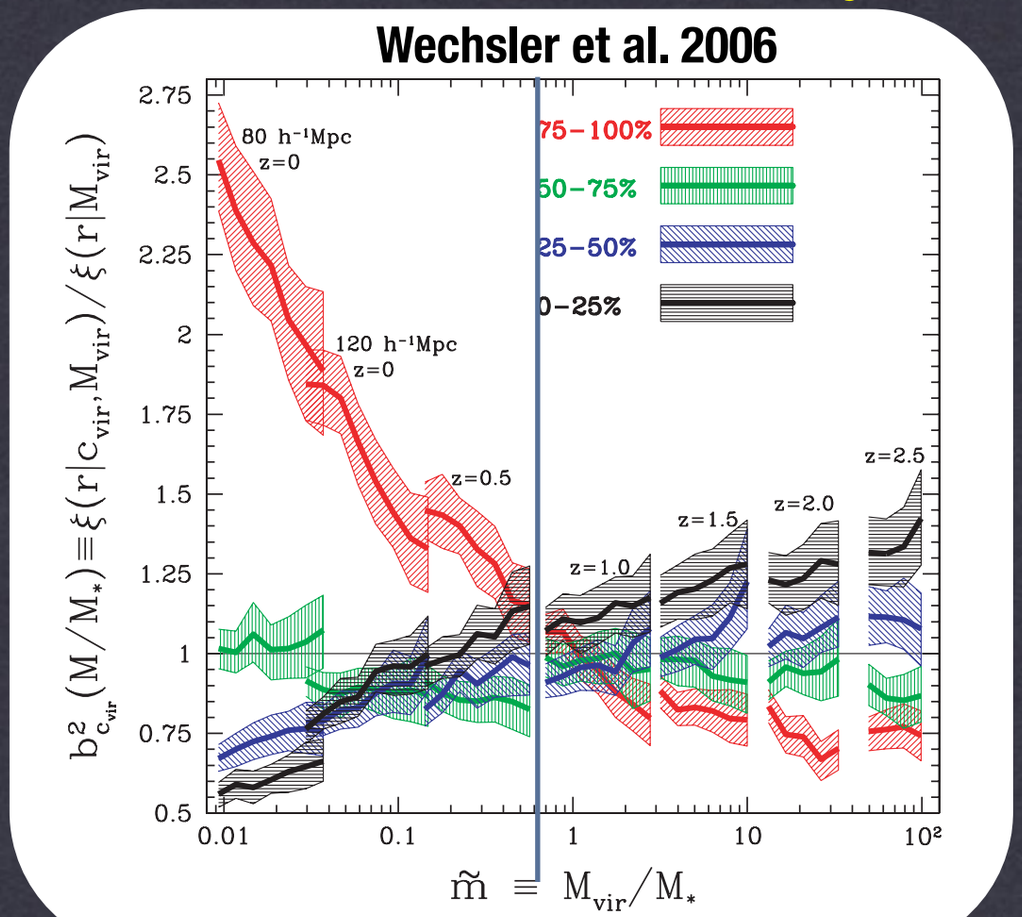
Collaborators: Hironao Miyatake (JPL), Masahiro Takada (Kavli IPMU), David Spergel (Princeton), Rachel Mandelbaum (CMU), Eduardo Rozo (Arizona), Eli Rykoff(Stanford), Benedikt Diemer & Andrey Kravtsov (UChicago)

Halo bias



- The spatial distribution of halos is biased with respect to the matter distribution
- The bias of halos changes with their mass, more massive halos are more strongly clustered : b(M)
- This dependence is used to infer halo masses of objects such as galaxies by measuring their clustering

Halo assembly bias



- Dependence of the large scale clustering amplitude on secondary parameters other than the halo mass.
- Notice the asymmetric behaviour on either side of Mnl.

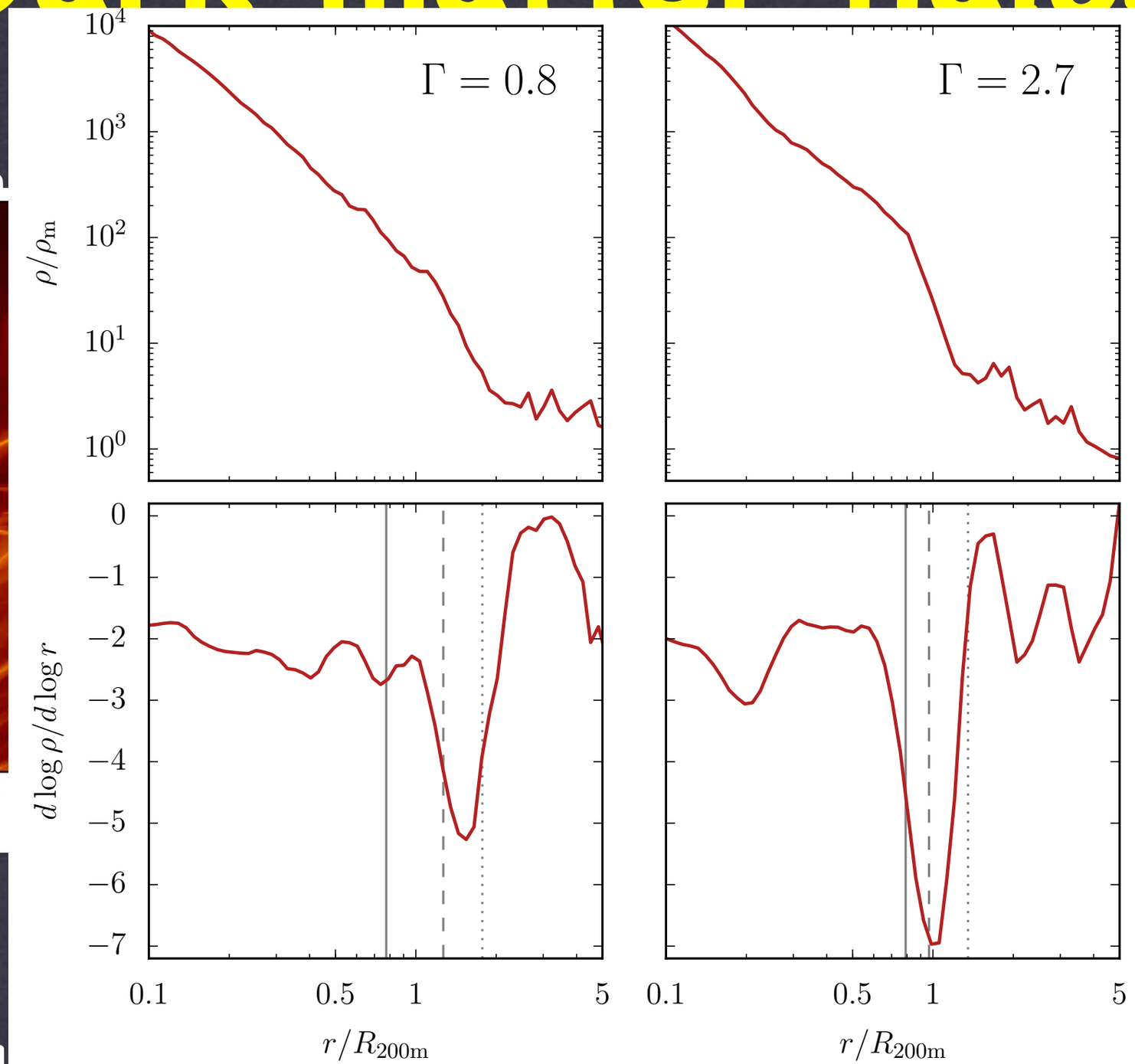
See also: Lemson & Kaufmann 99, Gao et al. 2005, 2008

