# Last Stand of the Quasars:

## the “radio mode” - “quasar mode” quenching connection

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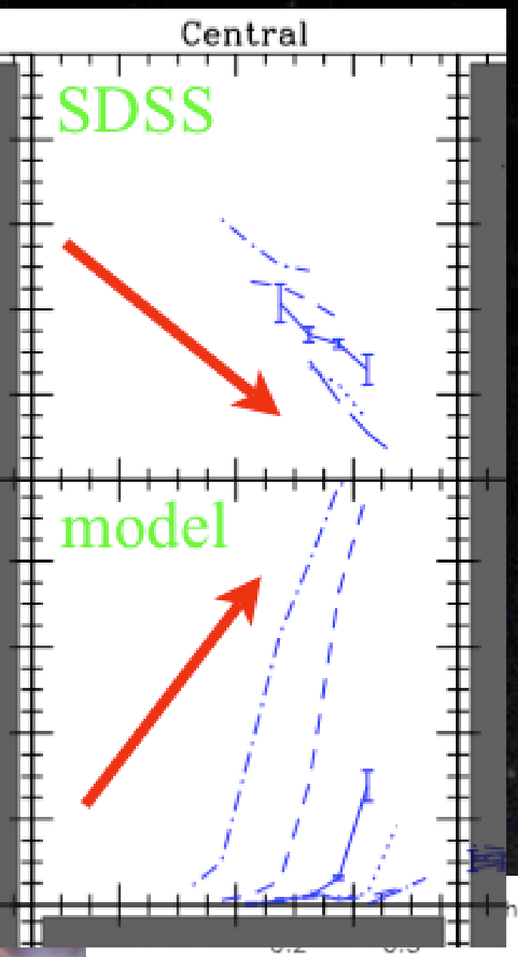
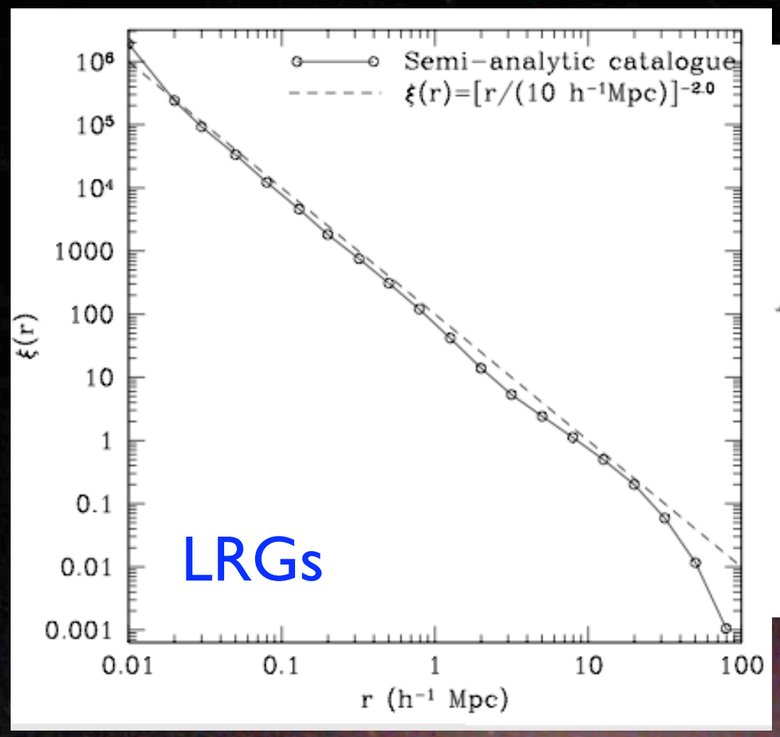
# The AGN bandwagon

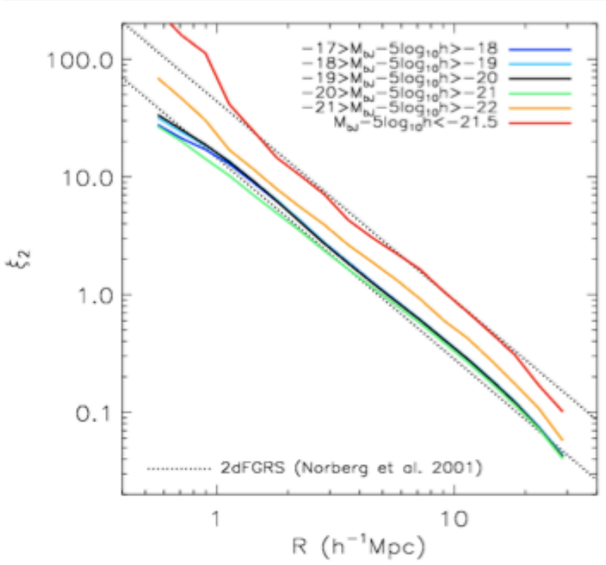
What is doing the quenching?

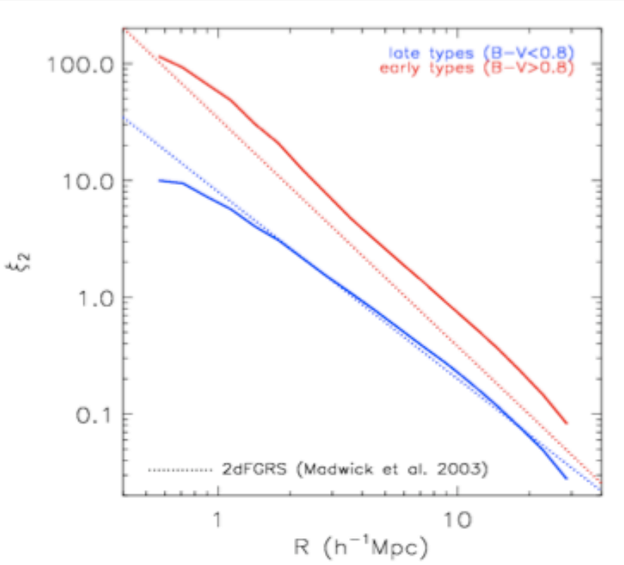
Do we even need it?

How can we measure it?

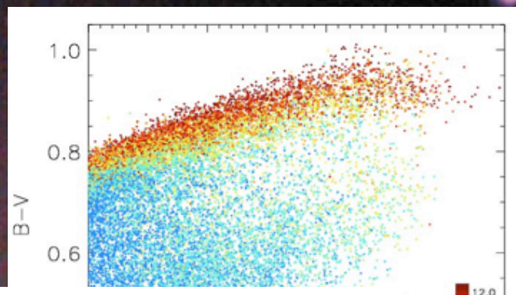


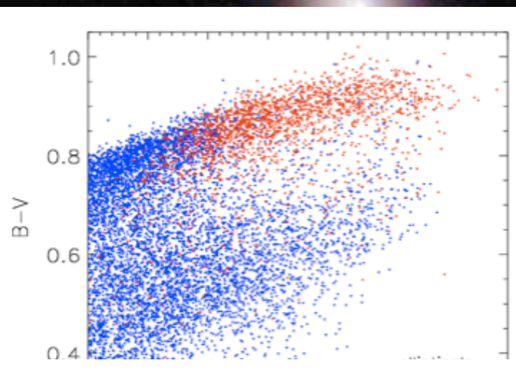



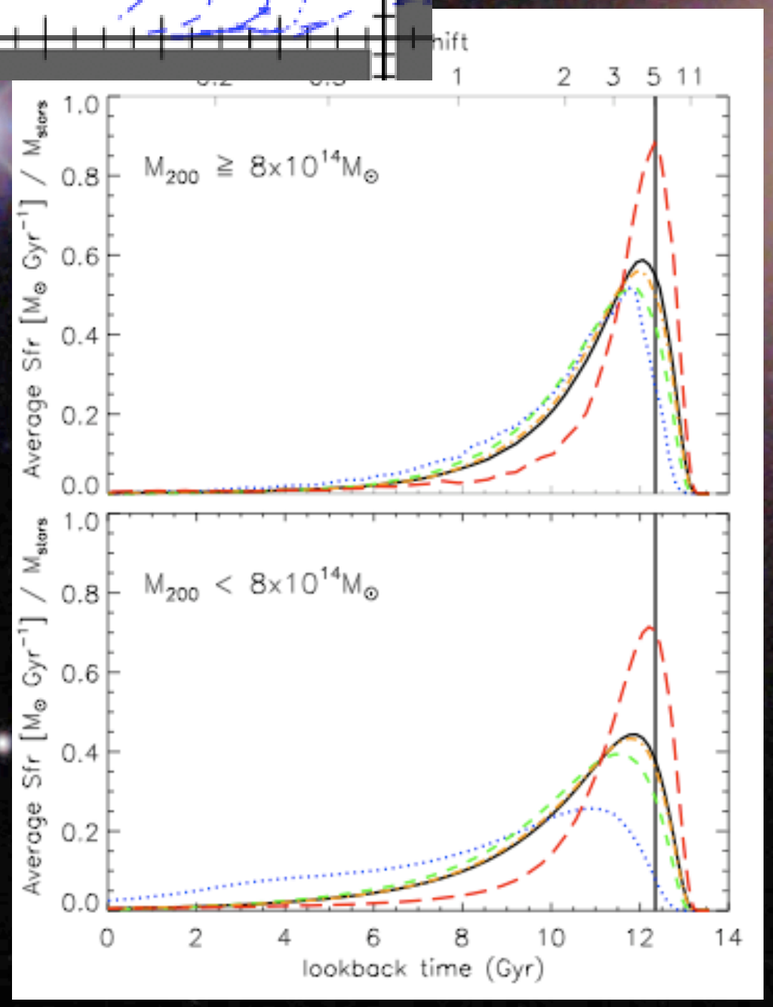



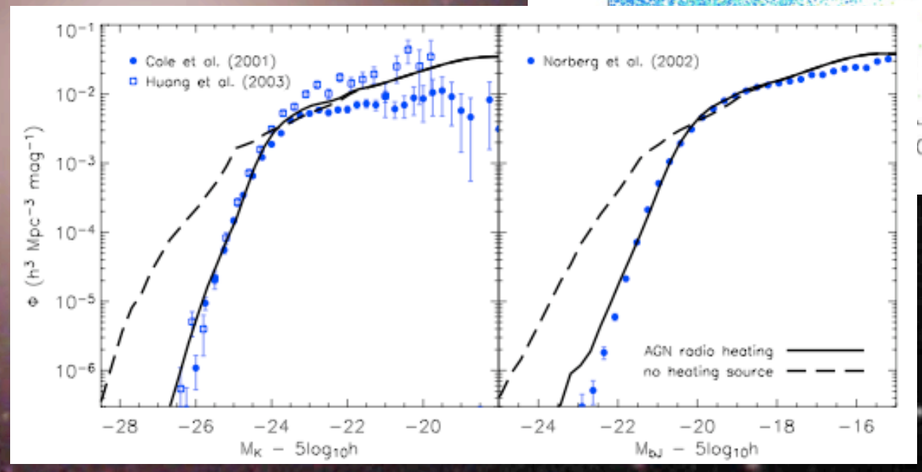



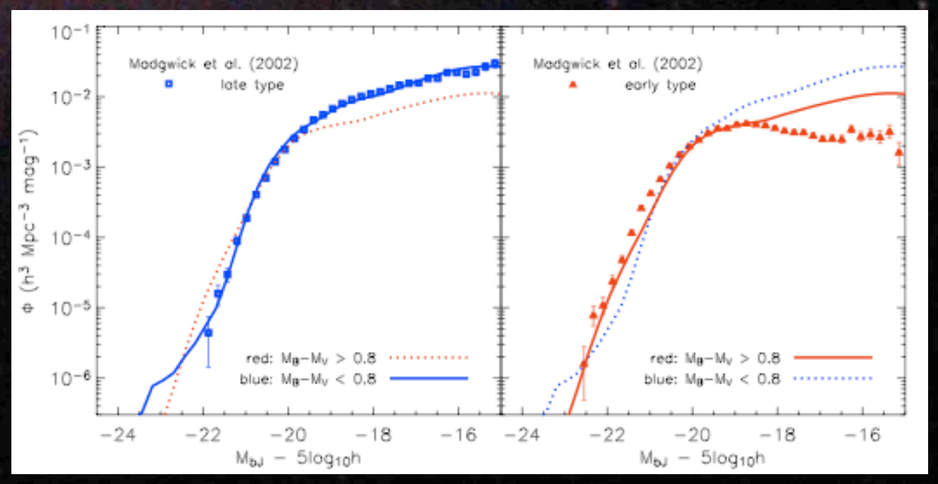

# The model so far ..

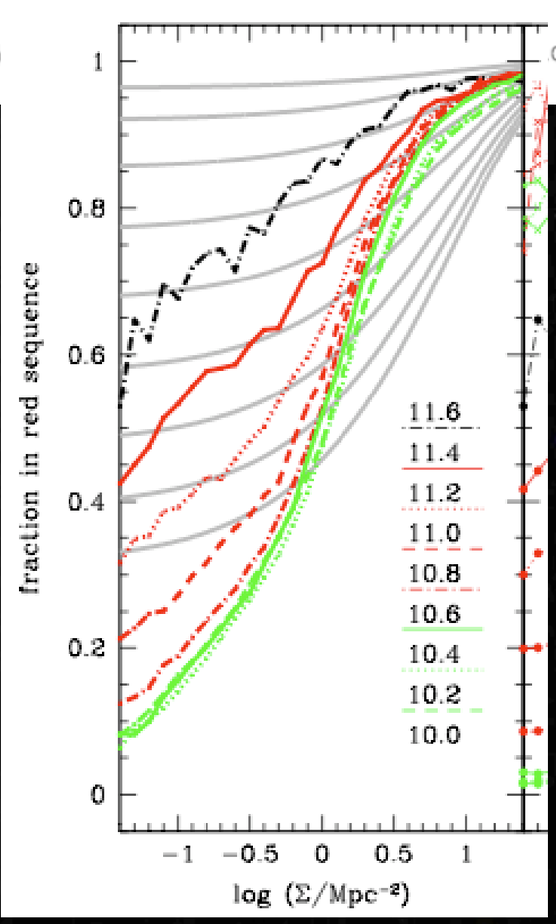


# Gas Heating

model Bondi accretion rate:

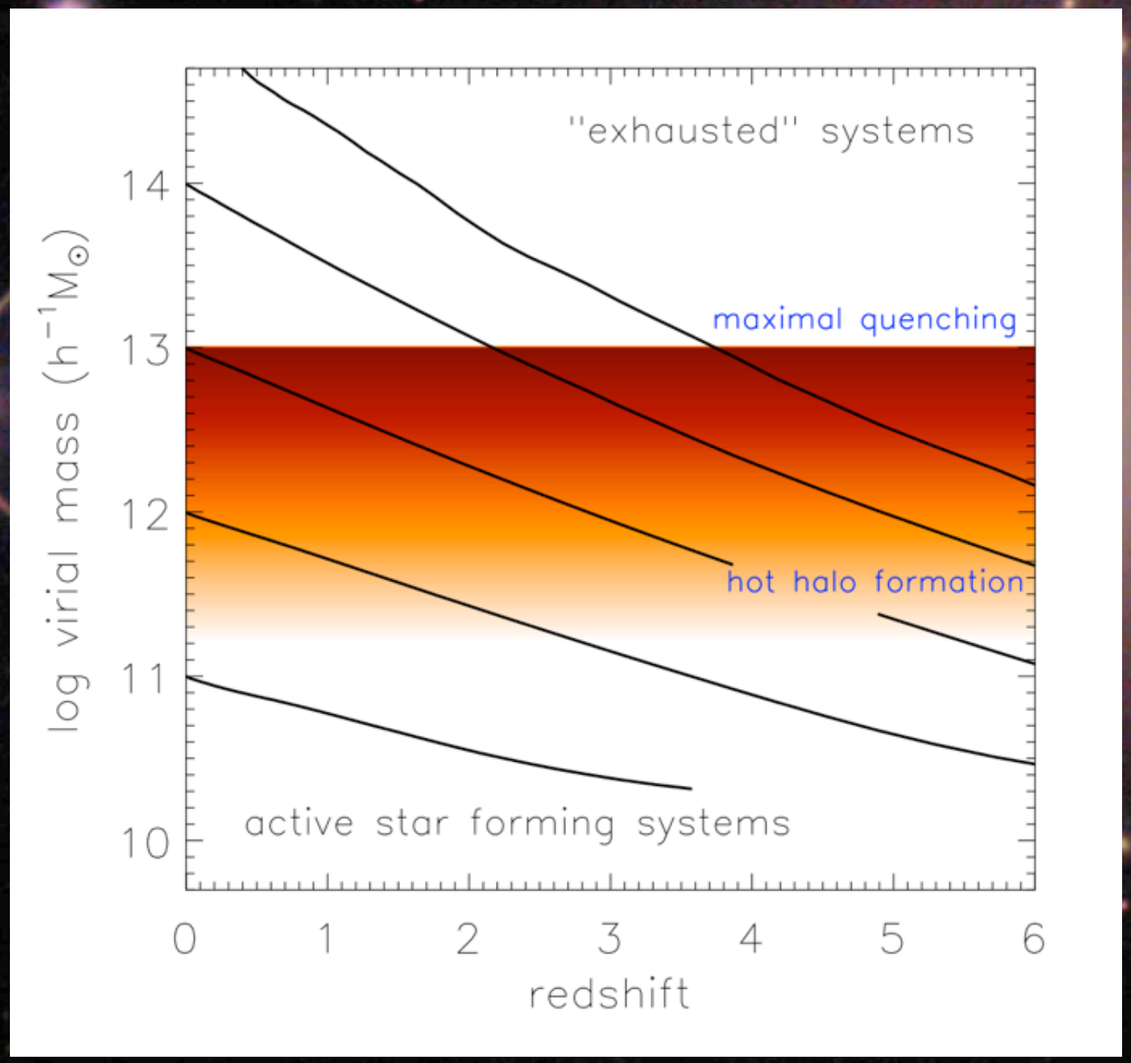
$$\dot{m}_{\rm Bondi} \approx {\rm G}\mu m_{\rm p} \frac{kT}{\Lambda} m_{\rm BH}$$

or a simple parameterized model to fuel the low luminosity AGN

$$\dot{m}_{\rm BH,R} = \kappa_{\rm AGN} \left( \frac{m_{\rm BH}}{10^8 M_\odot} \right) \left( \frac{f_{\rm hot}}{0.1} \right) \left( \frac{V_{\rm vir}}{200\,{\rm km\,s^{-1}}} \right)^3$$

... but both require the presence of a hot halo as a fuel source

# The growth of structure




Dark matter halos grow in mass until they can form a hot gaseous halo.

At this point the low luminosity AGN heating becomes increasingly important.

Heating balances cooling at approximately the critical mass, after which the cold gas supply runs out.

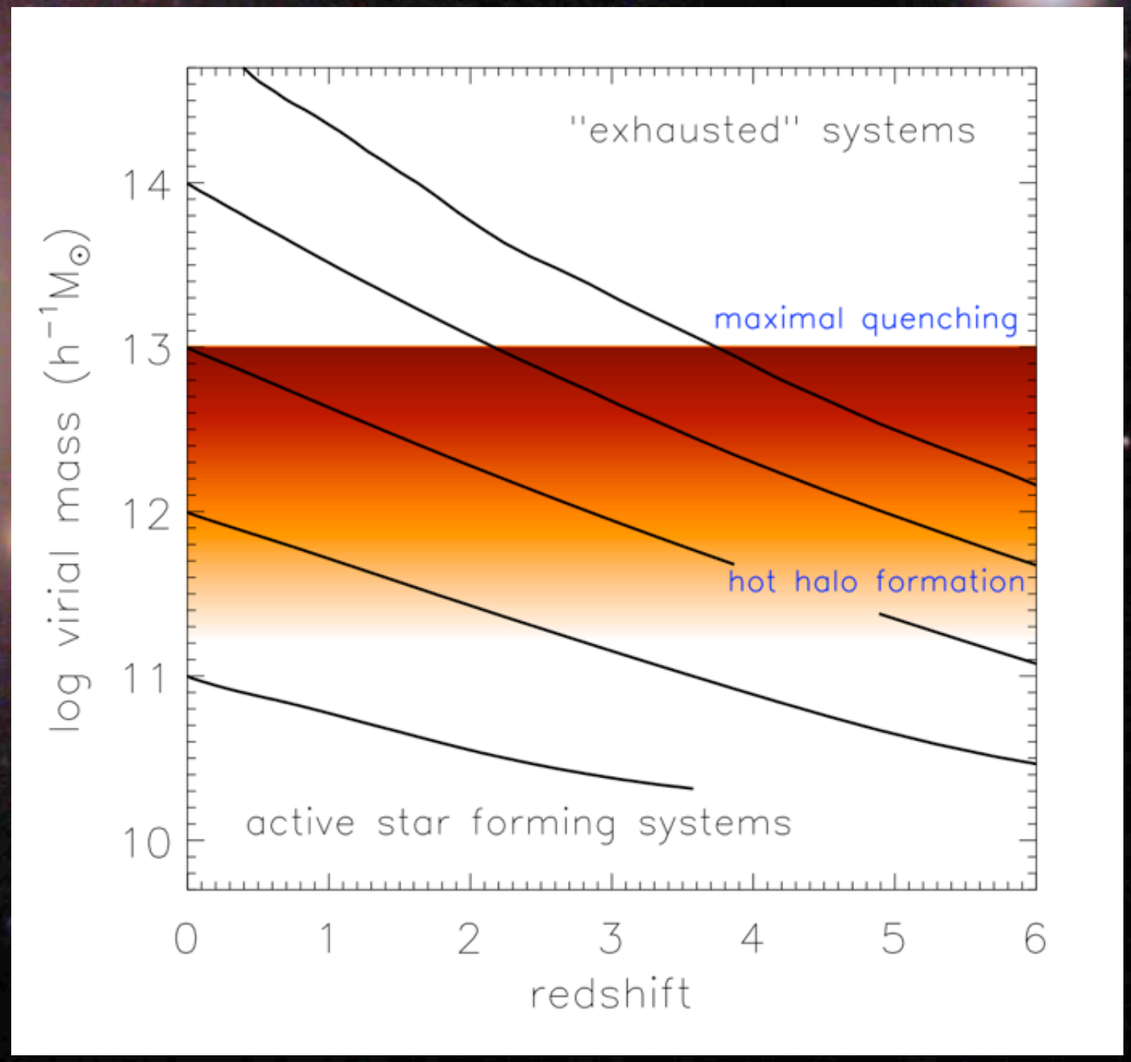
# Consequences of a critical quenching mass

Truncation of the growth of mass and luminosity ...

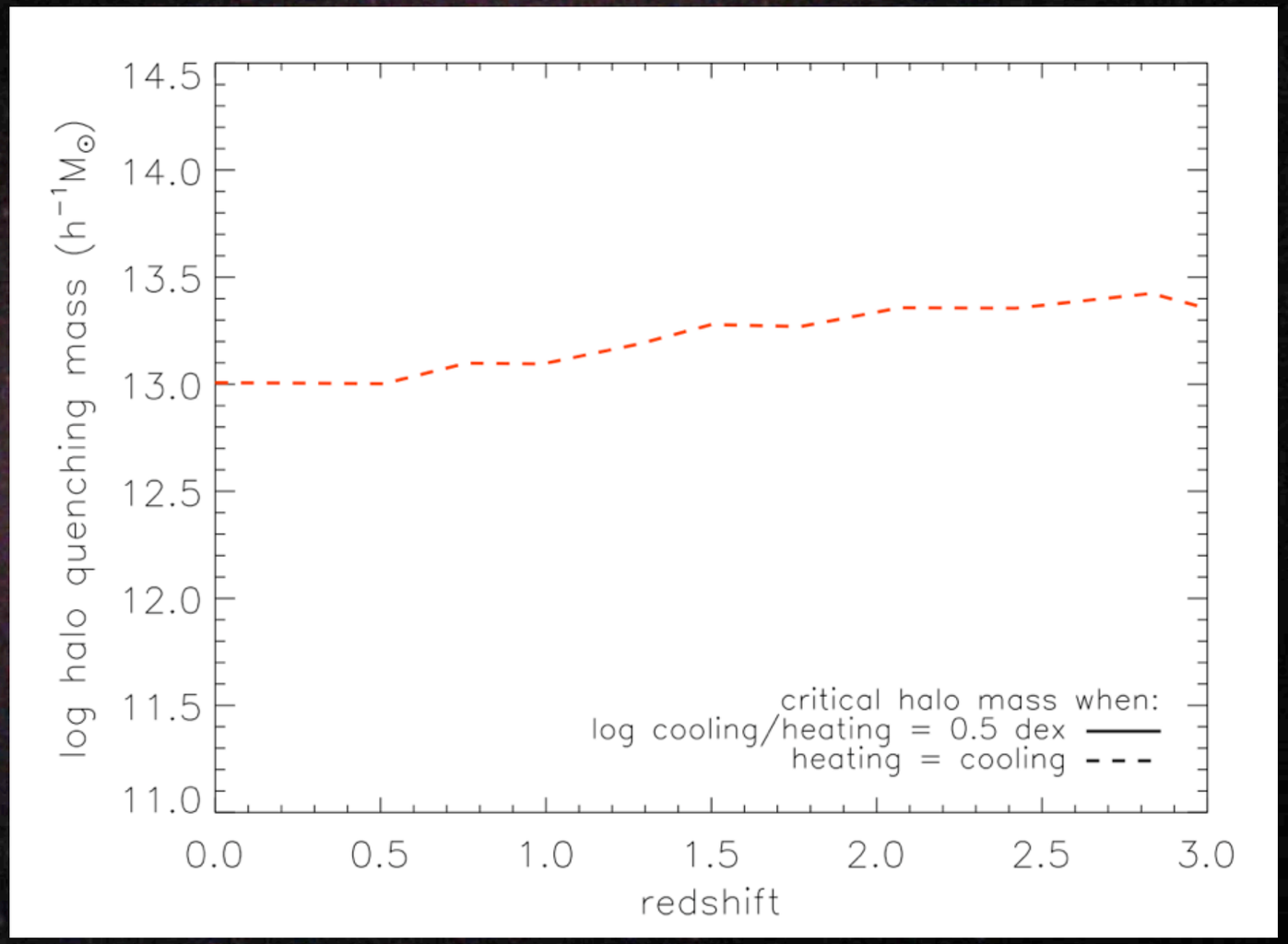
The appearance of a red sequence of galaxies ...

A critical halo mass for L* quasars

The evolution in the number density of quasars ...

