BAO with H

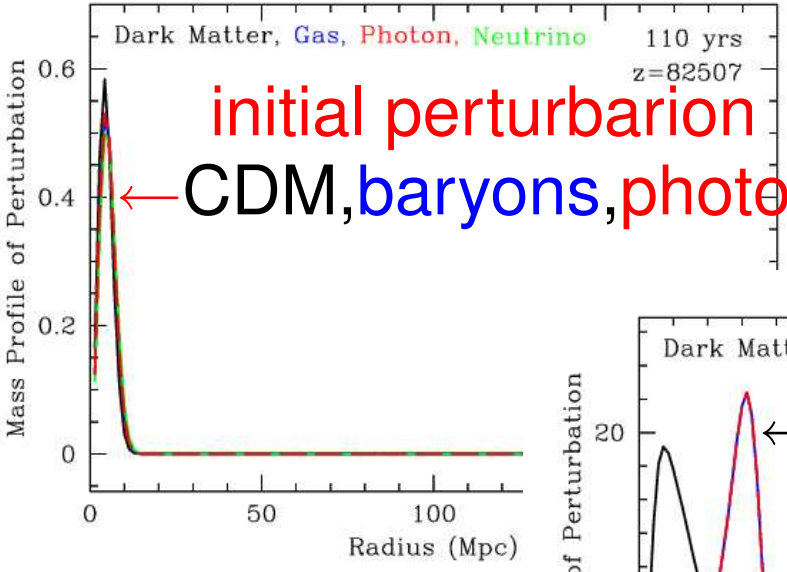
- BAO
- BAOα
- BAO21

Long, long ago, the Universe was hot and dense and filled with the sounds of the baryon-photon plasma.....

Evolution of a density perturbation (1/2)

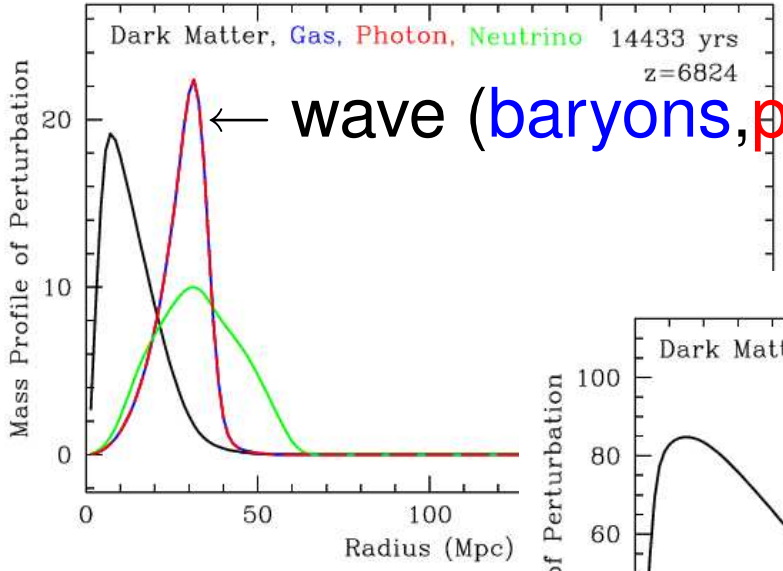
D. Eisenstein : http ://cmb.as.arizona.edu/ eisenste/acousticpeak/

Spherical barvon-photon sound wave propagation until recombination.



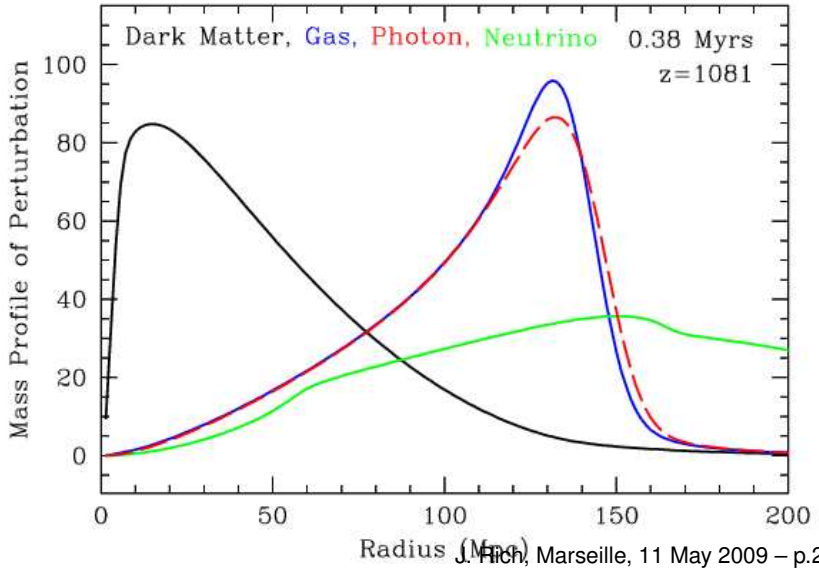
initial perturbarion

←CDM,baryons,photons,neutrinos



← wave (baryons,photons)

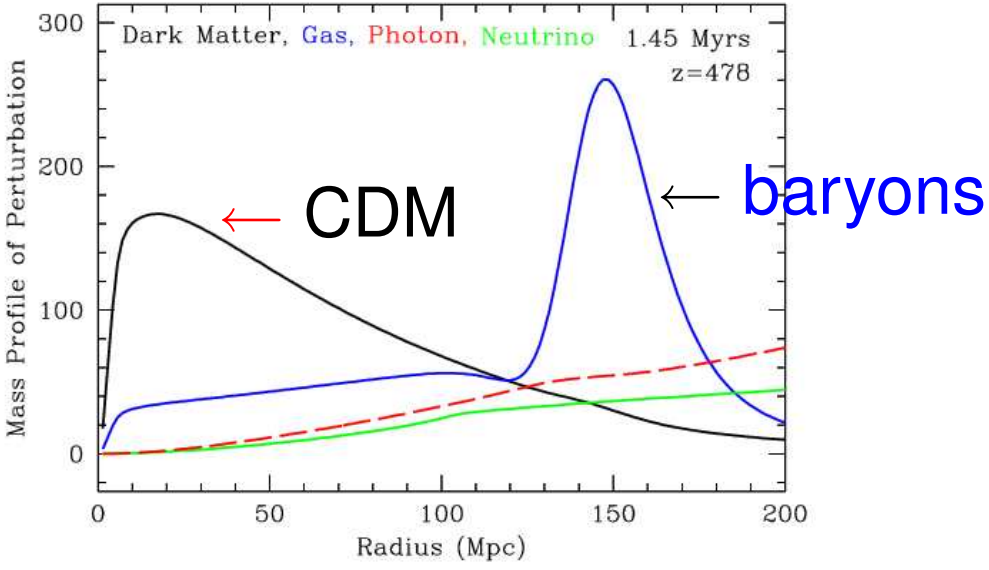
recombination →



Evolution of a density perturbation (2/2)

D. Eisenstein : http ://cmb.as.arizona.edu/ eisenste/acousticpeak/

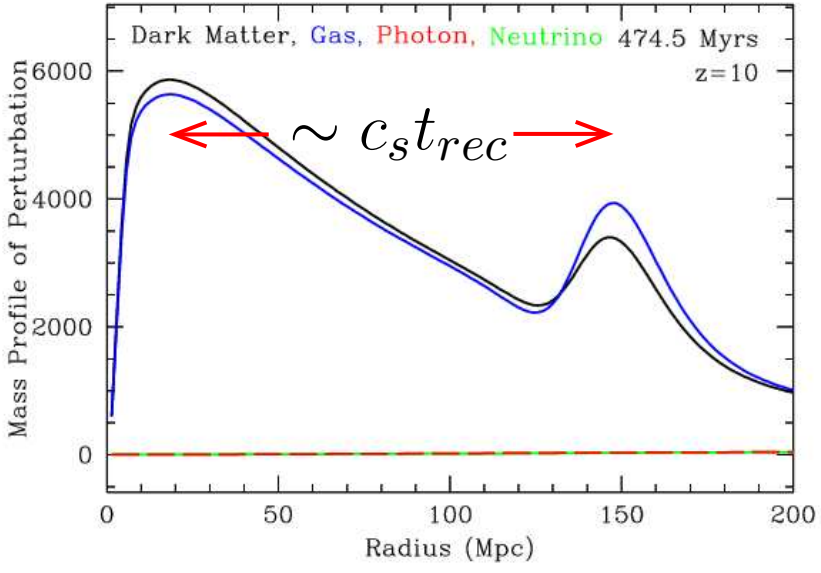
After Recombinartion the wave stops



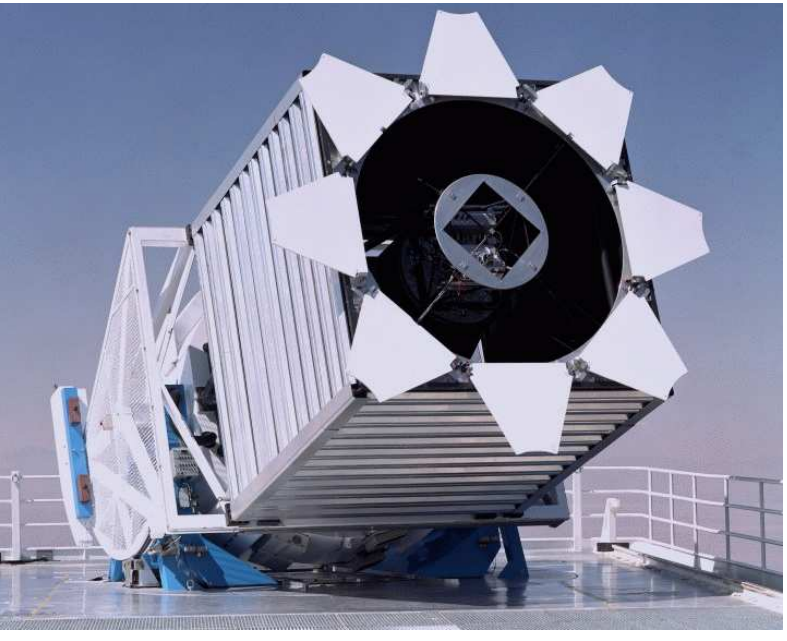
Galaxy formation :

