ACADEMIA DELLE SCIENZE DI TORINO

CMB@60 28 – 30 May 2025

CMB-SD Fourier Transform Spectroscopy: by SIMBAD*on the Moon!

*Spectroscopic Interferometer for Microwave BAckground Distortions

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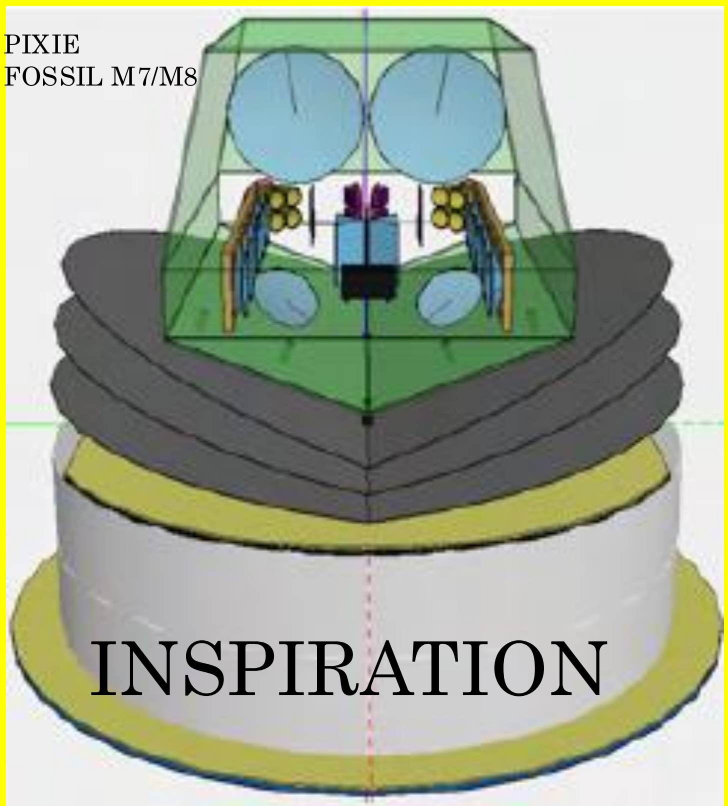
Institut d'Astrophysique de Paris

THE CMB SPECTRUM

consider **the Moon!**

Options: ESA L6
or with NASA/ESA ARTEMIS?



ESA large missions
L1 Juice 2023
L2 Athena 2037
L3 LISA   2035
L4 Icy Moons. 2045?
L5 Exoplanets/MWG 2055?
L6 Early universe. 2065?

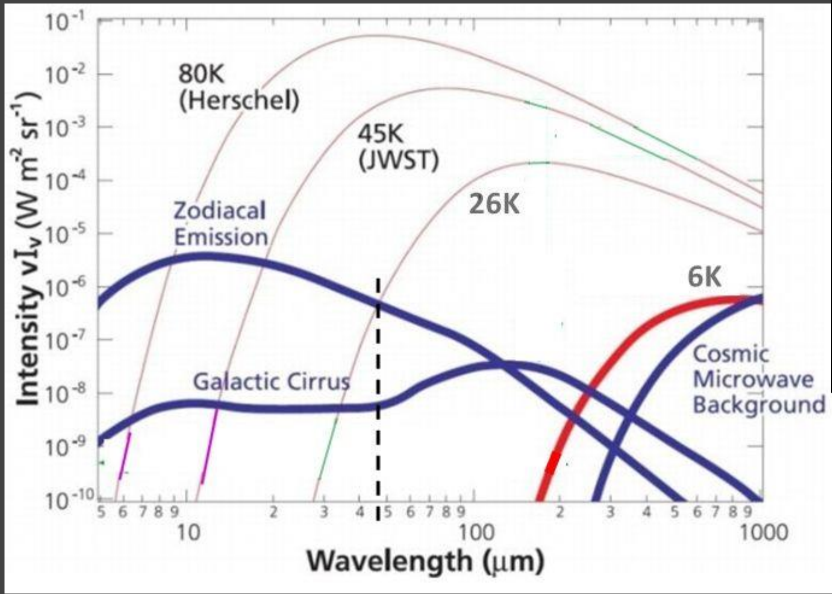
NASA flagship missions
JWST 2021
Roman ST 2027
HWO 2041
?

