

COSMO: Beyond the black-body Cosmic Microwave Background, towards the detection of spectral distortions

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on behalf of the COSMO collaboration
<https://cosmo.roma1.infn.it>

The 8th Workshop of SCAR AAA
Phuket, 15-19 September 2025



Università
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Astronomy and
Astrophysics from
Antarctica



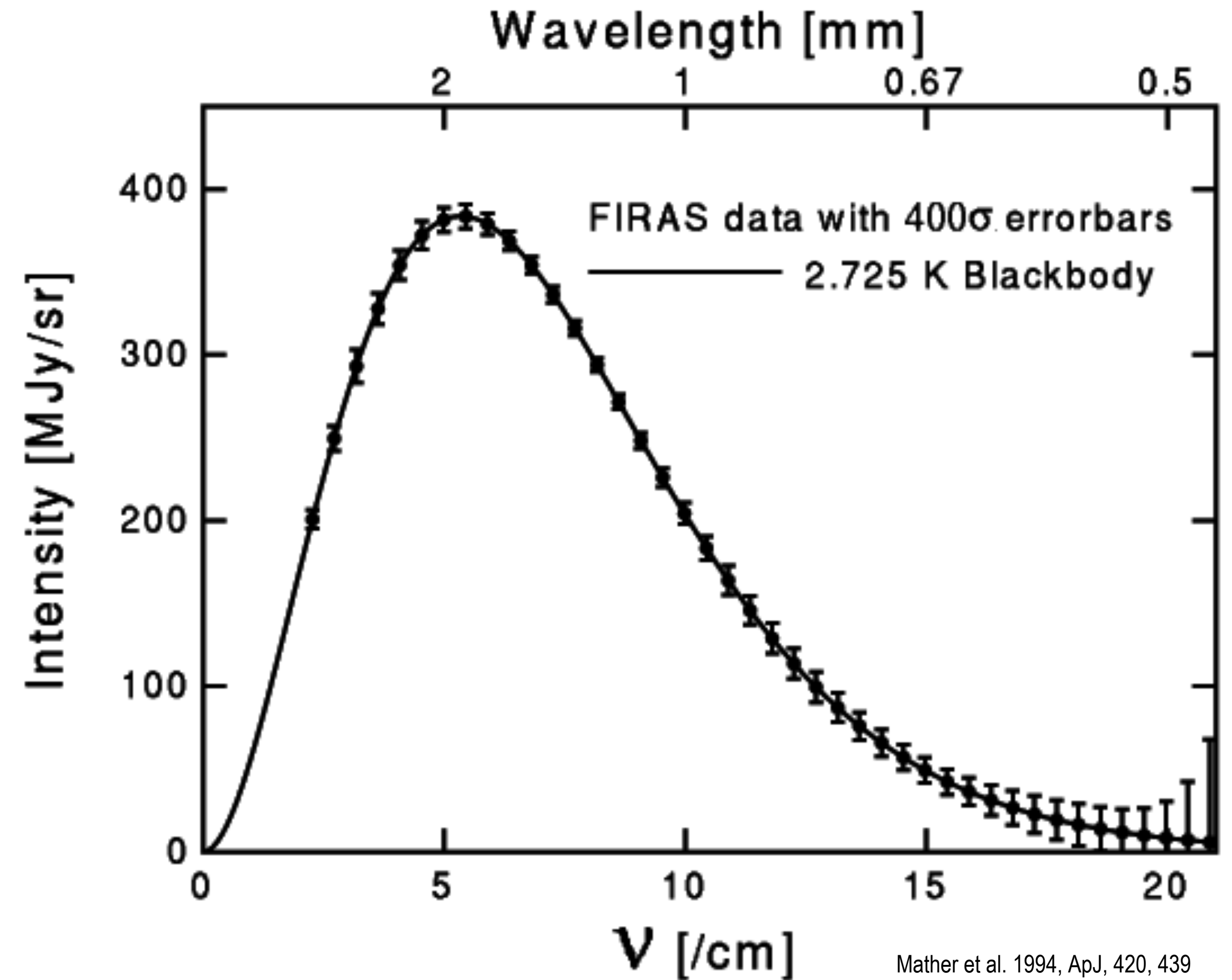
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The CMB in a nutshell

Scientific framework

The Cosmic Microwave Background (CMB) radiation is:

- a relic radiation coming from the primordial Universe
- a nearly perfect black-body at the temperature of $T_{CMB} = (2.725 \pm 0.001)K$, today
- tiny **spectral distortions** are expected due to different physics processes in the primordial Universe



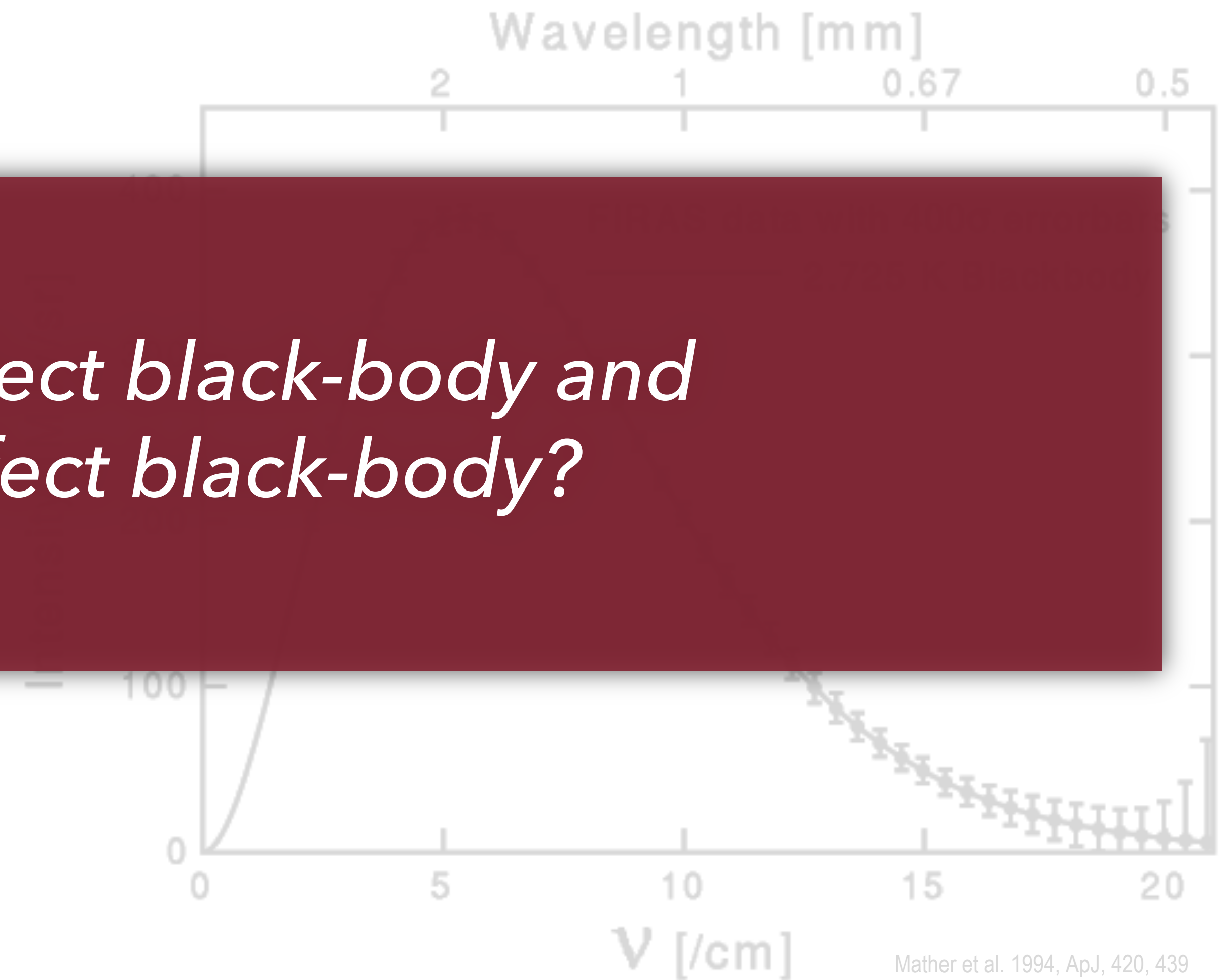
The CMB in a nutshell

Scientific framework

The Cosmic Microwave Background (CMB) radiation is:

Why an almost perfect black-body and not an ideal perfect black-body?

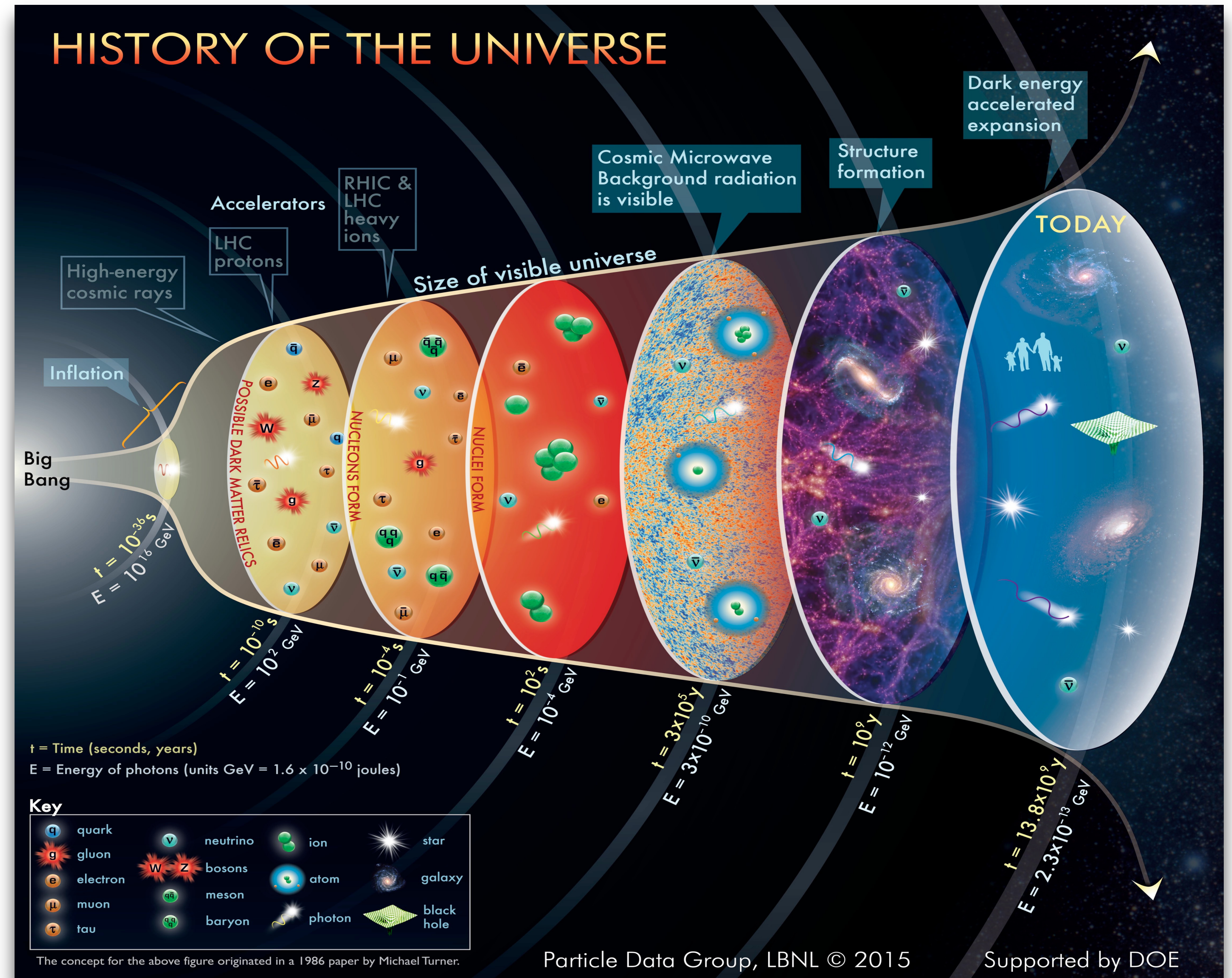
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The thermalization problem