$c_s t_{rec} \sim 150 Mpc$

$(\Omega_m = 0.27)$



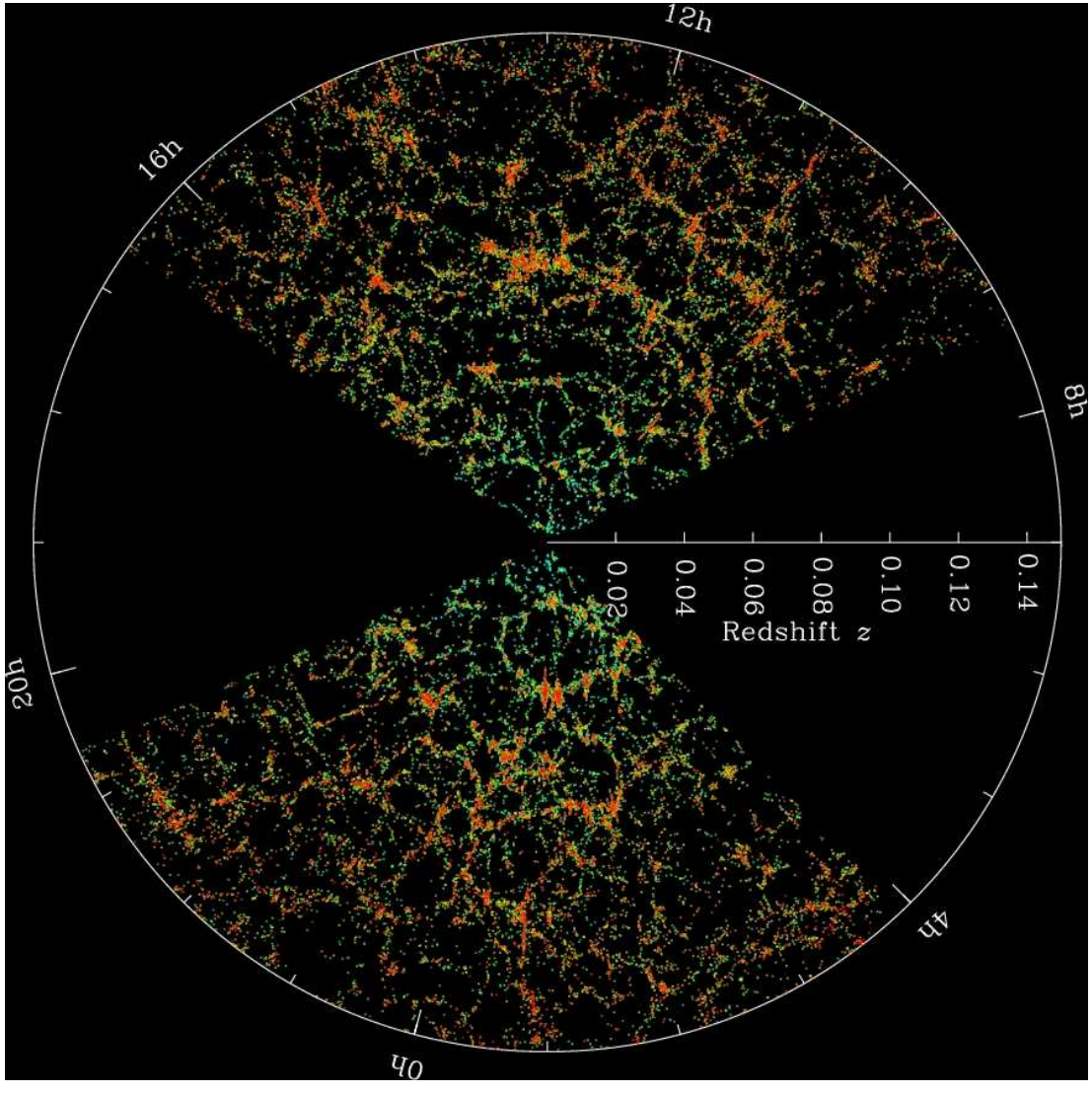
Sloan Digital Sky Survey



10^6 redshift galaxy survey
Apache Peak, New Mexico, USA

U. of Chicago, Fermilab, the Institute for Advanced Study,
the Japan Participation Group, The Johns Hopkins U.,
the Korean Scientist Group, Los Alamos National Lab.,
the Max-Planck-Institute for Astronomy (MPIA),
the Max-Planck-Institute for Astrophysics (MPA),
New Mexico State U., U. of Pittsburgh, U. of Portsmouth,
Princeton U., the United States Naval Observatory,
and the U. of Washington.

SDSS : slice of the Universe



150Mpc

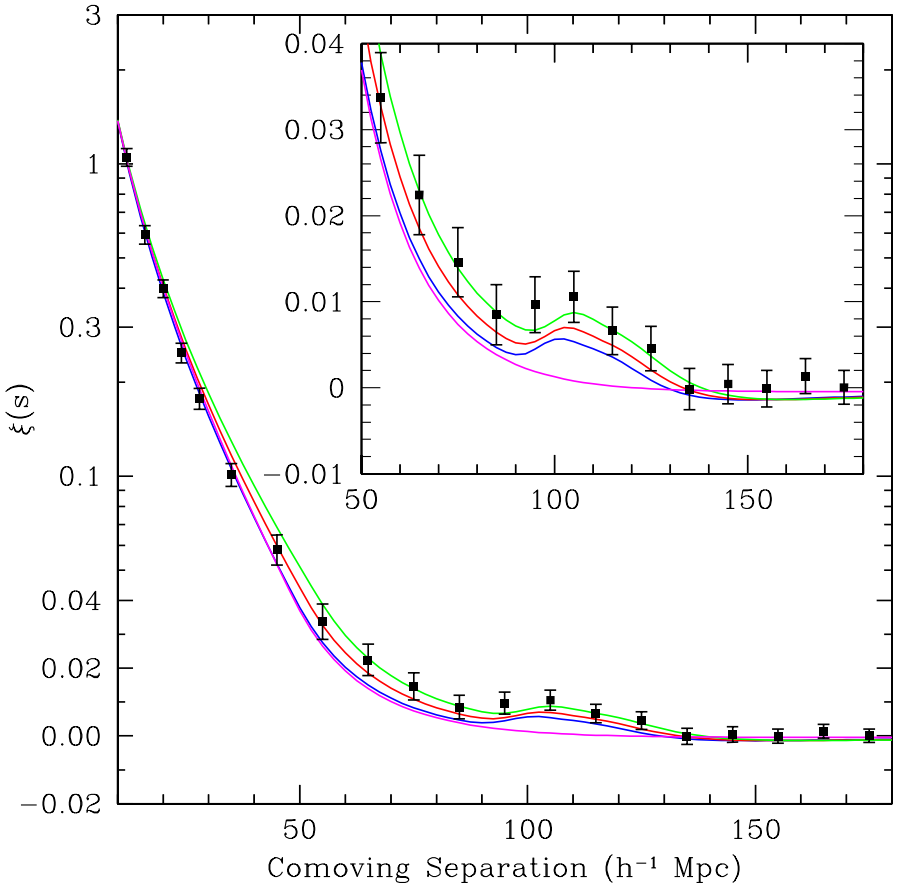
$\Rightarrow \Delta z = 0.035$

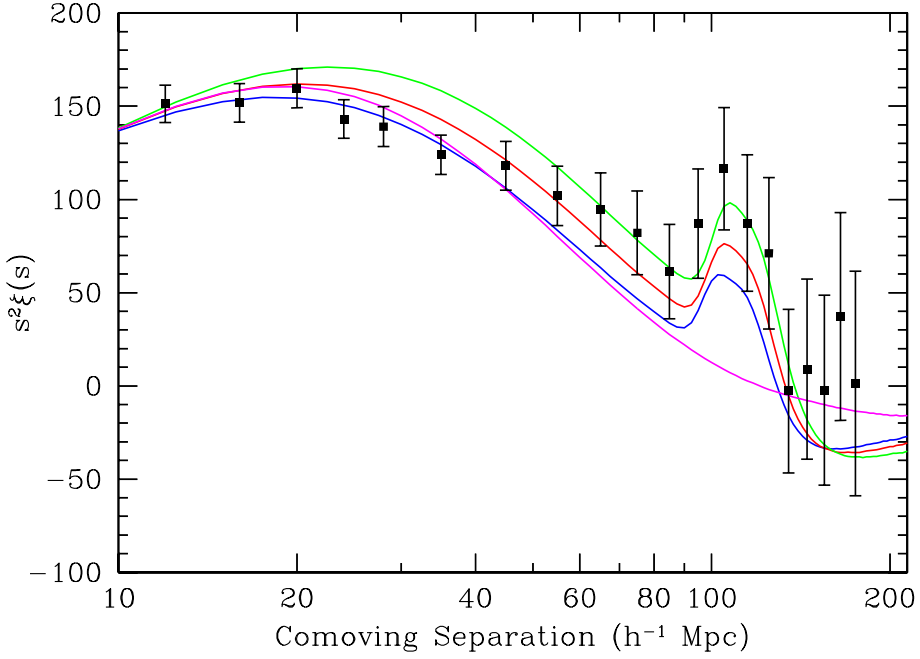
SDSS galaxy correllation function

(Eisenstein et al Astrophys.J. 633 (2005) 560-574)

Galaxies like to be separated by $105h^{-1}Mpc = 150Mpc$

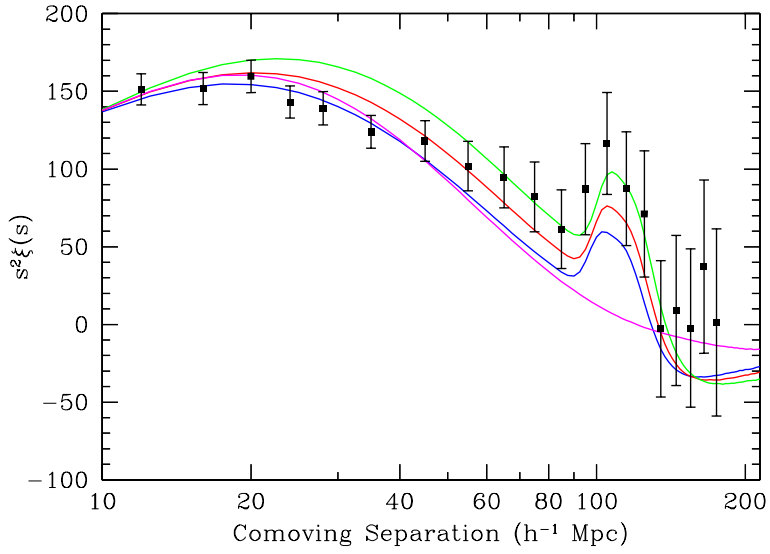
(distance traveled by a sound wave between big bang and recombination)





Future : optical and 21cm surveys at high redshift

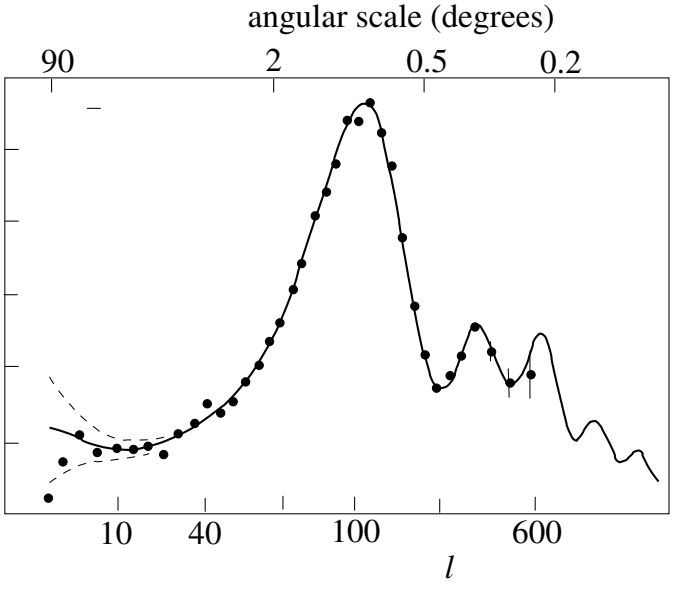
WMAP and SDSS acoustic peak



SDSS ($z \sim 0.3$)

