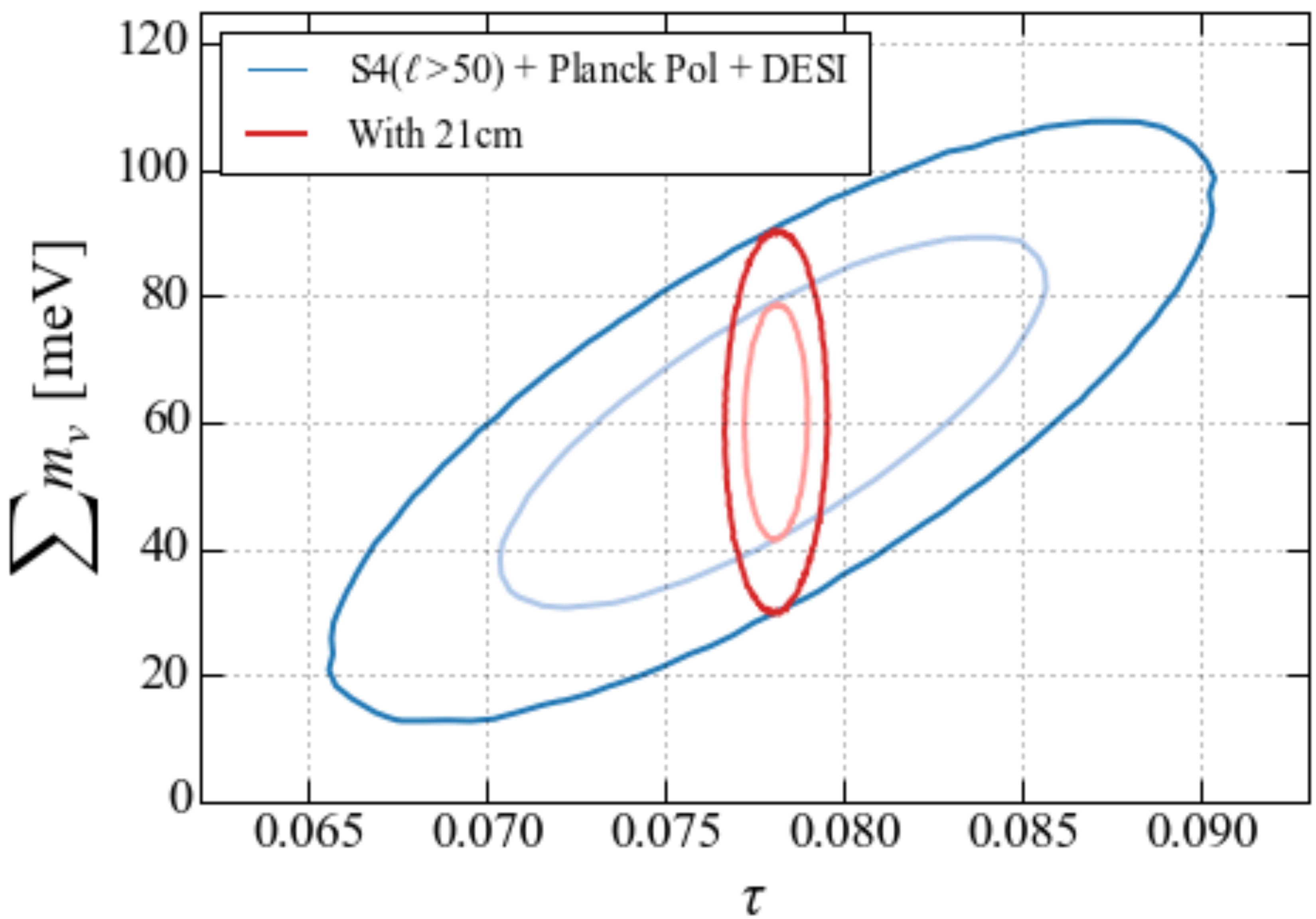
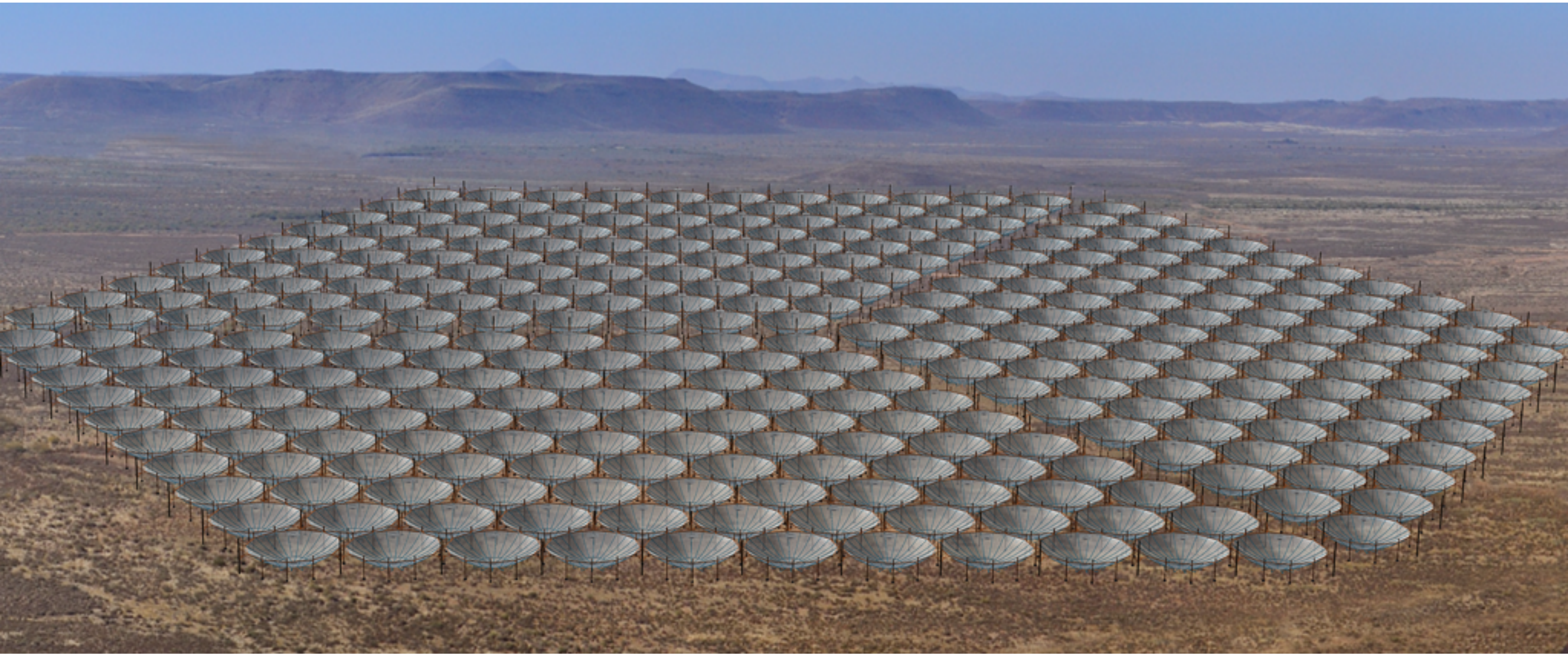
Astrophysical and Cosmological Constraints from HERA



Adrian Liu, UC Berkeley

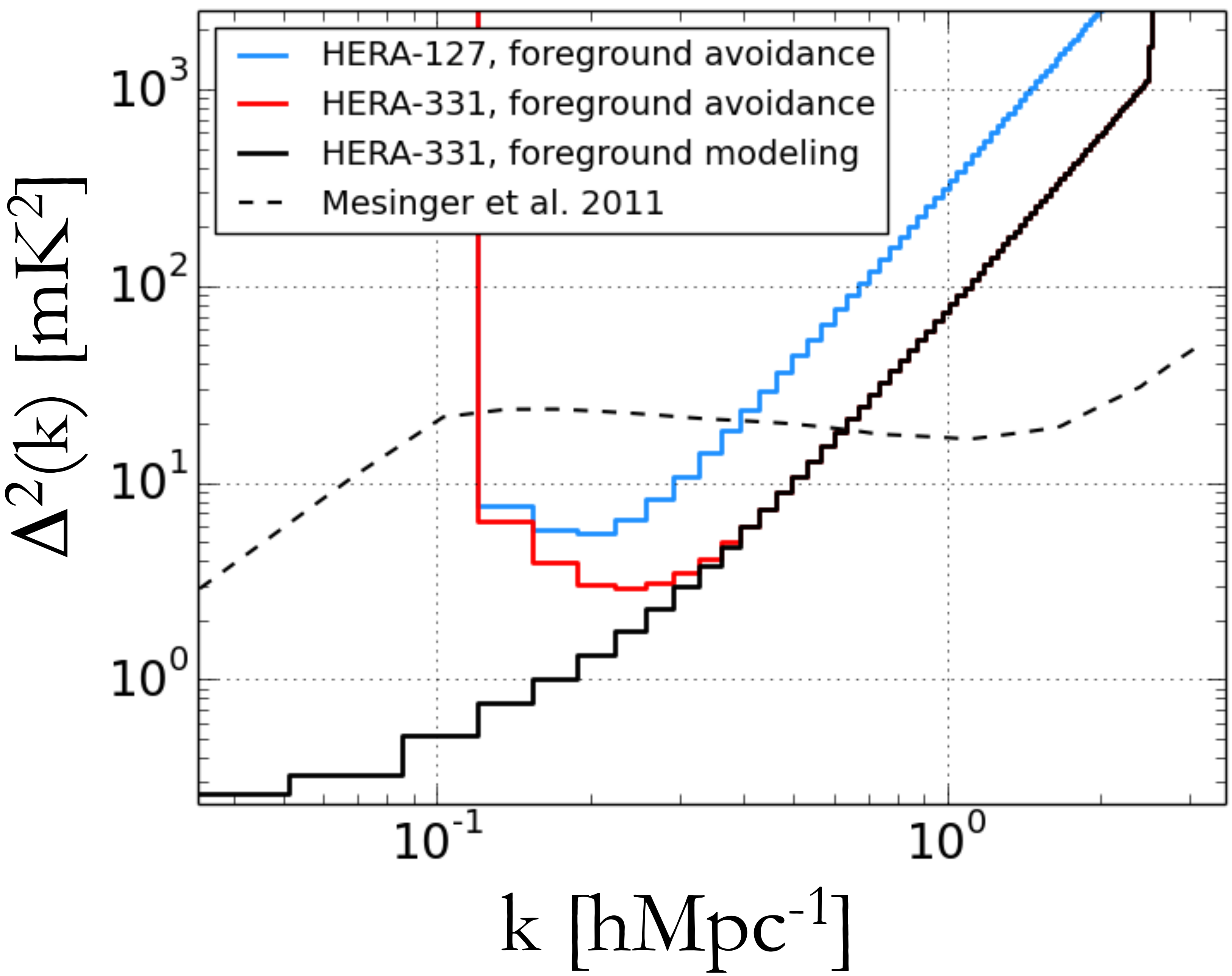
Hydrogen Epoch of Reionization Array (HERA)



