Astronomy/Geology 5835

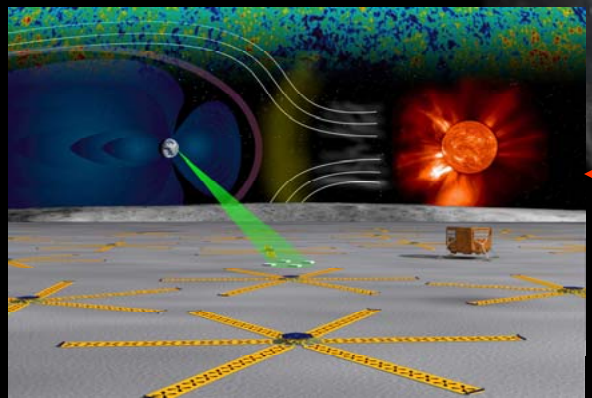
Interdisclinary Lunar Science Seminar

Class Syllabus & Website:

http://lunar.colorado.edu/~jaburns/astr5835

Science of the Moon

Science on the Moon



Science from the Moon

NASA Lunar Science Institute

WHAT IS LUNAR SCIENCE?

For the NLSI, lunar science is broadly defined to include studies:

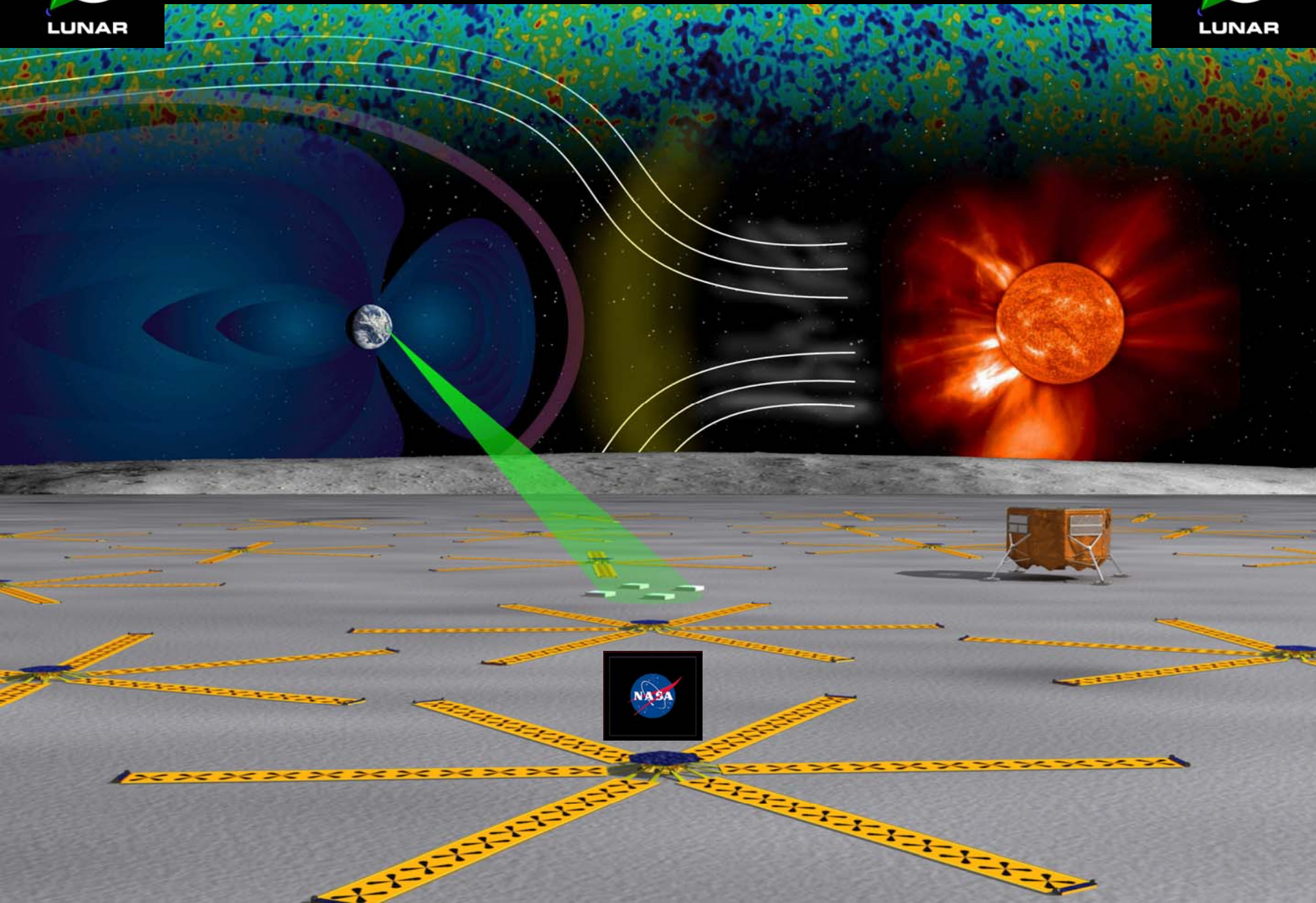
- ***Of the Moon:*** Investigations of the nature and history of the Moon (including research on lunar samples) to learn about this specific object and thereby provide insights into the evolution of our solar system

- ***On the Moon:*** Investigations of the effects of the lunar environment on terrestrial life and the equipment that supports lunar inhabitants, and the effects of robotic and human presence on the lunar environment

- ***From the Moon:*** Use of the Moon as a platform for performing scientific investigations, including observations of the Earth and other celestial phenomena that are uniquely enabled by being on the lunar surface.

