SSERVI Monthly Report
NESS/PI Burns - September, 2019

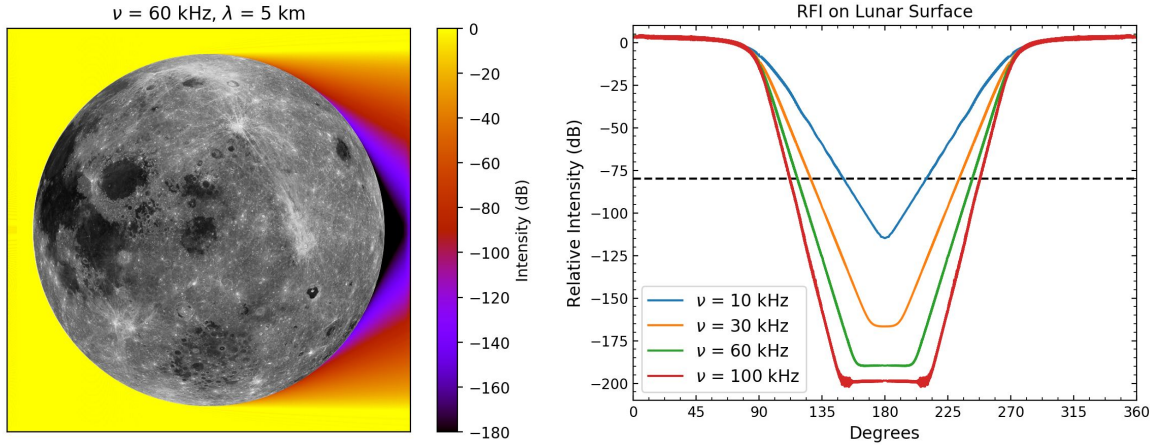
Progress Report

- **Papers:** (1) "FARSIDE: A Low Radio Frequency Interferometric Array on the Lunar Farside"; **Burns, Hallinan**, Lux, Romero-Wolf, Chang, Kocz, **Bowman, MacDowall, Kasper, Bradley, Anderson, Rapetti,** arXiv:1907.05407; (2) "Discovering the Sky at the Longest Wavelengths with Small Satellite Constellations", Chen, **Burns, Koopmans,...Falcke...Kasper...Monsalve…Klein-Wolt**, et al., arXiv:1907.10853; (3) "Peering into the Dark (Ages) with Low-Frequency Space Interferometers"; **Koopmans,...Bowman, Burns,...Falcke...Klein-Wolt**, et al., arXiv:1908.04296; (4) "Characterizing the Radio Quiet Region Behind the Lunar Farside for Low Radio Frequency Experiments", **Bassett, Rapetti, Burns, Tauscher, MacDowall**, to be submitted to Advances in Space Research.
- **News:** "The quest to unlock the secrets of the baby Universe" published in Nature by Castelvecchi in August 14 discusses low radio frequency measurements for hydrogen cosmology, including a quote from **Burns**.
- **Event:** Administrator Bridenstine visited CU Boulder and met with **Burns**, who also led a presentation at Fiske Planetarium on space exploration with participation from other NESS collaborators and students.
- **Outreach:** (1) On July 12, **Burns** presented "Our Future in Space: The Moon and Beyond" for the Apollo 11 50th Anniversary Celebration at Fiske Planetarium; (2) and on July 13, **Burns** presented it during the Apollopalooza celebration at the Wings Over the Rockies Air & Space Museum (video of his talk).
- **Talk:** At the University of Zurich on September 27 by **Mirocha** on "Testing Galaxy Formation Models with High Redshift 21-cm Signals and Upcoming Galaxy Surveys".
- **Meetings:** The **NESS Steering Committee meeting,** September 24-25 with talks by **Burns**, Schmidt, **Rapetti, Kasper, Hegedus, MacDowall, Furlanetto, Bassett, Tauscher, Hallinan, Bowman, Mahesh, Bradley, Fong, Kumar, Bell, Walker, Sfazir, Menon, Cichan**. The **NASA Exploration Science Forum (NESF) 2019**, July 23-25, included multiple NESS talks by **Burns**, **Furlanetto**, **MacDowall**, **Bassett**, **Walker** and posters by **Hegedus**, **Tauscher**, **Rapetti**, **Mahesh**, and **Kumar**, **Bell**, **Mellinkoff** & **Sandoval**. Talks at the **LunGradCon** (before NESF), July 22, by CU graduate students **Tauscher** and **Bassett**.

