# BCGs in Cosmological Hydro-Simulations

## Lo Bueno y Lo Malo...

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

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2013

**Brightest cluster galaxies in cosmological simulations: achievements and limitations of active galactic nuclei feedback models**

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# The Sample

Clusters with masses $M_{200} > 1e14\ M_{\odot}$
extracted from 29 Cosmological zoom-in Simulations of a parent simulation box 1 Gpc $h^{-1}$
run with custom version of Gadget-3;
softening 5 $h^{-1}$ kpc;
$M_{DM} = 8.5e8\ h^{-1}\ M_{sun}$; $M_{gas,ini}=1.5e8\ h^{-1}\ M_{sun}$)

Including:

**Cooling, Star Form. & SN Feedback (CSF)** **A OFF**

**CSF + AGN Thermal Feedback** **A ON**

(with quite standard recipes for AGN used used by most cosmo sims)

**~60 BCGs**

# BCGs Stellar Mass within 30 kpc/h vs Halo Mass

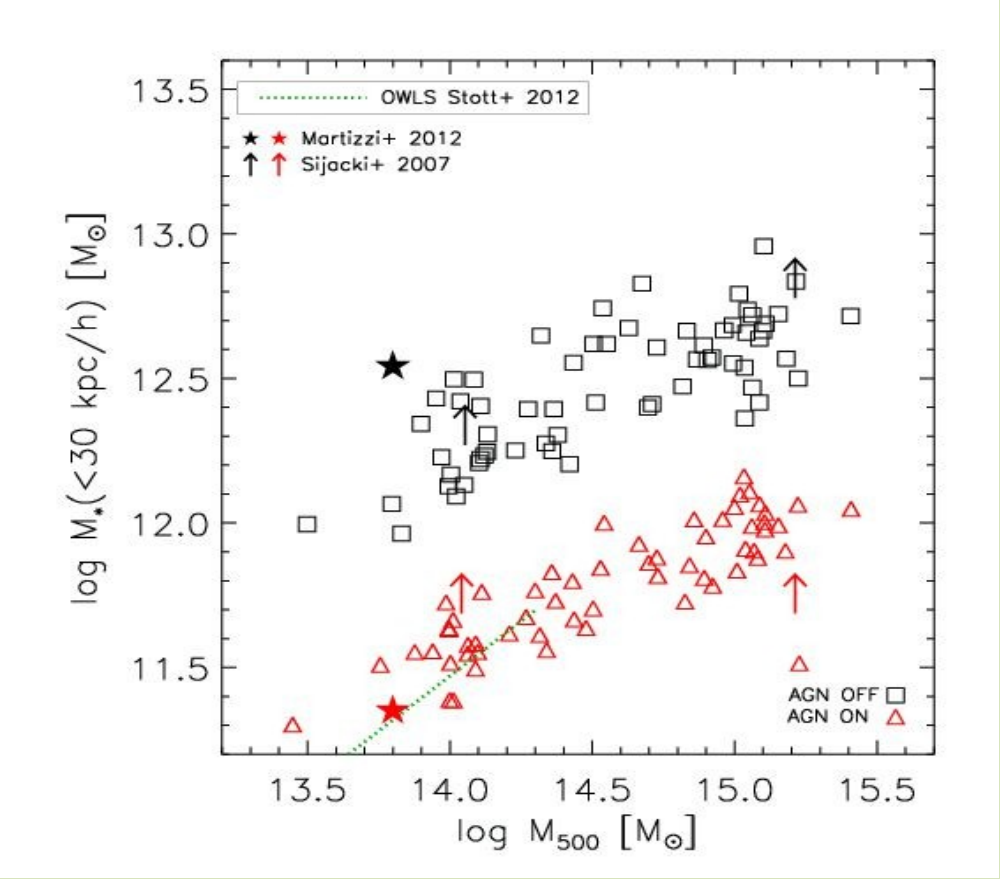
BCG mass within fixed radius (≈ 30 kpc), often “wrongly” adopted to compare with observations.

The fixed radius is far too small, and introduces mass and flavor dependent biases.

Here shown to compare with other sims results.

