Baryonic Acoustic Oscillations: BAO

Outline:

➔BAO: standard ruler

➔Present detections of BAO (SDSS, 2dF)

➔Simulations: predictions

➔ SKA: billion galaxies at 21cm, + WL ➔ DE

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SKA-PNC, 27 Octobre 2006

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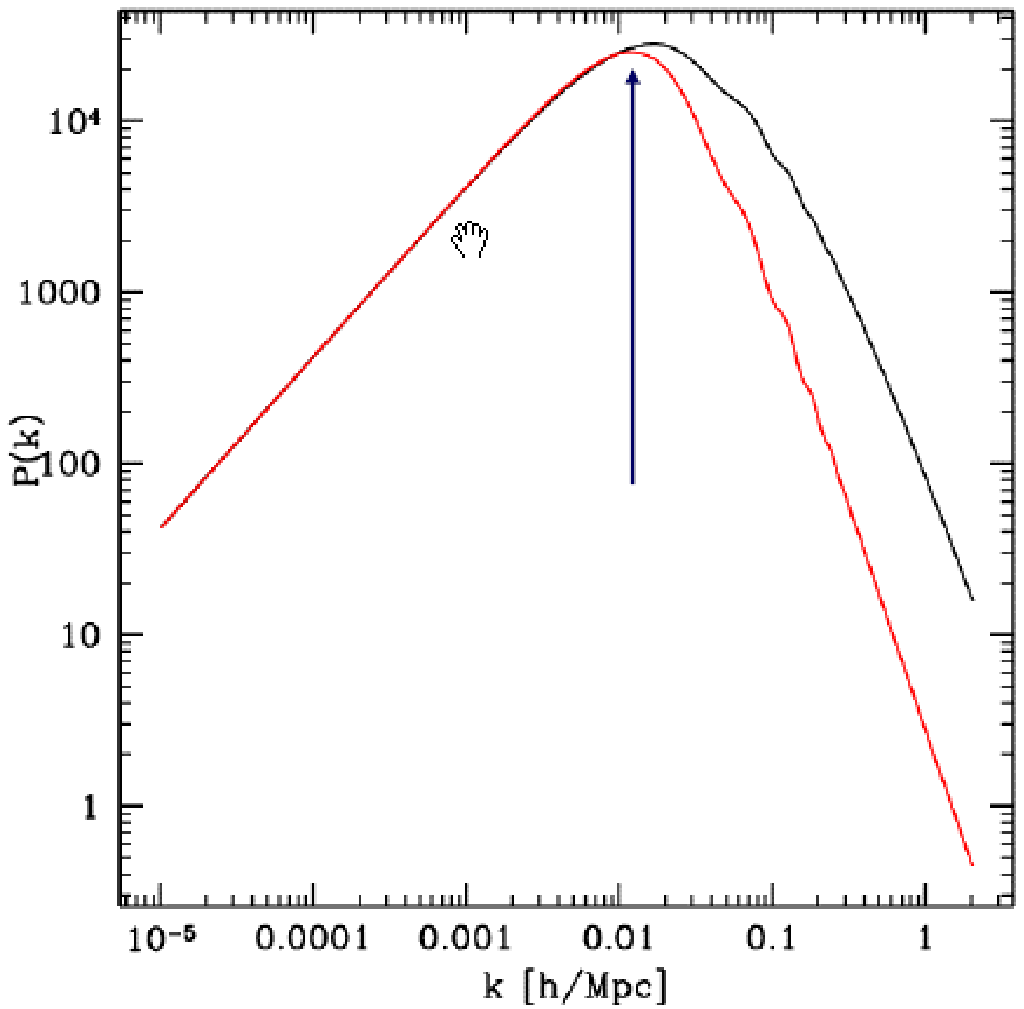
Linear power spectrum



Scale of the bend in P(k) is the size of the horizon at matter-radiation equality

