Nonlinear Cosmological Tests

Nice, January 2006

Jim Peebles

Anomalies, real or apparent, in the standard cosmology include the predictions of

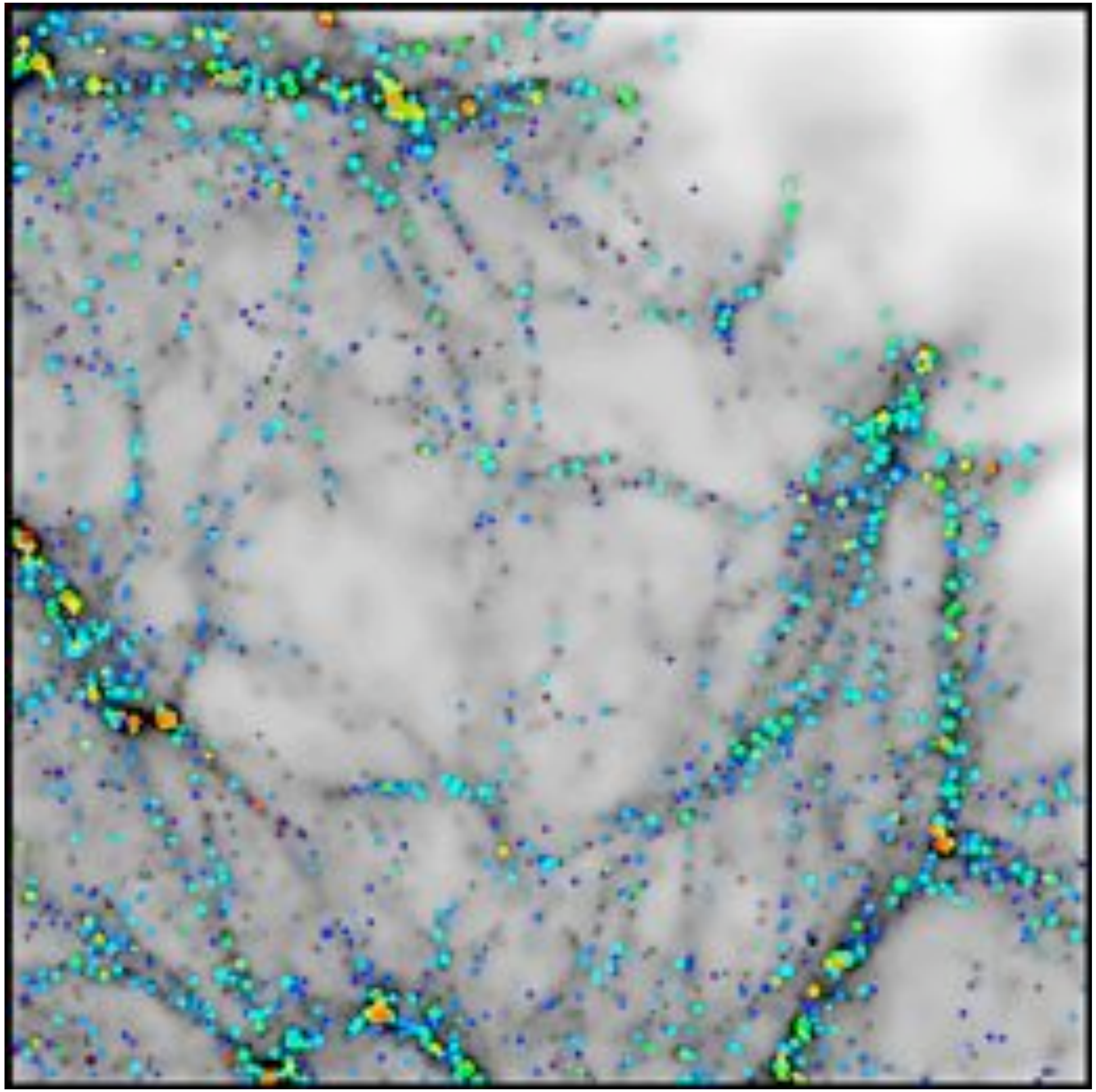
1) large numbers of low mass DM halos relative the observed numbers of dwarf and irregular galaxies,

2) rich structures within voids, which are not observed, and

3) a large rate of merging at low redshifts compared to what the observations suggest.

I discuss the evidence on issues (2) and (3). Adi Nusser will discuss a possible remedy

What is in the voids defined by normal galaxies?

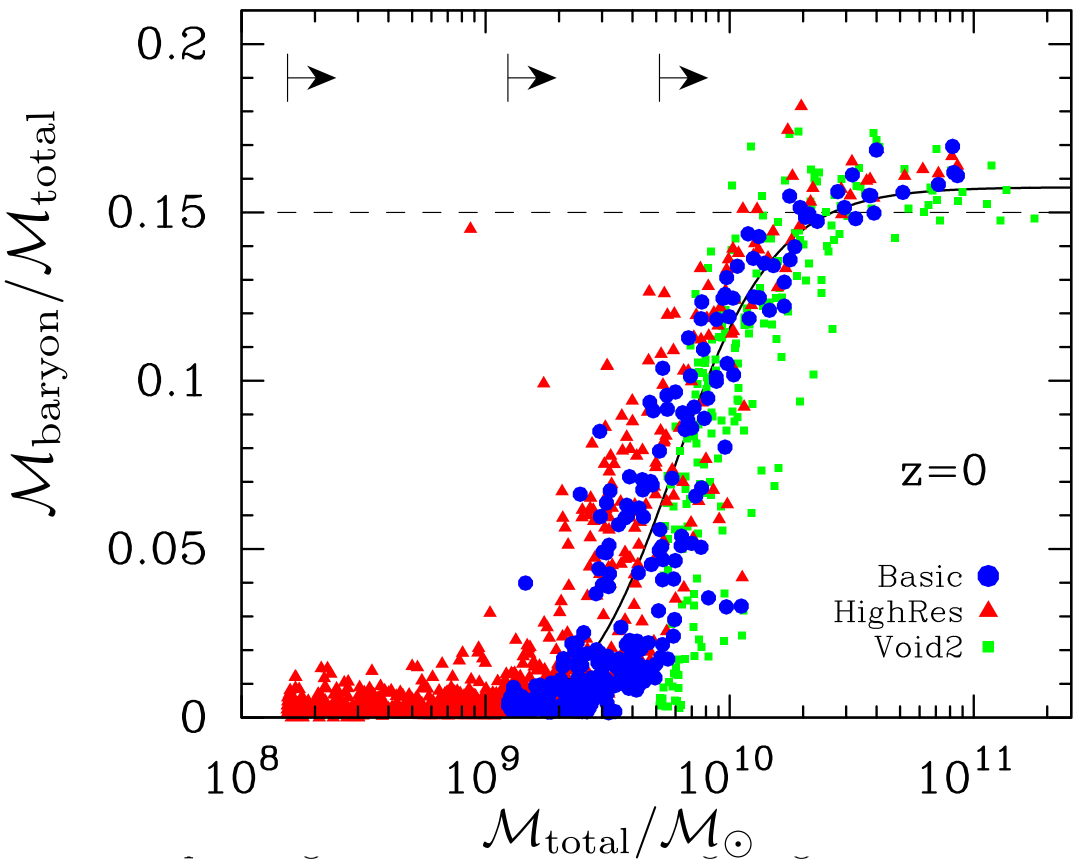


$50 \times 50 \times 15h^{-1}$ Mpc

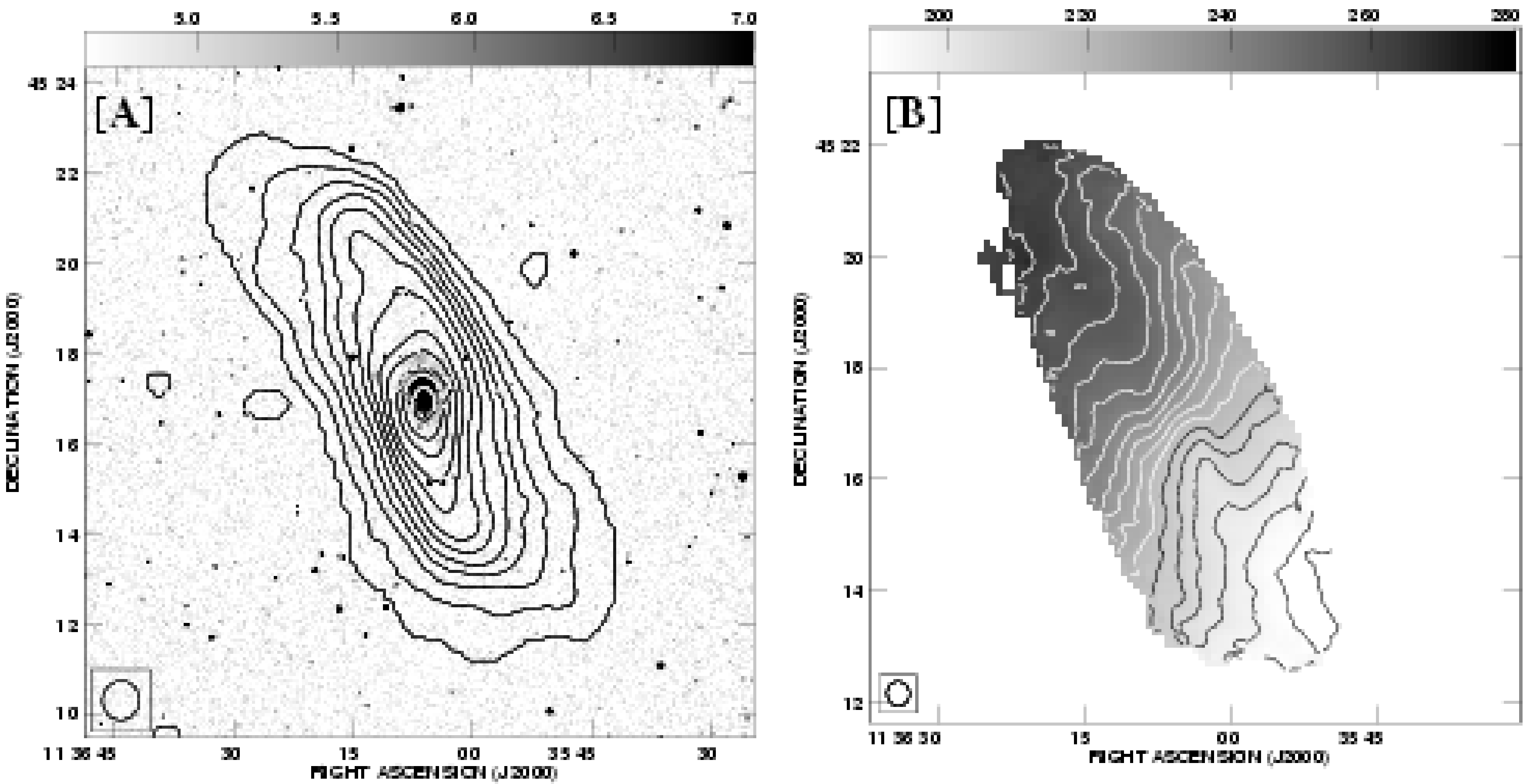
H. Mathis & S. D. M. White, MN 337, 1193, 2002

