Hot Spots in The XMM Sky 2016

Scaling Relations of High-Z Simulated Galaxy Clusters

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Introduction

- High-z cluster samples are expected in near future with: eROSITA (2017), EUCLID (2020), ATHENA (2028).

—> allowing to probe matter growth + Cosmic accelerating.

Challenge:

- Cluster mass can not be directly observed for every single cluster.

—> Need scaling relations (SRs) to relate mass to mass proxies.

Goal: *study simulated scaling relations between cluster mass and X-ray proxies: M-Mg, M-T, M-Yx, L-M, L-T.*

- **Comparing simulations to local observations of clusters.**
- **Investigating evolution of scaling relations (SRs) up to z=2.**

(Truong et al. to be submitted)

DIANOGA Simulation

numerical groups of Trieste and Munich

- **Re-simulations** of 29 regions from N-body simulation of 1 (Gpc/h)^3 (performed with Gadget 3, Springel 2005).
- **Three ICM models:** ***NR*** (Non-Radiative), ***CSF*** (Radiative Cooling + Star Formation + Supernovae Feedbacks), ***AGN*** (CSF+AGN Feedbacks).
- **Advanced features:** improved hydrodynamical scheme (Beck+2016), better AGN implementation (Steinborn+15)
- **Promising results on ICM properties:** producing coexistence of cool-core and non cool-core simulated clusters (*Rasia+15*).

