First low latitudes reconstruction of the dust **polarization** **S**pectral **E**nergy **D**istribution variation

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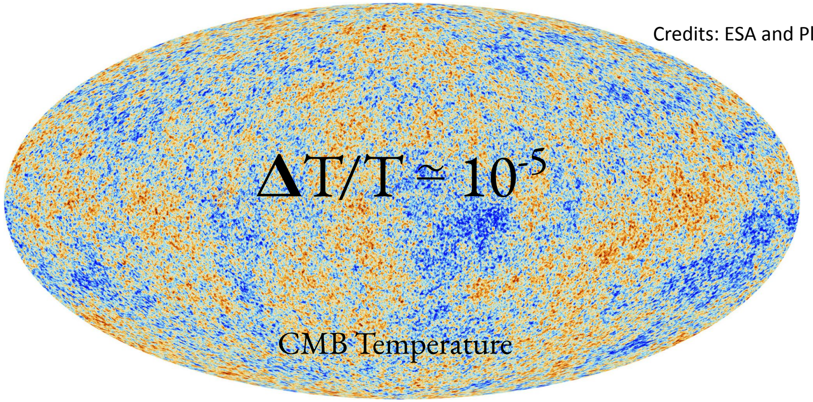
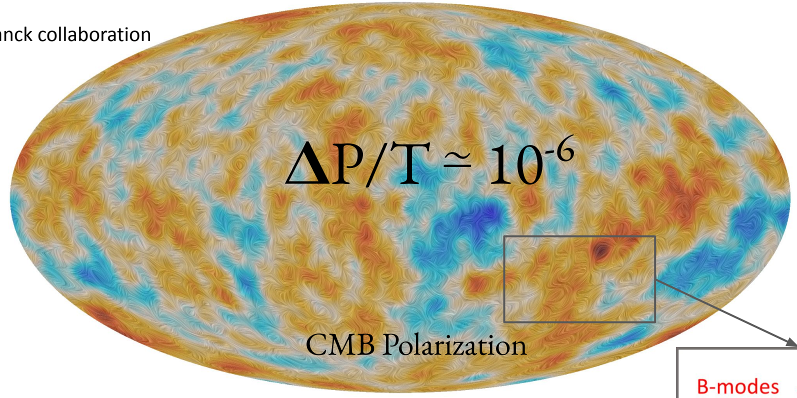
Outline

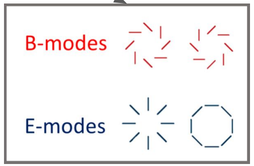
- Scientific context
- Dust variation maps in polarization
- Cross power spectra analysis
- Polarization dust SED extrapolation
- Conclusions and perspectives

Primordial Universe probe
The Cosmic Microwave Background

Credits: ESA and Planck collaboration





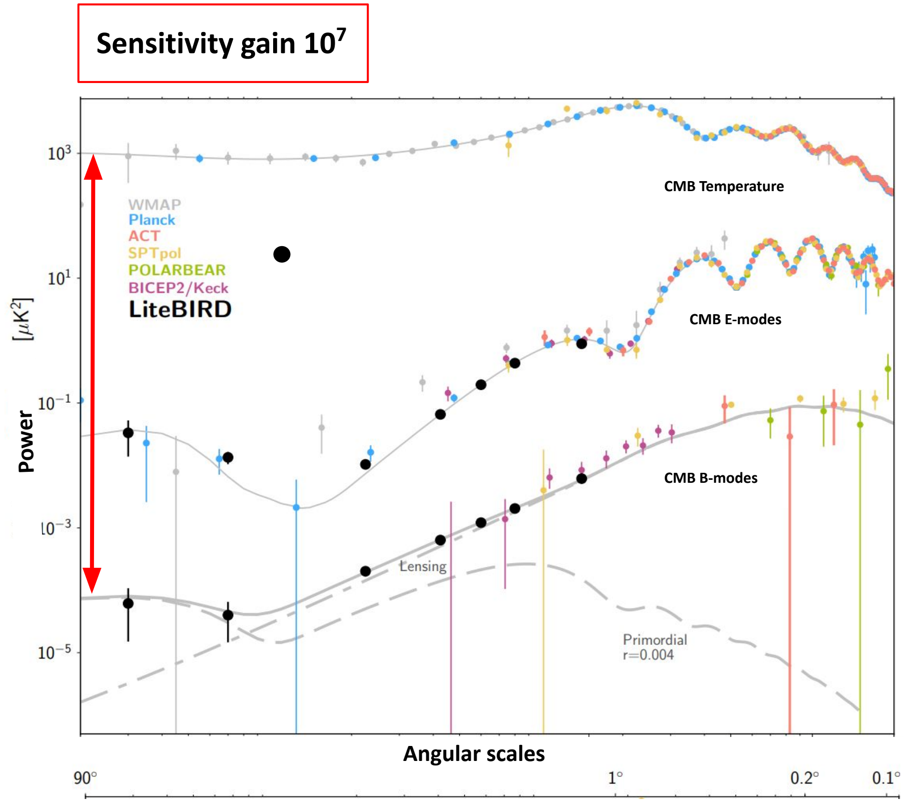


CMB polarization patterns can be expressed:
E-modes, of even parity, and the **B-modes**.

B-modes can only be produced by primordial gravitational waves in the early universe.

If detected, will probe the existence of the inflation and give us access to a physics beyond the current Standard Model.