Scientific framework

- Thermal history of the Universe
- Full thermodynamic equilibrium
- Energy release → spectral distortion
- Thermalization processes (Bremsstrahlung, Thompson Scattering, Double Compton)

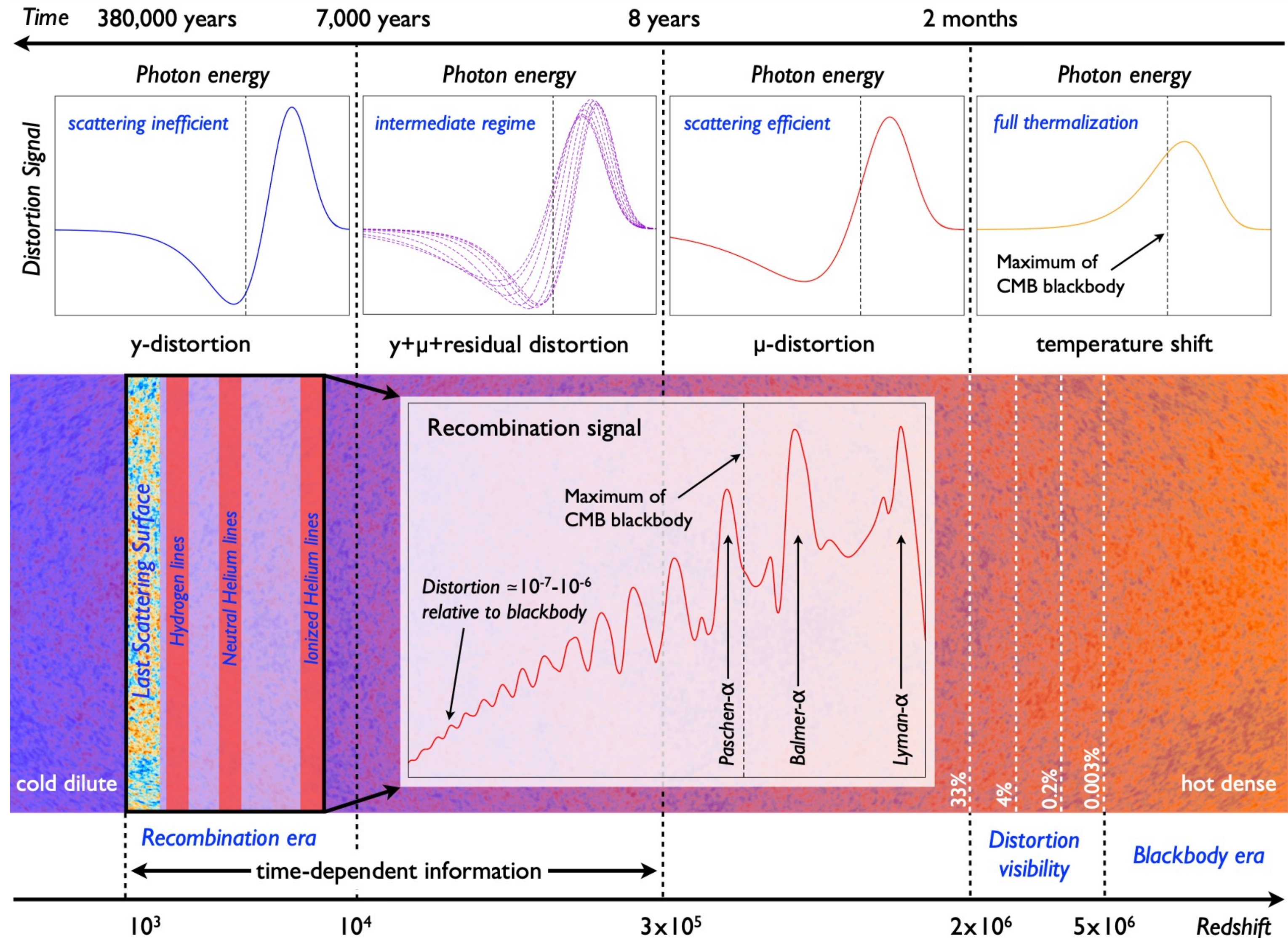


Types of spectral distortions

μ -type distortion

Early release of energy turns CMB spectrum into a Bose-Einstein distribution with non-zero μ

$$S_{\mu}(\nu; T, \mu) = \frac{2h\nu^3}{c^2} \frac{1}{e^{x+\mu}-1}$$



Types of spectral distortions

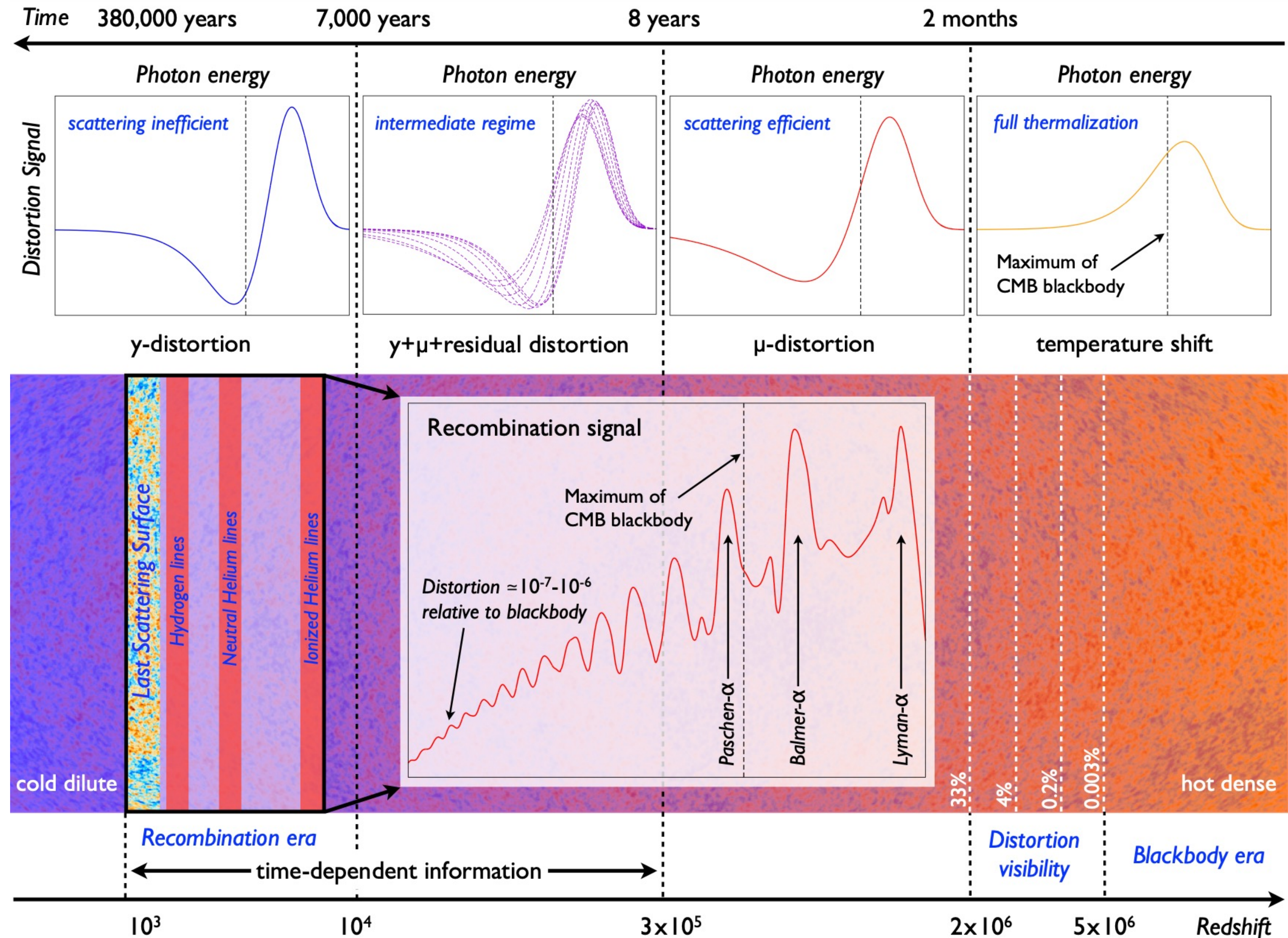
y -type distortion

Later release of energy in the non efficient scattering regime. Same physics of the tSZ effect.

