Title: Hints from galaxies to a still better cosmology

Date: Jun 17, 2010 03:30 PM

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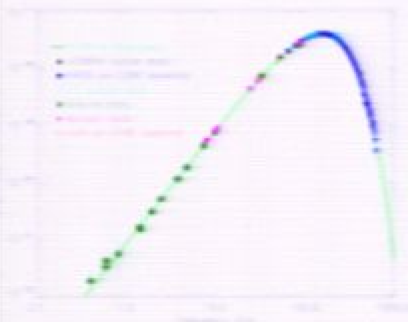
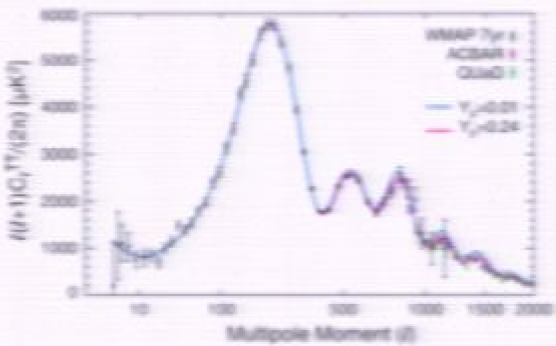
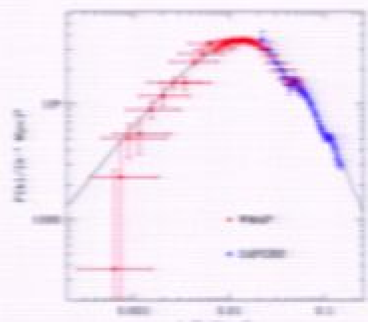
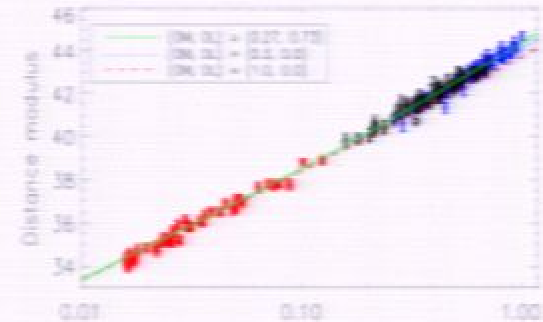
Abstract: The network of tests shows the LCDM cosmology is a good approximation to what actually happened, but that need not mean it has all the physics relevant to cosmology back to light element formation. I will review properties of galaxies that seem to be particularly difficult to understand within LCDM and might be pointing to still better physics.



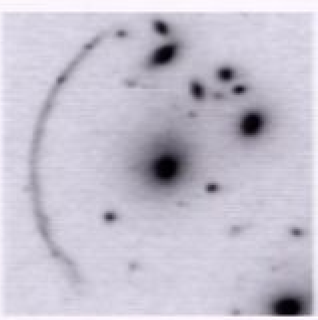


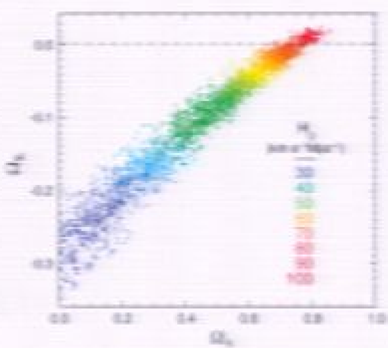


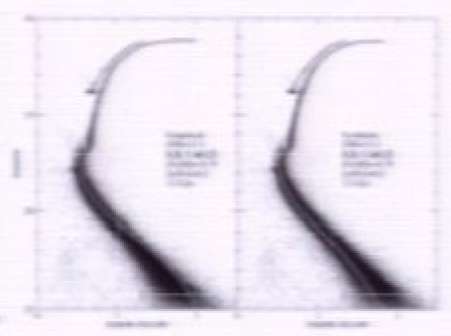


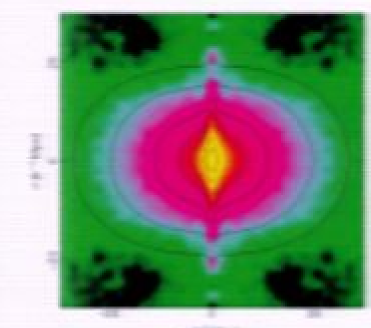
Hints from the nearby galaxies to a still better physical cosmology

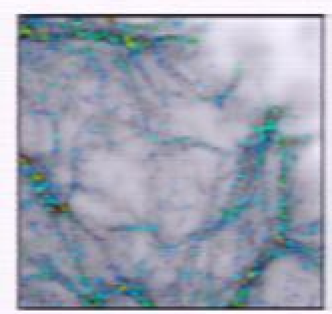
PJE Peebles
Perimeter Institute
June 2010











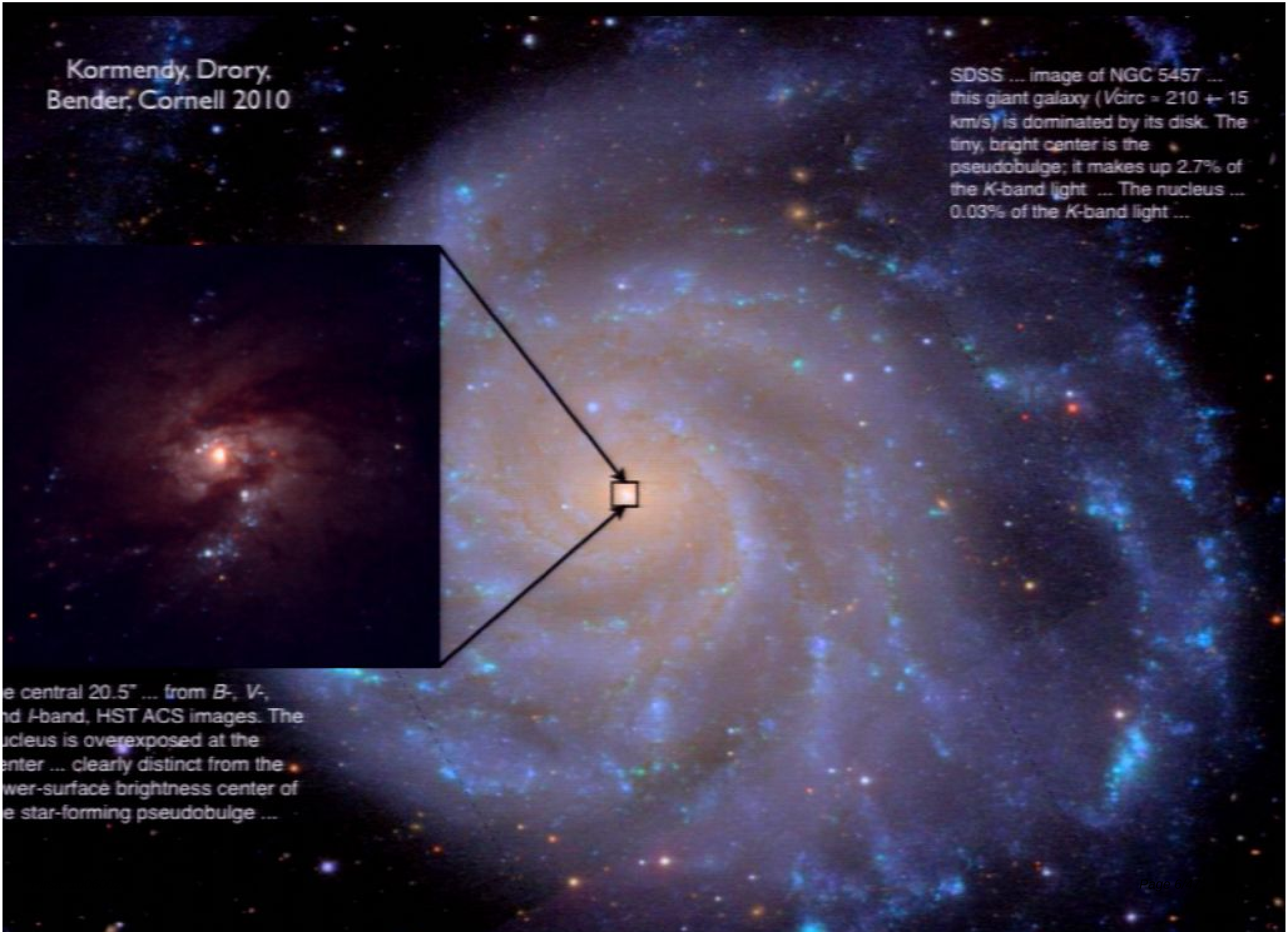
Three enigmatic aspects of galaxies at low redshift

1. Pure disk galaxies

2. Galaxies as island universes

3. The nearly empty Local Void

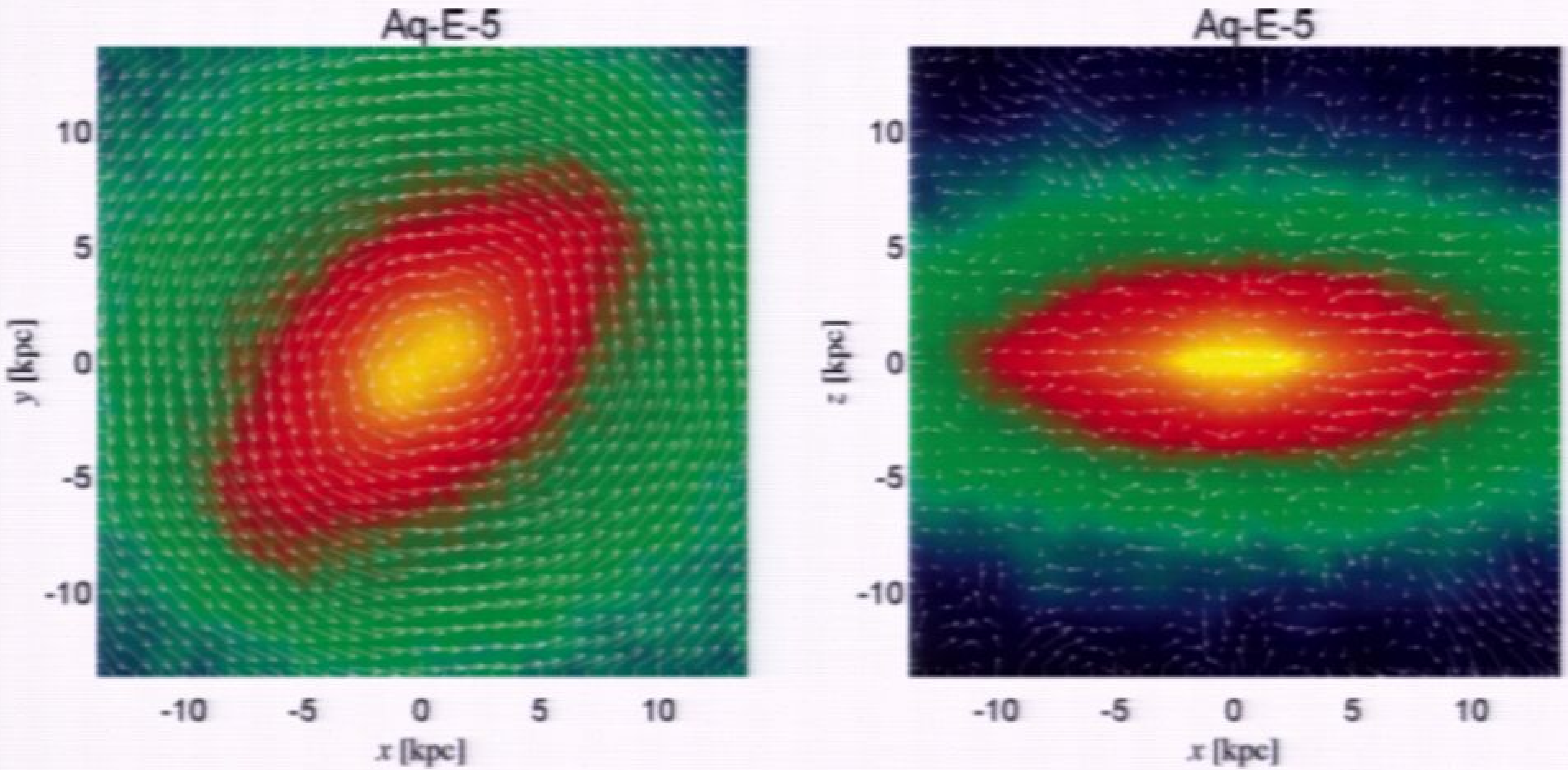
HST image

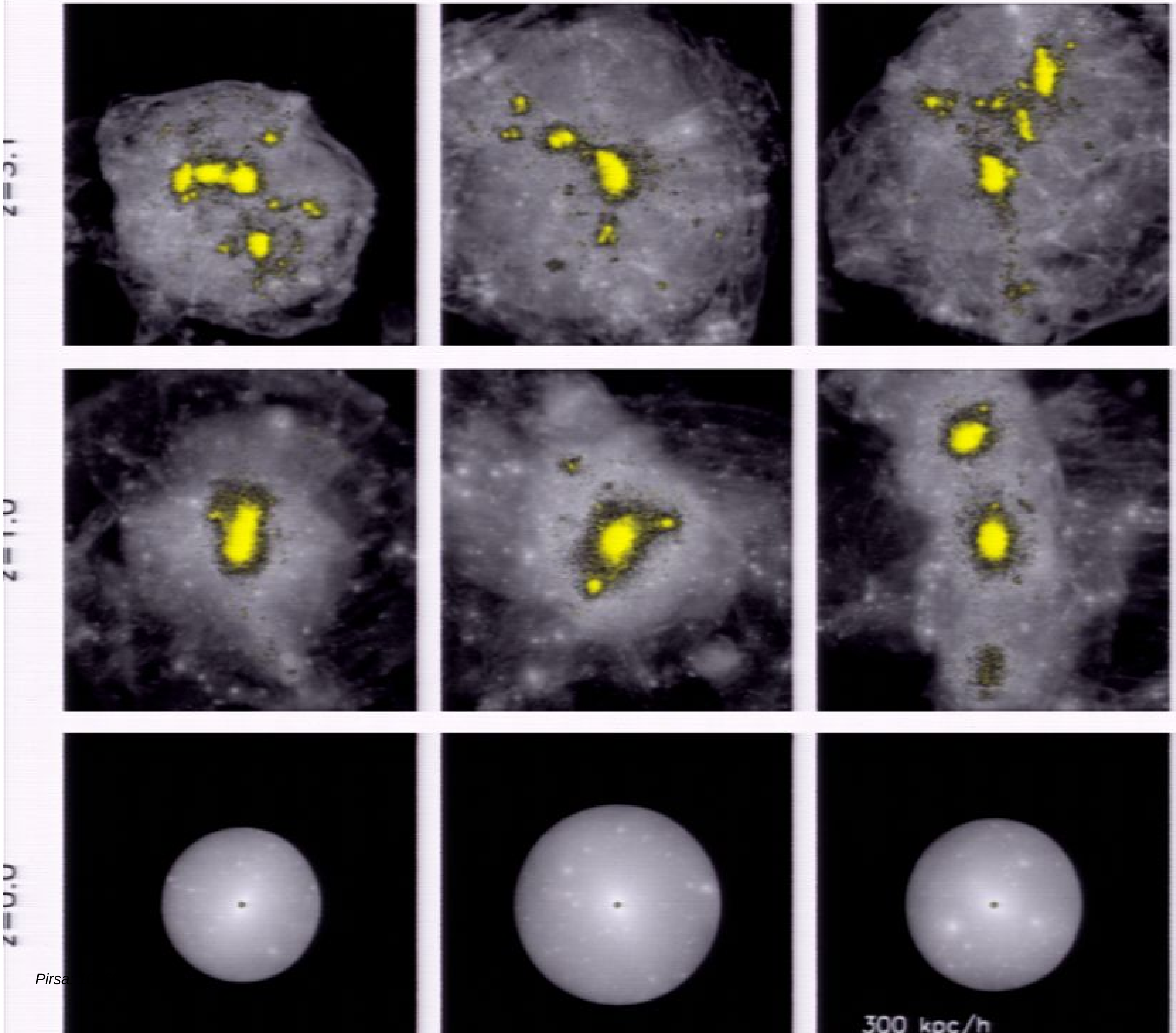

Kormendy, Drory,
Bender, Cornell 2010
SDSS ... image of NGC 5457 ... this giant galaxy (Vcirc = 210 +- 15 km/s) is dominated by its disk. The tiny, bright center is the pseudobulge; it makes up 2.7% of the K-band light ... The nucleus ... 0.03% of the K-band light ...
e central 20.5" ... from B-, V-, nd I-band, HST ACS images. The ucleus is overexposed at the enter ... clearly distinct from the wer-surface brightness center of e star-forming pseudobulge ...

