Does Planck 2015 Polarization Favor High Redshift Reionization?

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Chen Heinrich[1] & Wayne Hu[2]

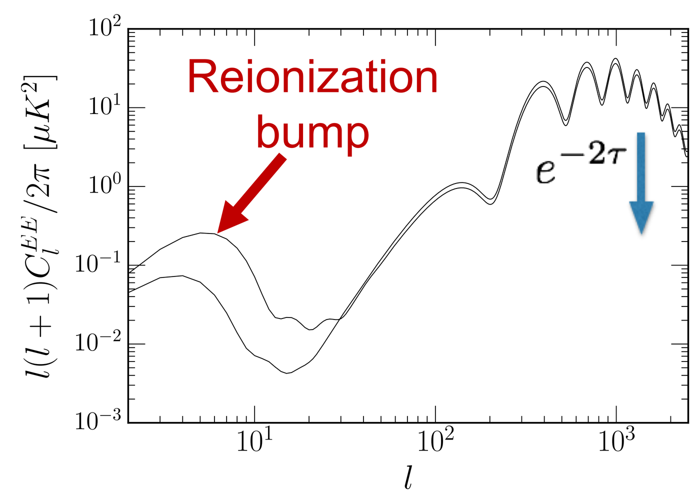
[1]Jet Propulsion Laboratory, Caltech, USA; [2]Kavli Institute of Cosmological Physics, University of Chicago, USA

National Aeronautics and Space Administration

How does the CMB probe reionization?

CMB E-mode polarization is generated at large scales from scattering of CMB γ with free e^- during reionization, roughly:

Peak height: how much scattering
Peak location: when it happened.



A: **The shape of reionization bump** in low-ℓ C_l^{EE} gives us coarse-grained information on the global ionization history.

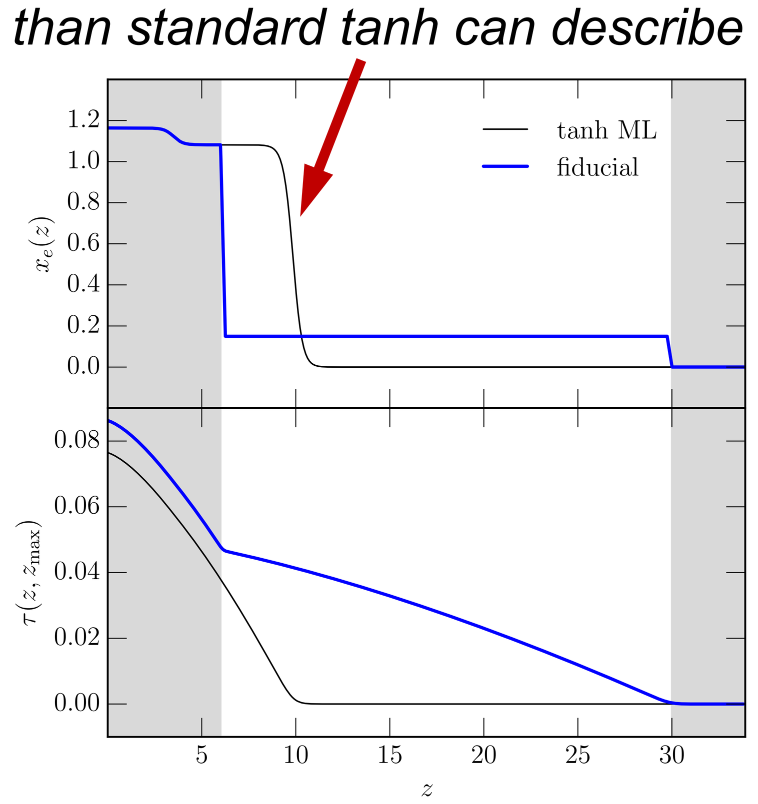
How to extract all the information?

