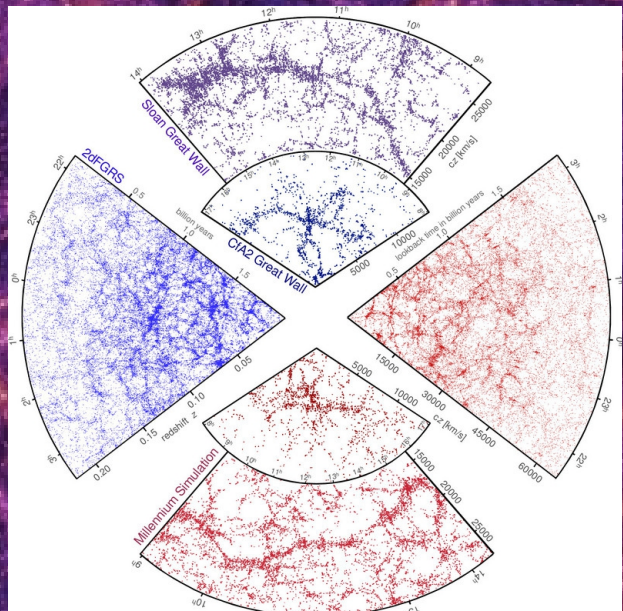
MPA October 2018

A Millennium Hausseminar

Simon White
Max Planck Institute for Astrophysics



A Millennium in Oberbayern

SW in 1996

~1000 weeks ago

The first ten Hausseminare

1	6. 5.91	G. Boerner	The Galaxy Distribution - Statistics and Formation Models
2	13. 5.91	H. Ritter	Cataclysmic Variables
3	27. 5.91	Ch. Jahn	Sunspots
4	10. 6.91	J. Cernohorsky	Neutrinos, Neutron Stars and Explosion Mechanisms
5	17. 6.91	J. Schaefer	Empirical Corrections for the H2-H2 Interaction Potential
6	24. 6.91	F. Matteucci	Galactic Chemical Evolution
7	1. 7.91	H. C. Thomas	ROSAT Observations of the Magnetic Cataclysmic Variable EF Eri
8	8. 7.91	E. Mueller	Theoretical Lightcurves and Gamma-Ray Signatures of Type Ia Supernovae
9	15. 7.91	B. Schmidt	Linear versus Non-linear Hydrodynamics in Cosmology
10	22. 7.91	P. Schneider	Lensing Statistics

Y2K?

IAU General Assembly 2002, Darling Harbor, Sydney

$$N = 10^{10}$$

SW + VS + the Millennium Machine@RZG, ~2005

The Millennium simulation was run on the *Regatta* supercomputer of the RechenZentrum Garching, finishing in 2004

REQUIRED RESOURCES

1 TByte RAM needed

16 x 32-way Regatta Node
64 GByte RAM
512 CPU total

CPU time requirement

330.000 processor hours

27 days on 512 CPUs/16 nodes
38 years in serial
~ 6% of annual time on total Regatta system

The Millennium simulation was run on the *Regatta* supercomputer of the RechenZentrum Garching, finishing in 2004

REQUIRED RESOURCES

1 TByte RAM needed

16 x 32-way Regatta Node
64 GByte RAM
512 CPU total

CPU time requirement

330.000 processor hours

27 days on 512 CPUs/16 nodes
38 years in serial
~ 6% of annual time on total Regatta system

c.f. Illustris-TNG50 on Hazel Hen at HLRS, to finish in 2019
~16,000 cpus, ~130,000,000 cpu-hrs, ~85 Tbyte RAM

2 June 2005 | www.nature.com/nature | £10

THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE

nature

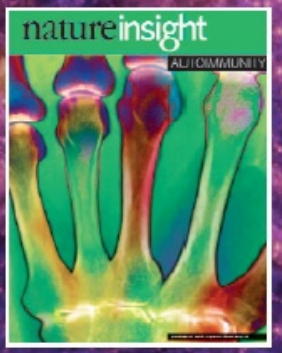
GENOME EDITING
Rewriting the rules for gene therapy

BCL-2 INHIBITORS
Potent new antitumour compounds

HUMAN BEHAVIOUR
Oxytocin — the 'trust hormone'

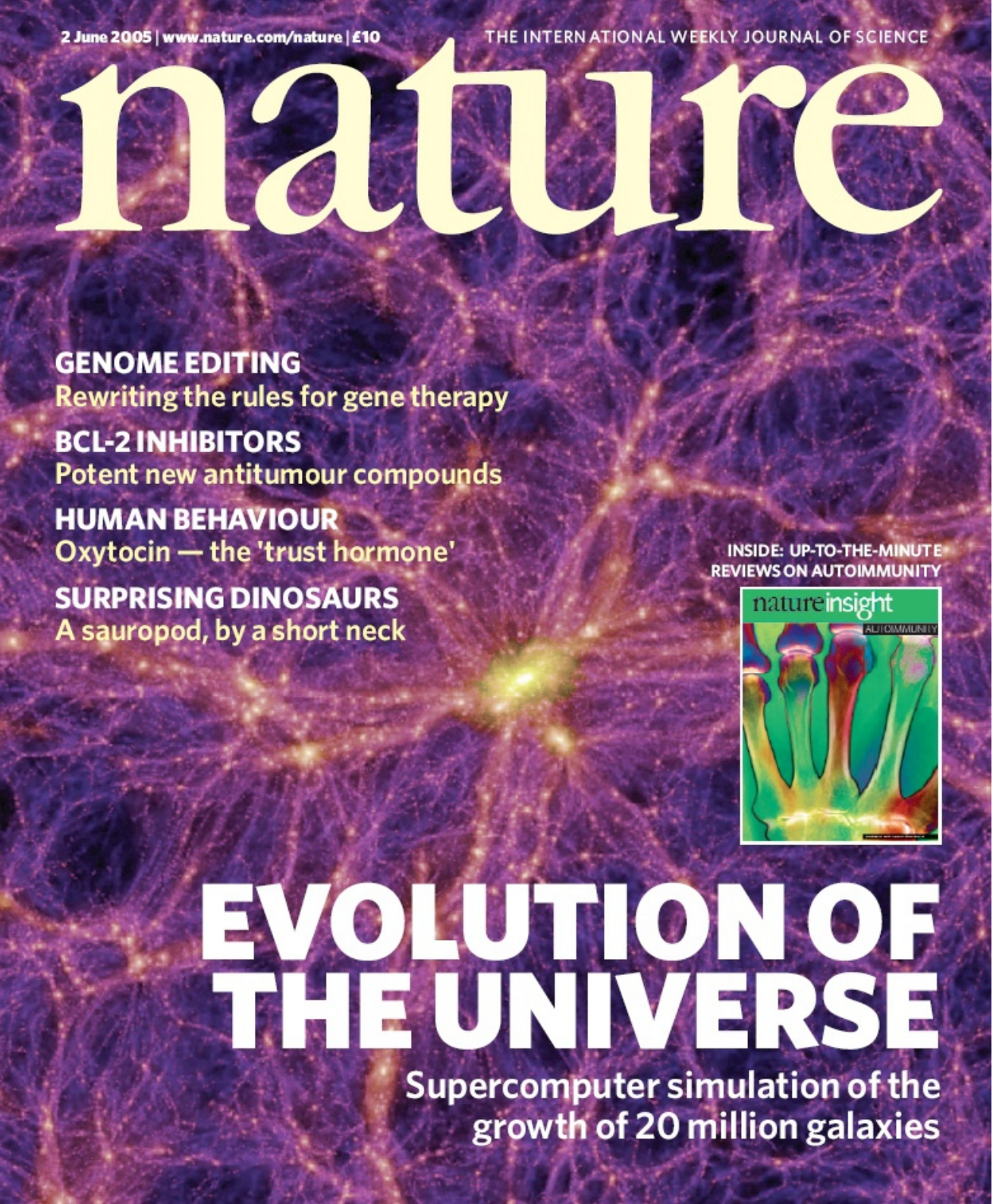
SURPRISING DINOSAURS
A sauropod, by a short neck

INSIDE: UP-TO-THE-MINUTE REVIEWS ON AUTOIMMUNITY



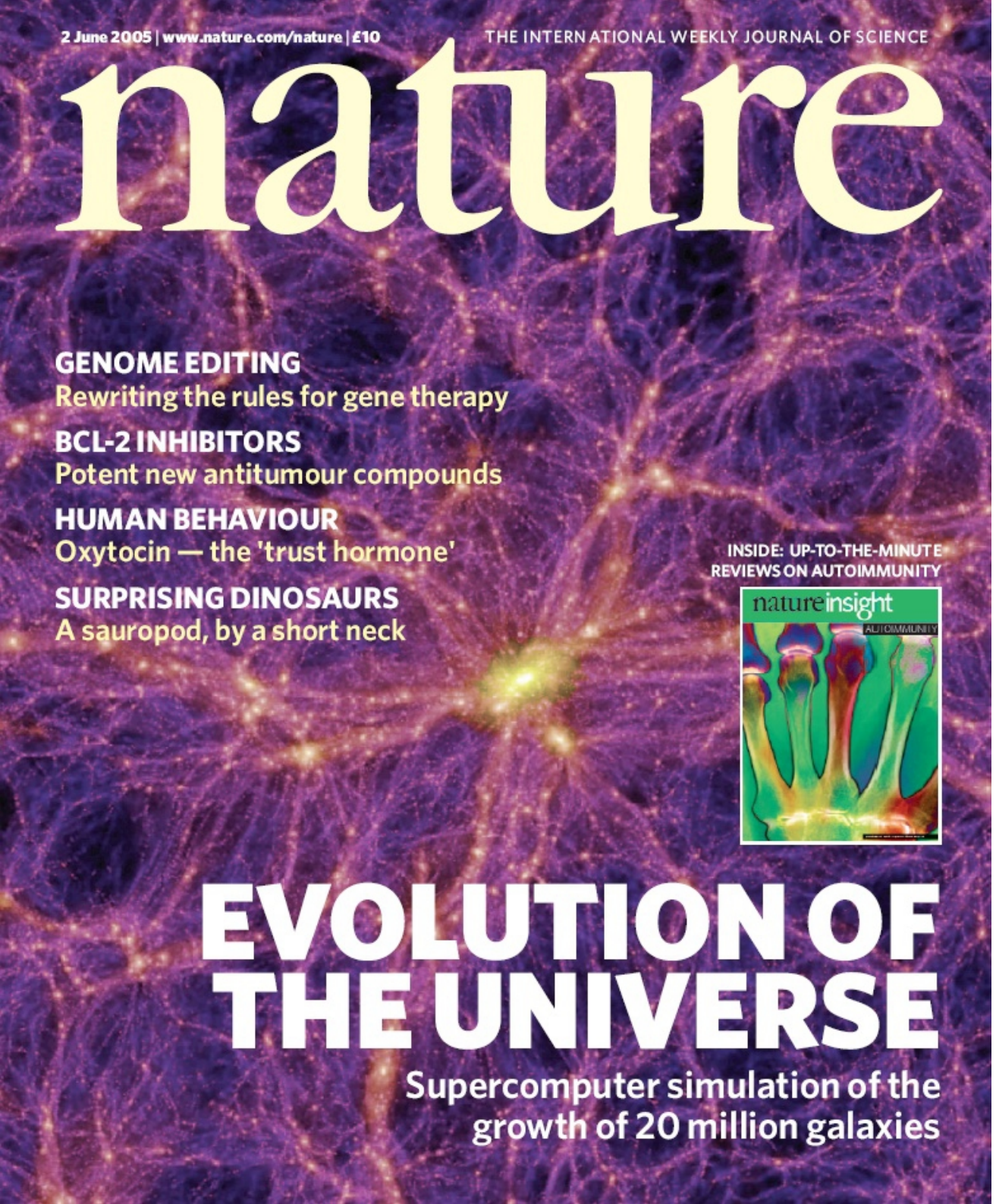
EVOLUTION OF THE UNIVERSE

Supercomputer simulation of the growth of 20 million galaxies



Most highly cited research papers in astrophysical theory in this Millennium

#3 Springel et al 2005
2892 citations



Most highly cited research papers in astrophysical theory in this Millennium

#1 Bruzual & Charlot 2003
5951 citations

#2 Springel 2005
3548 citations

#3 Springel et al 2005
2892 citations

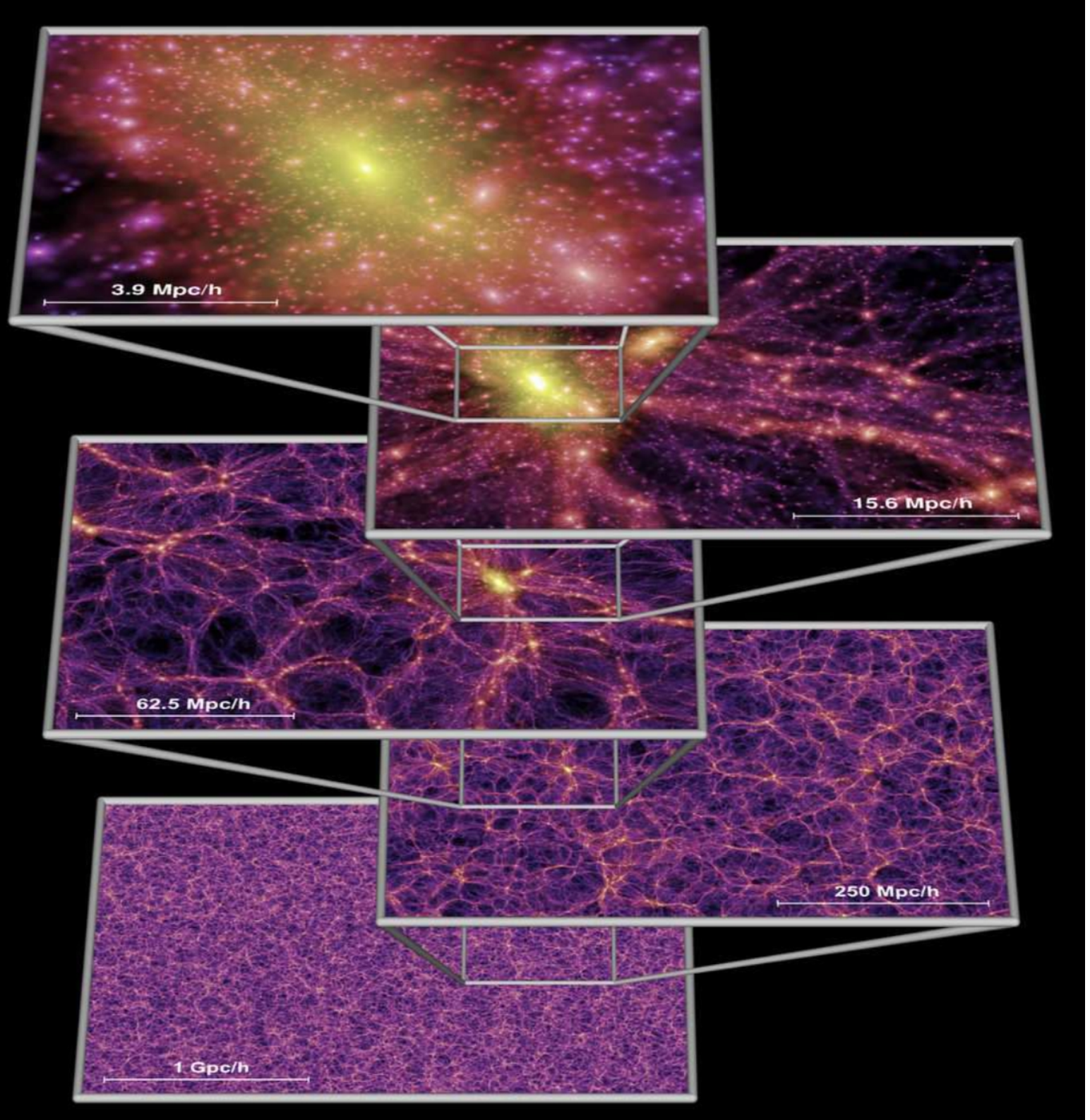


Figure 1

Nice pictures are important!

