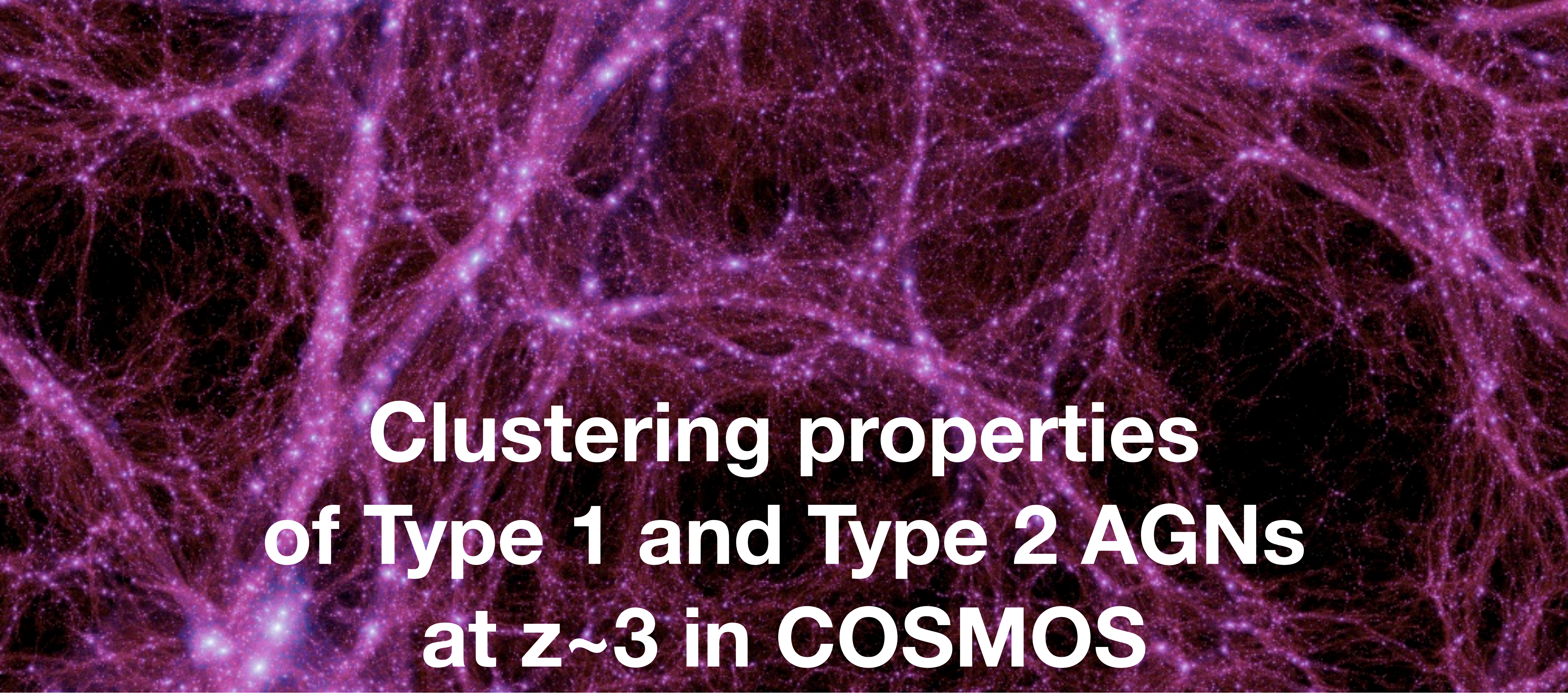


Clustering properties of Type 1 and Type 2 AGNs at z~3 in COSMOS

Viola Allevato

A. Finoguenov, F. Civano, N. Cappelluti, F. Shankar, T. Miyaji, G. Hasinger, M. Salvato, R. Gilli, G. Zamorani, XMM-COSMOS and C-COSMOS Team

UNIVERSITY OF HELSINKI

AGN 11 Trieste, 23-26 September

Large-scale Structure

- Projected 2PCF $w_p\,(r_p)$

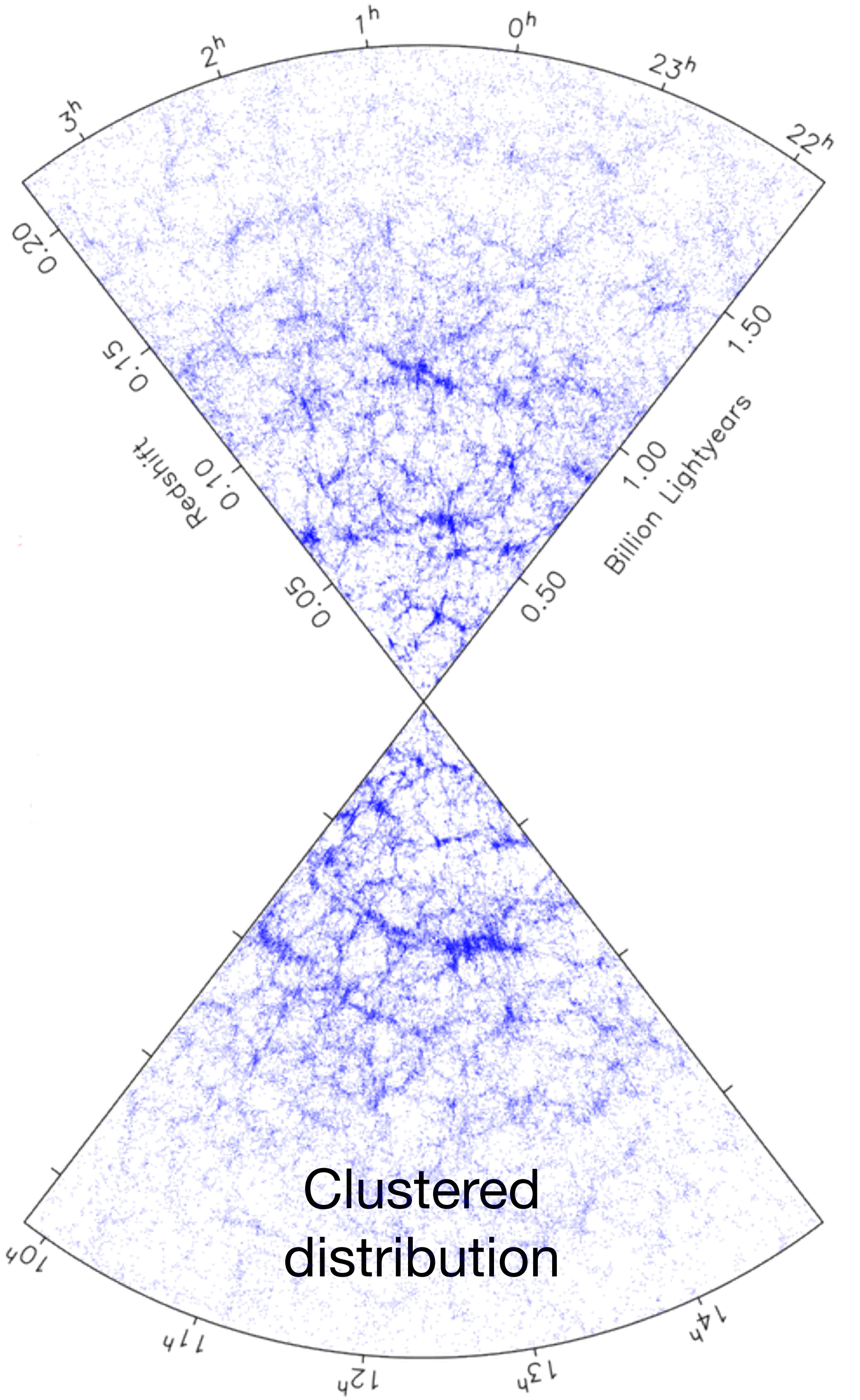
  (Davis & Peebles 1983)

  which measures the difference between the source distribution and an unclustered random distribution, as a function of the AGN separation;

- AGN Bias

  (e.g. Sheth et al. 2001, Tinker et al. 2005)

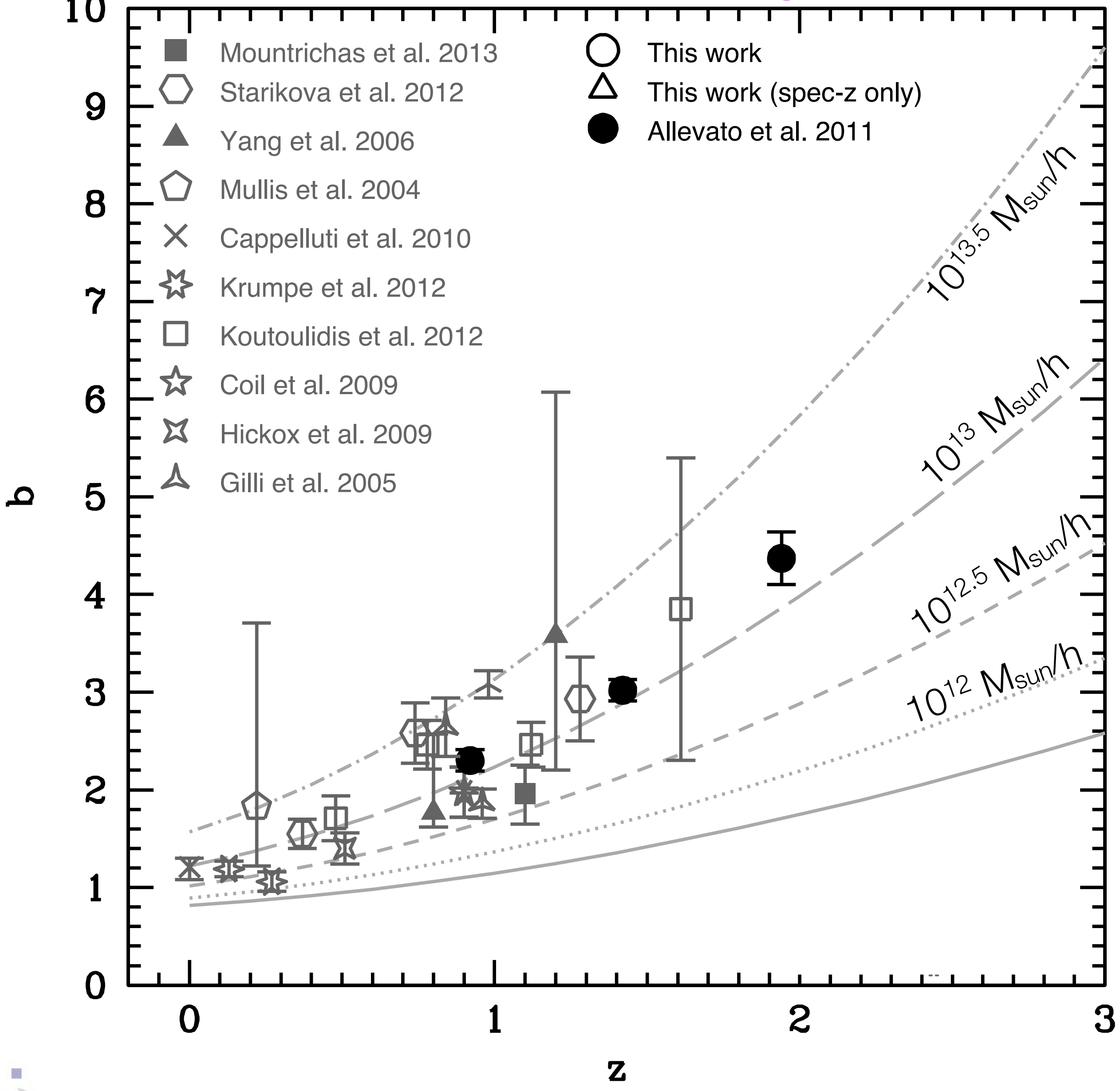
  which is related to the TYPICAL mass of hosting dark matter halos;



Clustered distribution

Clustering of X-ray AGNs

Cappelluti, Allevato & Finoguenov 2012



Clustering of X-ray AGNs

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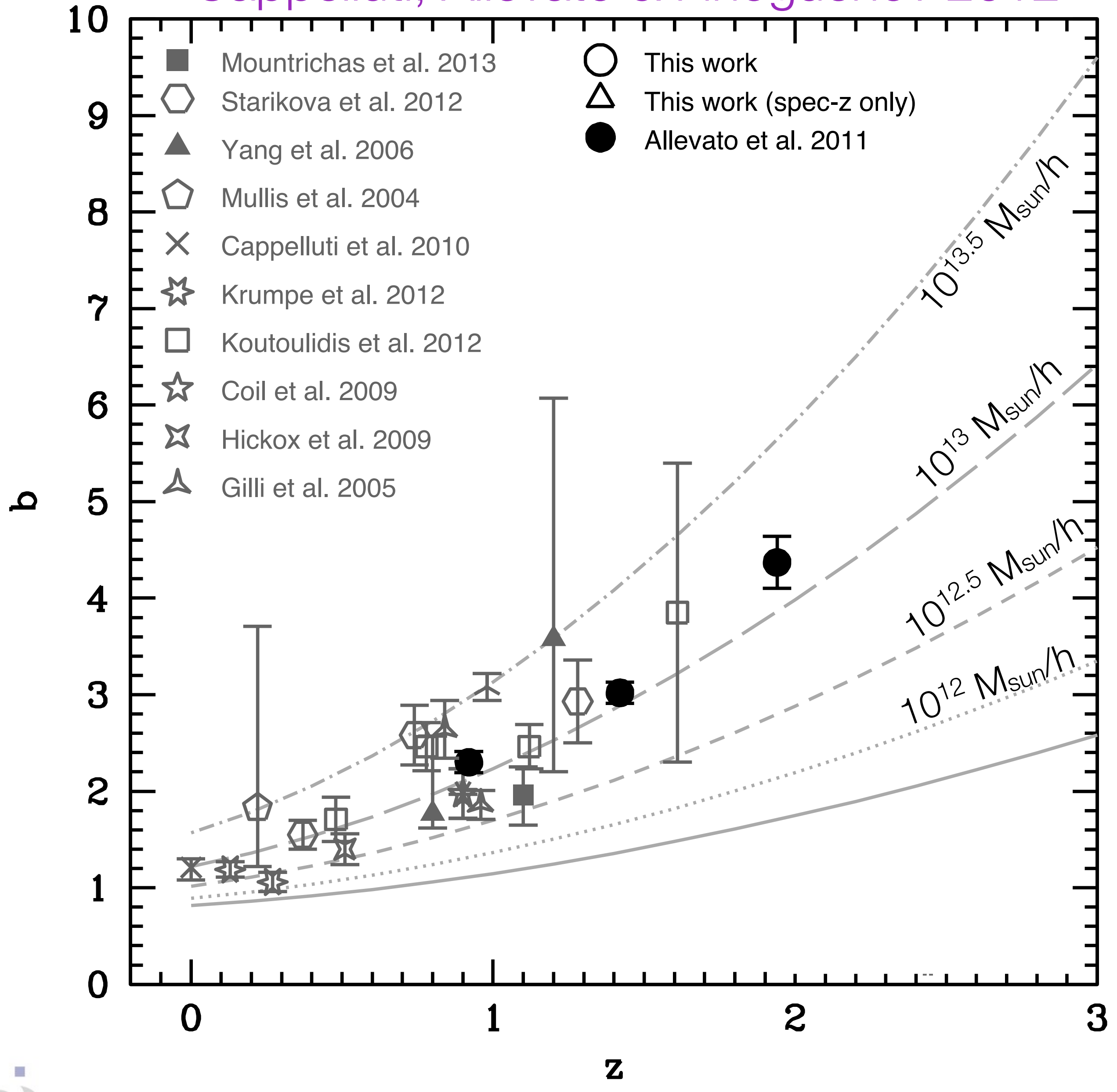
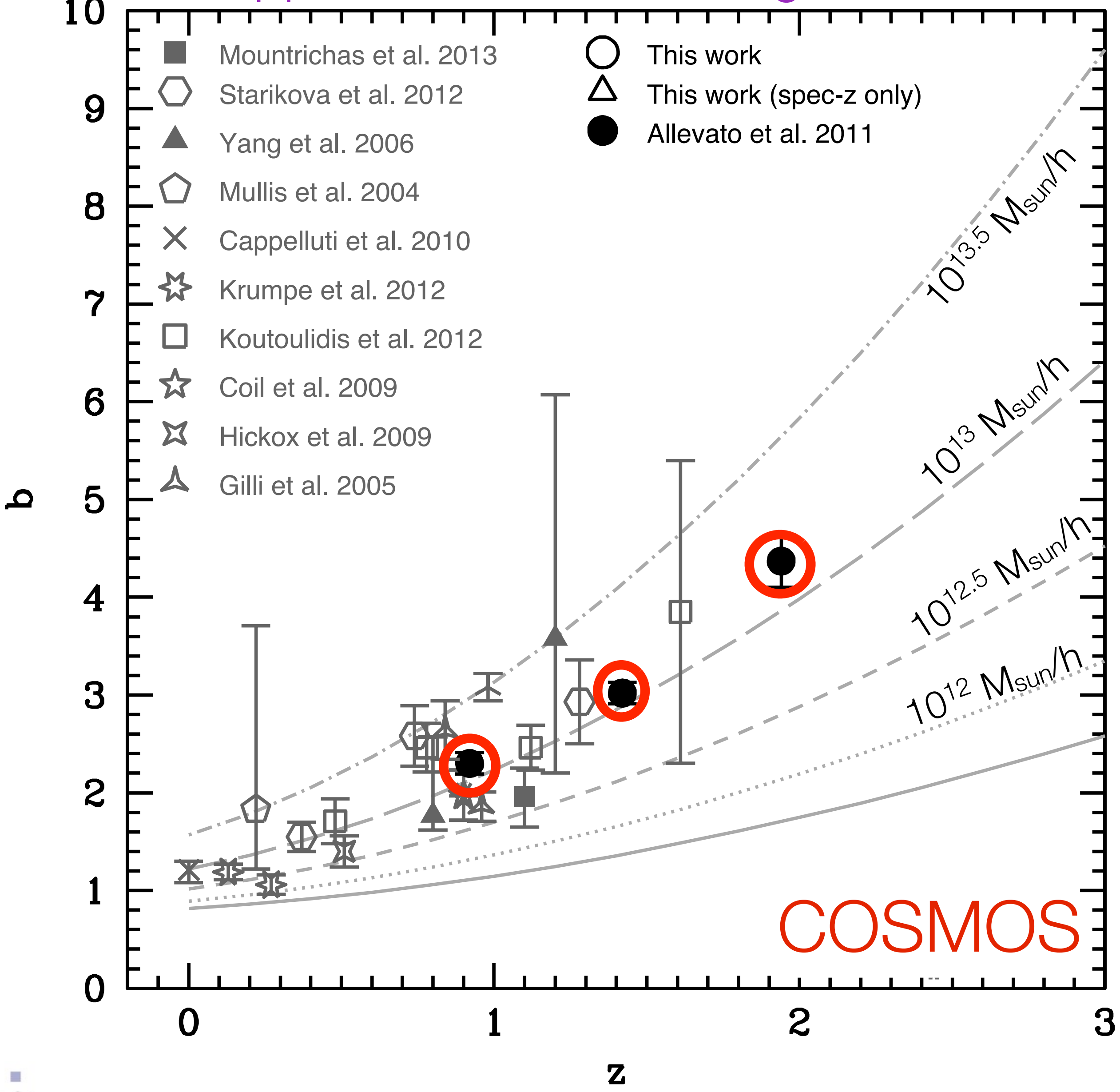


