MINI-PROJECT # 1 - ESTIMATING THE CMB FROM THE PLANCK/HFI DATA

Description of the data :

In this project you have access to the following data (either in FITS or MAT files) :

— **Data** is the data cube of size $256 \times 256 \times 6$, which corresponds to simulated Planck/HFI at the frequencies 100, 143, 217, 353, 545 et 857 GHz.

Each of these observations – which we denote by $\{x_i\}_{i=1,\cdots,6}$ – is corrupted with additive white Gaussian noise with standard deviation σ_i.

These observations are modeled as the linear combination of 3 components : i) the cosmological microwave background (CMB), ii) the Sunyaev - Zel'dovich effect (SZ), and iii) the thermal dust emission. The contributions of these components are assumed to be rank-1 matrices that are composed of the tensor product of a spectral signature and a spatial distribution.

The dust emission as well as the SZ effect can be assumed to be sparsely represented in the wavelet domain. All these components can be assumed to be statistically independent.

— **SpecCMB** vector array of size 6×1 that contains the spectral signature of the CMB.

— **SpecSZ** vector array of size 6×1 that contains the spectral signature of the SZ effect.

— **PowSpec** is an image of size 256×256 that contains the power spectrum of the CMB in the Fourier domain. More precisely, the La CMB map is theoretically modeled in the Fourier domain as $\tilde{x}[k] = \sqrt{\text{PowSpec}[k]}\, u[k]$ where u is a white Gaussian noise with variance 1.

— **FWHM** vector of size 6×1 that contains the resolution in arcmin of each of the 6 channels.

— **h** is a data cube of size $256 \times 256 \times 6$, which corresponds to the convolution kernels **in the pixel domain** (*i.e.* impulsive response) of each of the observations. It therefore defines the resolution of the input data. The observation x_i is therefore obtained as the following convolution : $x_i = h(*, *, i) \star \bar{x}_i + n_i$ where $\bar{x}_i$ stands for the data at infinite resolution.

— **SigmaNoise** is a vector of size 6×1 that contains the standard deviations σ_i of the noise that contaminates the data.

— **NoiseRealisation** is a noise realisation that corrupts the data.

Goal of the mini-project :

The goal of this project is to provide an estimation of the cosmological microwave background map (CMB) at a **resolution of** 5 **arcmin** from the Planck/HFI data.
In astrophysics, this map is widely used for testing cosmological models, for estimating cosmological parameters, for testing exotic physics, etc. **A good estimate of the CMB must have a very low level of contamination from the other astrophysical components** (i.e. SZ, dust, point sources, etc).

Evaluation :

The final mark will be based on a **document** that reports :
— the scientific protocol you propose to tackle the problem.
— illustrations of the numerical experiments you carried out during the mini-project.
— discussion of the limitations of your approach, the bottlenecks you are facing, and what you would propose to overcome these limitations.

All the necessary mathematical tools have been studied during the course, the mini-project can therefore be solved with these tools only. This does not preclude taking any inspiration outside the scope of the course.

In case you have questions : *jbobin@cea.fr*