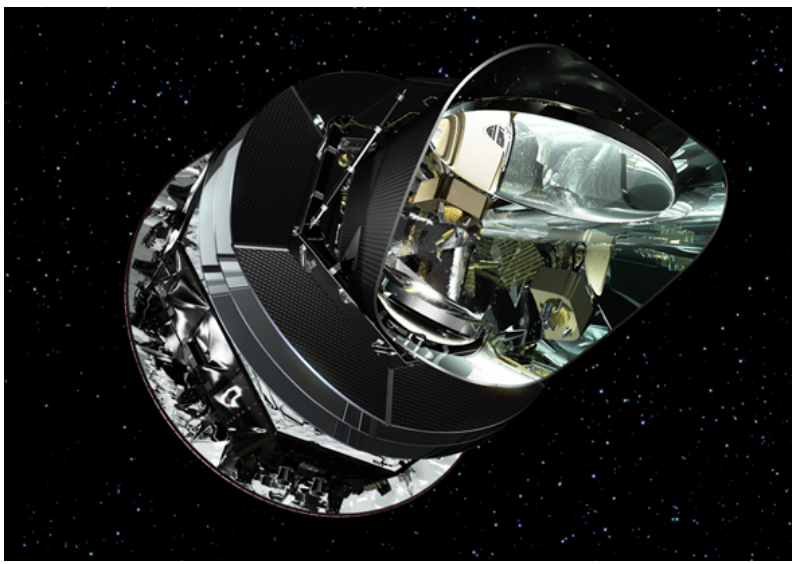
Constraints on neutrinos from the measurement of cosmic microwave background



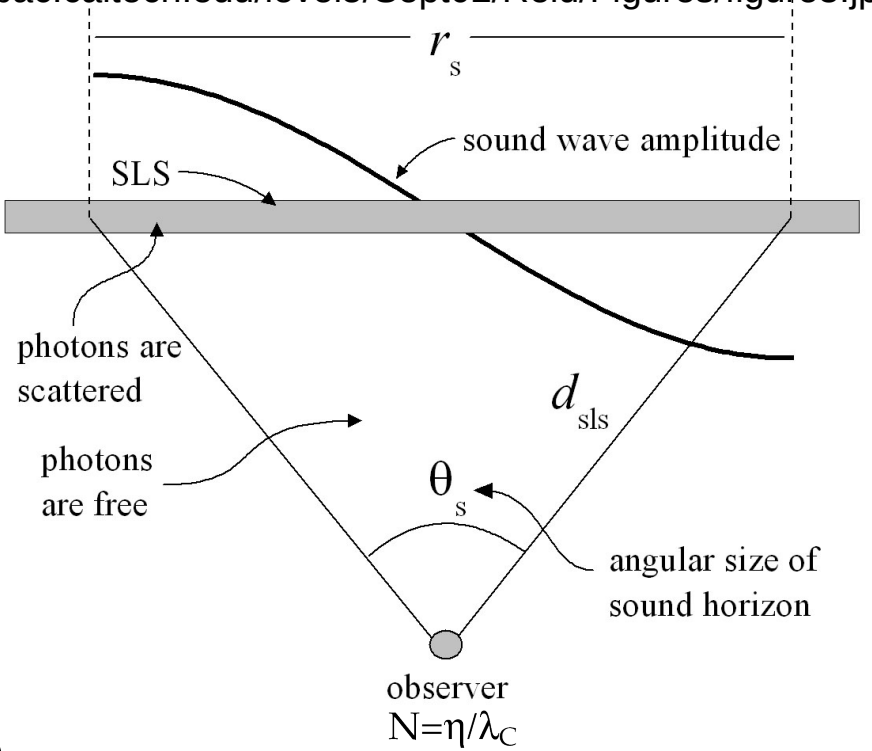
Zhen Hou
(UC Davis)

http://ned.ipac.caltech.edu/level5/Sept02/Reid/Figures/figure3.jpg

Two angular scales

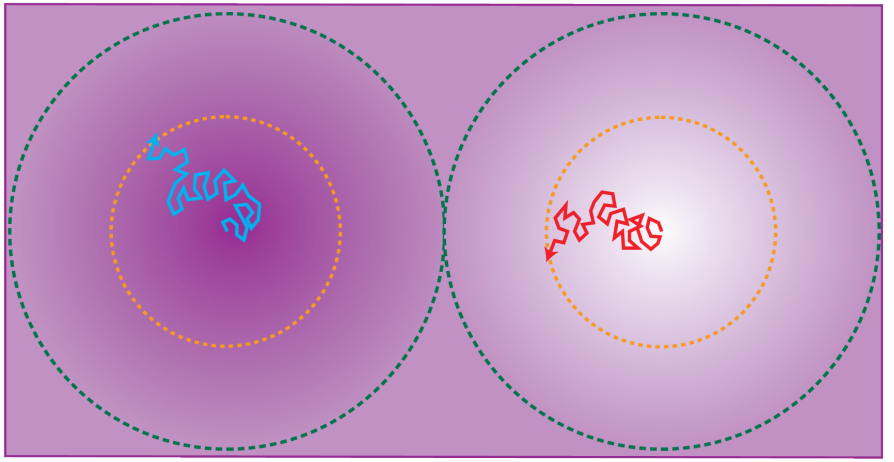
- Sound horizon scale

  Very precisely measured by the locations of acoustic peaks (0.06% from Planck in LCDM)