Challenges for the CMB B-modes detection

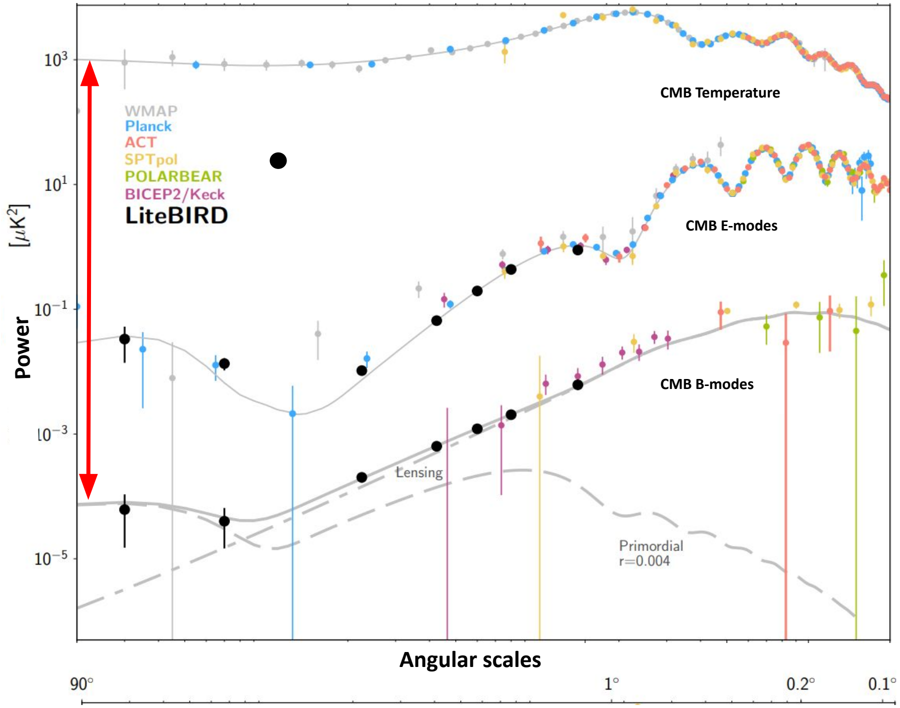


Hazumi et al. 2020 Proc. of SPIE

- Big arrays of high sensitive detectors to increase SNR
- Instrumental systematic effects control
- Absolute calibration of the polarization angle
- Accurate component separation of foreground emissions

Challenges for the CMB B-modes detection

Sensitivity gain 10^7



Hazumi et al. 2020 Proc. of SPIE

- Big arrays of high sensitive detectors to increase SNR
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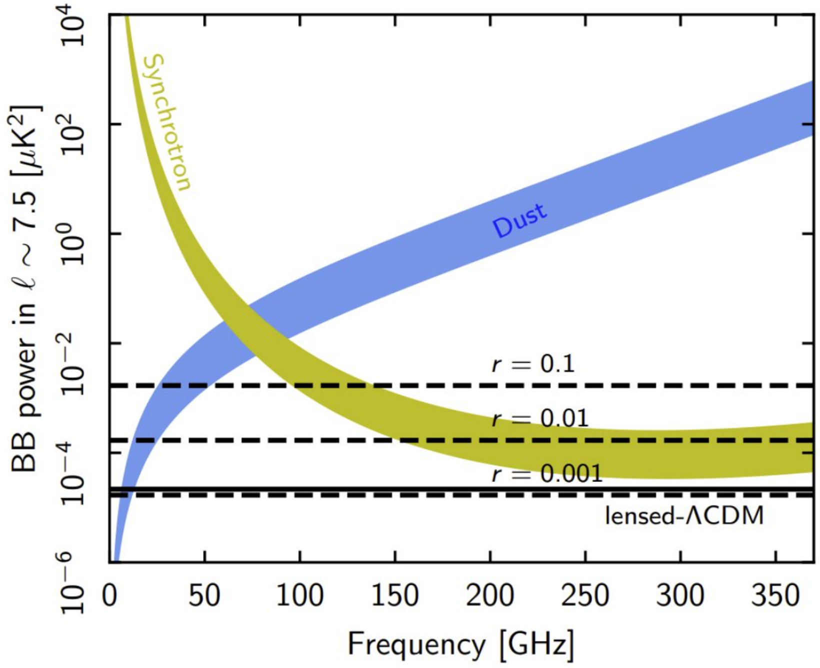
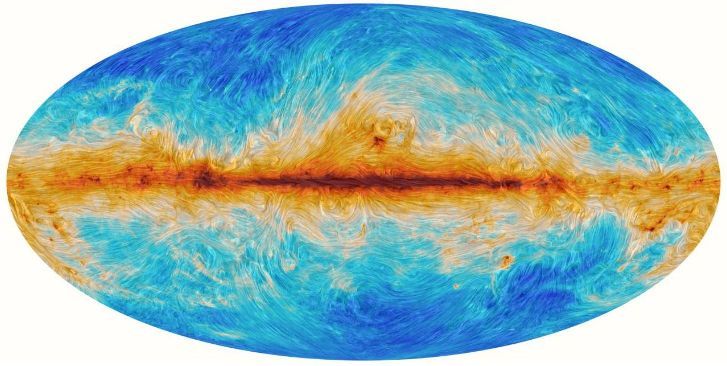
- **Accurate component separation of foreground emissions**