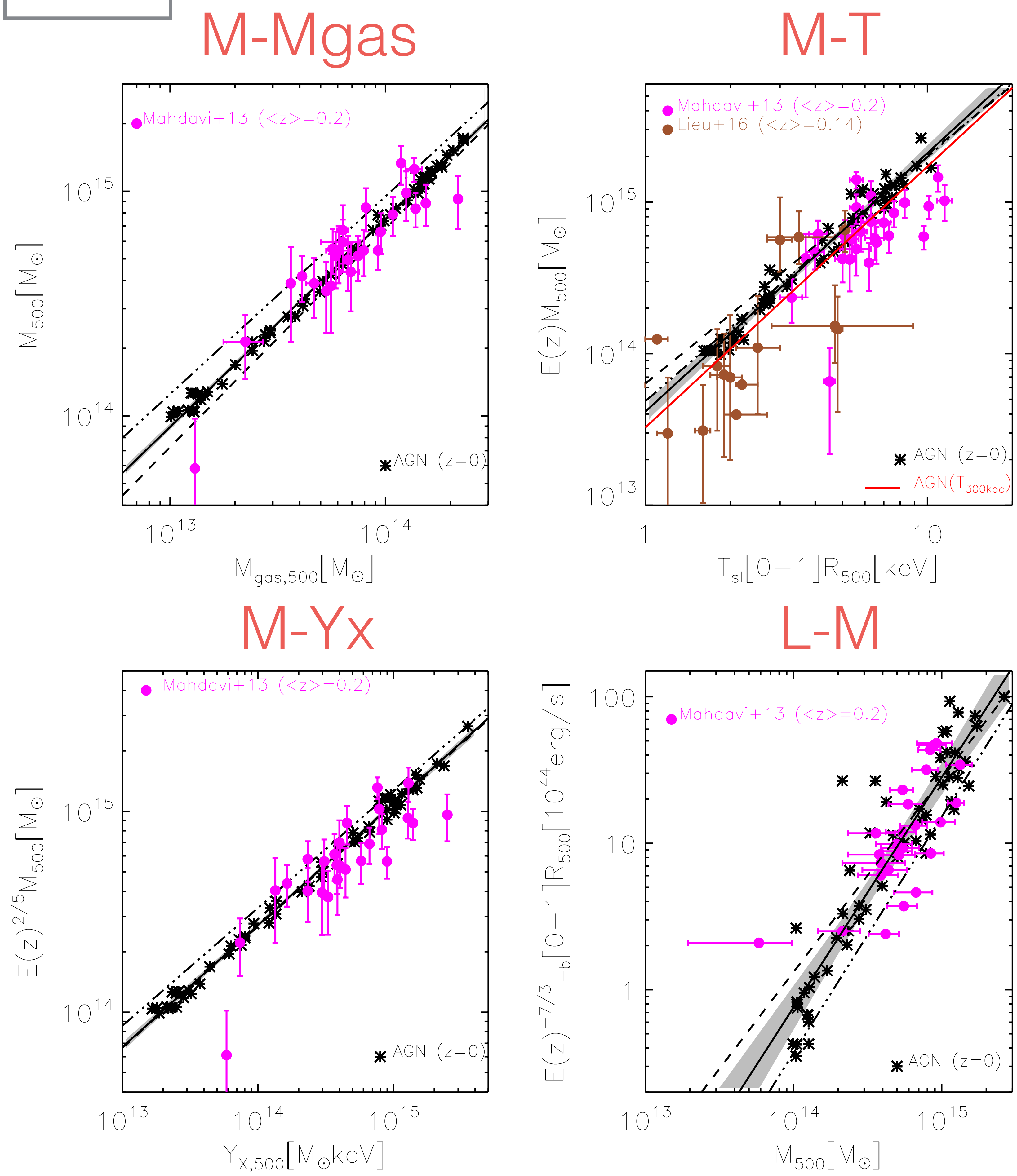
Simulation

vs

Observations

z=0

Comparison to Observations

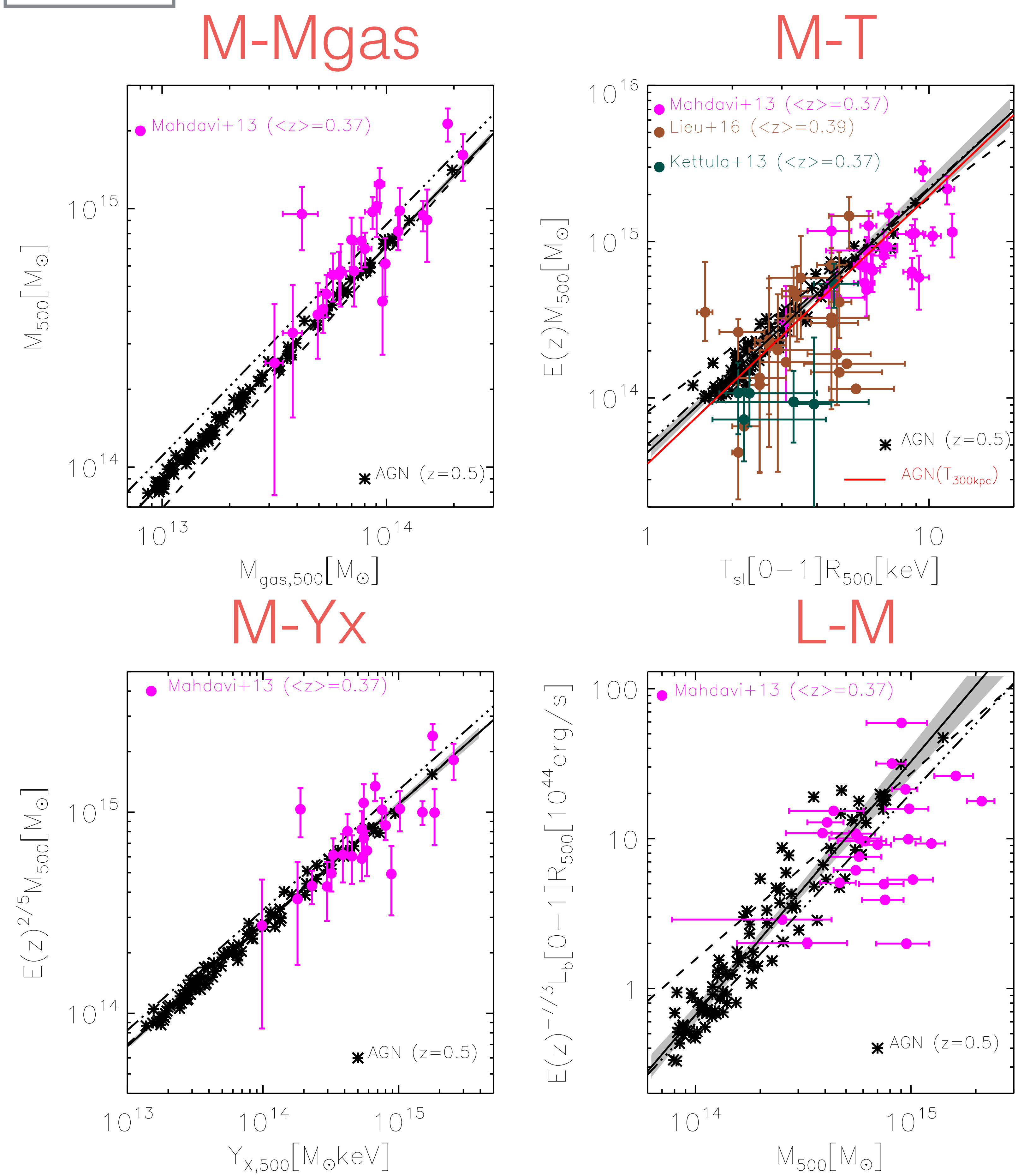


- **Observed mass is obtained from lensing analysis (Mahdavi+13, Lieu+15, Kettula+13).**

- **AGN run reproduces well local observed scaling relations.**

z=0.5

Comparison to Observations



- **The agreement is also present at z=0.5.**

Scaling Relations Evolution

Data & Model

- **Data:**

  - Samples selected at 8 redshifts:

z= 0, 0.25, 0.5, 0.6, 1, 1.5, 2.

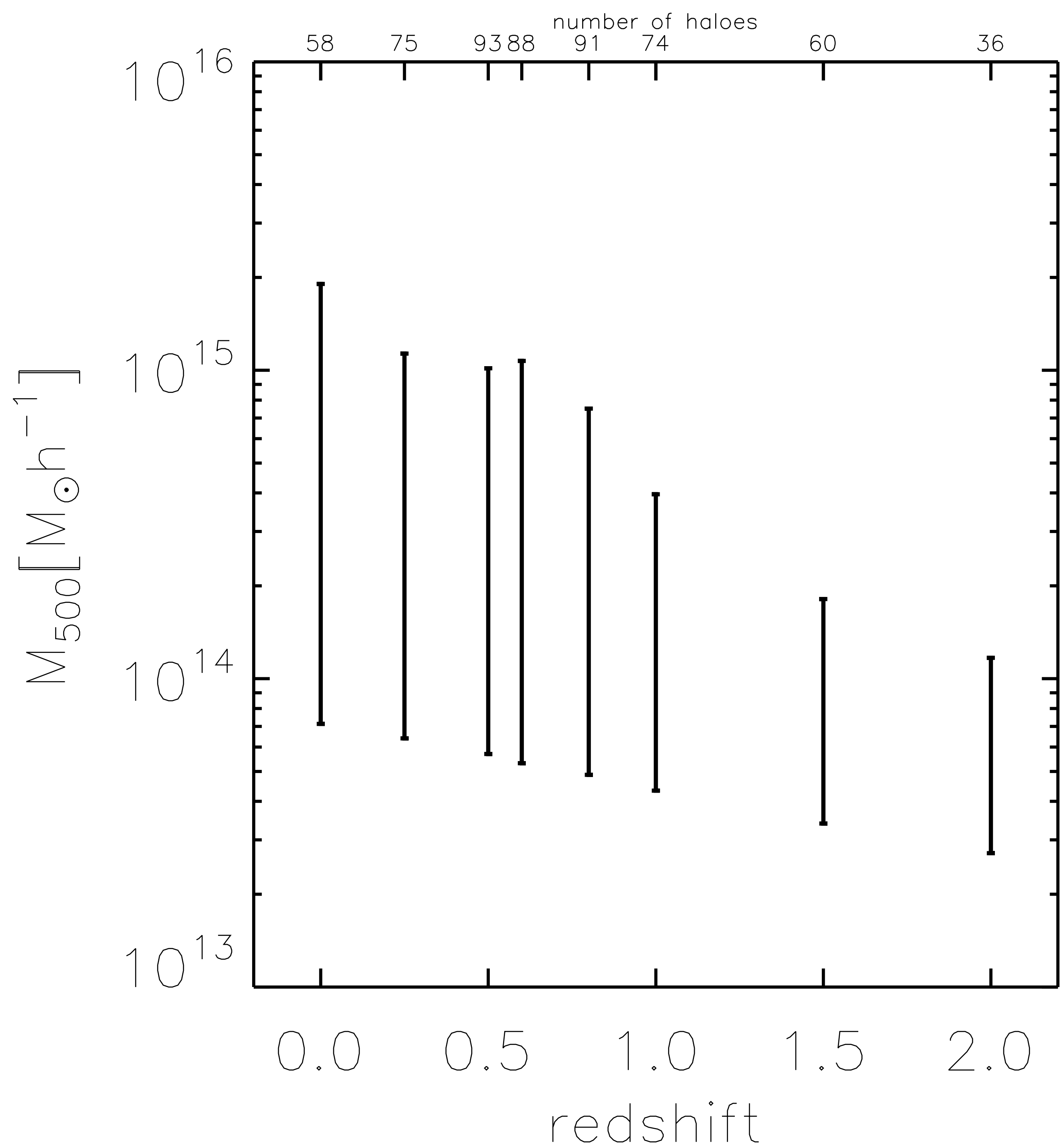
  - Mass limit: ***M_500 > 7.e13/E(z).***

