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Properties of AGNs predicted from a semi-analytic model of galaxy formation

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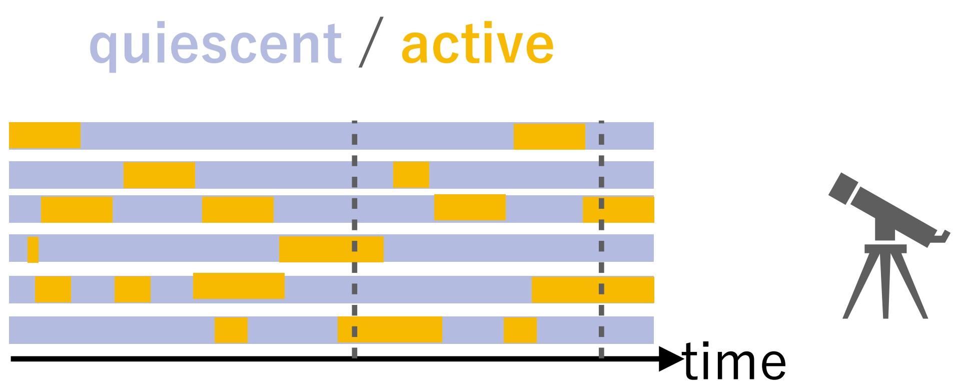
Introduction (1/2)

- Growth timescale of SMBHs,
  and triggering mechanisms of AGNs
  (‘frequency’ of AGN activities)

Their effects are degenerate to each other?



How about less luminous ($L_X < 10^{44}$ erg/s) AGNs?
How is this timescale determined? (physical processes)

- Triggering mechanisms of AGNs?

Introduction (2/2)

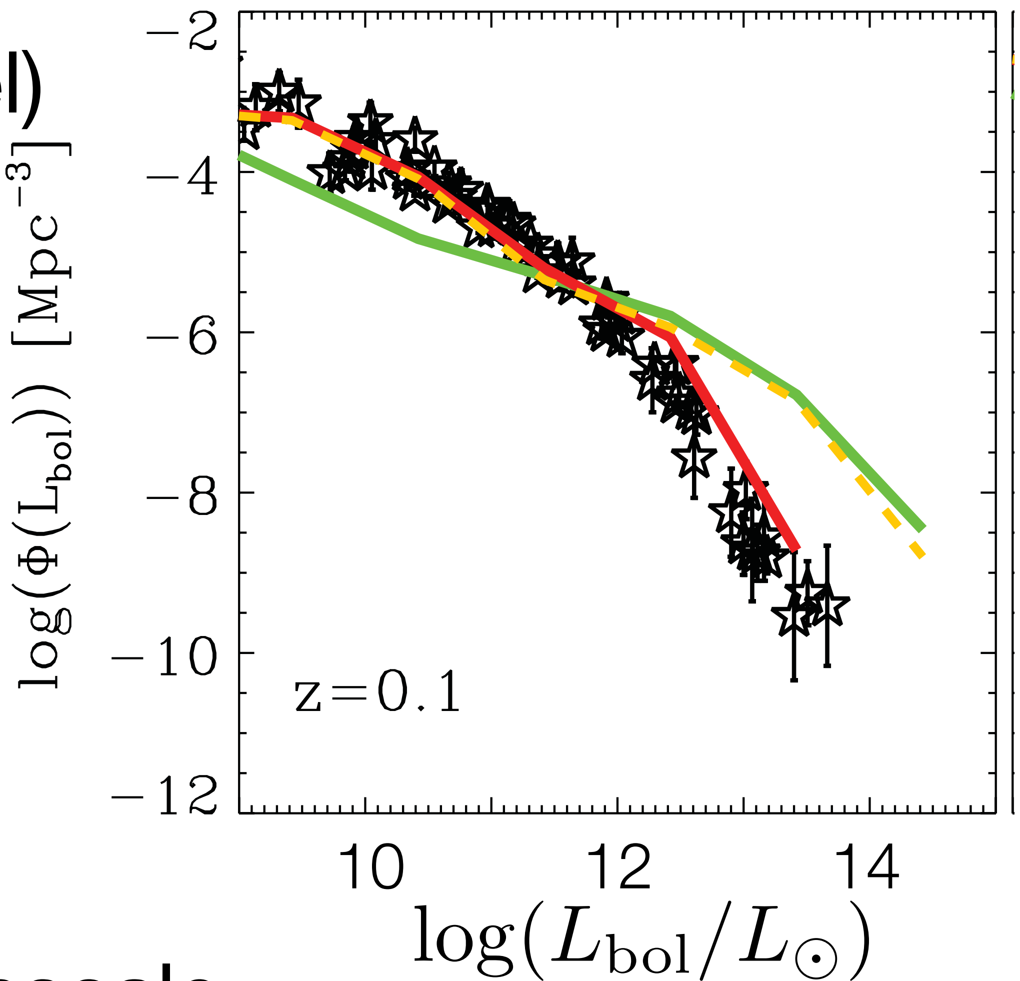
- Hirschmann +12 (with an SA model)

  mergers only:
  underestimate less
  luminous AGNs

  disc instabilities play a role.
  (but with simple modelling)

