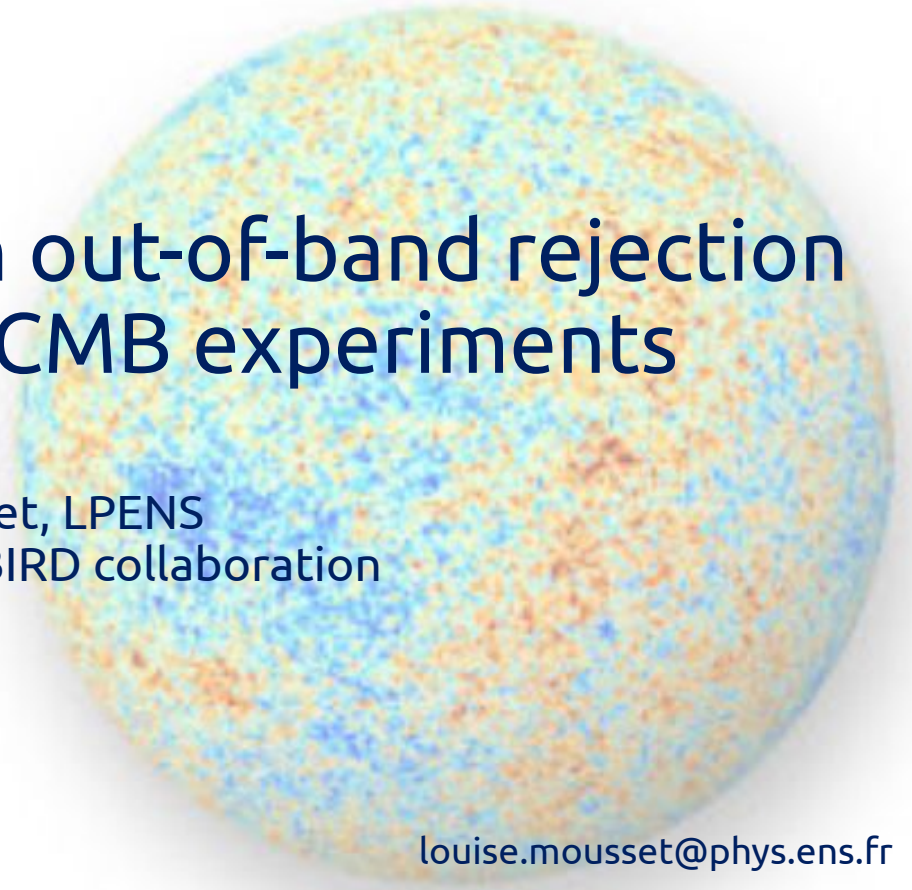
CMB-CAL @ BICOCCA

November 7, 2024

Setting requirements on out-of-band rejection for next generation CMB experiments



Louise Mousset, LPENS
On behalf of the LiteBIRD collaboration

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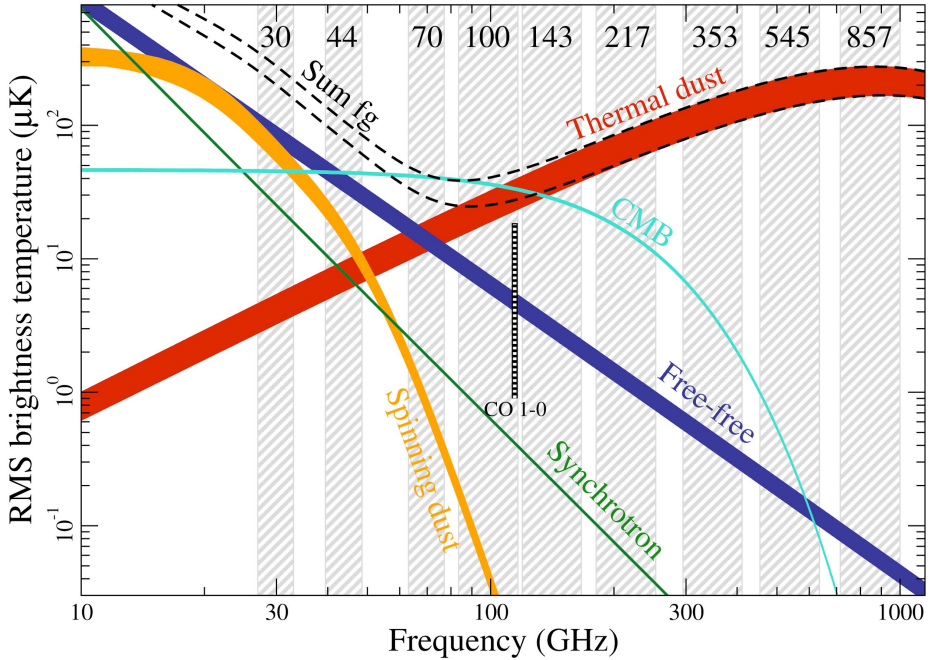
Objective

