COSPAR (Pasadena July 2018)

The High frequency maps and low ℓ likelihood

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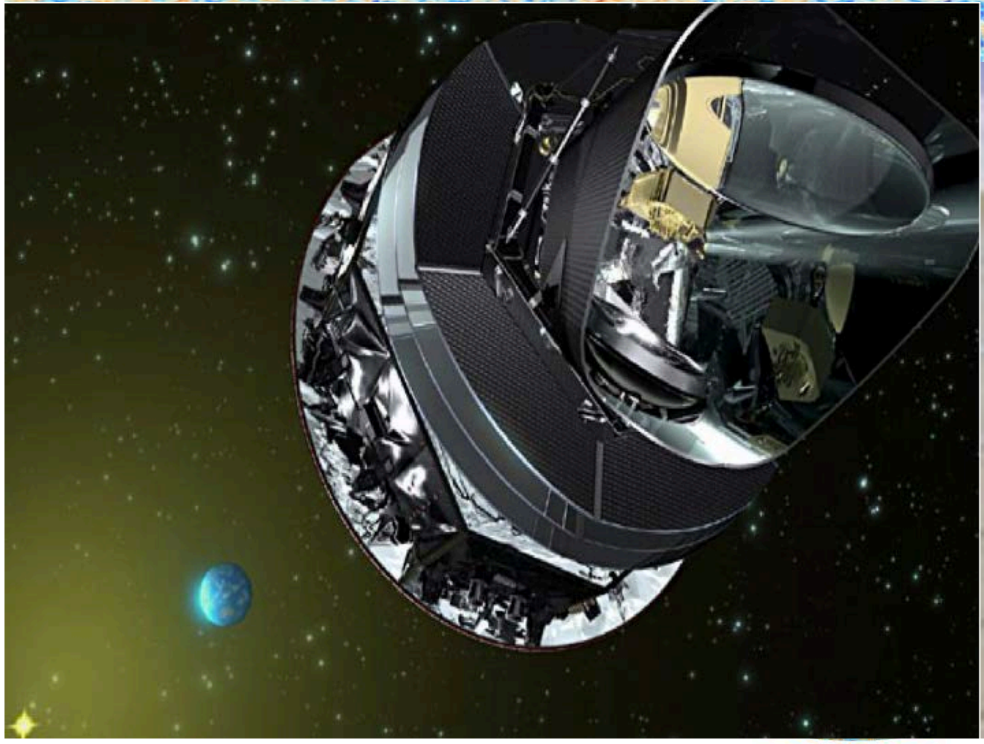
on the behalf of the Planck collaboration

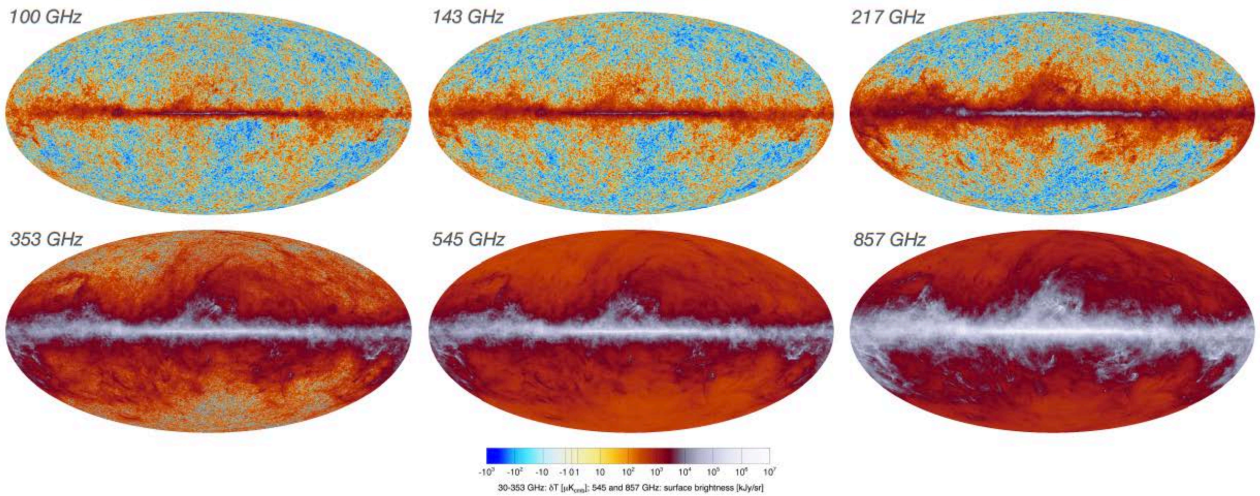
based on the July 2018 release, mainly Planck papers

III HFI data processing (Jean-Marc Delouis)

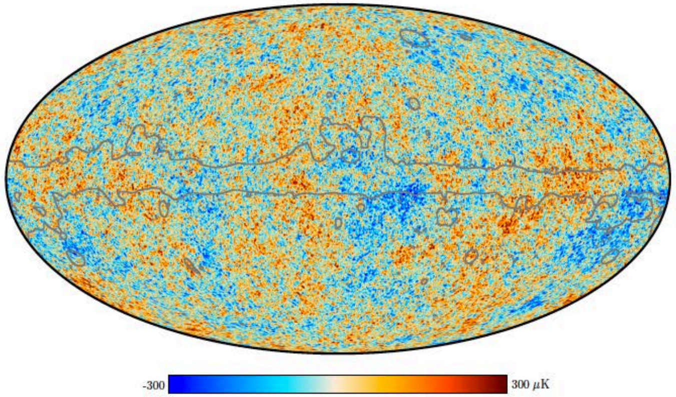
and V Likelihood (Luca Pagano)

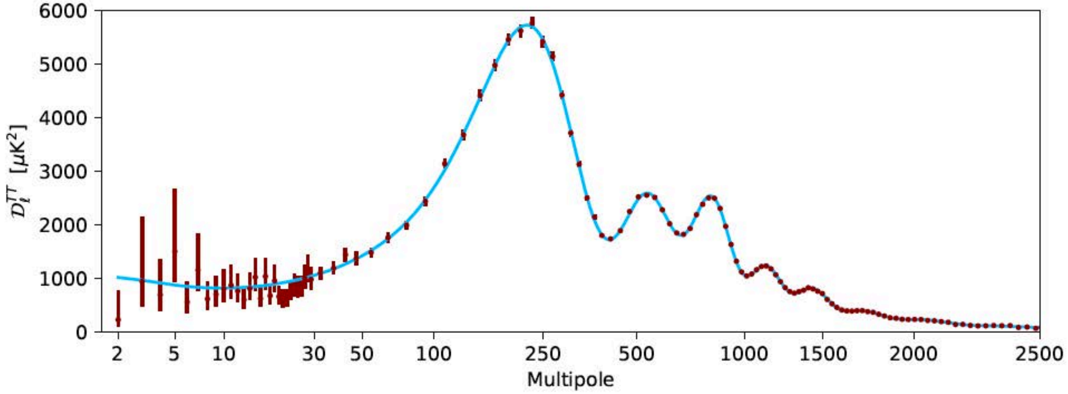
The improved high frequency maps

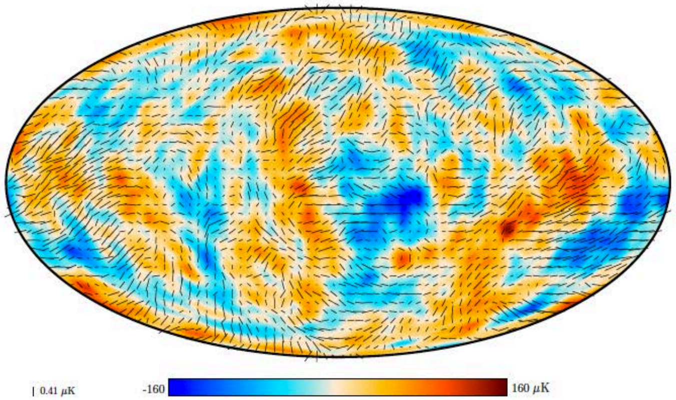


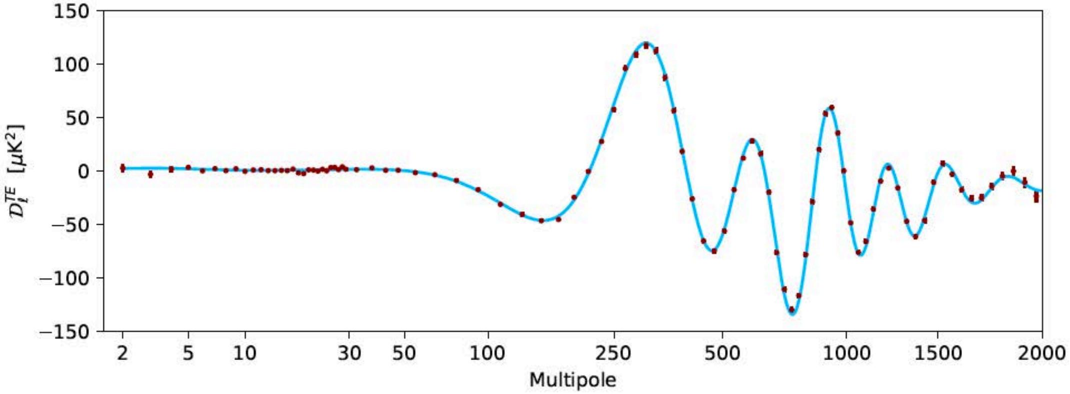


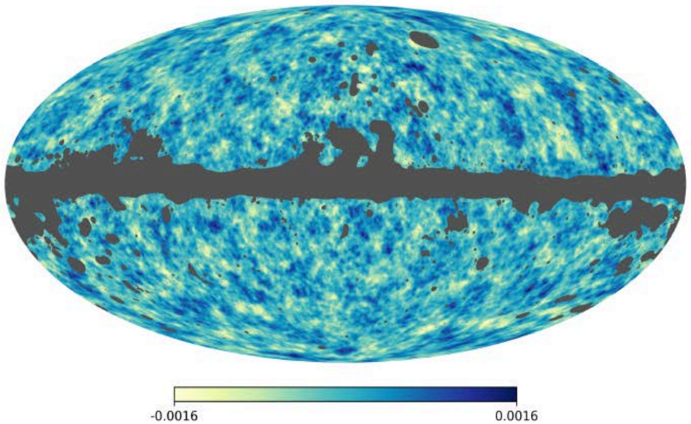
CMB TT, TE, EE and lensing potential maps and power spectra

