LUNAR COSMOLOGY

CAA, March 29, 2023

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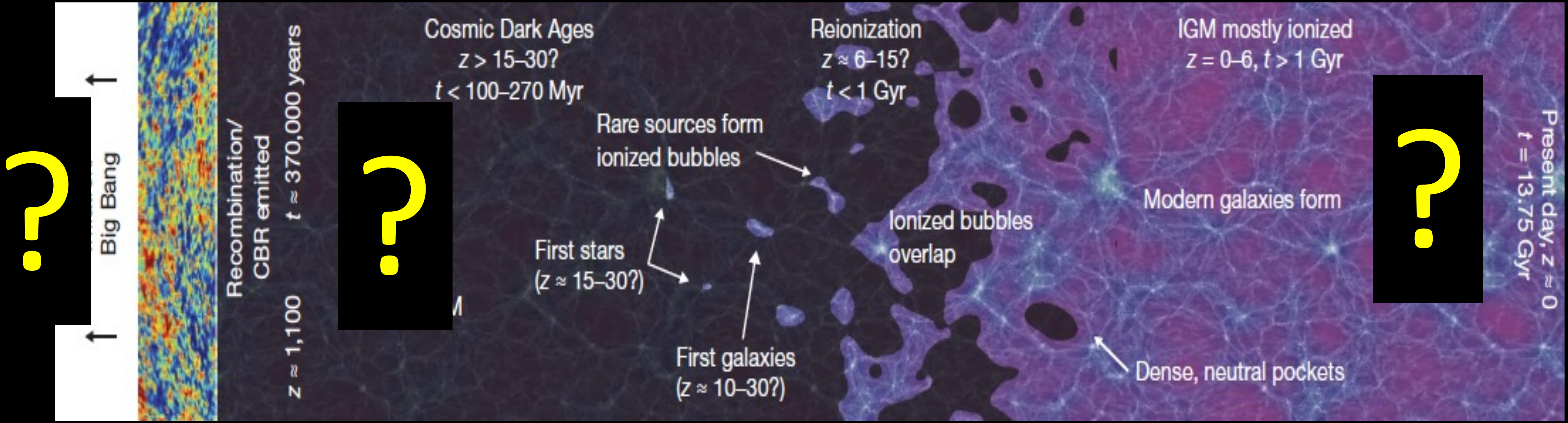
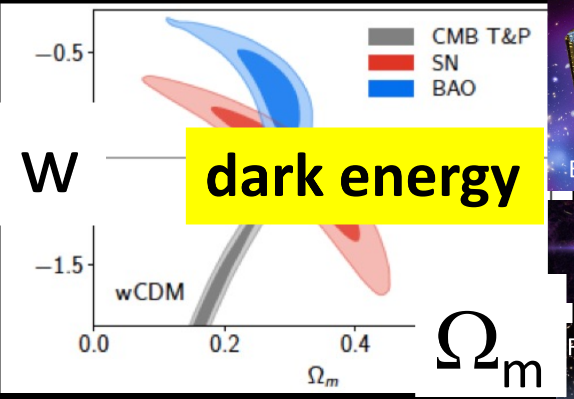
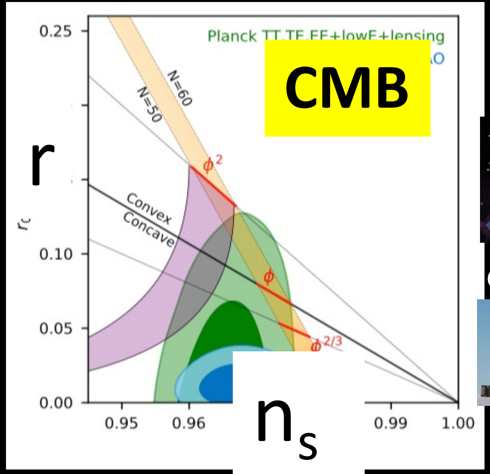
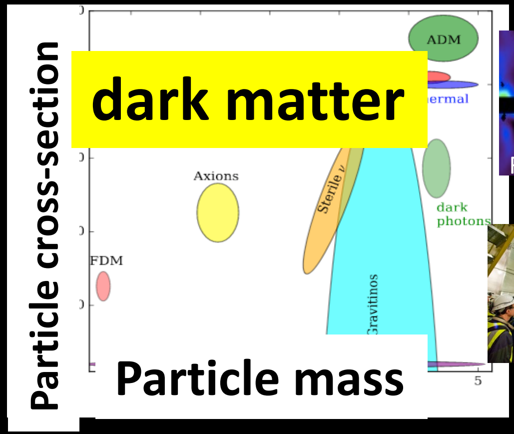


