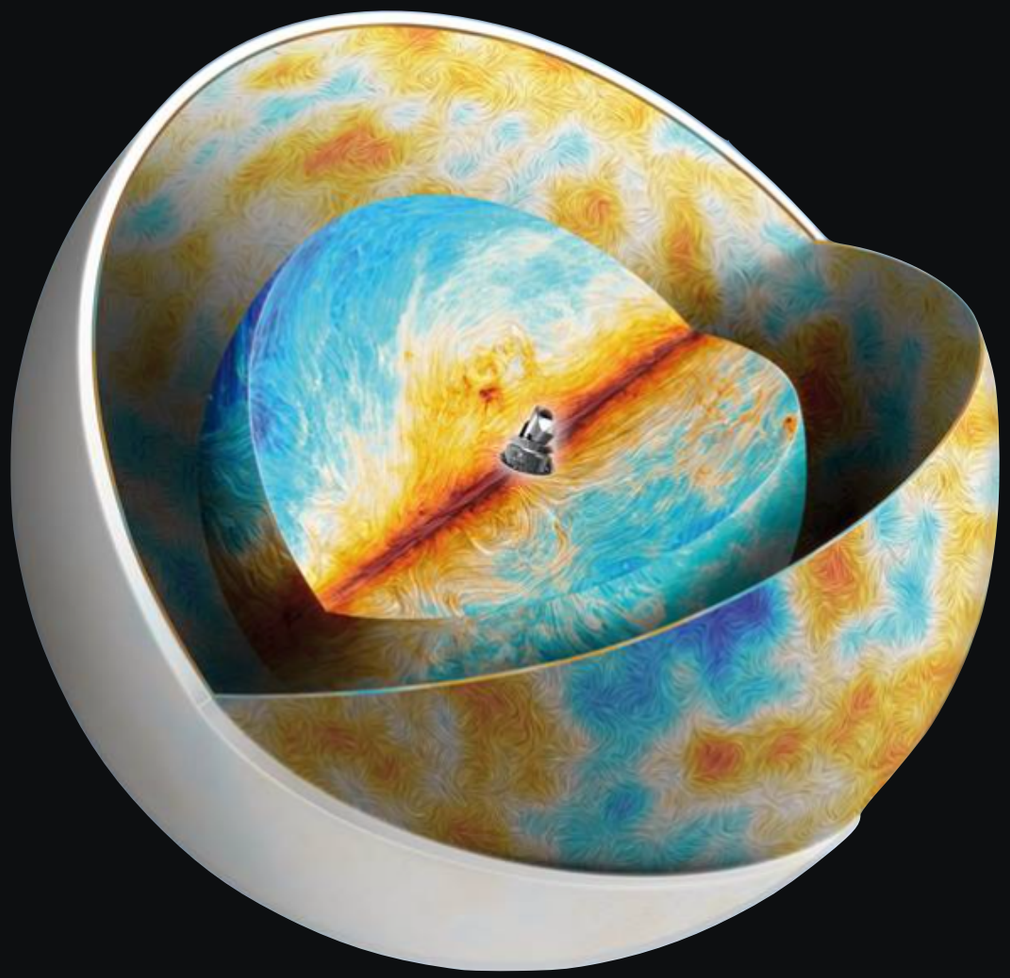
Polarized dust emission knowledge and CMB cleaning efficiency



Jonathan Aumont

IAS, Orsay, France

on behalf of the Planck Collaboration

with additional work in collaboration with:

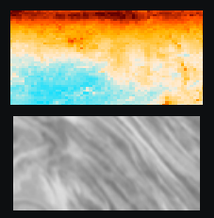
Ludovic Montier, François Boulanger

Friday, December 11th 2015

1. What did we already learn on dust from Planck data in the framework of CMB B-modes detection?

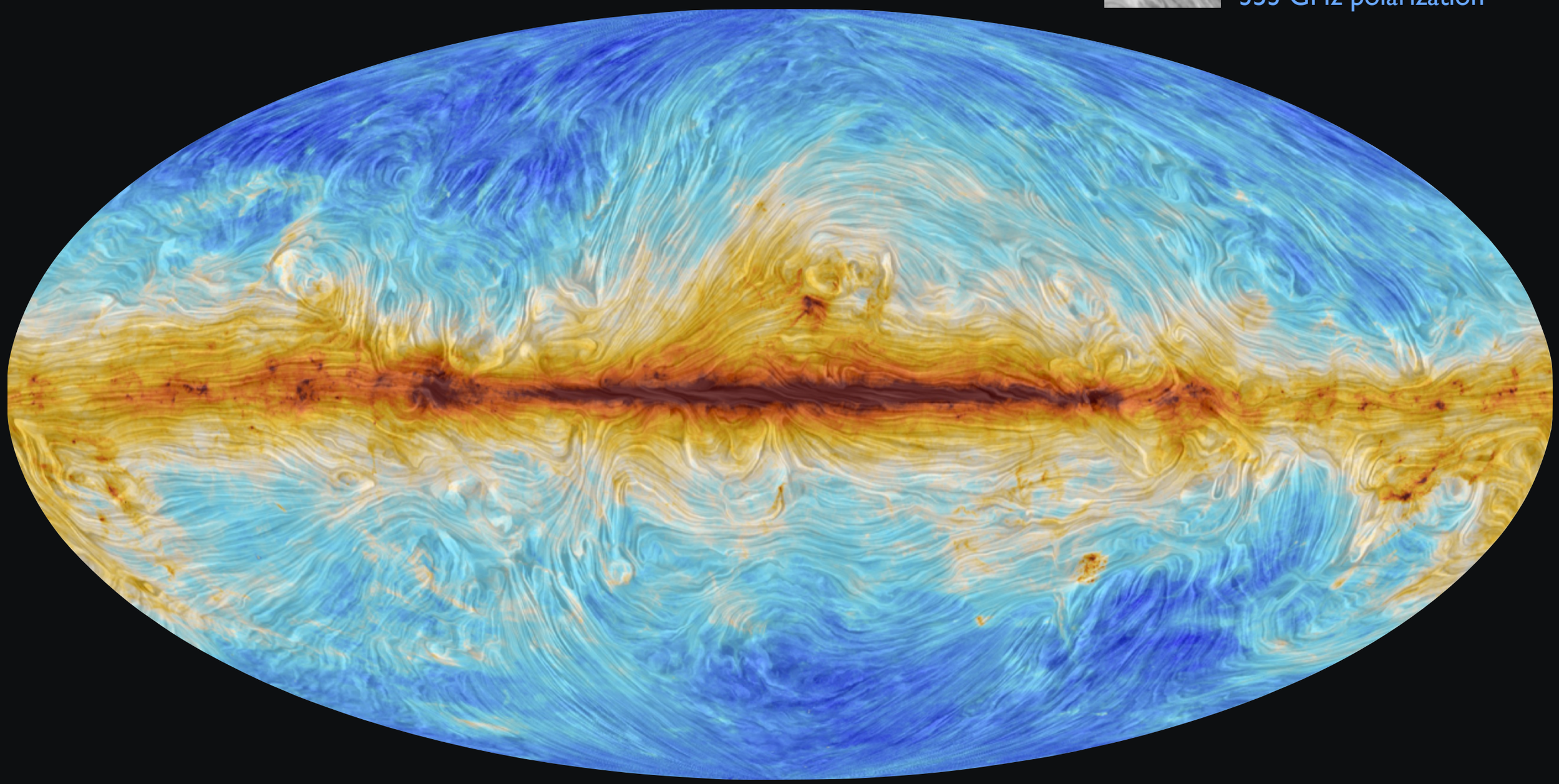
Dust at 353 GHz measured by Planck

[Planck Intermediate 2014 XIX-XXII]
[Planck Collaboration 2015 I]



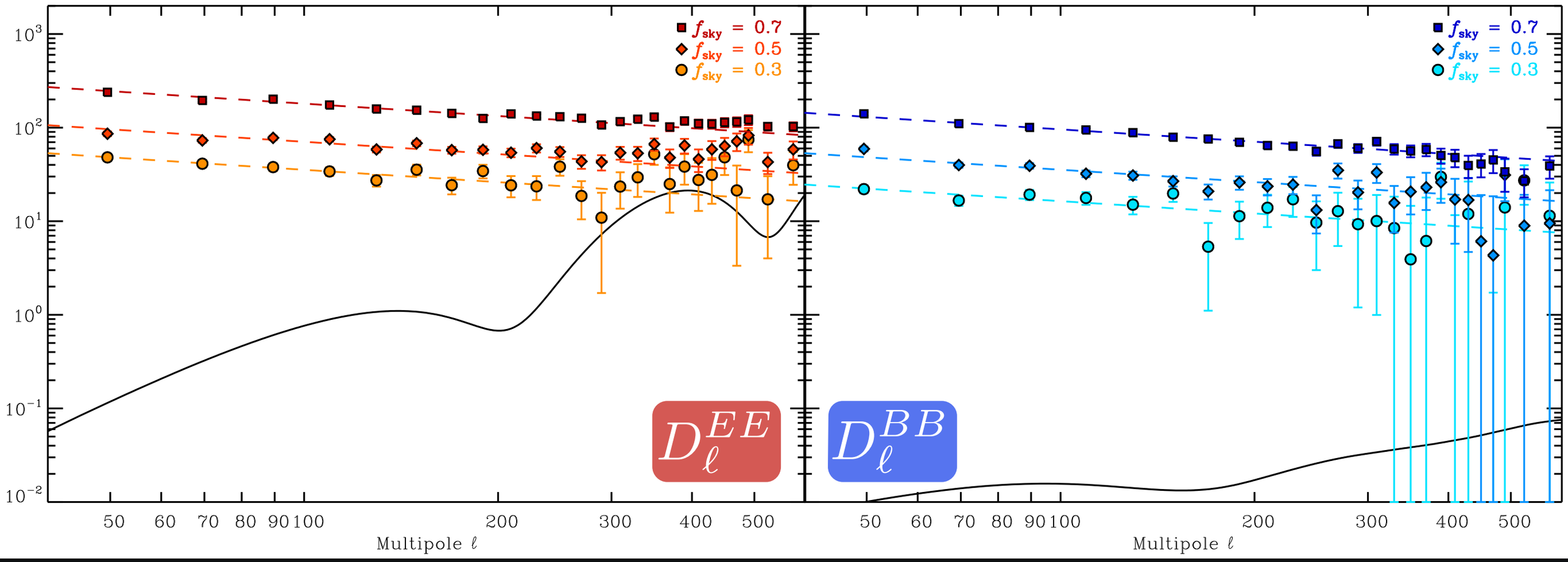
Dust intensity

Galactic magnetic field from 353 GHz polarization



★ Planck unveils a new sky!
★ Allows to study the interplay between matter and the Galactic magnetic field
★ Allows to understand a very important foreground for CMB polarization measurements

Dust polarization angular power spectra features at 353 GHz



[Planck Intermediate 2014 XXX]

