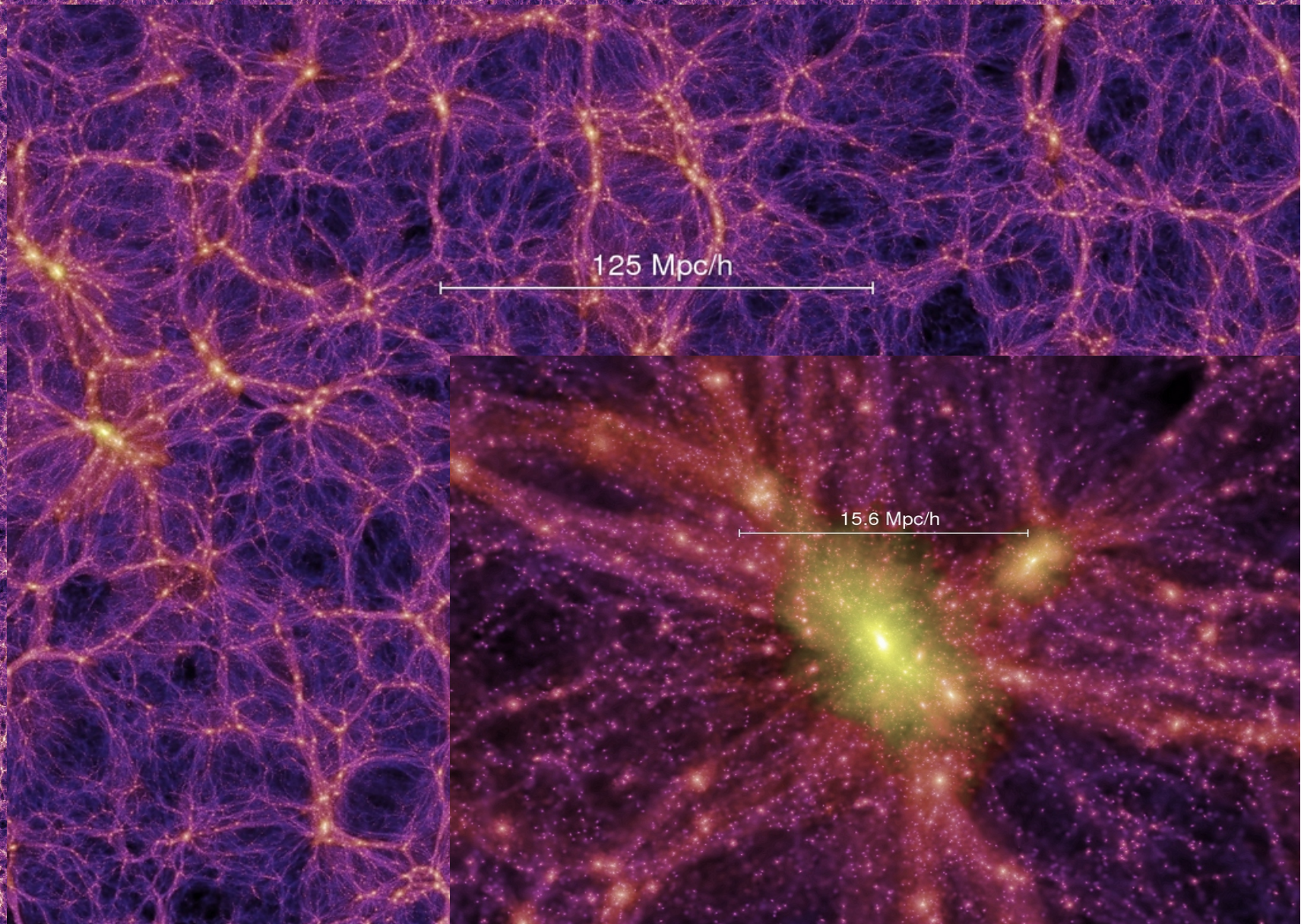
Carching, December 2012

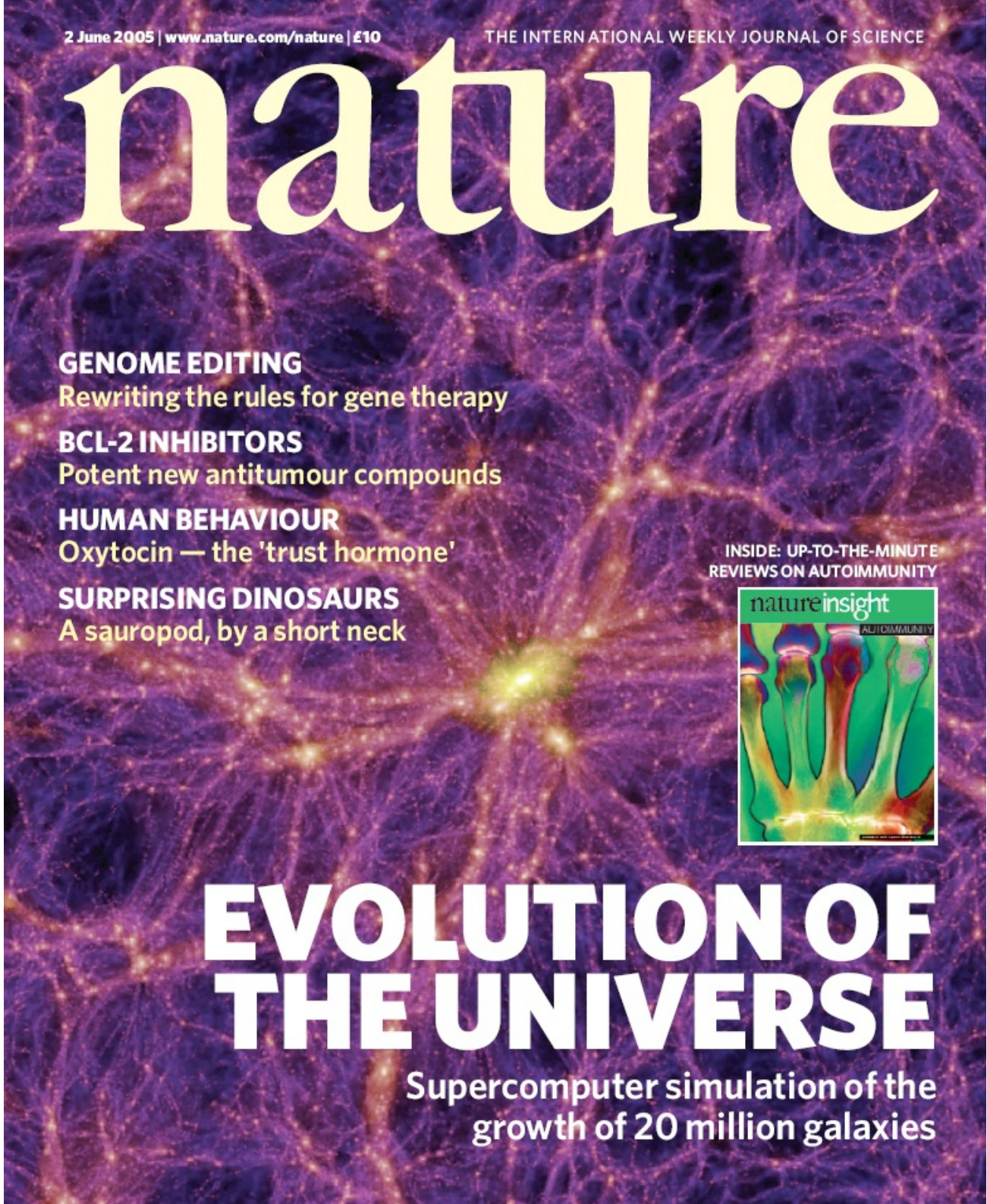
The Millennium Simulation Programme

Simon White, Max Planck Institute for Astrophysics



