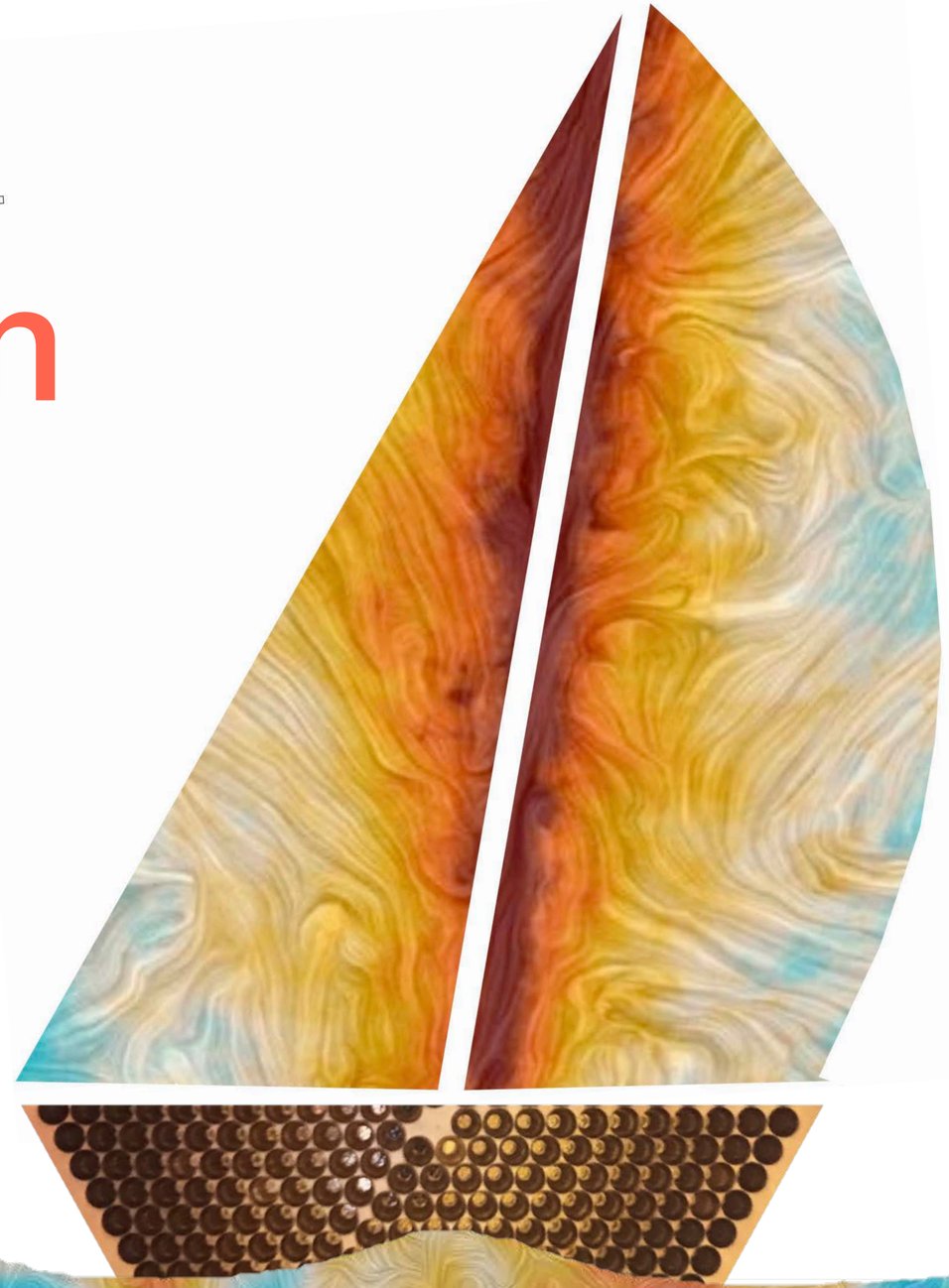
Dust polarization
Looking forward

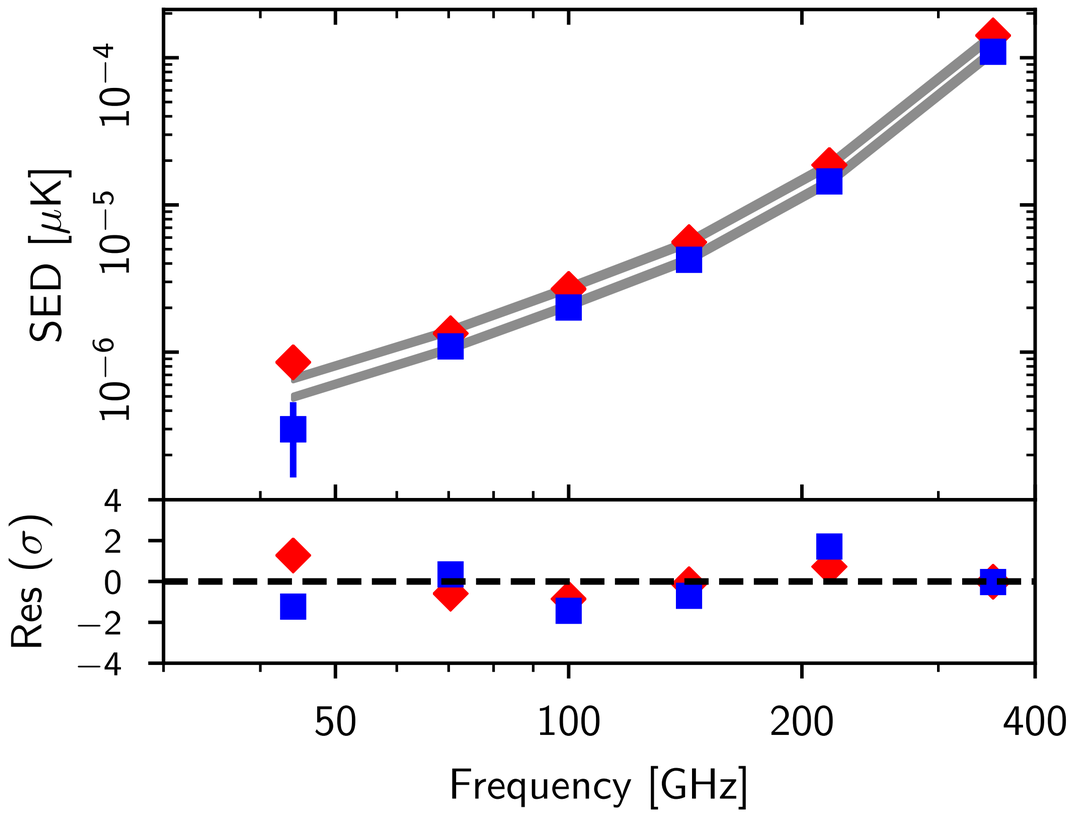
François Boulanger
LPENS - Paris



Dust polarization components

- The spectral energy distributions (SED) for polarisation is well fitted by a single modified blackbody. It is very close to that for total intensity.
- This is remarkably simple but what about :
