Quasar vs. Radio Mode AGN Heating and their Environment Dependence

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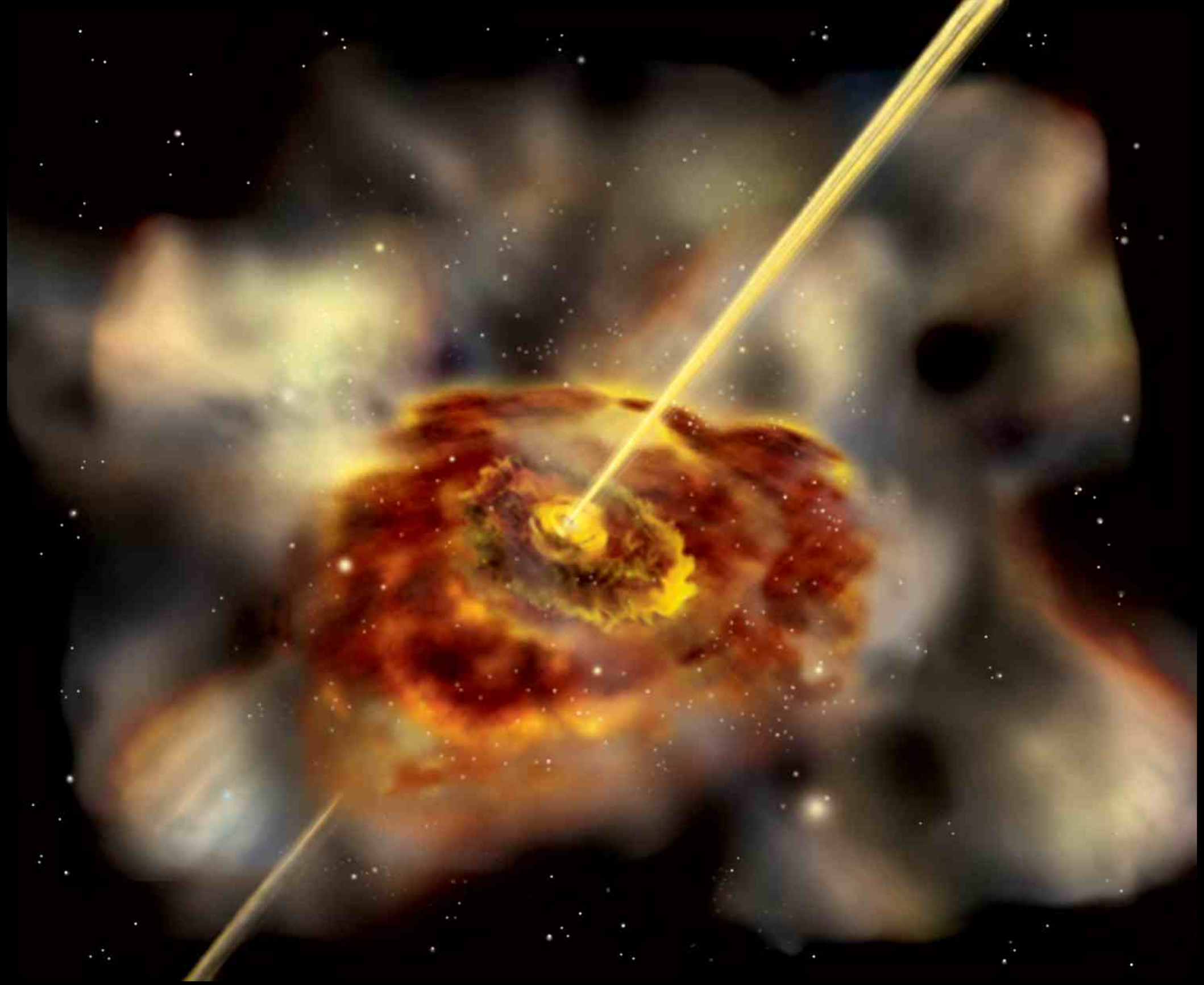
Quarryheads Ln
Potters Bank
South Rd
A177
St Mary's College
University of Durham
Elvet Hill Rd
South Rd
A177
Grey College
St Aidan's College
Durham University Oriental Museum
Trevelyan College
Hollingside Ln
Topline Secretarial & Businessservices
Teikyo University Of Japan
Mill Hill Ln
Van Mildert College
South Rd
Collingwood College
A177
Hollingside Ln



z>1: Quasar Epoch

quasar

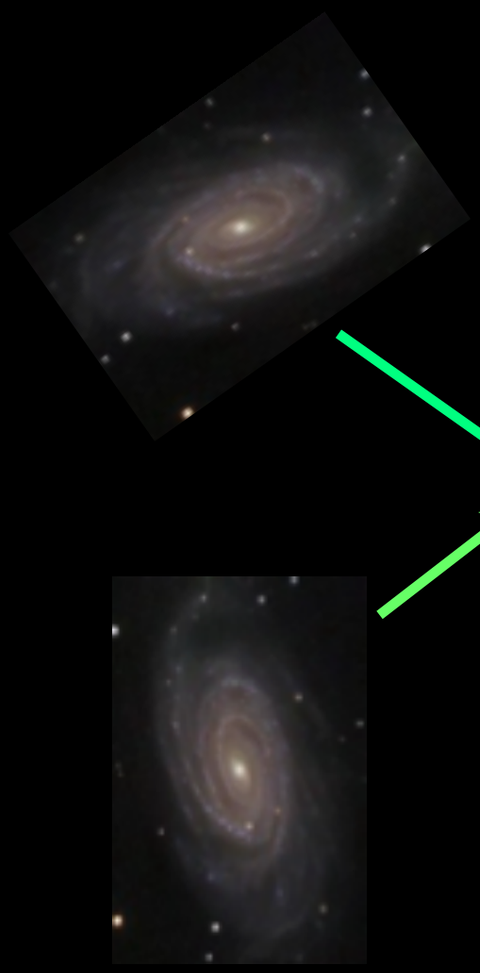
z>1: Quasar Epoch

quasar

infalling gas, hot halo build-up, cooling gas

z<1: hierarchical growth

z>1: Quasar Epoch



quasar

infalling gas, hot halo build-up

z<1: Radio Mode

	When?	Trigger?	Feeding?	Consequence?
Quasar Mode	at early times	gas rich mergers	cold gas	BH growth, sets properties of ellipticals
Radio Mode	at late times	BH & hot halo large enough?	hot gas? stellar winds?	suppresses cooling gas, shuts down SF

Croton et al. 2006

black hole accretion toy model (radio mode)

assumption: the hot gas around the black hole is static and has uniform density

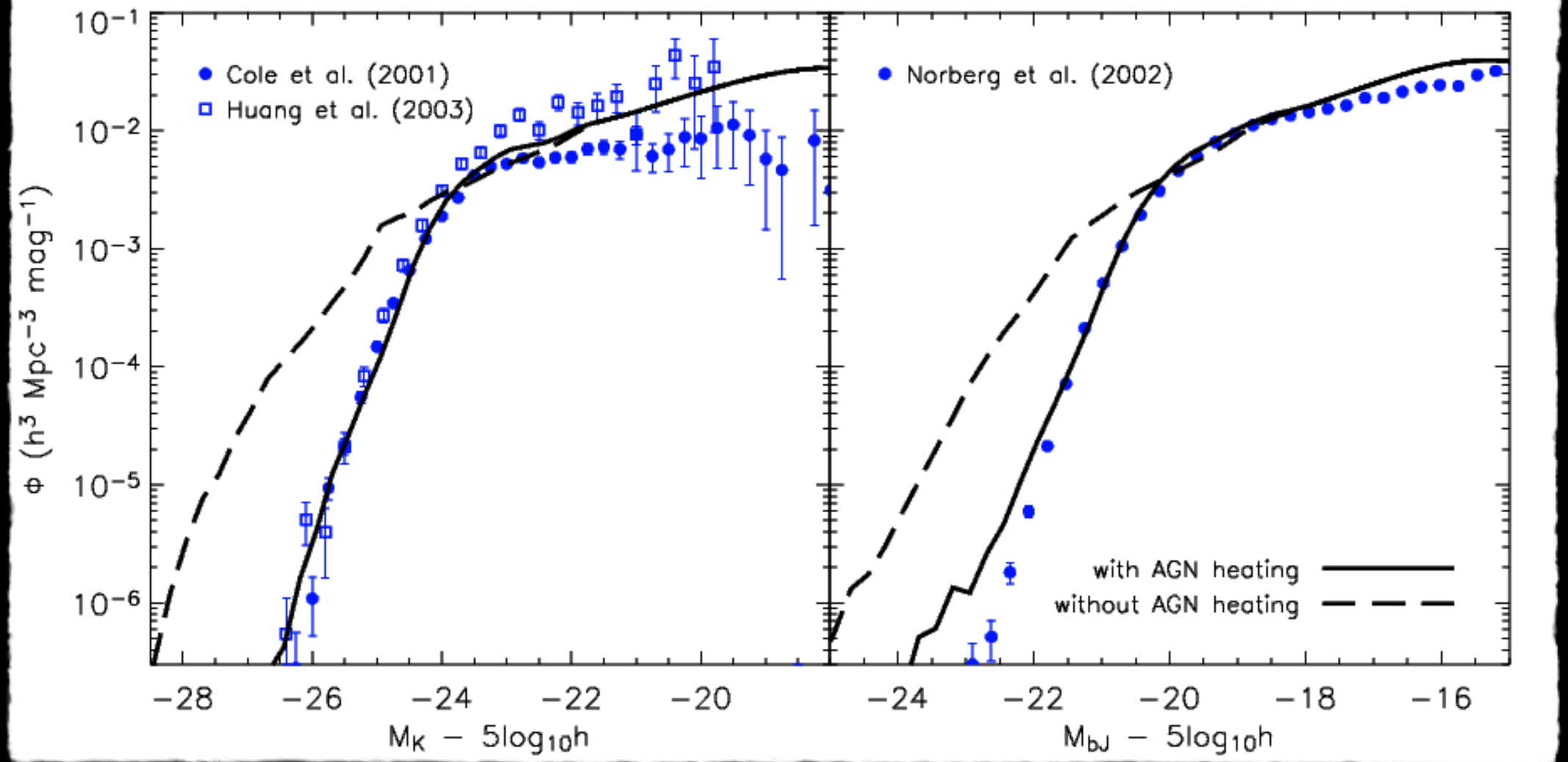
assumption: maximal cooling flow - at the Bondi radius, the gas density is determined by equating the cooling time to the free fall time