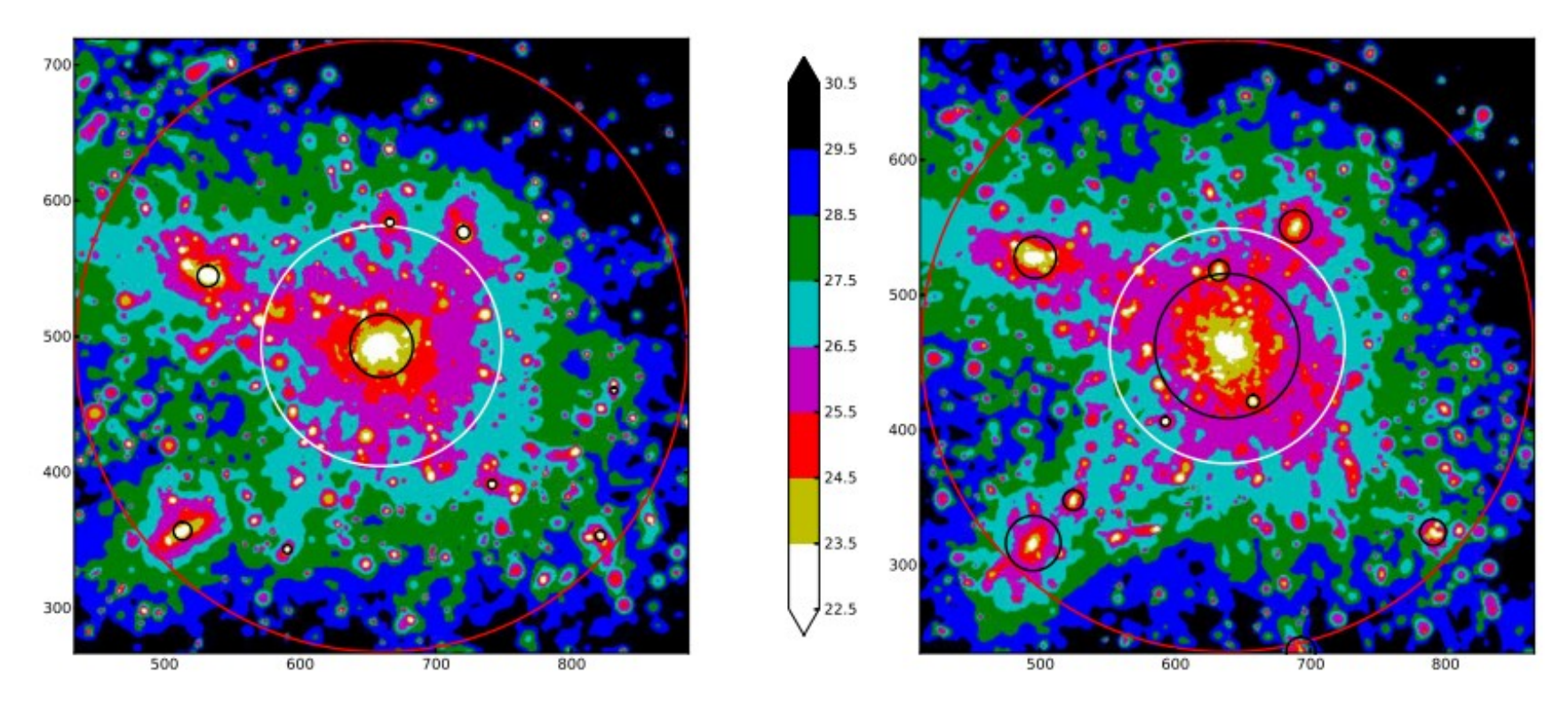
Good agreement with OWLS in the common mass range

Not obvius disagreement with other smaller samples of sims.




