PART II

The Parameters of Galaxy Formation

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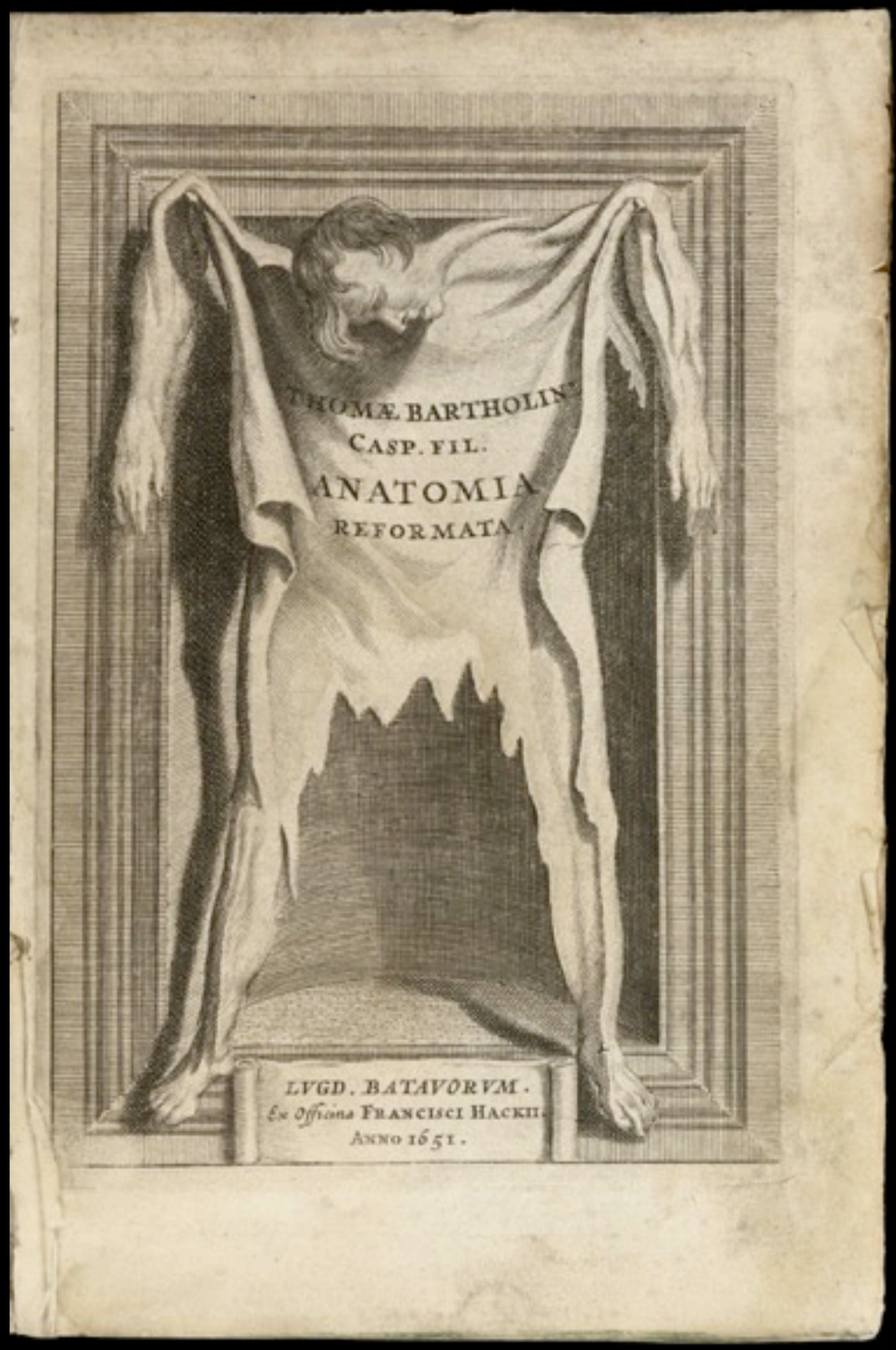
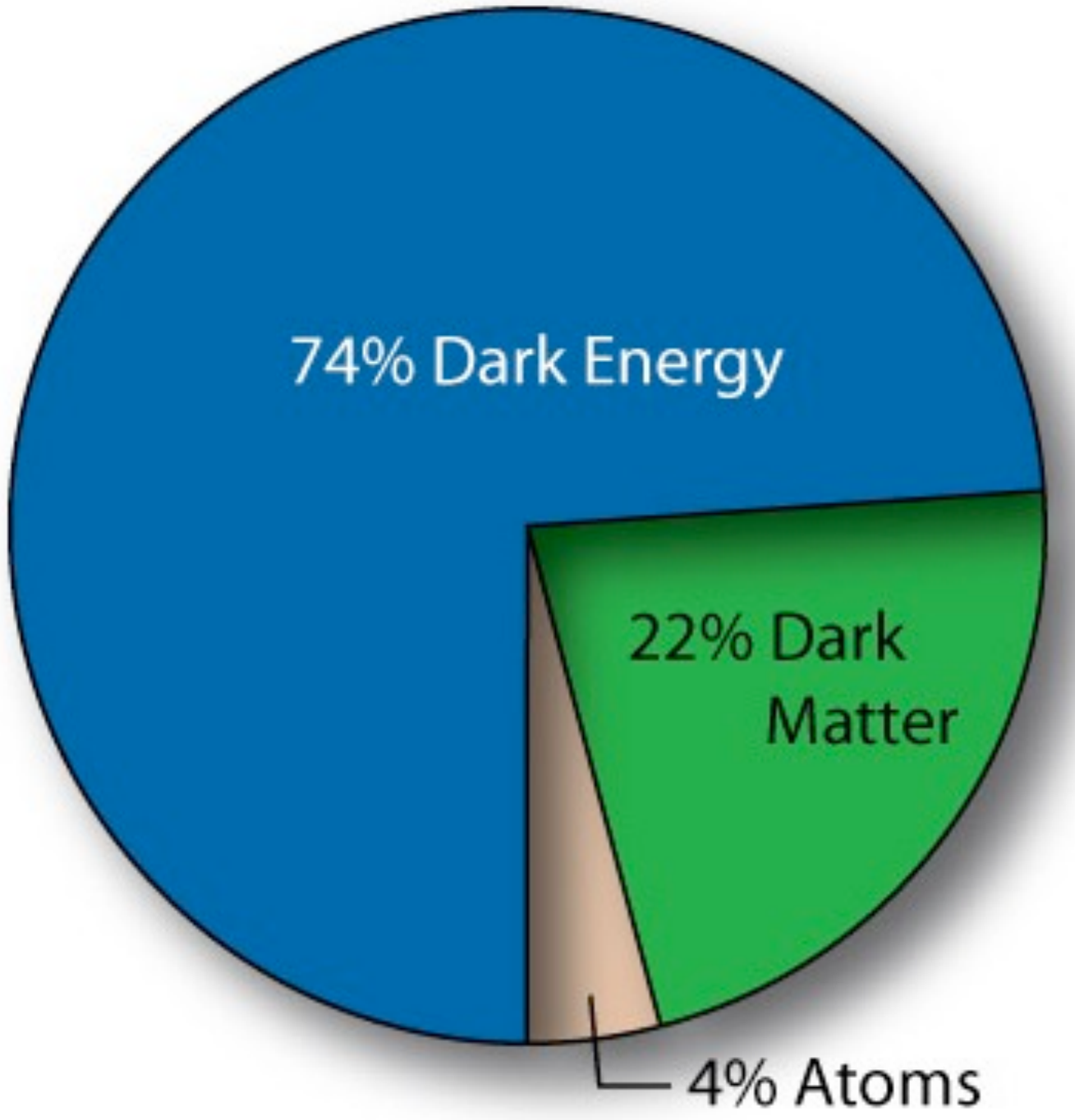
Let's recap...

