Title: The Theory, Practice, and Sociology of Physical Cosmology

Speakers: James Peebles

Series: Colloquium

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Abstract: Sociologists have interesting things to say about the practice of natural science. I will discuss the sociological phenomenon of multiples in scientific discoveries, with examples drawn from how the ?CDM cosmology grew, and examples of possible multiple discoveries to come from issues arising in our present well-tested but certainly incomplete cosmology.

The Theory, Practice, and Sociology of Physical Cosmology

PJE Peebles
Perimeter Institute
12 January 2022

William F. Ogburn and Dorothy Thomas
Political Science Quarterly, Vol. 37, No. 1 (Mar., 1922), pp. 83-98

ARE INVENTIONS INEVITABLE? A NOTE ON SOCIAL EVOLUTION

IT is an interesting phenomenon that many inventions have been made two or more times by different inventors, each working without knowledge of the other's research. There are a number of cases of such duplicate inventions or discoveries that are of common knowledge. It is well known, for instance, that both Newton and Leibnitz invented calculus. The theory of natural selection was developed practically identically by Wallace and by Darwin. It is claimed that both

79. Law of expansion of gases. By Charles (1783) and Gay-Lussac (1802).
80. Continuity of gaseous and liquid states of matter. By Ramsay (1880) and Jamin (1883).
81. Kinetic theory of gases. By Clausius (1850) and Rankine (1850).
82. Law of conservation of energy. By Mayer (1843), Joule (1847), Helmholz (1847), Colding (1847) and Thomson (1847).
83. Mechanical equivalent of heat. By Mayer (1842), Carnot (1830), Seguin (1839) and Joule (1840).

Clues to the hot big bang cosmology were there, in our collective face, well before they were recognized.

So are there other such clues not yet recognized? Maybe it's wishful thinking, but I see possibilities.

For example, most large galaxies are readily classified as elliptical or spiral.[a] That is, galaxy formation is a bistable process. What is the separatrix? It's a century-old question, but worth revisiting from time to time.

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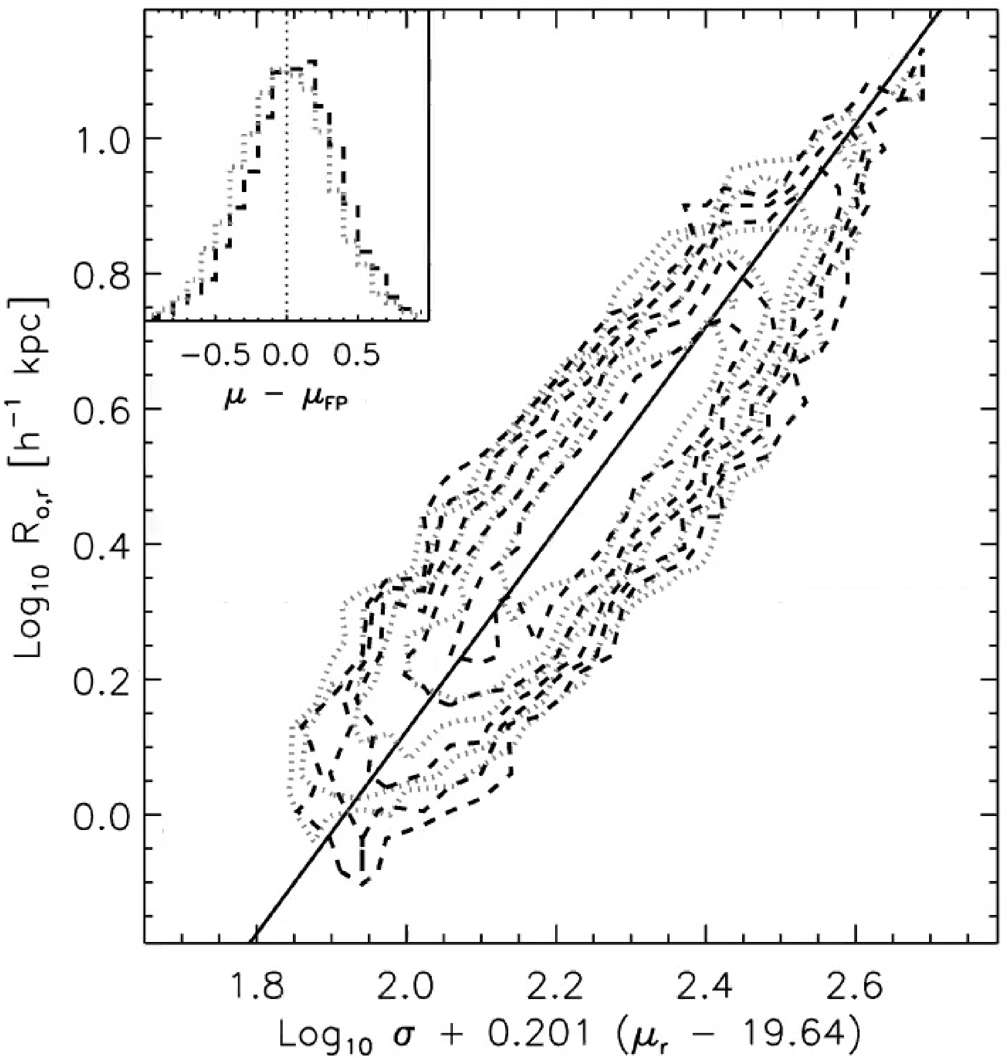
[a]So there are S0 or lenticulars that look like spirals that have lost all their gas, and some that look like remnants of mergers. They're not common, at least nearby.



Bernardi et al. 2006
An example of the evidence that ellipticals are well-approximated as a one-parameter family.

What is the separatrix for early- and late-type galaxies?

i. Not mass. There are large and small spirals and large and small ellipticals.

ii. Not angular momentum, if as seems likely angular momentum is transferred by gravity, which does not look likely to be bimodal.

iii. Not ambient density. The ratio of early to late types is larger than average in regions of greater than average density, but ellipticals are well approximated as a one-parameter sequence, independent of environment.

iv. I argue the separatrix is not captured by numerical simulations of spirals, which are better characterized as flattened rotating ellipticals, or S0s, as follows.

