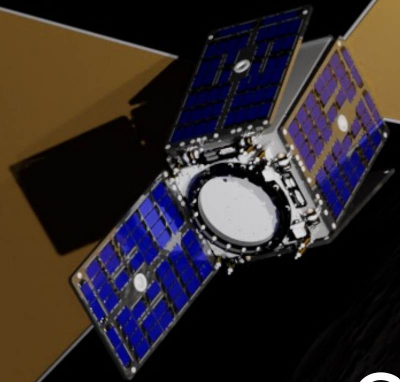
Eloy de Lera Acedo

University of Cambridge, UK



CosmoCube

Probing the Cosmic Dark Ages with a Miniature Radiometer in Lunar Orbit

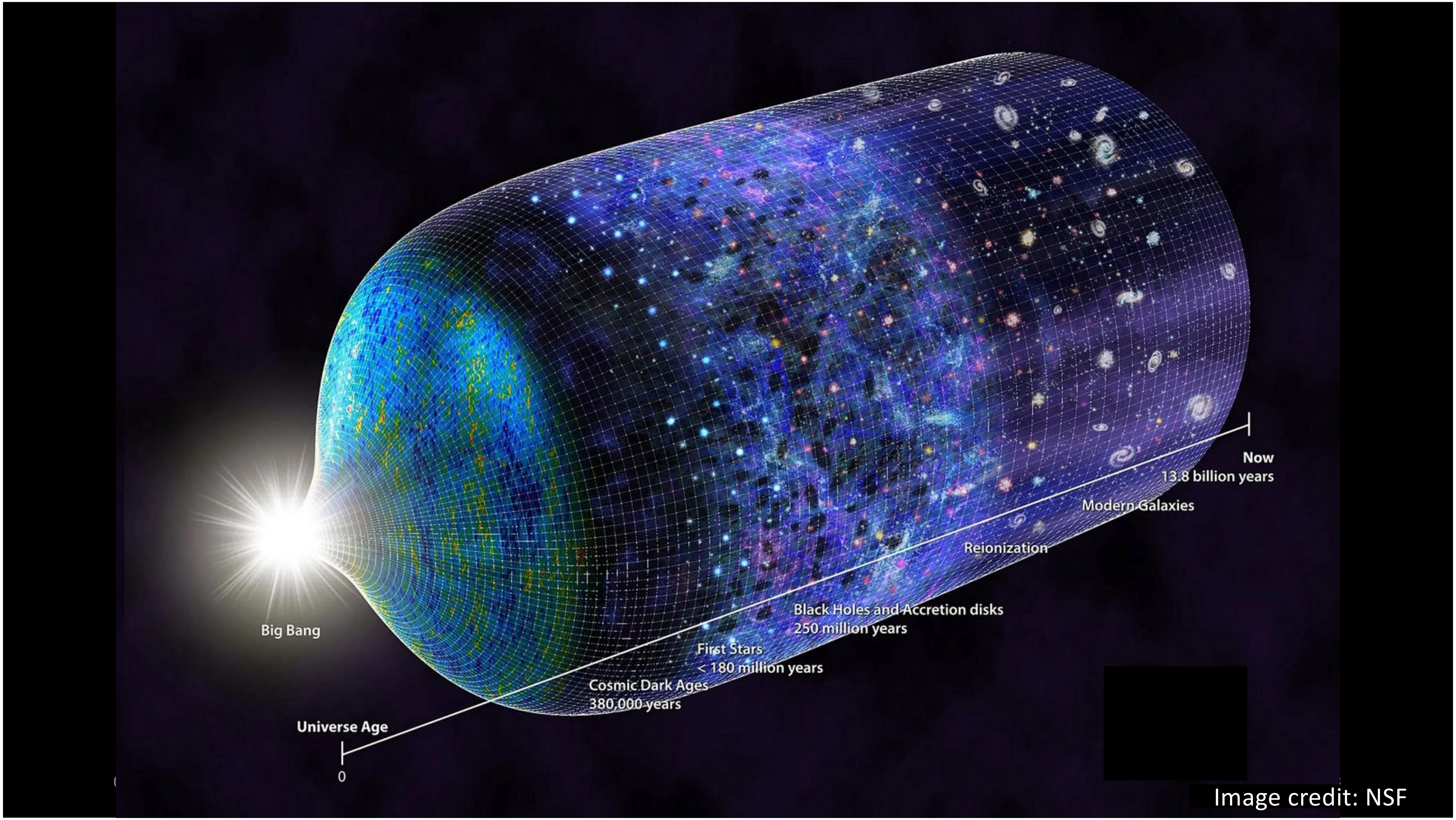


Image credit: NSF

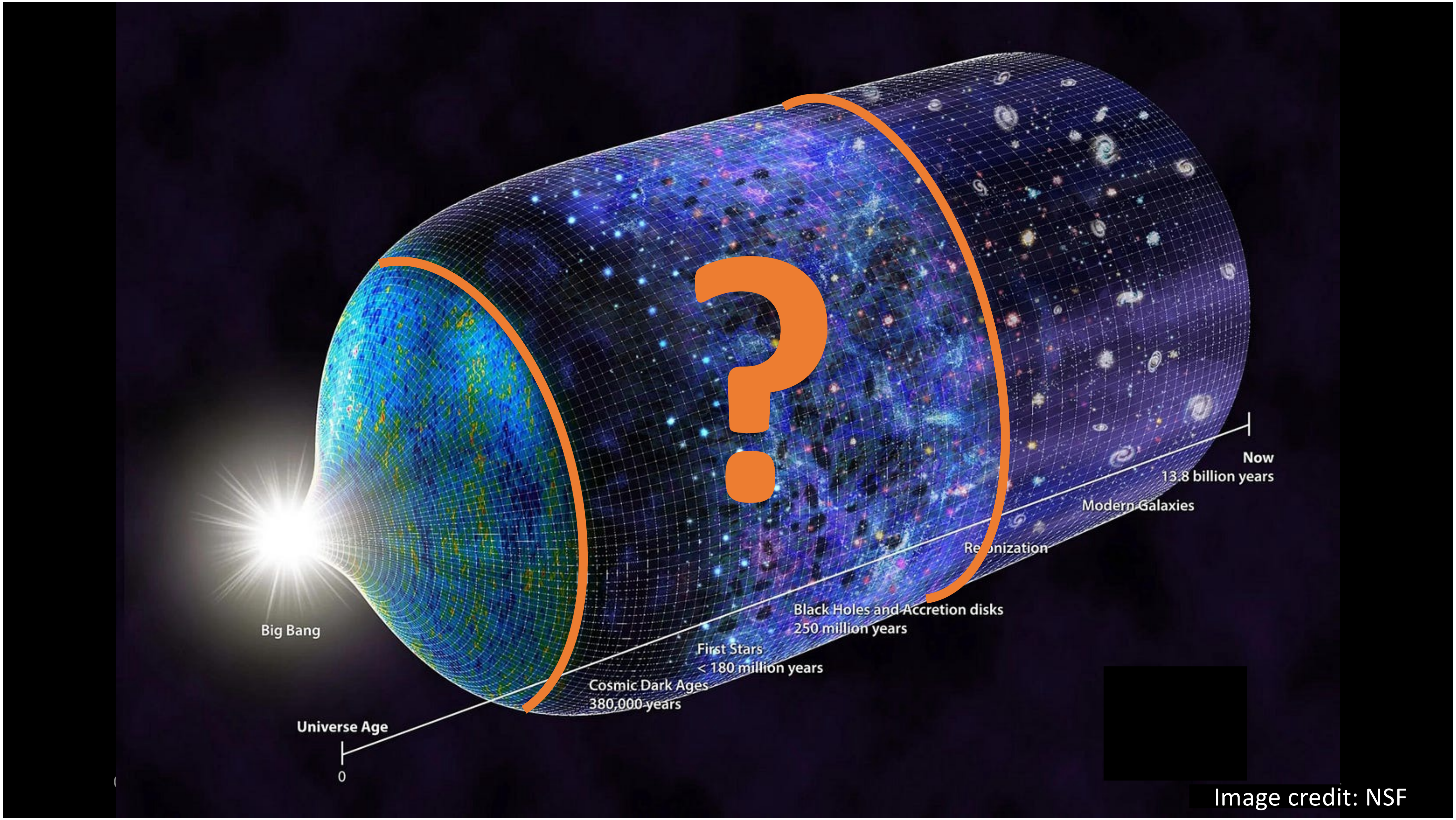


Image credit: NSF

