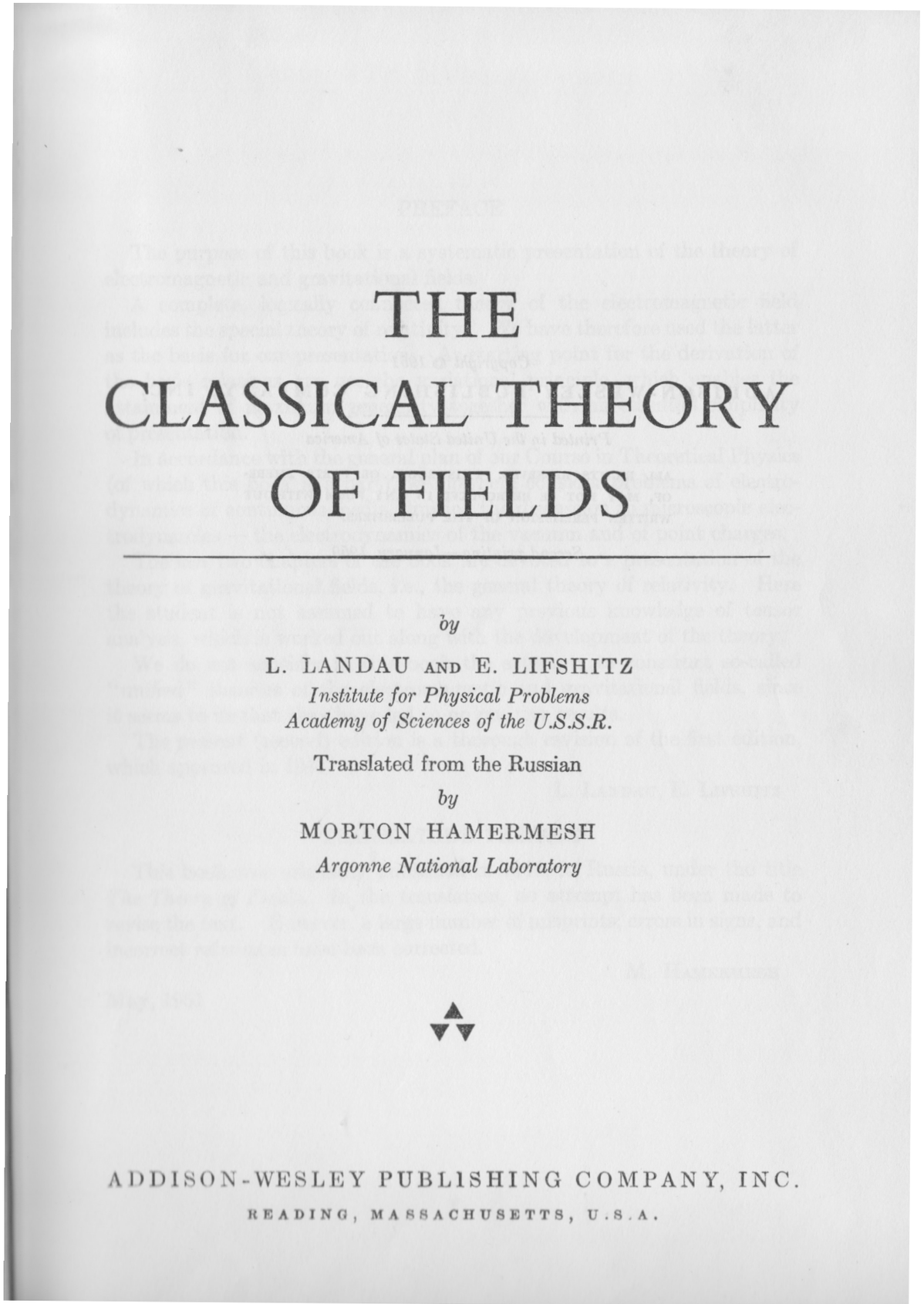
The Future of Empirically Established Cosmology

On the occasion of Joe Silk's 75th Birthday
IAP December 2017

PJE Peebles

(1) We all make non-empirical judgements, for better or worse.
(2) ΛCDM is empirically well established. It certainly is incomplete.
    (a) But all physics is incomplete. Consider Maxwell's equations $\rightarrow$ QED$\rightarrow$??
    (b) But surely there is a better cosmology for $z \lesssim 10^{10}$ than I guessed at in 1982 and 1984, with an empirically more interesting dark sector.
(3) Seeking detection of DM, evolution of Λ, and more interesting dark & gravity physics:
    (a) No compelling DM detection after decades of searches; no problem for ΛCDM.
    (b) Might completion of MOND or emergent gravity replace ΛCDM? A very long shot.
(4) Challenges to ΛCDM may point to a better theory, or only misreadings of the evidence. My choices of challenges that seem less likely to be misinterpretations:
    (a) Scaling laws & stellar halo luminosities challenge the expected growth by merging.
    (b) Stellar bulges of galaxy are much fainter than models. Can feedback, as by the enigmatic central massive black holes, resolve this long-standing problem?
    (c) Galaxies edging into the Local Void look similar to those in the Local Plane.
(5) Dreams of a final cosmology:
    (a) The empirical case for inflation is promising, but not persuasive.
    (b) Hazards of the Anthropic Principle: e.g. Λ, a superabundance of homes for us.
    (c) The nightmare: a final cosmology that is logically complete, fits all observations, but rotten at the core, which we'd never know if the core could not be probed.
(6) Dreams of empirical surprises to come:
    (a) Maybe it's successive incomplete approximations all the way down.
    (b) But final or incomplete, our universe is immense, surely full of empirical surprises.

