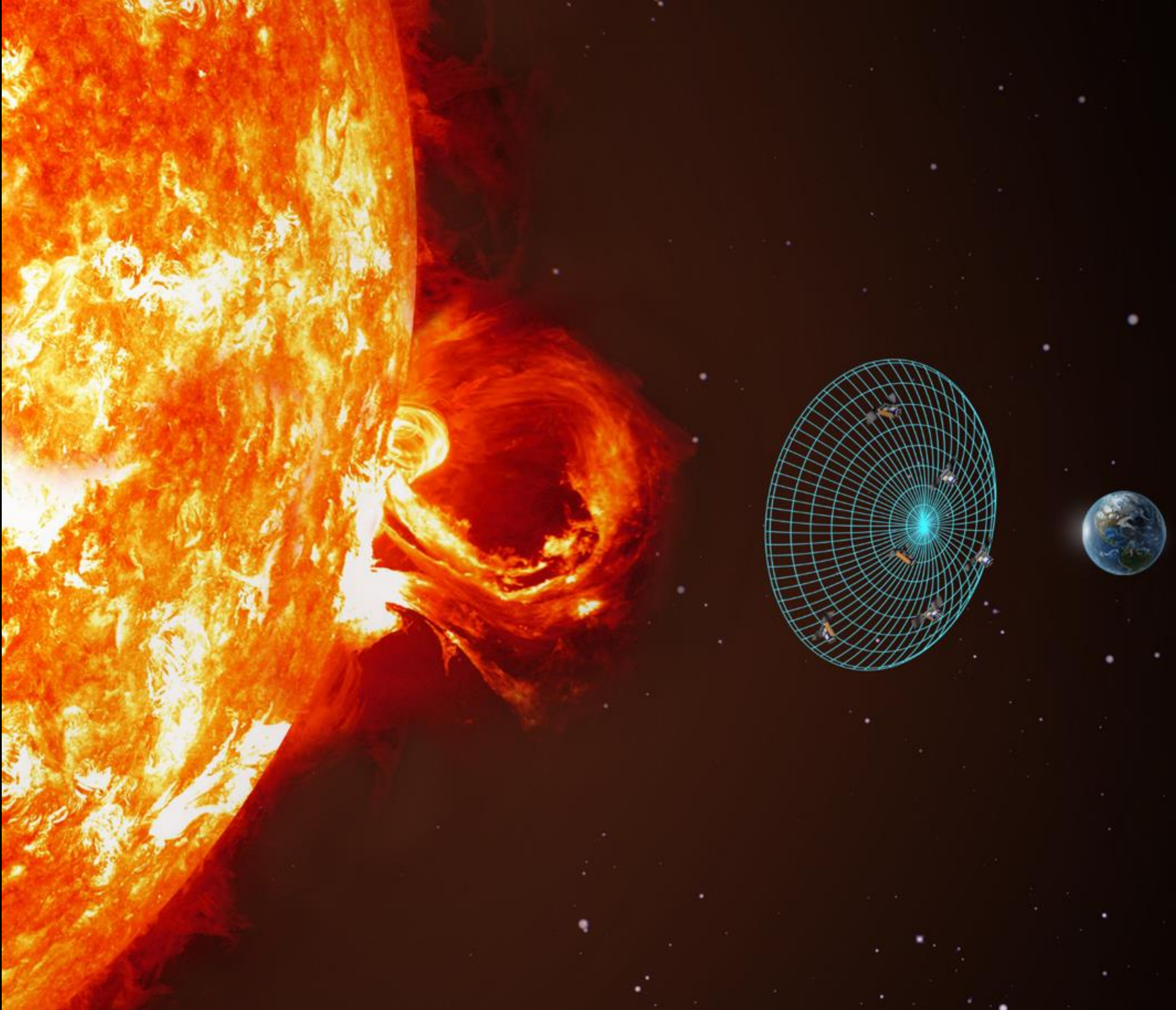
UNIVERSITY OF MICHIGAN

NASA

Jet Propulsion Laboratory
California Institute of Technology



The SunRISE Mission

Sun Radio Interferometer Space Experiment

Andres Romero-Wolf (Jet Propulsion Laboratory, California Institute of Technology)

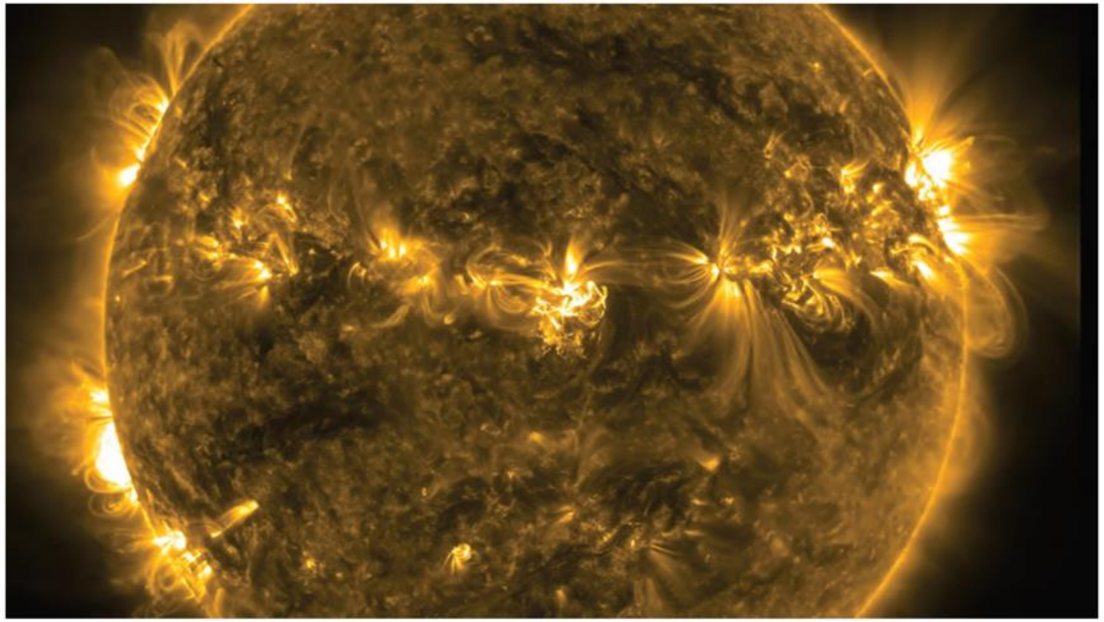
With help from:
Justin C. Kasper (University of Michigan)
T. Joseph W. Lazio (Jet Propulsion Laboratory, California Institute of Technology)
James P. Lux (Jet Propulsion Laboratory, California Institute of Technology)
Cate Heneghan (Jet Propulsion Laboratory, California Institute of Technology)
Tim Neilsen (Space Dynamics Laboratory)
And many, many others!

