DAPPER

The Dark Ages Polarimeter PathfindER

NESS
Network for Exploration and Space Science
A NASA-funded SSERVI Team

Principal Investigator:
Dr. Jack Burns, University of Colorado Boulder

Co-Investigators:
Dr. Stuart Bale, University of California at Berkeley
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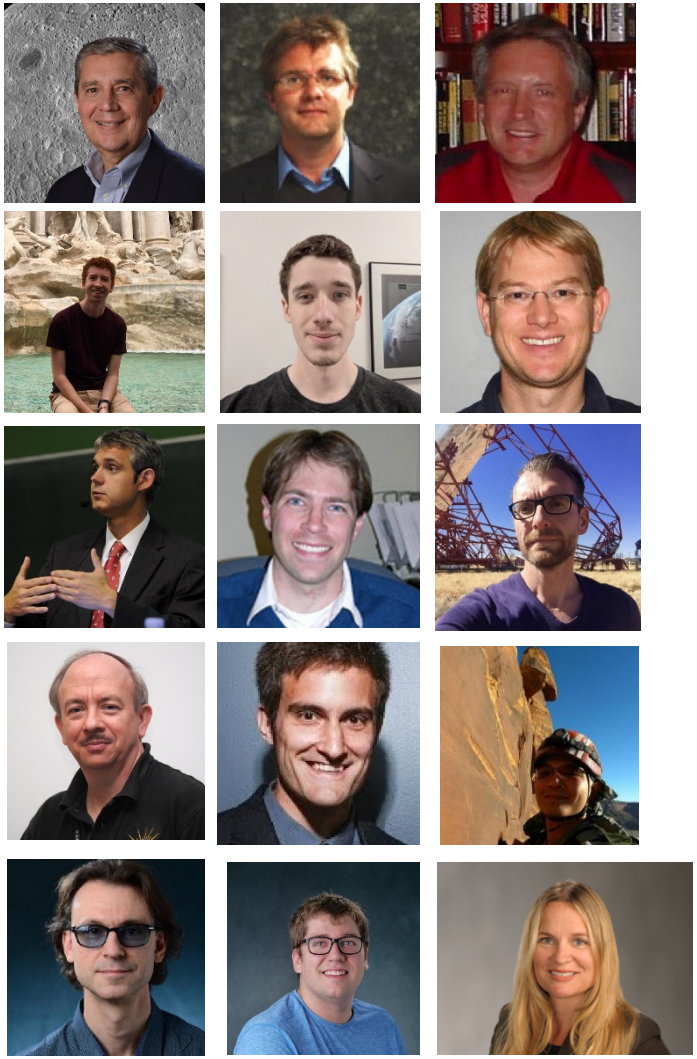
NASA Lead Center:
NASA Ames Research Center

NESS Team Meeting
Boulder, CO, 24-25 September 2019

DAPPER Team

MANAGEMENT & ORGANIZATION

DAPPER SCIENCE TEAM		
Member	Role	Institution
J. Burns	PI	University of Colorado
S. Bale	Co-I	UC Berkley
R. Bradley	Co-I	NRAO
N. Bassett	Grad Student	University of Colorado
D. Bordenave	Grad Student	University of Virginia
J. Bowman	Collaborator	ASU
H. Falcke	Collaborator	Radbound University
S. Furlanetto	Collaborator	UCLA
M. Klein-Wolt	Collaborator	Radbound University
R. MacDowall	Collaborator	NASA GSFC
J. Mirocha	Collaborator	McGill
B. Nhan	Collaborator	University of Virginia
D. Rapetti	SOC Lead	University of Colorado
K. Tauscher	Grad Student	University of Colorado



Jill Bauman, ARC
Project Manager

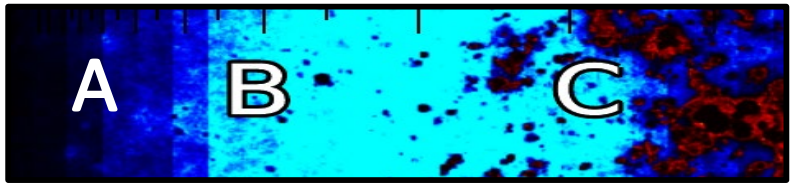
What is the 21-cm Global signal?