$$E(z) \equiv H(z)/H_0$$

- **Model:** single power law

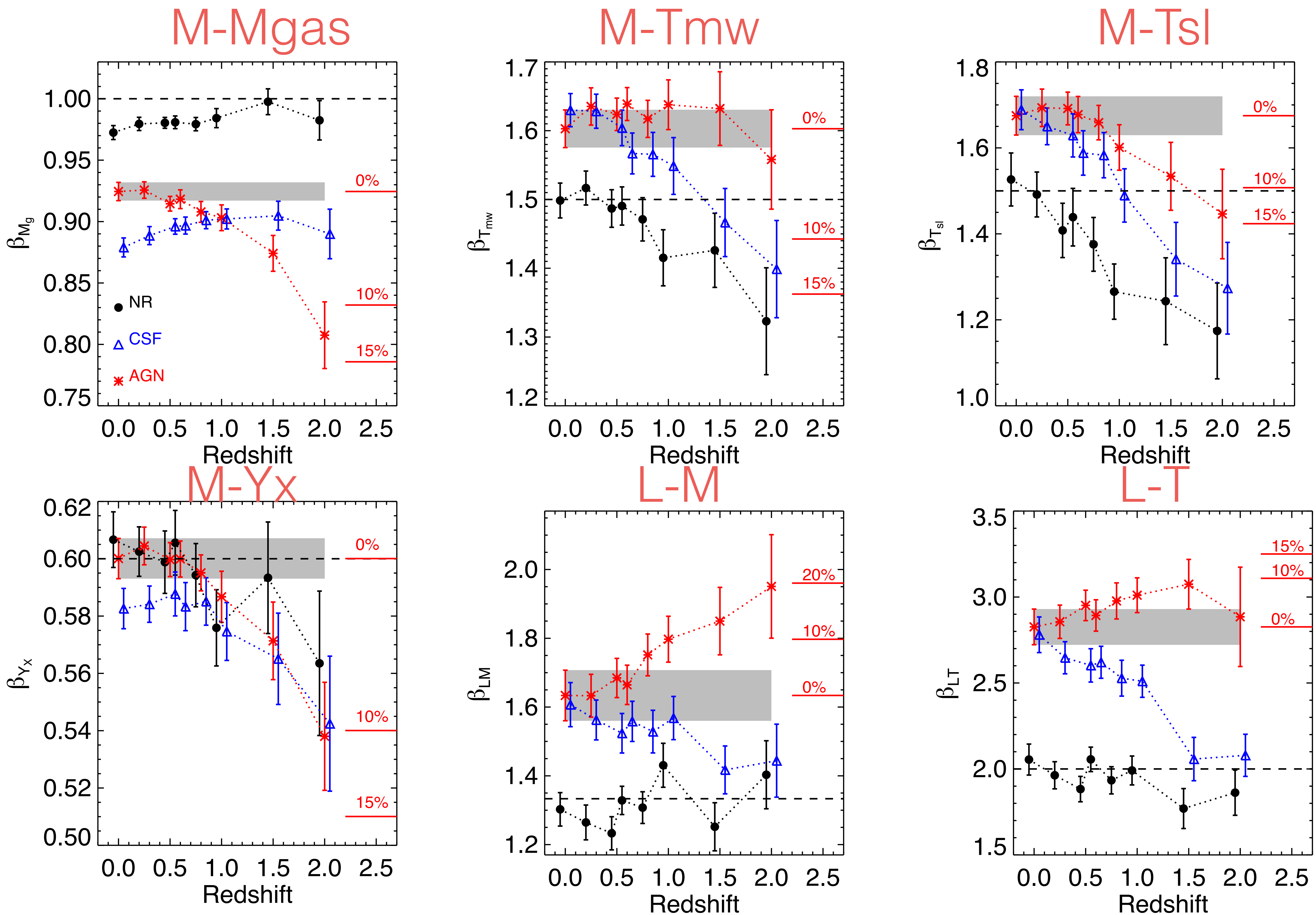
$$F_\Delta = C \times E(z)^\gamma \times \left(\frac{X_\Delta}{X_0}\right)^\beta$$

- **Fitting Method:** Bayesian linear regression (Kelly 2007).