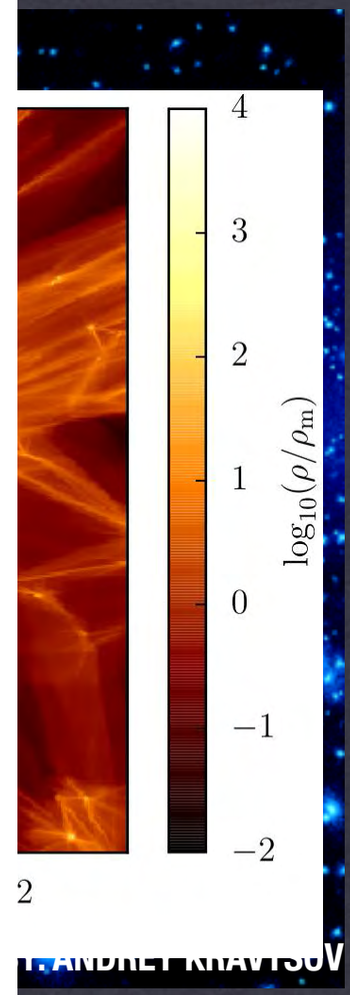
Observationally: Yang et al. 2006, Weinmann et al. 2006, Kauffmann et al. 2013, Hearin et al. 2014, but cf. Lin et al. 2015