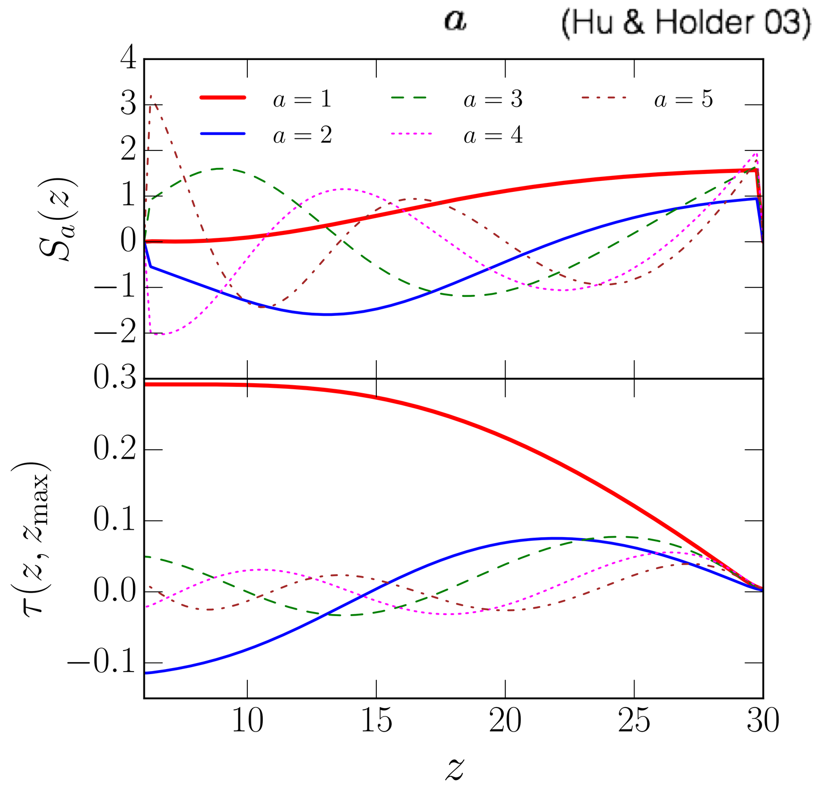
A: **Use principal components (PCs)**, the eigenfunctions S_a of Fisher matrix for C_l^{EE} wrt. ionization at different redshifts.

There is more info in the data than standard tanh can describe

$$x_e(z) = x_e^{\rm fid} + \sum_a m_a S_a(z)$$

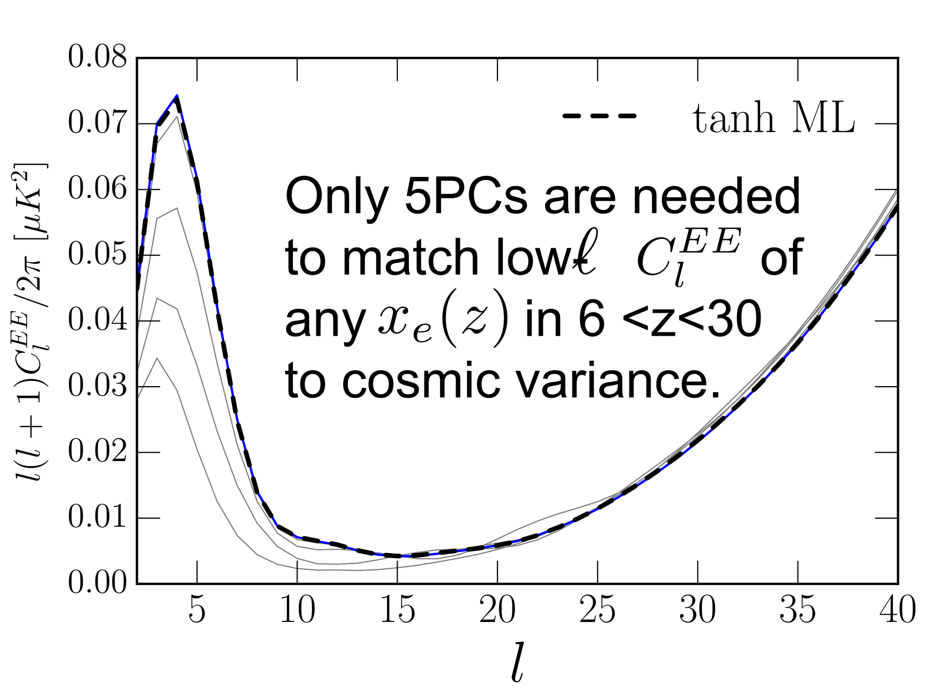
(Hu & Holder 03)