154 m

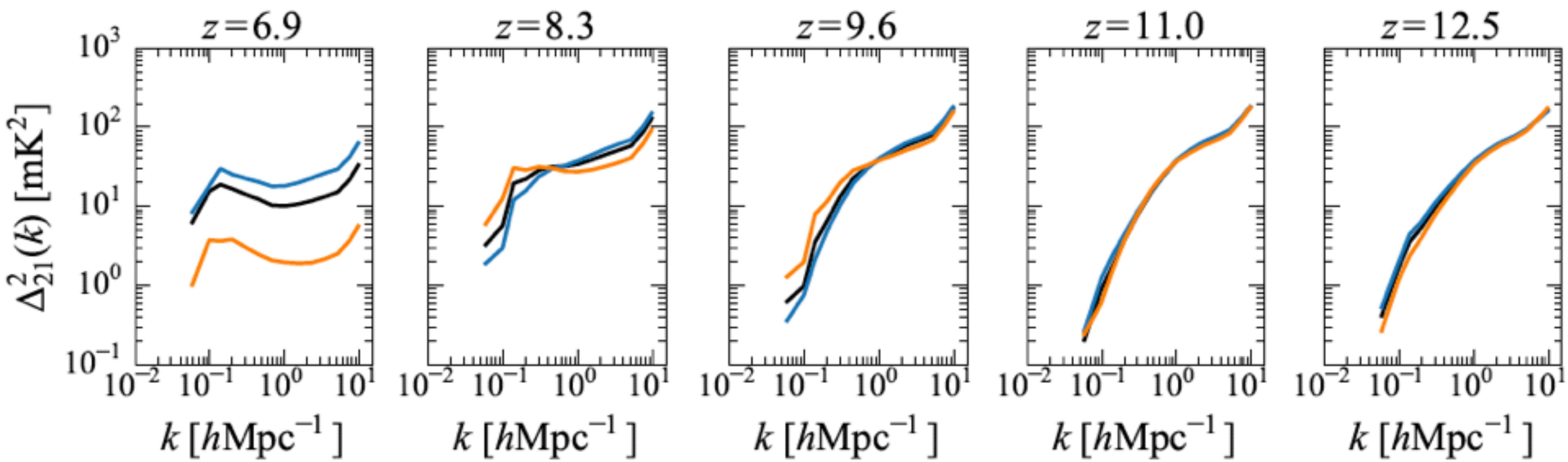
Astrophysical Parameters

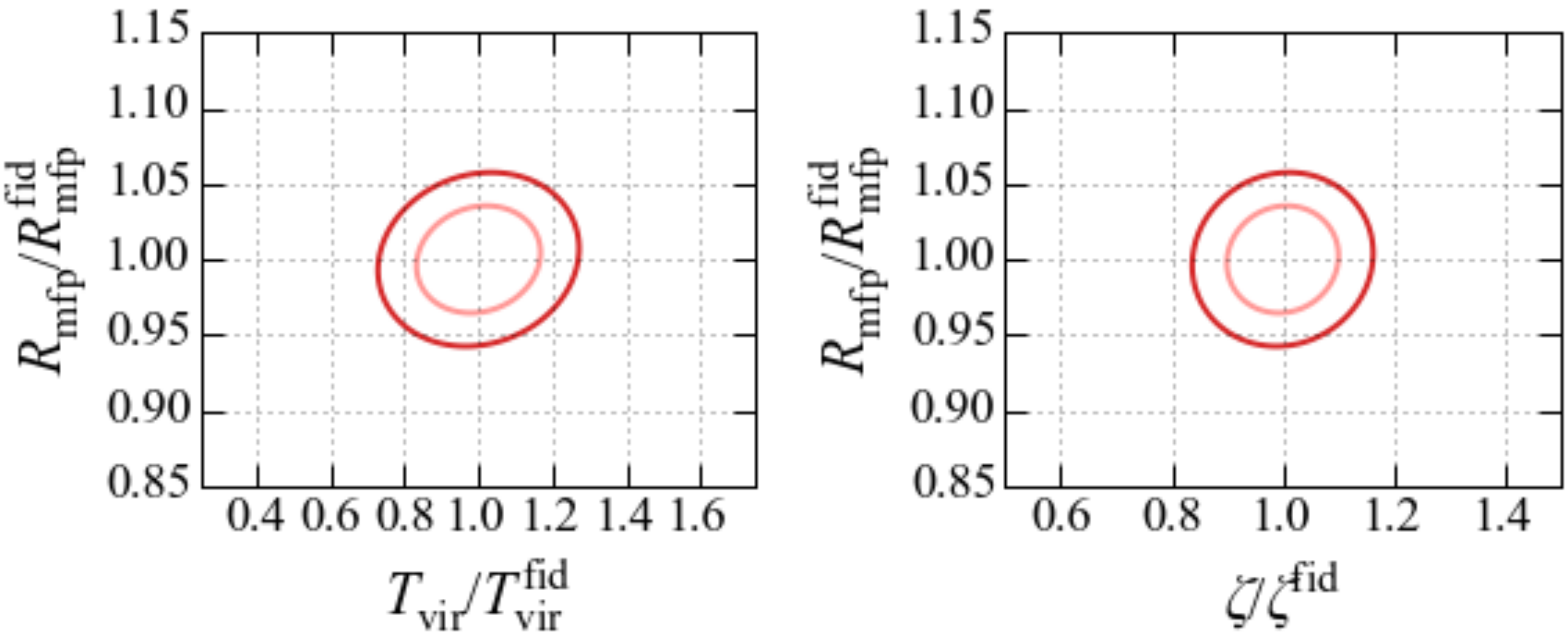
HERA will make a high significance measurement of the power spectrum

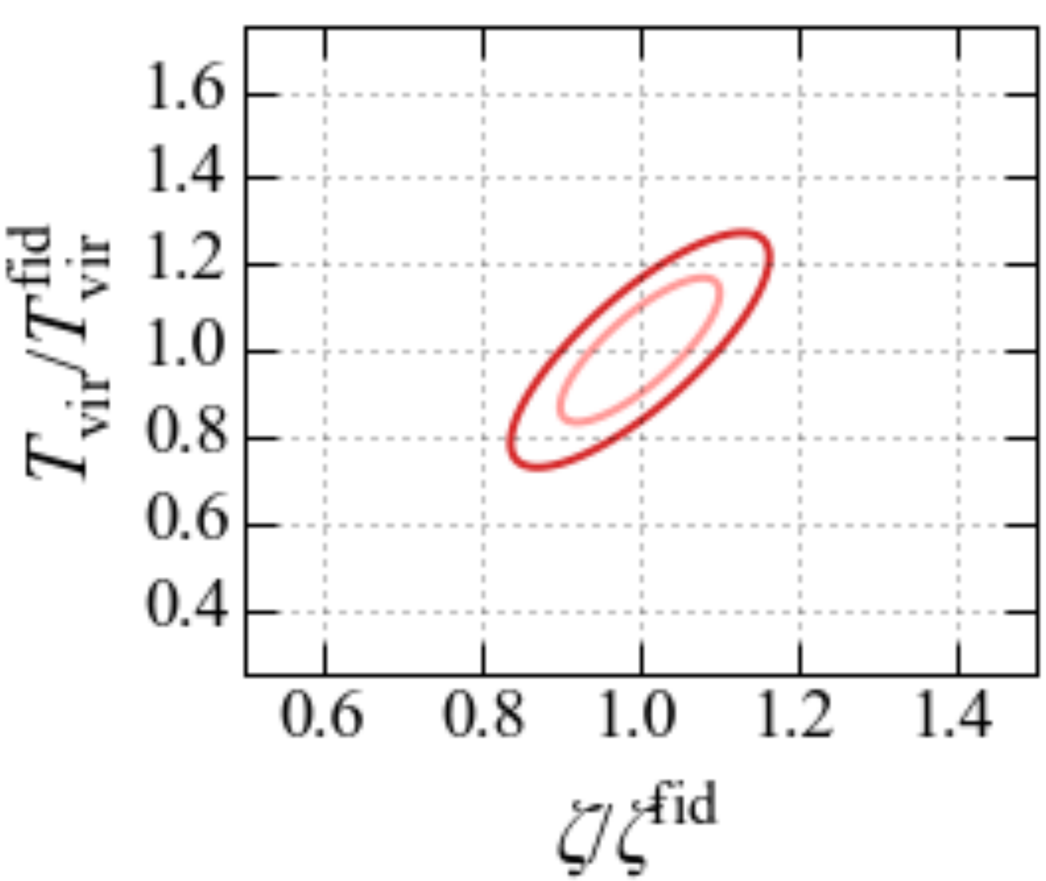


A three-parameter reionization model

- ζ: ionizing efficiency of first galaxies
- T_{vir}: minimum virial temperature (proxy for mass) of first ionizing galaxies
- R_{mfp}: mean free path of ionizing photons