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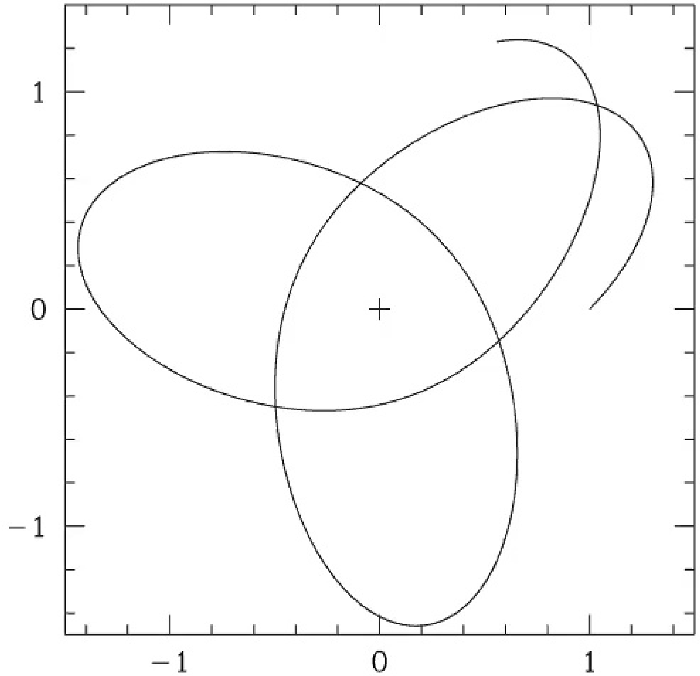
'he Circularity Parameter

Model galaxy discs and bulges often are characterized by the distributions of the circularity parameter ϵ of a star particle orbit,

$$\epsilon = J_z / J_c . \quad (1)$$

The component of the angular momentum of the star particle normal to the disc is J_z, and J_c is the angular momentum of a particle in a circular orbit in the plane of the disc with the same energy as the star particle.



Characterizing the shapes of the orbits of star particles moving in the disk of a model spiral.

This is the orbit of a star particle moving in the plane of the disk with ε = 0.8.

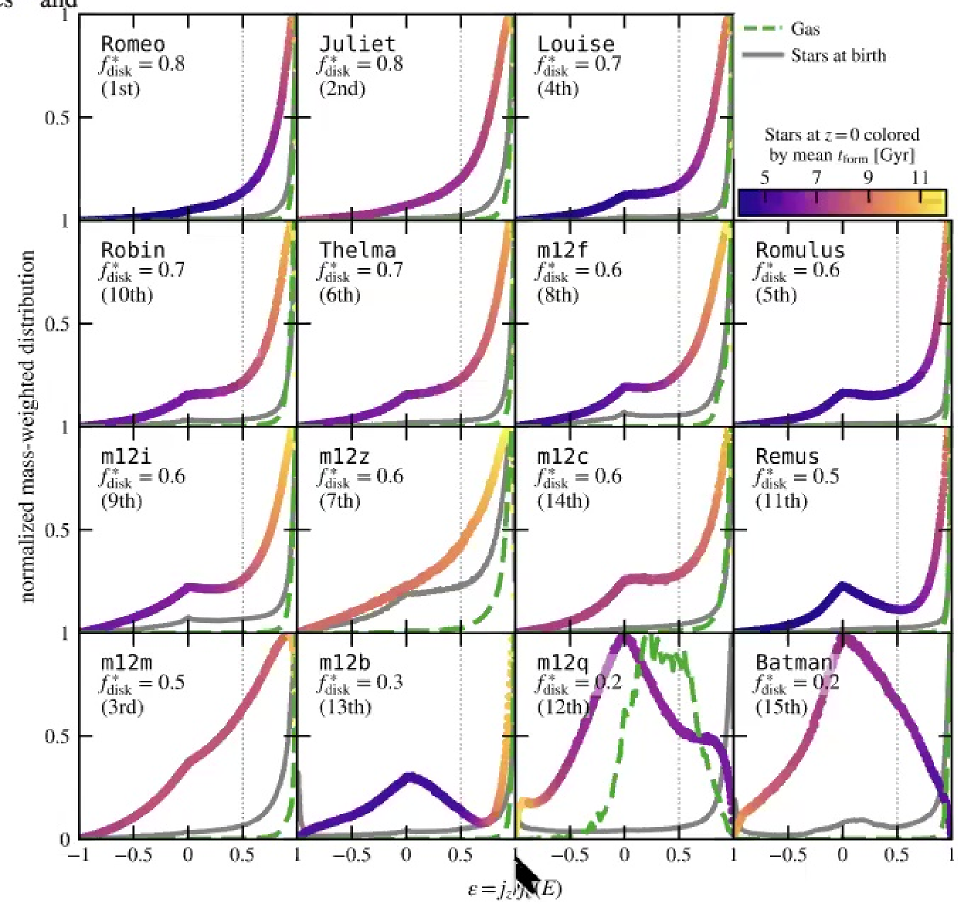
At ε = 0.8 the radial velocity dispersion is
σ_r = 0.45 v_c ~ 100 km/s

at ε = 0.9,
σ_r = 0.32 v_c ~ 70 km/s

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY
MNRAS 481, 4133–4157 (2018) doi:10.1093/mnras/sty2513
Advance Access publication 2018 September 14

The origin of the diverse morphologies and kinematics of Milky Way-mass galaxies in the FIRE-2 simulations

Shea Garrison-Kimmel,[1★†] Philip F. Hopkins,[1] Andrew Wetzel,[1,2,3‡] Kareem El-Badry,[4] Robyn E. Sanderson,[1,5] James S. Bullock,[6] Xiangcheng Ma,[1] Freeke van de Voort,[7,8] Zachary Hafen,[9] Claude-André Faucher-Giguère,[9] Christopher C. Hayward,[10] Eliot Quataert,[4] Dušan Kereš[11] and Michael Boylan-Kolchin[12]