How did Volker manage to make a 2 Gpc/h x 3 Gpc/h image with no repetitions from a 0.5 Gpc/h box with periodic B.C.'s?

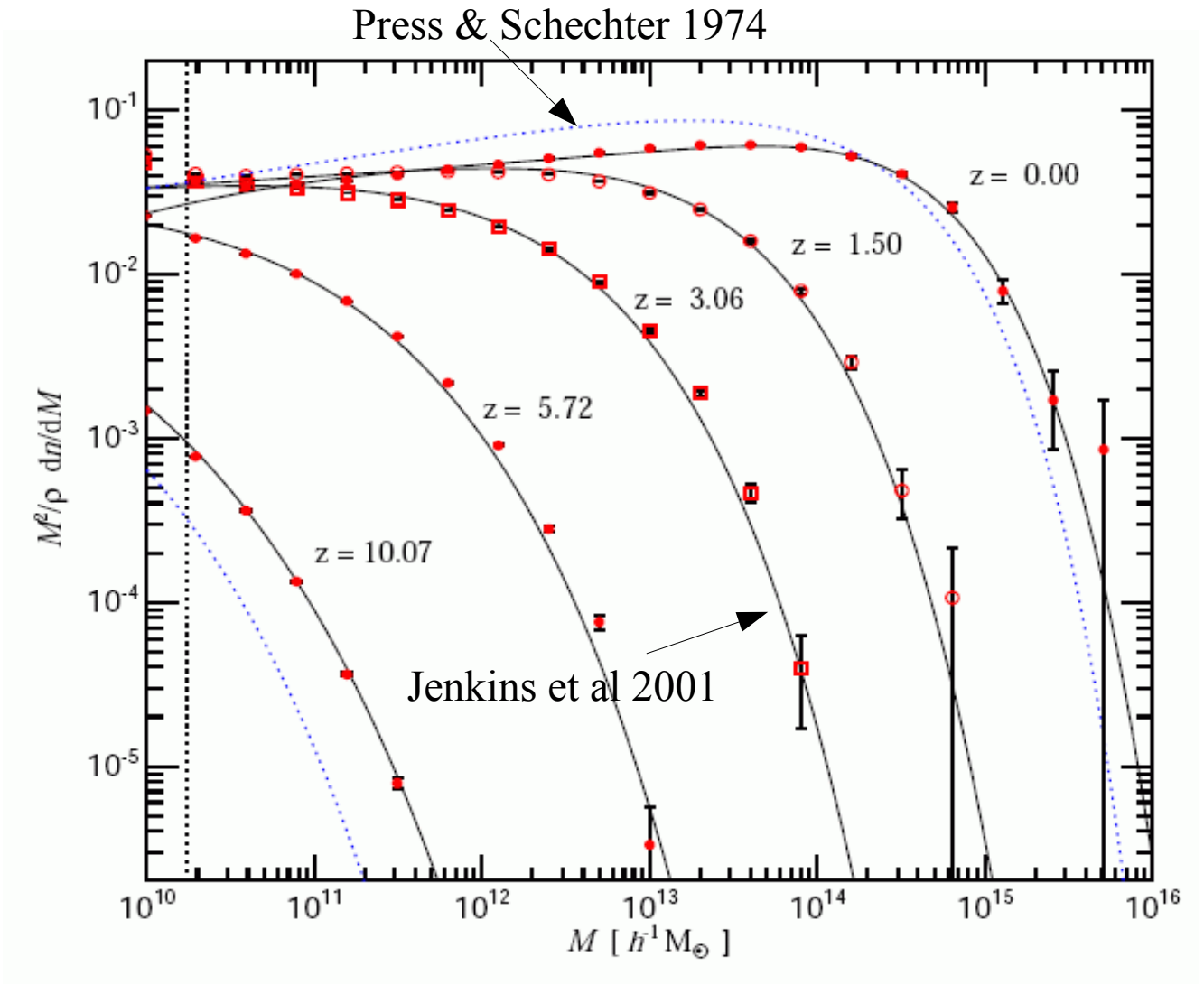


Figure 2

Unprecedented statistics and dynamic range for estimates of nonlinear properties of the DM – here halo mass functions

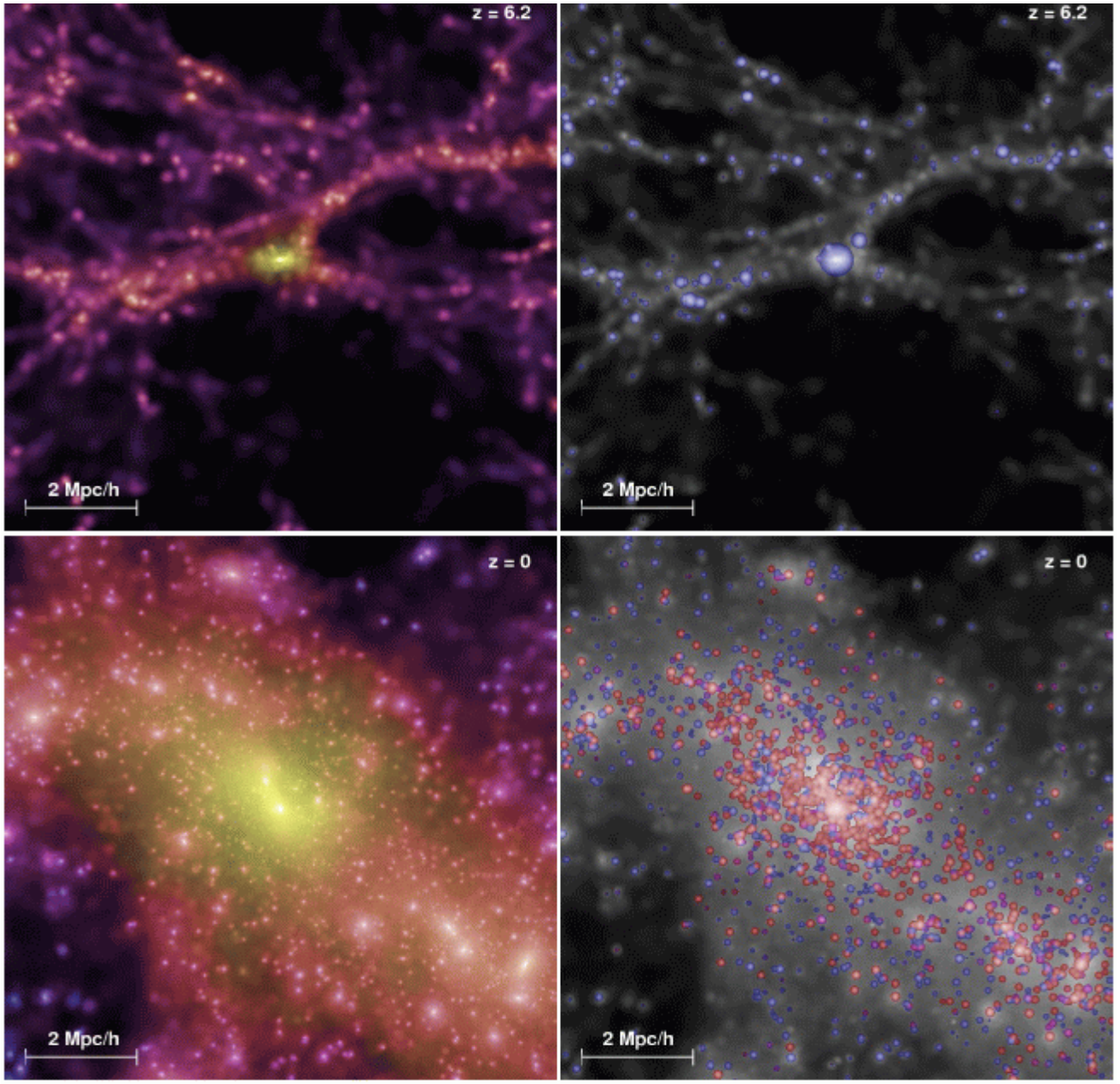


Figure 3

High resolution and large volume, together with galaxy populations, enable study of the formation and evolution of rare objects – here potential z=6 QSO's

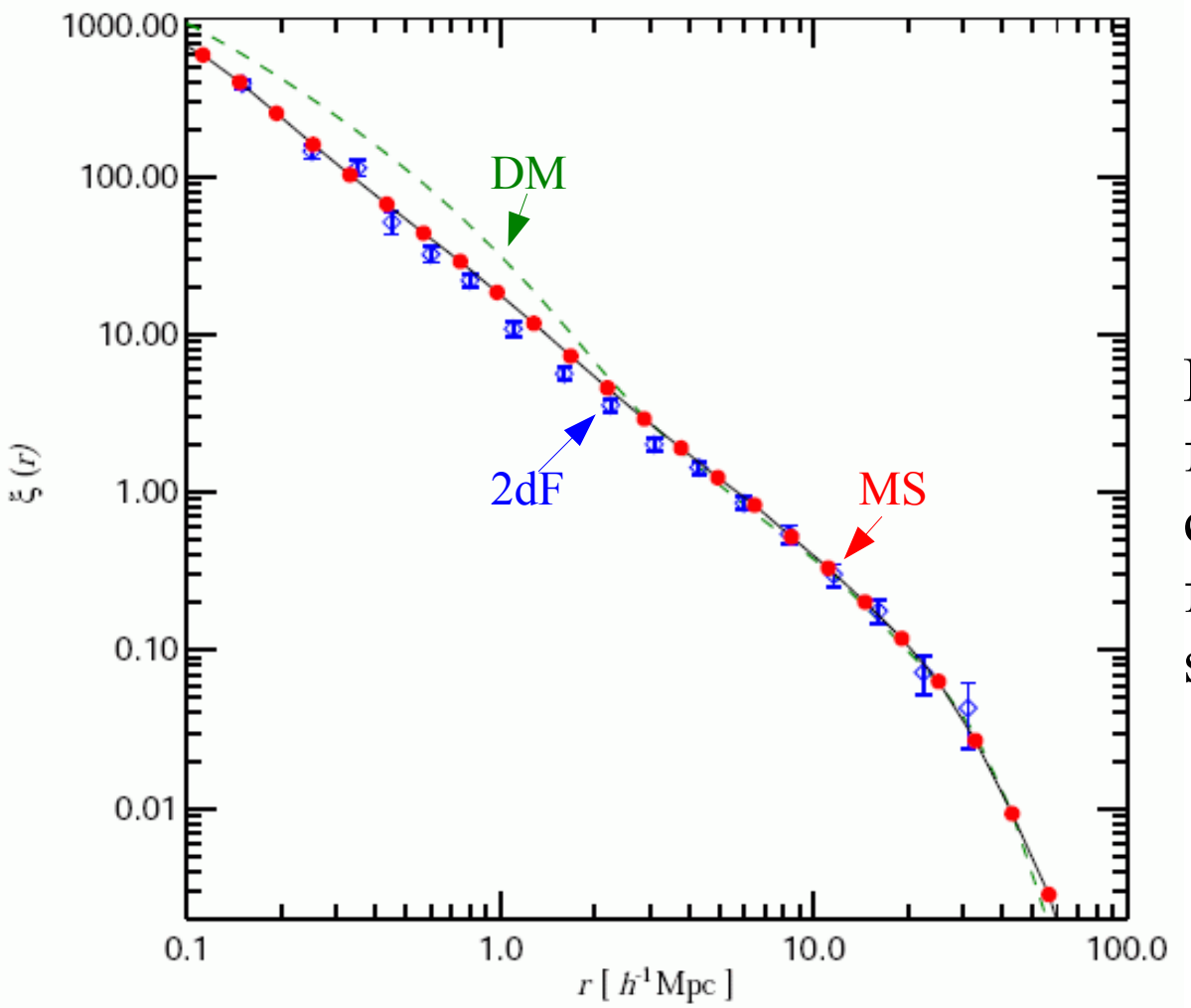
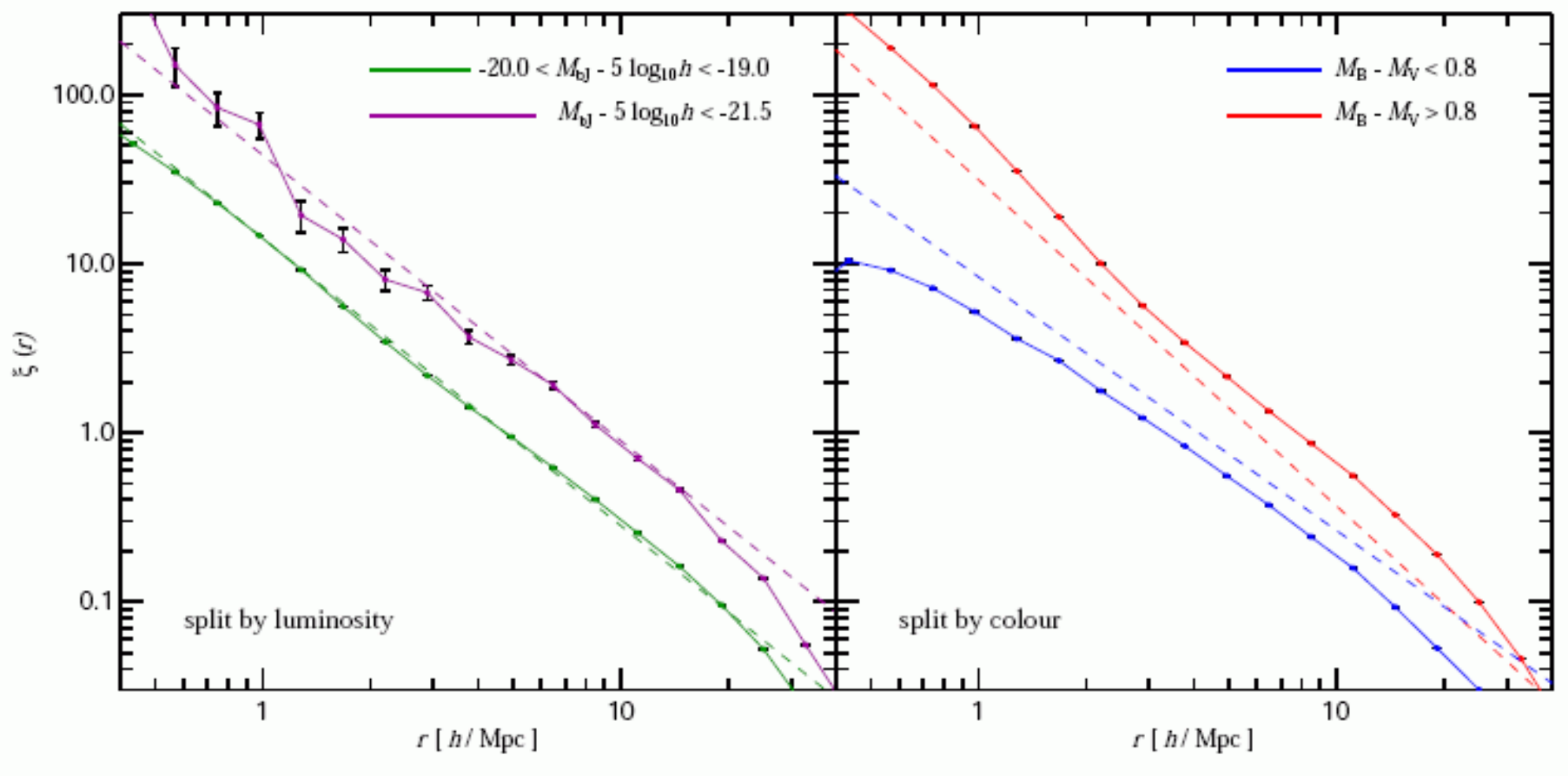


Figure 4

For the first time, a galaxy formation simulation can be compared with clustering data from a large galaxy redshift survey.

