ACCRETION MODELS FOR BLACK HOLE EVOLUTION

Francesco Shankar

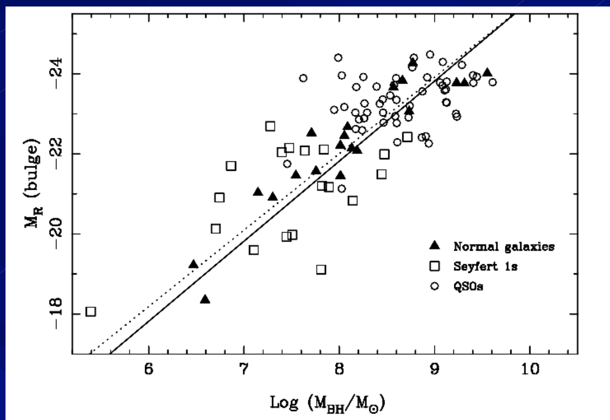
In collaboration with:

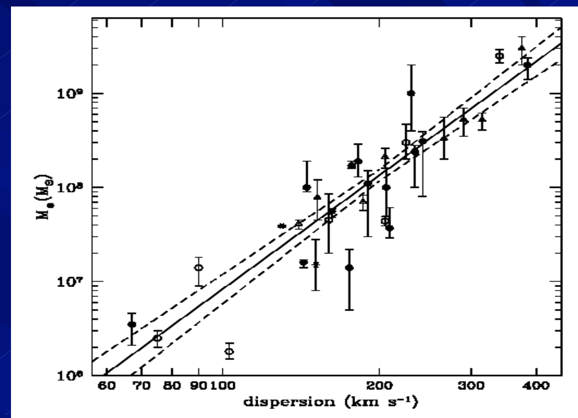
D. H. Weinberg

J. Miralda-Escude'

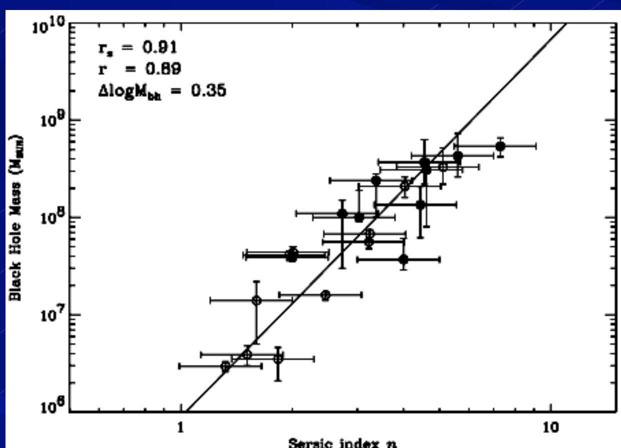
Massive Dark Objects → observed in all bulged-galaxies

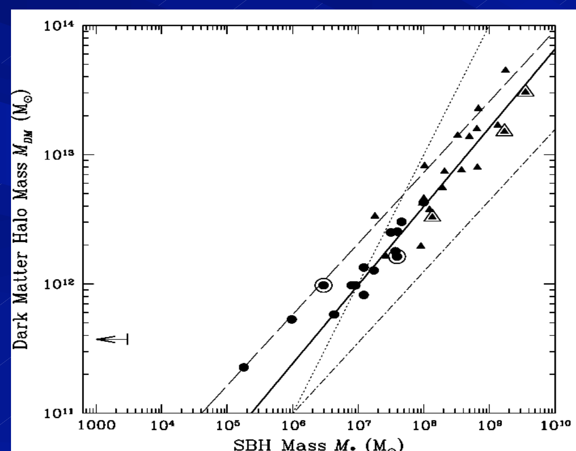
→ strong link with the host spheroid $M/n/\sigma$





Dunlop & McLure; Ferrarese et al.; Gebhardt et al.; Graham et al.; Haring & Rix; Lauer et al.; Magorrian et al.; Marconi & Hunt



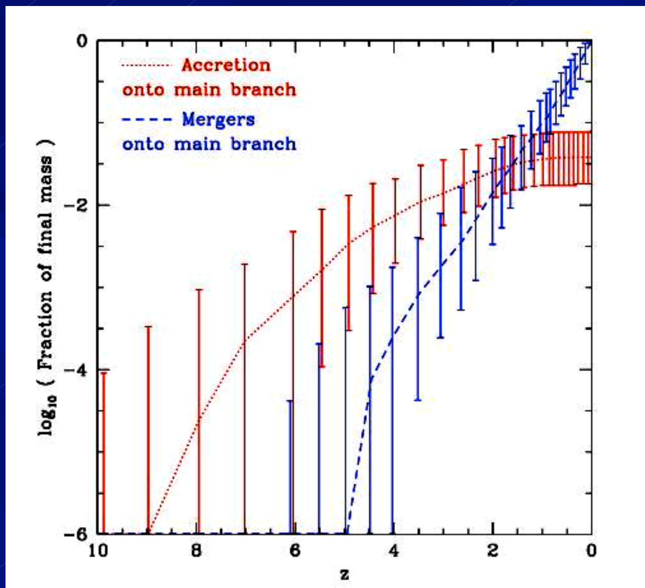


$\sigma = k \times V_c$

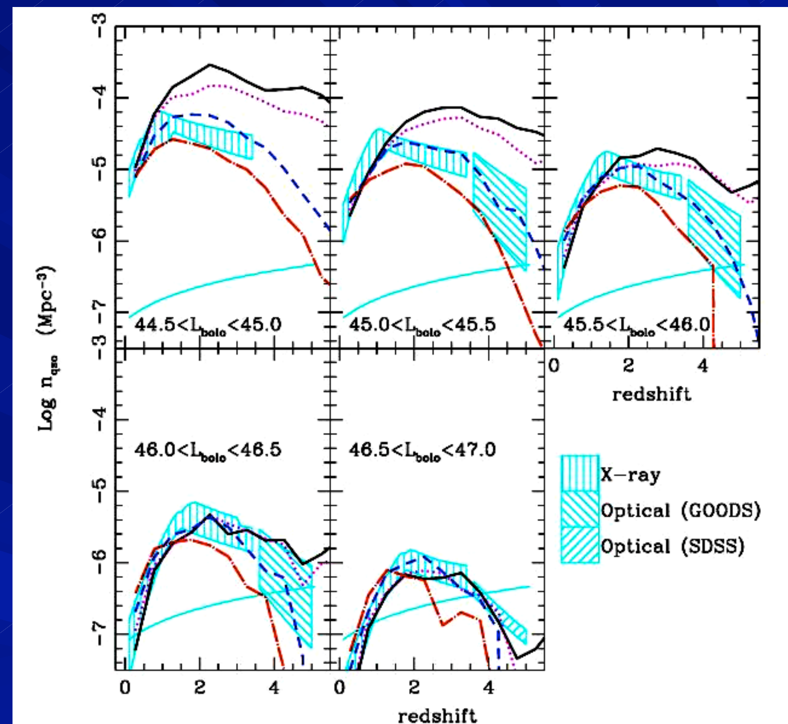
V_C+DM profile → $V_{VIR}(z_{vir}=0) \propto (M_{vir})^{1/3}$

What are MDOs? How and why are they connected with spheroids and DM? What is their role in shaping galaxies?

On the other hand SAM are working hard understanding what is going on…



Malbon et al.



Fontanot et al.

` `our knowledge on the physics of accretion onto BHs and their interaction with galaxies is still poor to draw firm conclusions"

GOAL:

- EMPIRICALLY CONSTRAIN BLACK HOLE EVOLUTION IN A *STATISTICAL* SENSE

– AGN CLUSTERING

WHAT I AM GOING TO SHOW....

ACCRETION WITH SINGLE MODES (one ε, one $\lambda = L/L_{Edd}$)

GOOD....BUT NOT ENOUGH....

BAD MATCH WITH:
- -SMALL SCALE CLUSTERING
- -AGN FRACTION

ACCRETION WITH MULTIPLE MODES (one ε, many λ)

BETTER BUT STILL NOT ENOUGH

MASS AND REDSHIFT DEPENDENCE of λ CAN FIT ALL THE DATA

PART I

AGNs and the LOCAL BH MASS FUNCTION

SMBH from **Merging/Dark Accretion** or through **Visible Accretion** detected in the AGN luminosity Functions?

Soltan argument

$$L_{Bol} = L \times K_{Bol} = \varepsilon \dot{M}_{ACC} c^2$$

$$\dot{M}_{BH} = (1-\varepsilon)\dot{M}_{ACC} \longrightarrow \text{Single object}$$

$$\rho_{total} = K_{Bol} \int_0^{z_{max}} dz \frac{dt}{dz} \int_{L_{min}}^{L_{max}} \frac{(1-\varepsilon)L}{\varepsilon c^2} \phi(L,z)\, dL$$

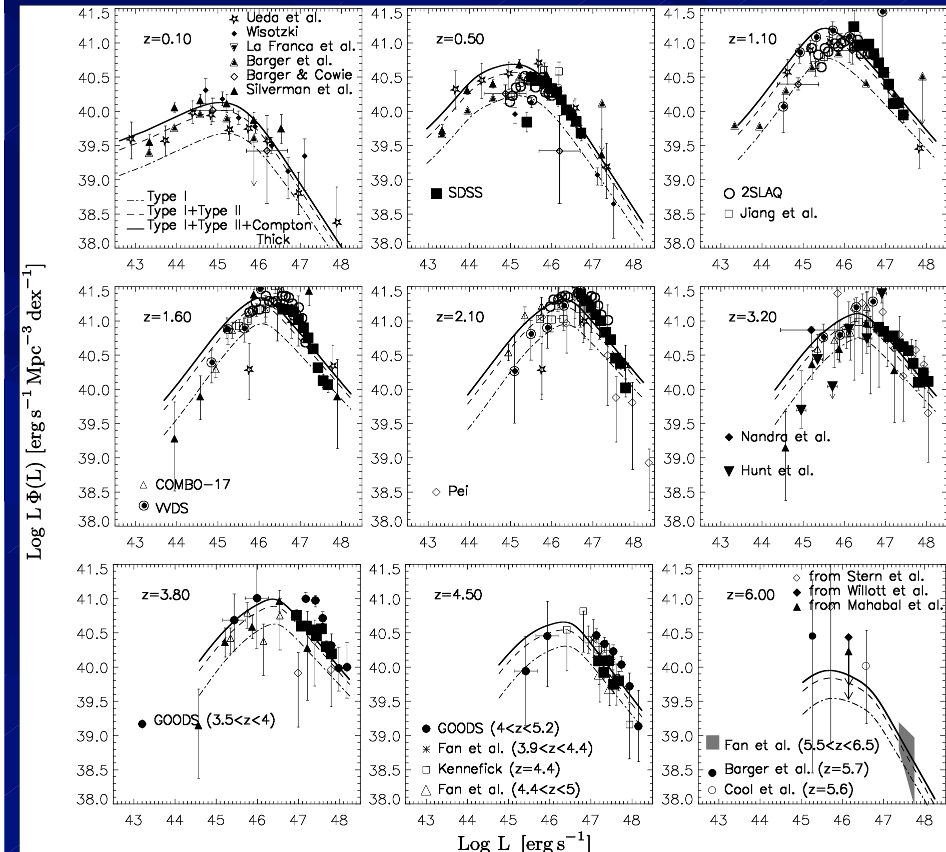
$$n(S,z)\, dS\, dz = \phi(L,z)\, dL \frac{dV}{dz} dz \quad \left[S = \frac{L}{4\pi D_L^2} \right]$$

$$dV = (D_A^2\, c\, dt)(1+z)^3 \qquad \frac{D_L}{D_A} = (1+z)^2$$

$$\rho_{total} = \frac{K_{Bol}(1-\varepsilon)}{\varepsilon c^2} \int_0^{z_{max}} dz\, (1+z) \int_{S_{min}}^{S_{max}} \frac{4\pi}{c} n(S,z) S\, dS$$

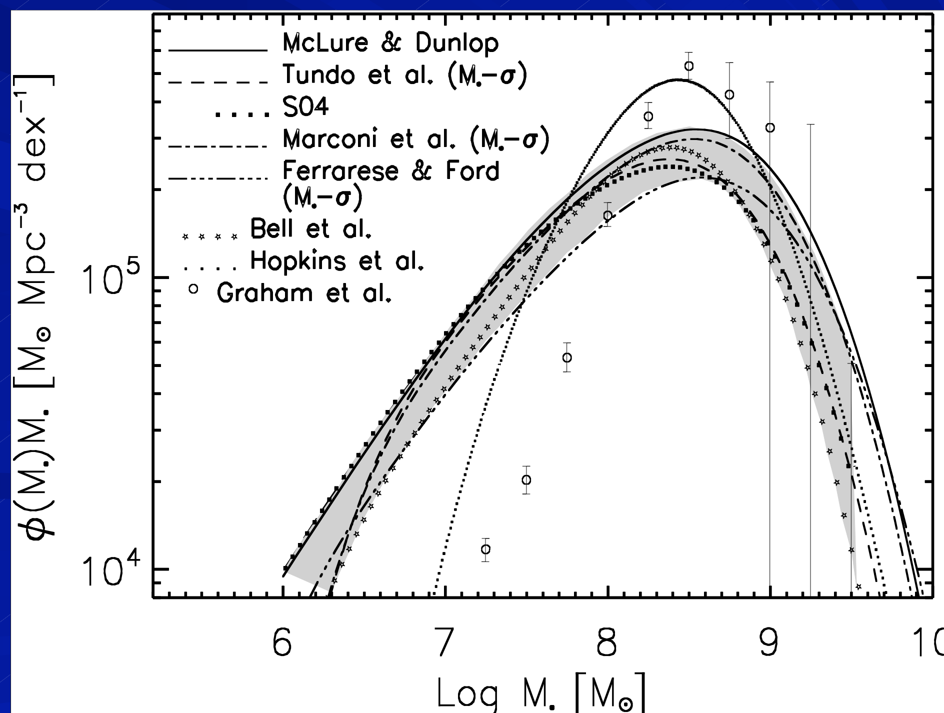
independent of cosm. par. but very **dependent** on the K_{bol}/ ratio!