$z = 6.9$
$z = 8.3$
$z = 9.6$
$z = 11.0$
$z = 12.5$
$\Delta^2_{21}(k)$ [mK^2]
k [hMpc^{-1}]

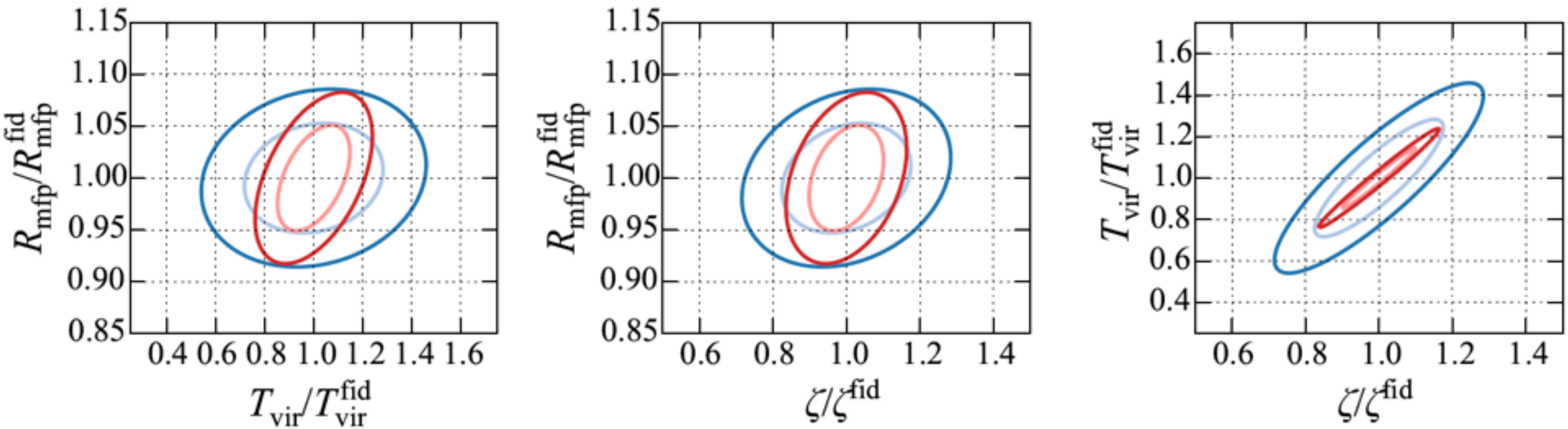




The recently commenced HERA experiment is forecasted to deliver ~5% errors on astrophysical parameters

AL & Parsons (2015b)