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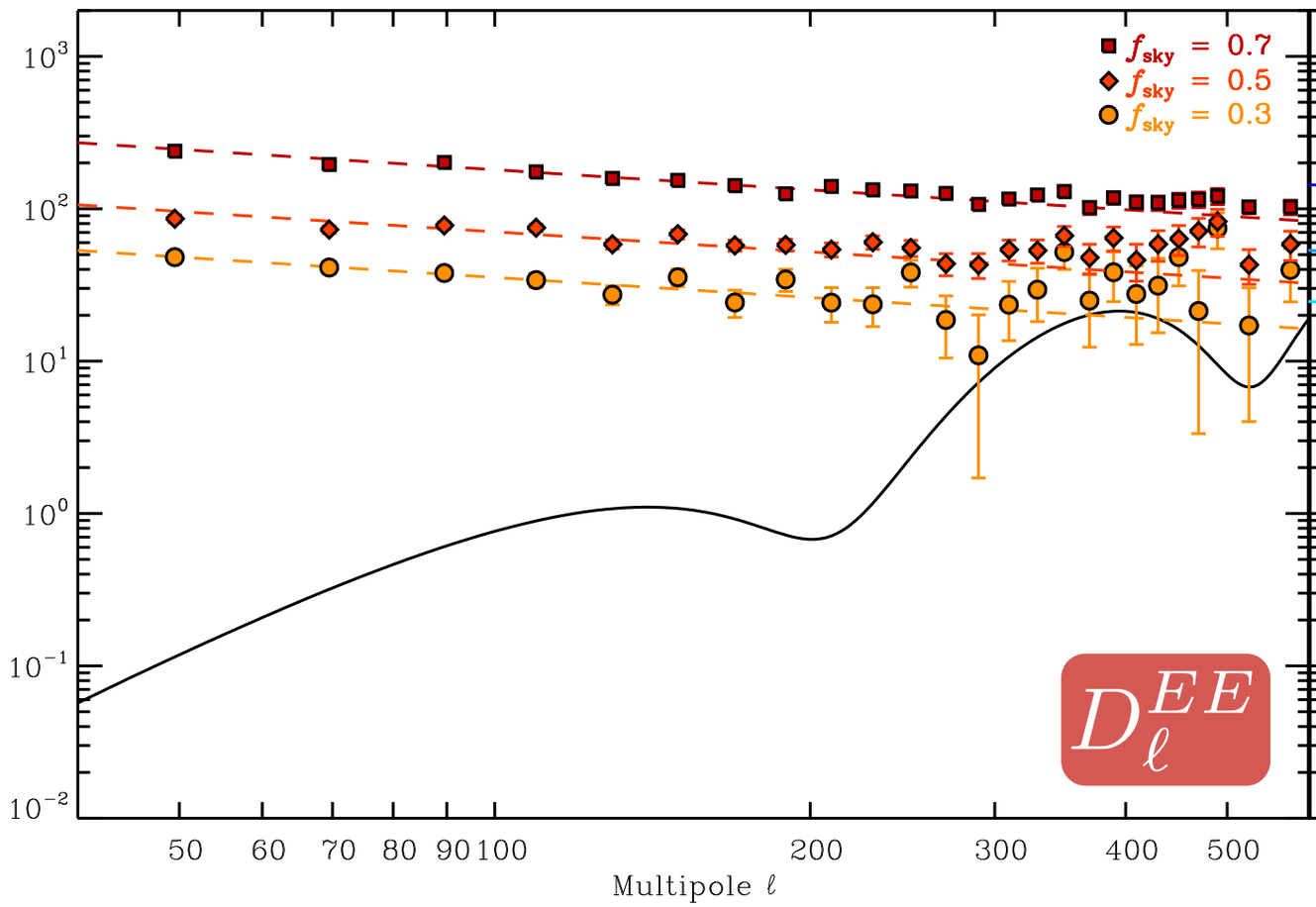
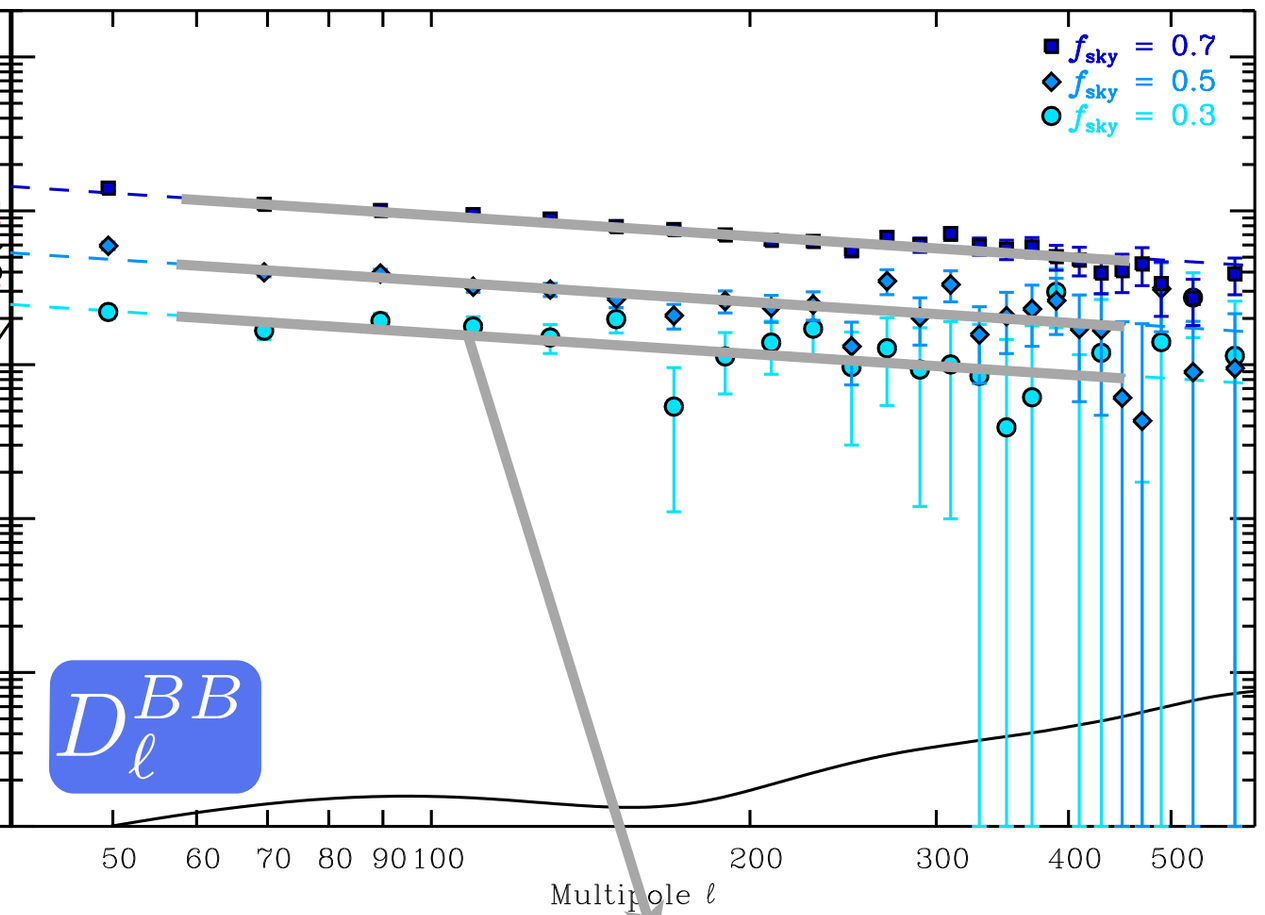
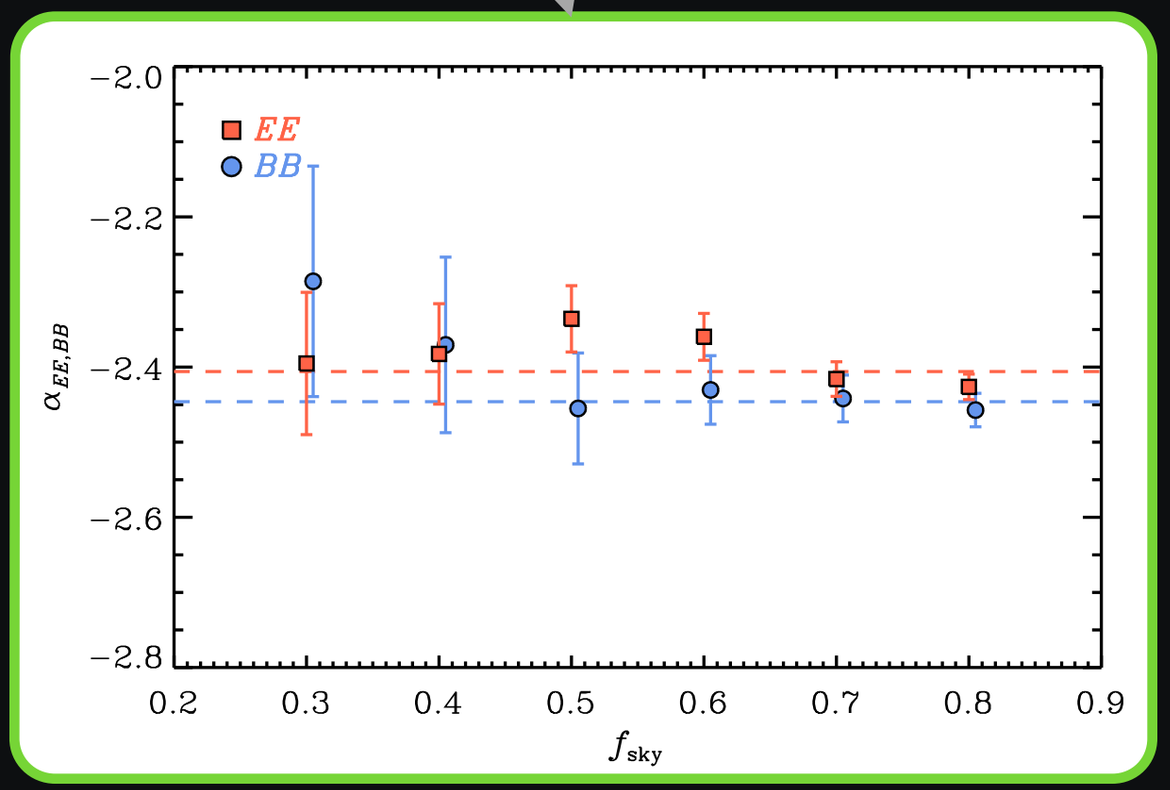




[Planck Intermediate 2014 XXX]

