Unveiling the early universe with CMB spectral distortions

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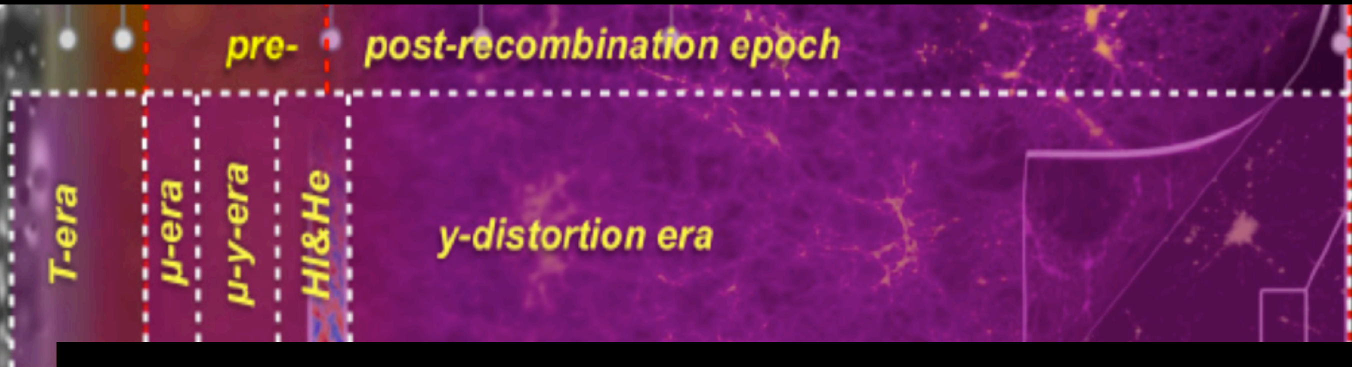
Space-like environment on Moon