Landau and Lifshitz,
the 1951 translation
of the 1948 Russian
Theory of Field



THE
CLASSICAL THEORY
OF FIELDS

by

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Academy of Sciences of the U.S.S.R.

Translated from the Russian

by

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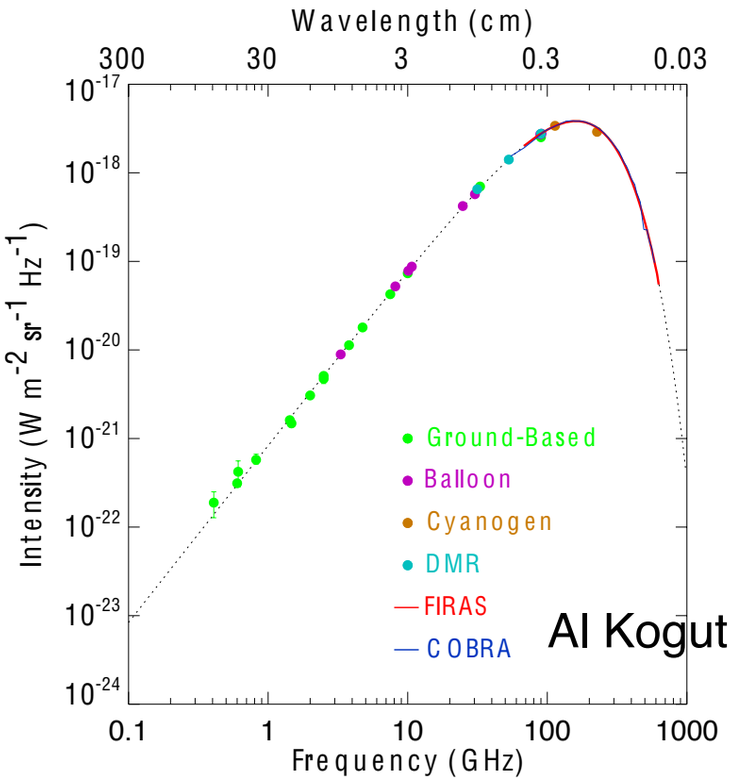
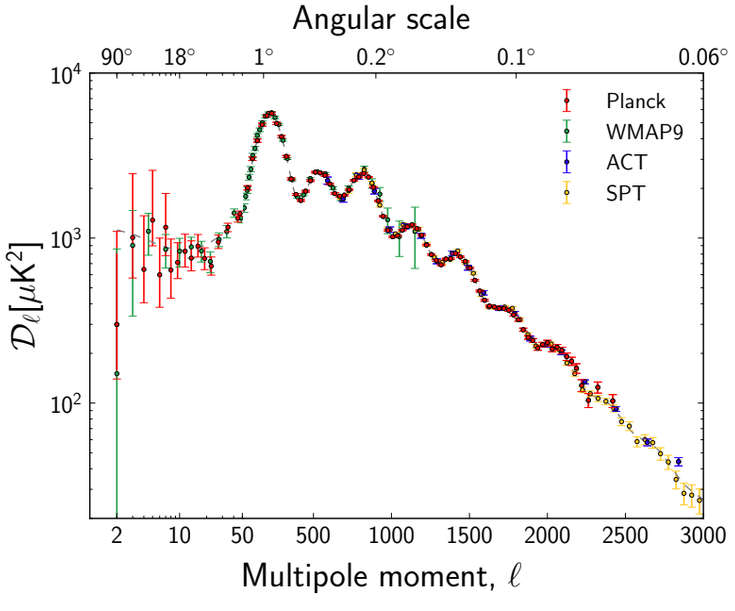
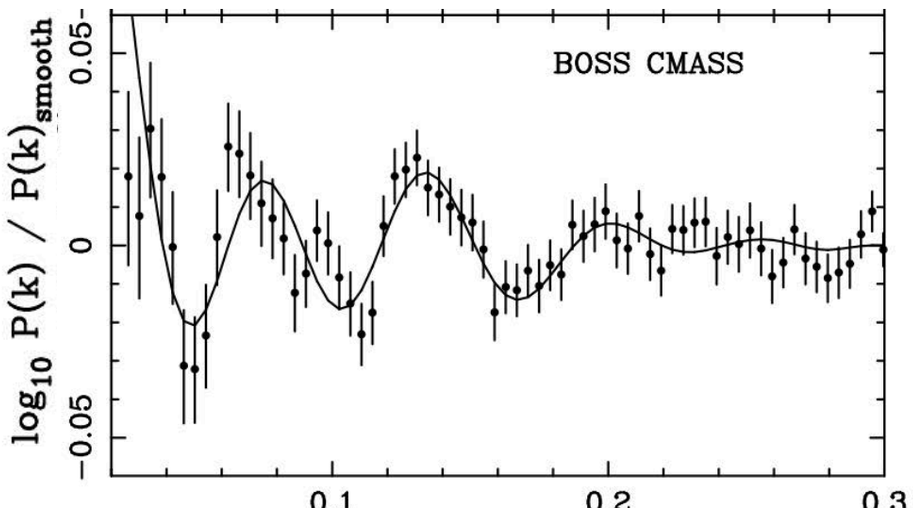
* Nowhere in our equations do we consider the so-called cosmological constant, since at the present time it has finally become clear that there is no basis whatsoever for such a change in the equations of attraction.