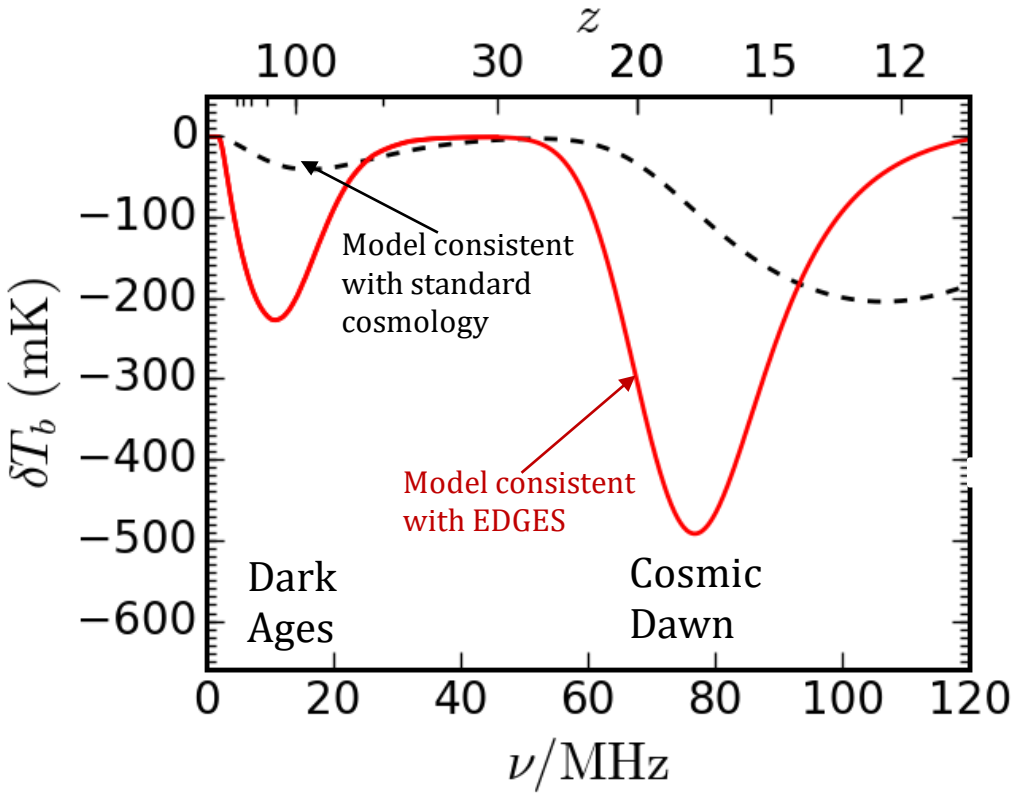
Spectral Features:

