The CMB Neutrino Connection

Gil Holder

McGill

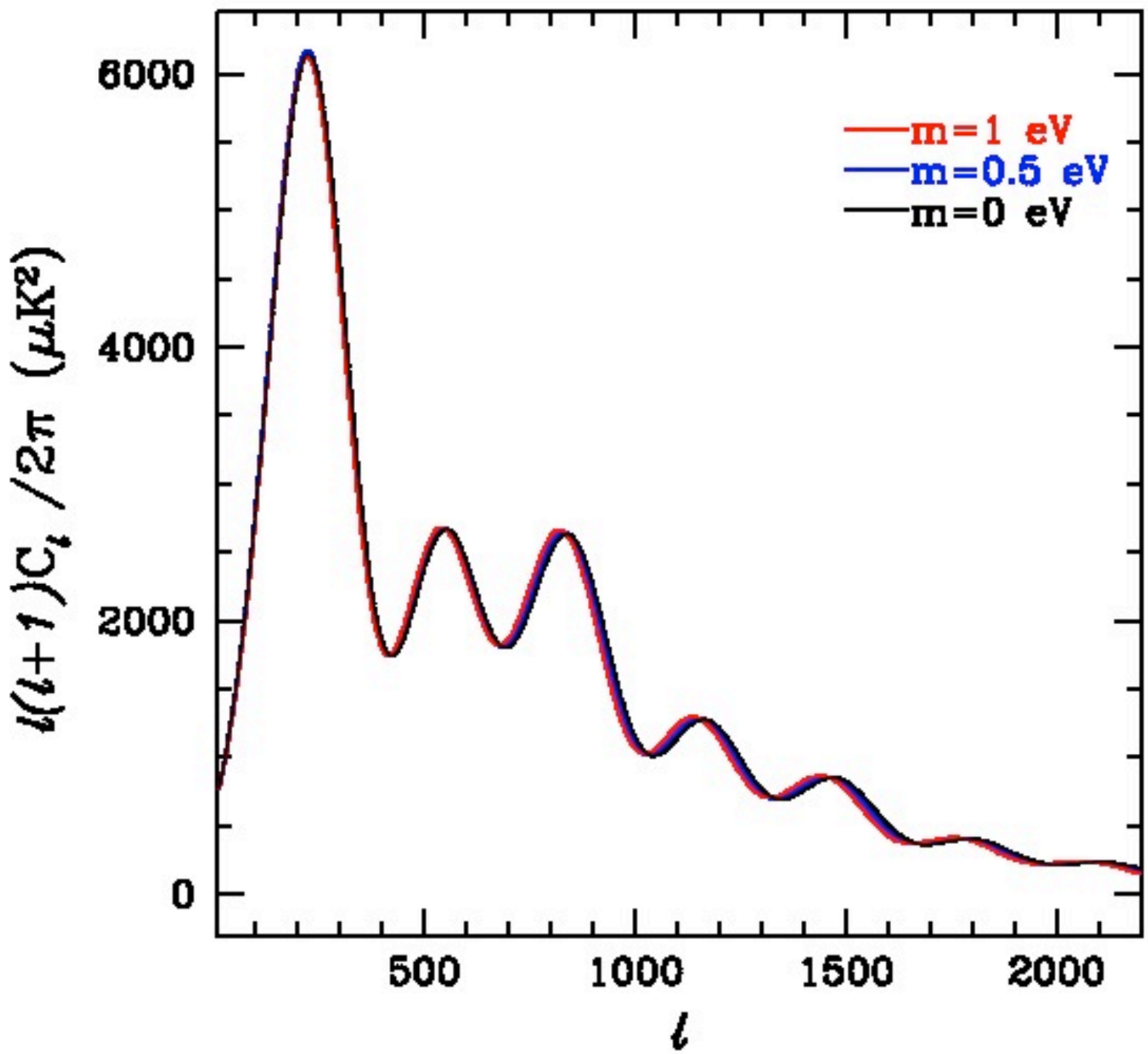
CIFAR
CANADIAN INSTITUTE for ADVANCED RESEARCH

Outline

- Neutrino masses
  - CMB lensing, not CMB acoustic peaks
- N_{eff}
  - be very careful with how you treat Helium and what you assume about BBN

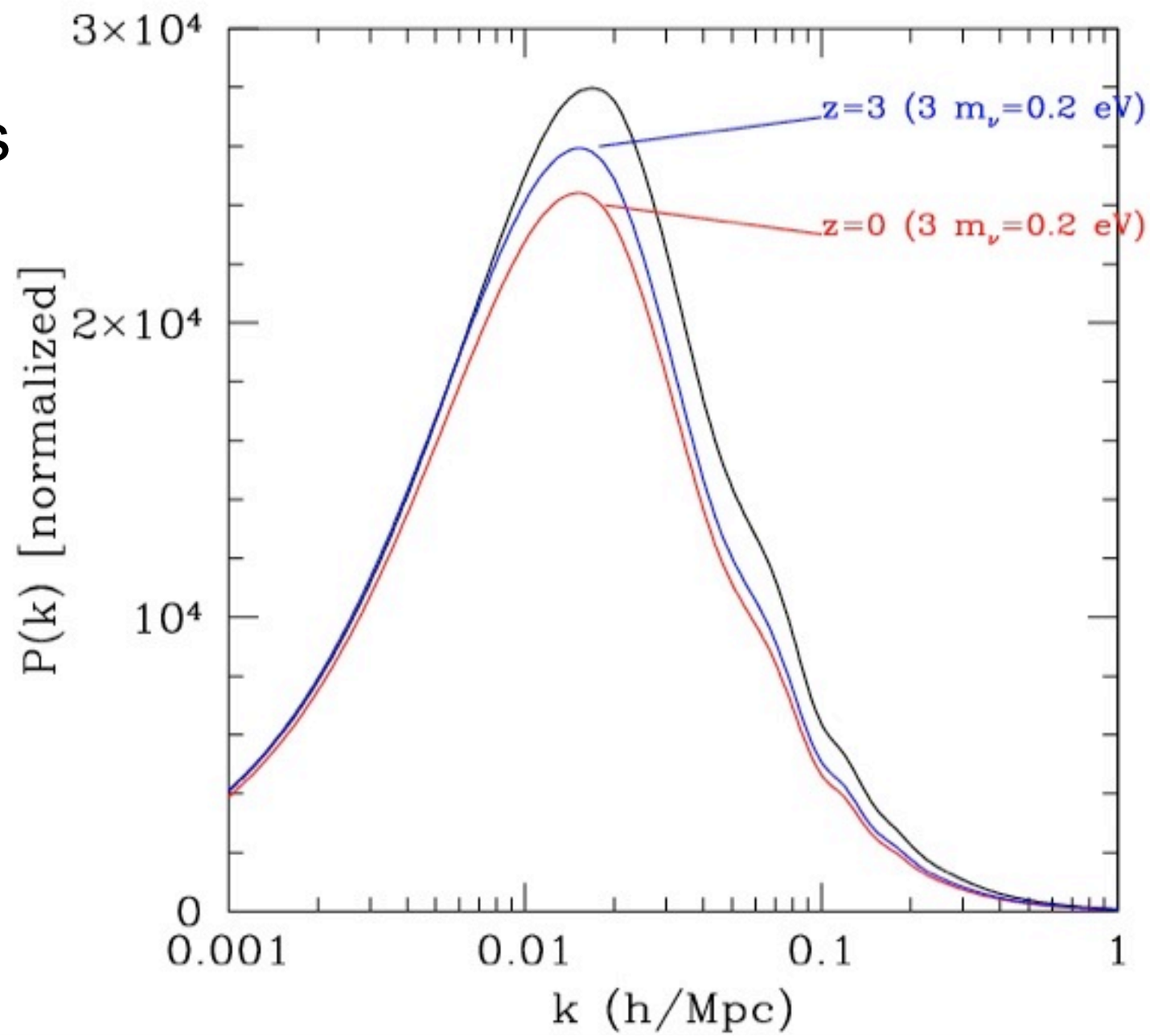
Neutrino Masses from CMB

- primary CMB not very sensitive to neutrino masses below ~1 eV
- WMAP7-only: m_ν<1.1 eV
- WMAP7+H0: m_ν<0.36 eV