COBE-FIRAS upper limits

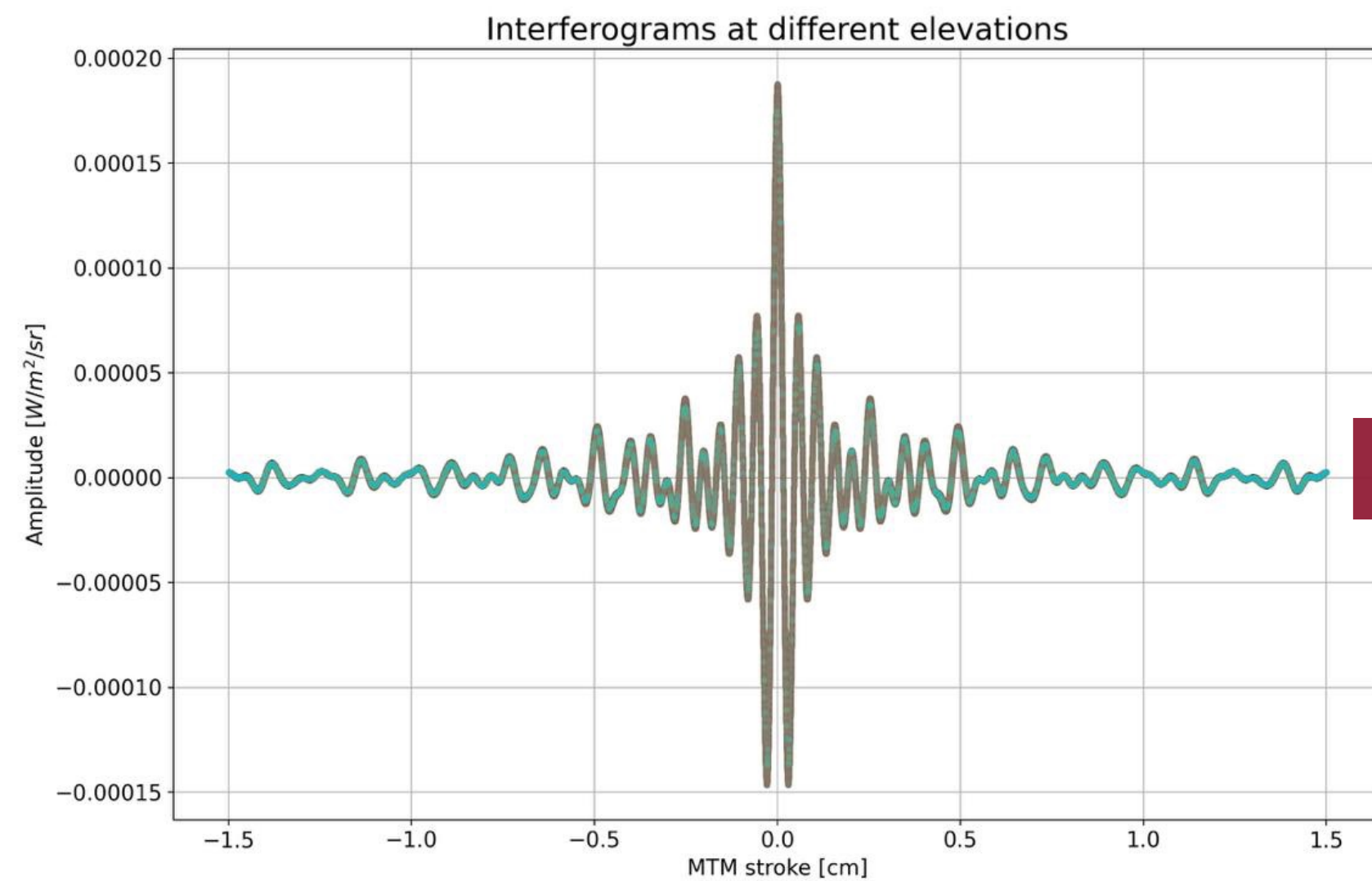
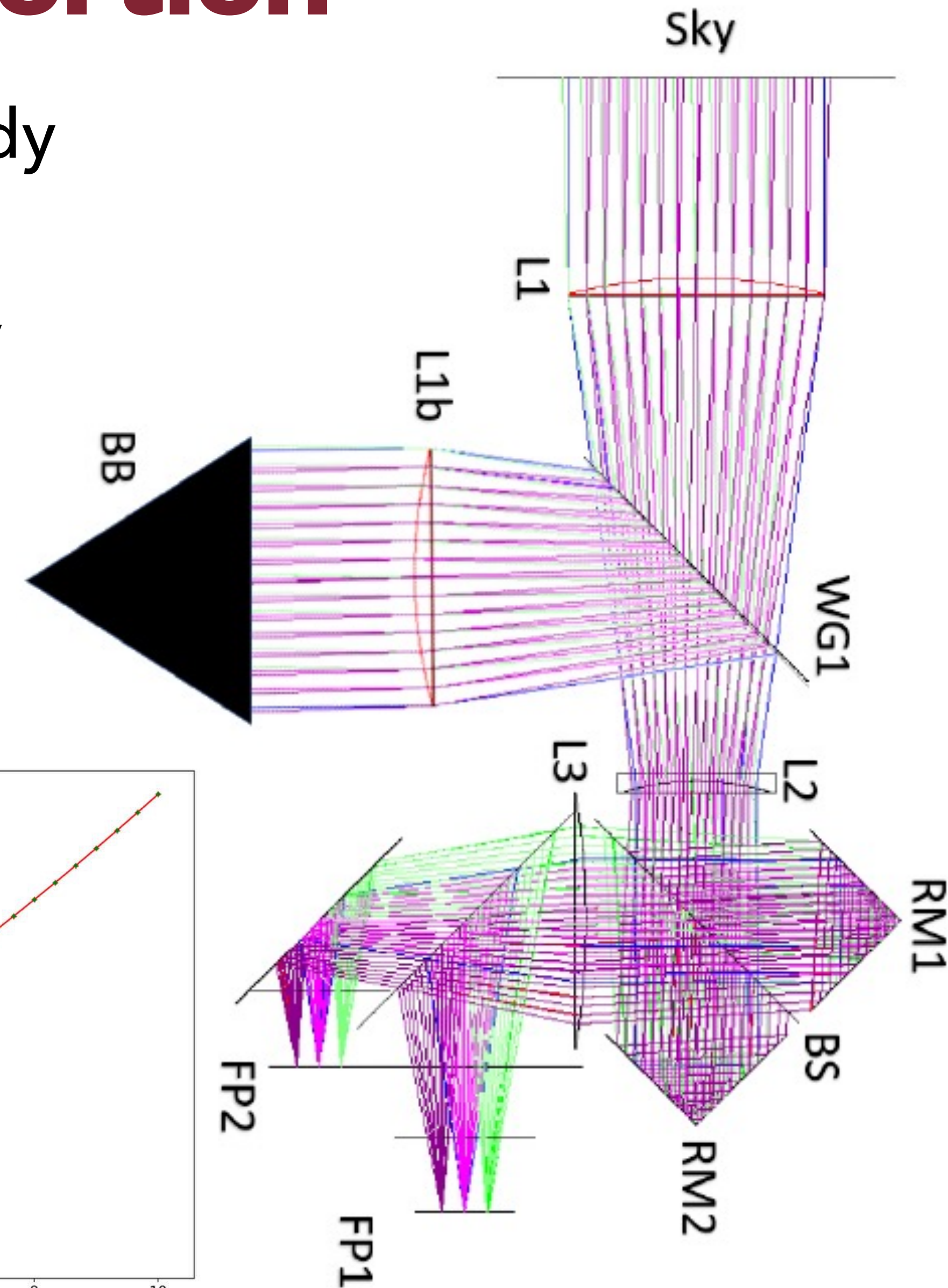
$$y < 1.5 \times 10^{-5} \text{ CL } 95\%$$

$$|\mu| < 9 \times 10^{-5} \text{ CL } 95\%$$

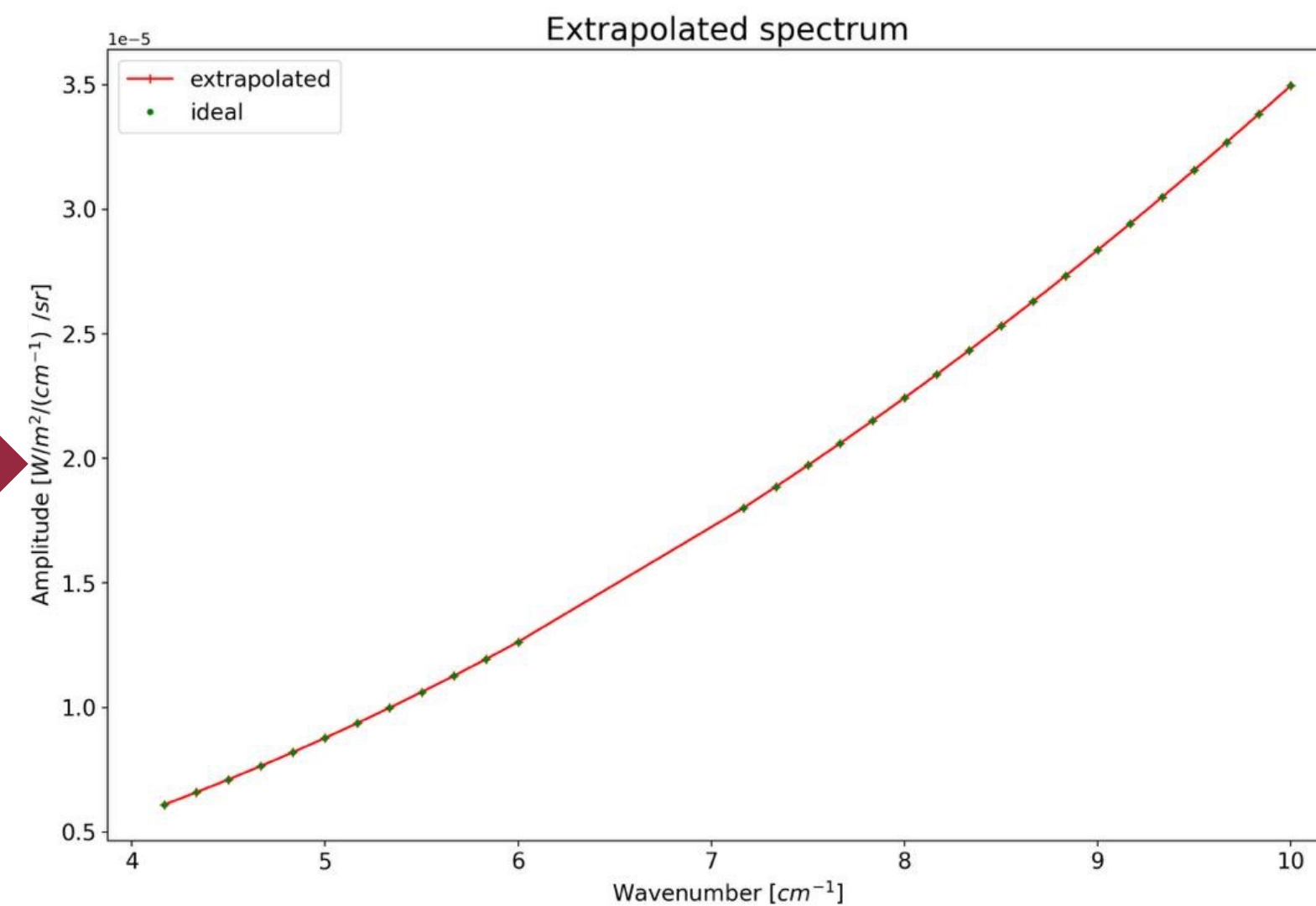


How to measure a Spectral Distortion

- Fourier Transform Spectrometer (FTS) with a black-body calibrator
- Measures the difference in brightness between the sky and the calibrator
- Movable roof mirror to obtain the interferogram
- Detectors at each output of the FTS