AGN Feedback reduces the final $M^*(<30\ kpc/h)$ by a mass independent factor ≈5

# mock images




AGN OFF

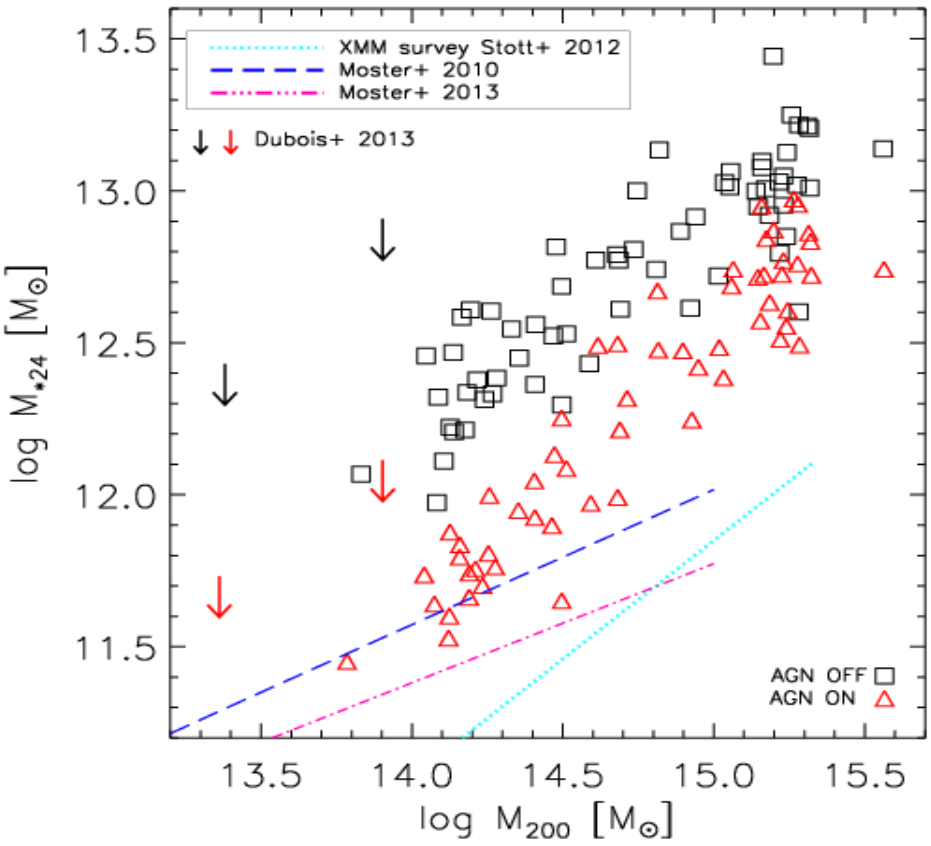
AGN ON

# BCGs Stellar Mass within μV = 24 mag arcsec2 vs Halo Mass

This mass measure is more suitable to compare with observations;

Even with AGN, stellar mass still over-predicted particularly at high mass end, where the effect of feedback becomes small;

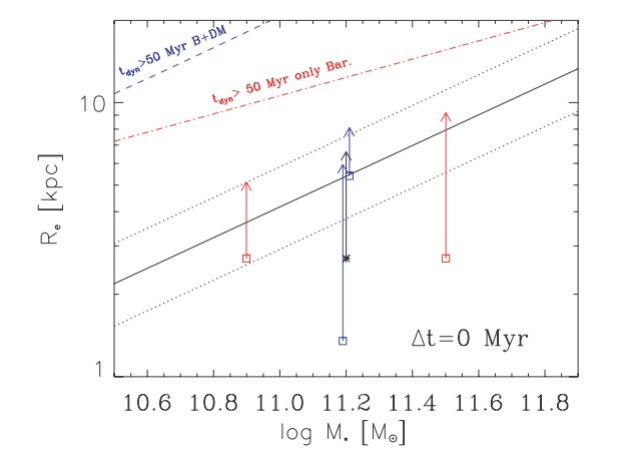
The use of M(>30 kpc/h) would largely mask the problem;




