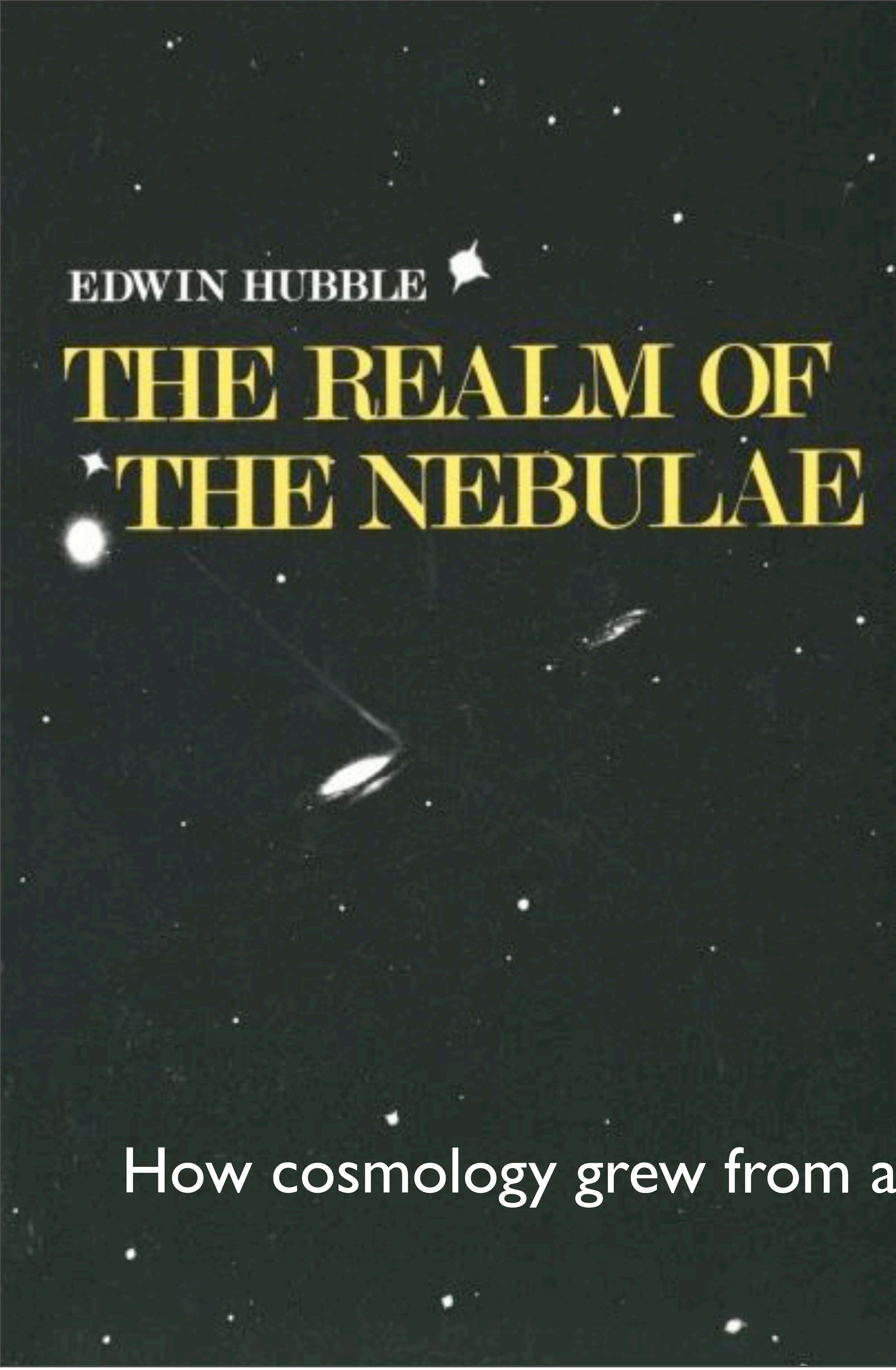
esa 47th eslab symposium
2 - 5 april 2013
THE UNIVERSE AS SEEN BY PLANCK
European Space Agency

The CMB in Perspective

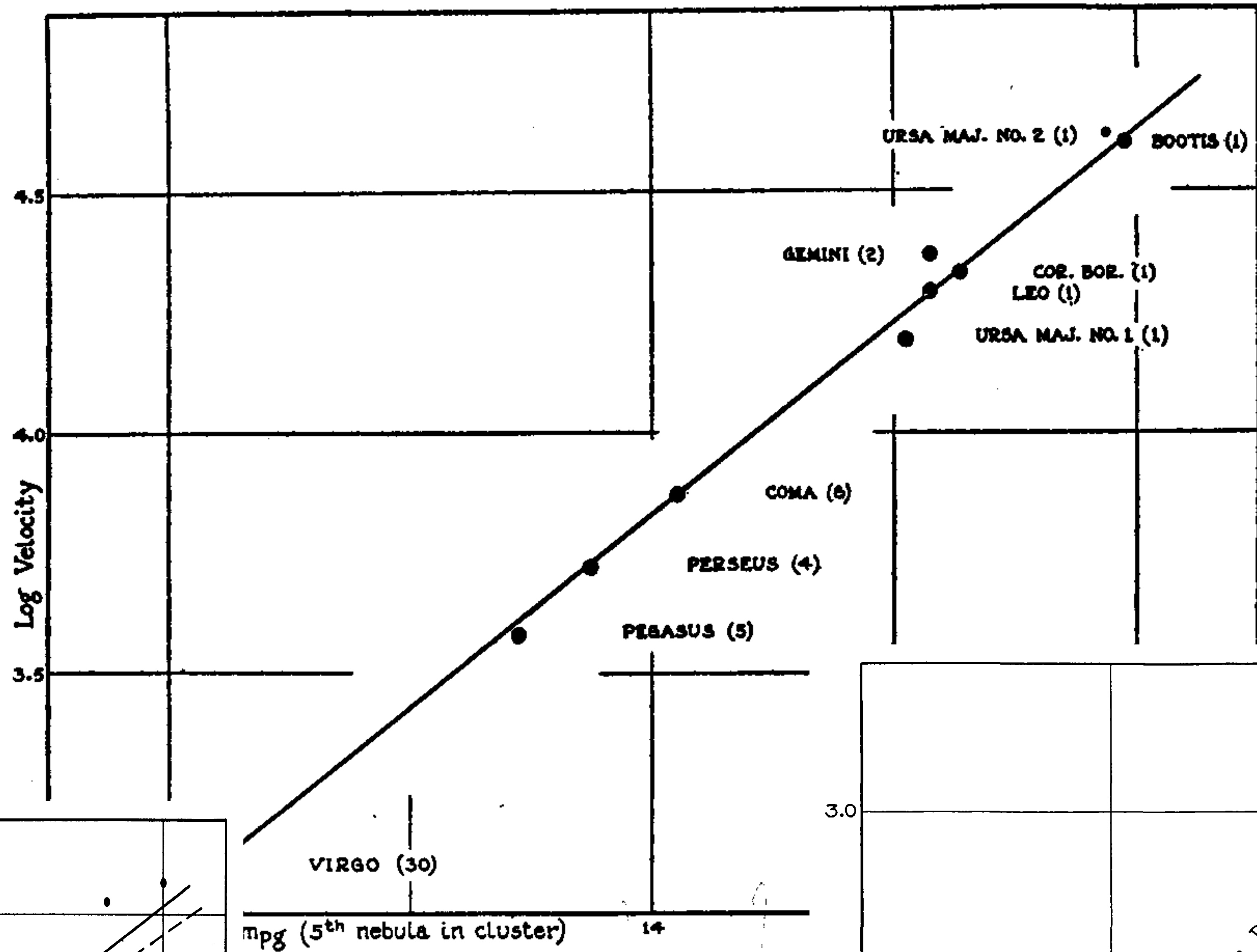
PJE Peebles

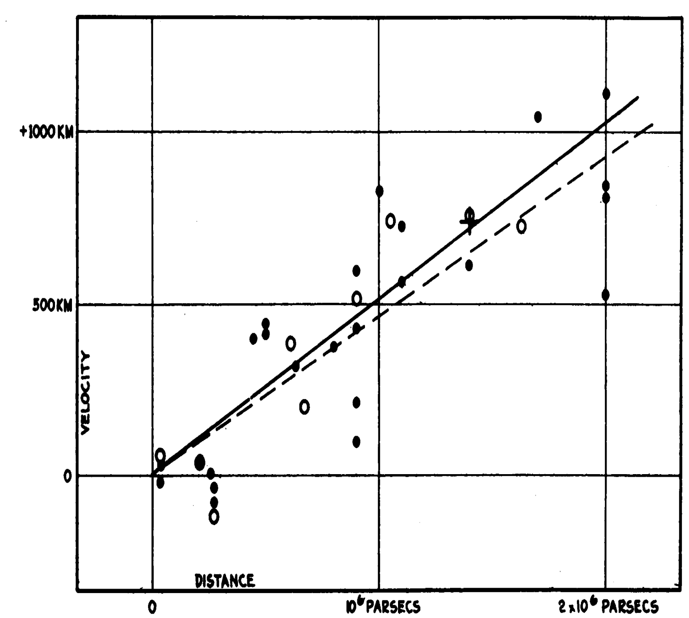


How cosmology grew from a small science to Big Science

Hubble and Humason ~ 1936

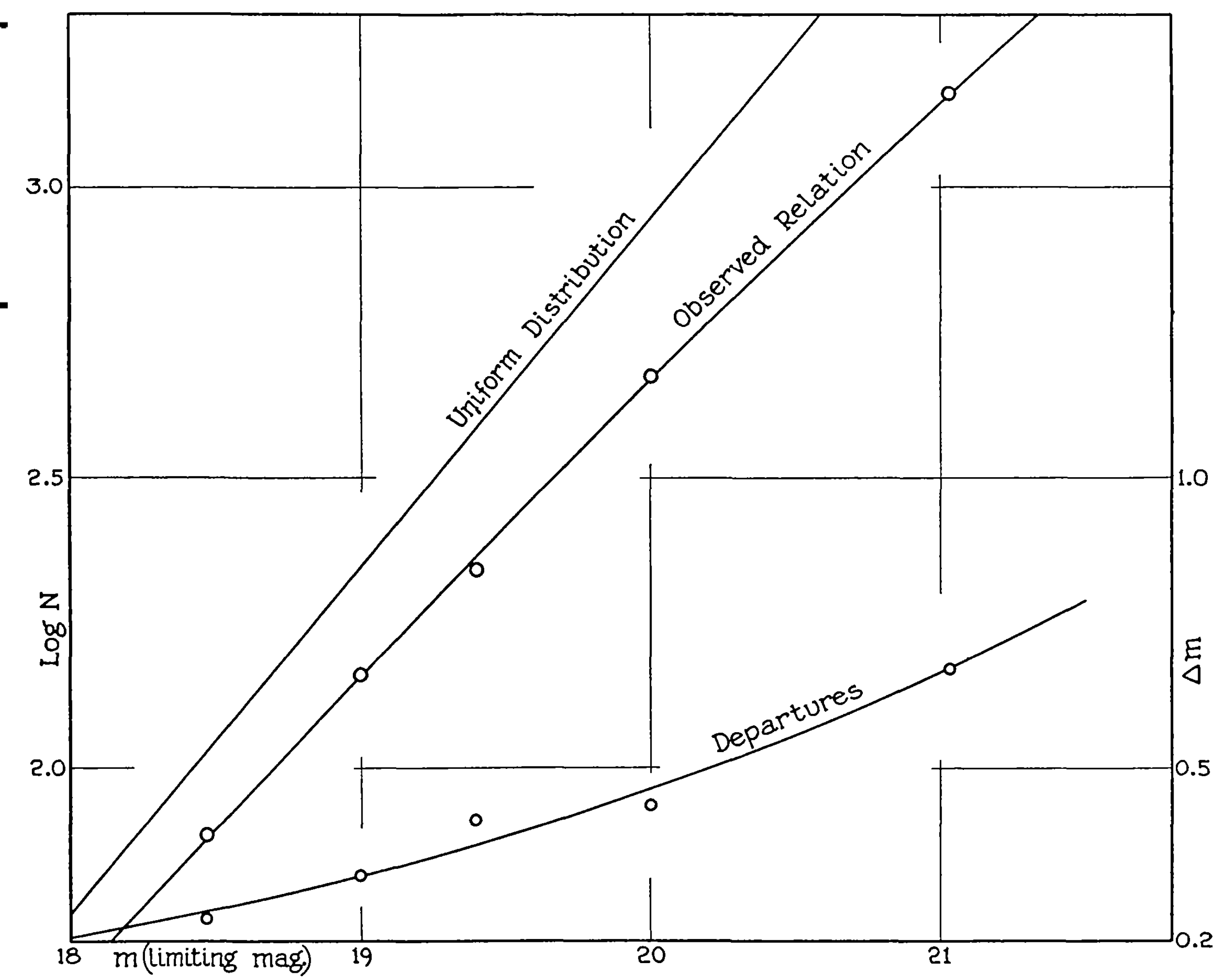
redshift
z = 0.1 →





Hubble 1929

Hubble 1936



Imagine in an alternative world Hubble and Humason were able to use SNeIa to extend the z—m relation to $z \sim 1$, revealing the curvature, and imagine a dialog in that world in 1950.