Millennium Run 2004

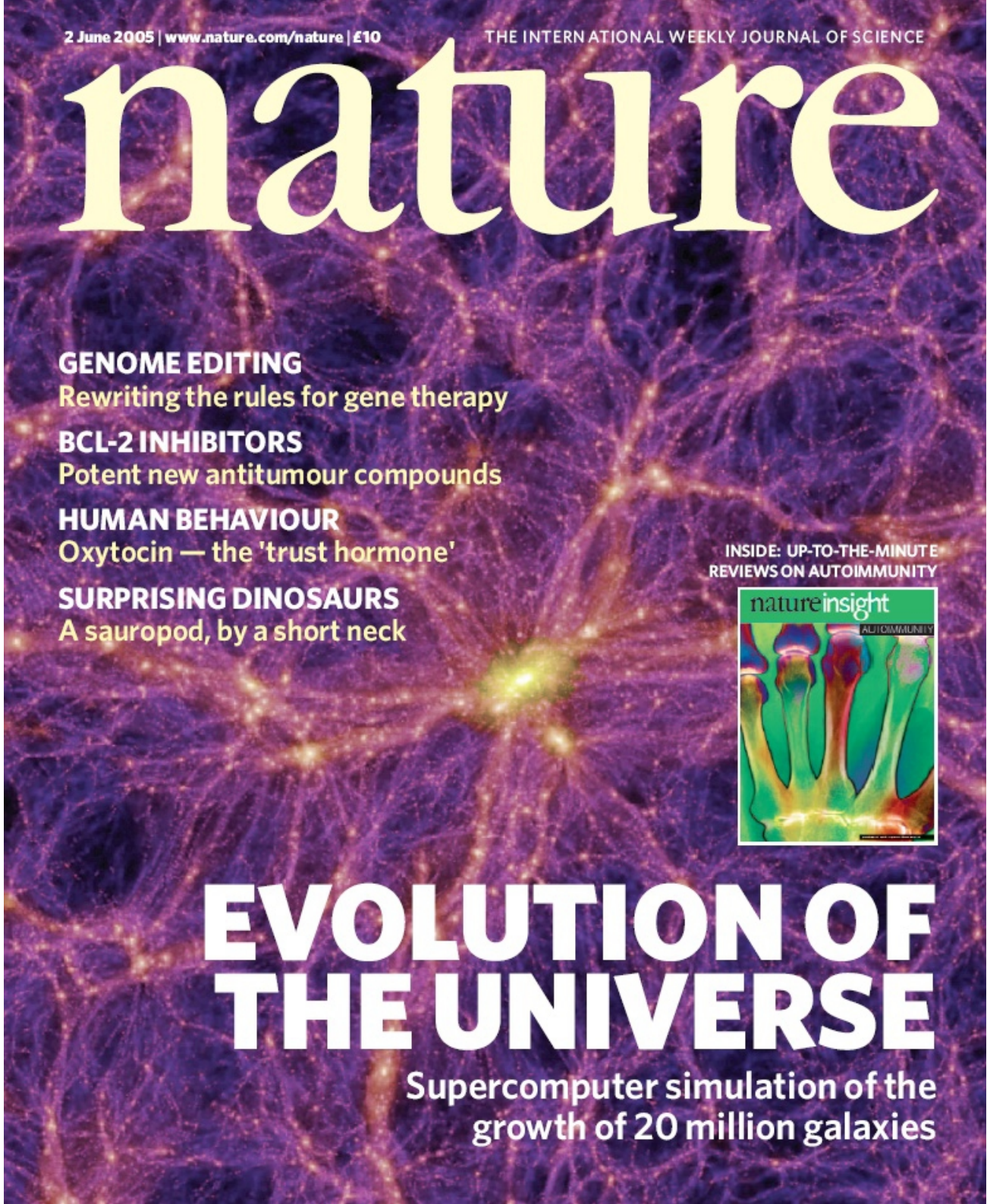
Springel et al 2005



Millennium Run 2004

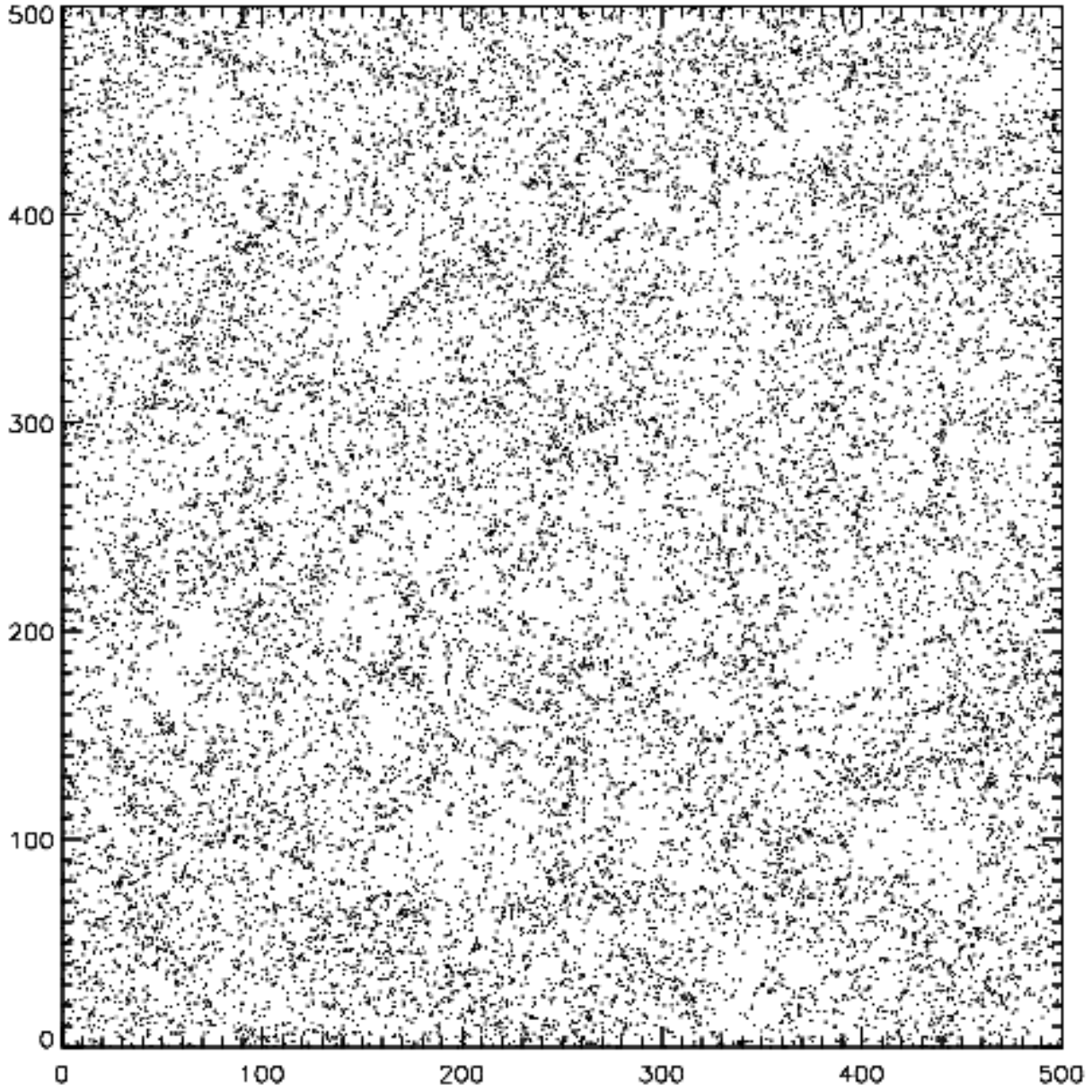
Goal: To carry out a DM-only ΛCDM simulation of a cosmologically relevant volume with sufficient resolution to follow the formation of galaxies in halos and subhalos using Semi-analytic techniques