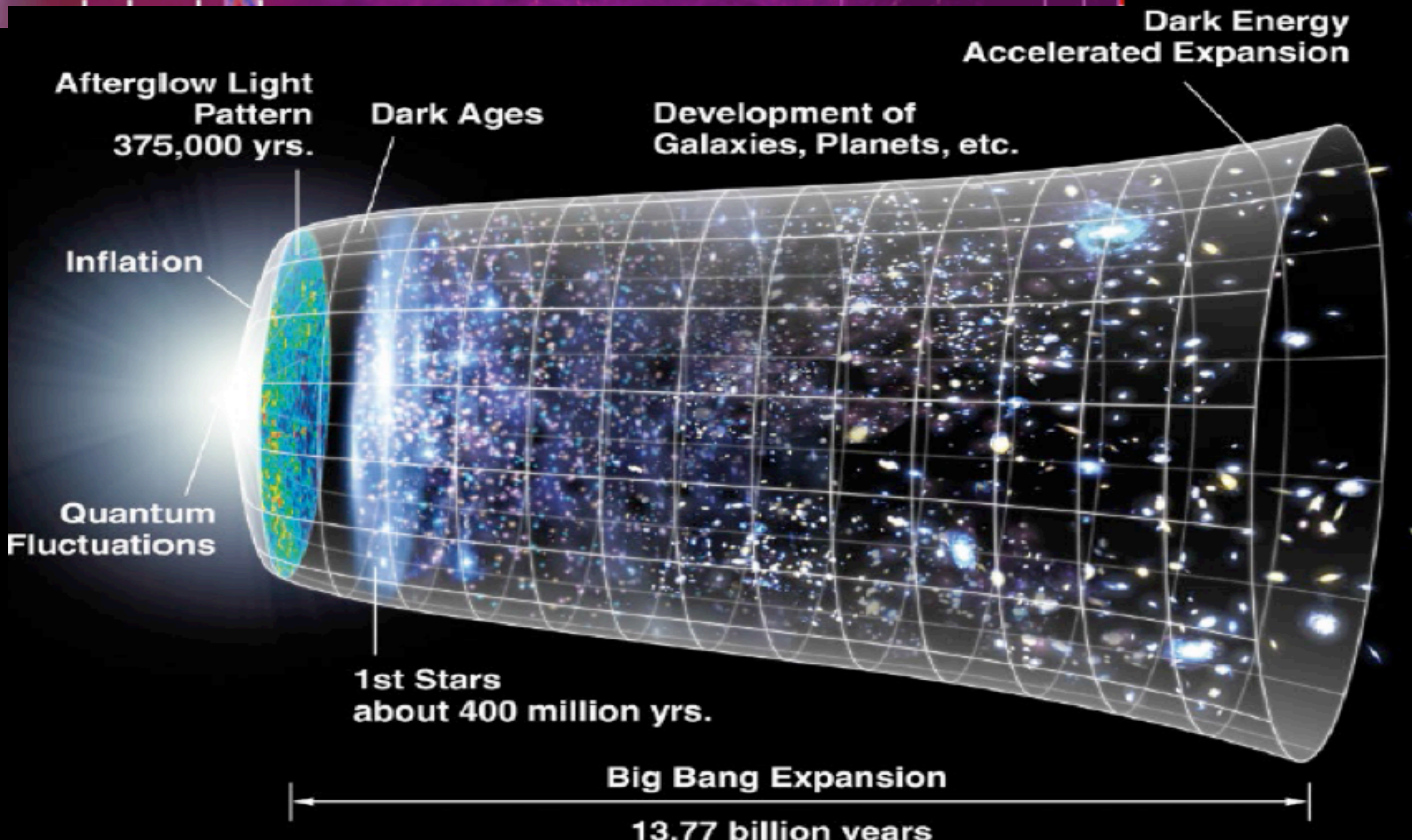
Radio astronomy at low frequencies

Optical astronomy

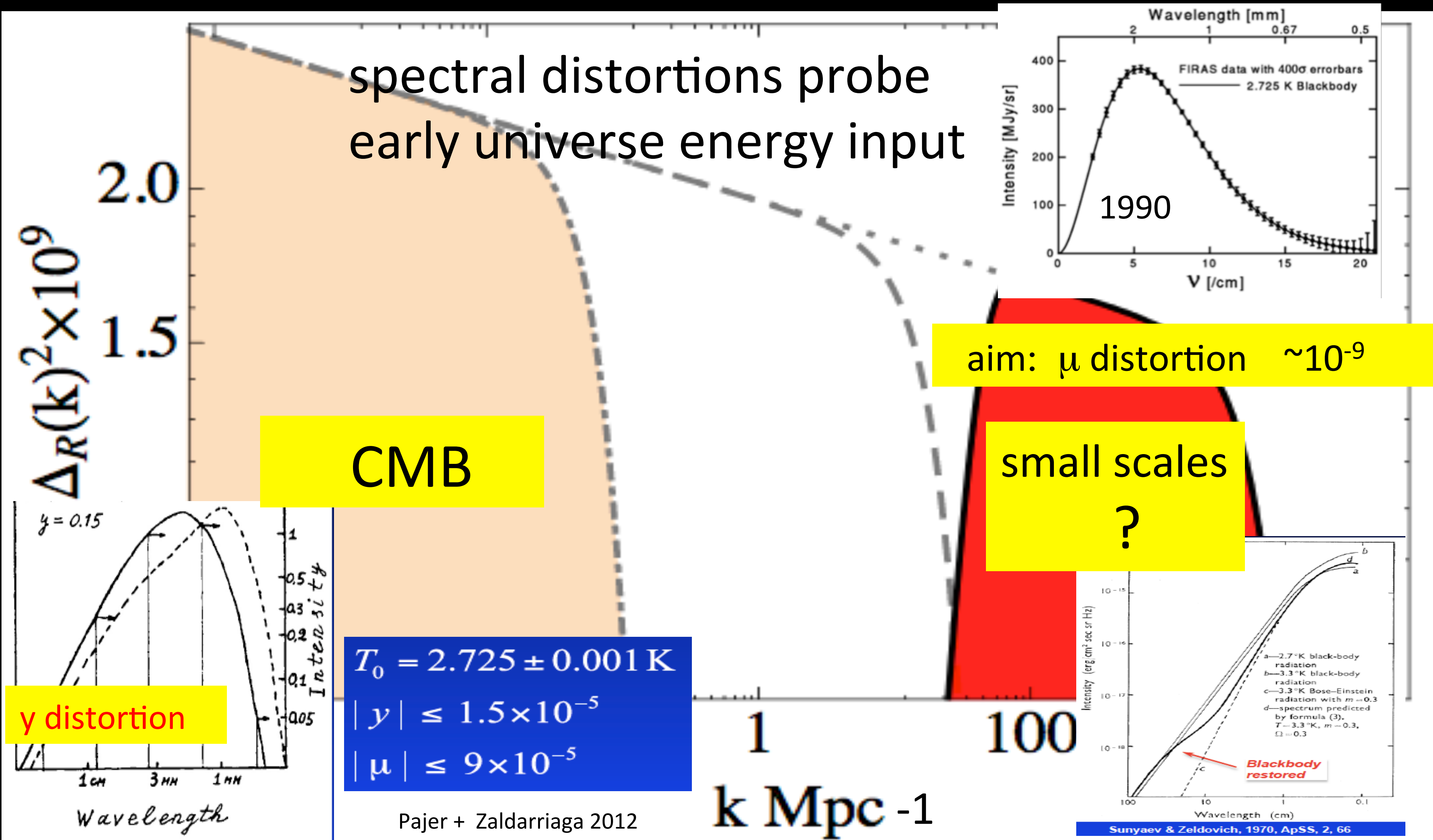
Gravitational wave astronomy

Far infrared astronomy


pre-
post-recombination epoch
T-era
μ-era
μ-y-era
HI&He
y-distortion era


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
375,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.77 billion years

CMB spectroscopic interferometry



Probing primordial energy input

μ distortion is our best hope: over z= 5.10^4 to 2.10^6

- z> 2.10^6: bremsstrahlung +double Compton creates blackbody photons