SUNRISE
SUN RADIO INTERFEROMETER SPACE EXPERIMENT

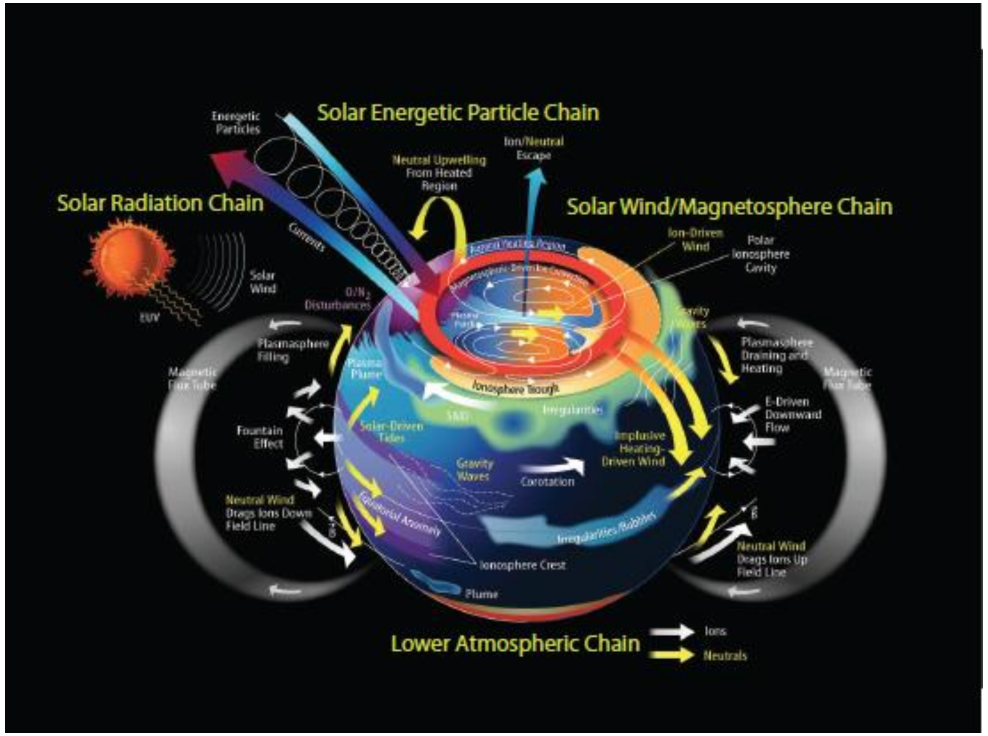
Heliophysics Decadal Survey (2013)

Key Science Goal 1. Determine the origins of the Sun's activity and predict the variations in the space environment.

Key Science Goal 2. Determine the dynamics and coupling of Earth's magnetosphere, ionosphere, and atmosphere and their response to solar and terrestrial inputs.



