SSERVI Monthly Report
NESS/PI Burns - October, 2019

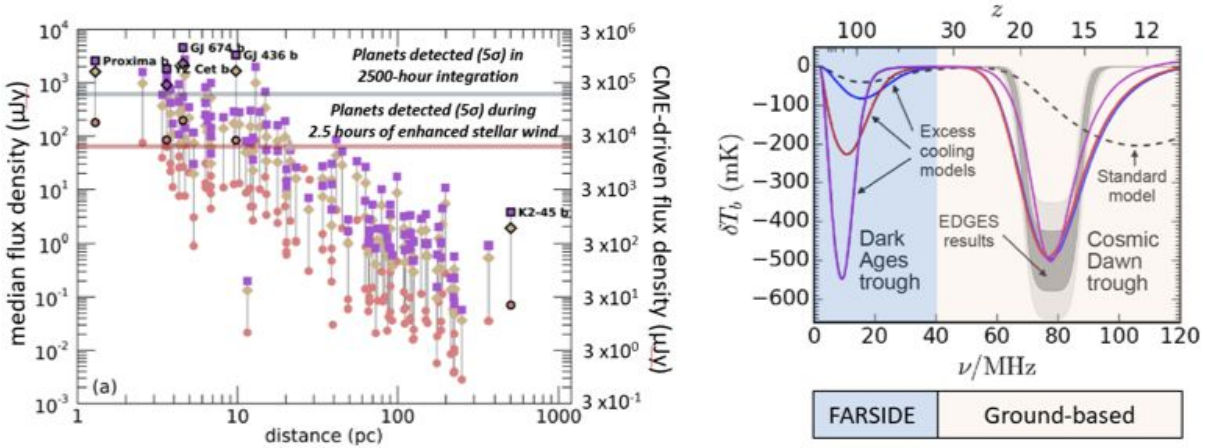
Progress Report

- **Papers:** (1) "Characterizing the Radio Quiet Region Behind the Lunar Farside for Low Radio Frequency Experiments", **Bassett, Rapetti, Burns, Tauscher, MacDowall,** submitted to Advances in Space Research; (2) "The Effects of Population III X-ray and Radio Backgrounds on the Cosmological 21-cm Signal", **Mebane, Mirocha, Furlanetto**, submitted to the Monthly Notices of the Royal Astronomical Society, arXiv:1910.10171.
- **News:** (1) Reuters reports "Ten years after 'suicide' mission, NASA thirsts for lunar water", including a quote from NESS PI **Burns**; (2) Atla reports "The Planet Hunting Machine", discussing FARSIDE with quotes from NESS members **Hallinan**, **Burns**, **Anderson**; (3) NASA announces the "New VIPER Lunar Rover to Map Water Ice on the Moon", which includes the participation of NESS member **Fong**.
- **Meetings:** (i) The **"2nd Global 21cm Workshop"** was held in Montreal, Oct. 7-9. NESS talks included: (1) **Tauscher** on "Moving away from analytical a priori foreground models in signal extraction"; (2) **Rapetti** on "Rigorously extracting and constraining global 21-cm signal model parameters"; (3) **Mirocha** on "The Global 21-cm Signal in the Context of High-z Galaxy Surveys"; (4) **Nhan** on "Constraining foreground spectrum with projection-induced polarization"; (5) **Bowman** on "EDGES overview"; (6) **Mahesh** on "EDGES beam modeling and data comparison"; (7) **Monsalve** on "EDGES Mid-Band analysis"; (ii) The **"Annual Meeting of the Lunar Exploration Analysis Group"** was held in Washington D.C. on Oct. 28-30: (1) **Bassett** presented a poster on "Opening a New Epoch of the Universe Using Low Radio Frequency Observations from the Farside of the Moon"; (2) **MacDowall** was a panelist in the "Science at the Moon Panel and Community Discussion"; (iii) On Oct. 10, **MacDowall** attended ROLSES commercial lander provider Intuitive Machine's Payload Mission Integration Review meeting in Houston, TX.
- **Outreach:** The annual International Observe the Moon Night was celebrated on October 5 at the Fiske Planetarium, in the CU Boulder campus.