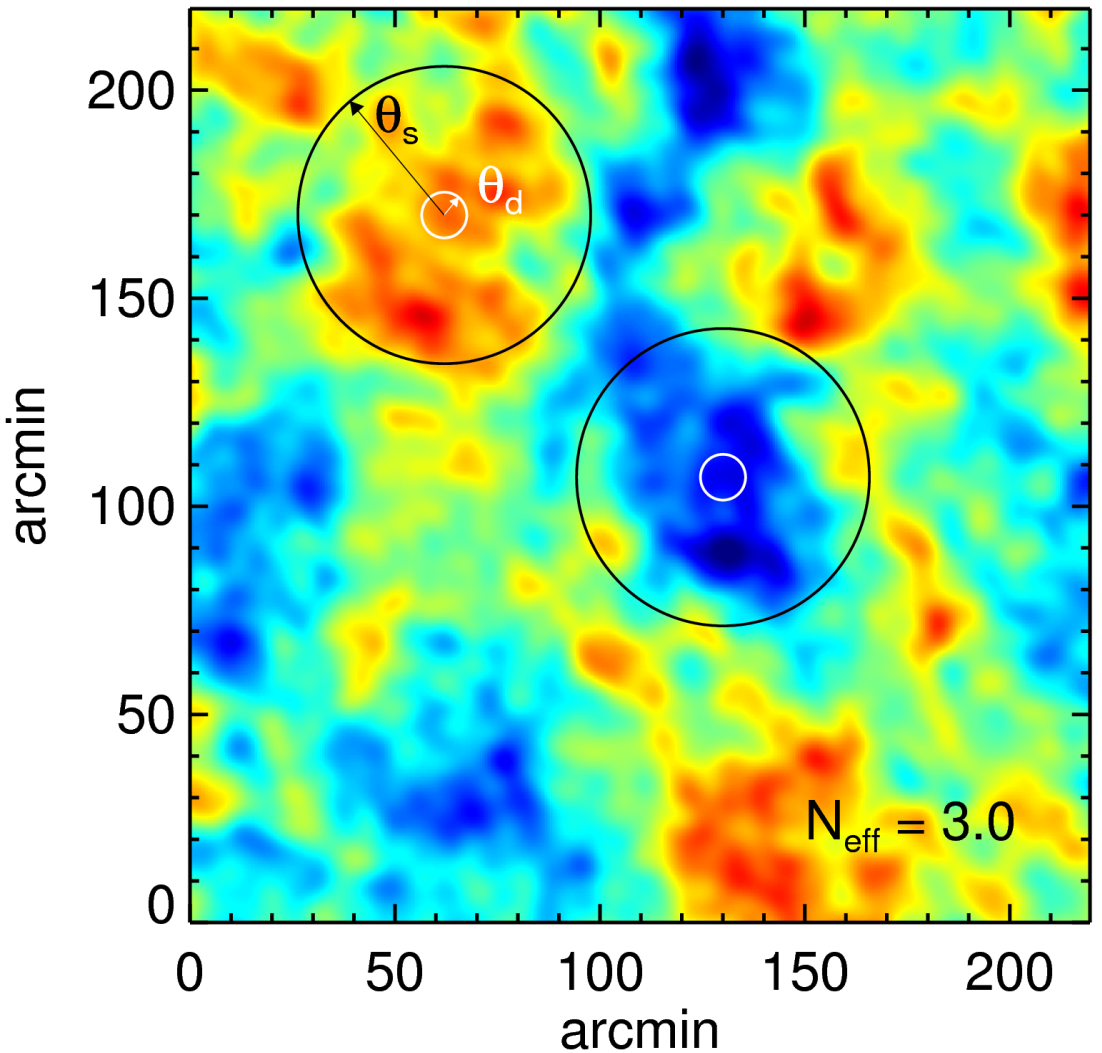
- Photon diffusion damping scale

  0.2% precision from Planck in LCDM

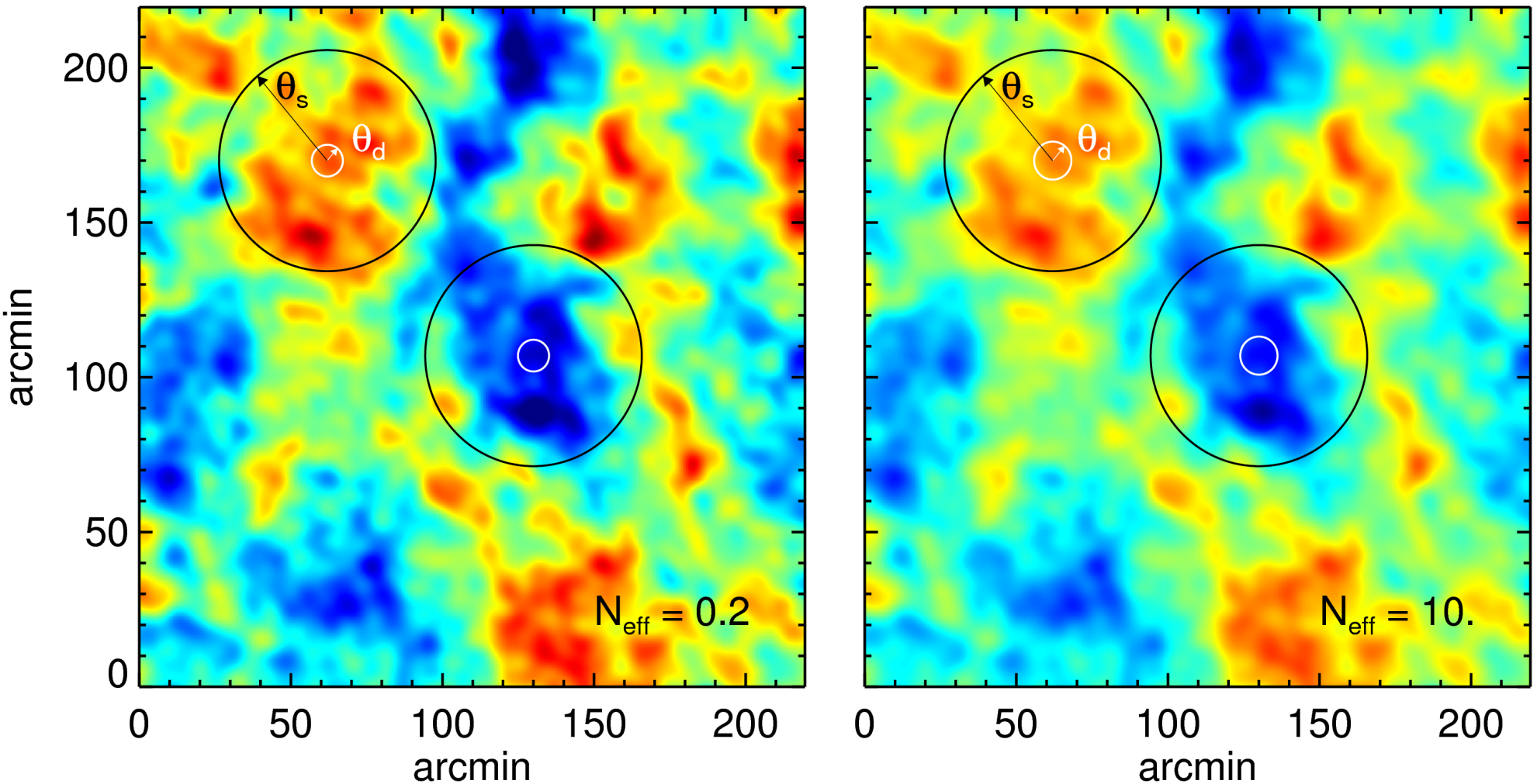


Wayne Hu
