Radio Heliophysics Science and Applications to NASA's Strategic Knowledge Gaps

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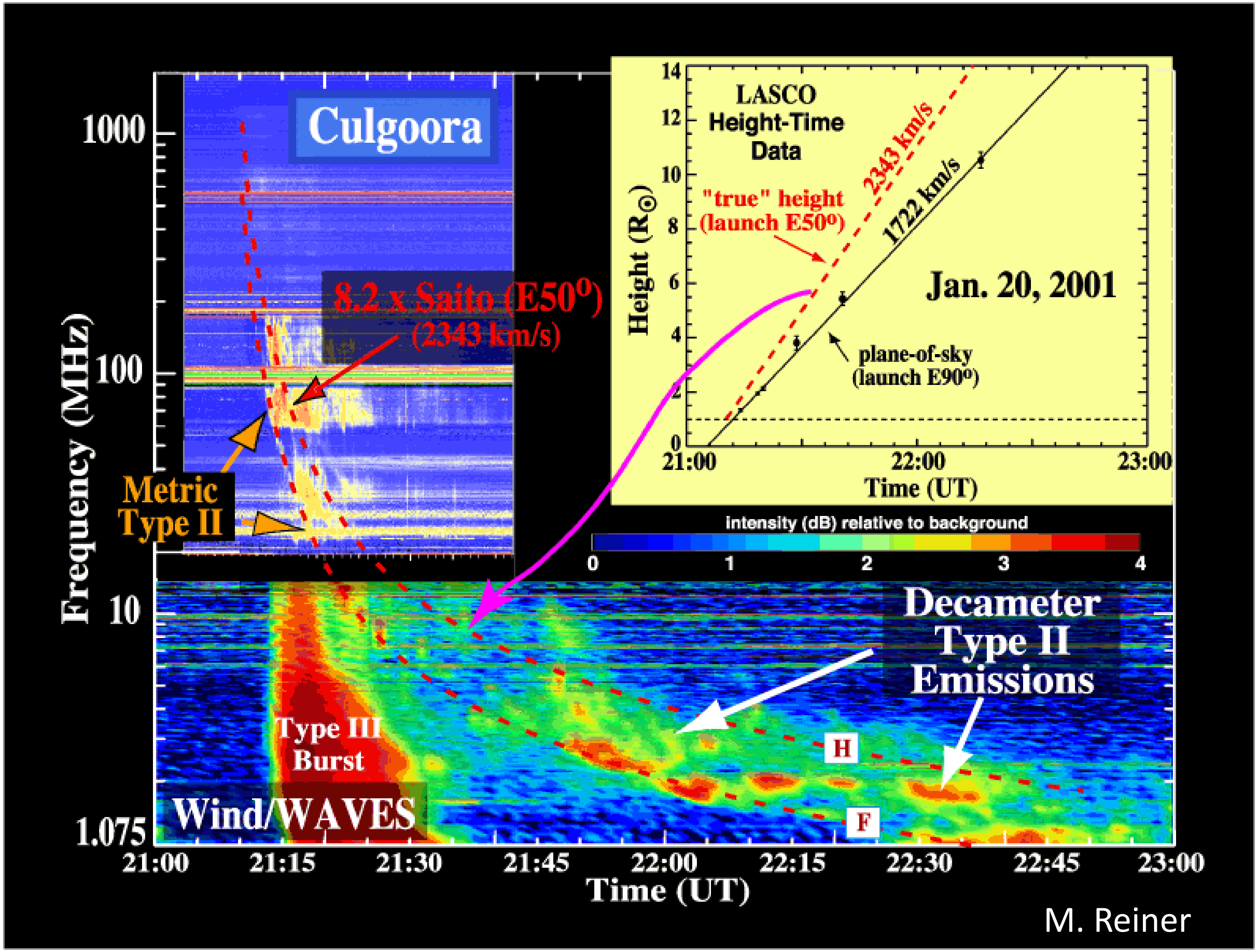
Solar radio bursts and coronal mass ejections



