Planck2016 PIP XLVI lowL pol

Reduction of large-scale systematic effects in HFI polarization maps and estimation of the reionization optical depth

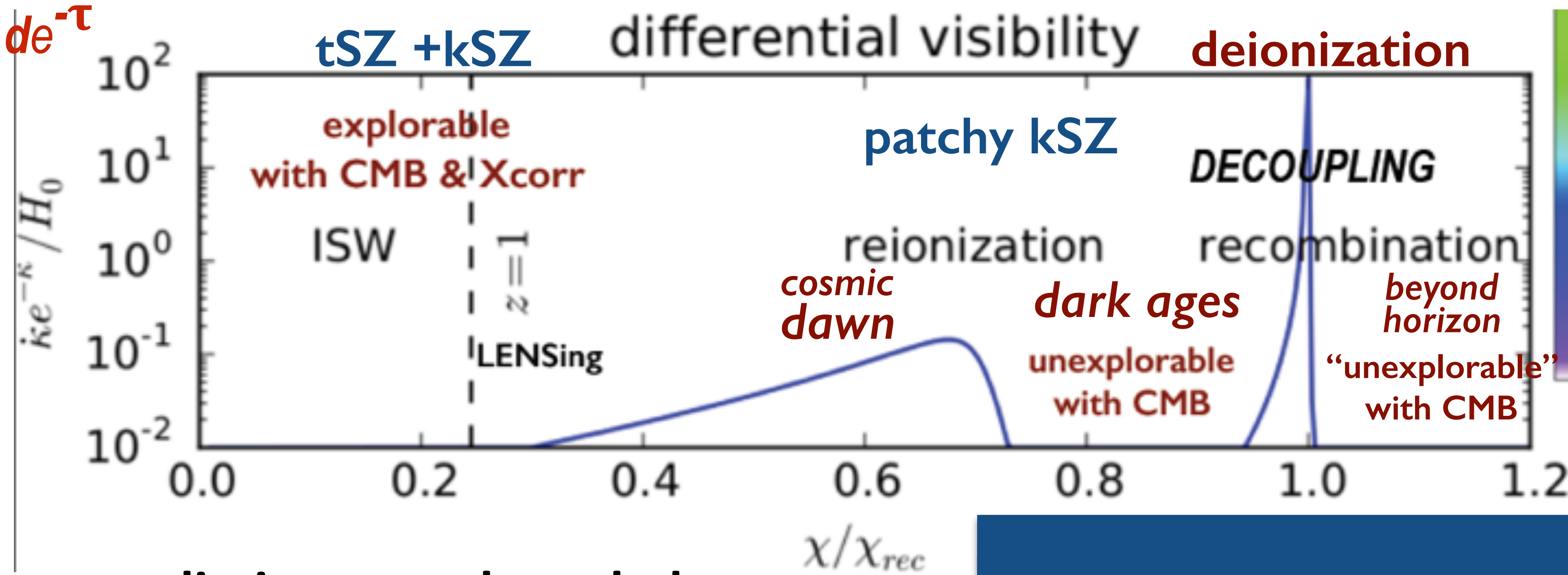
Compton Reionization depth τ

Planck 2016 intermediate results. XLVII.

Planck constraints on reionization history ***zre***

Planck is a project of the European Space Agency, with nstruments provided by two scientific Consortia funded by SA member states (in particular the lead countries: France and Italy) with contributions from NASA (USA), and telescope reflectors provided in a ollaboration between ESA and a scientific Consortium led and funded by Denmark.

Dick Bond @ Casca16 for the Planck collaboration



limits to our knowledge

CMB modes
~ $f_{sky} L_{max}^2$

CMB ~10,000,000 T/E modes of tΛCDM
≲500 modes of anomaly
≲100 modes reionization history