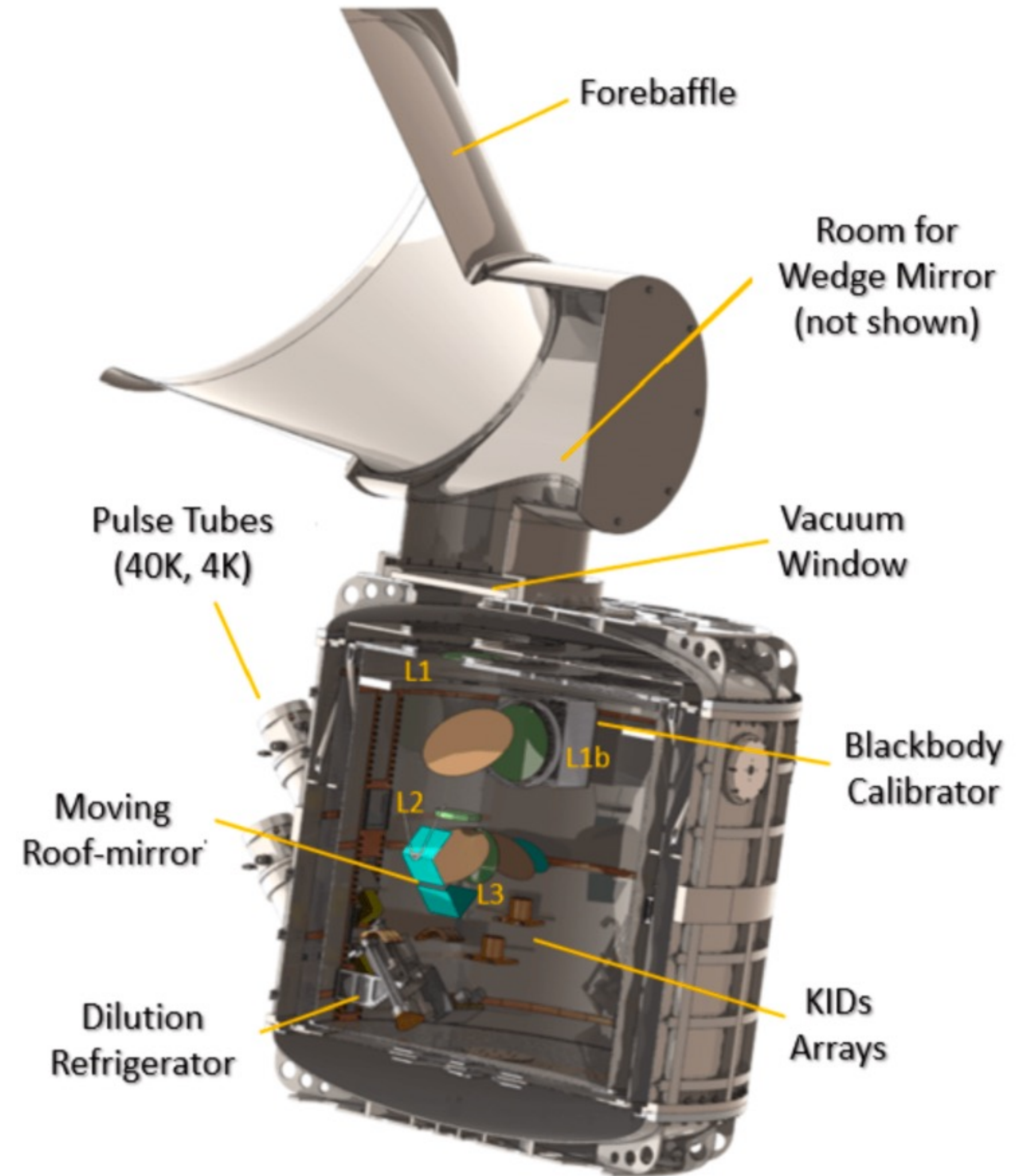
FFT



Credit @ E.Marchitelli

The COSMO experiment

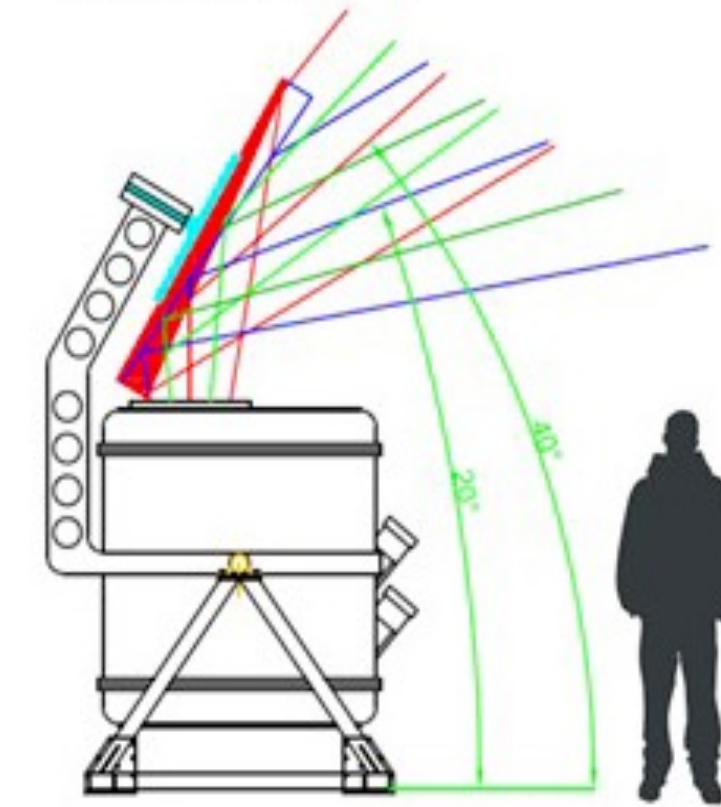
- Aims at measuring the y -type spectral distortion of the CMB monopole
- Is a cryogenic Differential Fourier Transform Spectrometer
- Has two multimode LEKID arrays centered at 150 and 250 GHz
- LEKIDs coupled with the DFTS via multi-mode horn arrays
- In the ground-based implementation will be operated from **Dome-C**, Antarctica



