Introduction

Special Session: Low Frequency Radio Astronomy for Cosmic Origins

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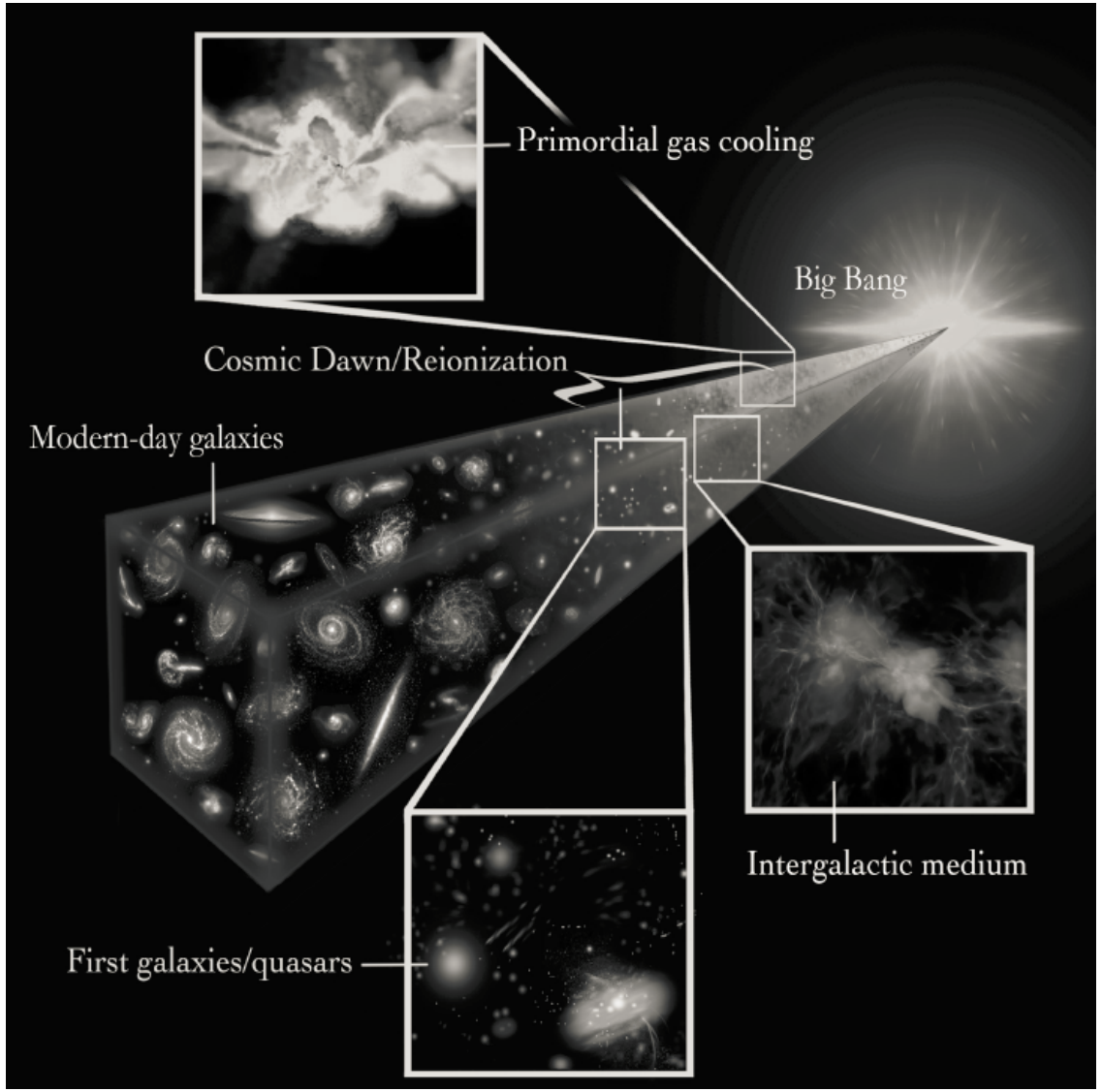
AAS Special Session
1/13/2021

Cosmic Dawn and Dark Ages

- What is the thermal and ionization history of the intergalactic medium?
- When did the first stars form and what were their properties?
- How did the first stars influence the next generations of stars?
- How did galaxies form and evolve?
- When did supermassive black holes first appear and how did they evolve?