60 000 yrs after Big-Bang

$f\nu = \Omega\nu/\Omega dm = 1/3$

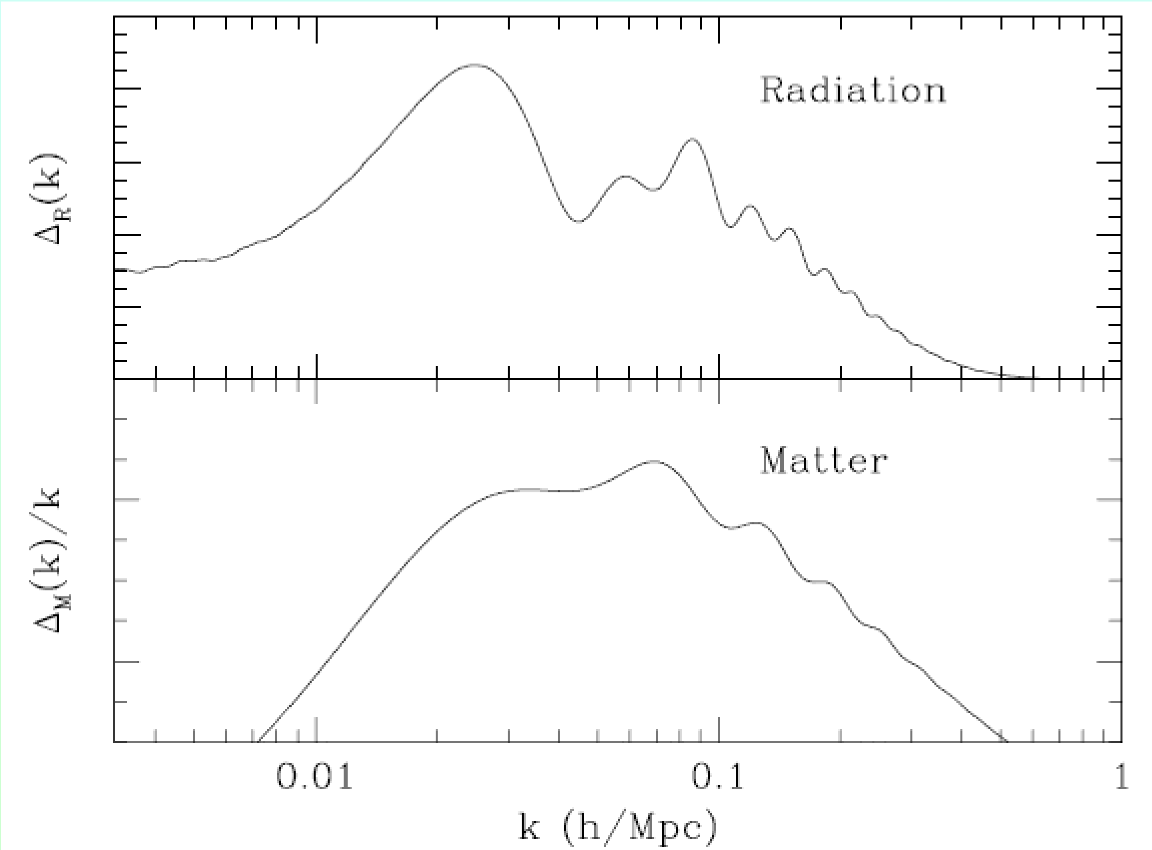
$\Sigma m\nu = 3.7ev$

Free-streaming reduces Small scale structure

Expected oscillations

Not in phase
At small scale
(velocities)
And twice the
Wavelength

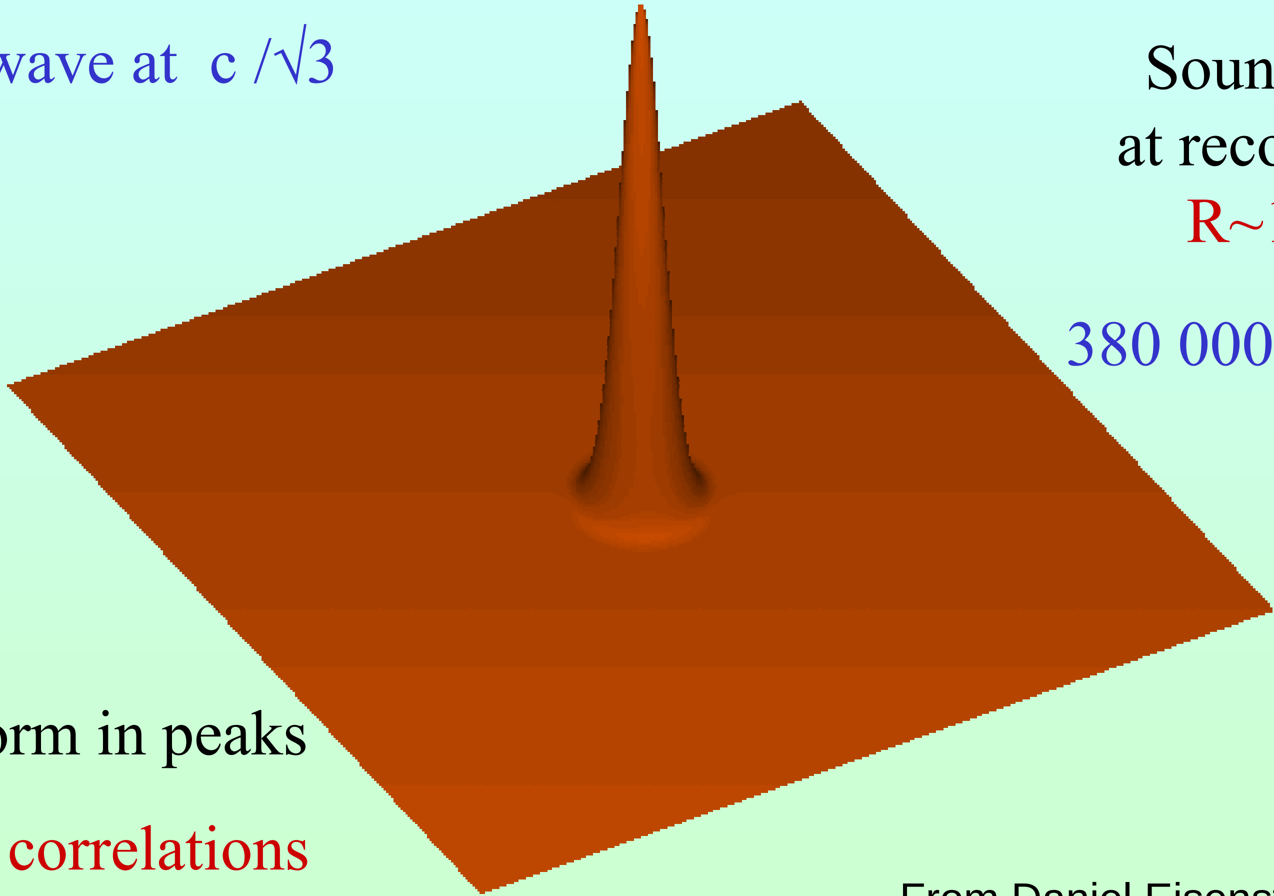
Hütsi 2005



A single perturbation

Creates a depression

➔ Sound wave at $c/\sqrt{3}$



Sound horizon
at recombination
R~150Mpc

380 000 yrs after BB

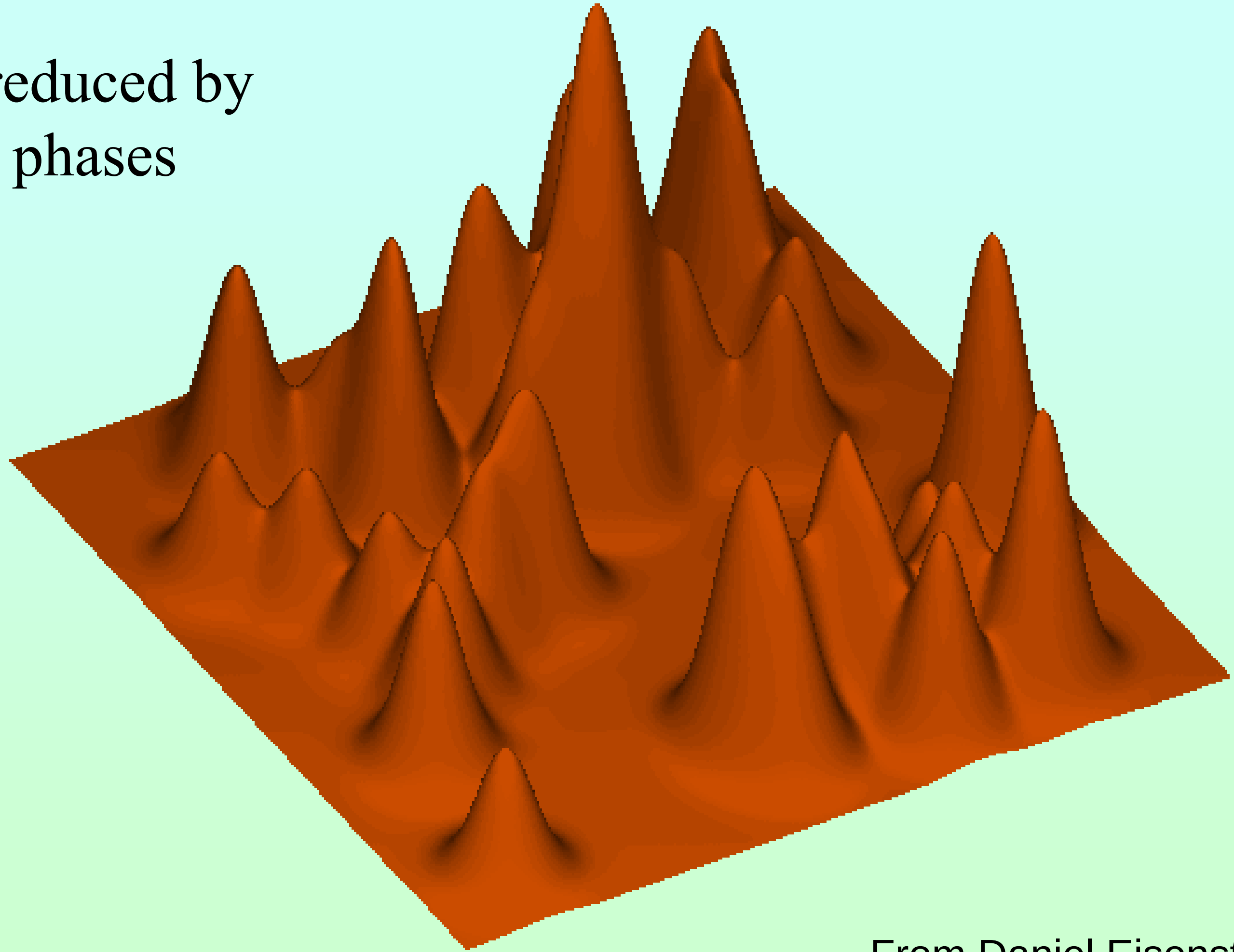
Galaxies form in peaks

➔ baryon correlations

From Daniel Eisenstein

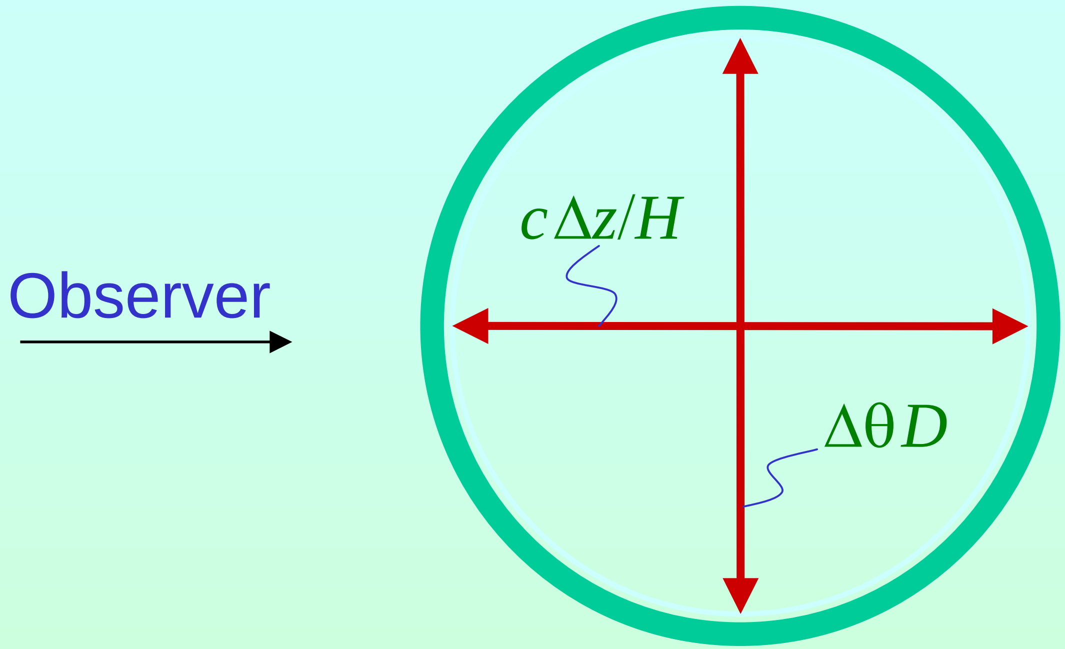
Random perturbations

Signal reduced by random phases



From Daniel Eisenstein

BAO: Standard Ruler



$$c\Delta z/H = \Delta\theta D$$

➔Possibility to determine H(z)