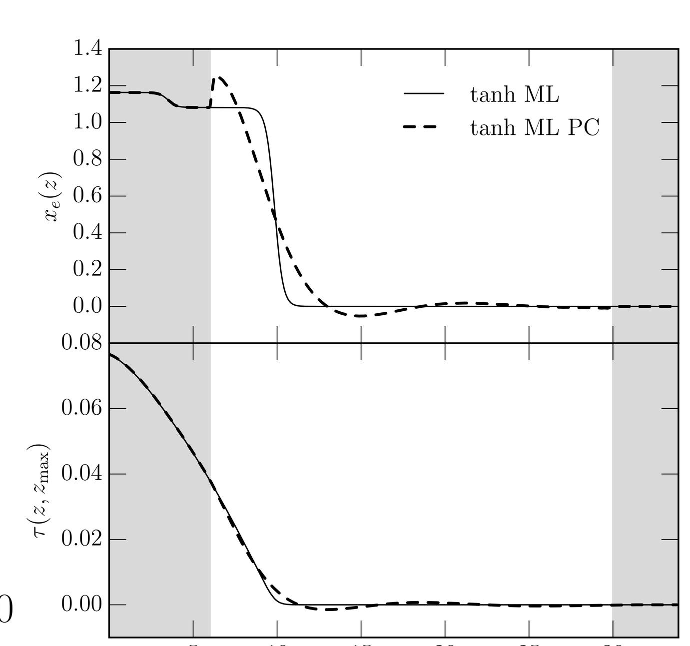




In what sense are PC analyses complete?

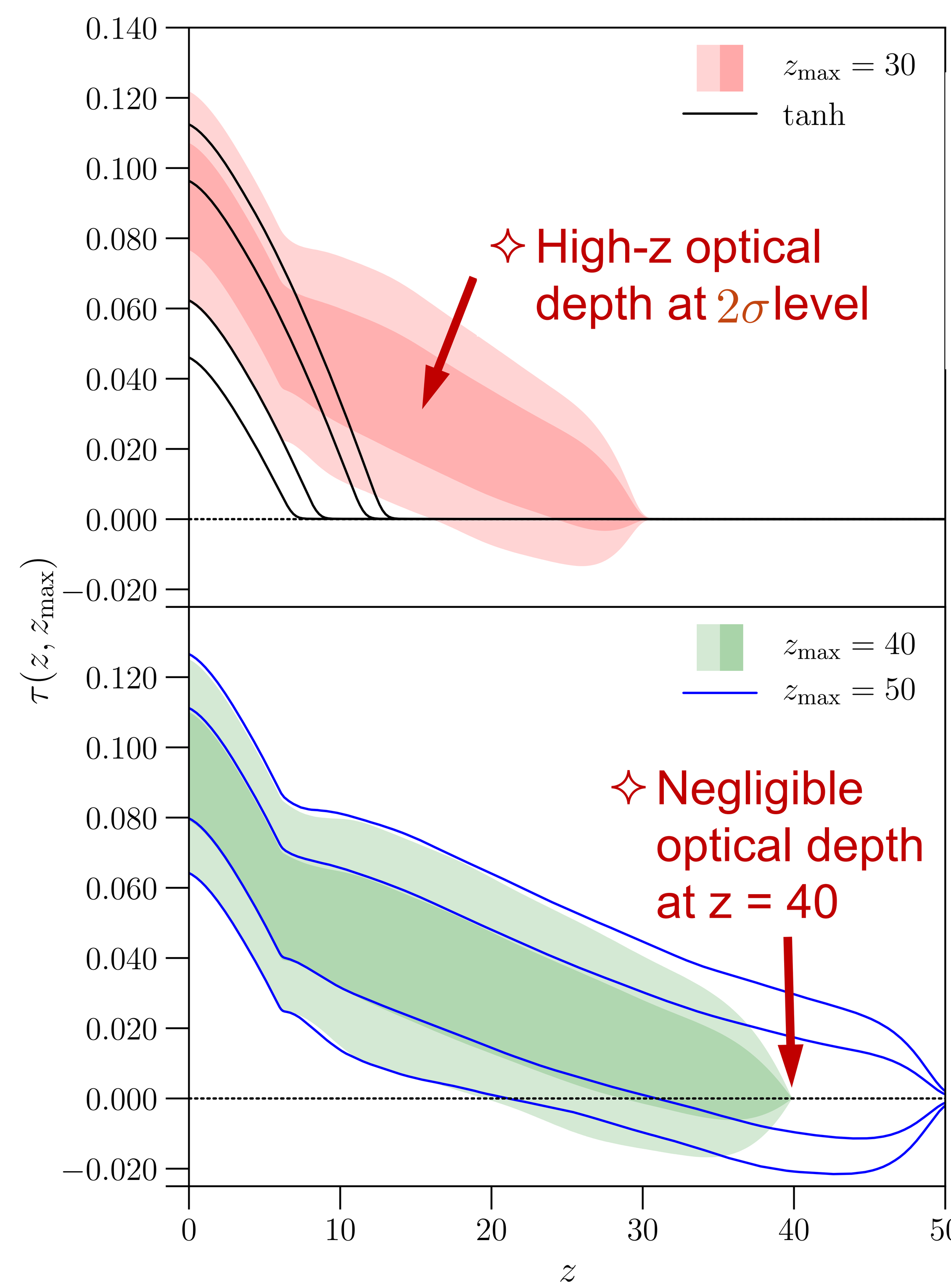
A: **PCs reproduce C_l^{EE} of any model to cosmic variance.**