Slope Evolution

$$F = C \times E(z)^{\gamma} \times \left(\frac{X}{X_0}\right)^{\beta}$$



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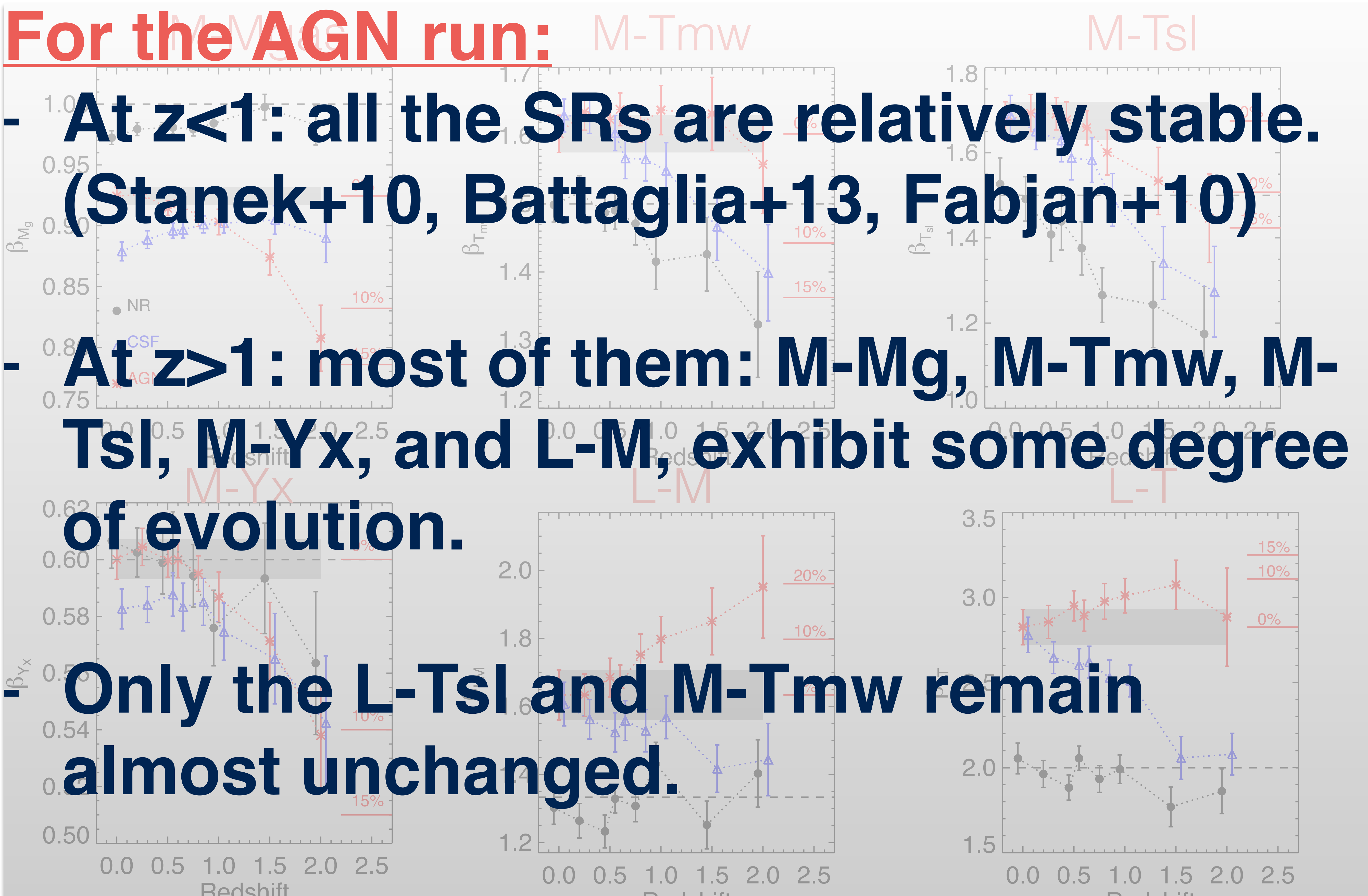
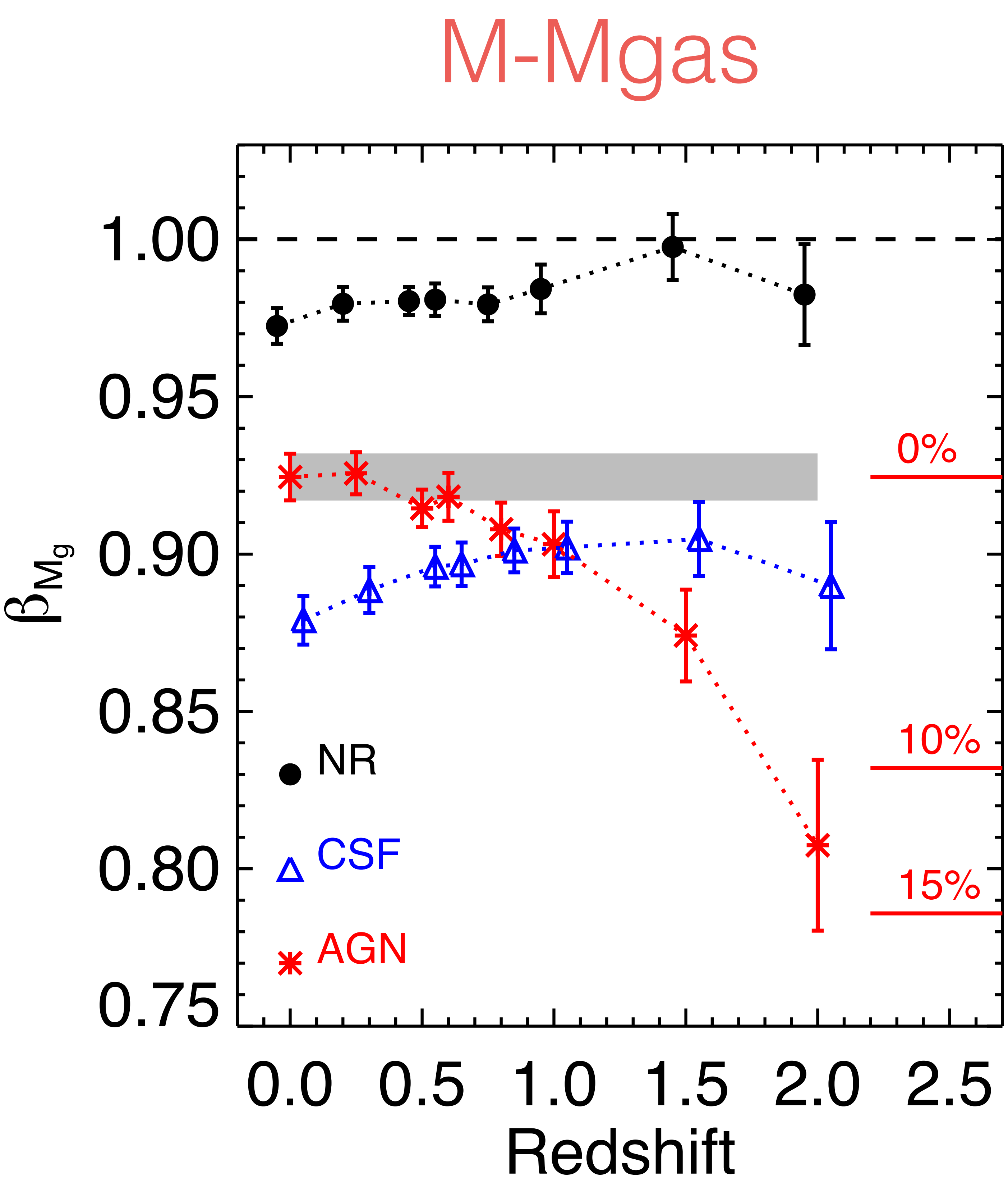


For the AGN run:

- **At z<1: all the SRs are relatively stable. (Stanek+10, Battaglia+13, Fabjan+10)**
- **At z>1: most of them: M-Mg, M-Tmw, M-Tsl, M-Yx, and L-M, exhibit some degree of evolution.**
- **Only the L-Tsl and M-Tmw remain almost unchanged.**

