Dust Polarization Modelling at large scale Over Northern Galactic Cap using Planck and EBHIS data

Debabrata Adak

IUCAA, India

Cosmic Dust and Magnetism, KASI

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Collaborators:

Tuhin Ghosh, Francois Boulanger, Urmas Haud, Peter MW Kalberla, Flavien Vansyngel

PhD Supervisor :Tarun Souradeep

Outlines

- **Motivation of modelling work.**
- **Modelling framework.**
- **Reproduction of data using model.**
- **Conclusion.**

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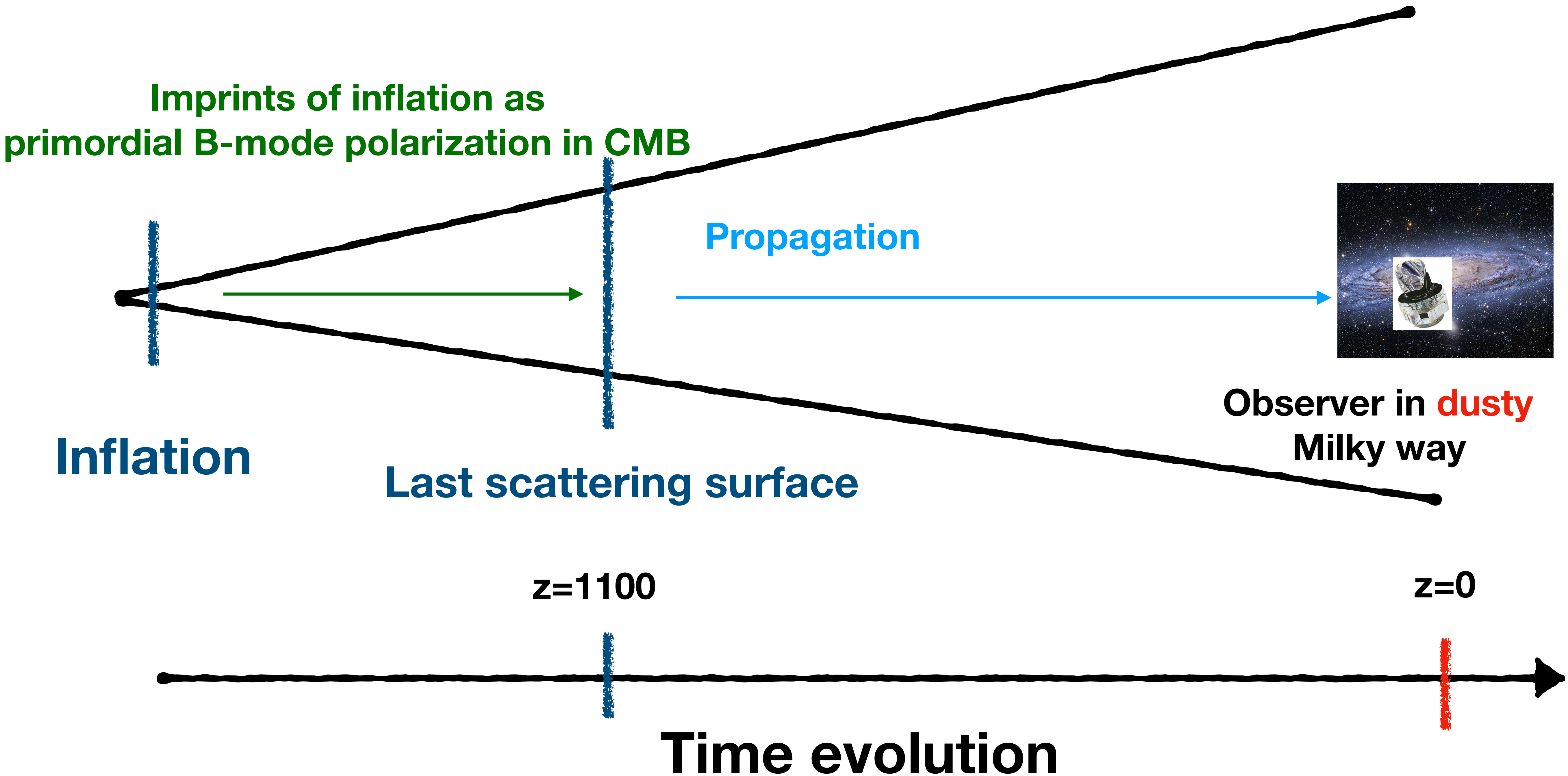
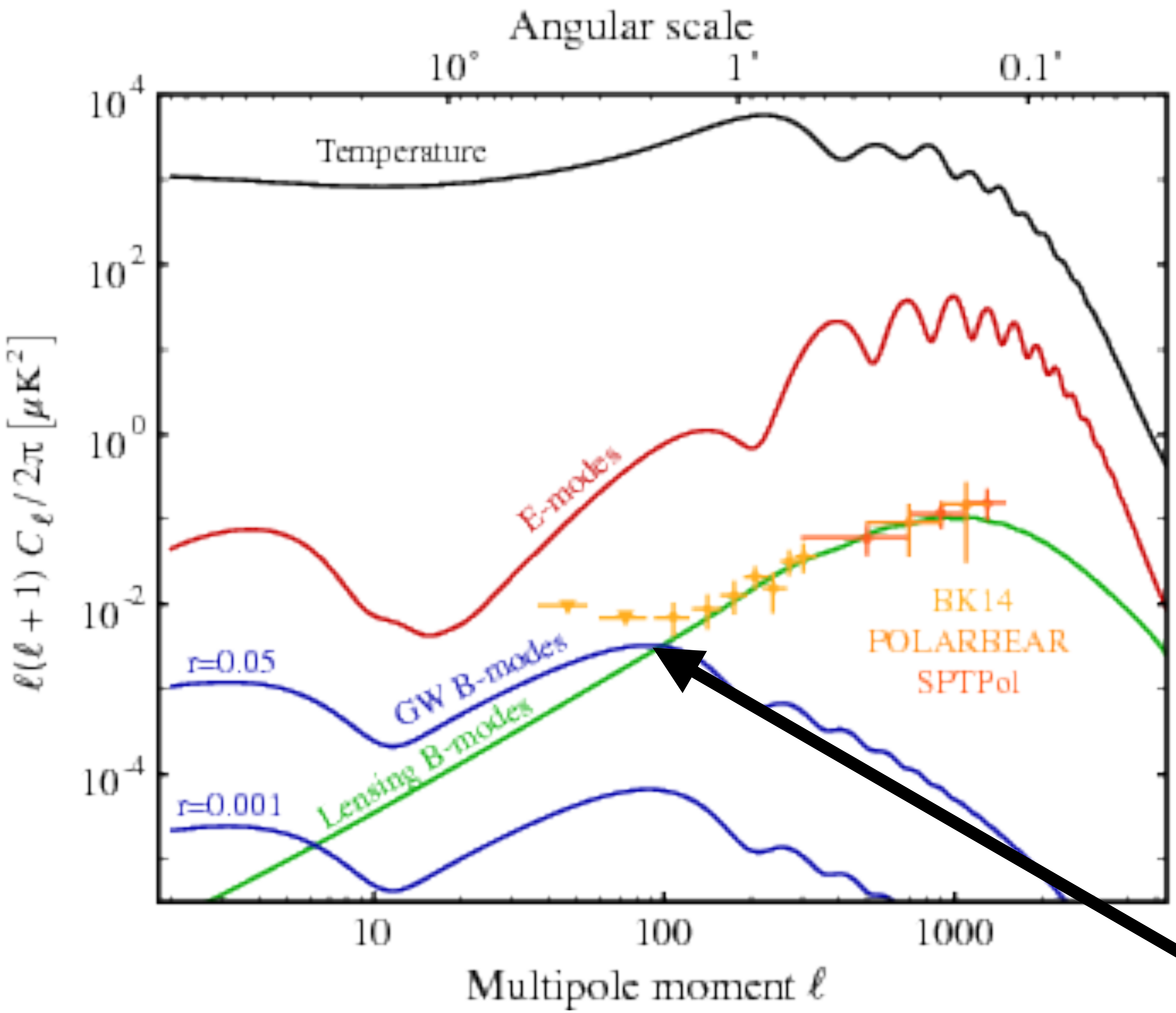
Cosmic evolution