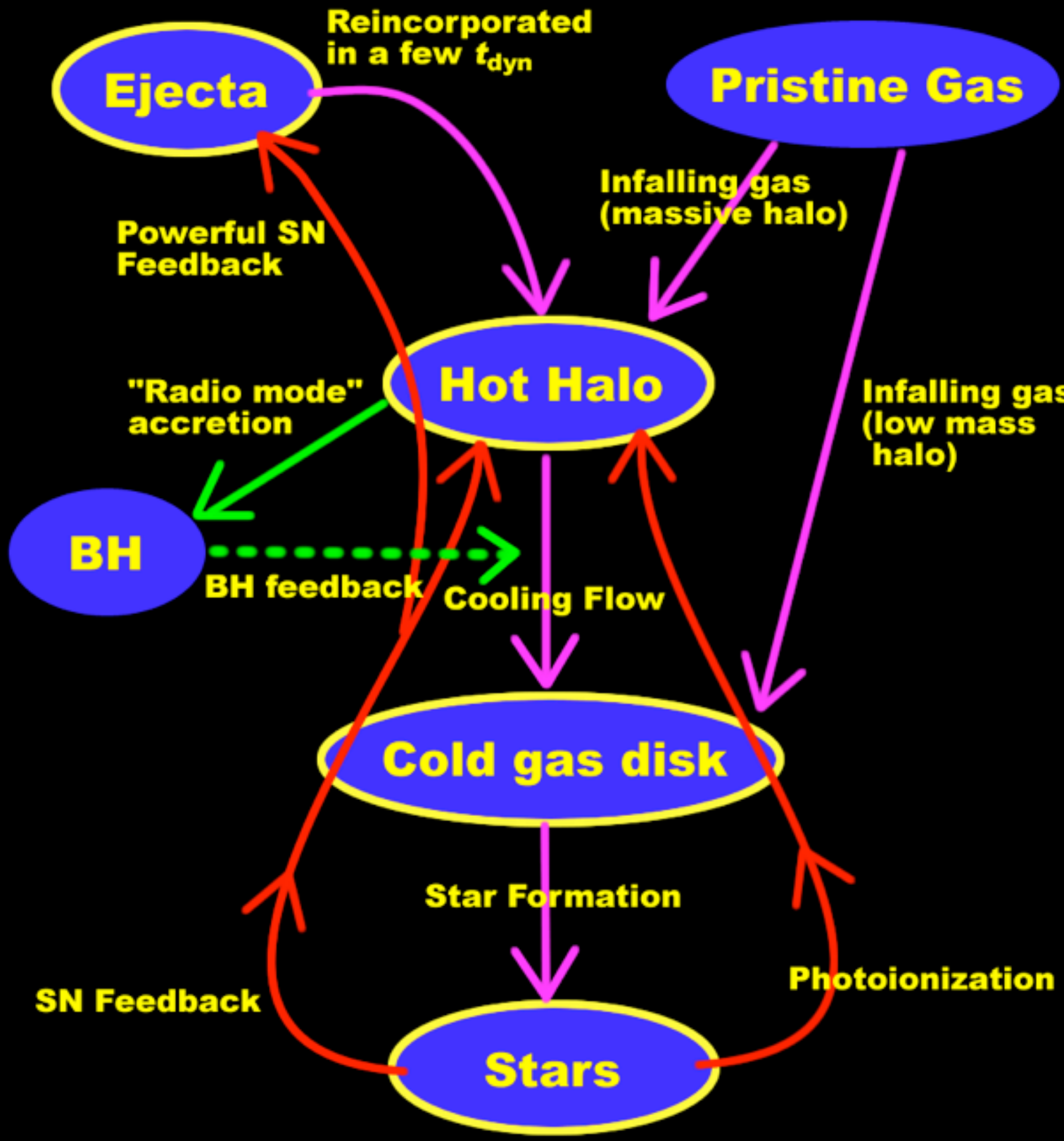
The skeleton



The flesh


Gordon


74% Dark Energy
22% Dark Matter
4% Atoms



- Schmidt law star formation
- SFR dependent SN winds
- satellite gas stripping
- morphological transformation
- assembly through mergers
- starbursts through mergers
- Magorrian relation BH growth
- jet & bubble AGN feedback