The formation and survival of discs in a ΛCDM universe

Cecilia Scannapieco,[1*] Simon D. M. White,[1] Volker Springel[1] and Patricia B. Tissera[2,3]

(bowdlerized)

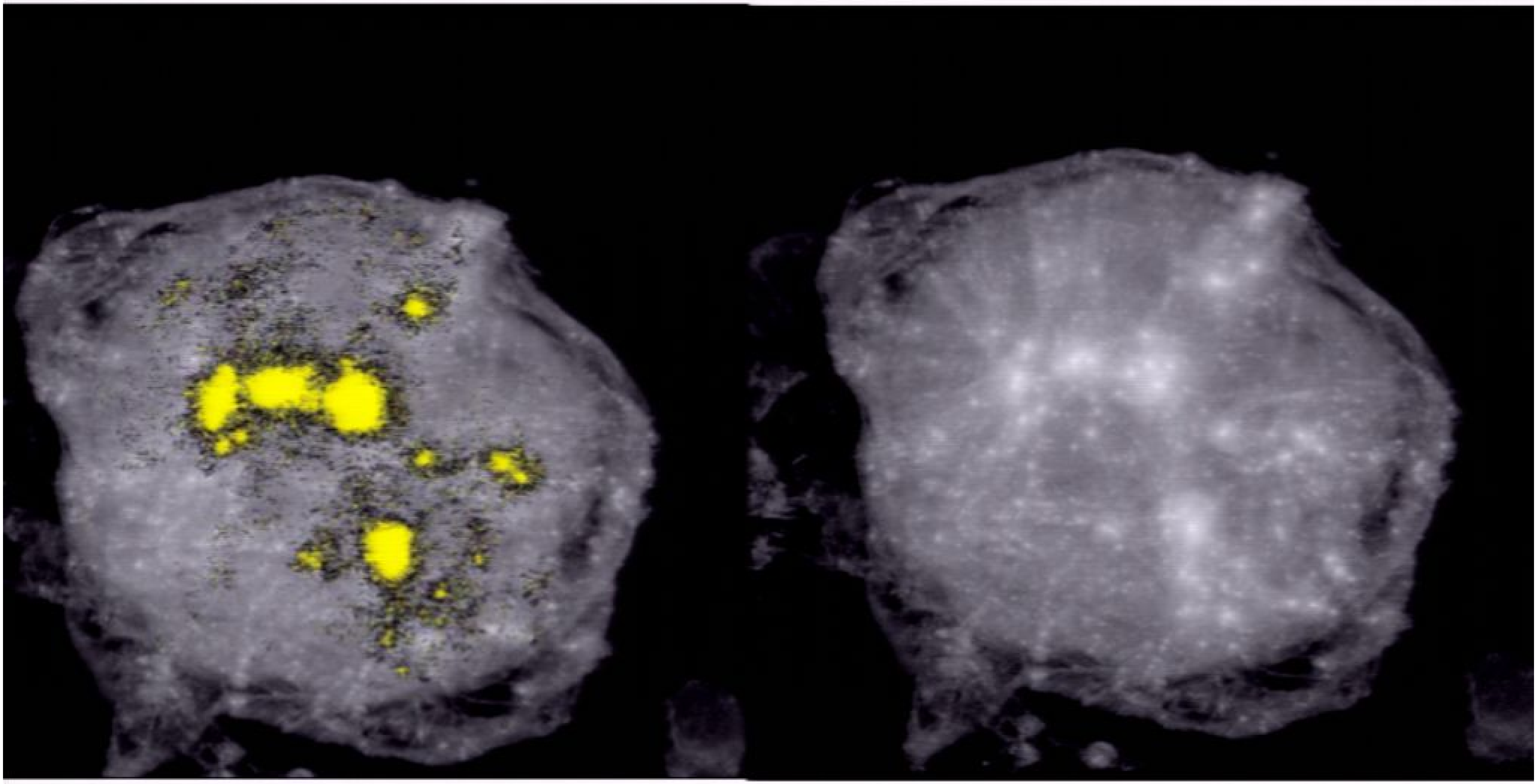




850 kpc

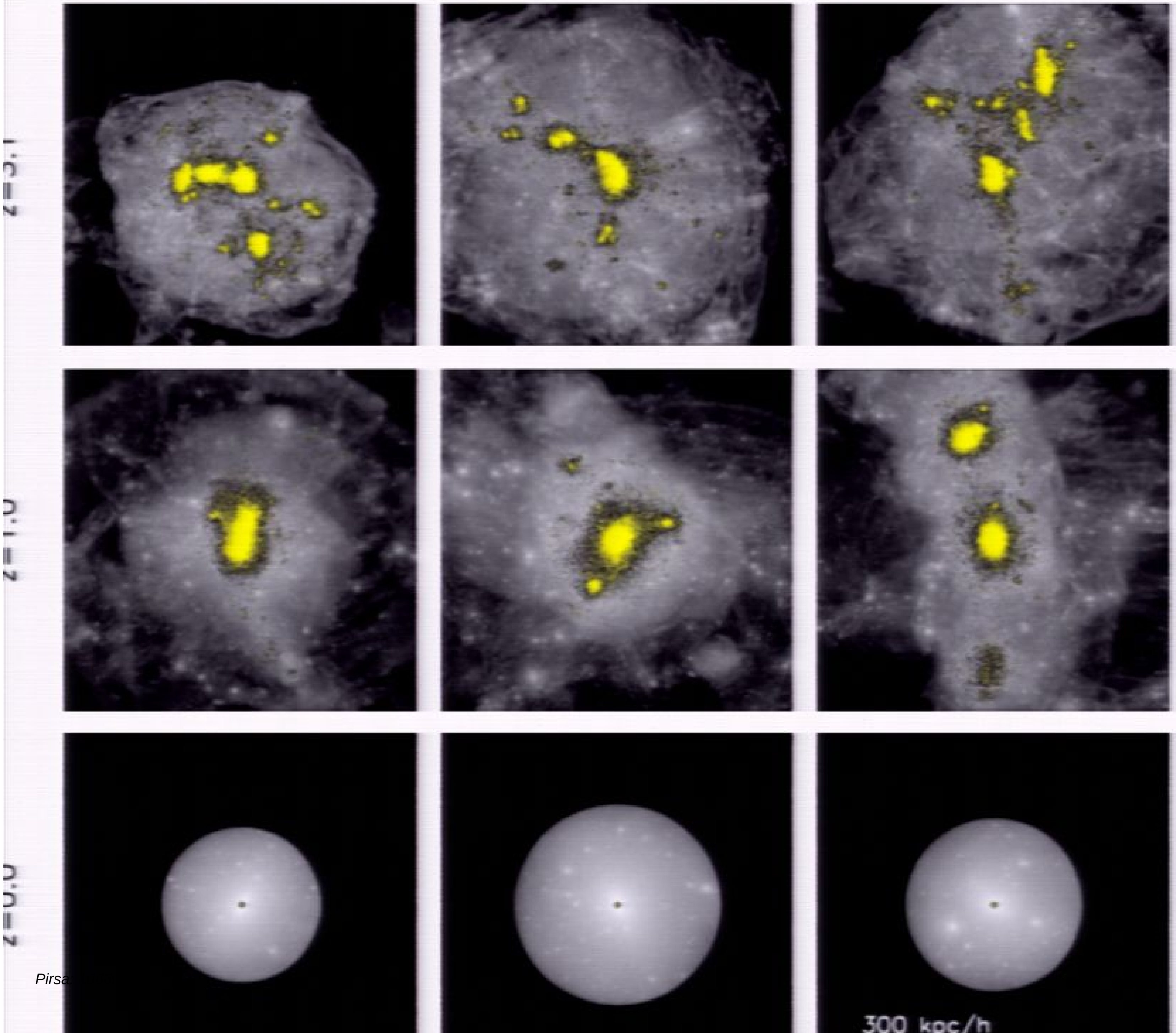
AQUARIUS pure DM halos of L* galaxies (Springel et al. 2008)

Images by Jie Wang, Durham



An AQUARIUS halo of an L* galaxy at z = 3.1
(Springel et al. 2008)

Images by Jie Wang, Durham



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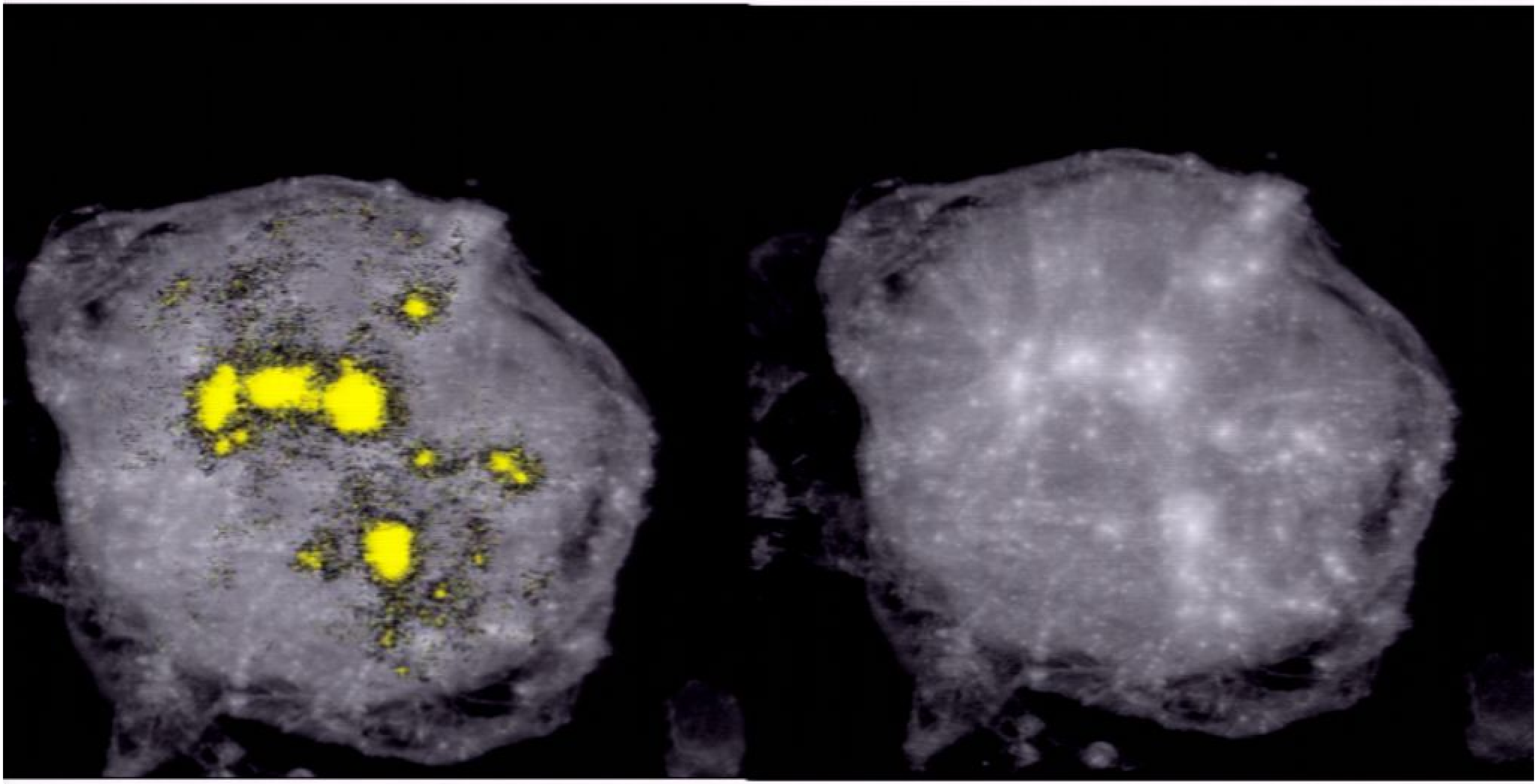

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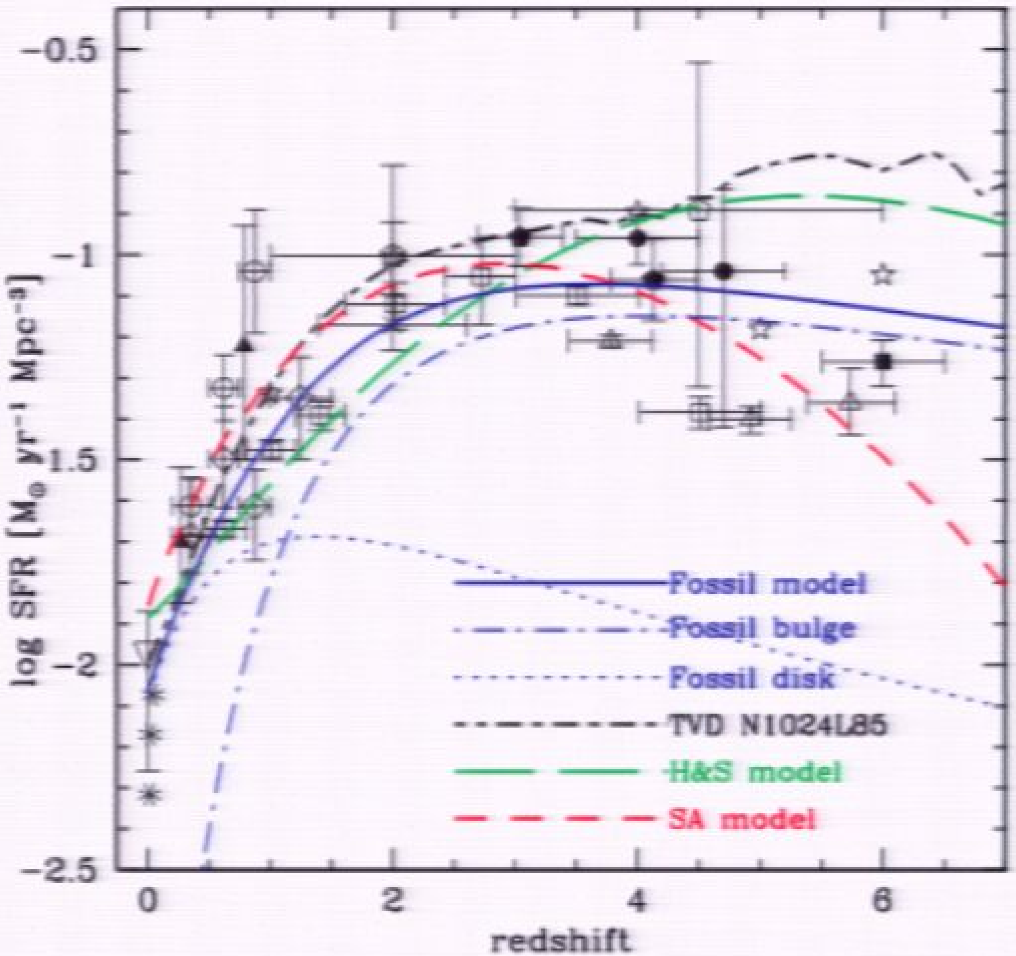