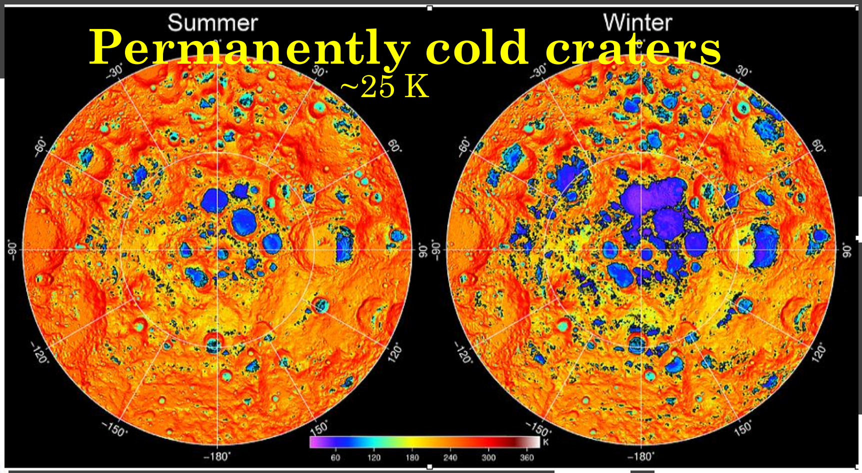
NASA lunar landing crewed missions
Artemis III 2027
Artemis IV 2028
Artemis V 2030
Artemis VI 2031
Artemis VII 2032

China lunar landing missions
Long March 10, 2030

Unique far-IR advantages of lunar polar sites

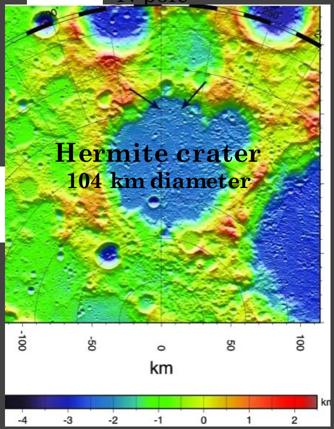
- **Space conditions** = access to all the electromagnetic spectrum
- **Passive cooling** of the telescopes at 26 K = better than at L2 (*45 K for JWST*) → main parasitic flux beyond ≈ 45 μm





S pole

N pole



ORIGIN of the CMB LUNAR PROJECT

- Discussion meeting of Royal Society in London (18 – 19 March 2020) organised by Joe Silk *et al*.

Astronomy from the Moon: the next decades

- There, J-P Maillard asked the question:

Is the Moon the future of infrared astronomy?

Next decade:
CMB spectroscopy y, μ + H/He recombination lines

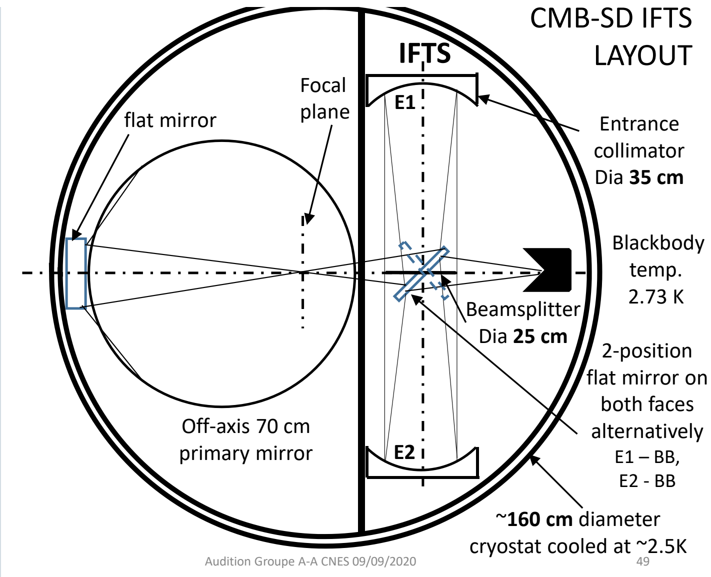
array of four fixed 1.5-m telescopes feeding FSS detector
in a permanently cold, polar lunar crater

