Diffuse polarized foregrounds from component separation with QUIJOTE-MFI

Elena de la Hoz and QUIJOTE collaboration, in preparation.

From Planck to the future of CMB. May 25, 2022

Cosmology group, Instituto de Física de Cantabria (UC-CSIC)

Motivation

- Major milestone of CMB science: detection of **primordial B-modes**.
- This signal is mixed with other B-mode sources: **Astrophysical foregrounds**, lensed E-modes, instrumental noise...
- A **good foreground characterization** of foregrounds is required to be able to detect this signal faint signal.
- In this study we have characterize diffuse polarized foregrounds with data from **QUIJOTE-MFI**, WMAP and Planck.
- ✔ **QUIJOTE-MFI** provides information at the **low-frequency range** (11-13 GHz) improving the characterization of low-frequency foregrounds.

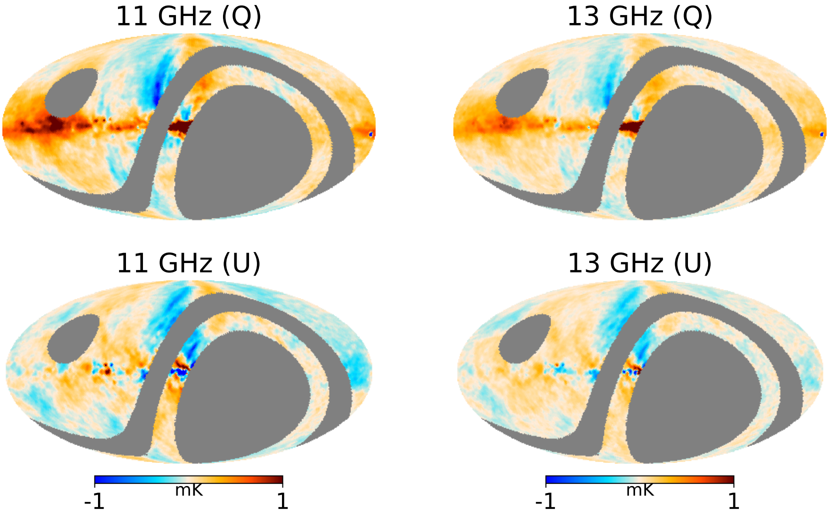
Data

Sky Signal Maps I. QUIJOTE-MFI

- Teide observatory.
- Nov. 2012 - Oct. 2018.
- 4 horns, 32 channels.
- 10-20 GHz.
- 4 frequency channels: 11, 13, 17, 19 GHz.
- $\Delta\nu = 2$ GHz.
- Polarization sensitivity: $\sim$ 35-40μK deg^{-1}.

More details in J. A. Rubiño-Martín talk on Thursday

Sky Signal Maps I. QUIJOTE-MFI



Wide survey: $\sim$ 51% of sky. 52 arc min resolution.

Sky Signal Maps II. Ancillary Data

Planck

- PR4 (NPIPE).
- Pol. LFI: 30, 44, 70 GHz.
- Pol. HFI: 100, 143, 217 and 353 GHz.

WMAP

- Polarized 9-year maps.
- K and Ka (22.8 and 33.1 GHz) bands.

All maps have:

- $N_{side} = 64$.
- $FWHM = 2$ deg.

Covariance matrices

- Among frequency detectors.
- From noise simulations.
- 11 and 13 GHz are correlated.
- The rest are independent.

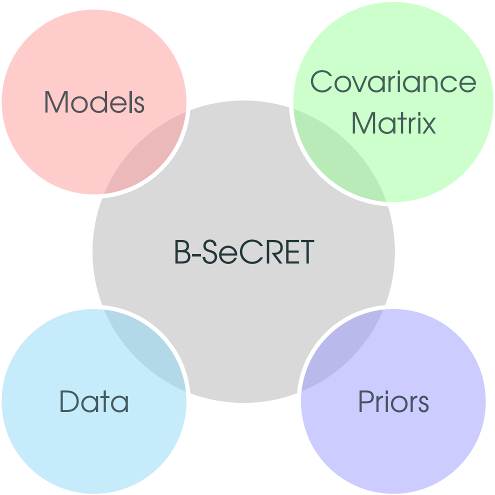
Component Separation Methodology

Component Separation Methodology. B-SeCRET

B-SeCRET

- Bayesian
- Parametric
- Maximum likelihood
- MCMC

E. de la Hoz et al., JCAP, 2020, 006



Polarized Sky Components. Models

Synchrotron

Power law model:

$$\begin{bmatrix} \mathbf{a_s}^{Q} \\ \mathbf{a_s}^{U} \end{bmatrix} \left(\frac{\nu}{\nu_s}\right)^{\beta_s}$$

Power law with curvature model:

- Uniform curvature.
- Spatially varying curvature.

$$\begin{bmatrix} \mathbf{a_s}^{Q} \\ \mathbf{a_s}^{U} \end{bmatrix} \left(\frac{\nu}{\nu_s}\right)^{\beta_s + \mathbf{c_s}(\nu/\nu_s)}$$

CMB

Black-body model:

$$\begin{bmatrix} \mathbf{c}^{Q} \\ \mathbf{c}^{U} \end{bmatrix} \frac{x^2 e^x}{(e^x - 1)^2}$$

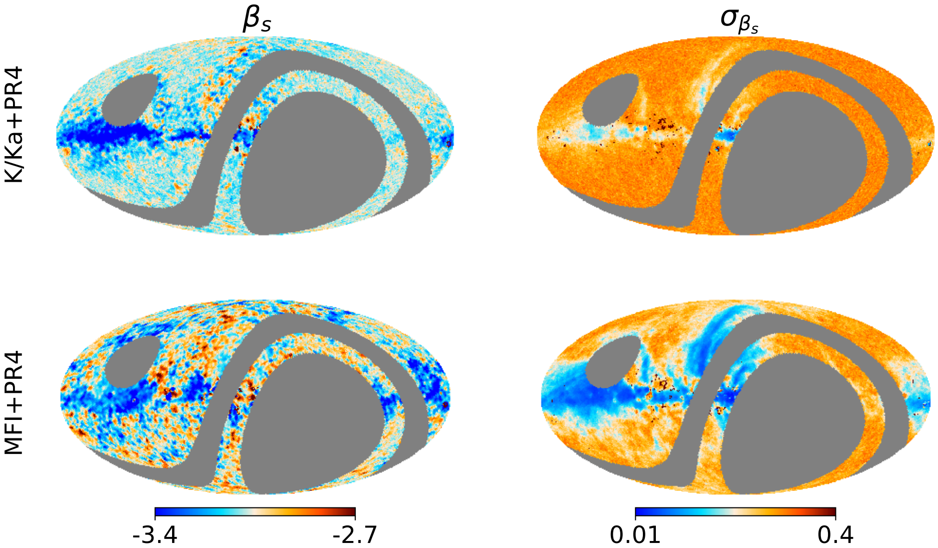
Thermal Dust

Modified black-body model:

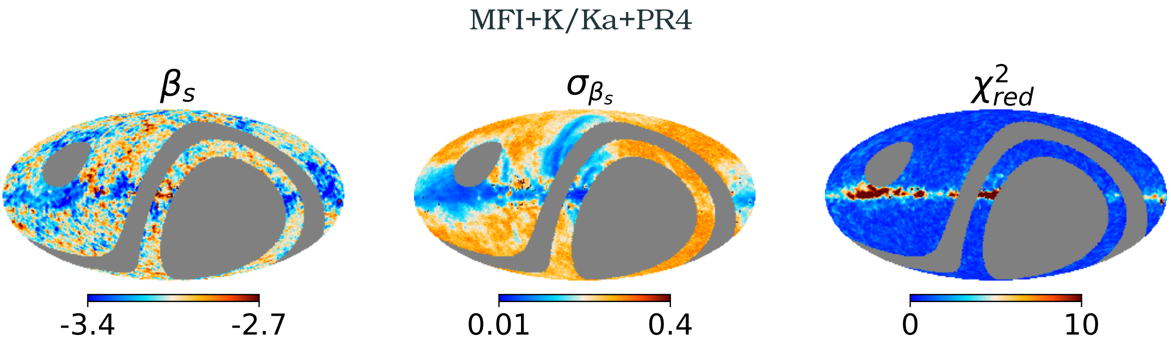
$$\begin{bmatrix} \mathbf{a_d}^{Q} \\ \mathbf{a_d}^{U} \end{bmatrix} \left(\frac{\nu}{\nu_d}\right)^{\beta_d - 2} \frac{B(\nu, \mathbf{T_d})}{B(\nu_d, \mathbf{T_d})}$$