(1) Steady State: We predicted the measured curvature.

(2) Big Bang: Our model fits equally well; just add Λ.

(3) Steady State: You're playing with free parameters.

And consider that the Big Bang model extrapolates GR by 14 orders of magnitude in length scale from its one serious test, the orbit of Mercury. Why pay attention to such an extreme extrapolation of such a poorly tested theory?

(4) Big Bang: At least we have a theory.

And consider that in the Big Bang conditions at $z \sim 1$ were different, SNeIa had to have been different, and arguments that the difference is small, though admirably careful, cannot be complete. Maybe the curvature is a systematic error, we don't need Λ, and you don't have a successful prediction.

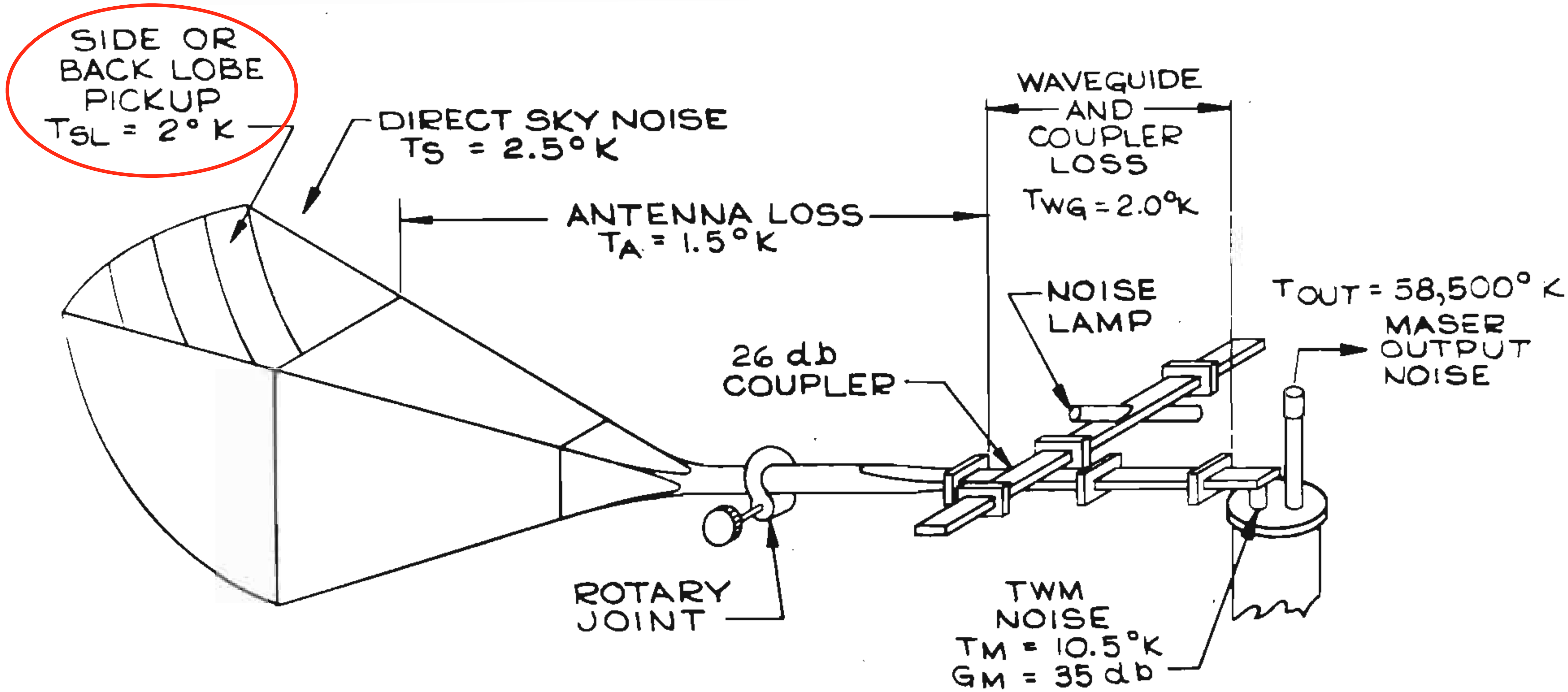
Microwave radiometer, "Shaggy Dog" measured atmosphere's absorption. E. Beringer, R. Kyhl, A. Vane, R. Dicke.

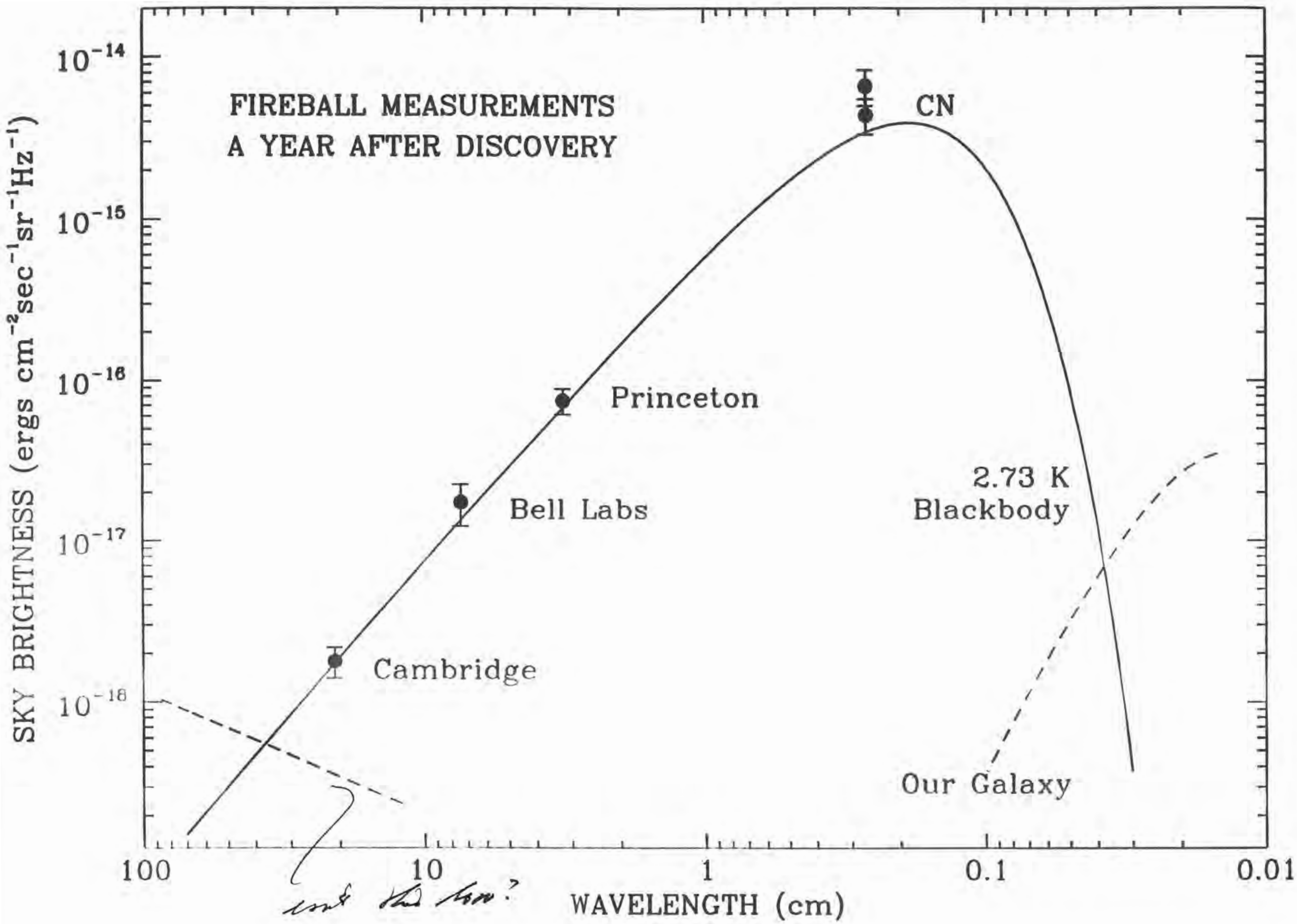
In 1948 George Gamow presented main elements of the now well tested theory of formation of deuterium and helium in the hot big bang, and Alpher and Herman noted that in Gamow's theory the present temperature would be about 5° K.

Dicke, Beringer, Kyhl and Vane (1946) used a Dicke radiometer to establish that "there is very little (< 20° K) radiation from cosmic matter" at ~1 cm wavelength.

Ultra-Low-Noise Measurements Using a Horn Reflector Antenna and a Traveling-Wave Maser

R. W. DeGrasse, D. C. Hogg, E. A. Ohm, and H. E. D. Scovil
Bell Telephone Laboratories, Inc., Murray Hill and Holmdel, New Jersey
(Received July 24, 1959)





FIREBALL MEASUREMENTS
A YEAR AFTER DISCOVERY
CN
Princeton
Bell Labs
Cambridge
2.73 K
Blackbody
Our Galaxy
SKY BRIGHTNESS (ergs cm⁻²sec⁻¹sr⁻¹Hz⁻¹)
WAVELENGTH (cm)
100
10
1
0.1
0.01

The Bakerian Lecture, 1968

Review of recent developments in cosmology

By F. Hoyle, F.R.S.

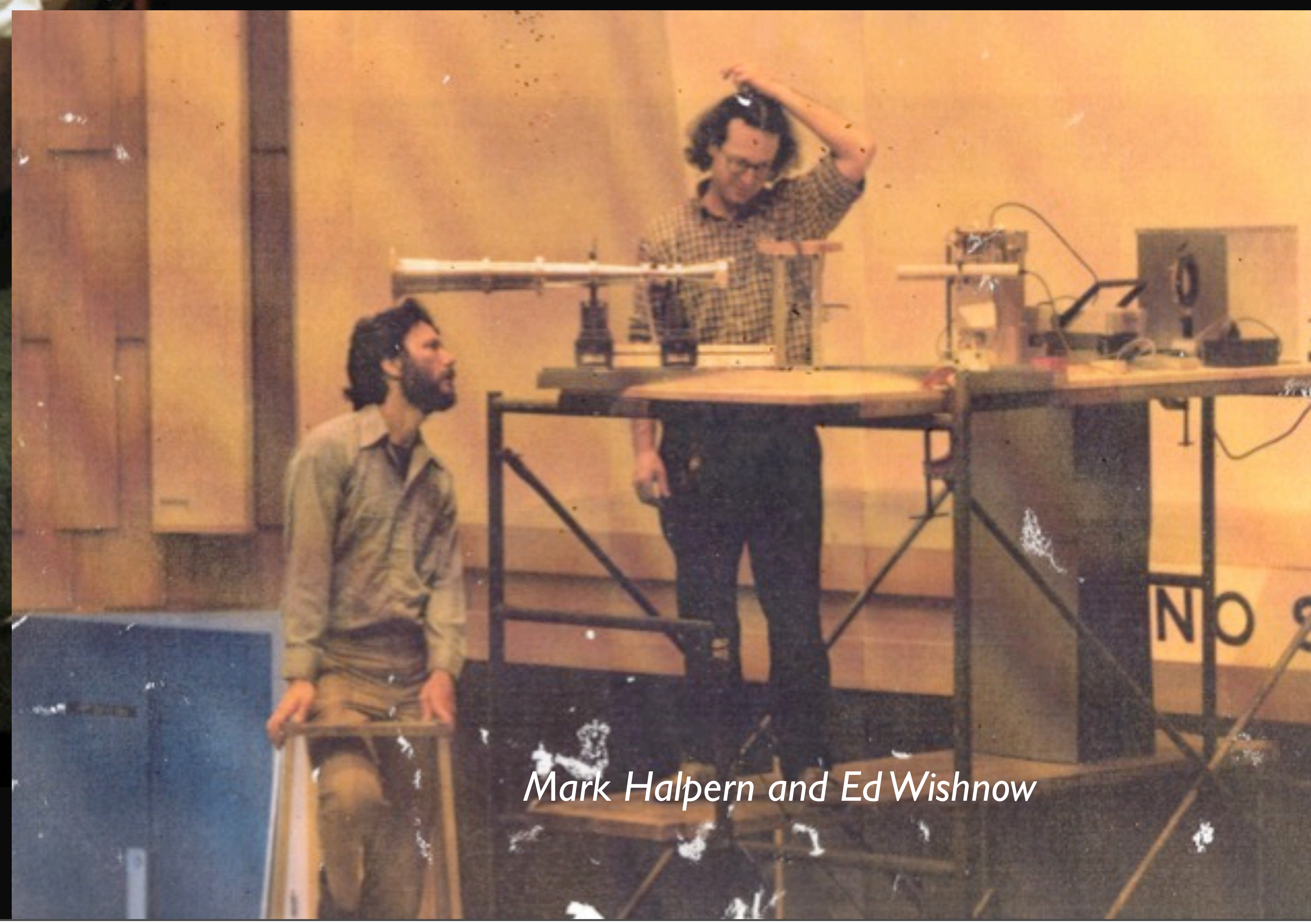
(*Delivered* 13 *June* 1968—*Received* 10 *July* 1968)

phenomenon	energy density (erg cm^{-3})
infrared from galaxies	$> 10^{-13}$
microwave background	4×10^{-13}
H → He conversion in galaxies	6×10^{-13}
starlight in our galaxy	8×10^{-13}
cosmic-rays	3×10^{-12}

