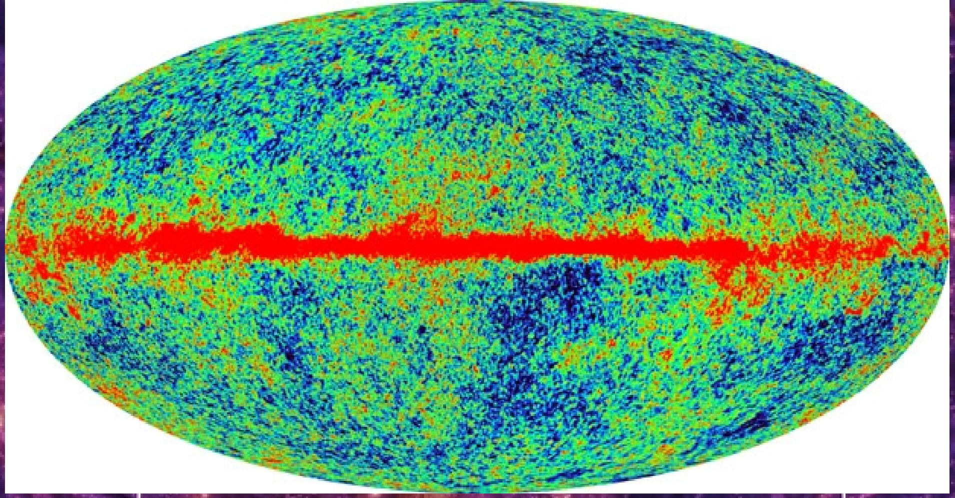


From stars to galaxies: Venice October 2006

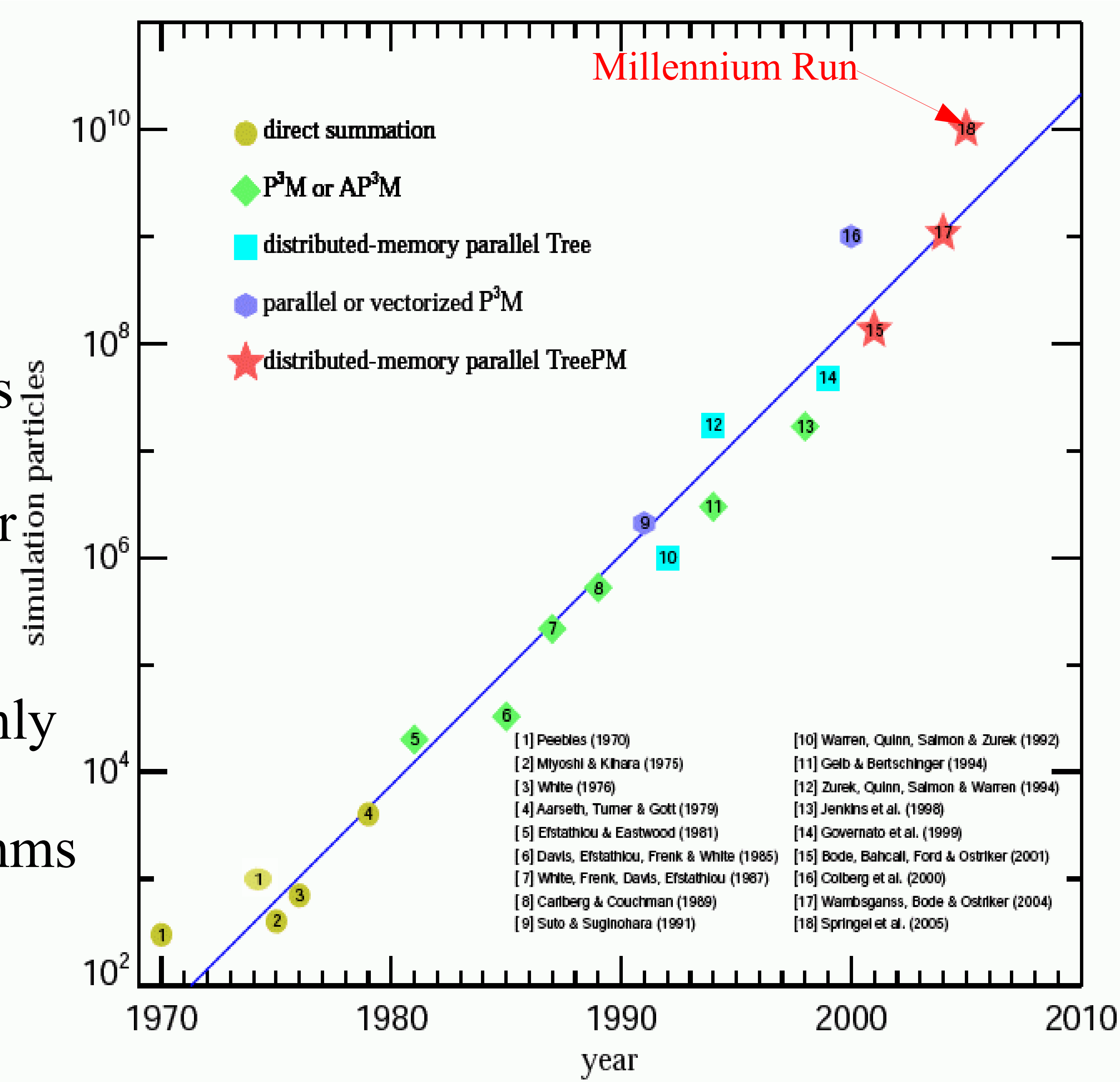
Large-scale Modelling of the: Evolution of galaxies

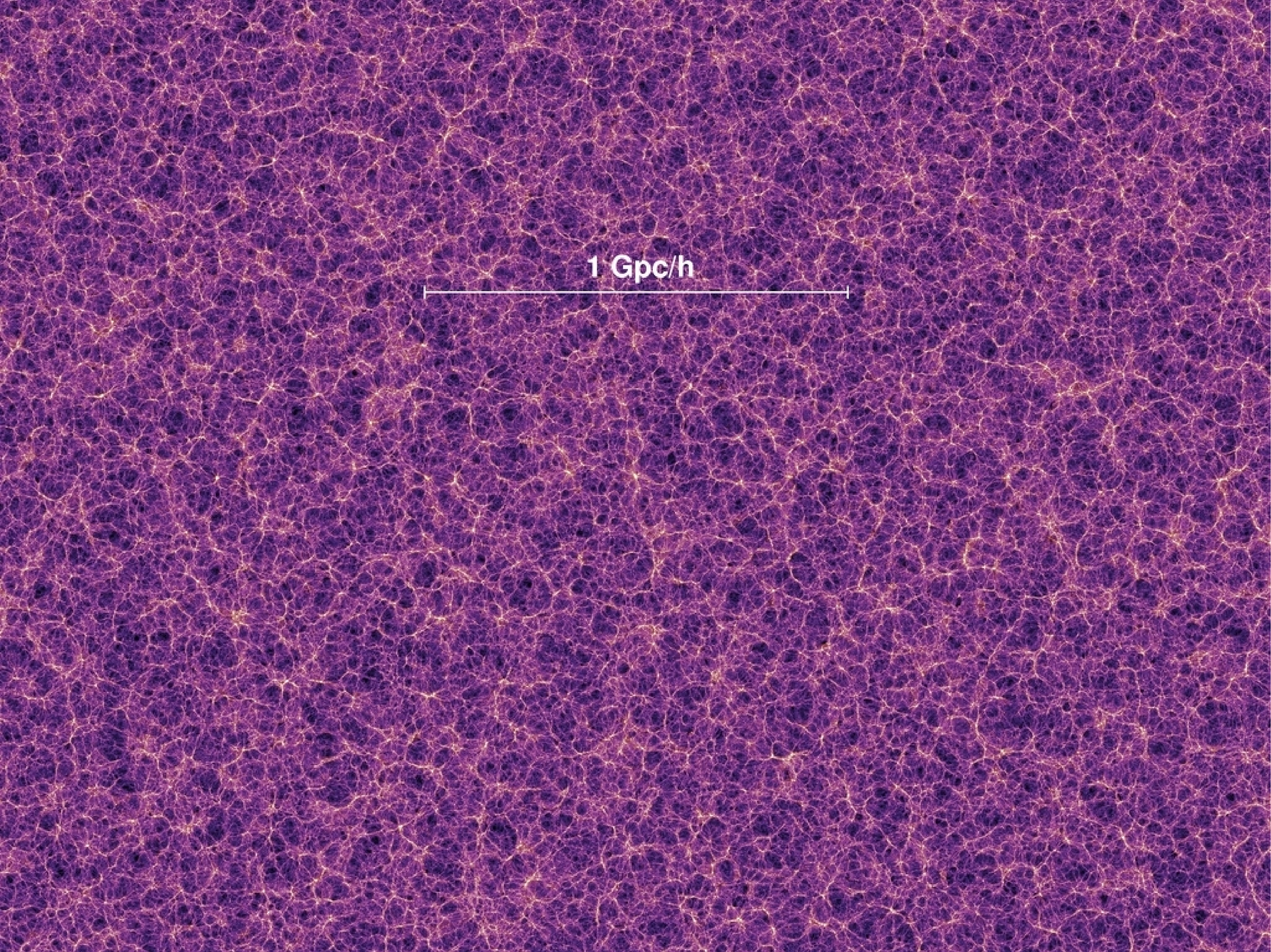
Simon White
Max Planck Institute for Astrophysics

Moore's Law for Cosmological N-body Simulations

Springel et al 2005

- 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




1 Gpc/h


3.9 Mpc/h

Simulating galaxies /AGN with the Millennium Run

Springel et al 2005; Croton et al 2006, De Lucia et al 2006, De Lucia & Blaizot 2006

- Build and store merger trees which encode the detailed assembly history of every z=0 halo <u>and</u> of the substructure within it

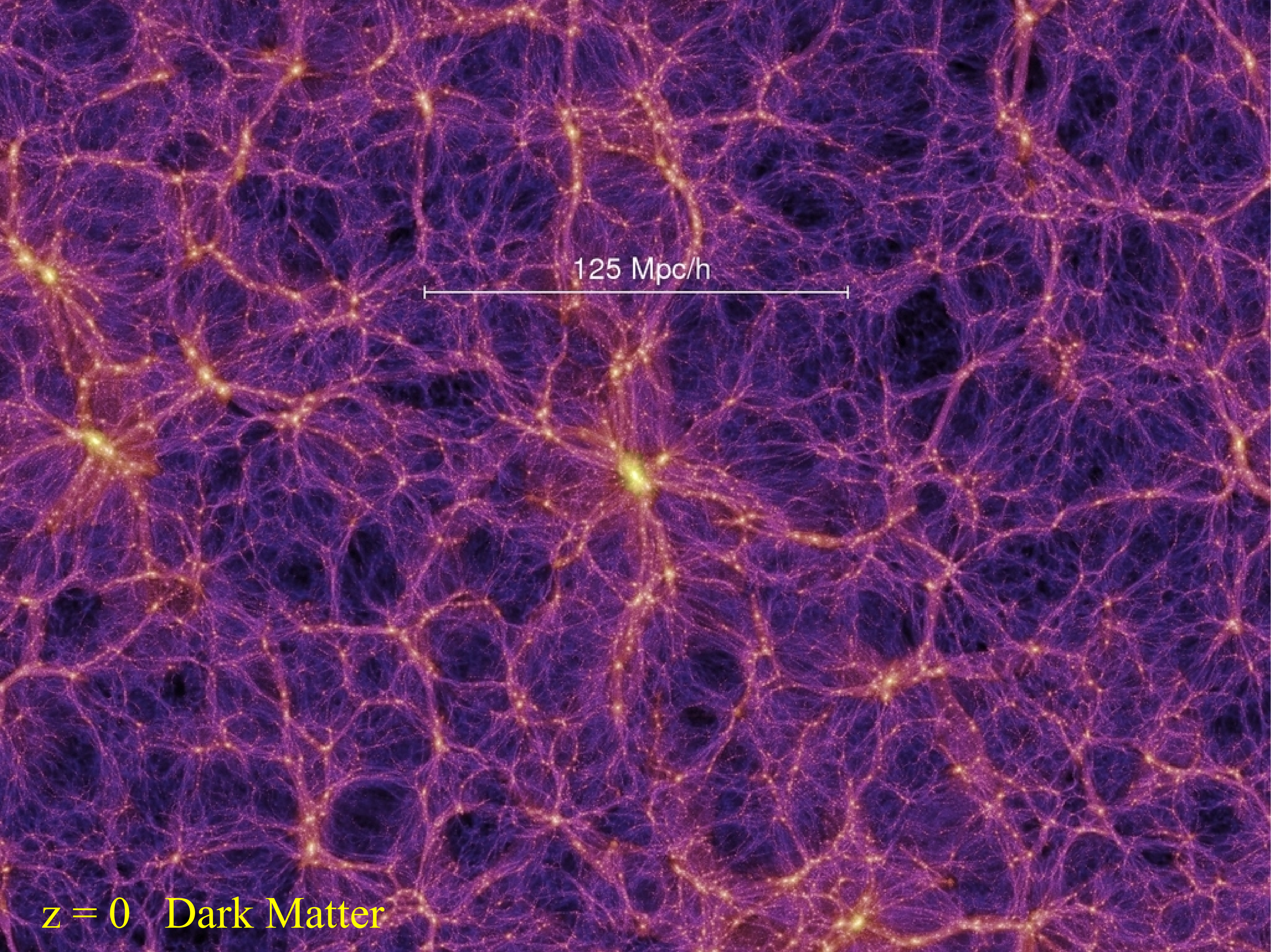
- Implement models for the formation/evolution of galaxies to follow
  - -- accretion, shock-heating and cooling of diffuse gas into disks
  - -- star formation from the ISM in disks
  - -- stellar evolution
  - -- SN feedback and stellar winds
  - -- chemical enrichment/dust formation
  - -- galaxy merging/morphological transformation

