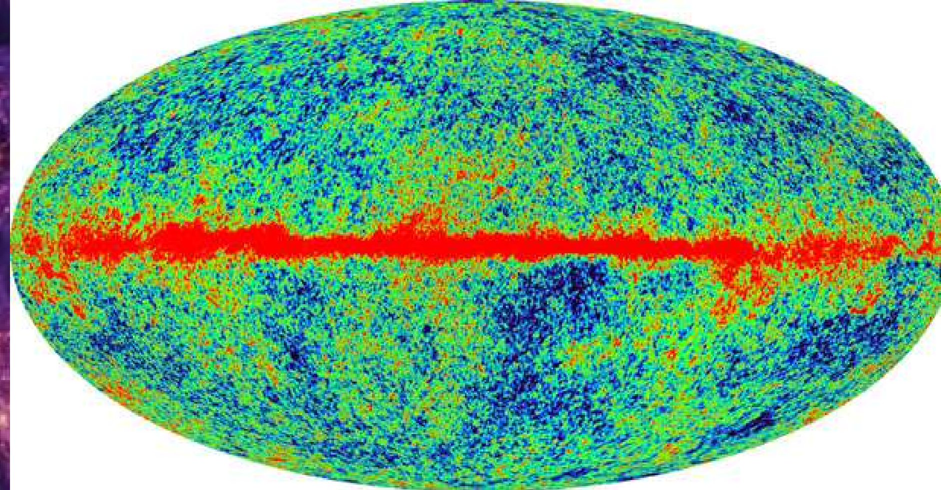


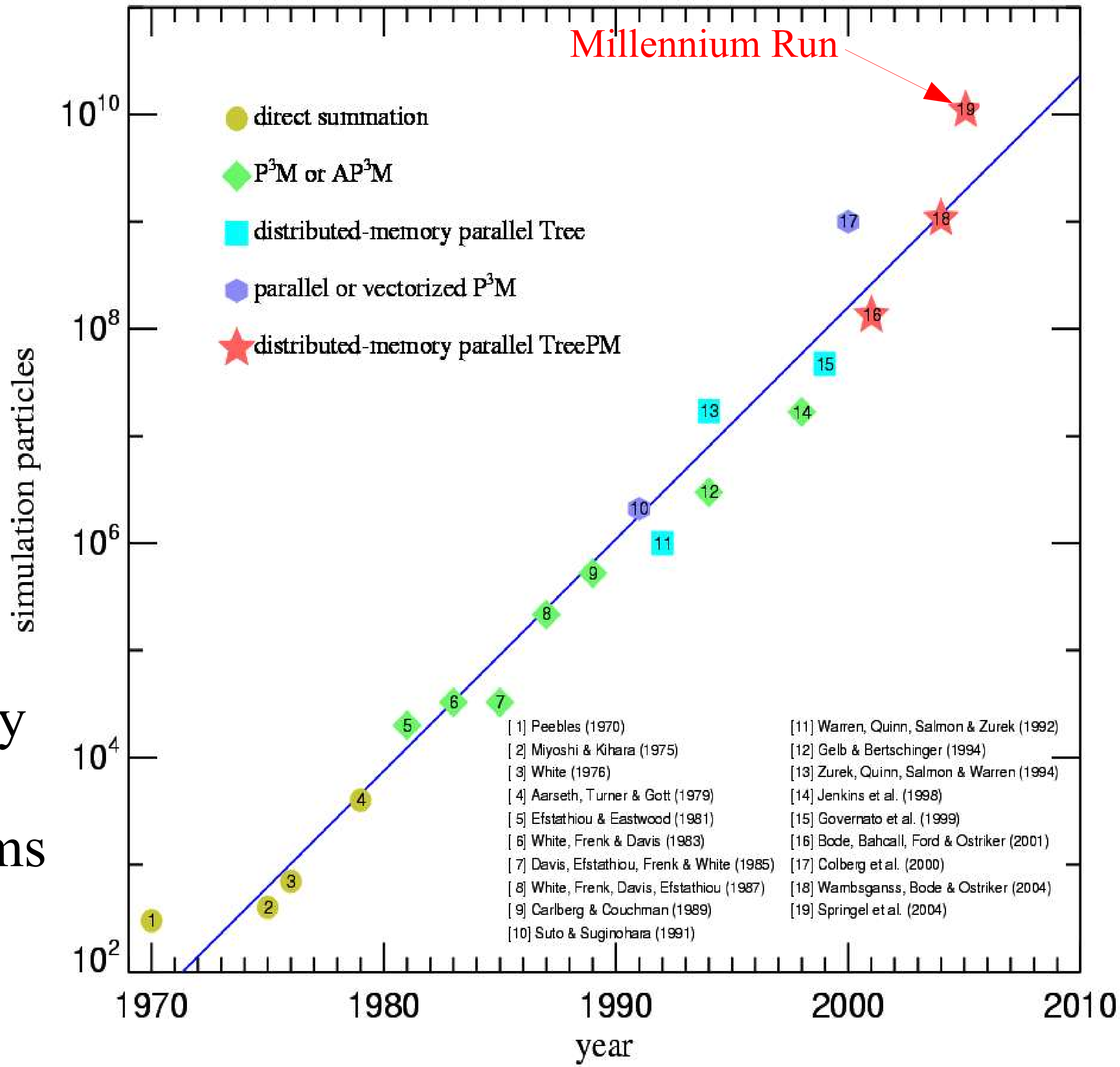
Large-scale Simulation of the Galaxy/AGN Population

Simon White
Max Planck Institute for Astrophysics

Moore's Law for Cosmological N-body Simulations

- Computers double their speed every 18 months
- A naive N-body force calculation needs N^2 op's
- Simulations double their size every 16.5 months
- Progress has been roughly equally due to hardware and to improved algorithms

Springel et al 2005



Millennium Run Statistics

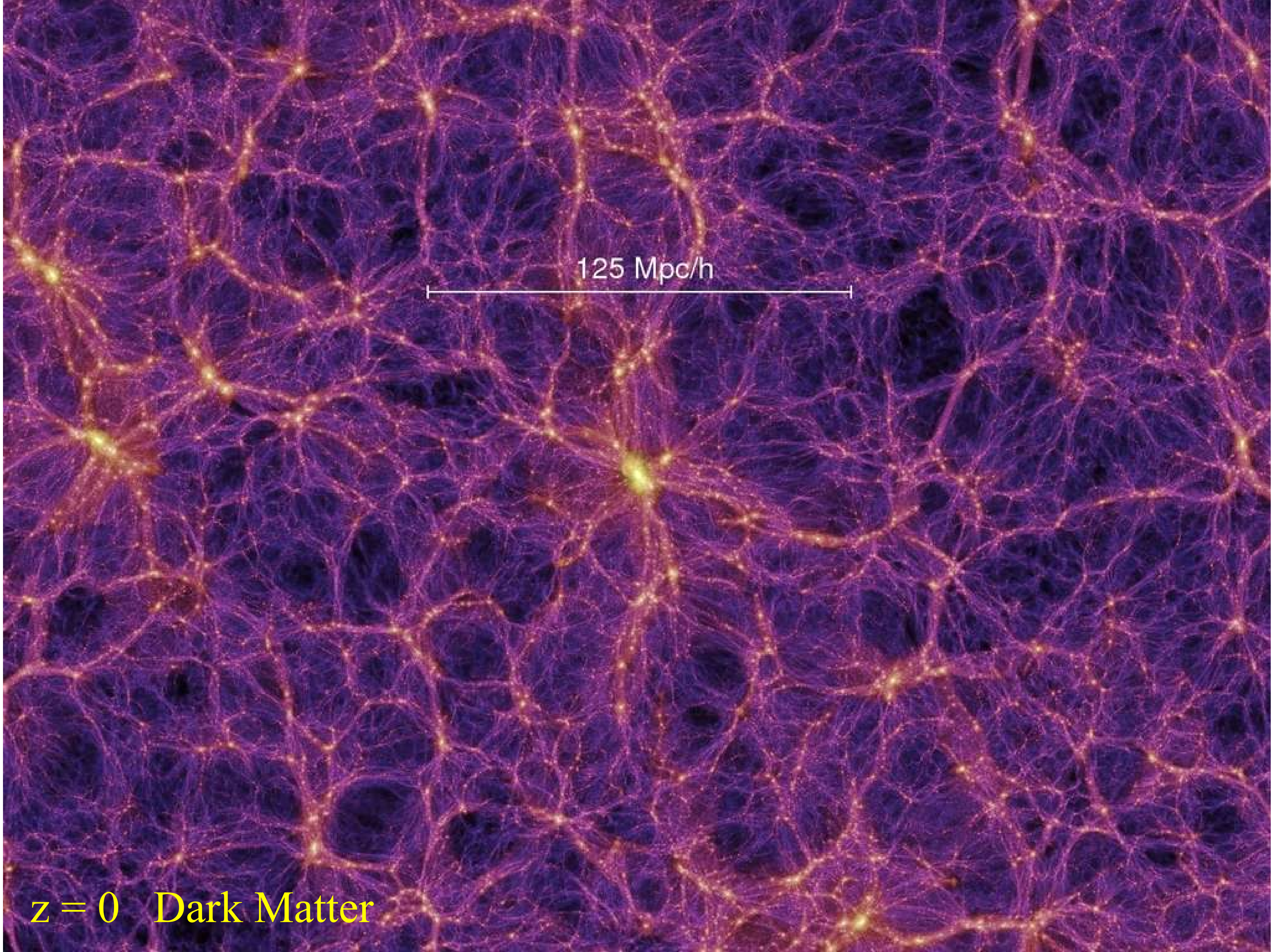
Springel et al 2005: The Virgo Consortium

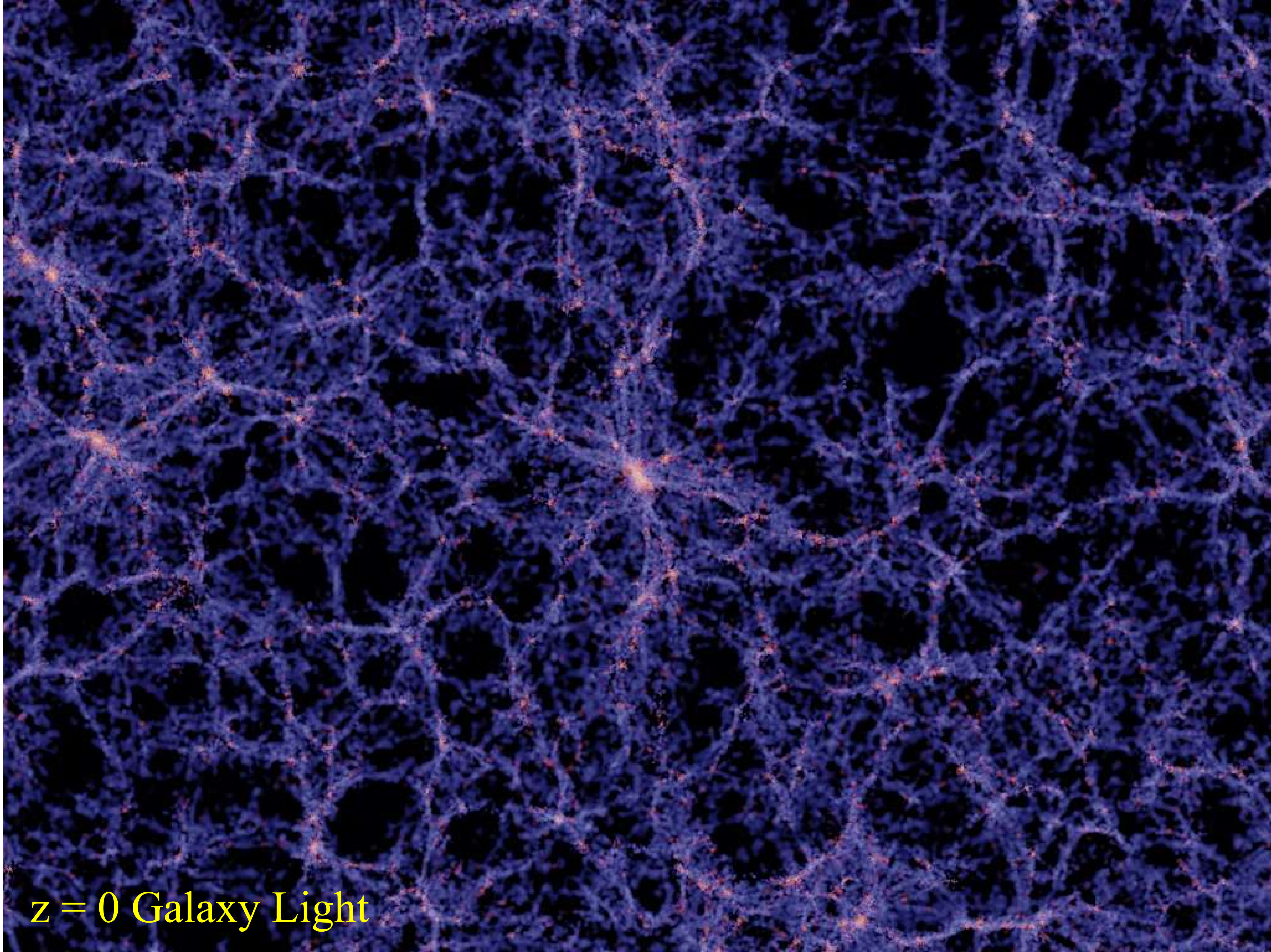
- DM particle number: $N = 2160^3 = 10{,}077{,}696{,}000 \approx 10^{10}$
- Box size: $L = 500$ Mpc/h, Softening: $\epsilon = 5$ kpc/h $\longrightarrow$ $L/\epsilon = 10^5$
- Initial redshift: $z_{init} = 127$
- Cosmology: $\Omega_{tot}=1$, $\Omega_m=0.25$, $\Omega_b=0.045$, $h=0.73$, $n=1$, $\sigma_8=0.9$
- 343,000 processor-hours on 512 nodes of an IBM Regatta
  (28 machine days @ 0.2 Tflops using 1 Tbyte RAM)
- Full raw and reduced data stored at 64 redshifts
  $\longrightarrow$ 27 Tbytes of stored data