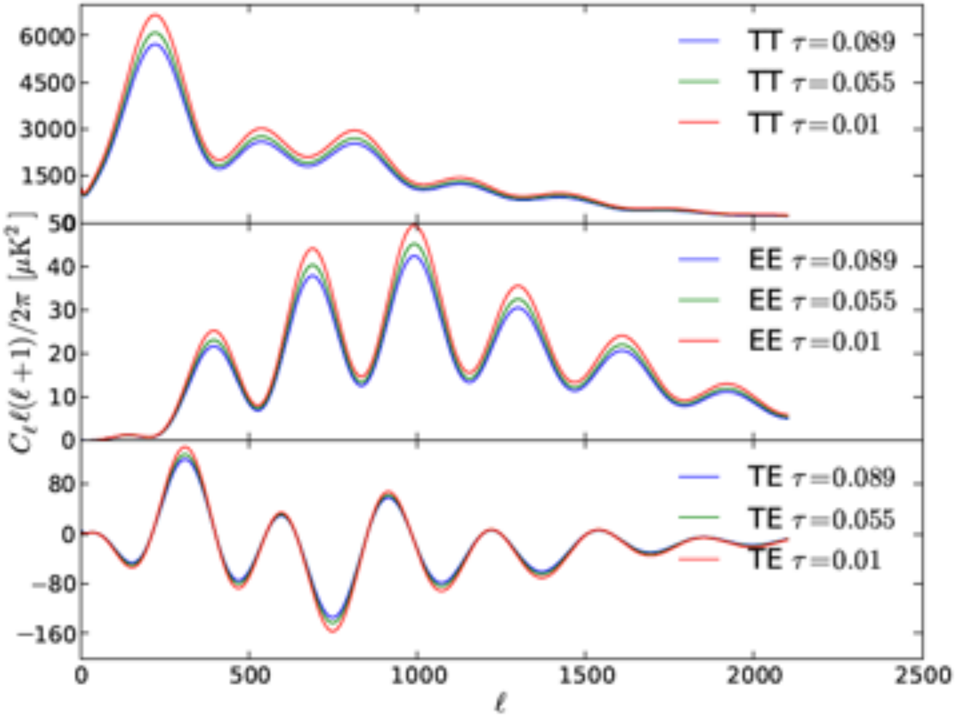
LSS tomography
X k_{max} d_{max}

Compton depth $\tau \sim \int n_e\, cdt$
Differential Visibility ~ $de^{-\tau}$

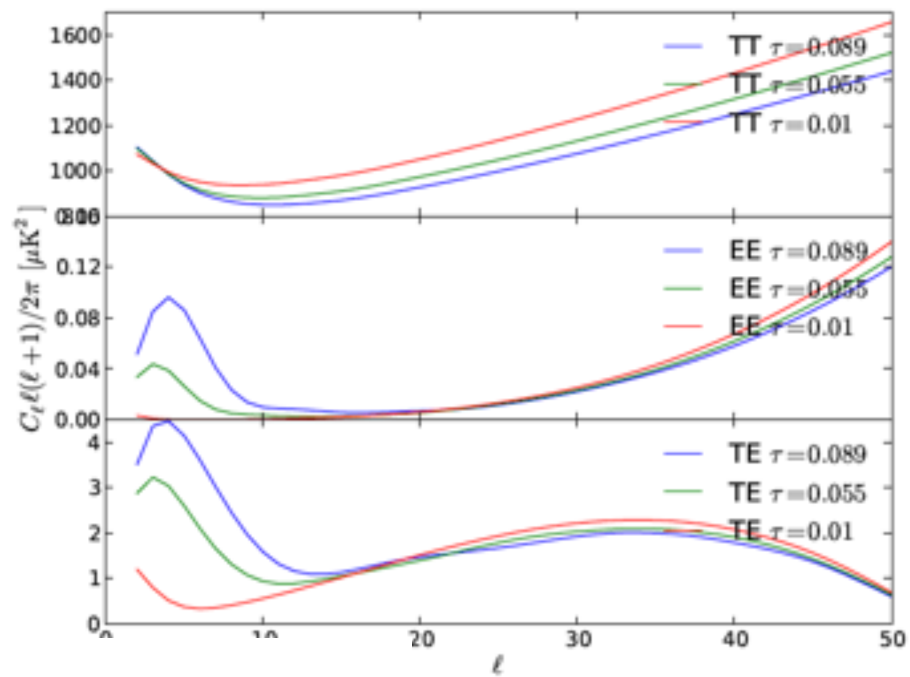
its all just Compton scattering
Thompson $de^{-\tau}$
kinetic SZ/ Doppler LoS v_e $de^{-\tau}$
thermal SZ $\langle v_e^2 \rangle$ $de^{-\tau}$
polarization [quadrupole] $de^{-\tau}$

E /B pol, GW natural

Planck 2015 parameters
reconstructed de-ionization history
3 modes, high L EE,TE important
same for reionization history ?? NO



- the scattering of CMB creates E mode polarization
- amplitude TT ~ $A_s \exp[-2\,\boldsymbol{\tau}]$
- EE /TE feature at low L
- EE ~ $A_s\,\boldsymbol{\tau}^2$, TE ~ $A_s\,\boldsymbol{\tau}$
- TT 1st acoustic peak 5600 μK^2 cf. EE reionization ~$10^{-2}\ \mu K^2$



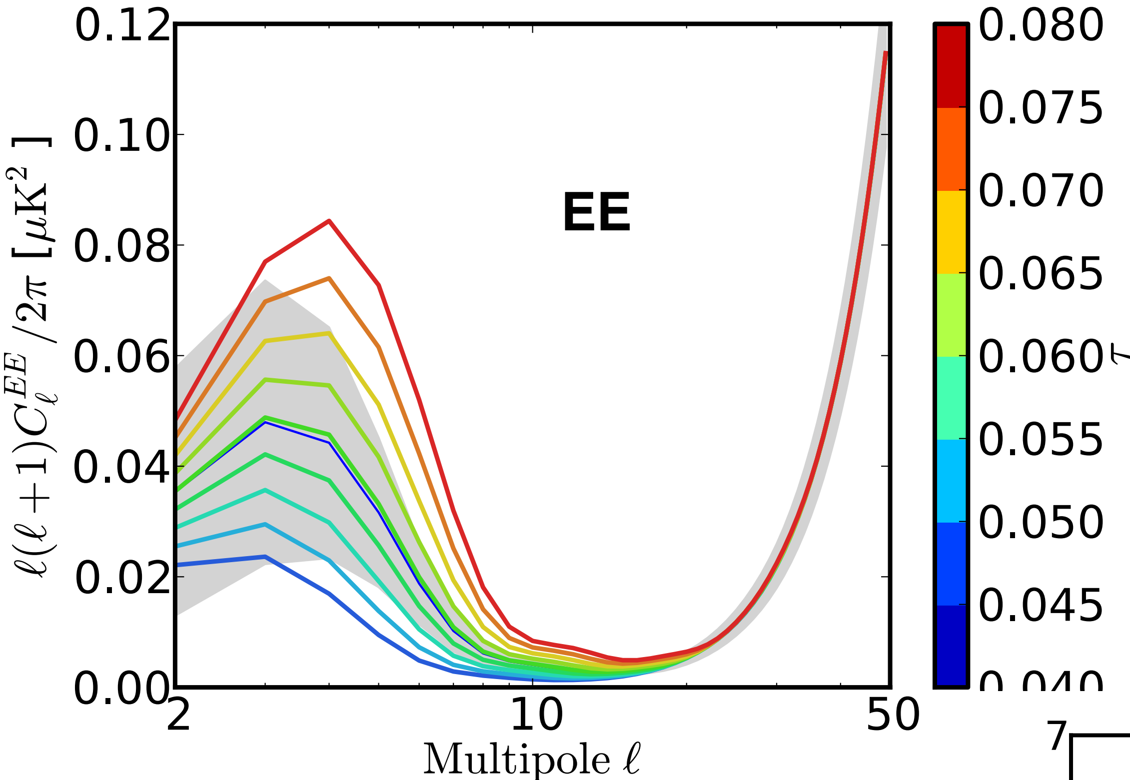
$\boldsymbol{\tau} \sim .07\ [(1+z_{re})/10]^{3/2}$