PhD Thesis Figure 1.6

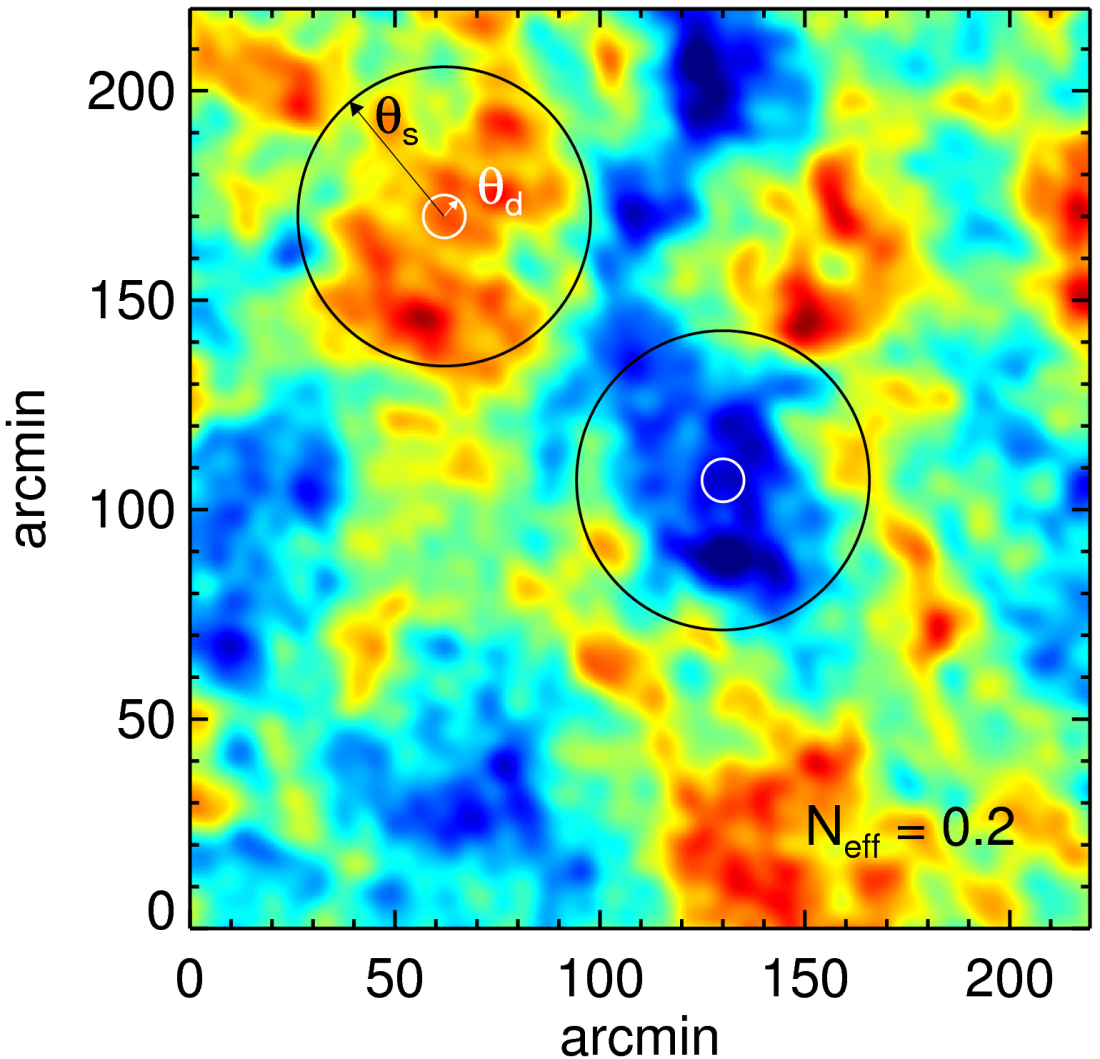
Two angular scales



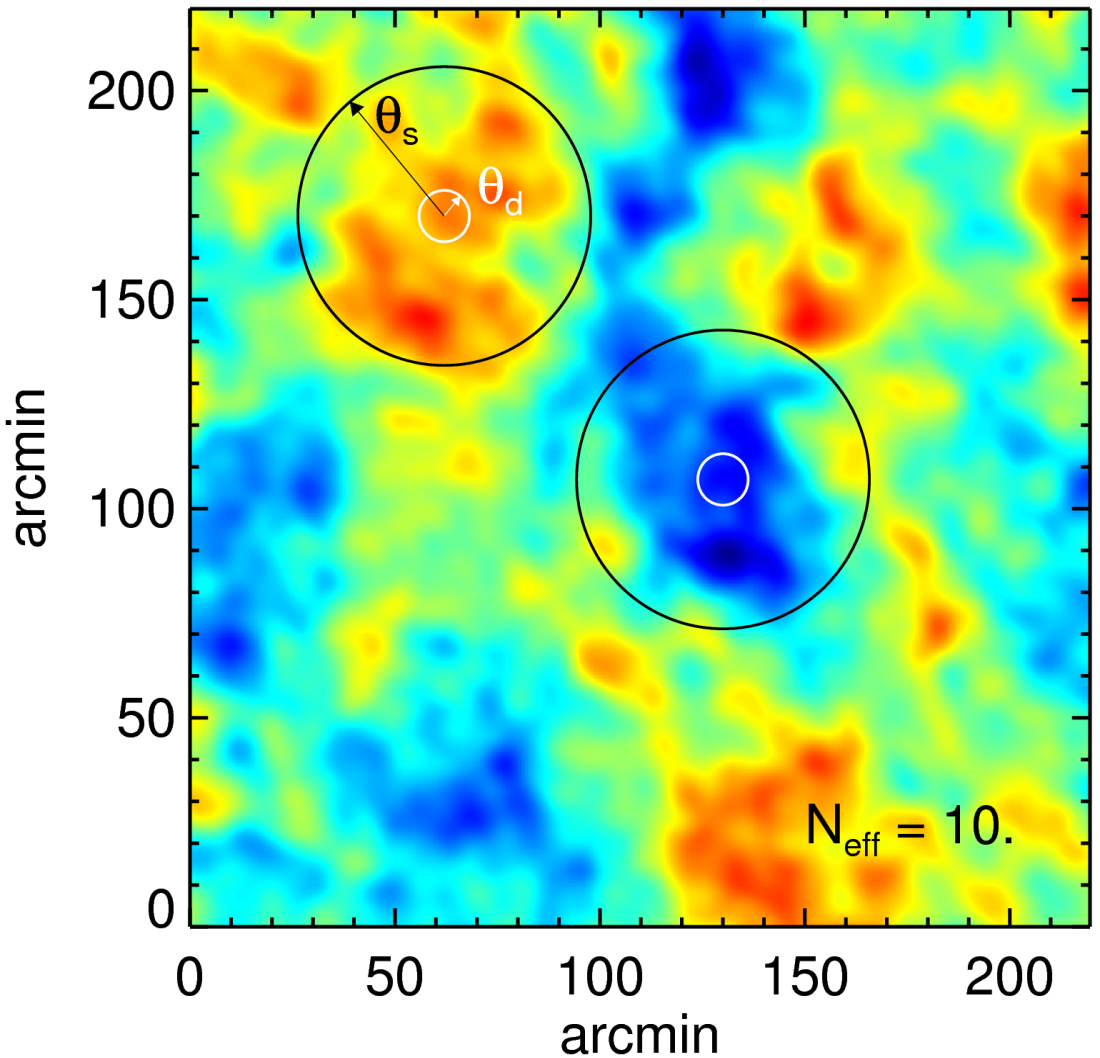
Two angular scales fixing $\Omega_b h^2$, $z_{\rm eq}$, θ_s

