Foregrounds contamination to CMB B-modes at degree angular scale

arXiv:1511.00532

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B-mode from space - IPMU

11th December 2015

MOTIVATION:

Provide a picture of the level of foregrounds contamination to CMB B-modes at degree angular scale

- Which are the regions where foreground emission is minimum?
- What is the level of foregrounds contamination to CMB primordial B-modes in the different sky regions?
- In these regions, what is the frequency of foreground minimum?
- At which frequencies the contamination to the CMB signal arises only from a single type of foreground?

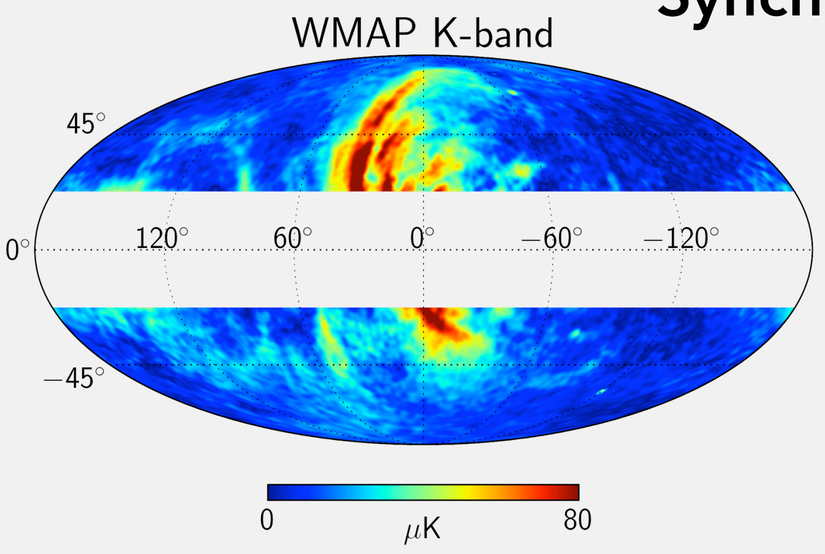
Planck and WMAP data

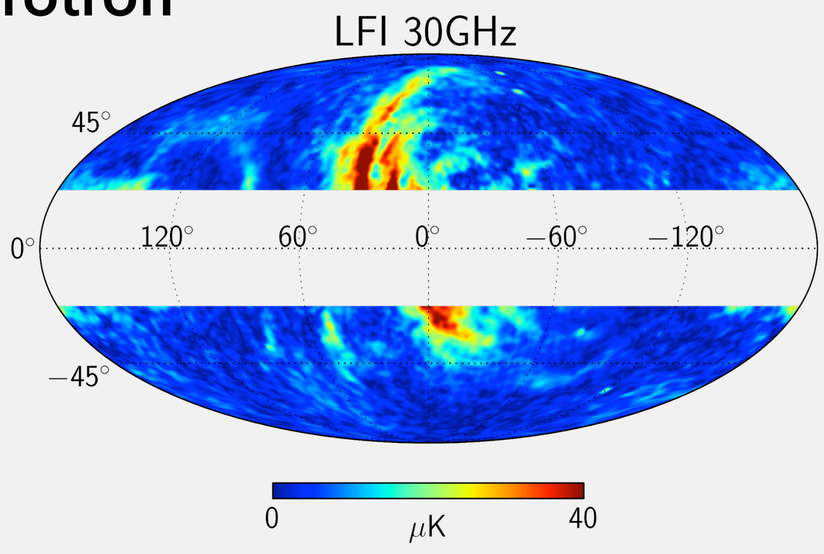
- Characterization of foreground emission using polarization power spectra

SYNCHROTRON: **$\mathbf{WMAP_K}$** X **$\mathbf{LFI_{30}}$** ($\nu_{\rm eff} \simeq 25.4\,{\rm GHz}$)

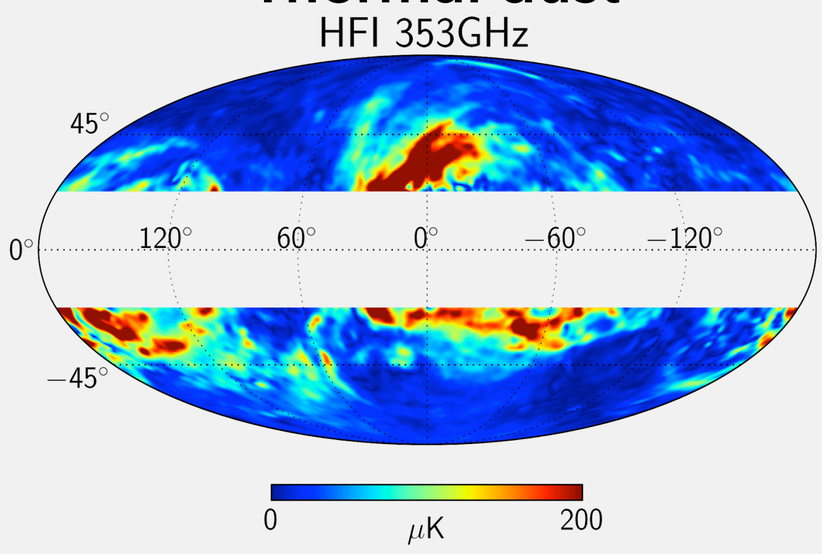
THERMAL DUST: **$\mathbf{HFI_{353\text{-}HM1}}$** X **$\mathbf{HFI_{353\text{-}HM2}}$**