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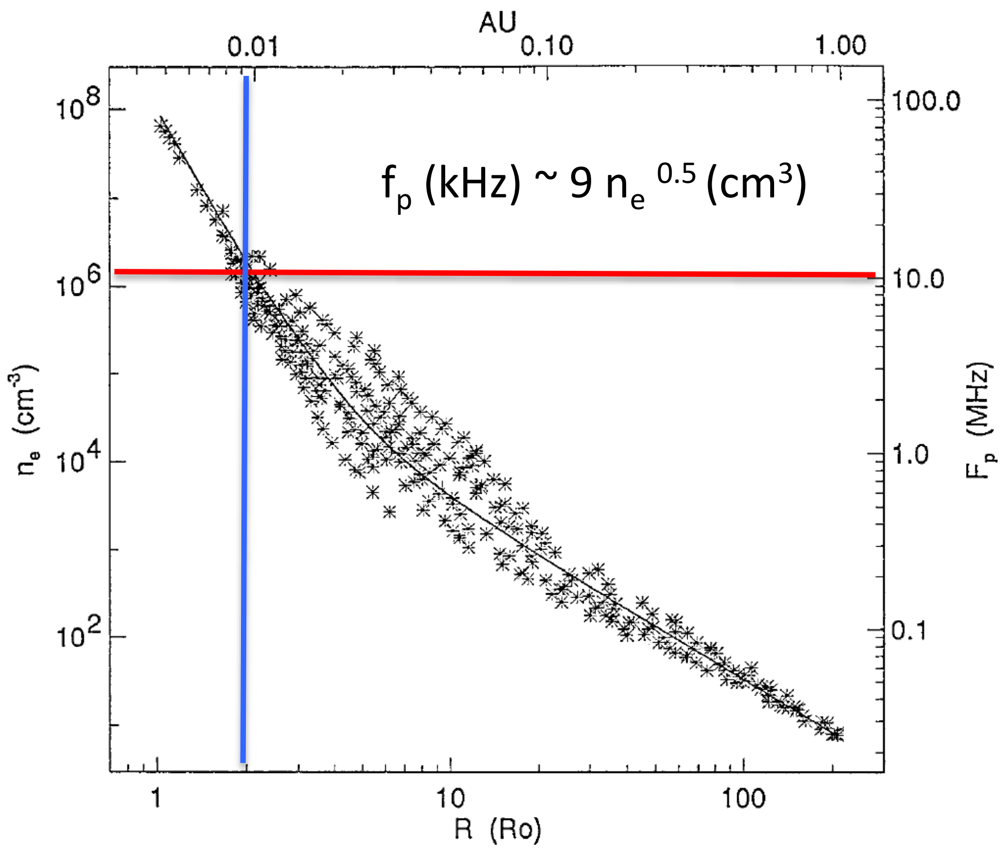
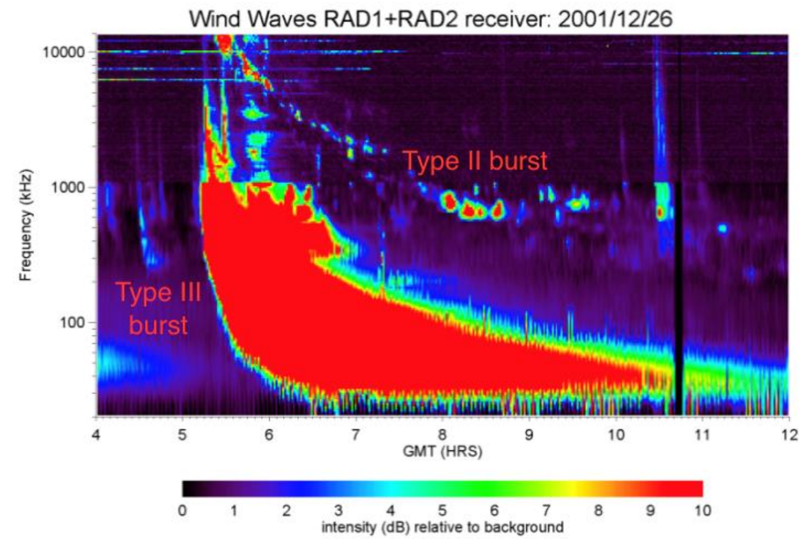
Heliospheric density scale

