AGNs:
populations, parameters and power
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Anti-hierarchical growth of black holes

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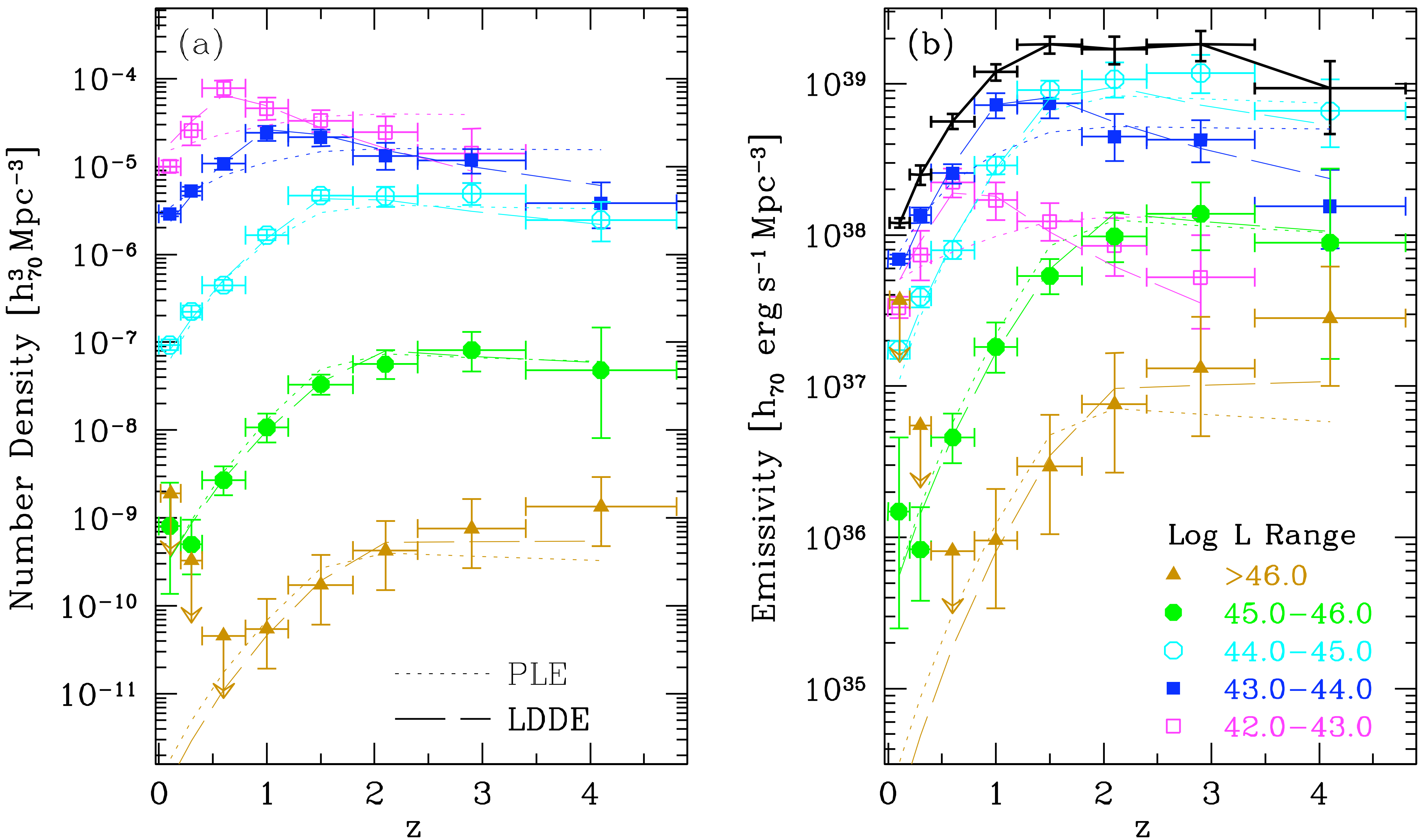
A. Burkert (University observatory, Munich)

I. Observations

AGNs from soft X-ray, *Hasinger et al. (2005)*



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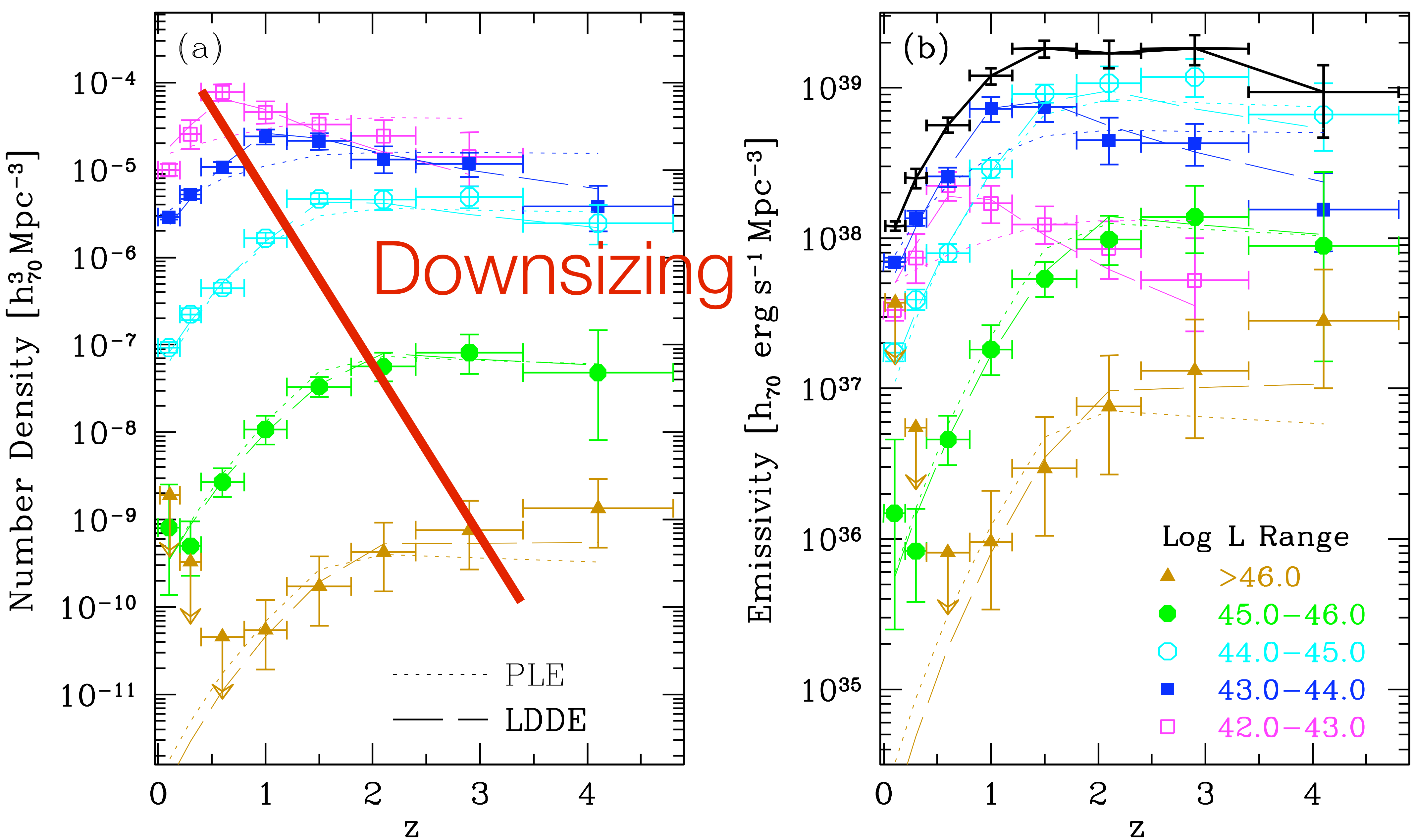


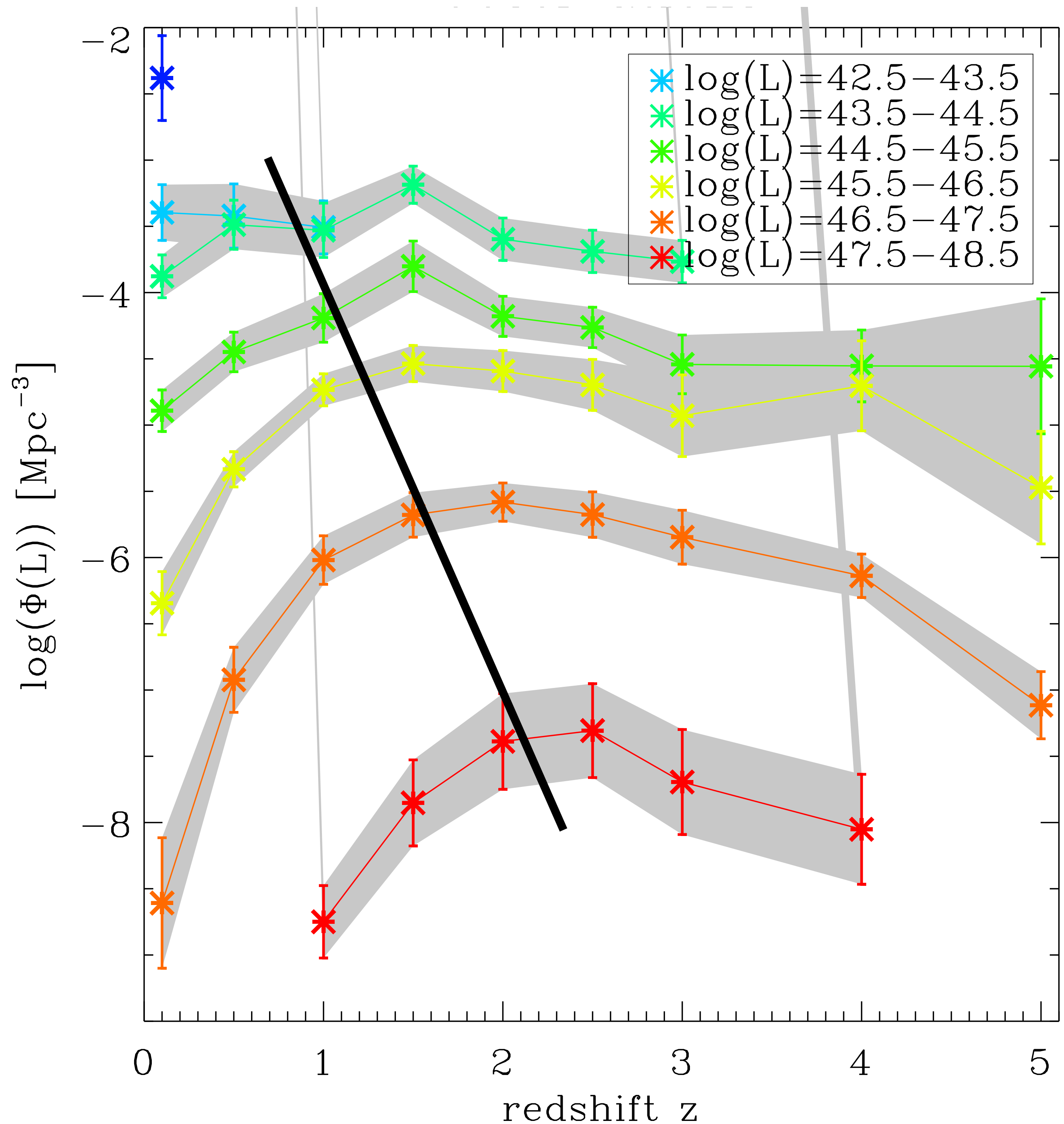
Aim of our study?

