Winter conferences: cosmology

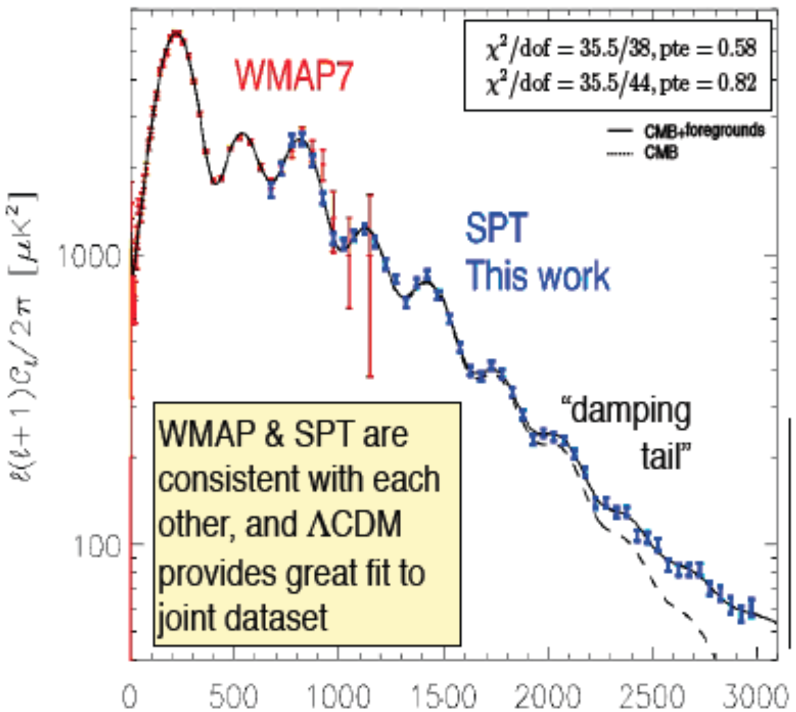
- CMB and inflation
- DE and GR tests
- neutrinos
- dark matter

CMB and inflation

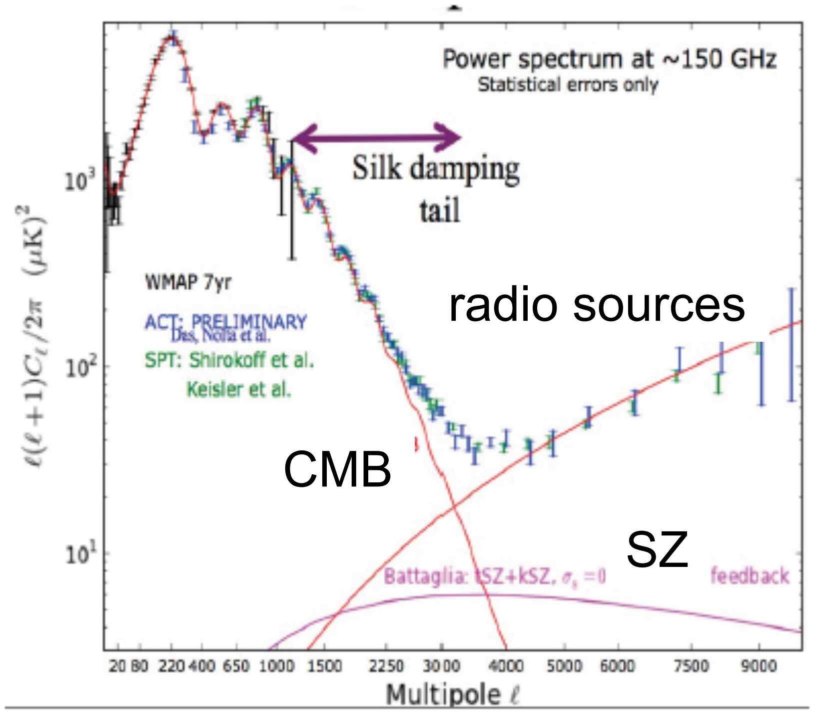
CMB Temperature

- SPT: 2500 deg² 5-year survey finished Nov 2011

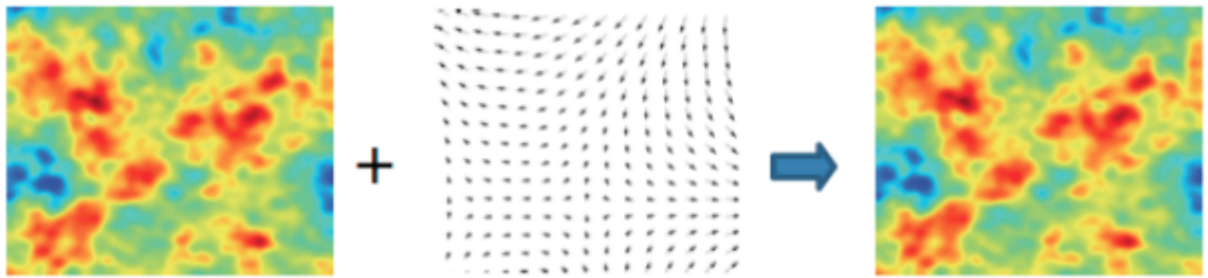
SPT



ACT



lensing P(k)

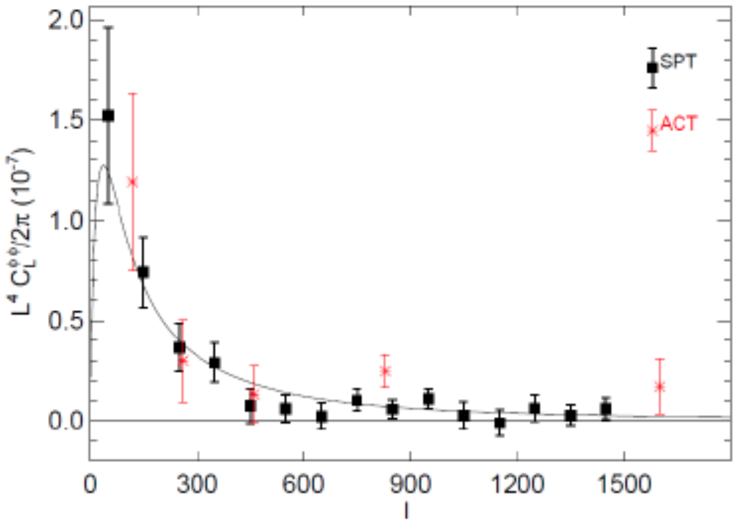


- Large scale structure potentials gravitationally deflect CMB photons by a lensing deflection angle $\mathbf{d}(\mathbf{n})$
- Measurement of the deflection field is a measurement of matter fluctuations AND the geometry of the universe

  -> very useful for cosmological constraints
- Can find lensing because it breaks Gaussianity: non-Gaussian part of lensed T 4-point function ~ deflection power spectrum

