The Distribution of Stellar Mass in Galaxy Clusters since *z*=1

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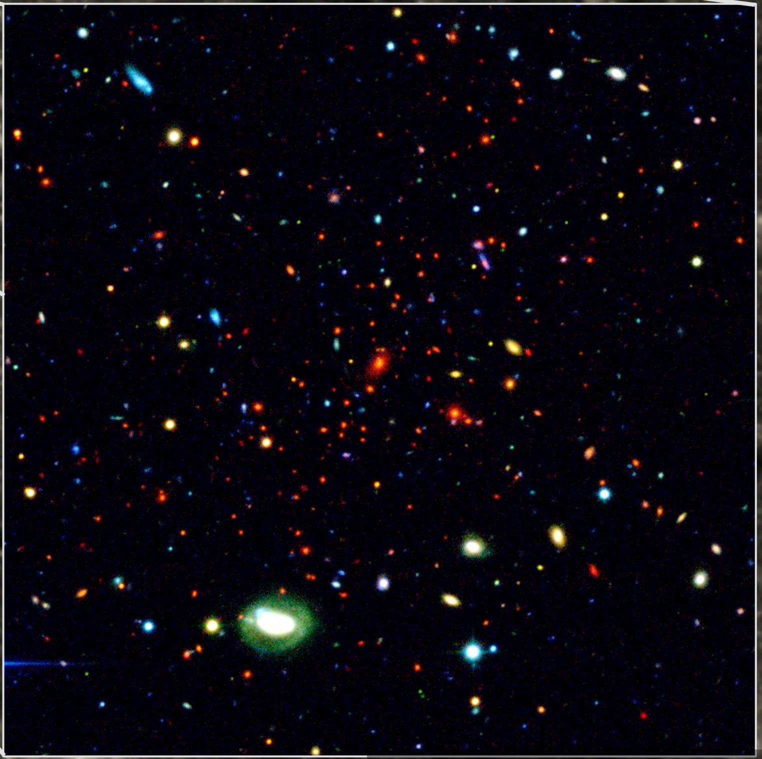
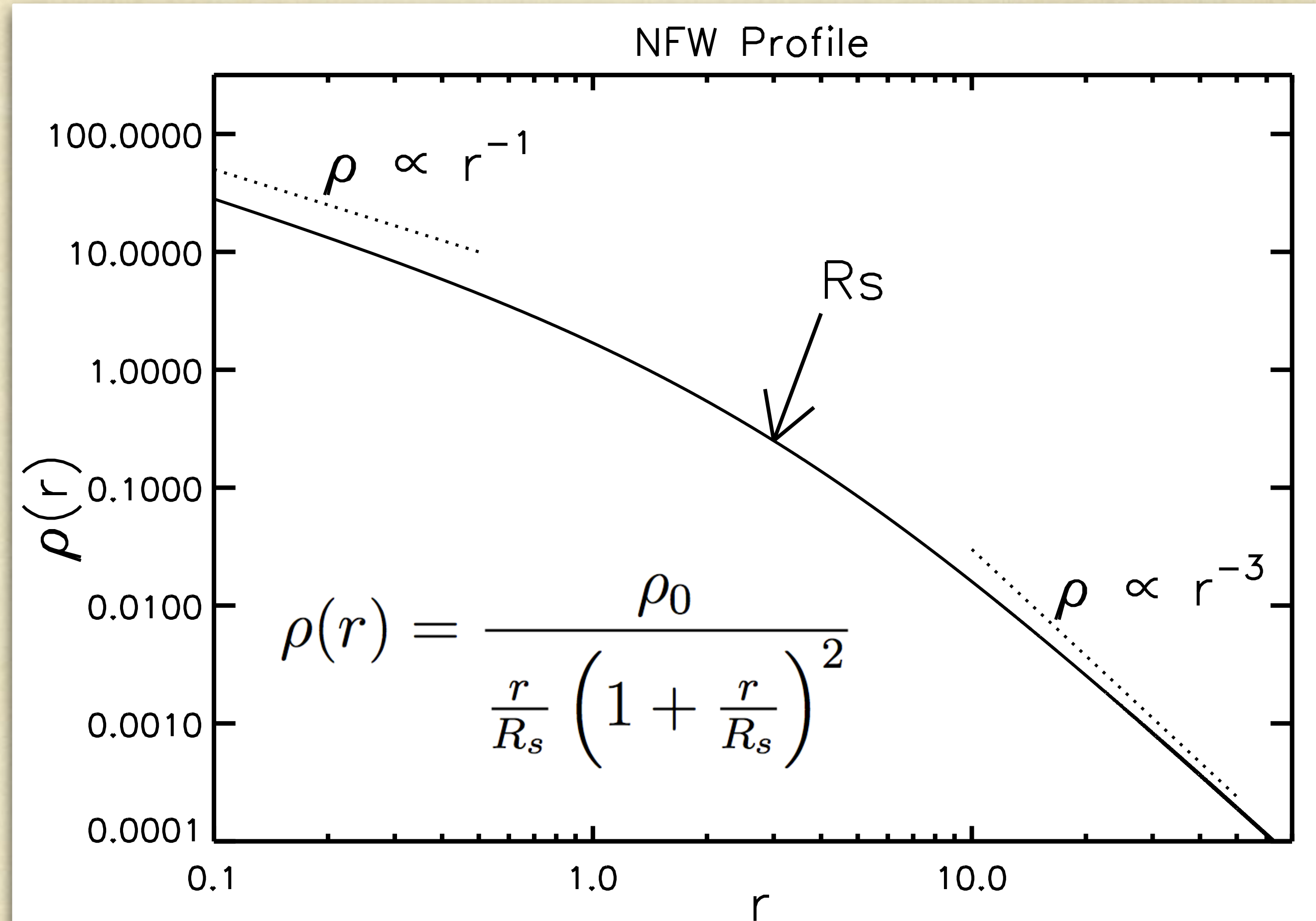