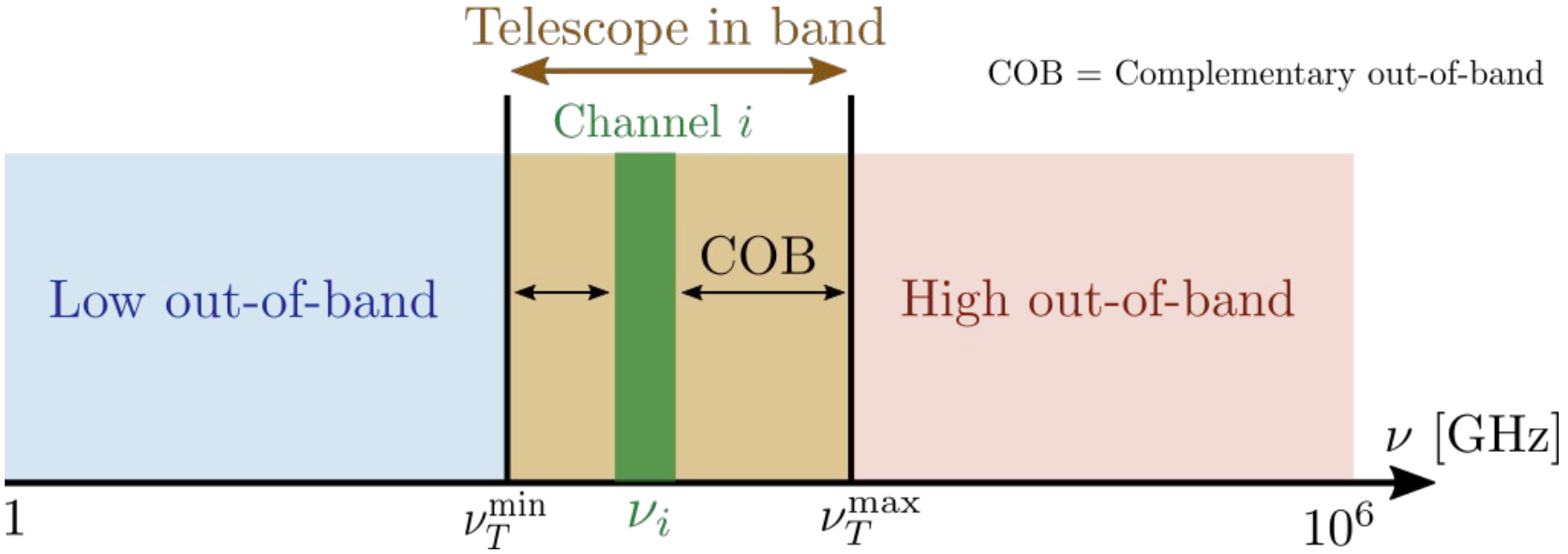
We observe the CMB among many astrophysical foregrounds.

How to define the instrument bandpass and the filtering scheme ?



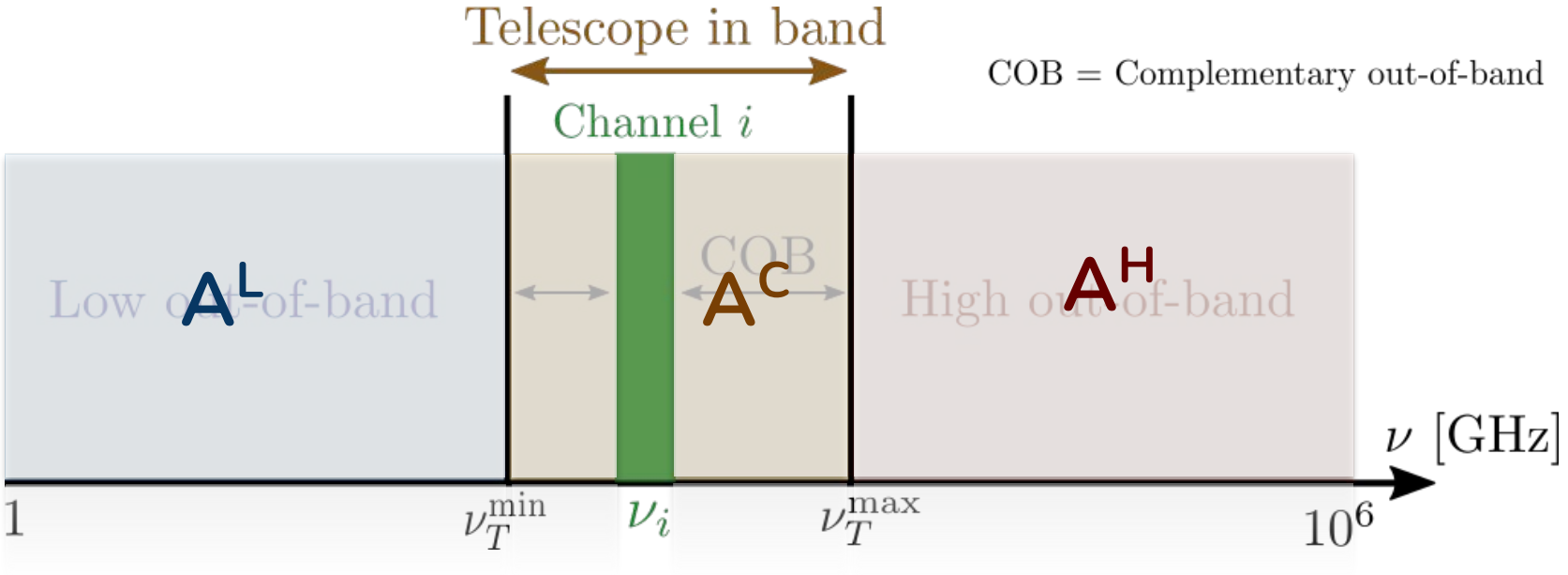
Definitions and assumptions

We consider frequencies from 1 to 10^6 GHz split in several domains.

