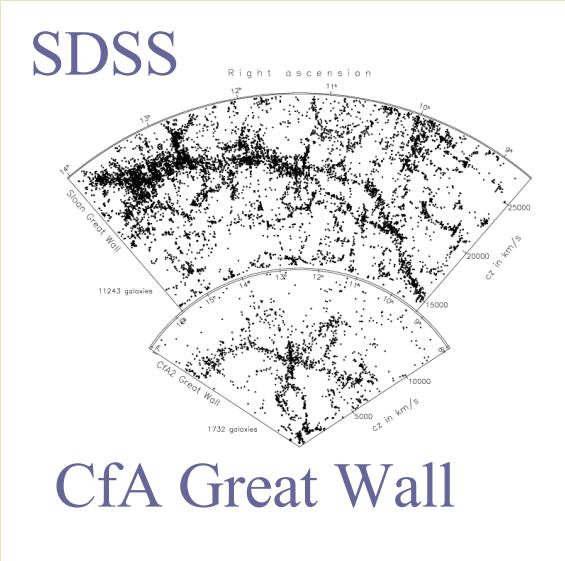
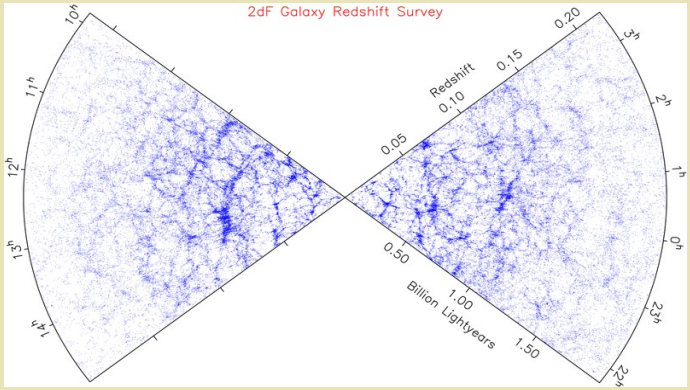
Large Scale Structure in 2dF, SDSS, and beyond



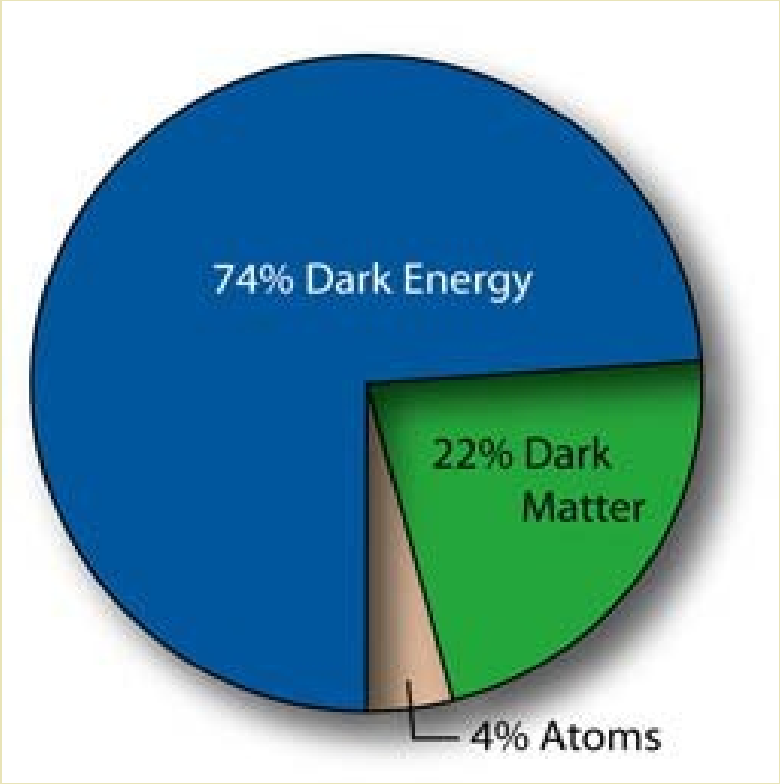


Ofer Lahav
University College London

Cosmic Probes

Observational data

- Type Ia Supernovae
- Galaxy Clusters
- Cosmic Microwave Background
- Large Scale Structure
- Gravitational Lensing



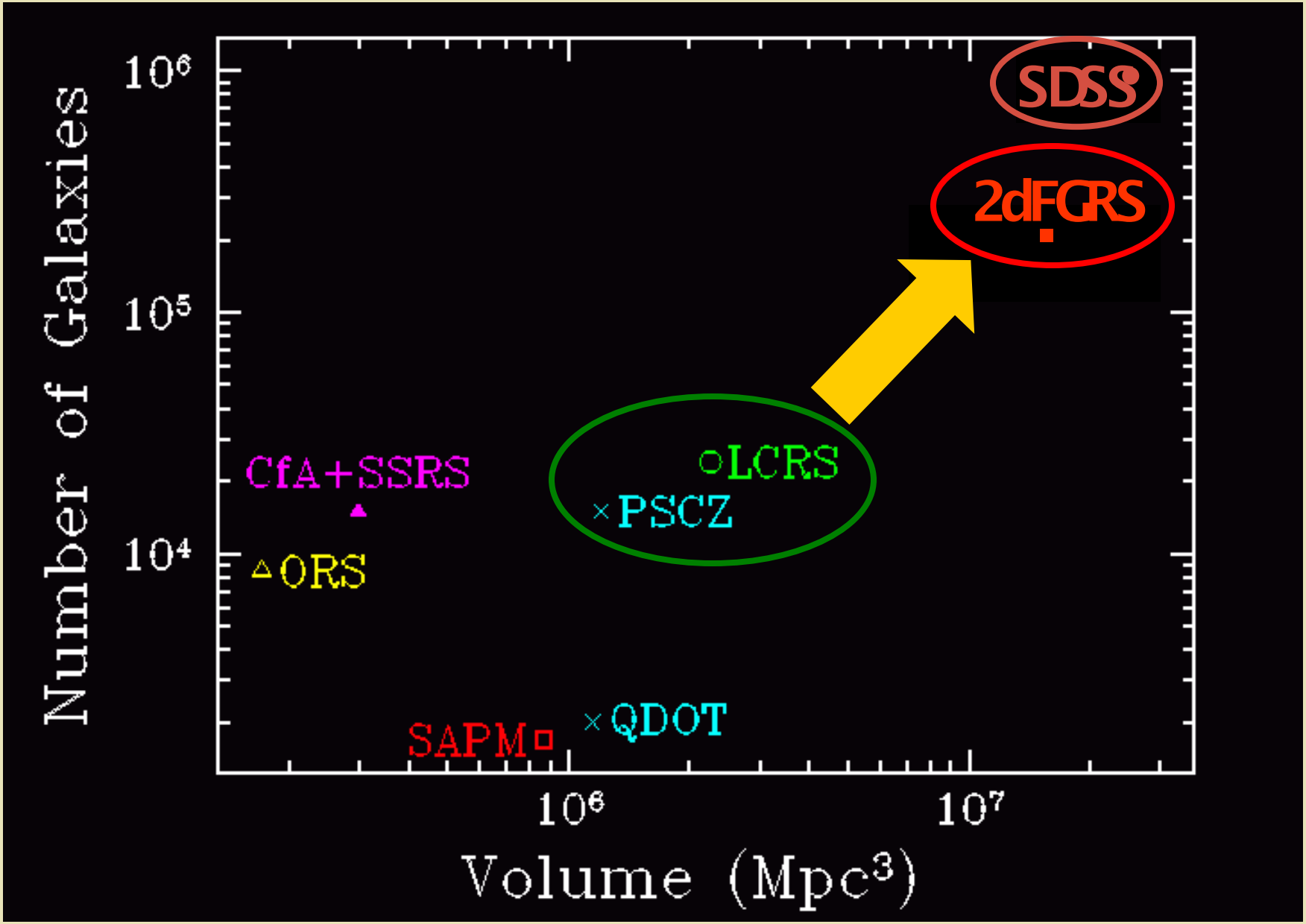
Physical effects:

- Geometry
- Growth of Structure

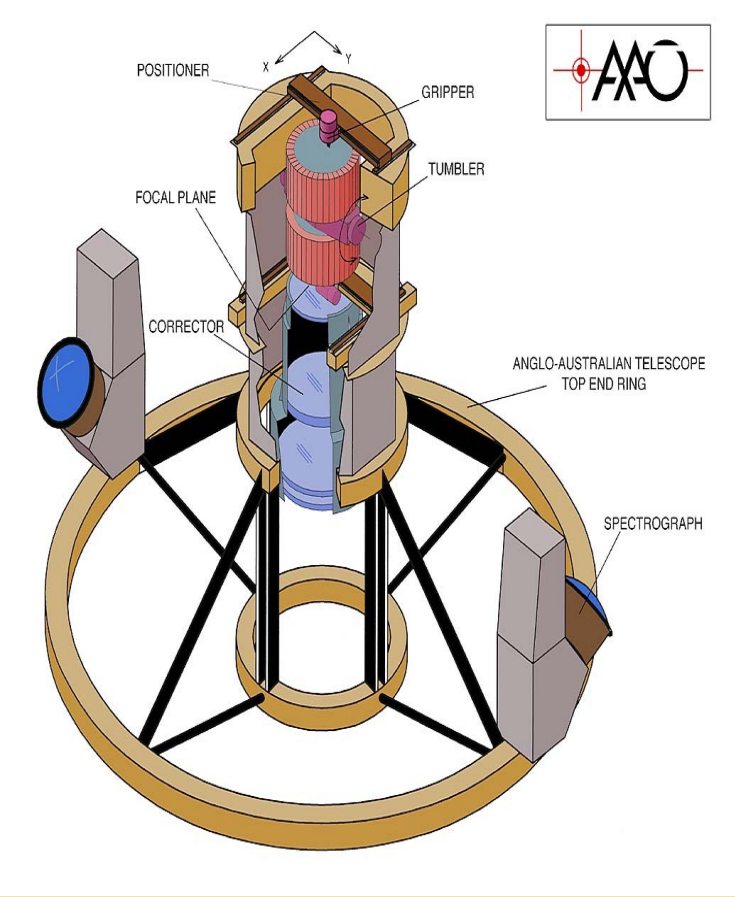
Both depend on the Hubble expansion rate:

$$H^2(z) = H^2_0 \ [g_M (1+z)^3 + g_{DE} (1+z)^{3(1+w)}] \qquad \text{(flat)}$$

The evolution of redshift surveys

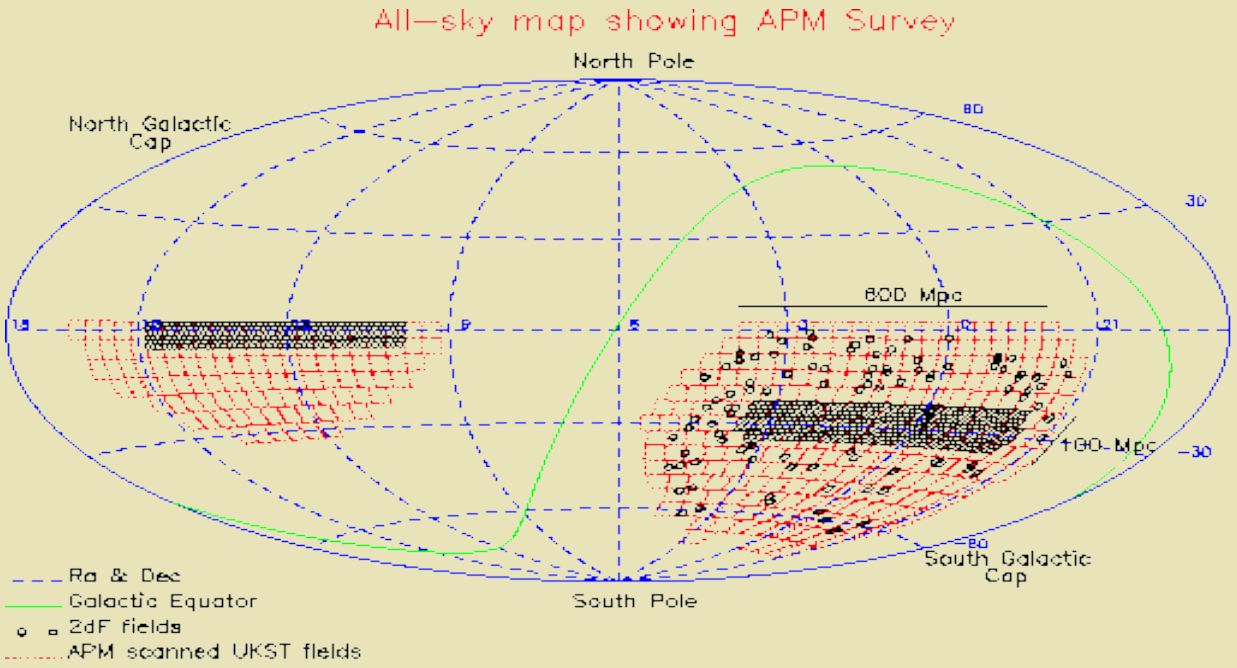


The 2dF Redshift Machine



400 fibres in 2 deg Field

Sky Coverage - 230k redshifts



The 2dFGRS Team

Ivan Baldry (AAO/JHU)

Carlton Baugh (Durham)

Joss Bland-Hawthorn (AAO)

Terry Bridges (AAO)

Russell Cannon (AAO)

Shaun Cole (Durham)

Matthew Colless (ANU)

Chris Collins (Liverpool)

Ed Conway (Nottingham)

Warrick Couch (UNSW)

Kathryn Deeley (UNSW)

Roberto De Propris (ANU)

Simon Driver (St And./ANU)

George Efstathiou (IoA)

Vincent Eke (Durham)

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Richard Ellis (IoA/Caltech)

Simon Folkes (IoA)

Carlos Frenk (Durham)

Ian Lewis (AAO/Oxford)

Stuart Lumsden (Leeds)

Steve Maddox (IoA, Nott.)