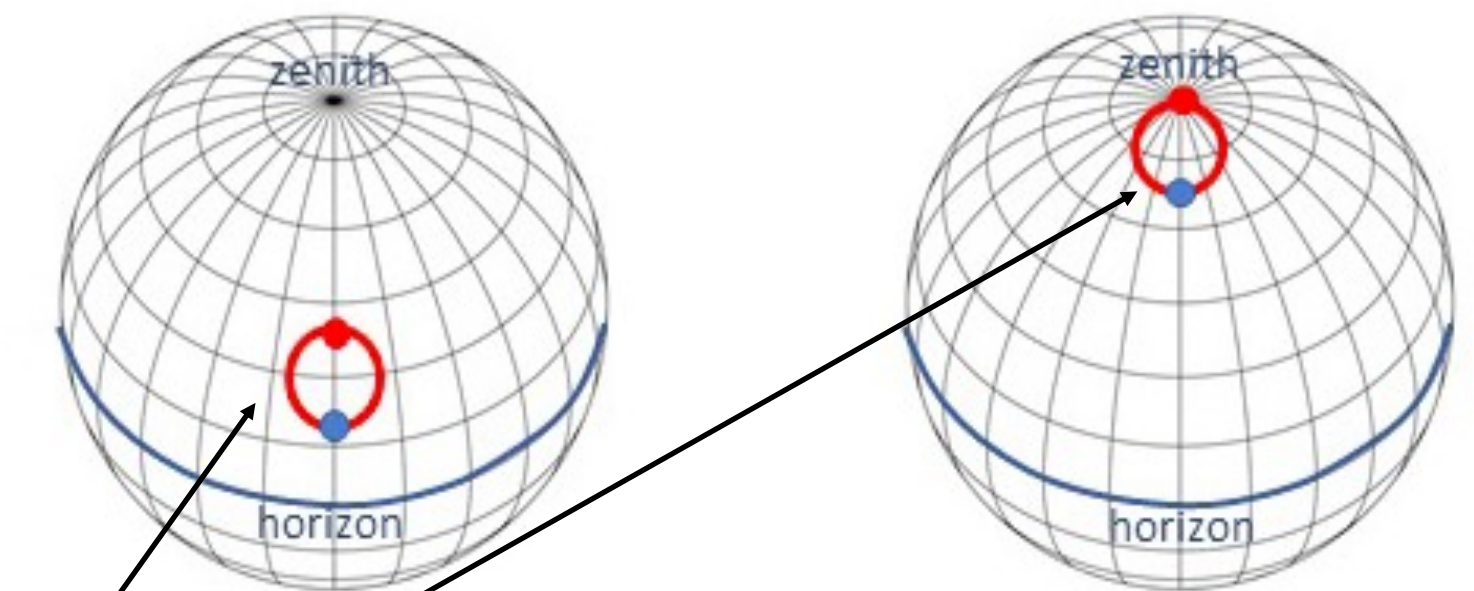
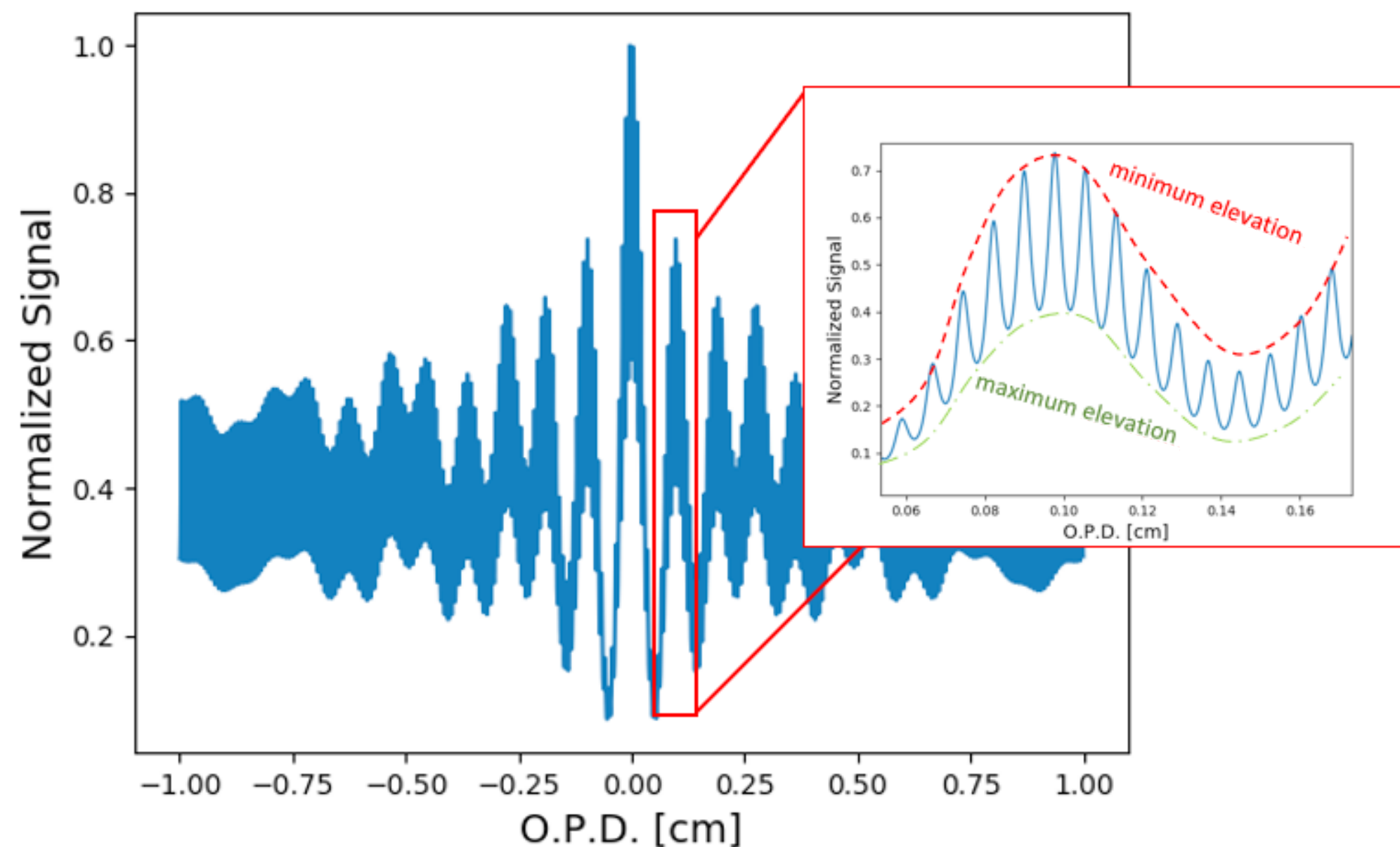
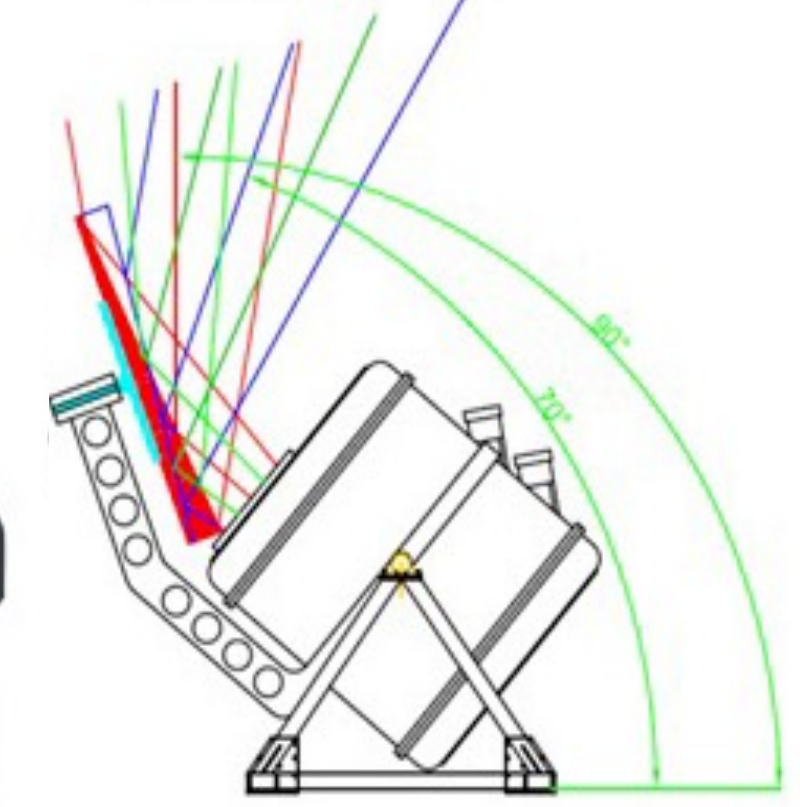
Measurement strategy

- Even if Dome-C is the best observation site on the Earth, the **atmospheric emission** contributes significantly to the signal.
- **Fast sky modulation** with a rotating wedge-mirror is required to separate the CMB monopole from the atmospheric emission.

Cryostat tilt = 0°
PT tilt = 40°
Min. elev. = 20°
Max. elev. = 40°



Cryostat tilt = 50°
PT tilt = -10°
Min. elev. = 70°
Max. elev. = 90°



Superposition of the CMB Monopole (const) and different air masses

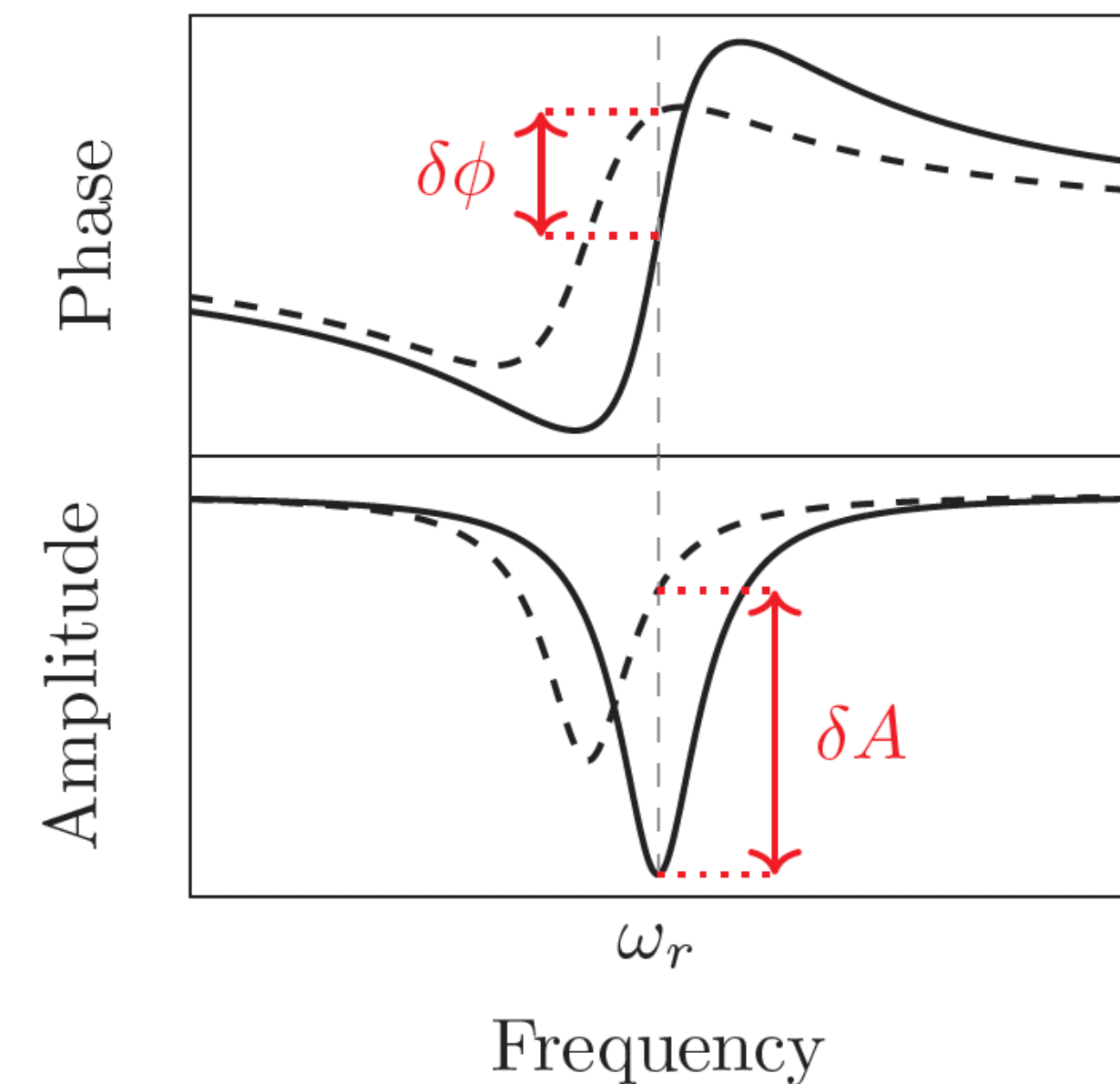
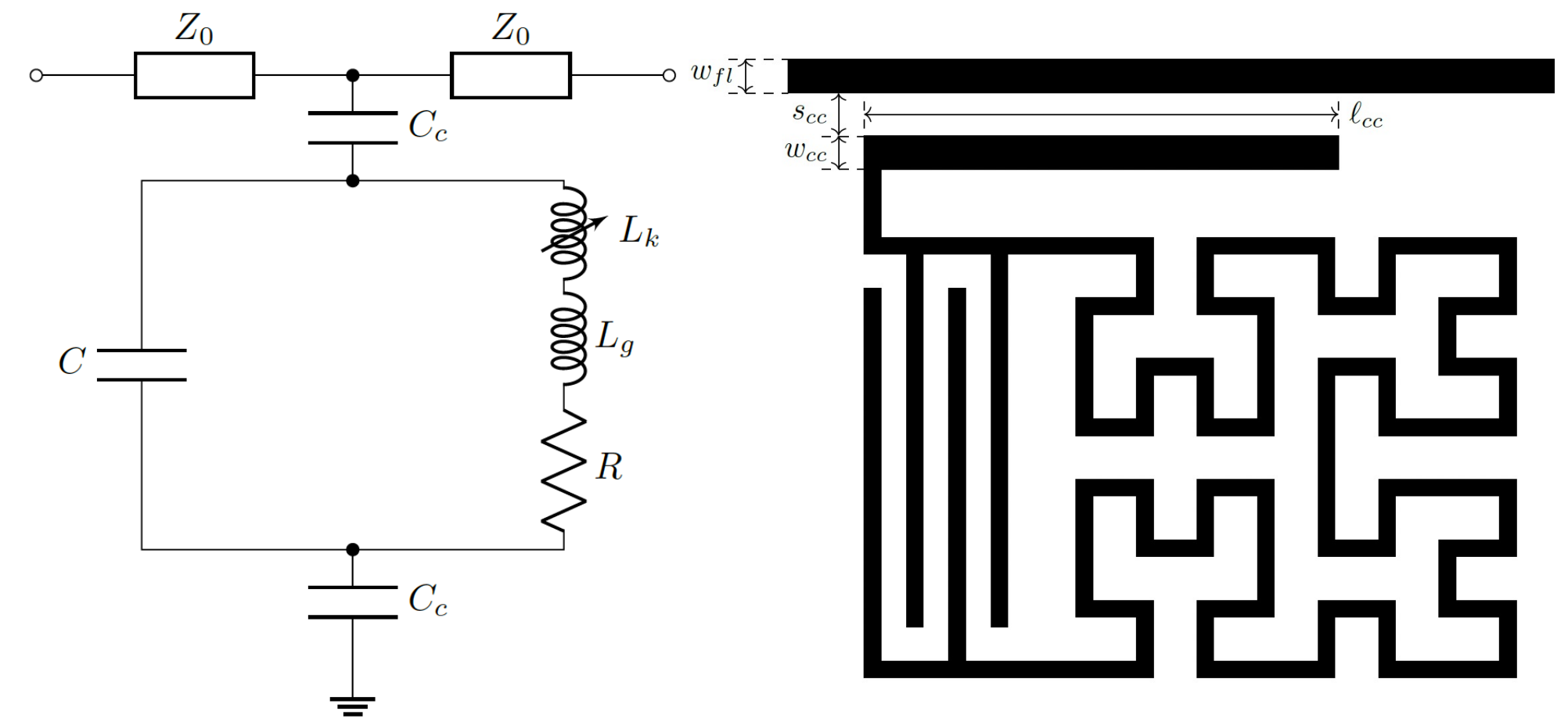
Kinetic Inductance Detectors