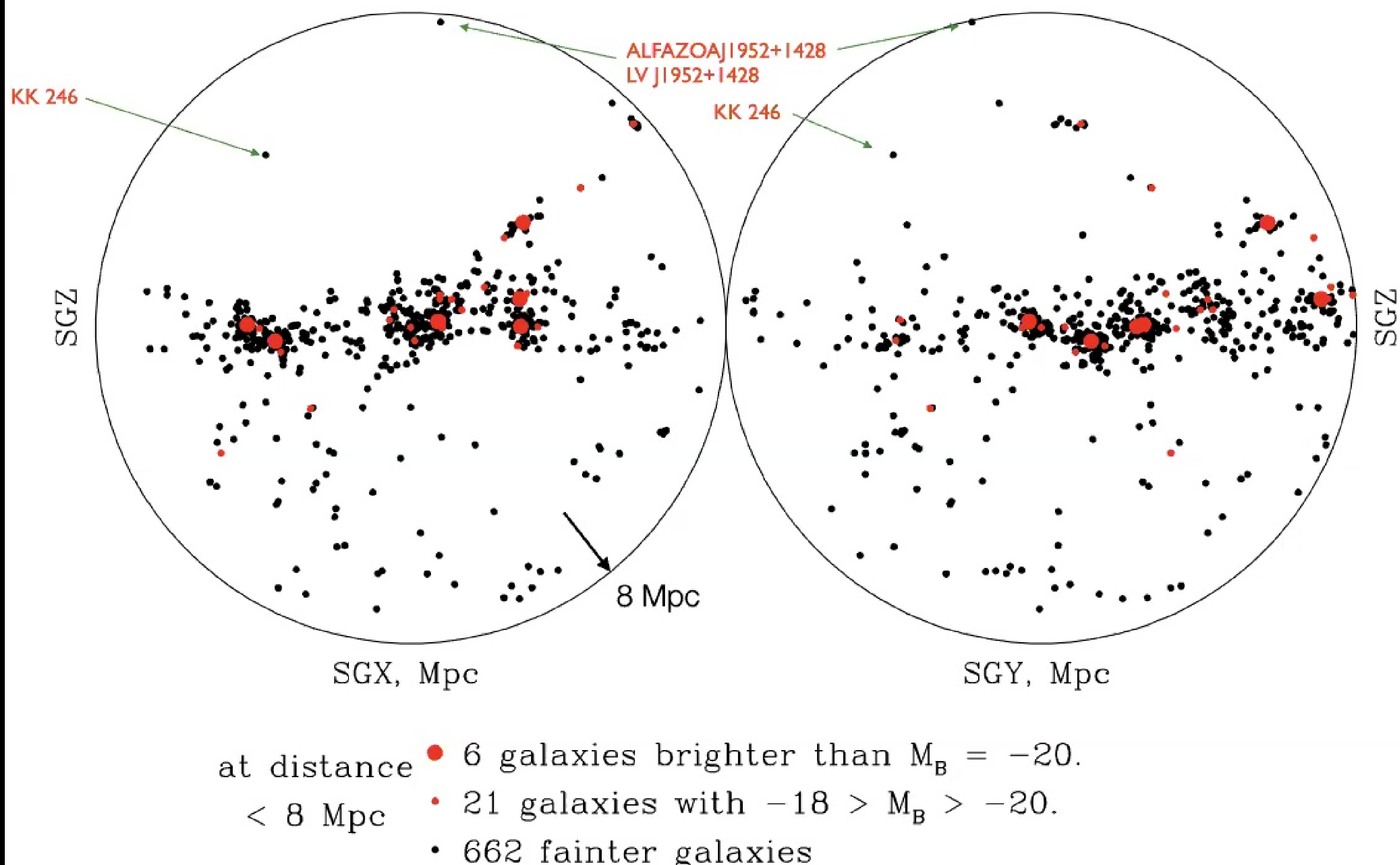
So we're faced with a simple phenomenon and an interesting puzzle:

What is the separatrix that accounts for the bimodal nature of large galaxies? What is the key idea?

People have debated this for a long time.

A decade from now, will people wonder why the community missed the key point for so long?

Another potentially informative issue: why is the local void so empty?



Based on the Karachentsev et al. compilation of local volume galaxy redshifts and distances, an ongoing project.

Is the Local Void really so empty?

It’s not easy to check for small clumps of stars in the Local Void.

It is possible to detect clouds of atomic hydrogen of modest mass by their 21-cm emission. The HIPASS scan of the sky at ~ 8 minutes integration time per beam clearly detected the HI cloud around KK246, but revealed no other cloud in this region of the Local Void it surveyed.

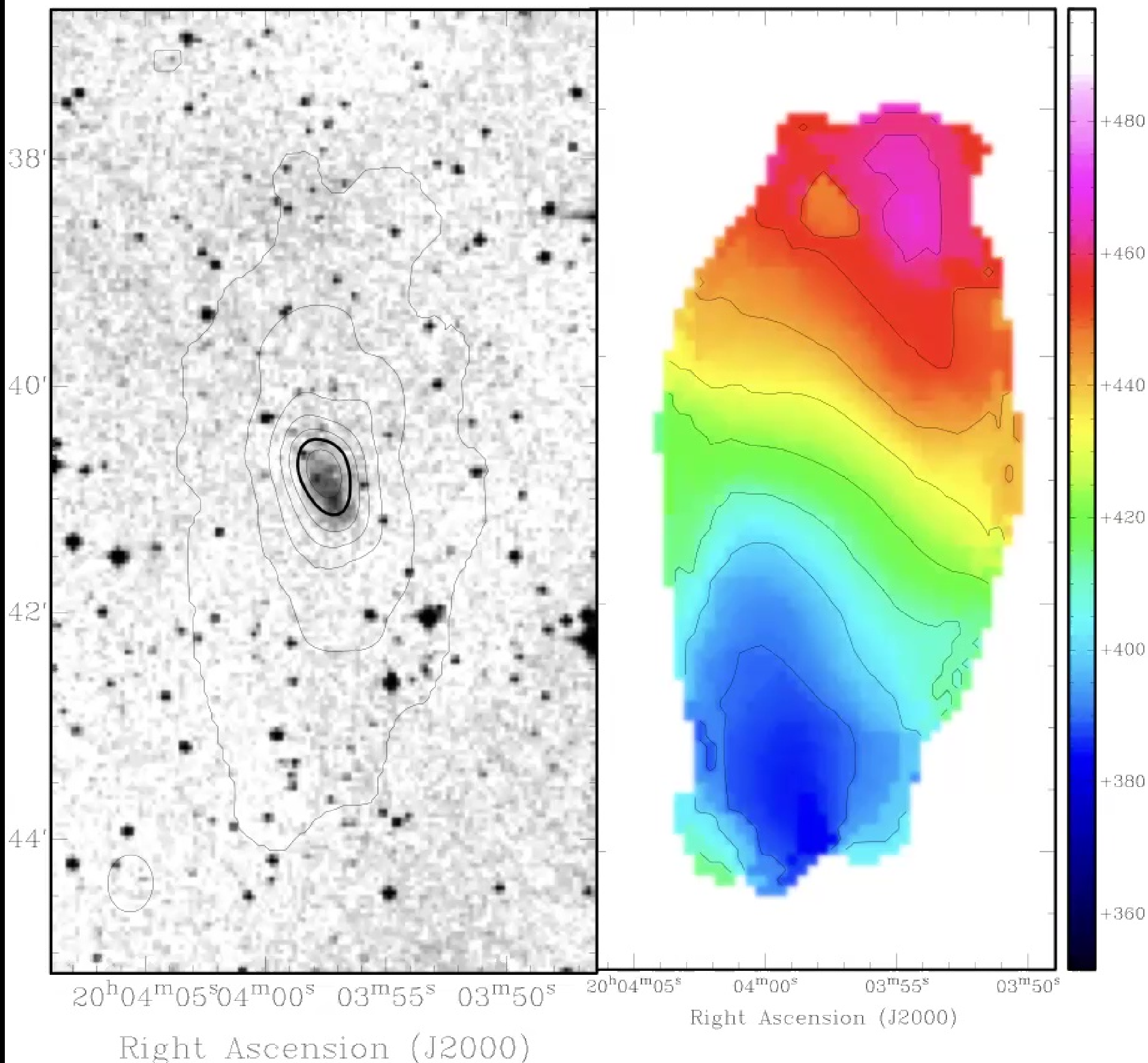
Arecibo identified another Local Void dwarf, but then the telescope collapsed.