Darren Madgwick (IoA)

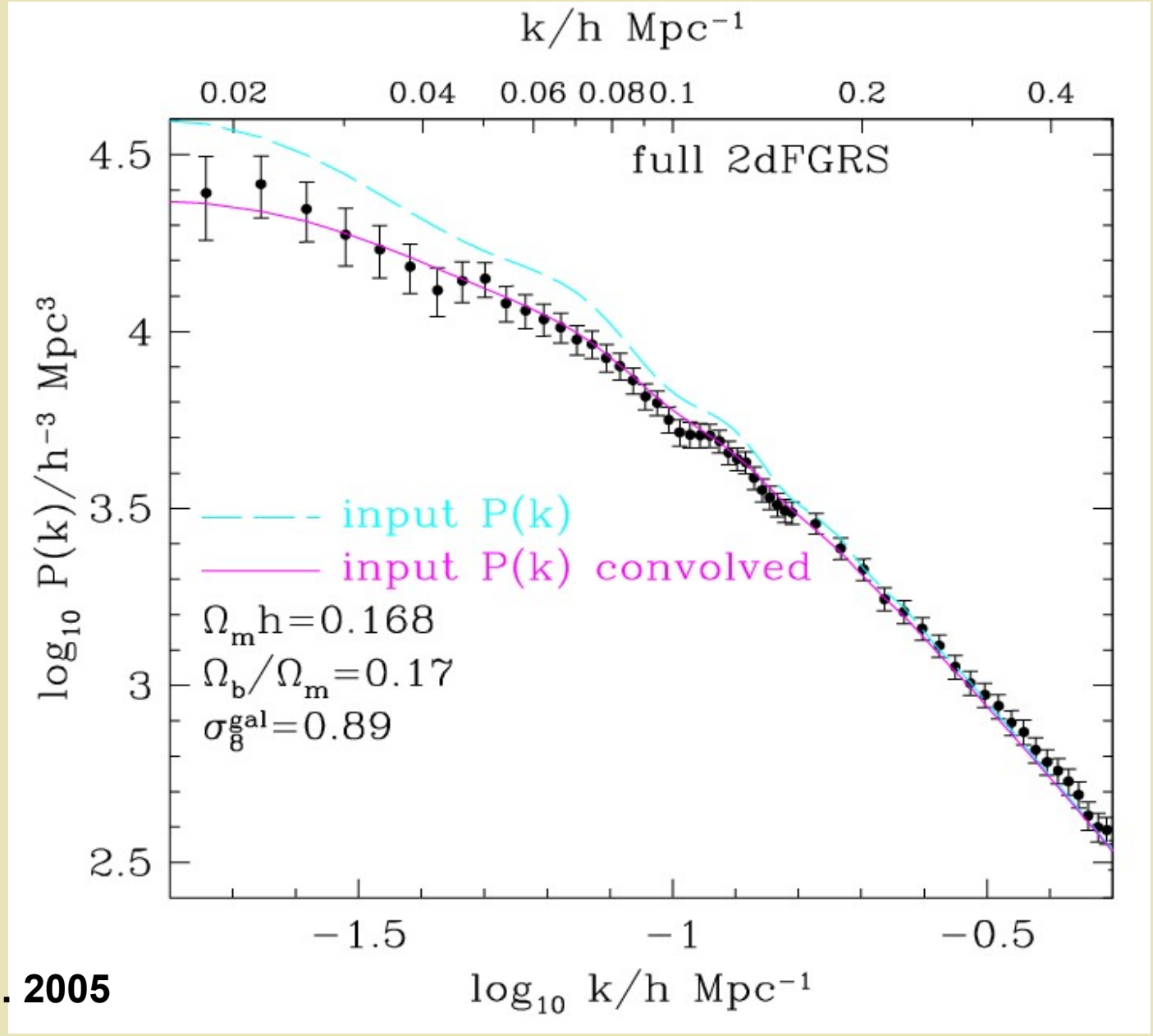
Peder Norberg (Durham)

John Peacock (Edinburgh)

Will Percival (Edinburgh)

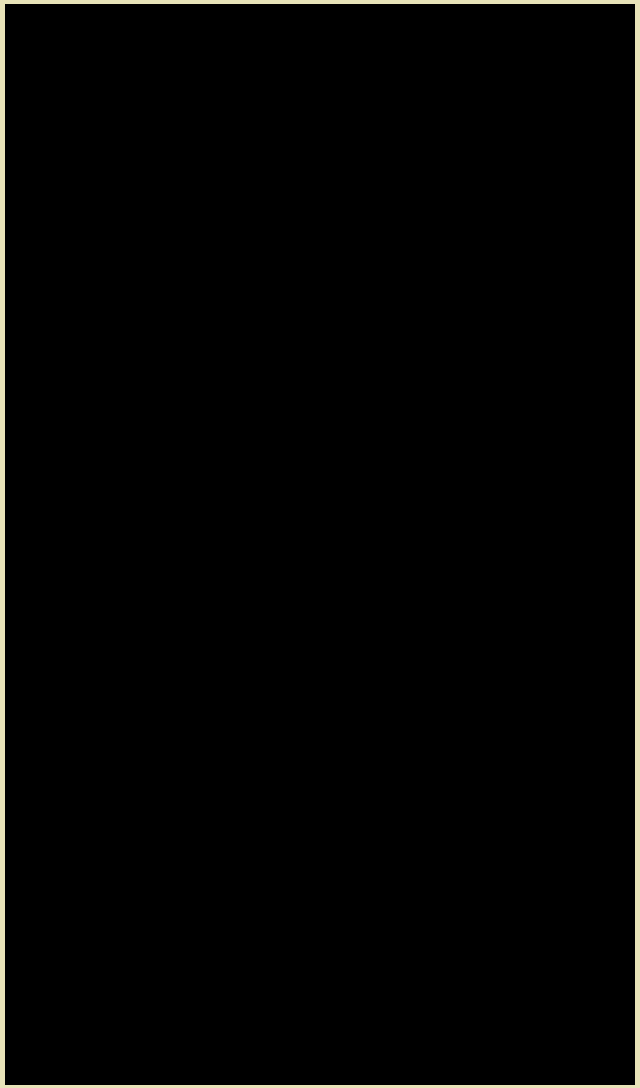
Bruce Peterson (ANU)

The final 2dFGRS Power Spectrum



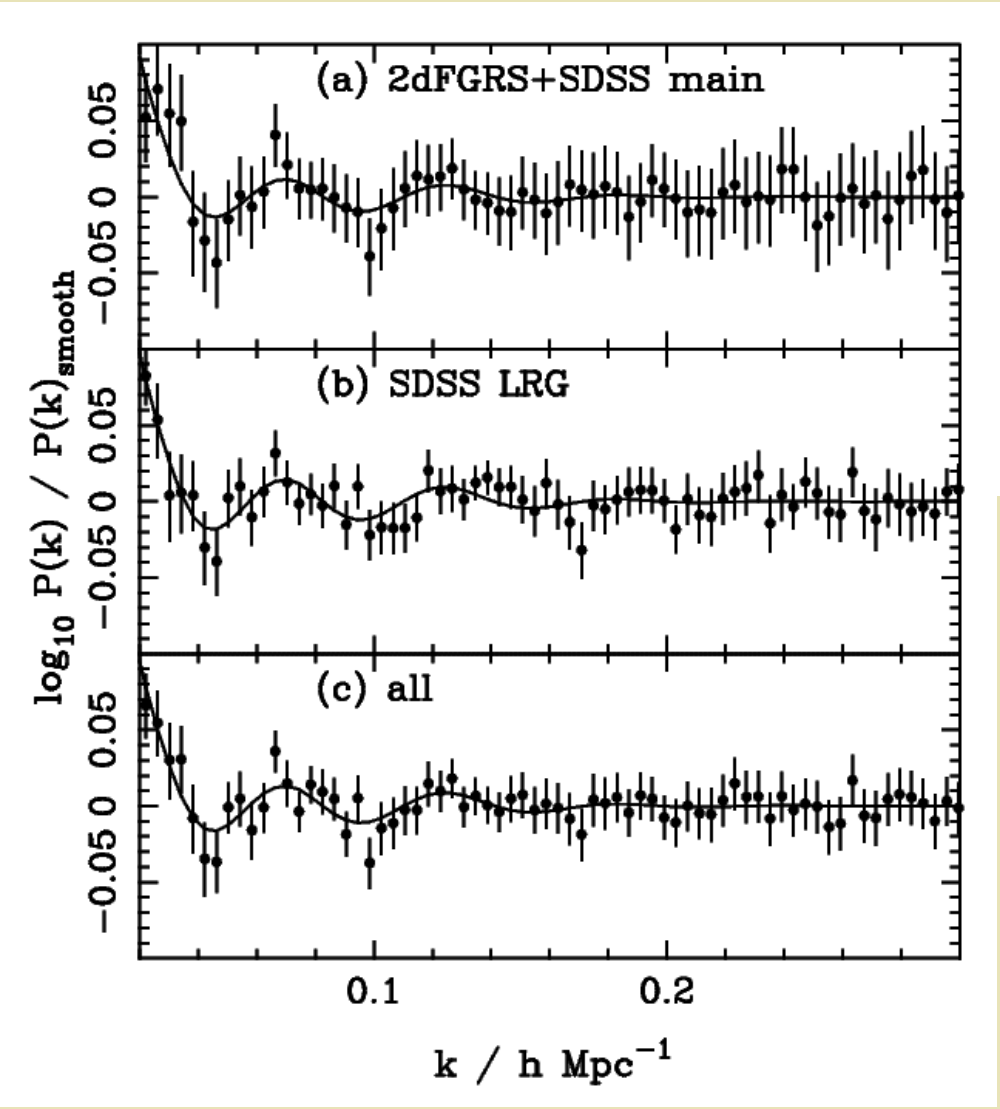
Cole et al. 2005

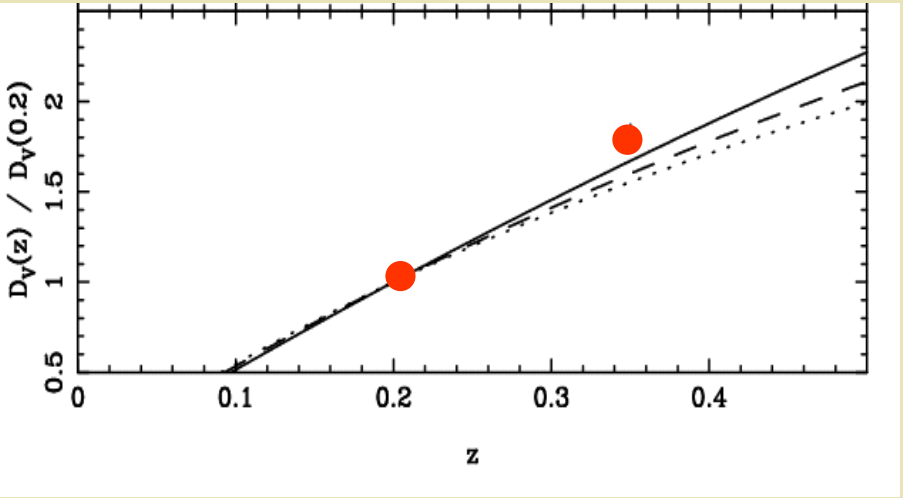
Precision Cosmology from LSS?
2dF- SDSS ‘tension’



Sanchez & Cole 2008

BAO from 2dF ad SDSS



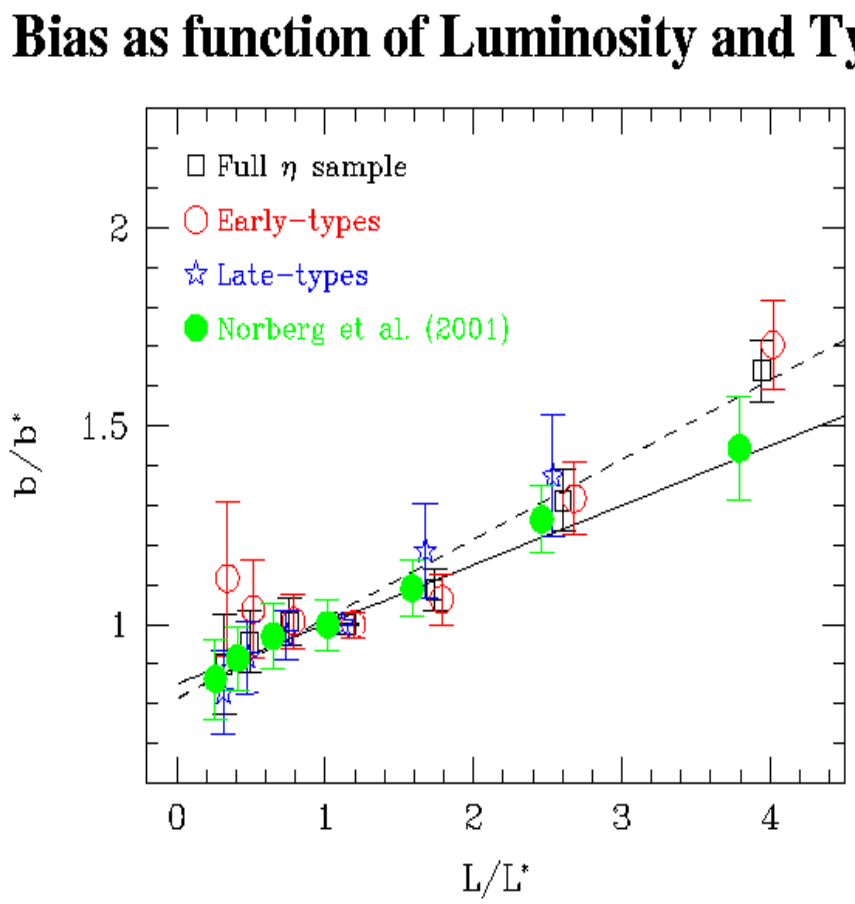


2.4-σ disagreement with cosmological constant?!