Massive Neutrinos in Cosmology

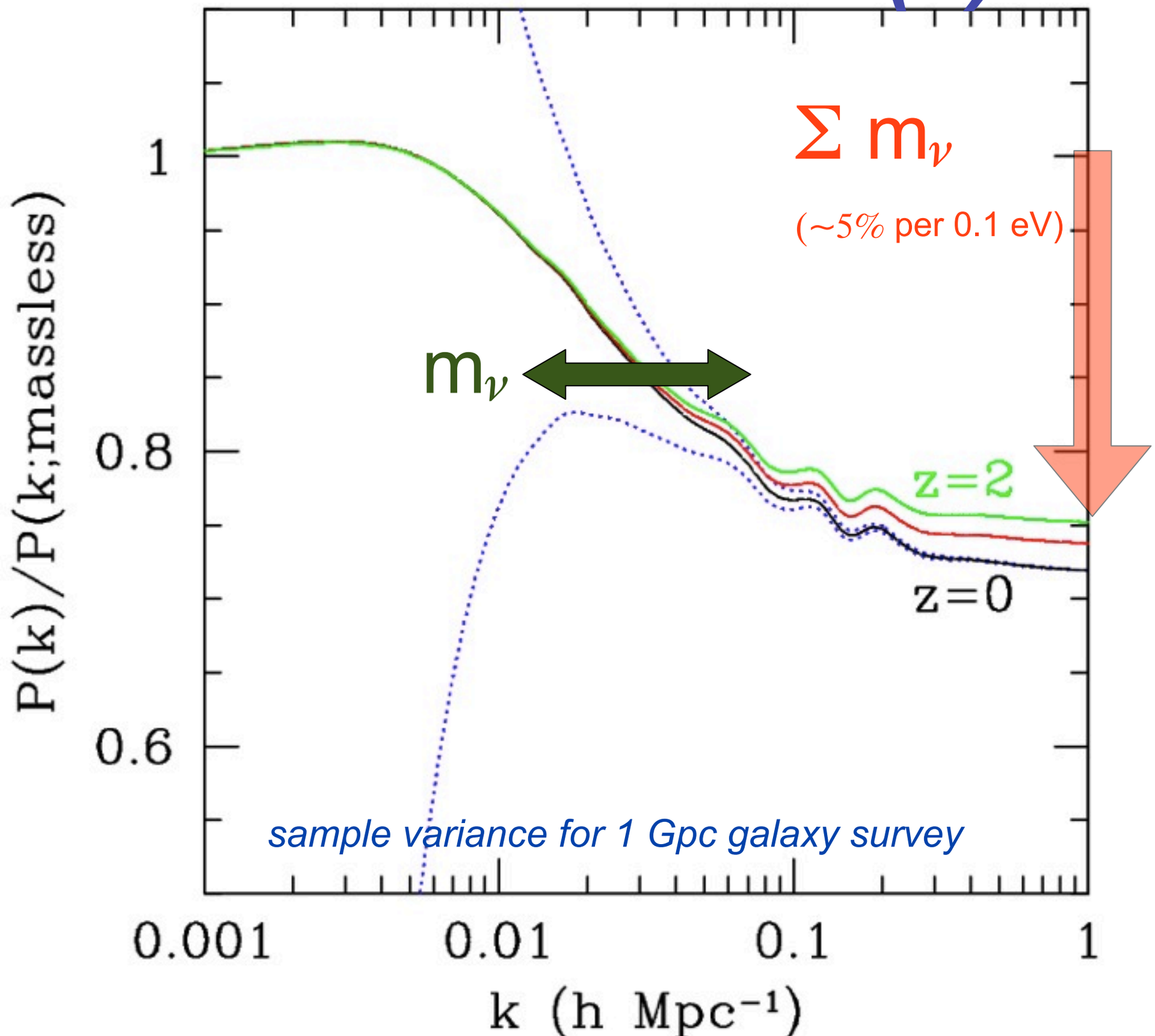
- Free streaming of neutrinos on small scales leads to time-dependent suppression of power
- CMB only sensitive to matter-radiation equality epoch (not affected by m<0.3 eV)
- Free-streaming scale roughly (m/1 eV) 0.1 h/Mpc



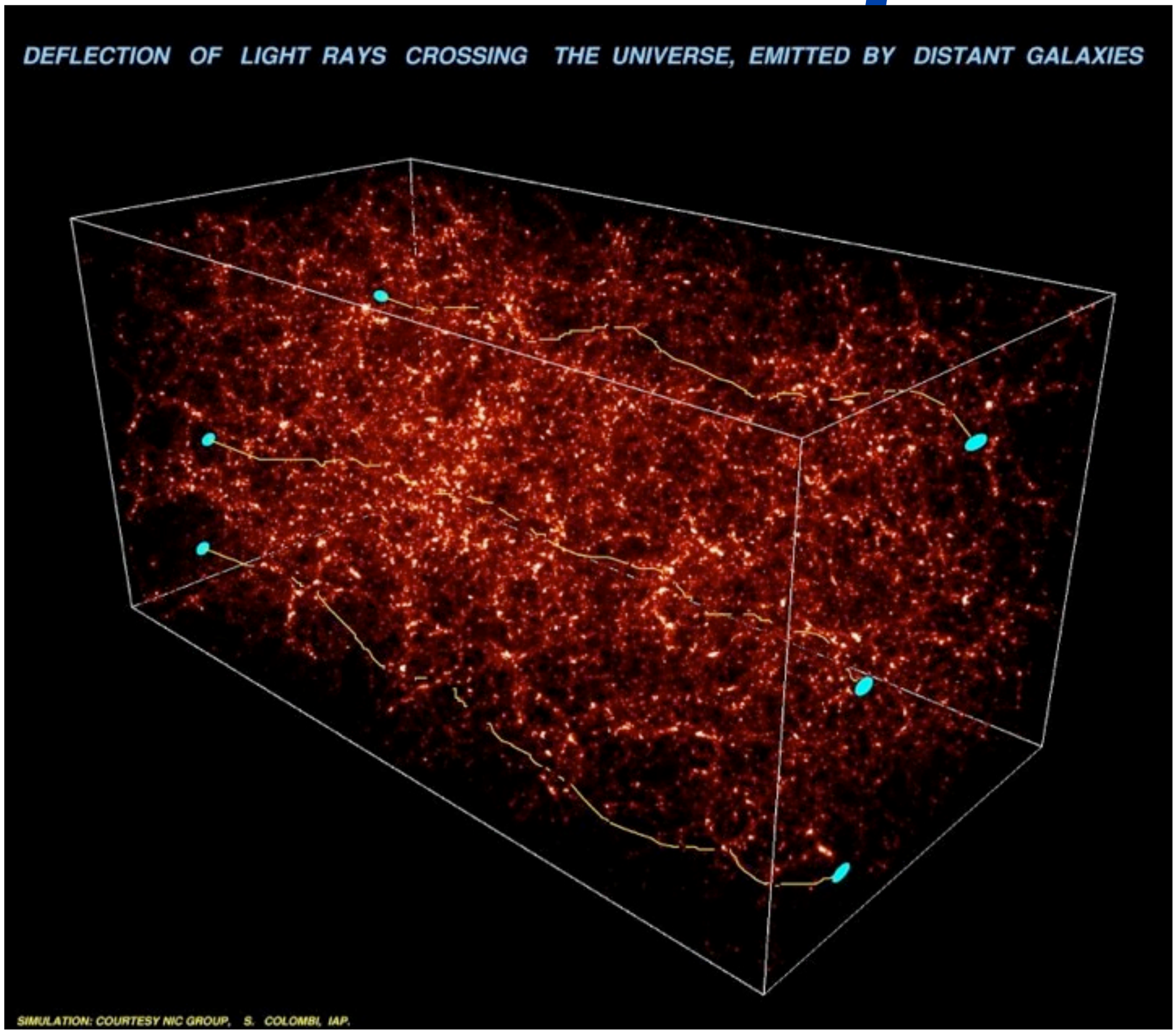
TIME DEPENDENT SCALE DEPENDENCE

Massive Neutrinos and P(k)