Results

Synchrotron's Spectral Index I. Datasets



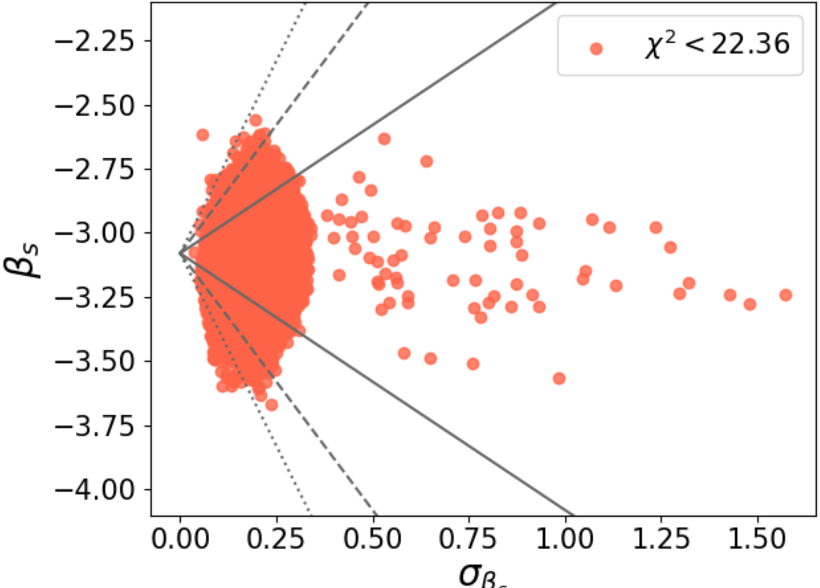
Synchrotron’s Spectral Index I. Datasets



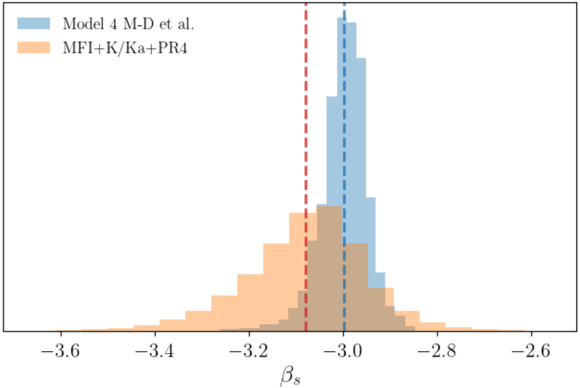
More complex regions are studied in more detail in other QUIJOTE papers. Check the **posters**:

- **M. Fernández-Torreiro**: AME spatial variations along the Galactic Plane.
- **R. González González**: New constraints on the AME polarisation with QUIJOTE in bright Galactic molecular complexes.
- **F. Guidi**: The Haze as seen by QUIJOTE.
- **D. Herranz**: Radio sources in the QUIJOTE-MFI wide survey maps.