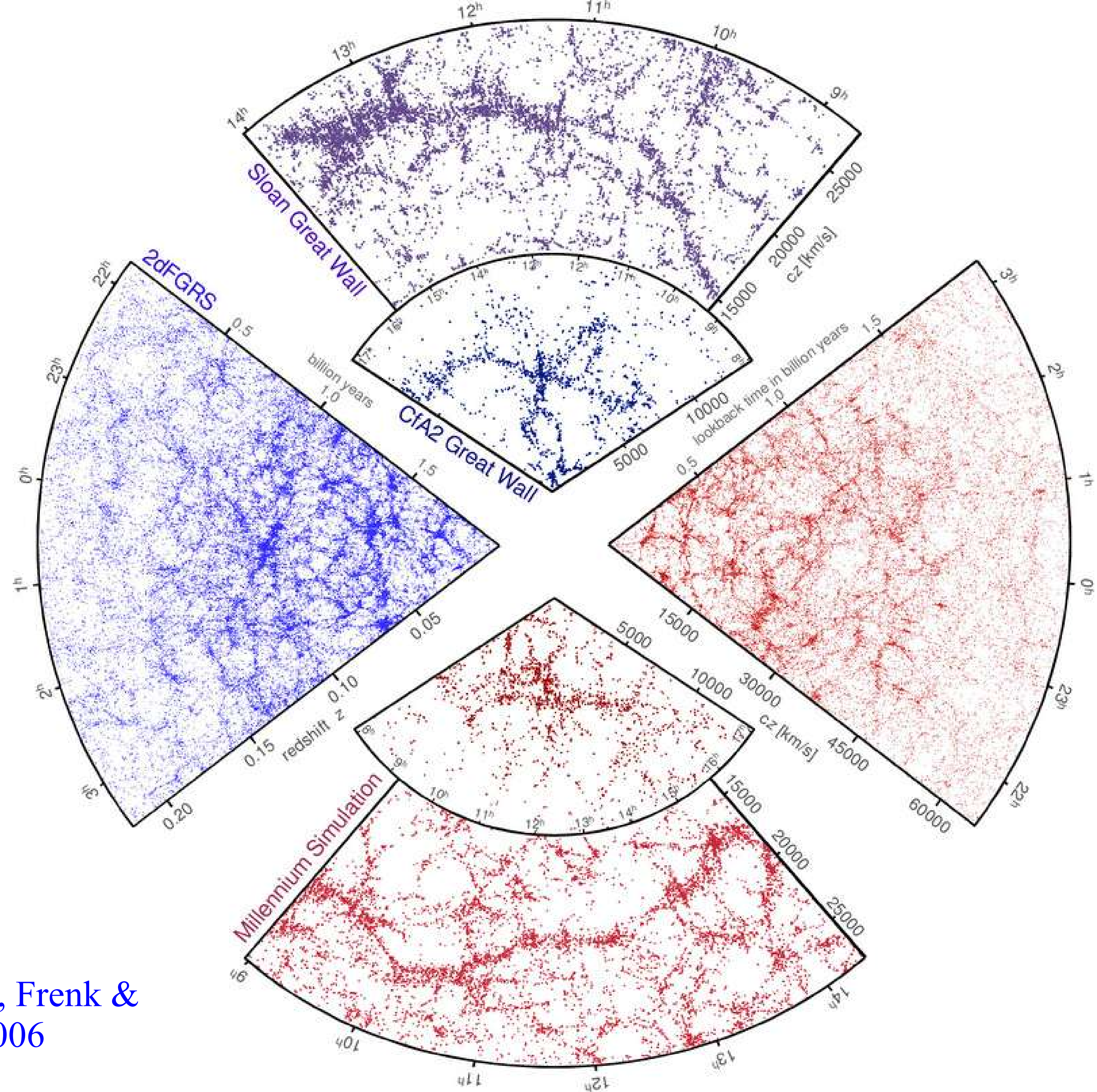
A testbed for simulating the formation of $\sim 10^7$ galaxies

Goals for simulations of galaxy/AGN evolution

- Explore the physics of galaxy formation
- Understand the links between galaxy and SMBH formation
- Clarify why galaxy properties are related to clustering
- Determine how environment stimulates galaxy activity
- Interpret new multi-wavelength surveys of galaxies
- Check if such surveys can provide precision tests of and parameter estimates for the standard ΛCDM paradigm

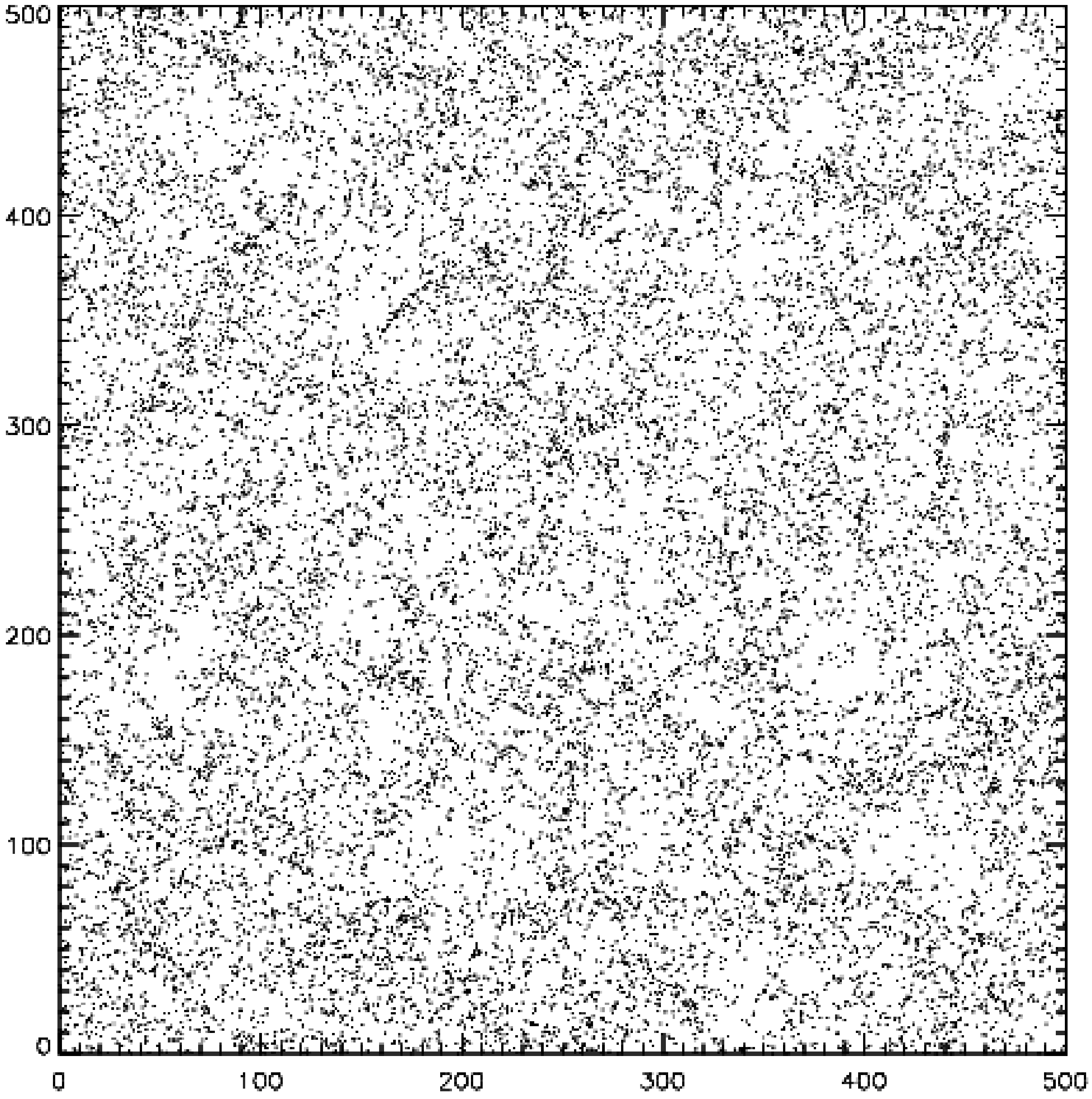

125 Mpc/h
z = 0 Dark Matter


z = 0 Galaxy Light



Springel, Frenk &
White 2006

Does halo clustering depend on formation history?

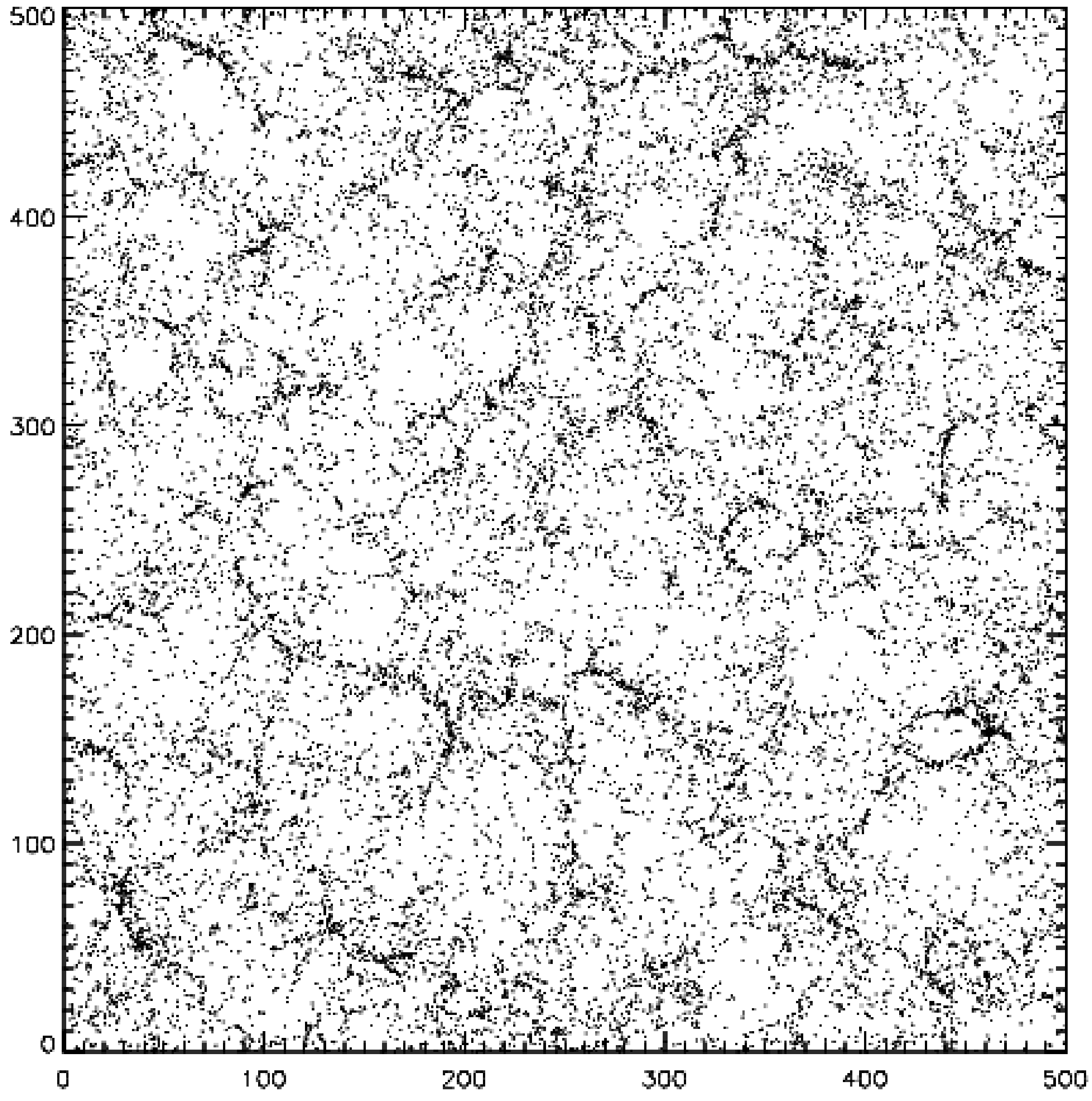


Gao, Springel & White 2005

The 20% of halos with the *lowest* formation redshifts in a 30 Mpc/h thick slice

$$M_{halo} \sim 10^{11} M_{\odot}$$

Does halo clustering depend on formation history?