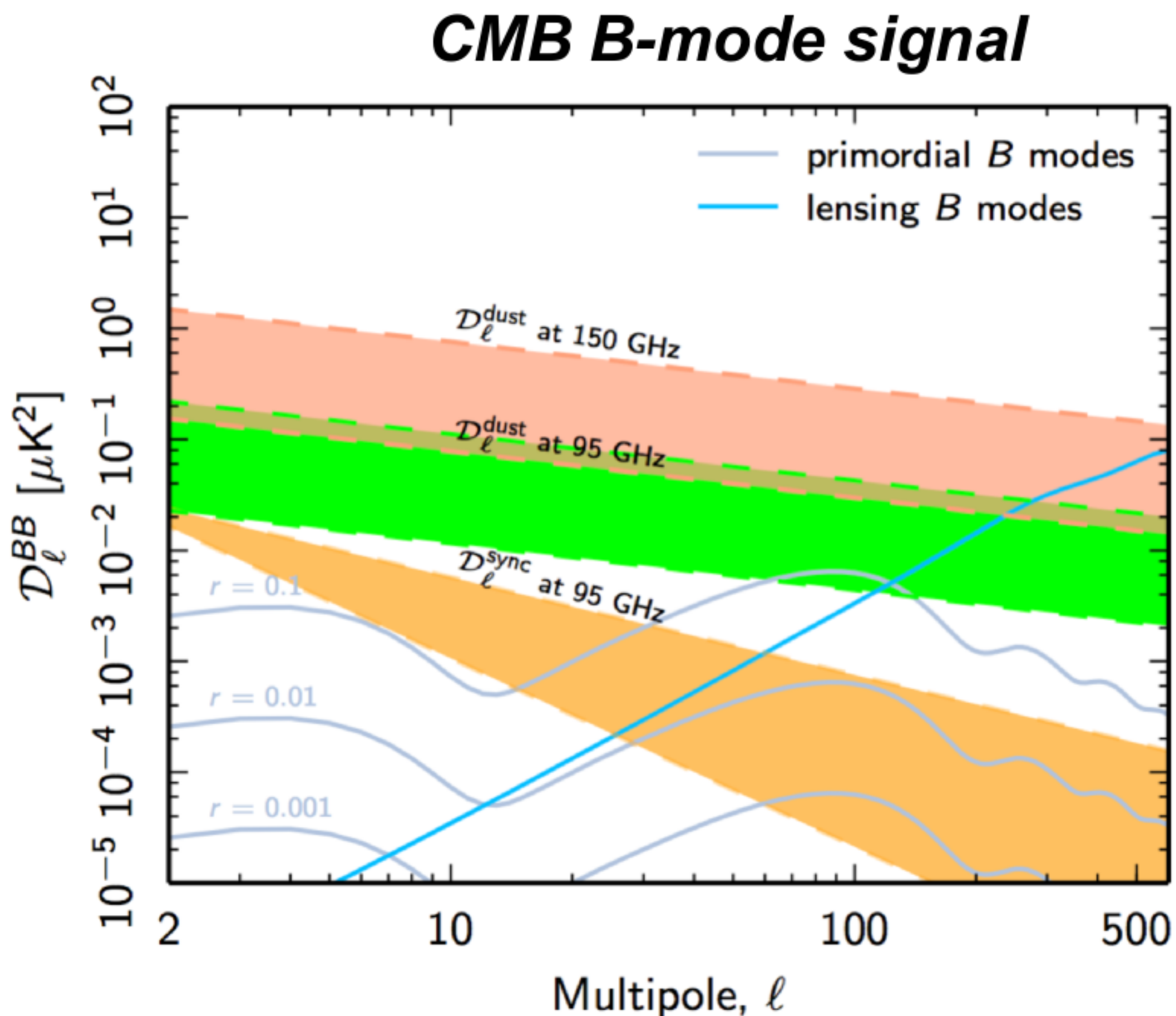
CMB power spectra



Recombination bump of primordial B-mode at l -> 80 (deg scale)

CMB S4 science book

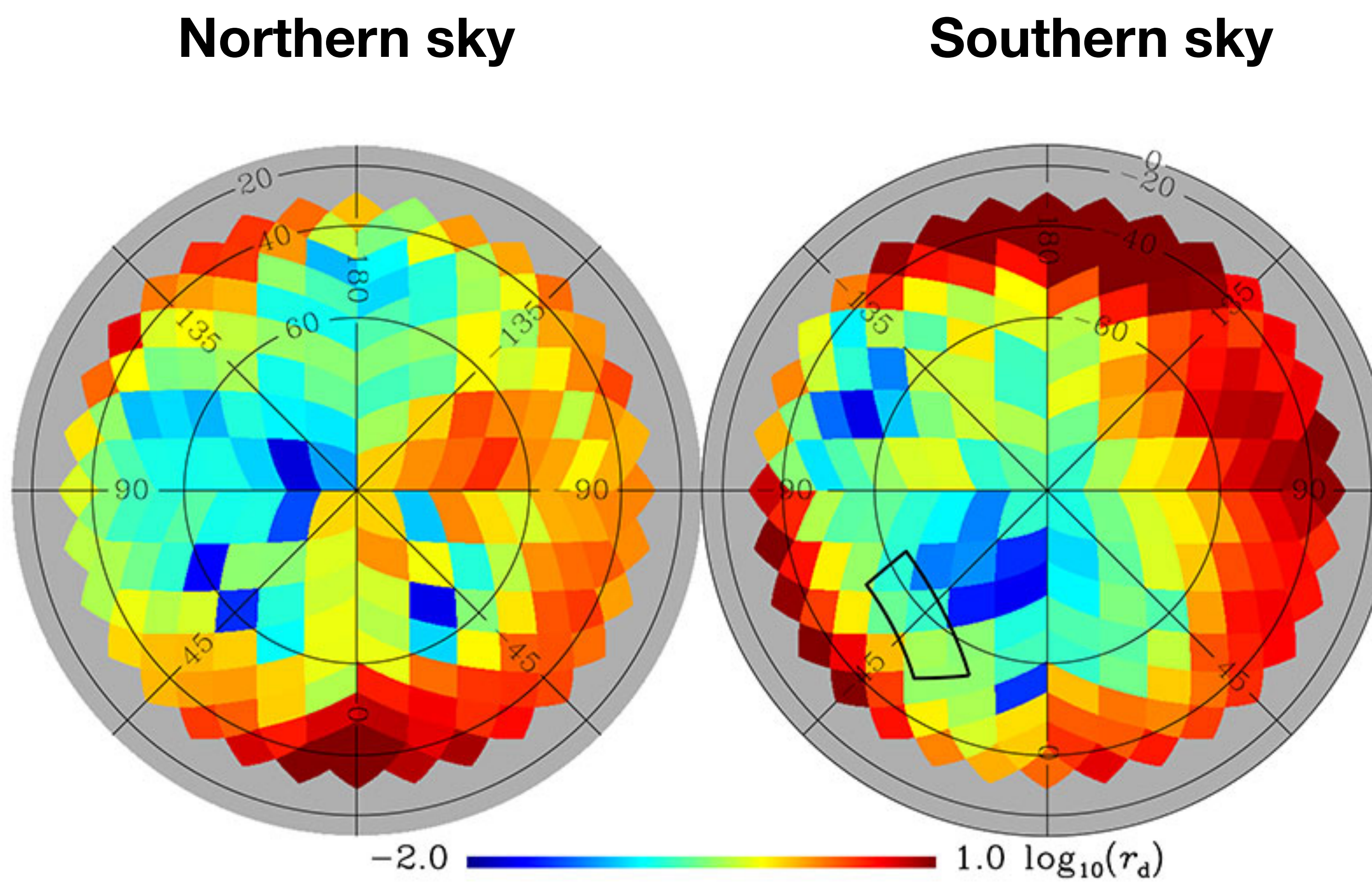
Major challenges are polarized foregrounds



Planck intermediate result.xxx2016

CMB-B-mode is subdominant at each scale and frequency

Dust B-mode level at 150 GHz from Planck



- r_d = 0.2 means dust-BB has same power as CMB-BB at l=80 for r=0.2

There is no sky region where dust can be neglected

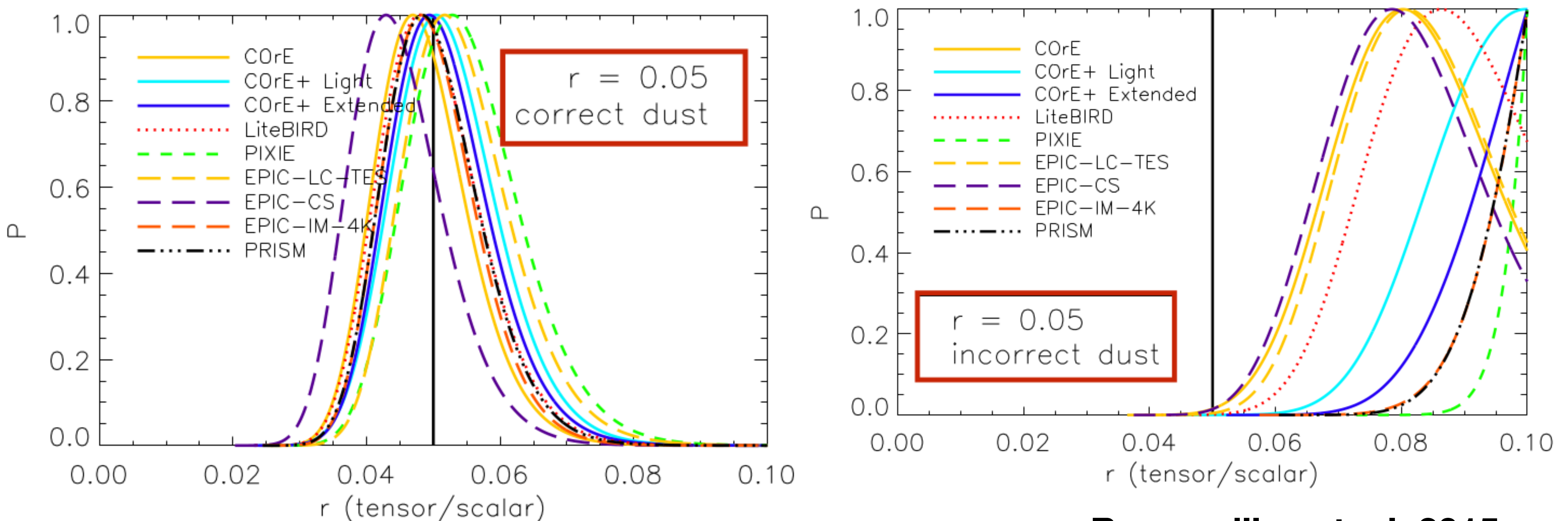
Planck intermediate result.xxx,2014

Questions?

- Given the present technology what level of B-mode we can detect ?
- Can the existing cleaning mechanism help us?
- How to quantify the confidence level of cleaning?