Upcoming Events

- **Meetings:** The Science at Low Frequencies (SALF) conference will be held at Tempe, Arizona on December 9-11. NESS talks include: (1) **Burns** on "Investigating Dark Matter and Exotic Physics using the Redshifted 21-cm Global Signal with the Dark Ages Polarimeter Pathfinder (DAPPER)"; (2) **Tauscher** on "A generalized analysis technique for global 21-cm signal experiment"; (3) **Mahesh** on "Beam Chromaticity of the EDGES Low-Band Blade Dipole"; (4) **Anderson** on "The OVRO-LWA: Science Results & Upgrade"; (5) **Pober** on "The Impact of Calibration Errors on 21 cm Global Experiments: A Bayesian Case Study with EDGES"; (6) **Monsalve** on "An absorption feature in the EDGES Mid-Band spectrum"; (7) **Hallinan** on "FARSIDE: A Probe-Class Mission to Place a Radio Telescope on the Lunar Farside". NESS posters include: (1) **Rapetti** on "Self-consistently constraining foreground and global 21-cm physical models using a novel training set methodology"; (2) **Bassett** on "RFI Mitigation Techniques for Space-based 21-cm Global Signal Experiments".

Moment of Science: FARSIDE Mission Concept Study



The FARSIDE radio array will pioneer advances in two key fields of astrophysics, exoplanets and high redshift cosmology. **Left:** The predicted average flux radio density at ~280 kHz of known exoplanets, orbiting M dwarfs, assuming a magnetic field of 0.1 G (10% of Earth's magnetic field). **Right:** FARSIDE will be a sensitive probe of cosmology in the very early Universe. The black dashed curve shows the brightness temperature of neutral hydrogen in the standard cosmological model with adiabatic cooling. The shape at z > 30 is independent of astrophysical sources. The solid curves are parametric models that invoke extra cooling to match the amplitude in the EDGES signal. FARSIDE will cleanly distinguish between the standard cosmology model with adiabatic expansion and models with added cooling, potentially due to new interactions with dark matter, at >5-sigma level.

11/13/2019

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

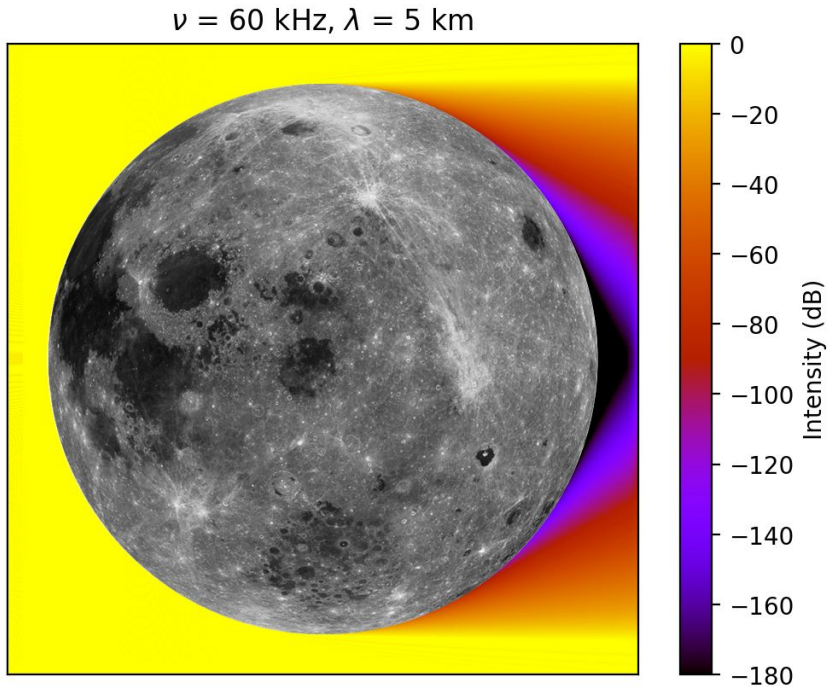
11:00 **Lunar Landers for Science and Exploration –** Cichan

