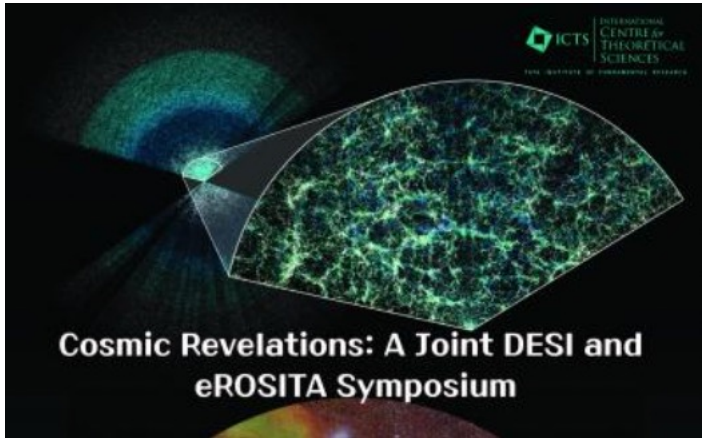
A short introduction to the long path to DESI & eROSITA

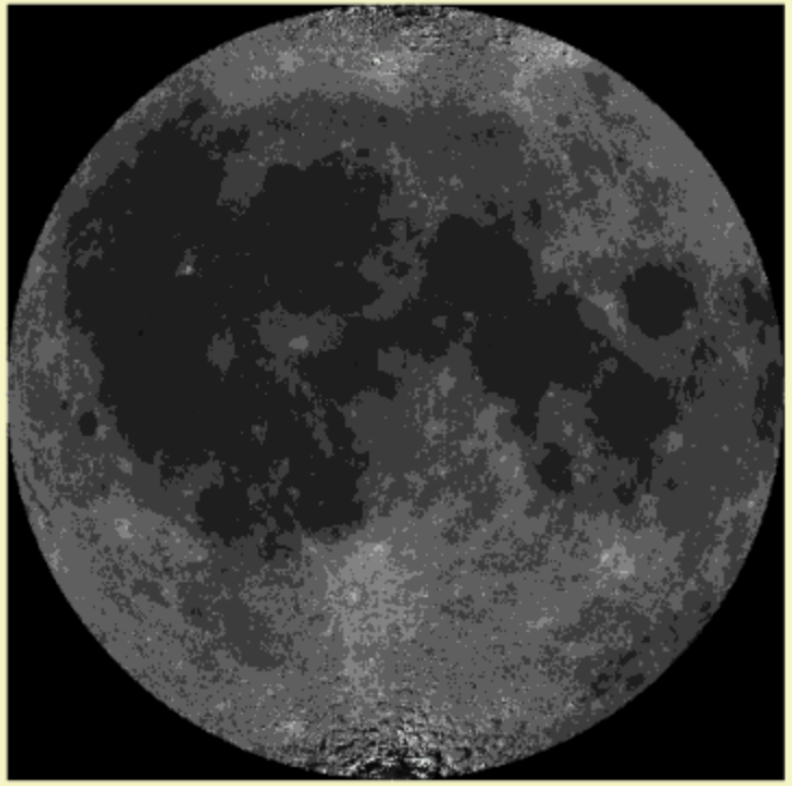
Subha Majumdar

TIFR, Mumbai



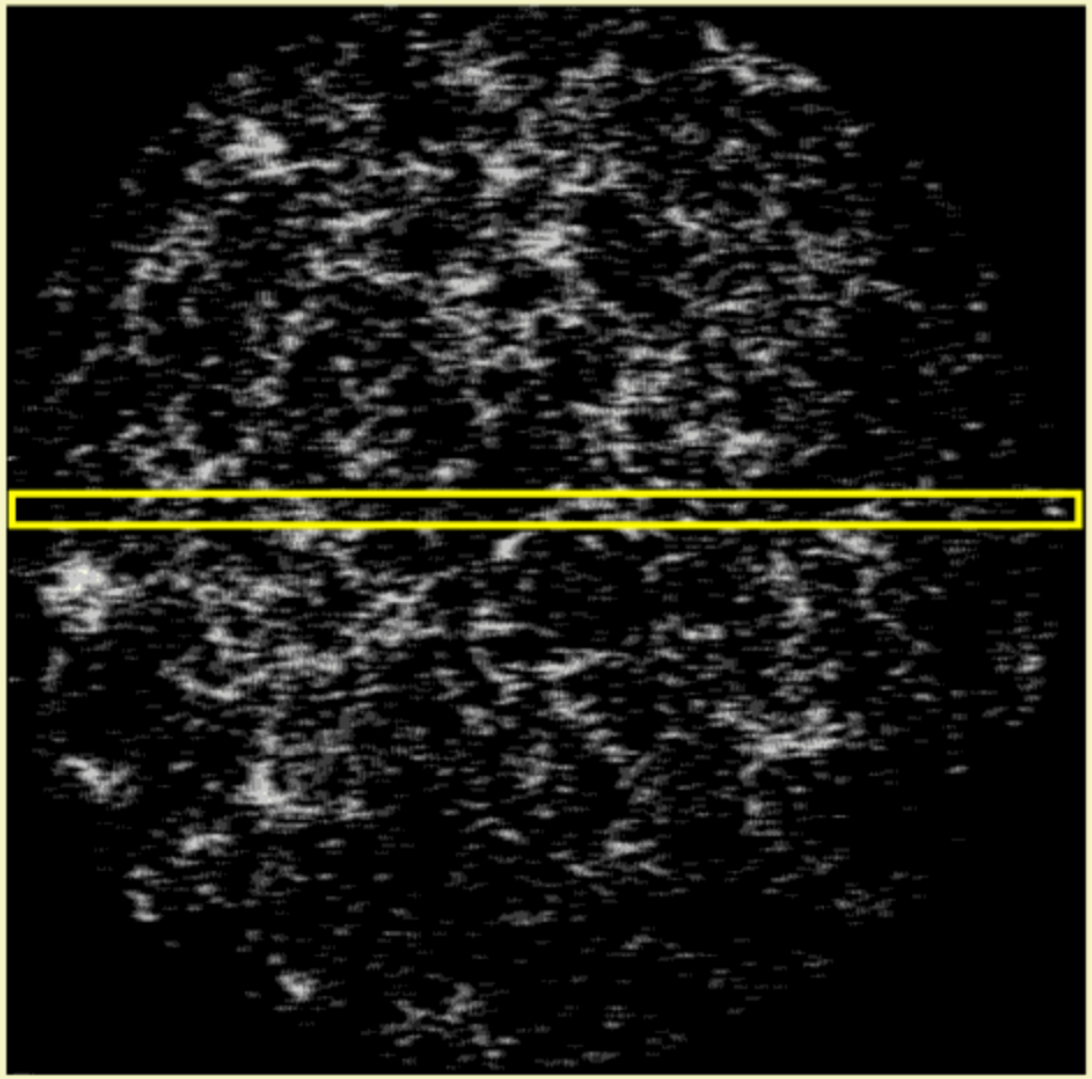
The night sky…

30 arcminutes = 1/2 degree



At 20th magnitude, most images are galaxies (1 million times fainter than the human eye - limit of photography on a 1m telescope)

The night sky…



1950s:

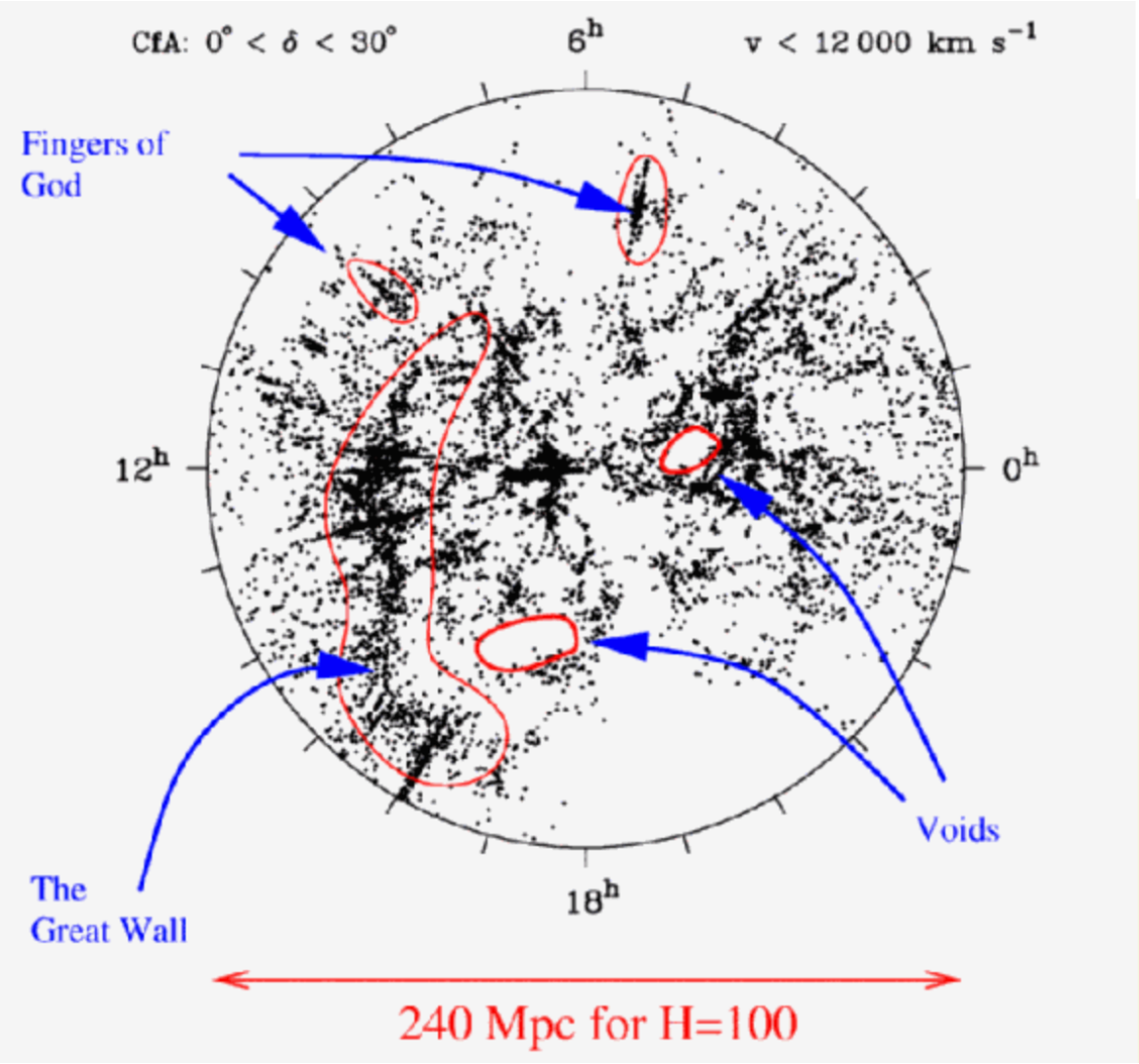
Shane & Wirtanen spend 10 years counting 1000,000 galaxies by eye

- filamentary patterns?

1980s:

Take a strip and get redshifts

The night sky…

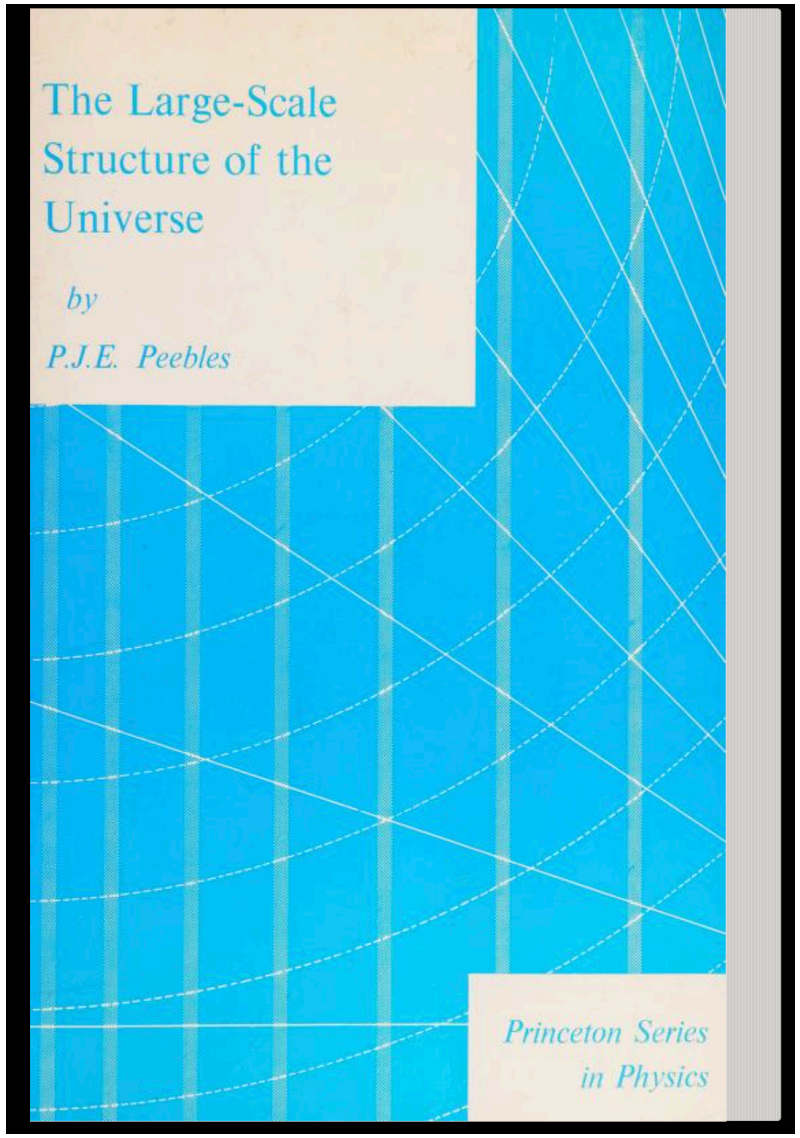


Redshift surveys (mid-1980s)

Inverting v = cz = Hd gives an approximate distance.

Applied to galaxies on a strip on the sky, gives a ‘slice of the universe’

Observations tickled the theoretical mind



The use of (mainly) 2-point statistics

and

Connecting it to theories of structure formation.

Mainly used for galaxies (the DESI connection)

Observations tickled the theoretical mind

THE ASTROPHYSICAL JOURNAL, 187:425–438, 1974 February 1

FORMATION OF GALAXIES AND CLUSTERS OF GALAXIES BY SELF-SIMILAR GRAVITATIONAL CONDENSATION*

WILLIAM H. PRESS AND PAUL SCHECHTER
California Institute of Technology
Received 1973 August 1

ABSTRACT

We consider an expanding Friedmann cosmology containing a "gas" of self-gravitating masses. The masses condense into aggregates which (when sufficiently bound) we identify as single particles of a larger mass. We propose that after this process has proceeded through several scales, the mass spectrum of condensations becomes "self-similar" and independent of the spectrum initially assumed. Some details of the self-similar distribution, and its evolution in time, can be calculated with the linear perturbation theory. Unlike other authors, we make no ad hoc assumptions about the spectrum of long-wavelength initial perturbations: the nonlinear N-body interactions of the mass points randomize their positions and generate a perturbation to all larger scales; this should fix the self-similar distribution almost uniquely. The results of numerical experiments on 1000 bodies are presented; these appear to show new nonlinear effects: condensations can "bootstrap" their way up in size faster than the linear theory predicts. Our self-similar model predicts relations between the masses and radii of galaxies and clusters of galaxies, as well as their mass spectra. We compare the predictions with available data, and find some rather striking agreements. If the model is to explain galaxies, then isothermal "seed" masses of $\sim 3 \times 10^7\ M_\odot$ must have existed at recombination. To explain clusters of galaxies, the only necessary seeds are the galaxies themselves. The size of clusters determines, in principle, the deceleration parameter q_0; presently available data give only very broad limits, unfortunately.

Subject headings: cosmology — galaxies — galaxies, clusters of

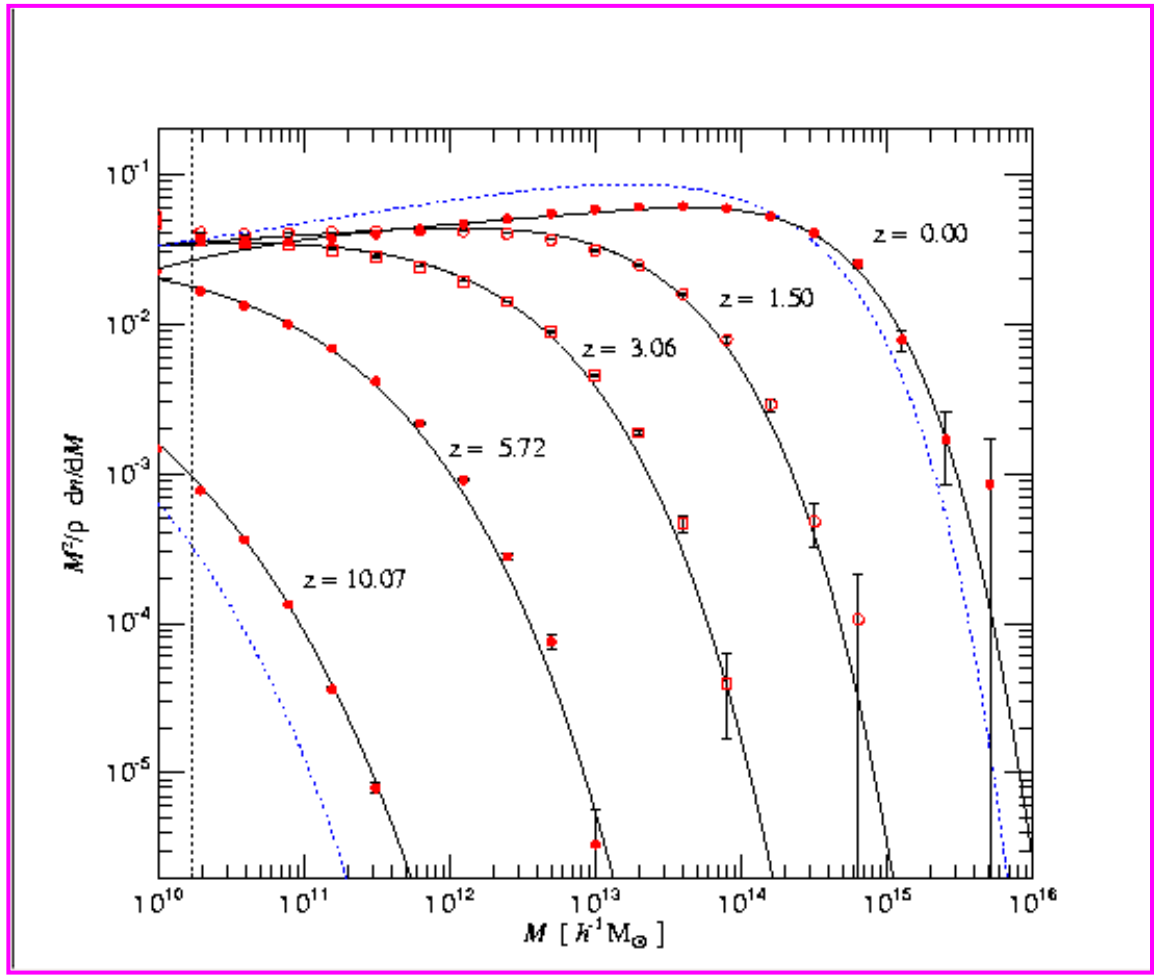
The use of (mainly) 1-point statistics, i.e just counts

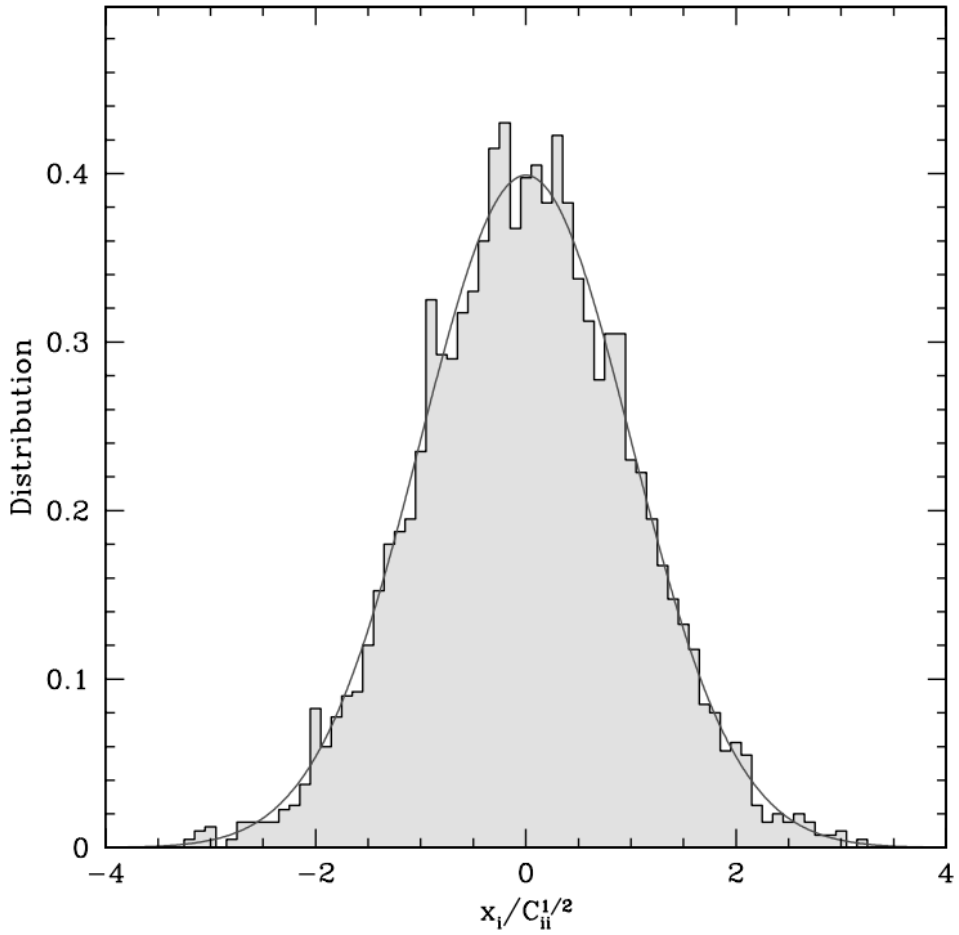
and

Connecting it to theories of structure formation.