INPUT/CONSTRAINTS FOR MODELS

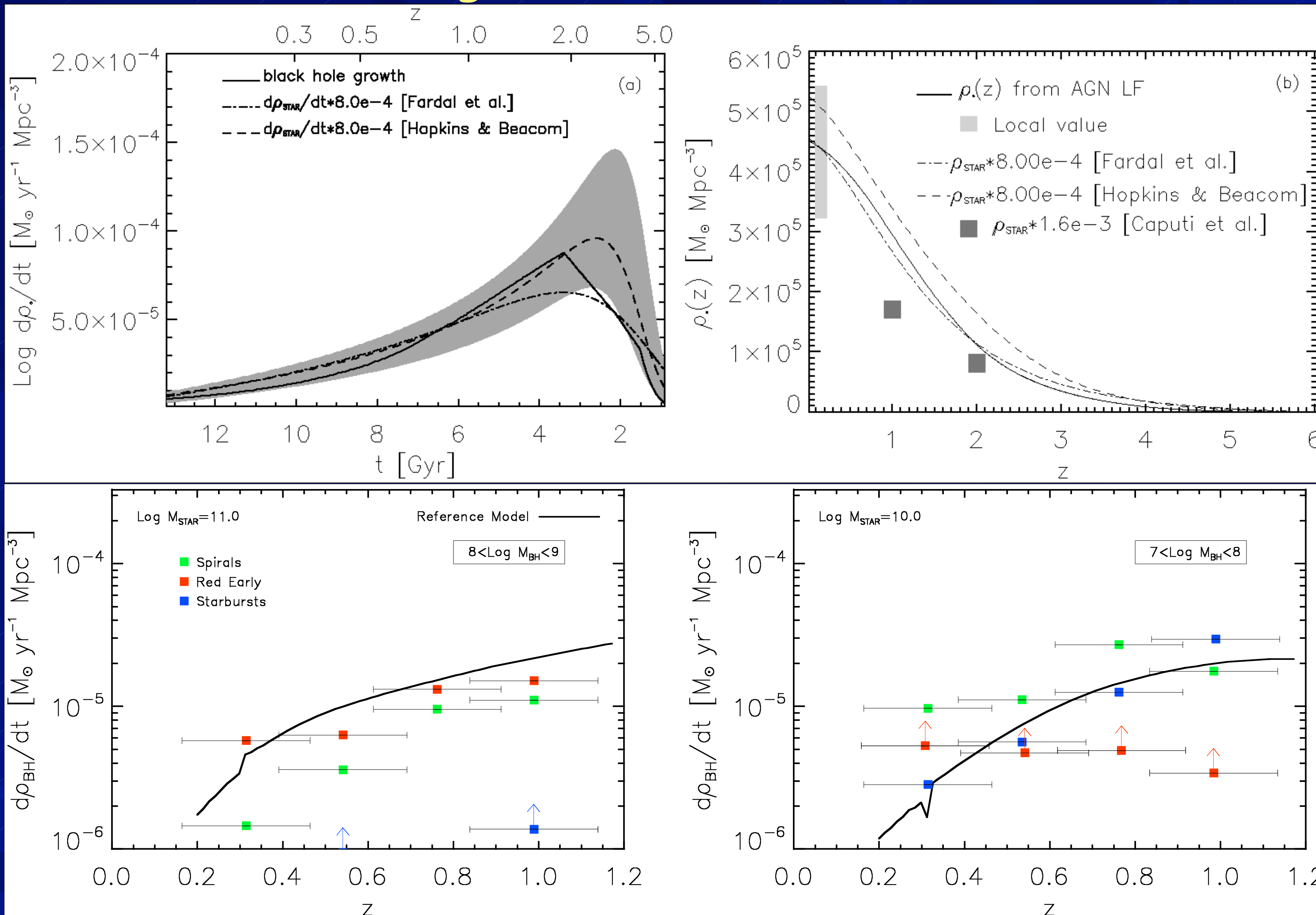


AGN LUMINOSITY FUNCTION

LOCAL BH MASS FUNCTION



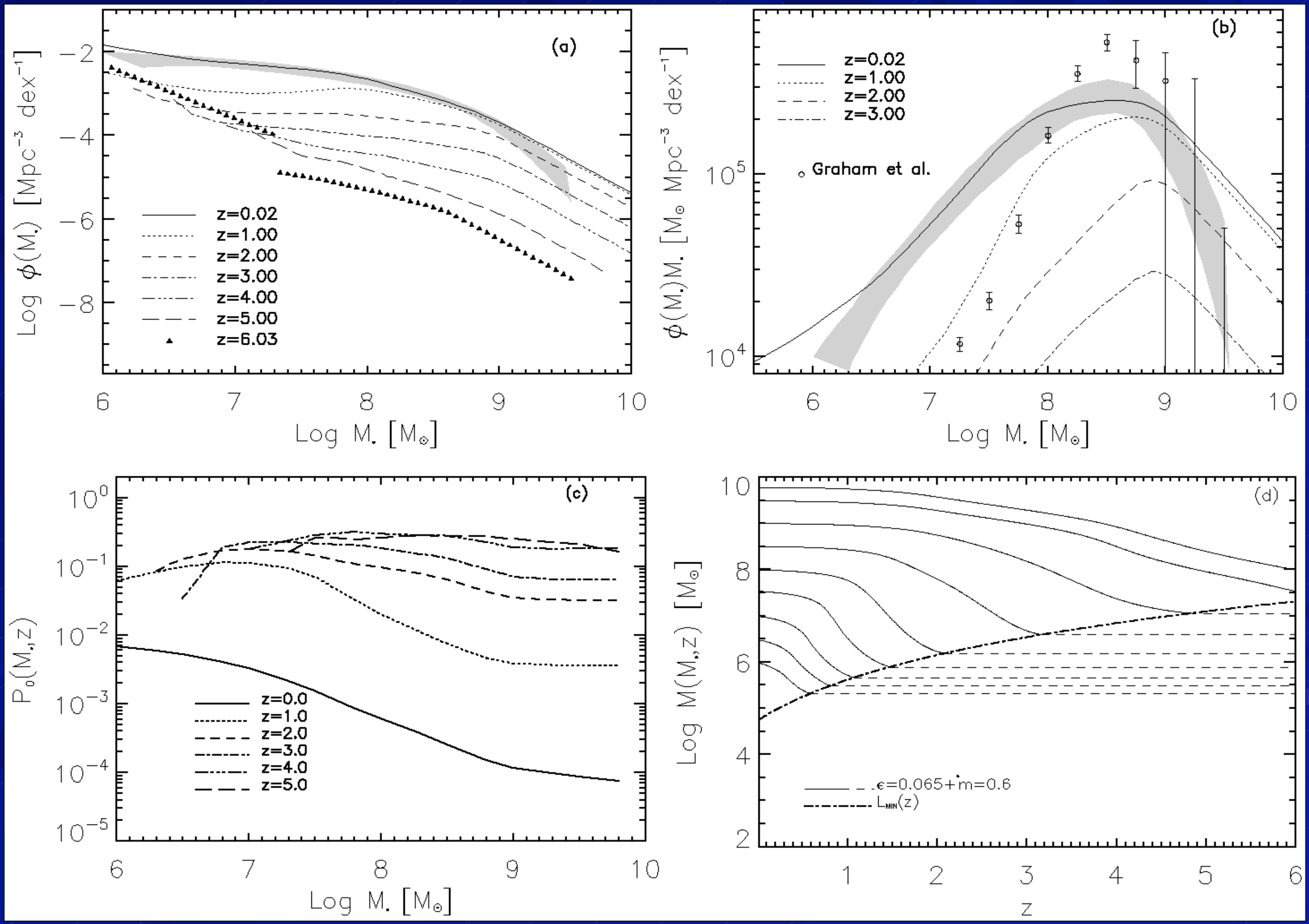
Do BHs grow faster than Galaxies?



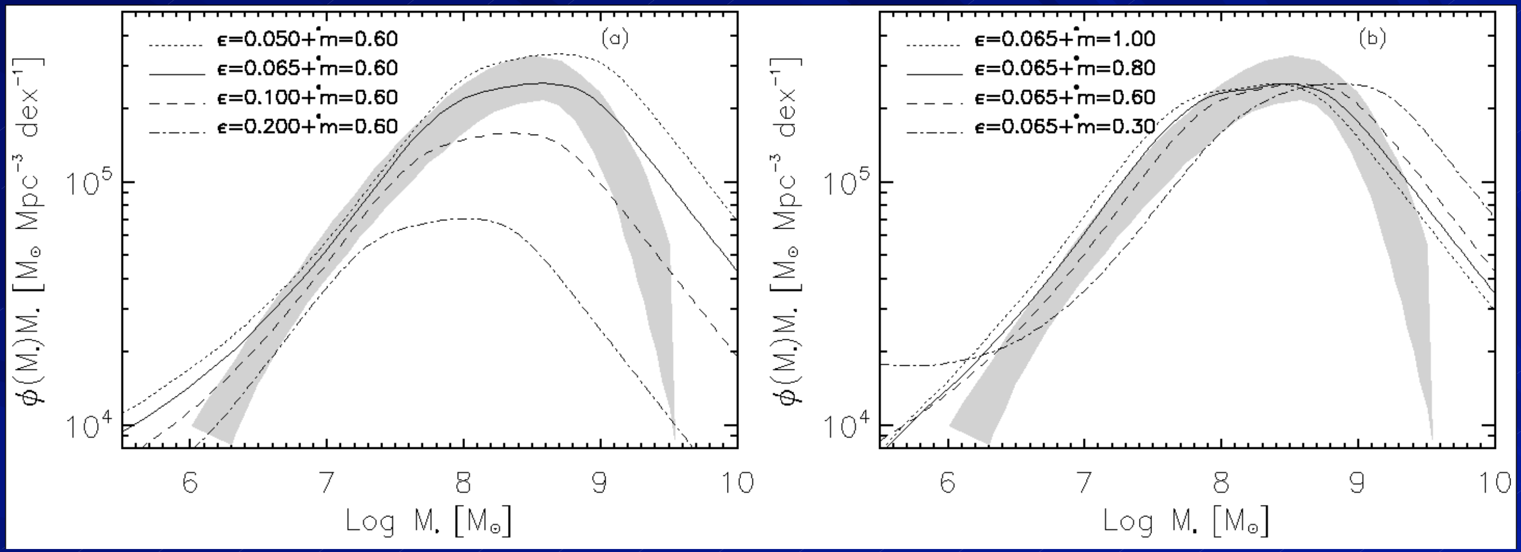
→ The ratio $\langle M_{BH}/M_{STAR} \rangle$ probably was nearly constant at all times at least up to z~1.5

$$\Phi(M_{BH},t) = -\frac{1}{t_{ef}\ln(10)}\int\frac{\partial\Phi(L,z)}{\partial\log L}\frac{dt}{dz}dz$$

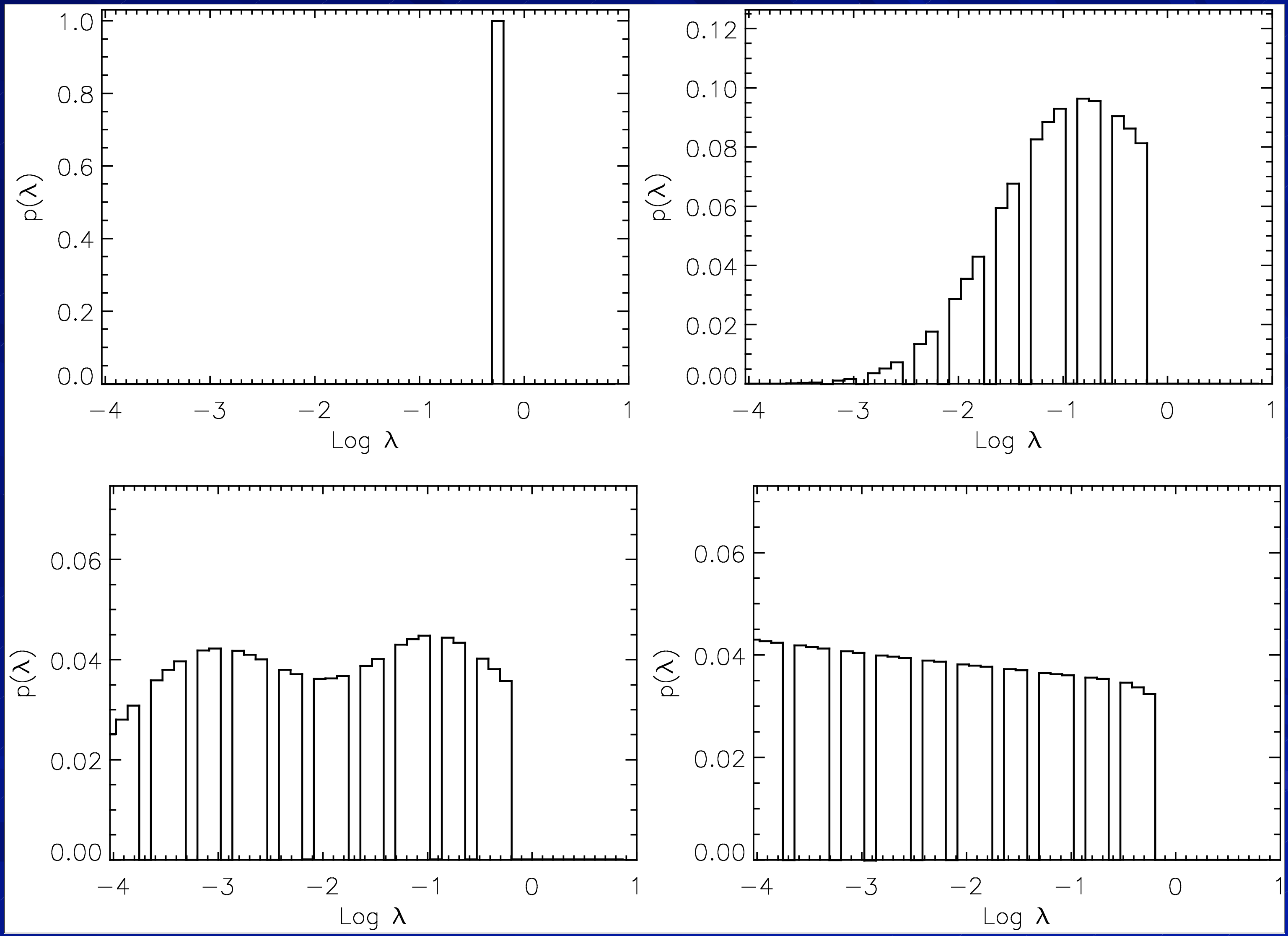
$L \propto \lambda M_{BH}$; $t_{ef} \propto \varepsilon/\lambda$