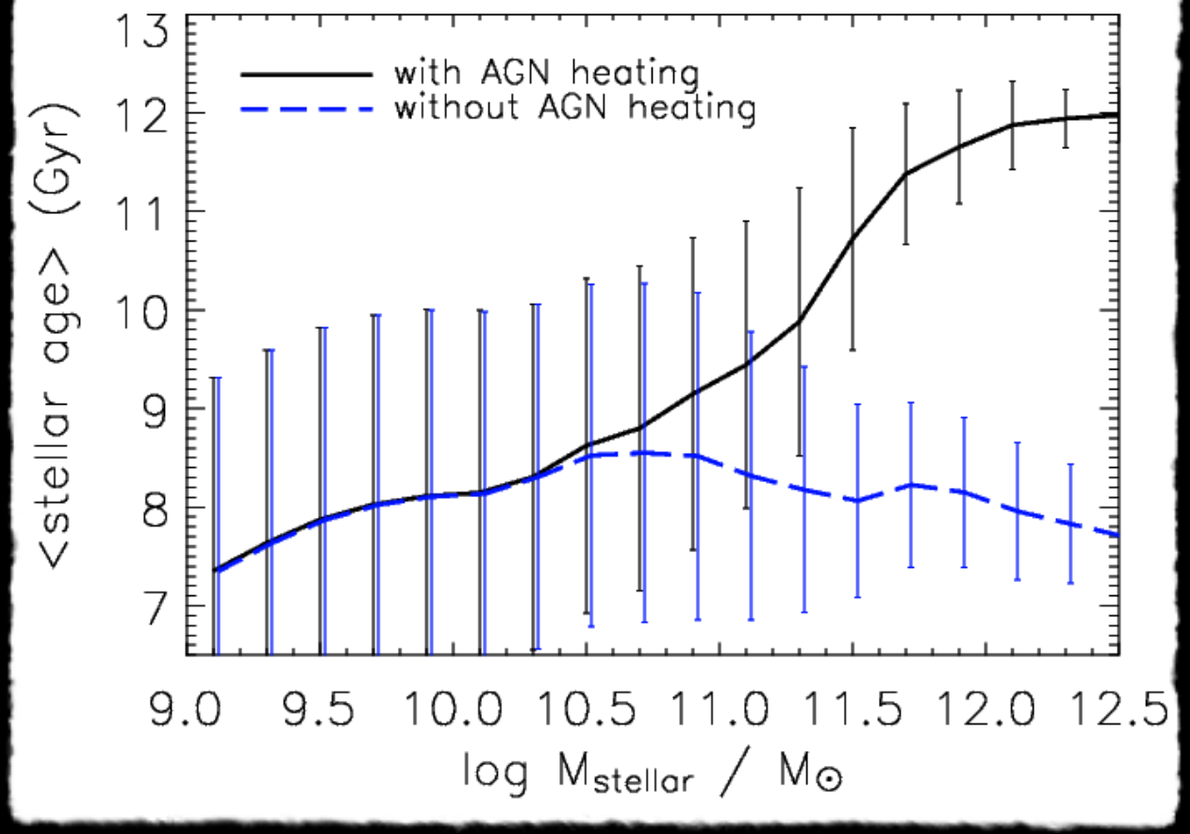
$$\dot{m}_{\rm Bondi} = 2.5\pi {\rm G}^2 \frac{m_{\rm BH}^2 \rho_0}{c_{\rm s}^3}$$

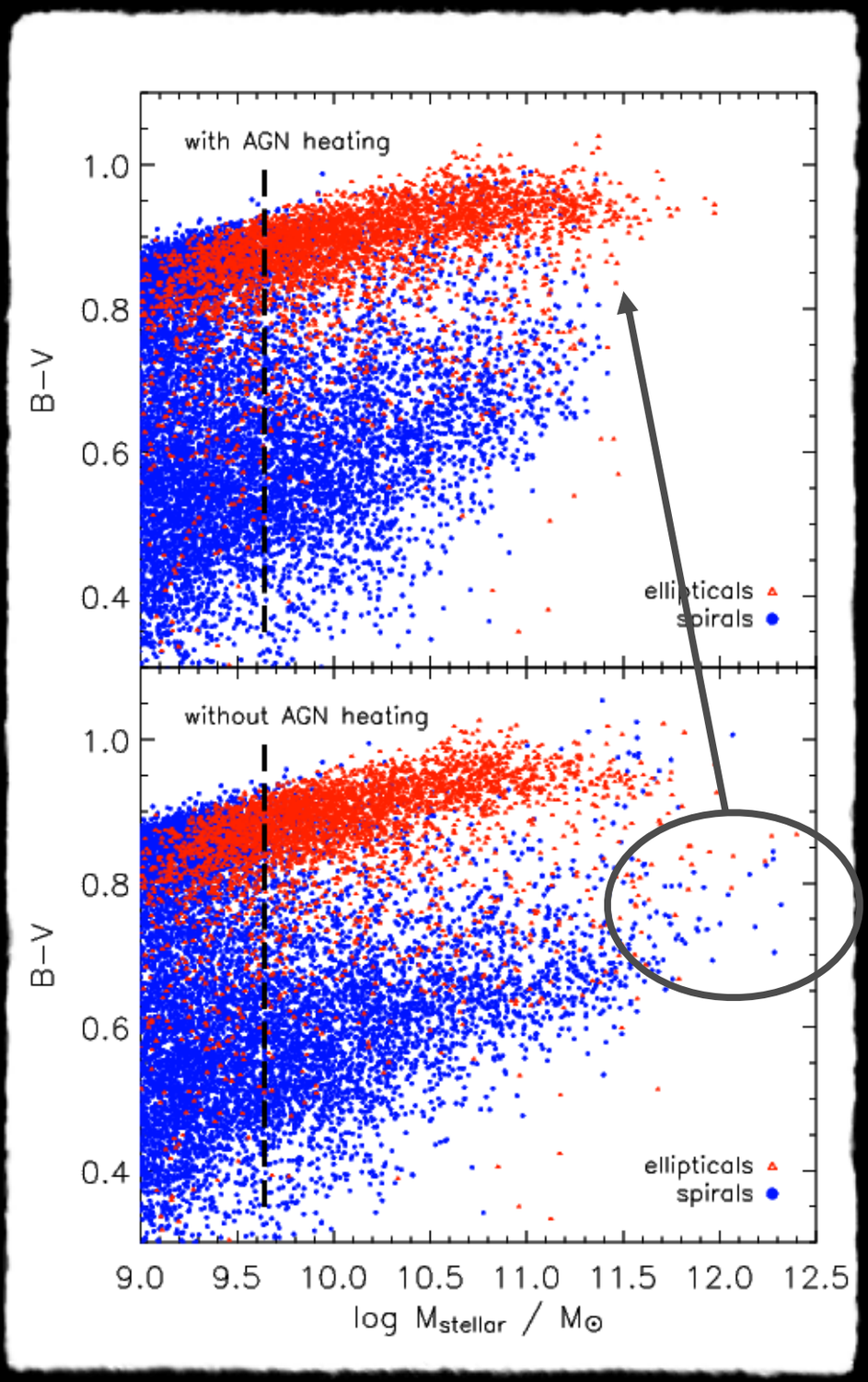
$$\frac{2r_{\rm Bondi}}{c_{\rm s}} \approx \frac{4{\rm G}m_{\rm BH}}{V_{\rm vir}^3} = \frac{3}{2}\frac{\bar{\mu} m_{\rm p} kT}{\rho_{\rm g}(r_{\rm Bondi})\Lambda(T, Z)}$$

$$\rho_0 = \rho_{\rm g}(r_{\rm Bondi}) = \frac{3\mu m_{\rm p}}{8{\rm G}}\frac{kT}{\Lambda}\frac{V_{\rm vir}^3}{m_{\rm BH}}$$

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

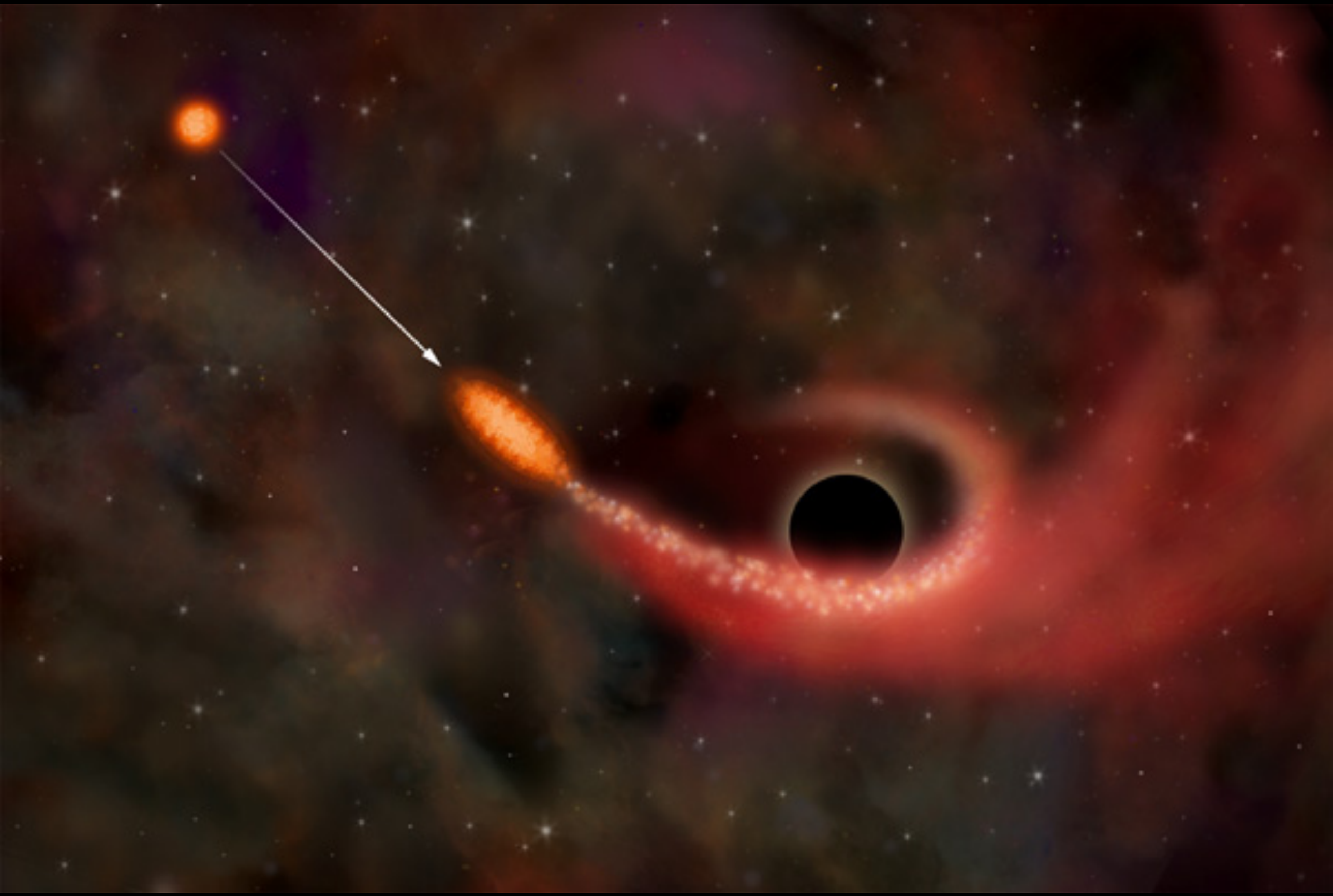

Cole et al. (2001)
Huang et al. (2003)
Norberg et al. (2002)
with AGN heating
without AGN heating
Φ (h^3 Mpc^{-3} mag^{-1})
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
−28
−26
−24
−22
−20
−24
−22
−20
−18
−16
$M_K - 5\log_{10}h$
$M_{bJ} - 5\log_{10}h$


with AGN heating
without AGN heating
<stellar age> (Gyr)
13
12
11
10
9
8
7
9.0
9.5
10.0
10.5
11.0
11.5
12.0
12.5
log Mstellar / M⊙


with AGN heating
without AGN heating
B−V
1.0
0.8
0.6
0.4
ellipticals
spirals
9.0
9.5
10.0
10.5
11.0
11.5
12.0
12.5
log Mstellar / M⊙

