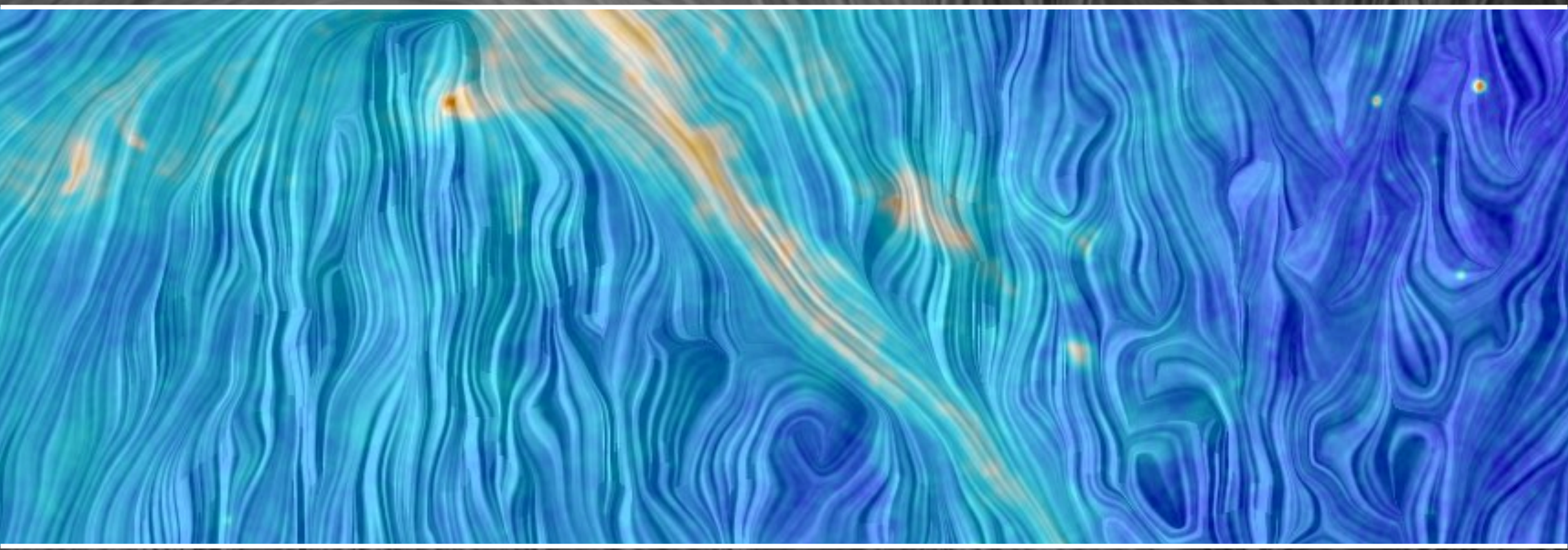
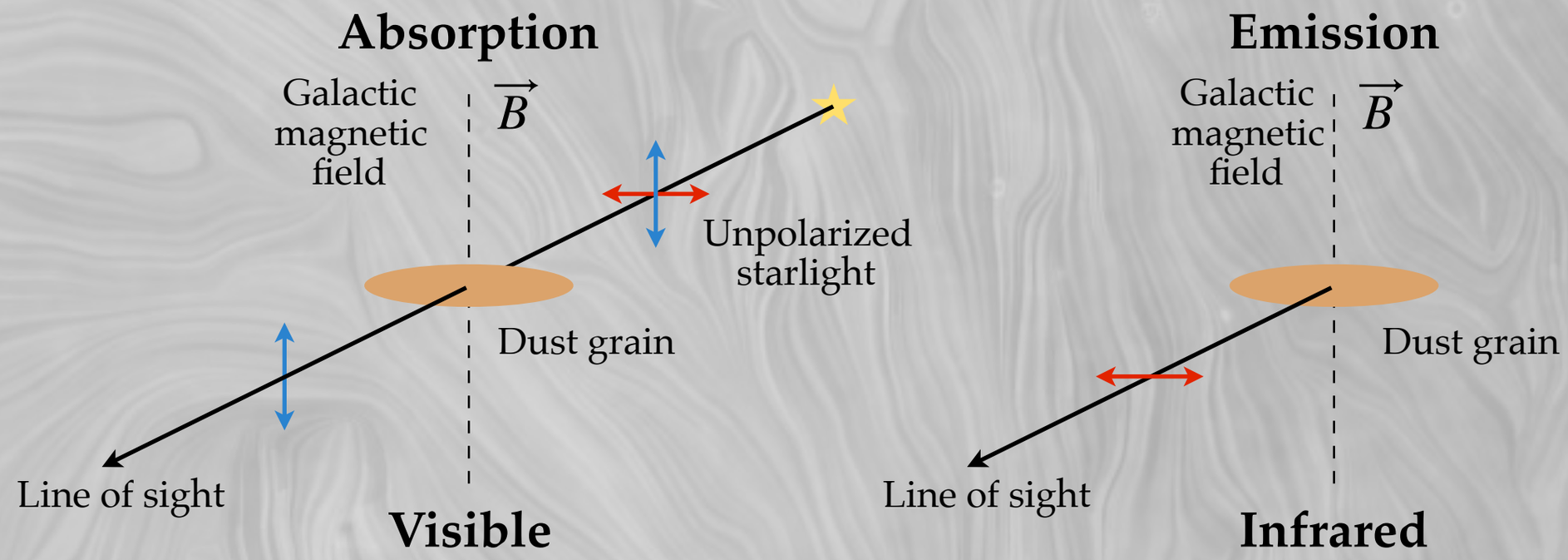
Dust Polarized Foreground from Planck



Jonathan Aumont
IRAP — Toulouse, France
on behalf of Jean-Loup Puget and the Planck Collaboration

CMB Foregrounds - Tenerife - October 16th 2018

INTRODUCTION: Dust Polarization

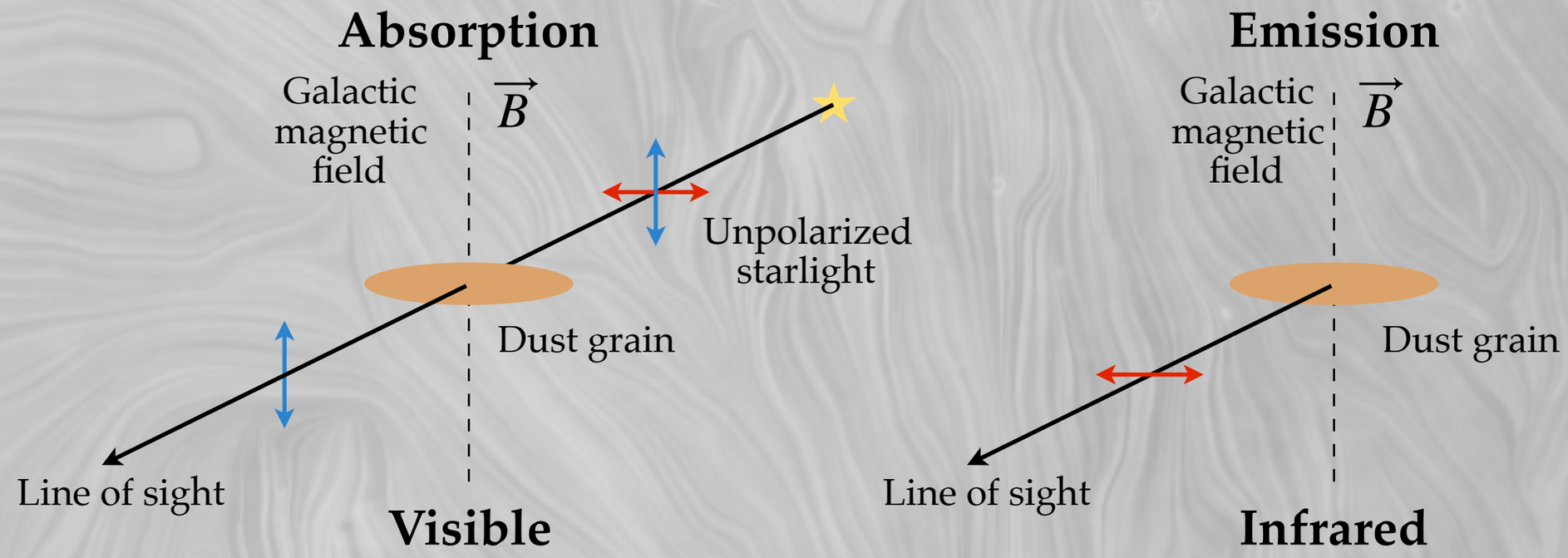


★ **Galactic dust polarization traces**:

- the structure of the Galactic magnetic field
- the alignment mechanisms and efficiency
- the nature of the dust grains

★ **Dust emission is a major polarized foreground to CMB B-modes**

INTRODUCTION: Dust Polarization



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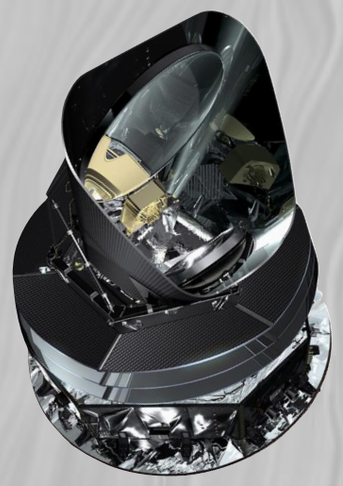


Planck 2018 results. XII. Galactic astrophysics using polarized dust emission

★ Statistical analysis of polarization fraction and angle

★ Correlation of dust polarization in emission (Planck sub-mm) and extinction (stellar optical data)