Dwarf galaxies in voids: Suppressing star formation with photo-heating

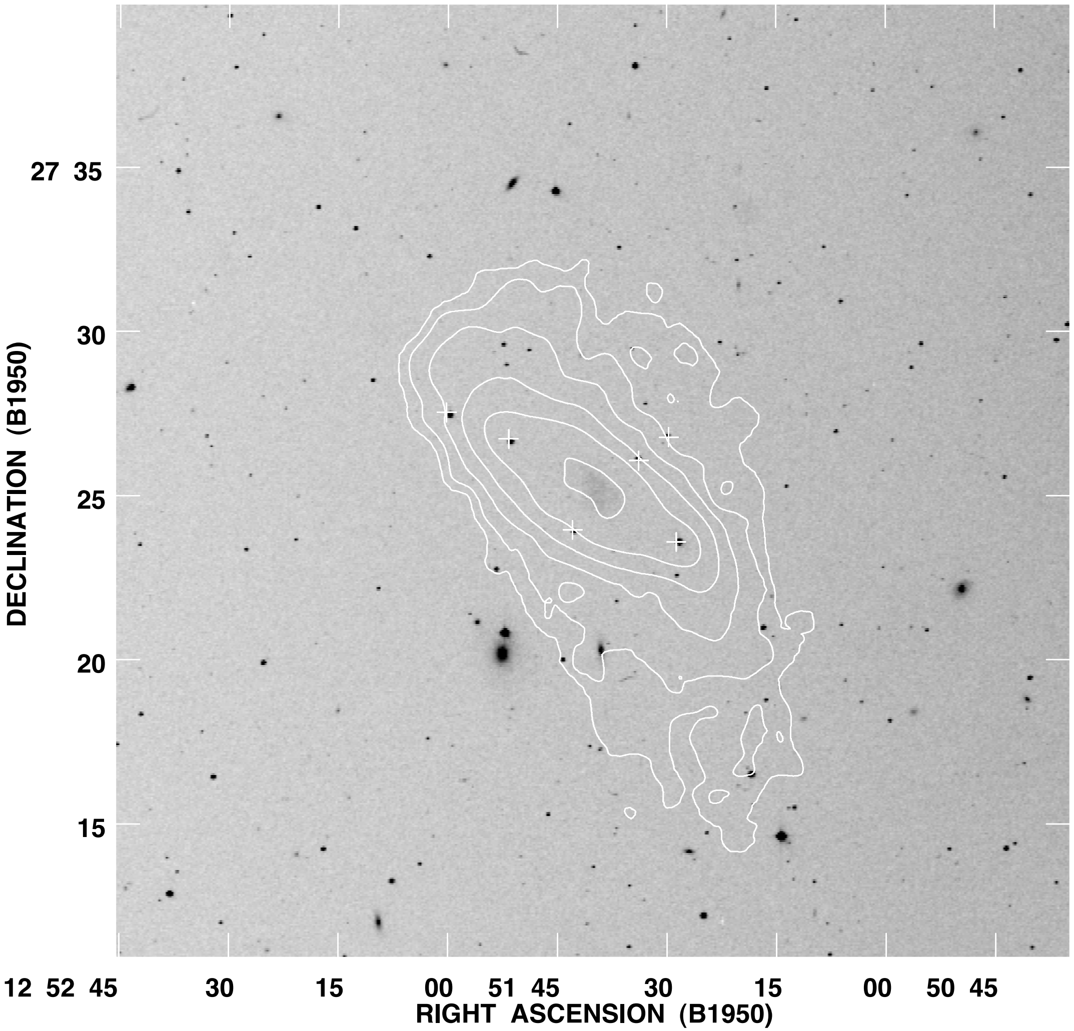
Matthias Hoeft[1], Gustavo Yepes[2], Stefan Gottlöber[3], and Volker Springel[4]

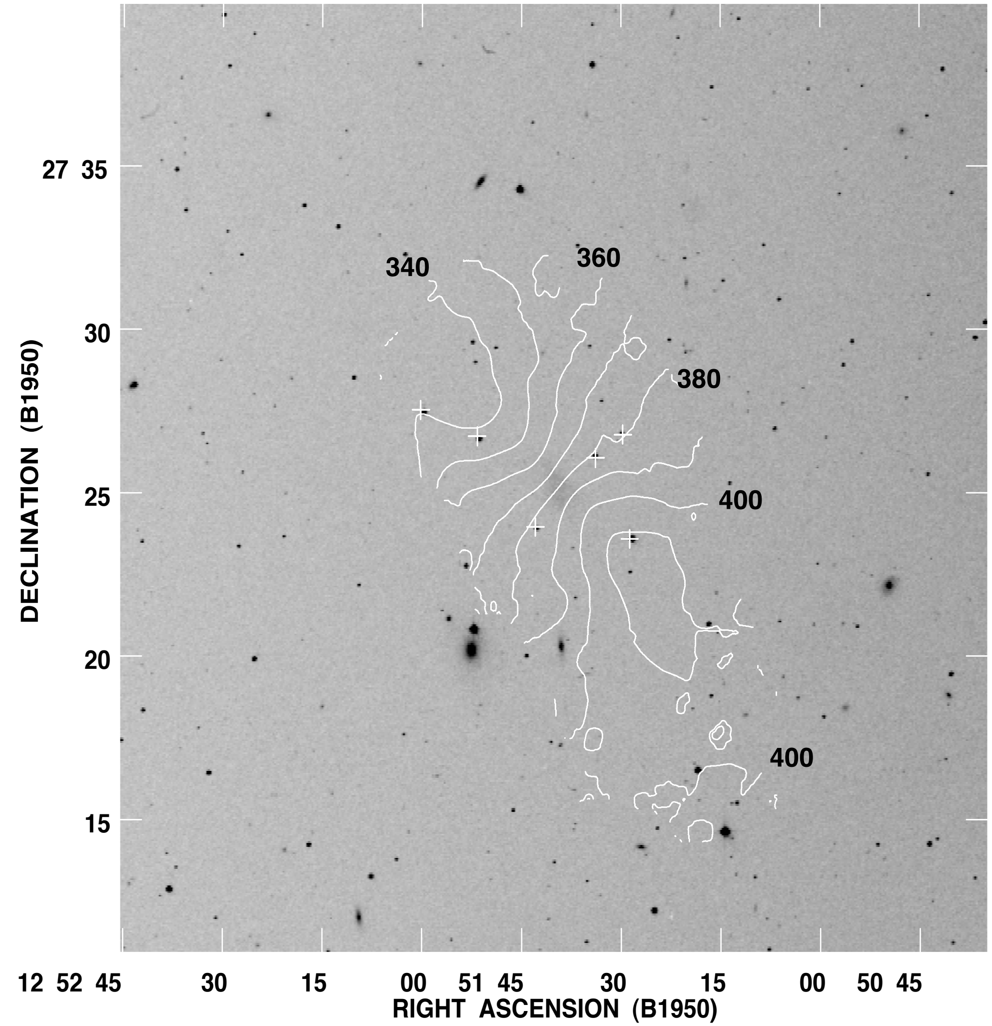


Gottlöber et al. (2003) predicted that a typical 20 h^{-1} Mpc diameter void should contain up to 1000 halos with mass $\sim 10^9\ h^{-1}\,\mathrm{M}_\odot$ and still about 50 halos with mass $\sim 10^{10}\ h^{-1}\,\mathrm{M}_\odot$. Assuming a magnitude of $M_B = -16.5$ for the galaxy hosted by a halo of mass $3.6 \times 10^{10} h^{-1}\mathrm{M}_\odot$ (Mathis & White 2002), they predict that about five such galaxies should be found in the inner regions of a typical void of diameter 20 h^{-1} Mpc.