SpARCS-1613, z=0.871
CFHT MegaCam+WIRCam
rzK_s colour composite image

Dark Matter Haloes follow NFW* Profiles

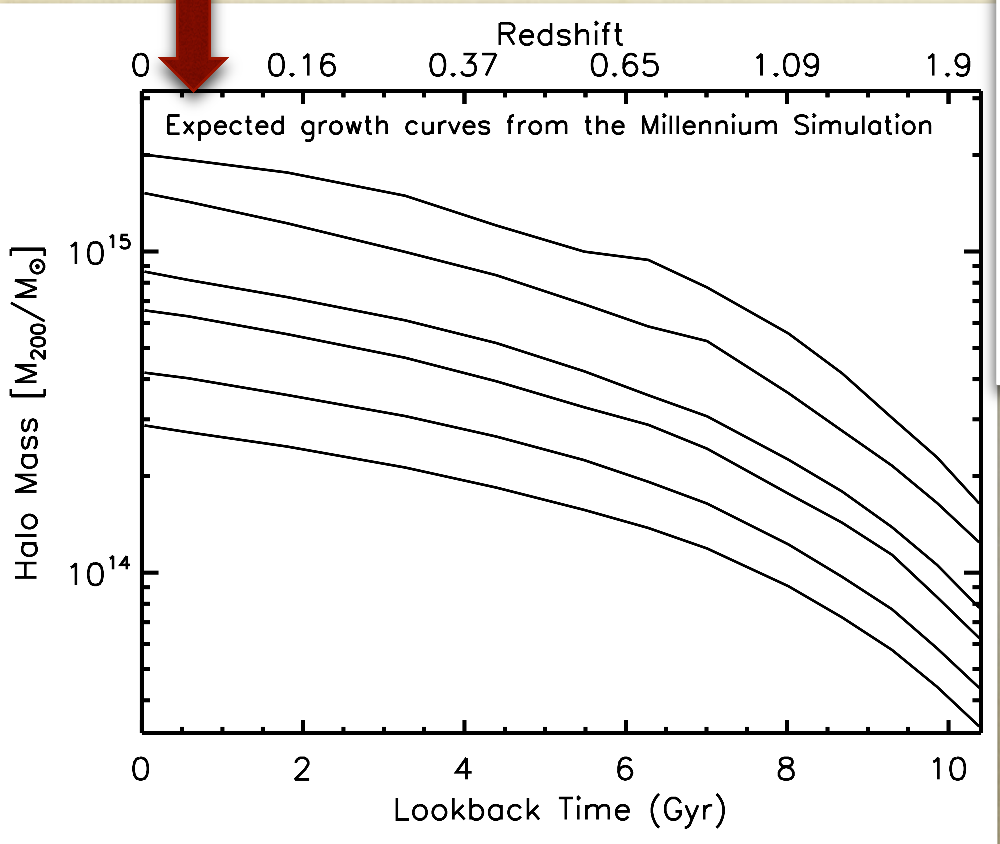
*Navarro, Frenk, White (1997)

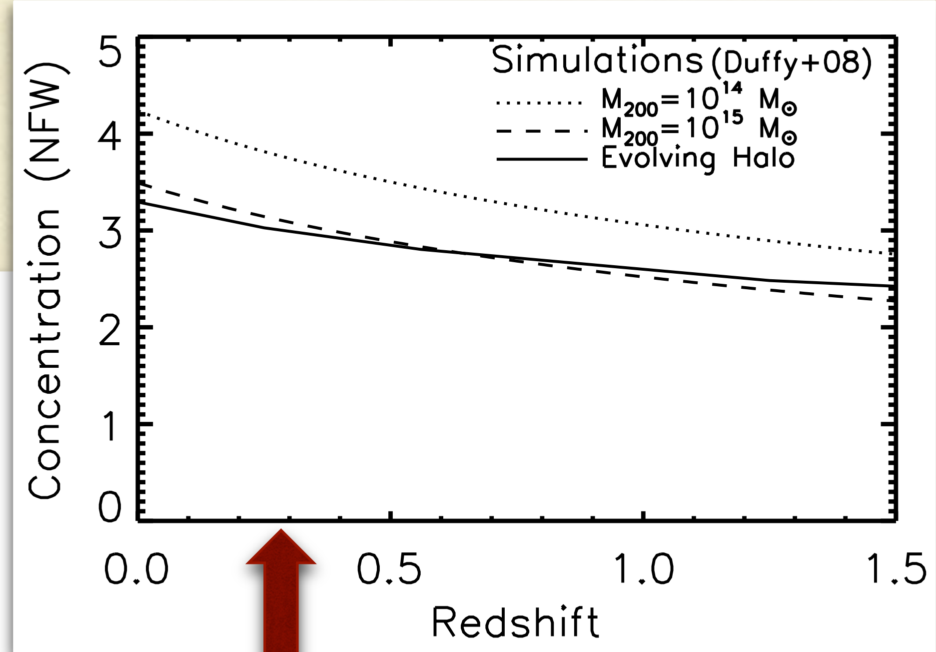


- R_{200}: Radius at which the average density inside is 200 times the critical density. M_{200}: enclosed mass within this sphere
- Concentration: $c = \frac{R_{200}}{R_s}$

Mass and Concentration of Dark Matter Haloes evolve with Redshift

Mass increase factor ~10 since z=2





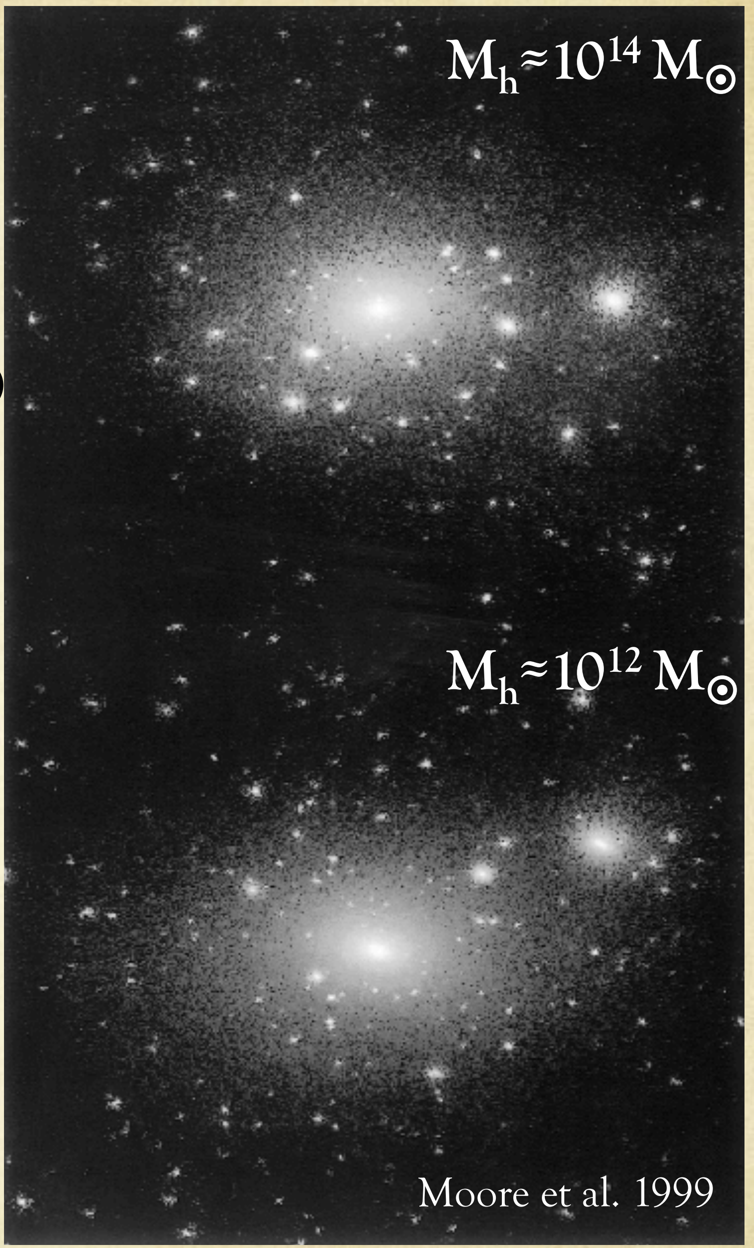
N-body simulations:
c~3 in this regime

Presence of Baryons can alter Distribution of Dark Matter

- Important for *accurate* cosmology with clusters (van Daalen+10, Cusworth+13)
- Baryons can cool and form stars
- Stellar/AGN feedback