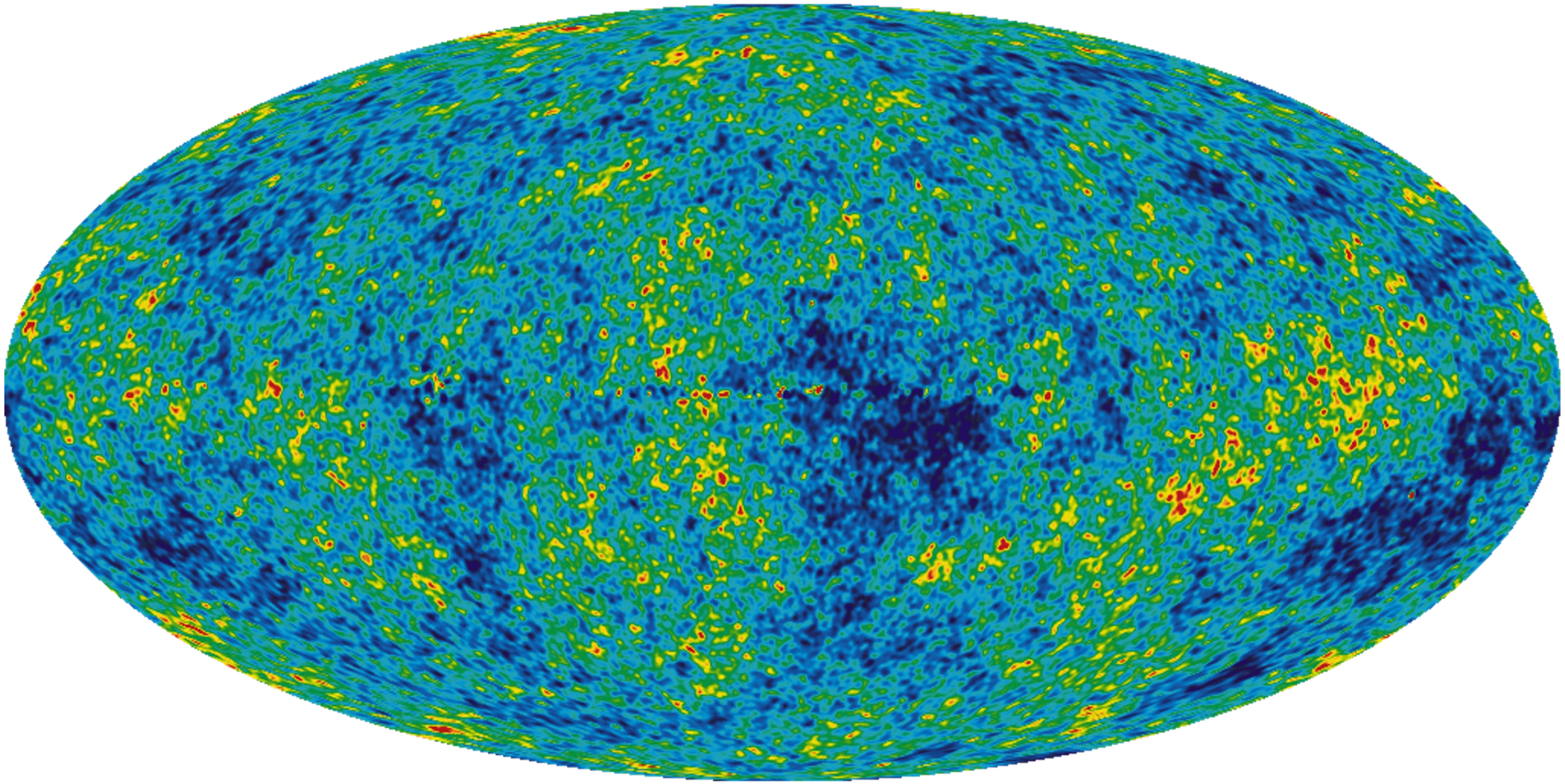
Mainly used for galaxy clusters.
(the eROSITA connection)

Observations tickled the theoretical mind (and later the simulators):





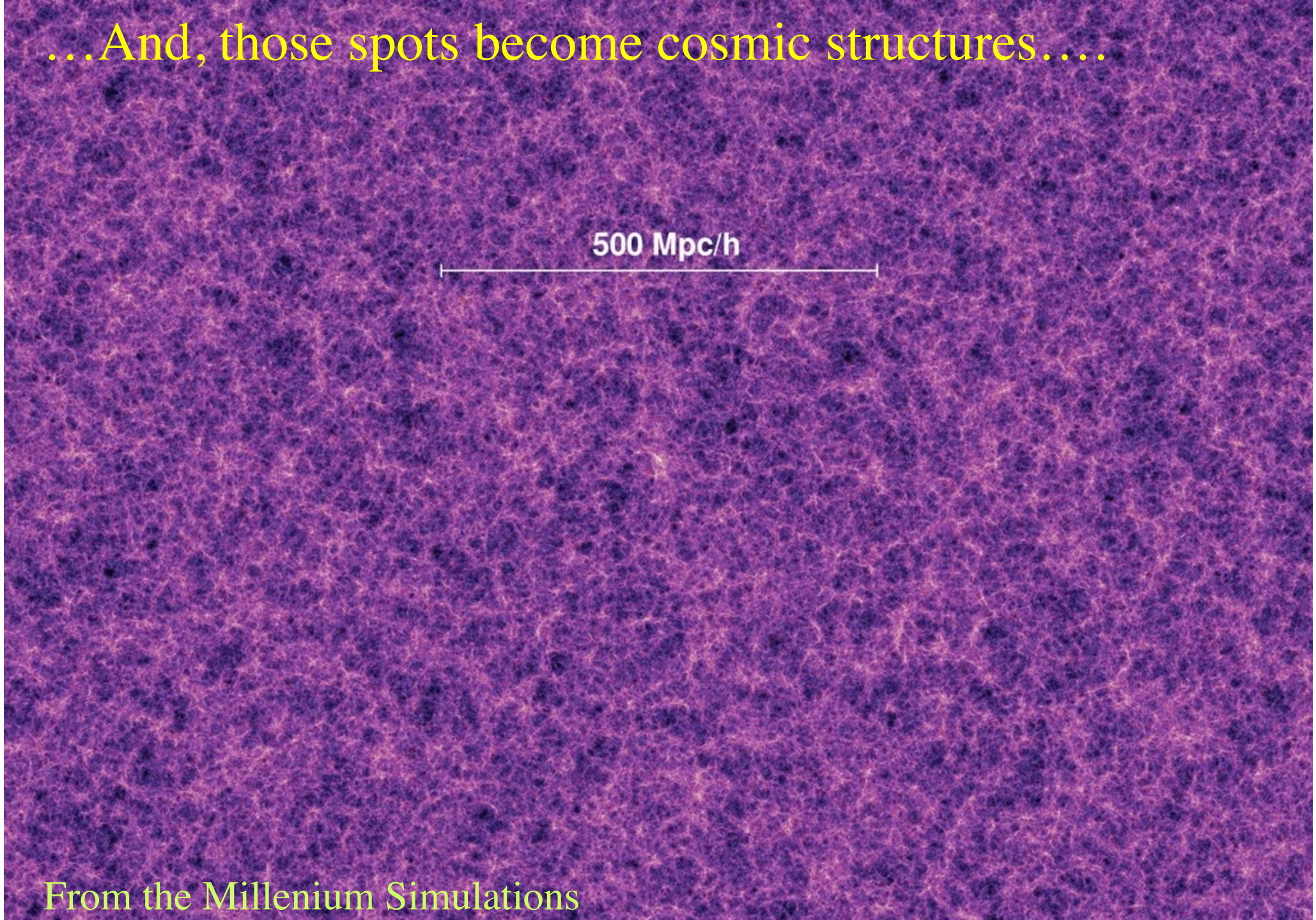
The other big connection:
CMB anisotropies to Large Scale Structures



…And, those spots become cosmic structures…..

From the Millenium Simulations

…And, those spots become cosmic structures…..



From the Millenium Simulations

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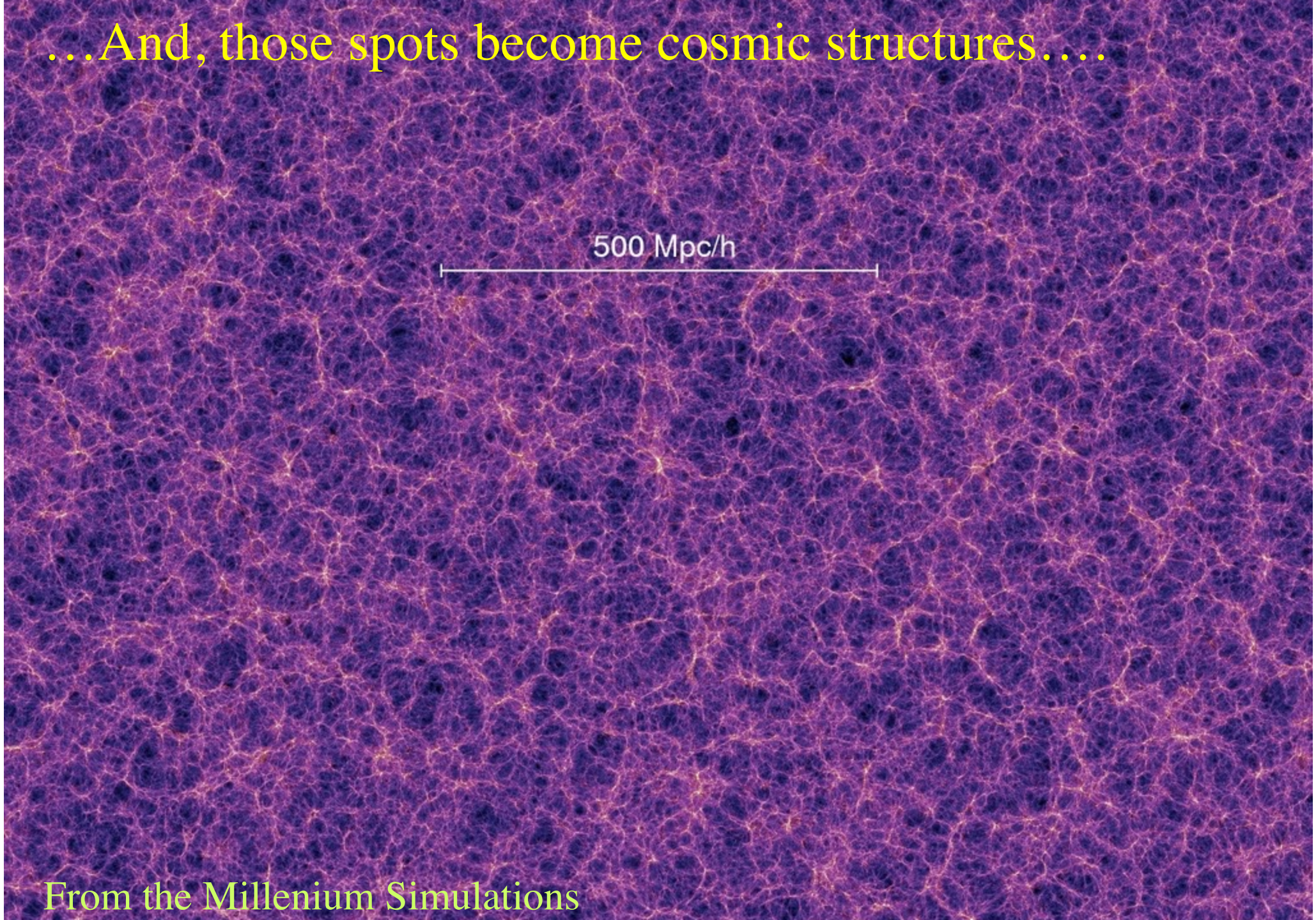
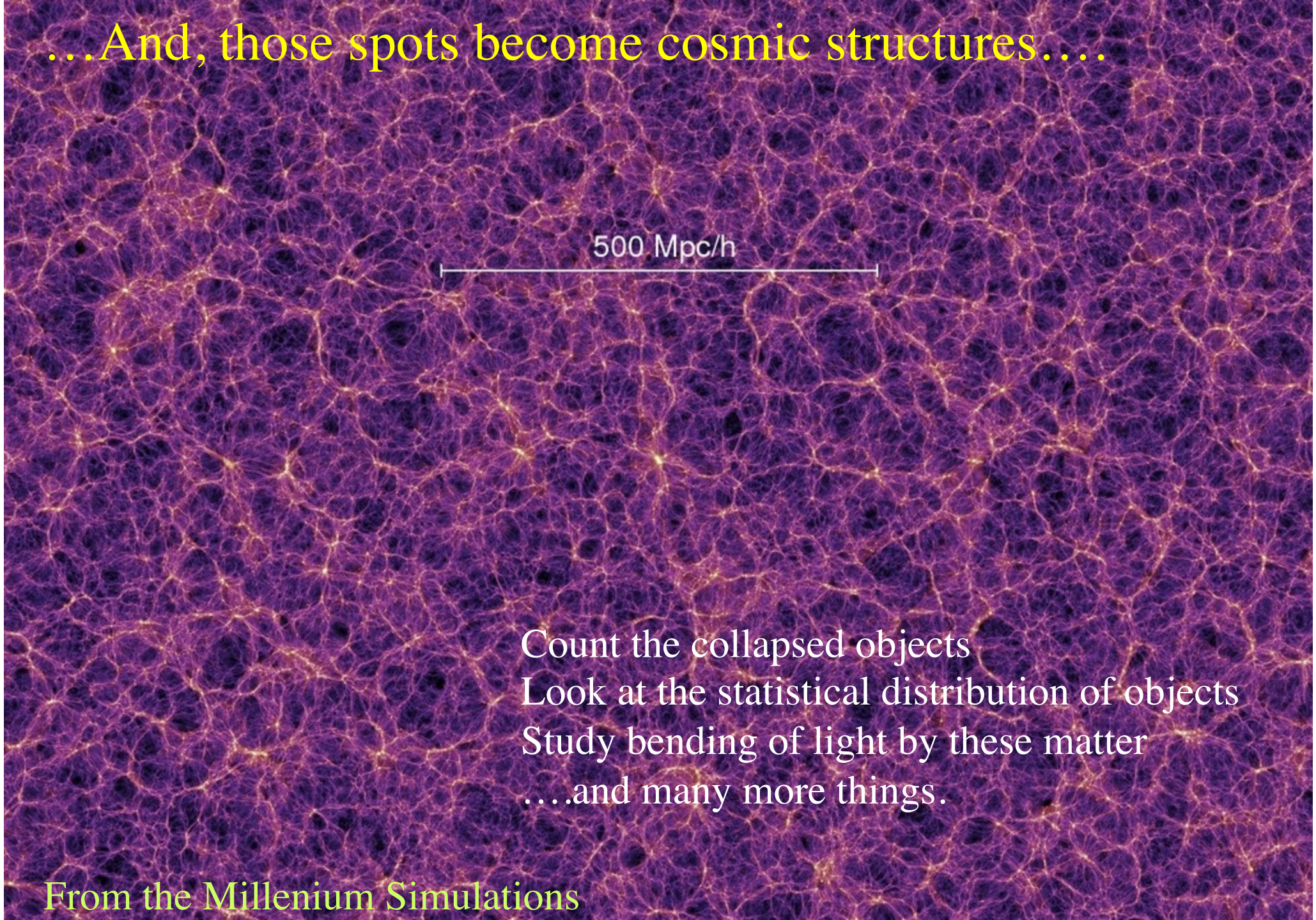


From the Millenium Simulations

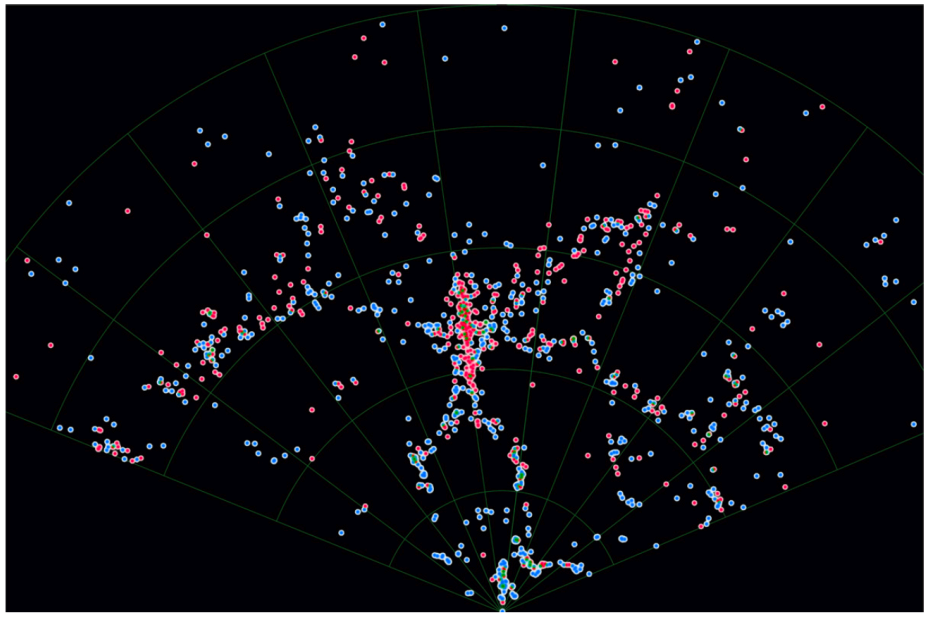
…And, those spots become cosmic structures…..