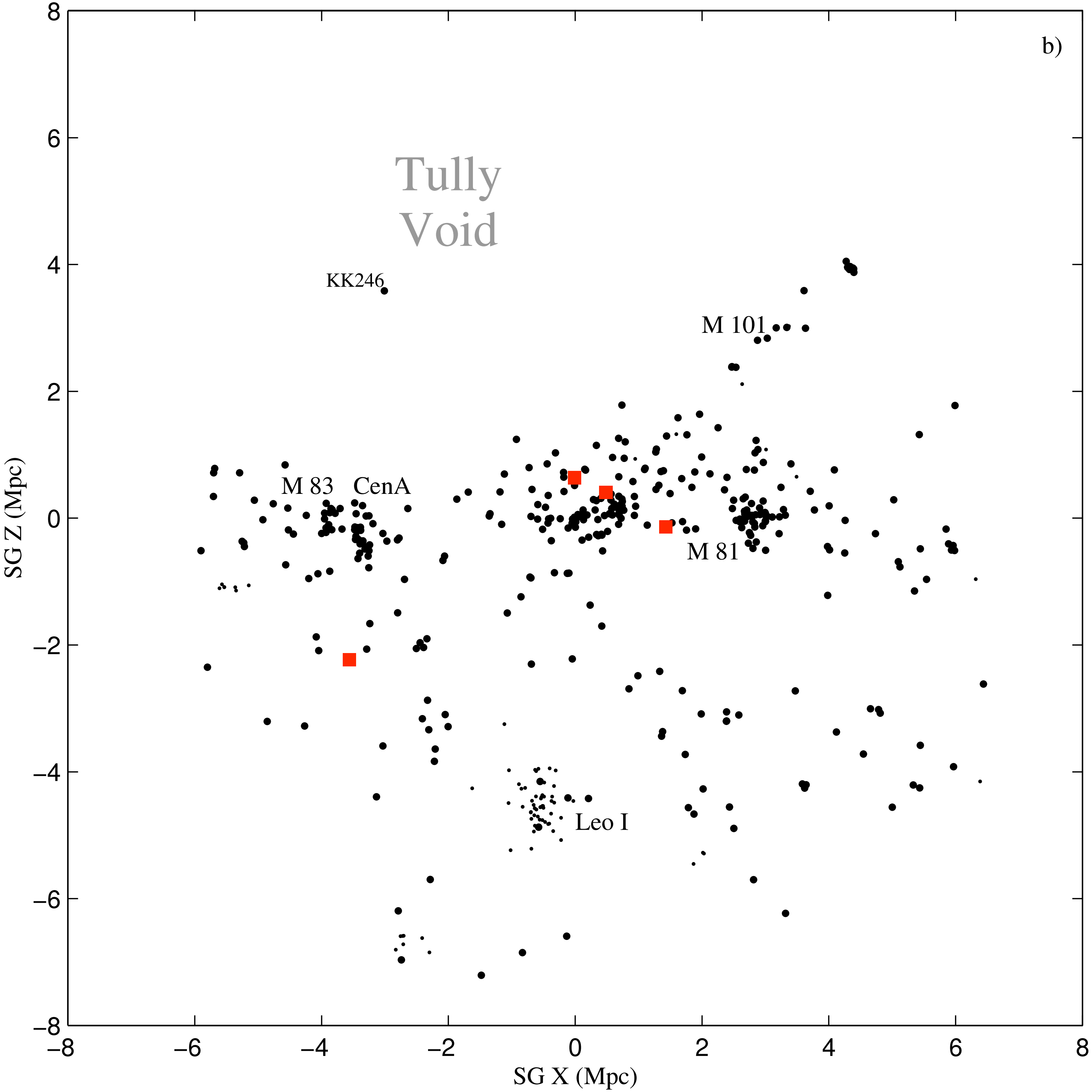
GMRT map of atomic hydrogen in NGC 3741 (Begum, Chengalur and Karachentsev 2005). The dynamical mass within the region of the detected HI is $3 \times 10^9 M_\odot$, with $M_{\rm HI}/L_b \gtrsim 6$.





The Carignan and Purton 21-cm surface density and velocity maps of DDO 154

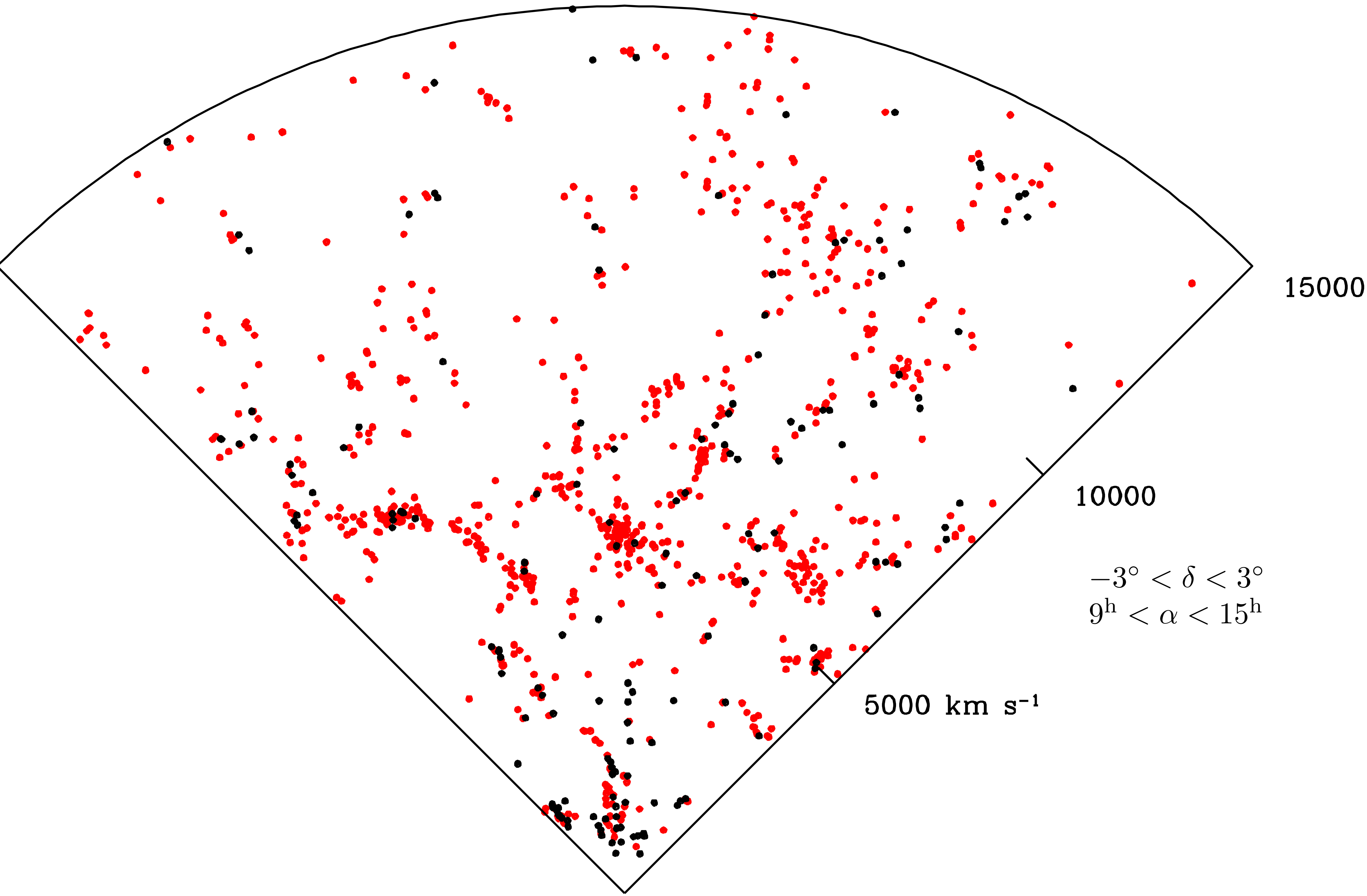
Stellar mass: $3 \times 10^7 M_\odot$
HI plus He mass: $2 \times 10^8 M_\odot$
total mass within 6 kpc: $3 \times 10^9 M_\odot$



The Karachentsev *et al.* (2004) Catalog of Neighboring Galaxies. The larger circles show the galaxies at $v_{\mathrm{LG}} < 550$ km s^{-1}. The smaller circles show galaxies at somewhat greater distance.

The red squares are, left to right, the gas dwarfs
ESO 215-G?009
DDO 154
UGCA292
NGC3741

The local sheet at SGZ = 0 is part of the Local Supercluster. The Tully Void is really empty.



The Zwicky galaxies with absolute magnitudes $M < -18$ from the Falco *et al.* (1999) compilation are ploted in red and the Impey *et al.* (1996) low surface brightness galaxies are plotted in black.

Maybe the problem with empty voids may be reduced to the previously solved problem of the excess number of low mass DM halos.

But is the solution to the previous problem reliable?

And are the problems equivalent? A void looks like such a tranquil place.

What is the role of galaxy merging and accretion at $z < 1$?