FIG. 5.—SFR density as a function of redshift. The curves represent the model predictions specified in the legend. The data are taken from (from low to high redshift): Heavens et al. (2004; *three asterisks*, at $z \sim 0$), Nakamura et al. (2004; *open inverted triangle*, at $z = 0$), Lilly et al. (1996; *open circles*), Norman et al. (2004; *filled triangles*), Cowie et al. (1999; *open diamonds*), Gabasch et al. (2004, *open squares*), Reddy et al. (2005; *cross*, at $z = 2$), Barger et al. (2000; *open pentagons*, at $z = 2$ and 4.5), Steidel et al. (1999; *filled pentagons*, at $z = 3, 4$), Ouchi et al. (2004; *filled circles*, at $z = 4, 5$), Giavalisco et al. (2004; *open triangles*, at $z = 3$–6), Bouwens et al. (2006; *filled square*, at $z = 6$), and Thompson et al. (2006; *open stars without error bars*). The data are converted to the values with the Chabrier IMF and common values are assumed for dust extinction for the UV

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Ellipticals, S0s, and bulges of spirals have old stars, in about the right amount.

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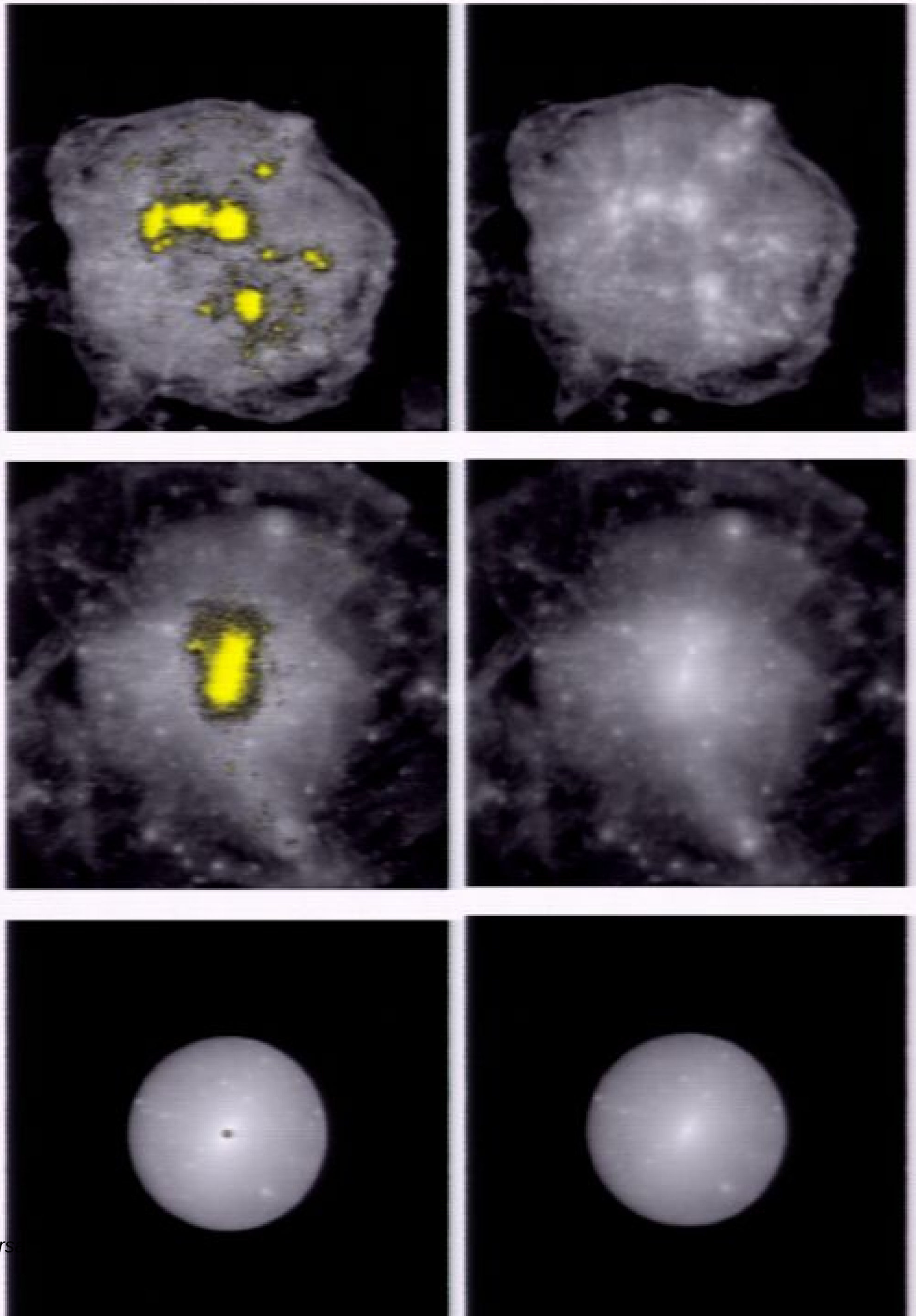

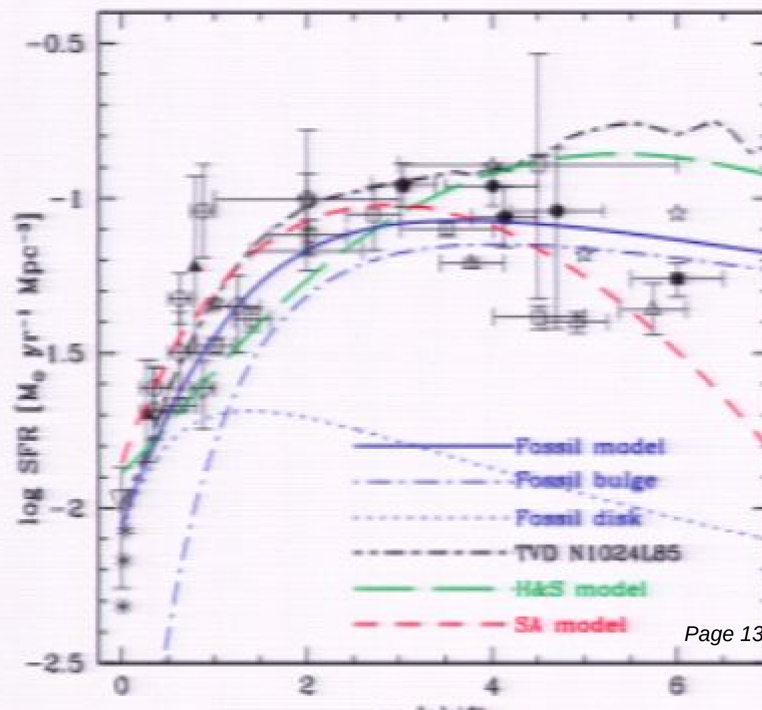
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Fossil disk
TVD N1024L85
H&S model
SA model

JOHN KORMENDY[3,4,5], NIV DRORY[5], RALF BENDER[4,5], AND MARK E. CORNELL[3]

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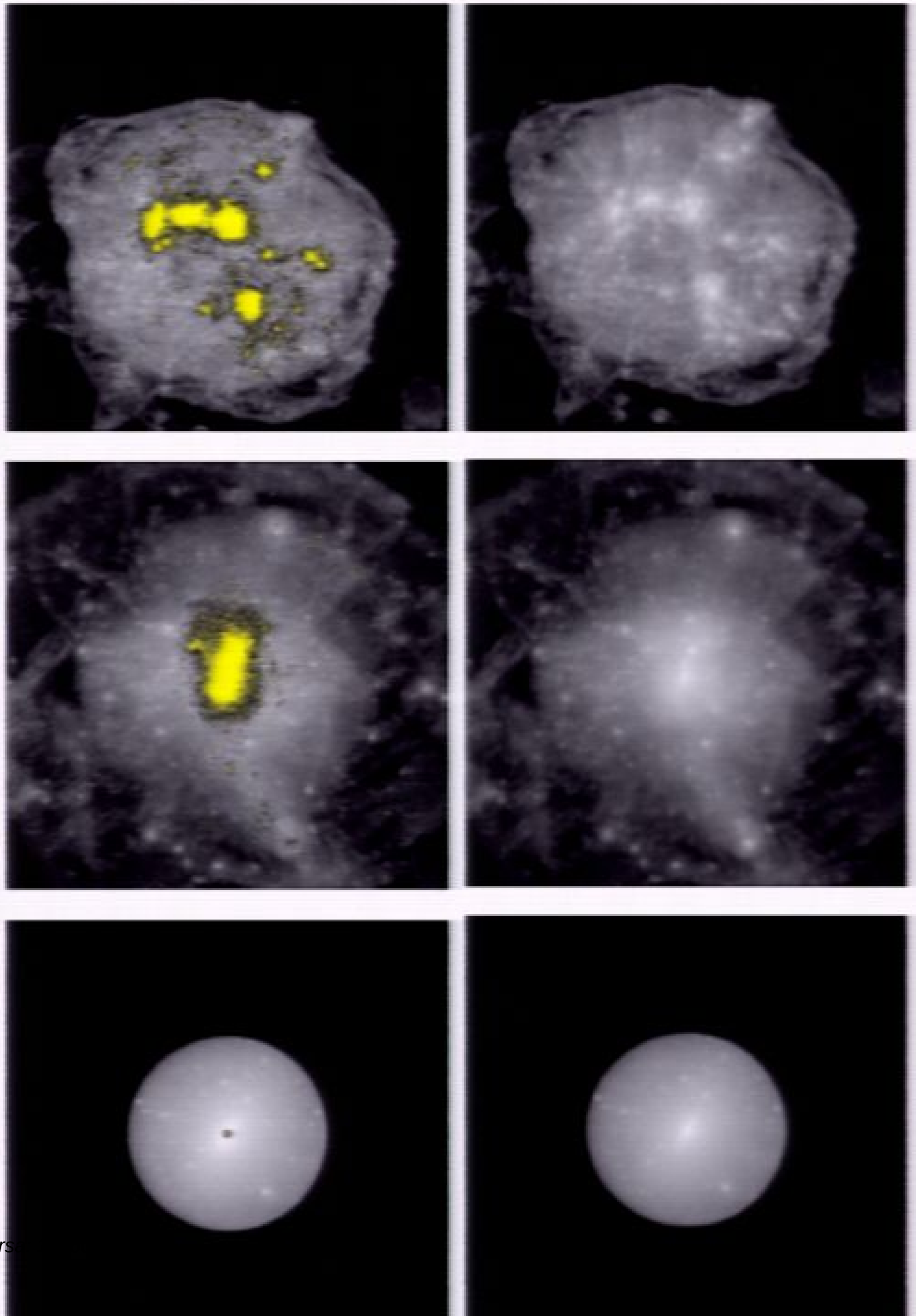

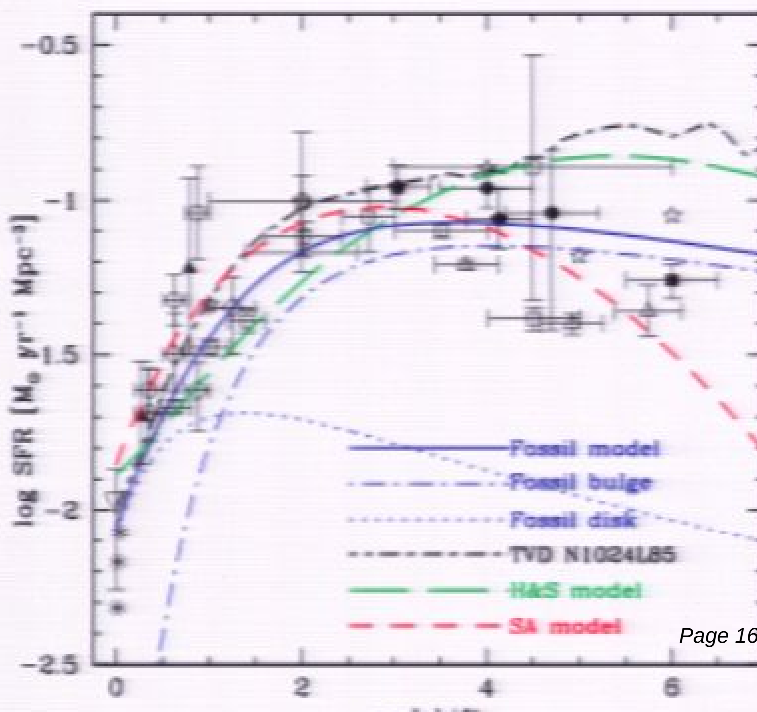
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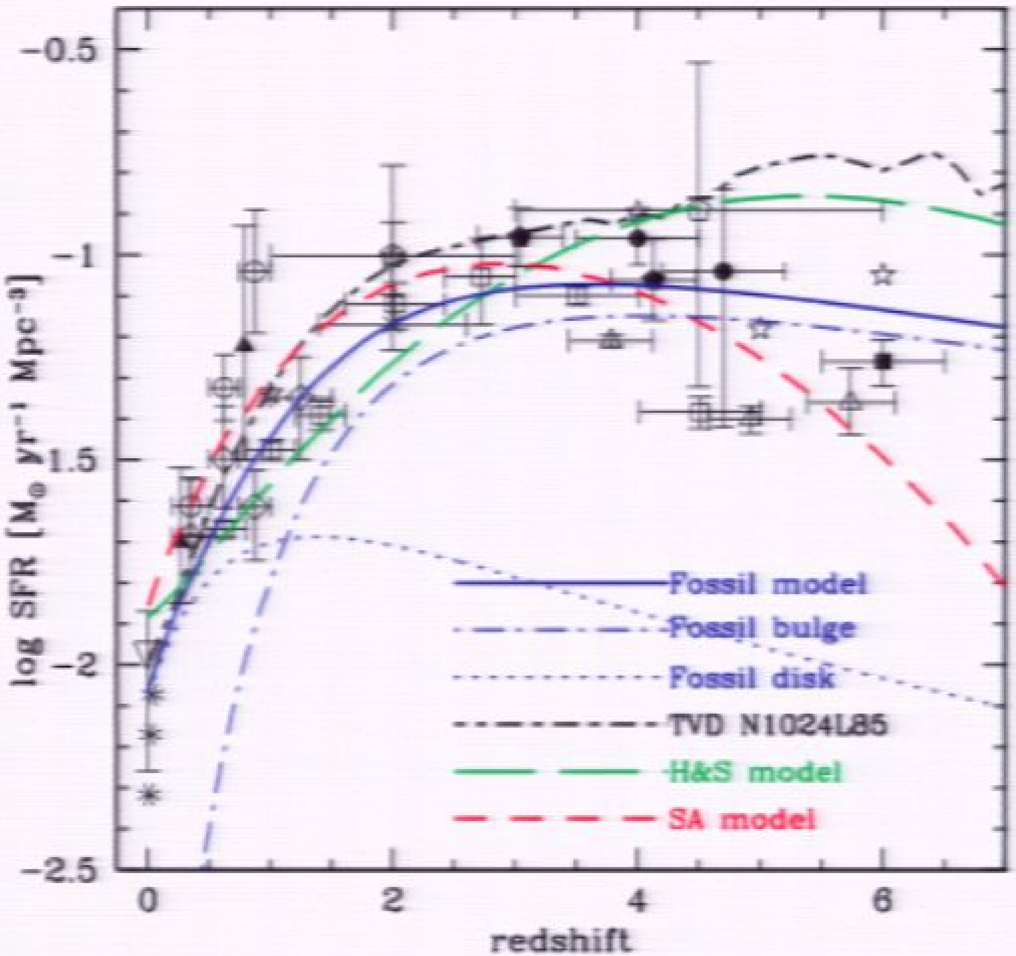