Working principle

- At $T < T_c$ there are two types of electrons: Cooper pairs and quasi-particles
- Radiation with $h\nu > E_B \simeq 3.528k_B T_c$ can break the Cooper pairs producing a change in L_k
- This causes a change in ν_r and in the quality factors

$$\nu_r \sim \frac{1}{\sqrt{L_{tot}C}}$$

$$L_{tot} = L_g + L_k$$



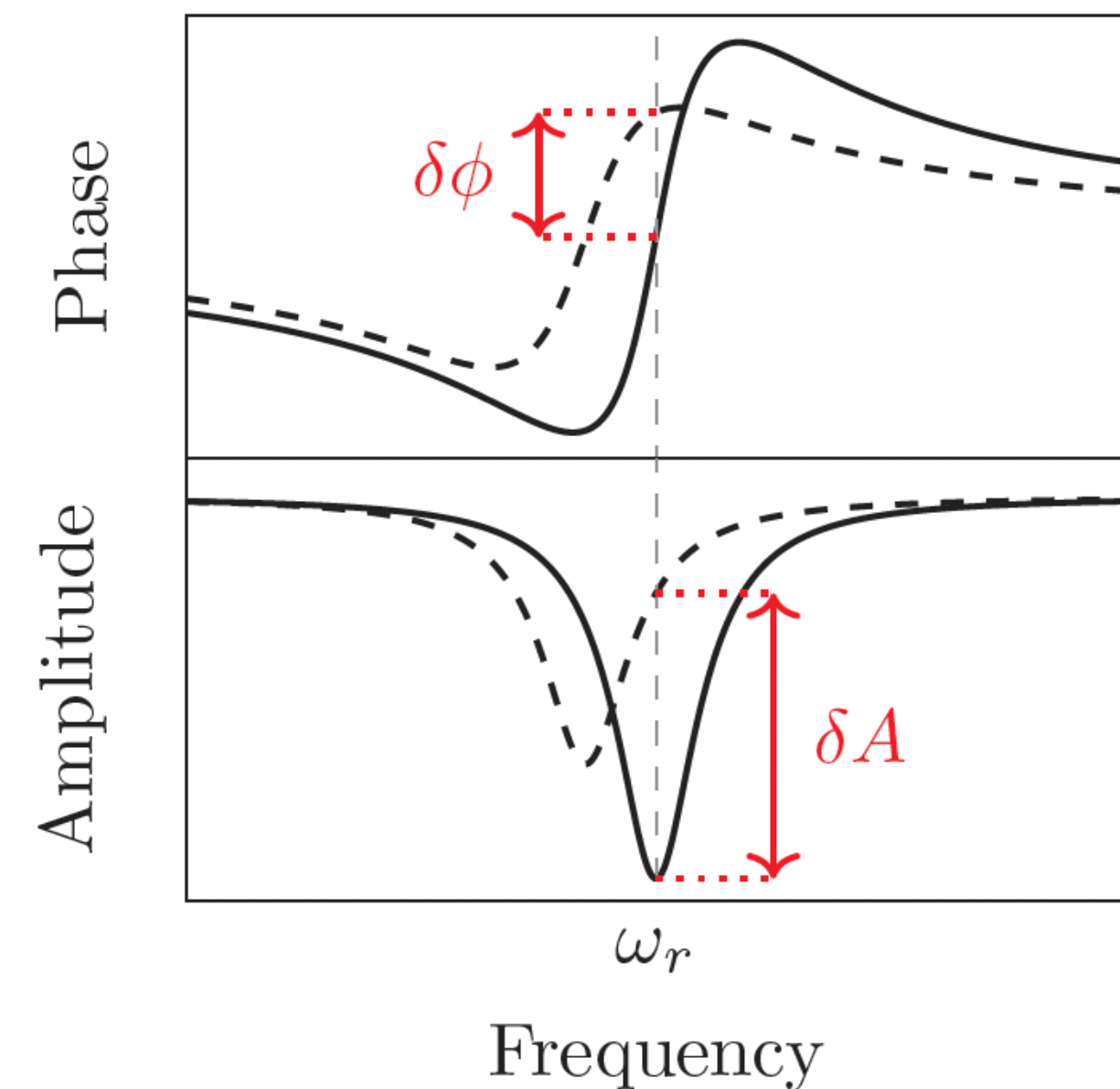
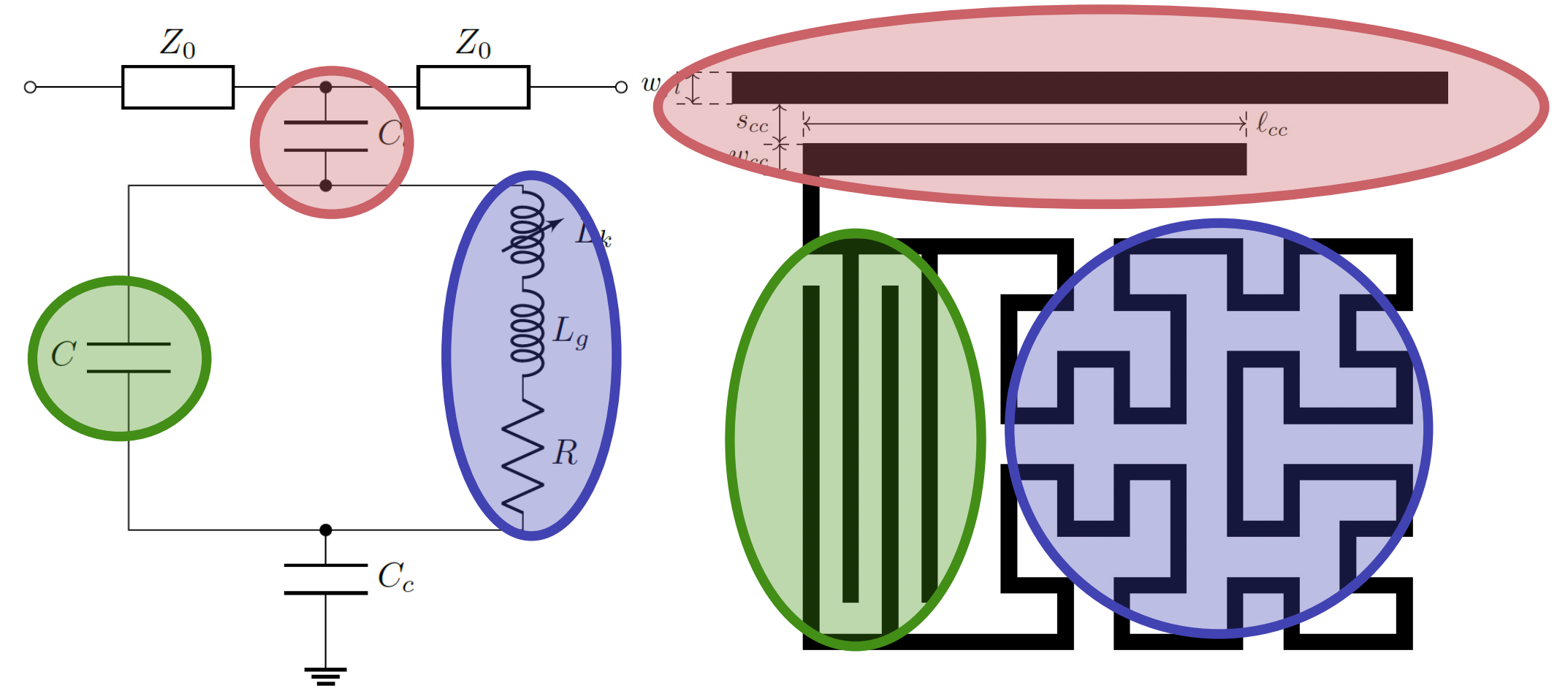
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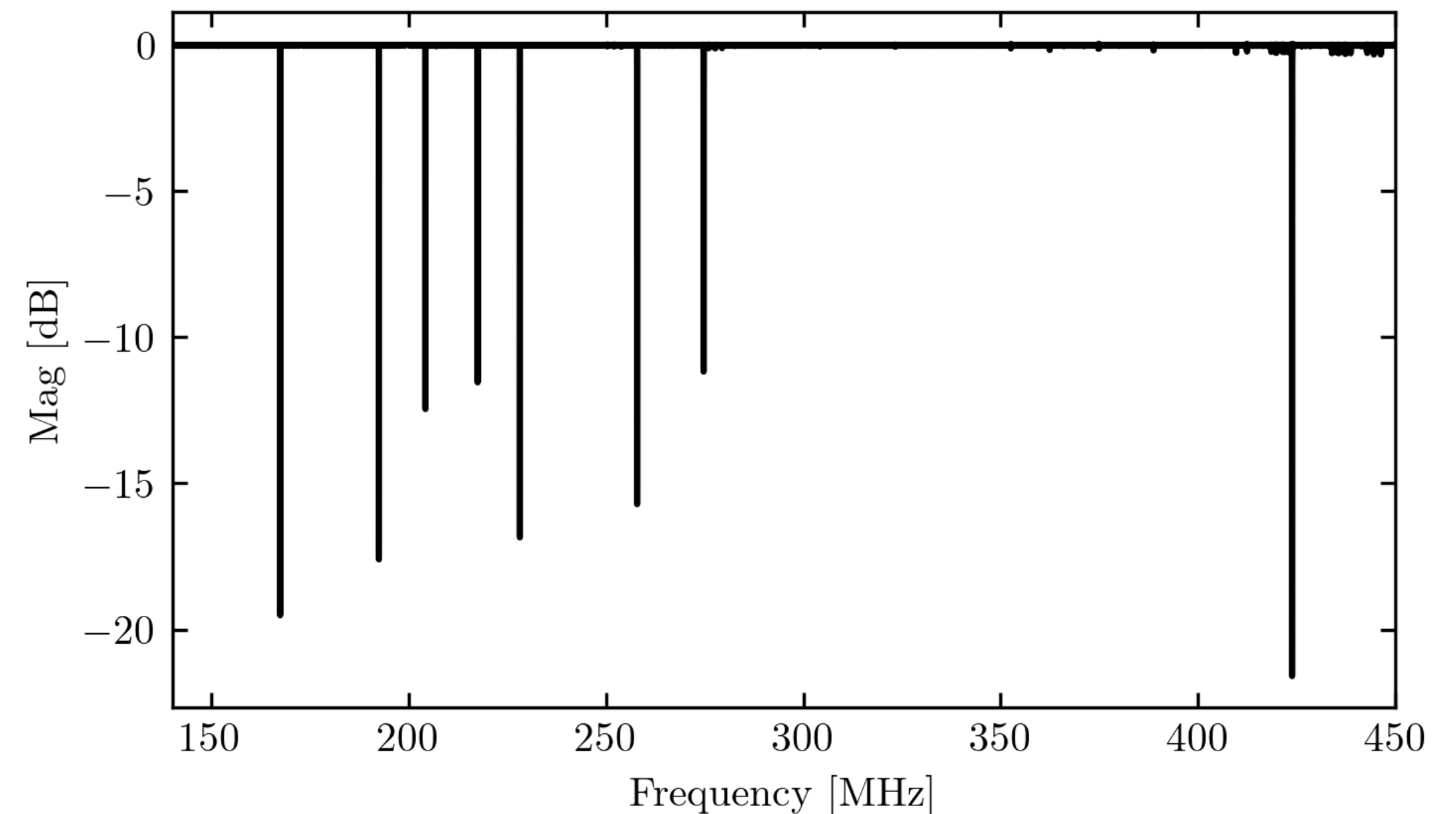
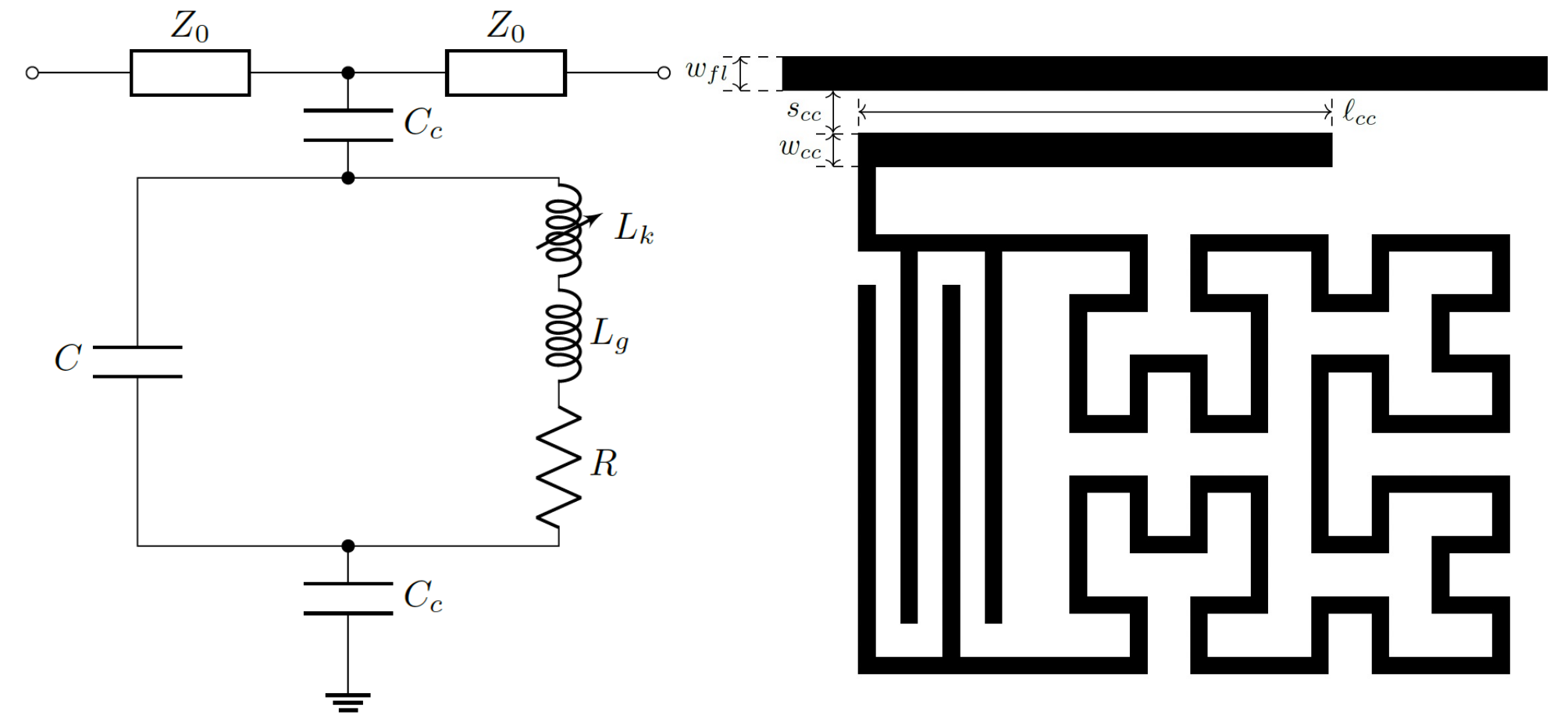
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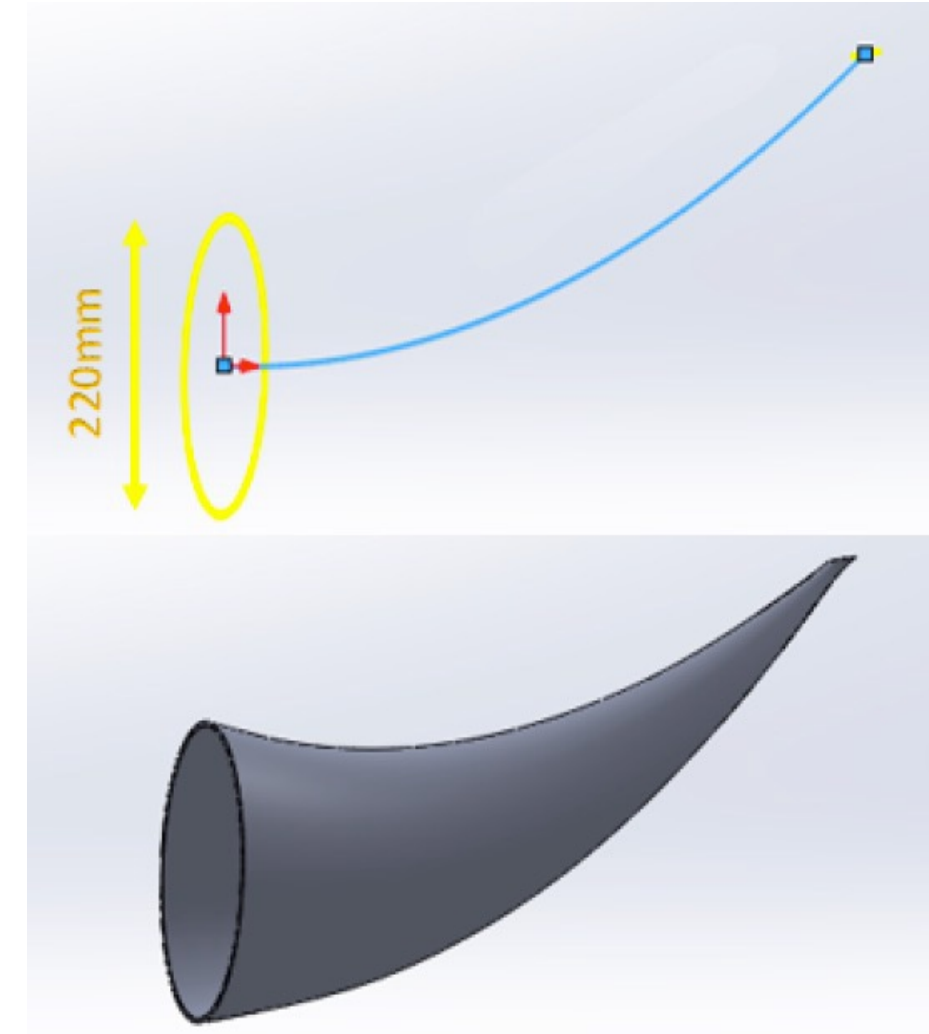
COSMO Lumped Element KIDs