A: Dark Ages: test of standard cosmological model

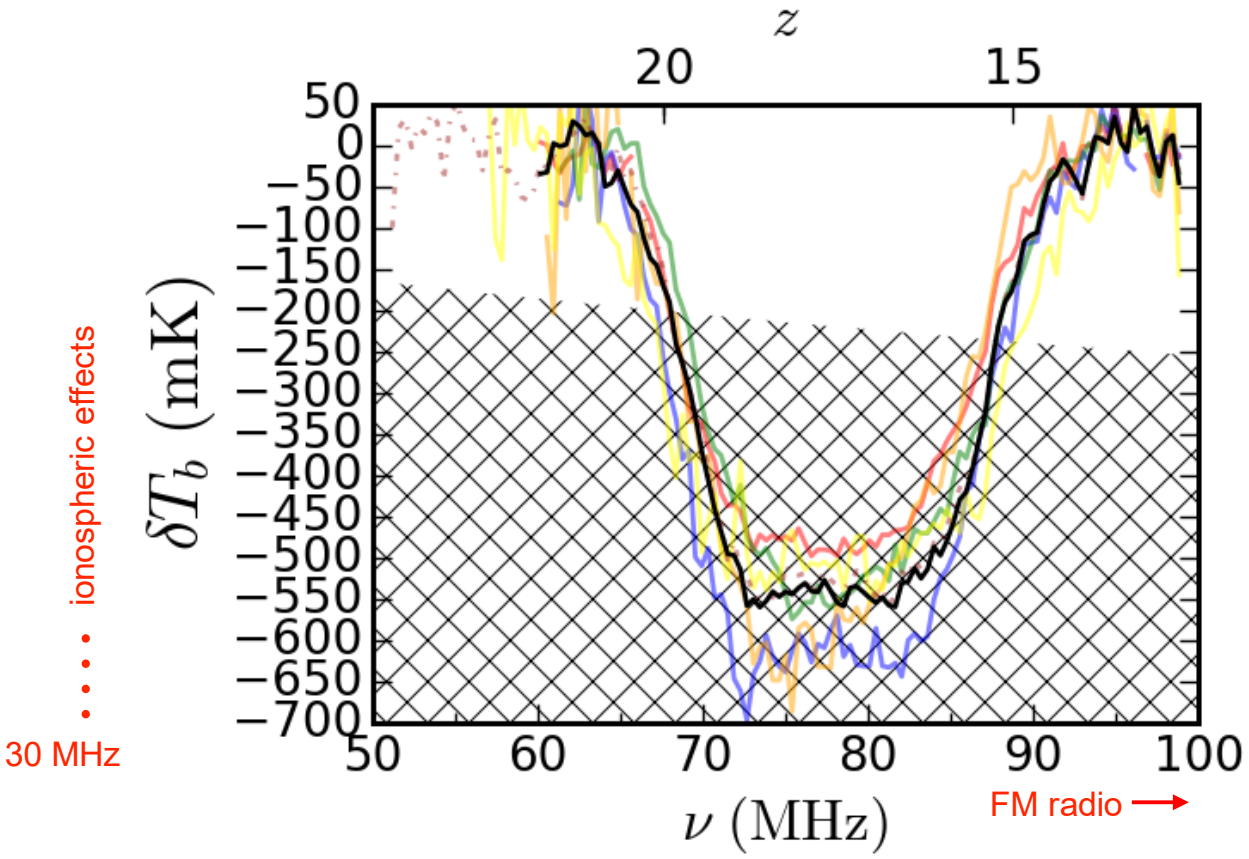
B: Cosmic Dawn: First stars ignite

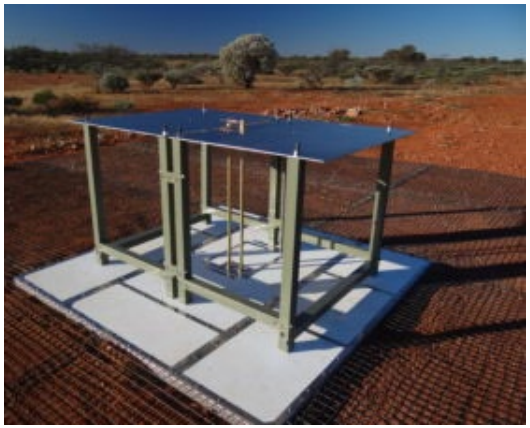
C: Black hole accretion begins





EDGES: Key Features





Bowman et al. 2018, Nature, 555, 67

Q. How to amplify signal by a factor of 2-3?

$$\delta T_b \simeq 27\, \overline{x}_{\mathrm{H\ I}}(1+\delta)\left(\frac{\Omega_{b,0}h^2}{0.023}\right)\left(\frac{0.15}{\Omega_{m,0}h^2}\frac{1+z}{10}\right)^{1/2}\left(1-\frac{T_{\mathrm{R}}}{T_{\mathrm{S}}}\right)\ \mathrm{mK}$$

1. Increase T_R via Dark Matter decay or synchrotron radiation from black holes, galaxies.
   - Feng & Holder, Ewall-Wice et al., Fraser et al., Mirocha & Furlanetto
2. Alter the cosmology.
   - McGaugh, Costa et al., Hill et al.
3. Decrease T_S via baryon-Dark Matter interactions which cools the hydrogen.
   - Barkana, Munoz & Loeb, Fialkov et al., Berlin et al., Slatyer & Wu