Note that cosmological parameter uncertainties are non-negligible

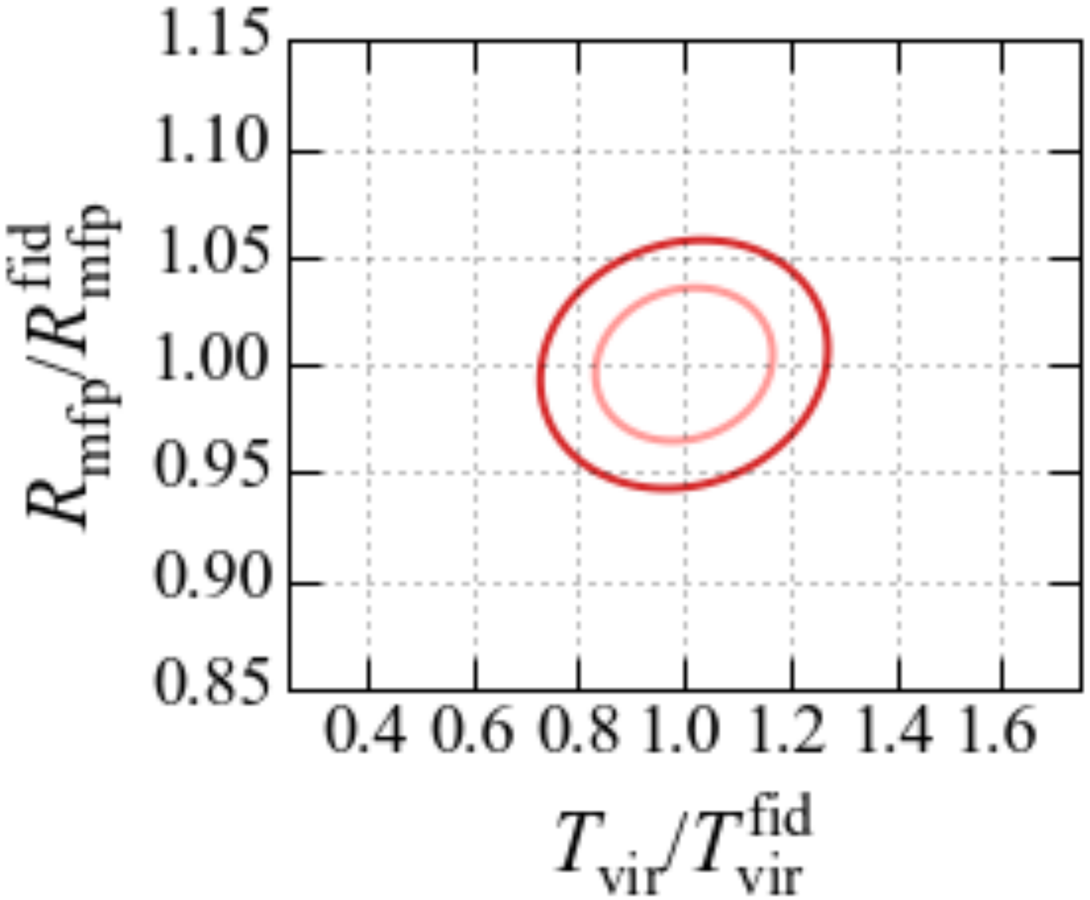


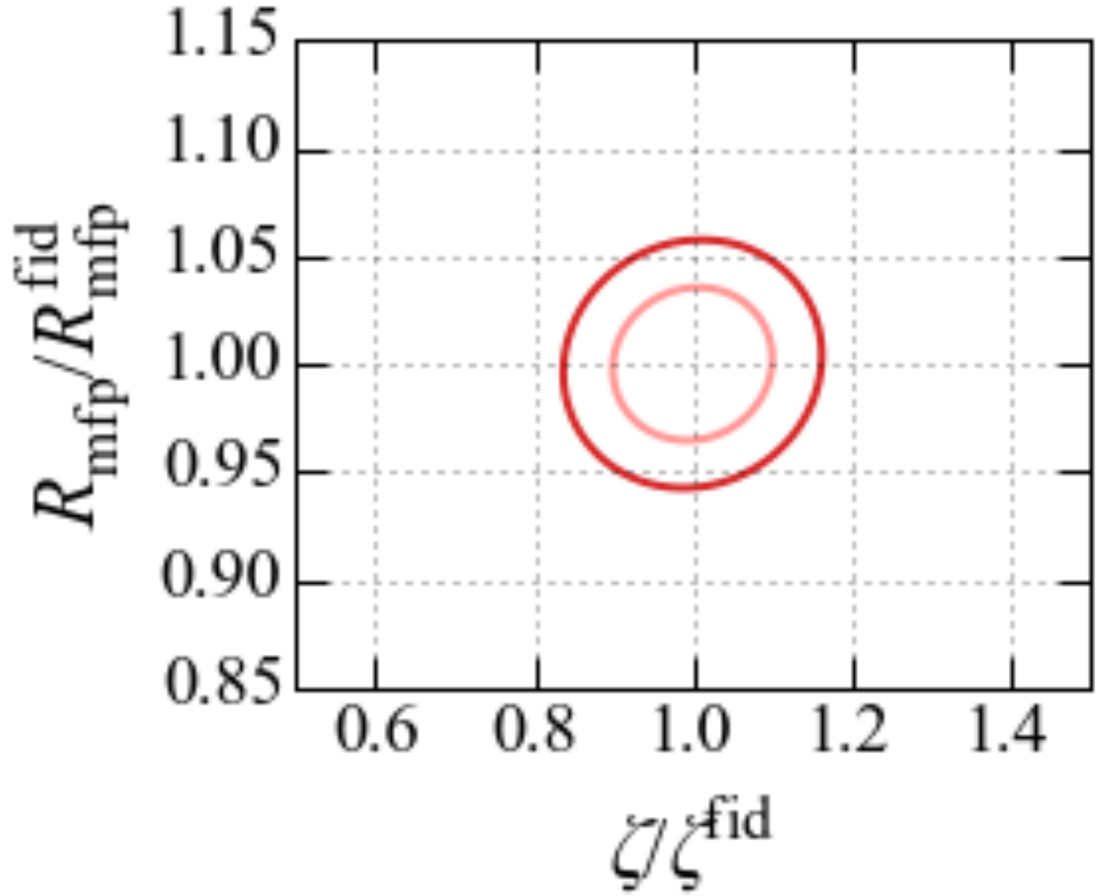
Cosmo params fixed

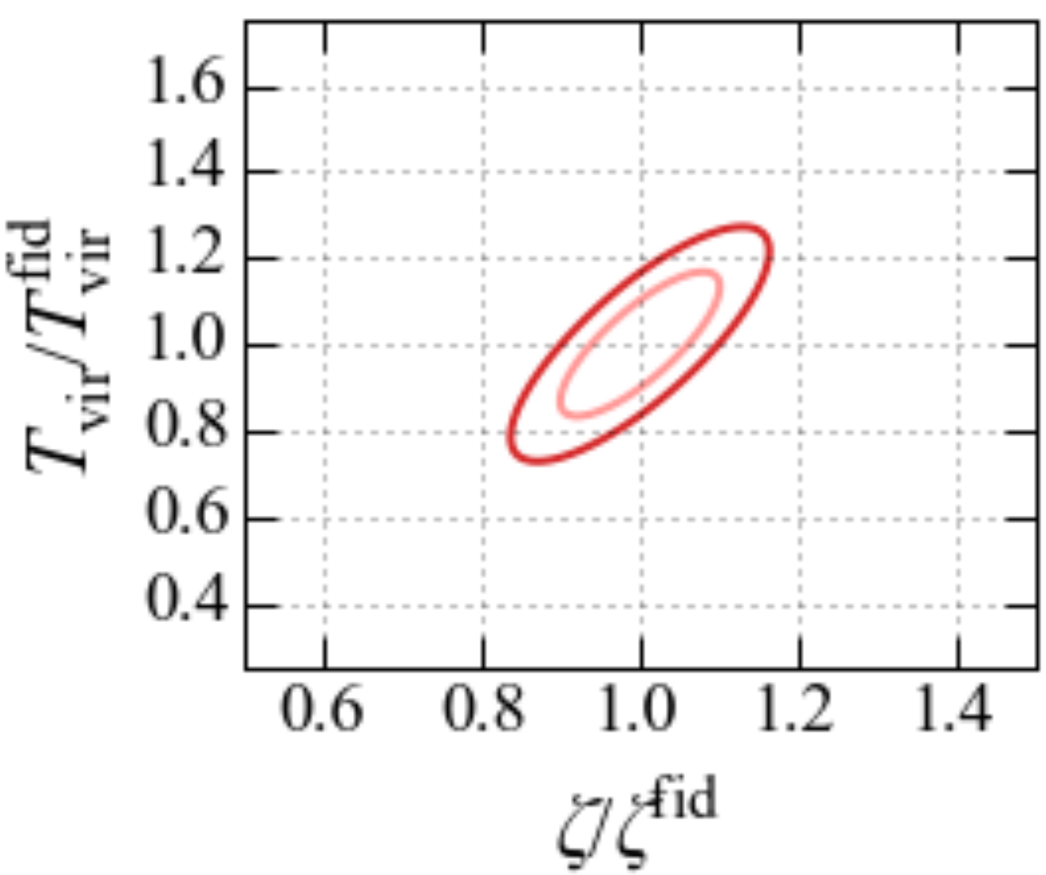
Cosmo params varied

AL & Parsons (2015b)

Kern, **AL** et al. (ongoing)







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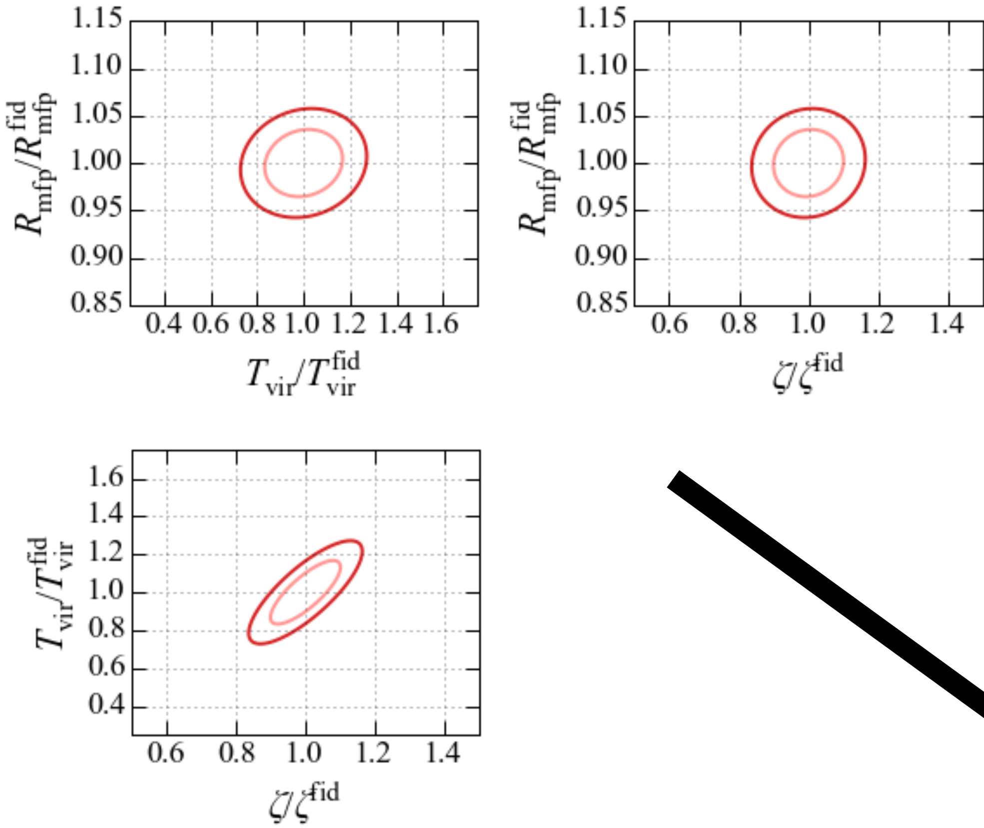
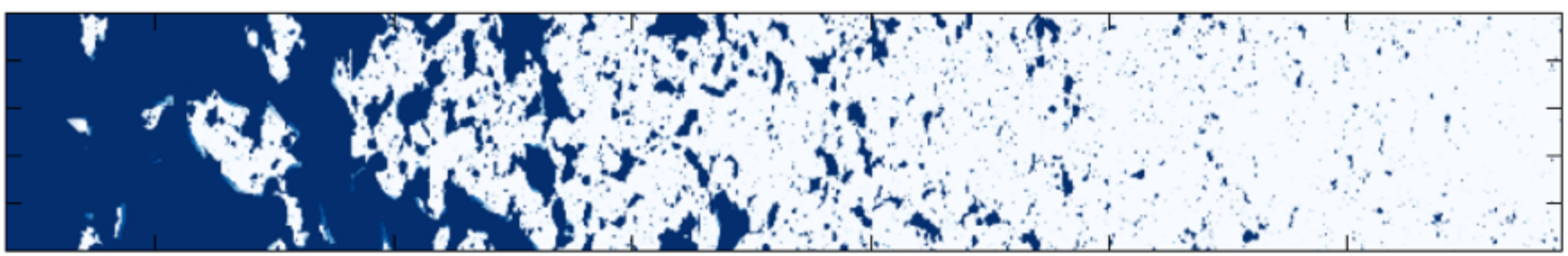
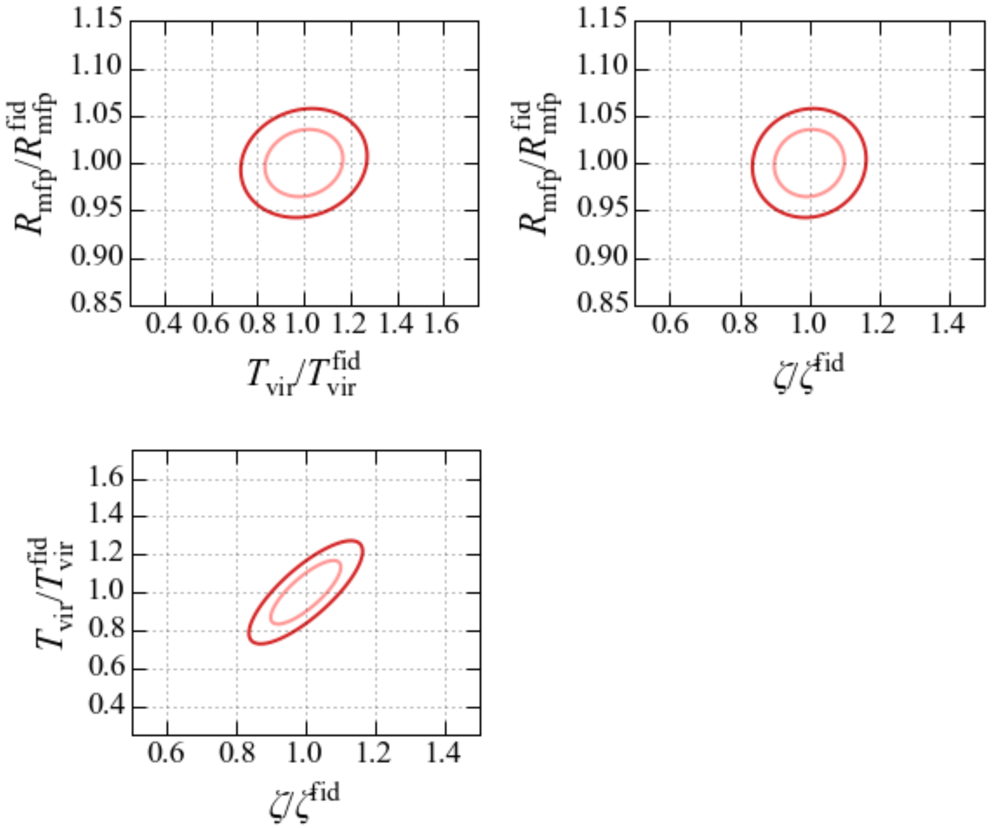