GSFC · CfA · VERITAS · JPL · NASA Lunar Science Institute · MIT Massachusetts Institute of Technology · NRAO · UCLA · UCSD · University of Maryland · UNM · CASA

Exploring the Cosmos from the Moon

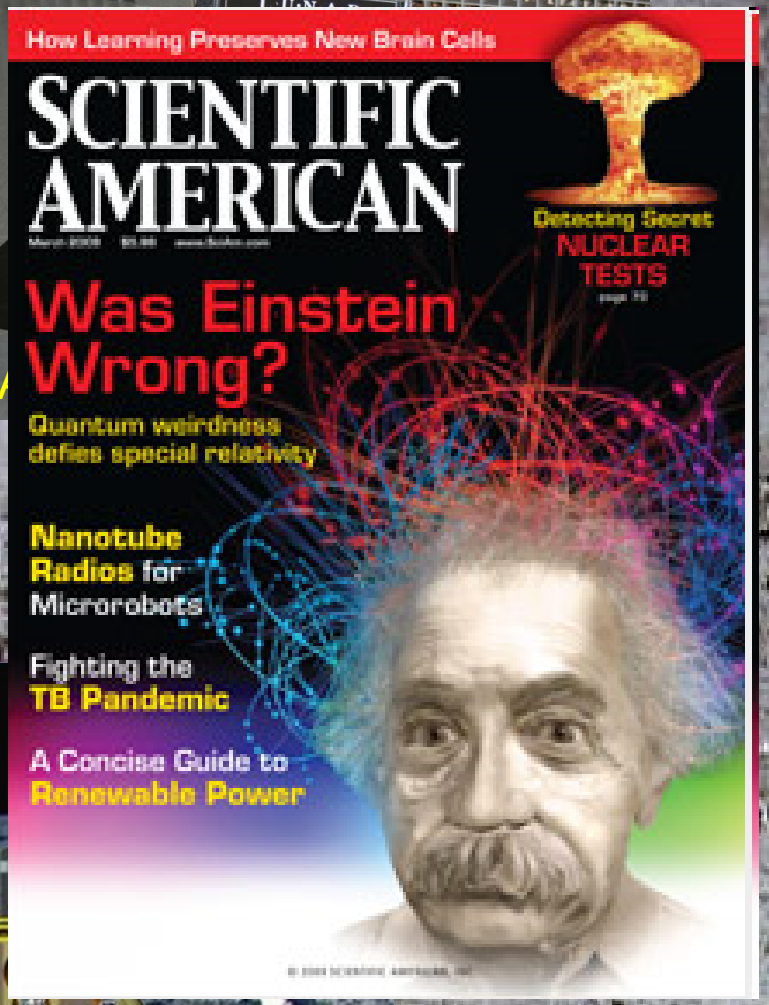


Gravitational Physics & Lunar Structure via Lunar Laser Ranging

Current Capabilities

- Accuracy ≈ 1 mm.
- Strong Equivalence principle $\eta < 4 \times 10^{-4}$.
- $\dot{G}/G < 6 \times 10^{-13}$ per year.
- Deviation from inverse-square law is $< 3 \times 10^{-11}$ times strength of gravity at 10^{8} m scales.