Which are the underlying physical processes causing the anti-hierarchical growth of black holes?

How can we reproduce this behaviour with a semi-analytic model (SAM)?

I. Observations

- Bolometric correction
- Dust correction factor, observable ‘fraction’ is approximated using



Hopkins et al., 2006

II. Semi-analytic model

Somerville et al., 2008

Radiative gas cooling

Photo-ionization: Suppression of gas collapsing into small mass halos

Quiescent star formation based on the empirical Schmidt-Kennicutt-law

Supernova feedback modeled as energy-driven winds

Merging history of the Millennium simulation

Star formation during a burst (triggered by mergers)

Black hole growth: Radio and Quasar mode

Metal enrichment

II. Semi-analytic model

Growth of black holes in the quasar mode

- Triggered by galaxy-galaxy major mergers (mass ratio > 0.1)

- Assumption: black holes in the two progenitor galaxies merge rapidly and form a new black hole (mass conservation)

- Accretion onto the BH: Self-regulated, based on numerical simulations (Springel et al. 2005, *Robertson et al. 2006, Cox et al. 2006, Hopkins et al. 2007*)

II. Semi-analytic model

Growth of black holes in the quasar mode

- Calculation of the final black hole mass (*Hopkins et al., 2007*):

$$M_{\rm BH,final} = f_{\rm BH,final}\ 0.158 \left(\frac{M_{\rm sph}}{10^2 M_\odot}\right)^{1.12} \Gamma_{\rm BH}(z)$$

- Regime I: below $M_{\rm BH,crit}$ black hole is allowed to *accrete at the Eddington rate* (till $M_{\rm BH,peak}$)

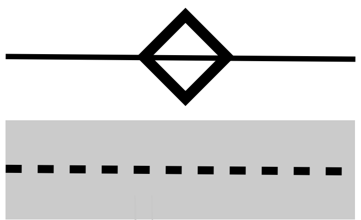
$$M_{\rm BH,crit} = f_{\rm BH,crit}\ 1.07 \left(\frac{M_{\rm BH,final}}{10^9 M_\odot}\right)^{1.1}$$

- Regime II: *blow-out phase*, power-law decline in the accretion rate (set to light curves from *Hopkins et al., 2006*)