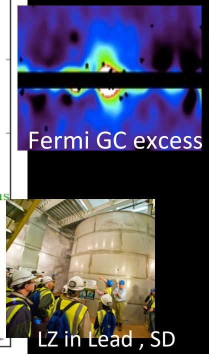
progress in cosmology

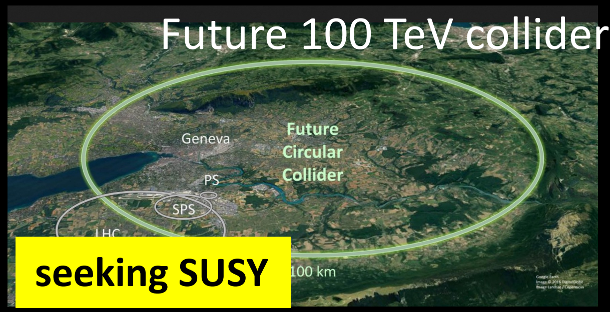
- nature of dark matter, dark energy?
- new frontier is the dark ages
- our origins? inflation needs verification

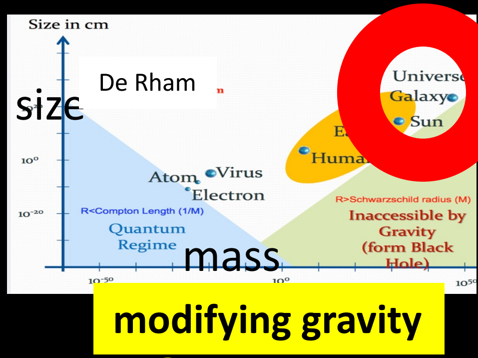












one common feature of all current or planned cosmology experiments:

no guaranteed return!

neutrino mass excepted....

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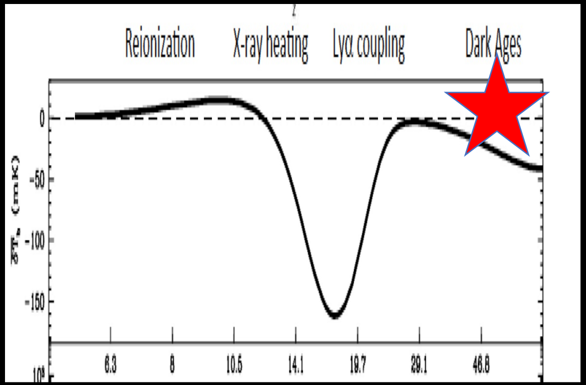
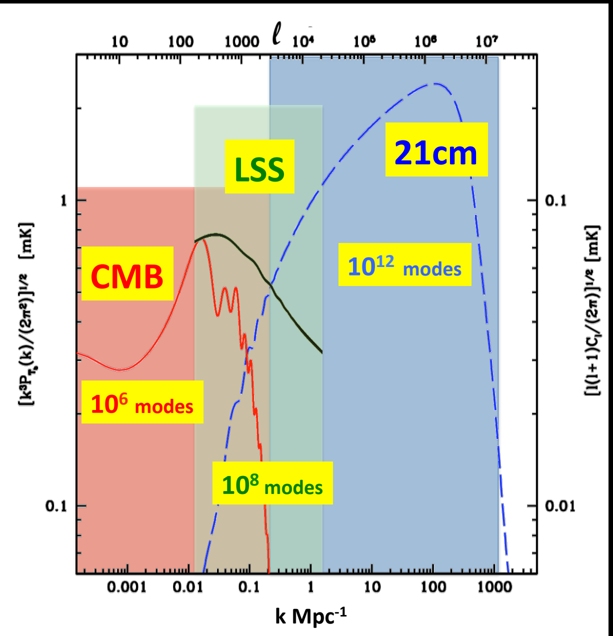
Dark ages is new frontier