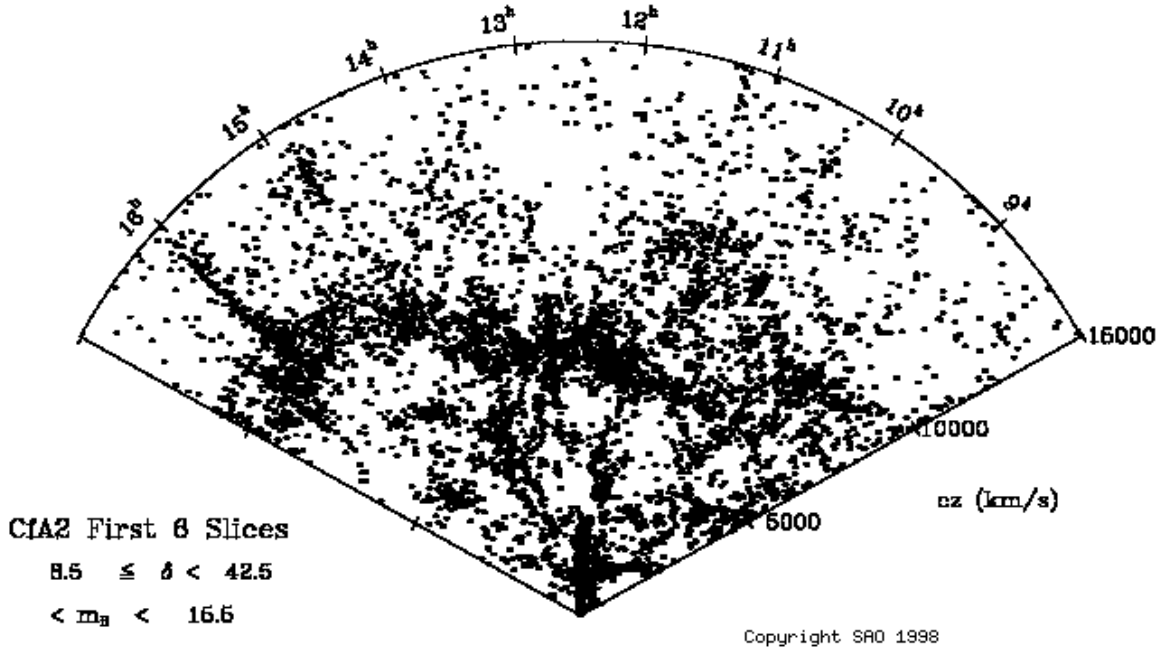


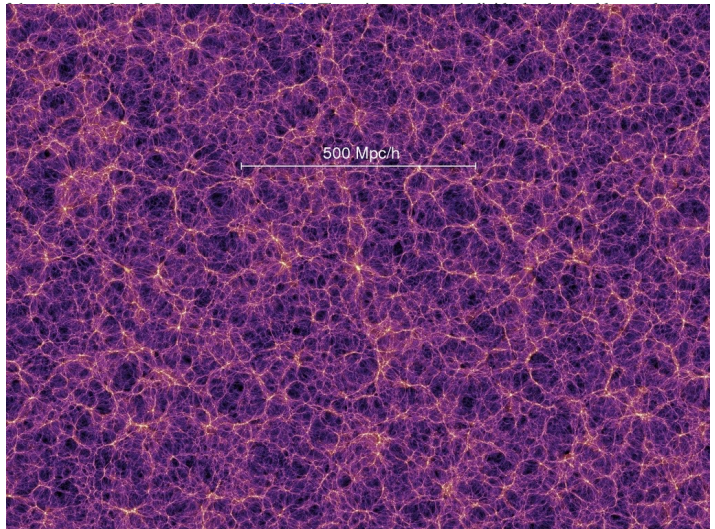
Count the collapsed objects
Look at the statistical distribution of objects
Study bending of light by these matter
….and many more things.

From the Millenium Simulations

The start of modern galaxy surveys…
(CfA1 1978-1982, CfA2 1985 -1995, 18000 objects with redshift)

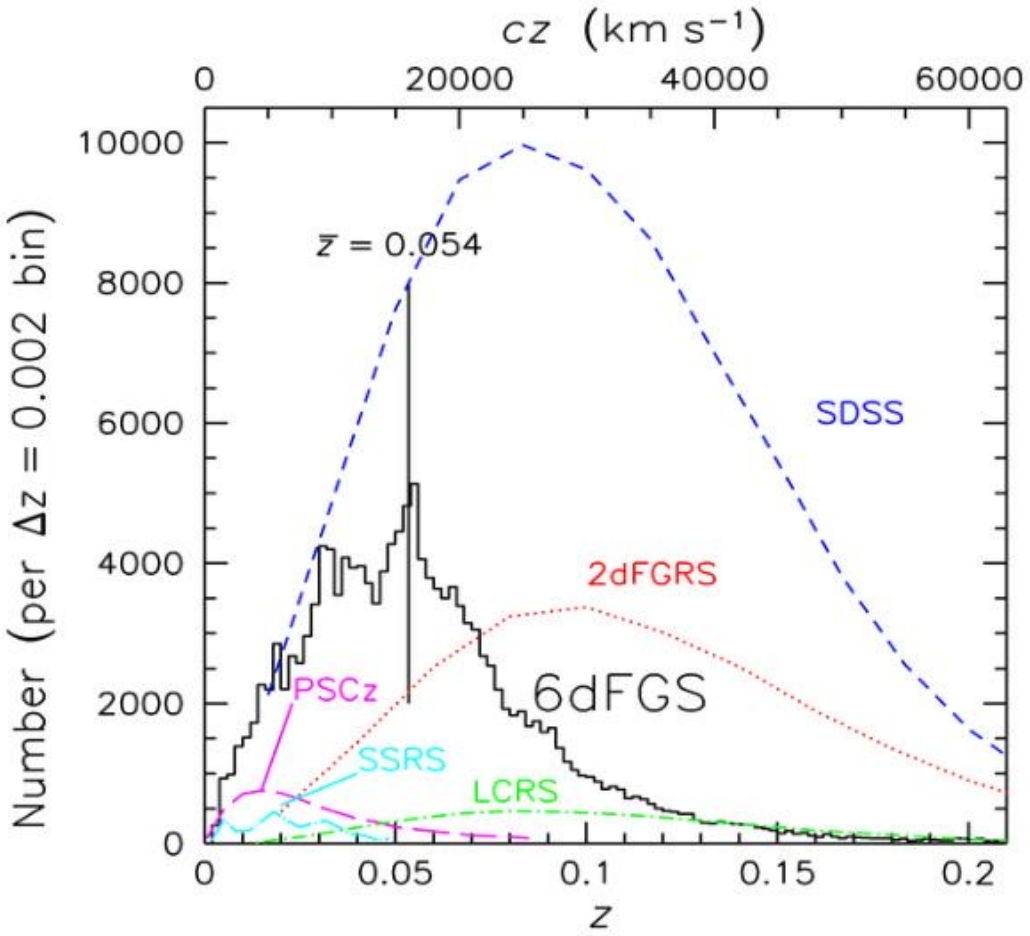


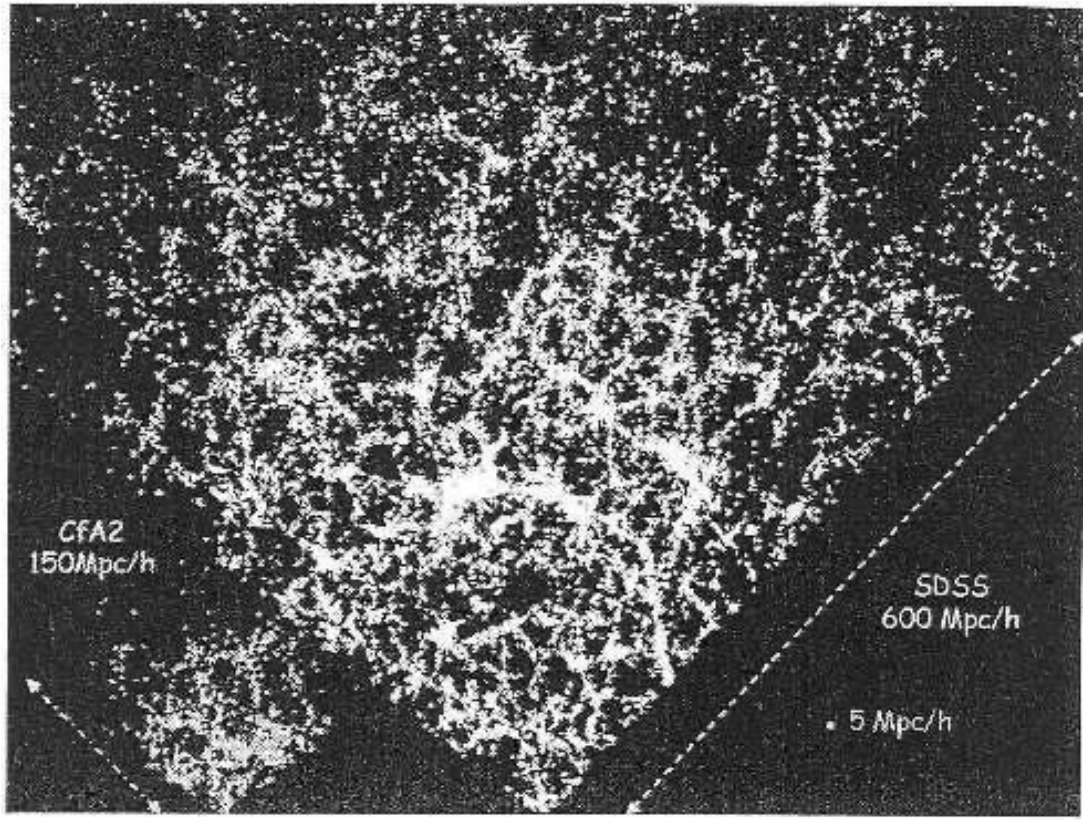




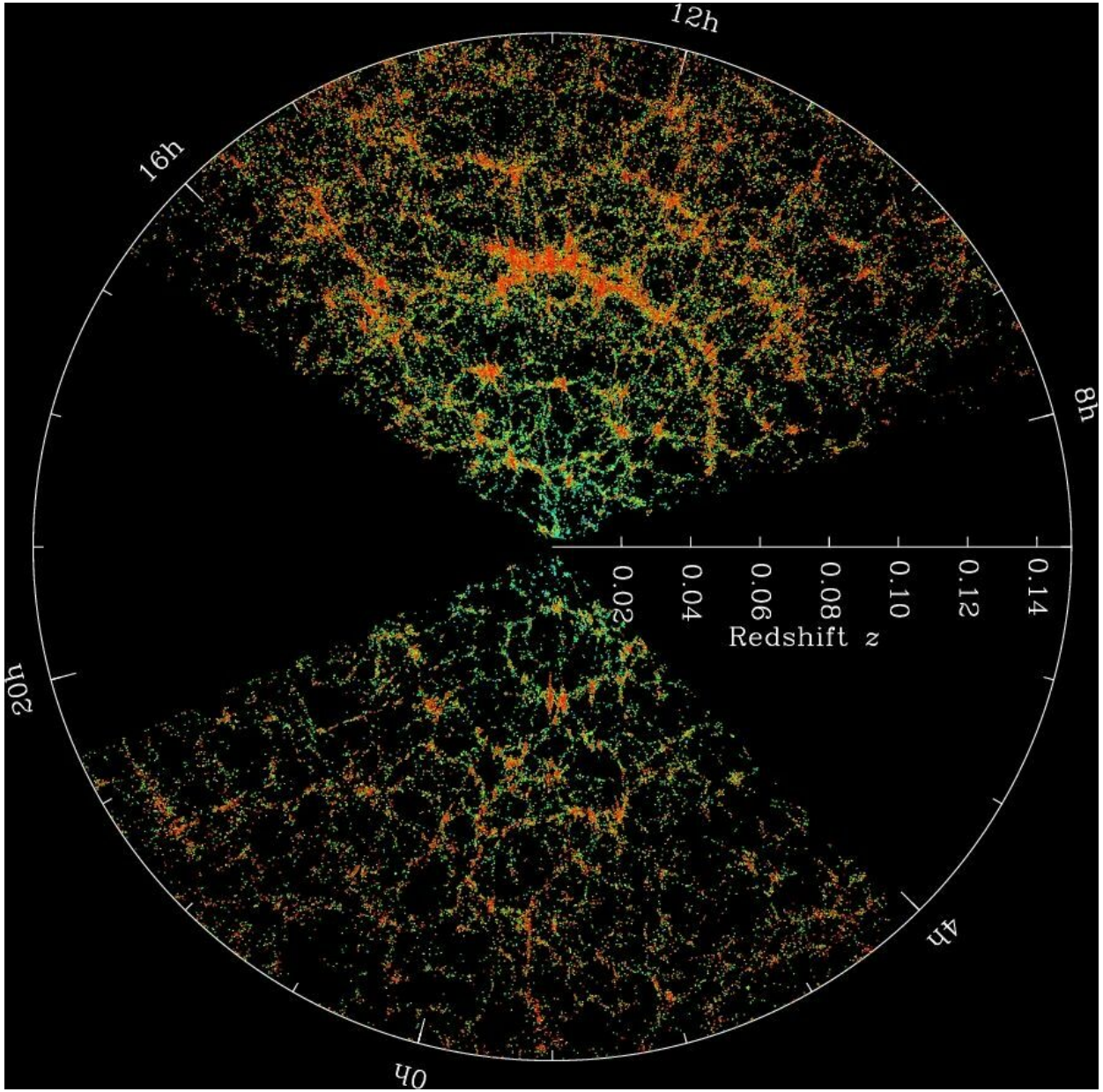
The COSMIC WEB from observations can now be compared to simulations

The next generation of surveys were planned (1995 – 2005)..

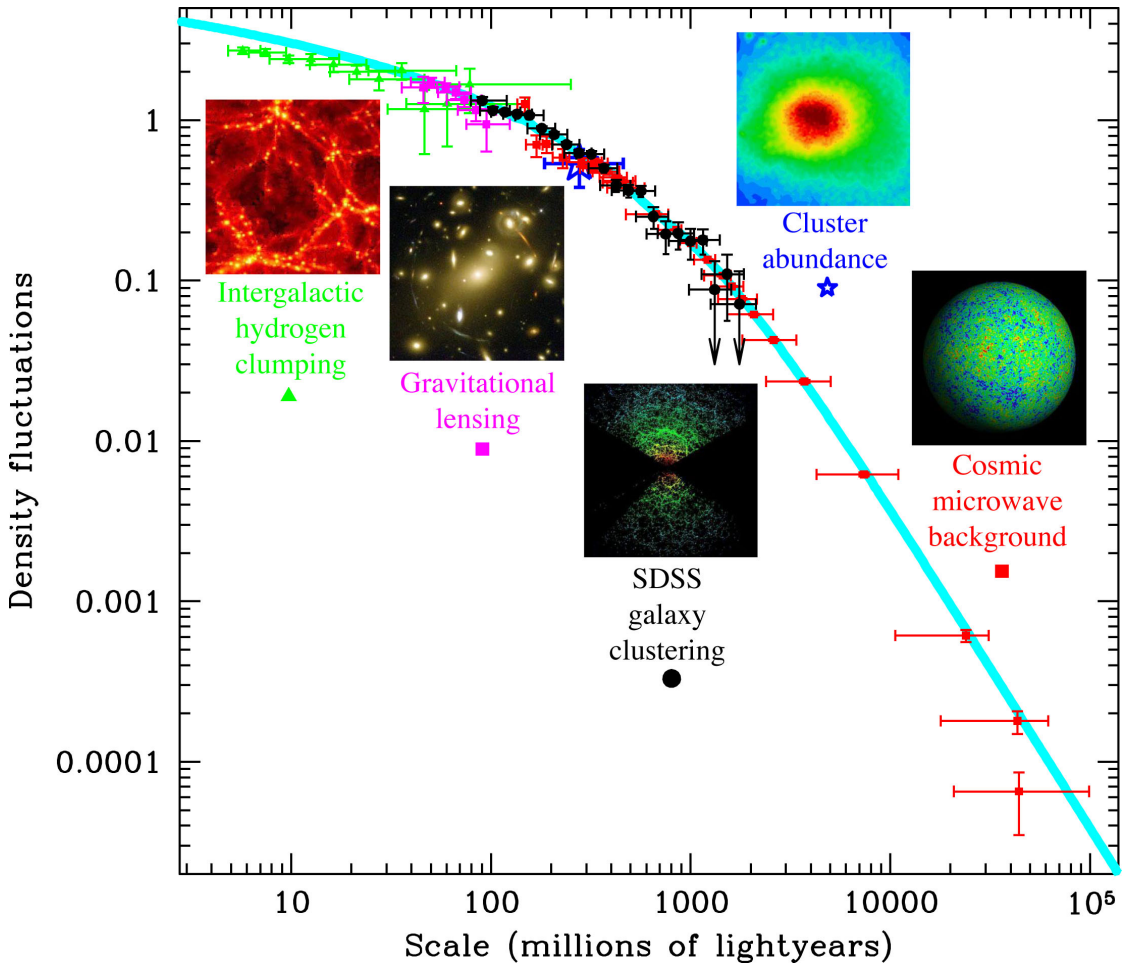


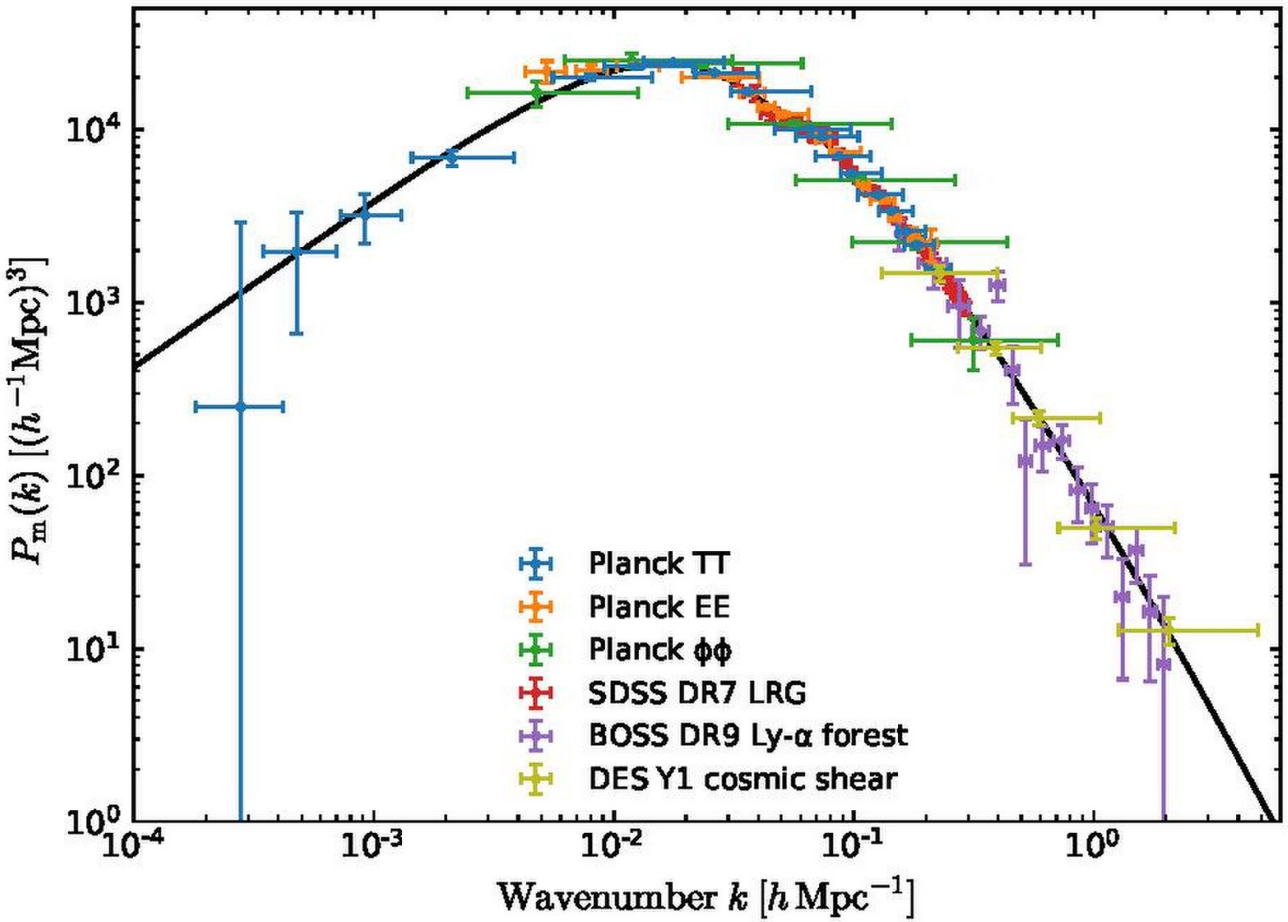


A spectacular map of the Universe (2000)