1. What is the primary growth mechanism for black holes (quasar mode)?

2. Can we observationally make a radio mode-quasar mode connection?



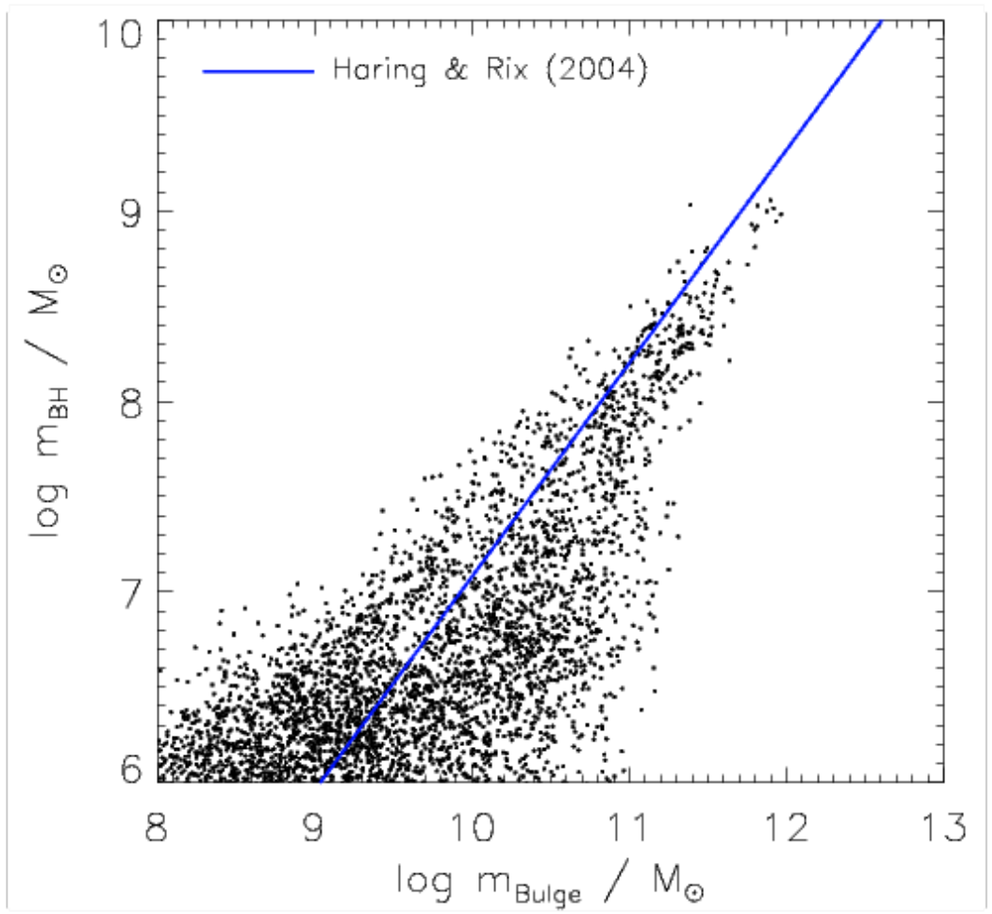
Merger driven growth

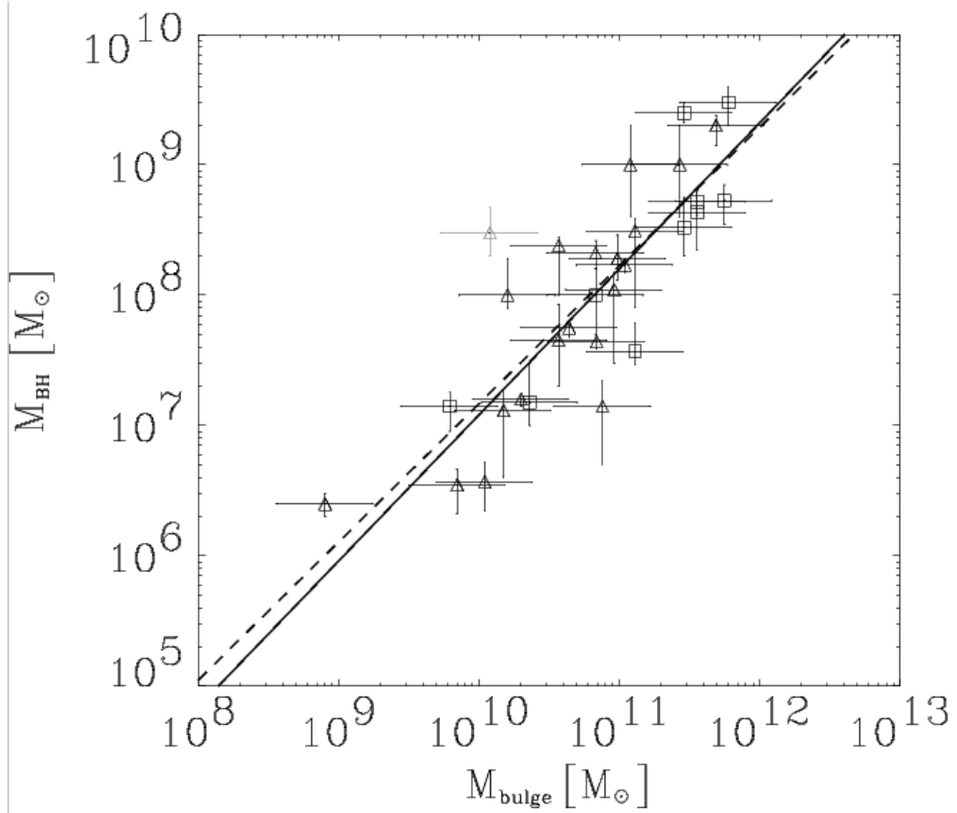
During the merger some fraction of the cold gas is driven onto the black hole

!$#"

black hole-bulge

merger driven growth



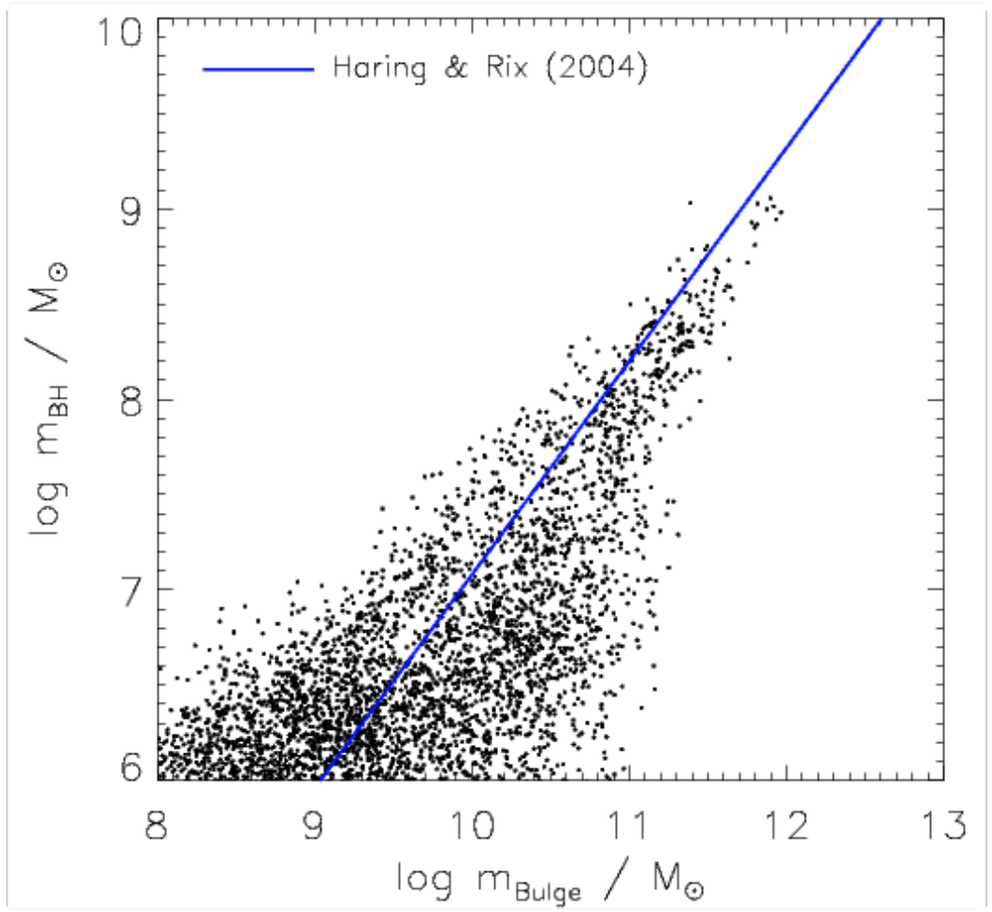


Secular driven growth

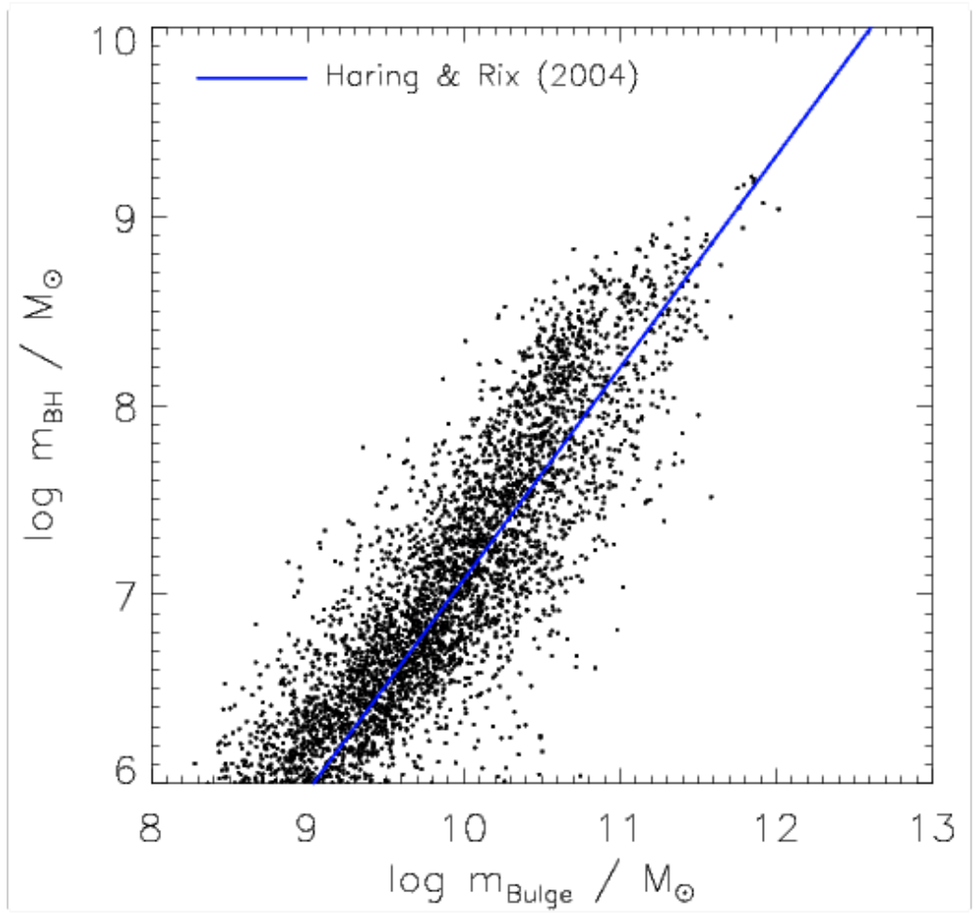
As the stellar disk becomes unstable, some fraction of the cold gas is dragged inward to accrete onto the black hole