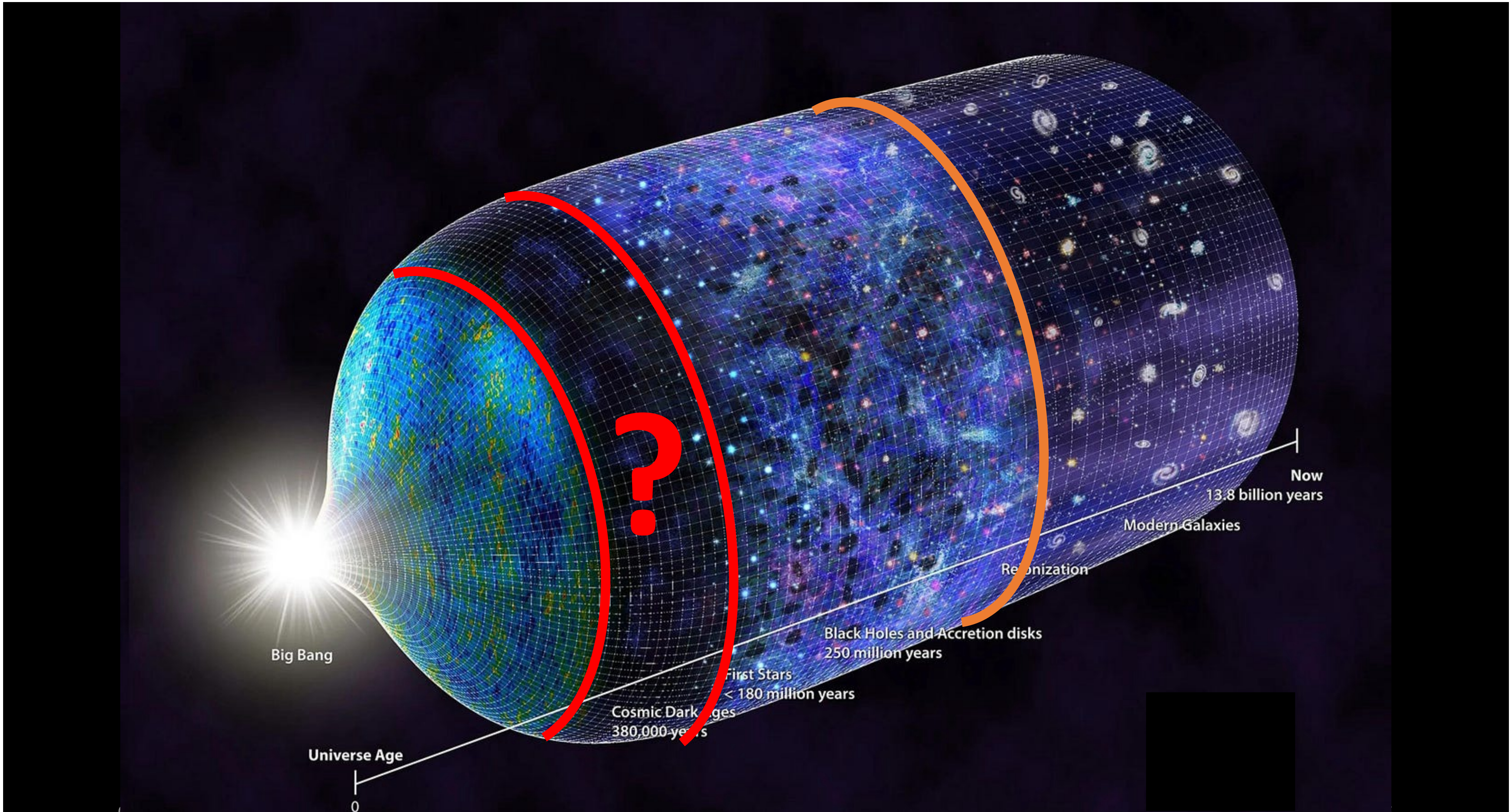
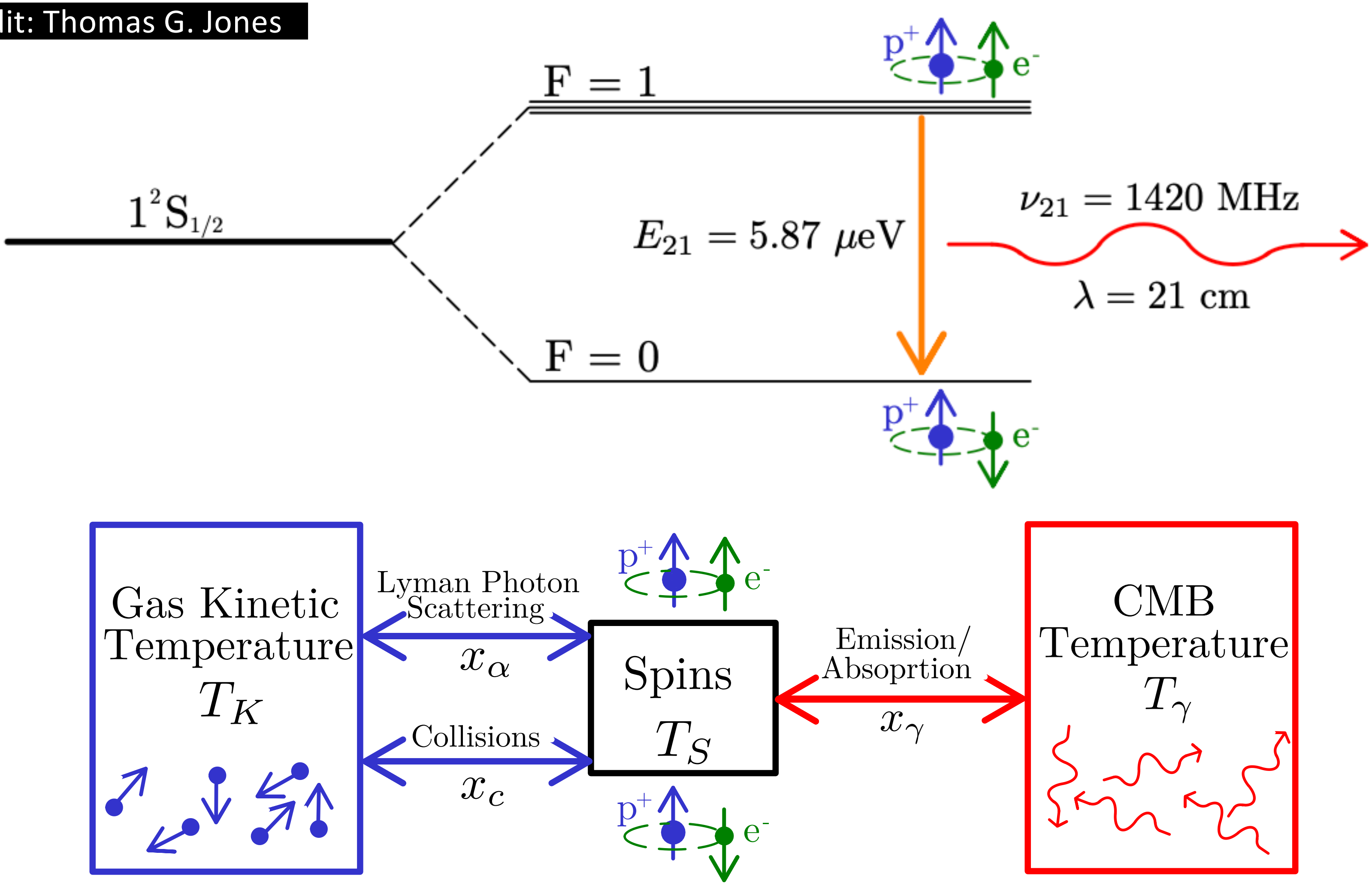
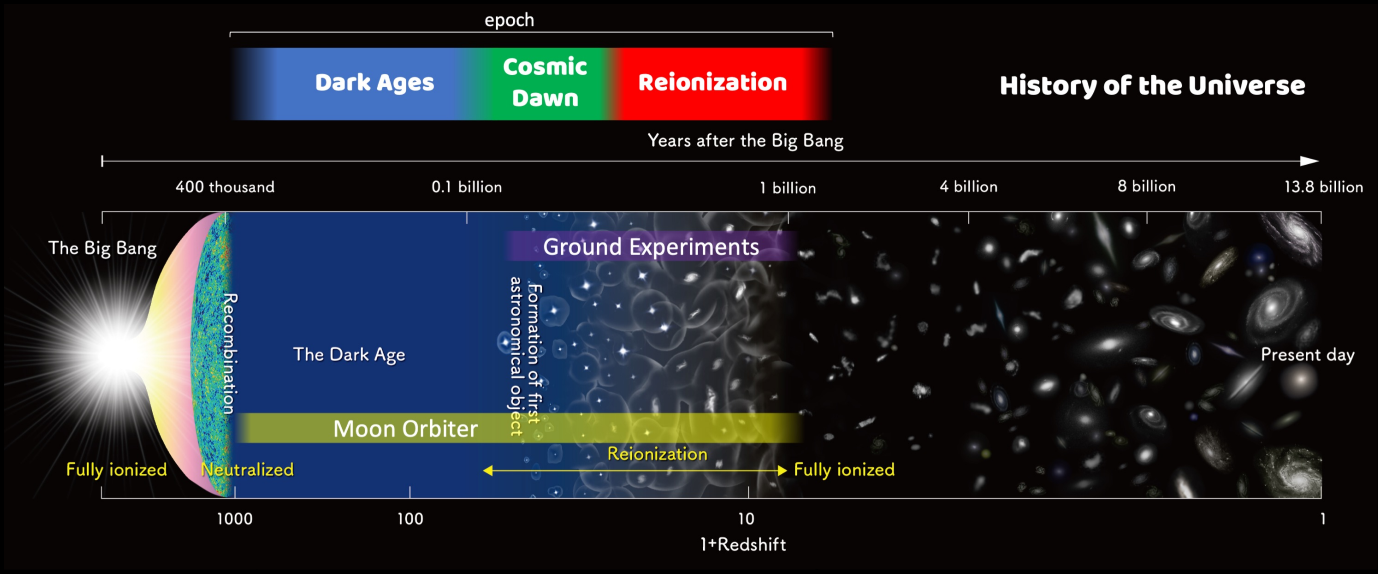
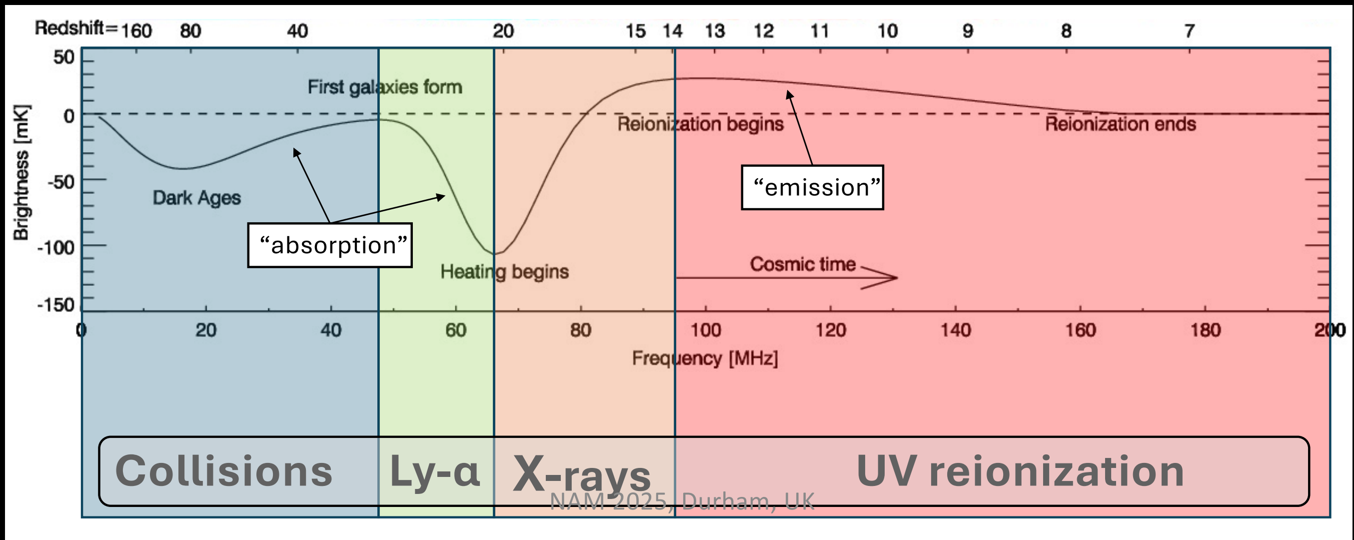