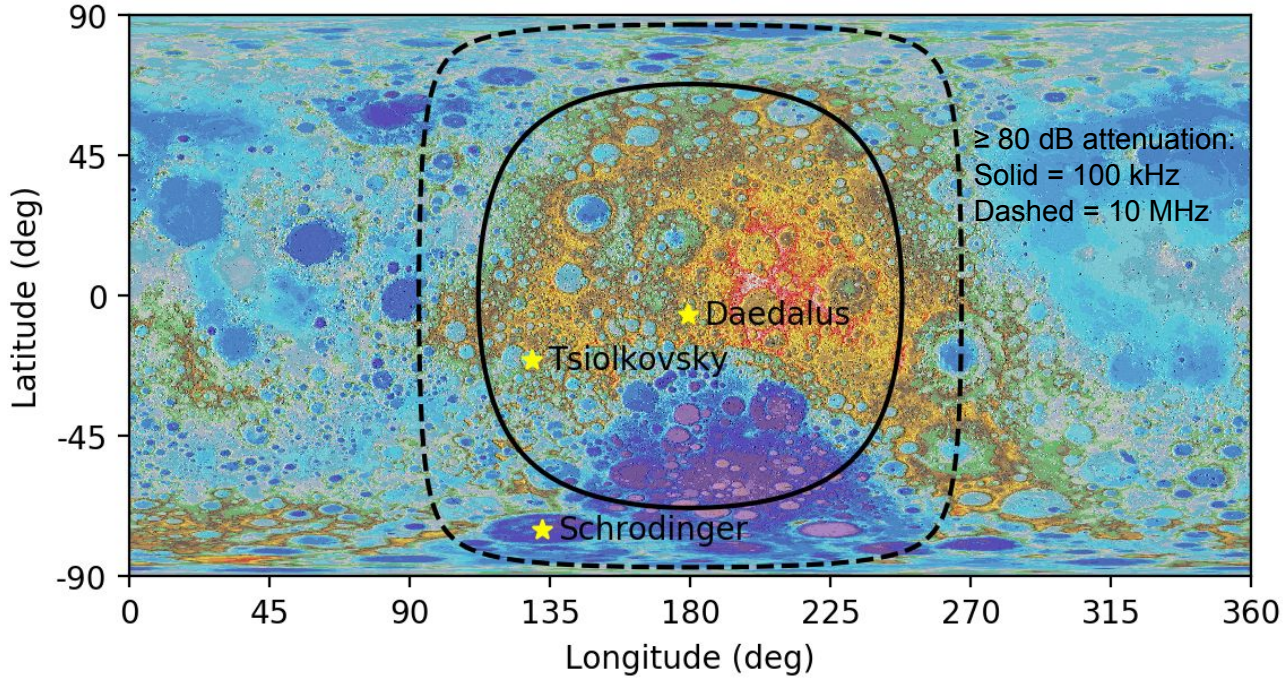
12:00 Lunch & Discussion

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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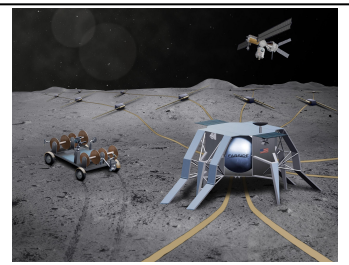