CMB polarization B-modes detection
foreground challenge

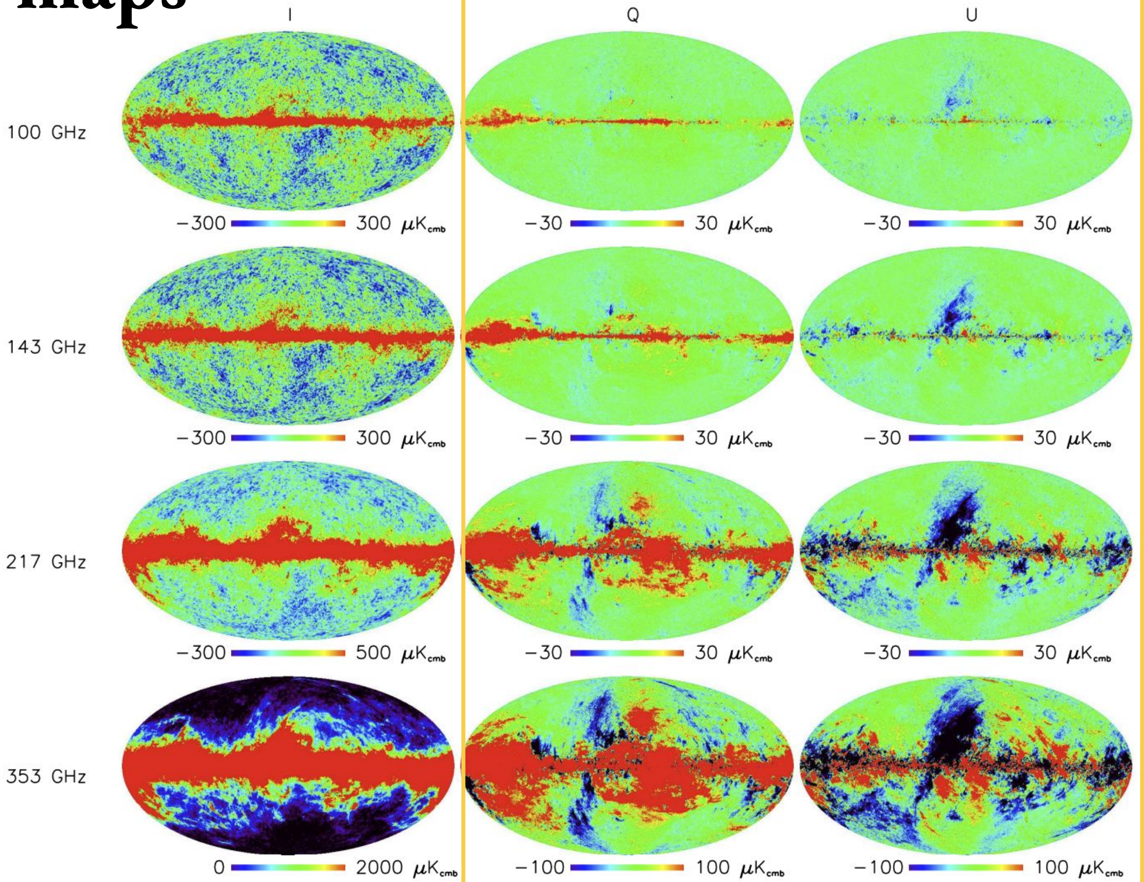


Planck Dust intensity with MF @353 GHz



Polarization and total intensity SED difference suggests that there might be **spatial variation SEDs**. (Planck 2018 XI)

Planck HFI maps
Sroll2 release



Delouis et al. A&A 629, A38 (2019)

Dust polarization Spectral Energy Distribution variations

mathematical definitions

Moment exp. 1st order $\boldsymbol{\beta}$ — Moment exp. 1st order T

Dust emission

$$D_\nu(\eta) = \frac{S_p(\nu)}{S_p(\nu_0)} \left(D_{\nu_0}(\eta) + \omega_\beta(\eta) \ln \frac{\nu}{\nu_0} + \omega_T(\eta) \times [\Theta_\nu(T_0) - \Theta_{\nu_0}(T_0)] \right)$$

Chluba et al. MNRAS 472, 1195–1213 (2017)
Mangilli et al. A&A 647, A52 (2021)

where $\Theta_\nu(T_0) = \frac{x}{T_0} \frac{e^x}{e^x - 1}$ $\quad x = \frac{h\nu}{k_B T_0}$

The mean polarization SED is accounted for in:

$$\gamma(\nu) = \frac{D_\nu * D_{\nu_0}}{D^2_{\nu_0}} \qquad \frac{S_p(\nu)}{S_p(\nu_0)} = \gamma(\nu) + \delta\gamma(\nu)$$

$$with \left| \frac{\delta\gamma_\nu}{\gamma_\nu} \right| << 1$$

$\boldsymbol{\delta\gamma(\nu)}$ is not zero if there is a frequency decorrelation

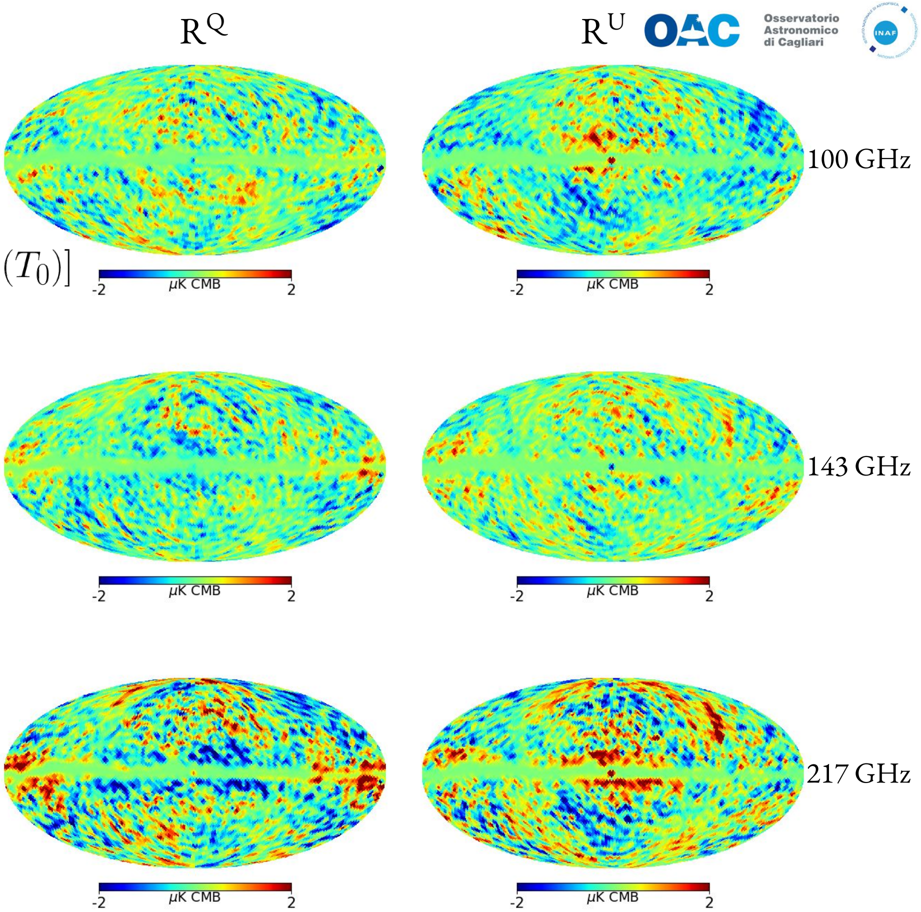
D_ν = Q_ν or U_ν
SED Q and U might differ
$\boldsymbol{\nu}$: 100, 143, 217, 353 GHz
with $\boldsymbol{\nu}_0$= 353 GHz
T_0= 19.6 K
$\boldsymbol{\eta}$: sky vector