Image credit: NSF

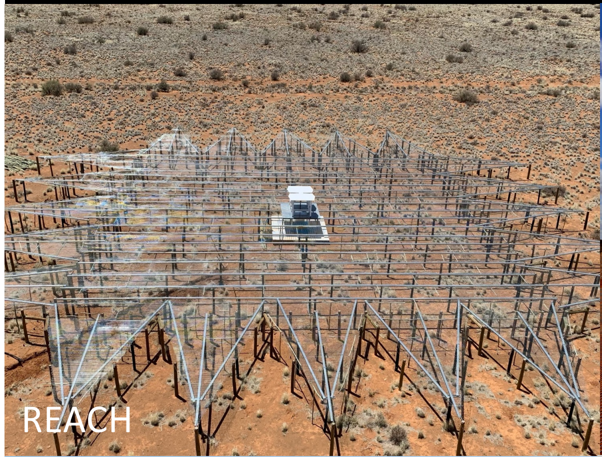
Image credit: Thomas G. Jones




epoch
Dark Ages
Cosmic Dawn
Reionization
History of the Universe
Years after the Big Bang
400 thousand
0.1 billion
1 billion
4 billion
8 billion
13.8 billion
The Big Bang
Recombination
The Dark Age
Ground Experiments
Formation of first astronomical object
Present day
Moon Orbiter
Reionization
Fully ionized
Neutralized
Fully ionized
1000
100
10
1
1+Redshift


Redshift=160
80
40
20
15
14
13
12
11
10
9
8
7
Brightness [mK]
First galaxies form
Reionization begins
Reionization ends
Dark Ages
"emission"
"absorption"
Heating begins
Cosmic time
Frequency [MHz]
Collisions
Ly-α
X-rays
UV reionization