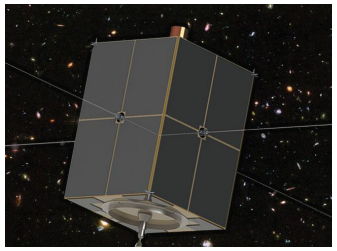
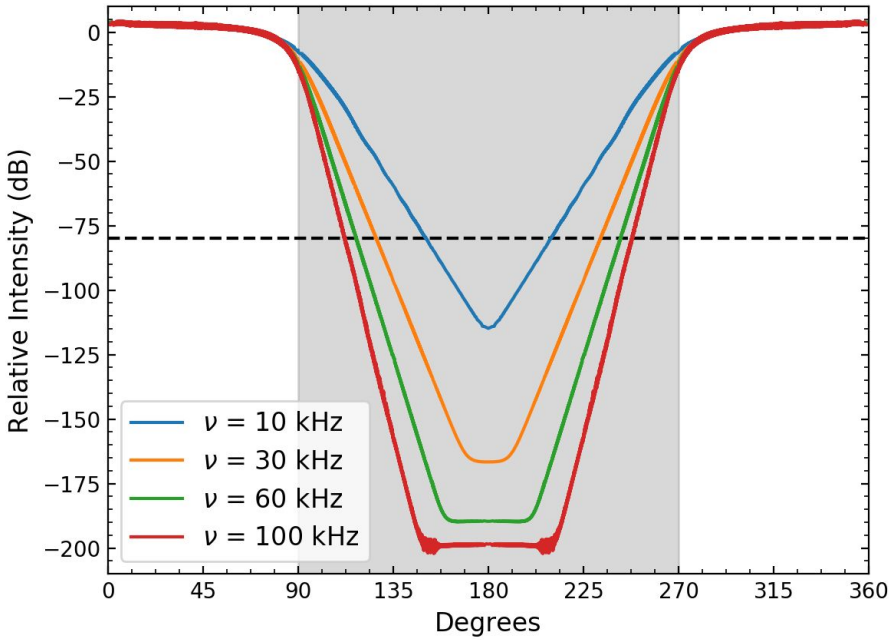
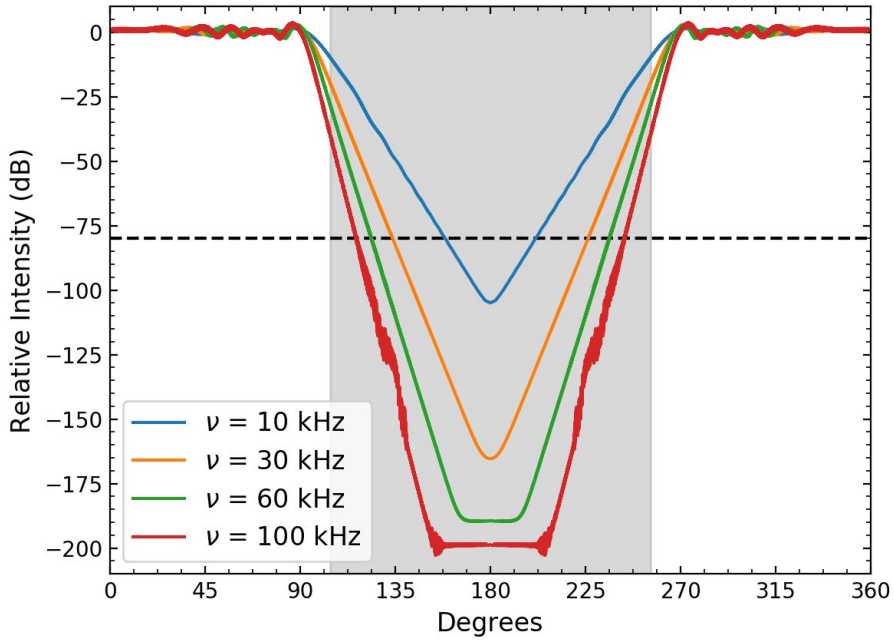


Surface
(FARSIDE)



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.