Caution: PCs not meant to reconstruct $x_e(z)$ (right top), but designed for forward modeling (left). Data better reflected in τ evolution (left bottom).

Complete constraints from Planck 2015



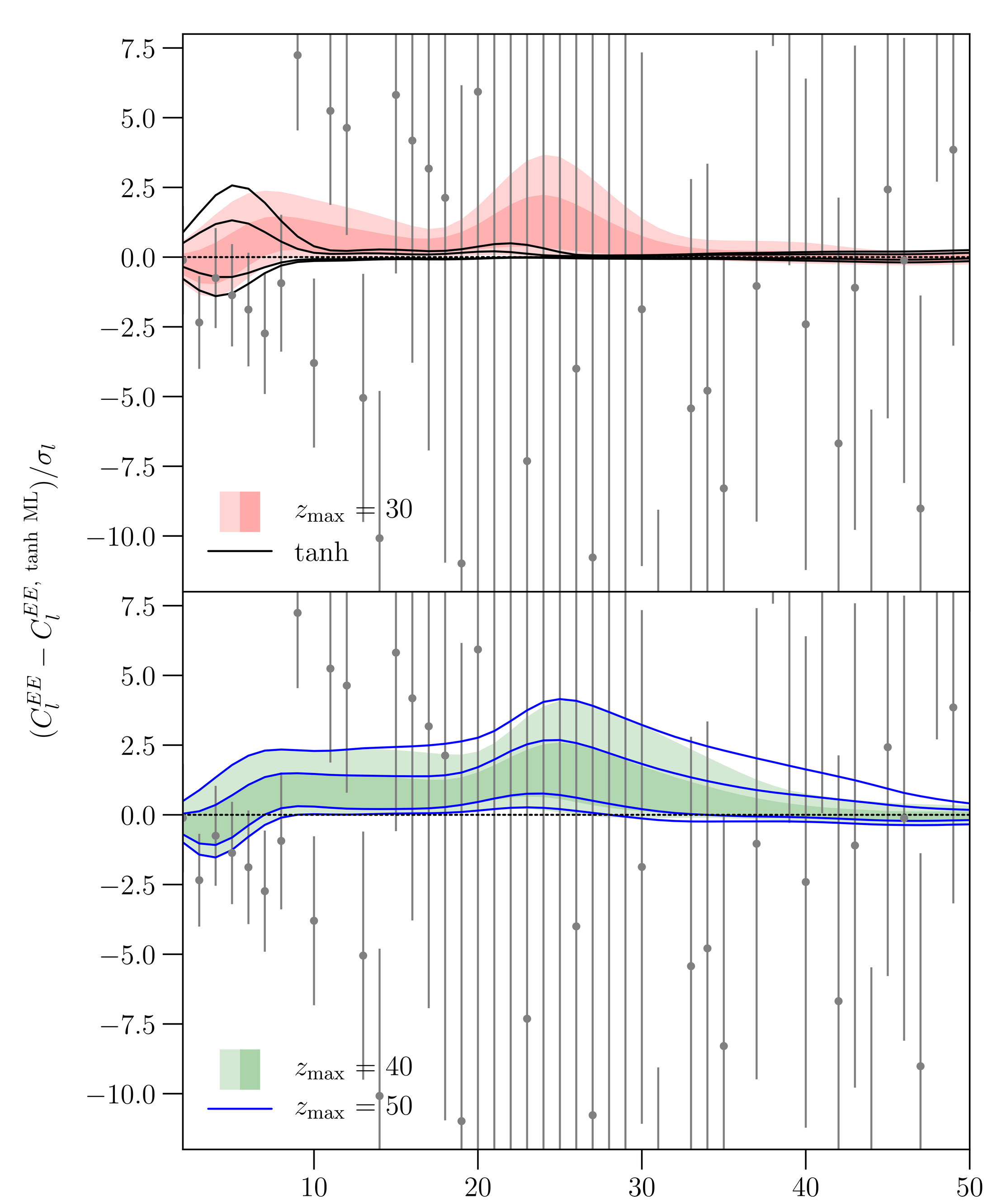
✧ Tanh misses this since its functional form assumes no ionization before the transition.

