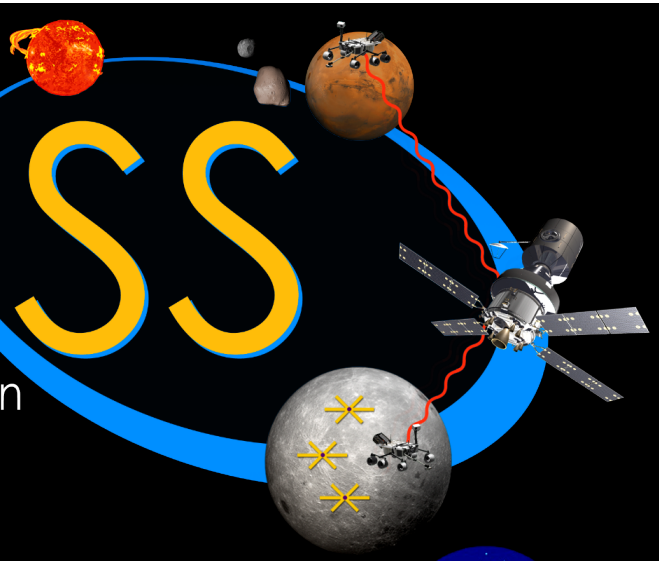
NESS

Network for Exploration and Space Science



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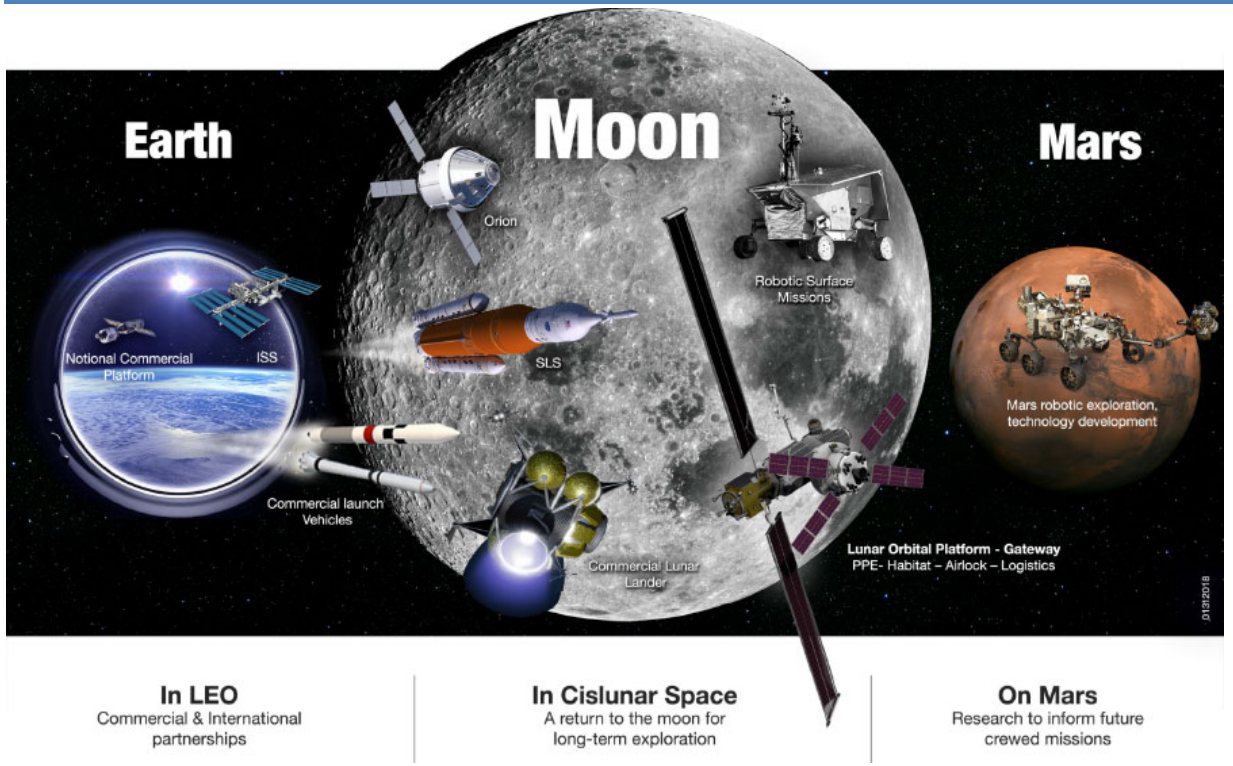
NASA's Exploration Campaign: Back to the Moon and on to Mars



Strategic Goals:

- Transition U.S. human spaceflight in low-Earth orbit to commercial operations, which support NASA and the needs of an emerging private sector market.
- Extend long-duration U.S. human spaceflight operations to lunar orbit.
- Enable long-term robotic exploration of the Moon.
- Enable human exploration of the Moon as preparation for human missions to Mars and deeper into the solar system.