Meerkat will do better. A devoted search of the sky in the redshift range around KK246 would do even better.

If you are fascinated by exploration of new territory here is a great opportunity: explore the conditions in the Local Void.

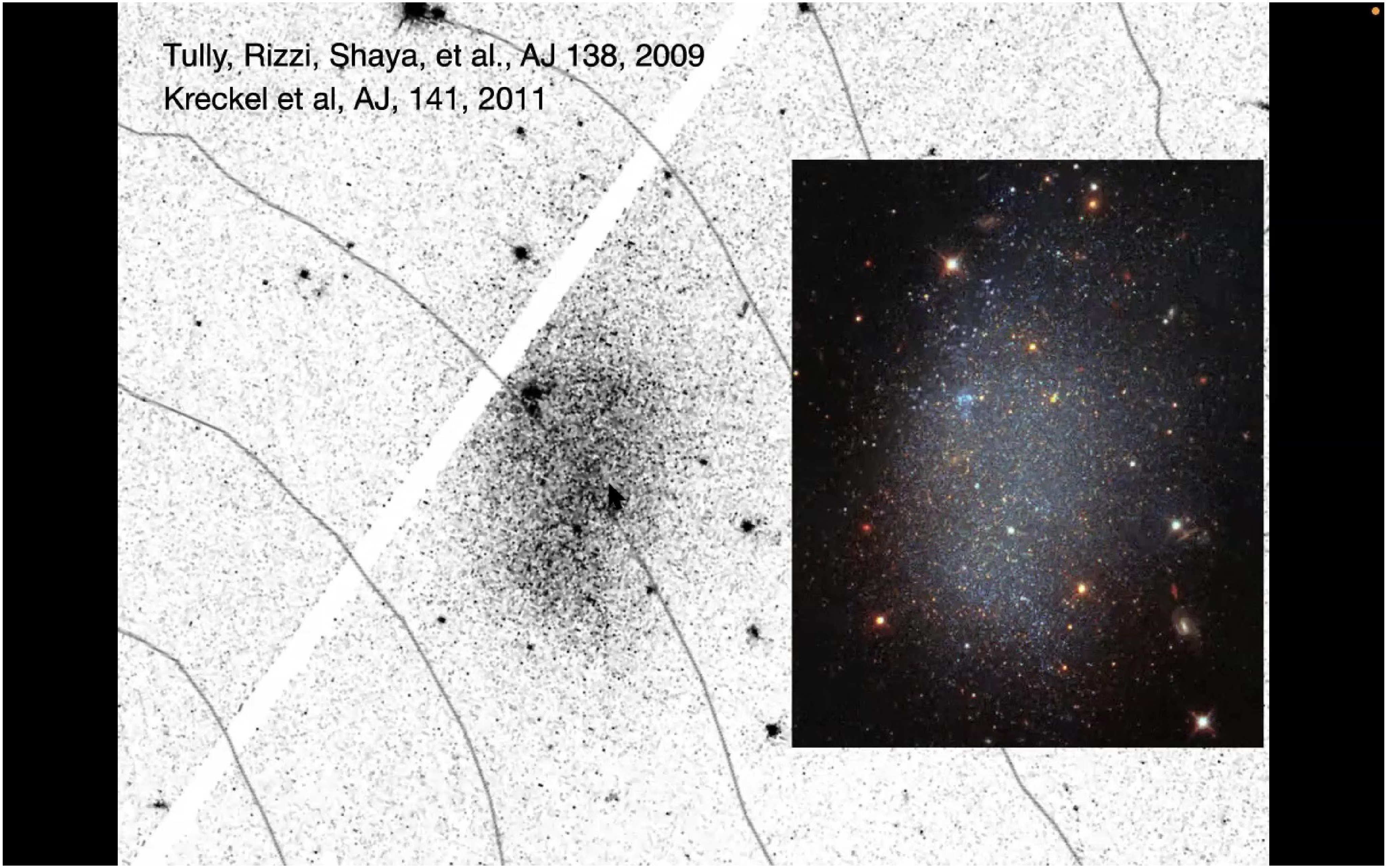
What are conditions in the Local Void?

We have hints from the two known most isolated Local Void galaxies that are closer than about 10 Mpc. Nearest known neighbors of both are 5 Mpc away (apart from a possible gas cloud and maybe starts near ALFAZOAJ1952+1428).



The cloud of atomic hydrogen around KK 246 is much larger than the dwarf galaxy of stars.

Kreckel et al. 2011


Tully, Rizzi, Shaya, et al., AJ 138, 2009
Kreckel et al, AJ, 141, 2011

What has KK 246 experienced in its apparently lonely position in the Local Void?

- The tilt of the rotation axis of the HI envelope from the short axis of the distribution of stars looks odd.
- The star distribution looks slightly disturbed to me.

What might this mean?

- Maybe KK 246 is two dwarf galaxies seen close in projection? If so the redshift distribution of the HI may have two peaks. I'm asking the experts.
- Or maybe there are nearby massive DM halos without detectible stars or HI?
- or maybe I'm dreaming

Is the nearly empty Local Void consistent with ΛCDM? The general opinion is that it can be so, as follows.