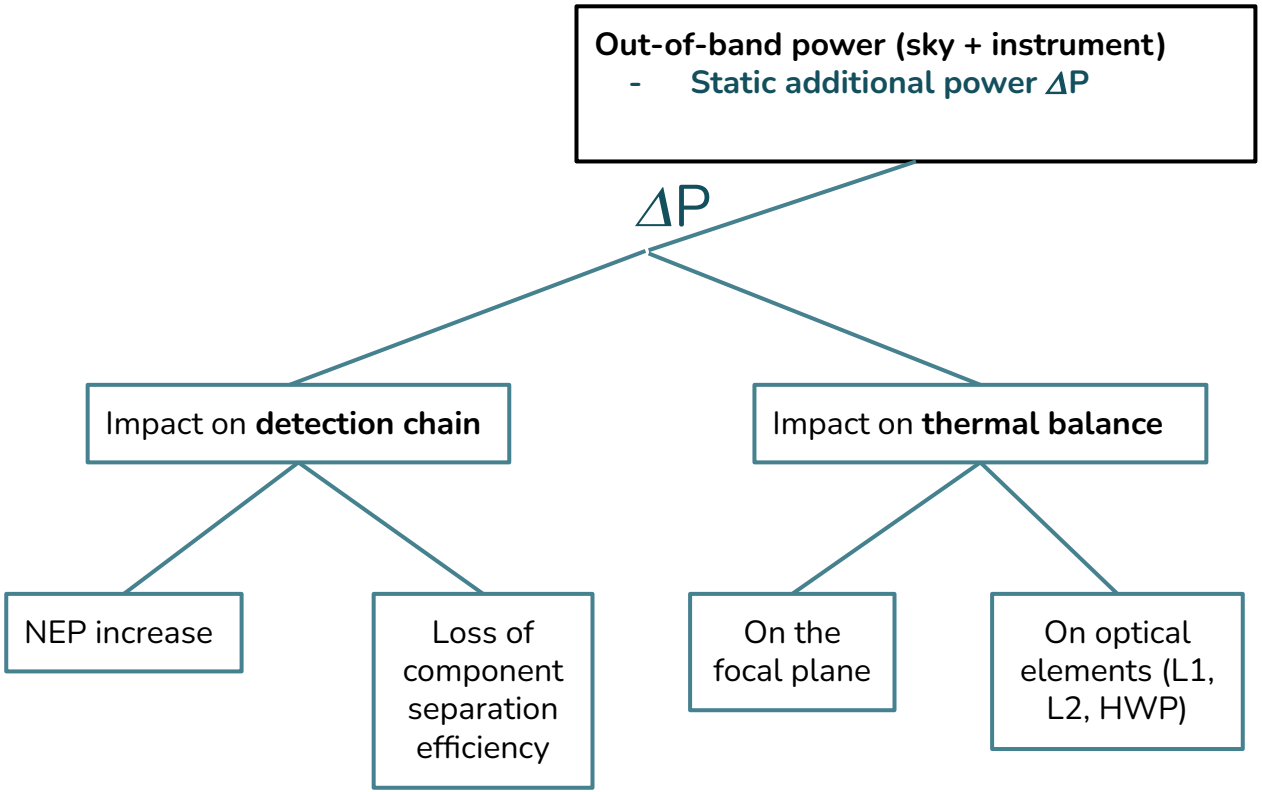


Definitions and assumptions

The goal is to constrain the **attenuation factors** A^L, A^C and A^H, assumed to be constant in each domain.



Impact of out-of-band power



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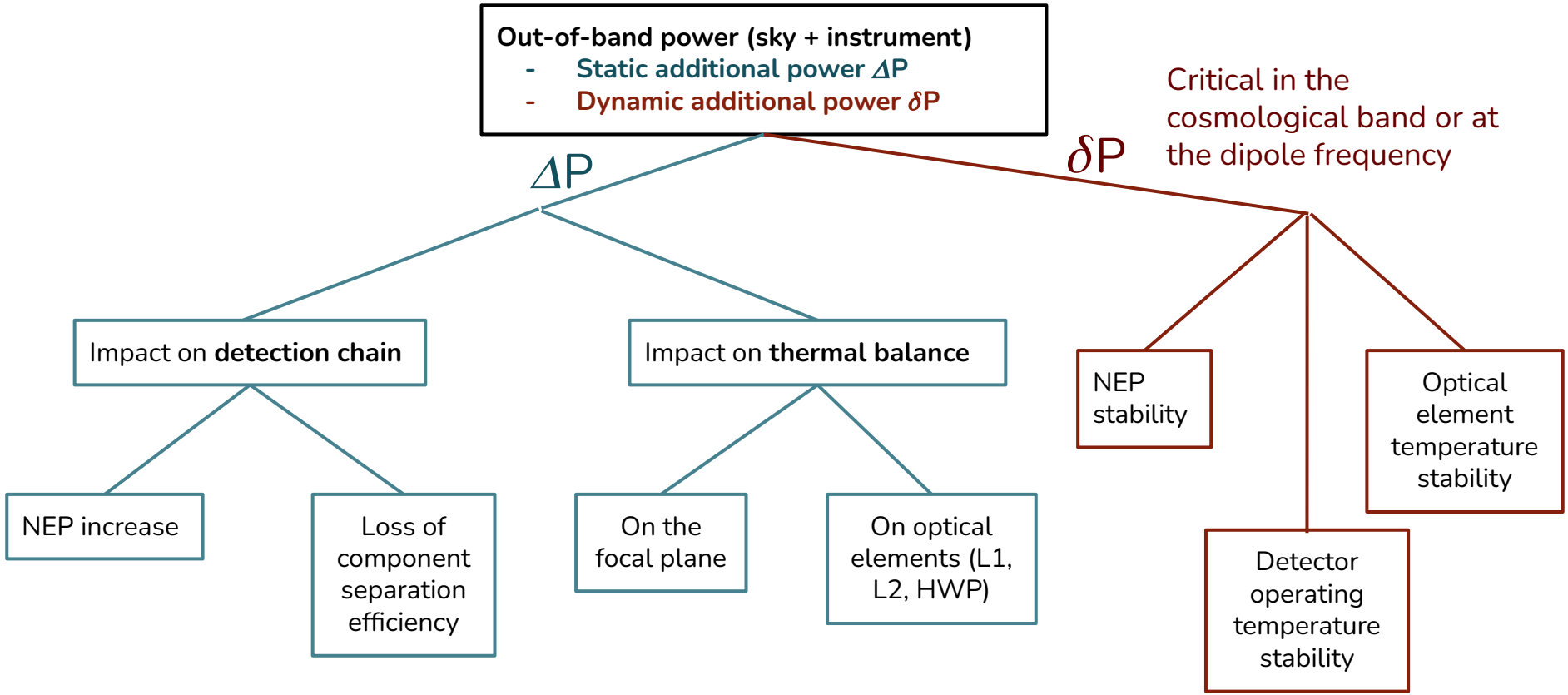