Synchrotron





Thermal dust



- E-modes and B-modes foreground spectra on **352 circular sky regions** with **$\mathbf{f_{sky}}$~1.5%** (covering the entire sky at **Galactic latitude |b|>20°**)

Planck Collaboration I 2015; Planck Collaboration Int. XXX 2014

Foreground amplitude at $\ell = 80$

Synchrotron and Thermal dust amplitude in the multipole bin: $\mathbf{60 < \ell < 100}$

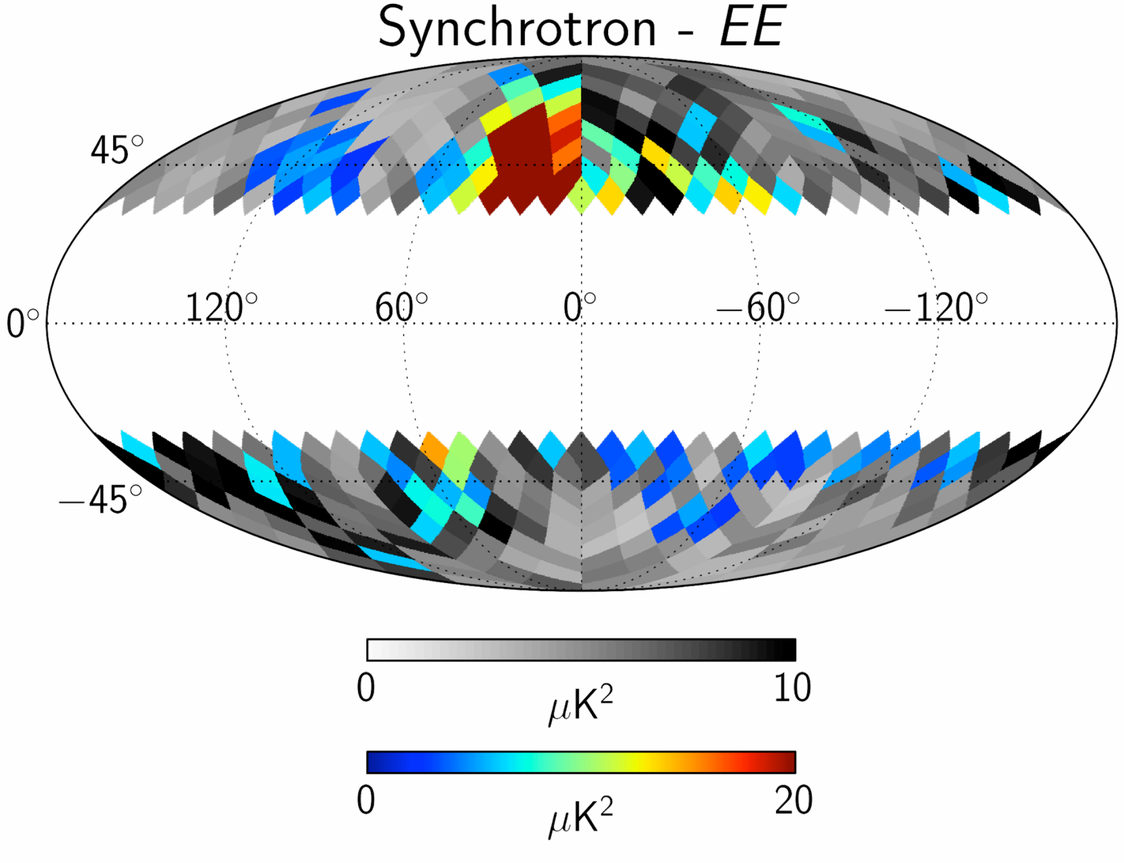
Detections (colored pixels):

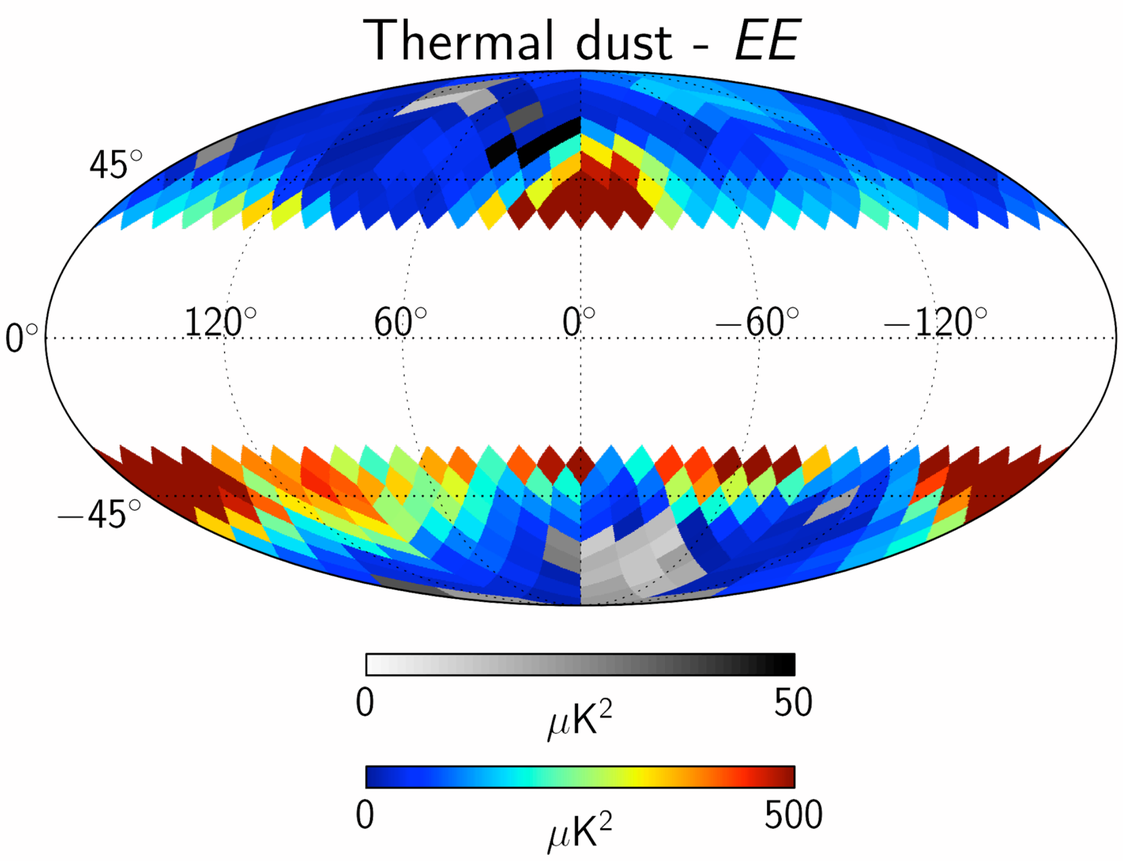
$$\mathcal{D}_{\ell 80} > 3\sigma(\mathcal{D}_{\ell 80})$$