In a simulation of cosmic structure formation in the ΛCDM theory, let

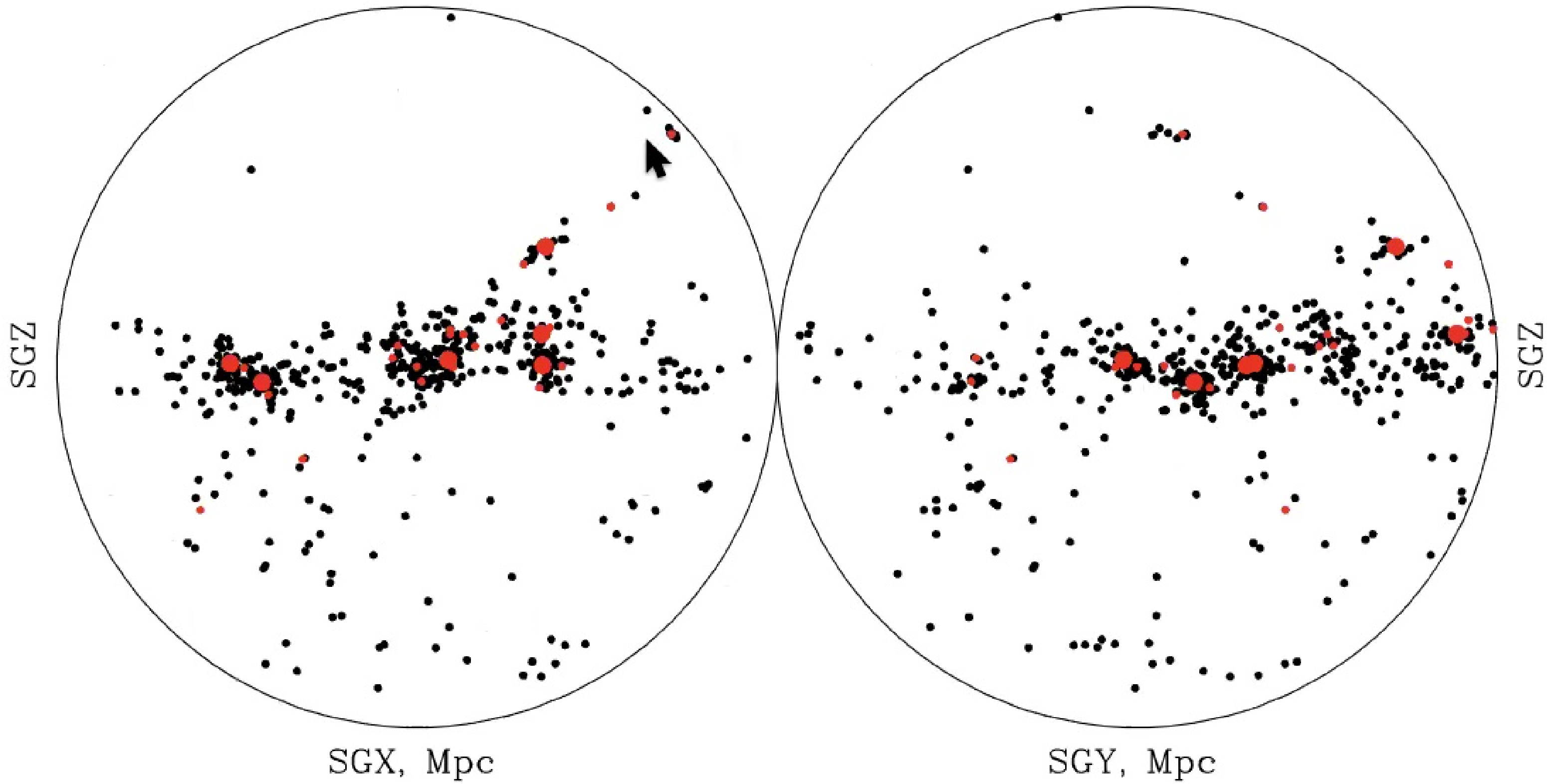
M_{halo} be the dark matter halo mass of a galaxy, and let

M_{stars} be the stellar mass to be assigned to this halo.

Choose the ratio M_{stars}/M_{halo} as a function of M_{halo} so that the the pdf of M_{halo} in the model agrees with the observed pdf of galaxy luminosities M_{stars}.

This abundance matching can account for the empty void, but by a prescription, not a prediction.