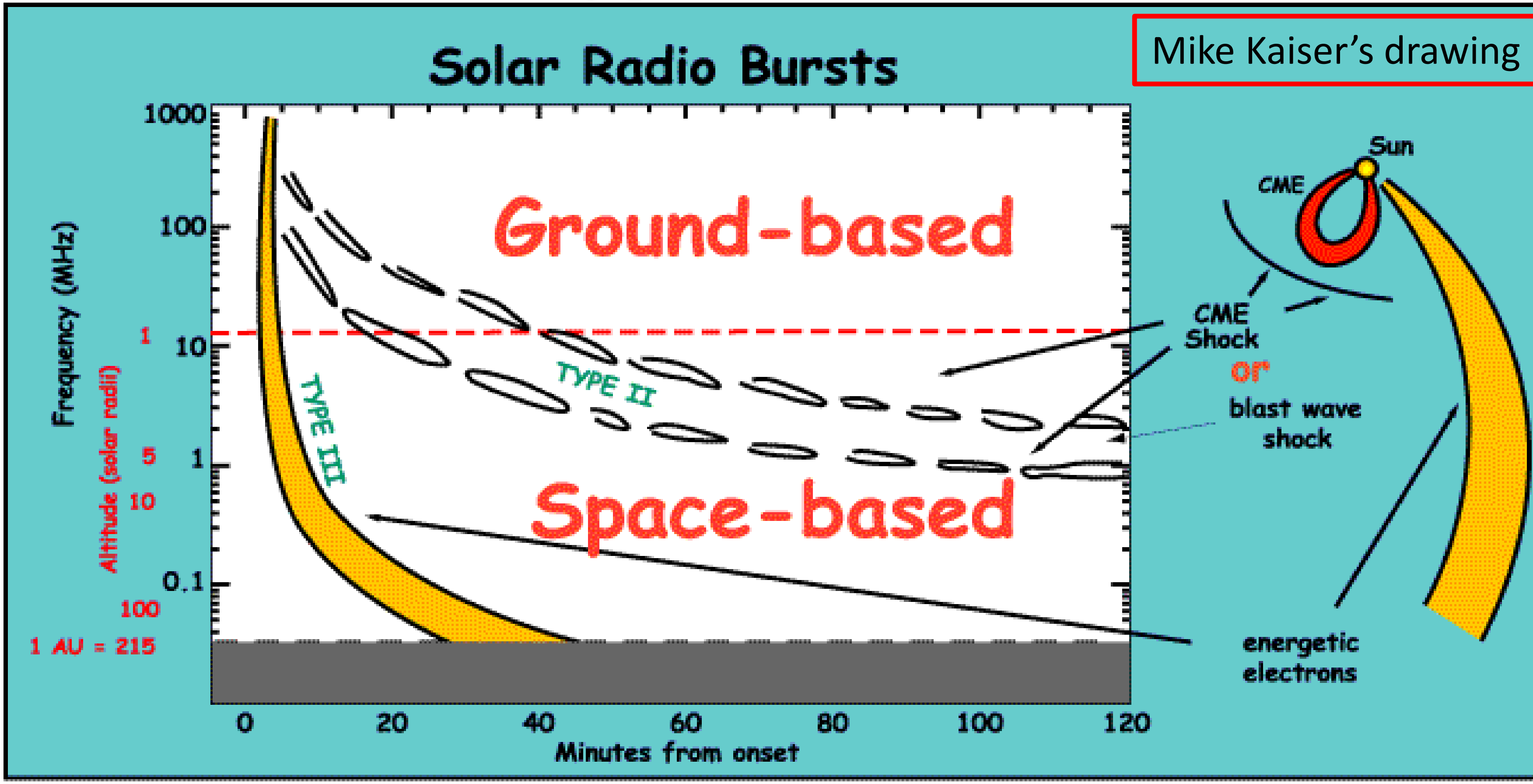


Density vs distance from Sun (R_o) derived from solar Type III radio bursts (Leblanc et al, 1998, Solar Physics)