✧ Extending zmax from 30 to 40, we find the point of 2σ excess moved from. z ~ 15 to 20.

✧ PC results are stable between zmax = 40 & 50

Recall: optical depth reflects data sensitivity better than $x_e(z)$.

Origin of the hint for high-z ionization

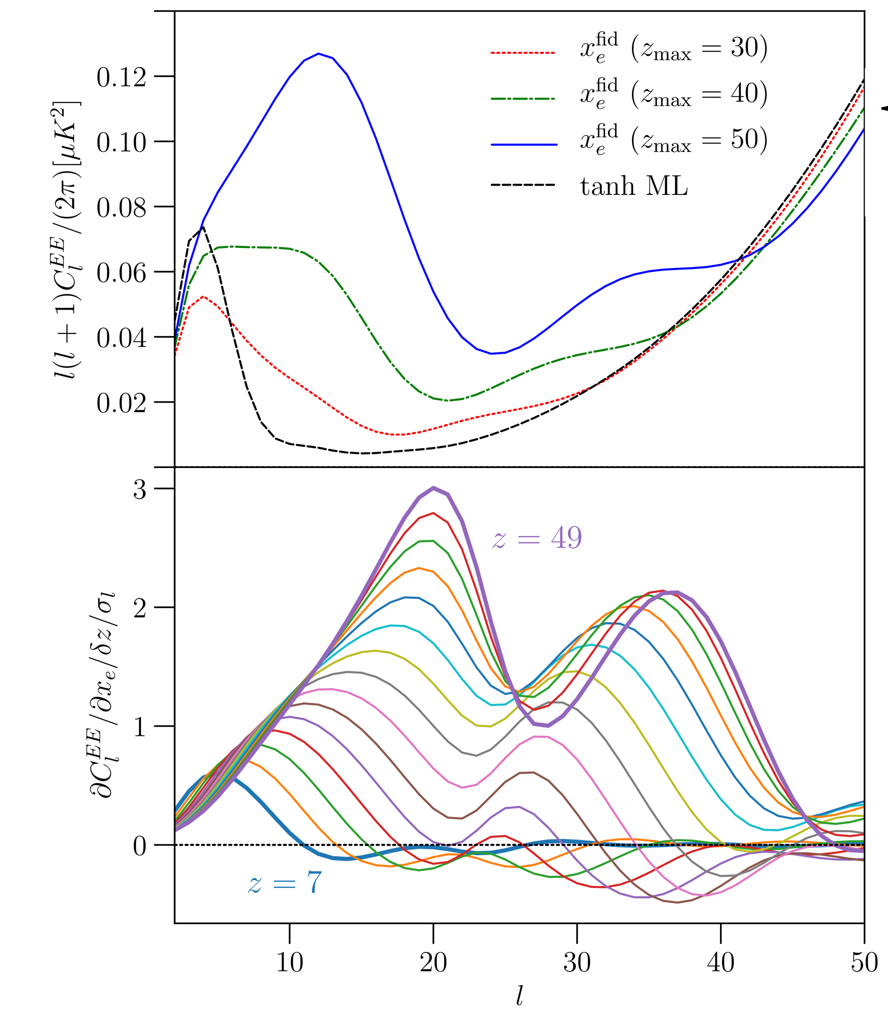


$\mathbf{l \leq 7}$
most constraining part (similar fit in all analyses)

$\mathbf{l \sim 10}$
PCs fit better than tanh at a few high points here (with high-z ion. allowed)

$\mathbf{l \sim 15-20}$
$\mathbf{l \gtrsim 30}$
CVL measurements here will discriminate high-z regime further (Planck 2015 has low S/N here)

From ionization to features in data



✧ To raise power at $l \sim 10$ requires $z \gtrsim 10$ ionization

✧ Most constraining part of Planck is at $l \lesssim 10$ in C_l^{EE}, but response is degenerate for $z \gtrsim 15$ ionization.