Source: 2013 Heliophysics Decadal Survey

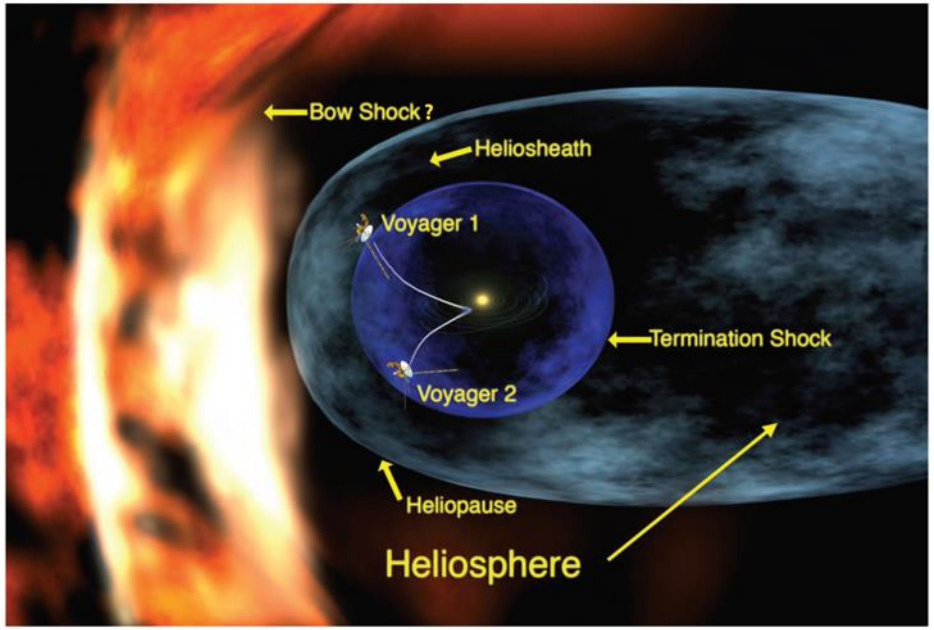


Source: 2013 Heliophysics Decadal Survey

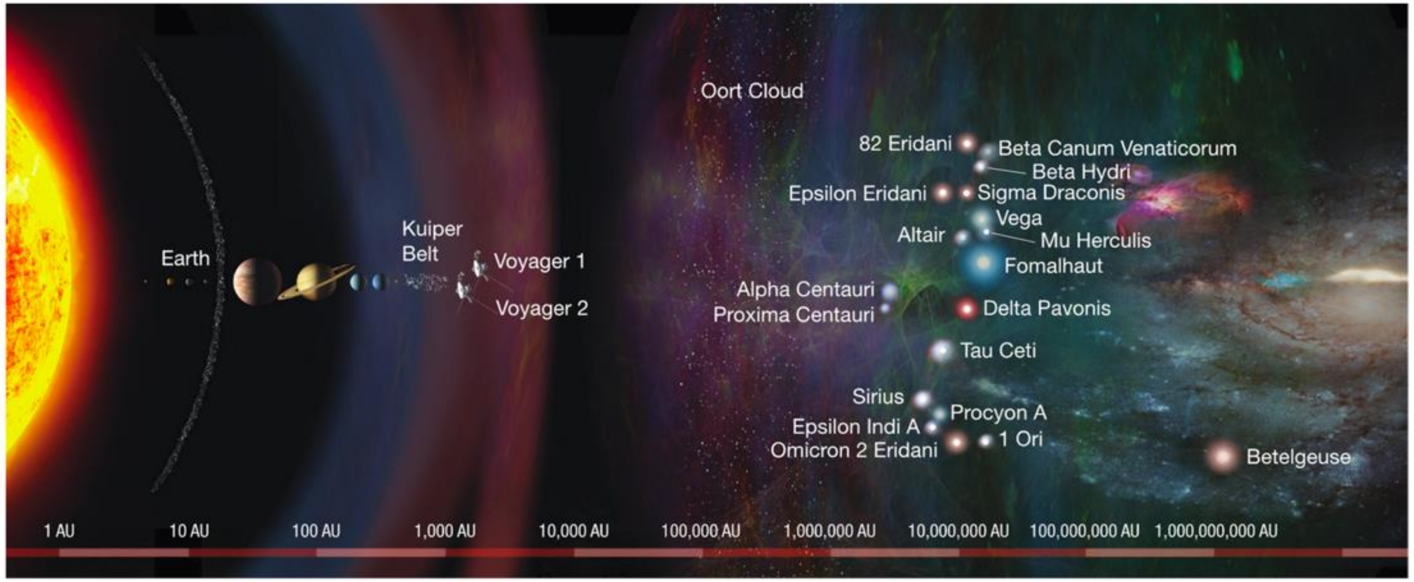
Heliophysics Decadal Survey (2013)

Key Science Goal 3. Determine the interaction of the Sun with the solar system and the interstellar medium.

Key Science Goal 4. Discover and characterize fundamental processes that occur both within the heliosphere and throughout the universe.

