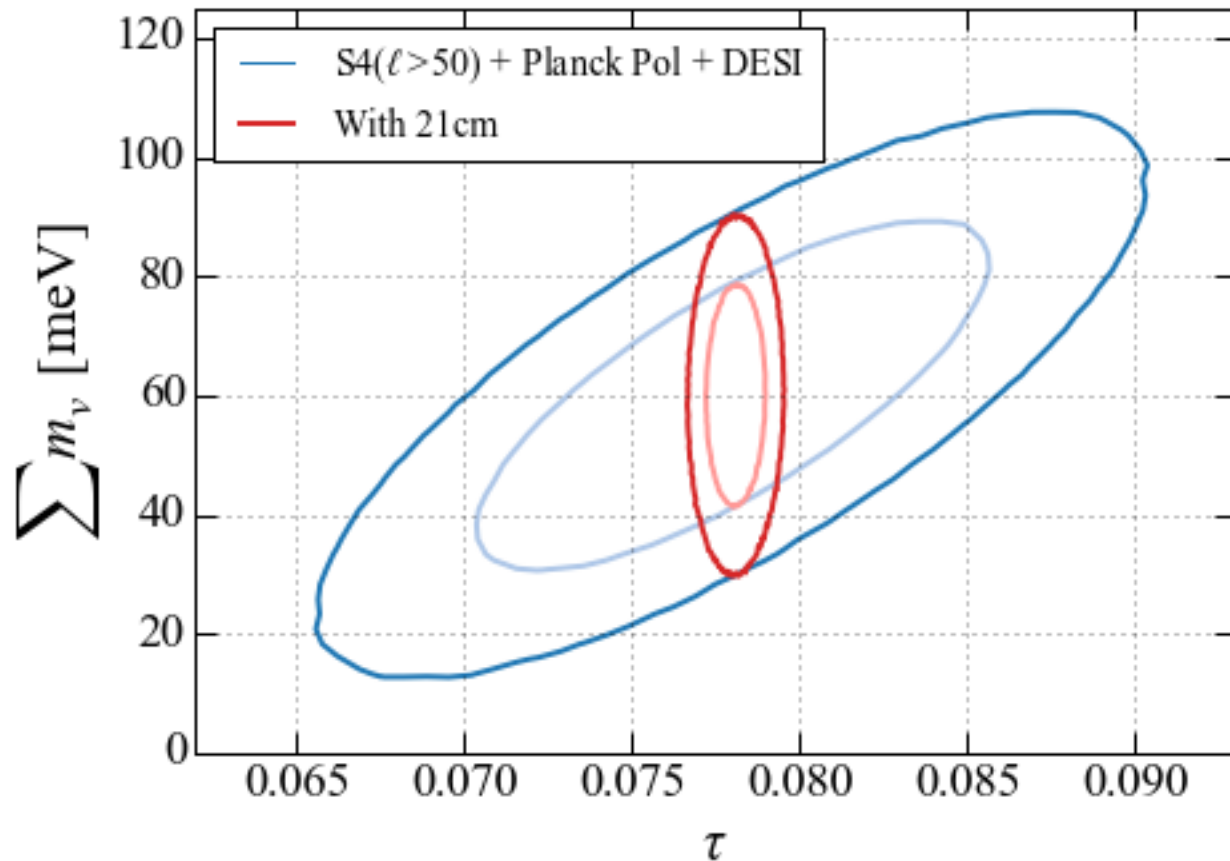


Improving CMB cosmological constraints using 21cm cosmology



Adrian Liu, UC Berkeley

State-of-the-art CMB results from Planck Satellite 2015

| Parameter | TT,TE,EE+lowP+lensing 68 % limits |
|------------------------------|--------------------------------------|
| $\Omega_b h^2$ | 0.02226 ± 0.00016 |
| $\Omega_c h^2$ | 0.1193 ± 0.0014 |
| $100\theta_{MC}$ | 1.04087 ± 0.00032 |
| τ | 0.063 ± 0.014 |
| $\ln(10^{10} A_s)$ | 3.059 ± 0.025 |
| n_s | 0.9653 ± 0.0048 |

One of these parameters is not like the others...

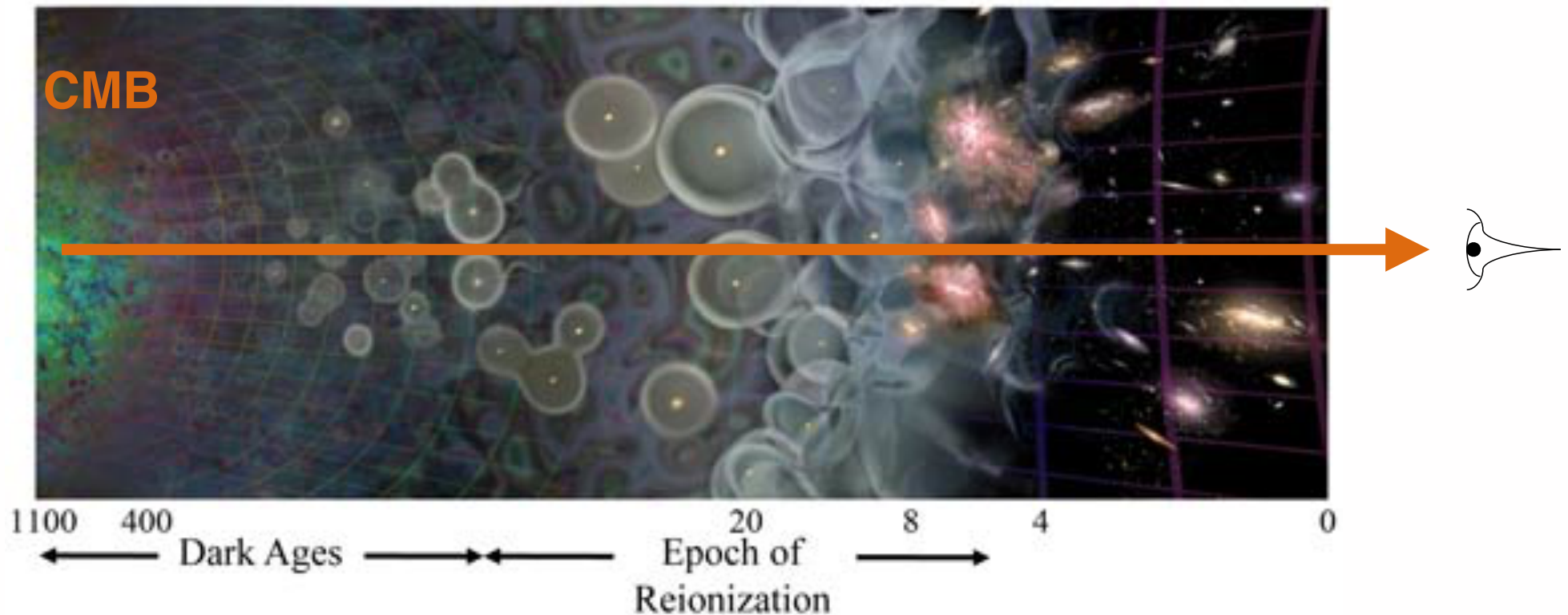
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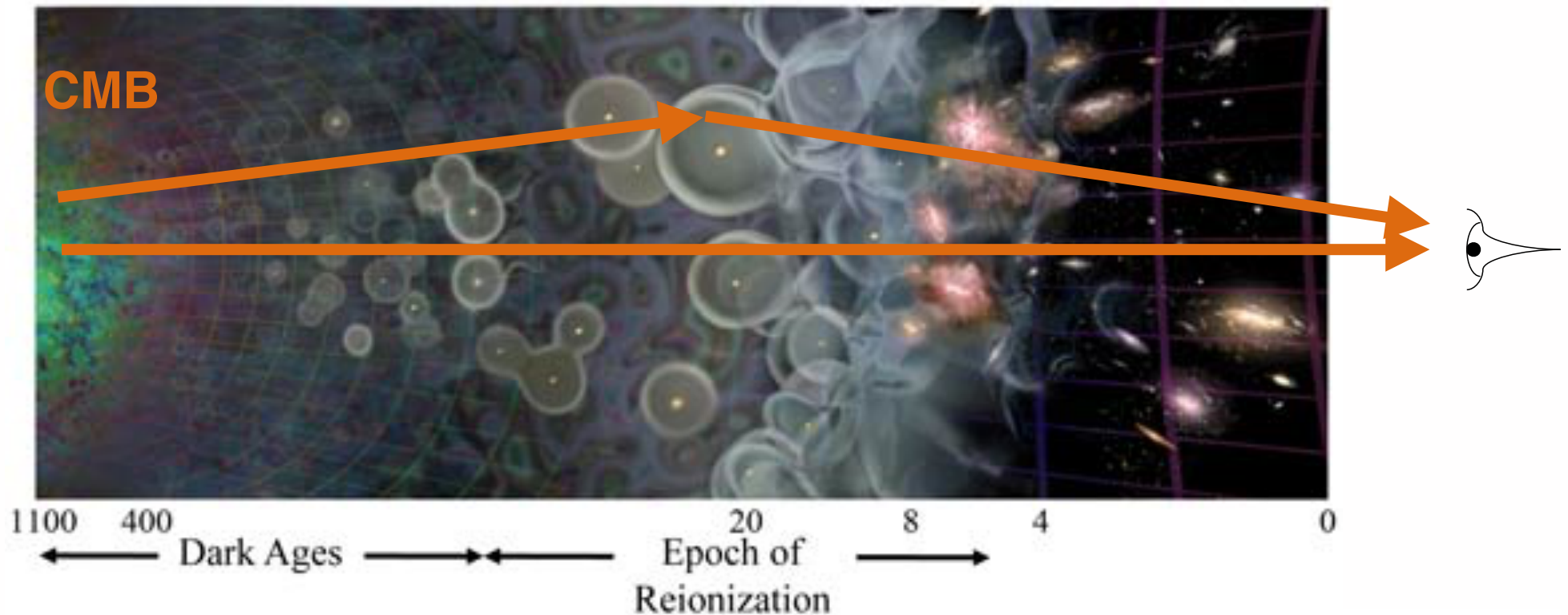
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Optical
depth to
CMB

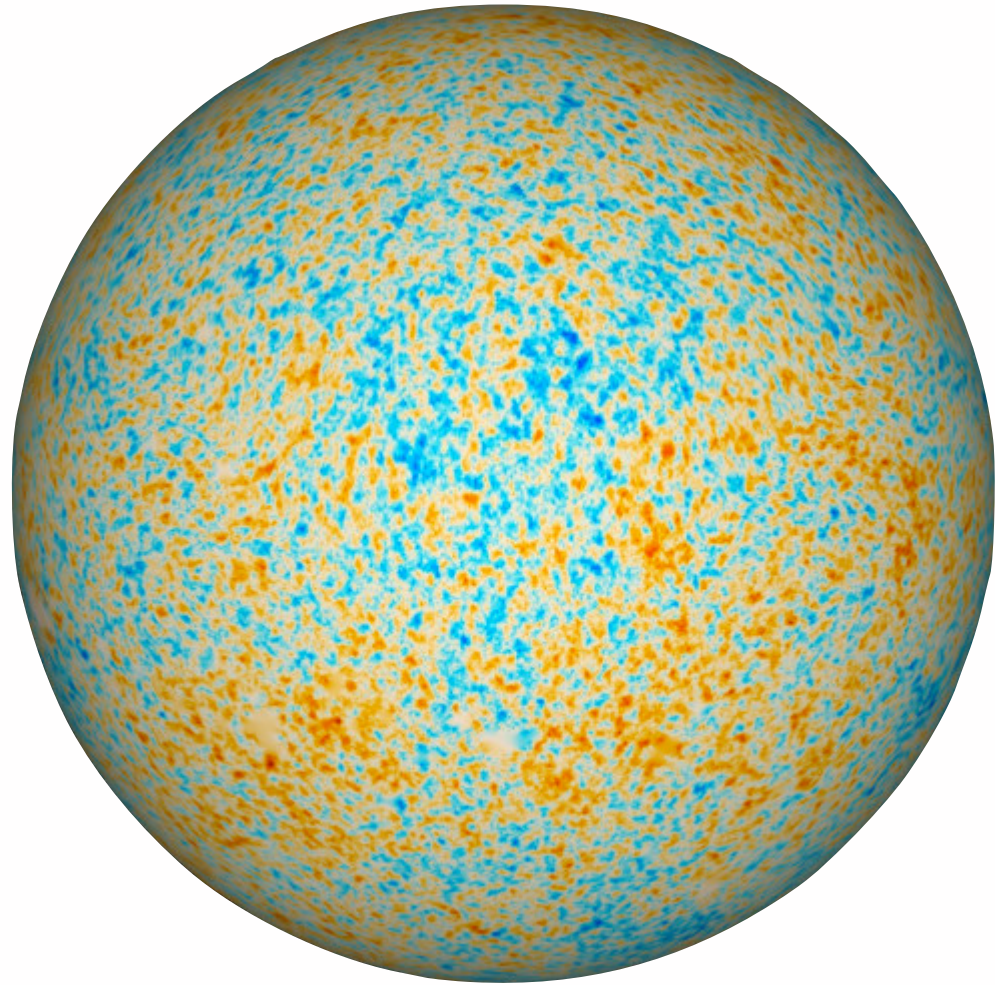
Reionization is a nuisance for CMB measurements