★ Dust polarization spectra follow power-laws of ℓ with a -2.42 slope



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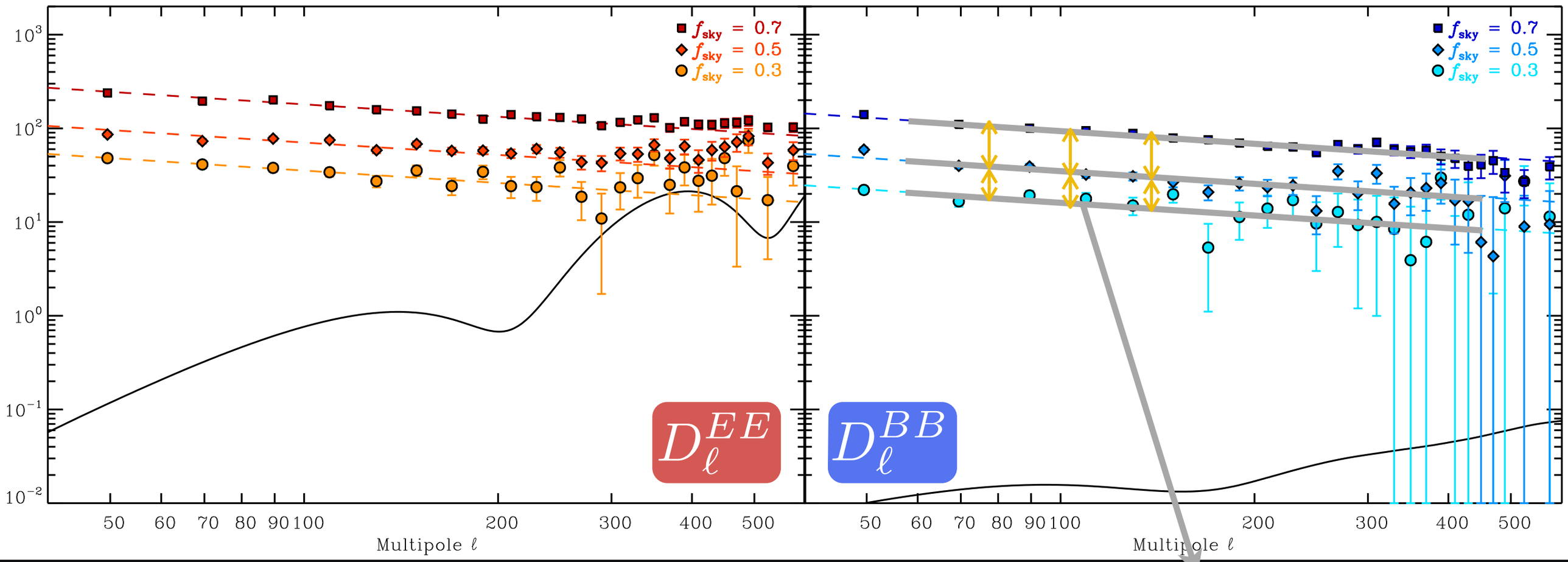
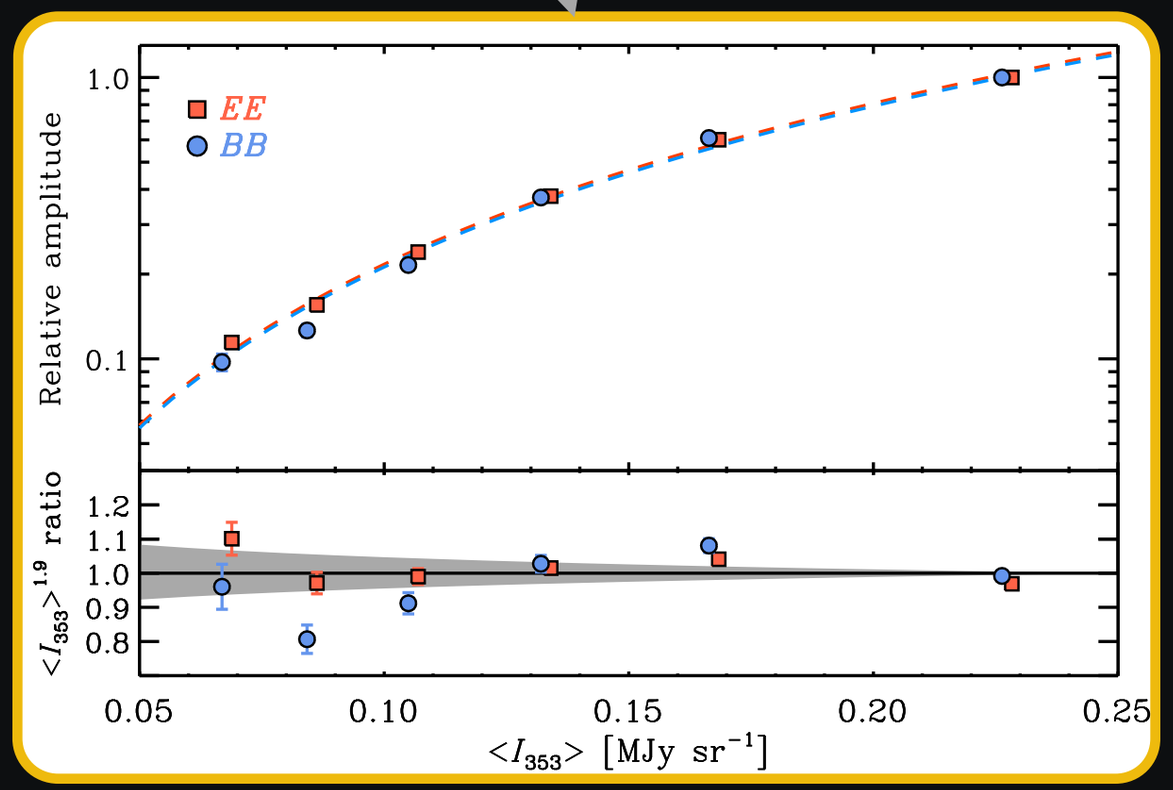


[Planck Intermediate 2014 XXX]

- ★ Dust polarization spectra follow power-laws of ℓ with a -2.42 slope
- ★ Spectra scale as a function of the mean intensity of the mask ($\langle I_{dust} \rangle^{1.9}$)



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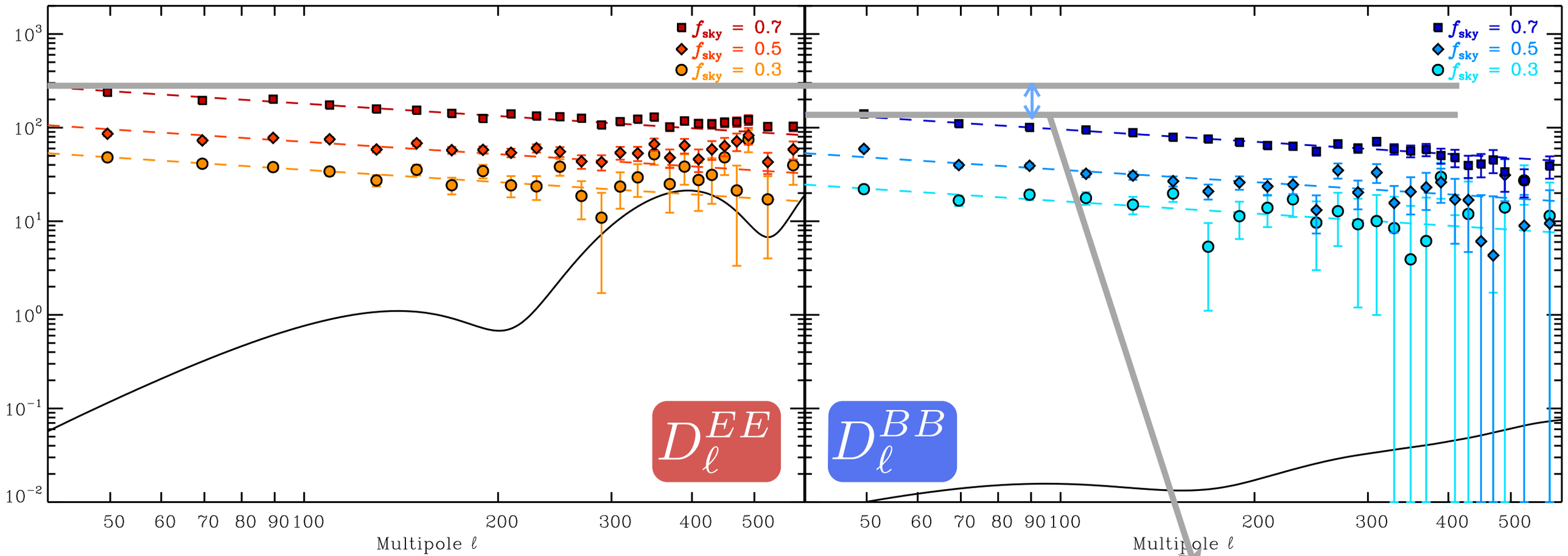
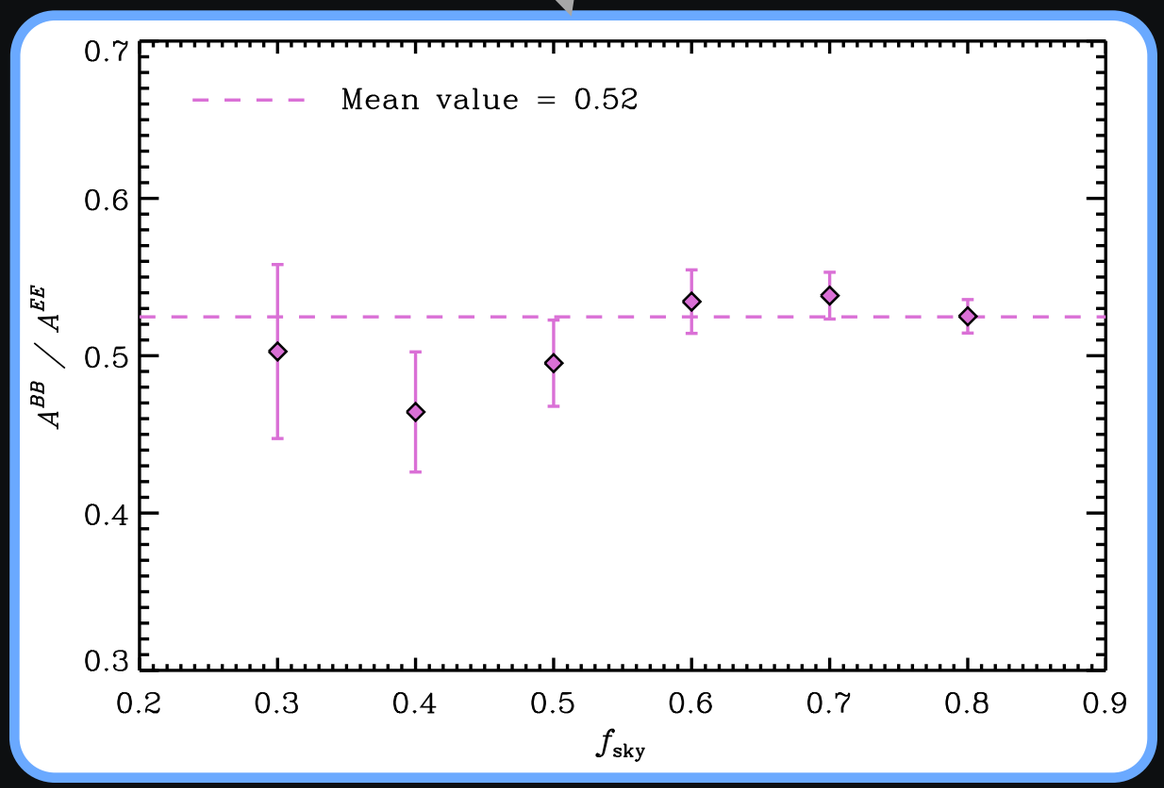