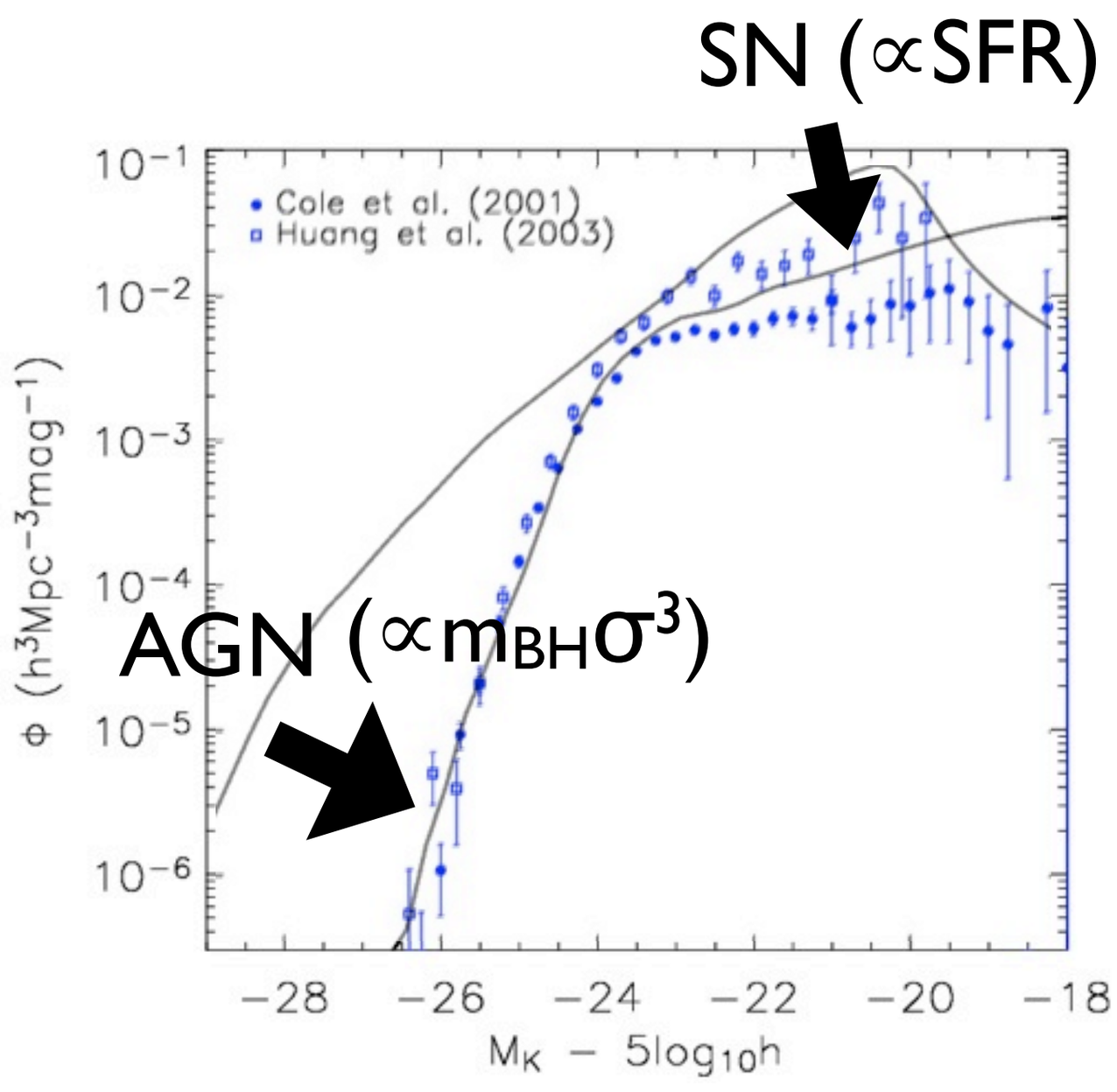
Croton et al. 2006

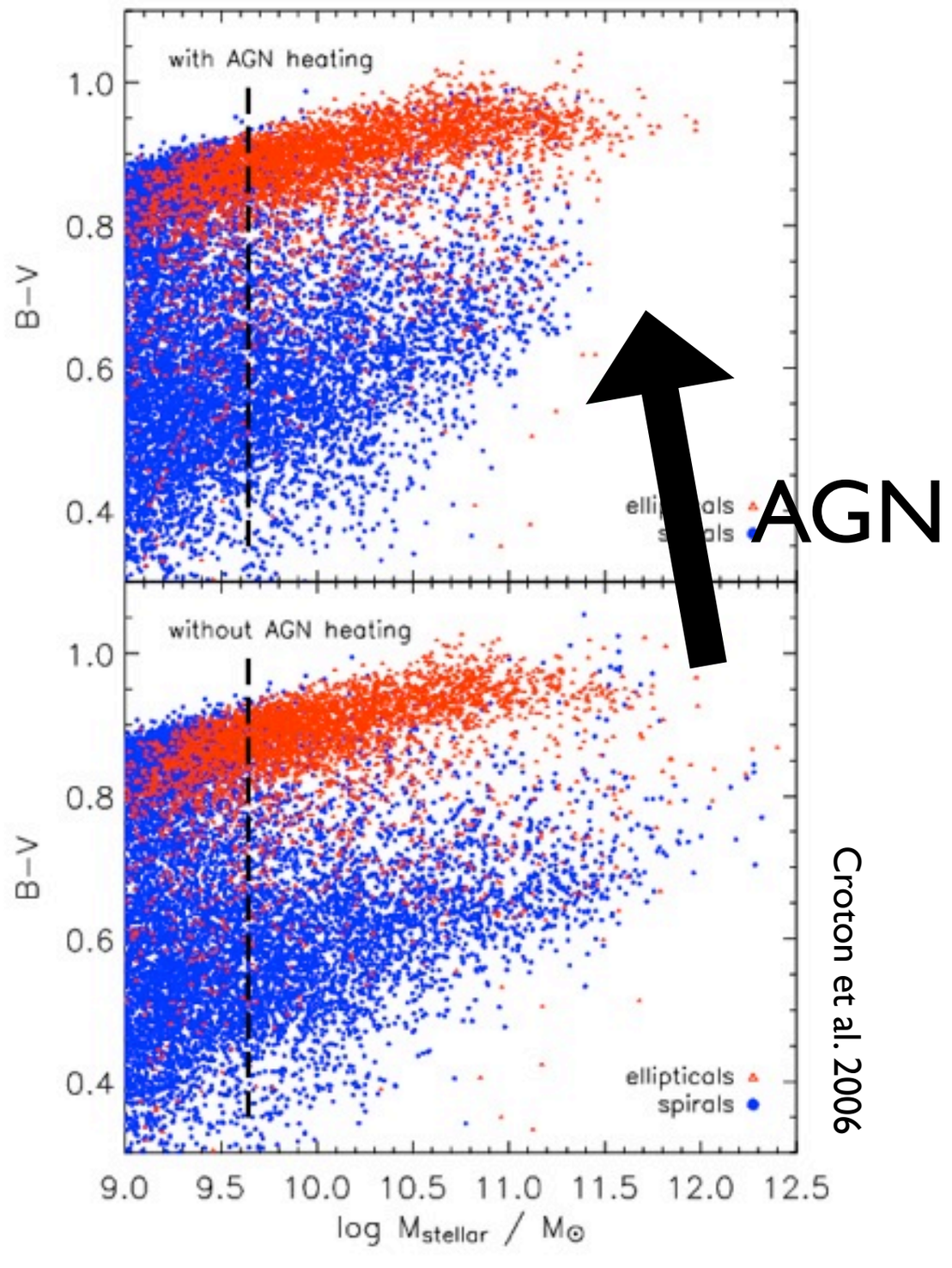
z=0 dark matter

125 Mpc/h

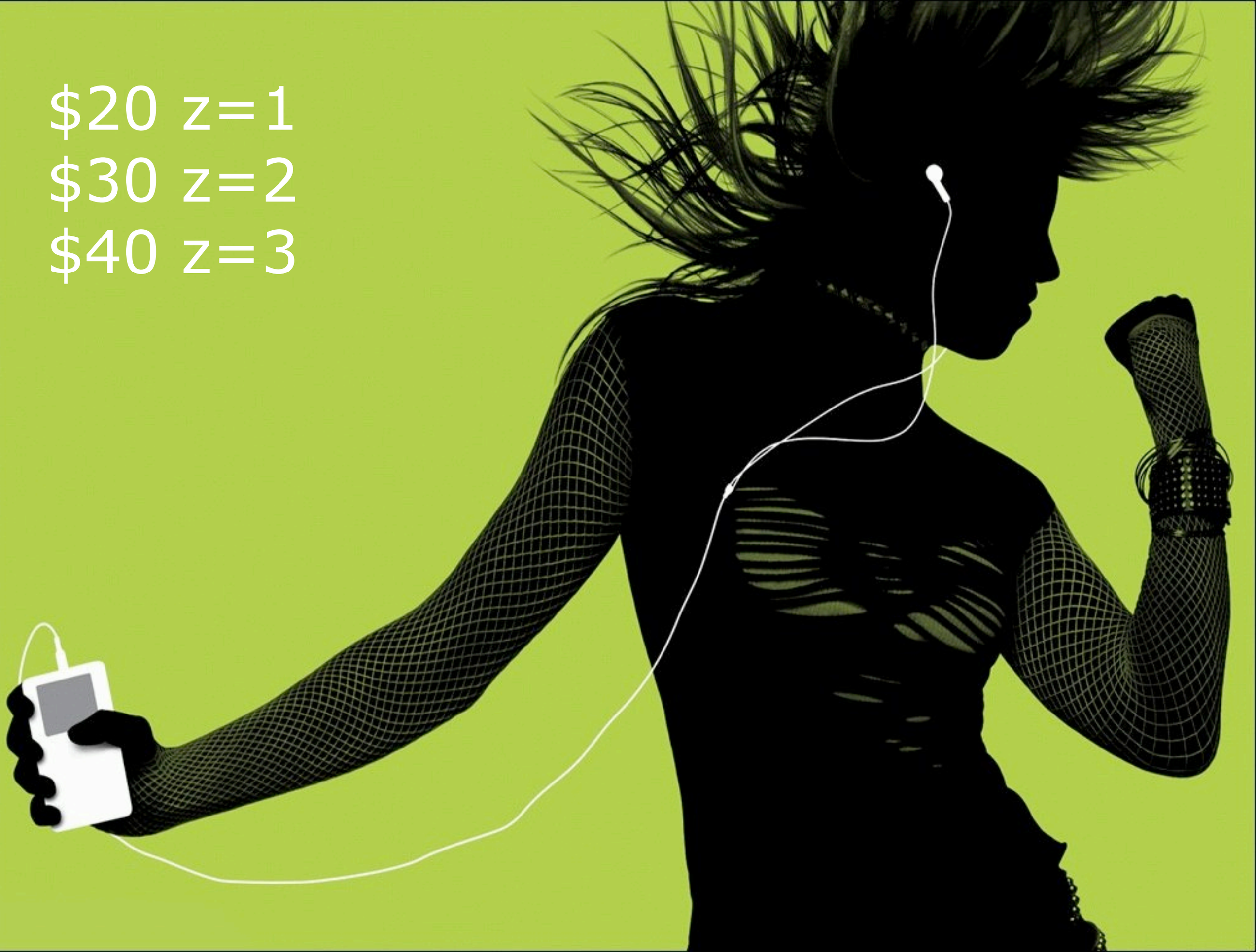
z=0 galaxy light

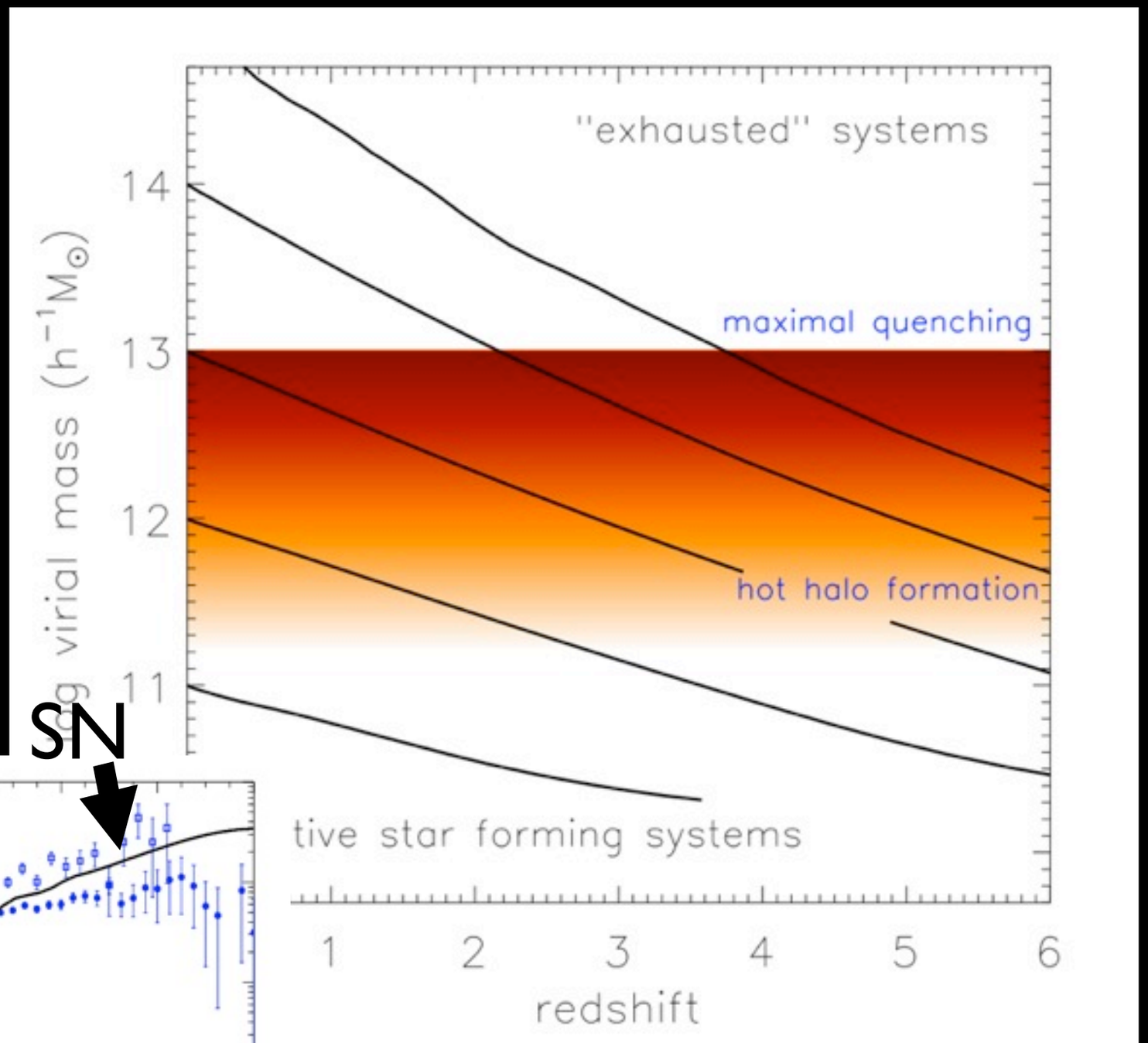
Physical consequences





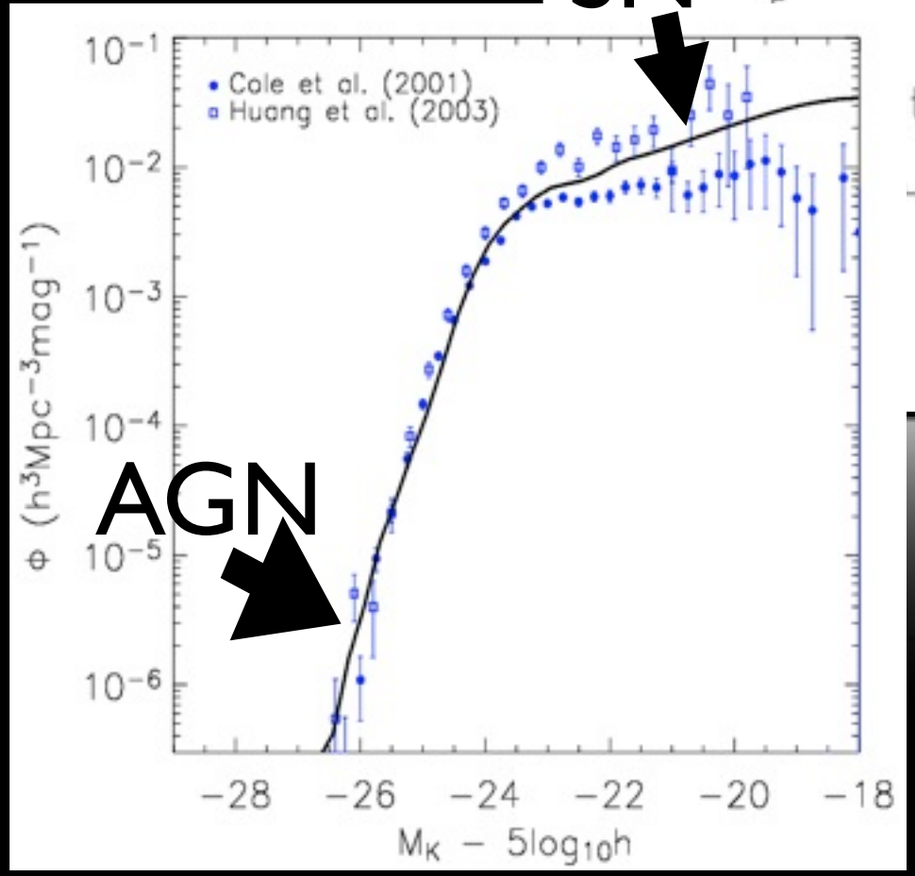
$20 z=1
$30 z=2
$40 z=3

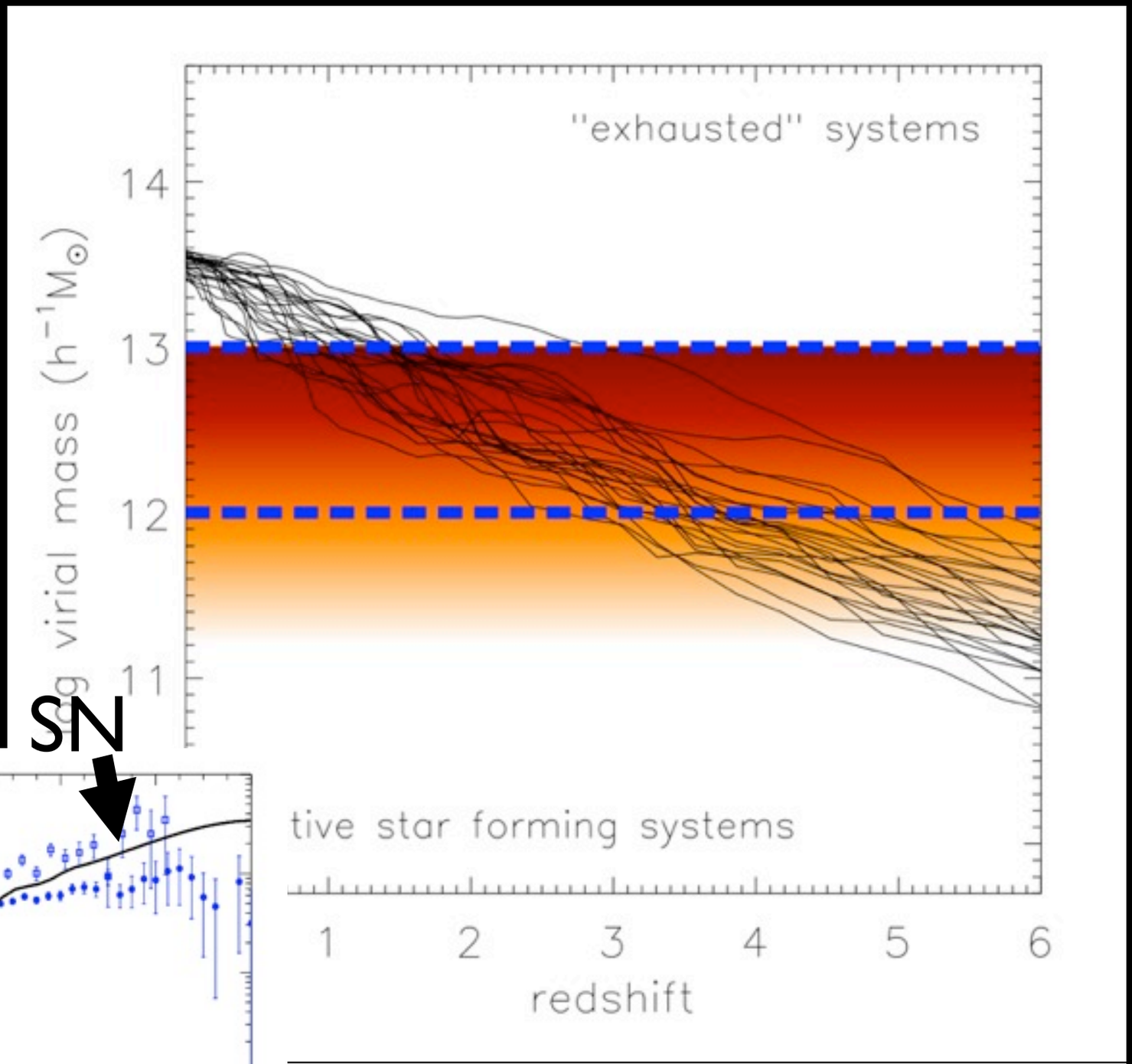



"exhausted" systems
maximal quenching
hot halo formation
tive star forming systems
14
13
12
11
g virial mass ($h^{-1}M_\odot$)
1
2
3
4
5
6
redshift

SN

AGN


Cole et al. (2001)
Huang et al. (2003)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