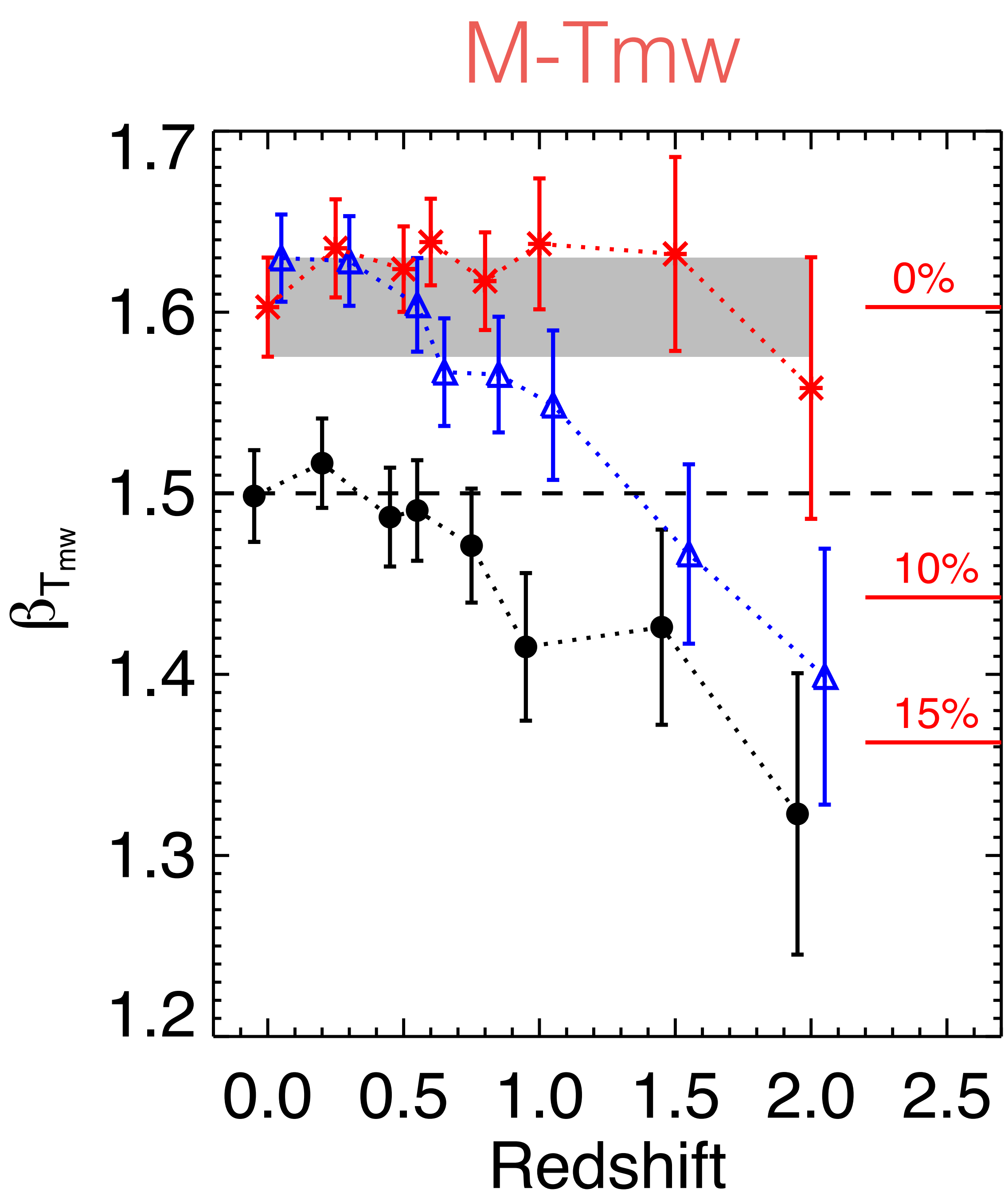
Slope Evolution: gas mass

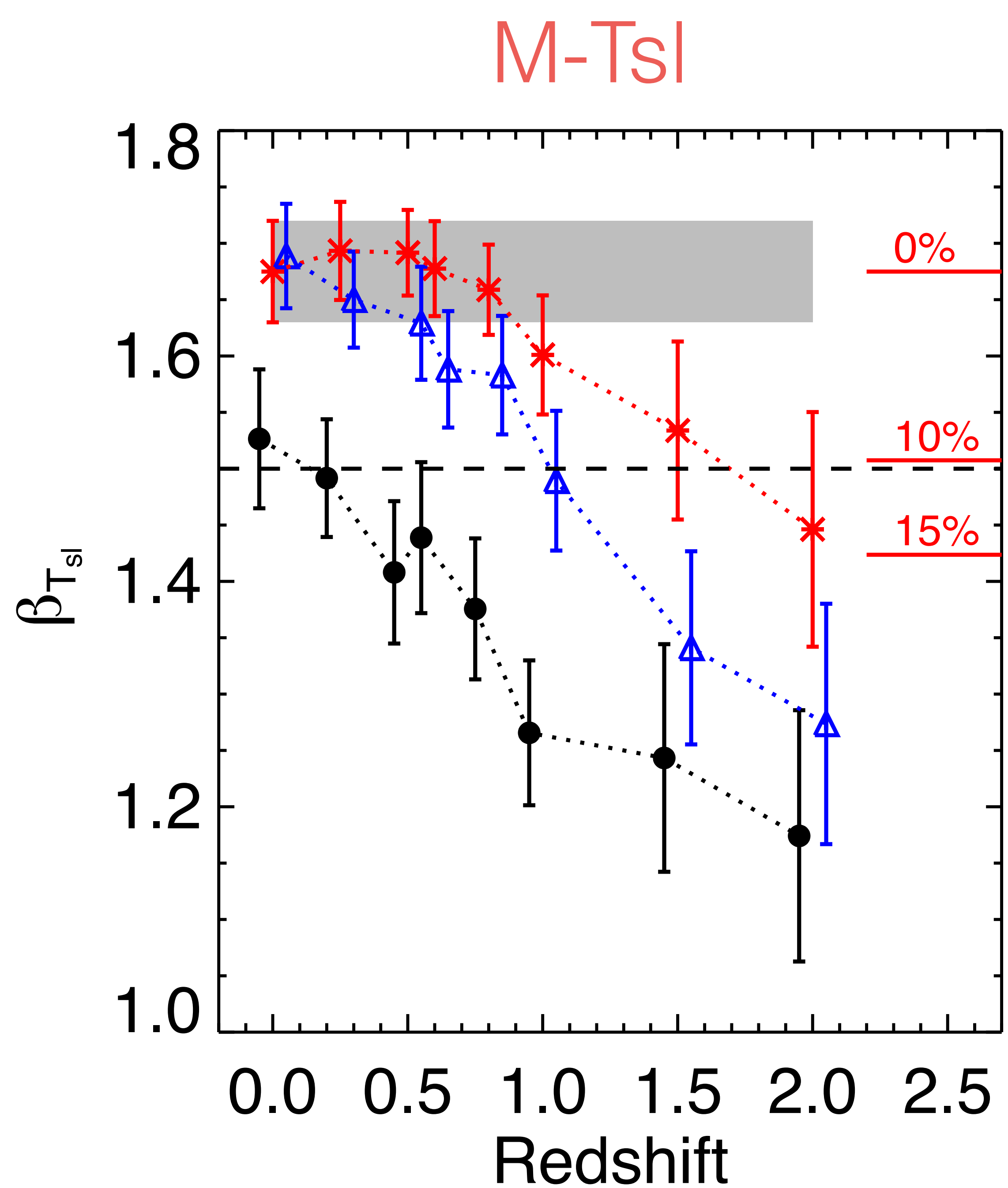


- AGN run shows Mgas slope reduced by ~14% at z=2.

=> AGN effect on low-mass systems at high-z.