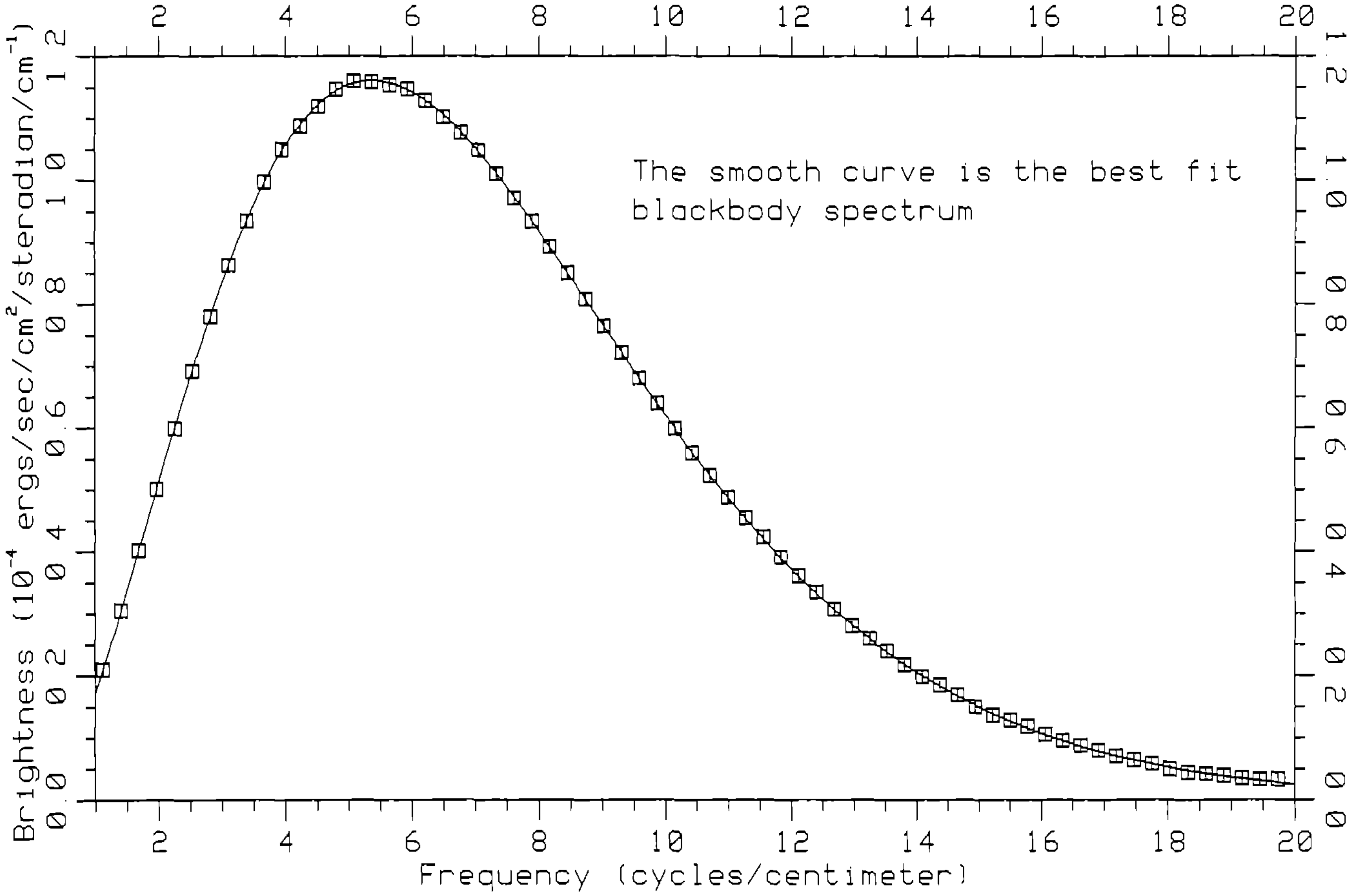
According to conventional astronomical views the similarity of the numbers are coincidental. Such views seem to me to arise out of ignorance. I simply cannot accept so many coincidences. There may be one accident—one criminal in the list—but it is unlikely there is more than one. The criminal could of course be the microwave background, which could be a fossil relic of a big-bang cosmology. But I do not think we are driven to this view today with any real force. . . .


Kelsall Weiss Smoot Hauser Wright Lubin Moseley Mather Gulkis Silverberg Janssesn Boggess Bennett Meyer Murdock Shafer Wilkinson Cheng
COBE Science Working Group