Percival et al. 2007

SDSS & 2dFGRS

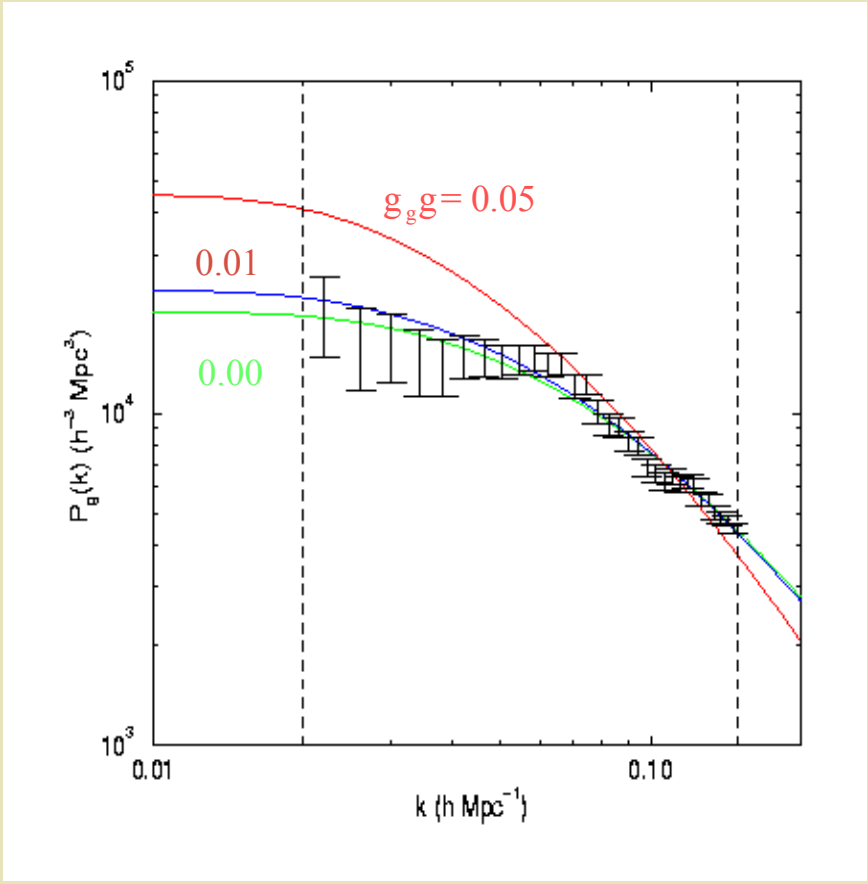
Galaxy Biasing on small scales



- Luminosity segregation
- Spectral Types
- Stochstic bias detected (Wild et al.)

- cf. SDSS (Zehavi et al.)

Weighing Neutrinos with 2dFGRS



Elgaroy , OL, & et al.,
astro-ph/0204152 , PRL

- Free streaming effect:

N $g_g/g_m g < 0.13 g$ □L

Total g mass < 1.8 eV

- R A 1□ d 4 $_g$g □L □ g □

(Oscillations) (2dF)

- a Four-Component Universe ?

Deriving Neutrino mass from Cosmology

Data	Authors	$M_g g L \square \quad m_i b$
2dF (P01)	Elgaroy, OL et al.02	< 1.8 eV
WMAP+LSS +SN…	Spergel et al. 06	< 0.68 eV
2dF (C05)+CMB	Sanchez et al. 05	< 1.2 eV
BAO+CMB+LSS +SN	Goobar et al. 06	< 0.62 eV
Ly-g + SDSS+ WMAP+…	Seljak et al. 04	< 0.17 eV
WMAP alone	Ichikawa et al. 04 Fukugita et al. 06	< 2.0 eV

All upper limits 95% CL, but different assumed priors !

Neutrino mass from KATRIN

- Next generation tritium beta decay spectrometer
- Sensitivity $m_\beta < 0.2$ eV at 90% C.L.
- 5σ detection threshold at $m_\beta = 0.35$ eV

www.fzk.de

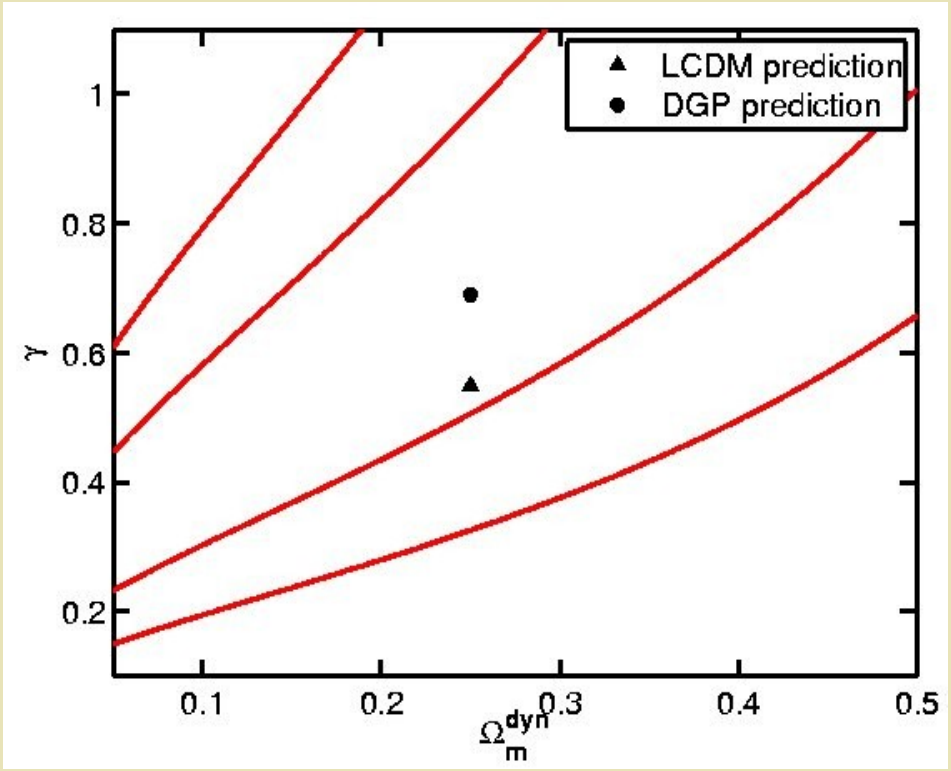
Dark Energy or Modified Gravity?

[redacted]

[redacted] LCDM

[redacted] DGP

[redacted]