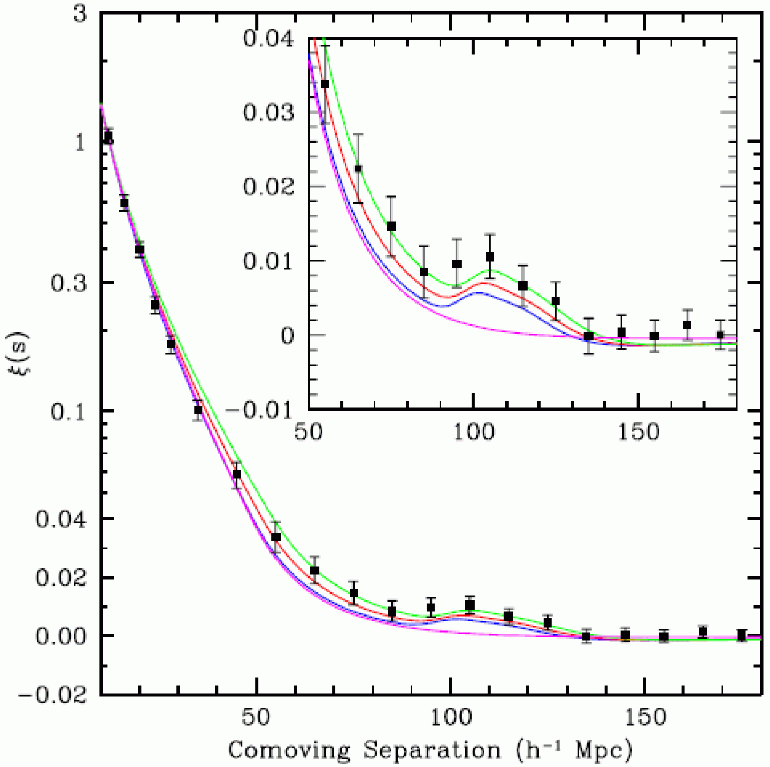
Alcok & Paczynski (1979)
Test of cosmological cst

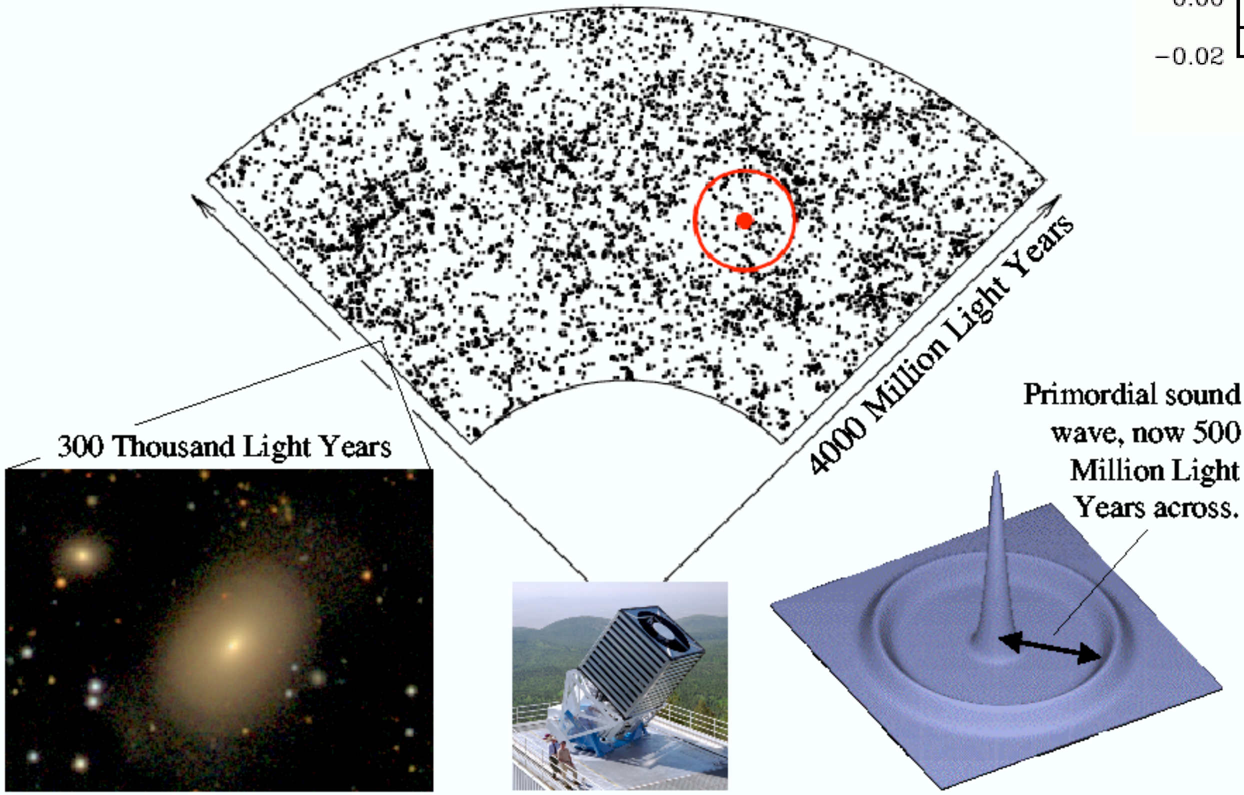
Could test the bias b
Or $\beta = \Omega_m^{0.6}/b$

