Brightest Group and Cluster Galaxies as Probes of Galaxy Evolution

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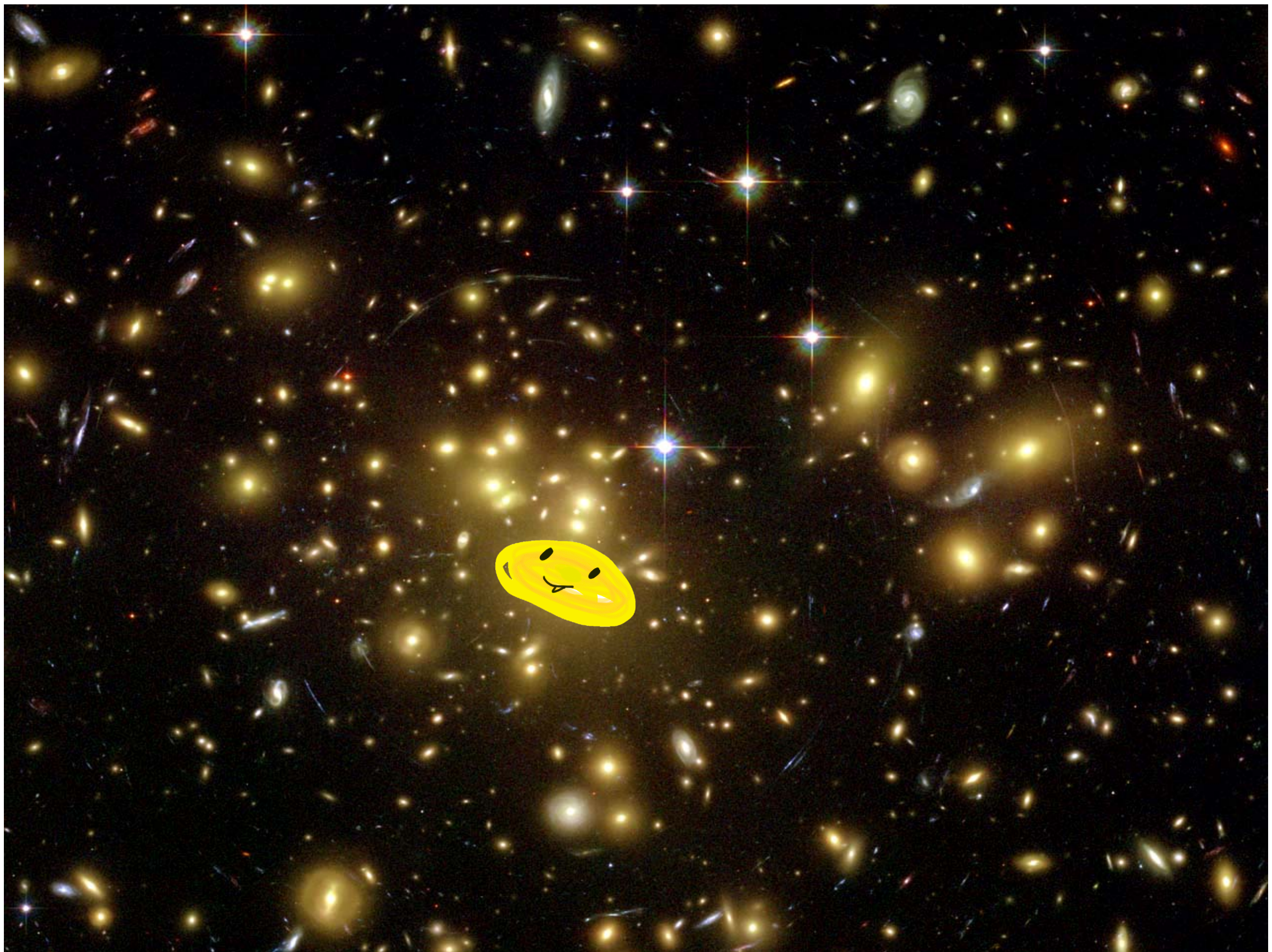
Outline

- Introduction
- Stellar mass growth of Brightest Group and Cluster Galaxies.
- Accretion Histories of Brightest Cluster Galaxies.
- Summary
- Upcoming research

Galaxy Groups and Clusters

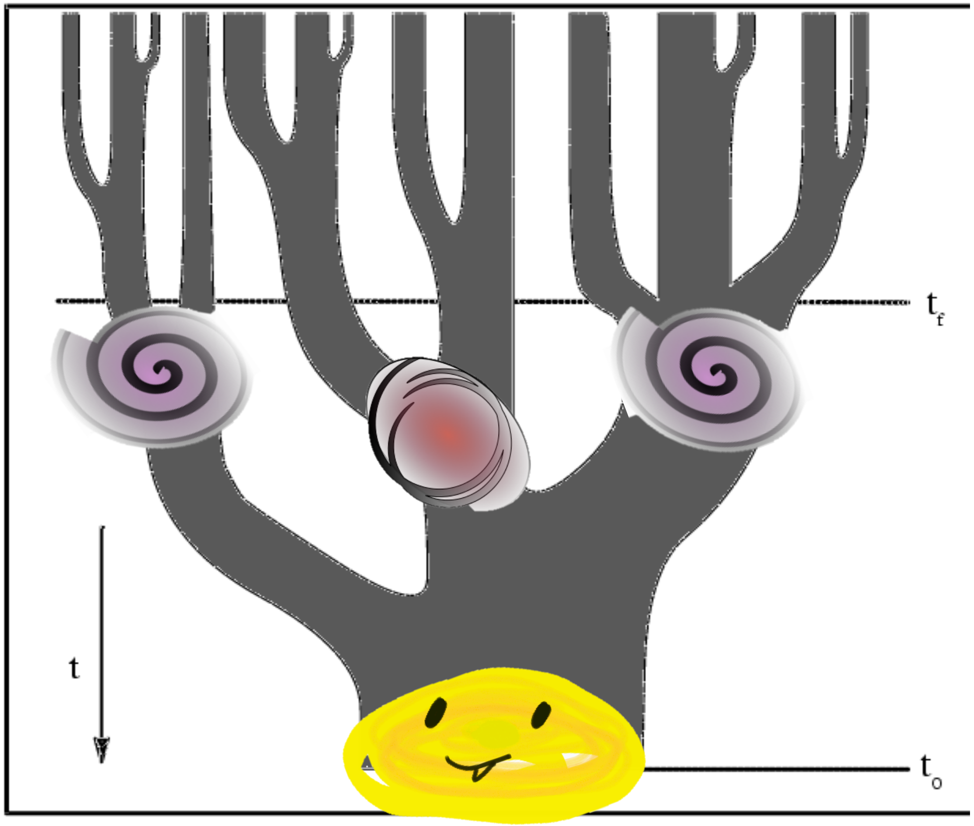


Abell 1689

Brightest Group and Cluster Galaxies (BGG/BCG)

- Giant early-type galaxy
- Centrally located
- Brightest and most massive
- Higher velocity dispersions than normal ellipiticals

Hierarchical structure formation model



Lacey & Cole (1993)

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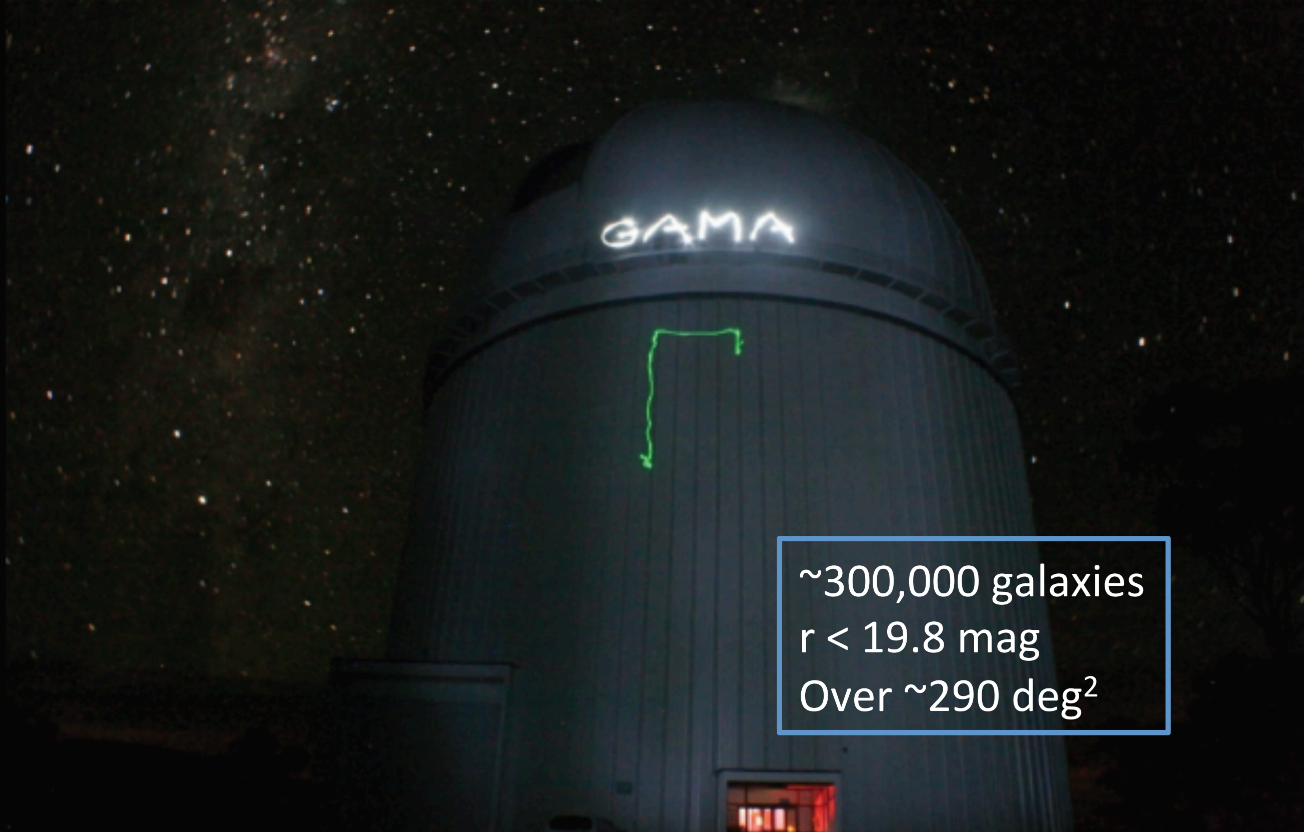
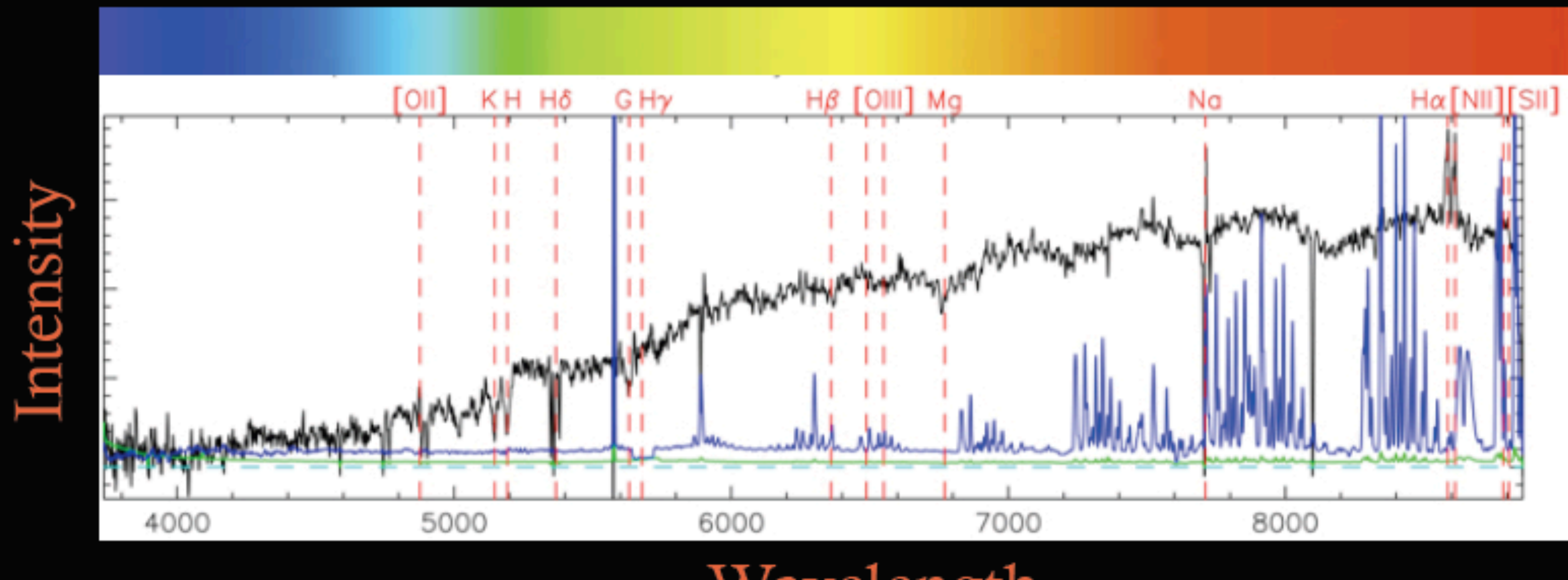
Galaxy And Mass Assembly