The effectiveness of AGN Feedback on M*24 decreases with increasing halo mass

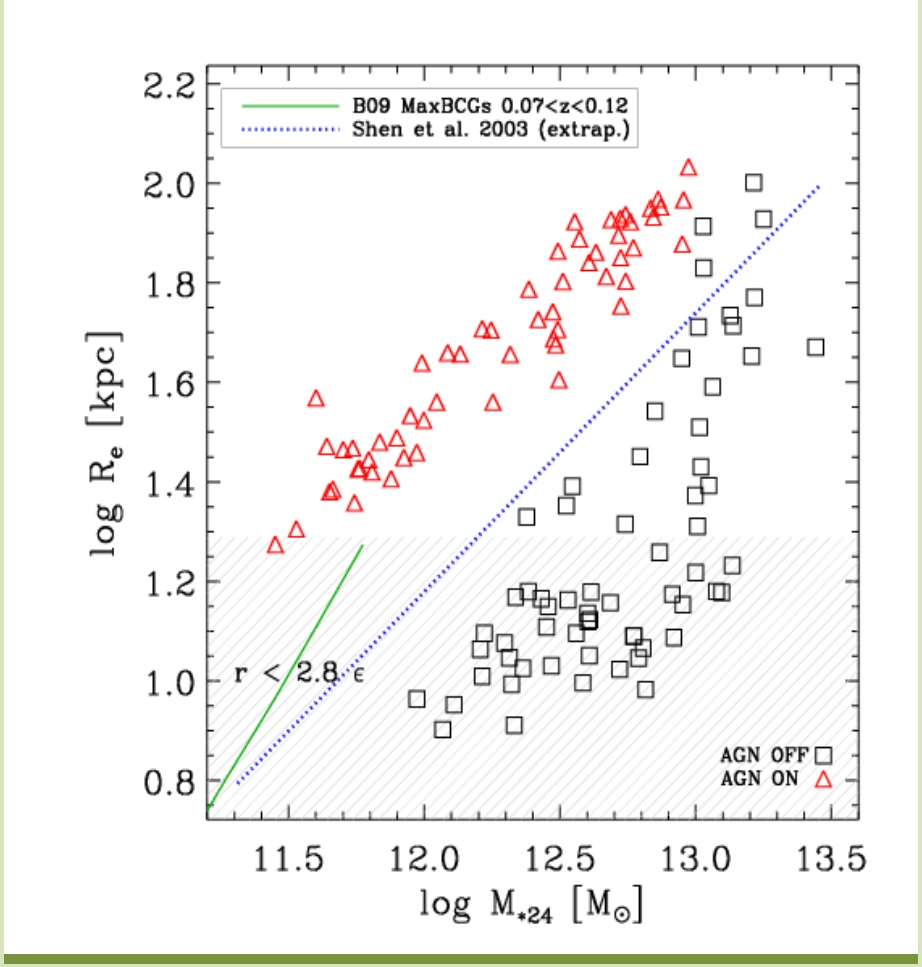
# Structure 1: Mass-Size Relation

- **AGN OFF** BCGs are too compact
  **AGN ON** BCGs maybe too expanded.
- In **AGN ON** runs, less dispersion than in **AGN OFF** runs.



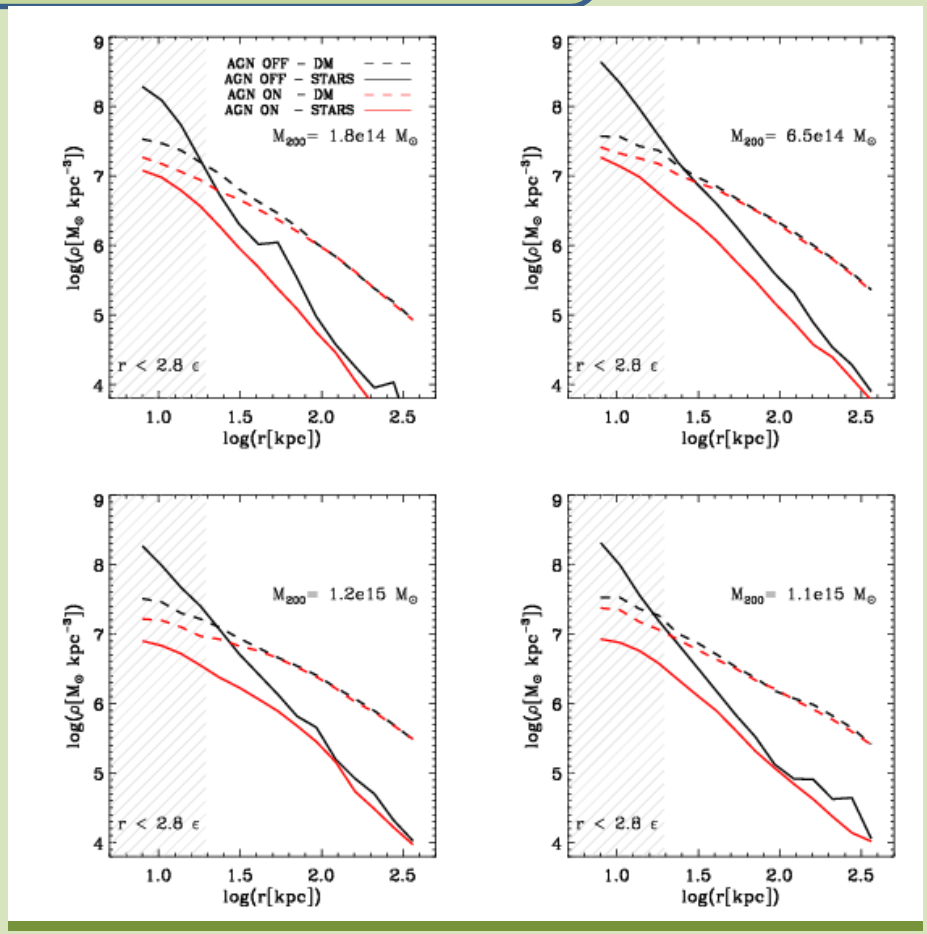

Ragone-Figueroa & GLG 11: final R(M) is an "attractor" under loss of much gas

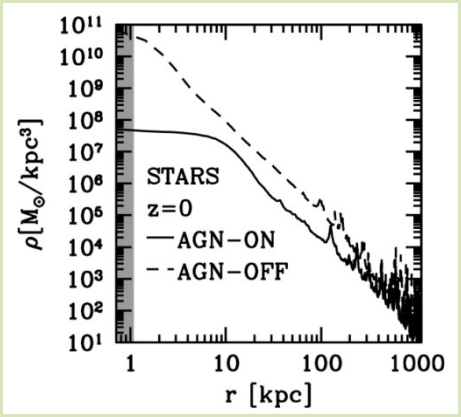
- In **AGN ON** runs, less dispersion than intrinsic in data. Over-simplification in the recipes modelling the AGN FB?