  - *Distinct carbon and silicate grains with distinct polarisation properties,*
  - *Magnetic dipole emission*
  - *Excess microwave emissivity from amorphous grains (two-level systems)*
  - *AME polarization*

These components could emerge as deeper observations become available.



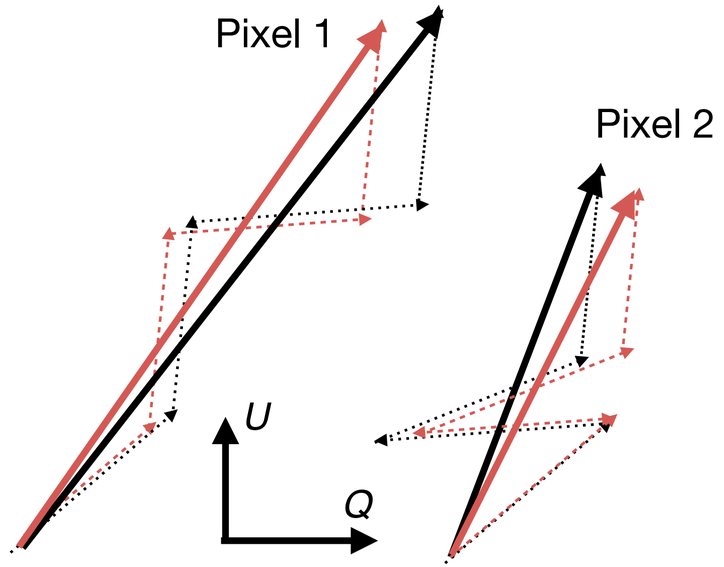
E & **B**-modes with modified black body fits

Planck 2018 results. XI.