$R_{\rm mfp}/R_{\rm mfp}^{\rm fid}$
$T_{\rm vir}/T_{\rm vir}^{\rm fid}$
$\zeta/\zeta^{\rm fid}$
$R_{\rm mfp}/R_{\rm mfp}^{\rm fid}$
$\zeta/\zeta^{\rm fid}$
$T_{\rm vir}/T_{\rm vir}^{\rm fid}$

model



time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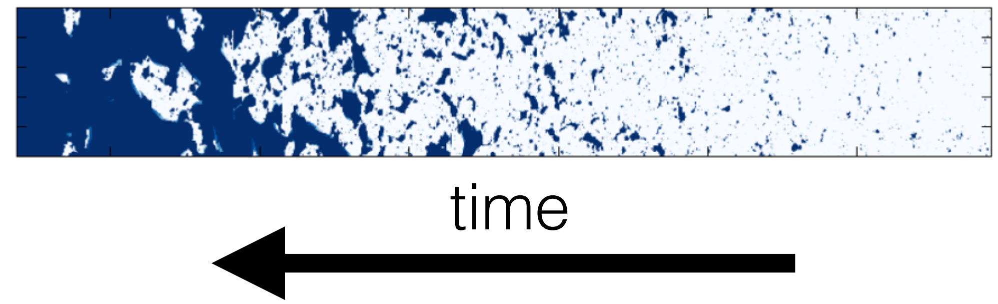
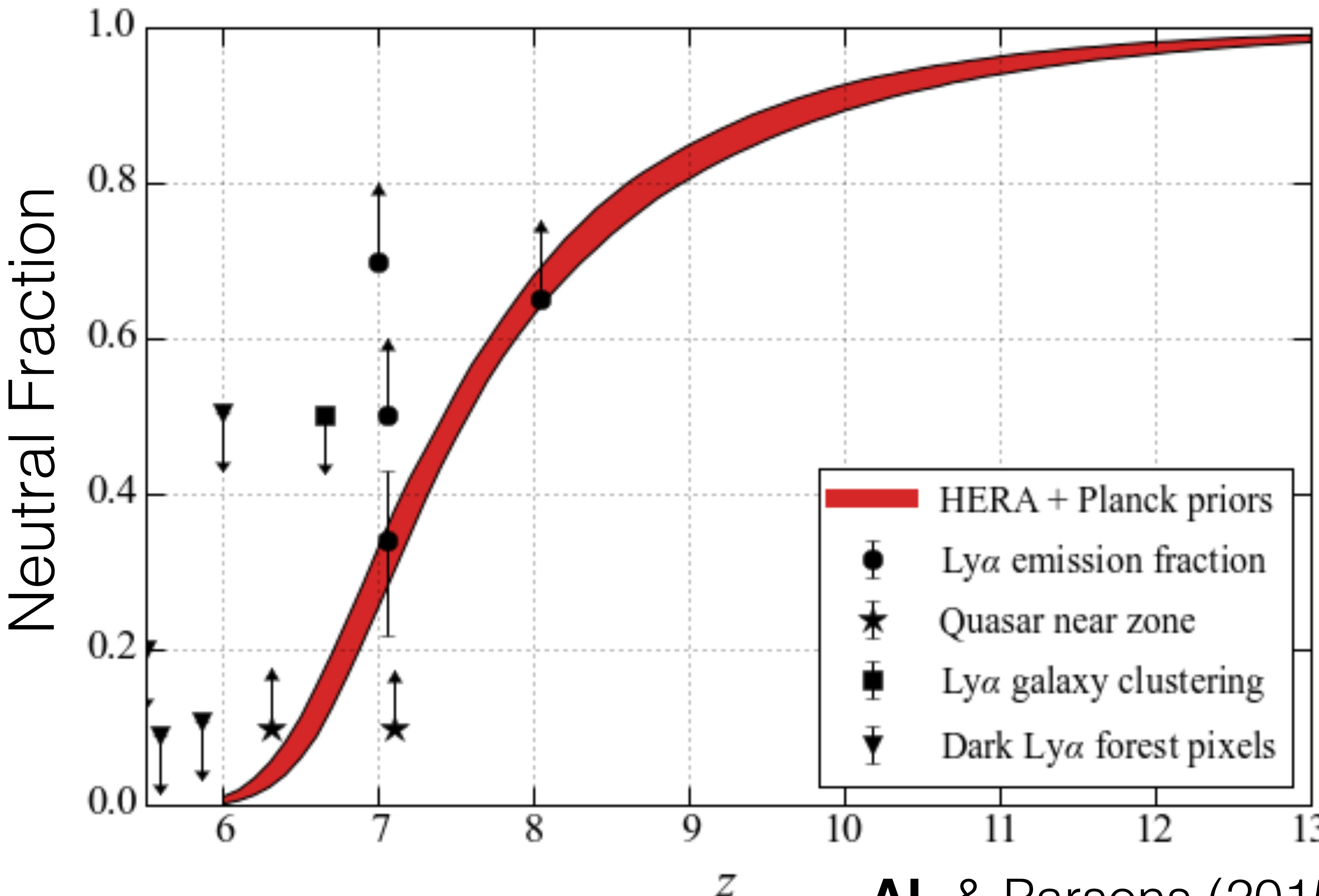
$\zeta/\zeta^{\rm fid}$

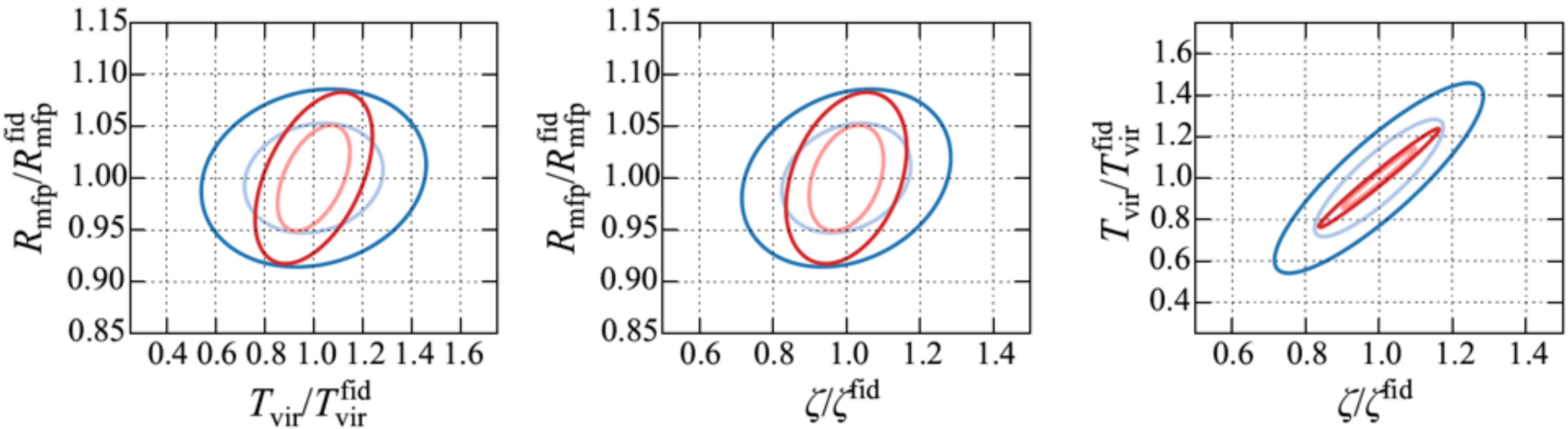

time



AL & Parsons (2015)
Presley, **AL** et al. (ongoing)

Cosmological Parameters

Just because you're affected by cosmological parameters, it doesn't mean you can access the information