Next-Generation Laser Retroreflector Array for the Moon

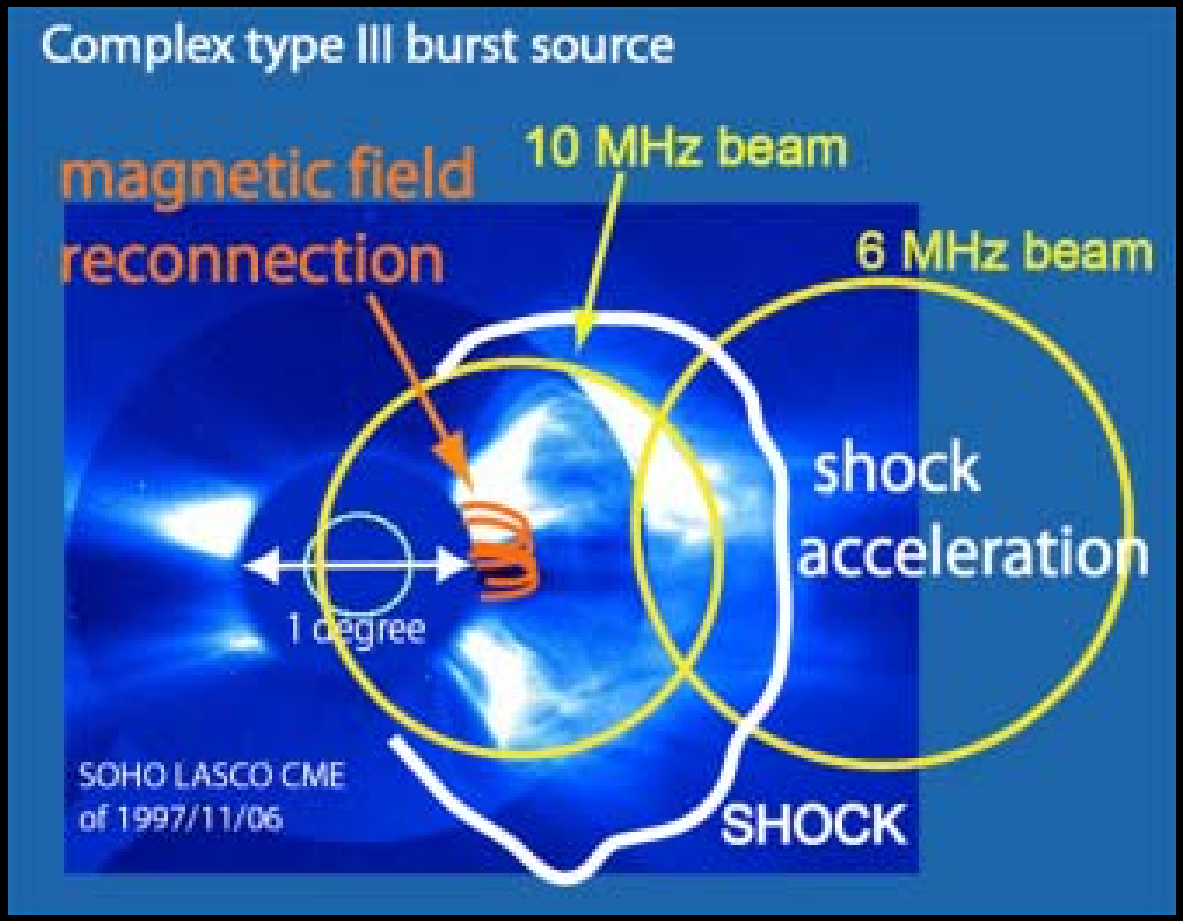


Fundamental Questions on Gravity:*

- Does Dark Energy exist?
- Is the Equivalence Principle exact?
- Does the strength of gravity vary with space and time?
- Do extra dimensions or other new physics alter the inverse square law?

*from Science White Papers submitted to Astro2010 & Planetary Sciences Decadal Surveys.

Radio Heliophysics from the Moon

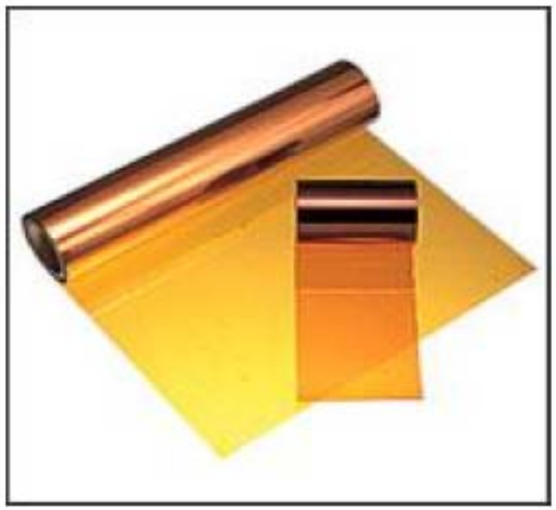


- How does cosmic ray acceleration occur within the heliosphere?
- A low frequency radio array will produce the first resolved (≤2° at 10 MHz), high time resolution images of solar radio emissions (outer corona).