Ground-based experiments



Foreground power: ~ 5,000.0 K

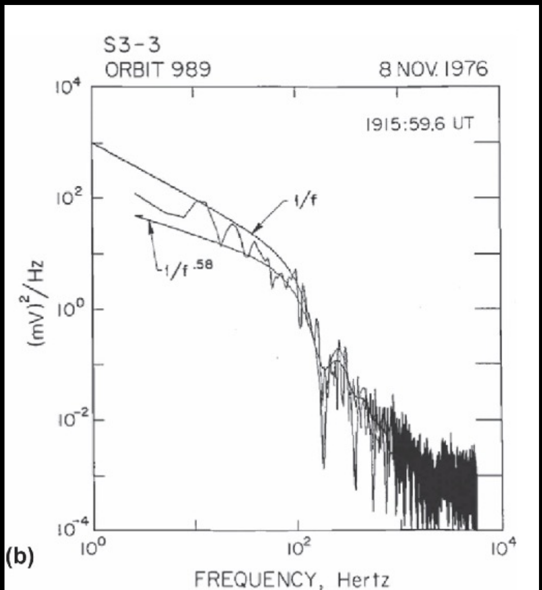
Systematics: ~ 100.0 K

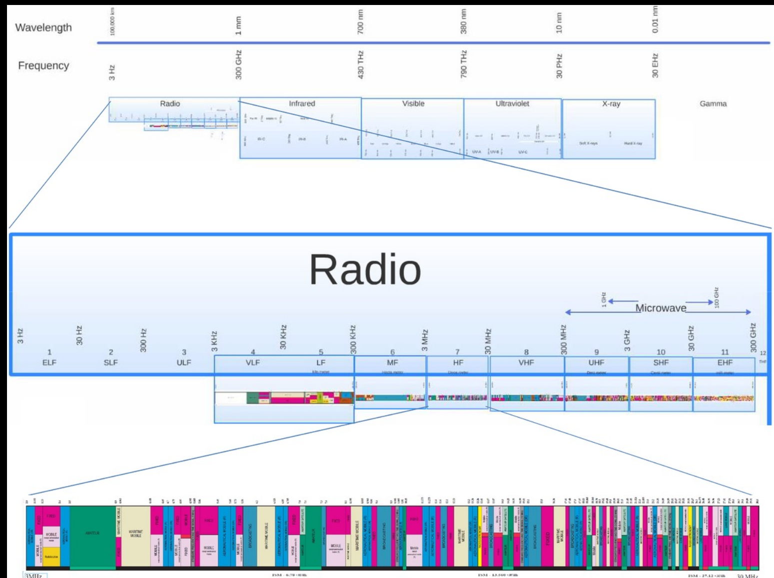
21-cm signal: ~ 0.1 K

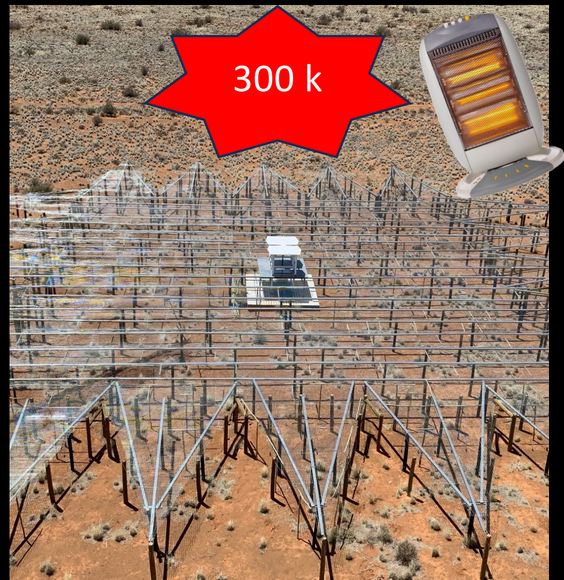
$\underbrace{\hspace{10em}}$

Exquisite foreground and radiometer calibration required

Challenges from the ground







Earth's Ionosphere

RFI

Near field emissions

Solutions in space

Earth's Ionosphere

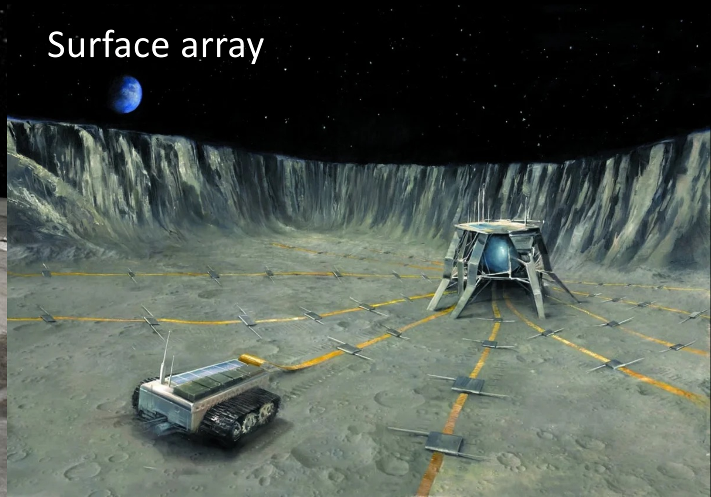
RFI

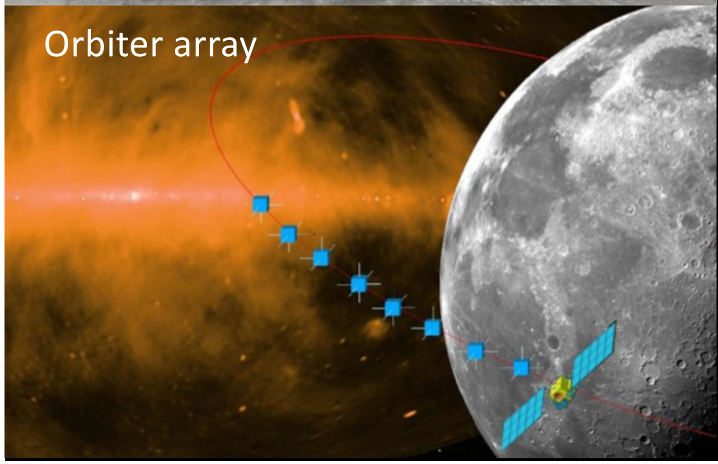
Near field emissions

A space mission on the far side of the Moon, in orbit

Unique opportunity if humankind's history, first time we are capable of doing this, but maybe the last time too…