- Different frequencies of the radio burst come from different distances from the Sun
- Can see from the plot at left that 10 MHz corresponds to ~ 1 R_o altitude
- Essentially all of space outside of the sphere of radius 2 R_o centered on the Sun has radio emission at lower frequencies

Space observation requirement for Type II & Type III bursts



- Ground-based observations down to ~10 MHz, correspond to an altitude above the solar surface of 1 R_solar. So, lower frequency radio bursts inside 1 AU that must be observed from above Earth's ionosphere correspond to > 99% of the total volume.

Solar radio burst science traceability

<table>
<tr><th colspan="4">Science Traceability Matrix</th></tr>
<tr><th>Decadal Science Goals</th><th>Science Objectives</th><th>Science Measurements</th><th>Instrument requirements</th></tr>
<tr><td rowspan="2">1) How do the heliosphere and planetary space environments respond to solar variability?</td><td>1) Where do solar radio bursts indicate that type II burst electrons are accelerated?</td><td rowspan="3">1) Image solar radio bursts with angular resolution < 2 degrees
2) Cover the freq. range 100 kHz-10 MHz
3) Obtain images every 10 sec or less
4) Continue observations for >1 yr during solar maximum</td><td rowspan="3">1) Aperture synthesis radio array on lunar surface
2) Radio receivers, timing system, etc., to provide data for synthesis
3) Hardware that is radiation & thermally tolerant to survive the lunar environment
4) Deployer for chosen antenna design</td></tr>
<tr><td>2) What are the sources of unusually complex type III radio bursts?</td></tr>
<tr><td>2) What are the impacts on humanity?</td><td>3) How can we use the detailed information from solar radio burst imaging to improve their diagnostic indications of energetic particles/space weather at 1 AU?</td></tr>
</table>

Value of solar radio bursts for space weather alerts

- There are essentially no dangerous Solar Energetic Particle (SEP) events without the related complex type III bursts and intense type II bursts.
- The solar radio burst events can supplement the white light coronagraph observations.
- If we could get a pathfinder Lunar Radio Telescope Array on the Moon for this solar Maximum (~ 2022-2024), we could directly demonstrate the value of the data as an SEP alert for astronauts (and hardware).
- It’s critical to develop an algorithm that is reliable.

Requirements for imaging these radio sources from the lunar surface

Table 3.4.1. Summary of ROLSS parameters

Parameter	Value	Comment
Wavelength (Frequency)	30–300 m (1–10 MHz)	• Matched to radio emission generated by particle acceleration in the inner heliosphere • Provide context for observations during Solar Probe Plus perihelion passes • Detect lunar ionosphere • Operate at frequencies below the terrestrial ionospheric cutoff
Angular Resolution	2° (at 10 MHz)	• Localize particle acceleration sites of CME shocks and Type III solar bursts • Order of magnitude improvement from present
Bandwidth	≥ 100 kHz	Track time-evolution of particle acceleration
Minimum Lifetime	~1 year	Obtain measurements during several solar rotations; avoid solar minimum

Radio Heliophysics Summary

- Solar radio bursts at frequencies < 20 MHz have never been imaged.
- The timing and location of the bursts provides an indication of energetic particle acceleration, and therefore, the potential of space weather alerts.
- Imaging the bursts will also provide data on the locations of electron acceleration, answering magnetic field configuration and other questions.
- Requirements for the pathfinder lunar surface radio telescope are modest, except for surviving the thermal environment, which includes surviving 14 days of lunar night. OK, maybe getting to the surface is still an issue…