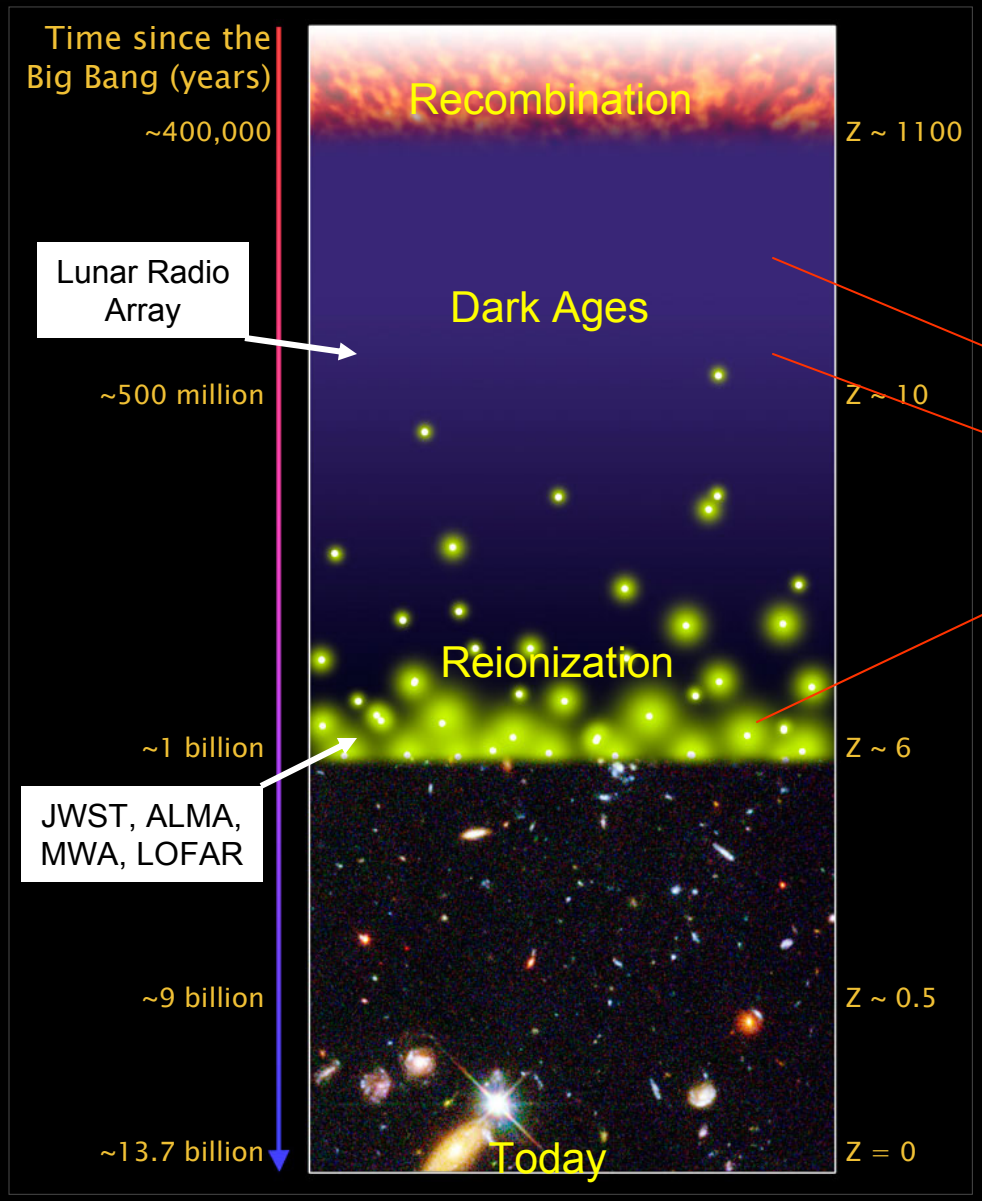
ROLSS: Radio Observatory for Lunar Sortie Science

A Pathfinder for a future long-wavelength farside lunar array (10-100 sq. km). Operating at 1-10 MHz (30-300 m). Array consists of three 500-m long arms forming a Y; each arm has 16 antennas.

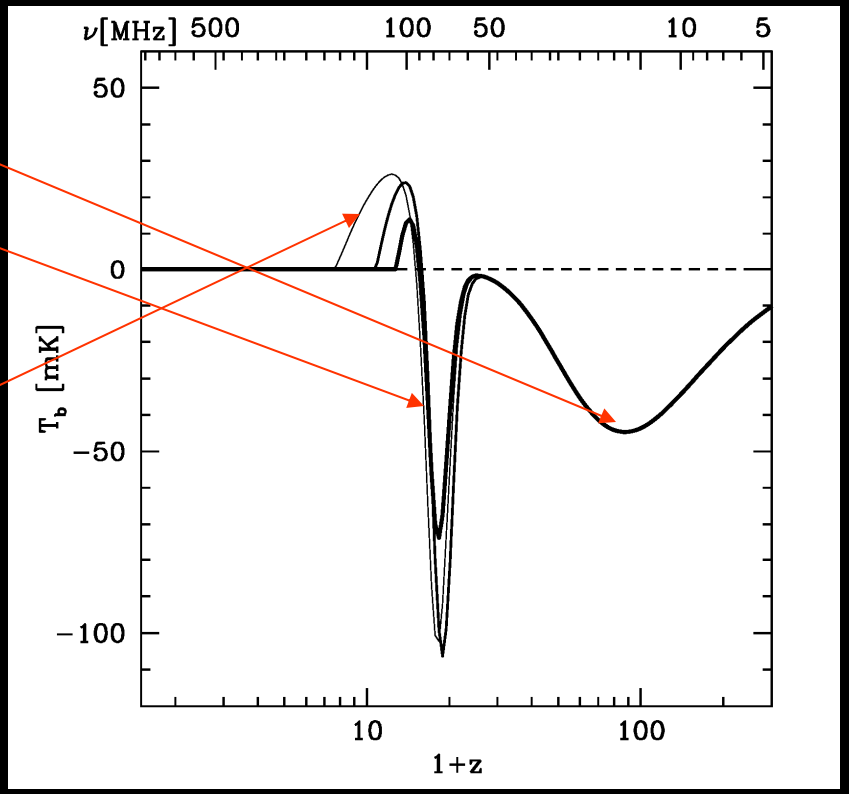
- Arms are thin polyimide film on which antennas & transmission lines are deposited.
- Arms are stored as 25-cm diameter x 1-m wide rolls (0.025 mm thickness).