New check/constraint for forthcoming large hydrodynamical simulations:

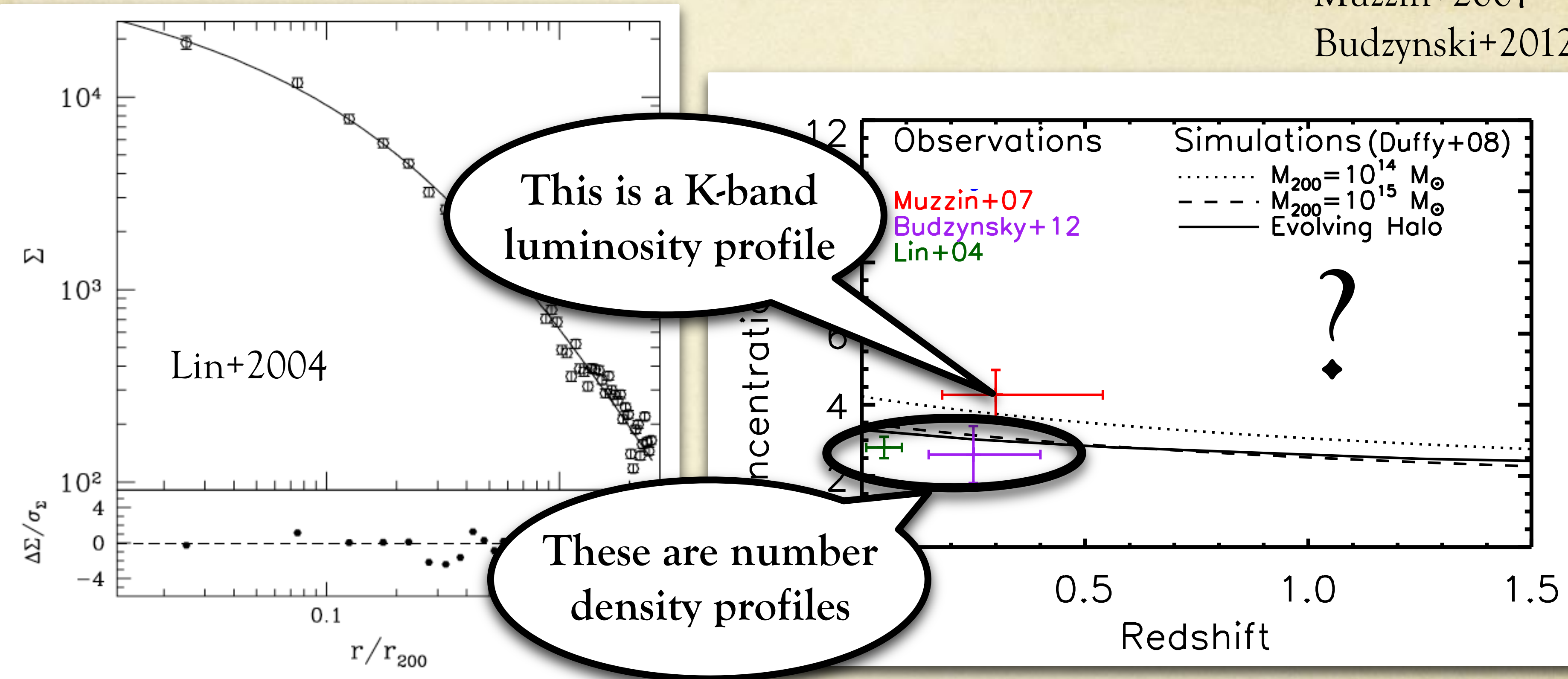
What is the radial distribution of stellar mass in high mass haloes?



Observed Stellar Mass Distributions

- Stellar Matter also well described by NFW profile

Lin+2004
Muzzin+2007
Budzynski+2012



- Concentration of stars (*observations*) is consistent with the concentration of the dark matter in similar haloes (*simulations*)

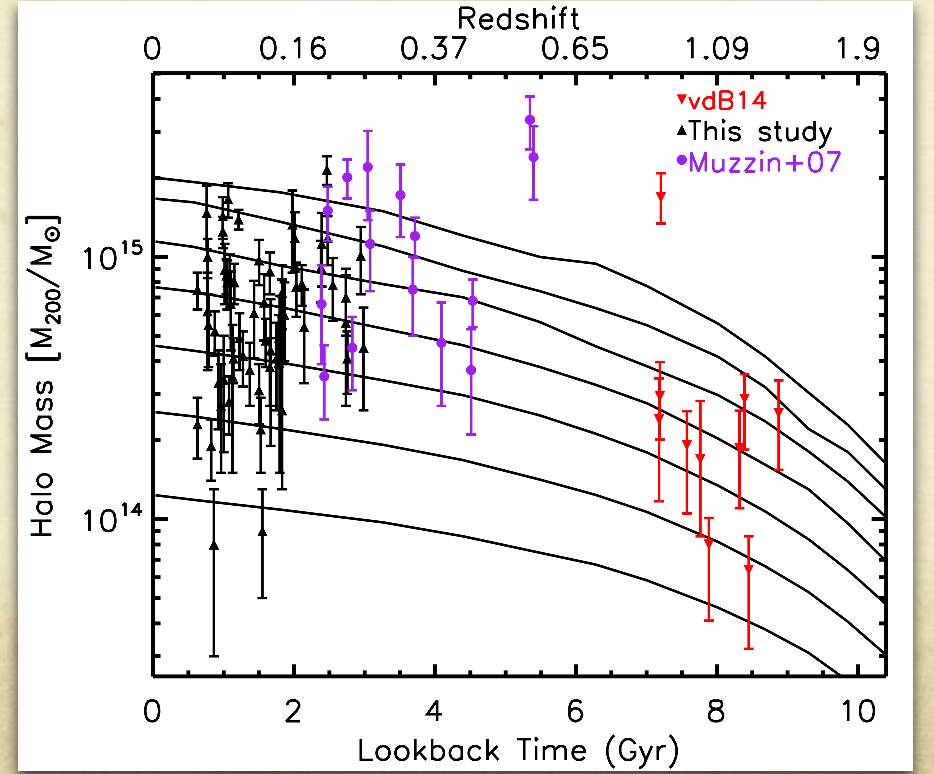
Different studies not homogeneous + unknown what happens at high *z*

Two Galaxy Cluster Samples

- 60 clusters at $0.05 < z < 0.26$
  - Canadian-Cluster-Comparison Project
  - Multi-Epoch Nearby Cluster Survey
- *ugri*-band photometry
- ~10,000 spectroscopic members (Sifón+2015)