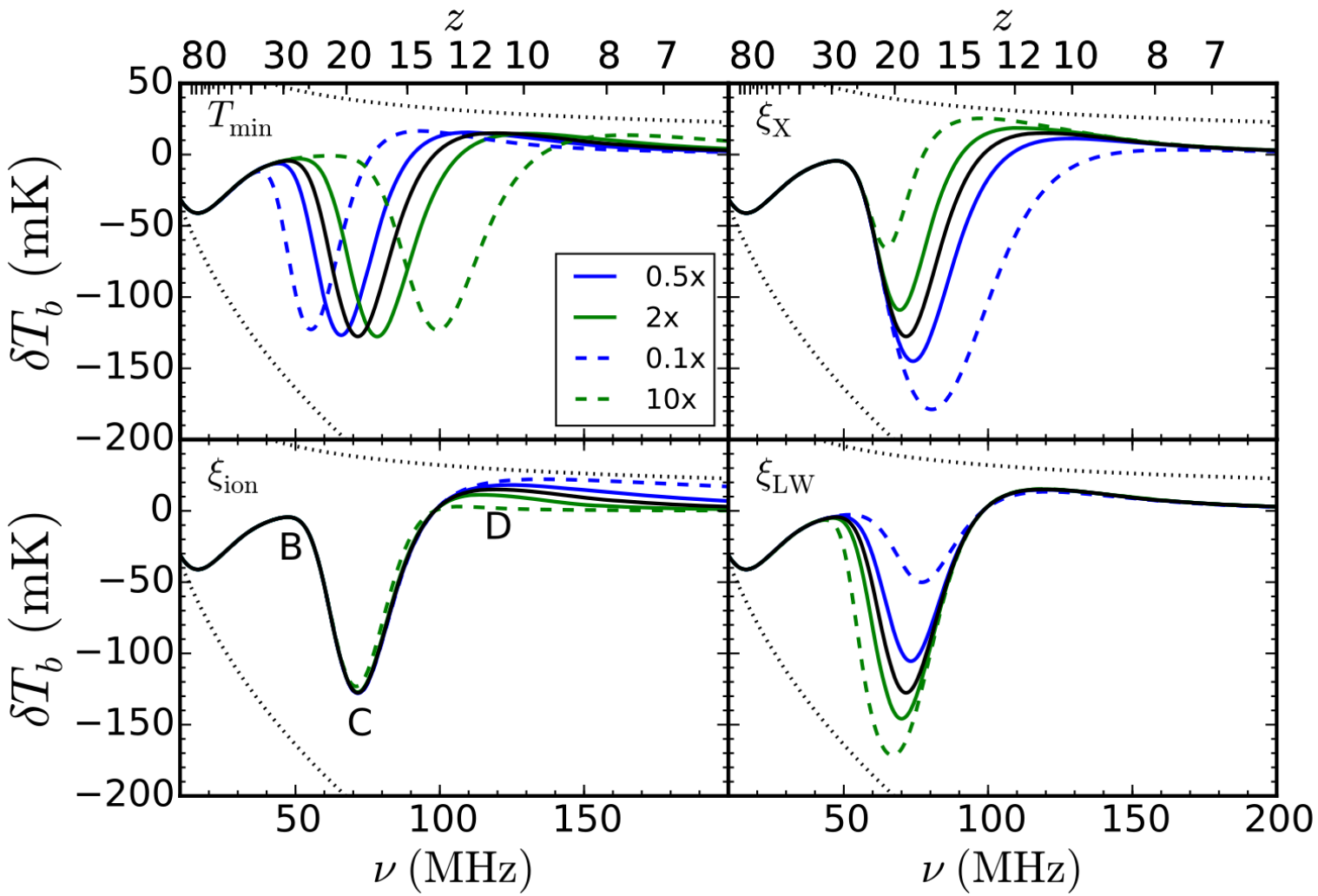


Cooray et al. 2019

21 cm signal

Redshifted 21 cm line of hydrogen is only direct probe of IGM at high redshift (z>6)