Upcoming Events

- **Meetings:** The **"2nd Global 21cm Workshop"** will be held at McGill University, Montreal, October 7-9: **Tauscher** will talk about "Moving away from analytical a priori foreground models in signal extraction"; **Rapetti** will talk about "Rigorously extracting and constraining global 21-cm signal model parameters"; **Mirocha** will talk about "The Global 21-cm Signal in the Context of High-z Galaxy Surveys"; **Nhan** will talk on "Constraining foreground spectrum with projection-induced polarization".
- **Outreach:** The annual International Observe the Moon Night on October 5 will feature events at the CU Boulder campus.

Moment of Science:



Bassett performed simulations of the propagation of radio waves in the vicinity of the Moon. Results show that terrestrial Radio Frequency Interference (RFI) is highly attenuated behind the Moon (see figures), making the lunar Farside an excellent location for performing low radio frequency experiments. NESS missions DAPPER and FARSIDE will both take advantage of the radio quiet environment of the lunar farside to perform sensitive low frequency observations.

09/25/2019

NESS Steering Committee Meeting, Boulder 2019

NESS Steering Committee Meeting

University of Colorado Boulder
Duane Physics/Astrophysics Building, D-322
September 24-25, 2019

September 24

8:15 Light Breakfast & Conversation

8:30 **Welcome & Overview of the day** – Burns

8:45 **Updates on NESS, SSERVI, and NASA**
- Overview of NASA's Artemis Program – Burns & Schmidt
- SSERVI Status - Schmidt
- NESS Budget for Year 3 - Burns
- NESS Website and Social Media Presence - Rapetti
- Monthly and Yearly Deliverables – Rapetti

9:30 **Radio Heliophysics Science**
- SunRise – Kasper (20 min)
- ROLSES – MacDowall (20 min)
- LuSEE – MacDowall & Burns (15 min)
- Observing the Sun and the Earth with a Lunar Low Radio Frequency Array – Hegedus & Kasper (20 min)
- Discussion (15 min)

11:00 Break

11:15 **Dark Ages and Cosmic Dawn – Theory & Simulations**
- Modeling of the 21-cm Signal – Furlanetto (25 min)
- Characterizing the Radio Quiet Region Behind the Lunar Farside for Low Radio Frequency Experiments – Bassett (20 min)

12:00 Lunch

12:45 **Dark Ages and Cosmic Dawn – Theory & Simulations (continued)**
- Simultaneous Constraints on Foreground and Global 21-cm Models via a Novel Pattern Recognition Technique – Rapetti (20 min)
- Using Dynamic Polarization as Leverage to Extract the Global Signal – Tauscher (20 min)
- Discussion (20 min)

13:45 **Farside Radio Array for Exoplanets and Cosmology**
- Update on Ground-Based Detection Efforts – Hallinan (15 min)
- FARSIDE – **F**arside **A**rray for **R**adio **S**cience **I**nvestigations of the **D**ark Ages and **E**xoplanets – Hallinan & Burns (25 min)
- Modelling Antennas for the Lunar Surface – Mahesh & Bowman (15 min)
- Discussion (20 min)

15:00 Break

15:15 **Dark Ages & Cosmic Dawn: Prototypes & Concept Studies of Lunar Low Radio Frequency Telescopes for Global 21-cm Observations**
- Experiment to Detect the Global Epoch-of-Reionization Signature (EDGES) – Bowman (25 min)
- The Cosmic Twilight Polarimeter (CTP) – Bradley (25 min)
- The Dark Ages Polarimeter Pathfinder (DAPPER) – Burns (25 min)
- Discussion (30 min)