Springel et al 2005



Millennium Run 2004

Provided unprecedented halo statistics



Gao, Springel & White 2005

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

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

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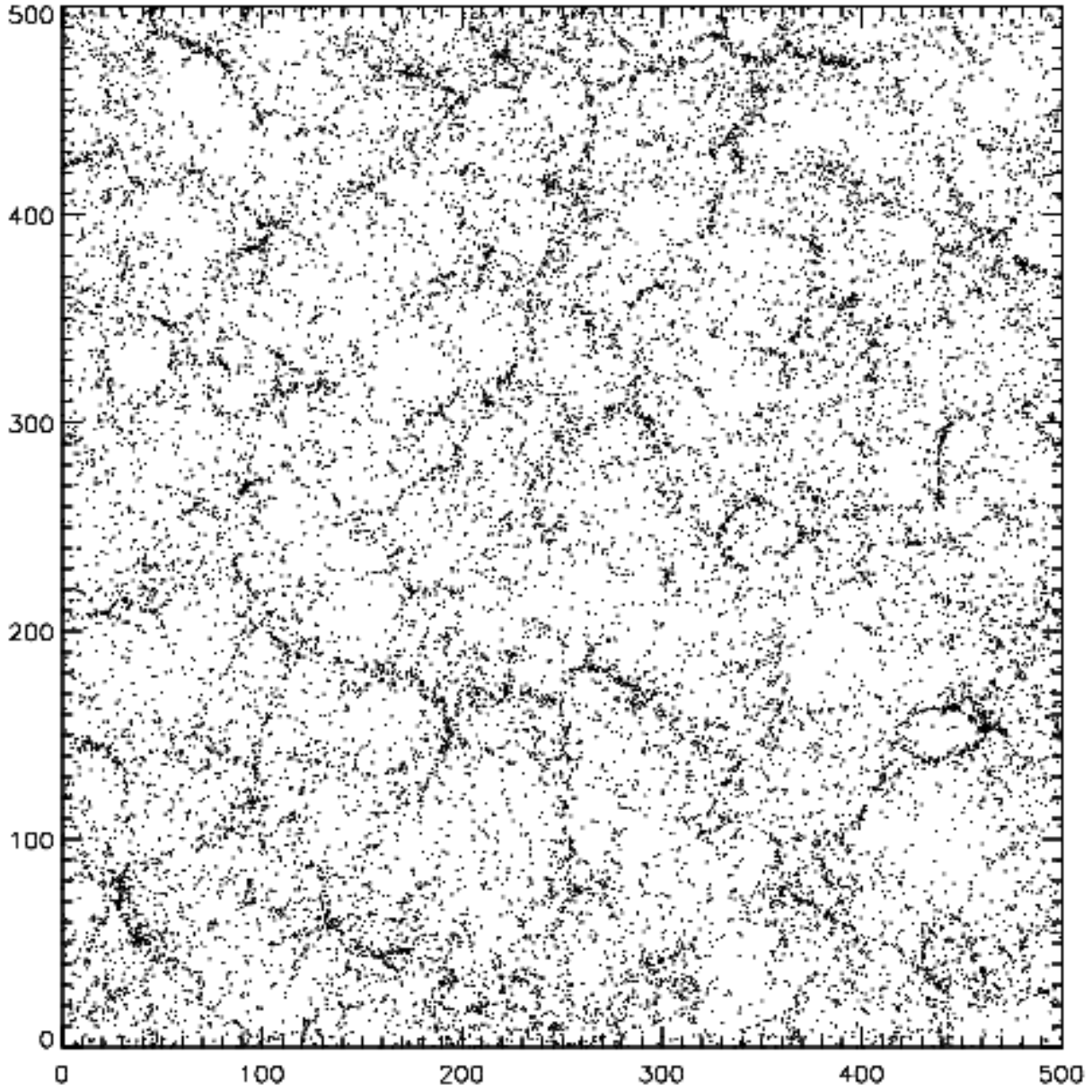
Provided unprecedented halo statistics