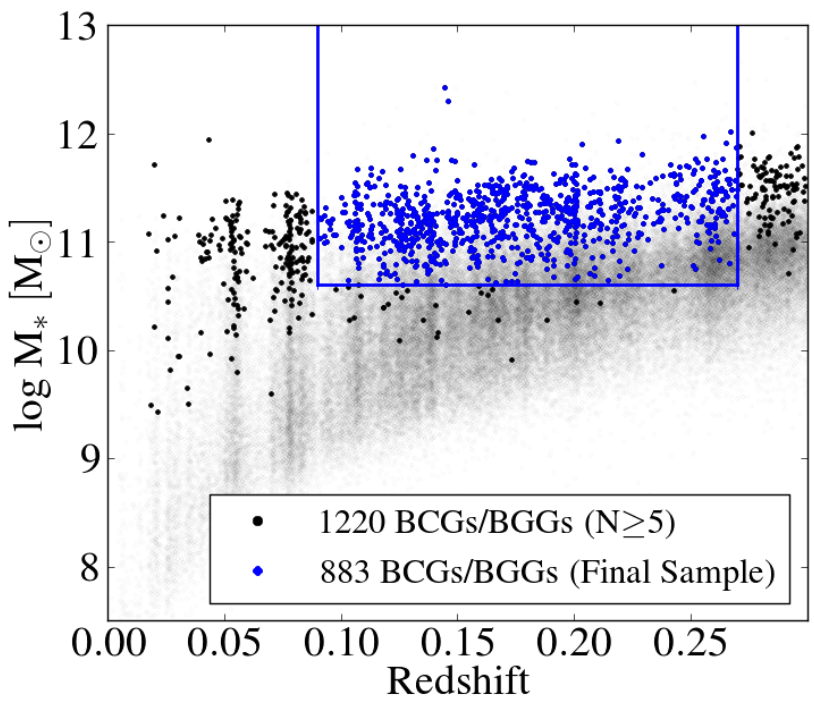


~300,000 galaxies
r < 19.8 mag
Over ~290 deg^2



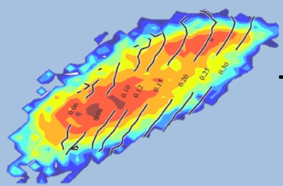
Sample:

883 BGGs/BCGs at z<0.3
in halos
$10^{12.5}M_{sun}<M_{halo}<10^{15}M_{sun}$
from
the Galaxy And Mass Assembly survey
(GAMA, Driver et al. 2011)



GAMA catalogues

Galaxy And Mass Assembly



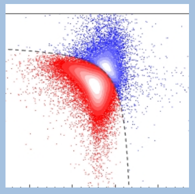
Taylor et al. 2010

Stellar Mass

From Spectral Energy Distribution (SED)

[NII/Hα] and [OIII/Hβ]

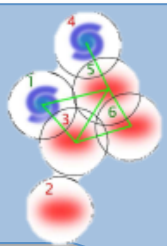
BPT: Kewley et al. (2001)



Gunawardhana et al. 2013

Emission Lines

GAMA catalogues



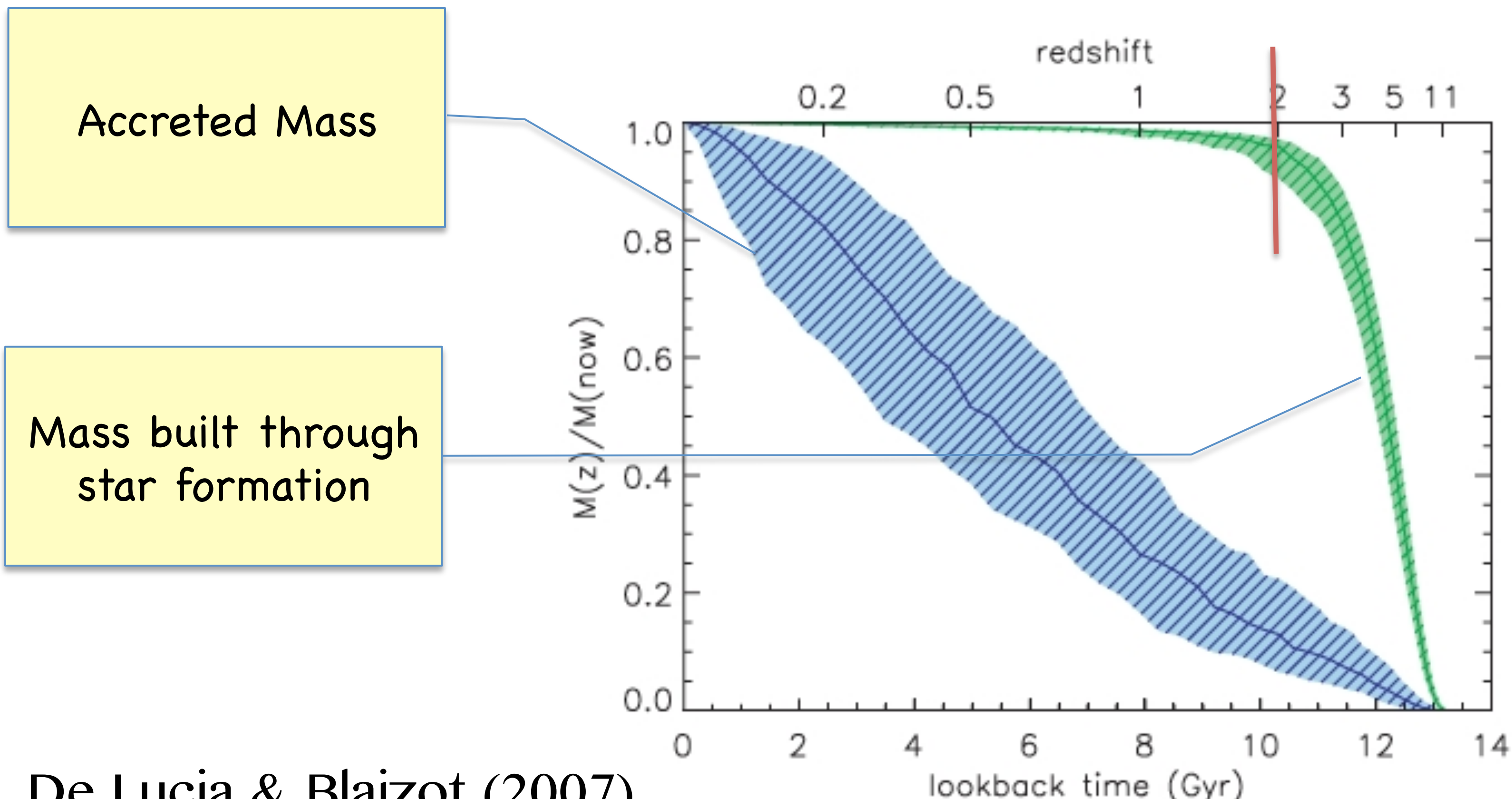
Robotham et al. 2011

Groups and Clusters

Halo Mass and position of the Central galaxy

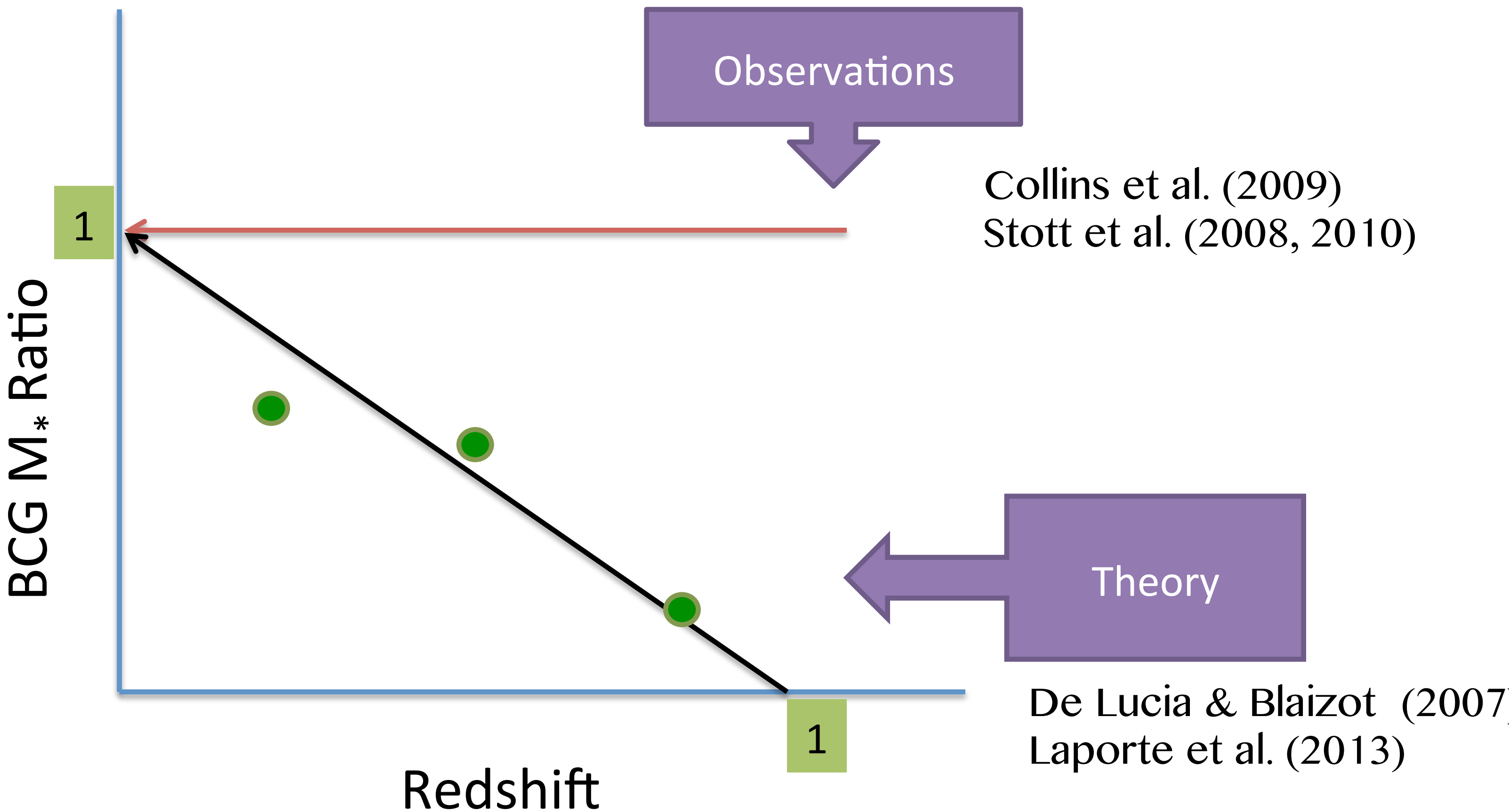
- Groups are selected by an adaptive friends-of-friends algorithm. Tested with mock catalogues.
- $M_{halo} \sim A\sigma_{halo} R_{50}$

Semi-Analytical models predict dry major mergers as the source of growth since z=1



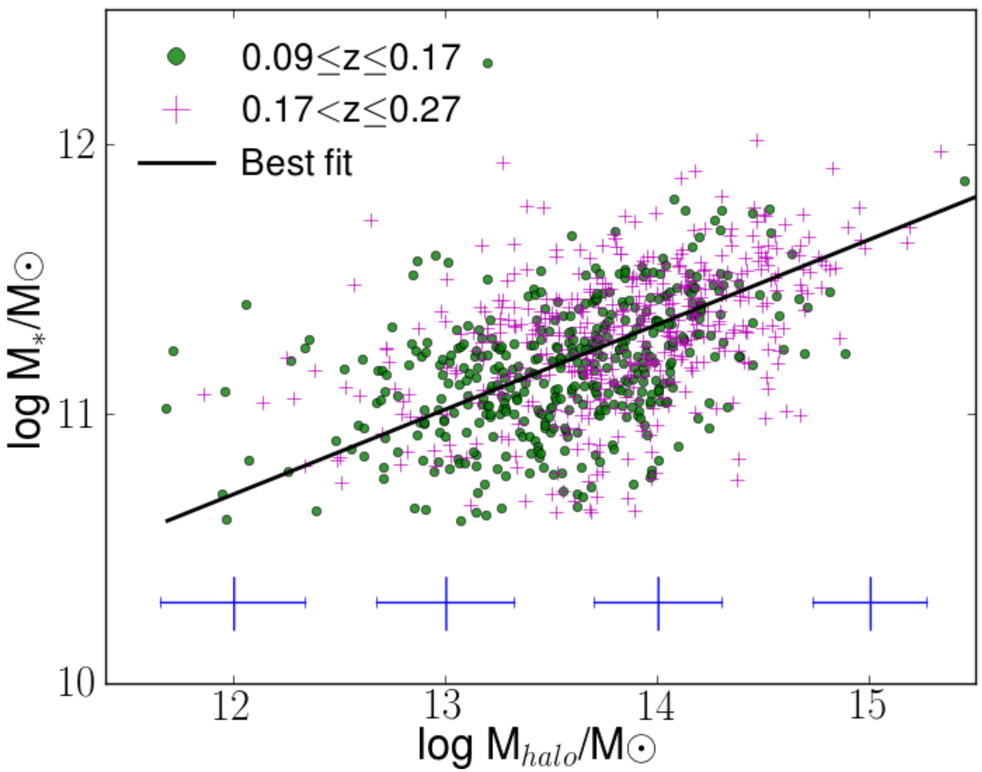
De Lucia & Blaizot (2007)

Thanks to Lidman et al. 2012!