Low-Frequency Cosmology & Astrophysics from the Moon



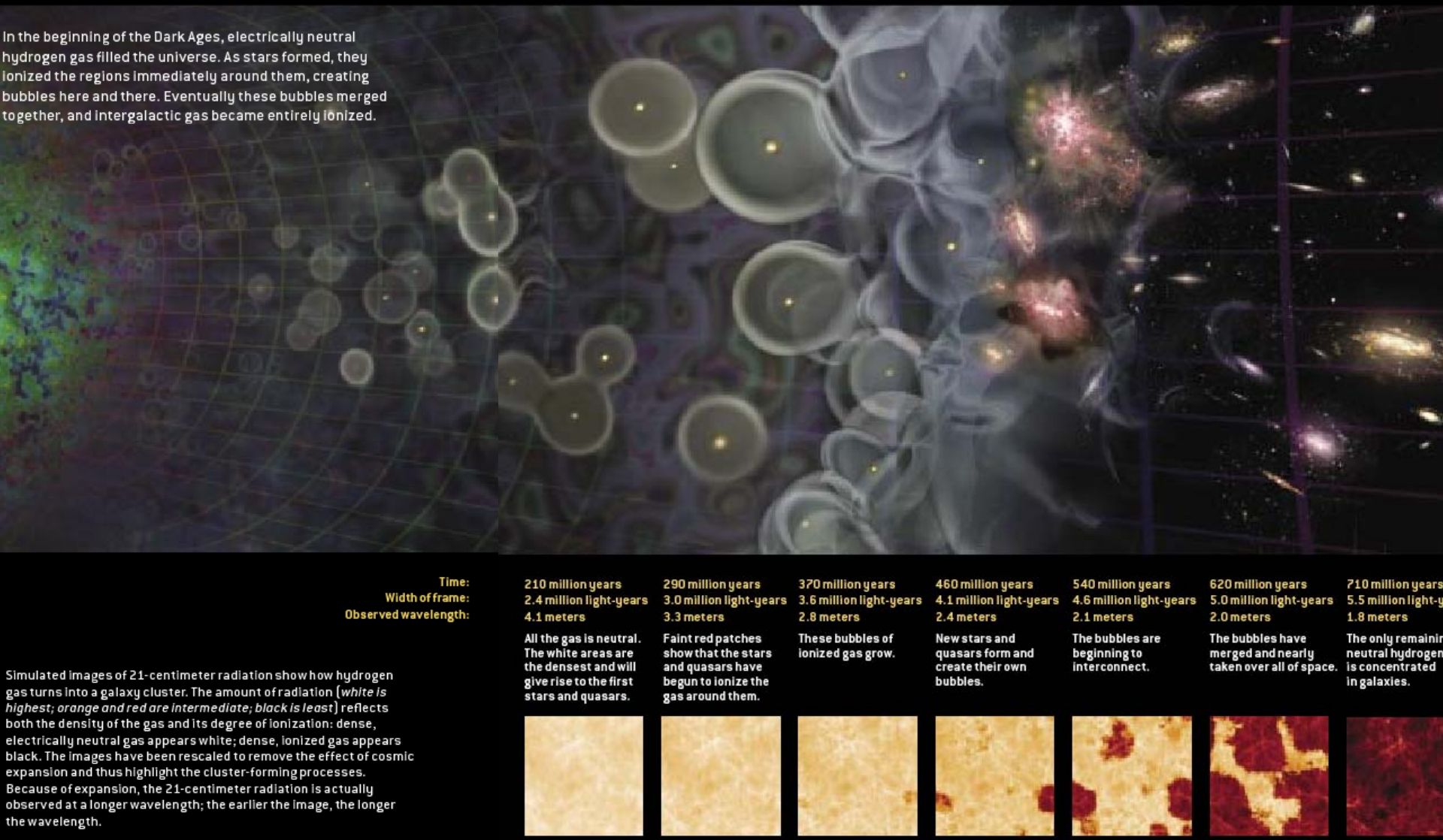
The Global (sky-averaged) HI Signal



Pritchard & Loeb, 2008, Phys. Rev. D., 78, 3511.

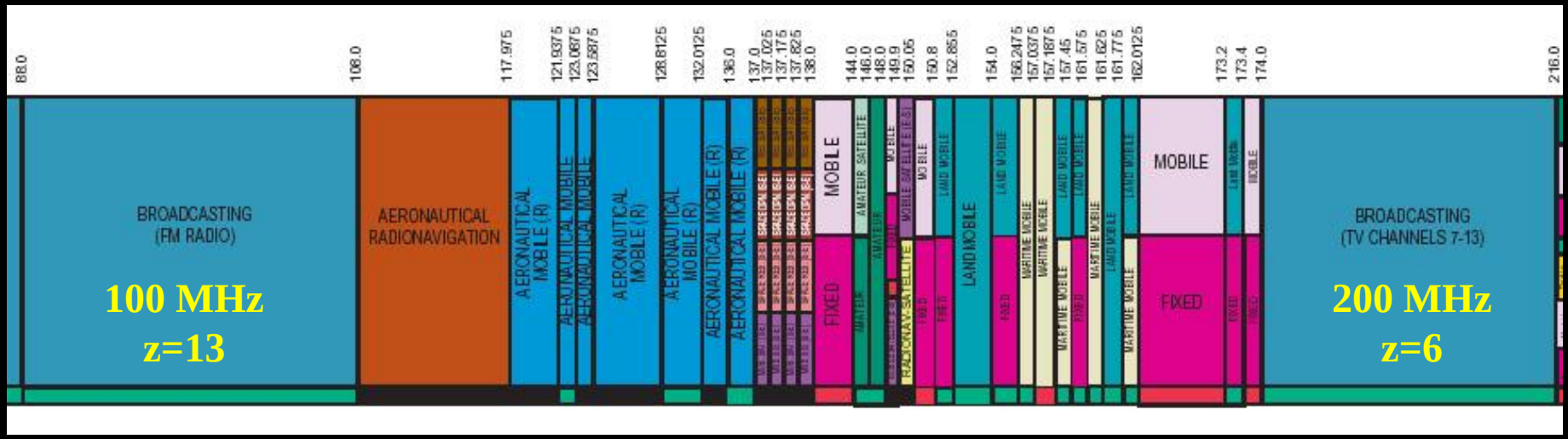
21 (1+z) cm = 1420/(1+z) MHz
At z=10, λ = 2.3 m (130 MHz)
At z=50, λ = 10.7 m (30 MHz)