Need precise dust polarization model

Fake B-mode signal due to incorrect Dust model



Remazeilles et. al, 2015

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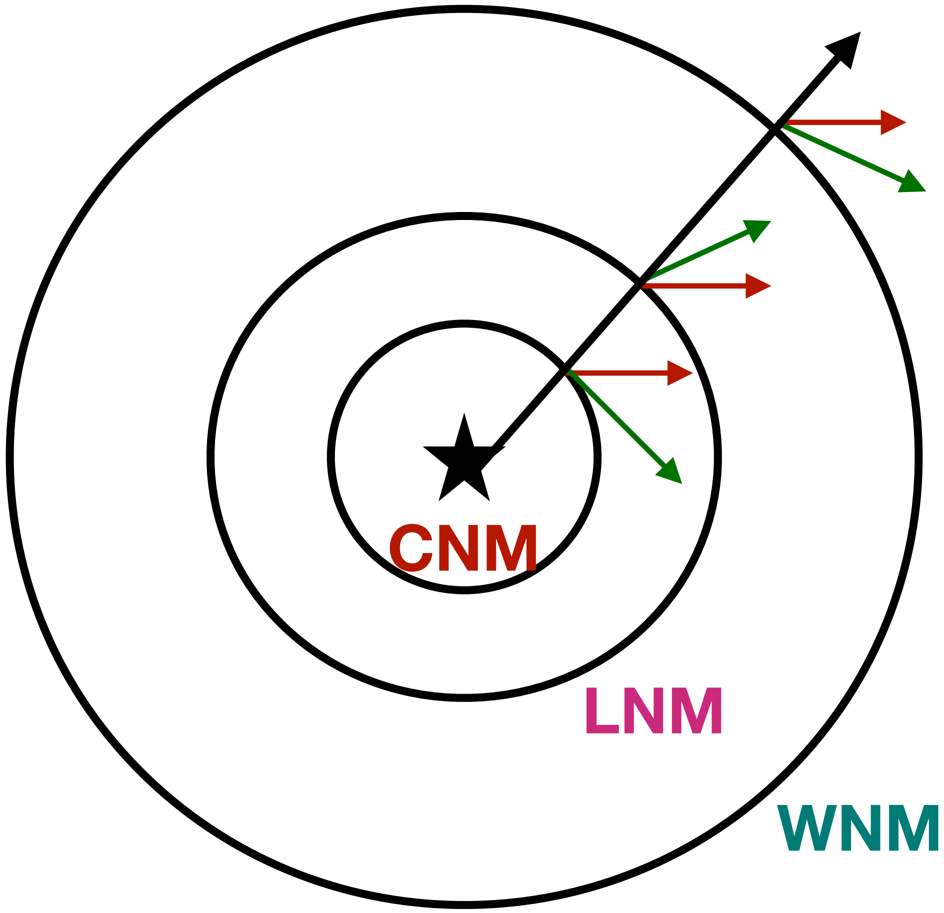
Modelling Approach

Assign three HI templates as a proxy of dust intensity.

Magnetic field: ordered + turbulent.

Simulate many realizations of Stokes Q and U maps integrating over layers along LOS and add end-to-end noise realizations.

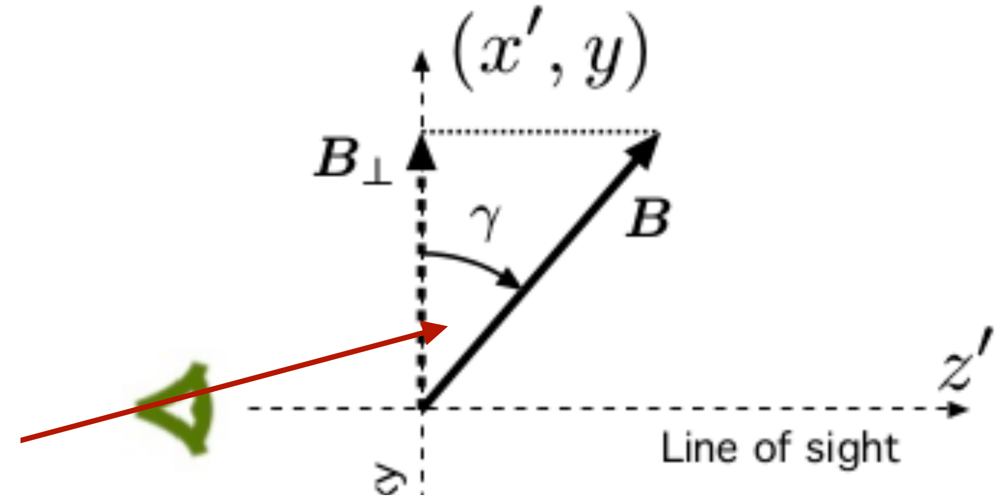
Fitting model parameters by matching one points functions and EE, BB, TE power spectra from data.

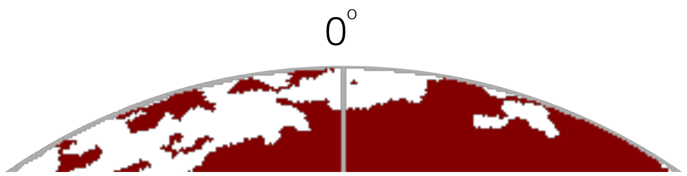


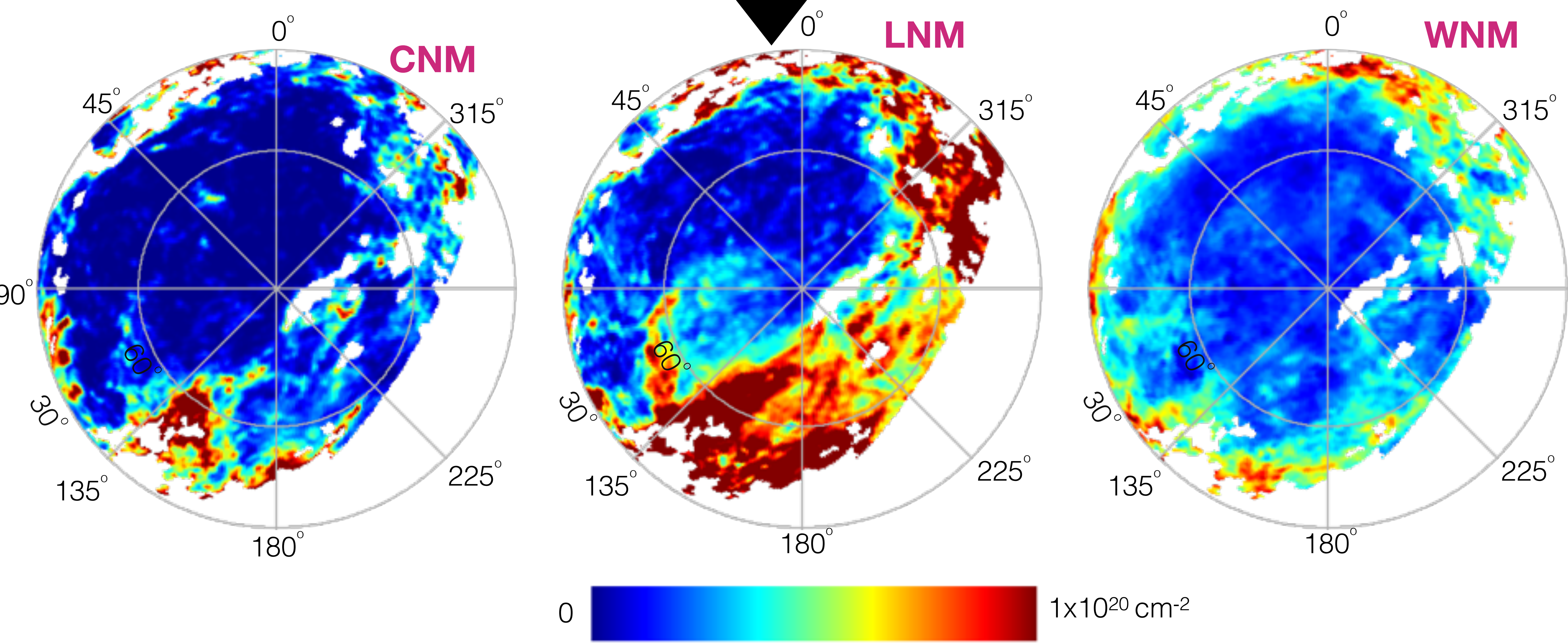
Model Framework

Stokes I, Q, U map at 353 GHz:

$$I(\nu) = \sum_{i=1}^{3} \left[1 - p_0 \left(\cos^2 \gamma_i - \frac{2}{3} \right) \right] \epsilon_i(\nu)\, N_{\mathrm{HI}}^{i};$$





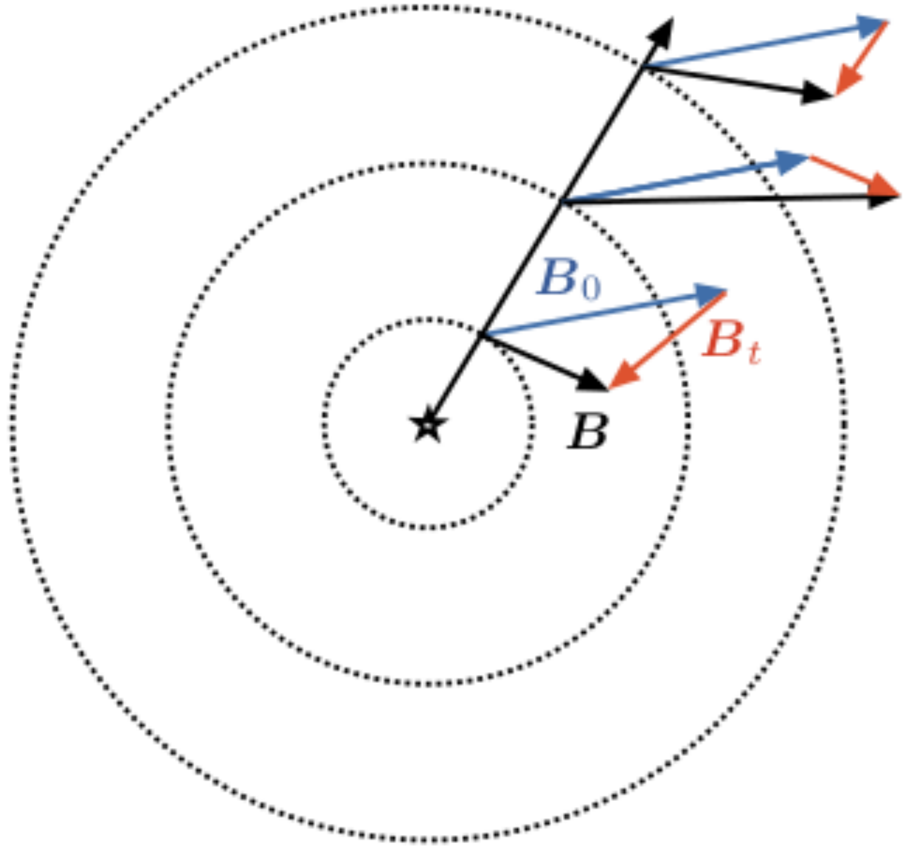


Magnetic field model

$$\boldsymbol{B}(\hat{\boldsymbol{n}}) = \boldsymbol{B}_{\rm ord}(\hat{\boldsymbol{n}}) + \boldsymbol{B}_{\rm turb}(\hat{\boldsymbol{n}})$$
$$= |\boldsymbol{B}_{\rm ord}|(\hat{\boldsymbol{B}}_{\rm ord}(\hat{\boldsymbol{n}}) + f_{\rm M}\hat{\boldsymbol{B}}_{\rm turb}(\hat{\boldsymbol{n}}))$$