Methodology

Main scientific driver:

$$\delta r < 0.001$$

?

Instrumental design

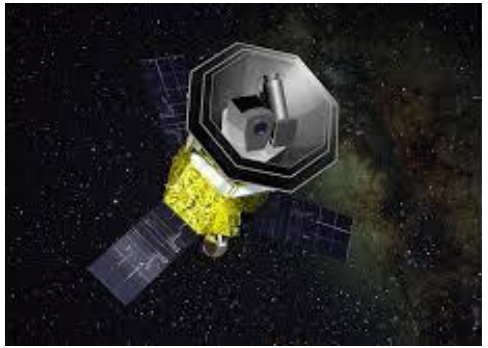
Methodology

Instrumental design

Main scientific driver:

$$\delta r < 0.001$$

?



Assumptions on A^L, A^C, A^H
Sky model
Instrument model

Performance code

Performance forecasts:
- detector sensitivity
- thermal balance
- uncertainty on r

Requirements on A^L, A^C, A^H

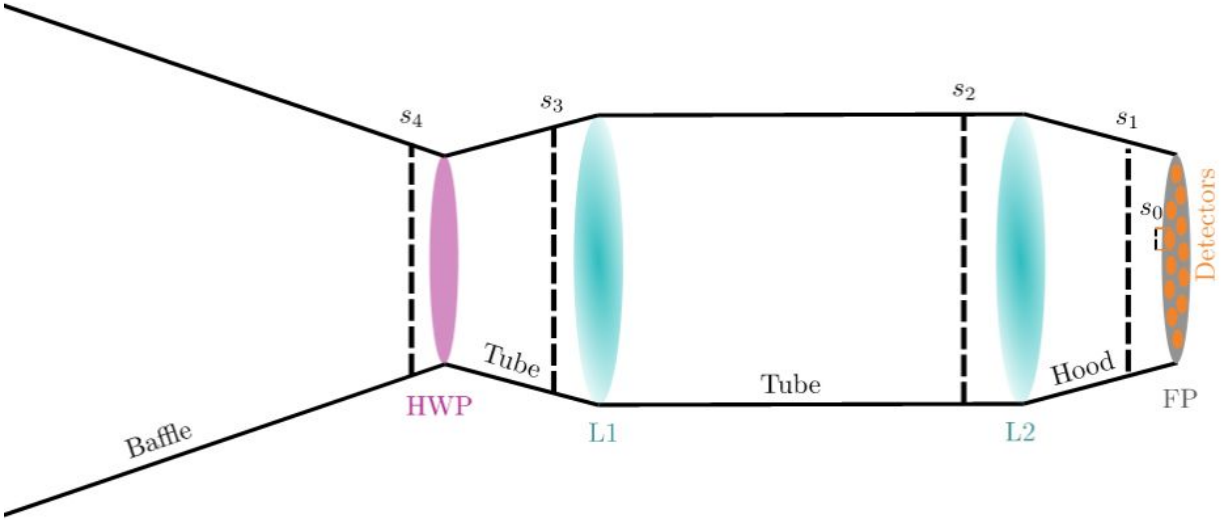
Simple refractive design

Mechanical and optical elements:

- Two lenses L1 and L2
- One half-wave plate (HWP)
- A focal plane (FP) paved with detectors
- Baffle + Tube + Hood
- Hypothetical filters at positions s0 (on-chip), s1, s2, s3, s4