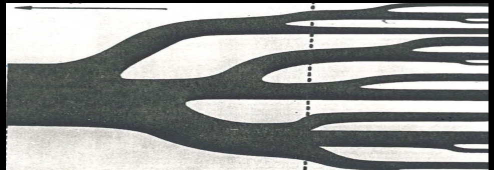
Dark ages in absorption

wealth of information

z=30-100 before any galaxies or stars



Seek building blocks



seek global signal

power spectrum of fluctuations

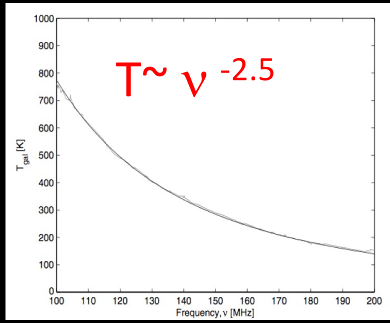
nongaussianity from inflation

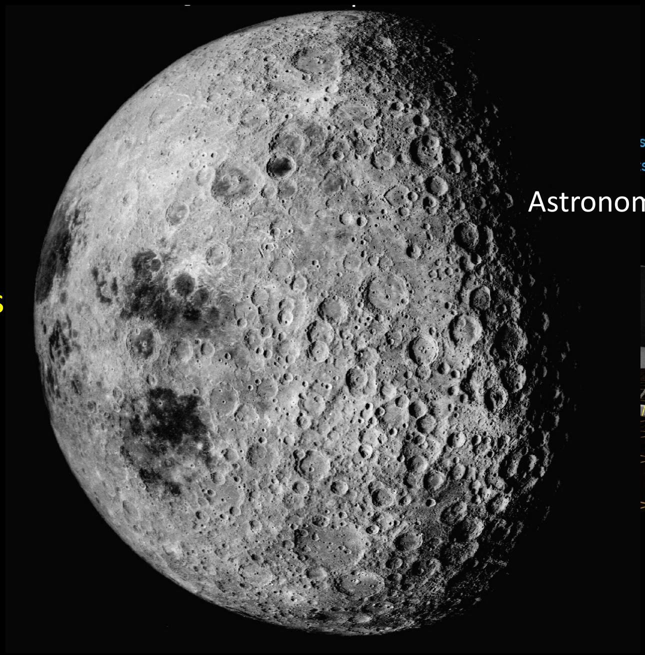
far side of MOON is most radio quiet environment in inner solar system @ 30 MHz + no ionosphere

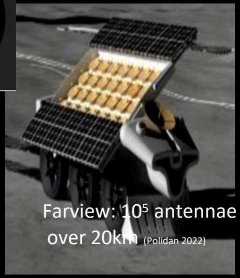
ultimate experiment
lunar radio interferometer

21cm: probe z=50 at λ~ 10 m
100 x CMB resolution ℓ ~ 10^5 or k~ $10 \mathrm{Mpc}^{-1}$
array ℓ $\lambda/2\pi$ over D ~100 km + millions of 10 m dipoles