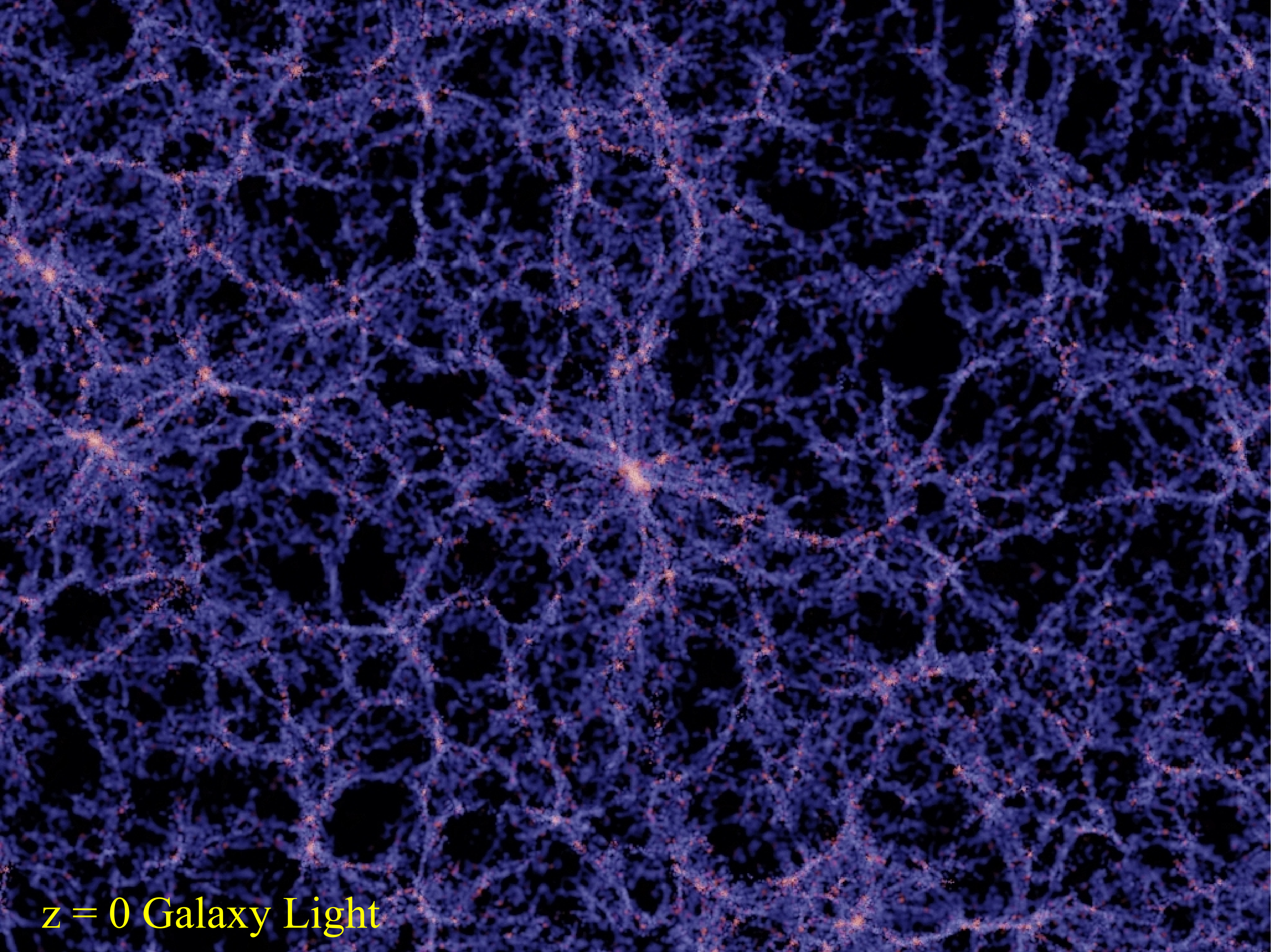
  [After Springel et al (2001) and De Lucia et al (2004)]

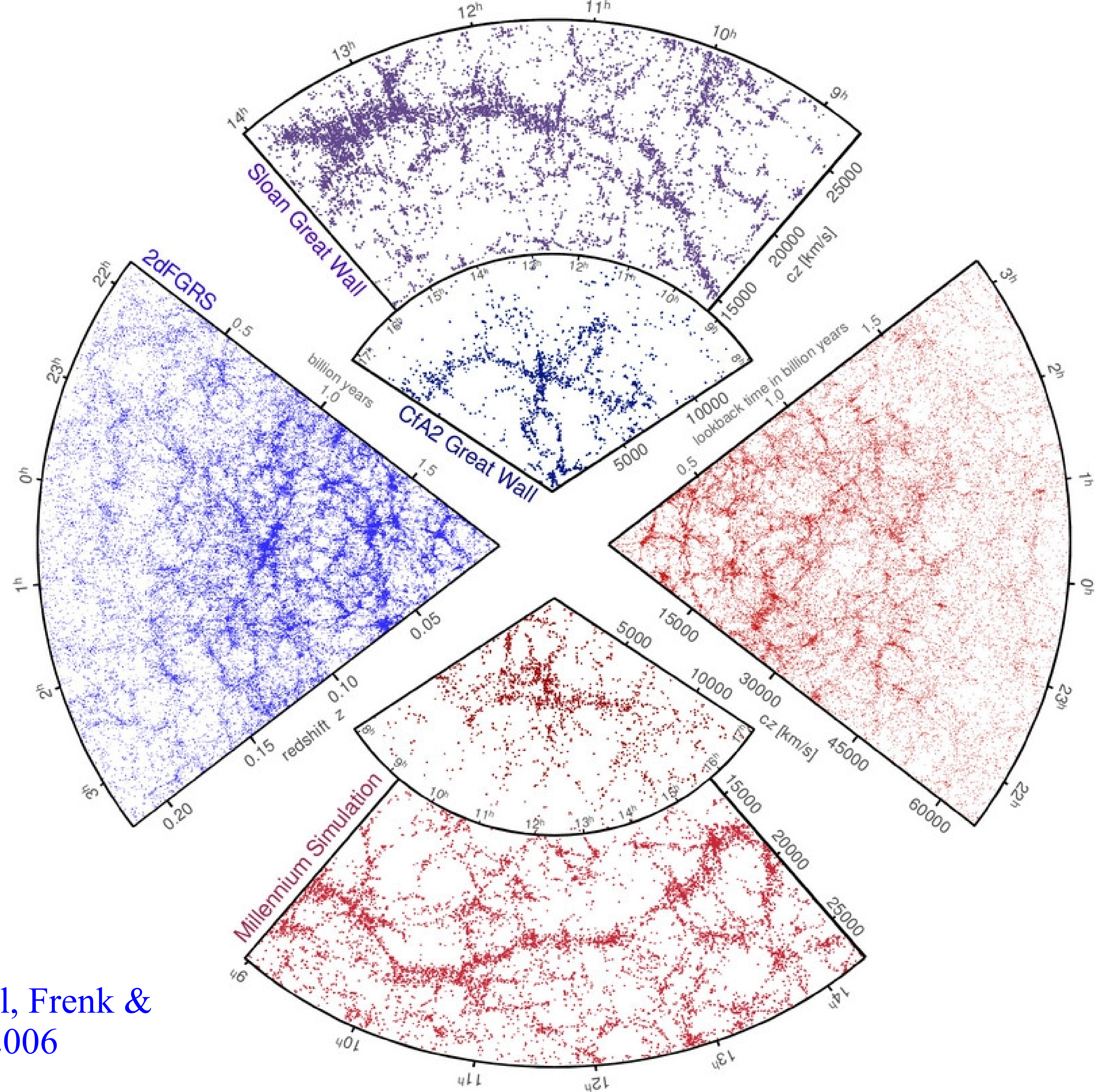
- Implement models for the growth of central black holes to follow
  - -- formation and growth from ISM gas during mergers
  - -- black hole mergers following galaxy mergers

  [After Kauffmann & Haehnelt (2000)]

- Include "radio mode" feedback from BH at cooling flow centres
  - -- energy feedback from BH in the central dominant galaxy depends on BH mass, gas temperature and gas mass fraction $\propto f_{gas} m_{BH} T^{1.5}$