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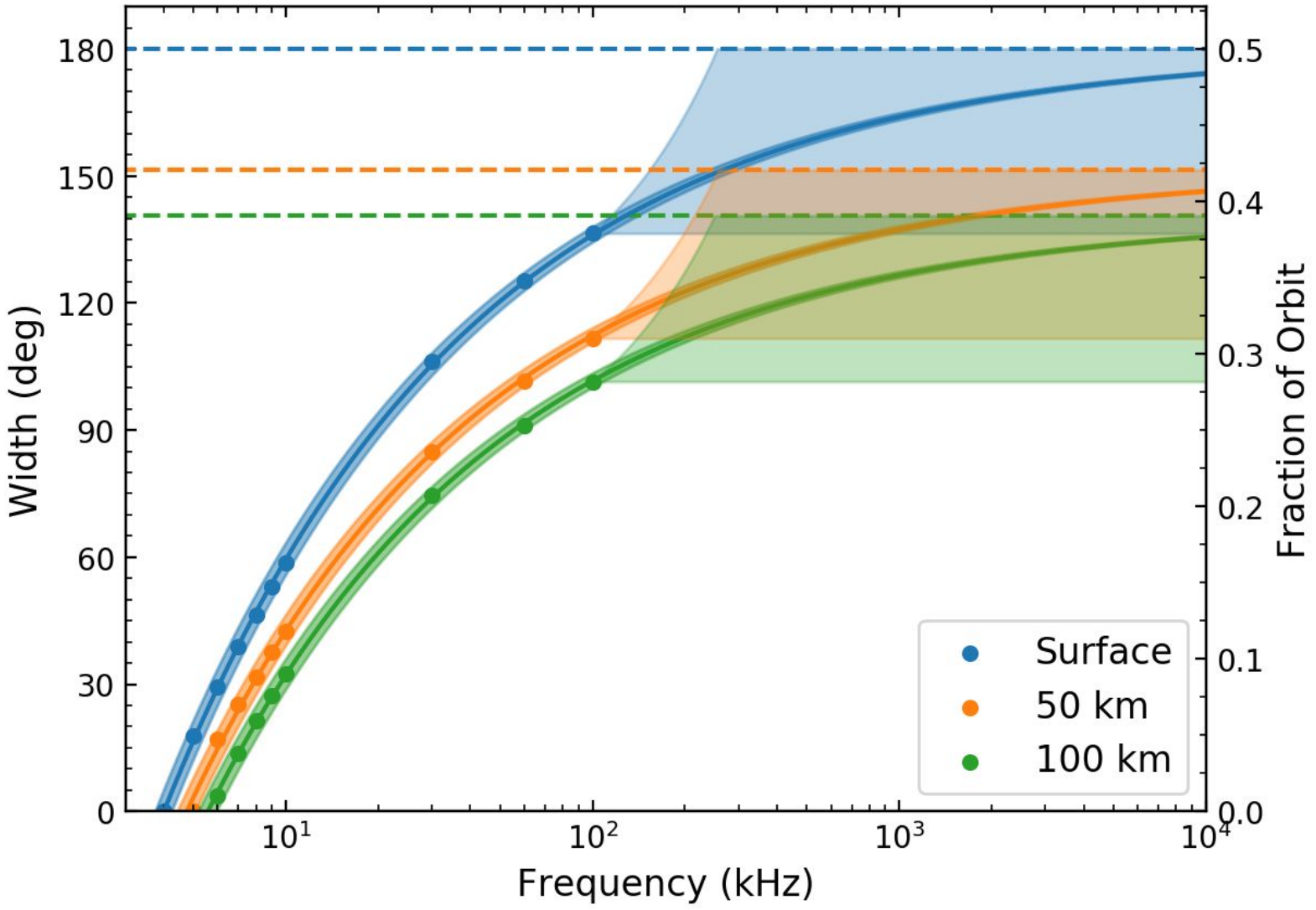

- Lighter shaded areas in plots indicate range of total possible sizes for quiet region at frequencies above 100 kHz
- Dashed lines show the geometric size of the quiet region when diffraction is ignored.
- Simulation results can be extrapolated to higher frequencies through a power law model motivated 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)