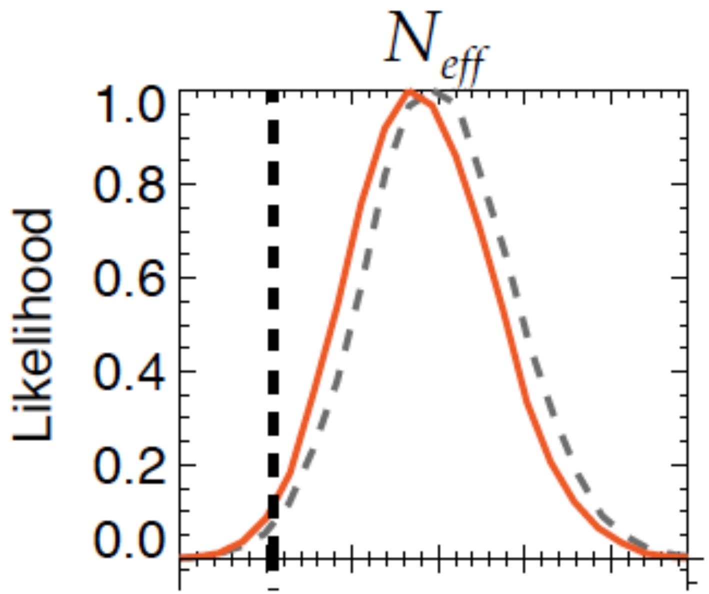
lensing P(k) detected

Detection of deflection power spectrum



Allows the breaking of degeneracies

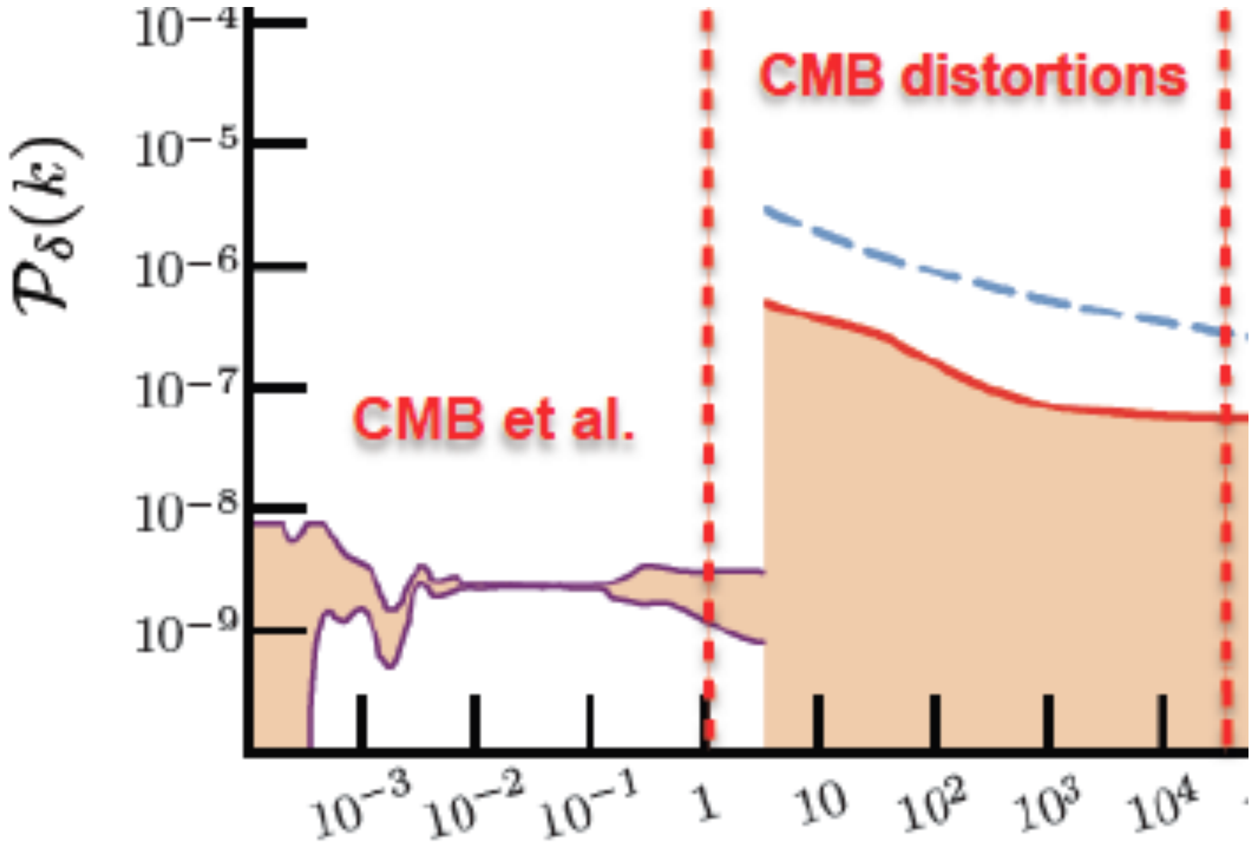
2σ in favour of >3 relativistic dof



N_{eff} = 3.91 +/− 0.42

Spectral distortions

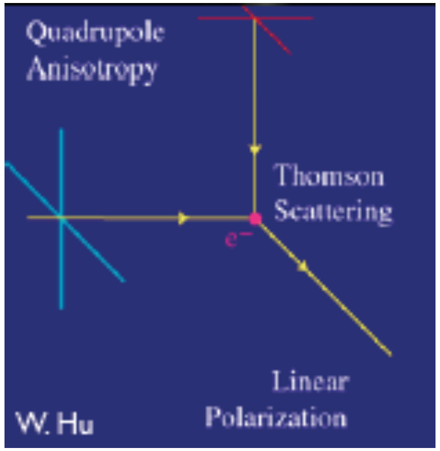
- P(k) unknown for k> 3 Mpc^{-1}
- spectral distortions wrt black body spectrum -> k ~ 10^4 Mpc^{-1}

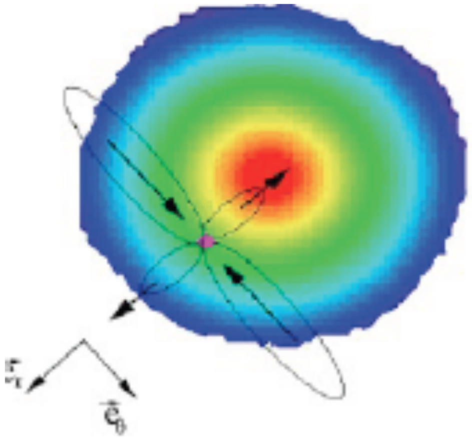


current upper limit

CMB polarization

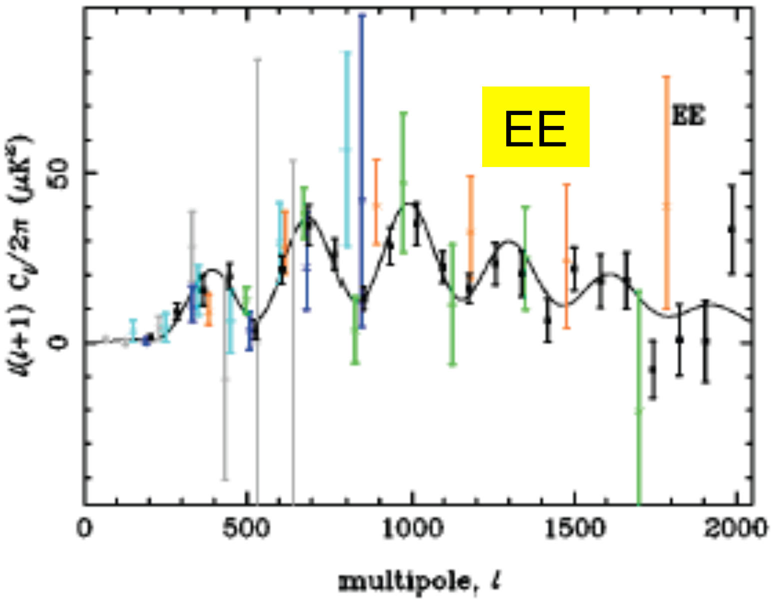
- density fluctuation -> Scalar perturbation
  -> E modes (parity even)
  ($\gamma\ e^- \rightarrow \gamma\ e^-$) => polarization
- gravitational waves -> Tensor perturbation
  -> E modes and B modes (parity odd)
- detecting B modes -> gravitational waves
- r = T/S current limit : r < 0.24 (95% CL)
- many projects : BICEP2, SPTPol, QUIET, ACTPol, PolarBear, QUBIC
- all aim at r = 0.01 – 0.02