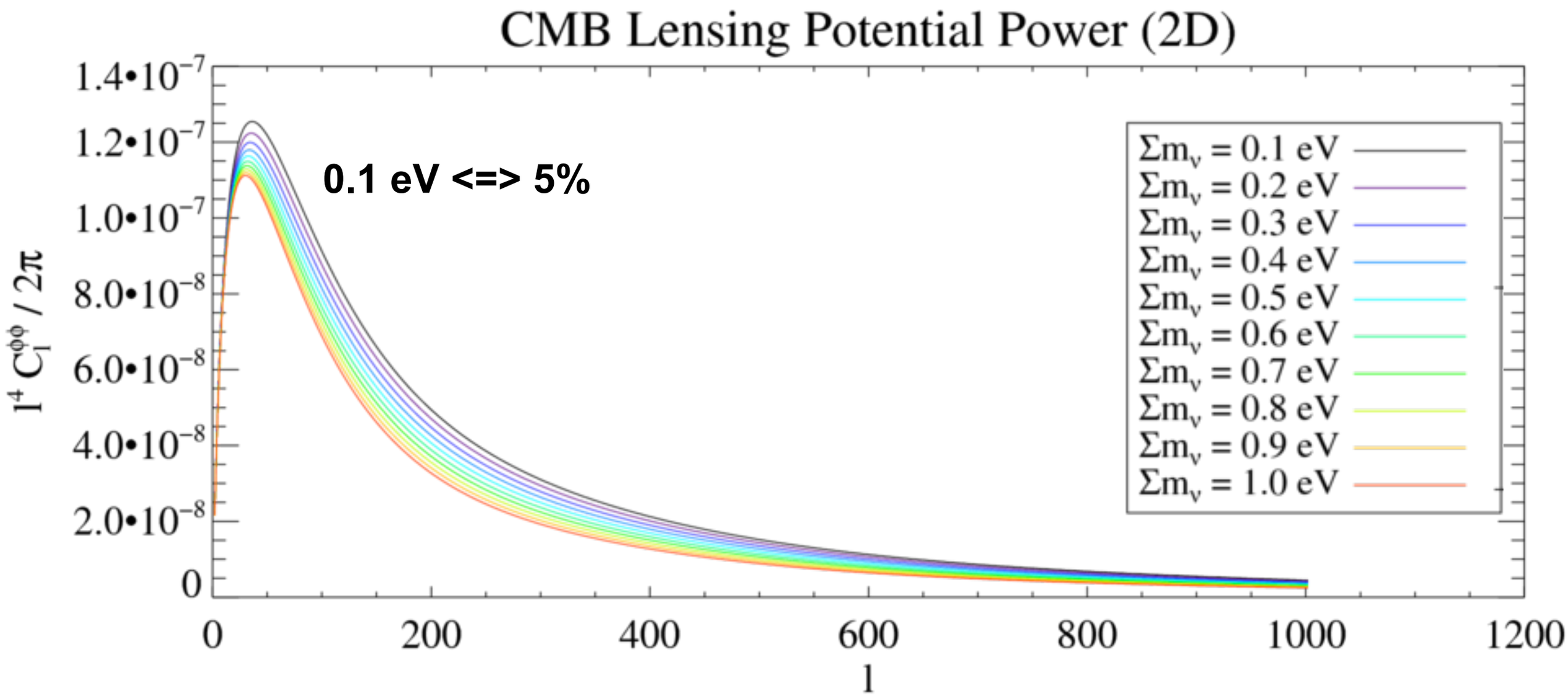
- e.g: 3 neutrinos, each 0.2 eV
- total amount of damping mainly set by sum of masses
- damping scale set by individual masses



Gravitational deflection

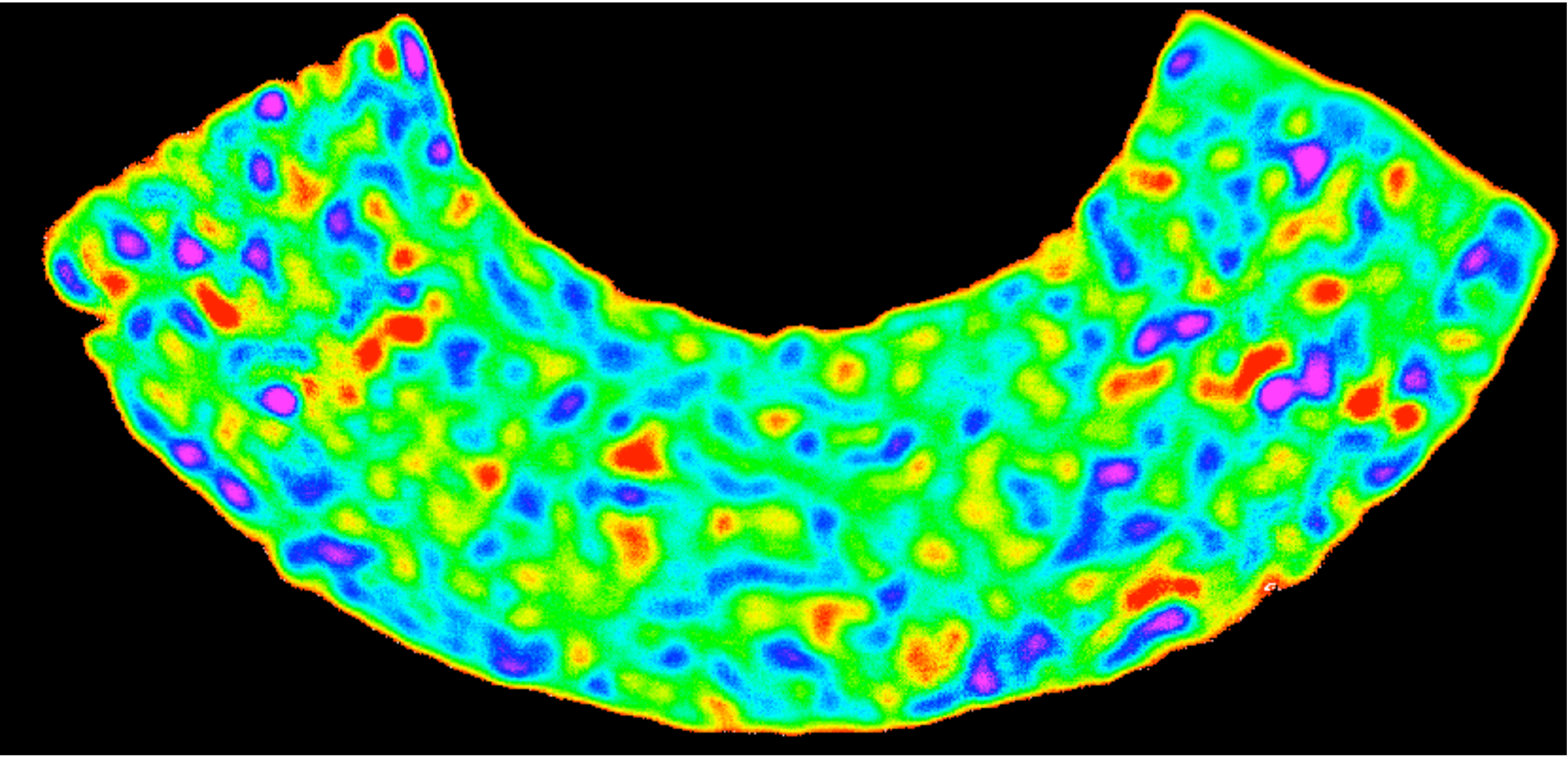


Neutrinos & CMB Lensing



- Peak at l=40 (k_{eq} =[300 Mpc]$^{-1}$ at z = 2): coherent over degree scales
- RMS deflection angle is only ~2.7'