Status of SSERVI: Healthy!

SSERVI

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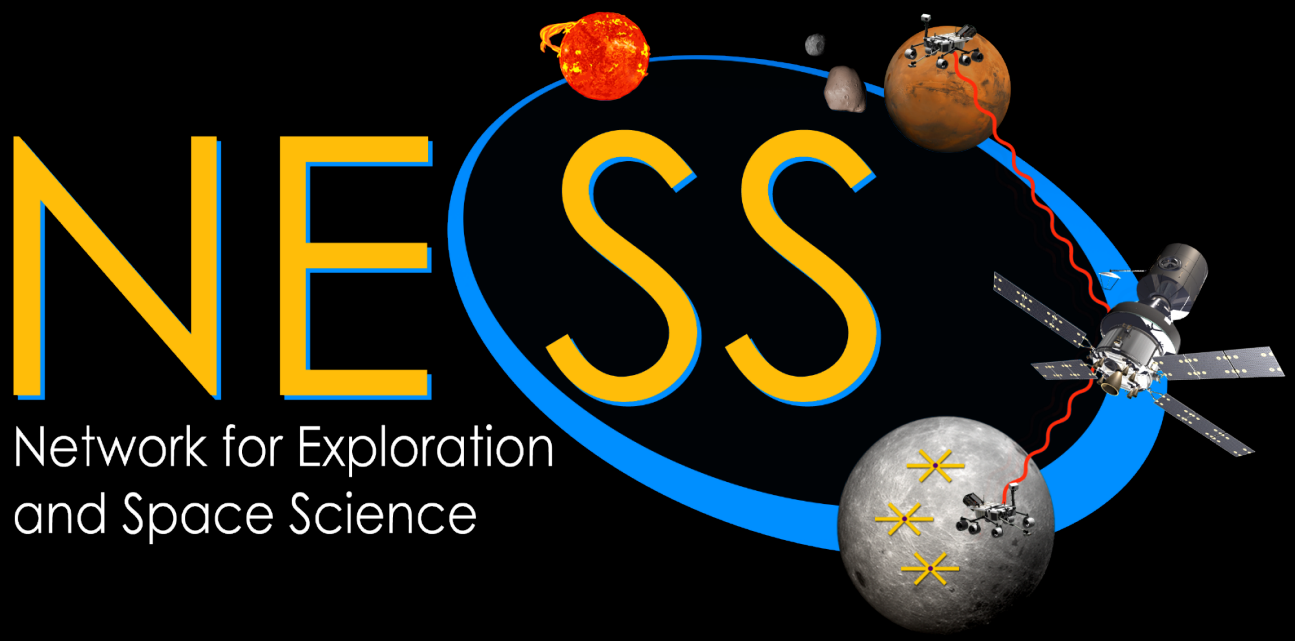
NESS Budget for Year 2: Raised to Even with Year 1



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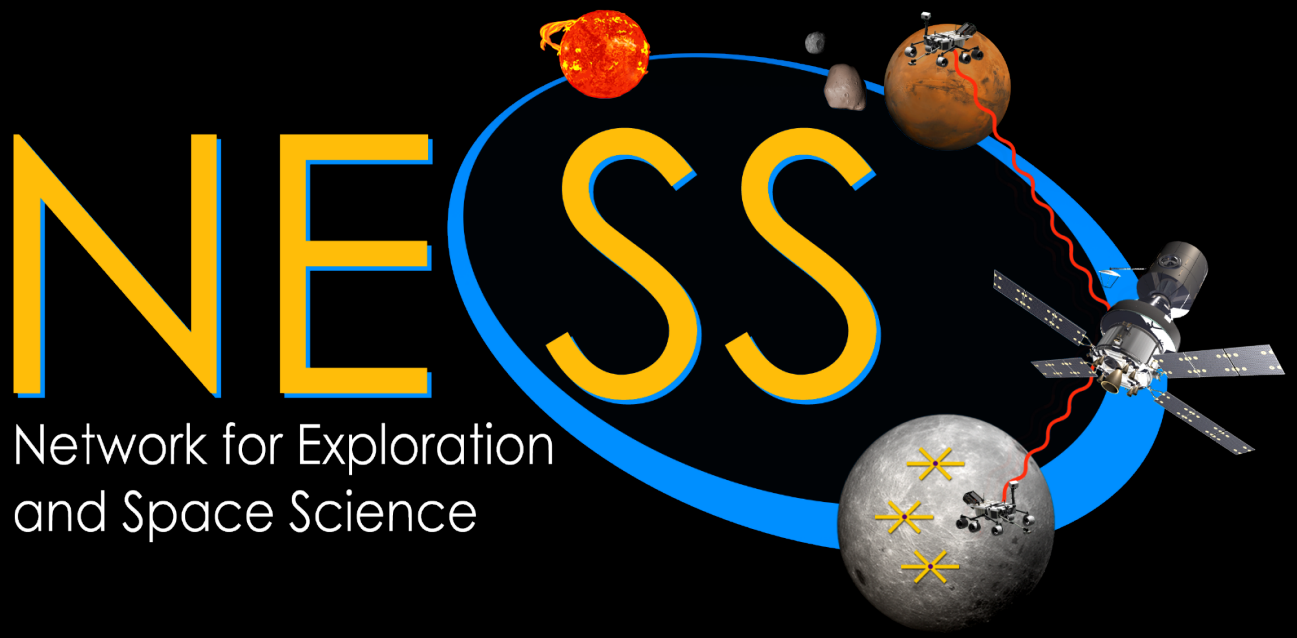
NESS Social Media Presence