Dust polarization angles

- The frequency dependence of dust polarisation data involves **polarisation angles**.
- When the dust SED and magnetic field orientation vary within the beam, the frequency scaling of the Stokes Q and U parameters differ.
- Polarisation angle variations must be correlated across frequencies, but the frequency dependence is not known a priori.

In this context, the calibration of polarization angles is intertwined with component separation



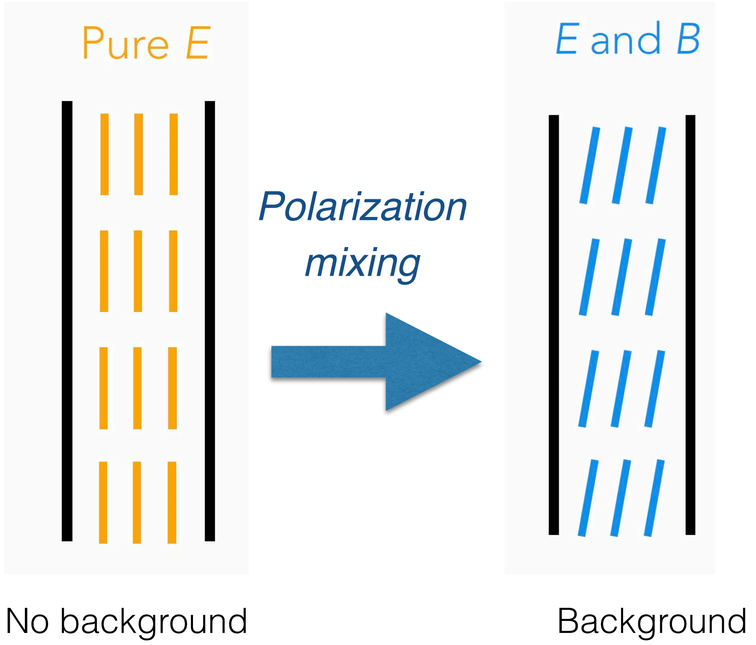
Frequencies ν_1 & ν_2

Interstellar polarization is a vector sum coupling magnetic field structure and dust properties

Planck intermediate results L

E - B Decomposition

- The TE correlation of dust polarization reflects the anisotropy of the magnetized ISM
- The origin of the TB correlation could result from the combination of magnetic field orientations between filamentary structures and background emission.
- Where dust emission properties differ between filaments and the background, the E, B decomposition of dust polarization depend on frequency.



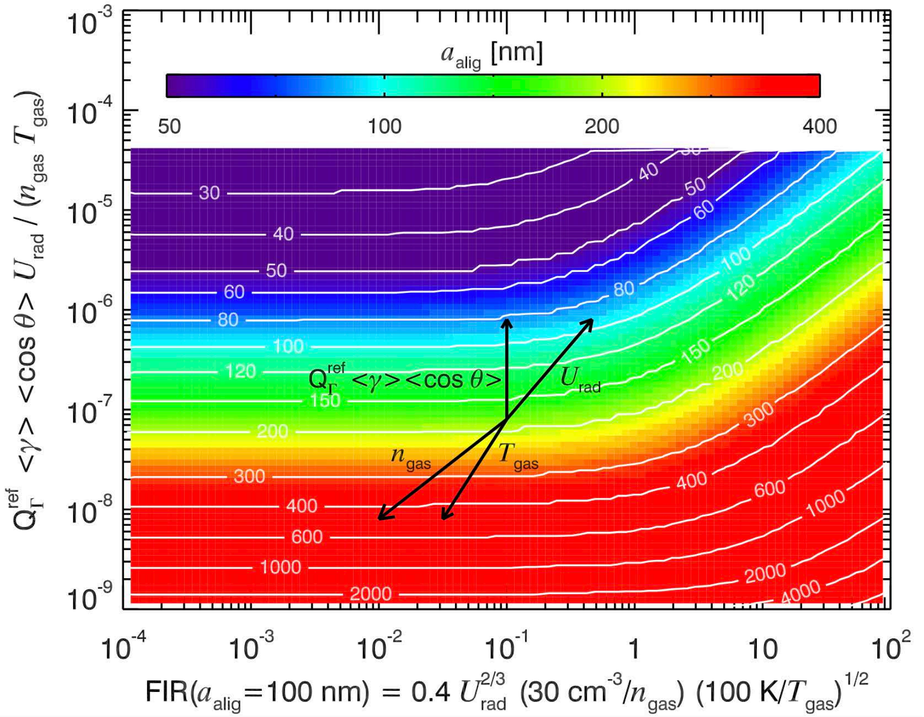
Background generates BB & EB power from EE, and TB from TE

Vacher+ 2023

Grain alignment

- Grain alignment is an essential element in the physics of dust polarization.
- Before Planck, we were preparing ourselves to take it into account.
- We grew confident that grain alignment through radiative torques is efficient in all phases of the diffuse ISM.