SPT Lensing Mass Map

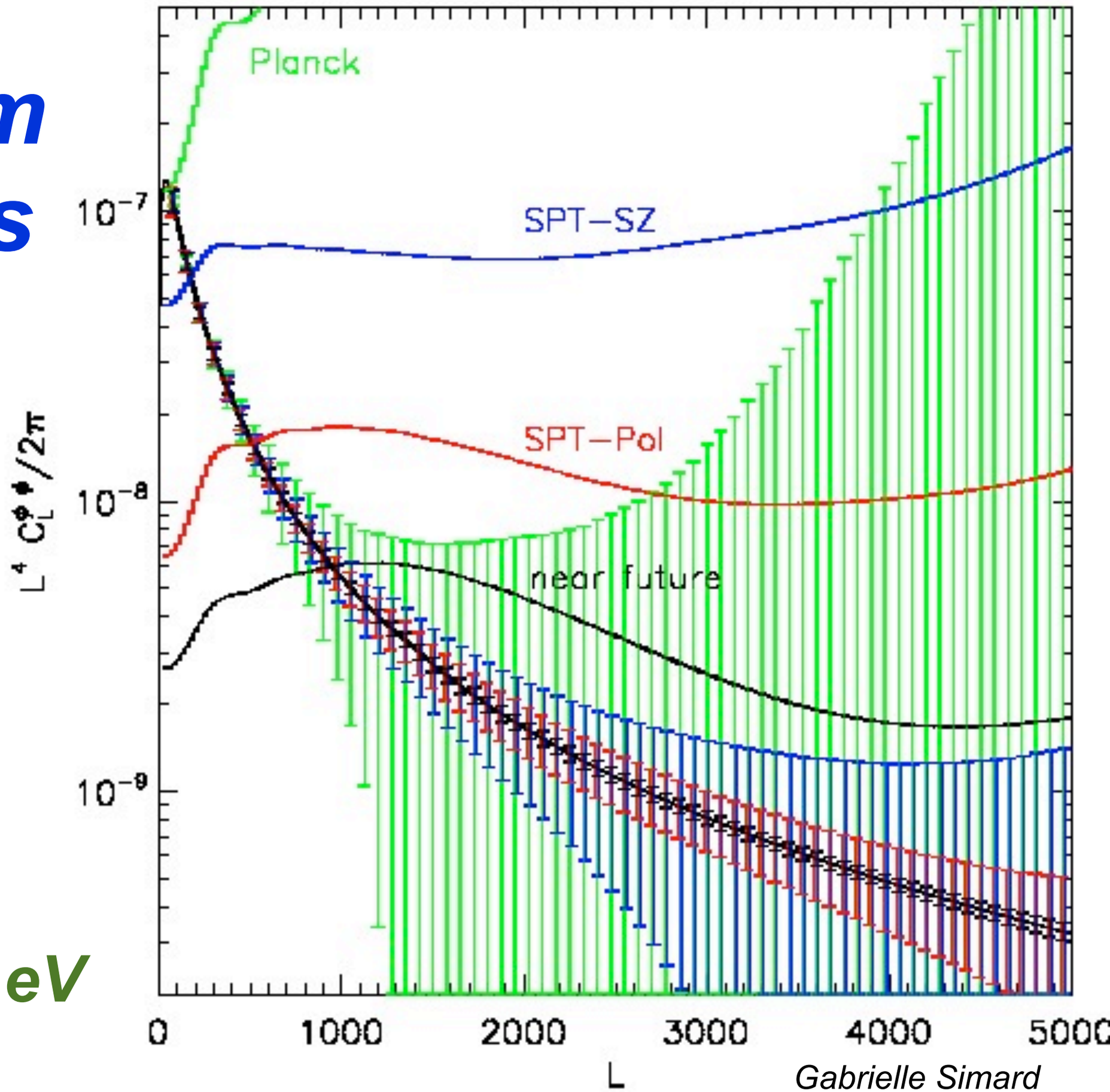


20h to 7h; -40d to -65d

features have S/N>1 but not by much

color stretch +-0.05

Near-term forecasts



<u>solid lines:</u>

noise level

<u>error bars:</u>

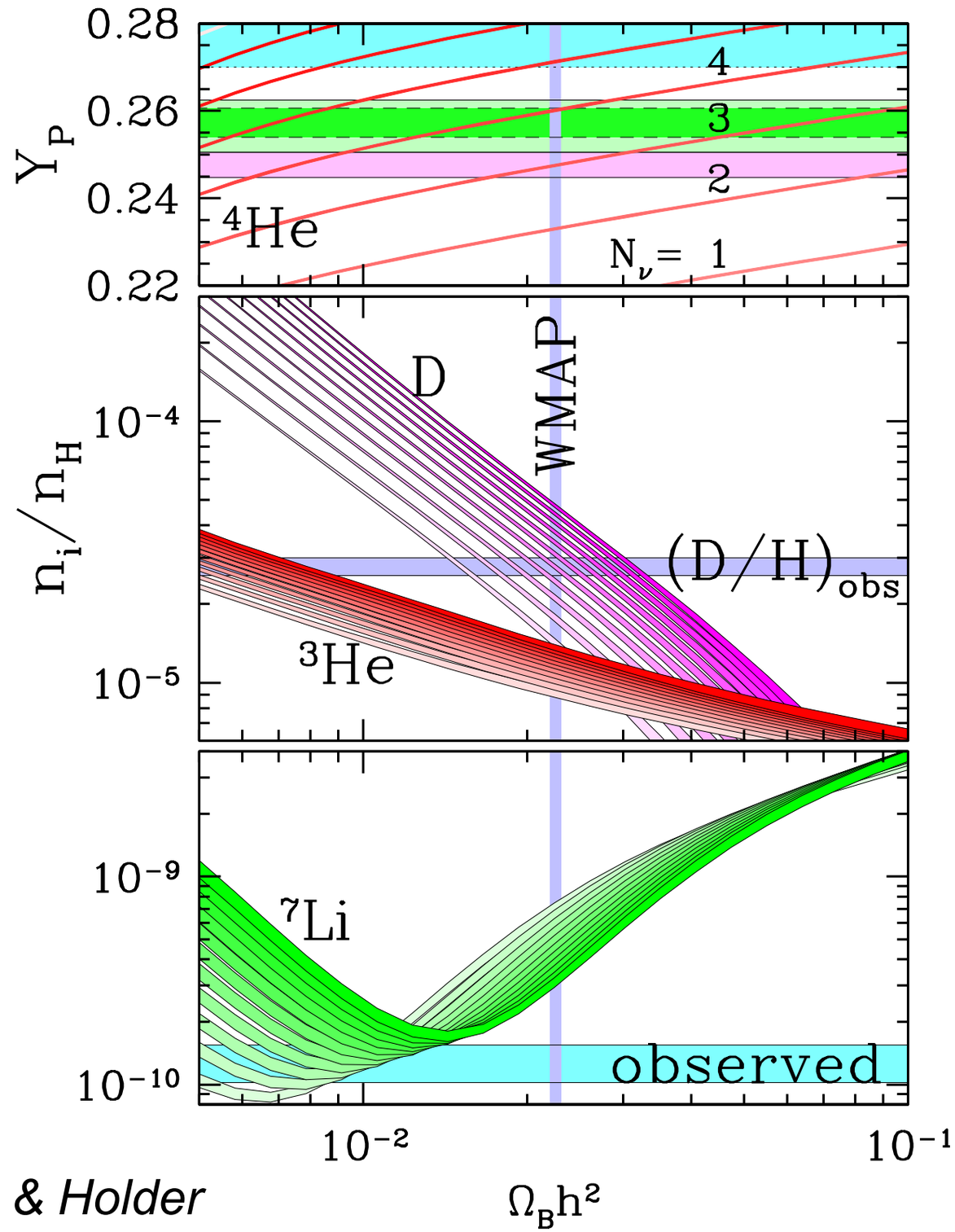
error on power spectrum

Planck: ±0.1 eV