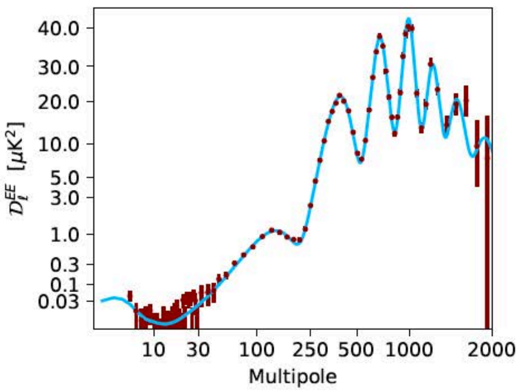


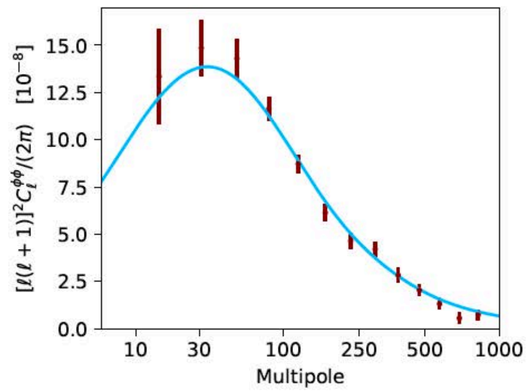










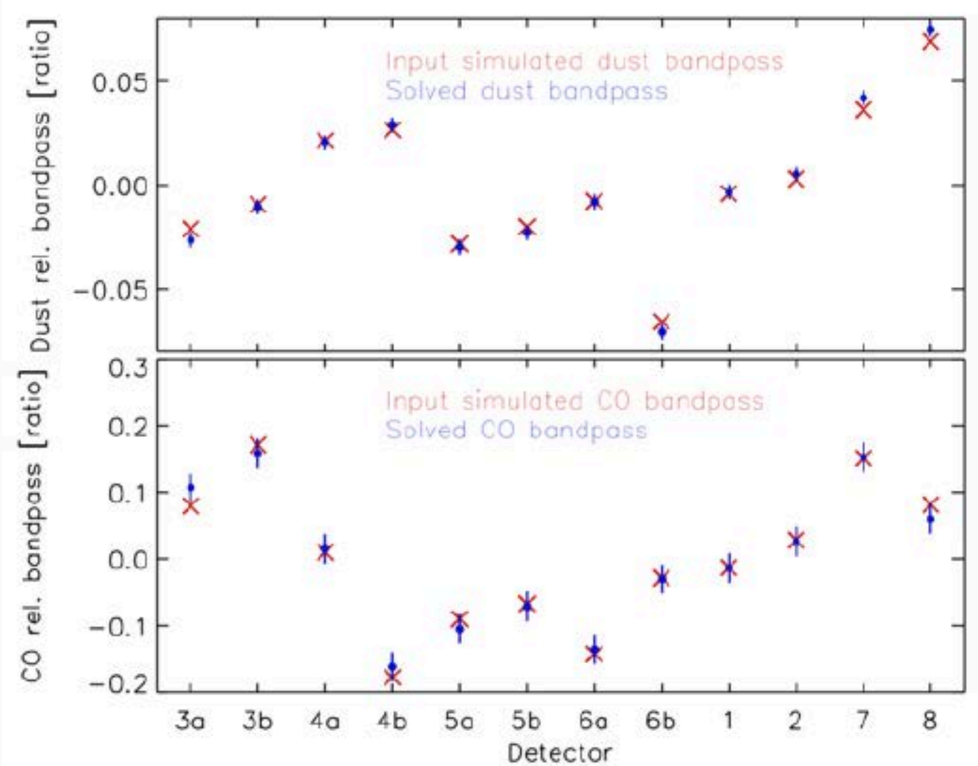


Improvements from the last release

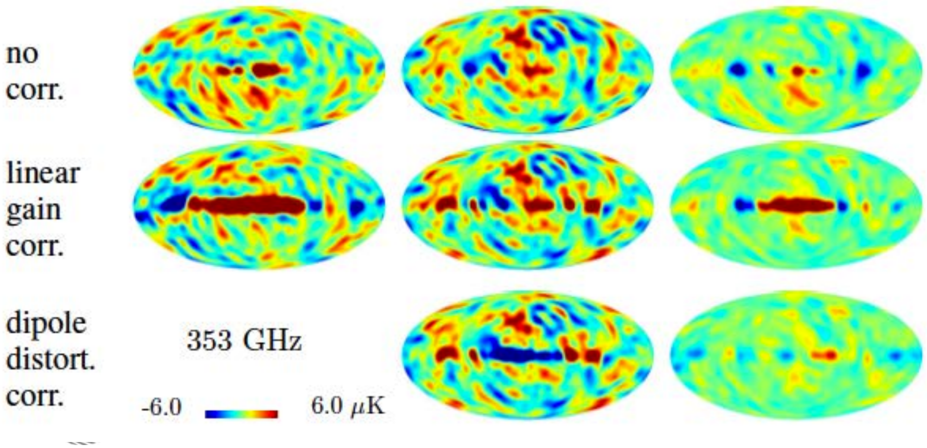
1. The map making has improve the polarization data by reducing the leakages of intensity into polarization and removing better other systematic effects
2. the time ordered data processing is the same as in 2015 except for the removal of the last 1000 rings of the mission.
3. the leakage parameters due to band-pass or calibration mismatch between detectors measuring orthogonal polar are now extracted from the sky data
4. The quality of the data is evaluated through null tests
    a. in 2015 we used detector sets, half rings and half mission
    b. in 2018 we used odd-even rings and half mission
5. odd even survey are scanned in opposite direction and test time constants and far side lobes
    a. systematic effect of very long time constant (30 sec) have been detected but not fully corrected
6. we developed end to end simulations which accounts very well for the null tests but this shows that we are partially limited by NG systematic effects

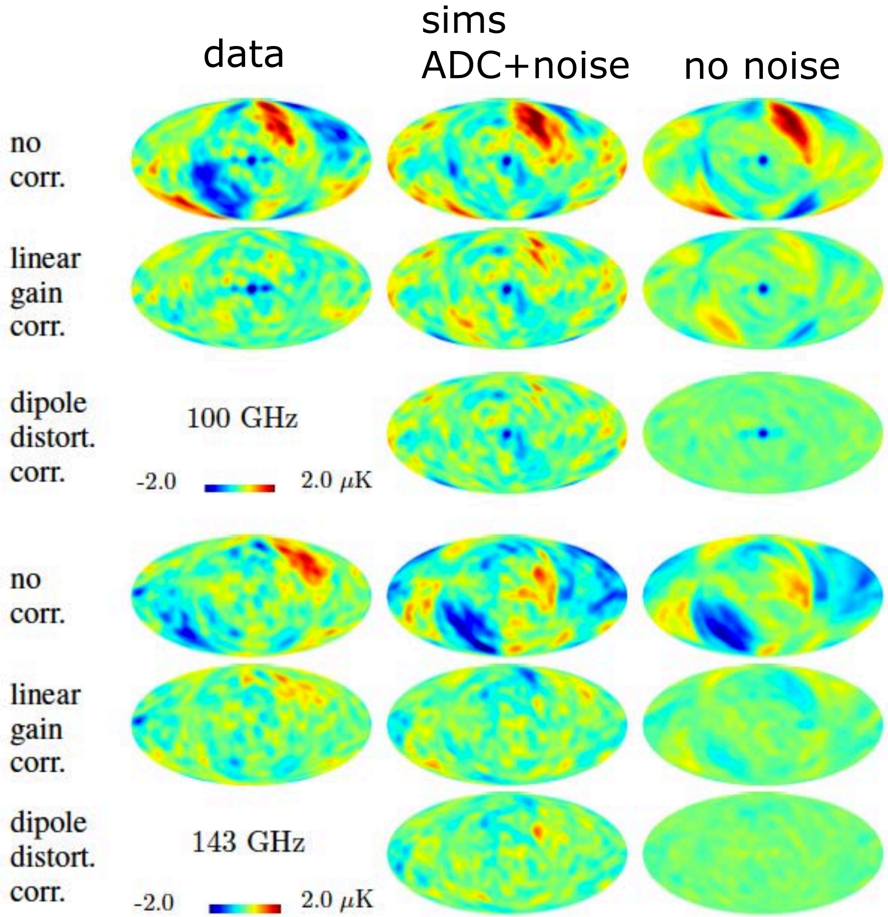
Bandpass mismatch

- Usually CMB map-making codes assume stationarity of the signal in a given pixel
- Any mismatch in the response causes leakage of power
  - Detector bandpass
  - Beam ellipticity
  - etc..