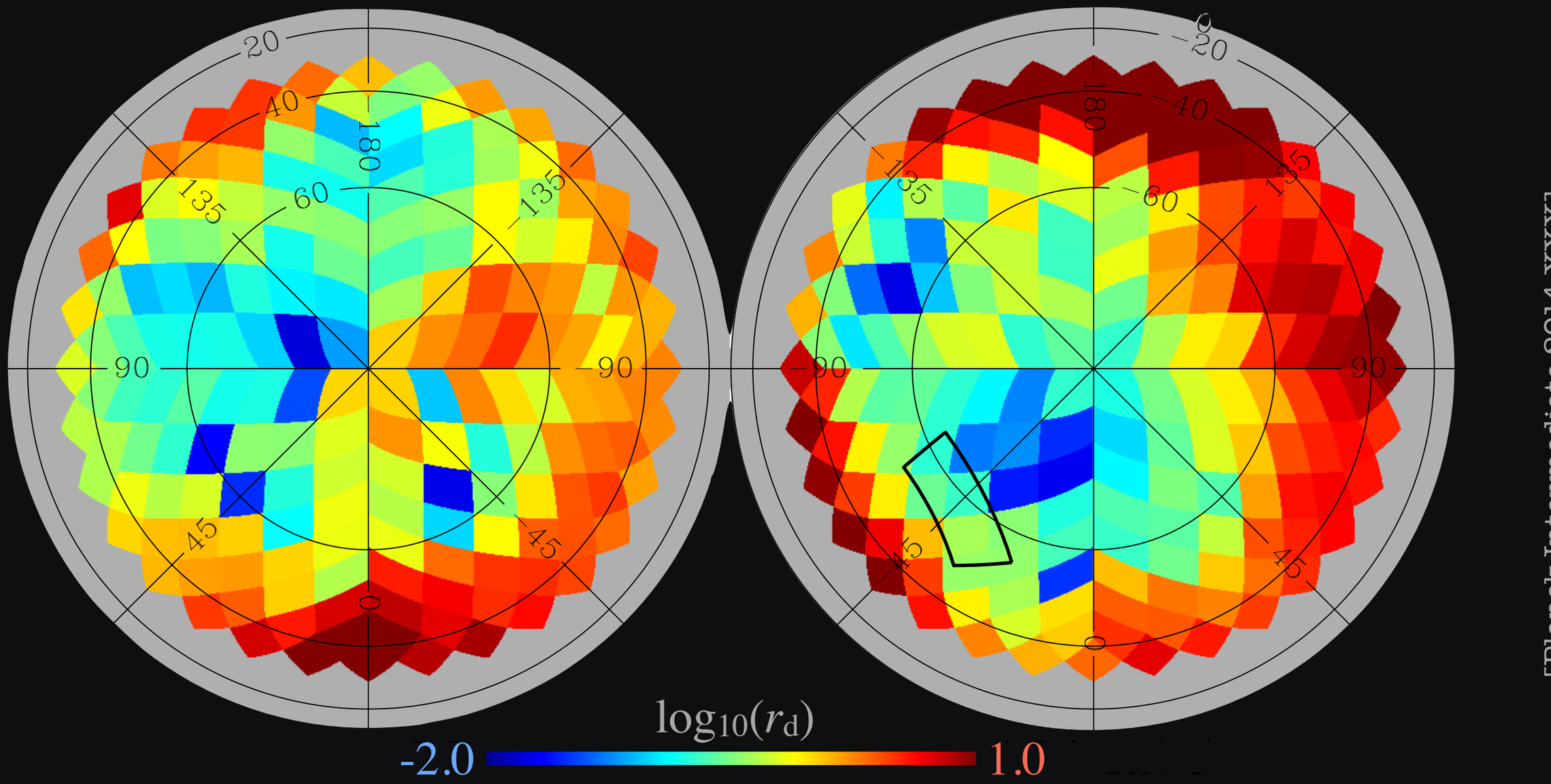
[Planck Intermediate 2014 XXX]
[Planck Intermediate 2014 XXXVIII]

- ★ Dust polarization spectra follow power-laws of ℓ with a -2.42 slope
- ★ Spectra scale as a function of the mean intensity of the mask ($<I_{dust}>^{1.9}$)
- ★ BB/EE ~ 0.5

- ★ This simple model will be a benchmark for CMB component separation and likelihood analyses



Dust B-modes predicted contamination at 150 GHz



[Planck Intermediate 2014 XXX]

- ★ Extrapolation of the *BB* amplitudes at 150 GHz
- ★ Amplitudes expressed in units of r_d (e.g. r_d = 0.2 means that the dust has the same level as the CMB r = 0.2 at ℓ=80)
- ★ The cleanest regions of the sky have $r_d \sim 0.01 \pm 0.06$
- ★ The dust polarization has to be assessed, everywhere on the sky, to measure the CMB primordial *B*-modes

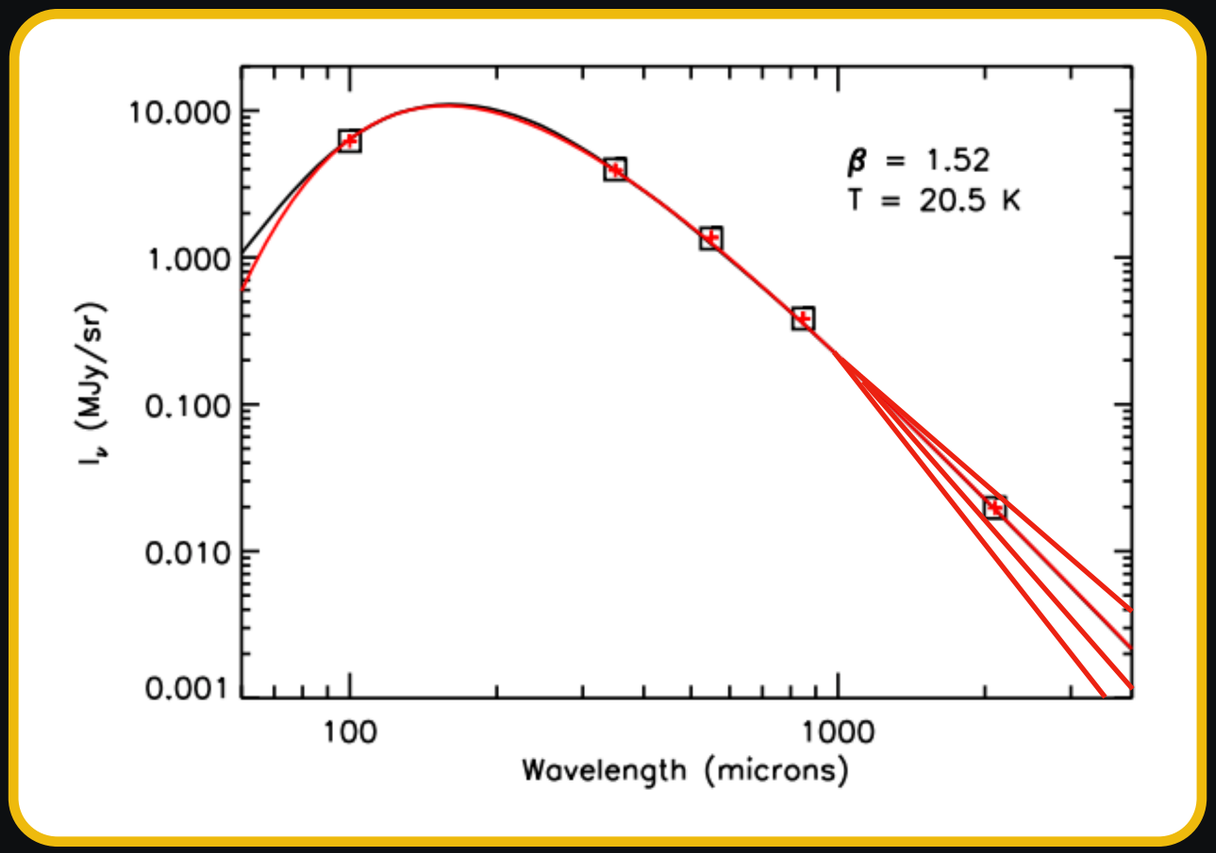
See Nicoletta Krachmalnicoff's talk

2. Is the dust polarization frequency scaling constant over the sky?

Dust polarization emission law

★ Dust polarization Spectral Energy Distribution (SED) described by a modified black-body spectrum:

$$I_\nu \propto \nu^\beta B_\nu(T_{\rm dust})$$



★ A variation of the dust SED, modeled by a $\Delta\beta$, can effectively represent any physical variation of the emission law between 353 and 100 GHz

- ✦ Dust temperature variations
- ✦ Emission law variations
- ✦ Line of sight mixing

Dust polarization emission law

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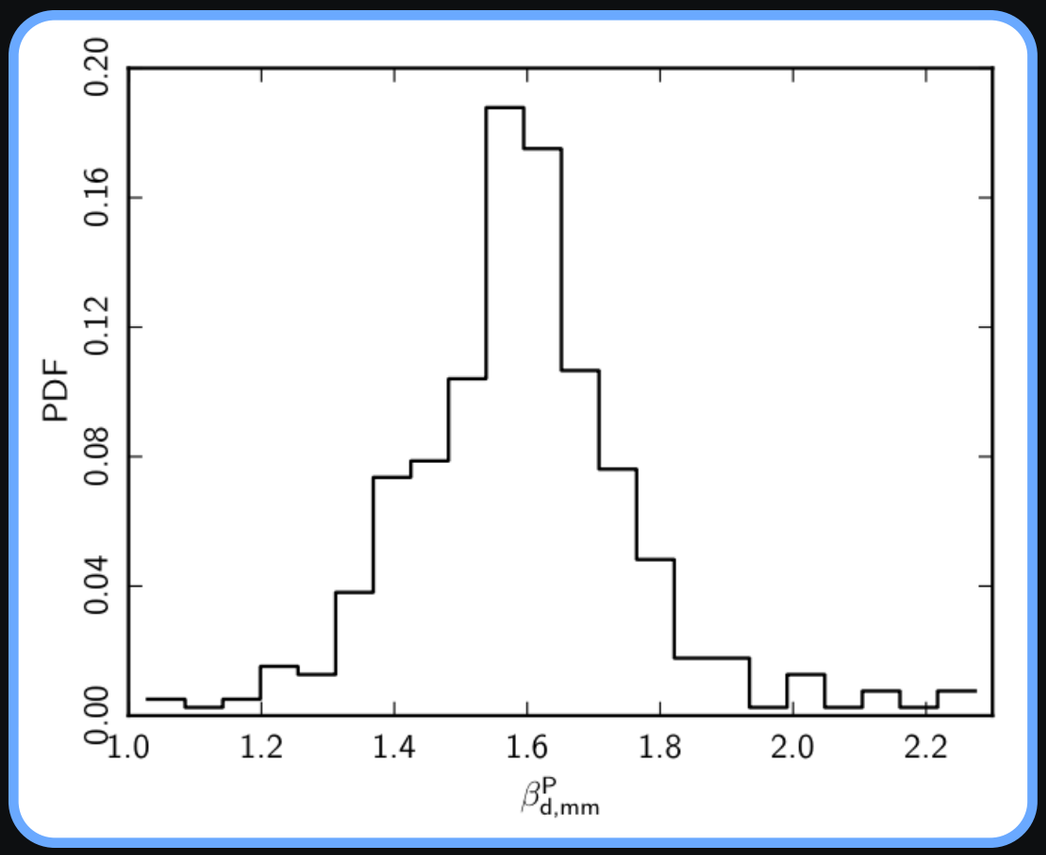
★ **PIP XXII:**

✦ $\beta_{\rm dust}$ = 1.59±0.17, no evidence for variations beyond Planck noise at high Galactic latitudes