(Eisenstein et al Astrophys.J. 633 (2005) 560-574)

$$\Rightarrow \Omega_{cdm} + \Omega_b \;=\; 0.273 \pm 0.025$$
$$+0.123(1+w) \;+\; 0.137(1-\Omega_T)$$



+WMAP ($z \sim 1100$)

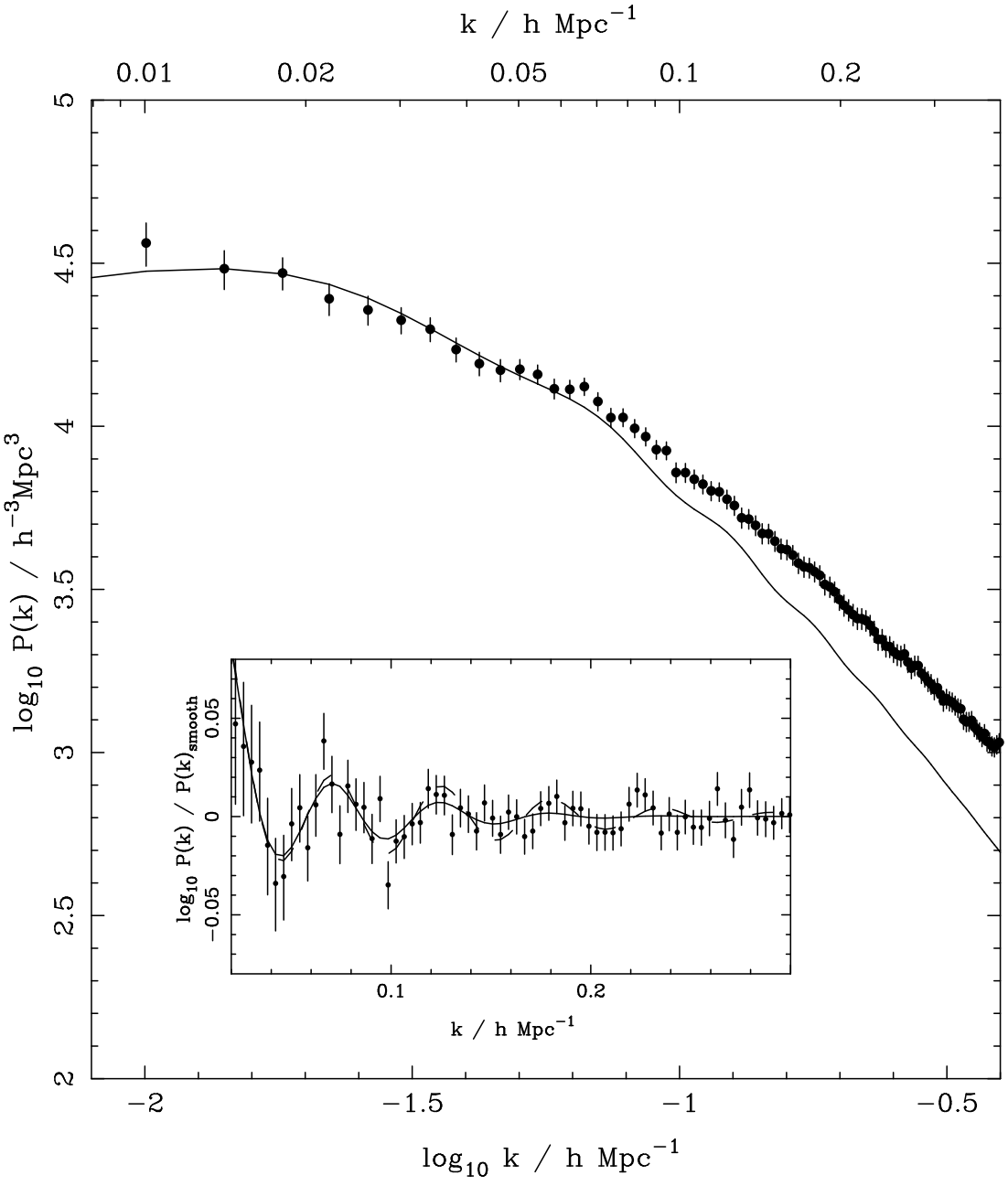
(Bennett et al,Astrophys.J.Suppl. 148 (2003) 97)