black hole-bulge

merger driven growth

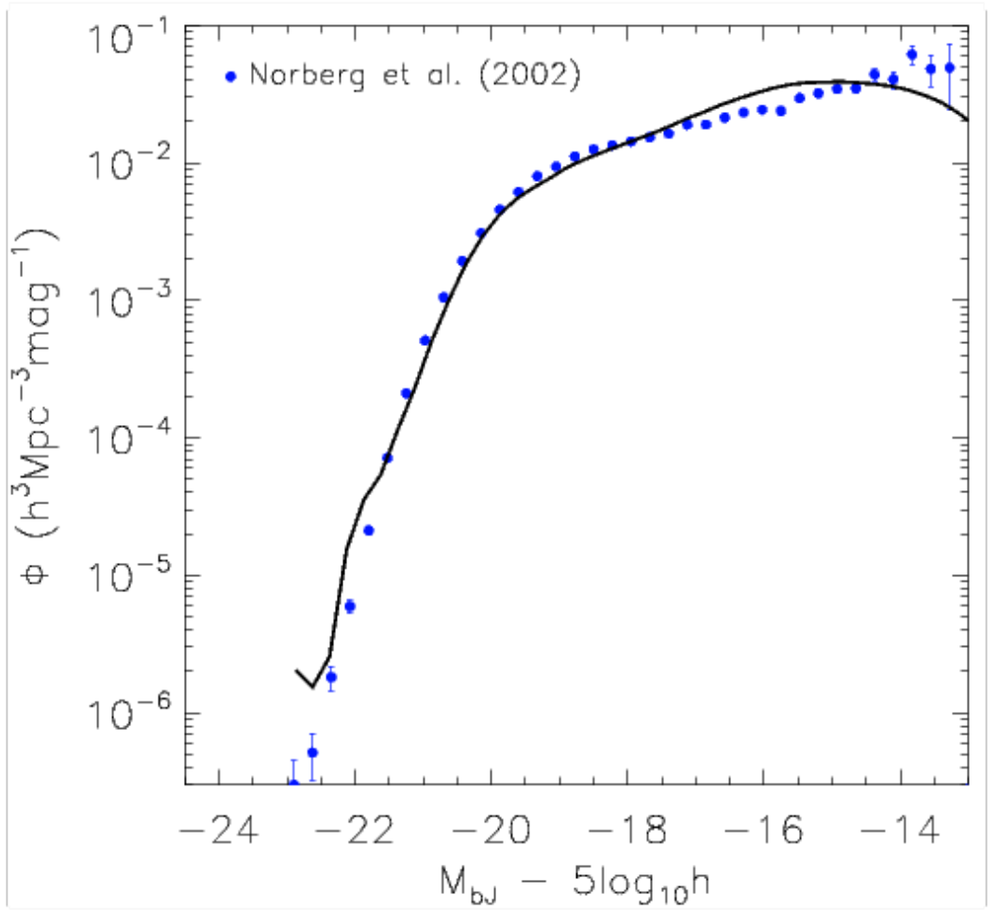


disk instability
driven growth

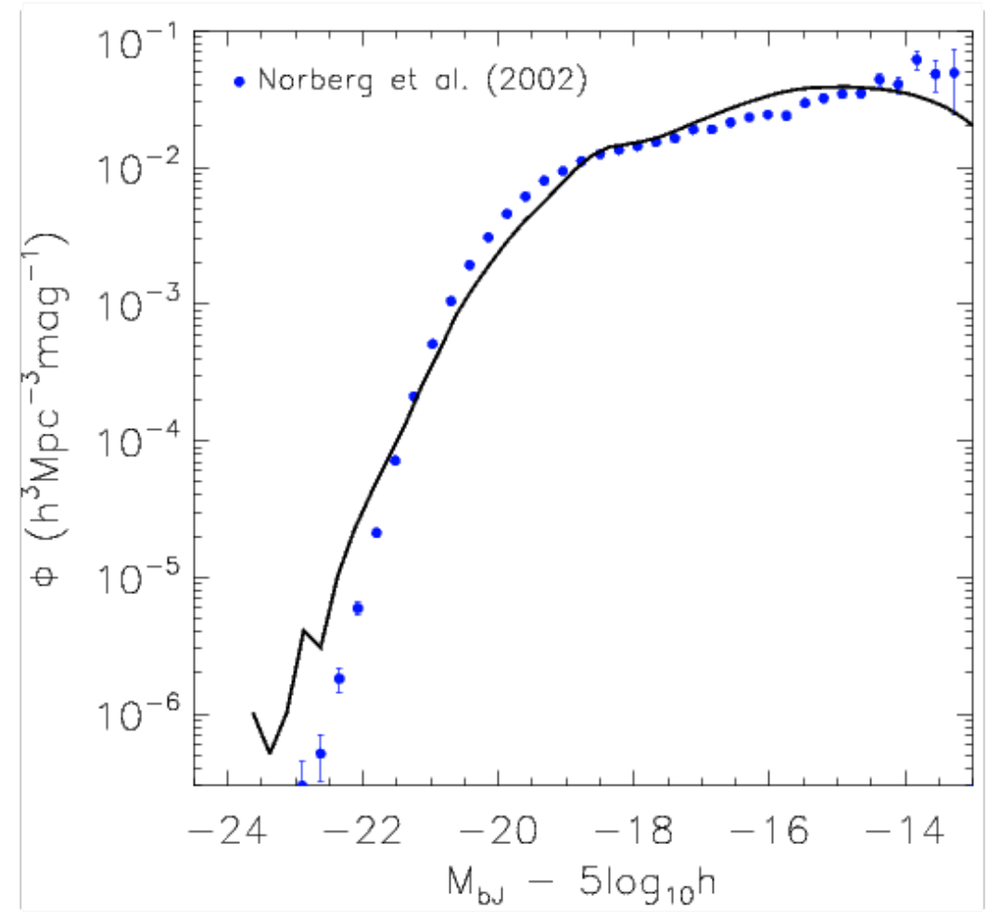


luminosity function

merger driven growth

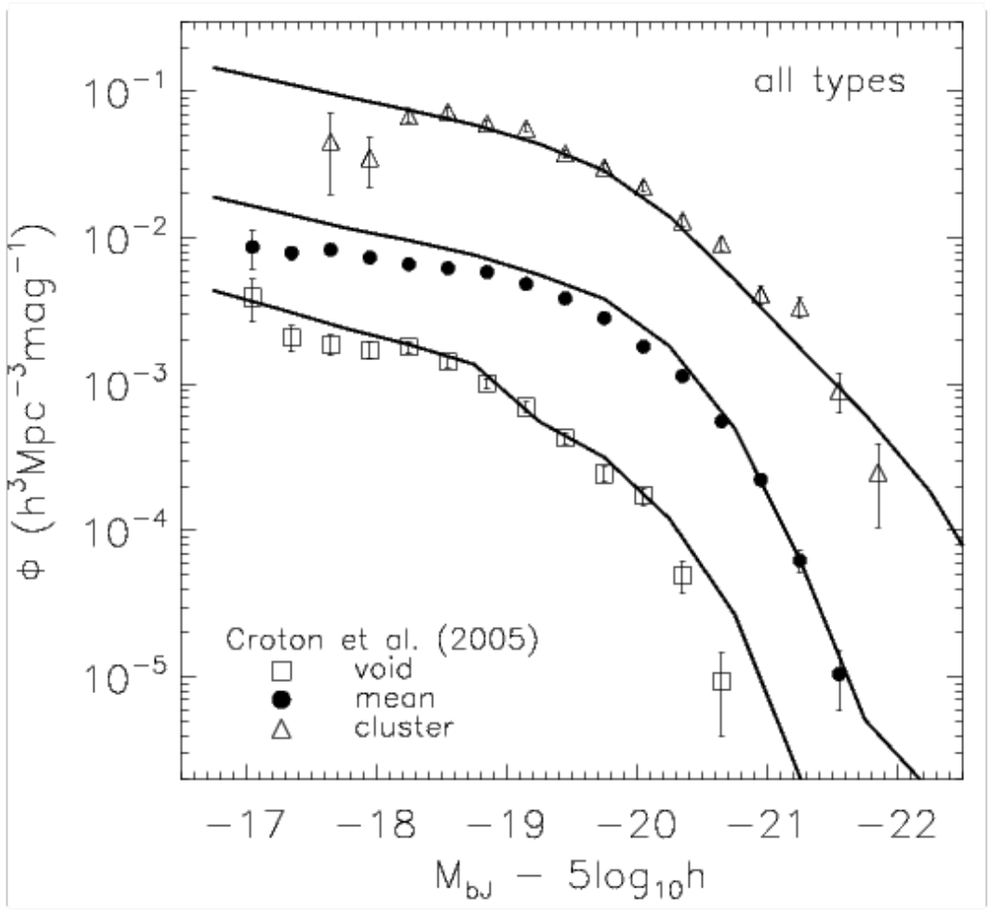


disk instability
driven growth