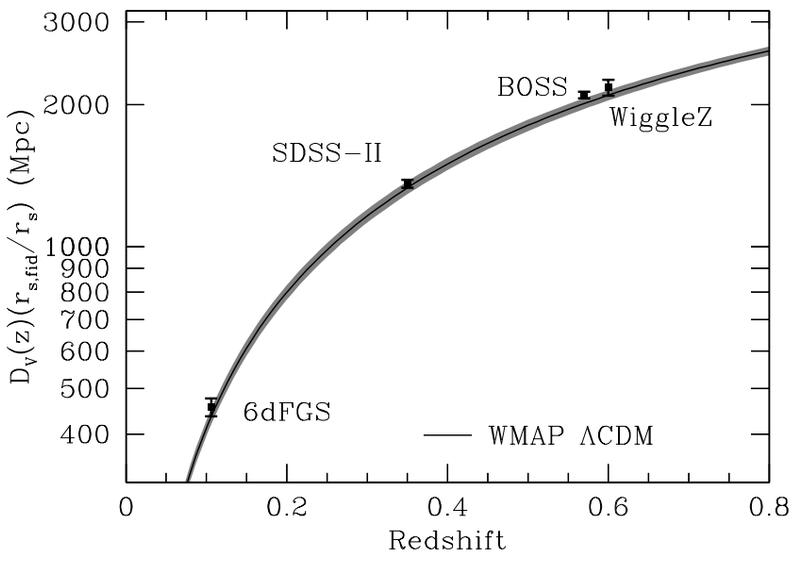


ΛCDM is is convincingly established as a good approximation to "reality" by passing far more empirical tests than guided its formulation.

ΛCDM is incomplete, as is all the rest of our physics.