$$\Rightarrow \Omega_T \;=\; 1.010 \pm 0.009$$

$$\Rightarrow \Omega_\Lambda \;=\; 0.73 \pm 0.03$$

assumptions about intergalactic absorption unnecessary

BAO in the SDSS power spectrum



$P(k) = \langle |FT\ of\ \rho(\vec{r})|^2 \rangle$

$P(k) = FT\ of\ \xi(r)$

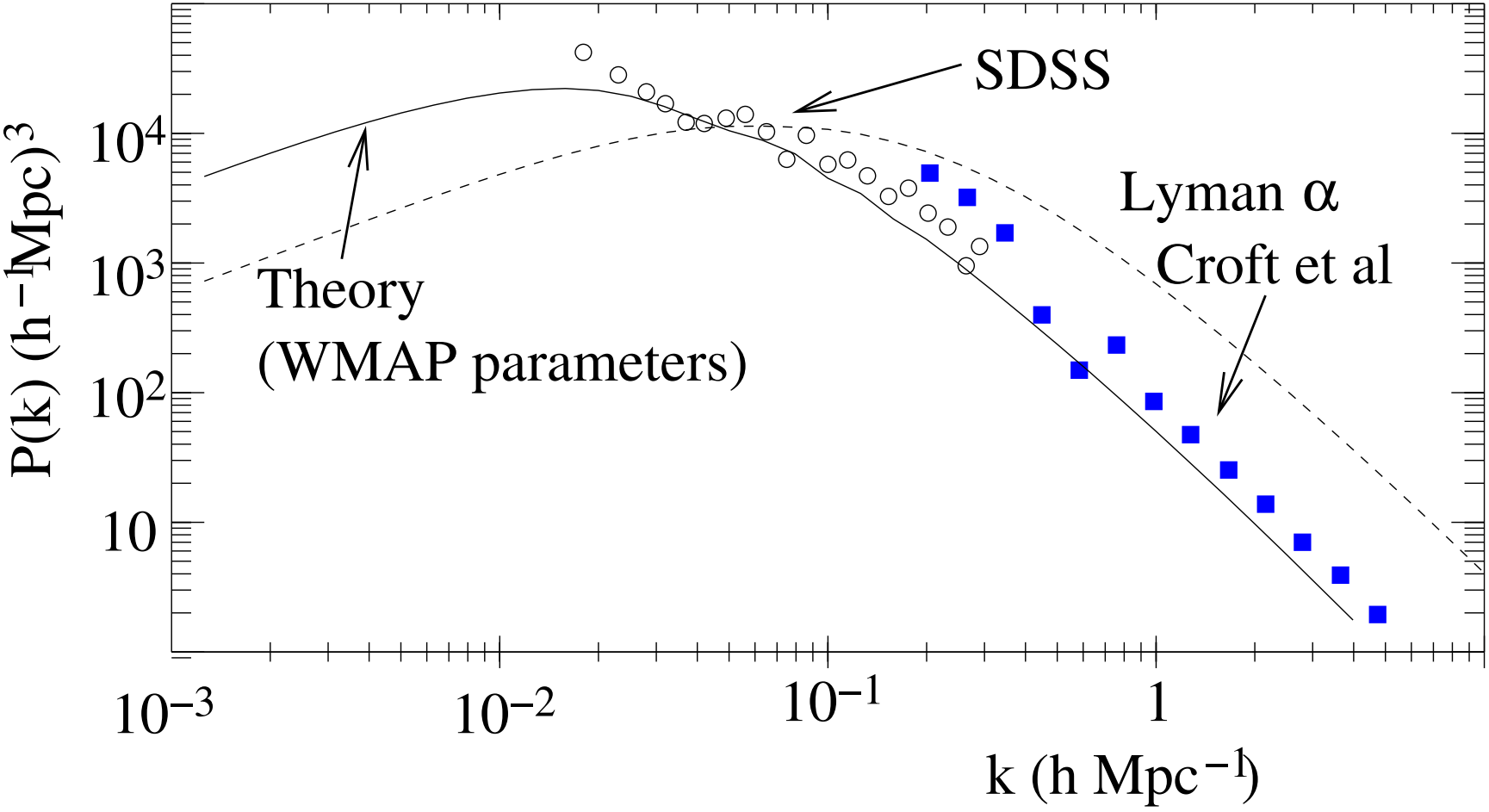
$FT =$ Fourier Transform

$\rho(\vec{r}) =$ density

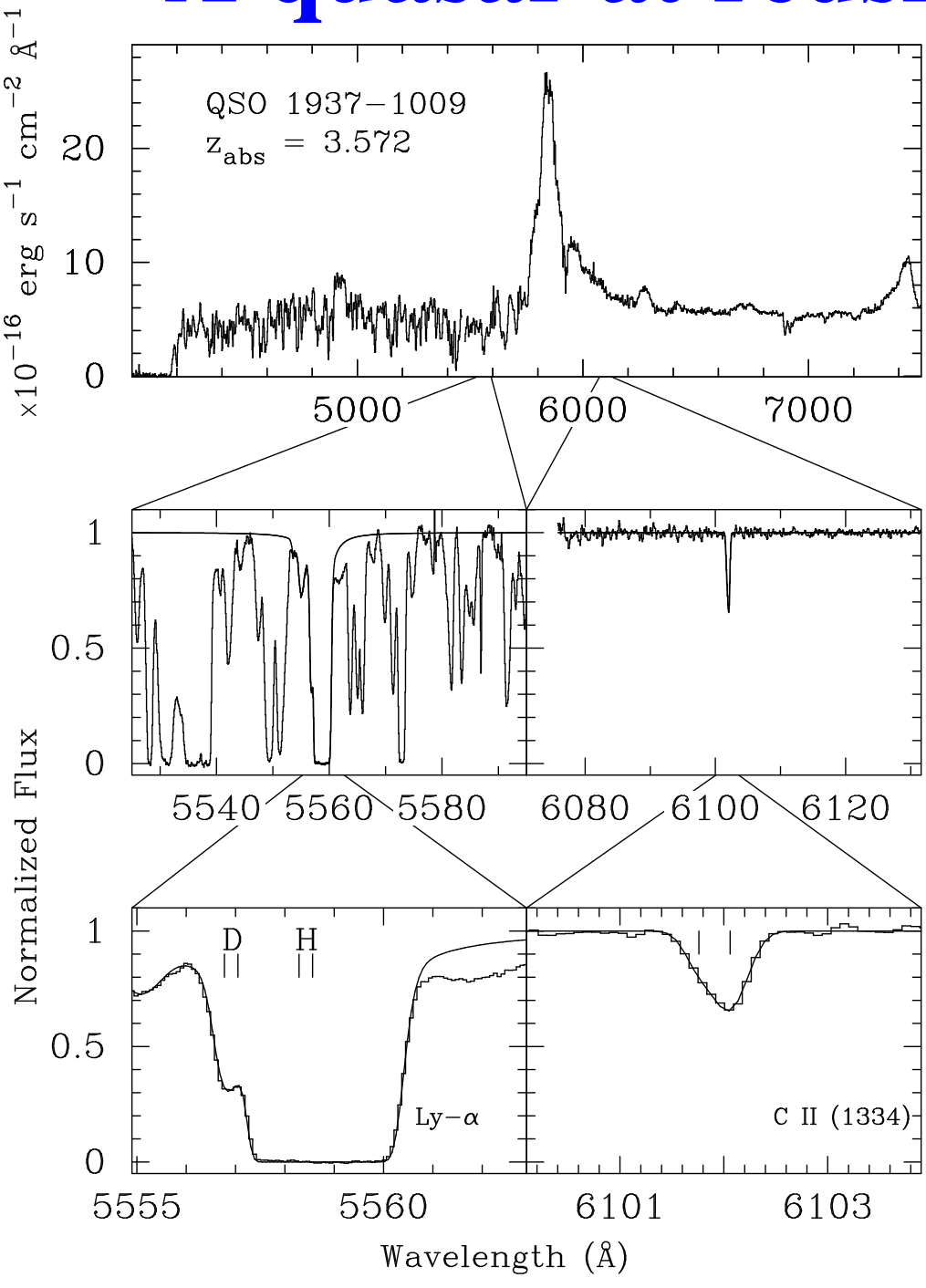
$\xi(r) =$ correlation function

Peak in $\xi(r)$ $\Rightarrow$
wiggles in $P(k)$

$P(k)$ from SDSS and Ly-α



A quasar at redshift $z_q = 3.78$



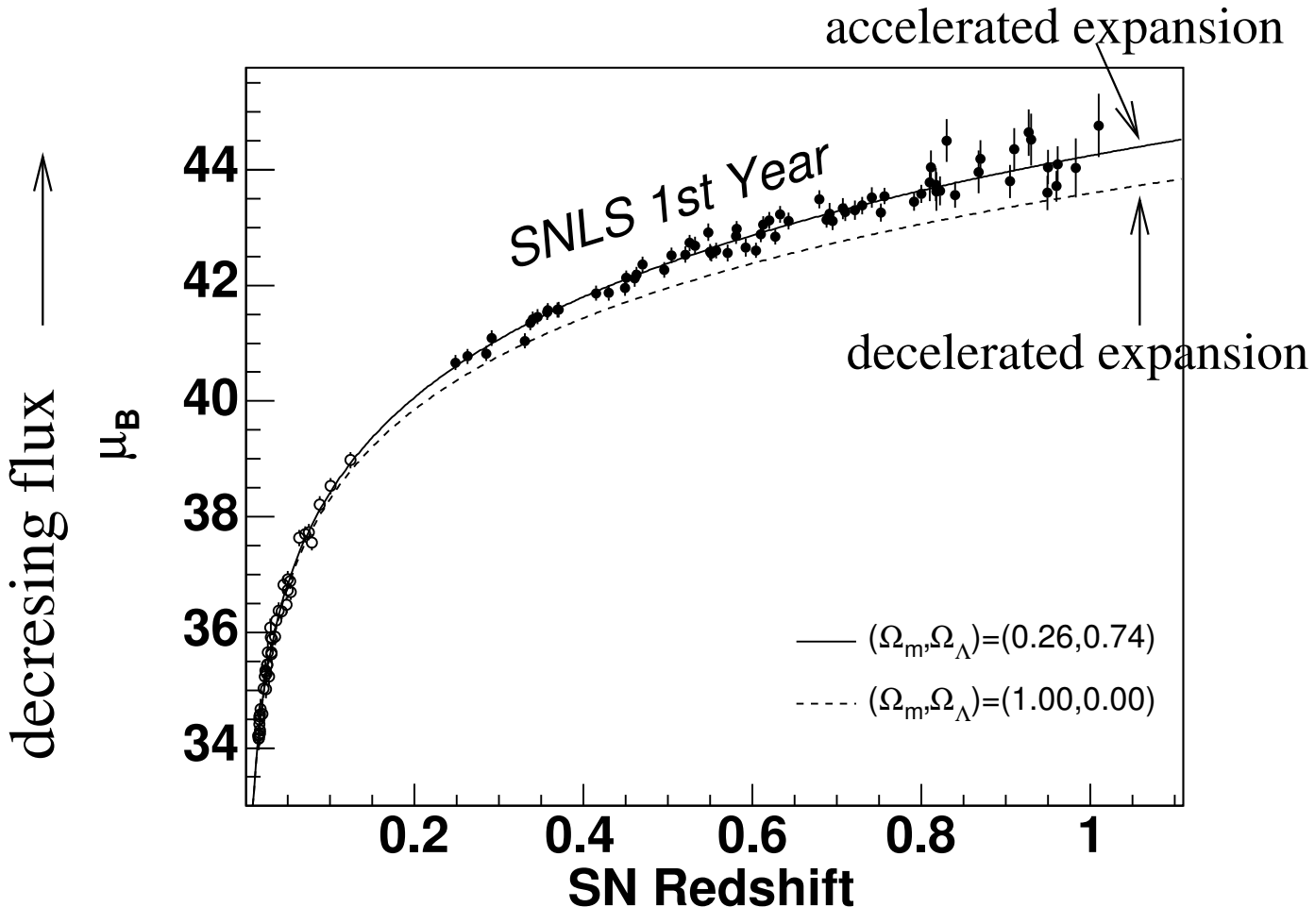
Ly-α emission (121.5nm) redshifted to 580nm

Ly-α absorption by intergalactic H

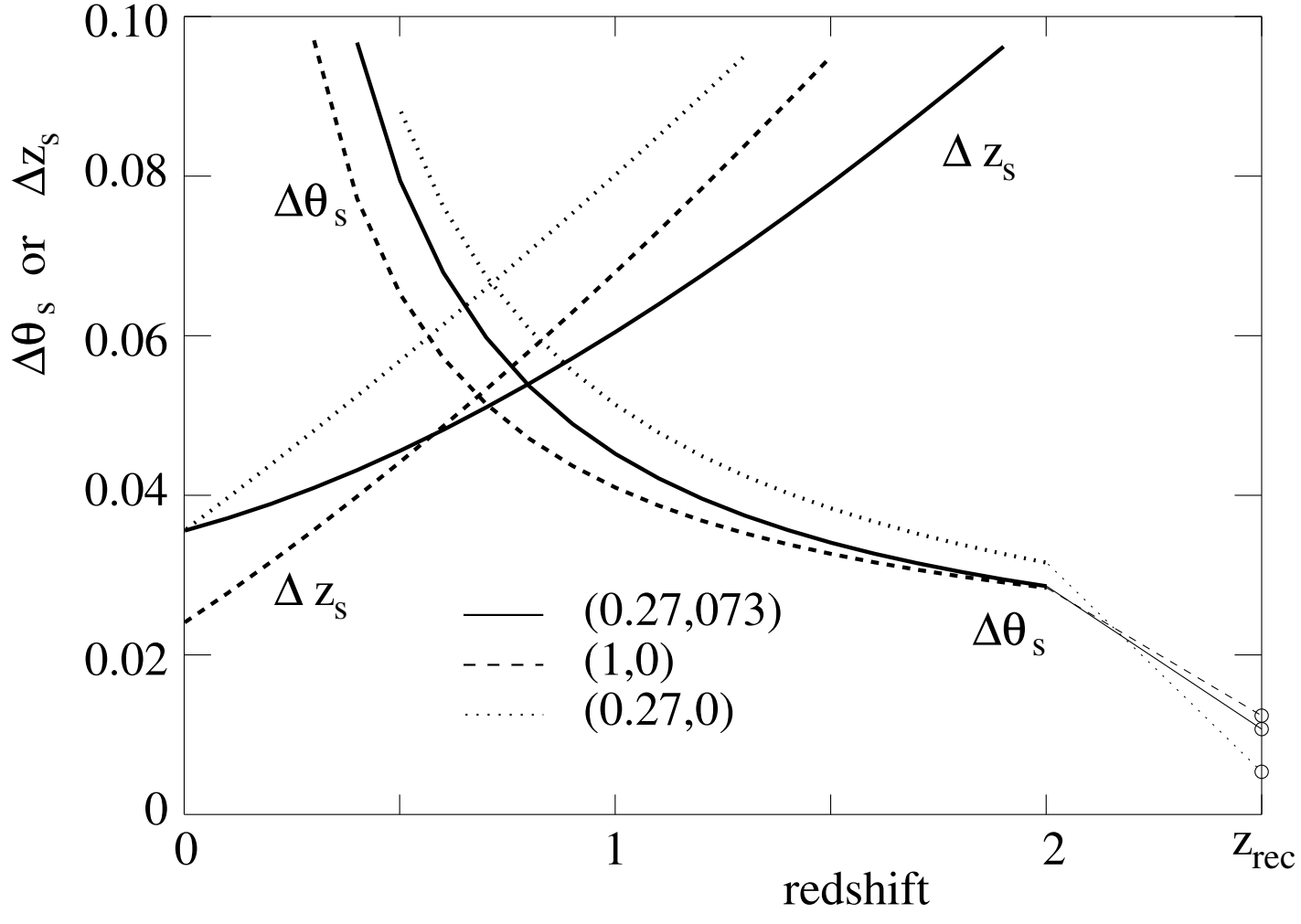
$$\frac{\lambda}{580nm} = \frac{1+z_q}{1+z_H}$$

Ly-α absorption by galaxy at $z = 3.572$

SNLS SNIa Hubble diagram



Future BAO Double Hubble diagram



SDSSIII : BOSS

- BOSS = Baryon Oscillation Spectroscopy Survey
- BAO with Ly-α
  20 quasars/deg^2, $2 < z < 3$
- BAO with galaxies
  $\sim 10^6$ bright galaxies BAO at $z < 0.8$
- $\sim 1\%$ precision on angular and hubble distances