From low-z SN Ia peculiar velocities

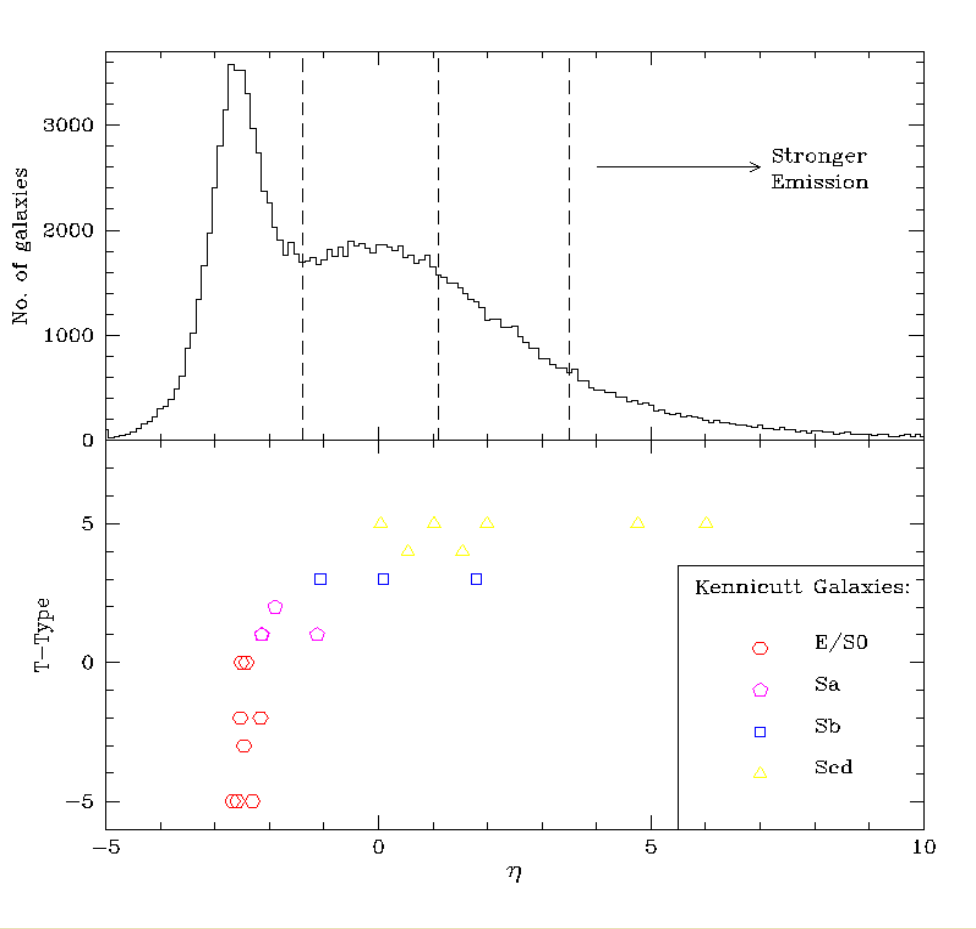
Abate & OL, arXiv:0805.3160

Redshift distortion - the 2dF experience

PCA: Red Blue

Madgwick, OL et al. 2003

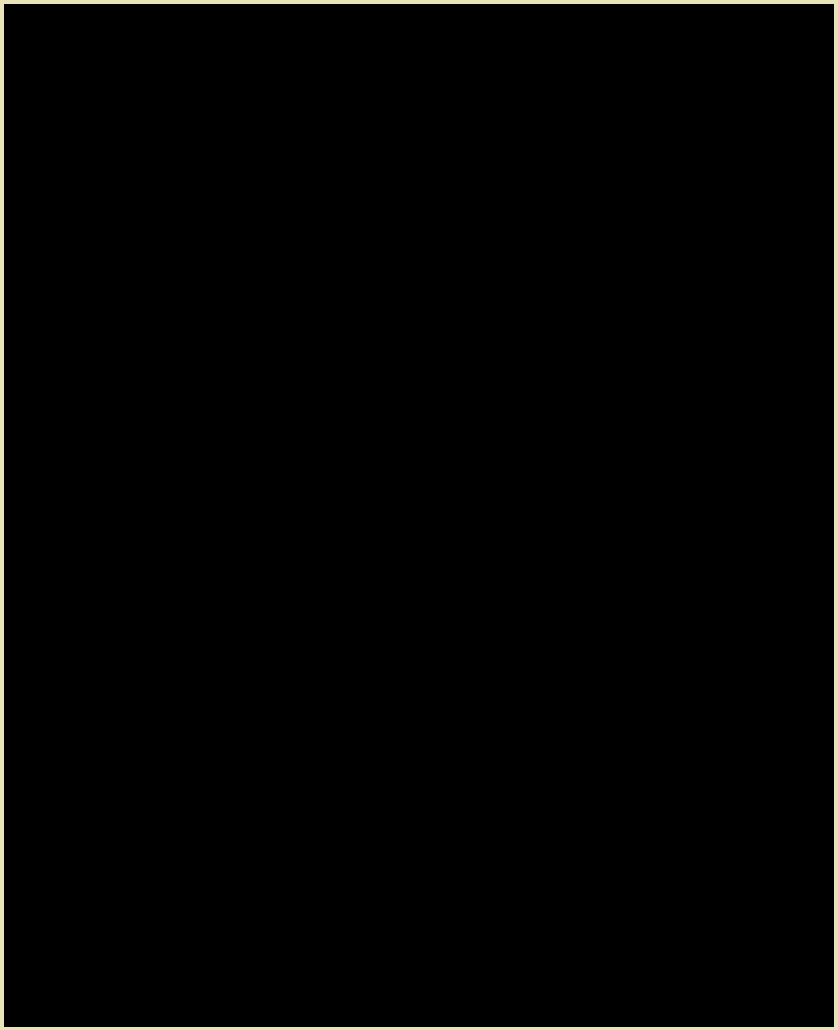
Bimodality in 2dF



$$g = 0.5\,pc_1 - pc_2$$

Madgwick, OL et al. 2003

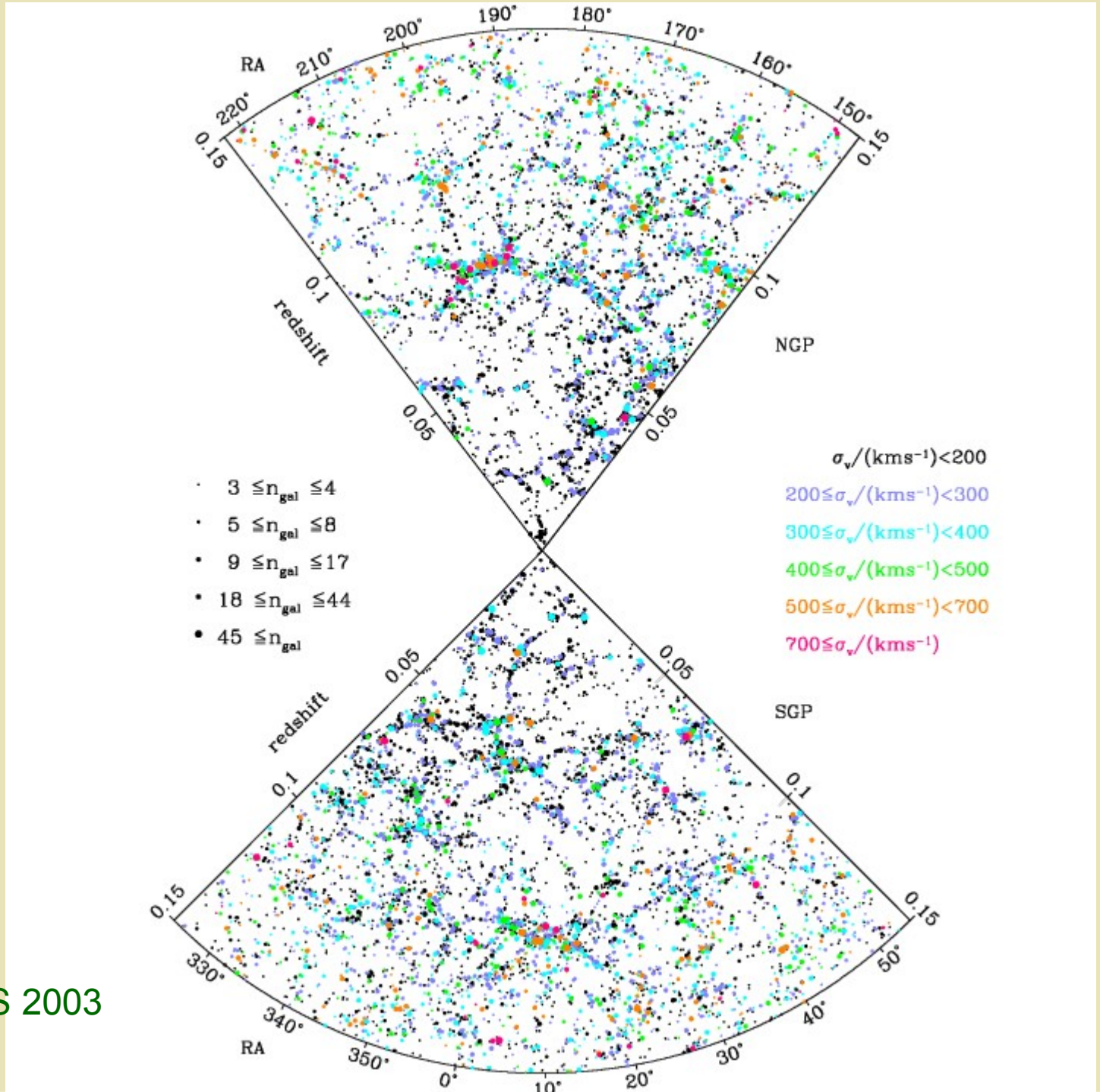
Redshift Distortion as a test of Modified Gravity



Guzzo et al. 2008

2PIGG:

Galaxy Groups in the 2dFGRS

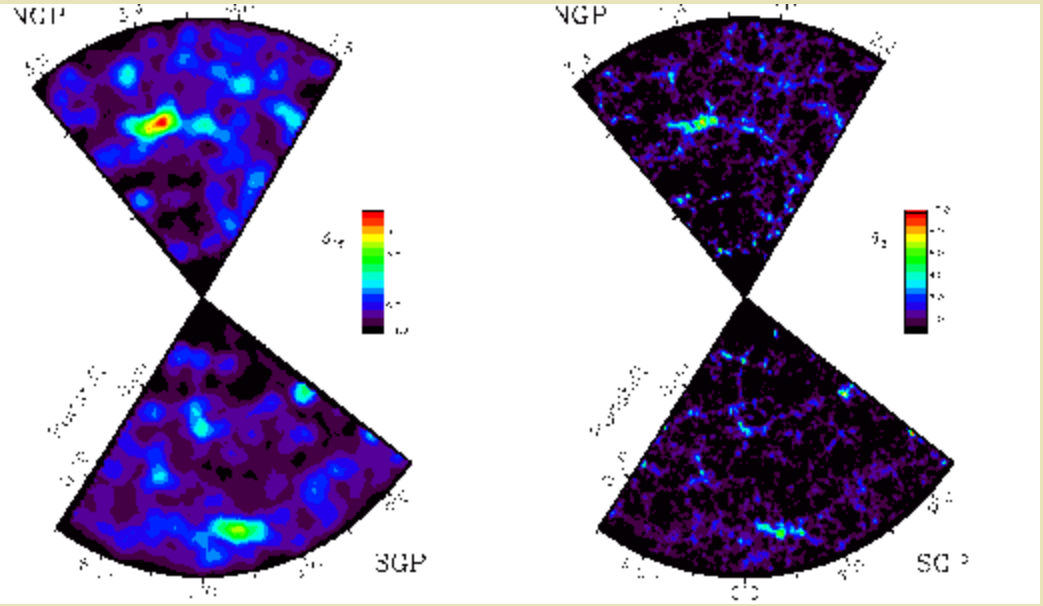


Eke et al., 2dFGRS 2003

Are the 2d Superclusters ‘typical’?

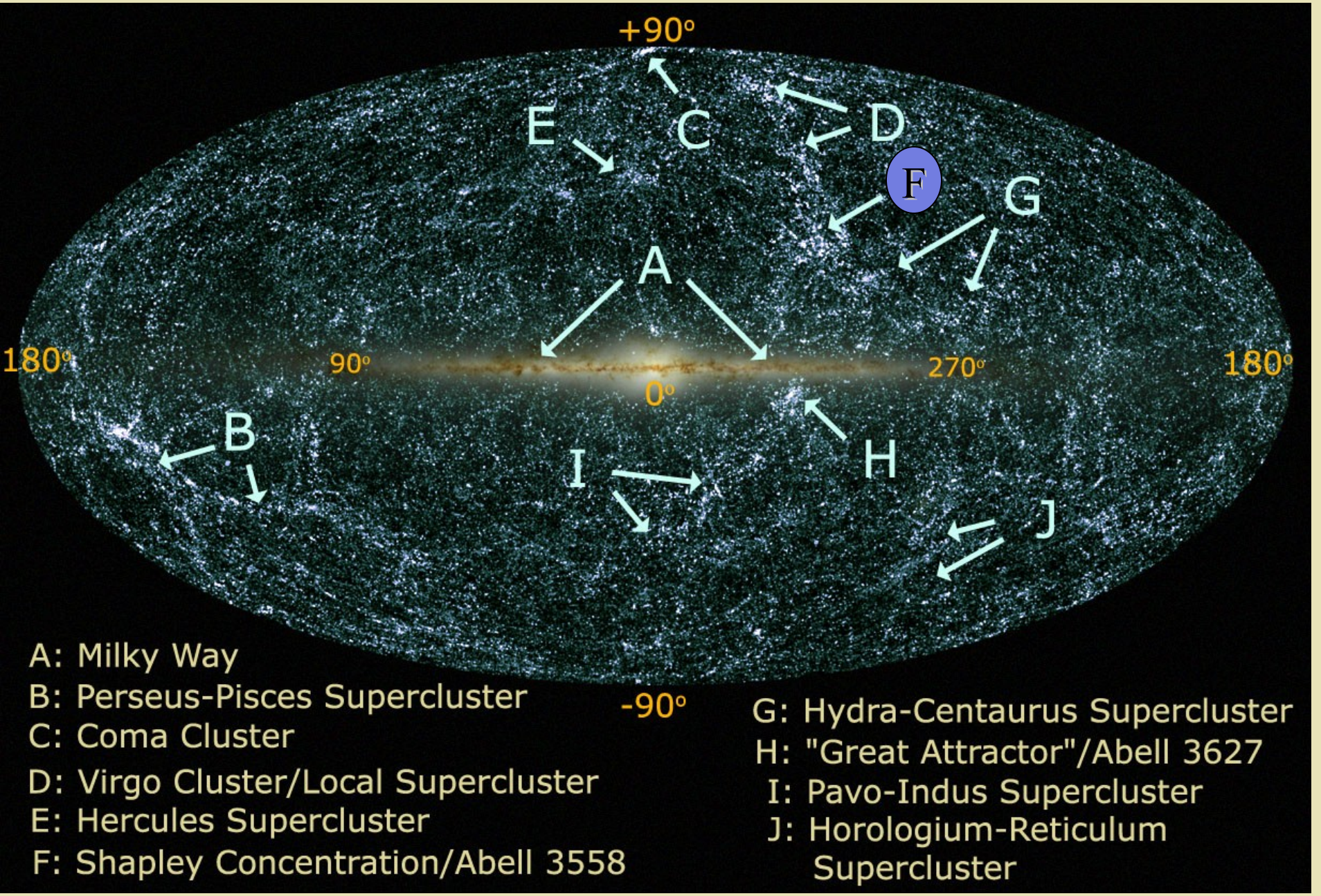
£ Abell clusters
77 groups (>8)

l□ Abell clusters
l□□ groups (>8)



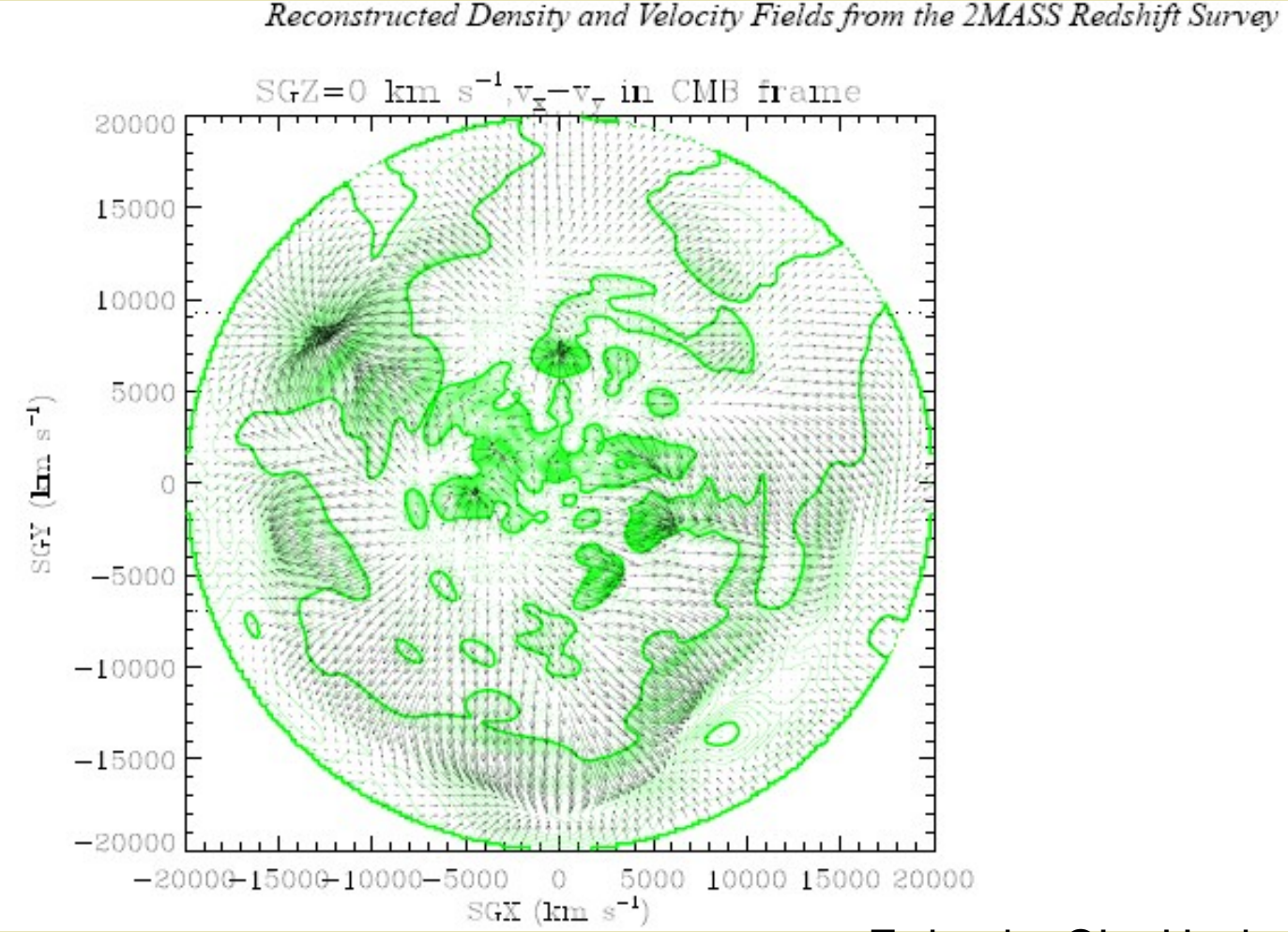
Baugh et al., Erdogdu et al.