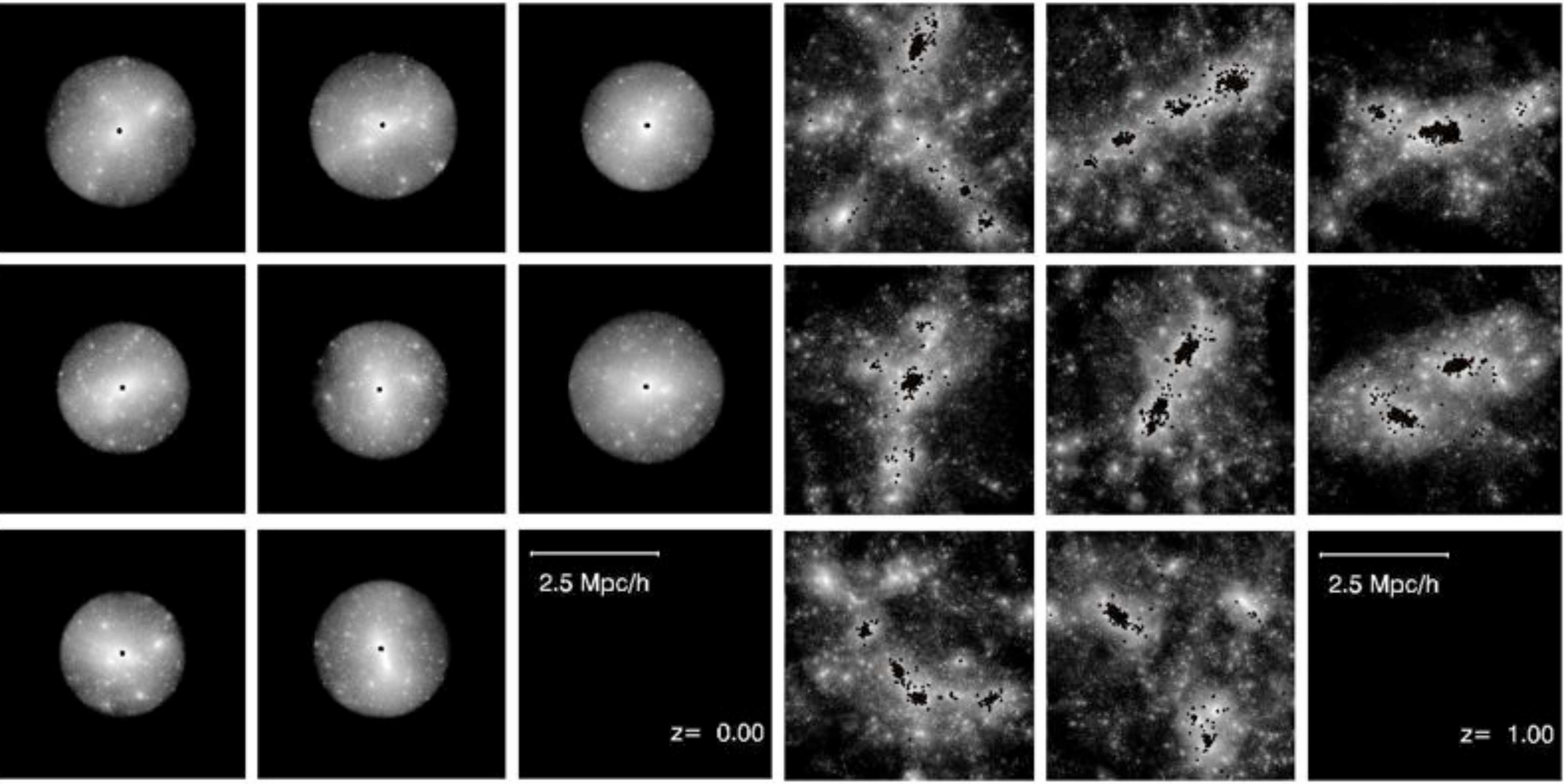


Fig. 2.— Images of the mass distribution at $z = 0, 1$ and 3 in our 8 simulations of the assembly of cluster mass halos. Each plot shows only those particles which lie within r_{200} of halo center at $z = 0$. Particles which lie within $10h^{-1}$ kpc of halo center at this time are shown in black. Each image is $5h^{-1}$Mpc on a side in physical (not comoving) units.

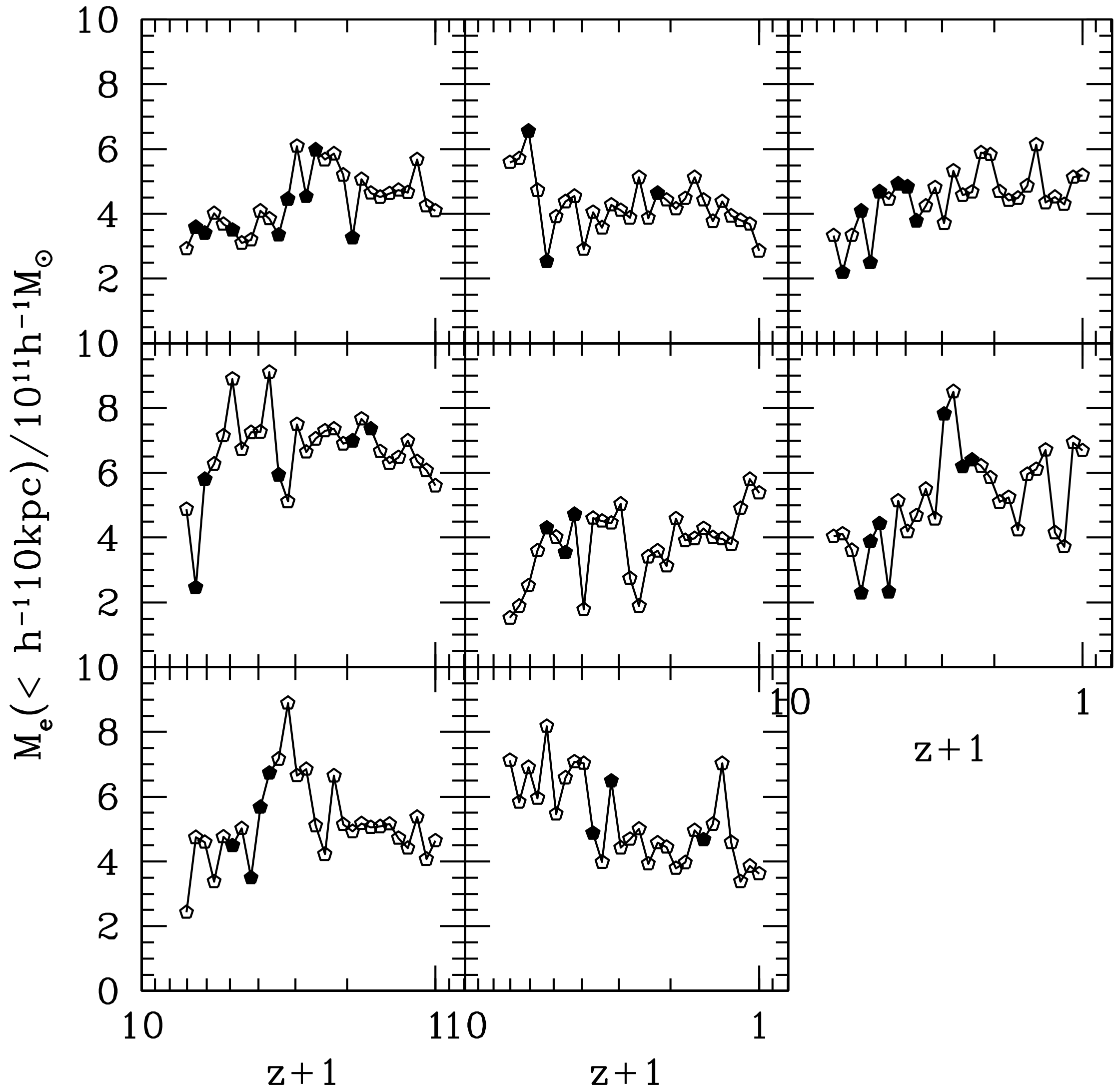


Fig. 3.— The total mass within physical distance $10h^{-1}$ kpc of the center of the most massive progenitor of the final halo at each time plotted and for each of our 8 simulations. Symbols switch between filled and open each time the identity of the most massive progenitor changes.

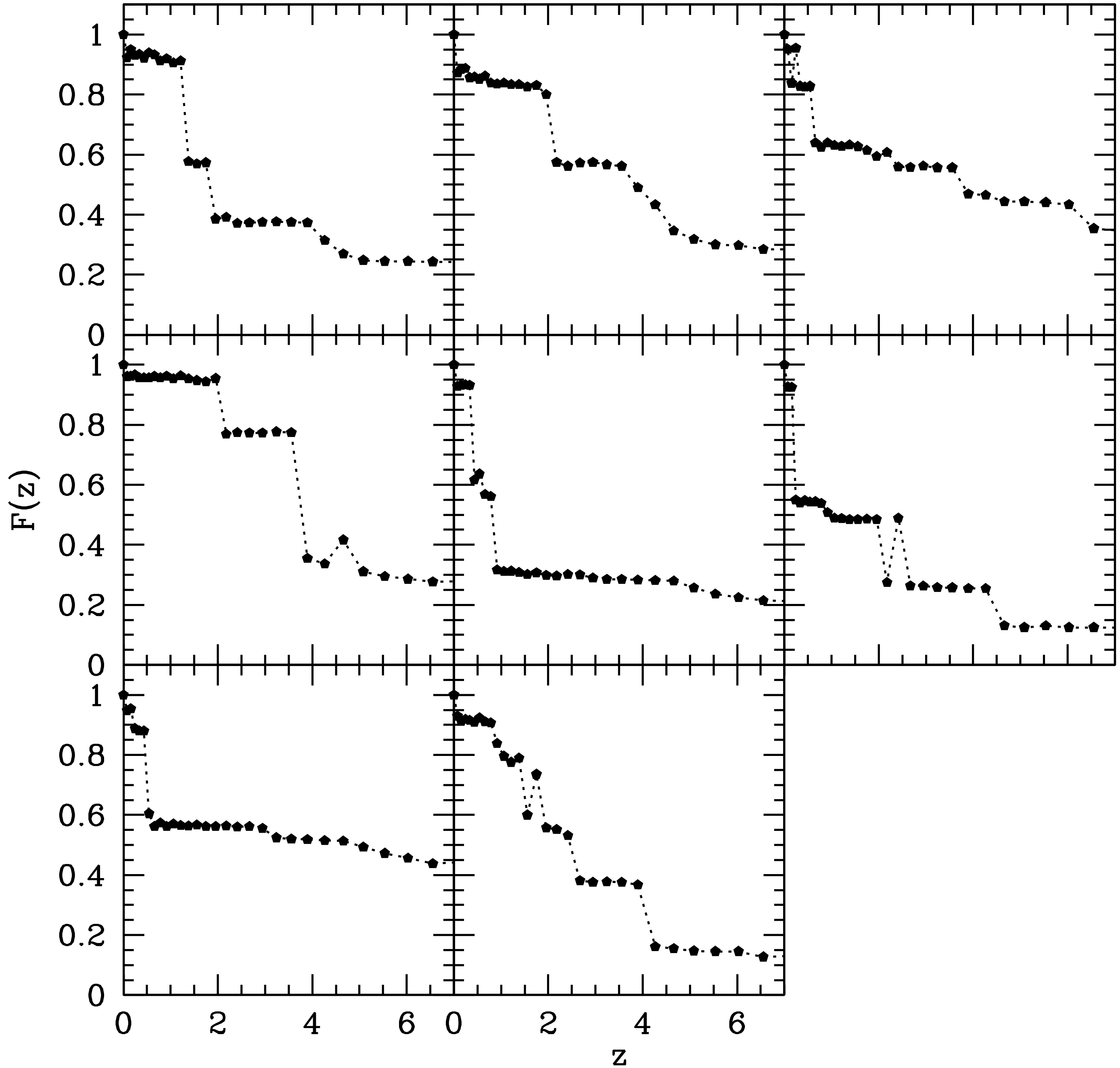


FIG. 4.—History of addition of the matter now in the central parts of massive halos. The black curves show the fraction of the particles at $r < 10\ h^{-1}$ kpc at $z = 0$, which lie within 100 h^{-1} kpc (physical) distance from the center of their main concentration at each earlier redshift z.