- X-ray AGN are from square-degree scale surveys sampling moderate luminosity **$\log L_{bol}$~44-46 erg/s**

Clustering of X-ray AGNs

Cappelluti, Allevato & Finoguenov 2012



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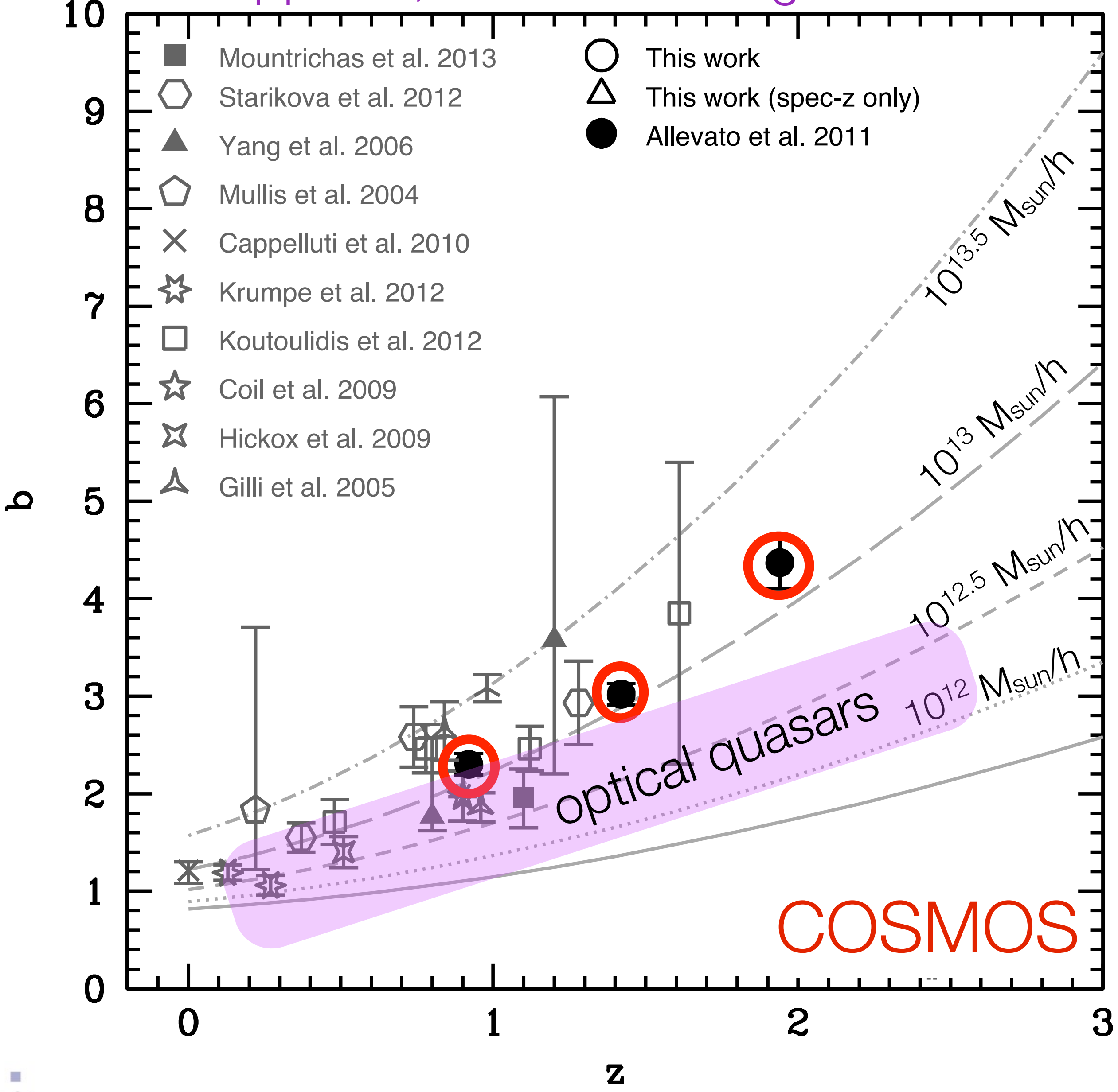
- **COSMOS-AGNs** reside in DMHs with **typical mass of ~ 10^{13} M_{sun}/h up to z=2** Allevato et al. 2011

Clustering of X-ray AGNs



Cappelluti, Allevato & Finoguenov 2012

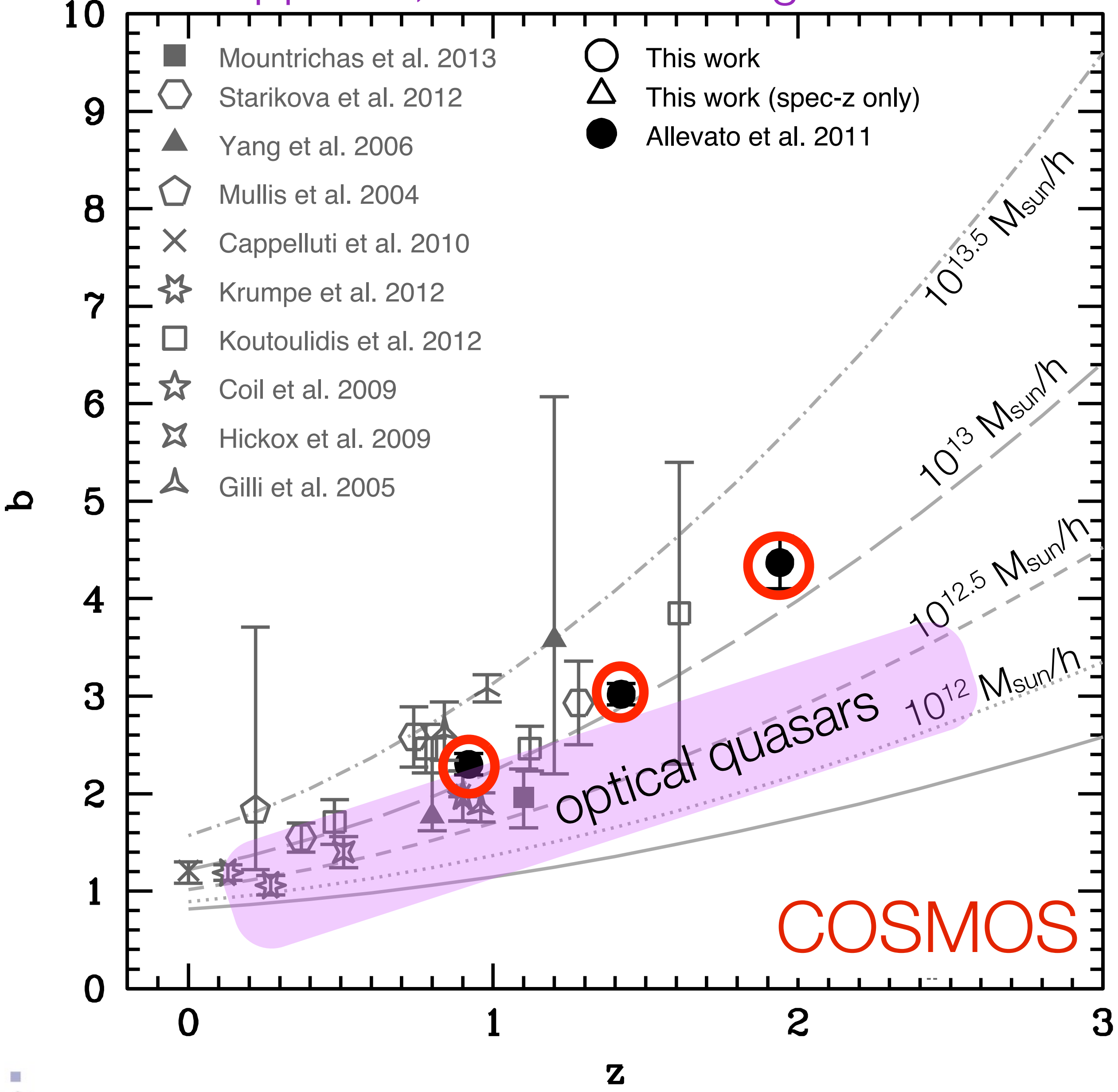
- X-ray AGN are from square-degree scale surveys sampling moderate luminosity **$\log L_{bol} \sim 44\text{-}46$ erg/s**

- **COSMOS-AGNs** reside in DMHs with **typical mass of ~ 10^{13} M_{sun}/h up to z=2** Allevato et al. 2011

- **Luminous quasars $\log L_{bol} > 46$ erg/s** reside in DMHs with typical mass of ~ **12-12.5 M_{sun}/h** up to z = 2-3
  e.g. Croom et al. 2005, 2009, Da Angela et al. 2005, 2008, Shen et al. 2008, Ross et al. 2009

Clustering of X-ray AGNs

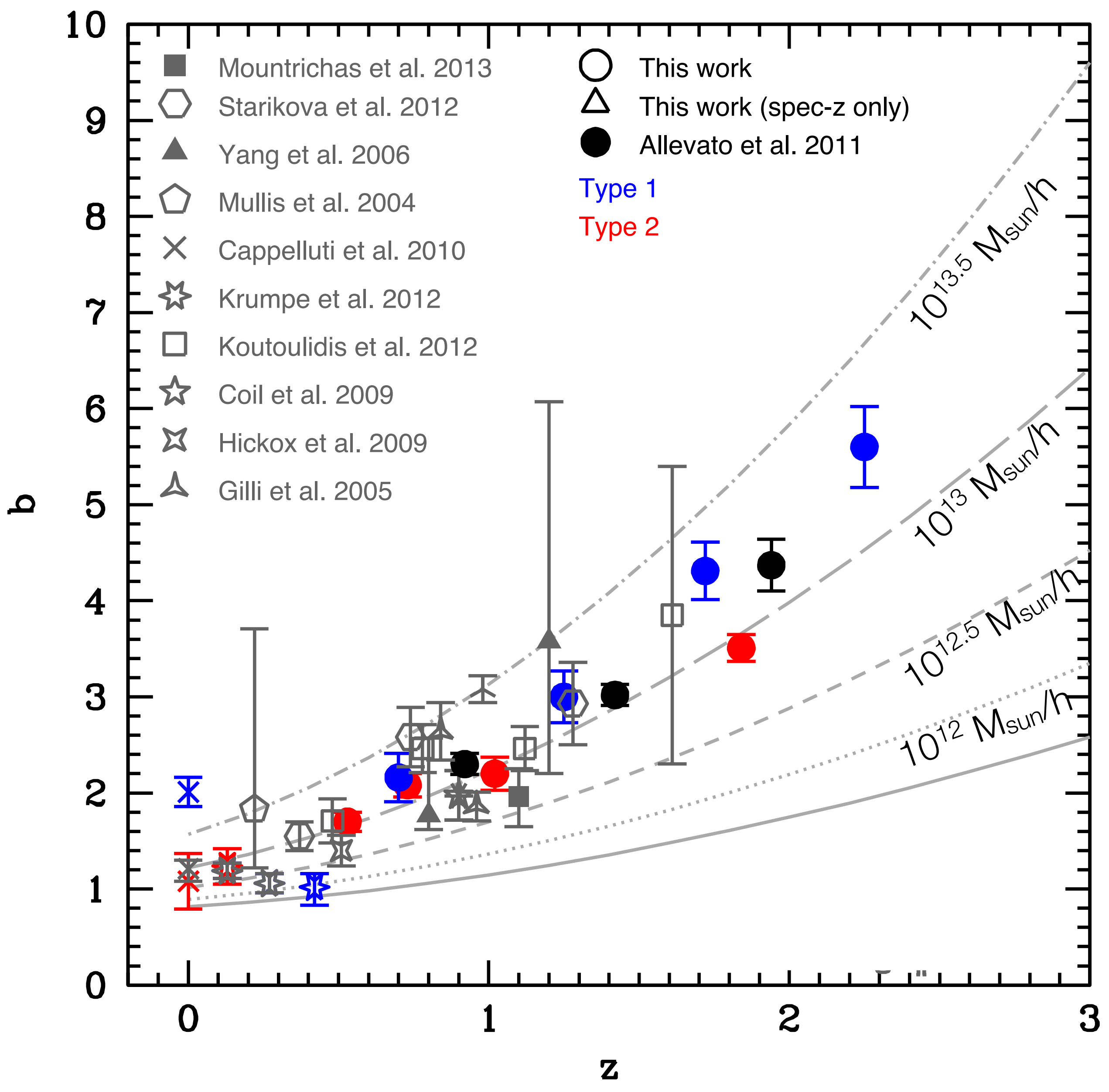
Cappelluti, Allevato & Finoguenov 2012



This difference in halo mass is interpreted as evidence against cold gas accretion via major mergers in X-ray AGNs and/or as support for multiple modes of BH accretions.