Note partial sky coverage:
SDSS 10000 sq des; 2dF 2000 sq deg


+90°
E
C
D
F
G
A
180°
90°
270°
180°
0°
B
I
H
J
-90°
A: Milky Way
B: Perseus-Pisces Supercluster
C: Coma Cluster
D: Virgo Cluster/Local Supercluster
E: Hercules Supercluster
F: Shapley Concentration/Abell 3558
G: Hydra-Centaurus Supercluster
H: "Great Attractor"/Abell 3627
I: Pavo-Indus Supercluster
J: Horologium-Reticulum Supercluster

2MASS Map

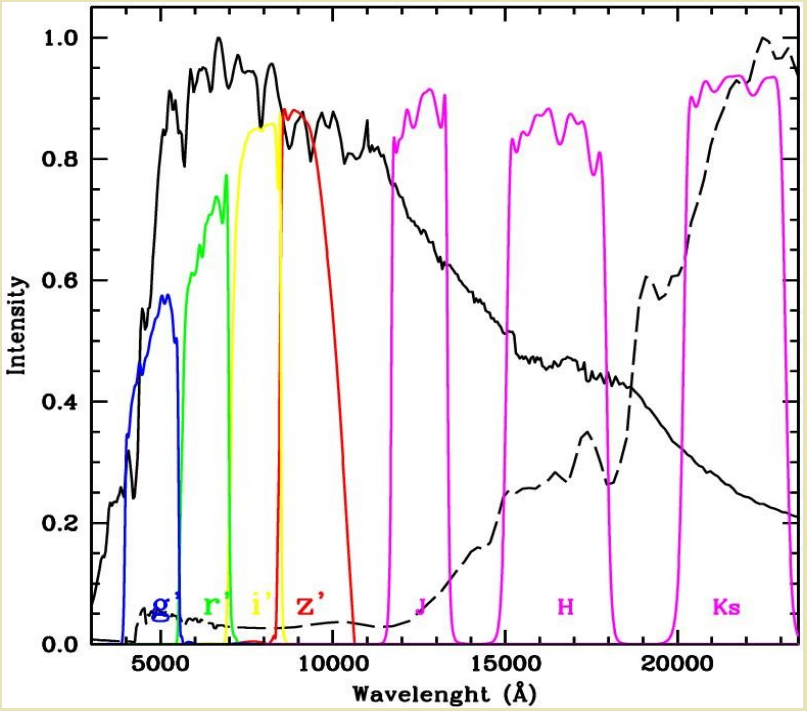
Density and velocity fields from the 2MASS 25k Redshift Survey



Erdogdu, OL, Huchra et al 2005

Photometric redshifts

- Probe strong spectral features (e.g. 4000 break)



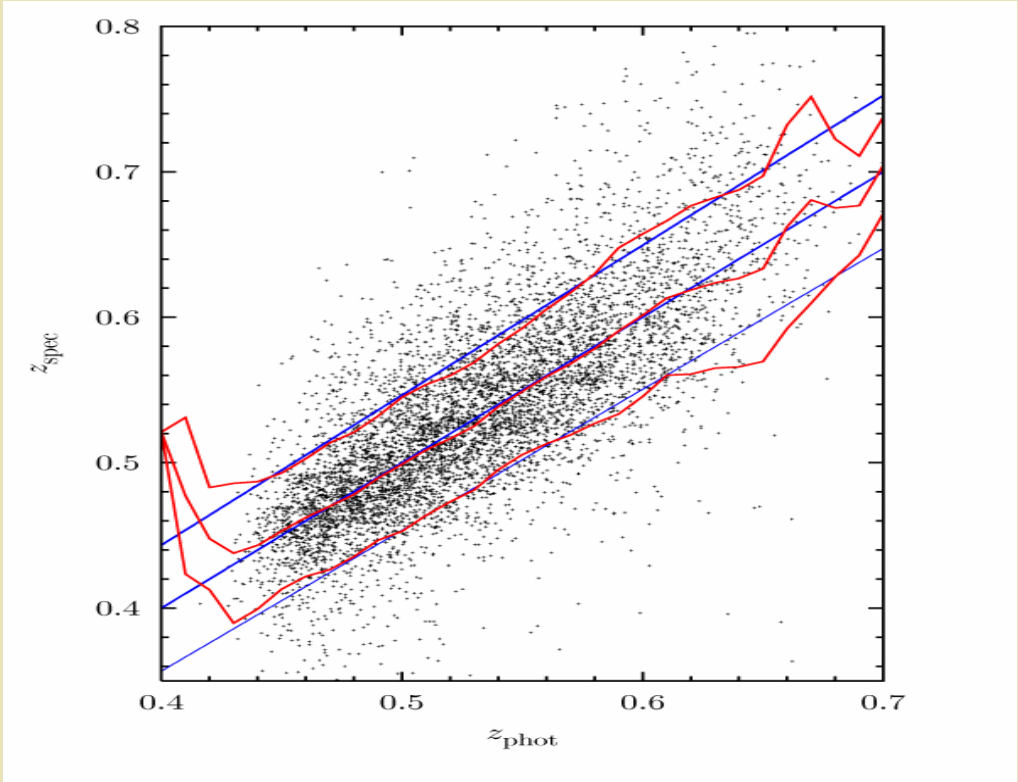
MegaZ-LRG

*Training on ~13,000 2SLAQ

*Generating with ANNz

Photo-z for ~1,000,000 LRGs

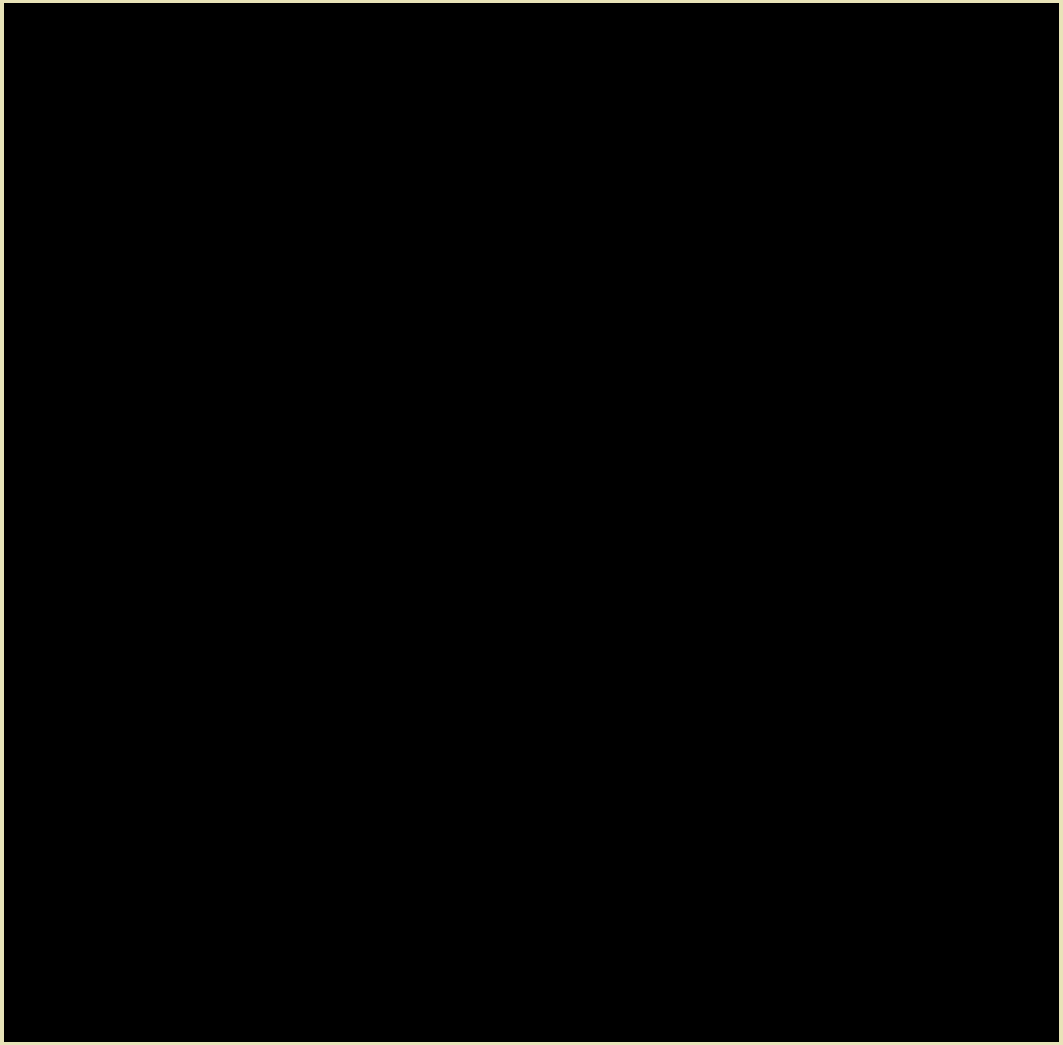
over 5,000 sq deg, 2.5 (Gpc/h)^3



$_z = 0.046$

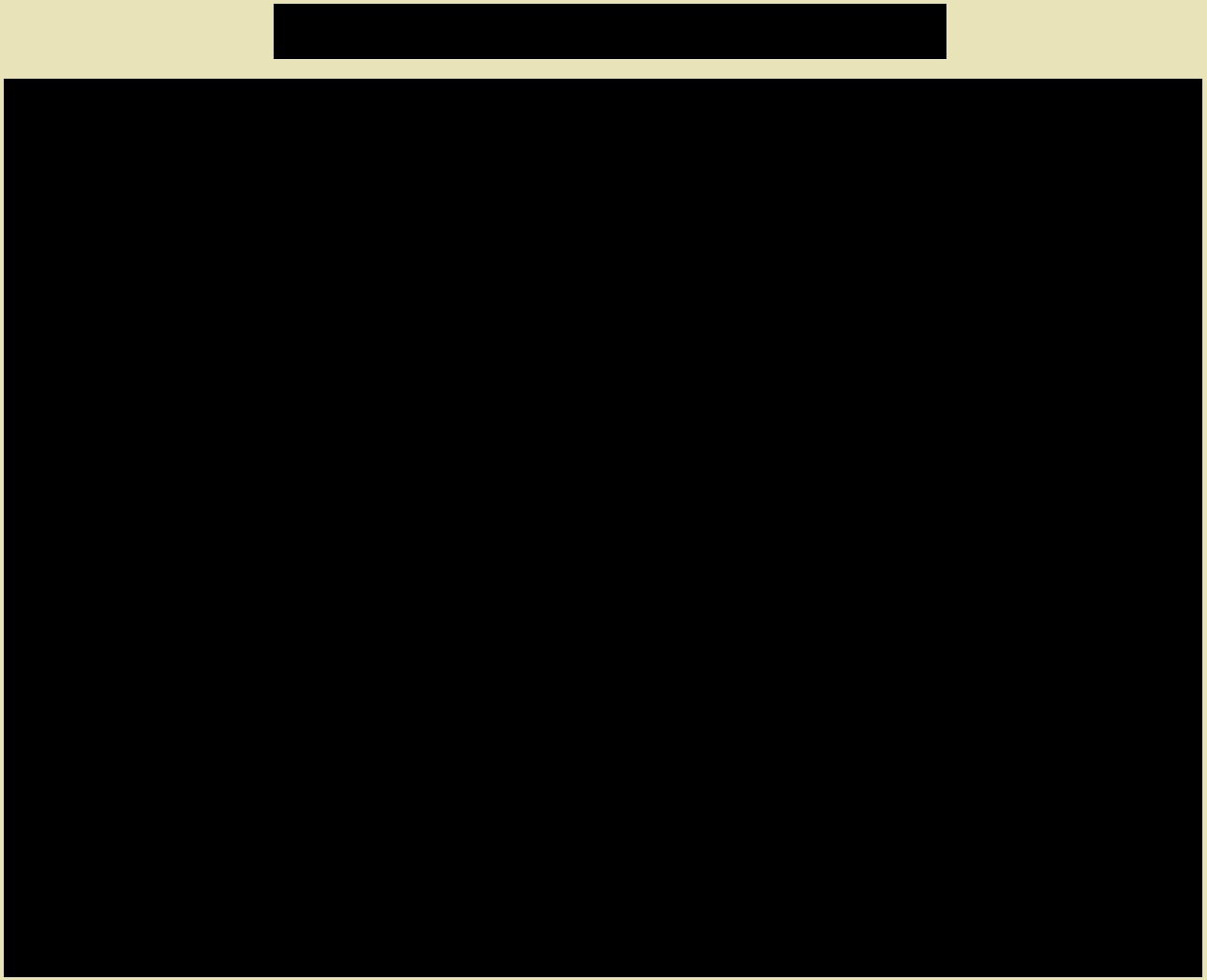
Collister, OL et al. 2006

LRG - photo-z code comparison



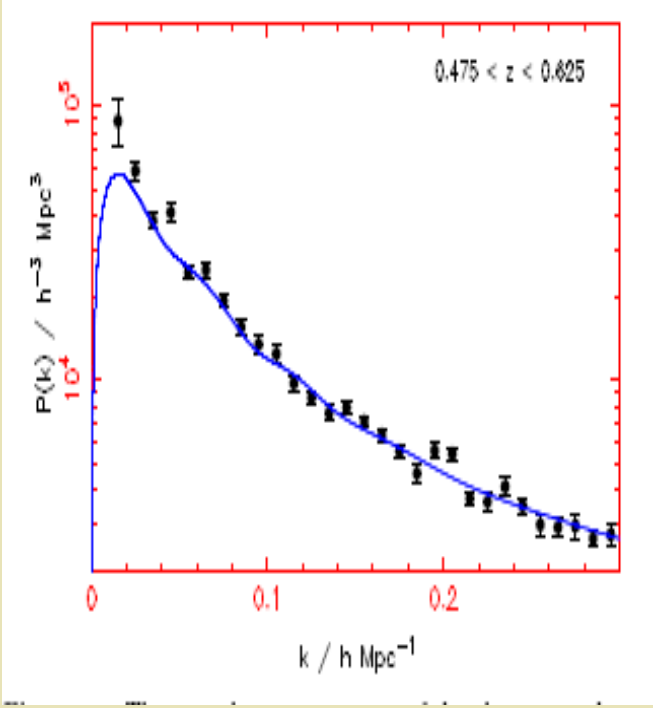
F. Abdalla, M. Banerji, OL, V. Rashkov, in prep

Halo fit to MegaZ-LRG

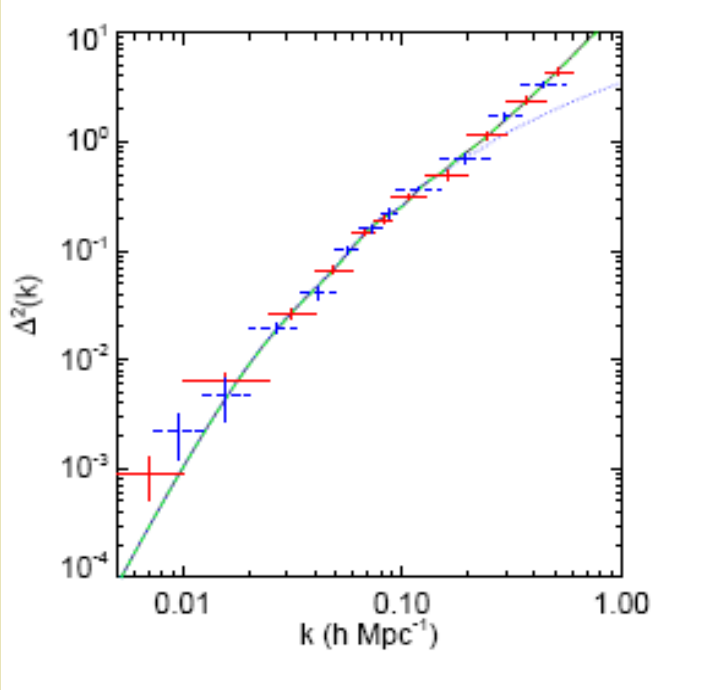


Blake, Collister & OL
0704.3377

LRGs: Excess Power on Large Scales?