Can M 87 have grown in the manner suggested by the CDM simulations?

Growth of the mass in early-type galaxies by merging is in line with van Dokkum's elegant images of low redshift field ellipticals,

THE RECENT AND CONTINUING ASSEMBLY OF FIELD ELLIPTICALS BY RED MERGERS

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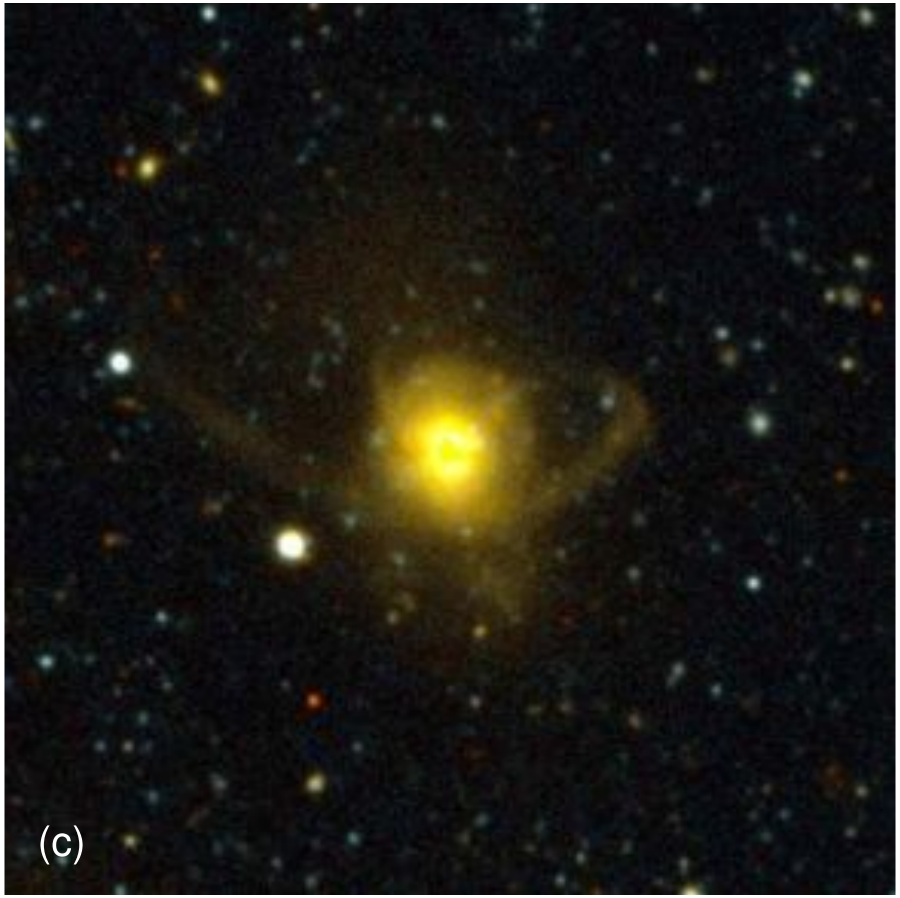

This field is about 200×200 kpc.

NEARLY 5000 DISTANT EARLY-TYPE GALAXIES IN COMBO-17: A RED SEQUENCE AND ITS EVOLUTION SINCE $z \sim 1$

Eric F. Bell,[1] Christian Wolf,[2] Klaus Meisenheimer,[1] Hans-Walter Rix,[1] Andrea Borch,[1] Simon Dye,[3] Martina Kleinheinrich,[1] Lutz Wisotzki,[4] and Daniel H. McIntosh[5]

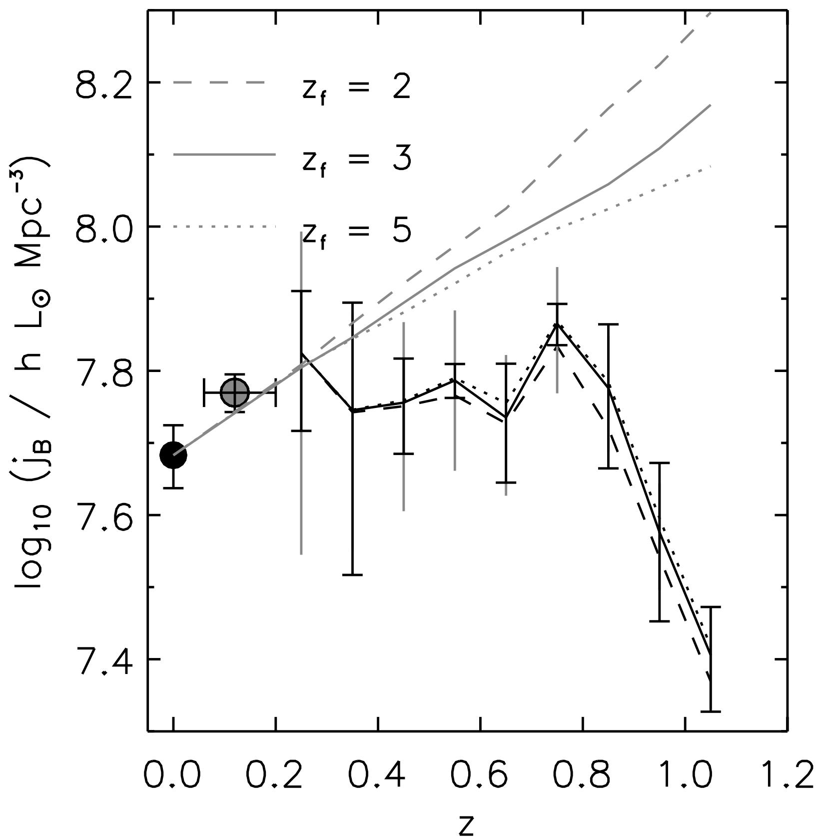

Fig. 5.—Luminosity density evolution of luminous red-sequence galaxies. The luminosity density of those red-sequence galaxies destined to evolve passively into galaxies brighter than $M_B - 5 \log h \leq -19.1$ at $\langle z \rangle = 0.25$ is shown by dashed, solid, and dotted black lines for $z_f = 2$, 3, and 5, respectively. The smooth gray curves show the expected evolution of a galaxy population that completely formed at high redshift and simply aged to the present day. The error bars show uncertainties from cosmic variance.

THE MASS ASSEMBLY HISTORIES OF GALAXIES OF VARIOUS MORPHOLOGIES IN THE GOODS FIELDS

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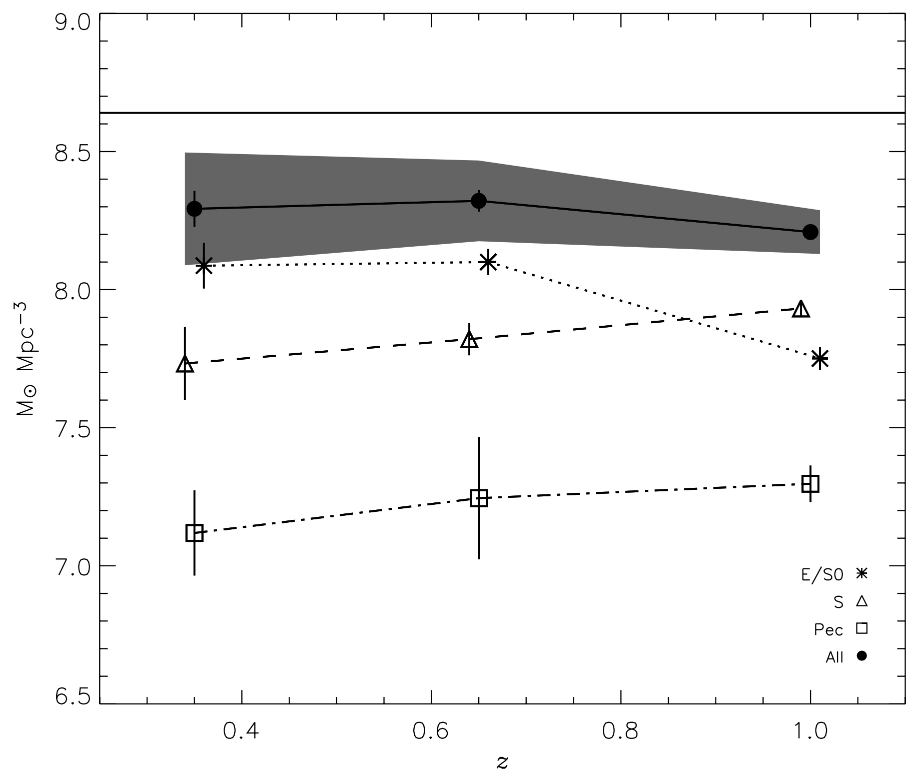

Fig. 8.—Integrated stellar mass density as a function of redshift, split by morphology and with a mass cut of $M_* > 10^{11}\ M_\odot$. The straight solid line at the top of the plot shows the local stellar mass density as measured by Cole et al. (2001). The shaded region illustrates the uncertainty from cosmic variance.

and with the evidence that the mass in stars in early-type galaxies has increased by a factor of two to three since redshift $z = 1$,

THE ASSEMBLY HISTORY OF FIELD SPHEROIDALS: EVOLUTION OF MASS-TO-LIGHT RATIOS AND SIGNATURES OF RECENT STAR FORMATION

Tommaso Treu,[1,2,3,4] Richard S. Ellis,[4] Ting X. Liao,[4] Pieter G. van Dokkum,[4,5] Paolo Tozzi,[6] Alison Coil,[7]
Jeffrey Newman,[2,7] Michael C. Cooper,[7] and Marc Davis[7]

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star formation activity is required. As for the M/L_B, the distribution is well reproduced by a composite population where the bulk of stellar mass is formed at high redshift (e.g., $z_{f1} \sim 5$) and on average 10% of the stellar mass is added at a later time ($z_{f2} \sim 0.5$–1) in secondary bursts.

but stars in ellipticals and spheroids of $L \gtrsim L_*$ galaxies tend to be old, so mergers at $z < 1$ would have to be dry, that is, avoid accretion of gas and young star populations, which seems OK in the Coma Cluster. But will the merger of the galaxies in the Centaurus Group produce a normal elliptical?