Allevato et al. 2011, Fanidakis et al. 2013, Mountrichas & Georgakakis 2012

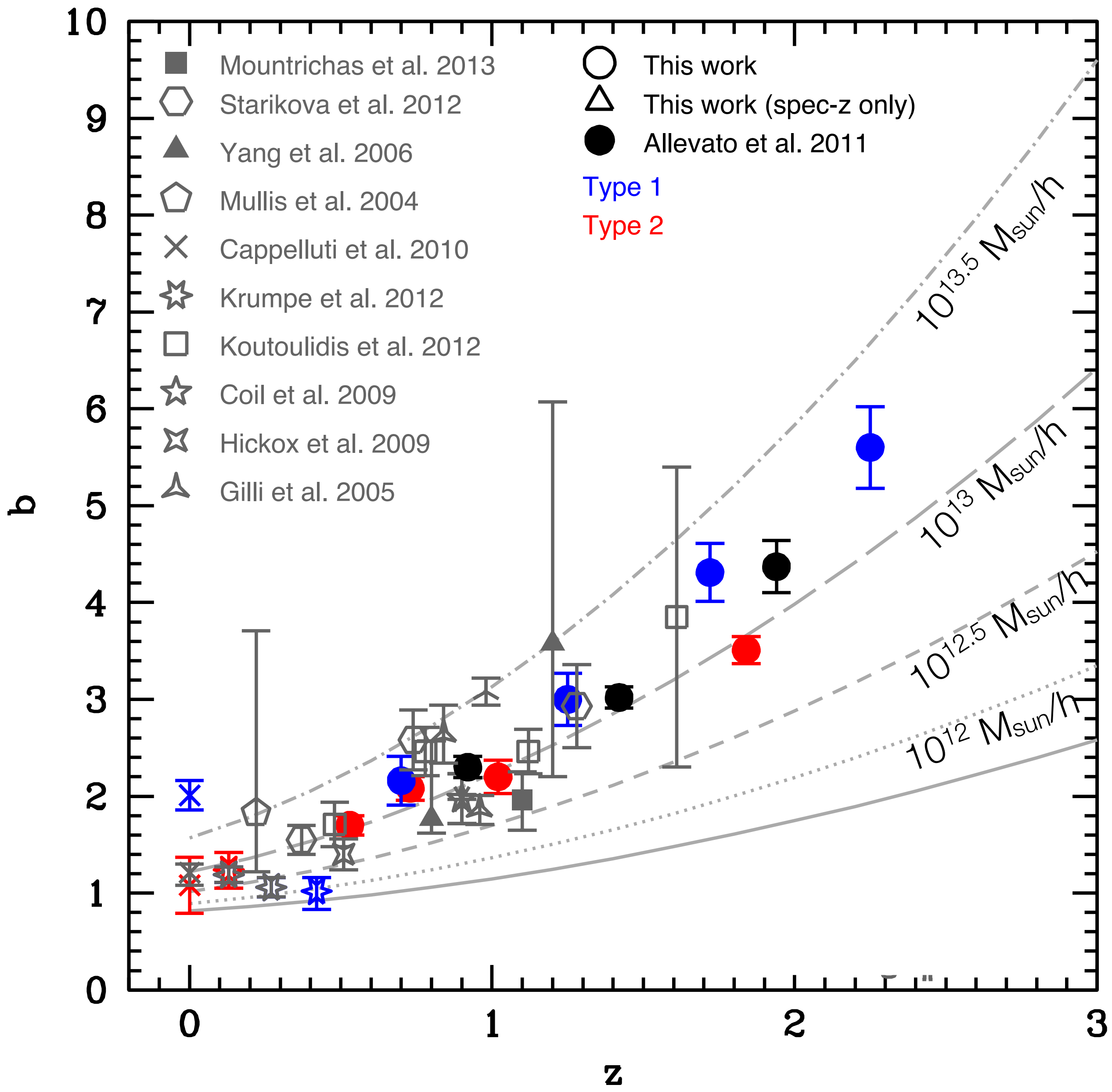
Type 1 & 2 AGNs



- Type 2 **AGNs** cluster less than Type 1 AGNs Cappelluti et al. 2010, Allevato et al. 2011

- Type 1 and Type 2 AGNs cluster similarly Gandhi et al. 2006, Gilli et al. 2009, Krumpe et al. 2012

Type 1 & 2 AGNs



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AGN unification models

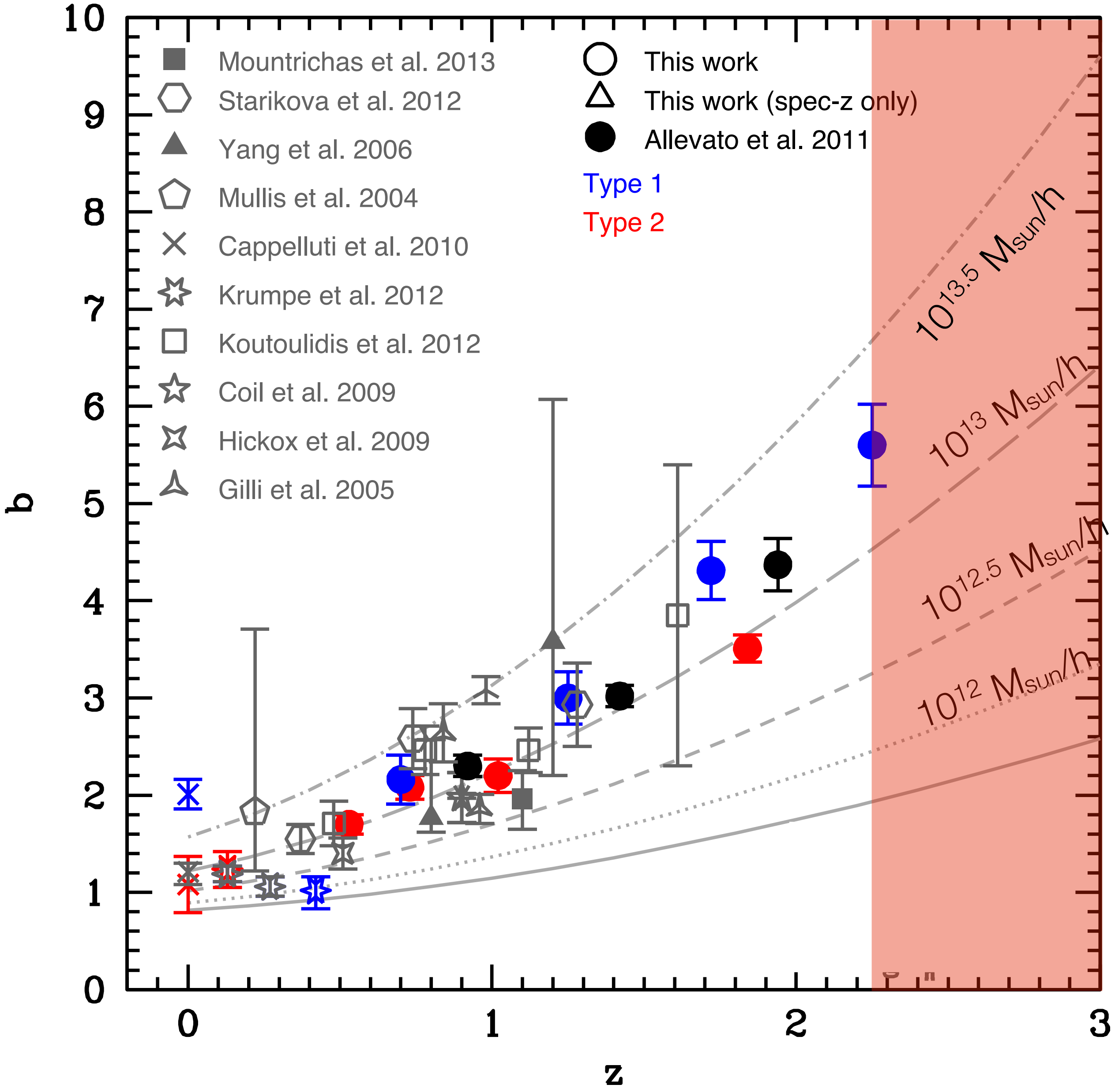
no difference in the clustering

vs

Evolutionary models

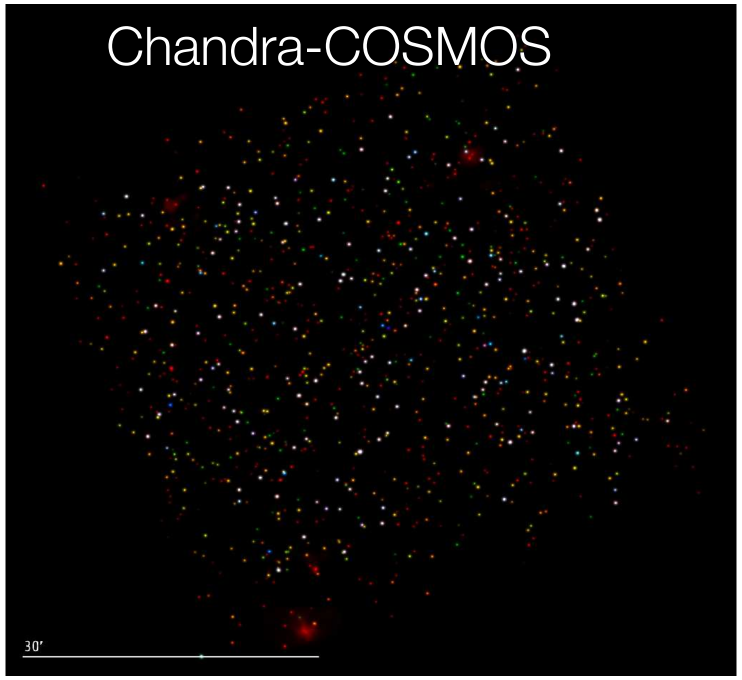
possible difference in the clustering

z > 2



- At z > 2 the clustering is poorly investigated and the bias known with large uncertainty;
- Can we extend the results to z >2 ?

COSMOS field



Chandra Catalog

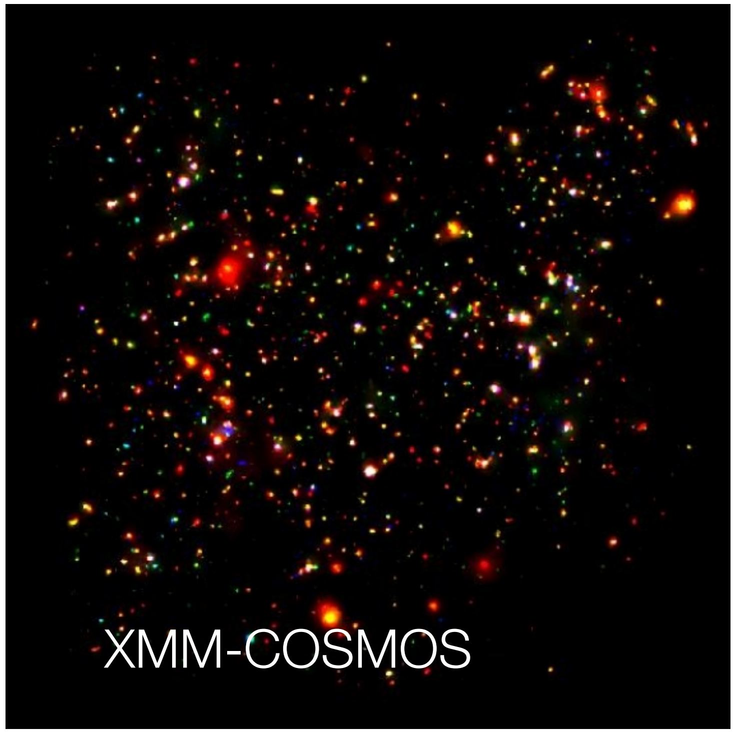
Civano et al. 2012, Elvis et al. 2009, Puccetti et al. 2009

- 0.92 $\deg^2$
- 1761 point-like sources
- spec-zs for ~60% of the sources
- phot-zs for ~96% of the sources Salvato et al. 2011

XMM Catalog

Brusa et al. 2010, Hasinger et al. 2007, Cappelluti et al 2009

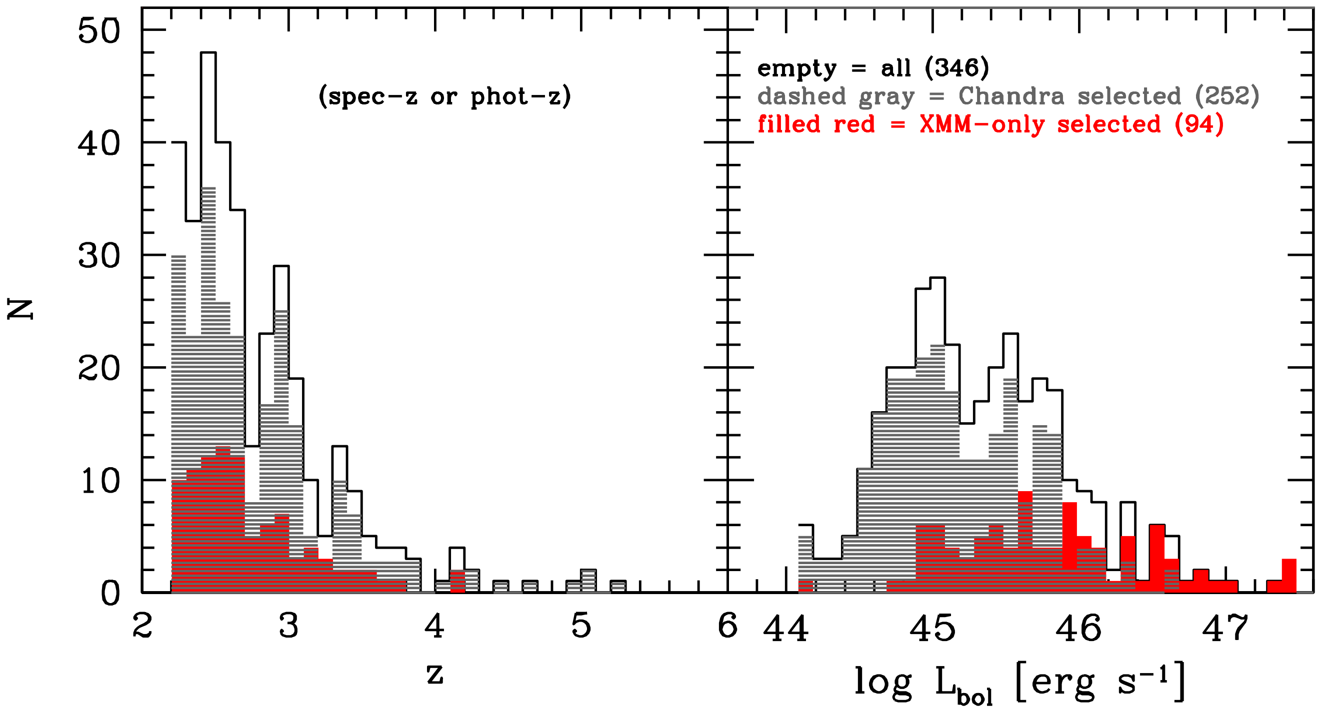
- 2.13 $\deg^2$
- 1822 point-like sources
- spec-zs for ~50% of the sources
- phot-zs for all the sources Salvato et al. 2009



COSMOS AGNs at z>2.2

- Chandra-XMM COSMOS:

- 346 AGNs
- spec or phot-z > 2.2 , ⟨**z**⟩ **= 2.9**
- **log⟨L$_{\mathbf{bol}}$⟩ = 45.32** erg/s Lusso et al. 2012