Figure 5



Also as a function of galaxy properties.

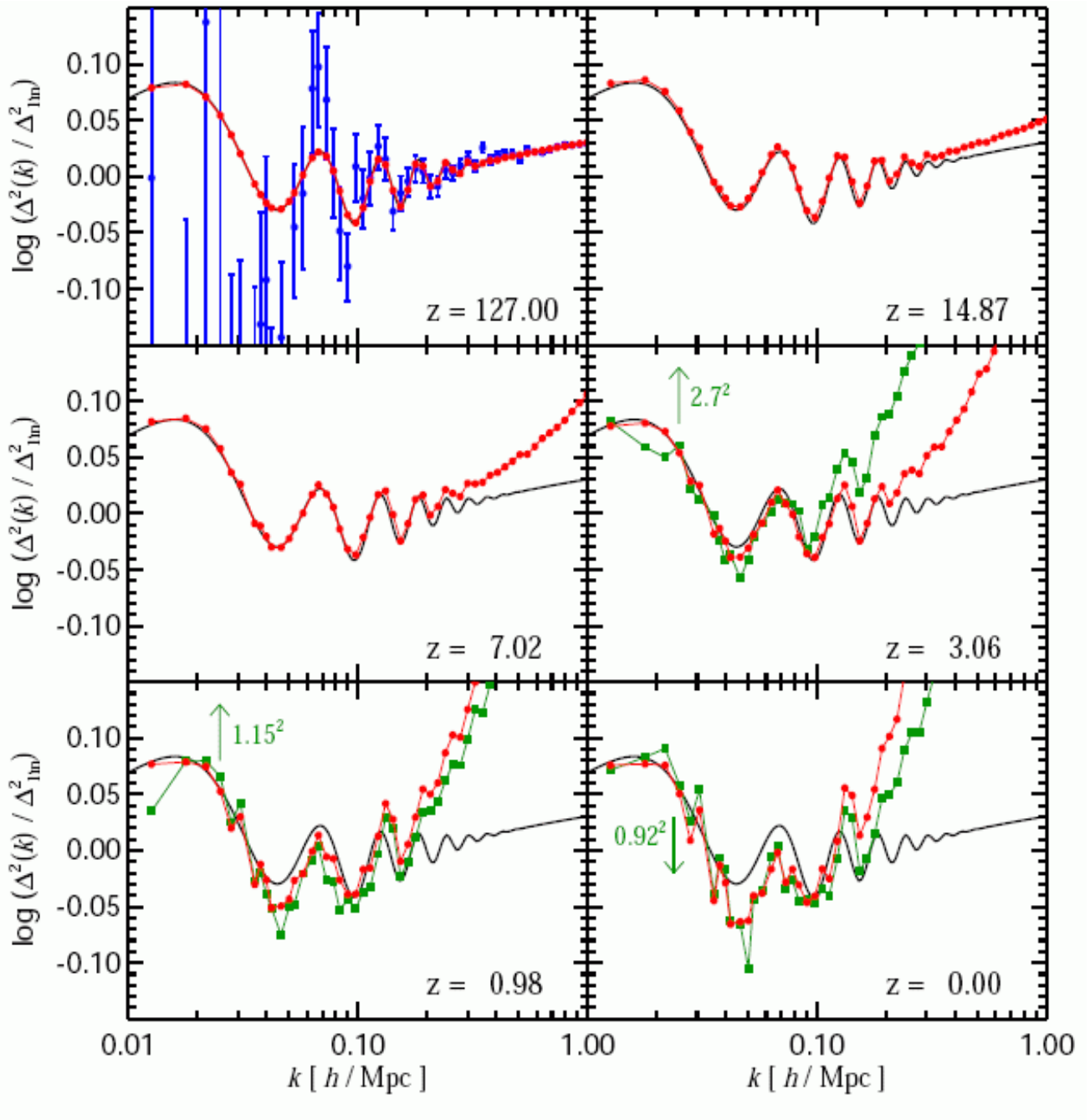


Figure 6

The box is (just) big enough to look at the BAO feature in the *galaxy* distribution – i.e. to do "cosmology"

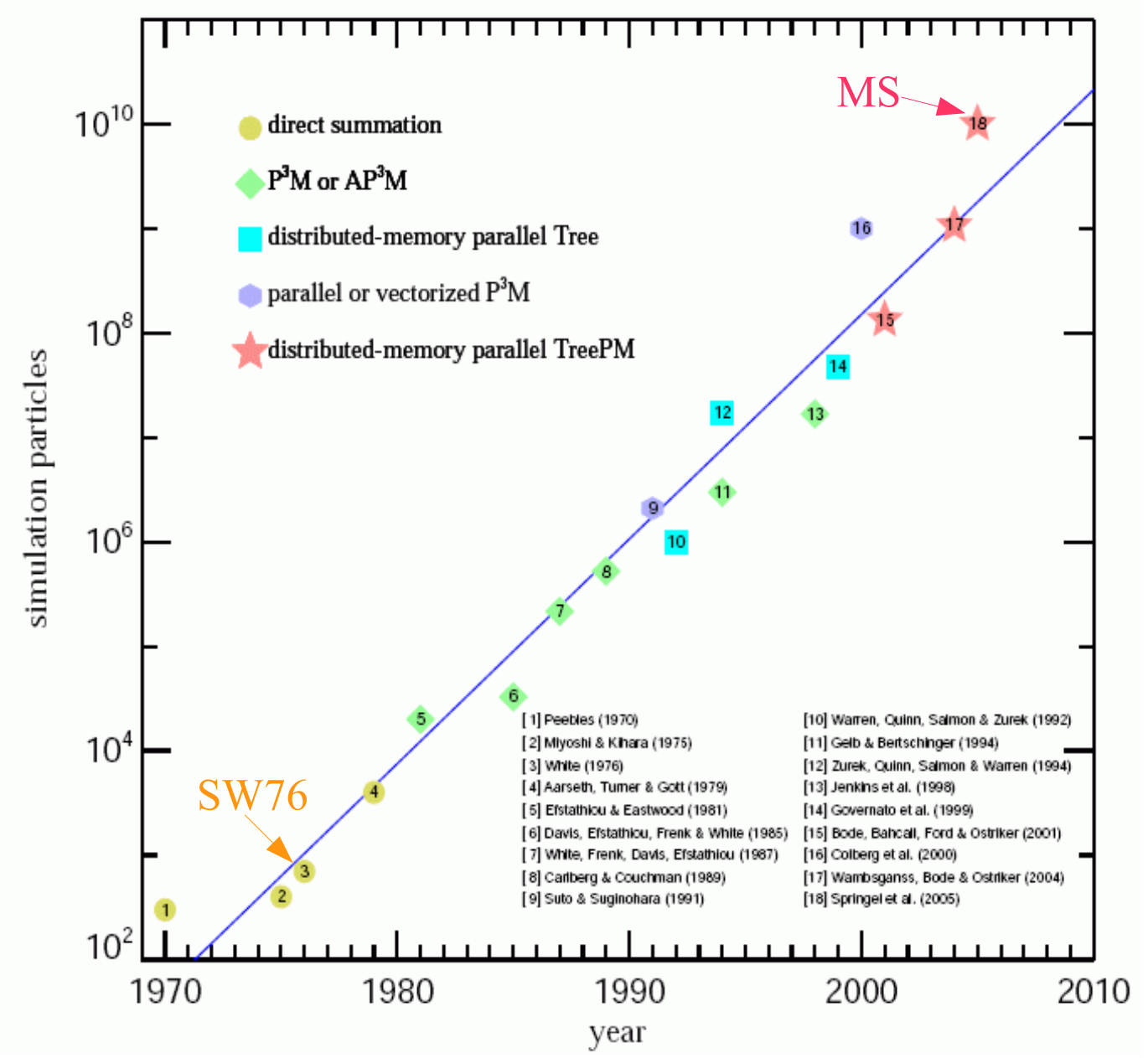


Figure 7

"Moore's Law" for cosmological N-body simulations

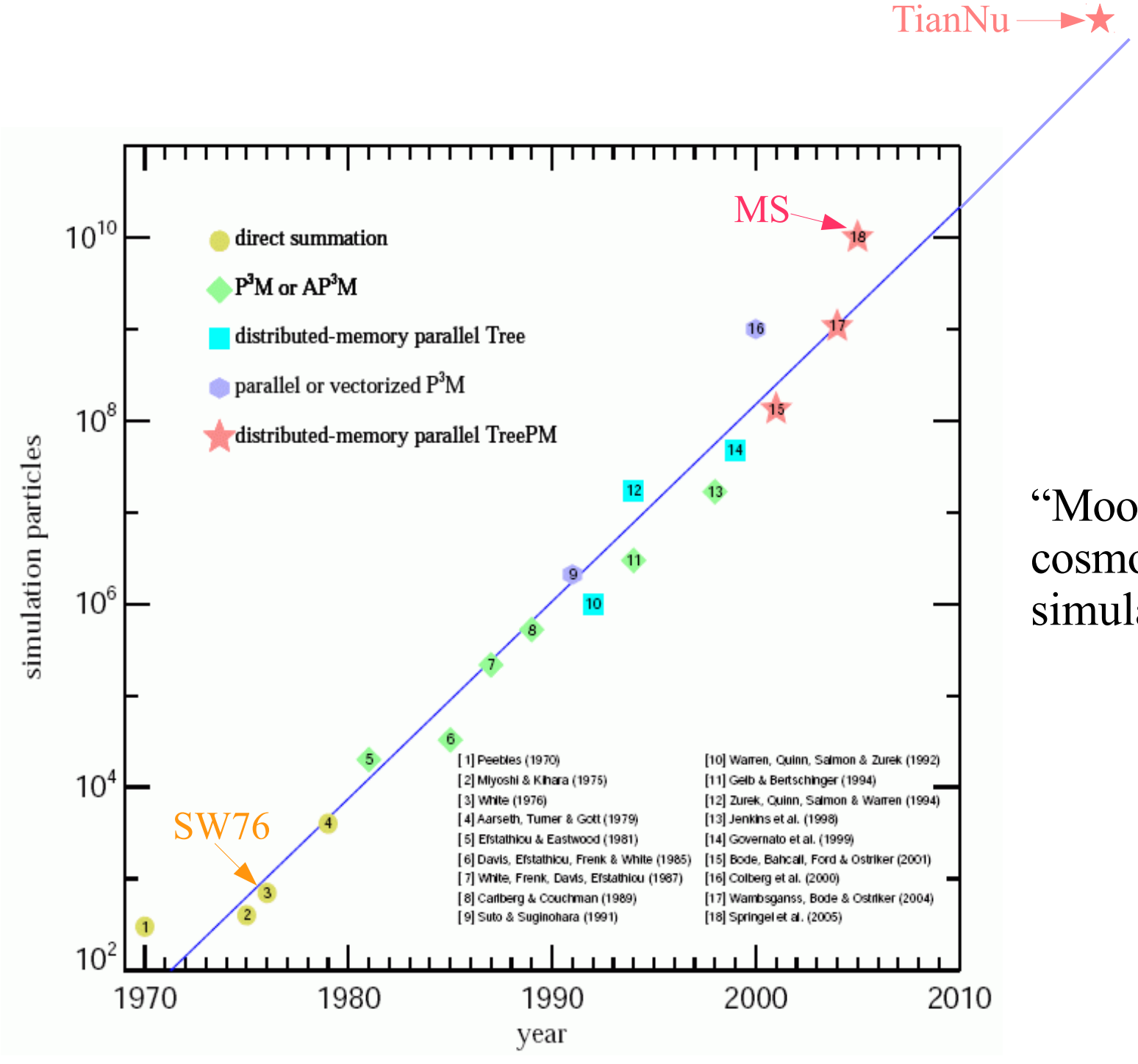
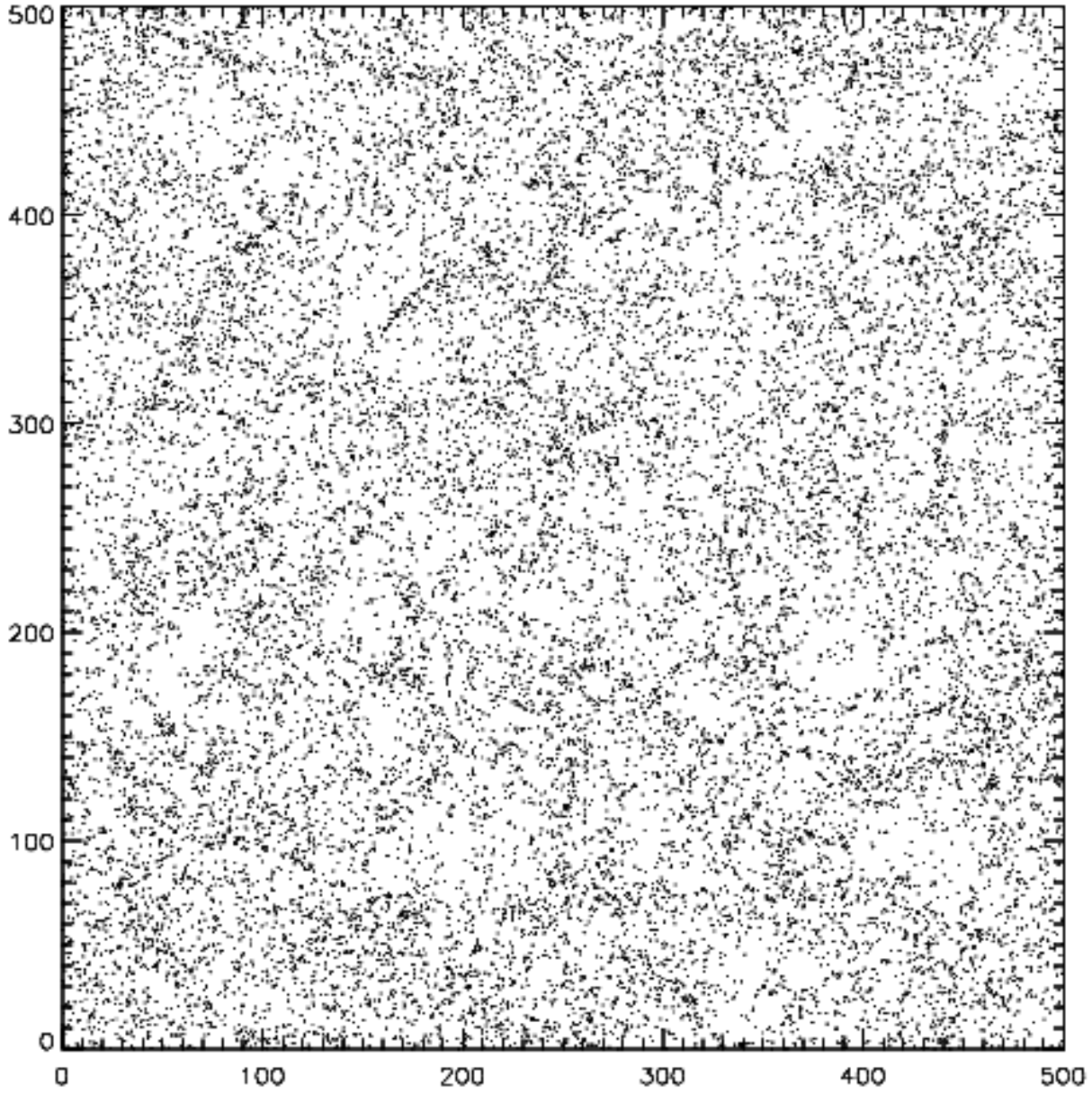


Figure 7

"Moore's Law" for cosmological N-body simulations

Does formation history depend on environment?