ADC non linearity

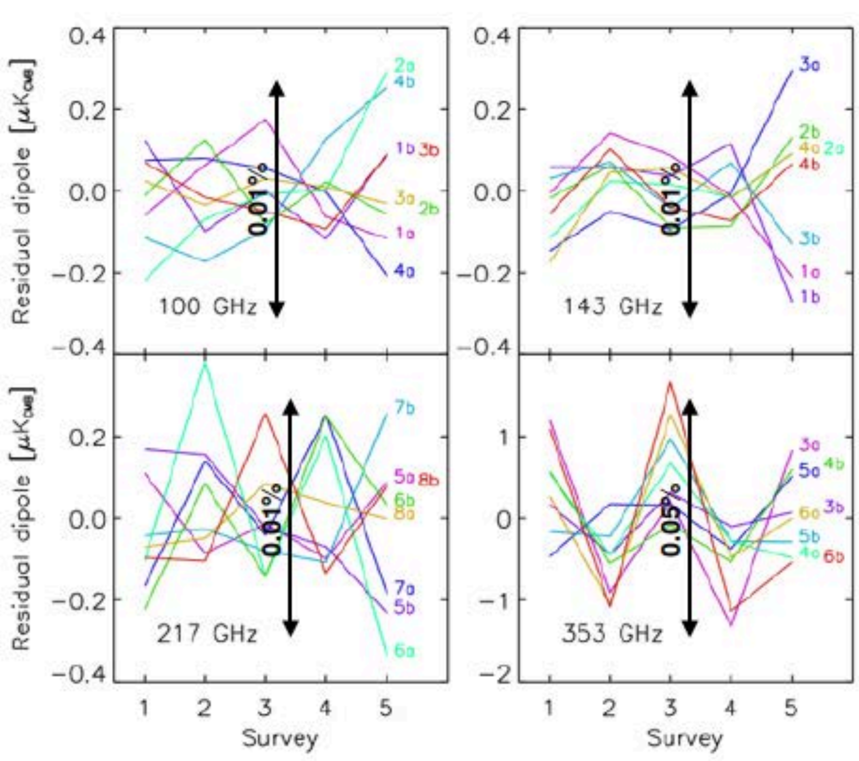


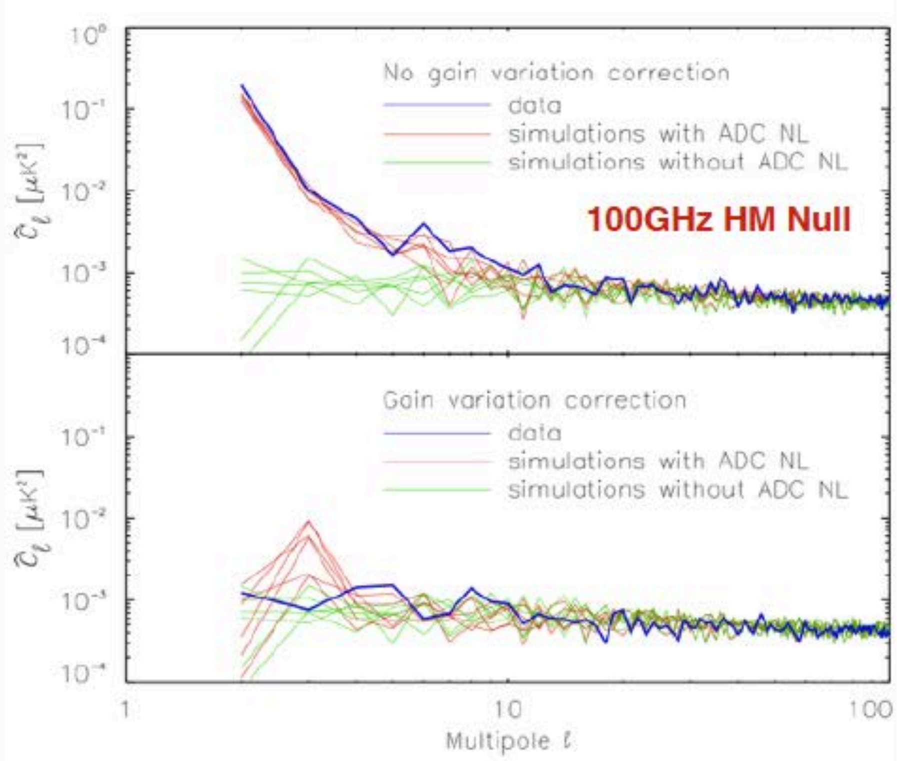


Improvements 2018 Map-making

Single detector, single survey calibration

Effect of variable gain





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HFI: 2015 odd-even surveys

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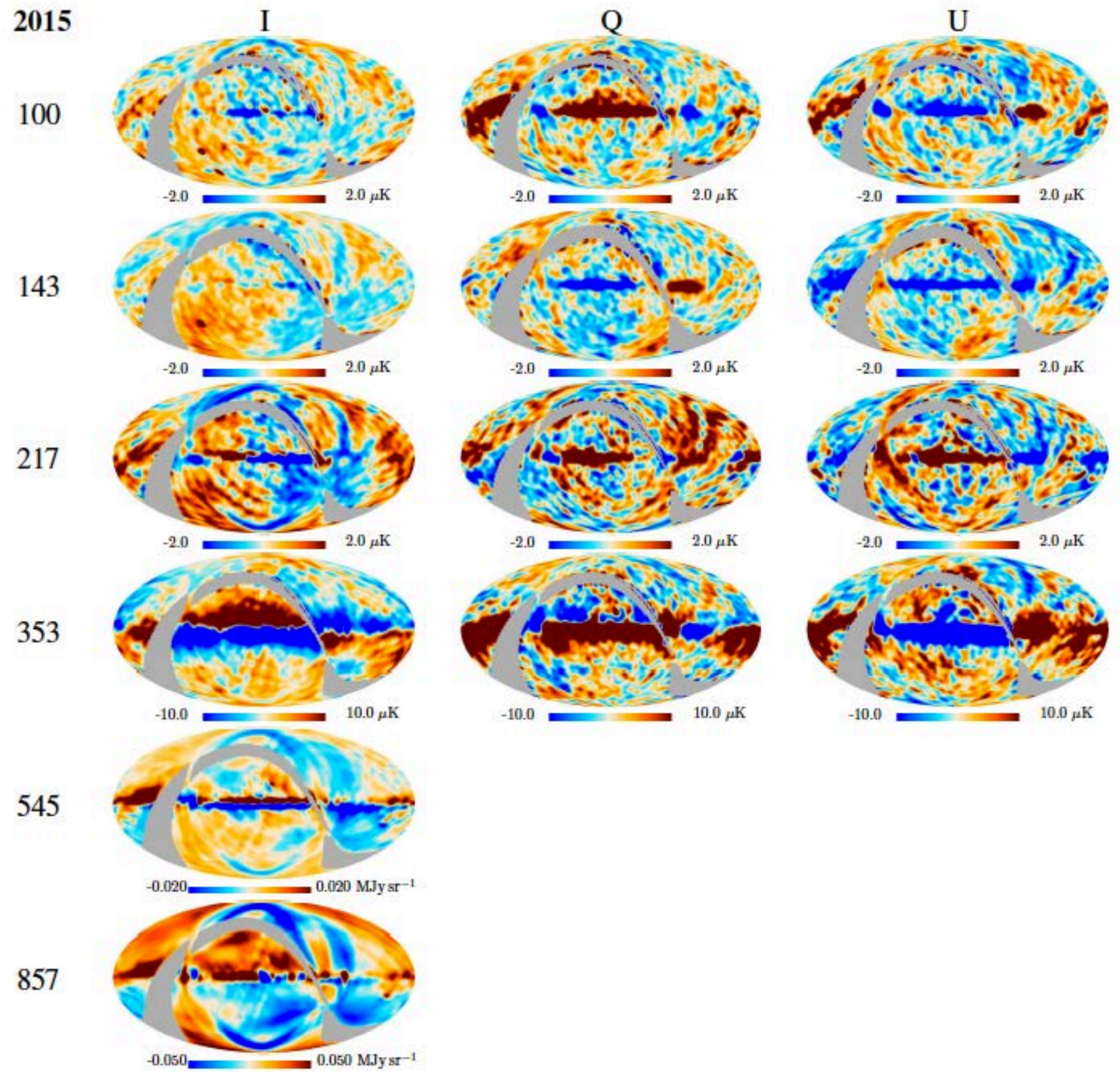
1. null test: (odd-even) surveys are scanned in opposite direction
2. this reveals time constant and far side lobes residual effects