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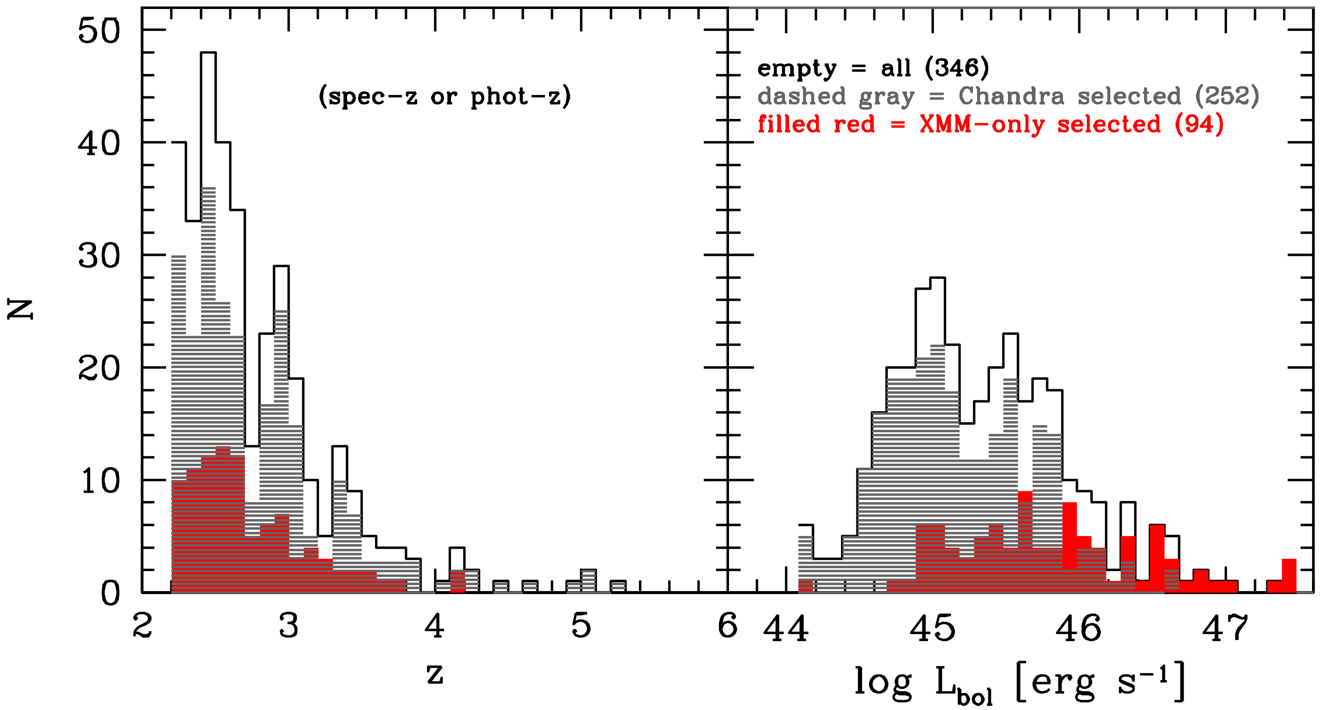
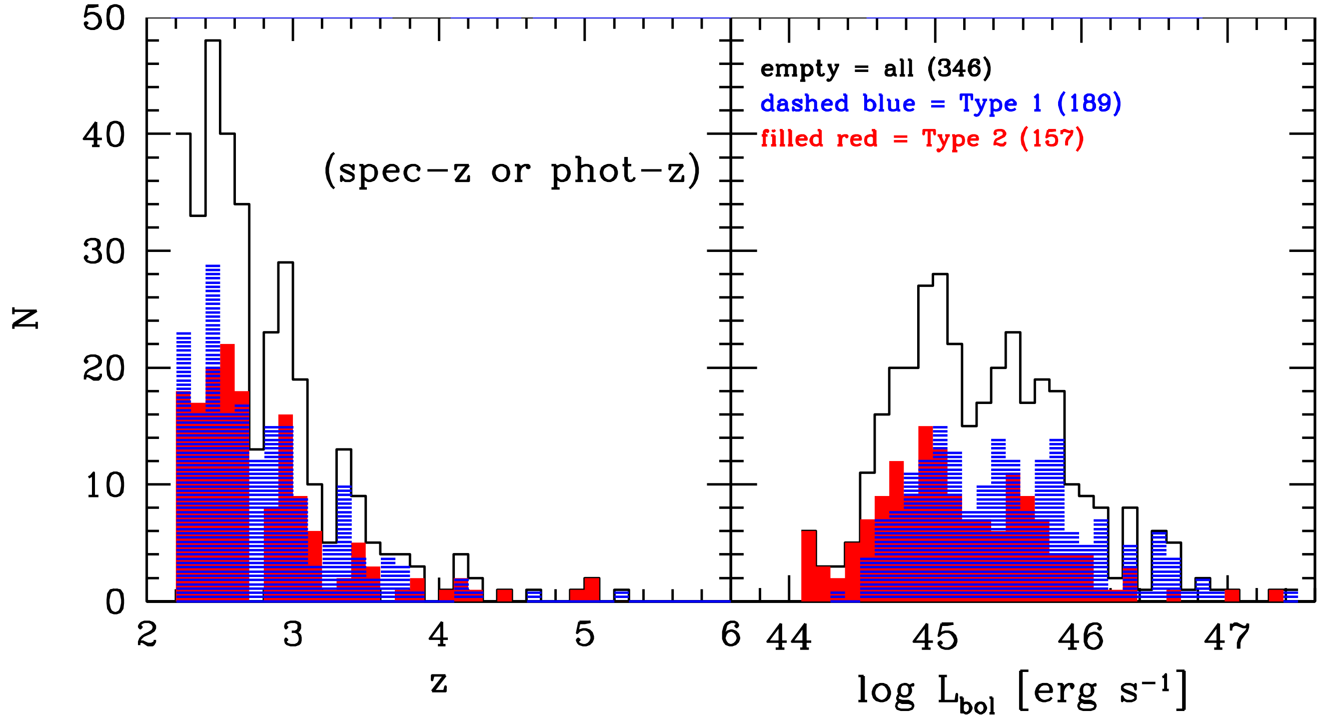




- Type 1

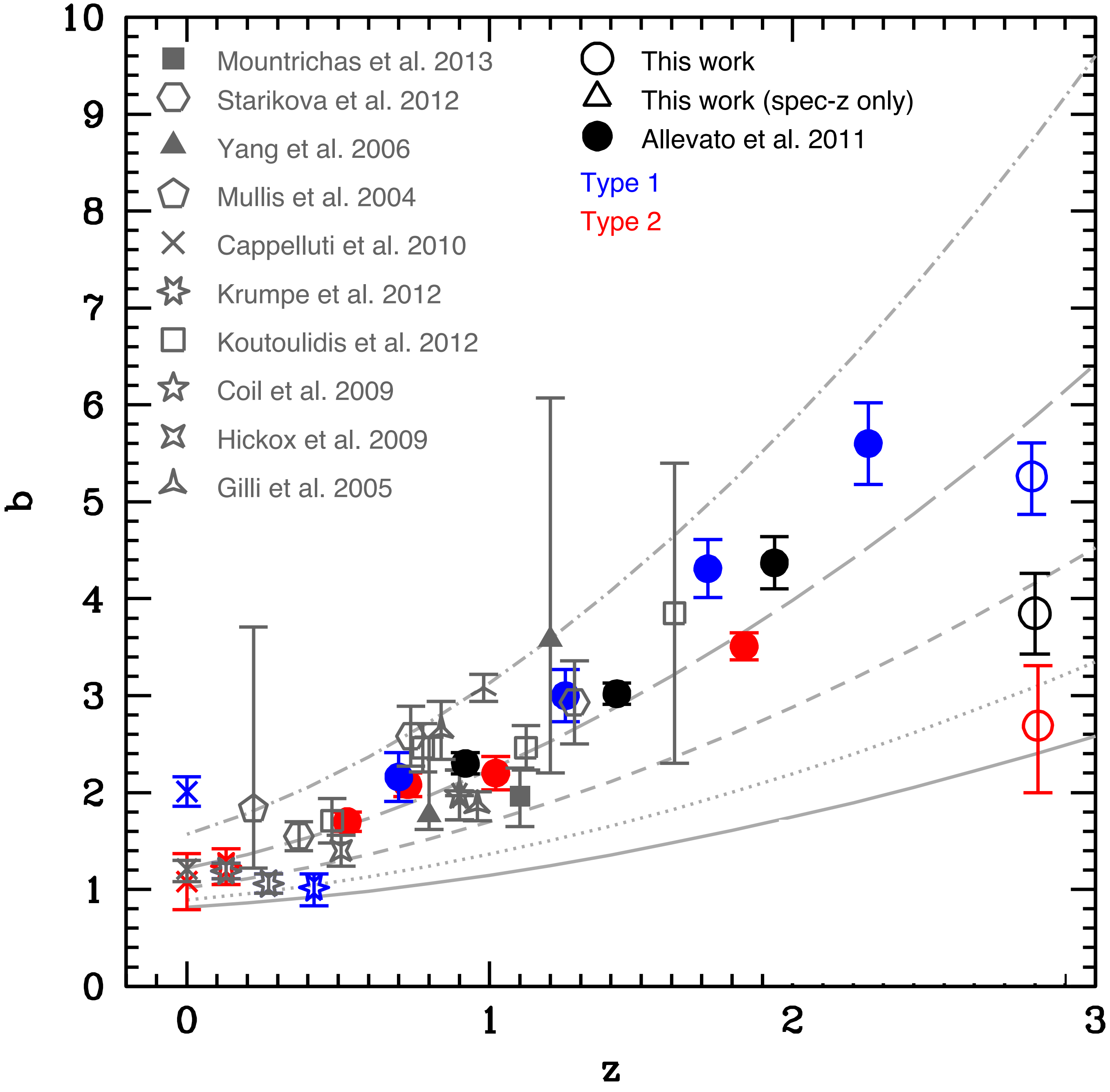
  log$\langle \mathbf{L_{bol}} \rangle$ **= 45.47** erg/s

- Type 2

  log$\langle \mathbf{L_{bol}} \rangle$ **= 45.15** erg/s

Redshift evolution of the bias

Allevato et al. 2014

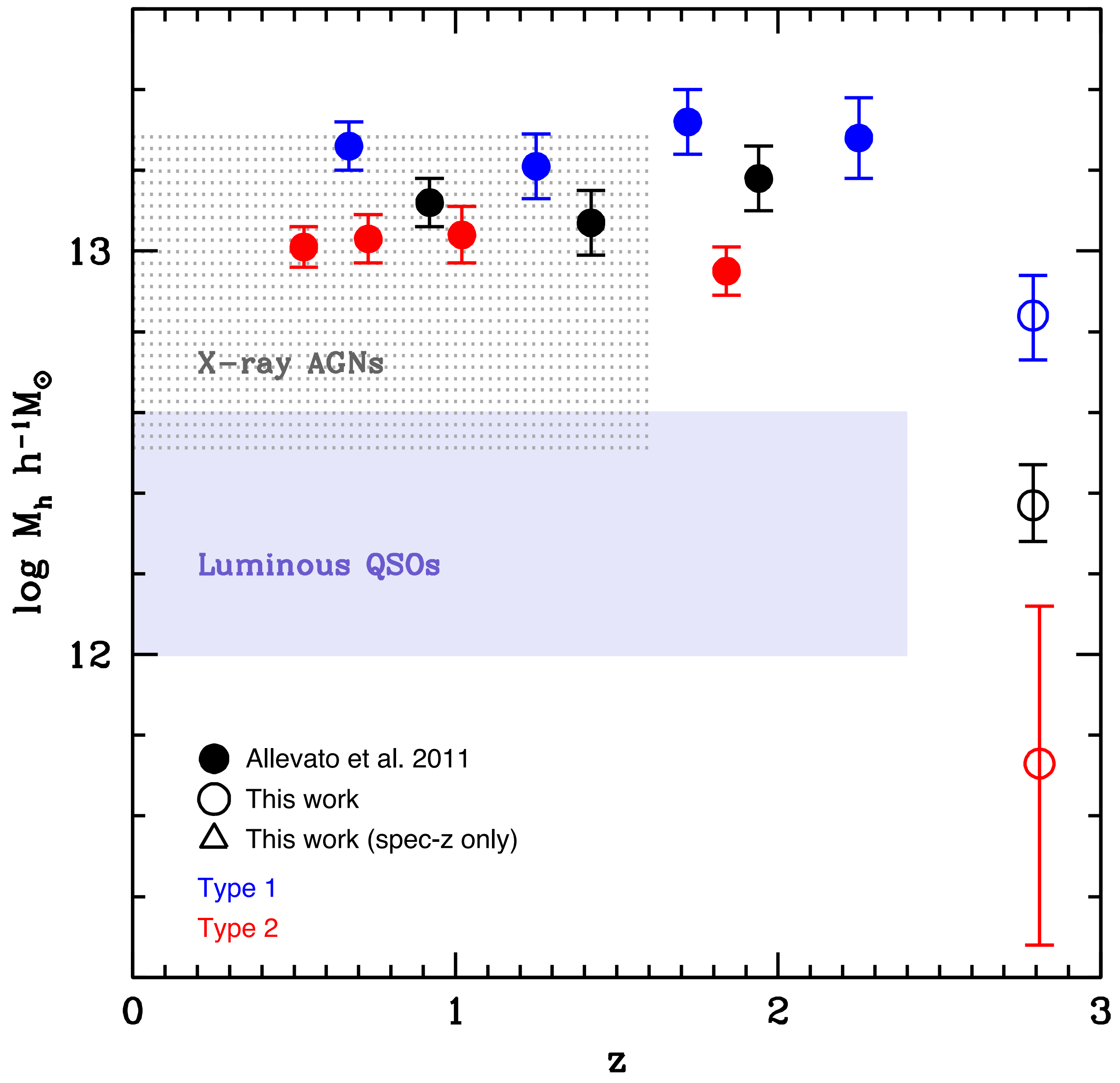


b	$\log M_h$ $h^{-1}M_\odot$
$3.85^{+0.21}_{-0.22}$	$12.37^{+0.10}_{-0.09}$

b	$\log M_h$ $h^{-1}M_\odot$
$5.26^{+0.35}_{-0.39}$	$12.84^{+0.10}_{-0.11}$
$2.69^{+0.62}_{-0.69}$	$11.73^{+0.39}_{-0.45}$