https://www.colorado.edu/ness/



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SSERVI Monthly Report
NESS/PI Burns - May, 2018

Progress Report

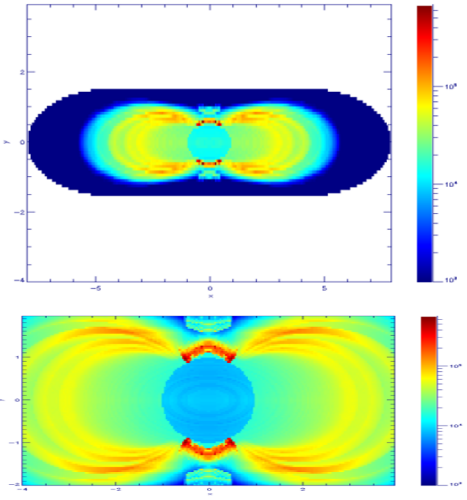
- **Meeting planning:** (1) American Astronomical Society (AAS) Meeting-in-a-Meeting (MiM), June 5-6, Denver, Colorado, "Low Frequency Radio Observations from Space"; (2) NESS Steering Committee Meeting, June 7-8, Denver, Colorado.
- **News and media with quotes from NESS team members:** (1) "Physicists in Earth's Remotest Corners Race to Reproduce 'Cosmic Dawn' Signal" by D. Castelvecchi, Nature news, April 27, correction May 2; (2) "Private Companies Took Over Rocket Launches. Can They Do the Same For Moon Landers?" by J. Bennett, Popular Mechanics, May 1; (3) "China's Moon Mission will Probe Cosmic Dark Ages" by D. Clery, Science, May 16.
- **Meetings:** *Triennial Earth-Sun Summit* in Leesburg, VA (May 20-24): (1) **MacDowall** presented on "Complex Type III radio bursts and Their Correlation with Solar Energetic Particle Events"; (2) **Hegedus & Kasper** presented on lunar radio arrays applied to tracking Type II & III bursts out to .5 AU. *URSI AT-RASC* in the Canary Islands, Spain (May 28-June 1): (3) **Rapetti** presented papers on "Spaced-based Extraction of the Global 21-cm Spectrum" and "SVD/MCMC pipeline for separating the global 21-cm signal from foregrounds/systematics"; (4) **Monsalve** talked about "Extracting the Global Cosmological 21-cm Signal from EDGES Data Using MCMC"; (5) **Bowman** described "The Dawn of 21cm Cosmology with EDGES". *PICO Collaboration Science Meeting* in Minneapolis, MN (May 1-2): (6) **Furlanetto** led a discussion on synergies between low-frequency radio and cosmic microwave background measurements. *Dark Matter Detection and Detectability: Paradigm Confirmation or Shift?* in Santa Barbara, CA (April 30-May 4): (7) **Mirocha** presented on "The first highly-redshifted 21-cm detection from EDGES: implications for dark matter and galaxy formation".

Upcoming Events

- **AAS MiM**: (1) **Kasper** will present on "Sun Radio Interferometer Space Experiment (SunRISE)", (2) **Falcke** on "The Netherlands-China Low Frequency Explorer on the Chinese Chang'e 4 Lunar Mission", (3) **MacDowall** on "Low frequency Radio Observatory on the Lunar Surface (LROLS)", (4) **Hallinan** on "Optimized Strategies for Detecting Extrasolar Space Weather", (5) **Burns** on "Space-based Observational Strategy for Characterizing the First Stars and Galaxies Using the Redshifted 21-cm Global Spectrum", (6) **Rapetti** on "Pattern Recognition and Experimental Design for Hydrogen Cosmology", (7) **Bowman** on "Toward a Cosmic Dawn Mapper".
- **NESS Steering Committee meeting**: Presenters will include: Burns, MacDowall, Rapetti, Furlanetto, Bowman, Tauscher, Bradley, Kasper, Hegedus, Hallinan, Cichan/Norman, Sandoval, Kumar, Walker, Szafir, Fong.
- **NASA Exploration Science Forum:** June 26-28, NASA Ames Research Center, numerous NESS talks and posters accepted.