Cryogenic systems not modeled

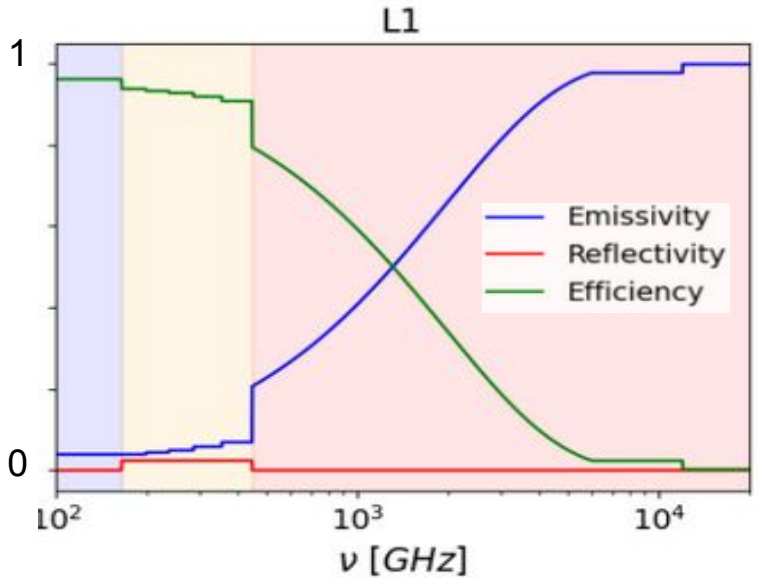
Instrumental emission => Black body at the element temperature



Optical model

Each optical element is modeled in terms of emissivity, reflectivity and efficiency such as

$$E(\nu) + R(\nu) + \varepsilon(\nu) = 1$$



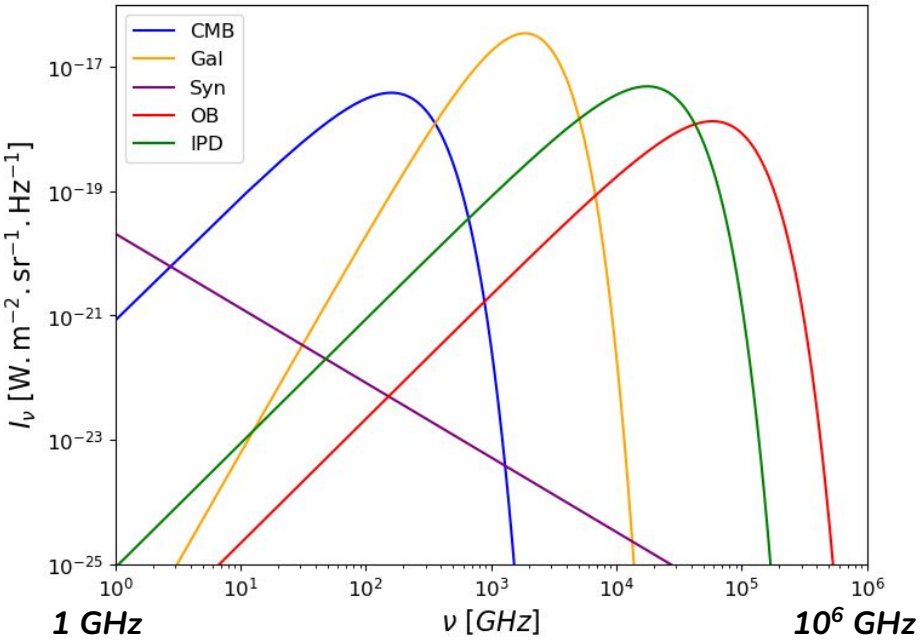
Sky modelling

We consider 5 components :

- CMB
- Thermal Galactic dust emission
- Synchrotron emission
- Interplanetary dust (IPD)
- O and B stars

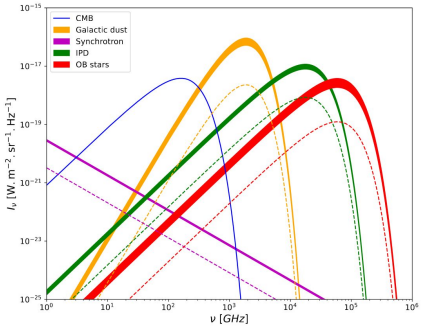
The SED amplitudes are scaled on available measurements taking into account the beam of the instrument.

Spectral radiance [W/m^2/sr/Hz]
(example for a 1° beam)