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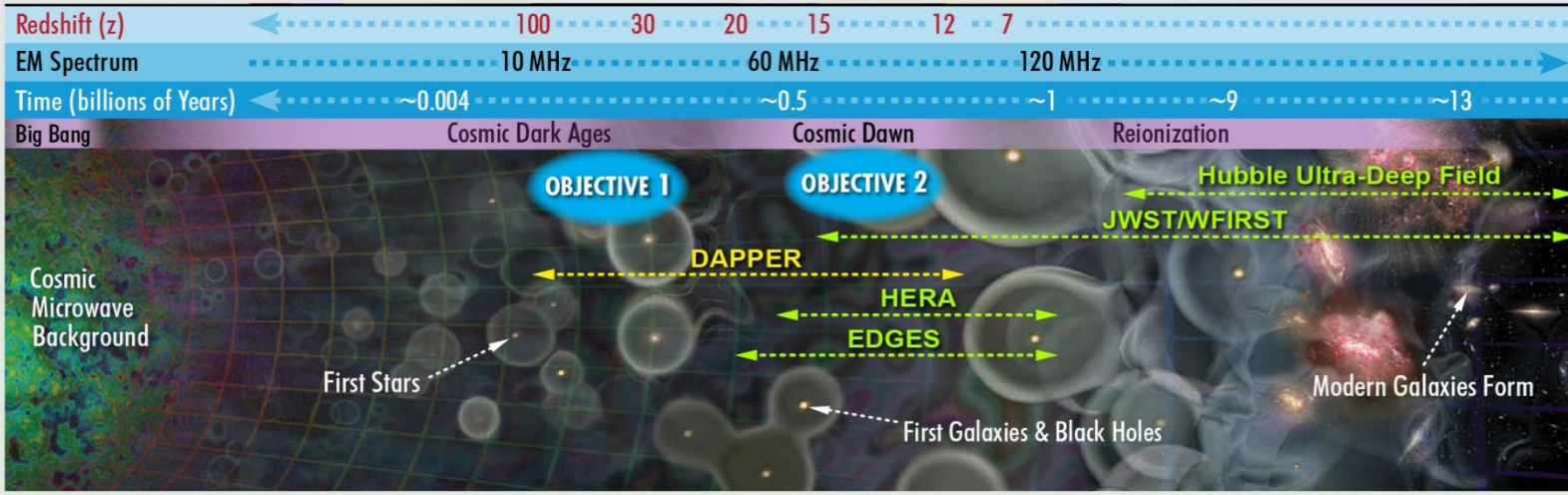
DARK COSMOLOGY:
INVESTIGATING DARK MATTER IN THE DARK AGES

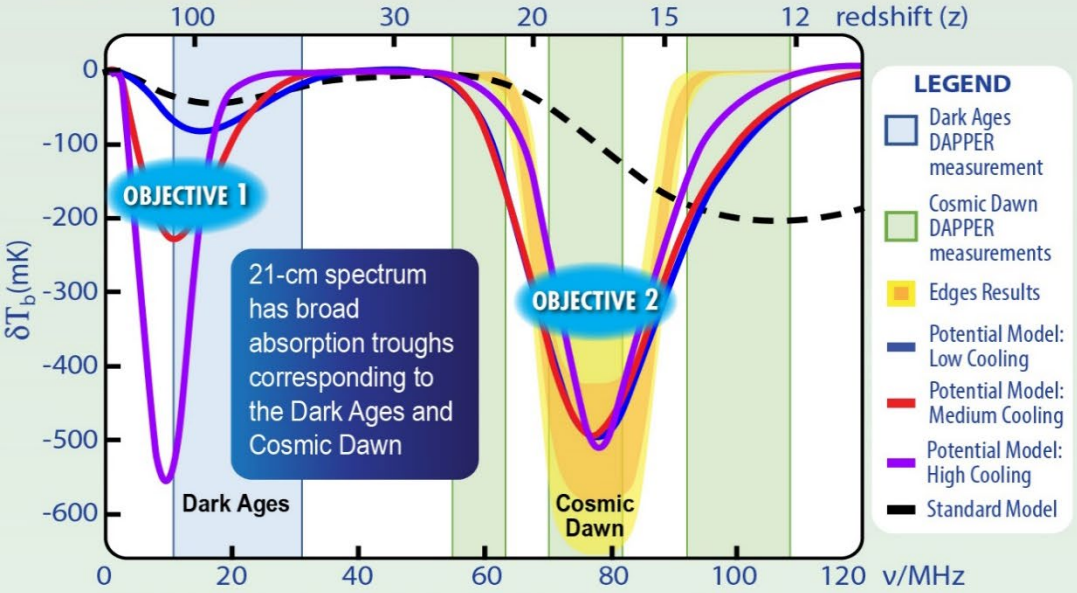
SCIENCE

OBJECTIVE 1:
- Determine the level of (dis)agreement with the standard cosmological model caused by dark matter in the Dark Ages.