Moment of Science: Revealing Earth's Radiation Belts

Simulated 100 kHz emission from radiation belts for all of geospace (top) and zoomed in near Earth (bottom).



There is currently no method for observing the 3D time dependent structure of Earth's radiation belts. The twin Van Allen Probes provide the state of the art with two point measurements.

Synchrotron emission from electrons in the radiation belt could reveal the time dependent spatial and energy distribution of the belts, but is at wavelengths below 2 MHz and absorbed by Earth's ionosphere. A lunar radio array would transform our understanding of radiation belt dynamics by allowing us to image the emission.

The simulations at the left are of the radiation belt at 100 kHz developed by Kasper & Hegedus through collaboration with French partners Quentin Nenon and Angelica Sicard (ONERA) based on a high resolution, time dependent radiation belt model. Next steps are to simulate observations of this emission from a lunar radio array on the near side and to see if dependence on wavelength can be related to energy spectra of the electrons as a function of location.

5/29/2018

June 26

Parallel Session 1: Human and Robotic Exploration Hardware

- VR SIMULATION TESTBED: IMPROVING SURFACE TELEROBOTICS FOR THE DEEP SPACE GATEWAY – Michael Walker

June 27

Parallel Session 5 Overview Talk: Astrophysics Enabled at the Moon, Terry Fong -- The Gateway: Enabling Infrastructure for a New Era of Lunar Robotics

Parallel Session 5: Astrophysics Enabled at the Moon

- SCIENCE ON THE LUNAR FAR SIDE FACILITATED BY LOW LATENCY TELROBOTICS FROM A LUNAR ORBITING PLATFORM-GATEWAY – Jack Burns
- Tracking Solar Type II Bursts to .5 AU with Radio Interferometers on the Lunar Surface – Alex Hegedus
- LOW-FREQUENCY RADIO OBSERVATIONS FROM THE MOON: THE ESSENTIAL NEXT STEP FOR PARTICLE PHYSICS, COSMOLOGY, AND GALAXY FORMATION – Jordan Mirocha

Posters:

- LOW-FREQUENCY RADIO OBSERVATORY PATHFINDER ON THE NEAR-SIDE LUNAR SURFACE - Bob MacDowall
- Integration of a COTS Robotic Arm and Rover for Future Low-Latency Telerobotic Assembly Experiments - Ben Mellinkoff, Alex Sandoval, Arun Kumar
- Global 21-cm Data Analysis Pipeline to Constrain Physical Parameters using Lunar-based Observations - David Rapetti
- Towards a lunar farside hydrogen cosmology telescope: characterizing the absorption trough observed by EDGES - Keith Tauscher

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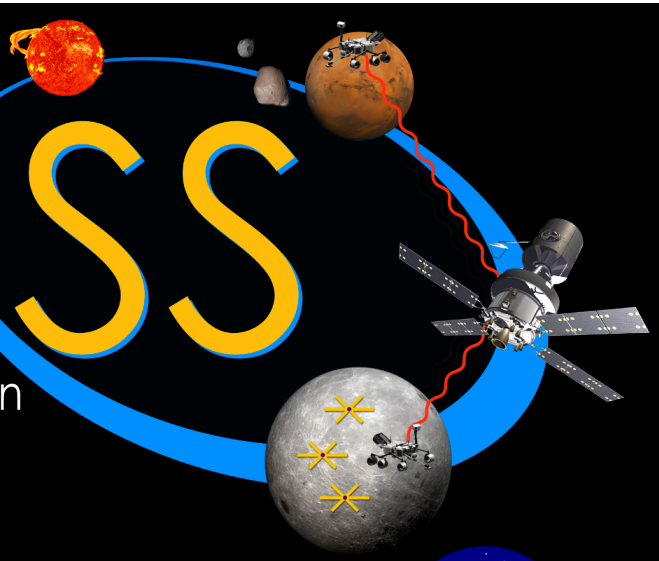