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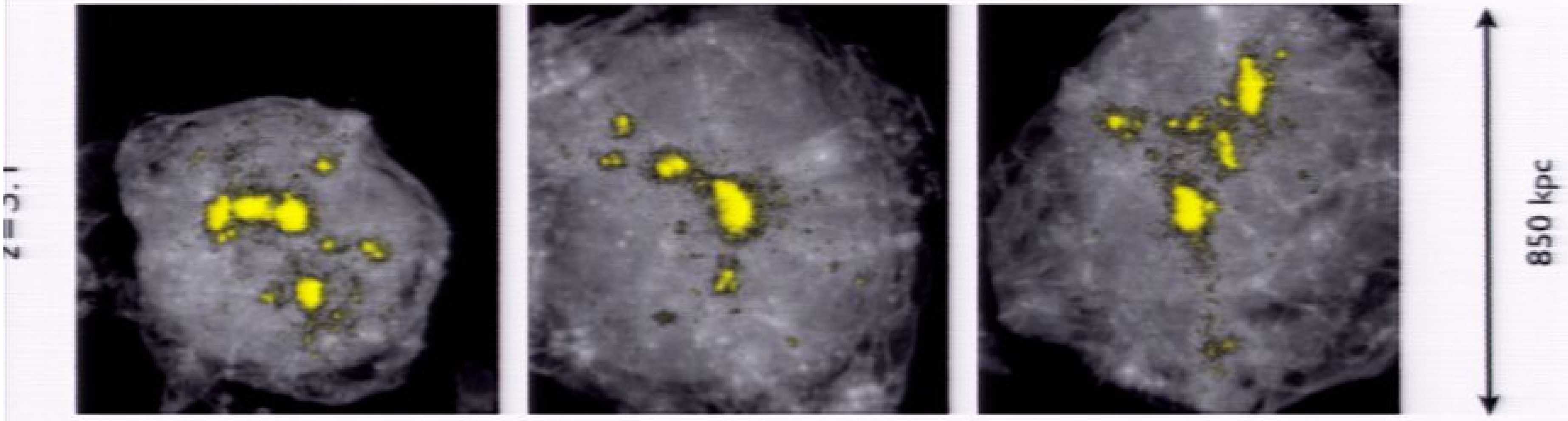

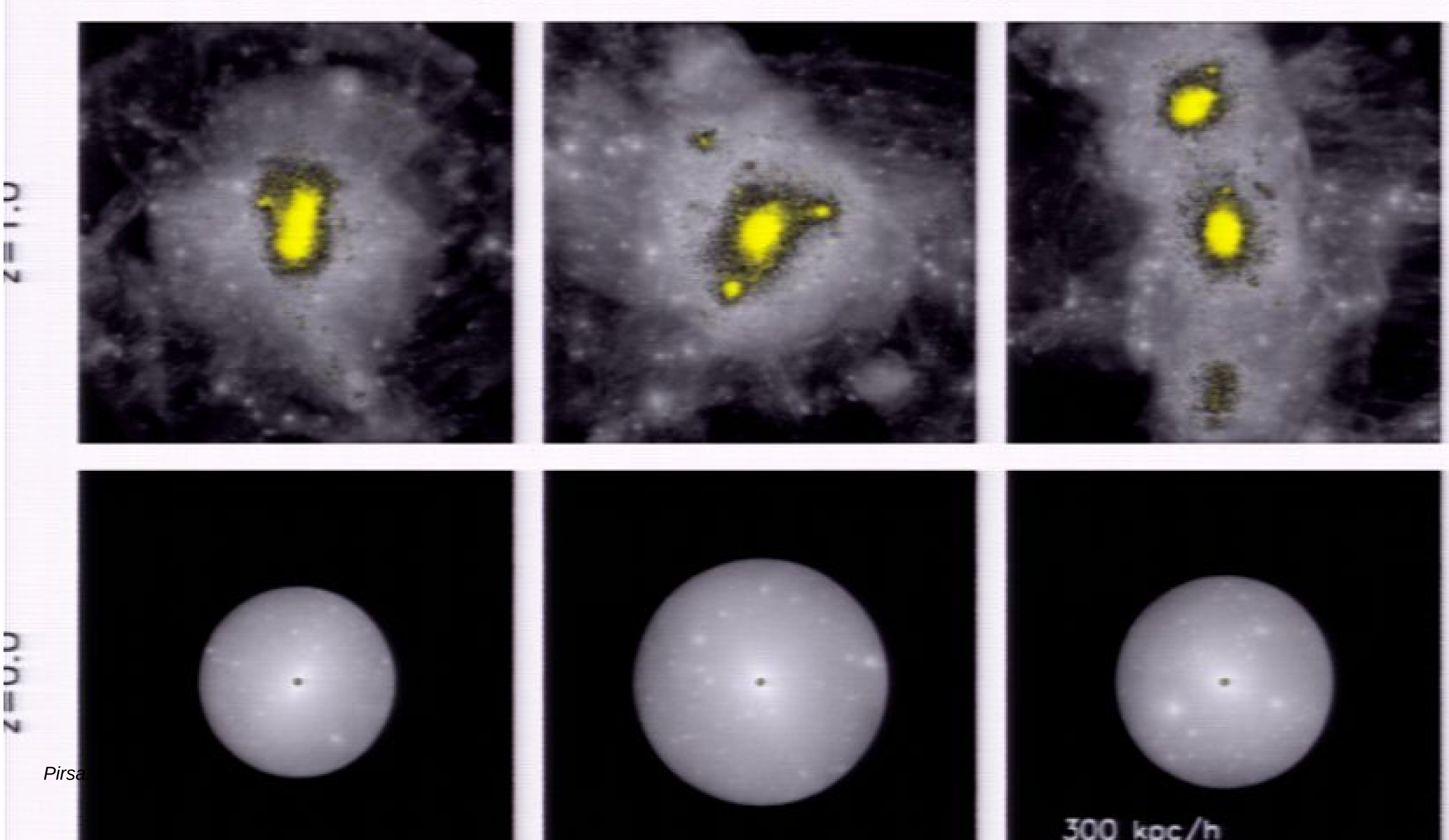

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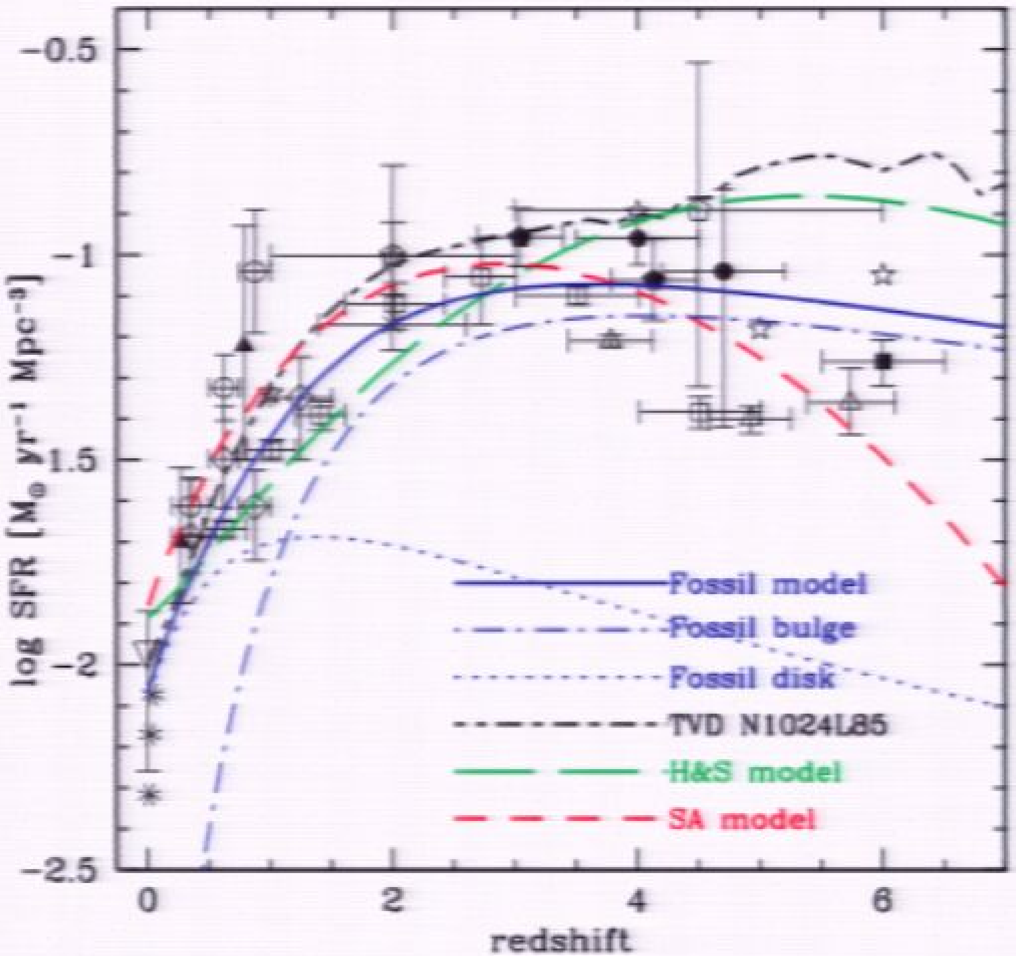

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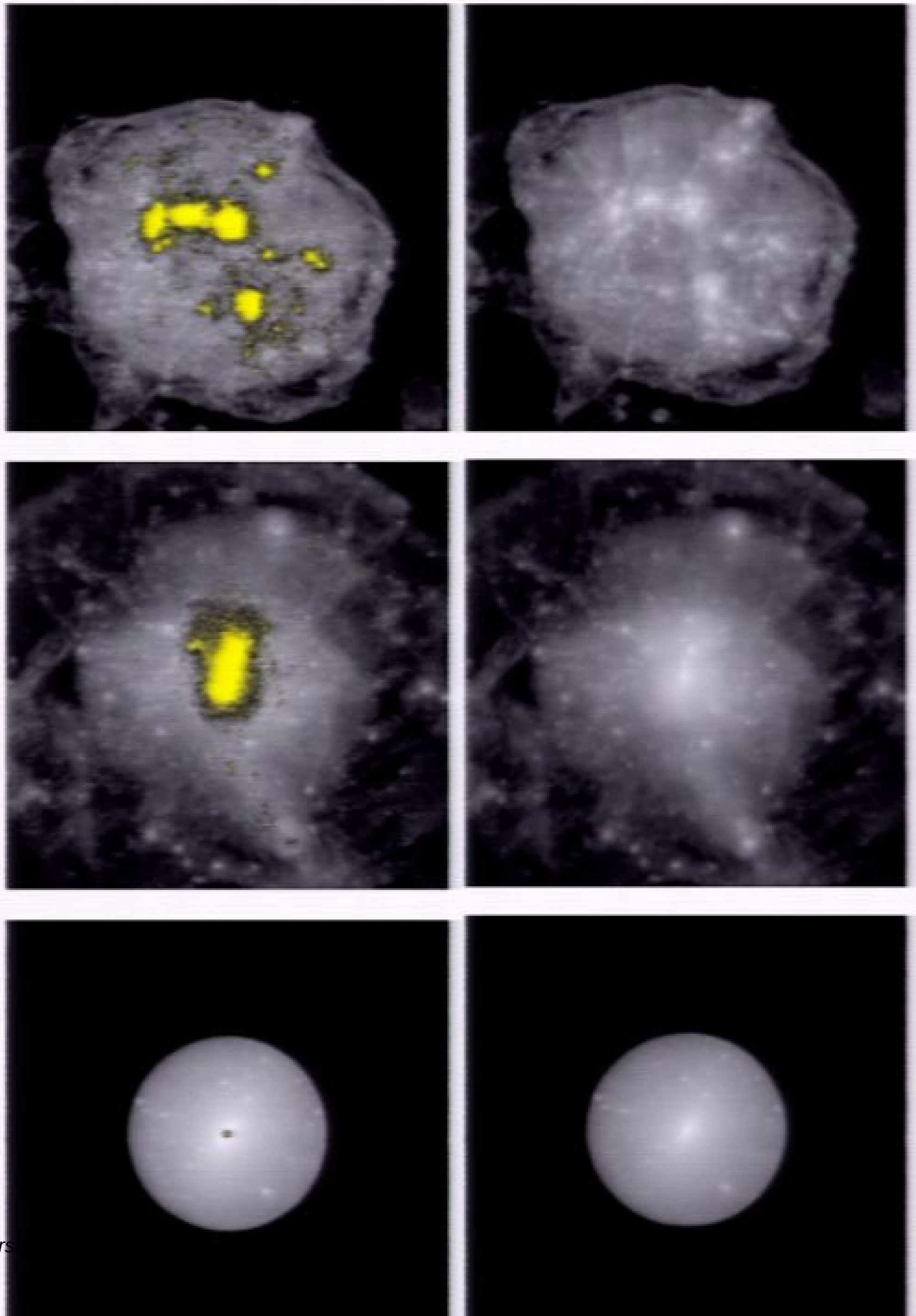