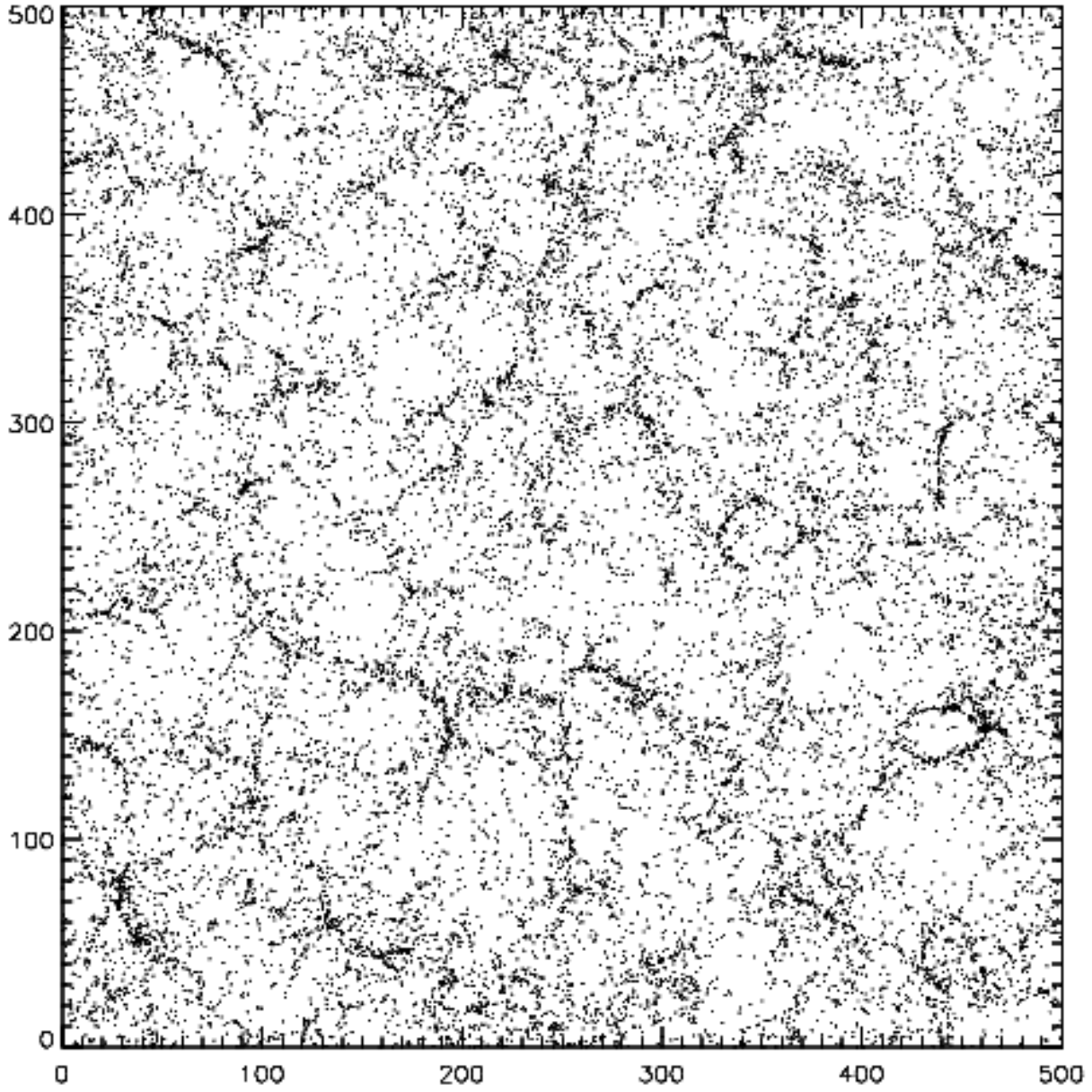


Gao, Springel & White 2005

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

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

Does formation history depend on environment?

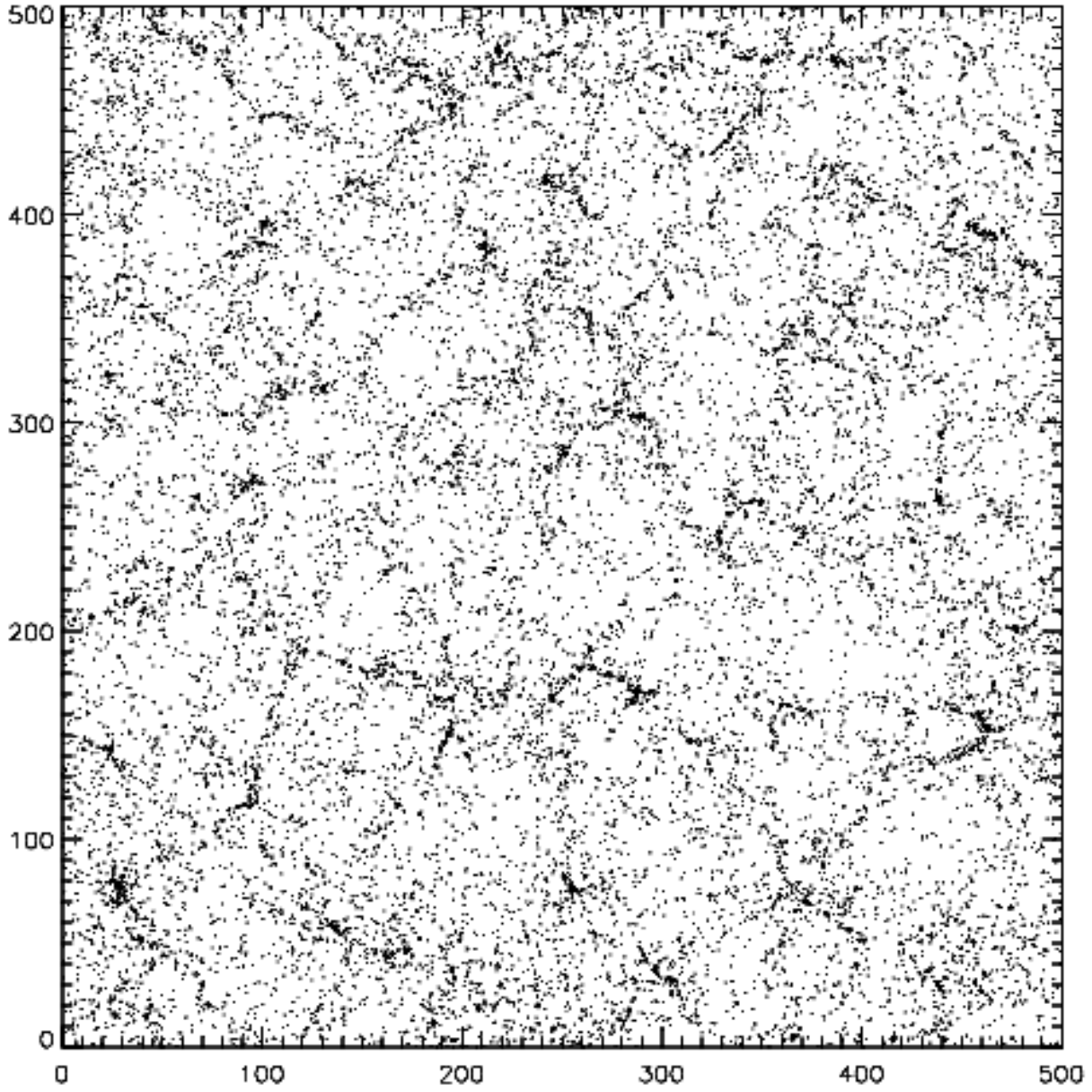


Gao, Springel & White 2005

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

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

Does formation history depend on environment?