17:00 Break

Evening at the Fiske Planetarium

18:00 Cocktails & Conversation

19:00 Dinner

20:00 Fiske Theater: Plans for and Segments of Planetarium Show on Space Exploration

September 25

9:00 **Surface Telerobotics**
- VIPER, Astrobee, & Smart Deep Space Habitats – Fong (25 min)
- Telerobotic Assembly of Radio Array using a Rover and Robotic Arm – Arun Kumar & Mason Bell (20 min)
- Virtual and Augmented Reality Simulations of Lunar Surface Telerobotics – Michael Walker & Dan Szafir (20 min)
- VR Simulations of the Effects of Light Reflections for Lunar Traverses – Midhun Menon (20 min)
- Discussion (20 min)

10:45 Break

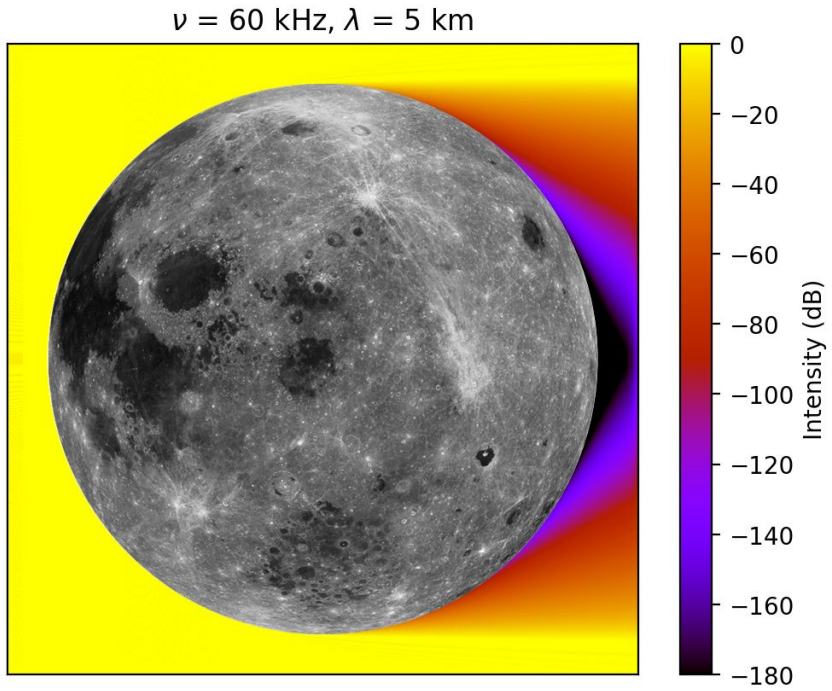
11:00 **Lunar Landers for Science and Exploration –** Cichan