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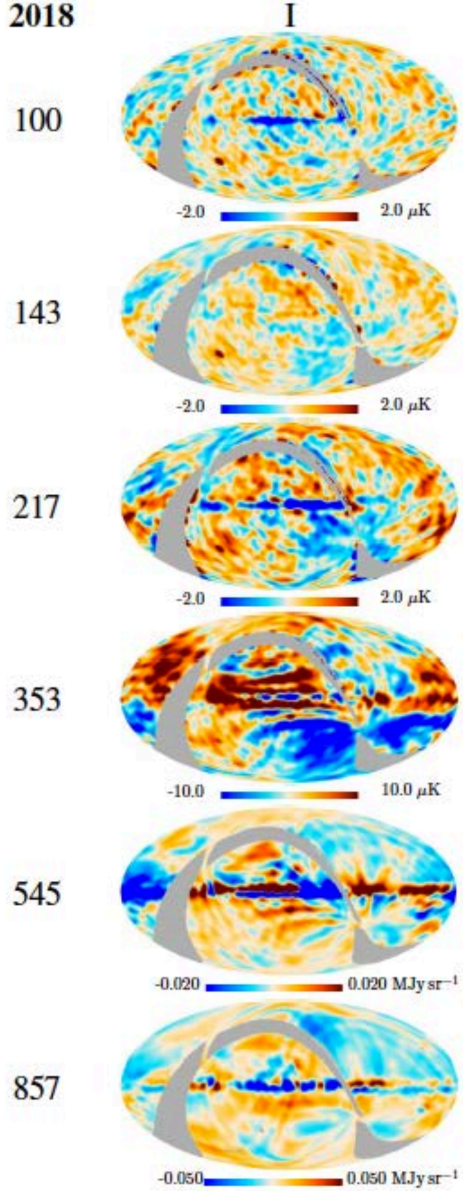
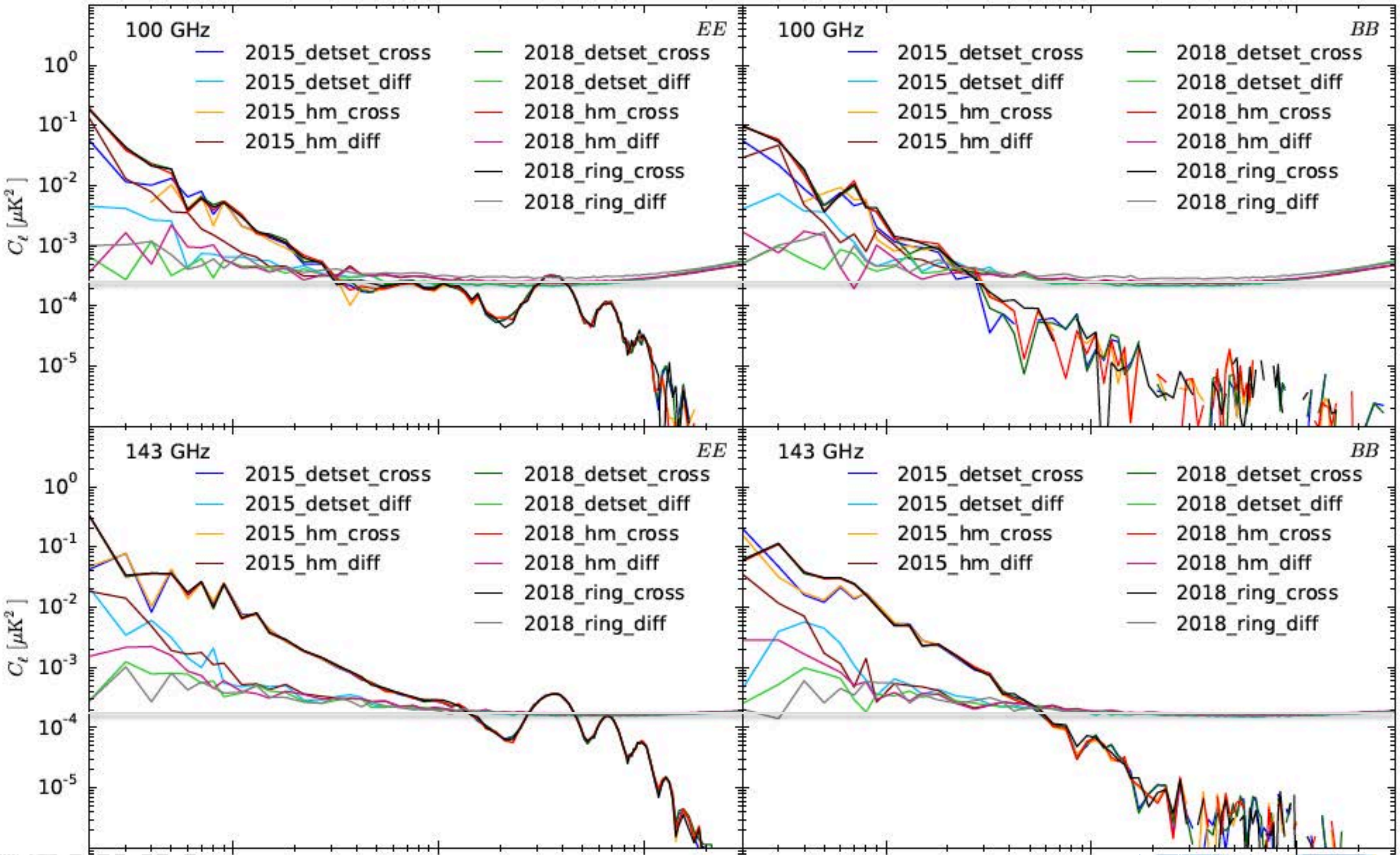
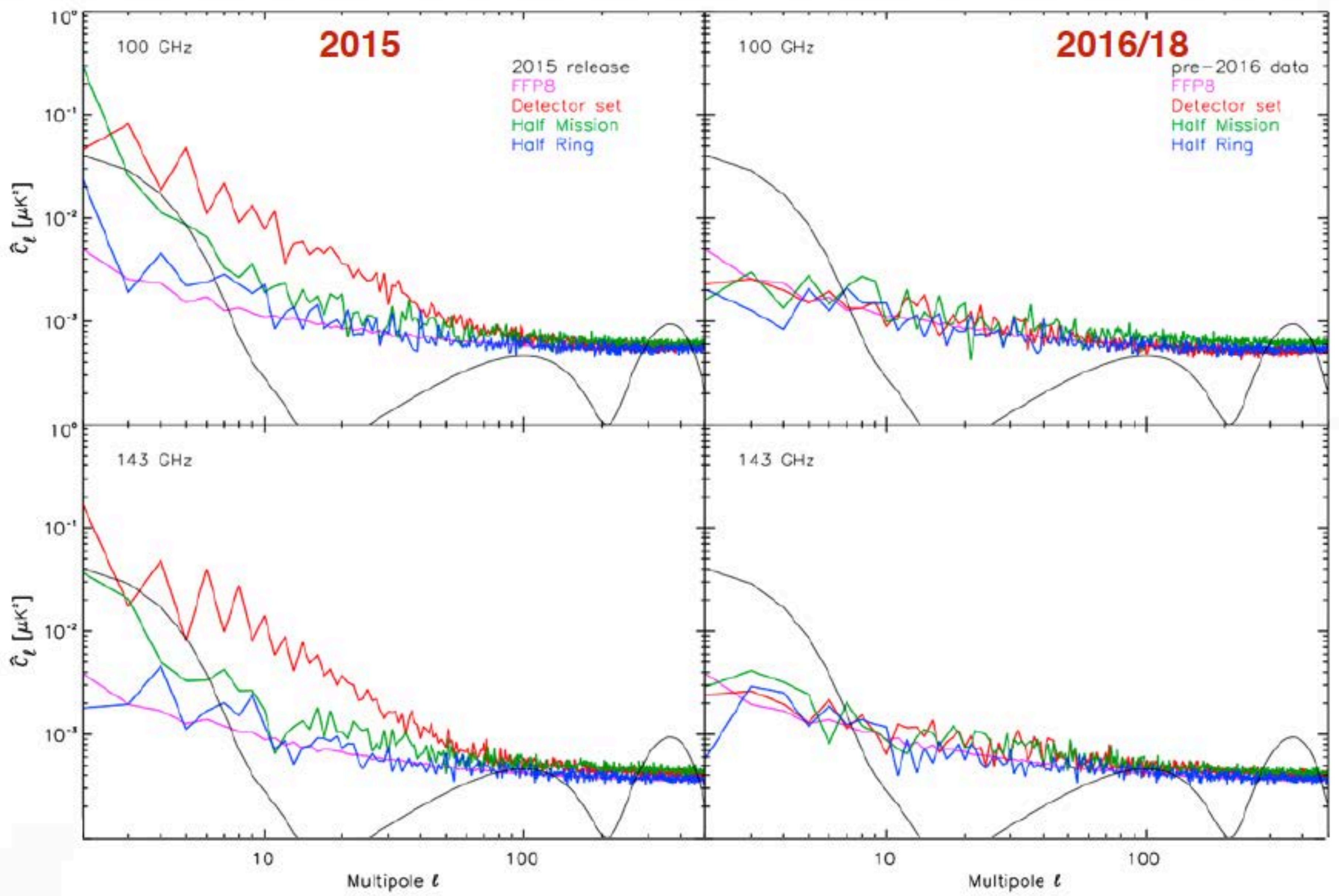
HFI: 2018 odd-even surveys



cross spectra (signal) ` differences (systematic effects residuals) on half data splits 100-143 GHz