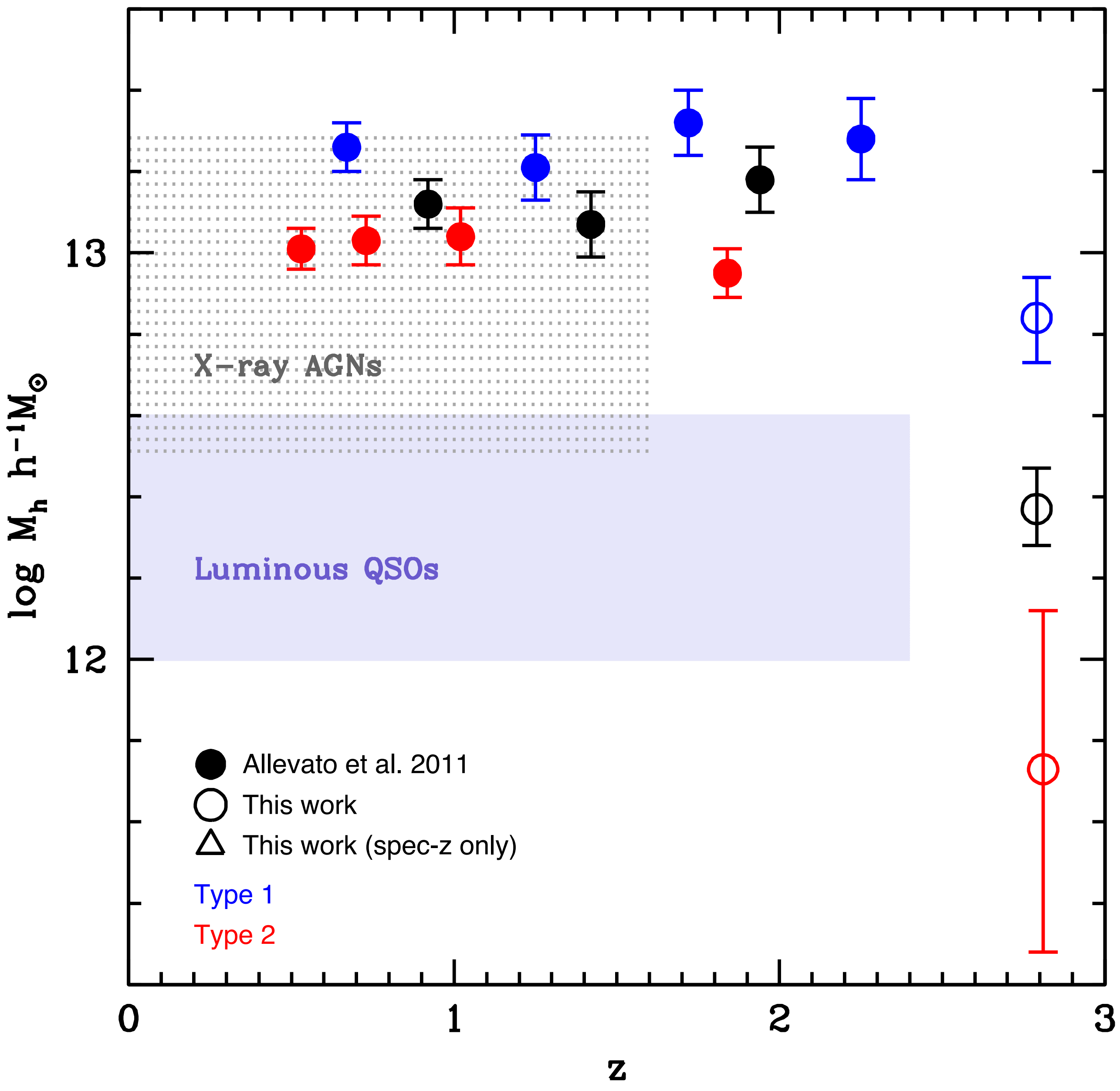
Redshift evolution of the bias

Allevato et al. 2014



- At z<2 the **bias** of moderate luminosity AGNs **increases with z tracing a constant group-sized halo mass up to z~2;**

Redshift evolution of the bias

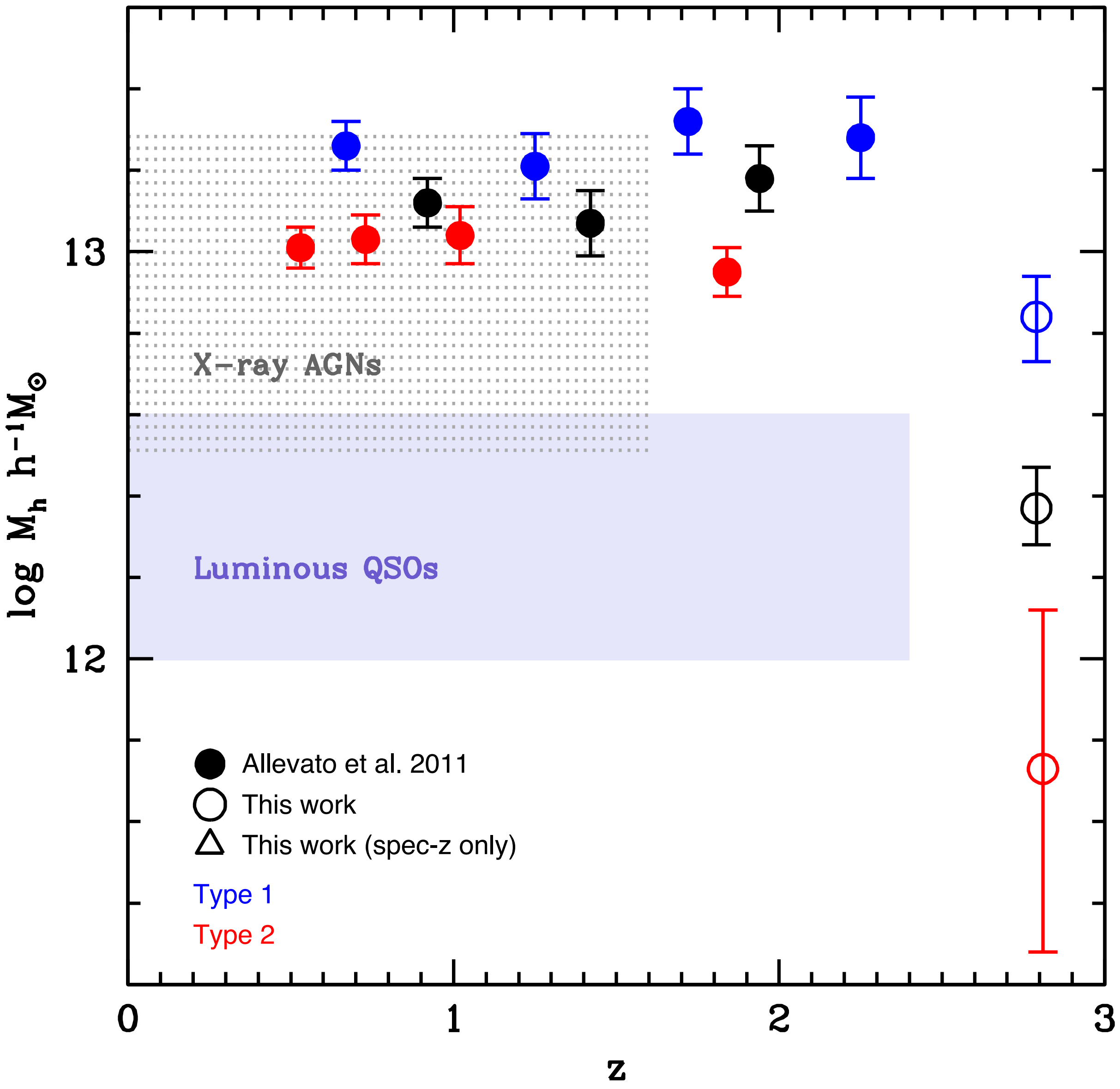


Allevato et al. 2014

- At z<2 the **bias** of moderate luminosity AGNs **increases with z tracing a constant group-sized halo mass up to z~2;**
- At z~3 **we observe a drop in the hosting halo mass** of Type 1 and 2 AGN compared to z<2 XMM-COSMOS AGN with similar luminosities;

Why do we observe a drop?

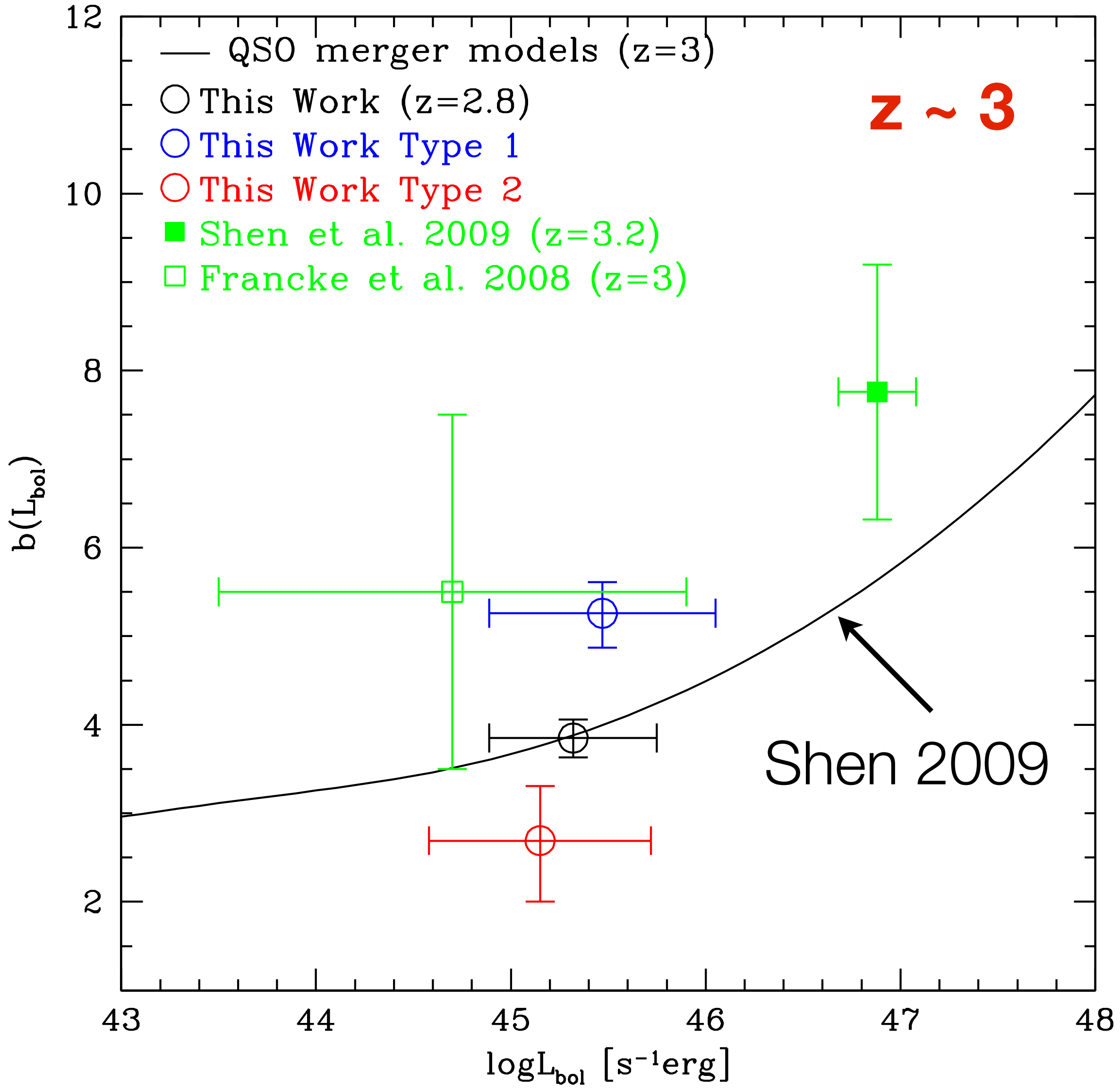
Allevato et al. 2014



- Progressive drop in the abundance of massive and rarer host halos at high redshift;
- Mapping of moderate luminosity AGN in progressively less massive halos (e.g. White et al. 2008, Shankar et al. 2010)

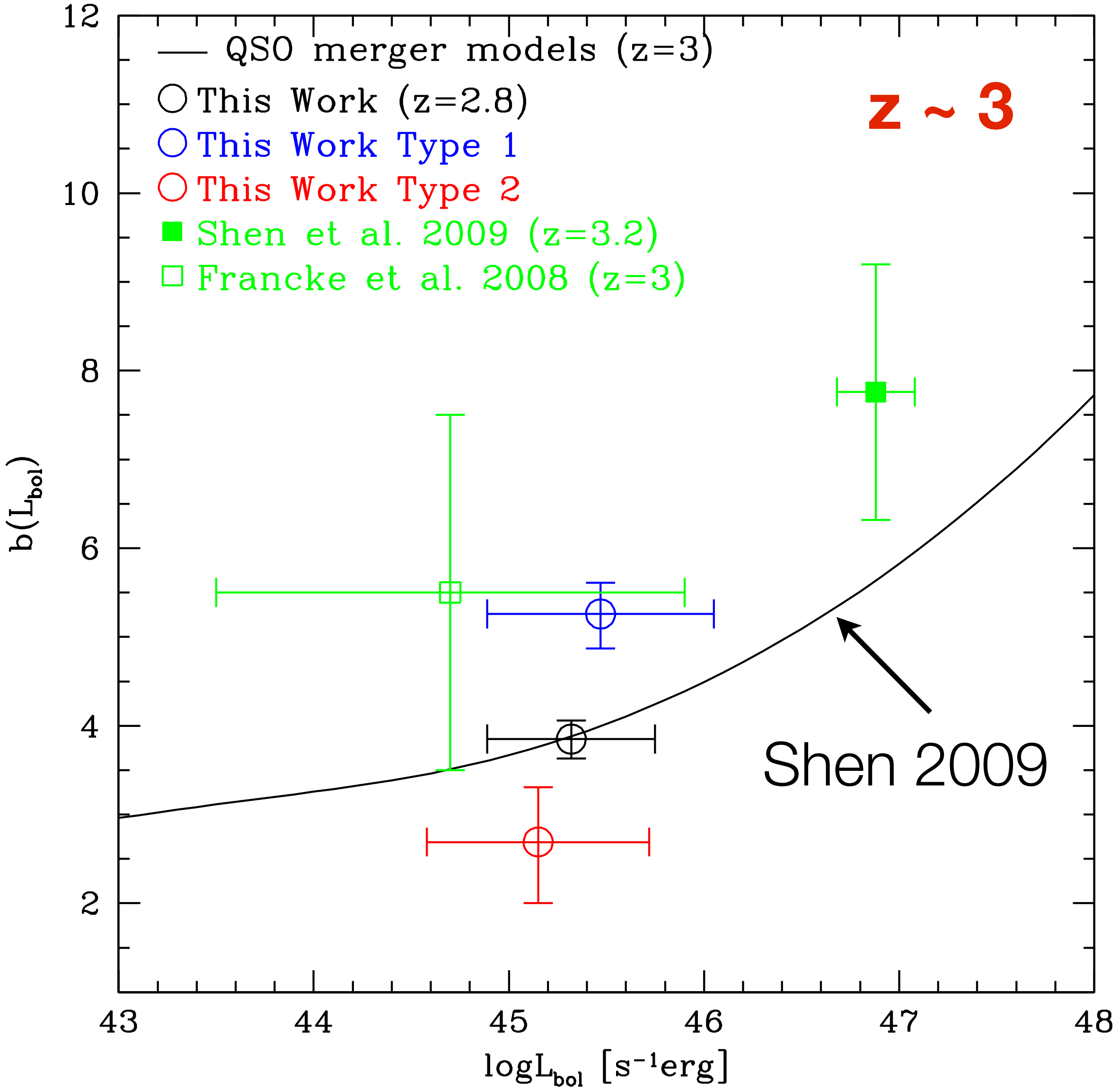
Major Mergers at z ~ 3

Allevato et al. 2014



Major Mergers at z ~ 3

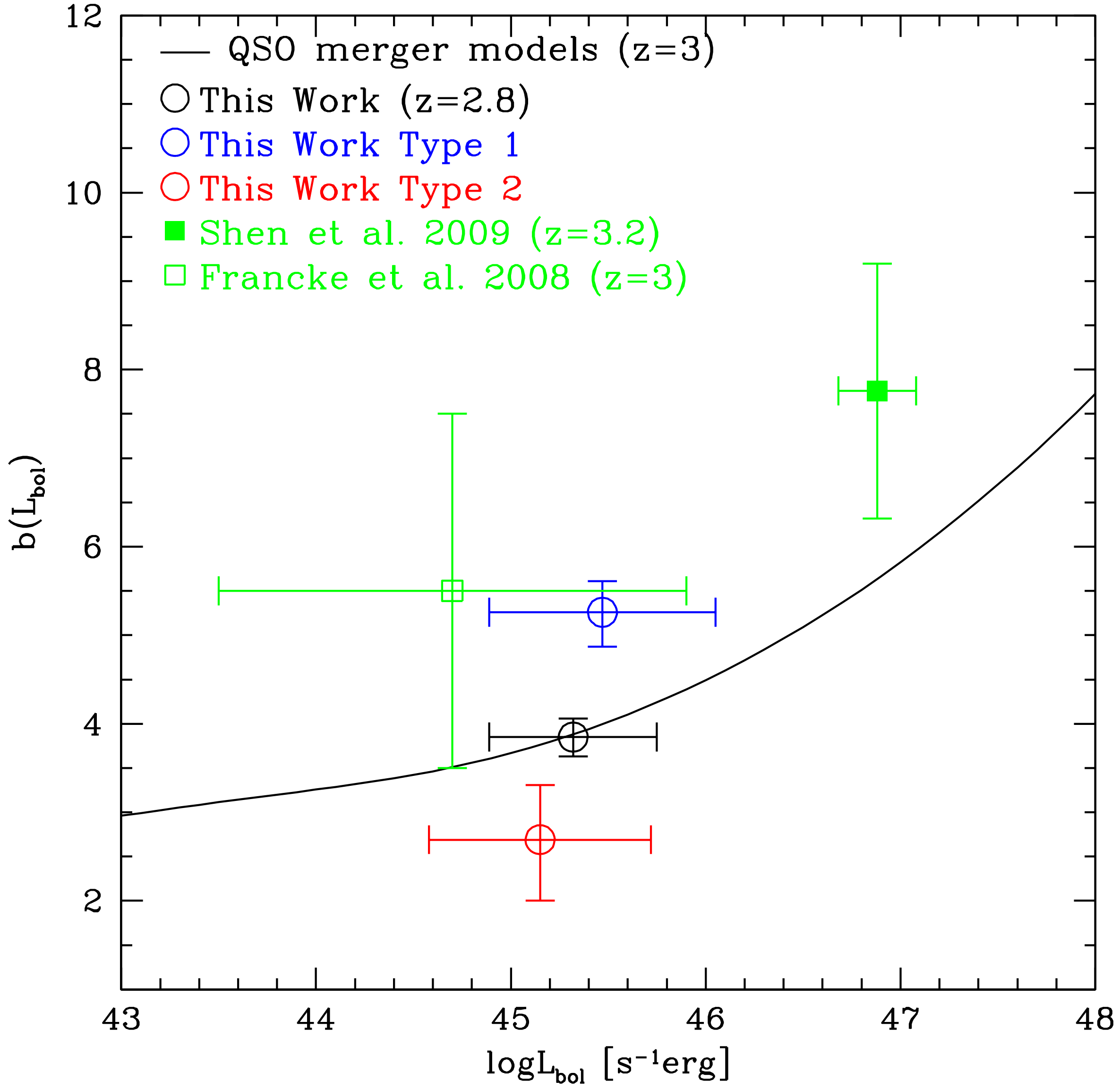
Allevato et al. 2014



- **Major merger model naturally reproduces the bias** of moderate luminosity COSMOS AGNs at z~3;
- **The evolution of the bias** traced by the data points marginally **confirms the luminosity-dependent bias predicted by major merger models**;