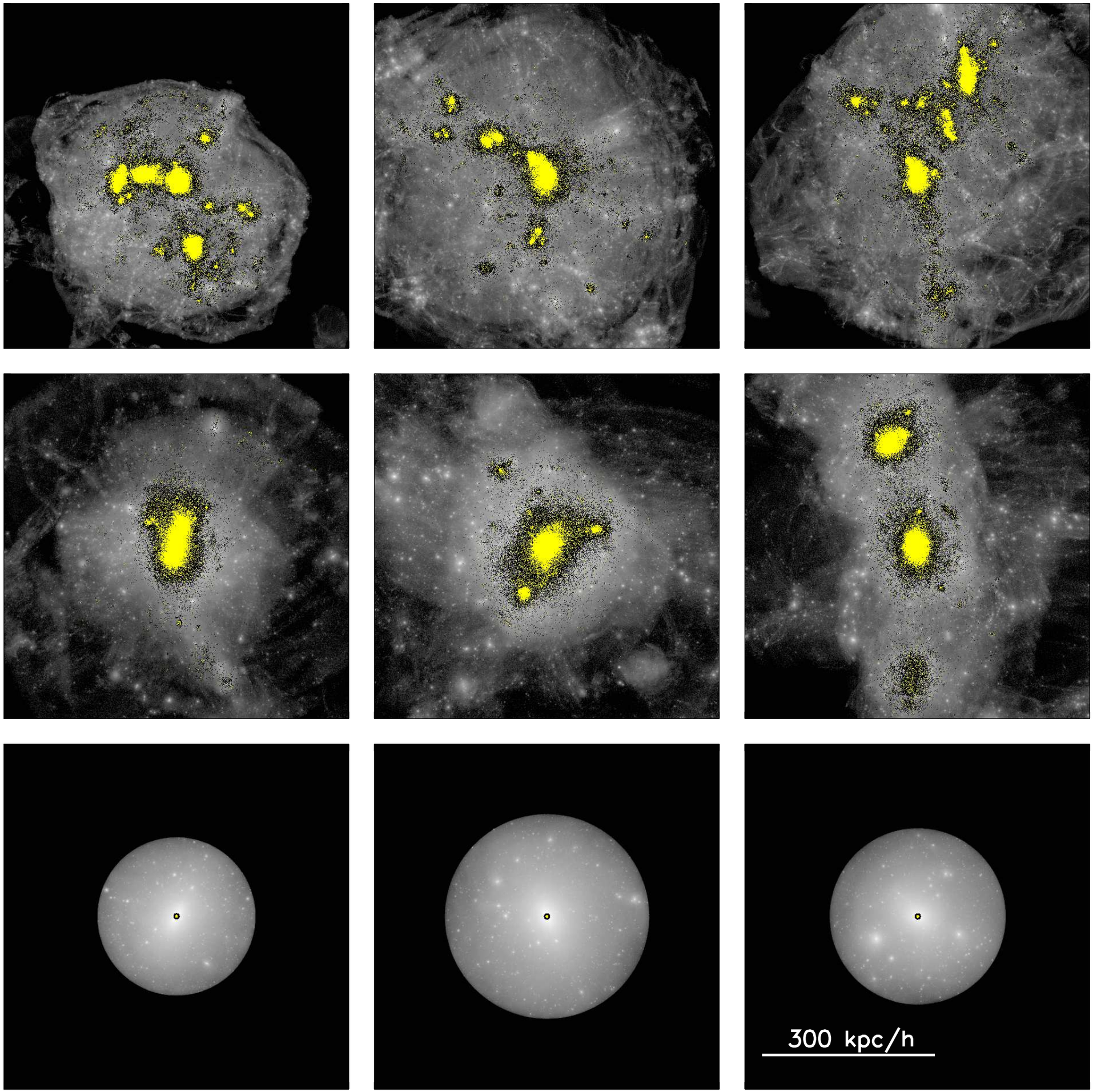




z=3.1

z=1.0

z=0.0



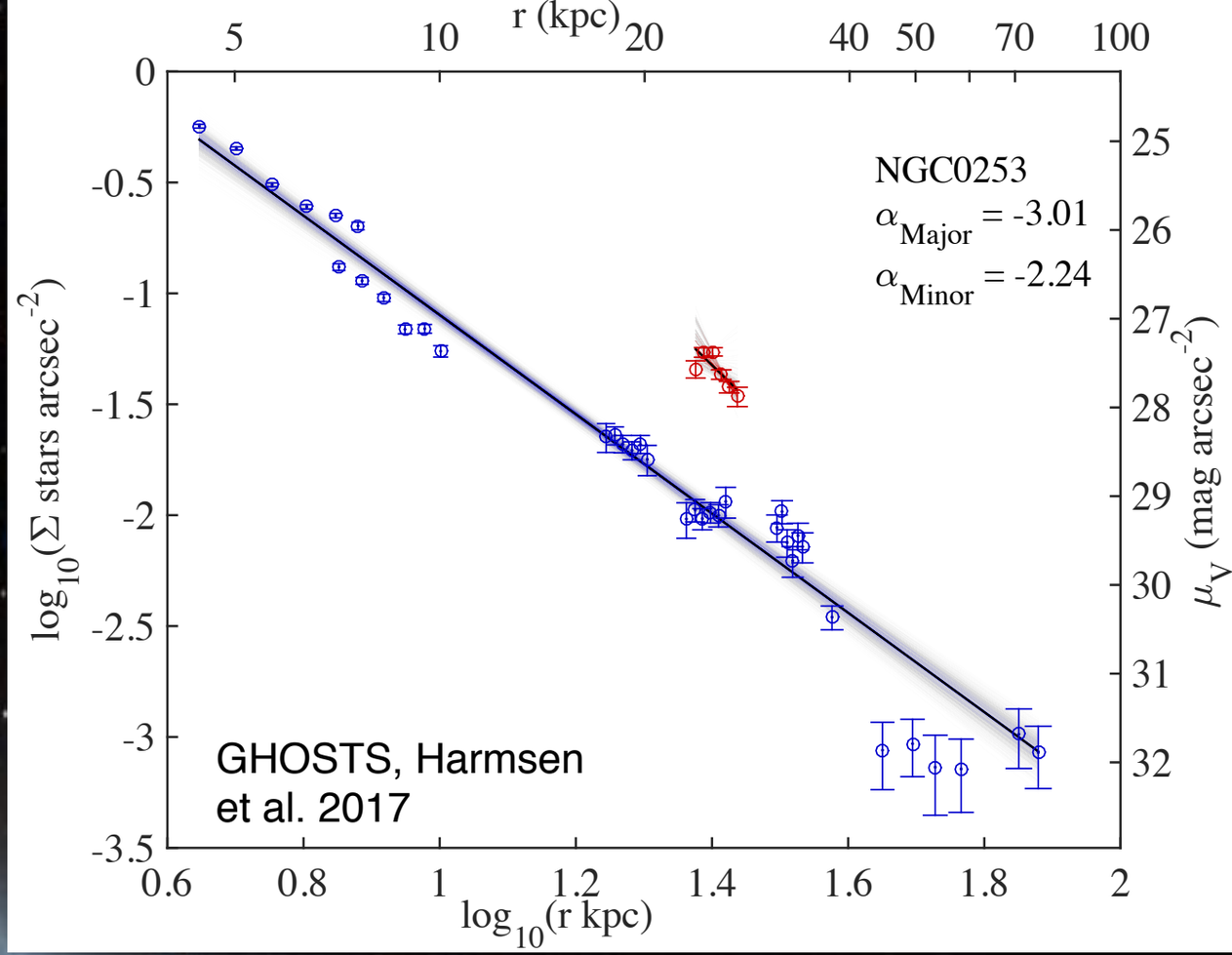
AQUARIUS pure DM halos of L~L* galaxies in ΛCDM (Springel et al. 2008). Lengths are physical.

Images by Jie Wang, Durham, in colaboration with Adi Nusser, Technion.