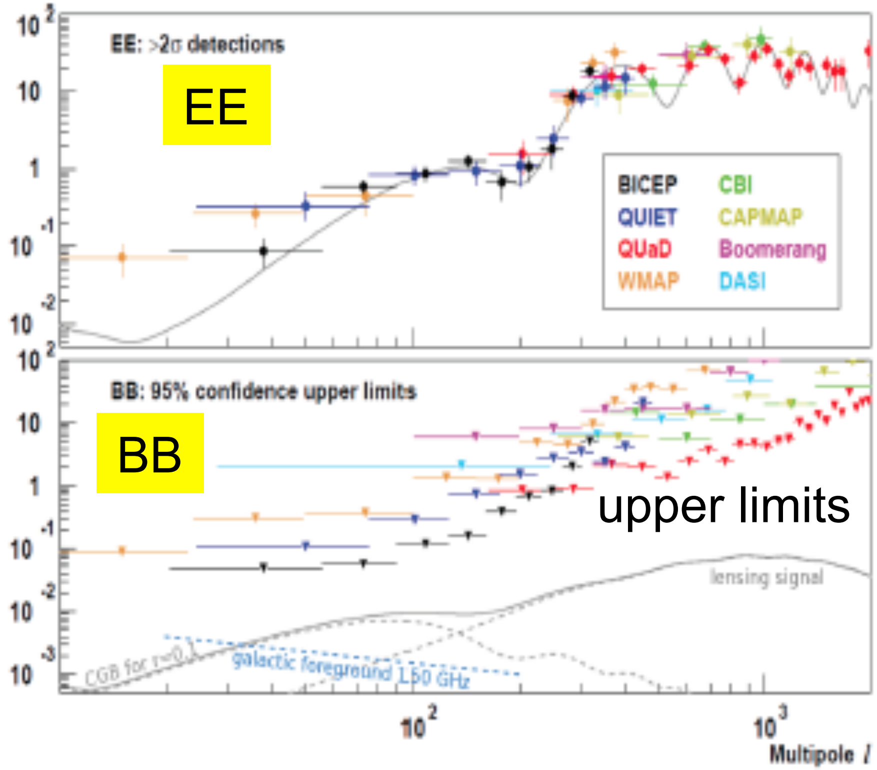


Present status CMB polar

QuAD



BICEP



- combining all data : r < 0.2

Dark Energy and GR test

Dark energy

- Supernovae
- Redshift surveys
  - BAO
  - Redshift Space Distortion
- Clusters
  - SZ
  - optical
  - X-ray
- Weak lensing

BAO

- at z >> 1000 : baryon-e⁻ plasma coupled to photons
- Over-density (overpressure)

  ⇒ acoustic waves
- Z ~ 1100 recombination : baryon-photon decoupling ⇒ pressure=0