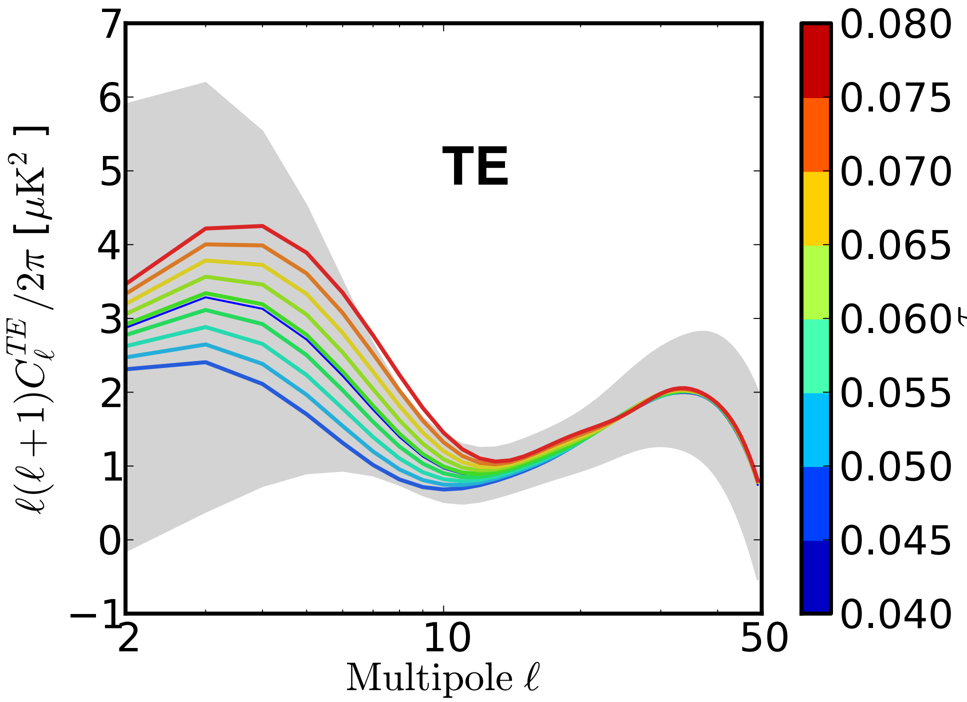
Compton depth sudden reionization

$\boldsymbol{\tau} \sim \int n_e\, c\, dt$

$$\tau = \frac{2c\sigma_T(1-Y_P)}{m_p}\frac{\Omega_b}{\Omega_m}\frac{H_0}{8\pi G}\left\{\left[\Omega_m(1+z_{re})^3+\Omega_\Lambda\right]^{1/2}-1\right\}$$

Cosmic Variance limits what we can learn





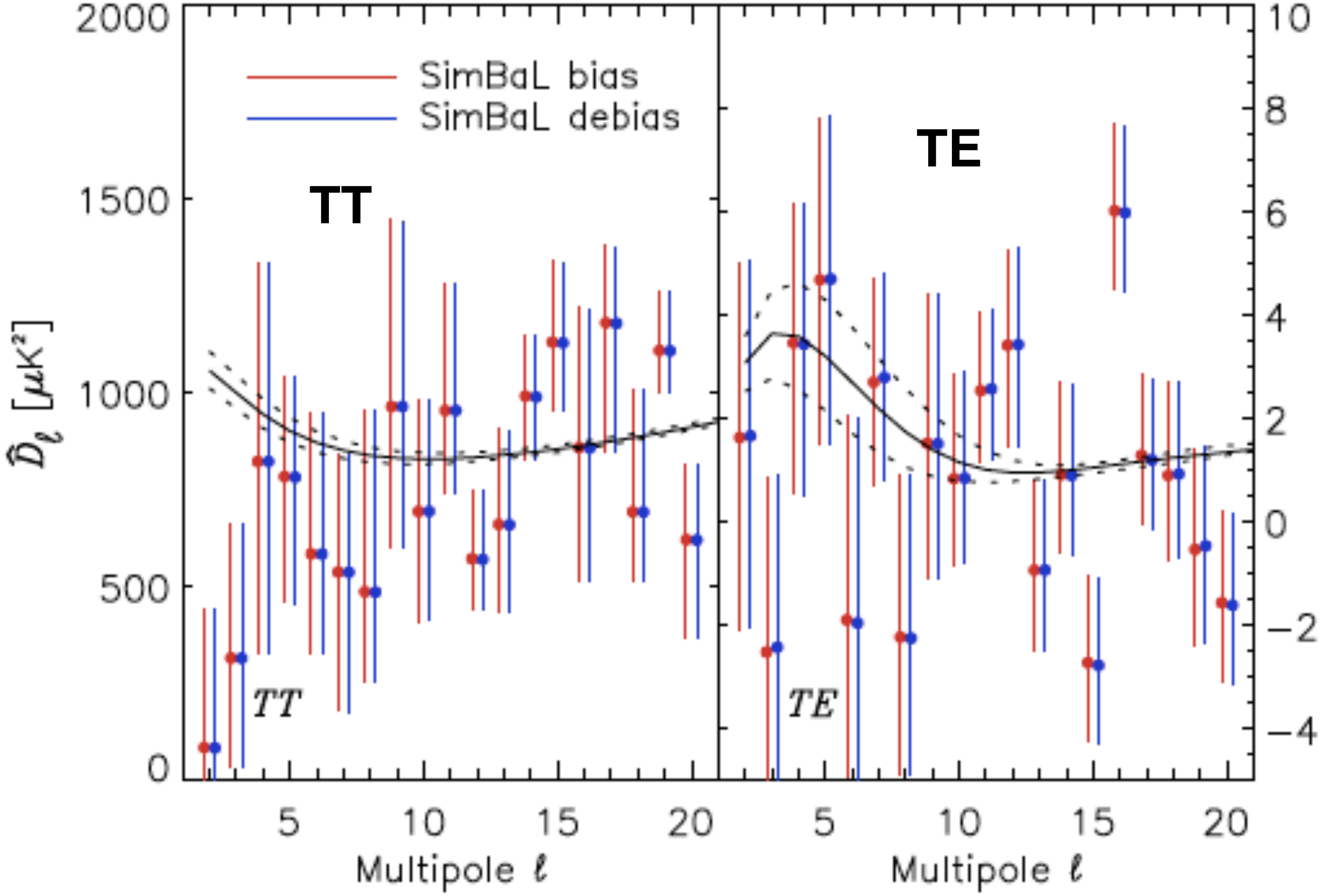
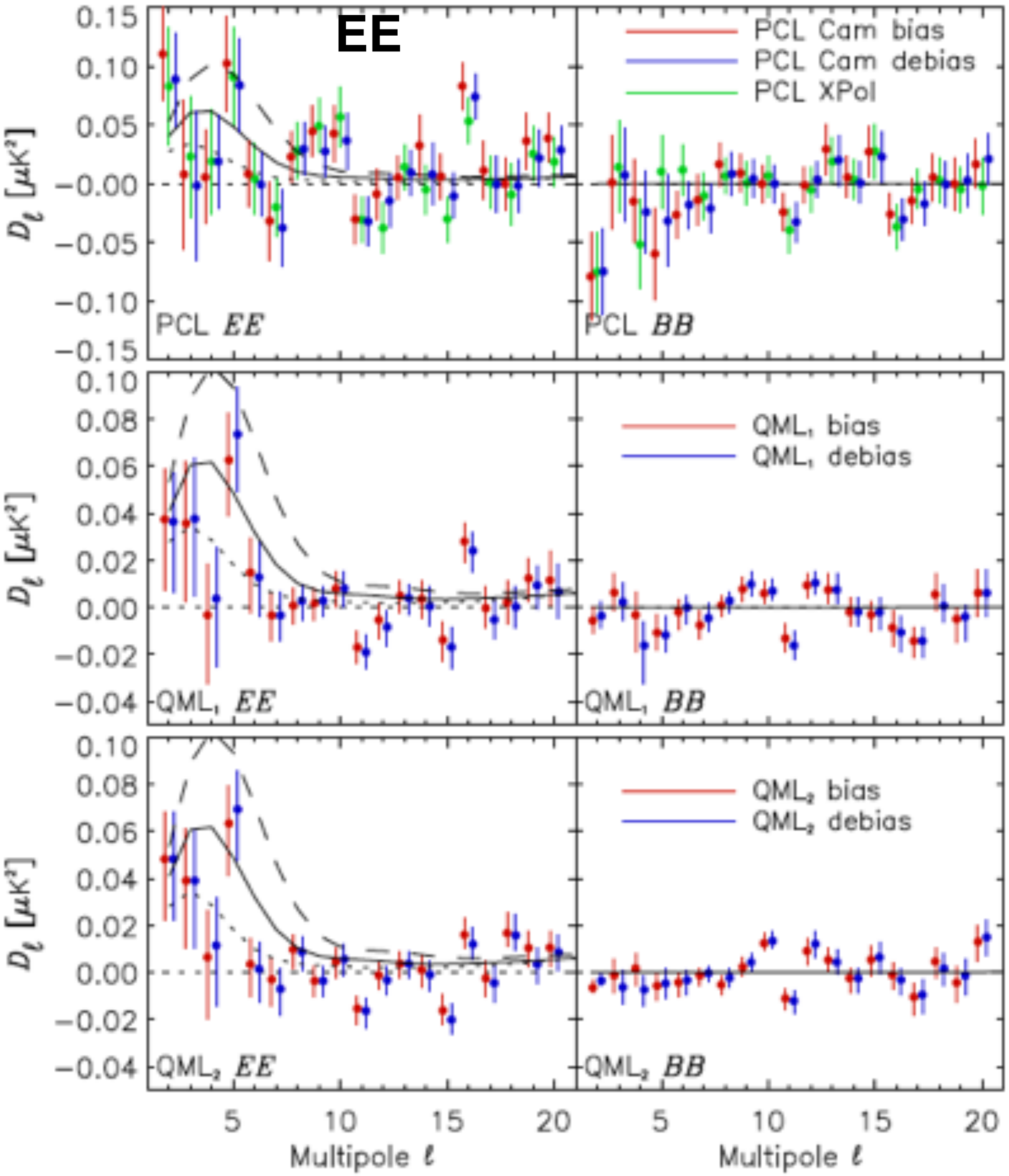