Φ (h^3Mpc^{-3}mag^{-1})
−28
−26
−24
−22
−20
−18
$M_K - 5\log_{10}h$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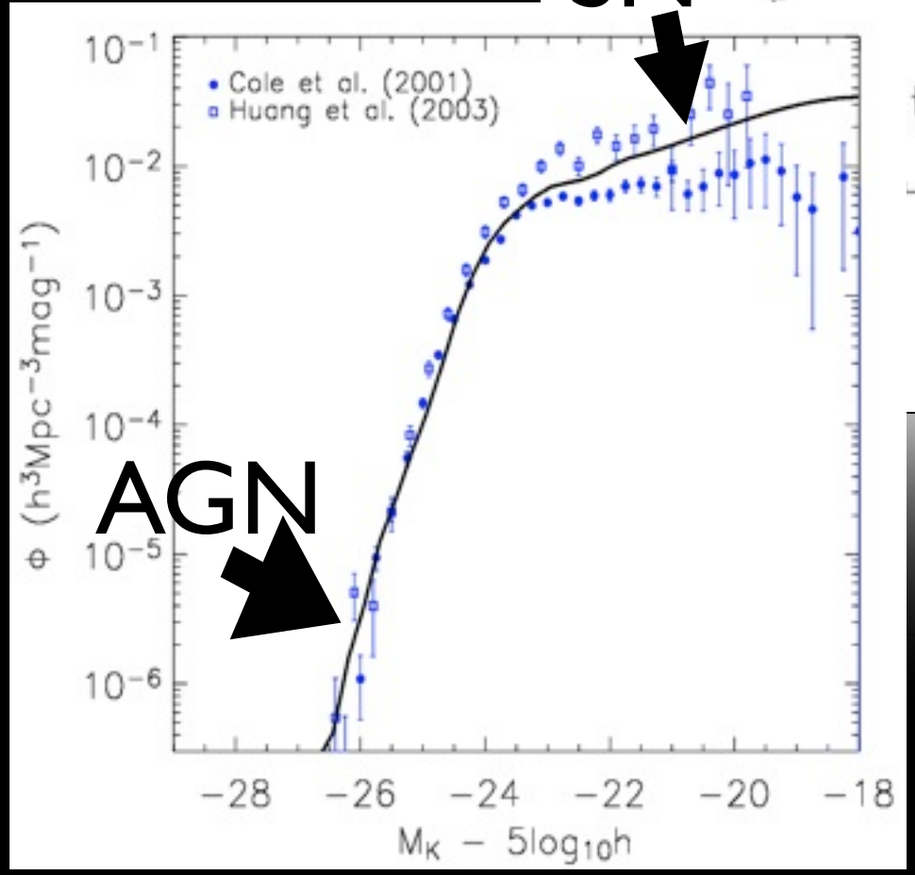
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Φ ($h^3Mpc^{-3}mag^{-1}$)
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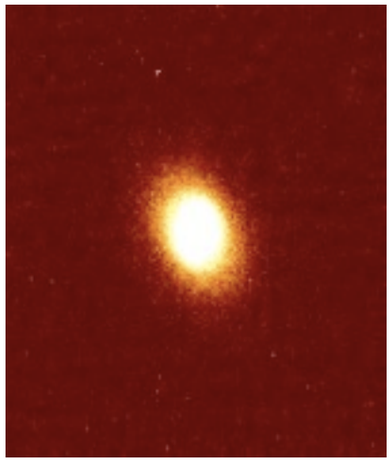
−24
−22
−20
−18
$M_K - 5\log_{10}h$

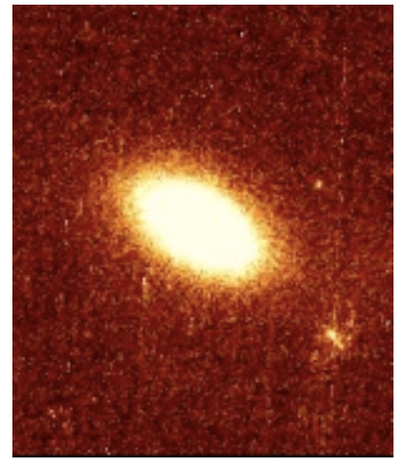
Our model is only as good as the questions we ask

For systems with infinite levels of complexity, our model can never be “correct”

What can semi-analytics actually tell us about galaxy formation?