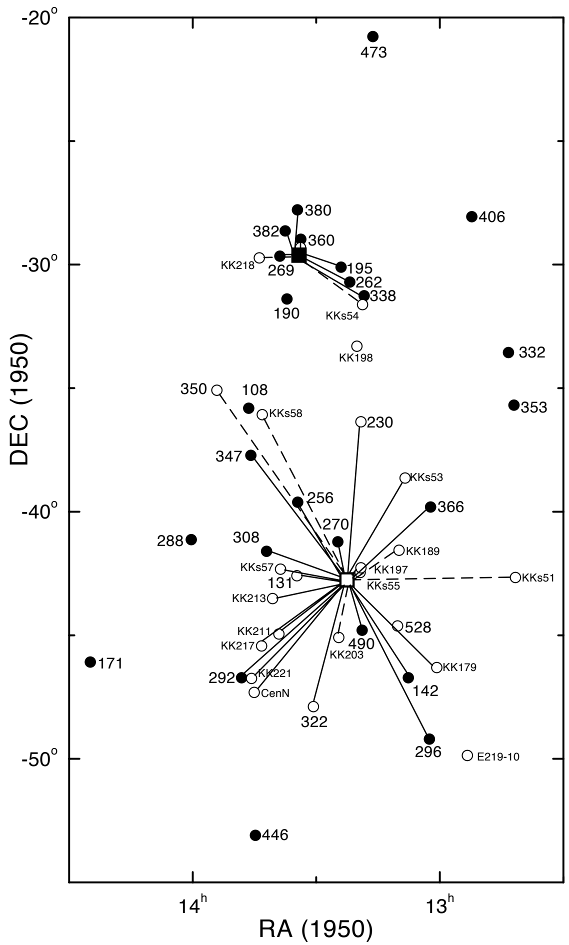


Fig. 4. The distribution of S, Irr galaxies (filled circles) and E, Sph galaxies (open circles) in the Centaurus complex. Companions of Cen A and M 83 are connected to the principal galaxies with straight lines. The large numbers next to the circles indicate the galaxy's radial velocity in $\mathrm{km\,s^{-1}}$ when known, transformed into the Local Group rest frame.

Karachentsev *et al.* 2002, *A&A* 385, 21

$L_B = 2 \times 10^{10} L_\odot$
$D_\perp = 0.9$ Mpc
$cz - cz_{\mathrm{CenA}} = -33$ km s^{-1}

The Tully luminosity is $L_B = 4 \times 10^{10} L_\odot$

$L_B = 3 \times 10^{10} L_\odot$
$D_\perp = 0.6$ Mpc
$cz - cz_{\mathrm{CenA}} = 16$ km s^{-1}


M49 1.3 Mpc


M58 0.5 Mpc


M59
0.9 Mpc


M60 1.0 Mpc


M61
2.4 Mpc


M84
0.4 Mpc


M85 .8 Mpc


M86 0.4 Mpc


M87


M88
0.6Mpc


M89
0.4 Mpc


M90 0.5 Mpc


M91 0.7 Mpc


M98 1.5 Mpc


M100 1.2 Mpc


M 99
1.1 Mpc

Future mergers by M87 won't be all that dry, either, and I suppose mergers since z = 1 have been wetter.

This shows Nigel Sharp's list of Messier galaxies in the Virgo cluster, with projected distances from M 87.
The images, from NOAO and 2MASS, have a roughly common angular scale, but contrasts can differ.

Major mergers of galaxies at $z < 1$ surely mix contents of late and early-type galaxies.

Can the substantial merging in the ΛCDM cosmology be consistent with the apparent differences of stellar ages and chemical abundances in spirals and ellipticals?

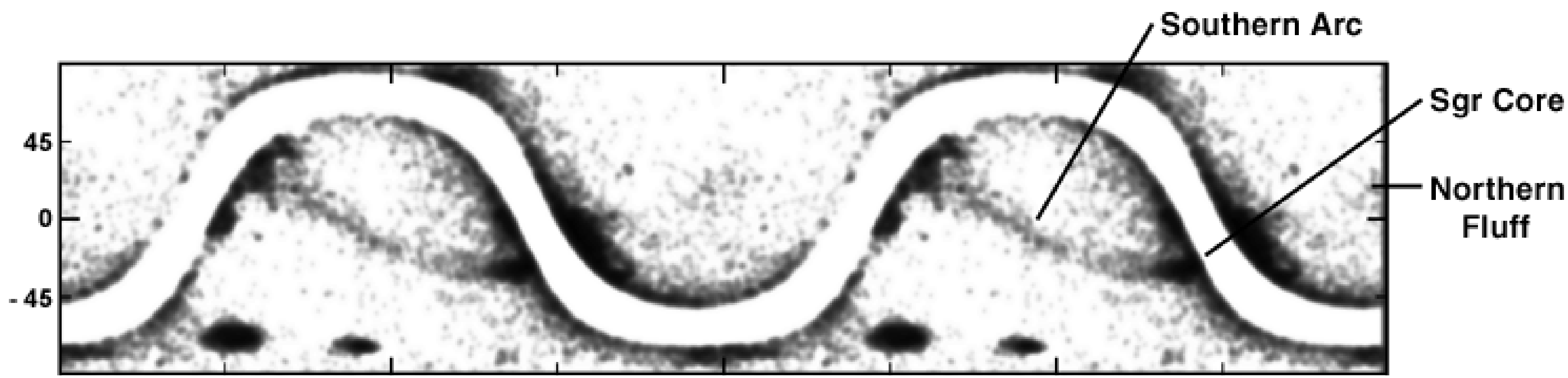
Can galaxies like this have grown in the manner suggested by the simulations?

NGC 4565 HST

there are arguments for: the Milky Way has shredded the Saggitaurius Dwarf sph,

A TWO MICRON ALL SKY SURVEY VIEW OF THE SAGITTARIUS DWARF GALAXY. I. MORPHOLOGY OF THE SAGITTARIUS CORE AND TIDAL ARMS

Steven R. Majewski,[1] M. F. Skrutskie,[1] Martin D. Weinberg,[2] and James C. Ostheimer[1]



though the stars in the halo of the Milky Way are unlike present dwarf spheroidals,

The Chemical Composition of Local Group Dwarf Spheroidals

Eline Tolstoy

It is clear from the histogram of [Fe/H] measurements in Scl dSph (see Figure 6) that this distribution lacks a low metallicity tail, in fact the lowest metallicity star in our sample of more than 300 stars is [Fe/H] $= -2.7$. We find a similar lack of low metallicity stars in Fornax and Sextans. Although it is difficult to make an accurate comparison with Galactic samples, where the completeness of different samples is hard to quantify, there appears to be a significantly different distribution between dSph and the (metal-poor) halo of the Milky Way.

and other arguments for

THE ASTROPHYSICAL JOURNAL, 514:818–843, 1999 April 1

HIGH-VELOCITY CLOUDS: BUILDING BLOCKS OF THE LOCAL GROUP

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Received 1998 February 20; accepted 1998 November 9

ABSTRACT

We suggest that the high-velocity clouds (HVCs) are large clouds, with typical diameters of 25 kpc, containing $3 \times 10^7\ M_\odot$ of neutral gas and $3 \times 10^8\ M_\odot$ of dark matter, falling onto the Local Group; altogether the HVCs contain $10^{10}\ M_\odot$ of neutral gas. Our reexamination of the Local Group hypothesis for the HVCs connects their properties to the hierarchical structure formation scenario and to the gas seen in absorption toward quasars. We show that at least one HVC complex (besides the Magellanic

6. LOCAL GROUP DYNAMICS

6.1. *Cosmological Background*

The continuing accretion of gas and dark matter onto galaxies and groups is a prediction of all hierarchical models of the formation of structure in the universe.

and against

trophysical Journal, 610:L17–L20, 2004 July 20

WHERE ARE THE HIGH-VELOCITY CLOUDS IN LOCAL GROUP ANALOGS?

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Received 2004 February 17; accepted 2004 June 10; published 2004 June 23

ABSTRACT

High-velocity clouds (HVCs) are clouds of H I seen around the Milky Way with velocities inconsistent with Galactic rotation; they have unknown distances and masses and controversial origins. One possibility is that HVCs are associated with the small dark matter halos seen in models of galaxy formation and distributed at distances of 150 kpc to 1 Mpc. We report on our attempts to detect the analogs to such putative extragalactic clouds in three groups of galaxies similar to our own Local Group using the Australia Telescope National Facility Parkes Telescope and Compact Array. Eleven dwarf galaxies were found, but no H I clouds lacking stars were detected. Using the population of compact HVCs around the Milky Way as a template, we find that our nondetection of analogs implies that they must be clustered within 160 kpc of the Milky Way (and other galaxies) with an average H I mass $\lesssim 4 \times 10^5\ M_\odot$ at the 95% confidence level. This is in accordance with recent limits derived by other authors. If our groups are true analogs to the Local Group, then this makes the original Blitz et al. and Braun & Burton picture of HVCs residing out to 1 Mpc from the Milky Way extremely unlikely. The total H I mass in HVCs, $\lesssim 10^8\ M_\odot$, implies that there is not a large reservoir of neutral hydrogen waiting to be accreted onto the Milky Way. Any substantial reservoir of baryonic matter must be mostly ionized or condensed enough as to be undetectable.

he Astrophysical Journal, 574:L39–L42, 2002 July 20

DECIPHERING THE LAST MAJOR INVASION OF THE MILKY WAY

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ABSTRACT

We present first results from a spectroscopic survey of ∼2000 F/G stars 0.5–5 kpc from the Galactic plane, obtained with the Two Degree Field facility on the Anglo-Australian Telescope. These data show the mean rotation velocity of the thick disk about the Galactic center a few kiloparsecs from the plane is very different than expected, being ∼100 km s^{-1} rather than the predicted ∼180 km s^{-1}. We propose that our sample is dominated by stars from a disrupted satellite that merged with the disk of the Milky Way some 10–12 Gyr ago. We do not find evidence for the many substantial mergers expected in hierarchical clustering theories. We find yet more evidence that the stellar halo retains kinematic substructure, indicative of minor mergers.