Fig. 36. TT and TE 100×143 cross-spectra, plotted for the SimBaL results with and without the bias correction. The black lines shows the fiducial spectra for $\tau = 0.05, 0.07$, and 0.09.

τ baseline results HFI 100x143 (283 simulations)
and check of consistency HFI x LFI (10 simulations)

PCL and QML 100x143 EE cross spectra



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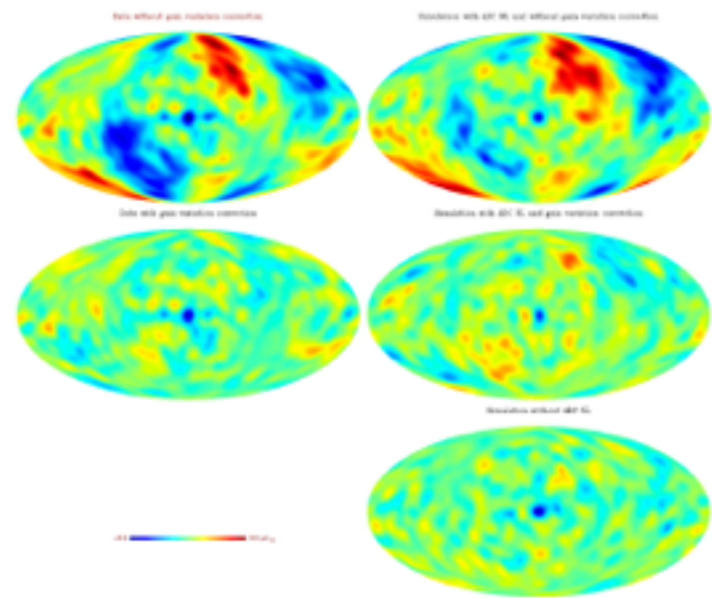
sets of PCL EE cross spectra,

- **very consistent,**
- **debiasing from the ADC NL dipole distortion small (only ell<4)**
- **QML consistent pattern with PCL, lower dispersion and error bars**



Analog to Digital Conversion major systematic to have included. Used warm HFI data
Foreground corrections also very important

τ baseline results HFI 100x143 (283 simulations)
and check of consistency HFI x LFI (10 simulations)