3. The curious nature of the Local Supercluster



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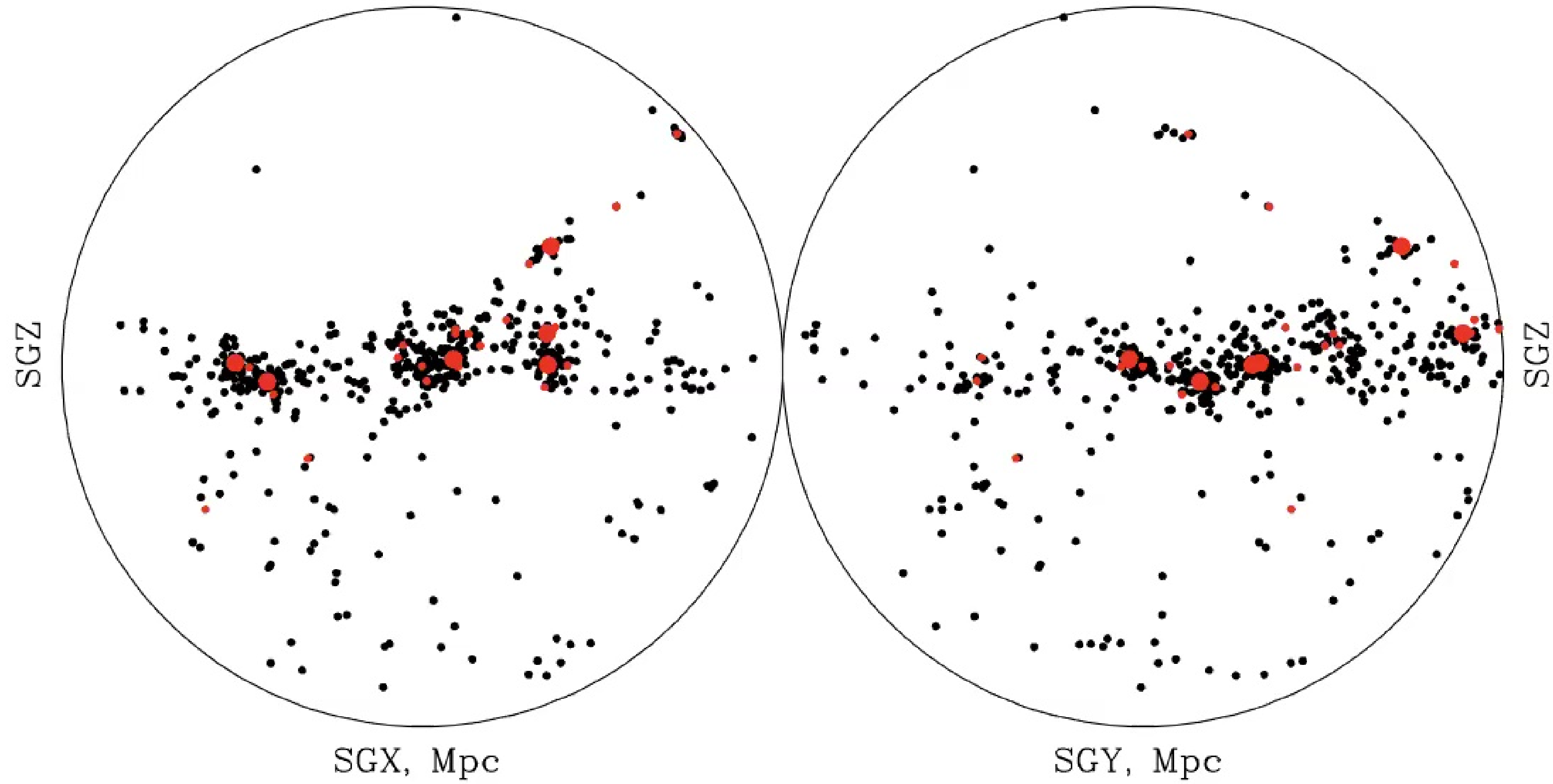
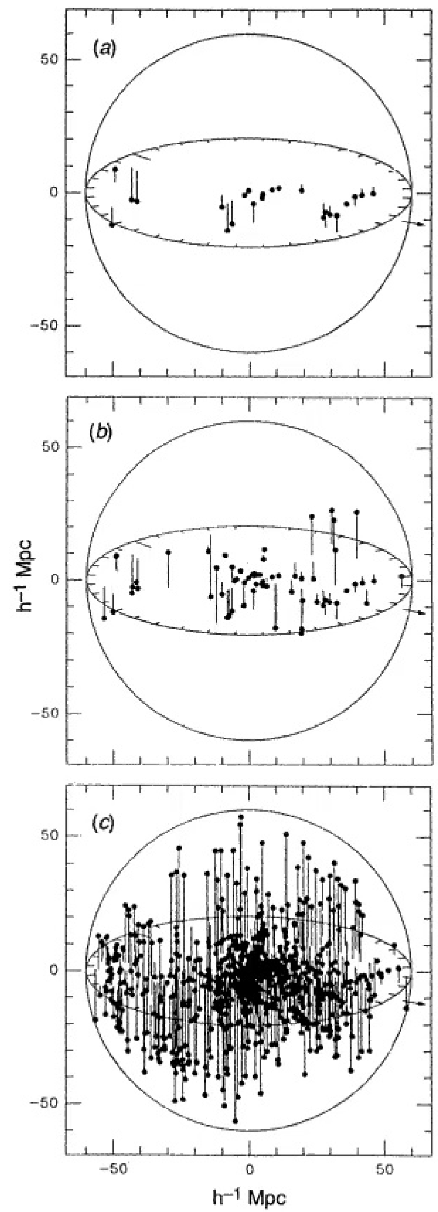


Peter Shaver,
Australian J. Physics
44, 759, 1991

A curious alignment of radio galaxies

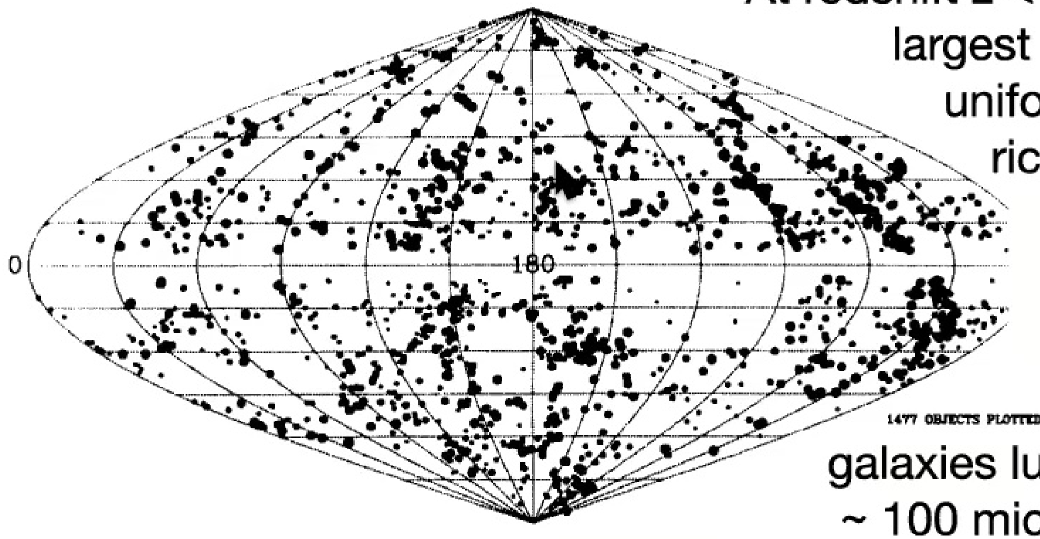


the most luminous radio galaxies

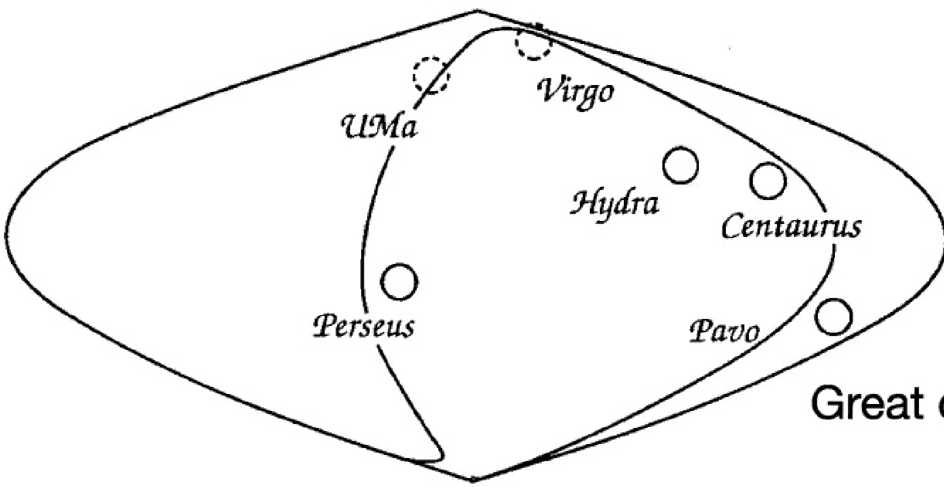
somewhat less luminous radio galaxies

ordinary large galaxies

At redshift z < 0.02 the galaxies with the largest stellar masses are pretty uniformly across the sky, while rich clusters are close to the plane of the Vaucouleurs Local Supercluster.



