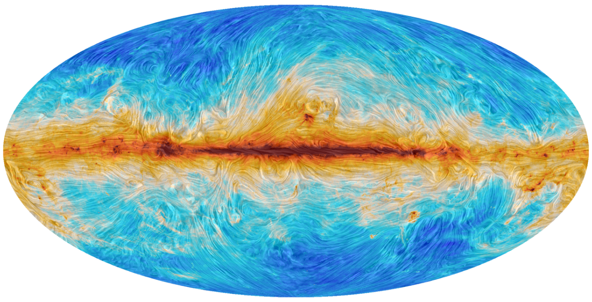
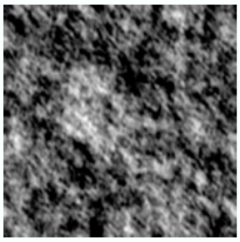
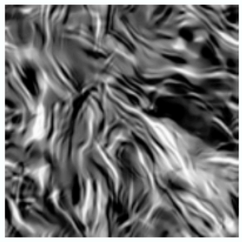


The Planck polarization sky

Input



Gaussian field



Wavelet scattering

Towards realistic models of polarized CMB foregrounds

The Planck all-sky map of polarized thermal emission from Galactic dust was a spectacular highlight of the ESA mission, which revealed the imprint of the magnetic field on interstellar matter. With the Planck data, the study of interstellar magnetic fields became closely related to a paramount objective of observational cosmology, the search for primordial gravitational waves (BICEP2/Keck and Planck Collaborations, 2015). As the primordial signal is buried deep below the polarized foregrounds from our own Galaxy at similar frequencies, any claim for a detection will face a critical assessment against alternative interpretations involving foregrounds. Thus, probing this new frontier of physics in the very early Universe rests on the accurate description of polarized Galactic foregrounds, whose properties are ultimately linked to those of the magnetized, turbulent ISM.

The structure of these polarized foregrounds (synchrotron and thermal dust emission) is closely related to the distribution of interstellar matter (electrons and dust grains) and to the topology of the interstellar magnetic field. As they corrupt the pristine cosmological signals in a way that depends on both the frequency of observation and its direction, the unbiased investigation of the physics of the early Universe must rely on multi-frequency measurements of the sky on the one hand, and high-precision modelling of the polarized foregrounds, on the other hand. The recovery of the cosmological signal rests on these two pillars, and is achieved through algorithms referred to as component separation methods.

These rely on the accurate statistical description of polarized foregrounds, capturing their hierarchy of coherent, anisotropic structures, and their interplay with dust and cosmic ray microphysics, across frequencies. We are thus faced with the problem of statistically characterizing complex sky images resulting from non-linear physics. The estimation of the probability measure of a statistical process given a realization observed over a finite domain is a generic problem of data science. In CMB analysis, this is routinely done using Gaussian random fields, but these models do not apply to describe random processes which include interactions across scales, as is inherent to non-linear physics. Indeed, when resorting to classical statistical tools, most of this complex information is lost.

The quest for non-parametric, low-dimensional, models providing accurate approximations of non-Gaussian phenomena is actually an active research field in mathematics, with applications in diverse fields of the natural and information sciences.

The proposed internship consists in applying cutting-edge developments in this field of mathematics to the characterization of polarized Galactic foregrounds. More specifically, the intern will work with the wavelet scattering transform introduced by Mallat (2011) and will apply it to analyze foreground polarization data from Planck as well as from the ACT ground-based and SPIDER balloon-borne experiments (ongoing collaborations). This algorithm effectively captures the multiscale and geometric properties of the signal and provides a non-parametric, low-dimensional, characterization of the input data, which can be used to generate random realizations mimicking the features observed in complex phenomena. This is an essential property for assessing and optimizing component separation methods for current and future CMB observations.

The intern will work at ENS Paris under the joint supervision of F. Levrier and F. Boulanger, who both have a strong expertise in the analysis of Planck polarization data and have initiated an inter-disciplinary collaboration with S. Mallat (ENS Department of Computer Science).

This internship work will be undertaken as part of the ANR project BxB (2017-2021, PI : F. Boulanger), and ERC project MIST (2017-2022, PI : E. Falgarone). A PhD position related to it will be open in 2018.

References

- **Group Invariant Scattering**, S. Mallat, ArXiv:1101.2286, 2011
- **Planck intermediate results. XIX. An overview of the polarized thermal emission from Galactic dust**, Planck Collaboration, Astronomy & Astrophysics, 576, 104, 2015
- **Planck intermediate results. XX. Comparison of polarized thermal emission from Galactic dust with simulations of MHD turbulence**, Planck Collaboration, Astronomy & Astrophysics, 576, 105, 2015
- **A Joint analysis of BICEP2/Keck Array and Planck Data**, BICEP2/Keck and Planck Collaborations, PRL, 114, 101301, 2015

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