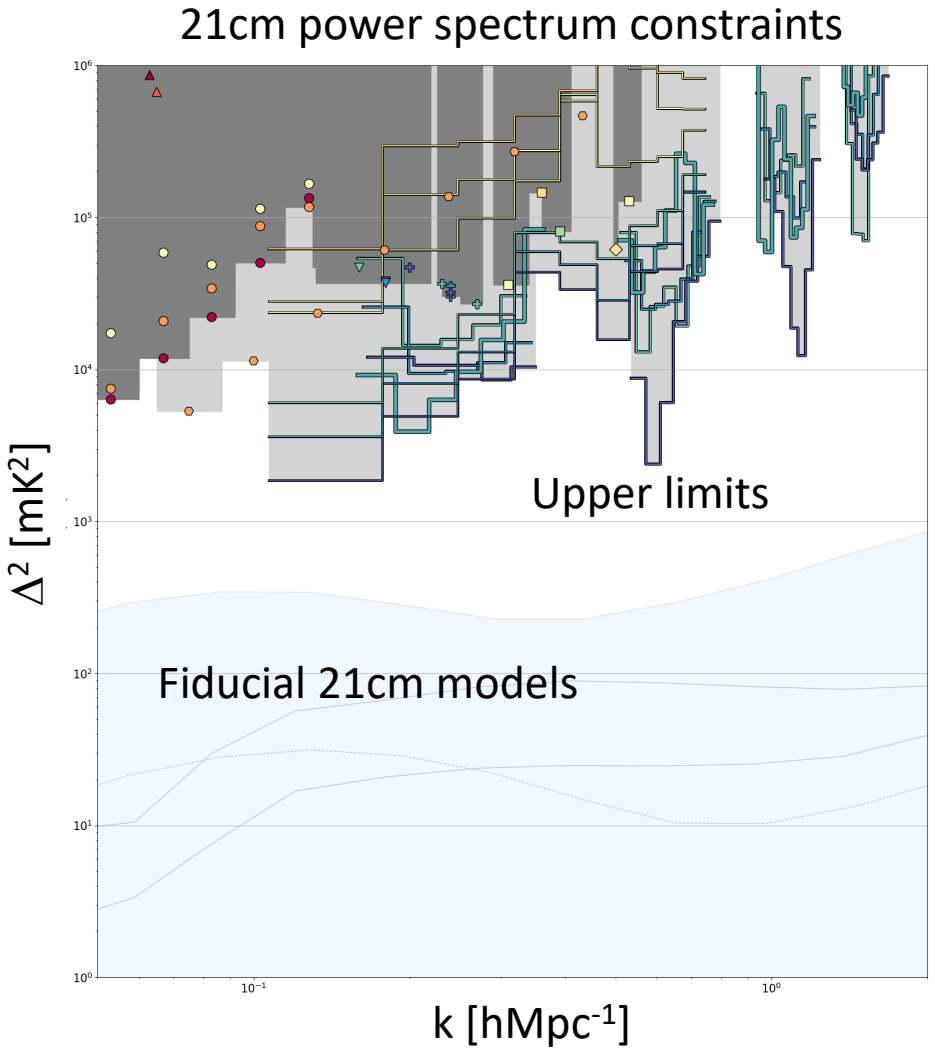
Frequency: <200 MHz Wavelength: >1.5 meters



Mirocha et al. (2015)

Critical 21cm progress in recent years

- Two decades of ground-based instrument and analysis development
- EDGES reported first evidence for detection of global (sky-average) 21cm signal at z=17
- Interferometer (LOFAR, MWA, PAPER) upper limits on 21cm power spectrum ruling out models with weak X-ray heating
- HERA radio telescope coming online now (3rd-generation instrument)
- Comparable to CMB in 1990s