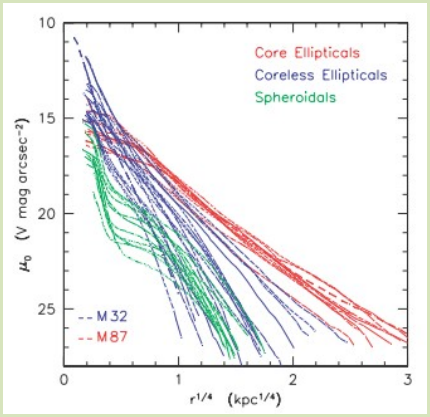
# Structure 2: Profiles

- AGN flattens profiles, hinting to a core at around 10 kpc
- Core found on similar scales in higher resolution sims. (5 times better, Martizzi et al. 2012).
- Cores NOT observed this large, by at least a factor 10 (e.g. Kormendy et al. 2009).




Martizzi et al. 2012

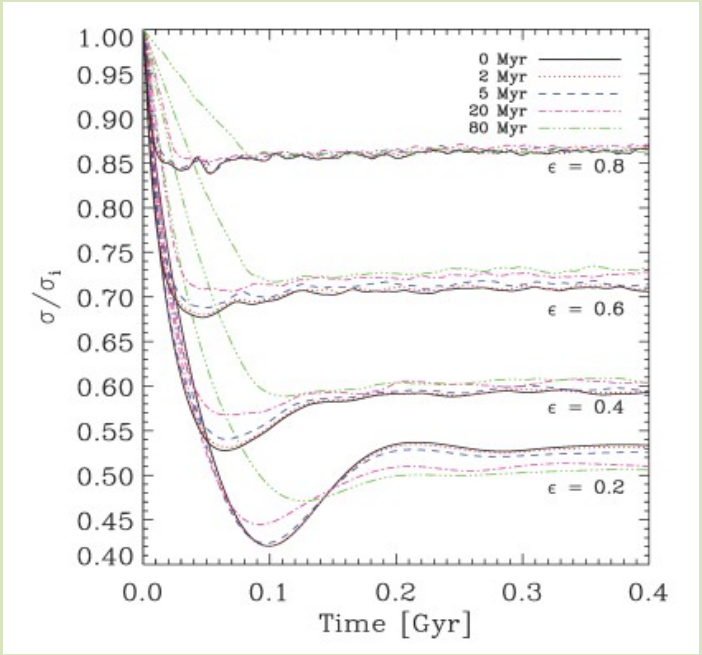


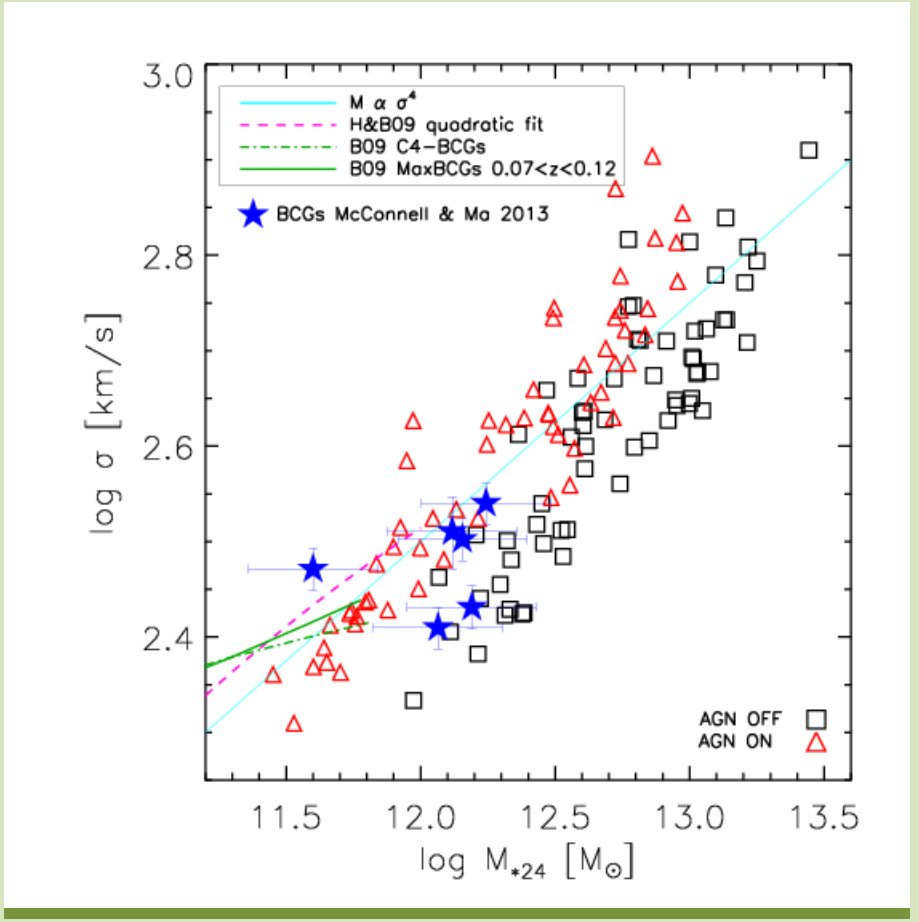

Kormendy et al. 2009

AGN Feedback too effective in the center (while too weak globally)?

# Stellar Velocity Dispersions - FJ

- Stellar velocity dispersions are very large, and increase too fast with M