Dark matter halos

- Near-un
- Arb

$\rho(r)$



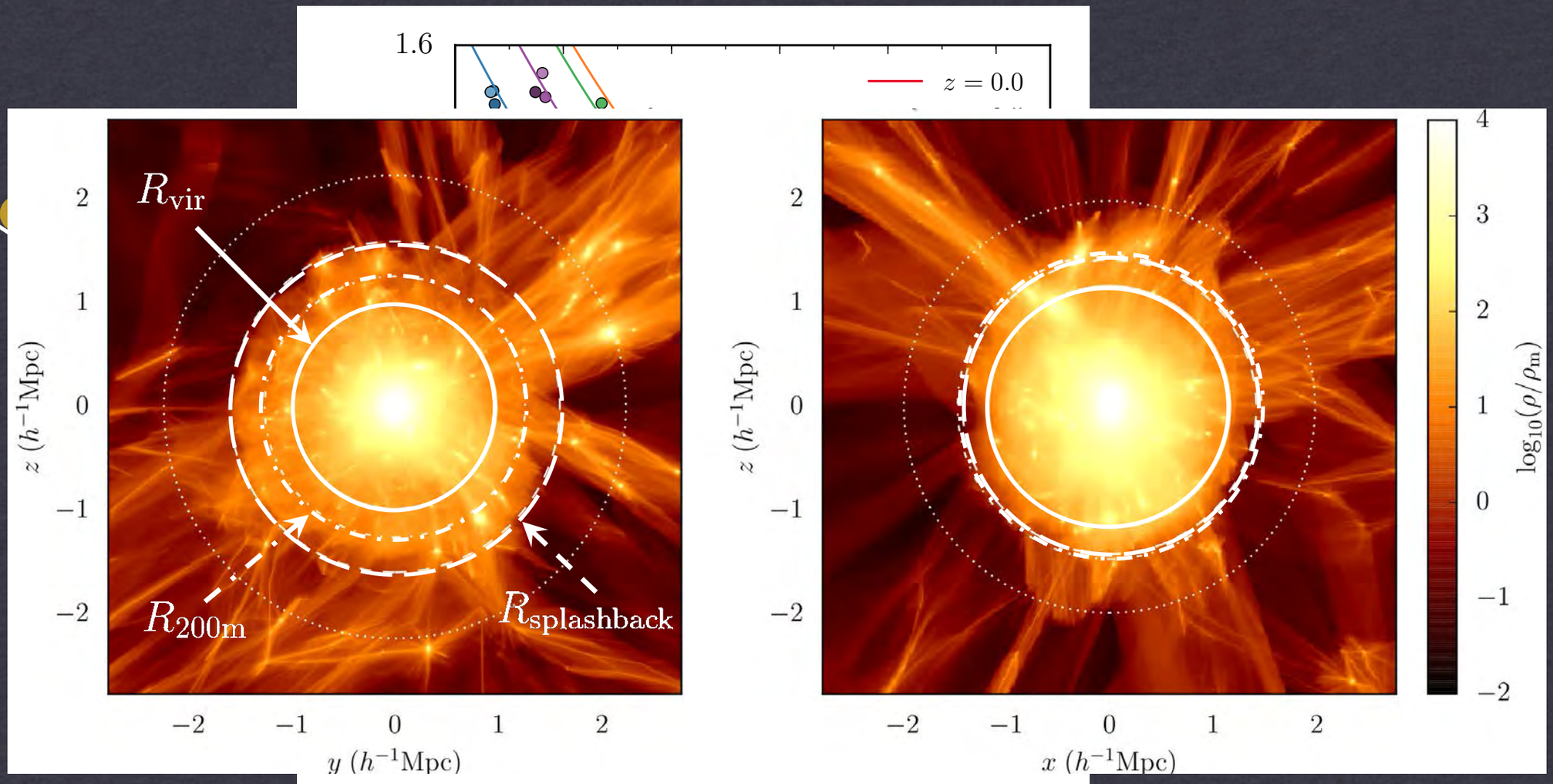


NFW profile

- Fundamental building block for structure in dark matter

Visualization based on a technique developed by Kaehler, Hahn and Abel 2013

Last caustic in the density profile

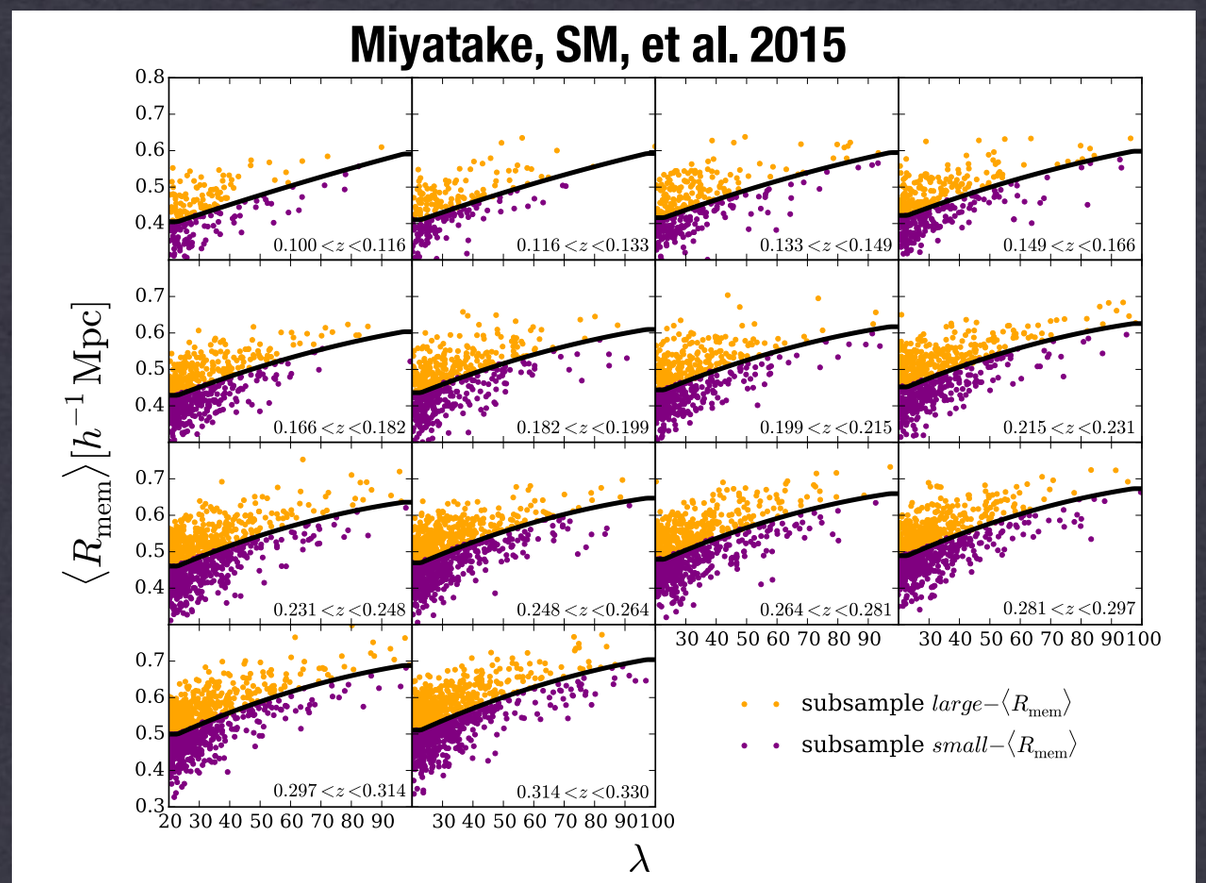


SM, DIEMER & KRAVTSOV 2015

- Depends upon the mass accretion rate
  - Faster accreting halos have smaller splash back radius