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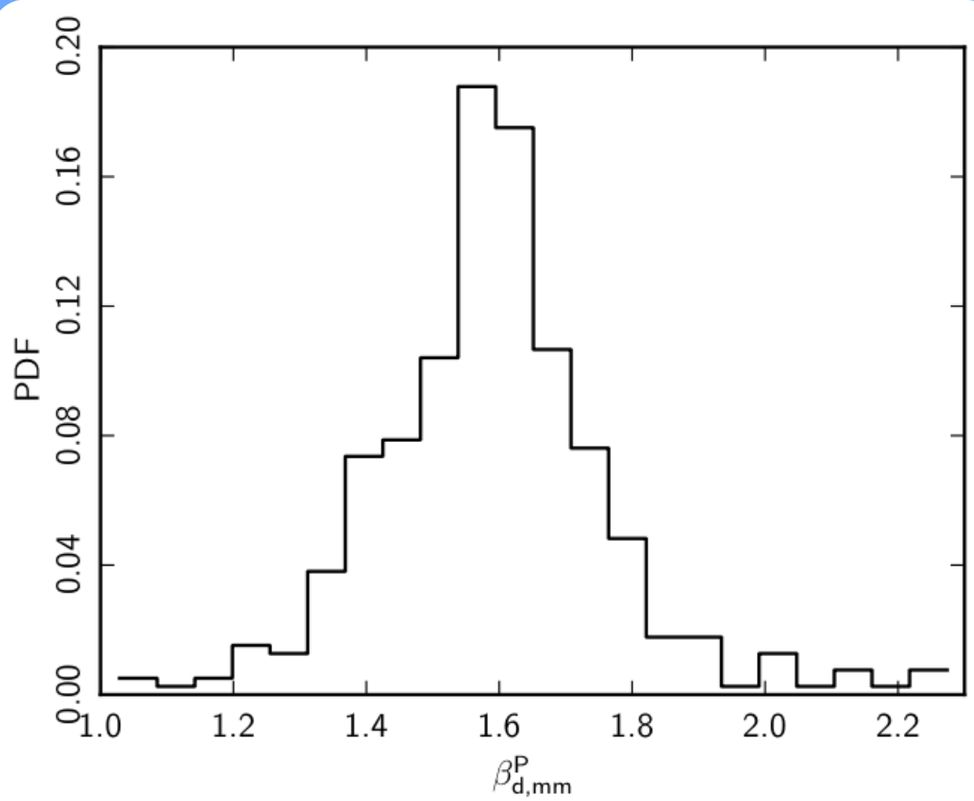
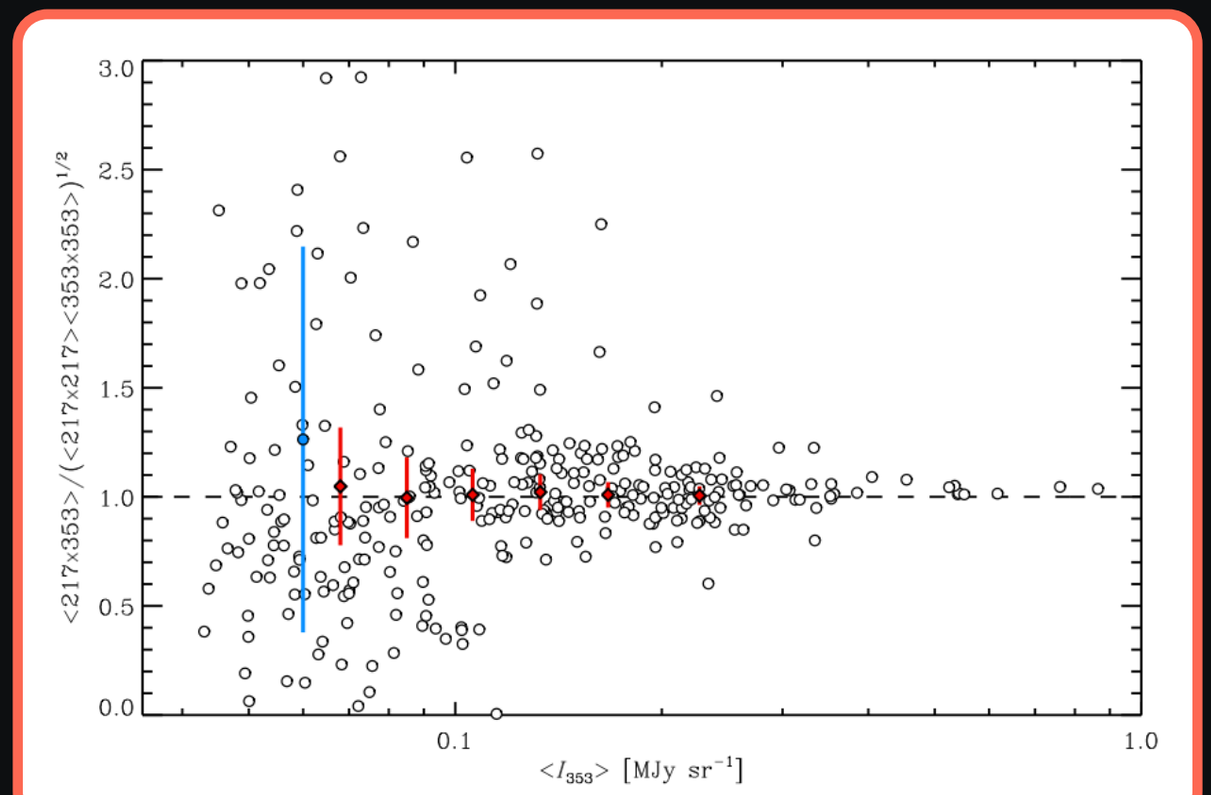


[Planck Intermediate 2014 XXII]

★ **PIP XXX:**

✦ No global decorrelation between 217 and 353 GHz polarization



[Planck Intermediate 2014 XXX]

★ Very good news for CMB polarization cleaning?

New results on decorrelation from Planck (I)

$$R_\ell^{BB} \equiv \frac{217 \times 353}{\sqrt{217 \times 217 \cdot 353 \times 353}}$$ as a function of the multipole ℓ

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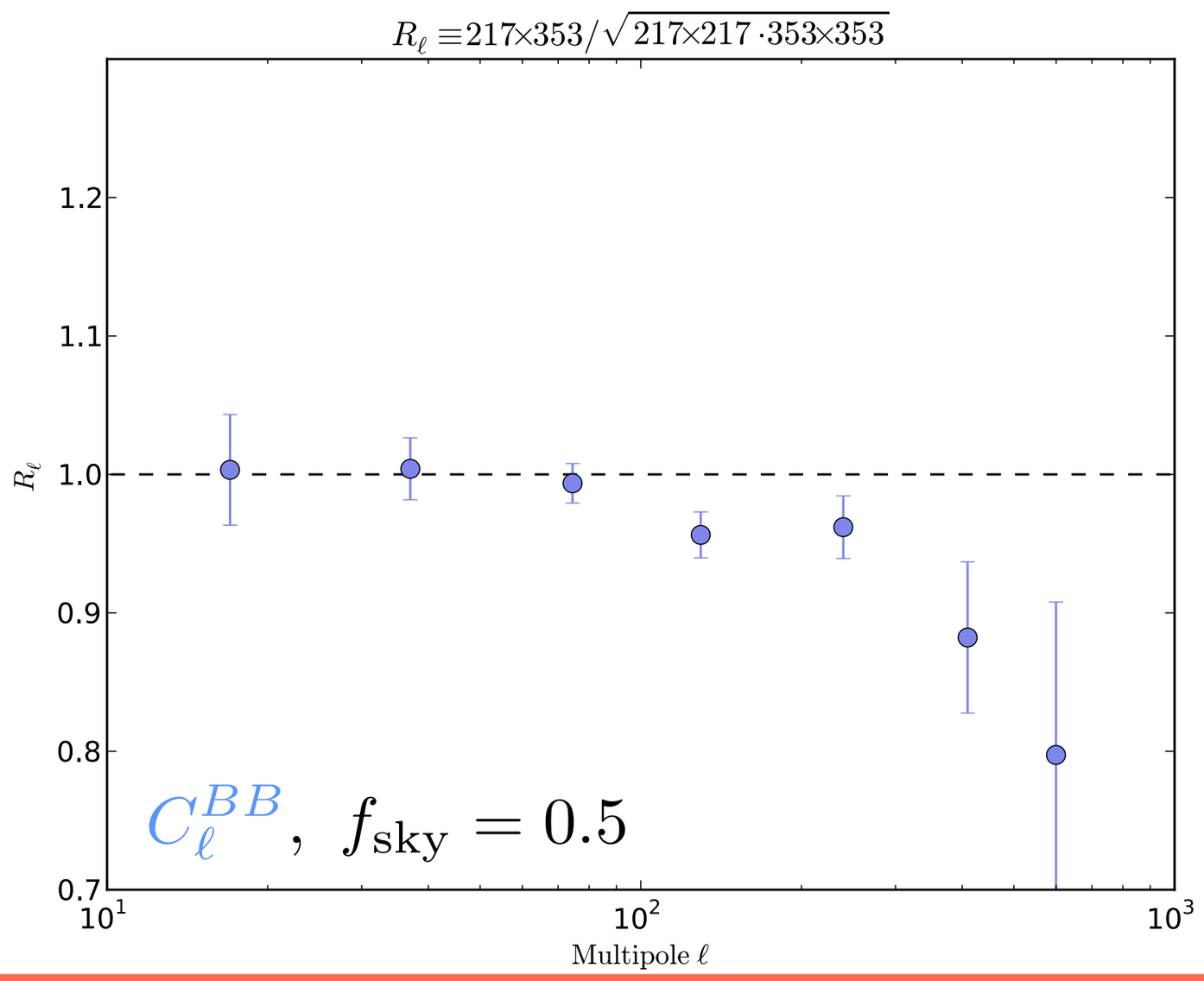
[Montier, Aumont et al., 2015, to be submitted]

PRELIMINARY



★ Can we reproduce this shape with simple simulations of the polarized dust?

Simulation of the dust polarization maps

★ **SPATIAL TEMPLATE OF THE DUST POLARIZATION**

★ New model of the dust polarization (uniform Galactic magnetic field component fitted on Planck data, 7 emission layers with independent realizations of the turbulent component of the magnetic field)

[Andrea Bracco,PhD thesis, Université Paris Sud, Orsay]
[Bracco, Vansyngel, Boulanger et al., 2015, to be submitted]

See Flavien Vansyngel's talk

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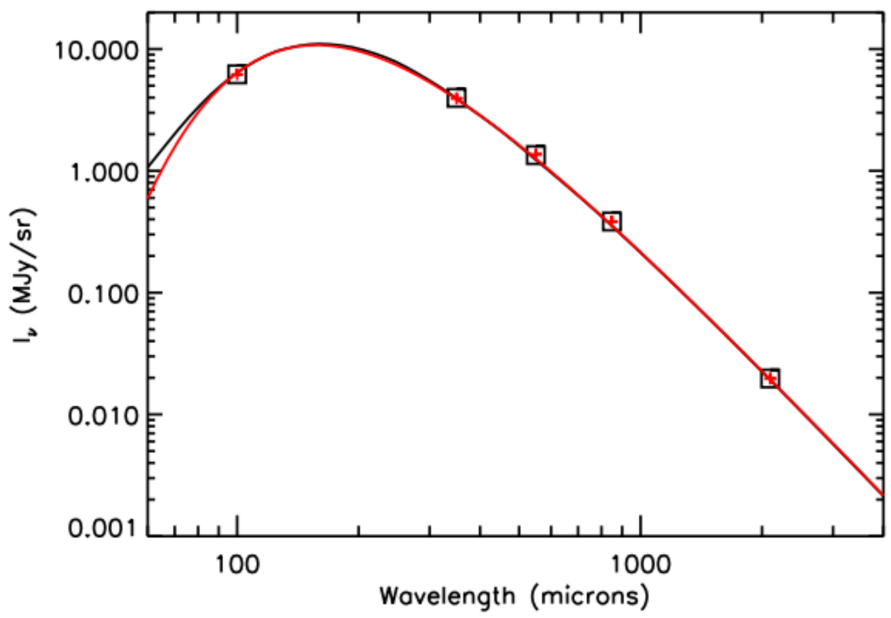
★ **SED TO EXTRAPOLATE BETWEEN FREQUENCIES**