This is a main question about ISM physics but does it matter for CMB component separation?



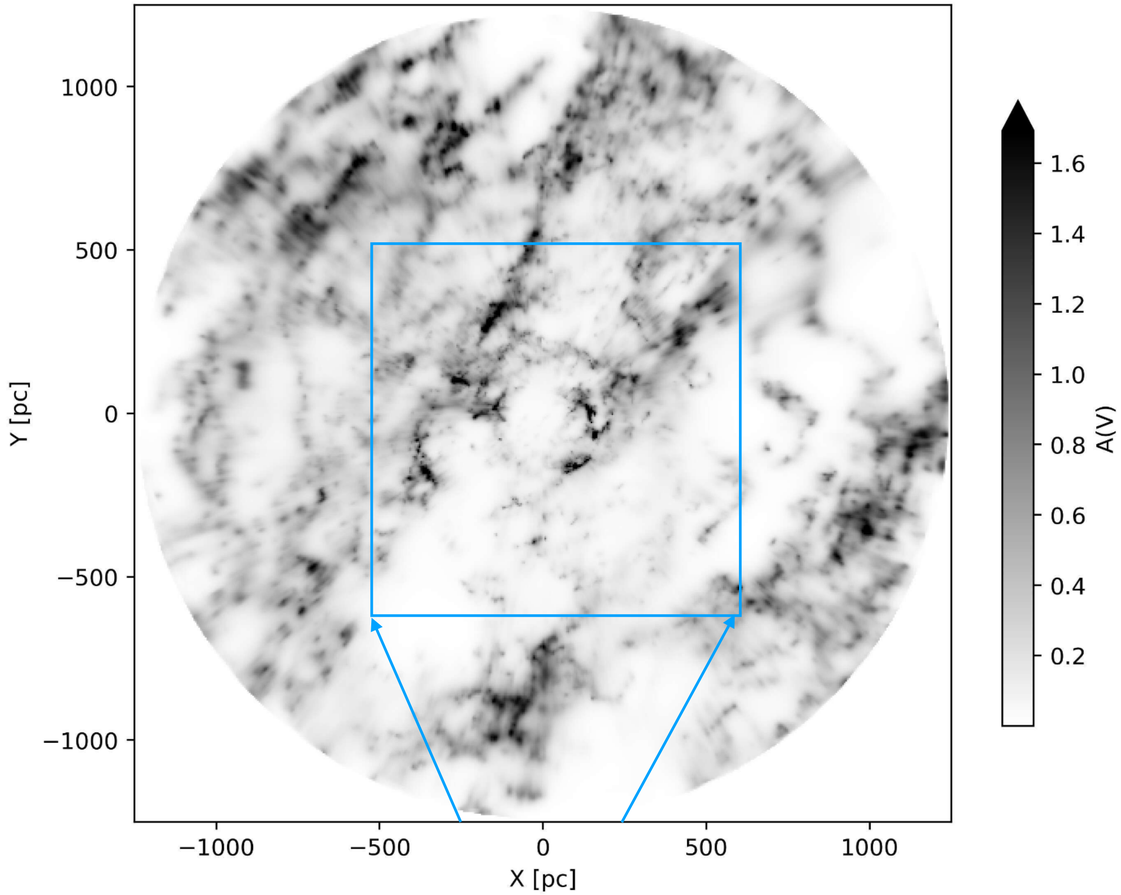
Minimum size of aligned grains versus physical conditions within the framework of radiative torques

Reissl+ 2023

Dust correlation with synchrotron

- The correlation between dust and synchrotron polarization at microwave frequencies is a main characteristic of Galactic foregrounds.
- It may result from a component of the synchrotron emission associated with the Local Bubble and its surrounding shell.

This is a specific example in which the CMB community could benefit from the development of 3D models of the Galaxy.