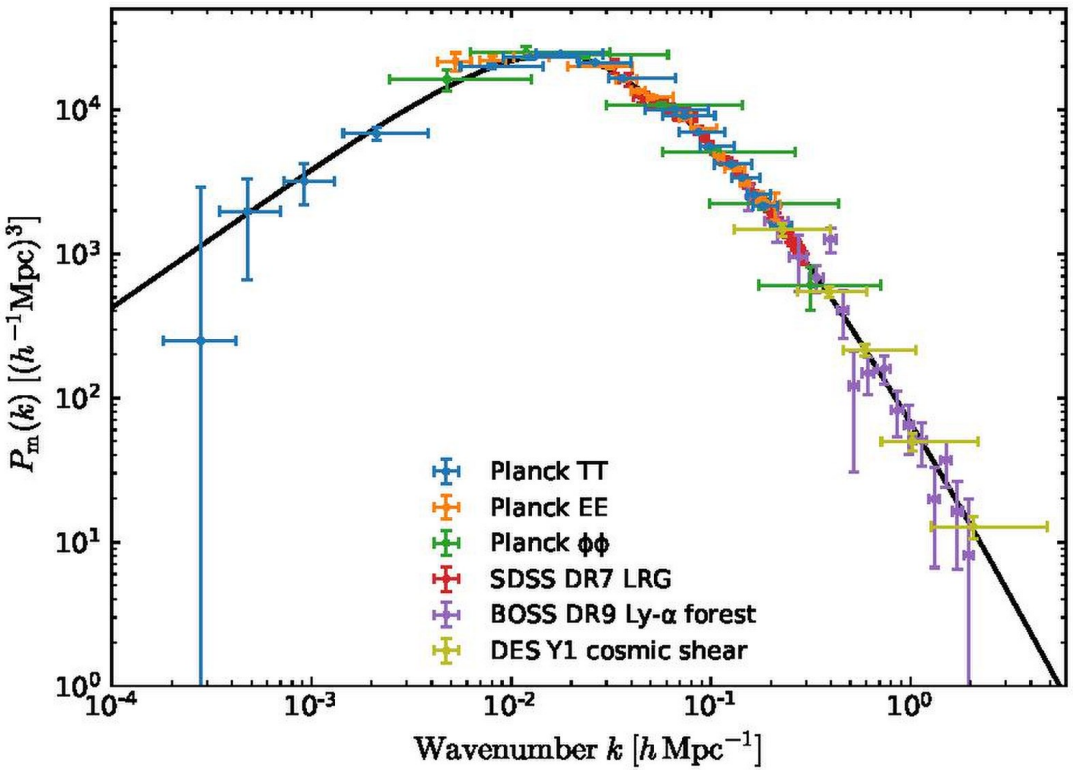


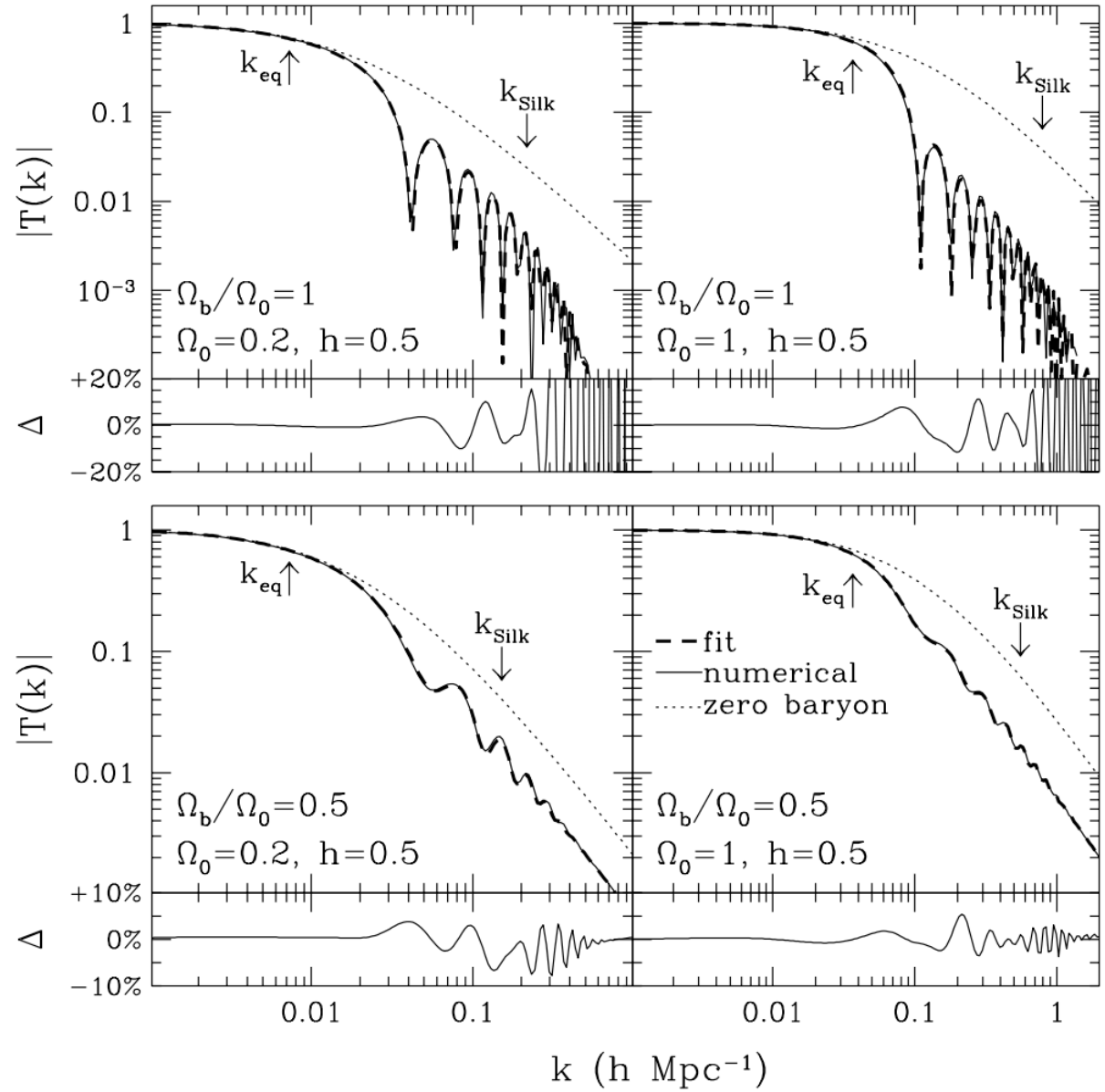
Large Scale structure starts to complement CMB to build the full picture (2000+) -2020s.



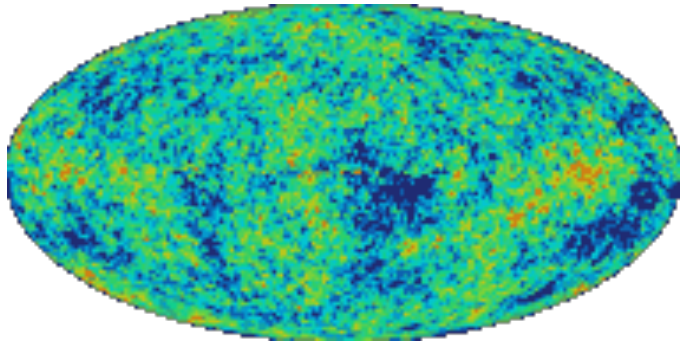


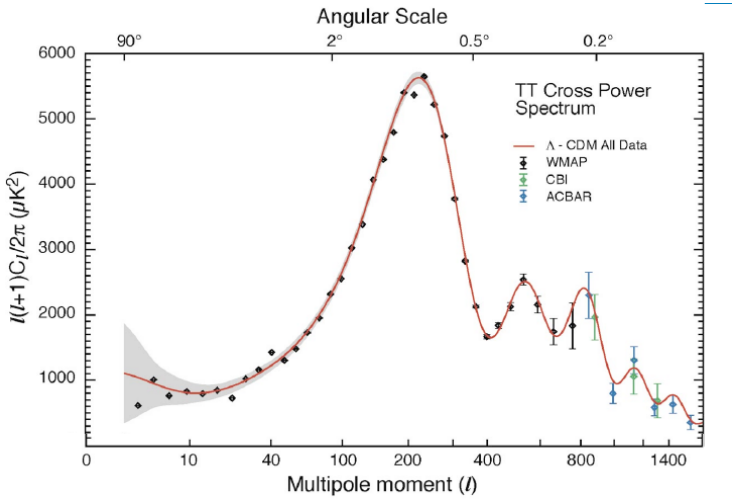
Features and scales in Pk



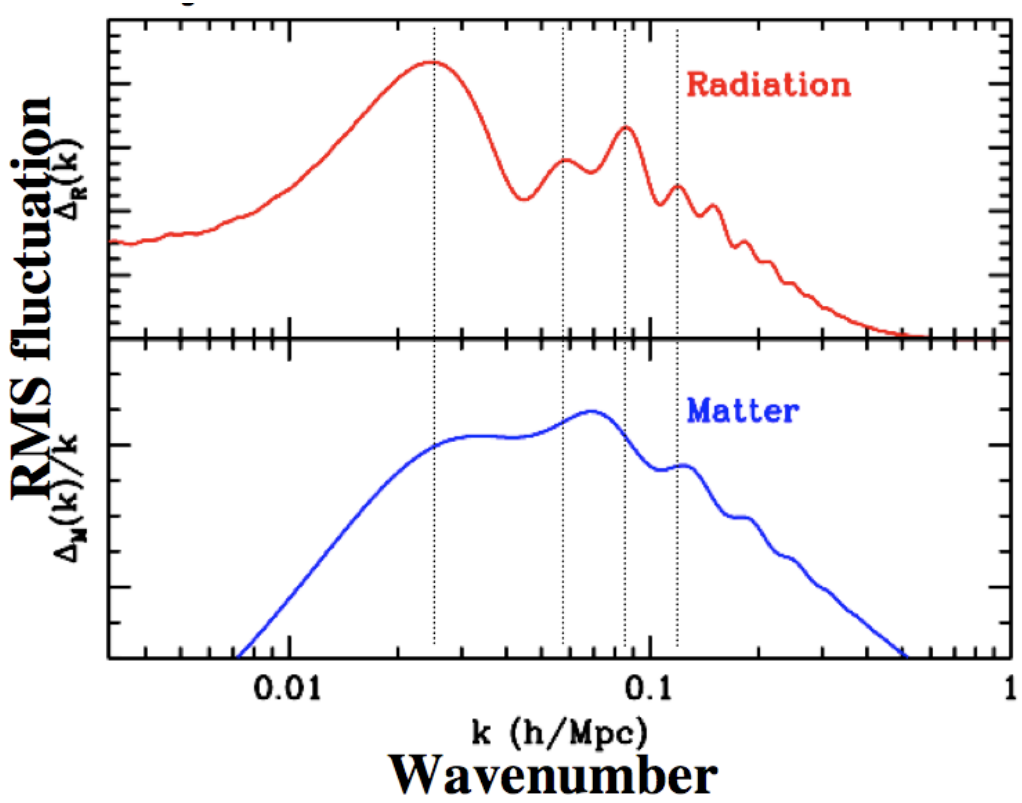


The big story today is not just about statistics. Its about a special feature called BAO





White (2005)



The same physical processes affect both the CMB and the matter power spectrum.