BOSS France= APC, IAP, LAM, SPP

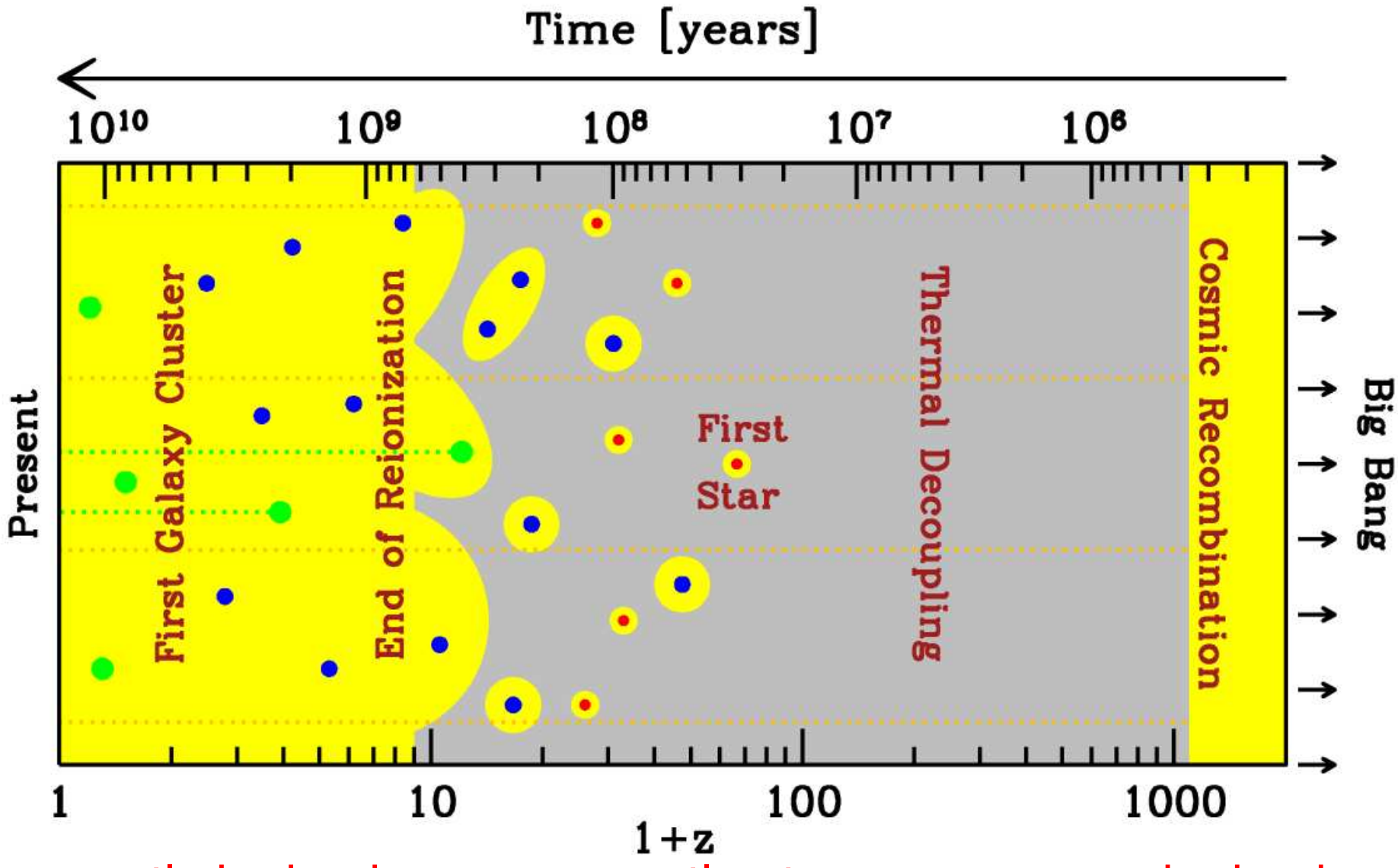
BAO from HI surveys

HSHS = Hubble Sphere Hydrogen survey

J. Peterson (Carnegie-Melon U.)
Ue-Li Pen (Toronto)
LAL-Orsay ; CEA-Saclay
FNAL, Wisconsin

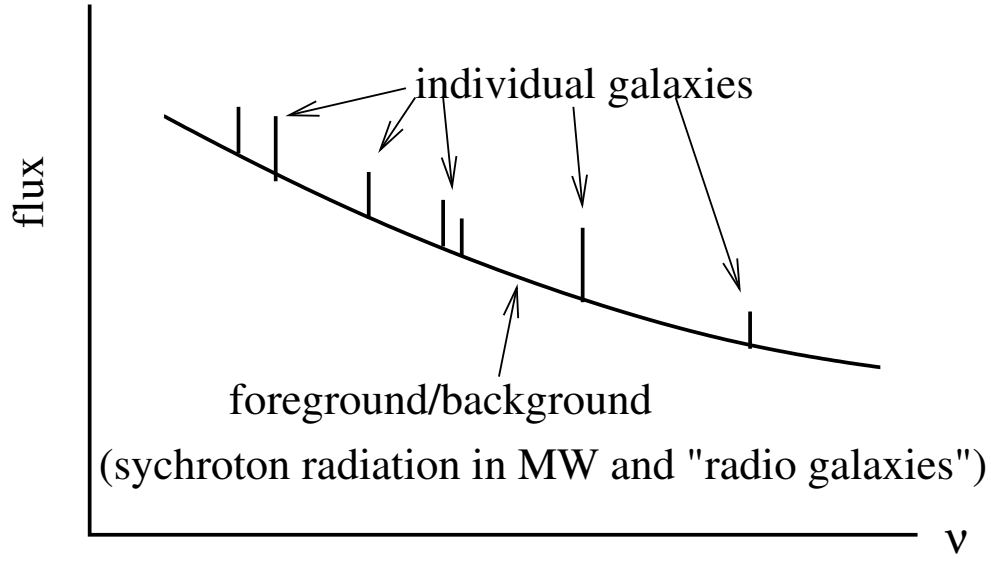
Atomic hydrogen (HI) observed through 21cm (1.42GHz) emission

History of Hydrogen



mostly ionized mostly atoms ionized

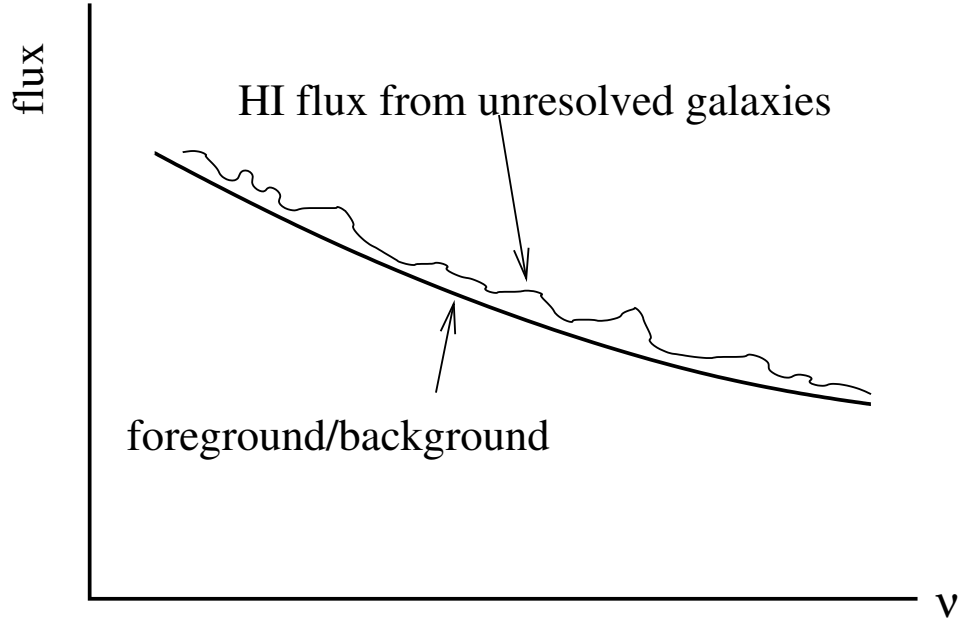
The sky at $\nu \sim 1.4GHz/(1+z) \quad z \sim 1.5$



baseline = 1km:

angular resolution=0.001

=>individual galaxies detected



baseline = 100m:

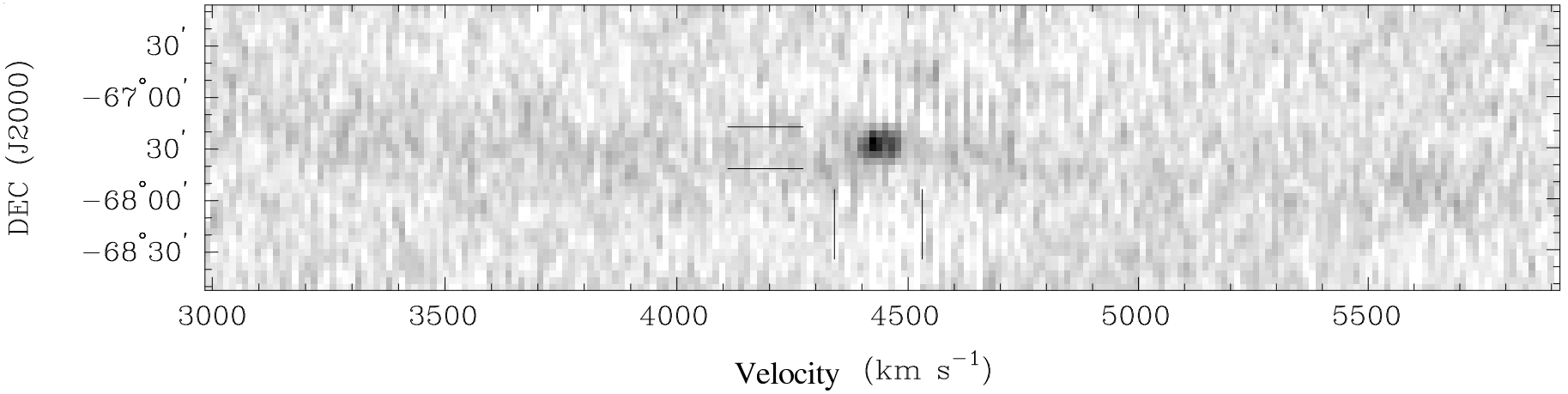
angular resolution=0.01

=> galaxies overlap

HI density field superimposed

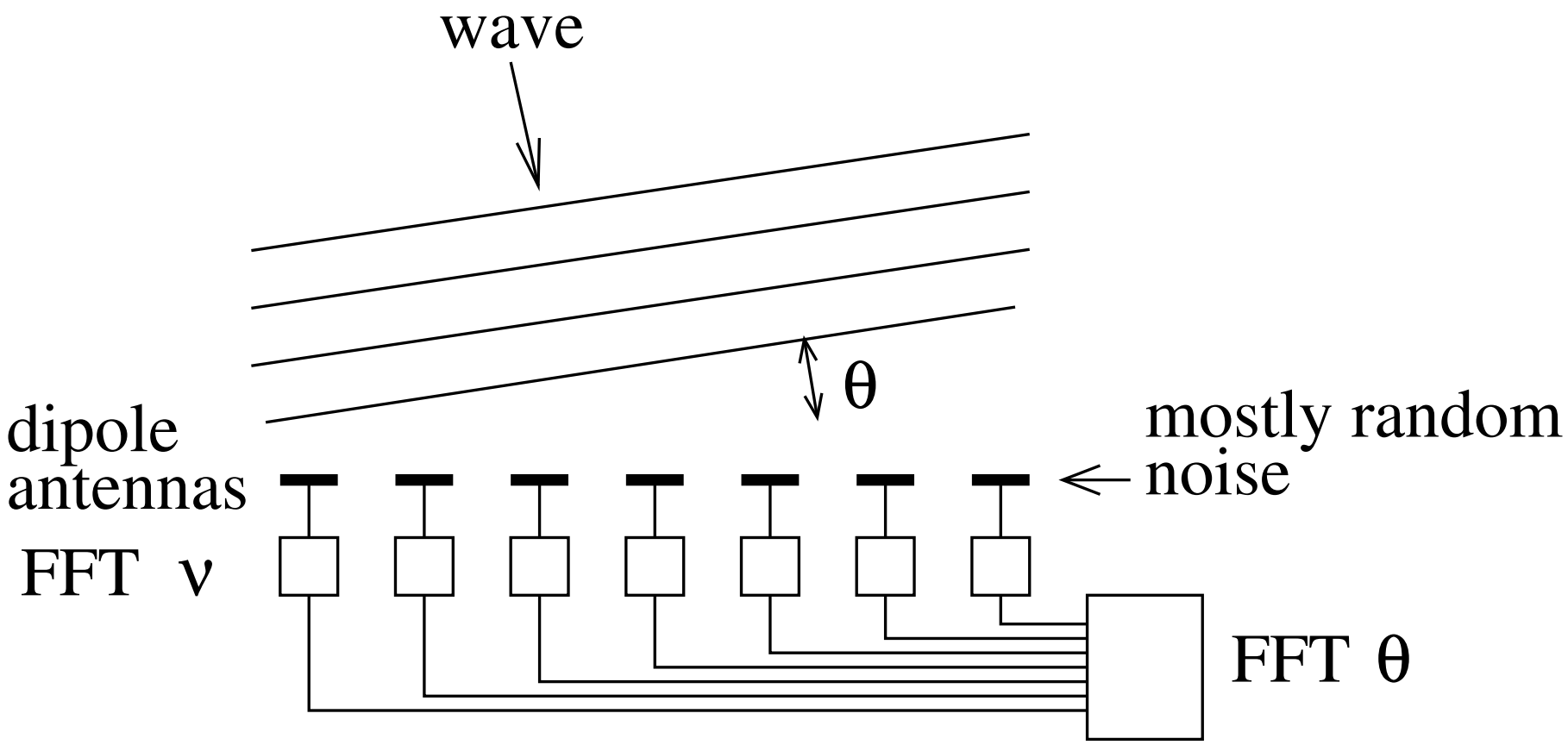
on smooth back/foreground

Galaxies easily detected in HI for $z < 0.1$



HIPASS catalog : $flux\ vs.\ (dec.,\ \nu)$

HI maps from Fourier bean synthesis



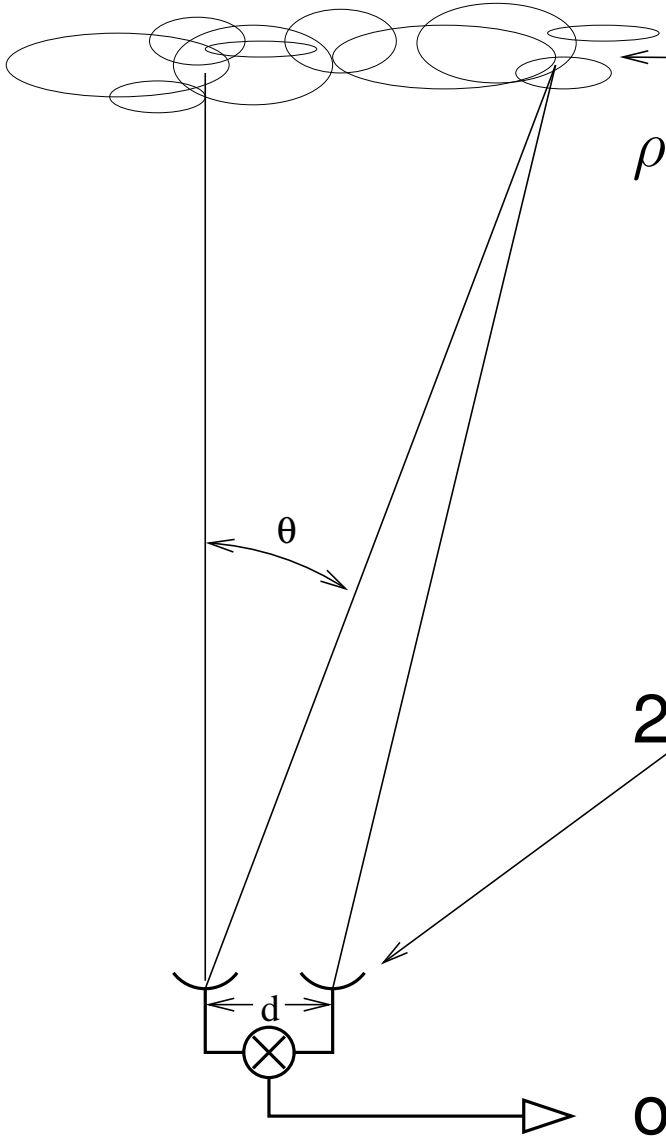
$$\Rightarrow flux(\theta, z)$$

$$\Rightarrow \rho_{HI}(\theta, z)$$

2 Cylinder prototype at Pittsburg

dipole antennas
on cylinder axis

Correllations between 2 cylinders



HI at $z \sim 1.5$

$$\rho_{HI}(\theta, z) = \sum_{\vec{k}} \phi(k_\theta, k_z) e^{i(k_\theta \theta + k_z z)}$$

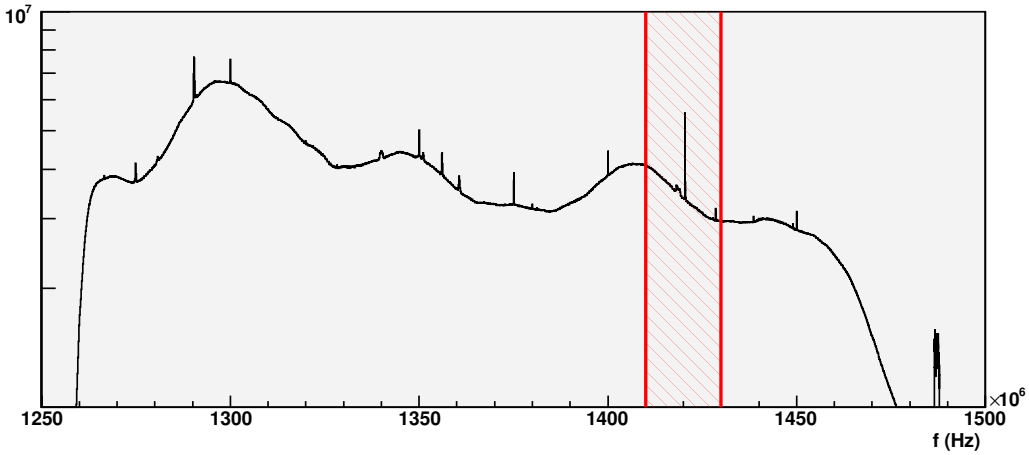
2 receivers separated by d

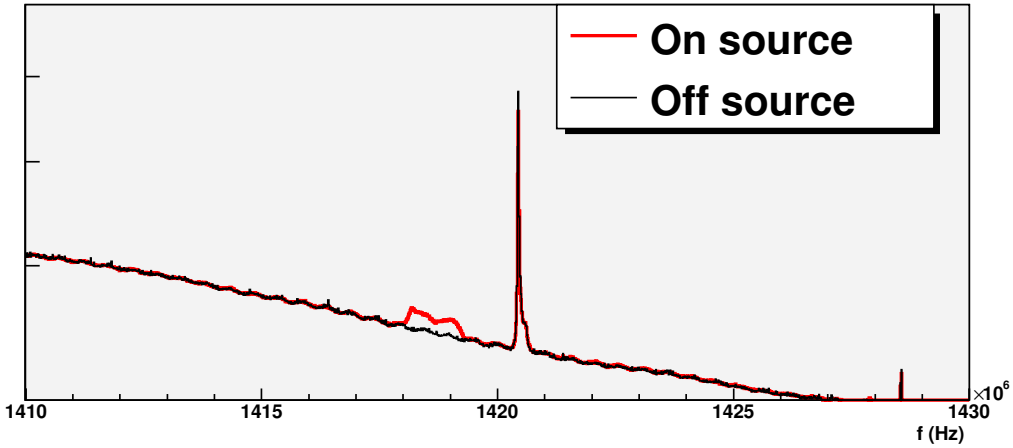
output $\propto \phi(k_\theta = 2\pi d/\lambda)$