Residual dust maps

$$R_\nu(\eta) = D_\nu(\eta) - \gamma(\nu) D_{\nu_0}(\eta)$$
$$= \delta\gamma(\nu) D_{\nu_0}(\eta) + \omega_\beta(\eta)\gamma_\nu \ln\frac{\nu}{\nu_0} + \omega_T(\eta)\gamma_\nu[\Theta_\nu(T_0) - \Theta_{\nu_0}(T_0)]$$

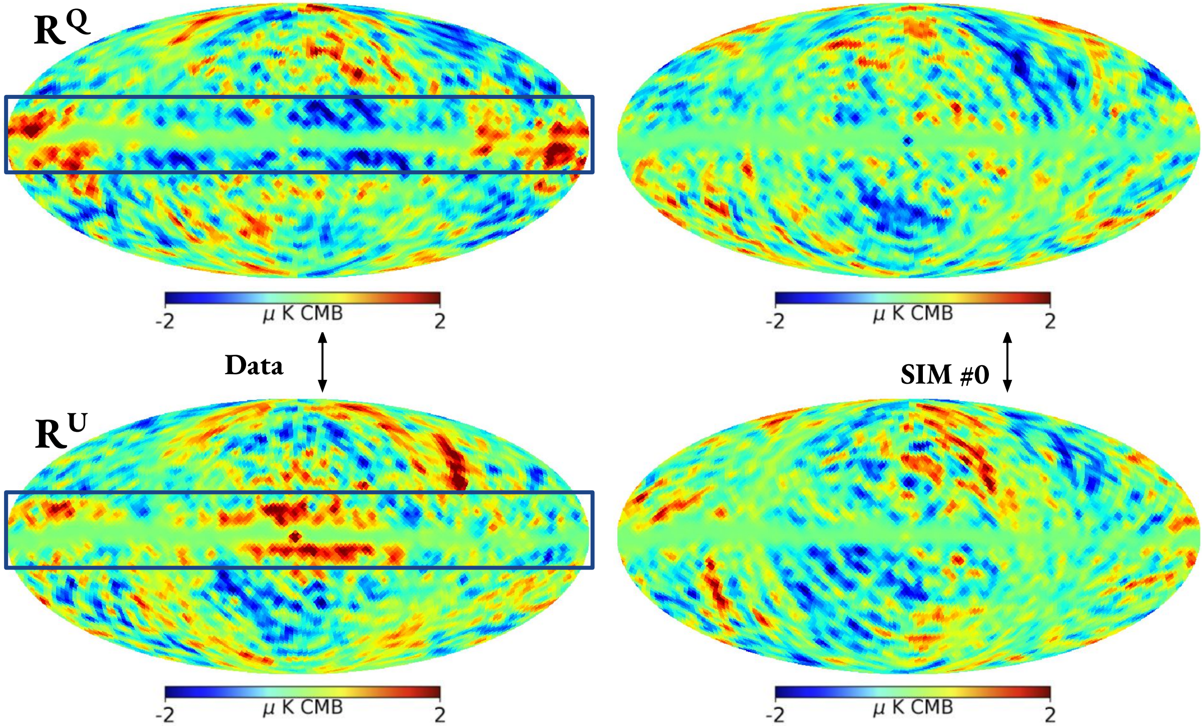
- Synchrotron emission is extrapolated and subtracted at 100 and 143 GHz
- **$\gamma(\nu)$** is estimated in a given mask
- Planck HFI Sroll2.0 release used
- Fraction of the sky 90%
- Nside=32

SED variations increase their significance with frequency



Residual dust maps

217 GHz
fsky 90%



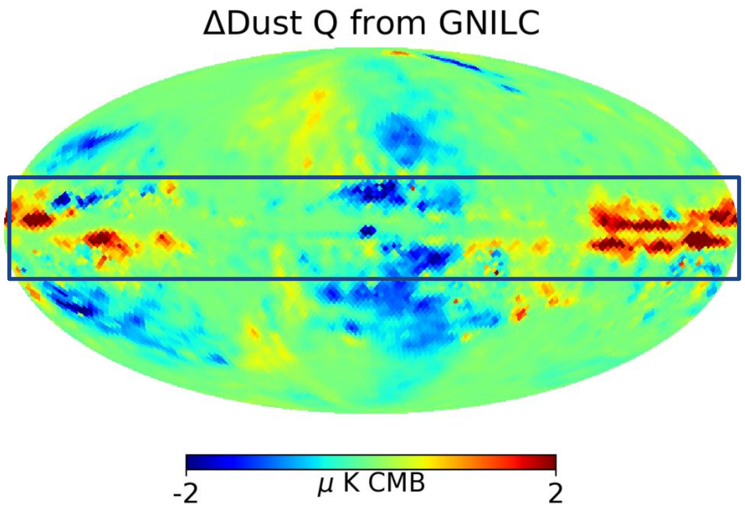
Most of the variation comes from the regions close to the mask threshold