The Dark Ages Viewed via the Highly Redshifted 21-cm Line



Loeb, A. 2006, *Scientific American*, 295, 46.

Lunar Advantage: No Interference



Destination: Moon!

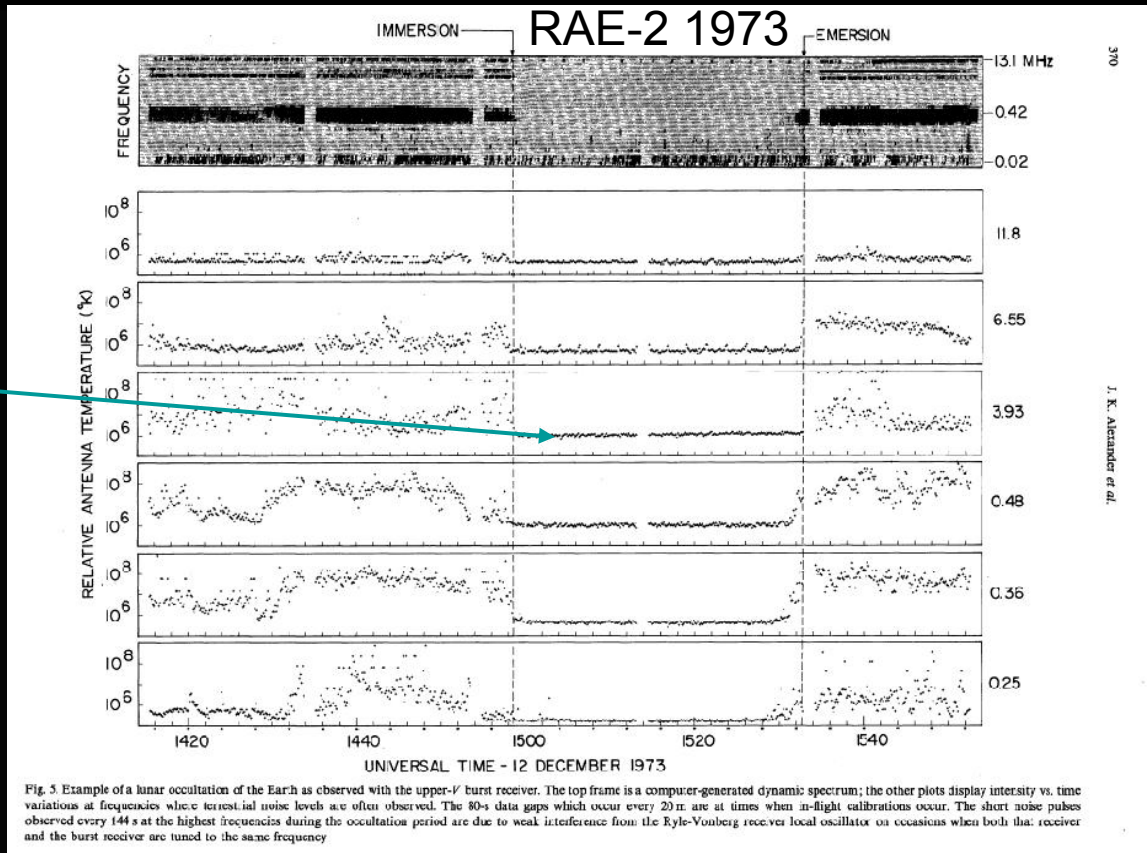


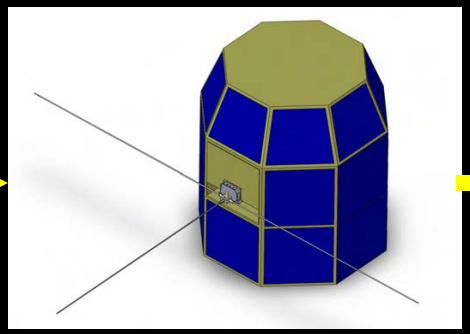
Fig. 3. Example of a lunar occultation of the Earth as observed with the upper-V burst receiver. The top frame is a computer-generated dynamic spectrum; the other plots display intensity vs. time variations at frequencies where terrestrial noise levels are often observed. The 80-s data gaps which occur every 20 m are at times when in-flight calibrations occur. The short noise pulses observed every 144 s at the highest frequencies during the occultation period are due to weak interference from the Ryle-Vonberg receiver local oscillator on occasions when both that receiver and the burst receiver are tuned to the same frequency