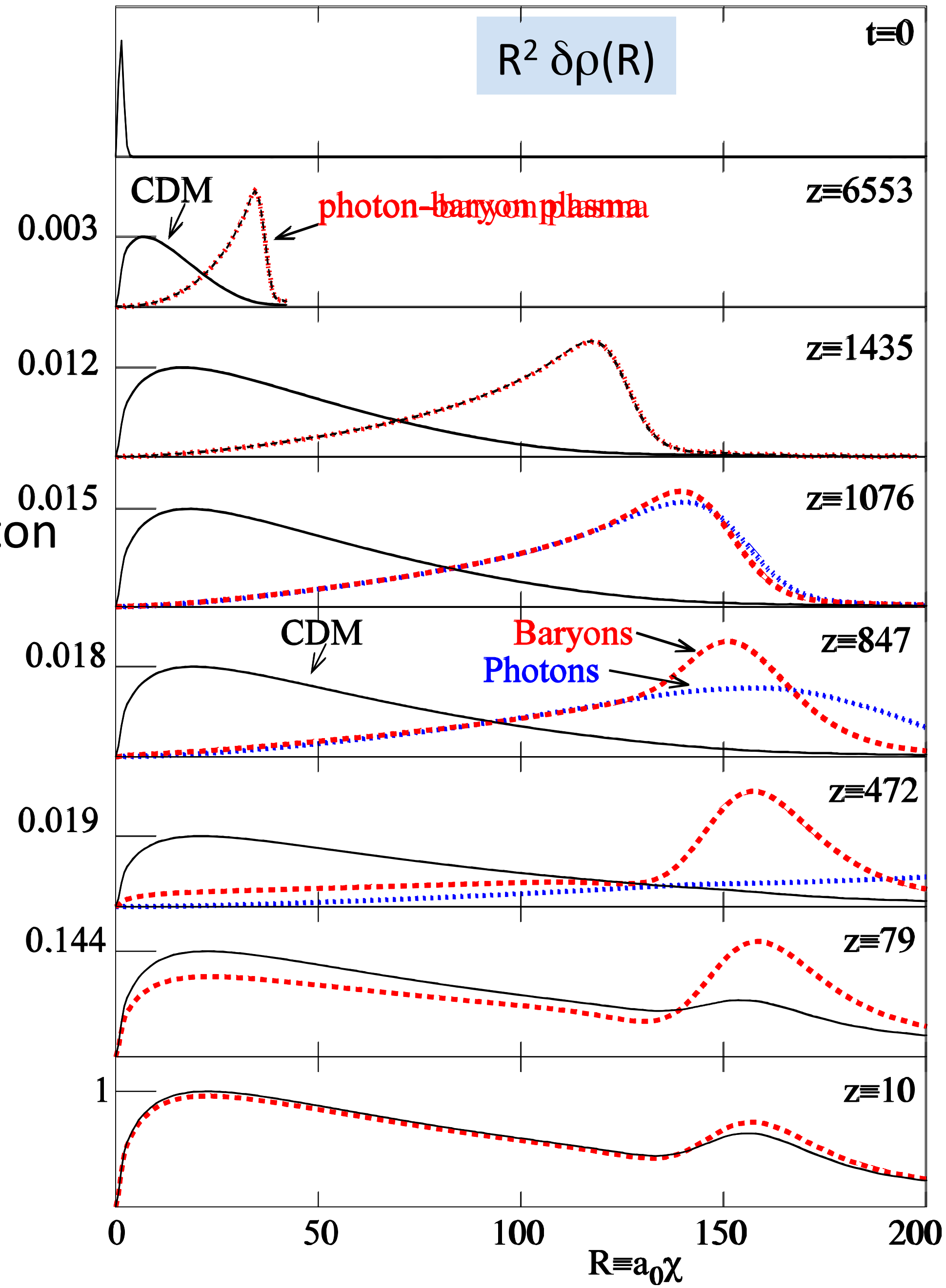
  ⇒ frozen wave has travelled

  s = 150 Mpc (commoving)
- Peak at 150 Mpc in autocorrelation function at all z

$$\xi(\vec{r}) = \langle \rho(\vec{x})\rho(\vec{x}+\vec{r}) \rangle$$

a 150 Mpc standard ruler

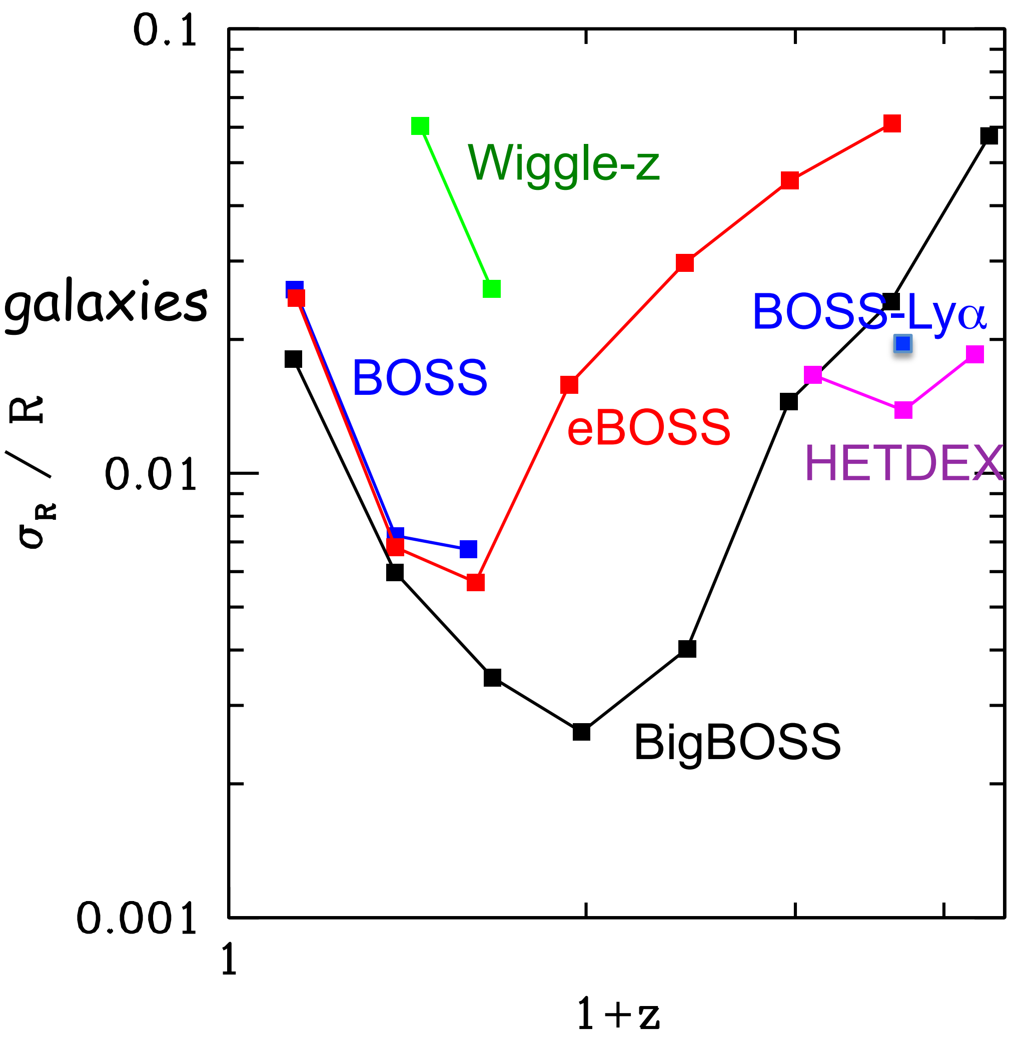
- Geometrical measurement, linear physics: low systematic



BAO

HETDEX

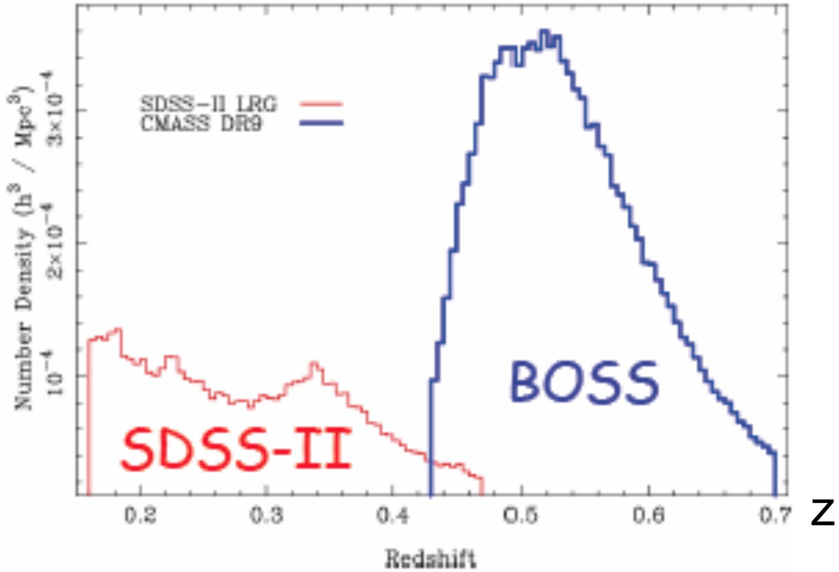
- 9.2 m telescope
- 0.75M Lyman-a emitting galaxies
- 1.9<z<3.5
- 300 deg^2
- start January 2013