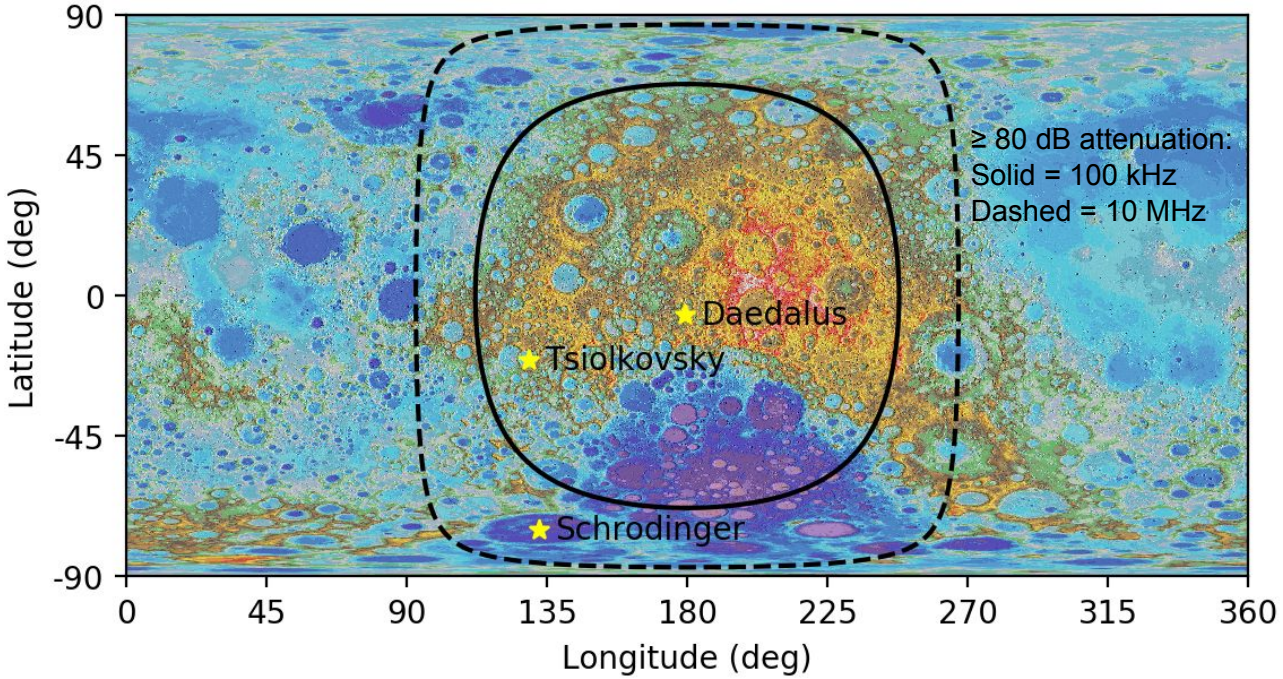
12:00 Lunch & Discussion

Radio Quiet Regions on the Lunar Farside

Characterizing the Radio Quiet Region Behind the Lunar Farside for Low Radio Frequency Experiments

N. Bassett (CU), D. Rapetti (CU/Ames/USRA), J. Burns (CU), K. Tauscher (CU), R. MacDowall (Goddard)





- Numerical simulations of the propagation of radio waves in the vicinity of the Moon were performed in order to characterize the level of attenuation of terrestrial radio frequency interference (RFI) behind the lunar farside.
- Results show that terrestrial RFI sources are heavily attenuated on the farside, even at frequencies as low as 100 kHz, providing a unique environment for performing sensitive low radio frequency observations.
- The farside is also unaffected by the Earth's ionosphere, which can contaminate the data, making it an excellent location for low frequency experiments.

Characterizing the Radio Quiet Region Behind the Lunar Farside for Low Radio Frequency Experiments