- They are not affected by the inclusion of AGN feedback.
- To reduce them, more outflows might be required. Kinetic FB?




Ragone-Figueroa & Granato (2011)

# $M_{BH}$- $M_*$ Correlation

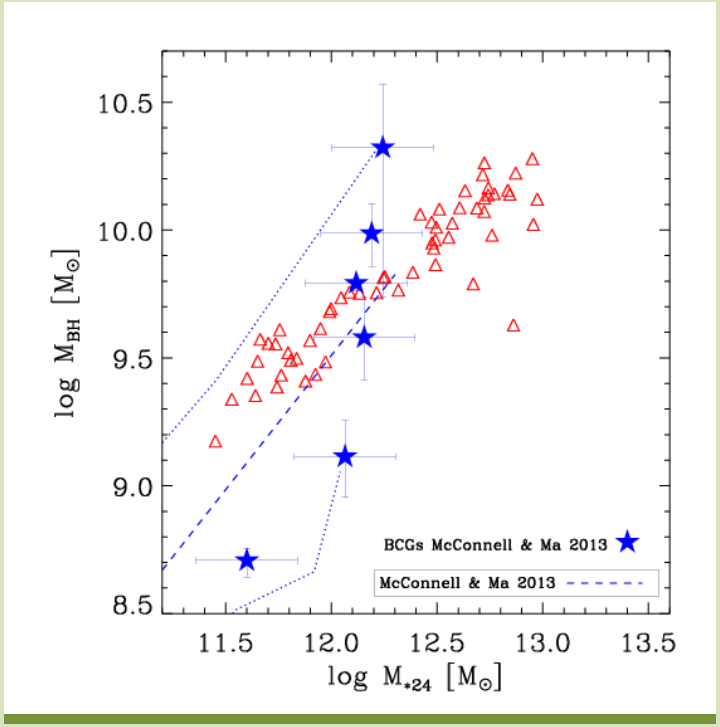
- $M_{BH} \propto M_*^{\alpha}$

Observation for a mixed sample: $\alpha \sim 1$

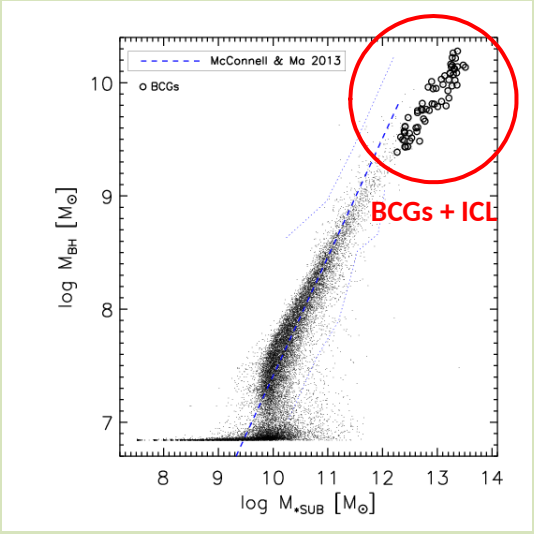
Dianoga Sims for BCGs: $\alpha \sim 0.7$

- No observational evidences indicating a different scaling relation for BCGs.

- The intrinsic dispersion of real galaxies around the relationship is larger than that of simulated galaxies.