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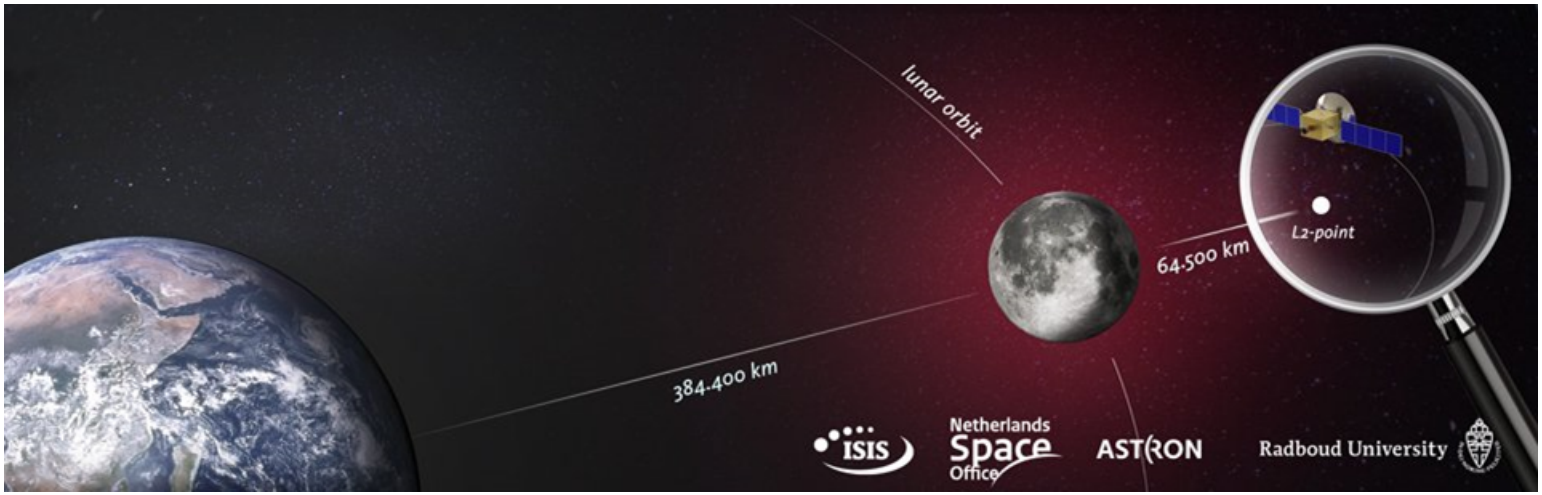
NETHERLANDS-CHINA LOW-FREQUENCY EXPLORER (NCLE)



- Will characterize the RFI environment in deep space at Earth-Moon L2.
- Will serve as precursor for future Hydrogen Cosmology missions and radio interferometry.
- Will attempt to detect CMEs from the Sun.
- 3 orthogonal, monopoles of 5-m length. Frequencies: 1-80 MHz.
- Heino Falcke is P.I.

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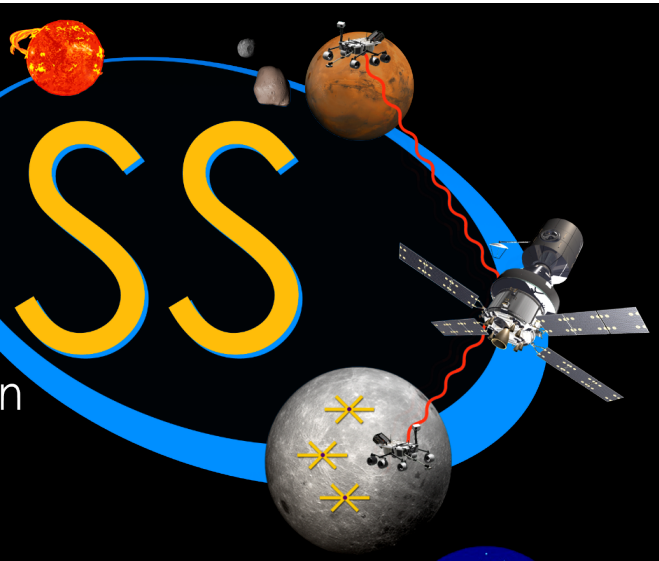

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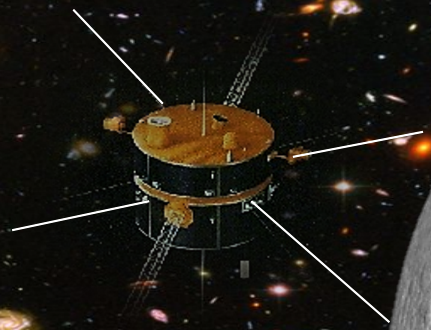
A NASA-funded SSERVI Team