Upper limits (B/W pixels):

$$\mathcal{D}_{\ell 80} > 0 : \; UL(\mathcal{D}_{\ell 80}) \equiv \mathcal{D}_{\ell 80} + 3\sigma(\mathcal{D}_{\ell 80})$$

$$\mathcal{D}_{\ell 80} < 0 : \; UL(\mathcal{D}_{\ell 80}) \equiv 3\sigma(\mathcal{D}_{\ell 80})$$

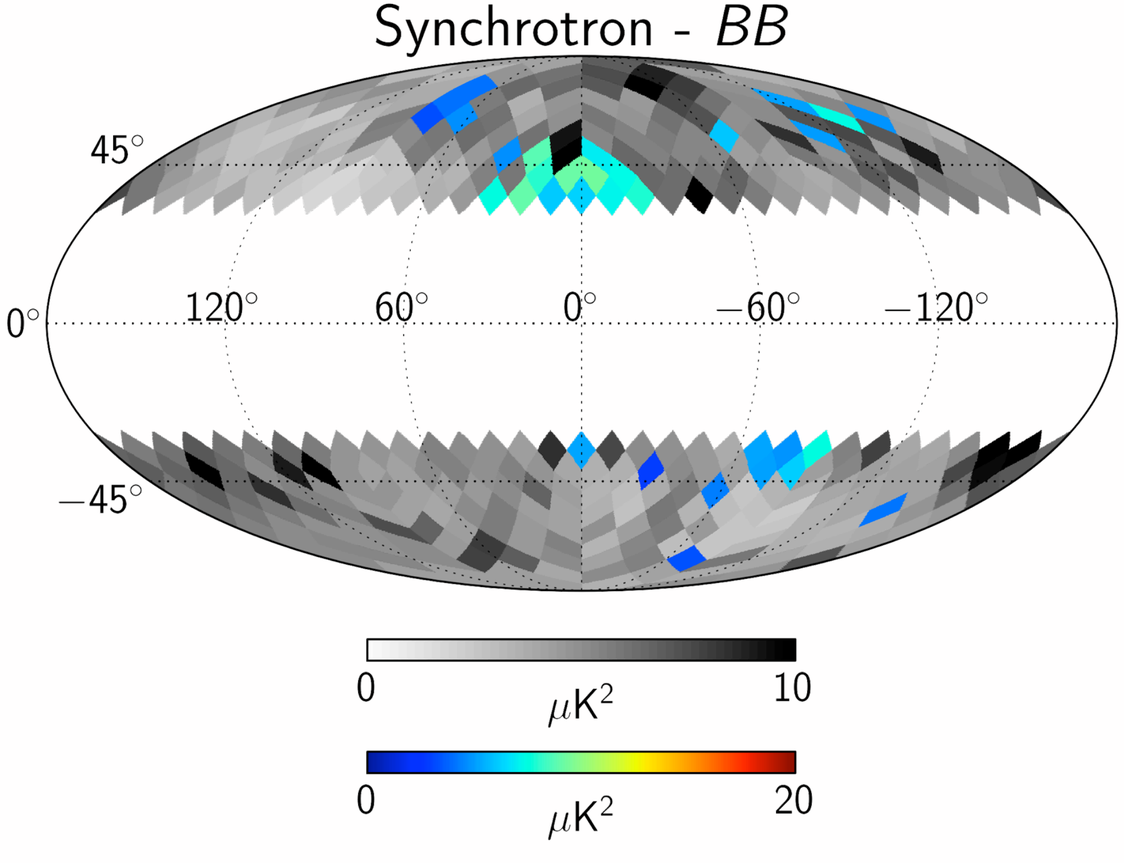


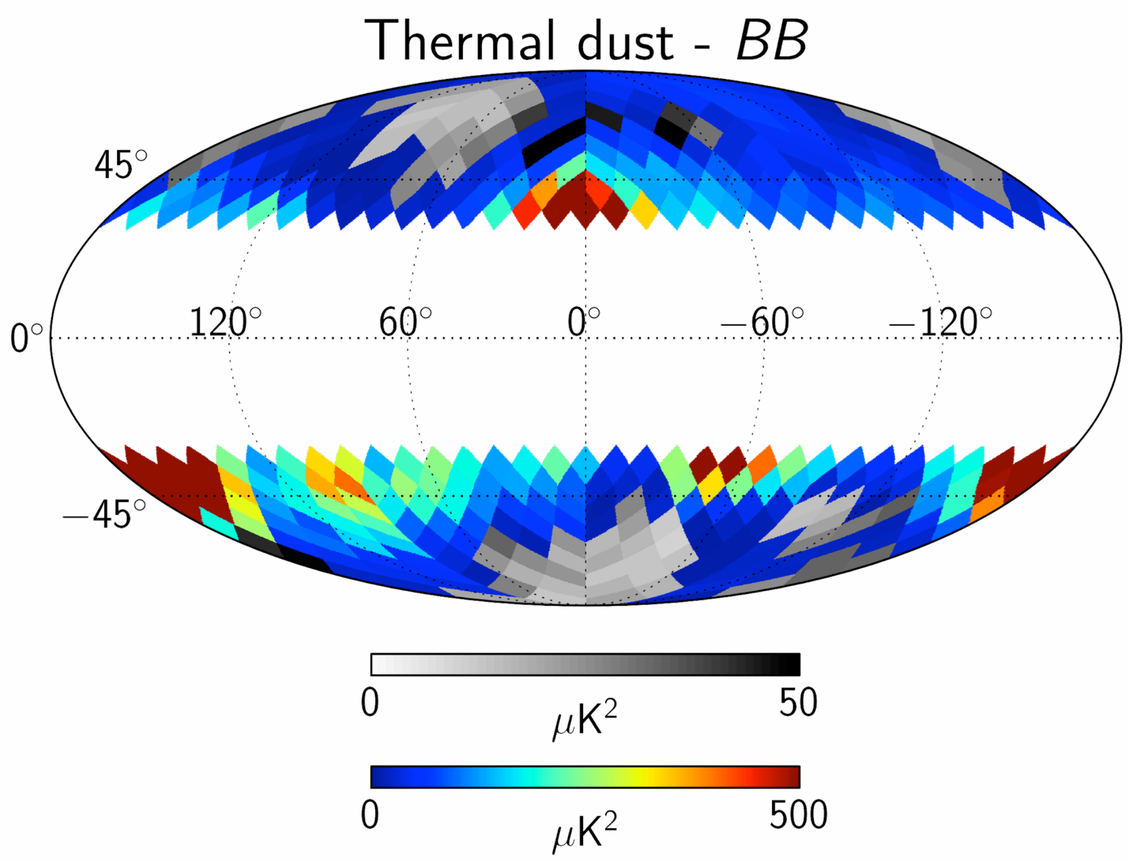