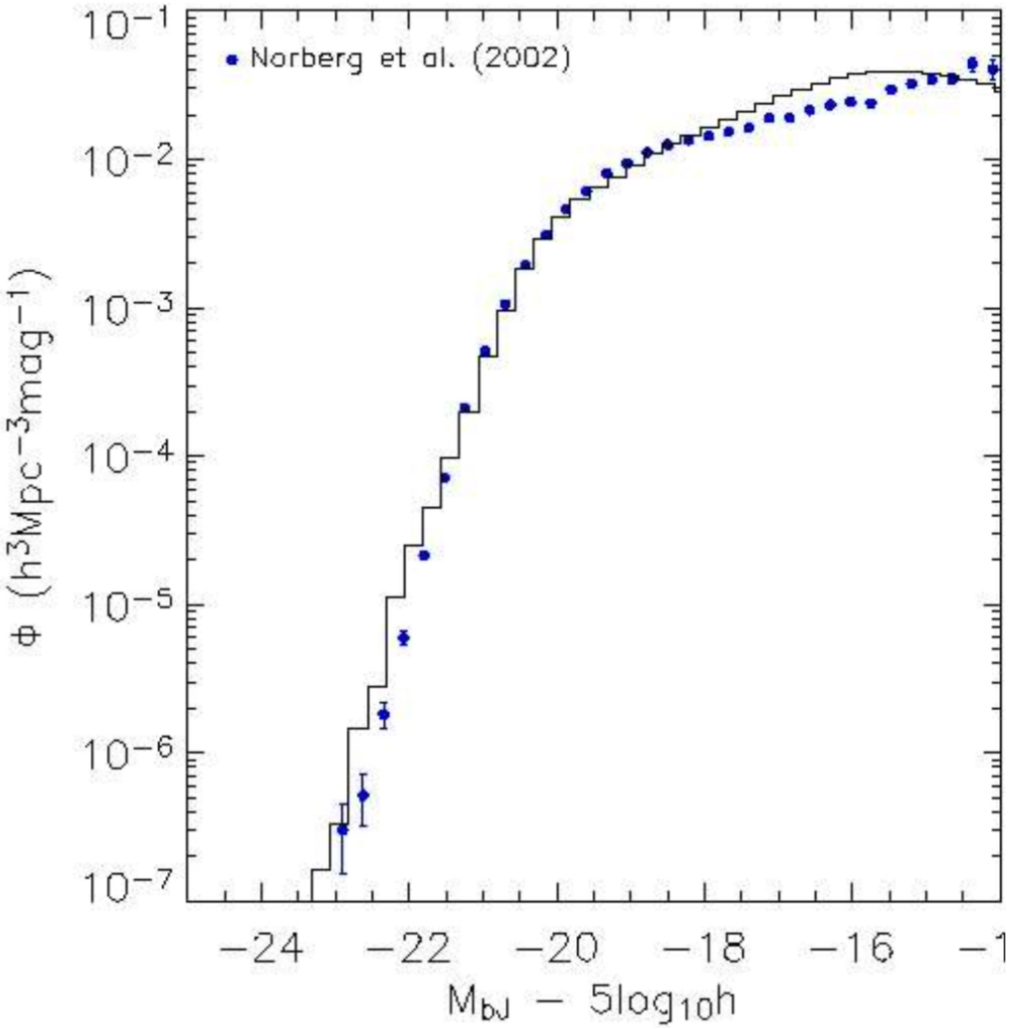


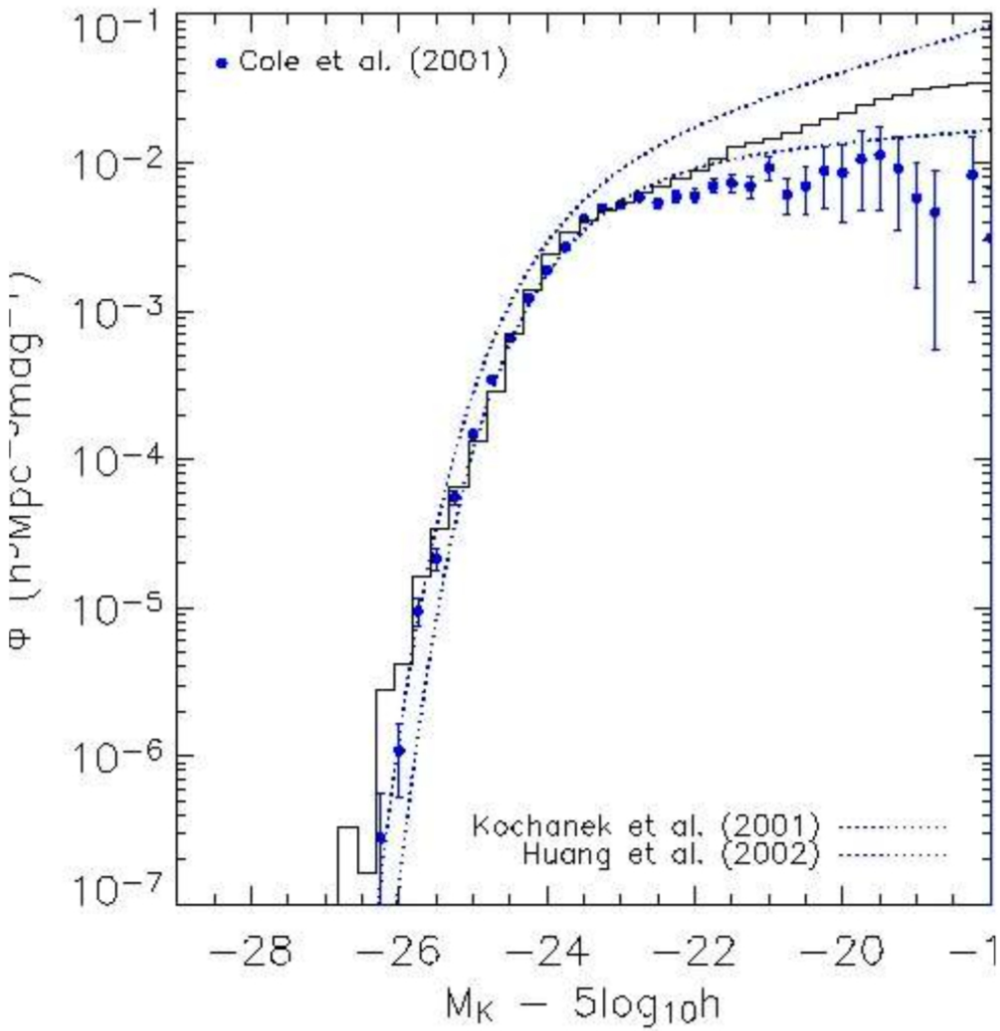
Gao, Springel & White 2005

An equal number of randomly chosen DM particles

This effect has become known as assembly bias

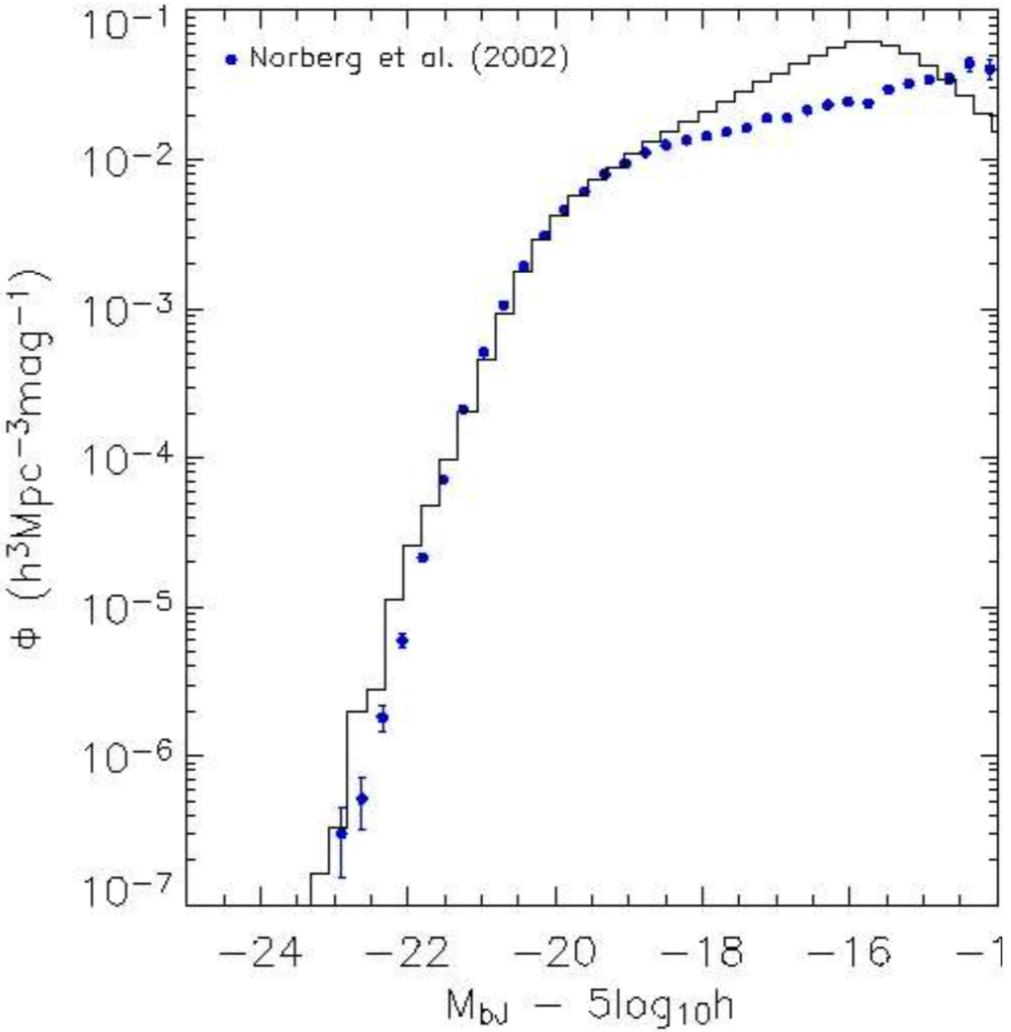
Effect of feedback on the Luminosity Function

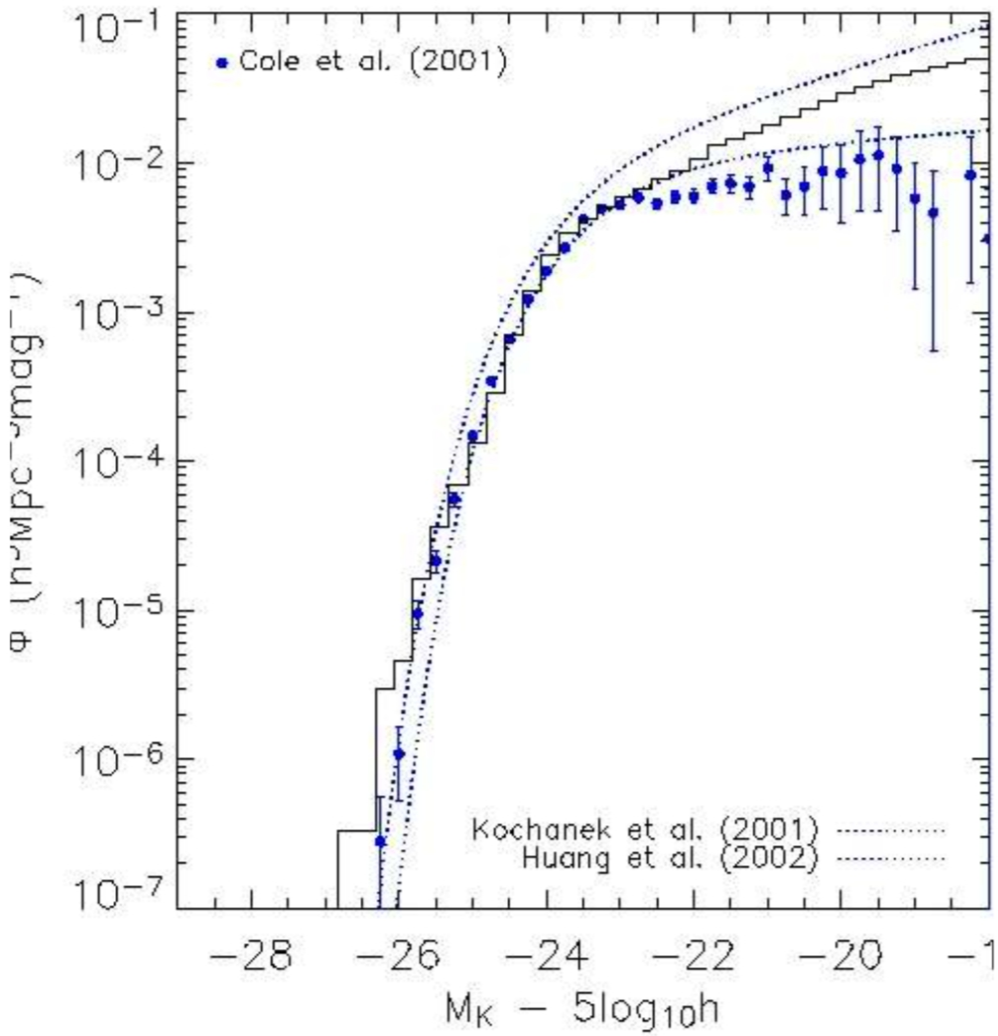




Full model with reionisation, AGN and SN feedback Croton et al 2005

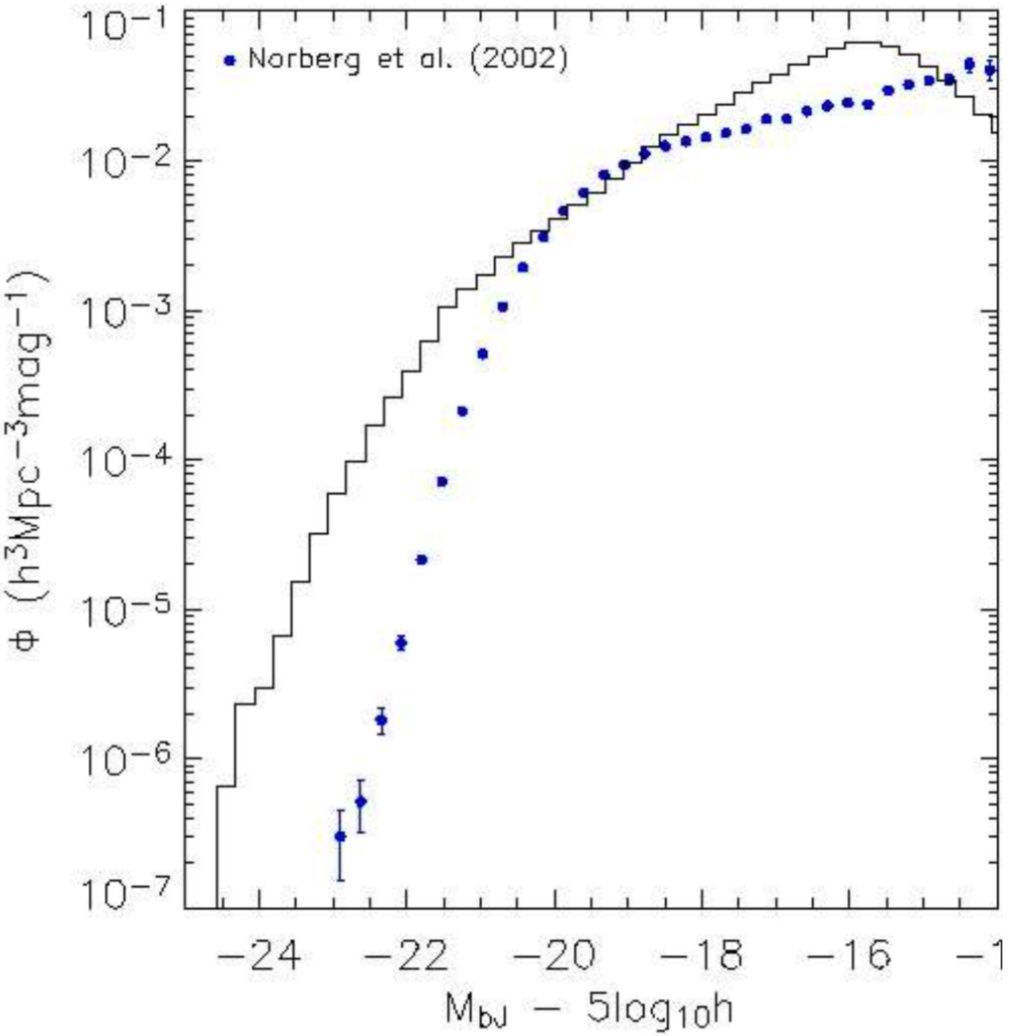
Effect of feedback on the Luminosity Function

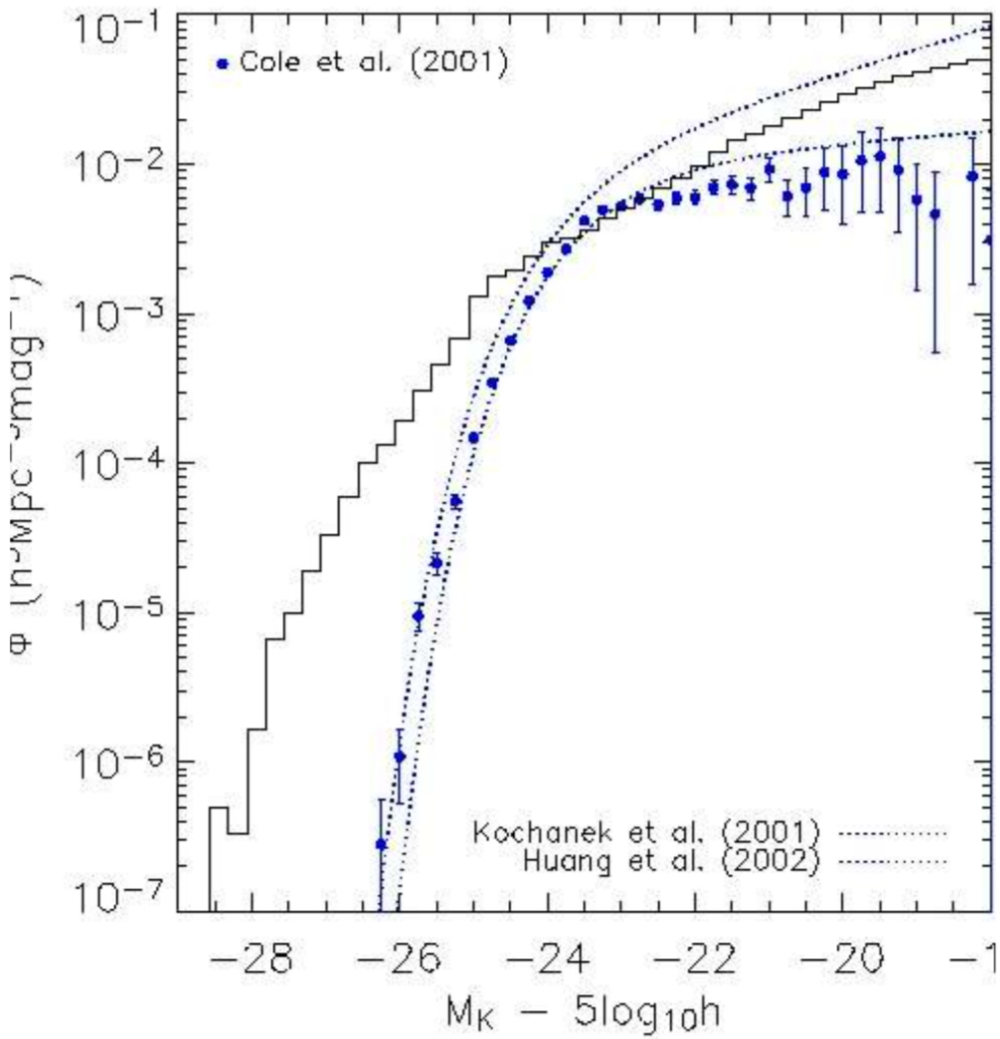




Full model with ~~reionisation,~~ AGN and SN feedback Croton et al 2005

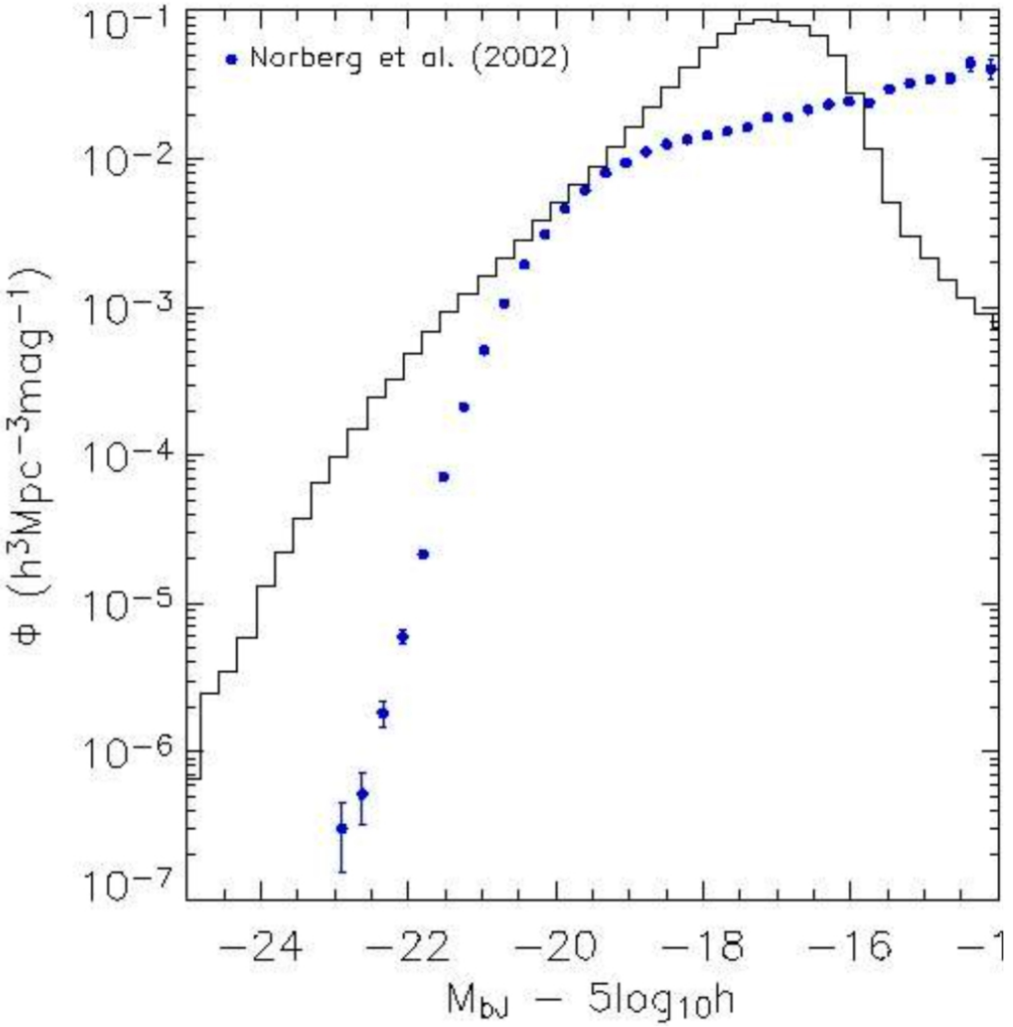
Effect of feedback on the Luminosity Function