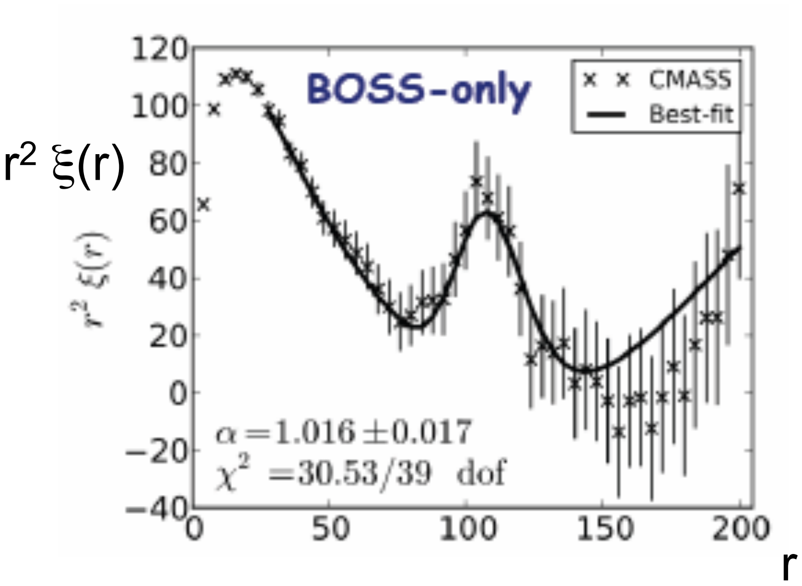


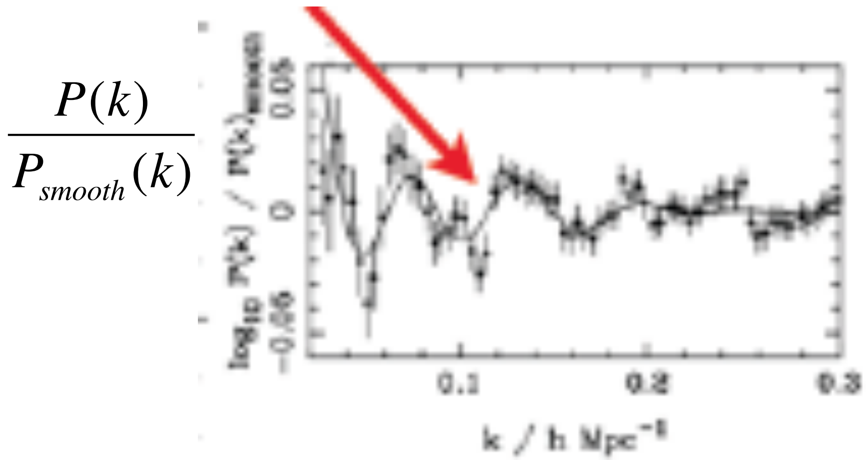
BOSS

- 2009-2014
- DR9: with 18% of data
- BAO BOSS alone : 5 σ

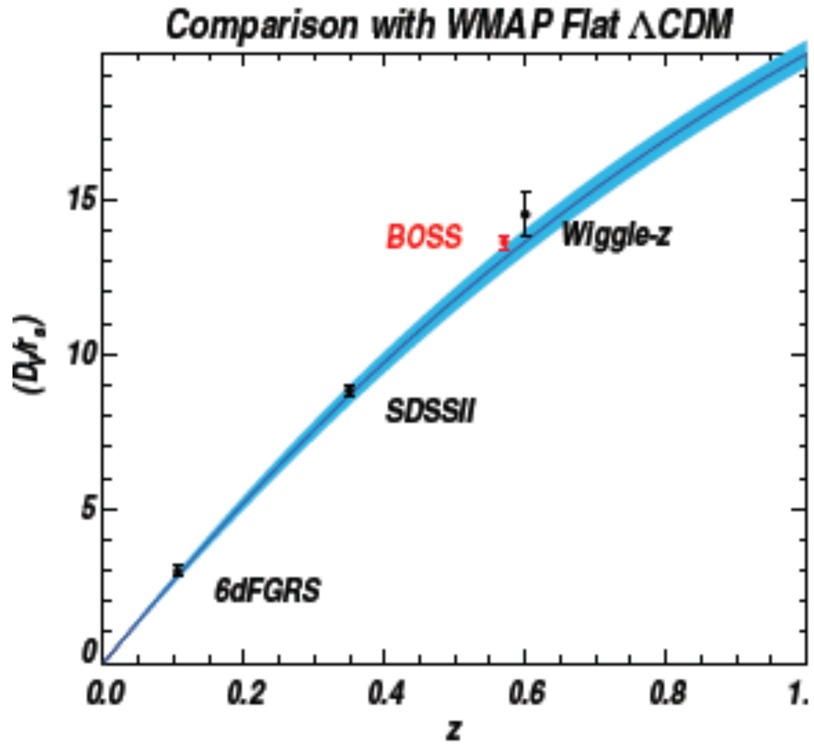
  BOSS + SDSSII: 7 σ
- $D_V(z)=[D_A{}^2(z)/H(z)]^{1/3}$

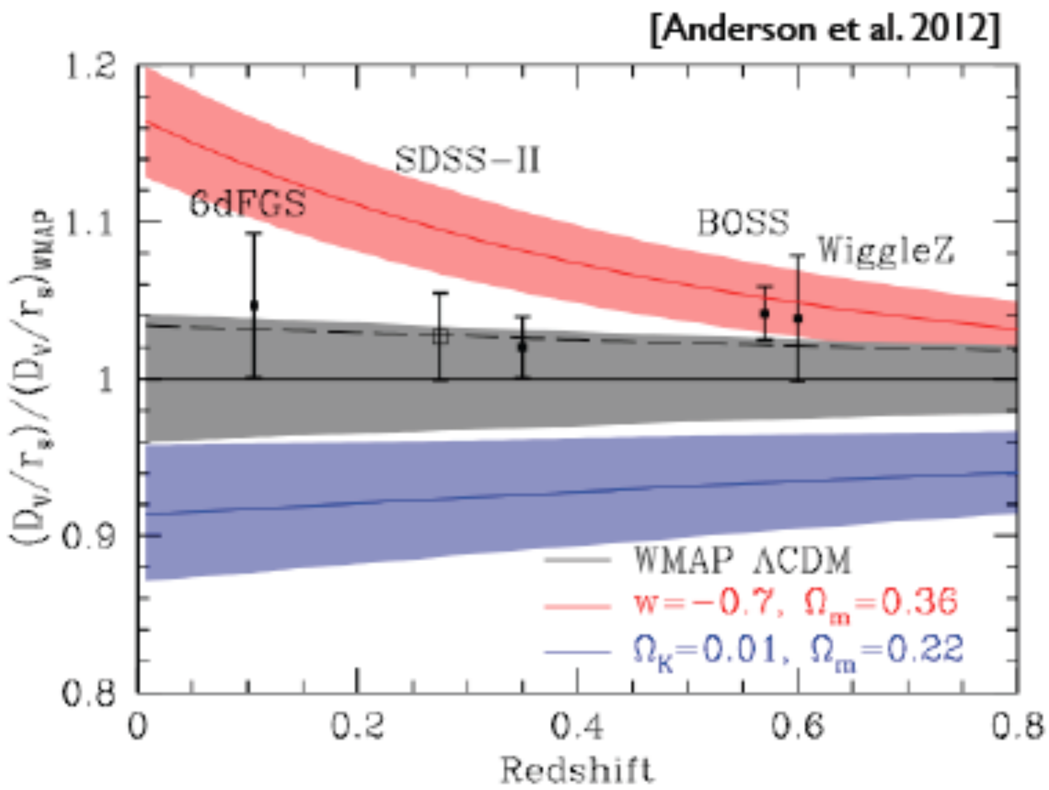






BOSS and Wiggle-Z





consistent with WMAP

Ω_m = 0.268 ± 0.029 (WMAP)

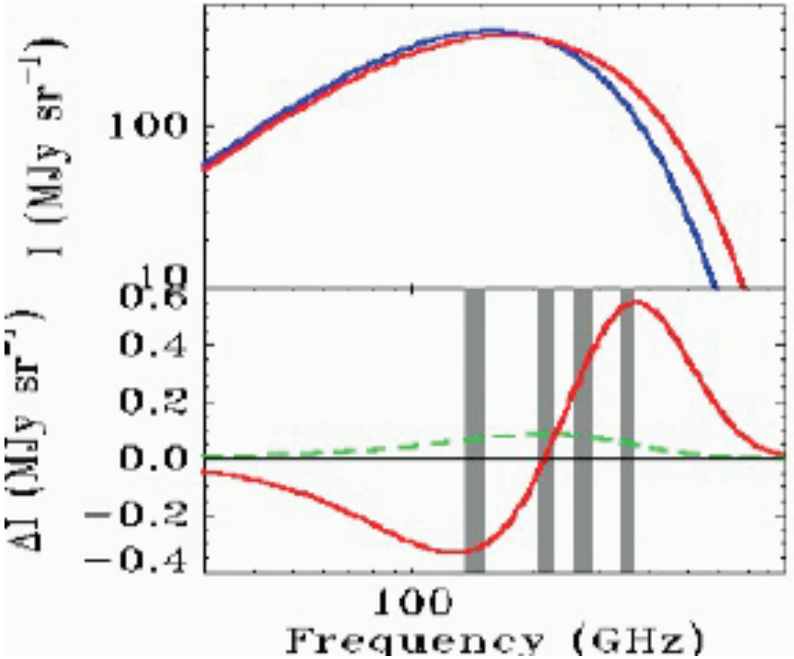
Ω_m = 0.293 ± 0.012 (WMAP+SDSS)