Dark Ages Polarimetry PathfindER



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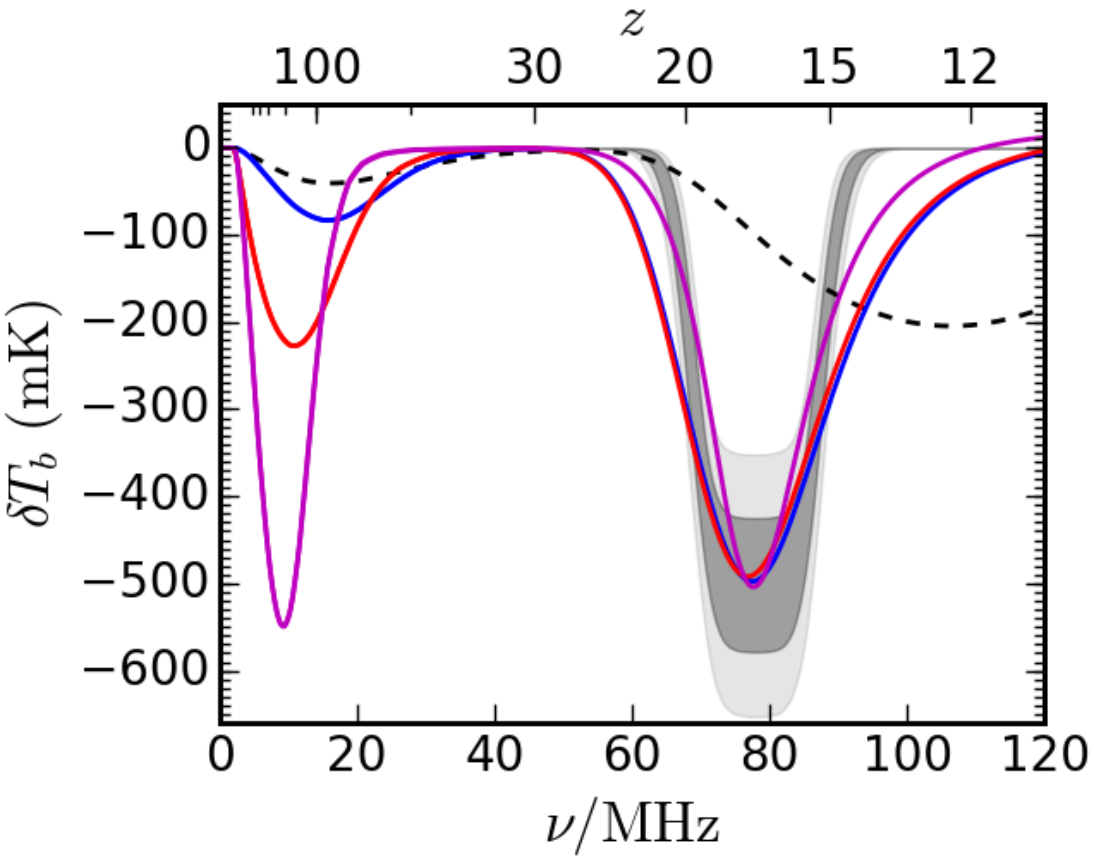
Extrapolation into the Dark Ages based upon EDGES Results

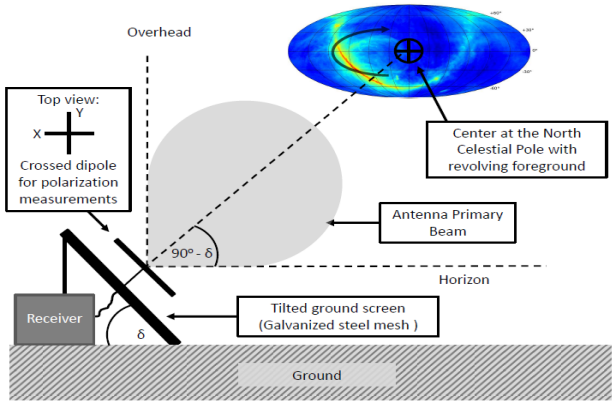


- **68 and 95% (dark and light gray) bands:** EDGES measurements of **Cosmic Dawn.**
- **Black, dashed curve:** Example of the **standard** astrophysical models ***inconsistent with EDGES results***.
- EDGES results *require exotic physics* such as e.g. interactions between baryons and dark matter particles.
- *Beyond-standard-physics* models of the **Dark Ages** trough consistent with the EDGES Cosmic Dawn signal:

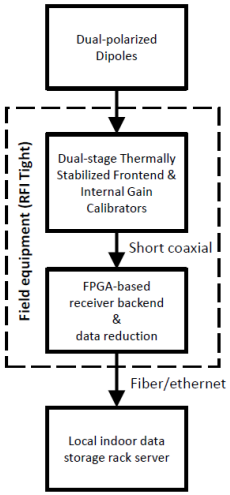
i. Blue curve: Maximum cooling rate is the adiabatic rate, but occurring earlier.
ii. Red curve: Cooling rate both lower and earlier.
iii. Magenta curve: Cooling rate not monotonically declining (i.e. there is a 'preferred epoch' of excess cooling).