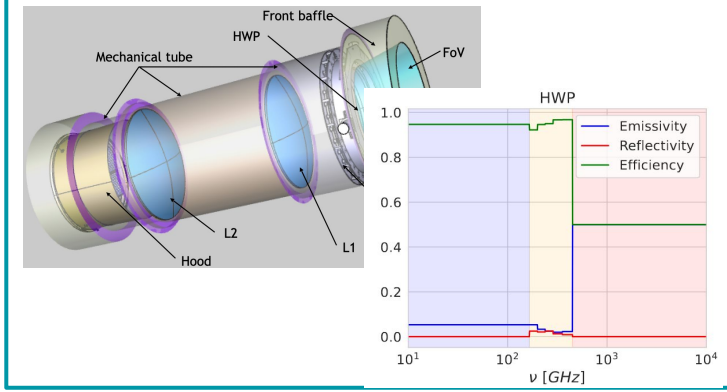


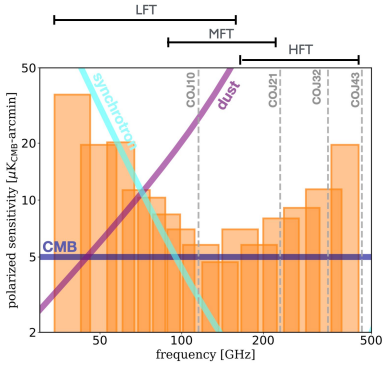
Performance code overview

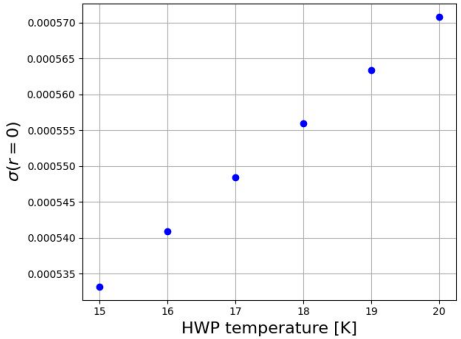
Sky model



Instrument model





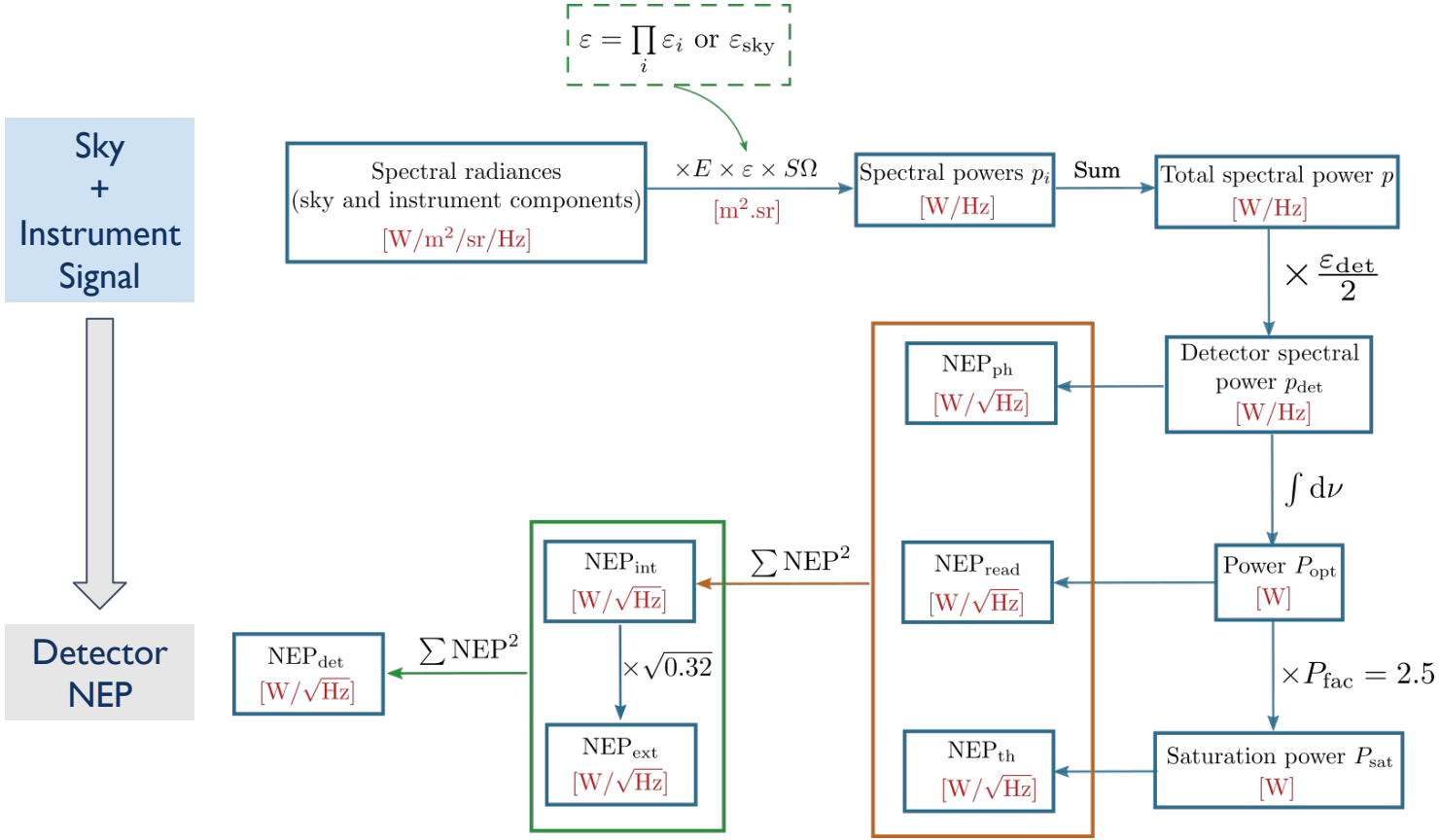


Sensitivities [μK-arcmin]