  accretion timescale ~ Salpeter timescale

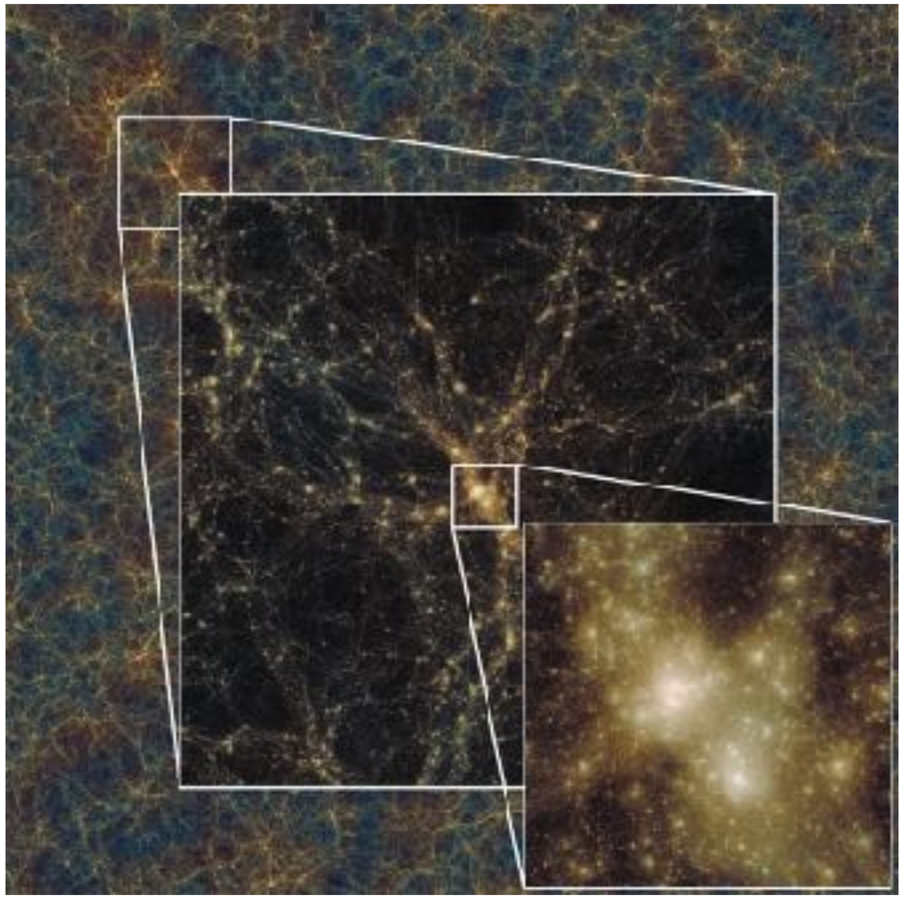
Hirschmann+12



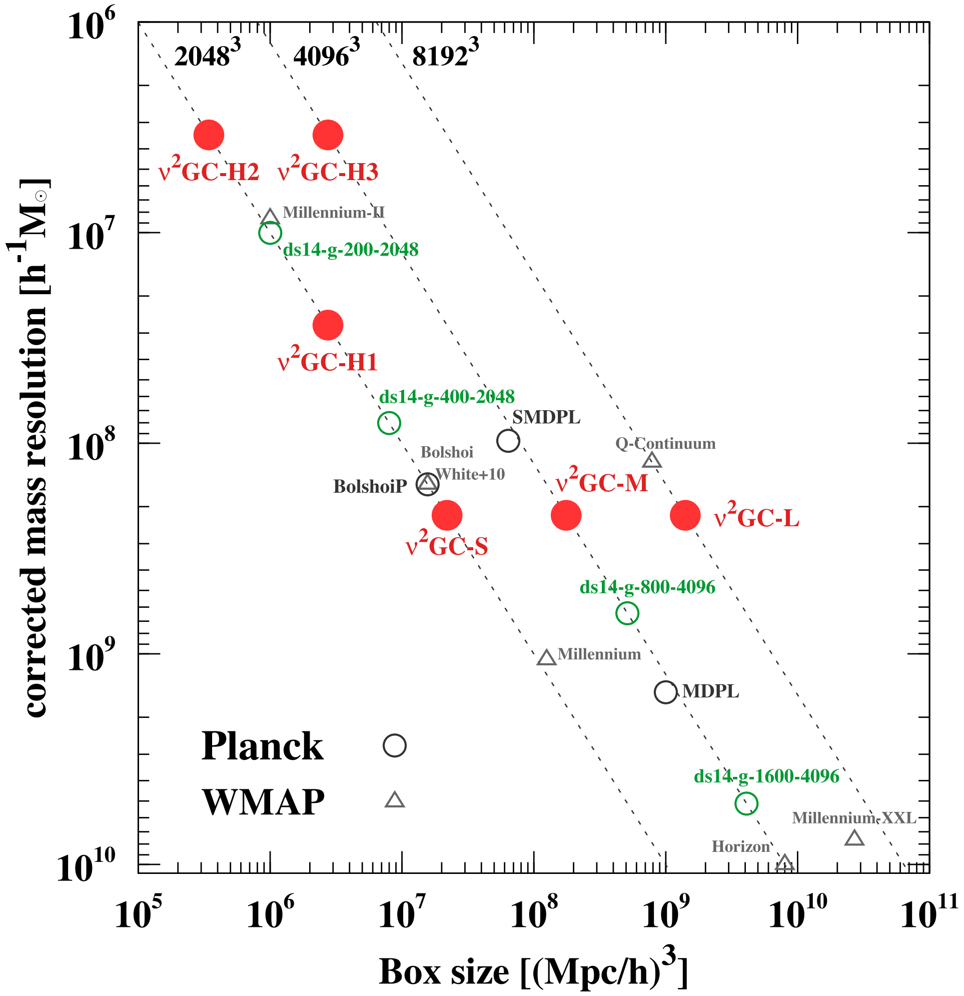
- Only one solution? ⟶ **No. Other possible scenario exists.**

ν^{2}GC (1/4)

N-body simulations (Ishiyama+ 15)



ν ^{2}GC-L (1120h^{-1}Mpc)



Minimum halo mass: (1.37 - 87.9)×10^8 M_{sun}

v^2GC (2/4)

SMBH growth (mergers and/or DI)

Mergers and/or disc instability → Starburst (bulge) / Normal SF (disc) → SMBH growth

Dynamical friction
Random collision
(Hopkins+09)

$$\frac{V_{\rm max}}{(GM_{\rm disc}/r_{\rm ds})^{1/2}} < \epsilon_{\rm DI,crit}$$

(Efstathiou+ 82)

- Including bulge potential
5% of the disc → bulge

Starburst (bulge)
Normal SF (disc)

SMBH growth

Accreted gas mass:
$\Delta M_{\rm acc} = f_{\rm BH} \Delta M_{*,\rm burst}$

SMBH-SMBH coalescence

$M_{\rm seed} = 10^3 M_\odot$

v²GC (3/4)

SMBH growth & AGNs

Starting time of an AGN activity

accretion rate: $$\dot{M}_{\rm BH} = \frac{\Delta M_{\rm acc}}{t_{\rm acc}} \exp\left(-\frac{t - t_{\rm start}}{t_{\rm acc}}\right)$$

$$L_{\rm Edd} = \frac{4\pi c G m_p}{\sigma_{\rm T}} M_{\rm BH},$$

$$\dot{M}_{\rm Edd} = L_{\rm Edd}/c^2$$

bolometric luminosity: $$\lambda_{\rm Edd} = \left[\frac{1}{1 + 3.5\{1 + \tanh(\log(\dot{m}/\dot{m}_{\rm crit}))\}} + \frac{\dot{m}_{\rm crit}}{\dot{m}}\right]^{-1}$$