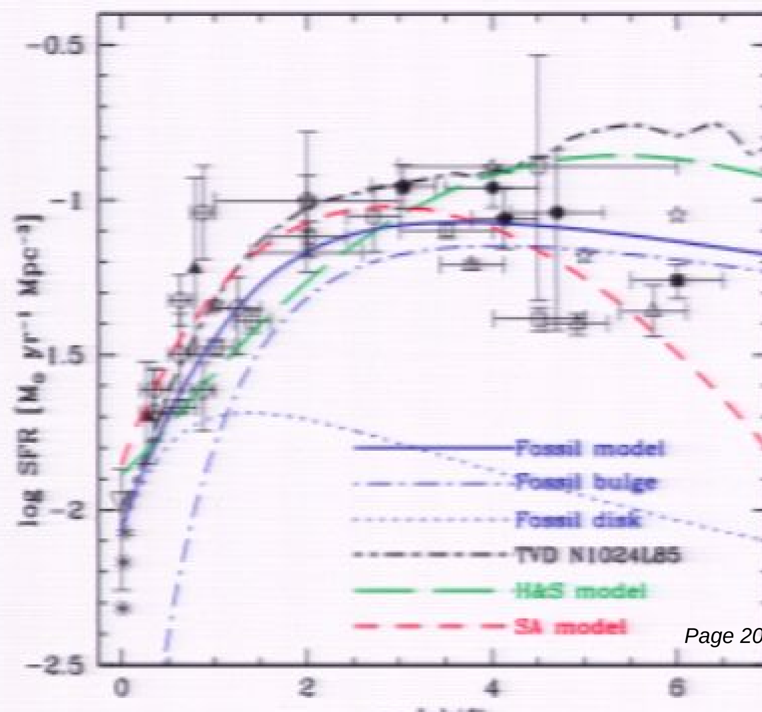
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JOHN KORMENDY[3,4,5], NIV DRORY[5], RALF BENDER[4,5], AND MARK E. CORNELL[3]

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Kormendy, Drory,
Bender, Cornell 2010
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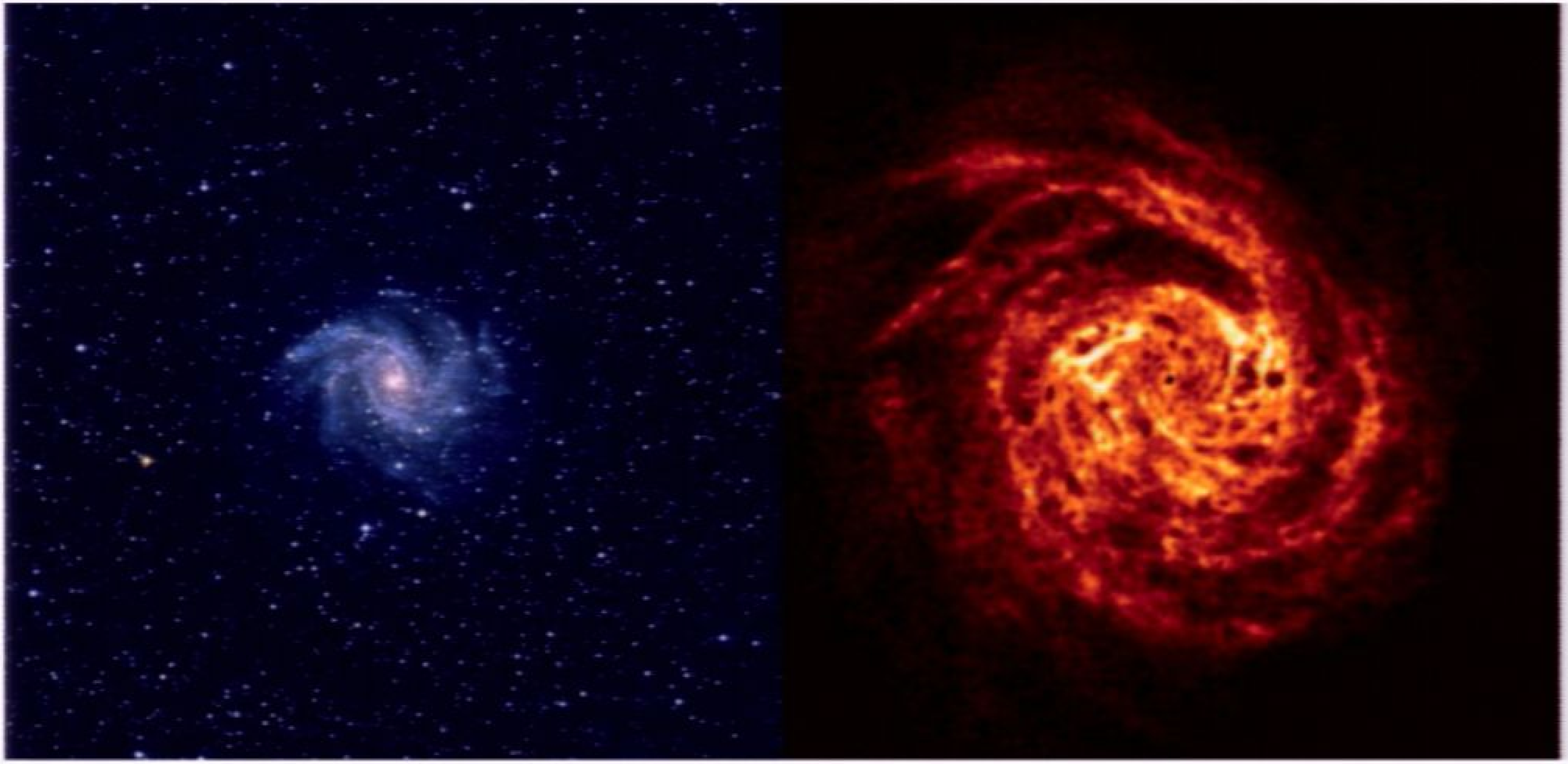
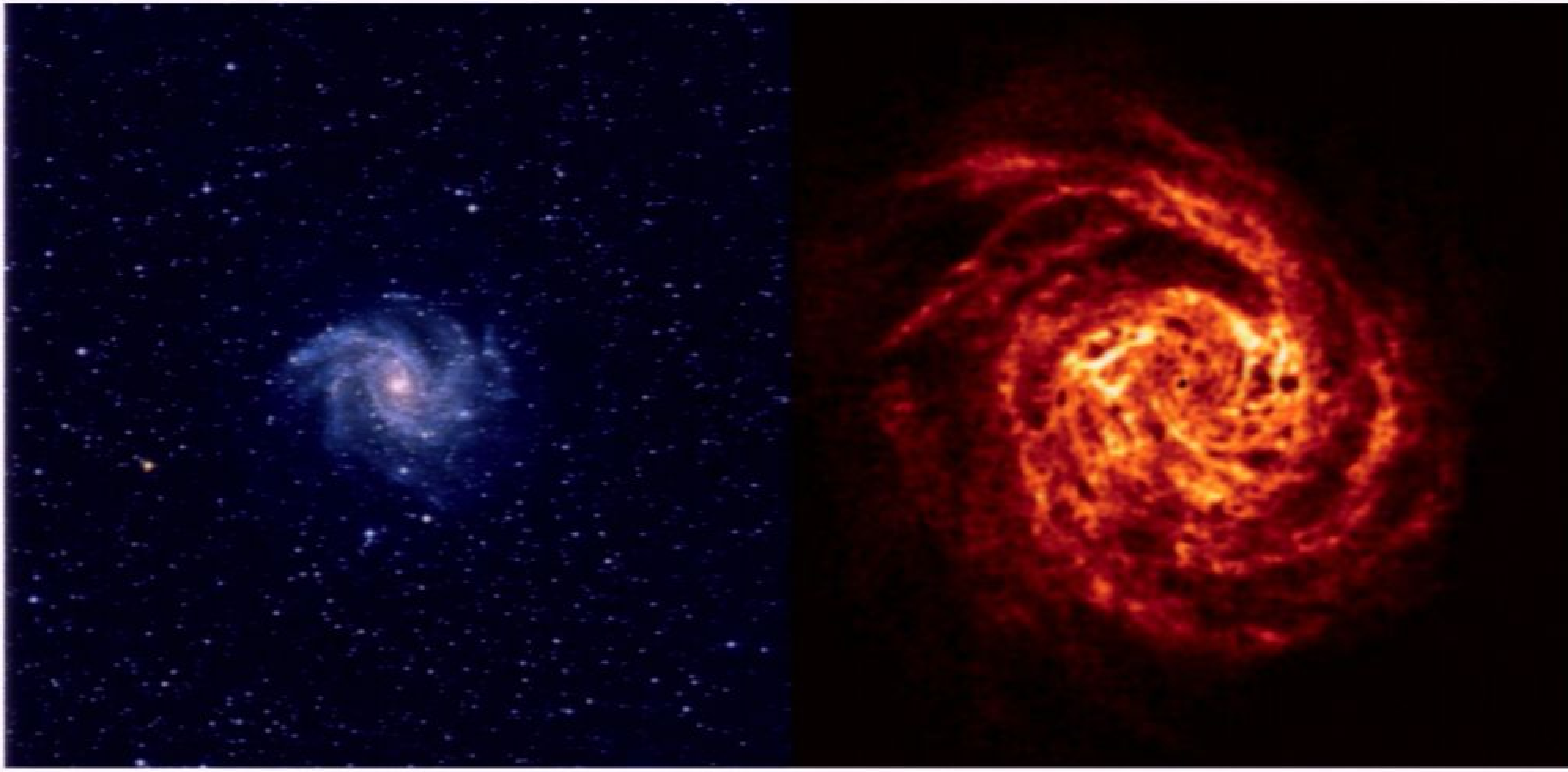


Figure 3– (Chapter 2) NGC 6946 at optical and 21-cm wavelengths. The left panel is a colour composite of the Digitized Sky Survey plates. The right panel is the deep (192 hours integration) H I image on the same scale as the optical.

Rense Boomsma, PhD dissertation, Groningen, 2007

- How did the extended HI disk of NGC 6946 survive buffeting by the ongoing flow of cool plasma onto the galaxy at $z \lesssim z_{1/2}$?

  This is part of the challenging hydrodynamics of disk formation, but maybe more readily analyzable in numerical simulations.



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What are observers saying?

BULGELESS GIANT GALAXIES CHALLENGE OUR PICTURE OF GALAXY FORMATION BY HIERARCHICAL CLUSTERING[1,2]

JOHN KORMENDY[3,4,5], NIV DRORY[5], RALF BENDER[4,5], AND MARK E. CORNELL[3]

classical bulges that contribute $\sim 1/3$ of the galaxy light. We conclude that pure-disk galaxies are far from rare. It is hard to understand how bulgeless galaxies could form as the quiescent tail of a distribution of merger histories. Recognition of pseudobulges makes the biggest problem with cold dark matter galaxy formation more acute: How can hierarchical clustering make so many giant, pure-disk galaxies with no evidence for merger-built bulges? Finally, we emphasize that this problem is a strong function of environment: the Virgo cluster is not a puzzle, because more than 2/3 of its stellar mass is in merger remnants.

What do current numerical analyses of galaxy formation in ΛCDM say?

The formation of disk galaxies in a ΛCDM universe

Oscar Agertz[1*], Romain Teyssier[1,2] and Ben Moore[1]

Our simulated disks span a large range of characteristics: stellar disk masses are in the range $M_{\rm disk,s} = 5 - 9 \times 10^{10}$ M$_{\odot}$, bulge masses of $M_{\rm bulge,s} = 2 - 7 \times 10^{10}$ M$_{\odot}$, B/D $\sim 0.23 - 1.2$ and gas fractions $f_{\rm g} = 0.05 - 0.28$. The disk scale radii, $r_{\rm d}$ vary from typical $4 - 5$ kpc up to > 10 kpc

What are galaxy formation theorists thinking?

I expect they'll stick with ΛCDM until forced from it by more manifest evidence than this.

What am I thinking?

The challenge looks serious, and would be relieved by earlier galaxy assembly.

What is the physics community thinking?

Three enigmatic aspects of galaxies at low redshift

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2. Galaxies as island universes