see François Boulanger's talk

Planck 2018 results. XI. Polarized dust foregrounds

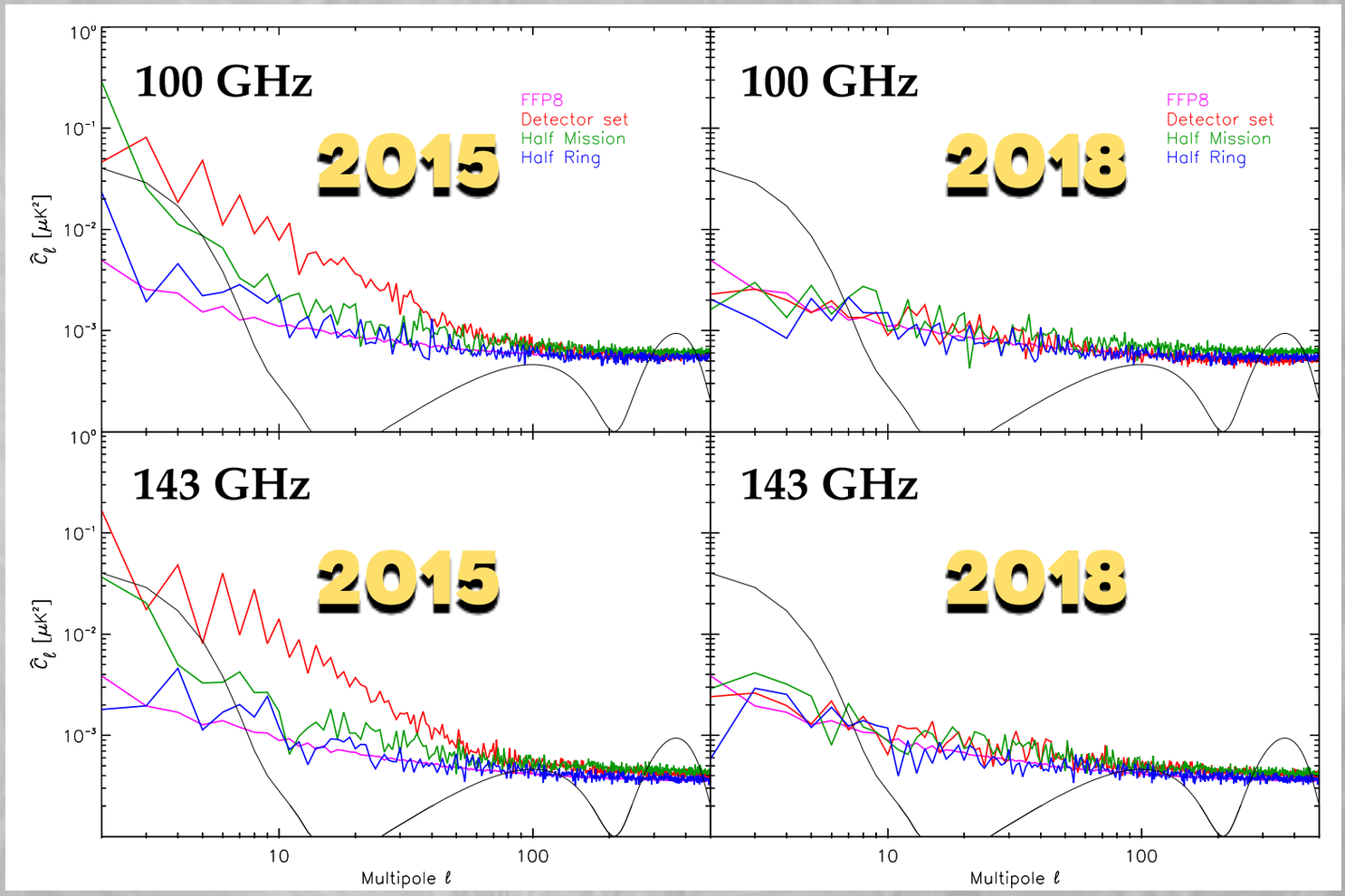
1. Power spectra analysis of dust polarization maps
2. Spectral energy distribution of dust polarized emission
3. Correlation of dust polarization over microwave frequencies

PLANCK 2018 III: Planck-HFI 2018 data

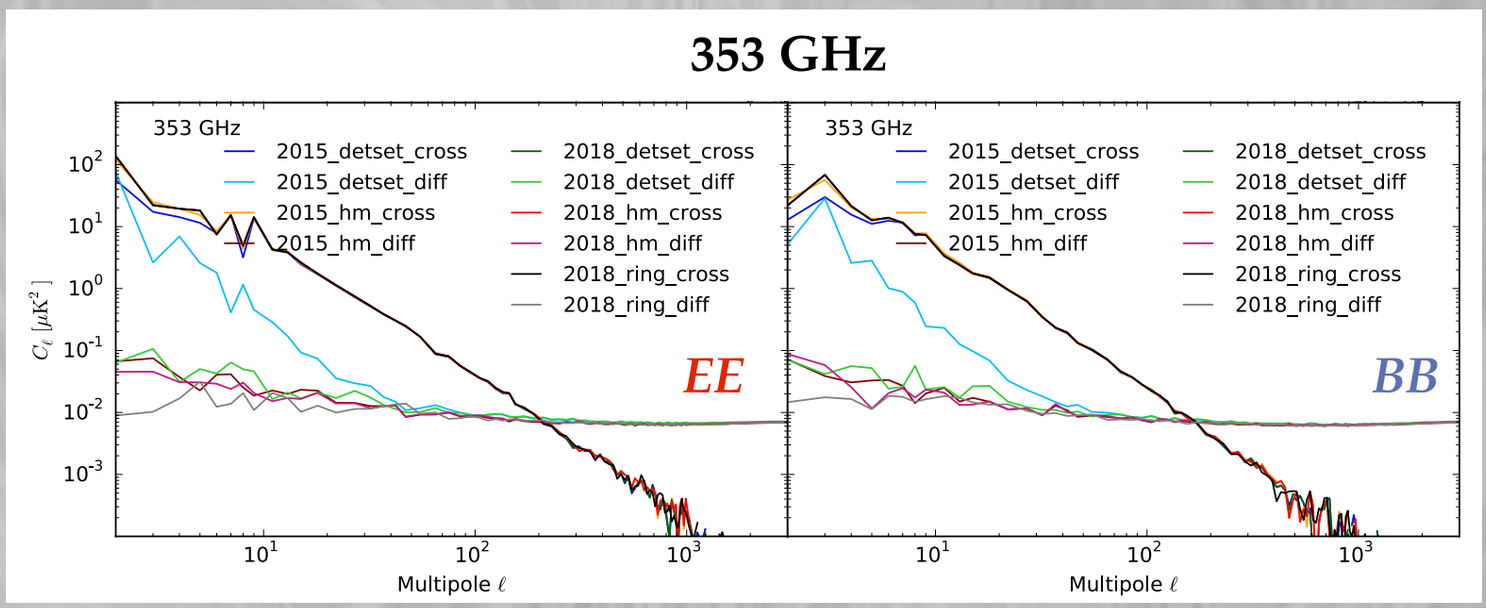
★ **Planck 2018 data quality has been significantly improved:**

- More accurate dipole calibration
- More accurate bandpass mismatch removal, at the map-making level
- ADC non-linearity residuals assessed and removed through accurate E2E simulations

★ **Planck CMB channels polarization noise dominated down to the lowest multipoles**

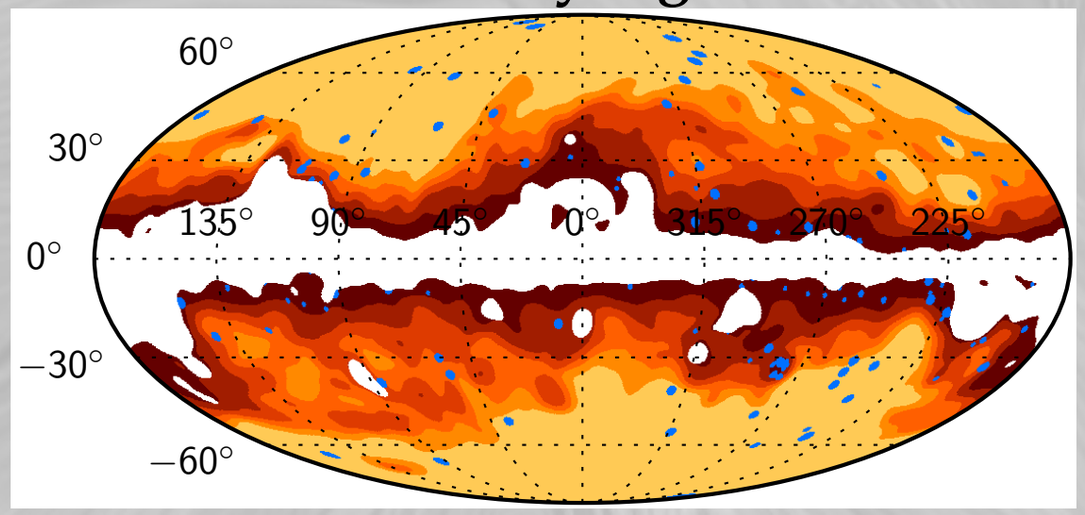


★ **We significantly reduced systematics at 353 GHz, but still to be improved**

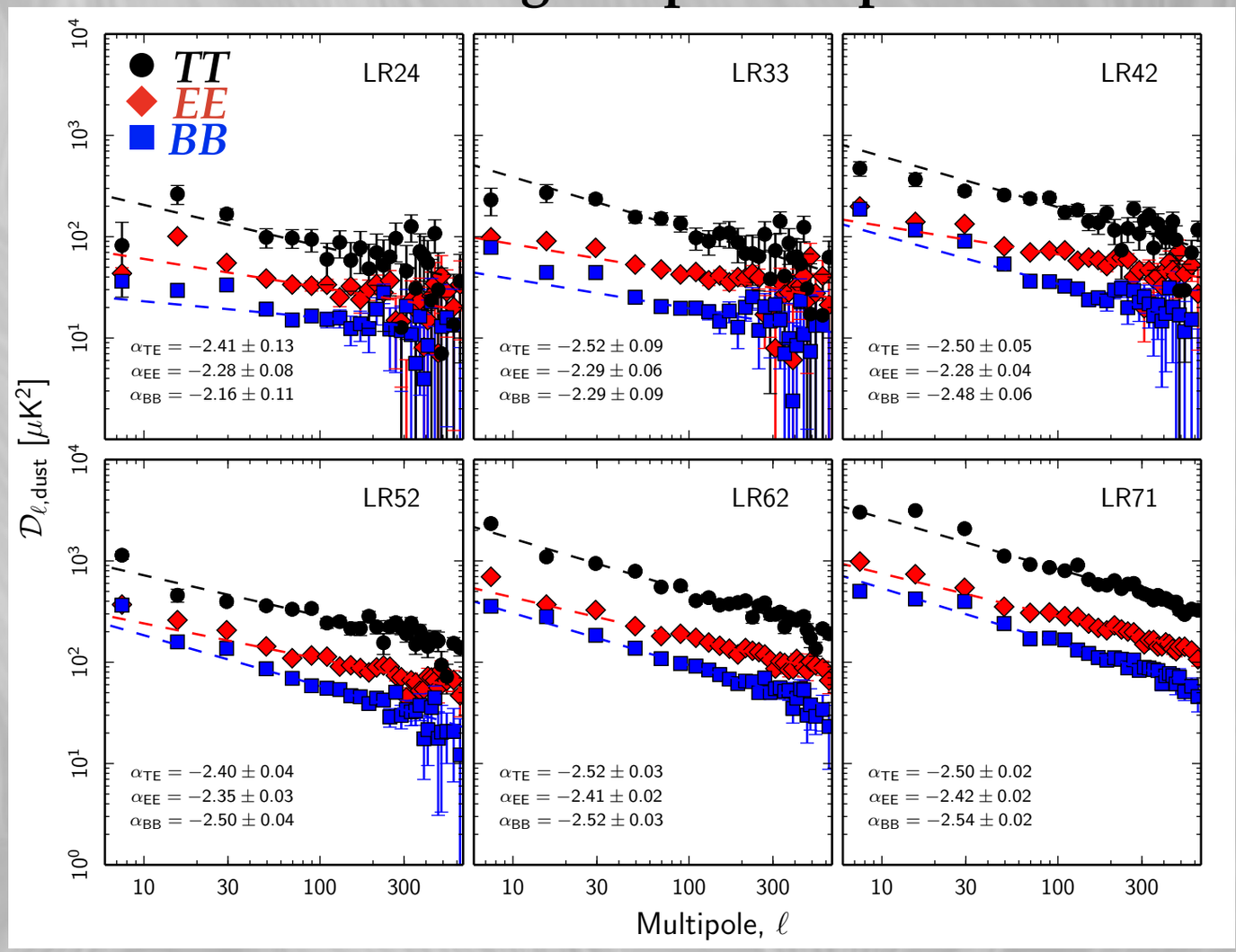


PLANCK 2018 XI: Dust angular power spectra

Nested sky regions



353 GHz angular power spectra



- ★ The power-law exponents for *EE* and *BB* are slightly different
- ★ Spectra are not well fitted by a single power-law over the full multipole-range