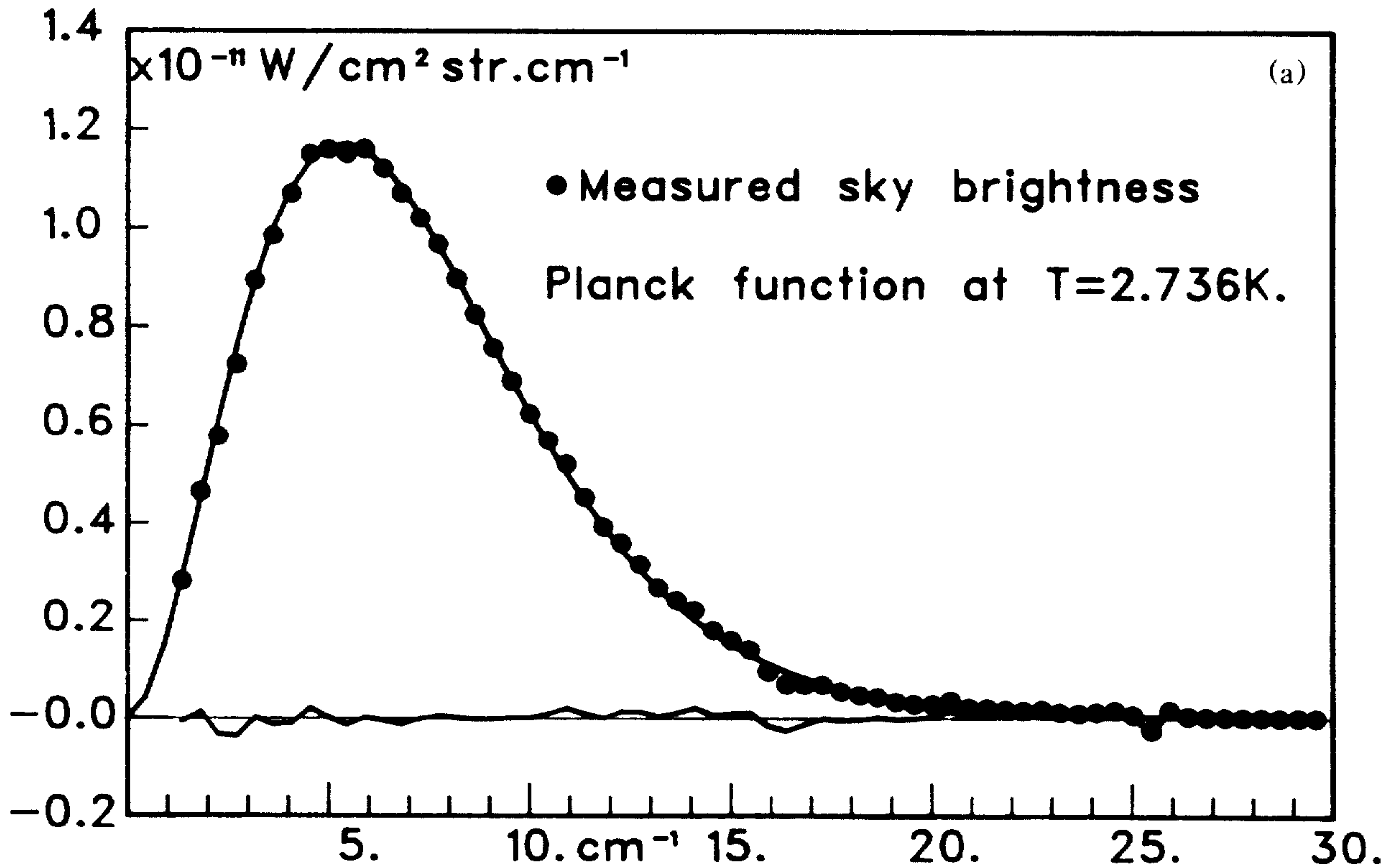
Herb Gush



Mark Halpern and Ed Wishnow

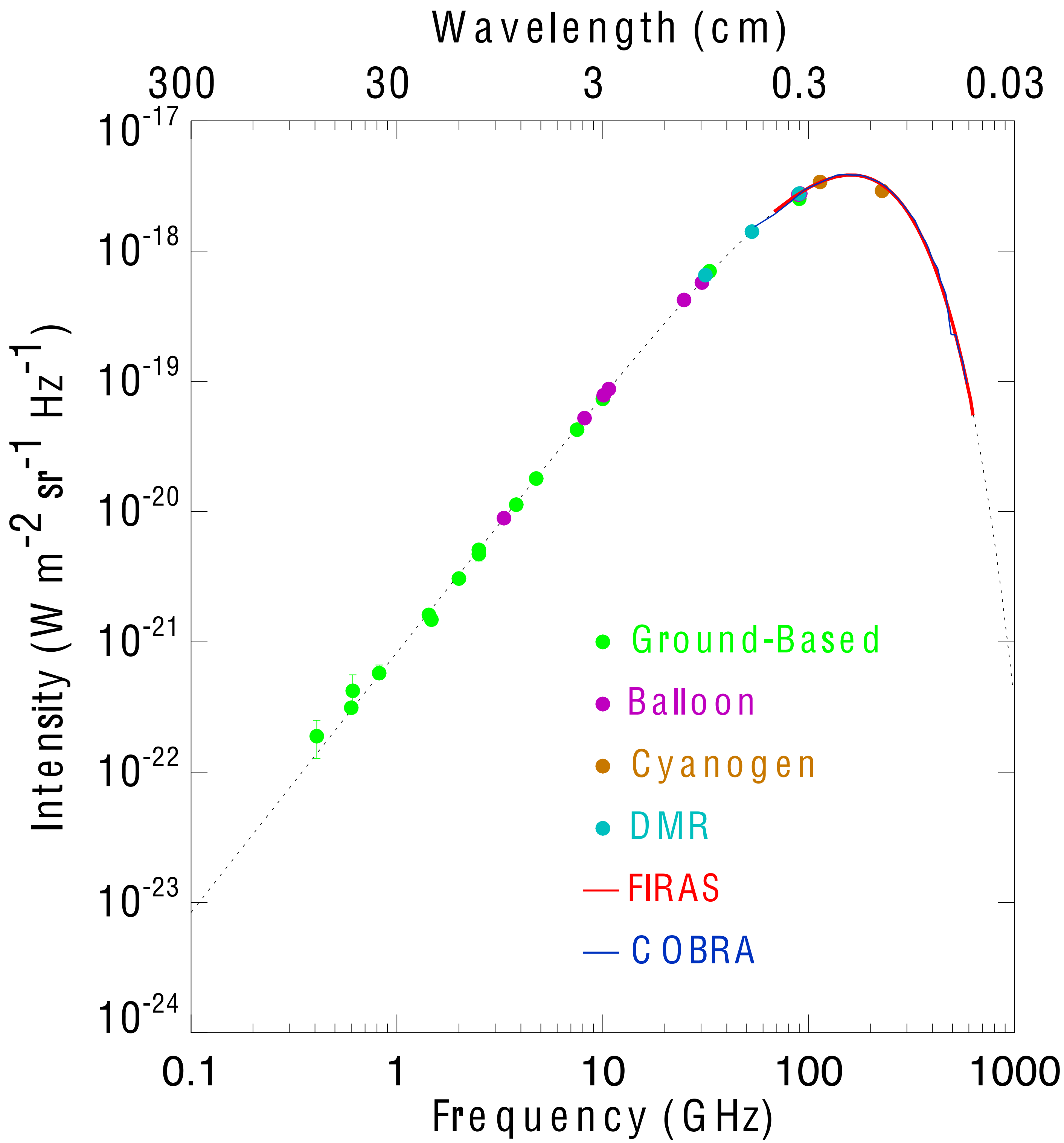


Mather et al. 1990

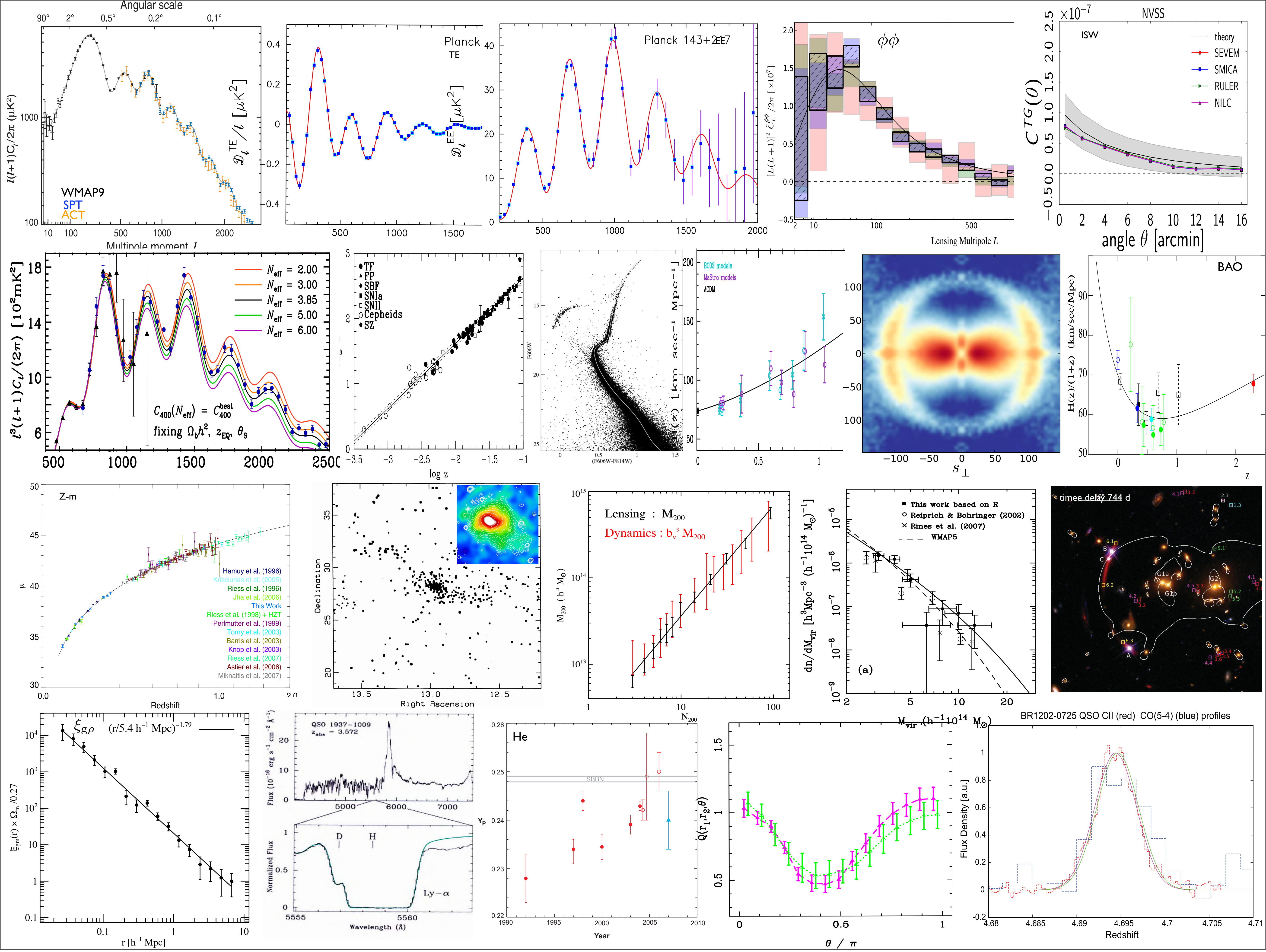


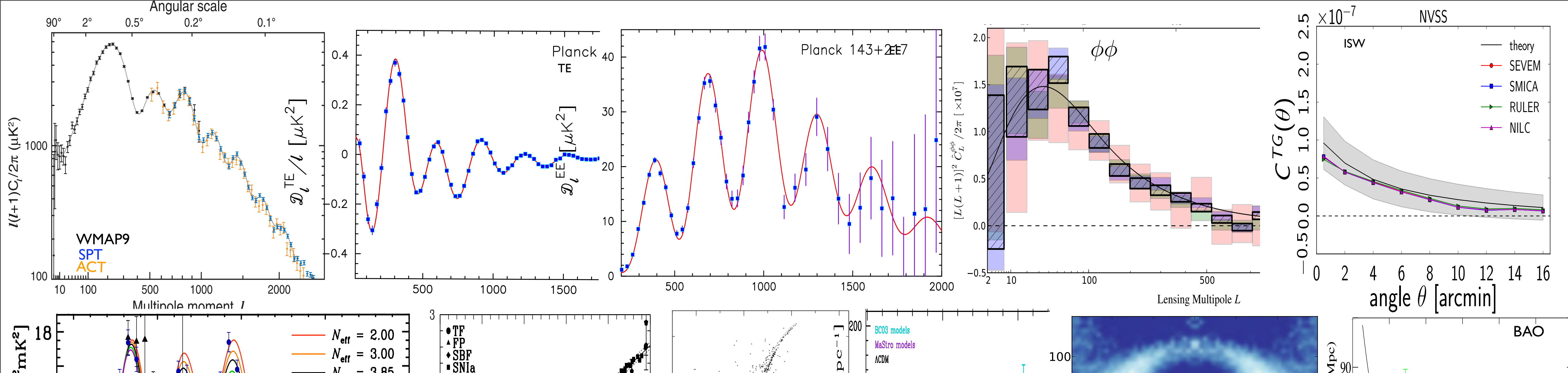
Gush et al. 1990

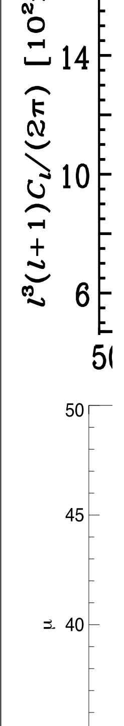
Selected Measurements of CMB Spectrum



Al Kogut


Angular scale
Multipole moment l
WMAP9
SPT
ACT
Planck
TE
Planck 143+217
EE
ϕϕ
Lensing Multipole L
NVSS
ISW
theory
SEVEM
SMICA
RULER
NILC
angle θ [arcmin]
C_400(N_eff) = C^best_400
fixing Ω_b h^2, z_EQ, θ_S
log z
TF
FP
SBF
SNIa
SNII
Cepheids
SZ
BC03 models
MaStro models
ΛCDM
BAO
H(z)/(1+z) (km/sec/Mpc)
Z-m
Redshift
Hamuy et al. (1996)
Krisciunas et al. (2005)
Riess et al. (1996)
Jha et al. (2006)
This Work
Riess et al. (1998) + HZT
Perlmutter et al. (1999)
Tonry et al. (2003)
Barris et al. (2003)
Knop et al. (2003)
Riess et al. (2007)
Astier et al. (2006)
Miknaitis et al. (2007)
Declination
Right Ascension
Lensing : M200
Dynamics : b_v^3 M200
This work based on R
Reiprich & Bohringer (2002)
Rines et al. (2007)
WMAP5
(a)
timee delay 744 d
r [h^-1 Mpc]
QSO 1937-1009
z_abs = 3.572
Wavelength (Å)
Normalized Flux
Ly-α
He
SBBN
Year
θ / π
BR1202-0725 QSO CII (red) CO(5-4) (blue) profiles
Flux Density [a.u.]
Redshift





or, according to skeptics, depending on the situation,

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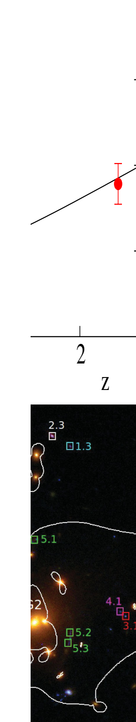
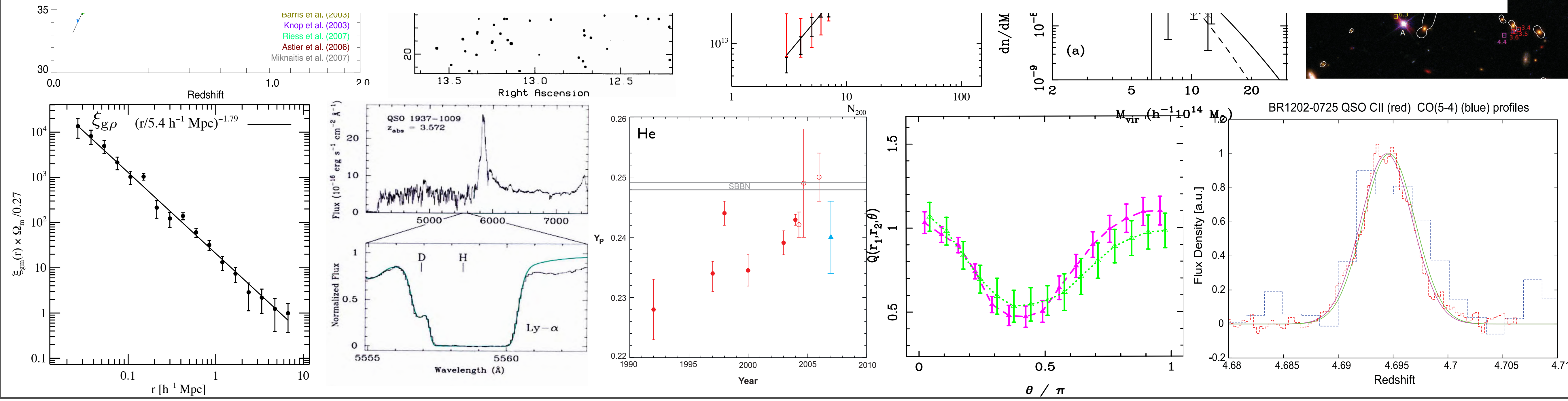
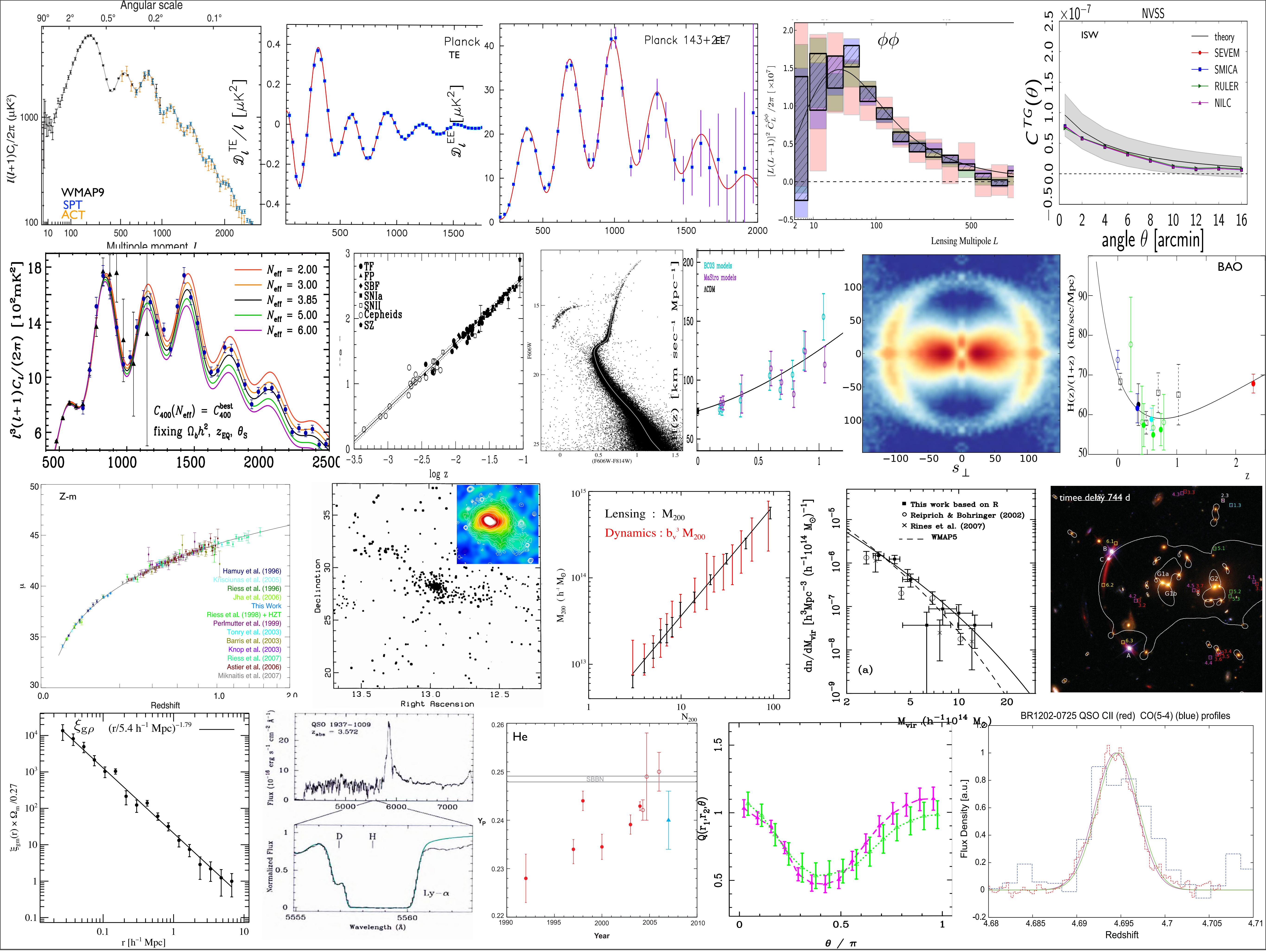