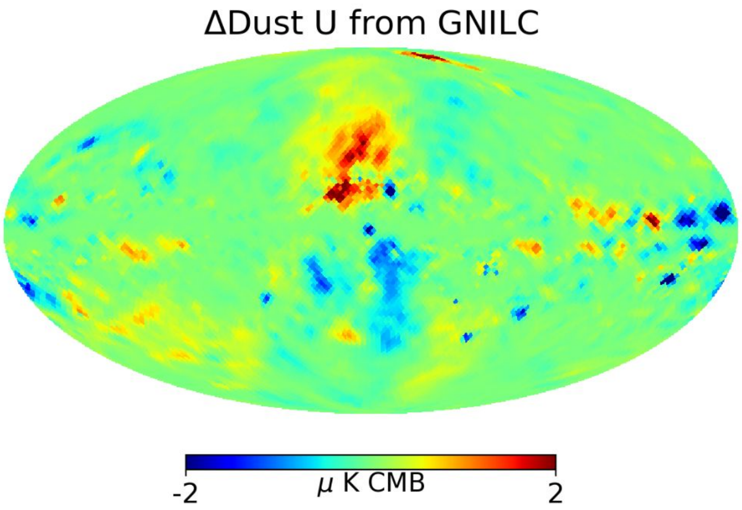
Extrapolating dust SED variation from Temp to Polar

Planck's law with T, $\boldsymbol{\tau}, \boldsymbol{\beta}$ GNILC maps

$$B_\nu(T,\tau,\beta) = \tau \frac{2h\nu^3}{c^2\left(e^{\frac{h\nu}{k_B T}}-1\right)}\left(\frac{\nu}{\nu_0}\right)^\beta \longrightarrow \Delta D_\nu(Q) = (B_\nu - B_{\nu_0})\frac{Q}{I}(\nu_0)$$