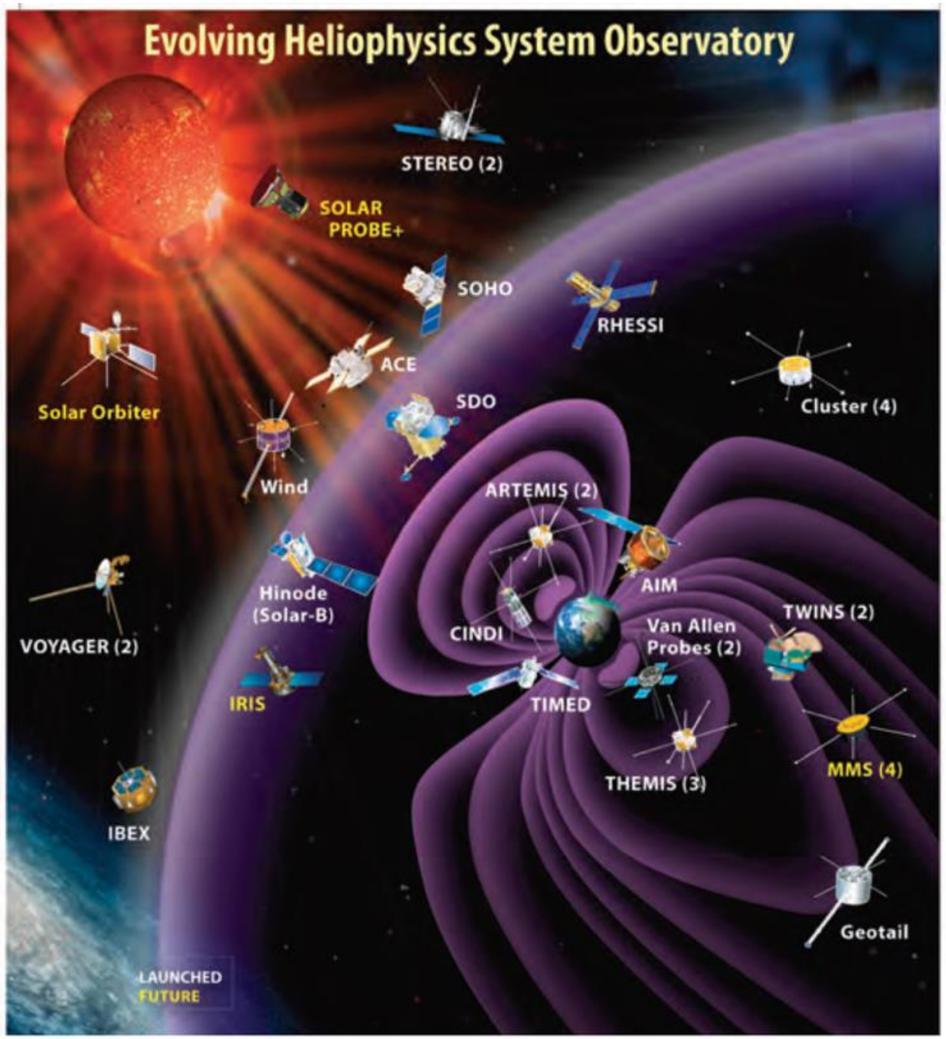


Source: 2013 Heliophysics Decadal Survey

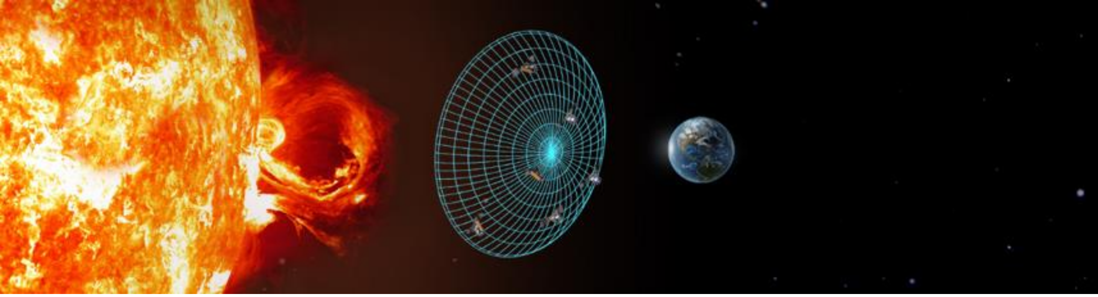


Source: Starshade Rendezvous Probe Report (2019)