τ results: baseline 100x143

consistency check

70x100 and 70x143

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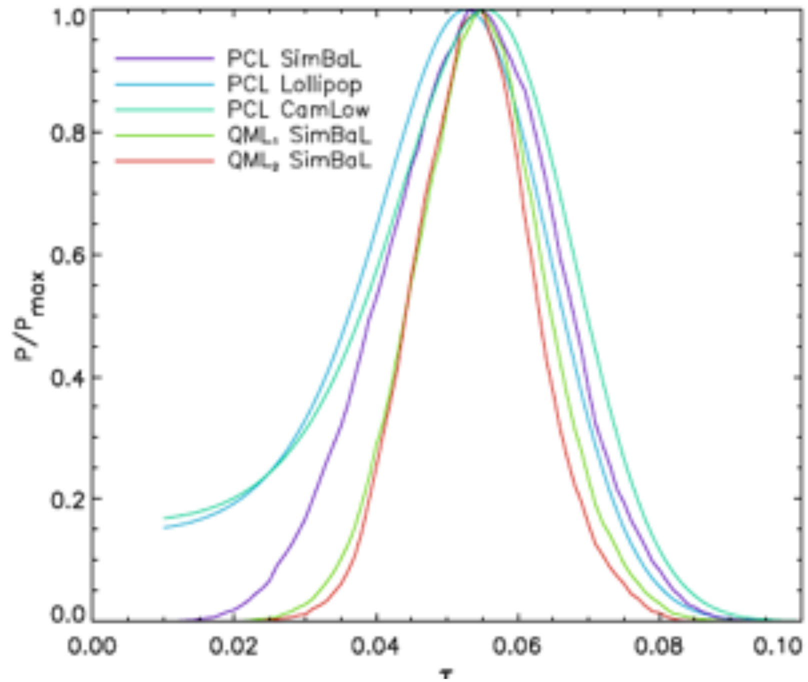
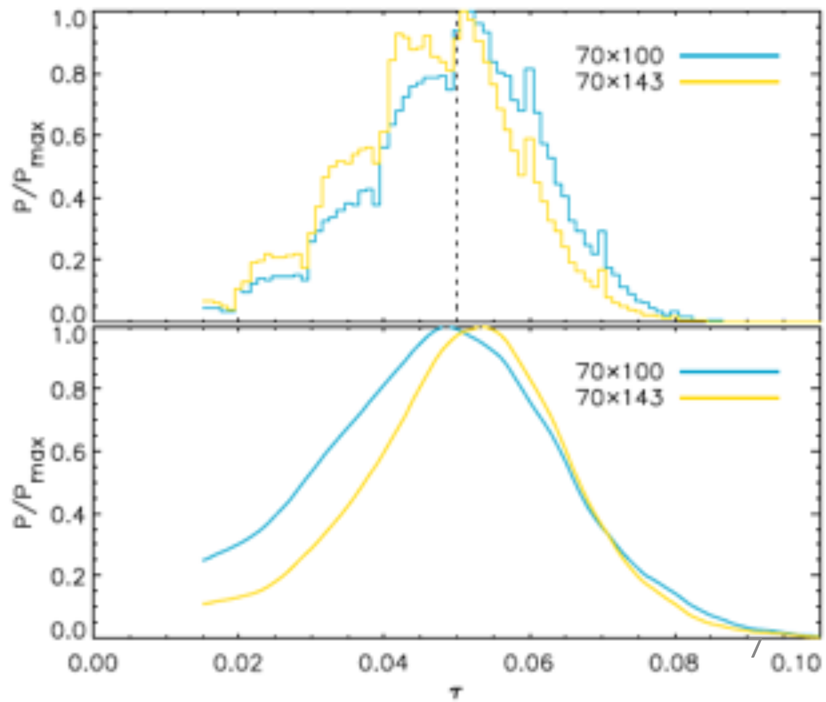
- PCL spectrum estimates have larger posterior
- the simulation based likelihood gives better results on low Tau
- QML estimator has narrower posterior distribution but the same peak value
- LFI-HFI give also nearly the same peak value but with larger uncertainties





τ from CMB (historical)

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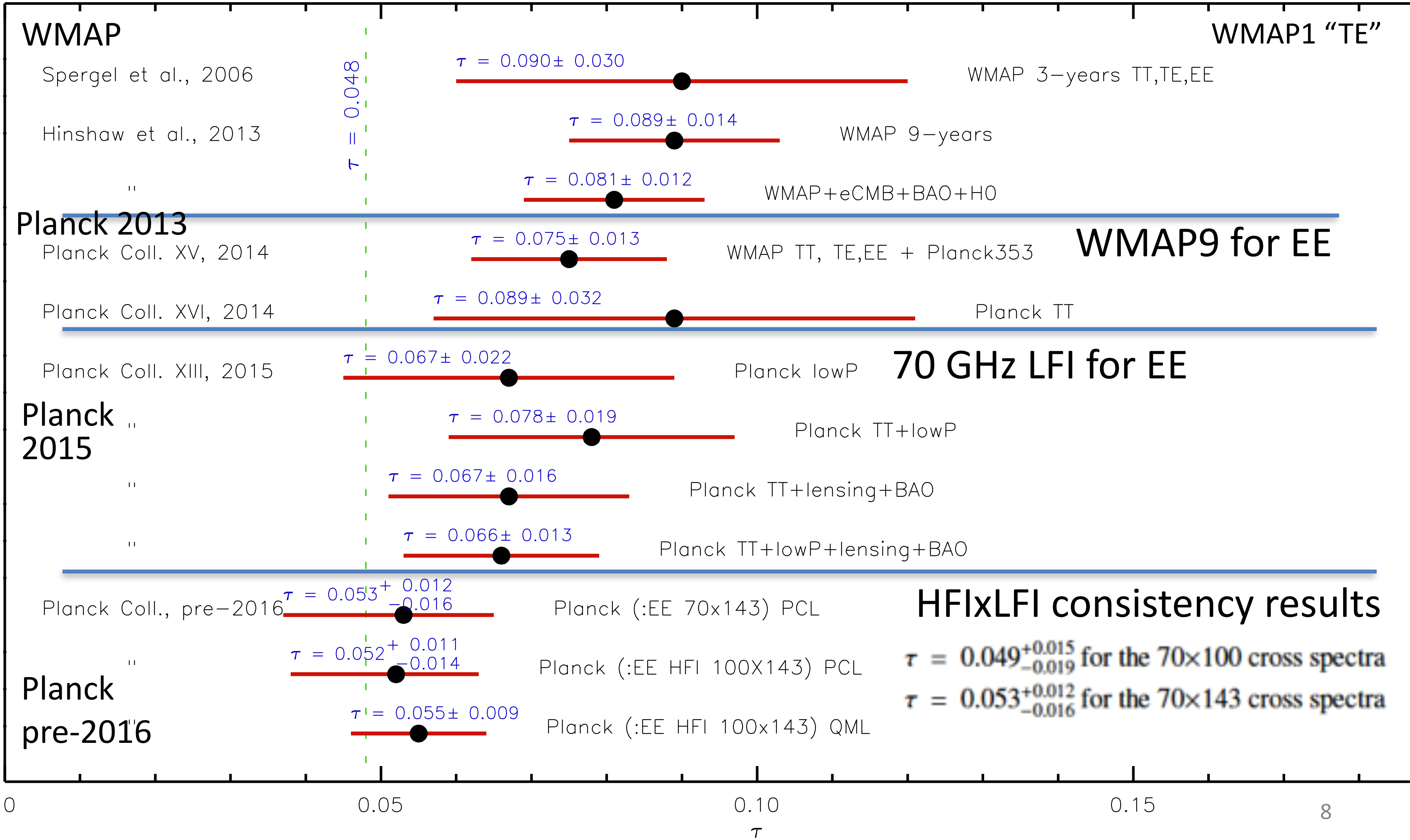
- consistency of all Planck τ results
- improvements of uncertainties
- drift towards lower values