galaxies luminous at ~ 100 microns wavelength



Great clusters of galaxies

PJE Peebles 1993

We are in a region ~ 200 Mpc across in which two types of objects are differently distributed:

I. clusters of galaxies, powerful radio galaxies, and the most luminous elliptical galaxies are close to the plane of the Local Supercluster,

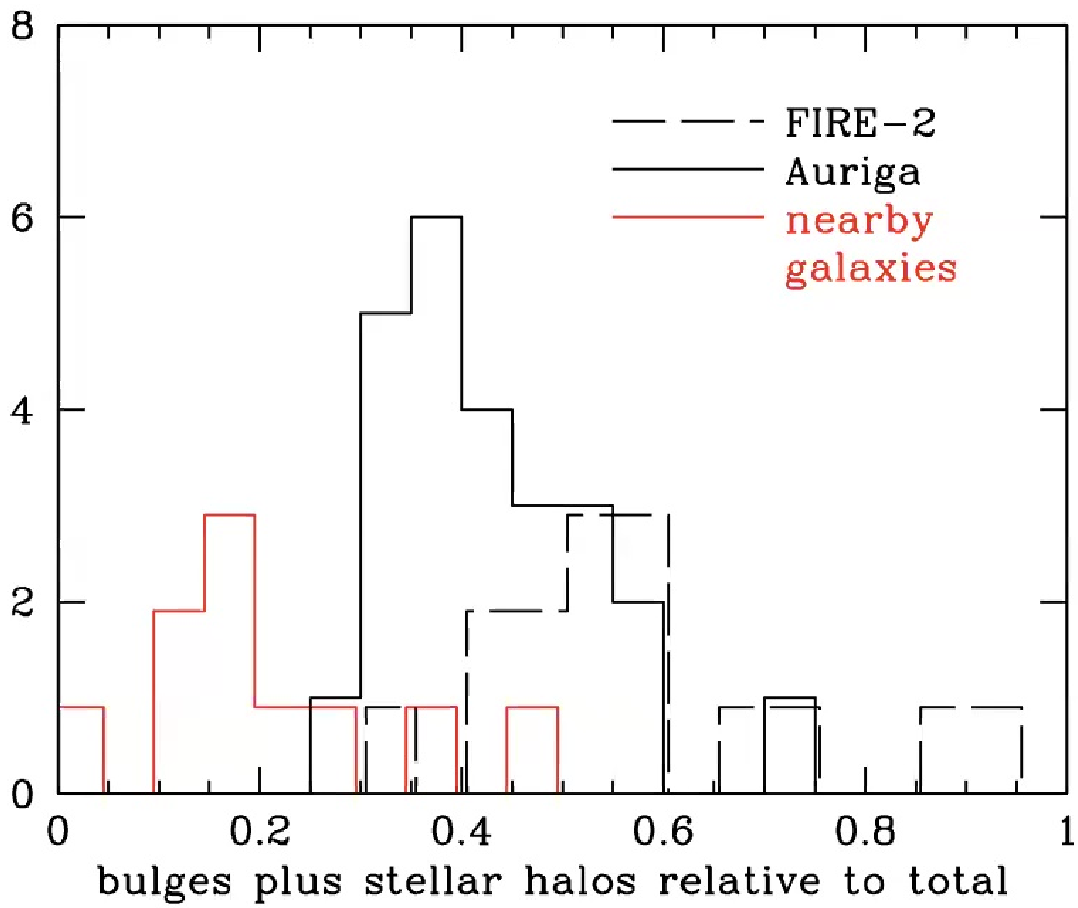
II. but the most luminous spiral galaxies, and the galaxies that are luminous at ~60 mμ wavelength, are not so closely aligned to this plane.

Black holes capable of powering radio sources, and present on clusters, seem common to type I.

So why is this type I common only near the plane of the Local Supercluster, while the type IIs are more broadly distributed?

NGC 253


M101, Kormendy, Drory, Bender & Cornell, ApJ **273** 2010
$M_{\rm BH} < 3 \times 10^6 m_\odot$
R. Gendler
HST images plus H-α and some ground-based data



From PJE Peebles MNRAS 498, Issue 3, pp.4386-4395

Lest I be misunderstood: I take the cosmological tests to make a compelling case that the ΛCDM theory is a good approximation to reality.

This theory is incomplete, but so are are all of our physical theories. Curiosity-driven research seeks to improve theories. We have ample room for research to improve ΛCDM.

The theory:

- What do we make of the quantum vacuum energy density and Einstein's cosmological constant?
- What was the universe doing before it was expanding?
- Why haven't decades of research revealed the dark matter?
- Are there primeval black holes, cosmic strings, or whatever?
- and on . . .

The evidence:

I side with Mr. Micawber: something new and interesting will turn up.