Gao, Springel & White 2005

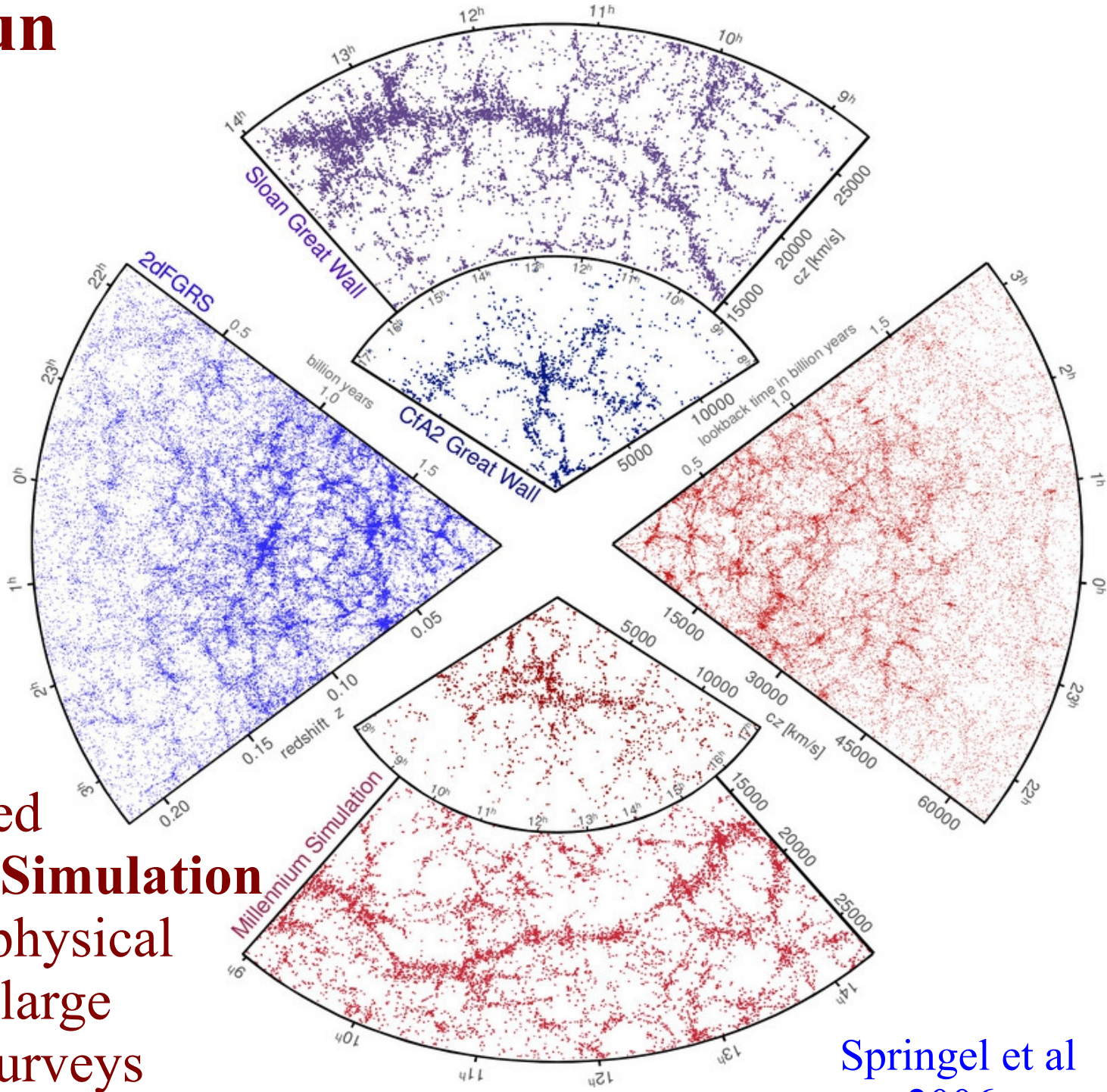
The 20% of halos with the *highest* formation redshifts in a 30 Mpc/h thick slice

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

"Assembly bias"

Millennium Run 2004

A simulation of the formation/evolution of 2×10^7 galaxies



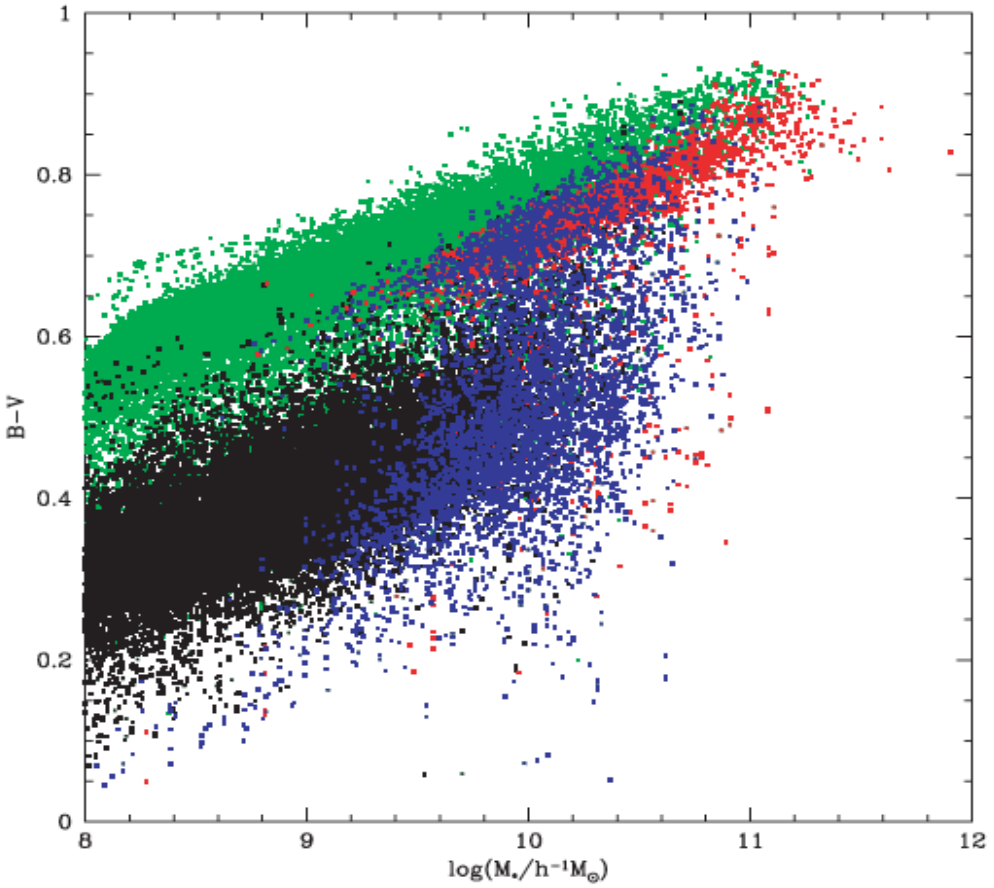
This established
Galaxy Population Simulation
as a tool for the physical interpretation of large galaxy redshift surveys