★ Frequency extrapolation using a typical Galactic dust modified black-body spectrum (β = 1.59, $T_{\rm dust}$ =19.6 K)

$$I_\nu \propto \nu^\beta B_\nu(T_{\rm dust})$$



Simulation of the dust polarization maps

★ Spatial template of the dust polarization

★ New model of the dust polarization (uniform Galactic magnetic field component fitted on Planck data, 7 emission layers with independent realizations of the turbulent component of the magnetic field)

[Andrea Bracco,PhD thesis, Université Paris Sud, Orsay]
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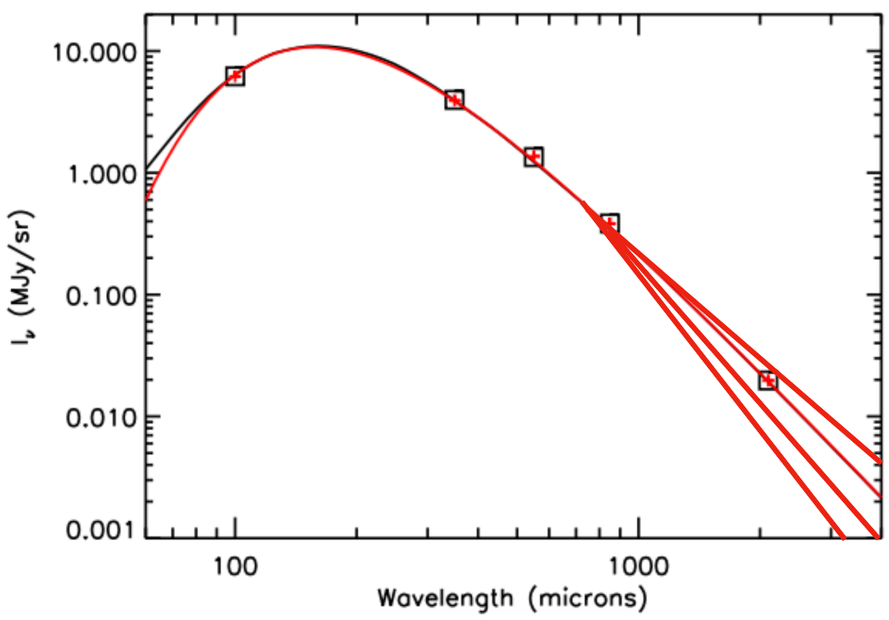
★ SED to extrapolate between frequencies

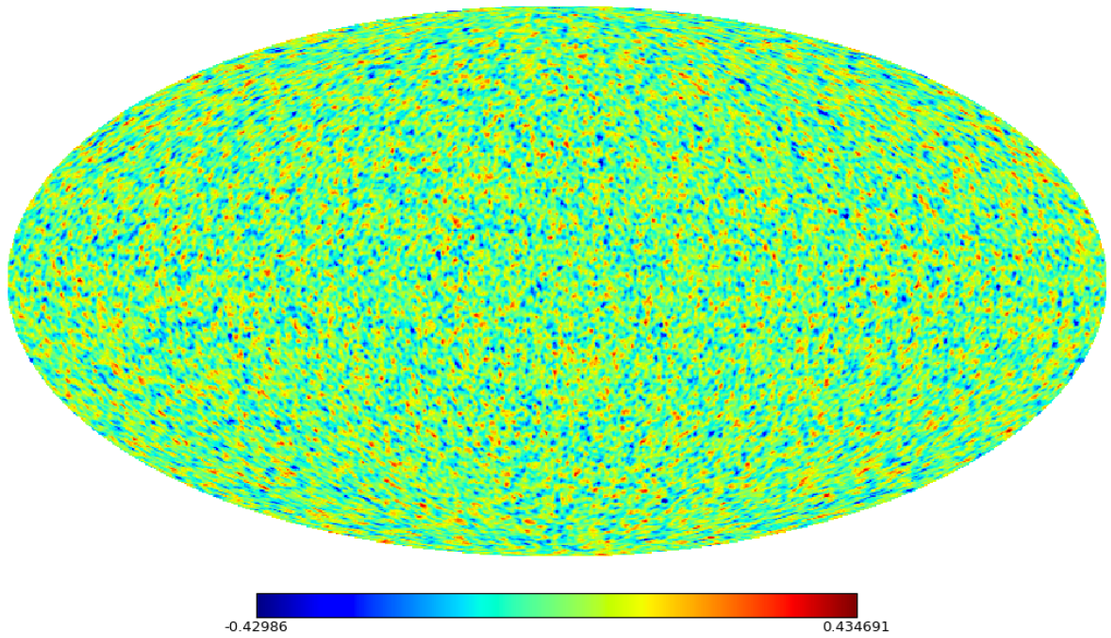
★ Frequency extrapolation using a typical Galactic dust modified black-body spectrum (β = 1.59, $T_{\rm dust}$ =19.6 K)

★ Spatial variations of the modified black body spectral index β

$$I_\nu \propto \nu^\beta B_\nu(T_{\rm dust})$$



$$\Delta\beta(1^\circ)$$



New results on decorrelation from Planck (II)

$$R_\ell^{BB} \equiv \frac{217 \times 353}{\sqrt{217 \times 217 \cdot 353 \times 353}}$$ as a function of the multipole ℓ

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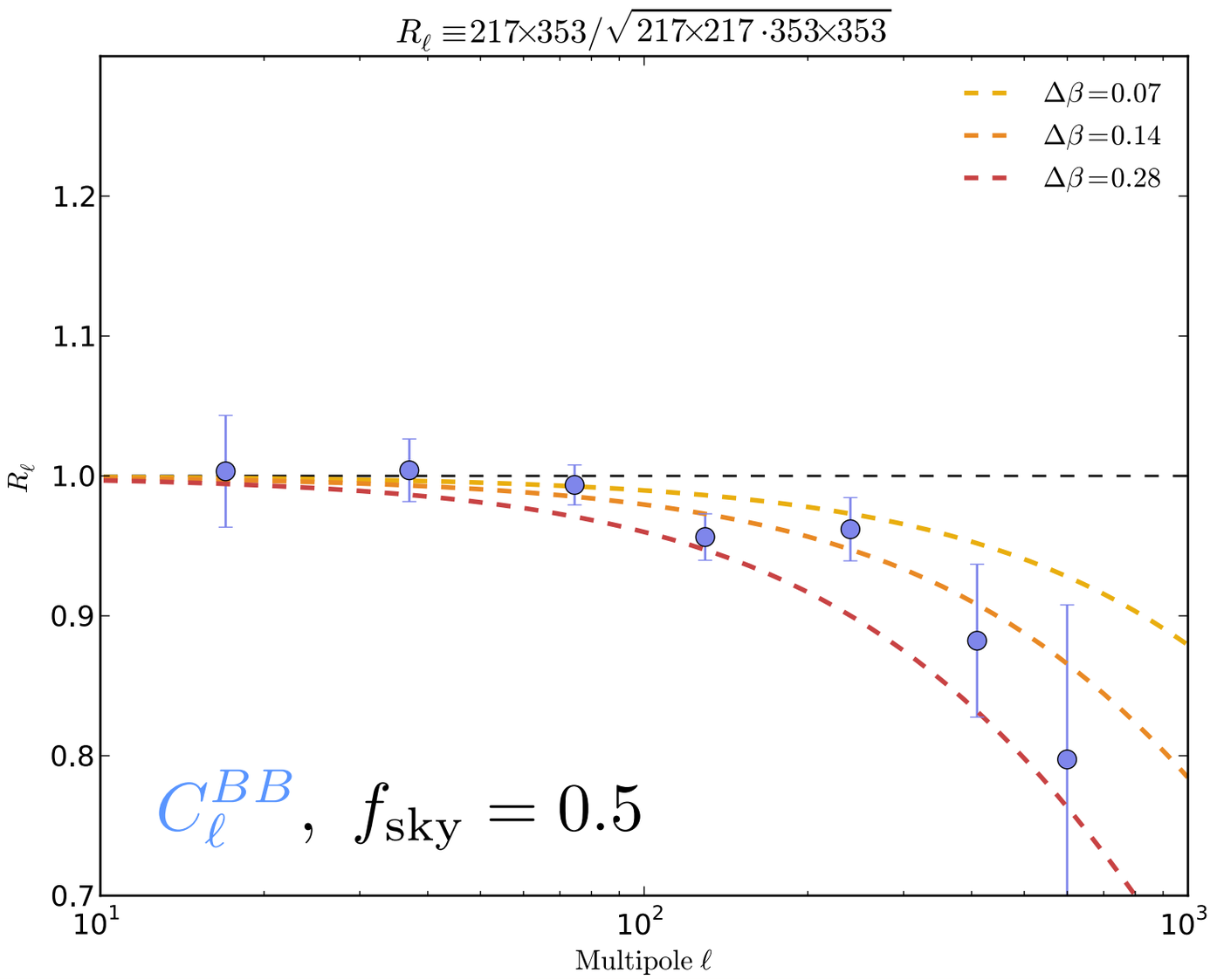
PRELIMINARY



★ Planck data favors $\Delta\beta = 0.14$

3. How spatial variations of the dust polarization frequency scaling would impact the measurement of CMB B-modes?

Residuals of dust at CMB observing frequencies

$$M' = (\alpha(\hat{\mathbf{n}}) - \tilde{\alpha})M, \text{ for } \Delta\beta = 0.14$$