Planck cosmic parameters *Planck 2015* *pre-2016*

Parameter	PlanckTT+lowP 68 % limits	PlanckTT+SIMlow 68 % limits	PlanckTTTEEE+lowP 68 % limits	PlanckTTTEEE+SIMlow 68 % limits
$\Omega_b h^2$	0.02222 ± 0.00023	0.02214 ± 0.00022	0.02225 ± 0.00016	0.02218 ± 0.00015
$\Omega_c h^2$	0.1197 ± 0.0022	0.1207 ± 0.0021	0.1198 ± 0.0015	0.1205 ± 0.0014
$100\theta_{MC}$	1.04085 ± 0.00047	1.04075 ± 0.00047	1.04077 ± 0.00032	1.04069 ± 0.00031
τ	0.078 ± 0.019	0.0581 ± 0.0094	0.079 ± 0.017	0.0596 ± 0.0089
$\ln(10^{10}A_s)$	3.089 ± 0.036	3.053 ± 0.019	3.094 ± 0.034	3.056 ± 0.018
n_s	0.9655 ± 0.0062	0.9624 ± 0.0057	0.9645 ± 0.0049	0.9619 ± 0.0045
H_0	67.31 ± 0.96	66.88 ± 0.91	67.27 ± 0.66	66.93 ± 0.62
Ω_m	0.315 ± 0.013	0.321 ± 0.013	0.3156 ± 0.0091	0.3202 ± 0.0087
σ_8	0.829 ± 0.014	0.8167 ± 0.0095	0.831 ± 0.013	0.8174 ± 0.0081
$\sigma_8\Omega_m^{0.5}$	0.466 ± 0.013	0.463 ± 0.013	0.4668 ± 0.0098	0.4625 ± 0.0091
$\sigma_8\Omega_m^{0.25}$	0.621 ± 0.013	0.615 ± 0.012	0.623 ± 0.011	0.6148 ± 0.0086
z_{re}	$9.89^{1.8}_{-1.6}$	8.11 ± 0.93	$10.0^{1.7}_{-1.5}$	8.24 ± 0.88
$10^9 A_s e^{-2\tau}$	1.880 ± 0.014	1.885 ± 0.014	1.882 ± 0.012	1.886 ± 0.012
Age/Gyr	13.813 ± 0.038	13.829 ± 0.036	13.813 ± 0.026	13.826 ± 0.025