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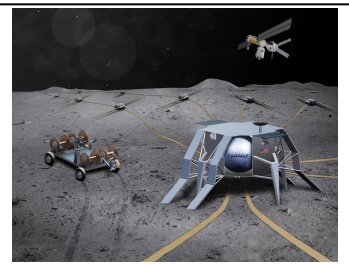
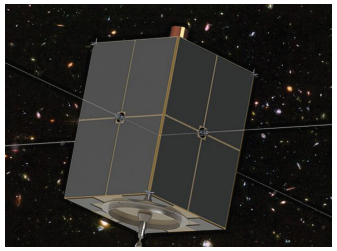
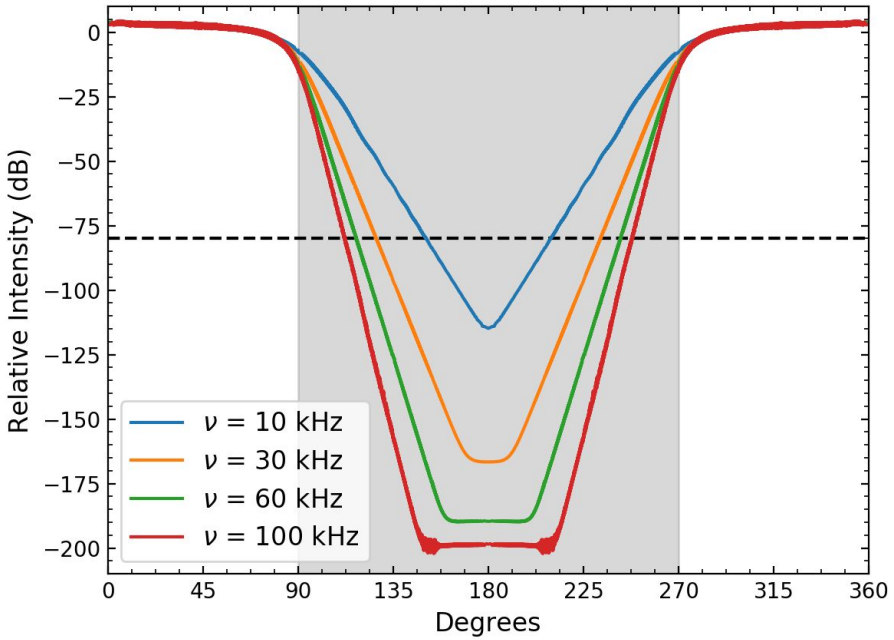
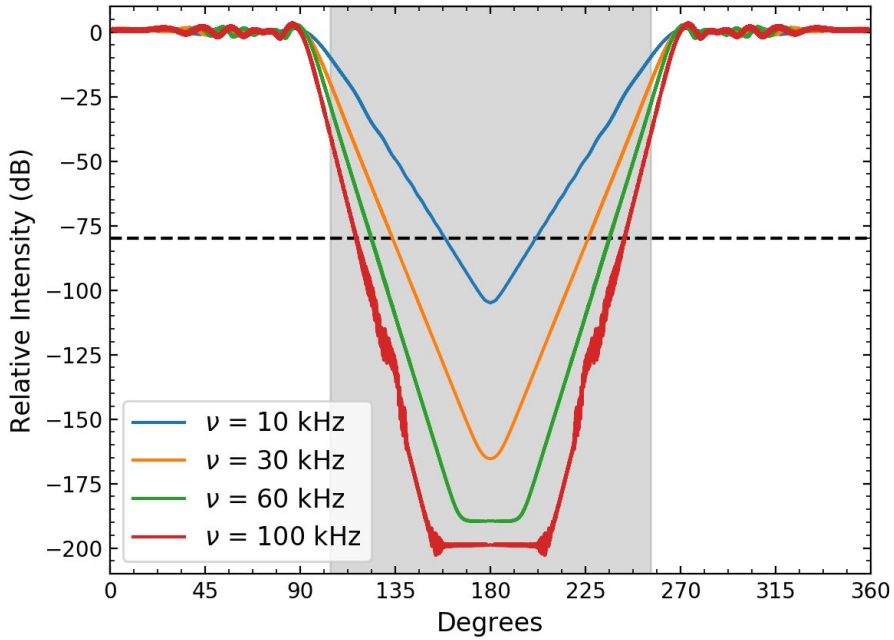


Surface
(FARSIDE)



50 km orbit
(DAPPER)





- Science observations will be taken in regions where terrestrial RFI sources are attenuated by at least 80 dB.
- As the frequency is increased, the size of the quiet region will increase due to the smaller effect of diffraction.
- The grey shaded regions in the plots above indicate the geometric quiet region, ignoring diffraction.