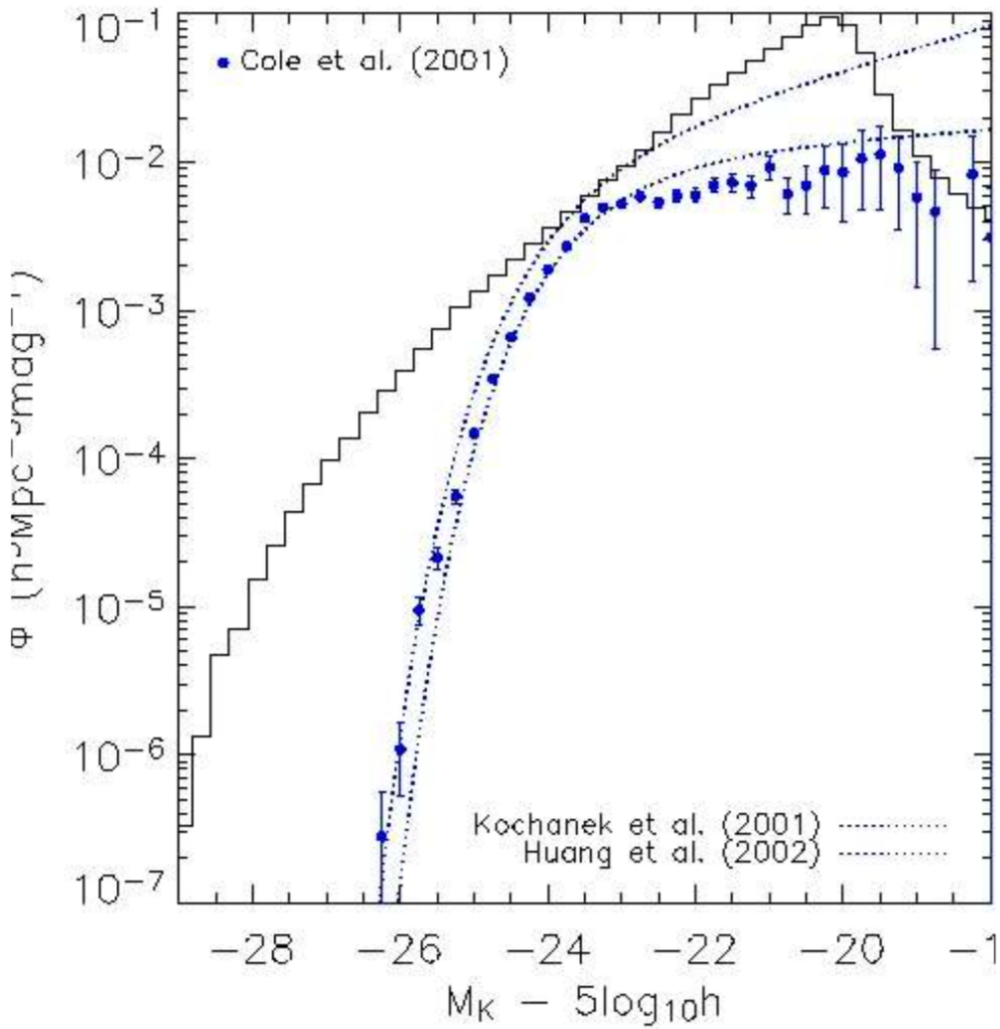




Full model with ~~reionisation~~, ~~AGN~~ and SN feedback Croton et al 2005

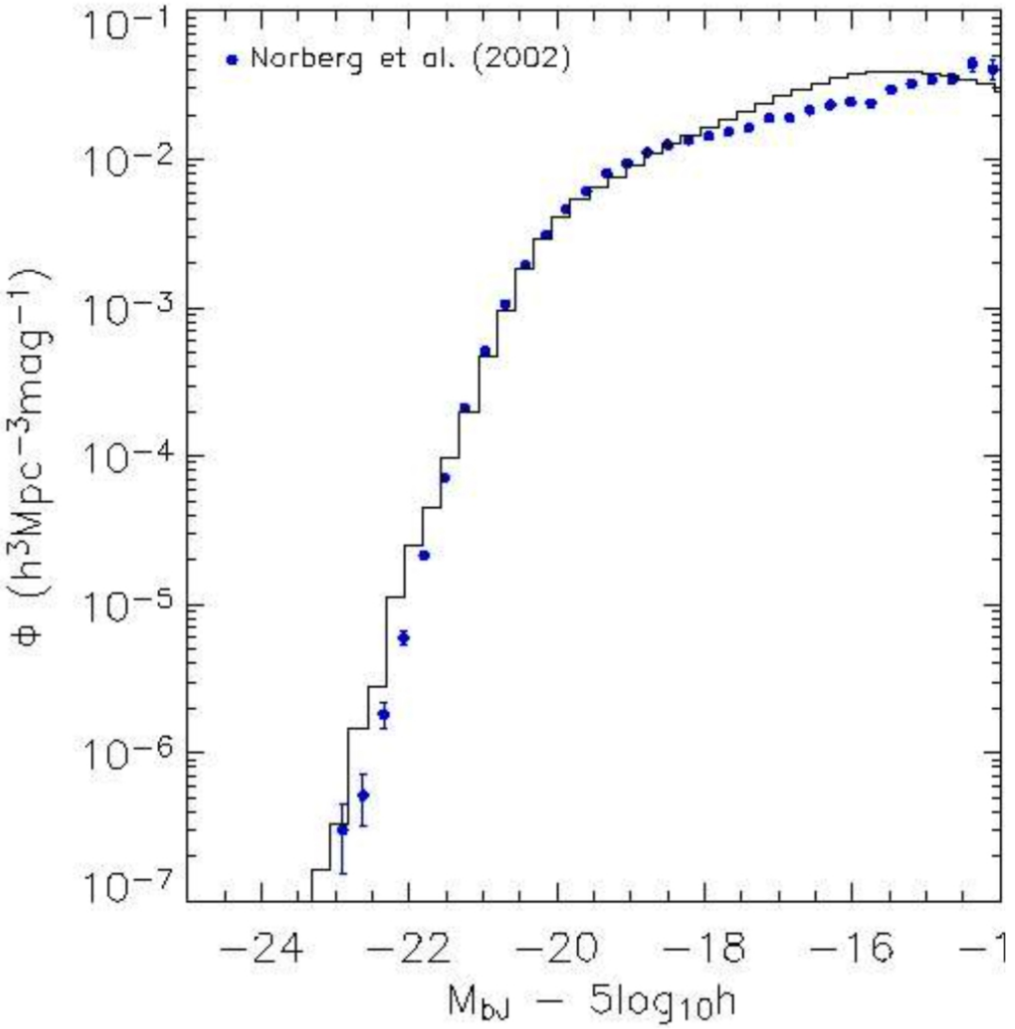
Effect of feedback on the Luminosity Function

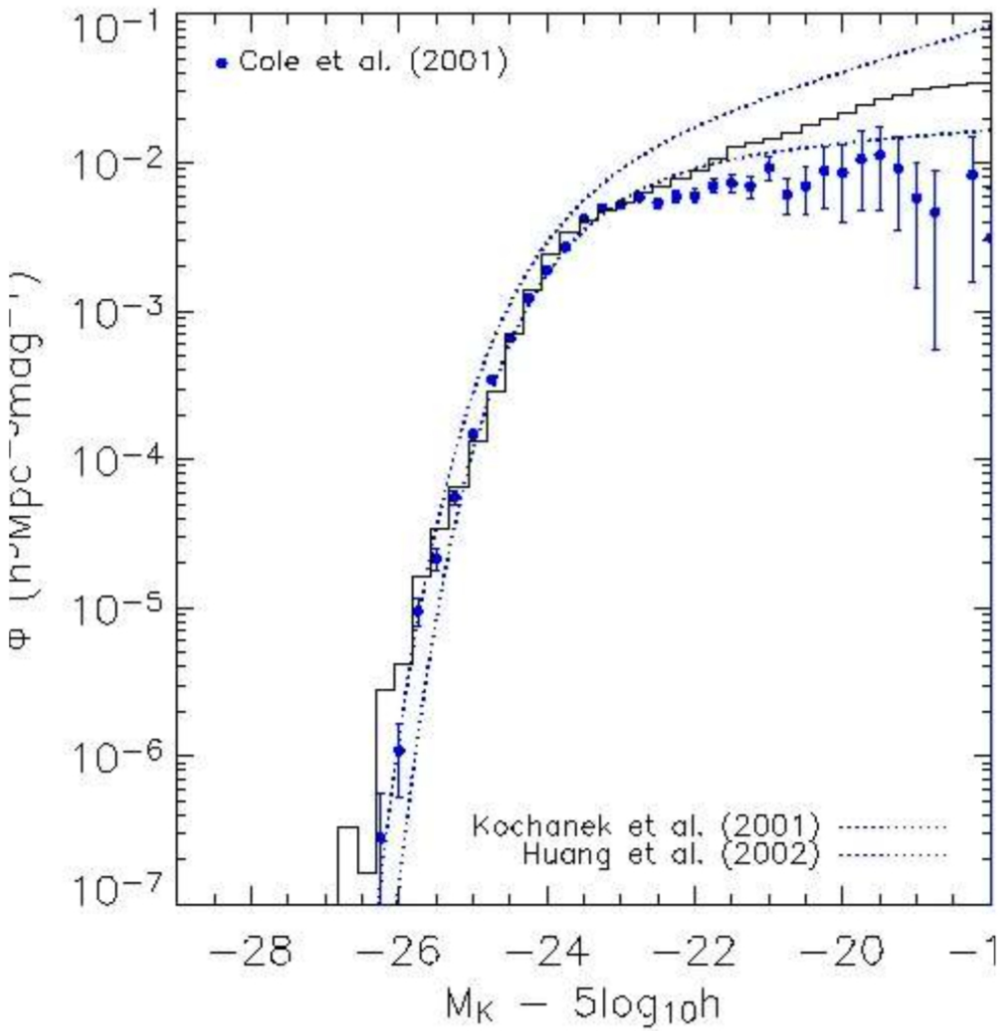




Full model with ~~reionisation~~, ~~AGN~~ and ~~SN~~ feedback Croton et al 2005

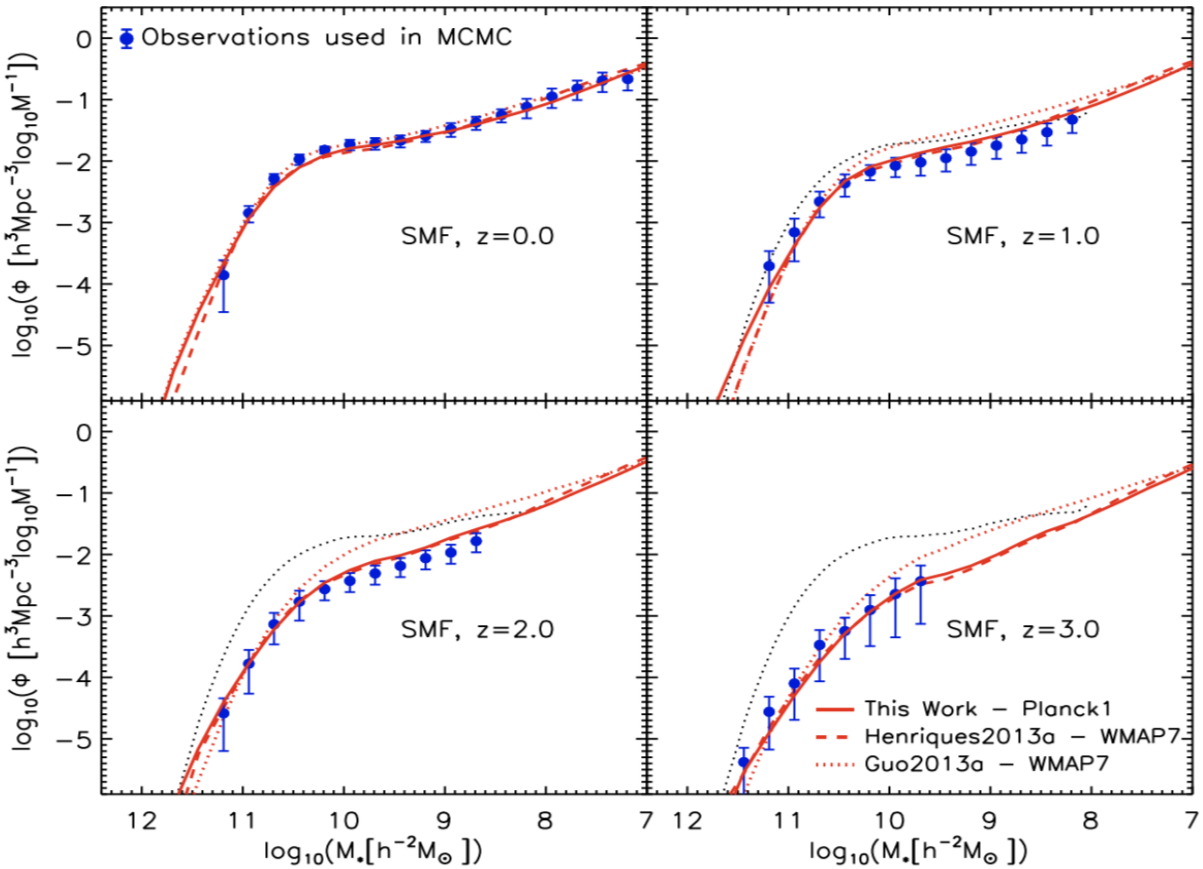
Effect of feedback on the Luminosity Function