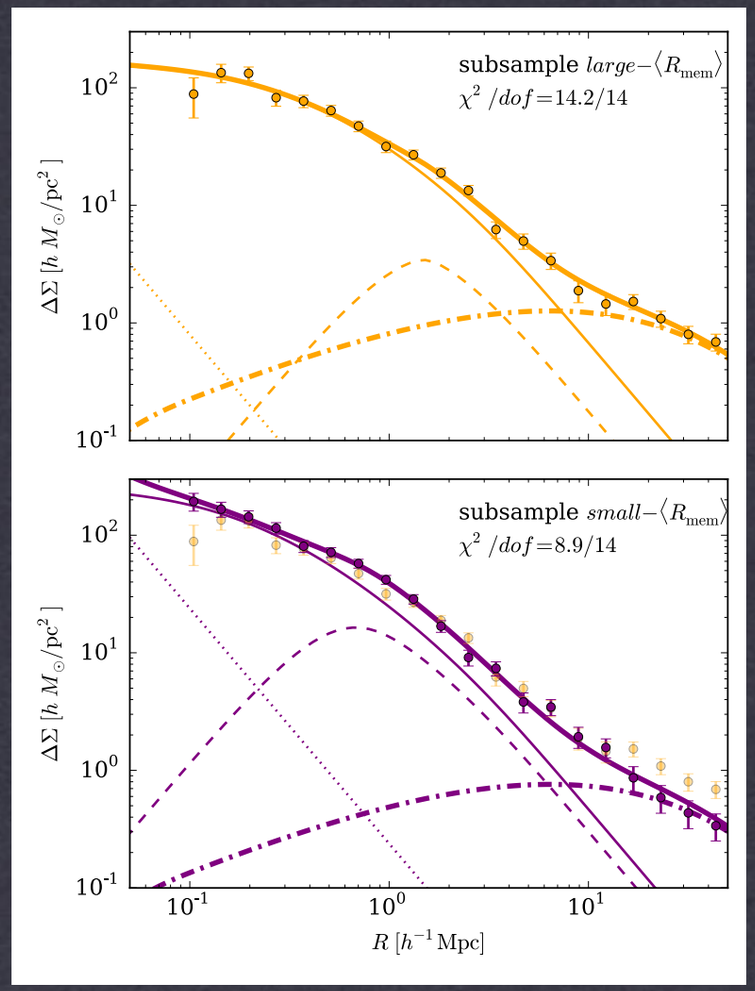
See also: Vogelsberger et al. 2011, Diemer & Kravtsov 2014, Adhikari, Dalal & Chamberlain 2014

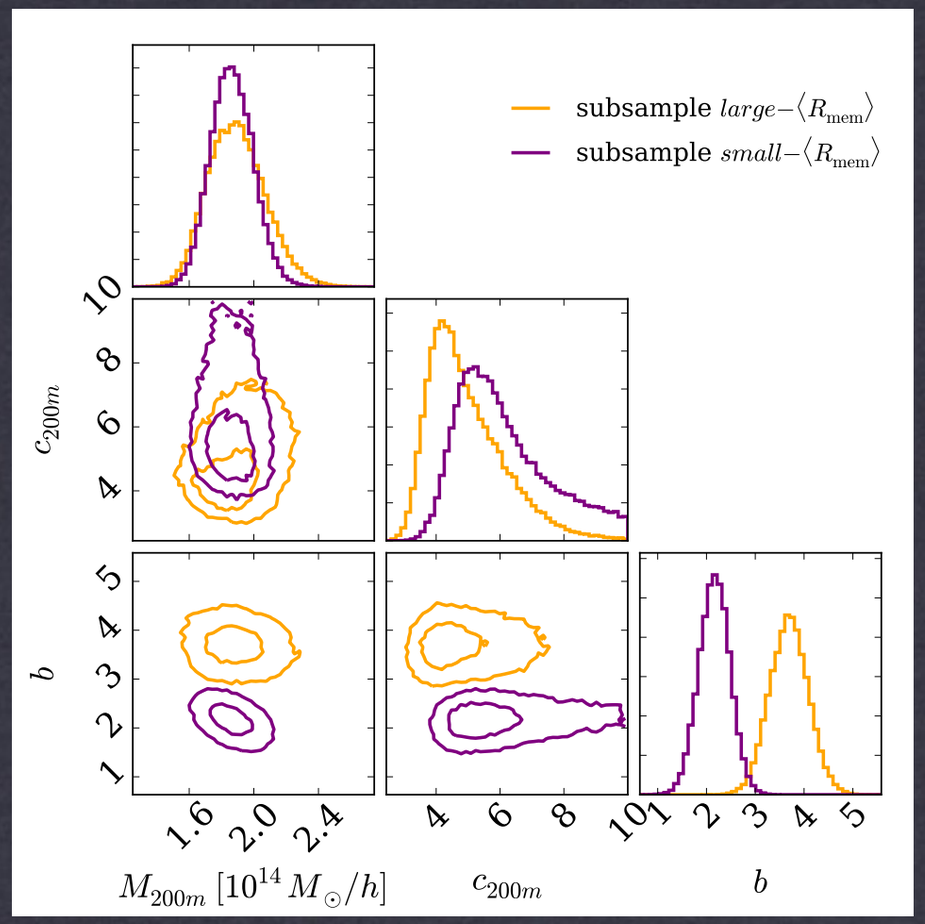
redMaPPer cluster subsamples



- 8648 redMaPPer clusters: $z \in [0.1, 0.33]$
- Subsamples based upon the average cluster-centric distance of member galaxies, $\langle R_{mem} \rangle$
- Control for halo mass using the weak lensing signal