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

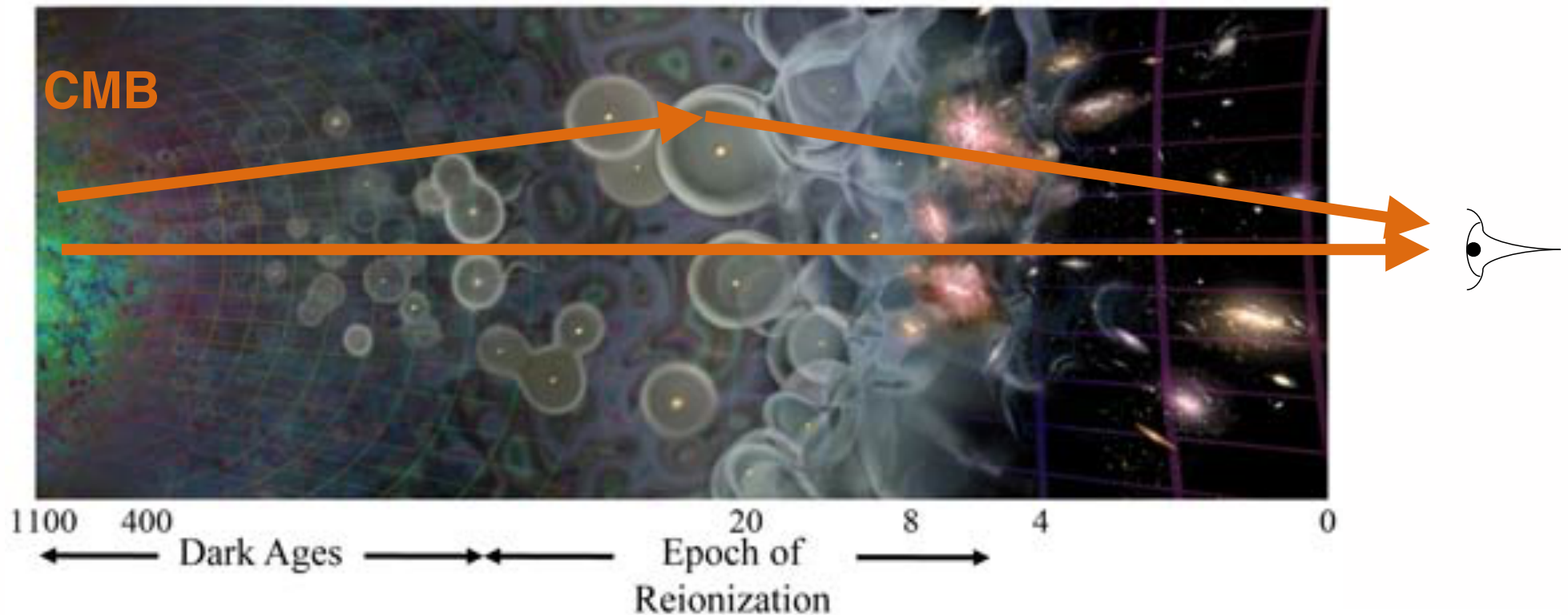


- Early reionization (higher optical depth)
+ Large primordial fluctuations A_s

VS

- Late reionization (lower optical depth)
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Reionization is a nuisance for CMB measurements



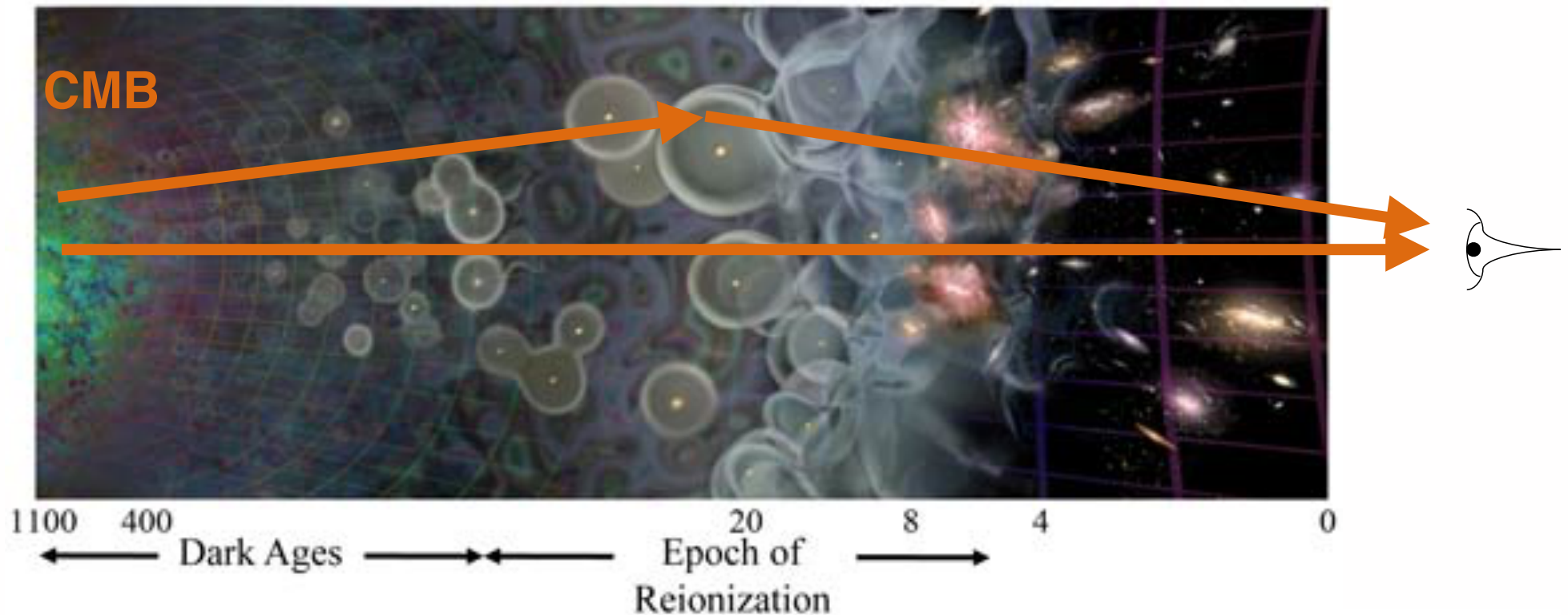
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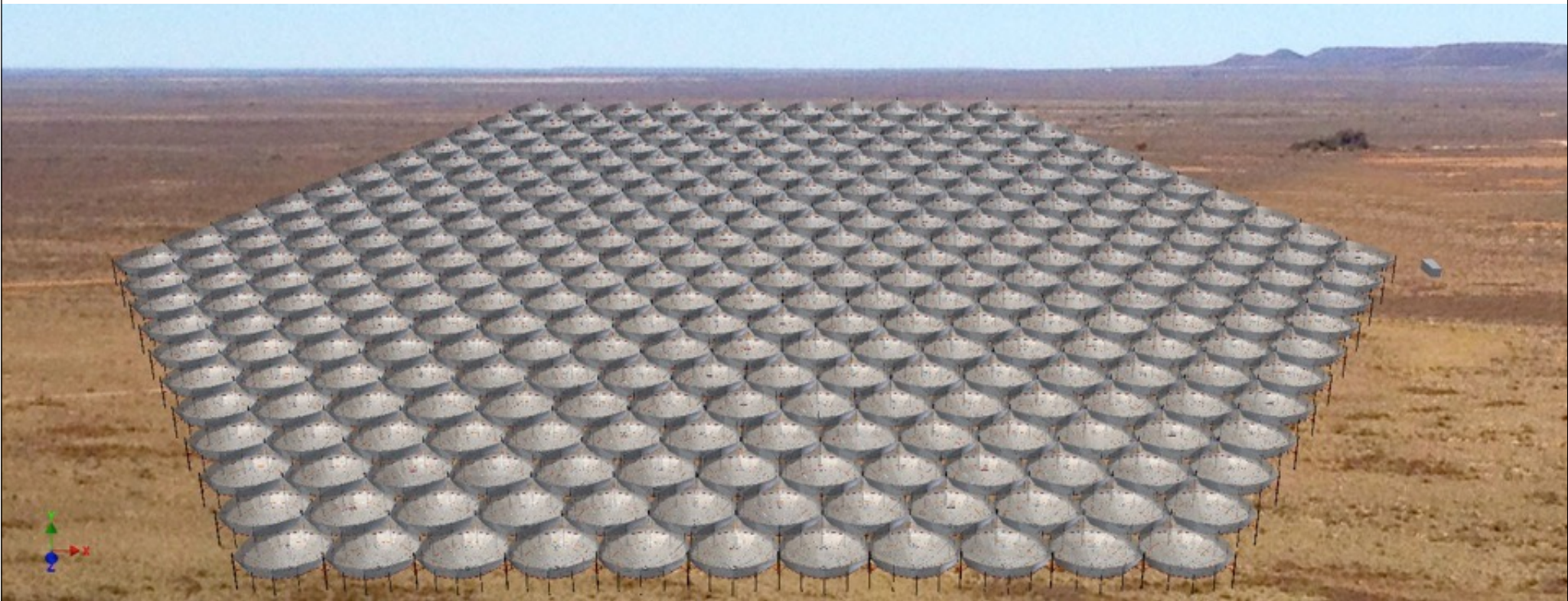
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Understanding reionization (especially the CMB optical depth) can improve constraints on other cosmological parameters

Better CMB through Better 21cm:

By reducing uncertainties and degeneracies arising from reionization, 21cm cosmology has the potential to improve cosmological constraints from the CMB.