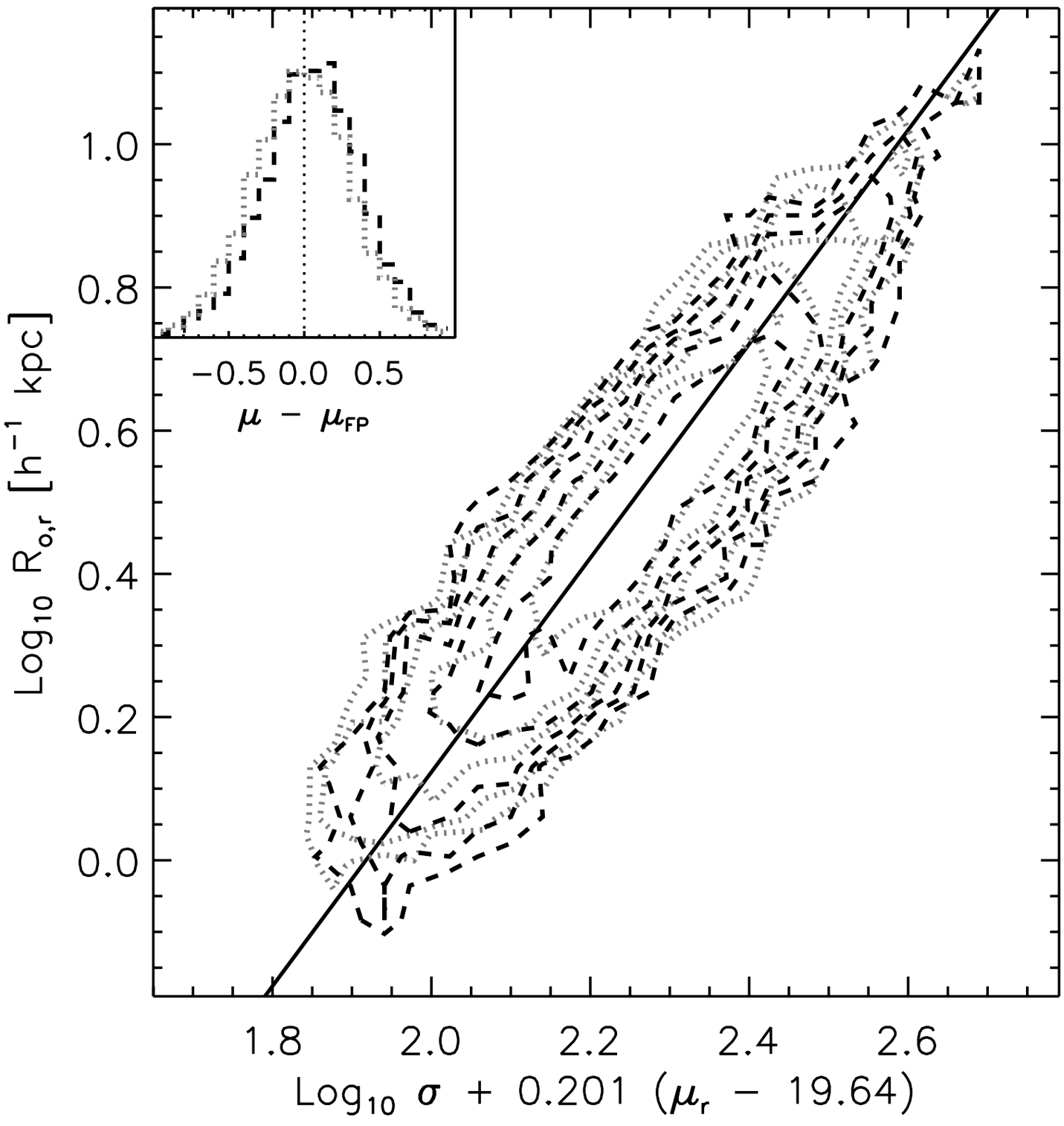
The grey scale shows particles that are at r200 > r > 7 kpc at z = 0.

Overplotted in black are particles at 3 < r < 7 kpc at z = 0.

Overplotted in yellow are particles at r < 3 kpc at z = 0.



RGB star counts converted to stellar halo mass
at $10 < c < 40$ kpc and $c/a = 0.6$ give halo/total mass ~ 0.02 to 0.03
in Sculptor. This is much fainter than models in which galaxies grew
by merging, placing early generations of stars in stellar halos.