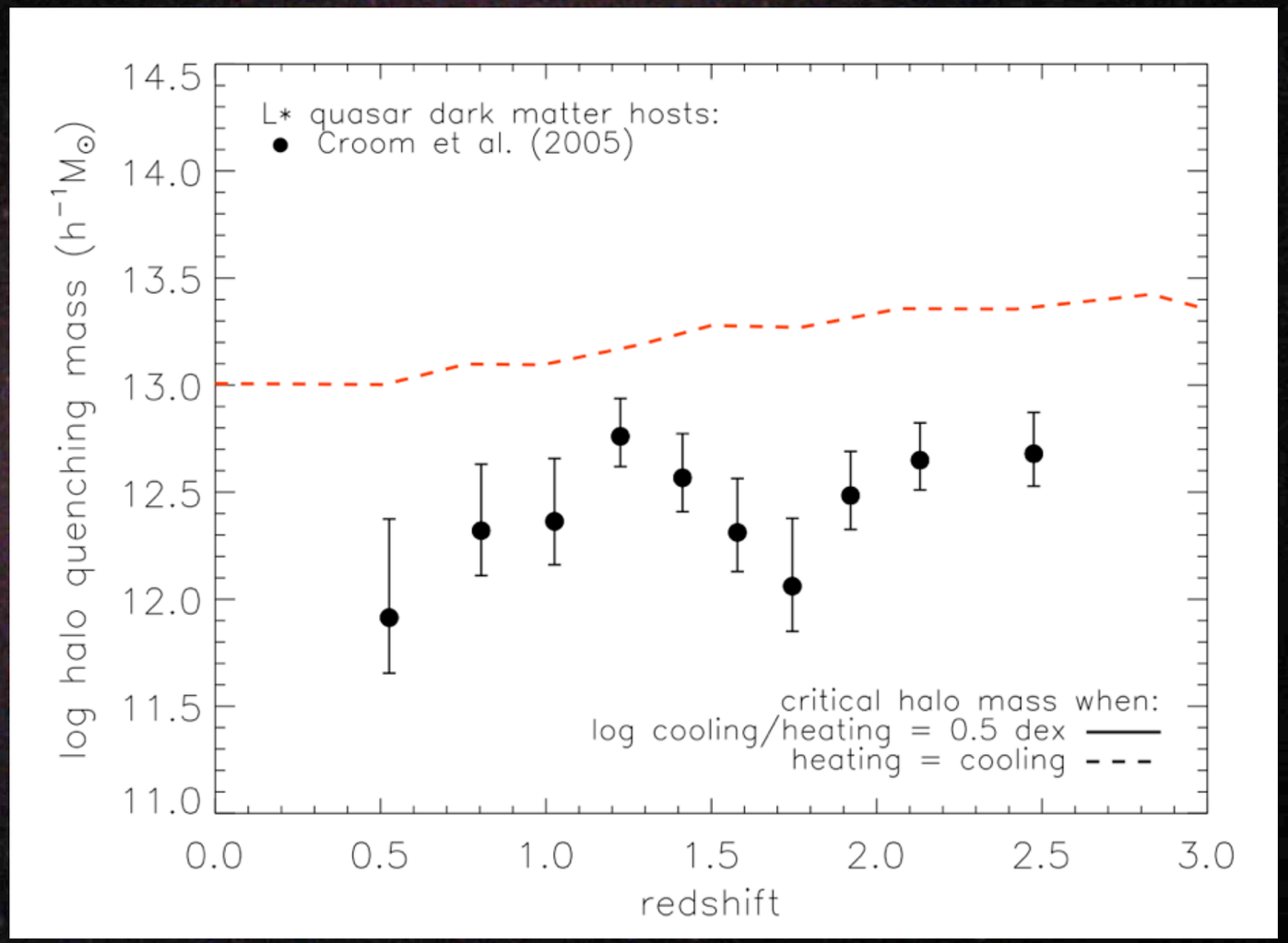


# What happens when heating balances cooling?



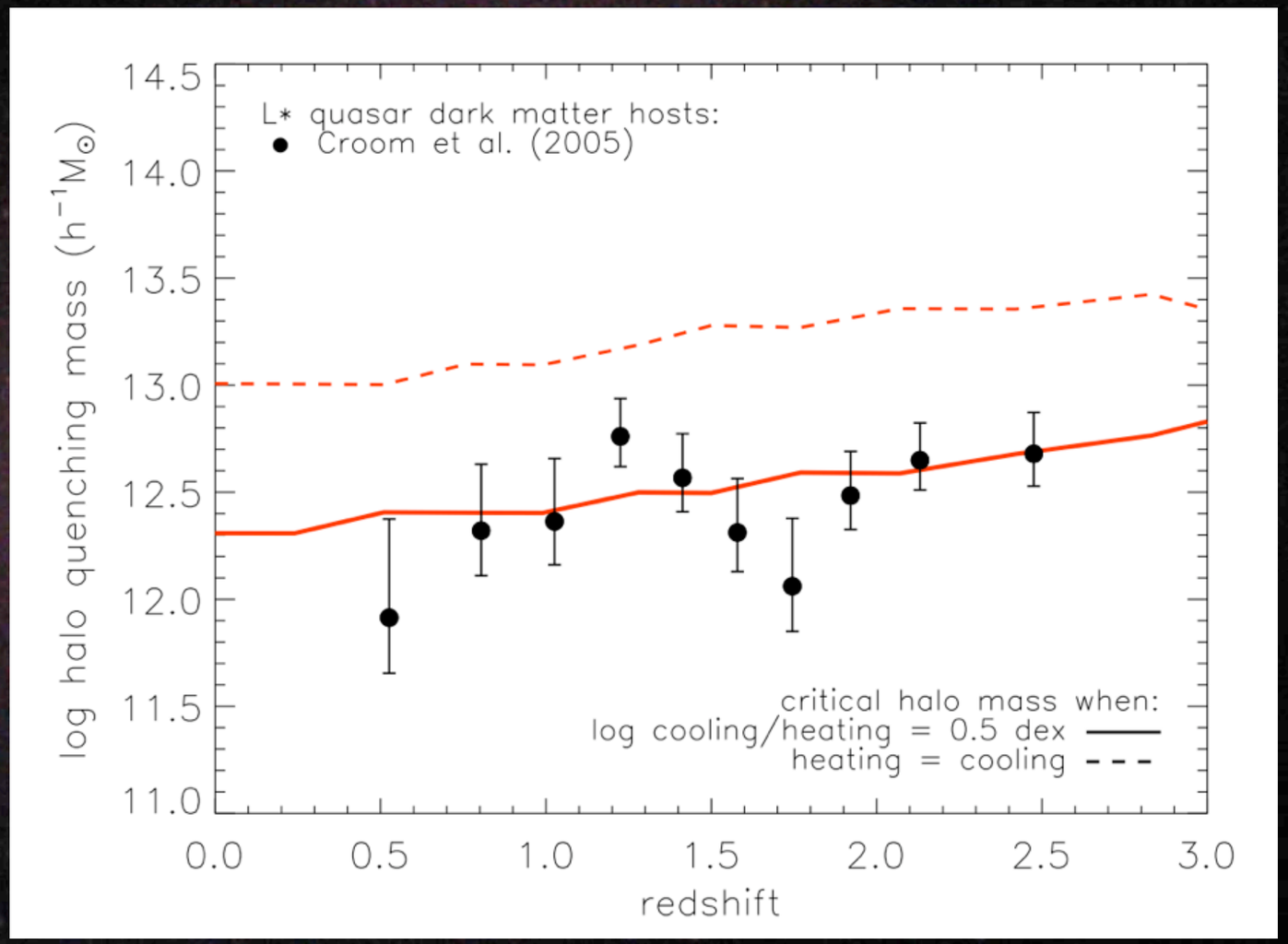

Critical halo mass when the heating rate balances the cooling rate of gas condensing out of the hot halo