Hydrogen Epoch of Reionization Array (HERA)



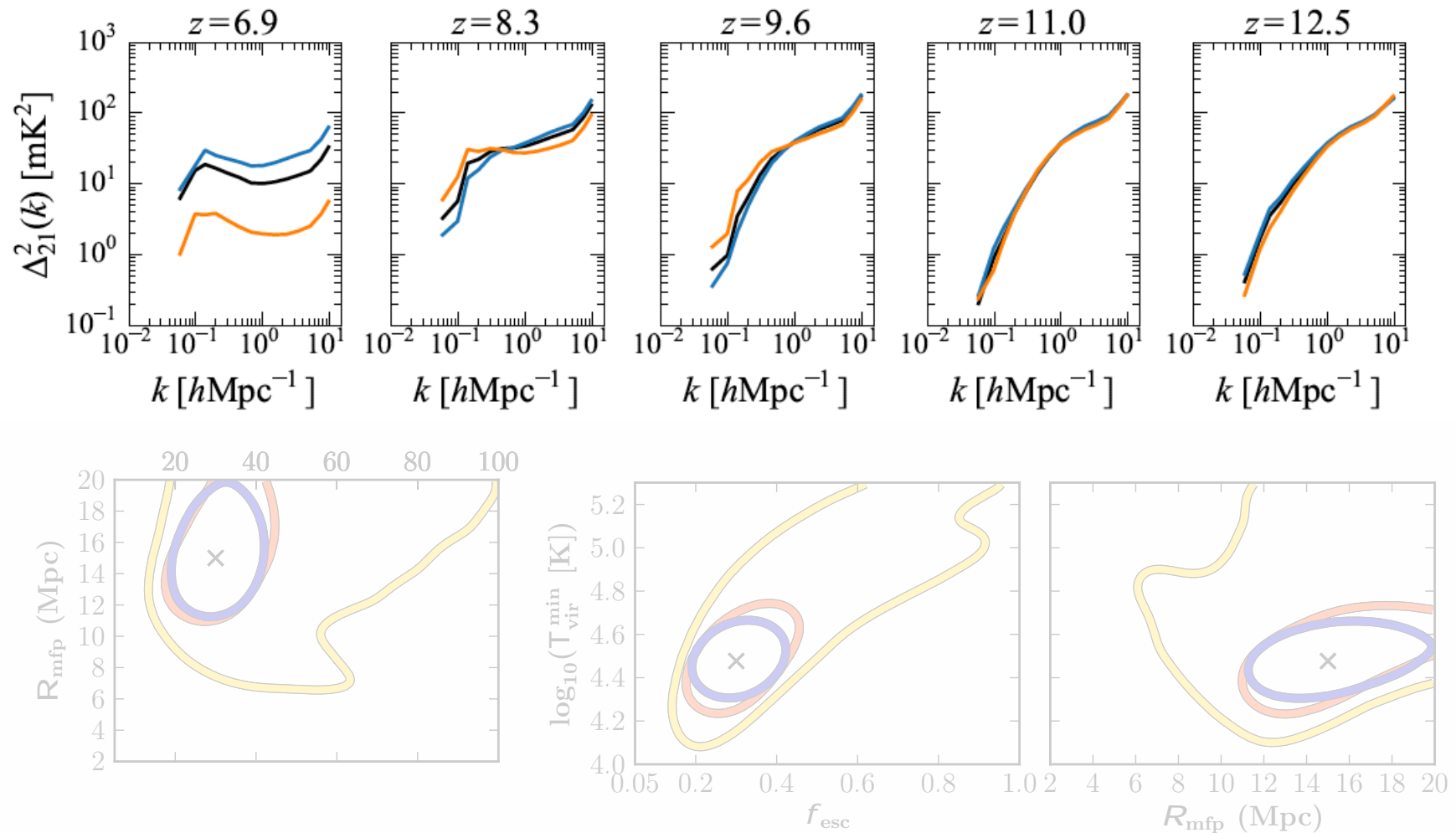
See reionization.org for more details!

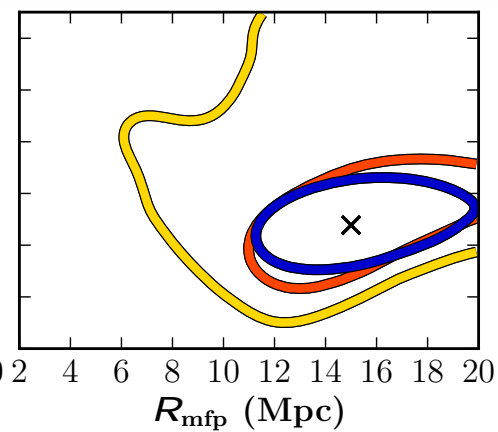
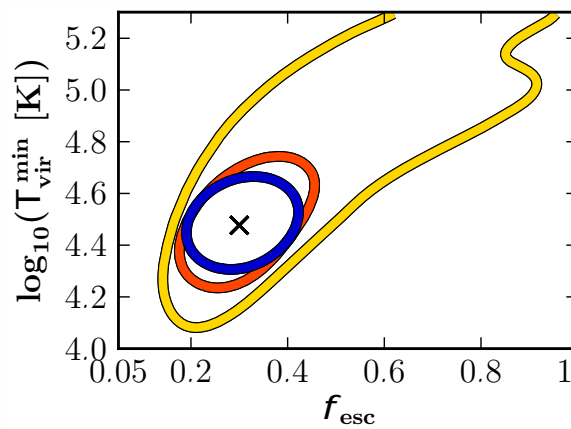
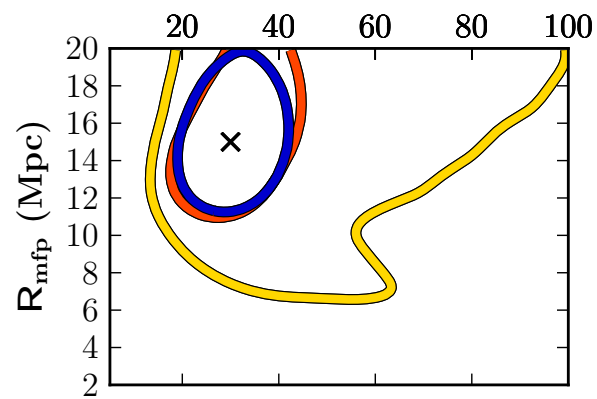
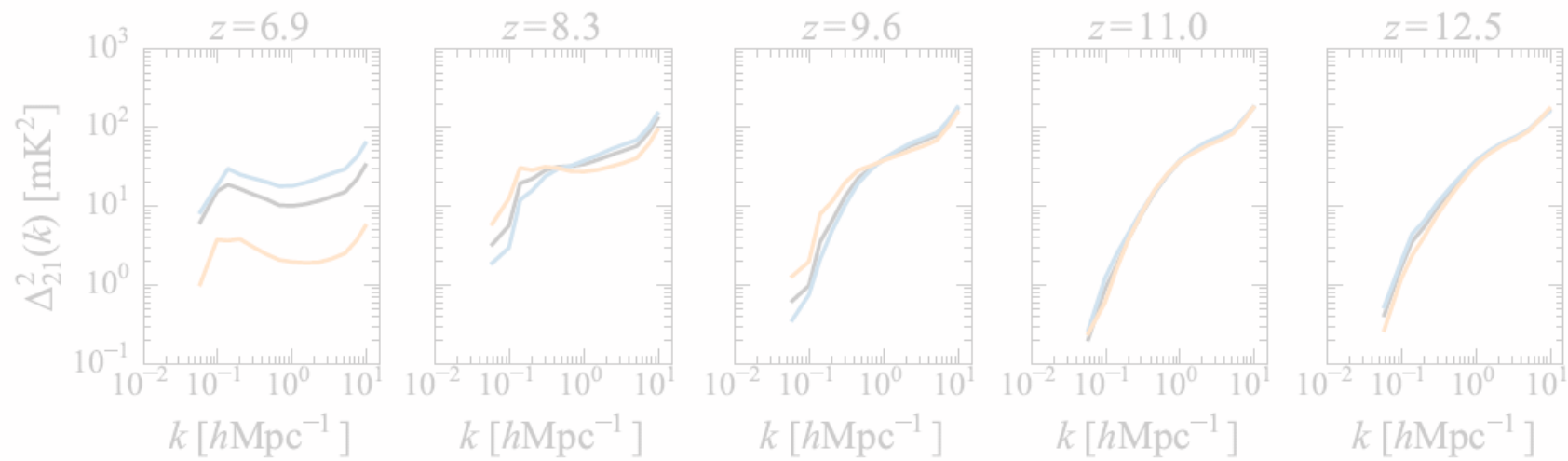


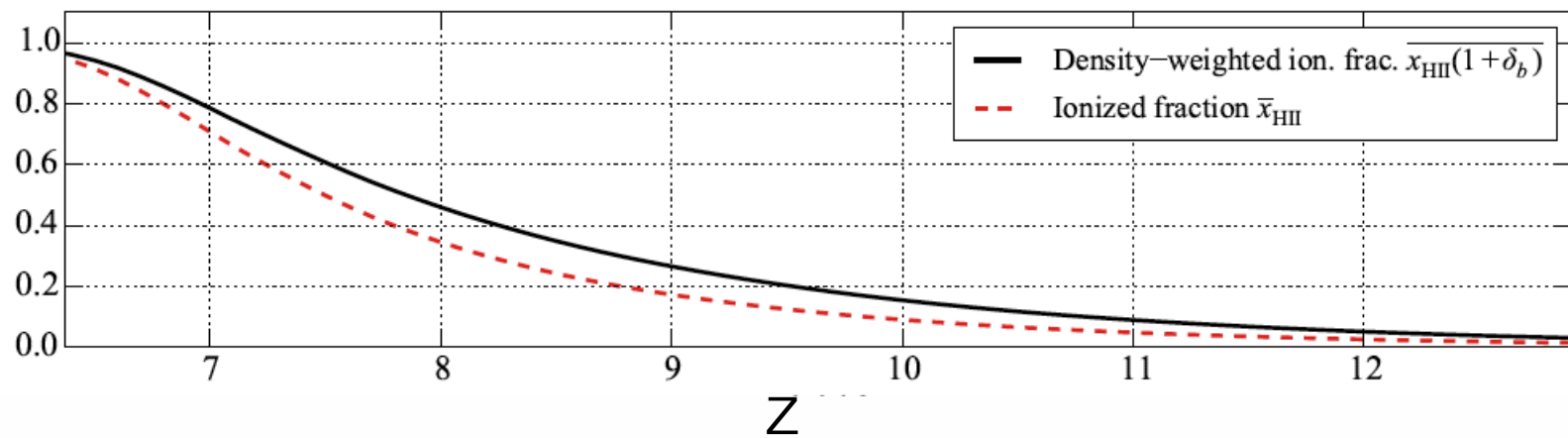
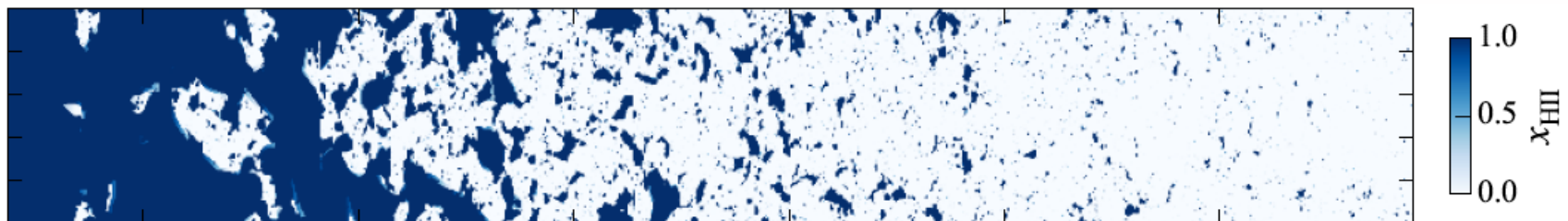
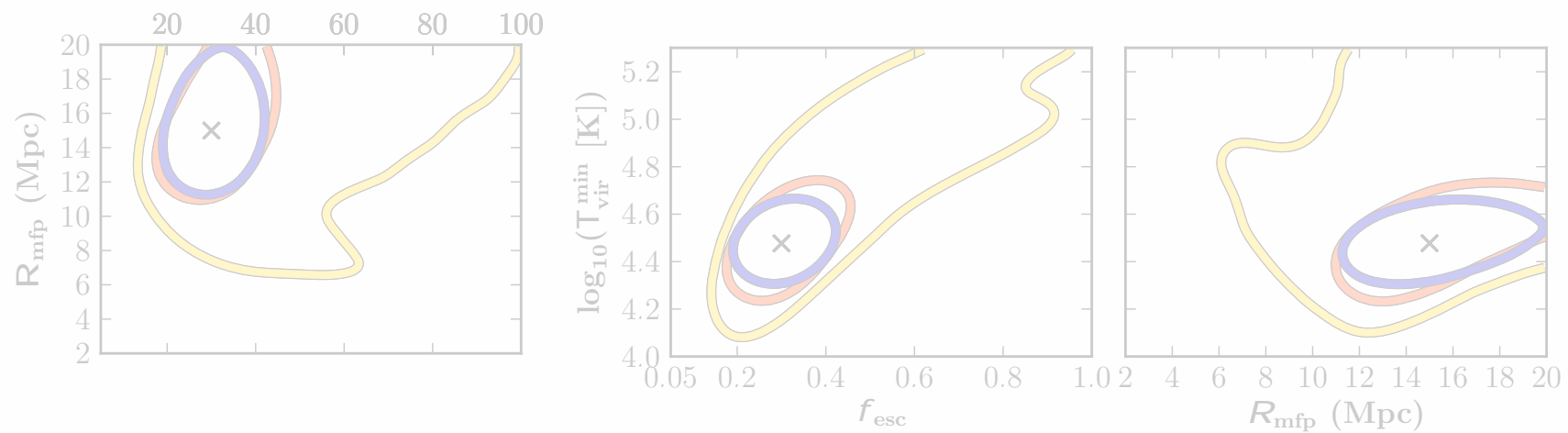