PLANCK 2018 XI: Dust angular power spectra

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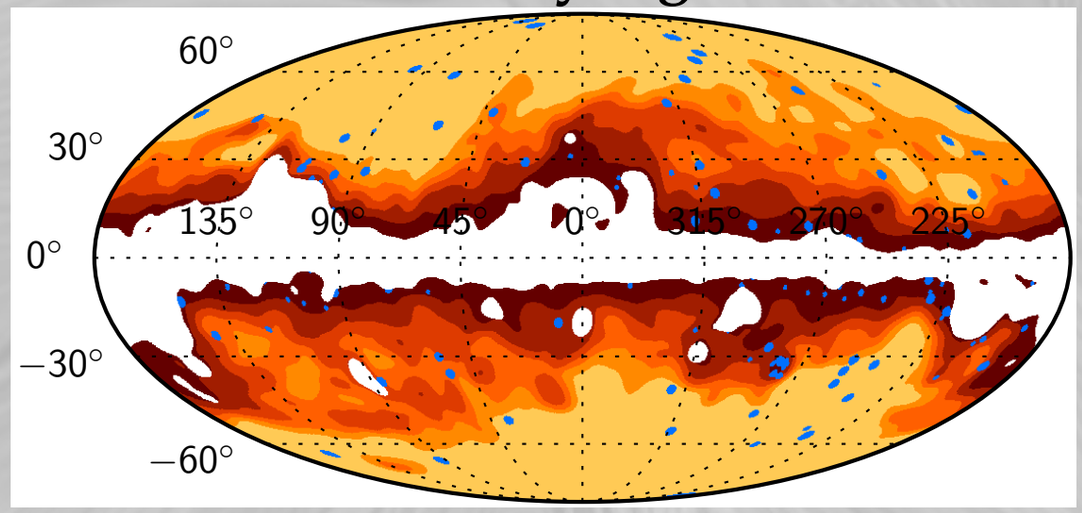
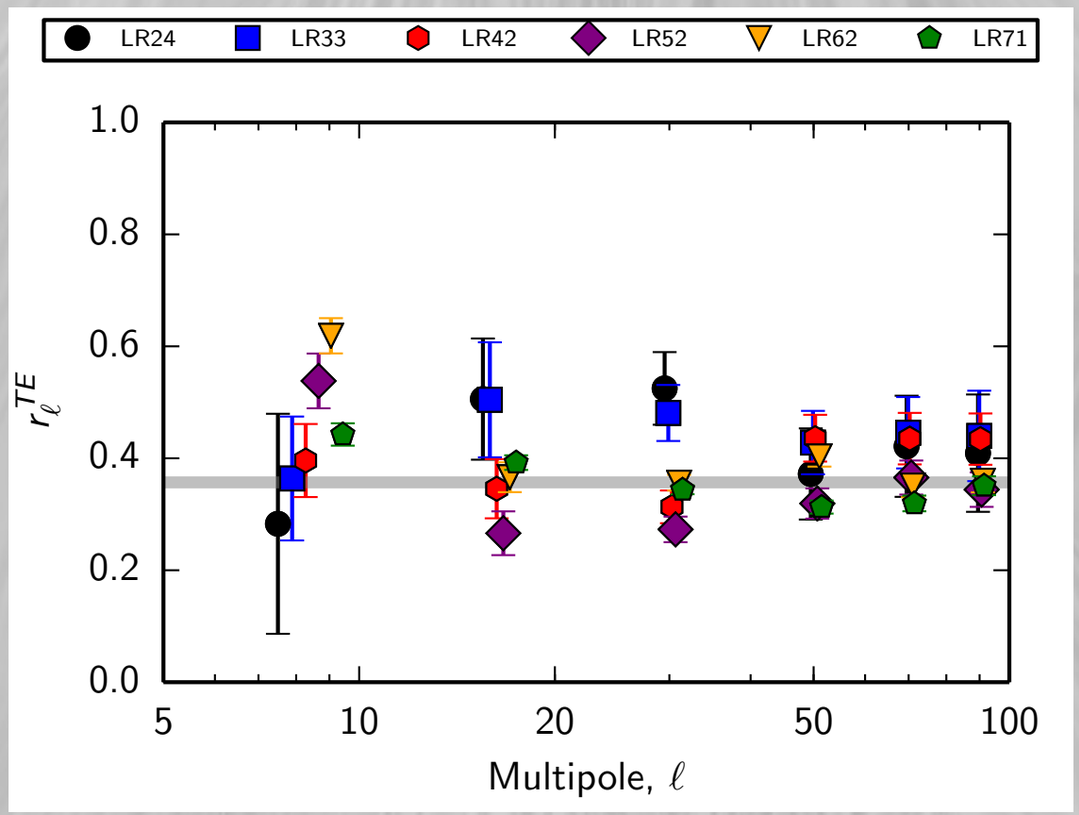
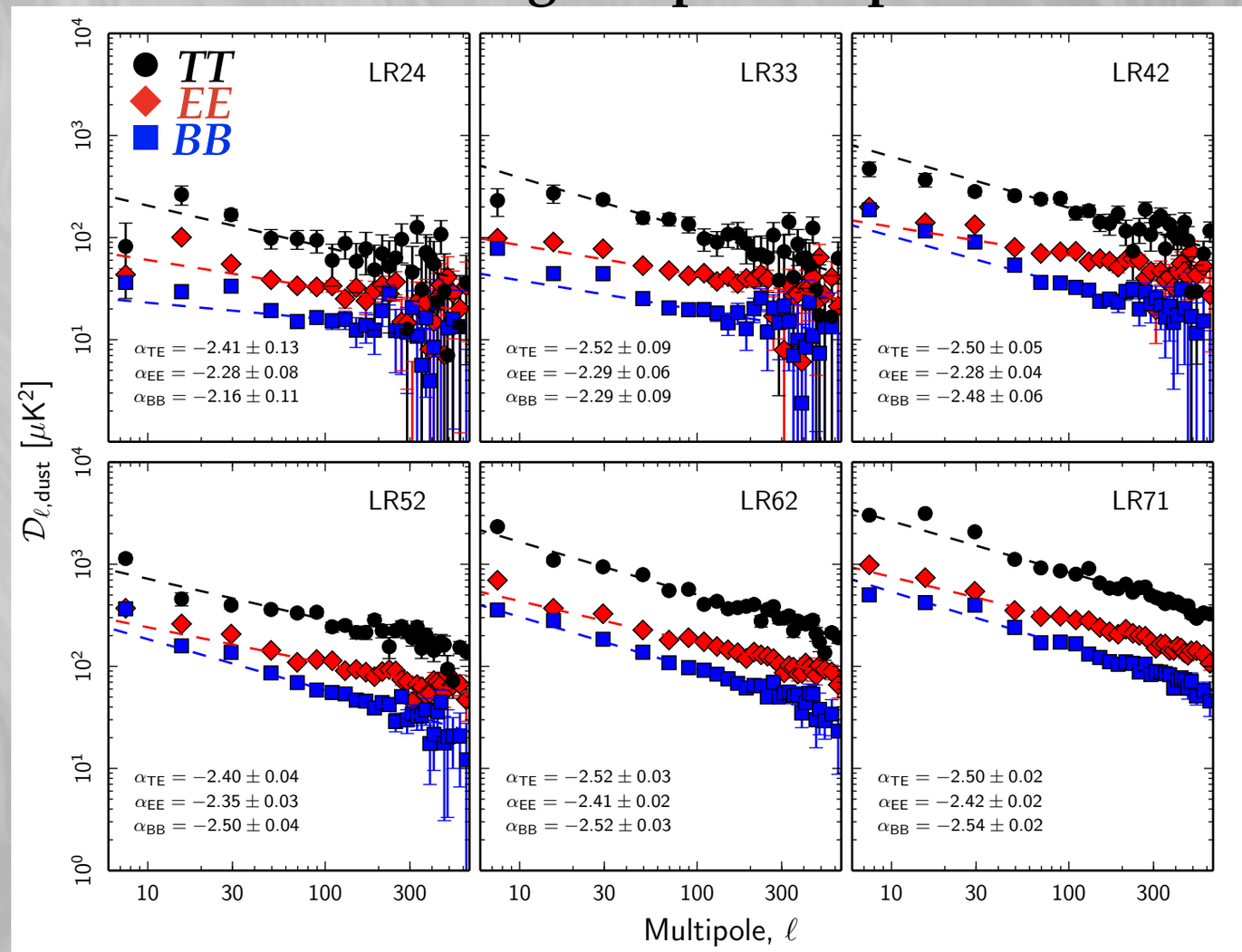


T-*E* correlation ratio



353 GHz angular power spectra

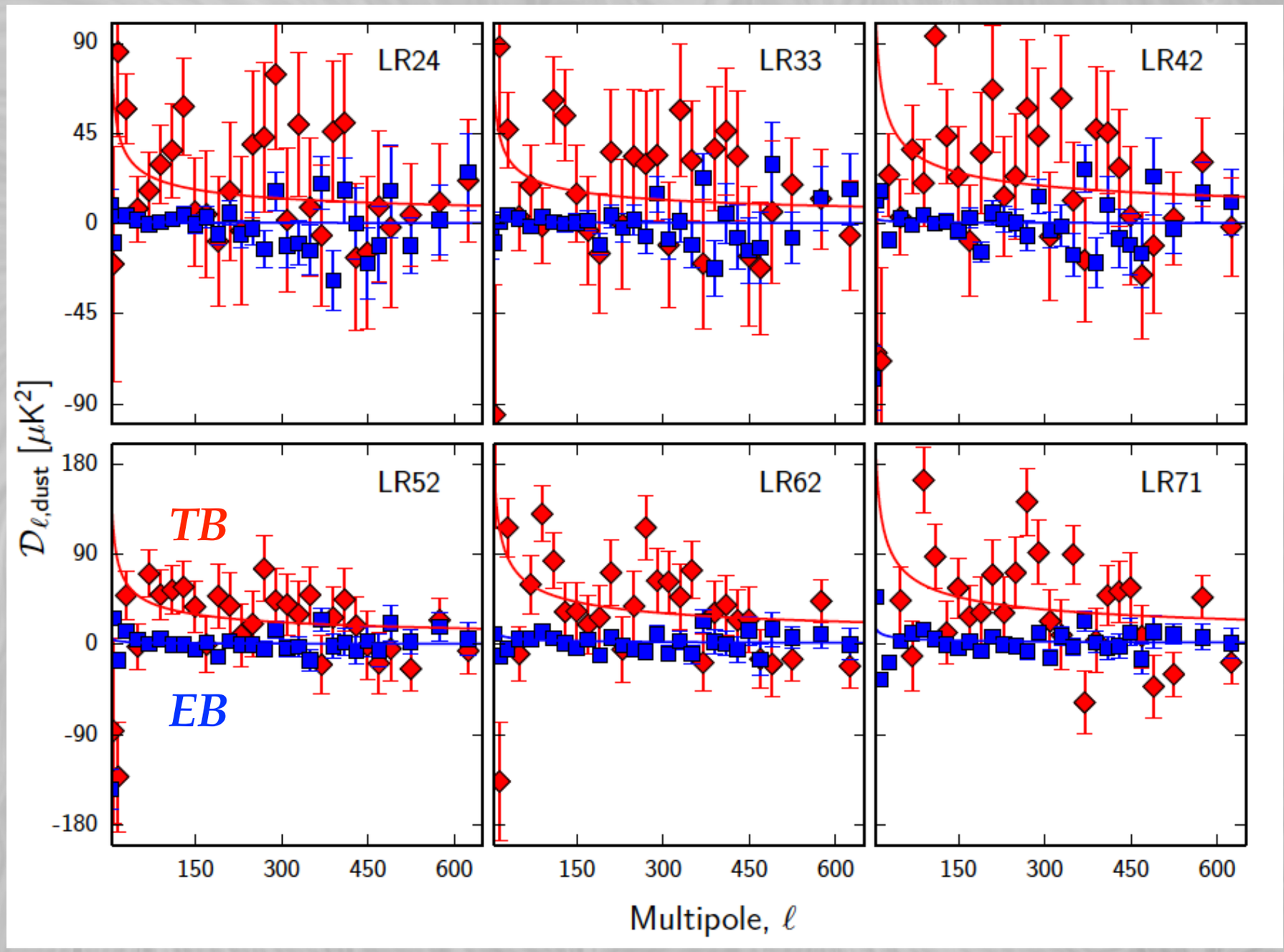


★ The power-law exponents for *EE* and *BB* are slightly different

★ Spectra are not well fitted by a single power-law over the full multipole-range