(based on Kawaguchi+ 03)

$$\lambda_{\rm Edd} = L_{\rm bol}/L_{\rm Edd} \qquad \dot{m} = \dot{M}_{\rm BH}/\dot{M}_{\rm Edd}$$

X-ray (2-10 keV) luminosity: $$\frac{L_{\rm bol}}{L_X} = g(L_{\rm bol})$$

(based on Marconi + 04)

v^2GC (4/4)

Accretion timescale for 1 accretion event

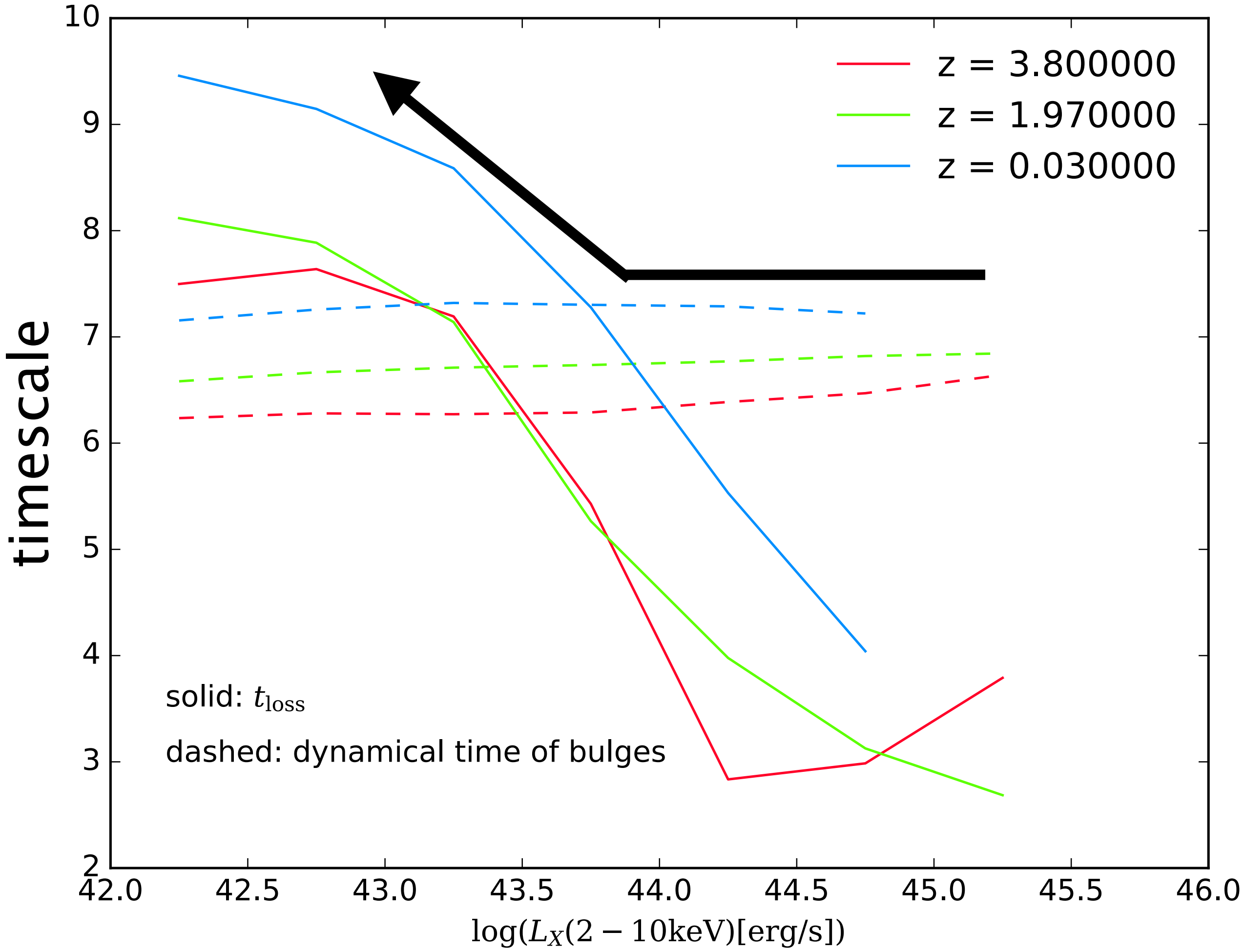
$$t_{\rm acc} = \underbrace{\alpha_{\rm bulge}}_{0.58} t_{\rm dyn,bulge} + t_{\rm loss}$$