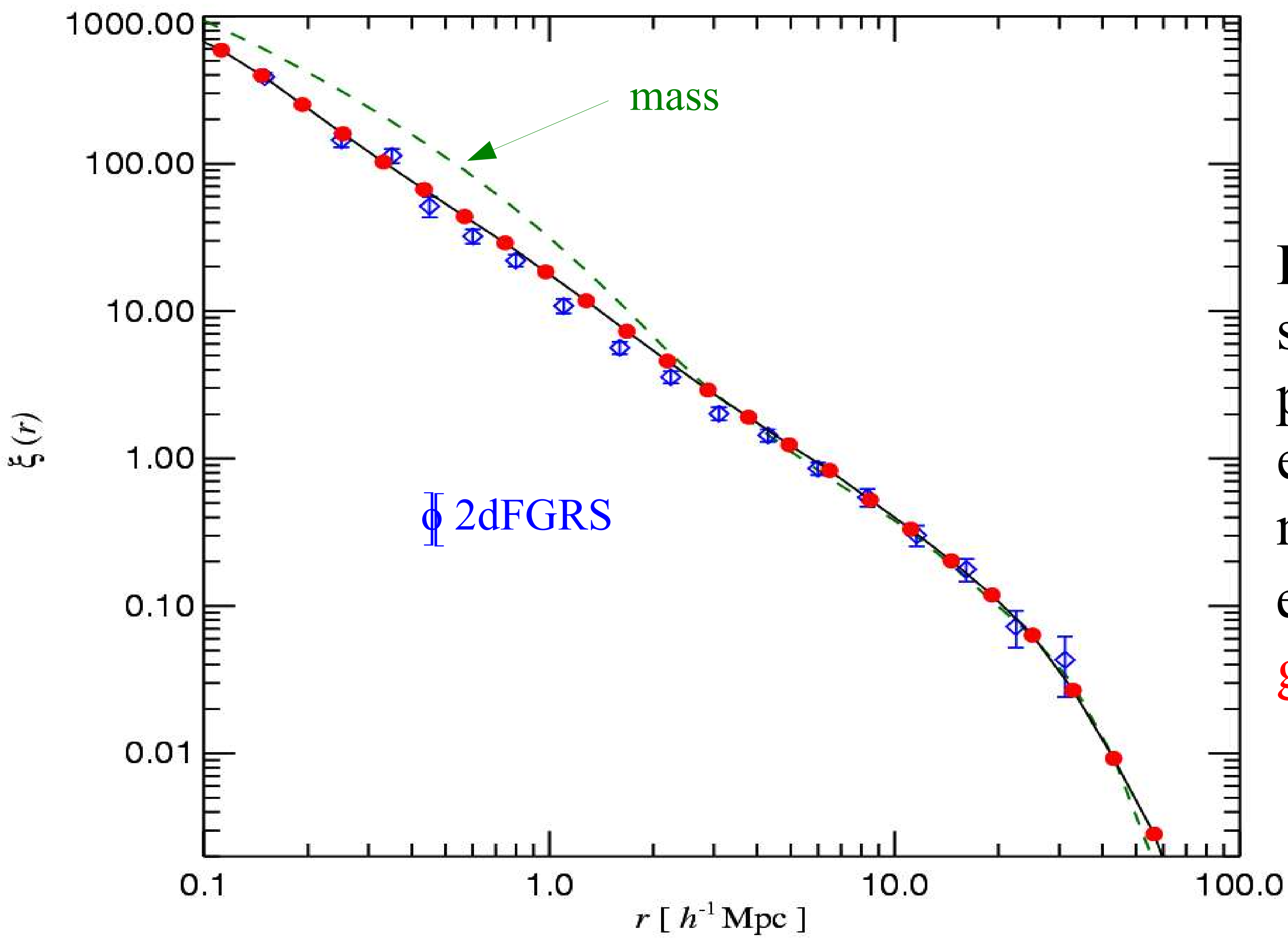
Gao, Springel & White 2005

The 20% of halos with the *highest* formation redshifts in a 30 Mpc/h thick slice

$$M_{halo} \sim 10^{11} M_{\odot}$$

Galaxy autocorrelation function

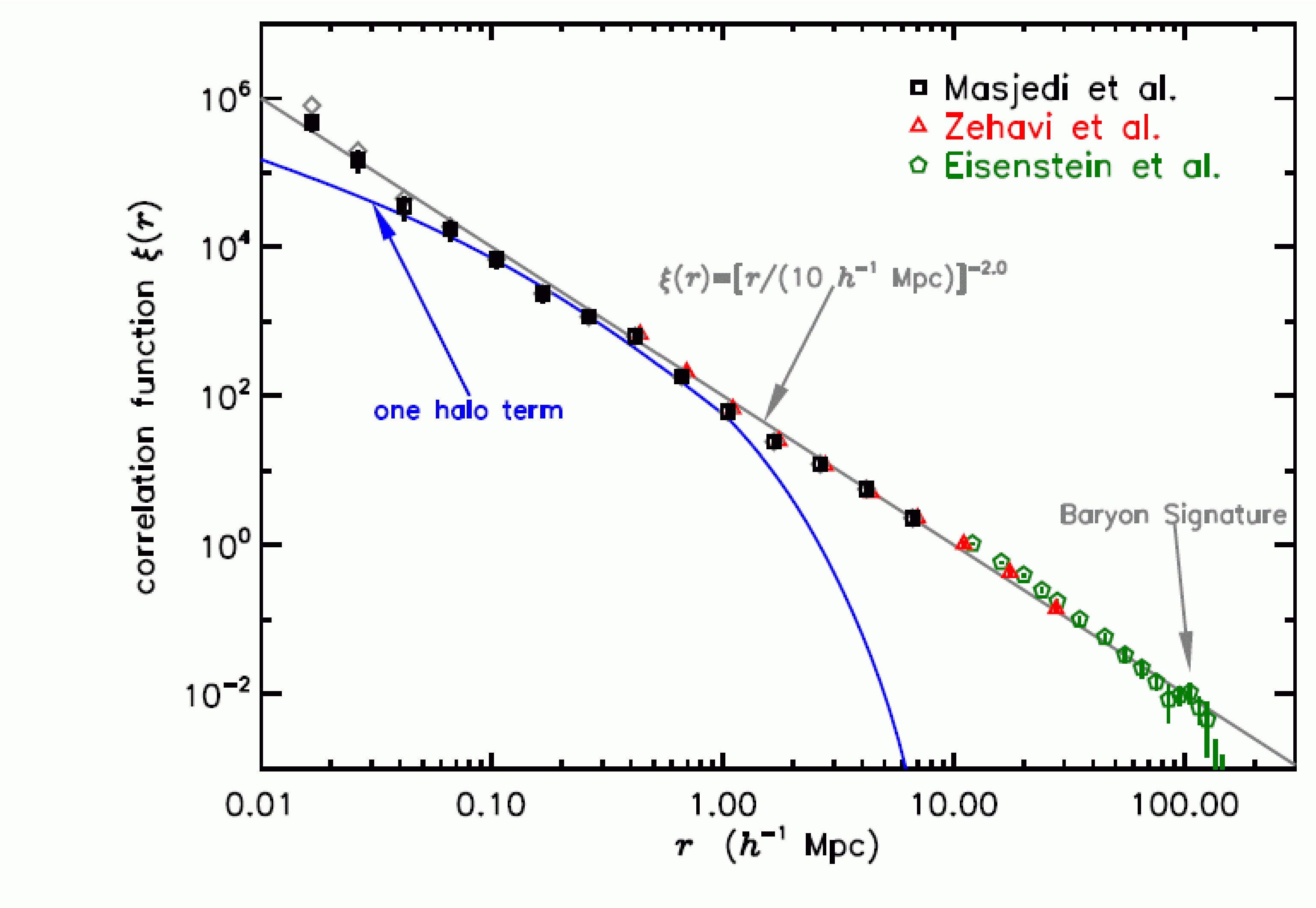
Springel et al 2005



For such a large simulation the purely statistical error bars are negligible on ξ even for the galaxies

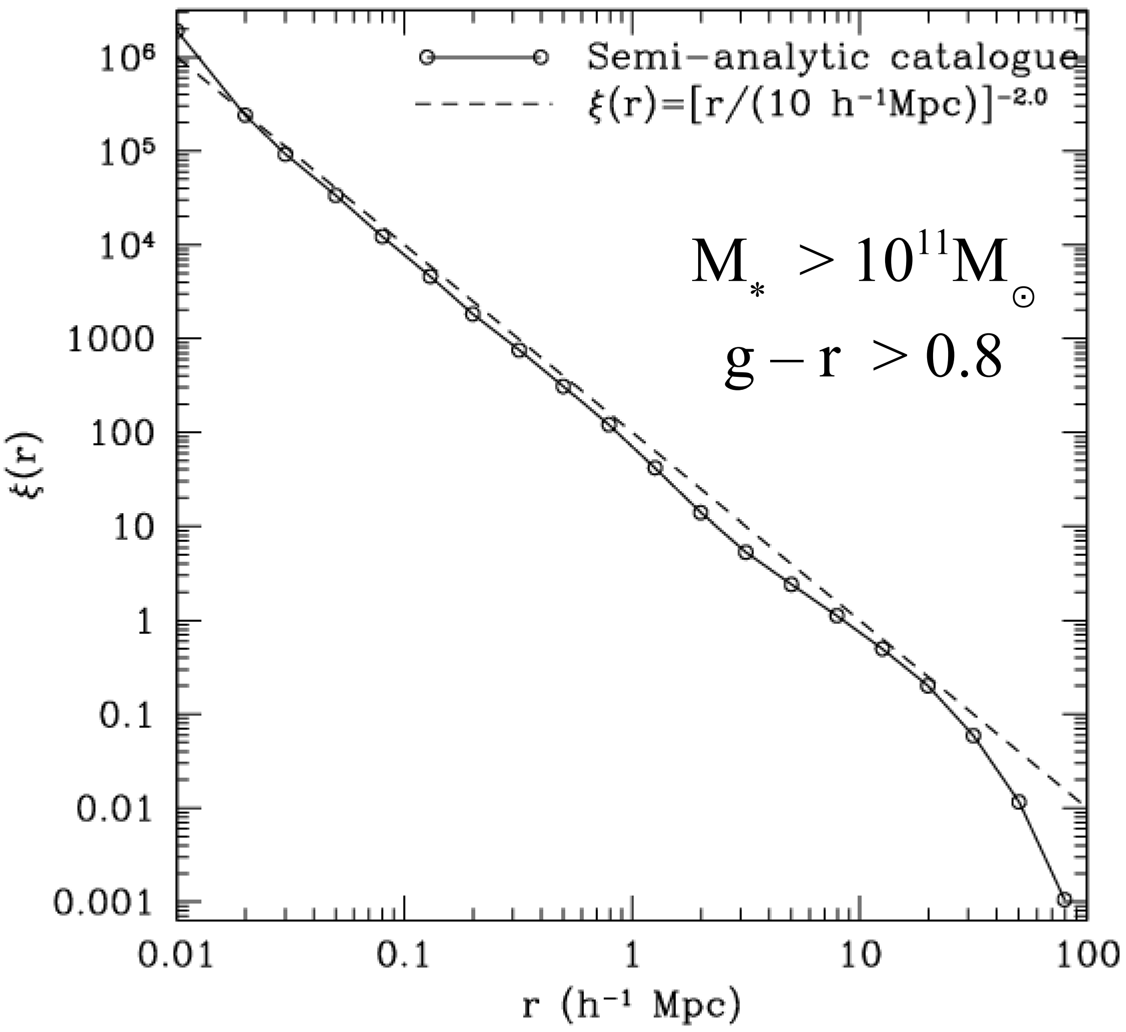
Precise estimates of autocorrelation functions Luminous red galaxies in the SDSS