★ The *E*/*B* asymmetry and *T*-*E* correlation extend to low multipoles

PLANCK 2018 XI: *TB* correlation



★ Evidence for positive ***T-B*** correlation

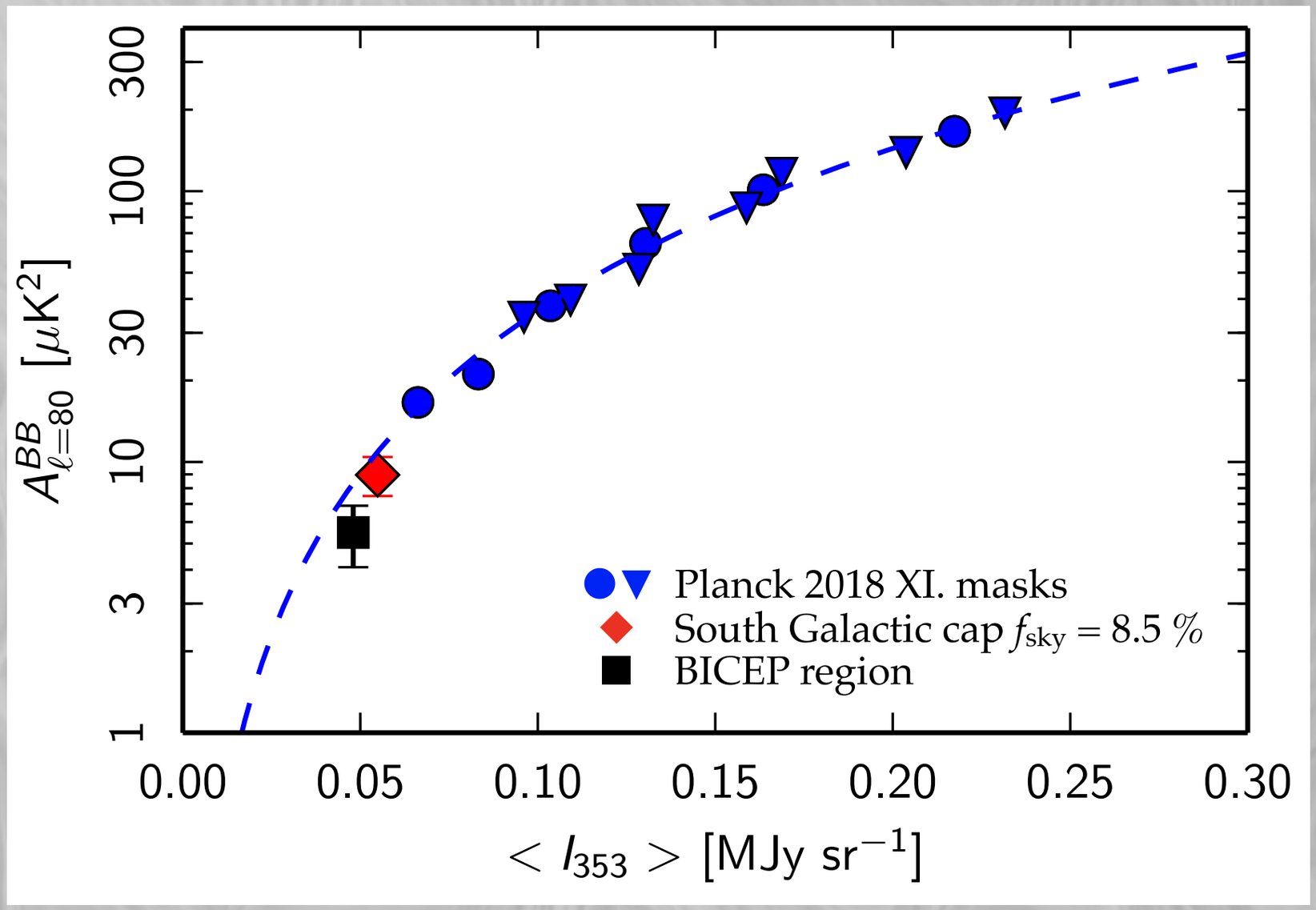
★ This result has not yet received an astrophysical interpretation

★ Non-zero dust ***T-B*** could have an impact on experiments calibrating the absolute polarization angle by minimizing this quantity

PLANCK 2018 XI: Power scaling

★ *BB* power well fitted by $(I_{353})^2$

★ BICEP region's Planck dust *BB* power is compatible with (but lower than) the fit on larger masks



PLANCK 2018 XI: Frequency analysis

★ Spectral model of ***EE*** and ***BB*** cross-spectra between frequencies ν_i and ν_j:

$$D_\ell^{XX}(\nu_i \times \nu_j) =$$

Synchrotron

$$A_{\rm s}^{XX} \left(\frac{\nu_i \nu_j}{30^2}\right)^{\beta_{\rm s}}$$

Dust

$$+A_{\rm d}^{XX} \left(\frac{\nu_i \nu_j}{353^2}\right)^{\beta_{\rm d}-2} \frac{B_{\nu_i}(T_{\rm d}) B_{\nu_j}(T_{\rm d})}{\left(B_{353}(T_{\rm d})\right)^2}$$

Synchrotron x Dust

$$+\rho^{XX} \left(A_{\rm s}^{XX} A_{\rm d}^{XX}\right)^{1/2} \left[\left(\frac{\nu_i}{30}\right)^{\beta_{\rm s}} \left(\frac{\nu_j}{353}\right)^{\beta_{\rm d}-2} \frac{B_{\nu_j}(T_{\rm d})}{B_{353}(T_{\rm d})} + \left(\frac{\nu_j}{30}\right)^{\beta_{\rm s}} \left(\frac{\nu_i}{353}\right)^{\beta_{\rm d}-2} \frac{B_{\nu_i}(T_{\rm d})}{B_{353}(T_{\rm d})}\right]$$

$X \in \{E, B\}$
$i = j$ or $i \neq j$

Same model as in
[Choi & Page 2015]

5 model parameters:

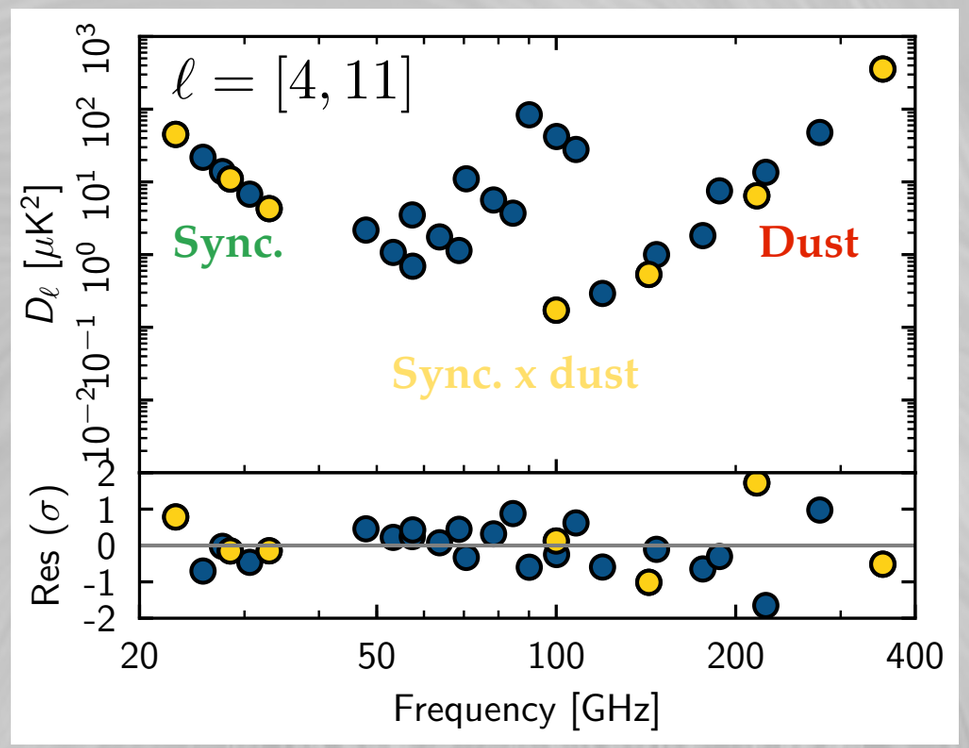
★ The synchrotron and dust amplitudes $A_{\rm s}$ and $A_{\rm d}$

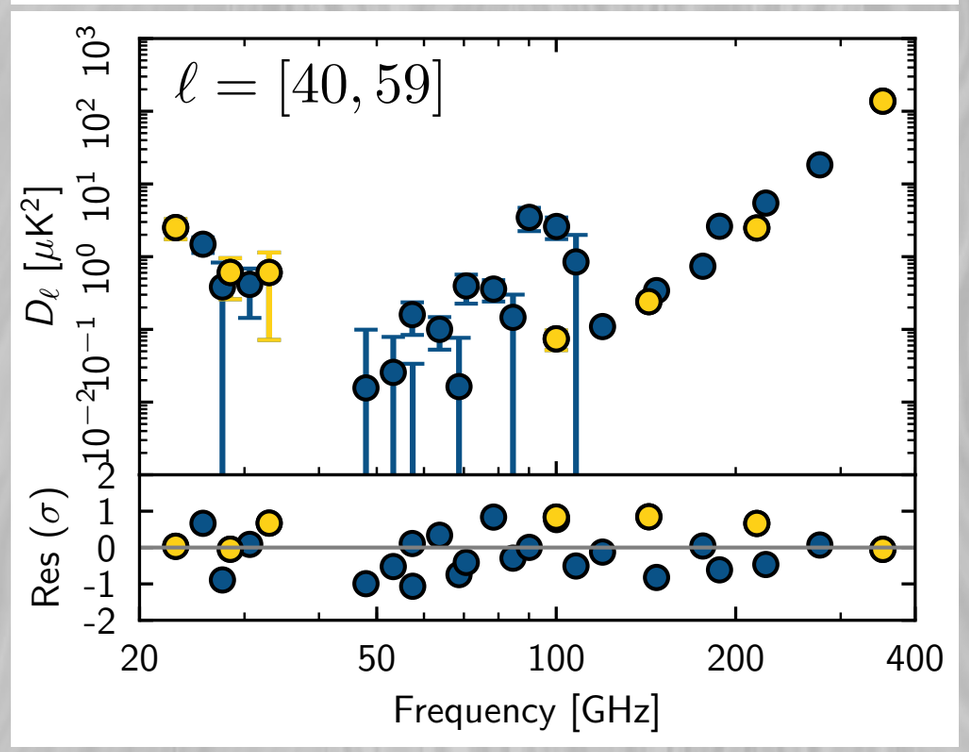
★ The two spectral indices $\beta_{\rm s}$ and $\beta_{\rm d}$