only ~ 10mK signal in bright foreground

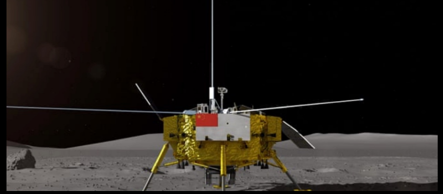


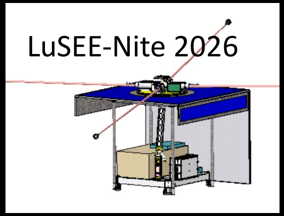




. Bandyopadhyay

Chang'e 4 2019 on far side

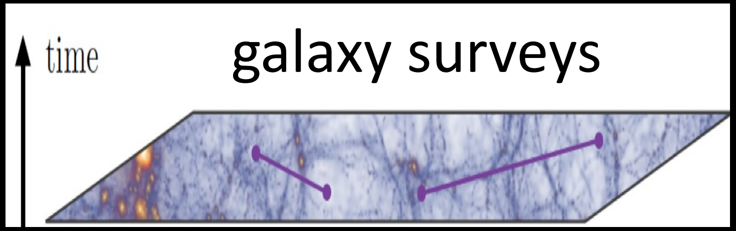




How to explore the dark ages

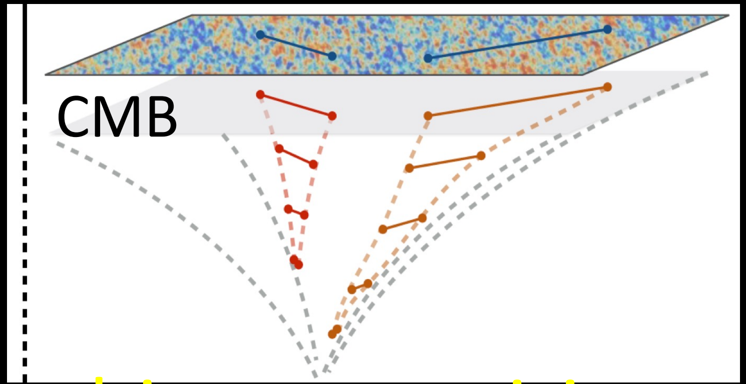
$\delta T/T\ (1+ f_{NL}\ \delta T/T)$ $f_{NL} \sim -5/12\ (n_s-1) \sim 0.01$ $n_s=0.96\ (9\ \sigma)$

Maldacena 2003, Cabass + 2017; Mattarese + 2021



CMB modes	$N \sim 10^6$	$f_{NL} \sim 10$
Galaxy surveys	$N \sim 10^8$	$f_{NL} \sim 1$
21 cm $z \sim 50$	$N \sim 10^{12}$	$f_{NL} \sim 0.01$

dark ages 21cm



Test inflation via primordial nongaussianity: ultimate precision cosmology

bottom-up formation is fundamental

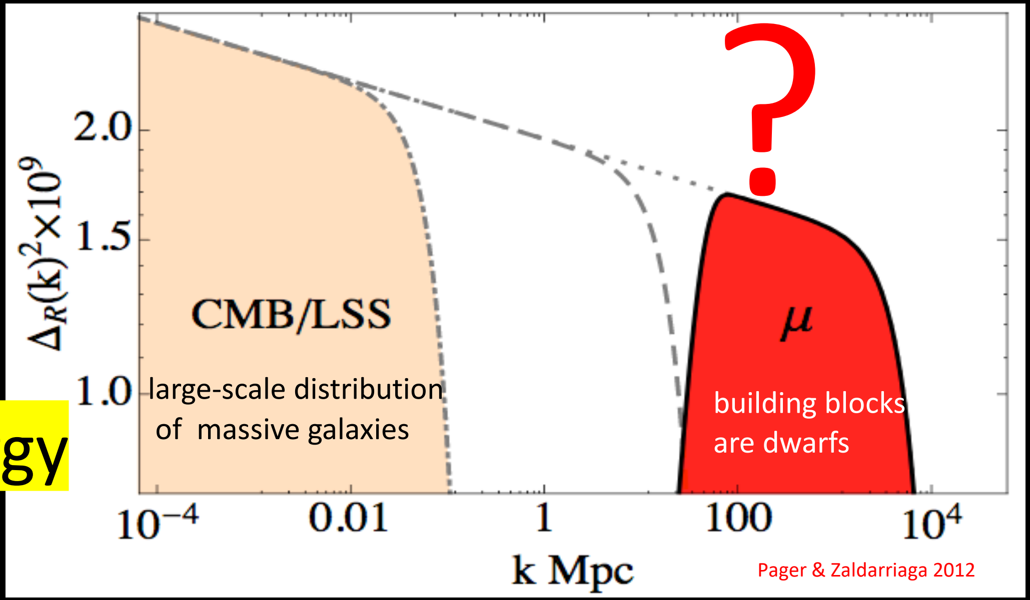
How to test this?