relaxing tension of clusters and primary CMB

$$10^9 A_s e^{-2\tau}$$

Planck 2013 sigma_8 ~0.83 (WMAP tau .089),

Planck 2015 0.83 (.815 + lens) (cleaned LFI tau .079 *(.017)*

Planck 2016 PIP: 0.817 (.812 + lens) (HFI tau .059 *(.009)***)**

τ, A_s, n_s degeneracies

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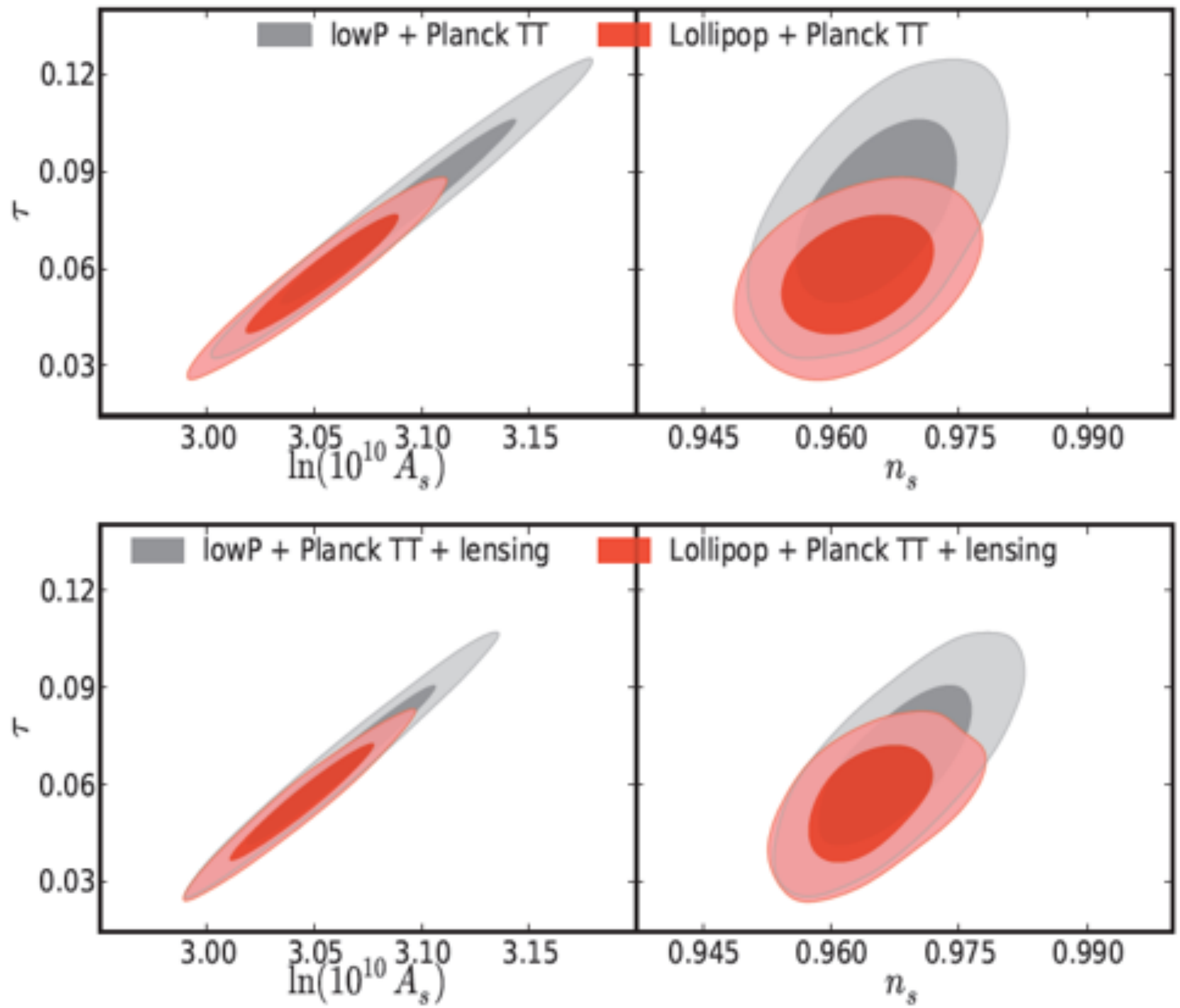
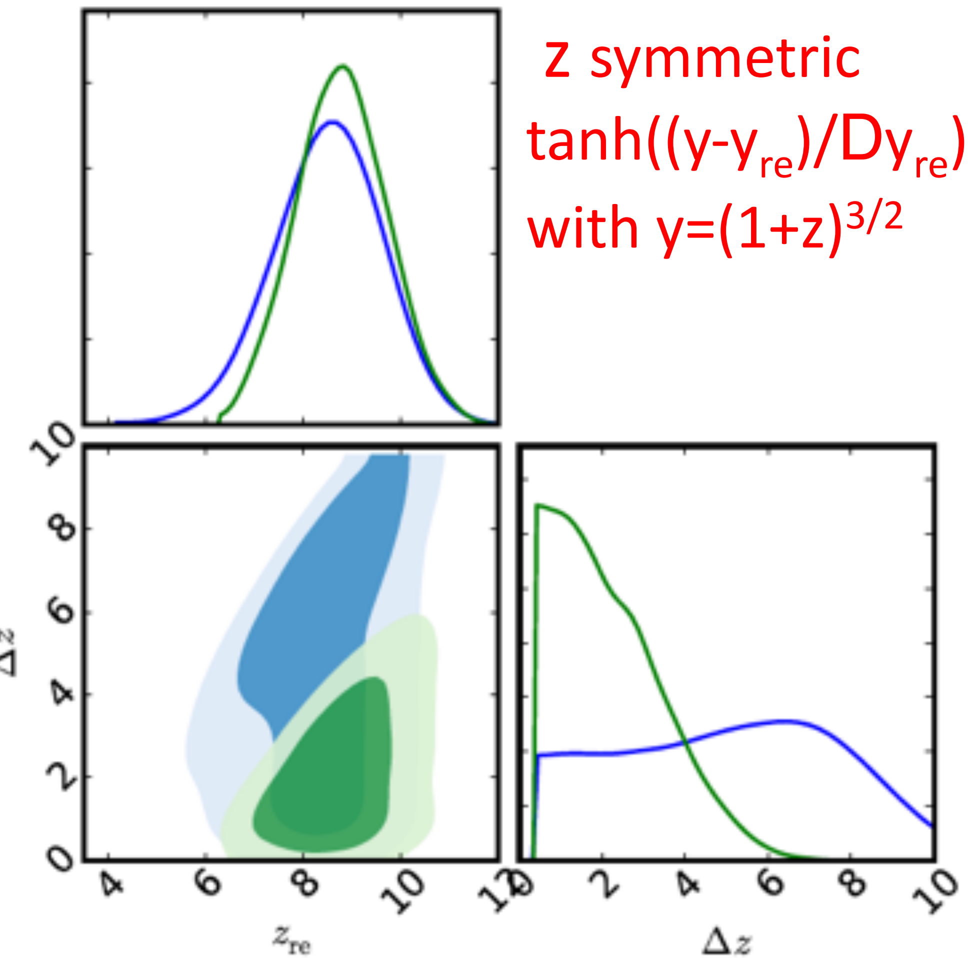
- better τ breaks almost completely the degeneracy with n_s and reduces the degeneracy with A_S

- adding lensing does not improve
- although τ breaks the degeneracy with n_s



Reionisation history constraints from Planck



z symmetric

$\tanh((y-y_{re})/Dy_{re})$

with $y=(1+z)^{3/2}$

- Constraints on z_{rec} ,Δz_{rec}
  for Dz =0.5
- **WMAP 9y** z_{re} = 10.3
- **Planck2015**
- TT+lowP $z_{re} = 9.9^{+-1.7}$
- TT+lowP+lens+BAO $z_{re}= 8.8^{+-1.3}$
- Planck pre 2016
- lowEH+TT+BAO $z_{re}=8.16^{+-1}$