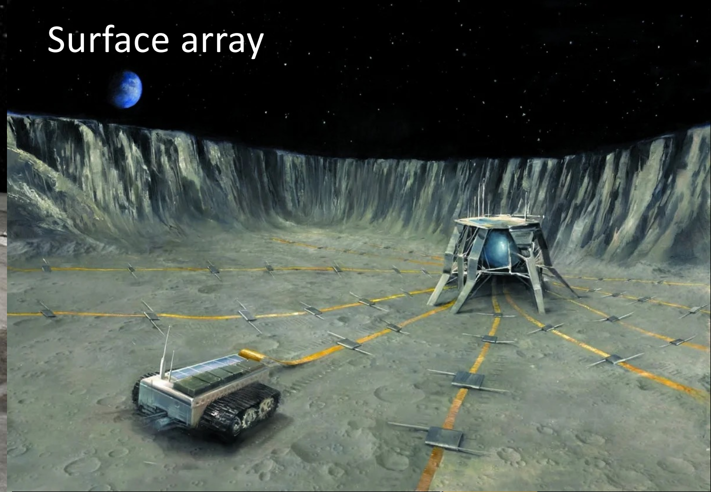
The Moon is back on the agenda

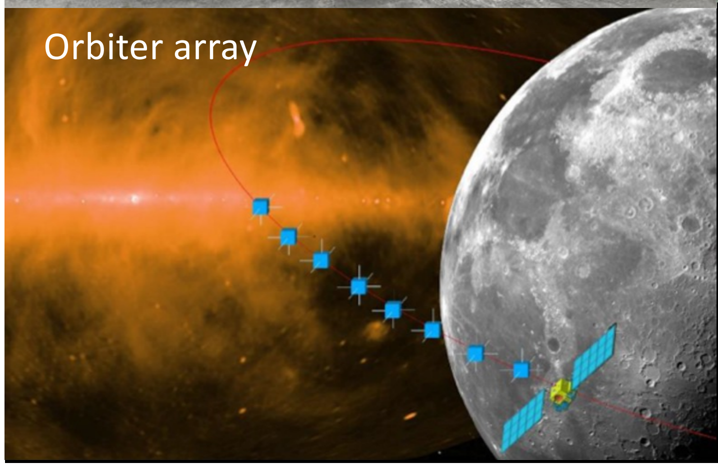


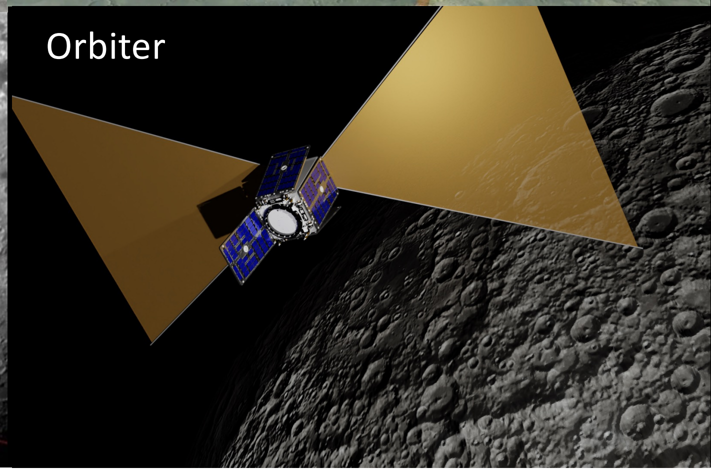


The Moon is back on the agenda


Single antenna lander


Surface array


Orbiter array


Orbiter

Funding

UK SPACE AGENCY

Core members

UNIVERSITY OF CAMBRIDGE

UNIVERSITY OF PORTSMOUTH

RAL Space

Collaborators

Jet Propulsion Laboratory
California Institute of Technology

SURREY

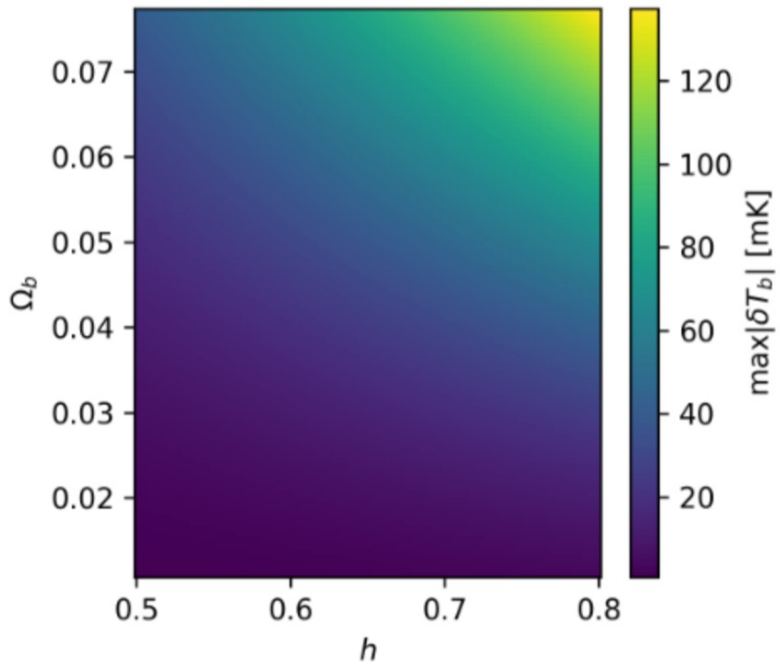
L-Università ta' Malta

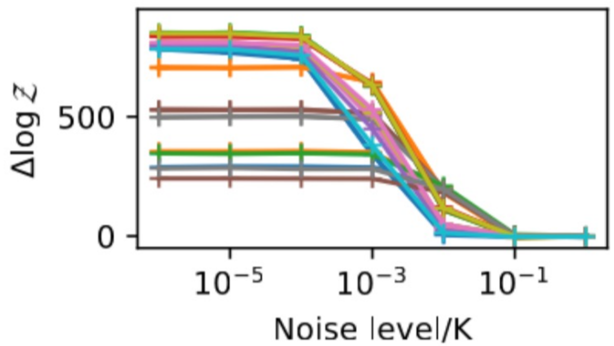
Embry-Riddle Aeronautical University 1926

ASU

^ *de Lera Acedo et al.,* 2025, in review. (Nat Ast)

Requirements



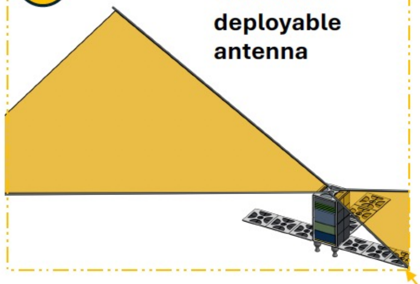


CosmoCube will be sensitive to baryon over density – hubble constant fluctuations with a radiometer noise of ~10 mK across 8-45 MHz in a 2-year mission in Moon's orbit

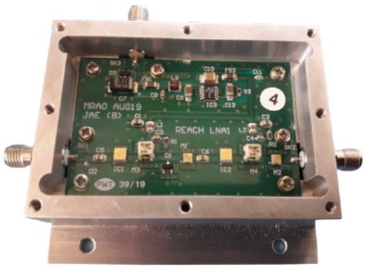
* *Kaan and de Lera Acedo,* RASTI 2024
~ *Zhu, de Lera Acedo et al.,* RASTI 2024