Foreground amplitude at $\ell = 80$

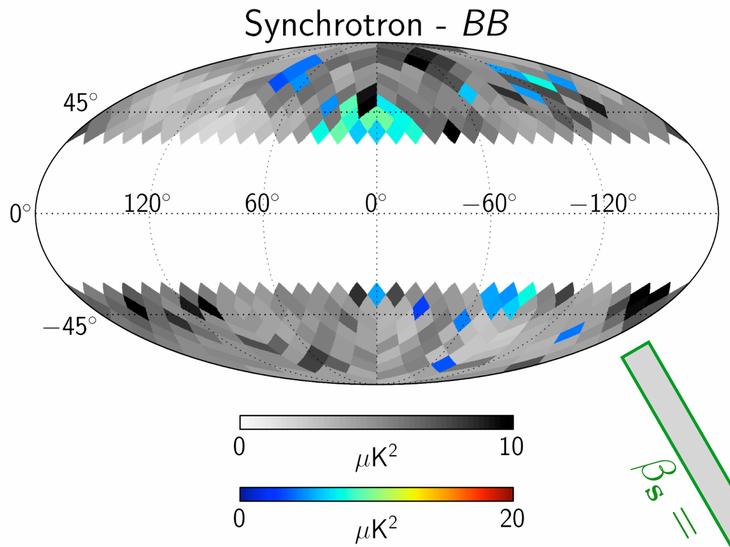
Four type of regions:

- **Detection of dust and synch:** 28 regions
- **Detection of dust, upper limit on synch:** 250 regions
- **Detection of synch, upper limit on dust:** 4 regions
- **Upper limit on dust and synch:** 70 regions