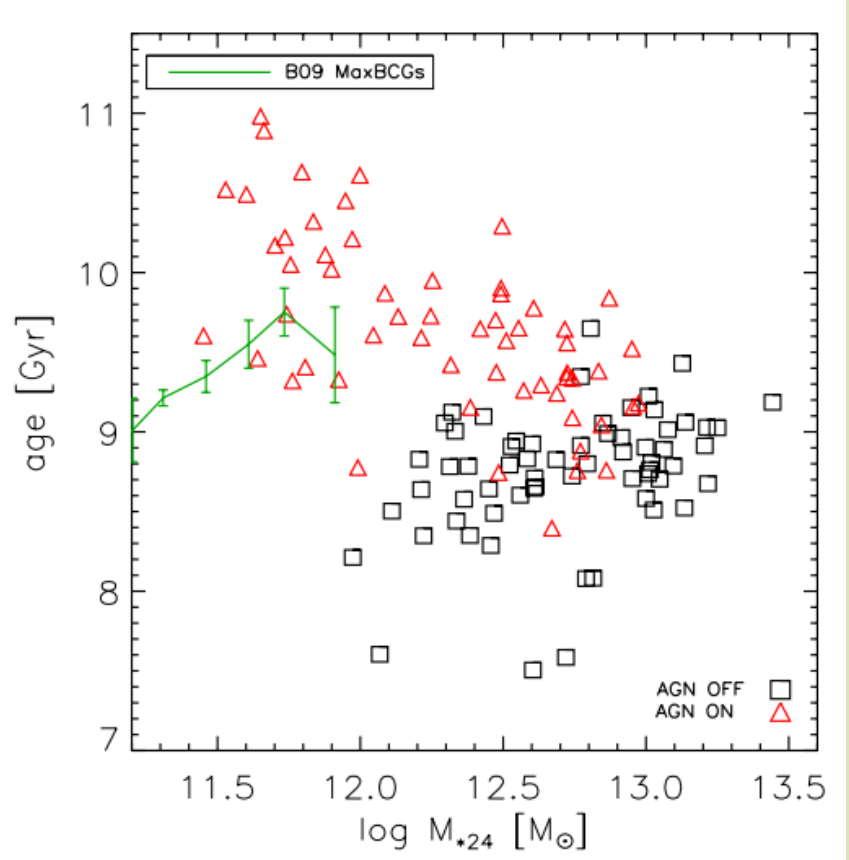

- Need for a looser physical link between Star Formation and BH Accretion , e.g.
  - Accretion is a chaotic phenomenon
  - Distribution of $\varepsilon_r$ (not a single value).
- Merging of glxs and their BHs tends to strengthen a preexisting correlation (Peng 2007).




The observed correlation between the SMBH mass and stellar mass (found for the spheroidal component of galaxies) is reproduced.

# Ages of stellar populations

- AGN FB increases the mass averaged stellar age by 0.5-2 Gyr
- It introduces a negative gradient with mass not confirmed by observations
- Likely another indication of insufficient  quenching effect of AGN at high mass end;



# On the originality of titles…

SPH

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AMR

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## Brightest cluster galaxies in cosmological simulations with adaptive mesh refinement: successes and failures