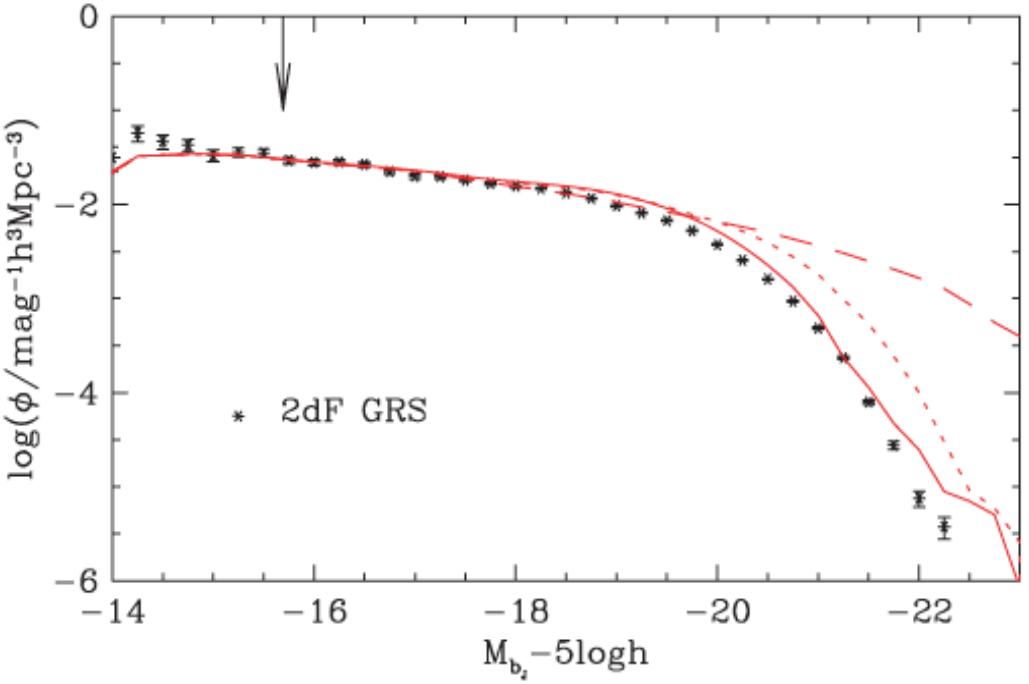
Springel et al 2006

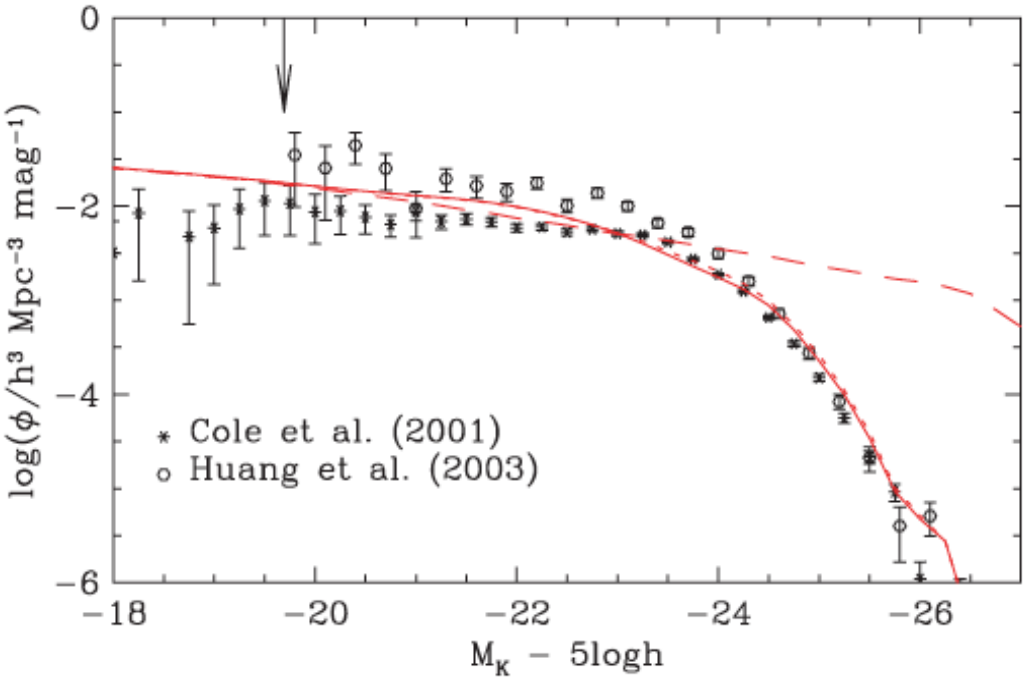
Millennium Run 2004

Bower et al 2006

Infrastructure intended for use by multiple groups, initially within the Virgo Consortium, but ultimately worldwide