Blake et al. 06



Padmanabhan et al. 06

Planned photometric and spectroscopic surveys

Photo-z / Cosmology Synergy

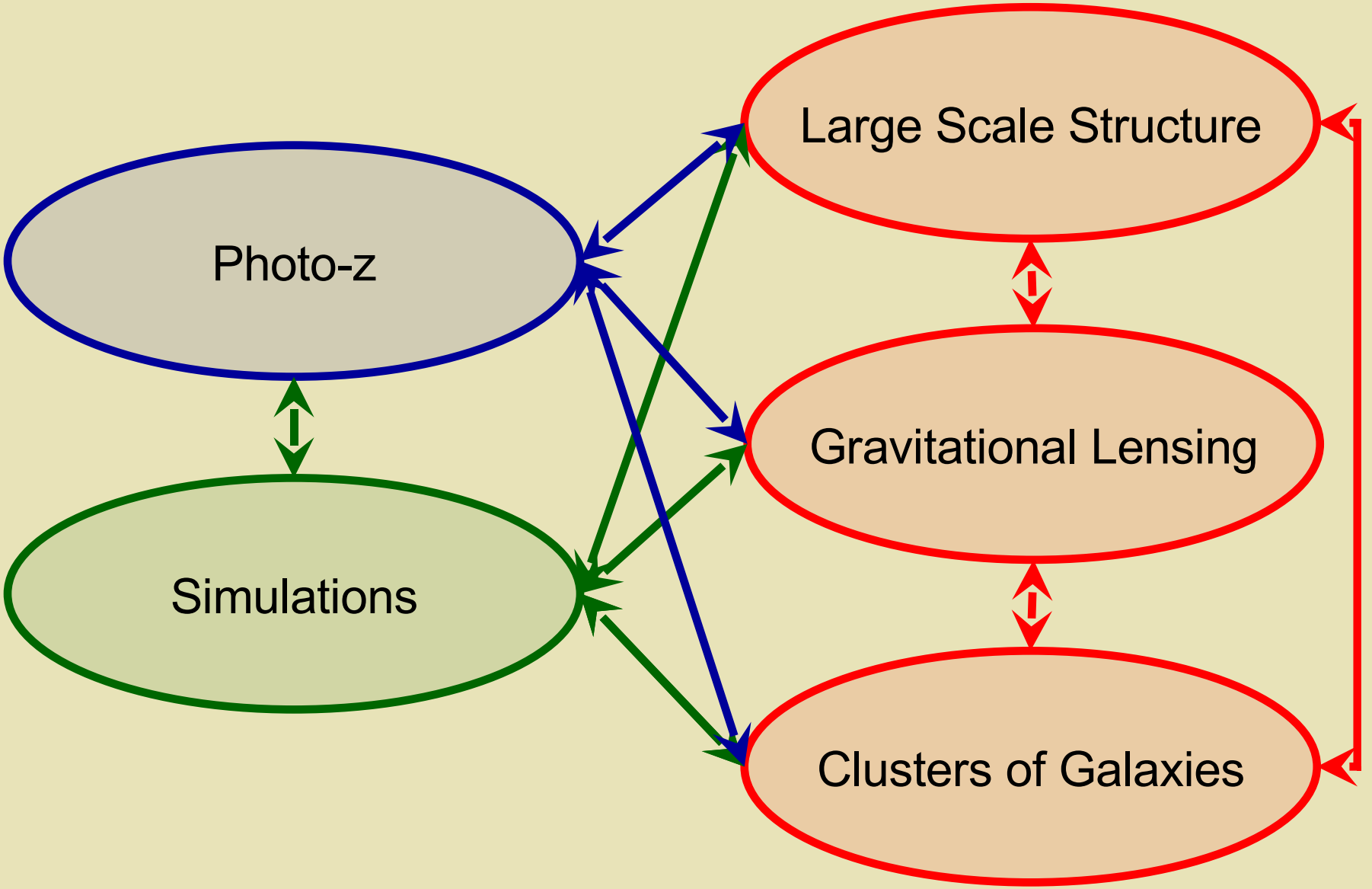


Photo-z –Dark Energy cross talk

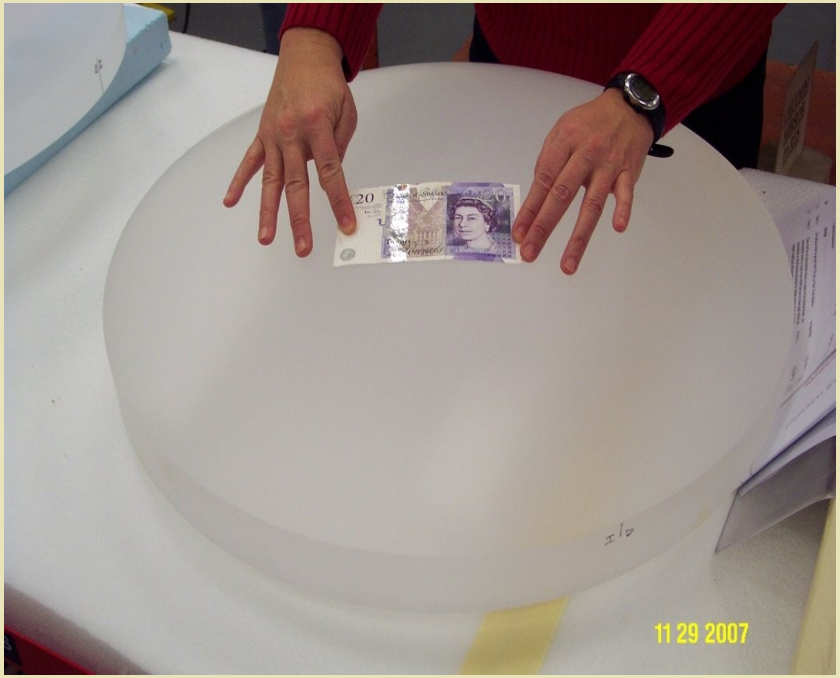
- Approximately, for a photo-z slice:

$$(\delta w/ w) = 5\,(\delta z/ z) = 5\,(\sigma_z/z)\,N_s^{-1/2}$$

=> the target accuracy in w and photo-z scatter σ_z dictate the number of required spectroscopic redshifts

$N_s = 10^5\text{-}10^6$

The Dark Energy Survey
300 million galaxies
starting 2011



Euclid: Dune + Space
ESA Cosmic Vision 2017

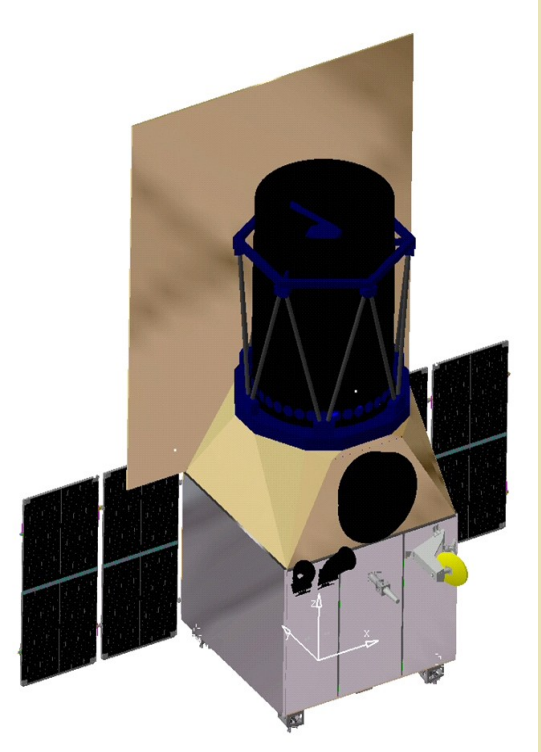
Mission baseline (Dune):

- 1.2m telescope

Surveys (3-year initial programme):

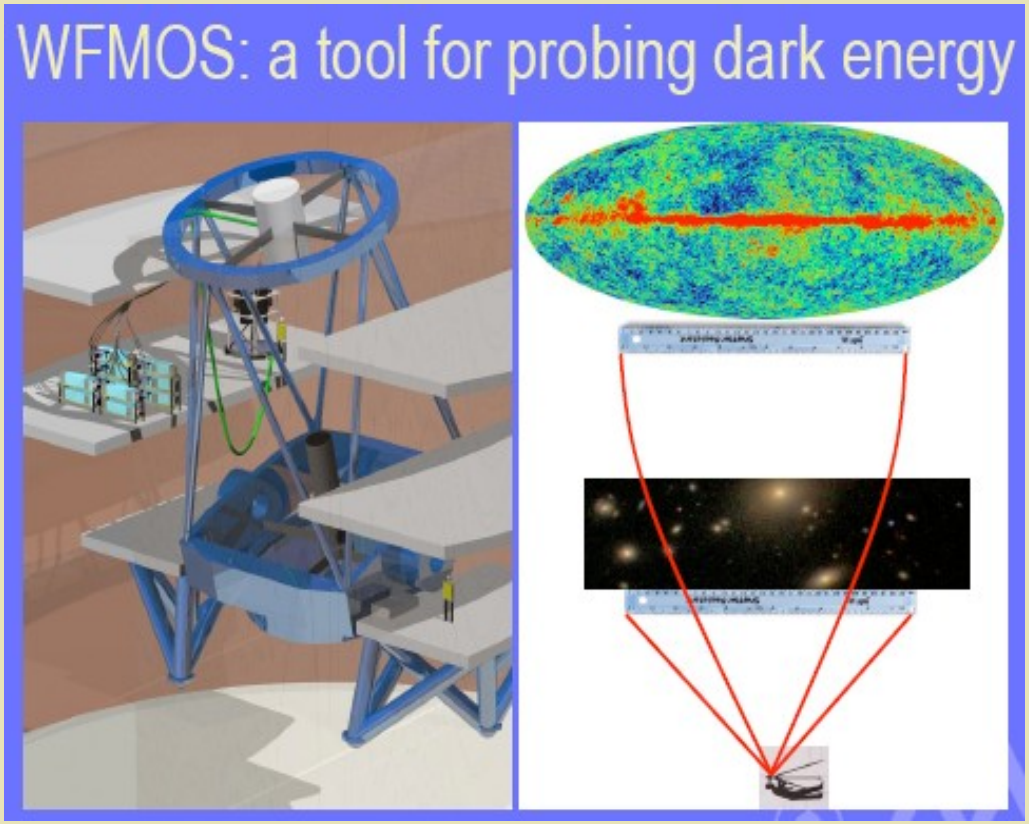
- WL survey: 20,000 deg^2 in
1 red broad band (<24.5), 35 galaxies/amin^2 with median z ~ 1,
ground based complement for photo-z's

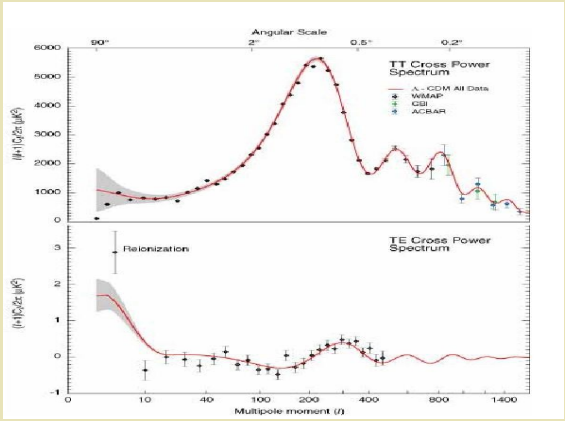
- Near-IR survey (Y,J,H) from space

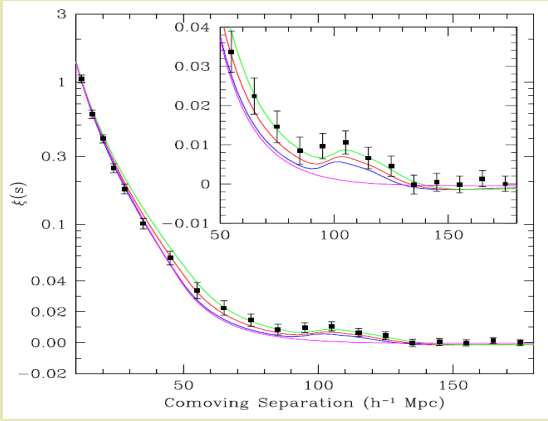


+ the spectroscopy (SPACE) for z< 2

WFMOS


WFMOS: a tool for probing dark energy


Angular Scale
TT Cross Power Spectrum
TE Cross Power Spectrum
Reionization
Multipole moment (l)


ξ(s)
Comoving Separation (h⁻¹ Mpc)

