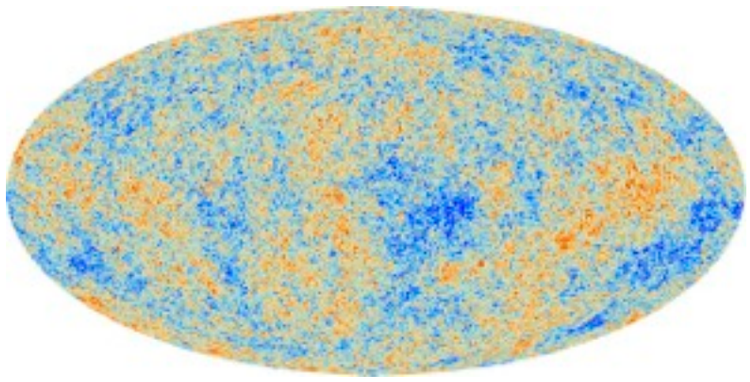
Microwave and Millimeter Wave Spectro-Photometry to target Cosmic Microwave Background Spectral Distortions

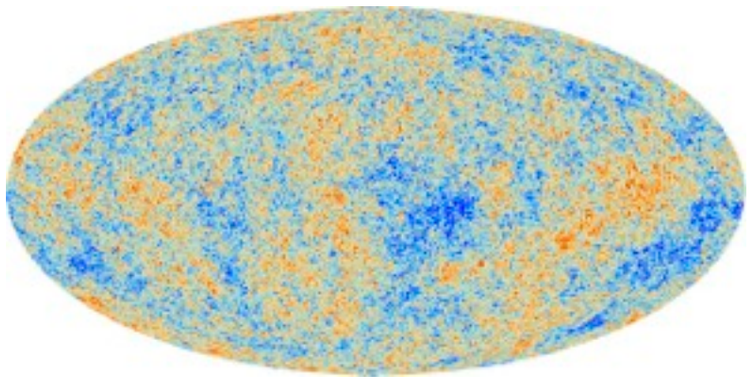
A. Tartari, APC & PCCP

Reconsidering the CMB frequency spectrum...



...and its **distortions** after energy release in the primordial Universe (+ atomic transitions during Recombination)

Reconsidering the CMB frequency spectrum...



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Key question: is it always possible for the photon-baryon fluid to relax towards full thermodynamical equilibrium after a perturbation? (Kompaneets, 1956)

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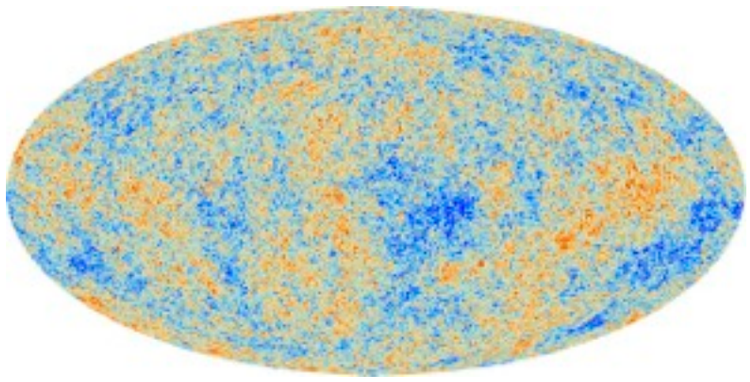