125 Mpc/h
z = 0   Dark Matter

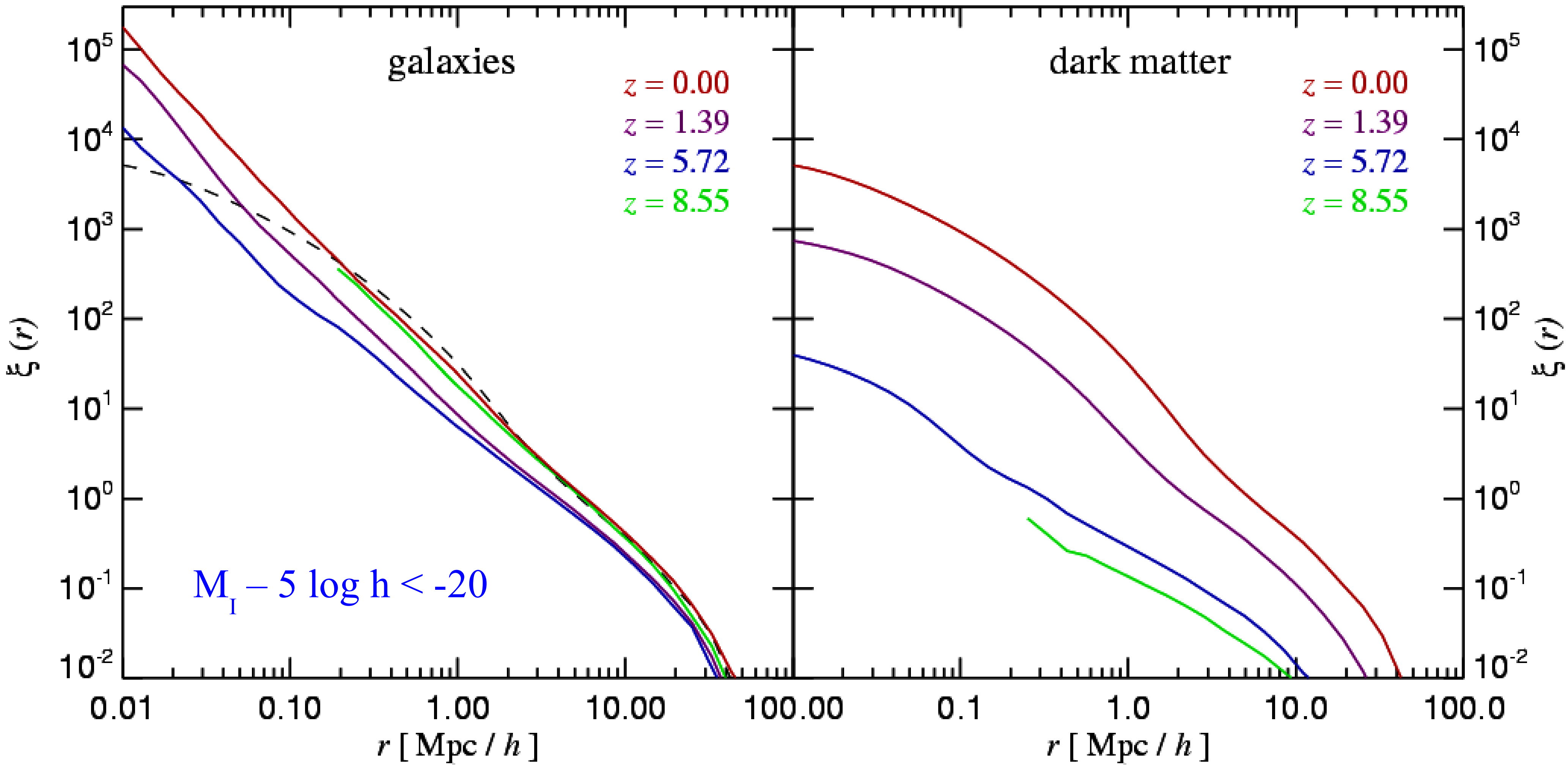

z = 0 Galaxy Light



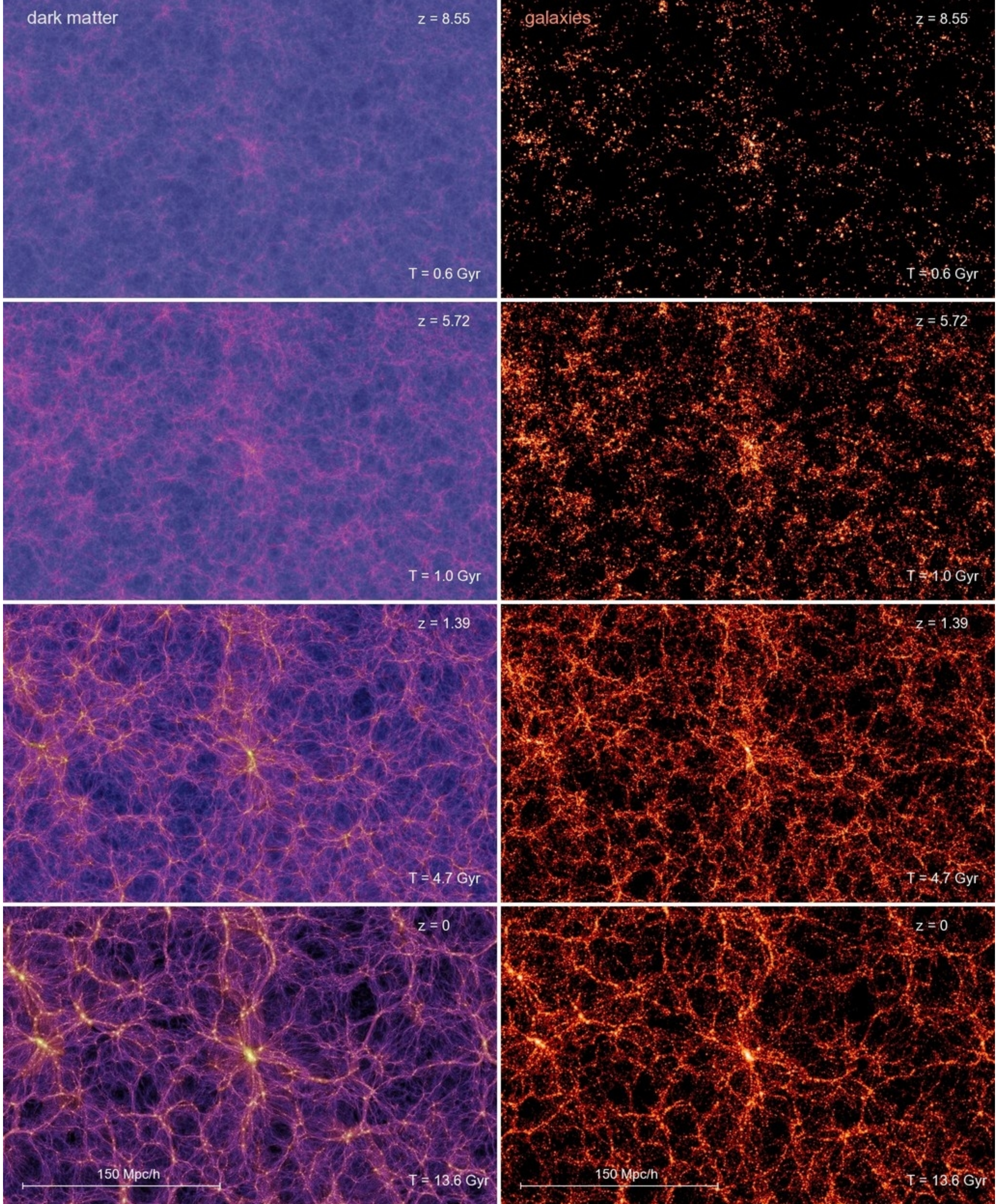
Springel, Frenk &
White 2006

Evolution of mass and galaxy correlations

Springel, Frenk & White 2006



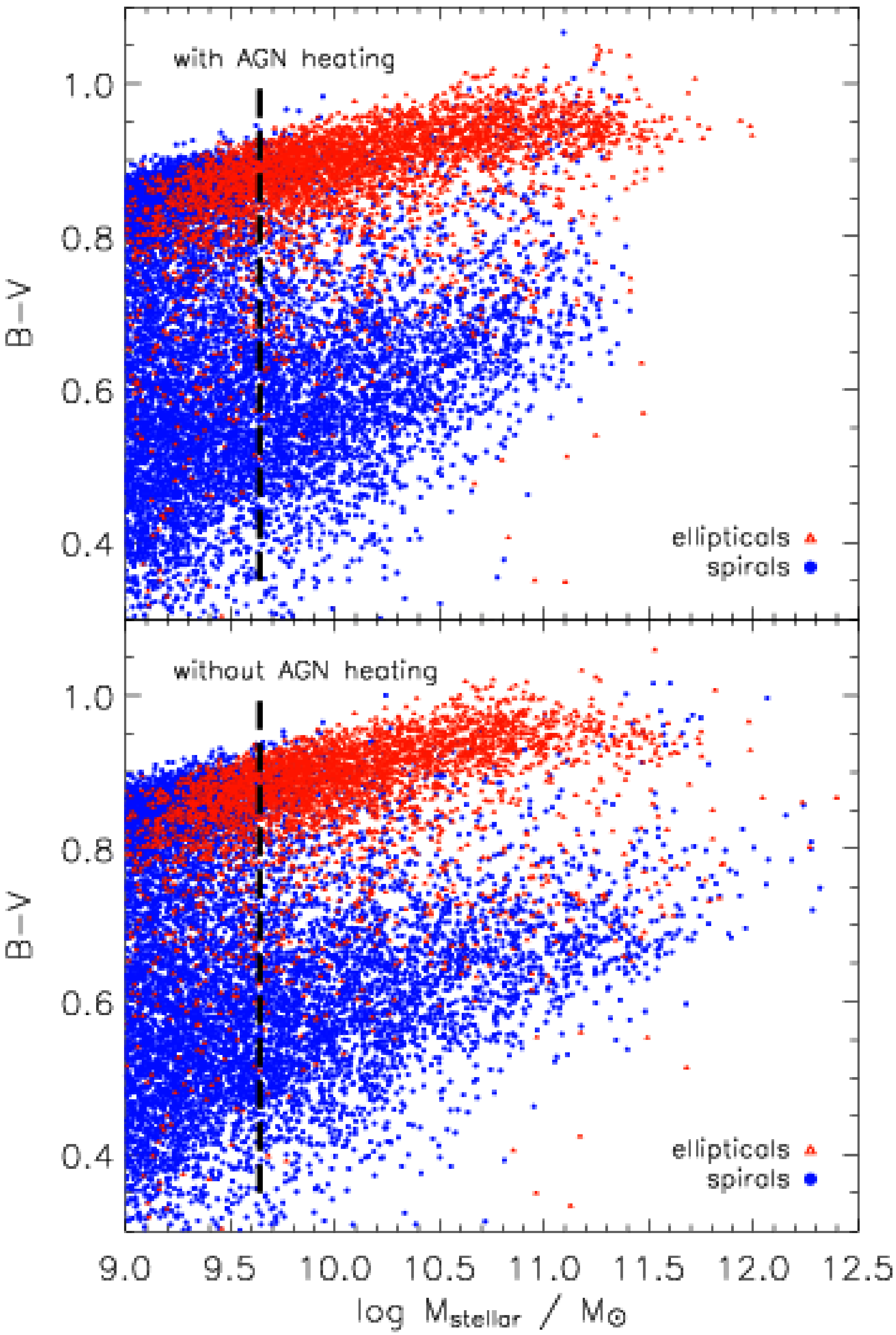
Large-scale structure at high redshift



Springel, Frenk & White 2006

Large-scale structure in the galaxy distribution evolves very little with redshift

It is as strong at z=8.5 as at z=0

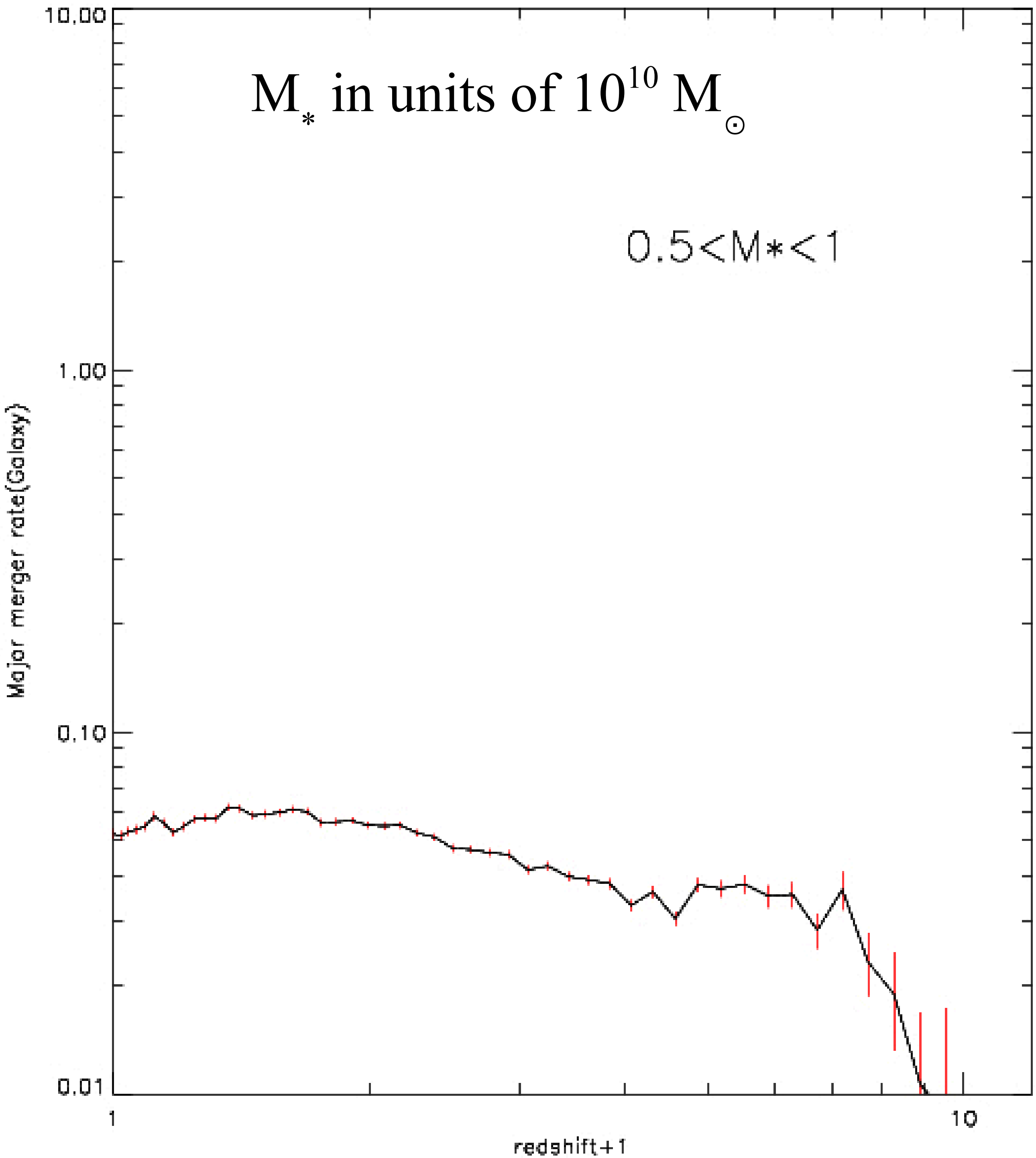


The effects of "radio mode" feedback on z=0 galaxies

Croton et al 2006

- 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

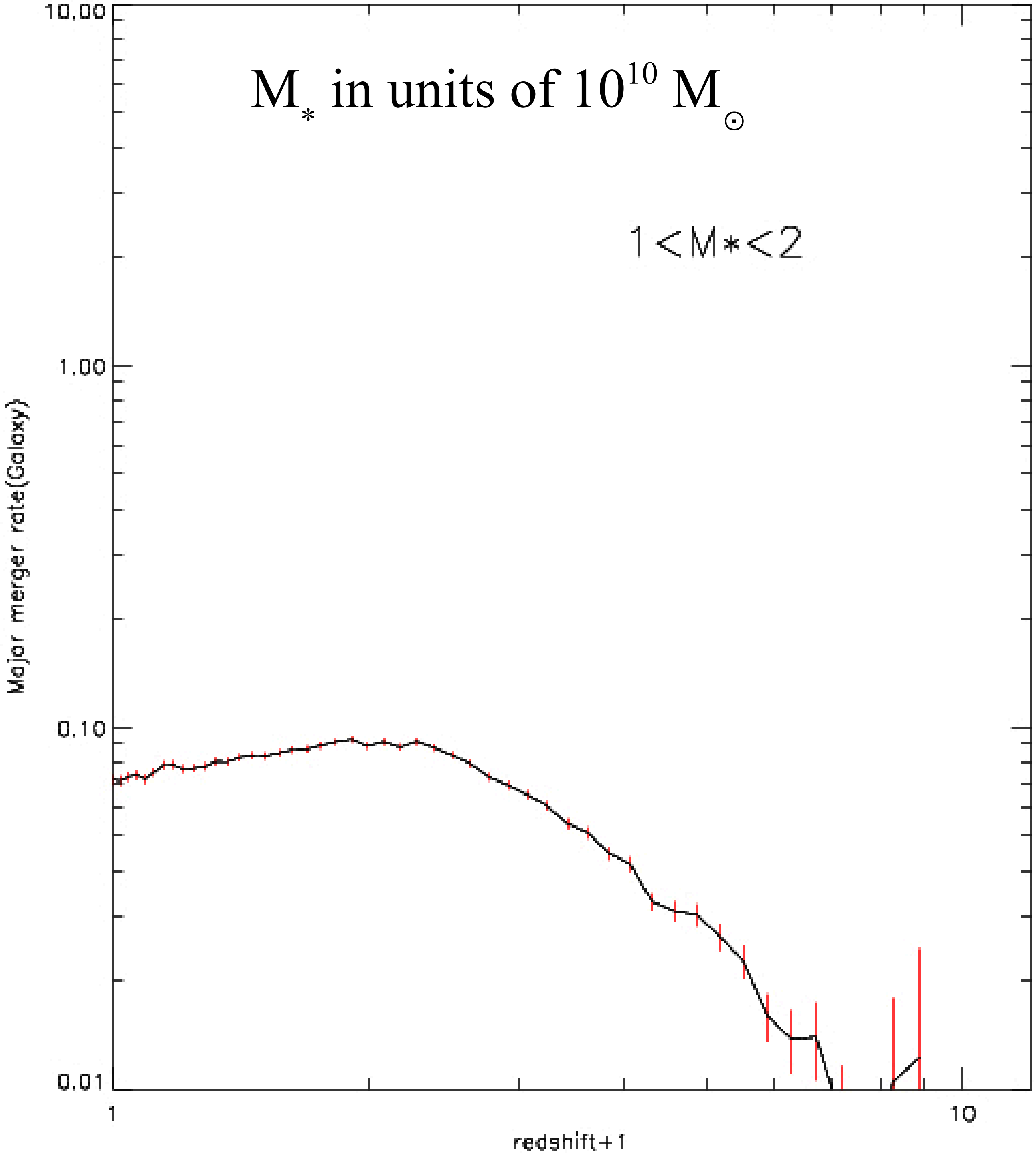


DIMENSIONLESS MAJOR MERGER RATES

Qi Guo & SW

$$R = \langle\, t_{Hubb}\ F \,/\, \Delta t \,\rangle$$

where F is the fraction of galaxies that had a major merger ($M_{proj,\,1} > M_{proj,\,2} / 3$) in the last $\Delta t \sim 0.2$ Gyr