# What happens when heating balances cooling?



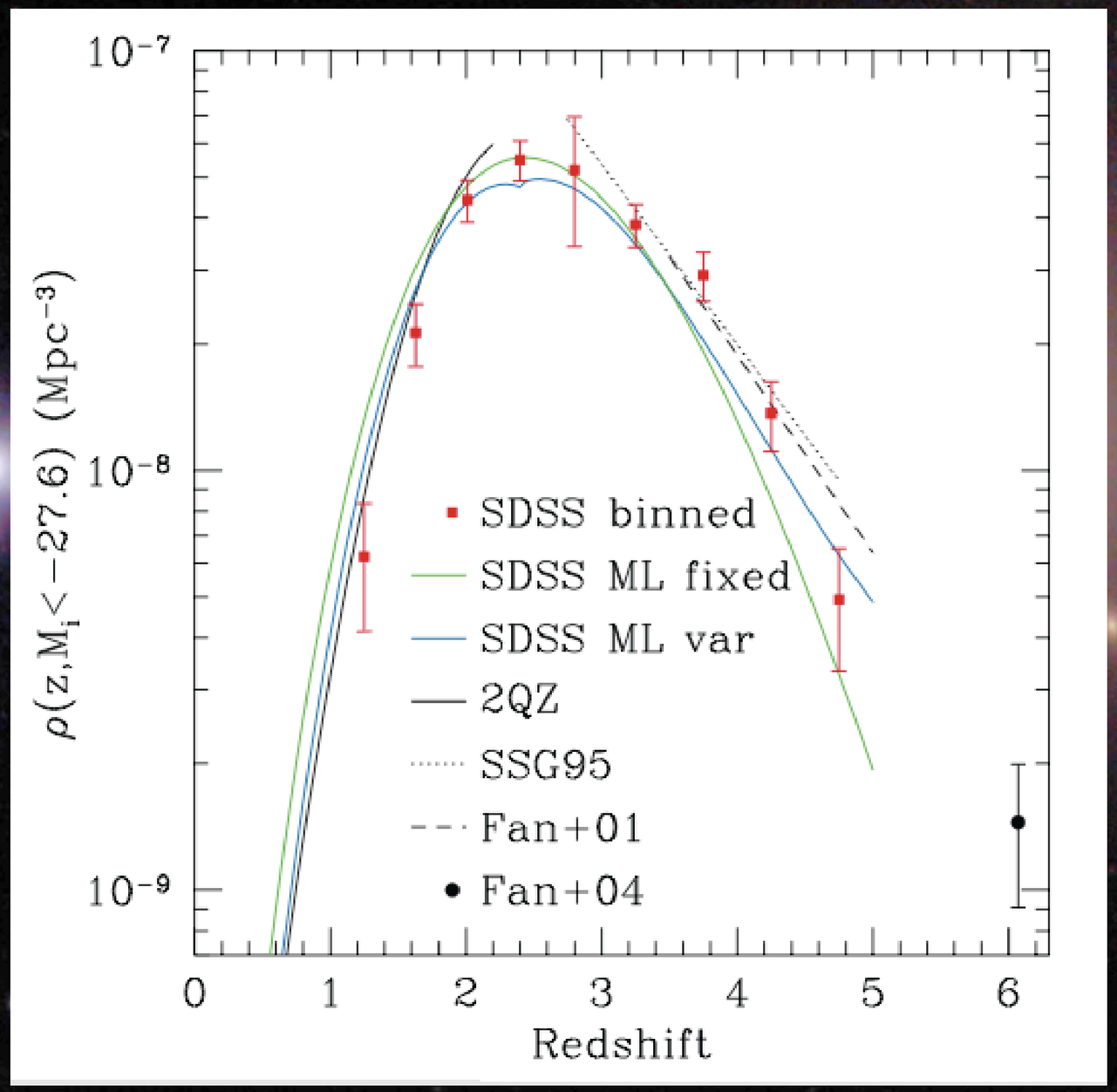

The characteristic halo mass in which L* quasars live

# What happens when heating balances cooling?

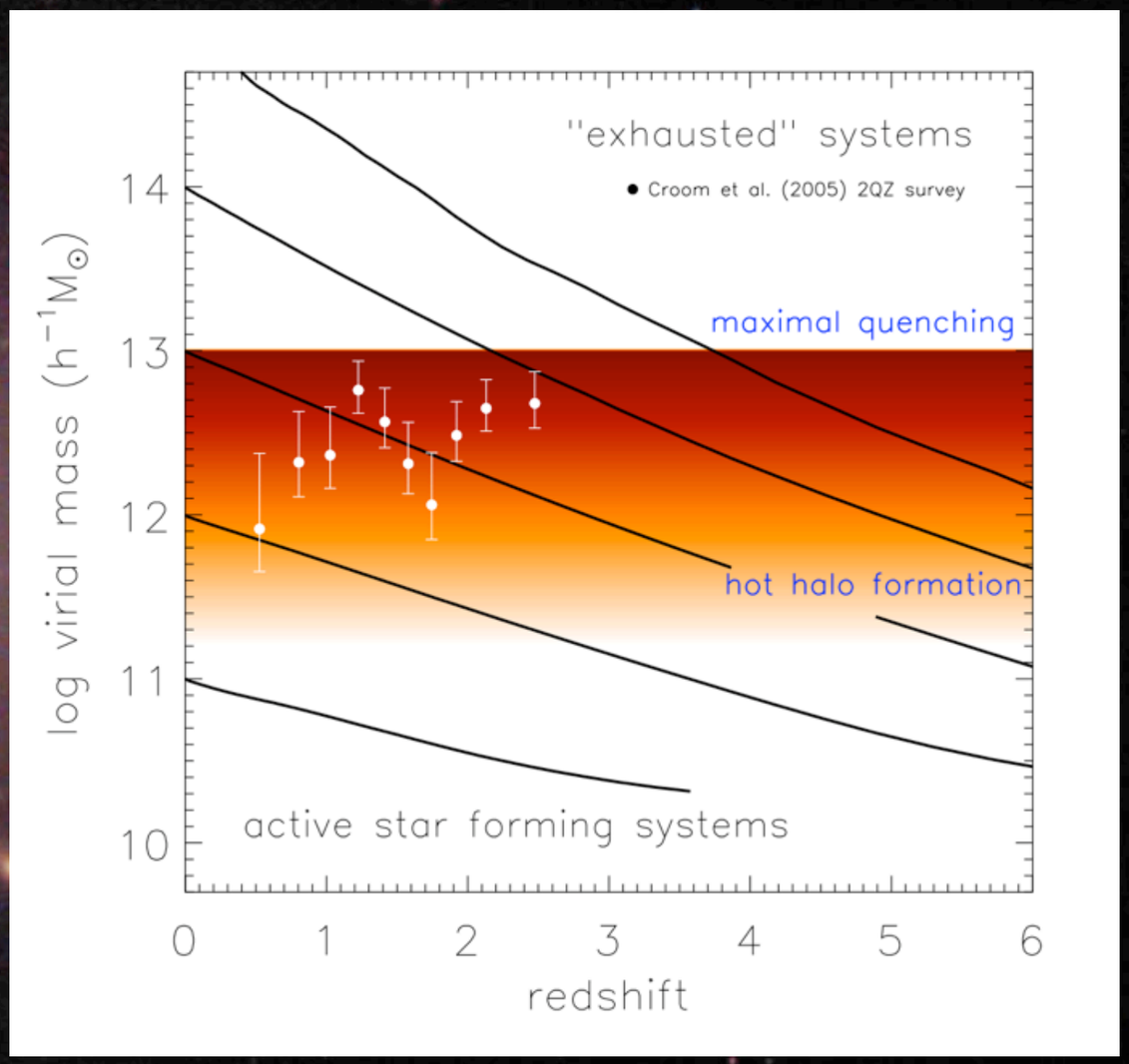



The halo mass for which heating is *nearly* maximally efficient, but not yet.

# The evolution of the number density of quasars

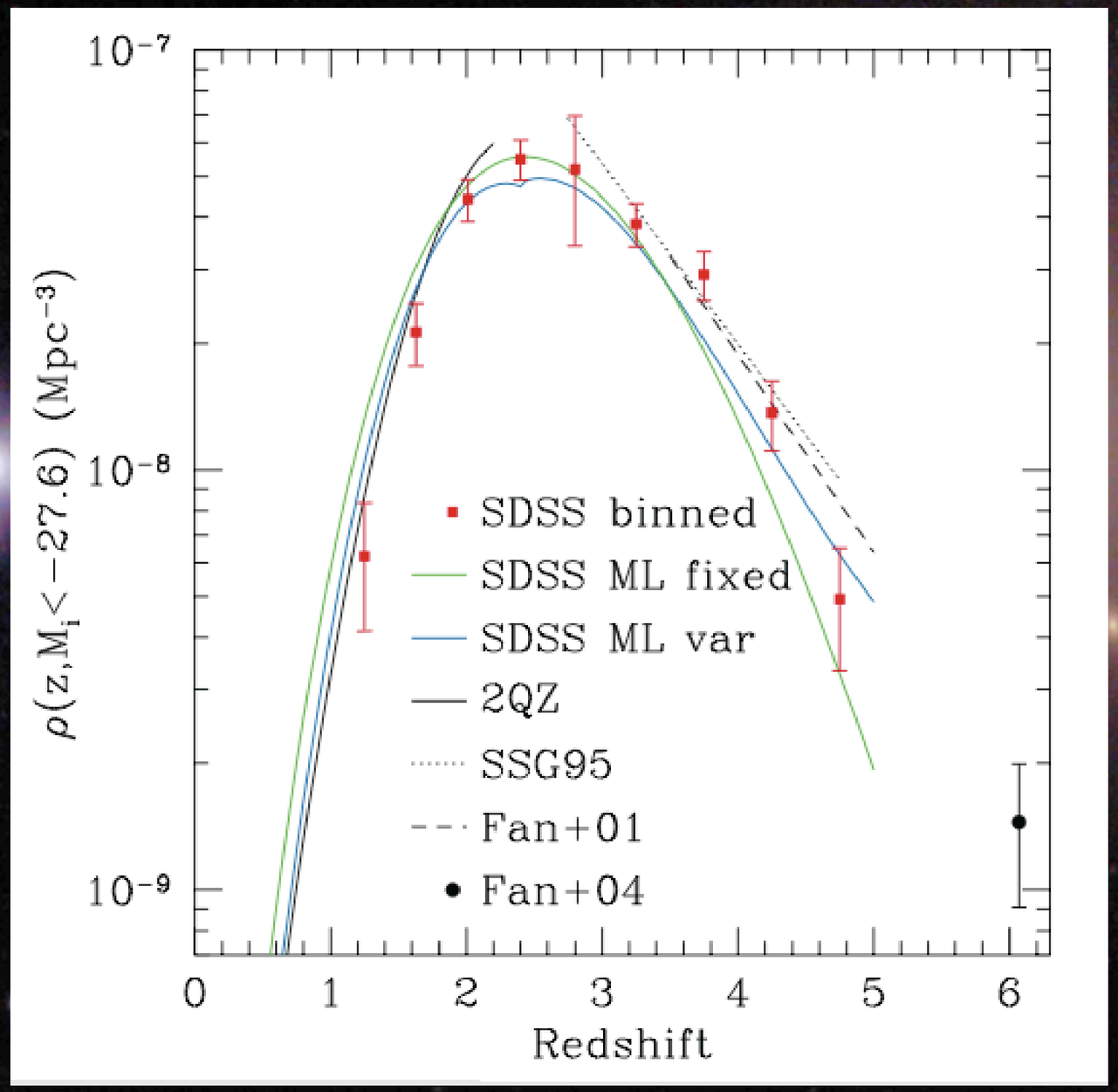



Richards et al. 2005

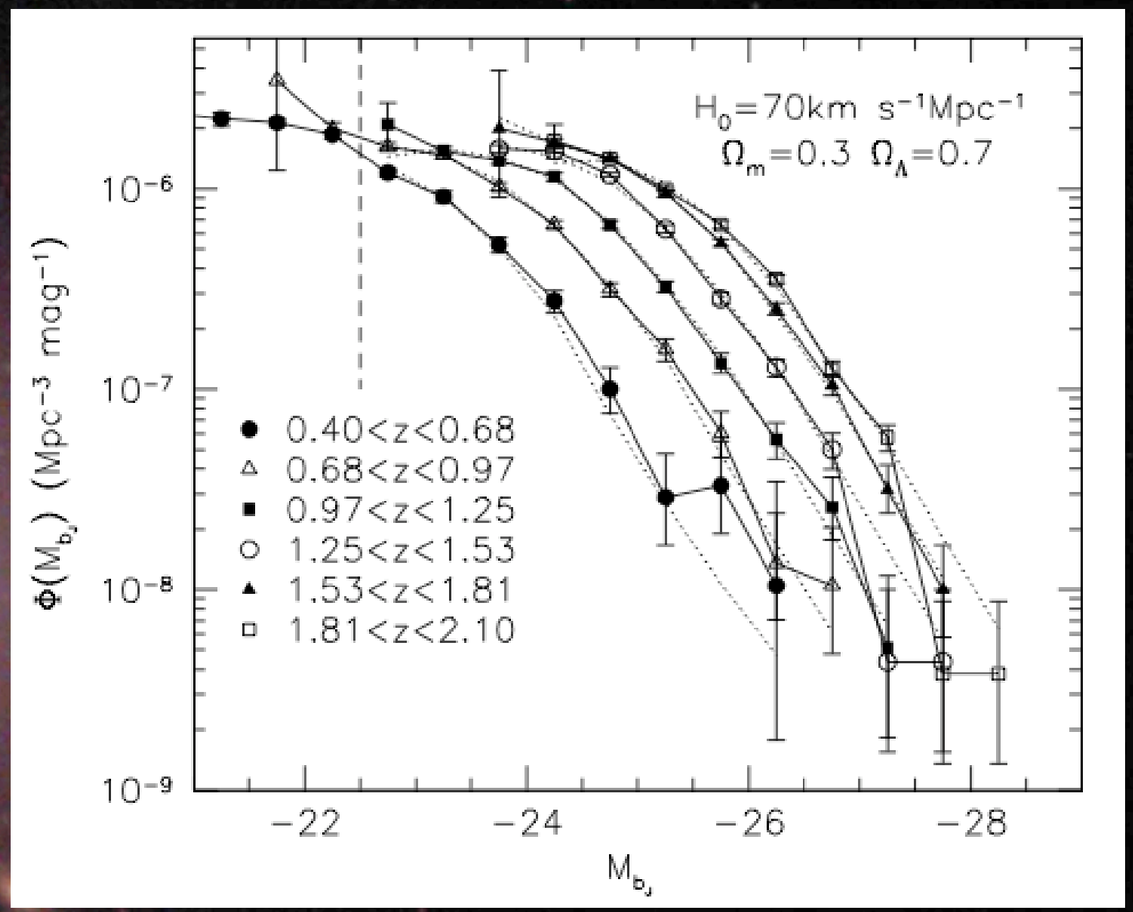



rate at which halos cross the critical threshold = rate of quasar decline?