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Key answer: NO

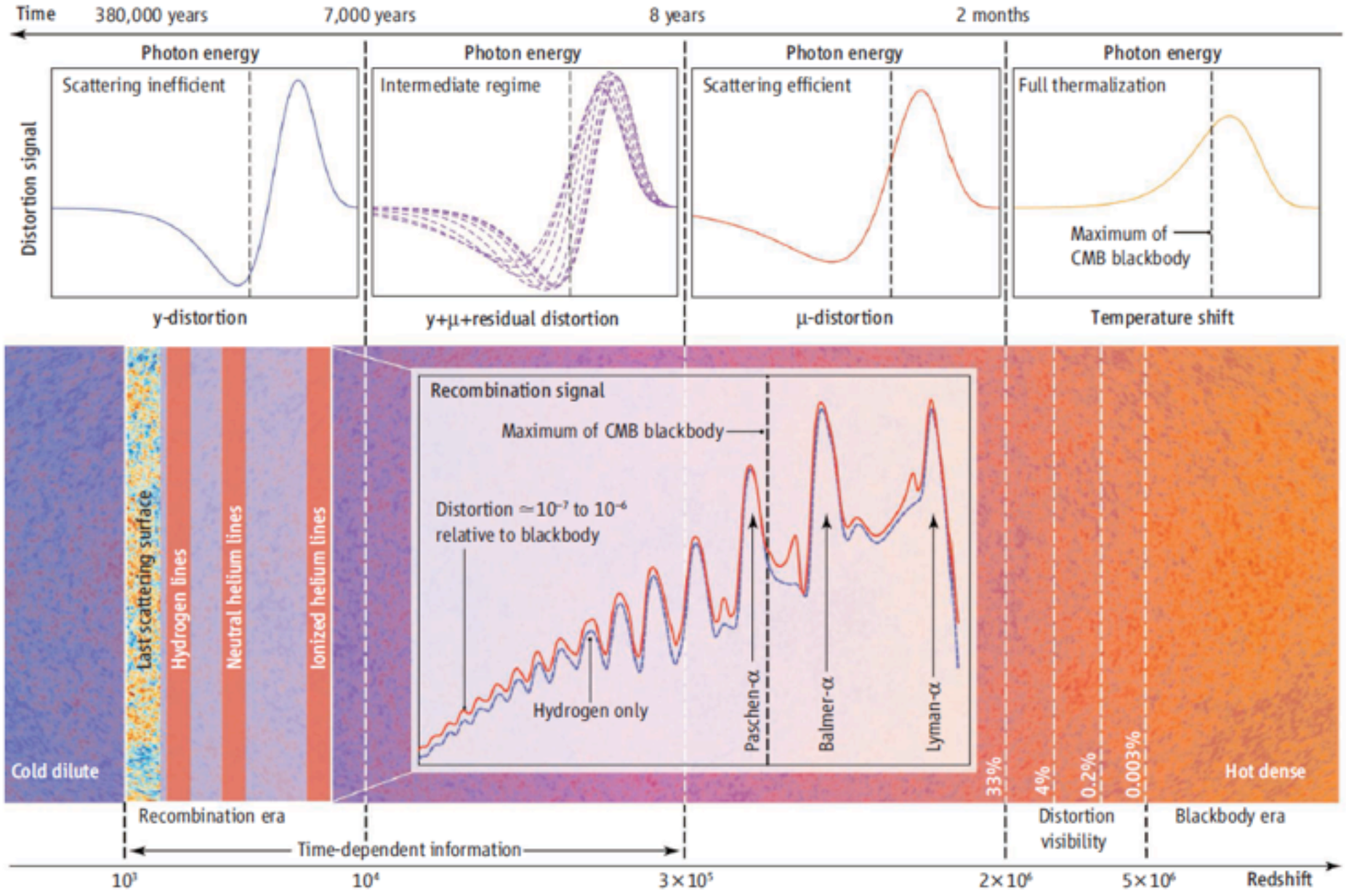
A possible view (Science, 9 May 2014)

ASTRONOMY

Next Steps for Cosmology

Recent observations from Planck and BICEP2 reveal key signatures of the Big Bang—what are the next questions for CMB cosmology in space?

Joseph Silk[1,2] and Jens Chluba[2]



Distortions and Cosmology (~0.5 GHz to ~600 GHz)