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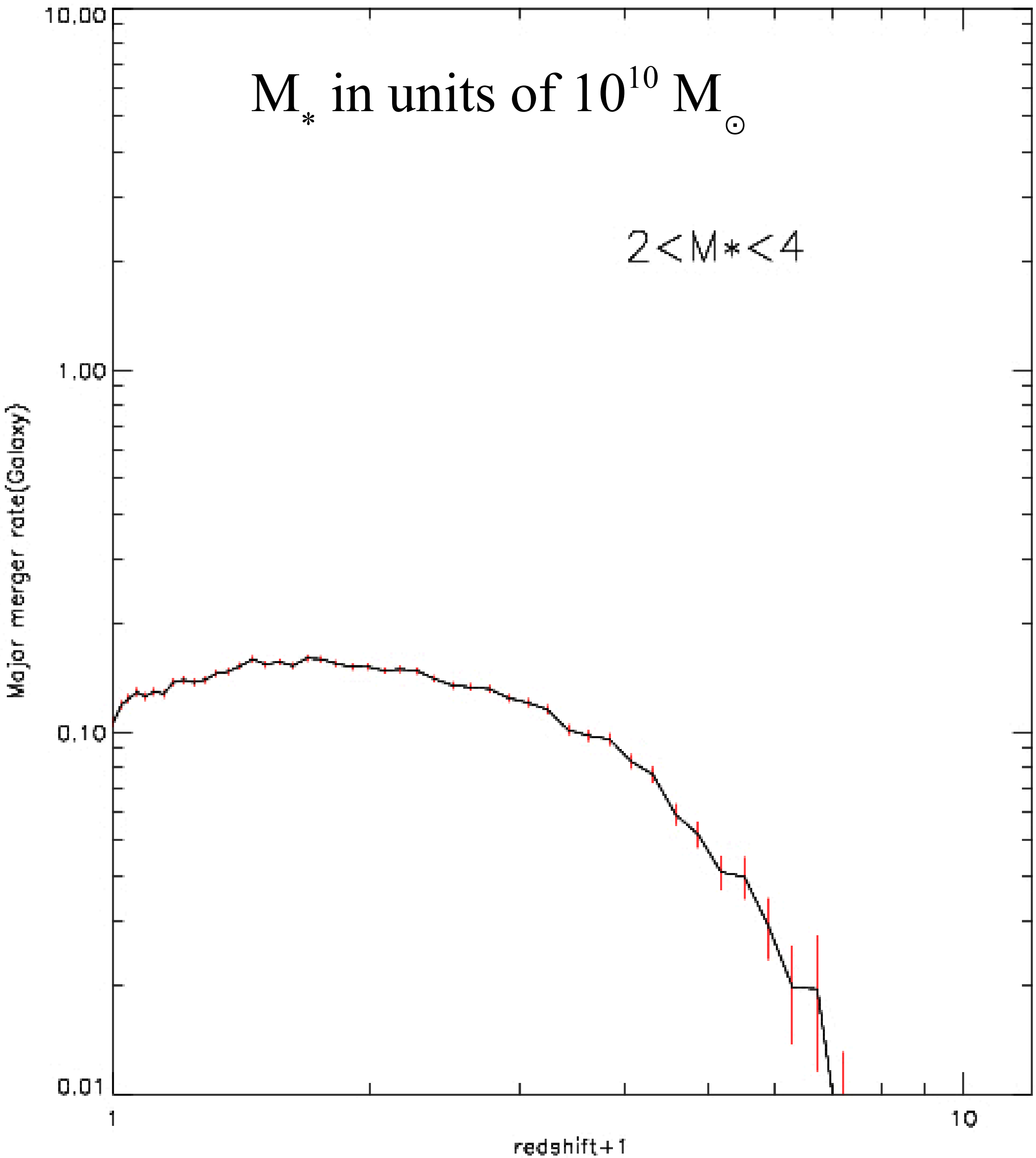

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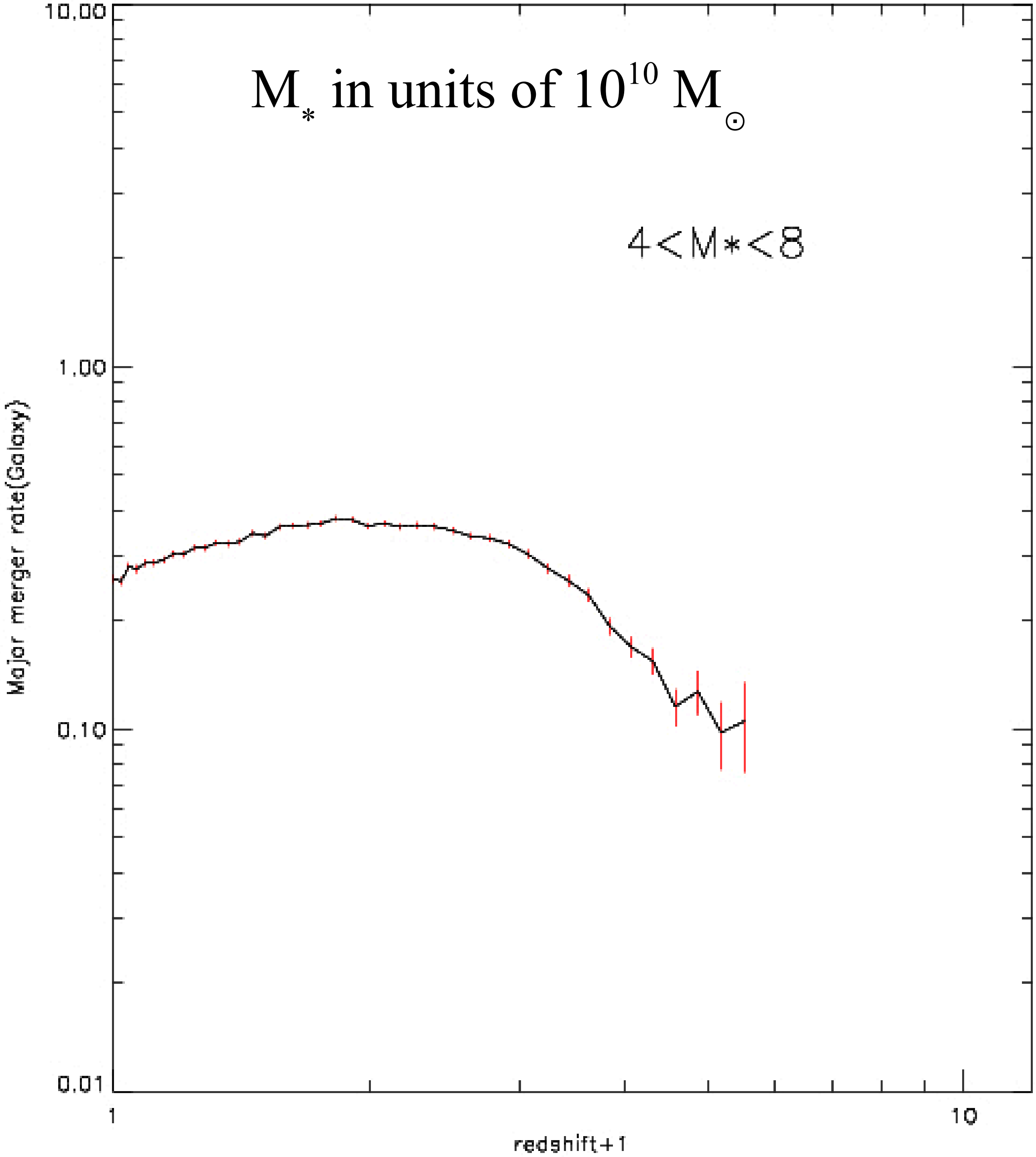

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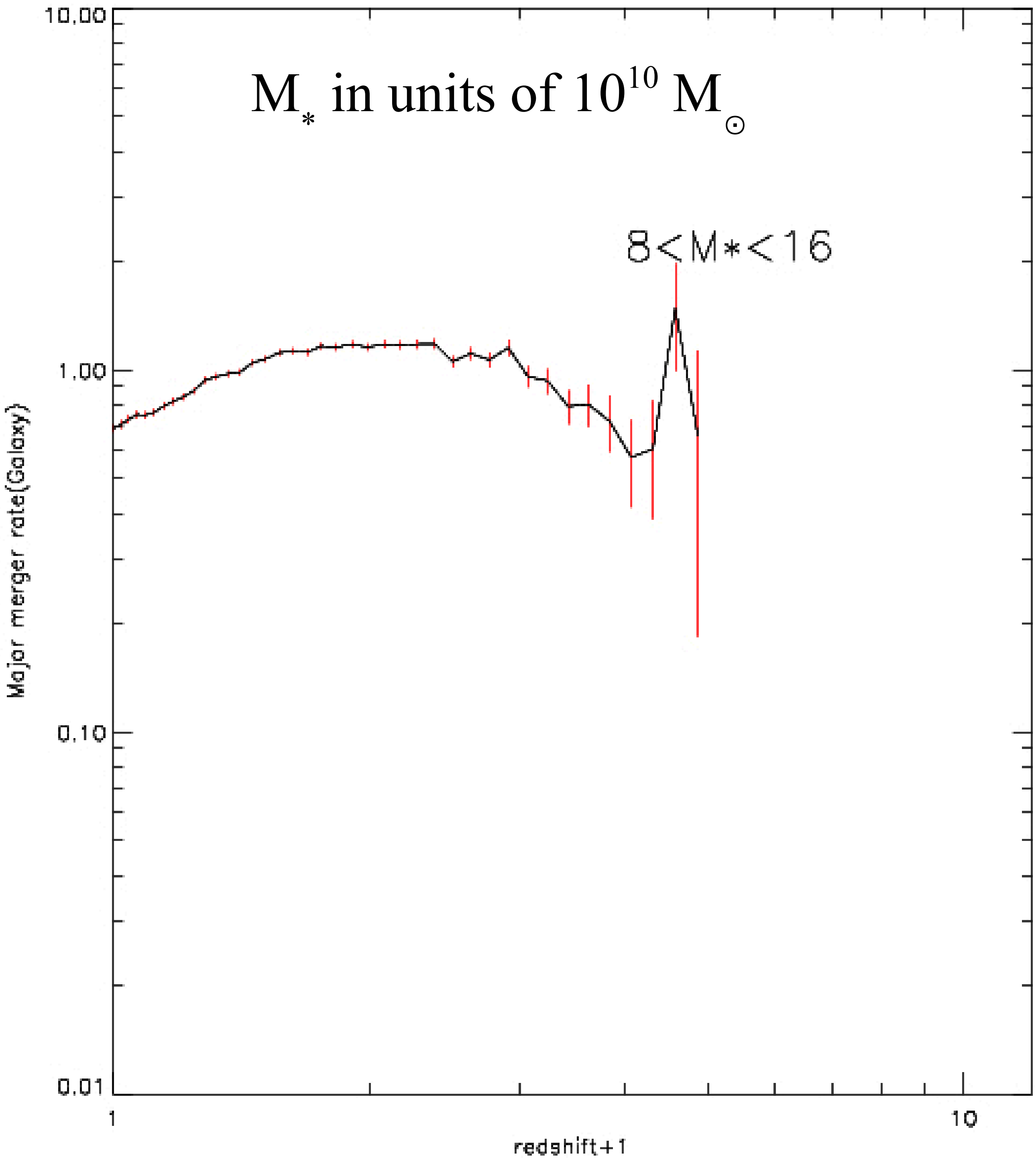

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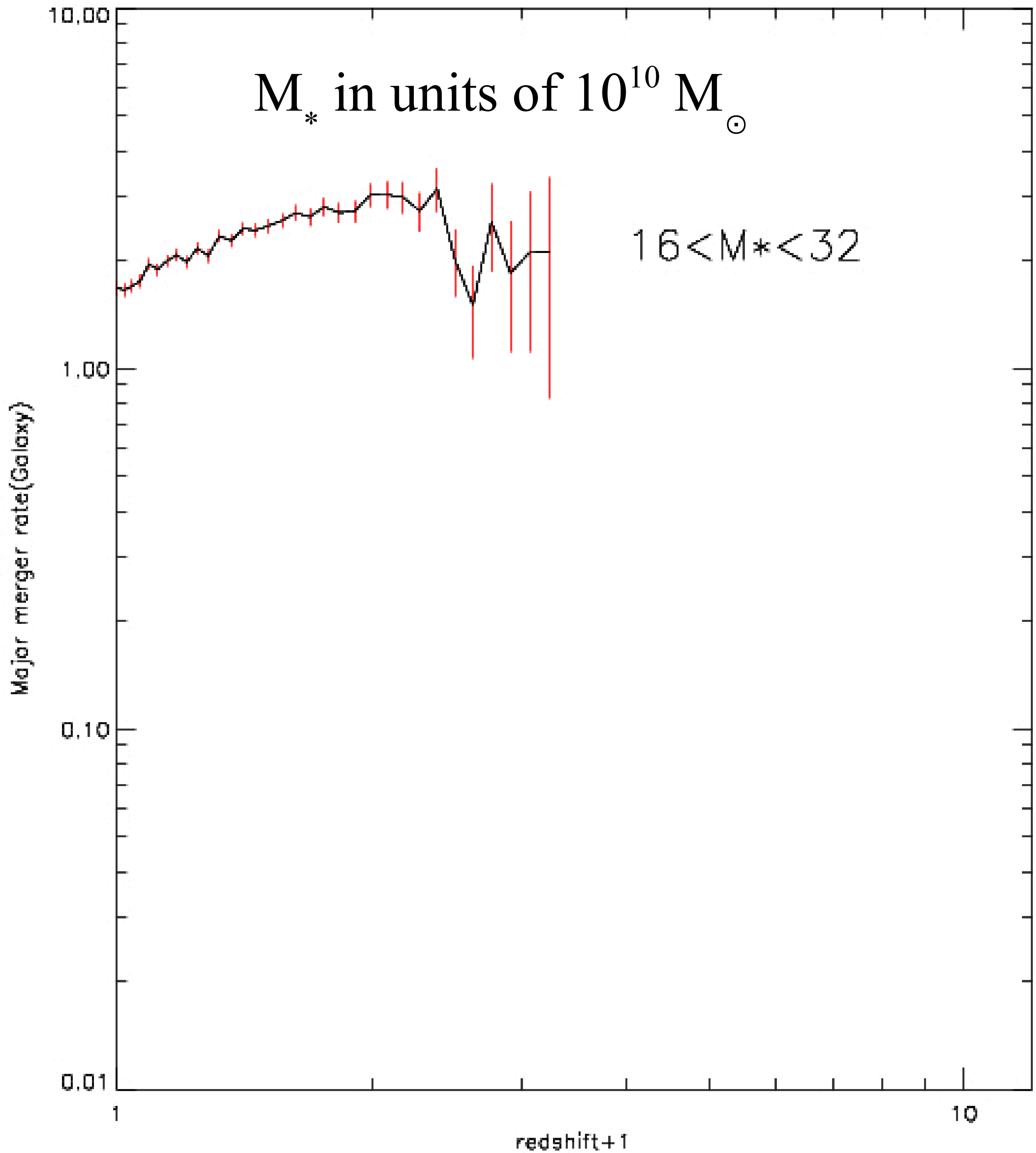