Example 1: Void galaxies





Croton et al. 2005

2dFGRS

late types
early types

cluster (δ_8>6.0)

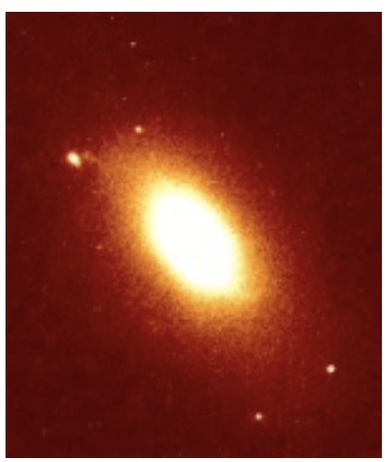
void (δ_8<−0.75)

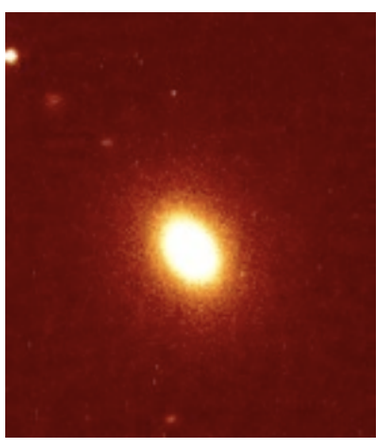
Φ (h^3Mpc^{-3} mag^{-1})

10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}

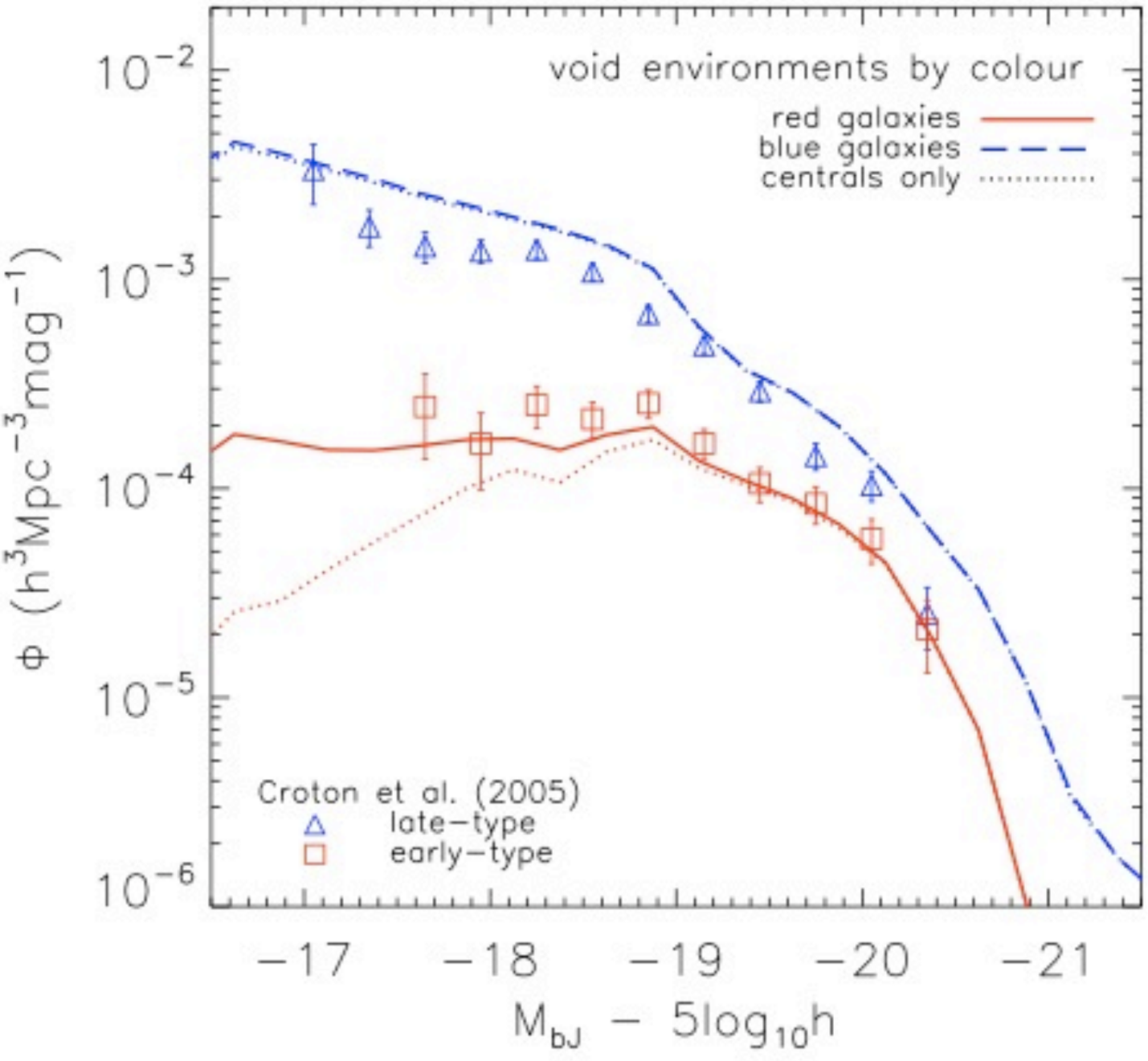
−17 −18 −19 −20 −21 −22

$M_{bJ} - 5\log_{10}h$





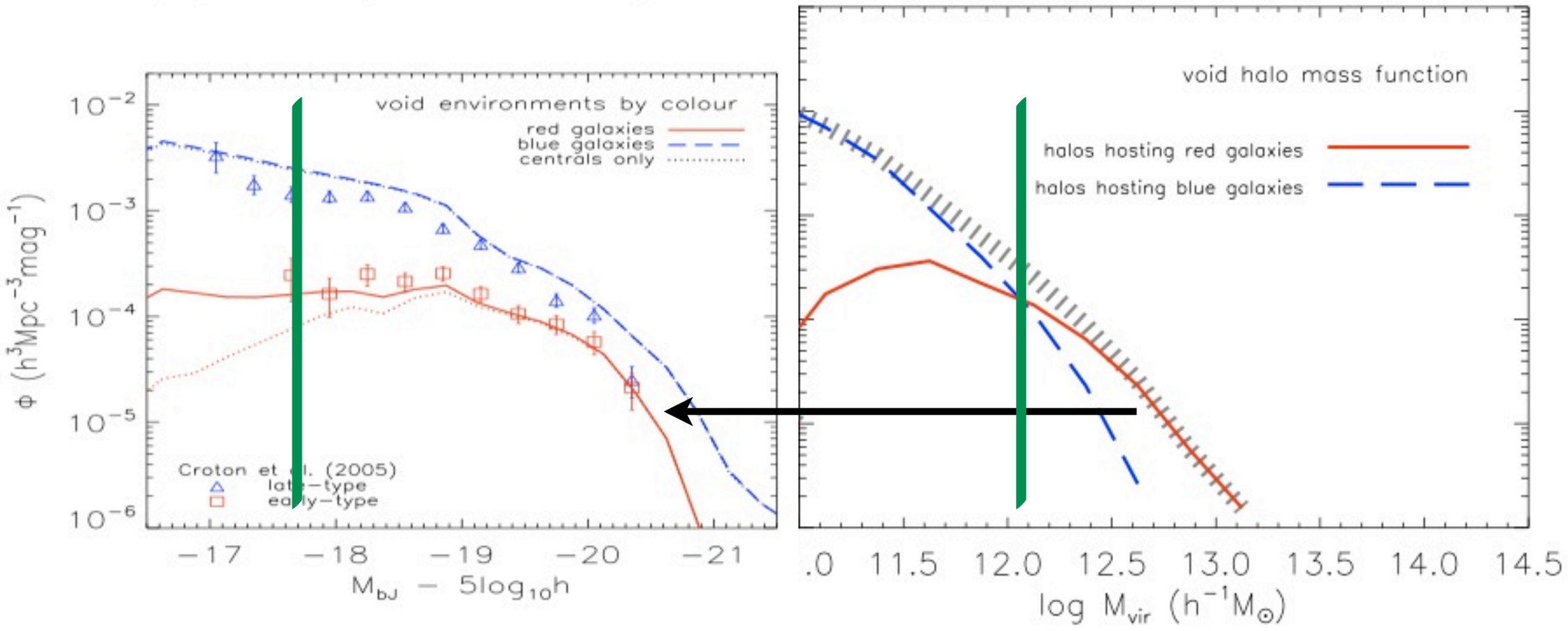
Croton & Farrar (2008)



The Millennium Simulation semi-analytic galaxy formation model

So what's special about early-type void galaxies?

Croton & Farrar (2008)



Halo mass function in different environments

Example 2:

BH growth - mergers or secular?