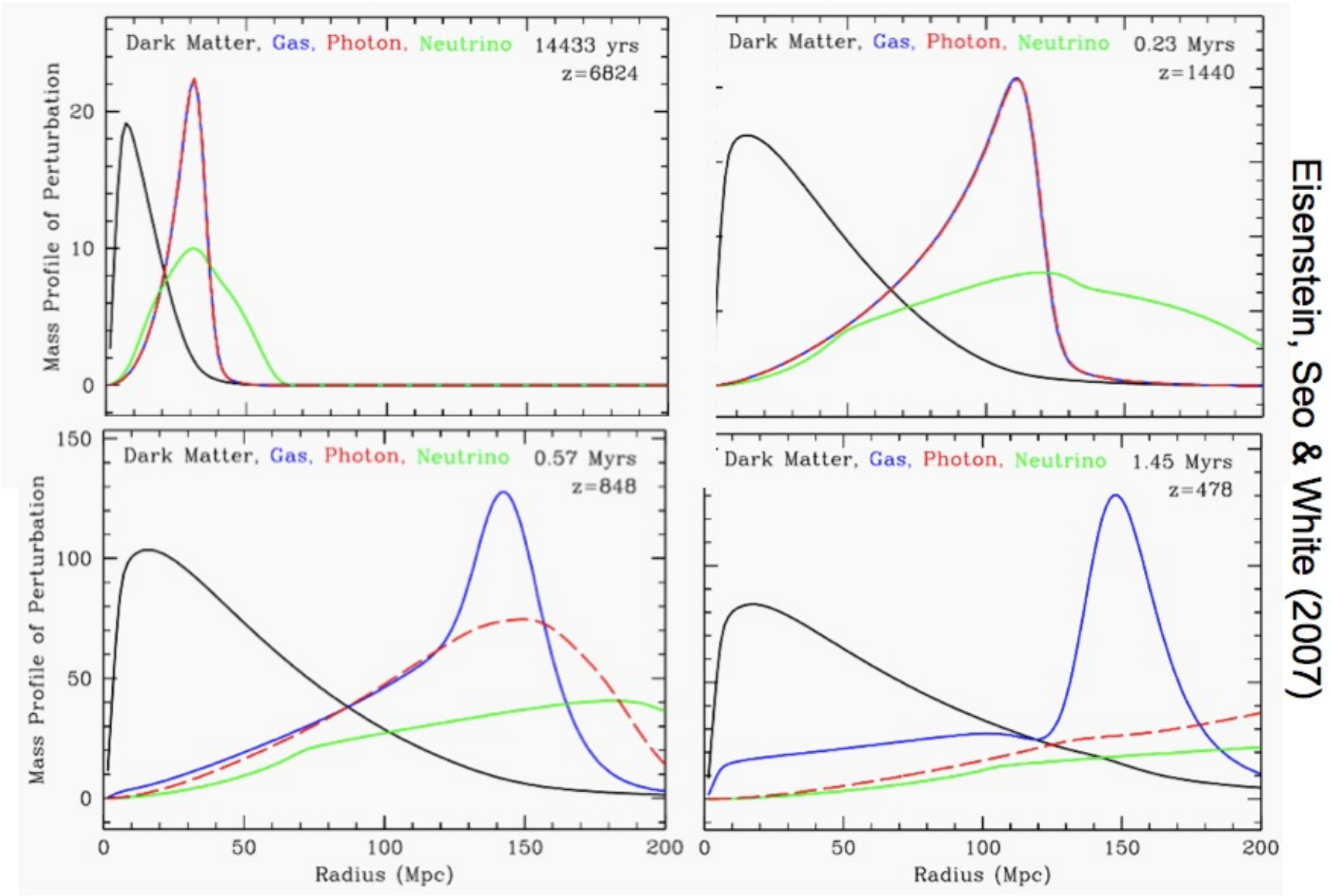
Plane-waves interfere with each other

Phases frozen at recombination

Gravity+hydro on small scale evolves perturbations

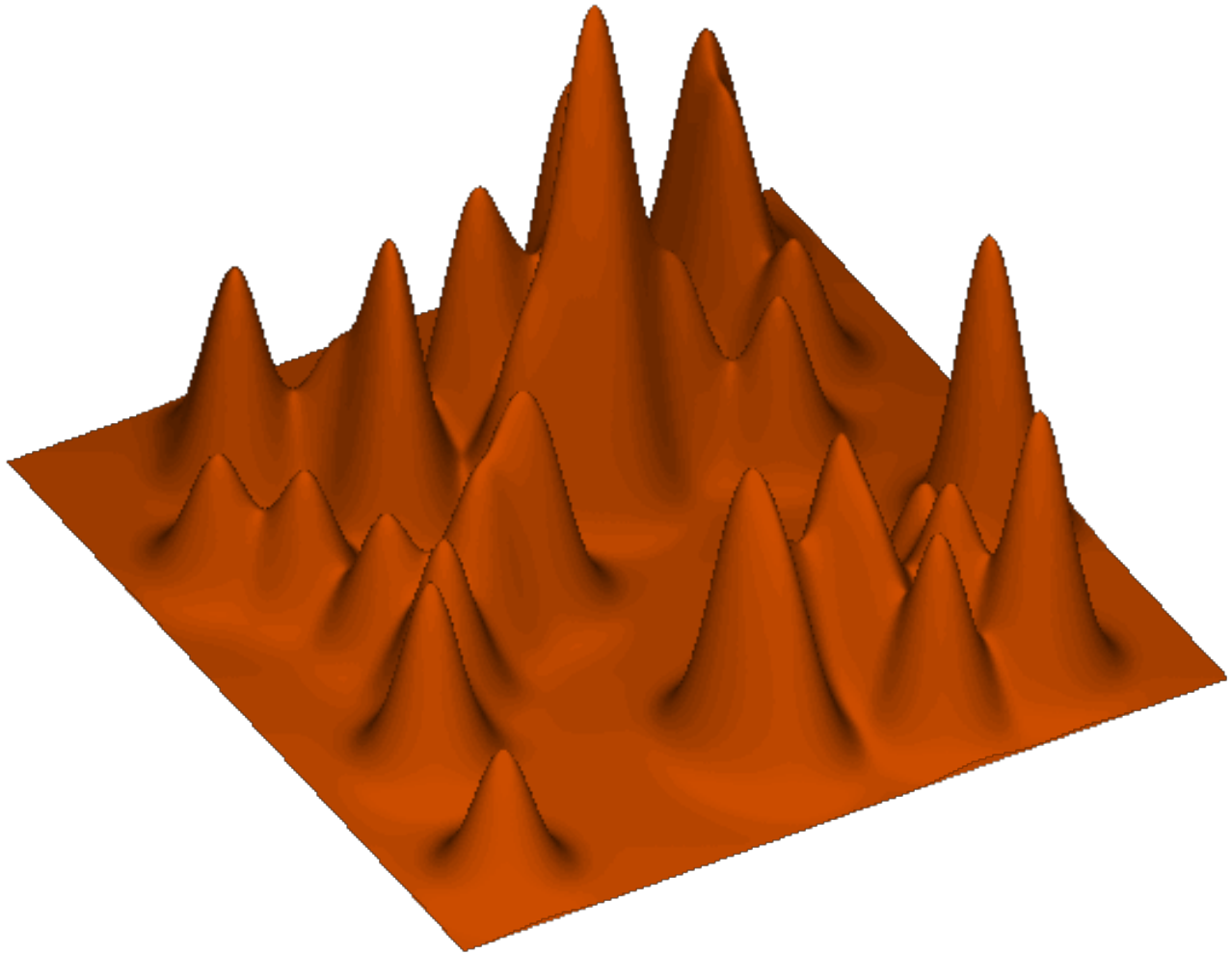
Small-scale silk damping

The BAO physics



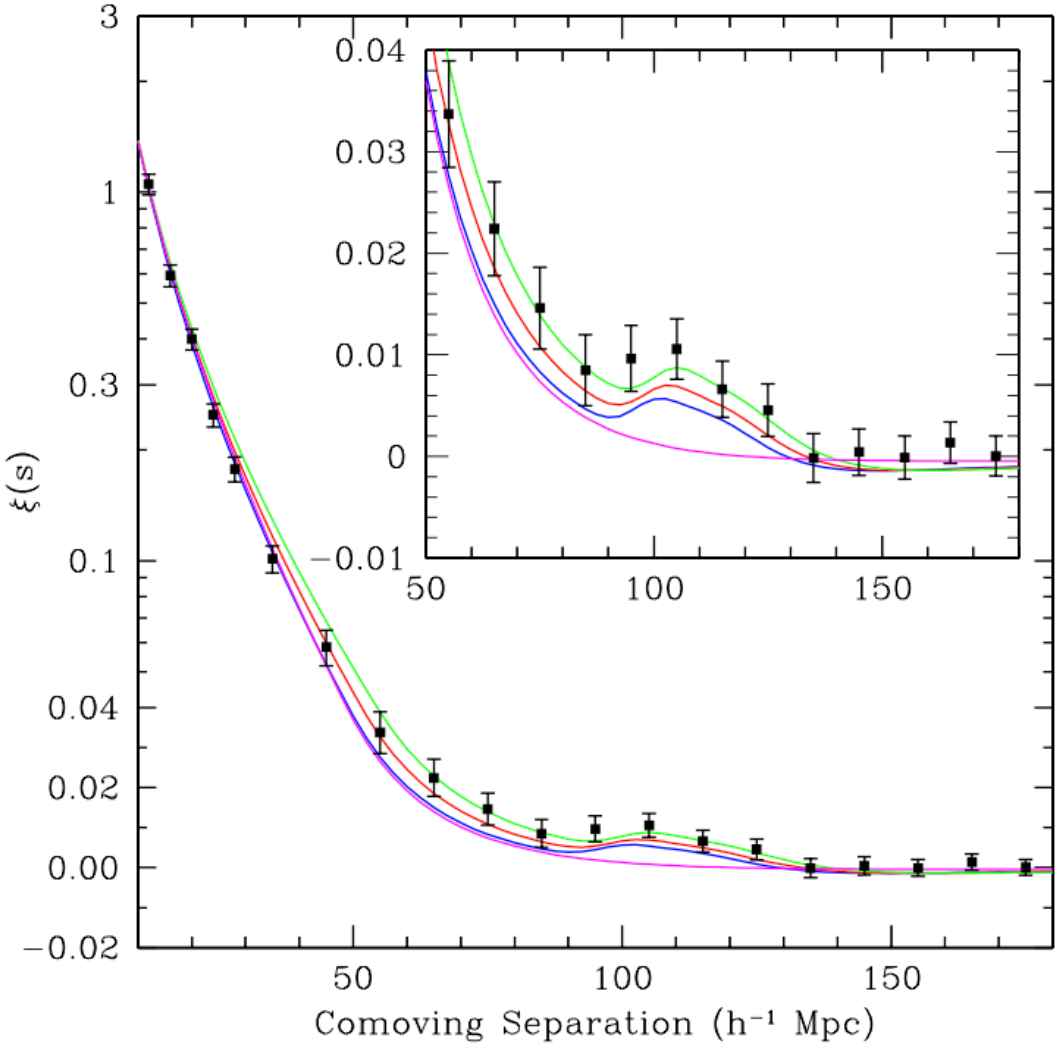
Pinging the Cosmic Drum…

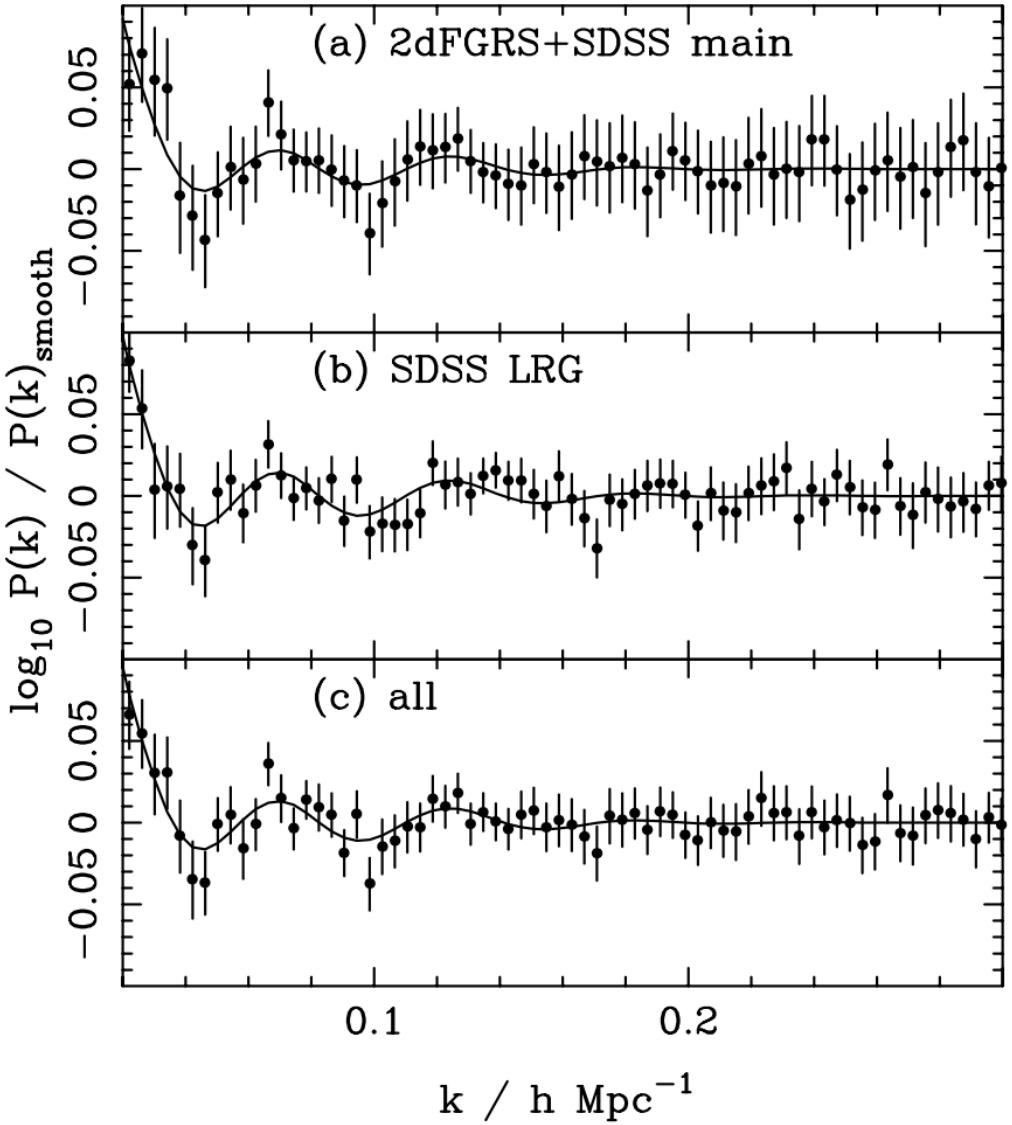
From Daniel Eisenstein



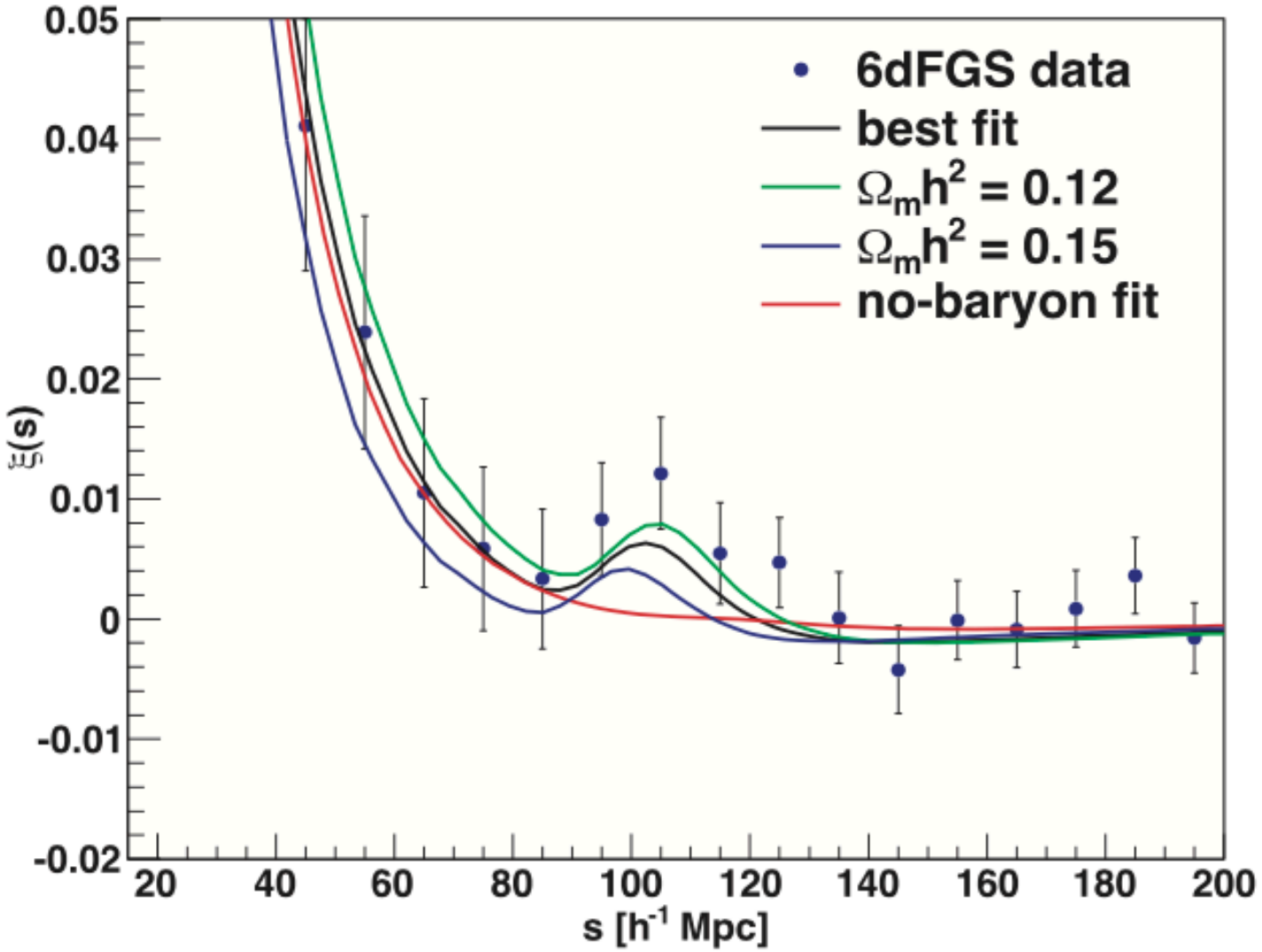
Random phases reduce signal in the real space correlation signal.
The scale is frozen in the Fourier Transform, i.e P(k)

Spectacular detection of BAO in SDSS & 2dF (2005)



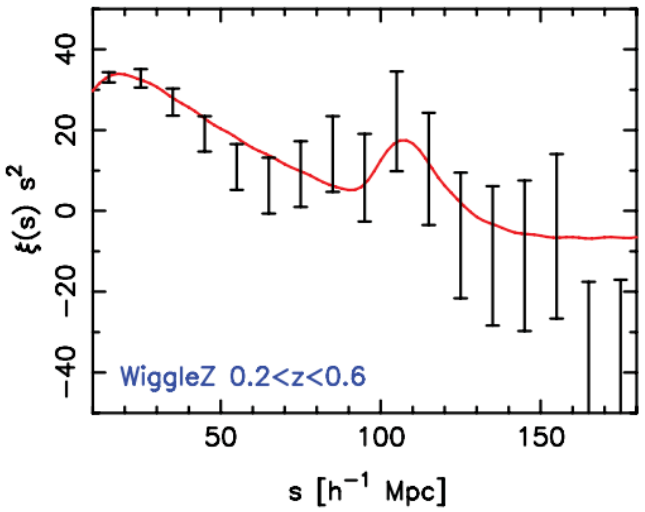


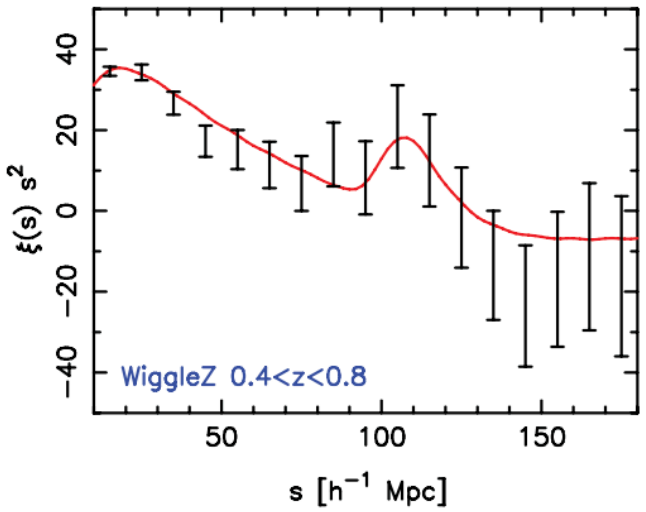
…and very soon in the 6dF survey

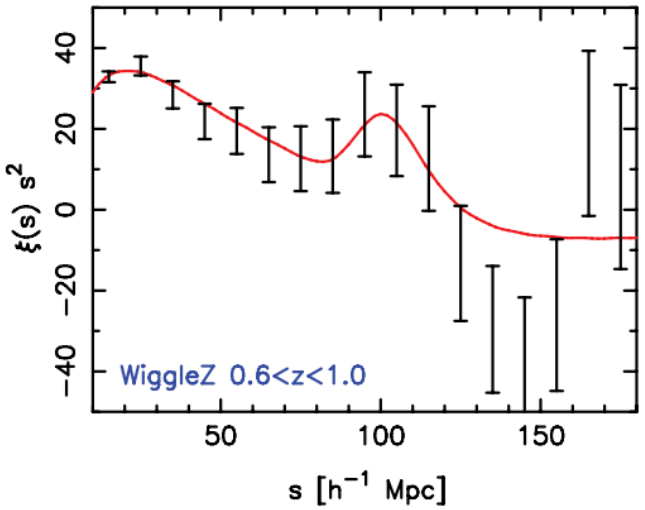


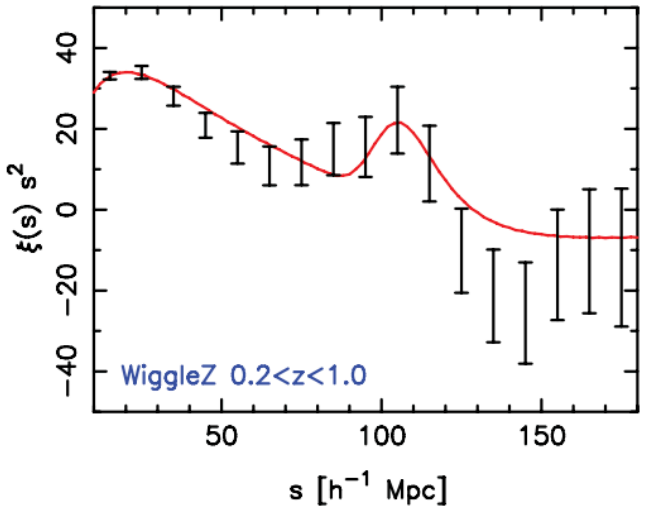
Notice the cosmological dependence in the Pk bump

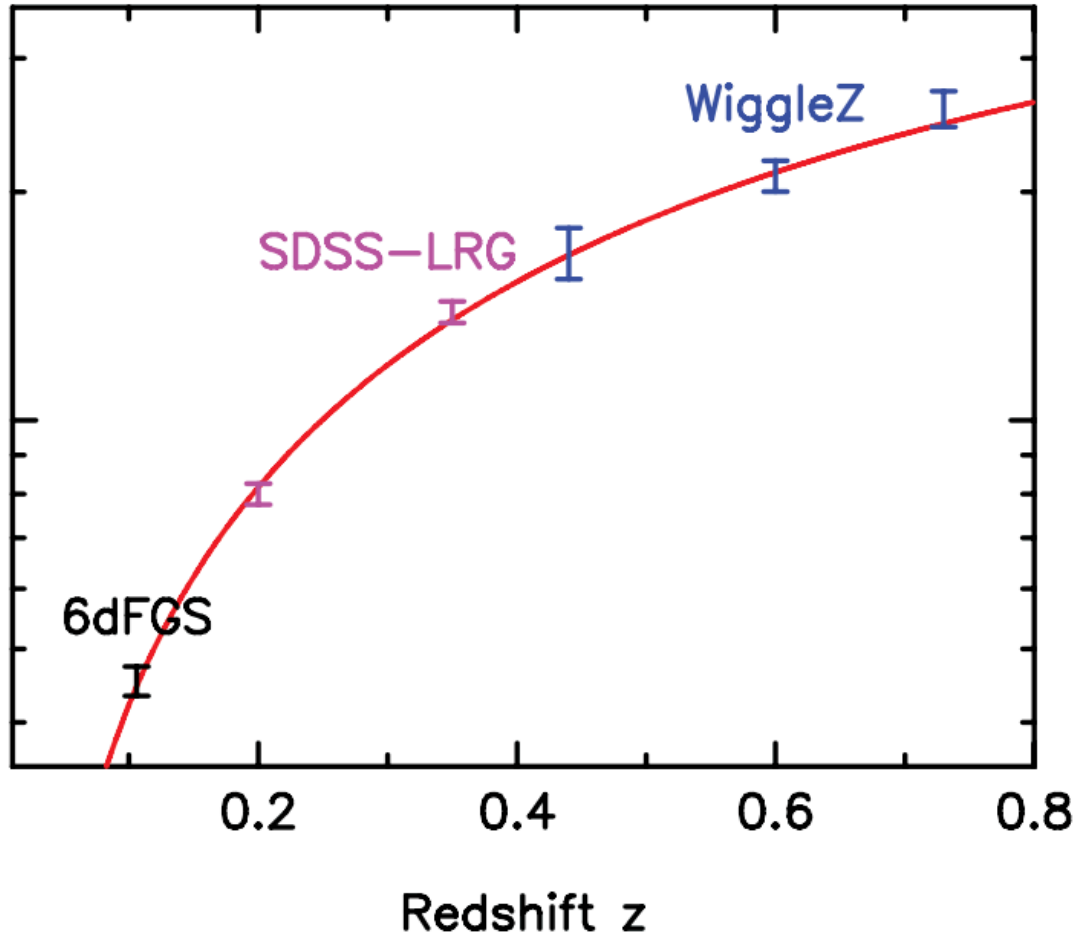
… to be followed by WiggleZ (2010s)







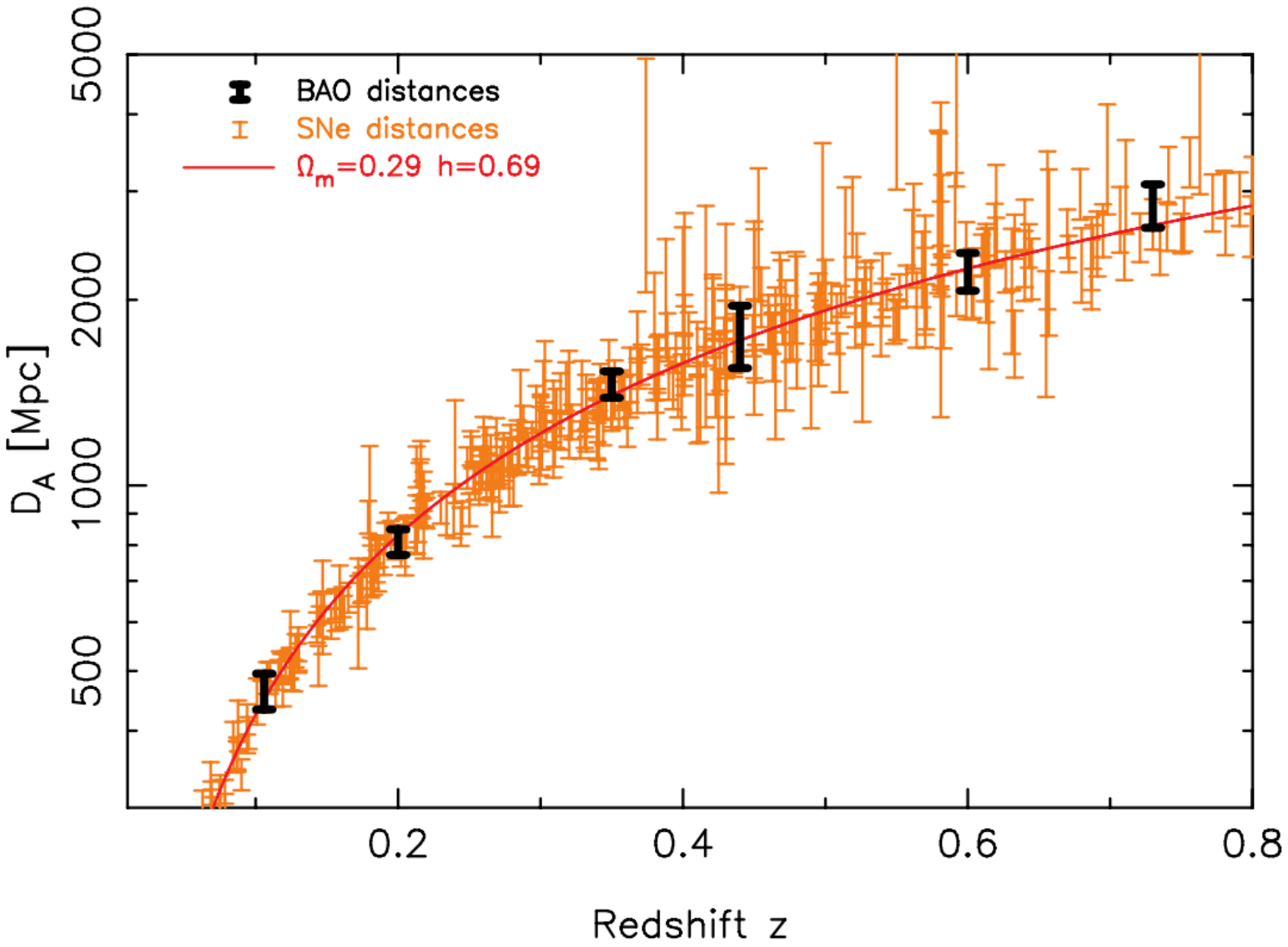




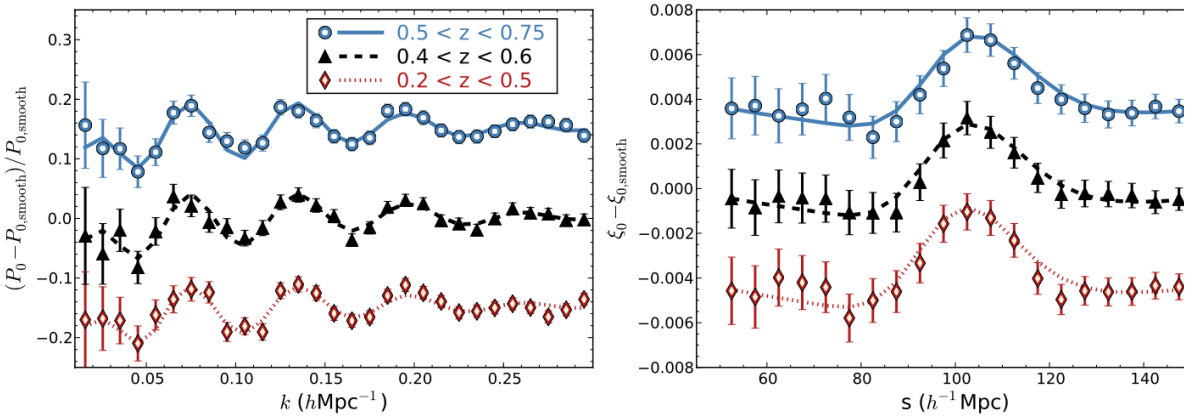
Measuring the BAO scale at diff redshifts --- eyeing dark energy