same for U

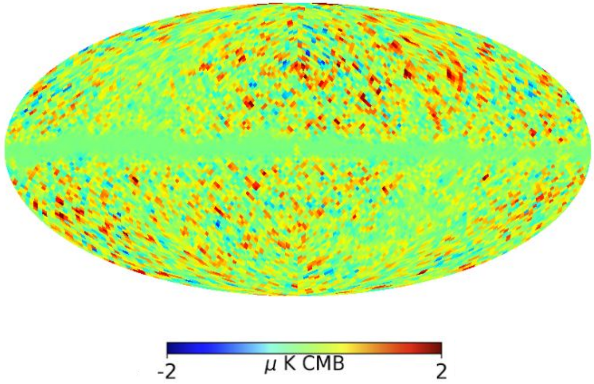




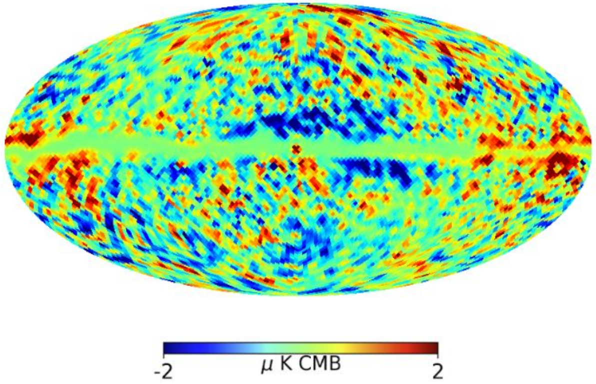
Residual dust Polarized intensity maps

217 GHz
fsky 90%

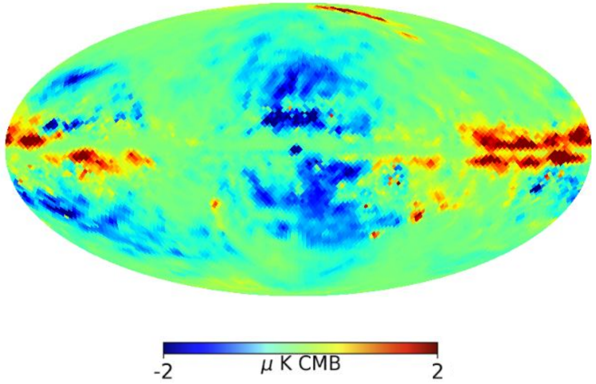
R^P SIM #0



R^P DATA



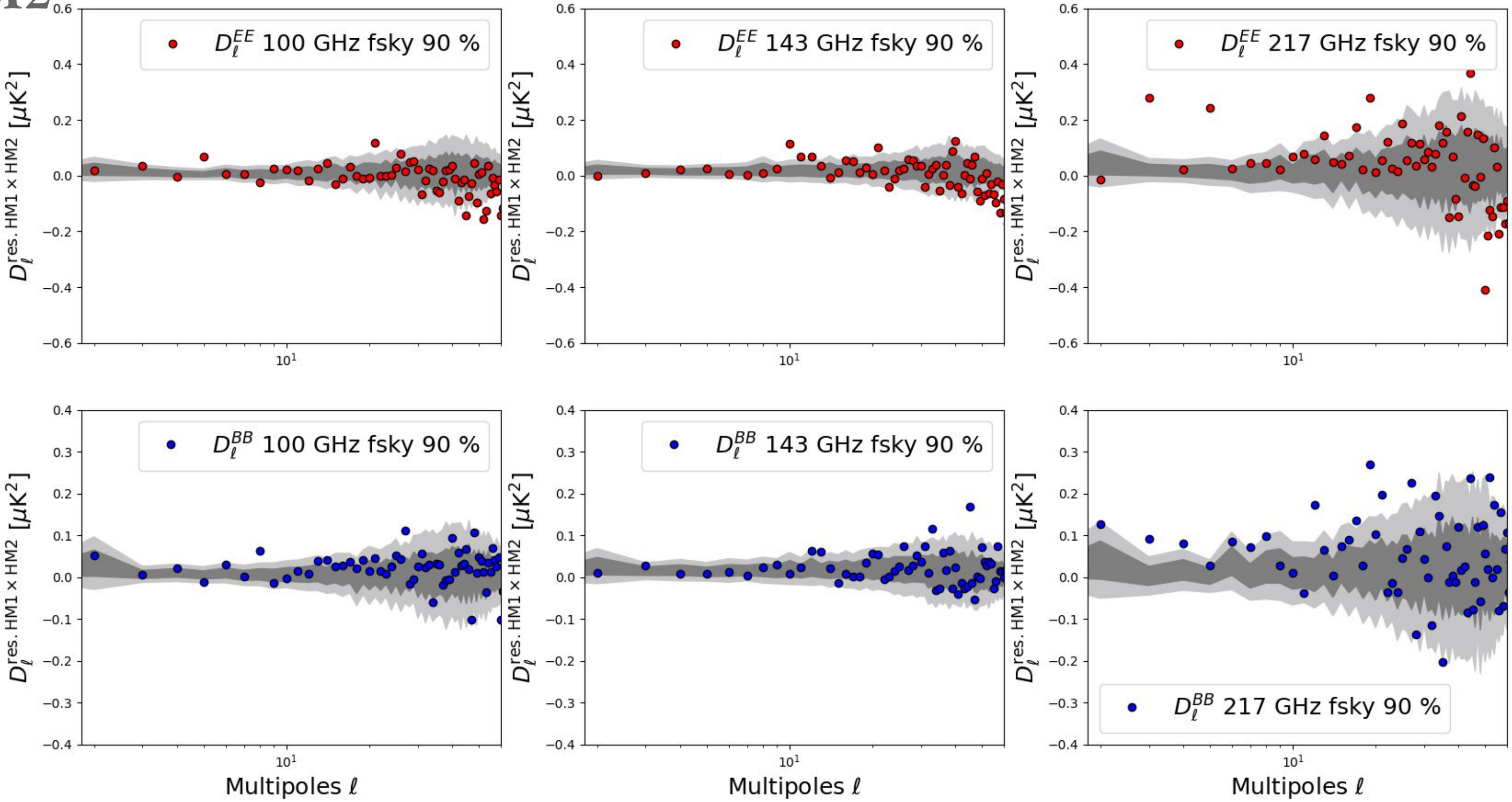
R^P GNILC



In polarized intensity P map we find SED variations correlated to dust FIR SED variations in total intensity from GNILC MBB fit