Masjedi et al 2005

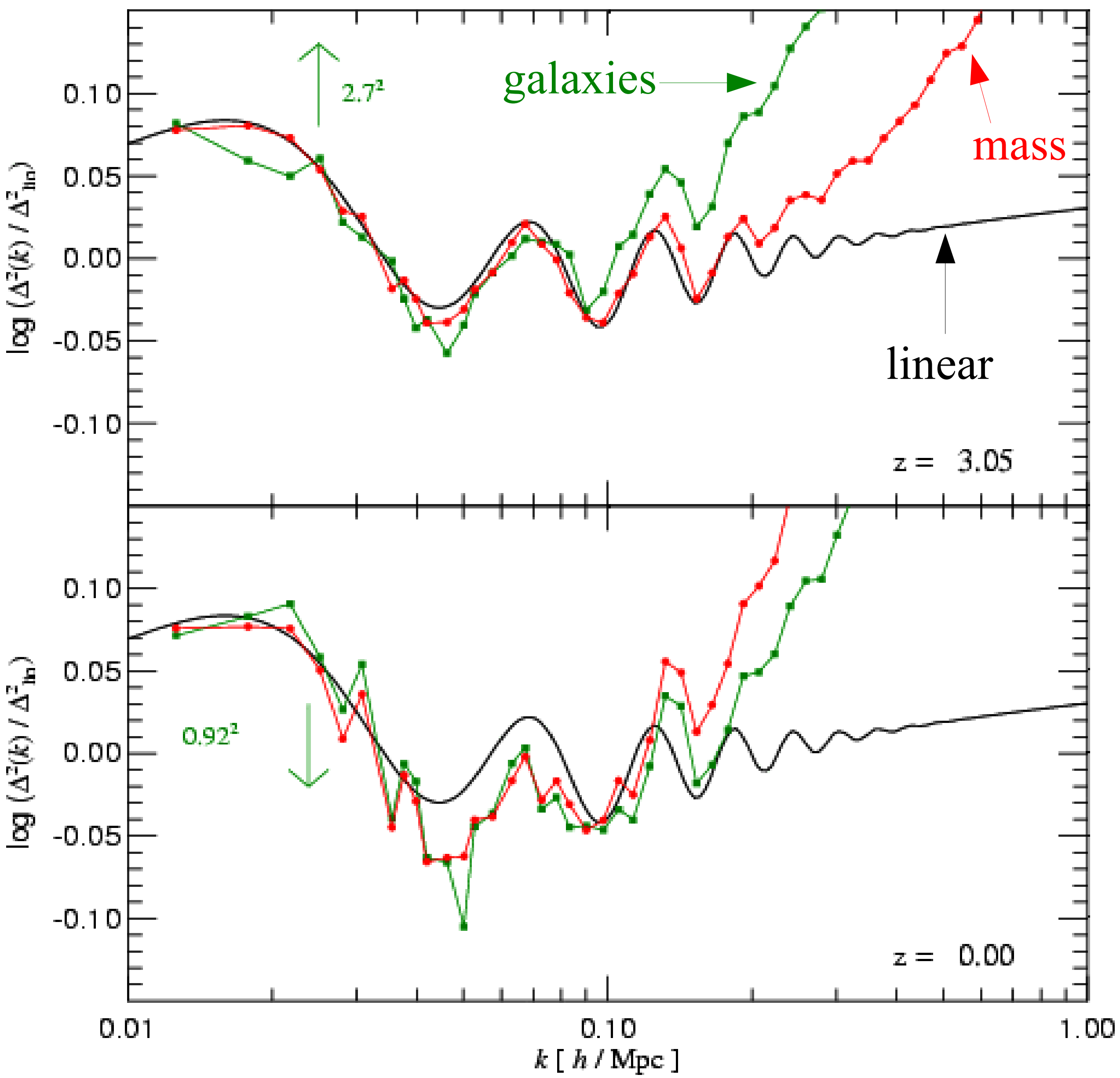


Precise estimates of autocorrelation functions Luminous red galaxies in the M.S.

From public Millennium Simulation data archive



Baryon wiggles in the *galaxy* distribution



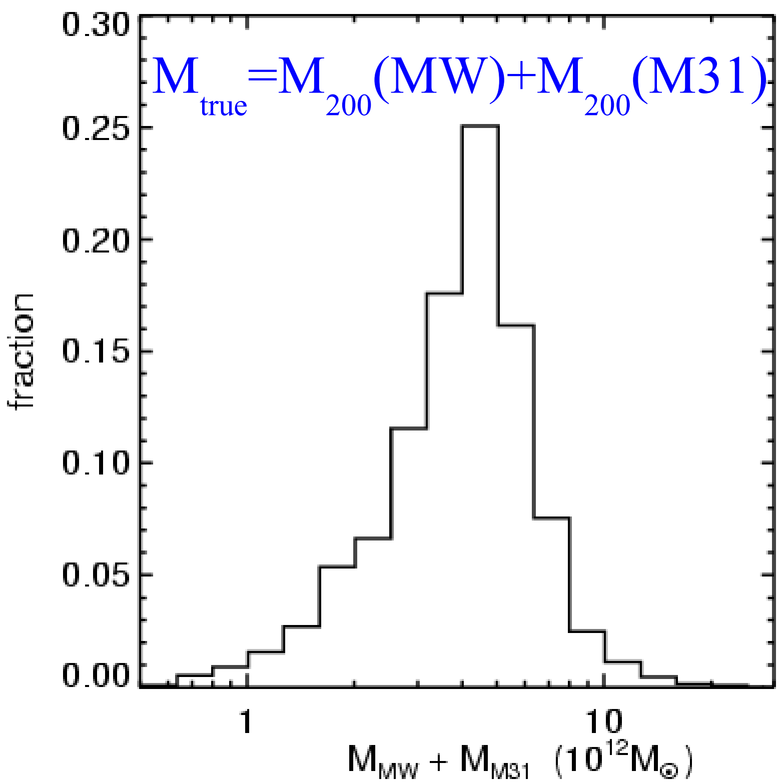
Springel et al 2005

Power spectra from the Millennium run divided by a baryon-free ΛCDM spectrum

Galaxy samples are matched to plausible large observational surveys at given z

Local Group "Timing Argument" mass estimates with a ΛCDM prior

Li & White 2006

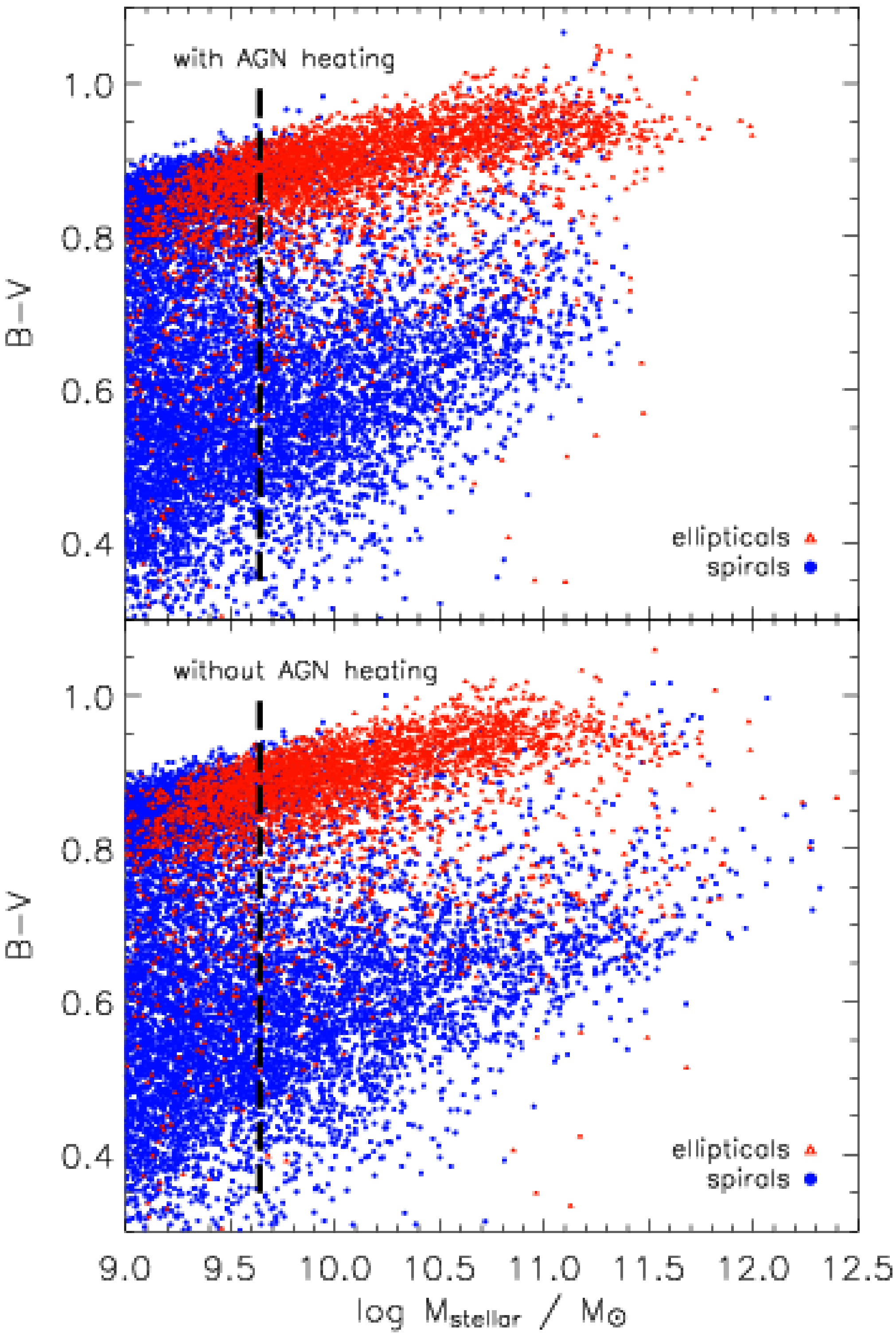


Find all isolated pairs of disk-dominated galaxies with:

- 150 km/s < $V_{max,halo}$ < 300 km/s
- - 80 km/s > V_{rad} > -180 km/s
- 500 kpc < D < 1 Mpc