Weak gravitational lensing





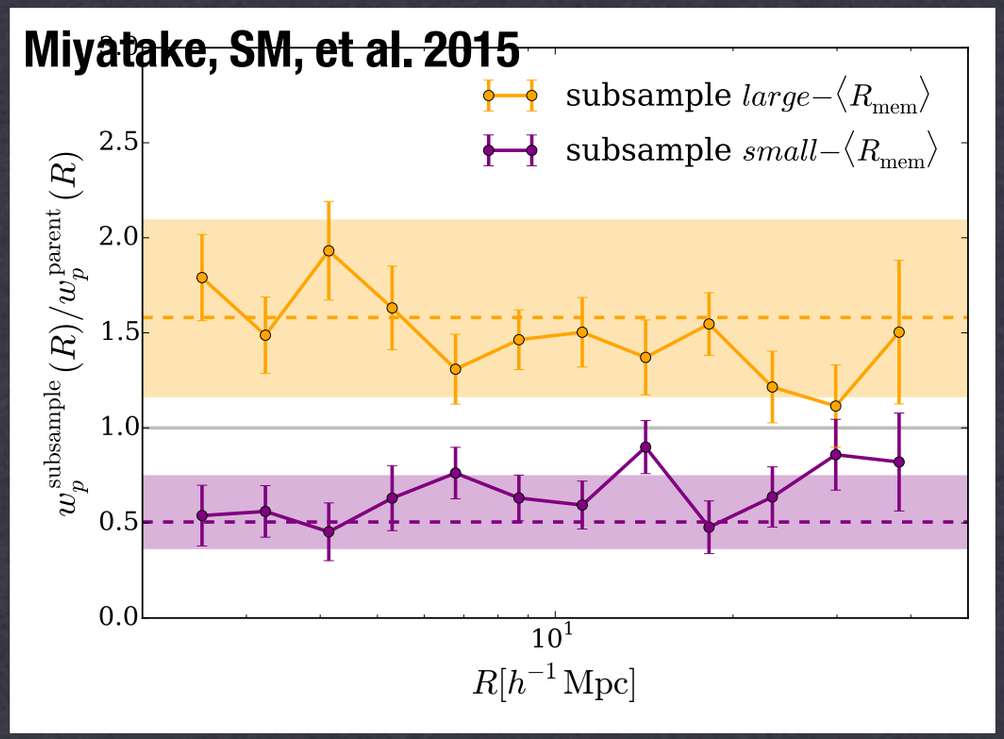
$$b^{{\rm large}-\langle R\rangle}/b^{{\rm small}-\langle R\rangle} = 1.64^{+0.31}_{-0.26}$$

- Same average halo mass, different large scale bias.
- Bias difference due to mass difference is 1.1 in the extreme case.

Miyatake, SM, et al. 2015

Cluster-cluster autocorrelation

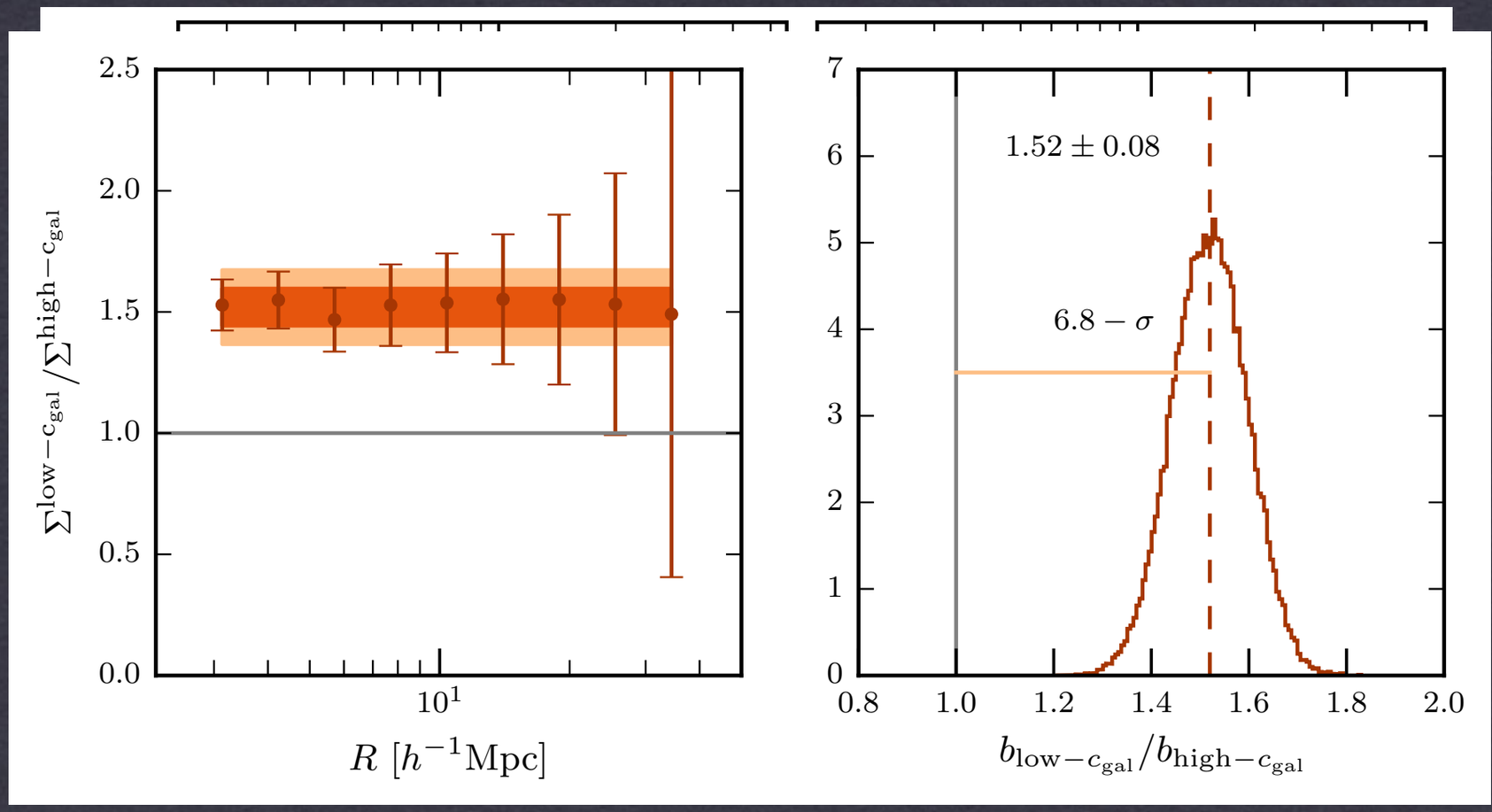
$b^{\mathrm{large}-\langle \mathrm{R} \rangle}/b^{\mathrm{small}-\langle \mathrm{R} \rangle} = 1.40 \pm 0.09$