Low Radio Frequency Instruments under construction or Mission Concepts led by NESS Team members

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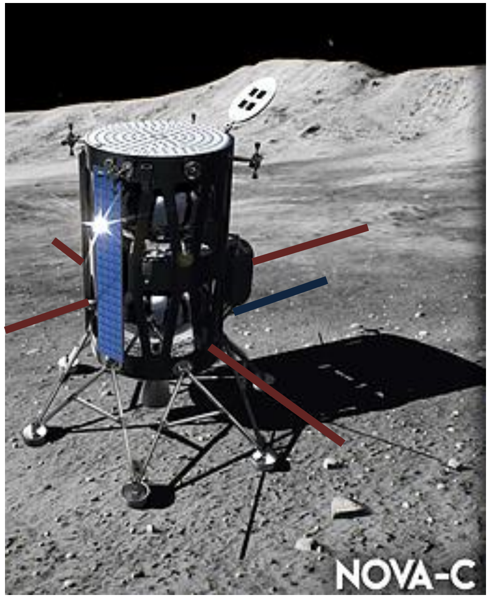
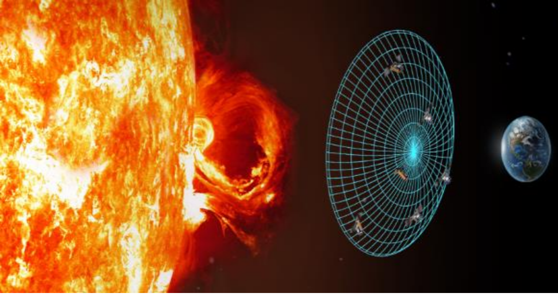
Selected Lunar Landed Payload – *Radio wave observations at the Lunar Surface of the photoElectron Sheath (ROLSES)*

- Team – Robert MacDowall (PI); William Farrell (Co-I), Damon Bradley (Co-I); GSFC collaborators – Nat Gopalswamy, Michael Reiner, Ed Wollack; and Jack Burns (U.Co)
- Objectives: determine
  - photoelectron sheath density from 0 to ~2 m above the lunar surface
  - spectra of radio frequency interference from terrestrial transmitters relating to a near side imaging solar radio burst array
  - dust detection rate, striking antennas
  - overall environment for near-side radio astronomy array
- Overall goal: aid the development of lunar radio arrays, for various science goals, including imaging of solar type II and III radio bursts, to answer science questions about them and improve their use as precursors of 1 AU space weather
- Plan – deliver instrument NLT 8/7/2020



- Radio spectrometer derived from previous Code 564 spectrometers (electronics)
- Four Stacer antennas, 2 @ 1 m & 2 @ 2m above lunar surface
- 14.6 kg, 18 x 15 x 15 cm for electonics box
- Need to deploy 4 Stacer antennas
- Power: 8 W, 10.5 W peak
- Any near side landing site is acceptable