★ The dust/synchrotron polarization correlation parameter ρ

PLANCK 2018 XI: Spectral fits

LR62 sky region





PLANCK 2018 XI: Spectral fits

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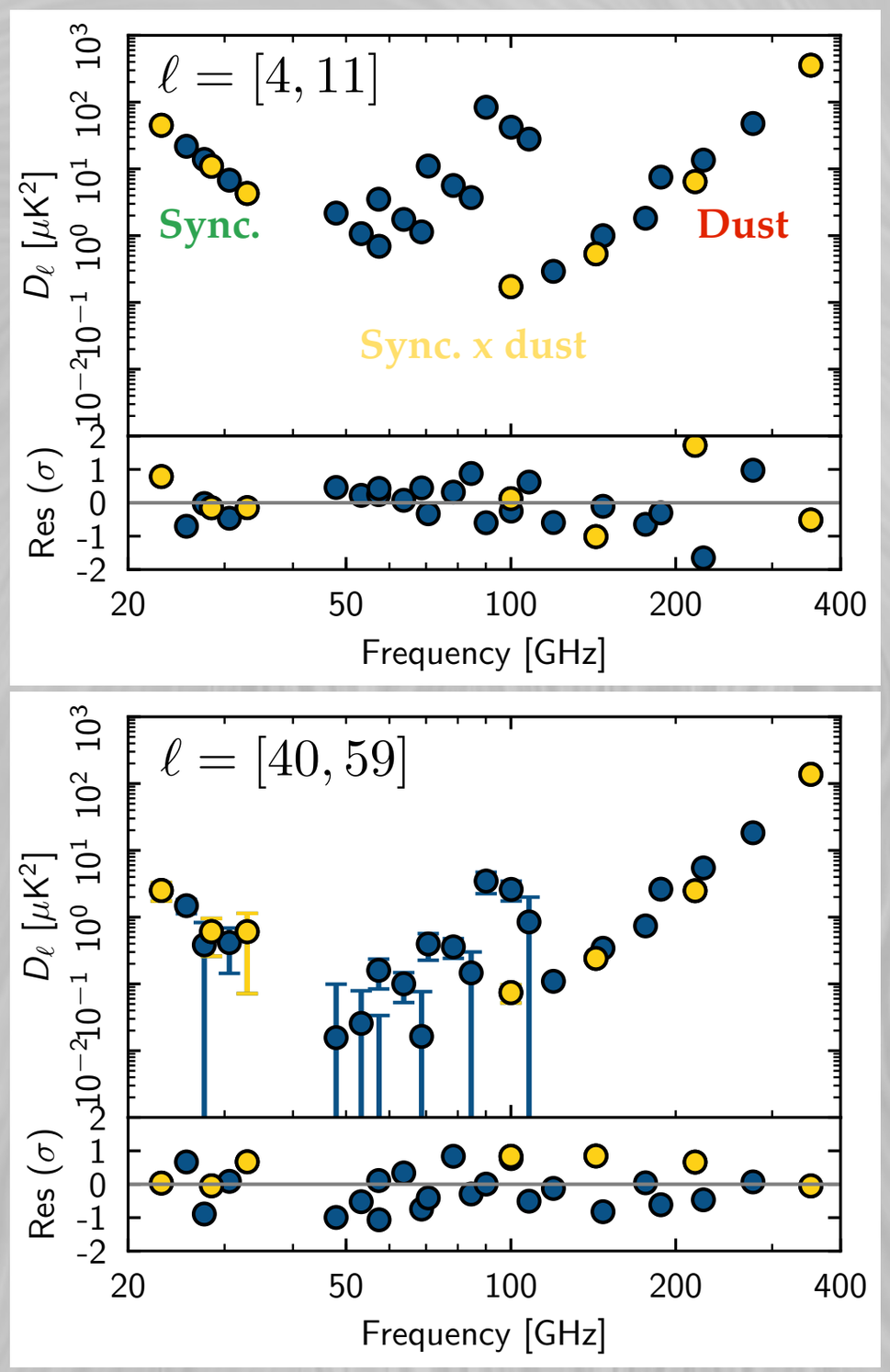
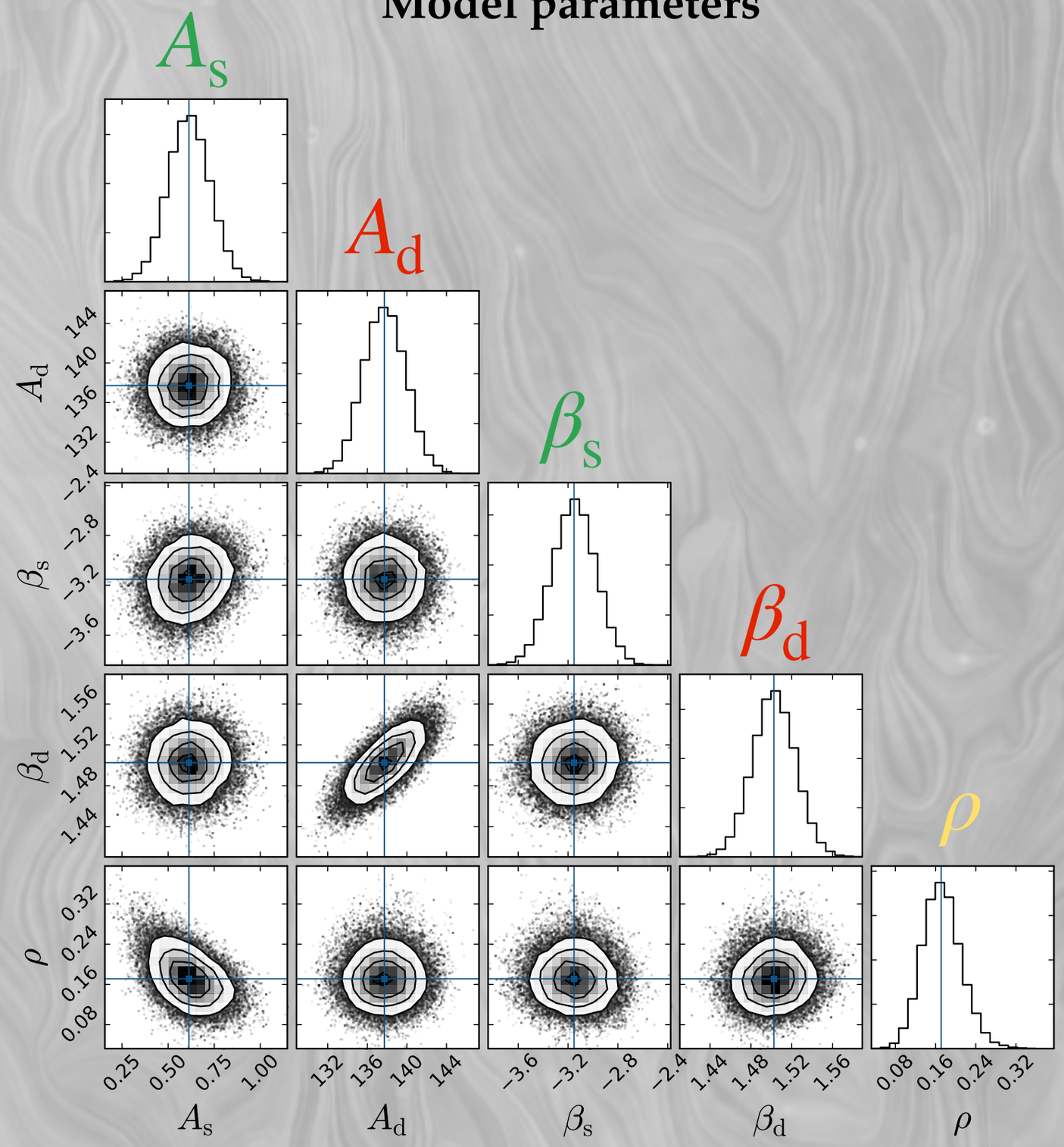
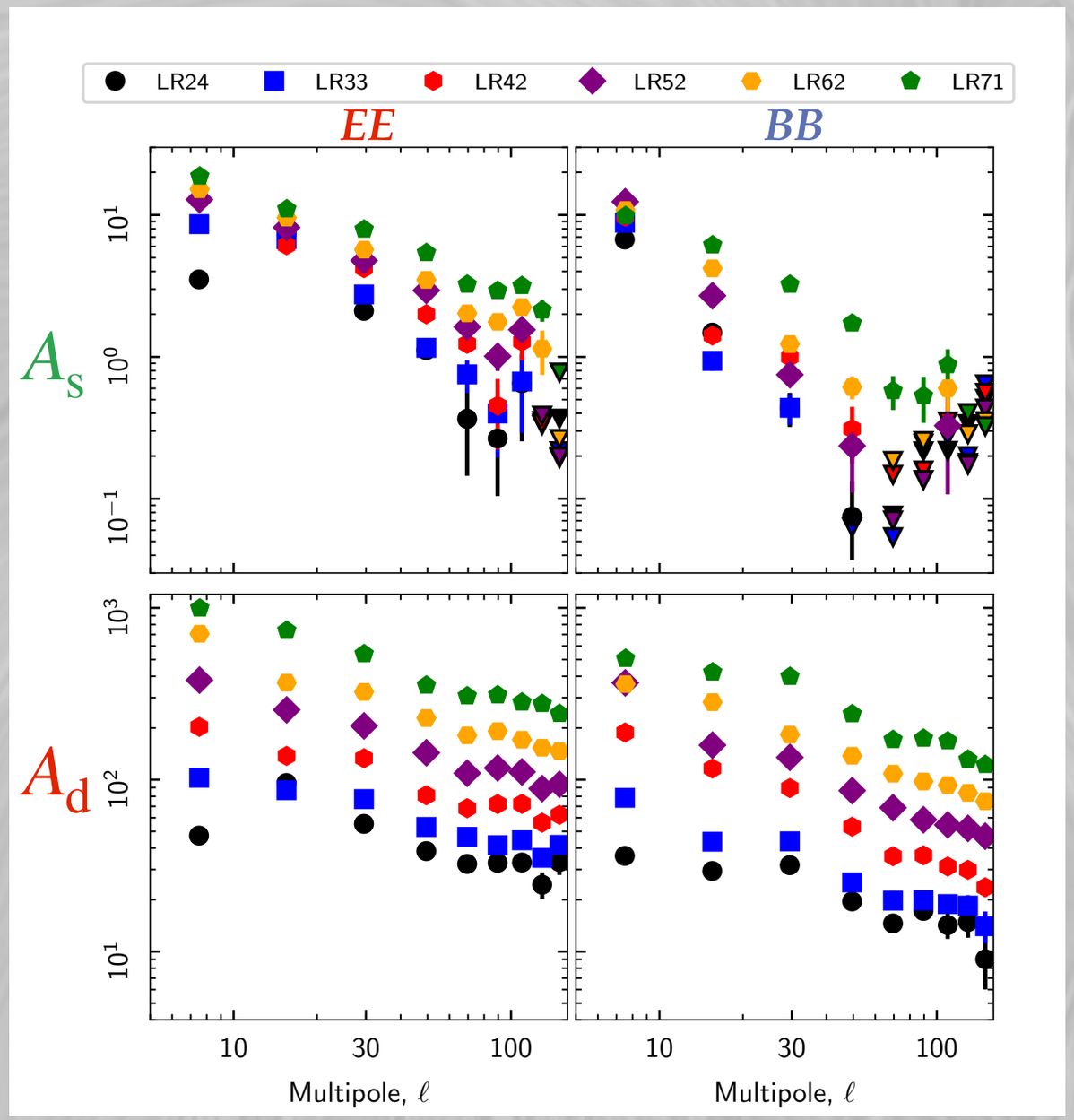