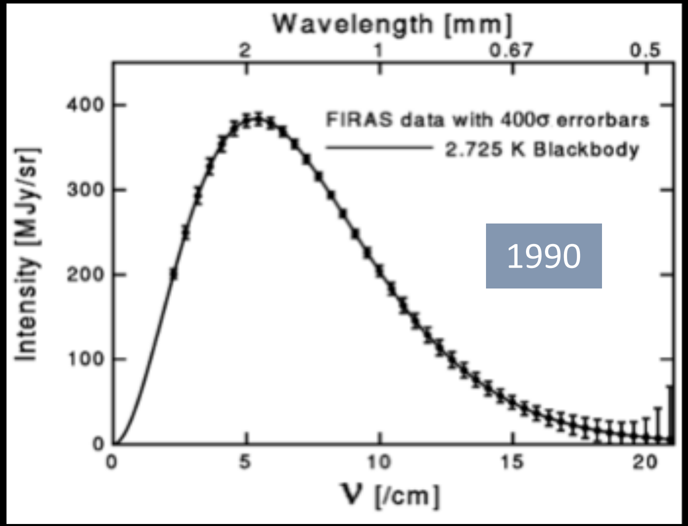
CMB can't be a perfect blackbody

2

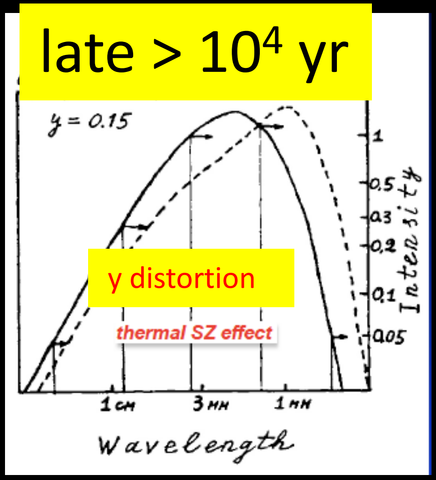
$$T_0 = 2.725 \pm 0.001\,\mathrm{K}$$
$$|y| \leq 1.5\times10^{-5}$$
$$|\mu| \leq 9\times10^{-5}$$

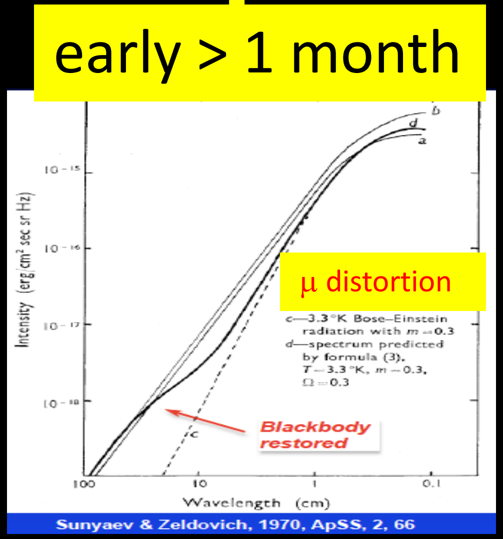
Friction of fluctuations against radiation in first months injects early energy