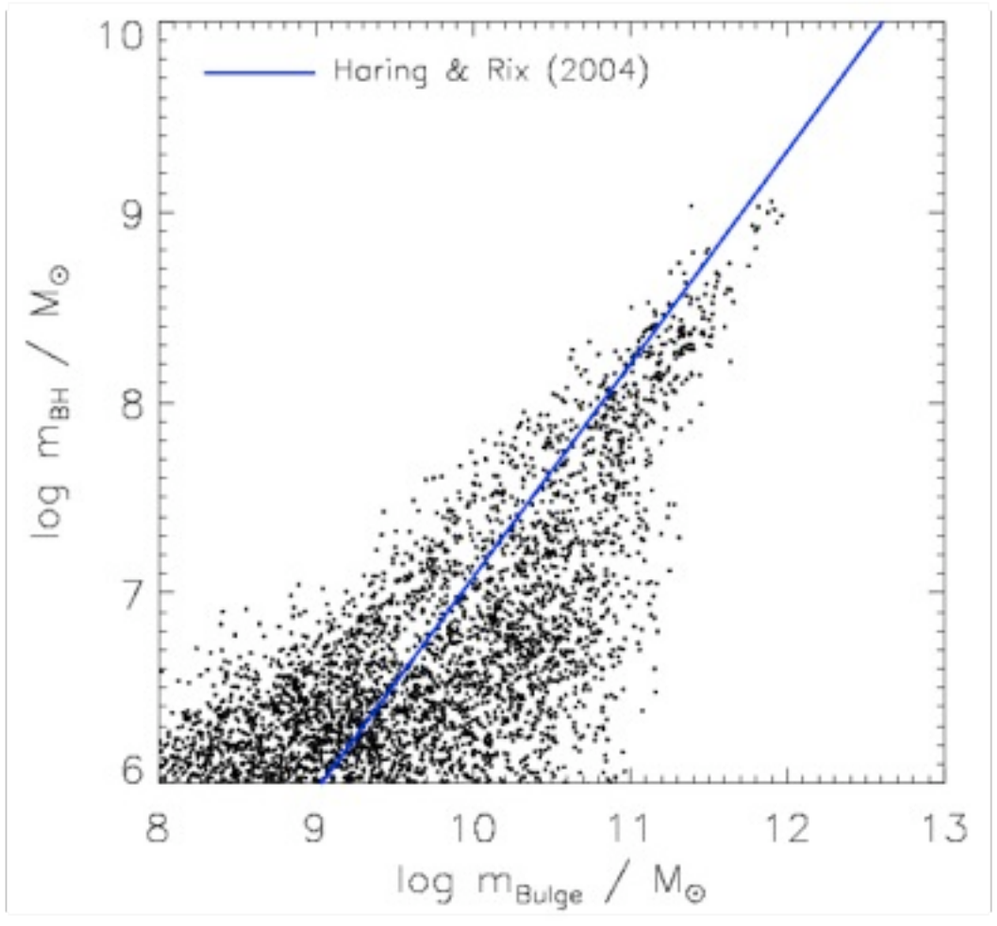
Merger driven growth

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

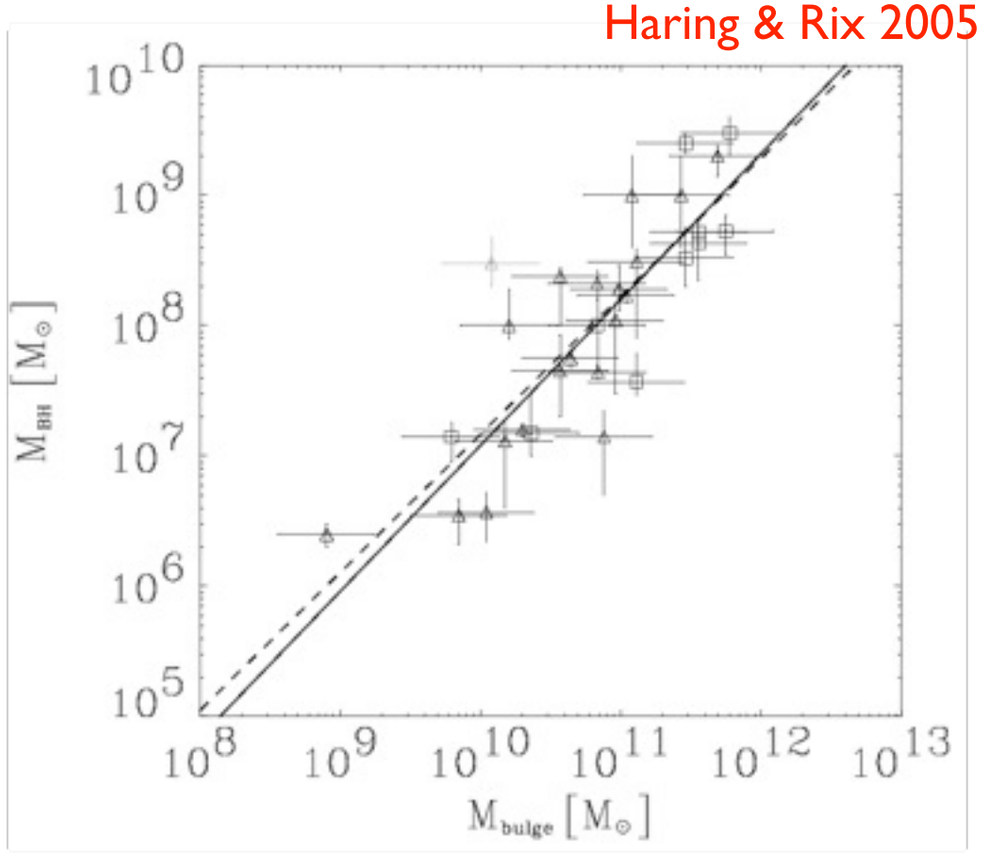
$$\Delta m_{\rm BH} \sim 0.03\ m_{\rm R}\ m_{\rm cold}$$

black hole-bulge

merger driven growth



Haring & Rix 2005



Secular driven growth

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

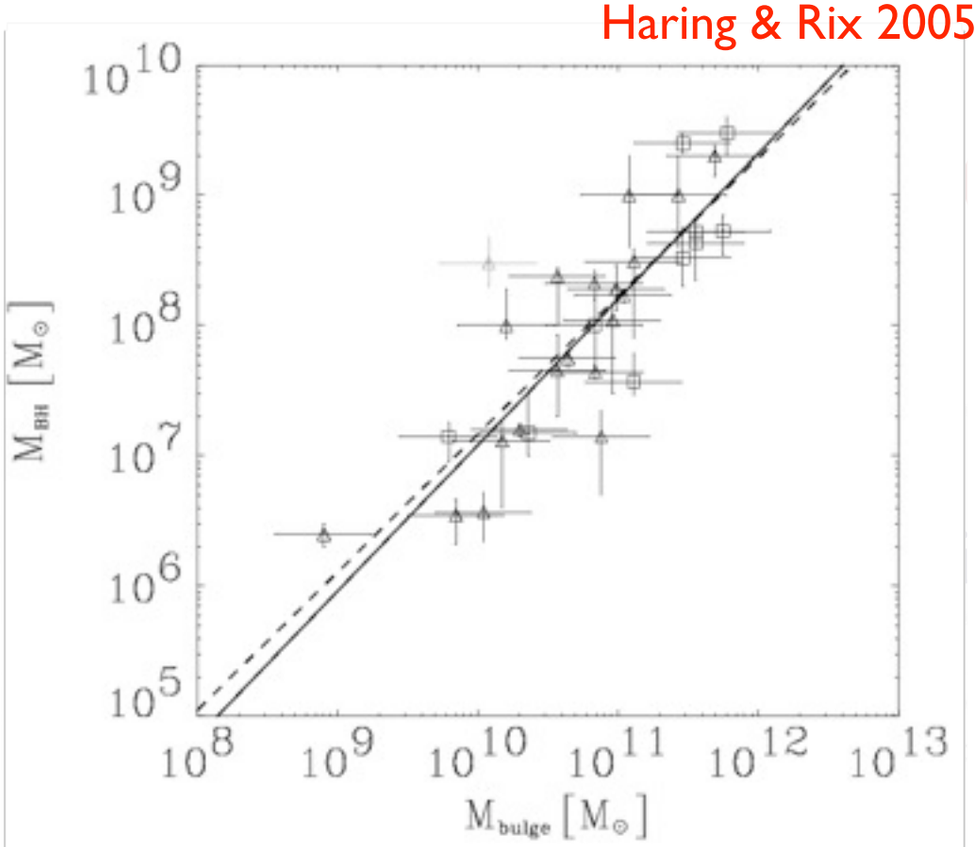
$$\Delta m_{\rm BH} \sim 0.01\ m_{\rm cold}$$