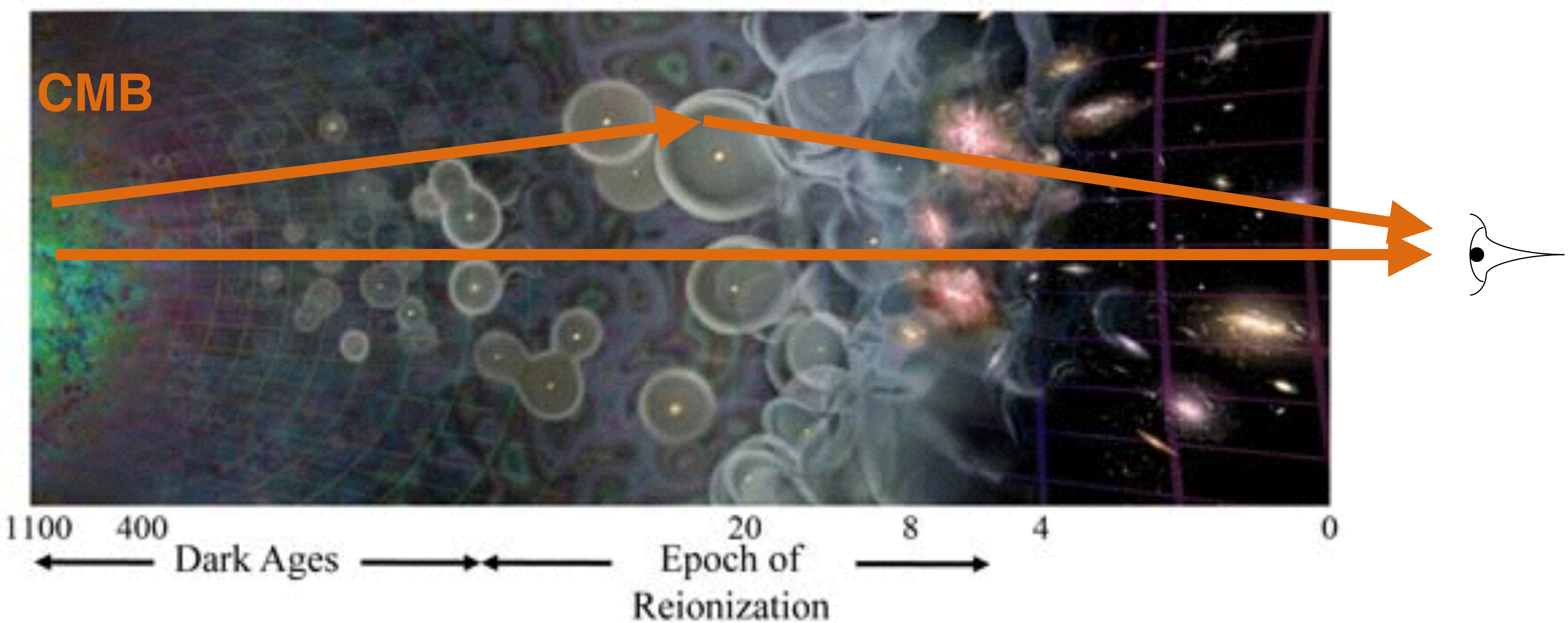


Cosmo params fixed
Cosmo params varied

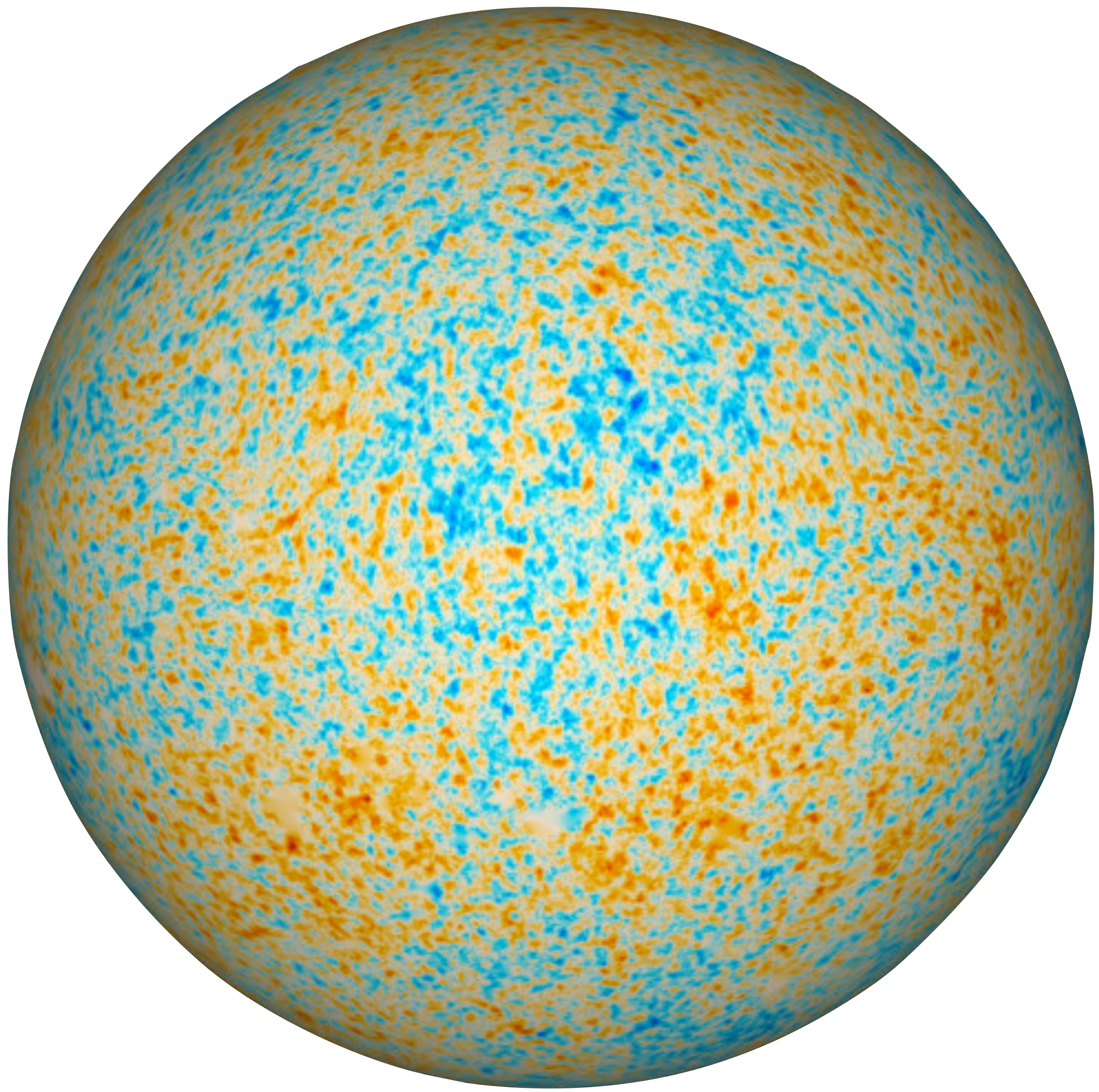
AL & Parsons (2015b)
Kern, **AL** et al. (ongoing)

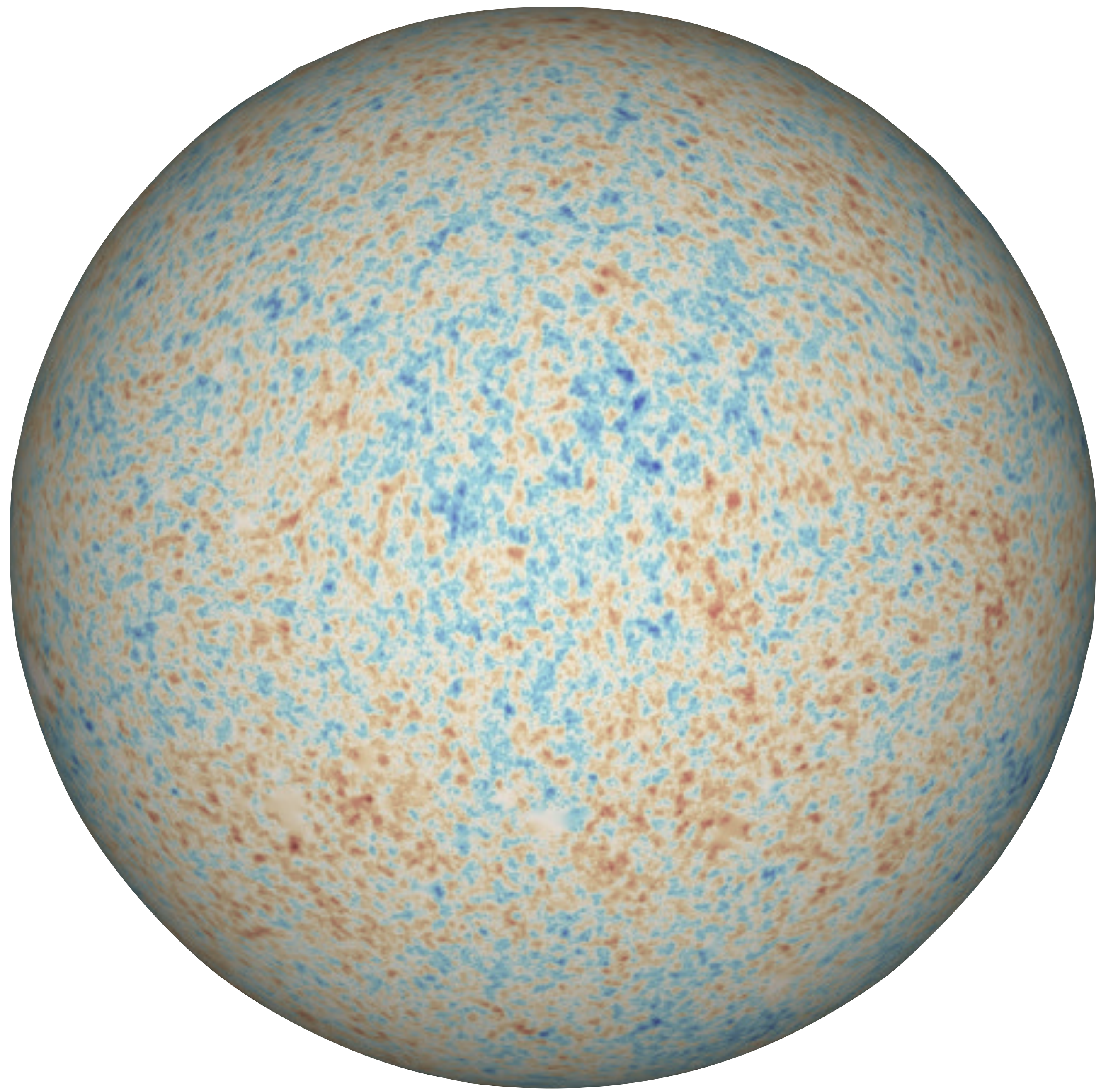
For now…better cosmology through better astrophysics!