Model parameters



★ Spectral fits characterize foregrounds as a function of ℓ and sky region, for *E* and *B*

PLANCK 2018 XI: Spectral fit parameters



★ Different scaling with respect to ℓ and sky regions for dust and synchrotron polarization

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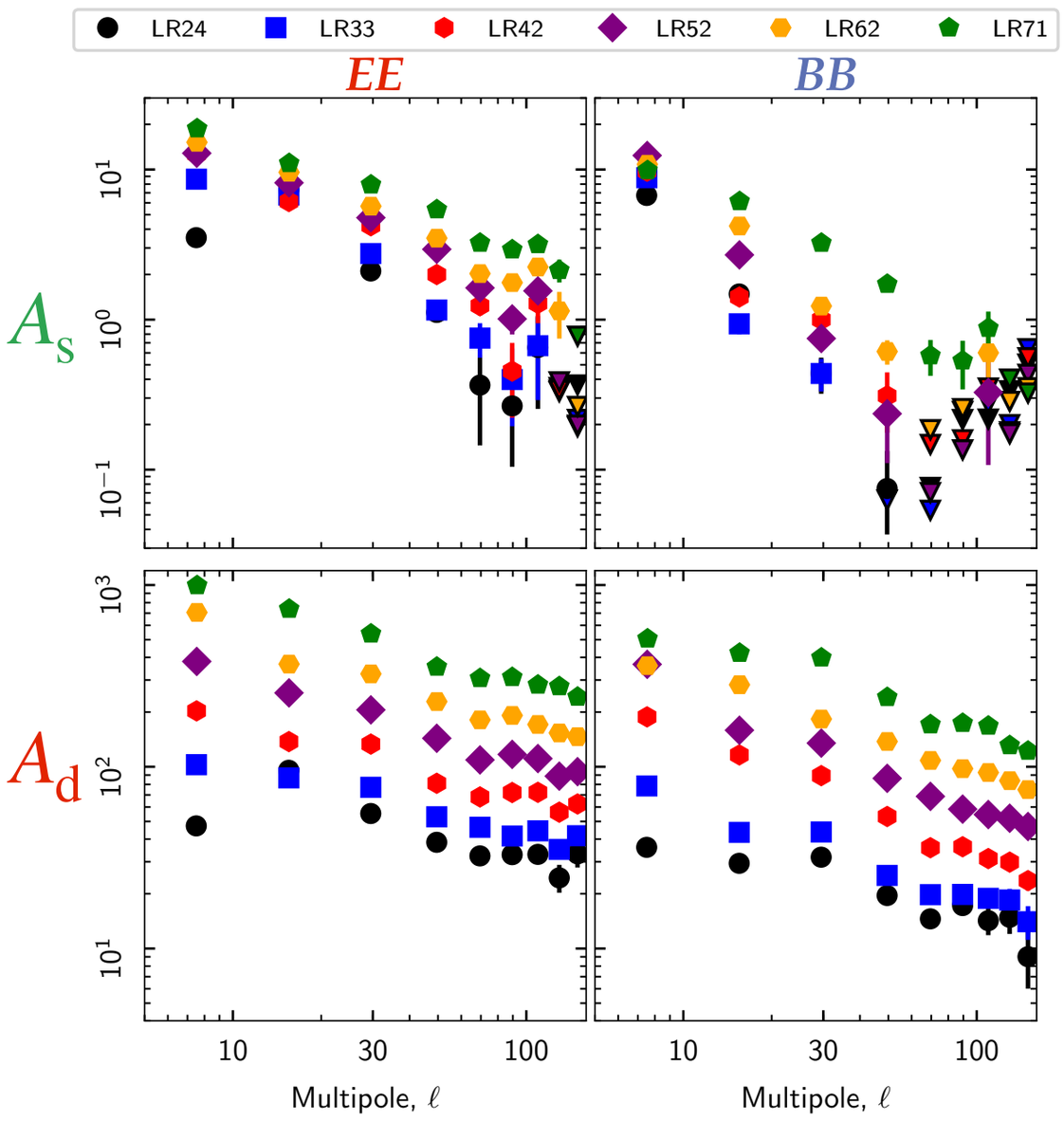
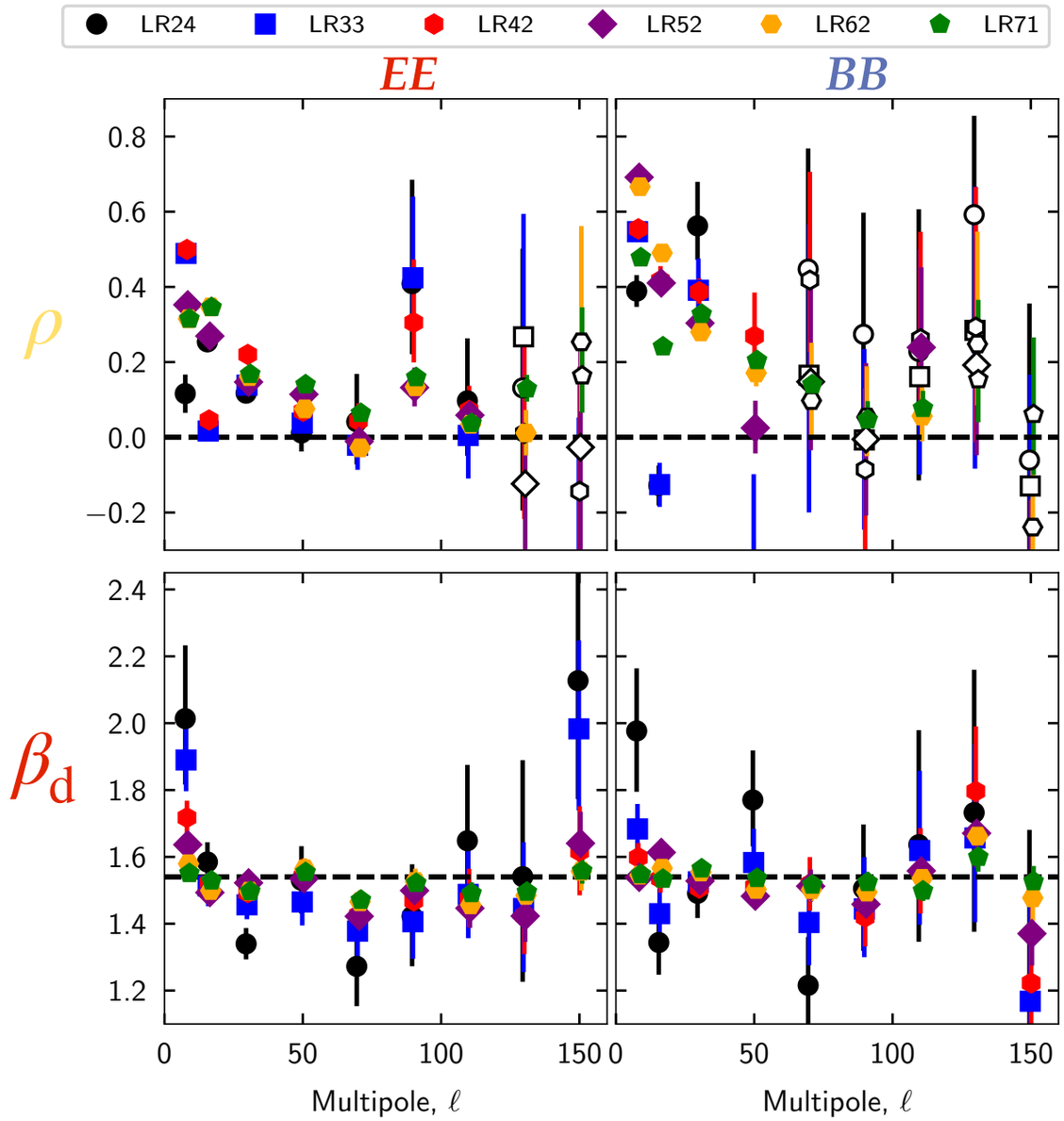