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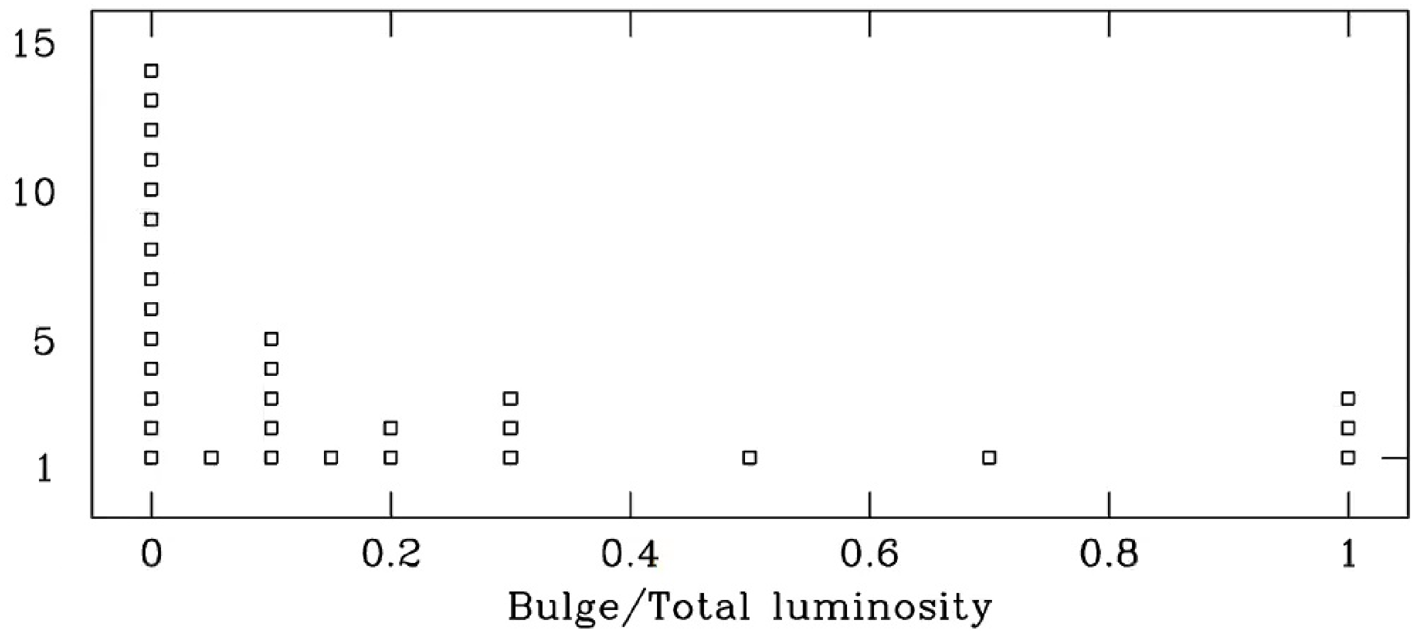

The distribution of bulge to total ratios of luminosities of the 38 galaxies within 10 Mpc and $L_K > 10^{10}$, from Kormendy et al 2010 and Fisher and Drory 2011.

Another Example of the Multiplicities of Scientific Advances

1973-74: Maybe dark matter is neutrinos with rest mass a few tens of eV, independently introduced by

Alex Szalay and George Marx, in Hungary
Ramanath Cowsik and J. McClelland, in the USA

1977: Maybe dark matter is a fourth neutrino with the standard interaction with baryons and mass ~ 3 GeV. This was introduced by five groups at close to the same time, apparently independently.

	date received	date published
Hut	25 April	18 July 1977
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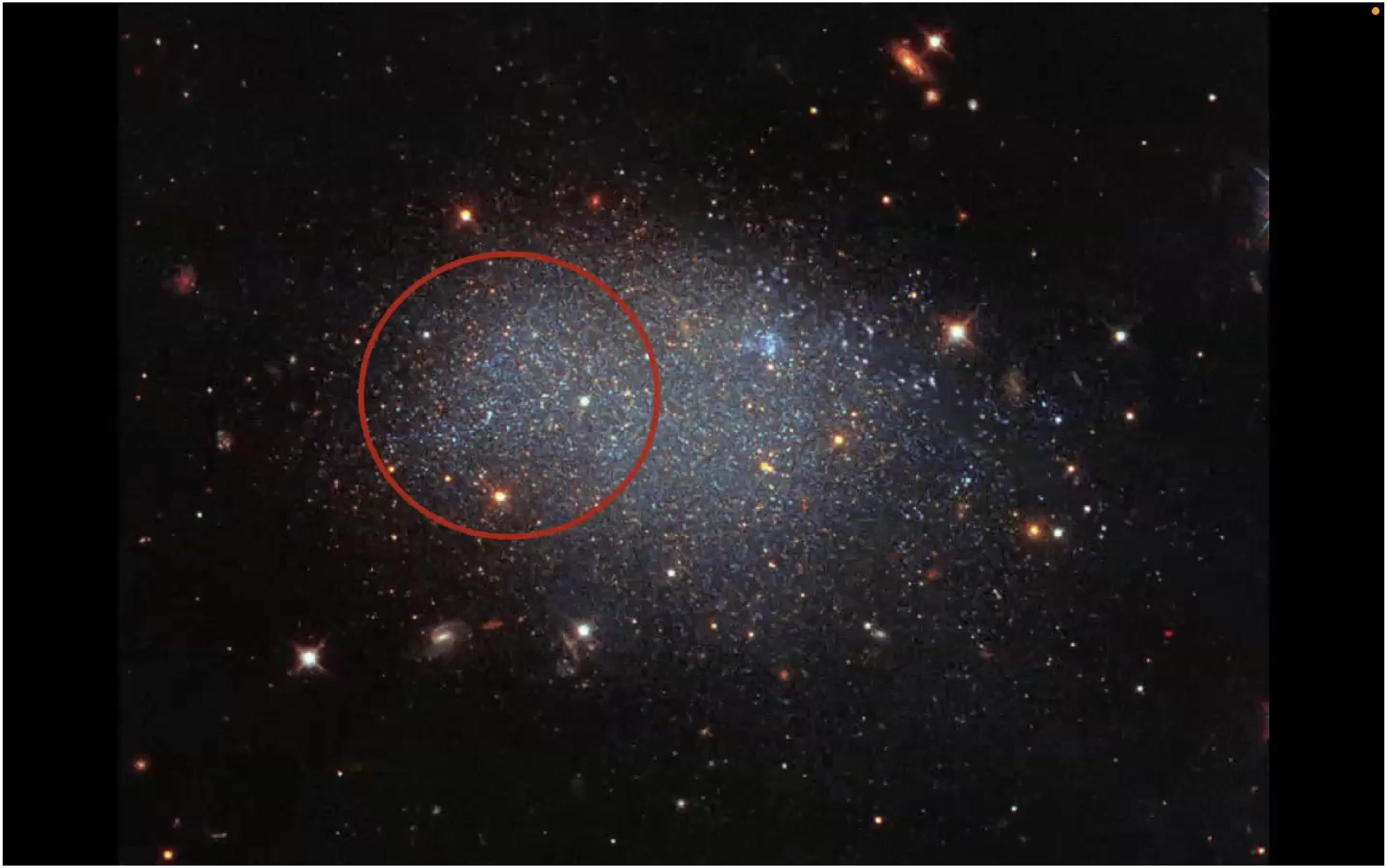

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