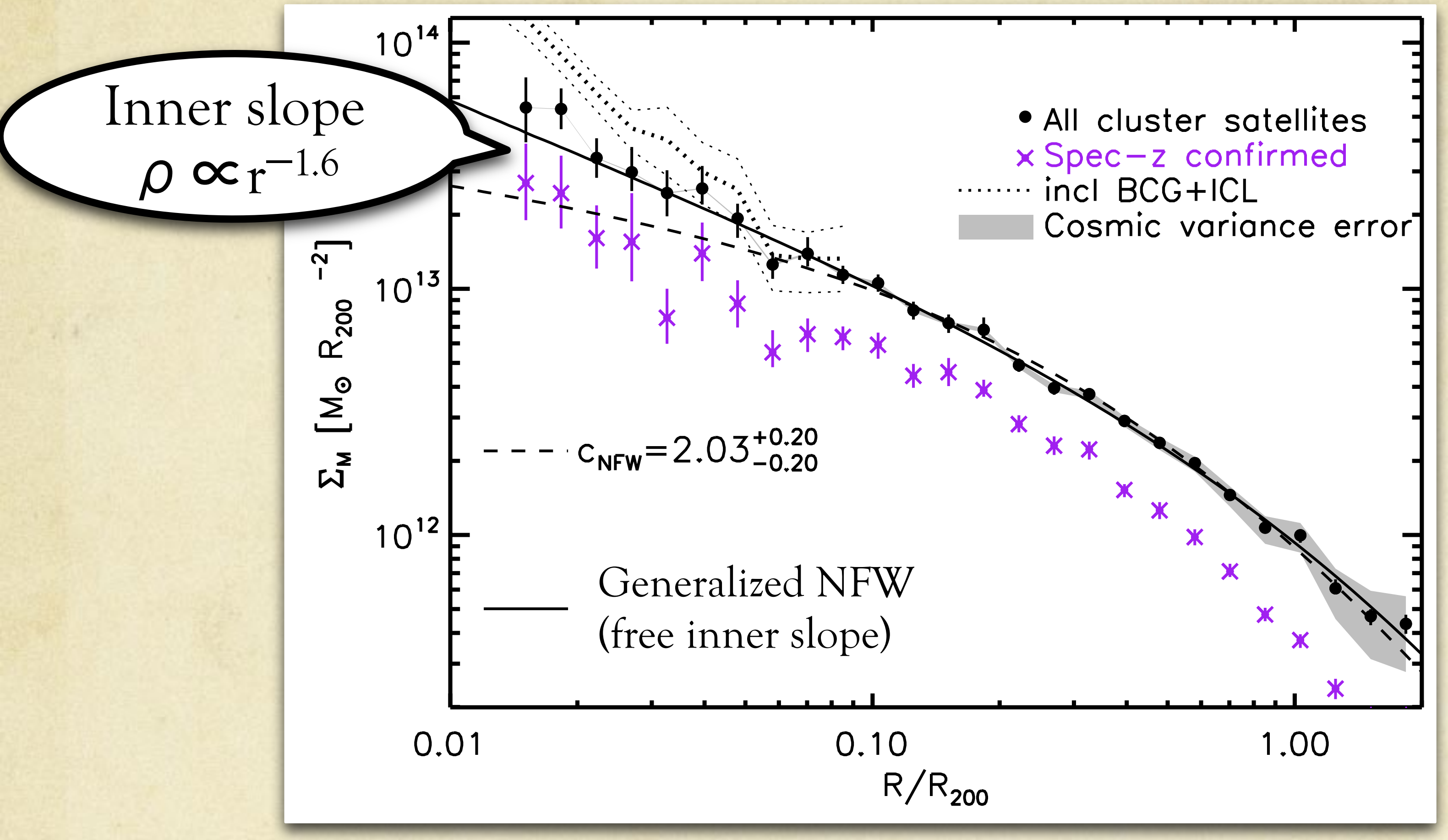
- 10 clusters at $0.86 < z < 1.34$ from 42 deg^2 SpARCS/SWIRE survey
  - Gemini CLuster Astrophysics Spectroscopic Survey (GCLASS) (Muzzin+2012)
- *ugriz*JKs + 4IRAC band photometry
- 457 spectroscopic members

vdBurg+15 (1412.2137)



vdBurg+13 (1304.5525)
vdBurg+14 (1310.0020)

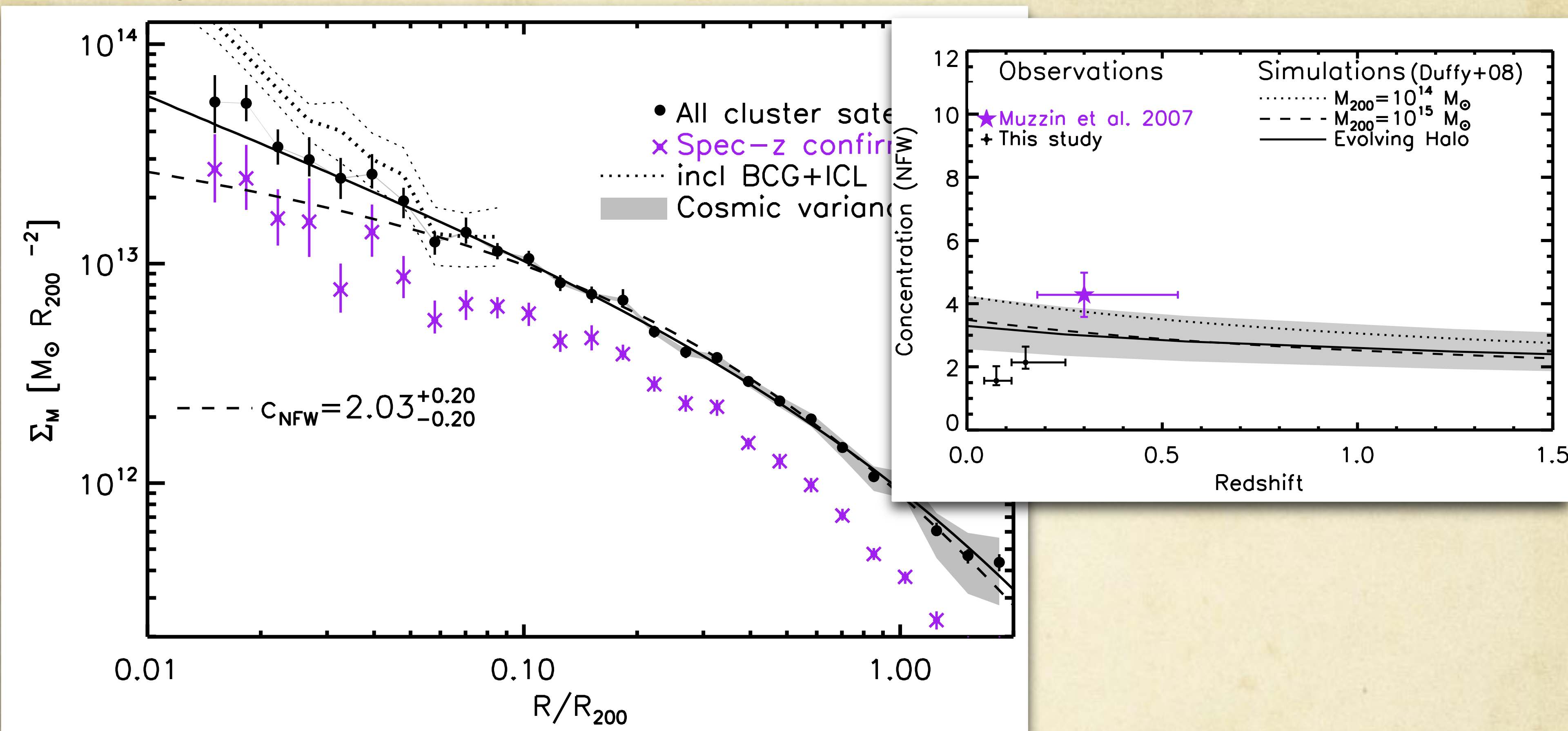
z≈0.15 Stellar Mass Distribution



vdBurg+15 (1412.2137)