Find ratio of the true mass to the "Timing Argument" estimate for each pair

Multiply by the TA estimate for the Local Group

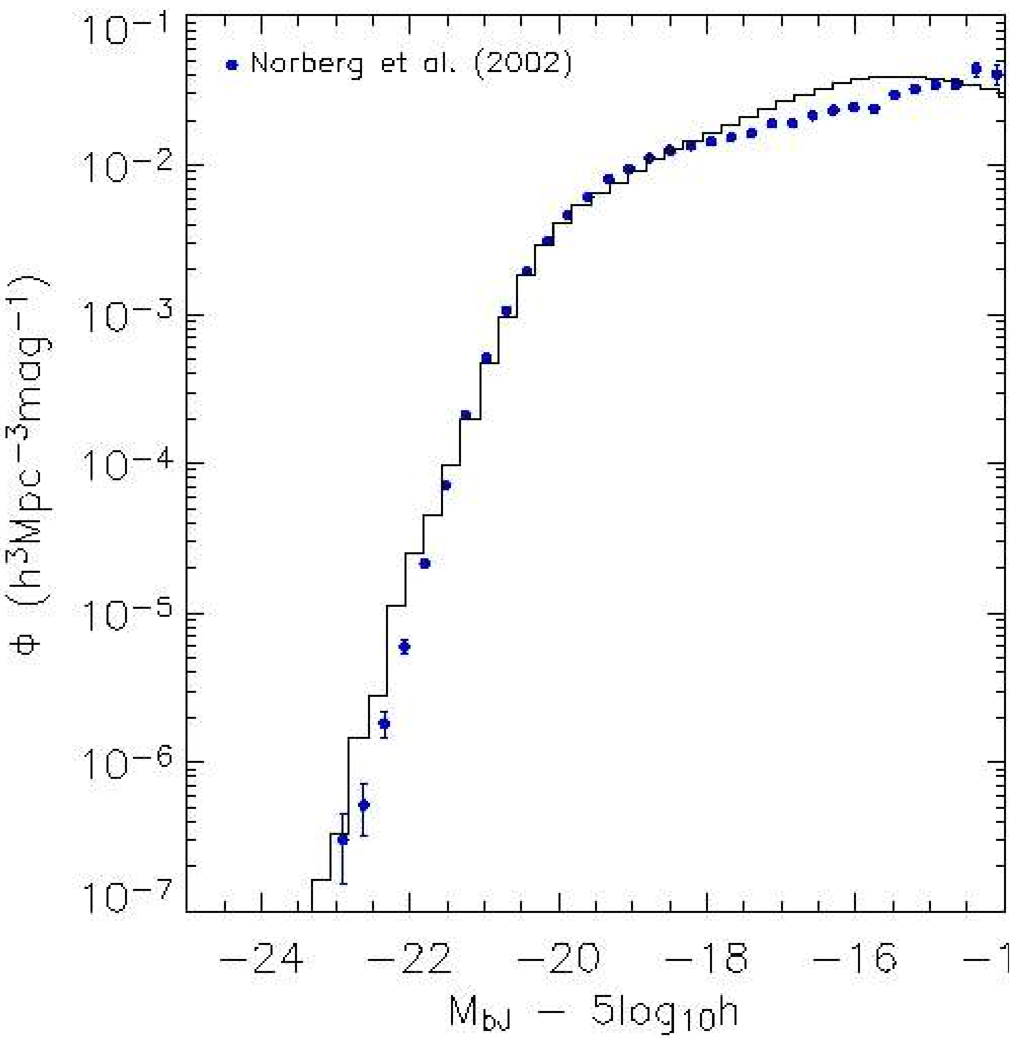


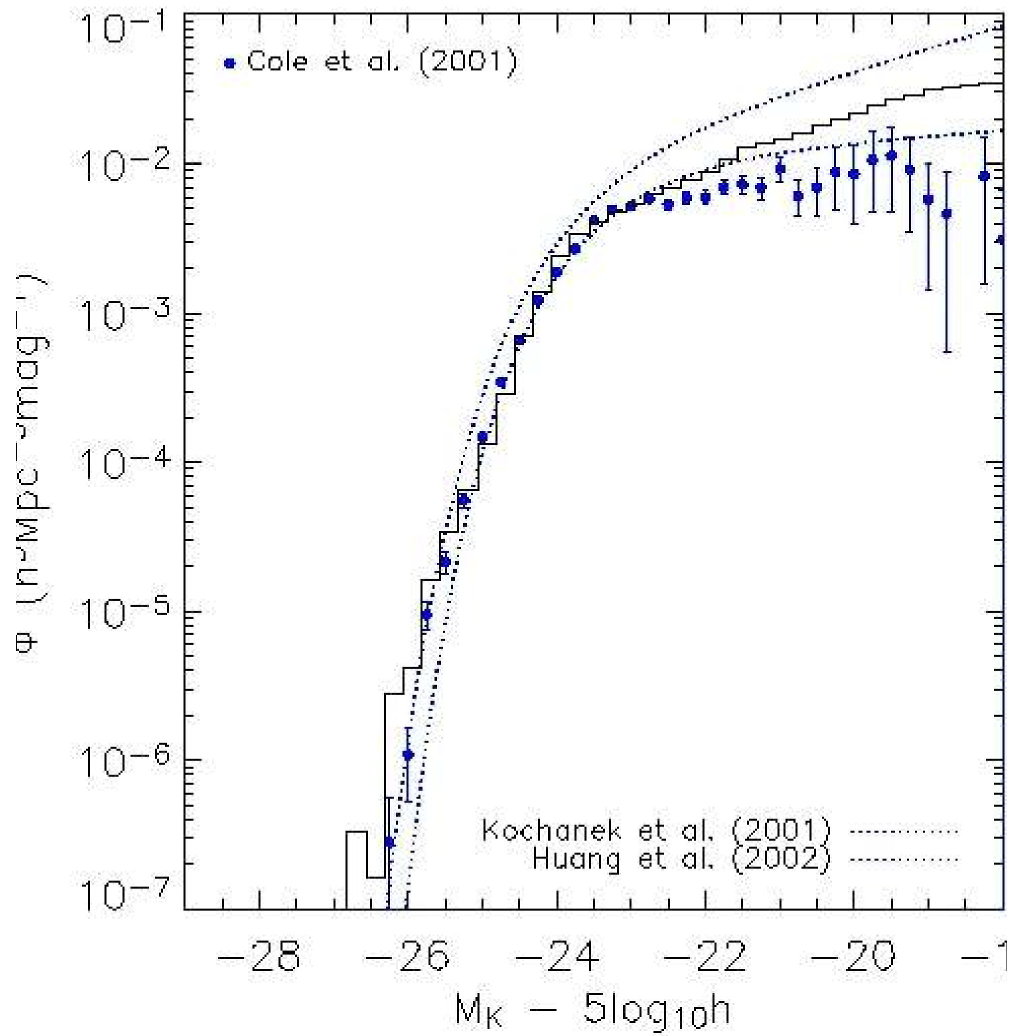
The effects of "radio mode" feedback on z=0 galaxies

Croton et al 2005

- In the absence of a "cure" for the cooling flow problem, the most massive galaxies are:
  - too bright
  - too blue
  - disk-dominated
- With cooling flows suppressed by "radio AGN" these galaxies are
  - less massive
  - red
  - elliptical

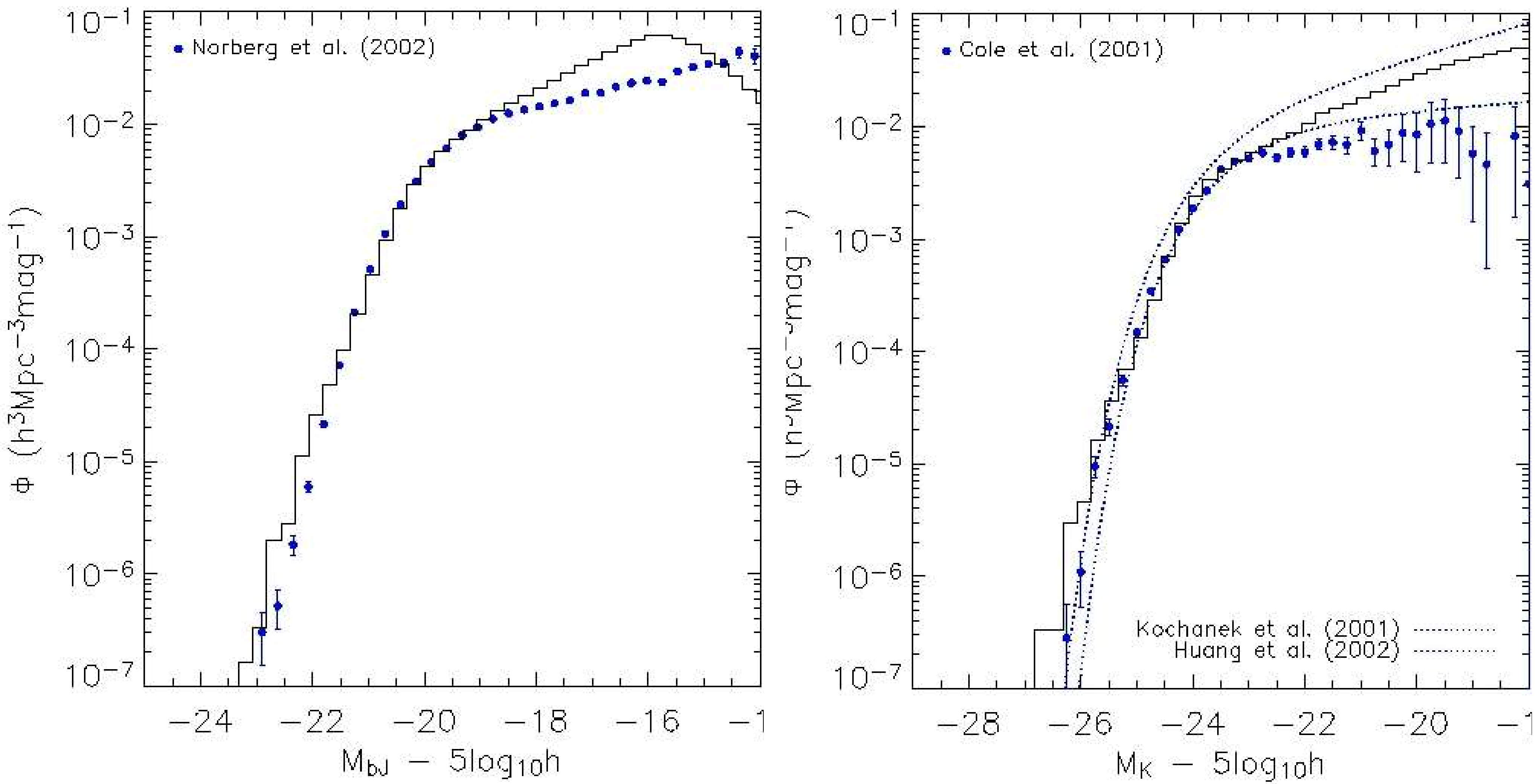
Effect of feedback on the Luminosity Function





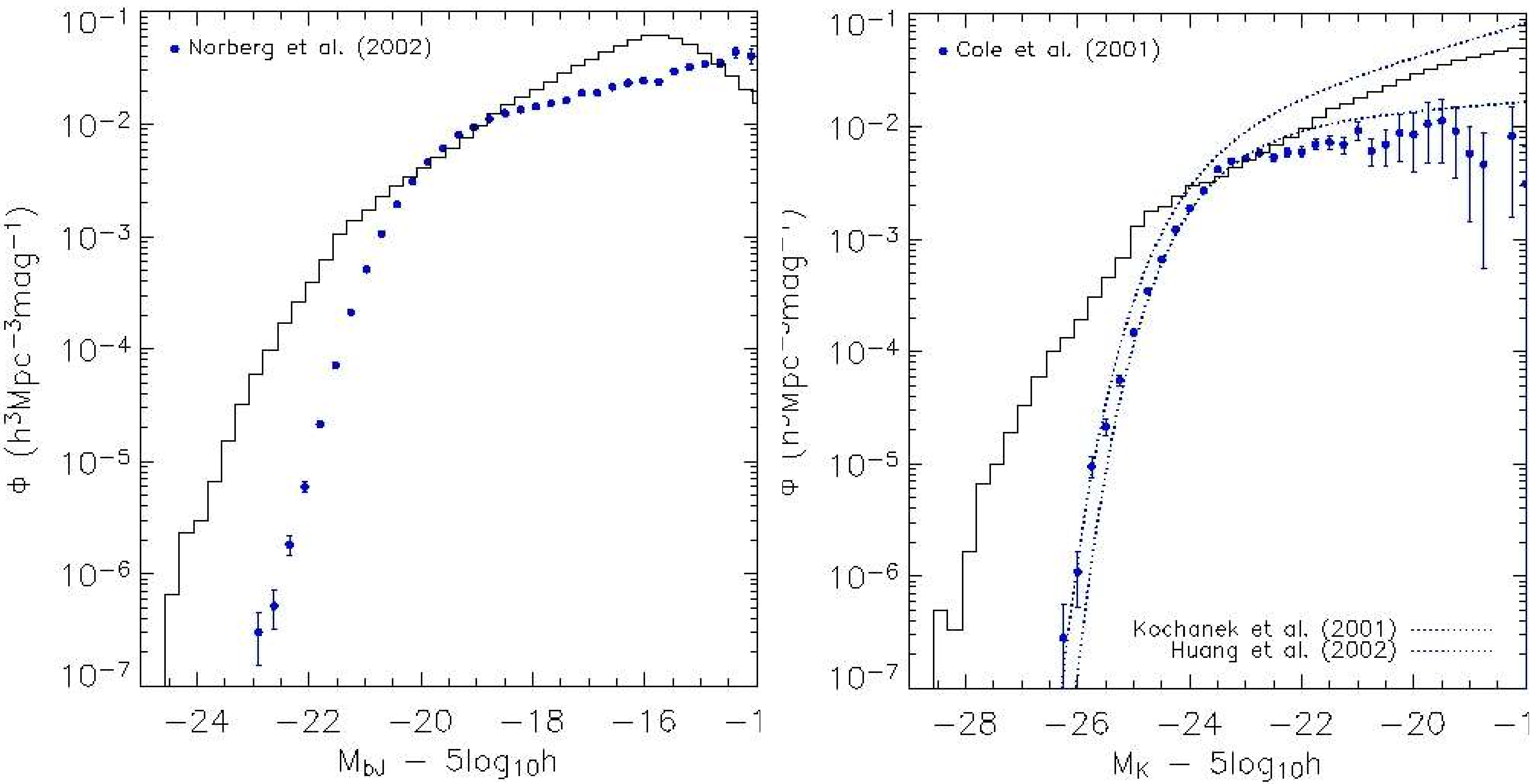
Full model with reionisation, AGN and SN feedback Croton et al 2005