- Multi-mode Lumped Element KIDs (LEKIDs)
- Fast detectors $\tau \simeq 100 \mu s$
- Two bands centered at 150 GHz (up to 19 modes) and 250 GHz (up to 42 modes)
- 9 pixels per array
- Electrical characterization at $T_{op} = 150mK$
- 8 alive KIDs, 1 at higher frequency



The Black-Body calibrator

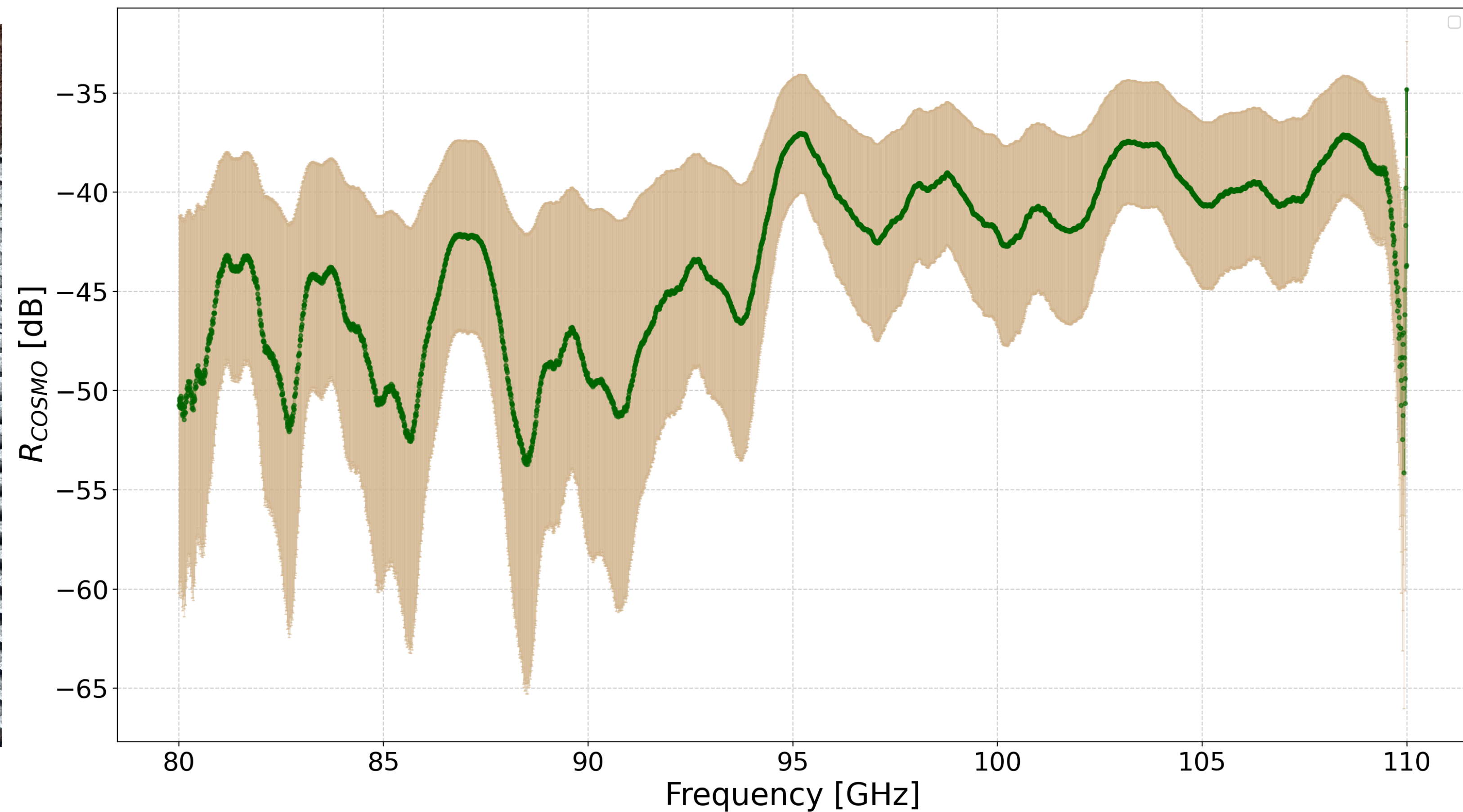
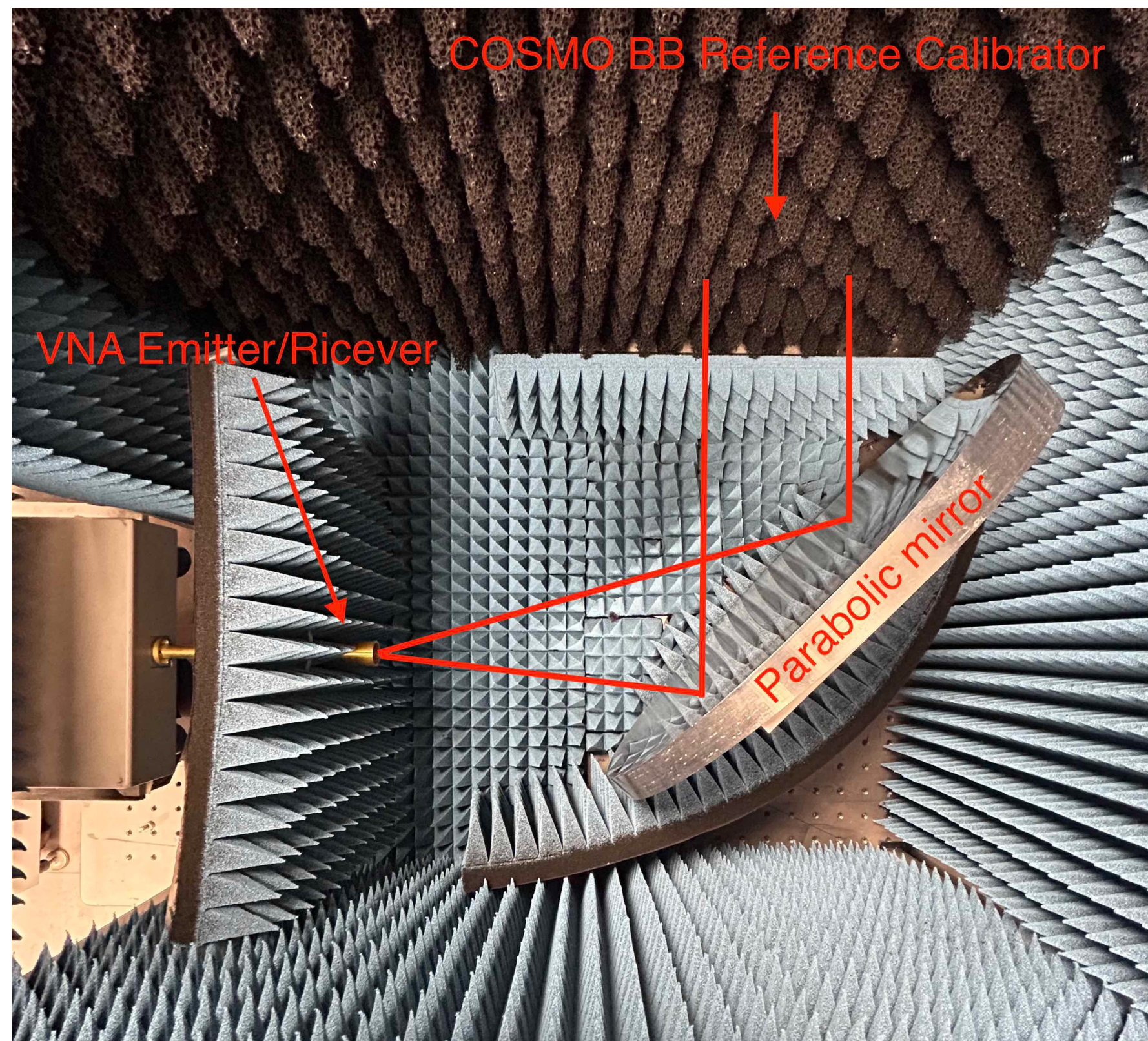
- The COSMO Black-Body calibrator is a circle swept along a parabola, with an aperture of 220 mm
- The external body is made of copper and the absorbing coating is a 10 mm thick layer of Eccosorb CR-110
- Eccosorb CR-110 is a bi-component epoxy resin, used as absorber at $\nu > 26\text{GHz}$
- We build and test a re-scaled version with an aperture of 60 mm



The Black-Body calibrator

VNA measurements

- We infer the emissivity of the calibrator by measuring its on-axis reflectivity as $\epsilon_{cal} = 1 - R_{cal}$



Take home messages

- The first detection of post-recombination y -distortion will set a standard for research into the formation of large-scale structures in the Universe. This will shed light on feedback processes and missing baryons.
- A differential approach is essential \longrightarrow We need a black-body calibrator
- COSMO will demonstrate the performance of the fast sky-dip method in removing the bulk of atmospheric emissions and their slow fluctuations
- LEKIDs are a cutting-edge detectors, without which the measurement strategy is impossible to implement.

Thank you !



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