GERMAN ASTROPHYSICAL 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

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

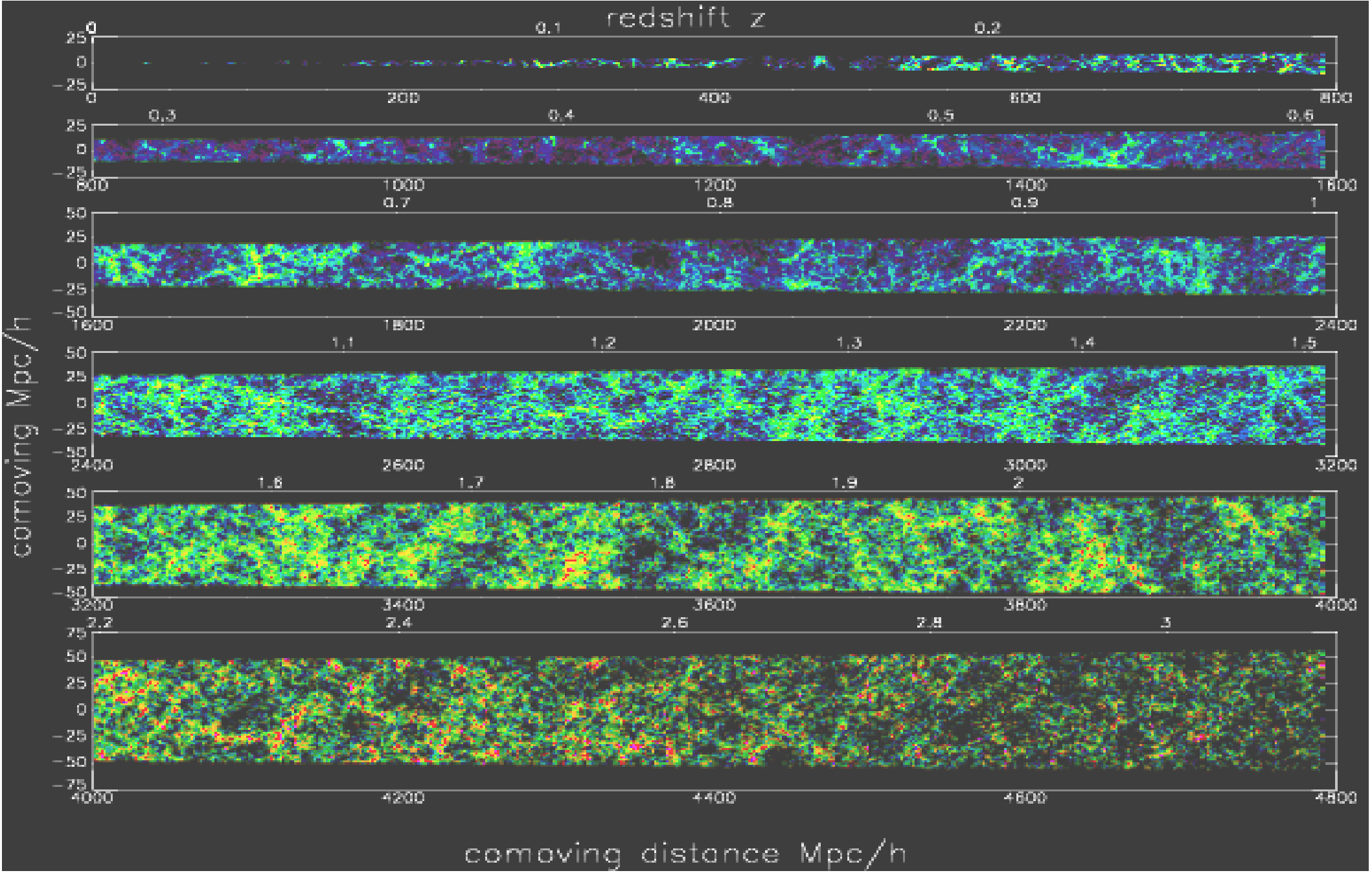
Plot (VOPlot)

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)

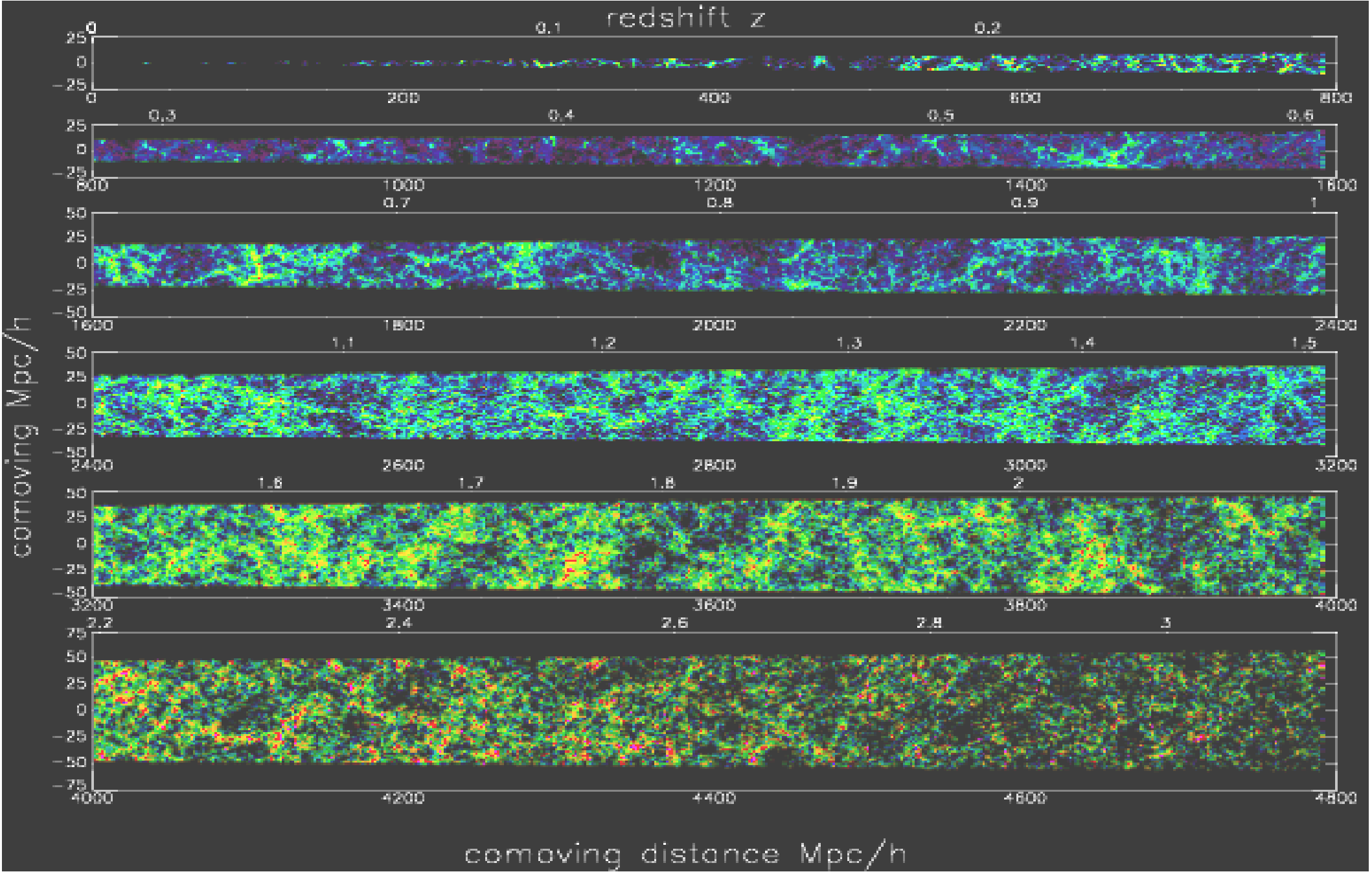
i_halo	snapnum	d_np	p1_np	p2_np
2576	60	1079	924	222