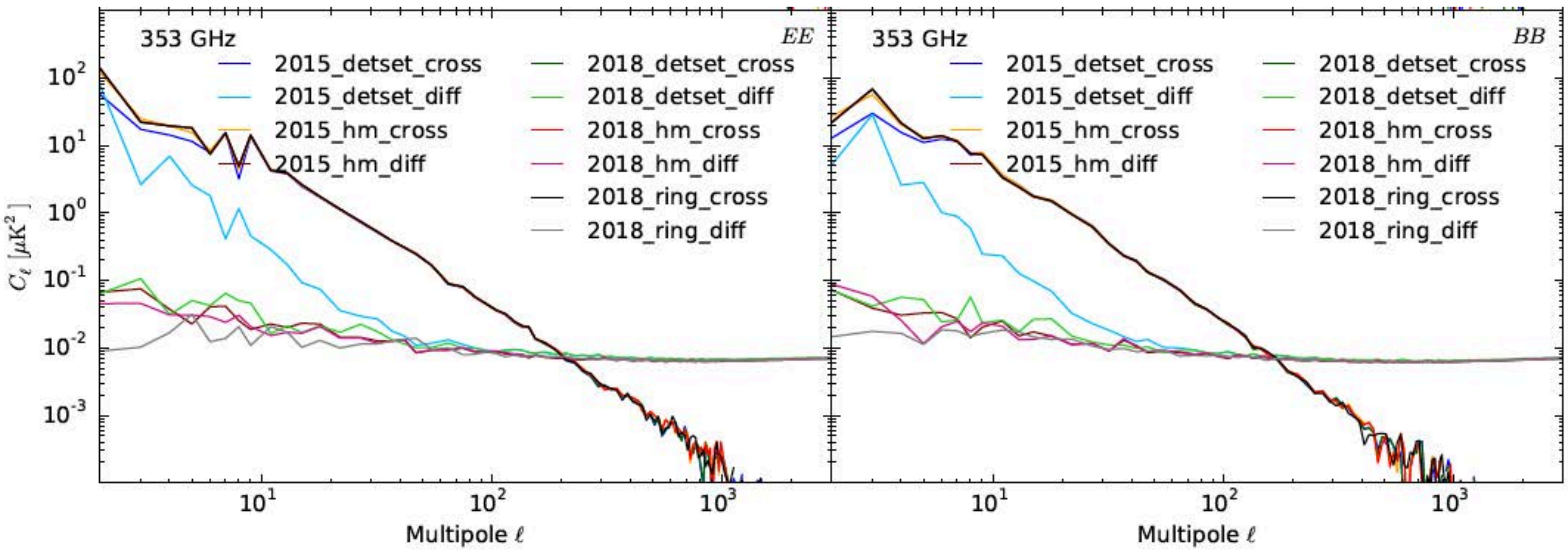


Improvements 2018 Map-making



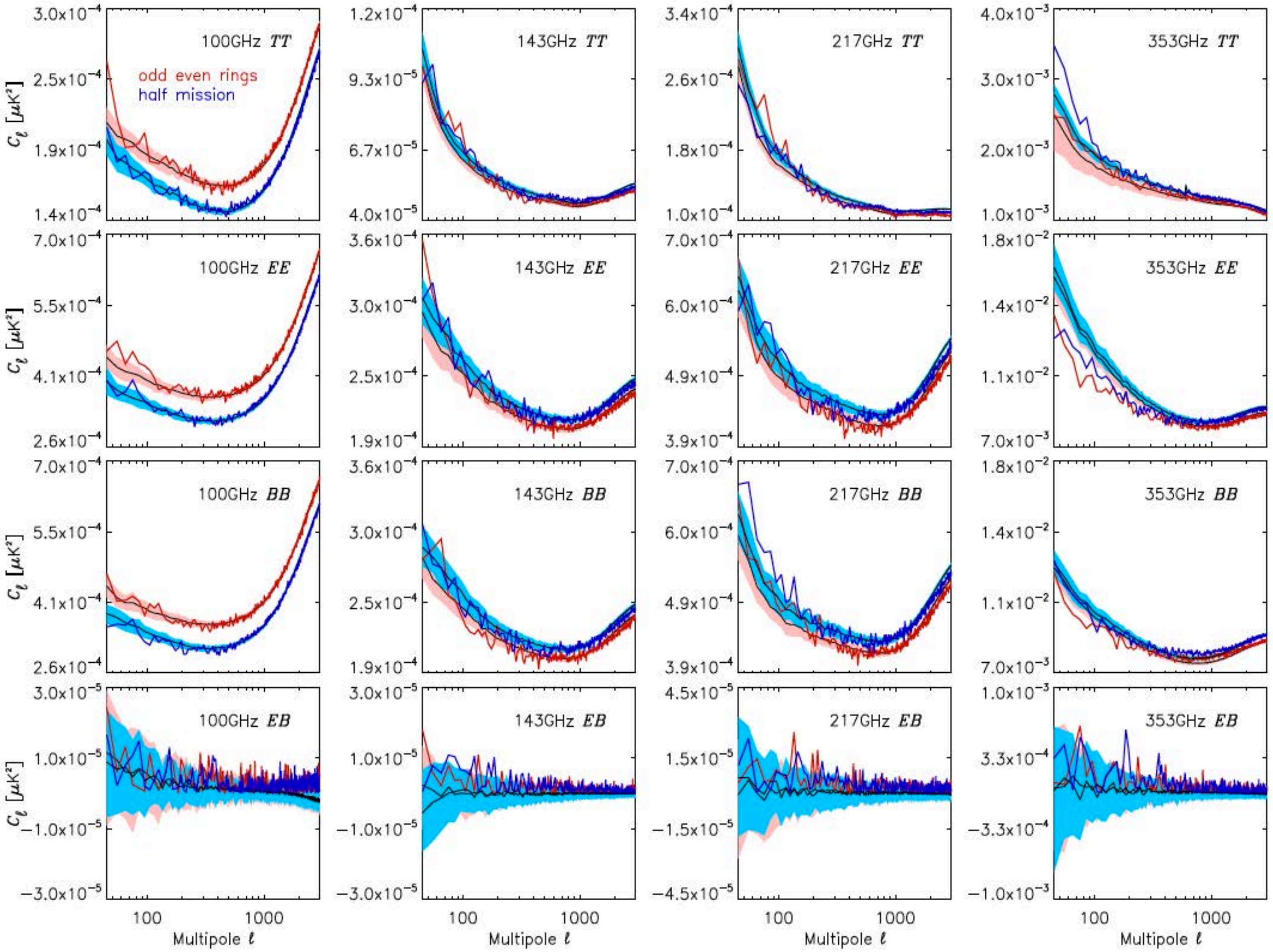
353 GHz cross power spectra differences on half data splits

1. 2015 release different detector sets (blue line) show big low ell residuals
2. 2018 show very reduced but still significant half mission (red line) and det sets (green) differences

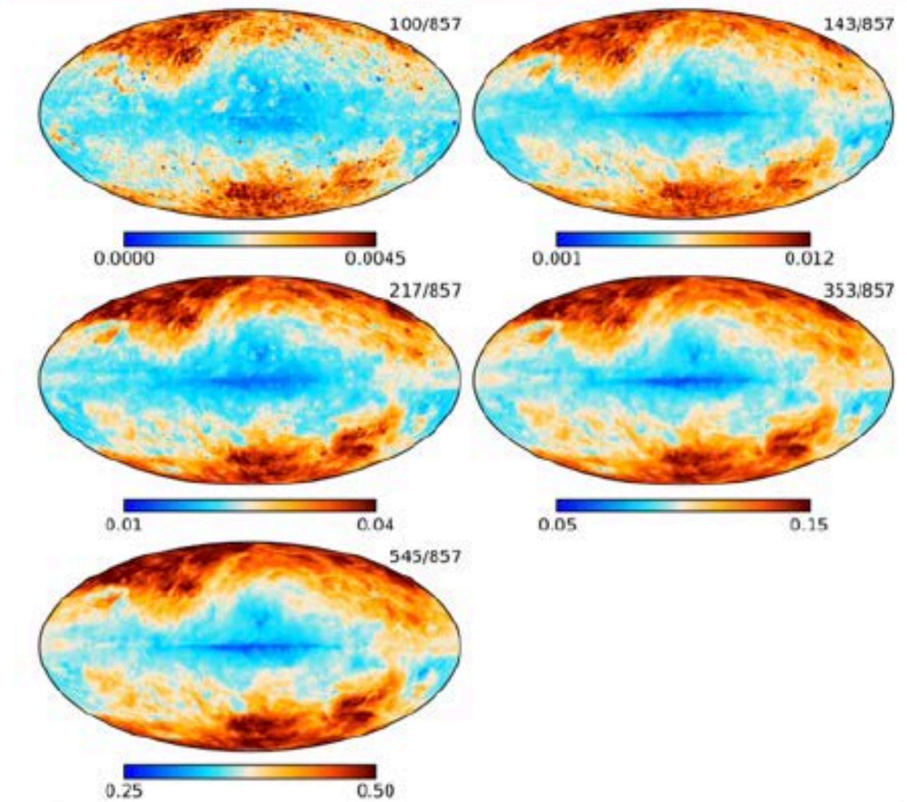


TT, EE, BB, EB power spectra of null test (half mission and odd/even rings splits)

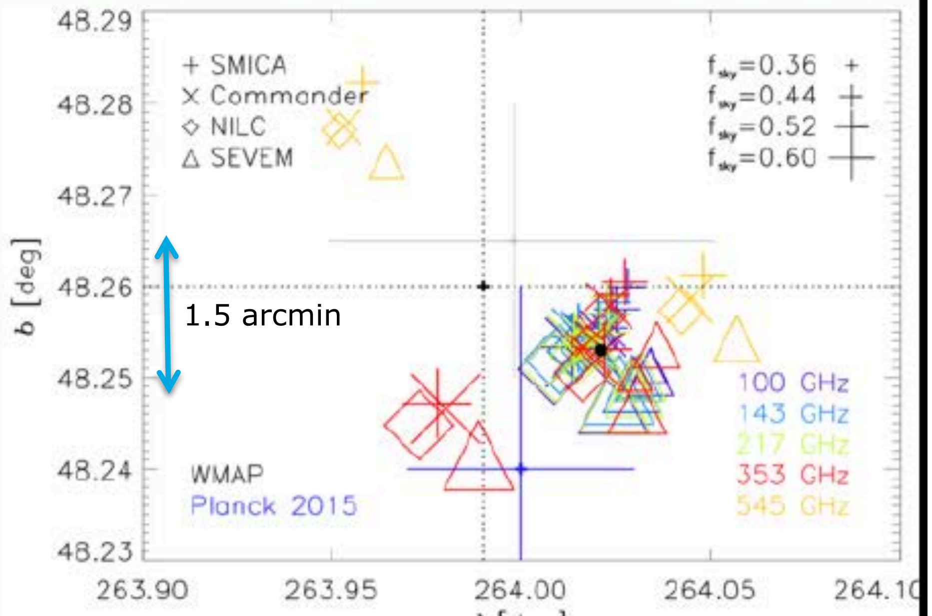
1. we carried out full simulations including all known systematic effects for HFI,
2. display: null test residuals, power spectra TT,EE,BB,EB
3. The sims gives an excellent description of the null tests at high ell (>30)
4. especially the differences between the two null tests:
    a. half mission,
    b. odd/even rings