Mariangela Bernardi 2006
early-type galaxies

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

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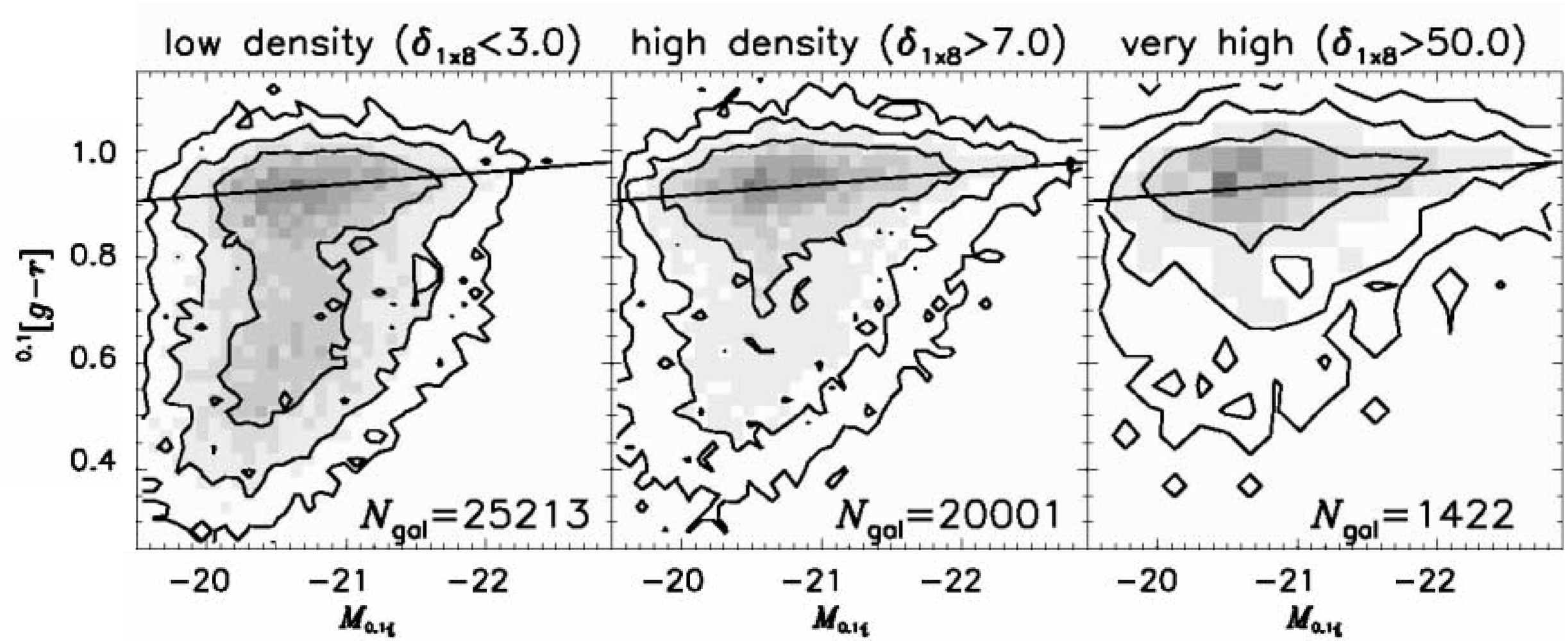
(bowdlerized)



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 $\sim 80\%$ of the nominal Petrosian magnitude, that is, well outside the half-light radius.

Mon. Not. R. Astron. Soc. **425,** 296–310 (2012) doi:10.1111/j.1365-2966.2012.21458.x

The Tully–Fisher relation for 25 000 Sloan Digital Sky Survey galaxies as a function of environment

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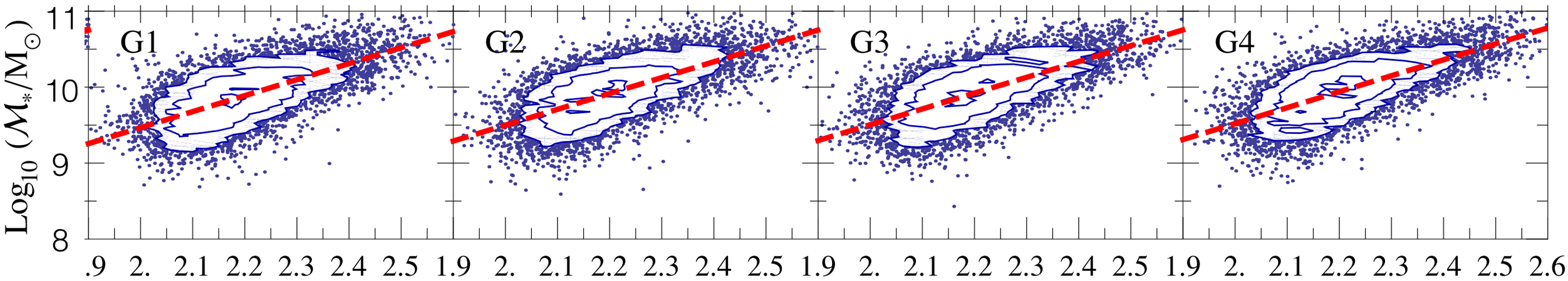
Late-type SDSS galaxies selected by color.
See the familiar insensitivity to ambient conditions.



lowest highest

quartiles in ambient density

ΛCDM predicts galaxies grew by merging, yet scaling says galaxies evolved pretty much as island universes.*

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* I mean evolution, not whatever caused the morphology-density relation.