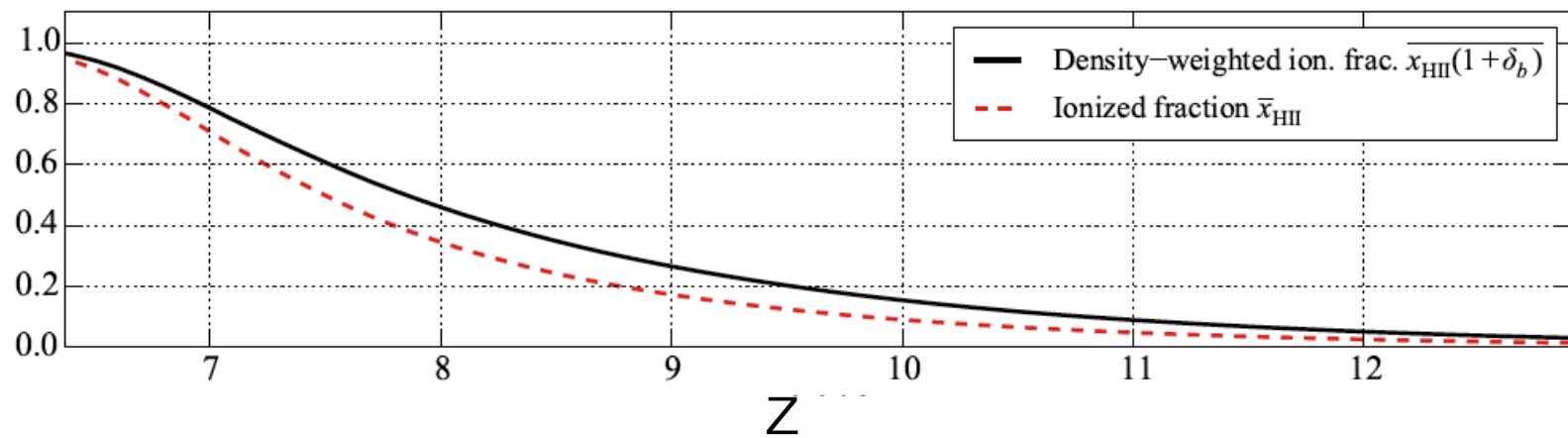
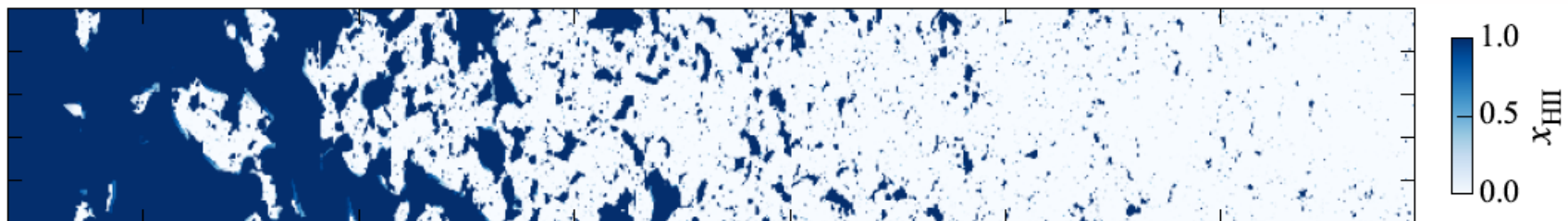
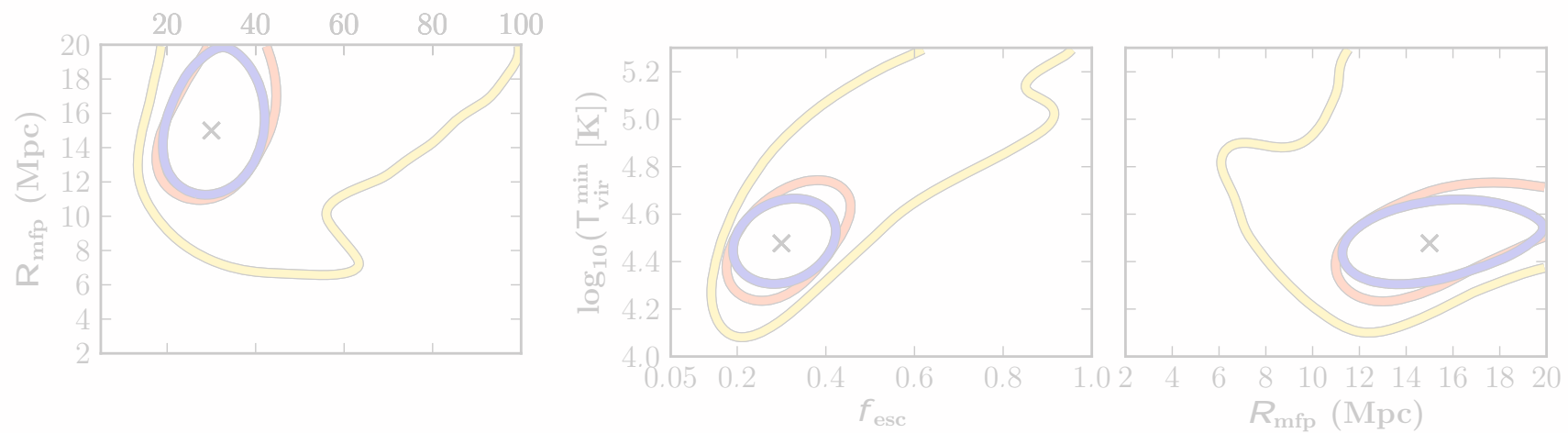
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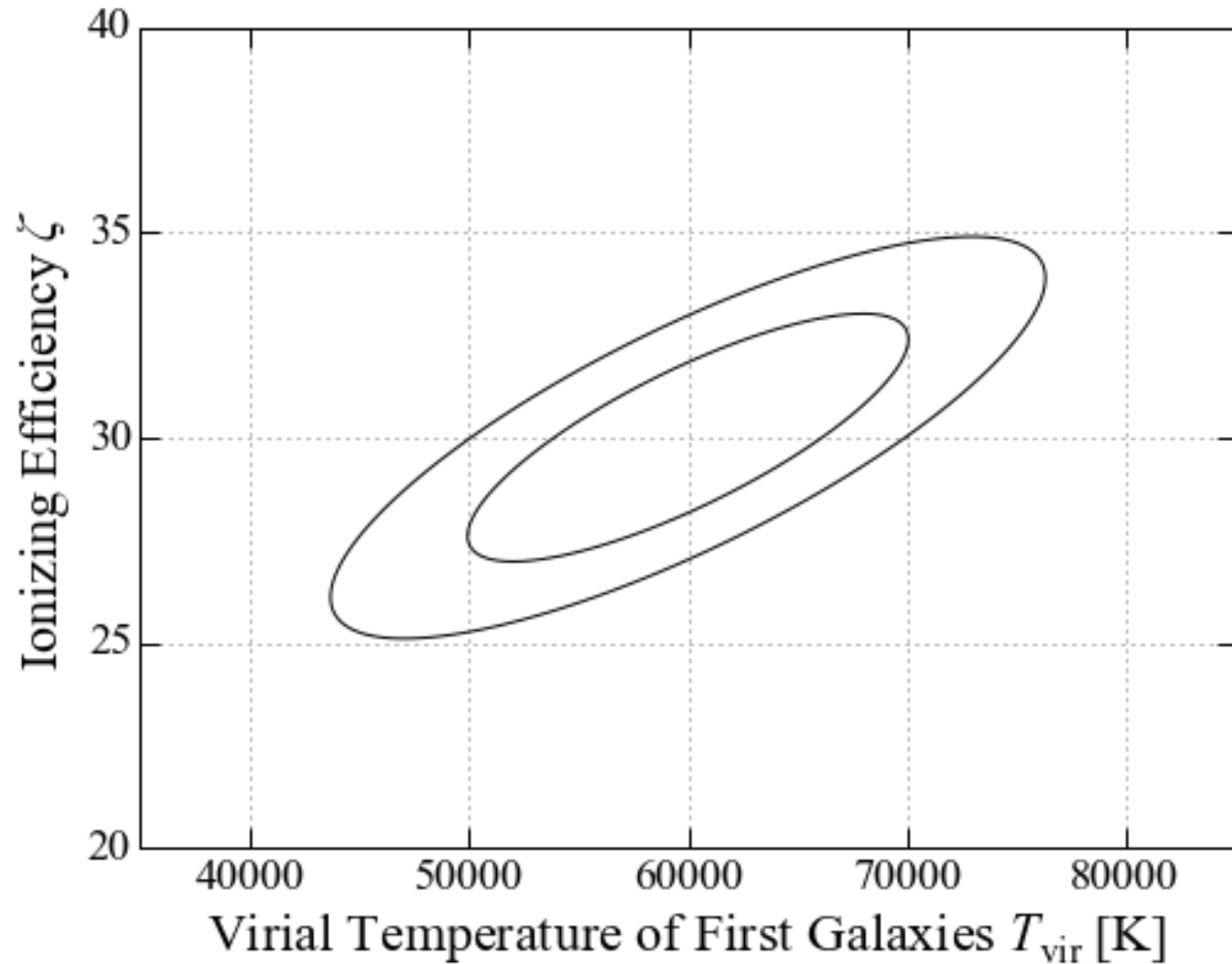