Baryonic acoustic peak

Waves detected today
In the distribution of baryons

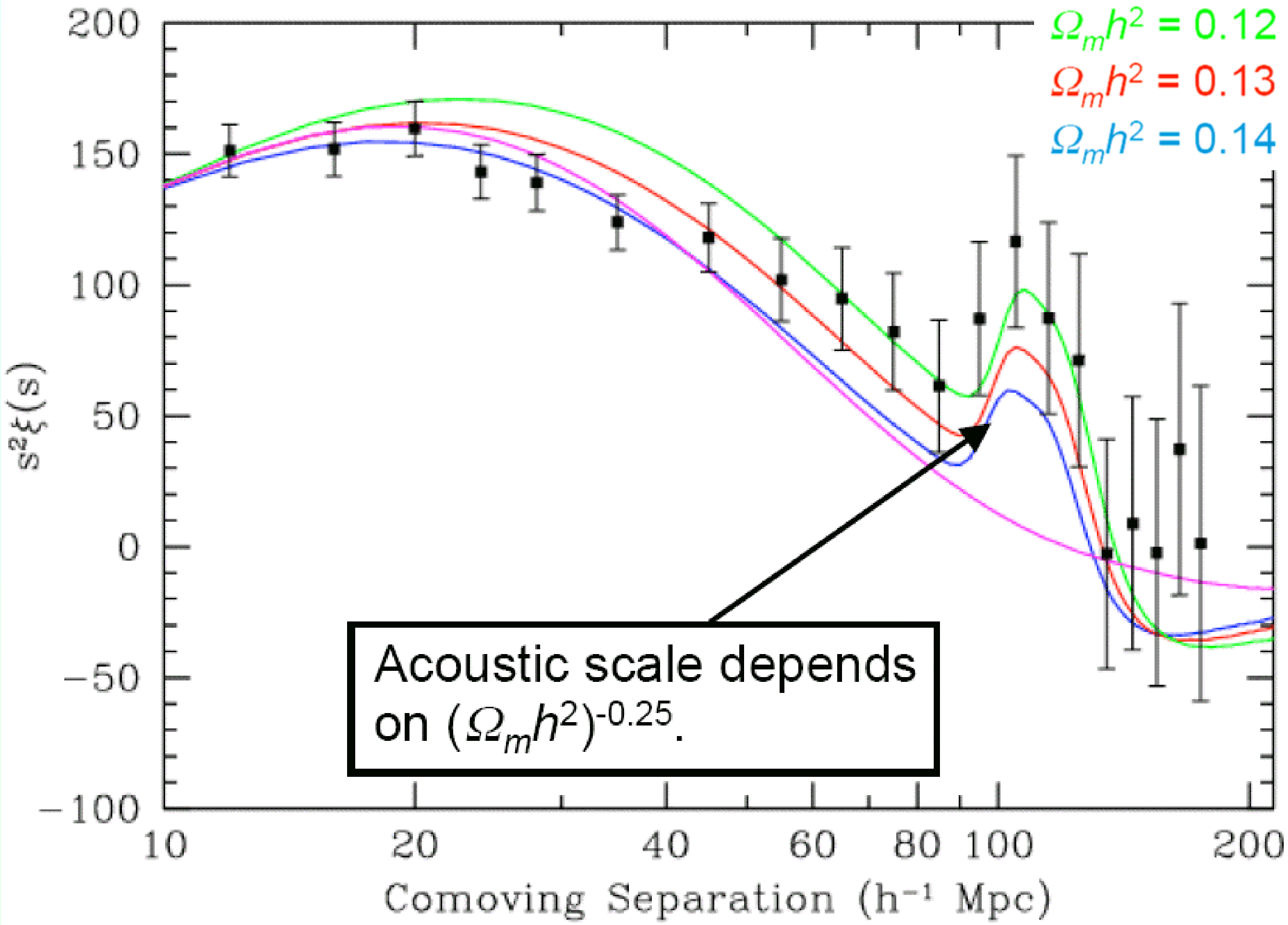
50 000 galaxies SDSS





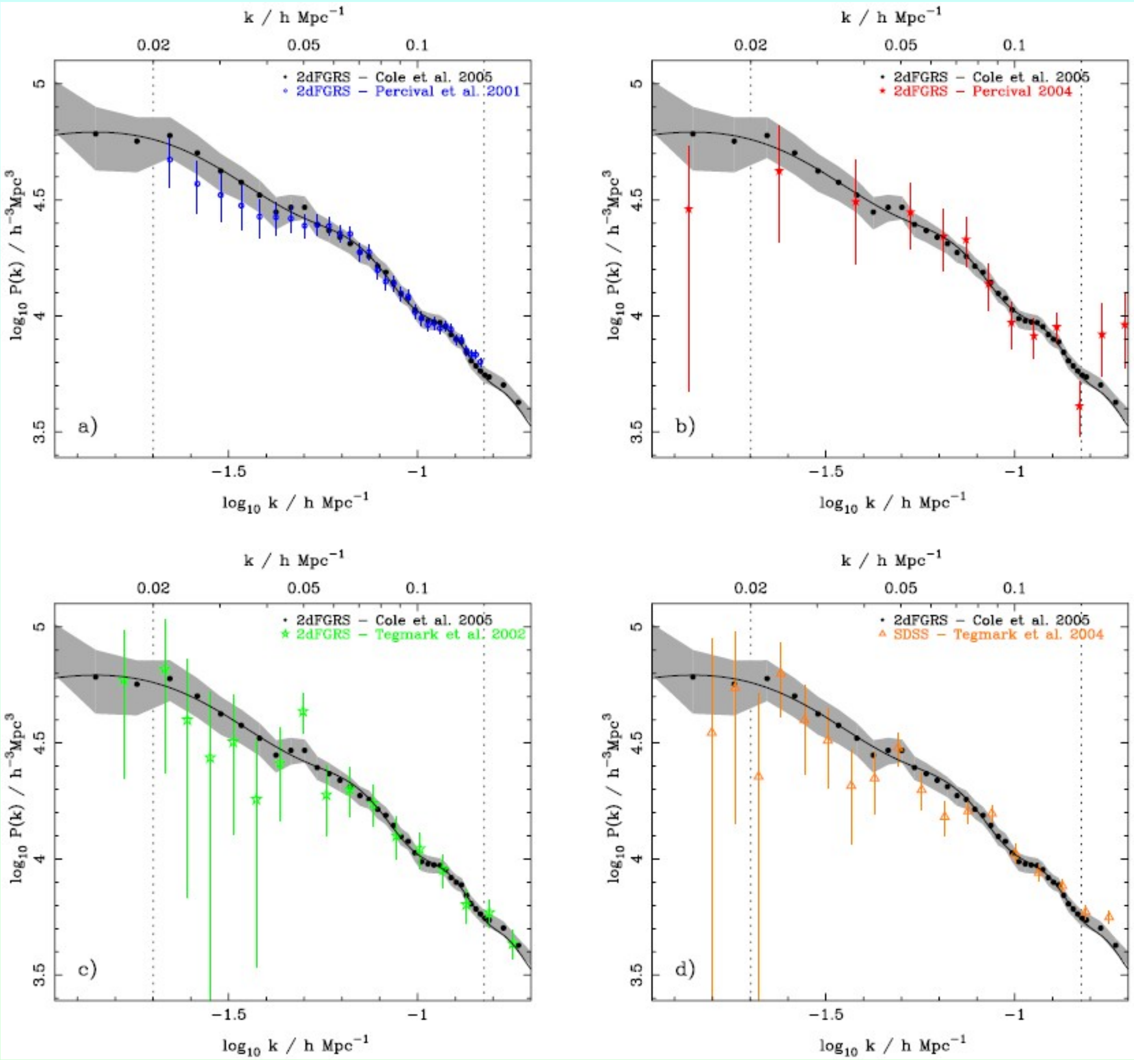
Eisenstein et al 2005

Detections: SDSS



Eisenstein et al. (2005)

Detections: 2dFGRS



Comparaison with previous estimations for 2dF
z< 0.3

Percival et al (01, 03)
Tegmark et al 04

Cole et al. (2005)

Final= 221414 galaxies, grey-scale 1σ errors

BAO Surveys

Survey	Selection criteria	Area (deg^2)	No. galaxy redshifts	Status
CFRS	$I_{AB} < 22.5$	$\sim$0.1	591	Released
CNOC-2	$R < 21.5$	1.5	6200	Released
COMBO17 (Photozs only)	$R < 24$	0.25	10 000	Released
SDSS DR3	$r < 17.1$	4188	374 767	Released
VVDS CDFS (Le Fevre et al. 2004)	$I_{AB} < 24$	21×21.6 arcmin^2	1599	Released
VVDS Deep	$I_{AB} < 24$	1.3	50 000	Ongoing
VVDS Wide	$I_{AB} < 22.5$	16	100 000	Ongoing
zCosmos	$I_{AB} < 23$	2	90 000	Ongoing
SDSS–2dF LRG	$i < 19.5$ plus colours for $0.4 < z < 0.8$	300	10,000	Ongoing
SDSS LRG	$i < 19.2$ plus colours for $0.15 < z < 0.4$	5000	75 000	Ongoing
SDSS-II	$r < 17.1$	10 000	$\sim 10^6$	Start 2005
DEEP2	$R_{AB} < 24.1$ plus colours for $z > 0.7$[1]	3.5	65 000	Ongoing
KAOS	TBD	$\sim$1000	$\sim 10^6$	Proposed
SKA	TBD	$\sim$ 30 000	$\sim 10^9$	Proposed

LAMOST
WFMOS/Subaru
HETDEX/Virus
LSST
etc…

Blake & Bridle (2005)