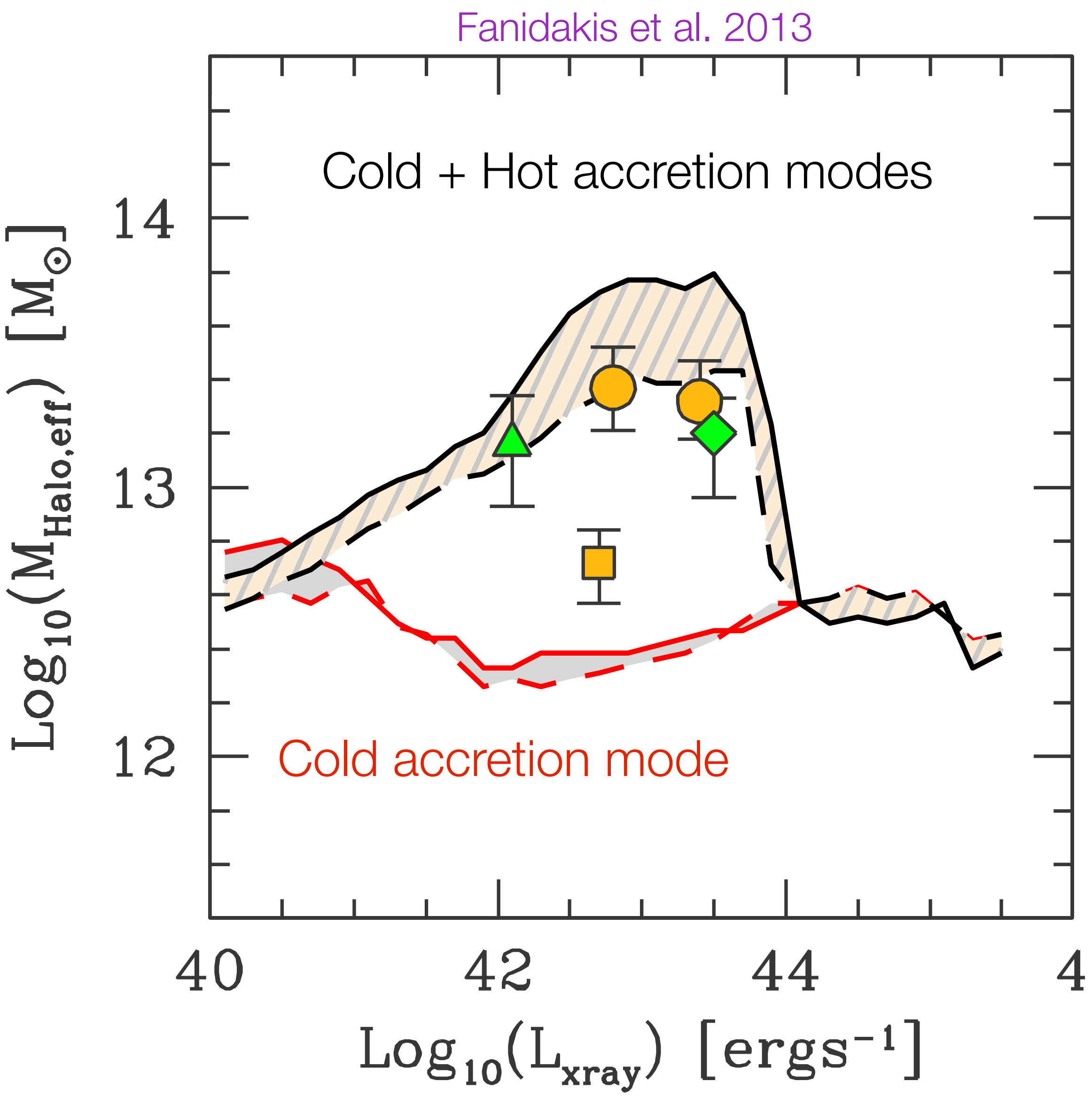
Type 1 VS Type 2 AGNs

Allevato et al. 2014

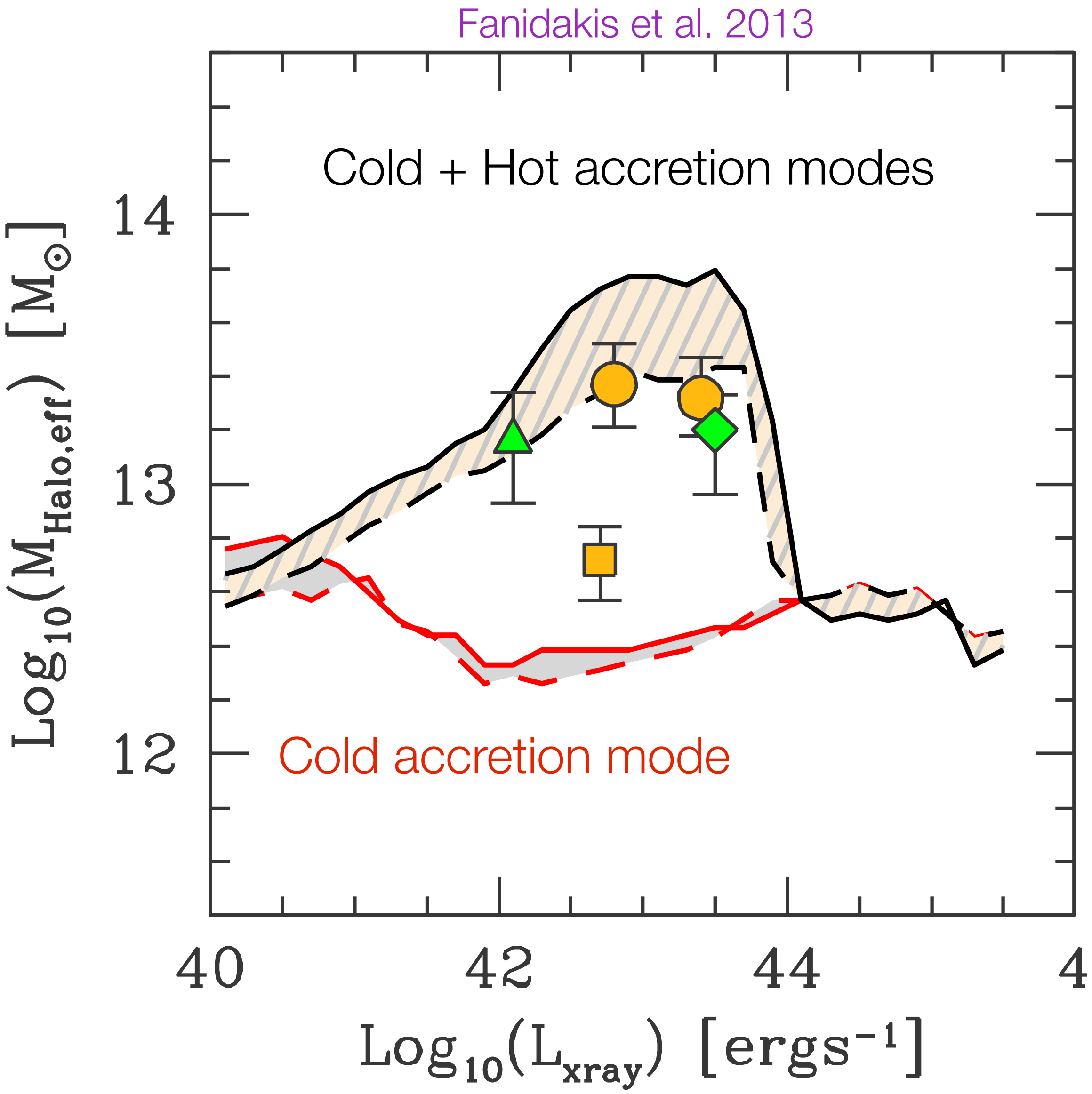


- **The difference in the bias** factor between Type 1 and 2 AGNs **can not be explained in terms of luminosity-dependent bias**;
- In terms of unified model, this result **rules out the simple picture that obscuration is purely an orientation effect;**

Major Mergers at z ~ 3



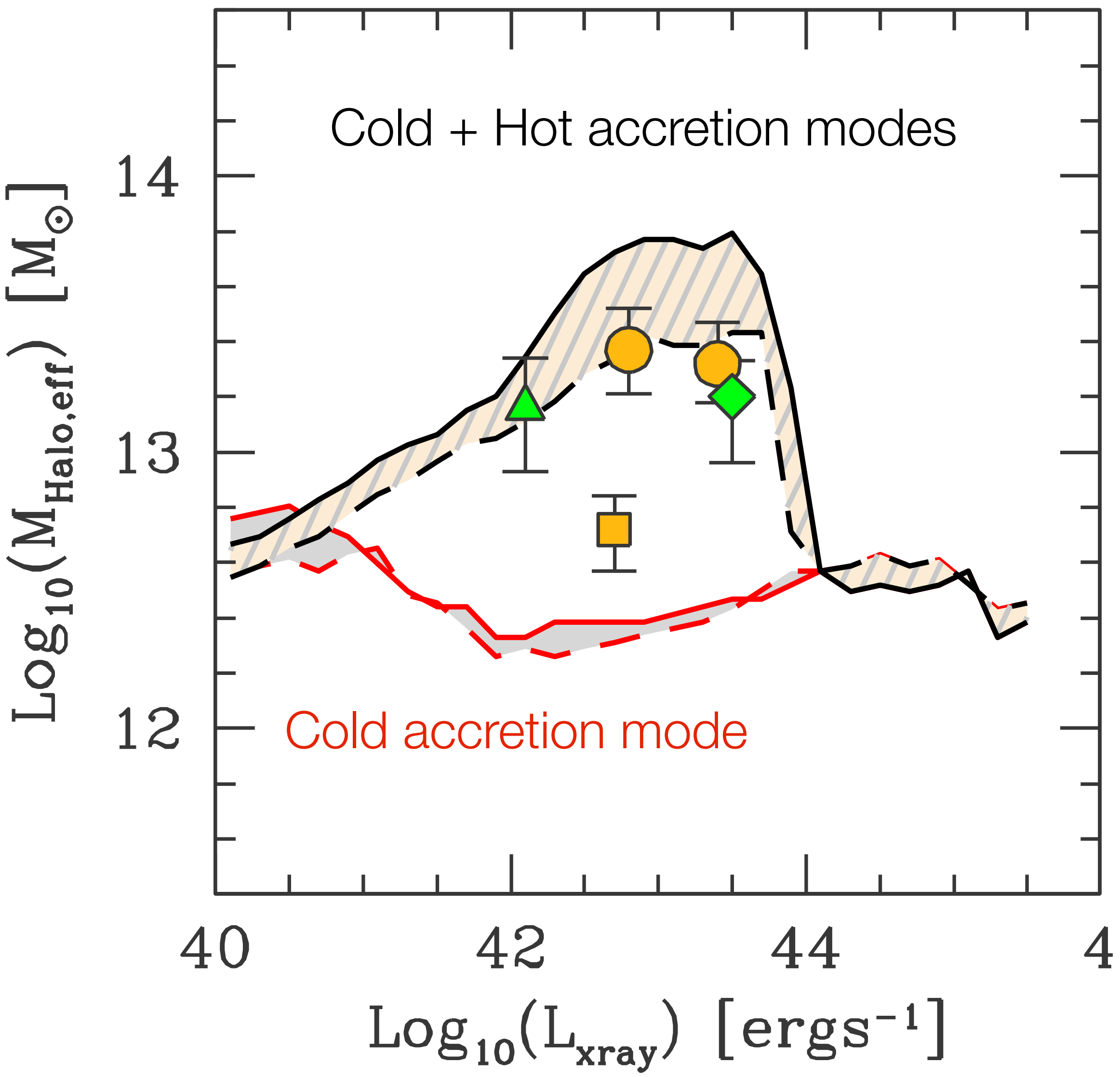
Major Mergers at z ~ 3



- **In the z~3-4 Universe**, the cold **accretion mode is solely responsible for moderate luminosity AGN**, while the AGN feedback is switched off;

Major Mergers at z ~ 3

Fanidakis et al. 2013

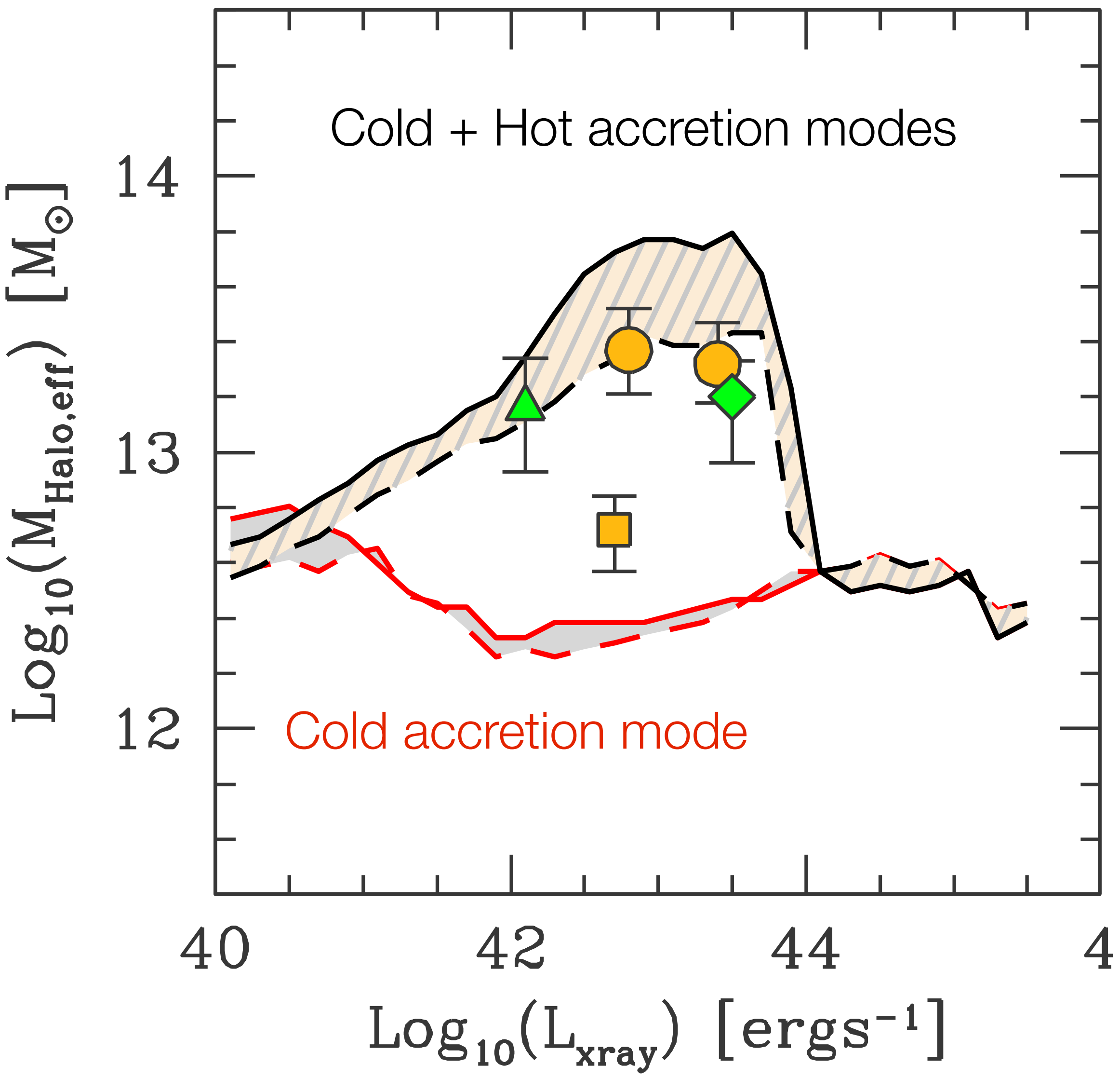


- **In the z~3-4 Universe**, the cold **accretion mode is solely responsible for moderate luminosity AGN**, while the AGN feedback is switched off;