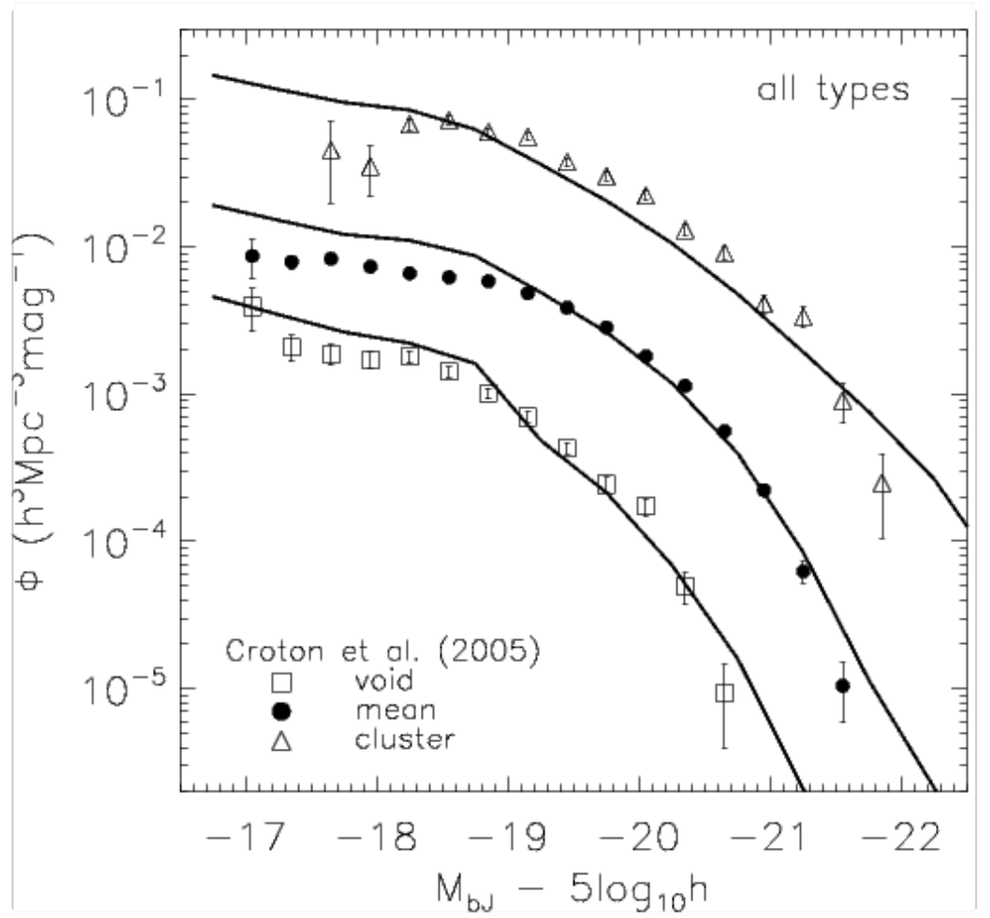


environment LFs

merger driven growth

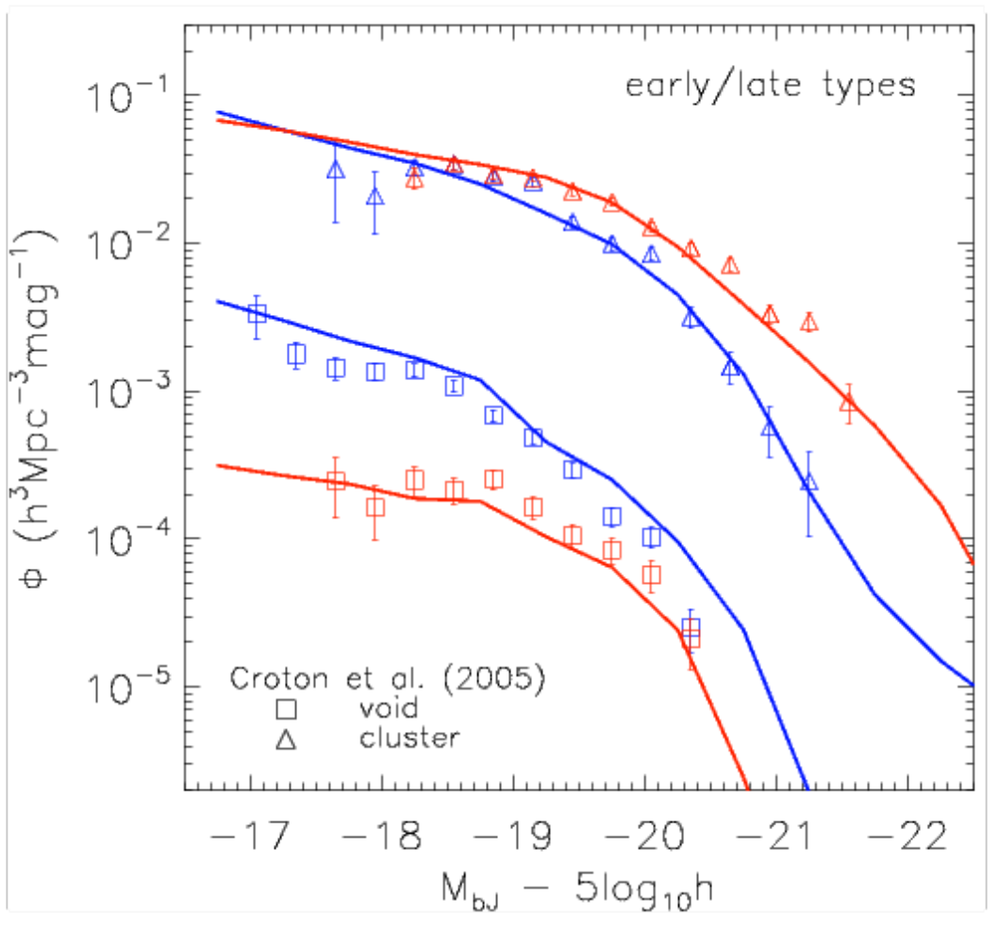


disk instability
driven growth

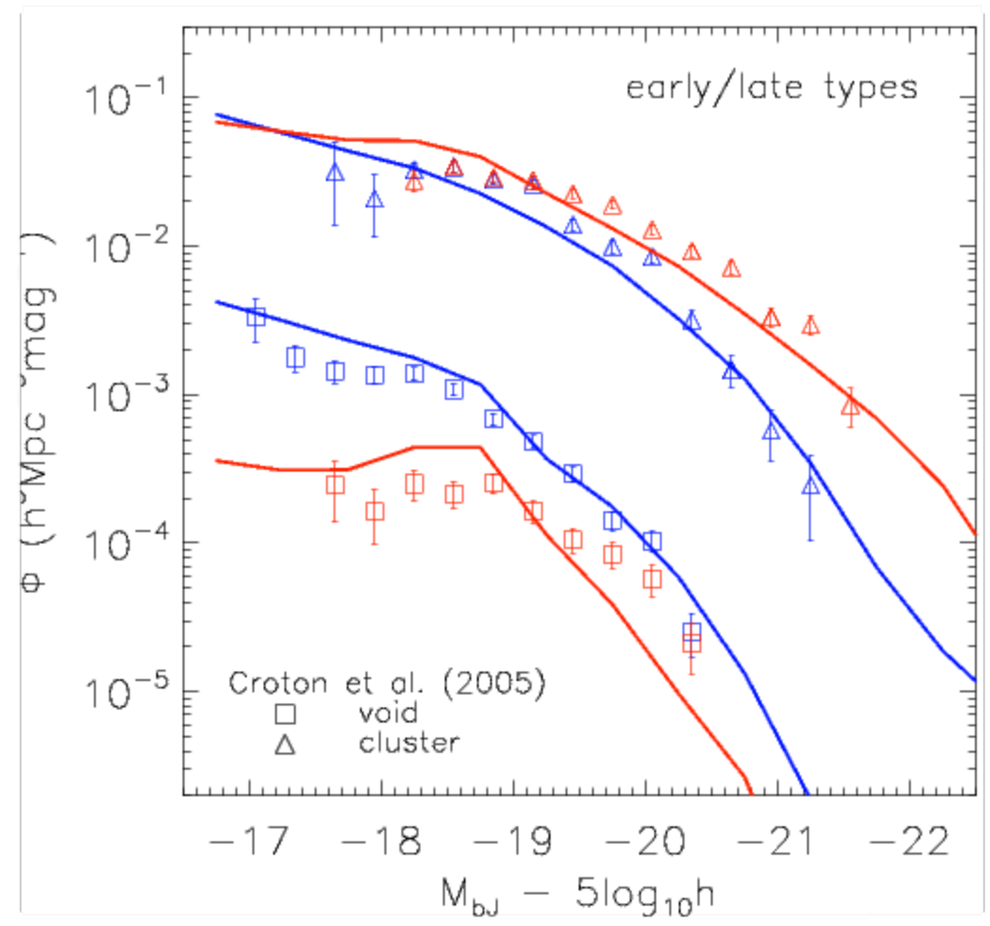


environment LFs - colour

merger driven growth

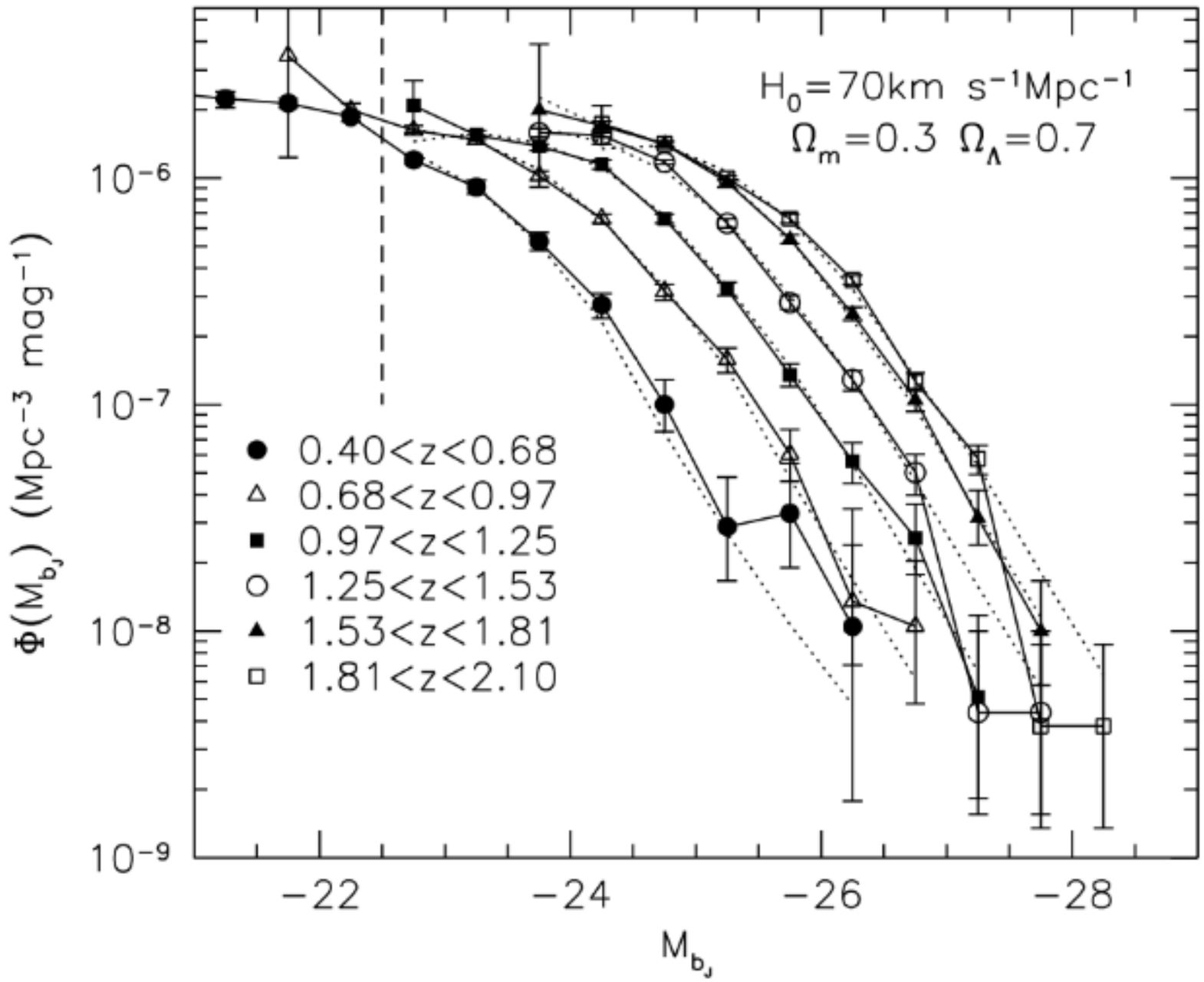