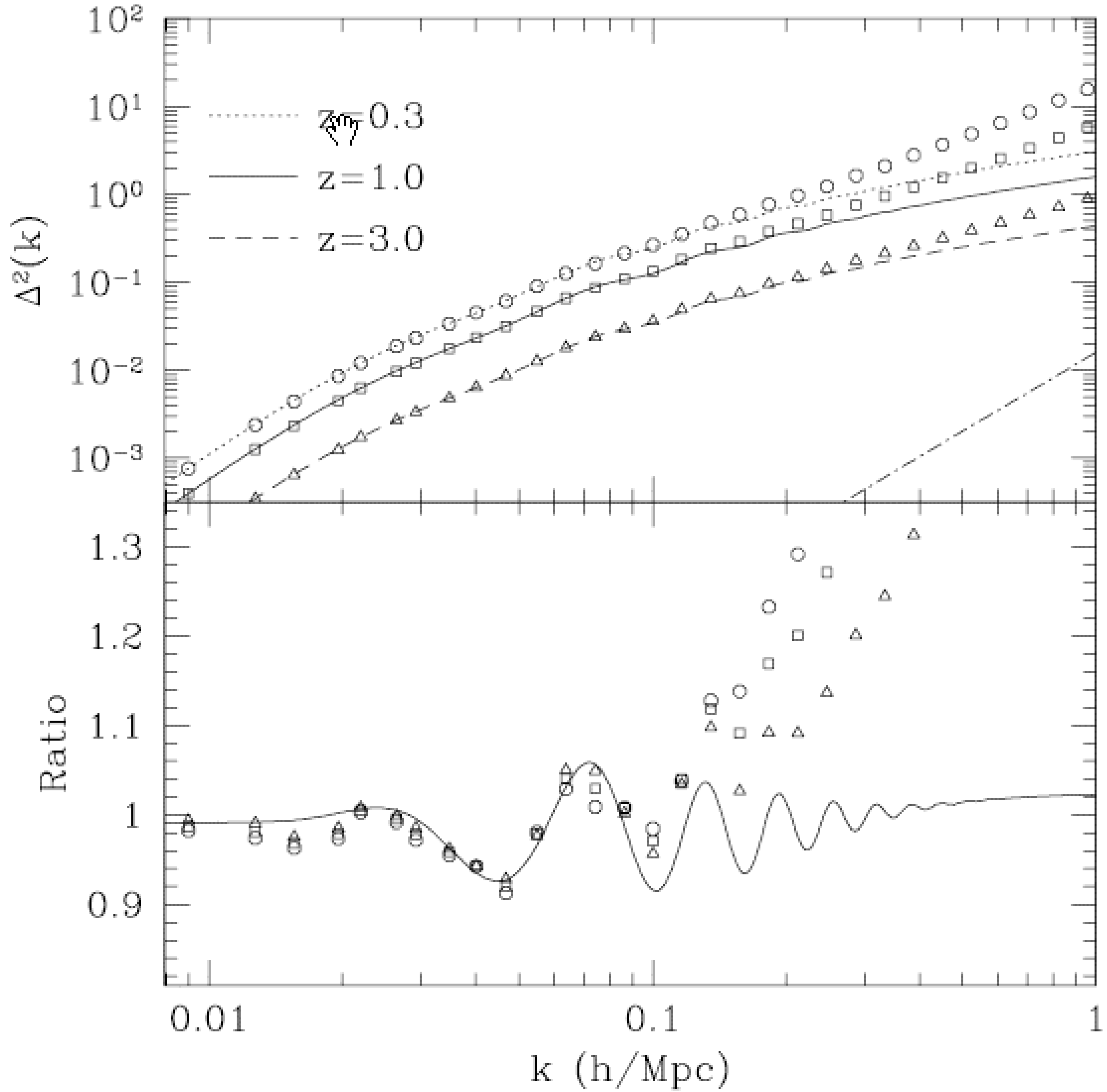
Non linearities

Can mix scales
and wash out structures

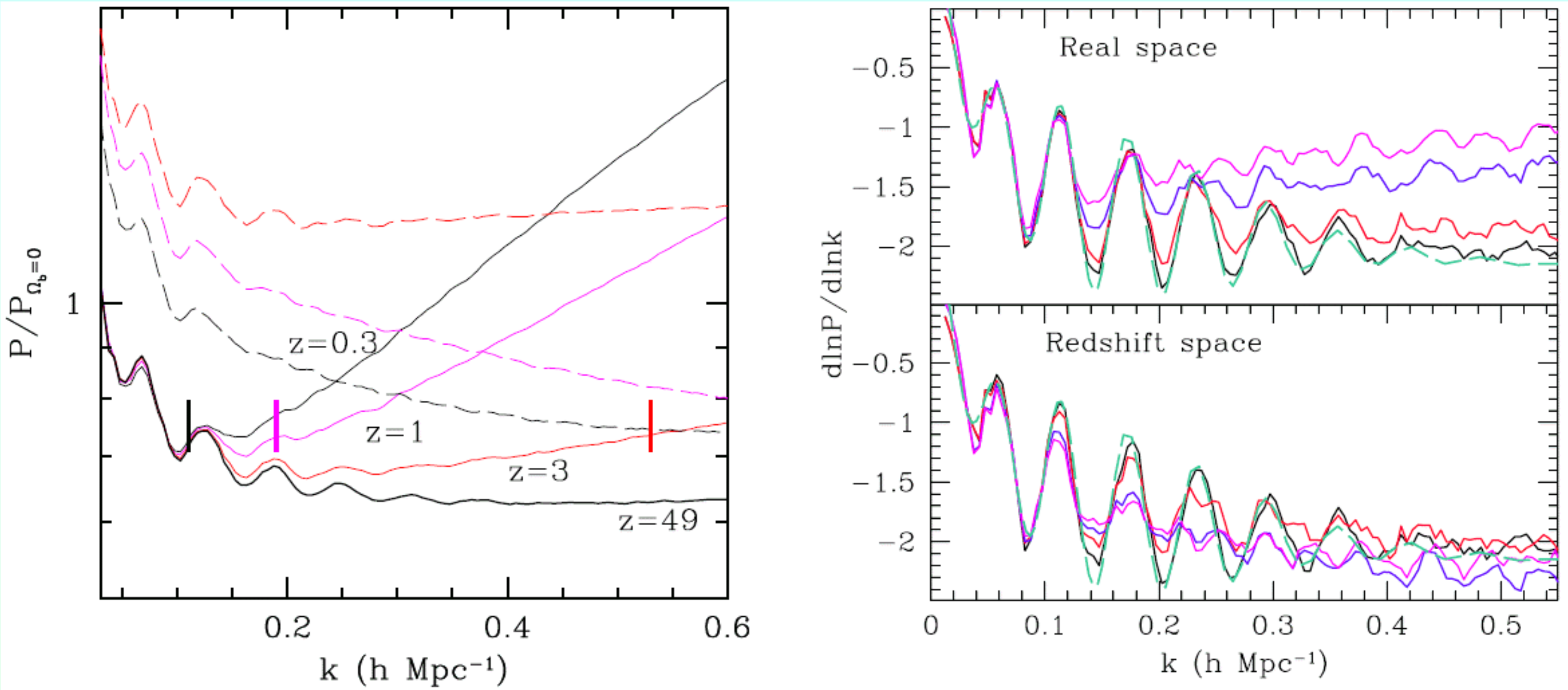
M. White 2005

Full line:linear prediction

Ratio with a smooth
spectrum



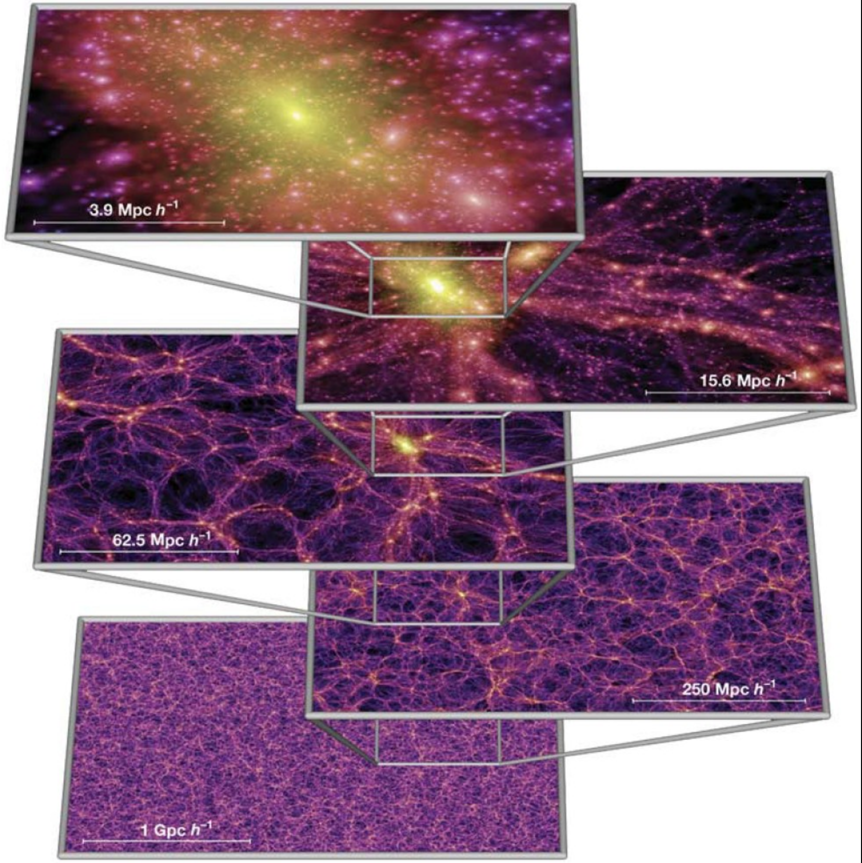
Nonlinearities

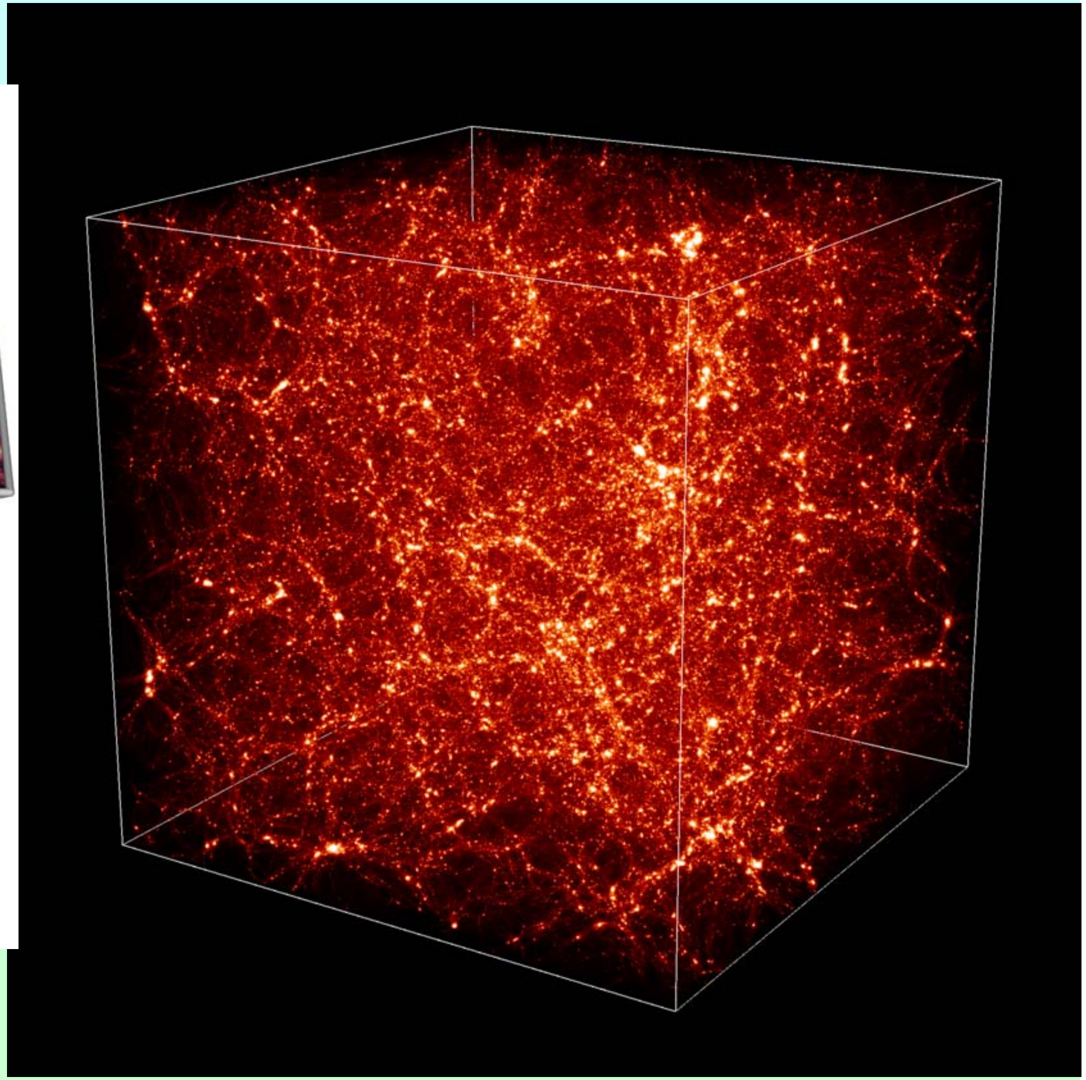


A maximum wavenumber is set in each redshift bin to reduce the contamination of nonlinear evolution.

Seo & Eisenstein (2005)