- **Spectra of turbulent magnetic field**

$$C_\ell \propto \ell^{\alpha_{\rm M}} \text{ for } \ell \geq 2$$



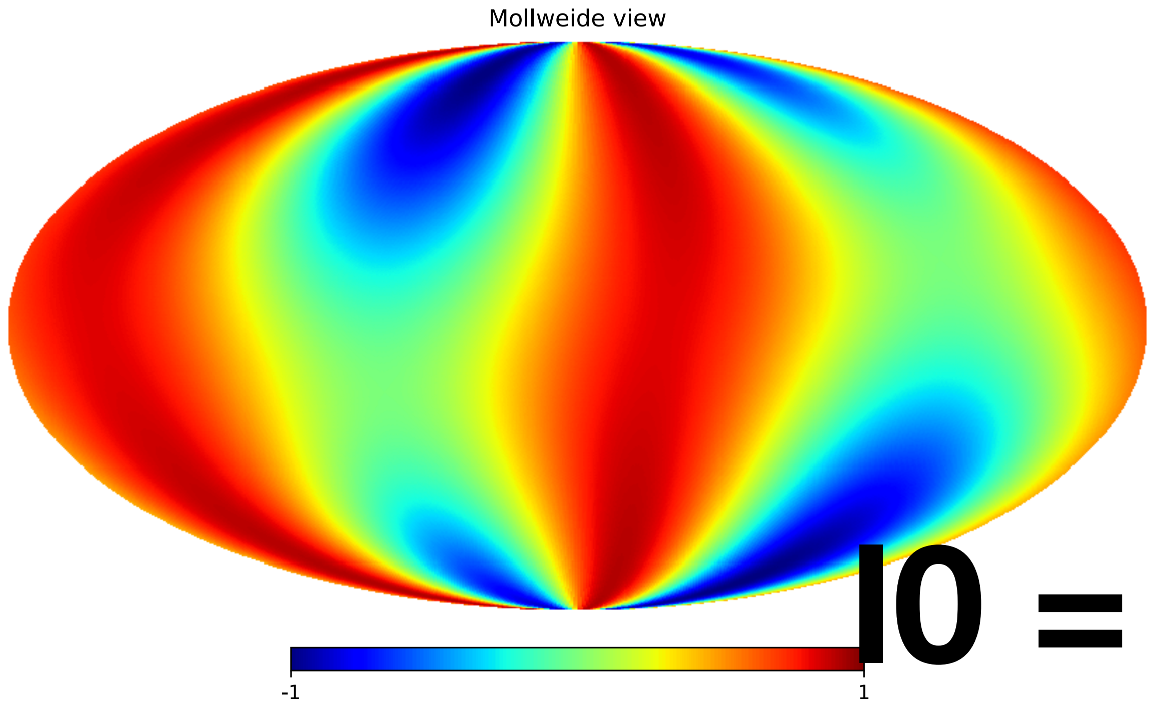
$$\boldsymbol{B} = \boldsymbol{B}_0 + \boldsymbol{B}_t$$