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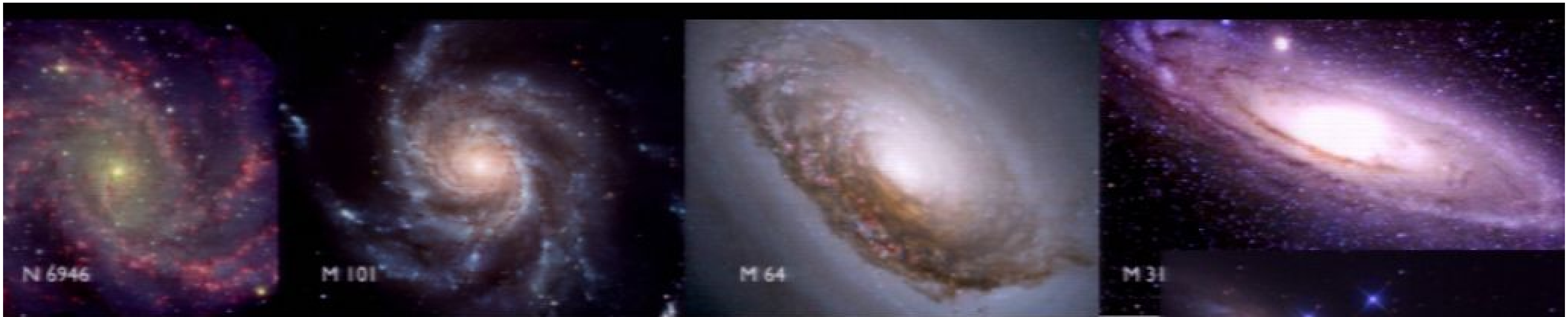
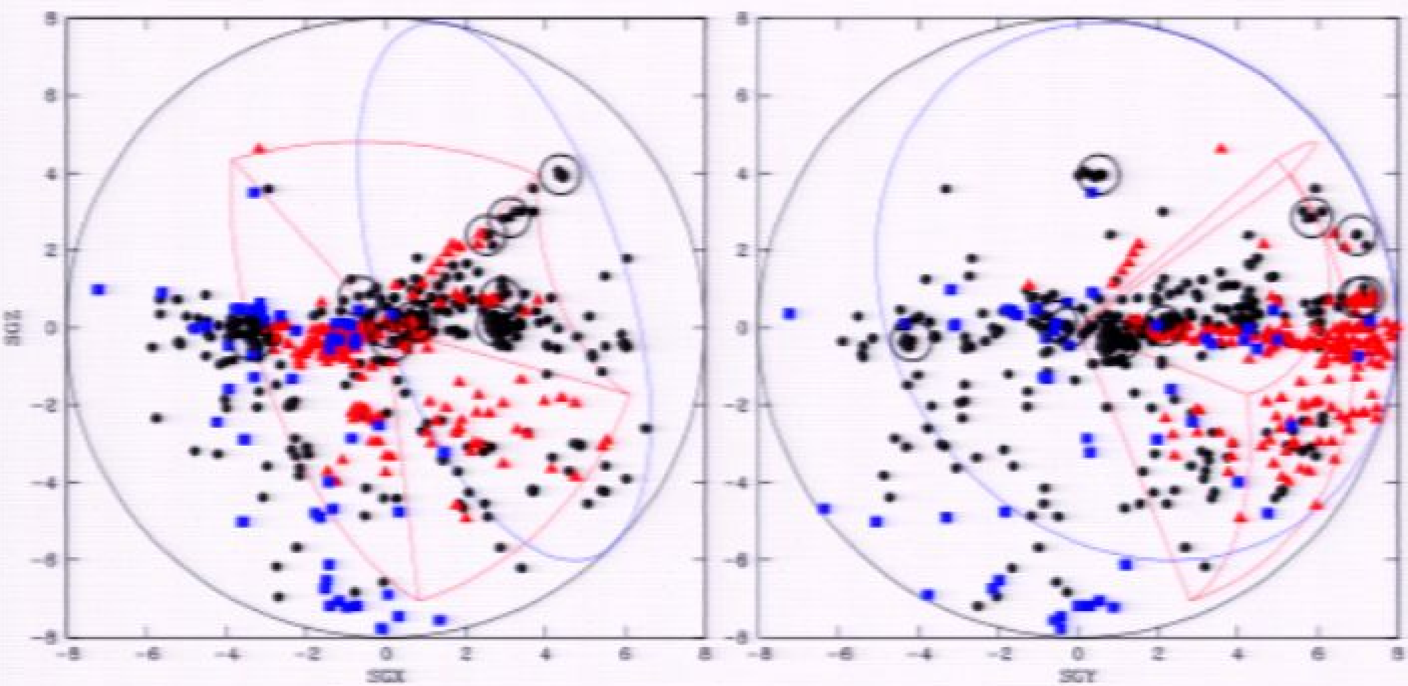
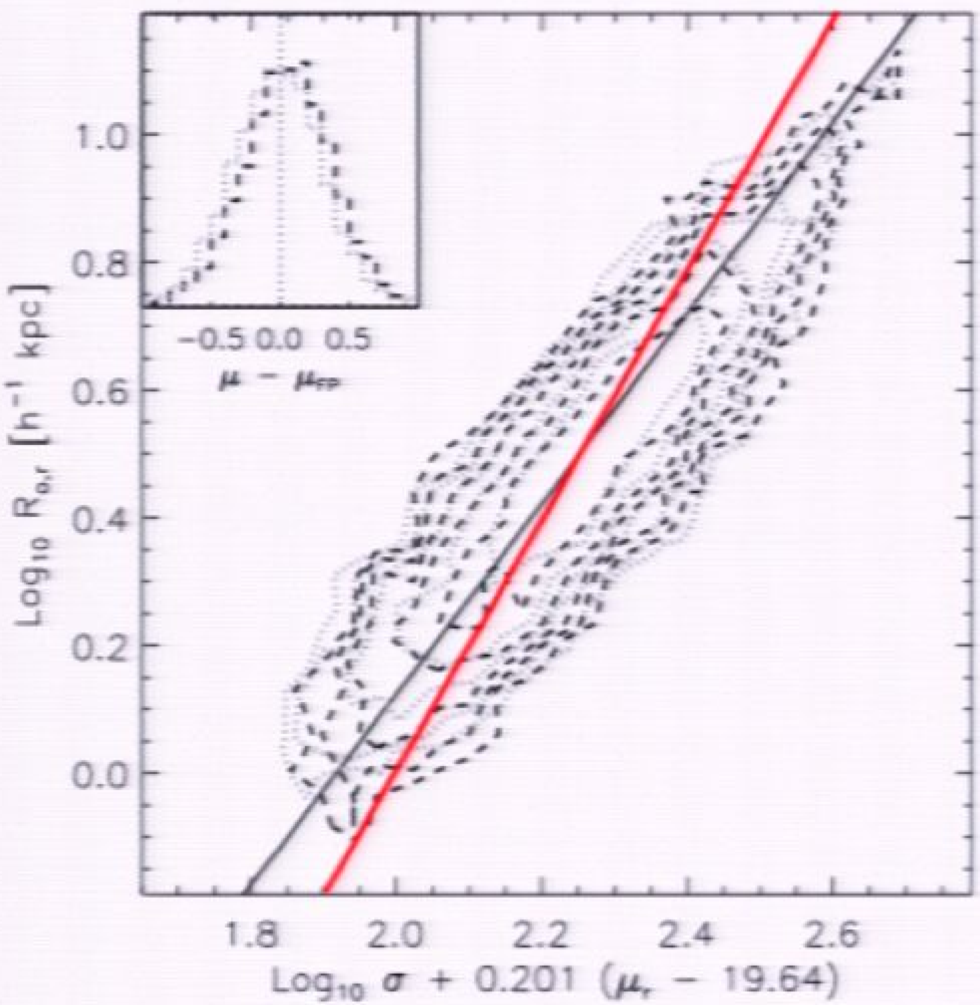




The 7 or 8 most luminous nearby galaxies have quite different local environments, yet they look quite similar.

The late merging puzzle. Large early-type galaxies give the impression of island universes.



M. Bernardi *et al.* (2006) study of the effect of environment on the fundamental plane for SDSS early-type galaxies. Dashed contours: galaxies at higher ambient density; dotted, lower density.

The red line is the relation

$$\log \sigma + 0.2\mu = 0.5 \log R + \text{ constant}$$

that follows from the virial theorem if M/L is constant. The scaling indicated by the tilt of the contours relative to the red line,

$$M/L \propto R^{0.3}$$

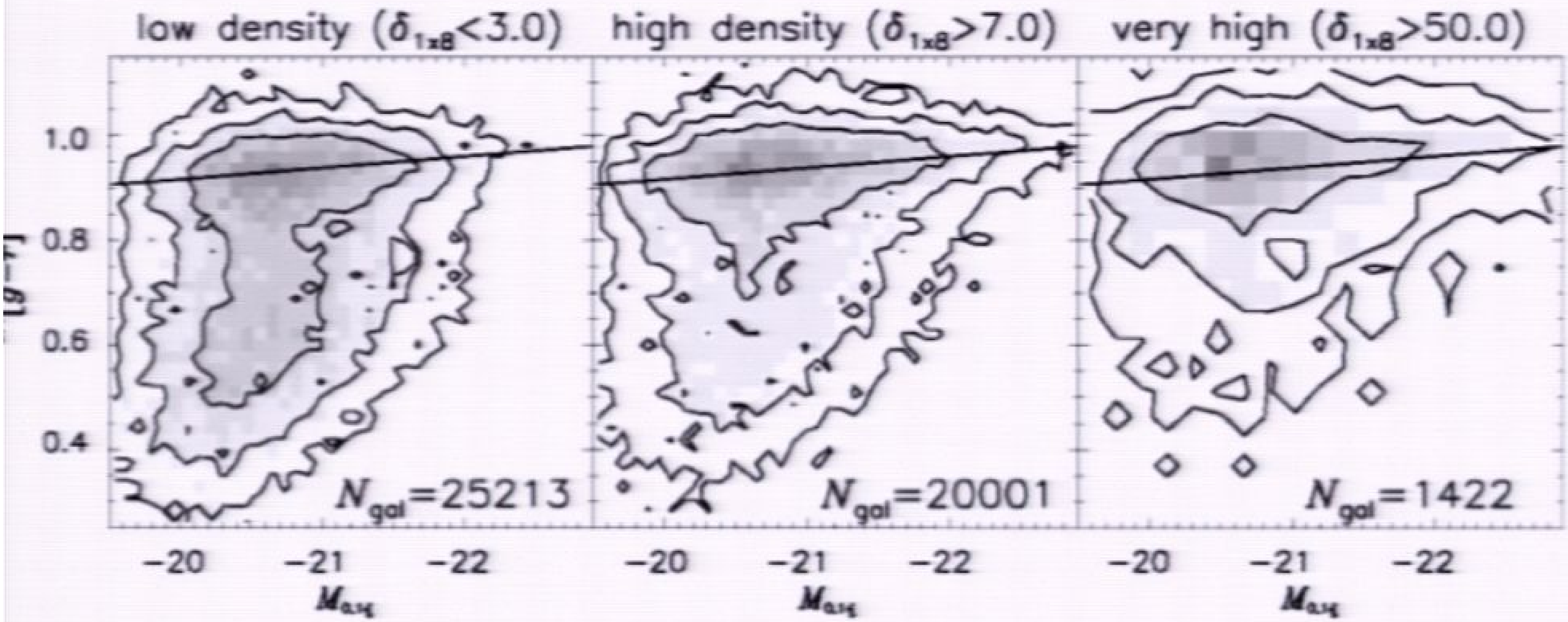
shows exceedingly little environmental effect.

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

David W. Hogg,[1] Michael R. Blanton,[1] Jarle Brinchmann,[2] Daniel J. Eisenstein,[3] David J. Schlegel,[4]
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

(bowdlerized)



The local number density contrast is the average within a cylinder of radius $1h^{-1}$ Mpc and half-length $8h^{-1}$ Mpc in redshift space.

The SDSS magnitudes and colors are measured at ~ 80% of the nominal Petrosian magnitude, that is, well outside the half-light radius.

The late merging puzzle. In ΛCDM simulations the most massive galaxies exchange considerable amounts of matter with their surroundings to distances of several megaparsecs.

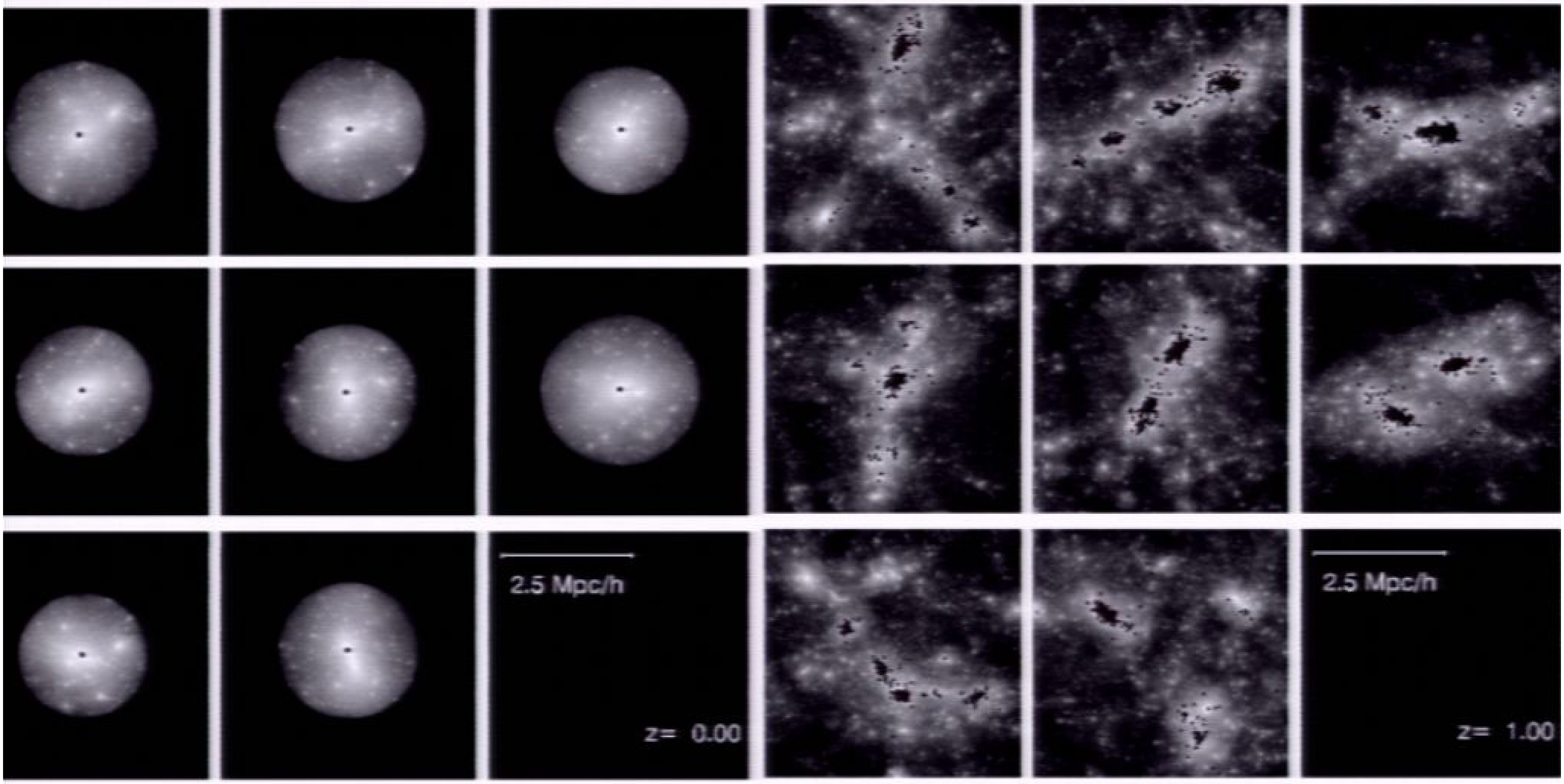
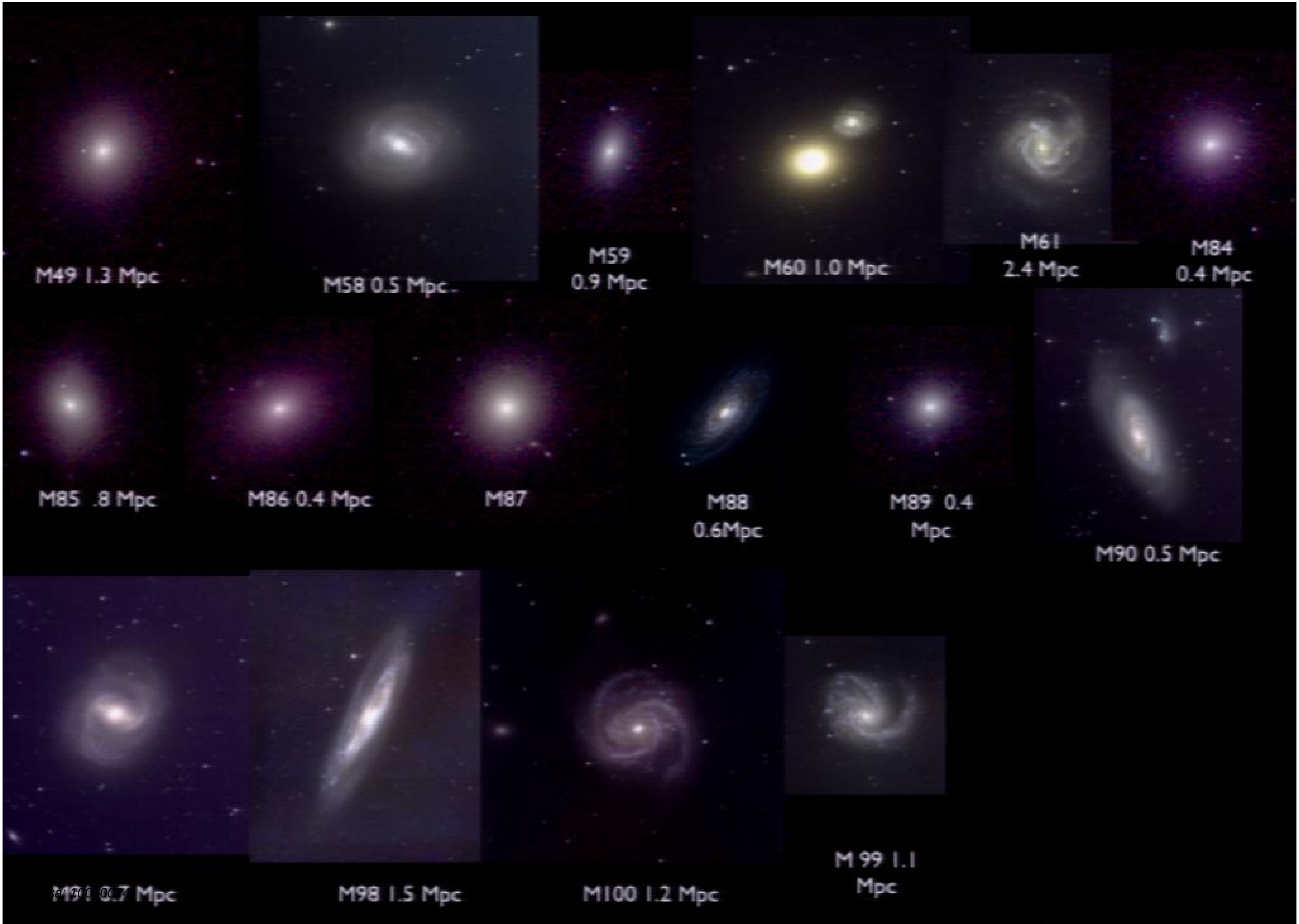


Fig. 2.— Images of the mass distribution at $z = 0, 1$ and 3 in our 8 simulations of the assembly of cluster mass halos. Each plot shows only those particles which lie within r_{200} of halo center at $z = 0$. Particles which lie within $10h^{-1}$ kpc of halo center at this time are shown in black. Each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

Early Formation and Late Merging of the Giant Galaxies



This shows Nigel Sharp's list of Messier galaxies in the Virgo cluster with projected distances from M 87. The

What are observers saying?