Slope Evolution: temperature

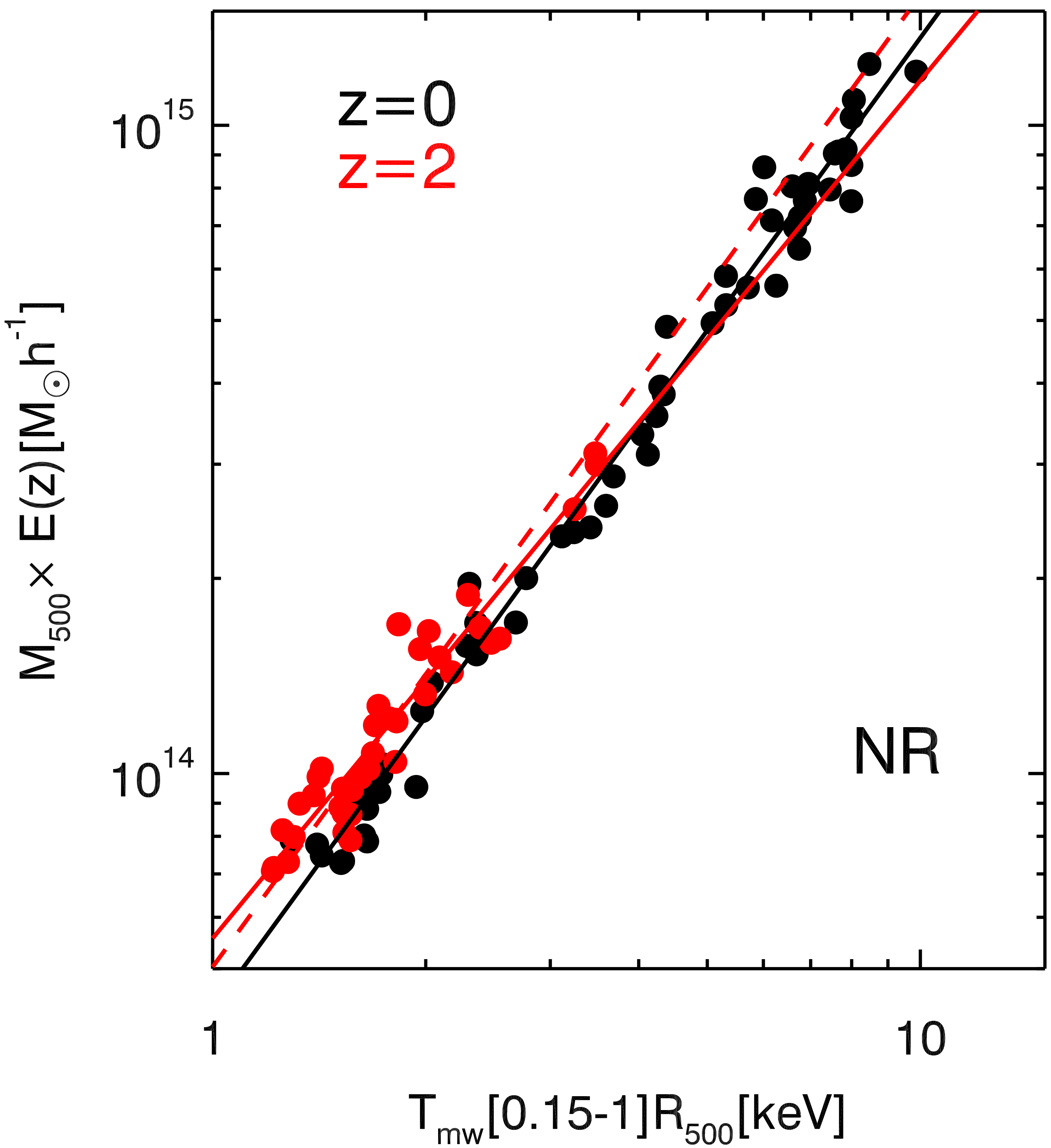




- **Temperature slope also drop at high-z in all the 3 runs.**

Mass-Temperature relation at high-z

Mass-weighted temperature

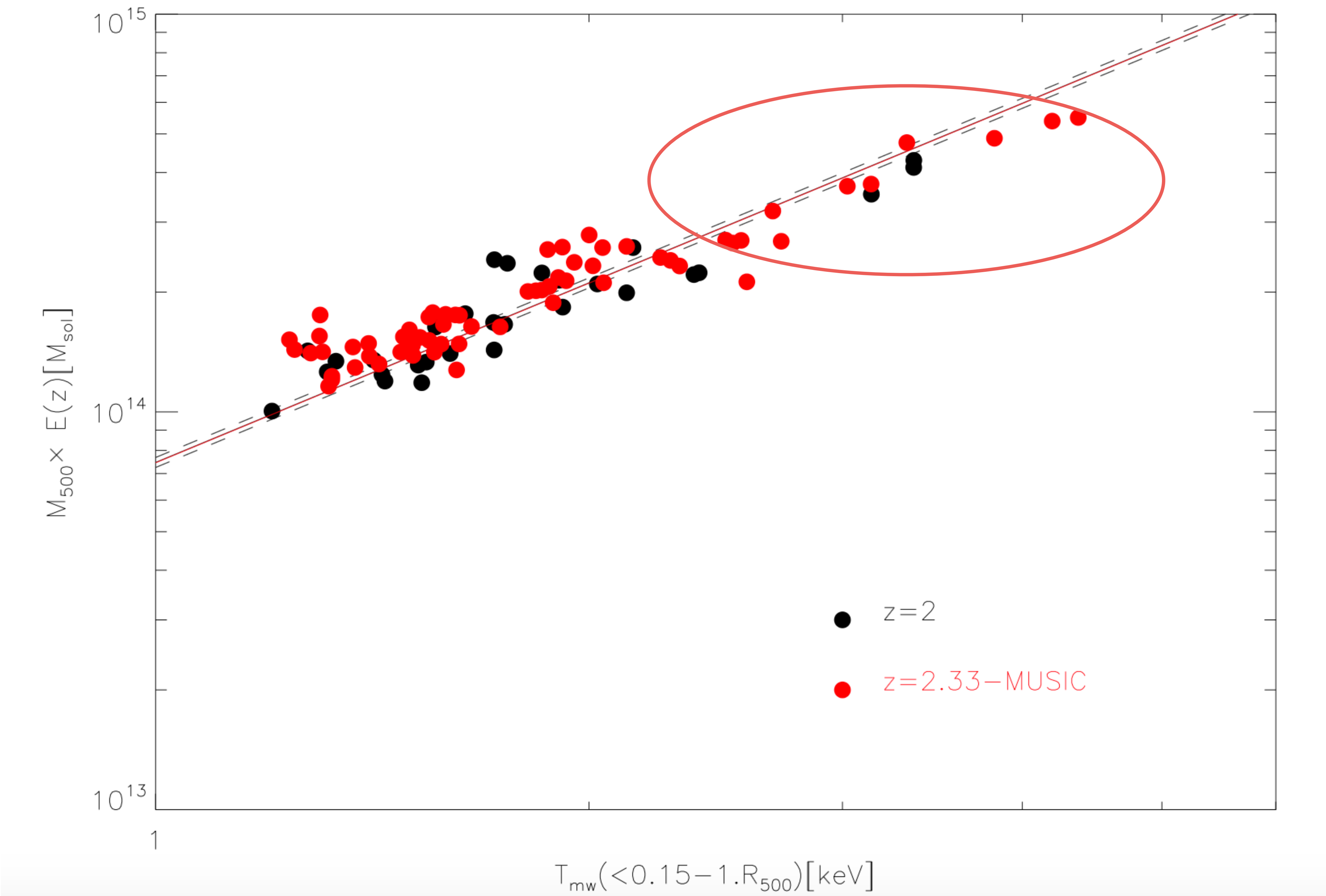


— Most high-z clusters (T<3 keV) are at lower degree of thermalization.