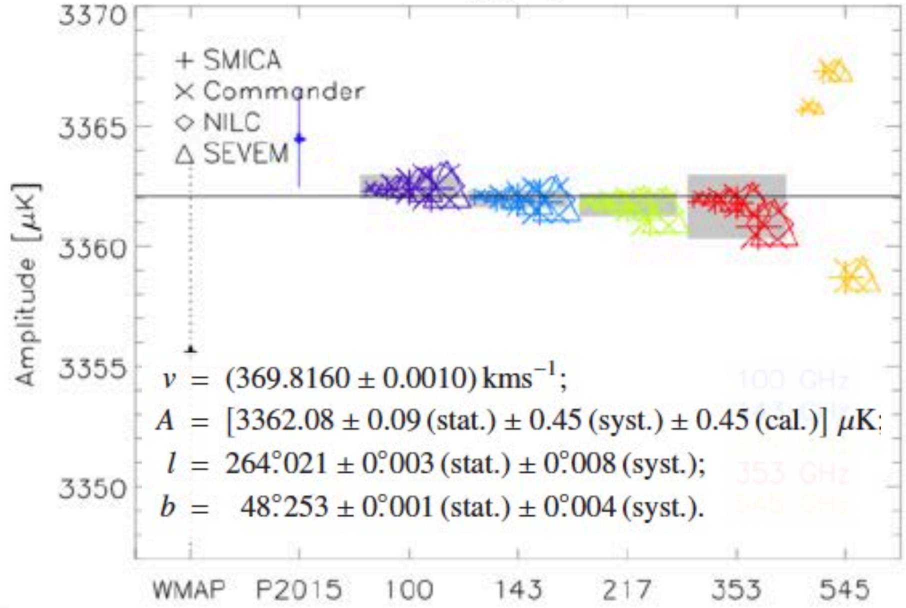


Dipole estimation



Frequency [GHz]	Amplitude [μK]	l [deg]	b [deg]
100	3362.48 ± 0.10	264.022 ± 0.006	48.253 ± 0.003
143	3362.02 ± 0.12	264.021 ± 0.004	48.253 ± 0.002
217	3361.73 ± 0.22	264.020 ± 0.004	48.253 ± 0.002
353	3361.68 ± 0.56	264.013 ± 0.023	48.252 ± 0.006
545	3356.59 ± 15.28	263.899 ± 0.189	48.225 ± 0.052

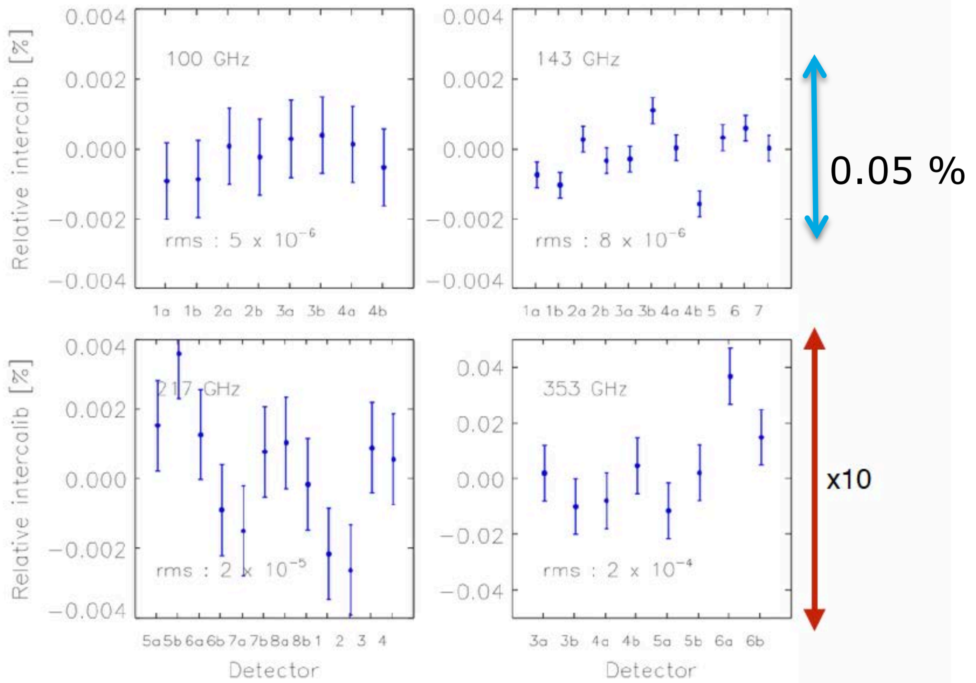




$$v = (369.8160 \pm 0.0010)\,\mathrm{km s^{-1}};$$
$$A = [3362.08 \pm 0.09\,(\mathrm{stat.}) \pm 0.45\,(\mathrm{syst.}) \pm 0.45\,(\mathrm{cal.})]\,\mu\mathrm{K};$$
$$l = 264.^\circ021 \pm 0.^\circ003\,(\mathrm{stat.}) \pm 0.^\circ008\,(\mathrm{syst.});$$
$$b = 48.^\circ253 \pm 0.^\circ001\,(\mathrm{stat.}) \pm 0.^\circ004\,(\mathrm{syst.}).$$

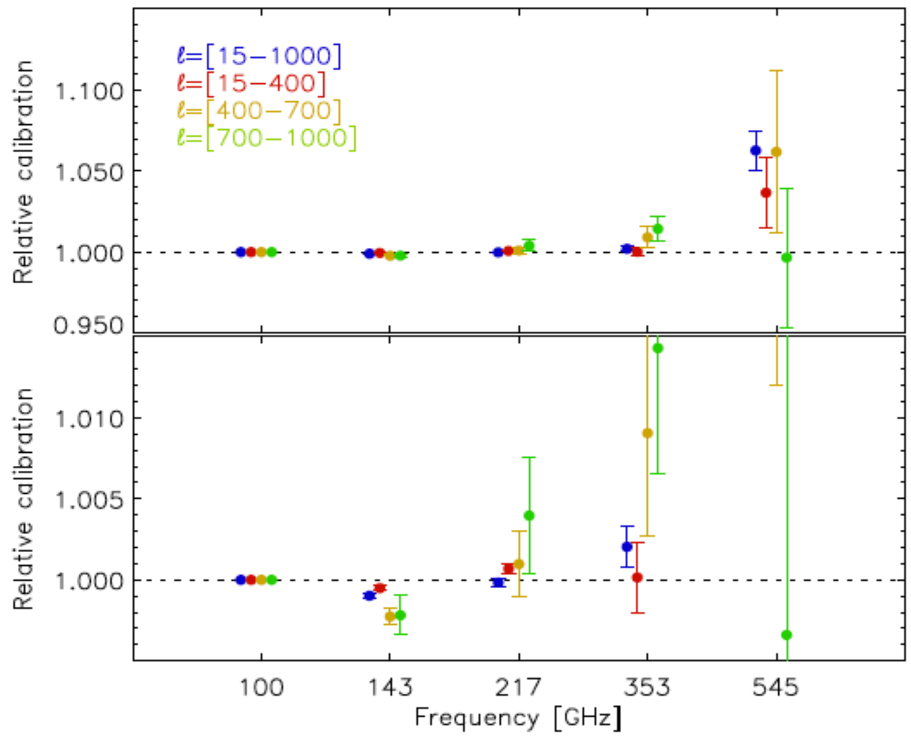
1. in CMB channels we expect S/N 10^5 on the dipoles
   a. 100 GHz rms 5. 10^{-6}
   b. 143 GHz rms 8. 10^{-6}
   c. 217 GHz rms 2. 10^{-5}
   d. 353 GHz rms 2. 10^{-4}
2. the solar dipole becomes an a-posteriori calibration and test tool
   a. interfrequency calibration
   b. absolute calibration bias from the map making (1 to 3 10^{-4} for 100 to 353 GHz)
   c. associated with CMB anisotropies it constrains transfer functions

Relative Calibration



intercalibration on the acoustic peaks (2018 P3)

1. intercalibration between frequencies is of order 10^{-3} at the 1st acoustic peak
2. no obvious trend on the transfer function comparing 1st, 2nd and 3rd acoustic peaks
3. polarization data depends also on polarization efficiency
   a. polar efficiencies have been measured on the ground with typically 1% accuracy
   b. inter-comparison of cross power spectra EE and TE allows to measure relative values
   c. assuming the best T cosmological model as a reference we can also derive quasi-absolute polar efficiencies



Frequency [GHz]	*EE* first peaks SMICA %	Cosmology driven Camspec %	Cosmology driven Plik %	Combined residuals %
100	+2.4 ± 0.5	+1.3 ± 0.5	+1.0 ± 0.5	+0.7 ± 1.0
143	Ref.	−1.6 ± 0.5	−1.7 ± 0.5	−1.7 ± 1.0
217	+3.6 ± 0.5	+2.5 ± 0.5	+2.0 ± 0.5	+1.9 ± 1.0