QSOs: t_{acc} ~ 10^7 yr

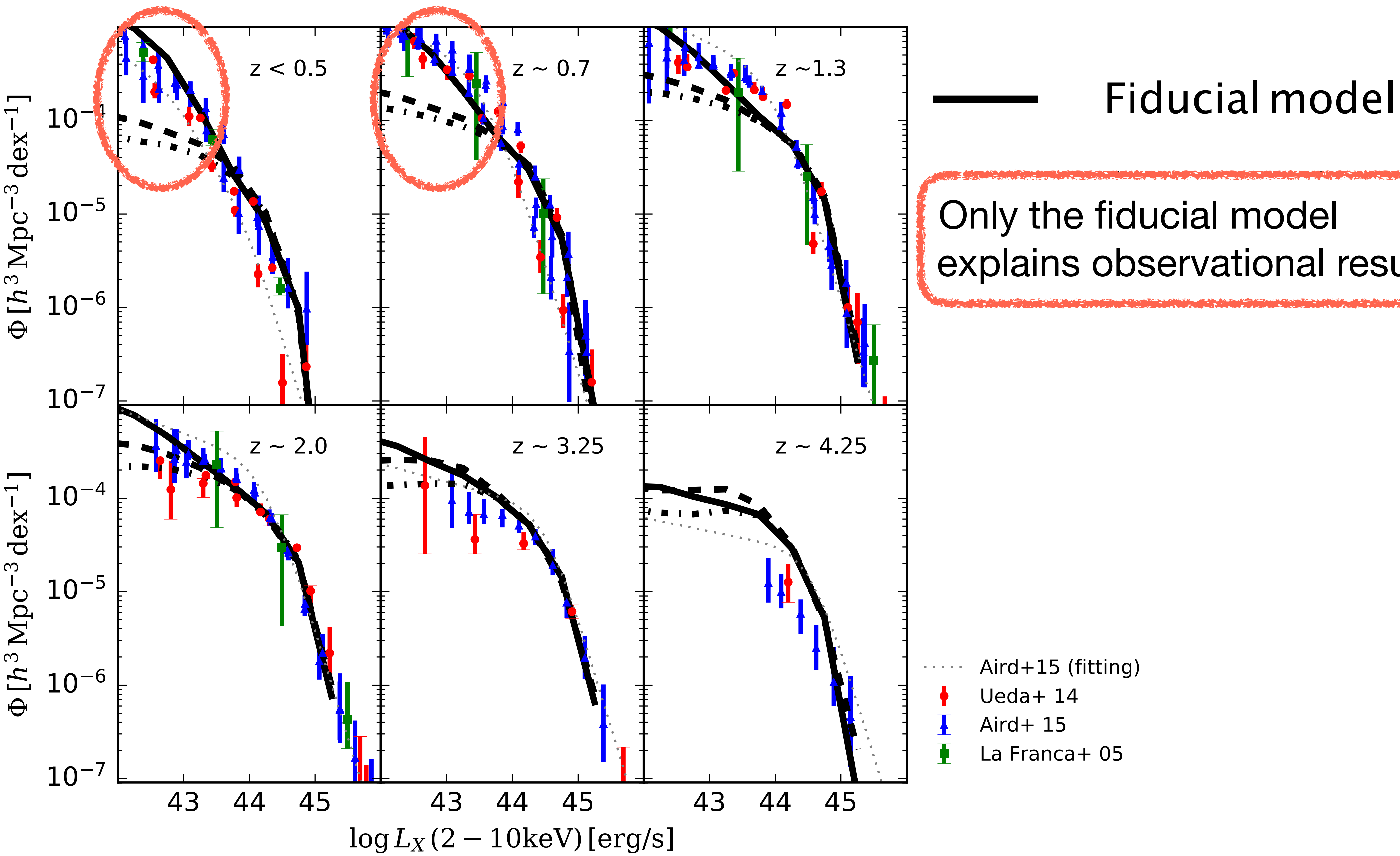
(e.g. Yu & Tremaine 2002)

~ $t_{dyn,\ bulge}$

$L_X < 10^{44}$erg/s: $t_{acc} > 10^8$ yr



Results (1/4)



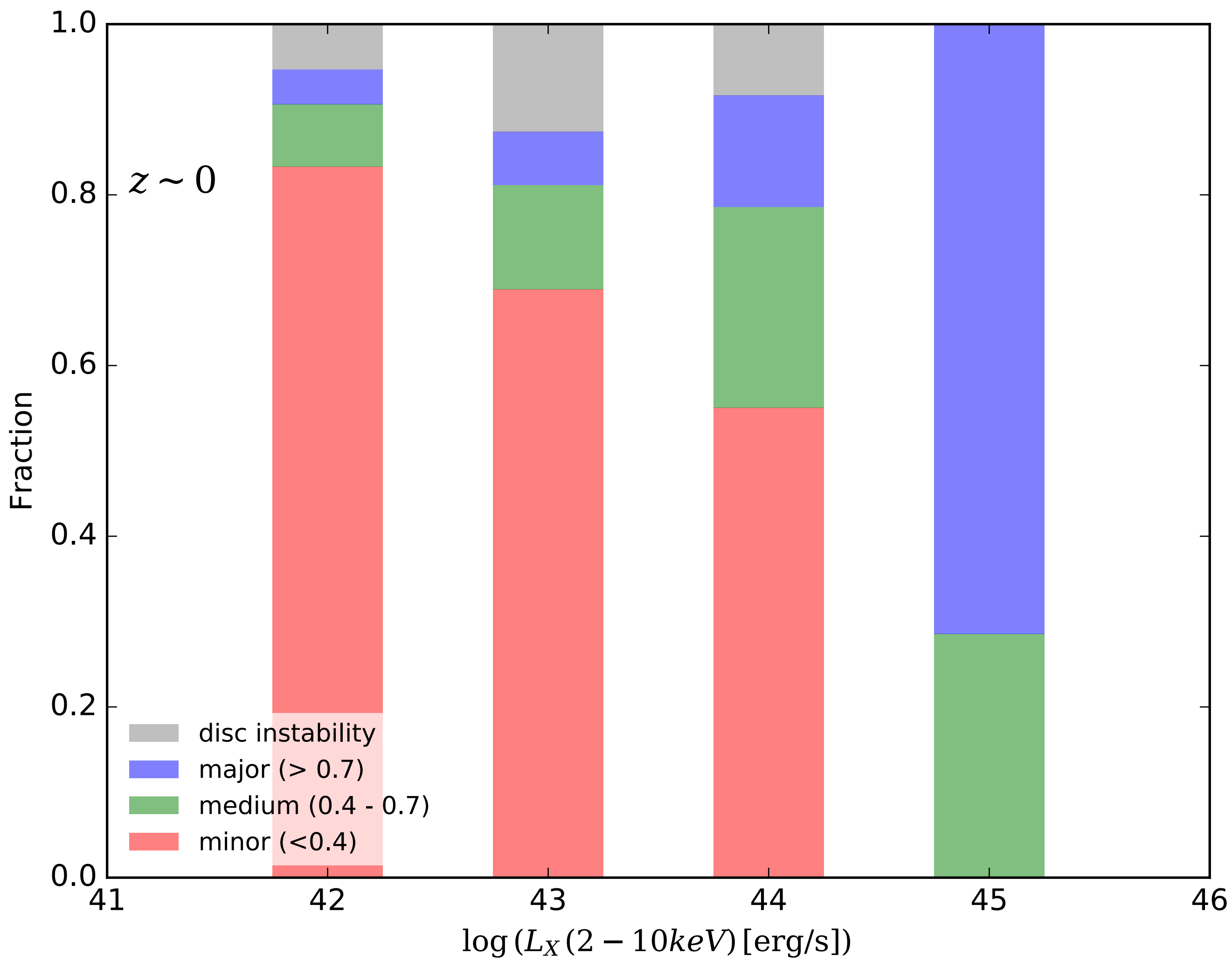
Only the fiducial model explains observational results.