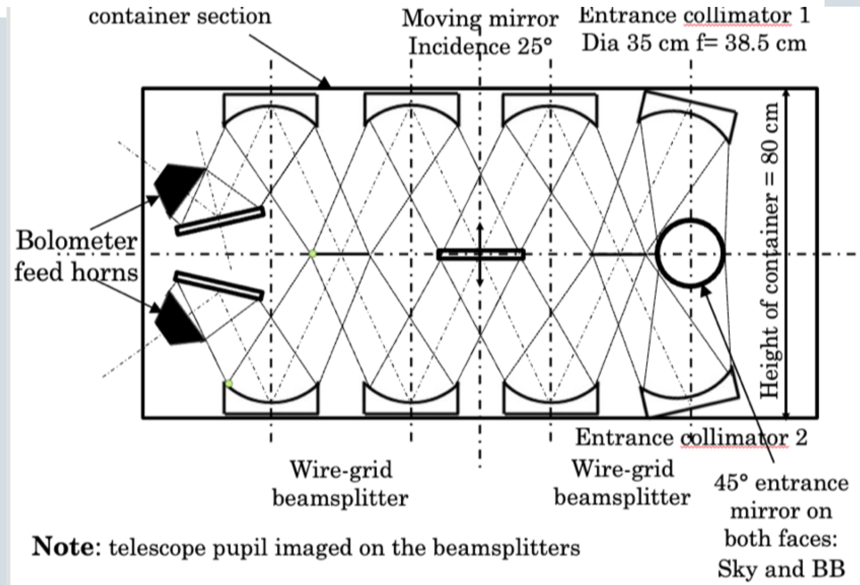
Beyond 2050:
high-resolution imaging: *100-m multi-mirror steerable telescope*
- minimum flexures due to low lunar gravity
- spectral range: 0.1 to ~ 200 μm (Mallard 2024)

ultimate interferometry: *km crater-spanning telescope array*
- μsec optical/IR imaging (Labeyrie 2024)

	Design	Gain factor
Dedicated mission	no polarimetry	$G = 2$
Add detectors	1 to 16-100	G=4-10
Telescope size	from 0.55m to 1-5m	$G = 2 - 10$
reduce bandwidth	from 2THz to 30GHz	G=1.5
increase observed sky fraction	to $f_{sky} = 0.7$	$G = 1.5$

Potential gains G over PIXIE: G is multiplicative





SIMBAD optical layout

multi- SIMBAD on the Moon

- Optimal design: 4 x1.5m SIMBAD modules set in a permanently cold polar lunar crater
- continuous data acquisition on full rings on the sky by using rotation of the Moon
- each unit equipped with an Imaging Fourier Transform Spectrometer (IFTS) cryocooled to 2.5 K covering 90 - 2000 GHz

challenges

- ✓ availability of launching vehicle with 8 m diameter internal fairing
- ✓ lunar rover near landing site
- ✓ solar panels on crater rim to provide power to each SIMBAD unit
- ✓ no schedule for this program
- ✓ requires preservation of a PSC for science

multiSIMBAD on the Moon vs a cosmological mission at L2

- ✓ a permanently cold environment (26 K) in a selected polar lunar crater → passive cooling better than at L2
- ✓ no need of a propellant system for maintenance at a L2 halo orbit → other saving = no limit of duration
- ✓ development of identical units → minimum time increase
- ✓ up to 4 modules = **multi-SIMBAD in a single launch**