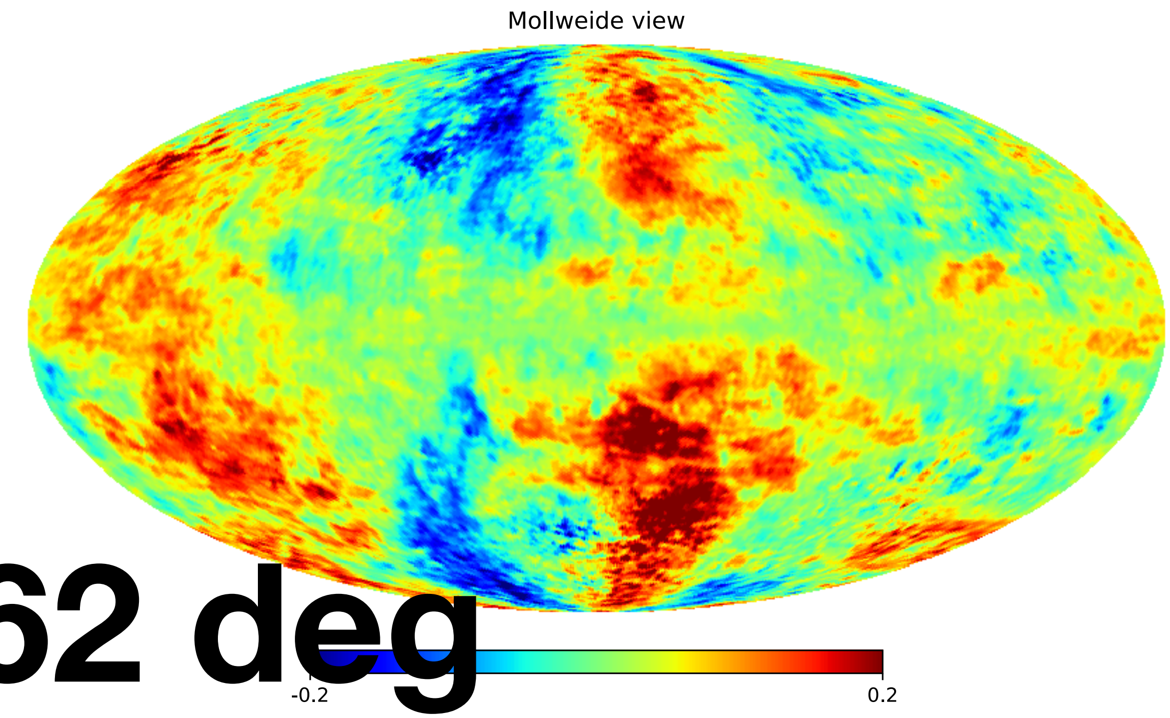
Ordered Turbulent

Ordered magnetic field

Model without turbulent field | **Planck maps at 353 GHz**

Q/I map

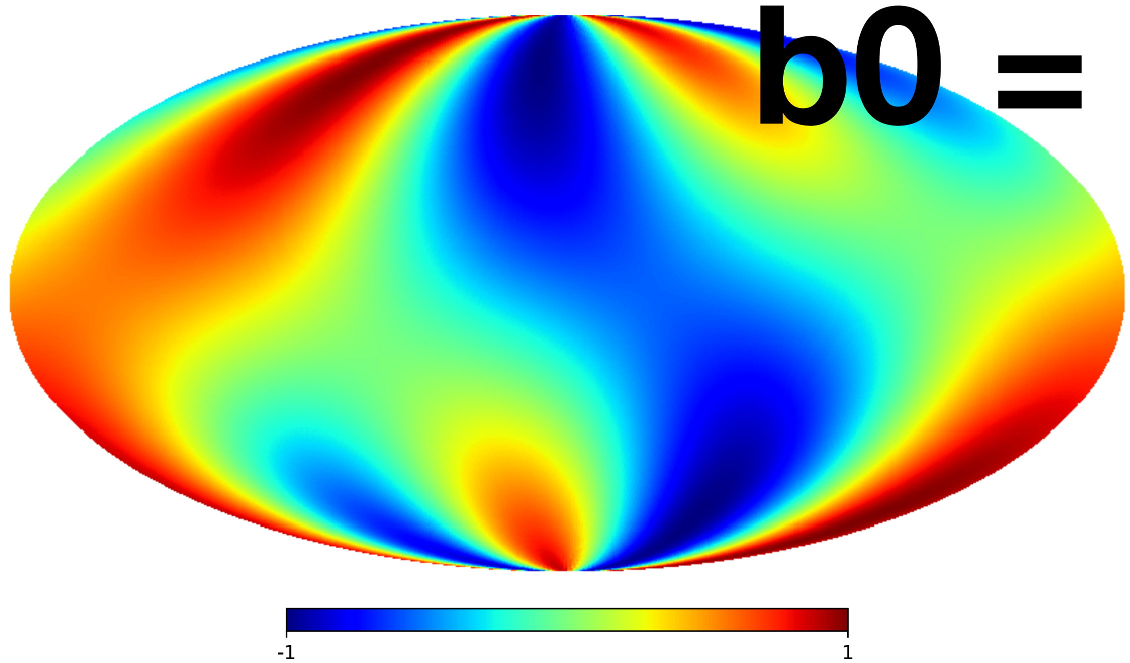


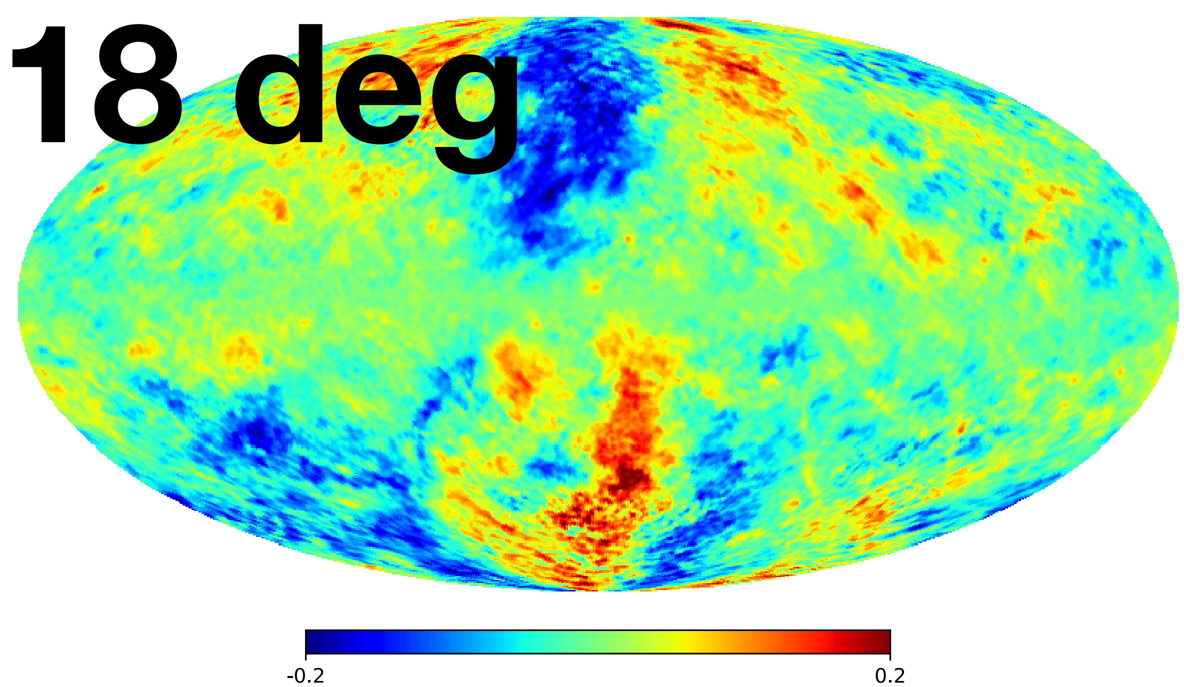


l0 = 62 deg

b0 = -18 deg

U/I map





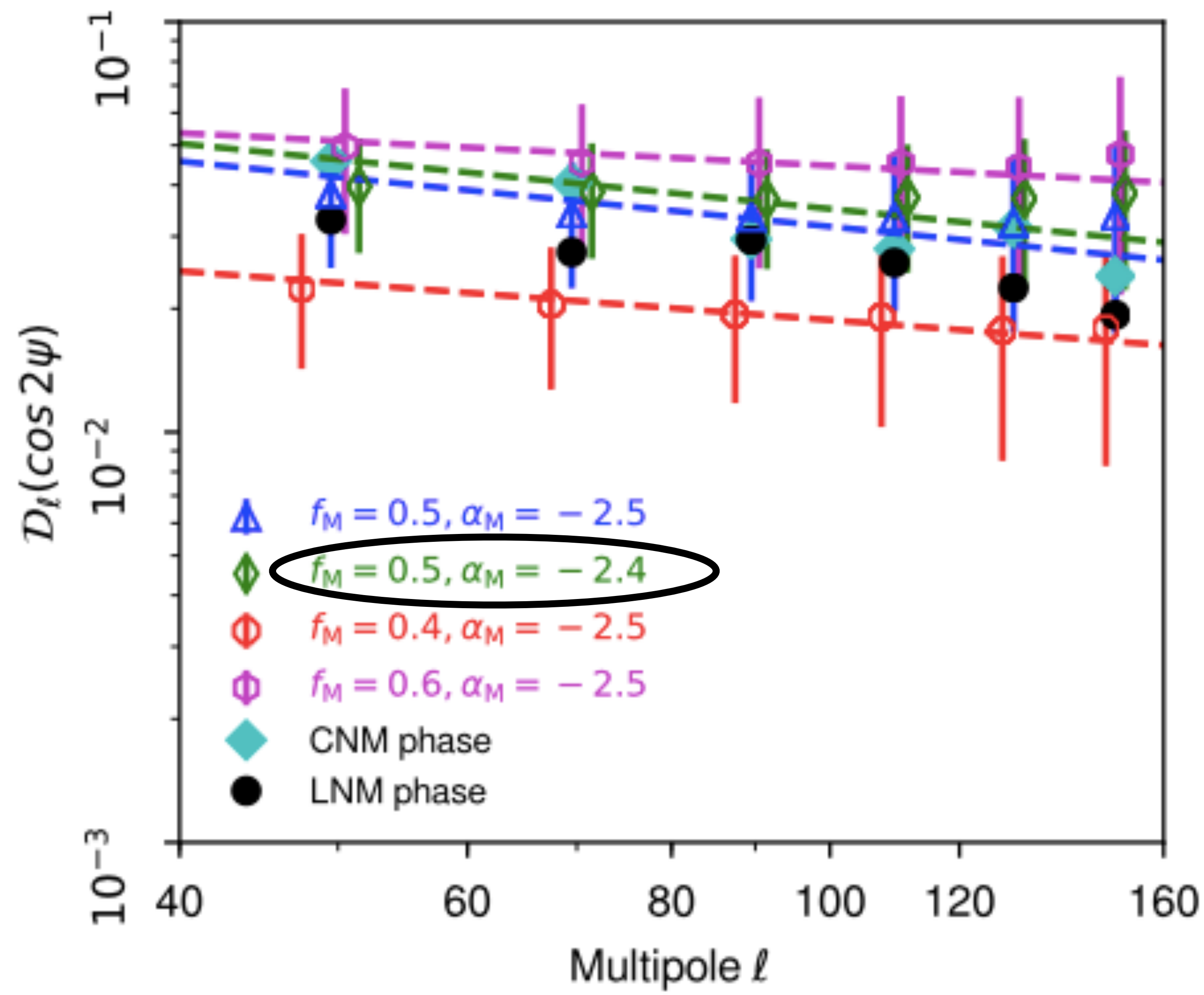
Alignment of CNM & LNM with magnetic field

- **TE correlation and E/B power asymmetry are produced by aligning CNM and LNM structures in magnetic field.**

$$(Q_{\mathrm{T}} \pm iU_{\mathrm{T}})(\hat{\boldsymbol{n}}) = \sum_{\ell=2}^{\infty} \sum_{m=-\ell}^{\ell} a_{\ell m} \ {}_{\pm 2}Y_{\ell m}(\hat{\boldsymbol{n}}) ,$$

T.Ghosh et. al. A&A,2017

- **Model does not support high turbulence in WNM.**
- **Less turbulence in WNM to produce less depolarization.**



Adak et al. in Prep.

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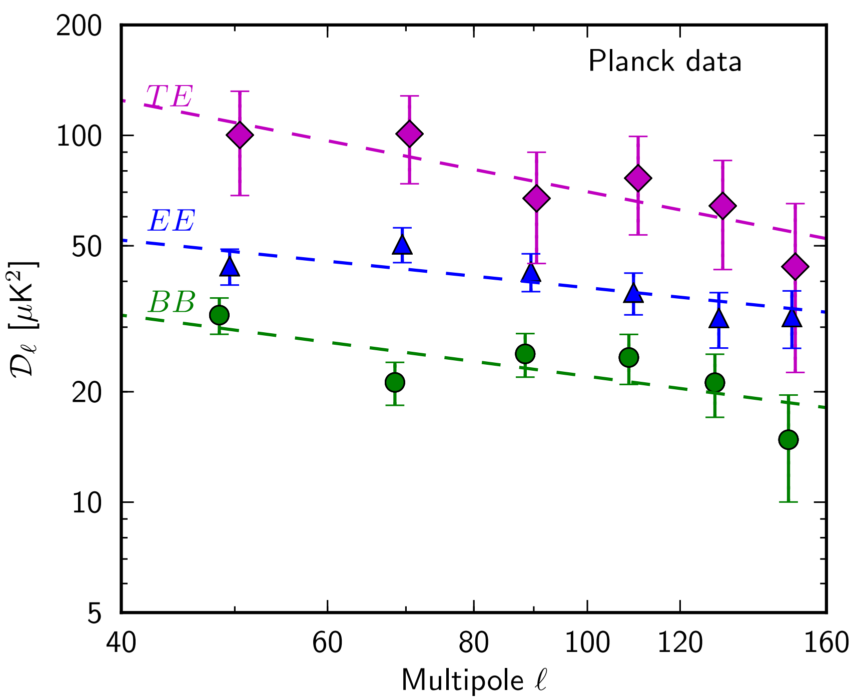
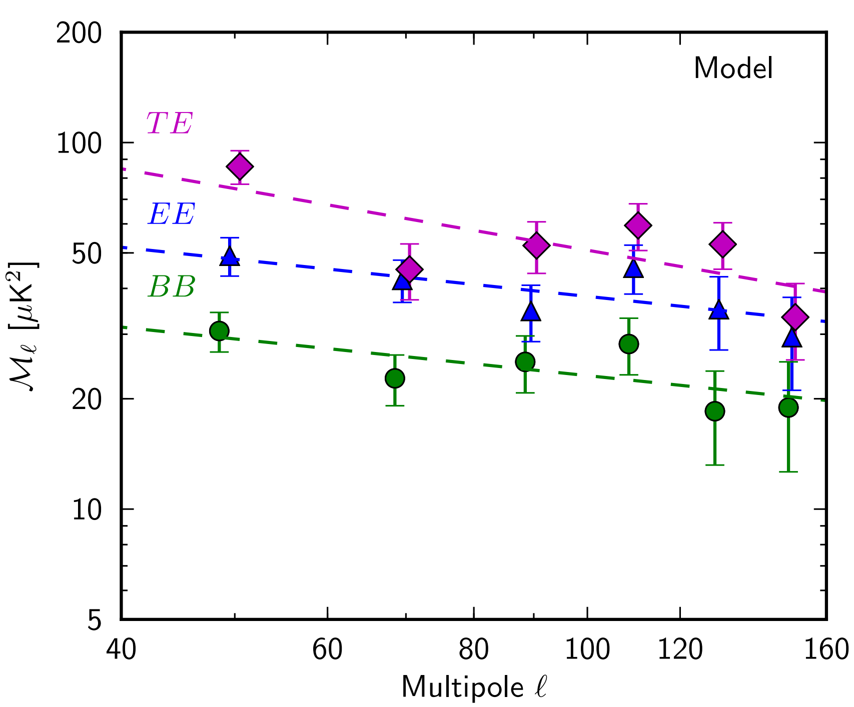
Dust Power spectra