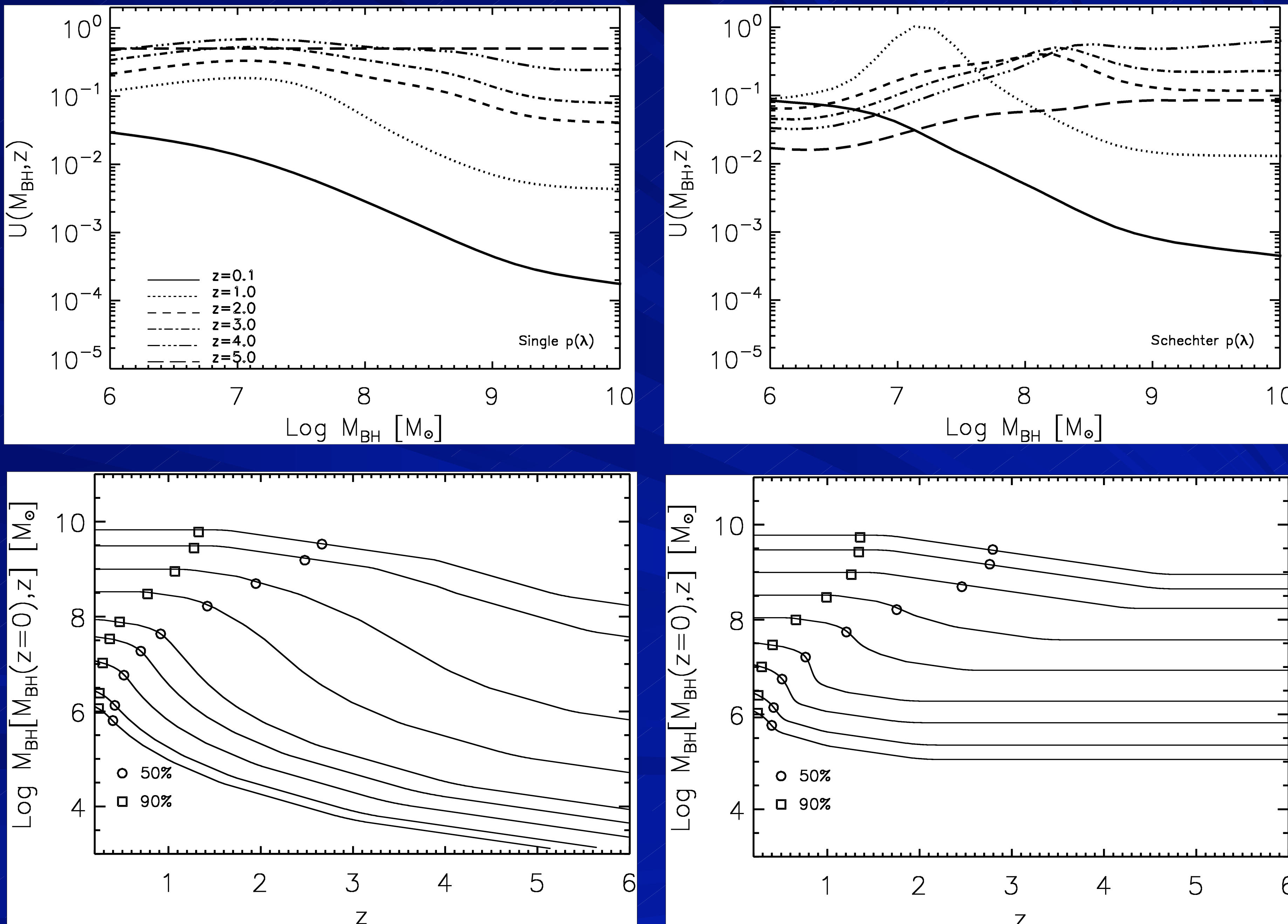
Varying the Reference Model…



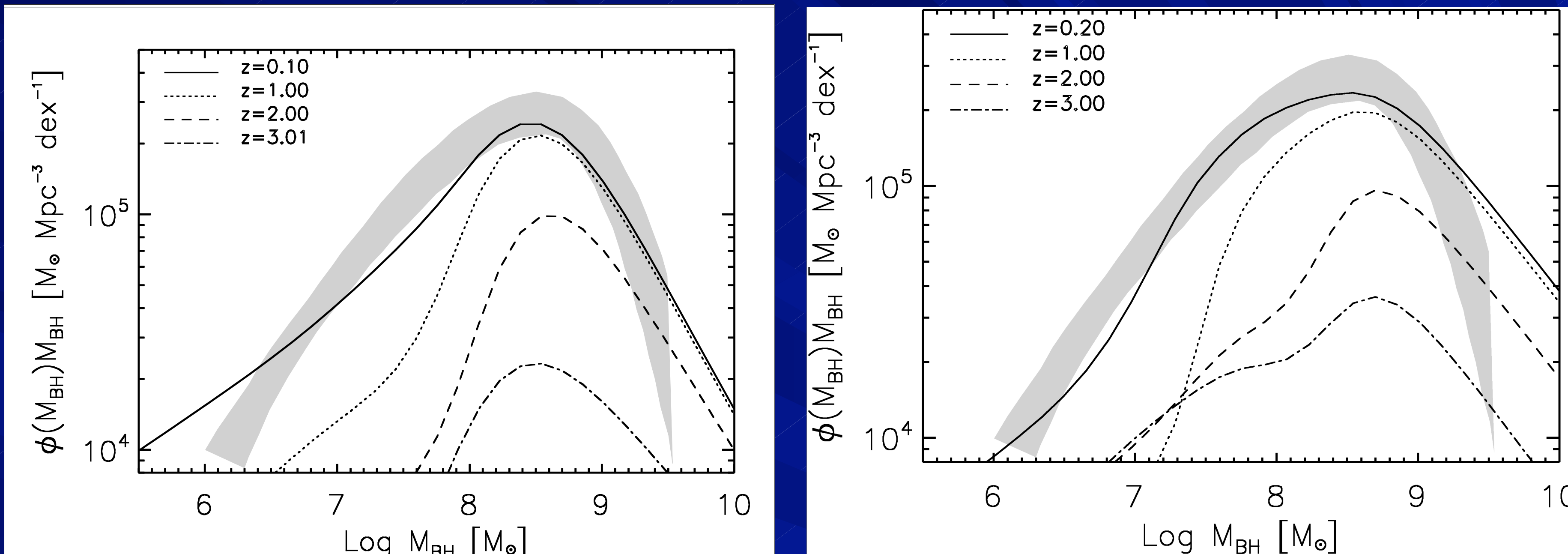
Broad Eddington ratio Distributions I



...Same DOWNSIZING....



Broad Eddington ratio Distributions II



Hopkins et al. LF+ Broad p(λ) peaked at higher λ

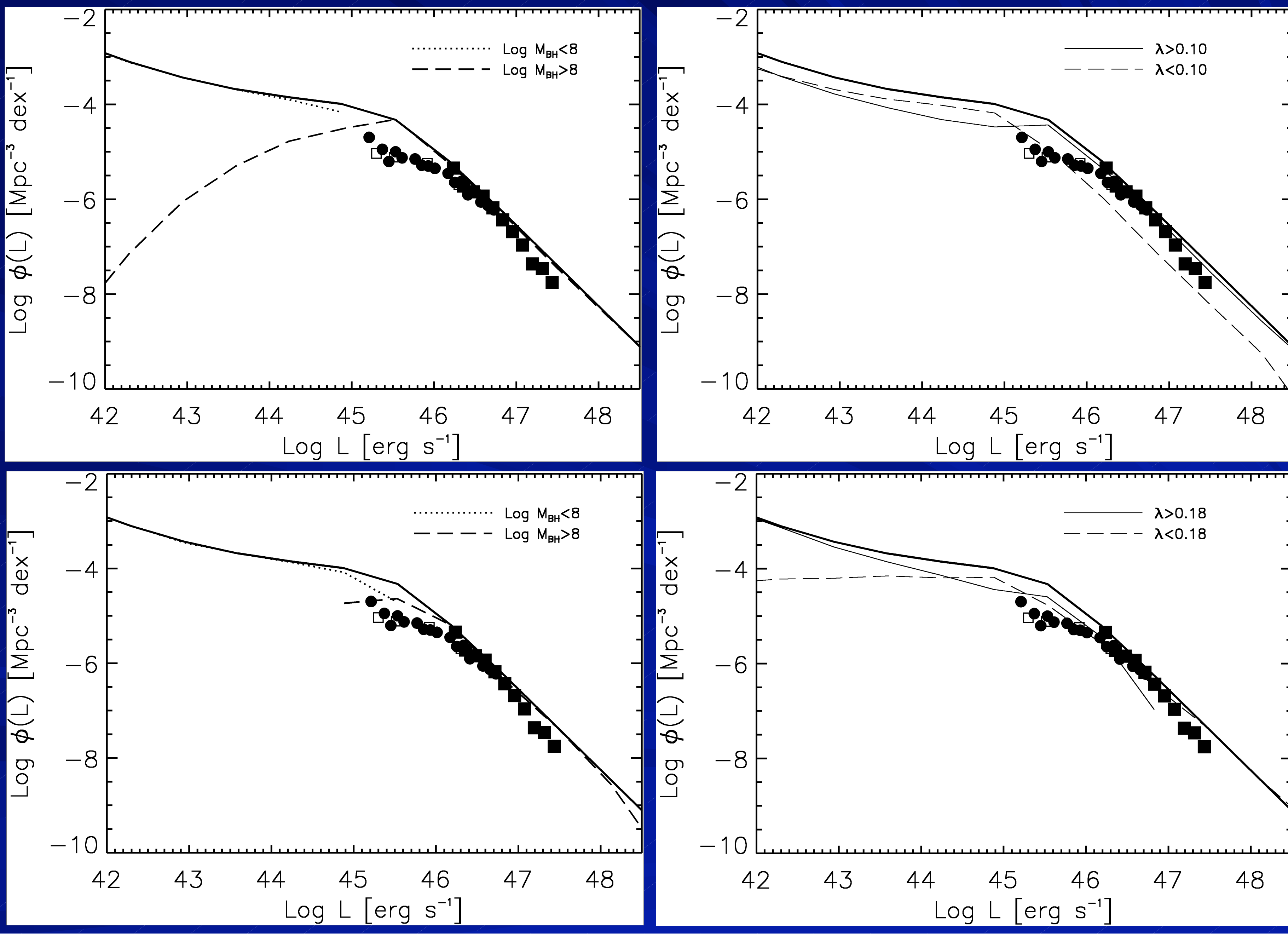
Very Broad p(λ)

SO FAR WE HAVE CONSIDERED MODELS
WITH ***CONSTANT***
EDDINGTON RATIO DISTRIBUTIONS

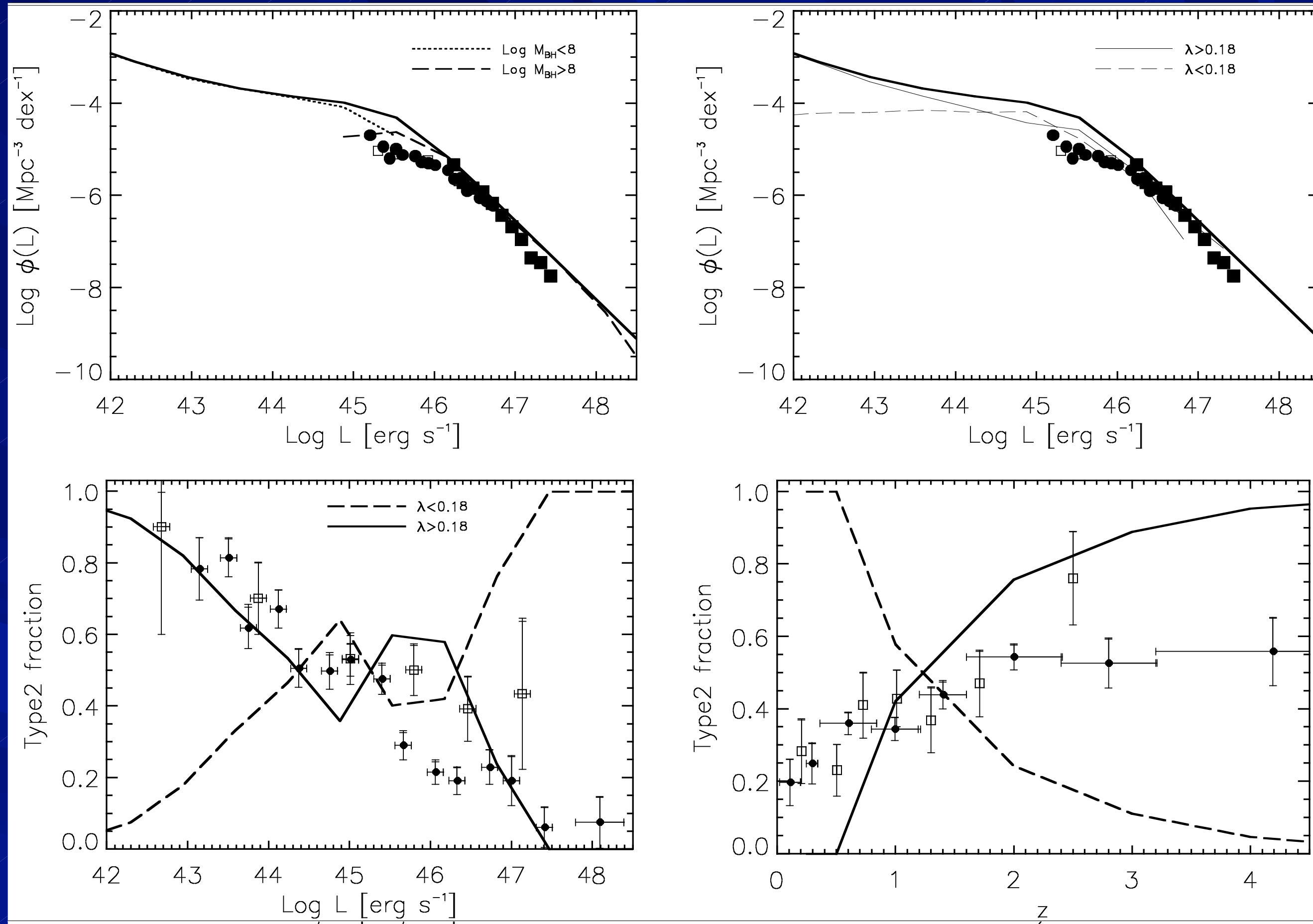
↓

WE NOW ALLOW FOR THE ACCRETION RATES λ
TO ***DEPEND ON REDSHIFT***
(INCREASE/DECREASE WITH z)
AND, AT FIXED TIME,
TO ***DEPEND ON BLACK HOLE MASS***
(INCREASE/DECREASE WITH M_{BH})

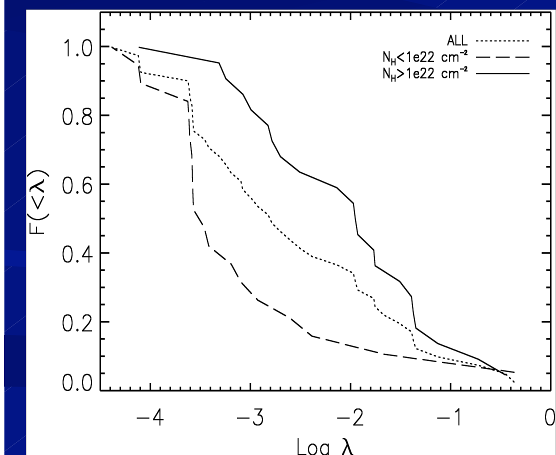
Broad Distributions III: The Obscured Fraction



Broad Distributions III: The Obscured Fraction



$\lambda \propto M_{BH}^{-}$–



Hasinger; Akylas et al.