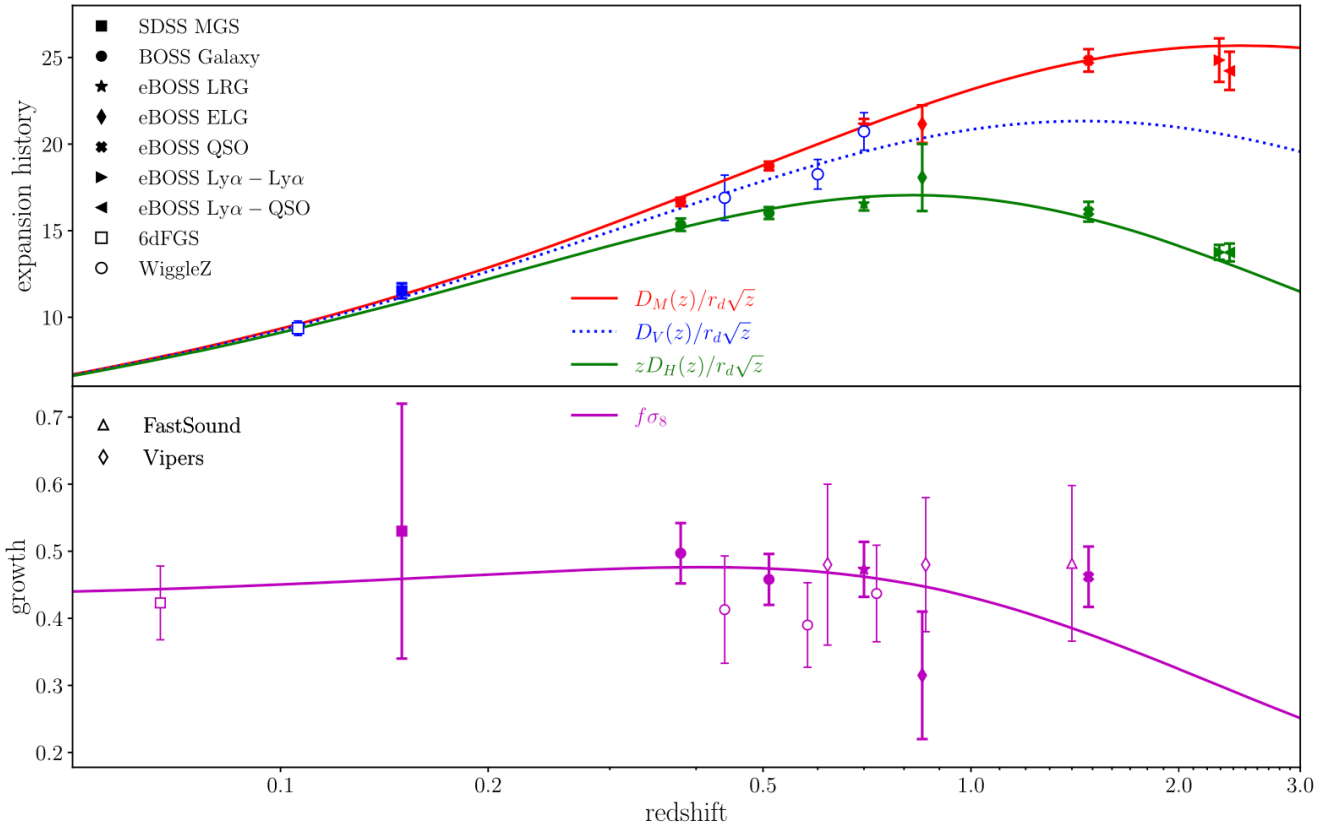
Start of precision cosmology with BAO

By 2010+ BAO starts becoming competitive to SNe



The 2010 – 2020 decade:
BOSS, eBOSS, DES and precision cosmology





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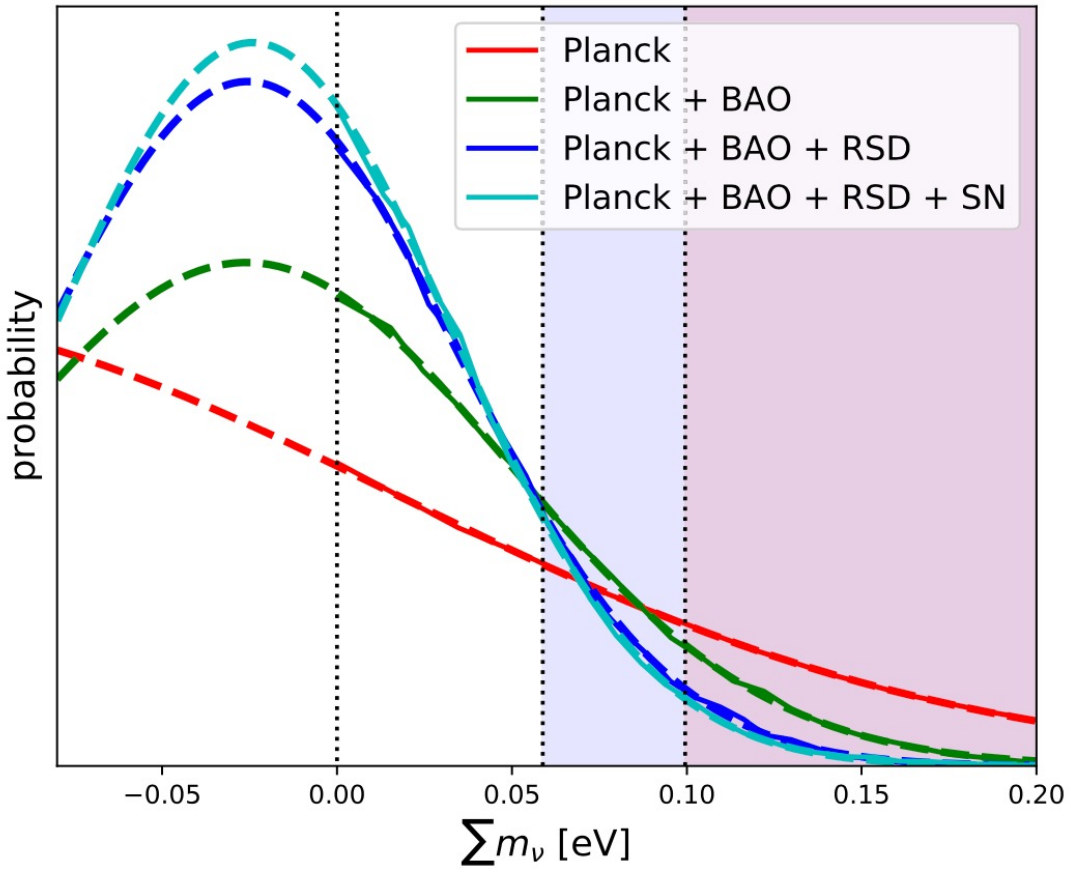
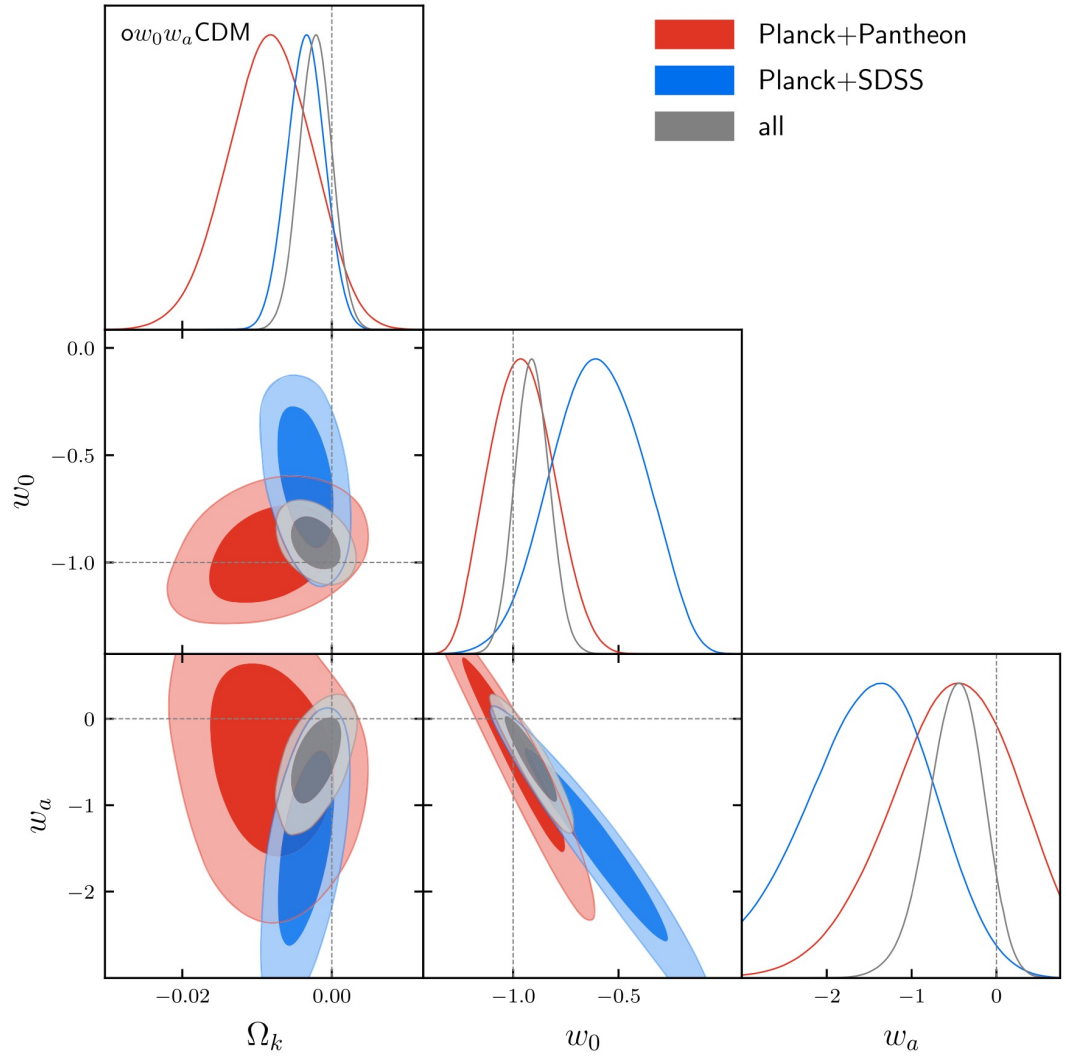
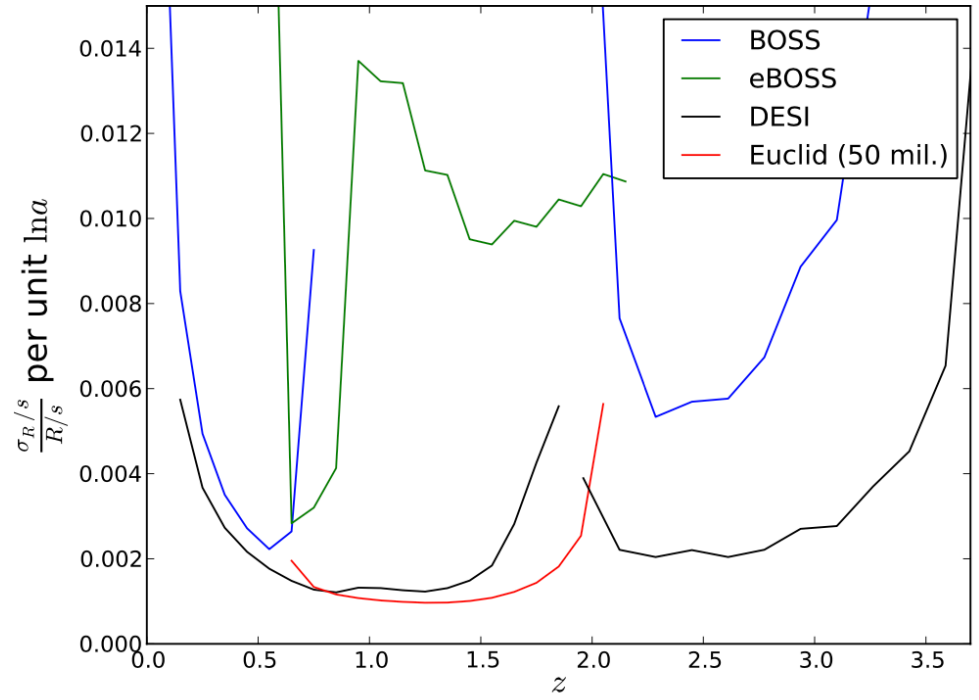
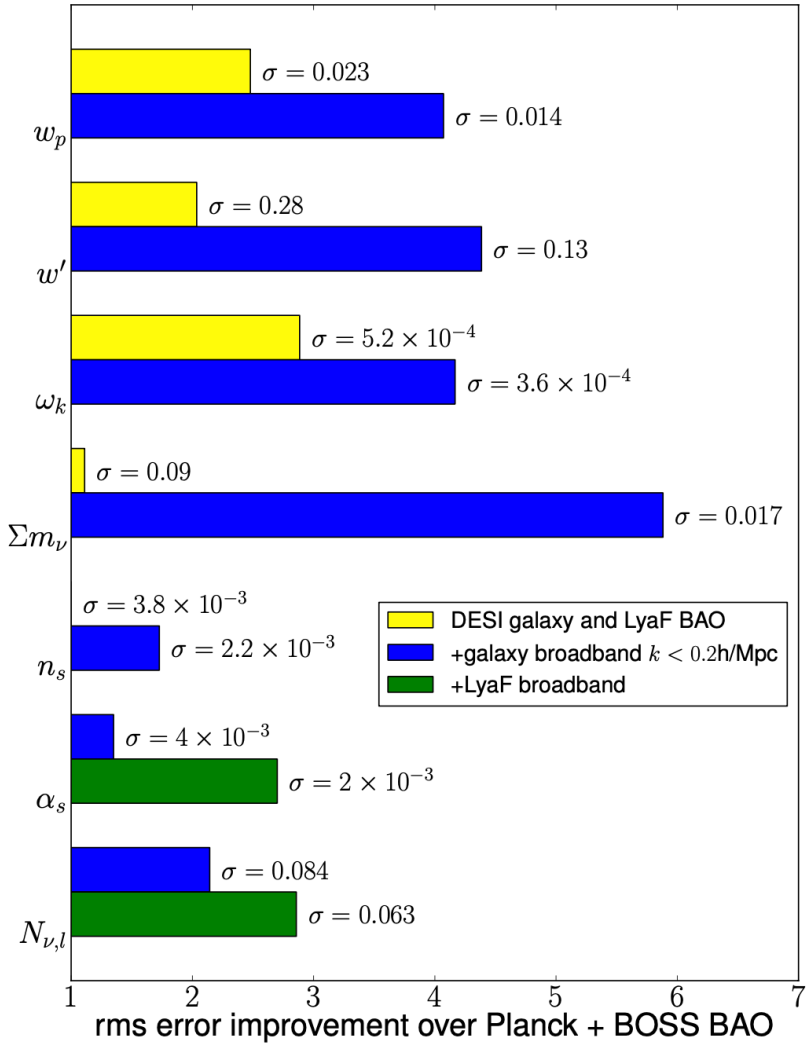




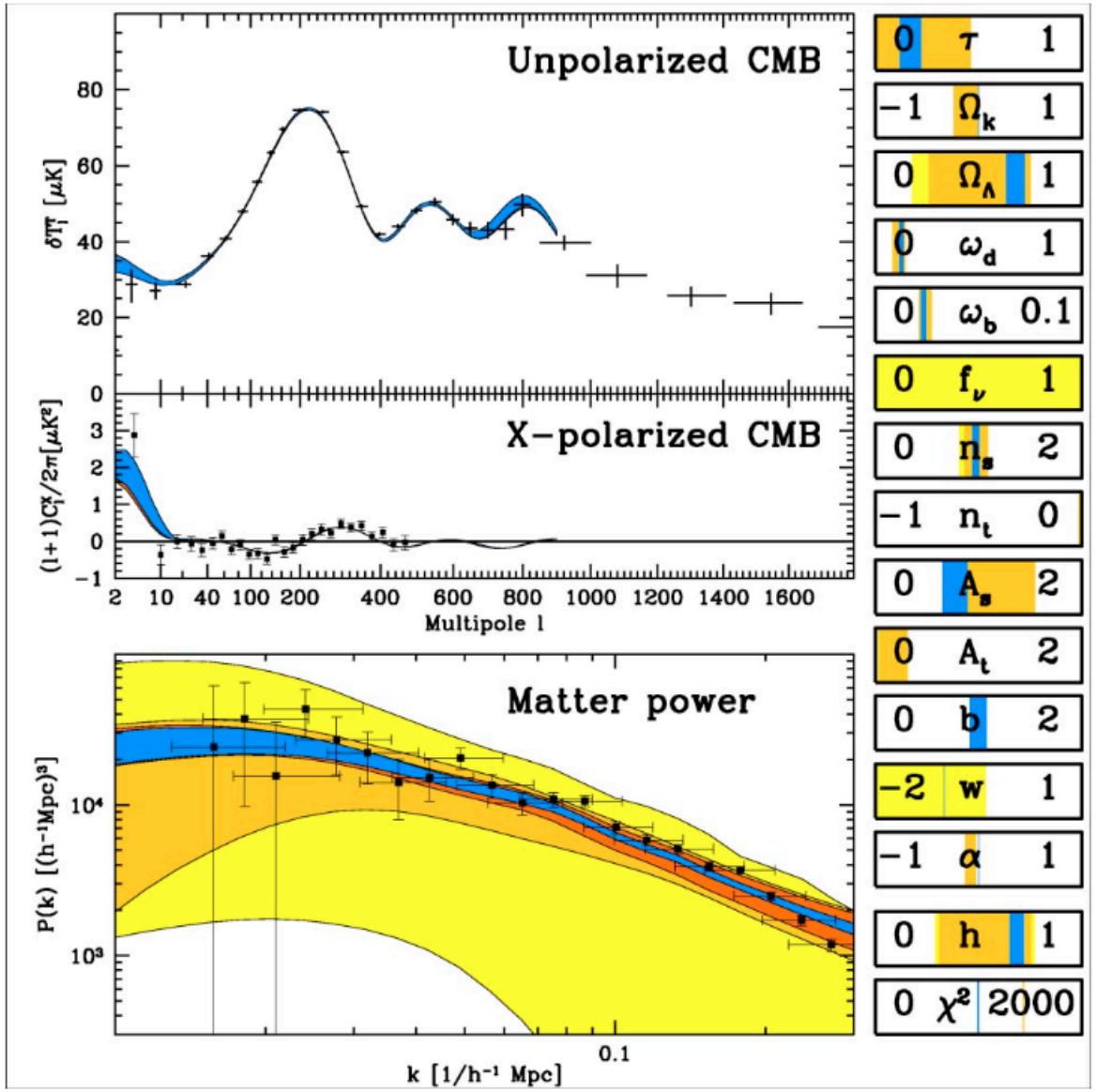
And that brings us to DESI and its promises…

Instrument	Telescope	Nights/ year	No. Galaxies	sq deg	Ops Start
to page 14 I+II	APO 2.5m	dedicated	85K LRG	7600	2000
Wiggle-Z	AAT 3.9m	60	239K	1000	2007
BOSS	APO 2.5m	dedicated	1.4M LRG+160K Ly-α	10000	2009
HETDEX	HET 9.2m	60	1M	420	2014
eBOSS	APO 2.5m	180	600K LRG + 70K Ly-α	7000	2014
DESI	NOAO 4m	dedicated	+20M + 800k Ly-α	14000	2018
SUMIRE PFS	Subaru 8.2m	20	4M	1400	2018
4MOST	VISTA 4.1m	shared facility	6-20M bright objects	15000	2019
EUCLID	1.2m space	dedicated	52M	14700	2021