https://github.com/EoRImaging/eor_limits

Earth's ionosphere is fundamental limit to ground-based observations

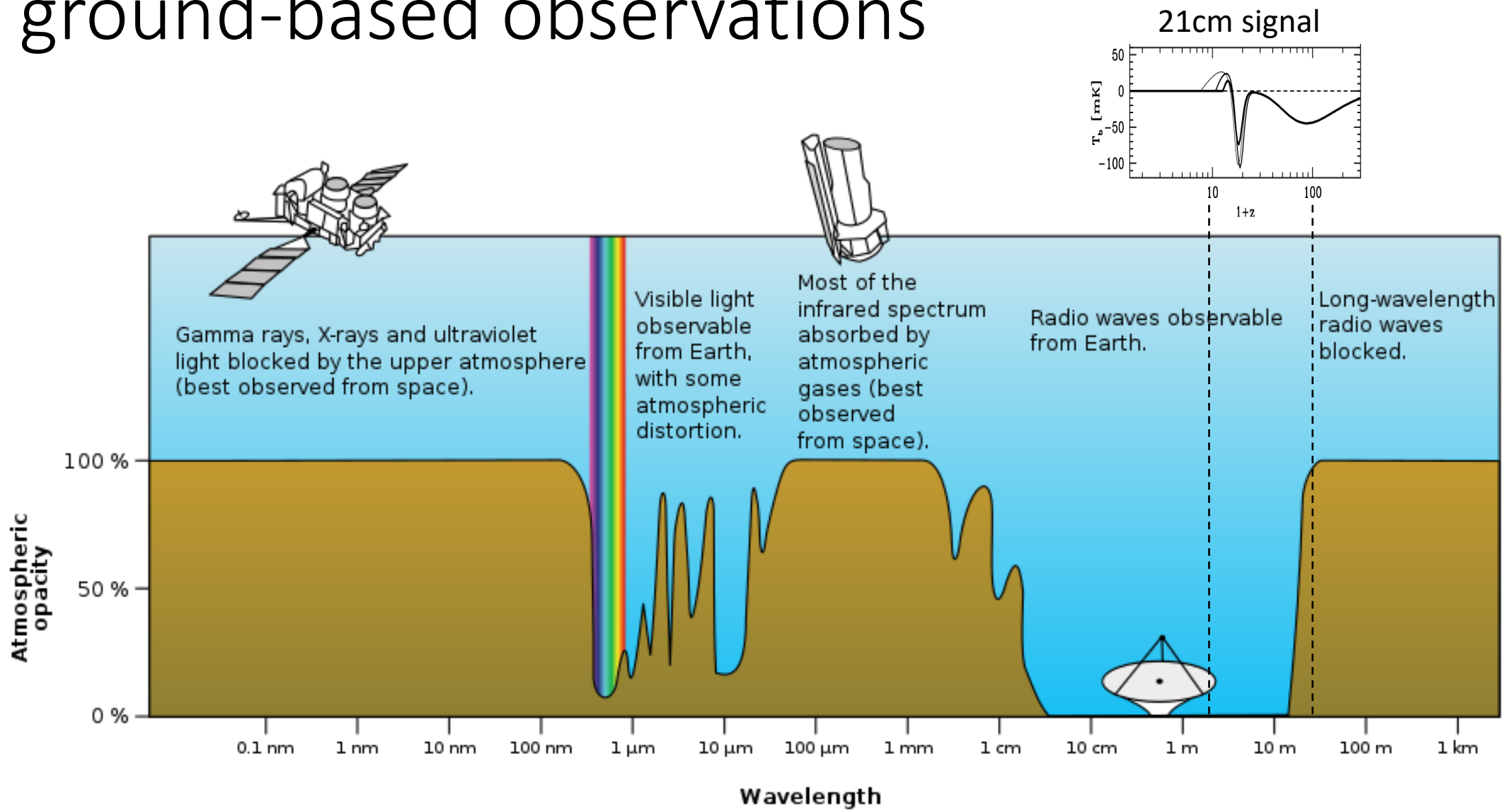
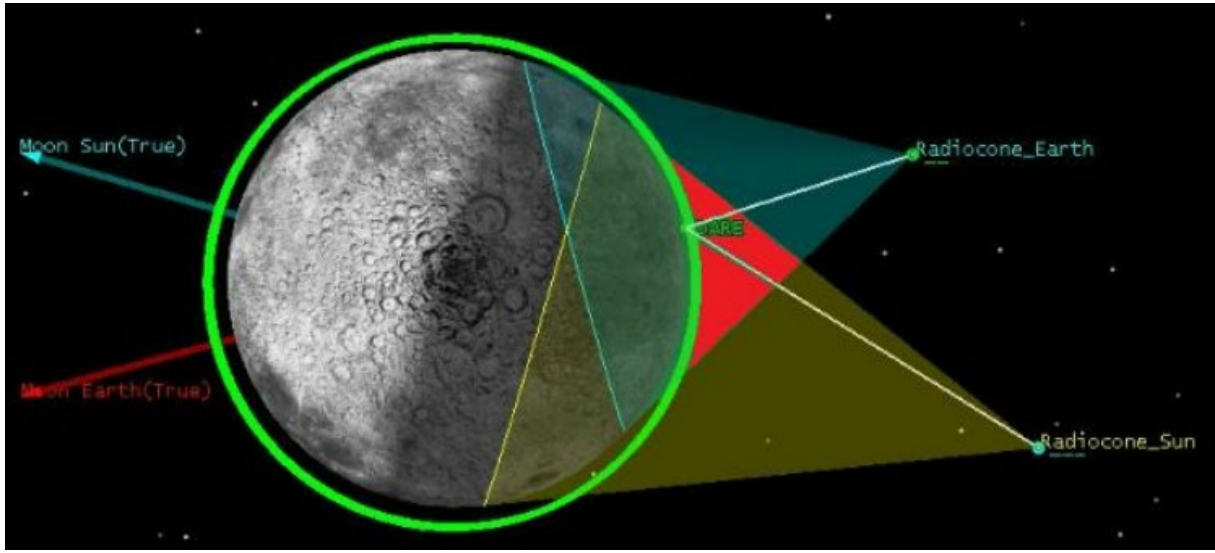