Heliophysics Observatories

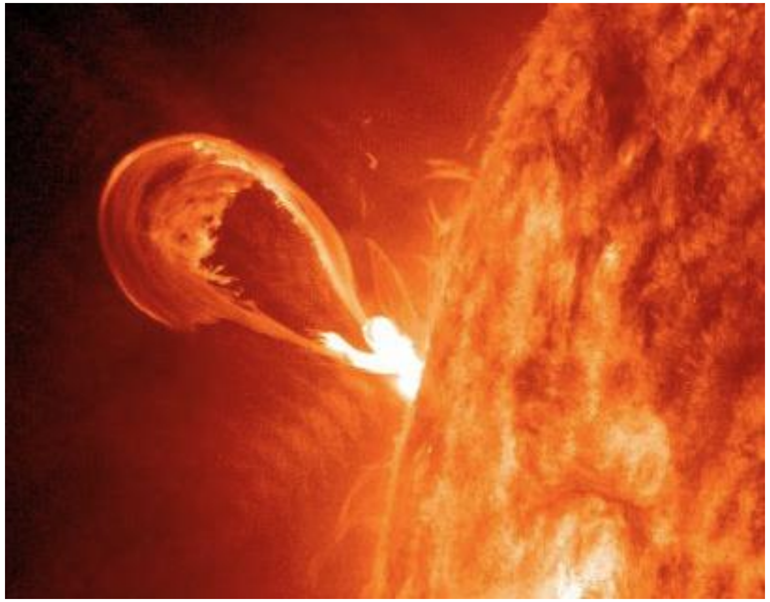


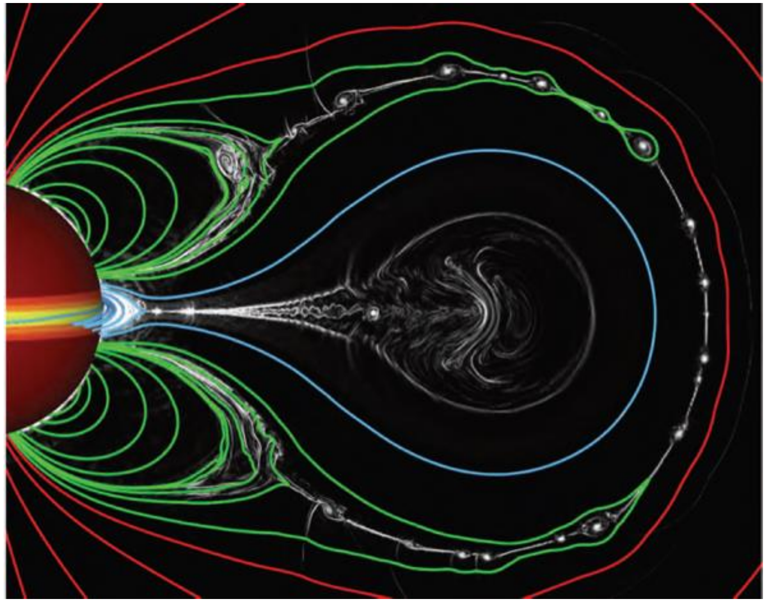
Goals

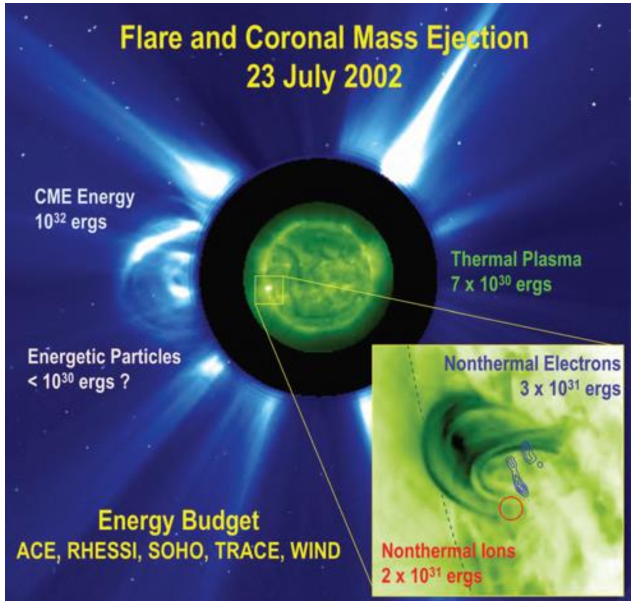


The Sun and Heliosphere

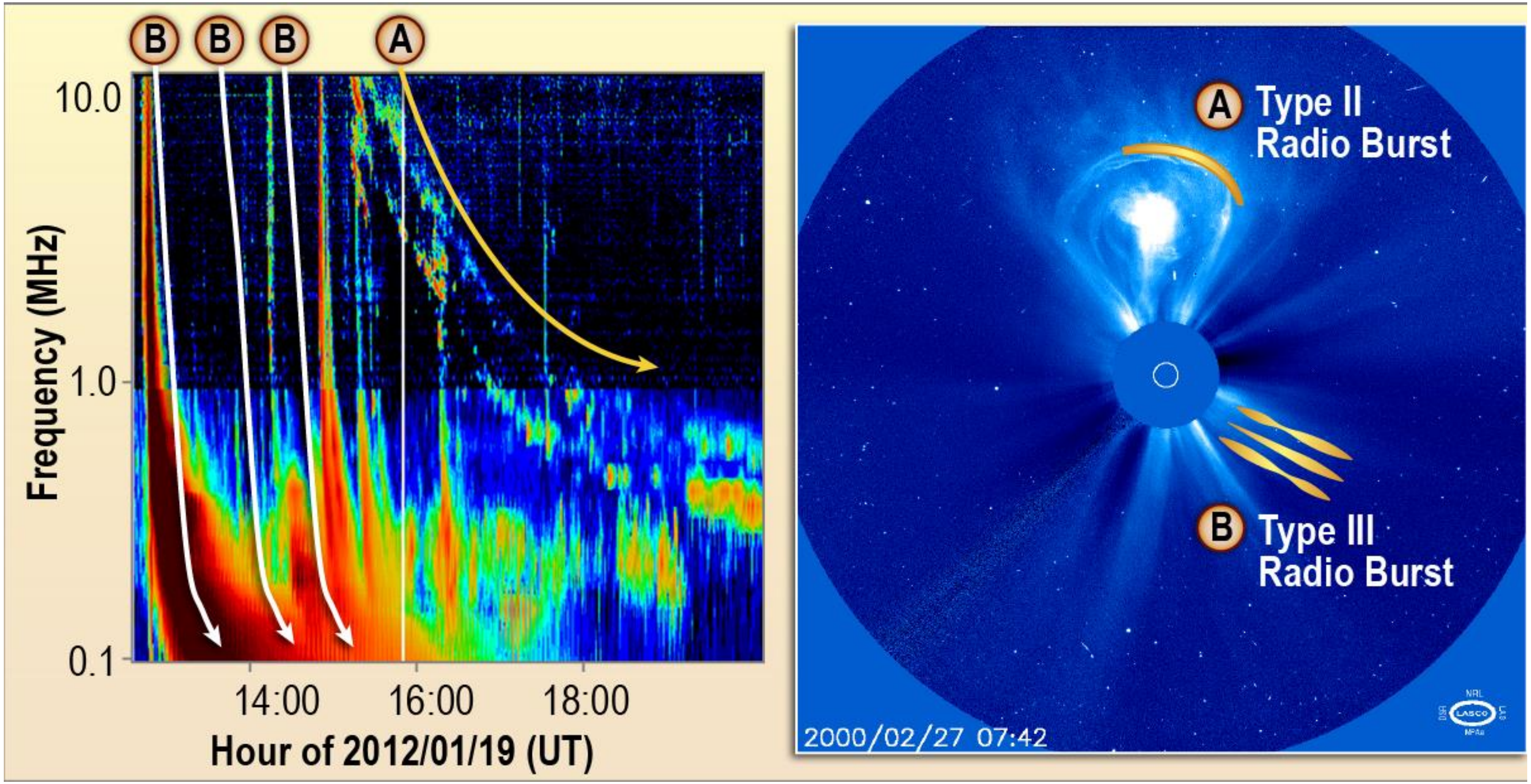
SHP-1	Understand how the Sun generates the quasi-cyclical magnetic field that extends throughout the heliosphere.
SHP-2	Determine how the Sun's magnetism creates its hot, dynamic atmosphere.
SHP-3	Determine how magnetic energy is stored and explosively released and how the resultant disturbances propagate through the heliosphere.
SHP-4	Discover how the Sun interacts with the local interstellar medium.