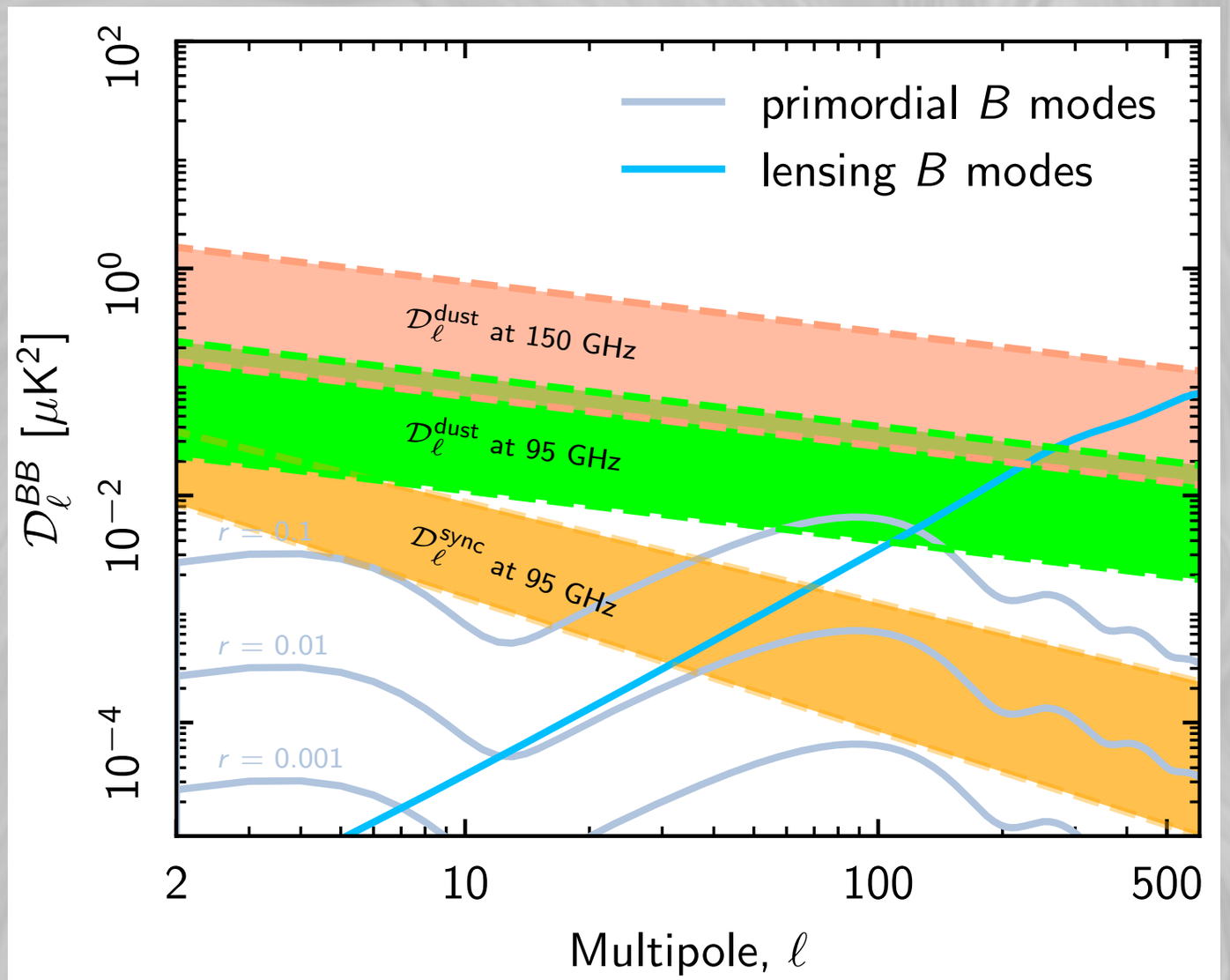


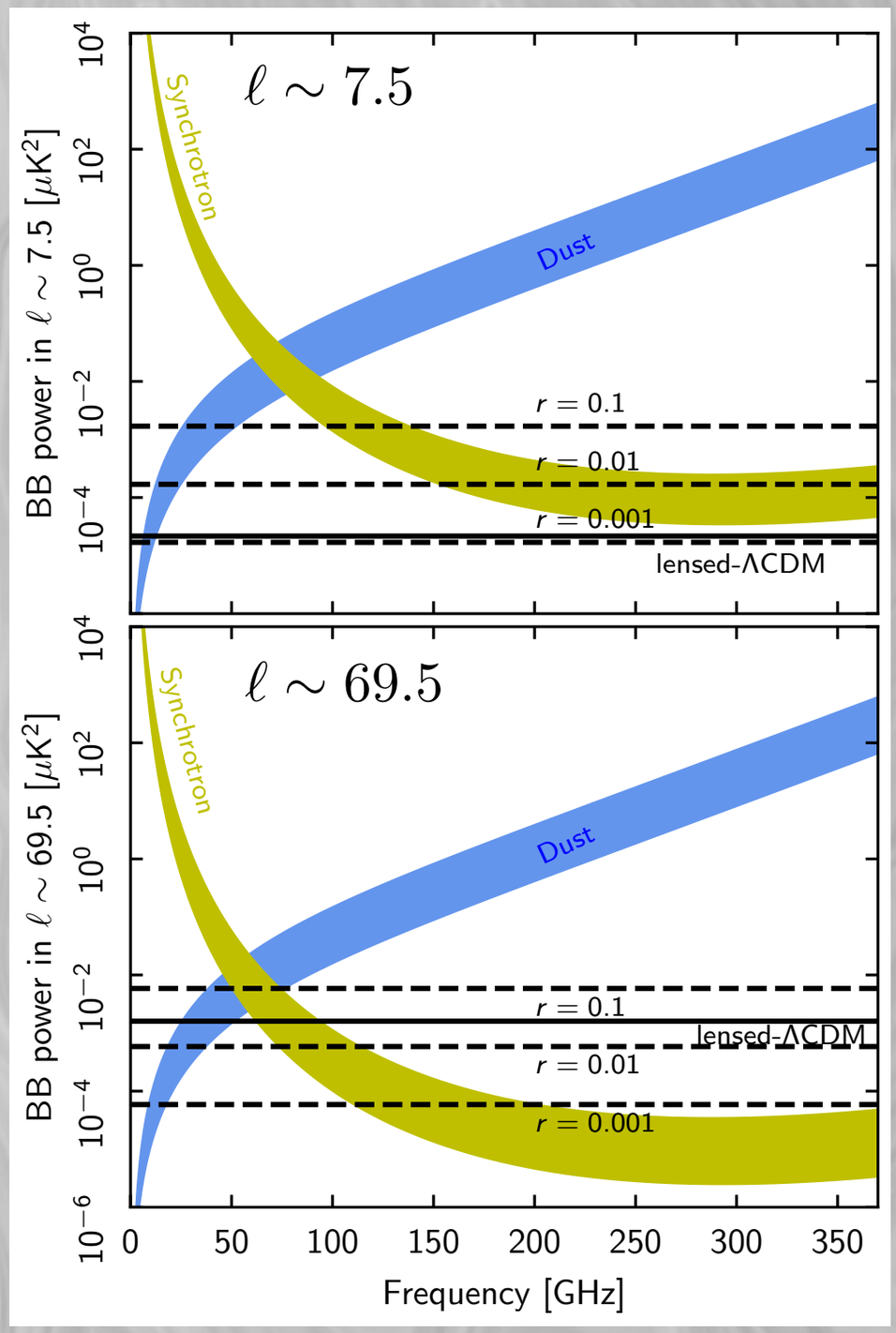
★ Different scaling with respect to ℓ and sky regions for dust and synchrotron polarization

★ Significant dust-synchrotron correlation at $\ell \lesssim 50$

★ No evidence for dust spectral index ℓ dependence

PLANCK 2018 XI: Polarized foregrounds power summary



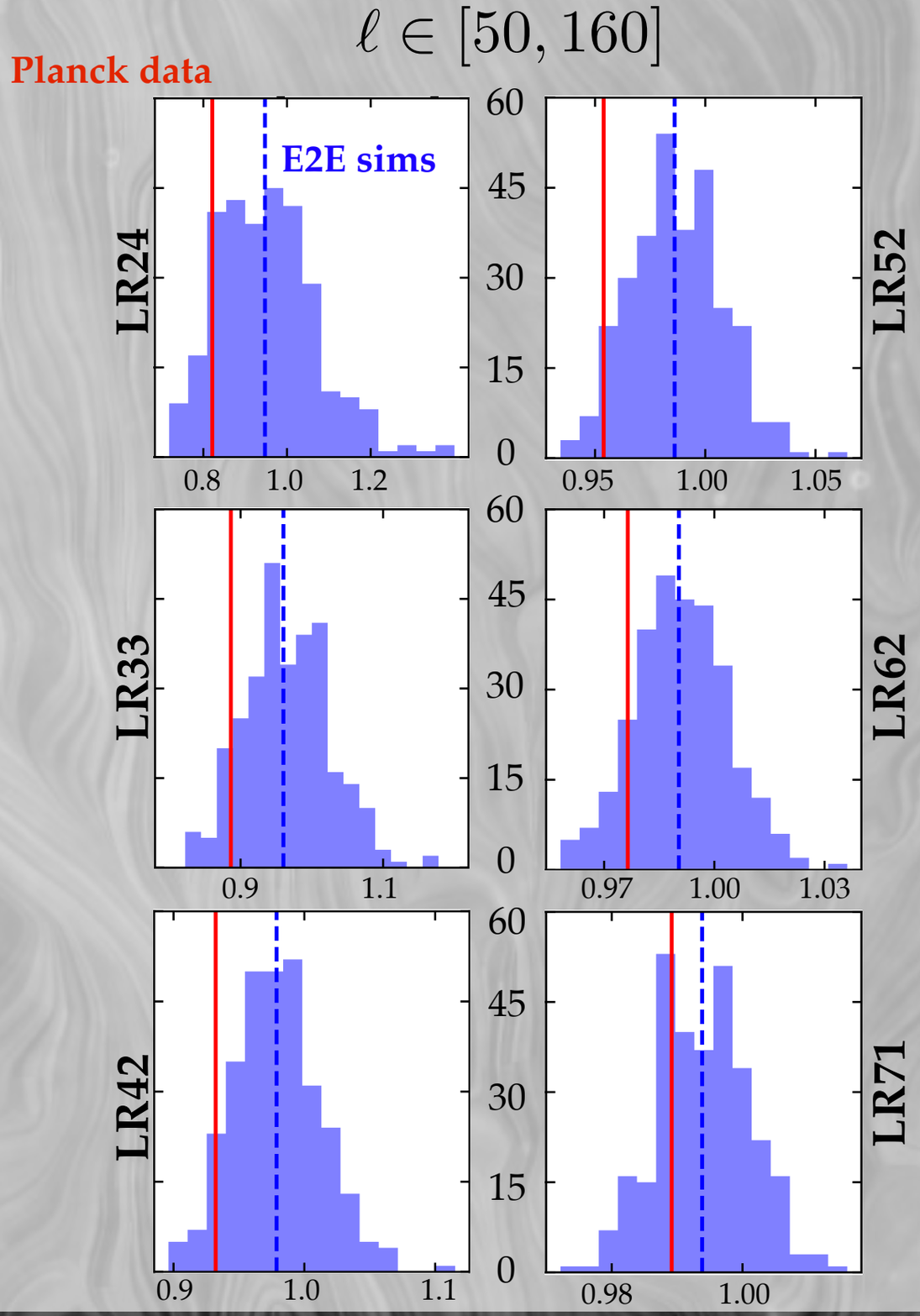


★ Planck data quantify the challenge of the component separation required for measuring the low-ℓ CMB *E*-mode reionization signal, and detecting the recombination and reionization peaks of primordial CMB *B*-modes

PLANCK 2018 XI: Dust frequency correlation

- ★ Frequency decorrelation due to effective SED spatial variations has to appear at some level
- ★ We study again the correlation ratio between Planck 217 and 353 GHz in *BB* spectra **[Planck Intermediate XXX, Sheehy & Slosar 2017]** and compare it to our E2E simulations

$$\mathcal{R}_\ell^{BB} = \frac{C_\ell^{BB}(217\times353)}{\sqrt{C_\ell^{BB}(217\times217)C_\ell^{BB}(353\times353)}}$$