Cosmological Simulations

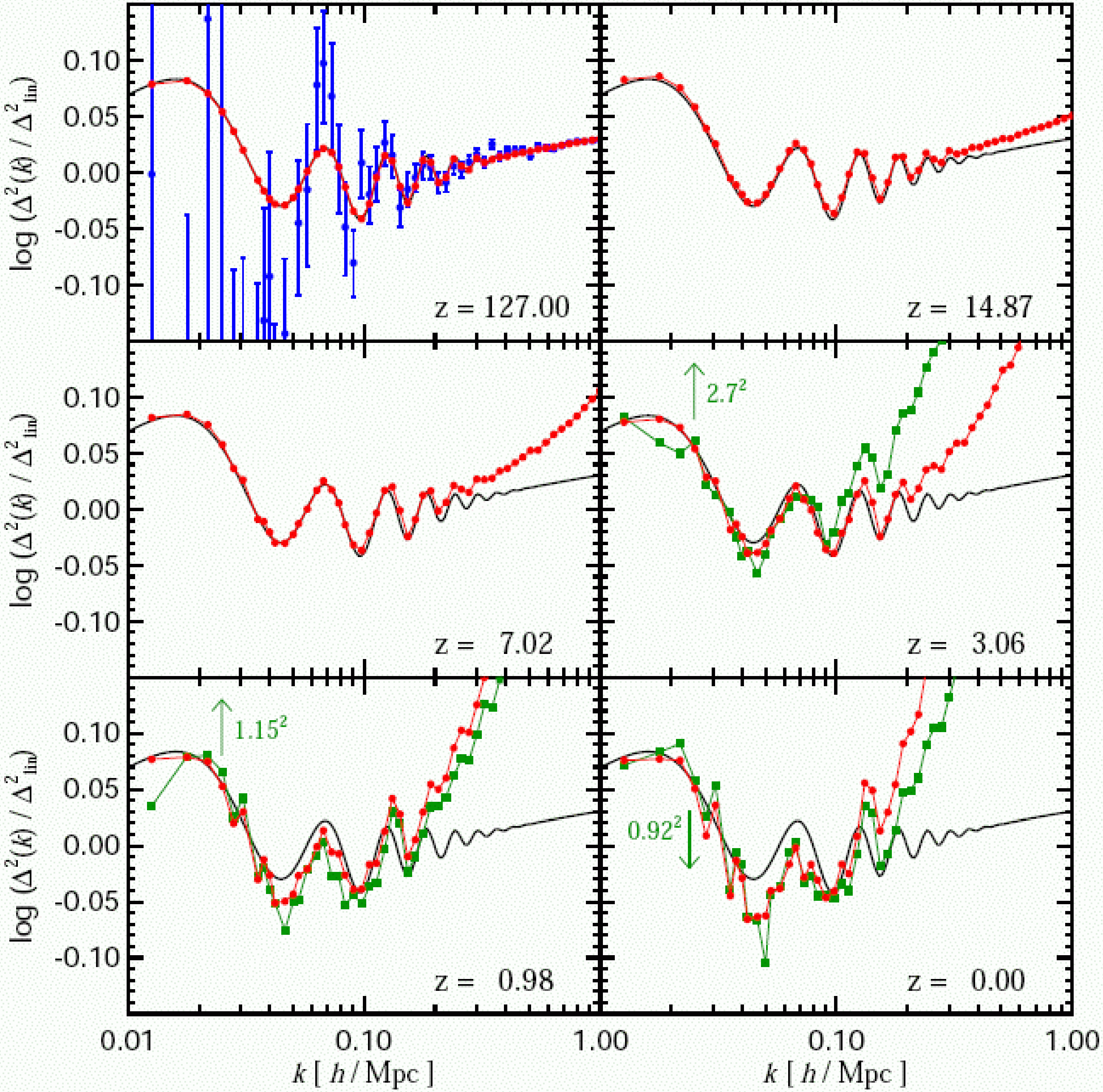




Millenium
Springel et al 2005

HORIZON

L=1 billion light-yrs
T=1, 3 & 13 billion yers

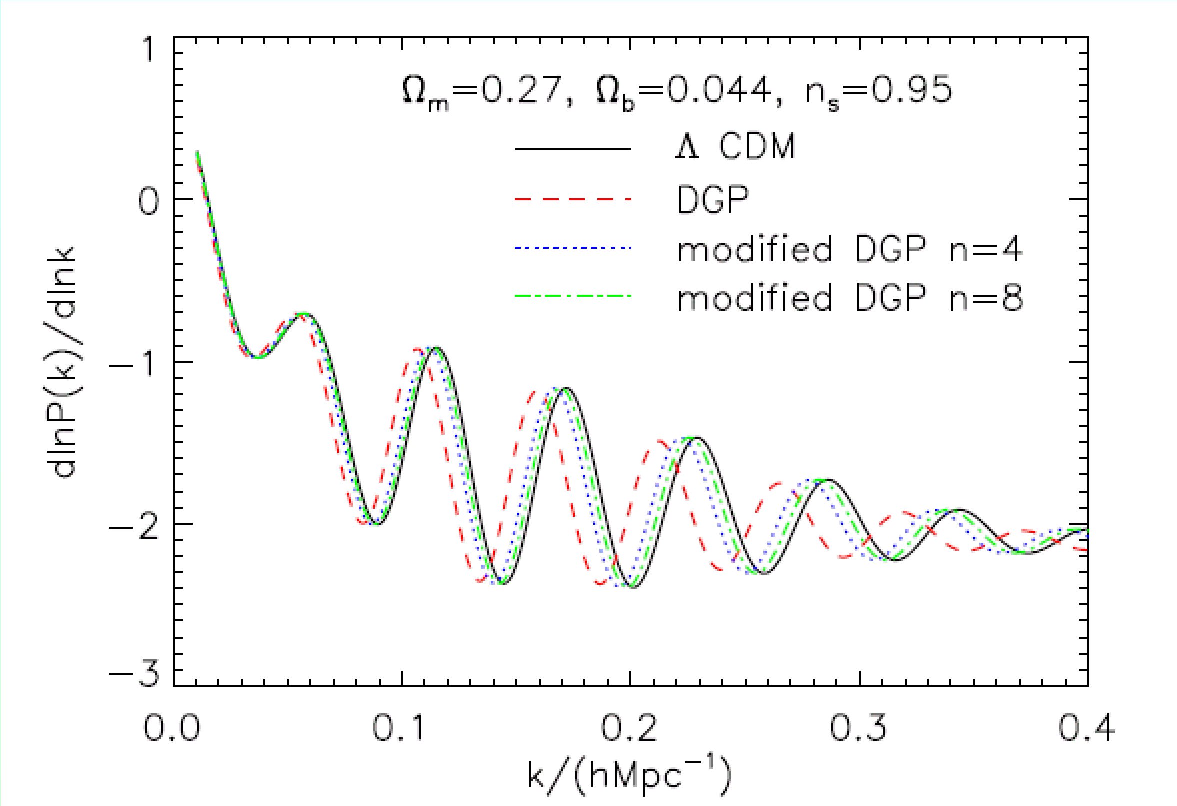


Simulations Springel et al 2005

Power spectra of DM and galaxies in the BAO region (divided by a CDM linear power spect.)

Blue: scatter
Black: mean

Testing models of gravity



Yamamoto et al 2006

Dvali-Gabadadze-Porrati DGP model

KP 4 - Galaxy evolution and cosmology

1- HI line surveys

All-sky survey would contain **a billion galaxies** out to z~1.5

➔ Galaxy evolution studies using the most abundant element

2- 'Dark Energy-measuring-machine'

- acoustic peaks in baryons as function of z
- weak gravitational lensing in large fields