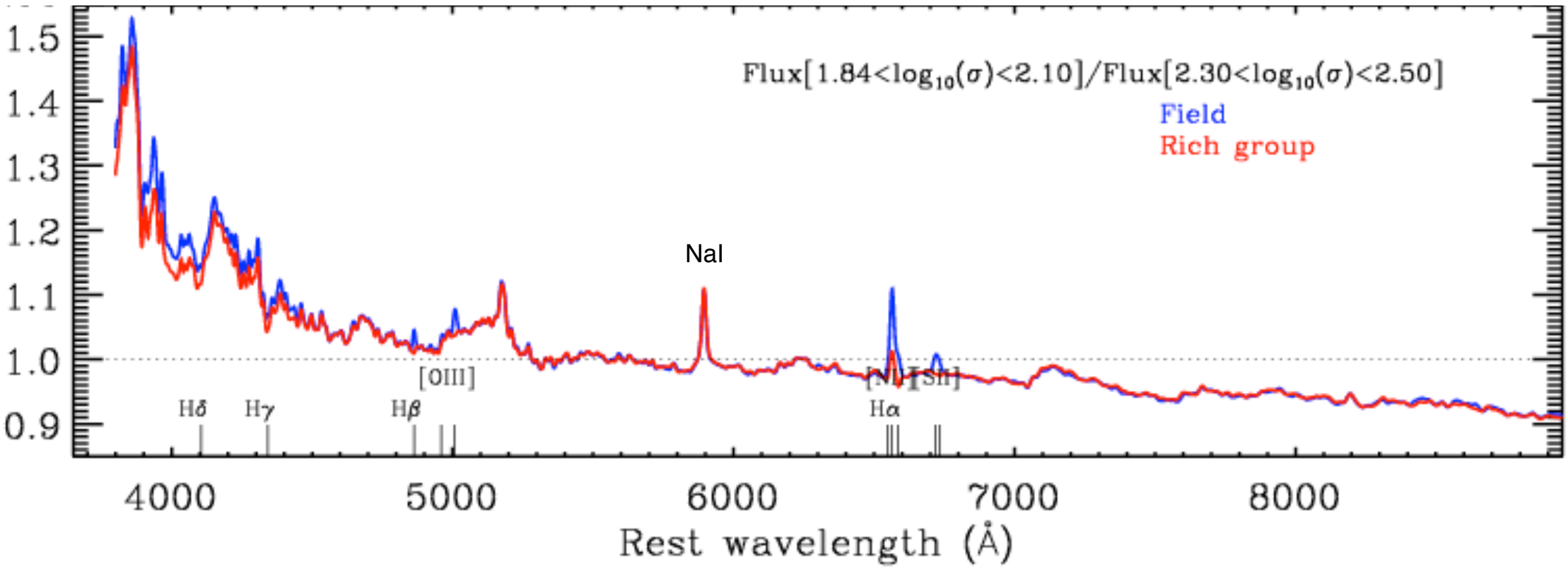

Figure courtesy of private communication from Guangtun Zhu, based on analyses of SDSS data in

STELLAR POPULATIONS OF ELLIPTICAL GALAXIES IN THE LOCAL UNIVERSE ApJ 2010

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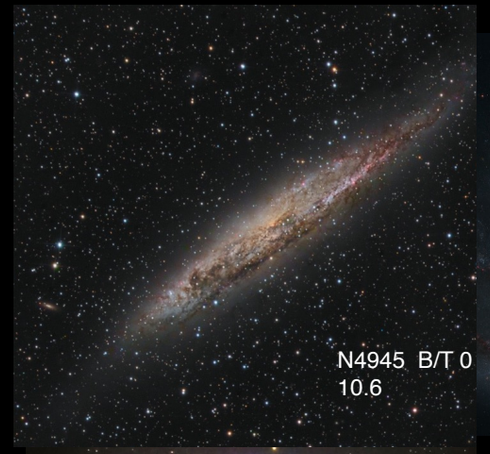
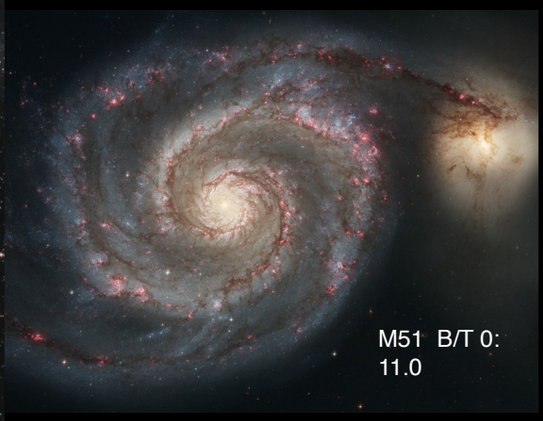
M 101

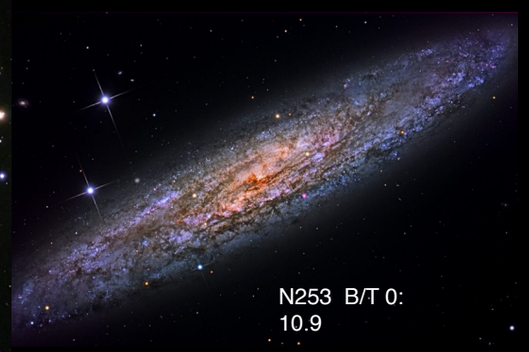
Robert Gendler

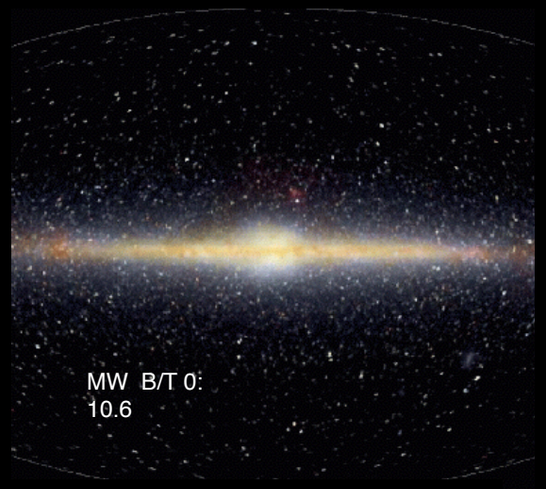
Composite image, HST and ground-based

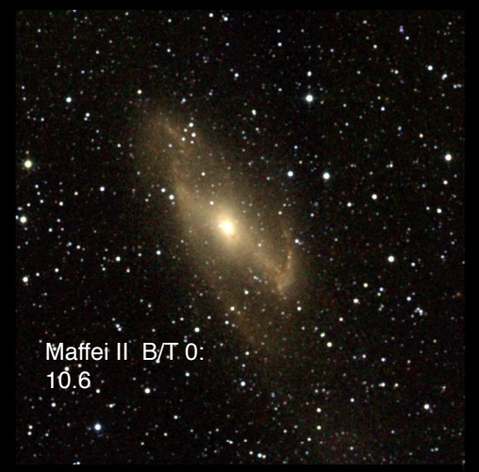
galaxy classical bulges are far less luminous than models: might feedback succeed?