Gabrielle Simard

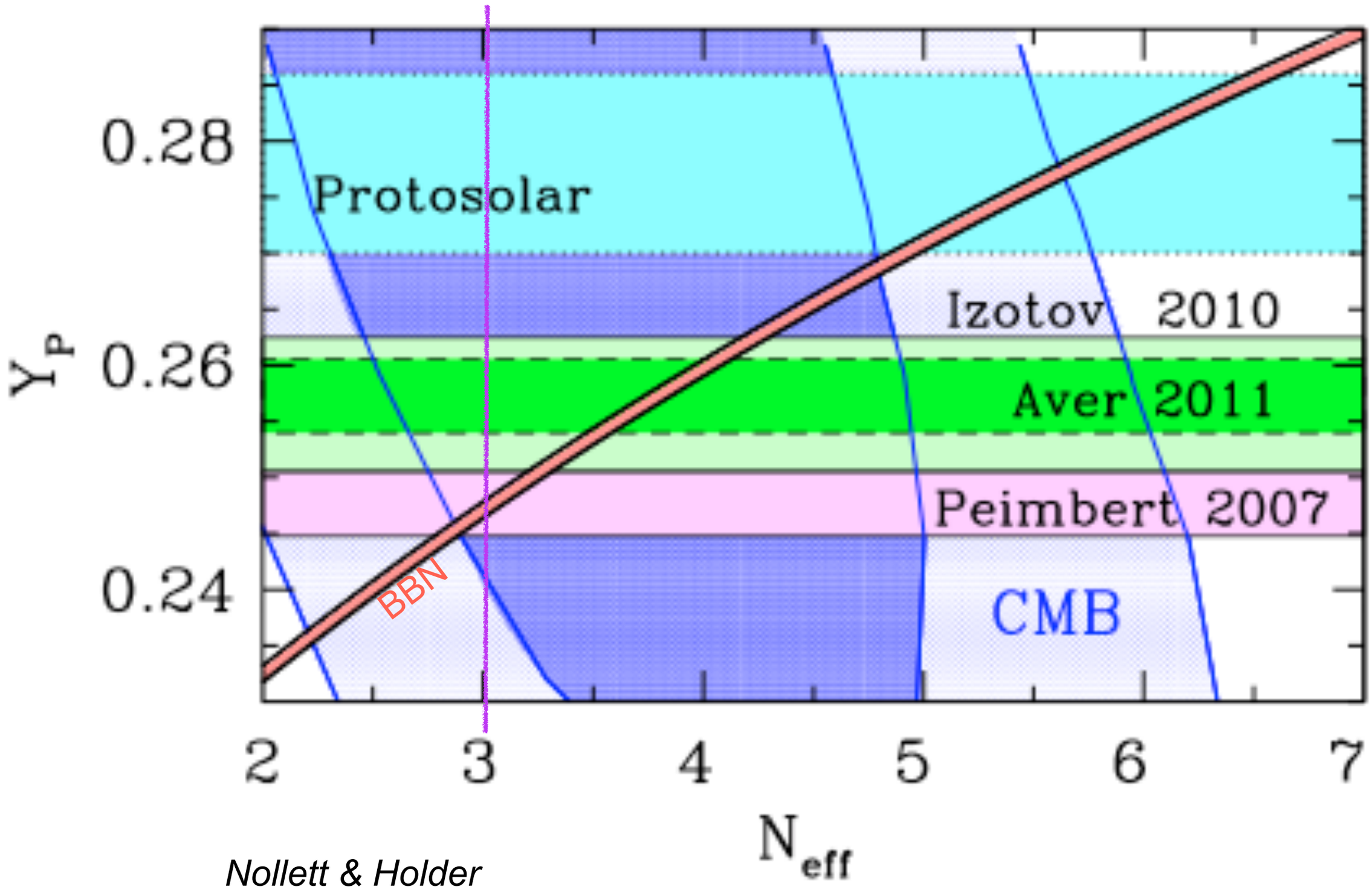
CMB Informs BBN Constraints

- acoustic peaks tell you baryon density



Nollett & Holder

Helium and # of Neutrinos

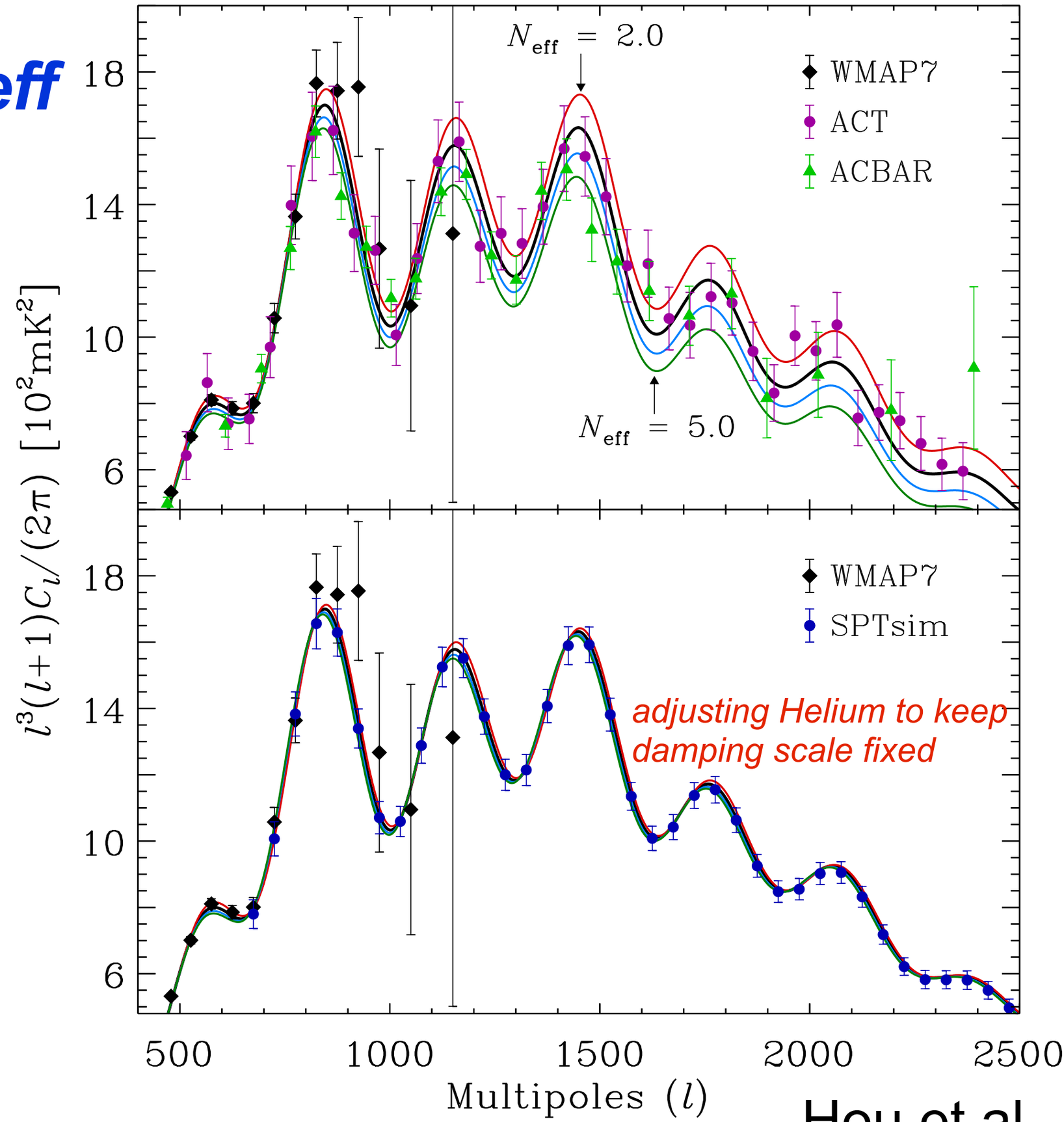


Nollett & Holder

(BBN predictions include theory error and marginalized over baryon density)