— 3 most massive clusters undergone major mergers.

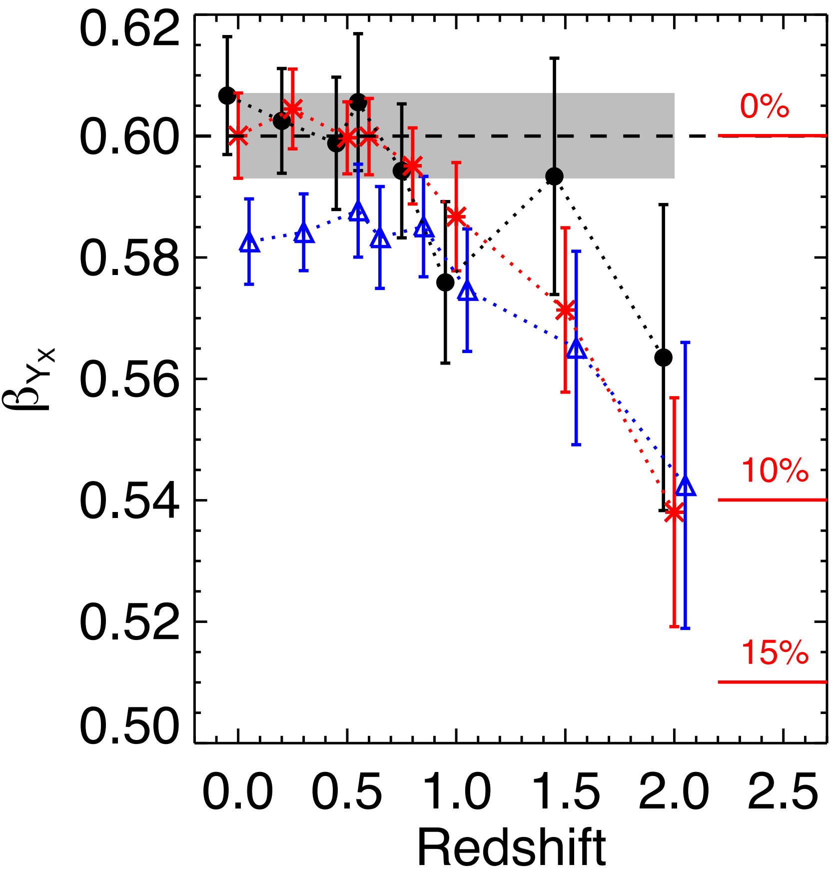
Mass-Temperature relation at high-z

Cross-check with MUSIC Sample (Sembolini +14)



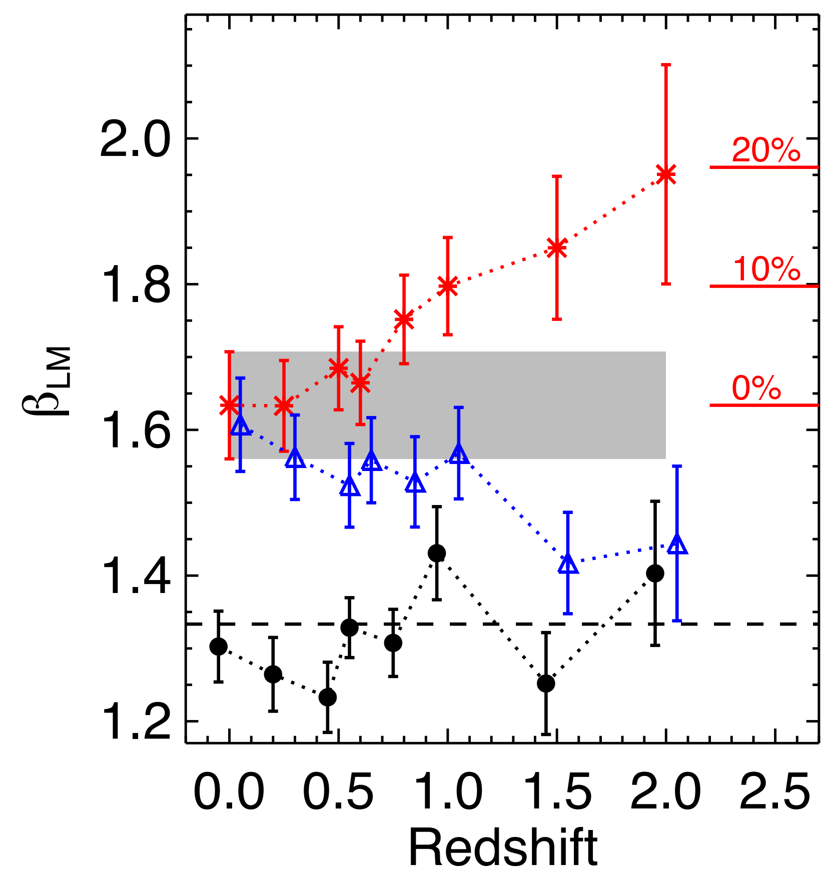
Slope Evolution: Yx and luminosity

M-Yx



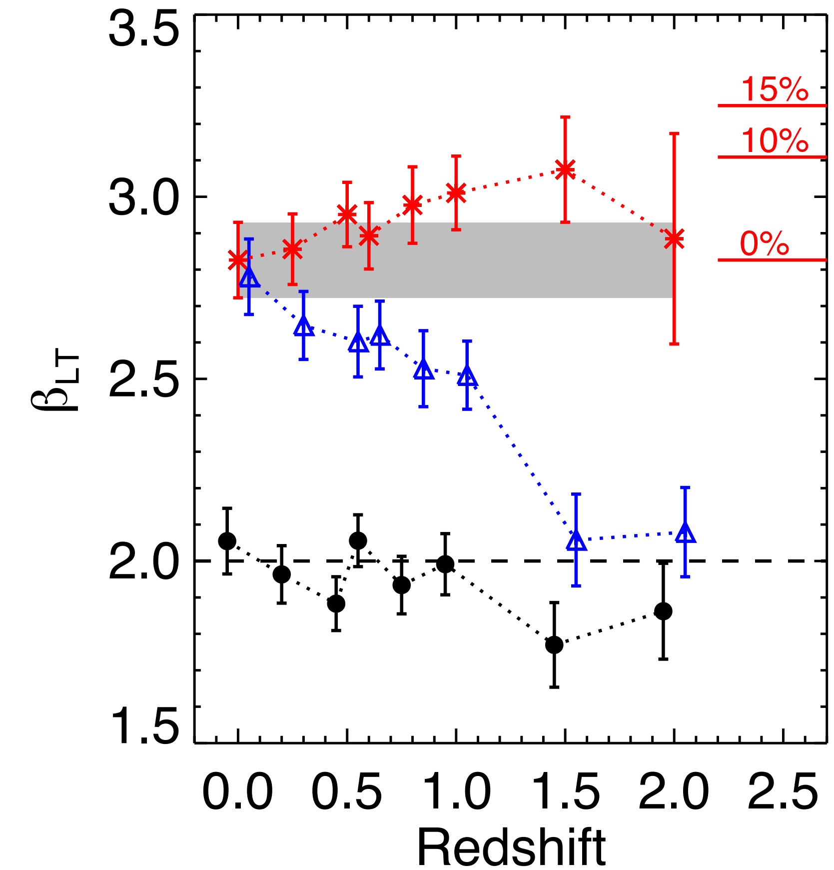
$$\beta_{Y_X} = \frac{1}{1/\beta_{M_g} + 1/\beta_{T_{sl}}}$$