- **At low redshifts the hot halo mode becomes prominent** in DMHs with logM>12.5 M⊙/h where the AGN feedback operates;

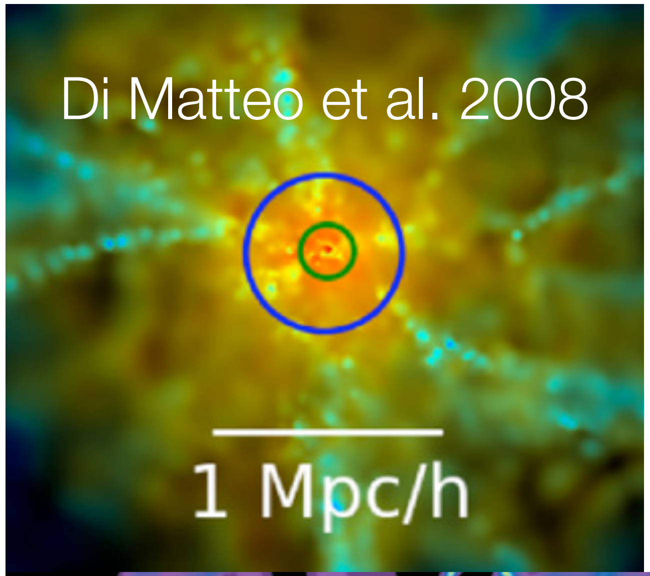
Major Mergers at z ~ 3

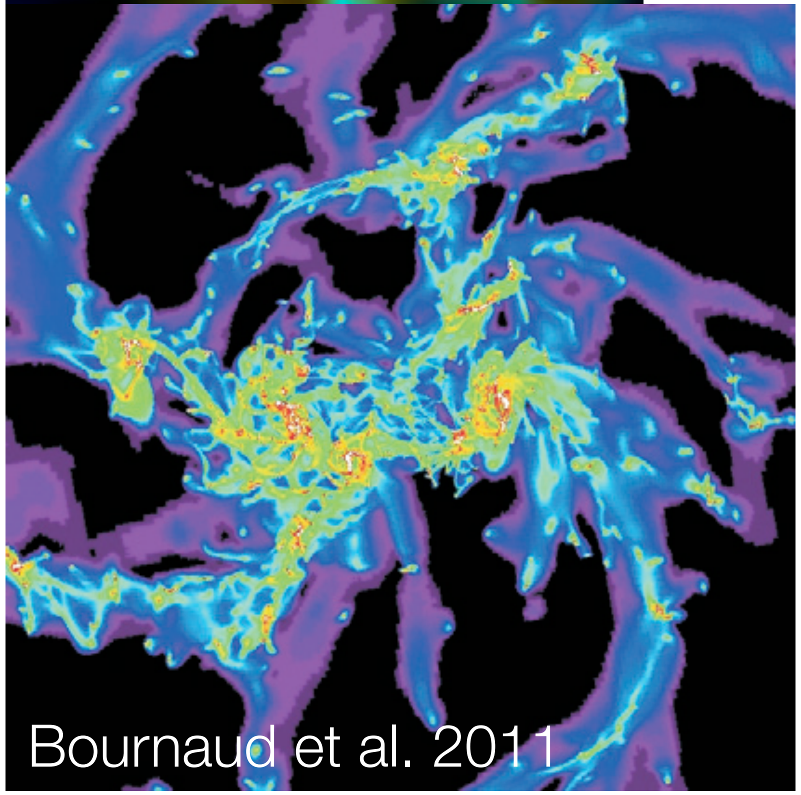
Fanidakis et al. 2013



- **In the z~3-4 Universe**, the cold **accretion mode is solely responsible for moderate luminosity AGN**, while the AGN feedback is switched off;
- **At low redshifts the hot halo mode becomes prominent** in DMHs with logM>12.5 $M_\odot$/h where the AGN feedback operates;
- Our results confirm that z~3 is the epoch when the hot-halo mode is still a negligible fuelling channel.

Fast growing BHs at z ~ 3


Di Matteo et al. 2008


Bournaud et al. 2011

✓ **An early phase of fast BH growth could be induced by cosmic flows or disk instabilities** (Dekel 2006, 2009, Di Matteo et al. 2008, Dubois et al. 2012, Bournaud et al. 2012)

- High-z disks are different from nearby spirals, with a much higher gas fraction;

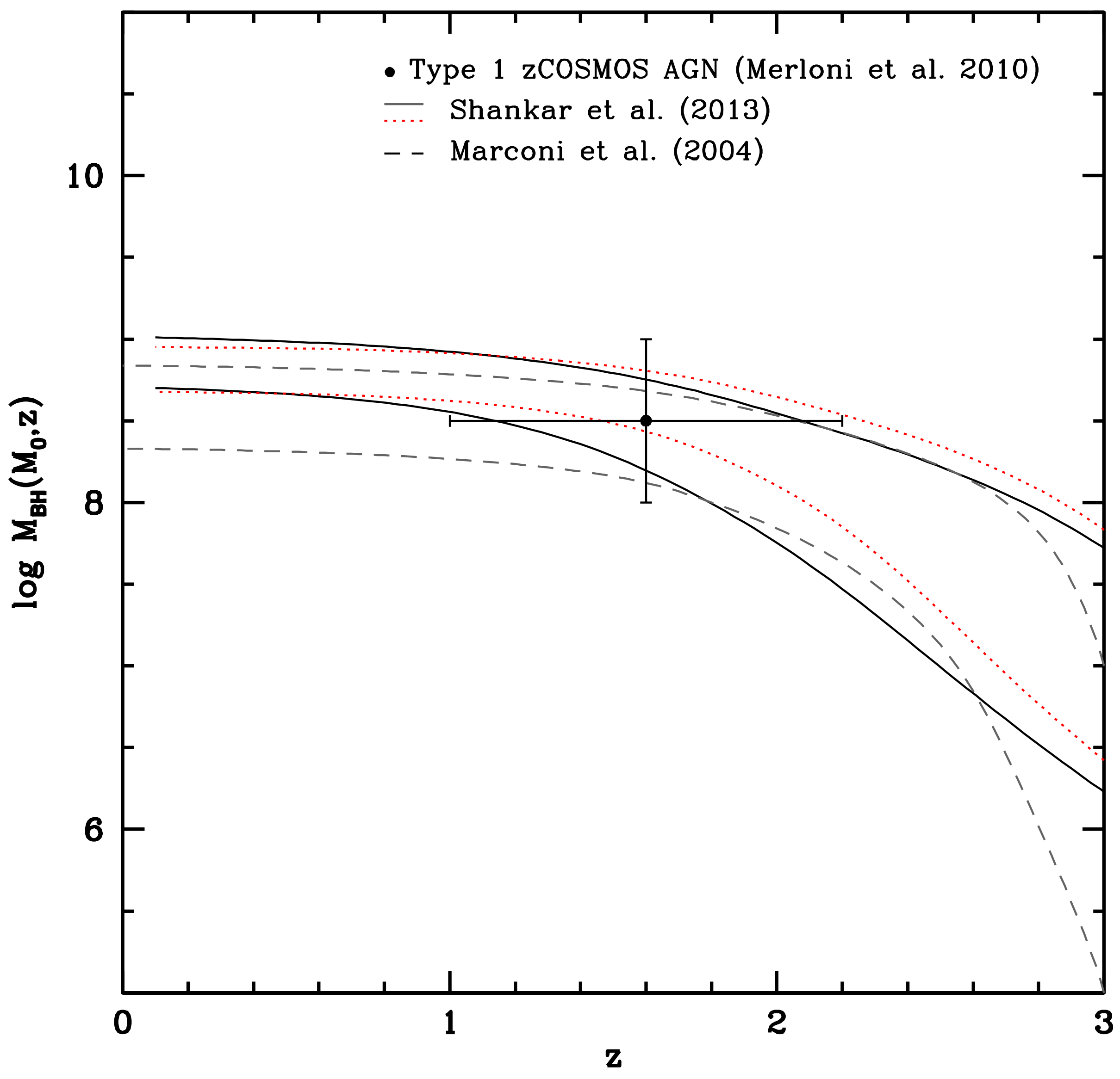
- Cold flows and disk instabilities in high-z galaxies operate on short timescales and are more efficient, producing a mass inflow similar to a major merger but spread over a longer period (high duty cycle);

Fast growing BHs at z ~ 3

z>2 is the epoch of rapid BH growth.
The duty cycle and Eddington ratio are close to unity at z ~ 3

Fast growing BHs at z ~ 3

Allevato et al. 2014



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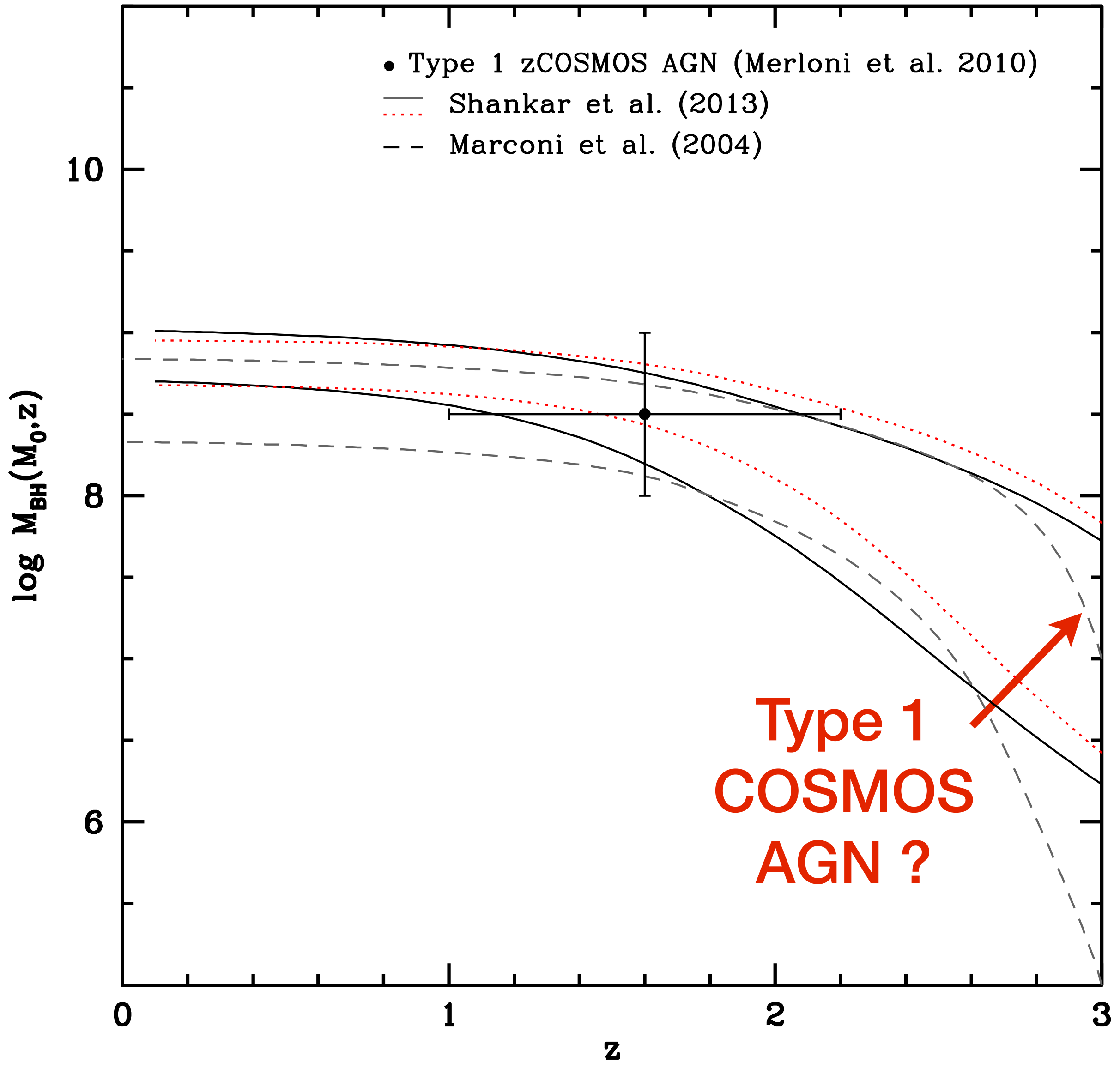
Fast growing BHs at z ~ 3

Allevato et al. 2014



Type 1 COSMOS AGN ?

z>2 is the epoch of rapid BH growth. The duty cycle and Eddington ratio are close to unity at z ~ 3

- **Type 1** COSMOS AGNs at z~3 mainly include moderate luminosity ($\log L_{bol} = 45$ erg/s) sources and are **representative of AGNs with fast growing BHs with mass of ~$10^{7\text{-}8}$ $M_\odot$;**