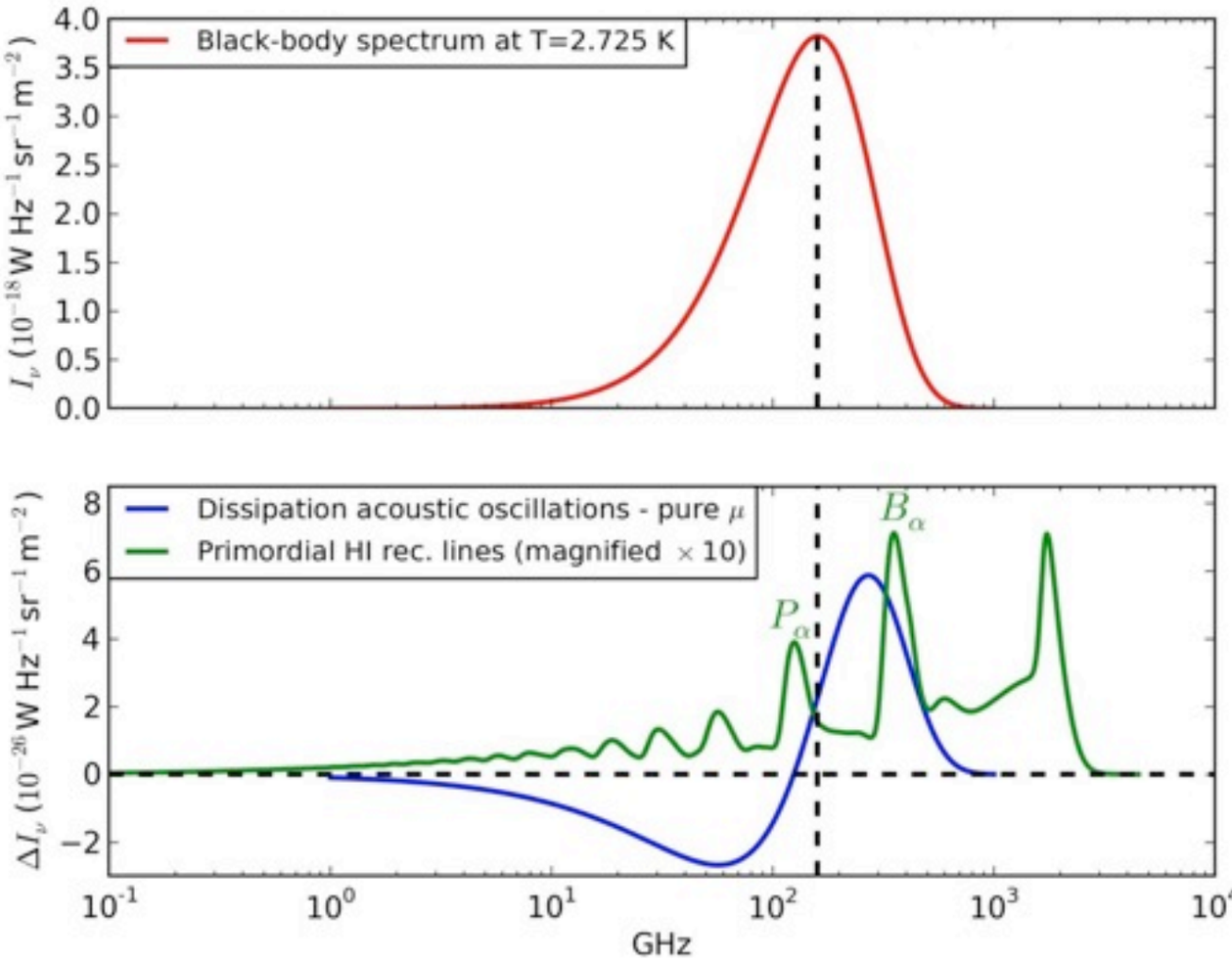
Chluba & Sunyaev MNRAS 2012 (and references therein)

1. Silk damping & Inflation
2. Electron cooling with Universe expansion
3. Atomic Line emission @ z>1000
4. Reionization

4. Relic Particle decay (Hu & Silk, PRL 1993)
5. Relic Particle annihilation (Mc Donald, PRD 2000)
6. Primordial Magnetic field dissipation (Jedamzik et al PRL 2000)
7. CMB Non-gaussianity (Pajer & Zaldarriaga, PRL 2012)
8. ...

+ Discovery potential (e.g. ARCADE2 excess)

Signals & Techniques



$$\frac{\Delta I_\nu}{I_\nu} \sim 10^{-7} \div 10^{-9}$$

Reionization (y)

Recombination (lines)

✓ Fourier Transform Spectrometers (e.g. Michelson Inferferometer)

✓ Set of Photometers covering different frequencies

✤ Other options to be explored? Filter-banks? (ERC-CoG, *submitted*)

✤ Need of cryogenic detectors

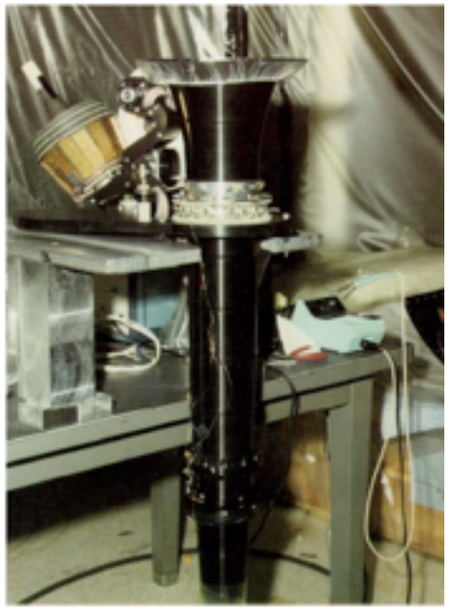
The calibrator(s): thermal sources

$$P = \varepsilon k_B T \Delta\nu \frac{x}{e^x - 1}$$

R.H.Dicke, late 40s

"shaggy dog"