- **Power-law power spectra:**

$$\mathcal{D}_\ell^{X\bar{X}} = A_{X\bar{X}}(\ell/80)^{\alpha_{X\bar{X}}+2}$$



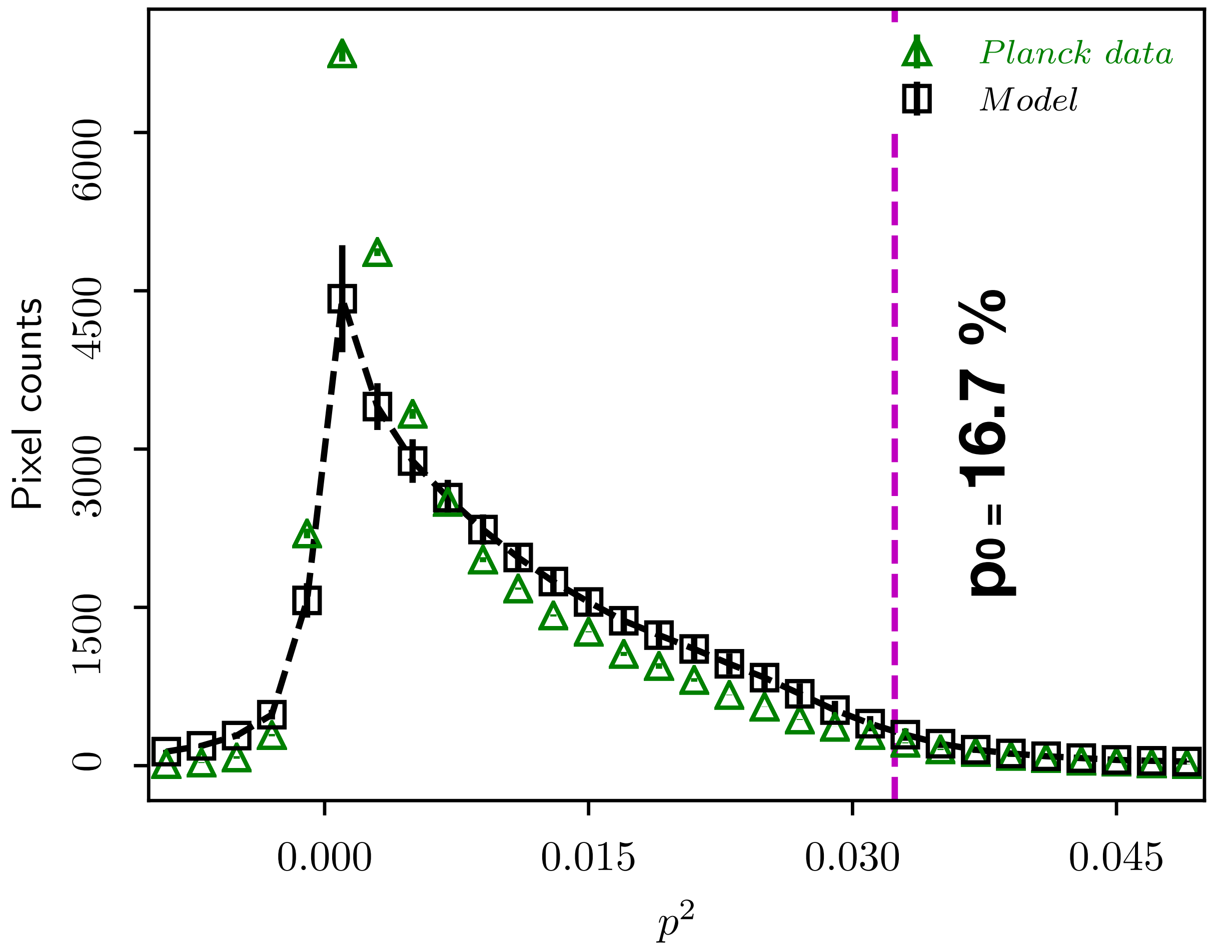


Parameter	*Planck* 353 GHz data	Dust model
α_{EE}	-2.30 ± 0.14	-2.36 ± 0.12
α_{BB}	-2.40 ± 0.20	-2.35 ± 0.16
α_{TE}	-2.63 ± 0.35	-2.57 ± 0.11
$\chi^2_{EE}(N_{\mathrm{d.o.f.}} = 4)$	2.27	0.35
$\chi^2_{BB}(N_{\mathrm{d.o.f.}} = 4)$	3.96	0.25
$\chi^2_{TE}(N_{\mathrm{d.o.f.}} = 4)$	1.26	0.59
A_{EE} [μK^2_{CMB}]	42.0 ± 2.34	42.4 ± 1.8
A_{BB} [μK^2_{CMB}]	24.5 ± 1.63	25.6 ± 1.5
A_{TE} [μK^2_{CMB}]	81.2 ± 11.06	73.6 ± 3.3
$\langle A_{BB}/A_{EE} \rangle$	0.58 ± 0.05	0.60 ± 0.04
$\langle A_{TE}/A_{EE} \rangle$	1.80 ± 0.26	1.71 ± 0.10