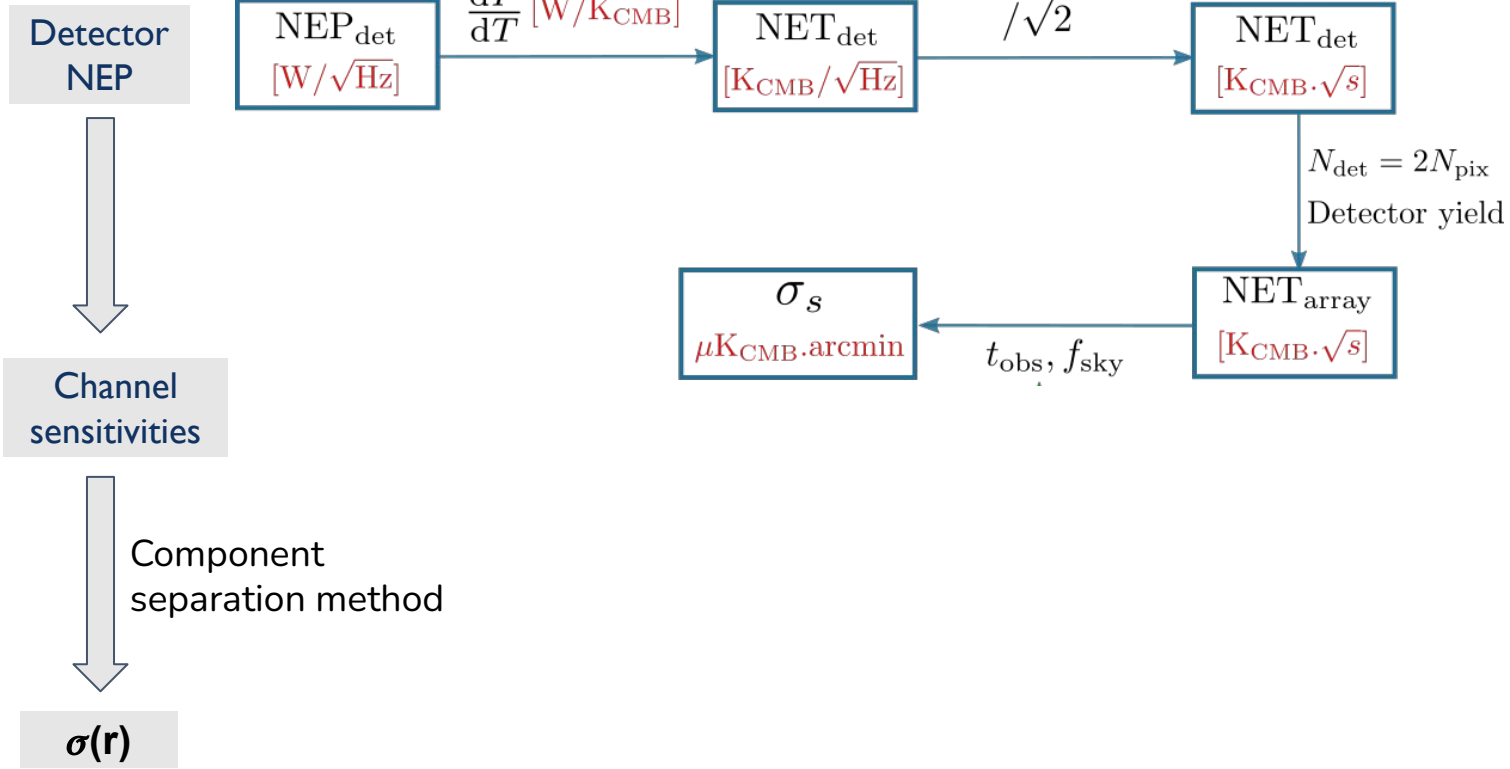
$\sigma(r)$

Performance computation

Performance code : detector NEP computation

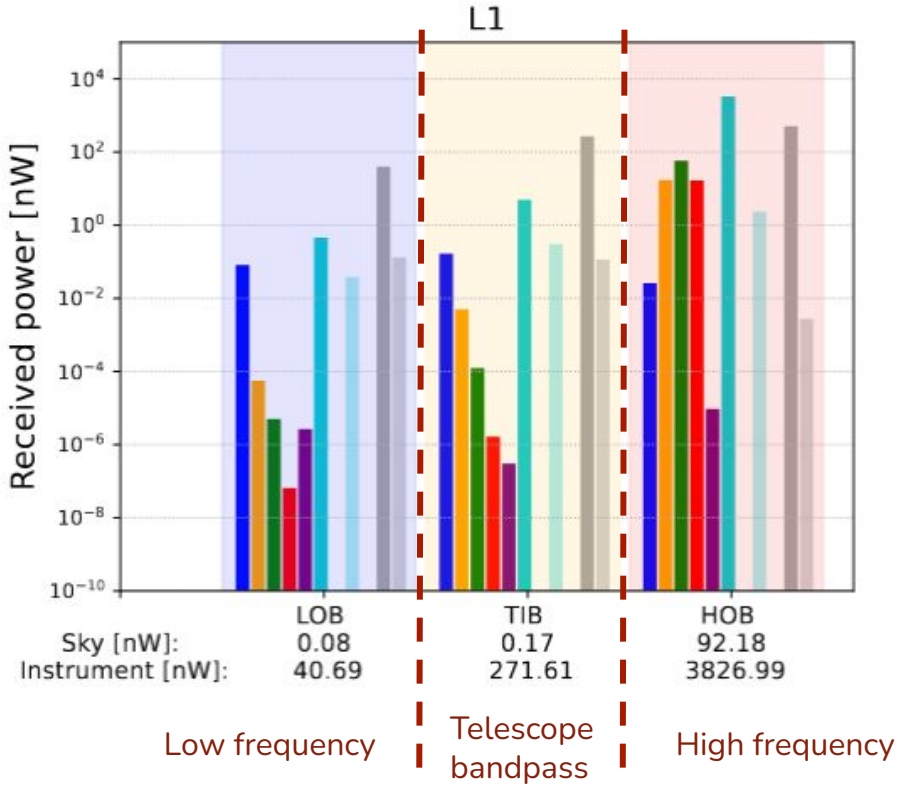


Performance code : channel sensitivities and σ(r)