Models courtesy of Jordan Mirocha

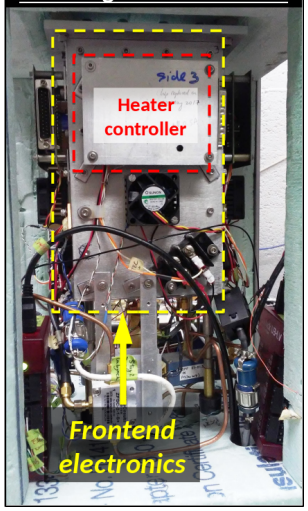
The Cosmic Twilight Polarimeter (CTP):
Dynamic Polarimetry Testbed

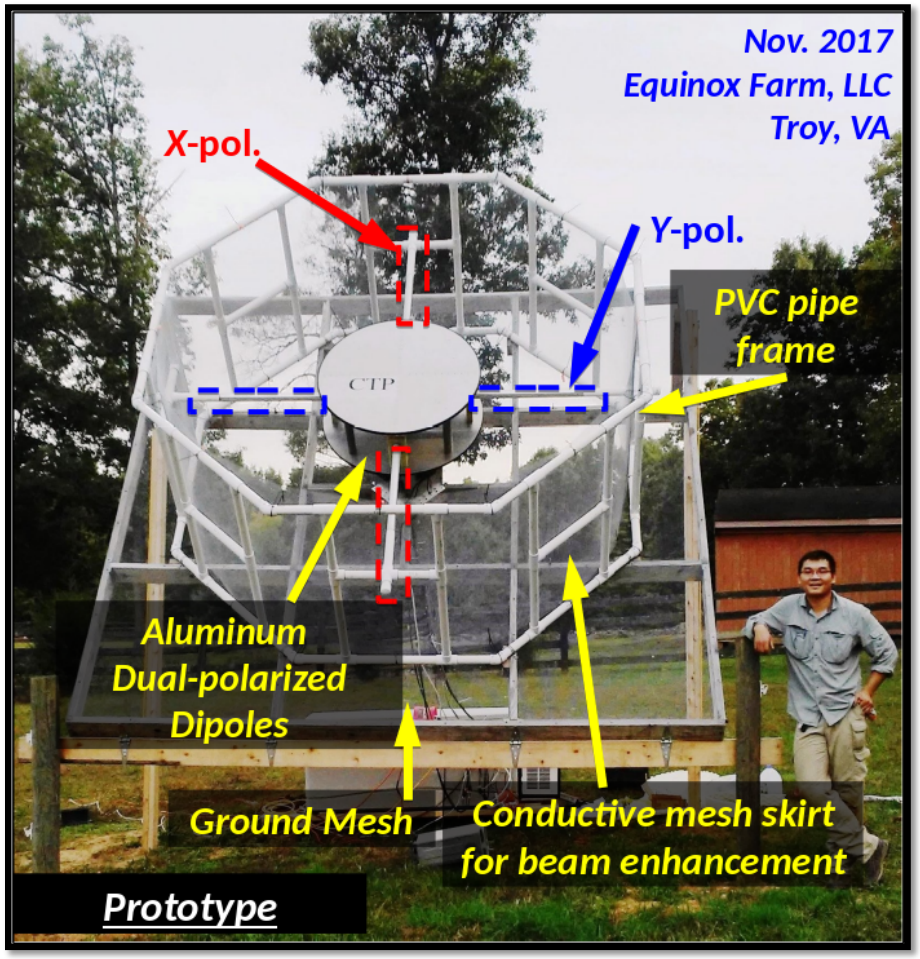


System Block Diagram



Dual-stage thermal control

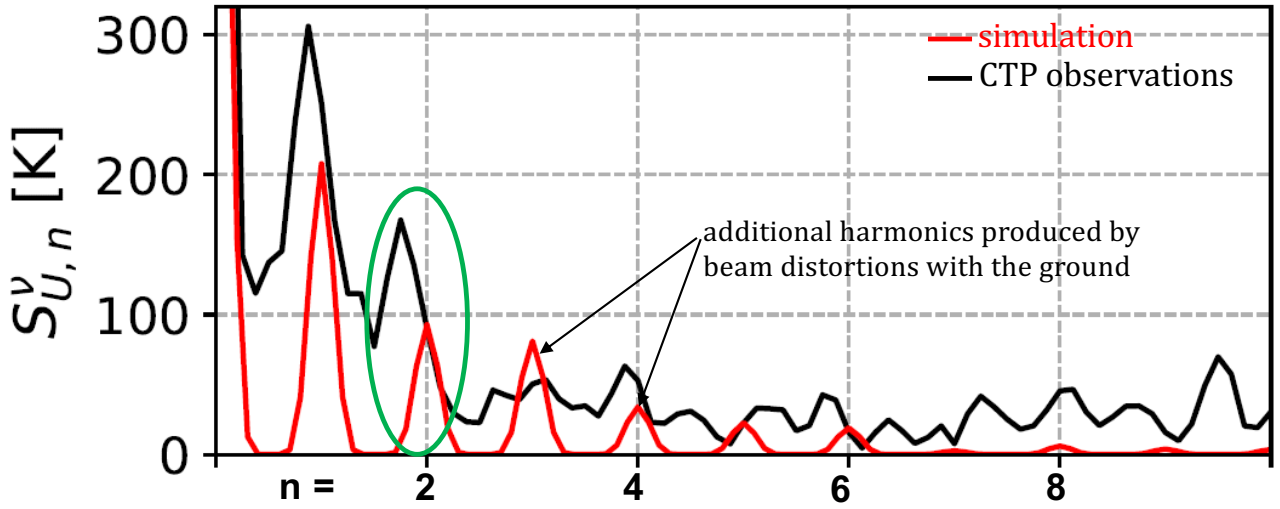




Operates at 60-80 MHz

Initial Results from the Cosmic Twilight Polarimeter

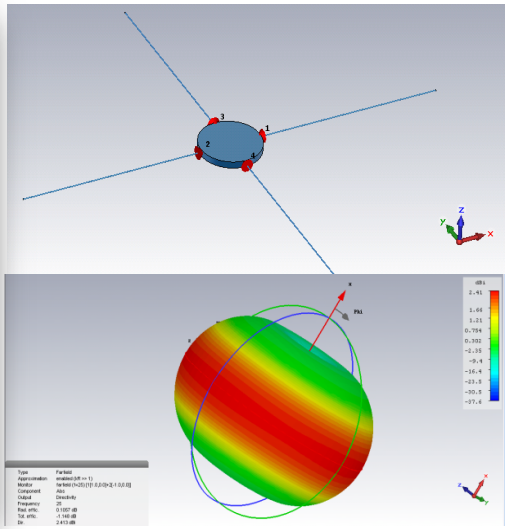
Nhan, B., 2018, Ph.D. dissertation, U. Colorado

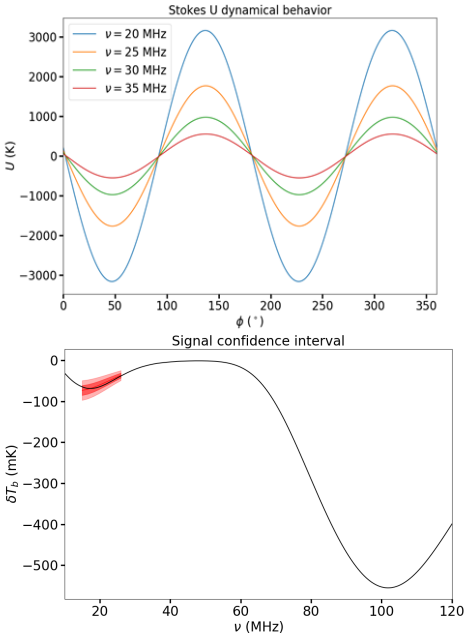


- Data consist of Stokes I,Q,U,V in frequency channels as a function of time at ≈82 MHz.
- After extensive RFI editing and averaging, Fourier transform binned data channels to measure dynamical frequencies (n) for Stokes Q,U.
- n = 2 is expected twice diurnal signal and is tentatively detected in these data.
- Caveats:
  - Simulation only contains first order models of beam distortions due to ground and horizon effects.
  - Very few clean channels due to severe RFI.

The Dark Ages Polarimetry PathfindER (DAPPER): A Space-based SmallSat Testbed

- DAPPER will be placed in proximity to NASA's Lunar Orbital Platform-Gateway to reduce Earth-based RFI.
- Operates over bandwidth of 15-30 MHz ($93 \geq z \geq 46$).
- Dual orthogonal ≈ 7-m tip-to-tip wire dipole antennas deployed successfully many times (e.g., WIND/WAVES).
- Low noise amplifiers & dual channel receiver to measure all 4 Stokes parameters. Based upon FIELDS instrument to be flown on Parker Solar Probe.





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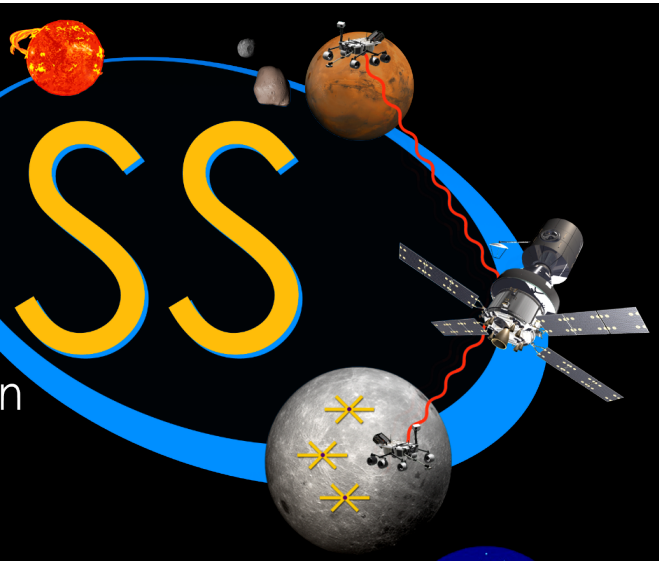

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Action Items