# The evolution of the number density of quasars



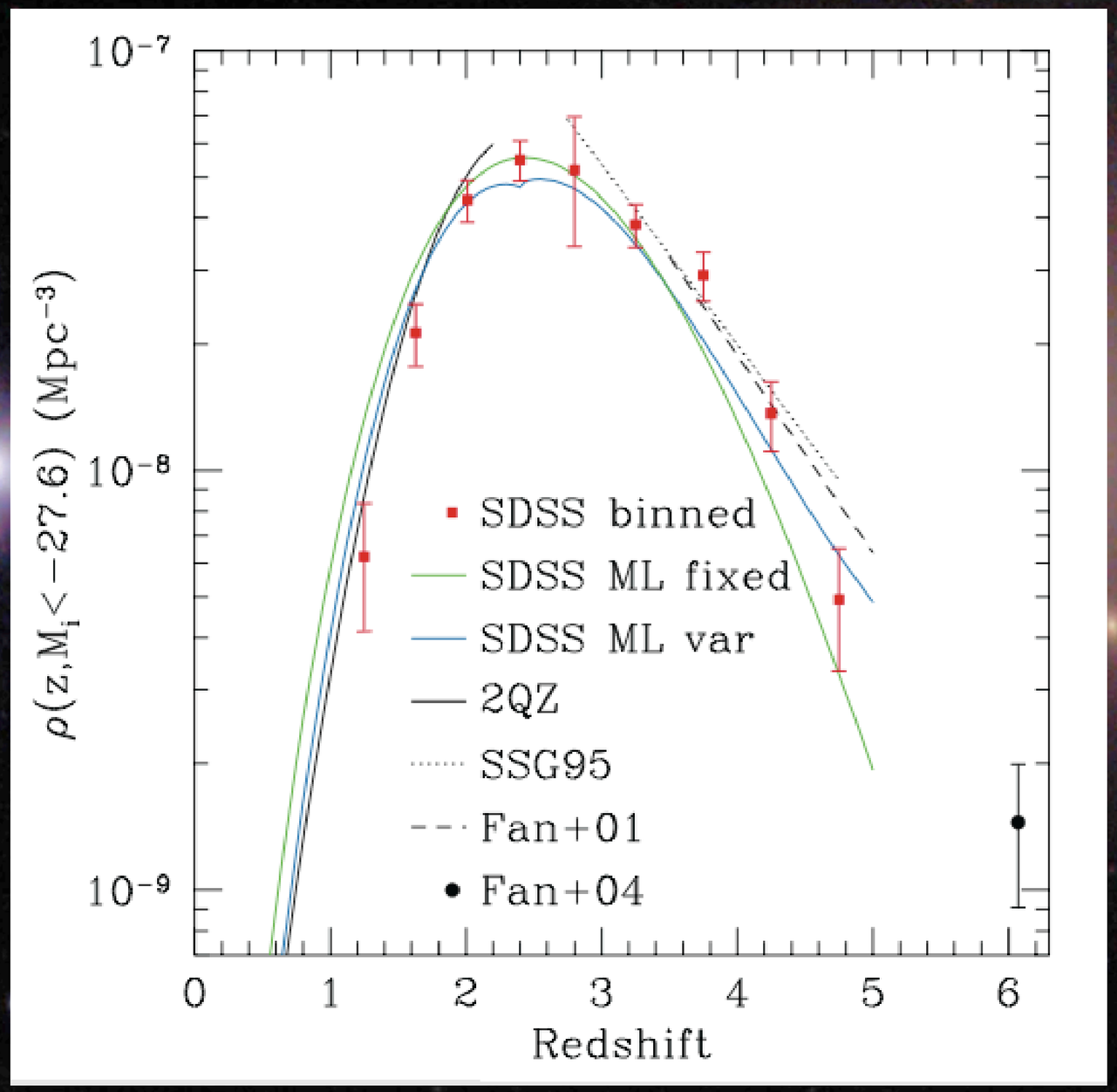

Richards et al. 2005



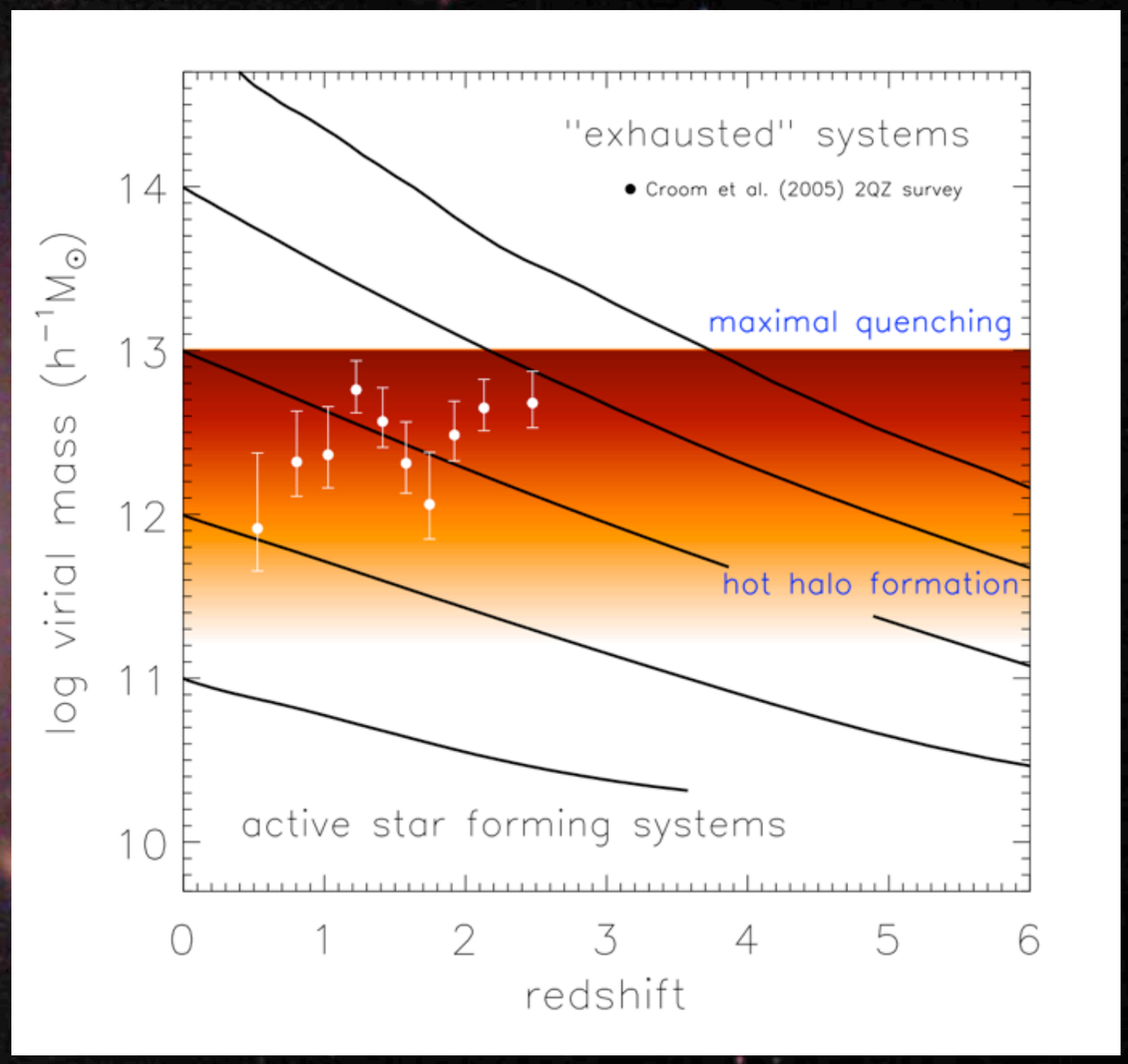

Croom et al. 2005

Perhaps not, since quasar density evolution is usually plotted using a fixed quasar luminosity threshold at all redshifts

# The evolution of the number density of quasars

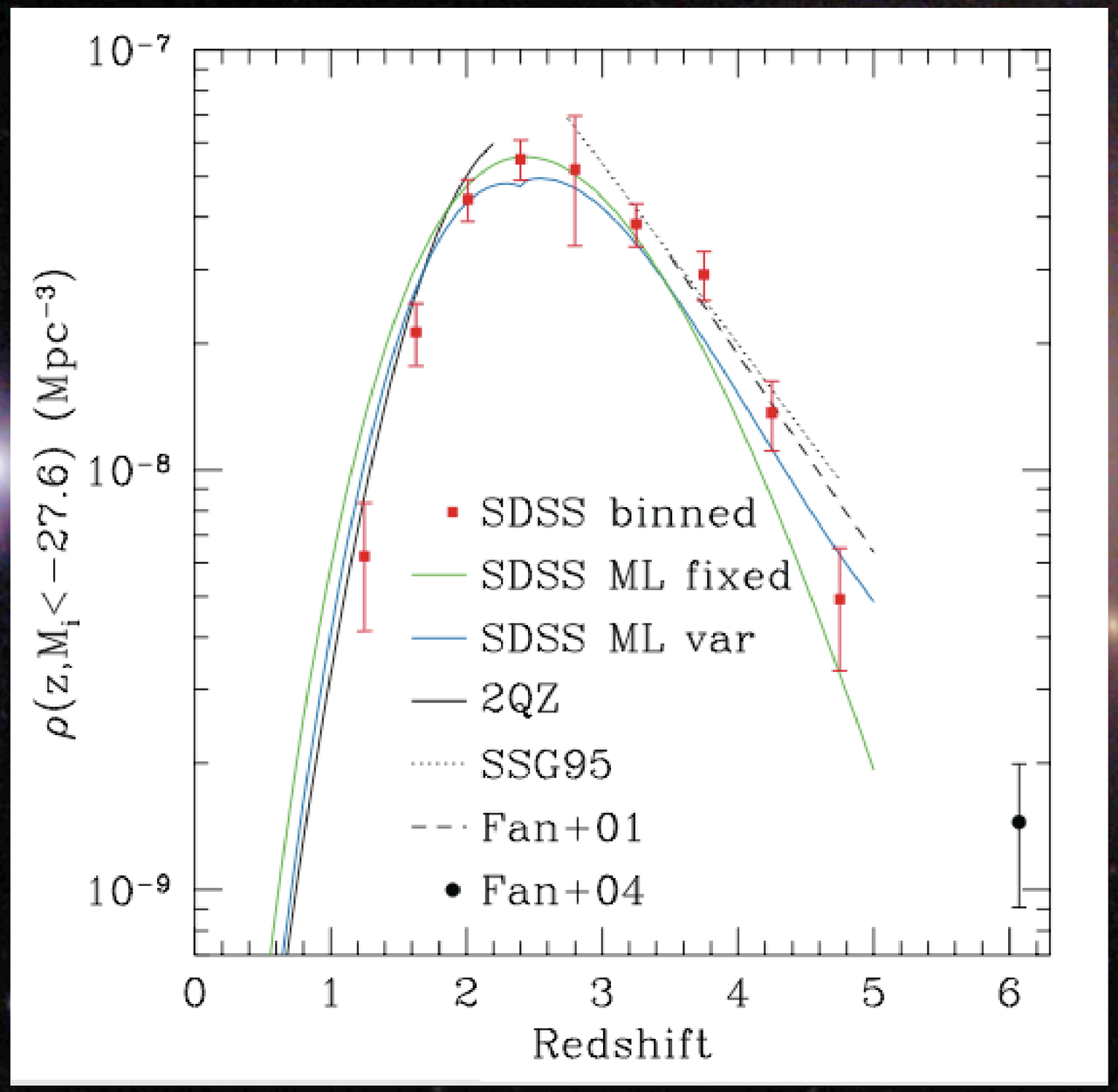


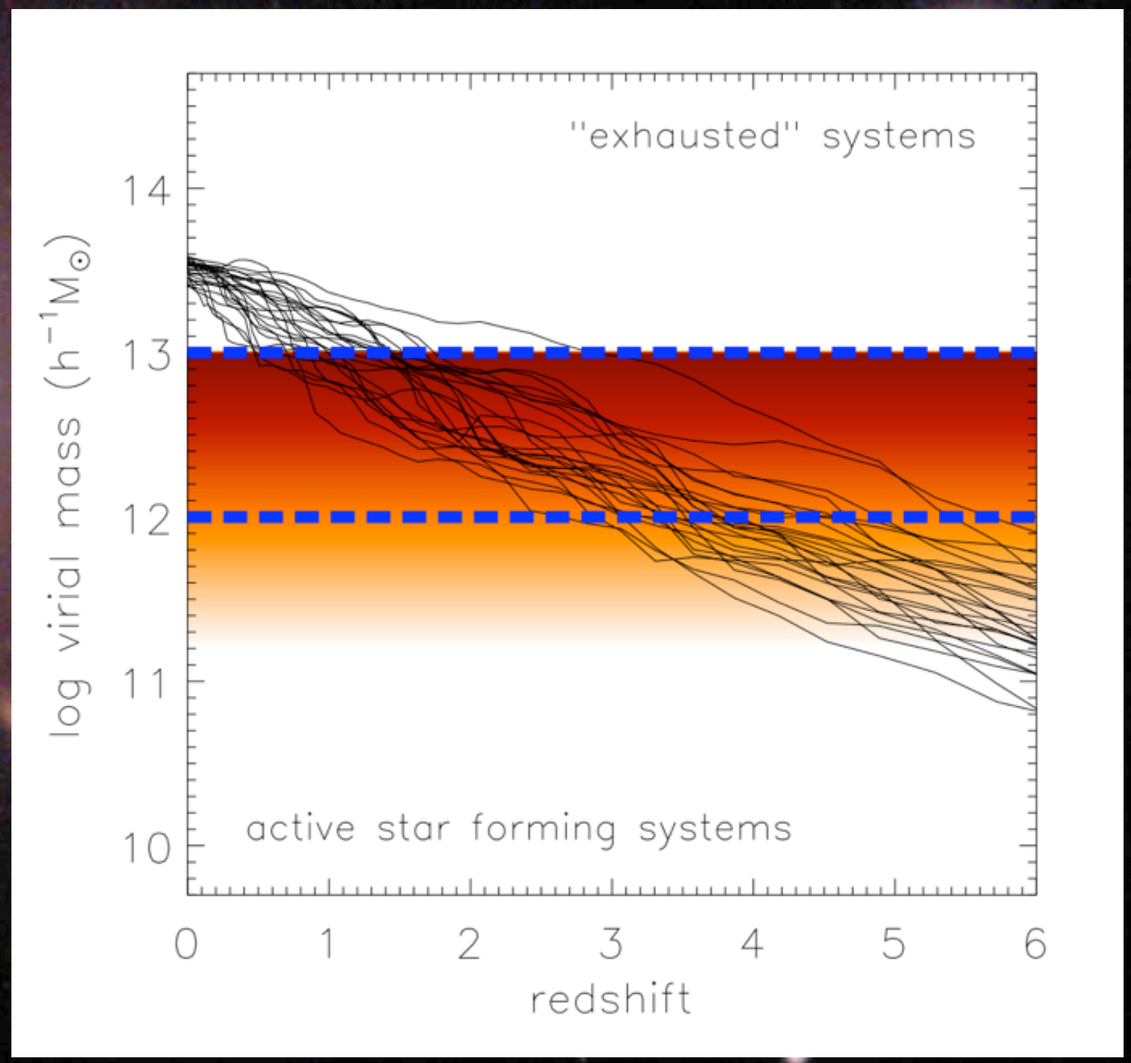

Richards et al. 2005




As an exercise, take L* quasars at z=2-3 and look at the number density evolution of their z=0 progenitors, inside the critical mass range