- μ=1.4 δ $E_{injection}$ due to Compton scattering

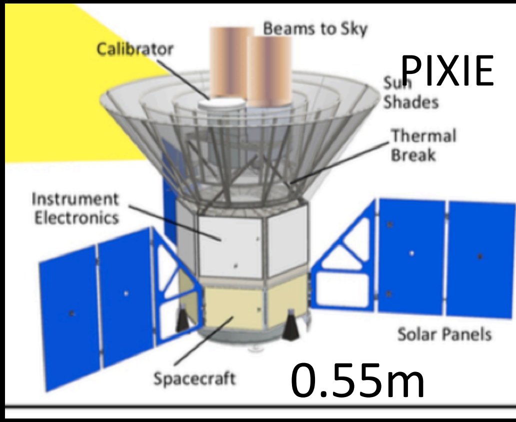
  adds energy, conserves photon number, 2.10^6 > z> 5.10^4 : μ distortion
- 5.10^4 > z: Thompson transfers energy : y distortion

- Many papers on this: eg, decaying particles, primordial black holes…
- No guaranteed signal of exotica
- Robust probe of ΛCDM

Moon for CMB/IR spectroscopy

Unprecedented reach for a Fourier transform spectrometer

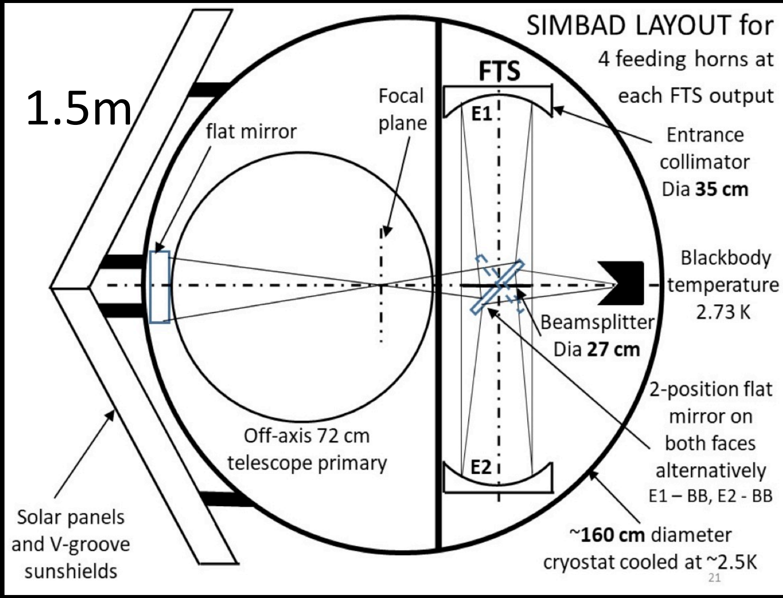
PIXIE (x10^{-3} FIRAS)
rejected (twice) by NASA
55cm telescope + 1 detector
WHAT NEXT?