Summary

- SDSS (main and LRG): both photometry & specroscopy - a winning combination!
- LSS in 2dF and SDSS: agreement with LCDM, but some tension due to cross talk between comology & biasing (halo model). Both produced science not originally plannaed.
- SDSS and 2dF: wide field, but not whole sky (cf. 2MASS, Euclid)
- Next generation of (separate?) imaging and spectroscopy: current motivation is Dark Energy (but not only), photoz challeneges
- SDSS and 2dF: started a new culture of big collaborations in Astronomy

The End

2dFGRS PhD students & collaborators

Spectral classification (PCA):
S. Folkes, S. Ronen, D. Madgwick

Biasing from 2dF+CMB: S. Bridleg

Neutrino mass: O. Elgaroy

Wiener Reconstruction: P. Erdogdu

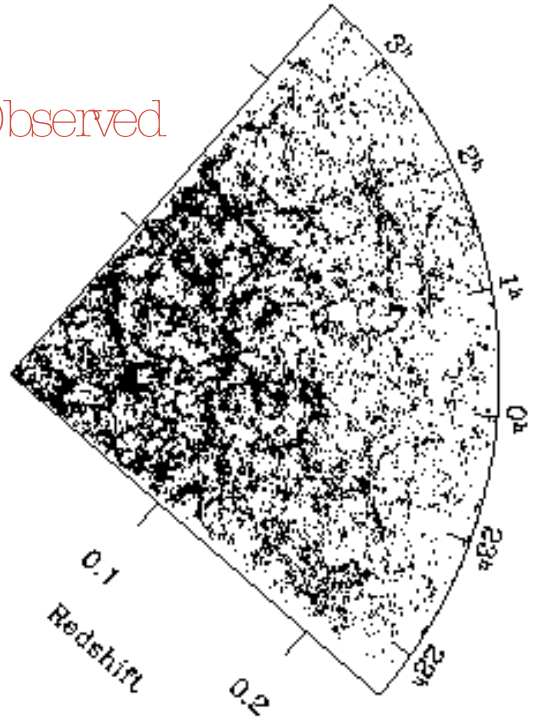
Stochastic Biasing: V. Wild

Testing the halo model: A. Collister

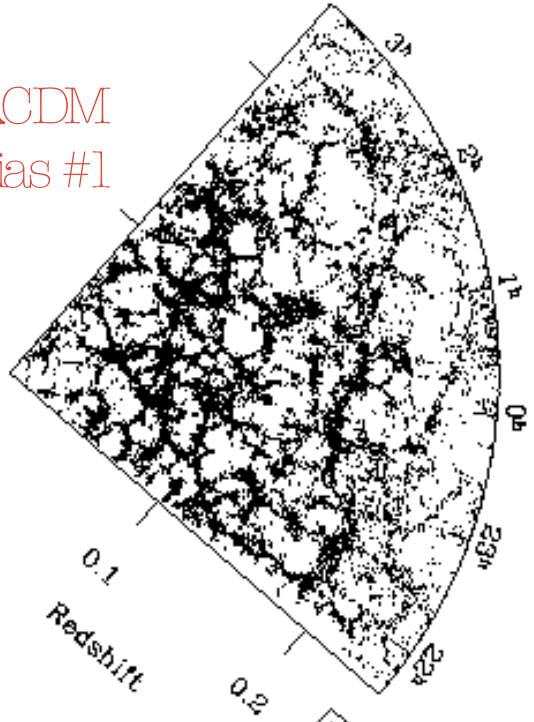
Ofer Lahav, UCL

Cosmology by eye!

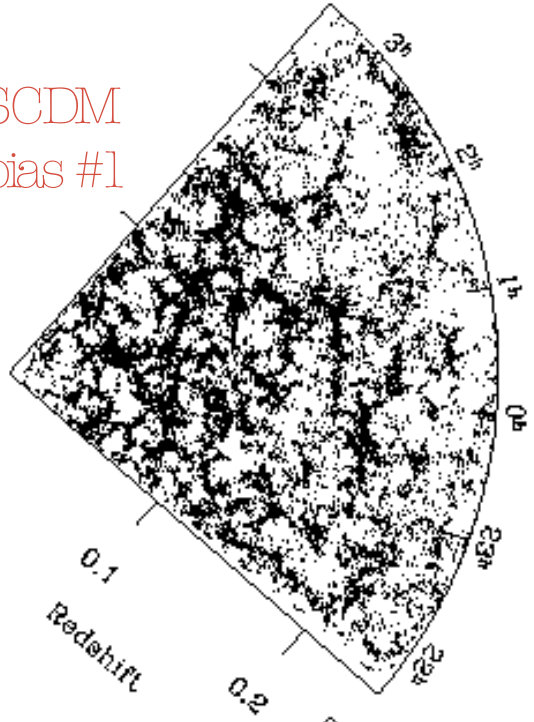
Observed



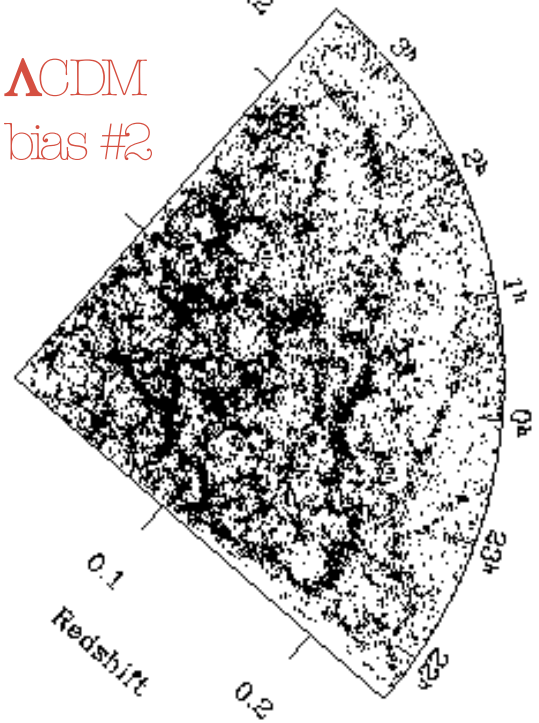
ΛCDM bias #1



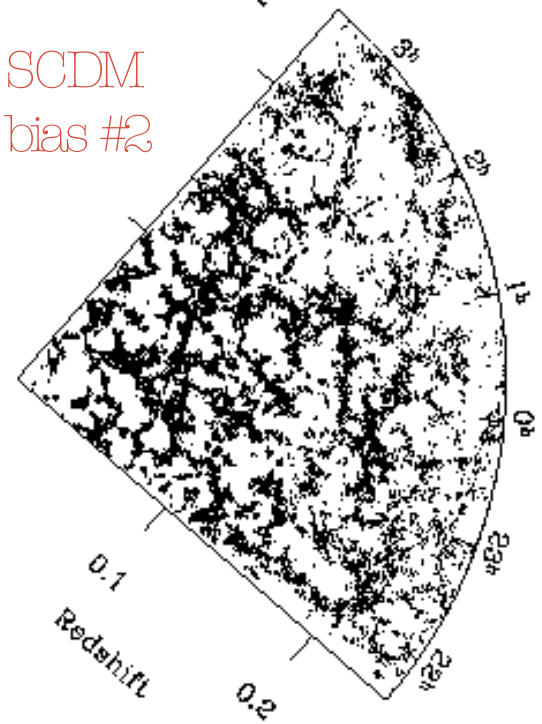
SCDM bias #1



ΛCDM bias #2

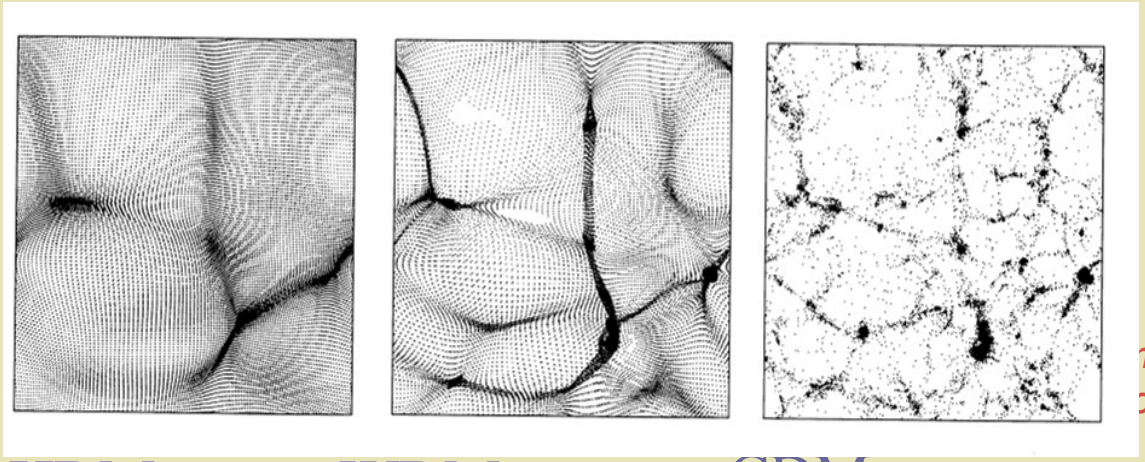


SCDM bias #2



Neutrinos decoupled when they were still relativistic, hence they wiped out structure on small scales

$k > k_{nr} = 0.026 (m_b / 1\ eV)^{1/2} b_m^{1/2}$ h/Mpc



CDM+HDM WDM CDM

mbi, Dodelson, & ow 1995

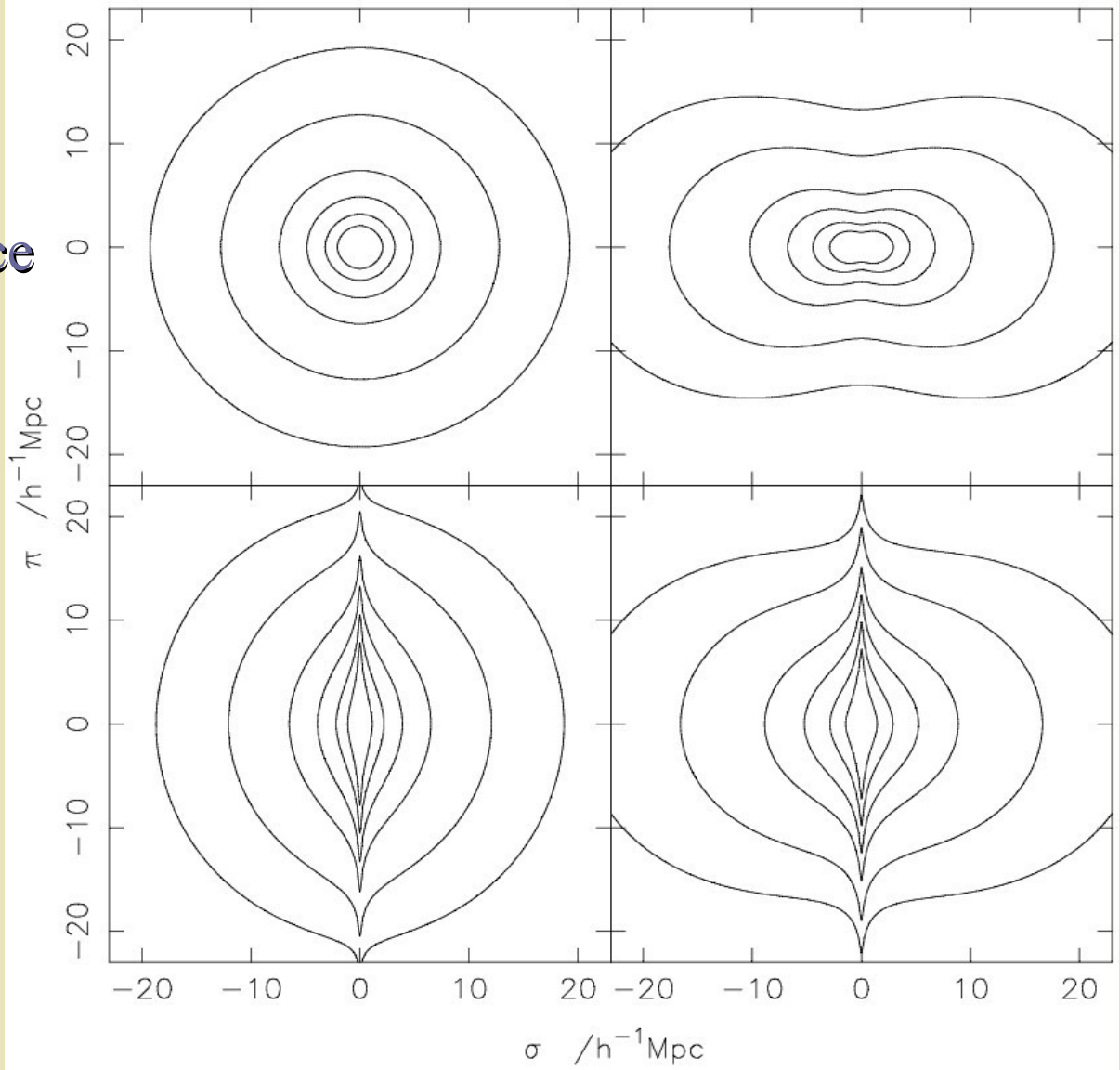
Massive neutrinos mimic a smaller source term

$$\ddot{\delta} + 2\frac{\dot{a}}{a}\dot{\delta} = 4\pi G\rho_0(1 - f_\nu)\delta$$