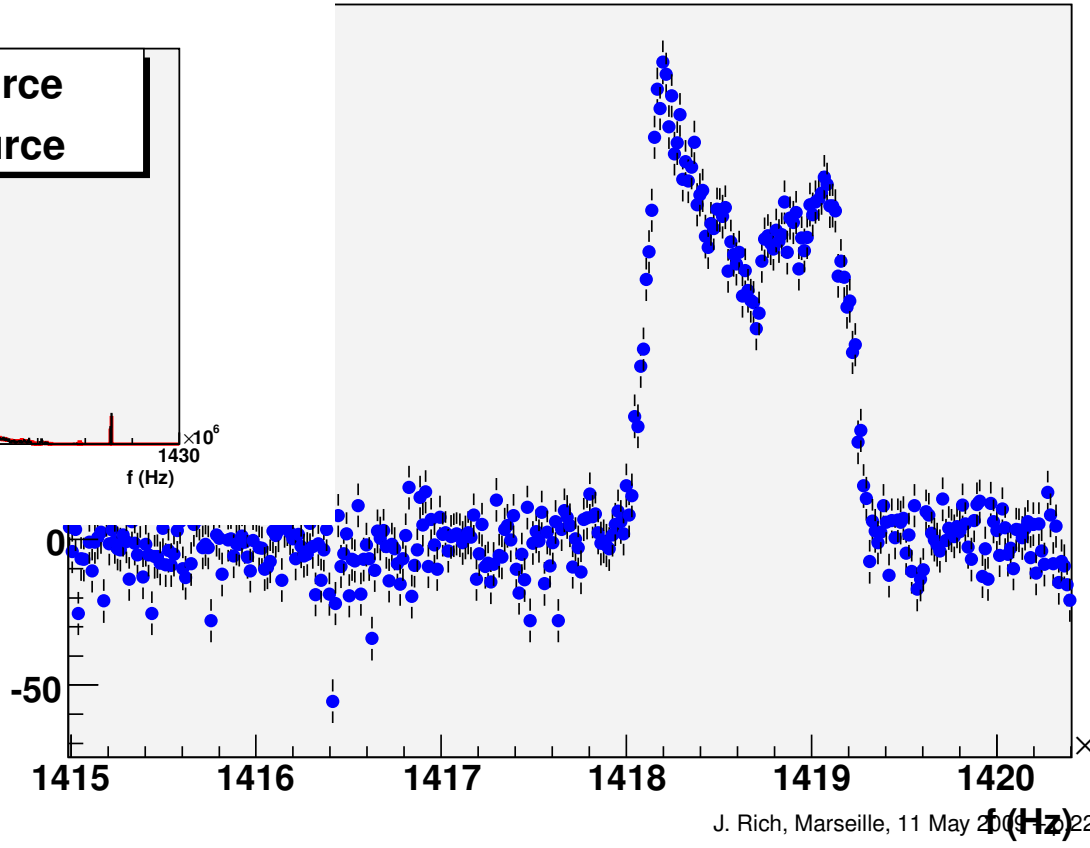
$\Rightarrow$ power spectrum

Tests of LAL/SPP electronics at Nancay

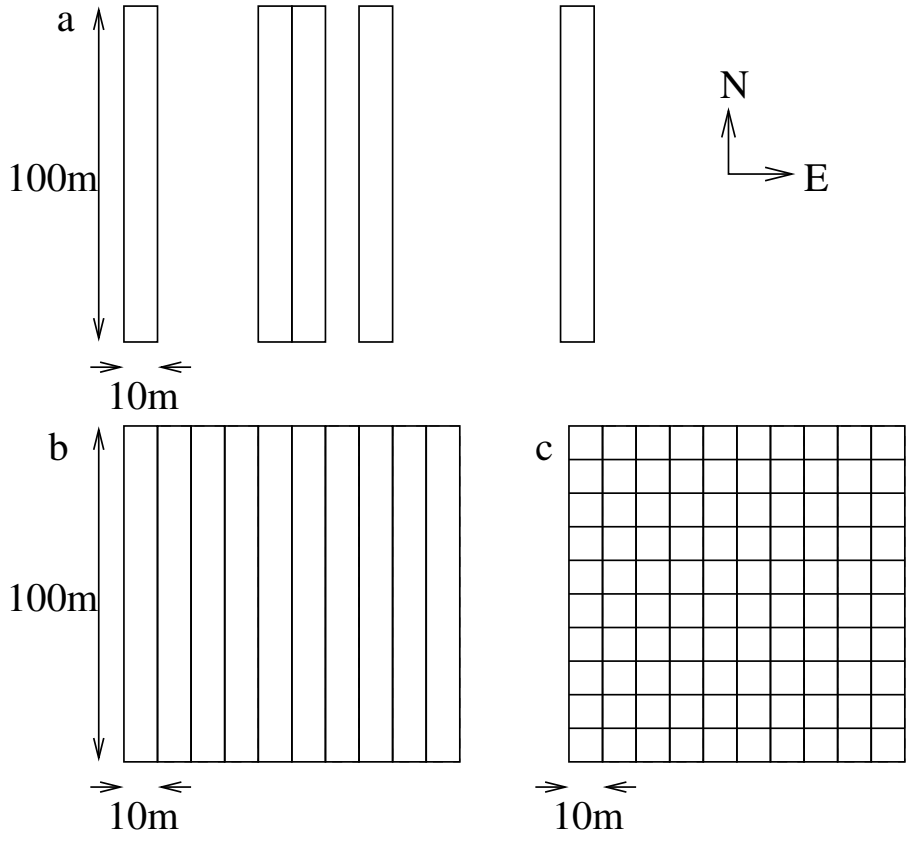
First 21cm galaxy detected by SPP







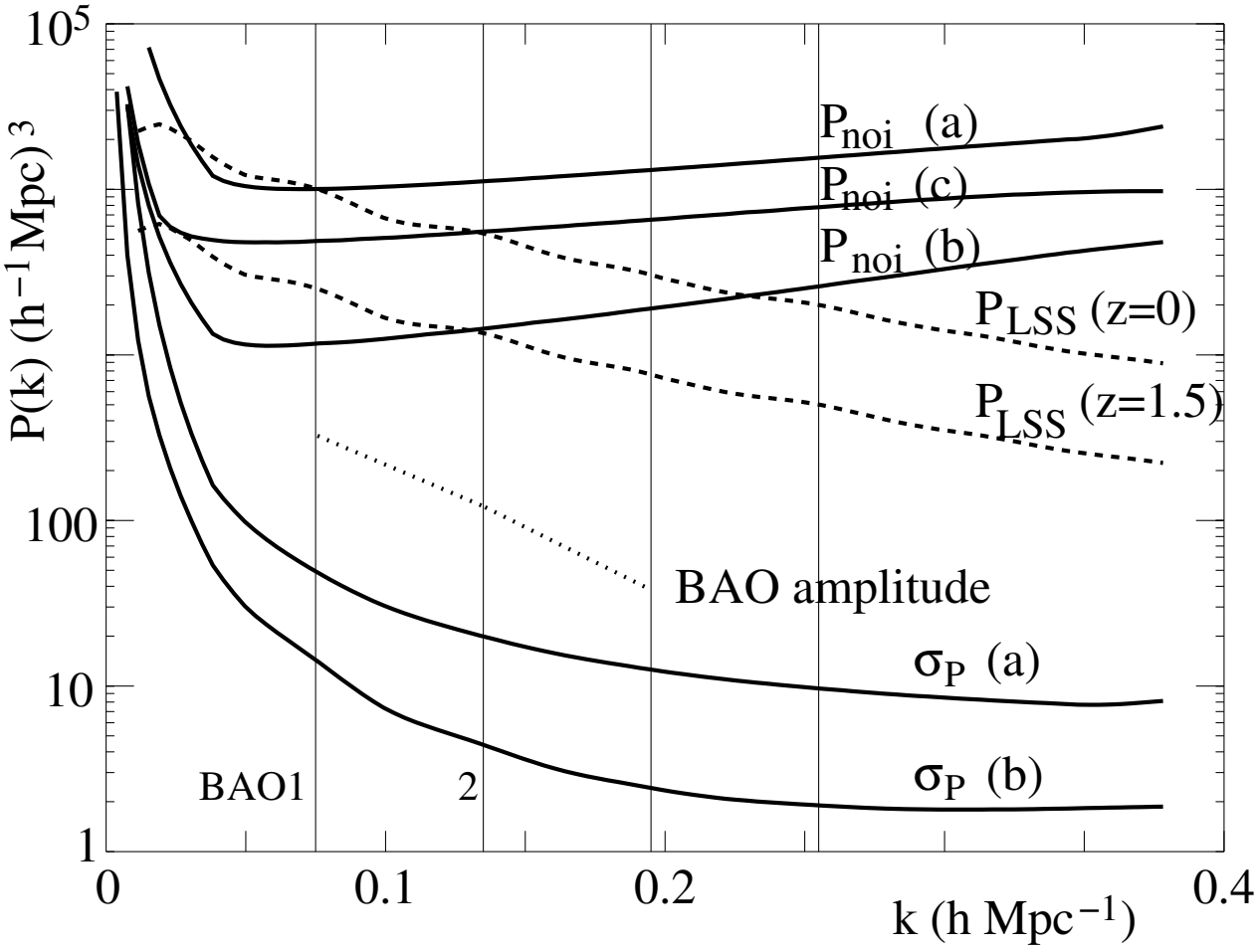
Three generic configurations



a, b : fully-instrumented cylinders (~ 1000 antennae).
pointings in (δ, ν) by FFT, in α by Earth rotation