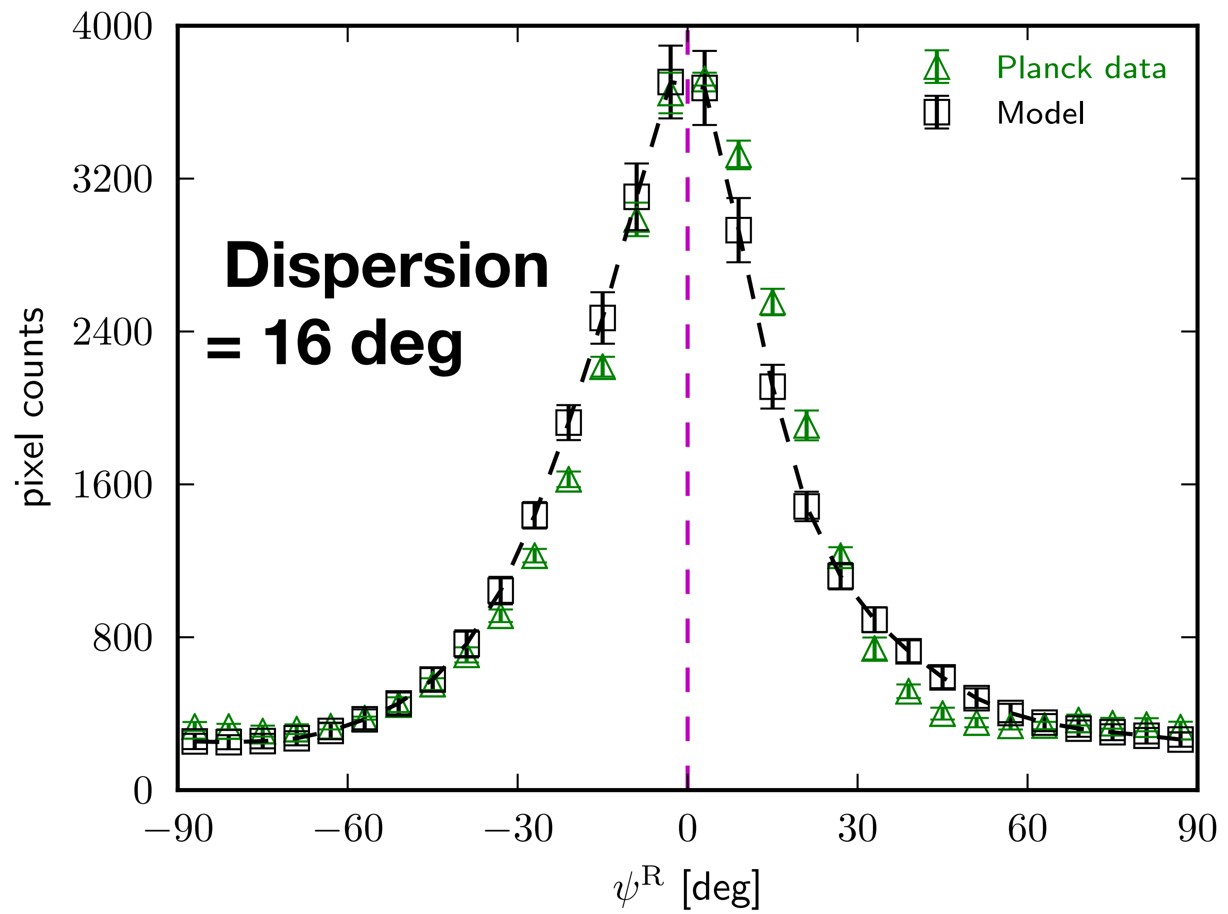
Adak et al. in prep

Polarization fraction and angle distribution

Polarization fraction



Polarization angle



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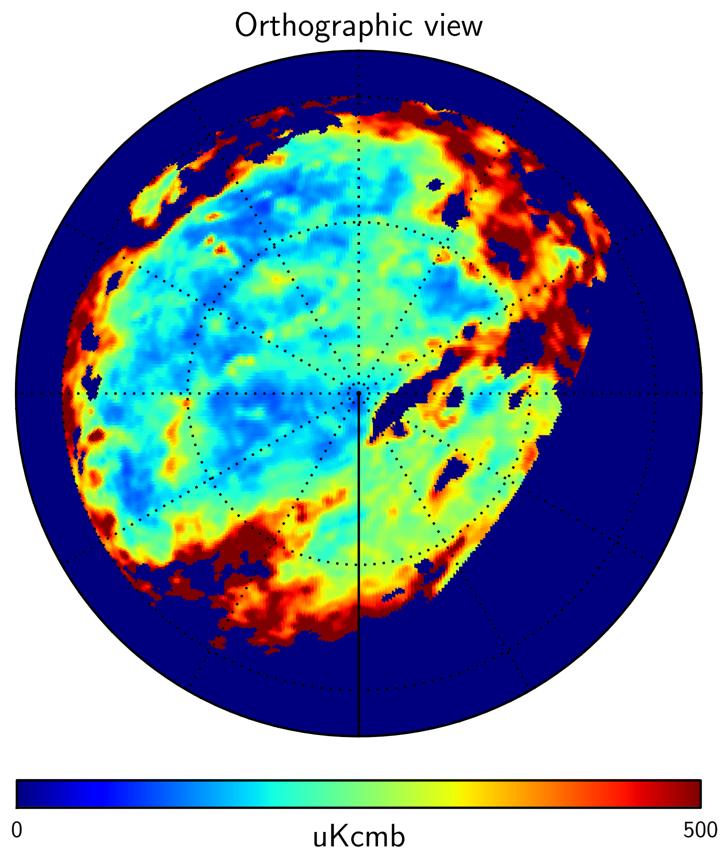
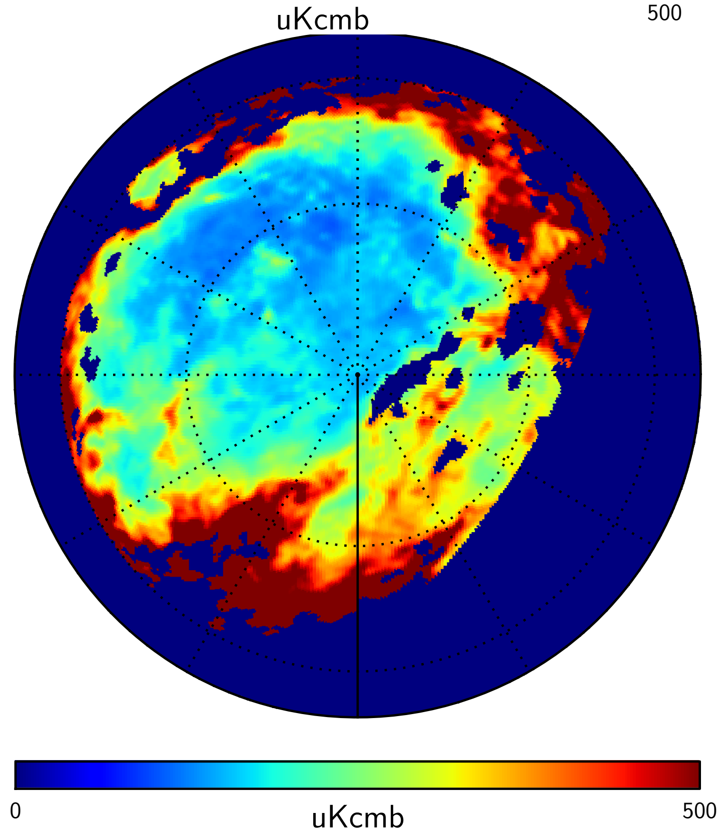
Dust Intensity

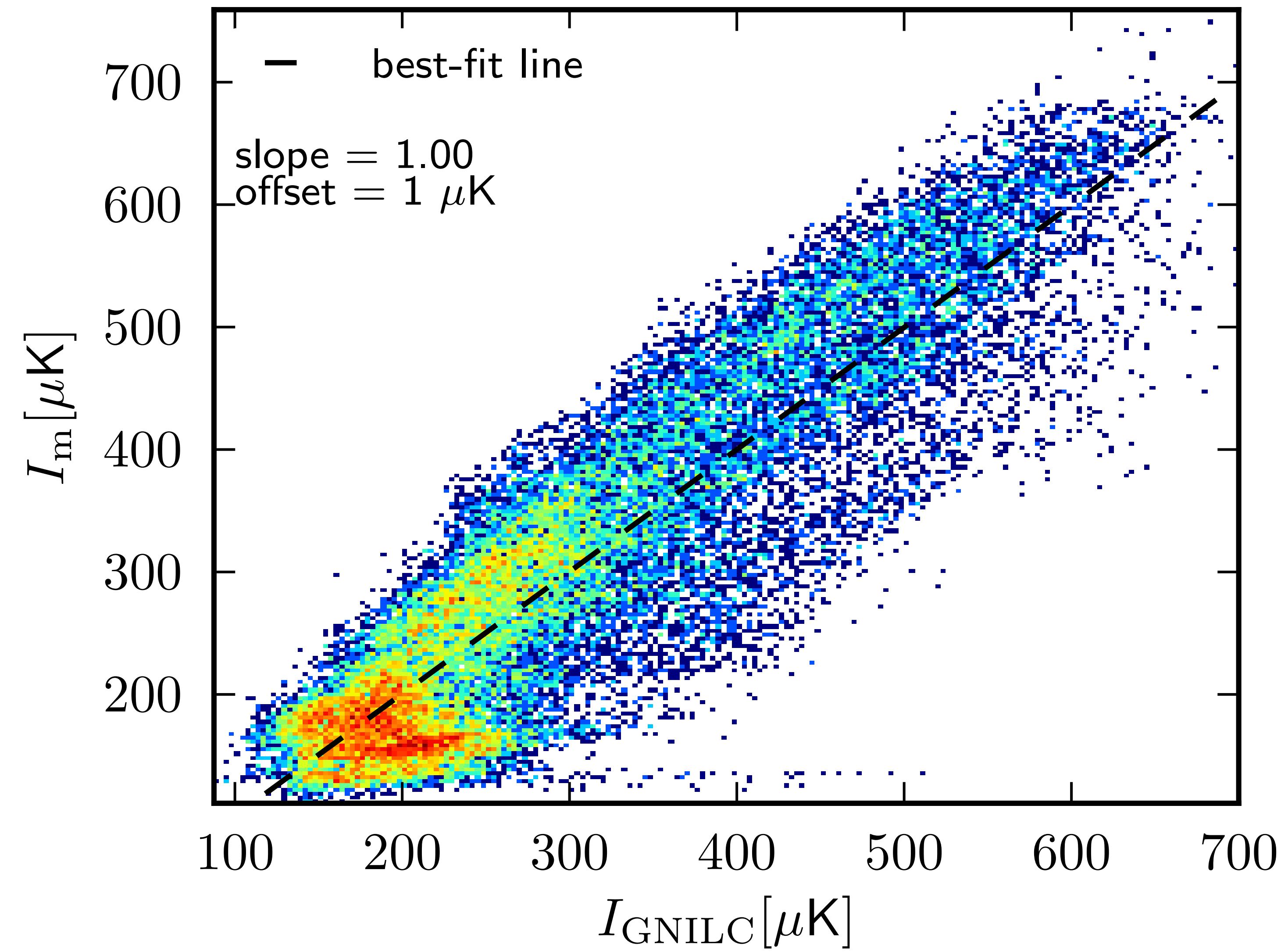
Planck dust intensity



Model dust intensity



Correlation between data and model dust intensity



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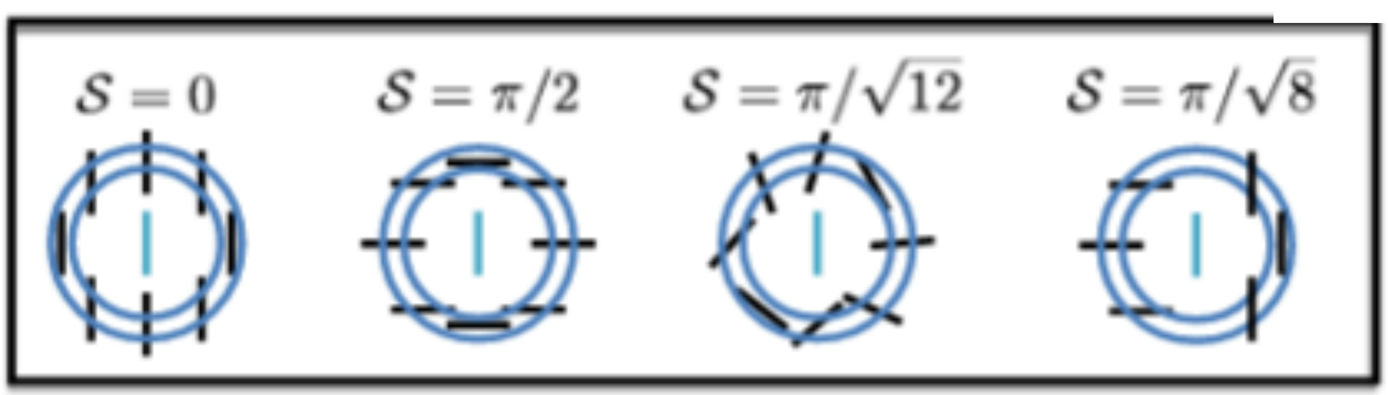
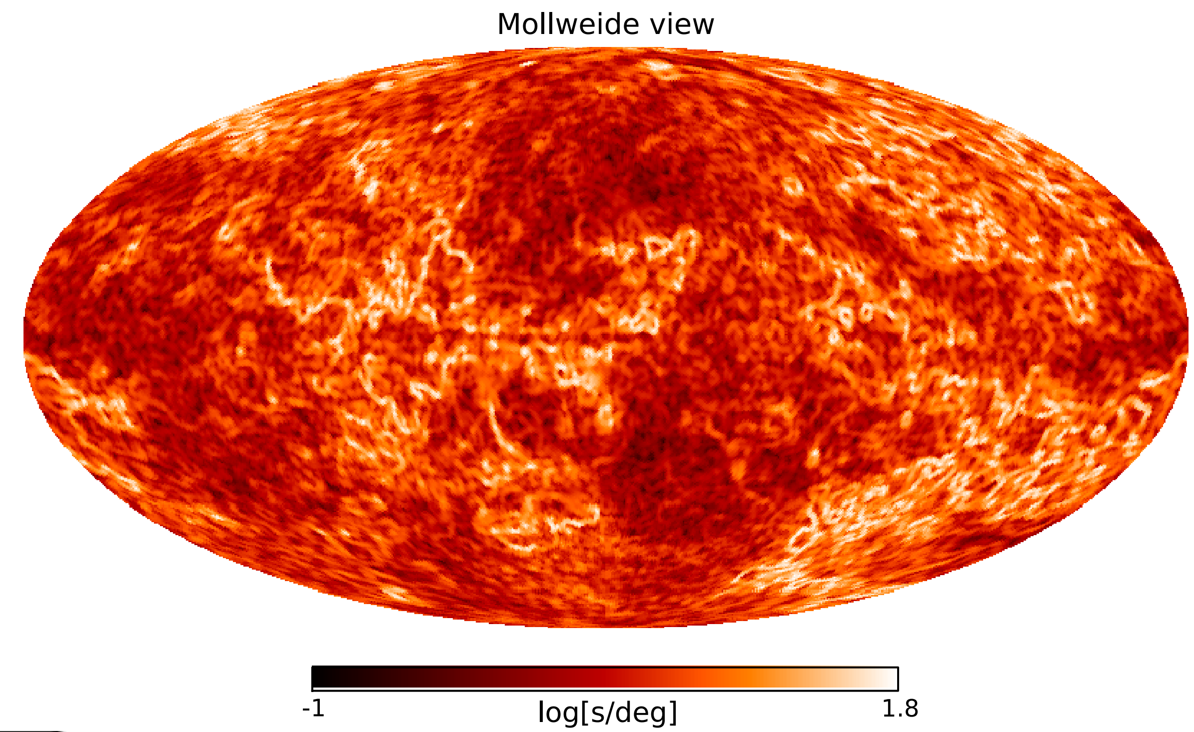
Polarization angule dispersion

