Anisotropic models of polarized thermal dust emission from the magnetized interstellar medium

The Planck all-sky map of polarized thermal emission from Galactic dust was a spectacular highlight of the mission, which revealed the fingerprints of the Galactic magnetic field on interstellar matter.

With this data, the study of interstellar magnetic fields became closely related to a paramount objective of observational cosmology: the quest for B-mode polarization of the cosmic microwave background (CMB), which is expected to arise from primordial gravitational waves produced during the inflation era in the very early Universe, and is buried deep below the polarized foregrounds due to our own Galaxy at similar frequencies.

These polarized foregrounds (synchrotron and thermal dust emission) are indeed closely connected to interstellar magnetic fields, and must be modelled and removed with high precision in order to allow investigating the physics of the early Universe. The analysis of Planck data has thus proved of great value to improve our knowledge and understanding of Galactic dust polarization in the sub-millimetre and microwave wavelength ranges.

The statistical characterization of this dust emission - both its total, unpolarized intensity (T) and its polarized intensity (E and B modes) - has led to a number of unexpected results. In particular, we have found an asymmetry in the amplitudes of the E and B angular power spectra, a positive T-E correlation, and an exponent of polarization spectra (-2.4) which is significantly larger than the Kolmogorov value. Our data analysis shows that all these results may be related to the structure of the Galactic magnetic field, the anisotropy of MHD turbulence and its interplay with the density structure of matter, but our understanding of these results in terms of the physical properties of the interstellar medium is still very sketchy.

To this end, we have started developing a framework to build synthetic polarization maps out of analytic 3D models (based on fractional Brownian motion fields) representing the interstellar dust density and magnetic field. Through a comparison with actual polarization data, we are able to constrain the statistical properties of these fields, and thus show that the spectral index of the magnetic field is equal to that of polarization maps (-2.4).

However, this approach is currently unable to reproduce the filamentary structures observed in the column density of dust, or the strong anisotropy which characterizes the observed topology of the magnetic field. It is also not suited to take into account the correlation between dust density and magnetic field, which is also an observational result from Planck. Consequently, it fails to reproduce the E/B asymmetry or the T-E correlation observed in Planck data.

Ideas have recently emerged to remedy these shortcomings: Firstly, ridged multi fractal fields are a generalization of fractional Brownian motions that are of wide use in terrain-generating algorithms, and may be used to build anisotropic, filamentary fields with controlled statistics to simulate realistic dust density and magnetic fields. Secondly, the correlation between dust density and magnetic field may be implemented, while keeping controlled statistics for both, by imposing the identity of Fourier phases over a certain range of scales.

The work proposed in this internship consists in implementing those ideas into our analysis framework, building simulated polarization maps using that framework (which is readily available), and establishing constraints on the interstellar dust density and magnetic fields from a comparison to Planck data.

The intern will work at ENS Paris in close collaboration with F. Levrier (ENS) and F. Boulanger (IAS Orsay), who have a strong expertise in the analysis of Planck polarization data and interstellar medium studies.

References

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