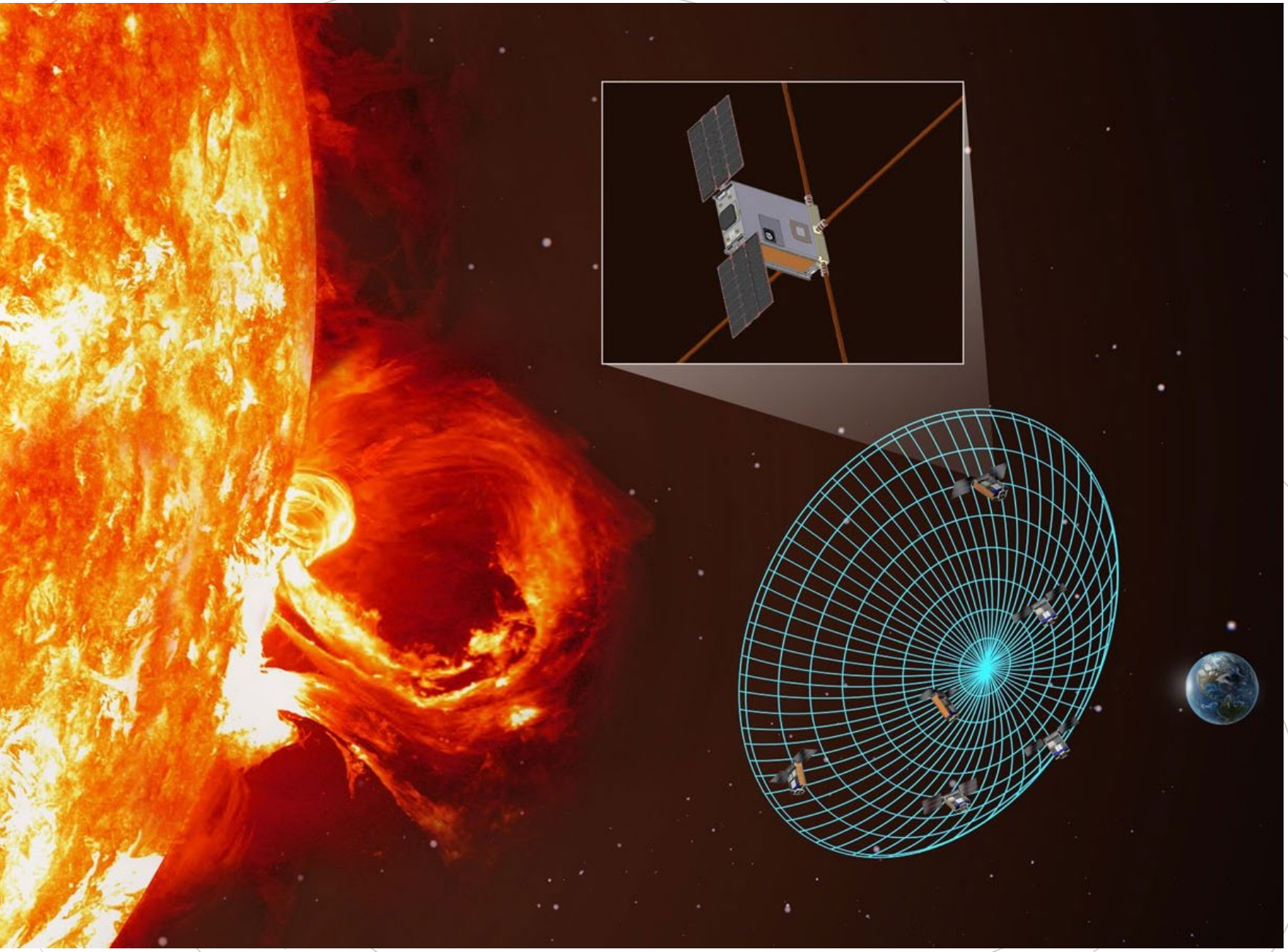
Image from wikipedia

Lunar farside is best location in Solar System

- Limitations on Earth
  - Ionosphere (opacity, emission, scintillation, refraction)
  - Human-generated radio interference
  - Complex environmental factors
- Advantages of lunar farside
  - Minimal ionosphere
  - Shields Earth interference
  - Shields Earth auroral emission
  - Shields solar wind (plasma noise)
  - Surface or orbit