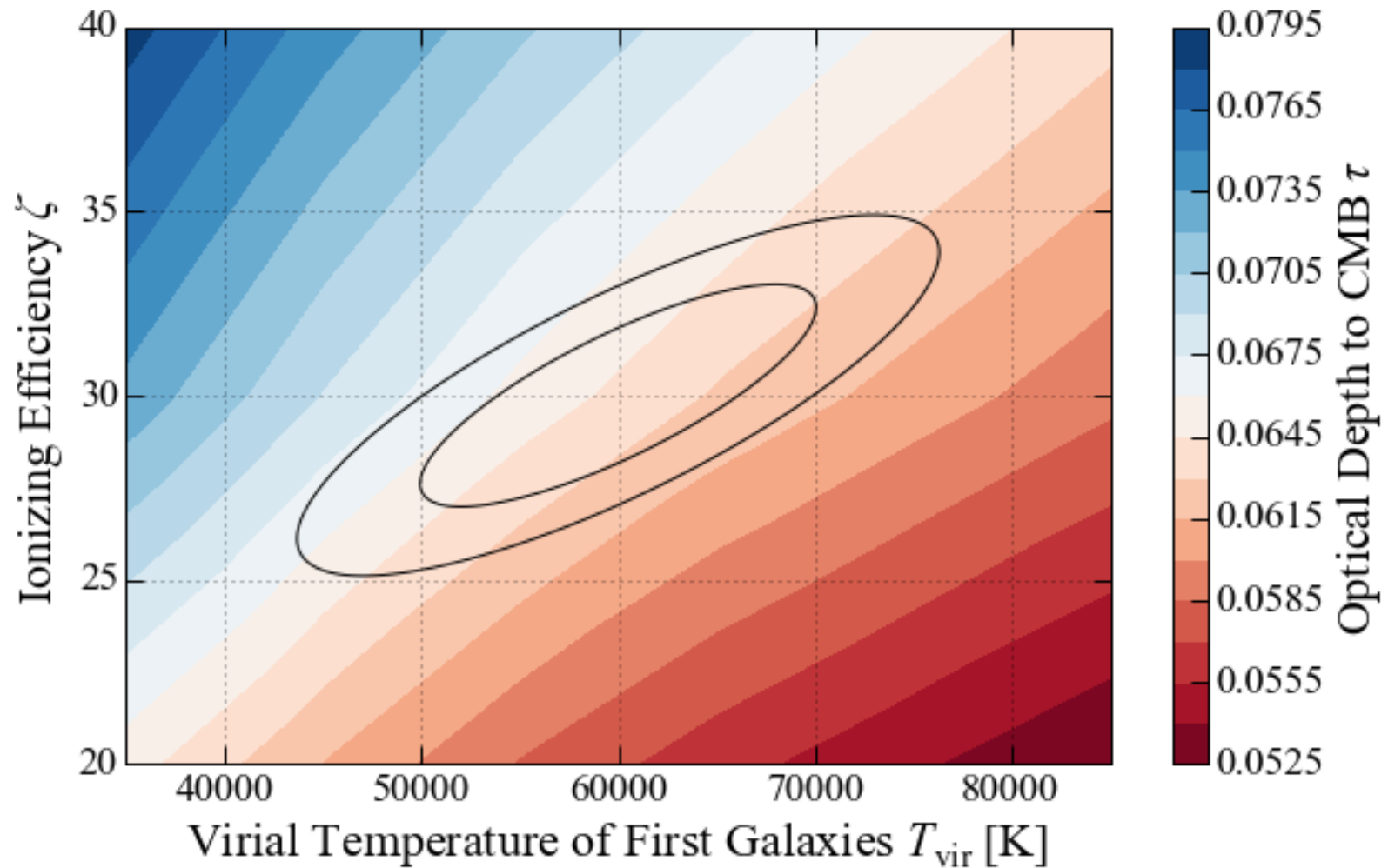
$$\tau \propto \int \langle x_i \rho_b \rangle dz$$

Parameter degeneracies will exist
even with HERA's sensitivity



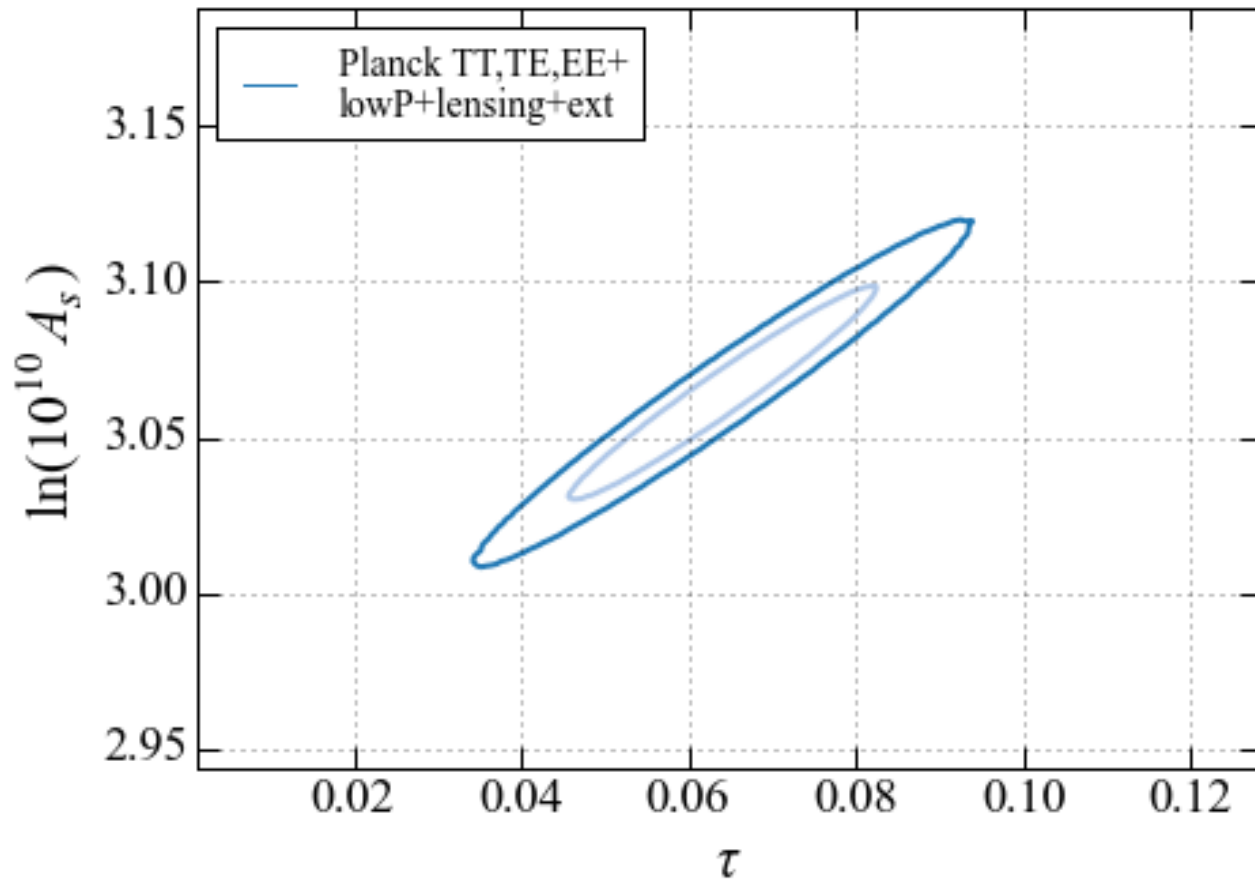
AL & Parsons (2015)

The degeneracies don't detract too much from our ability to measure τ

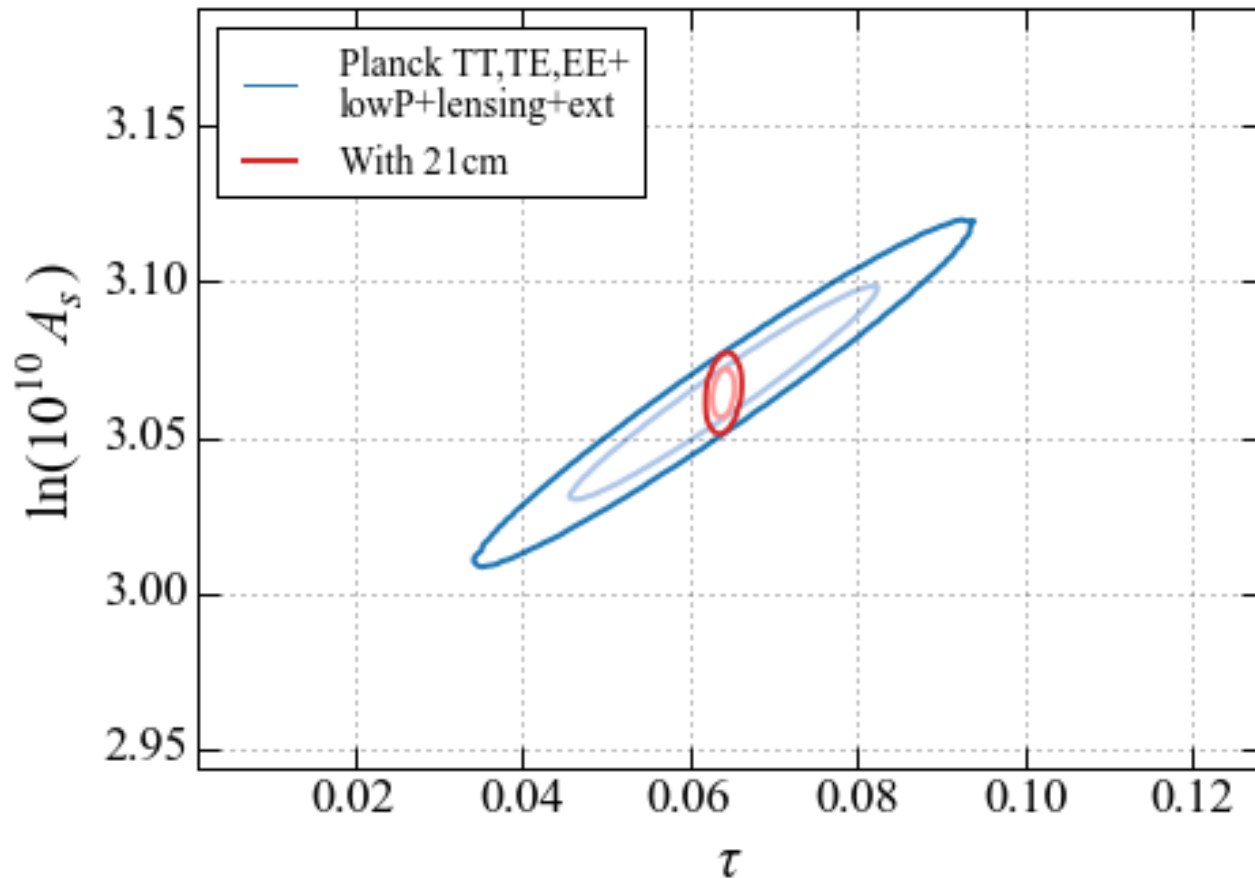


AL et al. (2015)

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

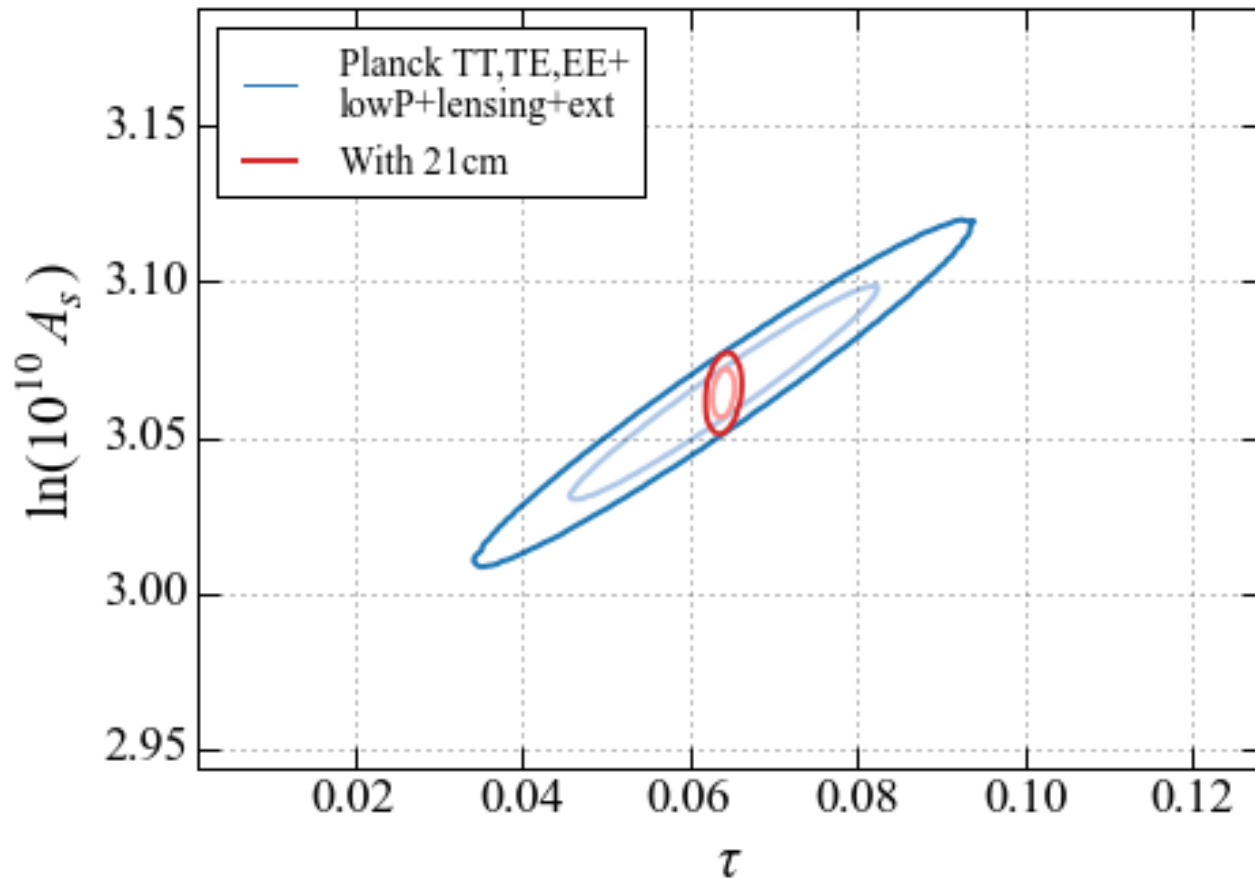


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$$\Delta \ln(10^{10} A_s) = \pm 0.023 \longrightarrow \pm 0.0053$$