3D view at the local interstellar medium from stellar reddening and parallaxes

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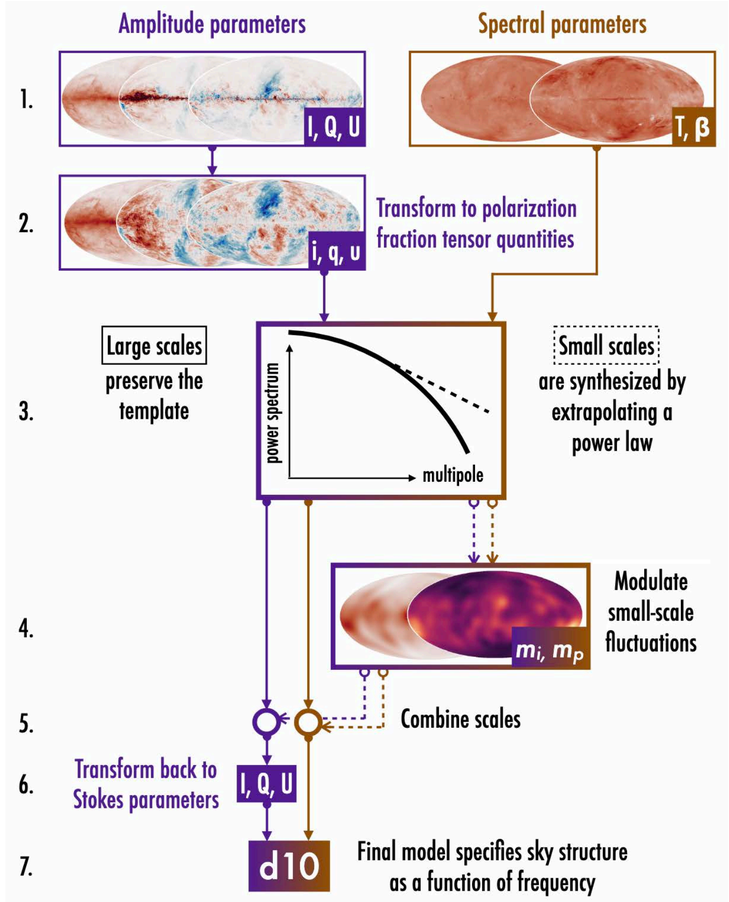
Model requirements

- Dust foreground maps reflect the structure of the magnetized ISM: the structure of the dust density, of dust emission properties (temperature and emissivity) and of magnetic fields.
- The interplay between these three physical fields that are correlated to some degree make foregrounds complex to model.

How accurate and elaborate models of dust polarization need to be to optimize CMB experiments and validate component separation methods?