Genova et al. 2015



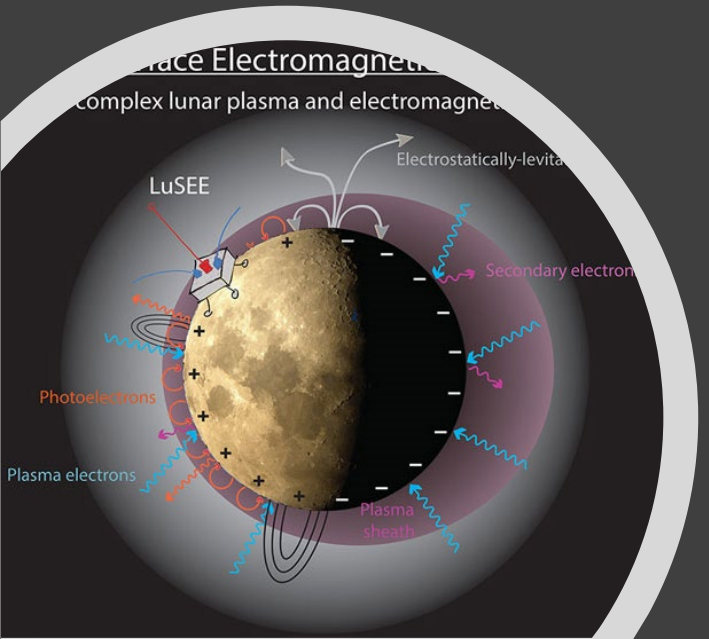
Radio interferometry missions are already in development

Sun Radio Interferometer Space Experiment (SunRISE)

Six 6U cubesats in a geo-stationary orbit constellation to be launched in 2023

See Alex Hegedus talk

Netherlands-China Low Frequency Explorer (NCLE) antennas deployed in lunar orbit in 2019



Pathfinder radio science is underway from the Moon

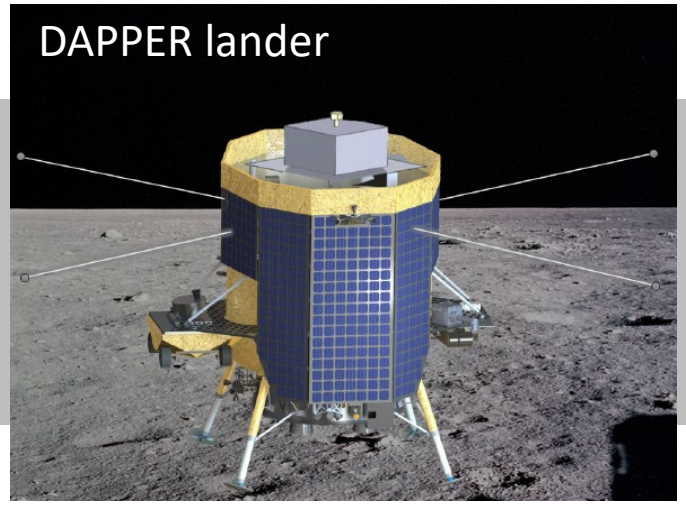
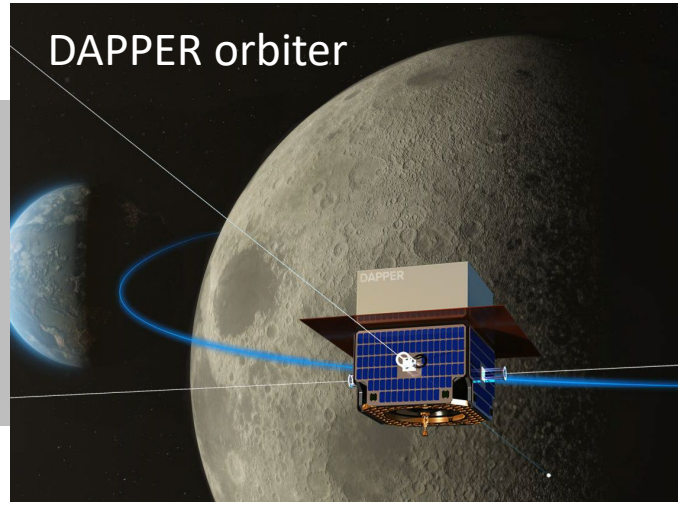
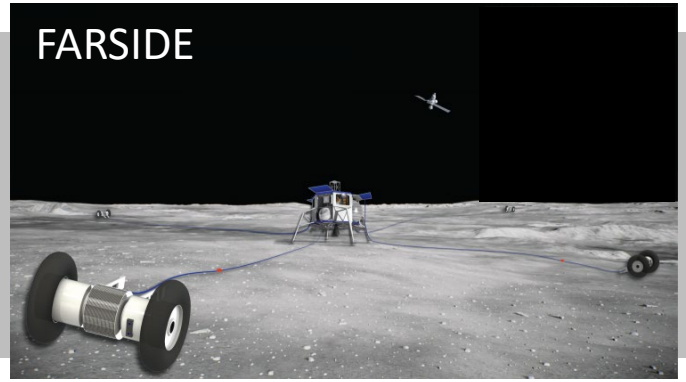
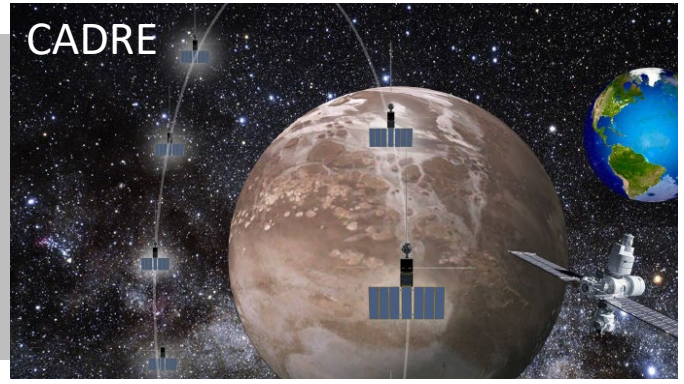
Two new instruments to be delivered to lunar surface through NASA's Commercial Lunar Payload Services (CLPS):