SIMBAD: Spectroscopic Interferometer for Microwave Background And Distortions

target $\mu \sim 10^{-9}$ with 10 detectors on 1.5m telescope + 4 modules

~10^{-5} FIRAS sensitivity

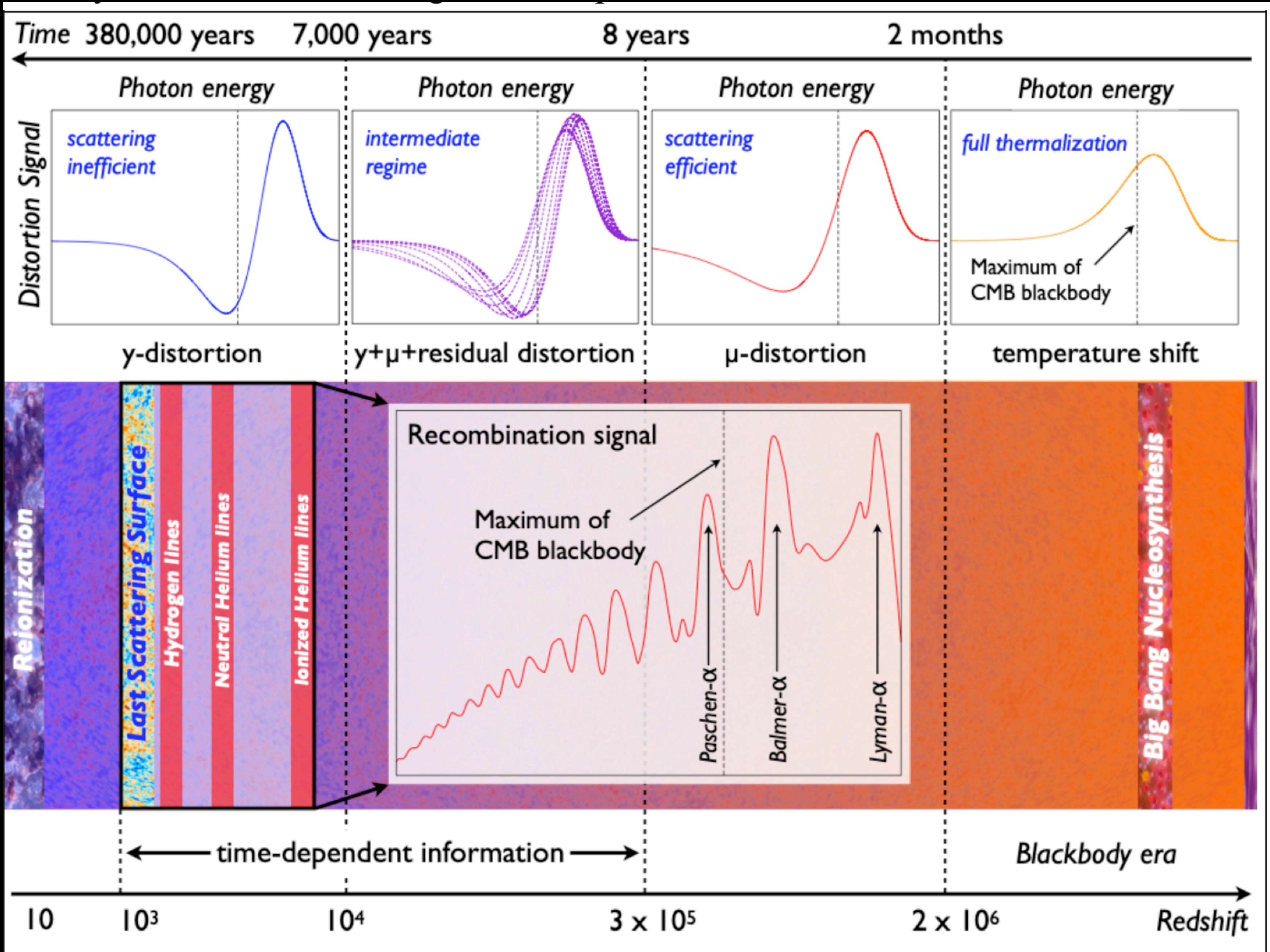


Maillard 2021

Far infrared science

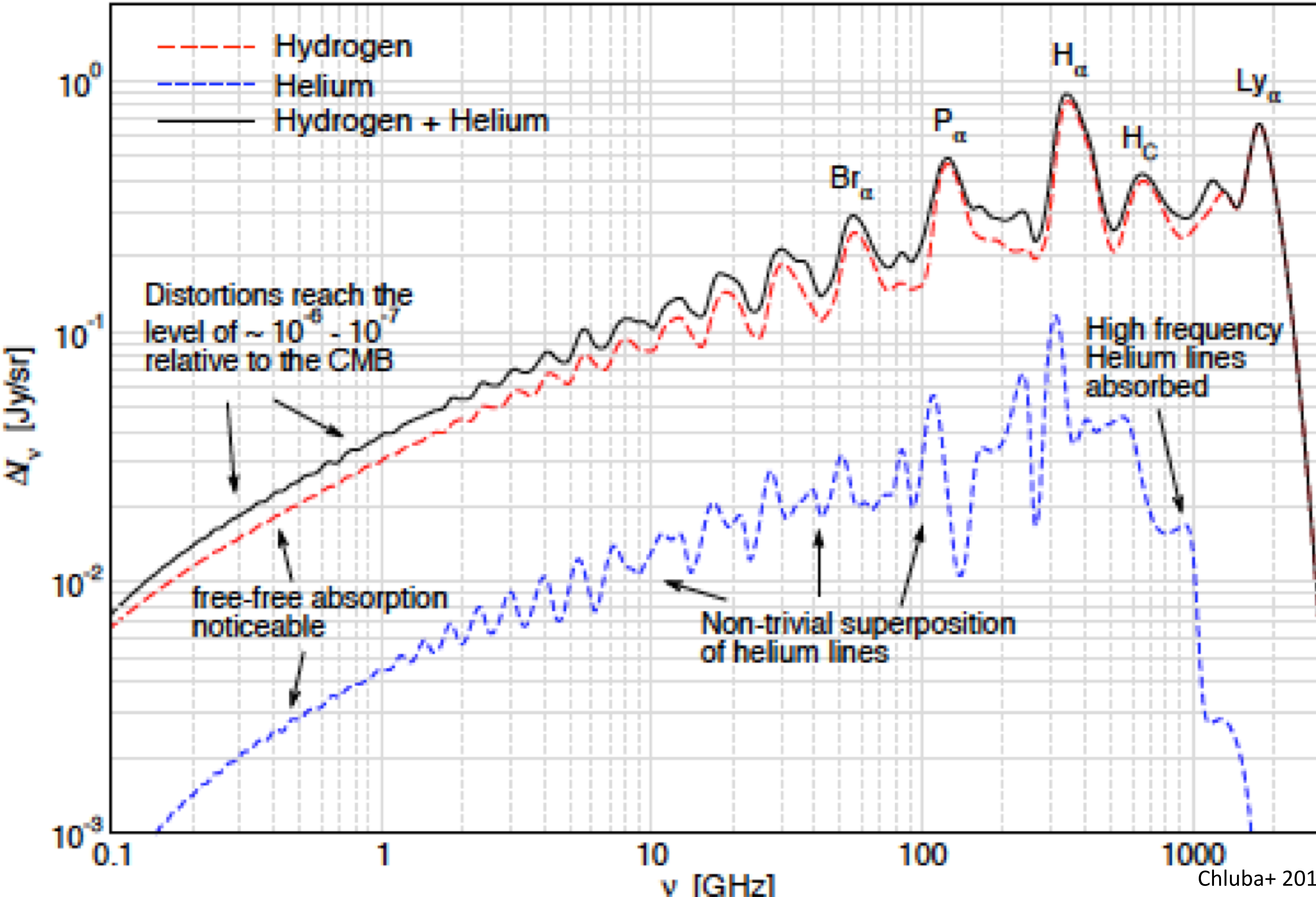
- dual input Fourier transform interferometer
- fed by sky and reference blackbody at 2.7 K
- bolometer array, cooling of telescope plus FTS to 2.5 K.
- 1.5 m telescope diameter, frequency range 90 to 2000 GHz
- Up to 4 modules in 1.5 ton payload.
- Sky scanning by lunar rotation
- Permanently shadowed cold crater at lunar south pole
- Aim for improvement over FIRAS by 5 orders of magnitude.