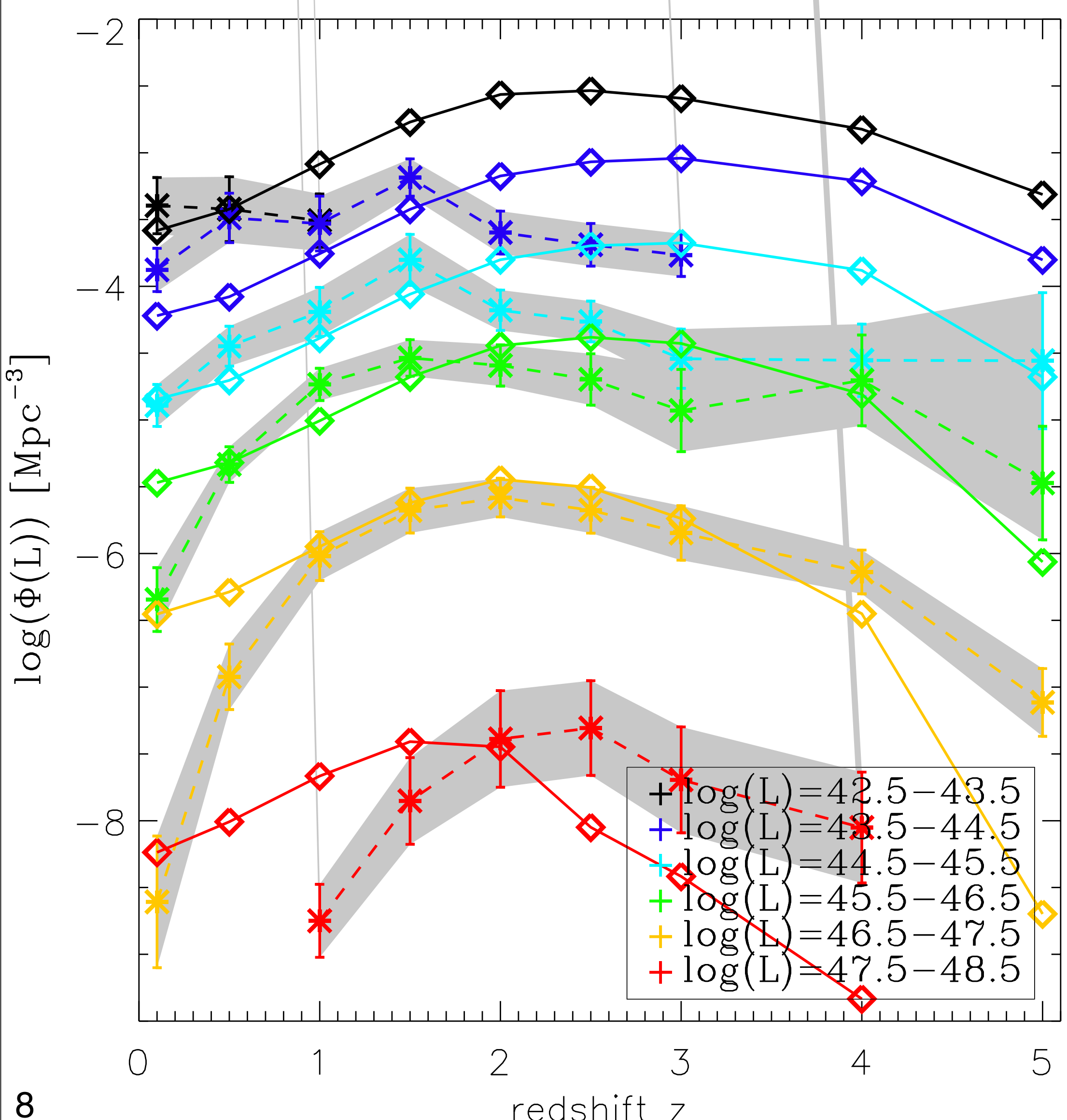
III. Results from SAMs

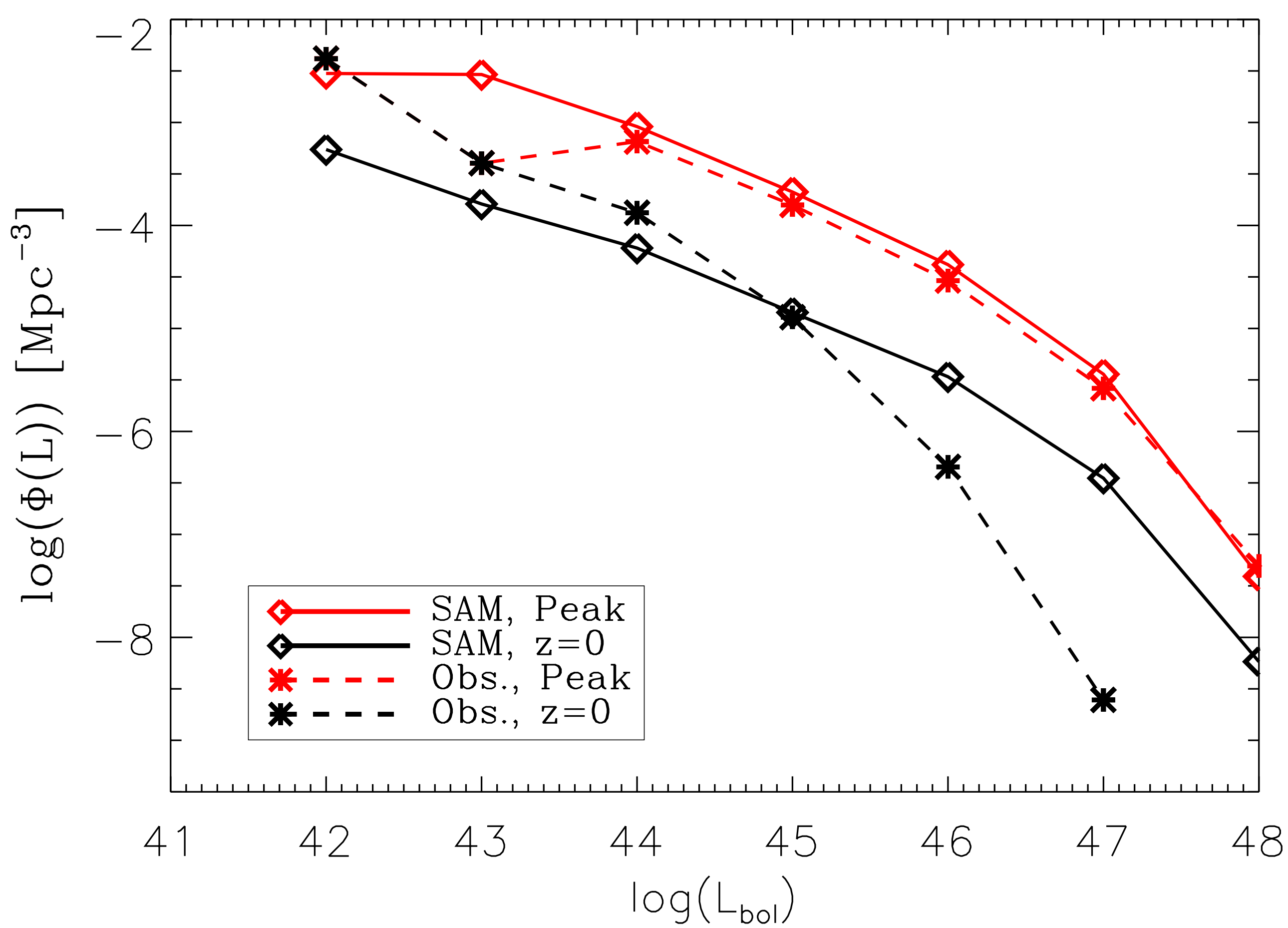
Original code

Somerville et al., 2008


SAM output
Observations

$$L = \frac{\epsilon_r}{1-\epsilon_r} \cdot \frac{dM_\bullet}{dt} \cdot c^2$$





III. Results from SAMs

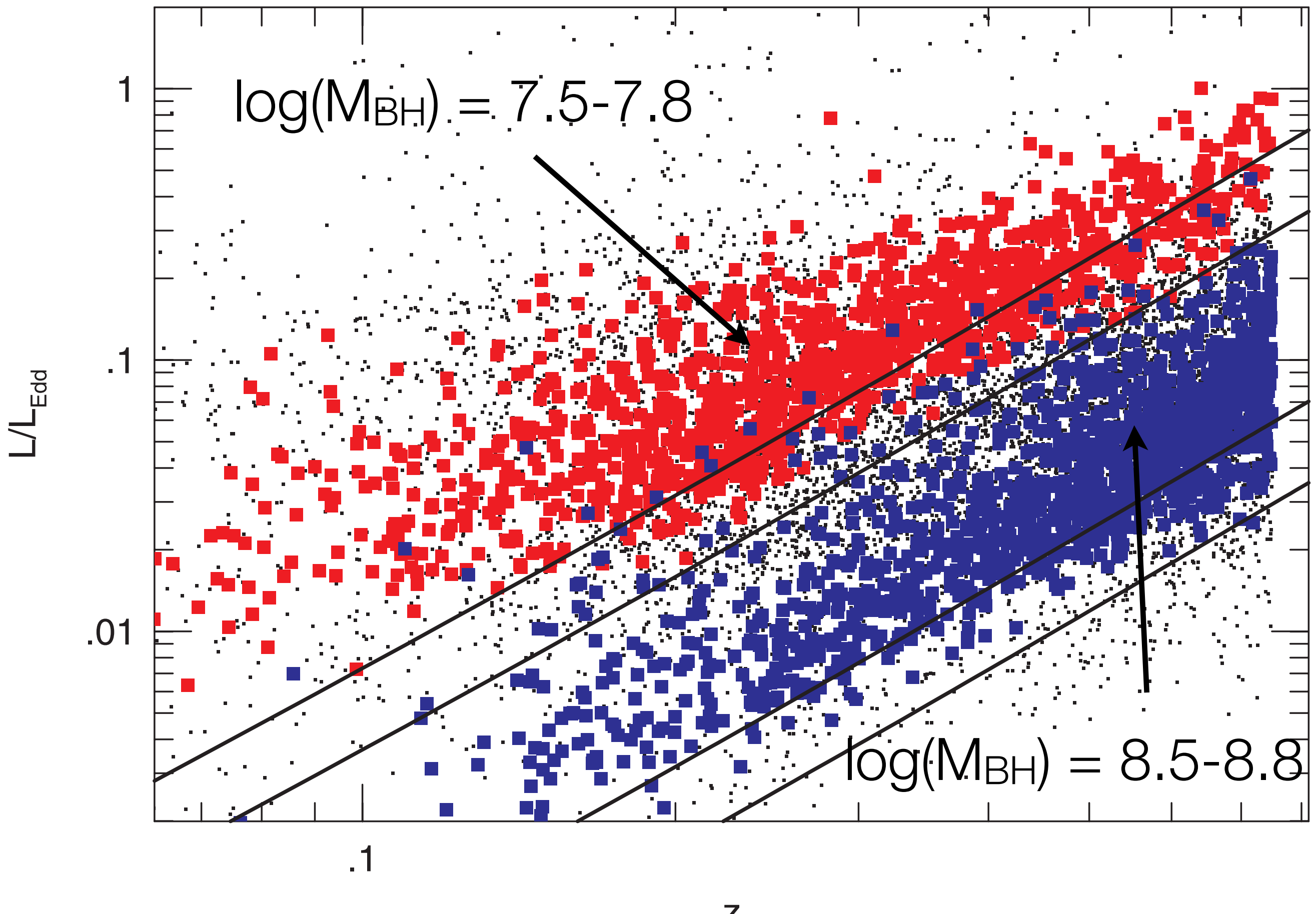
Which *additional physical mechanisms* do we need in order to achieve a better agreement with observations?

III. Results from SAMs

Assuming a redshift & mass dependent Edd-ratio

Observations: *Netzer et al. (2007) (also: Hickox et al., 2009; Shen et al., 2008; Kollmeier et al.,2006; Padovani et al.,1989)*

Type-1 AGN for z < 0.75



$$L/L_{\mathrm{edd}} \propto z^{\gamma(M)}$$

Assumptions in our model:

III. Results from SAMs

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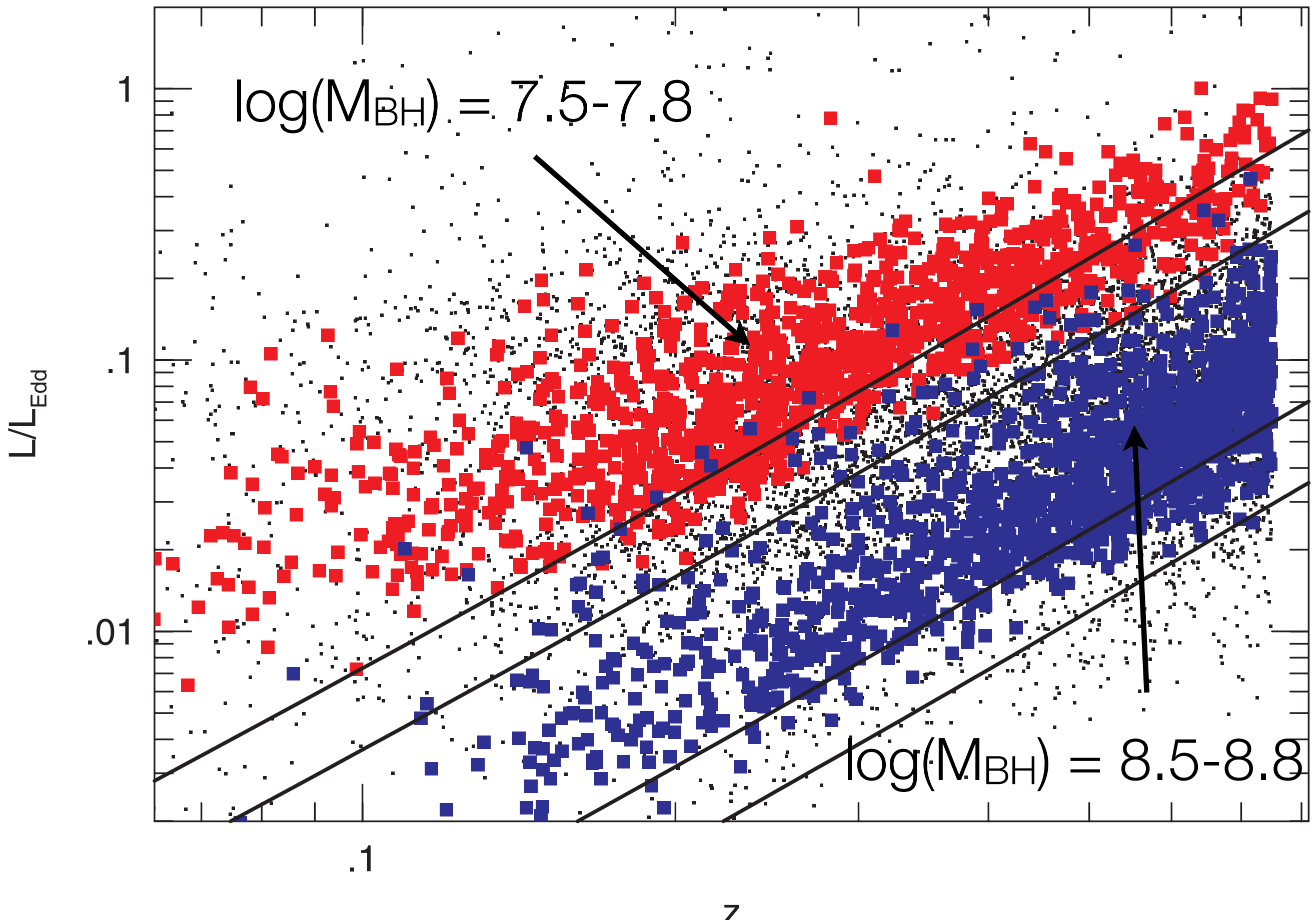