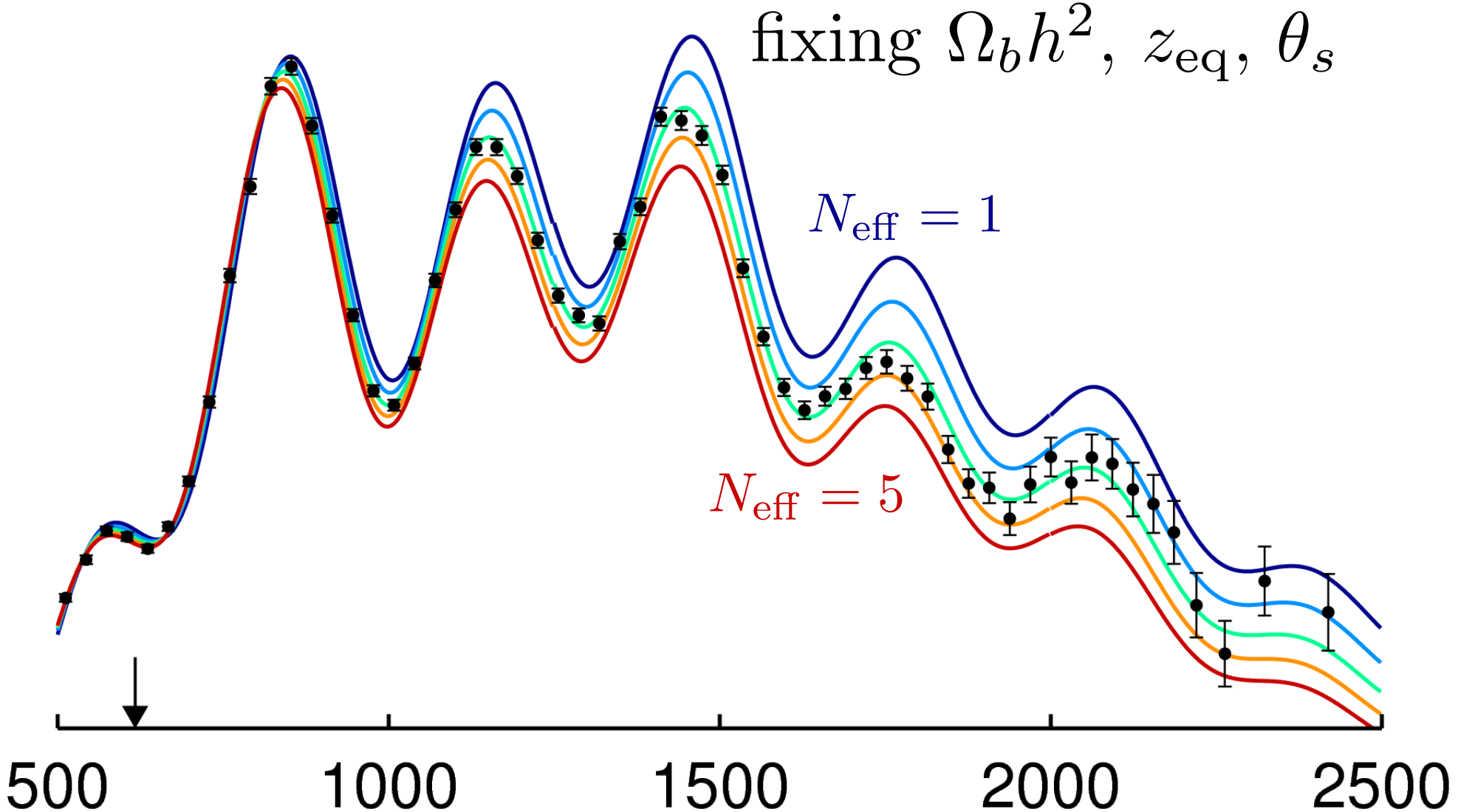


Two angular scales

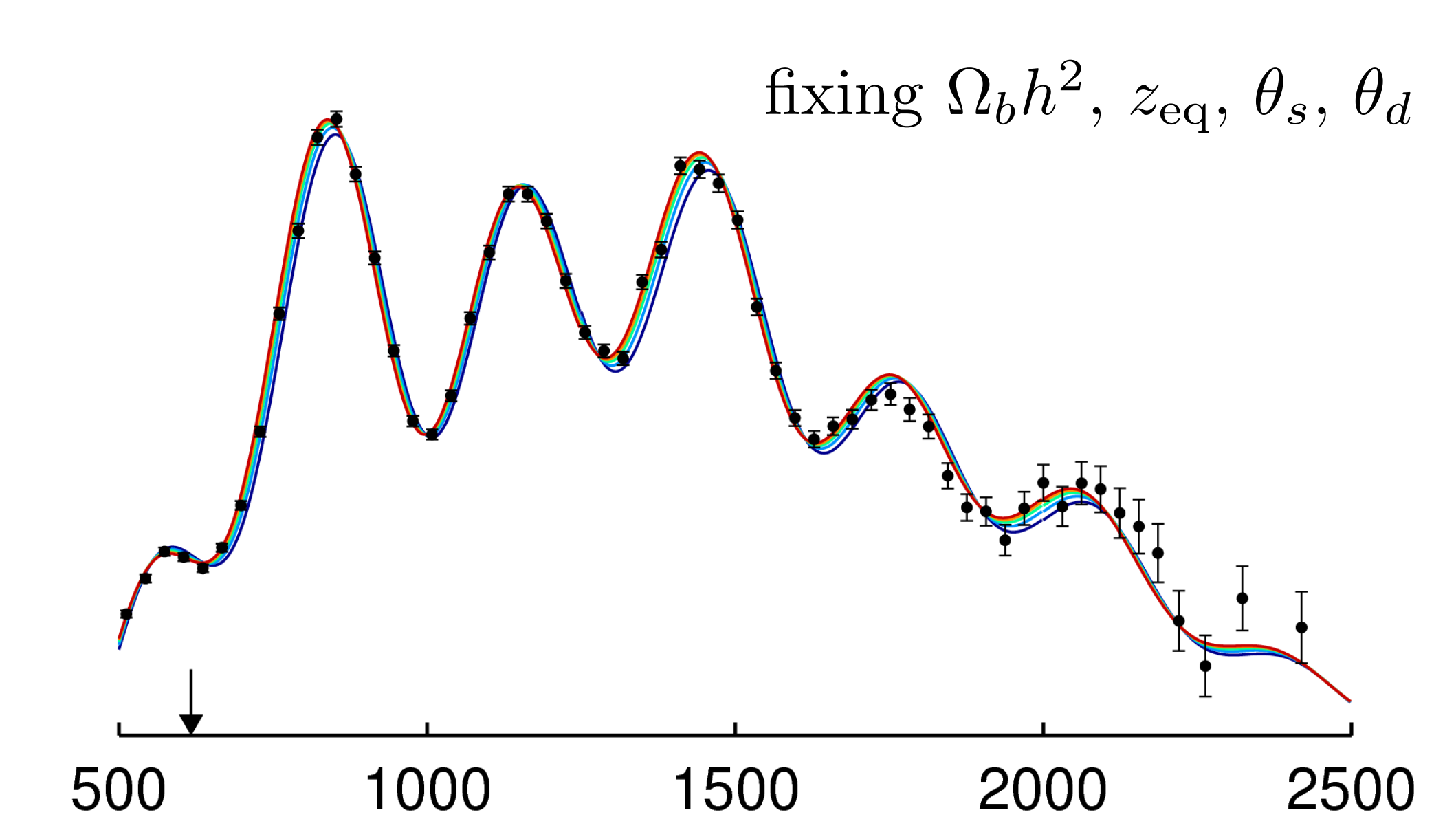


Two angular scales

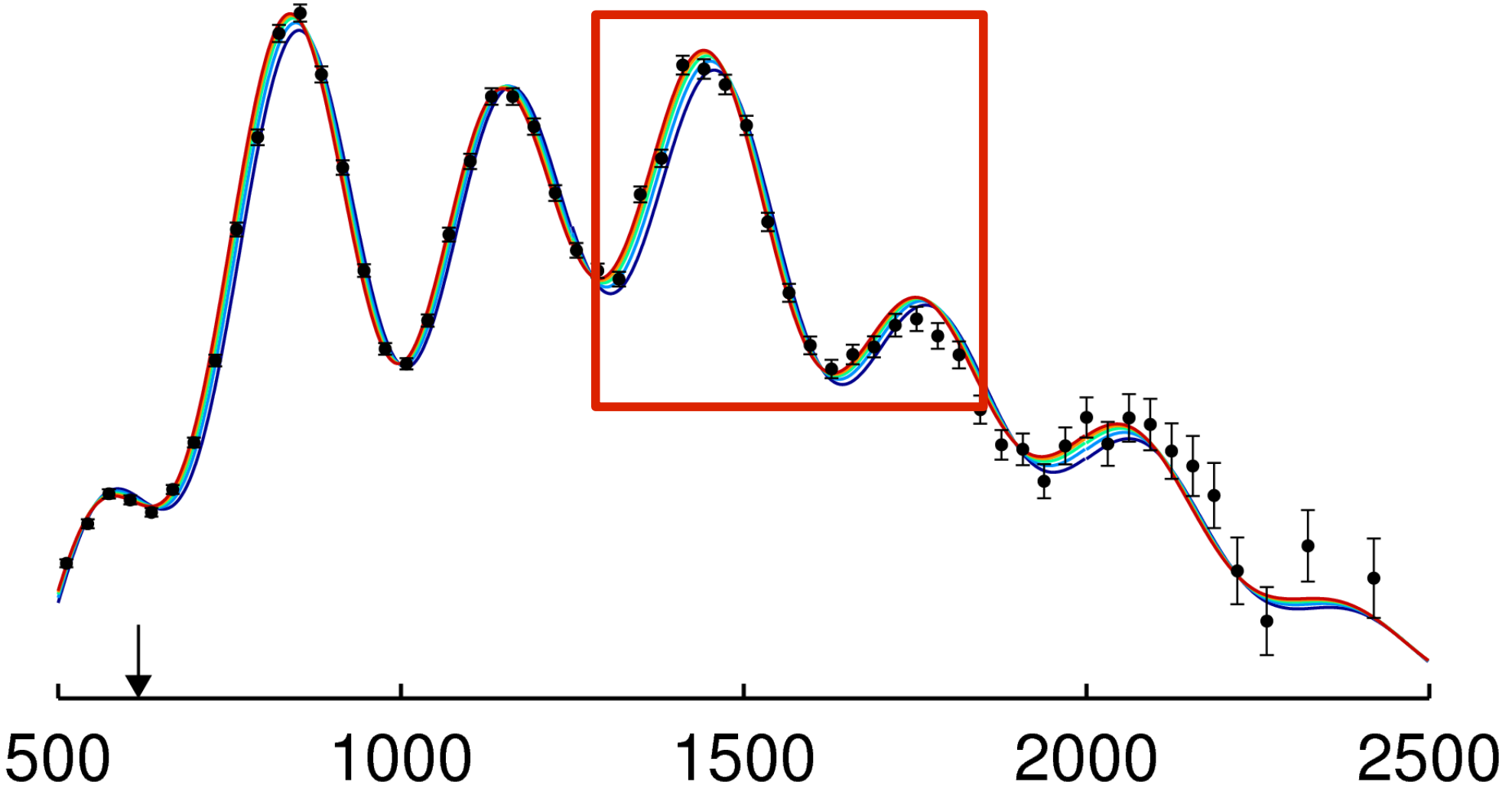




Hou et al., arXiv:1104.2333