PLANCK 2018 XI: Dust frequency correlation

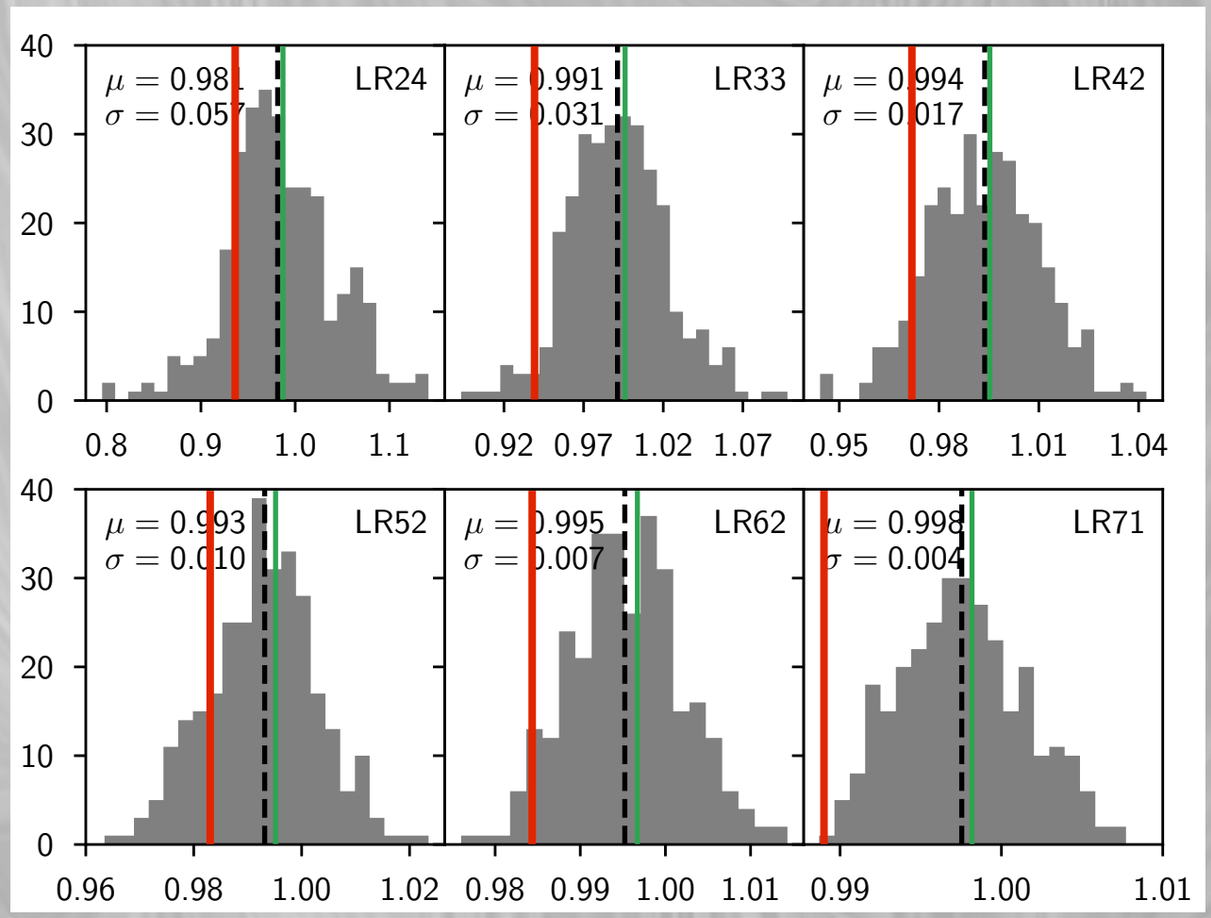
★ Frequency decorrelation due to effective SED spatial variations has to appear at some level

★ We add a decorrelation parameter to our MCMC spectral model analysis

$$D_\ell^{BB_{\rm d}}(\nu_i \times \nu_j) = A_{\rm d}^{BB} \left(\frac{\nu_i \nu_j}{353^2}\right)^{\beta_{\rm d}-2} \times \frac{B_{\nu_i}(T_{\rm d}) B_{\nu_j}(T_{\rm d})}{\left(B_{353}(T_{\rm d})\right)^2} \times f_{\rm d}(\delta_{\rm d}, \nu_i, \nu_j)$$

and

$$f_{\rm d}(\delta_{\rm d}, \nu_i, \nu_j) = \exp\left\{-\delta_{\rm d}\left[\ln\left(\nu_i/\nu_j\right)\right]\right\}$$



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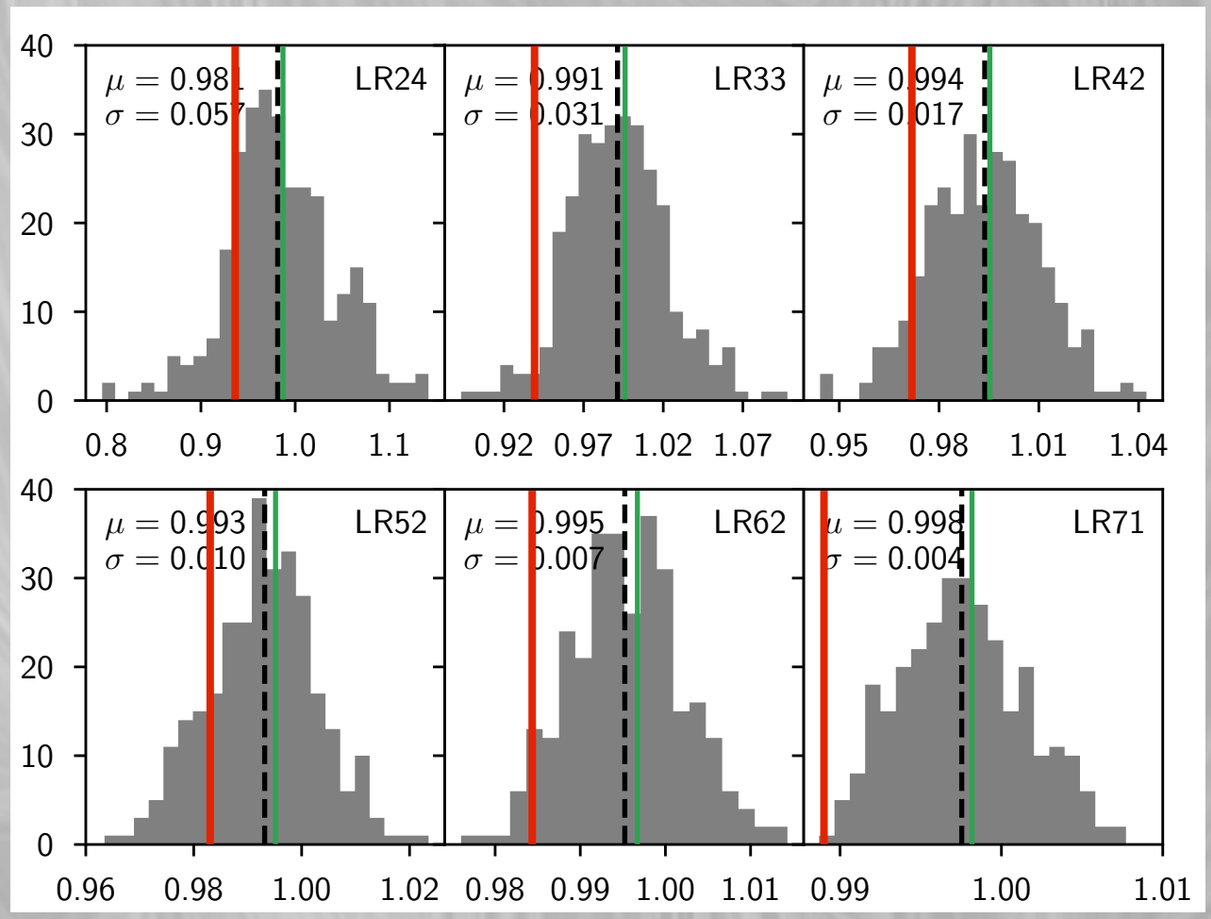
Planck *BB* data

Simple dust model with β and T variations from intensity fit

E2E simulations median



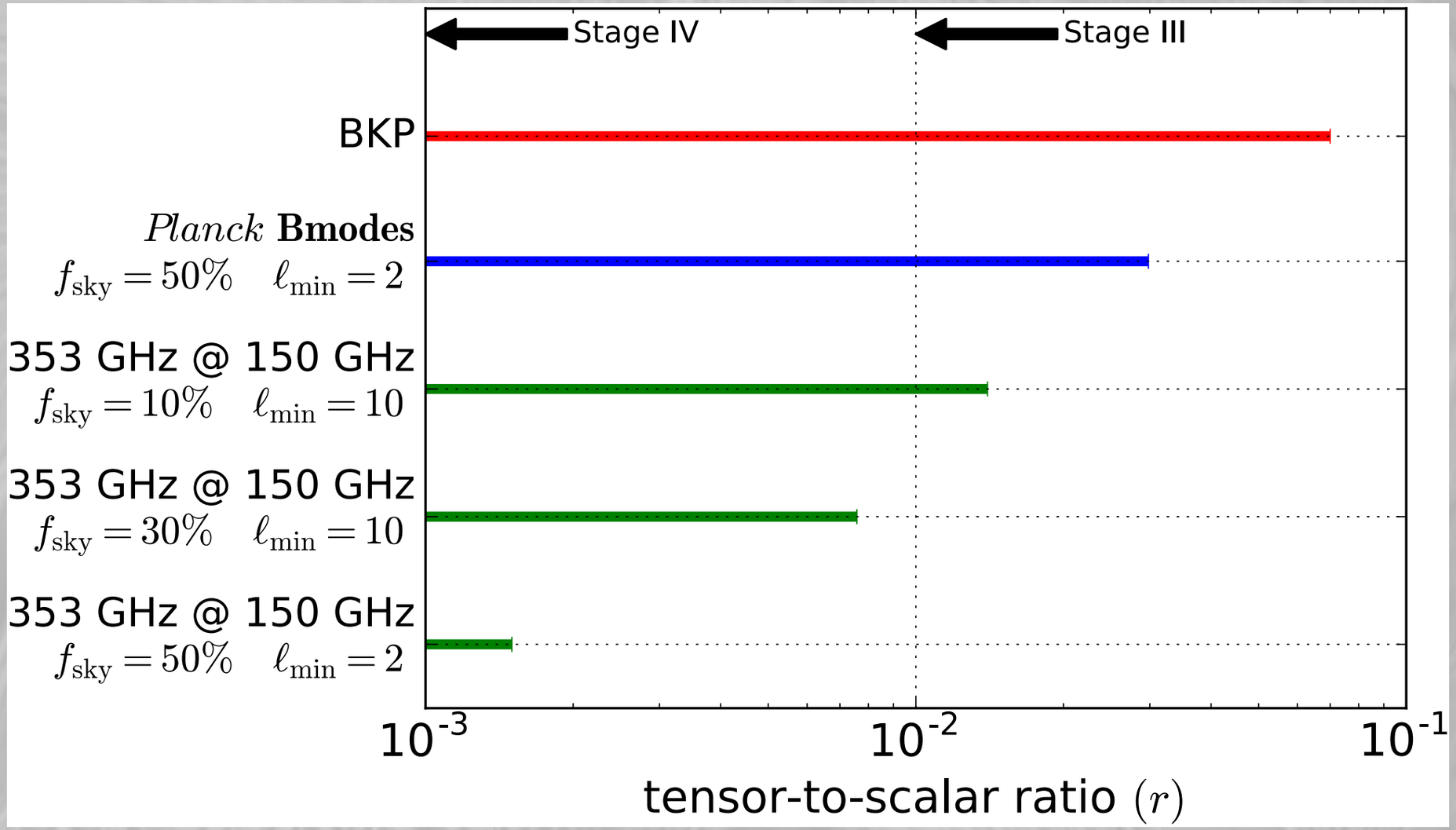
★ No conclusive evidence for frequency decorrelation at Planck sensitivity

★ New data sets (e.g. PILOT @ 1.2 THz), development of new method to model decorrelation…

see my talk on PILOT

see Anna Mangilli's talk

FUTURE OF THE 353 GHZ CHANNEL



- ★ Work continues to upgrade the systematics analysis at 353 GHz
- ★ Hope to be able to reduce these effects to the noise, down to the lowest multipoles
- ★ Planck 353 GHz data will continue to set stringent limits on the dust *B*-mode amplitude, competitive for next generation(s) of CMB *B*-mode experiments

SUMMARY AND PERSPECTIVES

★Planck has provided the observational inputs needed to understand and model Galactic polarized foregrounds for preparing future experiments, and optimizing and assessing component separations

- Dust polarization power spectra measured down to the lowest multipoles
- Spectral model of the polarized foregrounds including dust-synchrotron correlation
- Upper limits on frequency decorrelation of dust polarization

★Planck 353 GHz data will continue to be upgraded