HFI Low ell likelihood

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1. one cosmological parameters (the re-ionization optical depth τ) in Λ-CDM can be measured nearly independently of the others; this allowed to built a simulation based likelihood for a single parameter (or a very small number of parameters)
2. for very low ell, the prob. dist. of the C_ℓ values using an analytical shape approximation does not agree with the one obtained in the end-to-end sims
3. the results are unstable in front of very small changes in the data
4. the proper mathematical description of the noise + residuals of systematic and component separation effects does not exist
5. we thus built a likelihood based on the 300 sims first in Planck Coll. Int. XLVI (2016): SimBaL, SimLow (τ only), and statistics of 300 end-to-end sims * 1000 CMB sims (for each ell) in an improved version: SimAll for the 2018 release (A_s, τ, r).
6. the sims contain all known systematics and also reproduce the cleaning of foregrounds procedure (the dust foreground dominates and is better simulated
7. this approach is safer but limited by the number of sims, itself limited by computing power (these sims were built on the NERSC computers)
8. even if future experiments will be built to avoid some of the Planck-HFI polarized systematic effects, they will probably be limited by interstellar foregrounds which are also very non gaussian (turbulence)
9. this problem is not going to go away easily

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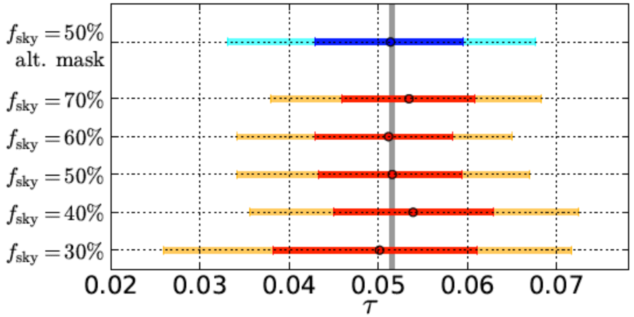
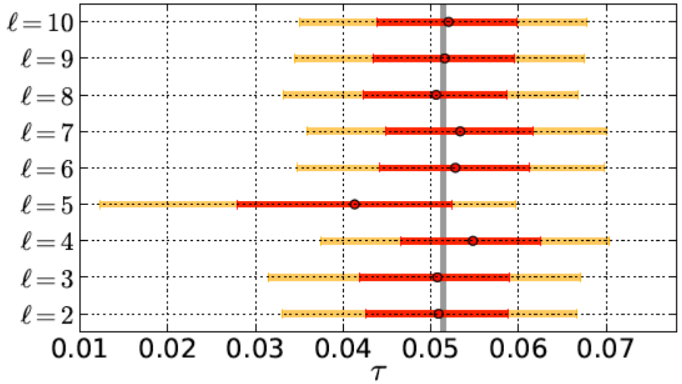
HFI PLANCK

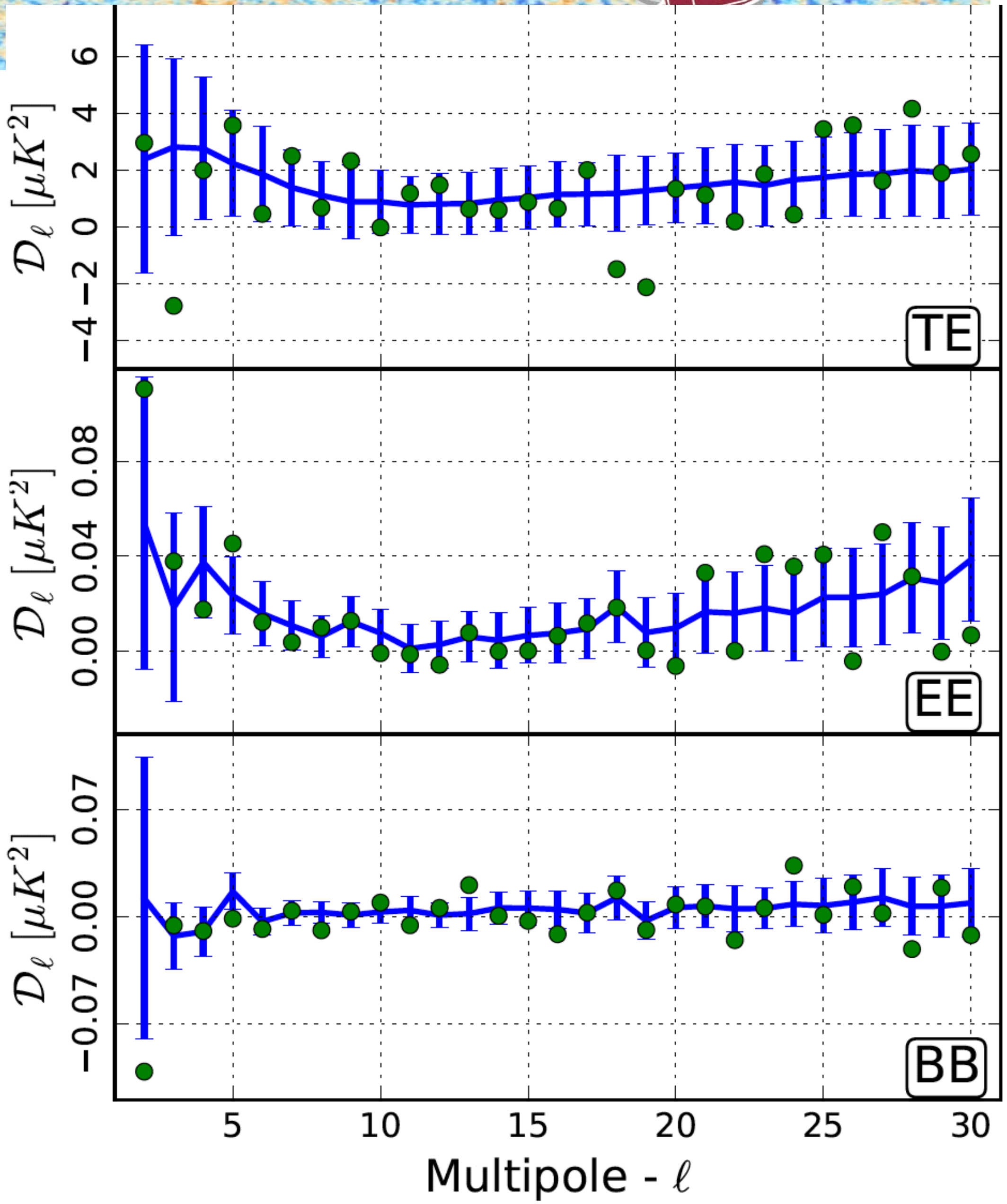
HFI quasi QML polarization cross power spectra at low ℓ

1. for 100x143 TE,EE,BB f_{sky} =0.5
2. green points are the data
3. blue are 300 end-to-end simulations

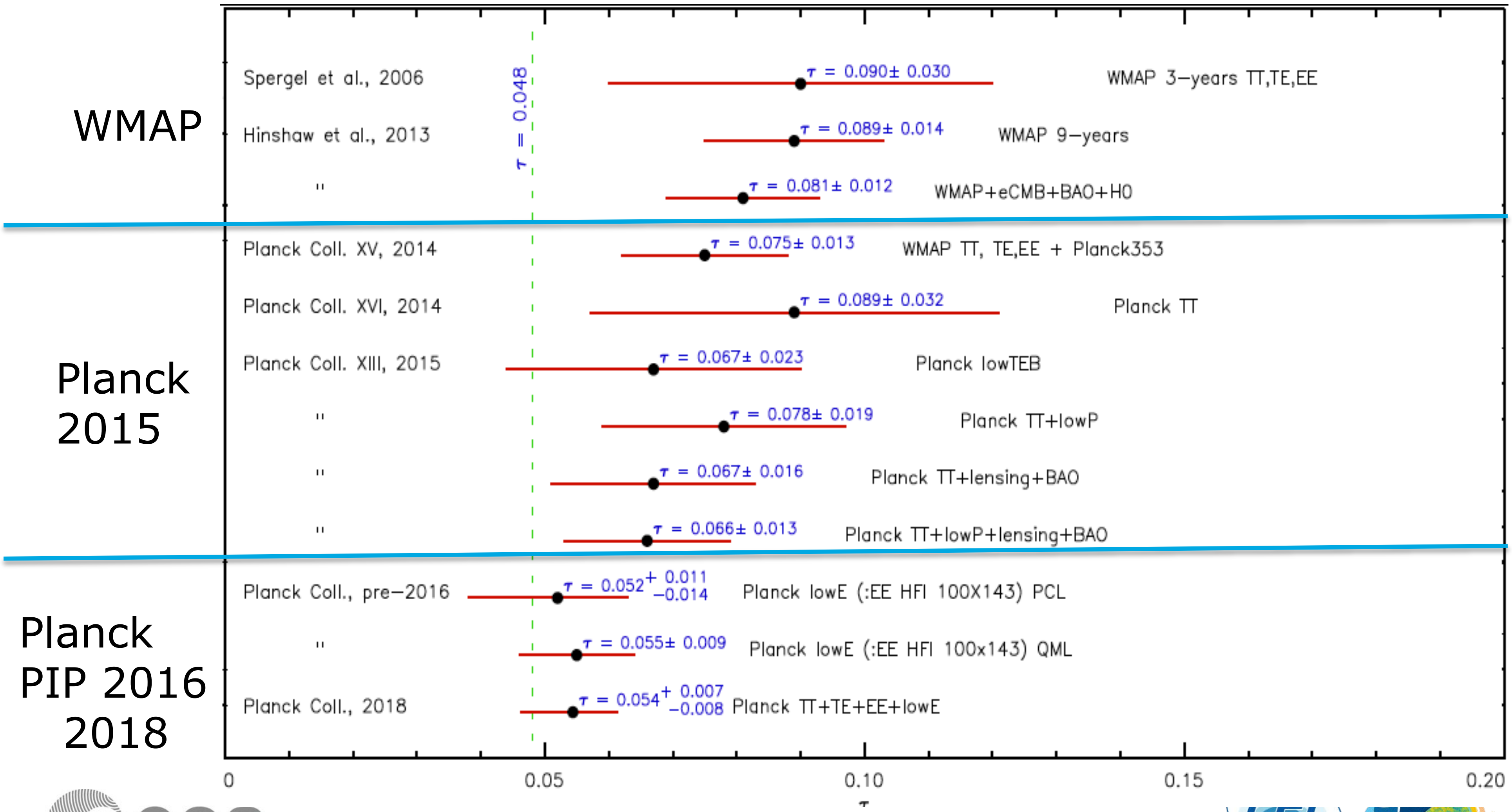
Parameter	ΛCDM	ΛCDM + r
$\ln[10^{10}A_s]$	2.924 ± 0.052	$2.863^{+0.089}_{-0.062}$
τ	0.0506 ± 0.0086	0.0503 ± 0.0087
$r_{0.002}$	–	≤ 0.41
$A_s e^{-2\tau}$	$1.685^{+0.083}_{-0.091}$	$1.59^{+0.11}_{-0.13}$