$$\boxed{L/L_{\mathrm{edd}} \propto z^{\gamma(M)}}$$

Assumptions in our model:

$$M_\bullet < 3 \times 10^8 M_\odot :$$

$$z > 1 : f_{\mathrm{edd}} = \frac{L}{L_{\mathrm{edd}}} = 1$$

$$z < 1 : f_{\mathrm{edd}} = \frac{L}{L_{\mathrm{edd}}} = 0.99 \cdot z + 0.01$$

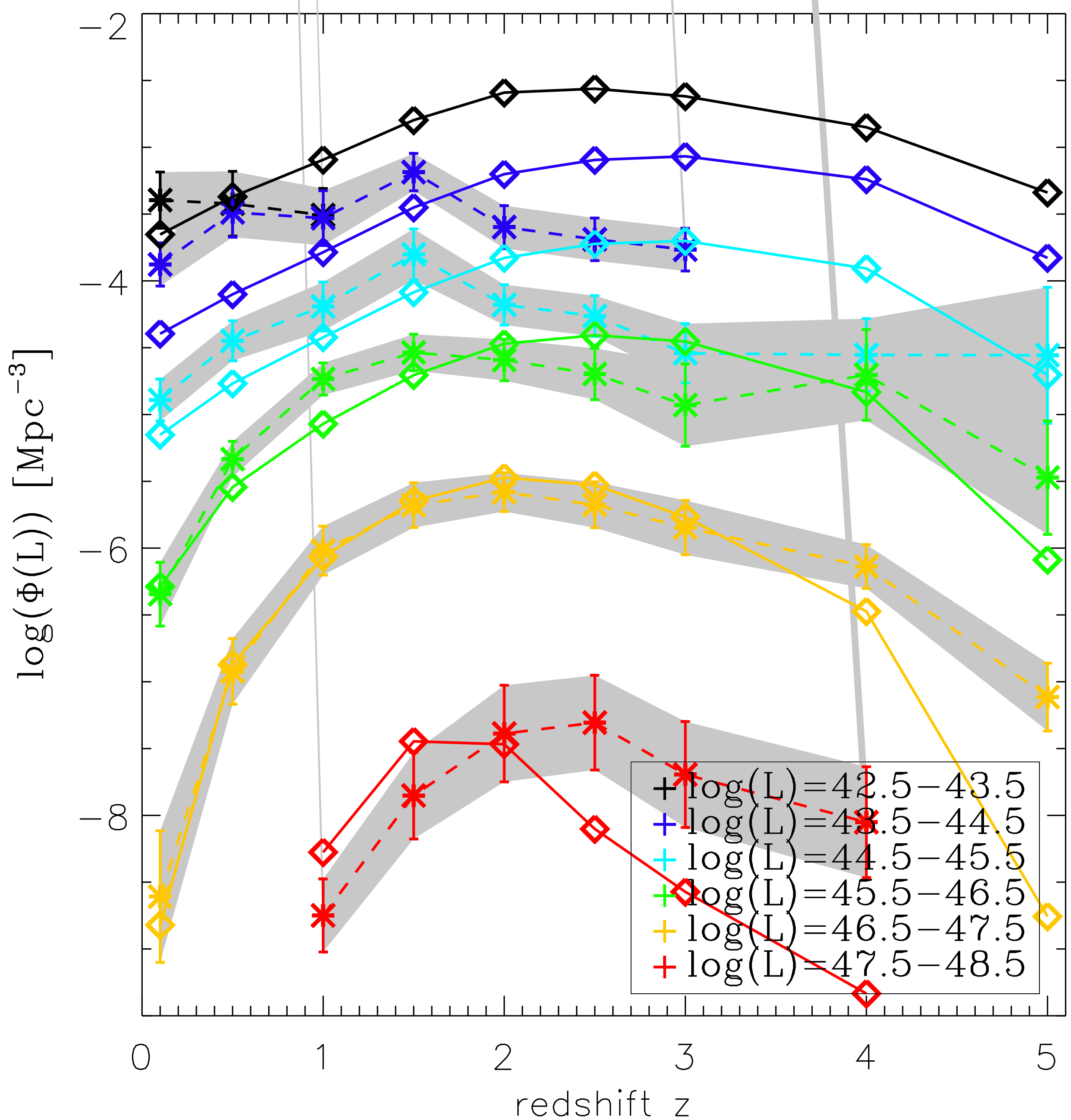
$$M_\bullet > 3 \times 10^8 M_\odot :$$

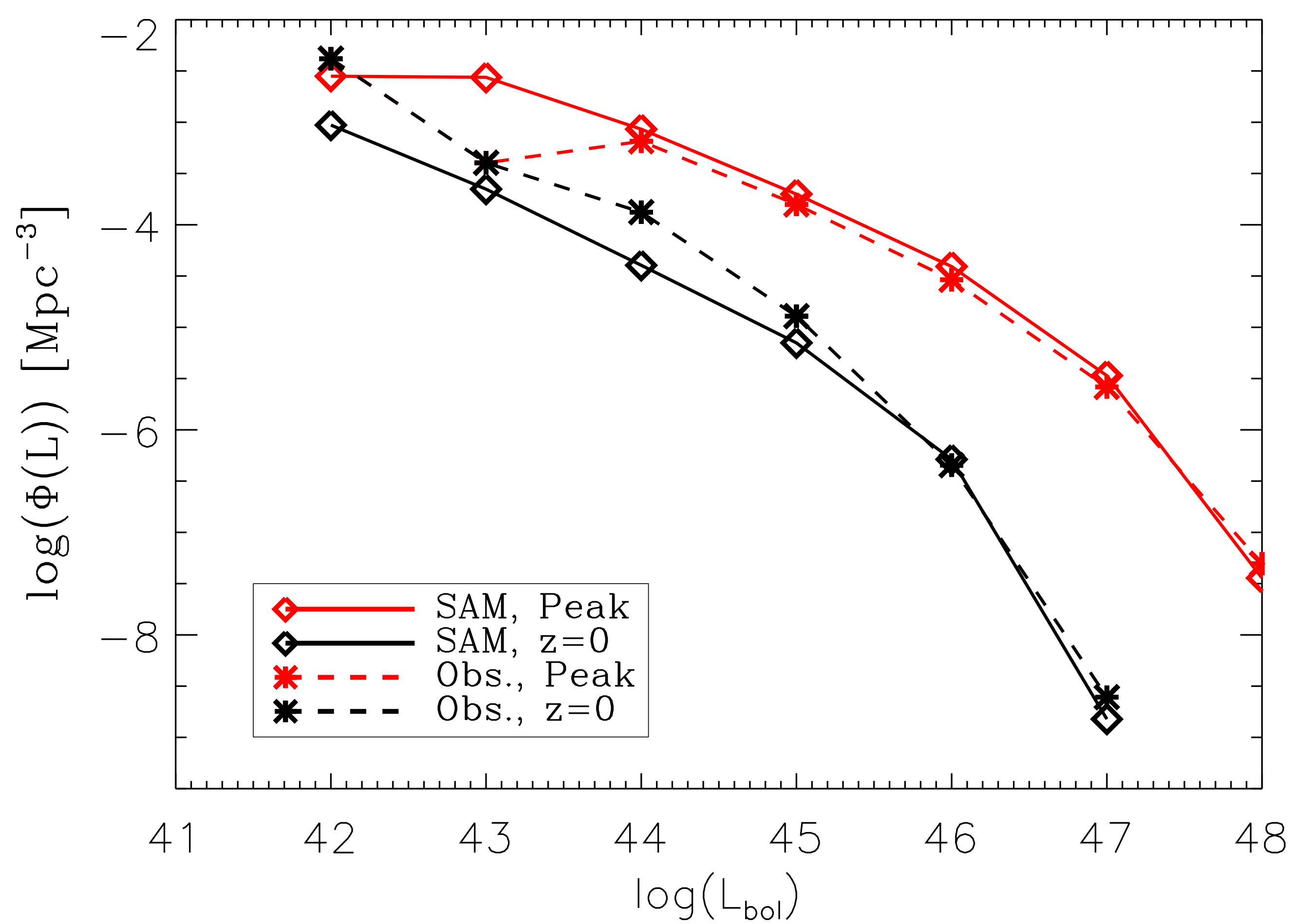
$$z > 1.5 : f_{\mathrm{edd}} = \frac{L}{L_{\mathrm{edd}}} = 1$$

$$z < 1.5 : f_{\mathrm{edd}} = \frac{L}{L_{\mathrm{edd}}} \approx 0.39 \cdot z^{2.3}$$

III. Results from SAMs

Assuming a redshift & mass dependent Edd-ratio





Steeper slope for more luminous objects at low z

III. Results from SAMs

Additional accretion onto the black hole due to disk instabilities

Stability criterion for disks:

$$M_{\rm disk,crit} = \frac{v_{\rm max}^2 \; R_{\rm disk}}{G \; \epsilon}$$

Efstathiou et al., 1982

Stability parameter

III. Results from SAMs

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$$M_{\rm disk,crit} = \frac{v_{\rm max}^2 \; R_{\rm disk}}{G \; \epsilon}$$

Efstathiou et al., 1982

Stability parameter

If $M_{disk} > M_{disk,crit}$:

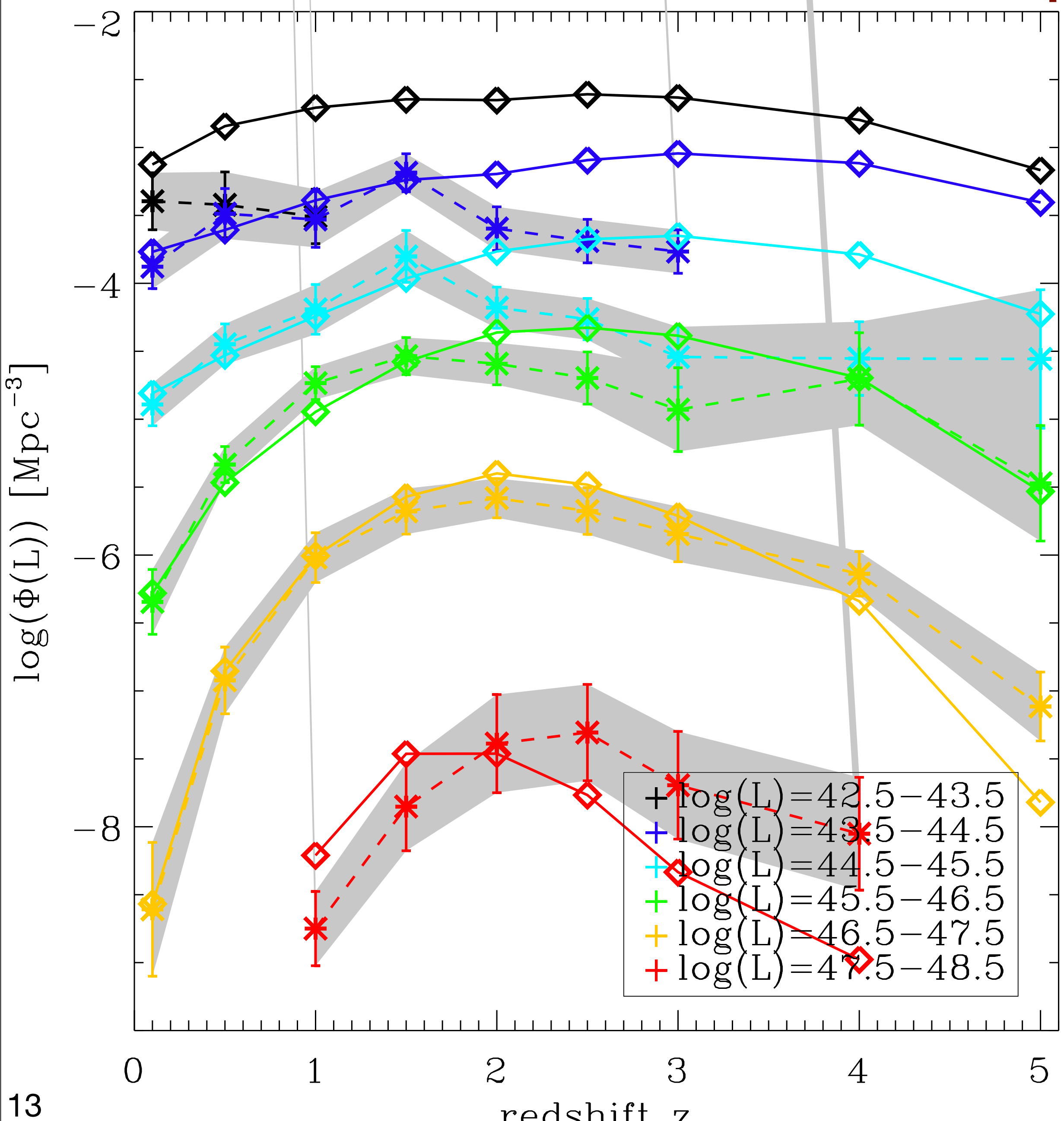
Difference (M_{disk} - $M_{disk,crit}$) goes into the bulge component

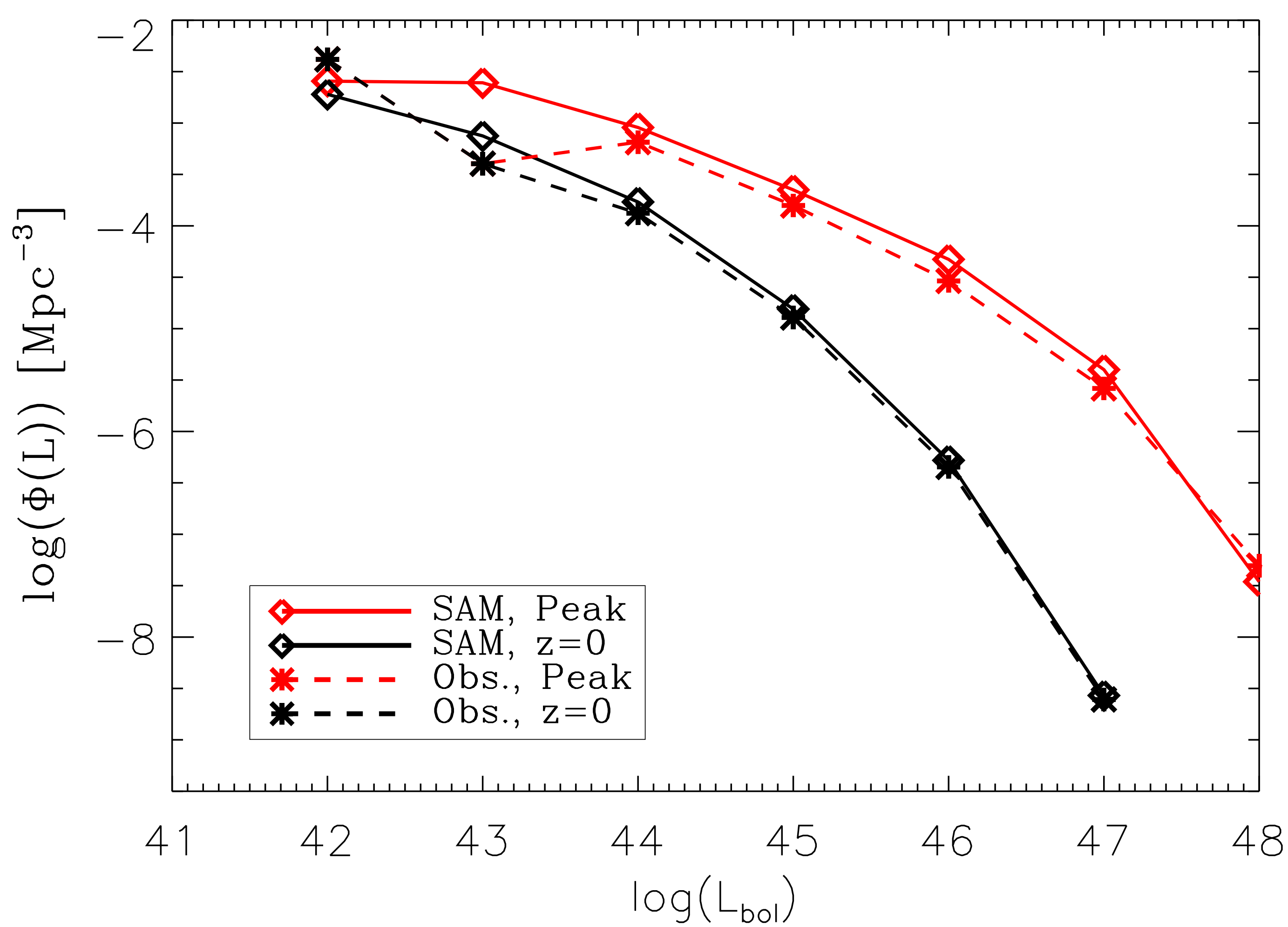
Certain fraction is accreted onto the black hole:

$$\Delta M_\bullet = f_{\rm BH,disk} \cdot (M_{\rm disk} - M_{\rm disk,crit})$$

III. Results from SAMs: *Best fit model*

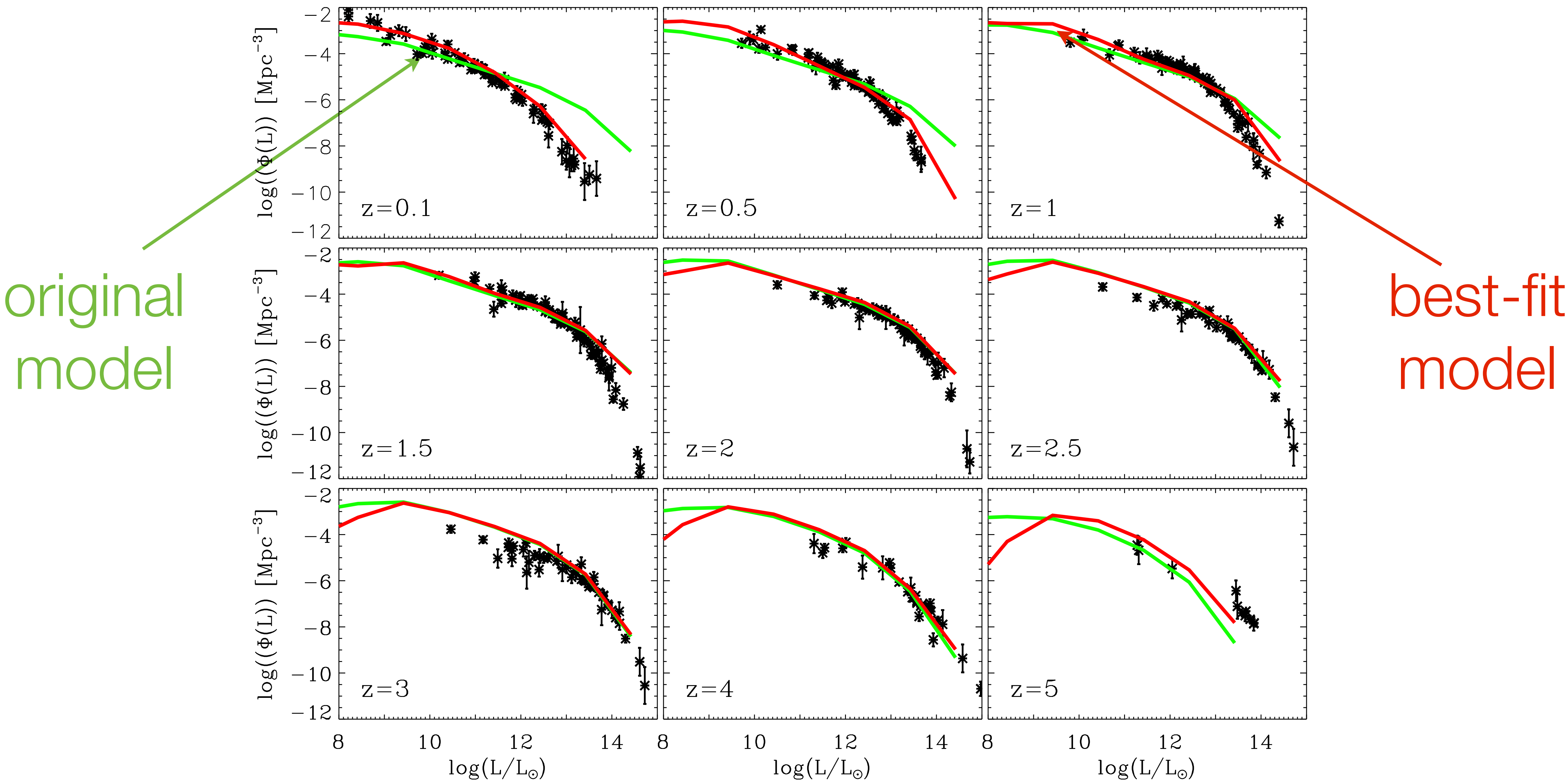
Consider disk instabilities *and* redshift & mass dependent Eddington-ratio