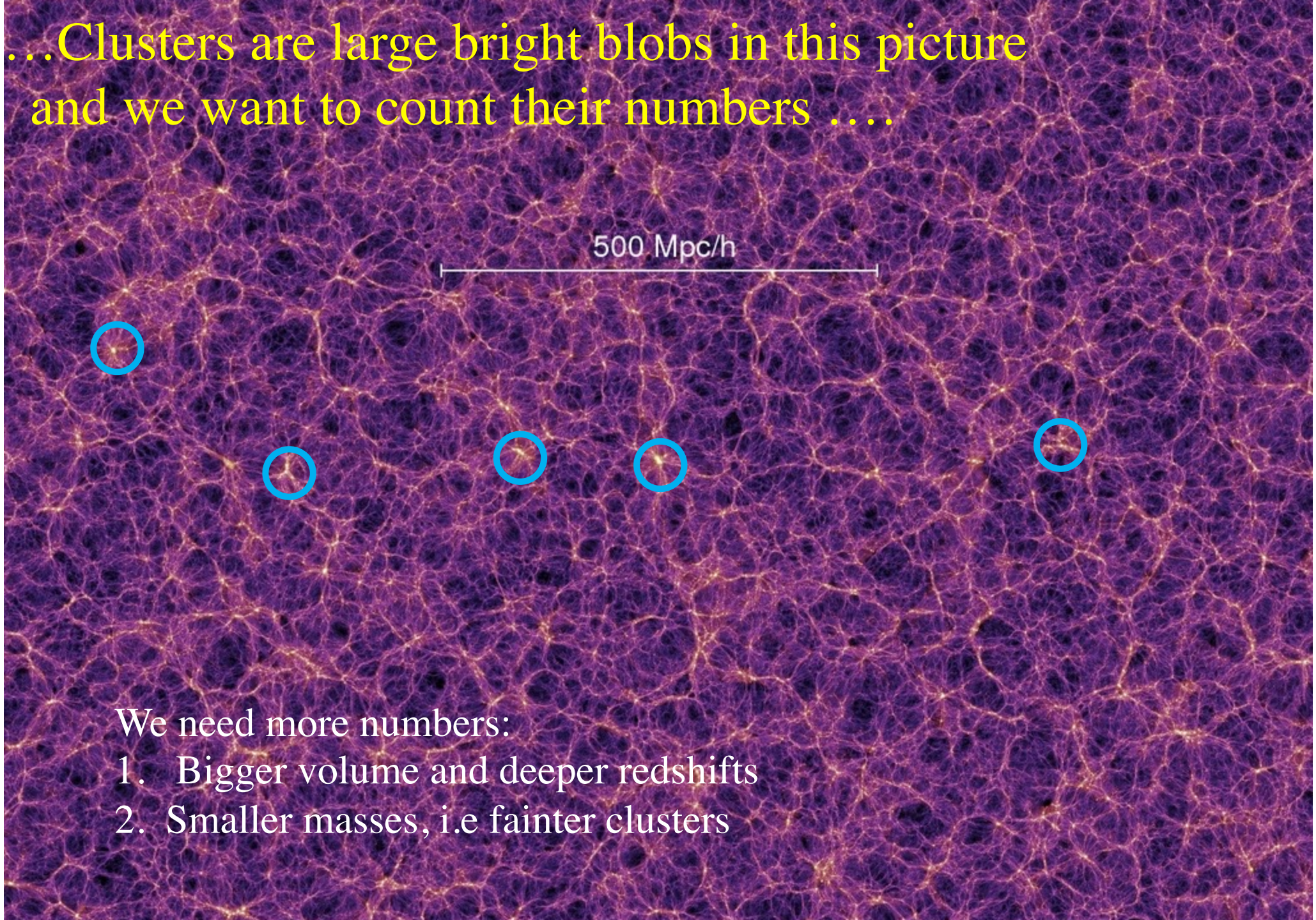




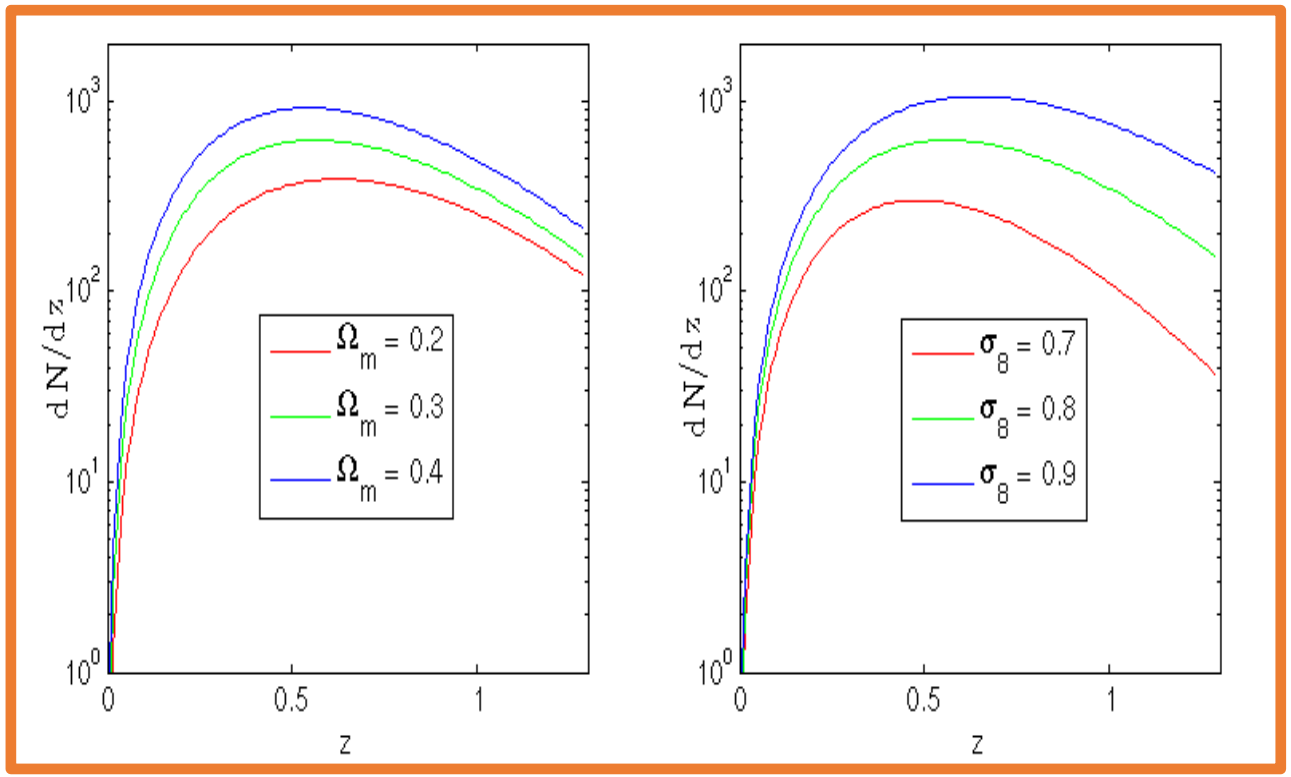
Lets not for get the long way…started like this

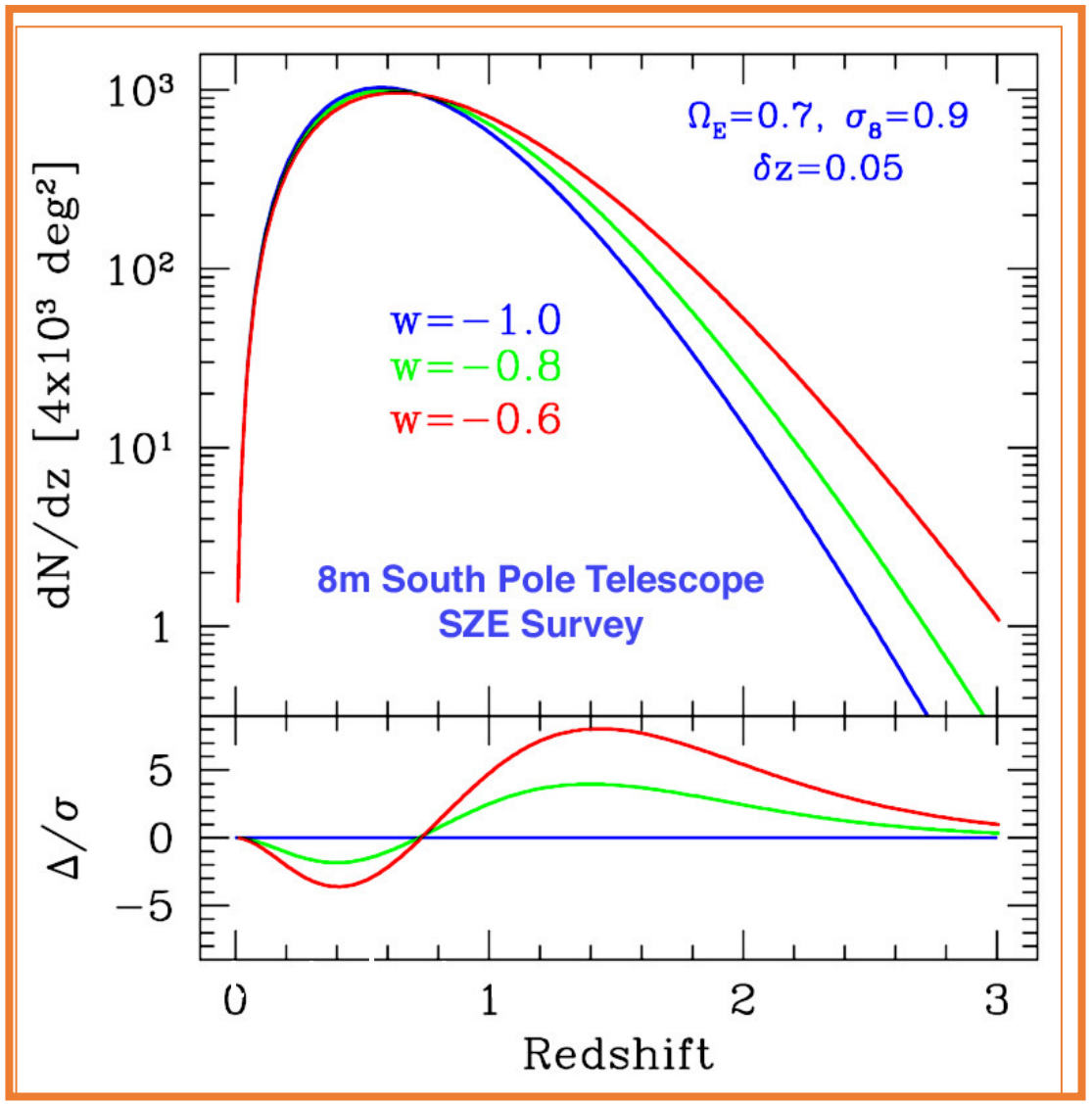


BAO to Cluster counts : DESI to eROSITA


…Clusters are large bright blobs in this picture
and we want to count their numbers ….
500 Mpc/h
We need more numbers:
1. Bigger volume and deeper redshifts
2. Smaller masses, i.e fainter clusters

Cluster numbers are “exponentially” sensitive to cosmology



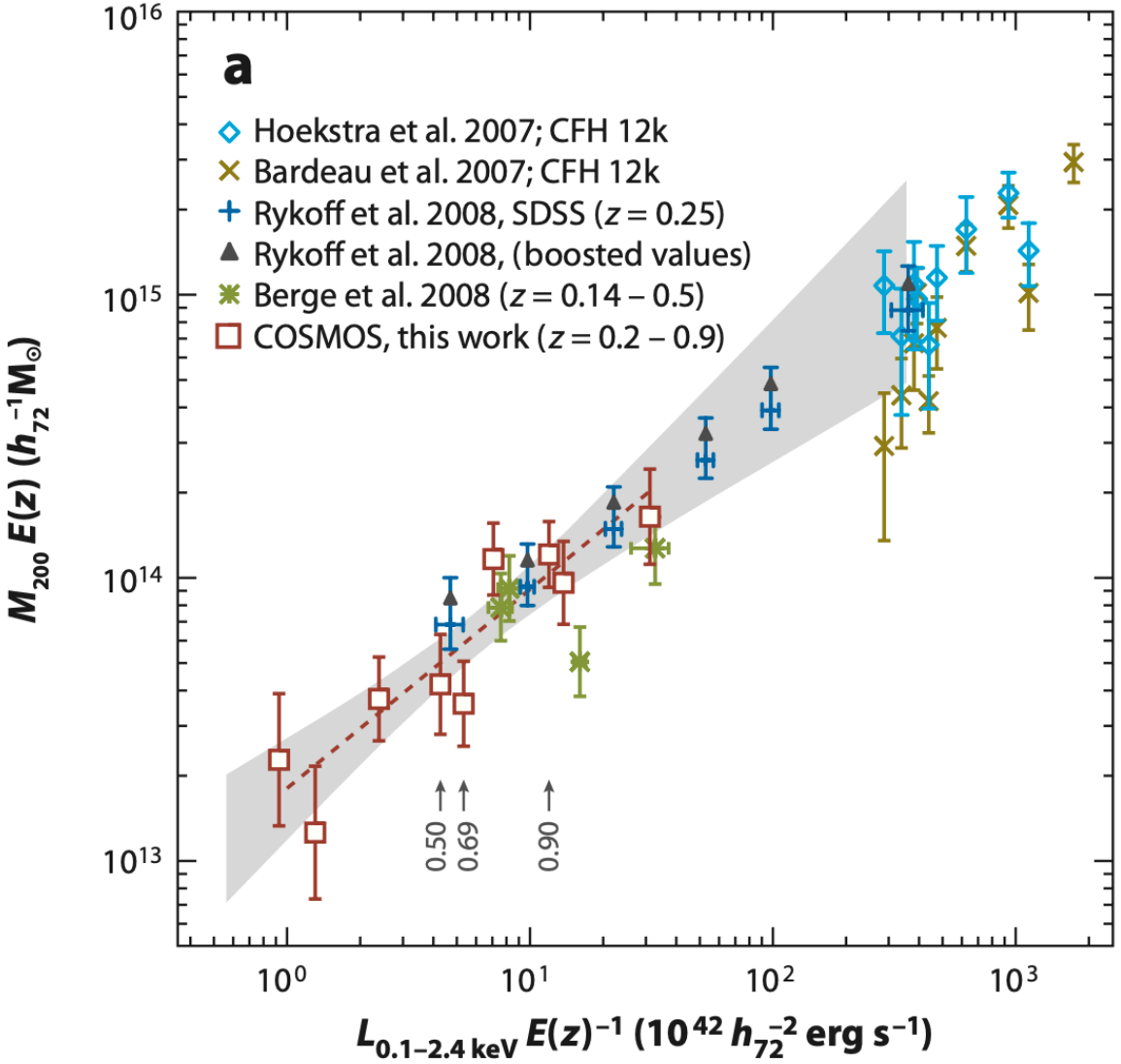


Cluster numbers are “exponentially” sensitive to mass systematics

Typically needs additional surveys, like weak lensing, to measure mass

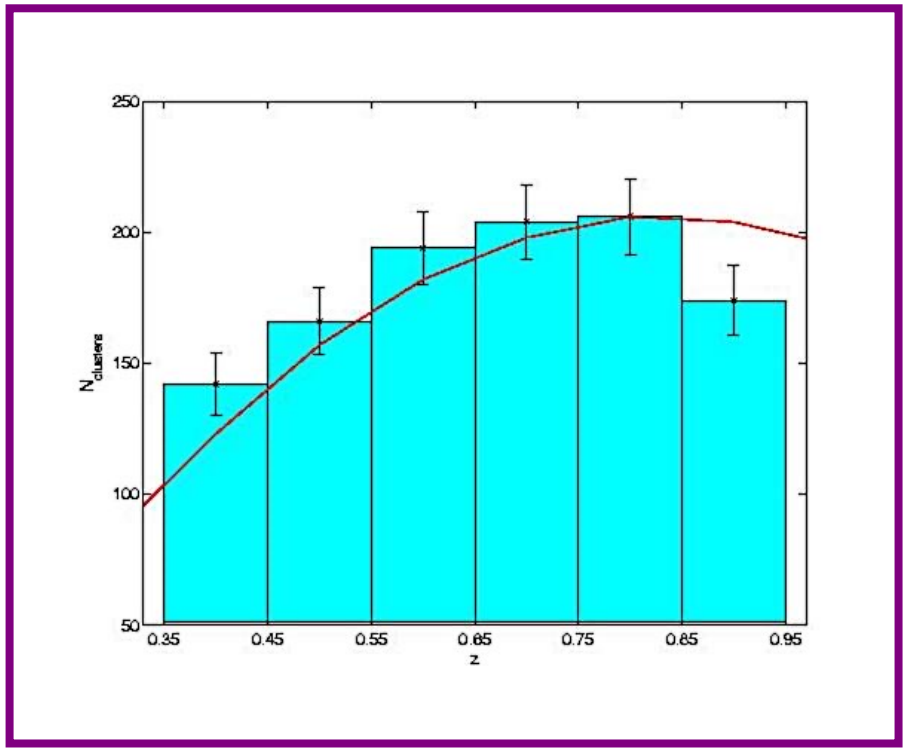
or

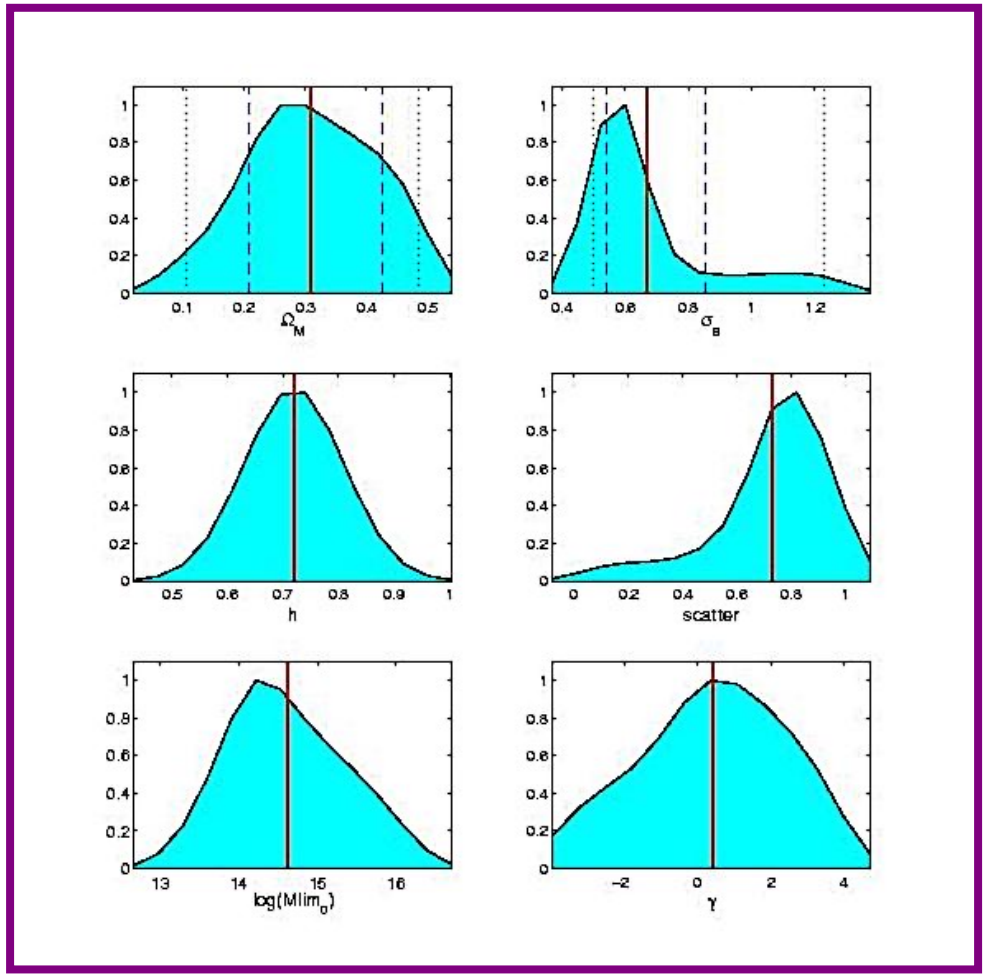
Rely on self-calibration techniques



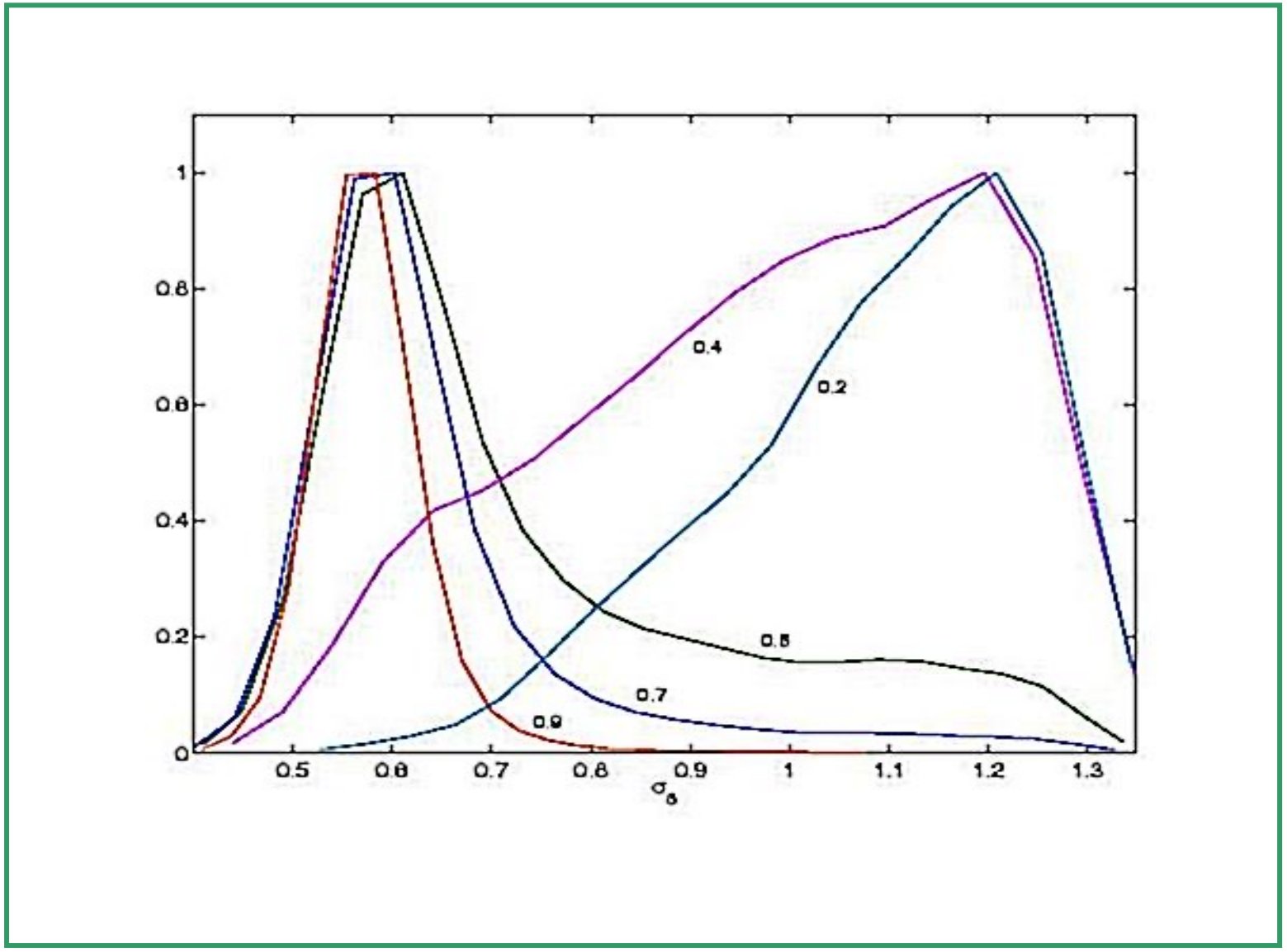
The first ever cluster count cosmology
The Red-Sequence Survey 1 (RCS1) - 2006….