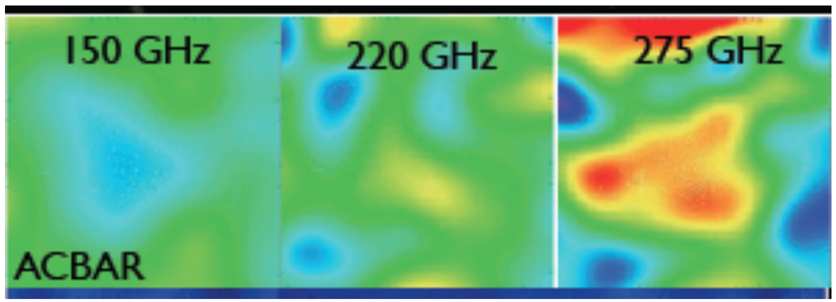
cluster detection

- X : hot gas (10^7K)
  - T -> Mass relation
    for virialized clusters
  - luminosity $1/D_L^2$

- Sunyaev-Zeldovich
  γe -> γe on hot gas
  distortion of CMB spectra
  - independent of z
  - M and z degenerate
  confirmation in optical -> z

- dN/dMdV(z) -> cosmology





cluster perspectives

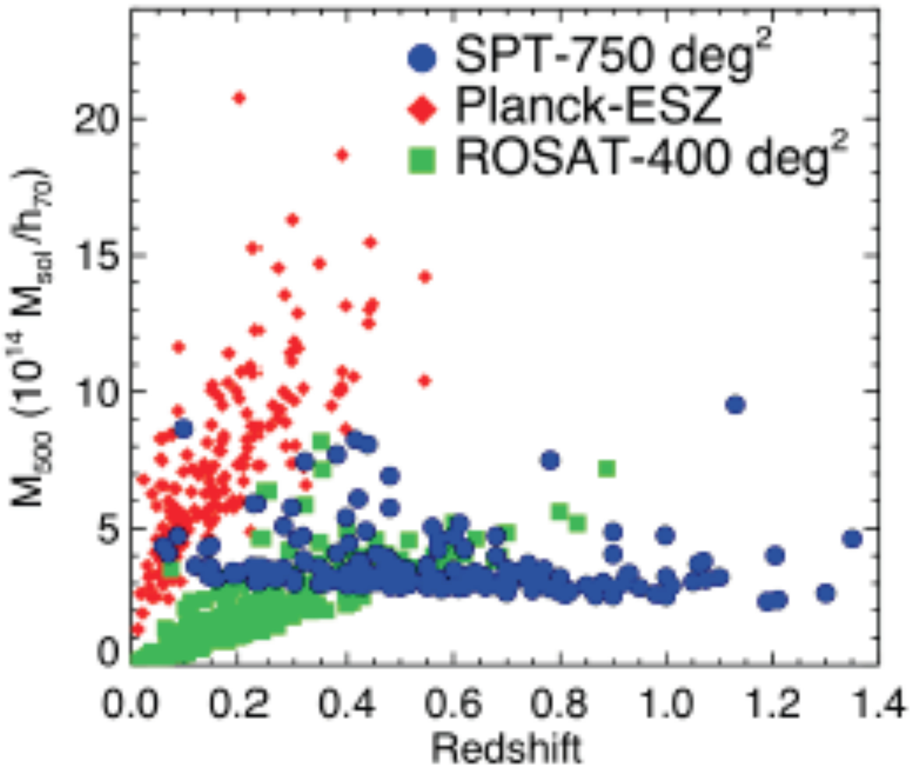
- X :

  ROSAT
- SZ:

  Planck: already 189

  SPT: expect 500

  ACT: already 100



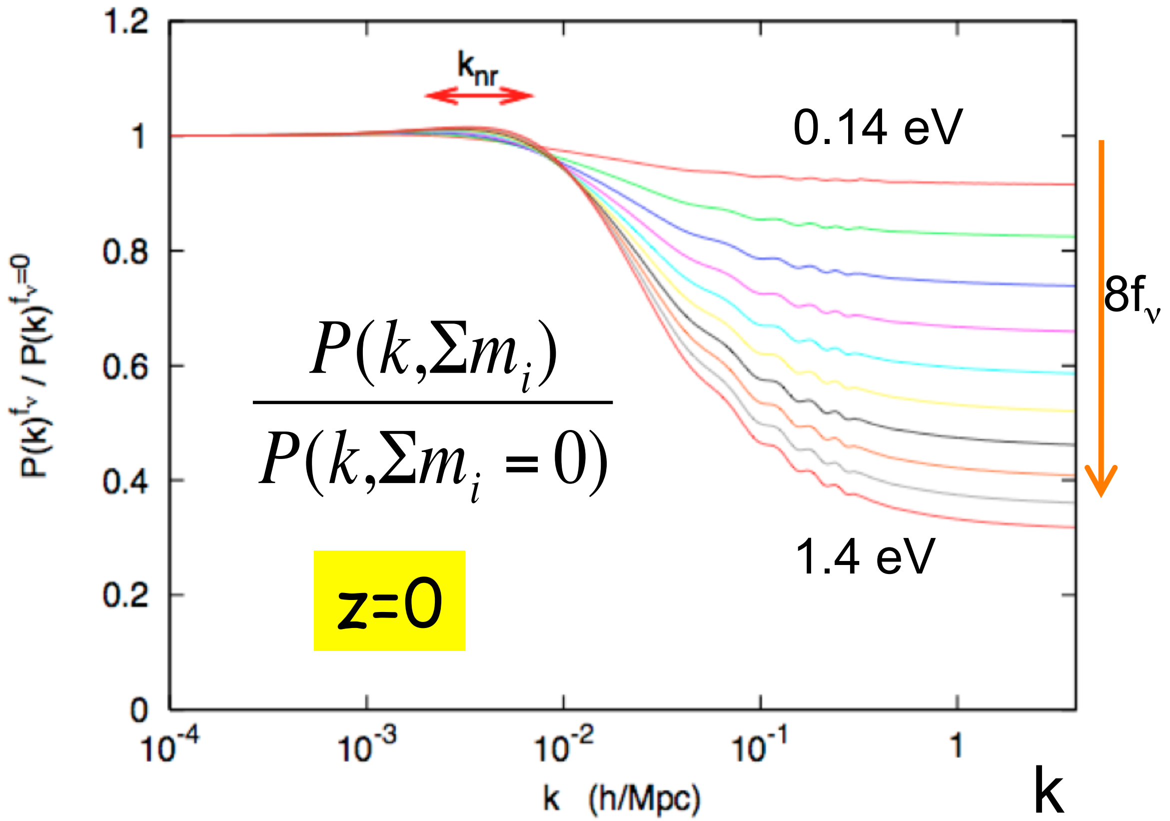
- studies about biases in M
- many results to come in next years