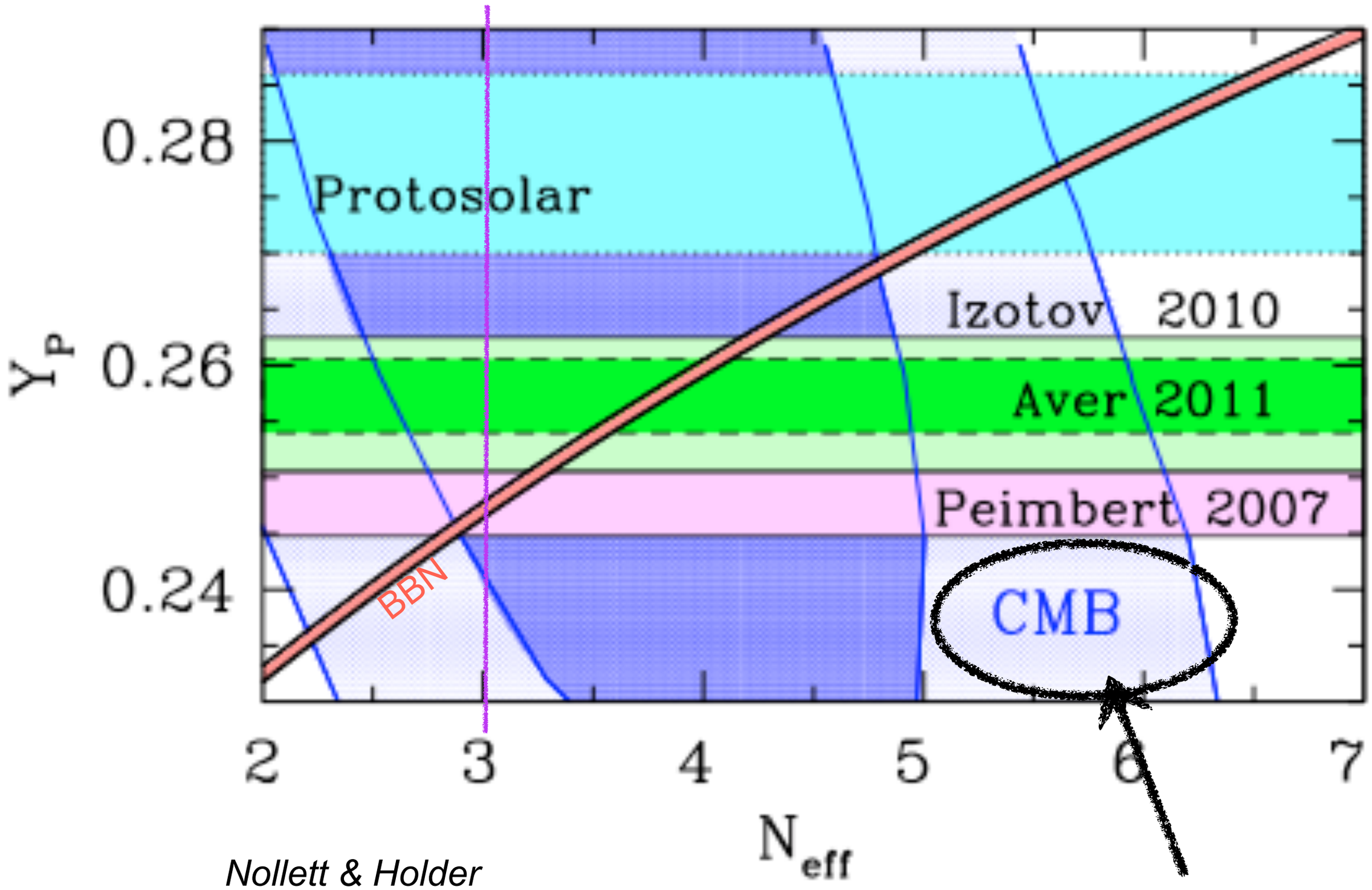
Helium & N_{eff}

- extra light species change expansion rate at early times
- changes age of universe at recombination
- changes damping scale