Localize Radio Bursts that Precede Solar Energetic Particle (SEP) Acceleration

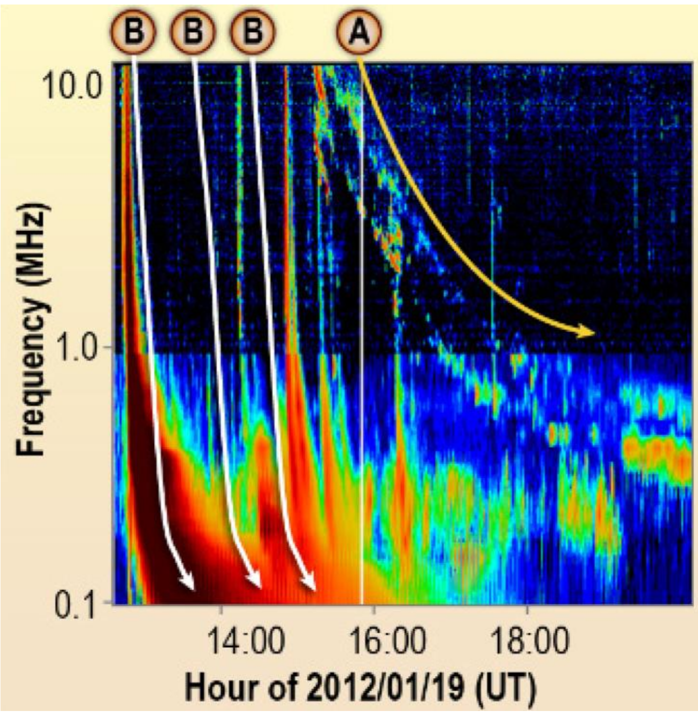
J. Kasper, U. Michigan & NESS, P.I.

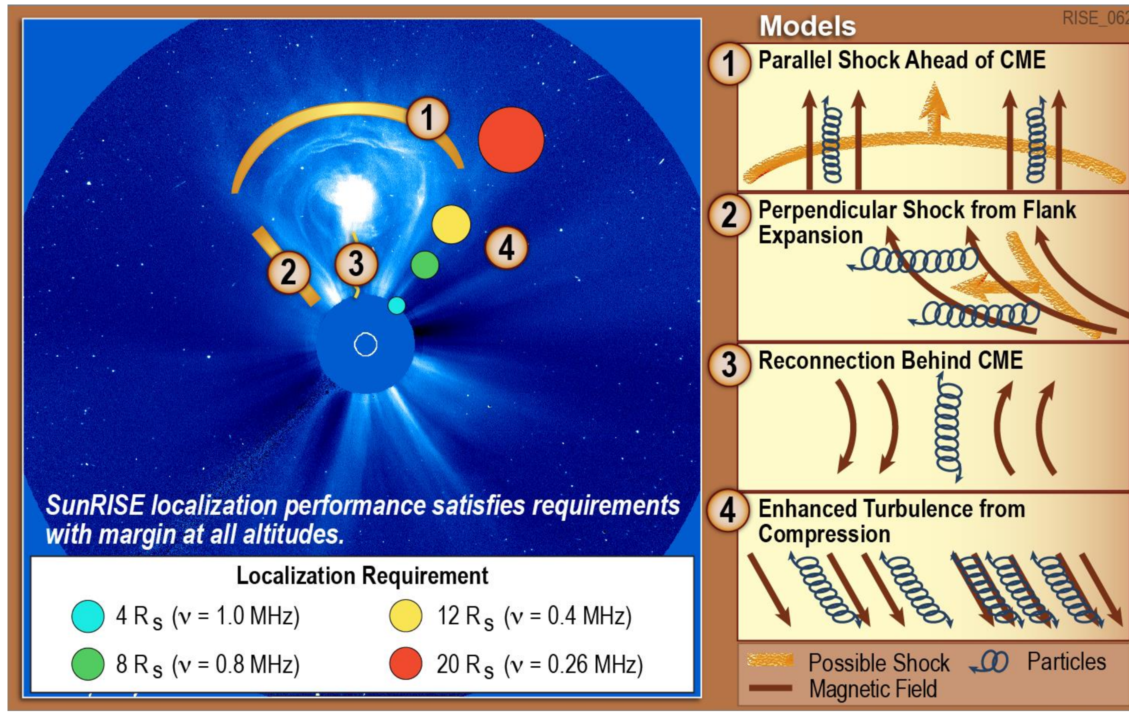
Selected Heliophysics Mission of Opportunity

SunRISE

Sun Radio Interferometer Space Experiment

Precursor Low Radio Frequency Space-based Array to observe Solar Coronal Mass Ejections





Science Overview

Lunar Low Radio Frequency Array Concept – J. Burns, G. Hallinan, P.I.s