Characterizing the Radio Quiet Region Behind the Lunar Farside for Low Radio Frequency Experiments

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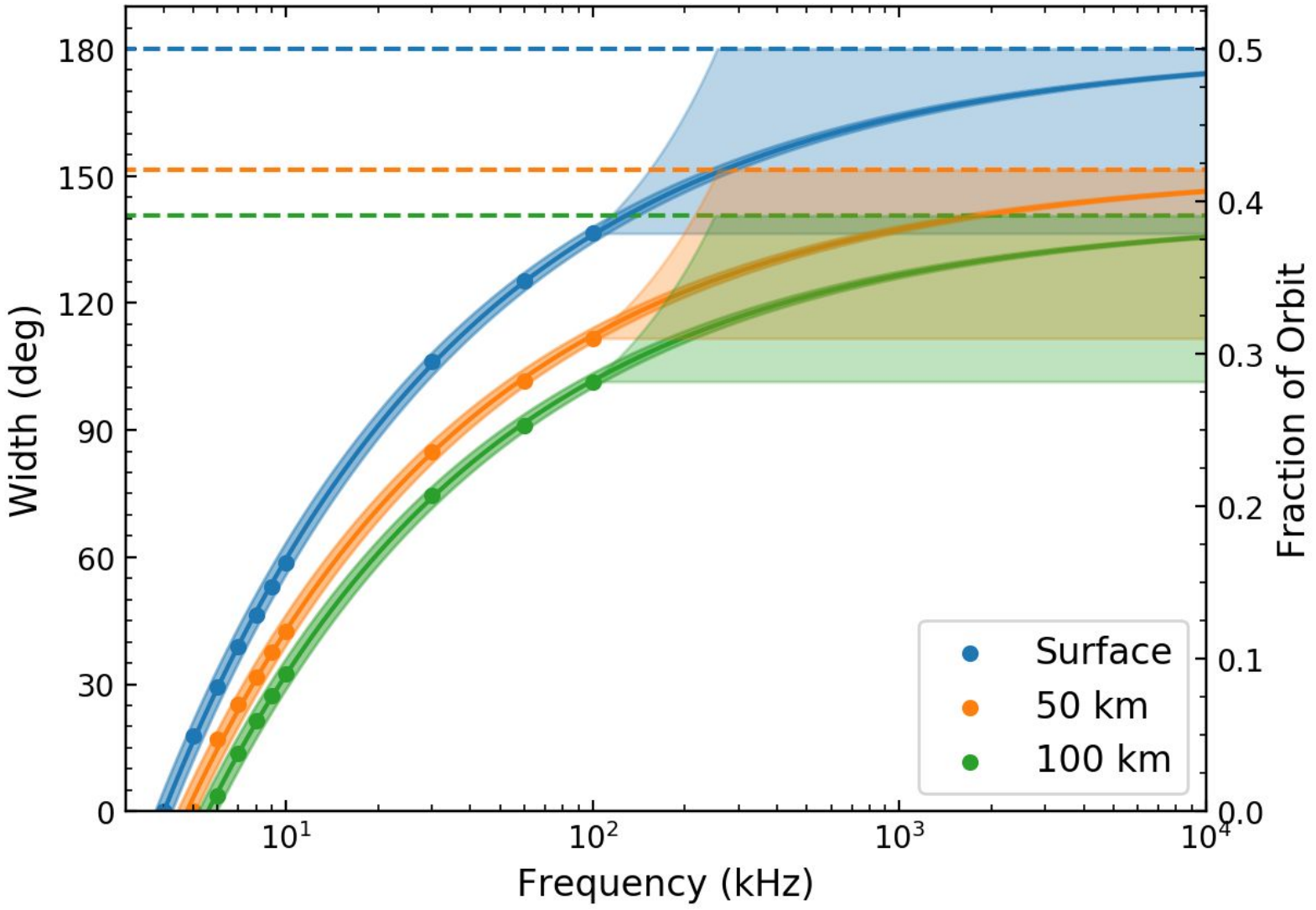

- Lighter shaded areas in plots indicate range of total possible sizes for quiet region at frequencies above 100 kHz
- Dashed lines show the geometric size of the quiet region when diffraction is ignored.
- Simulation results can be extrapolated to higher frequencies through a power law model motivated by the scale invariance of the system.
- Darker shaded bands indicate first order estimates of uncertainty in the model
- The uncertainty of the model decreases at higher frequencies as the quiet region size converges to the geometric limit (dashed lines)