Foreground amplitude at $\ell = 80$

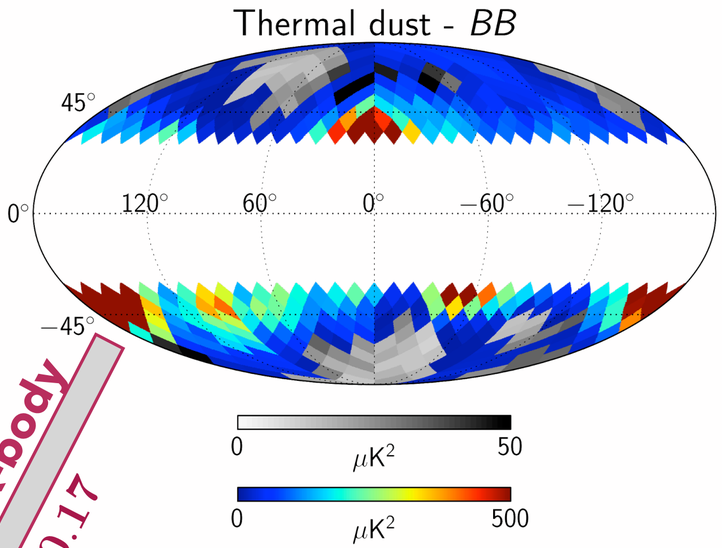


25.4 GHz

power-law

$\beta_s = -3.12 \pm 0.04$

353 GHz



modified black-body

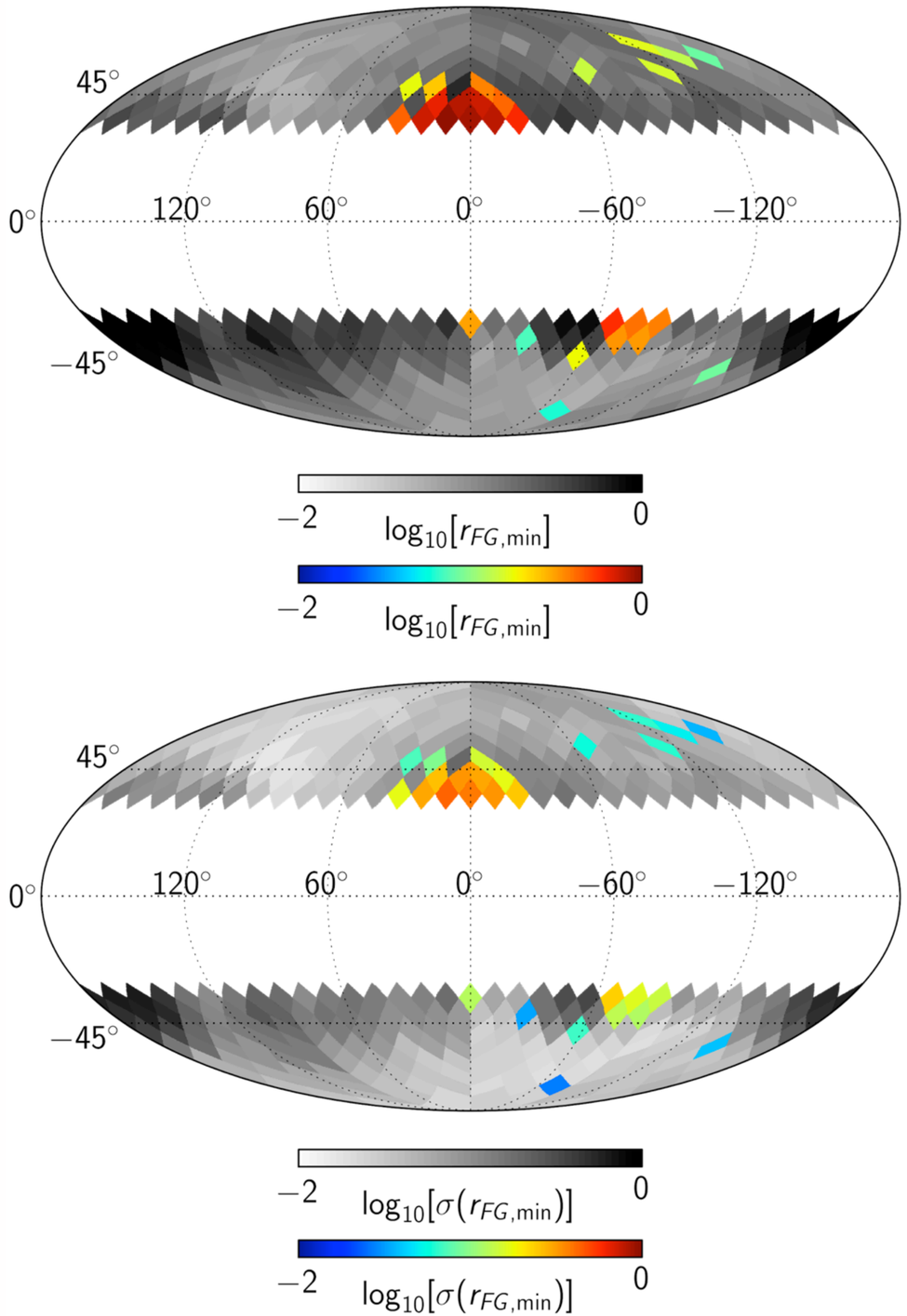
$\beta_d = 1.59 \pm 0.17$

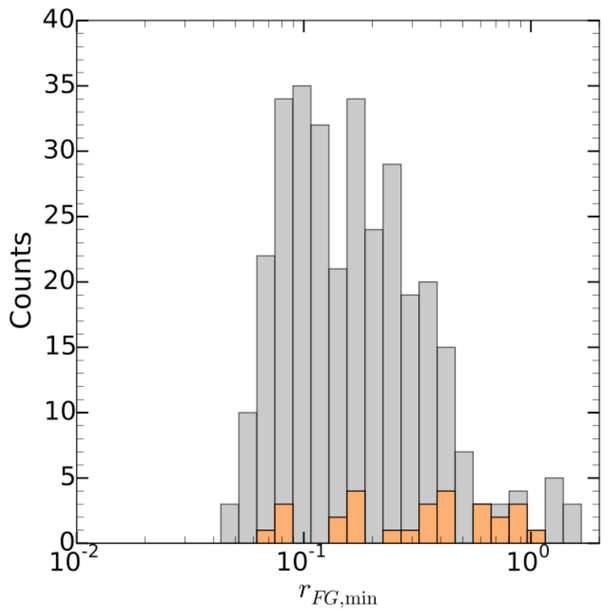
$T_d = 19.6\,K$

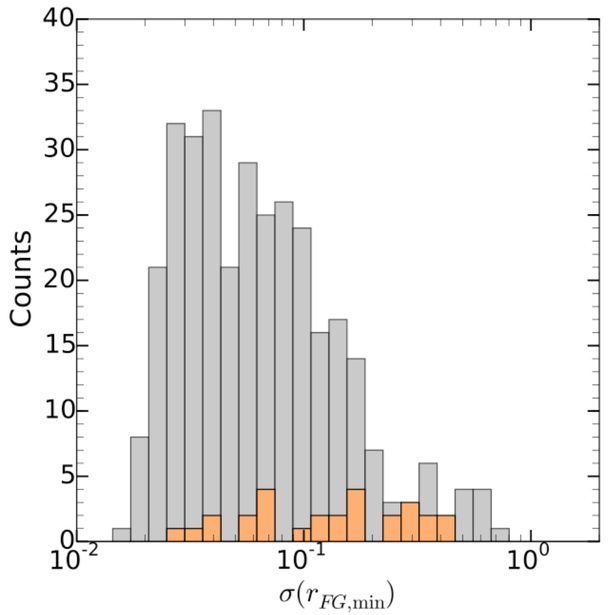
Frequency scaling allows to estimate the **minimum foreground contamination** to CMB B-modes (or the upper limit on it) and the **frequency** at which this minimum is reached