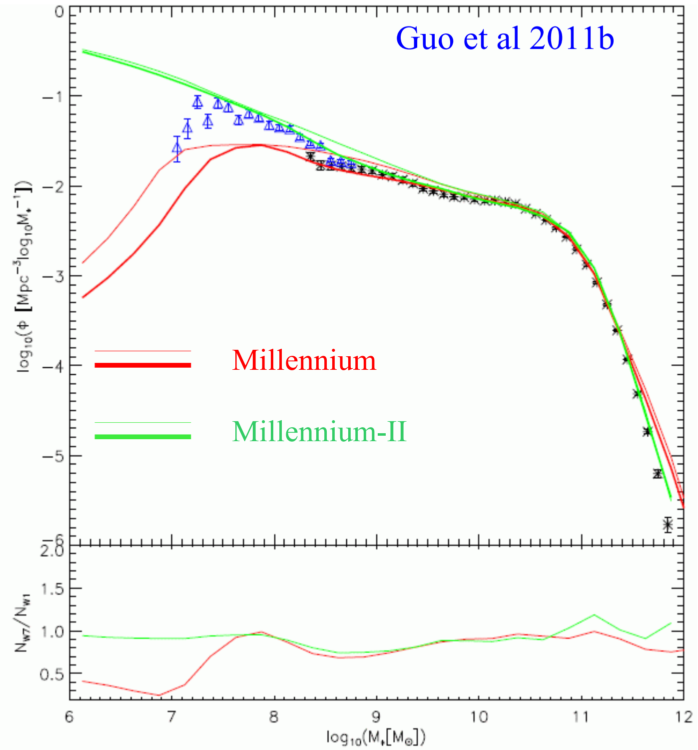




Monday, April 1, 2013

If there is a still better cosmology finding it might be aided by clues in the rich phenomenology of galaxies.

NGC 1200 NASA



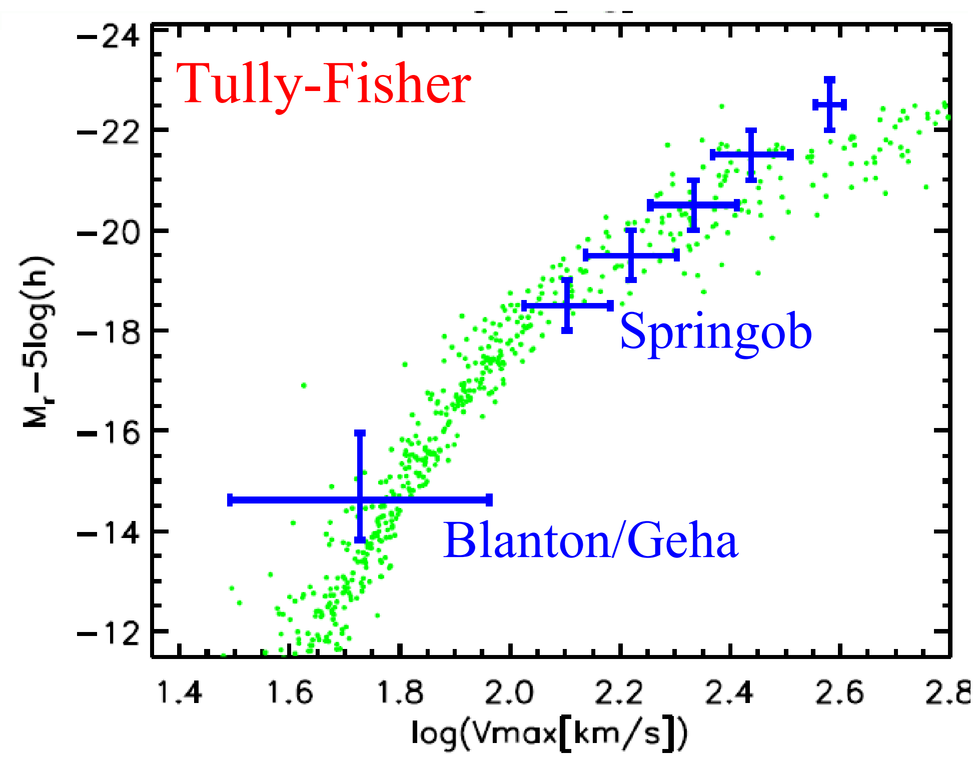
Switching from WMAP1 to WMAP7

Small shifts in the parameters of the galaxy formation model allow the galactic stellar mass function to be fit equally well in the two different cosmologies despite

$\sigma_8 = 0.90 \longrightarrow \sigma_8 = 0.81$

Parameter	Description	WMAP1	WMAP7
α	Star formation efficiency	0.02	0.015
ϵ	Amplitude of SN reheating efficiency	6.5	4.5
β_1	Slope of SN reheating efficiency	3.5	4
V_{reheat}	normarlization of SN reheating efficiency dependence on Vmax	70	80
η	Amplitude of SN ejection efficiency	0.32	0.33
β_2	Slope of SN ejection efficiency	3.5	6.5
V_{eject}	normarlization of SN ejection efficiency dependence on Vmax	70	80
κ	Hot gas accretion efficiency onto black holes	1.5×10^{-5}	6.0×10^{-6}

figures from Simon White's lecture at the conference, Galaxy Formation, Durham, 2011



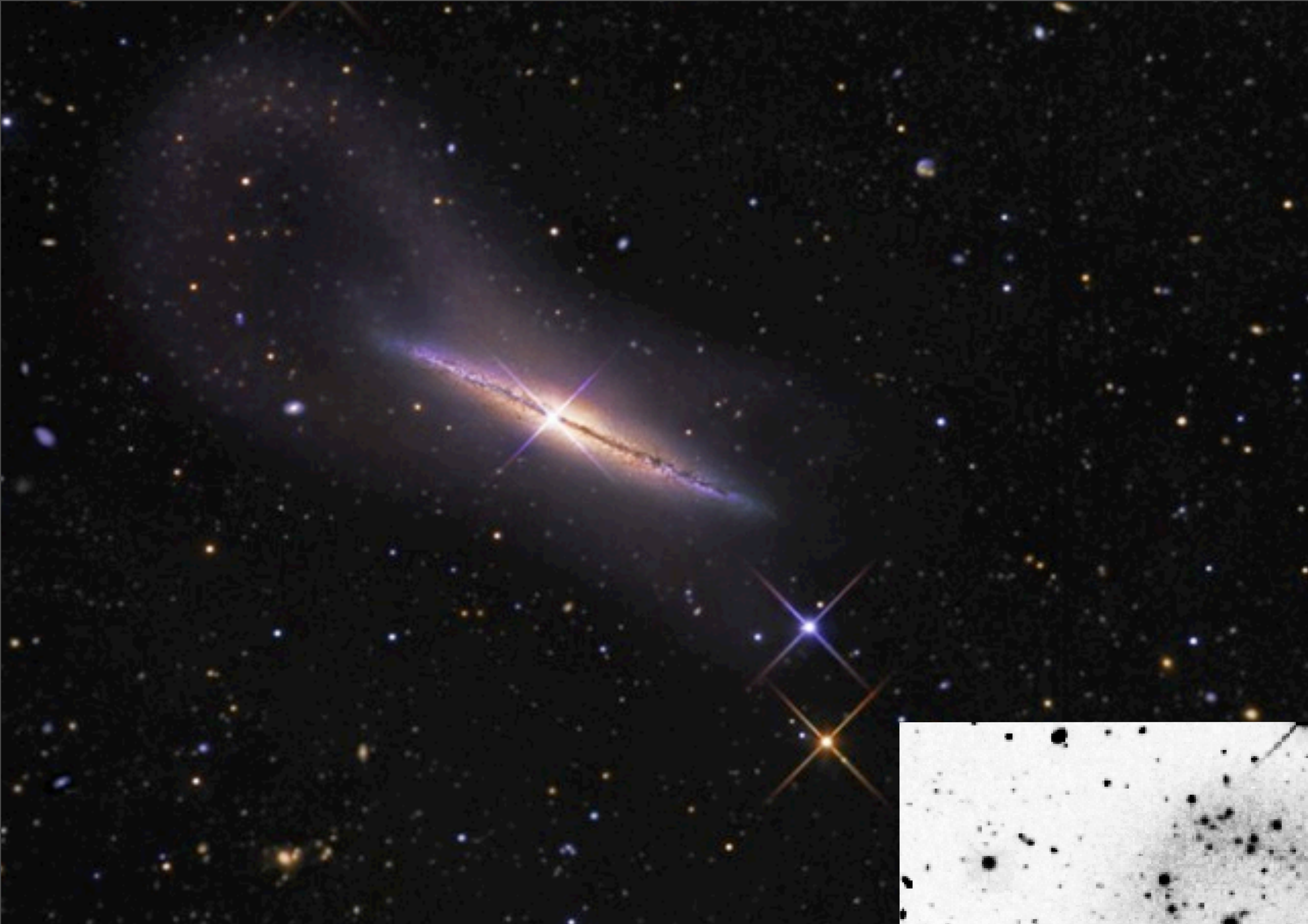
ΛCDM is rightly celebrated for its promise as a basis for galaxy formation theory. Indeed, ΛCDM is not inconsistent with many properties of galaxies, though this necessarily depends on adjustments of baryon physics parameters.

But there are properties of galaxies that seem particularly challenging to LCDM even with due attention to the complexities of the baryon physics.

Here is an example.