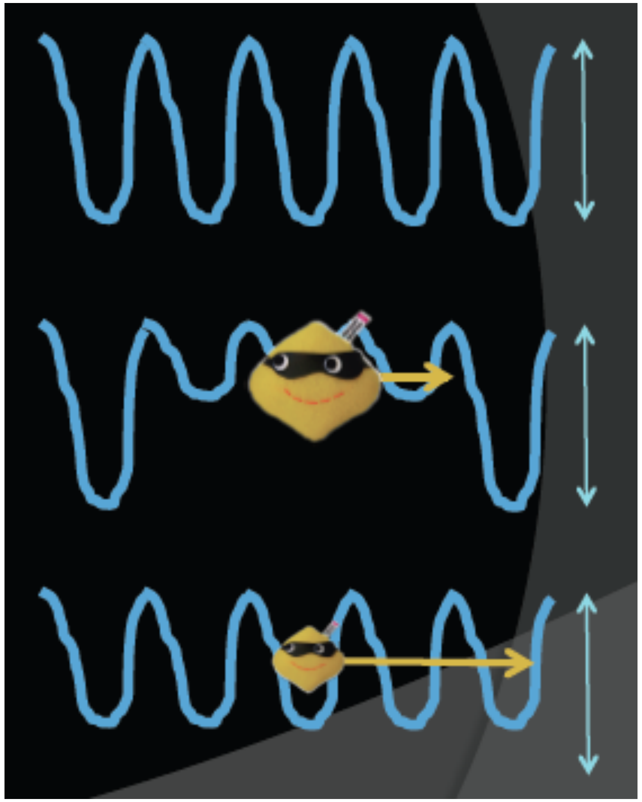
neutrinos and dark matter

Σm_ν and P(k)

neutrinos "free stream" and spread out gravitational potential

Heavy ν: strong suppression over short range
light ν: weak suppression over long range





results for Σm_ν

- direct experiments : 0.06 < Σm_ν < 6 eV
- CMB : Σm_ν < 1.3 eV (Komatsu 2010)
- CMB + SDSS : Σm_ν < 0.62 eV (Reid 2010)
- CMB + SDSS + Lyman α : Σm_ν < 0.28 eV (Seljak 2006) but …
- Lyman α alone : Σm_ν < 0.9 eV (Viel 2010)

  NEW
- cluster (SPT) : Σm_ν < 0.28 eV (de Putter 2011)
- Wiggle Z : Σm_ν < 0.29 eV (Riemer-Sorenson 2011)

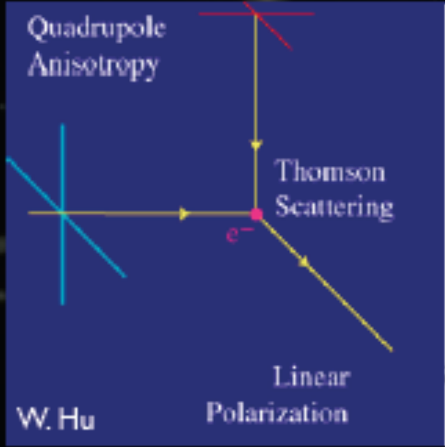
  FUTURE
- BOSS Lyman α : Σm_ν < 0. eV
- Euclid : Σm_ν < 0.1 eV
- SKA (radio) : Σm_ν < 0.05 eV -> measurement

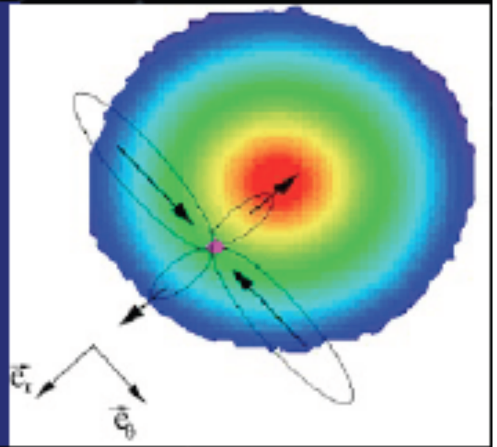
SPARES

Le CMB est polarisé à ~ 10%

★ *Paramètres de Stokes :*

$$
\begin{aligned}
I(\vec{n}) &= \left\langle |E_\parallel(\vec{n})|^2 \right\rangle + \left\langle |E_\perp(\vec{n})|^2 \right\rangle & \text{(scalaire)}\\
Q(\vec{n}) &= \left\langle |E_\parallel(\vec{n})|^2 \right\rangle - \left\langle |E_\perp(\vec{n})|^2 \right\rangle & \text{(spin 2)}\\
U(\vec{n}) &= \langle E_\parallel(\vec{n}) E_\perp^\star(\vec{n}) \rangle + \left\langle E_\perp(\vec{n}) E_\parallel^\star(\vec{n}) \right\rangle & \text{(spin 2)}\\
V(\vec{n}) &= i\left(\langle E_\parallel(\vec{n}) E_\perp^\star(\vec{n}) \rangle - \left\langle E_\perp(\vec{n}) E_\parallel^\star(\vec{n}) \right\rangle \right) & \text{(spin 2)}
\end{aligned}
$$





N. Ponthieu

★ *Décomposition en harmoniques sphériques de spin +/- 2*

$$
\begin{aligned}
Q(\vec{n}) + iU(\vec{n}) &= \sum_{\ell m} a_{2,\ell m} \; {}_2Y_{\ell m}(\vec{n})\\
Q(\vec{n}) - iU(\vec{n}) &= \sum_{\ell m} a_{-2,\ell m} \; {}_{-2}Y_{\ell m}(\vec{n})
\end{aligned}
$$

★ *Tout champ de polarisation peut être décomposé en 2 champs scalaires E et B*

$$
\begin{aligned}
a_{E,\ell m} &= -\frac{a_{2,\ell m} + a_{-2,\ell m}}{2} & \text{(pair)}\\
a_{B,\ell m} &= i\frac{a_{2,\ell m} - a_{-2,\ell m}}{2} & \text{(impair)}
\end{aligned}
$$

$$
\left.\right\} \quad C_\ell^{TT} \quad C_\ell^{TE} \quad C_\ell^{EE} \quad C_\ell^{BB}
$$

m_ν and density fluctuations

- at high z, ν are relativistic
  they "free stream" over all scales : $\delta_\nu \approx 0$
- when $z < z_{nr}$ = 1890 (m_ν /1eV) : ν non relativistic
  free streaming length
  large scales $\delta_{CDM} \propto a$
  small scales $\delta_{CDM} \propto a^{1-0.6 f_\nu}$ $f_\nu = \dfrac{\Omega_\nu}{\Omega_m}$