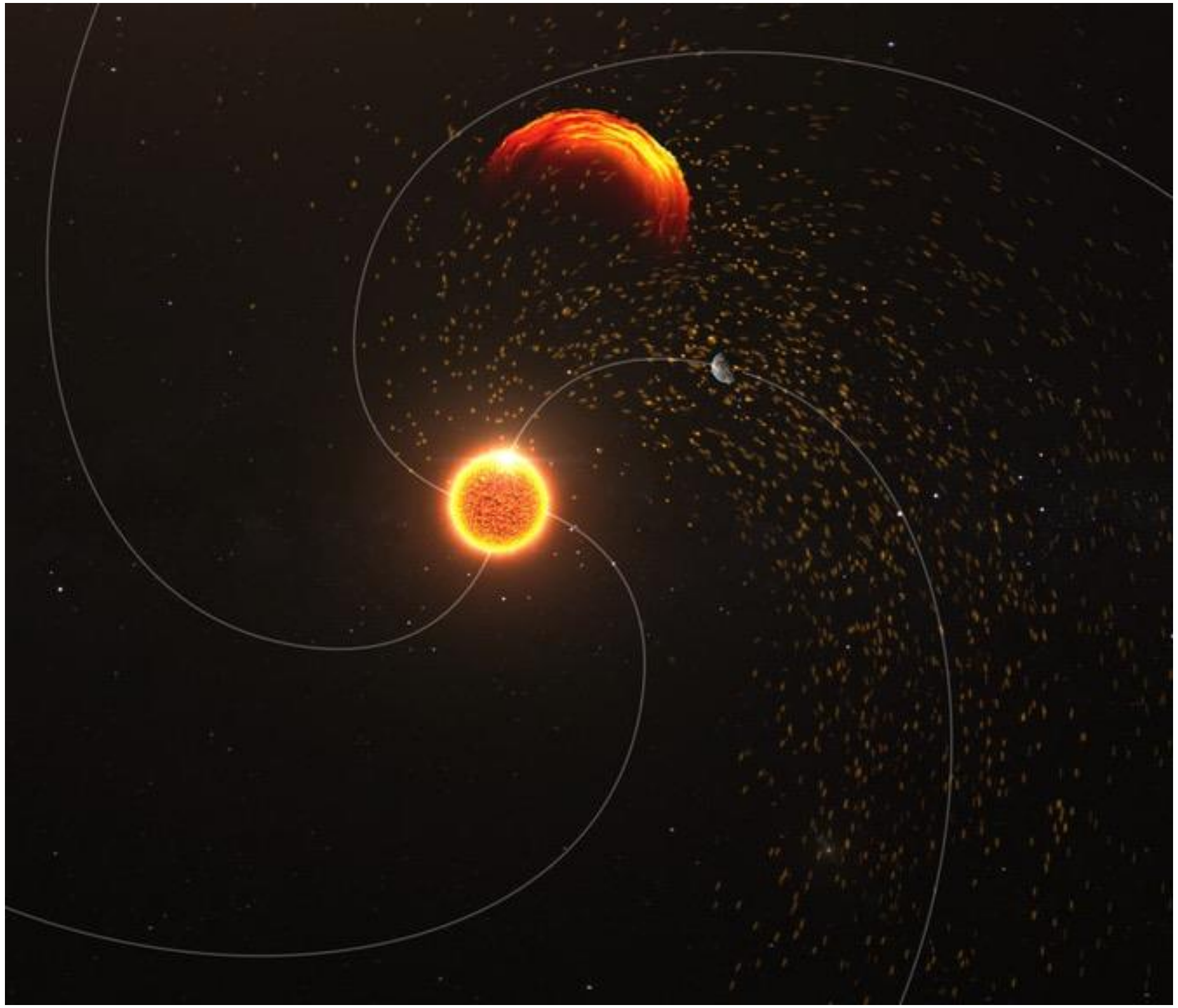


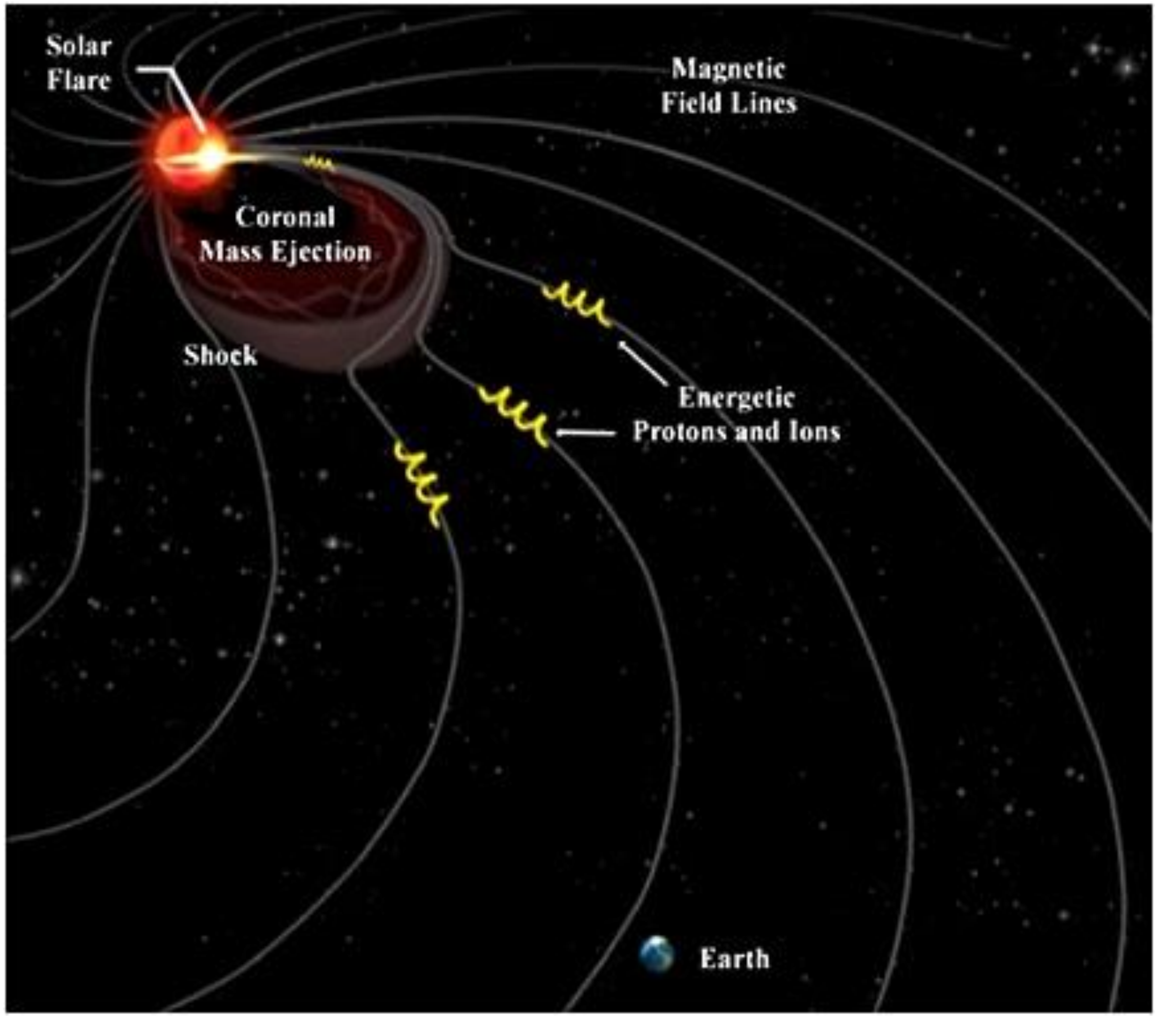


Solar Radio Bursts: Type II and III



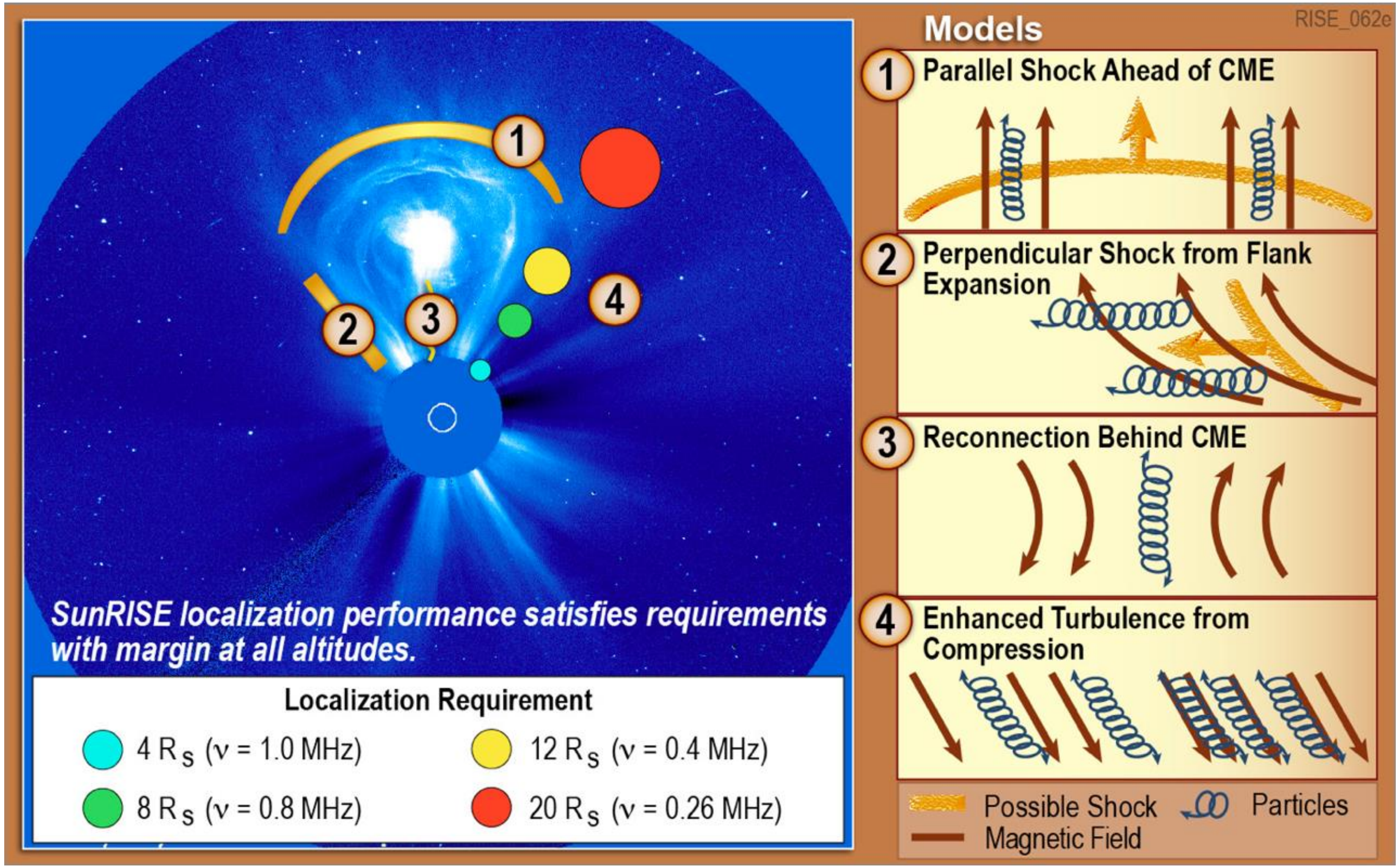
Solar Energetic Particles



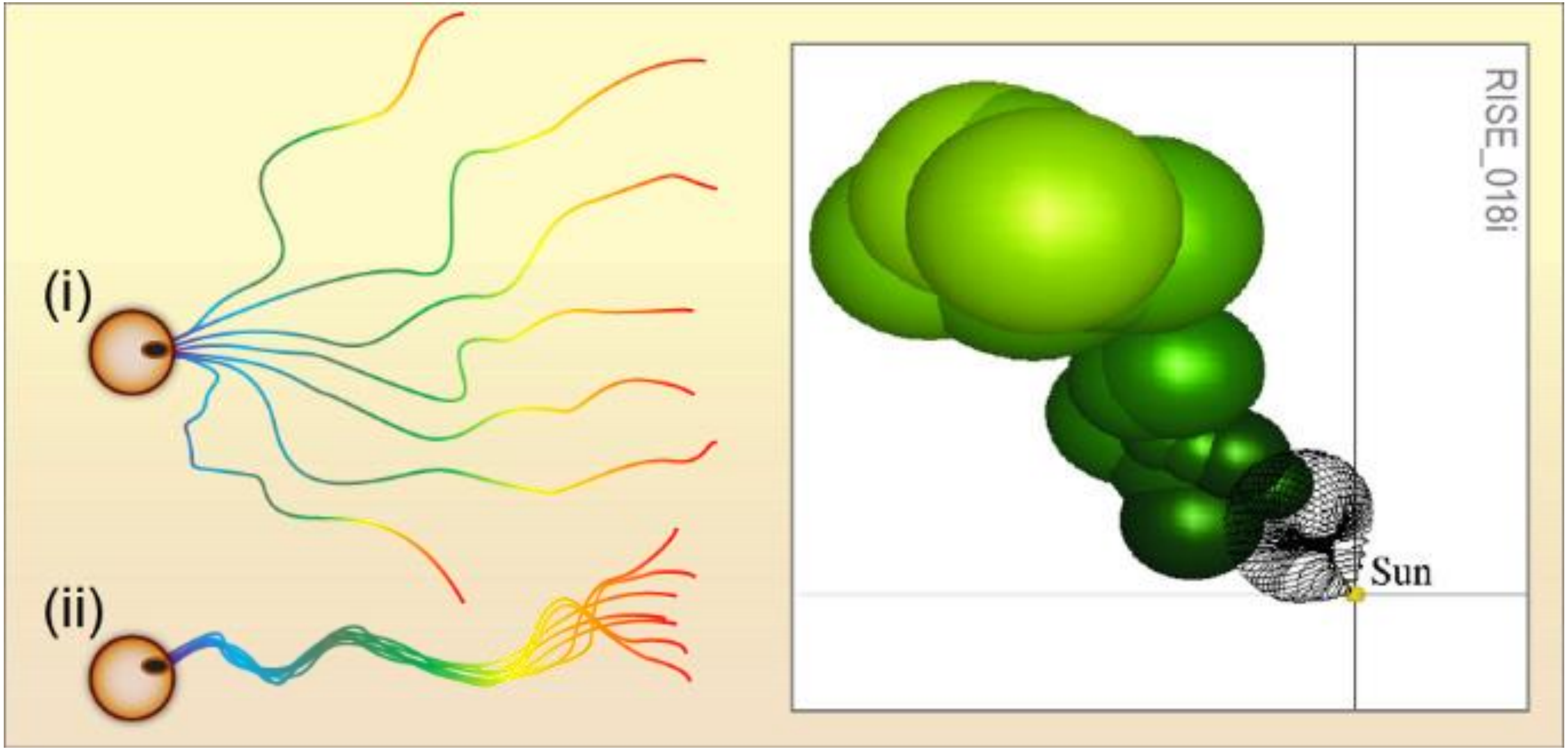