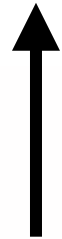
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Variance of matter fluctuations on
 $R = 8 h^{-1} \text{Mpc}$ scales today

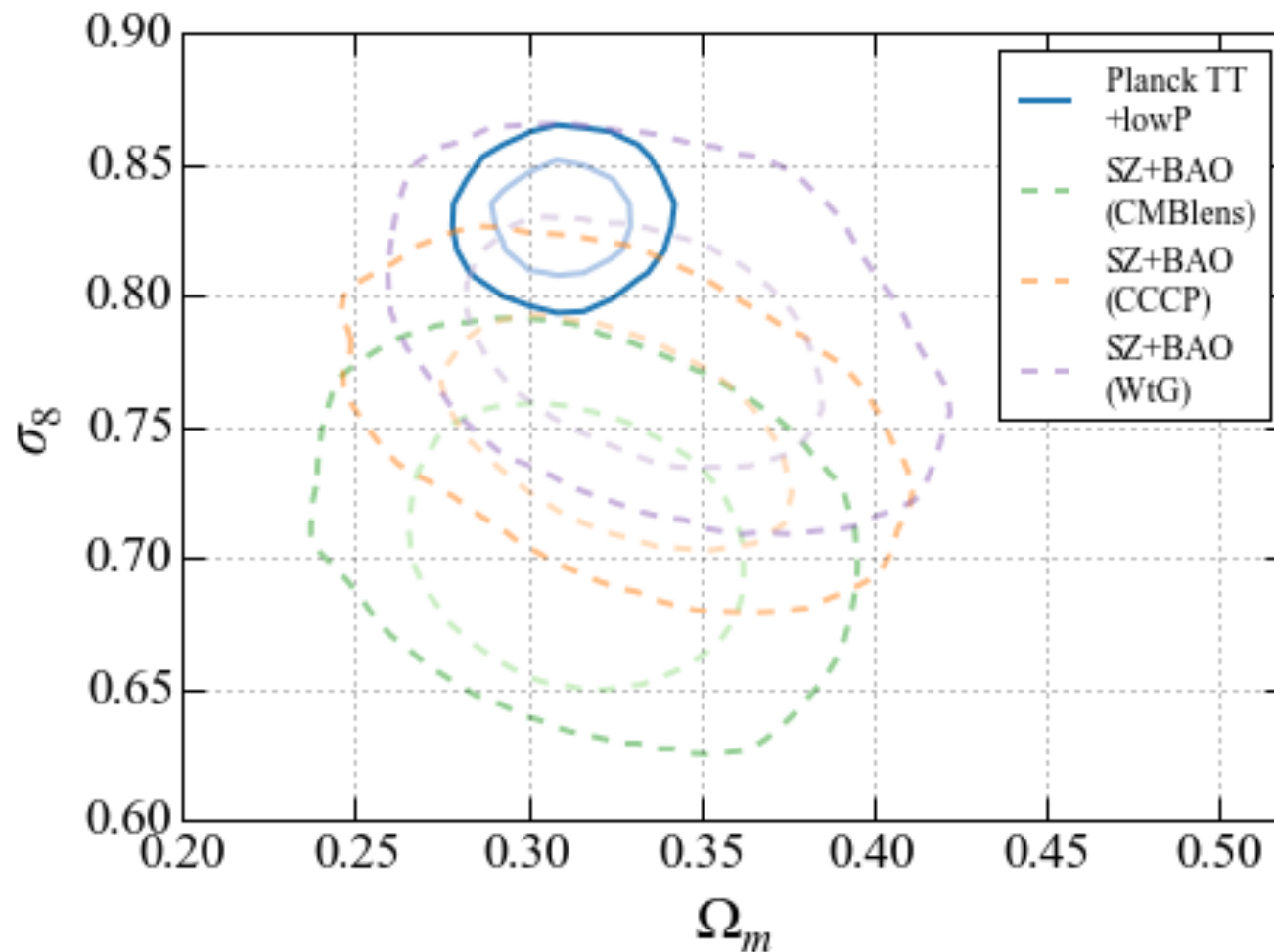
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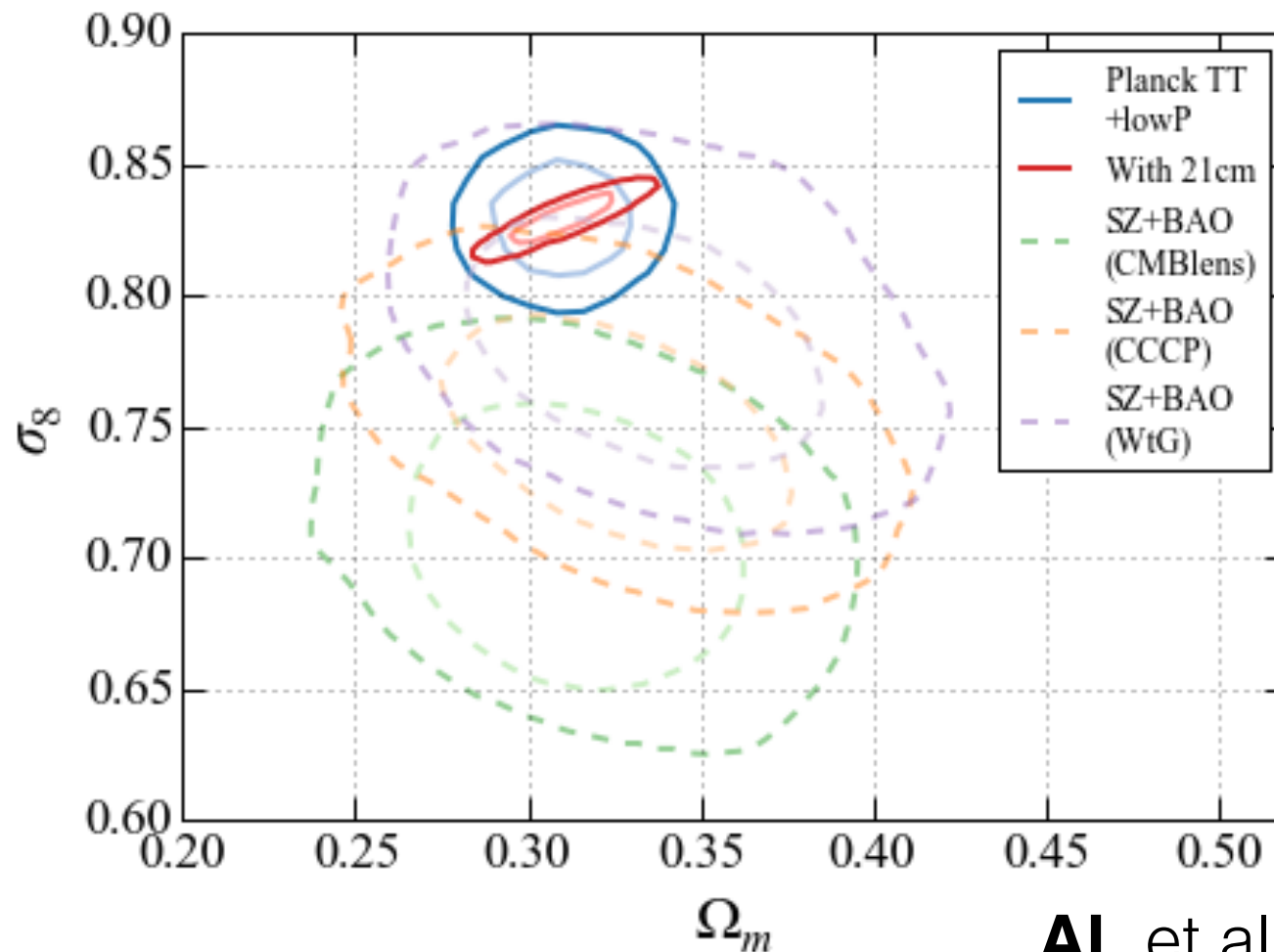
Variance of matter fluctuations on
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Matter power spectrum today
Depends on both initial conditions
(e.g. A_s) and growth of structure

21cm information may shed light on current tensions between high and low redshift cosmology



21cm information may shed light on current tensions between high and low redshift cosmology



AL et al. (2015)

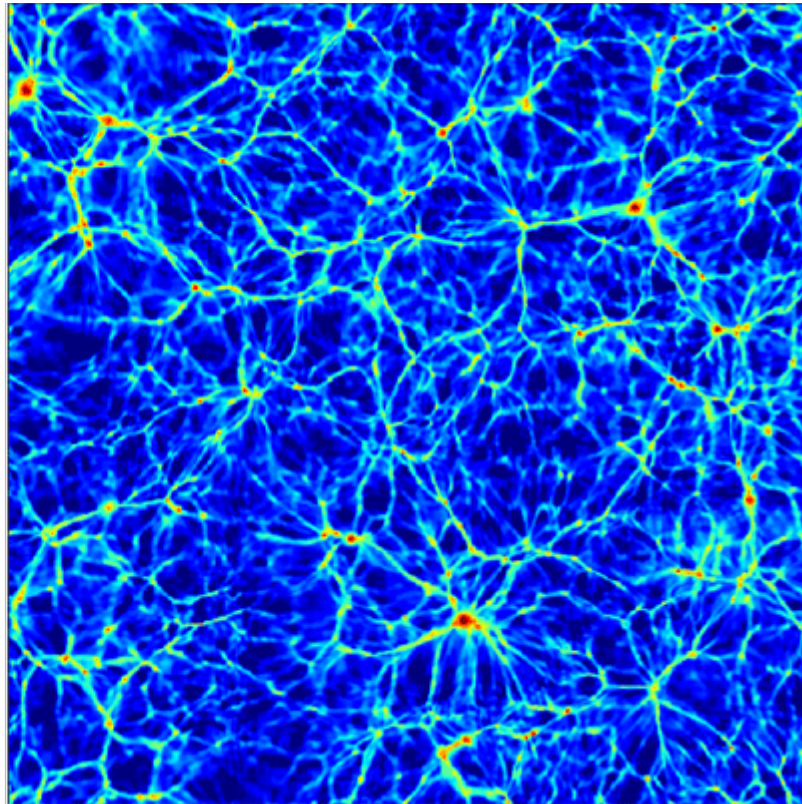
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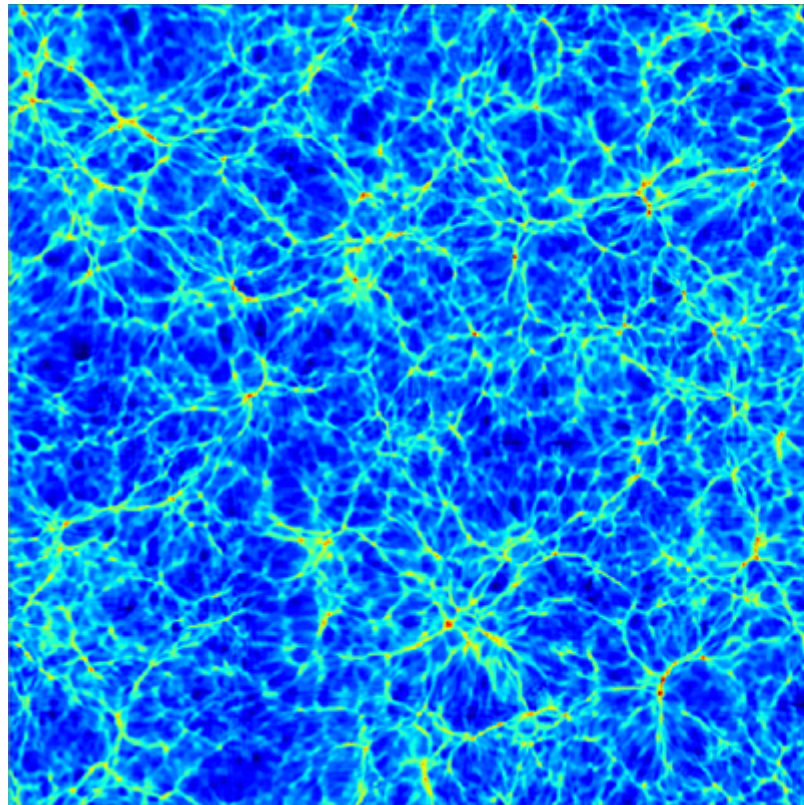