disk instability
driven growth

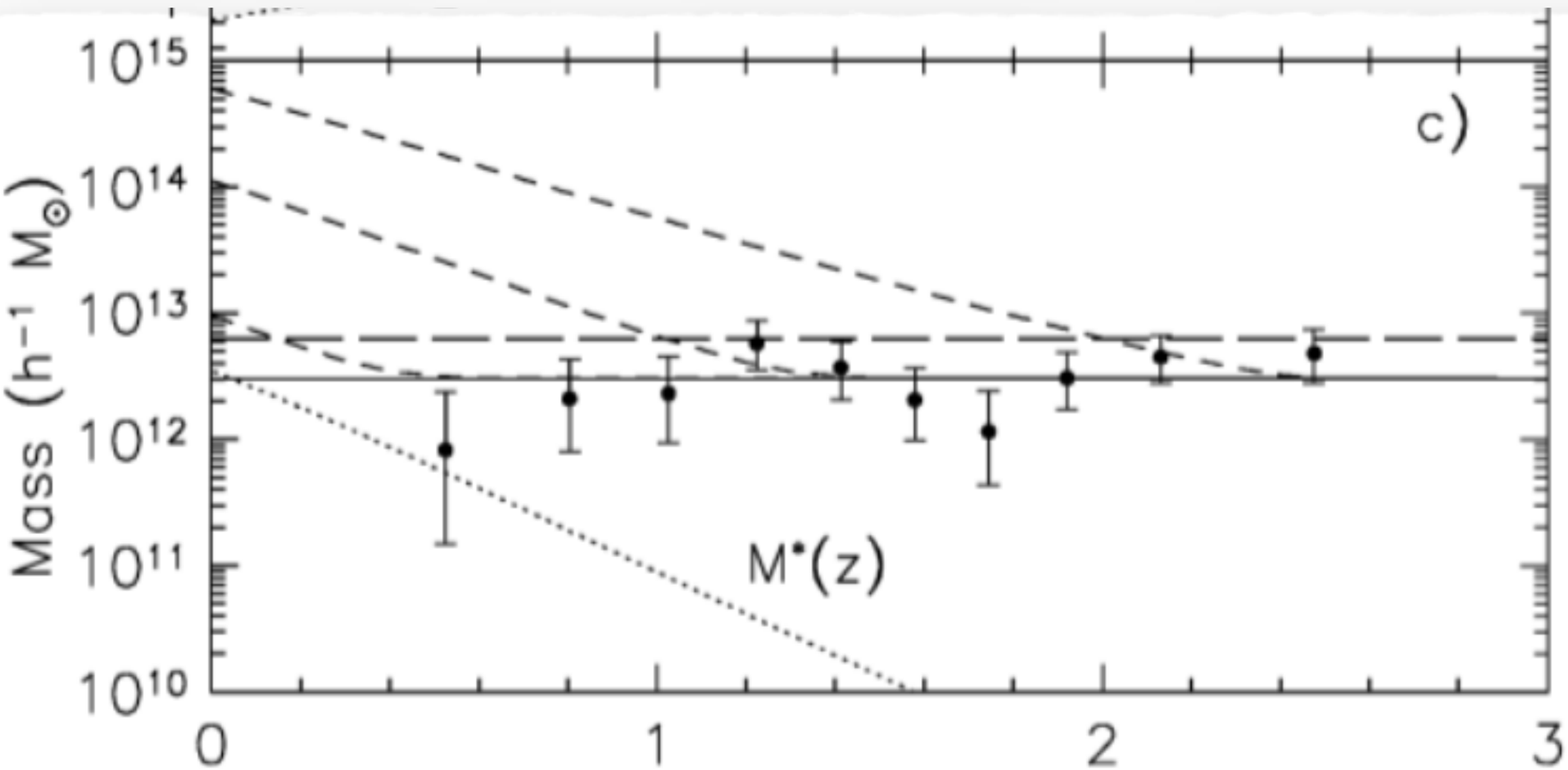


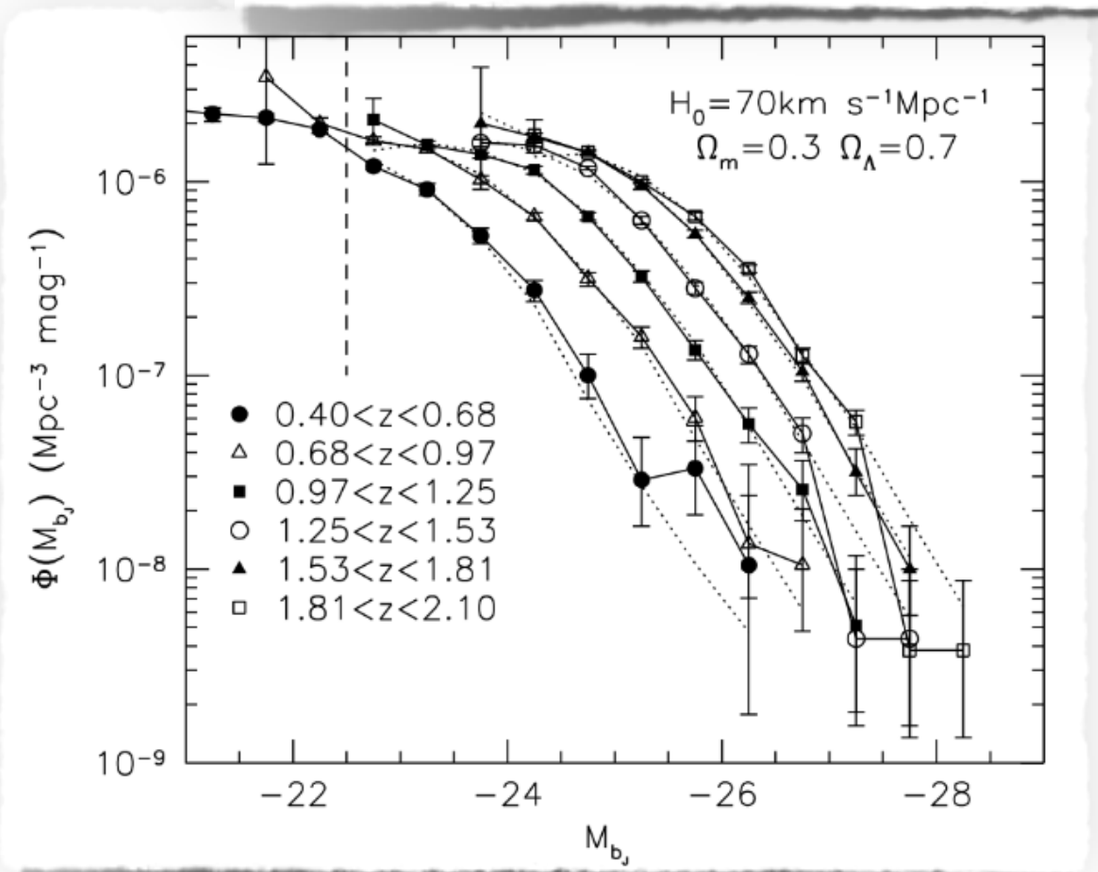
Simple secular vs merger models of black hole growth do not show any obvious observational signatures to differentiate them

(BH-bulge, LFs, environment)