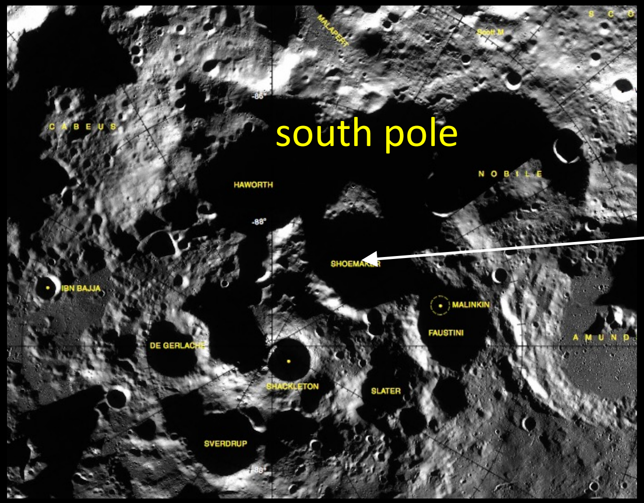


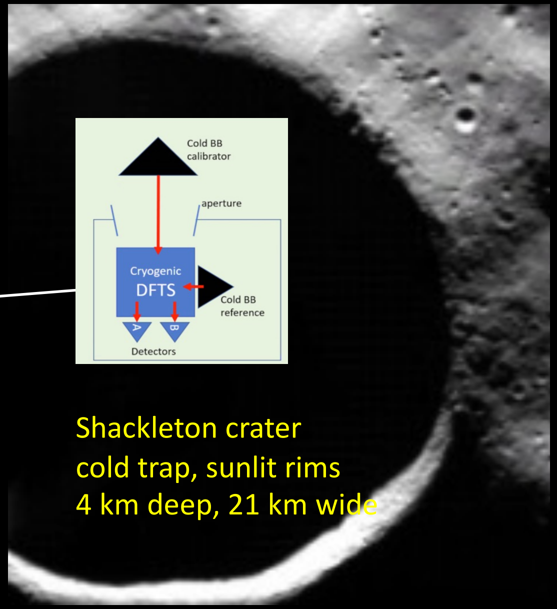
seek spectral distortions





look again with FIR spectrometer

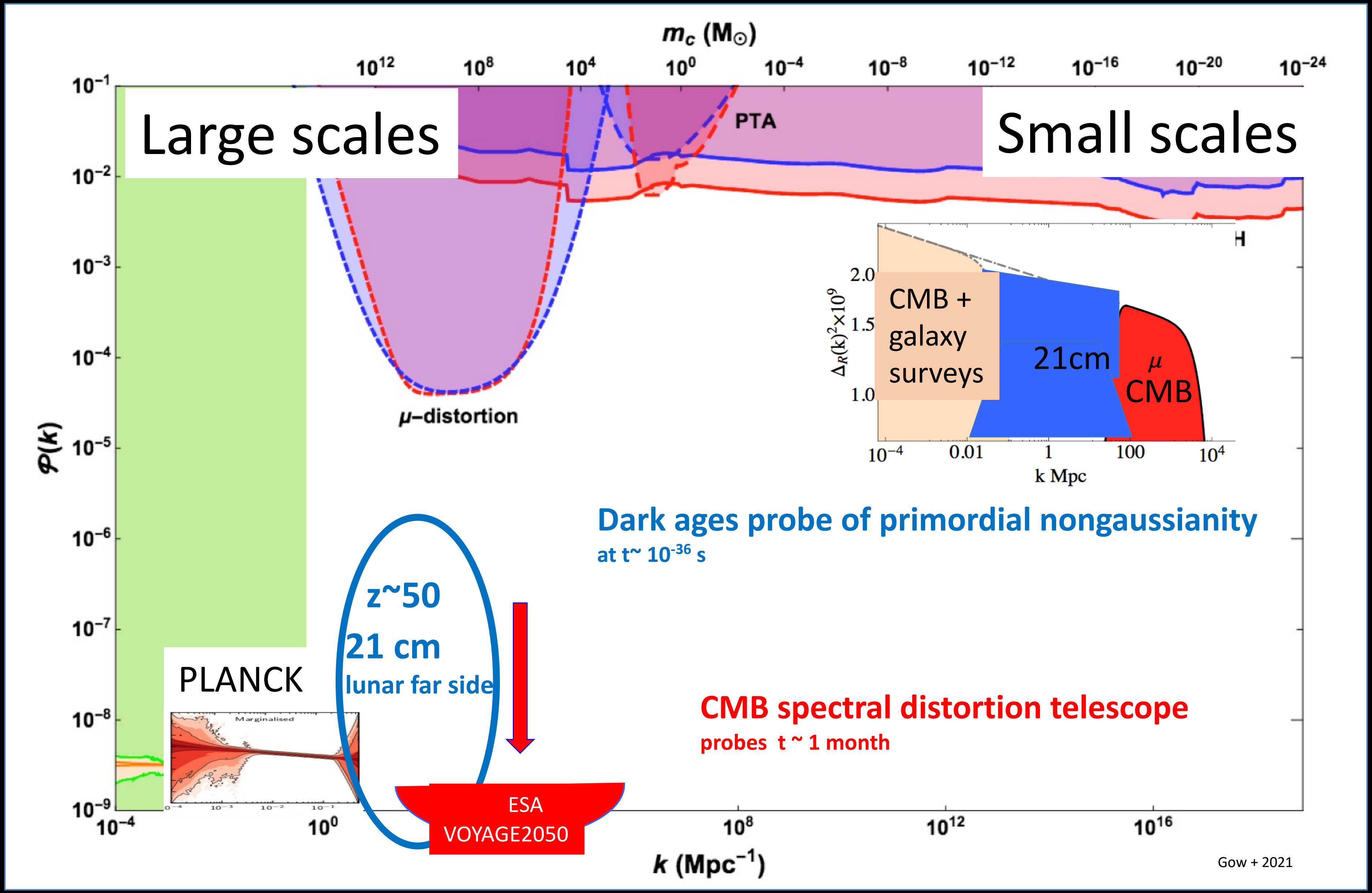




Fourier transform interferometer
90--2000 GHz bolometer array
in ~30K permanently dark crater
1.5 m telescope cooled to 2.5 K.