Shaded bands from weak lensing

- Projected clustering of galaxy clusters shows a significant and consistent difference as well

SDSS photometric galaxies around redMaPPer clusters

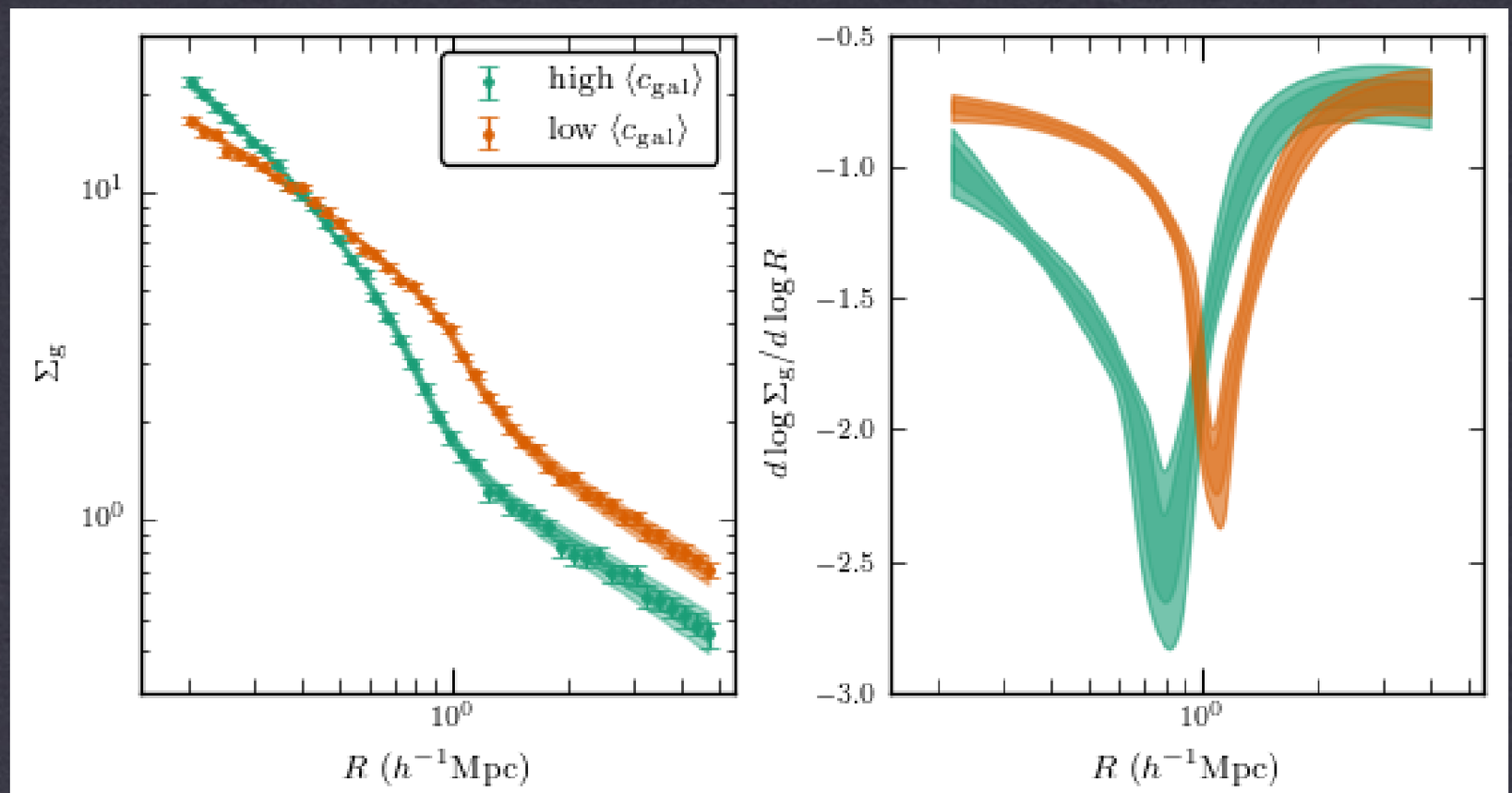


- Use photometric galaxies with M_i-5 log h <-20.42 (assuming cluster redshift)

- Surface number density of such galaxies as a function of radius

SM, et al. 2015 (in preparation)