- NFW profile (c≈2) fits ensemble distribution for radii $R > 0.10\ R_{200}$
- Significant excess in the centre, $\approx 10^{11}\ M_\odot$ per cluster
  - No dependence on: redshift, halo mass, BCG stellar mass, cluster central entropy, richness

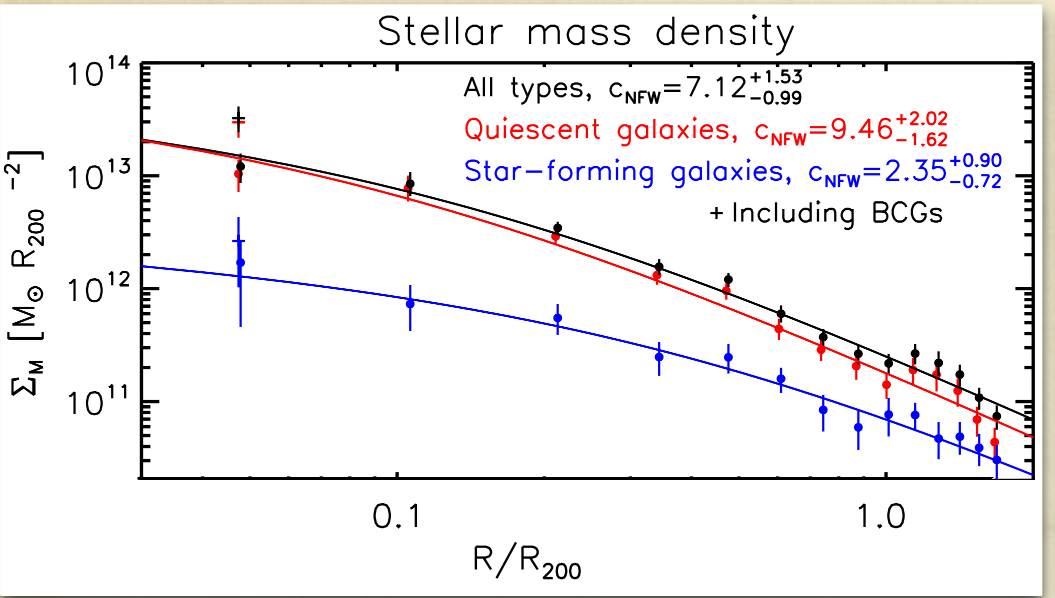
$z \approx 0.15$ Stellar Mass Distribution

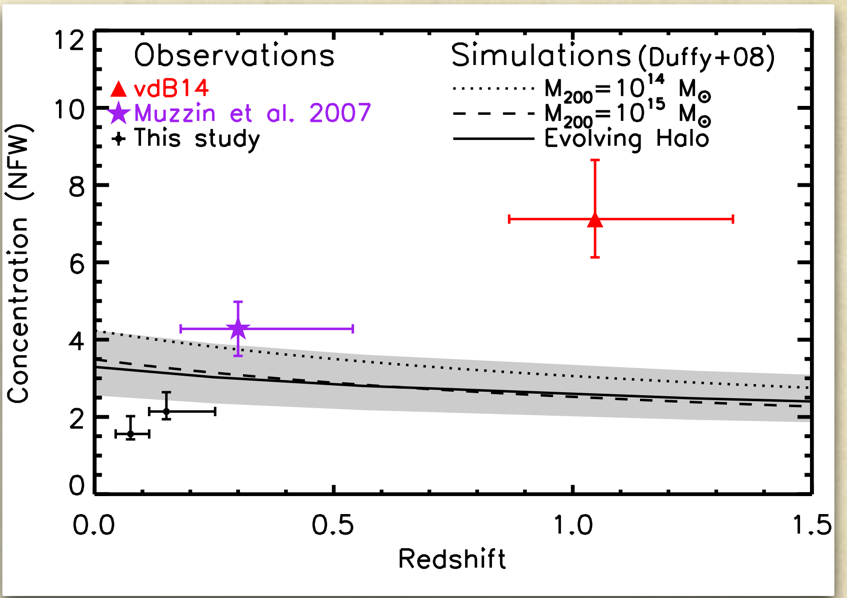


- NFW profile (c≈2) fits ensemble distribution for radii $R > 0.10\ R_{200}$
- Reasonable agreement with dark matter distribution (N-body simulations)

z≈1 Stellar Mass Distribution

vdBurg+14 (ArXiv:1310.0020)

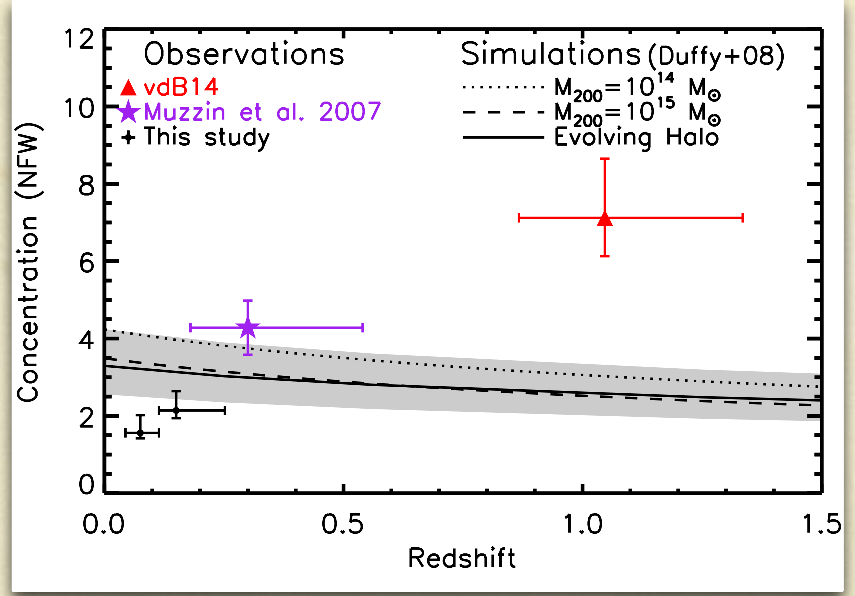




- Well fitted by NFW profile with concentration parameter c≈7
- Stellar Mass at z=1 significantly more concentrated than
  - Dark matter in N-body simulations
  - Likely descendants at lower redshift (z=0.15)