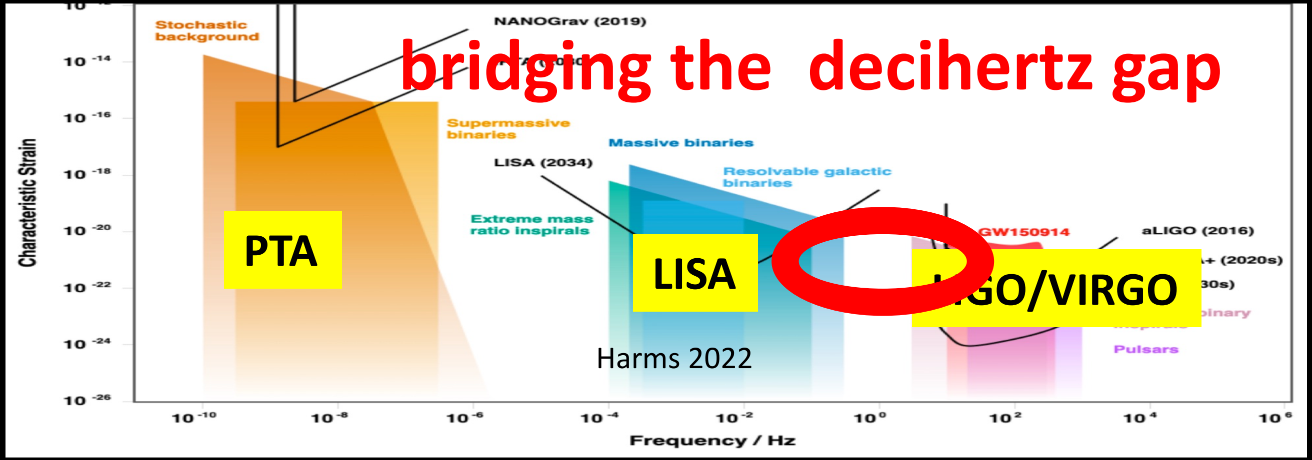
Scan sky by lunar rotation
Sunlit rims for solar power