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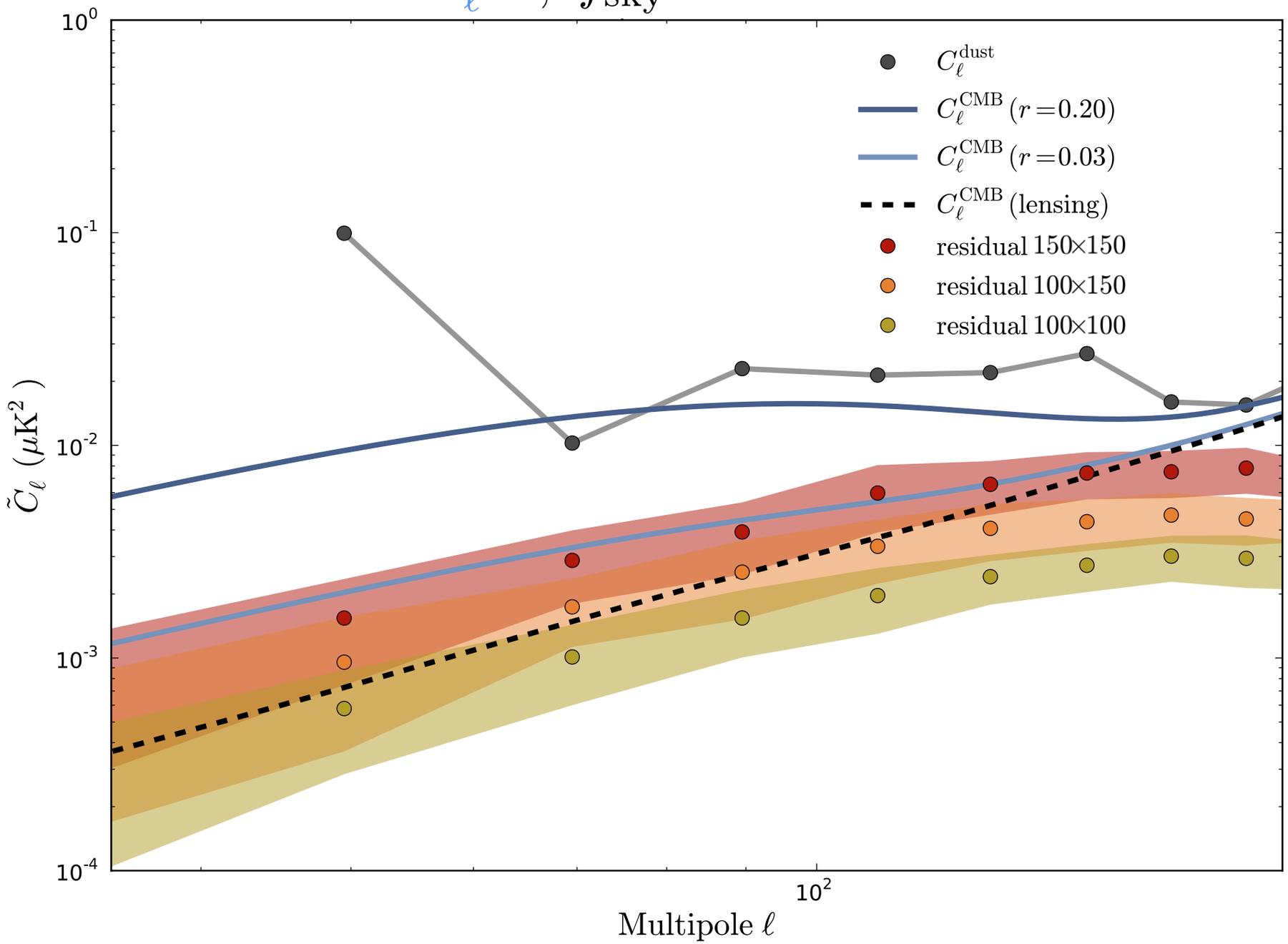
C_ℓ^{BB}, $f_{\rm sky}$ = BICEP2



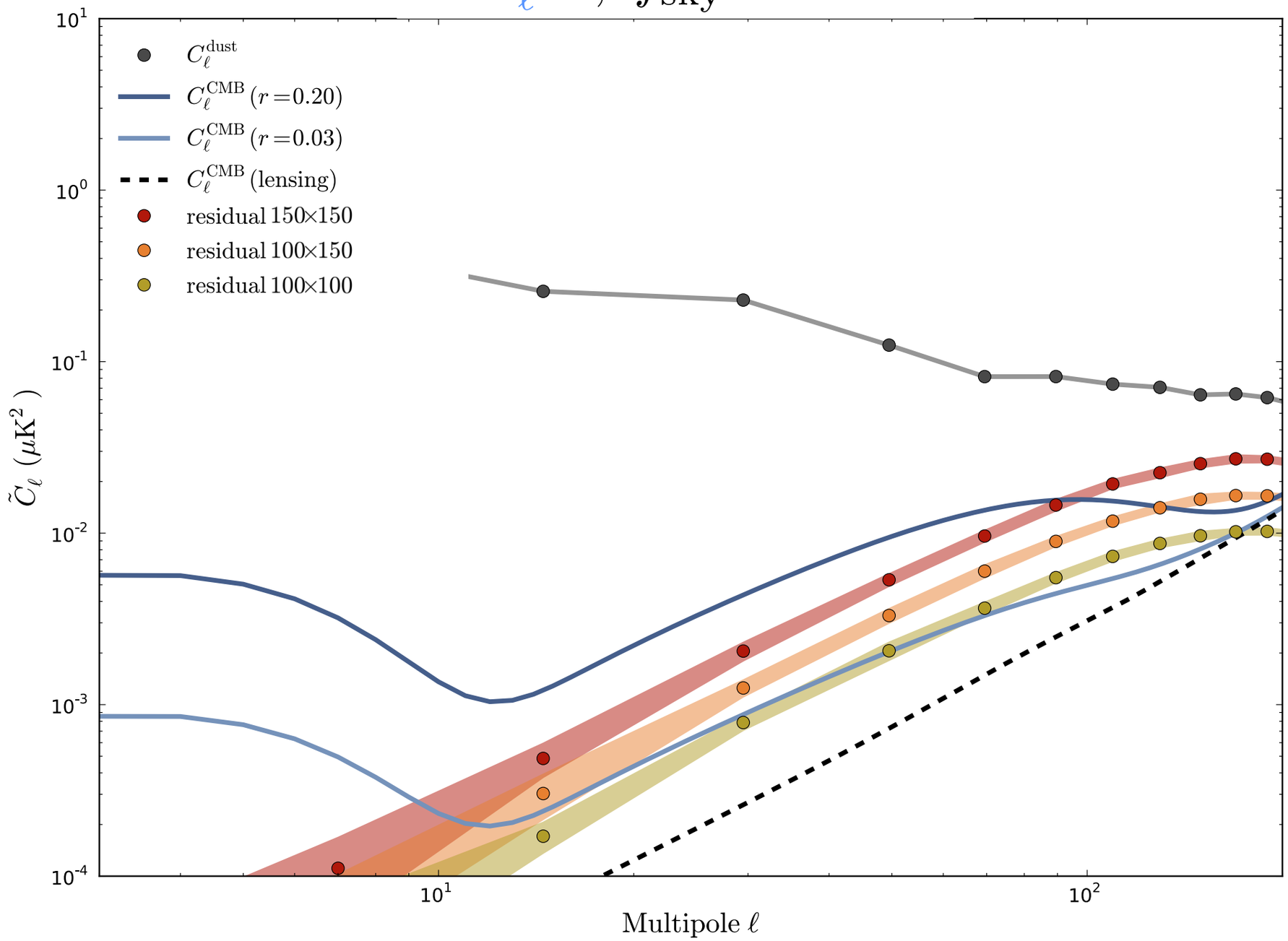
PRELIMINARY

[Montier, Aumont et al., 2015, to be submitted]

Residuals of dust at CMB observing frequencies

$$M' = (\alpha(\hat{\mathbf{n}}) - \tilde{\alpha})M, \text{ for } \Delta\beta = 0.14$$

C_ℓ^{BB}, $f_{\rm sky} = 0.5$

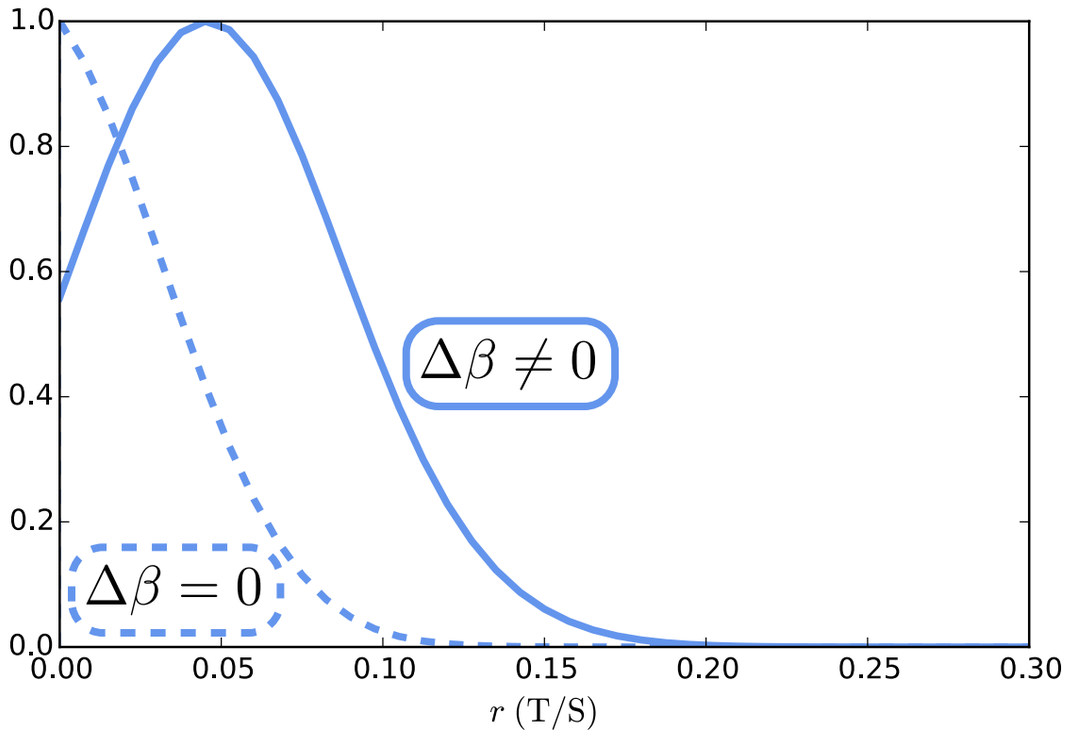


PRELIMINARY

[Montier, Aumont et al., 2015, to be submitted]

Simulation of the BICEP2-Keck/Planck analysis

PRELIMINARY



BICEP2 mask

BB only

BICEP2 ℓ bins

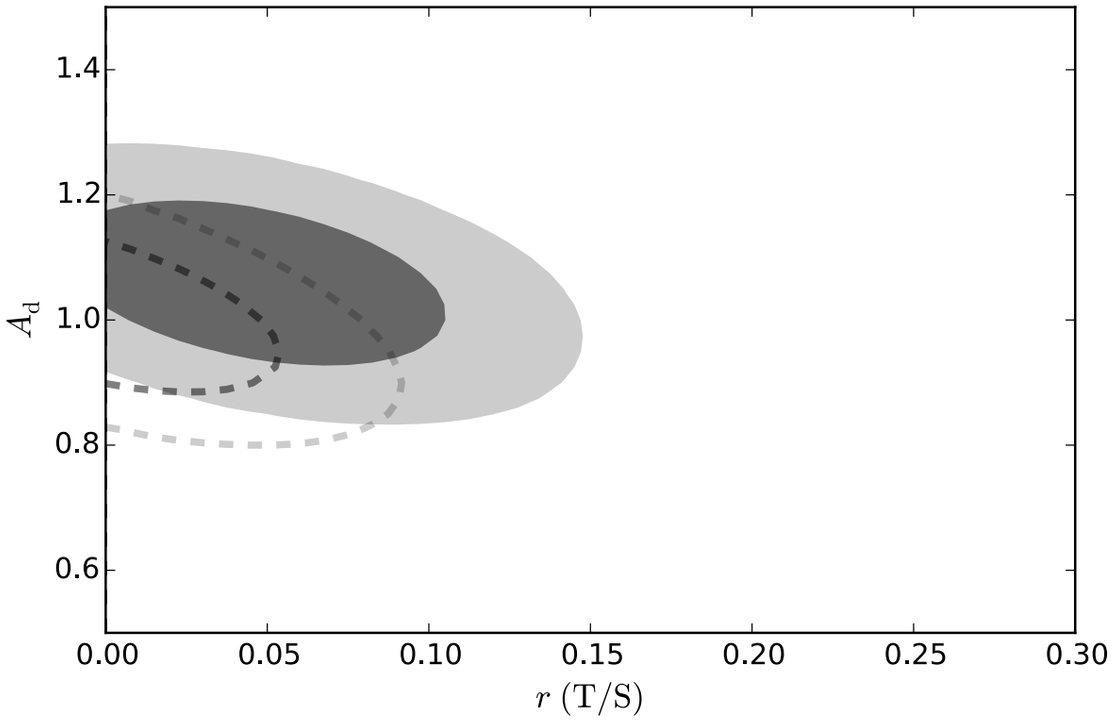
BICEP2 and Planck 353 GHz noise realizations