BGG/BCG M_* - M_{halo} relationship

Oliva-Altamirano et. al. (2014)



Slope: 0.32 +/- 0.09

883 BGGs/BCGs

group multiplicity >5

$0.09 < z < 0.27$

Previous work:

Lin & Mohr (2004): $z < 0.09$, ~0.26

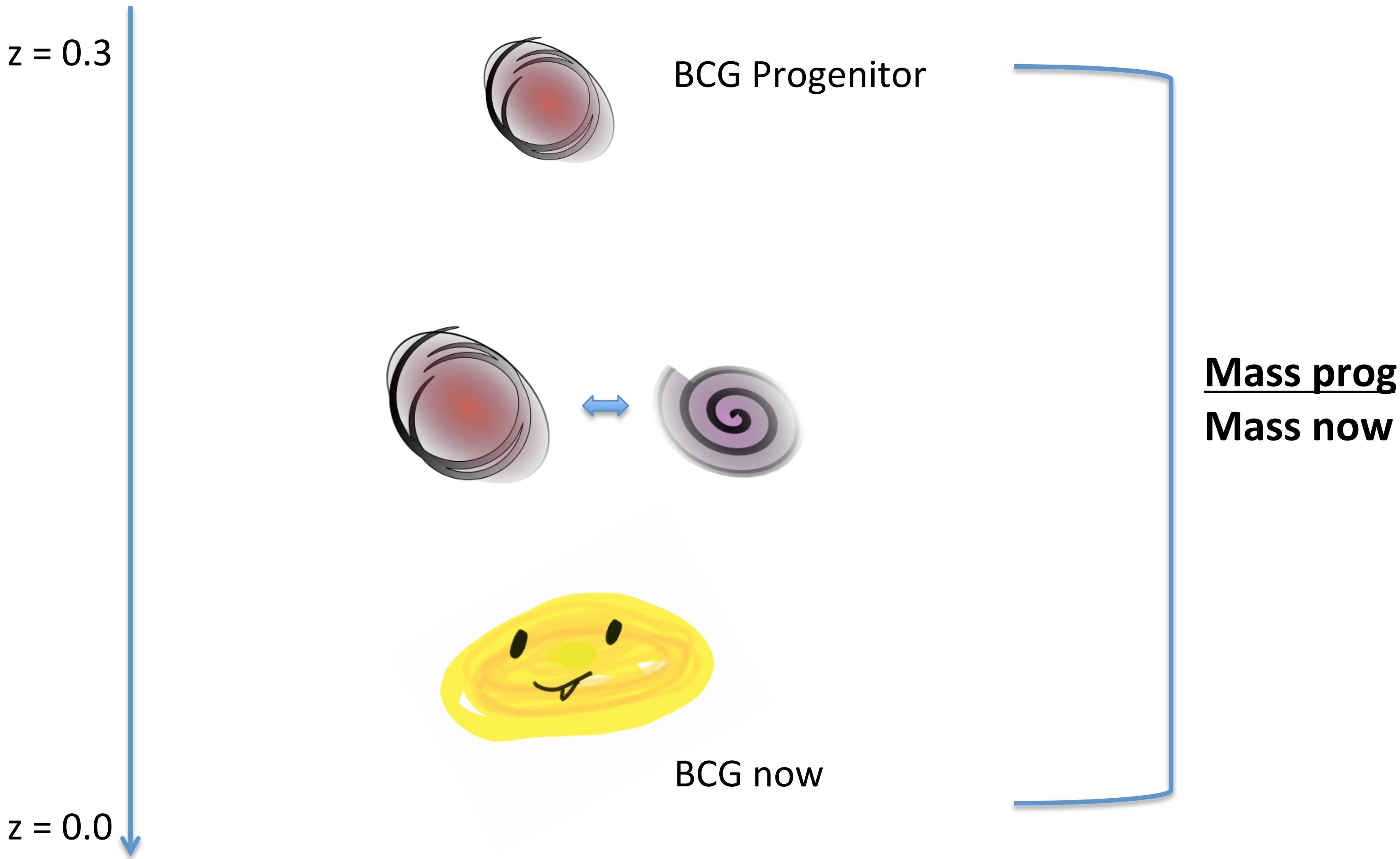
Brough et al. (2008): $z < 0.1$, ~0.24

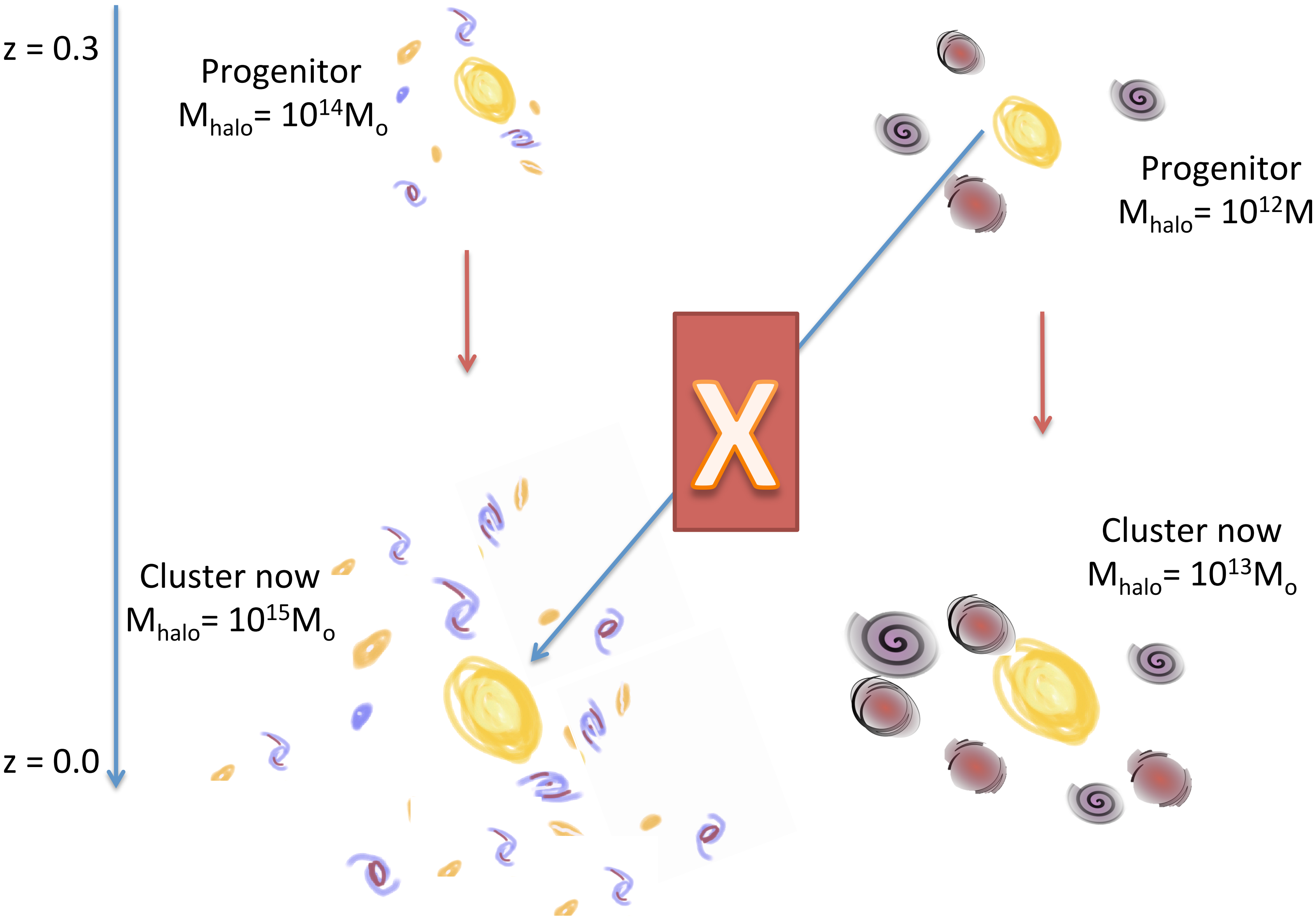
Hansen et al. (2009): $0.1 < z < 0.3$, ~0.3

Lidman et al. (2012): 0.63+/-0.07

$0.05 < z < 1.6$

Measuring the Stellar Mass Growth

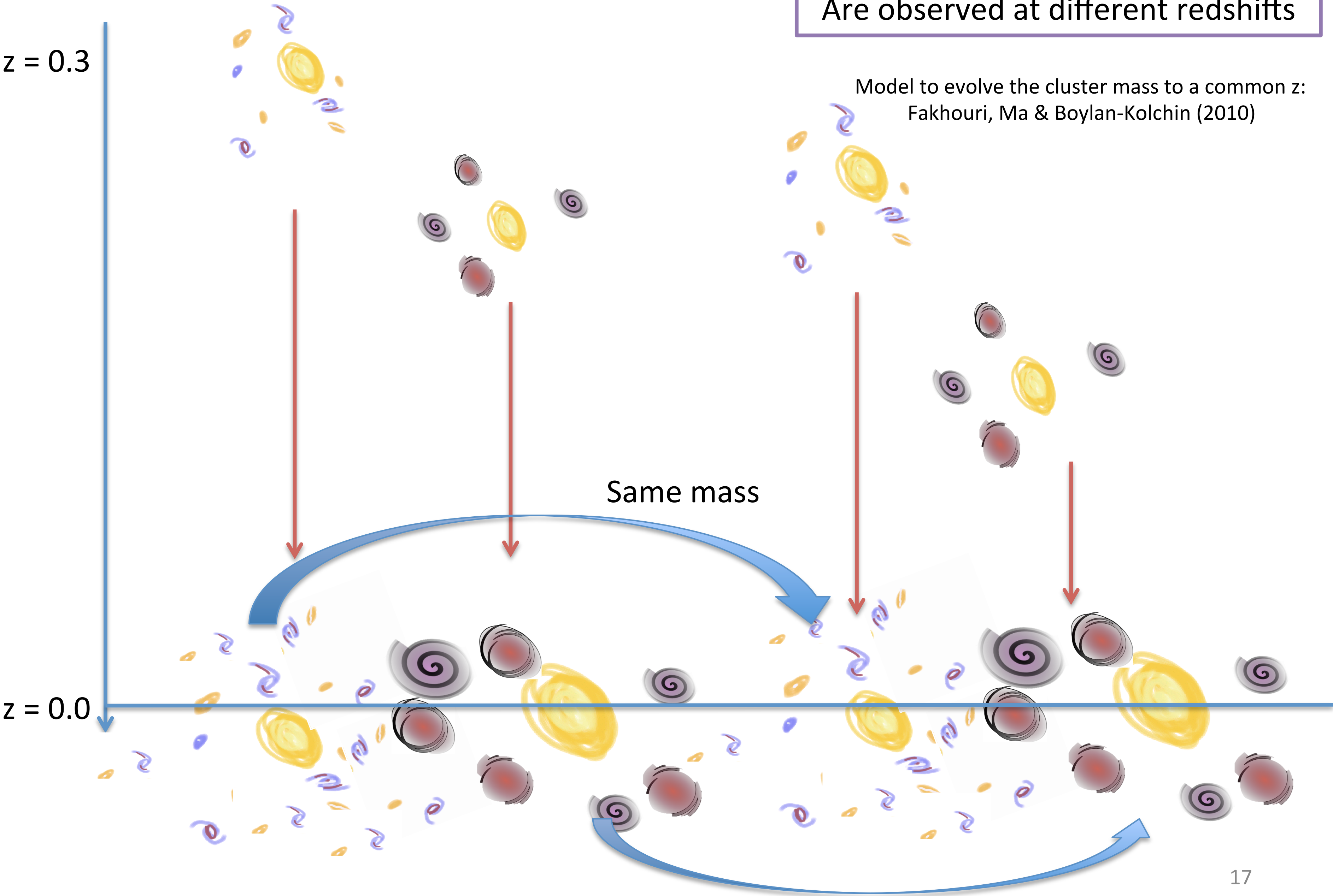




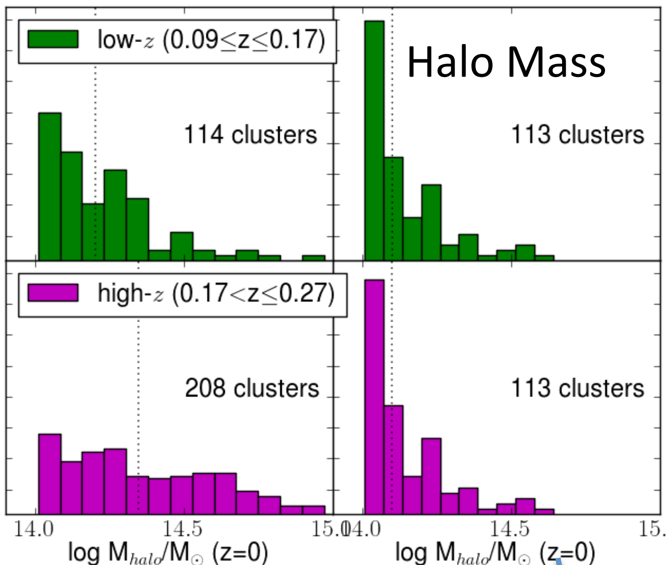
z = 0.3
Progenitor
M_{halo}= $10^{14}M_o$
Progenitor
M_{halo}= $10^{12}M_o$
X
Cluster now
M_{halo}= $10^{13}M_o$
Cluster now
M_{halo}= $10^{15}M_o$
z = 0.0

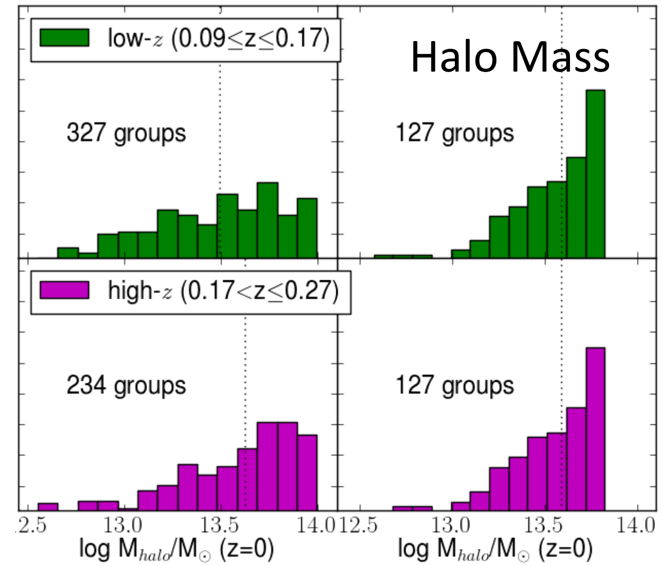
All the clusters!
Are observed at different redshifts

Model to evolve the cluster mass to a common z:
Fakhouri, Ma & Boylan-Kolchin (2010)



In order to make an accurate comparison we select all the halos of similar mass at z = 0