SLS
New Glenn
Saturn V
Starship
N1
Long March 9

Internal fairing up to

9 m diameter

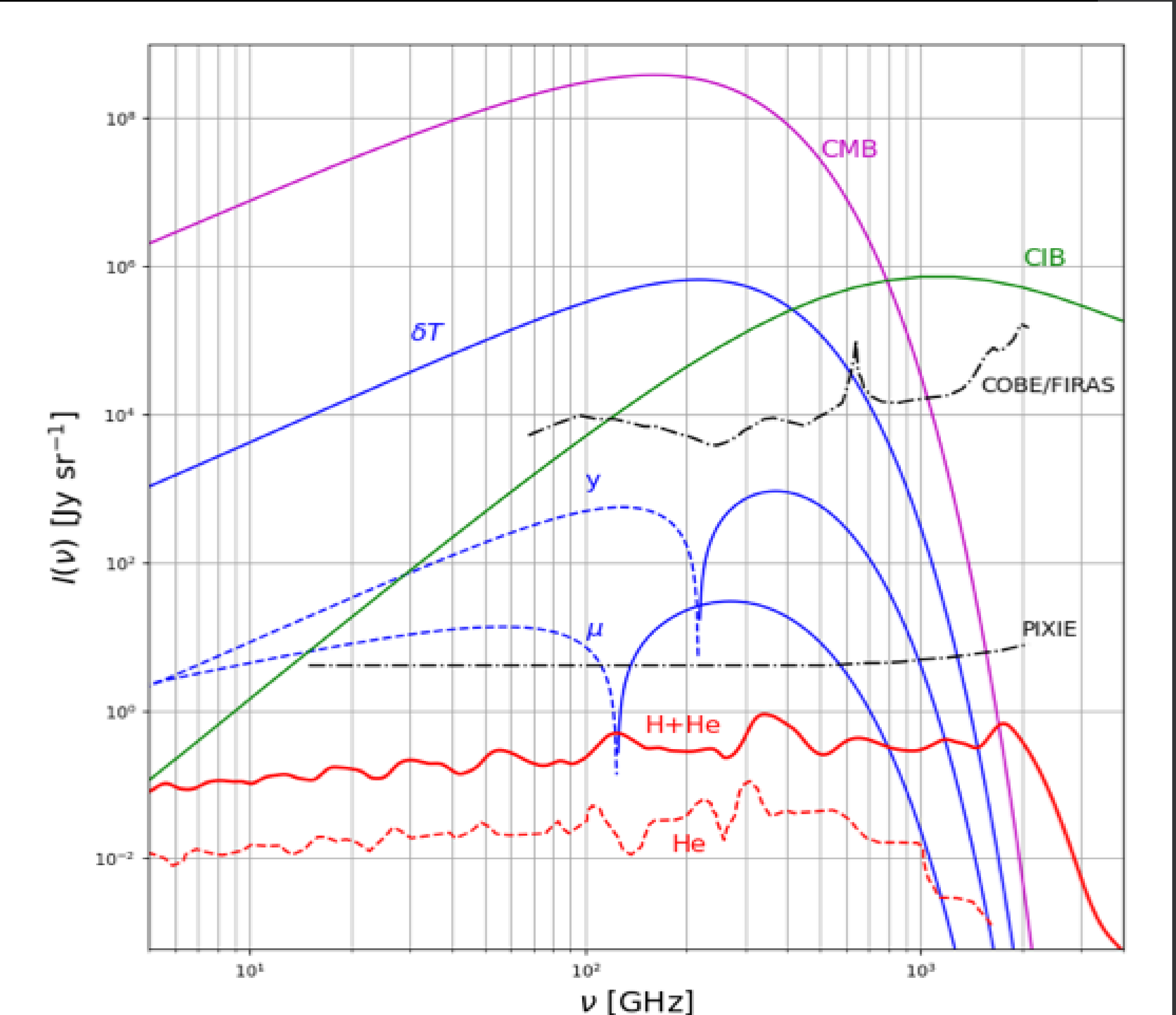
20 m height

Payload to translunar injection ***> 40 tons***

Launch cost	*Development*
$4b (SLS)	**$25b**
$100m (Starship)	**$5b**

SENSITIVITY TO SPECTRAL DISTORTIONS

Holy grail!