Maybe the merging history of the Milky Way is atypical: we happen to live in a tranquil neighborhood.

But if the merging history is a strong function of present environment how do we understand the near universality of the Tully-Fisher, fundamental plane, and color-magnitude relations?

THE DEPENDENCE ON ENVIRONMENT OF THE COLOR-MAGNITUDE RELATION OF GALAXIES

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James E. Gunn,[4] Timothy A. McKay,[5] Hans-Walter Rix,[6] Neta A. Bahcall,[4]
J. Brinkmann,[7] and Avery Meiksin[8]

Received 2003 July 11; accepted 2003 December 2; published 2004 January 16

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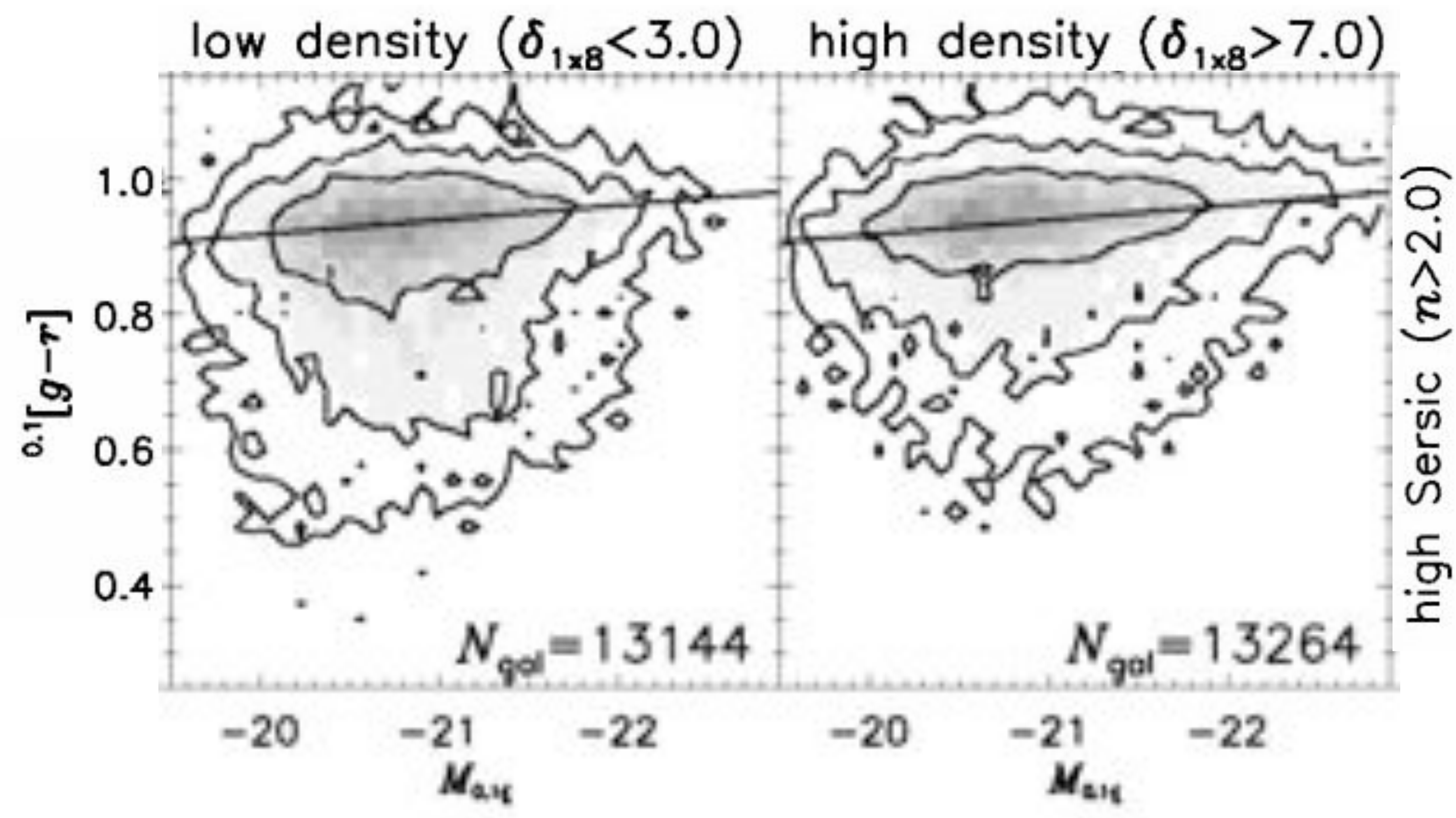

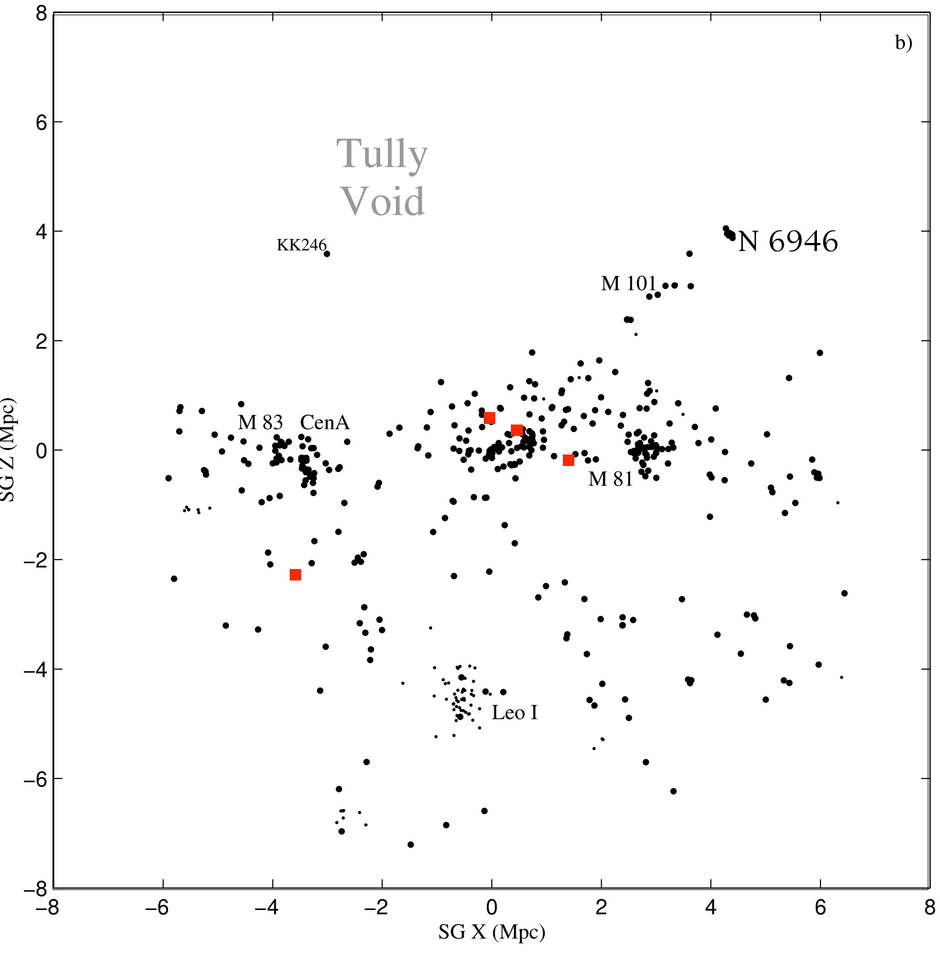

b)
Tully
Void
KK246
N 6946
M 101
M 83
CenA
M 81
Leo I
SG X (Mpc)
SG Z (Mpc)

N 6946; 2MASS

Yet another complaint: scale-dependent biasing seems an awkward way to account for the power law forms of the low order galaxy position correlation functions