The payload

1 **Wideband deployable antenna**

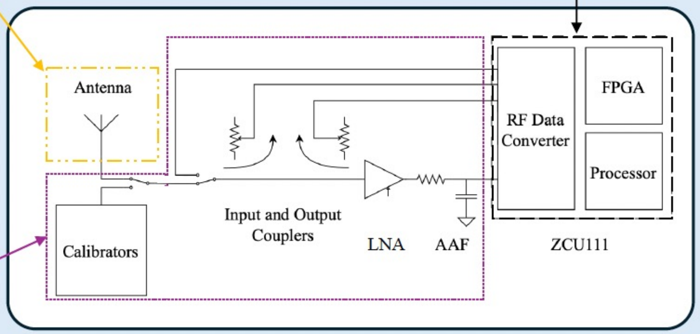


2 **Low Noise Amplifier and calibrators**



3 **Fully integrated RFSoC receiver**

- ✓ ADC
- ✓ Spectrometer
- ✓ VNA for calibration
- ✓ Basic onboard processor



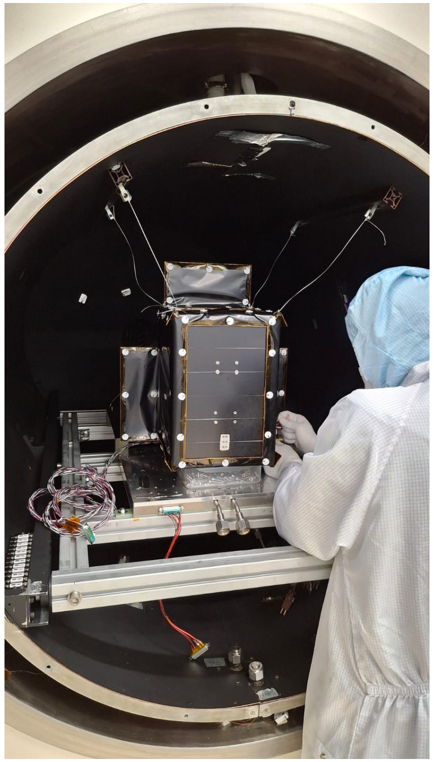
CosmoCube payload diagram

Main payload specifications

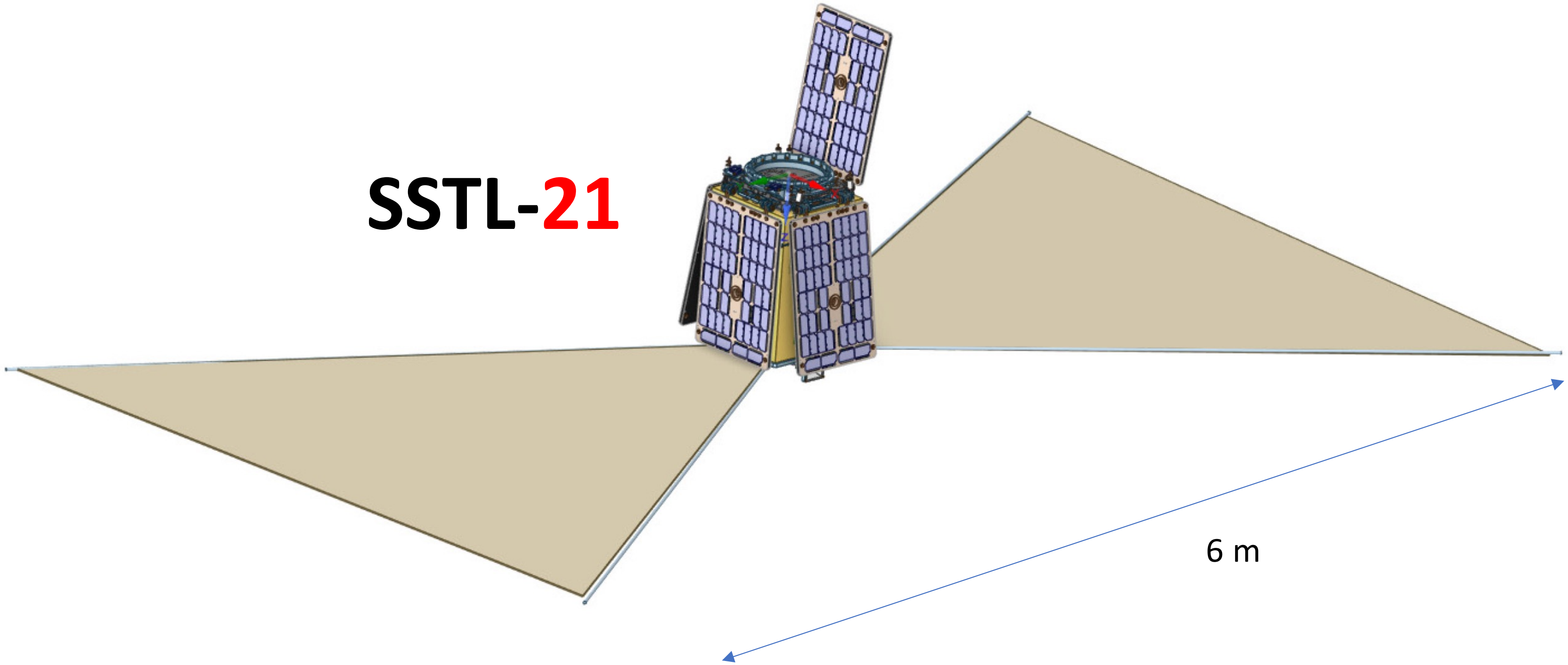
6-m wideband dipole
Single polarization
Deployable structure
Low achromatic losses

"Dicke" switch calibrator
15 calibrators
Switches – IL < 0.5 dB
Switches – Iso > 60 dB
Low Noise Amplifier with S_{11}<-30 dB

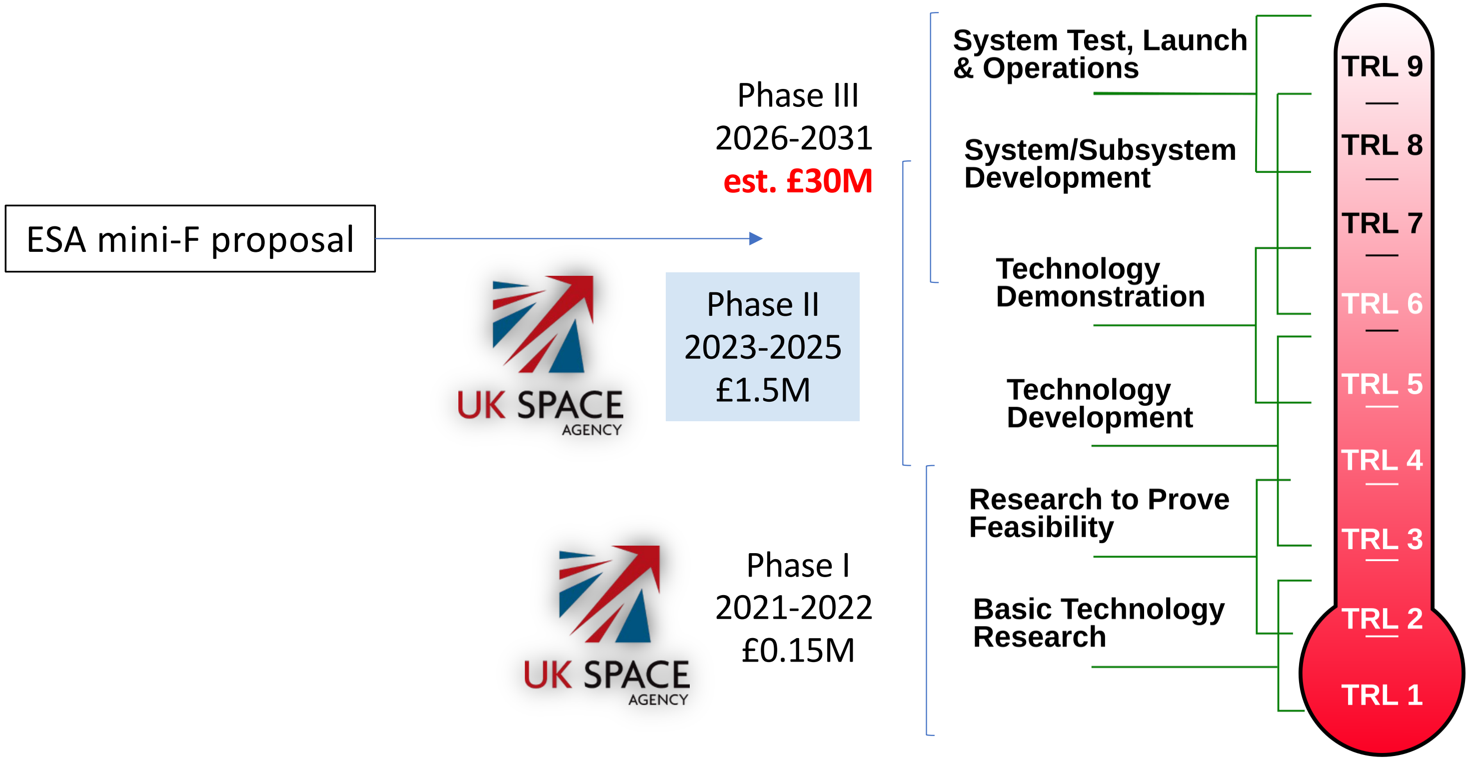
<u>ADC + Spectrometer</u>
8 – 46 [100] MHz
14 bits ADC
10 KHz narrow channels
100 KHz wide channels
SFDR > 70dBc
<u>VNA</u>
1 channel VNA function
$|\Delta S_{11}|$<0.05dB