Results (2/4)

- Less luminous AGNs @ z ~ 0 are mainly merger driven

Typically long-lived AGNs
(> 10^9 yr)

- Need further comparison with observations



Summary

- Using ν^2GC (a semi-analytic model of galaxy formation), we find that…

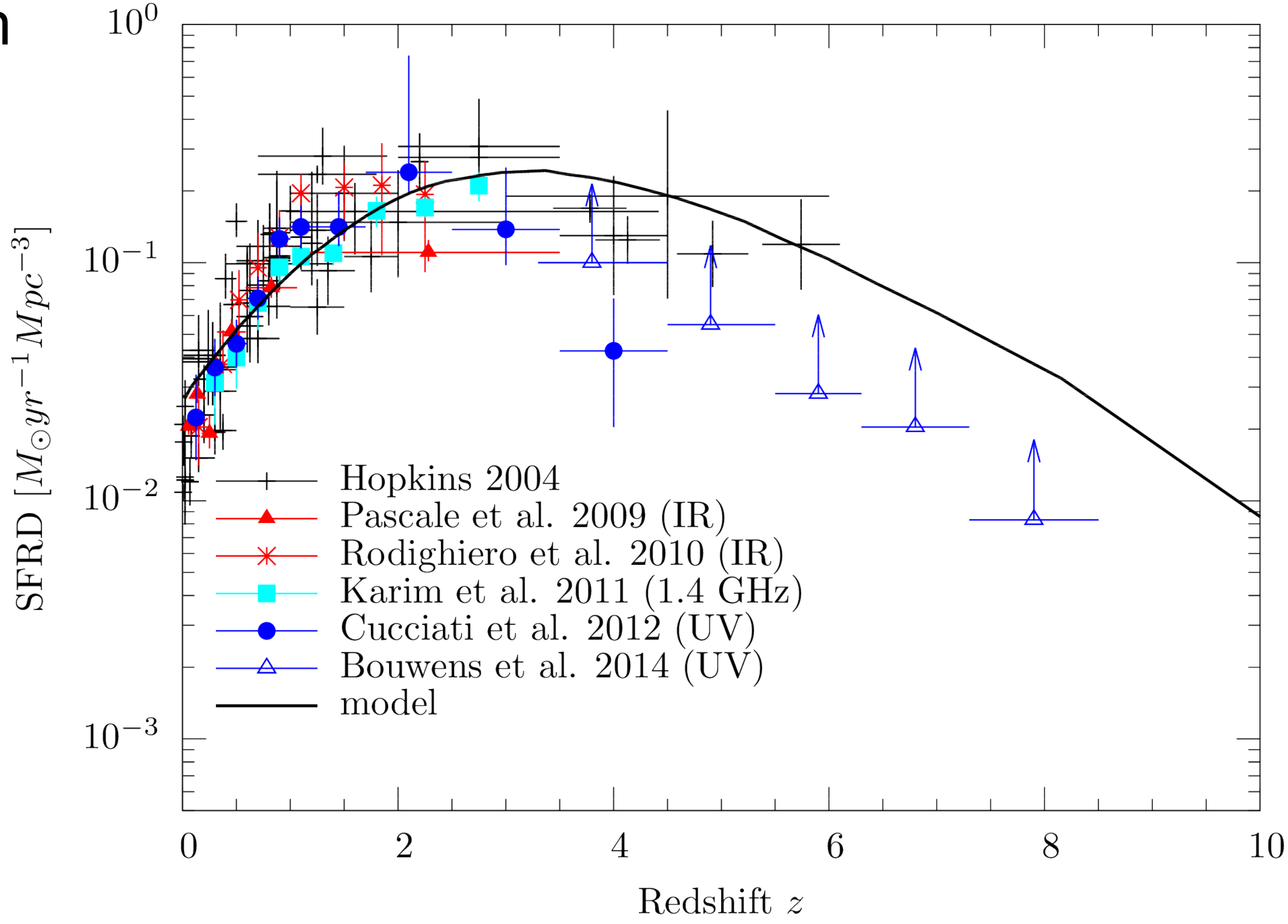
  - Faint end slopes of AGN LFs @ $z < 1.5$ can be explained
    by (1) “long-lived, merger-driven” AGNs
    or (2) “short-lived, disc instability driven” AGNs.

  - Eddington ratio distribution function is important to
    might solve this discrepancy
    (but, many uncertainties and free parameters…)

- Contact us if you are interested in using ν^2GC.