Performance code : thermal balance control

Radiative heat load on L1 from sky and instrument components :



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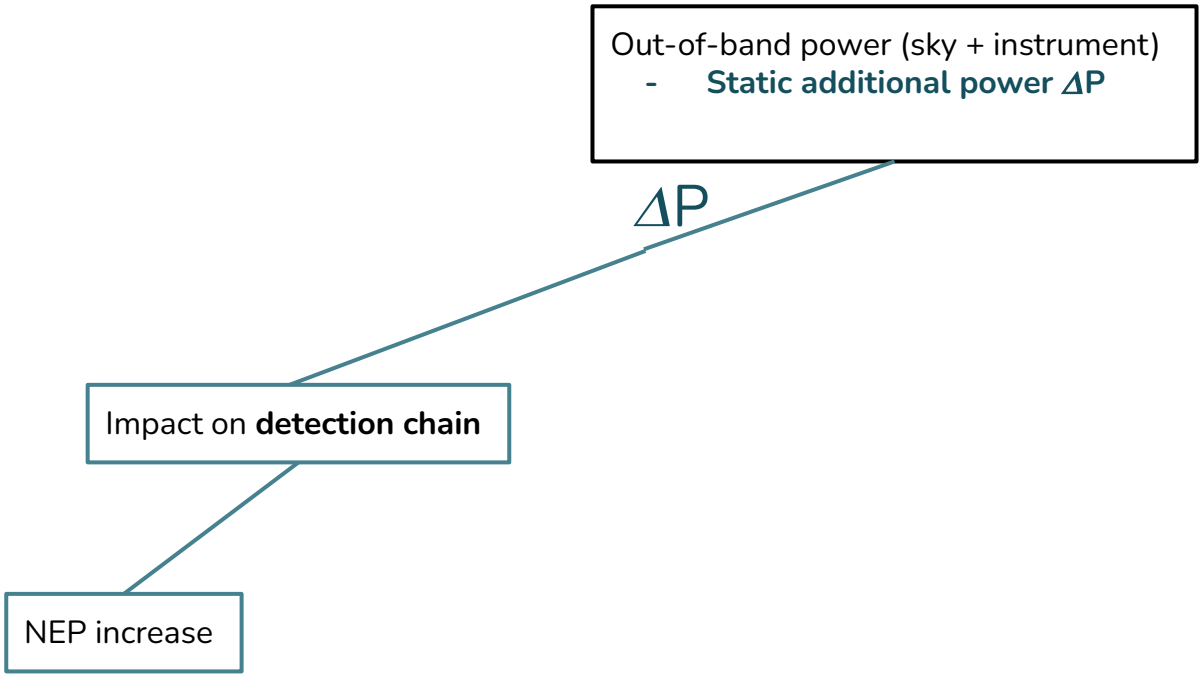
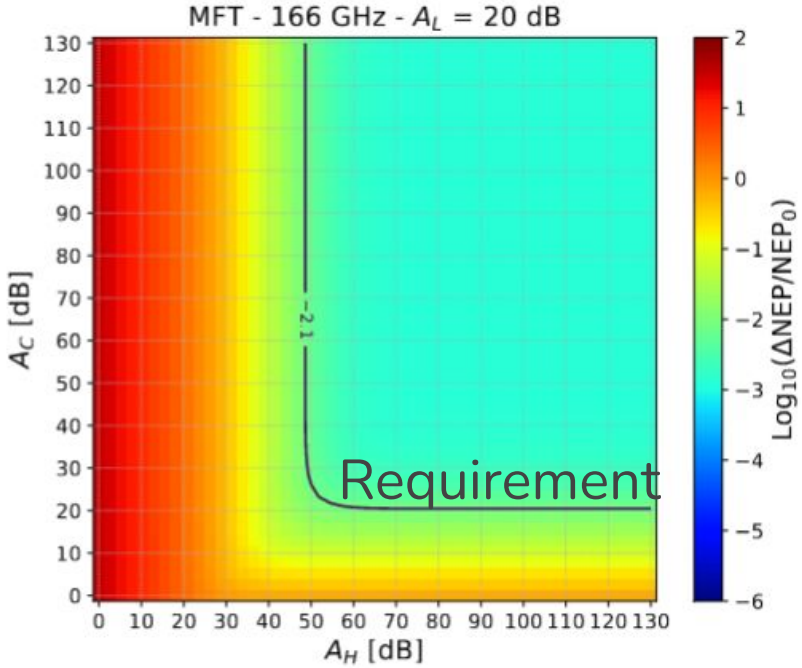


Additional NEP and corresponding requirements

$$\delta r < 0.001 \longrightarrow \Delta\mathrm{NEP} \leq 0.14\,\mathrm{aW}/\sqrt{\mathrm{Hz}}$$



Reference NEP with no out-of-band power

Summary

- I presented a general approach to set requirements on out-of-band rejection level for a CMB instrument.

- This method was applied to the LiteBIRD instrument design and the results will be published in a paper.

- This work was accompanied by the development of a performance code for the instrument, now available within the collaboration.

Thank you for your attention !

Backup slides

Noise budget allocation