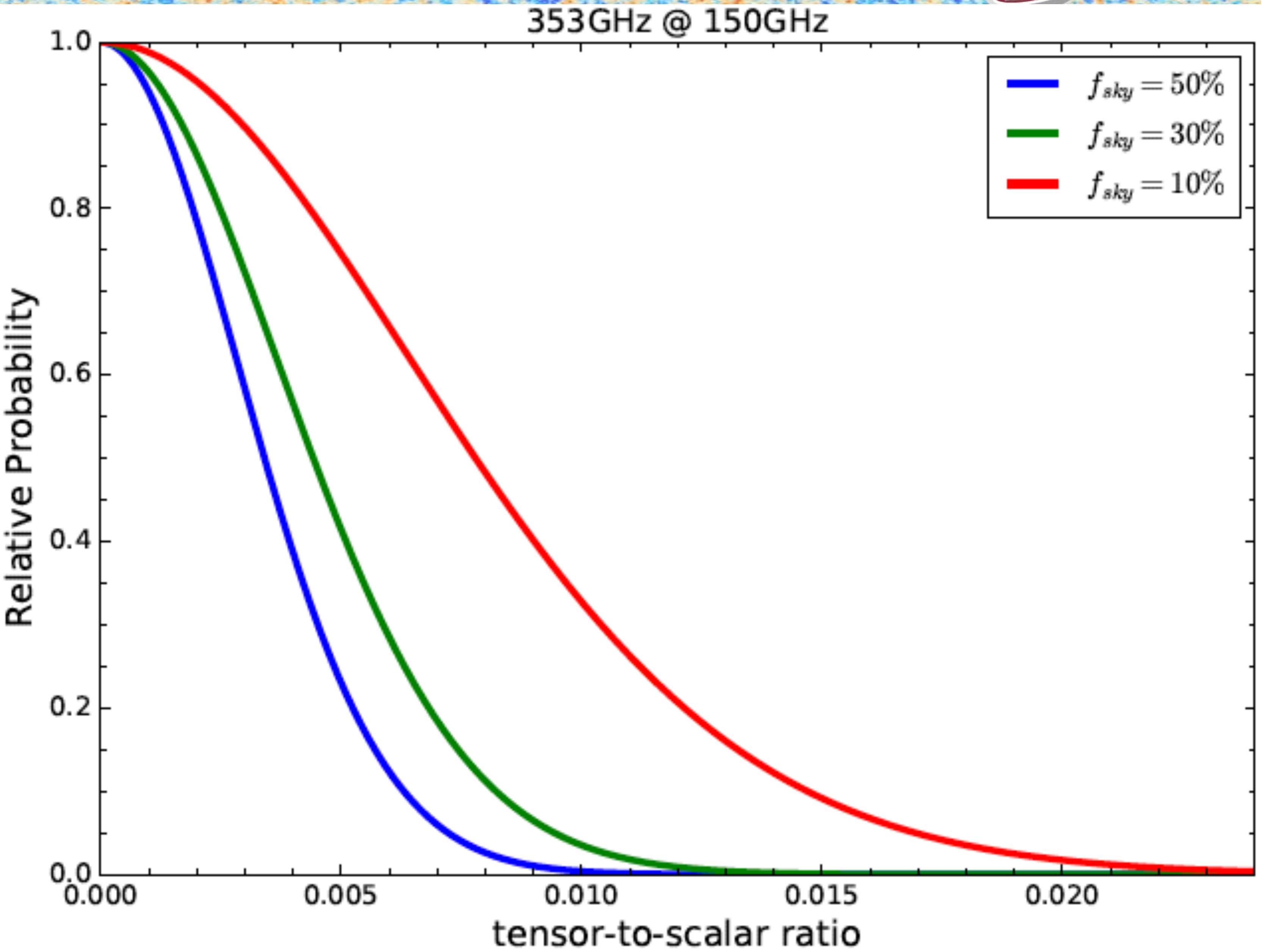
τ from CMB (historical)



HFI 353 GHz as a dust cleaning frequency to search for B modes on large f_{sky}

1. The 353 GHz is still not at the white detector noise for large scale polarized signals
2. we know what is the remaining systematic effect: very long time constants of order half a minute
3. if 353 GHZ polarized maps are cleaned to bring the large scales to be white noise dominated and combined with much more sensitive than Planck HFI in large sky surveys in the 100 to 150 GHz range we can compute what is the limit on r (tensor to scalar ratio) introduced by a dust correction based on the HFI 353 GHz data

dust removal limited posterior on r parameter
(HFI 353 Ghz white noise)



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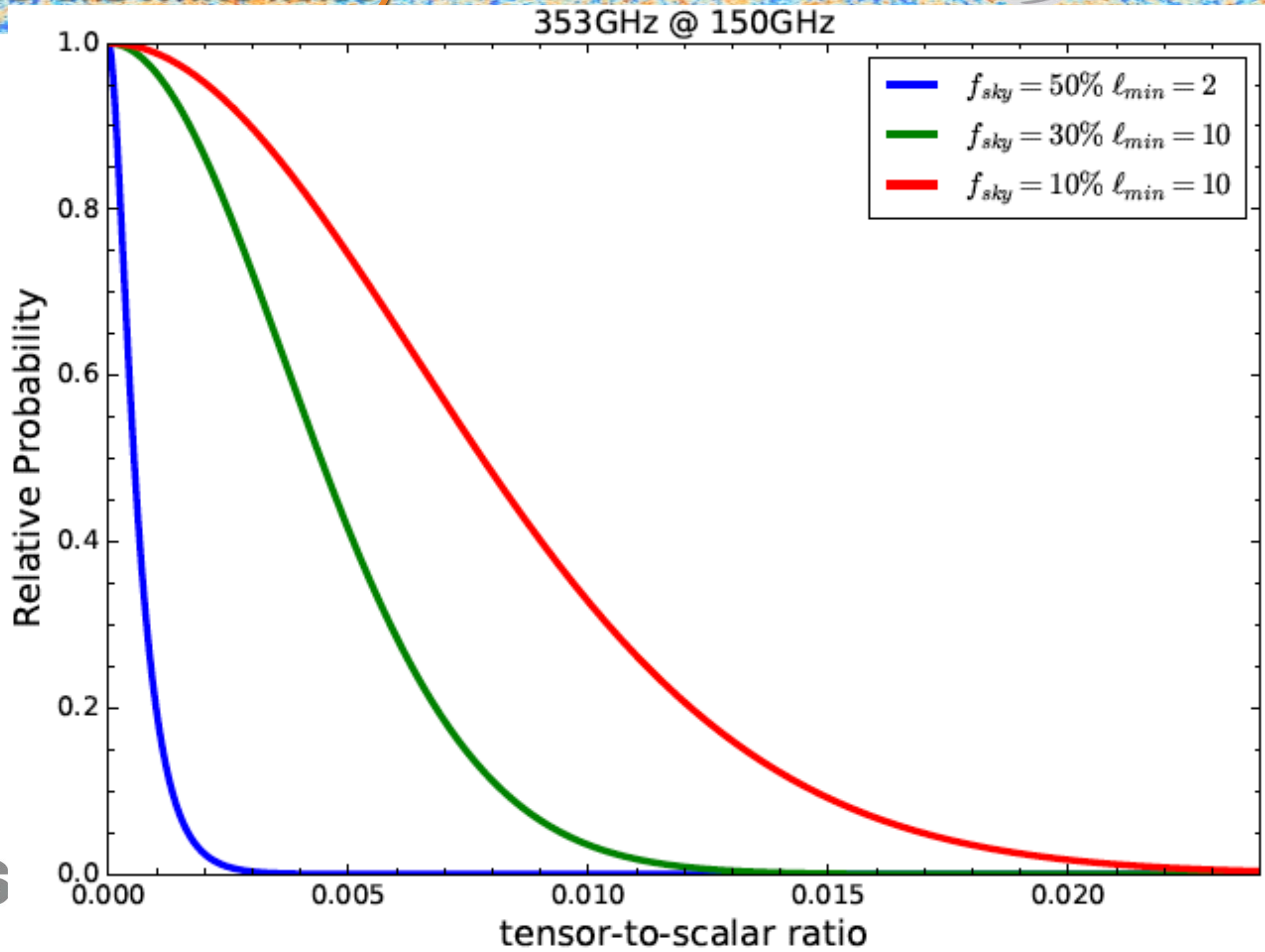

Conclusions

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1. very significant improvements on the removal of systematic effects at large scale in the polarized maps
2. the systematic effects residuals are not like a Gaussian noise
3. the end to end simulations are a key tool for the low ell likelihood
4. this is best illustrated by the determination of τ
5. the 353 GHz will probably remain for several years the best channel to clean the dust in the search of the primordial gravitational waves on large fraction of the sky

The scientific results that we present today are a product of the Planck Collaboration, including individuals from more than 100 scientific institutes in Europe, the USA and Canada.

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