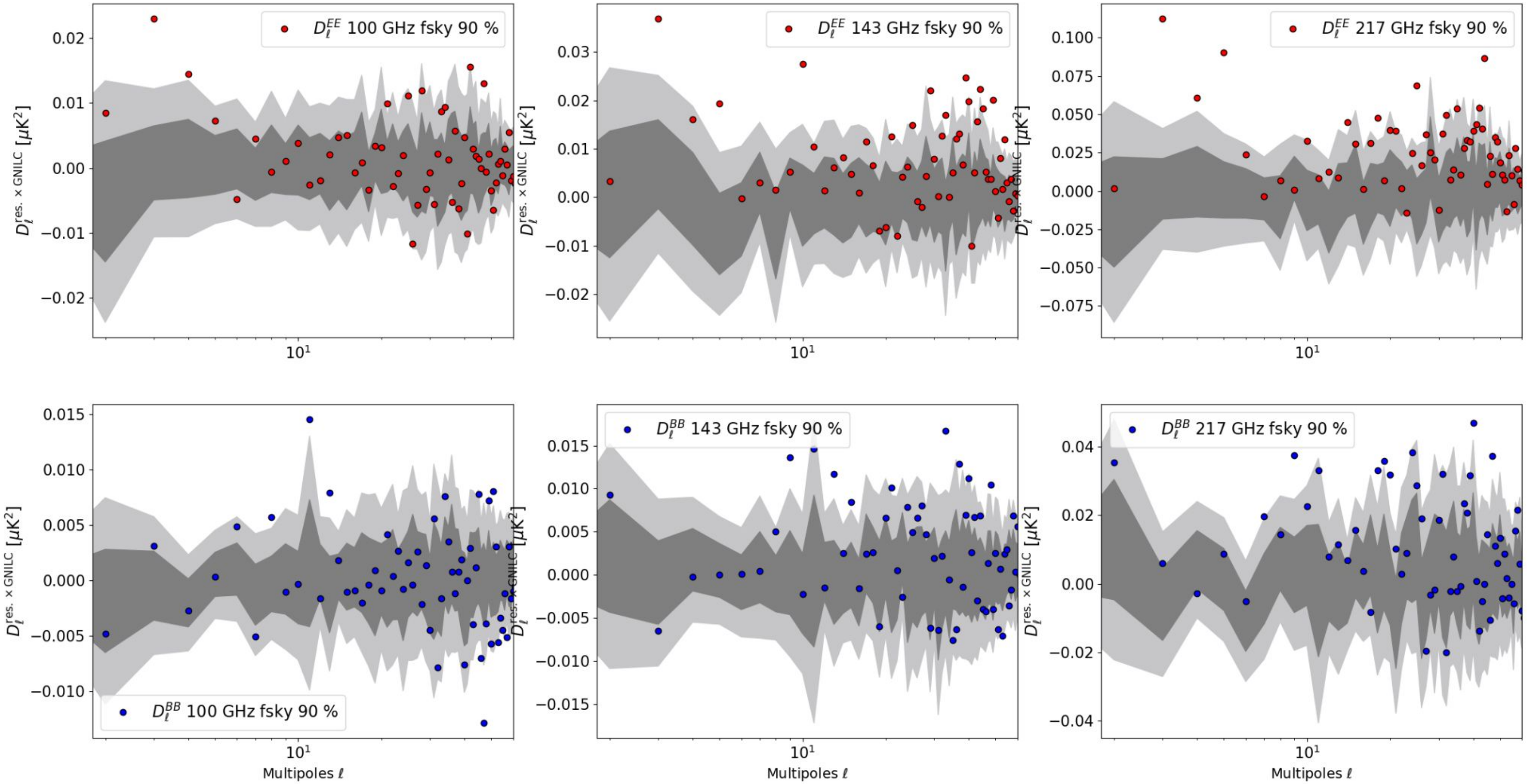
Cross Power Spectra analysis

HM1× HM2



Cross Power Spectra analysis

Full-mission ✕ GNILC



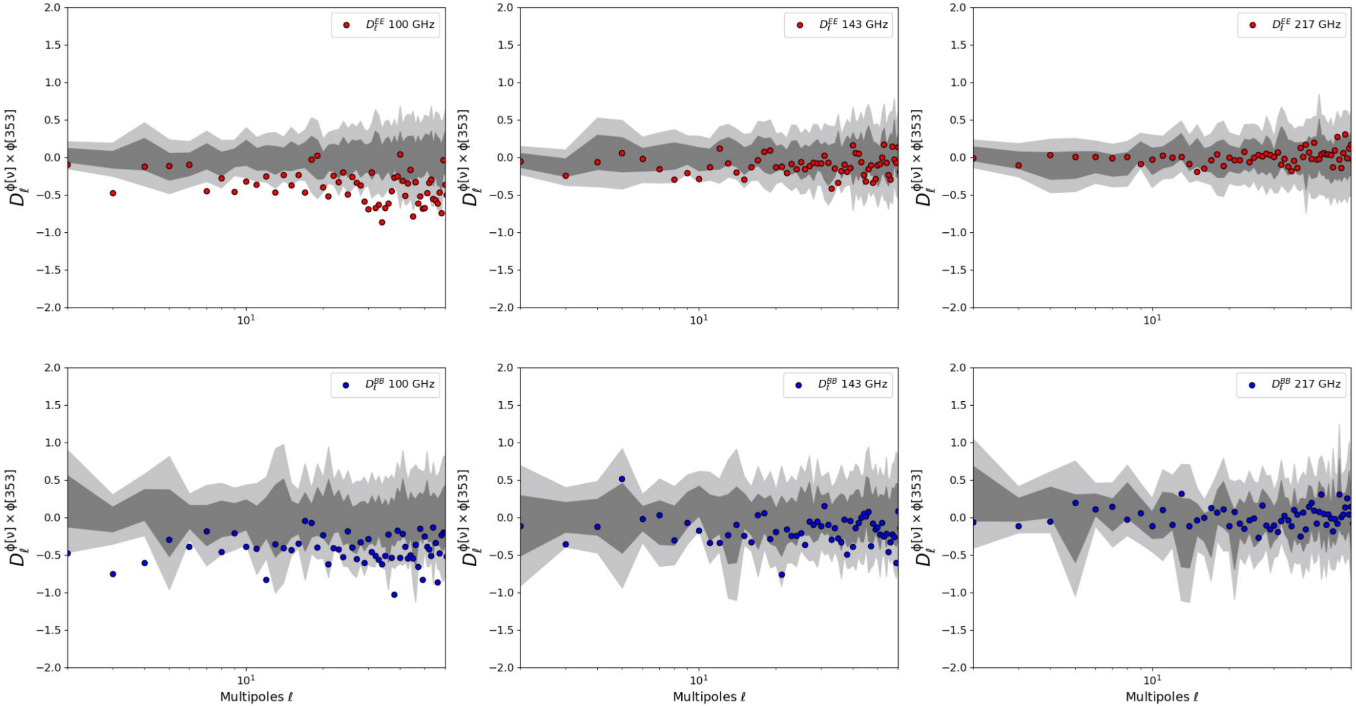
Dependance on polarization angle variation ϕ