III. Results from SAMs: *Best fit model*

Consider disk instabilities *and* redshift & mass dependent Eddington-ratio



IV. Summary

- Additional physical processes to achieve better agreement with observations:

→ DOWNSIZING!

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1. Assume decreasing Edd.-ratio with z & M_{BH}
→
Decrease of number densities for high luminous objects at low z

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IV. Summary

- Additional physical processes to achieve better agreement with observations:

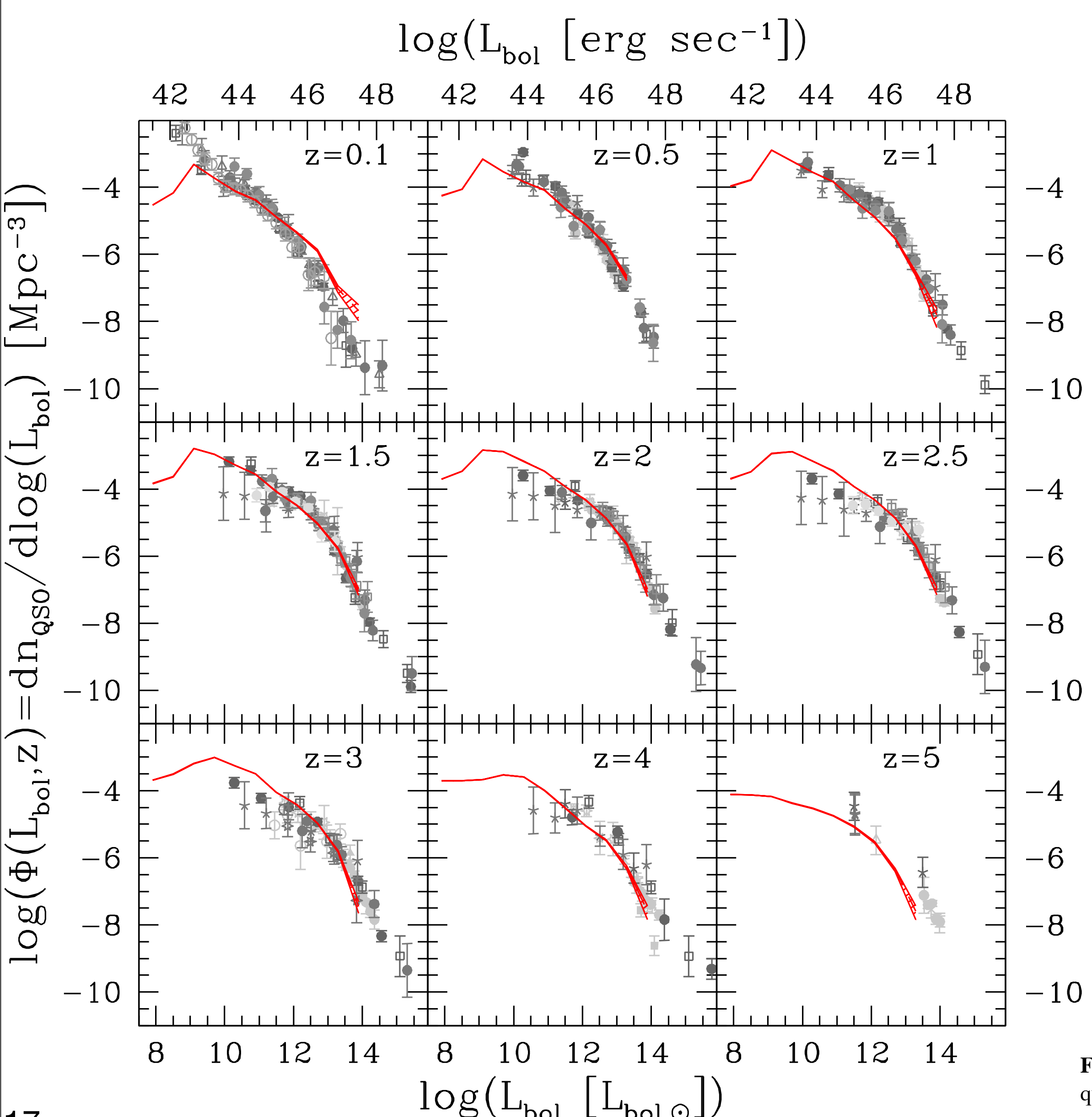
1. Assume decreasing Edd.-ratio with z & M_{BH} → Decrease of number densities for high luminous objects at low z	2. Additional accretion channel due to disk instabilities → Increase of number densities for low-luminous objects at low z

→ DOWNSIZING!

...Thanks for your attention...

II. What has been done so far?

Marulli et al., 2008



Bonoli et al., 2009

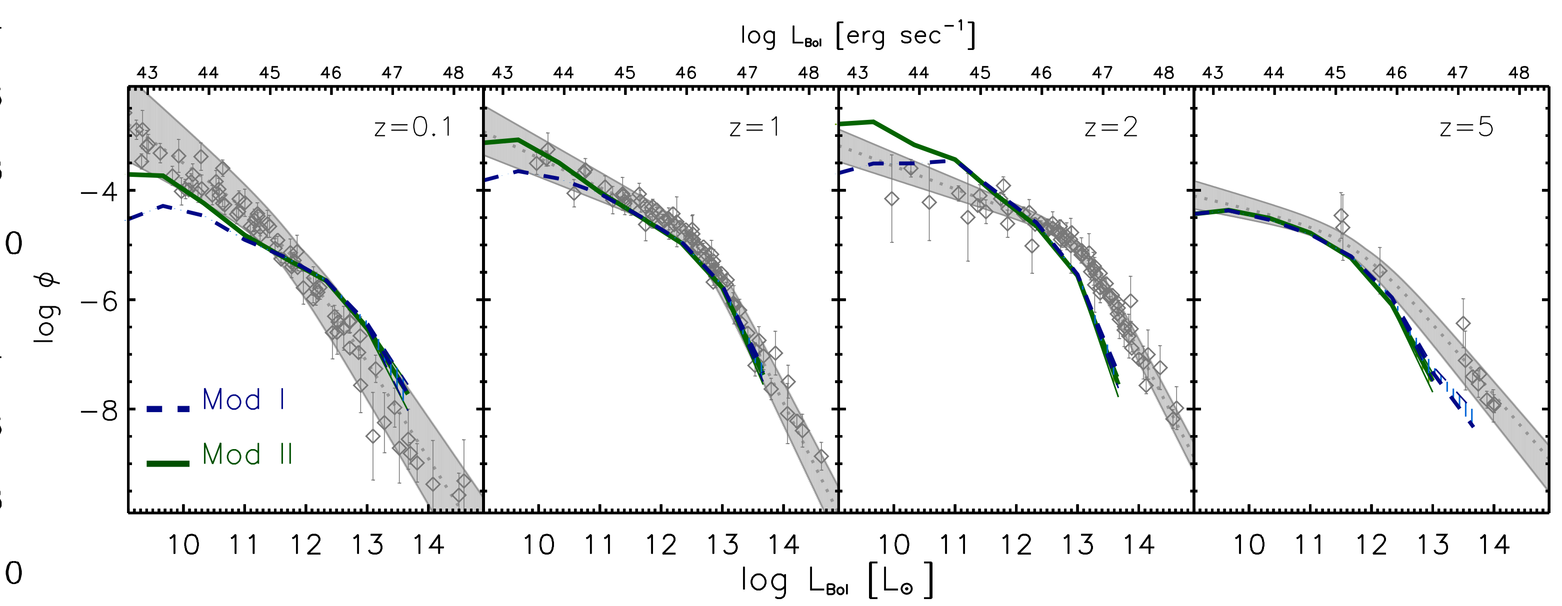


Figure 3. Bolometric luminosity function assuming Eddington-limited accretion (Mod I, blue-dashed curve), or Eddington-limited accretion followed by a quiescent phase of low luminosity (Mod II, green-solid curve), with errors calculated using Poisson statistics. The luminosity functions are compared with the compilation of Hopkins et al. (2007) (grey points with best fit given by the grey band).