middle: Radio-wave Observations at the Lunar Surface of the photo-Electron Sheath (ROLSES)

lower-left: Lunar Surface Electromagnetics Experiment (LuSEE)

See Robert MacDowall talk

Mission profiles for radio astronomy

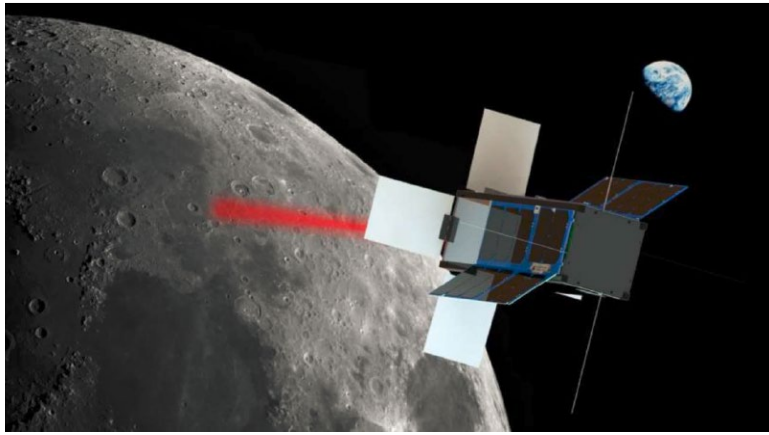
	Ground heritage	Lunar surface	Lunar orbit
Global 21cm (single antenna)	 *See Nivedita Mahesh talk*	 *See Keith Tauscher talk*	
Multipurpose Interferometer	 *See Marin Anderson talk*	 *See Gregg Hallinan talk*	

Technology development

Common, underlying technical challenges:

- Low temperature electronics to survive lunar nights
- Low power/mass/volume radio receivers and signal processing (RFSoC, ASICs, etc.)
- Thermal stability
- Built-in test equipment / in-situ calibration, including antenna beam characterization
- Wideband, achromatic antennas
- High data rate communication (RFoF, optical comms networks)