- Nair, van den Bergh, & Abraham: "It is not clear why objects that might have been assembled in such very different ways, from different ancestral objects, should have had evolutionary tracks that converged to show small dispersions around simple power law forms for their size-luminosity relations."
- Disney, Romano, Garcia-Appadoo, West, Dalcanton, & Cortese: "Such a degree of organization appears to be at odds with hierarchical galaxy formation, a central tenet of the cold dark matter model in cosmology."

What does this island universe phenomenon suggest?

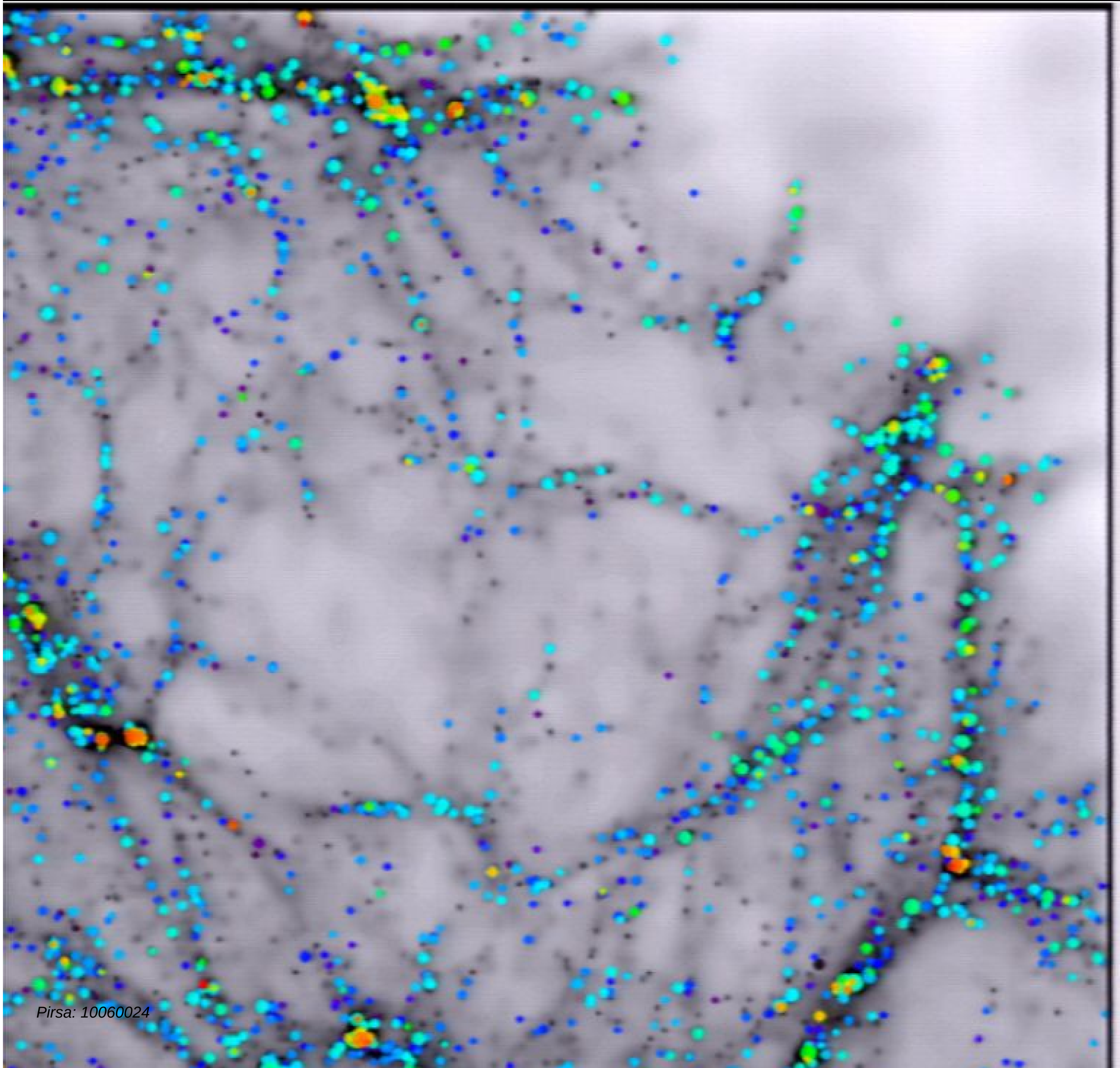
- Galaxy assembly that is closer to complete than predicted in ΛCDM at $z \simeq 2$ would help suppress commingling of the parts that end up in different galaxies.

Three enigmatic aspects of galaxies at low redshift

1. Pure disk galaxies

2. Galaxies as island universes

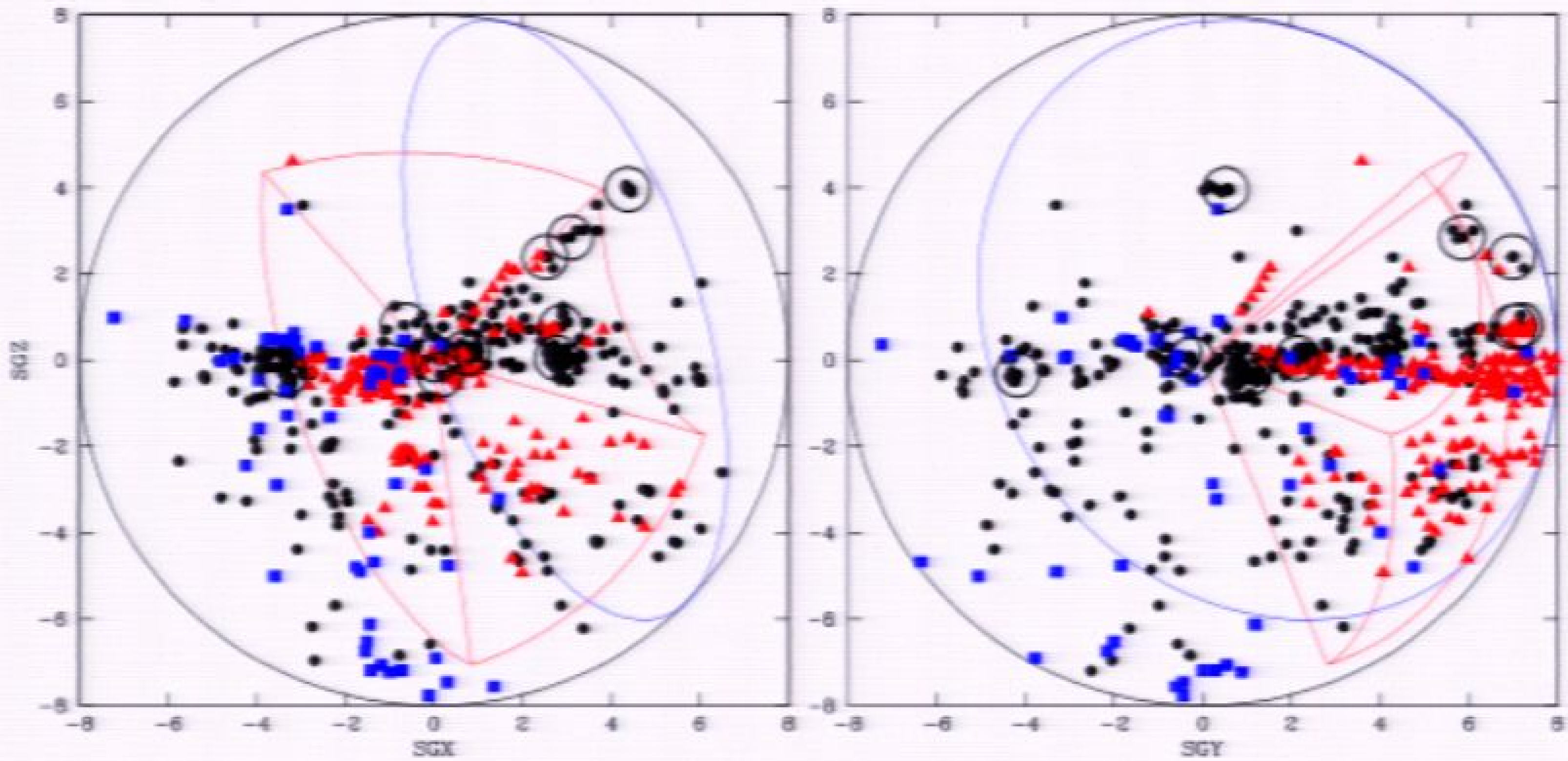
3. The nearly empty Local Void



Mathis and White 2002

The most massive CDM halos, which would be good homes for the largest galaxies, prefer the densest regions. This is a Good Thing.

Low mass CDM halos trail into voids defined by more massive halos. This is a Curious Thing.



SGZ
SGX
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The curious scarcity of galaxies in the Local Void

This is one of the 2 or 3 known LV galaxies, courtesy of Kathryn Stanonik, to be published

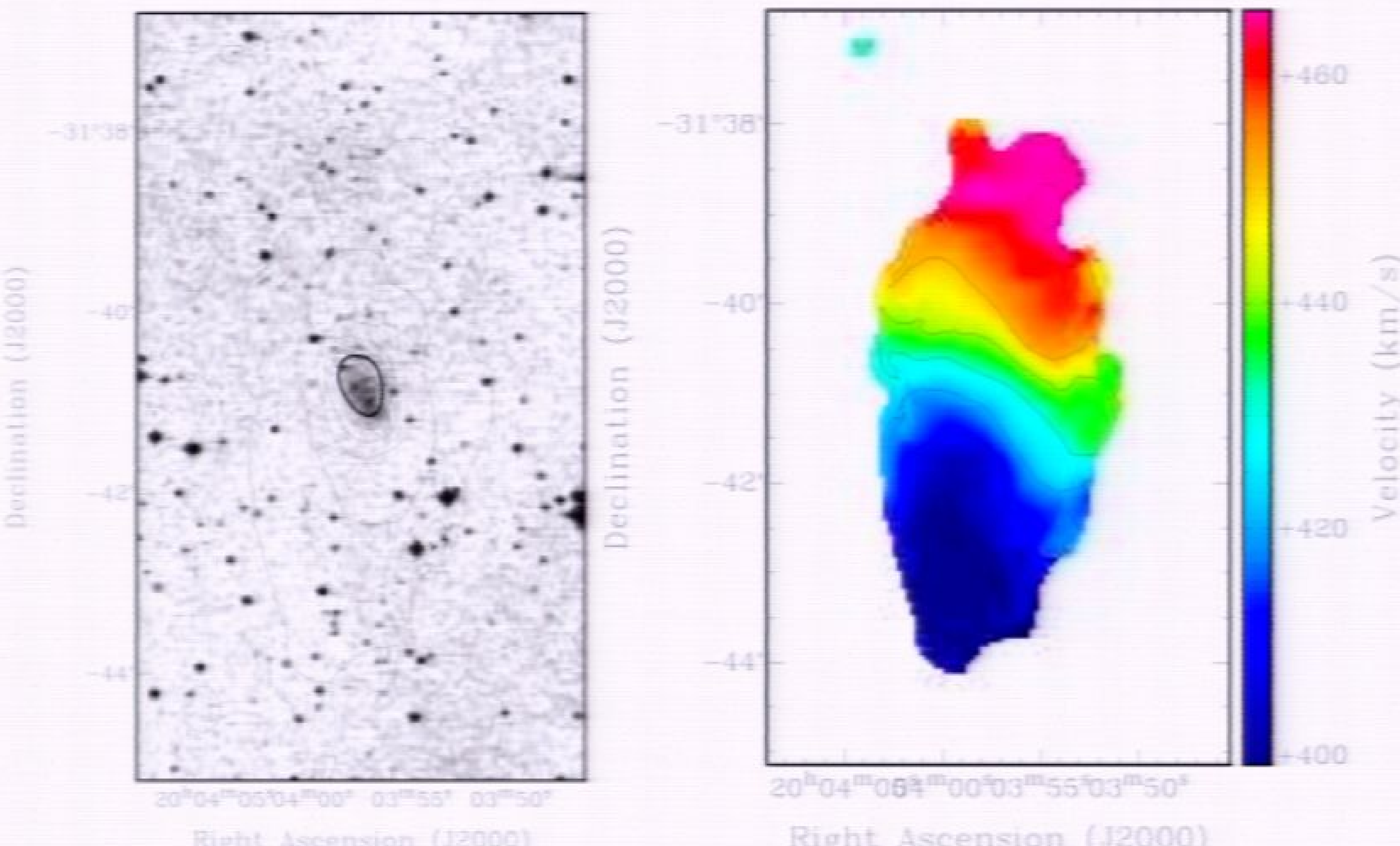
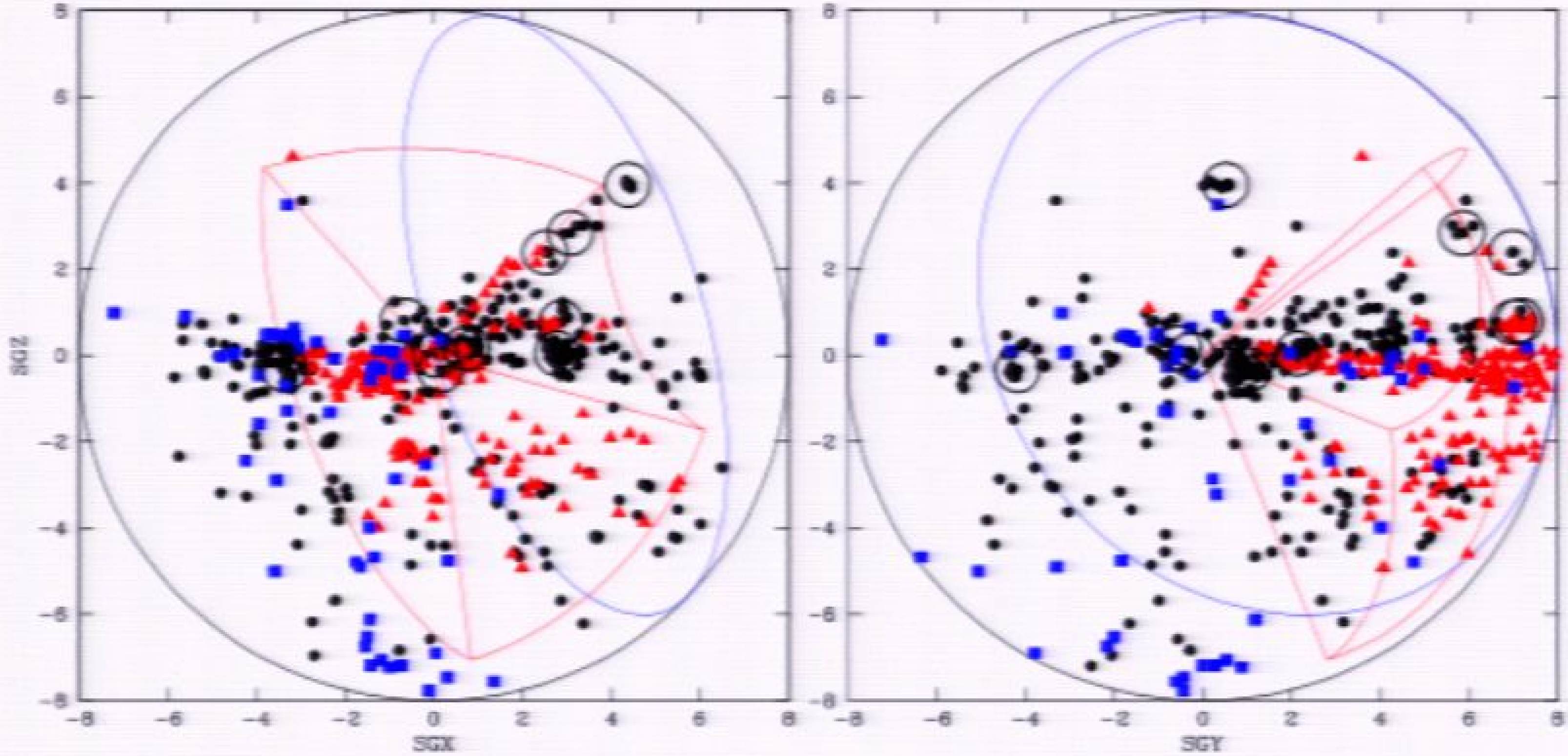