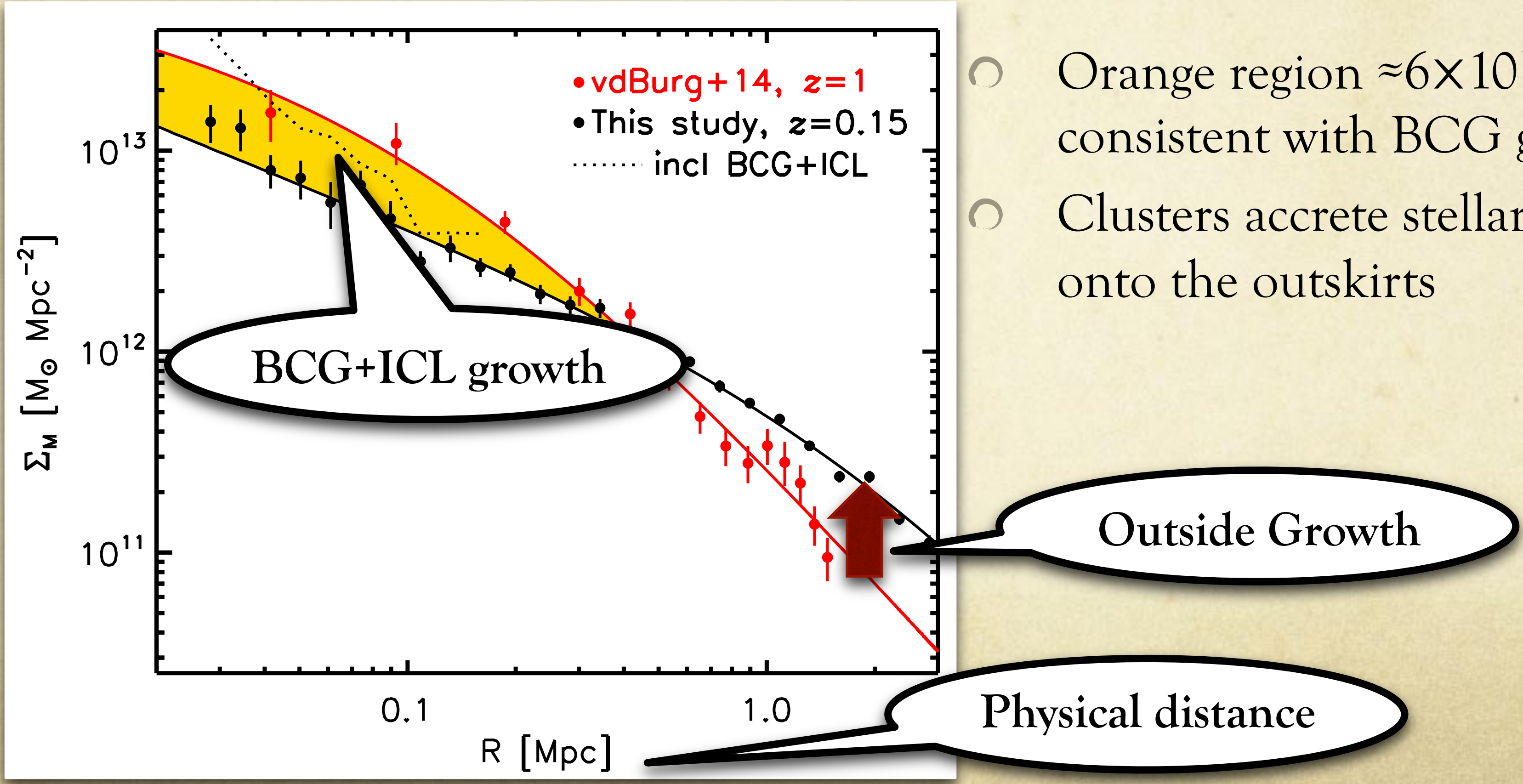
Observed Evolution

- Complications:
  - NFW profile no good fit to low-*z* at small radii
  - Pseudo-evolution complicates interpretation (e.g. Diemer+13, Wetzel+15)



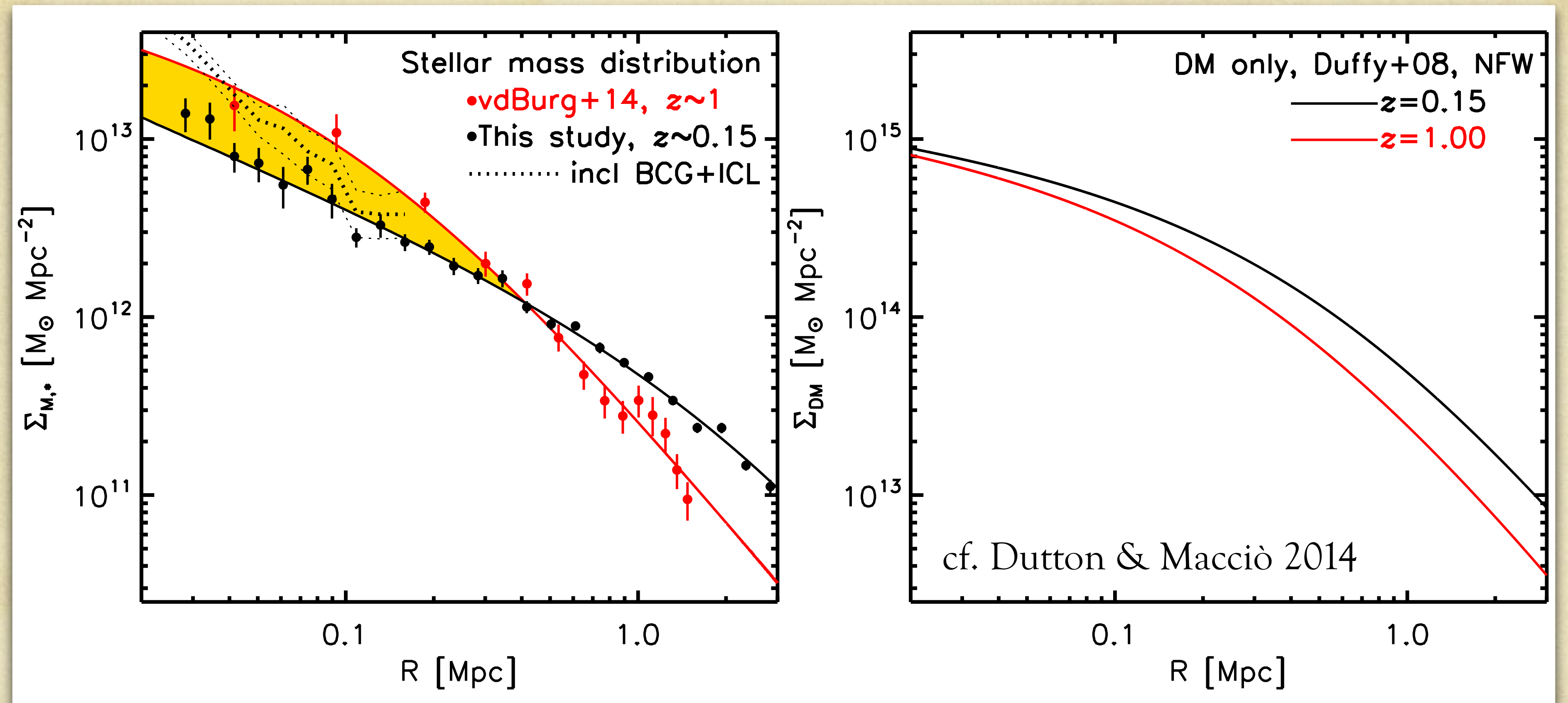
Observed Evolution

- Complications:
  - NFW profile no good fit to low-z at small radii
  - Pseudo-evolution complicates interpretation (e.g. Diemer+13, Wetzel+15)
- Cluster samples are linked progenitors-descendants
  - Compare profiles on the same physical scale