Effect of feedback on the Luminosity Function



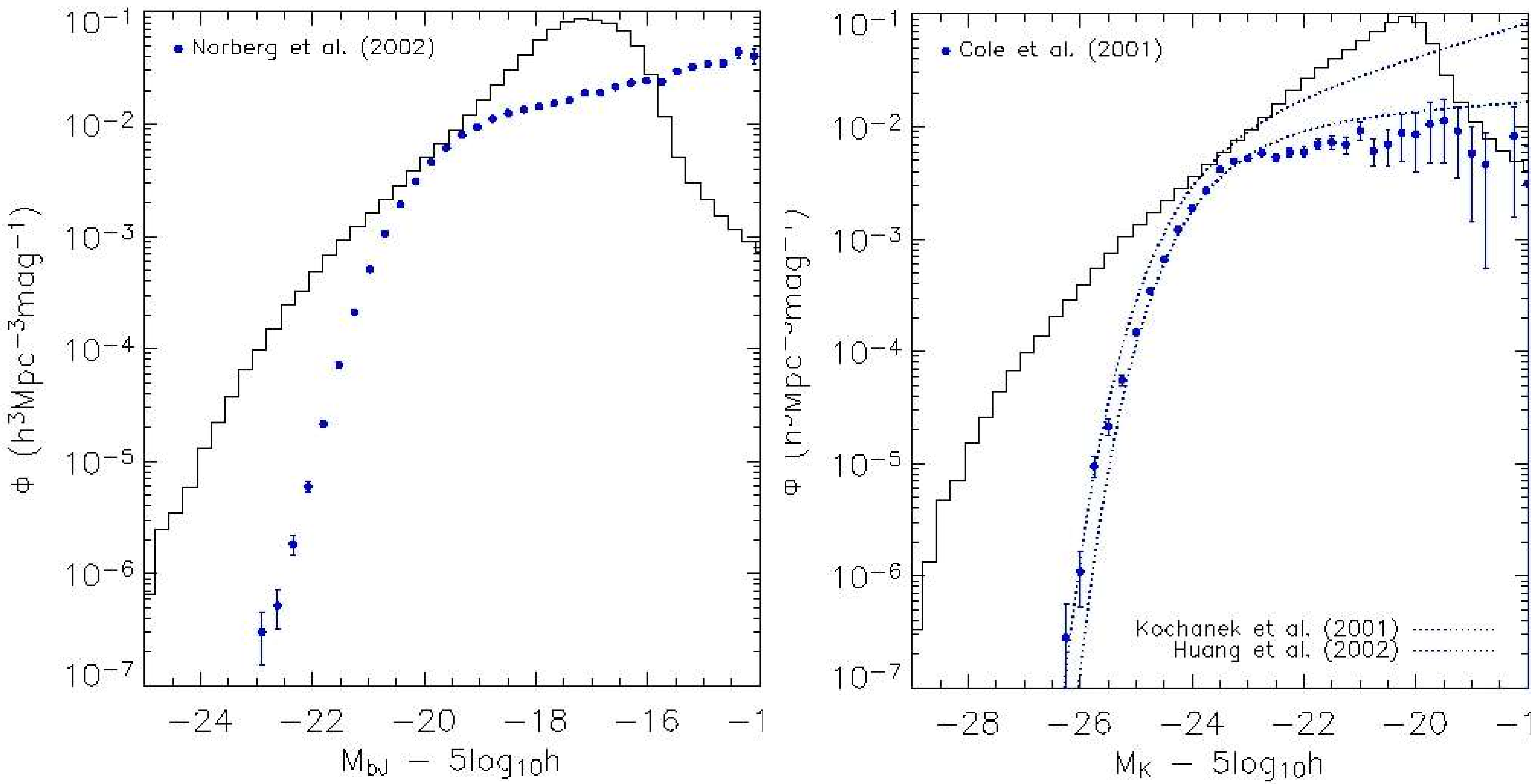
Full model with ~~reionisation~~, AGN and SN feedback Croton et al 2005

Effect of feedback on the Luminosity Function



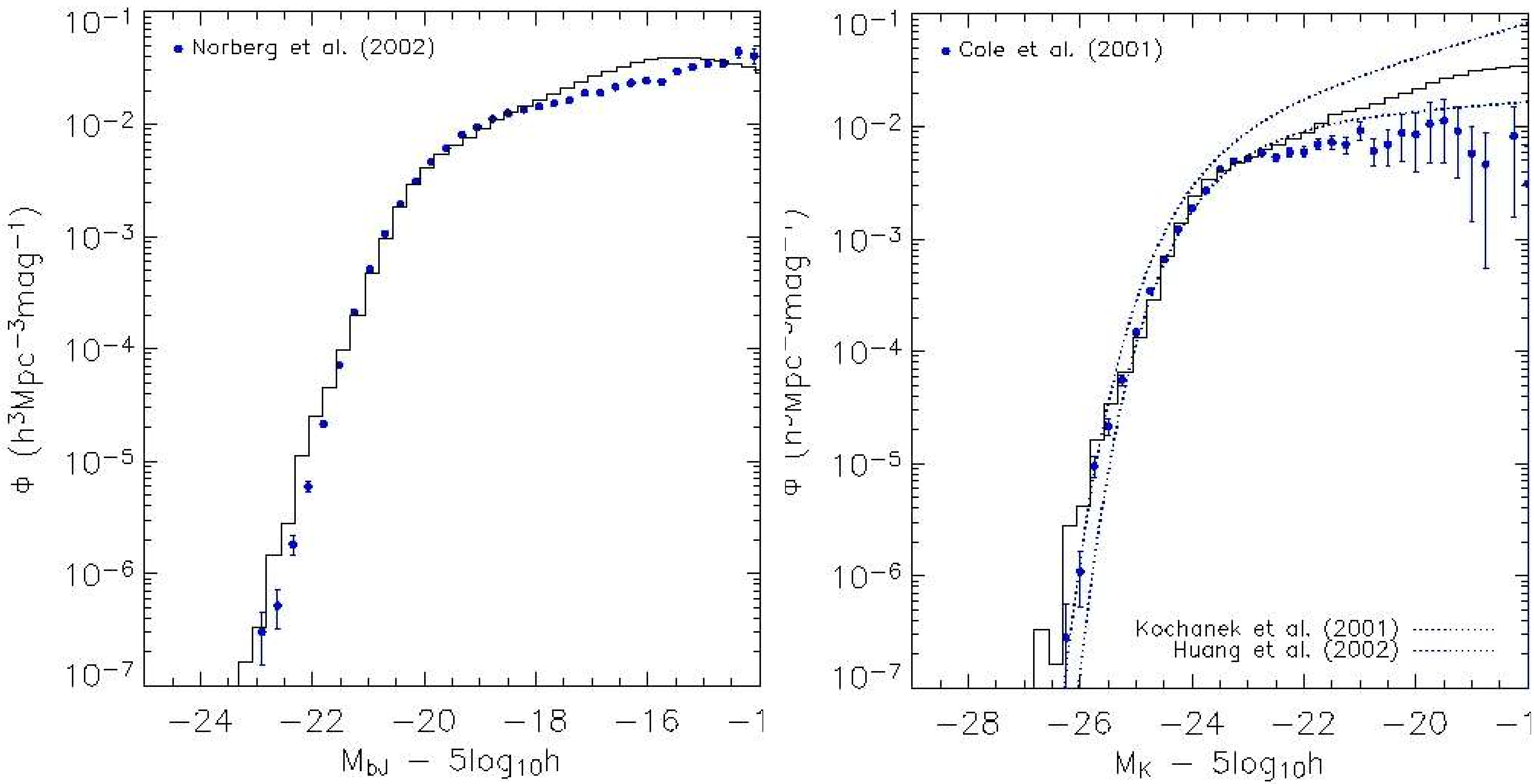
Full model with ~~reionisation~~, ~~AGN~~ and SN feedback   Croton et al 2005