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



Simulation of 2×10^7 galaxies from z=10 to z=0 allows construction of deep light-cones

Kitzbichler & White 2007



522 papers making direct use of data from the MS (17-12-2012)
Most by authors unassociated with the consortium
Most use the galaxy catalogues, particularly mock surveys

Limitations of the Millennium Simulation

- Limited modeling of *structure* of galaxies, gas components
- Limited resolution – too poor to model formation of dwarfs
- No convergence tests – are galaxy results numerically converged?
- Limited volume – too small for BAO work, precision cosmology
- Only one ("wrong") cosmology
- Users unable to test dependences on parameters/assumptions
- Comparison with observations remains at catalogue level

Limitations of the Millennium Simulation

- Limited modeling of *structure* of galaxies, gas components
  Jian Fu, Qi Guo, Cedric Lacey, Claudia Lagos, Rob Yates
- Limited resolution – too poor to model formation of dwarfs
  Millennium-II: Mike Boylan-Kolchin, Qi Guo
- No convergence tests – are galaxy results numerically converged?
  Millennium-II: Mike Boylan-Kolchin, Qi Guo
- Limited volume – too small for BAO work, precision cosmology
  Millennium-XXL: Raul Angulo
- Only one ("wrong") cosmology
  WMAP1 → WMAP7 → Planck? → ???: Raul Angulo, Qi Guo
- Users unable to test dependences on parameters/assumptions
  New interfaces: Gerard Lemson, Matthias Egger
- Comparison with observations remains at catalogue level
  Millennium Run Observatory: Roderik Overzier, Gerard Lemson

Garching, December 2012

The GALFORMOD Project

Simon White
Max Planck Institute for Astrophysics

European Research Council

ERC Advanced Grant
Research proposal (Part B1)

Galaxy formation models for the next generation of evolutionary and cosmological surveys

GALFORMOD

Simon D.M. White
Max Planck Institute for Astrophysics

Proposal duration : 60 months 2010 -2014

Goals

- Carrying out simulations which allow treatment of the full range of scales relevant to the galaxy formation and fundamental physics issues of interest. This requires simulations of much higher resolution and of much larger volume than the Millennium Simulation
- Demonstrating that simulations of differing resolution give convergent results so that the formation of all galaxies larger than Local Group dwarf spheroidals can be simulated throughout volumes as large of those of next-generation surveys
- Developing techniques to scale dark matter simulations in size and in time and to correct their large-scale quasi-linear structure so that the evolution of the galaxy population can be simulated accurately in *all* currently viable cosmologies, not just in that of the Millennium Simulation
- Developing techniques to explore the space of galaxy formation and cosmological parameters in order to determine the uncertainties in those parameters and the correlations between them.
- Embedding all these capabilities in a Virtual Observatory compatible public data archive with associated services, based on, but greatly extending the Millennium Simulation archive. Remote users will eventually be able:
  - to access all dark matter halo data for the underlying large simulations as well as galaxy data (including light cone data) for standard galaxy formation models implemented on them
  - to retrieve scaled halo data for cosmologies with parameters other than those of the original Millennium Simulation, in particular, with different dark energy models
  - to make their own galaxy catalogues (including light cone cataloguess) for galaxy formation models and cosmologies with user-specified parameters
  - to carry out Markov Chain Monte Carlo searches of parameter space to explore the galaxy formation models and cosmologies which are consistent with chosen observational datasets
  - to modify the assumptions underlying the galaxy formation models by introducing new modules for any of the baryonic and radiative processes
  - to study the statistics of lensing by ray-tracing through the simulated mass distributions