COBE-FIRAS, late 80s



"trumpet mute"

ARCADE2, Early XXI Century

"carousel"

- emissivity = 0.9999999, or "darker", and flat vs frequency
- Isothermal
- Perfectly matched to antenna system
- 1D (resistor), 2D (waveguide absorber), 3D (cavity)

CMB spectral research is a *terra incognita*:

- the monopole scale is hard (no differencing)
- accuracy limit of a laboratory blackbody source?

- impact of absolute measurement fully understood?
- impact of absolute measurements *beyond* CMB? E.G.: diffuse galactic/ExtraGalactic emission?

- Spectro-polarimetry?
- angular distribution of primordial distortion signals?

General Consideration & Perspectives

- Need to go 100-1000 times deeper than FIRAS (precision + accuracy). From COBE-DMR to BICEP2...
- Smaller, intermediate steps to assess:
    1. spectro-photometric architercture
    2. sensitive cryogenic detectors
    3. calibration requirements **vs** science case
    4. artificial calibrator + antenna system

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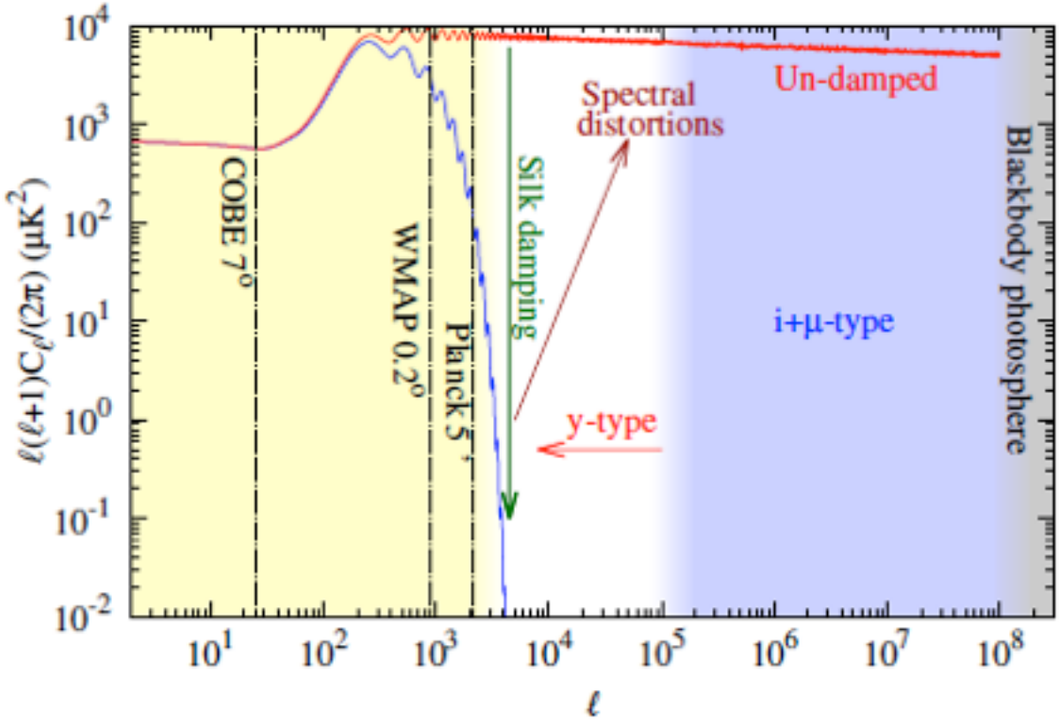
➡ Concept study?

➡ Subsystems? e.g.: the calibrator

➡A balloon demonstrator? It could target Reionization signal (~ 20 days on sky), ARCADE2 excess, Galactic Diffuse Emission.

CMB spectral distortions vs CMB polarization (WP F2)

Independent probe of Inflation. Measuring all those acoustic modes that will never reach the last scattering, that will never produce anisotropies, nor BAO



Khatri & Sunyaev

+ Unique probe of the thermal history of the Universe up to **z~10⁶**

+ Recombination physics