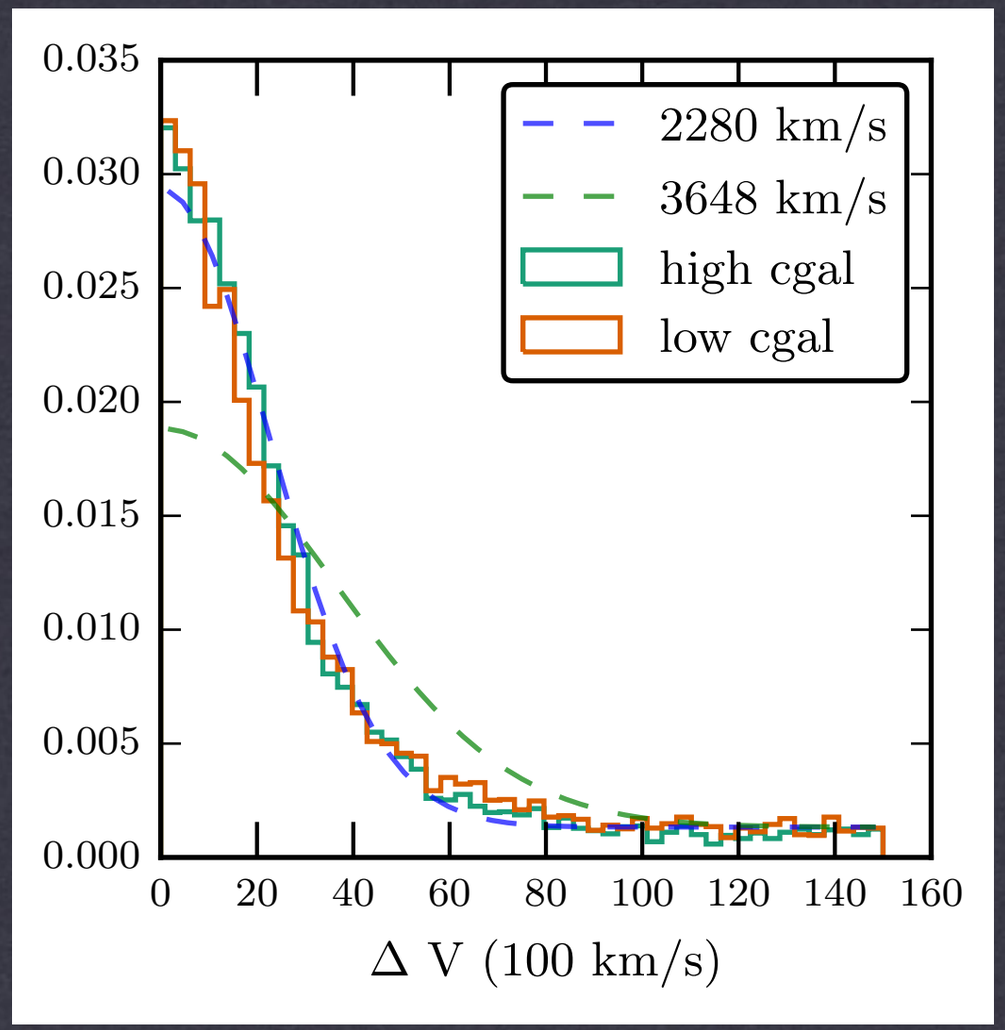
Splashback radius



- The steepening corresponding to the splash back radius is also seen in the photometric galaxy profiles
- High c_{gal} subsample should have a higher current accretion rate than the low c_{gal} subsample

SM, et al. 2015 (in preparation)

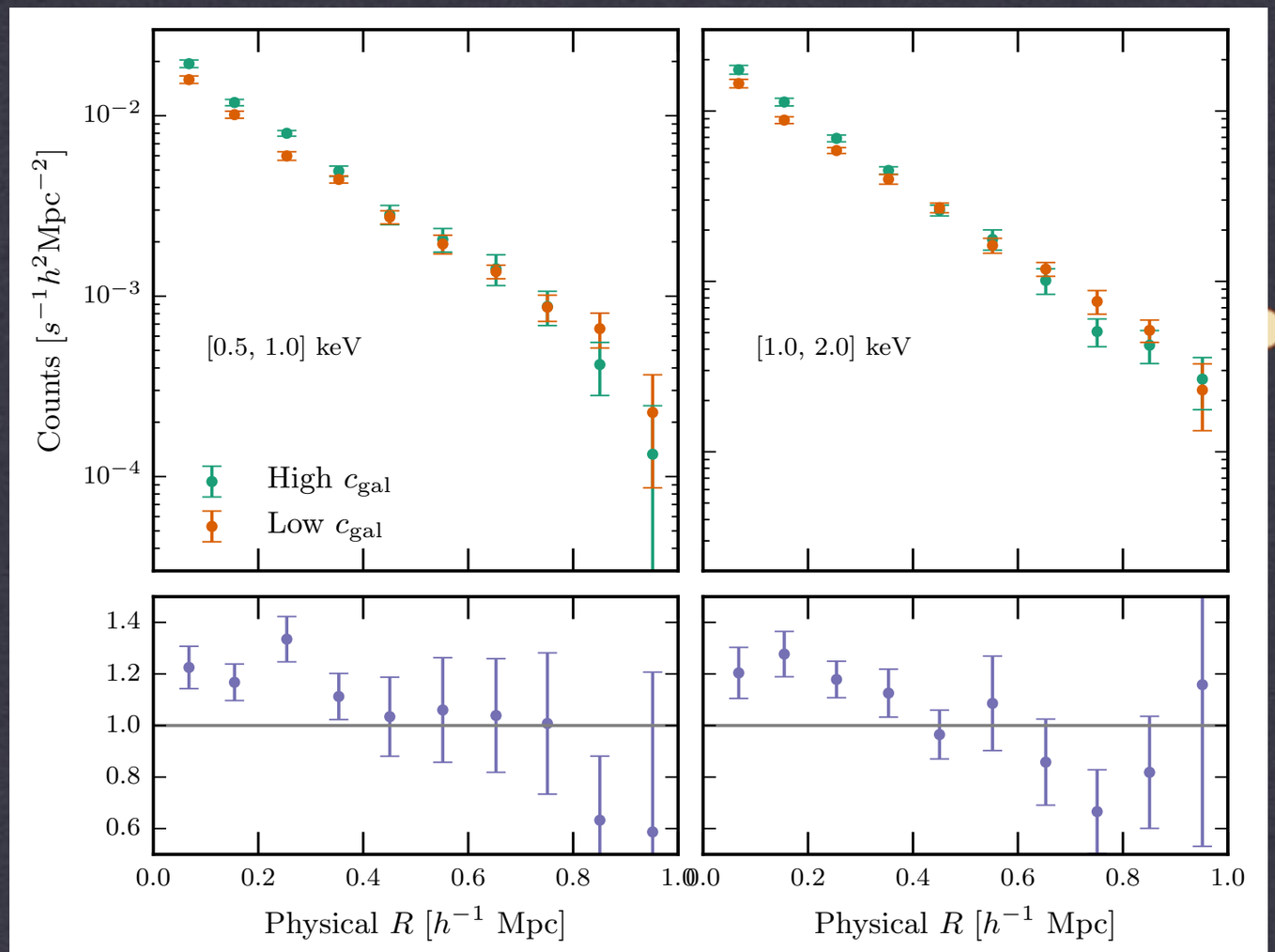
Weak lensing systematics ???