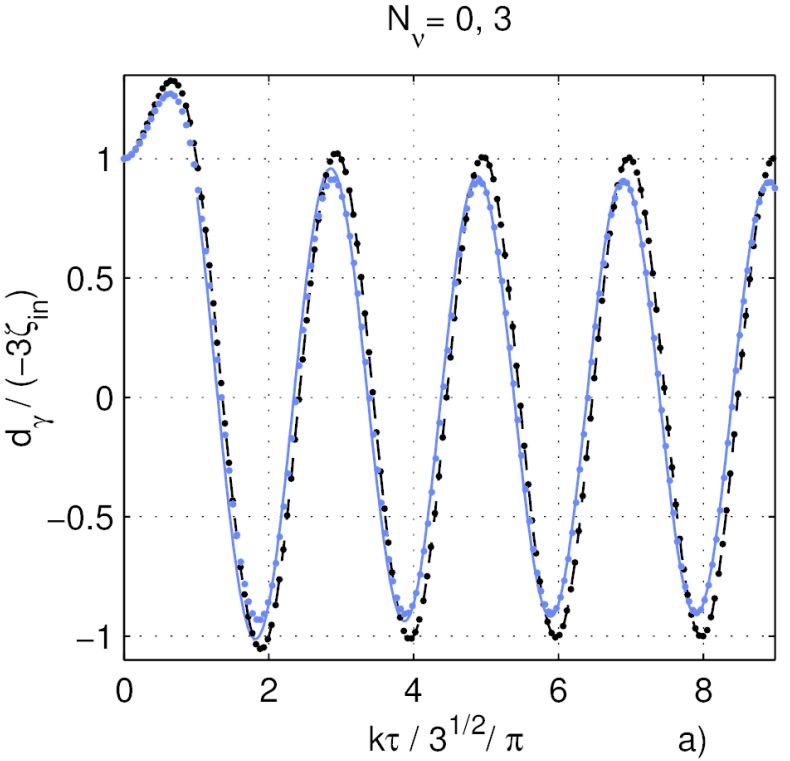
Hou et al., arXiv:1104.2333

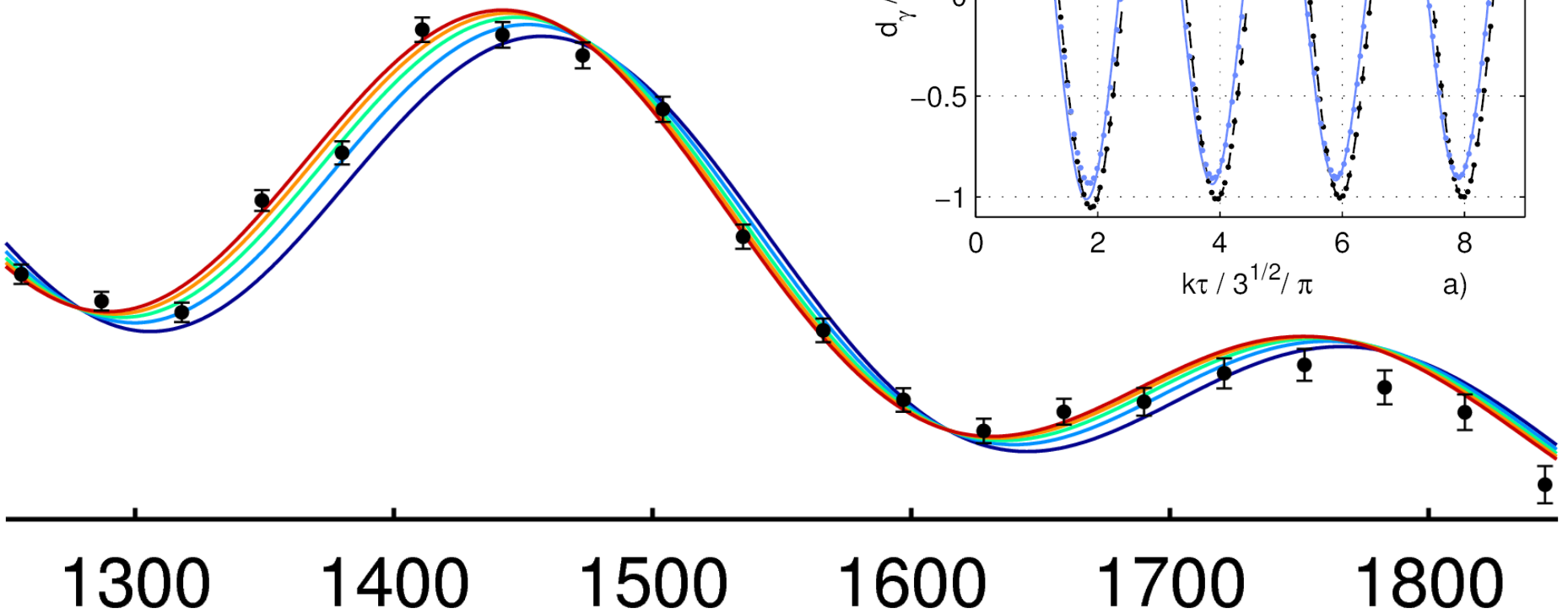


Hou et al., arXiv:1104.2333

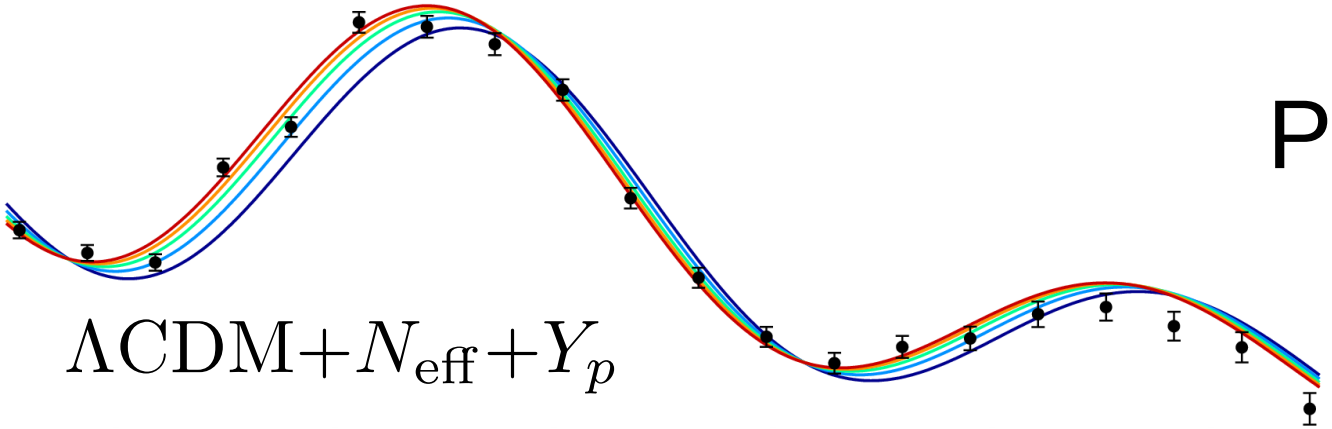
fixing $\Omega_b h^2$, $z_{\rm eq}$, θ_s, θ_d