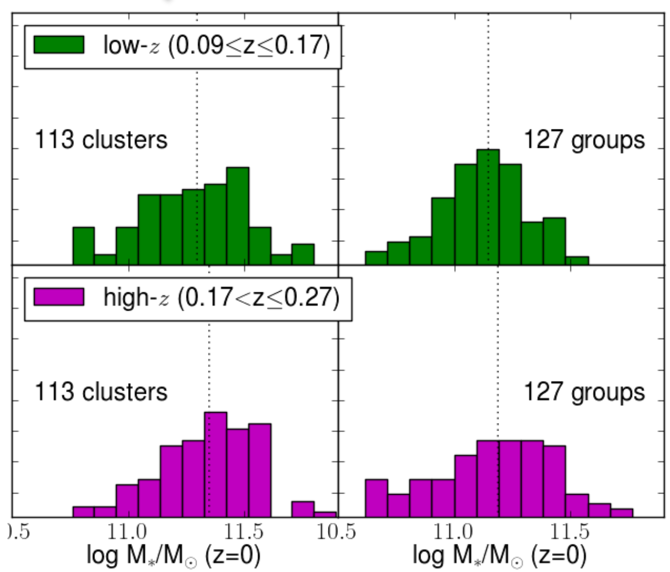




BGG/BCG Stellar Mass

$<M_*> = 10^{11.29} M_o$

$<M_*> = 10^{11.34} M_o$



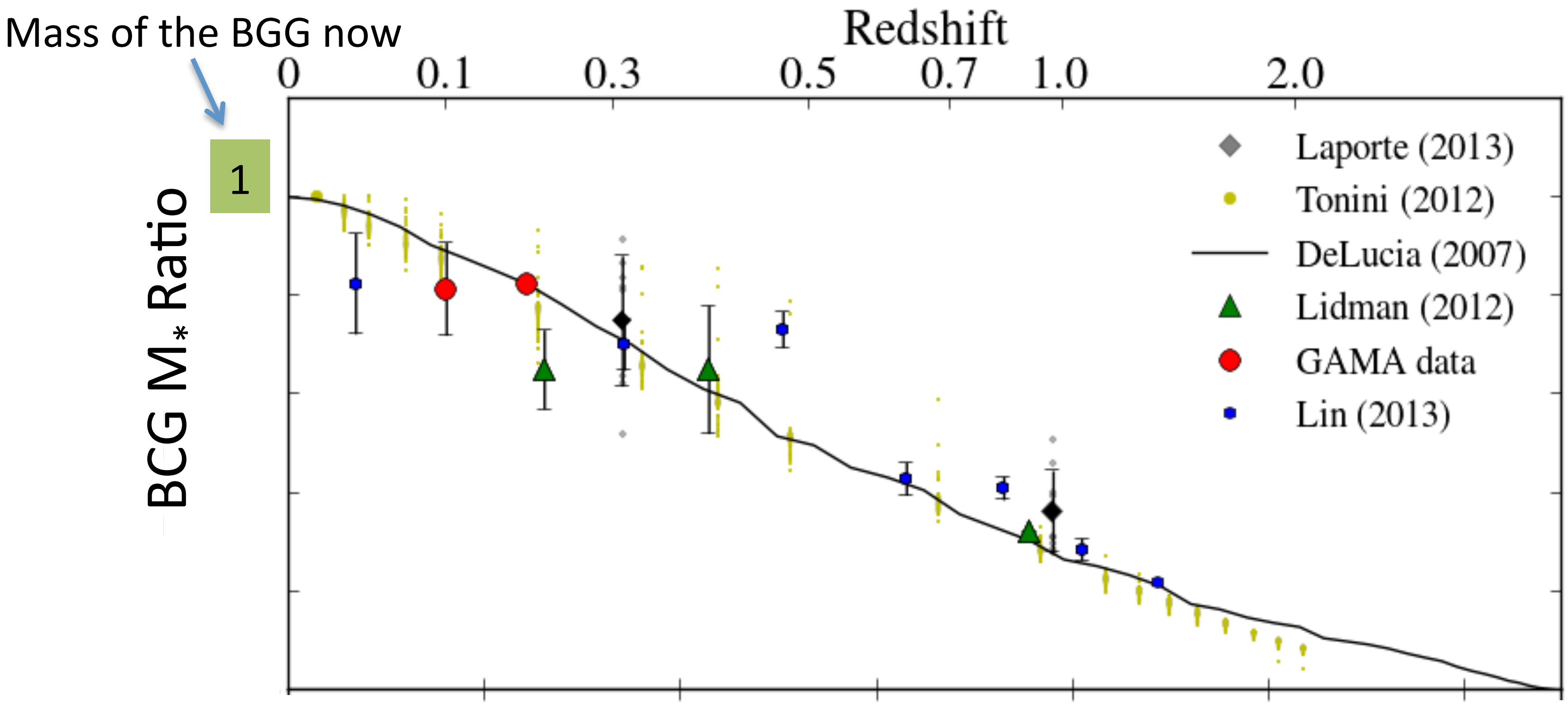
$<M_*> = 10^{11.18} M_o$

$<M_*> = 10^{11.14} M_o$

We find that:
BGGs and BCGs have M_* growth rate in the last 3 billion years is

M_* low-z/M_* high-z
$=0.94 \pm 0.09$

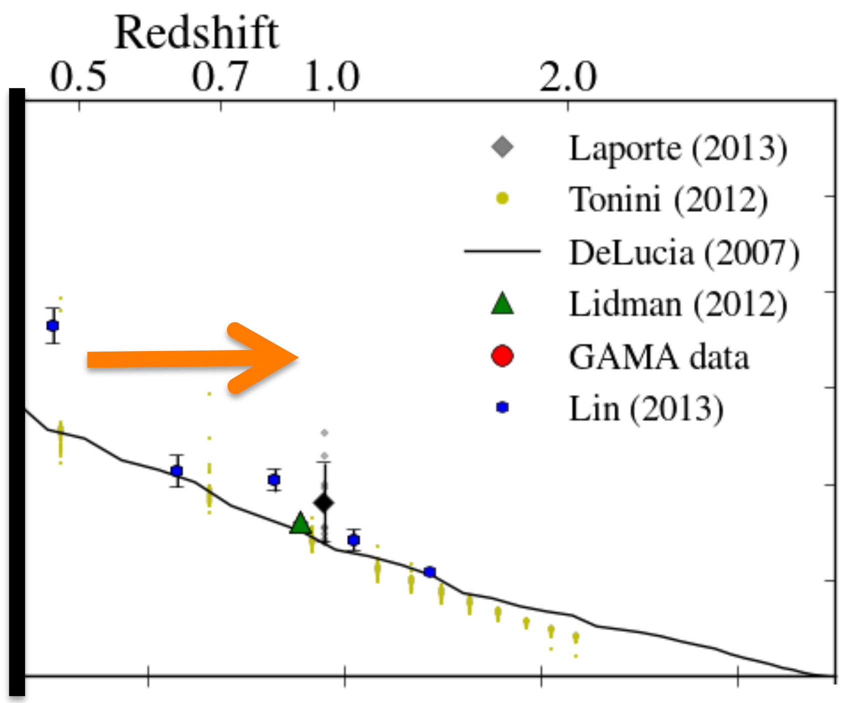
Clusters



Semi-Analytical models

they do not take into account the M_* - M_{halo} relationship

Clusters



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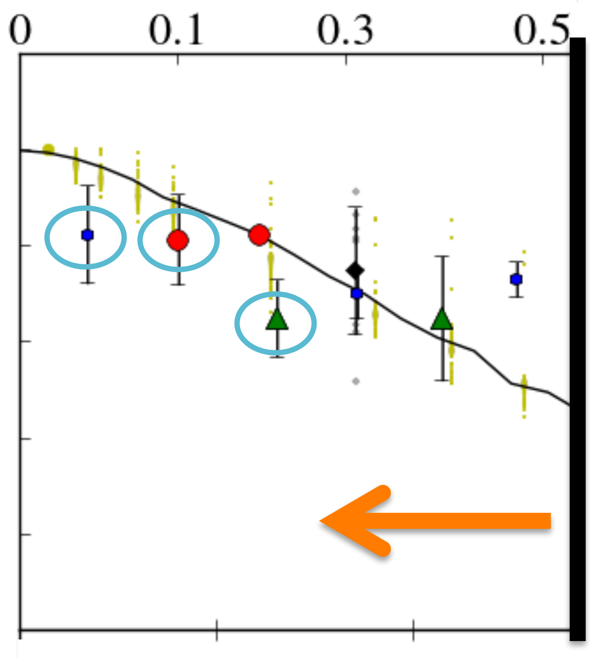
Clusters

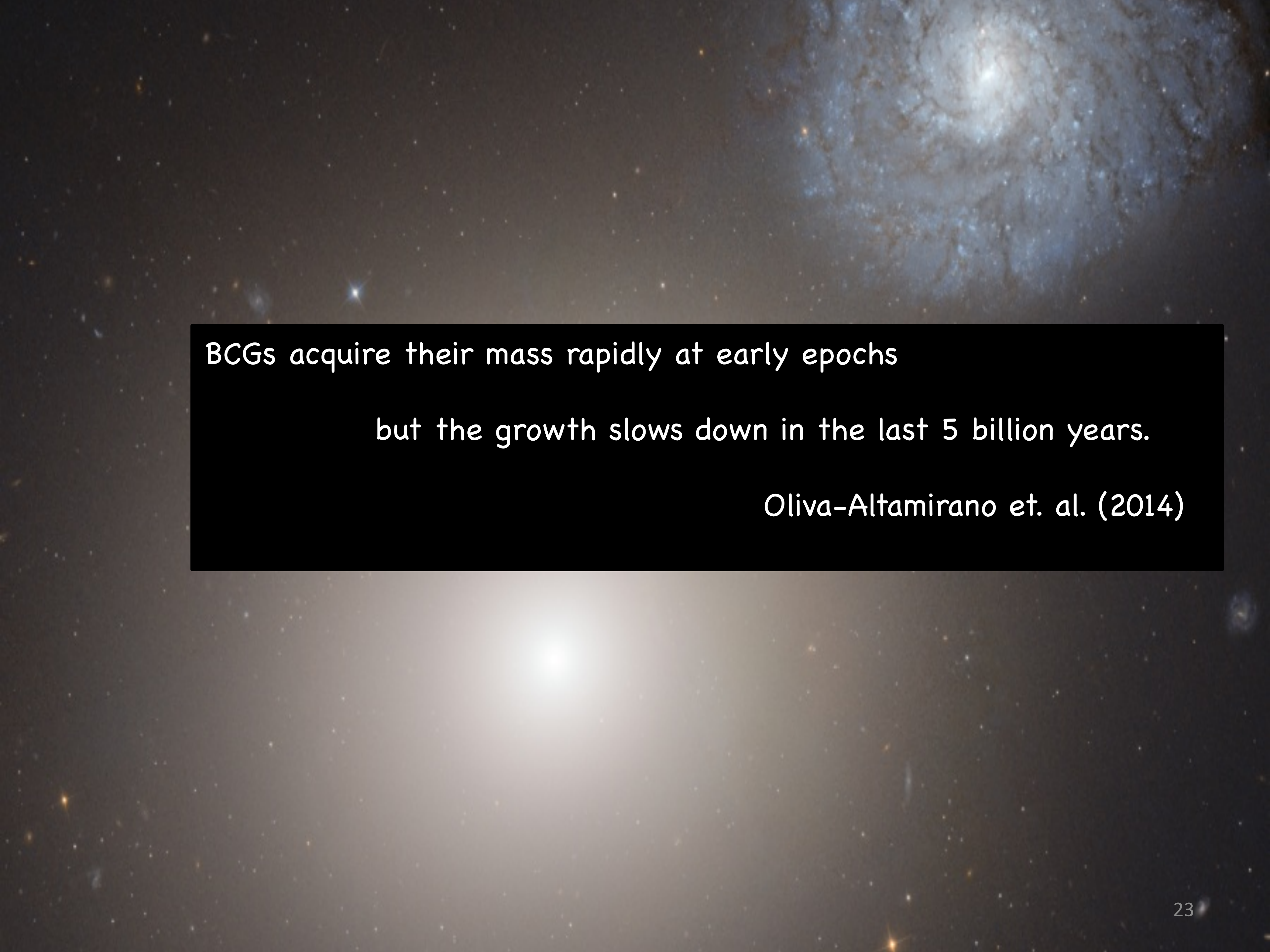


SAMs suggest a 30% growth since z=0.4
Observations suggest a 10% growth since z=0.4

In agreement with Inagaki et. al. (2014) who found a growth of about 10% between z = 0.4 and z = 0.2

Semi-Analytical models

they do not take into account the M_{*} - M_{halo} relationship

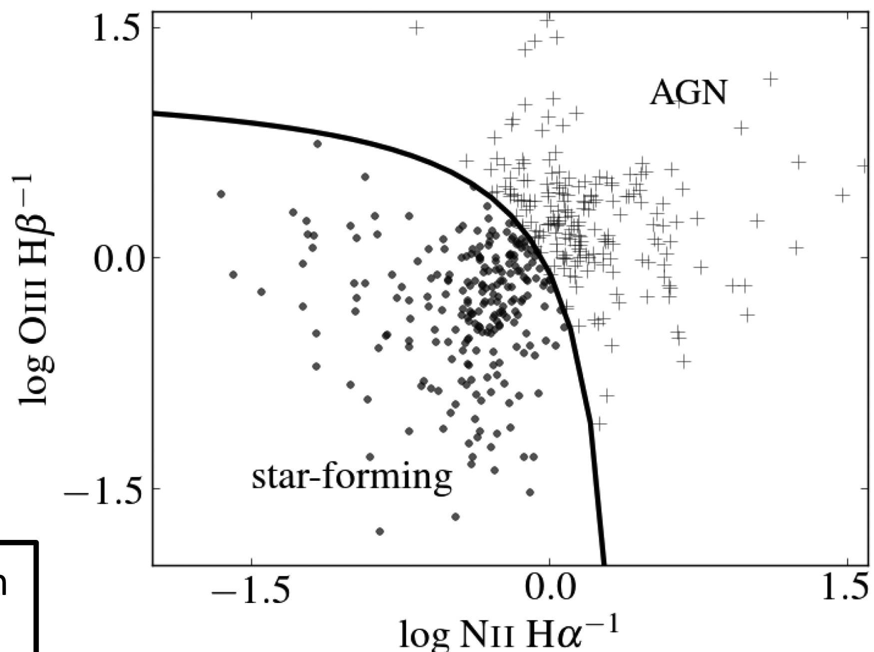


BCGs acquire their mass rapidly at early epochs

but the growth slows down in the last 5 billion years.