- Orange region ≈6×10^{11} $M_\odot$: consistent with BCG growth
- Clusters accrete stellar mass onto the outskirts

Observed Evolution



- Inner ~400kpc of the stellar mass distribution already present in the centre by z=1
- Different from evolution of dark matter distribution in N-body simulations

Outlook- Simulations

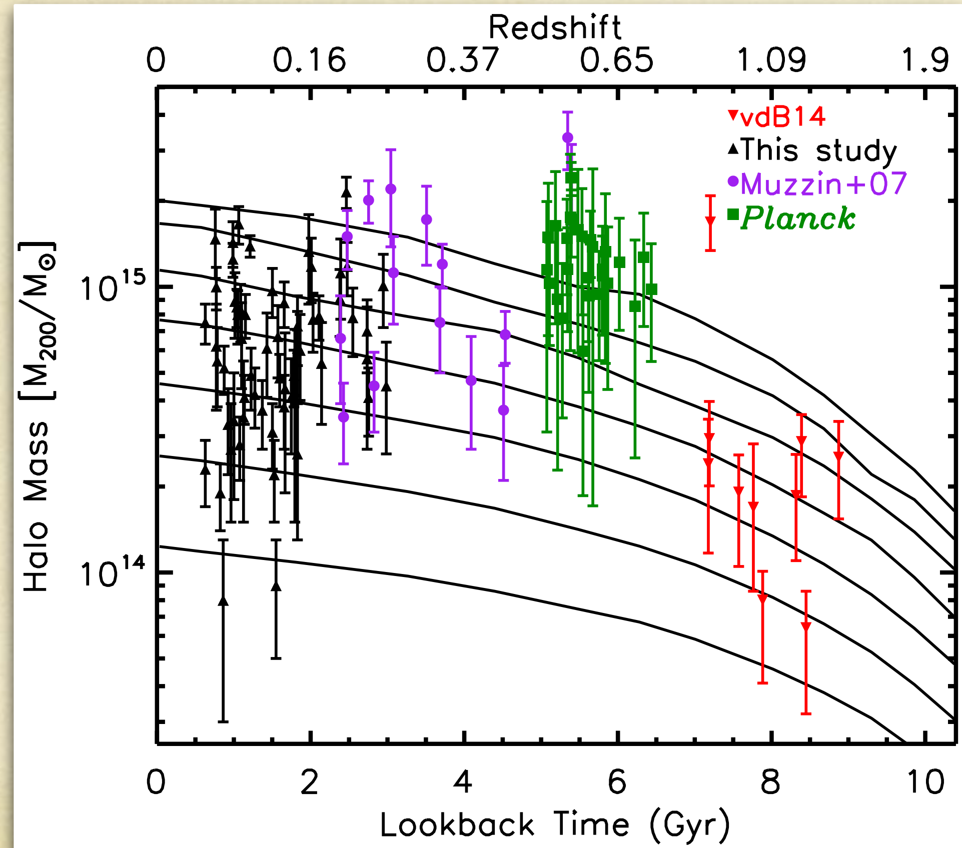
- So far simulations with only dark matter
- Sub-haloes get destroyed near the centre (Nagai+05)
  - Test semi-analytic models (sub-halo abundance matching)
  - Test recipes for tidal stripping/dynamical friction

(In collaboration with Ian McCarthy, Sean McGee, Amandine Le Brun)

- Compare with hydro-dynamical simulations
  - Cosmo-OWLS (Le Brun+14)
  - The BAHAMAS project (McCarthy+16)

Outlook- Observations

- So far limited sample at high-*z* (10 systems)
- Now studying 22 of the most massive clusters at 0.5<*z*<0.7, selected based on Sunyaev-Zel'dovich effect with Planck

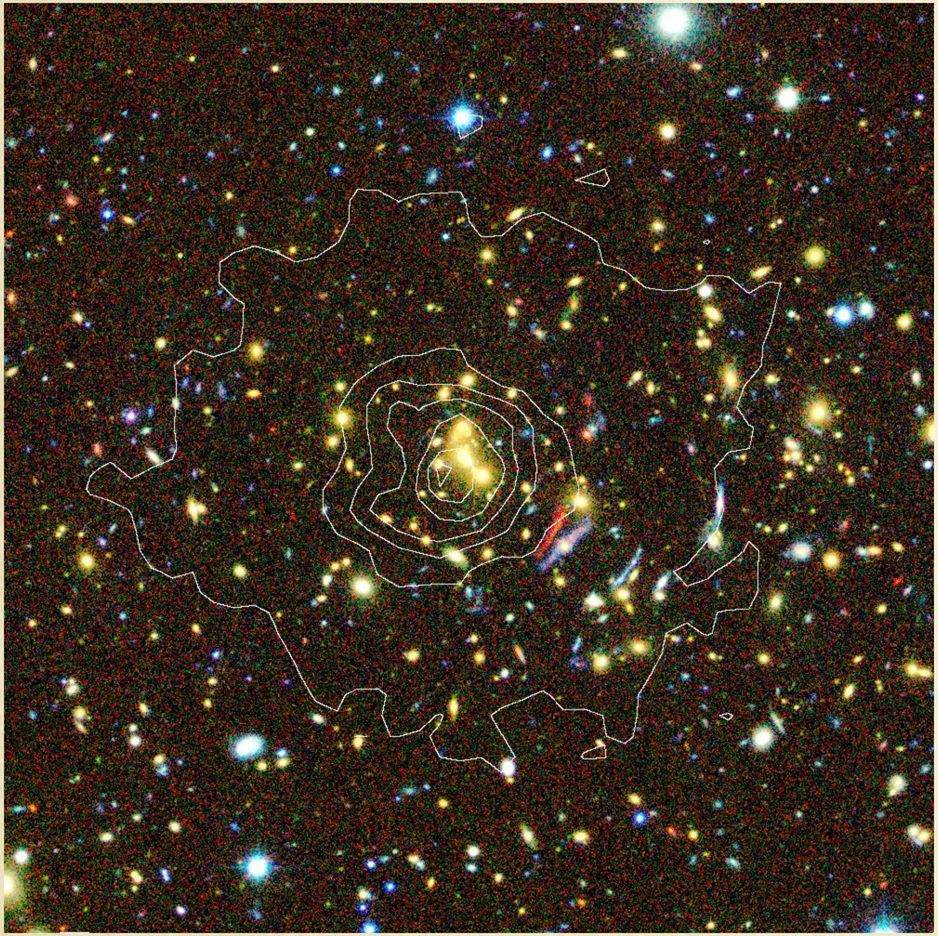


- 7 band photometric data
  - Photo-z's and stellar masses
- Deep XMM+Chandra data to probe the hot gas
- Still accessible for ground-based weak lensing
- Deeper SZ follow-up with NIKA2@IRAM