Redshift Distortion

Real Space

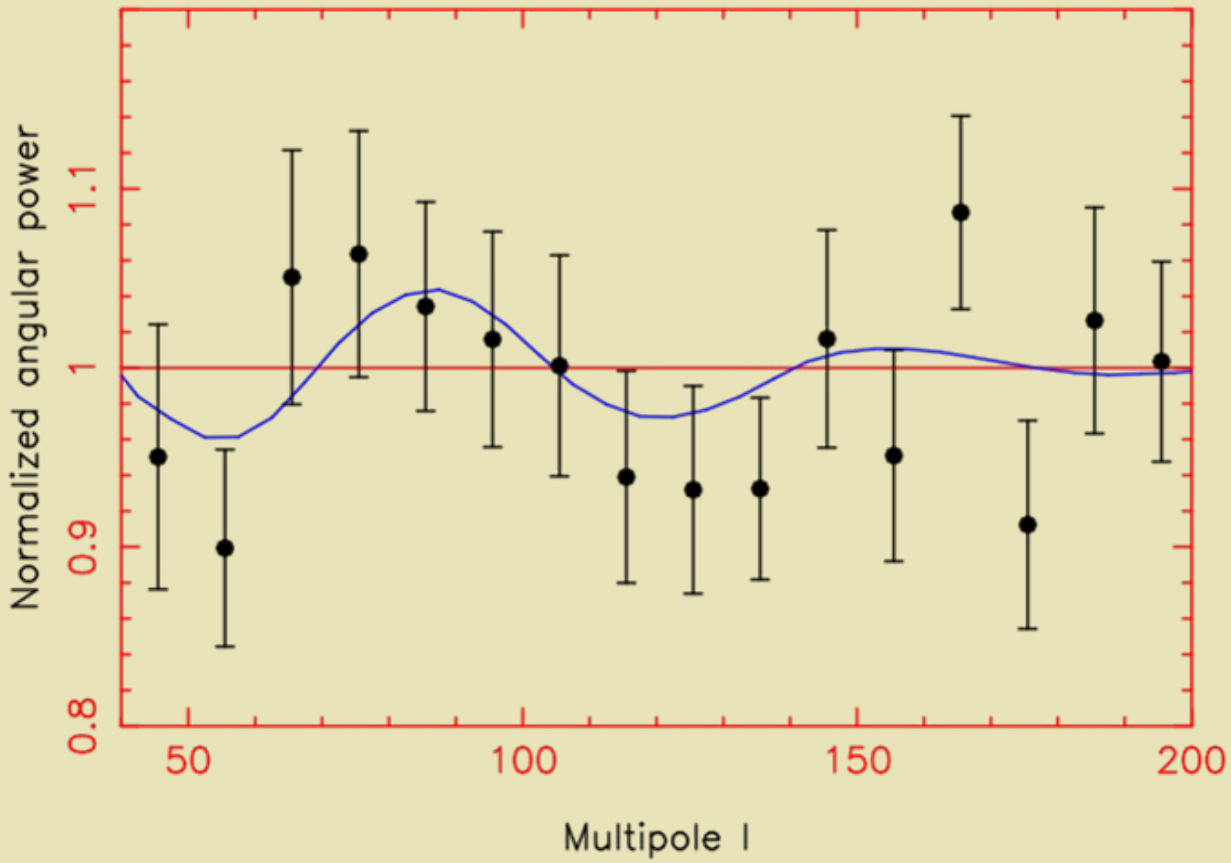
Linear collapse



FoG

Linear+FoG

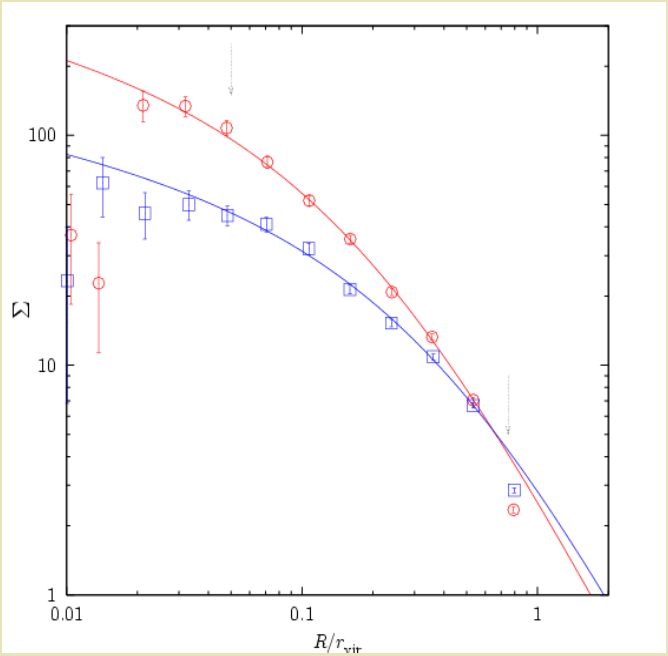
Baryon oscillations



Blake, Collister, Bridle & Lahav; astro-ph/0605303

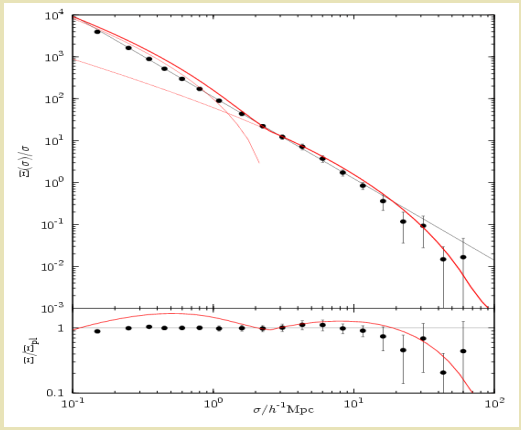
The halo model

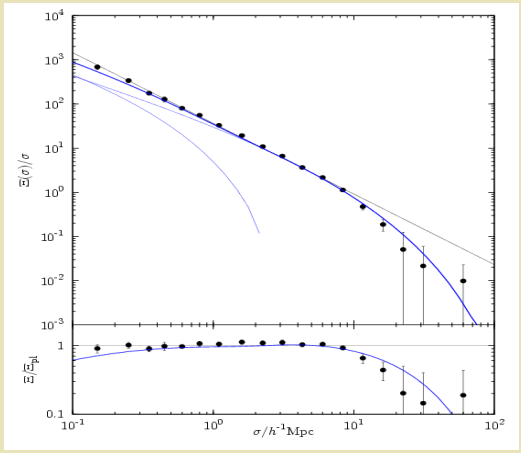
$$P(k) = P_{lin}(k) + P_{halo}(k)$$



$$\langle N|M\rangle = (M/M_0)^{\beta}$$

$$for\ M > M_{cut}$$





Red galaxies

β=1.05 §0.19

C=3.9§0.5

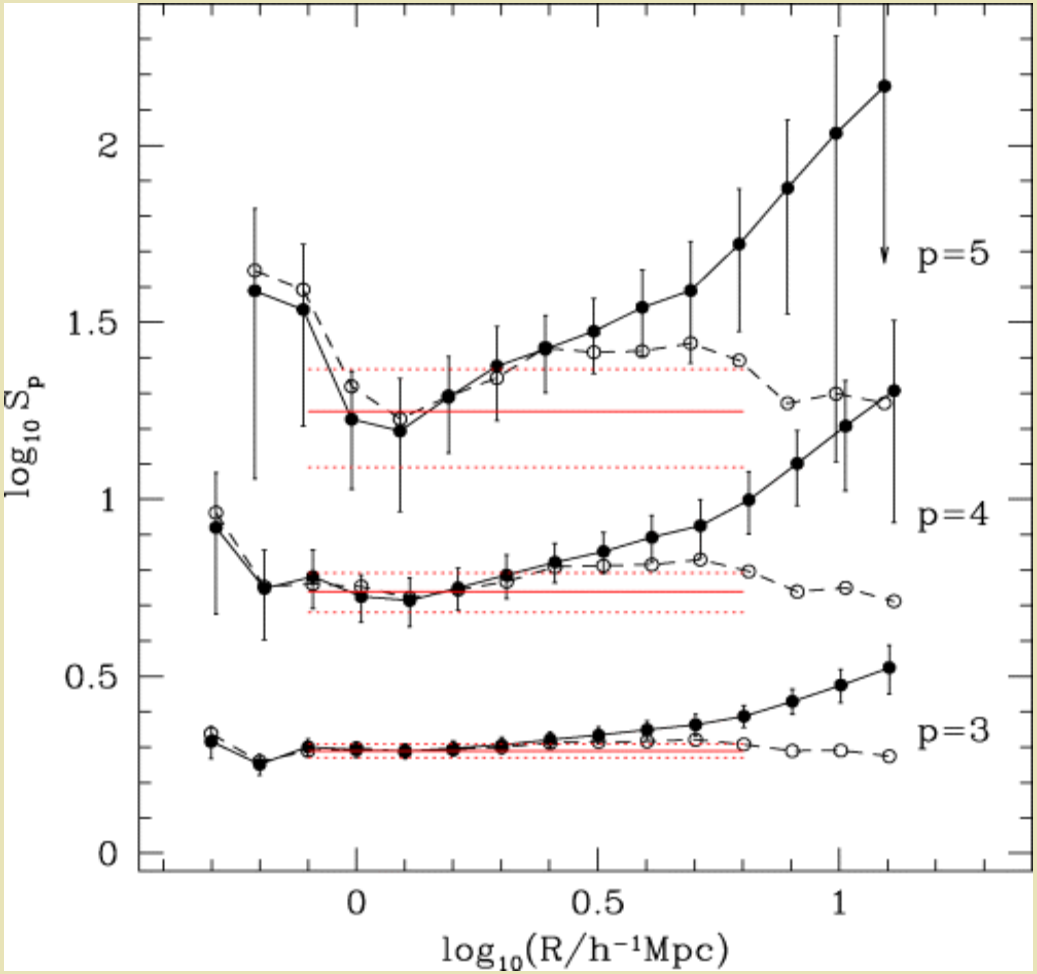
Blue galaxies

β = 0.88§0.17

C=1.3§0.2

The effect of the two SC on higher moments

$S_p = \langle \delta^p \rangle / \langle \delta^2 \rangle^{p-1}$



Baugh et al.

Comology-halo parameters cross talk

(c-g, g-g, both)

Wide Field Photometry

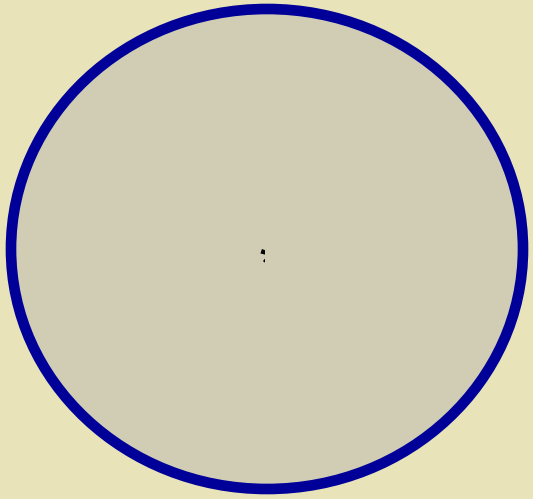
Survey	Diameter (m)	FOV (deg^2)	Area (deg^2)	start
CFHTLS	3.6	1	172	2003
KIDS (VST)	2.6	1	1700	2008
DES (NOAO)	4	2	5000	2009
HSC (Subaru)	8	2	2000?	2011
Pan-STARRS	1.8(x4)	7(№4)	30000	2007(12)
LSST	8	7	30000	2014

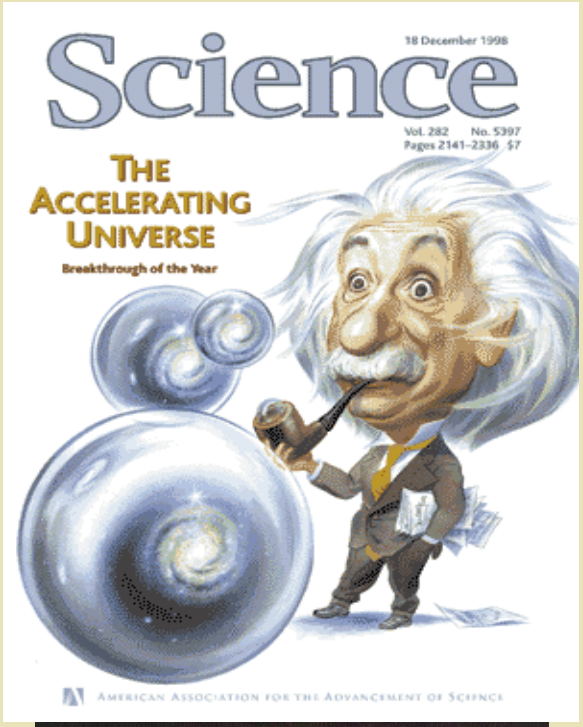
cf. Multi-Object Spectroscopy:
VLT/VIMOS, WFMOS, JWST, BOSS, HET-DEX

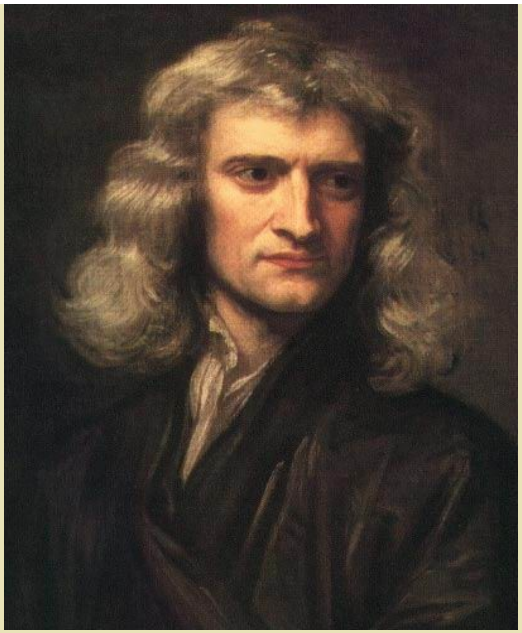
Dark Energy: back to Newton?

$$F = -GM/r^2 + b/3\ r$$

X







"I have now explained the two principle cases of attraction…
which is very remarkable" - Newton, Principia

Calder & Lahav, 0712.2196