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

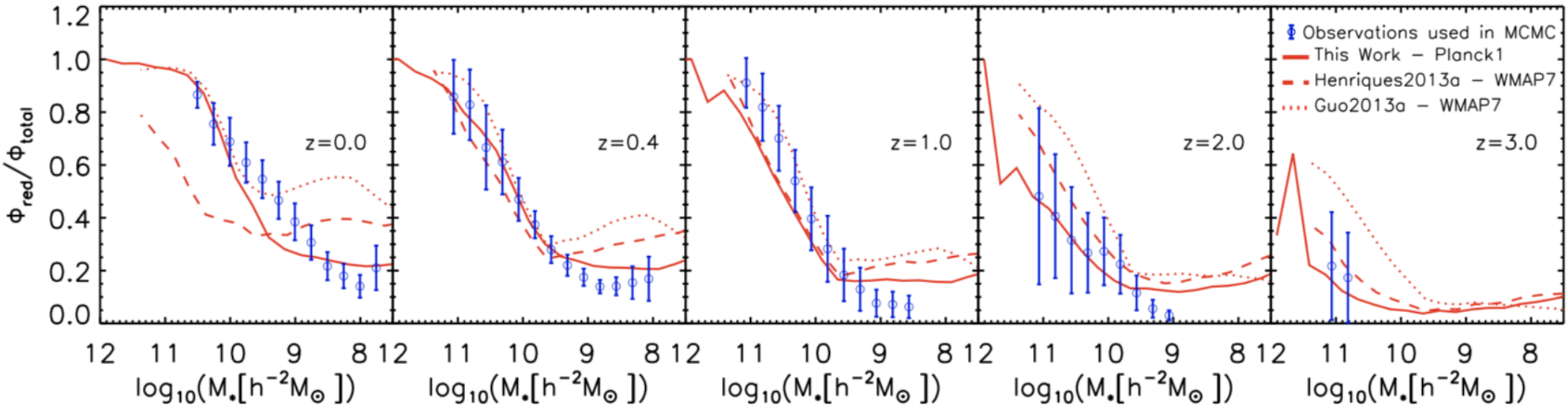
Stellar mass functions



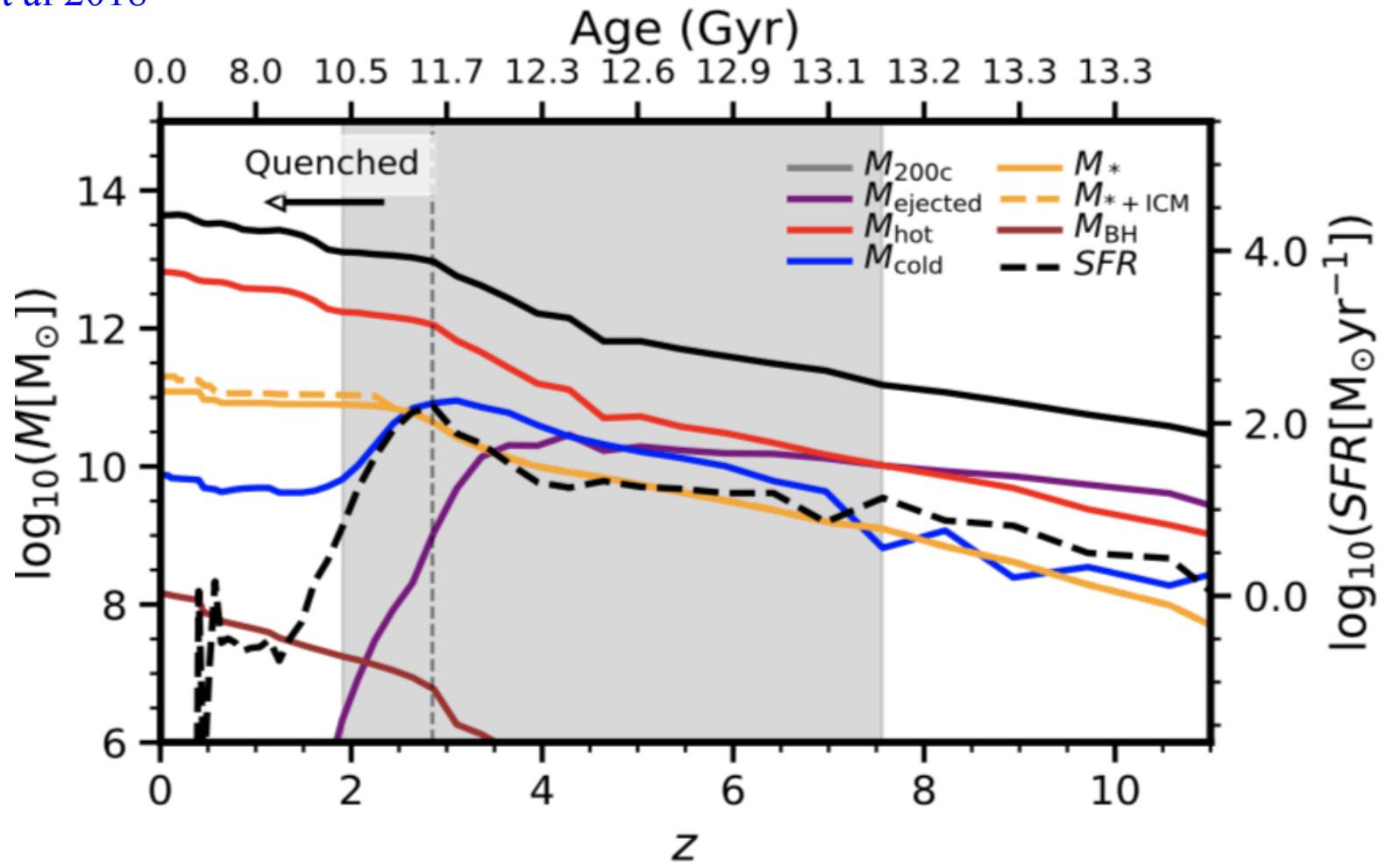
The most recent public versions of the galaxy formation models are fit to observed galaxy stellar mass functions and quenched fractions over $0 \leq z \leq 3$ and adopt a *Planck* cosmology

Henriques et al 2015

Quenched fractions



Henriques et al 2018



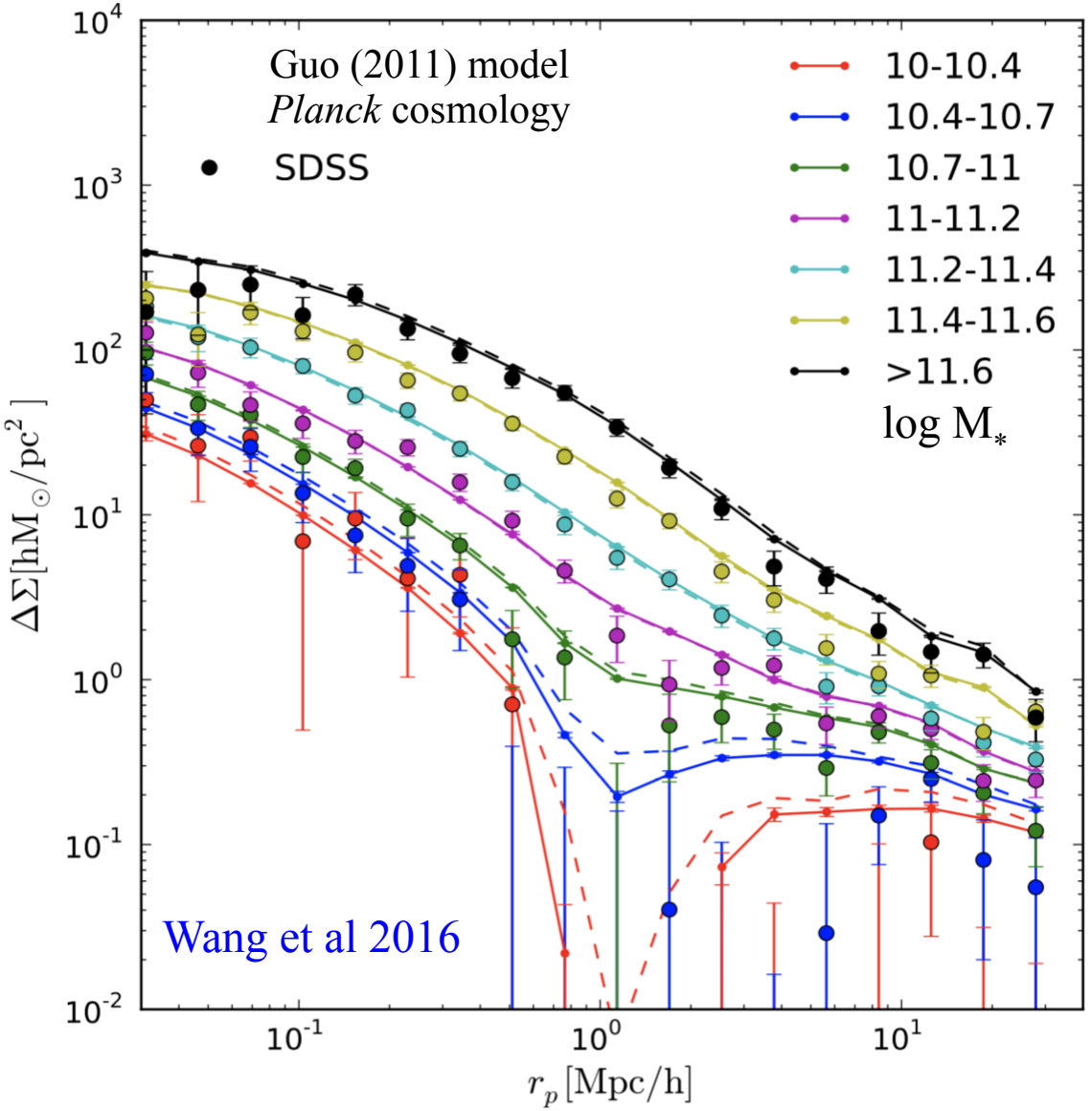
They predict the evolution of galaxies with $8 \leq \log M_* \leq 12$ subject

a) to the observational constraints over $0 \leq z \leq 3$

b) to physically consistent growth in a *Planck* ΛCDM cosmology

This example shows growth of the central galaxy in a small $z = 0$ cluster

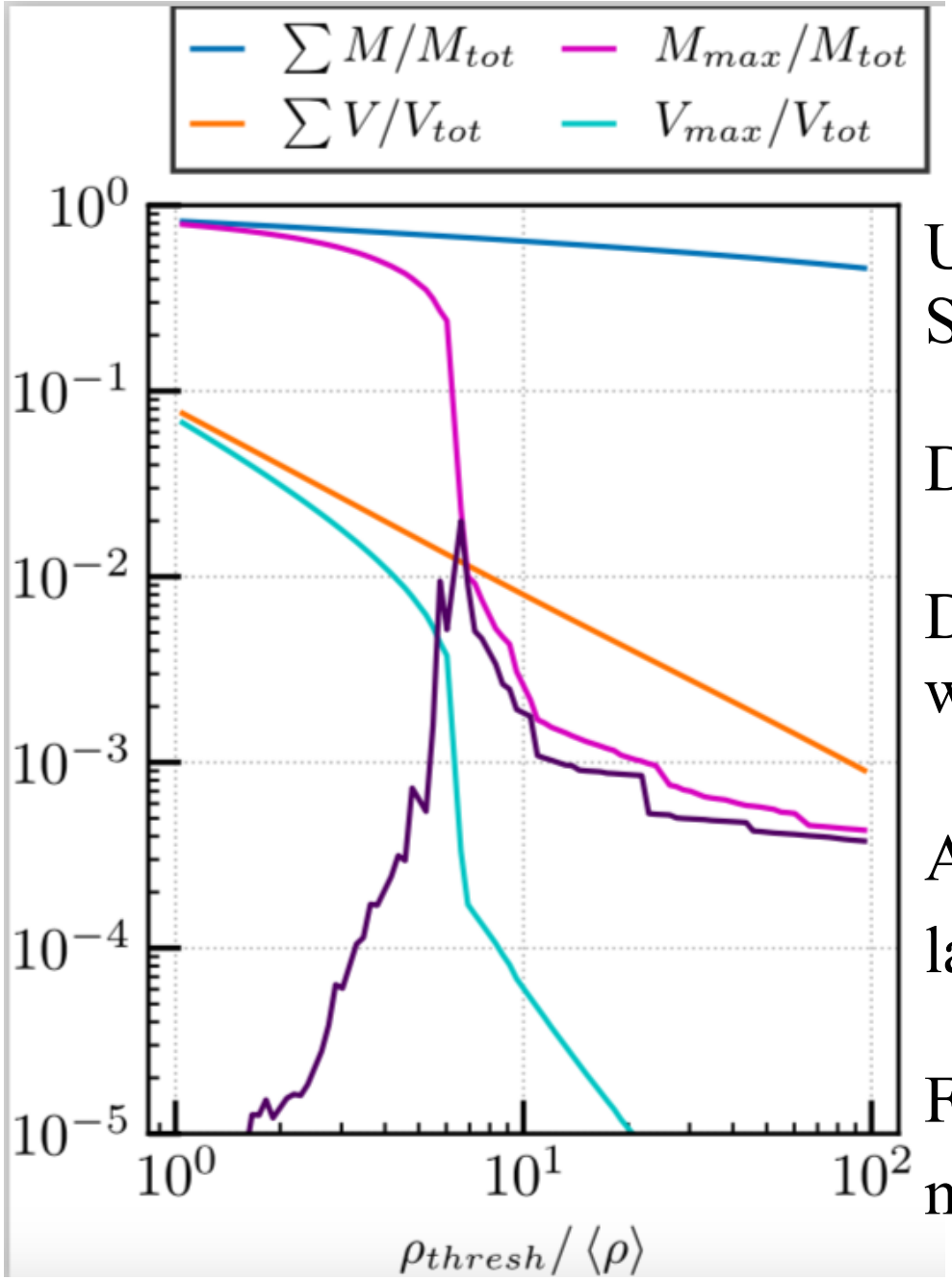
Projected mass distribution around Locally Brightest Galaxies as inferred from galaxy-galaxy lensing observations



After parameters are set to fit the evolution of galaxy abundances and passive fractions, galaxy clustering provides a parameter-free *test* of the ΛCDM paradigm.