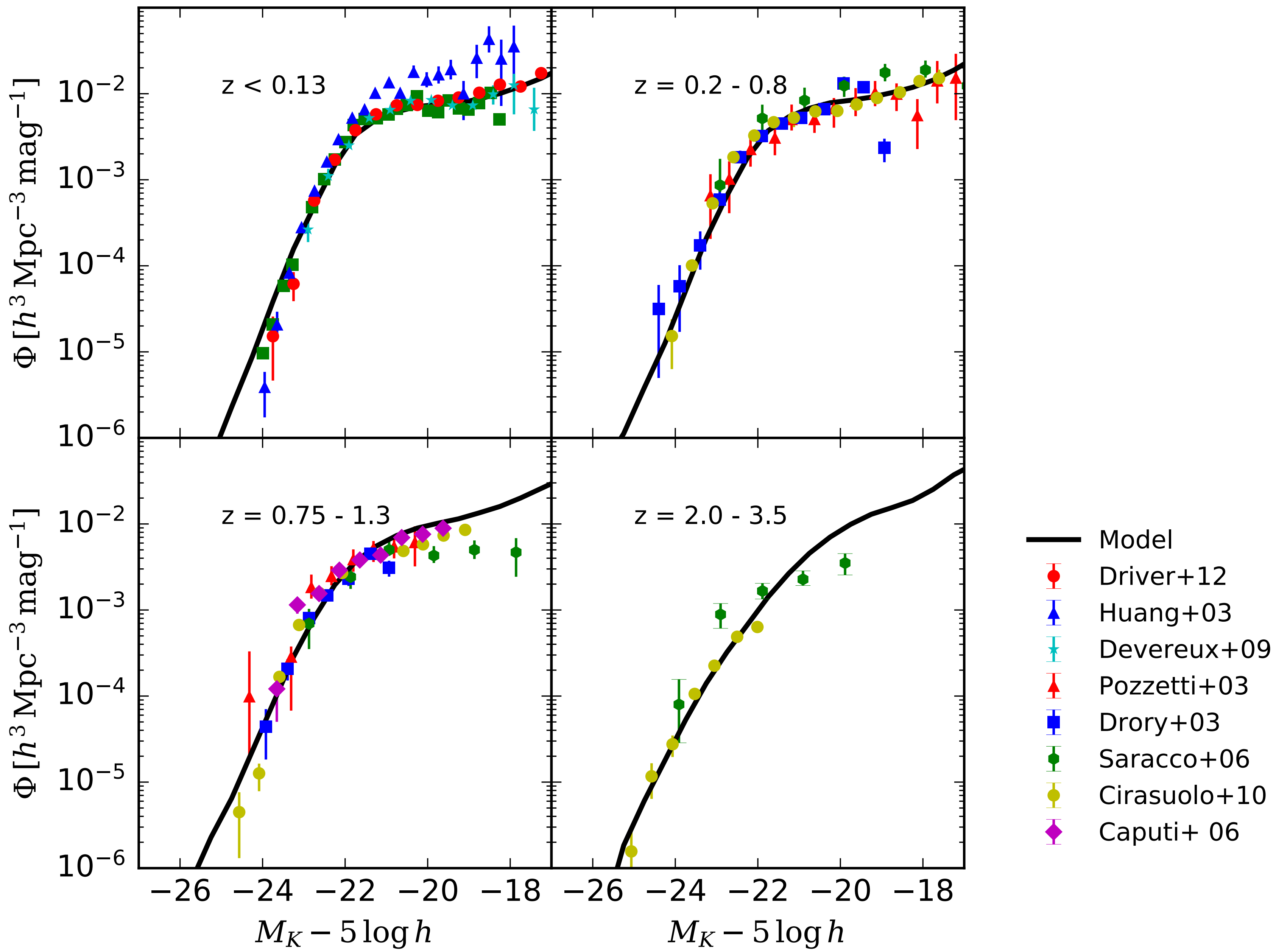
Appendix

- Star Formation Rate Density



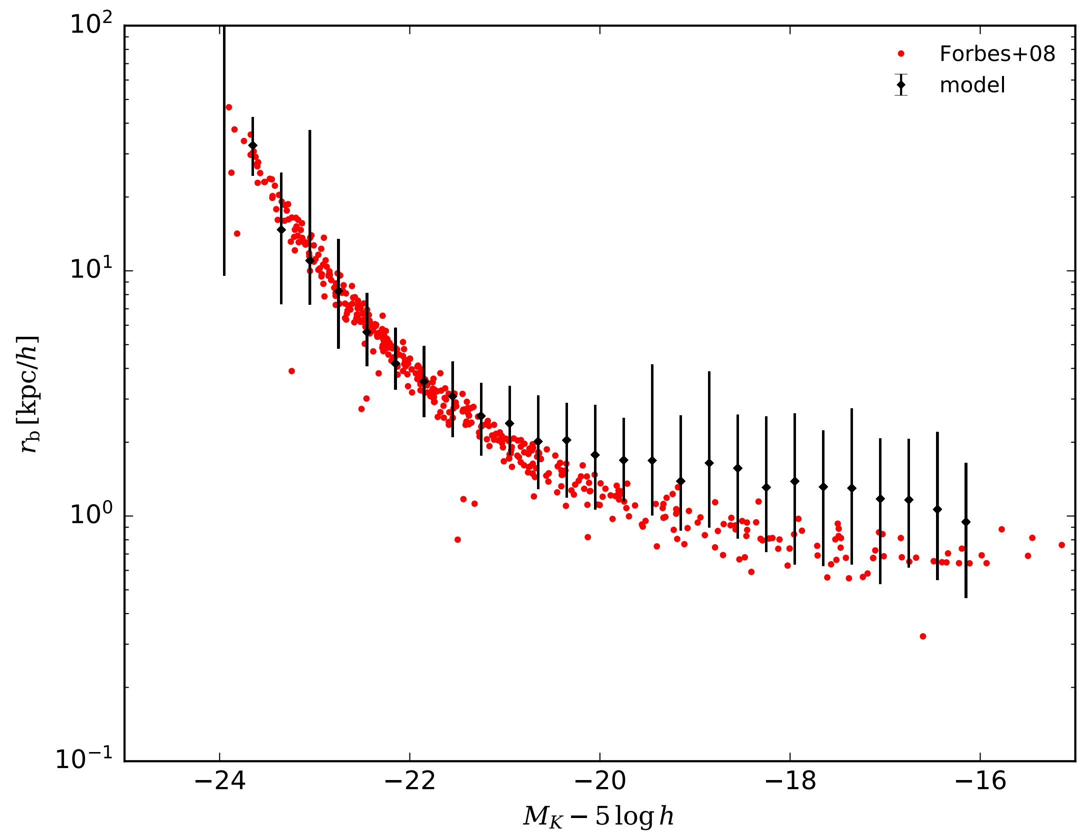
Appendix

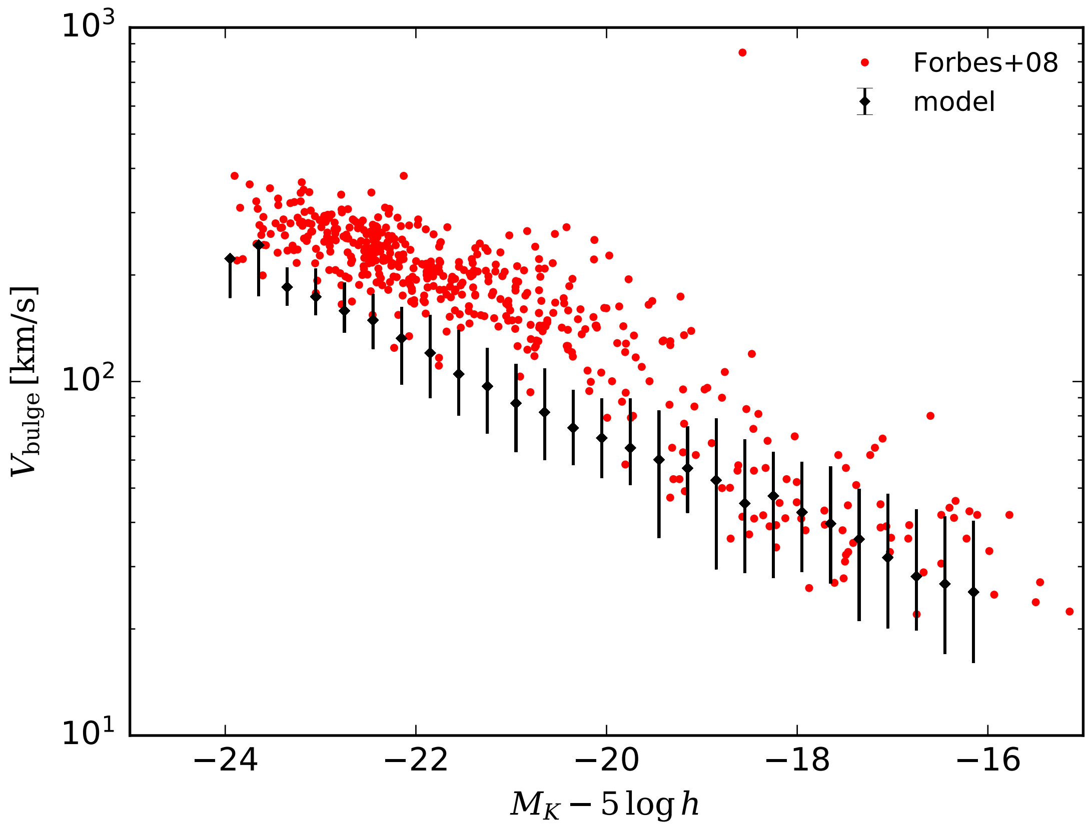
- K-band LF (galaxy)