Oliva-Altamirano et. al. (2014)

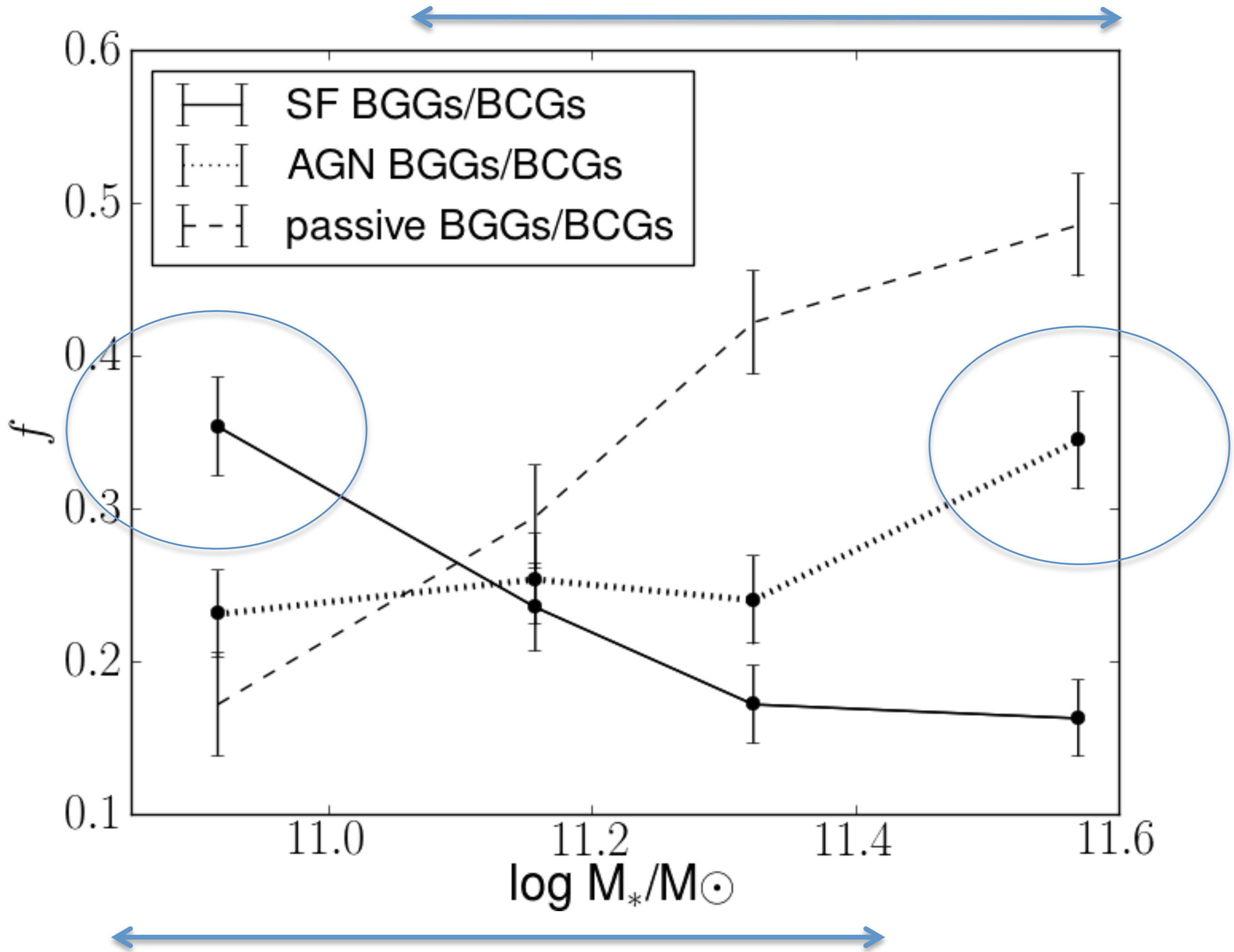
BCGs Star formation and AGN activity in the last 3 billion years



~60% of the BGGs/BCGs show Hα in emission

27% of the galaxies are star forming
27% show AGN activity

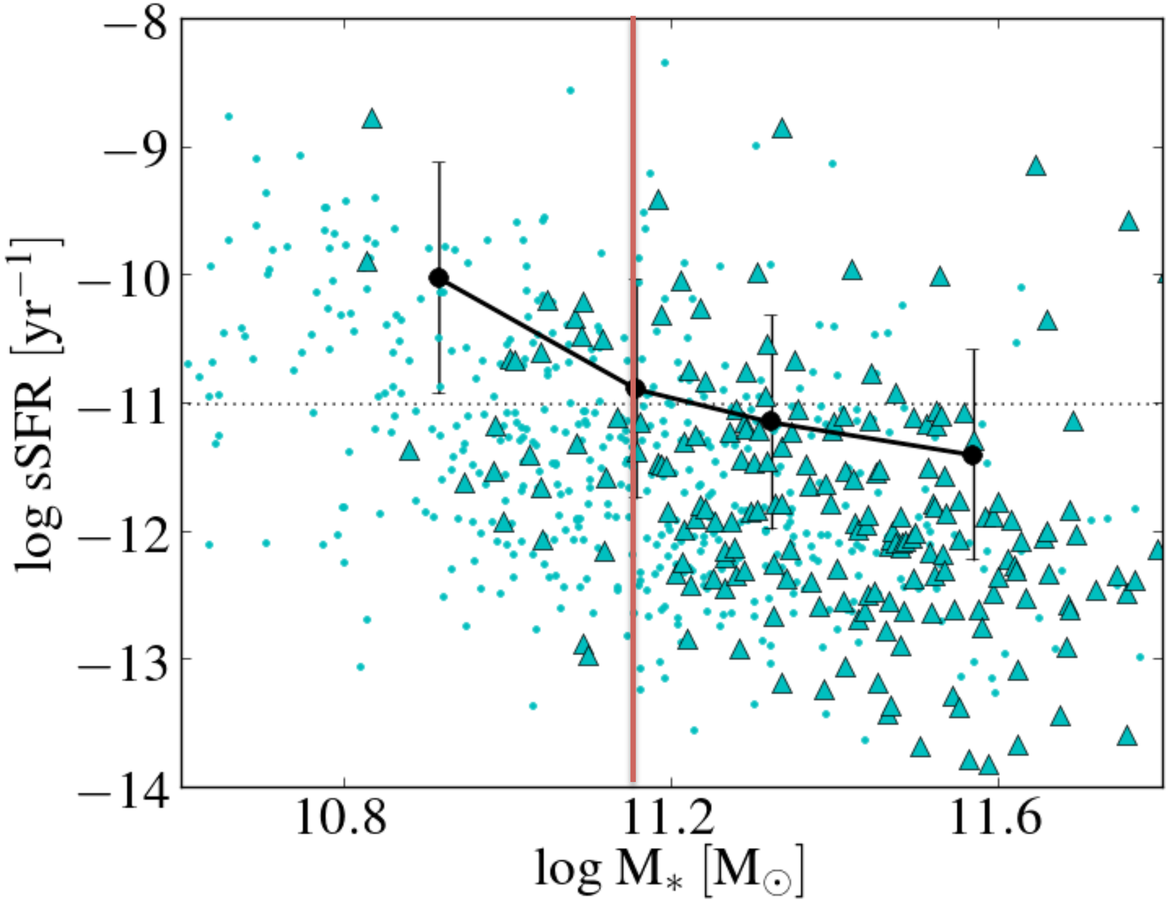
Clusters (i.e. BCGs)



Groups (i.e. BGGs)

Oliva-Altamirano et. al. (2014)

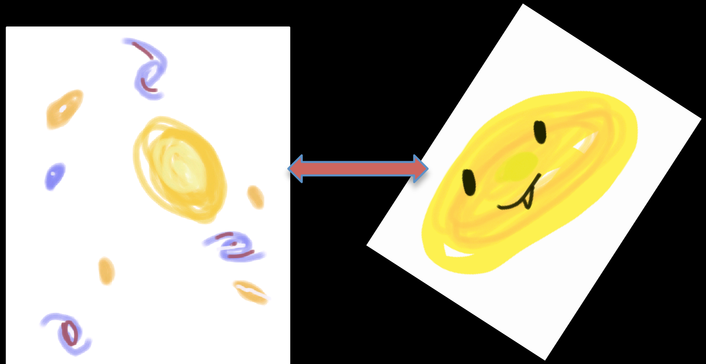
The specific star formation rate in BGGs and BCGs it is not significant as to contribute on the stellar mass growth

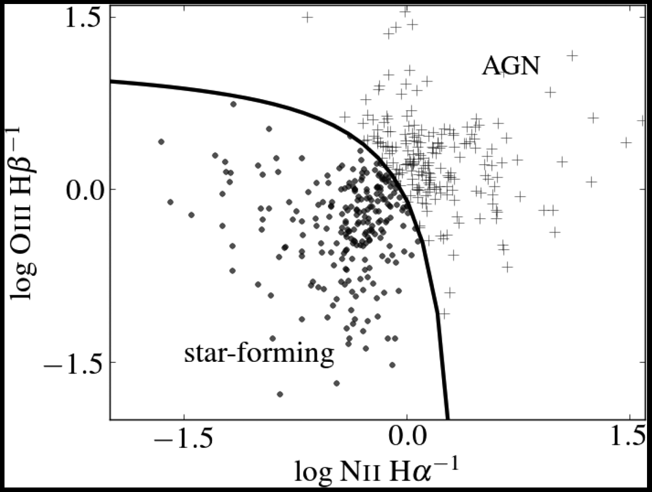


However this cannot be ignored in SAMs. See Tonini et. al. (2012)

Conclusions

BCGs show no growth in the last 4 billion years.





See Oliva-Altamirano et. al. (2014)

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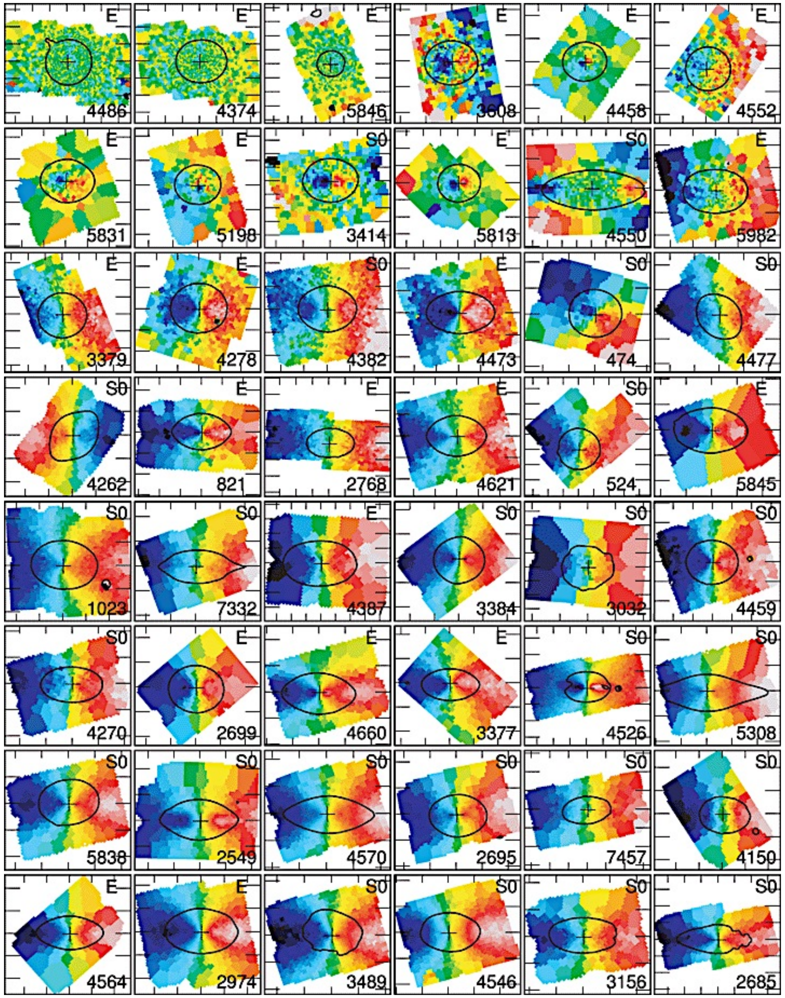
The importance of major and minor mergers in BCGs

Burke & Collins et. al. (2013), Lidman et. al. (2013) and Edwards & Patton (2012):

- BGC stellar mass grows by major mergers at $0.8 < z < 1.5$
- BGC stellar mass grows by minor mergers at $z < 0.3$

Nevertheless major mergers are not impossible to occur at low redshifts (Brough et. al., 2011).

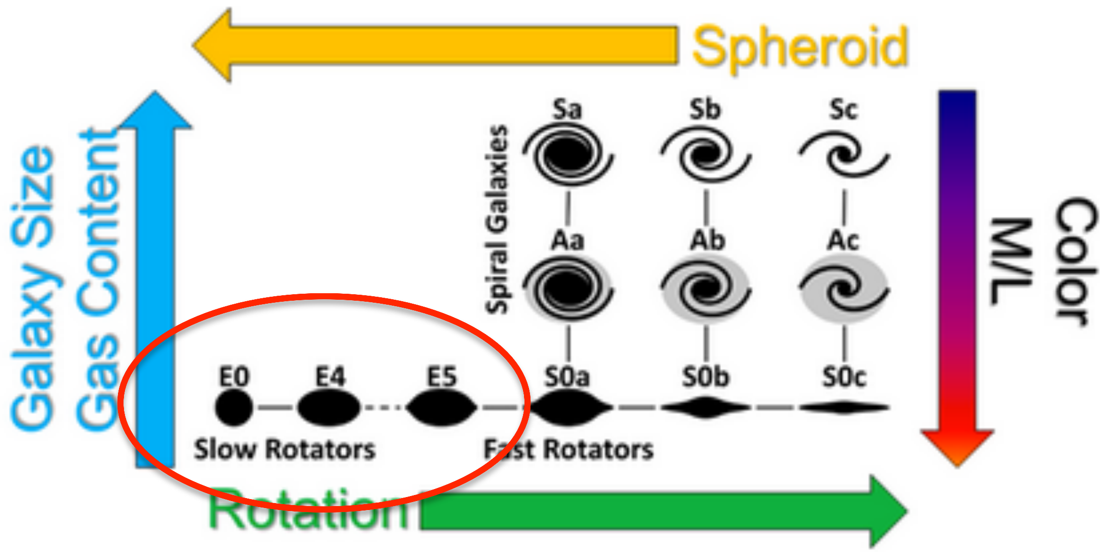
Integral Field Unit (IFU) Spectroscopy



BCG are predicted to be slow rotators…

- Angular momentum: SAURON λ_R parameter, Emsellem et al. (2007)

  ATLAS^{3D} ellipticity parameter Cappellari et al. (2011)