- Kinematics of member galaxies around the redMaPPer clusters (using spectra from SDSS DR12 BOSS)

SM, et al. 2015 (in preparation)

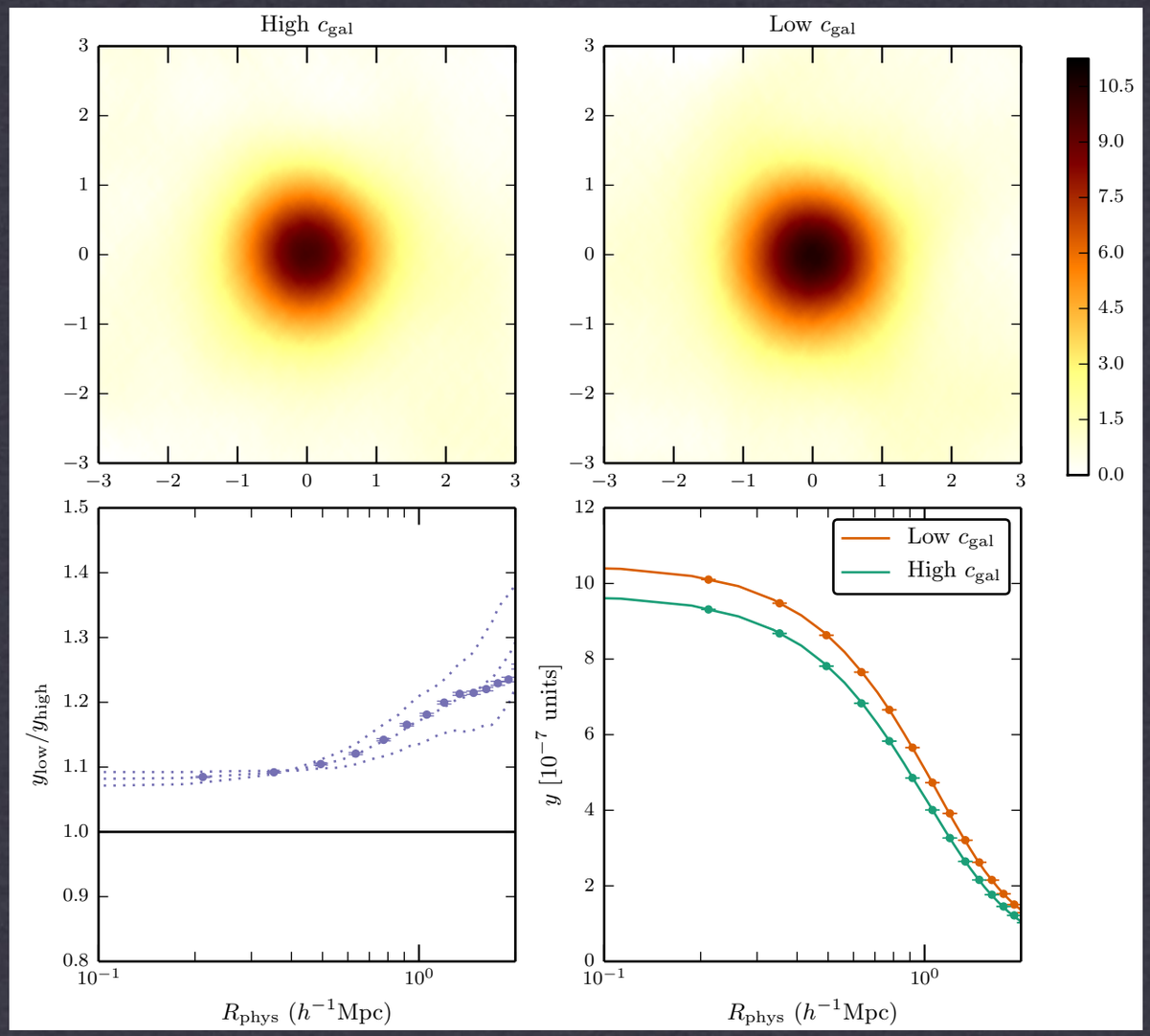
Xray properties



Stacked ROSAT all sky survey data

- Differences in the inner regions (perhaps different from theoretical expectations).

SZ properties



- Stacked Planck Compton y - maps

- Differences in the outer regions (similar to theoretical expectations).

See e.g., Lau et al. 2014

Summary table

Dark Matter				
	Low c_{dm}	High bias	Small Rsp	Form late
	High c_{dm}	Low bias	Large Rsp	Form early
Subhalos	I	I	X	X
	High c_{gal}	Low bias	Small Rsp	Form late
	Low c_{gal}	High bias	Large Rsp	Form early

- Concentration of galaxies is not same as concentration of dark matter (I see a similar effect in sims) SM, et al. 2015 (in preparation)

Conclusions

- Detection of halo assembly bias and the splash back radius on cluster scales

- Difficult to get theoretical predictions for assembly bias matching the observational criteria (but work in progress, **ask me**).

- Other results: Galaxy properties (conditional luminosity function, stacked BCG spectra, red fractions, etc.) Gas properties: SZ, Xray

Thank you!!!