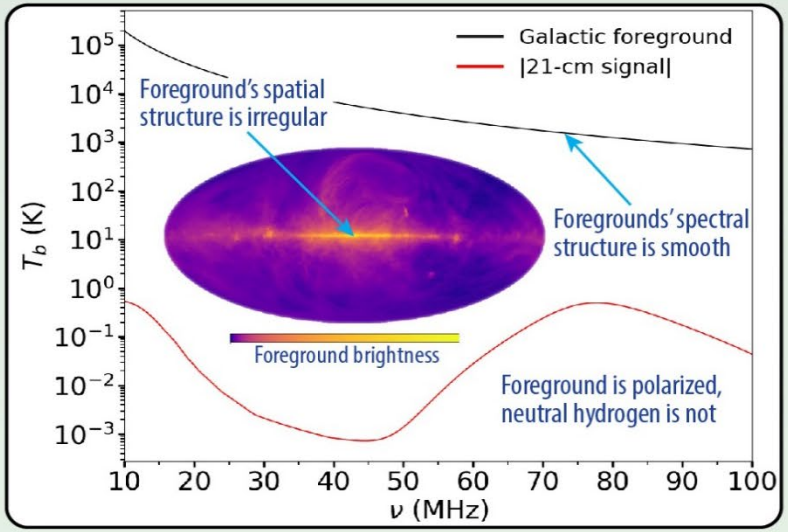
OBJECTIVE 2:
- Determine the level of excess cooling above the adiabatic limit for Cosmic Dawn.
- Determine when the first stars and black holes formed.

Will the observed behavior of redshifted neutral hydrogen redefine the standard cosmological model?





DAPPER uses the 21-cm all-sky signal to observe redshifts z = 83-12, associated with the Dark Ages and the Cosmic Dawn.



DAPPER separates Galaxy foreground from 21-cm signal using differences in spectral shapes, spatial structure, and polarization.

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DARK COSMOLOGY:
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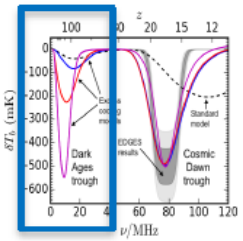
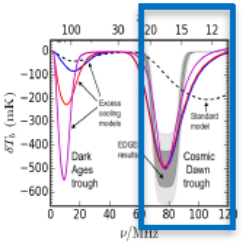
Science Objectives	Science Measurement Requirements: Physical Parameter	Science Measurement Requirements: Observable	Approach	Instrument: Functional Requirement	Instrument: Projected Performance	Mission Requirements (Table 7.1-1, left column)
• Determine the level of (dis)agreement with the standard cosmological model caused by dark matter in the Dark Ages. (see §2.2).	Brightness temperature of neutral hydrogen[4].	• Redshifted 21-cm spectrum from redshifts z=36 to 83 (z=48-64). (see §3.2). 	Spectroscopic & polarimetric data.	• **Frequency range:** 17-38 MHz (22-29 MHz). — • **Spectral resolution** to remove RFI: 50 kHz. — • **Noise in 4 Stokes parameters:** 20 mK RMS. — • **Receiver gain:** tracked to 5 ppm/sec. (see §3.3).	• 17-38 MHz (22-29 MHz). — • 40 kHz. — • 15 mK RMS. — • 1 ppm/sec. (see §3.3).	• Acquire stable lunar orbit. • Make observations in Moon's RF shadow.[5] • Deploy antennas to lengths (cm uncertainty) of 5.82 m, 7.57 m, 4.41 m. (Table 3.0-2). • Science data integration times for each antenna deployment of 3457 hrs, 926 hrs, 231 hrs. (Table 3.0-2). • RFI brightness temperature: <15 mK RMS (see §4.3). • Thermal control: limit temperature variations for RFSP to ±1°C for each science integration period. • Rotate S/C for duration of science phase. • Single antenna pointing direction perpendicular to orbit plane with accuracy of ±1°. • Provide power to payload during science observations. • Downlink data after each antenna deployment.
• Determine the level of excess cooling above the adiabatic limit for Cosmic Dawn. • Determine when the first stars & black holes formed. (see §2.3).		• Redshifted 21-cm spectrum from z= 12 to 25 (z=16-19). (see §3.2). 		• **Frequency range:** 55-107 MHz (71-81 MHz). — • **Noise:** 20 mK • Other requirements same as above.	• Sample 55-107 MHz (71-81 MHz)[6]. — • <2 mK • Other projected performance same as above.	

Mission Overview

- DAPPER will deploy from vicinity of NASA's Lunar Gateway & transfer to a 50×125 km low lunar orbit.
- Operates over primary bandwidth of 17-38 MHz ($83 \geq z \geq 36$) and sparse secondary sampling from 55-107 MHz ($25 \geq z \geq 12$).
- Low noise amplifiers & dual channel receiver to measure all 4 Stokes parameters. Based upon FIELDS instrument currently flying on Parker Solar Probe (TRL = 8).
- Projection-induced polarimetry used to independently constrain foreground.
- Baseline mission duration = 26 months.