Fuskeland et al. 2014; Planck Collaboration X 2015; Planck Collaboration Int. XXII 2015

Estimation of foreground minimum







Foreground minimum

expressed in terms of equivalent *r*

Detections:

$$0.06 \lesssim r_{\mathrm{FG,\ min}} \lesssim 1.0$$

Upper limits:

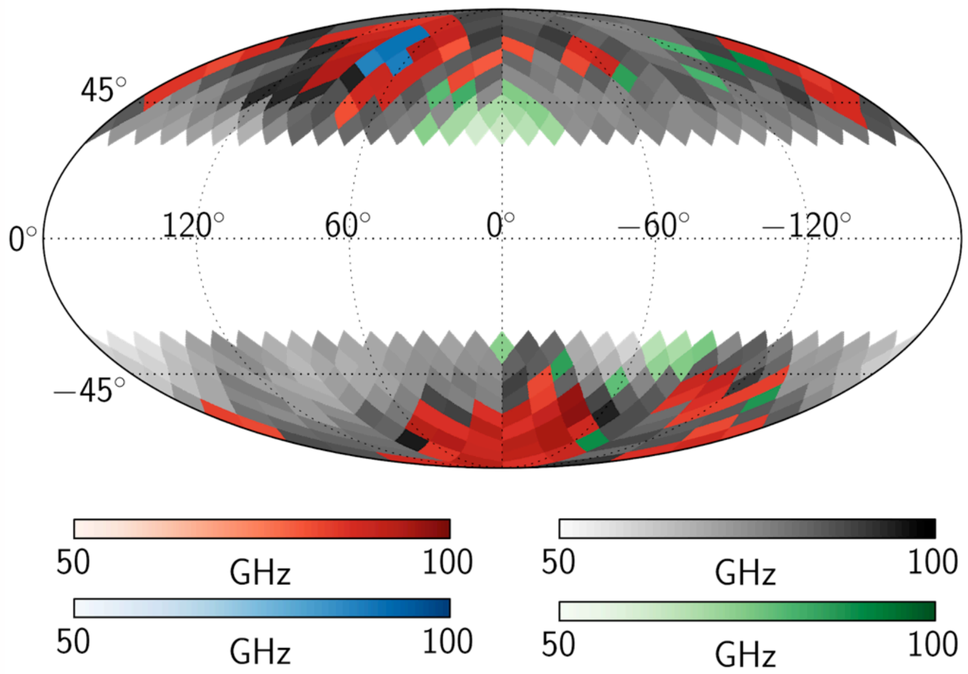
$$0.048 \lesssim r_{\mathrm{FG,\ min}} \lesssim 1.5$$

Errors

quadratic sum of statistical errors and uncertainties coming from the frequency scaling