Synchrotron's Spectral Index II. Spatial Variability

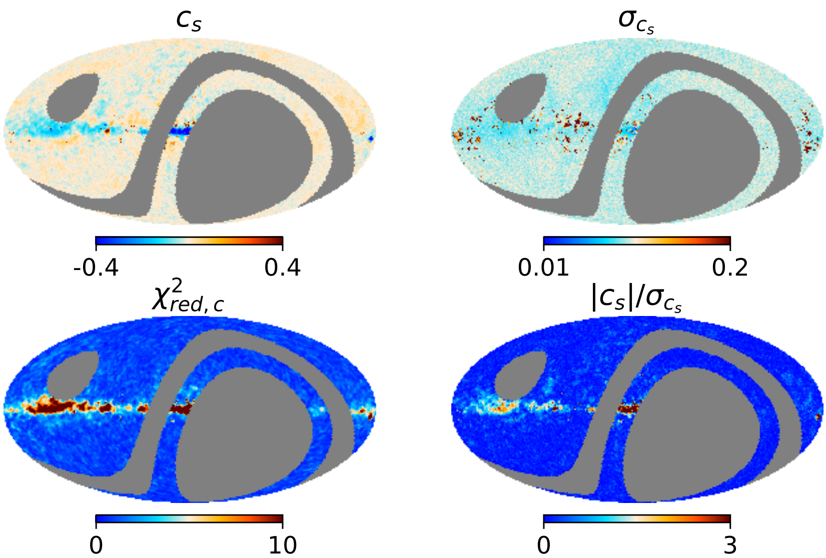


Synchrotron's Spectral Index III. Comparison with other β_s templates

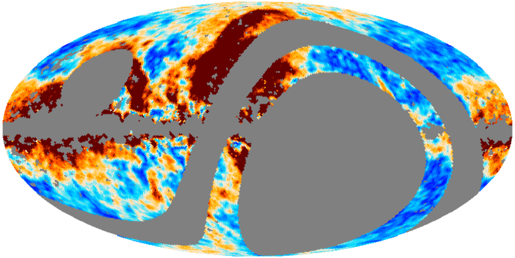


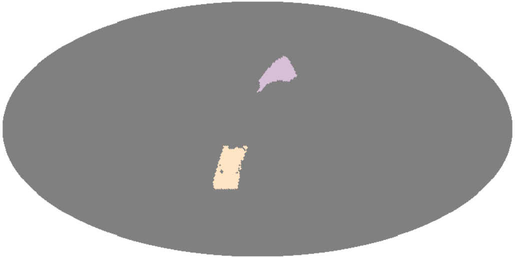
- Only pixels whose χ^2 is at 95% confidence.
- MFI+K/Ka+PR4: $\mathcal{N}(-3.08, 0.13^2)$.
- PySM: $\mathcal{N}(-3.00, 0.05^2)$.
- $\frac{\sigma_{\beta_s}(MFI + K/Ka + PR4)}{\sigma_{\beta_s}(PySM)} \sim 2.6\,.$

Curvature I. Power law with Spatially Varying Curvature



Curvature II. Power law with Uniform Curvature



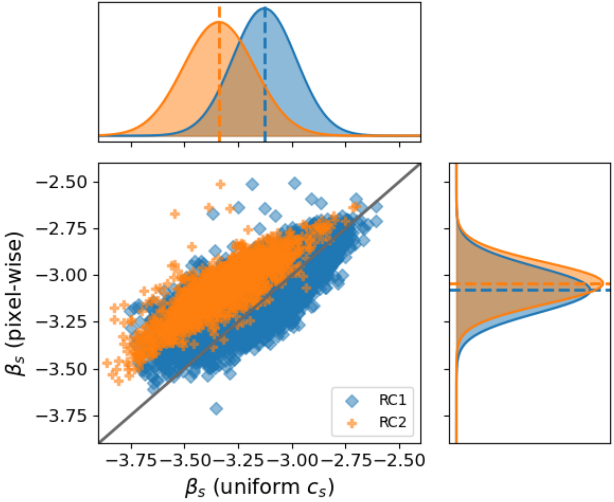


Region	c_s^R	$\sigma_{c_s^R}$	$\lvert c_s^R \rvert / \sigma_{c_s^R}$
RC1	-0.0797	0.0012	63.75
RC2	-0.2768	0.0017	161.57
Haze	0.041	0.010	4.23
North bubble	-0.083	0.007	11.43

Not statistical significant results to elucidate which model agrees better with the data