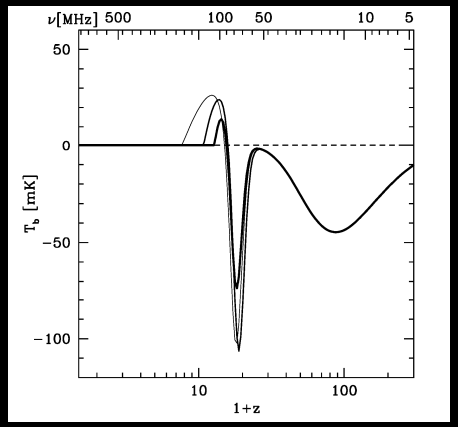
Roadmap to the Early Universe via Earth & the Moon

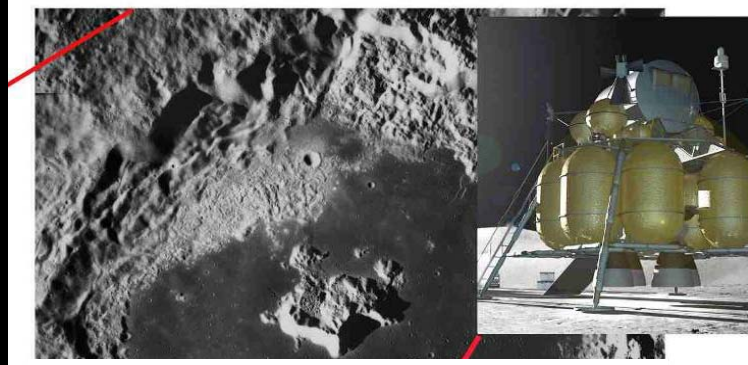
Western Australia

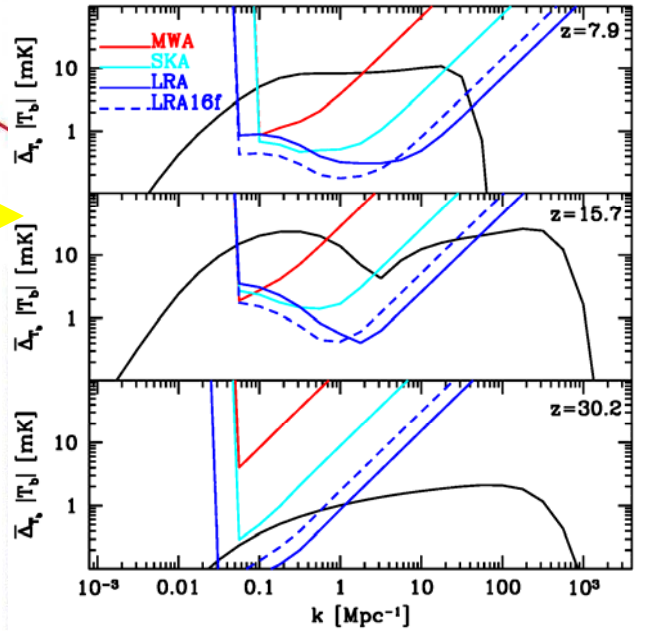
Lunar Orbit

Lunar Farside



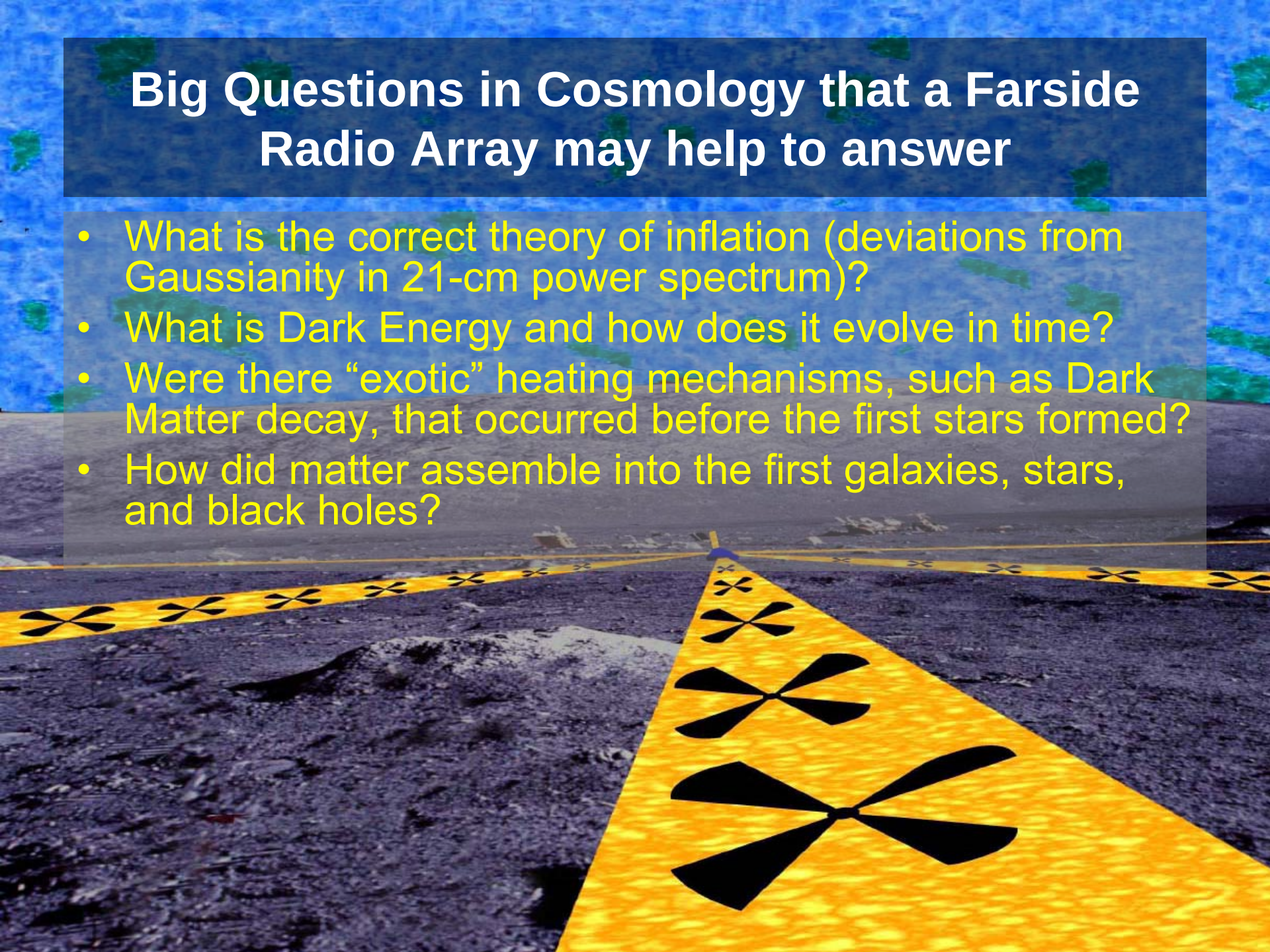






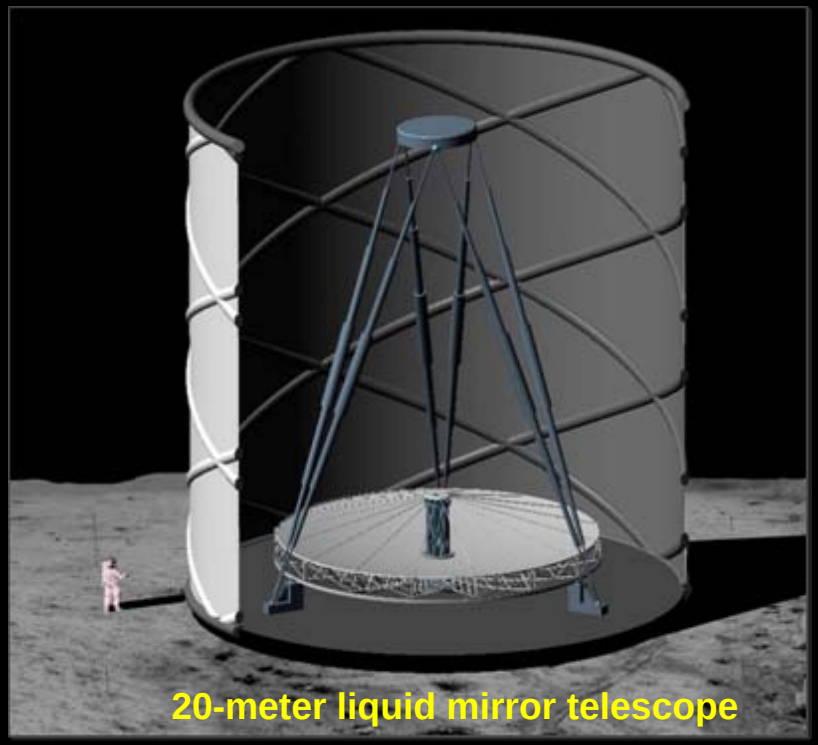
Big Questions in Cosmology that a Farside Radio Array may help to answer

- What is the correct theory of inflation (deviations from Gaussianity in 21-cm power spectrum)?
- What is Dark Energy and how does it evolve in time?
- Were there “exotic” heating mechanisms, such as Dark Matter decay, that occurred before the first stars formed?
- How did matter assemble into the first galaxies, stars, and black holes?



Possible Other Astrophysics Enabled by a Return to the Moon

8-meter monolithic telescope inside Ares V



20-meter liquid mirror telescope

Lunar Cosmic Ray Detector

Summary of LUNAR Components

- Gravitational Physics via Lunar Laser Ranging.
- Low Frequency Radio Heliophysics.
- Low Frequency Cosmology & Astrophysics.
- Assessment of other Astrophysics from the Moon.