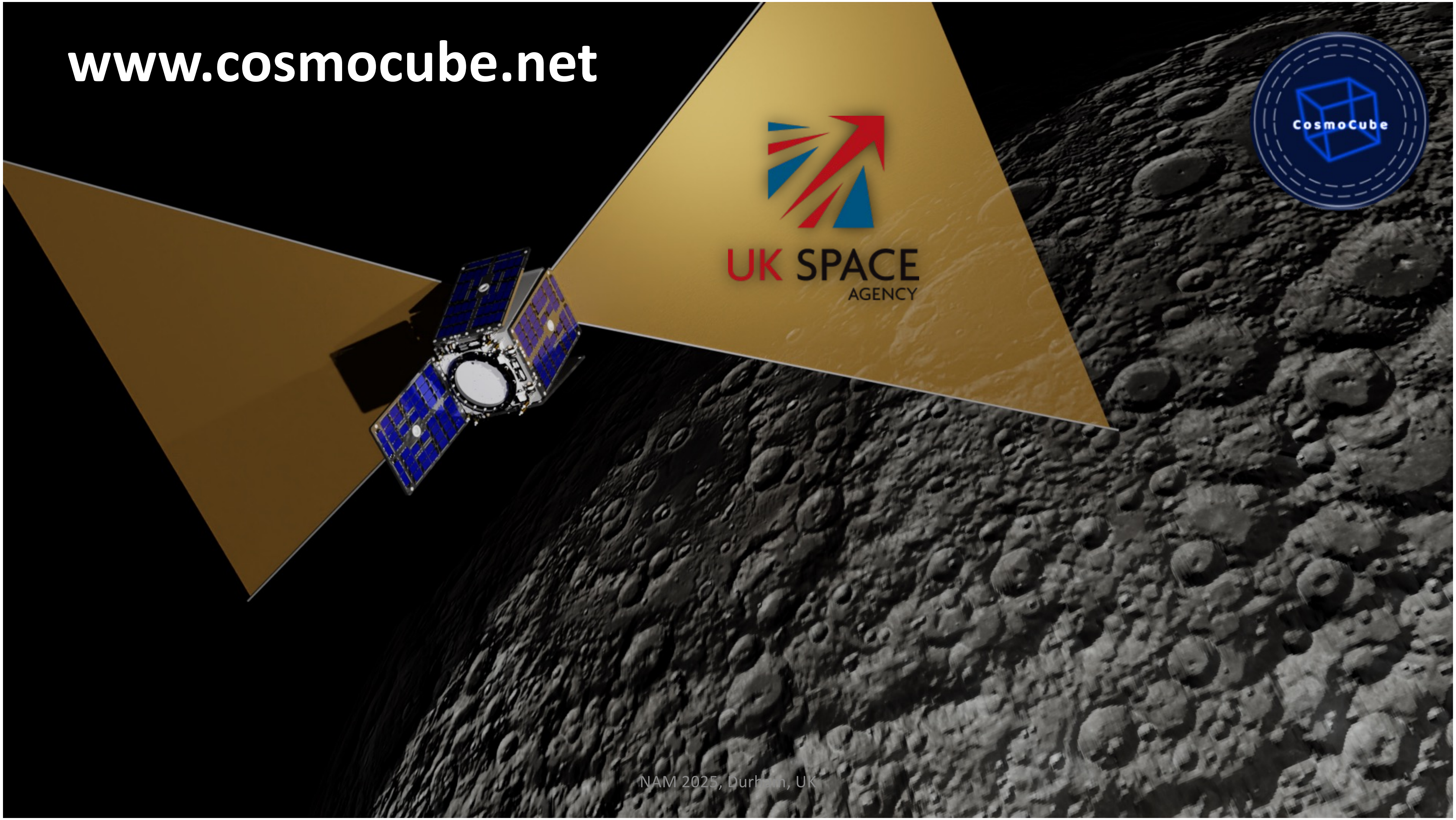


The platform

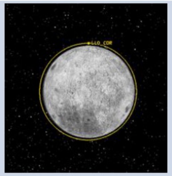


Mission status




www.cosmocube.net
UK SPACE
AGENCY
CosmoCube
NAM 2025

The orbit

	Circular polar orbit	LLO 100	Frozen orbit 41x190	Frozen orbit 70x166	Frozen orbit 100x199	Frozen orbit 90x190
						
Hp x Ha (km x km)	100 x100	100.58 x 100.62	41 x 190	70.537 x 166.663	100x199	90x190
a (km)	1837.4	1838.00	1853.201	1856	1887.117	1877.3639
e	0	1.00E-05	0.04036	0.025896	0.026291	0.0266139
i (deg)	90	94	90	91	90	90
RAAN (deg)	0	0	0	0	0	0
AoP (deg)	270	90	270	270	270	270
M (deg)	0	0	0	0	0	0
Time in RF shield per year [hr]	998	1023.7	957	955	840	872
Time in RF shield and Sun eclipse per year [hr]	389	415.72	363	373	307	324
Minimum lifetime for 1296 in RF shield [years]	1.30	1.27	1.35	1.36	1.54	1.49
Minimum lifetime for 1296 with in RF shield and Sun eclipse [years]	3.33	3.11	3.57	3.47	4.22	4

Dealing with the Sun

Reducing the impact of the **Earth** and the **Sun**