Bashinsky & Seljak, 2004

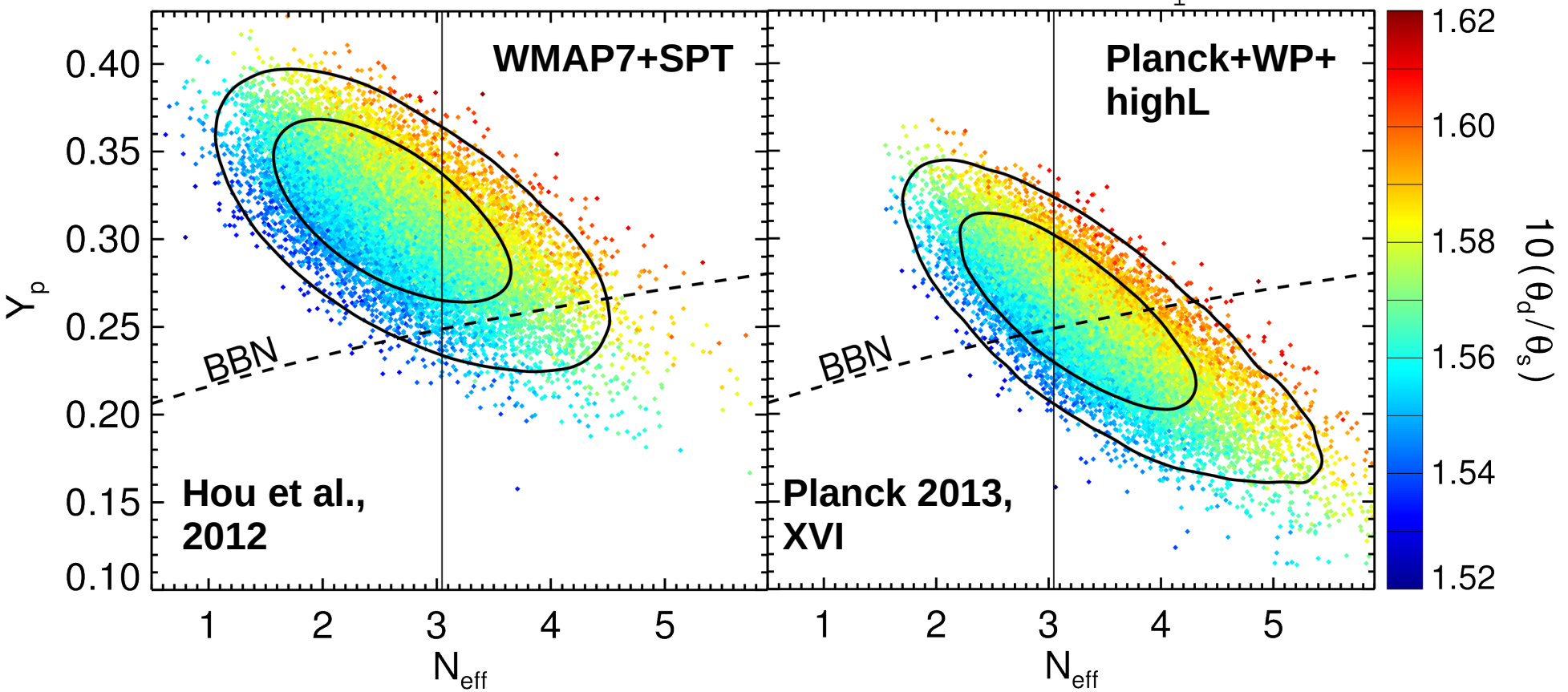




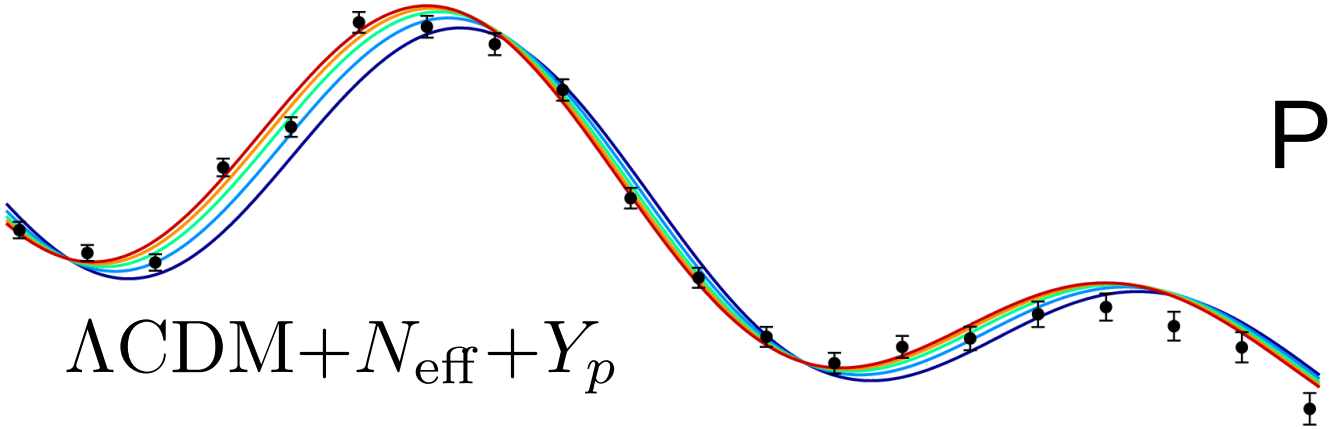
Phase shift



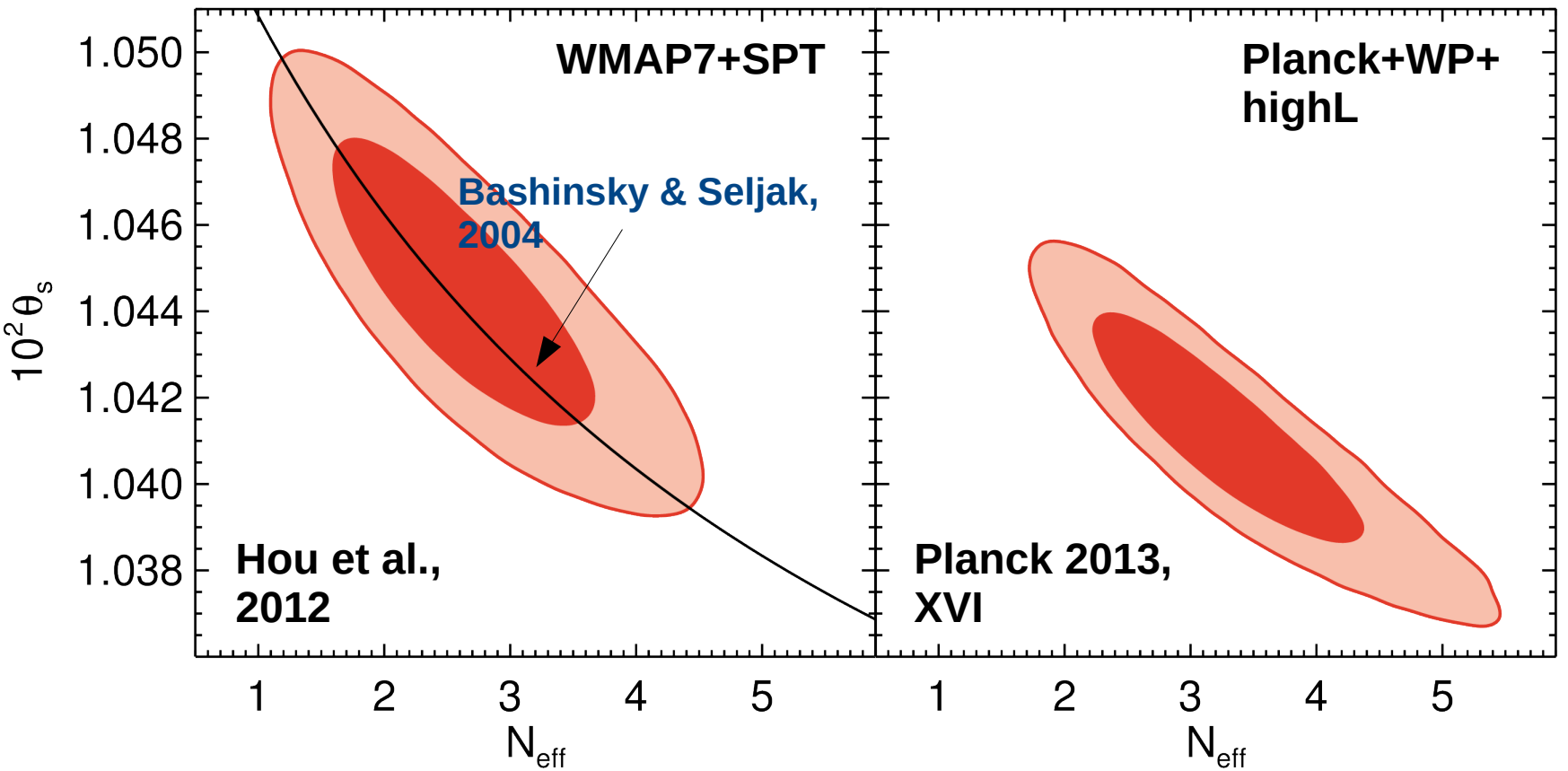
$\Lambda\mathrm{CDM}+N_{\mathrm{eff}}+Y_p$