Appendix

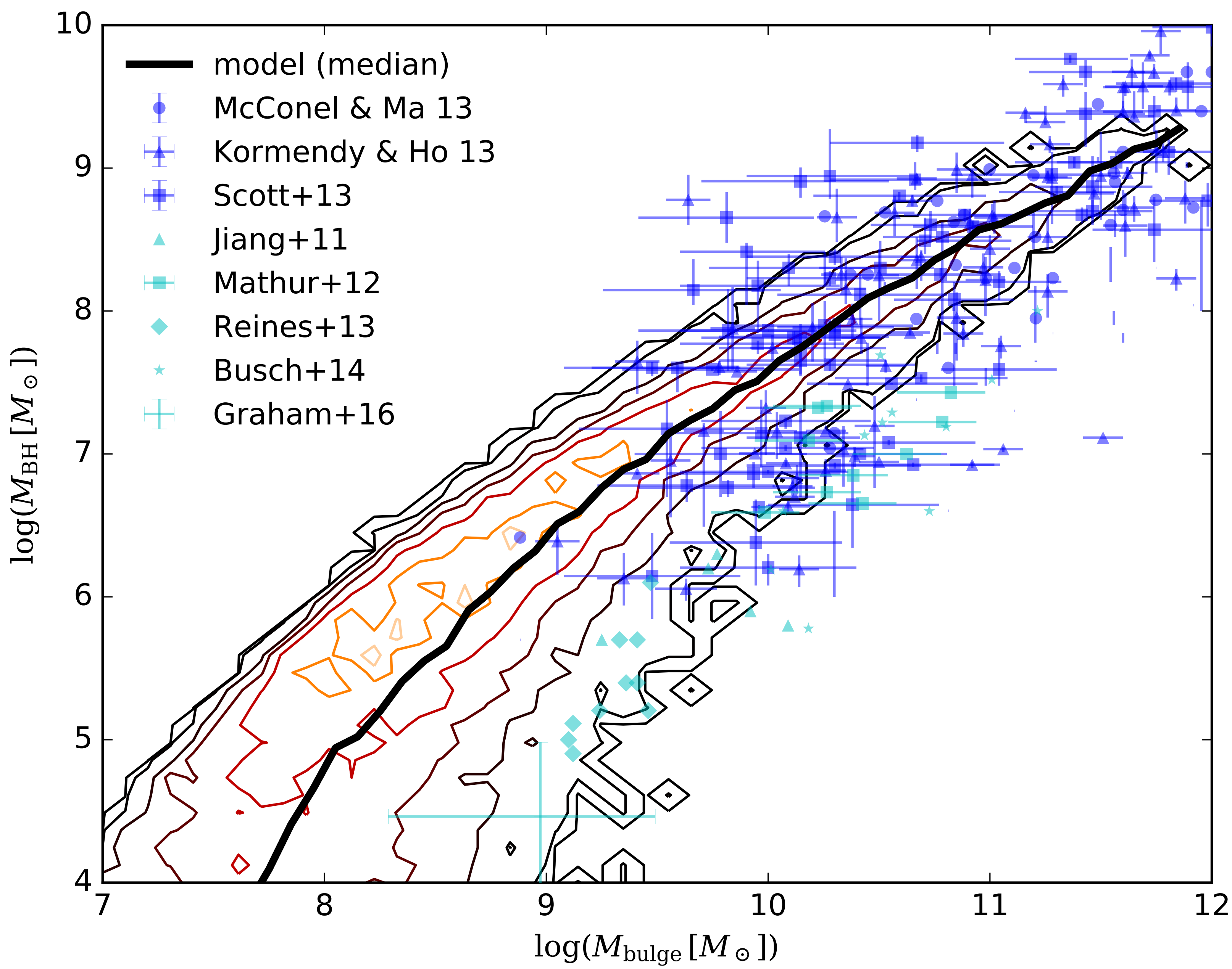
- Bulge size, velocity





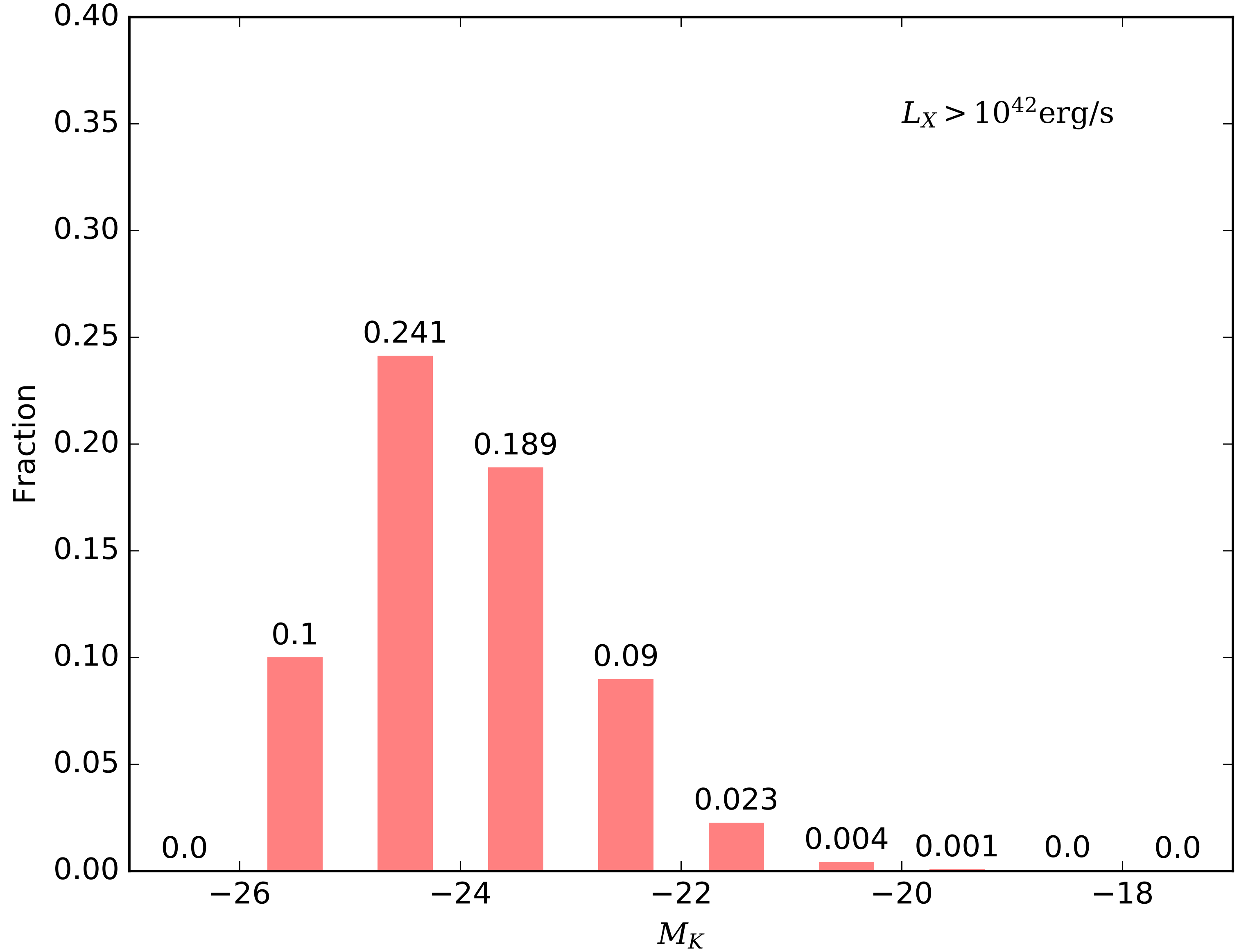
Appendix

- M_{BH} — M_{bulge} @ z ~ 0



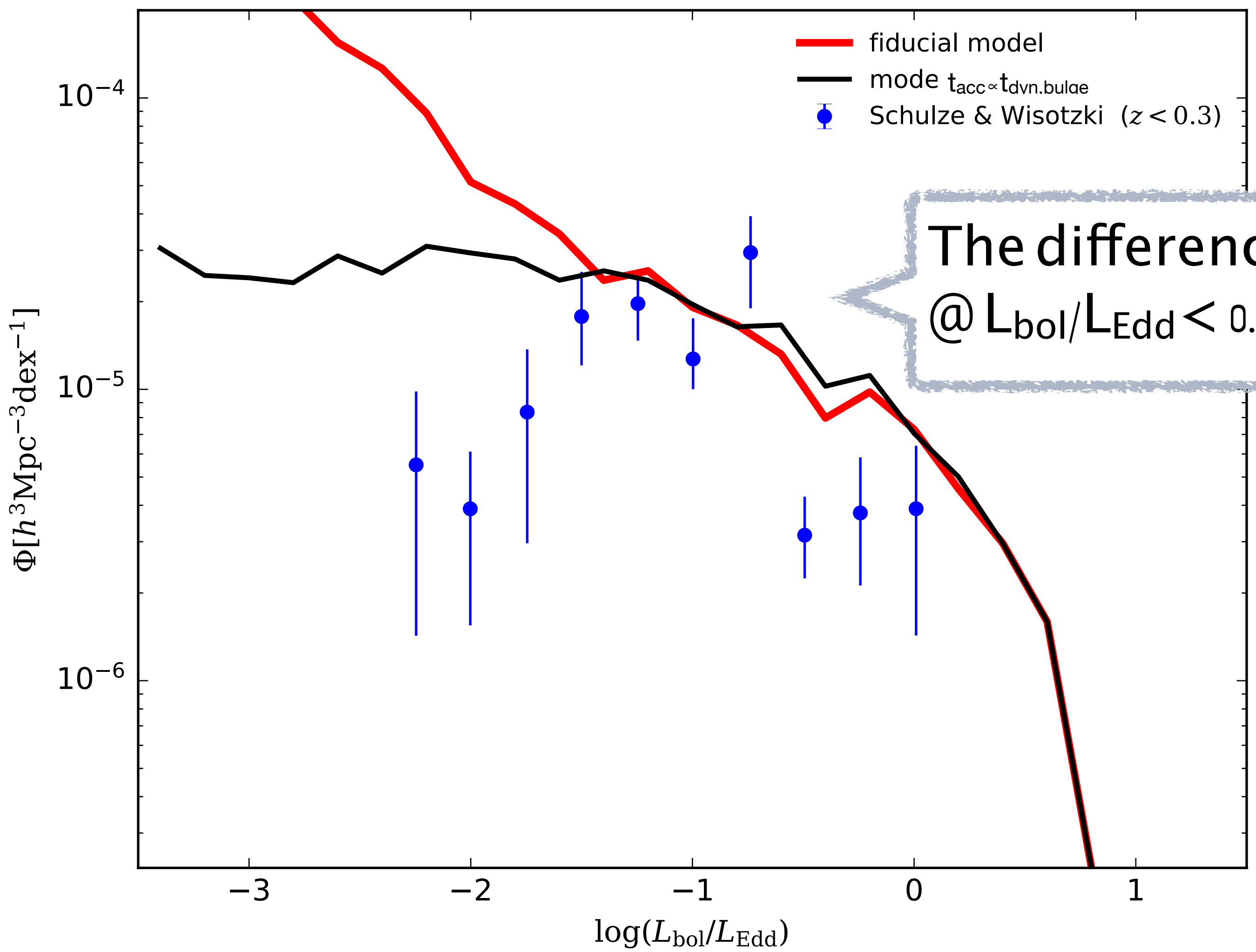
Appendix

- Active fraction of AGNs @ z~0 (fiducial model)



Appendix

- How is the Eddington ratio distribution different by t_{acc}?



The difference appear @ $L_{bol}/L_{Edd} < 0.01$ ← difficult to observe

(※ Assuming Type-2 fraction = 0 for model results)

Appendix

- Eddington ratio distribution
  at higher redshift