Without
neutrinos

Agarwal &
Feldman 2011

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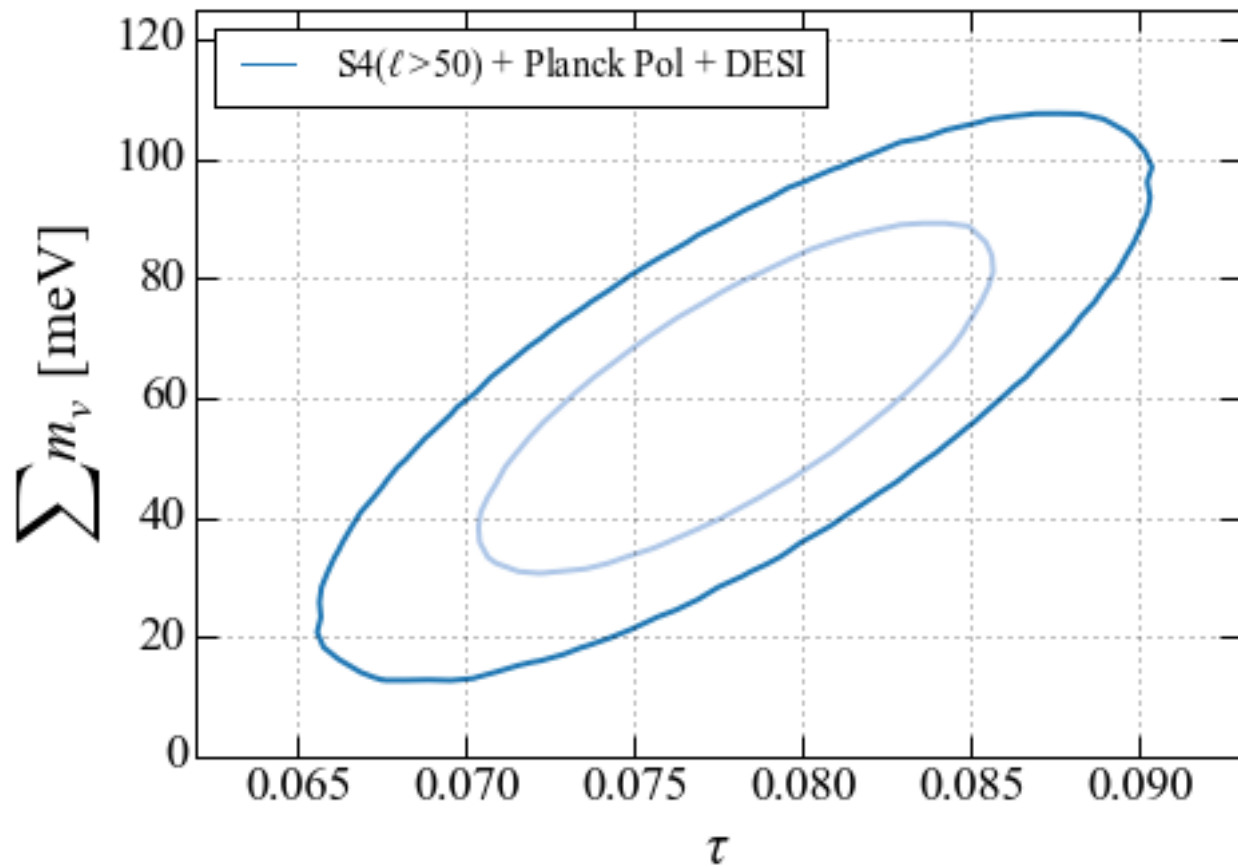


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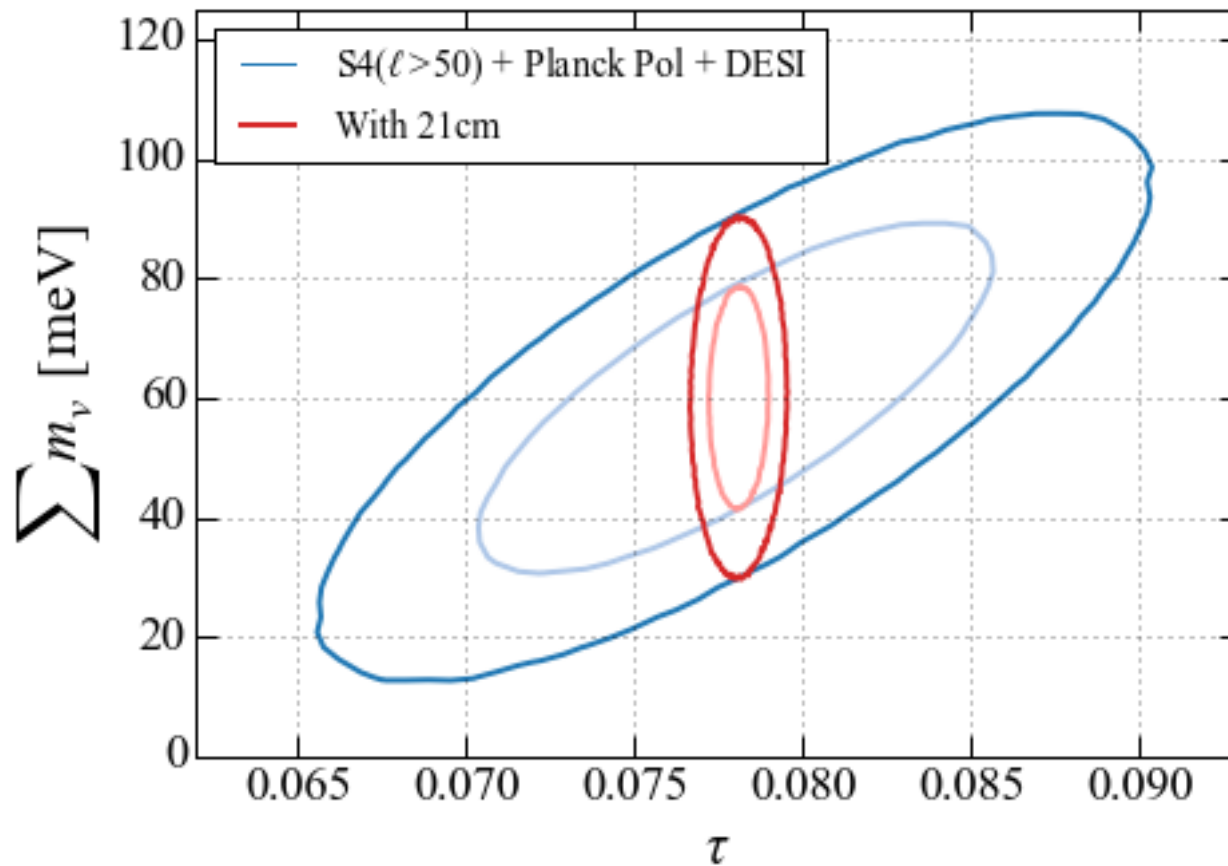
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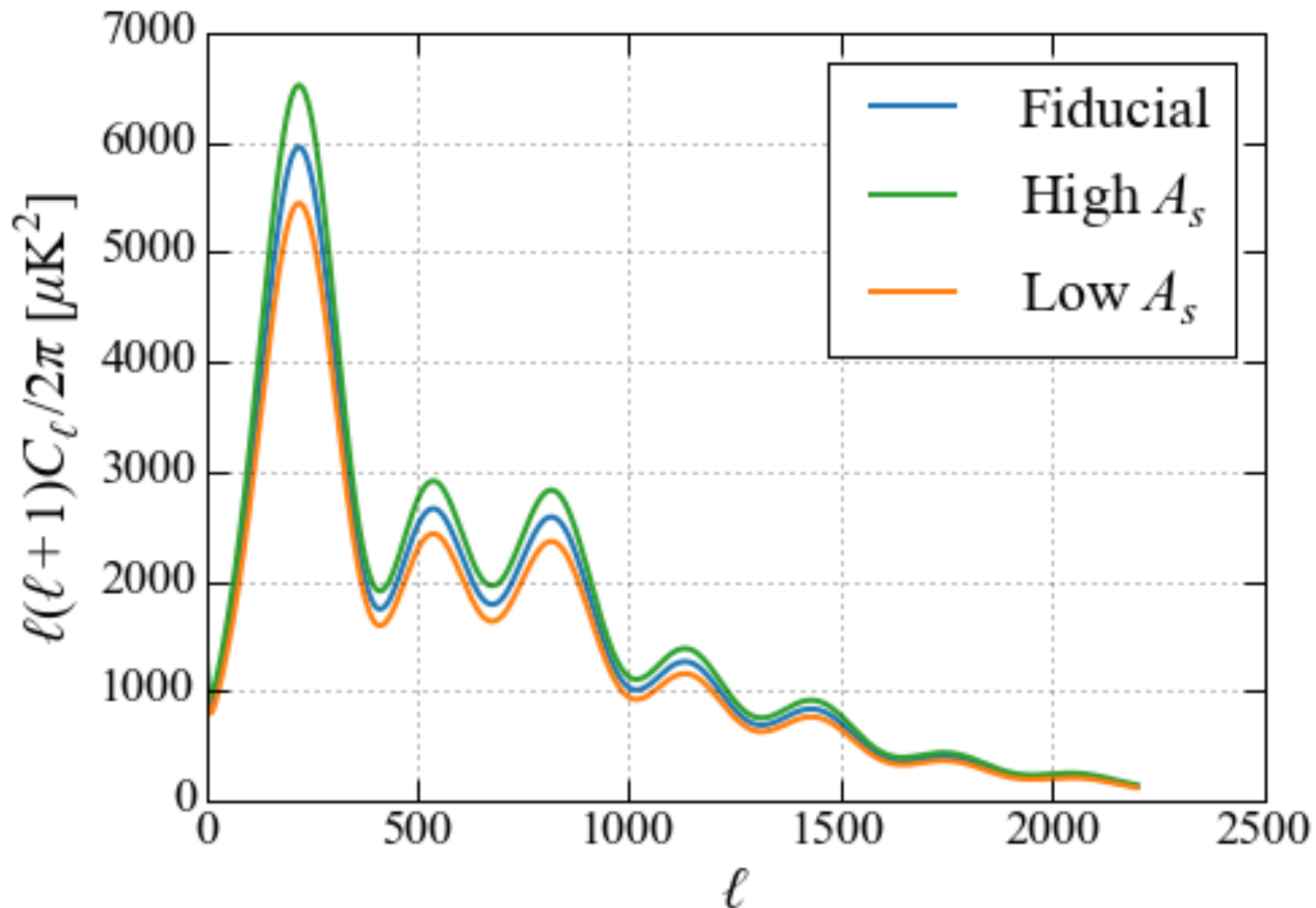
$$\sum m_\nu = 60 \pm 19 \text{ meV} \longrightarrow \pm 12 \text{ meV}$$