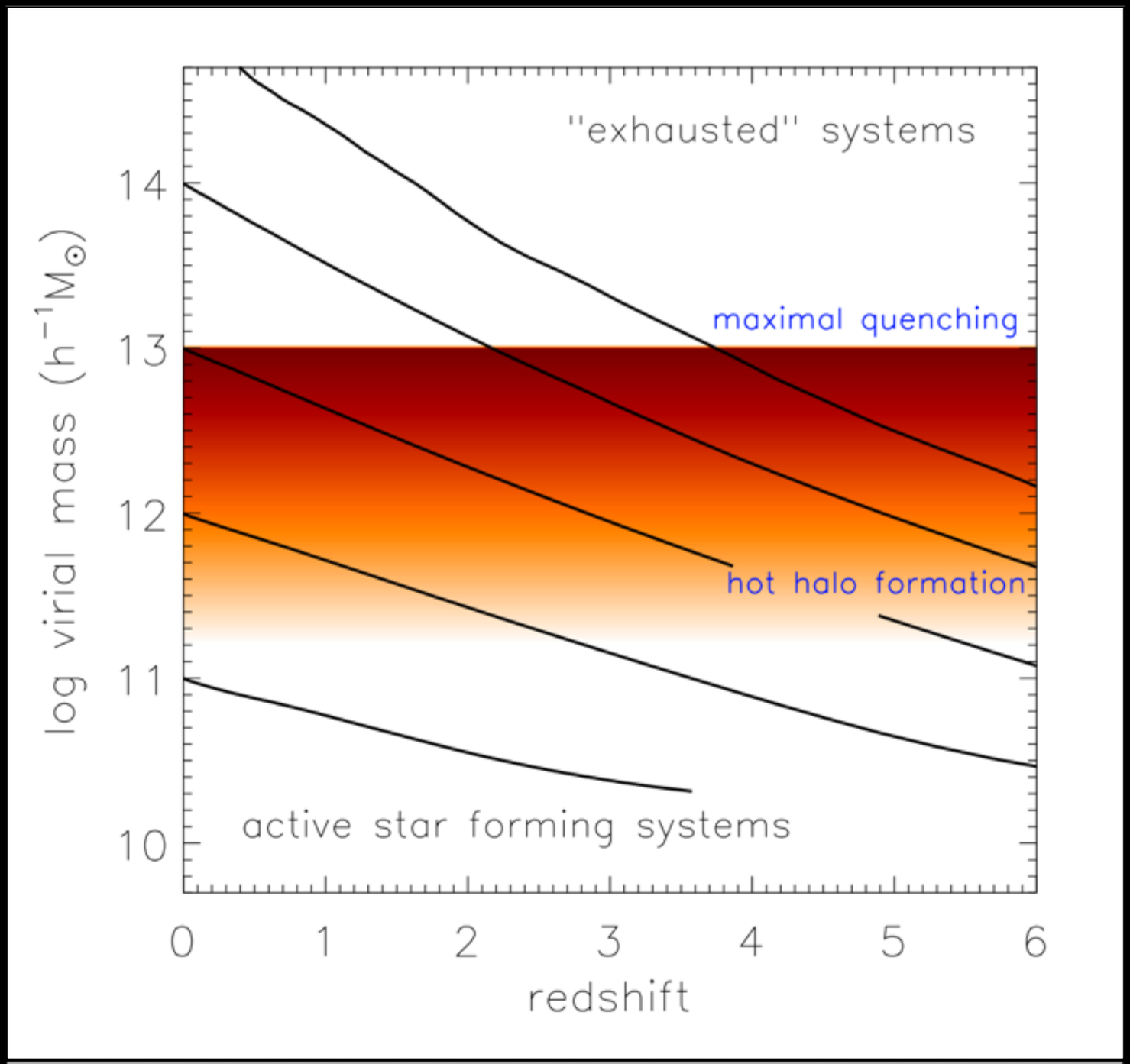
Croom et al. 2004

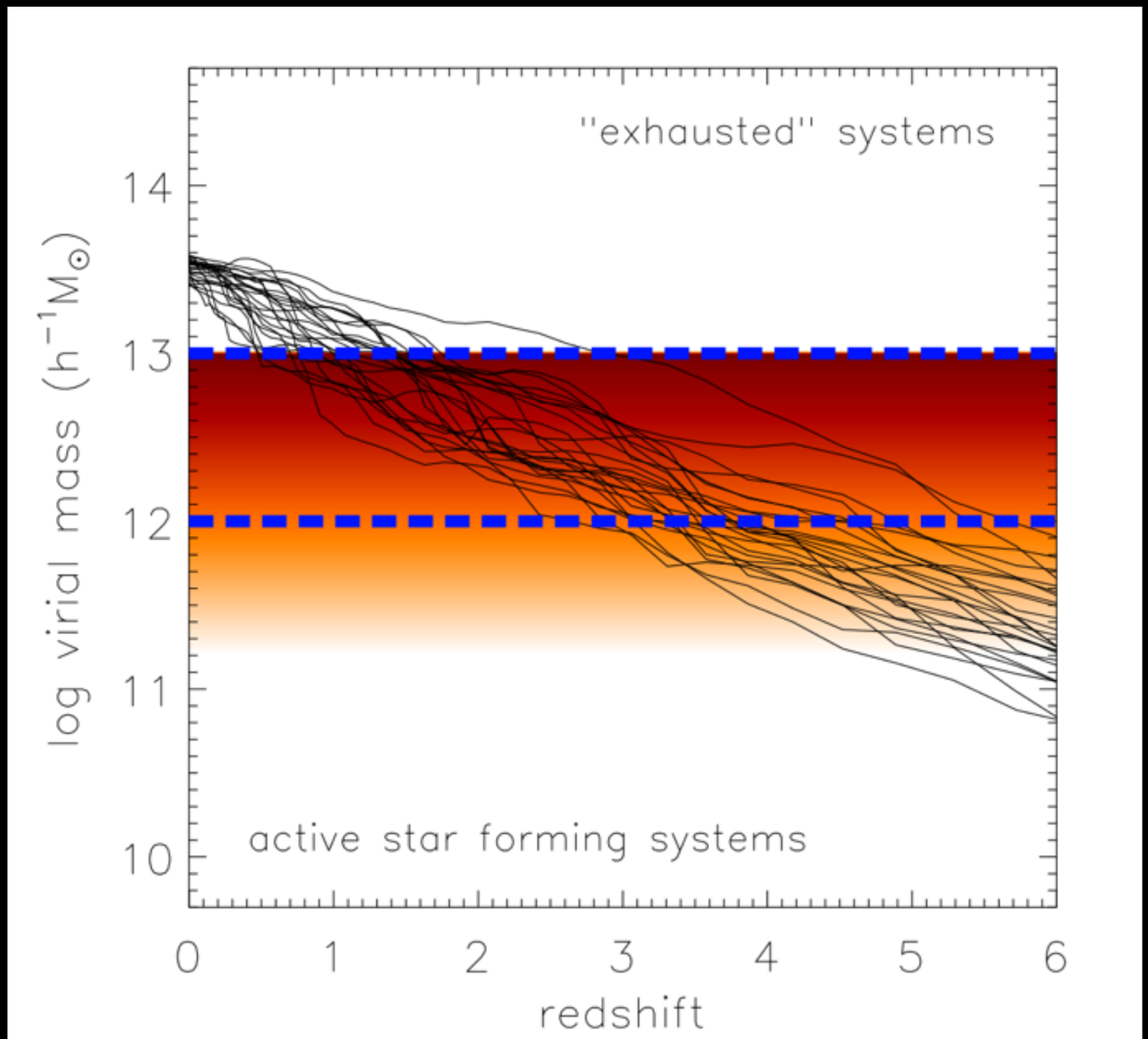




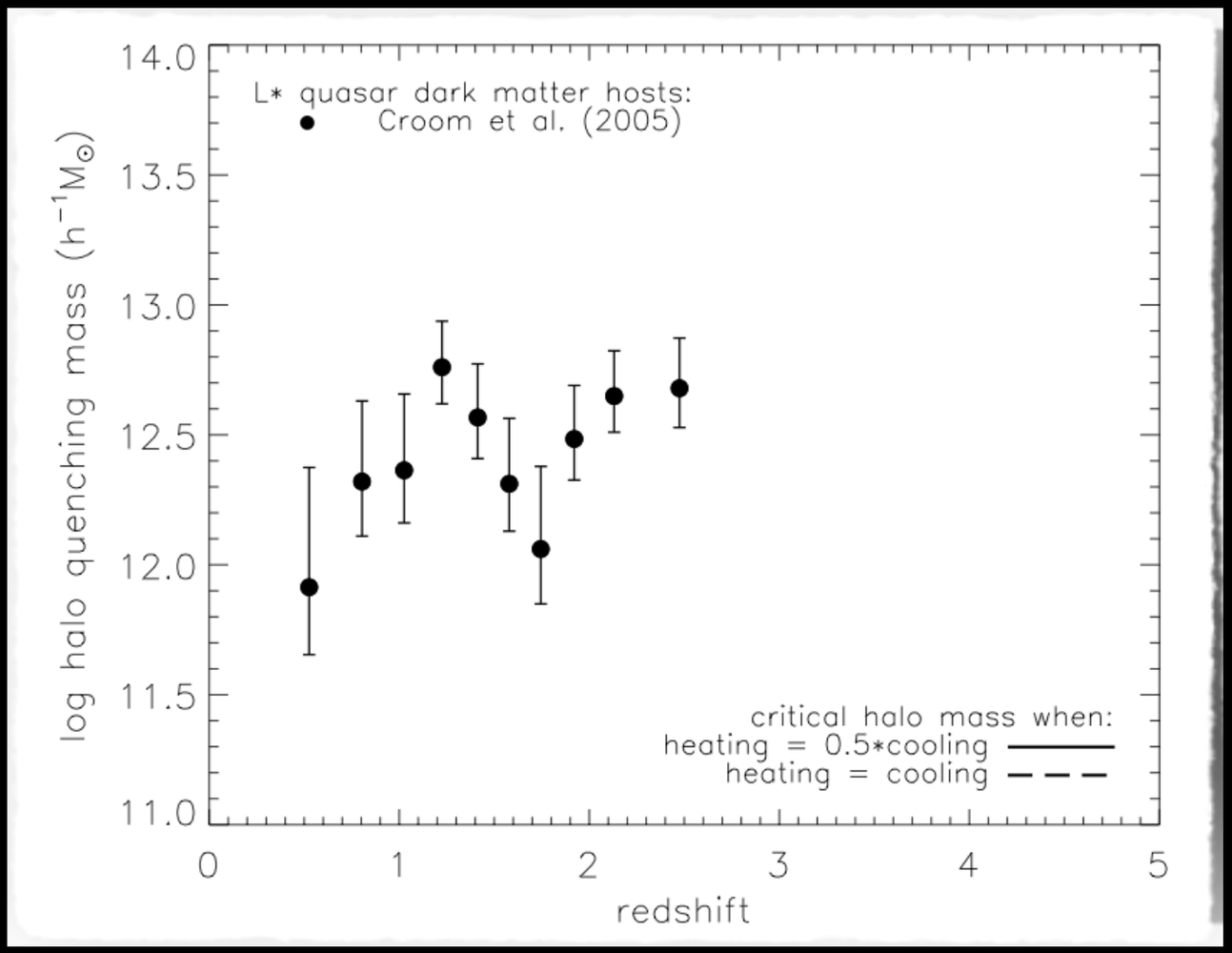
Croom et al. 2005

Croom et al. 2004


"exhausted" systems
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

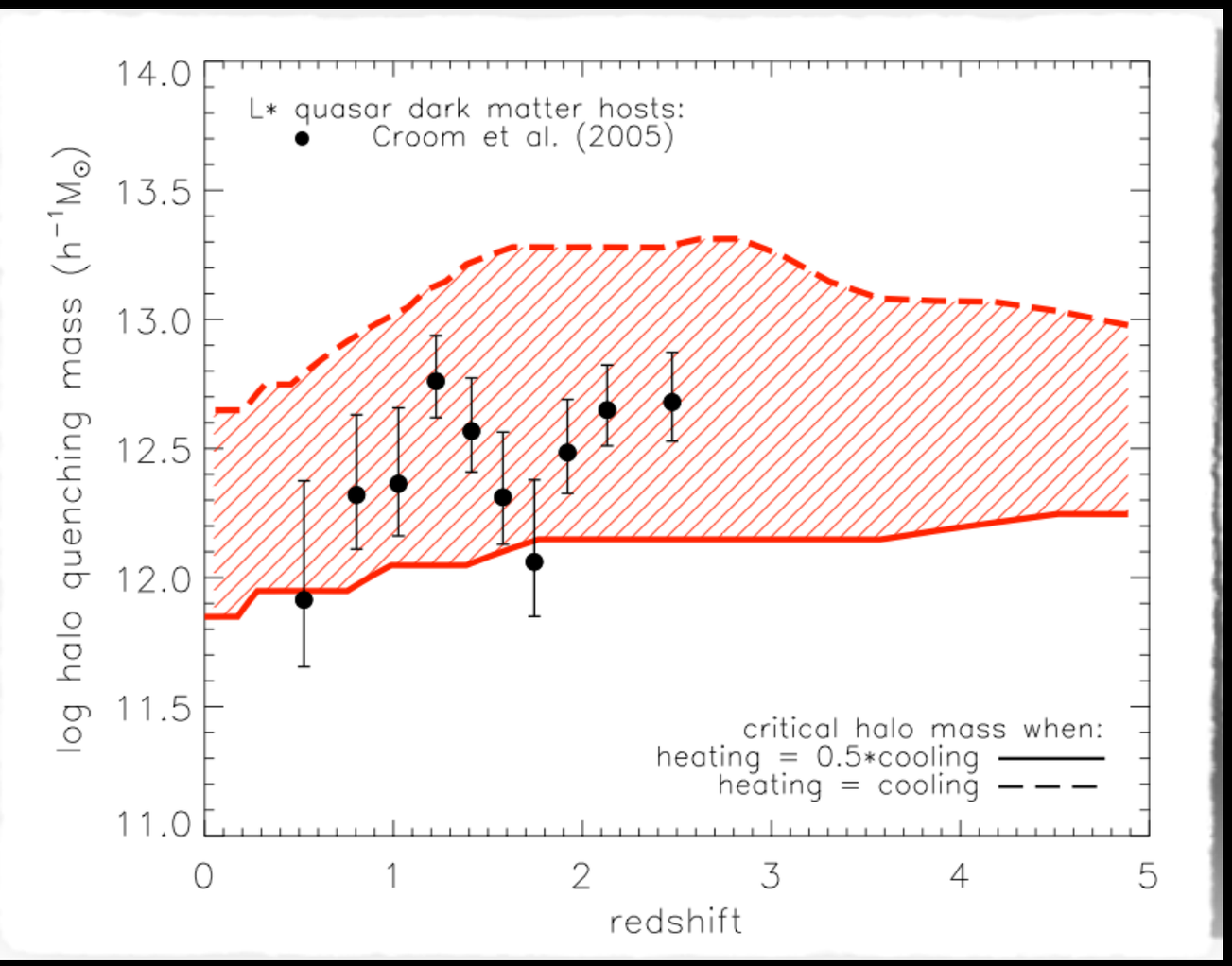

"exhausted" systems
active star forming systems
log virial mass ($h^{-1}M_\odot$)
14
13
12
11
10
0
1
2
3
4
5
6
redshift

The last stand of the quasars ...