THE ASTROPHYSICAL JOURNAL, 499:20–40, 1998 May 20

EVOLUTION OF STRUCTURE IN COLD DARK MATTER UNIVERSES

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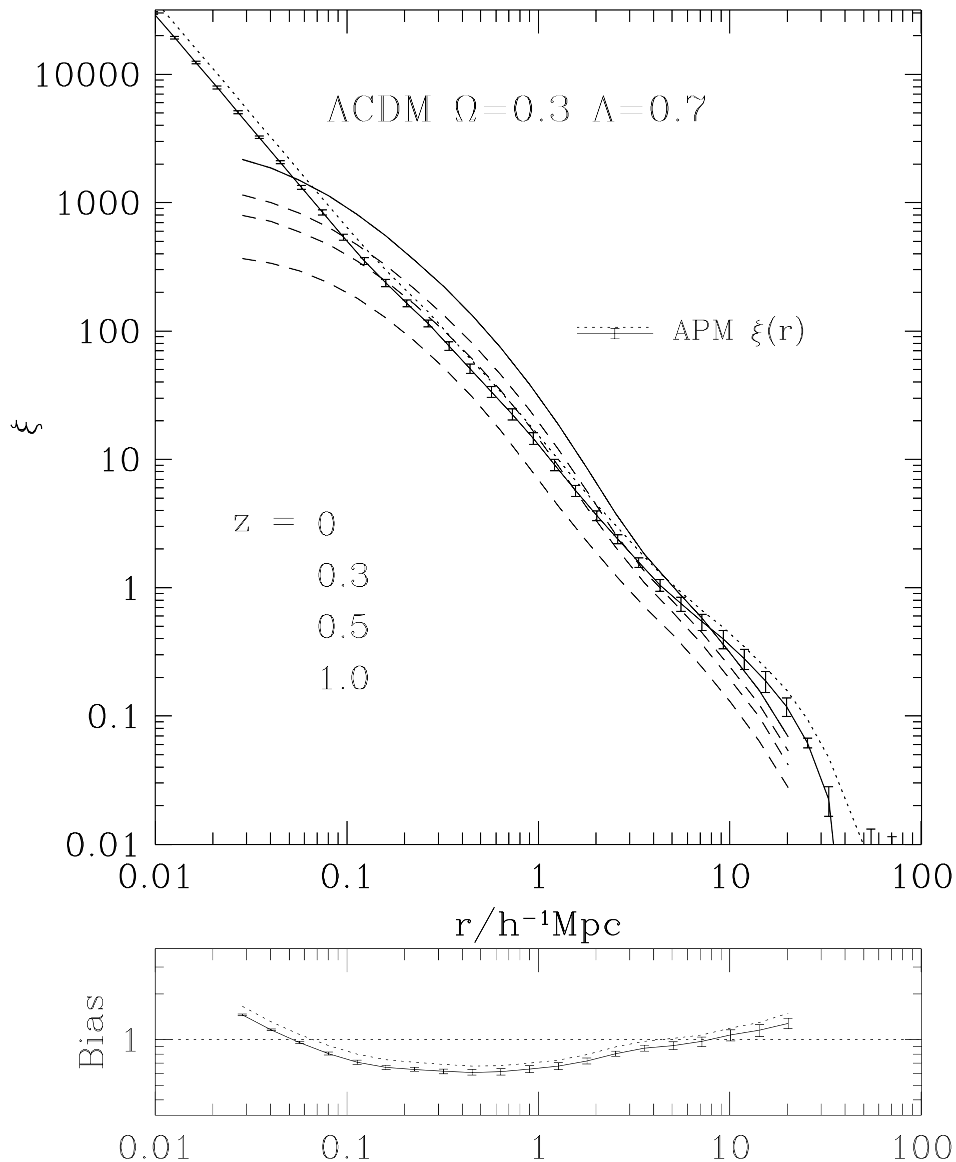
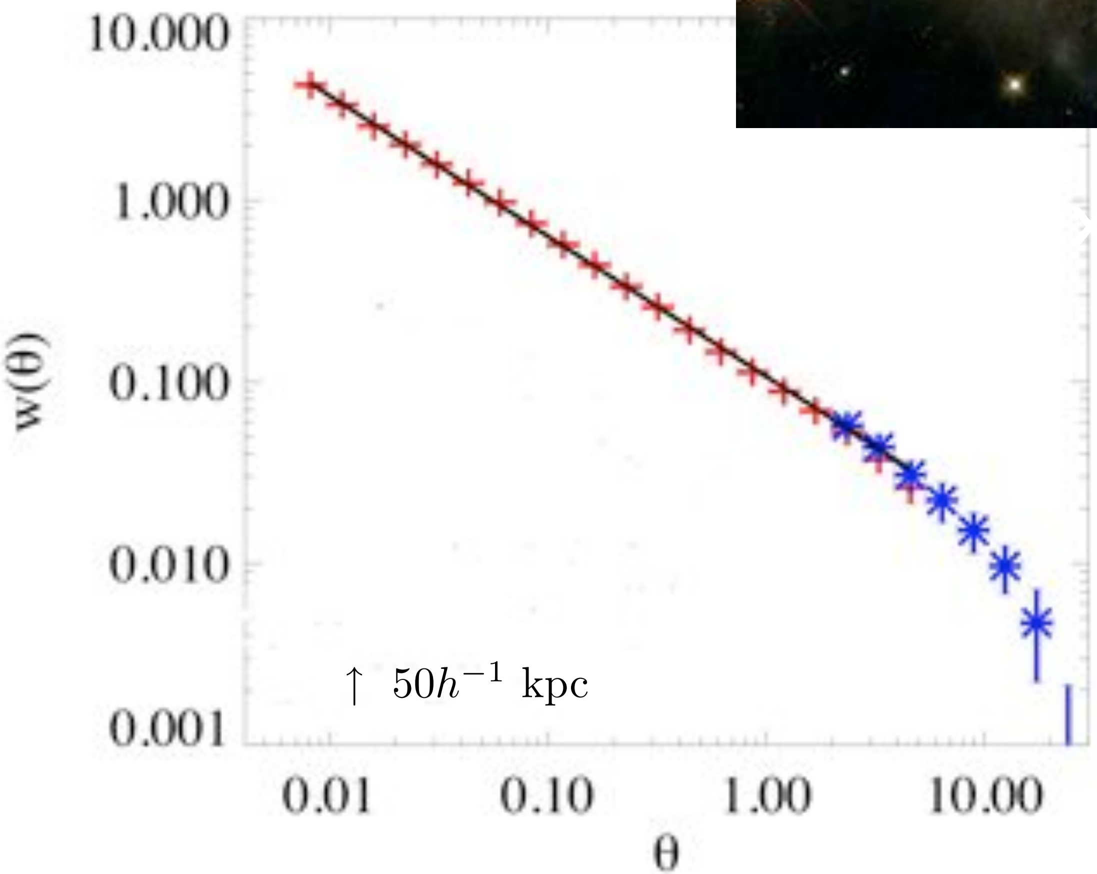
J. A. PEACOCK,[5] G. EFSTATHIOU,[6] AND A. H. NELSON[7]
(THE VIRGO CONSORTIUM)



HST image of NGC 2207 & IC 2163



Maller, et al. astro-ph/0304005 analysis of 2MASS

2MASS image of NGC 4782/3

VERY SMALL-SCALE CLUSTERING AND MERGER RATE OF LUMINOUS RED GALAXIES

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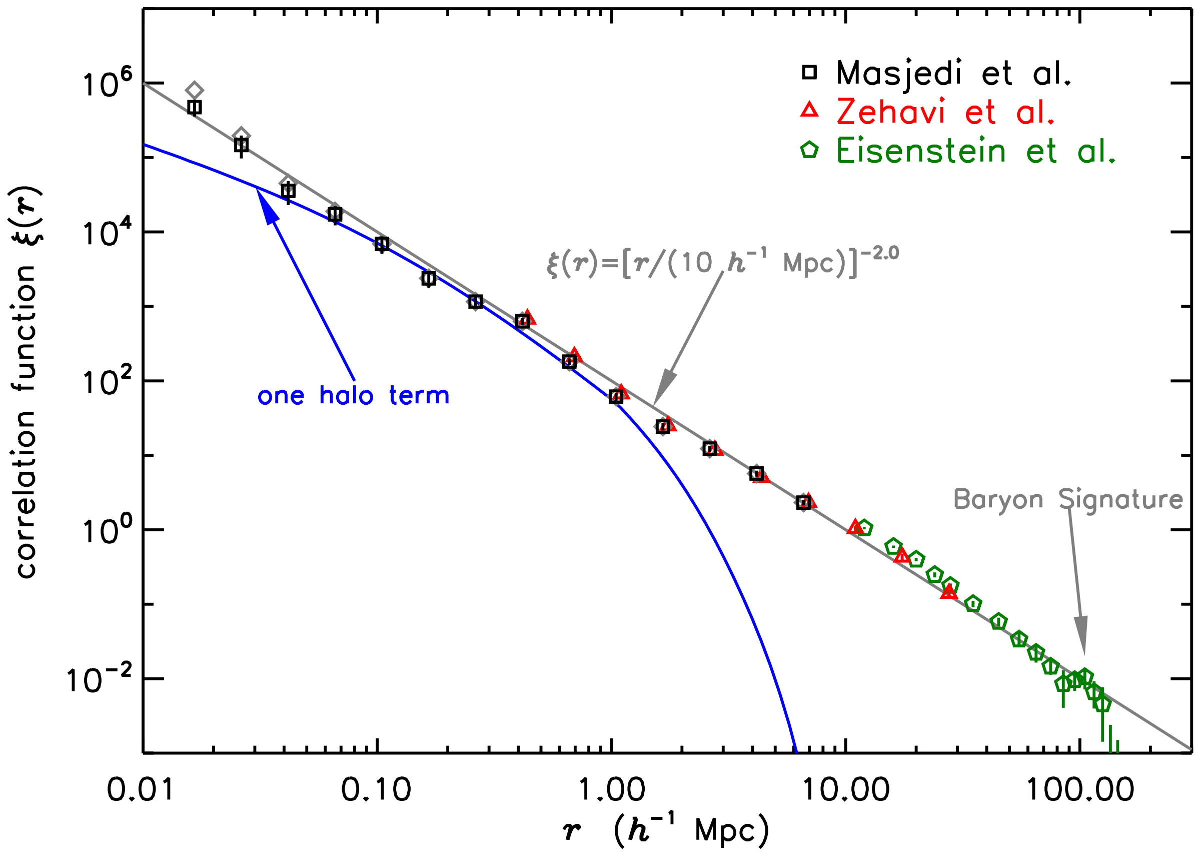

Fig. 4.— Real-space correlation function $\xi(r)$ for the LRG sample ($-23.2 < M_g < -21.2$ and $0.16 < z < 0.36$) calculated as described in the text on small scales, combined with real-space correlation function on intermediate scales from Zehavi et al. (2005a) and redshift-space correlation function $\xi(s)$ on large scales from Eisenstein et al. (2005) (data points from Zehavi results are shifted by 5% in the radial direction for illustration purposes). The gray diamonds show the result without photometric correction as in figure 1. The Blue line shows the 1-halo term of the correlation function calculated for the HOD parameters given by Zehavi et al. (2005b).

Giant galaxies cluster more strongly than optically selected $L \sim L_*$ galaxies, as expected in the standard cosmology. But why is the clustering of dwarfs and L_* galaxies so similar? Why are the voids so strikingly empty?

Galaxies merge, as expected in the standard cosmology. But why is there so much evidence that galaxies at redshift $z \lesssim 1$ by and large behave as island universes? And are the power law forms of the low order galaxy correlation functions really consistent with rapid merging of close galaxy pairs?