II. What has been done so far?

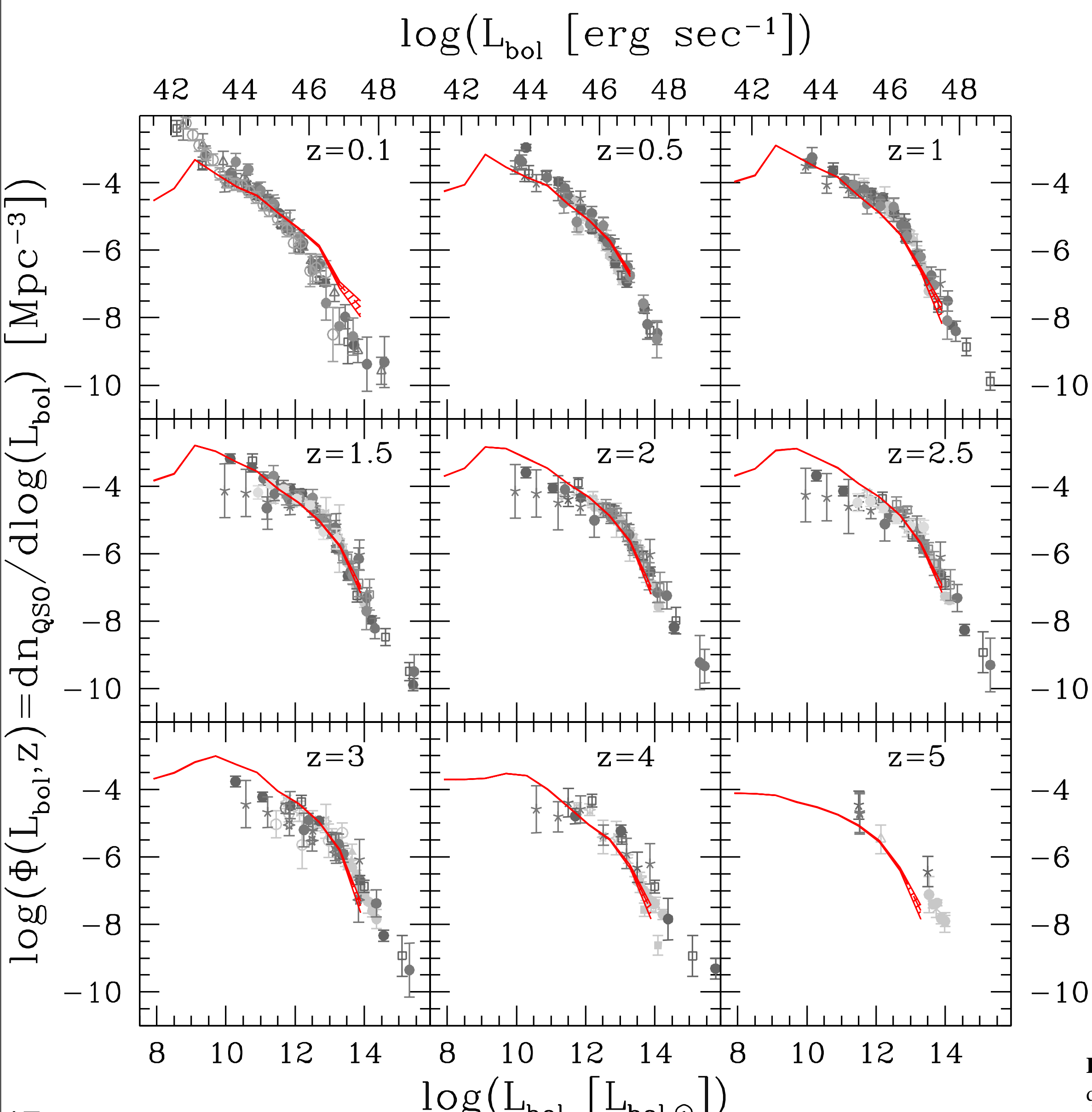
Basic problems:

Underprediction of low luminous objects and overprediction of high luminous objects at low z