L-M



$$\beta_{LM} = \frac{2}{\beta_{M_g}} + \frac{1}{2\beta_{T_{sl}}} - 1$$

L-Tsl



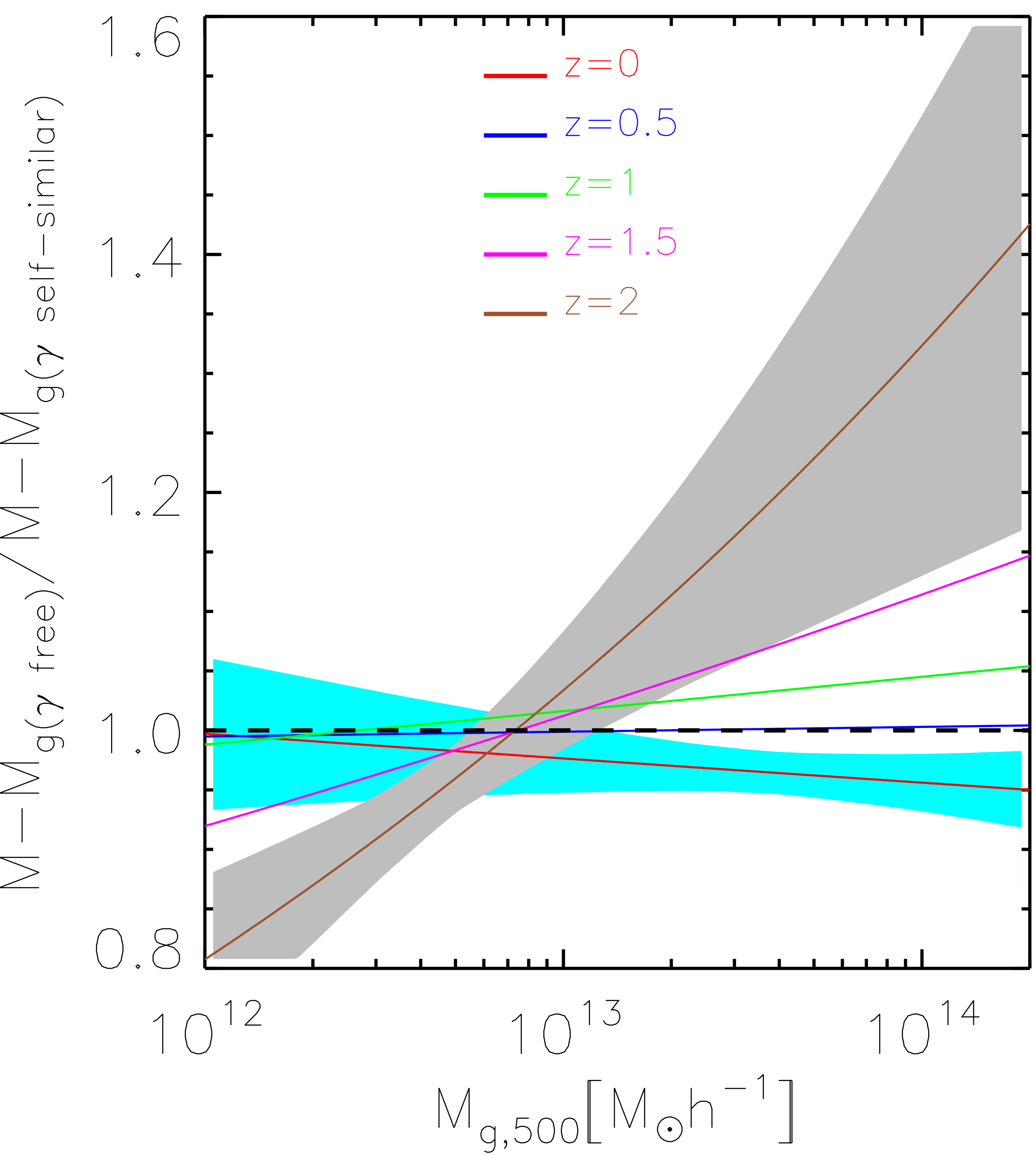
$$\beta_{LT} = \beta_{T_{sl}} \left(\frac{2}{\beta_{M_g}} - 1 \right) + \frac{1}{2}$$

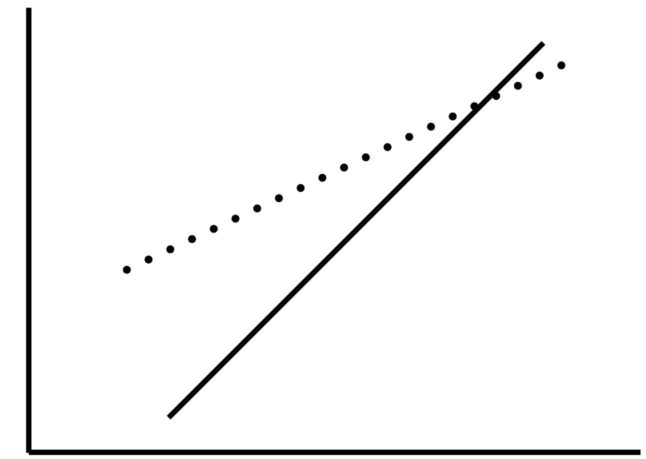
- Evolution of derived SRs can be explained, qualitatively, in terms of the two fundamental relations: M-Mgas and M-T. (See also Maughan +14)

Slope Variation Impact on Normalisation Evolution

$$F_\Delta = C \times E(z)^{\gamma} \times \left(\frac{X_\Delta}{X_0}\right)^{\beta}$$

M-Mgas





- When slope evolves, normalisation evolution can not be defined for a single power law.

Conclusion

- **Our AGN simulation reproduces well various scaling relations from low and intermediate redshifts.**
- **By comparison SRs at low- and high-z one can learn about the effect of AGN feedbacks.**
- **Scaling Relations can be described by a power law with a single slope safely up to z=1.**