Fig. 1.— On the left: KK246, B-band DSS image, overlaid with HI contours. The column density contours are 1.9×10^{19} cm^{-2}+$1.9\times10^{20}cm^{-2}$, darker contour about where it reaches $1.0\times10^{21}cm^{-1}$. On the right, the velocity field, with increments of 10 km/s marked.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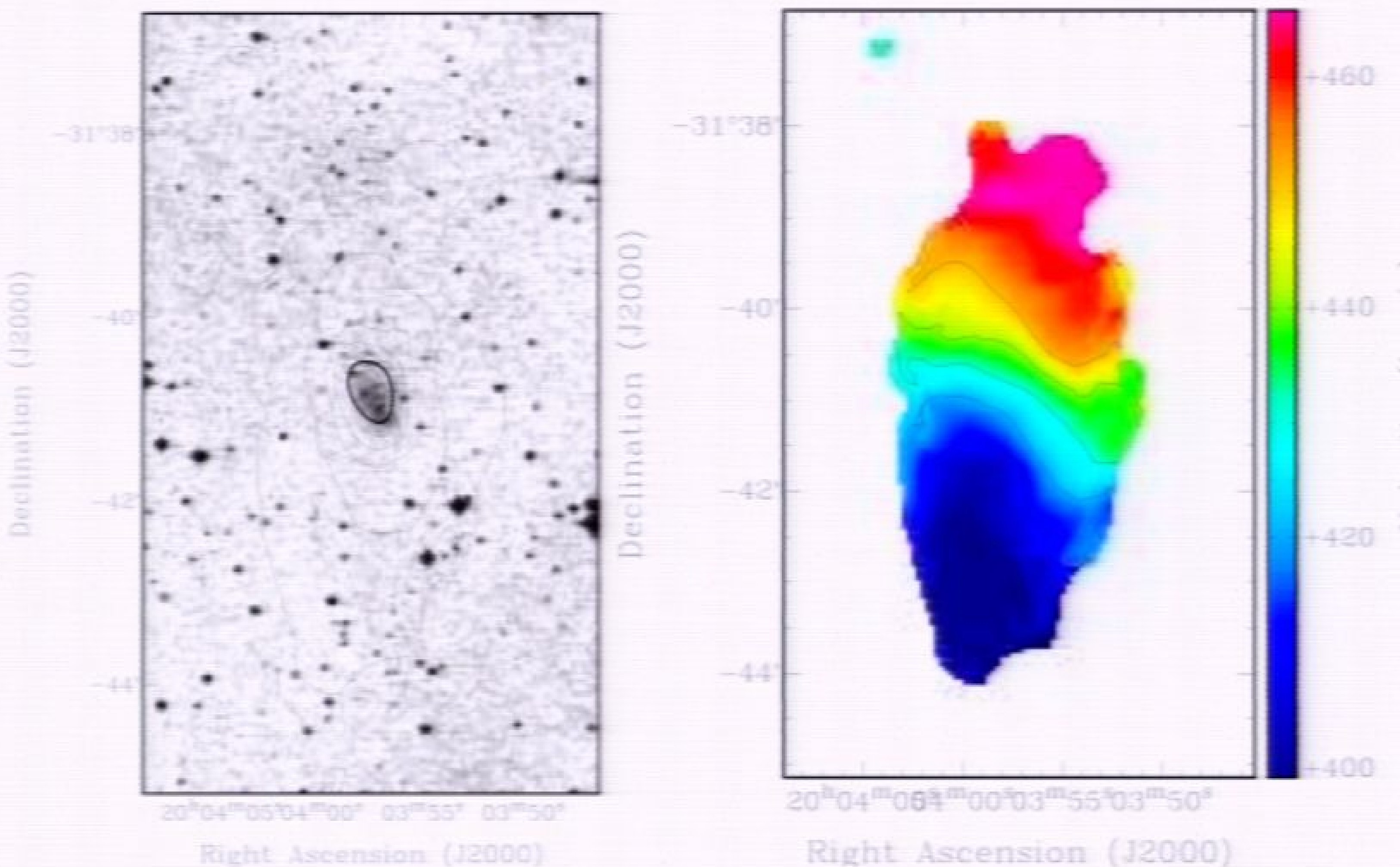

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There are two dwarf galaxy issues

1. ΛCDM predicts many more low mass DM halos than the observed numbers of dwarf galaxies.

   This does not seem problematic; low mass halos may lose their baryons.

2. ΛCDM seems to predict many more dwarf galaxies in the Local Void than are observed.

   There are 562 known galaxies at distance $1 < D < 8$ Mpc.

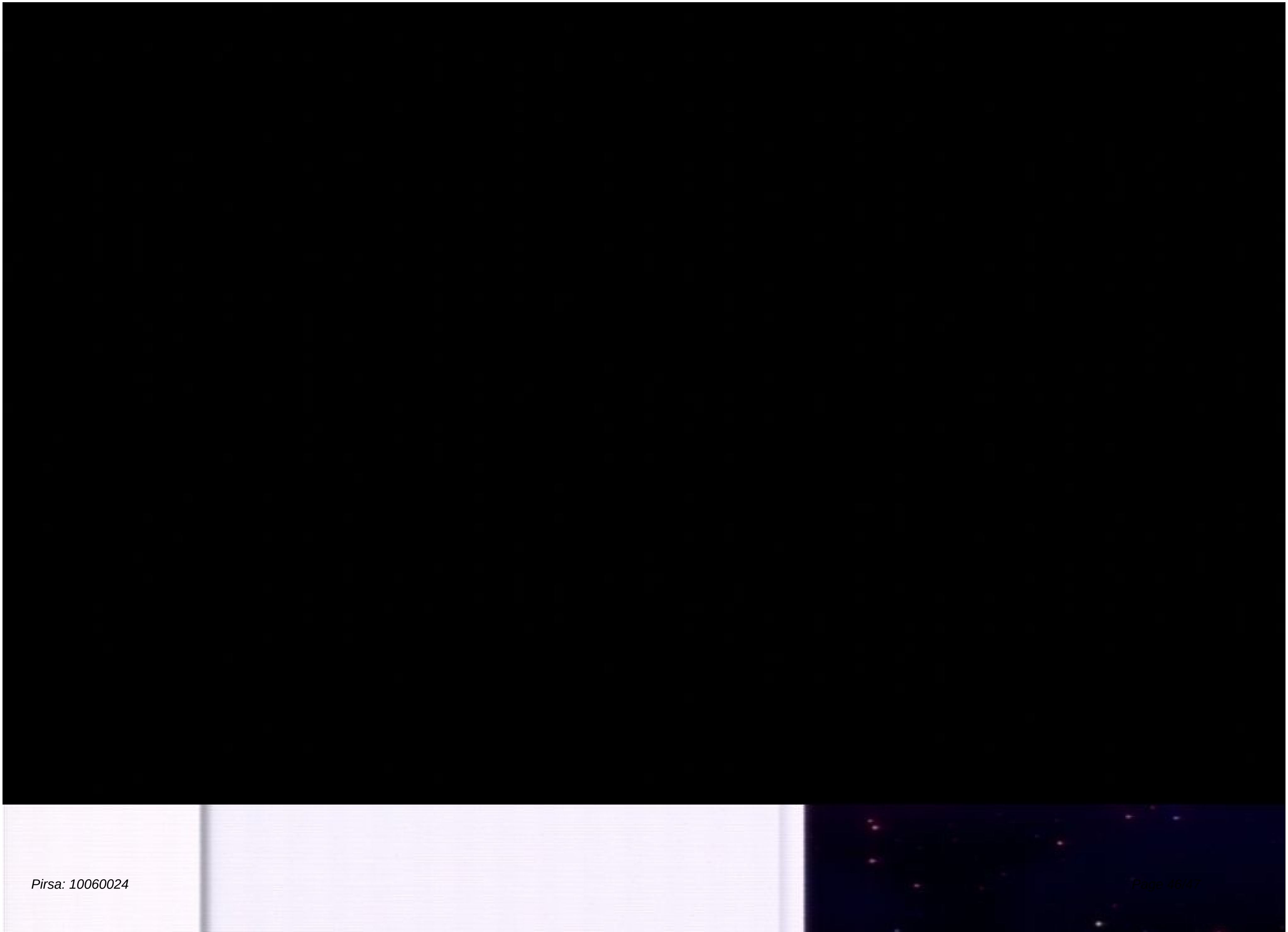
   Scaling from halo counts in low density regions in ΛCDM simulations indicates that about 19 of 562 are expected to be in the LV.

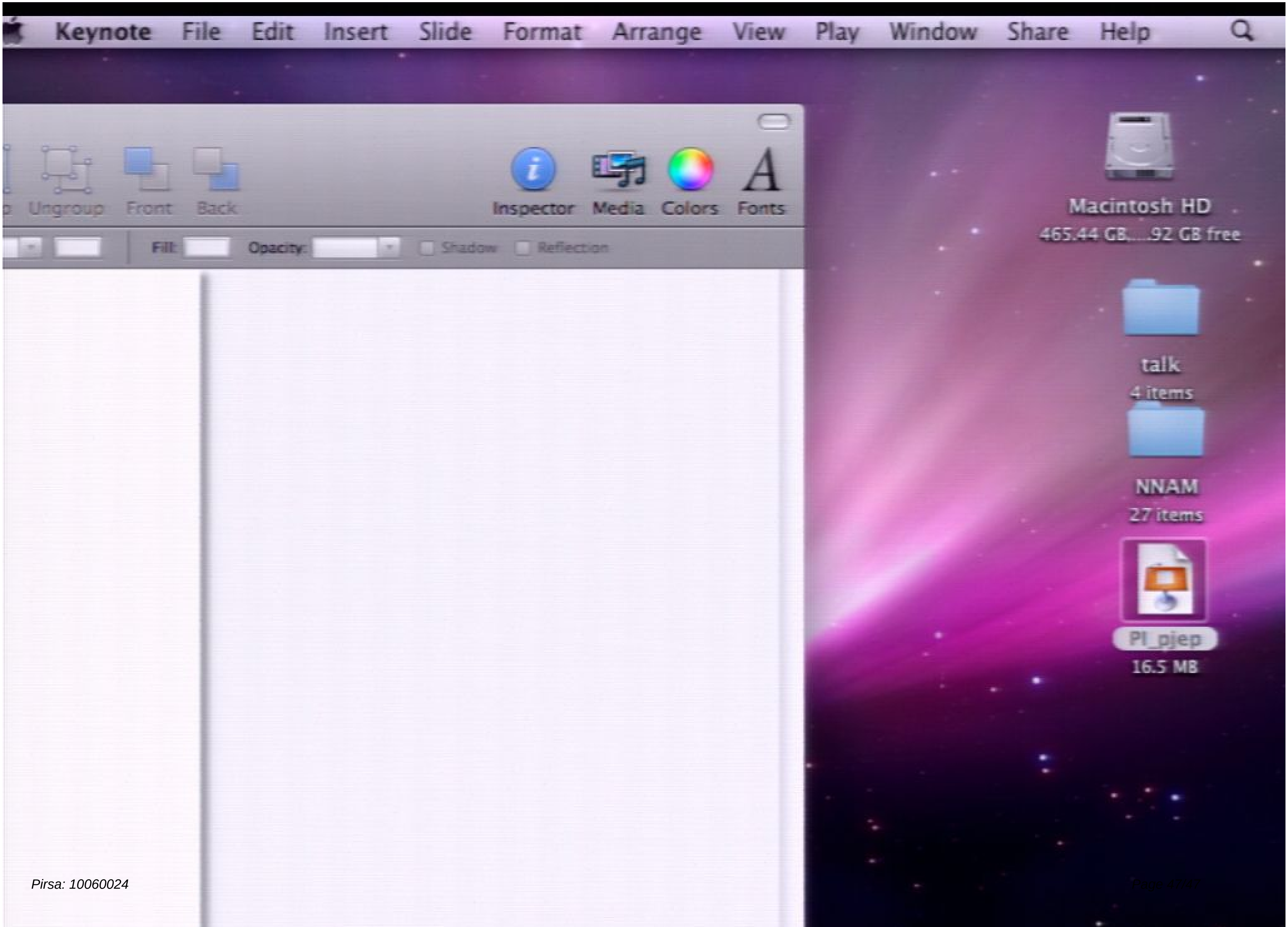
   But HI disks like the one in KK 246 survive/are observable only in low density regions. The greater survival probability in low dense regions would lead one to expect to find more than 19 galaxies in the Local Void.

   Just 2 or 3 are known. This seems problematic.

What have we learned?

1. Galaxy formation is not well understood, in theory or practice.
2. We are learning a lot about the phenomenology from observations of distant galaxies — seen as they were when they were young — and, equally important, from observations of nearby galaxies that can be examined in much greater detail.
3. A central issue: do the enigmatic properties of galaxies signify
   a. inadequate understanding of complex processes in standard physics, or
   b. the need for better physics.
4. A common feature of the three enigmas I have discussed is that on the scale of galaxies matter seems to be assembled too late in ΛCDM.

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