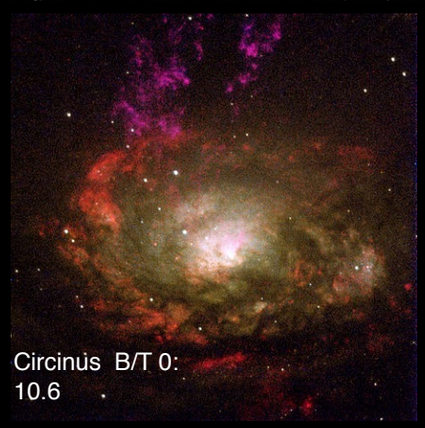


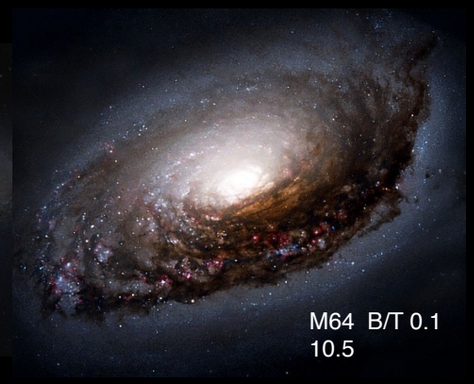


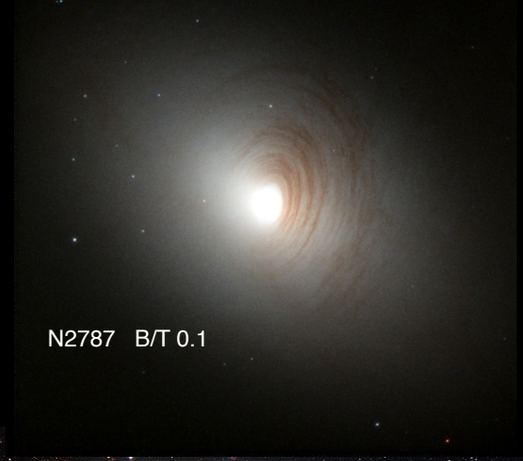


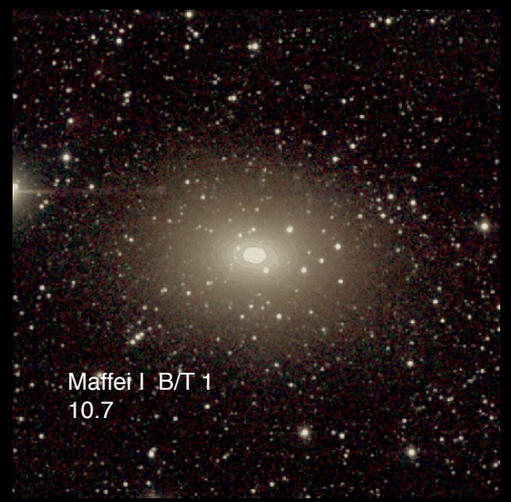


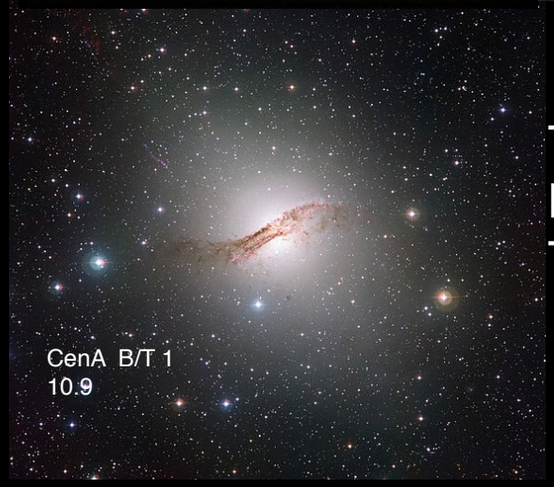












The 19 galaxies with Kormendy et al. B/T, Tully D < 10 Mpc, $L_K > 10^{10.5}$.

PJEP April 2016

N4559 B/T 0

N463
10.4

M82 B/T 0
10.6

N925 B/T 0.1
10.1

N2903 B/T 0.1
10.8

N4517
10.2

6744 B/T 0.15
1.0

N891
10.9

N3621 B/T 0.01
10.3

N4490 B/T 1

N3344 B/T 0.1
10.3

M66 B/T 0.1

M63 B/T = 0.2
10.9

M108 B/T 0.2

M96 B/D 0.3

M104 B/T 0.5
11.3

N2784
10.8

N2640
10.9

M 105 B/T 1
11.3

19 more galaxies at
D < 10 Mpc,
$L_K > 10^{10}$,
some with Fisher and
Drory B/T

PJEP April 2016