https://ideas.esa.int/servlet/hype/IMT?documentTableId=45087631495636486&userAction=Browse&templateName=&documentId=d7513ee471c4617ecf87df4e34e3f113



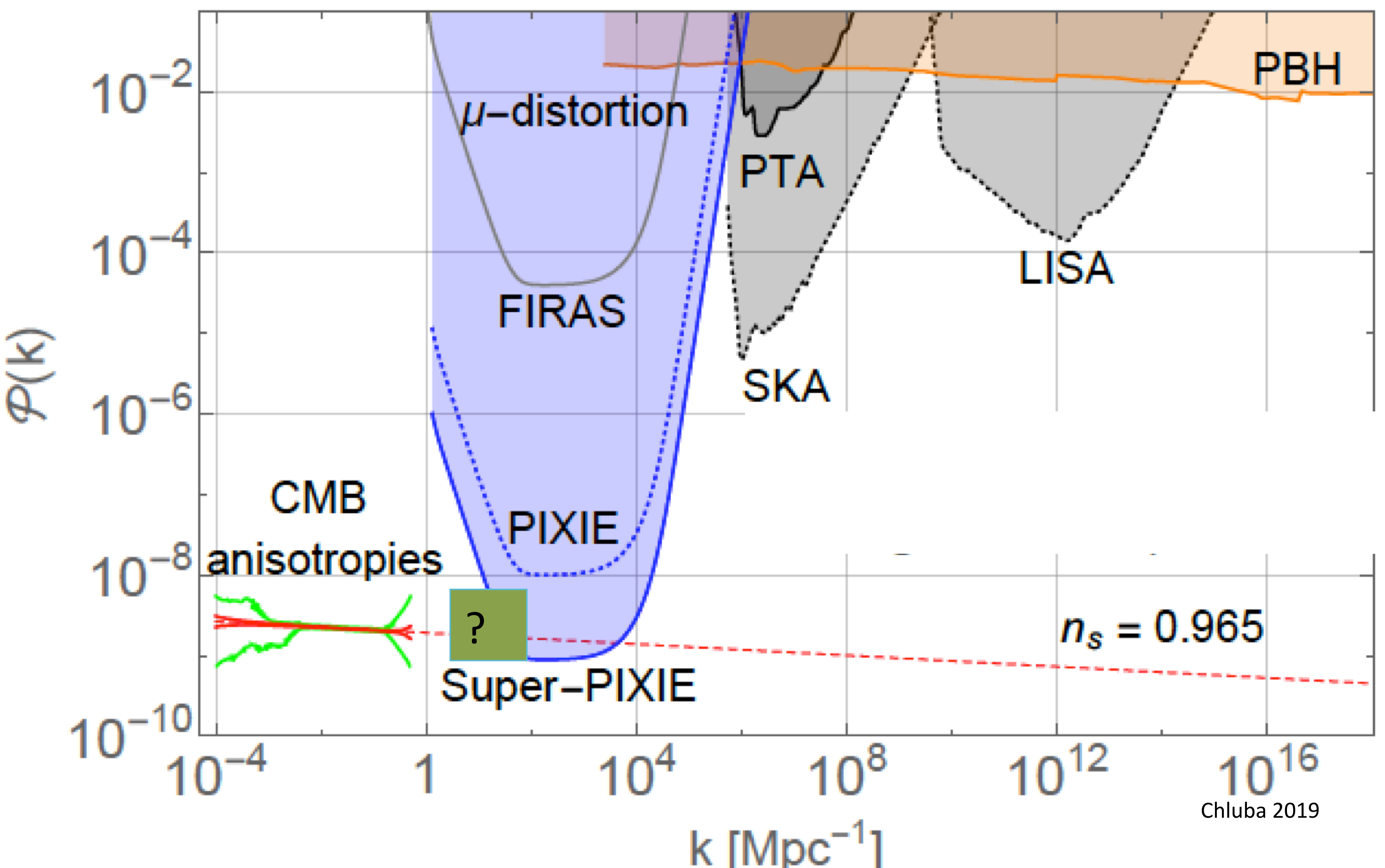
Chluba & JS 2014

Going for primordial helium

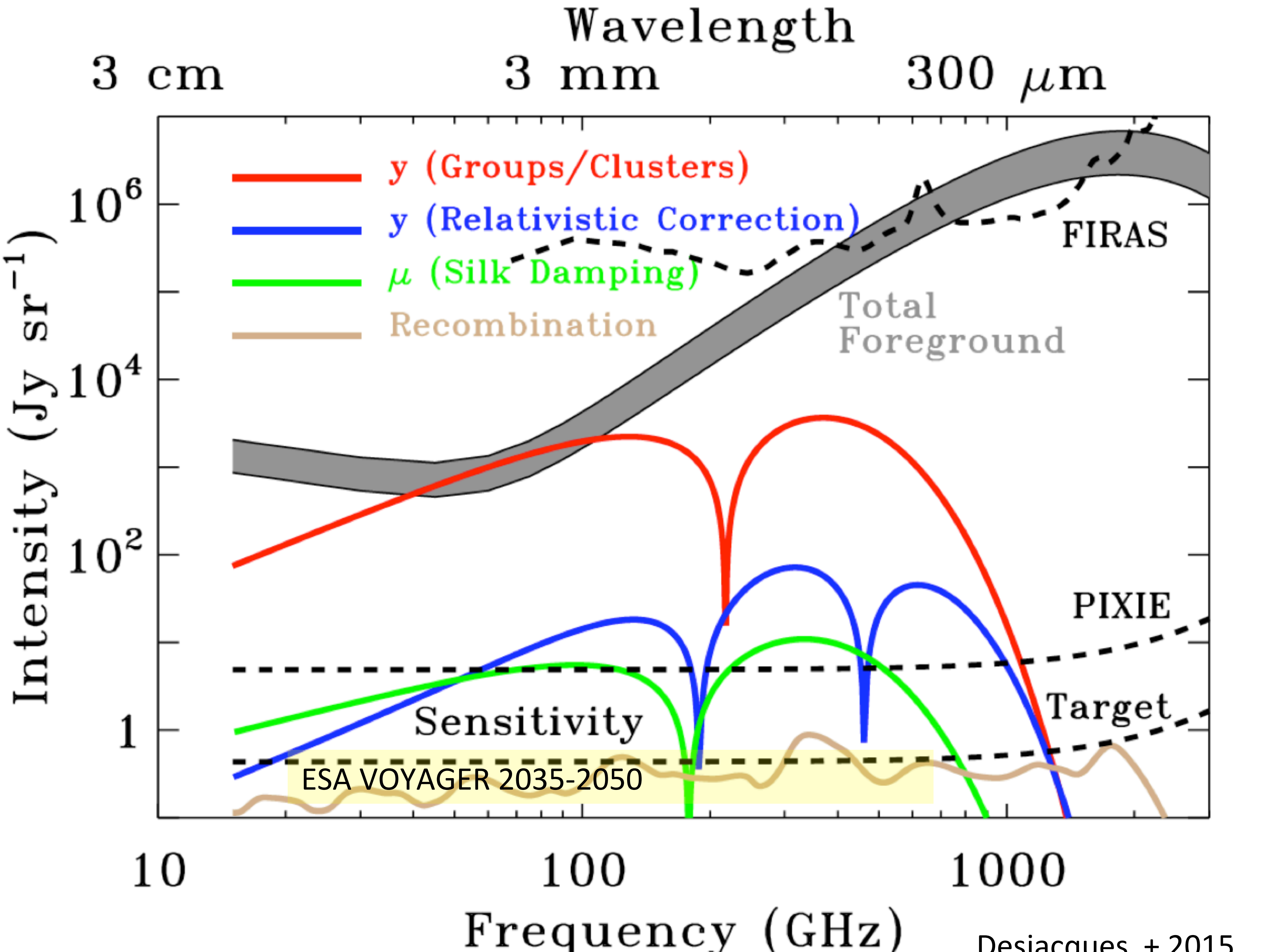


Chluba+ 2019

a guaranteed signal



Chluba 2019



Desjacques + 2015

Lunar telescopes

- It's futuristic (2030+) but will happen
- Space agencies are planning a lunar space station and a lunar village, so telescope logistics shouldn't be a problem
- Really big projects in science have long lead times, eg a 100 TeV particle collider in ~ 2050
- Lunar telescopes can do unparalleled cosmology, unachievable on earth or even in space

FIR spectrometer to test ΛCDM

Detect H/He recombinations @ $z \sim 10^3 - 10^4$

Search for exotic early energy input