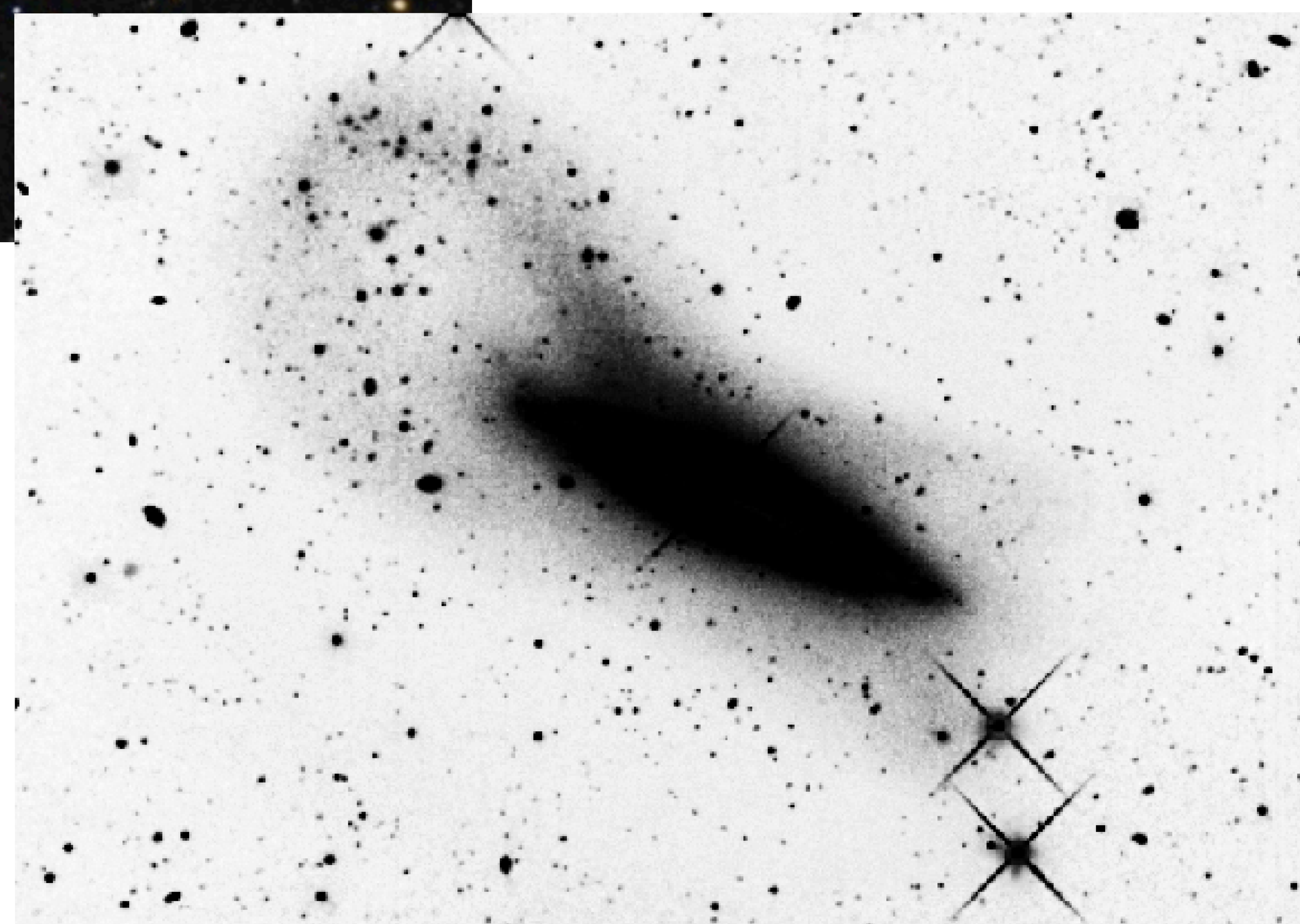

M 101 NASA/ESA

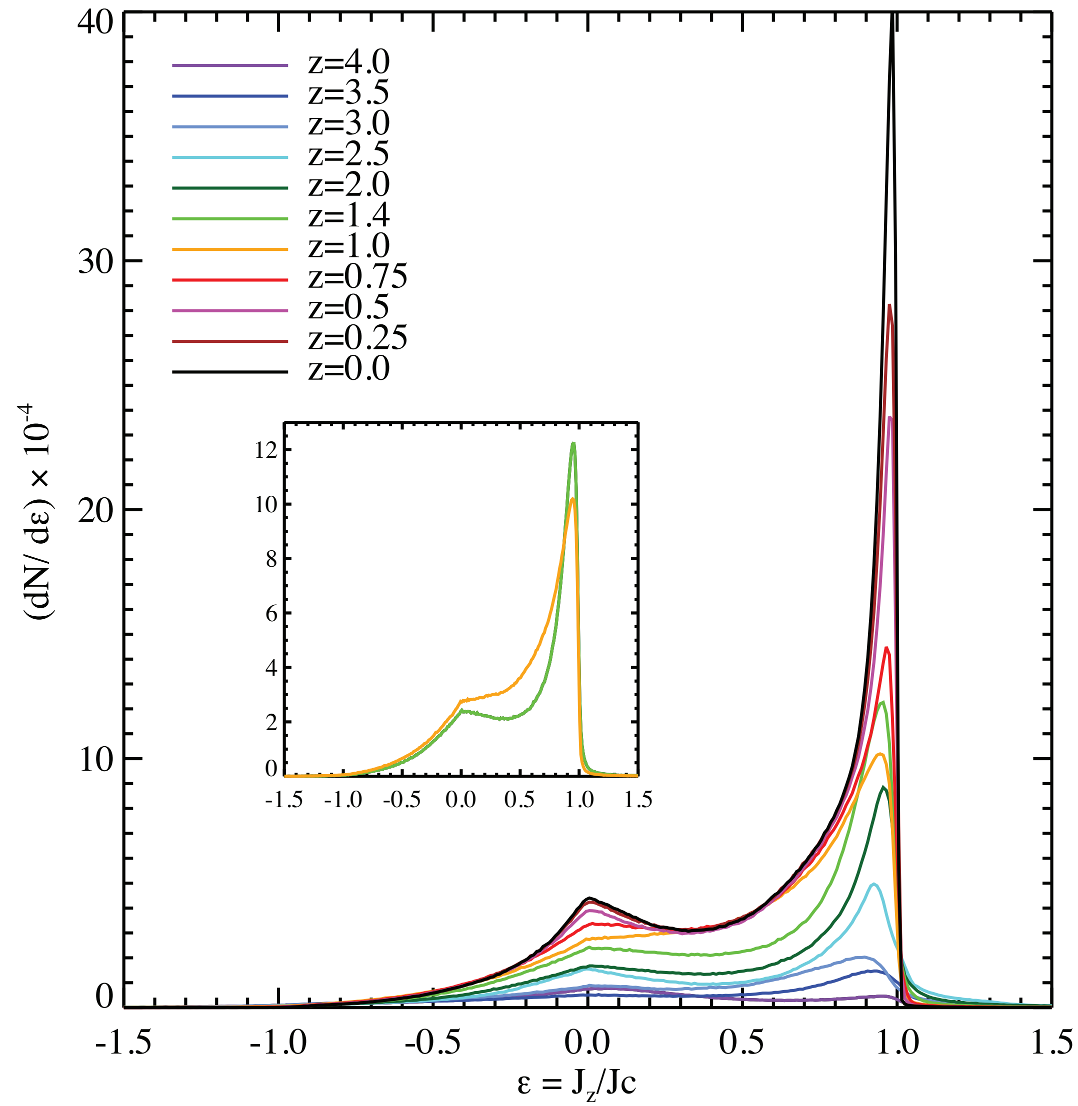
NGC 253 Star Shadows Remote Observatory



NGC 4013; R. Jay GaBany et al. 2009

Thin disk galaxies have stellar halos and streams characteristic of growth by mergers of star clusters, but that added a only few percent to the stellar mass.

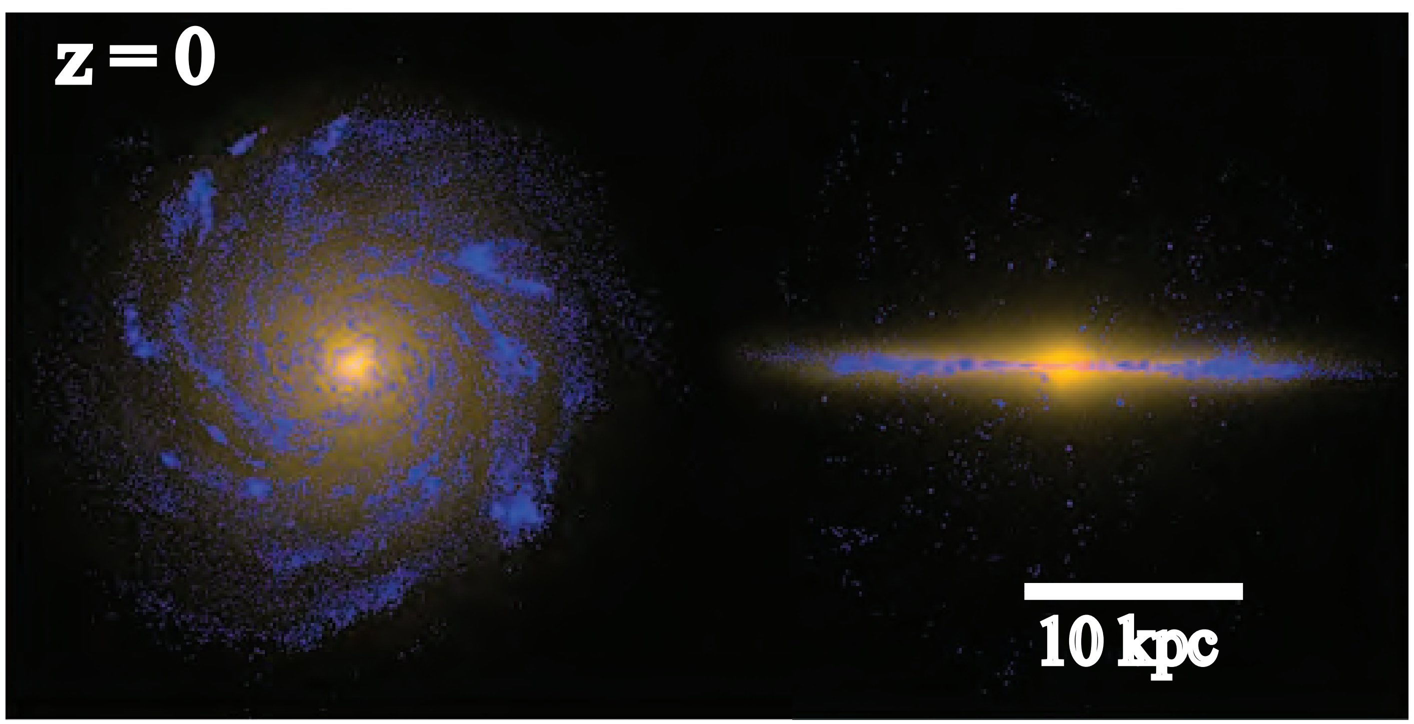


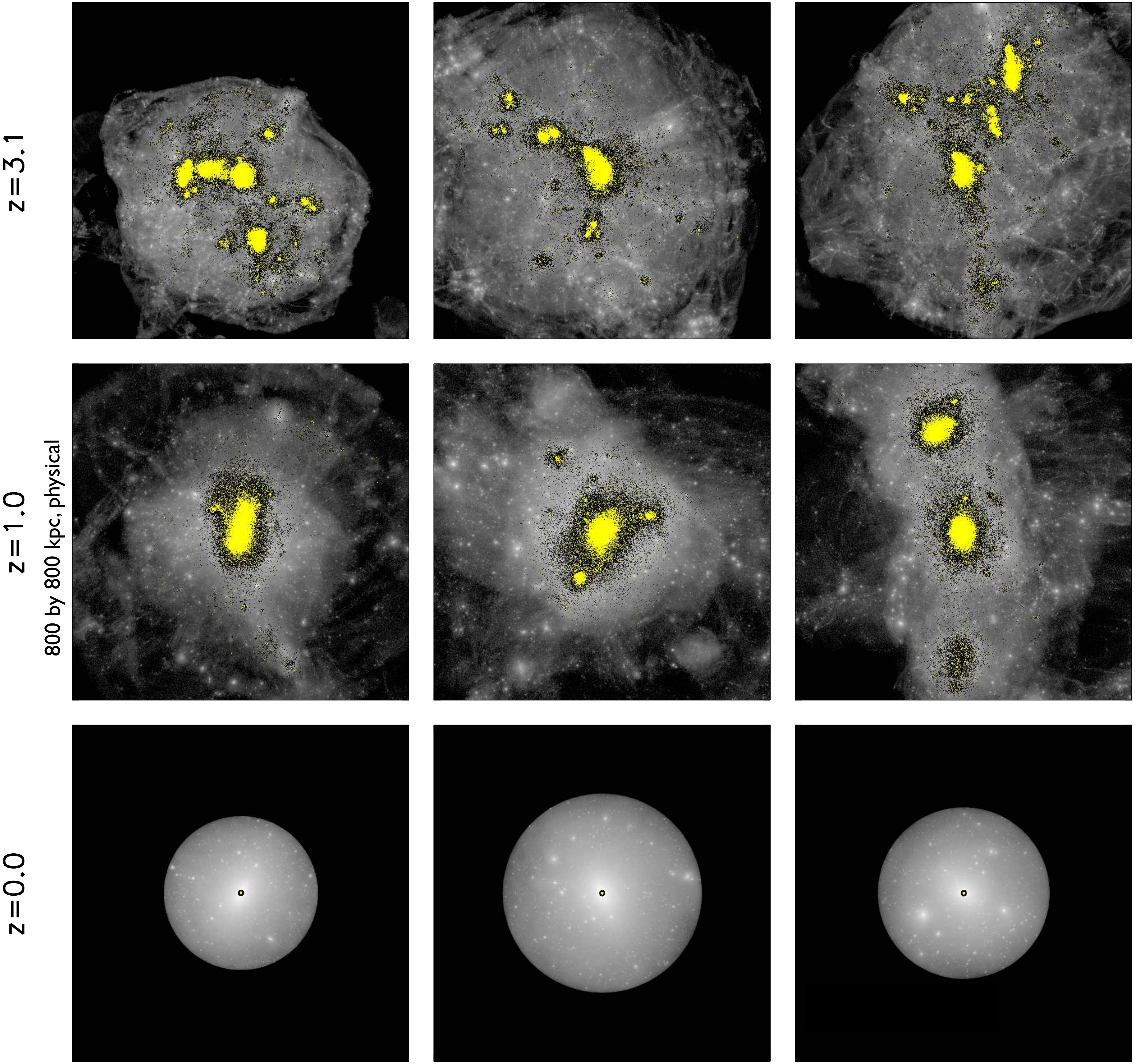


Guedes et al. present an impressively good simulation of a spiral galaxy in ΛCDM, but I think it has a classical bulge, like M31 or M81, with B/D~0.3.

