Modeling CMB Spectral Distortion measurement prospects

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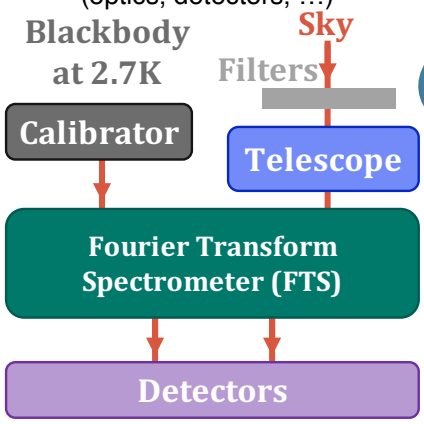
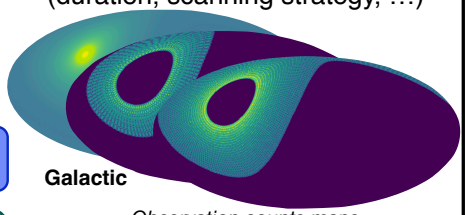
In 1990s the COBE/FIRAS mission showed that the CMB spectral energy distribution is close to a perfect blackbody [1]. However, the CMB spectrum contains tiny departures from a perfect blackbody to $\Delta I_\nu / I_\nu \simeq 10^{-5}$, referred to as spectral distortions, that encode information about the full thermal history of the Universe. High-precision spectroscopy of the CMB is one of the three themes that have been selected by the ESA Voyage 2050 programme [2]. Refining the instrumental concept of future dedicated missions is needed to measure those challenging signal. I will present an effort undertaken to define future missions and instruments dedicated to the measurement of the CMB spectral distortions. It combines two models allowing for sensitivity estimates that could be reached by such projects.

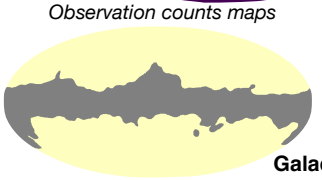
1. Instrumental model

Photometric model (optics, detectors, …) + **Mission parameters** (duration, scanning strategy, …)





Observation counts maps

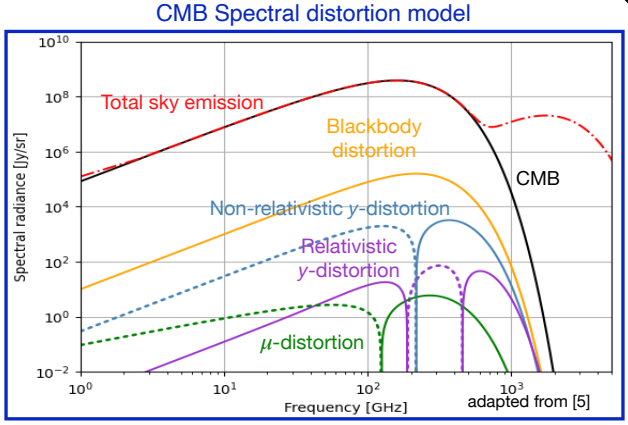


Masks (galactic, point sources, sun, …)

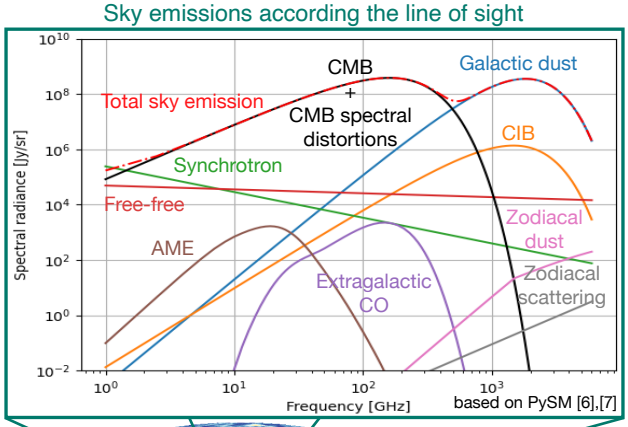
This instrumental concept baseline is a 2-inputs - 2-outputs absolute **Fourier Transform Spectrometer** realizing a differential measurement between the CMB sky signal and a **calibrator** at the CMB temperature based on past proposal concept [3],[4]. The FTS have a **spectral resolution around 15GHz** and allow to measure from **10GHz to a few THz**.
While observing, one of the input beam is directed towards the **calibrator** while the other input is looking at the **sky**. The two outputs are focused onto **multimoded feedhorn-coupled detectors** cooled down to sub-K temperature.