$$D_\ell = (\tilde{Q},\tilde{U})_\nu \times (\tilde{Q},\tilde{U})_{\nu_0}$$

$$\tilde{Q}_\nu = \cos(2\phi_\nu)$$

$$\tilde{U}_\nu = \sin(2\phi_\nu)$$

$$\phi = \frac{1}{2}\tan^{-1}\left(\frac{U}{Q}\right)$$



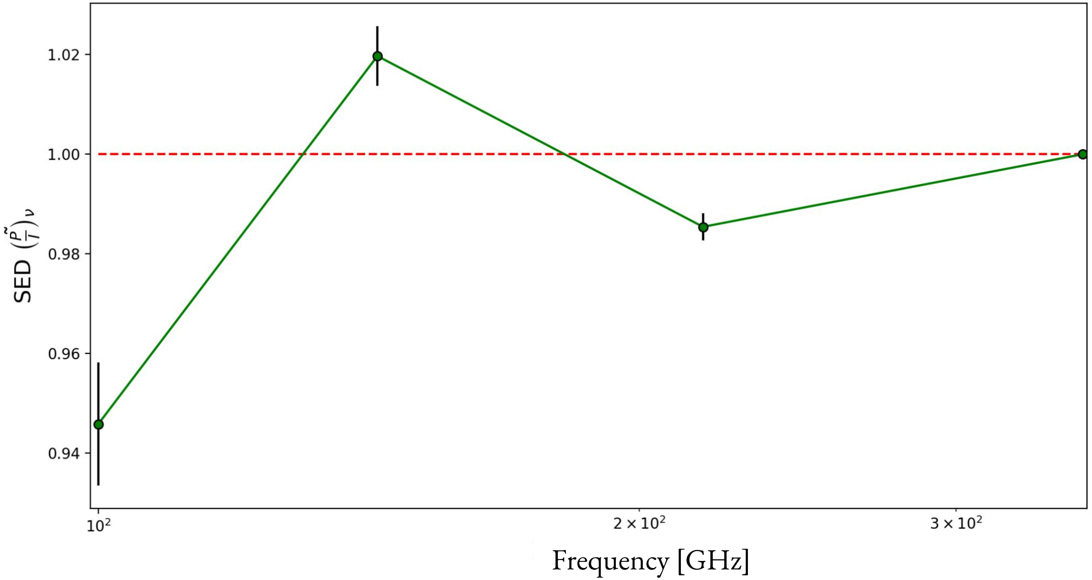
The farthest we go from ν_0 the decorrelation increases

Dust mean SED polarization vs total intensity

PRELIMINARY

The ratio between the polarization SED coefficients estimated on Sroll2.0 polarization maps $\boldsymbol{\gamma}^{P}$ with respect to GNILC total intensity $\boldsymbol{\gamma}^{g}$ is given by:

$$\frac{\tilde{P}}{I} = \frac{\gamma_\nu^p}{\gamma_\nu^g}$$



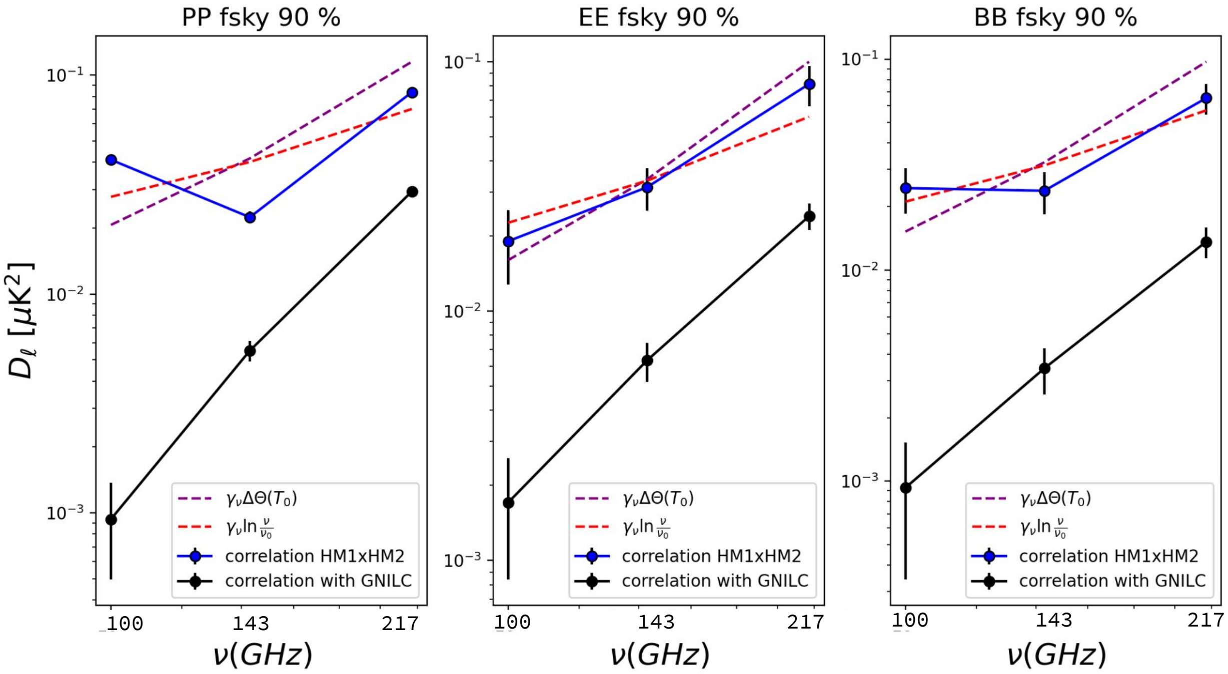
Deviation from the unity is evidence of a small difference of SED between polarization and total intensity.

But remember that our estimate of mean dust polarization SED is biased by frequency decorrelation.

SED extrapolation binned spectra ℓ=[4,30]

$$R_\nu(\eta) = D_\nu(\eta) - \gamma(\nu) D_{\nu_0}(\eta)$$
$$= \delta\gamma(\nu) D_{\nu_0}(\eta) + \omega_\beta(\eta)\gamma_\nu \ln\frac{\nu}{\nu_0} + \omega_T(\eta)\gamma_\nu[\Theta_\nu(T_0) - \Theta_{\nu_0}(T_0)]$$

PRELIMINARY



Conclusions and perspectives

We are making progress in characterizing Galactic dust polarization!

- Variations of dust SED in polarization detected close to the galactic plane;
- Residuals from total intensity GNILC maps correlates with polarization **but** this correlation accounts only for part of the signal;
- We observe frequency decorrelation from changes of polarization angles increasing from 217 to 100 GHz;
- Two possible interpretations need to be considered:

  1) variation of dust spectral index and temperature;
  2) additional polarization galactic component.

THANK YOU FOR THE ATTENTION!

Coefficients γ_ν estimated for:

fsky 90%

fsky 80%

fsky 70%