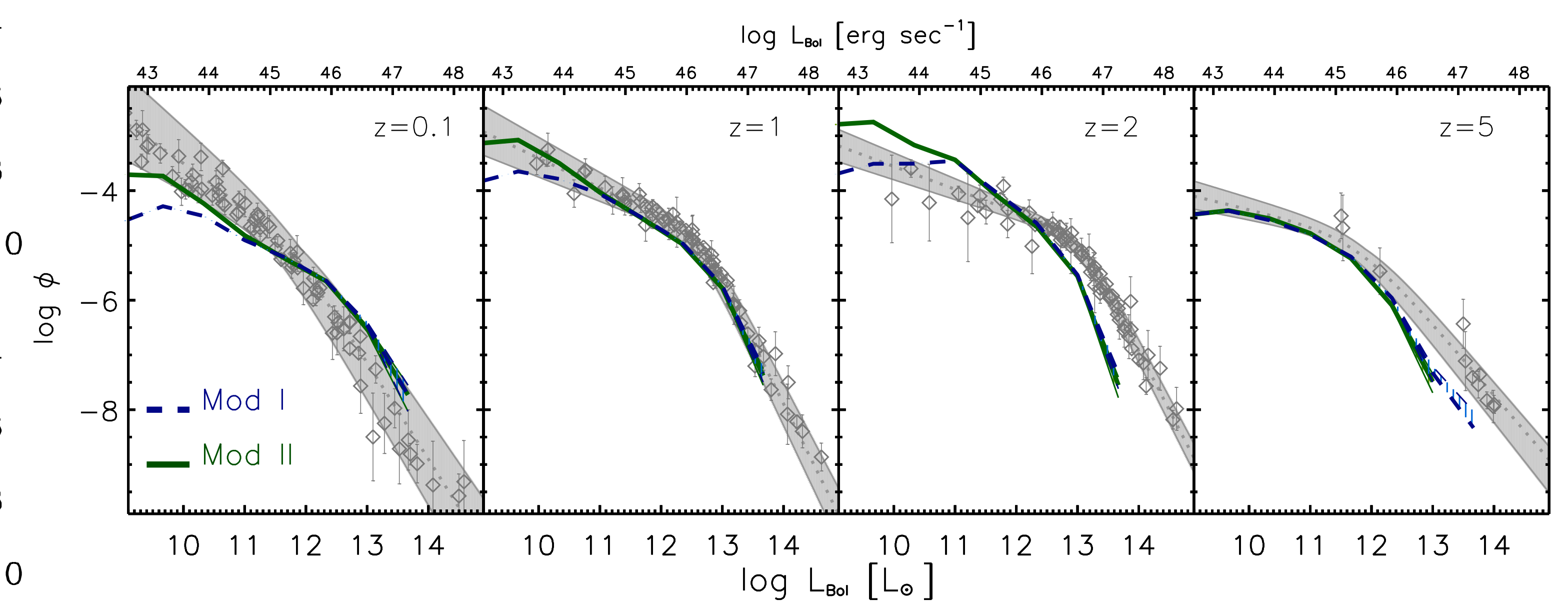
&

Too less high luminous objects at high z

Marulli et al., 2008



Bonoli et al., 2009



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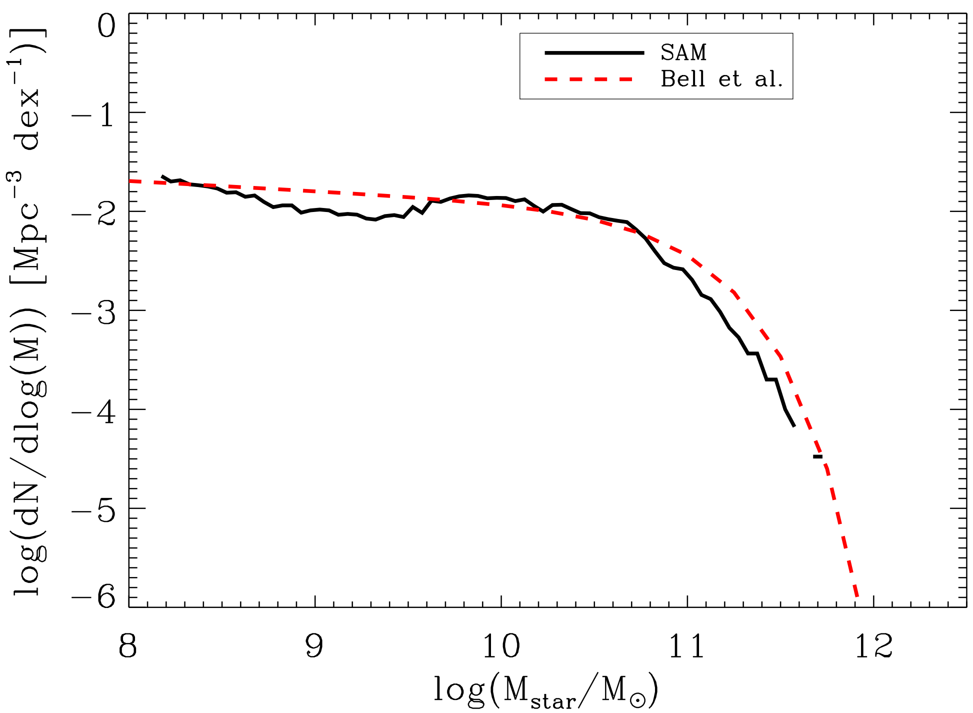
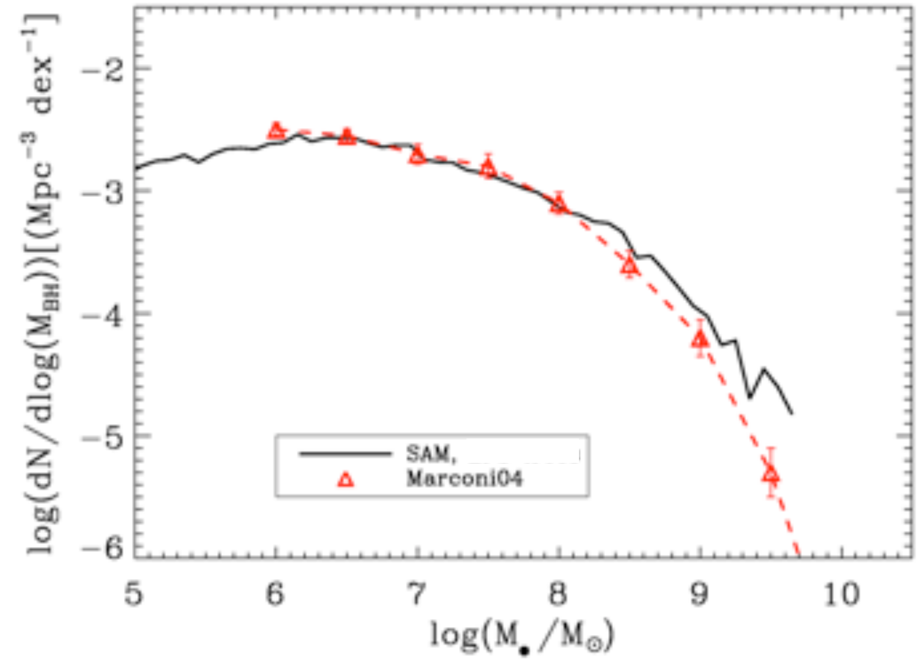
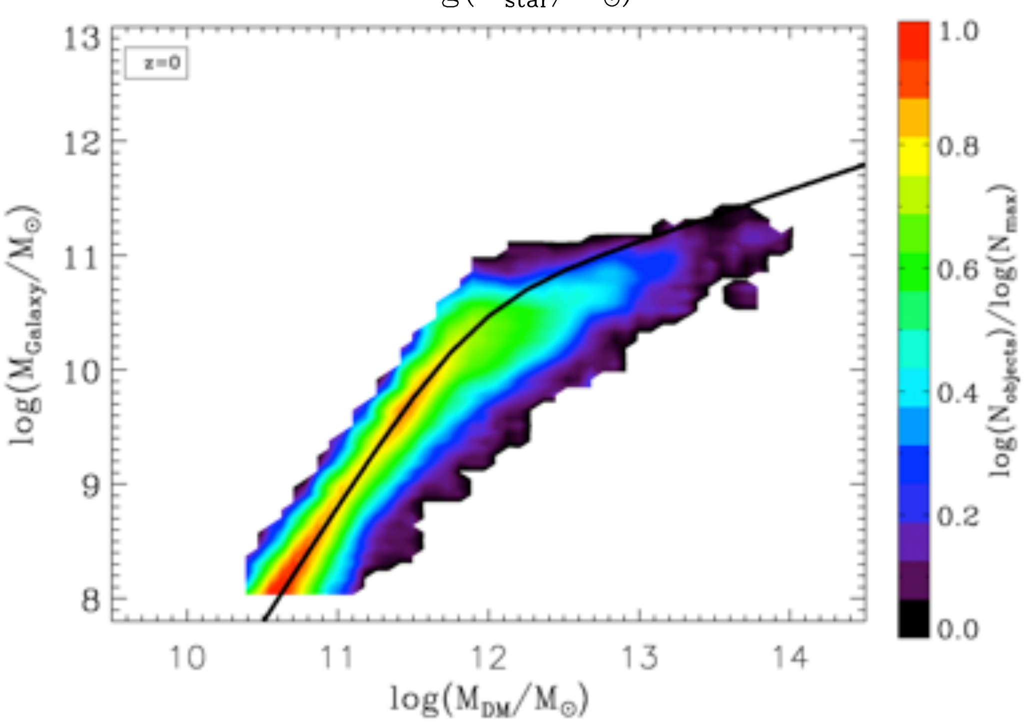
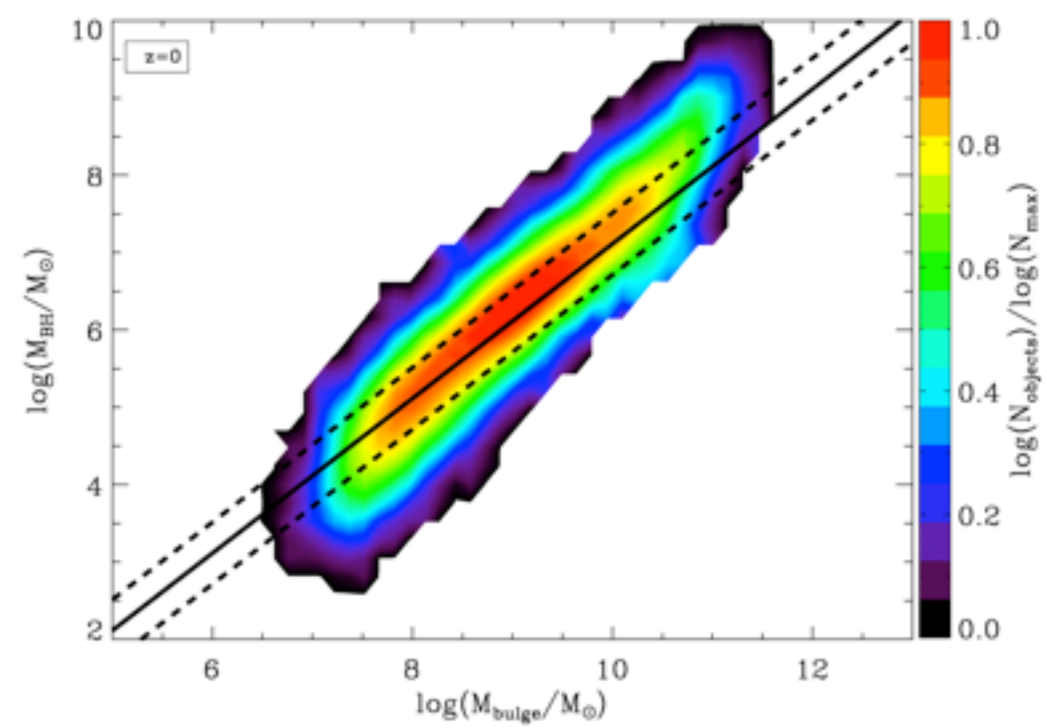
III. Results from SAMs: *Best fit model*

Can we still reproduce obs. constraints??



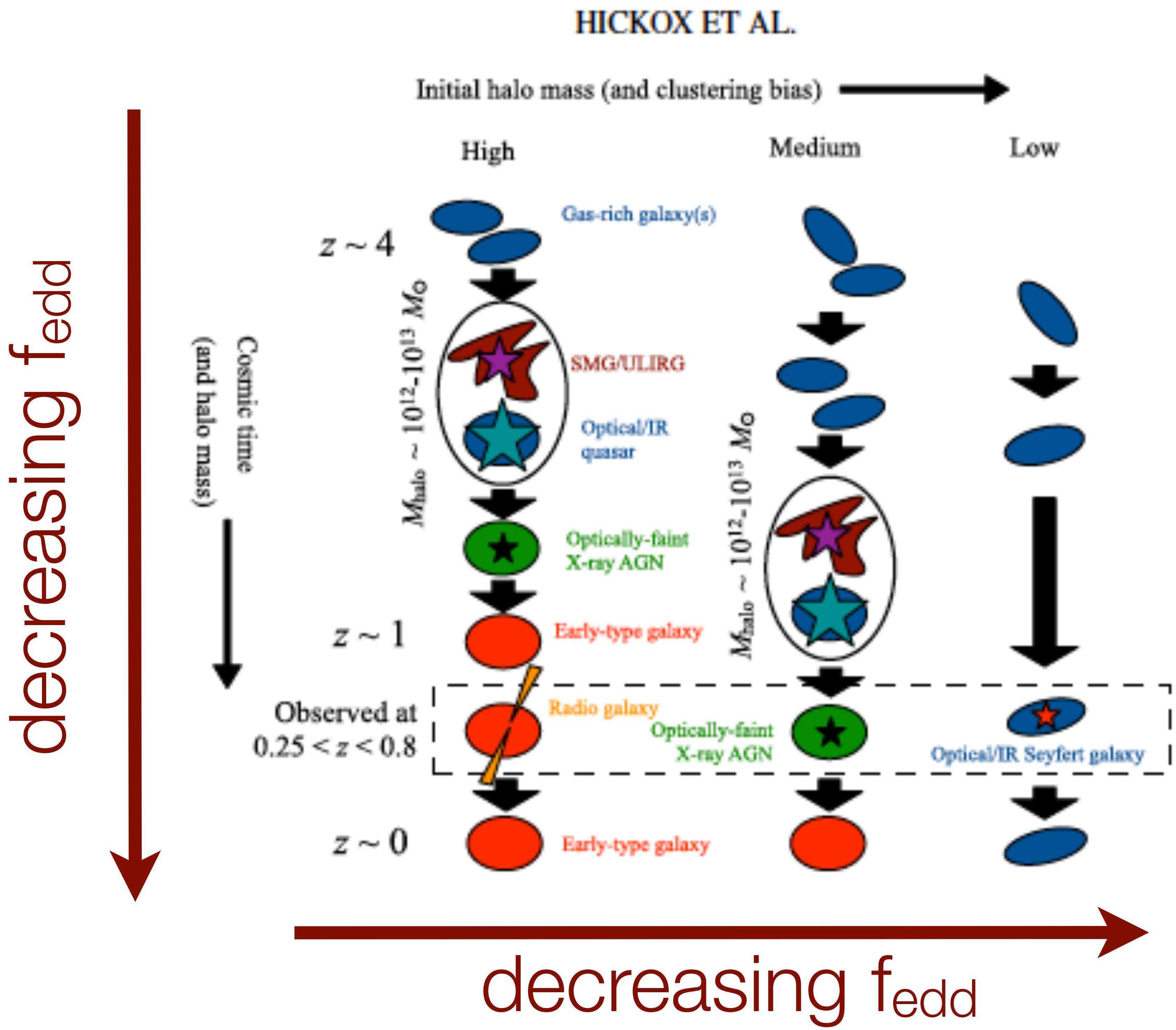






III. Results from SAMs: *Best fit model*

Schematic picture of galaxy evolution



Cold gas content is essential for downsizing