Babic et al.; Tozzi et al.;
Alexander et al.

PART II

THE CLUSTERING OF AGNs

MODELING THE z>3 QUASAR CLUSTERING

1-Assuming monotonic relation between BH and Halos

M_{BH} ~ _ (M_{HALO})– ---> _(M_{HALO},z) ---> _(M_{BH},z)

The growth of the halo MF determines the BH growth

2-Assuming ε, λ we know how much energy is radiated and at which L

$$\Phi(L,z) = -t_{ef} \ln(10) \int \frac{\partial \Phi(M'_{BH}, z)}{\partial z} \frac{dz}{dt} \left| \frac{d \log L}{d \log M'_{BH}} \right| d \log M'_{BH}$$

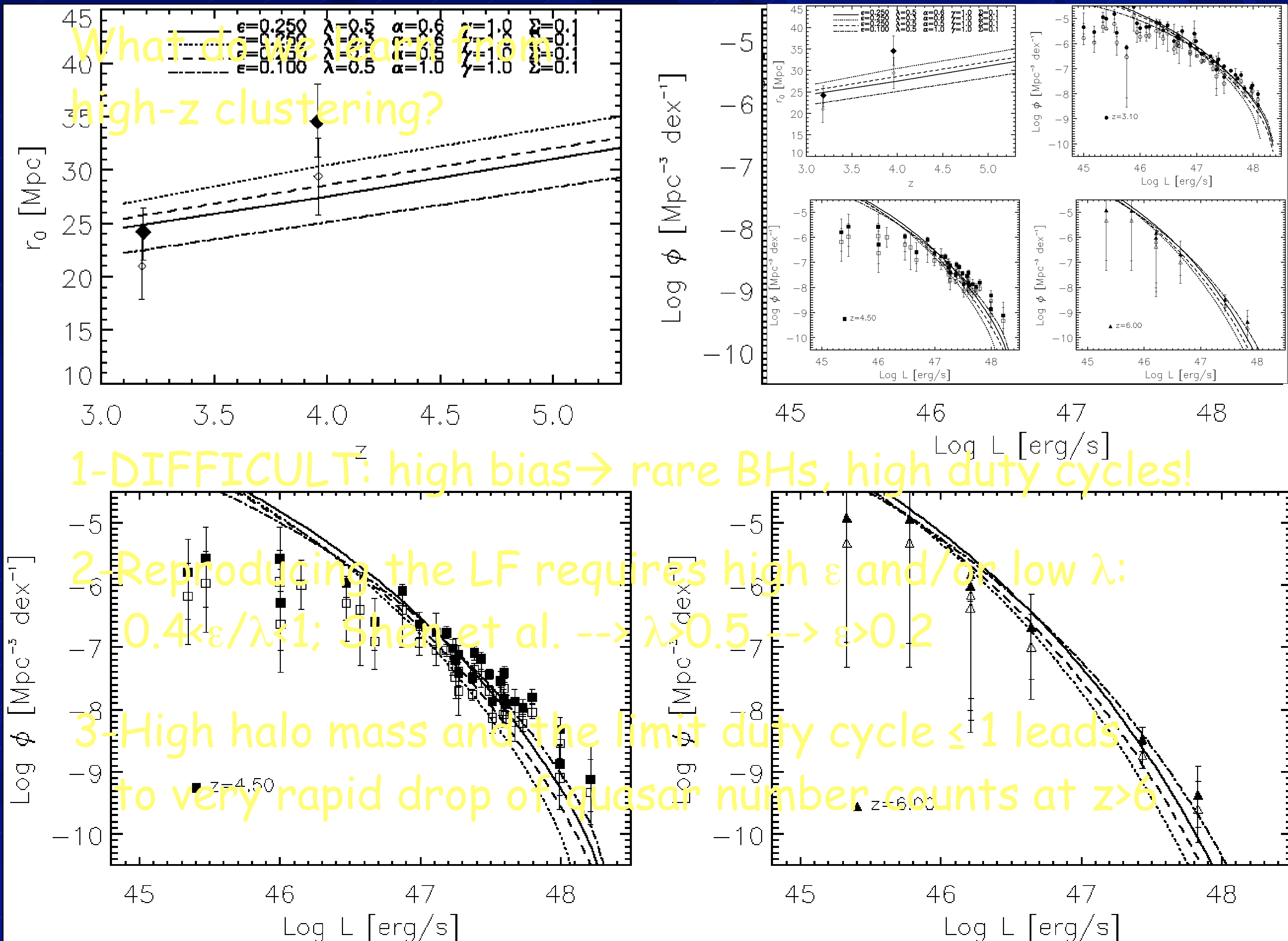
t_{ef}~ε/λ

3-The parameters we use are: ε,λ,α,Σ,γ

$$M_{BH} = \alpha\, f(\Omega_m, z) \left(\frac{M}{10^{12} M_\Theta} \right)^{1.28} \left(\frac{1+z}{4.1} \right)^{\gamma}$$

Scatter Σ weakens the bias

What do we learn from high-z clustering?



1-DIFFICULT: high bias→ rare BHs, high duty cycles!

2-Reproducing the LF requires high ε and/or low λ: 0.4<ε/λ<1; Shen et al. --> λ>0.5 --> ε>0.2

3-High halo mass and the limit duty cycle ≤1 leads to very rapid drop of quasar number counts at z>6

MODELING THE low-z QUASAR CLUSTERING

1-The previous method breaks down at low-z: **multiple quasars** in halos!

2-We return to our previous accretion modeling tied to the observed AGN Luminosity Function: BH mass function predicted from **continuity equation**

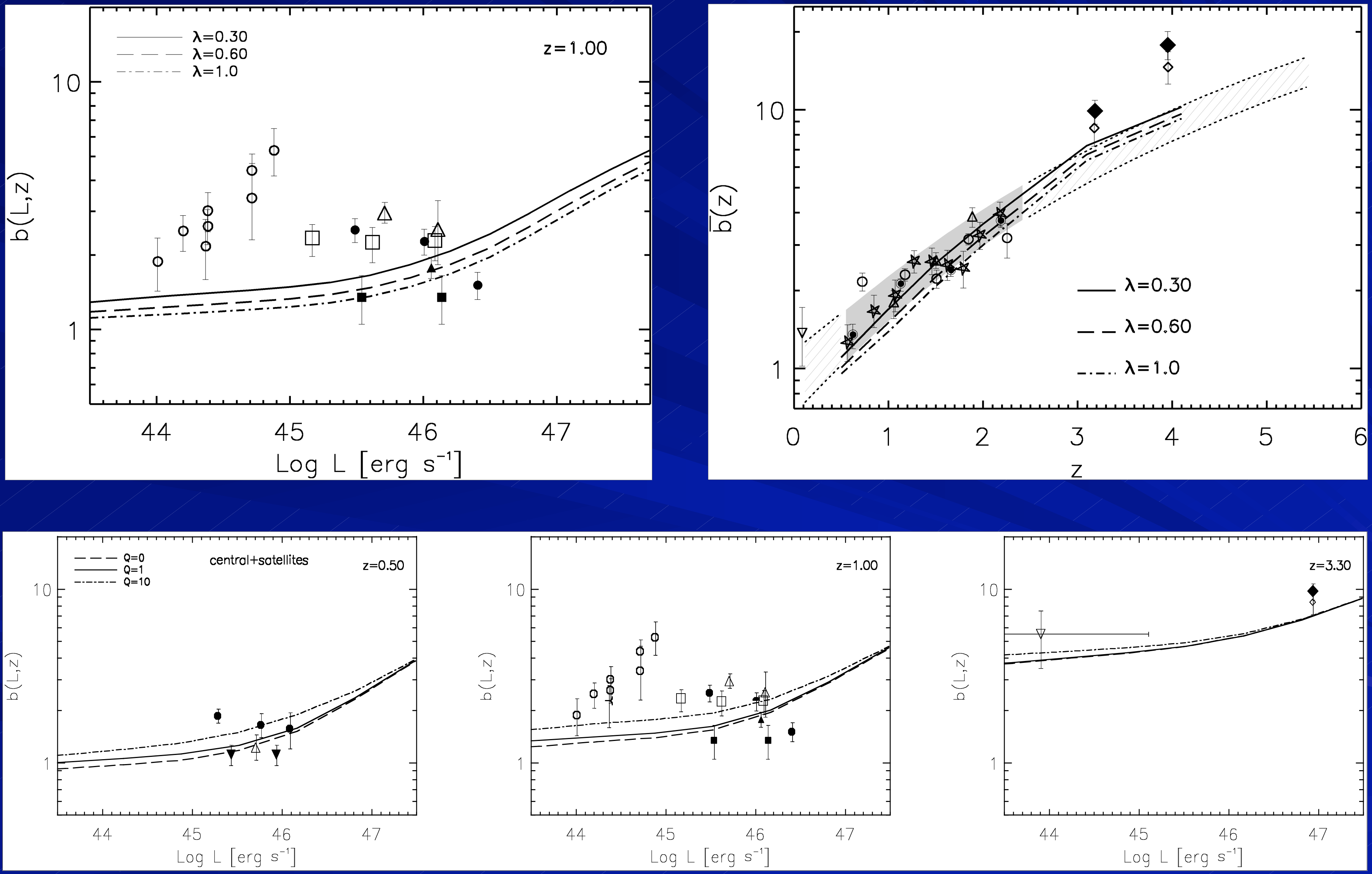
3-We add the assumption that BH mass is a **monotonic function** (with scatter) of halo mass or the maximum mass of the subhalo

4-**Scatter** between L and M_{HALO} can come either from scatter in M_{BH}-M_{HALO} or from a broad $p(\lambda,z)$ distribution

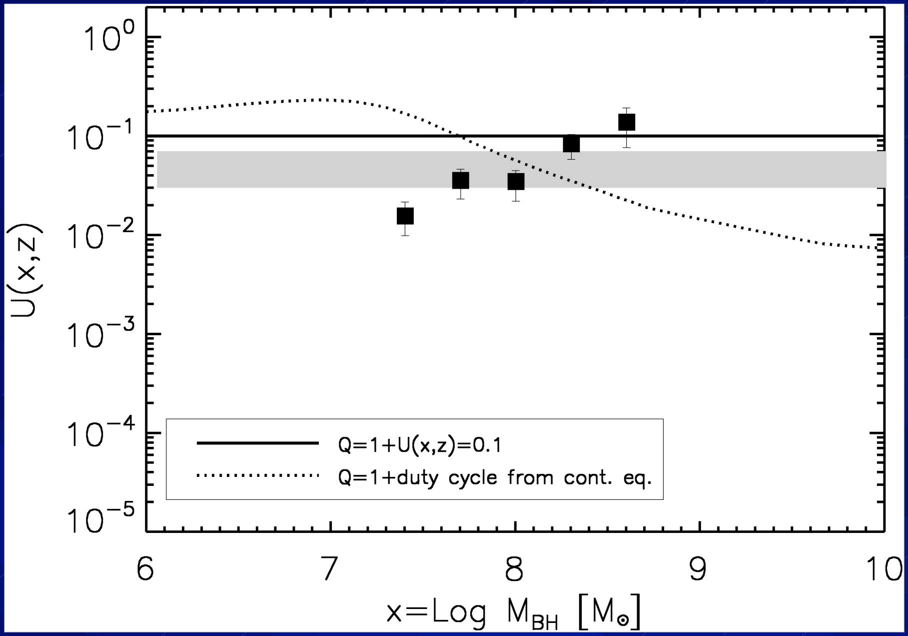
5-Add **new physical parameter** $Q=P_s/P_c$!
Small difference at large scales, significant at small ones