➔Measure DE parameters w_0 and w_1 to 1% accuracy

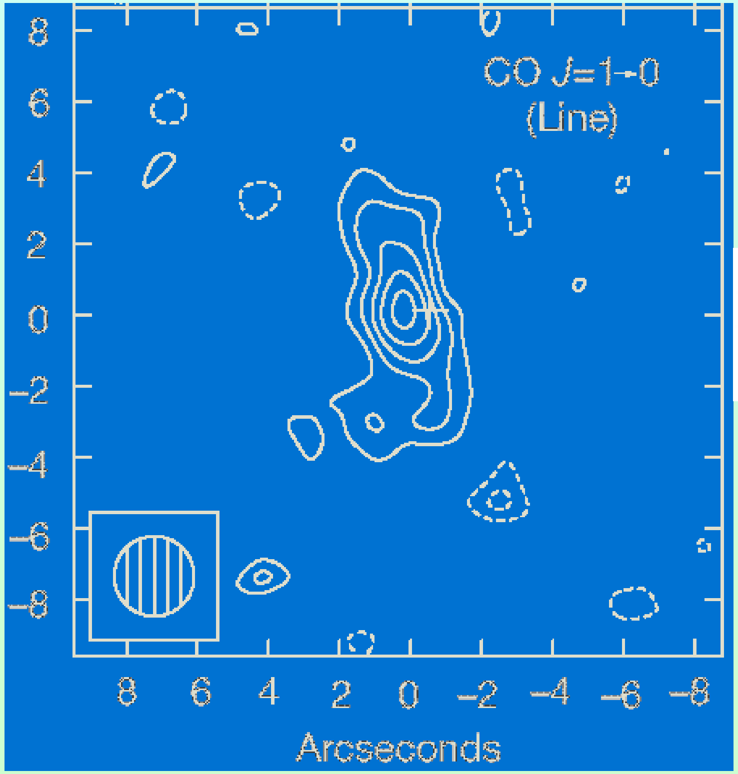
Galaxies at high z

M83: optical

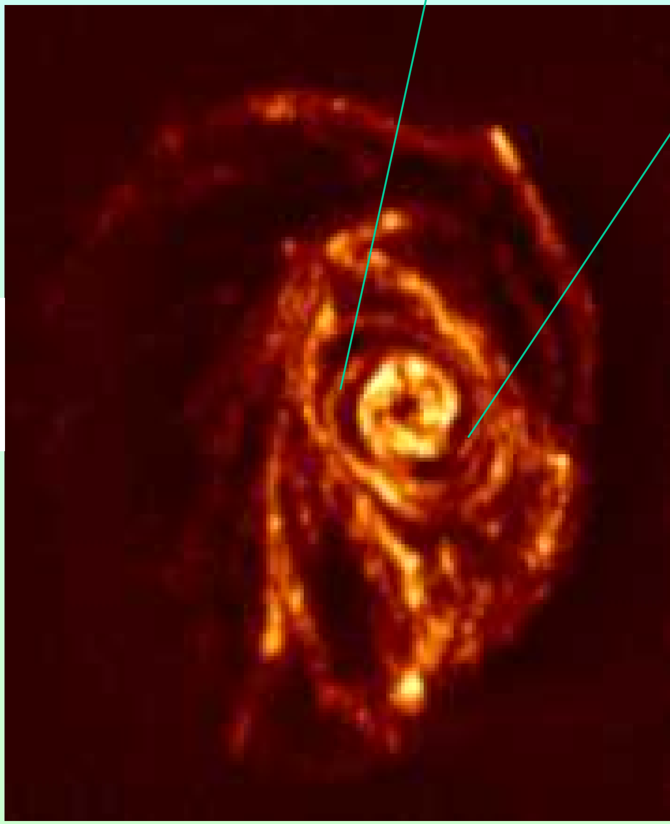
Possible in CO, not in HI

HI at $z \leq 0.03$

CO at $z = 4$

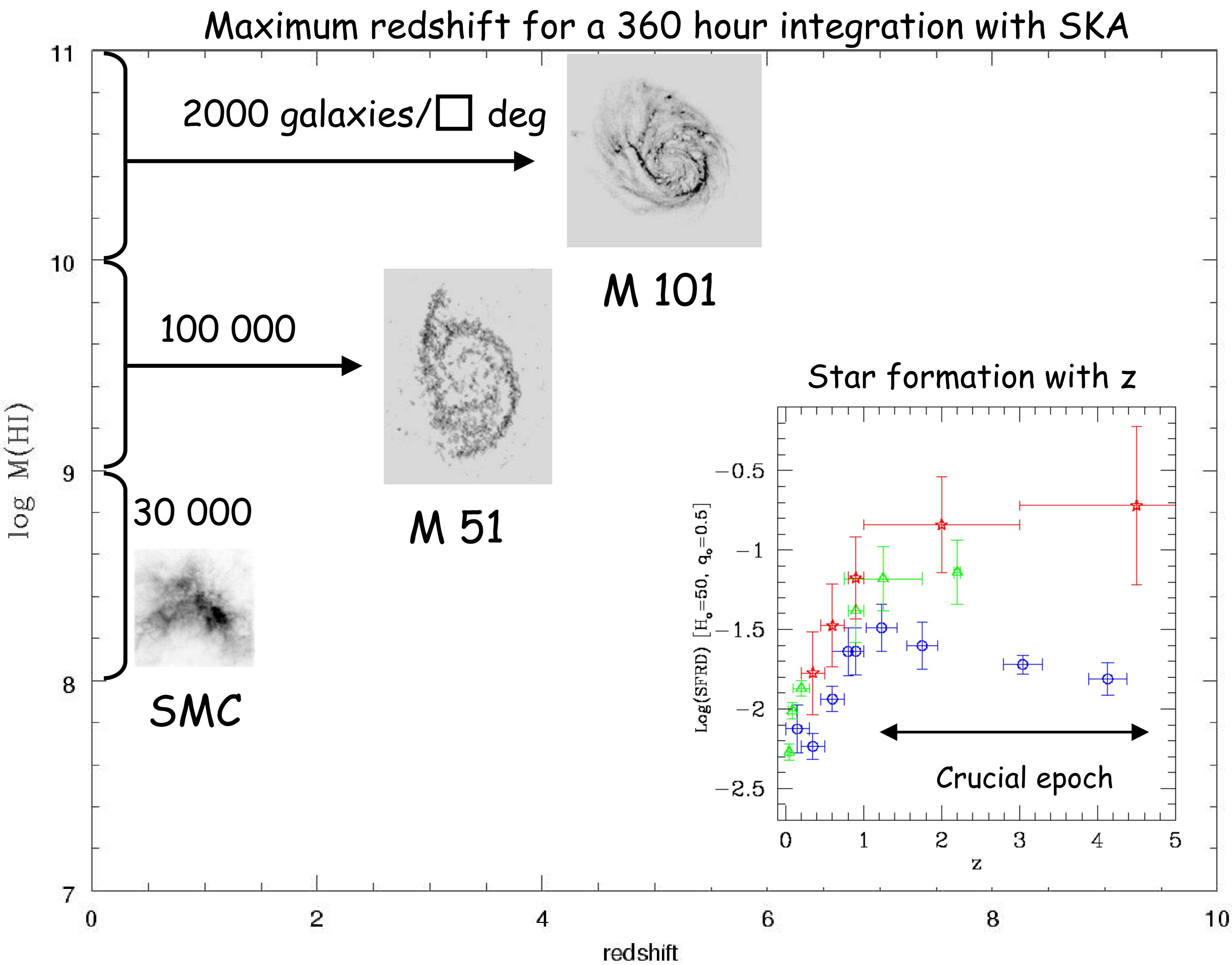


$\Leftrightarrow$



Ultraluminous galaxy

Milky Way-like spiral (10^9 $M_\odot$ of HI): M83



Maximum redshift for a 360 hour integration with SKA
2000 galaxies/□ deg
100 000
30 000
M 101
M 51
SMC
log M(HI)
redshift
Star formation with z
Log(SFRD) [H₀=50, q₀=0.5]
z
Crucial epoch

Dark energy measuring machine: I-Wiggles

Map the acoustic oscillations, or wiggles, in the galaxy power spectrum P(k) as function of redshift:

Only the SKA can get the required billion all-sky redshifts out to z=1.5

II- Weak Shear

10 billion galaxies,

10 nanoJy

But precision is not all!