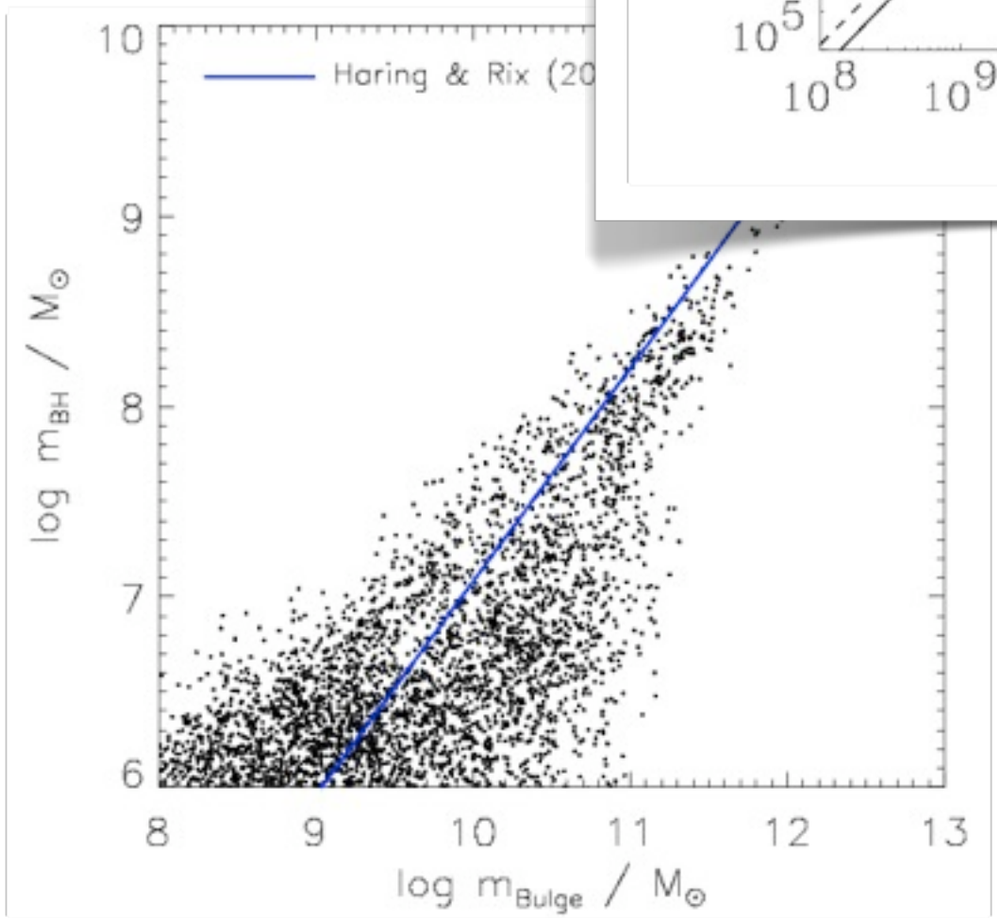
bl ge

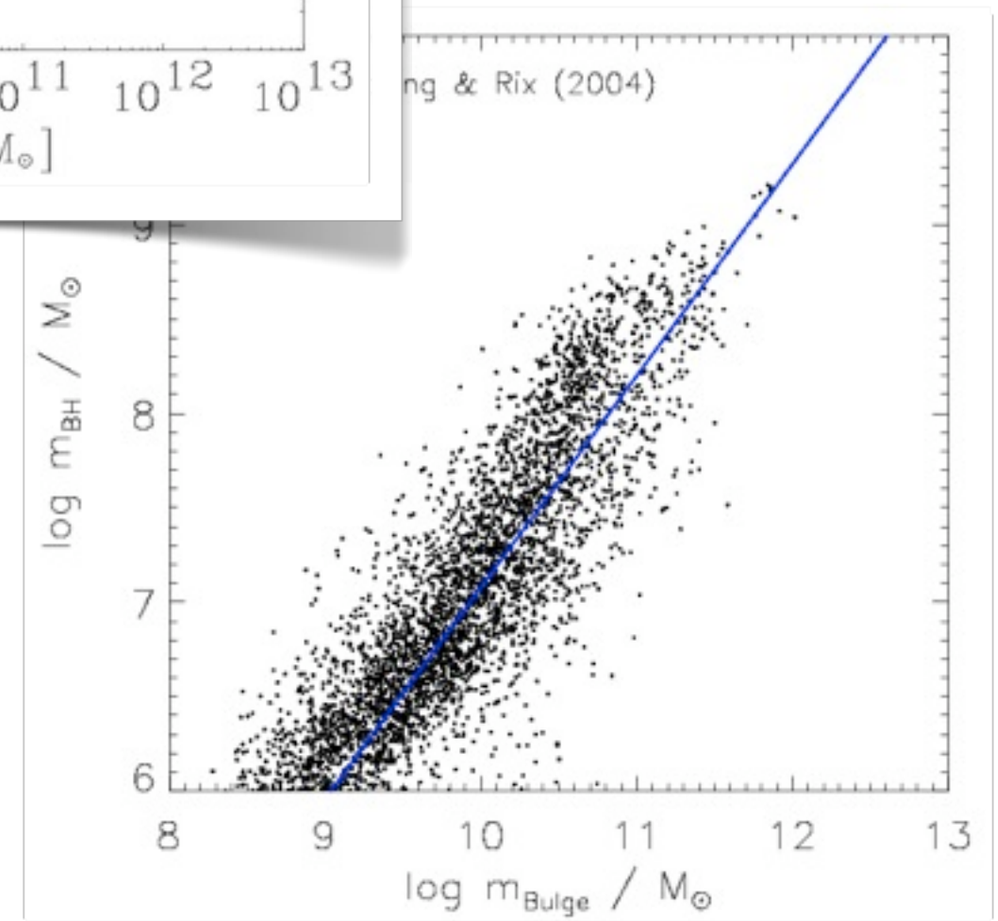
merger driven

t instability
ven growth

Haring & Rix 2005

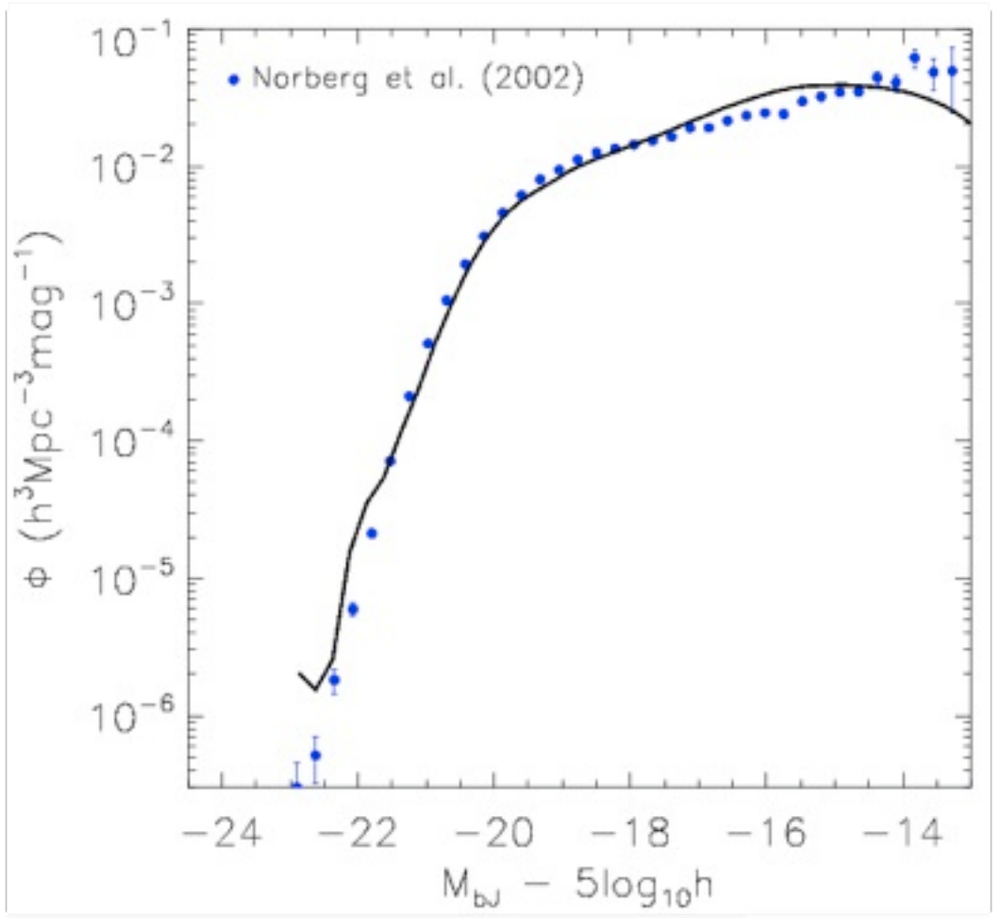




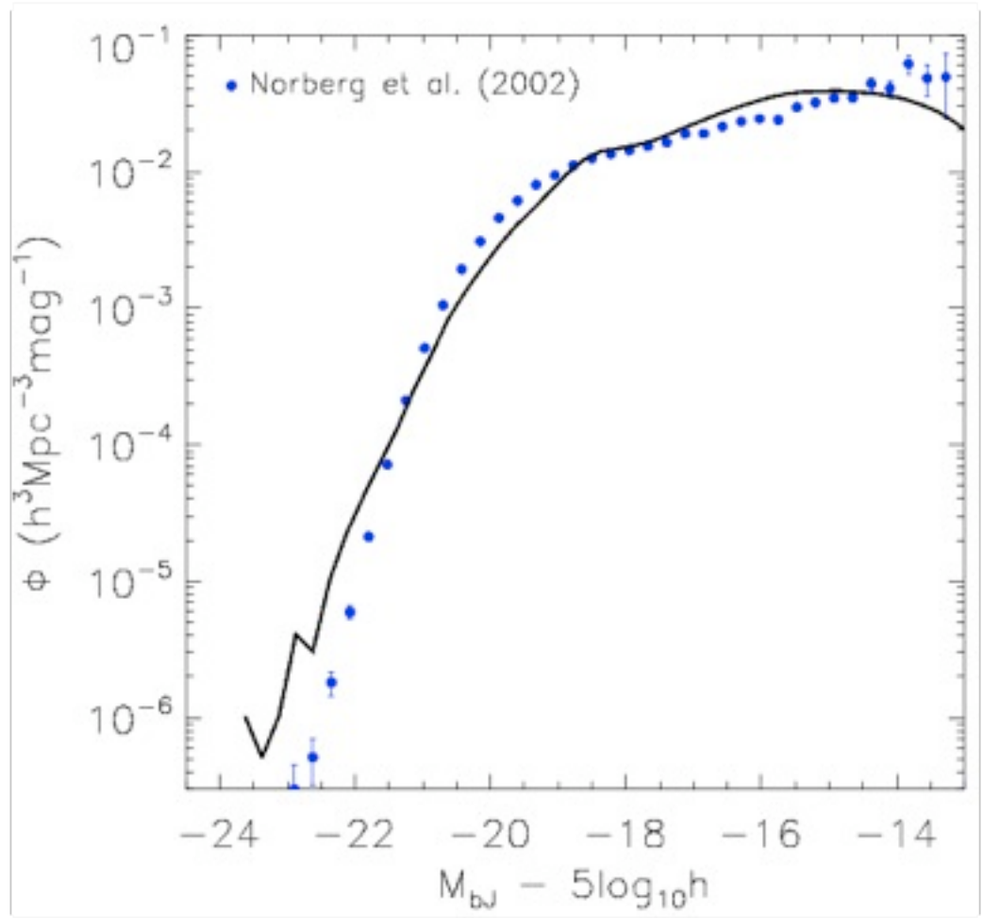


luminosity function

merger driven growth

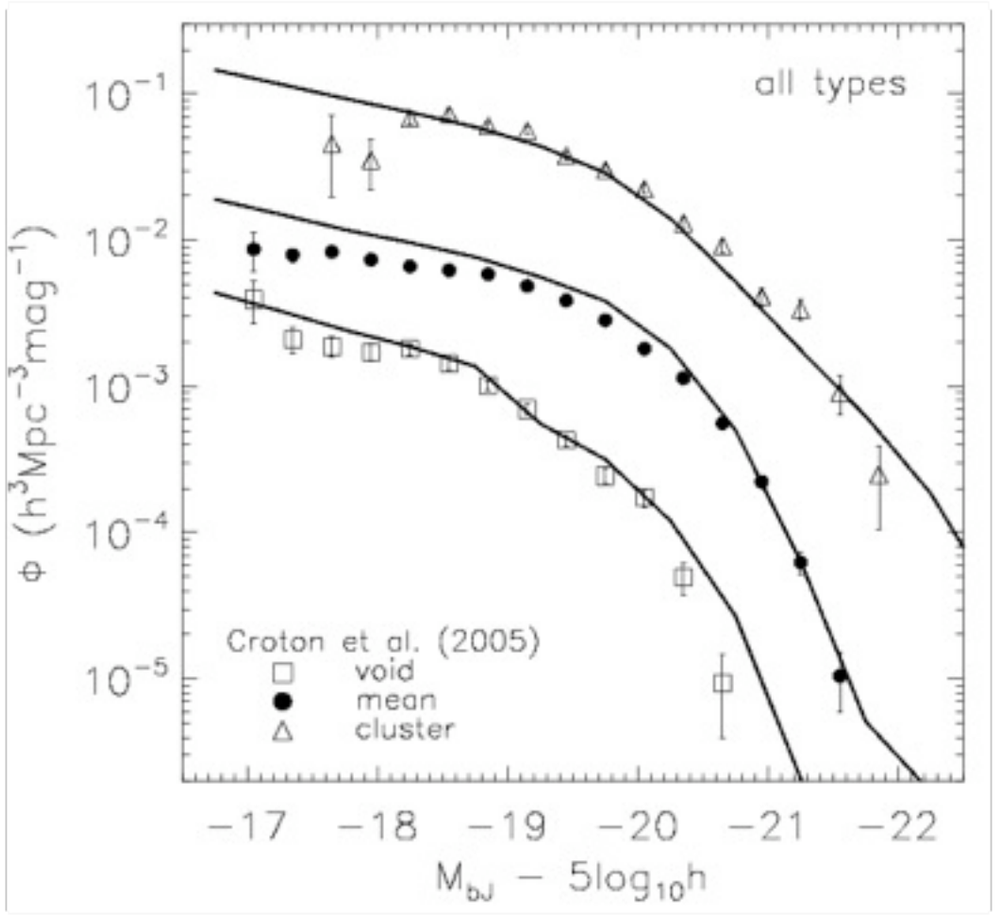


disk instability driven growth

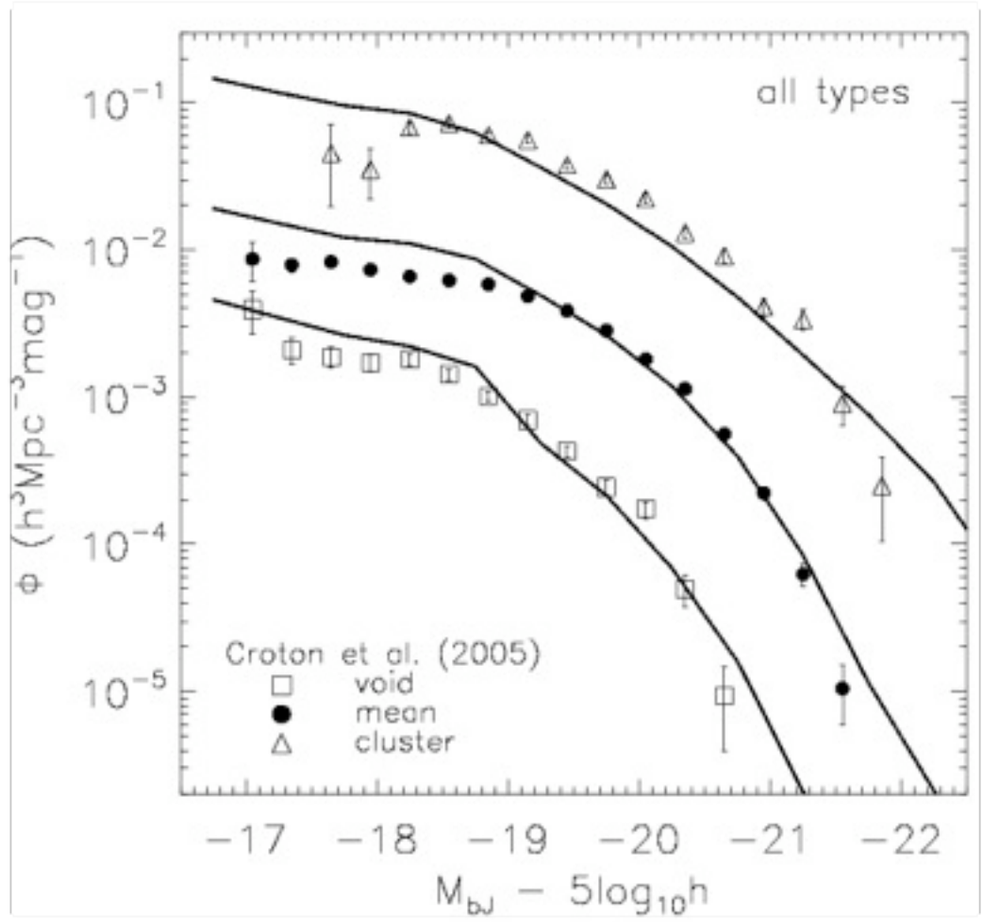


environment LFs

merger driven growth



disk instability driven growth



The down and dirty

Semi-analytics (mostly) assume:

- the cosmology is correct
- local correlations extend to higher redshift
- the baryon fraction is universal
- halo properties determine galaxy properties
- ...

Semi-analytics are at the mercy of:

- the IMF
- stellar population models
- the quality of constraining observations
- the quality of the underlying simulation
- ...

Table 1. A summary of our main model parameters and their best values and plausible ranges, as described in the text. Once set, these values are kept fixed for all results presented in this paper, in particular for models in which AGN feedback is switched off.