✧ Future measurements can better discriminate high-z ionization with $l \sim 15-20$ and $l \gtrsim 30$.

Conclusion

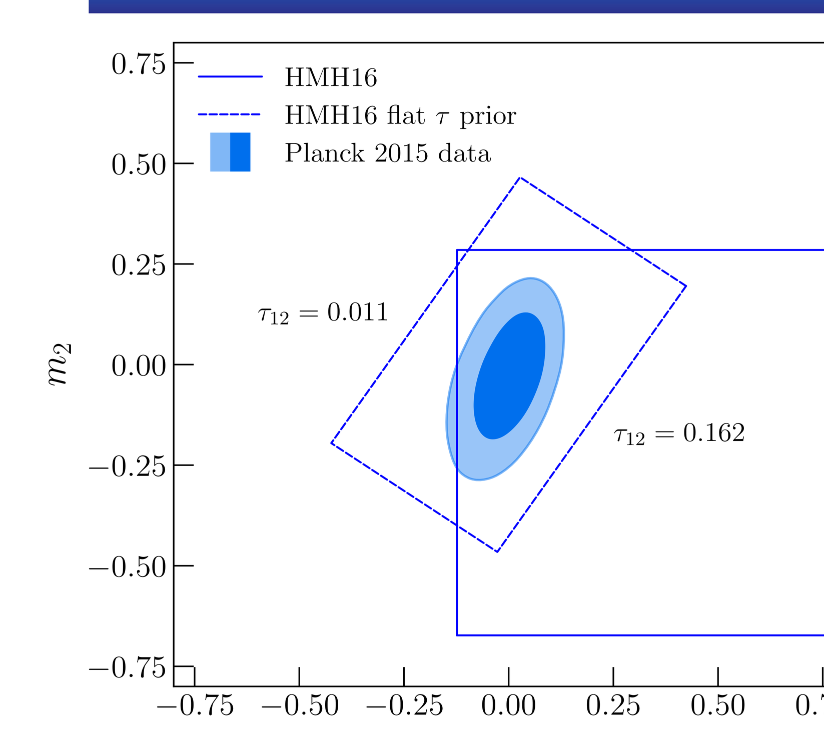
✧ **For models that allow it, high-z ionization is allowed and even preferred at 2σ level in the Planck 2015 data.**

✧ For models that don't allow high-z ionization (e.g. tanh), poorer fit indicates **systematic or statistical fluctuations**.

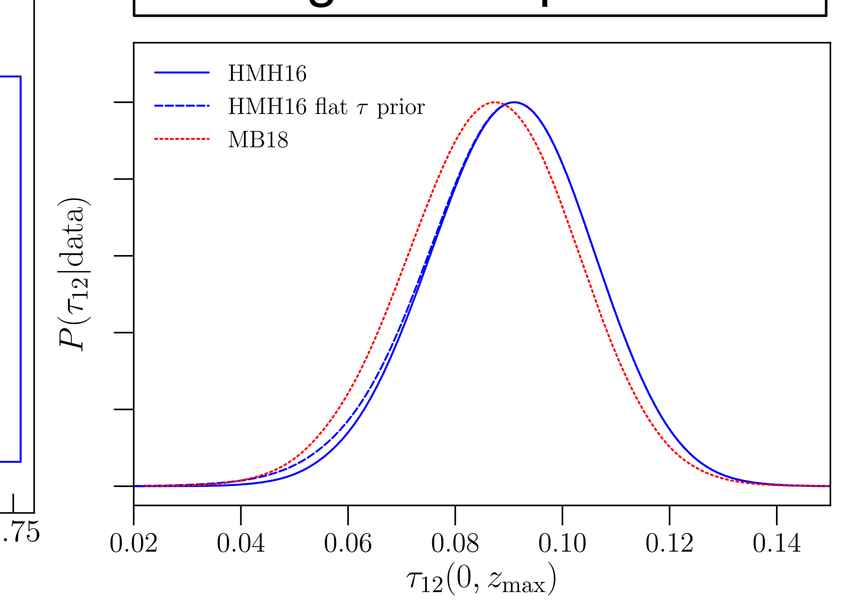
✧ Origin: higher C_l^{EE} data at $l \sim 10$ than tanh can fit.

✧ Planck 2015: negligible ionization at z > 40; CVL C_l^{EE} at $l \sim 15-20$ and $l \gtrsim 30$ can do better.

A note on priors



✧ Our results are robust to using flat tau prior.



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