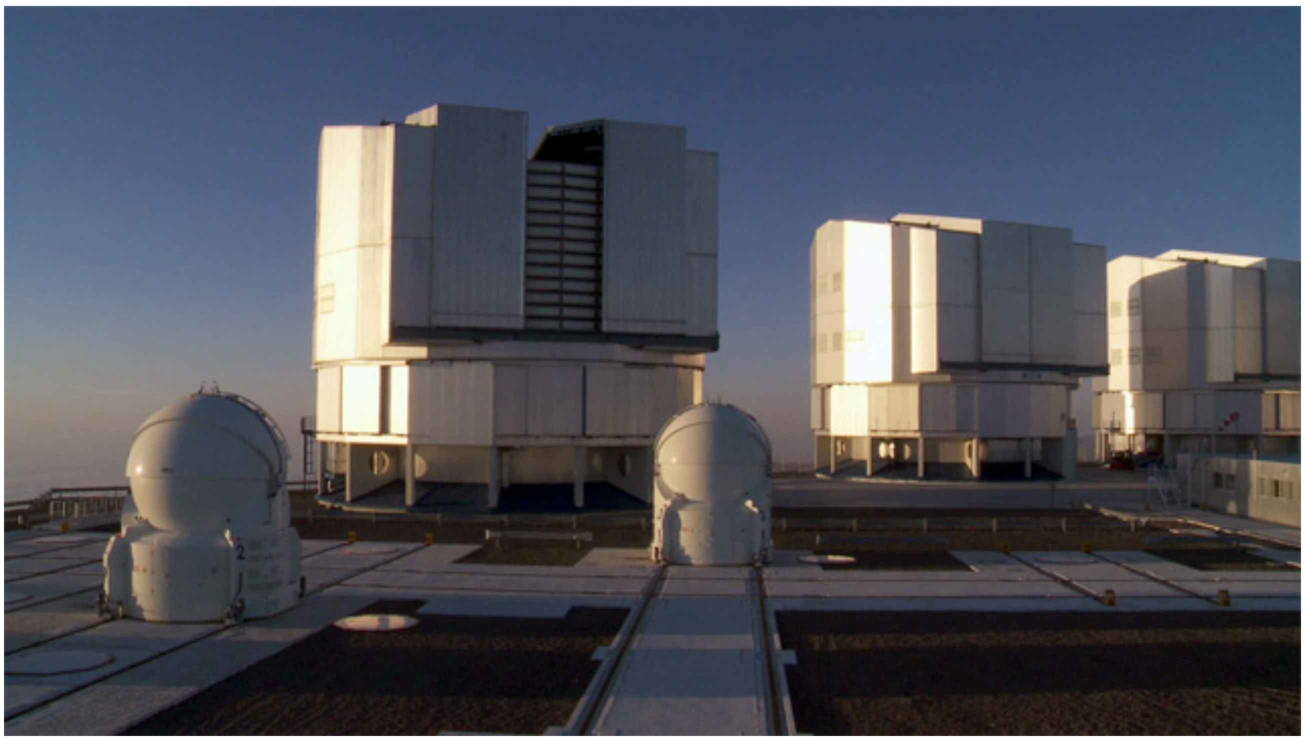
The ATLAS^{3D} comb (2011)

The SAURON sample contains only 9 galaxies with $M_* > 10^{11.3} M_{sun}$, and only 1 of them is a BCG

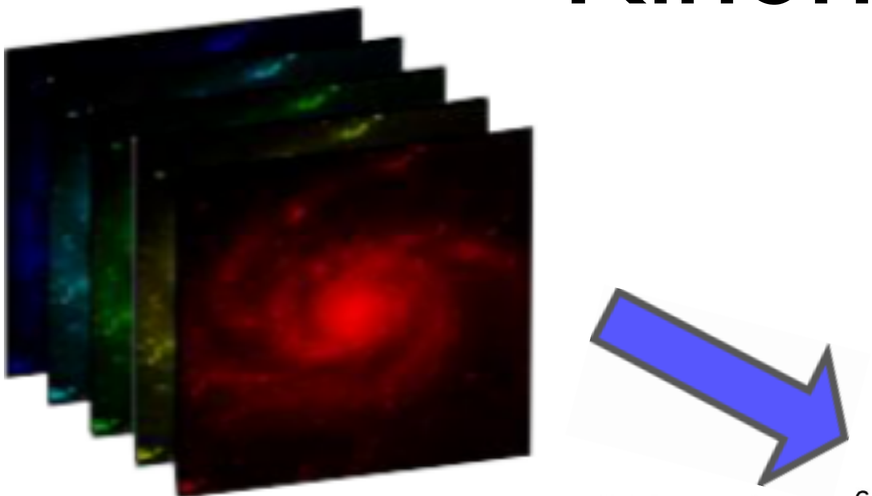
Data

9 BCGs and 3 of them with close similar mass companions.
Observed with VIMOS on the VLT, selected from SDSS.

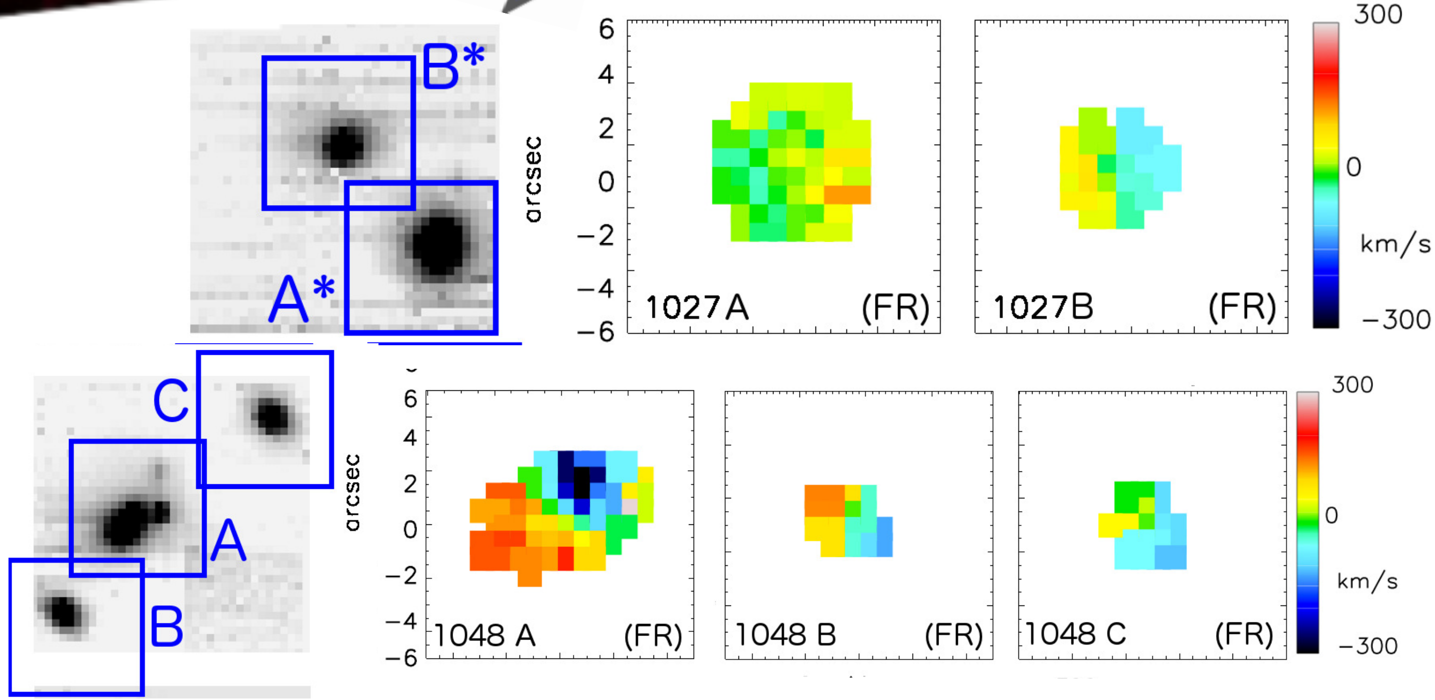
VIMOS IFU, VLT



Kinematics

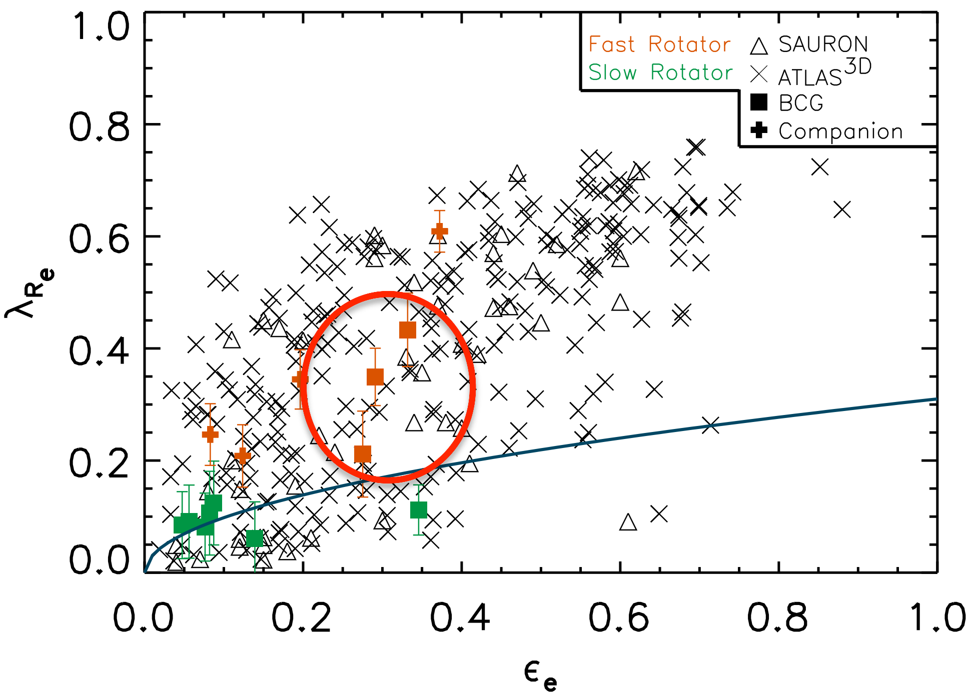


In collaboration with
Kim-Vy Tran and Jimmy
(Texas A&M University)

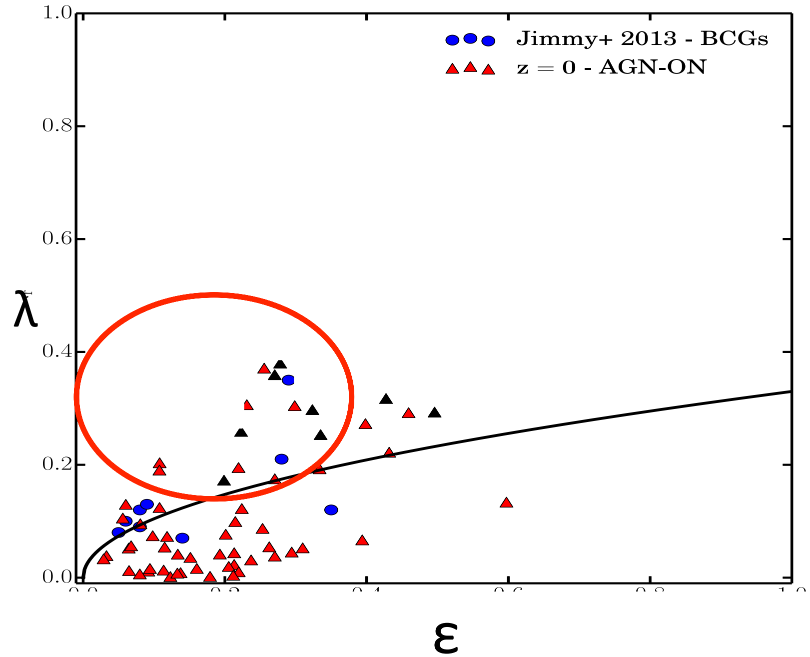


Brough et. al., 2011, Jimmy et. al. (2013)

~30% of BCGs are fast rotators

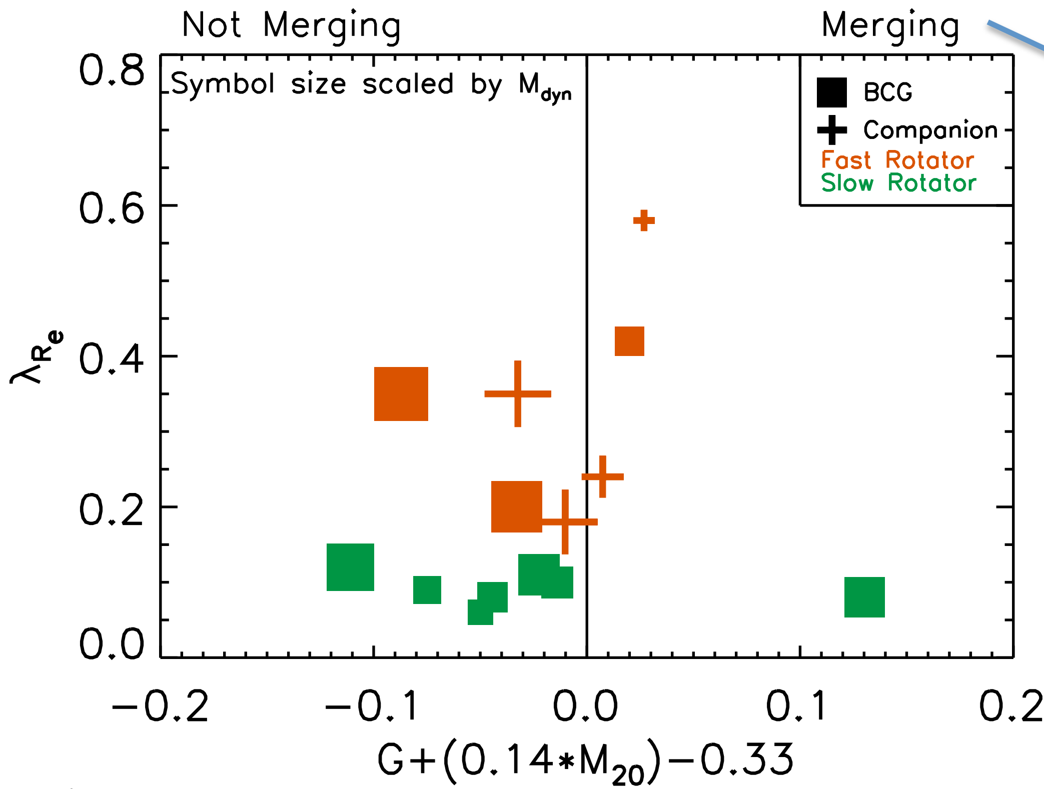


Jimmy et. al. (2013)



AMR simulations of Martizzi et. al. (2014)

Is the angular momentum a good indicator of ongoing mergers?