M_* in units of $10^{10}\ M_\odot$

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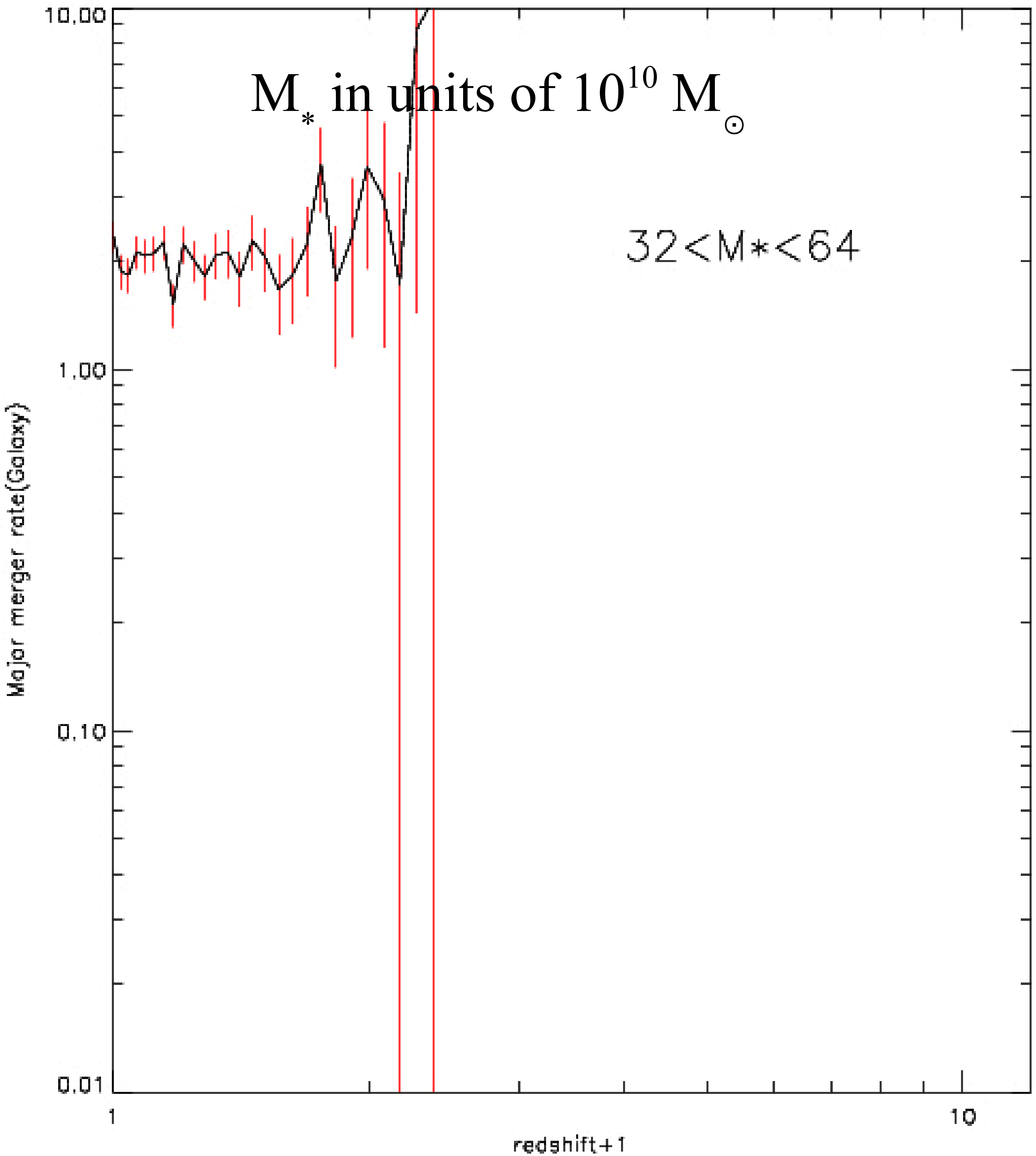

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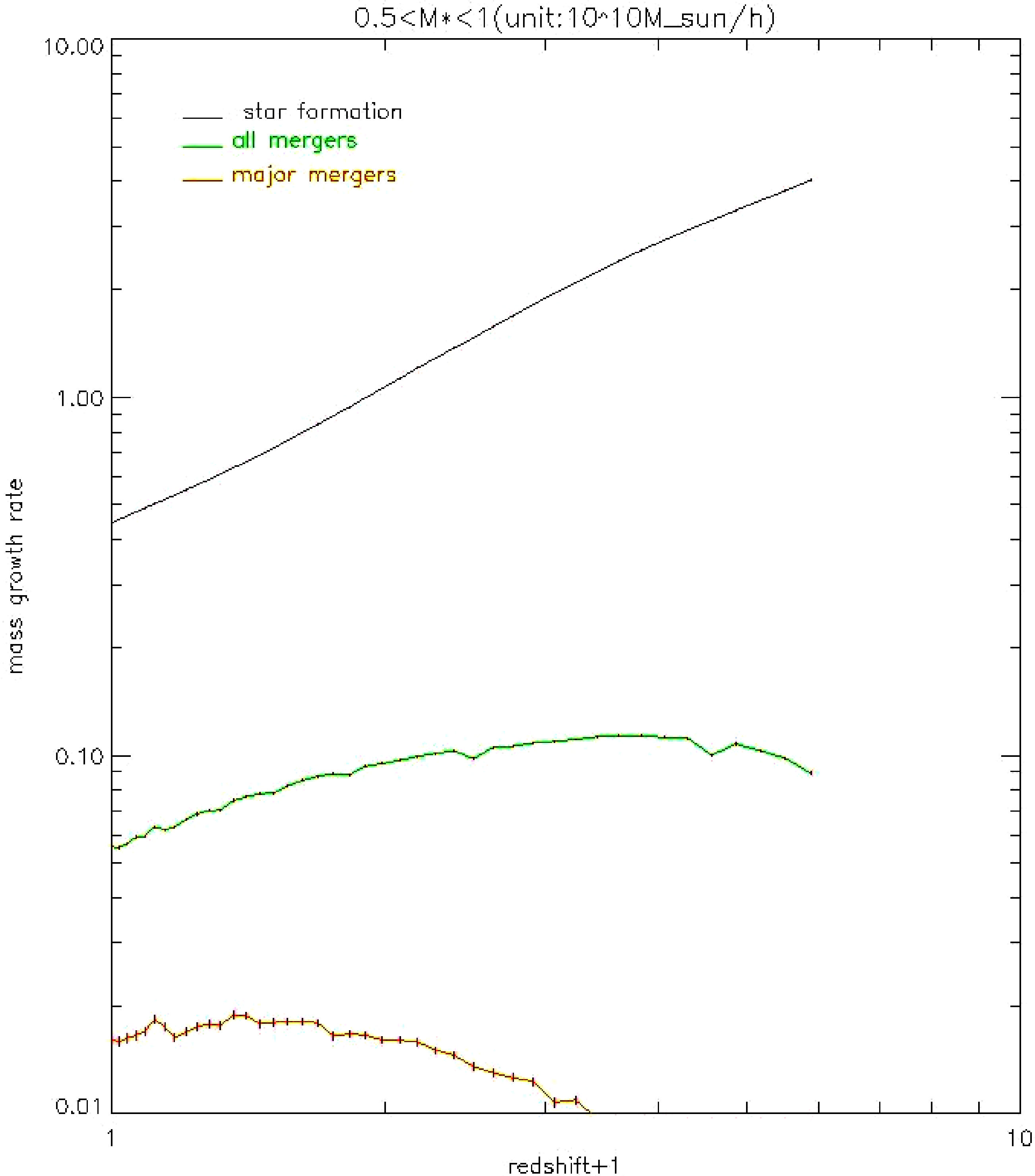


DIMENSIONLESS GROWTH RATES IN STELLAR MASS

Qi Guo & SW

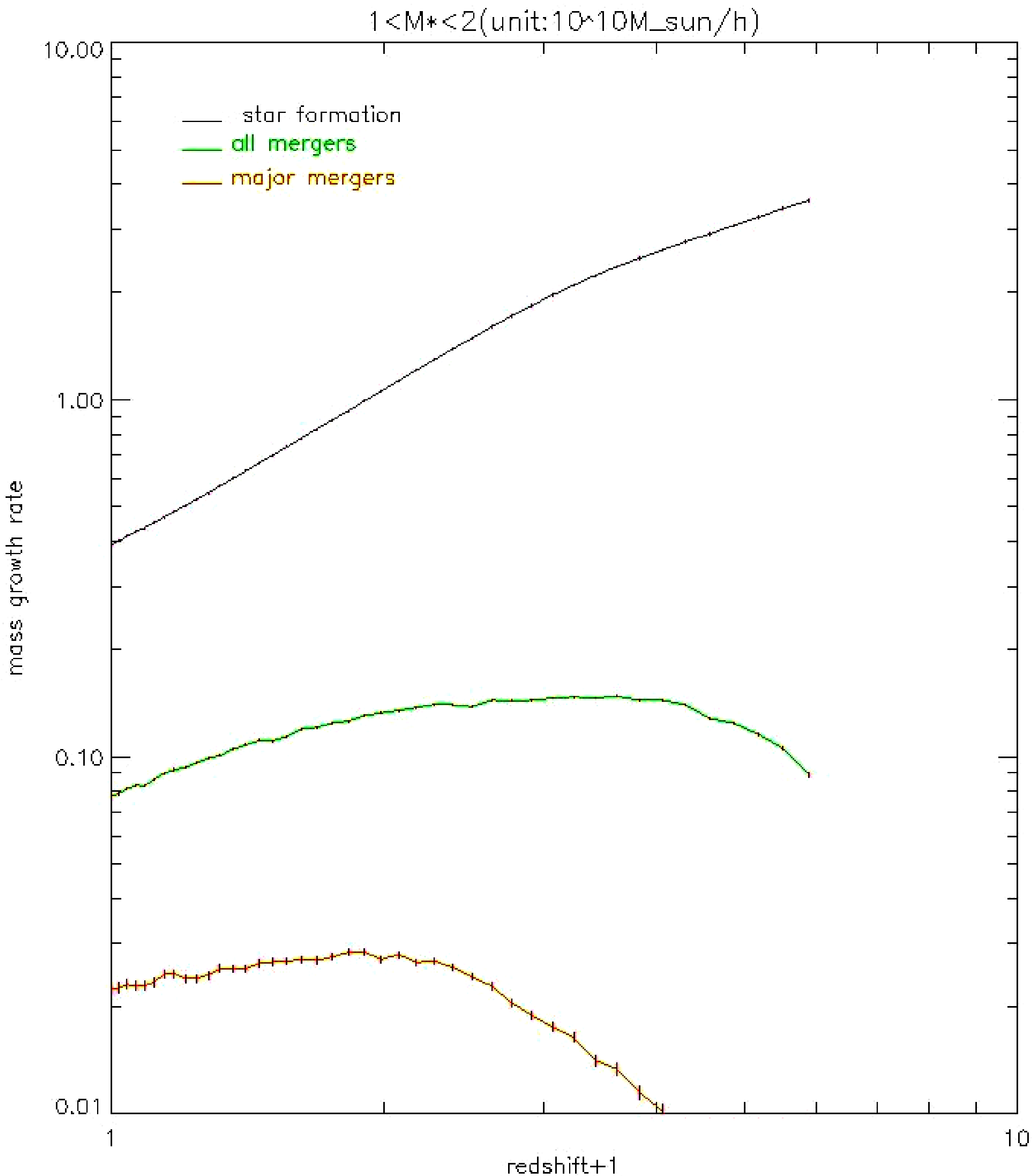
$$R = \langle\, t_{Hubb}\, \Delta M \;/\; M\, \Delta t \,\rangle$$

where $\Delta M/M$ is the stellar mass fraction added over the last ~0.2Gyr through