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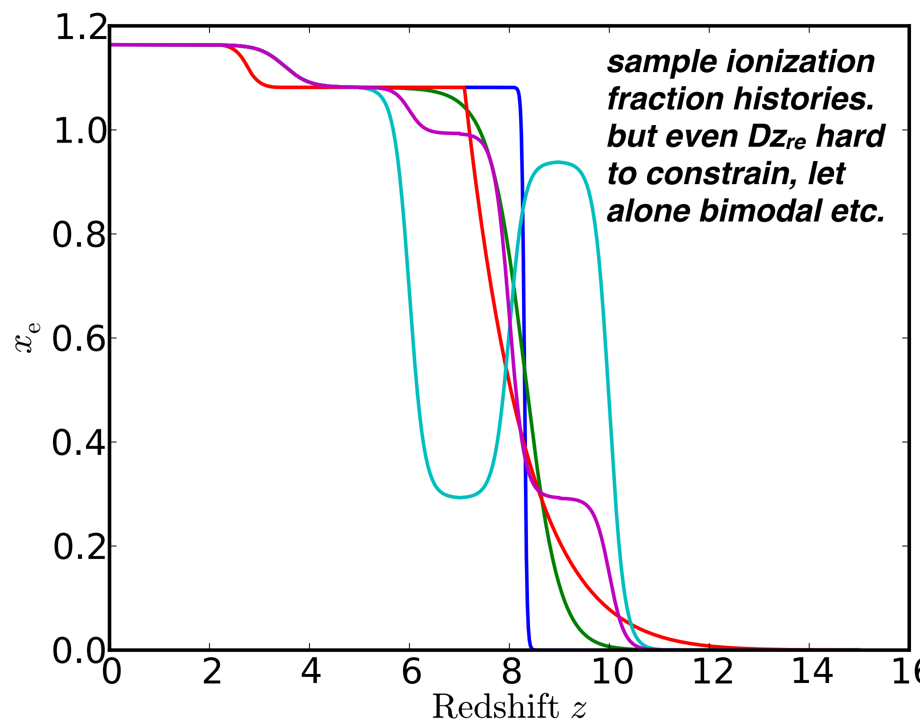
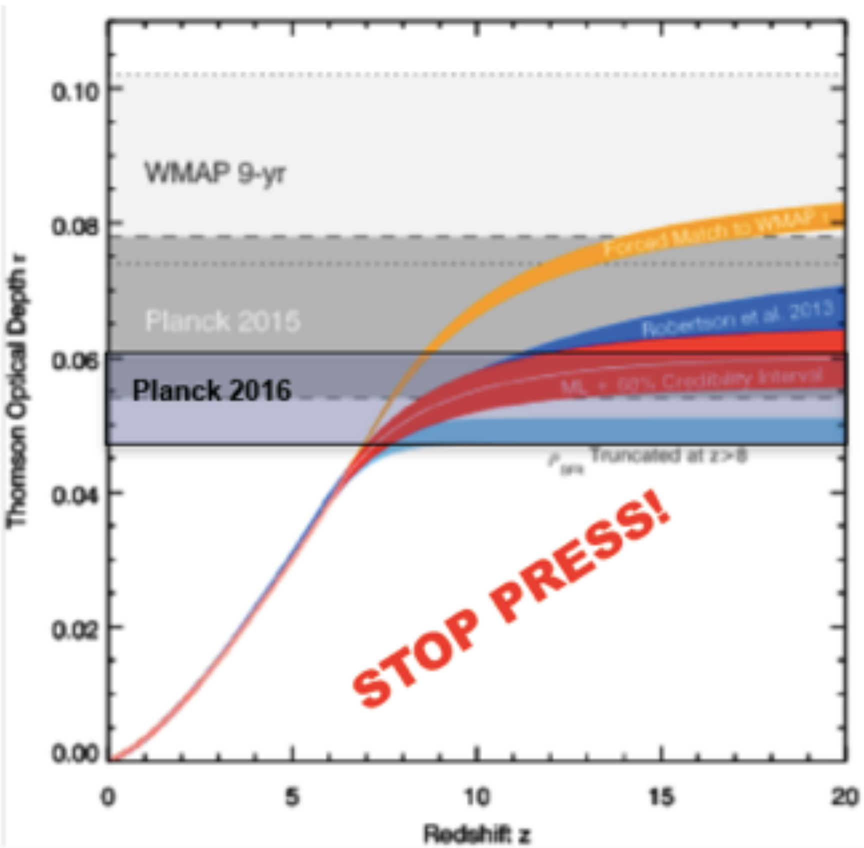
$$z_{re} = 8.53^{+1.03}_{-1.13} \quad ,$$

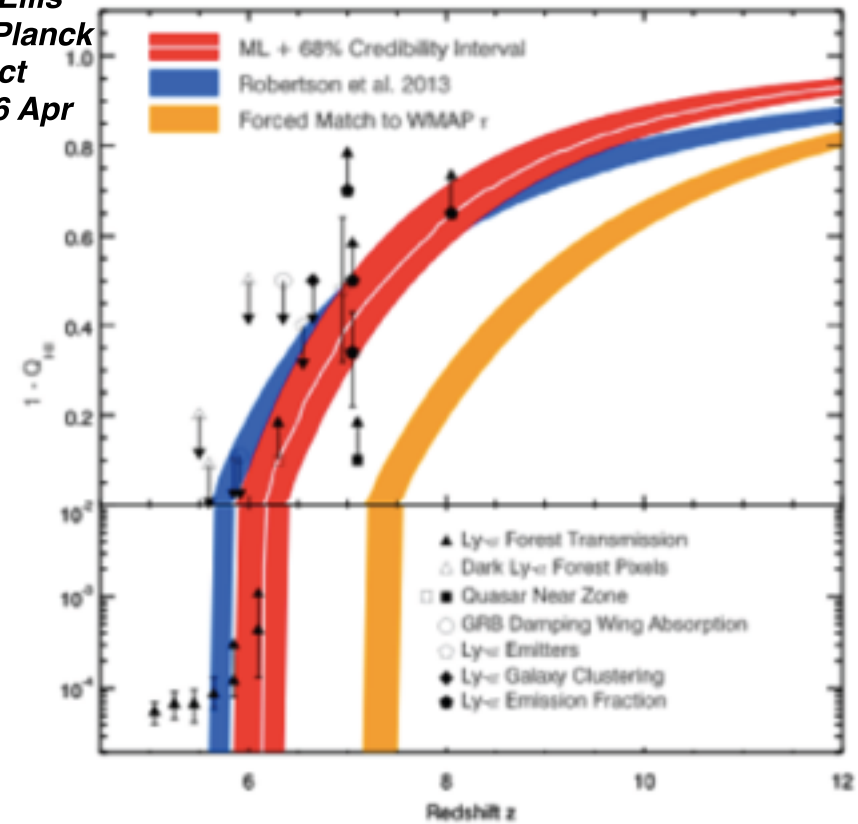
$$z_{re} = 8.77^{+0.94}_{-0.92} \quad \text{(with prior } z_{end} > 6) .$$



Planck & HST: Reionisation over 6 < z < 12



RIchard Ellis slide of Planck z_{re} impact CIFAR 16 Apr



Planck indicates `Fast Reionization': Making (questionable) assumptions about their ionizing output the demographics of early galaxies can match the Planck τ with reionisation contained with 12 < z < 6 *Ly alpha, but OIII, CIV, CIII*

4 with z > 7.5, eg 2015 z=7.7 may, 8.68 july, what about z=11.1 ? ~March HST grism ??

Focus now turns to measuring the ionizing output of early galaxies

+ EoR redshifted 21 cm cosmic dawn experiments: P16 => shift in in frequency target

Robertson et al (2015), see also Bouwens+(2015), Mitra+(2015)

Summary

- First use of Planck HFI EE low Ell spectra and τ value with smallest uncertainties. major systematics improvement and modelling with End to End simulations of HFI maps
- τ measurement almost independent of the other cosmological parameters

τ lower than previous CMB hence z_{re} lower

- Removes tension between CMB and model of reionization based on the formation of first stars and galaxies.
- no need for early "ring of fire" of exotic early BHs at z~11+ as seemed to be the case with WMAP, more conventional BUT still
- a glorious future for interplay with earliest "optical" galaxies (HST, .. JWST), Ly alpha and future OIII and other metal lines
- cosmic dawn detectability with redshifted 21 cm still on track
- no "patchy reionization" kinetic SZ detection (yet), but cluster kSZ detection