$$0.017 < \sigma(r_{\mathrm{FG,\ min}}) < 0.7$$

Frequency of foreground minimum



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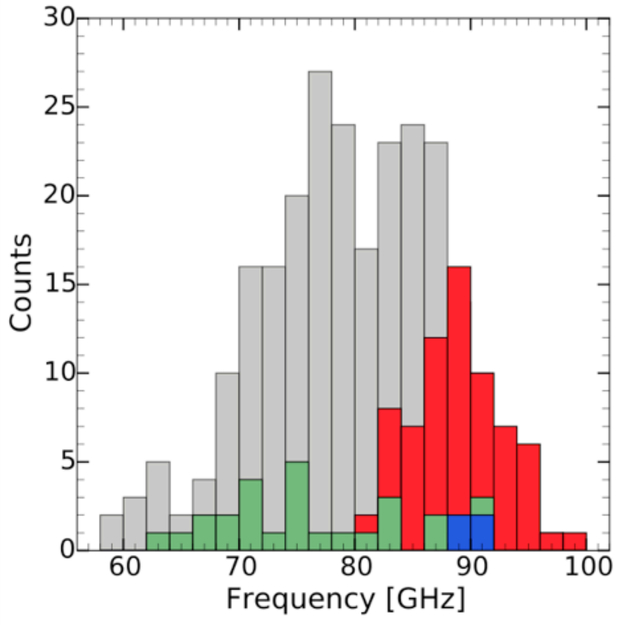
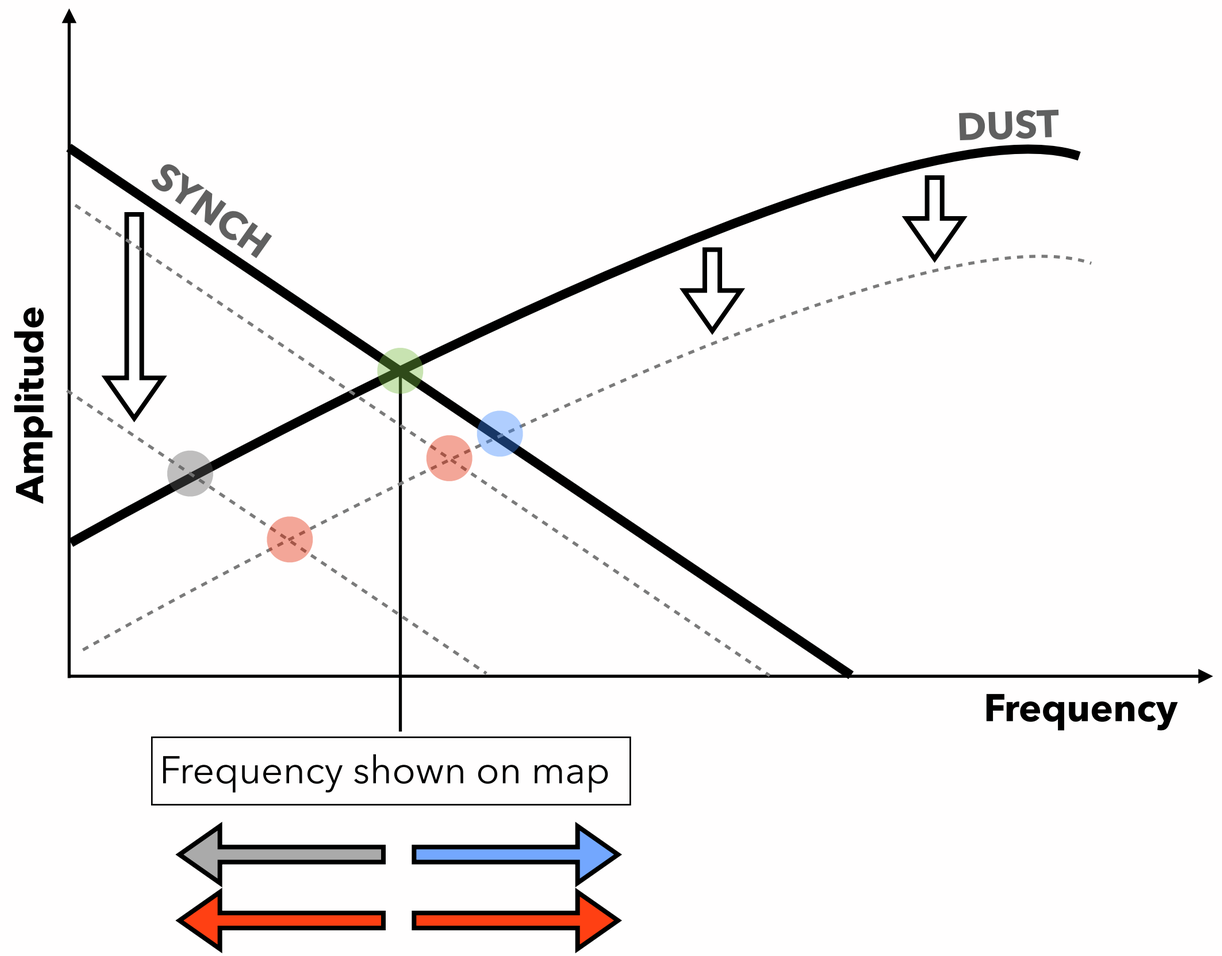