probing origins of galaxies



more than cosmology

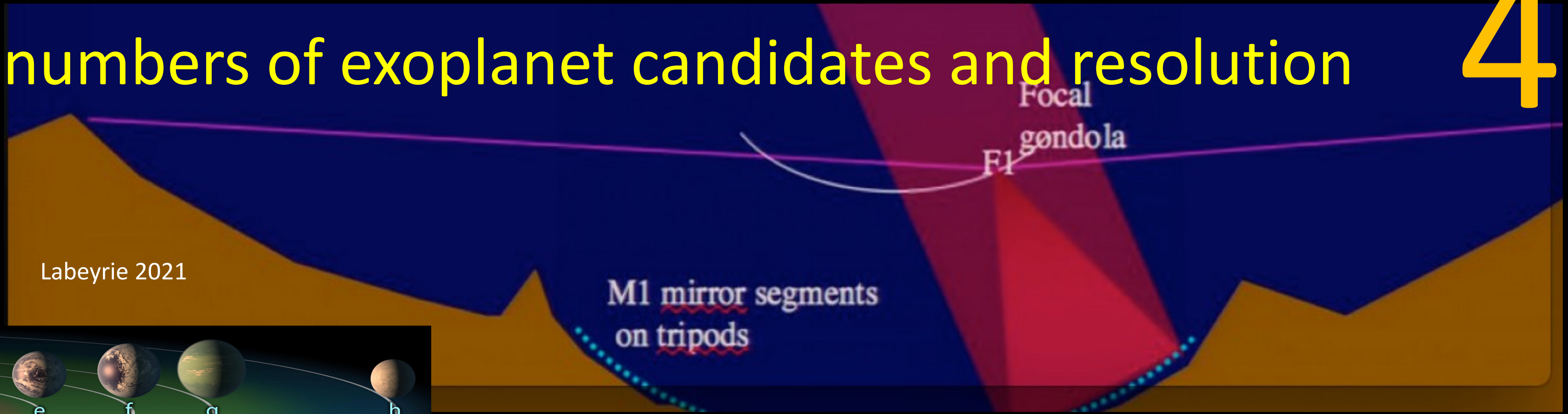
3



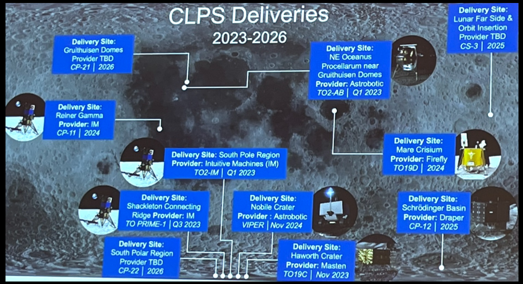
telescope size counts

greatly increase numbers of exoplanet candidates and resolution

4

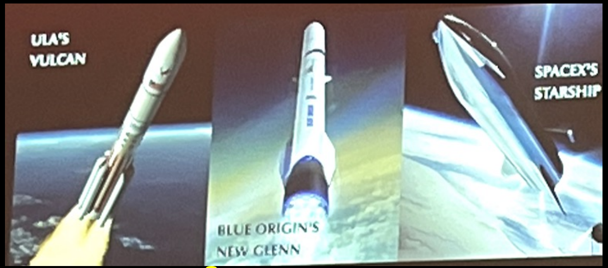


Compelling science



probe dark ages

far side of MOON is most radio-quiet environment in inner solar system, no ionosphere



CMB spectral distortions

With perpetual solar power availability and permanent cold/darkness, no atmosphere

current renaissance in lunar science projects

Decreasing launch cost
NASA CLPS: ROLSES, LuSEE-Nite
ESA Argonaut lunar lander/Terrae Novae
CNSA: DSL, LARAF

larger lunar payloads

What were our cosmic origins?

number of suitable sites is limited

RADIO FAR SIDE

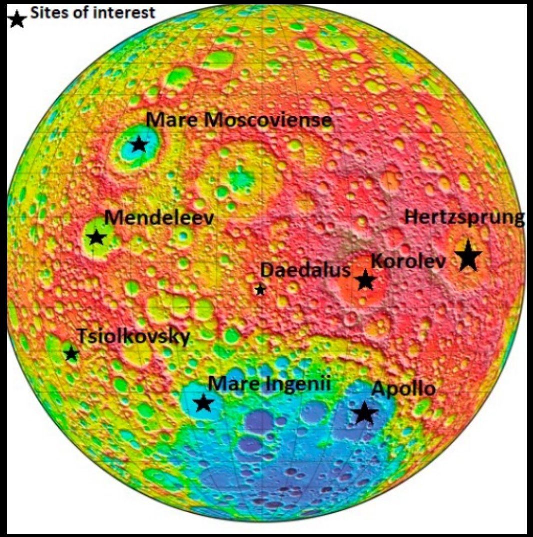
5-50 km scale
smooth
mild slopes
far side for low terrestrial interference

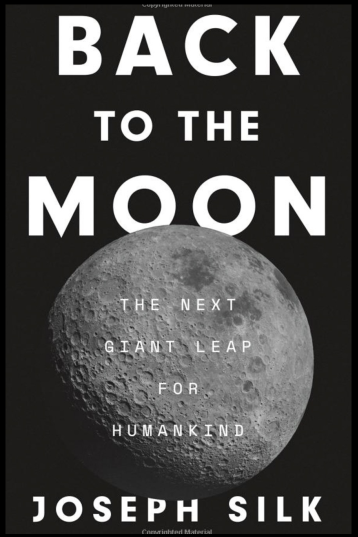
GRAVITY WAVE/FIR PSCs

Permanently shadowed polar craters
cold to very cold
low water content
High rims for solar. Powe

ORBITING SATELLITES

Radio noise





international coordination
multidecadal planning