Effect of feedback on the Luminosity Function

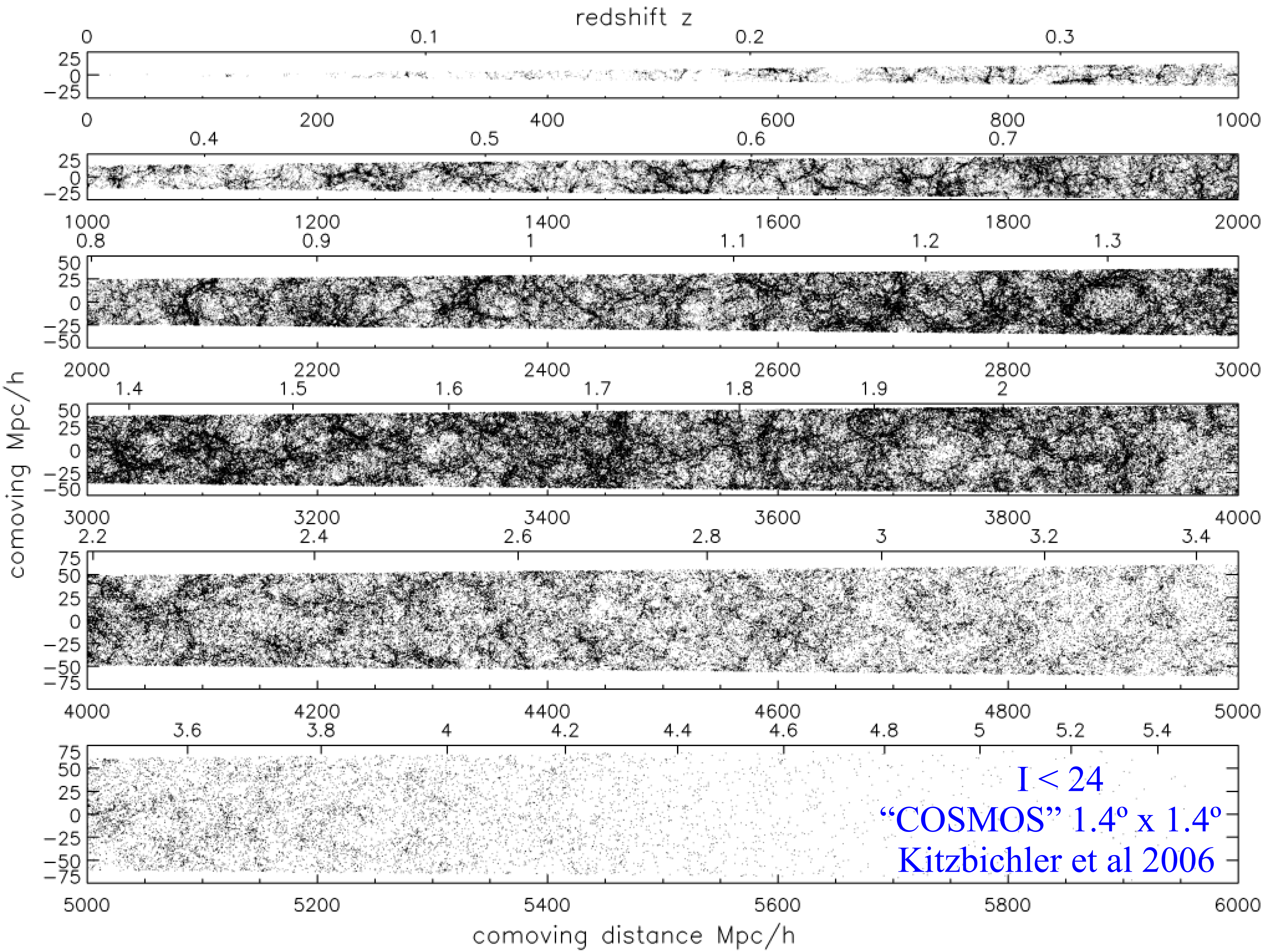


Full model with ~~reionisation~~, ~~AGN~~ and ~~SN~~ feedback Croton et al 2005

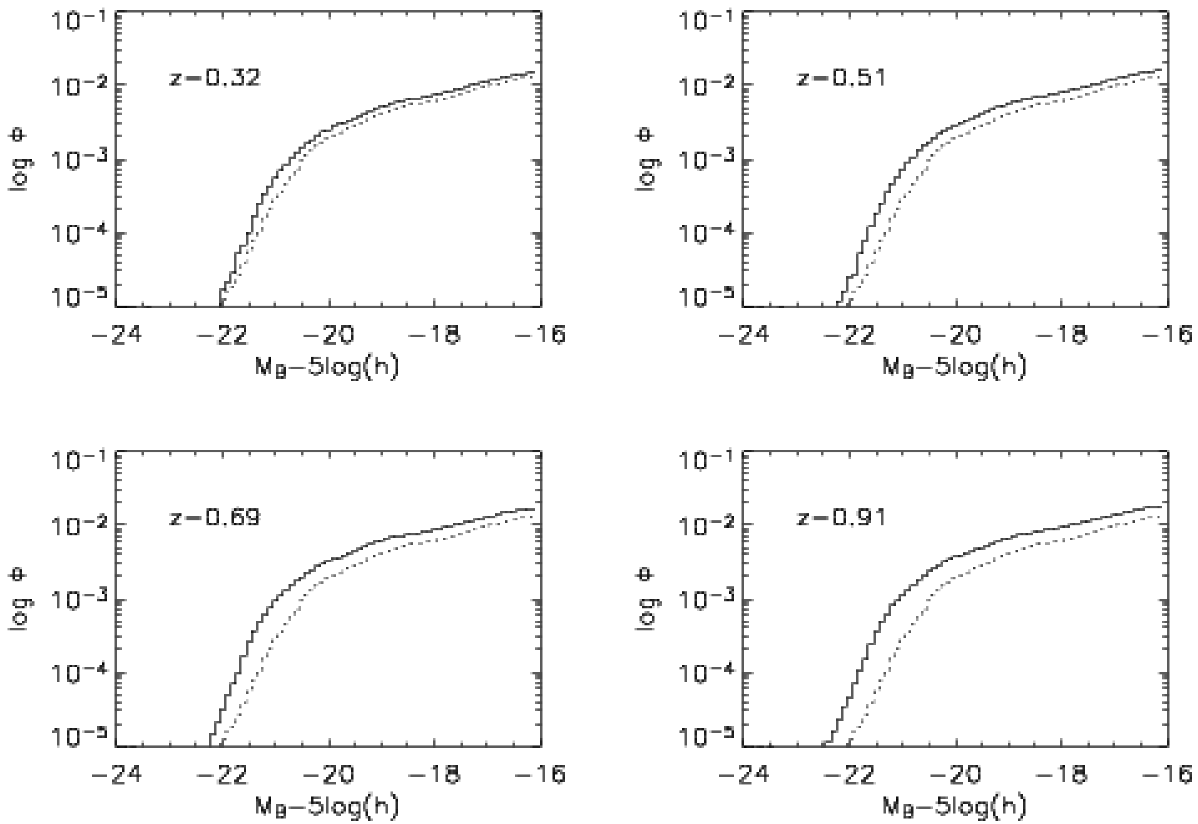
Effect of feedback on the Luminosity Function



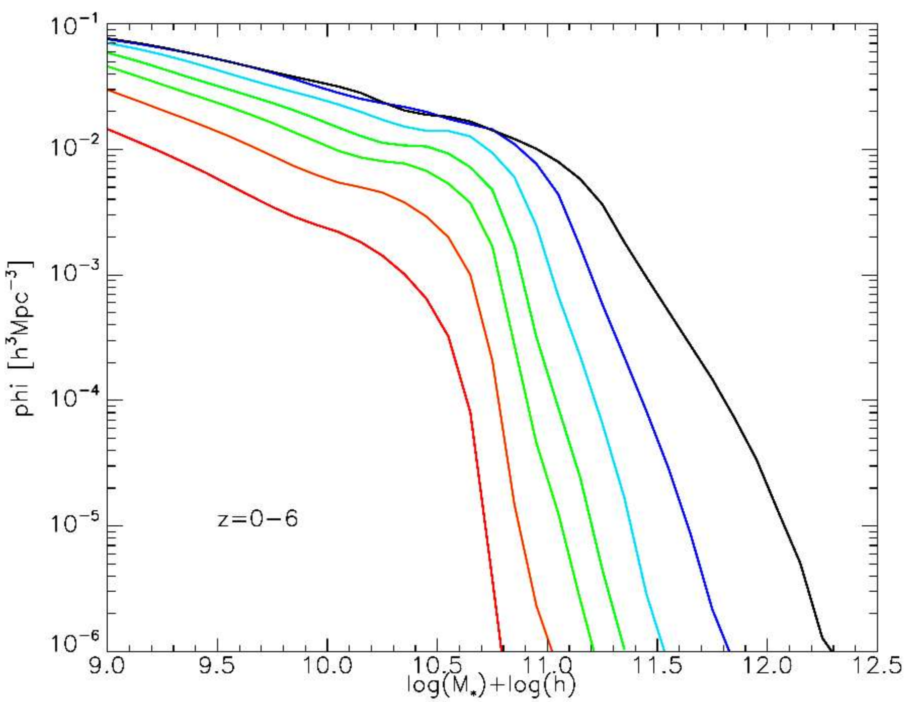
Full model with reionisation, AGN and SN feedback Croton et al 2005



redshift z
comoving Mpc/h
comoving distance Mpc/h
I < 24
"COSMOS" 1.4º x 1.4º
Kitzbichler et al 2006