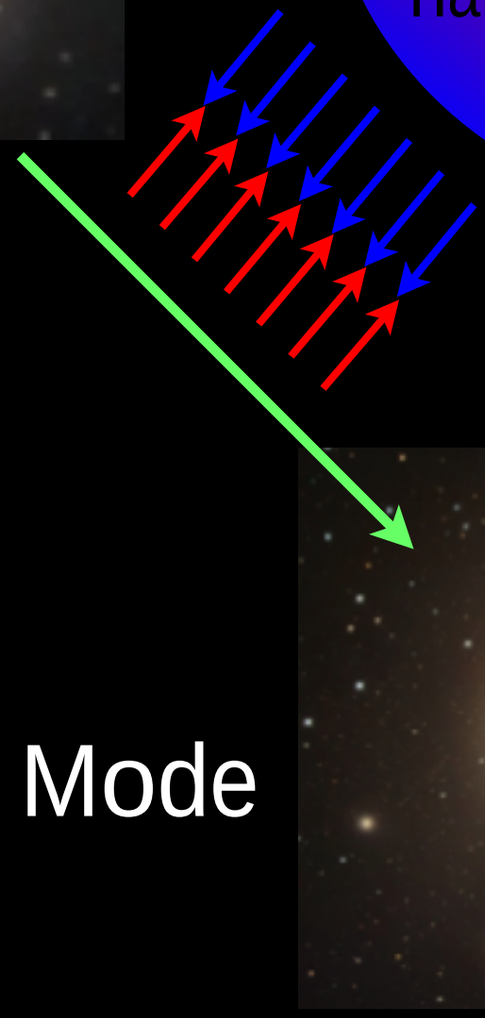


infalling gas, hot halo build-up

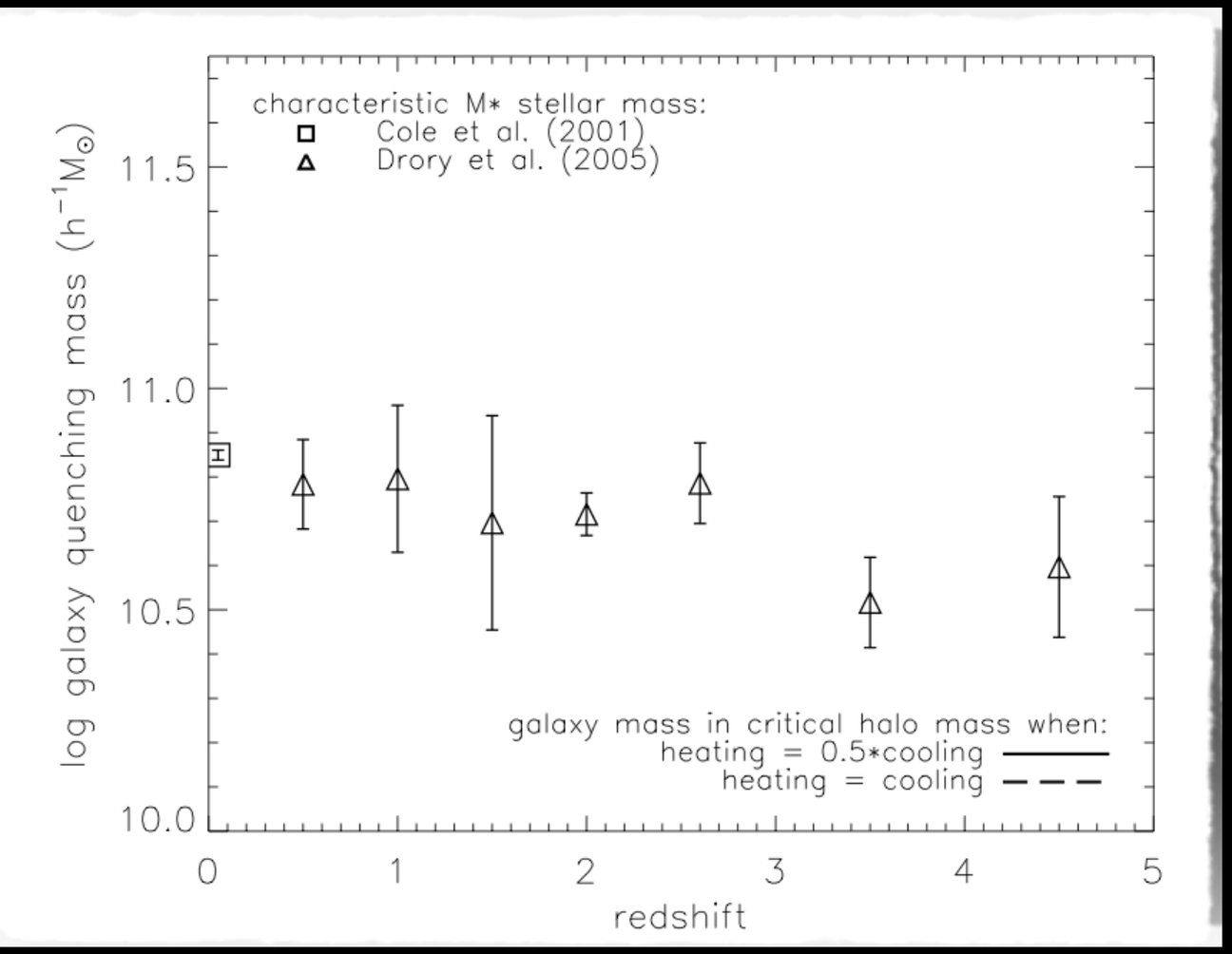
z<1: Radio Mode



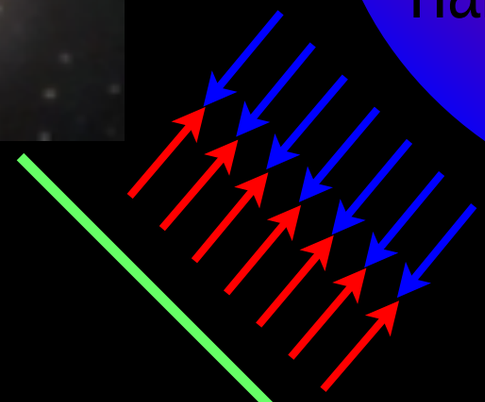
infalling gas, hot halo build-up



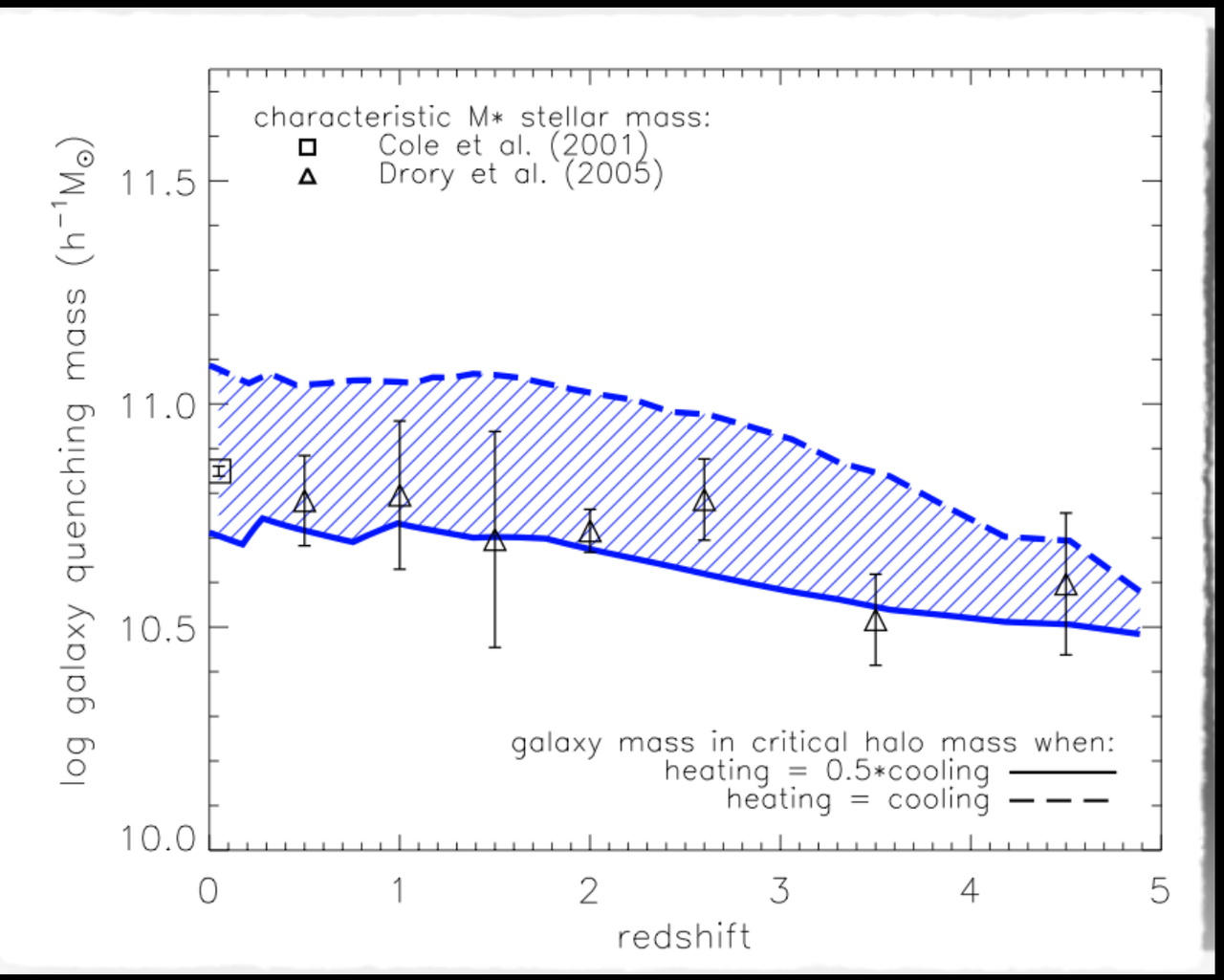
z<1: Radio Mode



infalling gas, hot halo build-up



z<1: Radio Mode



infalling gas, hot halo build-up

z<1: Radio Mode

L* quasars track the halo quenching mass and can be observed out to high redshift.

They should mark the transition from quasar to radio mode.

So what does all this mean ...

1. Toy models are a valuable tool to explore plausible AGN scenarios

2. It's hard to distinguish merger vs. secular driven black hole growth

3. The current "radio mode" models naturally predict the masses of L* quasar hosts