Hou et al

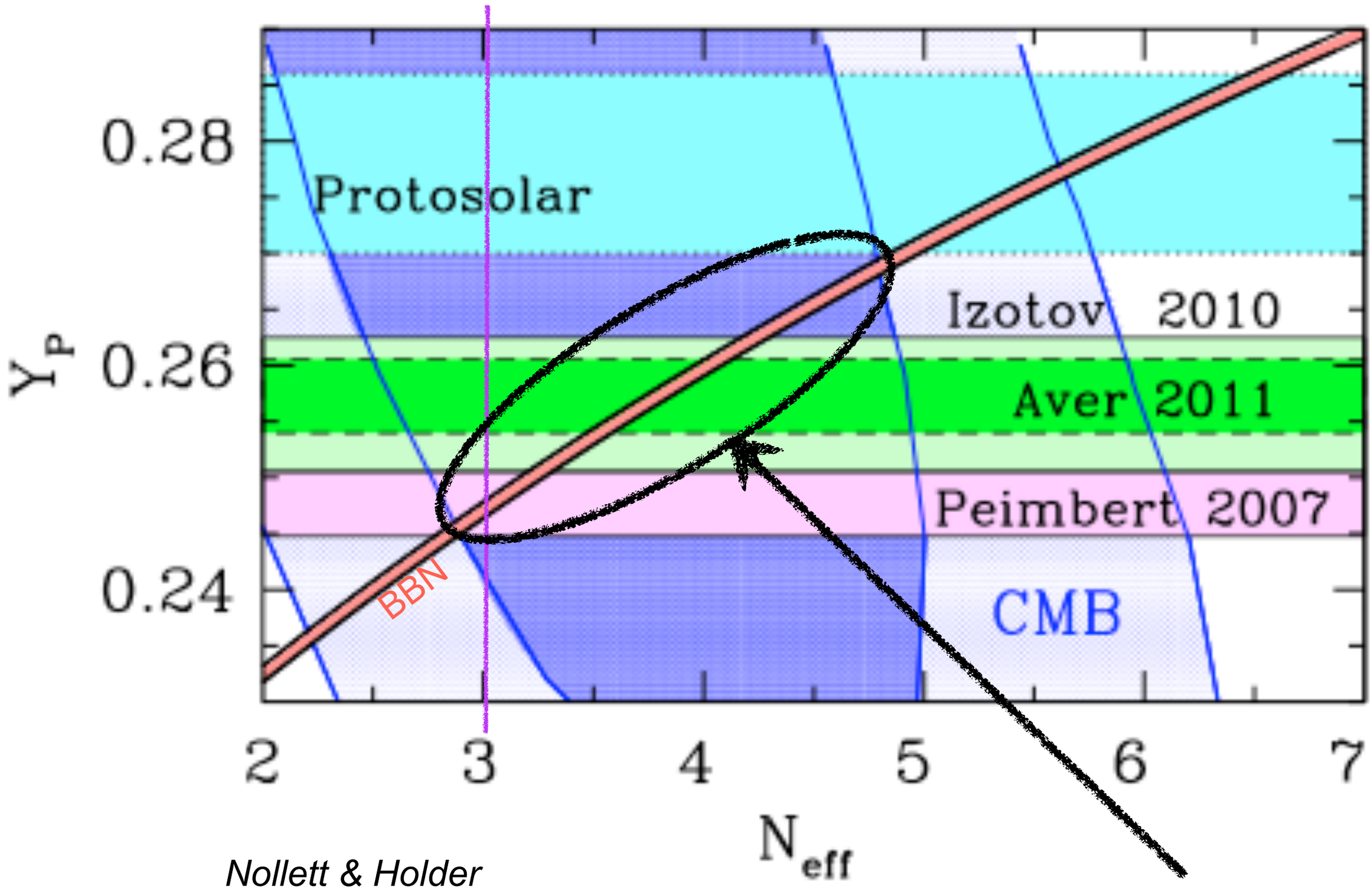
Helium and # of Neutrinos



Nollett & Holder

N_{eff}=3.4 ± 1.0

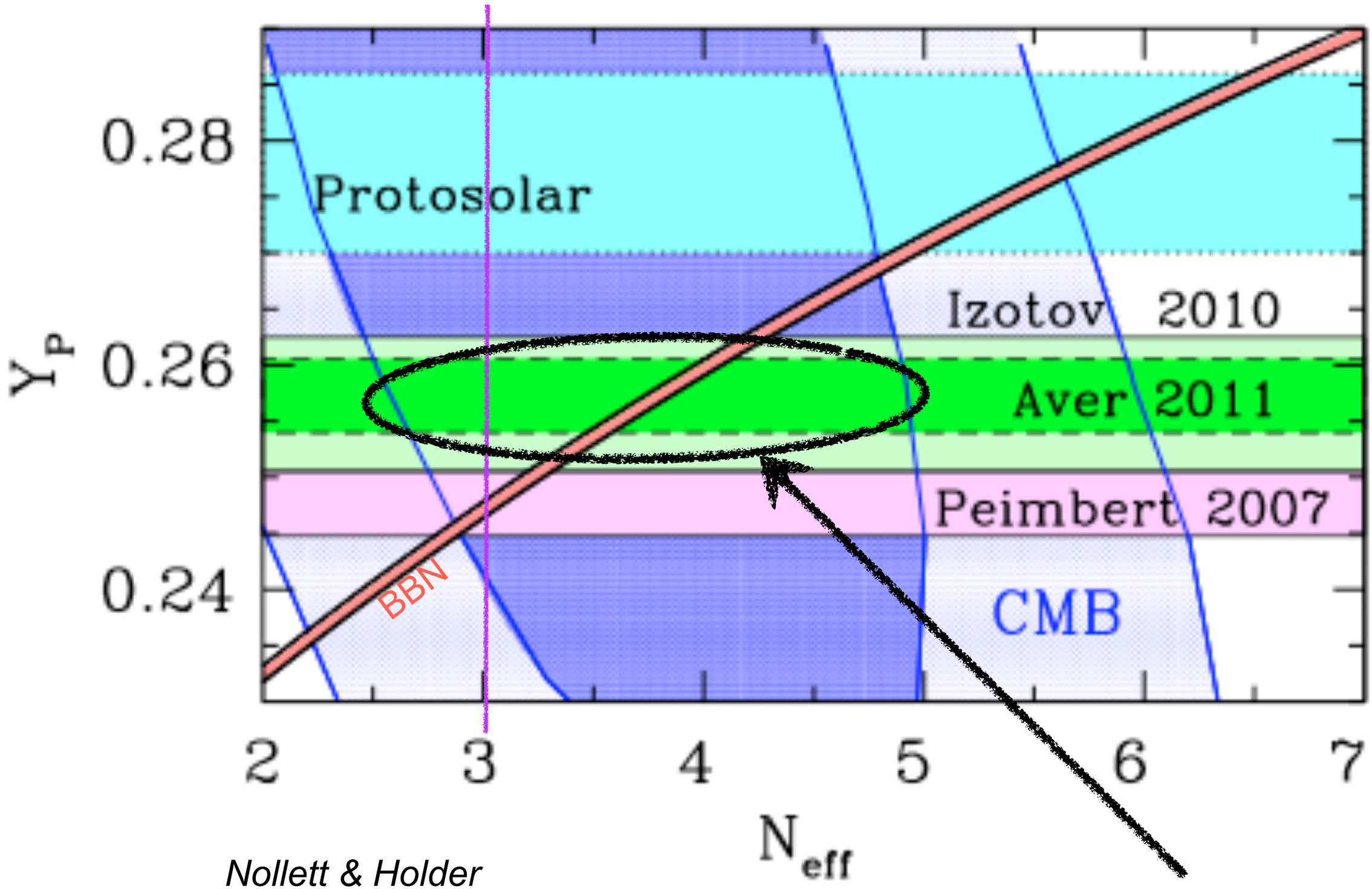
Helium and # of Neutrinos



Nollett & Holder

N_{eff}=3.9 ± 0.6

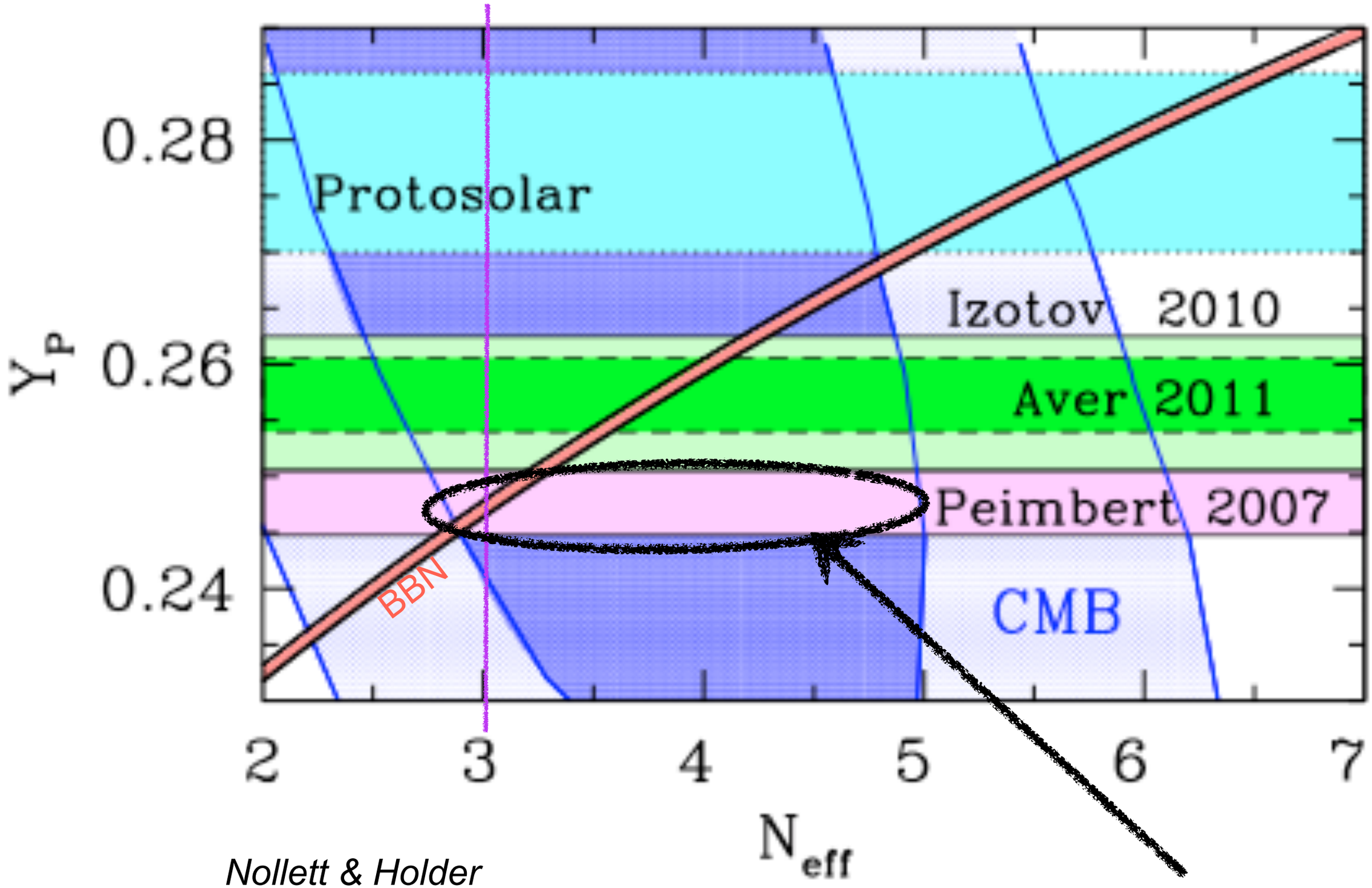
Helium and # of Neutrinos



Nollett & Holder

N_{eff}=3.8 ± 0.7

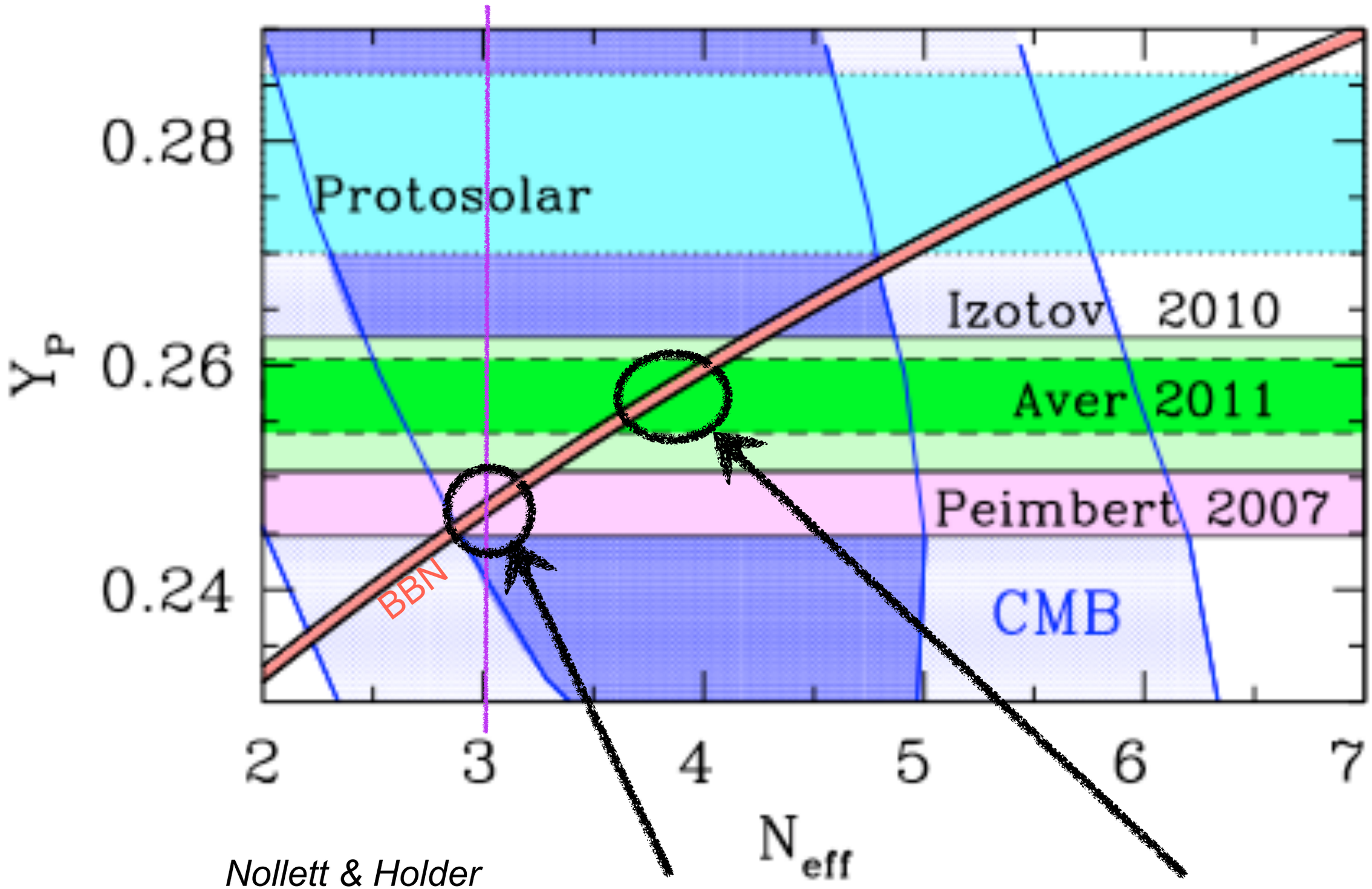
Helium and # of Neutrinos



Nollett & Holder

N_{eff}=4.0 ± 0.8

Helium and # of Neutrinos

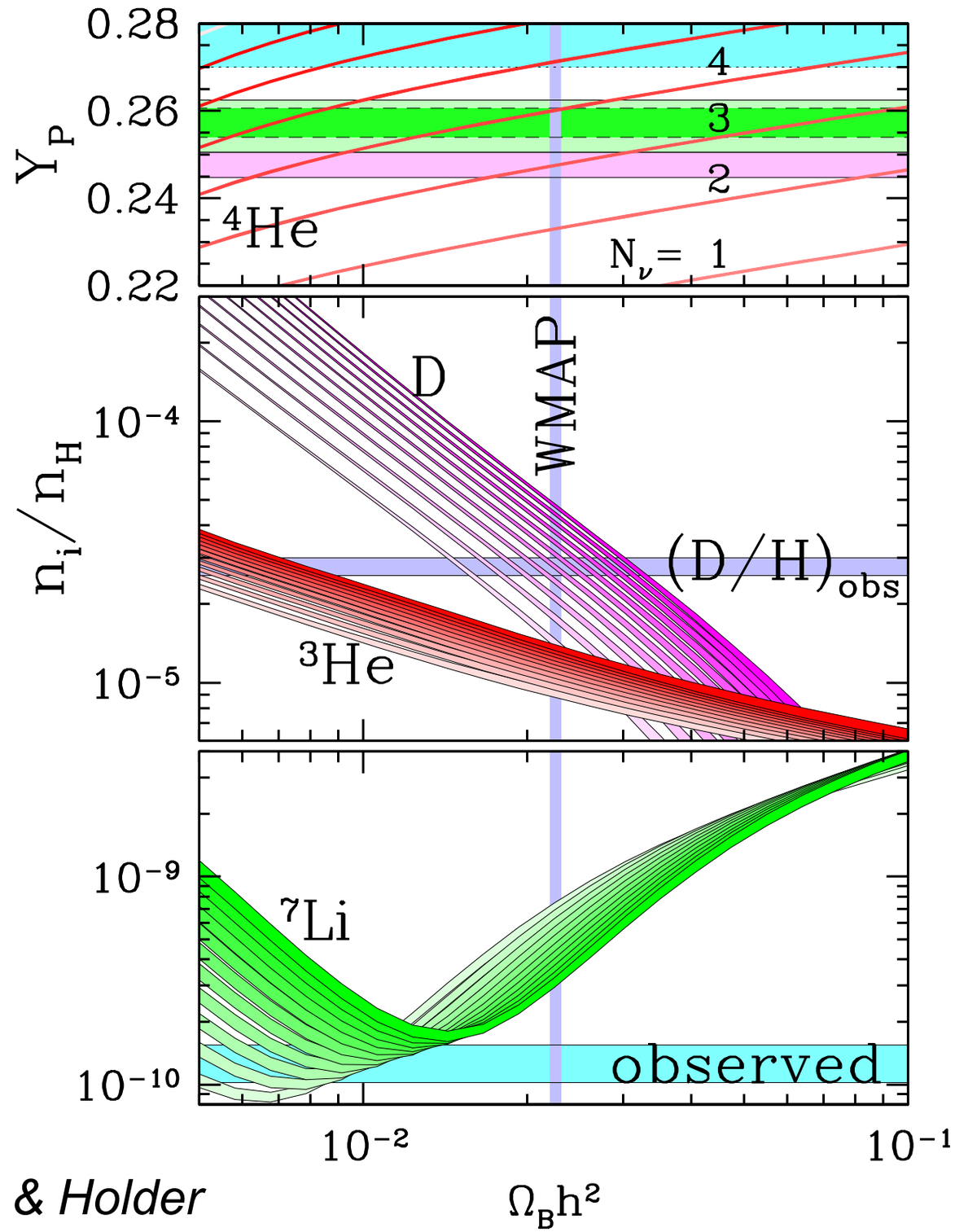