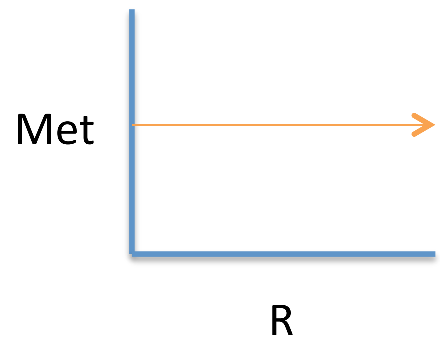


In the last 0.2Gyr (Lotz et. al., 2008)

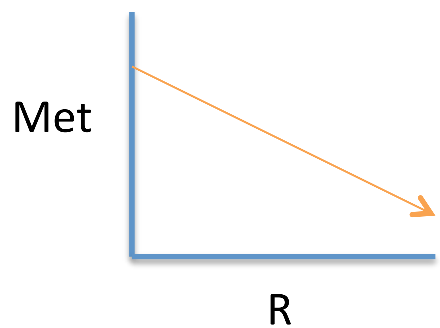
Jimmy et. al. (2013)

Irregularities in the galaxy's light distribution are morphological signatures of merging

Accretion histories from stellar population gradients



Flat gradients are the result of major dissipationless mergers.
Met gradient < -0.3

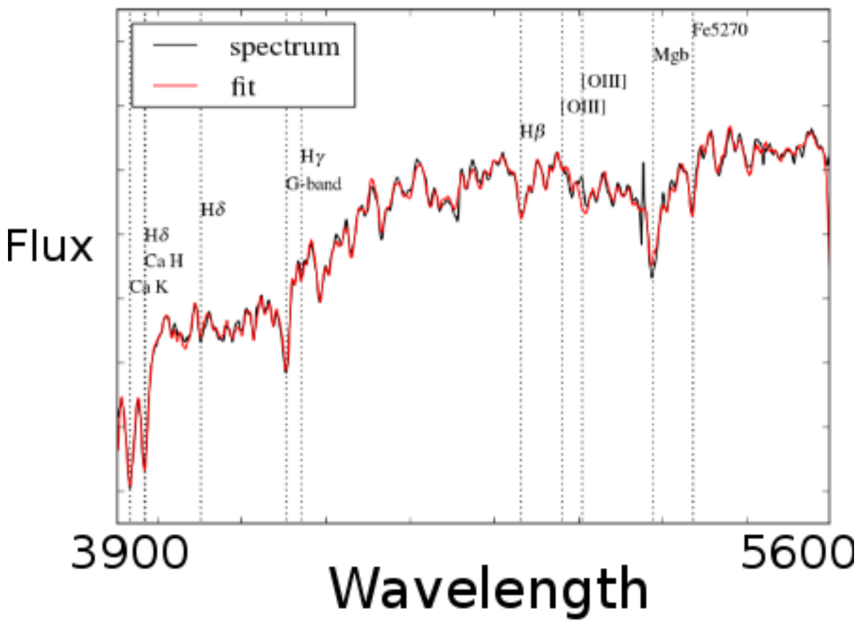


Steep gradients could be due to a core collapsed formation or major mergers Involving high fractions of gas.
Met gradient > -0.4

Kobayashi et. al. 2004, Hopkins et. al. 2009, Hirschmann in prep.

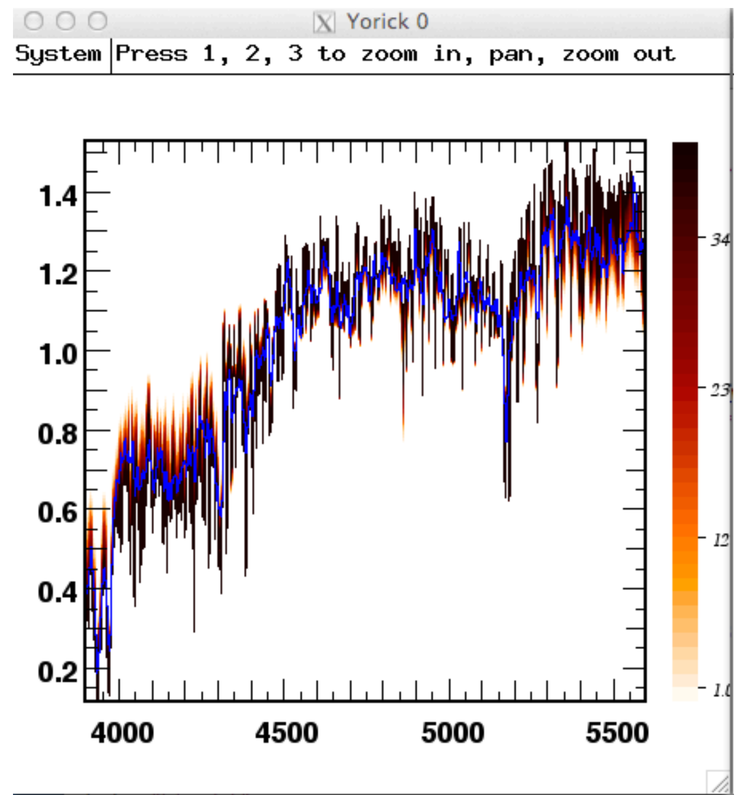
Age and metallicity estimations

Models: Vazdekis et. al. 2010
Library: MILES Sánchez-Blázquez et. al. 2006

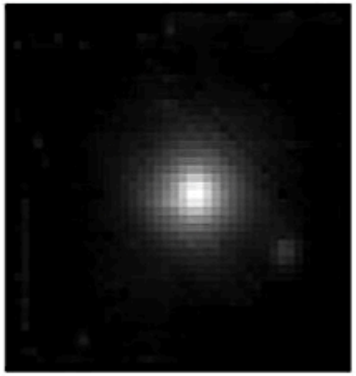


Oliva-Altamirano et. al. (submitted)

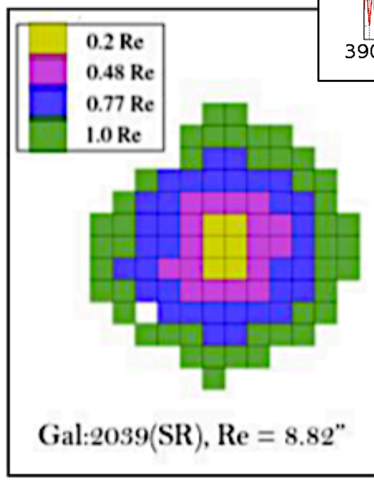
STECKMAP (Ocvirk et al. 2006a,b) uses Bayesian statistics to estimate the stellar population from the spectra. As a result we obtain stellar metallicities and ages



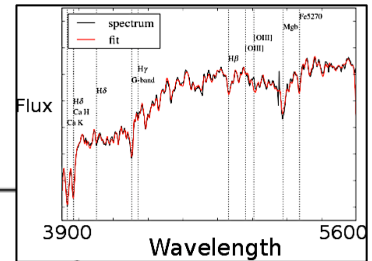
Method



VIMOS Field-of-view
27"X27"

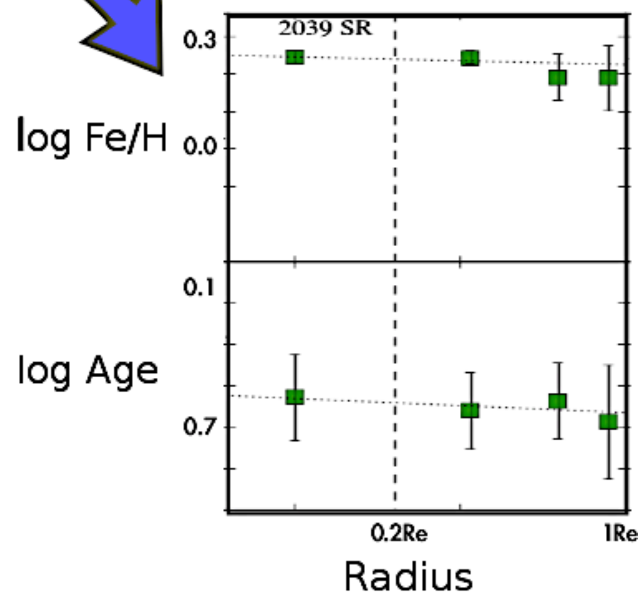


The galaxy is divided into annuli that follow flux

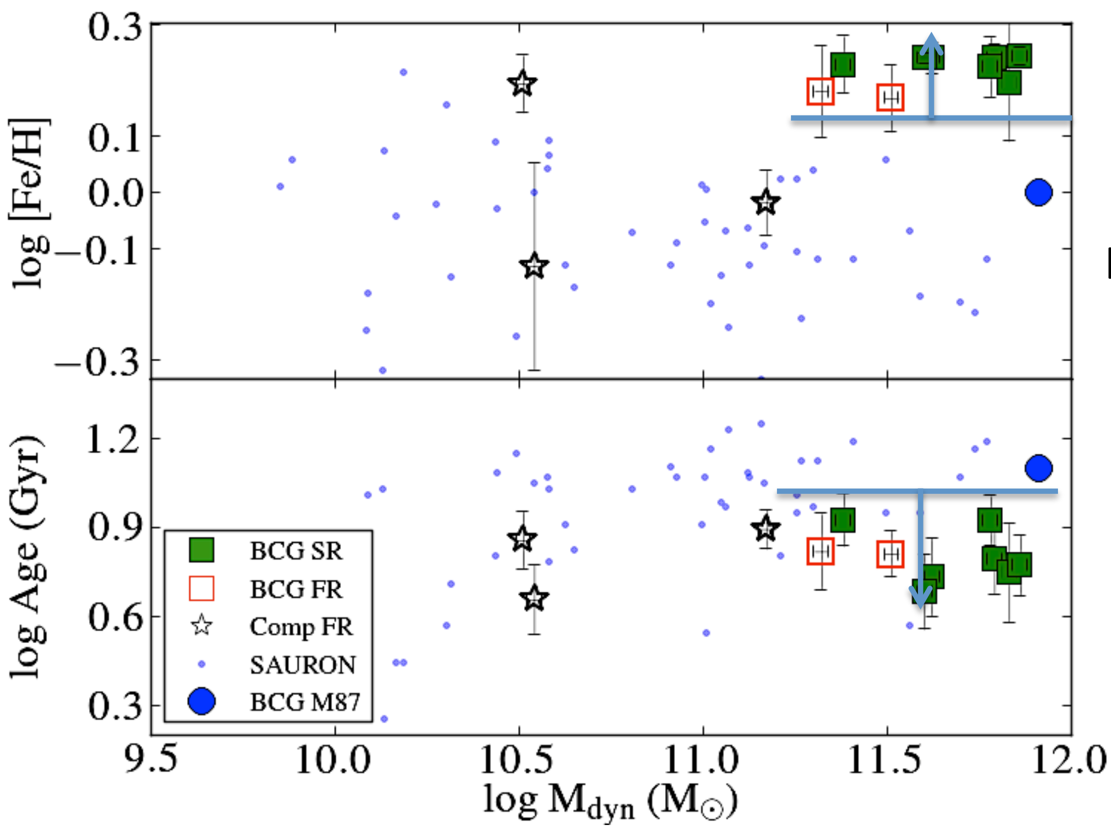


The result: one spectrum per annulus

Age and metallicity per spectrum as a function of radius



BCGs have high central metallicities and intermediate central ages.



BCG [Fe/H]=0.22±0.01

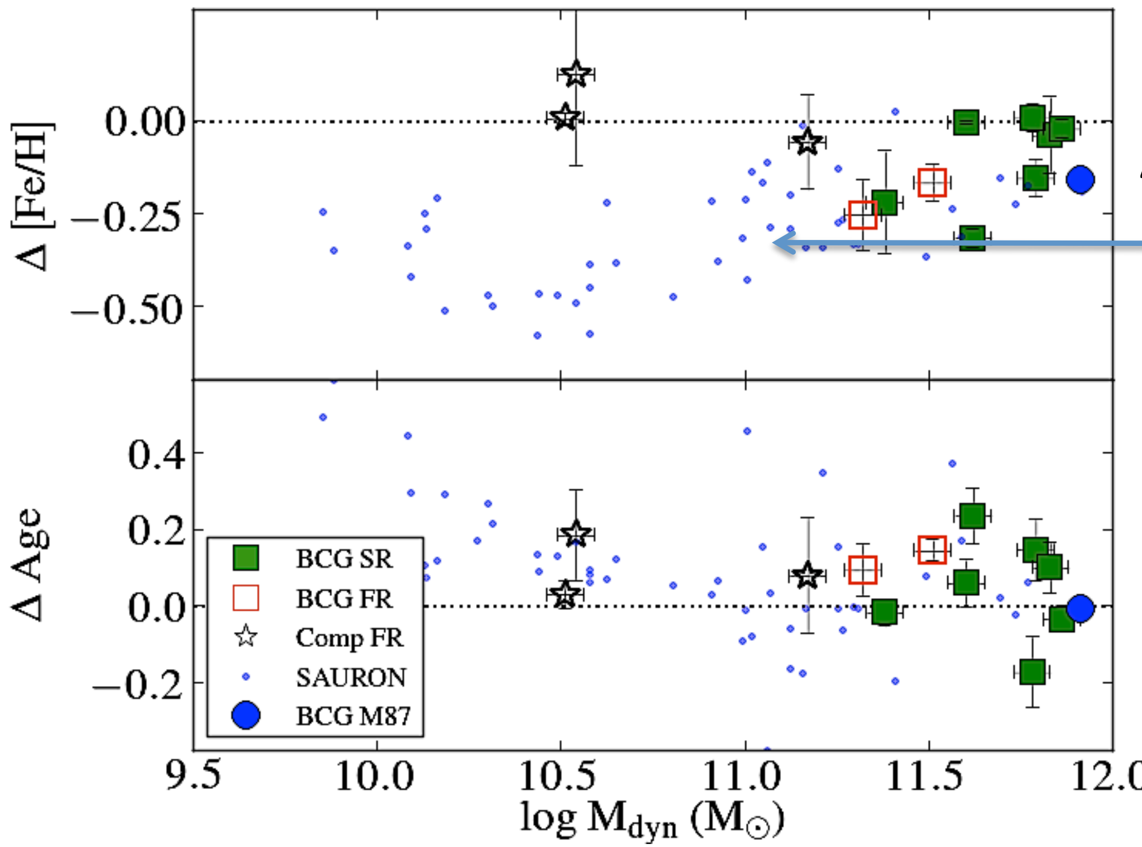
[Fe/H]=-0.12±0.02

Age=11.5±1.3 Gyr

BCG Age=6.4±0.4 Gyr

The central stellar populations are very different compared to those of early-type galaxies.