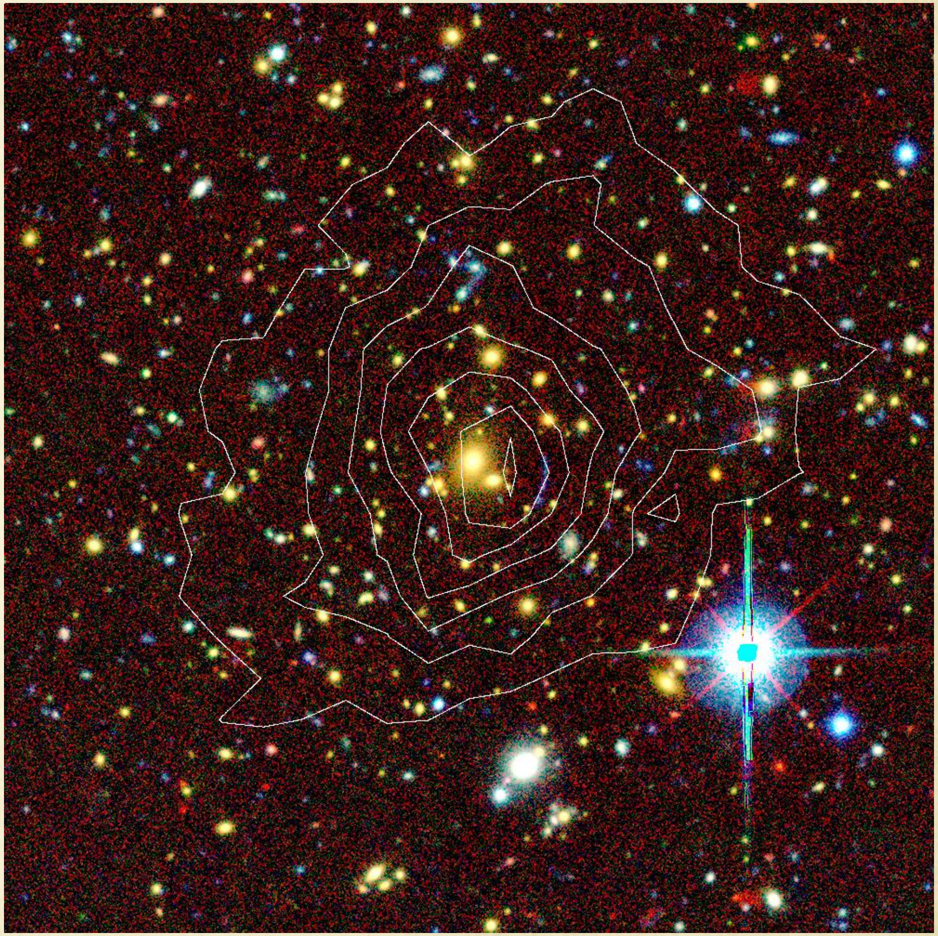
With Monique Arnaud, Hervé Aussel, Gabriel Pratt, Jean-Baptiste Melin, Håkon Dahle, Amandine Le Brun, Jessica Démoclès, Iacopo Bartalucci, …

Outlook

A full census of baryons in *Planck*-selected clusters at $0.5<z<0.7$



PLCKG73.3+67.5, z=0.61



PLCKG99.9+58.4, z=0.62

With Monique Arnaud, Hervé Aussel, Gabriel Pratt, Jean-Baptiste Melin,
Håkon Dahle, Amandine Le Brun, Jessica Démoclès, Iacopo Bartalucci, ...

The abundance and spatial distribution of ultra-diffuse galaxies in nearby galaxy clusters

vdBurg+16b, A&A, 590, A20 (ArXiv:1602.00002)

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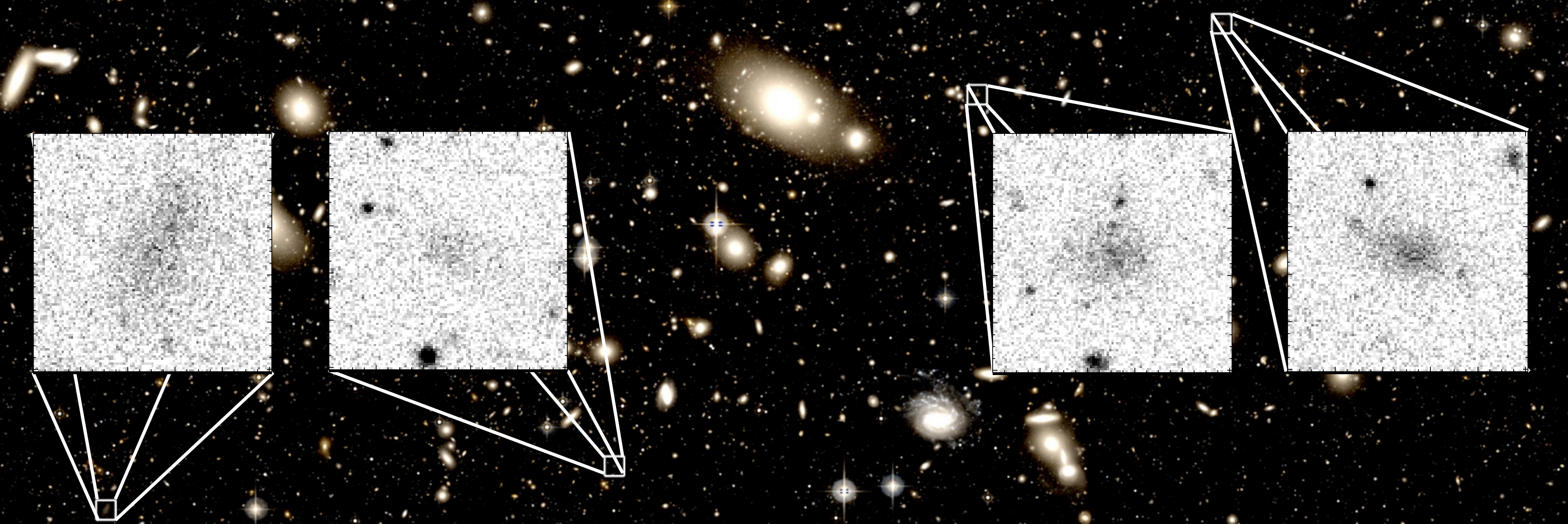

Also see van Dokkum+15, Mihos+15

Conclusions

An observational study of the build-up of stellar mass in galaxy clusters by combining samples which are progenitors/descendants:

- Comparison on the same physical scale indicates inside-out growth of the stellar mass distribution since $z=1$
  - Stellar material is already present in the centre (R < 0.4 Mpc)
  - Significant growth onto the outskirts

vdBurg+15

- Now studying an SZ-selected sample of the most massive galaxy clusters at $0.5<z<0.7$
  - Ideal for comparison with simulations
  - Comparing with X-ray studies, deep SZ follow-up, lensing measurements