1. The Milky Way pseudobulge has significant rotational support, J/Jc ~ 1.

2. The distribution of J/Jc in the MW stellar halo is closer to zero, but the halo has just a few percent of the luminosity.





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

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

The grey scale shows particles 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.

At least half present-day mass in stars had formed at z = 1.

If these stars formed in the yellow or red regions they have to have strongly avoided the present-day thin disk galaxies that are so common in our neighborhood.

The Challenge

1. ΛCDM indicates considerable merging of dark matter clumps at redshifts $1<z<3$.

2. At $1<z<3$ star formation was rapid. Where would these stars have formed? Surely in the clumps, despite the complexities of baryons.

3. Elliptical galaxies seem to be natural products of merging of starry (dry) clumps. This is a Good Thing.

4. But thin disk galaxies, common nearby, had to have grown by accretion of clumps that contained few stars, because the stars would end up in classical bulges or stellar halos.

5. How could the rapid star formation at $1<z<3$ have been confined to the clumps that were going to merge to make ellipticals, and avoid the clumps that were going to flow onto thin disk spirals?

Conclusions

- The case for ΛCDM at $z \lesssim 10^{10}$ is about as good as it gets in natural science.
- The case for the ΛCDM-based galaxy formation theory is mixed, but this fluid situation is observationally-driven.
- The simple ΛCDM model for the dark sector is a default, pending tighter tests.
- Inflation rests on elegant ideas that may be buttressed by observations in progress.

Conclusions

- The case for ΛCDM at $z \lesssim 10^{10}$ is about as good as it gets in natural science. I am amazed.
- The case for the ΛCDM-based galaxy formation theory is mixed, but this fluid situation is observationally-driven.
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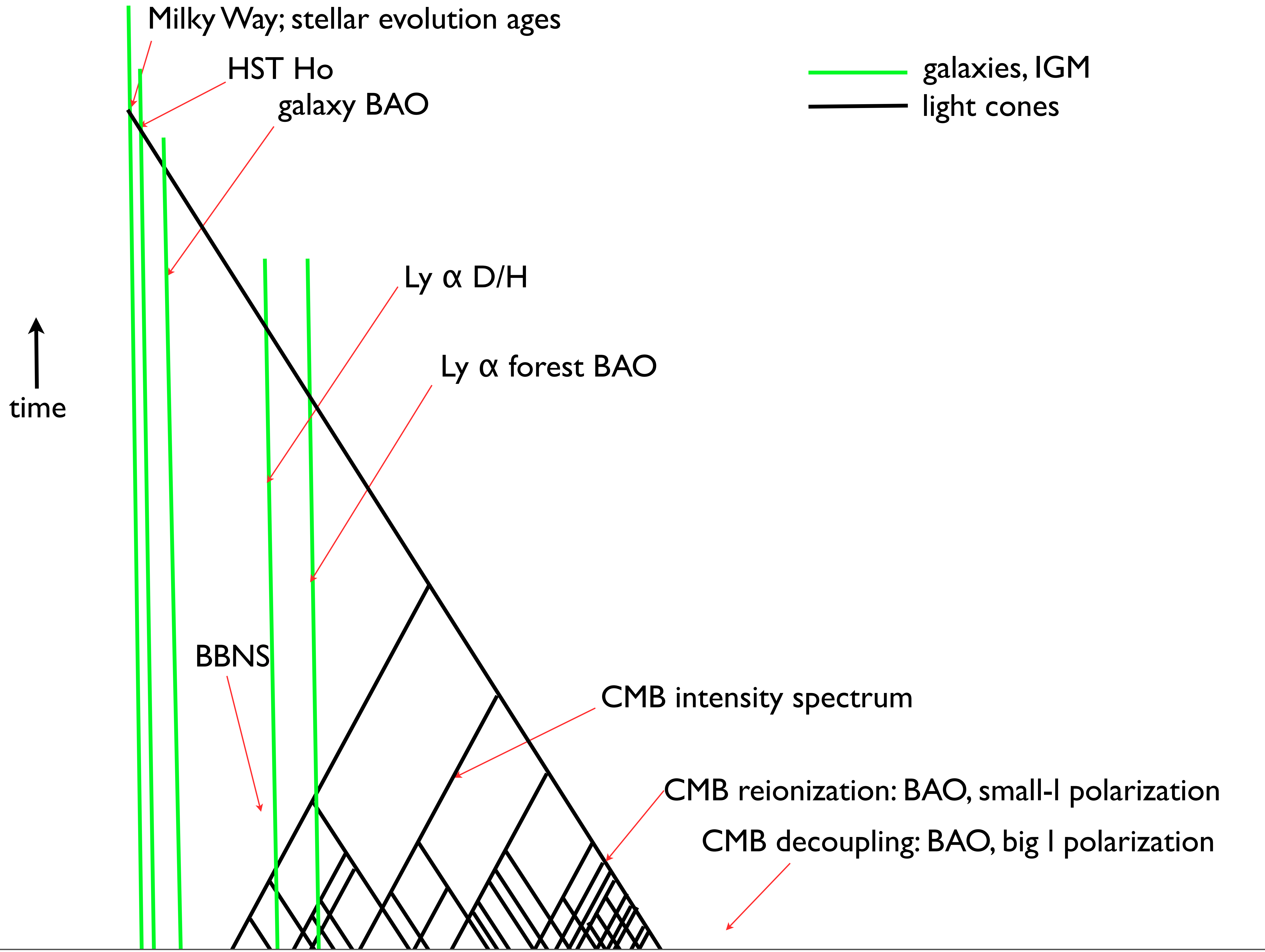
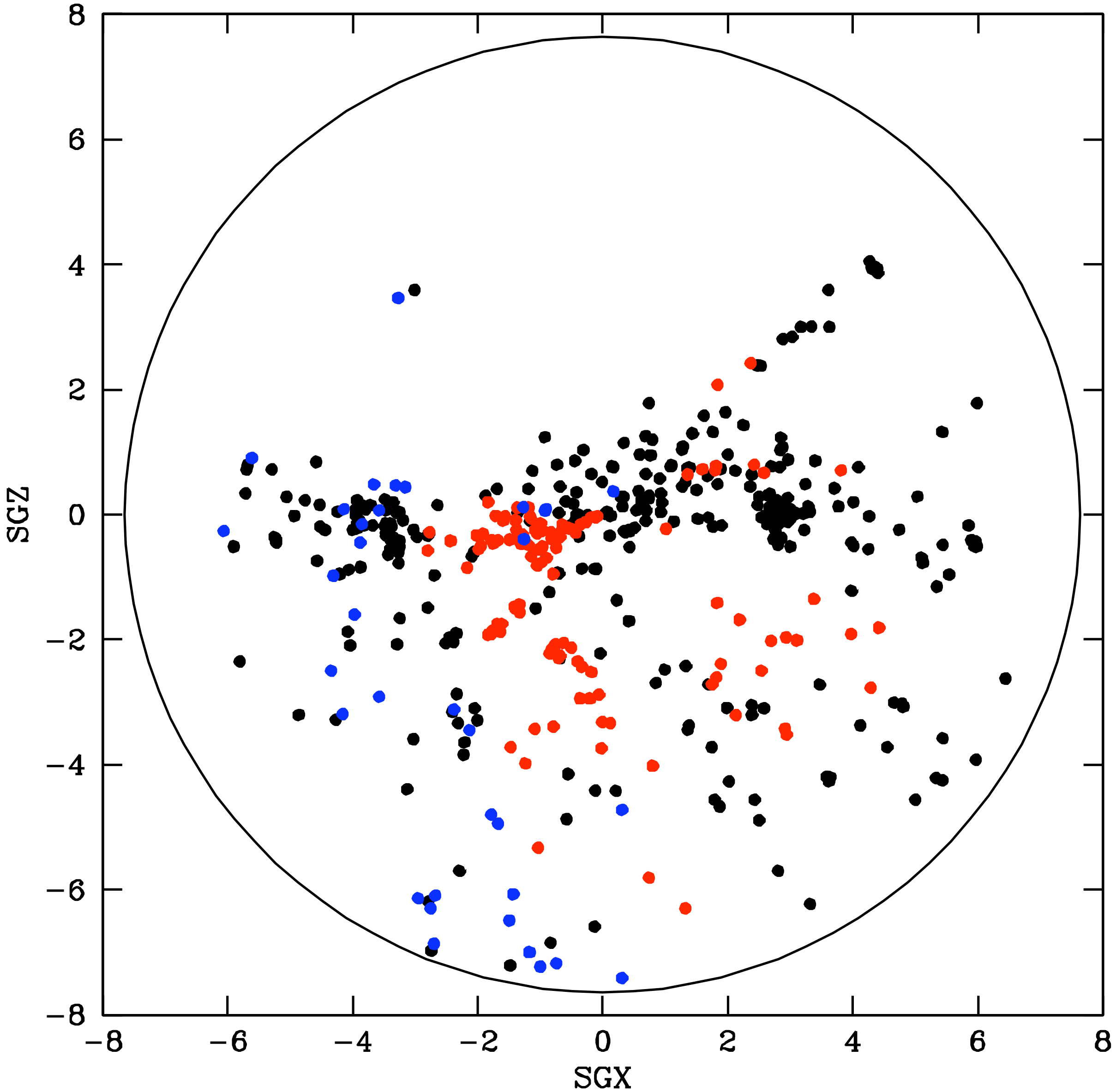

Milky Way; stellar evolution ages
HST Ho
galaxy BAO
galaxies, IGM
light cones
Ly α D/H
Ly α forest BAO
time
BBNS
CMB intensity spectrum
CMB reionization: BAO, small-l polarization
CMB decoupling: BAO, big l polarization



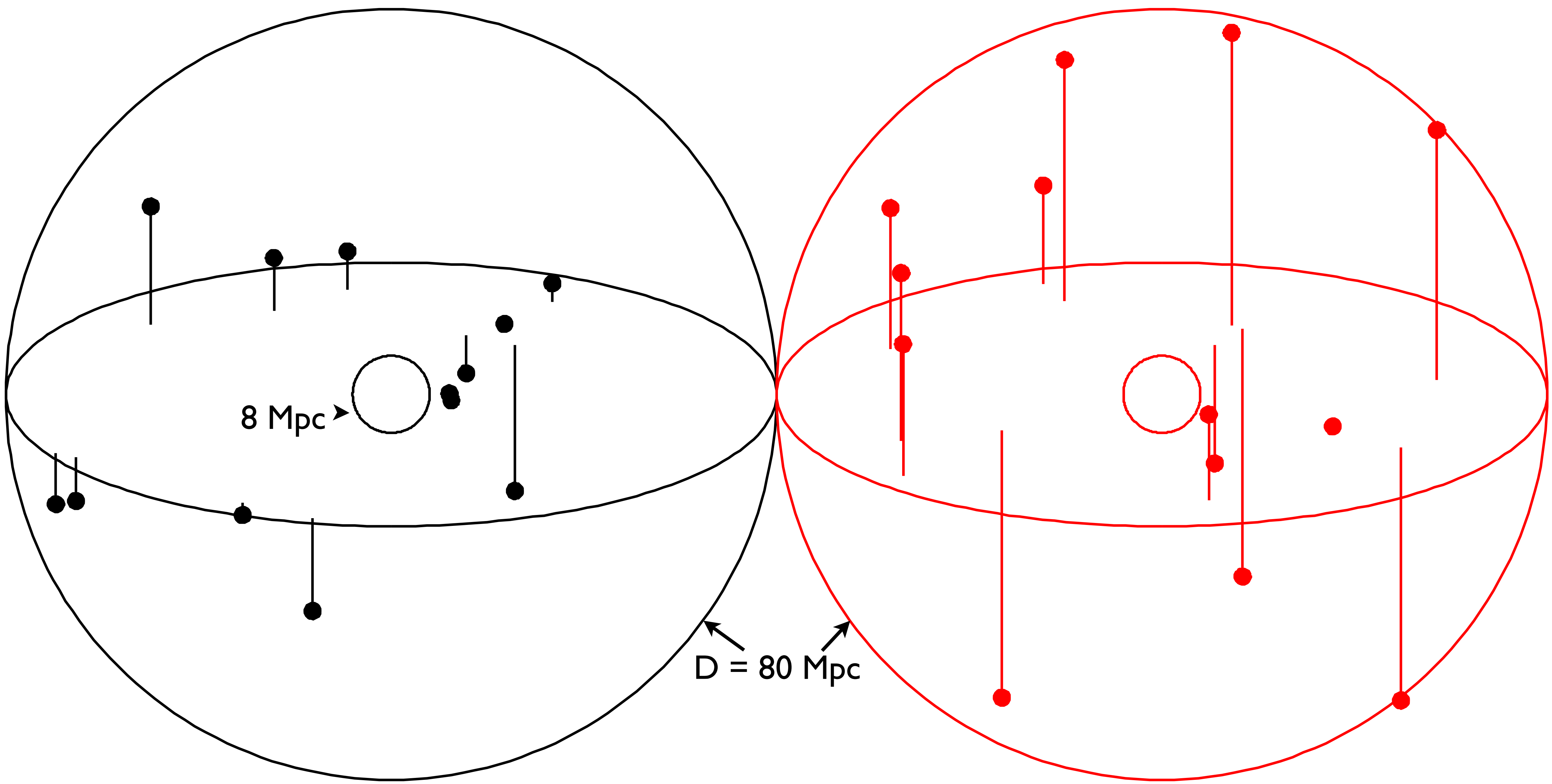
The de Vaucouleurs (1953)
Local Supercluster

Gérard and Antoinette de Vaucouleurs in Paris, 1962.