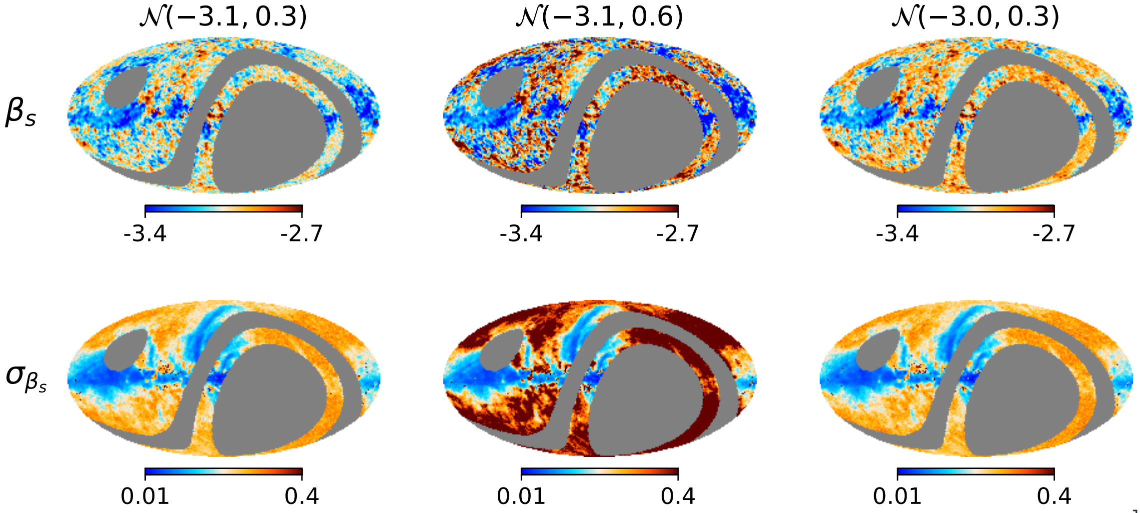
F. Guidi et al., 2022, MNRAS, in prep.

Curvature III. Recovered β_s with spatially varying and uniform curvature

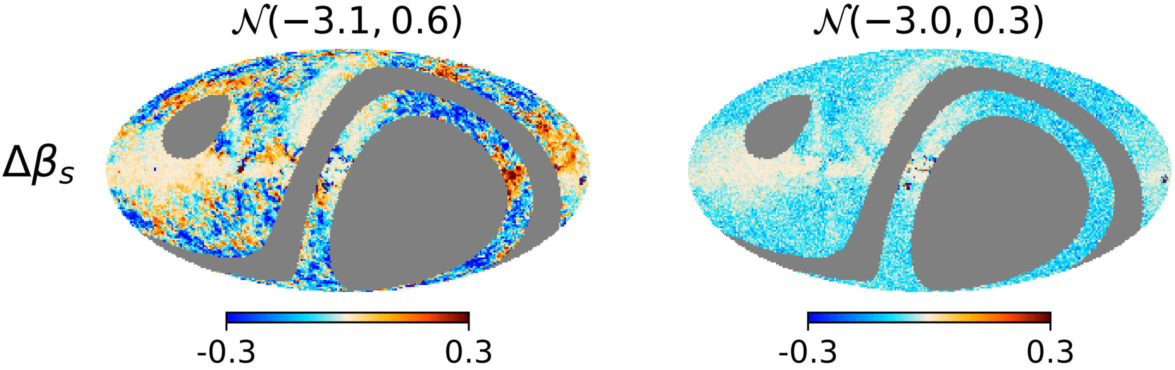


β_s and c_s are not independent. Either more sensitive data at the QUIJOTE frequencies or data at lower frequencies are required to break the degeneracy.

Robustness with respect to the Prior Information



Robustness with respect to the Prior Information



Conclusions

Take home message

- The characterization of astrophysical foregrounds is crucial, both to be able to remove them from the signal sky maps and to make realistic simulations of the sky used in current future CMB experiments forecasts.

- The QUIJOTE-MFI instrument data help improvement significantly with the characterization of the synchrotron emission.