Parameter	Description	Best value	Plausible range
$f_{\rm b}$	Cosmic baryon fraction (Section 3.3)	0.17	fixed
z_0, $z_{\rm r}$	Redshift of reionization (Section 3.3)	8, 7	fixed
$f_{\rm BH}$	Merger cold gas BH accretion fraction (Section 3.4.1)	0.03	002–004
$\kappa_{\rm AGN}$	Quiescent hot gas BH accretion rate ($M_\odot\ yr^{-1}$) (Section 3.4.2)	6×10^{-6}	$(4–8) \times 10^{-6}$
$\alpha_{\rm SF}$	Star formation efficiency (Section 3.5)	0.07	005–015
$\epsilon_{\rm disc}$	SN feedback disc reheating efficiency (Section 3.6)	3.5	1–5
$\epsilon_{\rm halo}$	SN feedback halo ejection efficiency (Section 3.6)	0.35	01–05
$\gamma_{\rm ej}$	Ejected gas reincorporation efficiency (Section 3.6)	0.5	01–10
$T_{\rm merger}$	Major merger mass ratio threshold (Section 3.7)	0.3	02–04
R	Instantaneous recycled fraction of SF to the cold disc (Section 3.9)	0.3	02–04
Y	Yield of metals produced per unit SF (Section 3.9)	0.03	002–004

Croton et al. 2006, 2012 (in prep.)

The *exact* values of the parameter choices are (mostly) meaningless

Let’s now look at some code...

...and the story continues in the next lecture with "The universe in the cloud"