72 deg on the sky, 1100 rich clusters, z=0.2-0.9
No mass followup. Self calibrated

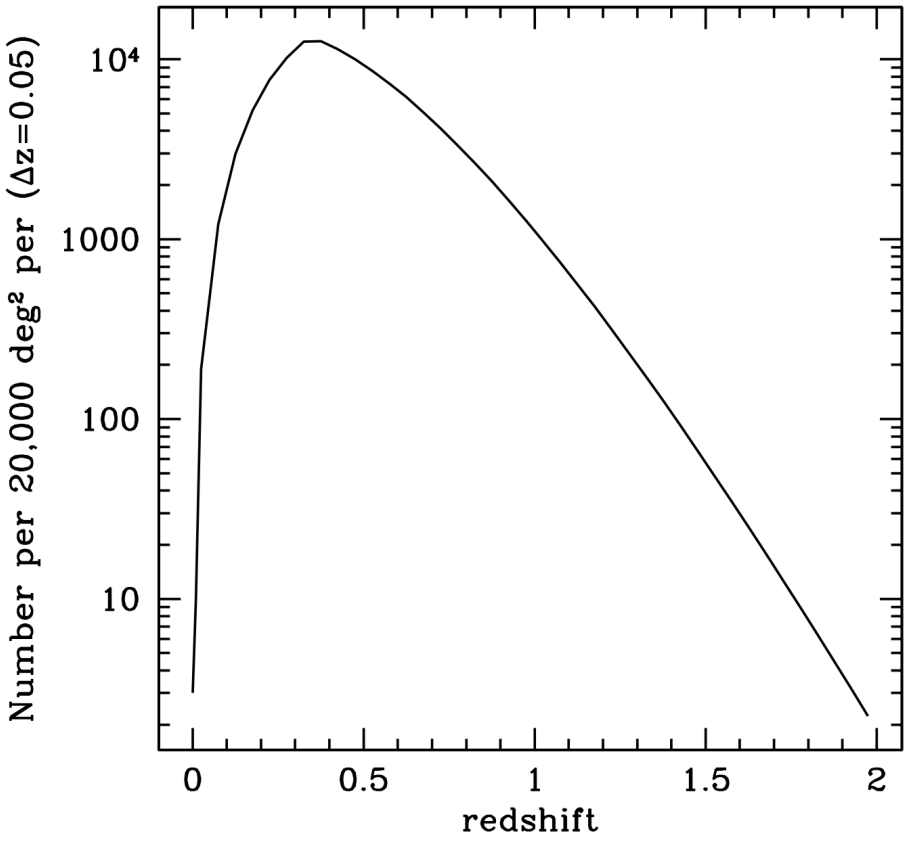




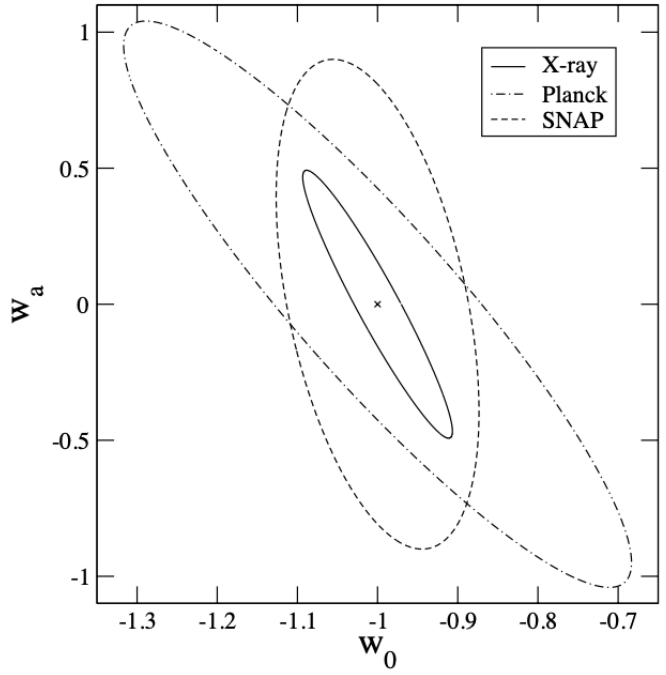
The crucial importance of scatter: an example

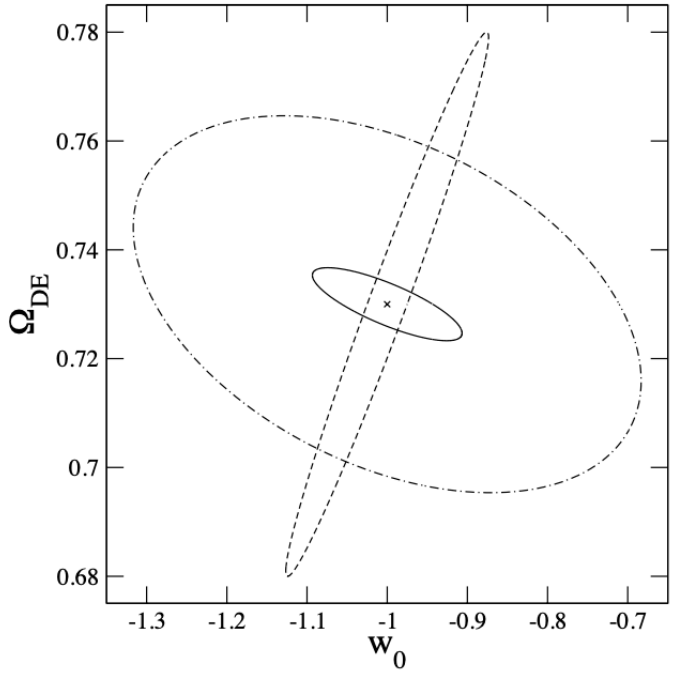


The first aim for a mega cluster survey (2005)



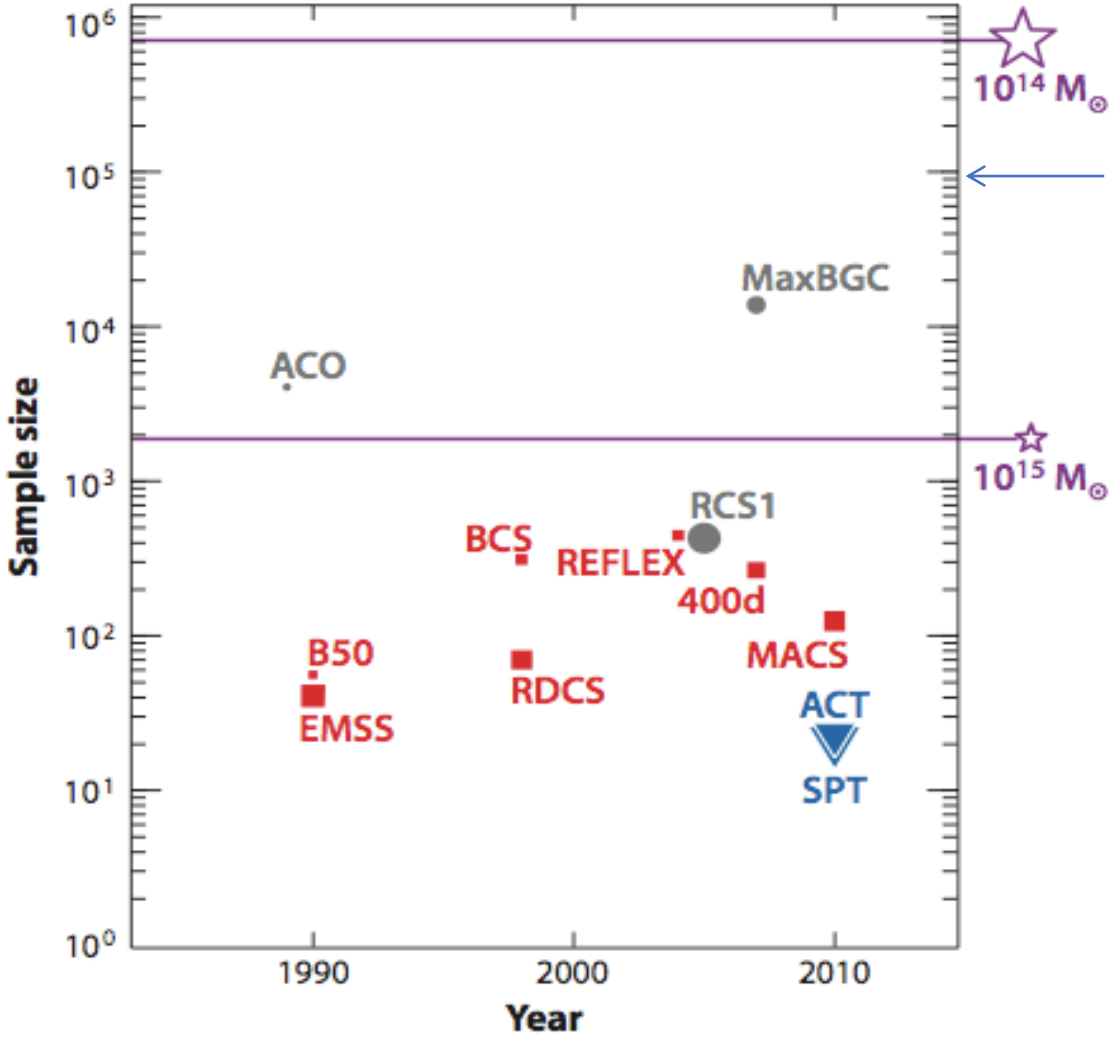
The NASA DUET survey



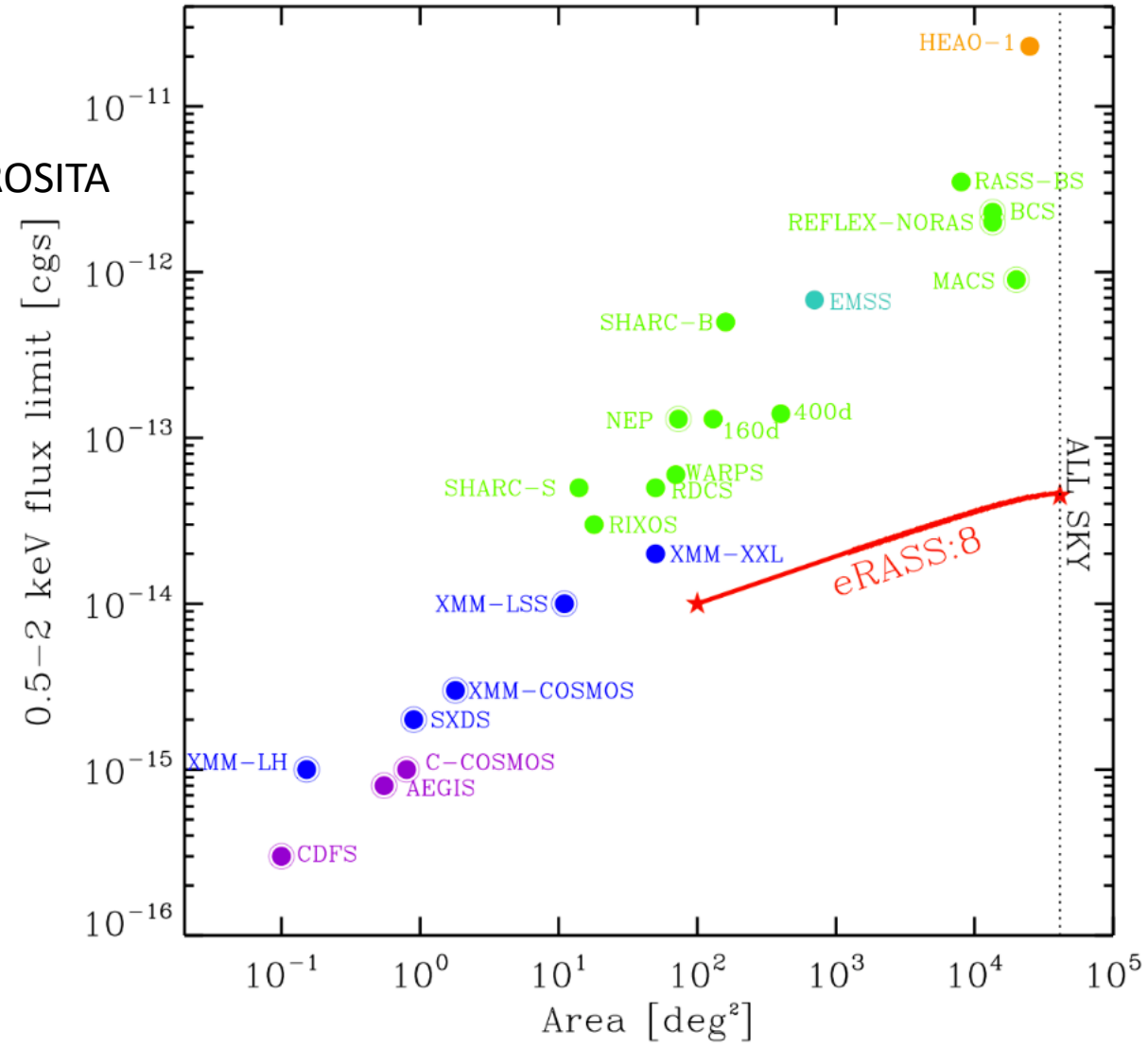


Self–Calibrated Experiment(s)	$\sigma(w_0)$	$\sigma(w_a)$	$\sigma(\Omega_{\rm DE})$
X-ray	0.093	0.490	0.0067
X-ray + Planck	0.054	0.170	0.0052
X-ray + Planck[a]	0.016	-	0.0045
Ideal Experiment[b]			
X-ray	0.021	0.120	0.0030
X-ray + Planck	0.013	0.066	0.0027
X-ray + Planck[a]	0.0087	-	0.0019

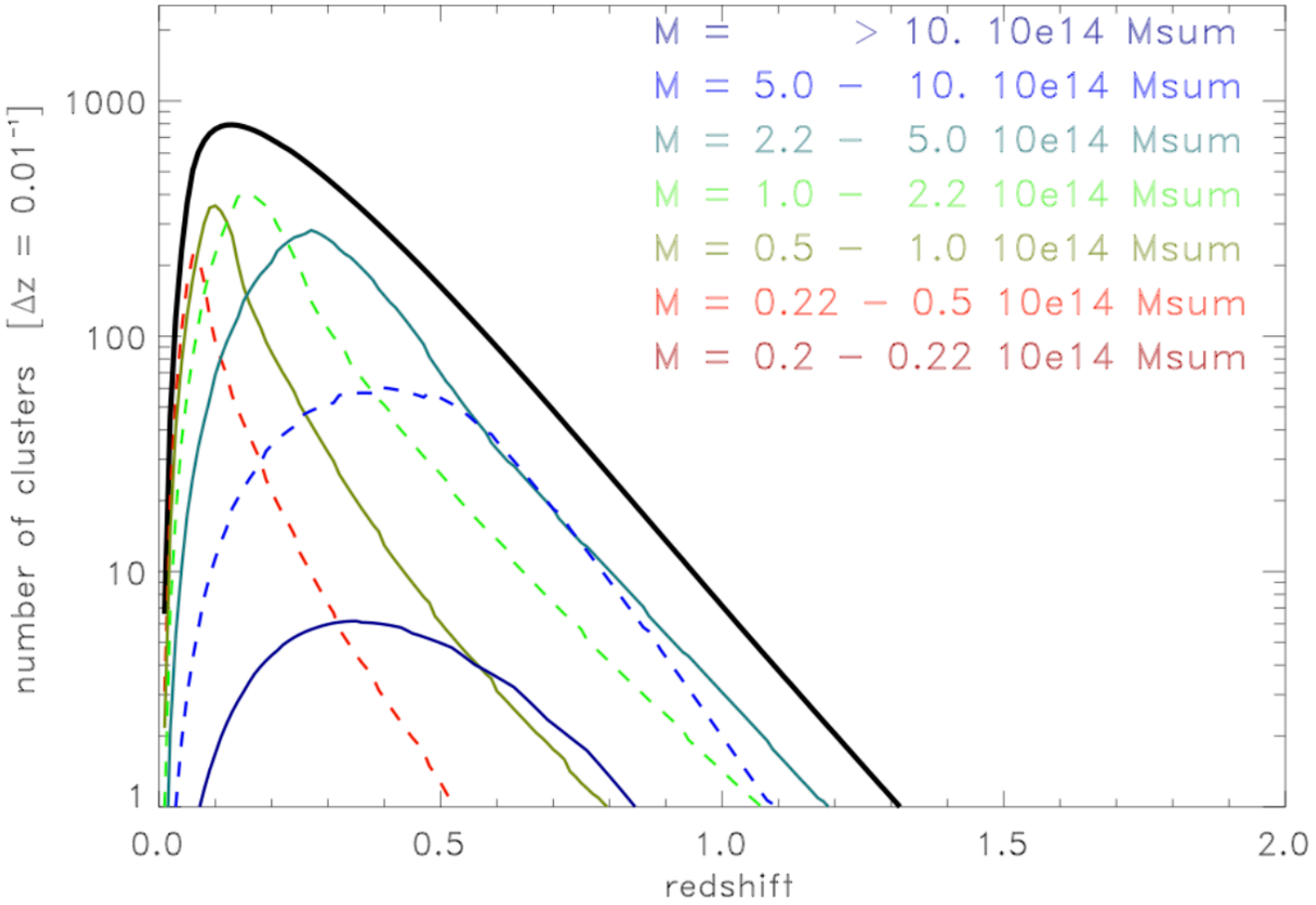
Clusters and Cluster Surveys – 30+ years



eROSITA



The first aim for a mega cluster survey (2012+)



The aim of eROSITA ….

- We will **discover all massive galaxy clusters** in the observable Universe away from the Galactic plane;
- We will **constrain cosmological parameters** with 1-2 orders of magnitude better statistics than currently available X-ray cluster samples;
- We will be able to probe the statistics of the very **large scale matter density distribution** (power spectra and correlation function) in the Universe on scales exceeding 1 Gpc;
- We will **study the detailed (thermo-)dynamical structure of nearby clusters** with the high spectral resolution of *eROSITA* over their entire large projected sizes;
- We will use large sample of clusters detected with high number of counts to study the **evolution of the thermal structure and chemical enrichment with redshift**;
- We will take advantage of the all-sky nature of the *eROSITA* surveys to search for the rarest and most extreme clusters, such as **massive objects at high redshift**, that could constitute crucial tests to cosmological and structure formation models.

This is where I hand over to DESI and eROSITA

Thank you!