Major Mergers

All Mergers

Star Formation



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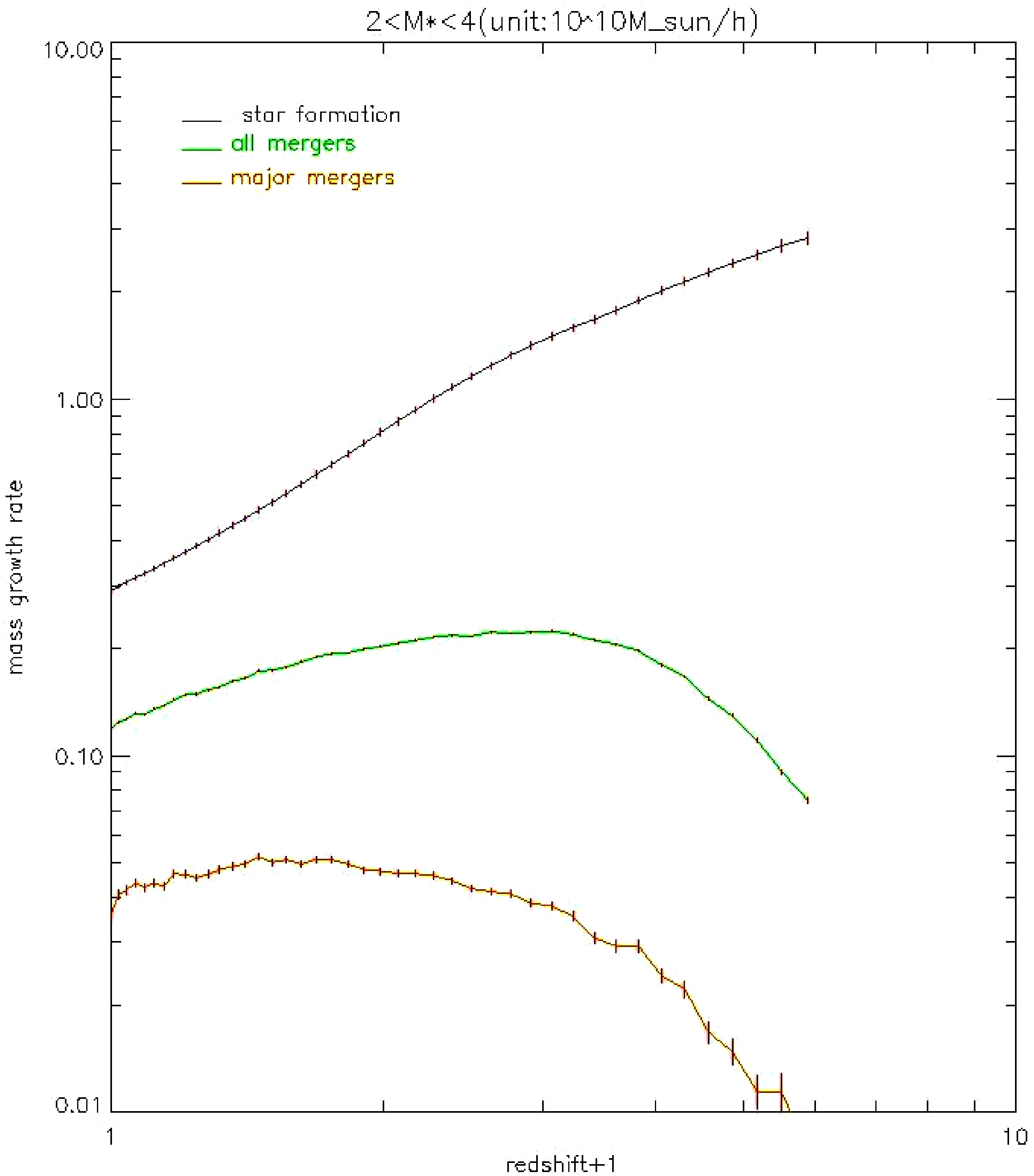

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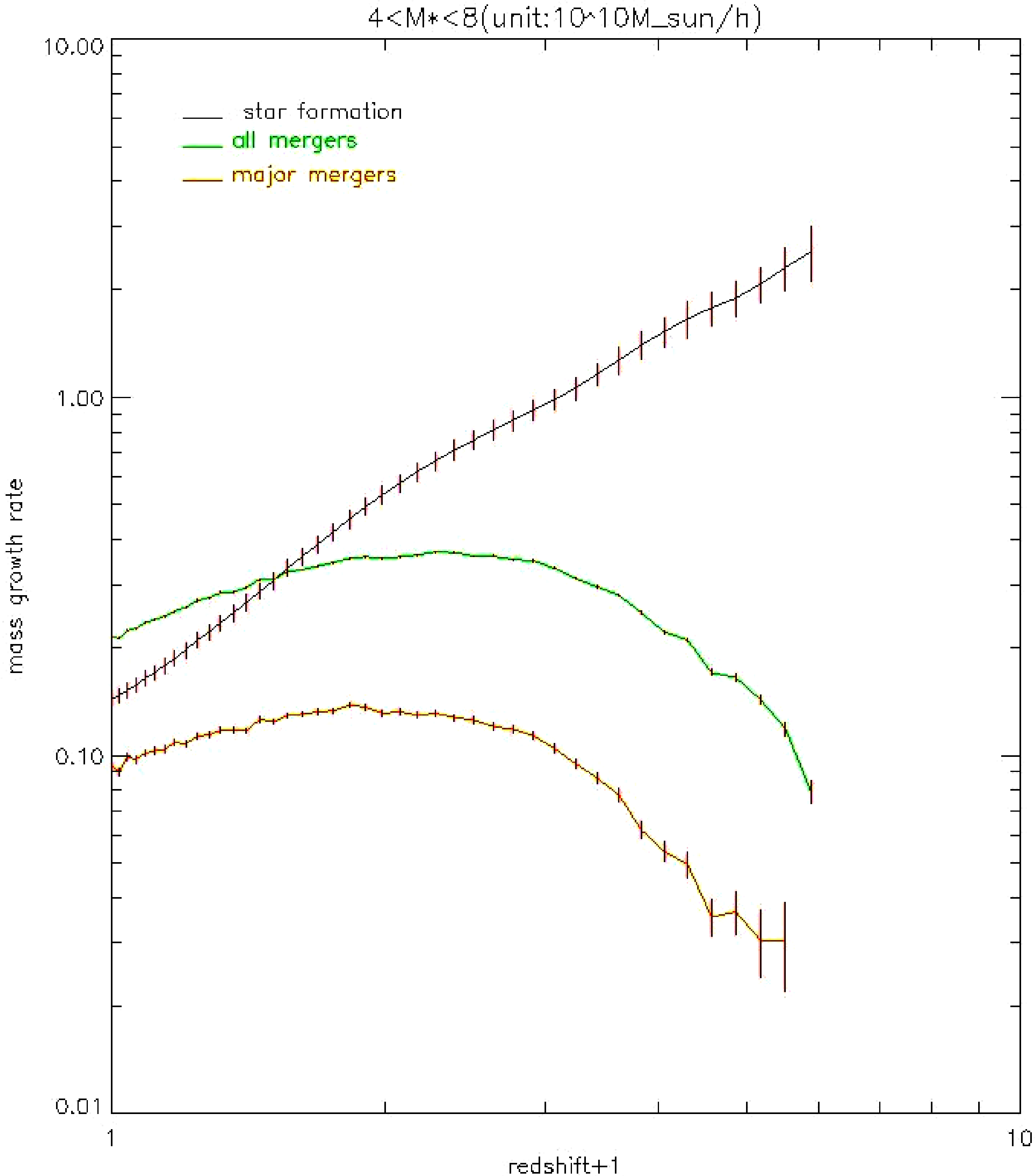

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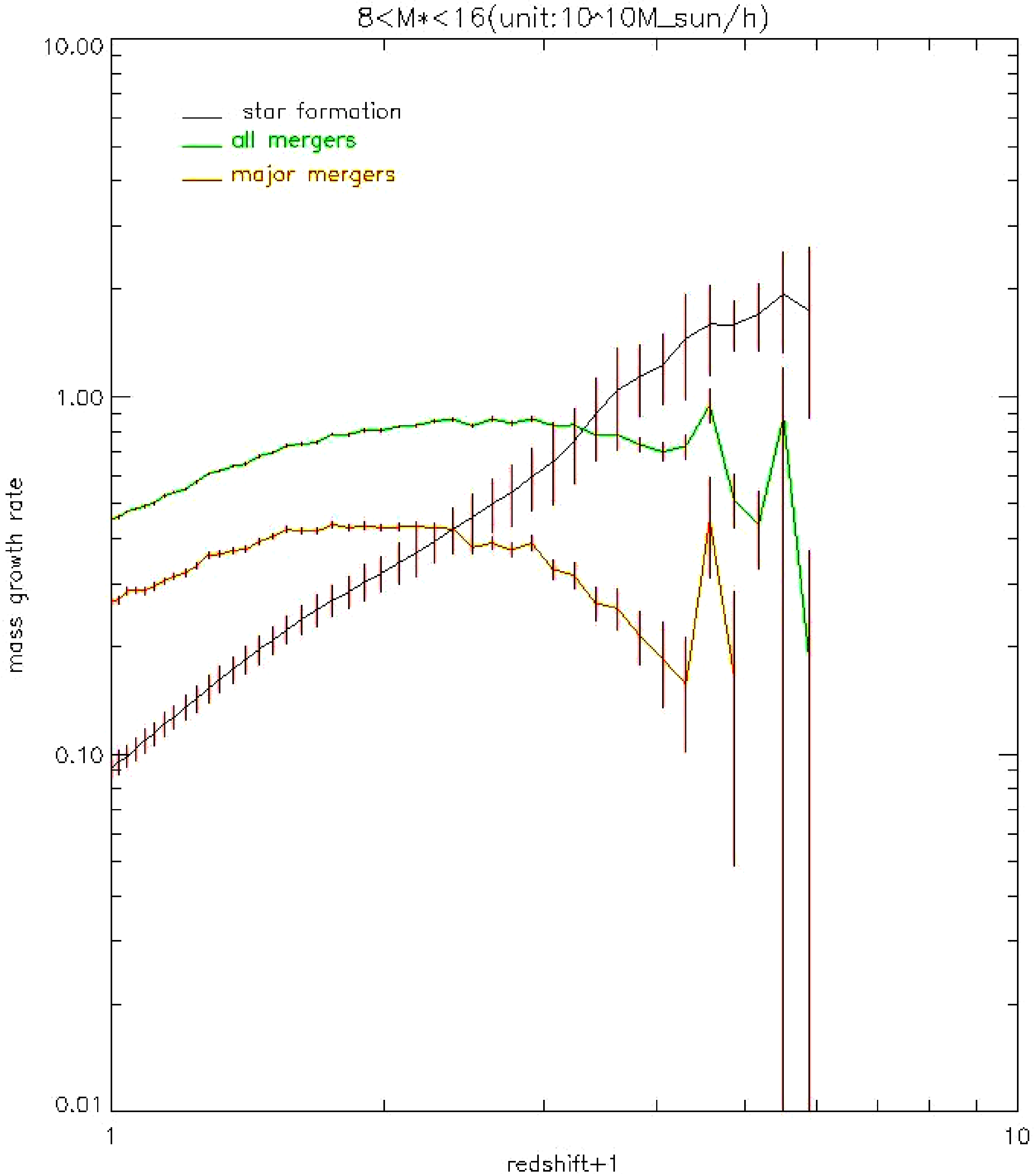

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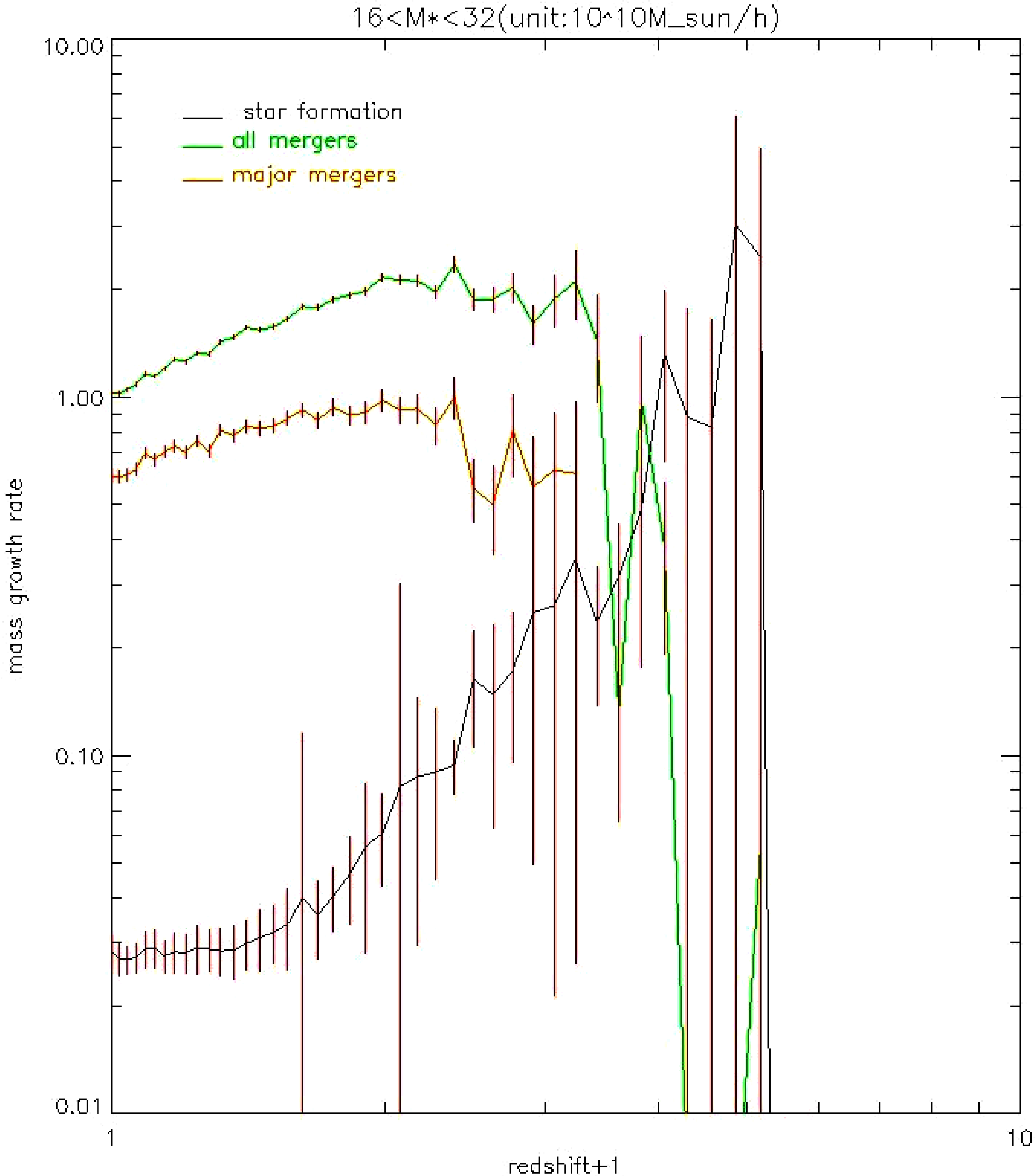