c : square dishes
pointings in (ν) by FFT

Noise Power



$z = 1.5$

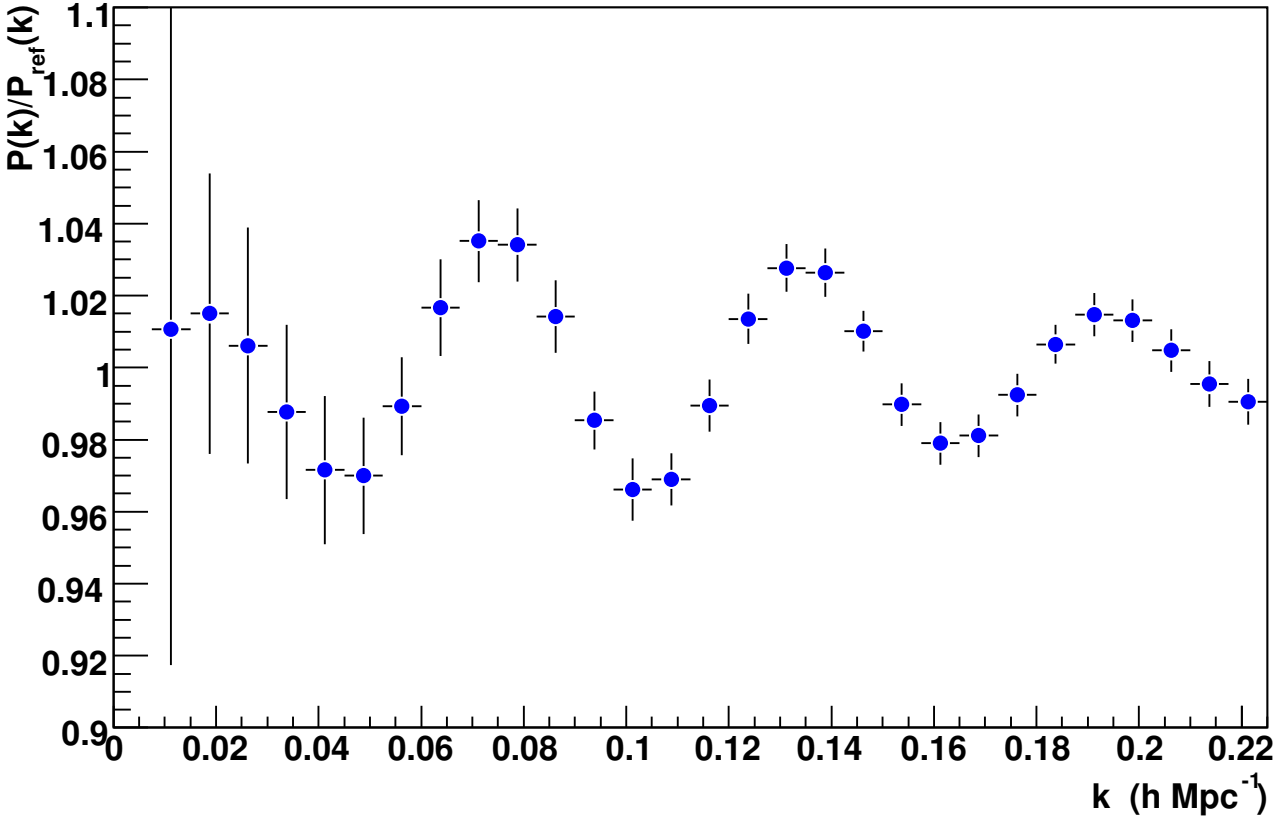
$2\pi sr \times 3months$

resolution a

Reconstucted $P(k)$ diverges for $k < k_{min} = 2\pi D/(\lambda d_T)$

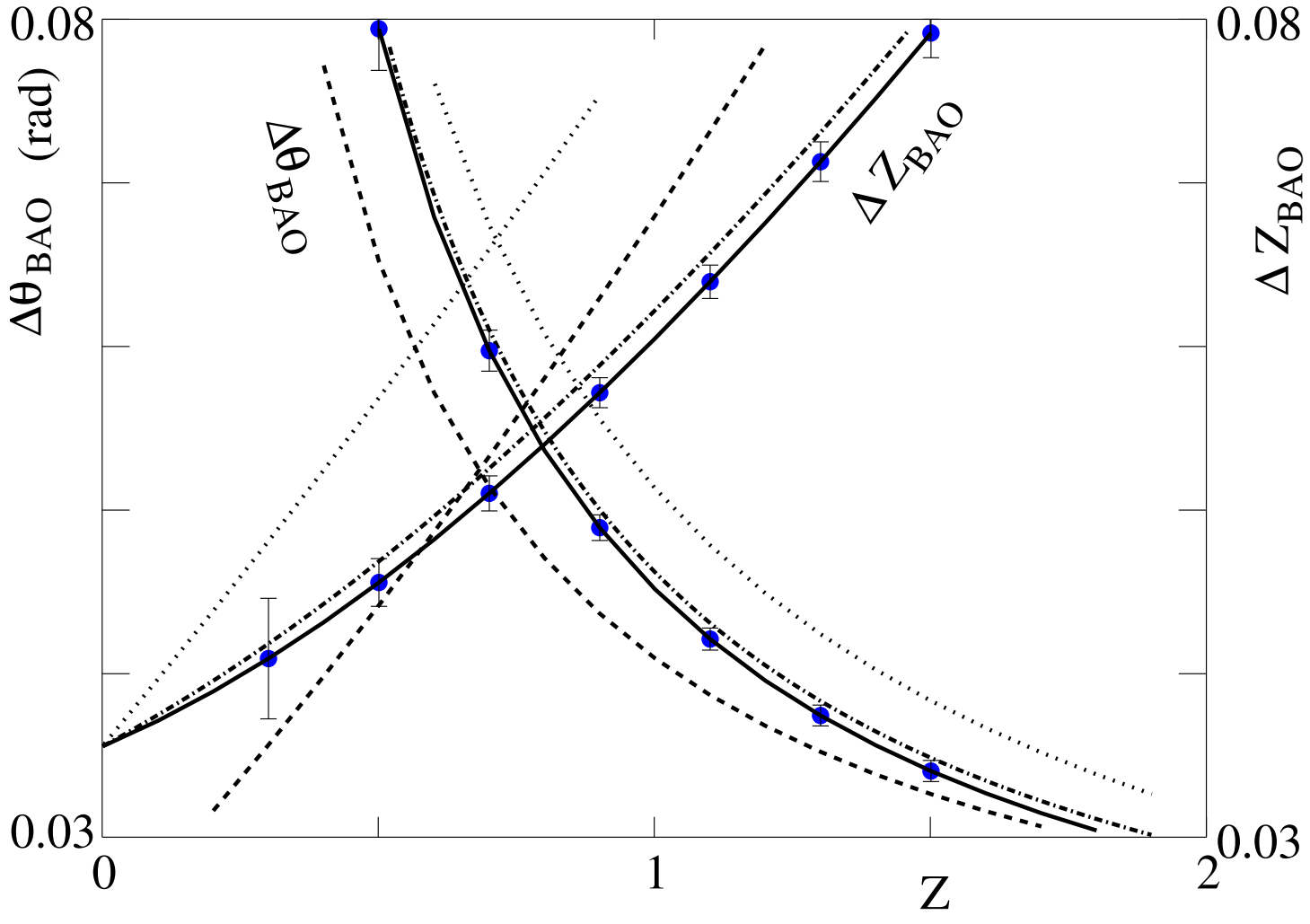
$P(k > k_{min}) \propto 1/[N_{pointings} \times N_{pairs}(\vec{k})]$

HSHS wiggles



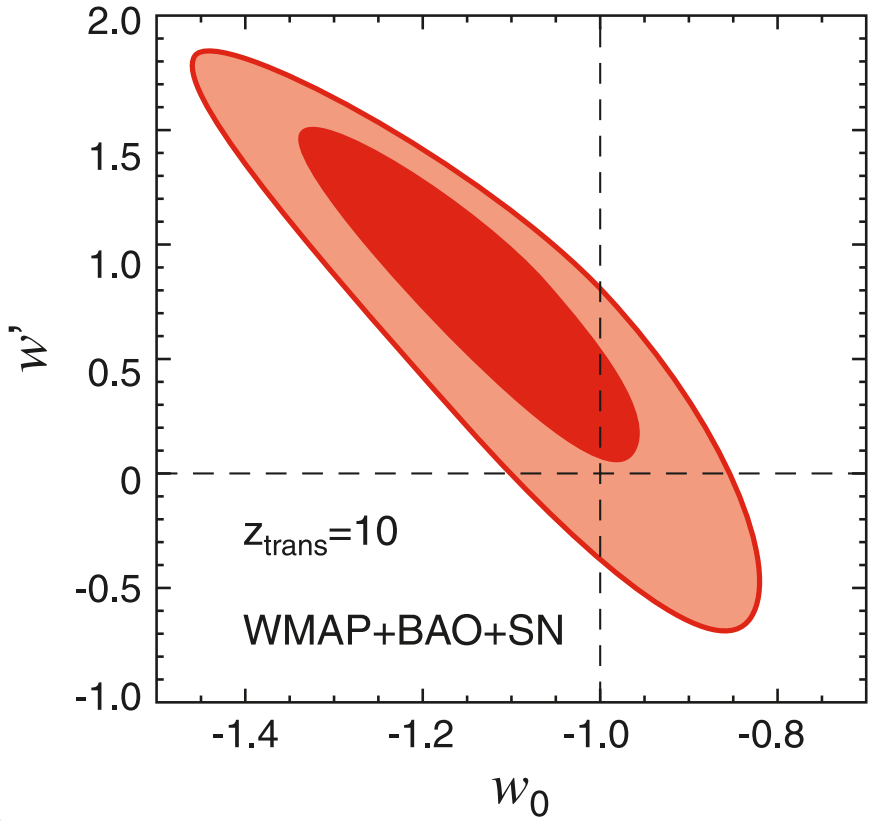
Ansari et al. : arXiv 0807.3614

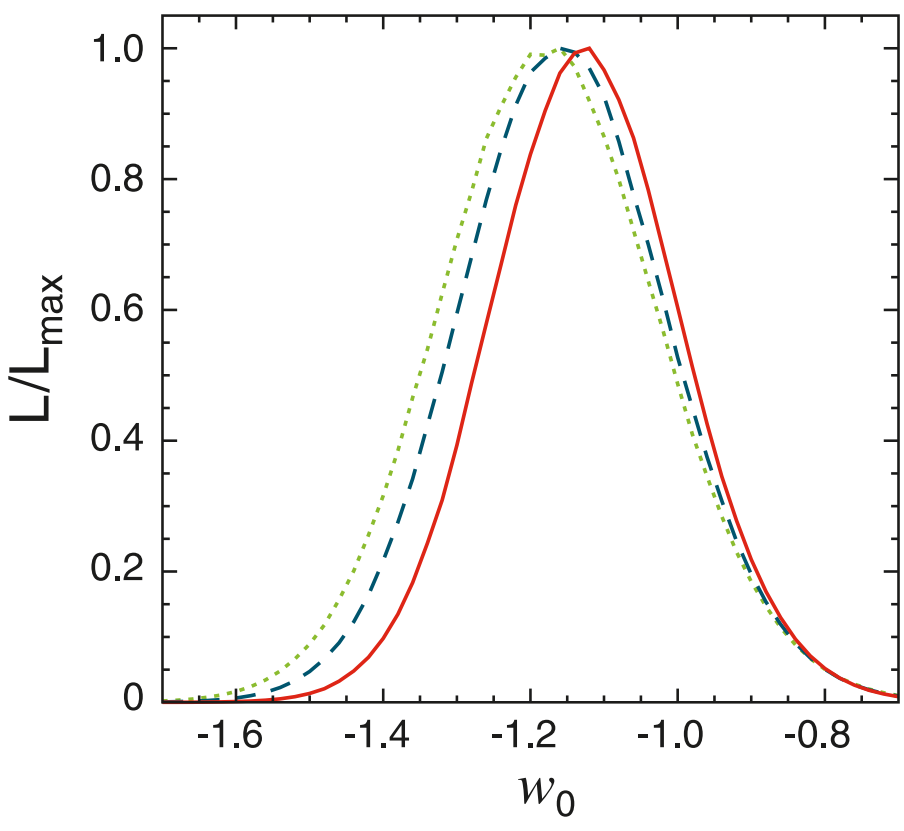
HSHS Hubble diagrams



Ansari et al. : arXiv 0807.3614

Dark energy and its ellipses



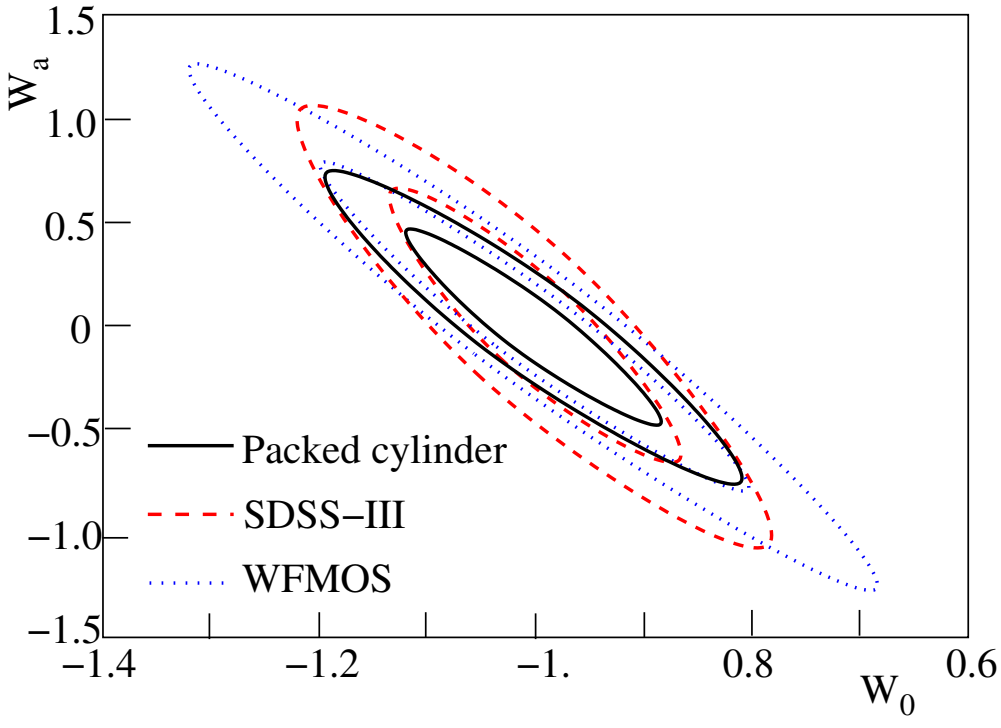


$(w_0, w') \Rightarrow$ time derivatives of dark energy density

$(-1, 0) \Rightarrow$ time independent dark energy density
(dynamically equivalent to a cosmological constant)

Future projects will reduce area of ellipse by factor > 10

HSHS+Planck constraints



Ansari et al
arXiv 0807.3614

to do

- Test beam synthesis with cylinders
- Find a design costing <10M$
  cheap cell-phone technology
- Study radio source subtraction
- Find low-noise site
  January test in Morocco