# The evolution of the number density of quasars




Richards et al. 2005

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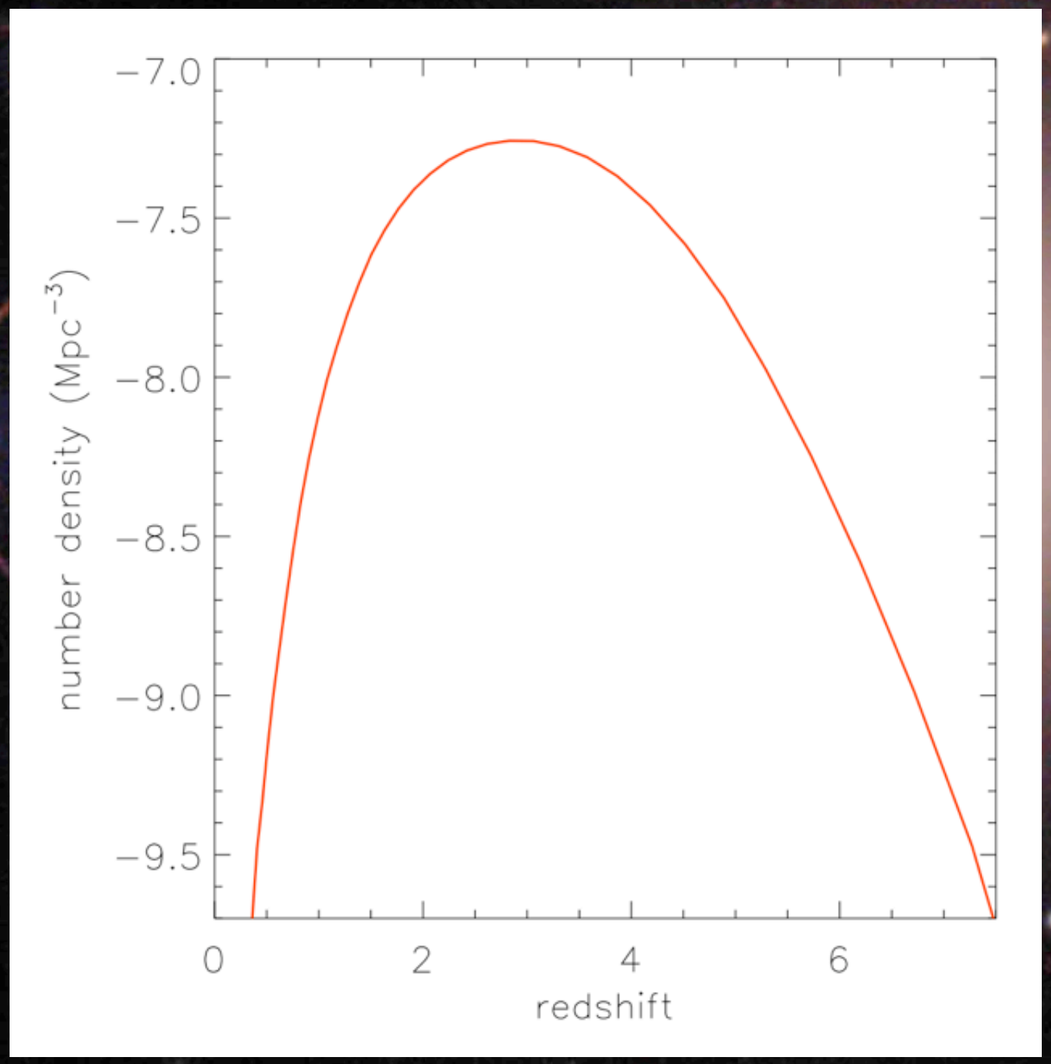
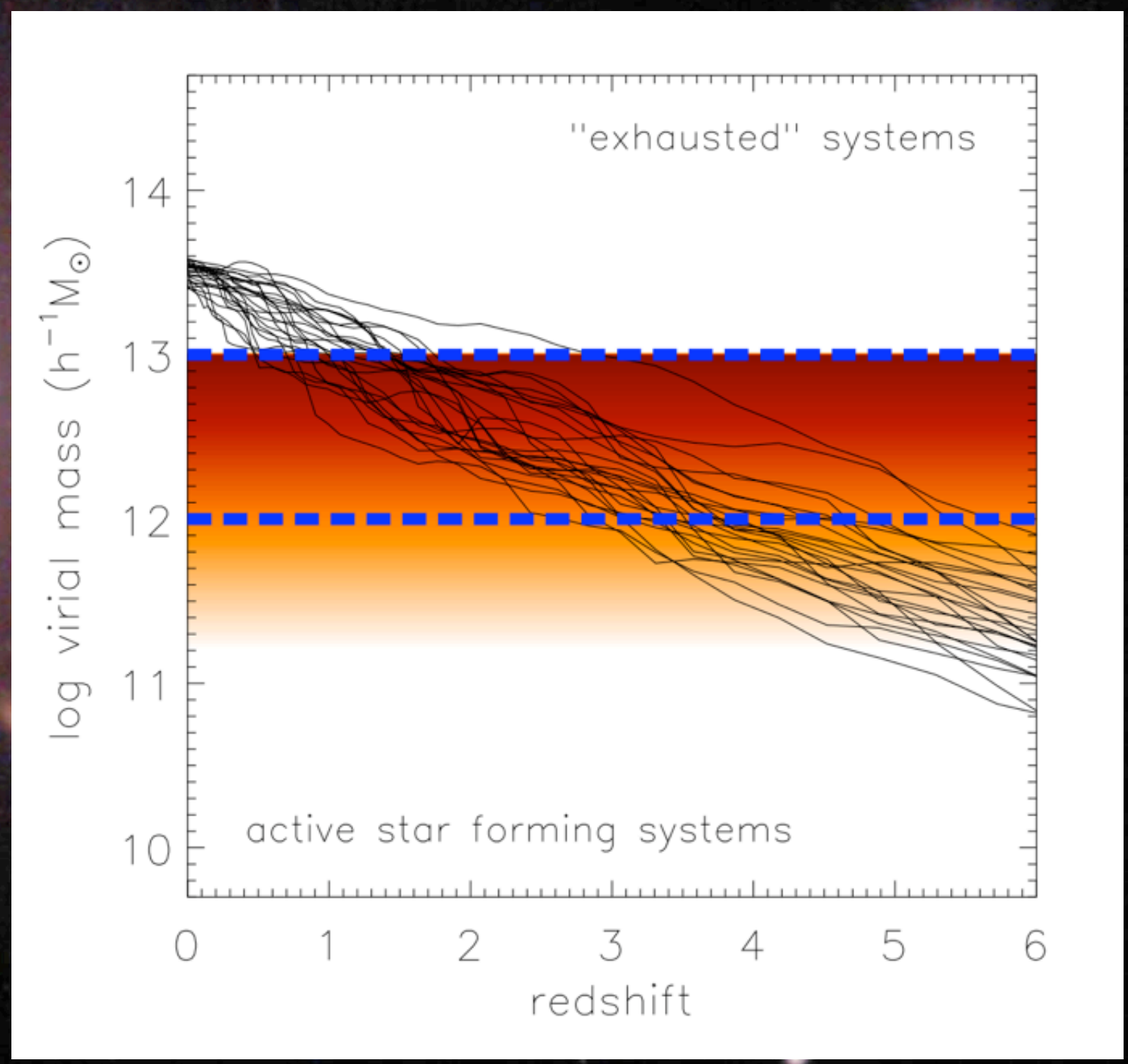
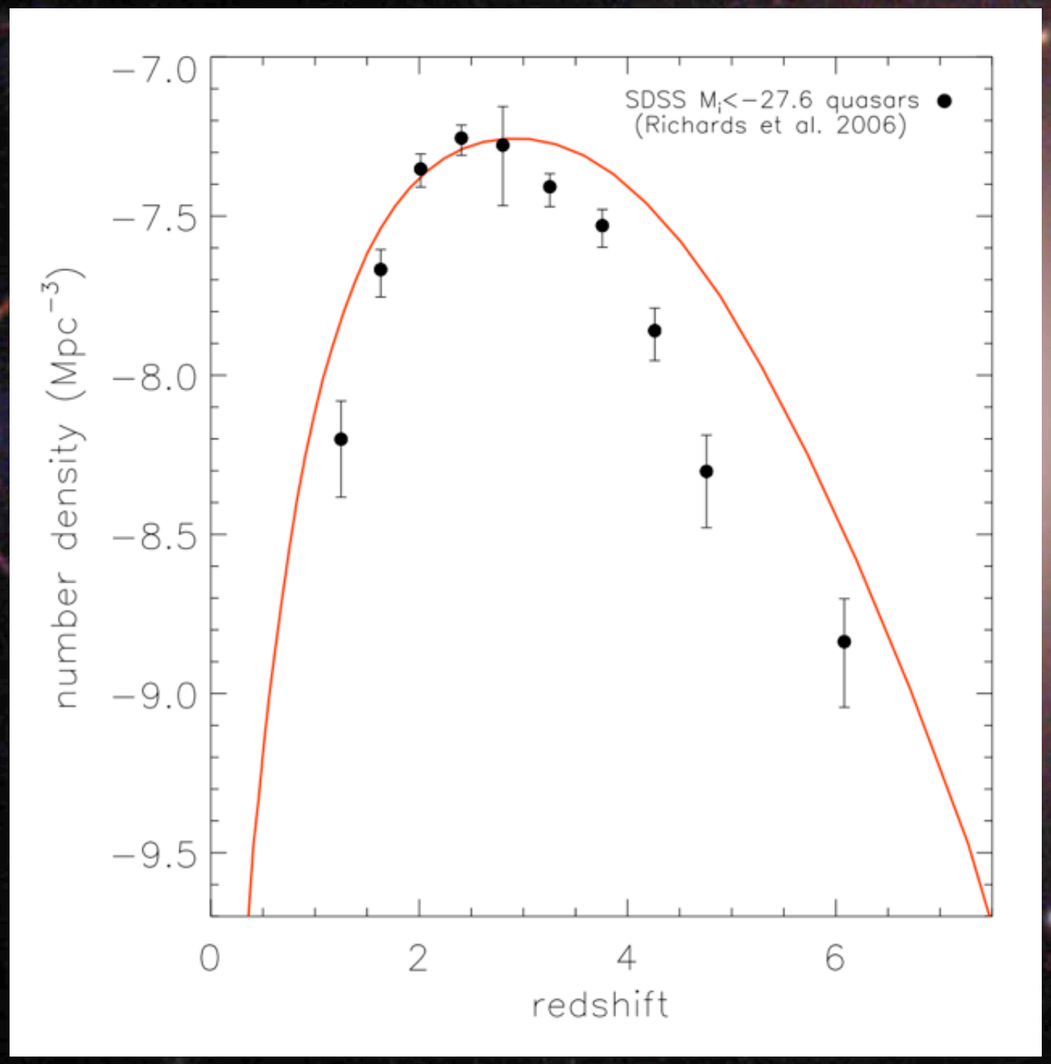
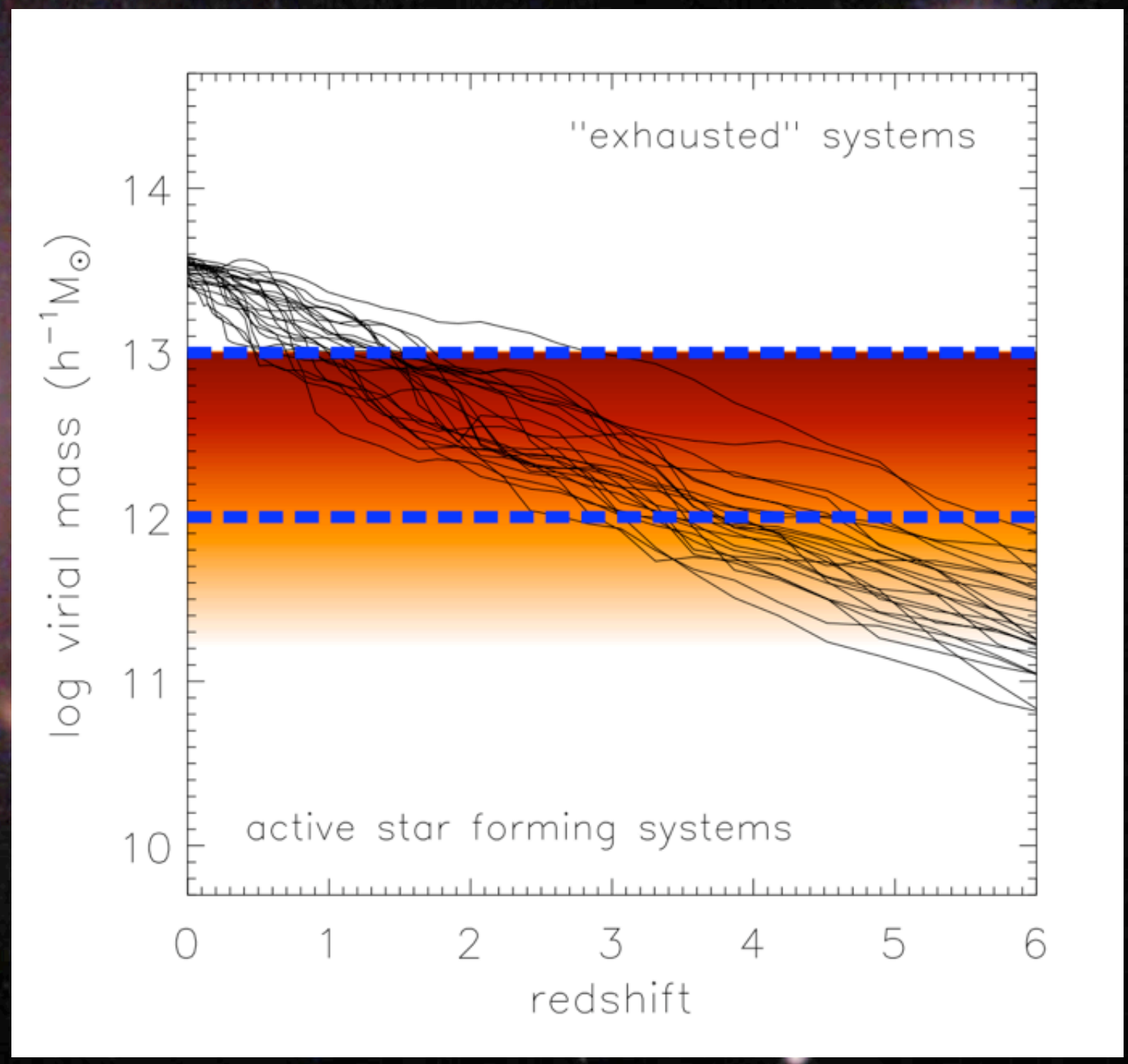



Number density of the progenitors of halos that end up with masses $>10^{13.5}$Msun, and lie within $10^{12}$-$10^{13}$Msun at any given redshift.