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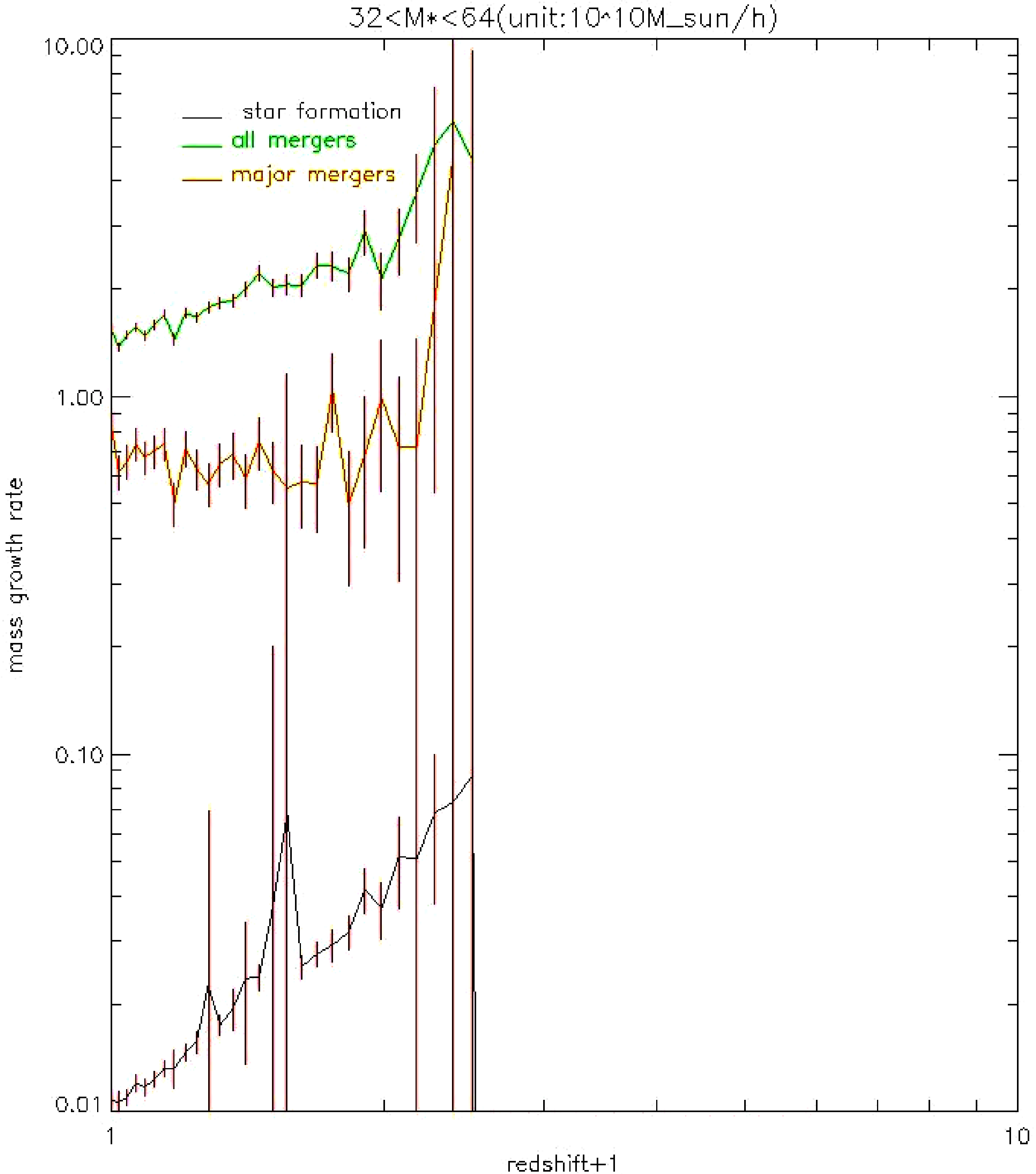

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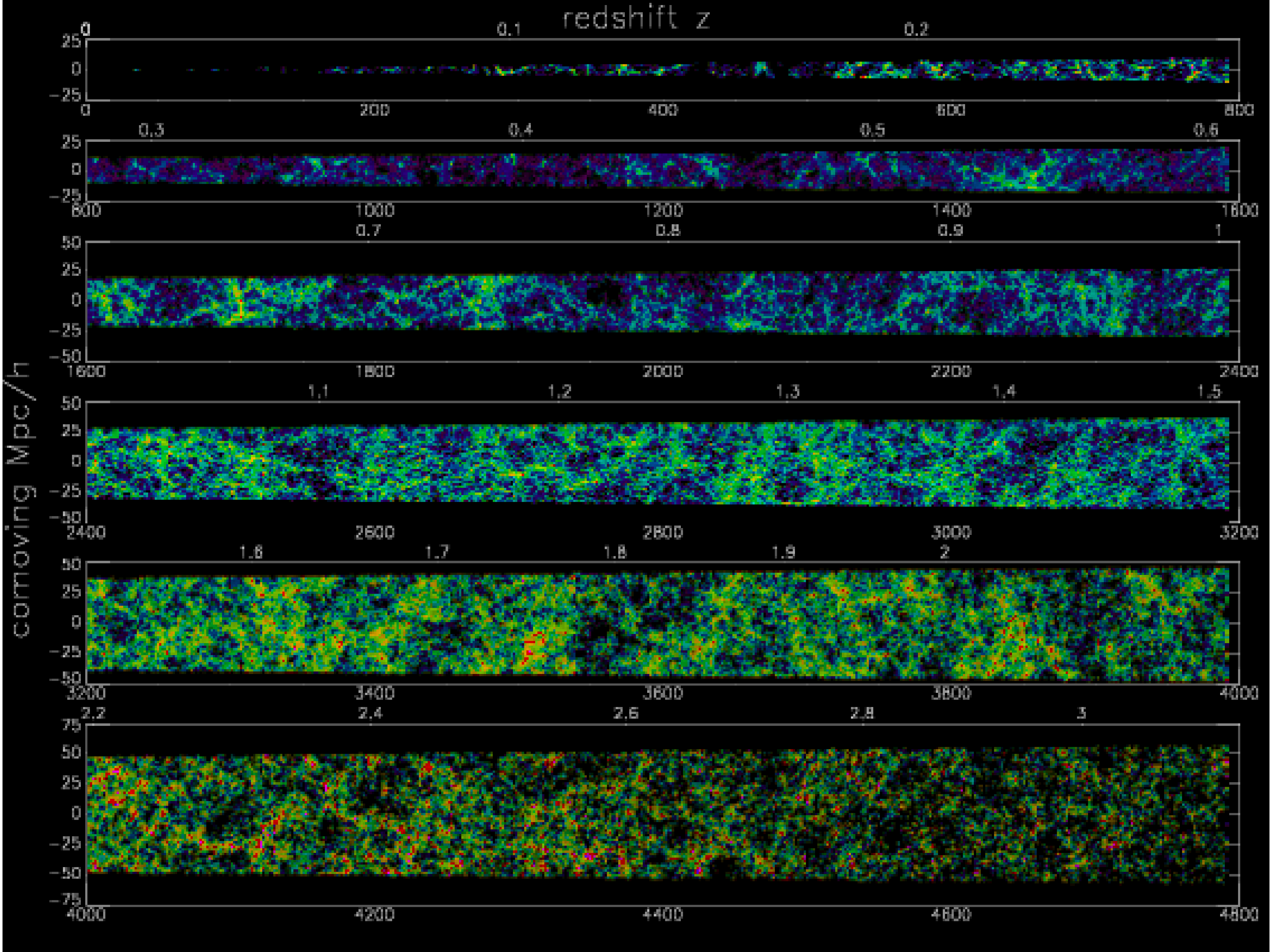
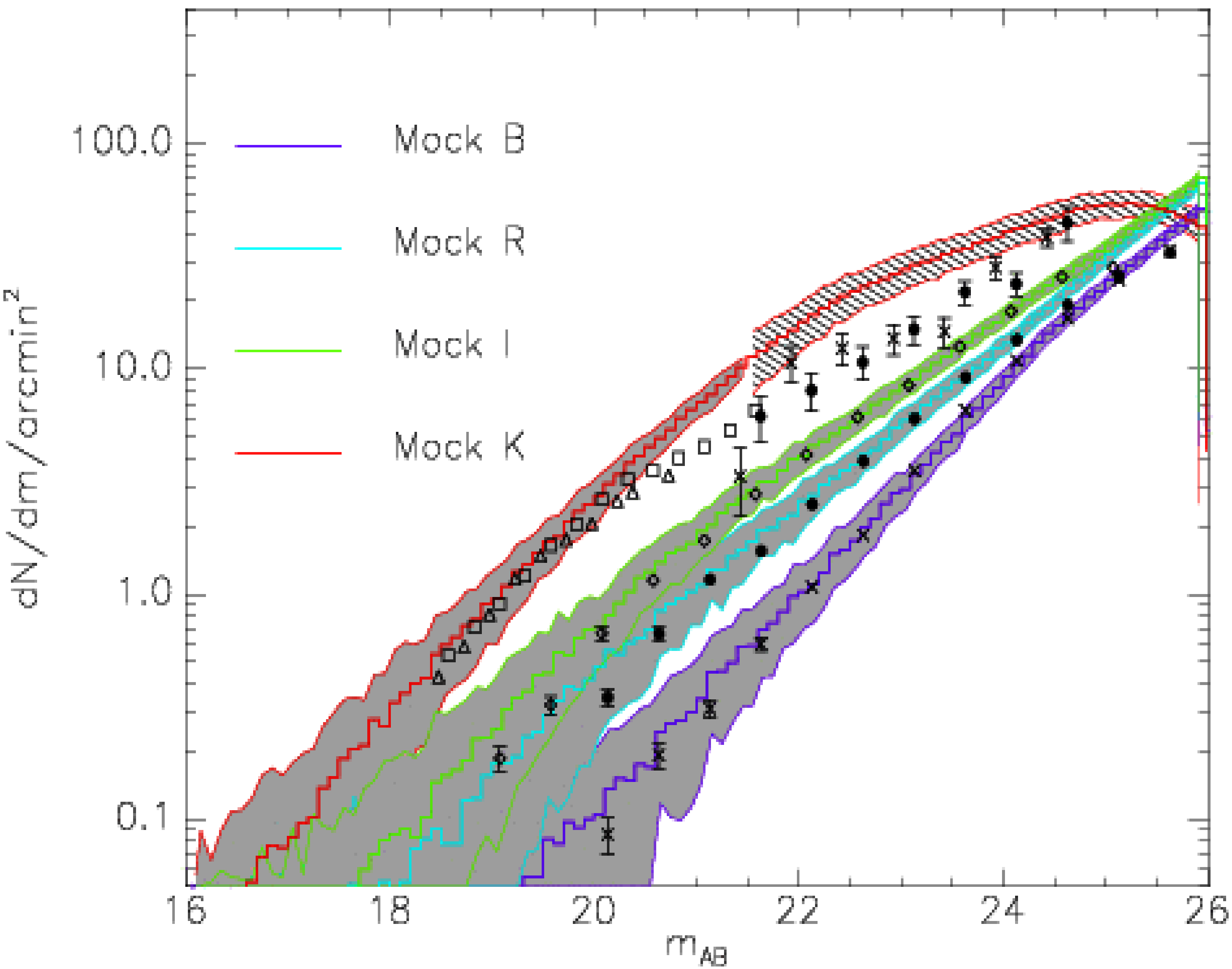