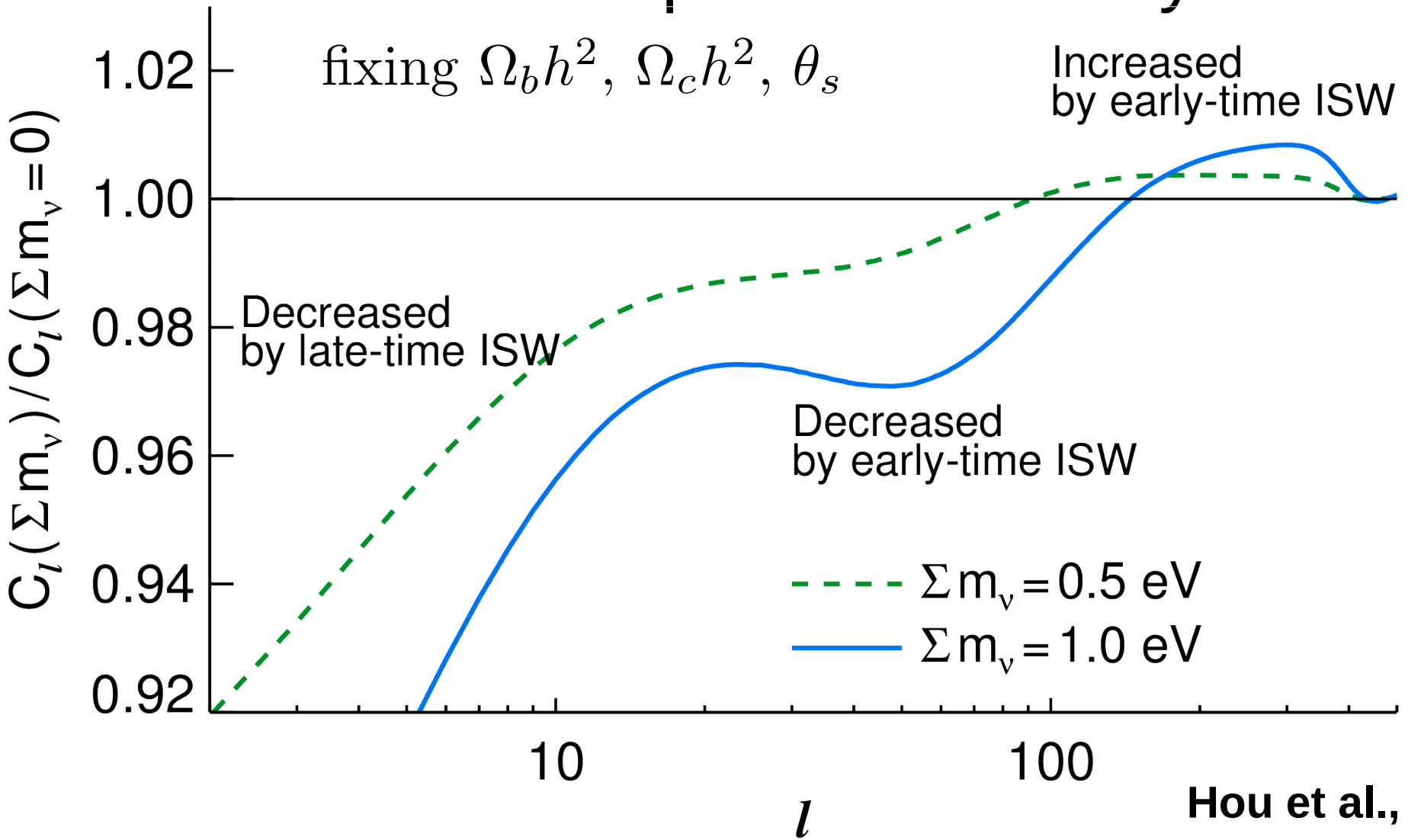
Phase shift



$\Lambda\mathrm{CDM}+N_{\mathrm{eff}}+Y_p$

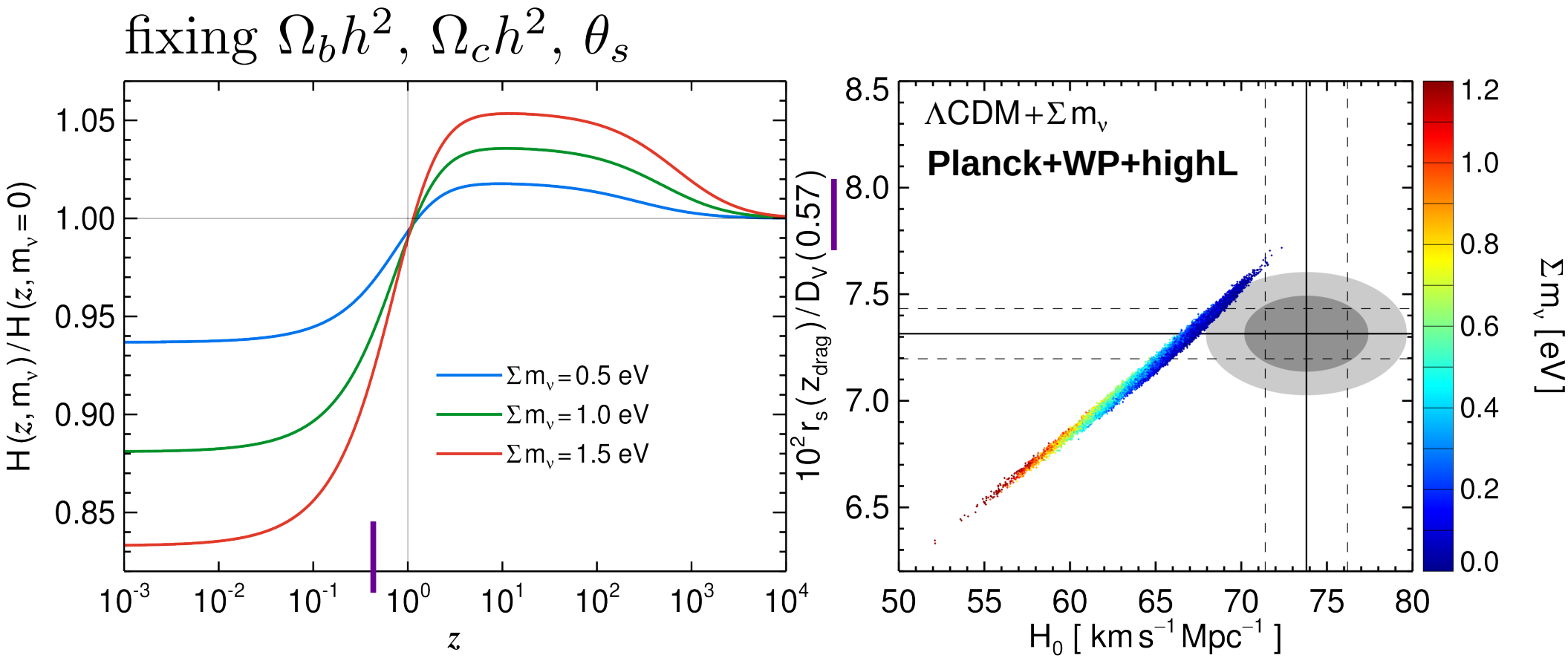


Neutrino mass imprint on CMB by ISW

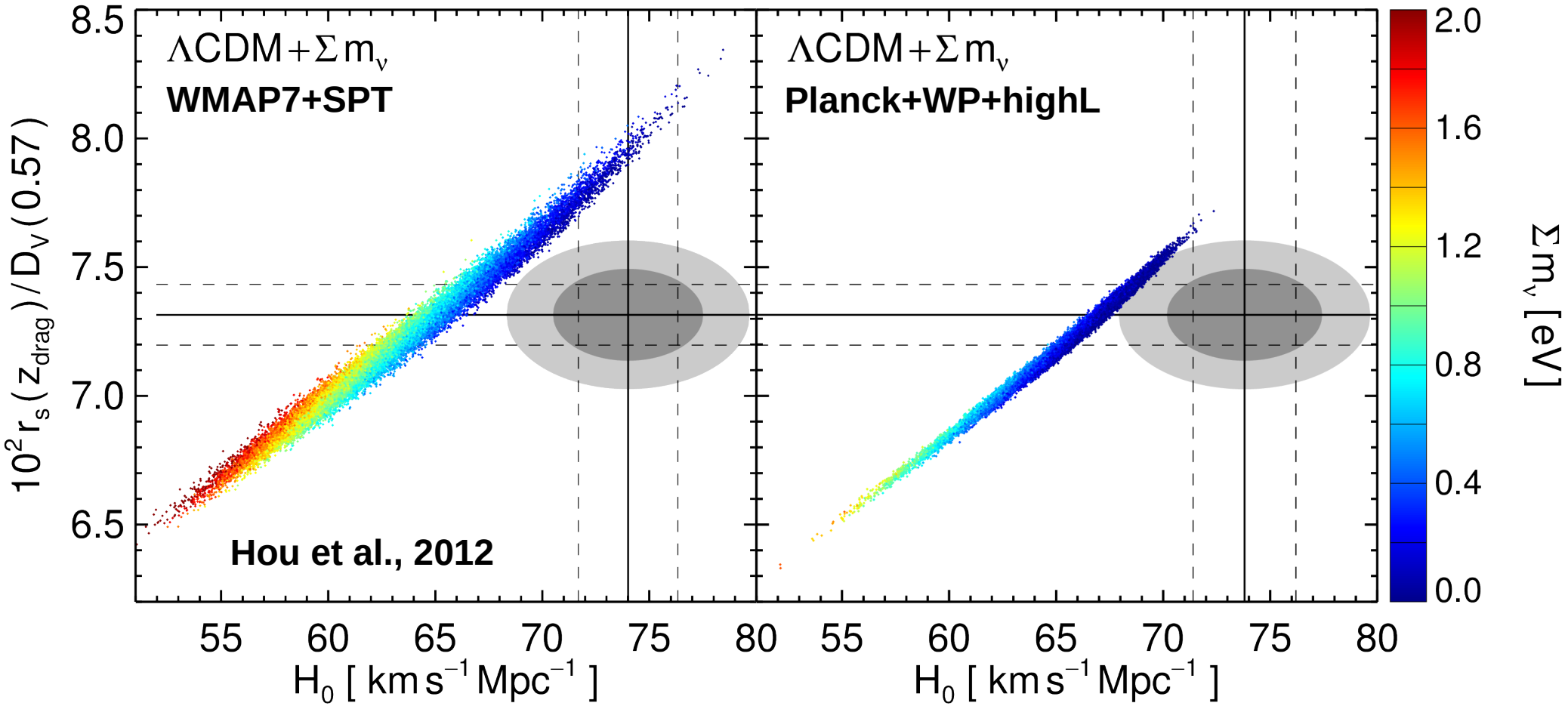


Hou et al., 2012

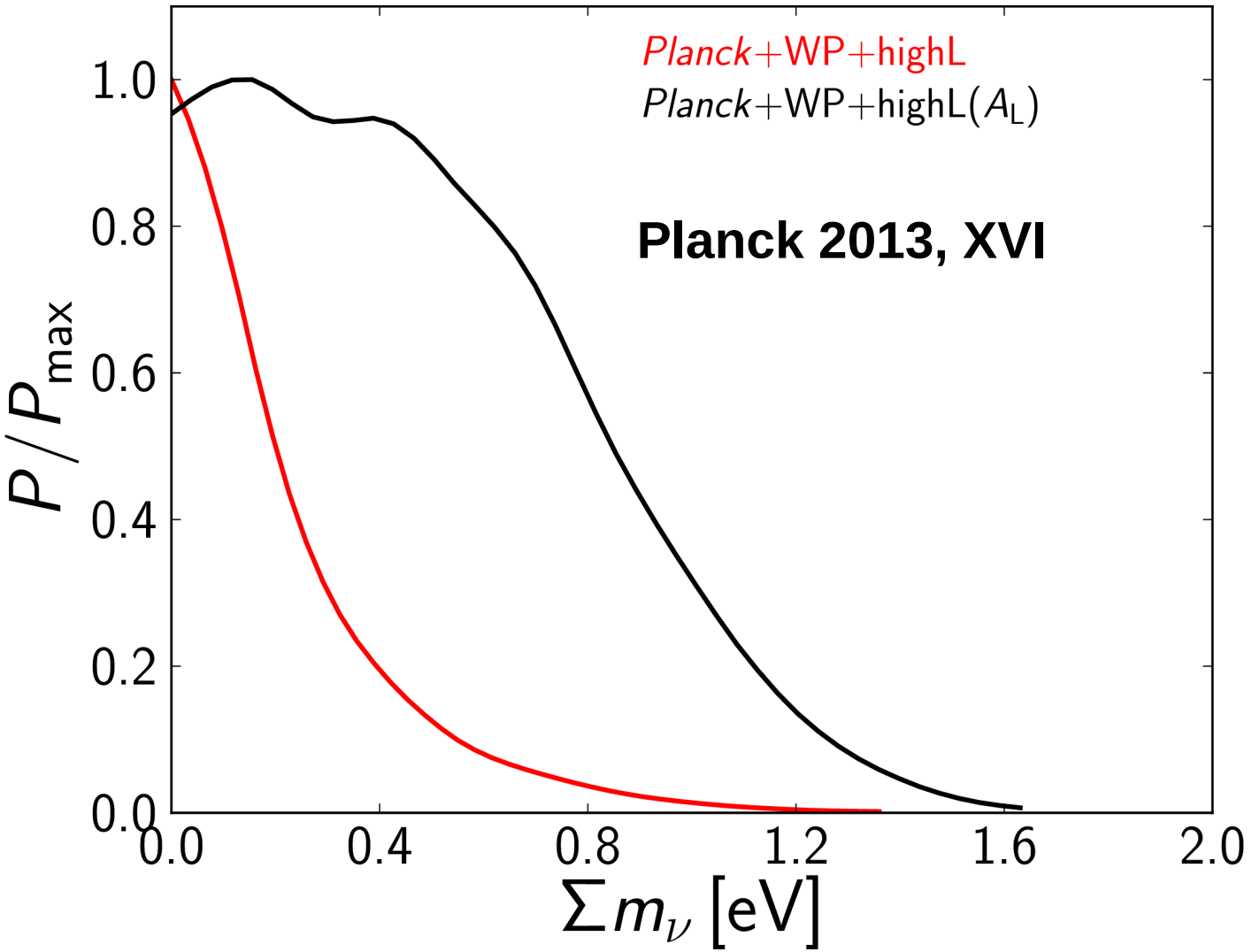
Expansion rate with neutrino mass



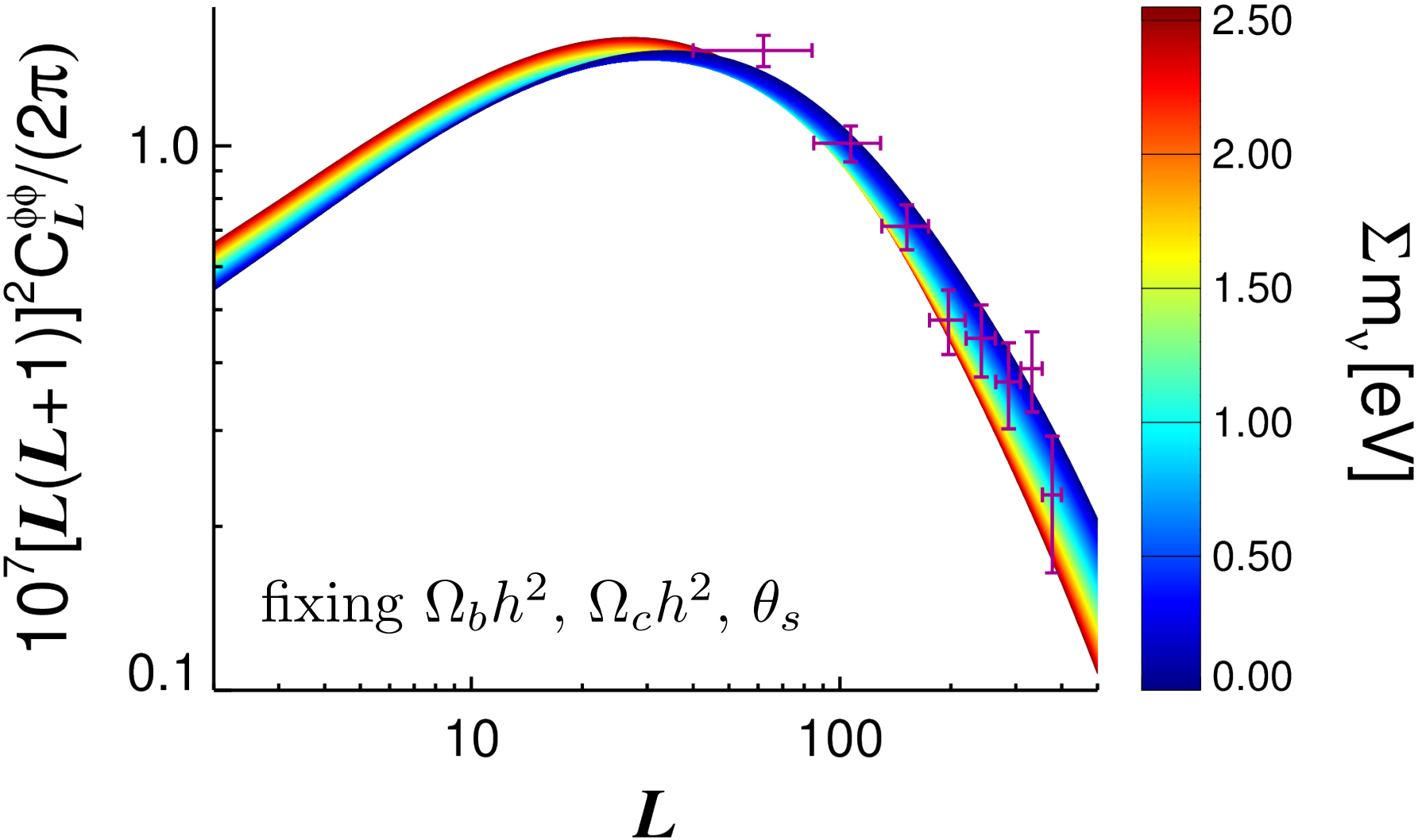
BAO, H0 and neutrino mass



CMB lensing and neutrino mass



CMB lensing and neutrino mass



Summary

- The ratio between θ_d and θ_s dominates the constraint on $N_{\rm eff}$ from CMB temperature power spectrum measurement. The phase shift by neutrino perturbation contributes to further constraint on $N_{\rm eff}$.
- Important contribution from early ISW effect to neutrino masses constraint.
- Given CMB data, the shape variation of the expansion rate by the neutrino mass – additional sensitivity from BAO, H0 measurement
- CMB lensing is also important for neutrino masses.