Nollett & Holder

N_{eff}=3.2 ± 0.2 ***N_{eff}=3.8 ± 0.2***

CMB Informs BBN Constraints

- acoustic peaks tell you baryon density



Nollett & Holder

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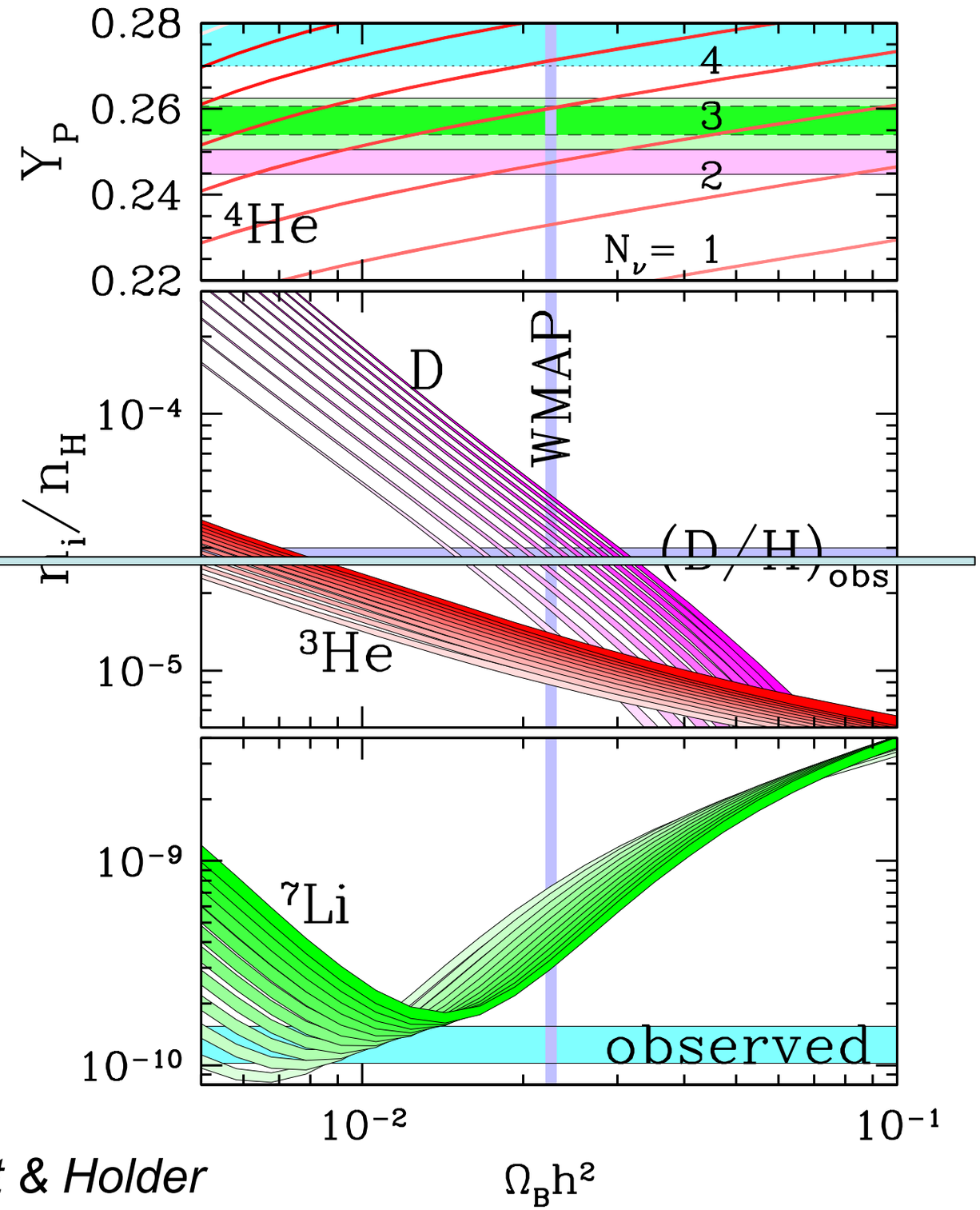

New today
Pettini & Cooke

Nollett & Holder

Summary

- CMB will best probe neutrino masses with CMB lensing; results coming soon
- CMB probes of N_{eff} are partly degenerate with primordial Helium abundance, so inferences are sensitive to what you assume