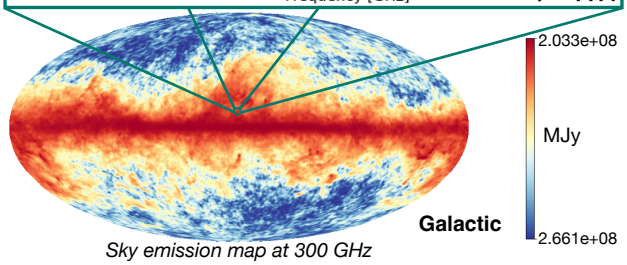
2. Sky model

CMB Spectral distortion model



Sky emissions according the line of sight





Sky emission map at 300 GHz

Combining the results of our **CMB spectral distortion** and **foreground emission** models (based on PySM [6],[7]), we generate sky emission maps by taking into account various galactic and extra-galactic foregrounds at frequency relevant for CMB spectrum measurement.

3. Sensitivity estimation

- Power on the detectors
- Noise Equivalent Power (NEP)
- Sensitivity Estimate

4. Forecast observables

- Instrument Noise covariance matrix
- Fisher information matrix
- Signal Noise Ratio (SNR) on sky model parameters

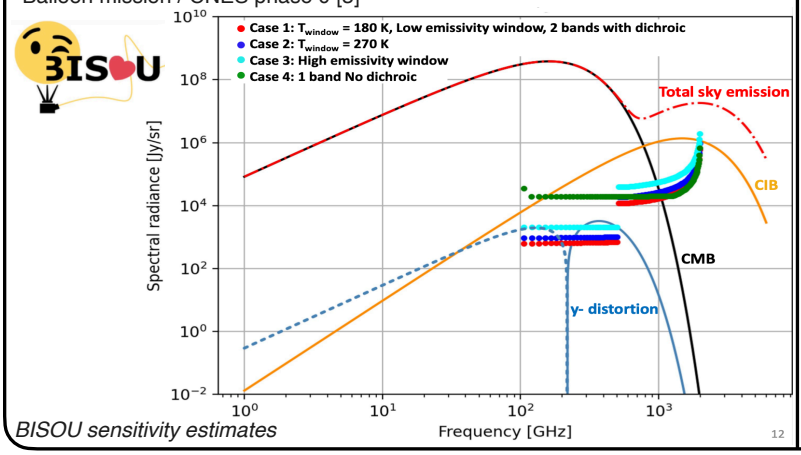
5. Optimization of instrument parameters

Combining the outputs of those models allow us to obtain sensitivity estimates that could be reached by projects dedicated to CMB spectral distortion measurement.
Through forecasts and iterations, the optimization of both instrument concept and mission parameters can be achieved.

6. Iterate

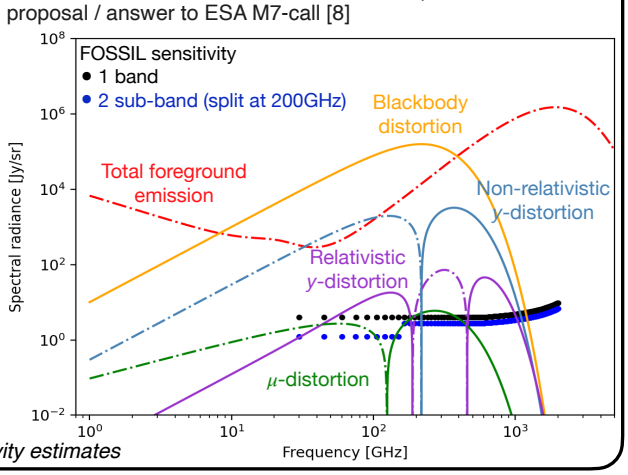
7. Application cases

BISOU (Balloon Interferometer for Spectral Observation of the Universe)
Balloon mission / CNES phase 0 [3]



BISOU sensitivity estimates

FOSSIL (FTS fOr CMB Spectral diStortIon expLoration)
Space mission proposal / answer to ESA M7-call [8]



FOSSIL sensitivity estimates

8. Results

SNR (σ)	y	kT_{eSZ}	μ	A_{CIB}
BISOU	5.6			2.8
FOSSIL	186	37	1	76

References

[1] Fixsen et al. (1996), [2] Chluba et al. (2021), [3] Maffei et al. (2021), [4] Kogut et al. (2016), [5] Abitbol et al. (2017), [6] Zonca et al. (2021), [7] Thorne et al. (2021), [8] https://www.ias.u-psud.fr/en/content/fossil