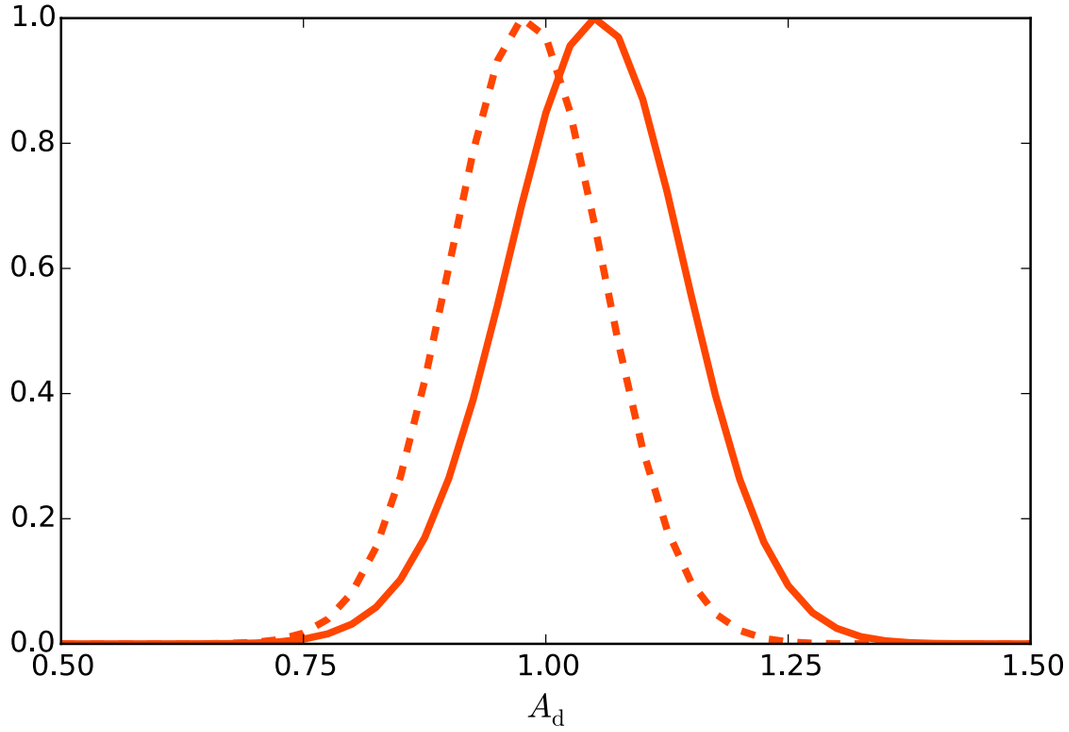
CMB with $r = 0$

dust simulation with a $\Delta\beta = 0.14$ extrapolation

analysis similar to [BICEP2/Keck and Planck 2015]

2000 simulations





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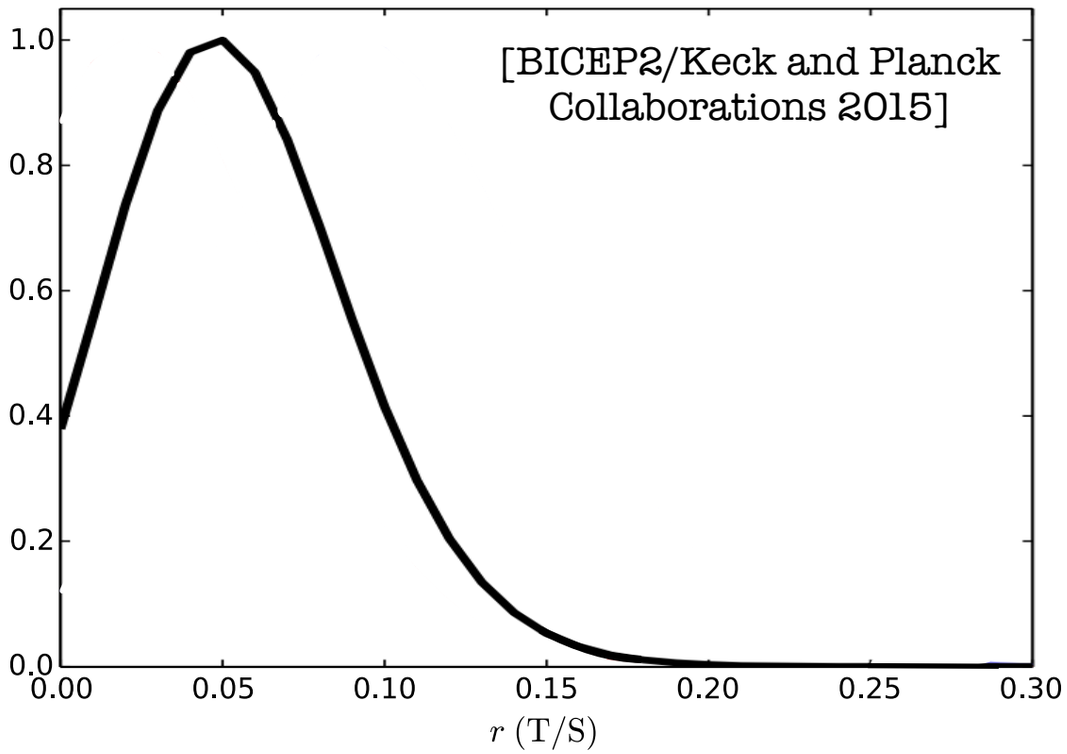

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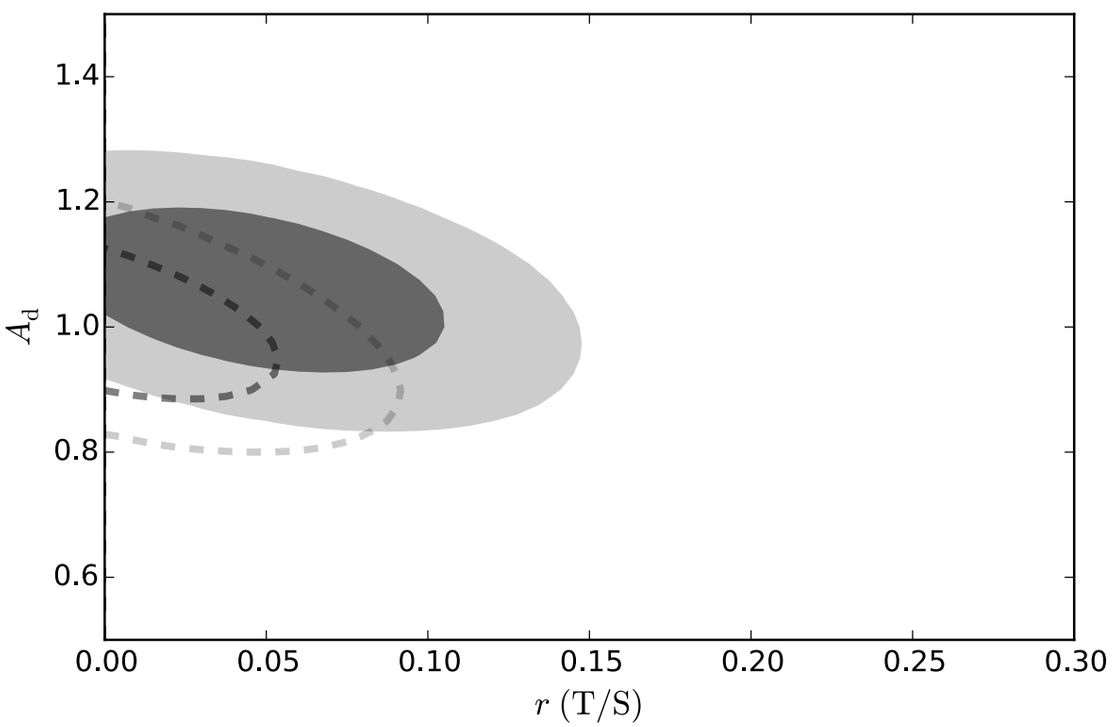

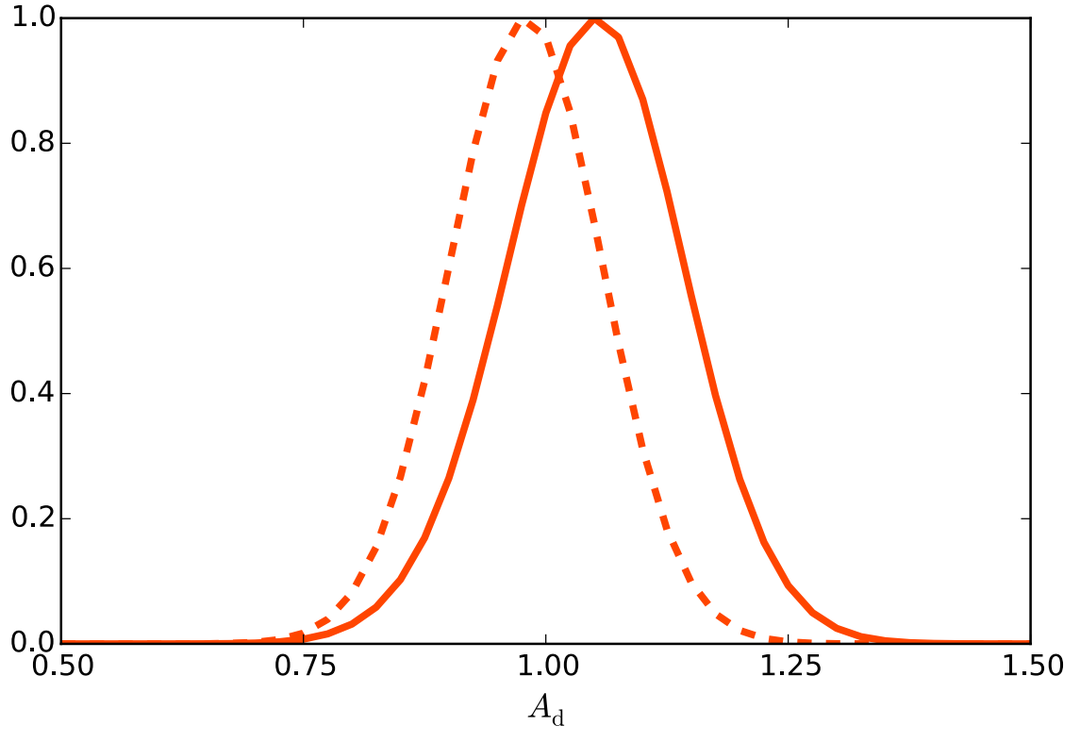

[Montier, Aumont et al., 2015, to be submitted]

Conclusions and perspectives

★Planck showed that the Galactic dust polarization can not be neglected in the tentative measurements of the CMB primordial B-modes

★Nevertheless, Planck showed that dust polarization power spectra have properties that can be used to separate CMB and dust

★We showed that Planck data prefers spatial variations of the dust polarization SED

★We showed that such variations would translate in non-zero spurious detections of the CMB primordial B-modes if not accounted for properly

★Measurement of maps of the spatial variations of the dust polarization SED may be required

★This would mean having at least 2 frequencies measuring dust at high signal to noise ratio

[Montier, Aumont et al., 2015] will be out soon, stay tuned!