Kitzbichler & White 2006

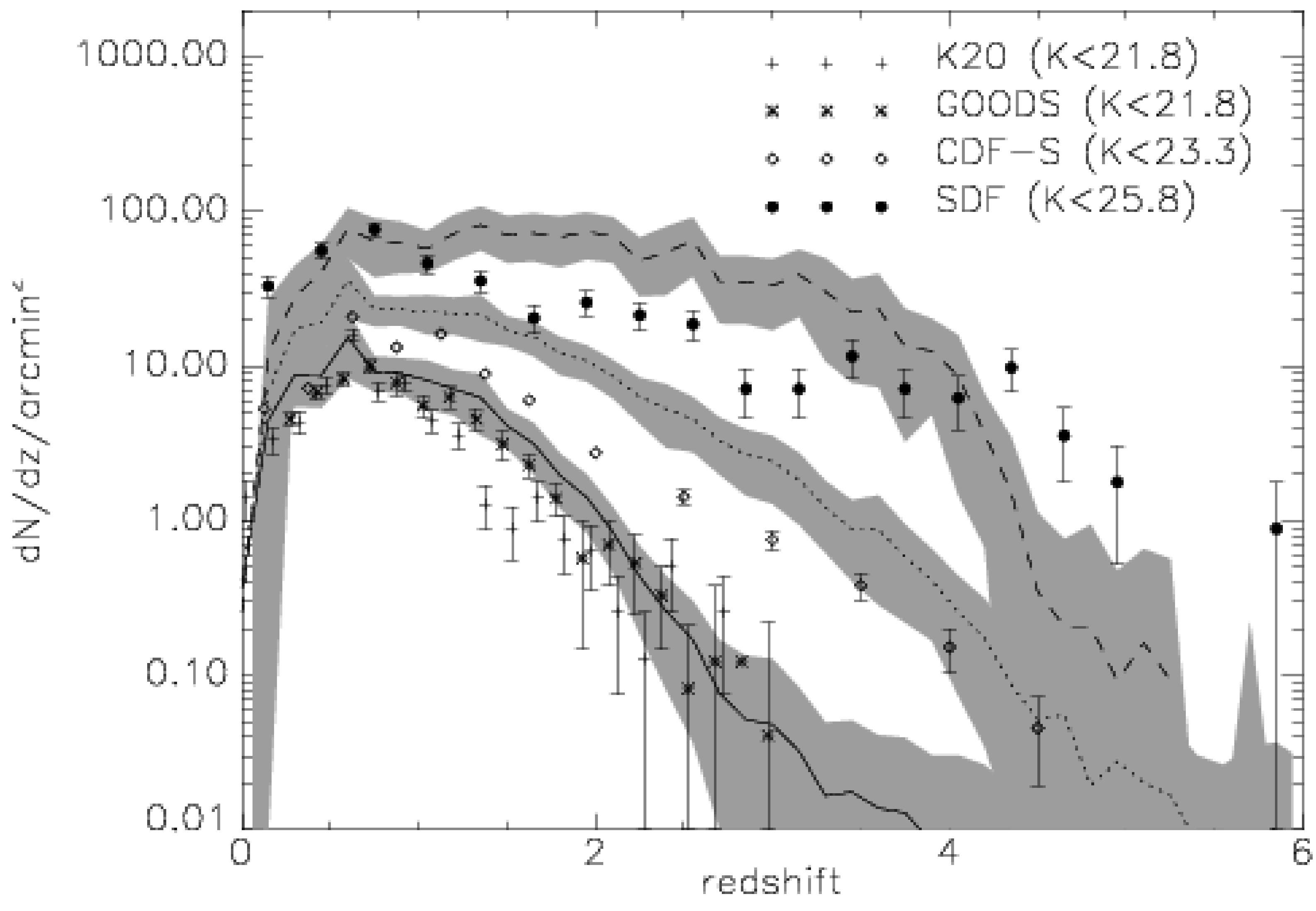
Deep Galaxy Counts

Kitzbichler & White 2006



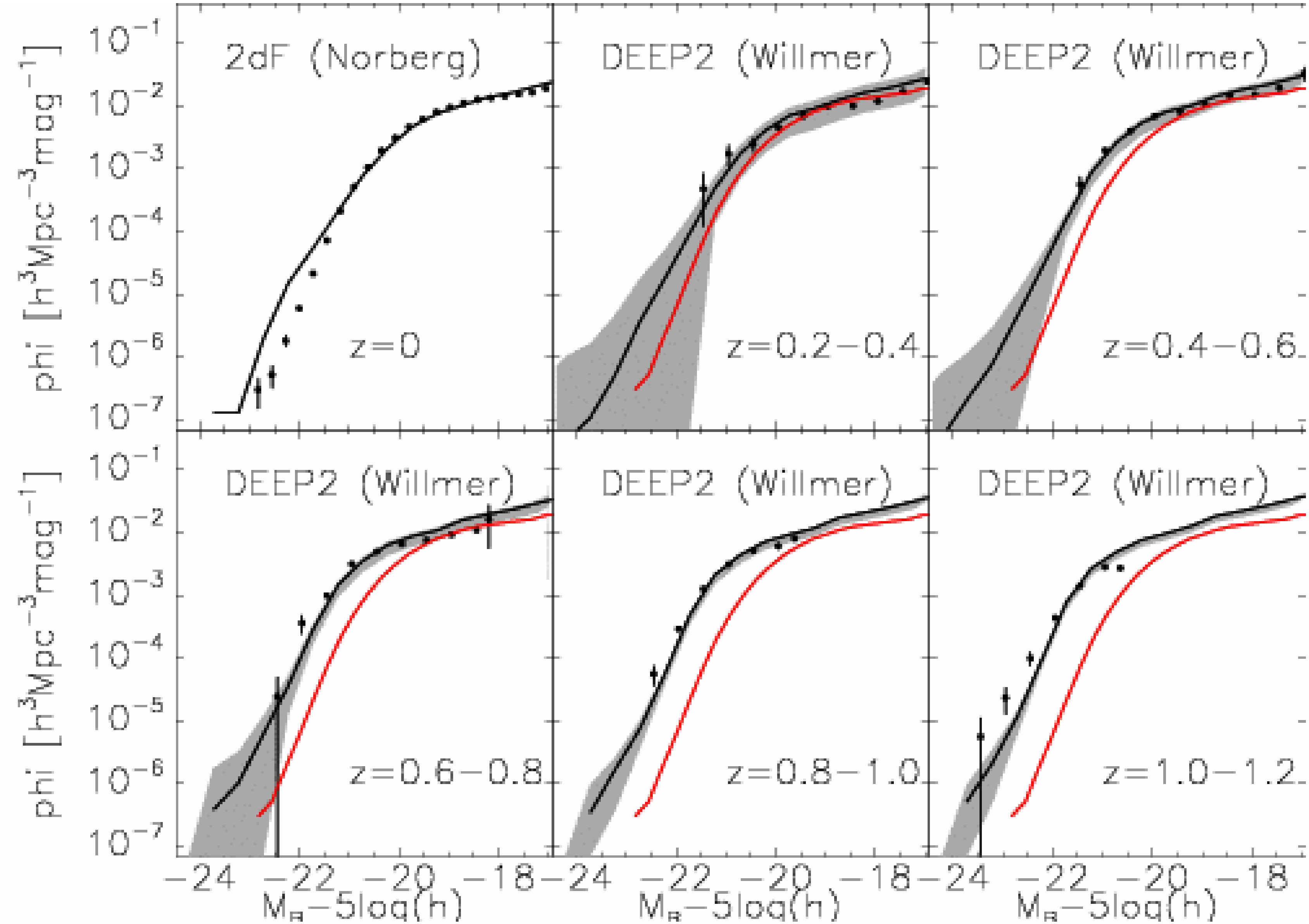
Deep Galaxy Redshift Distributions

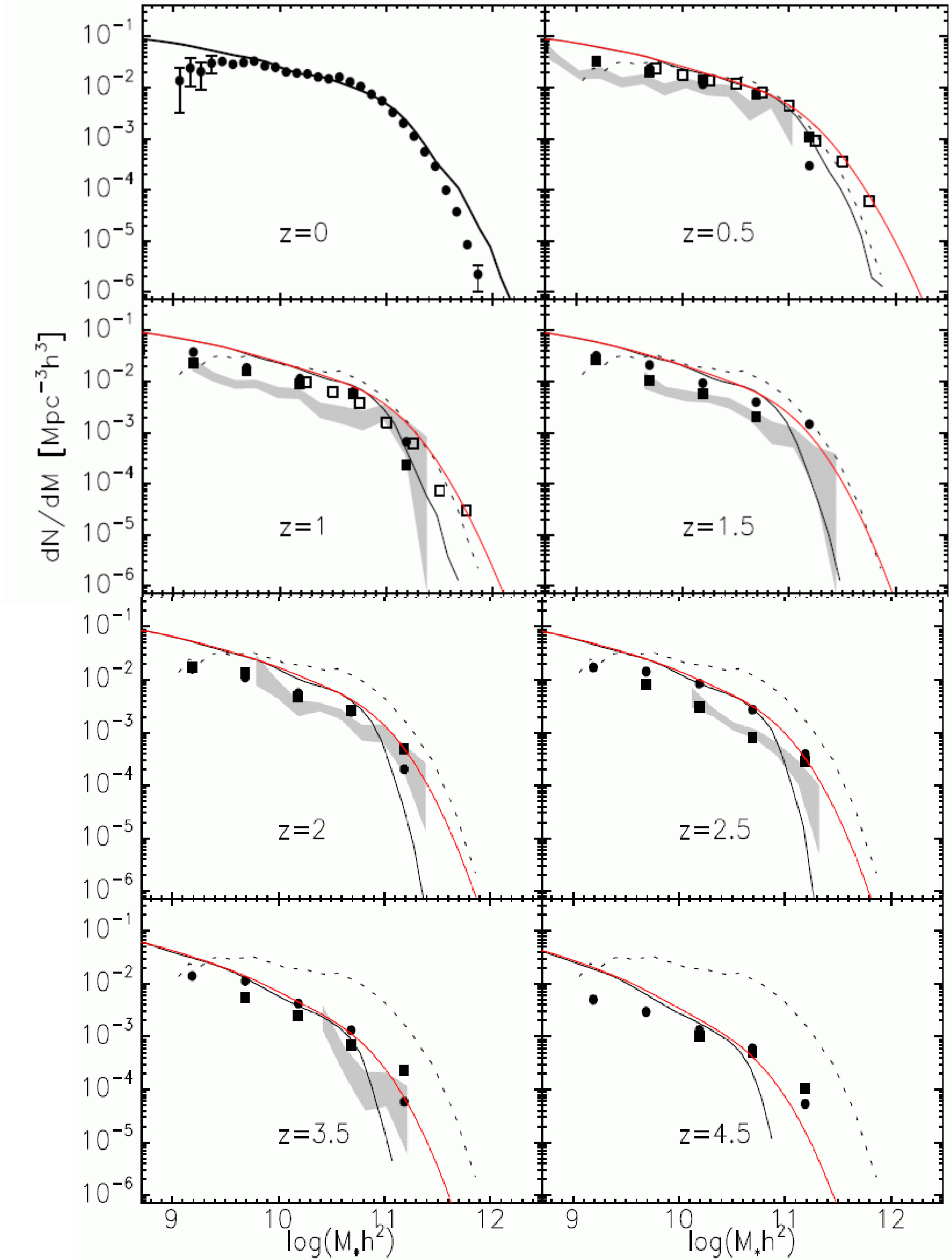
Kitzbichler & White 2006



Deep galaxy luminosity functions

Kitzbichler & White 2006





Deep galaxy mass functions

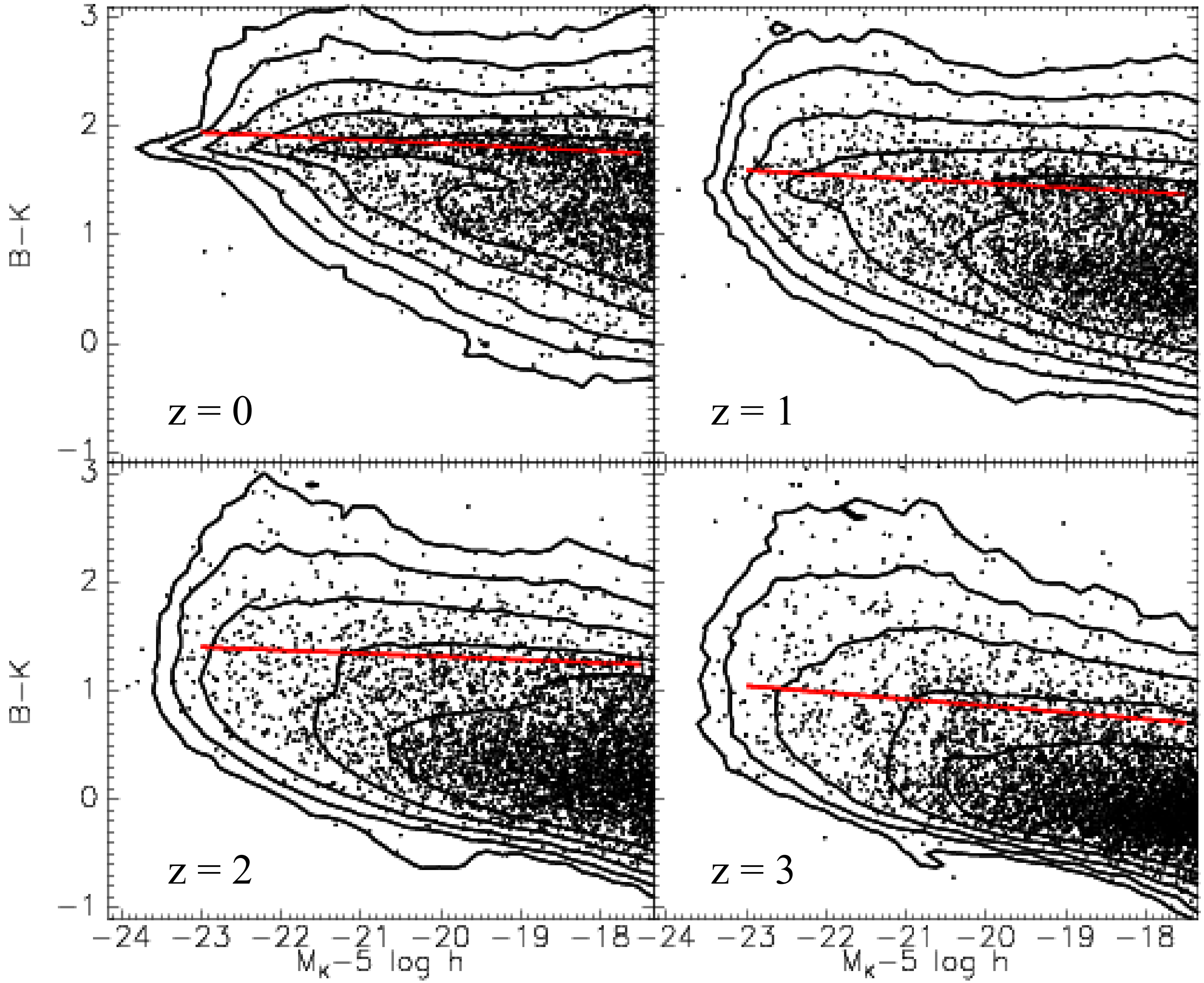
Kitzbichler & White 2006

Observational estimates:

Cole et al (2001) $z = 0$
Drory et al (2005) $z = 0.5$ to 4.5
Fontana et al (2006) $z = 0.5$ to 3.5

Colour-magnitude relation evolution

Kitzbichler & White 2006



- This particular galaxy formation model is close to most high-z data on abundances and clustering

- It seems to predict slightly too many massive galaxies at redshifts between 1 and 3

- Dust modelling is critical to many comparisons

- For $M_* < 5 . 10^{10}\ M_\odot$ most stars added by *in situ* star formation

  For $M_* > 10^{11}\ M_\odot$ most stars added by mergers

  This is a consequence of the adopted model for radio feedback

- Full data on the formation histories of the galaxies and dark halos in this model are available from:

  http://www.mpa-garching.mpg.de/Millennium

GERMAN ASTROPHYSICAL GAVO VIRTUAL OBSERVATORY

Exploring the milli-Millennium simulation with a relational database

Documentation


```
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

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

http://www.mpa-garching.mpg.de/Millennium