Reionization is a nuisance for CMB measurements



Extra optical depth parameter: $\tau \propto \int \langle x_i \rho_b \rangle dz$

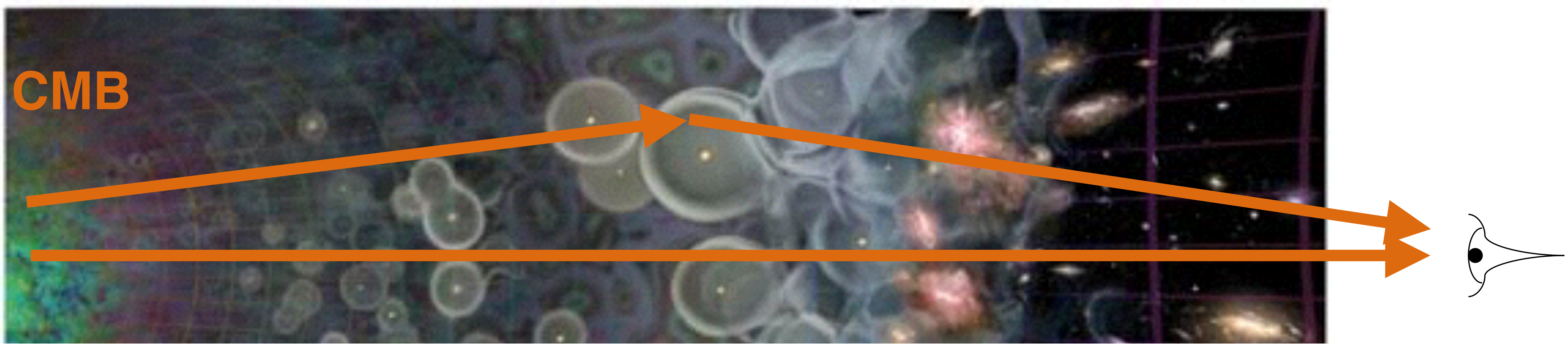




- Early reionization (higher optical depth) + Large primordial fluctuations A_s

VS

- Late reionization (lower optical depth) + Small primordial fluctuations A_s



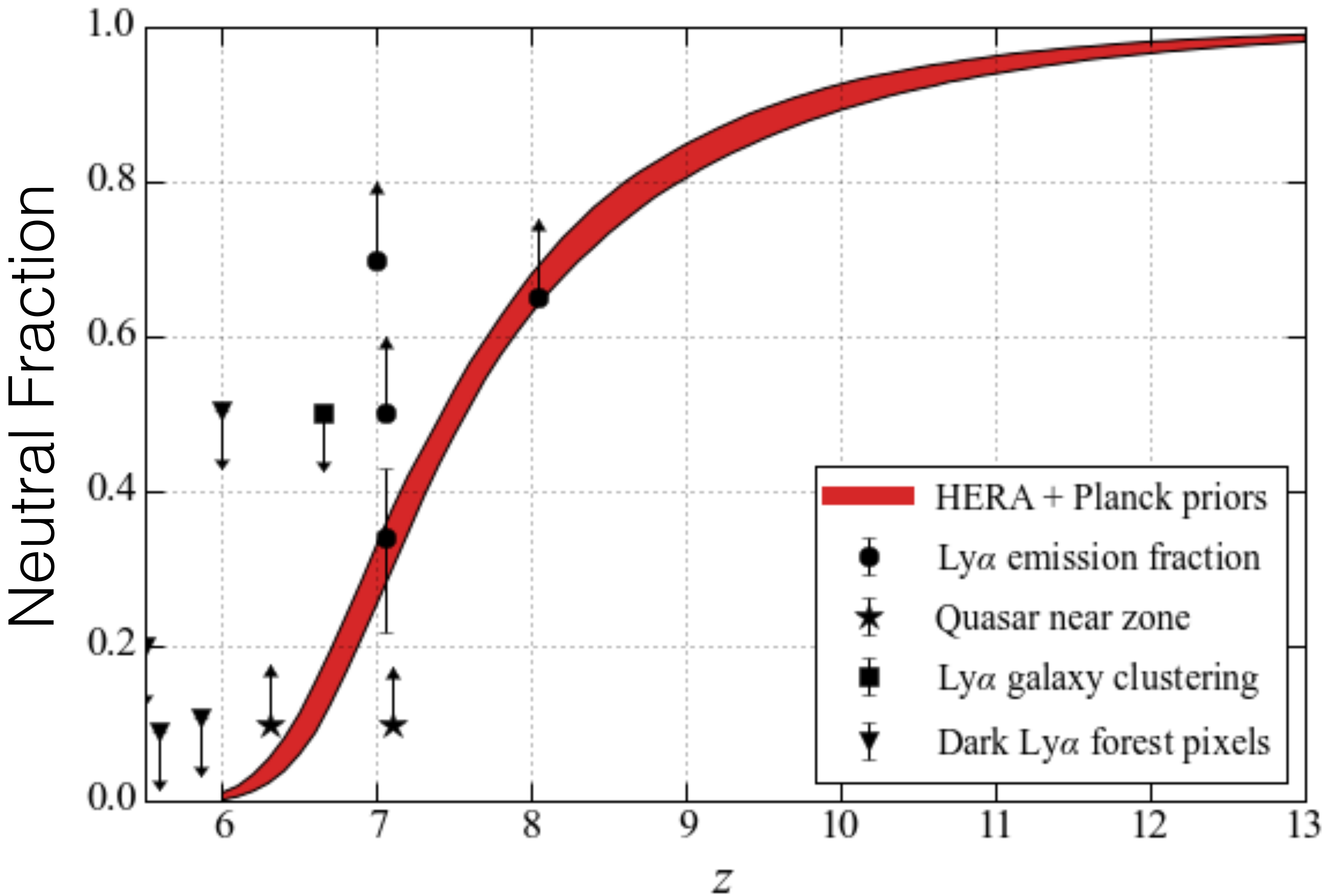
- Early reionization (higher optical depth)
  + Large primordial fluctuations A_s

vs

- Late reionization (lower optical depth)
  + Small primordial fluctuations A_s

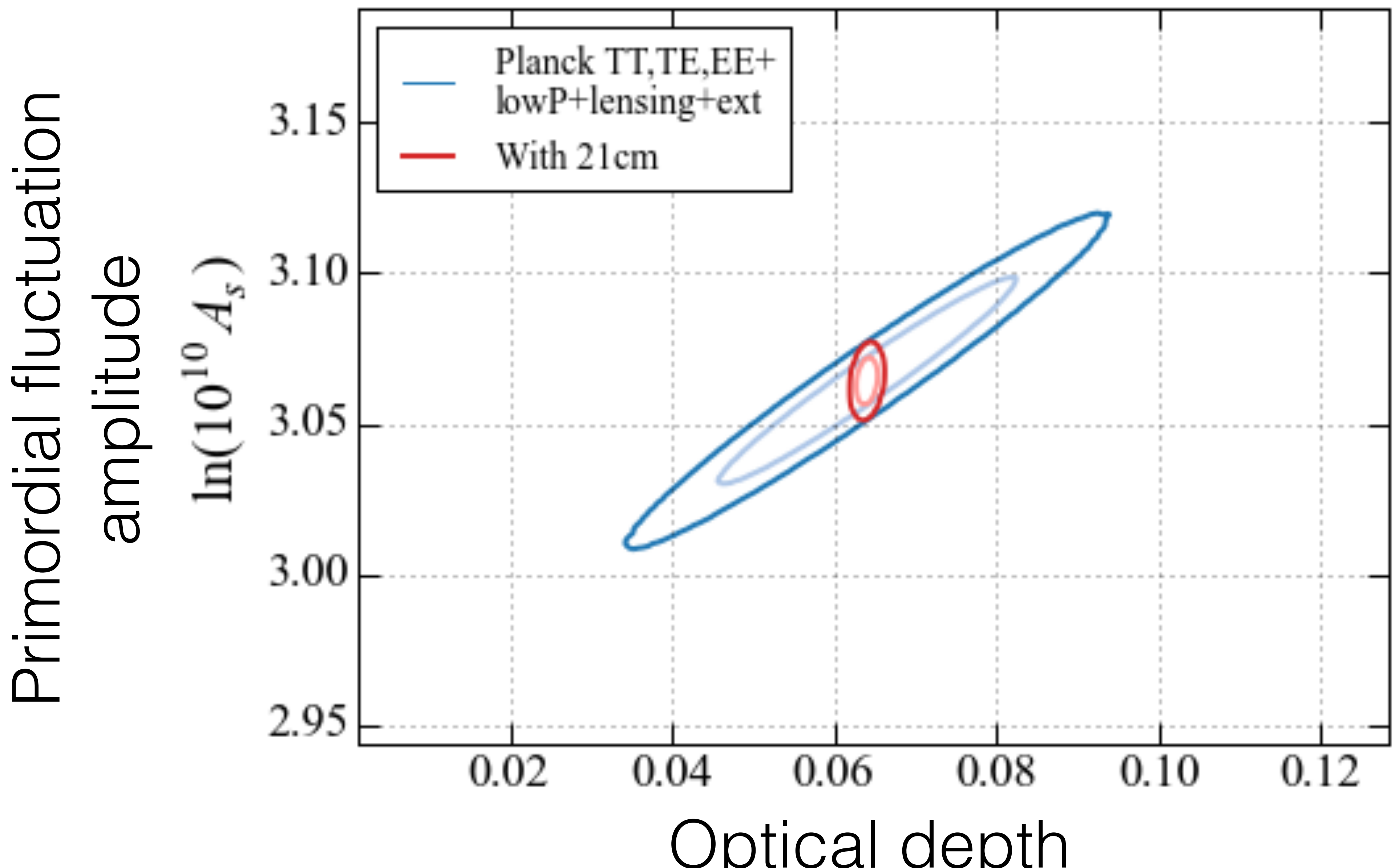
Understanding reionization (especially the CMB optical depth) can improve constraints on other cosmological parameters

HERA provides us with exactly what we need



See also:
Fialkov & Loeb (2016a): 1601.03058
Fialkov & Loeb (2016b): 1602.08130

21cm information breaks the degeneracy between the amplitude of fluctuations and the optical depth

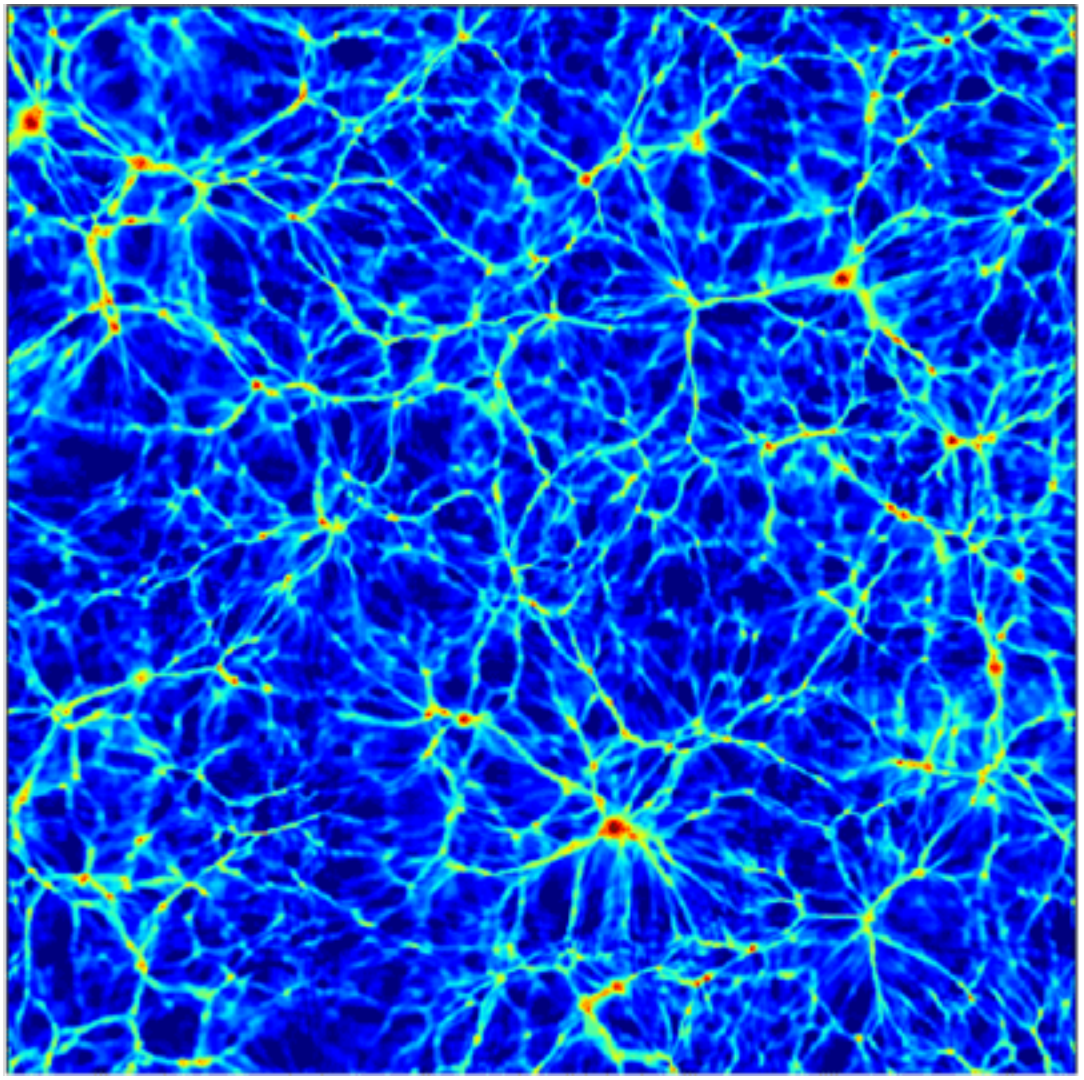


AL et al. (2015a)