Not so many failures but smaller mass sample

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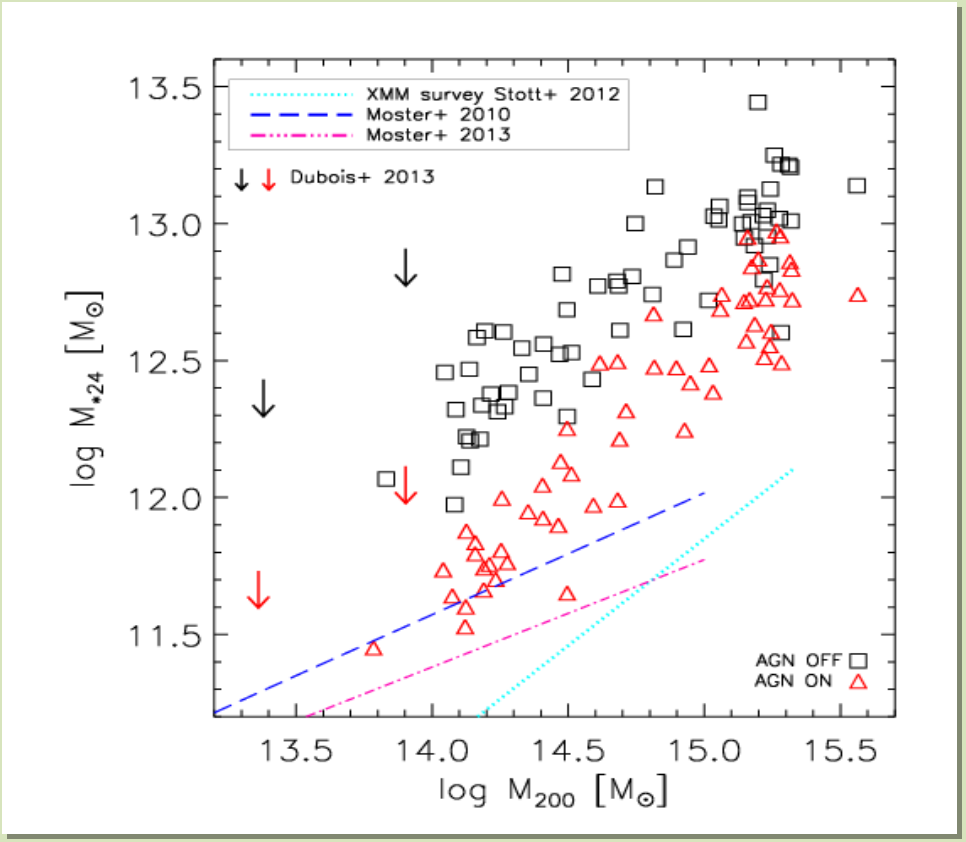
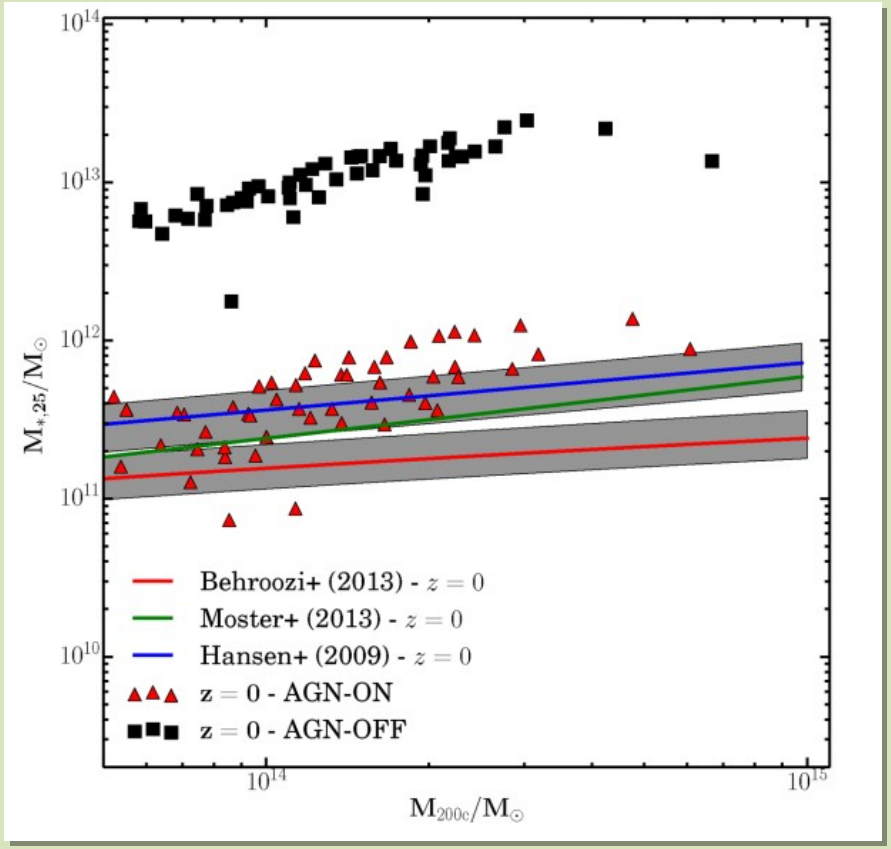
# BCGs Stellar Mass vs Halo Mass




Ragone-Figueroa+ 2013




Martizzi+ 2014

# Summary

- **AGN ON** simulations go in the right direction but…
- …the stellar mass remains still too large by a significant factor >2 and increasing with halo mass. The problem is shared by other sims. FB too weak?
- BCGs basic structural features show some disagreement with observations (possibly sizes and cores); FB too concentrated in the center?
- AGN feedback affects very little the predicted stellar velocity dispersion. Kinetic feedback required?
- Relationships obtained for **AGN ON** BCGs are characterized by a similar or lower spread than those obtained from **AGN OFF** runs (particularly evident for the mass-size relations).
- The dispersions of the $M_{BH}- M_{*}$ and $M_{BH}- M_{\sigma}$ relations produced by the simulations is significantly smaller than the observed. Less strict link between the growth of stellar mass and that of the SMBH than that produced by the prescriptions we adopt?