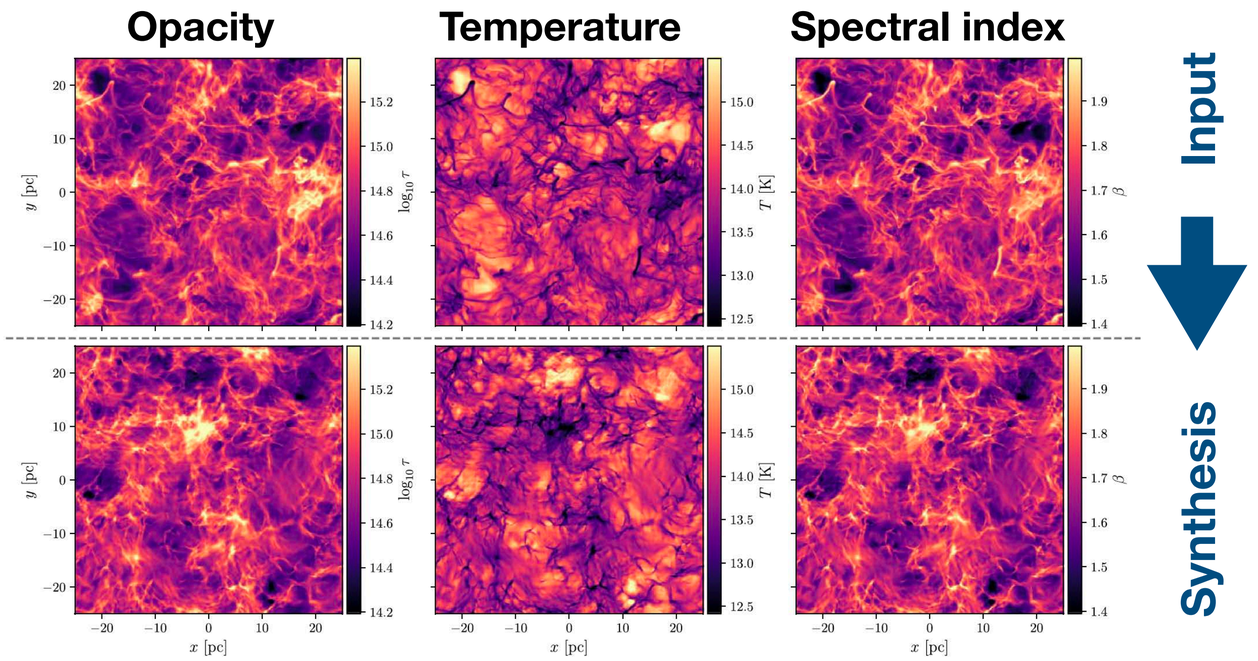
Python sky models

Pan-Experiment Galactic Science Group 25

Generative models

- Mathematical tools are being developed (e.g. convolution neural networks, scattering statistics) to build generative models of the dust foreground from observations (CMB complemented with ancillary data).
- The tools must marginalize on CMB polarization and data noise without biasing dust polarization properties.

Will this promising approach replace the current sky models in PySM?



Multi-frequency generative model of dust total intensity built from an MHD simulation using scattering statistics

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Validation CMB analysis

- Any claim of the detection of primordial B-modes or cosmic birefringence must be validated against an alternative interpretation involving residual foregrounds.

- For this validation to be robust, cosmology and galaxy experts must combine their respective contributions without knowing the methods implemented by each other.

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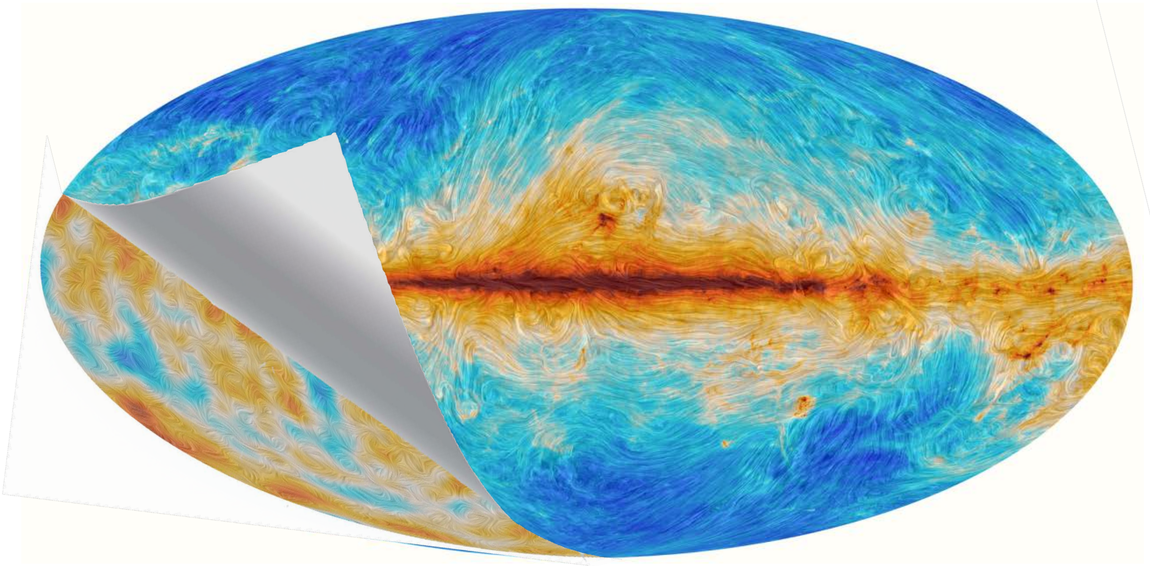
The algorithms used by both teams need to be distinct. The algorithms used by both teams should also be different. How can we organize it?



CMB polarization revealed beneath the foreground dust veil shown with Planck sky images

Questions

- Most dust models and component separation methods rely on the modified black body spectral model. Is this a robust approach?
- The calibration of polarization angles is intertwined with component separation. Do we have a calibration approach do handle this difficulty with the required accuracy?
- How the CMB community could benefit from the development of 3D models of the Galaxy?
- The E, B decomposition of dust polarization is likely to depend on frequency. Can we develop CMB component separation methods that take this into account?
- Are generative models a promising approach that will take over current sky models of Galactic foregrounds?
- How accurate and elaborate models of dust polarization need to be to optimize CMB experiments and validate component separation methods?