Effect on different scales

small scale modes

$\delta_\nu \approx 0$

$\delta_{CDM} \propto a^{1-0.6 f_\nu}$

integrated to z=0

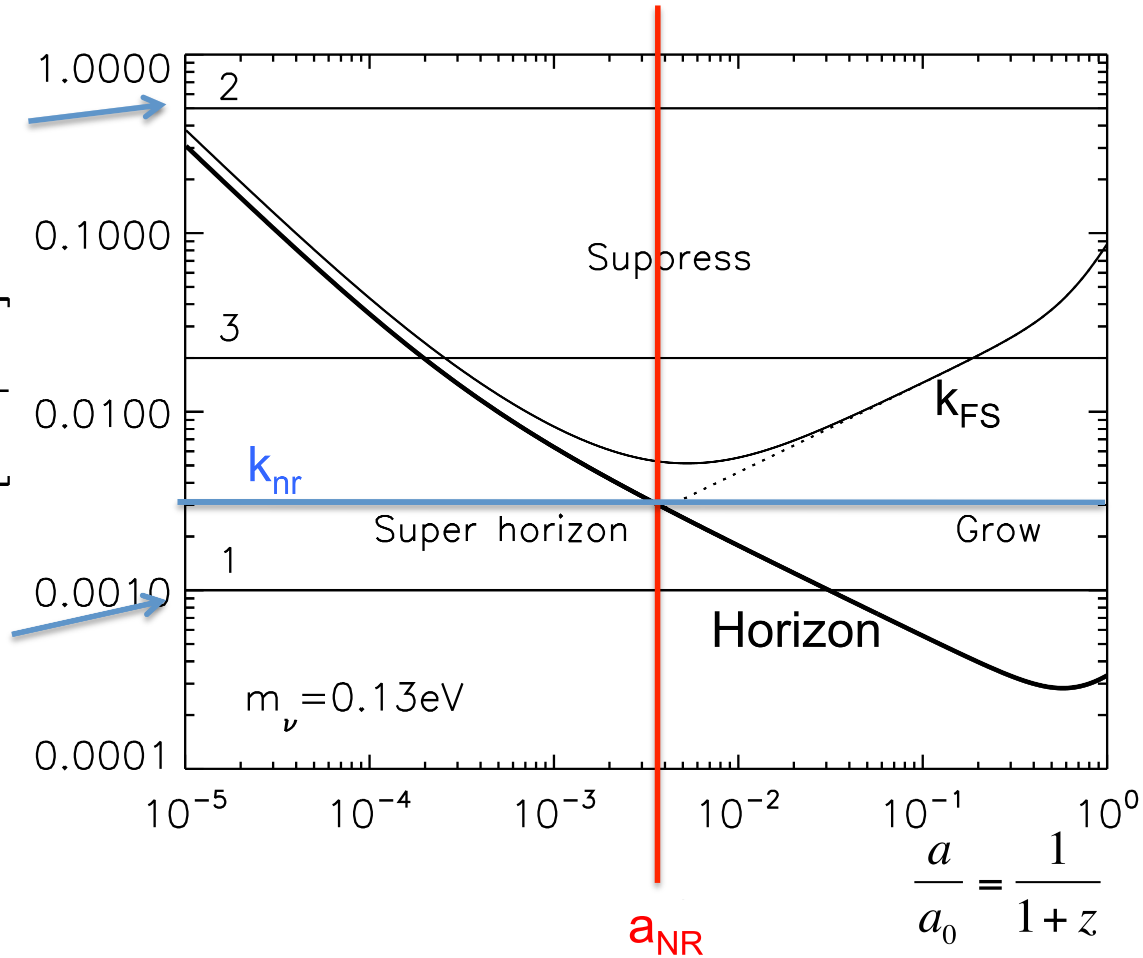
-> $\Delta P(k) = -8 f_\nu P(k, m_\nu = 0)$

large scale modes ($k < k_{nr}$)

$\delta_\nu \approx \delta_{cdm}$

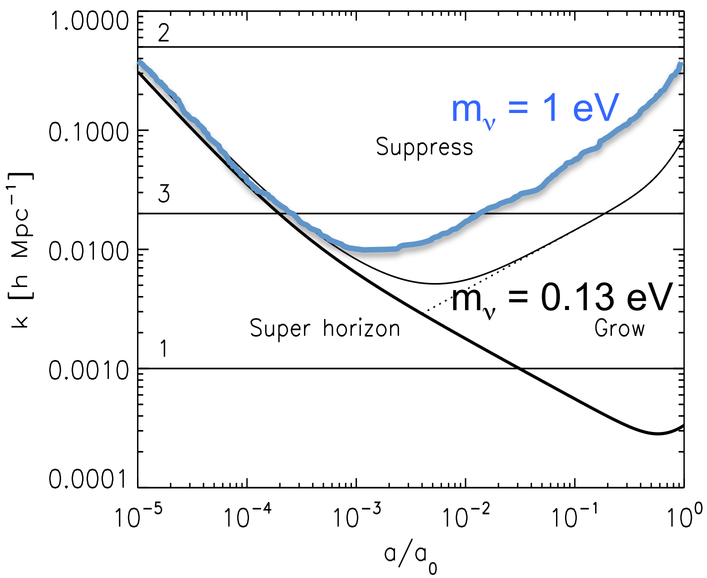
P(k) not reduced by m_ν

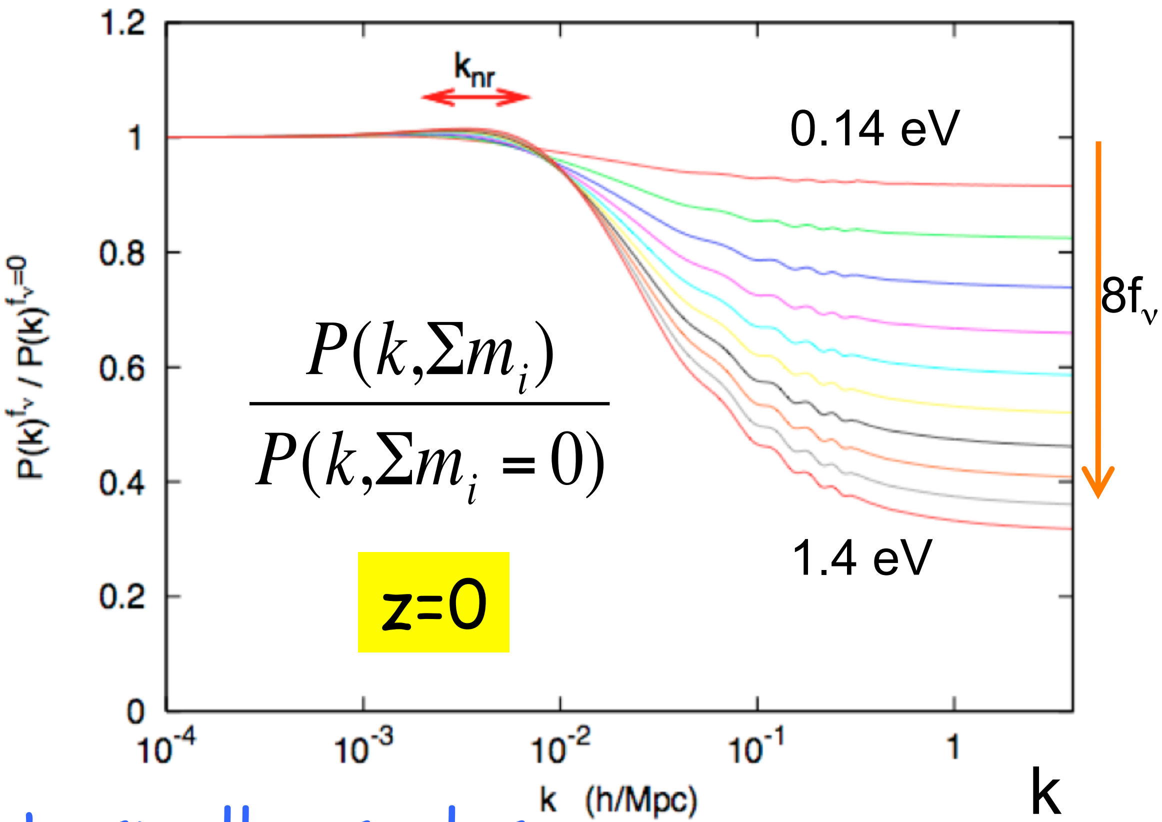
(Shoji Komatsu 2011)



Resulting P(k)

When m_ν increases :





k_{nr} increases

$|\Delta P/P| = 8\ f_\nu$ increases

more effect but limited to smaller scales

shape z dependent