$$\Delta \ln(10^{10} A_s) = \pm 0.023 \longrightarrow \pm 0.0053$$

Futuristic cosmology experiments targeting the neutrino mass also benefit

- Neutrinos free-stream out of over-densities and dampen structure formation



Without neutrinos

Agarwal & Feldman 2011

Futuristic cosmology experiments targeting the neutrino mass also benefit

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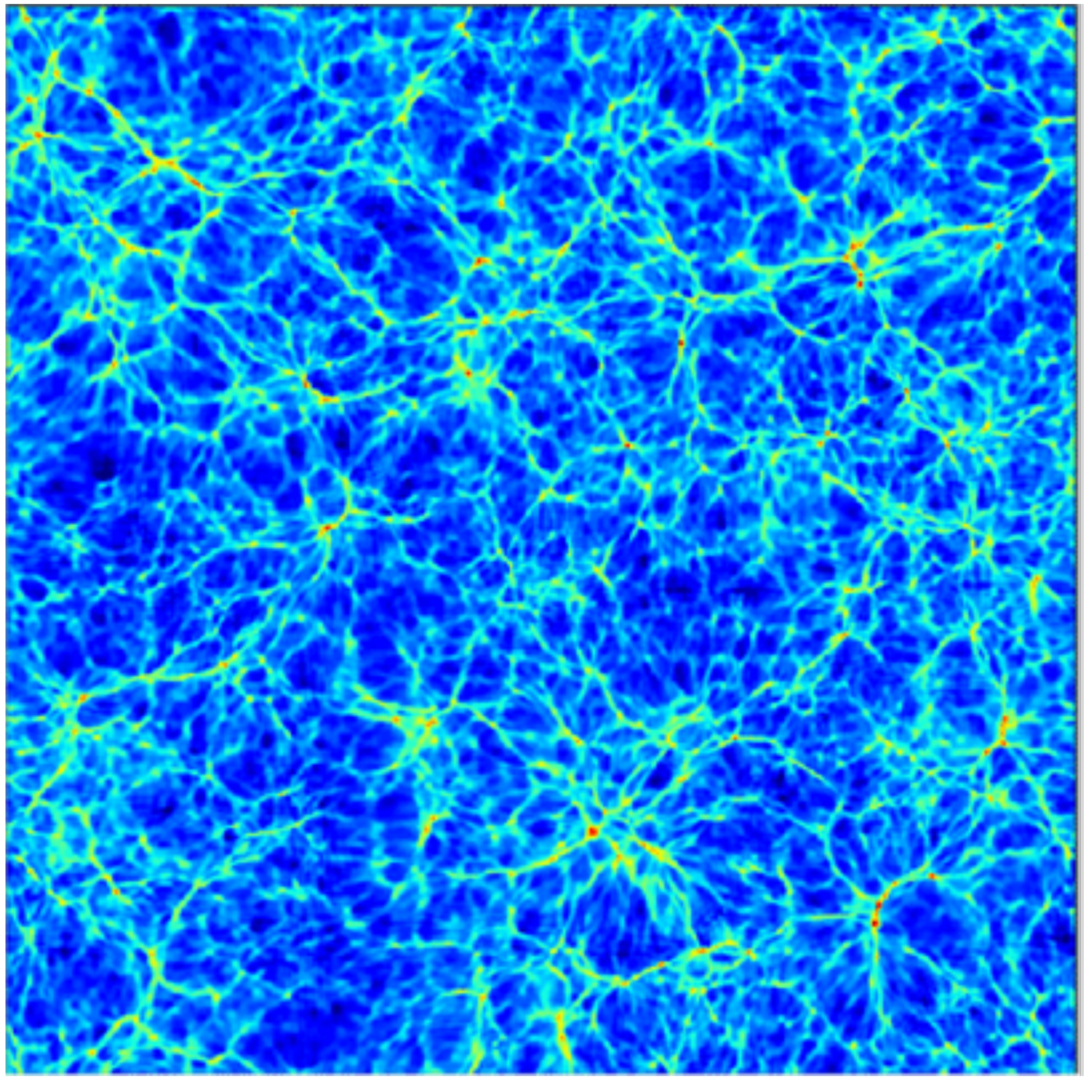
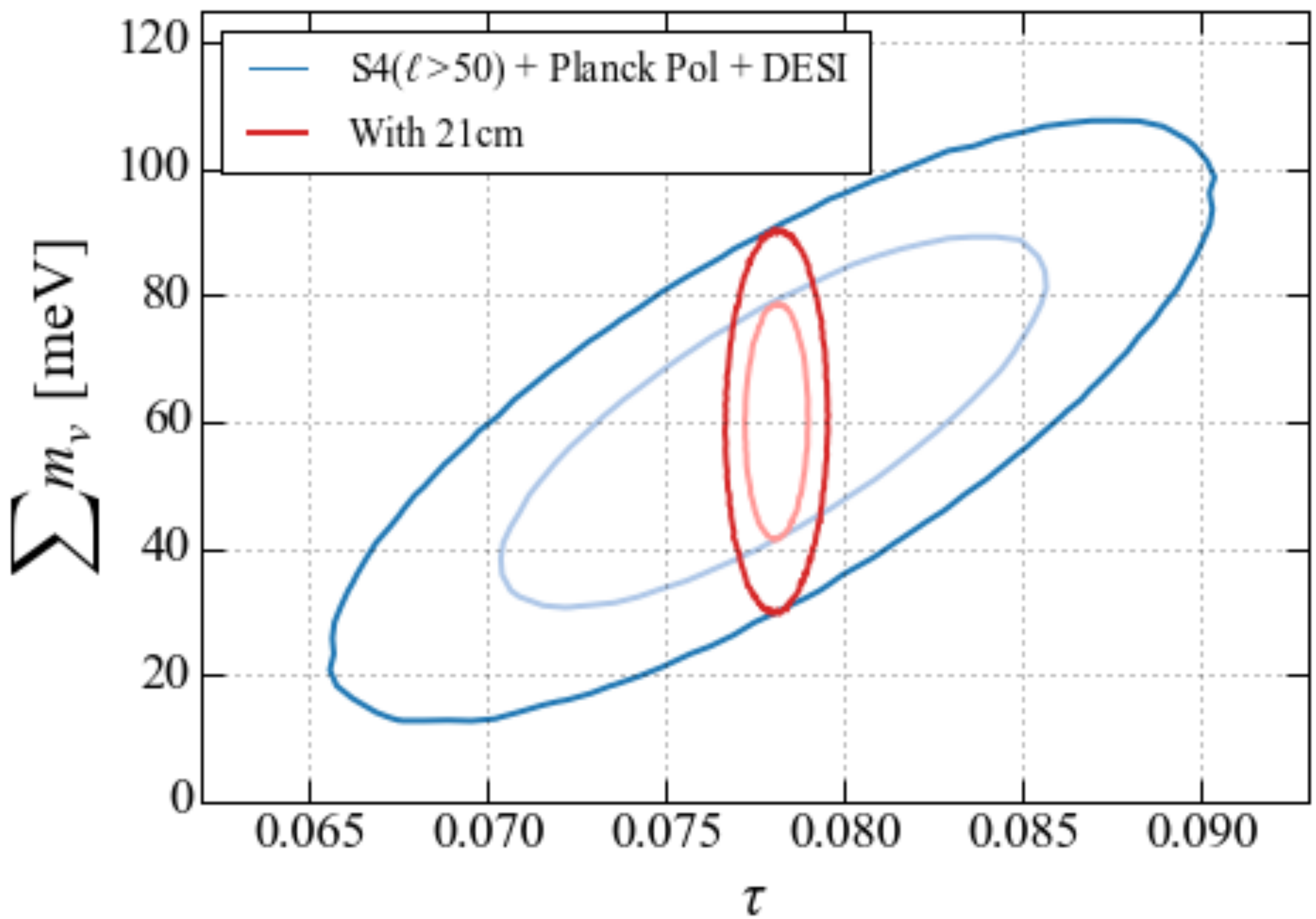


With neutrinos

Agarwal & Feldman 2011

Both the neutrino mass and the optical depth can affect the observed amount of small scale structure, leading to degeneracies



Allison et al. (2015)

AL et al. (2015a)

$$\sum m_\nu = 60 \pm 19\,\mathrm{meV} \longrightarrow \pm 12\,\mathrm{meV}$$

- HERA power spectrum measurements will provide ~5-10% level constraints on astrophysical parameters after marginalizing over cosmological uncertainties.

- HERA measurements can improve CMB cosmological constraints by breaking degeneracies, although such improvements will be model-dependent.

Liu & Parsons 2016, MNRAS 457, 1864
Liu et al. 2016, Phys. Rev. D 93, 043013