An Illustration of the Shaver–Pierre (1989, 1991) Effect

The 13 clusters of galaxies at $R < 80$ Mpc are close to the plane defined by the galaxies at $R < 8$ Mpc.

The 13 most luminous galaxies at 60 μ and $R < 80$ Mpc are little correlated with the plane of galaxies at $R < 8$ Mpc.



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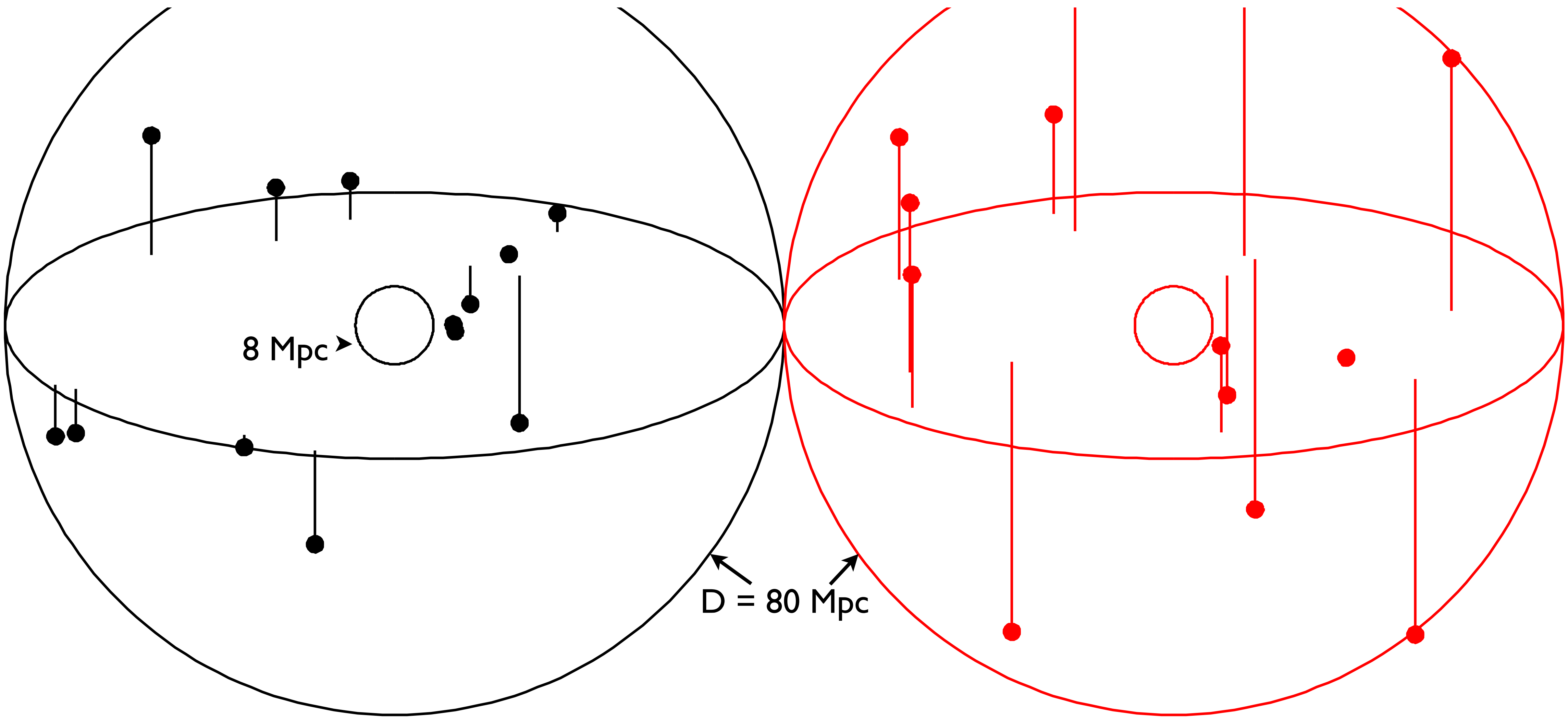
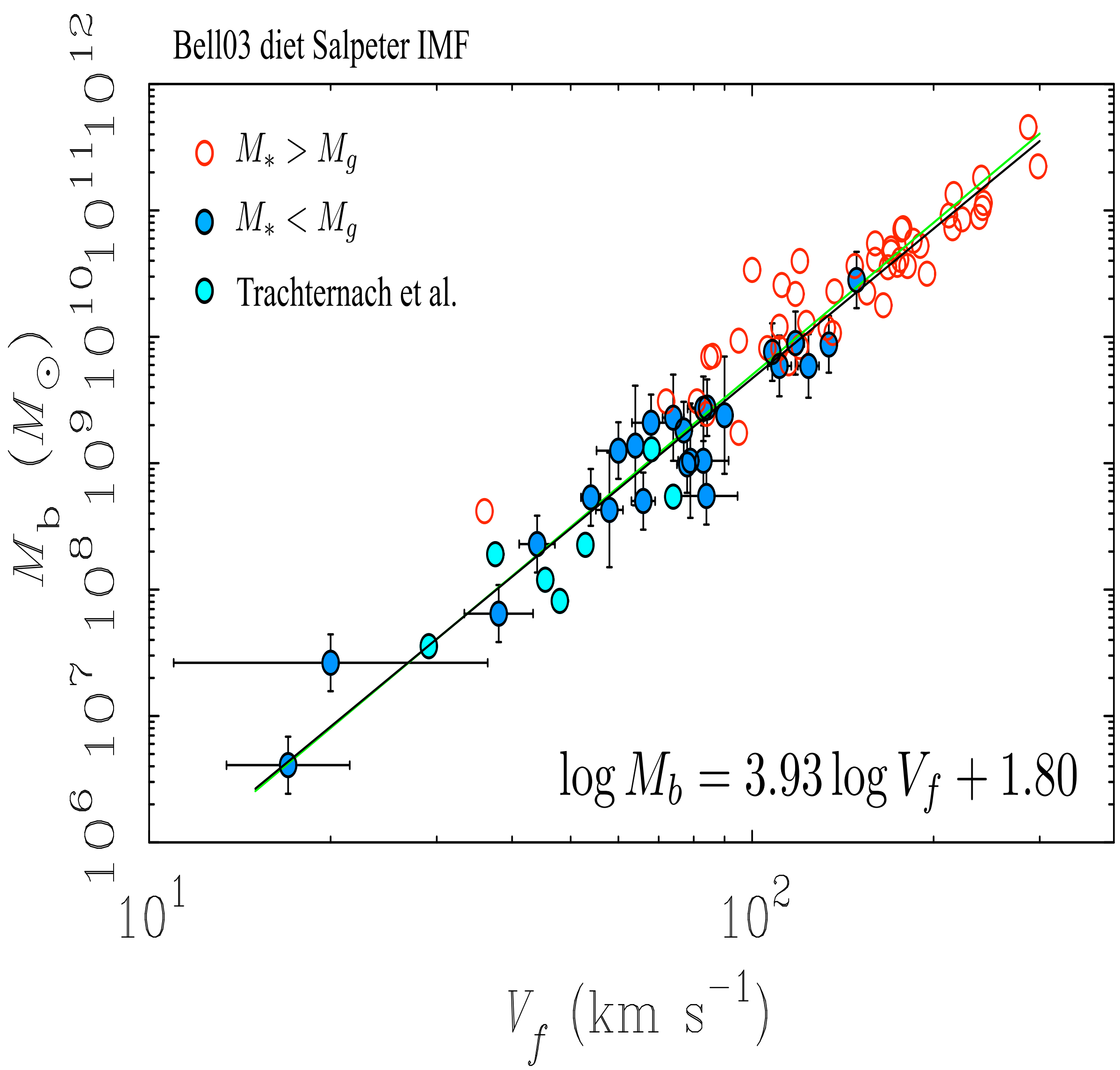


Baryonic Tully-Fisher Relation

Stark, McGaugh, & Swaters (2009 AJ, 138, 392)



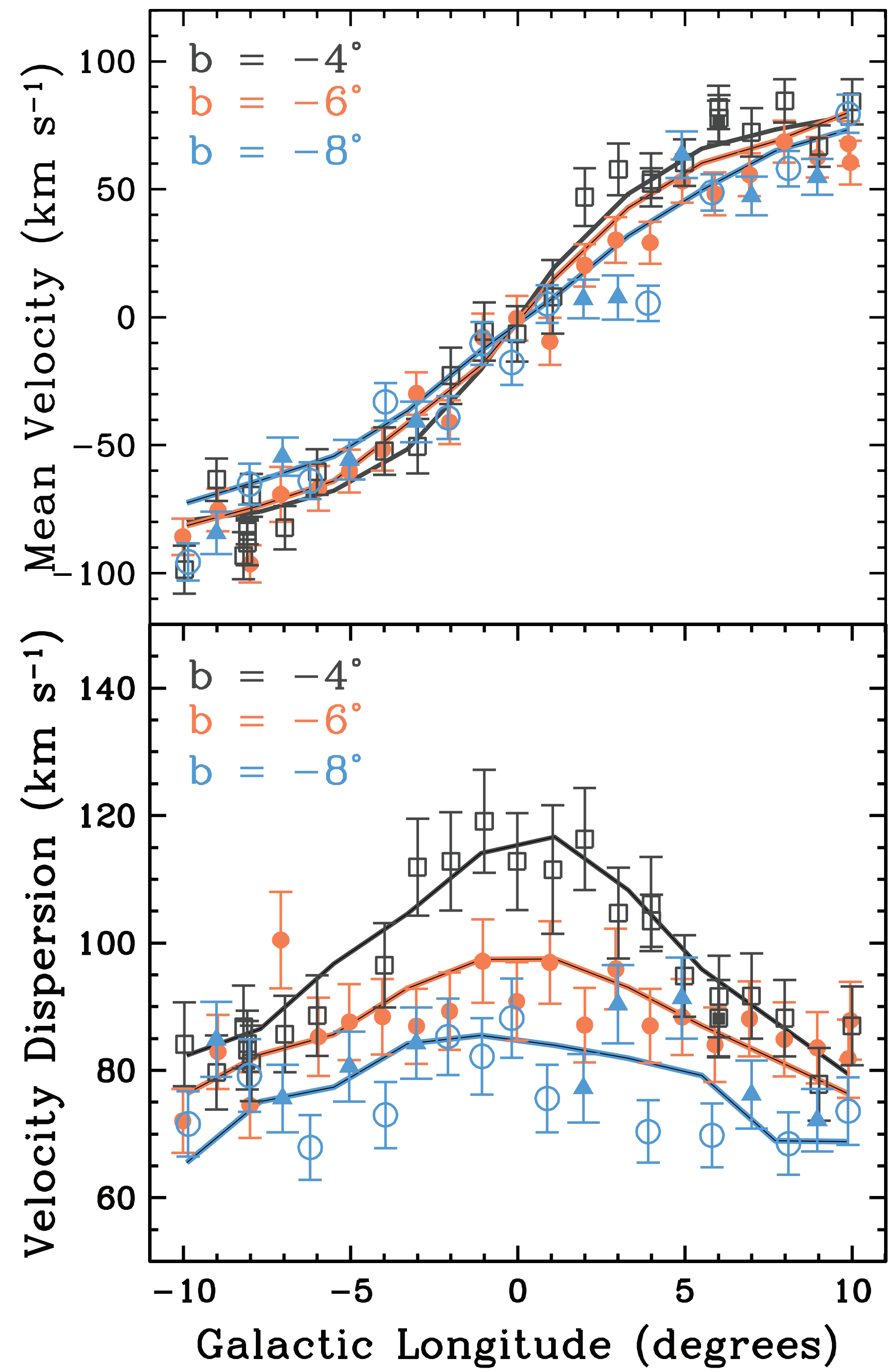


Figure 11. Velocity dispersion profile (bottom) and rotation curve (top) for the $b = -4°$, $-6°$, and $-8°$ strips. The filled symbols indicate data already published and the open symbols indicate the data presented here.

(A color version of this figure is available in the online journal.)

BRAVA, 2012