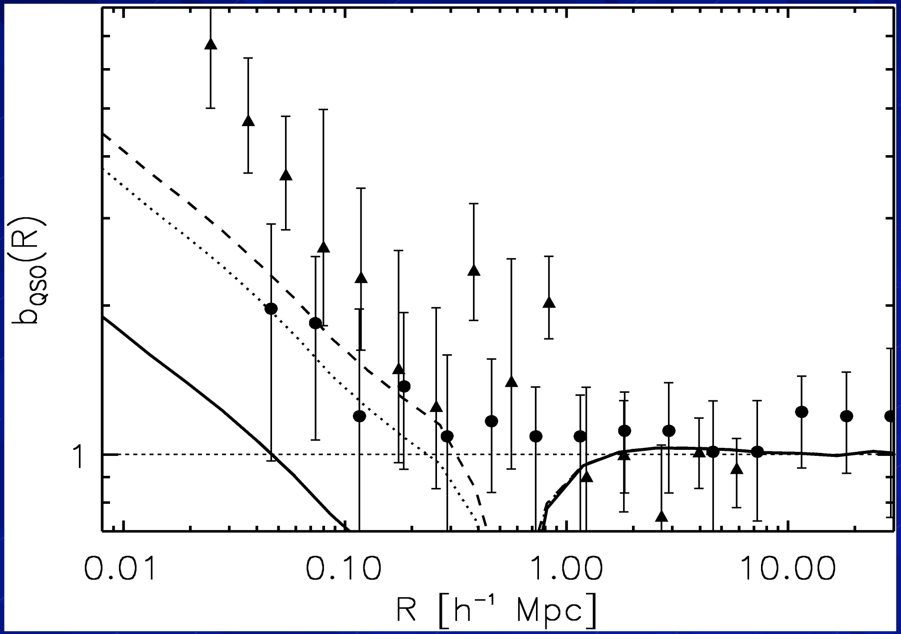
Low-z Clustering: RESULTS

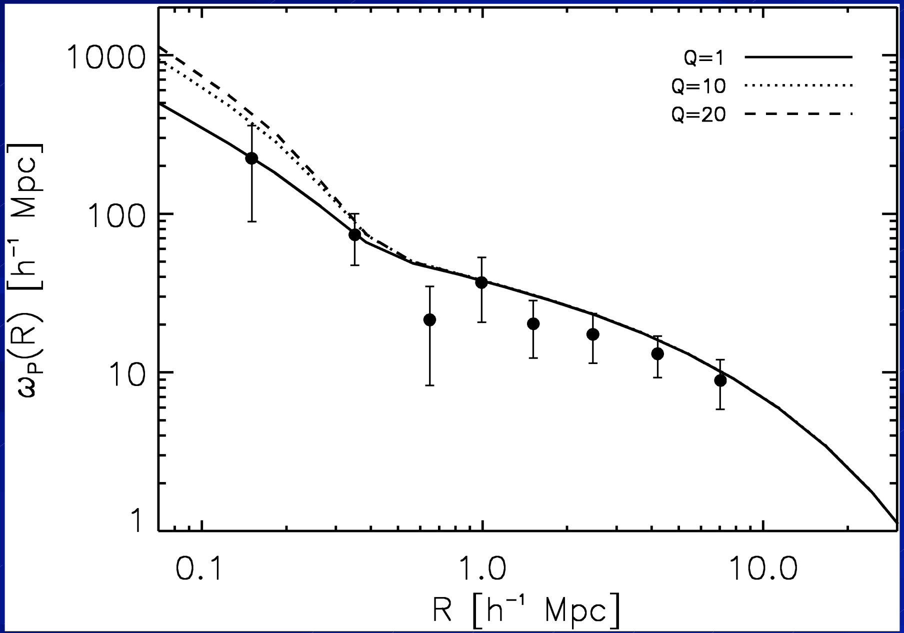
Coil et al.; Croom et al.; da Angela et al.; Francke et al.; Hennawi et al; Mountrichas et al.; Myers et al.; Padmanabhan et al.; Plionis et al; Porciani et al.; Shen et al.



Good constraints from the small scales….







Towards a successful Model:

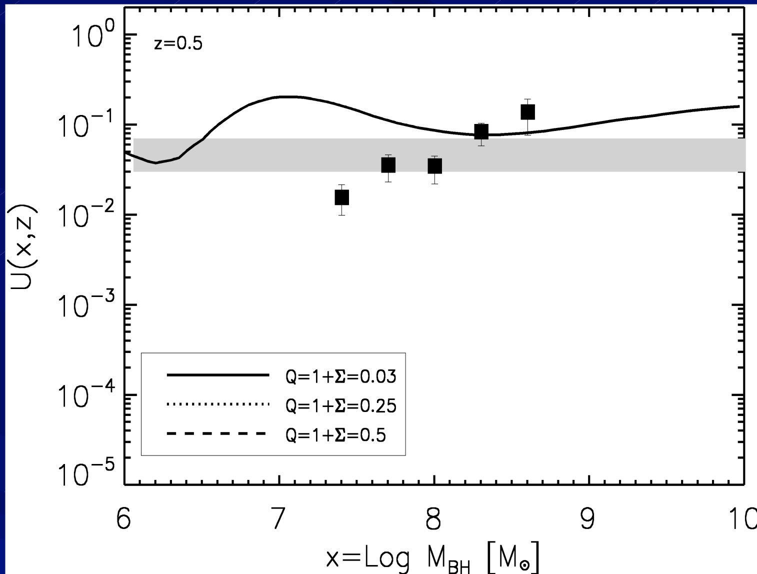
-We already saw in PART I: mass dependence
can match the obscured fraction
-A reasonable match to duty cycles and low-z clustering can be found if:

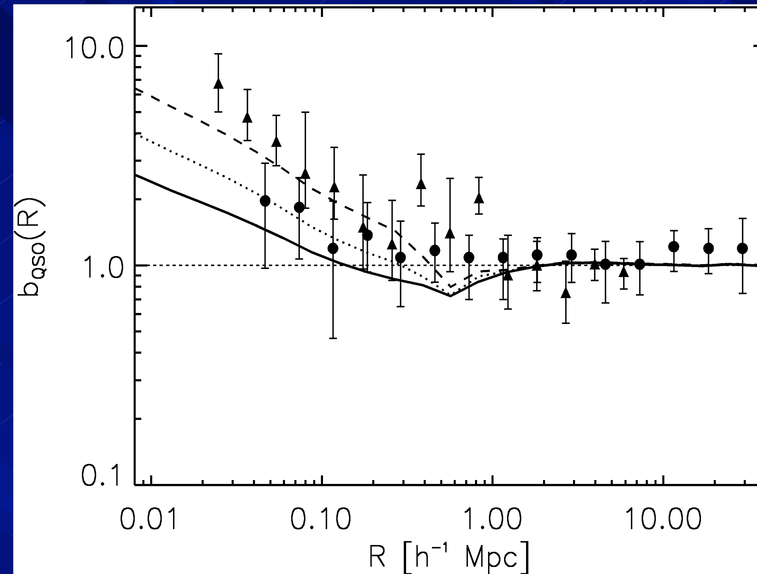
1- $\lambda \propto M_{BH}^{-1/3}$

2- $\lambda \propto f(z)=[1-\exp(z/2)]$

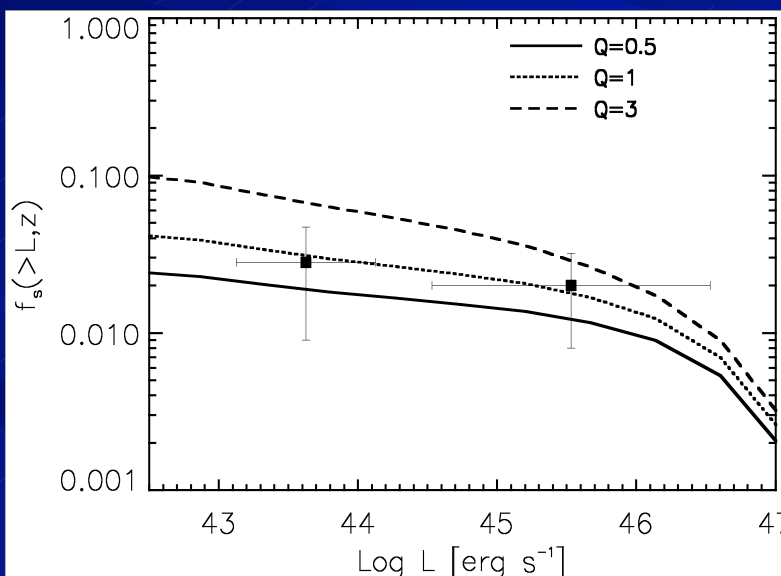
3- $Q=0.5-1$

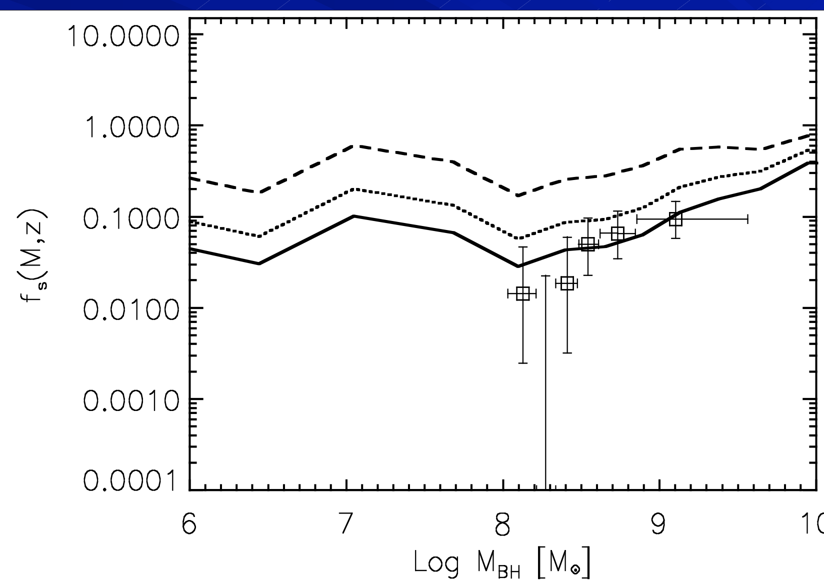
4-Scatter in M_{BH}-Mhalo
~0.3-0.5 dex





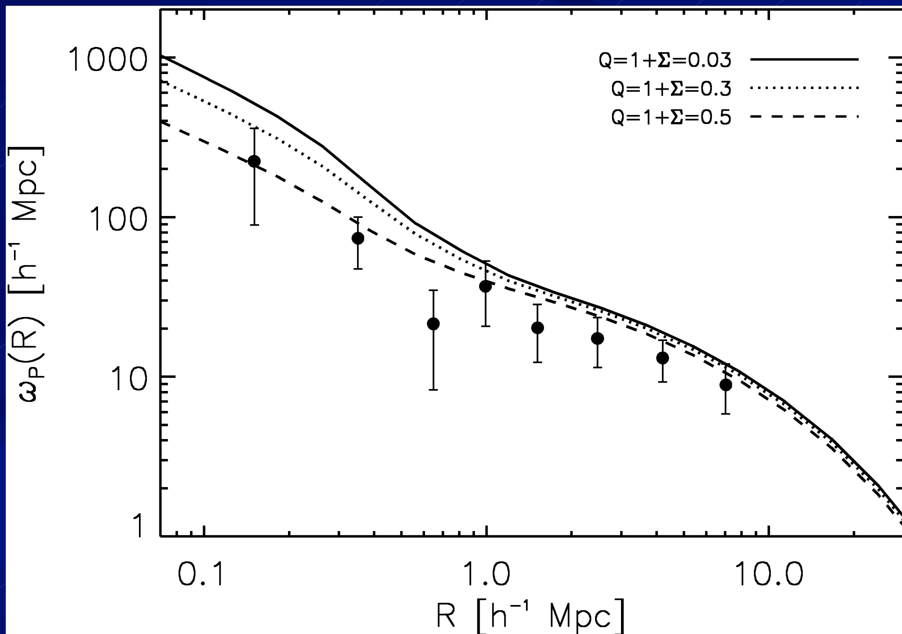
f_s= fraction of AGNs which are satellites

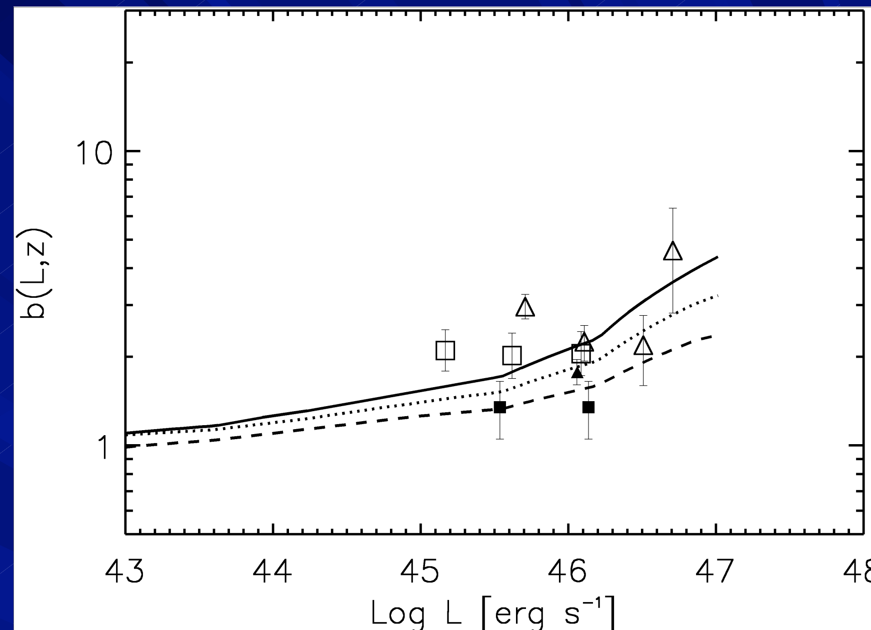


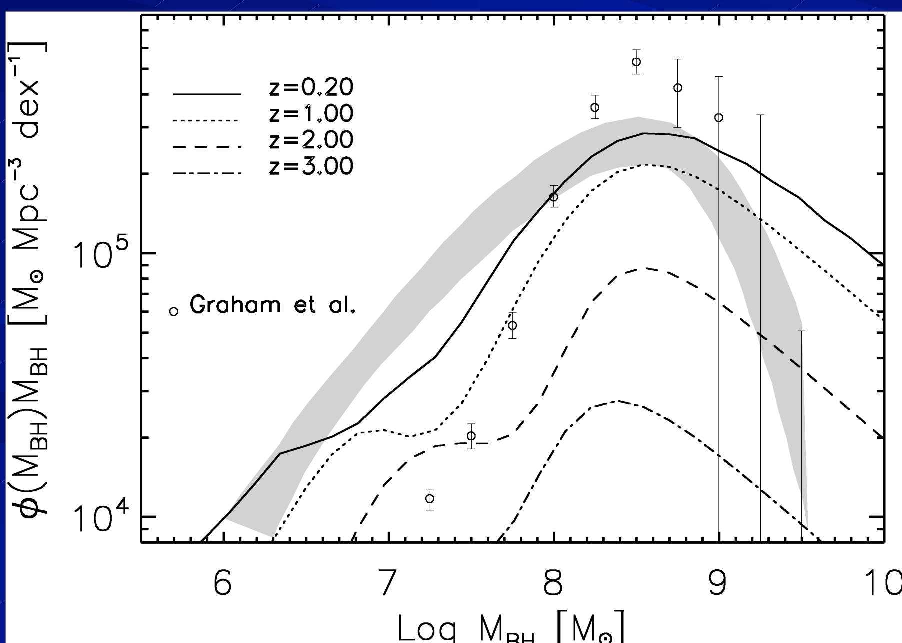


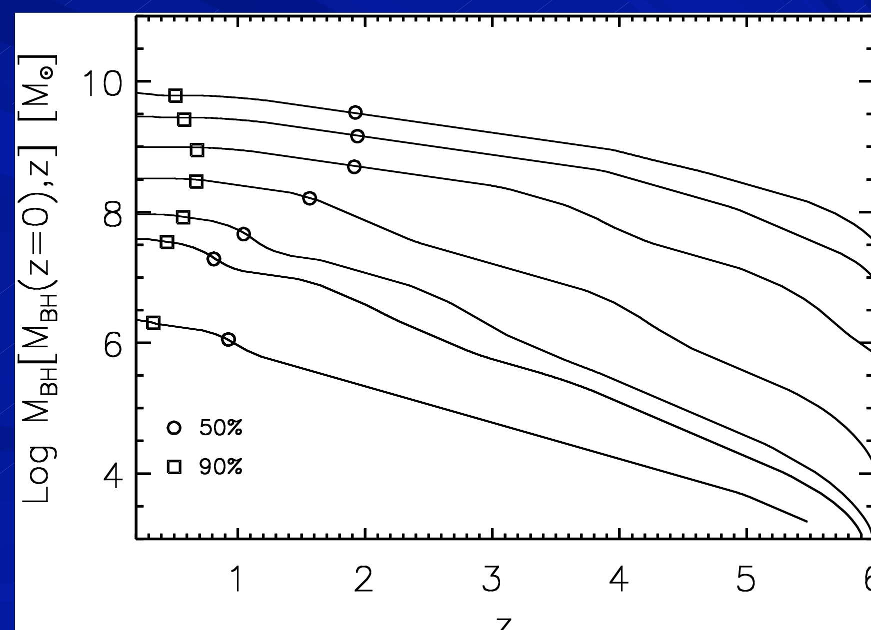
Eastman et al.; Martini et al.; Sivakoff et al.