Desjaques + 2025

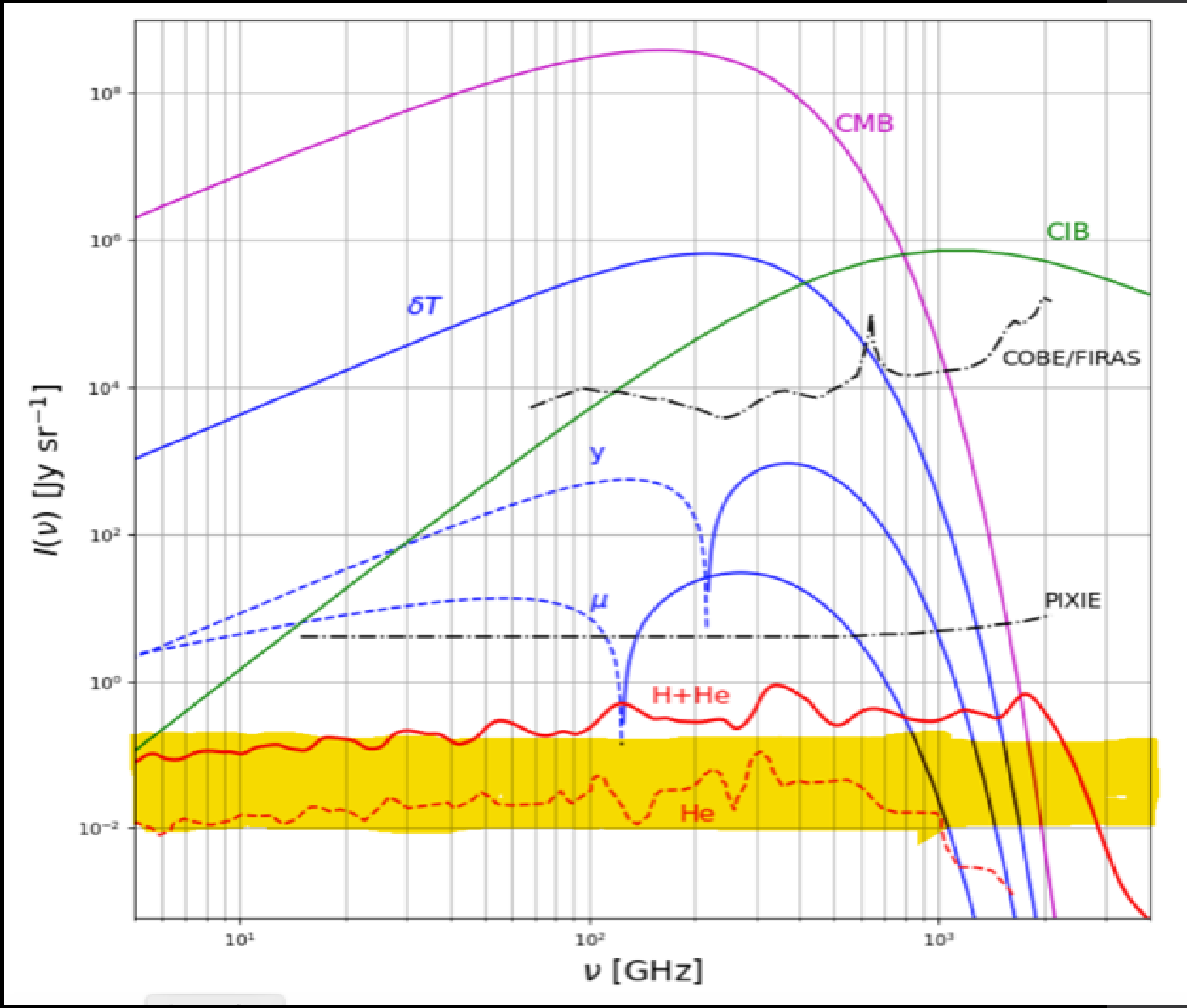
SENSITIVITY TO SPECTRAL DISTORTIONS

VOYAGE 2050
(~2065)

or

MULTISIMBAD

(via ARTEMIS
~ now??)



Helium recombination lines are ultimate goal!

CONCLUSION

Moon is a promising site for infrared astronomy in the next decades

especially for spectroscopy of the CMB with MULTI-SIMBAD!