Polarization angle dispersion function

$$\mathcal{S}(\boldsymbol{r},\delta)=\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left[\psi(\boldsymbol{r}+\boldsymbol{\delta}_i)-\psi(\boldsymbol{r})\right]^2}$$

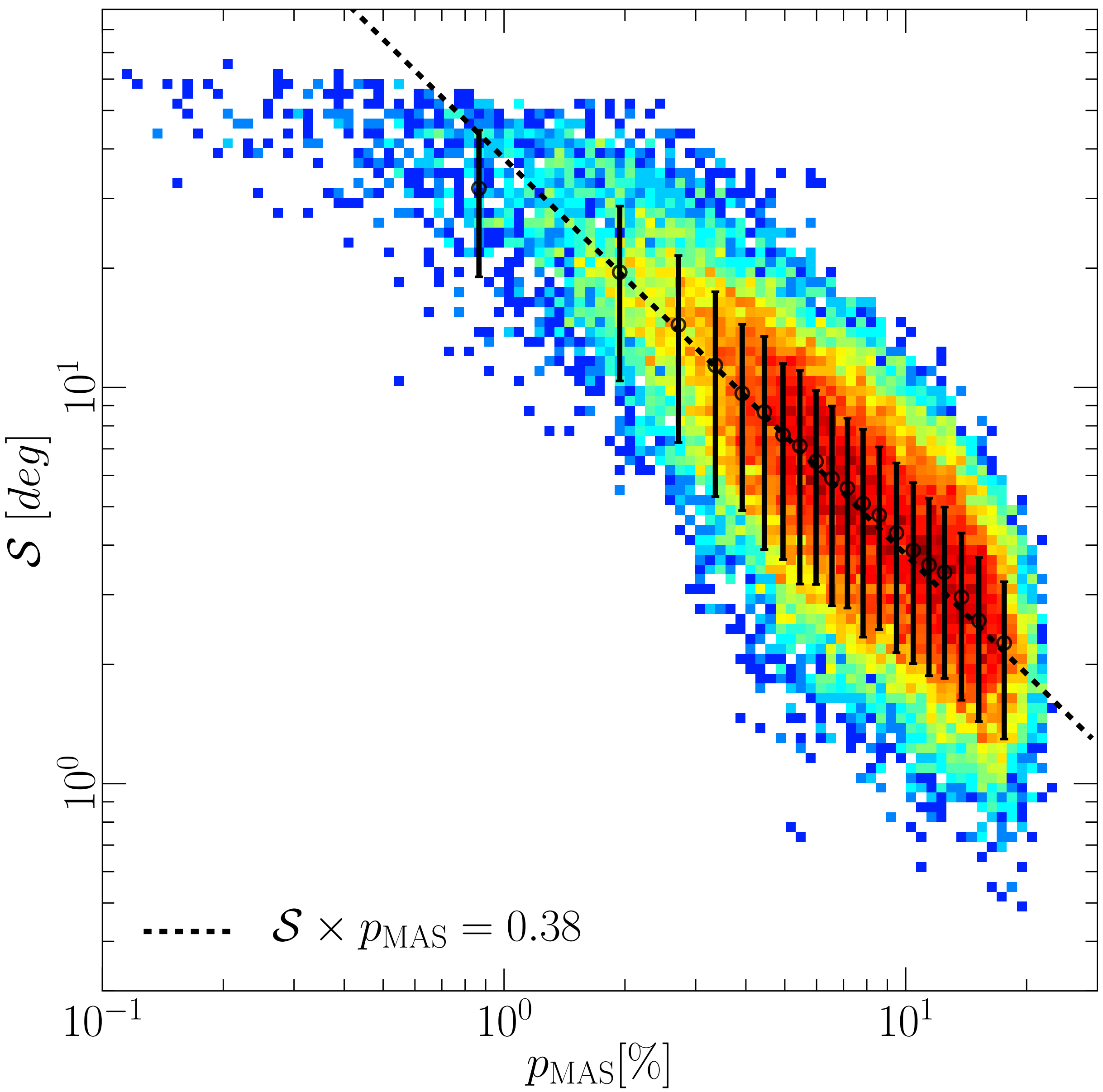


80 arcmin smoothed model map of dispersion function with lag = 40 arcmin

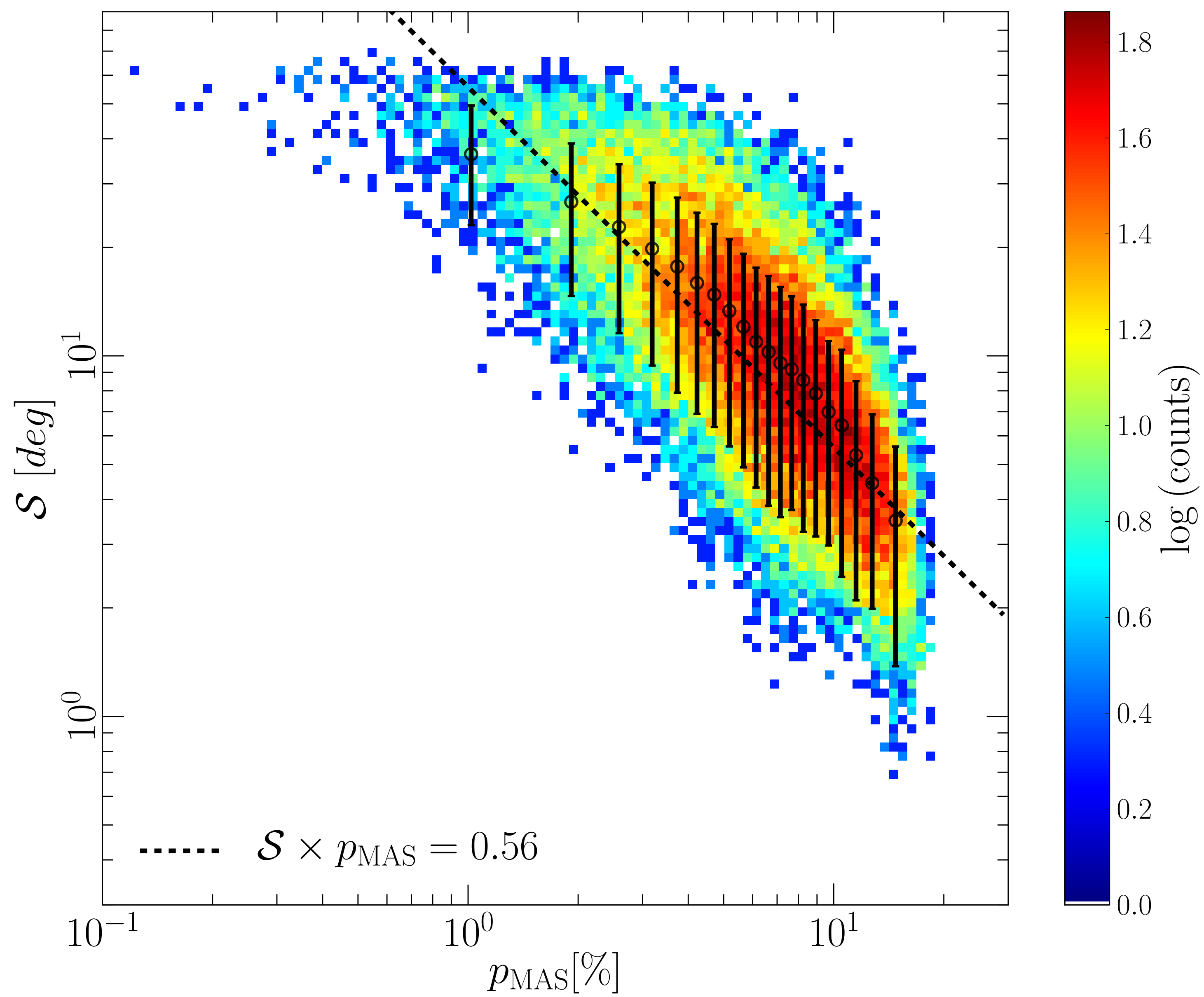


Anti-correlation between polarization fraction and dispersion function

Planck data



Model



$$p_{MAS} = p - b^2 \frac{1 - e^{-p^2/b^2}}{2p}$$

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Conclusion

- CMB B-mode is subdominant in comparison with dust over whole sky at all scale.
- Accuracy of component separation should be high in detection of primordial B-mode signal: A big challenge.
- Statistical dust modelling is necessary step to claim detection confidently.
- Our model is useful towards this goal building a physical understanding of dust polarization.
- We are able to reproduce observed dust properties using our model over a reasonable sky fraction.