# The evolution of the number density of quasars

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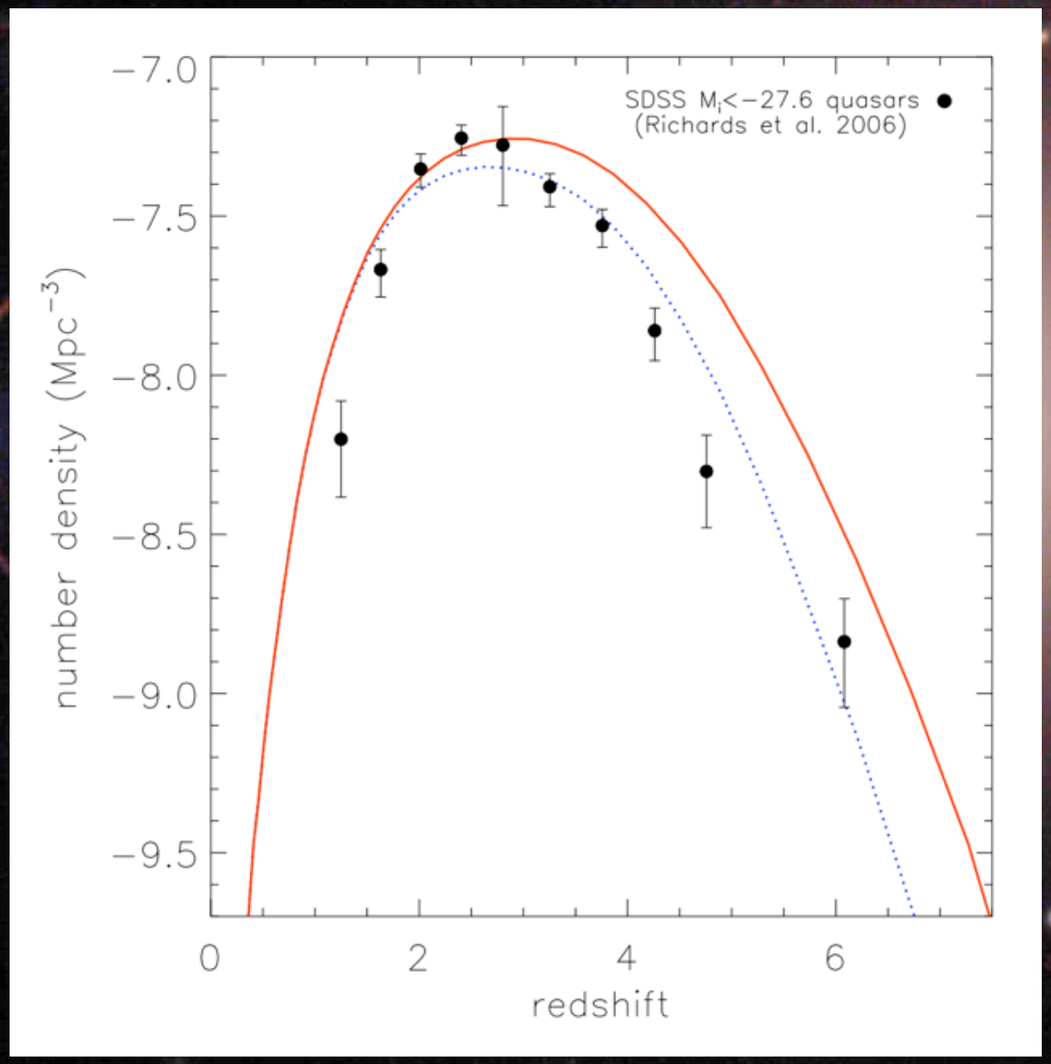
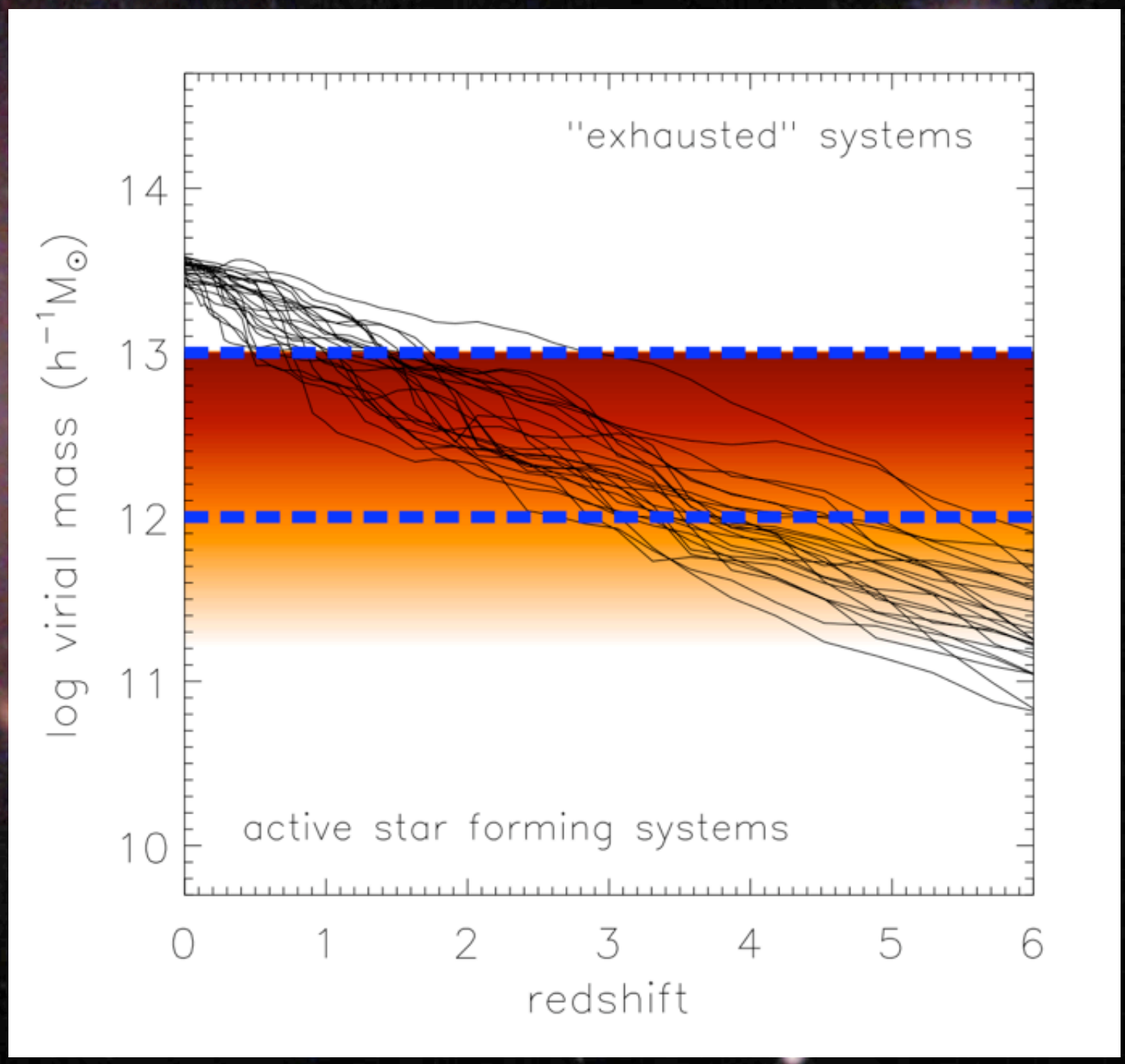
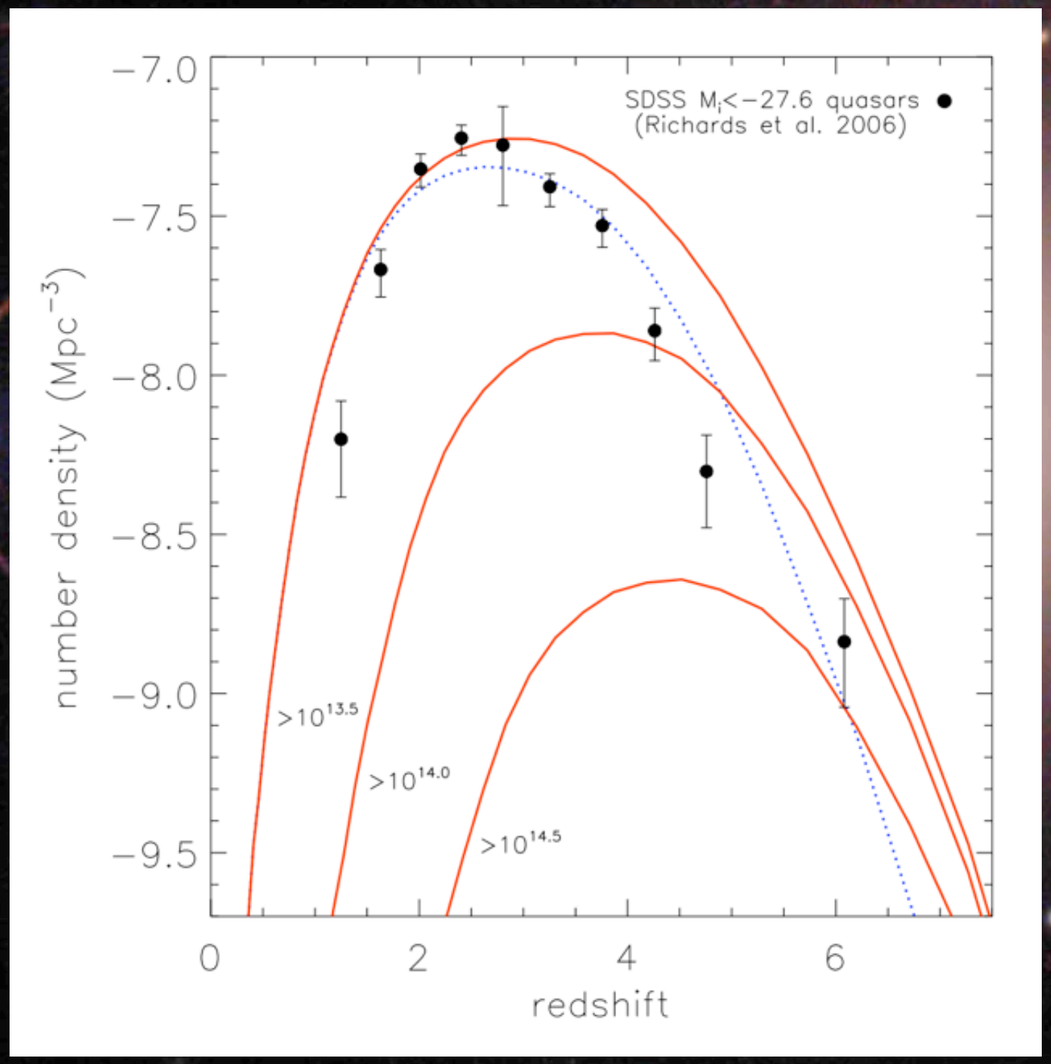


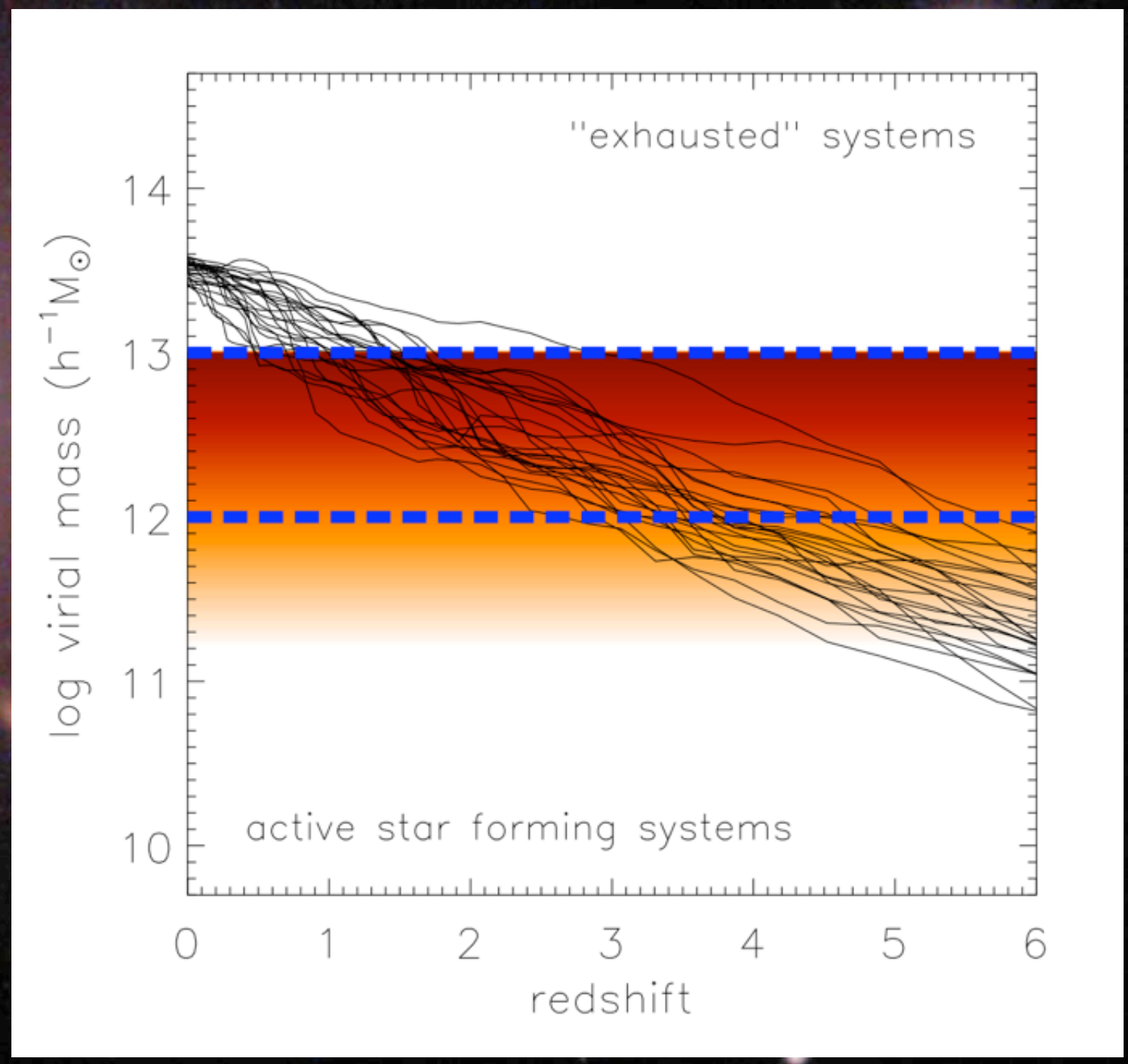




Number density of the progenitors of halos that end up with masses $>10^{13.5}$Msun, and lie within $10^{12}$-$10^{13}$Msun at any given redshift.