Bias $f_b=\Omega_b/\Omega_m$ assumed linear (Blake et al 2004)

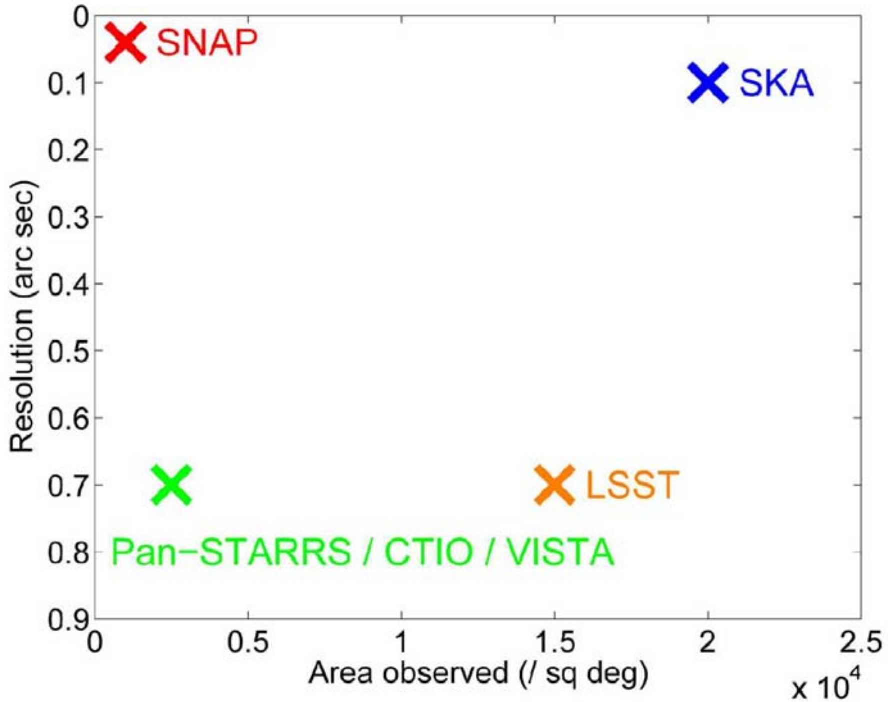
SKA contour
In red
SDSS in blue

Worries about systematics, so that targeted experiments should certainly be cleaner.

Testing DE with wiggles

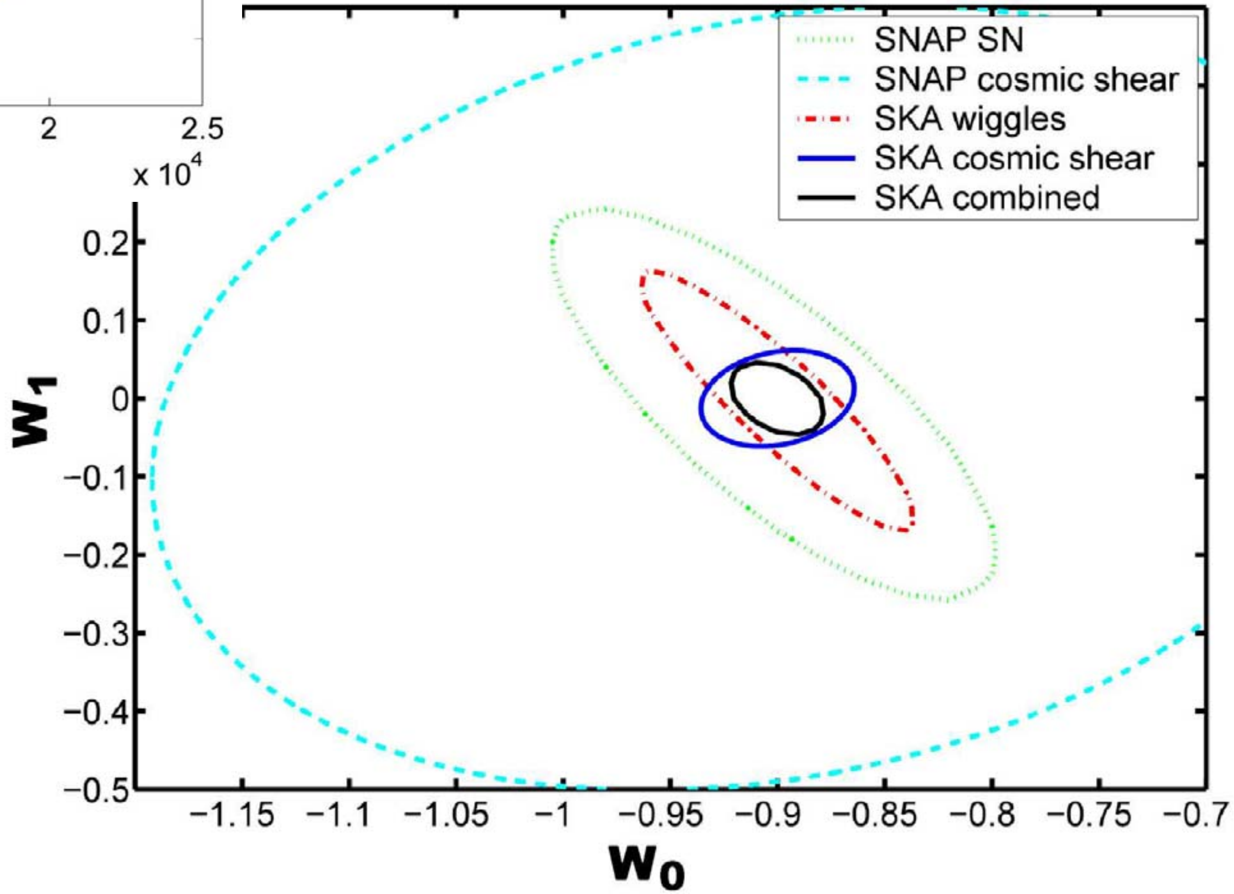
Note, still needs `priors' on $\Omega_m h^2$ and h (with Planck and/or, e.g., SKA masers)

SNAP and SKA compared



Resolution and
Sky area

2000 SN 0.1<z<1.7



Conclusion

➔Baryon acoustic oscillations measure Rs (150 Mpc, CMB) and are used as a standard ruler to measure the distance D_A and H(z)

➔Bias measured by Alcock-Paczynski test

➔SKA will be unique for large volume and high resolution
1 billion galaxies at 21cm, 10 billion for WL

➔Together with WL, determine DE parameters with 1% precision

➔Non-linearities: to be simulated with cosmological simulations