BCGs have shallow stellar population gradients.



BCG Δ[Fe/H]=-0.13±0.04

Δ[Fe/H]=-0.22±0.04

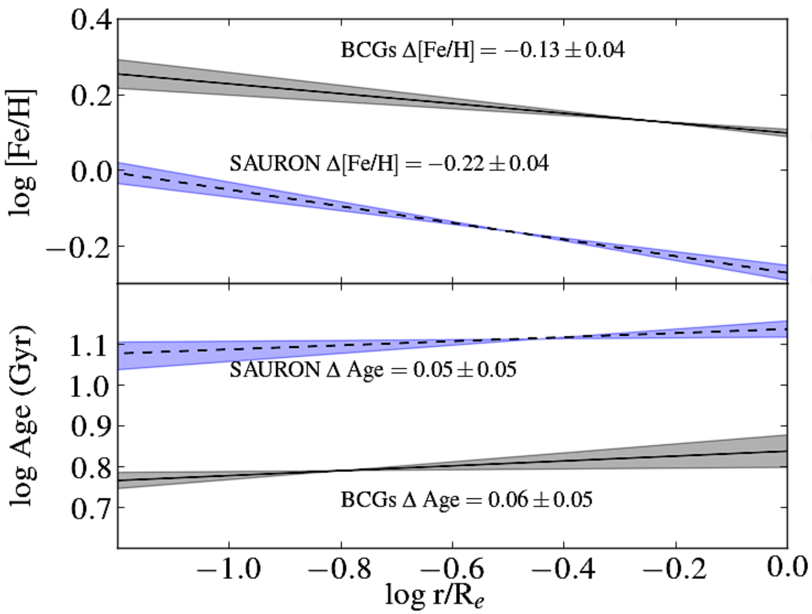
Gradient = -0.3

BCG ΔAge=0.06±0.05

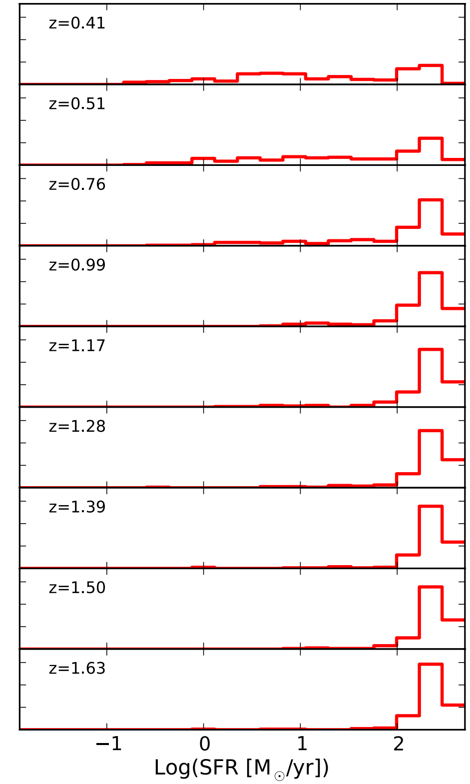
ΔAge=0.05±0.05

The stellar population gradients are similar to those of early-type galaxies at the same mass.

Merger Histories



Difference
In the central
Stellar Populations



Early- type galaxies:
Old–metal poor central stellar populations.
Shallow stellar population gradients.

Agrees with early-type galaxy simulations:
Naab et. al. 2013, Hirschmann et. al. 2013, Peeple et. al. 2014.

They experience **passive** accretion histories (No star formation since z = 2).

Brightest cluster galaxies:
Intermediate age-metal rich central stellar Populations.
Shallow stellar population gradients.

Disagrees with SAM De Lucia et. al. 2007
Agrees with Tonini et. al. 2012.

They experience **active** accretion histories (Star formation up to z = 1).

Conclusions

The dense environments where BCGs evolve allow them to experience many mergers in time. These ongoing accretion events will trigger star formation at $z > 1$ resulting in intermediate central ages, and will disrupt the metallicity gradients at $z < 1$.

Oliva-Altamirano et. al. (submitted)

This is what we don't know…

- Are this models suitable to study BCGs?
- When did exactly the SF quenched?
- What is going on out side 1 $R_{e?}$

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Summary

- BCGs provide critical tests for galaxy formation and evolution models.
- BCGs grow at fast rate from z = 1 to z = 0.5 slowing down in the last 5 billion years.
- BCGs experiment **an active accretion history** throughout their cosmic time. These mergers contribute to the growth of stellar mass in time. At **high redshifts** the BCG stellar mass is accreted **mostly by major mergers** (Lidman et al., 2013; Burke & Collins, 2013). At **lower redshifts** their stellar mass growth is a result of **minor mergers** (Edwards & Patton, 2012).

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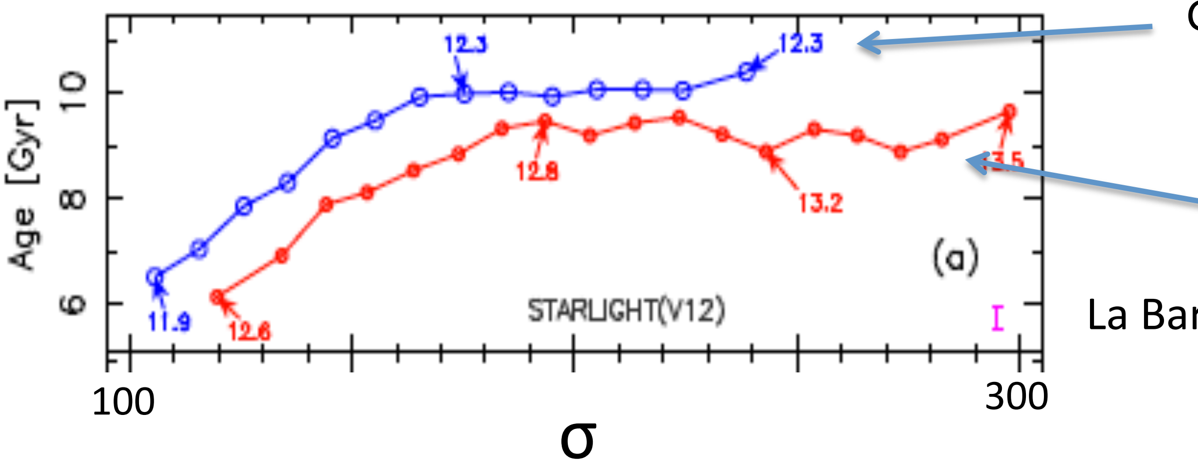
Upcoming work…



La Barbera et. al. 2014

1. What is the influence of environment on the angular momentum and stellar populations of central galaxies?
2. Are BGGs simply a step in the evolution of BCGs or do they have distinct accretion histories?

Upcoming work…

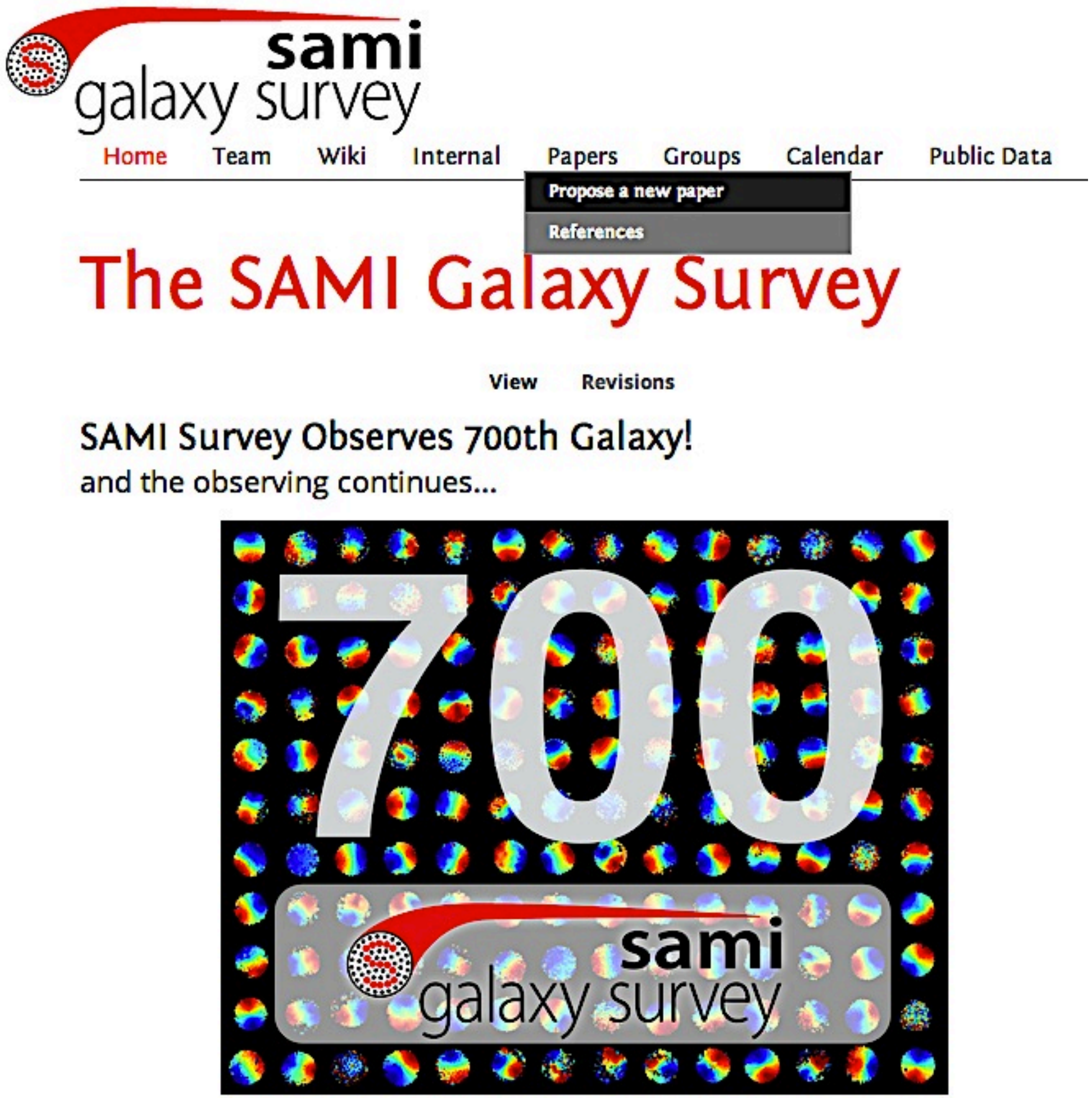
- SPIRAL IFU Observations (May 2012)

18 Brightest **Group** Galaxies from the GAMA.

- Kinematics
- Central stellar populations
- Stellar population gradients
- Other properties of the group: dominance, masses, emission lines.

Anglo Australian Telescope (AAT)

New Australian IFUs

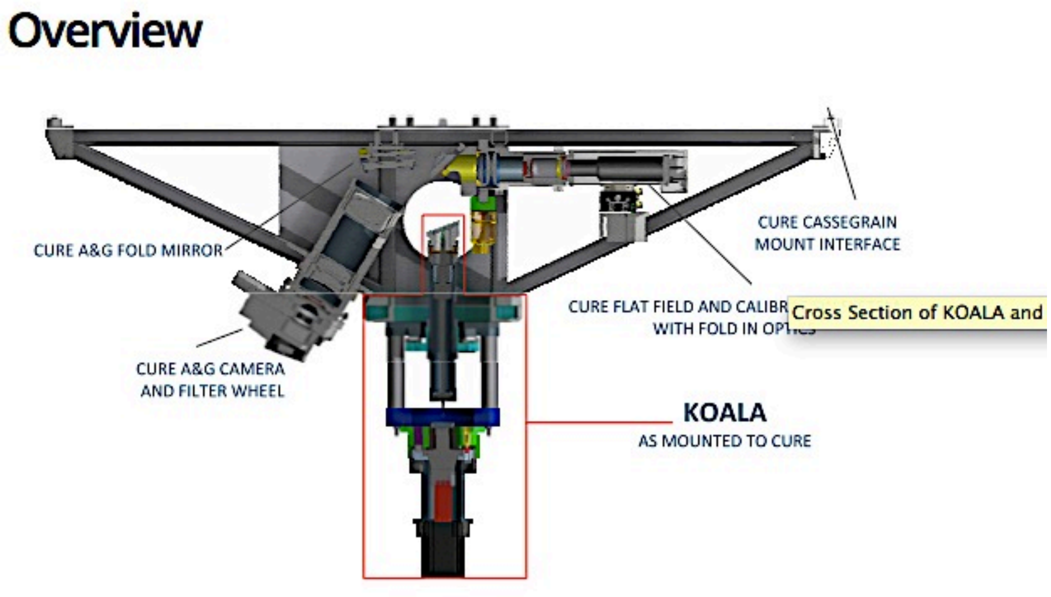


Puts together 13 fused hexabundles each containing 61 fibers.
FOV 1 deg^2
3000 galaxies across a large range of environment.

First Public Data Release
107 galaxies
http://sami-survey.org/edr

New Australian IFUs

KOALA Kilofibre Optical AAT Lenslet Array



1000 hexagonal lenslets in a rectangular array.

FOV
15.3 X 28.3 arcsec, 0.7" sampling
27.4 X 50.6 arcsec, 1.25" sampling

science/instruments/current/koala/overview

Thanks for your attention!

http://www.aao.gov.au/conference/massive-galaxies-2015

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The Most Massive Galaxies and their Precursors

9th - 12th February 2015, Sydney

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