Towards a successful Model II:









SO…WHAT DID WE LEARN ON HOW BHs EVOLVE?

- ***<u>Single-λ models</u>*** can reproduce the local BH mass function; preferred parameters are $0.5<\lambda<1$ and $0.07<\varepsilon<0.1$.

- ***<u>Broad p(λ) distributions</u>*** yield similar BH growth histories if λ is independent of BH mass.

- The ***<u>high-z clustering</u>***, especially at z=4 measured in SDSS, requires very high host halo masses and matching the AGN luminosity function requires $0.4<\varepsilon/\lambda<1$, i.e., $\varepsilon>0.2$ if $\lambda>0.5$!

- If the ***<u>Eddington ratio decreases with BH mass and z</u>***:
  -match to the AGN fraction in the field and clusters
  -match to small-scale clustering
  -match to the obscured fraction

TO GET FINAL ANSWERS:

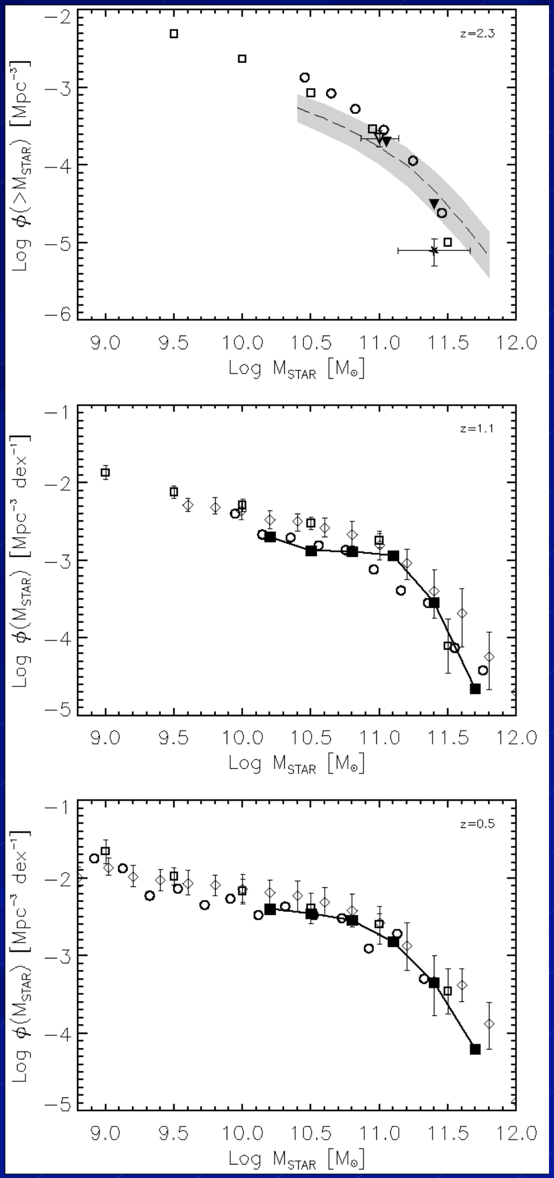
FROM OBSERVATIONS:

- Resolve systematics in the AGN LF knee and bright end
- Understand biases in the λ-distributions
- Systematics in the mean bias values

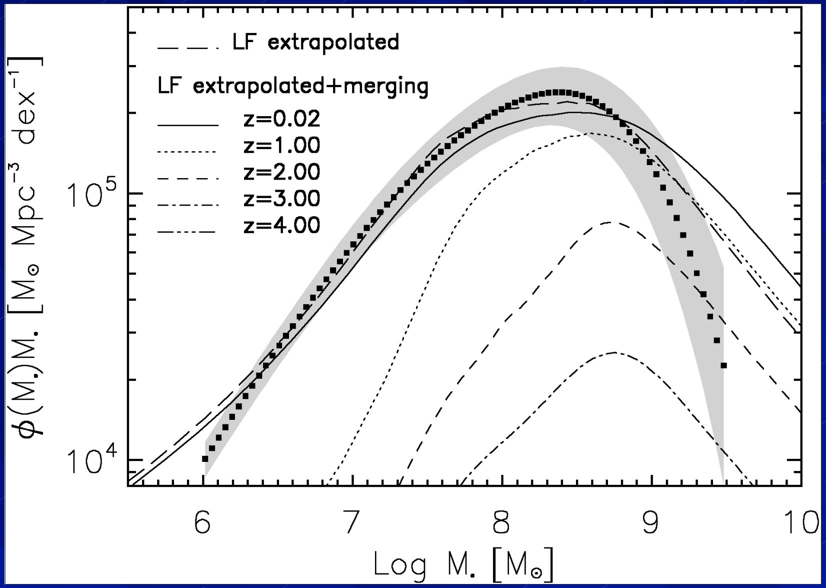
FROM THEORY:

- Convolve continuity Equation with BH merger rates
- Get final BH mass function at all z consistent with ALL observables
- Predict the BH mass function from SAM

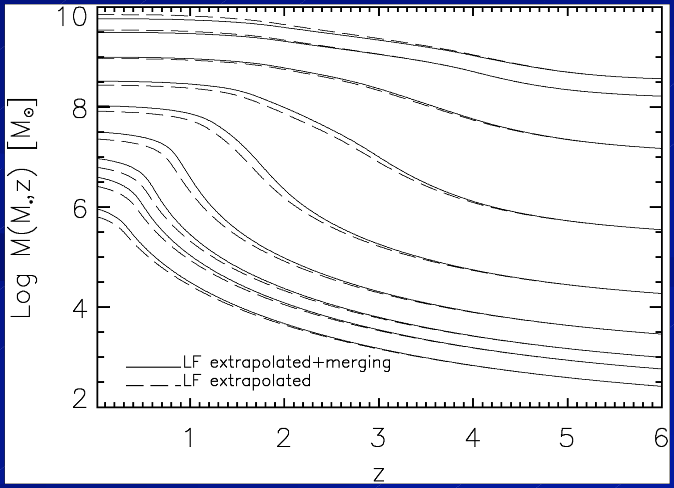
Duty cycle of AGNs: fraction of "Active" Galaxies

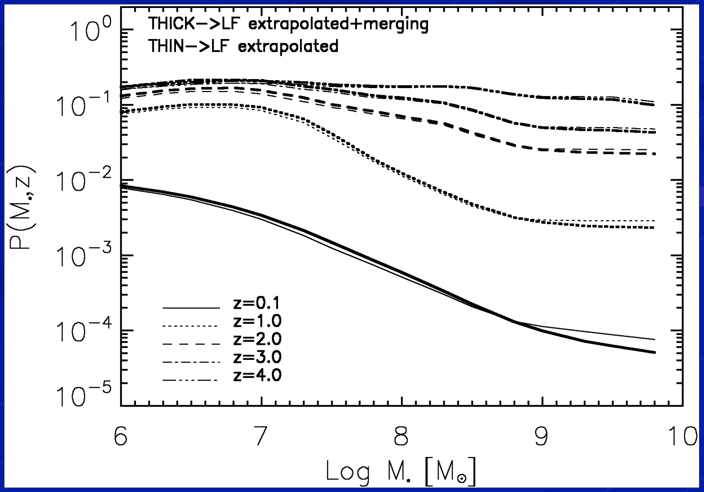


The Effect of SMBH Merging...

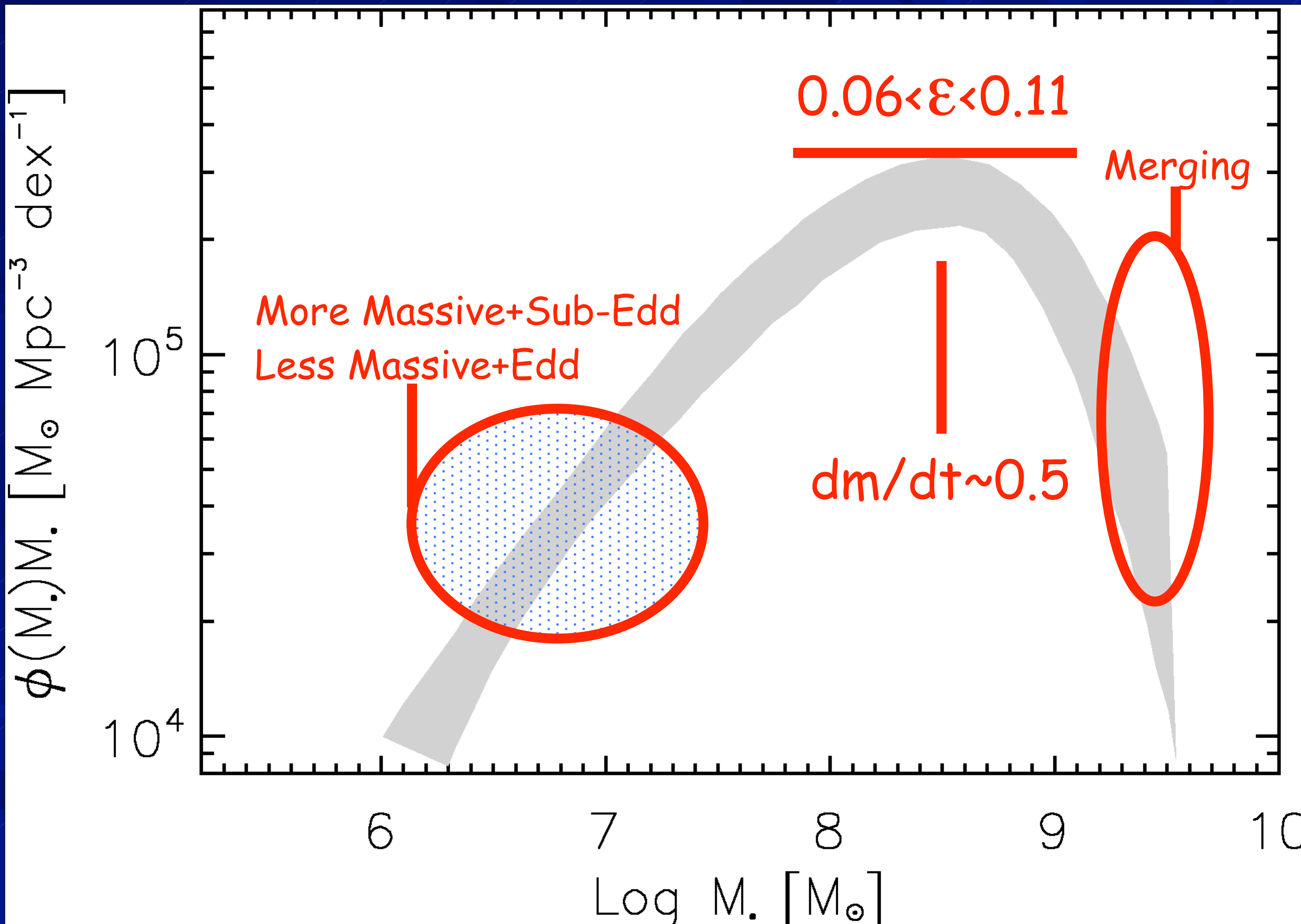


Negligible effect on accretion histories and duty cycles:

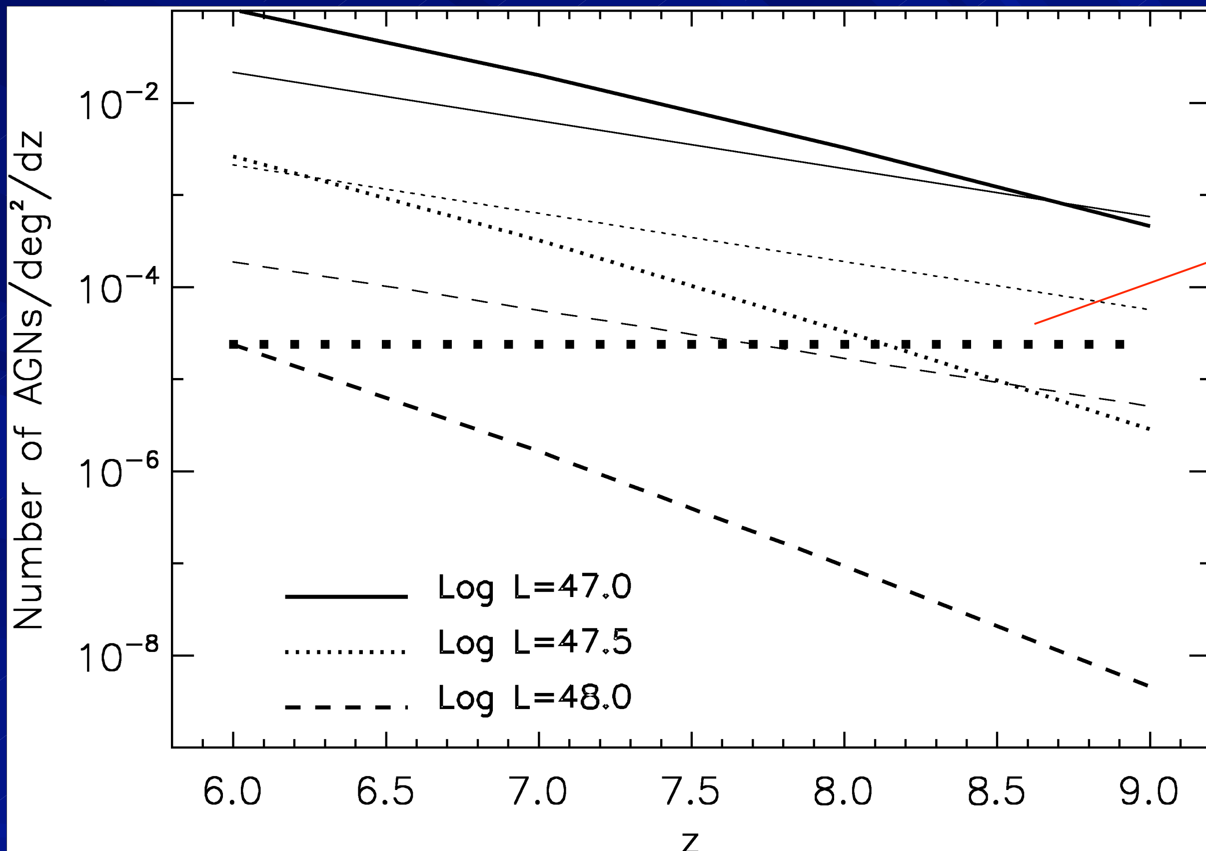




CONCLUDING on THE LMF

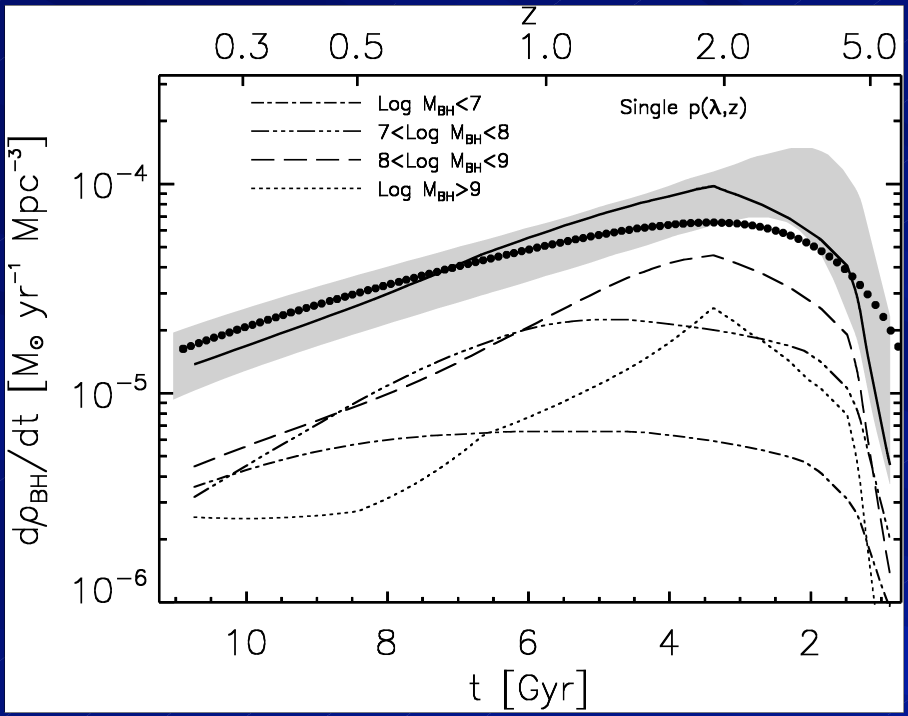


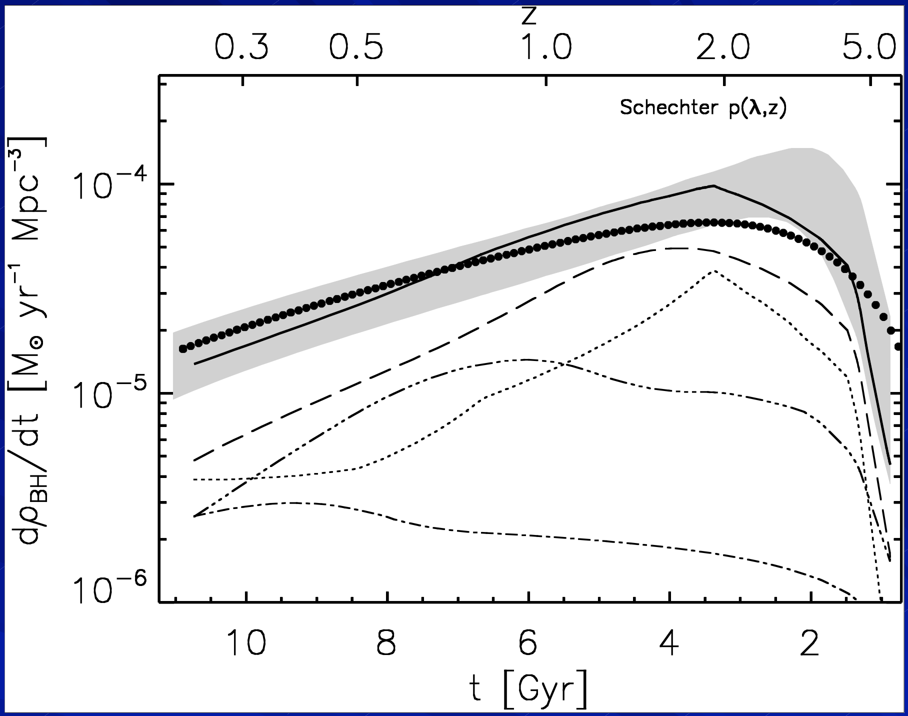
WILL WE BE ABLE TO OBSERVE z>6 QSOs?



1 QSO over the whole sky

Same RedShift Distributions…but… more Accretion for the more Massive BHs

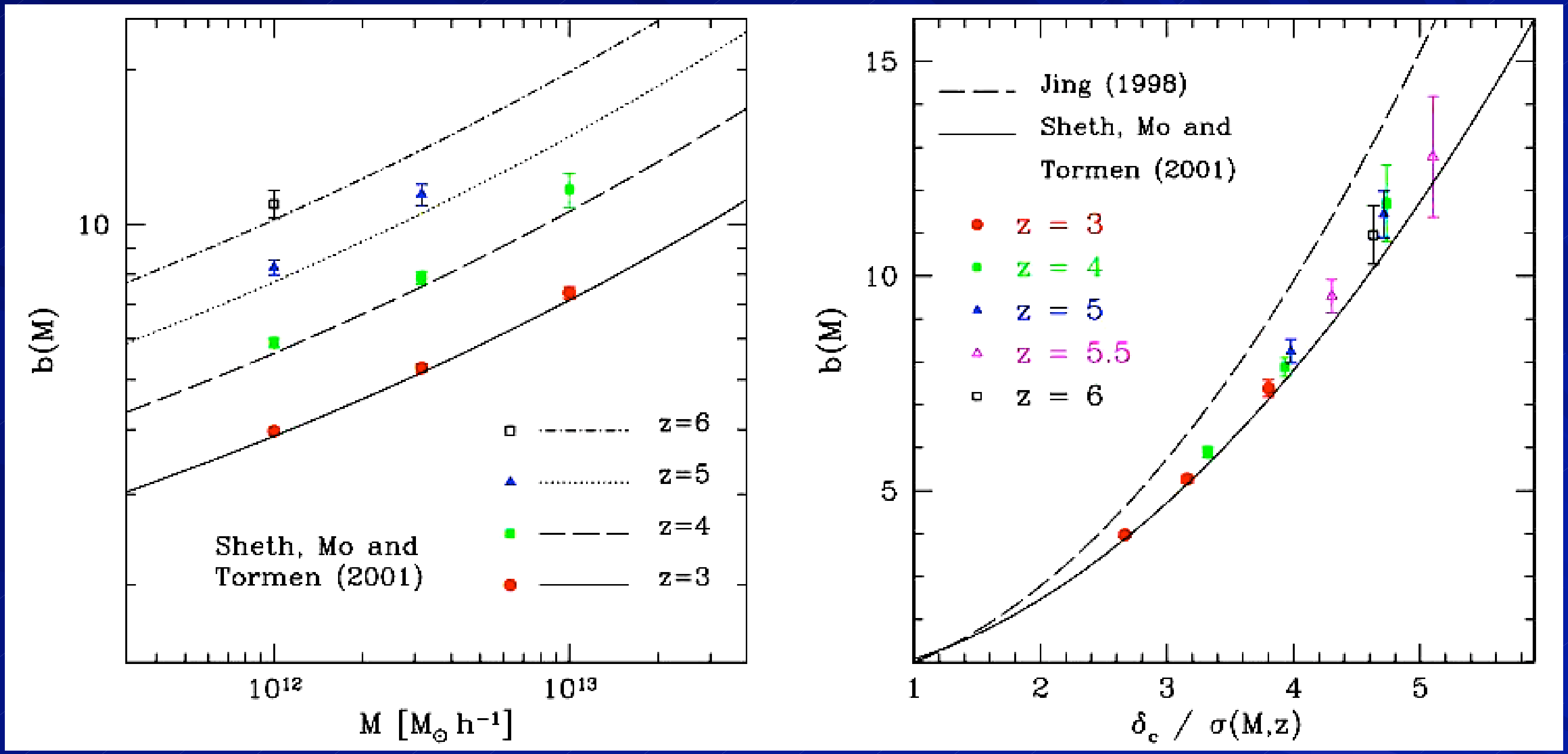




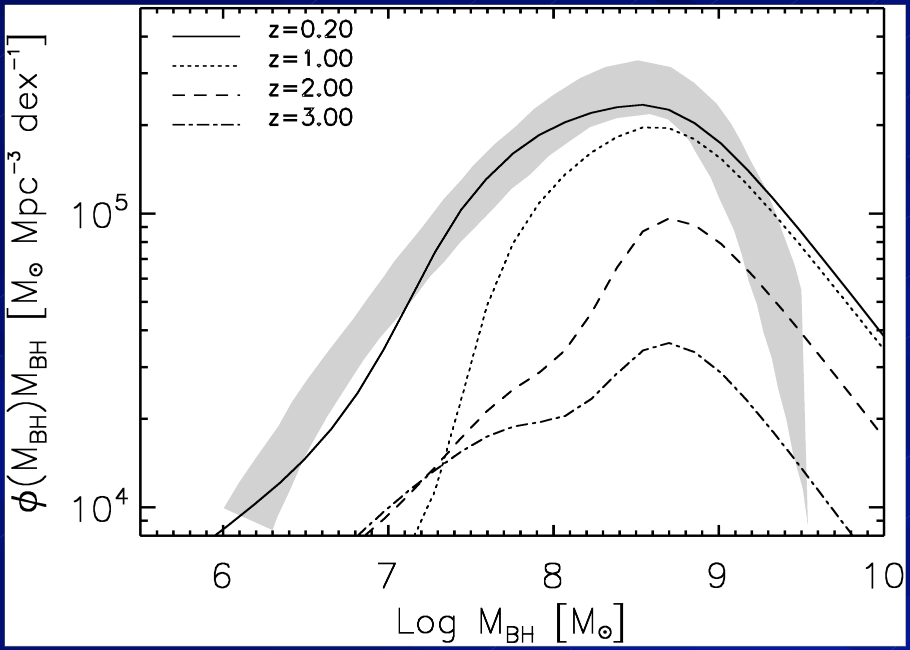
Very Narrow p(λ)

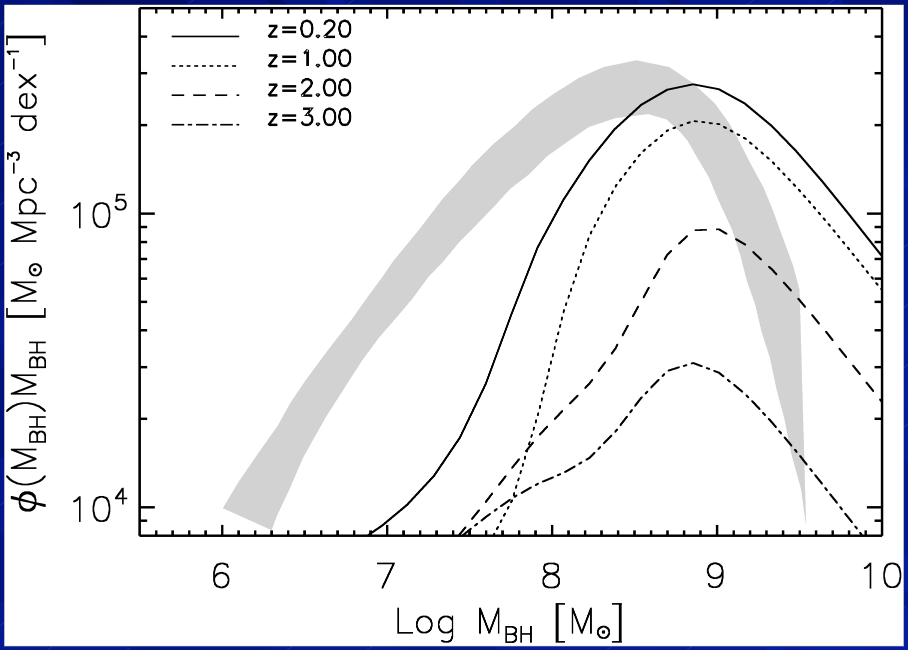
Very Broad p(λ)

We have checked we are using the right bias....