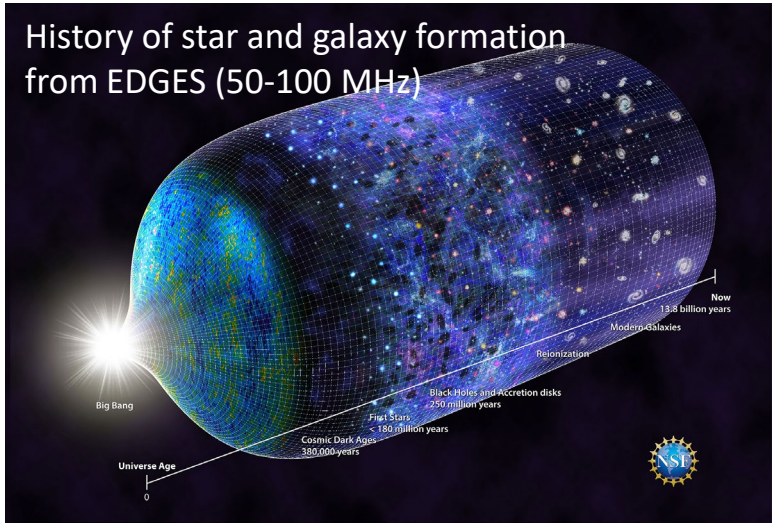
Xilinx RFSoC development board

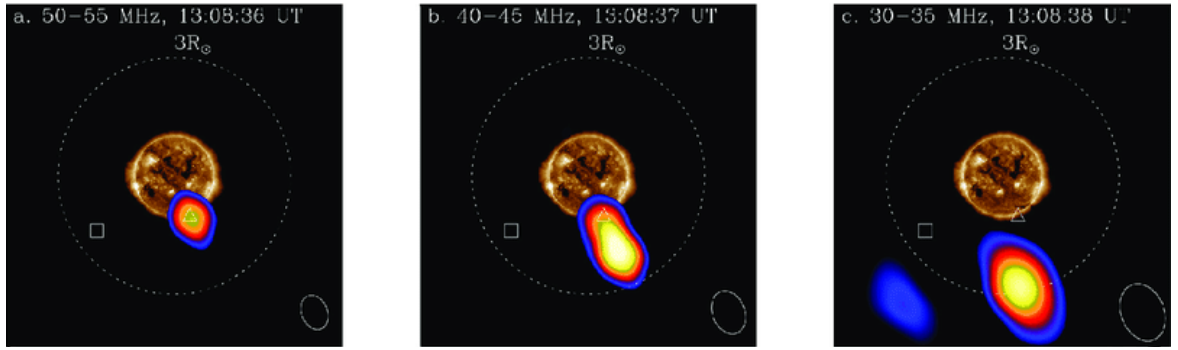


Deployable Optical Receiver Array (DORA) NASA-STP test program

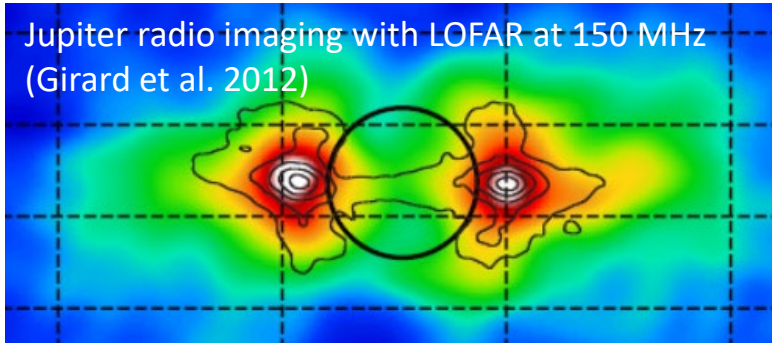
Science impact

- **Cosmic origins**: First stars, galaxies, and supermassive black holes
- **Fundamental physics**: Dark matter and non-standard physics
- **Exoplanets**: Magnetospheres of habitable (terrestrial) exoplanets
- **Planetary science**: Magnetospheres and radiation belts of outer Solar System planets
- **Heliophysics and space physics**: Solar bursts, CMEs, and solar wind





Solar burst radio imaging with LOFAR at 50-30 MHz (Morosan et al. 2014)



Session Agenda

Time (EST)	Speaker	Title
12:11 pm	Jack Burns	The Opportunity of the Lunar Farside
12:22 pm	Alex Hegedus	SunRISE: A Low Frequency Pathfinder Array in Earth Orbit
12:33 pm	Robert MacDowall	Radio Science from NASA Commercial Lunar Payload Services Landers: ROLSES and LuSEE
12:44 pm	Nivedita Mahesh	Ground-based Global 21-cm Experiments: Preparing for the Moon
12:55 pm	Keith Tauscher	Probing the early universe with the Dark Ages Polarimeter PathfindER (DAPPER)
1:06 pm	Marin Anderson	Extrasolar Space Weather Monitoring from the Ground: Paving the way for FARSIDE
1:17 pm	Gregg Hallinan	The lunar FARSIDE Low Radio Frequency Array