# The evolution of the number density of quasars

Various mass thresholds shift the peak, however all show a sharp decline in number density at low z.




Normalisation is arbitrary
(here 1 in 750 halos in the critical range shine) as a quasar)

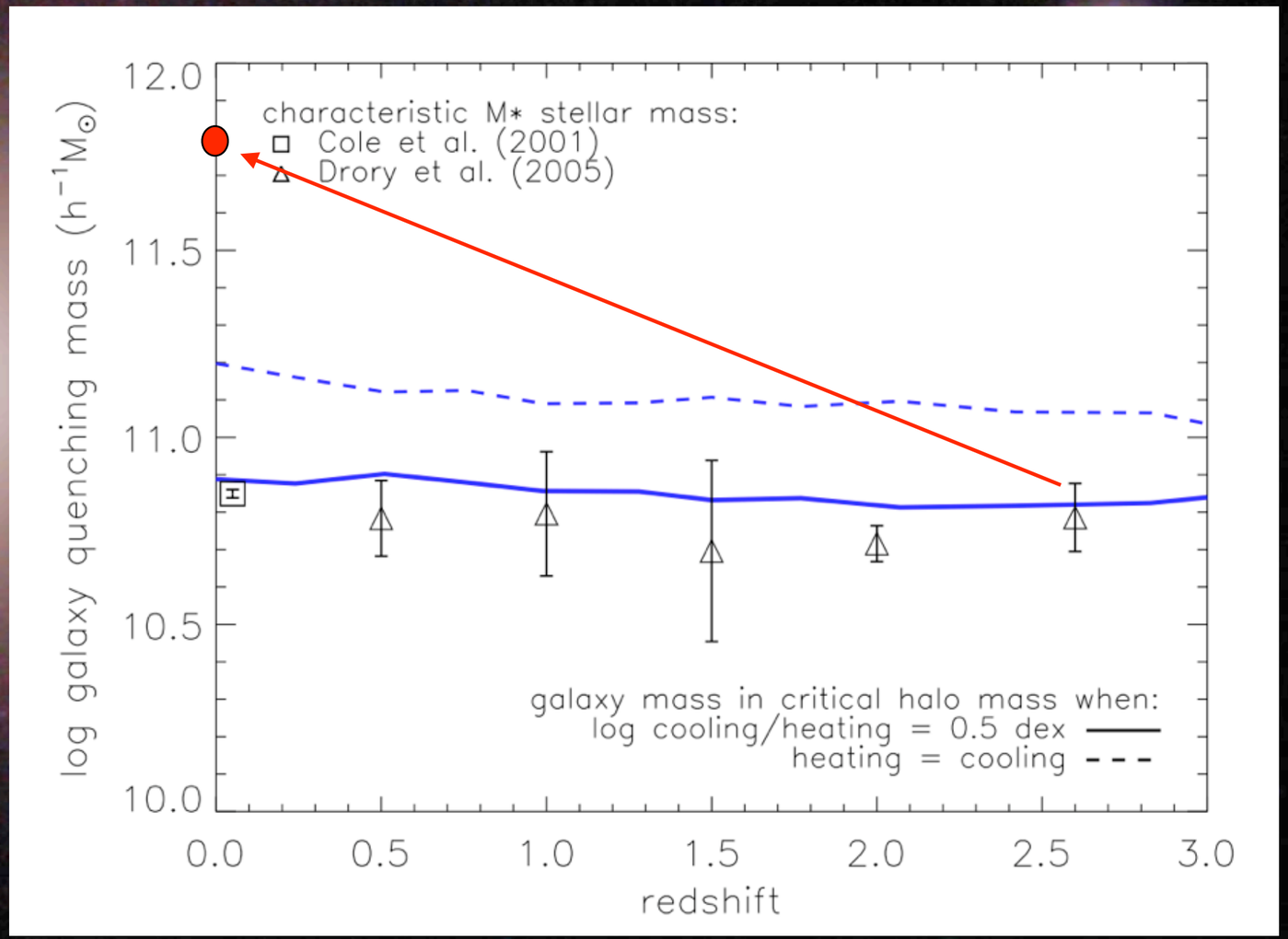
# A final word about “down-sizing”

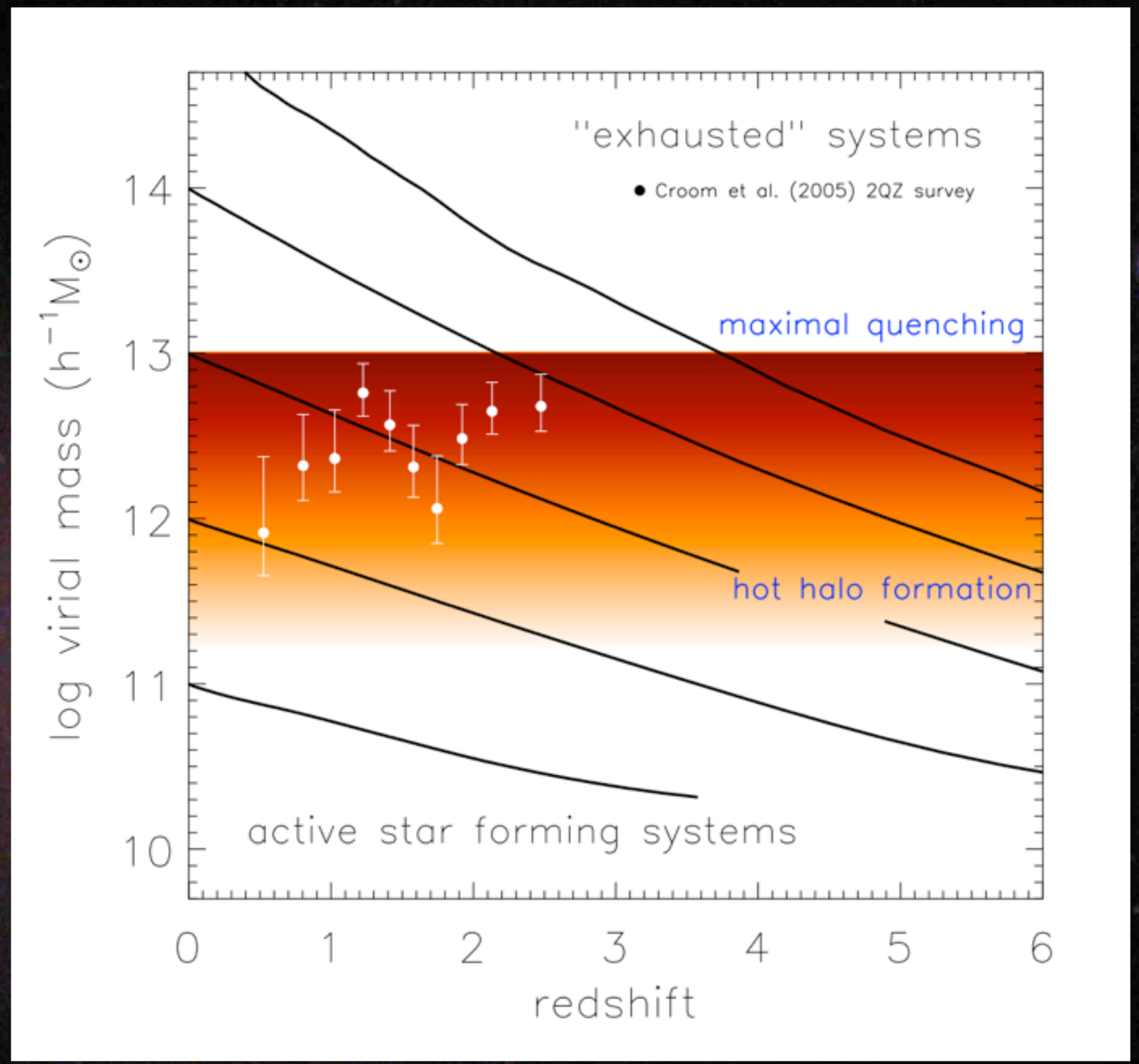
We need to be careful to distinguish between:

***“Archaeological down-sizing”***

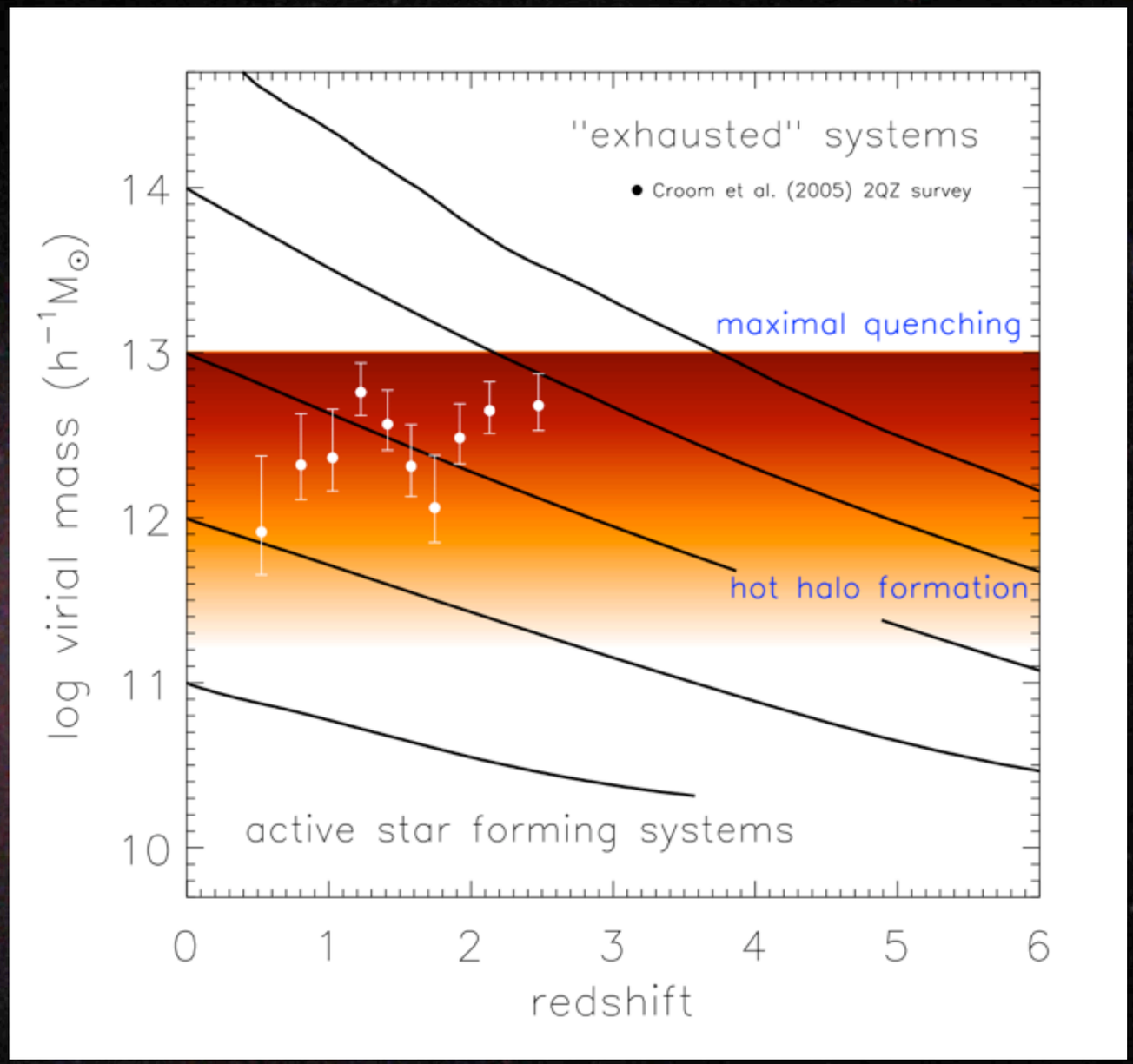
and

***“Cosmological down-sizing”***




"exhausted" systems
Croom et al. (2005) 2QZ survey
maximal quenching
hot halo formation
active star forming systems
log virial mass ($h^{-1}M_\odot$)
14
13
12
11
10
0
1
2
3
4
5
6
redshift

# This picture has bones but no meat




We can look for consistency with observations regarding the consequences of different quenching models,
but we still need to understand the mechanism(s) itself.