Here the DM mass distribution around Locally Brightest Galaxies is tested over 3.0 dex in radius and 1.5 dex in stellar mass

Defining the cosmic web at high resolution



Busch & White 2018

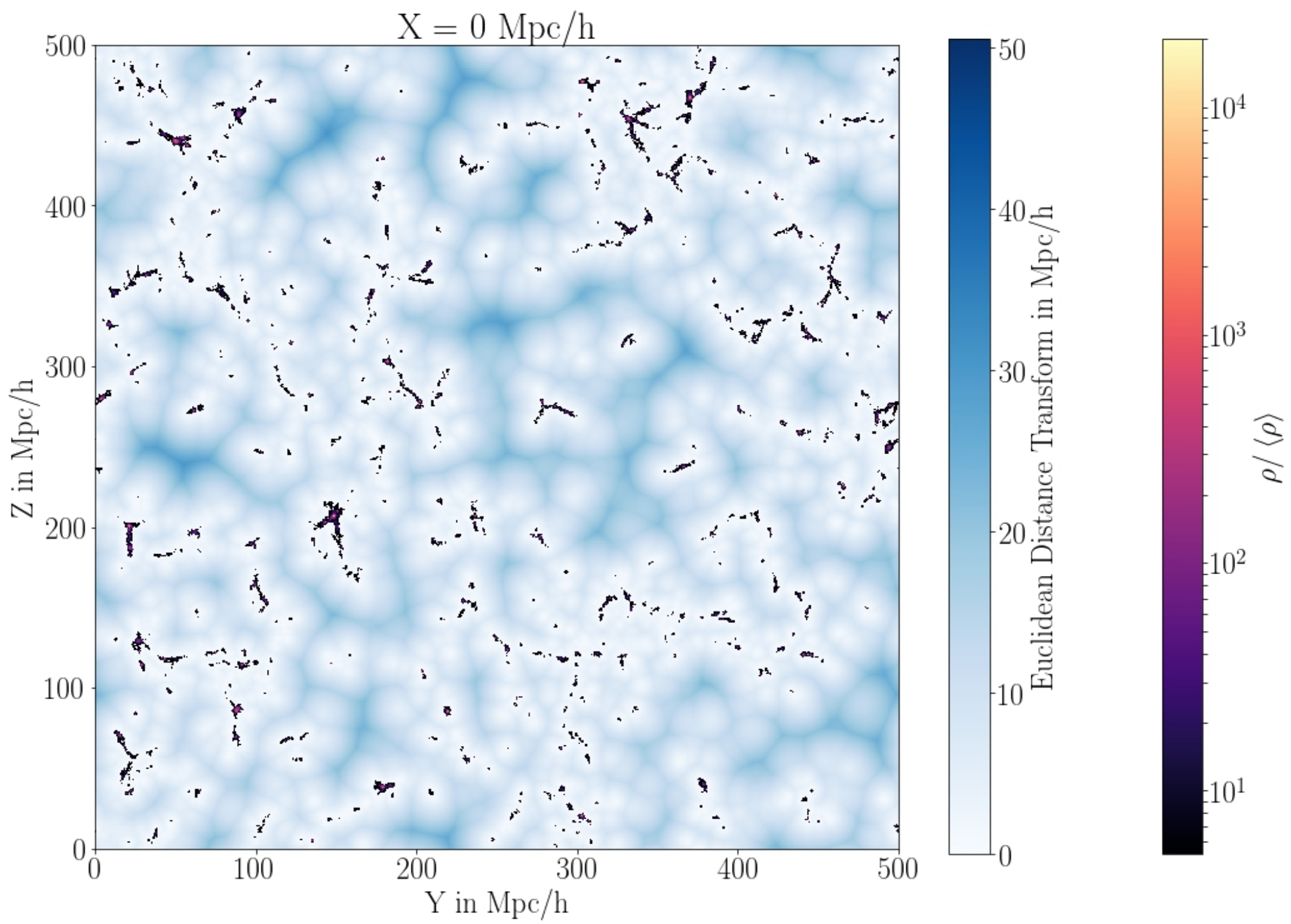
Use the 10^{10} particles in the Millennium Simulation to build a Voronoi tesselation

Define m/V as the density of each cell

Define objects as connected sets of cells with density exceeding ρ_{thresh}

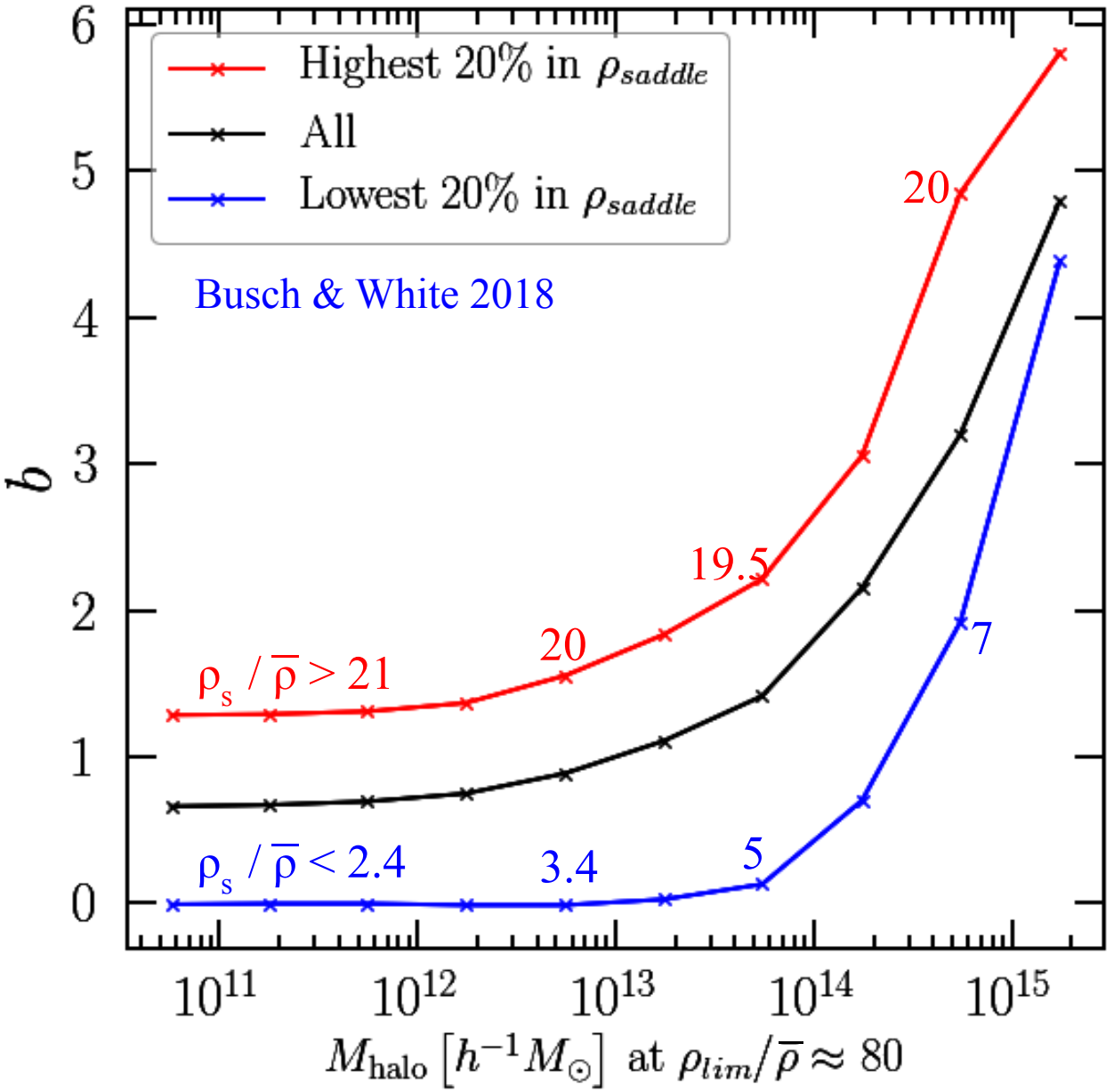
As $\rho_{thresh}/\langle\rho\rangle$ drops from 10 to 5 the largest object percolates

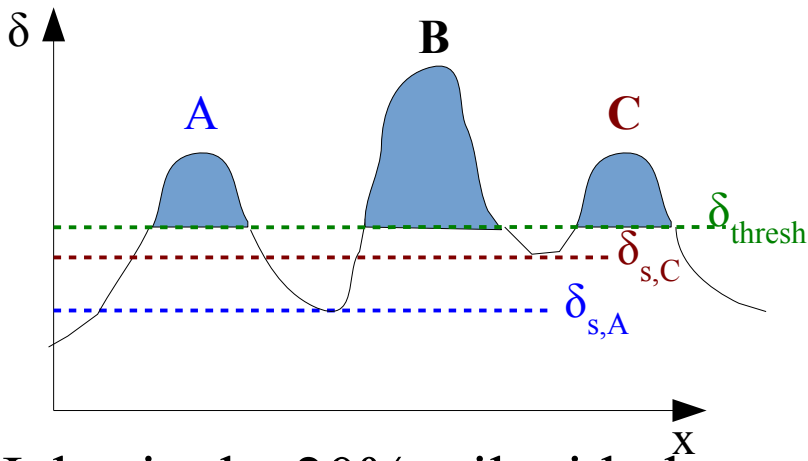
For $\rho_{thresh}/\langle\rho\rangle = 5$ it contains 35% of all mass but fills only 0.6% of the volume


X = 0 Mpc/h
Z in Mpc/h
Y in Mpc/h
0
100
200
300
400
500
Euclidean Distance Transform in Mpc/h
0
10
20
30
40
50
$\rho / \langle \rho \rangle$
10^1
10^2
10^3
10^4

Bias as a function of mass and saddle point density

Millennium data: ρ from Voronoi tesselation





Halos in the 20% tail with the smallest saddle point density are uncorrelated with the mass density field for halo masses like those of galaxies.
Hence, $b_{lo} = 0$!

Halos in the 20% tail with highest saddle point density are much more strongly biased than typical halos

Strongest known assembly bias

Virgo - Millennium Database

Documentation

CREDITS/Acknowledgments

Registration

News

FAQ

Public Databases
- DGalaxies
- DHaloTrees
- Guo2010a
- Guo2013a
- Henriques2012a
- MField
- MillenniumII
- millimil
- miniMilII
- MMSnapshots
- MPAGalaxies
- MPAHaloTrees
- MPAMocks
- Snapshots

Private (MyDB) Databases
- sampling_db (r)
- swhite_db (rw) (context)

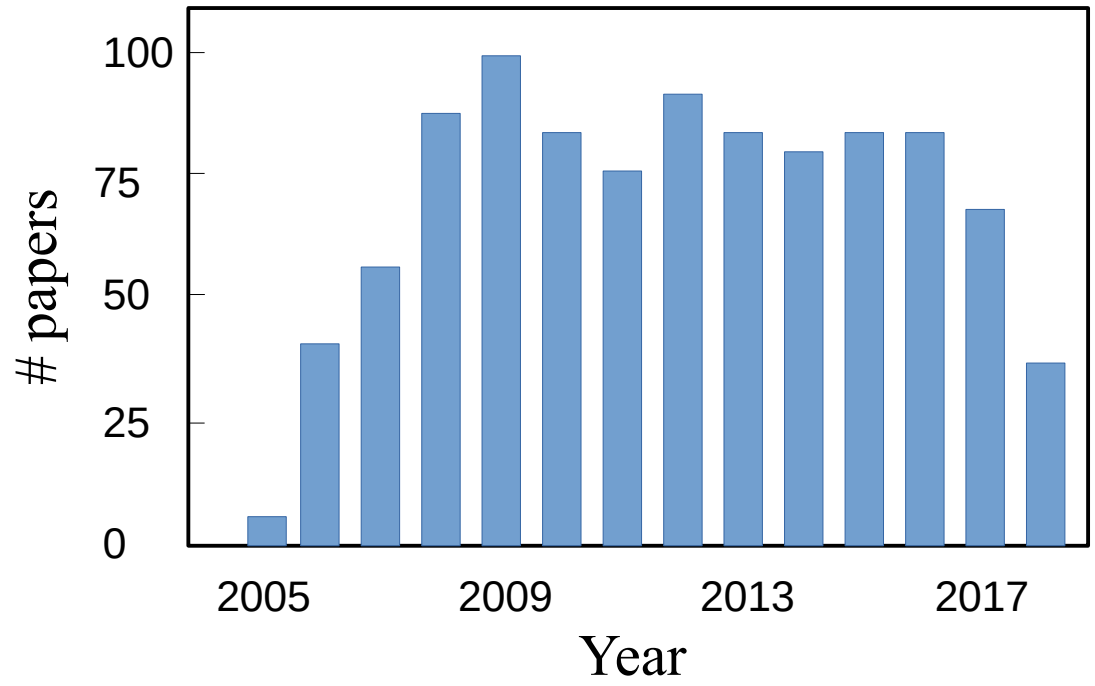
Welcome Simon White.
Streaming queries return unlimited number of rows in CSV format and are cancelled after 420 seconds.
Browser queries return maximum of 1000 rows in HTML format and are cancelled after 30 seconds.

- The MS halo and galaxy databases have been public since 2006
- >970 papers have used these predictions
- Most use the galaxies and are by authors unassociated with the Virgo Consortium

Query (stream)

Query (browser)

Help



scribed in some more detail on this page.

e state of a private database.

yDB Table Size

966. astro-ph/1808.09516 [abs, ps, pdf, other]:
Title: Magnification bias in the shear-ratio test: a viable mitigation strategy
Authors: Sandra Unruh, Peter Schneider, Stefan Hilbert
Comments: 9 pages, 7 figures

967. astro-ph/1808.10051 [abs, ps, pdf, other]:
Title: Improving Hickson-like compact group finders in redshift surveys: an implementation in the SDSS
Authors: Eugenia Diaz-Gimenez (1), Ariel Zandivarez (1), Antonela Taverna (1,2) ((1) IATE/CONICET/UNC - OAC/UNC - (2) FaMAF/UNC)
Comments: 17 pages, 8 figures, 8 tables. Accepted for publication in Astronomy & Astrophysics. Tables D1 and D2 will be available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via this http URL or this https URL

968. astro-ph/1809.01154 [abs, ps, pdf, other]:
Title: The origin of the mass scales for maximal star formation efficiency and quenching: the critical role of Supernovae
Authors: Bruno Henriques (ETH), Simon White (MPA), Simon Lilly (ETH), Eric Bell (Michigan), Asa Bluck (ETH), Bryan Terrazas (Michigan)
Comments: 12 pages, 8 figures, submitted to MNRAS

969. astro-ph/1809.01274 [abs, ps, pdf, other]:
Title: H0LiCOW - IX. Cosmographic analysis of the doubly imaged quasar SDSS 1206+4332 and a new measurement of the Hubble constant
Authors: S. Birrer, T. Treu, C. E. Rusu, V. Bonvin, C. D. Fassnacht, J. H. H. Chan, A. Agnello, A. J. Shajib, G. C.-F. Chen, M. Auger, F. Courbin, S. Hilbert, D. Sluse, S. H. Suyu, K. C.Wong, P. Marshall, B. C. Lemaux, G. Meylan
Comments: 30 pages, 17 figures, submitted to MNRAS

970. astro-ph/1809.06026 [abs, ps, pdf, other]:
Title: Starburst galaxies in semi-analytic models of galaxy formation and evolution
Authors: Lan Wang, Gabriella De Lucia, Fabio Fontanot, Michaela Hirschmann
Comments: 16 pages, 11 figures, submitted to MNRAS

971. astro-ph/1810.05173 [abs, ps, pdf, other]:
Title: Morphological evolution and galactic sizes in the L-Galaxies SA model
Authors: Dimitrios Irodotou, Peter A. Thomas, Bruno M. Henriques, Mark T. Sargent

This Millennium continues to be a success...

… so on towards the next generation