B-band luminosity function evolution



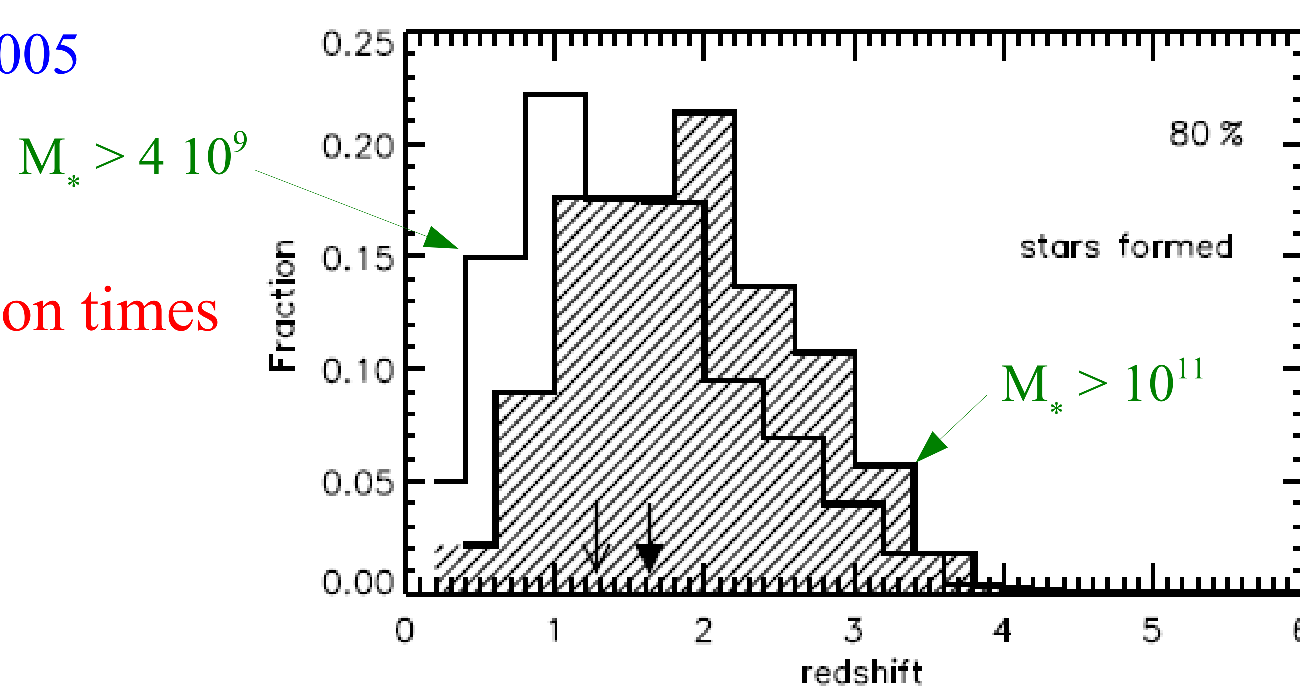
Mass function evolution

Kitzbichler et al 2006

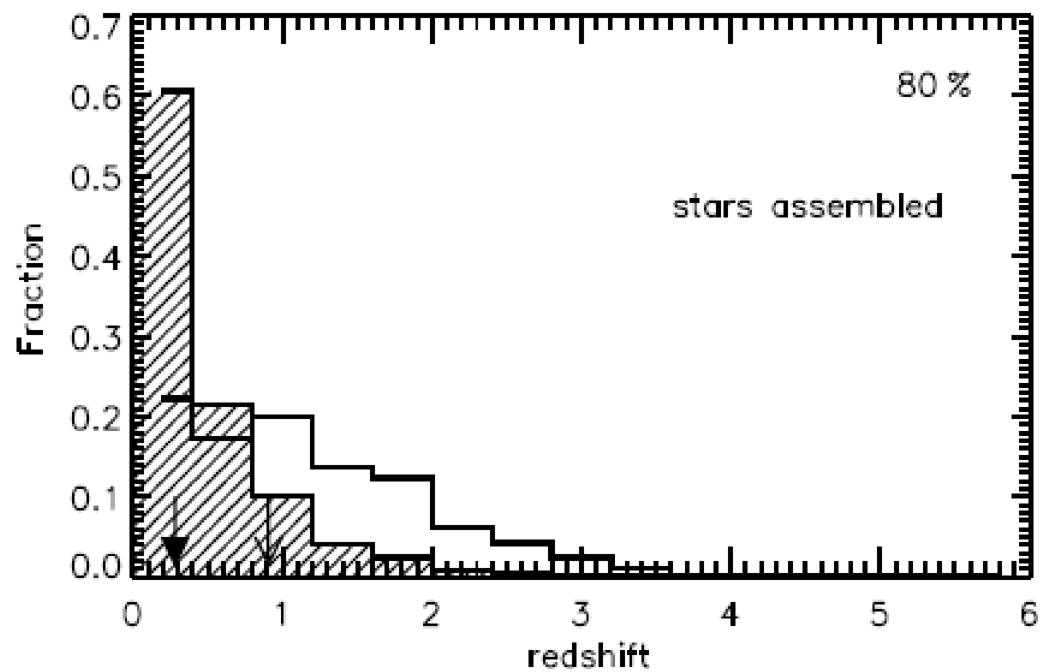
Formation histories of ellipticals

De Lucia et al 2005

Distribution of star formation times

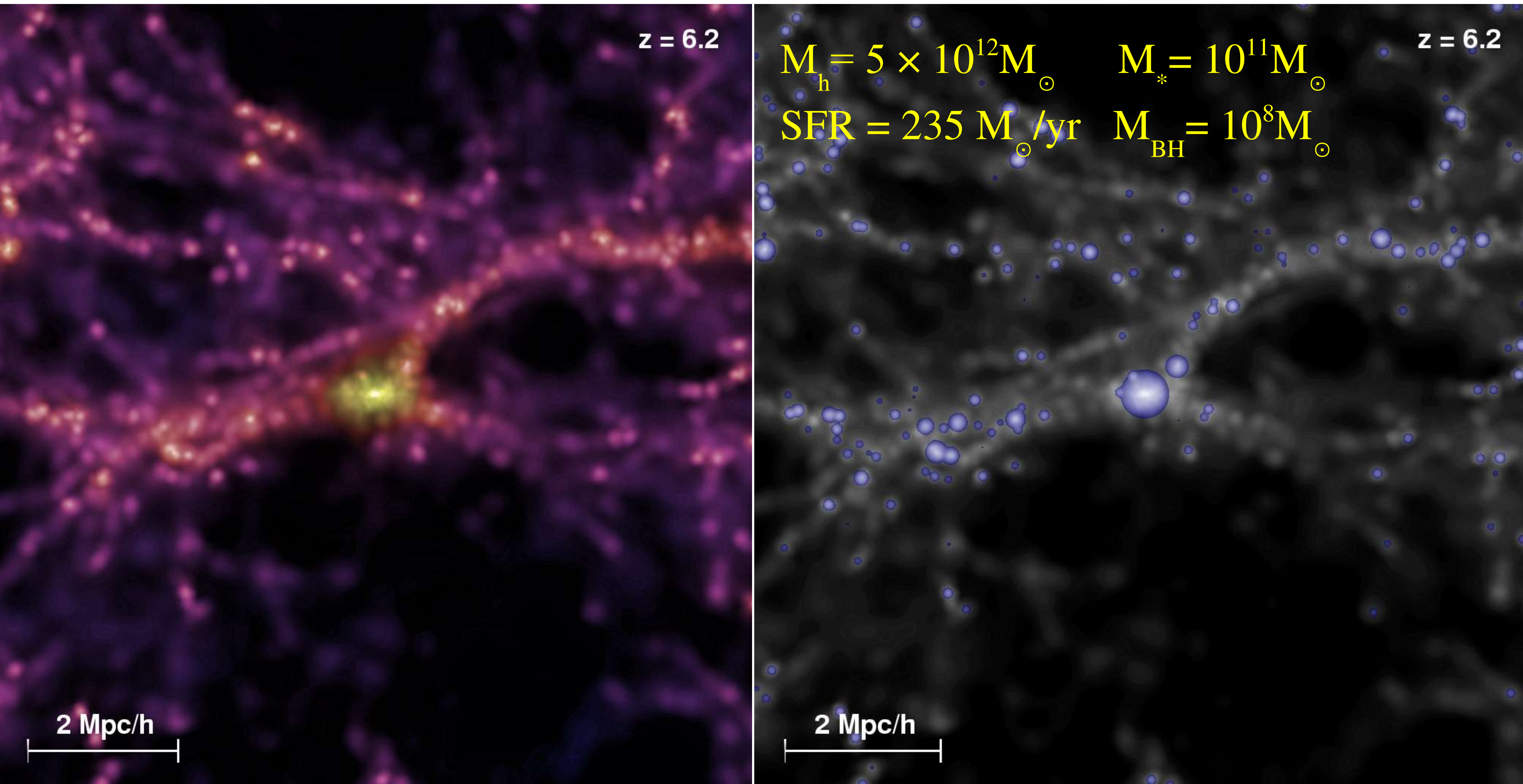


Distribution of assembly times



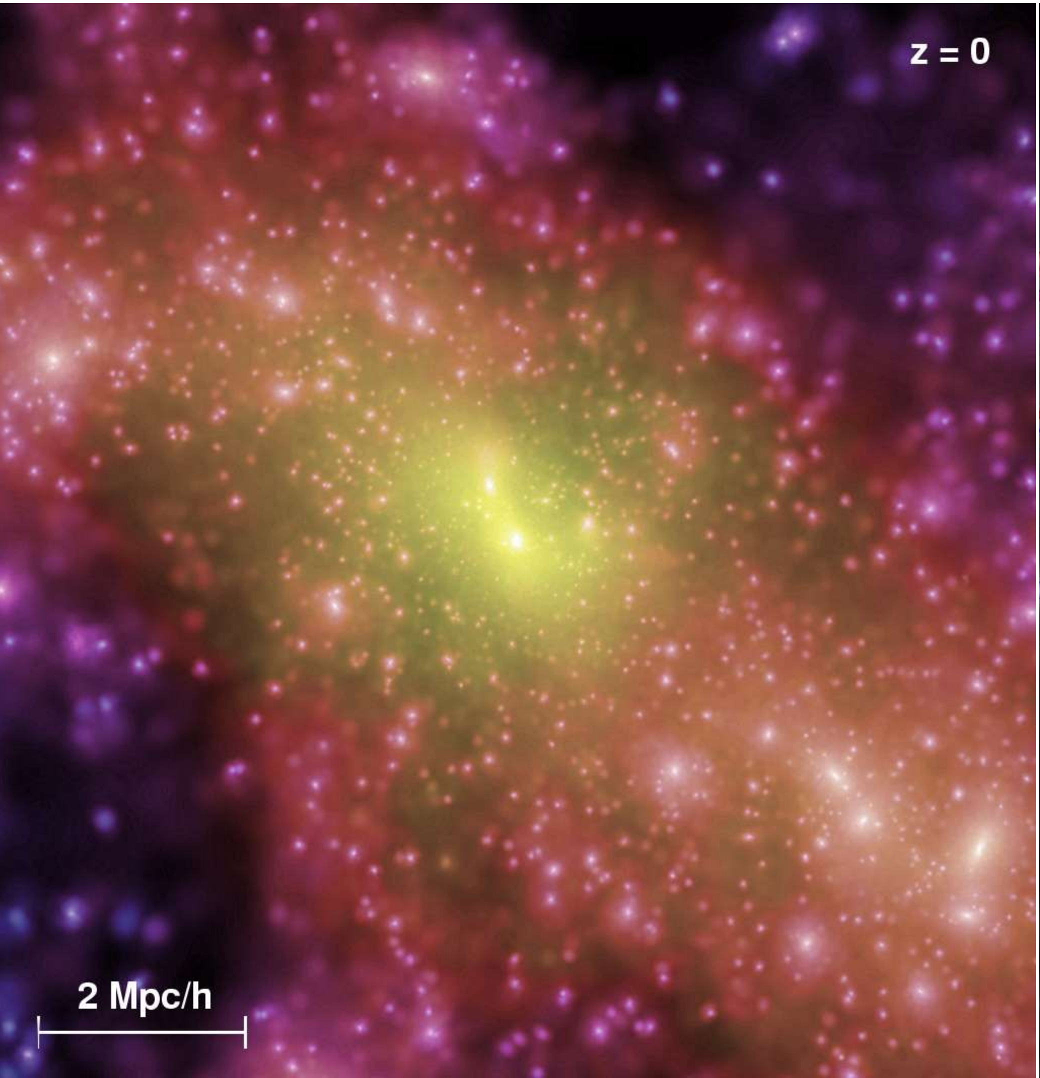
A bright quasar and its surroundings at 1 billion years

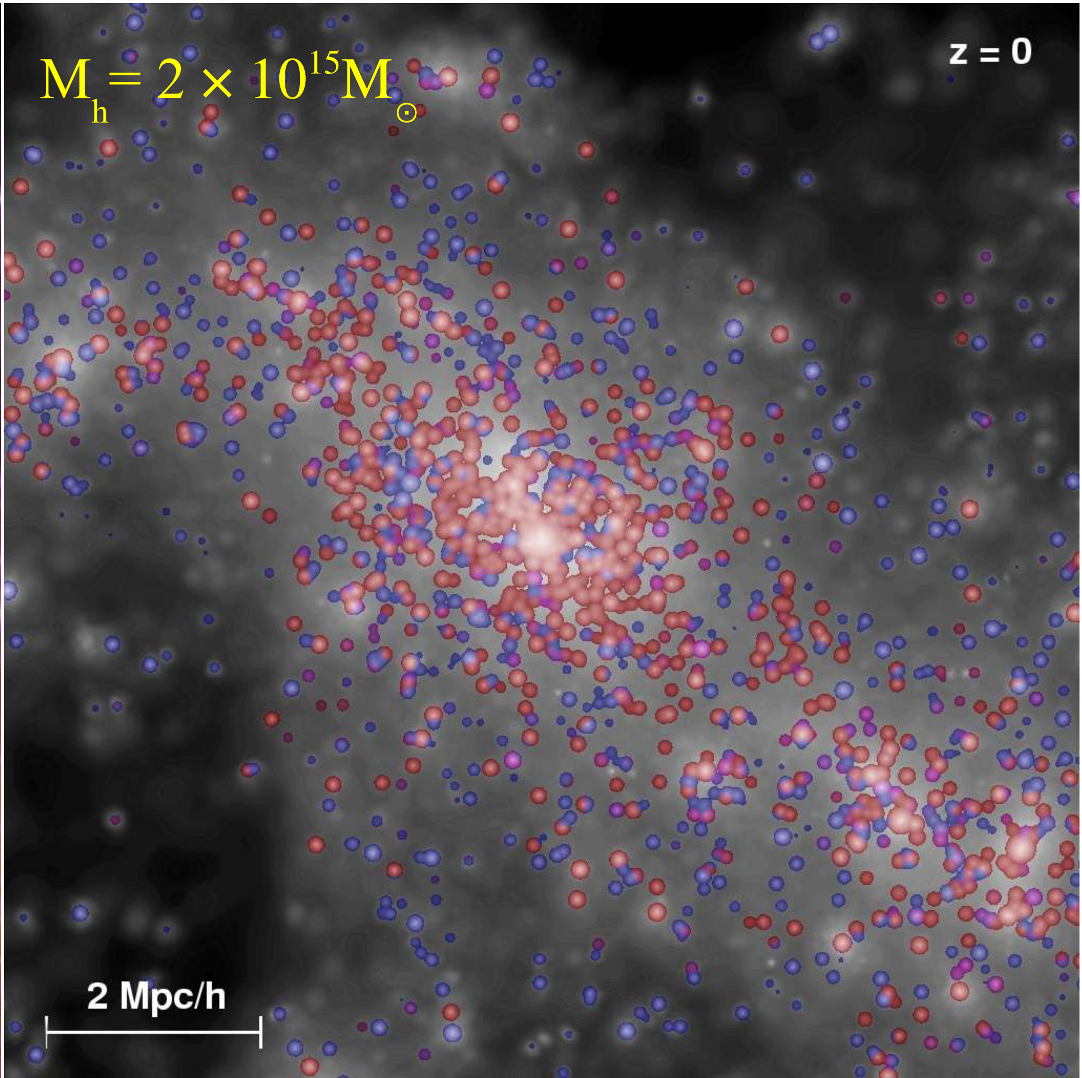
One of the most massive dark matter clumps, containing one of the most massive galaxies and most massive black holes.



The quasar's descendant and its surroundings today, at t = 13.7 billion years

One of the most massive galaxy clusters. The quasar's descendant is part of the central massive galaxy of the cluster.





GERMAN ASTROPHYSICAL GAVO VIRTUAL OBSERVATORY

Exploring the milli–Millennium simulation with a relational database


```
select D.I_HALO,
       D.SNAPNUM,
       D.N_P as D_NP,
       P1.N_P as P1_NP,
       P2.N_P as P2_NP
  from HALO P1,
       HALO P2,
       HALO D
 where P1.SNAPNUM=P2.SNAPNUM
   and P1.I_HALO < P2.I_HALO
   and P1.I_DESCENDANT = D.I_HALO
   and P2.I_DESCENDANT = D.I_HALO
   and P1.N_P >= .2*D.N_P
   and P2.N_P >= .2*D.N_P
   and D.N_P > 1000
```

Execute Query

Clear all

Help

http://www.g-vo.de

Maximum number of rows to return to the query form: 10

Previous queries :

Halo 1 Galaxy 1 Find halos/galaxies at a given redshift (SNAPNUM) within a certain part of the simulation volume (X,Y,Z).

Halo 2 Find the whole progenitor tree, in depth–first order, of a halo identified by its id (I_HALO)

Halo 3 Find the progenitors at a given redshift (SNAPNUM) of all halos of mass (N_P) greater than 4000 at a later redshift (SNAPNUM). The progenitors are limited to have mass >= 100.

Halo 4 Find all the halos of mass (N_P) >= 1000 that have just had a major merger, defined by having at least two progenitors of mass >= 0.2*descendant mass.

Halo 5 Galaxy 5 Find the mass/luminosity function of halos/galaxies at z=0 using logarithmic intervals.

Galaxy 6 Find the Tully–Fisher relation, Mag_b/v/i/k vs V_vir for galaxies with bulge/total mass ratio < 0.1. Subsample by about 1% (RANDOM between 20000 and 30000).

Reformat CSV

Plot (VOPlot) This button wil attempt to start up VOPlot within an applet, so that the current result can be explored graphically. This clearly requires that the browser has been configured for viewing applets.
DISCLAIMER This functionality has been partially tested only. Any problems are our responsibility, not VOPlot's.
It seems that the applet does not work properly with Konqueror.

Query time (in millisec) = 15623
Number of rows retrieved from database = 12 (Maximum # = 10000)

i_halo	snapnum	d_np	p1_np	p2_np
2576	60	1079	924	222