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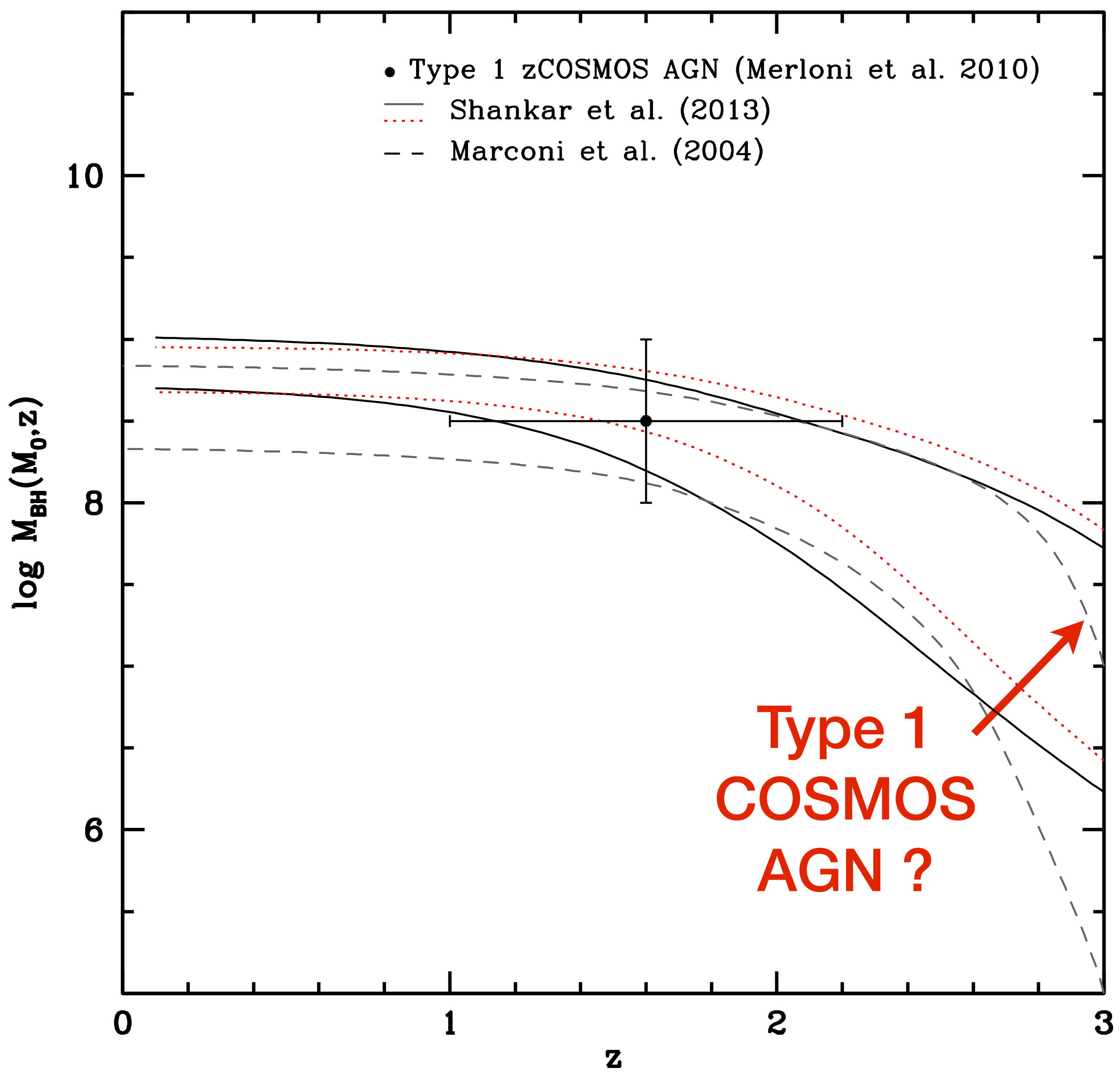
Fast growing BHs at z ~ 3

Allevato et al. 2014

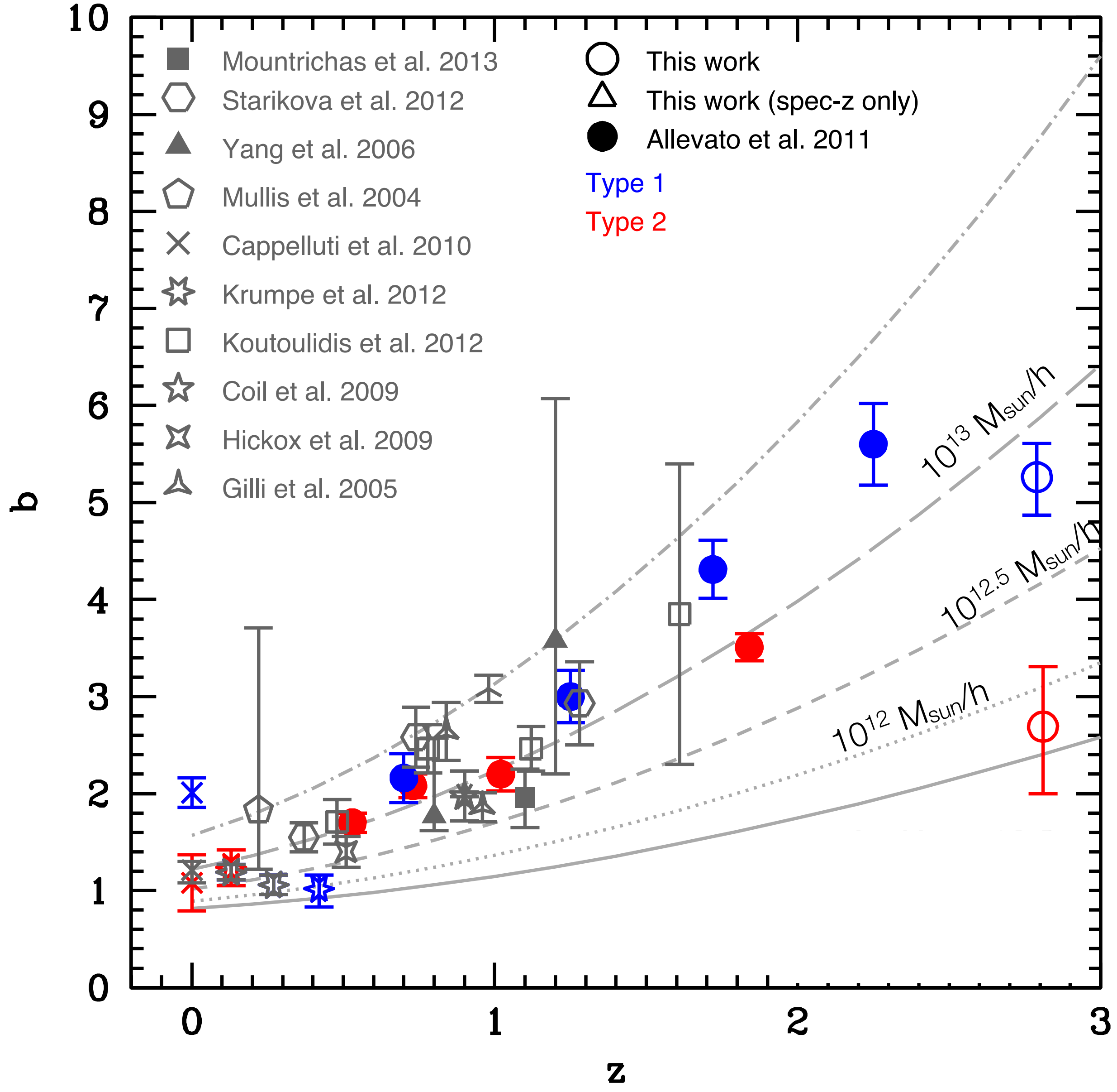


z>2 is the epoch of rapid BH growth. The duty cycle and Eddington ratio are close to unity at z ~ 3

- **Type 1** COSMOS AGNs at z~3 mainly include moderate luminosity ($\log L_{bol} = 45$ erg/s) sources and are **representative of AGNs with fast growing BHs with mass of ~10^{7-8} $M_\odot$**;
- These **fast growing BHs reside in DMHs with typical mass of ~ $10^{12.8}$ $M_\odot$/h,** which is the mass inferred for Type 1 hosting halos

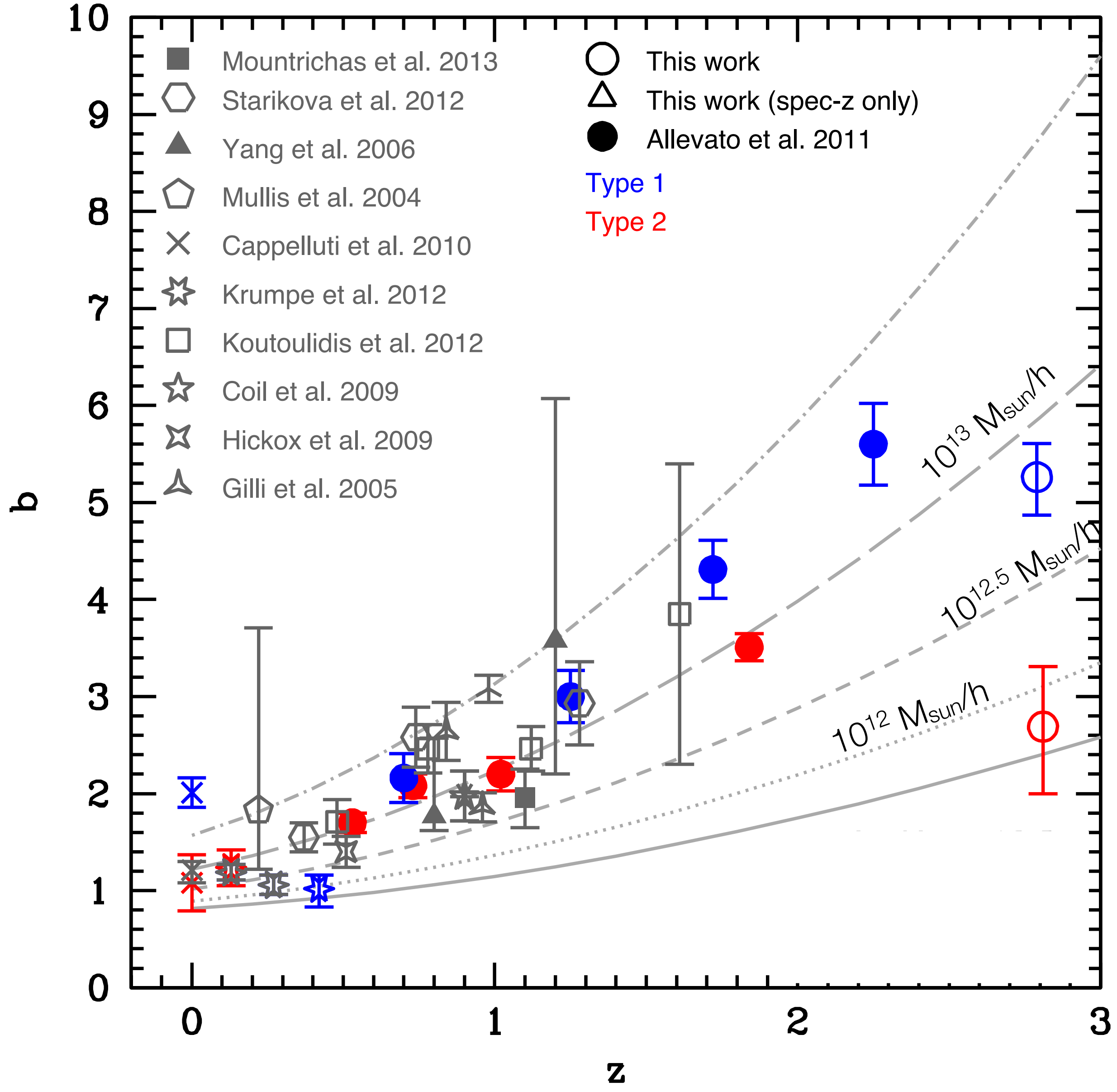
Fast growing BHs at z ~ 3

Allevato et al. 2014



Fast growing BHs at z ~ 3

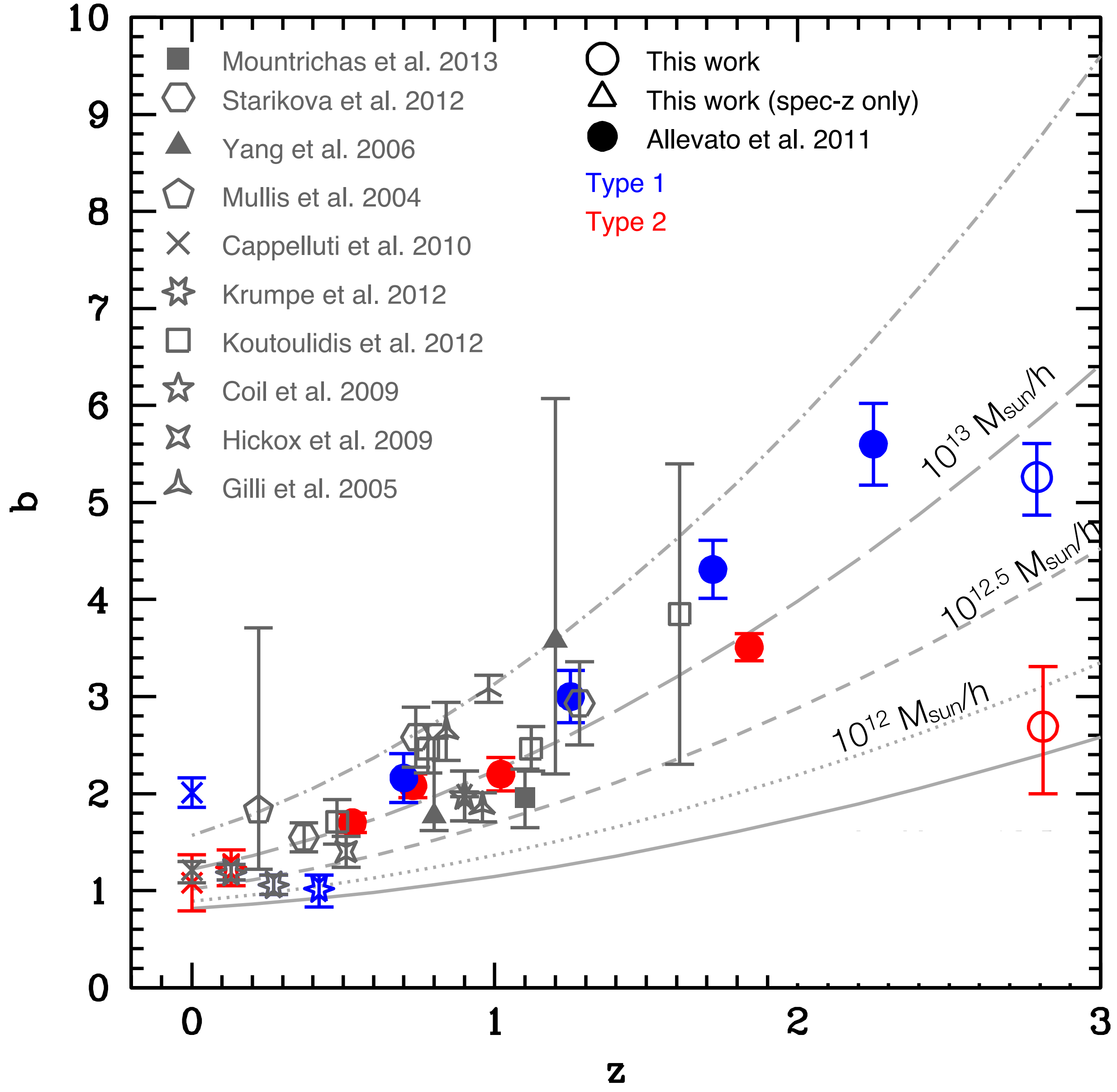
Allevato et al. 2014



- **Between z=3 and z=2, the halo and the BH mass of Type 1 AGN increases**, while the duty cycle and the Eddington ratio decline with decreasing z;

Fast growing BHs at z ~ 3

Allevato et al. 2014



- **Between z=3 and z=2, the halo and the BH mass of Type 1 AGN increases**, while the duty cycle and the Eddington ratio decline with decreasing z;

- **At z<2, the bias** of Type 1 AGN starts to **follow the constant halo mass track**;

Conclusions

- At $z \sim 3$, Type 1 and 2 **COSMOS AGNs reside in DMHs with typical mass of $10^{12.84}$ and $10^{11.73}$ $M_{\odot}/h$. This result requires a drop in the halo masses** at $z \sim 3$ compared to $z<2$ results;

- **At $z \sim 3$, Type 1 AGNs reside in more massive halos than Type 2 AGNs at 2.6σ level**. In terms of unified model, this result **rules out the simple picture that obscuration is purely an orientation effect;**

- A plausible explanation of the drop in the halo mass is that, unlike at $z<2$, COSMOS AGN at $z \sim 3$ are triggered by galaxy major mergers.

- Alternatively, **Type 1** COSMOS AGNs at $z\sim3$ are possibly **representative of moderate luminosity AGN associated to an early phase of fast growing BHs induced by cosmic cold flows or disk instabilities.** Following our results, these **fast growing BHs at $z\sim3$ reside in DMHs with typical mass of ~ $10^{12.8}$ $M_{\odot}/h$**