Broad Eddington ratio Distributions II

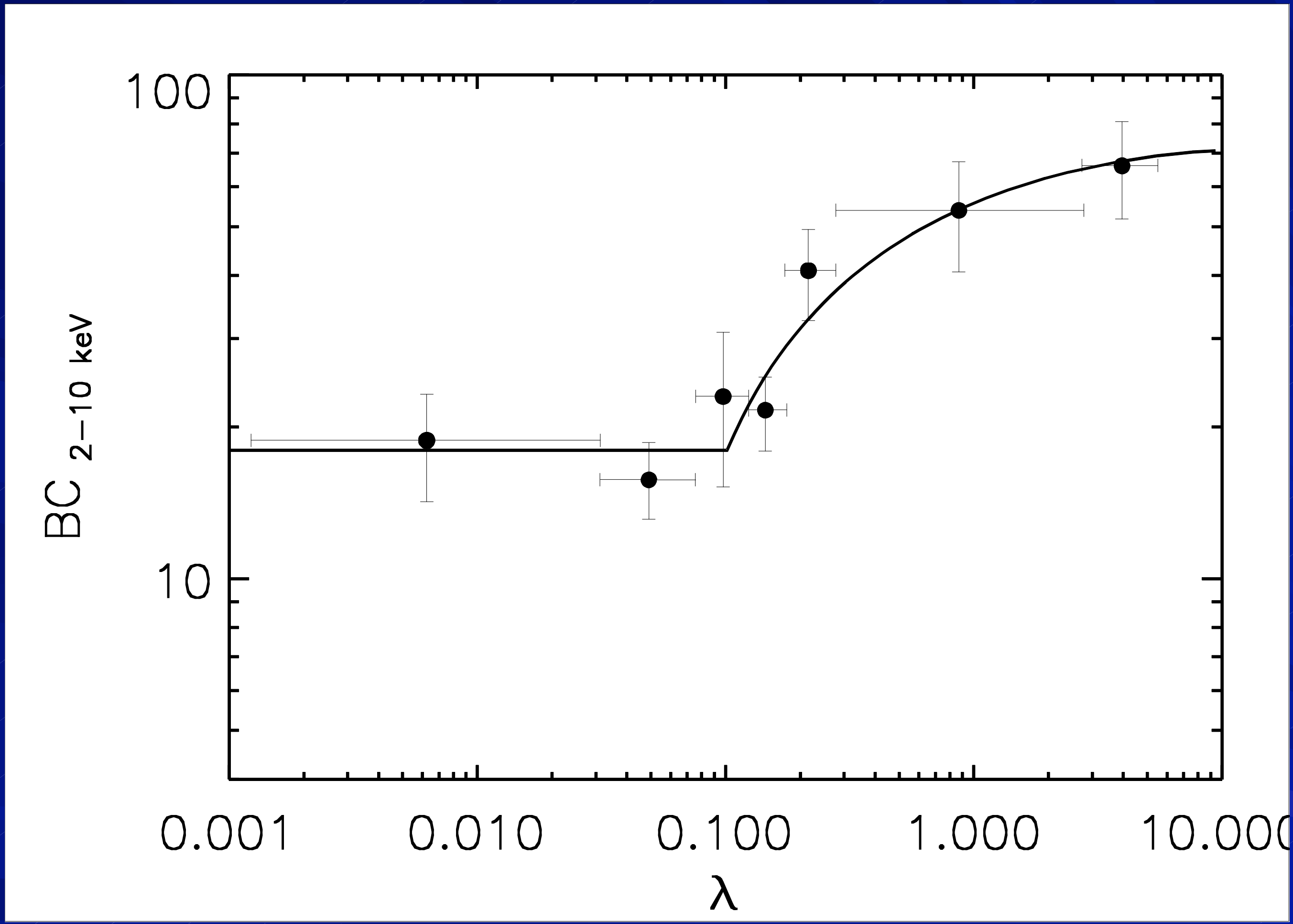




Very Broad $p(\lambda)$

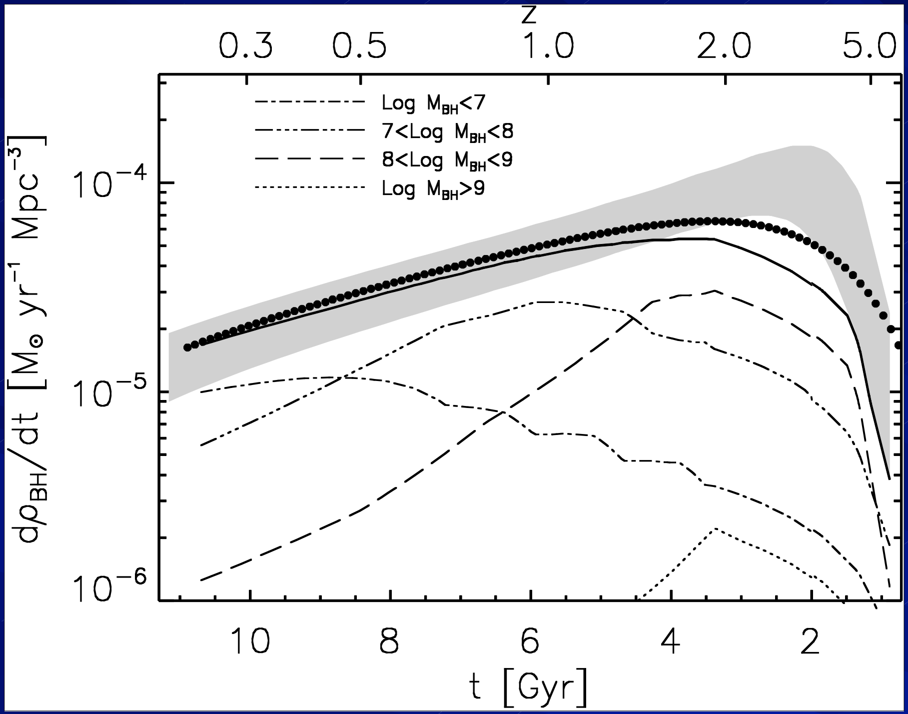
Very Broad $p(\lambda)+f(z)$

SPECIAL MODELS: λ-dependent Bolometric Correction

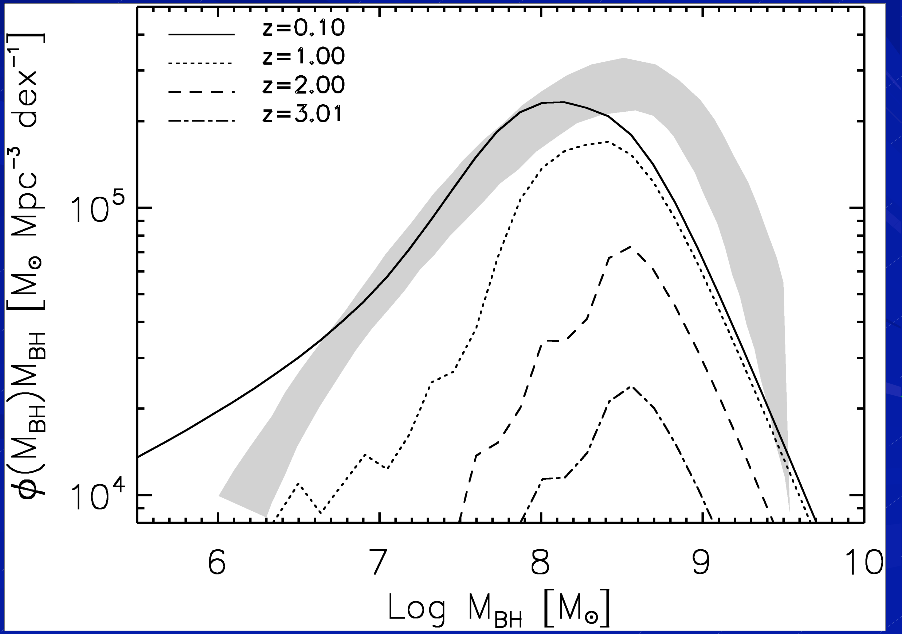


Vasudevan & Fabian 2007

Low Radiative Efficiency+Low Eddington ratios

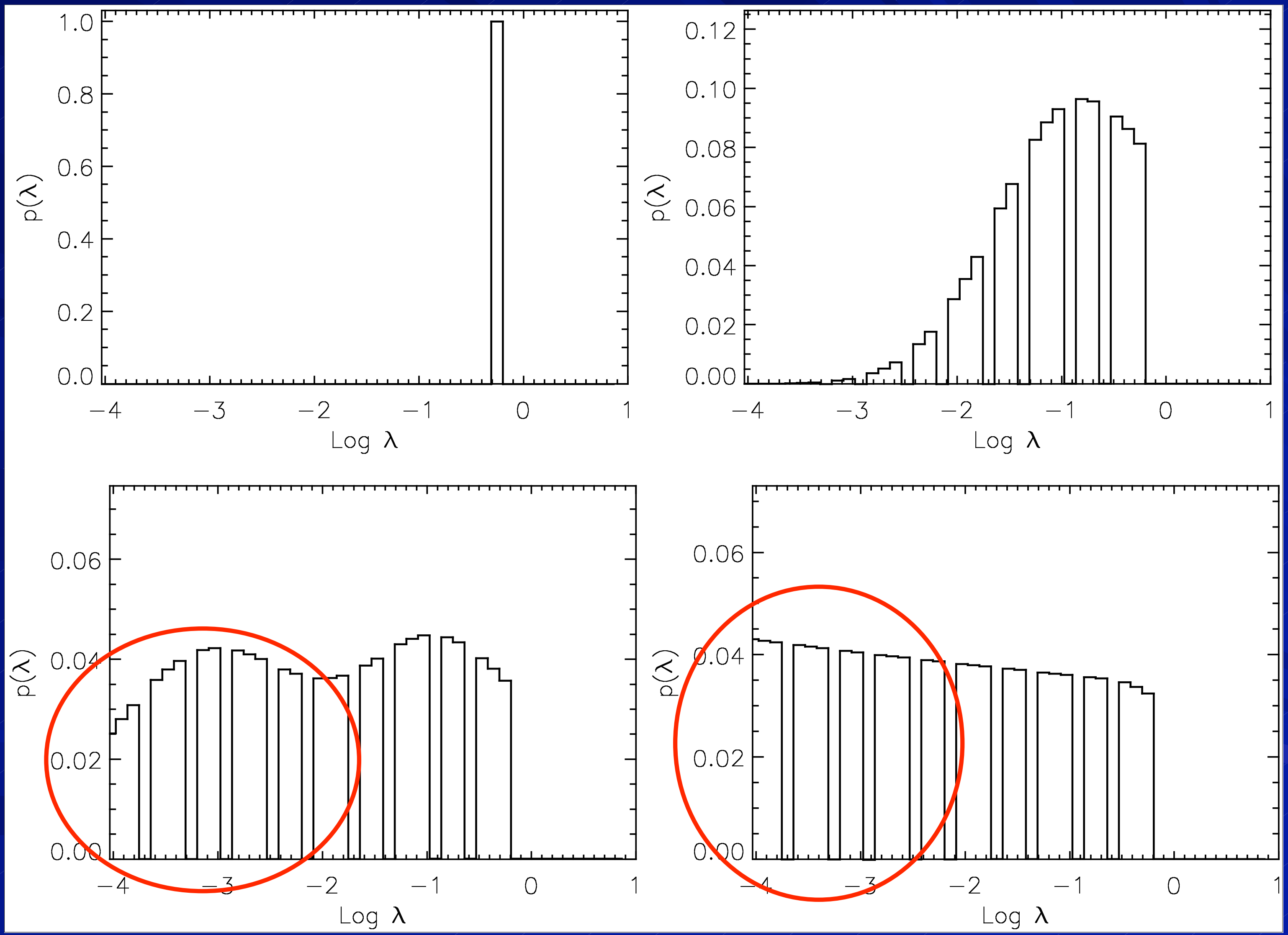


Similar Downsizing

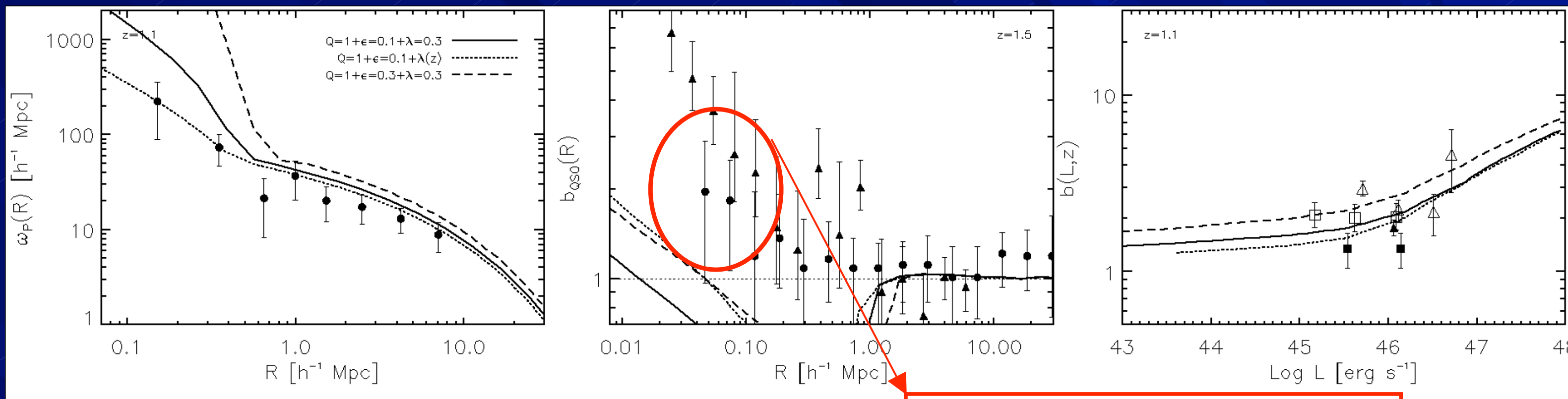


Harder to match the local BHMF: λ<0.1; ε<0.06

SPECIAL MODELS II: Low Accretion in ADAF modes



Low-z Clustering: Small and Large Scales



NO match at the small scales

$$b(L)=\frac{b(M)n(M)P,c+\int_M^{\infty} b(m)n(m)P,s(m)N(M[L]\,|\,m)dm}{n(M)P,c+\int_M^{\infty} n(m)P,s(m)N(M[L]\,|\,m)dm}$$

$$Q=\frac{P,s}{P,c}$$