Better CMB through Better 21cm:

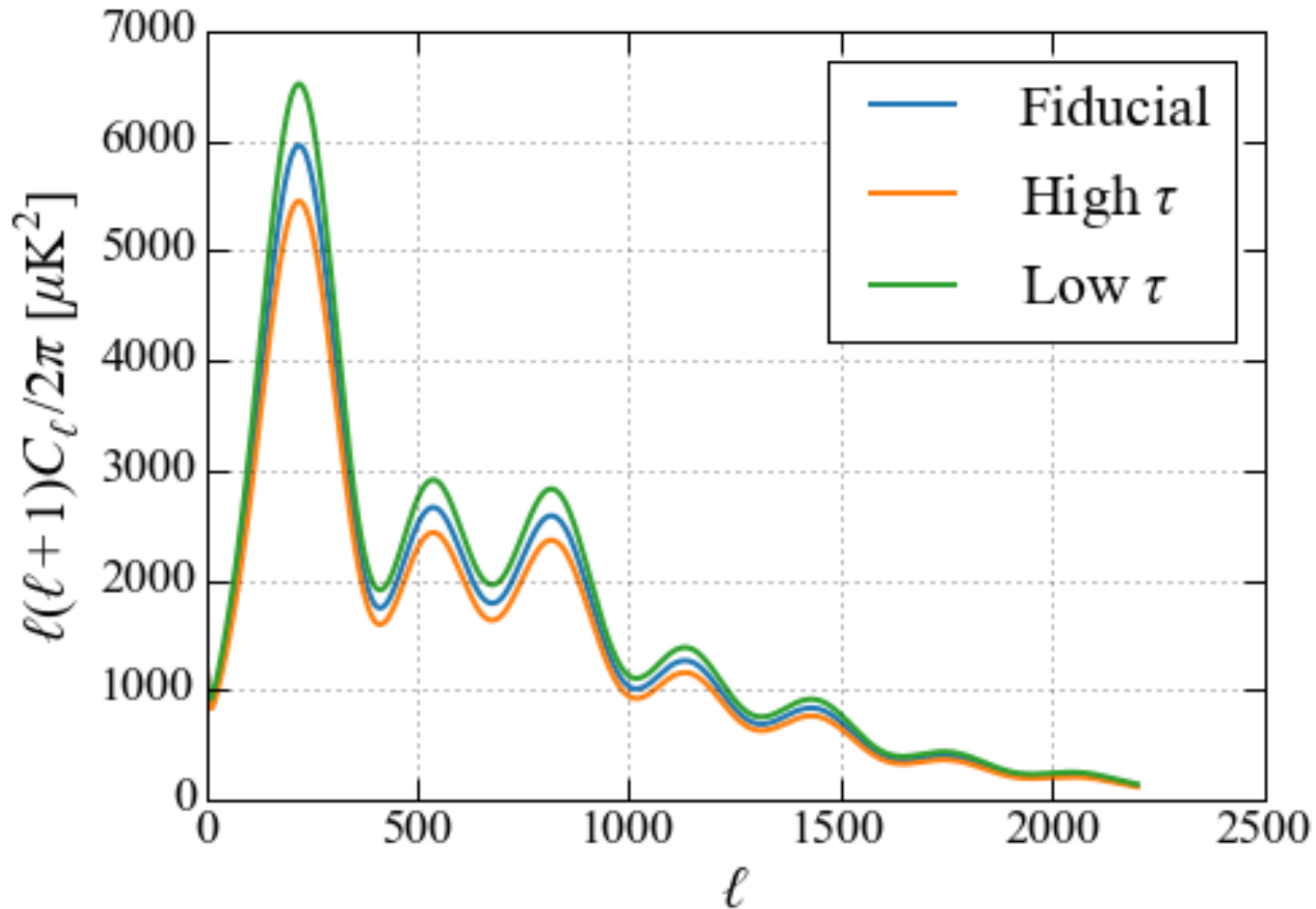
By reducing uncertainties and degeneracies arising from reionization, 21cm cosmology has the potential to improve cosmological constraints from the CMB. HERA stands a good shot at doing this!

For details, see **AL** et al. (2015), arxiv: 1509.08463
AL & Parsons (2015), arxiv: 1510.08815

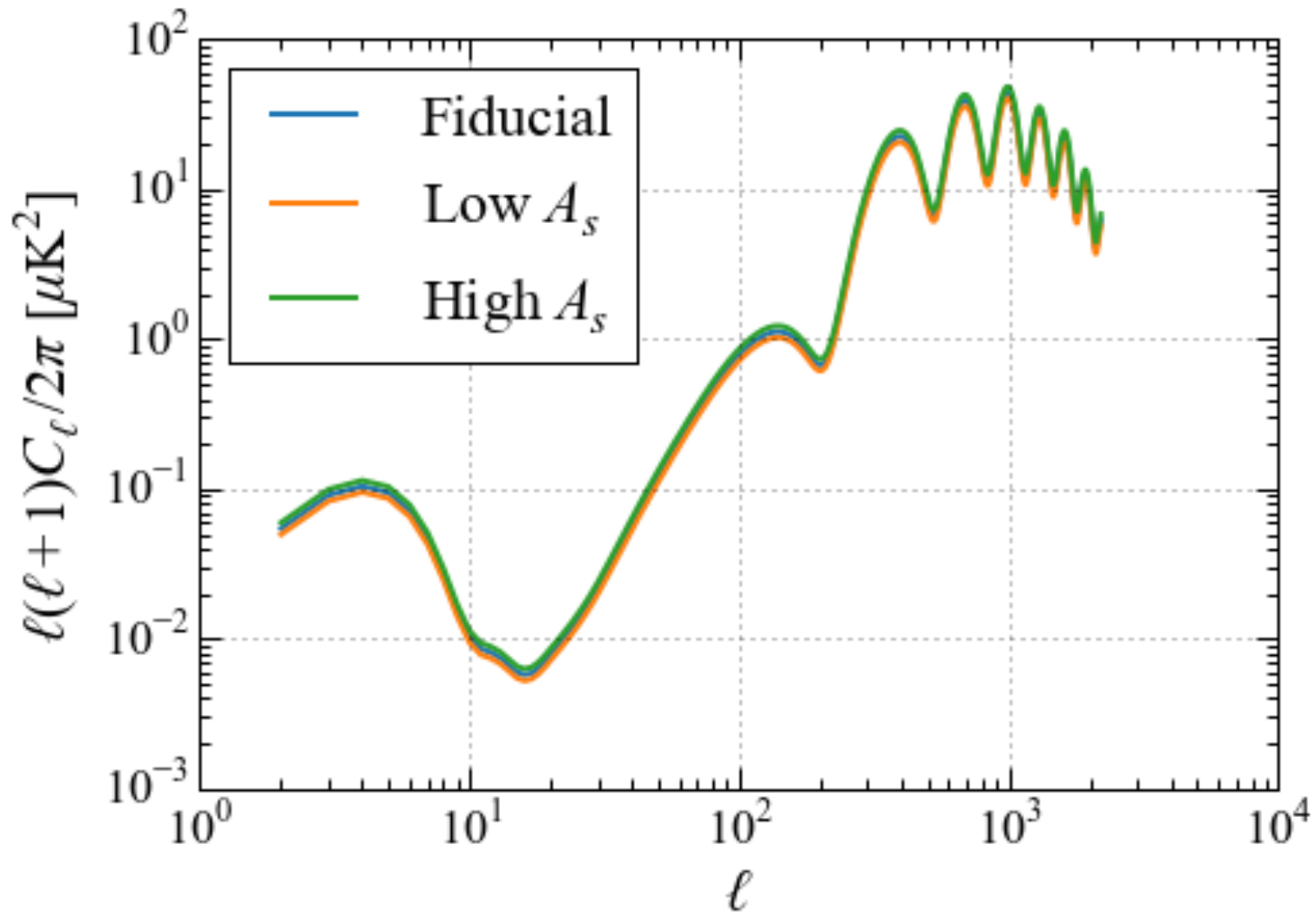
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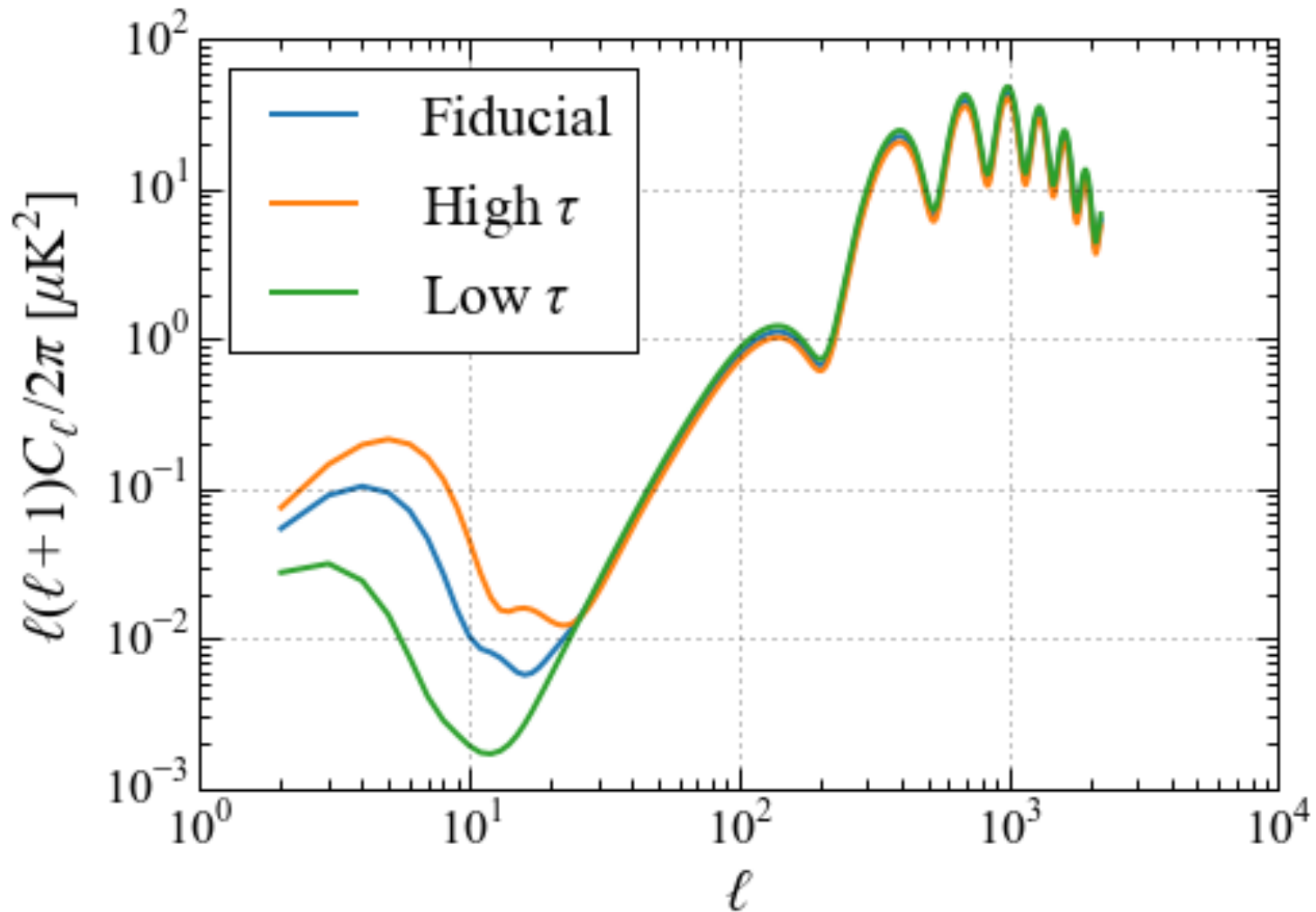
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Reionization sources new polarization anisotropies, and thus can potentially break degeneracies...



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...but it's hard