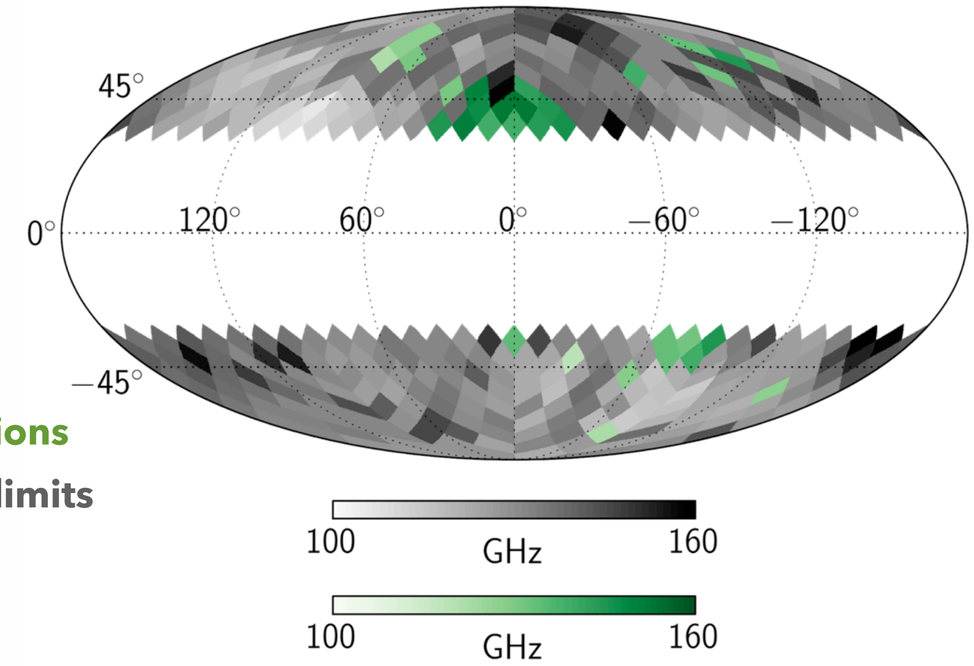


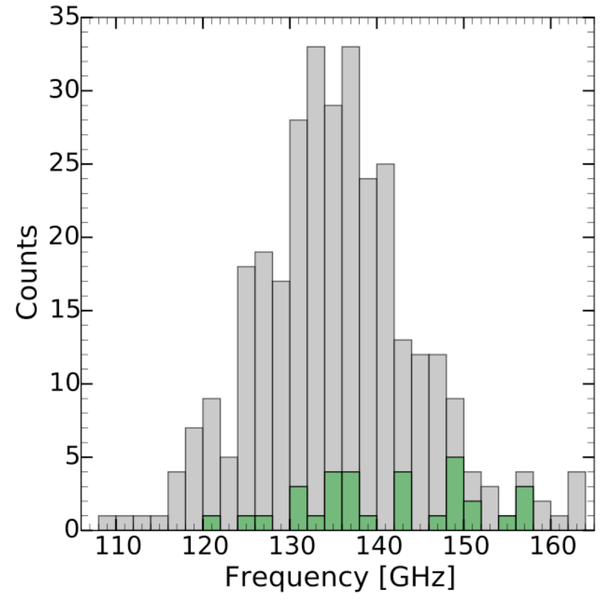
Single foreground contribution

Only dust:

Min frequency at which

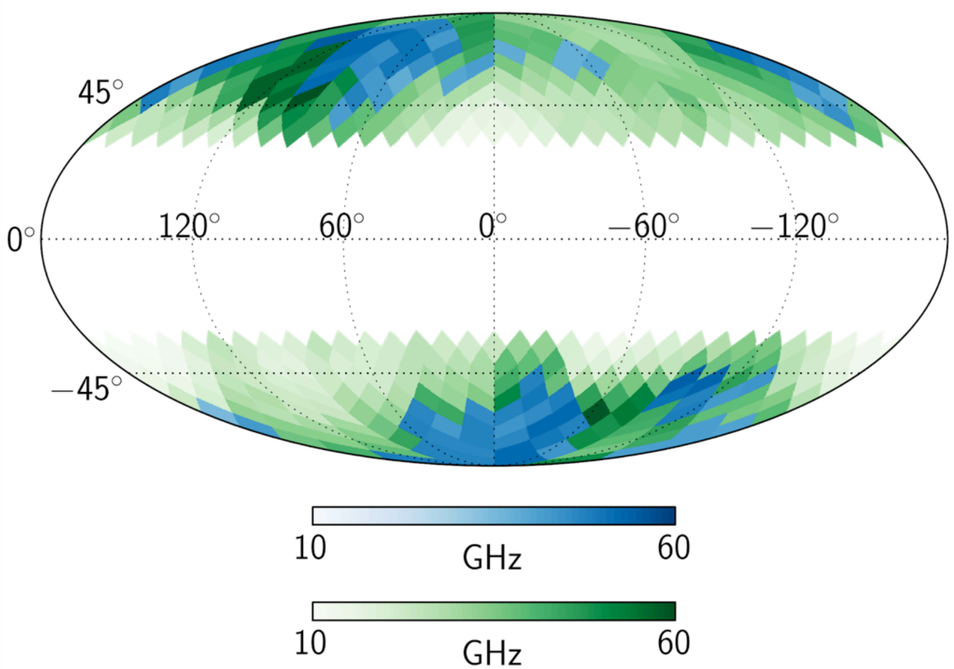
$$r_s < 0.005$$

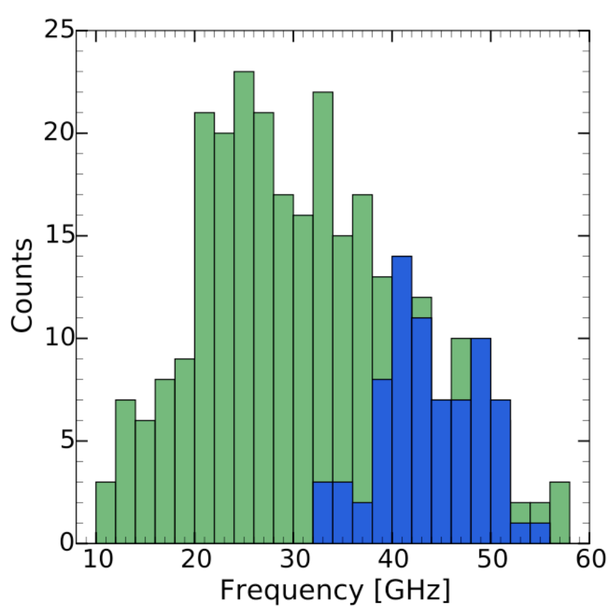




Detections

Upper limits





Only synchrotron:

Max frequency at which

$$r_d < 0.005$$

Detections

Lower limits

Summary

- Complete picture of the level of foreground contamination to CMB B-modes at degree angular scale

- few regions with detection of both synchrotron and thermal dust at high Galactic latitude giving $r_{\mathrm{FG,\ min}} \simeq 0.06$ @ ~ 90 GHz

- Most stringent upper limits give $r_{\mathrm{FG,\ min}} \lesssim 0.05$

- Synchrotron contribution: negligible (in some regions and at the level $r_s < 0.005$) only for frequency above ~ 110 GHz

- Thermal dust contribution: negligible (in some regions and at the level $r_d < 0.005$) only for frequency below ~ 60 GHz

- New data, covering both low and high frequencies, are essential to further constraint r and eventually apply component separation algorithm