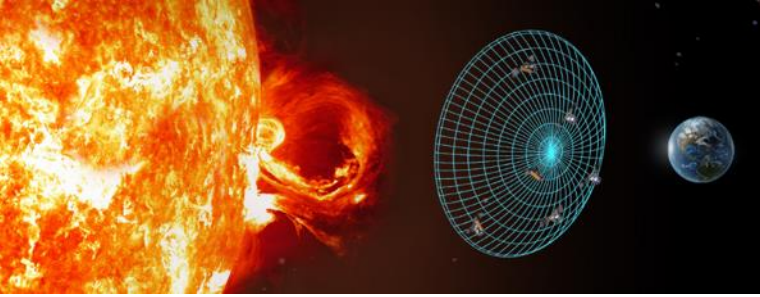
Source: https://swatnet.eu/solar-energetic-particles/

SunRISE Objectives



SunRISE Objectives

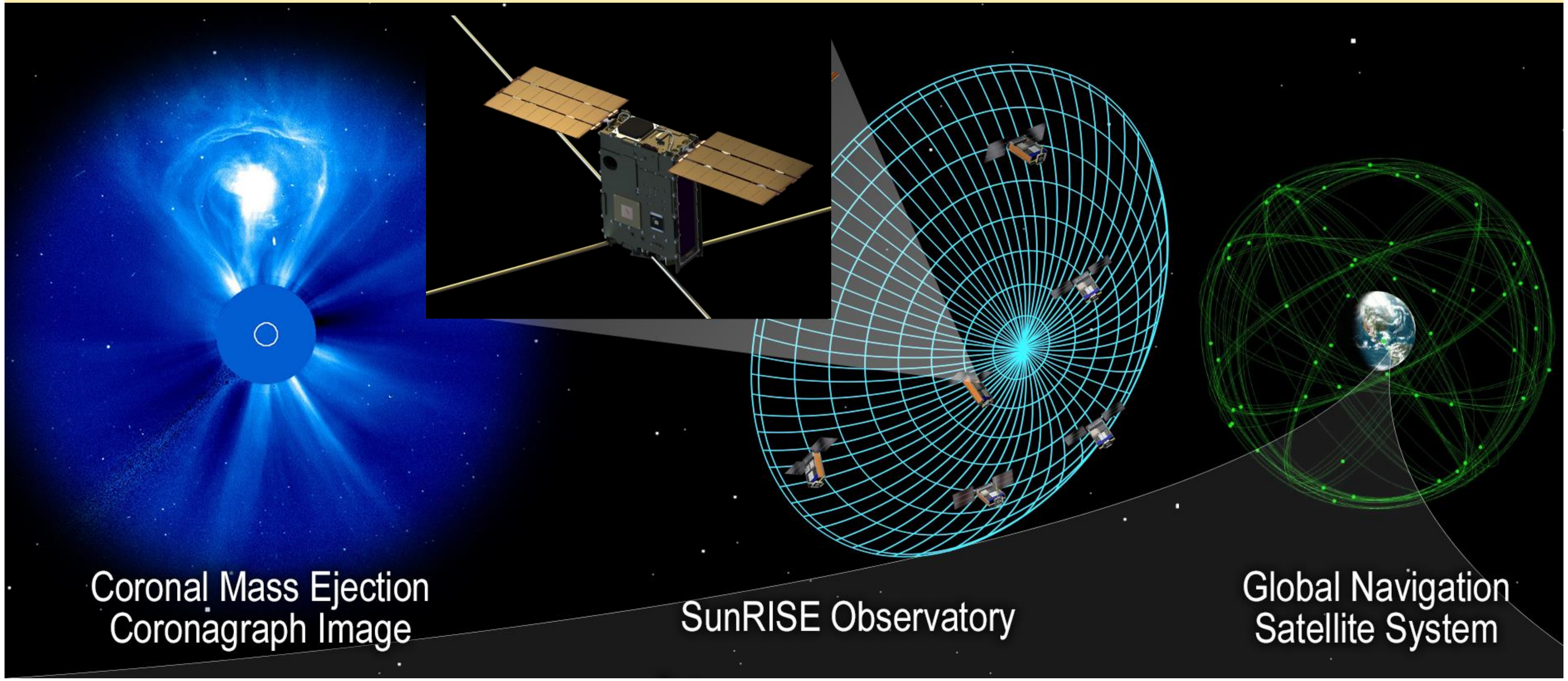




SunRISE Concept

SunRISE is the first spaceborne imaging radio interferometer

Uses existing technology to form a synthetic aperture for imaging Solar bursts at radio frequencies of 100 kHz to 23 MHz.



SunRISE images solar activity at decametric-hectometric (DH) radio frequencies.

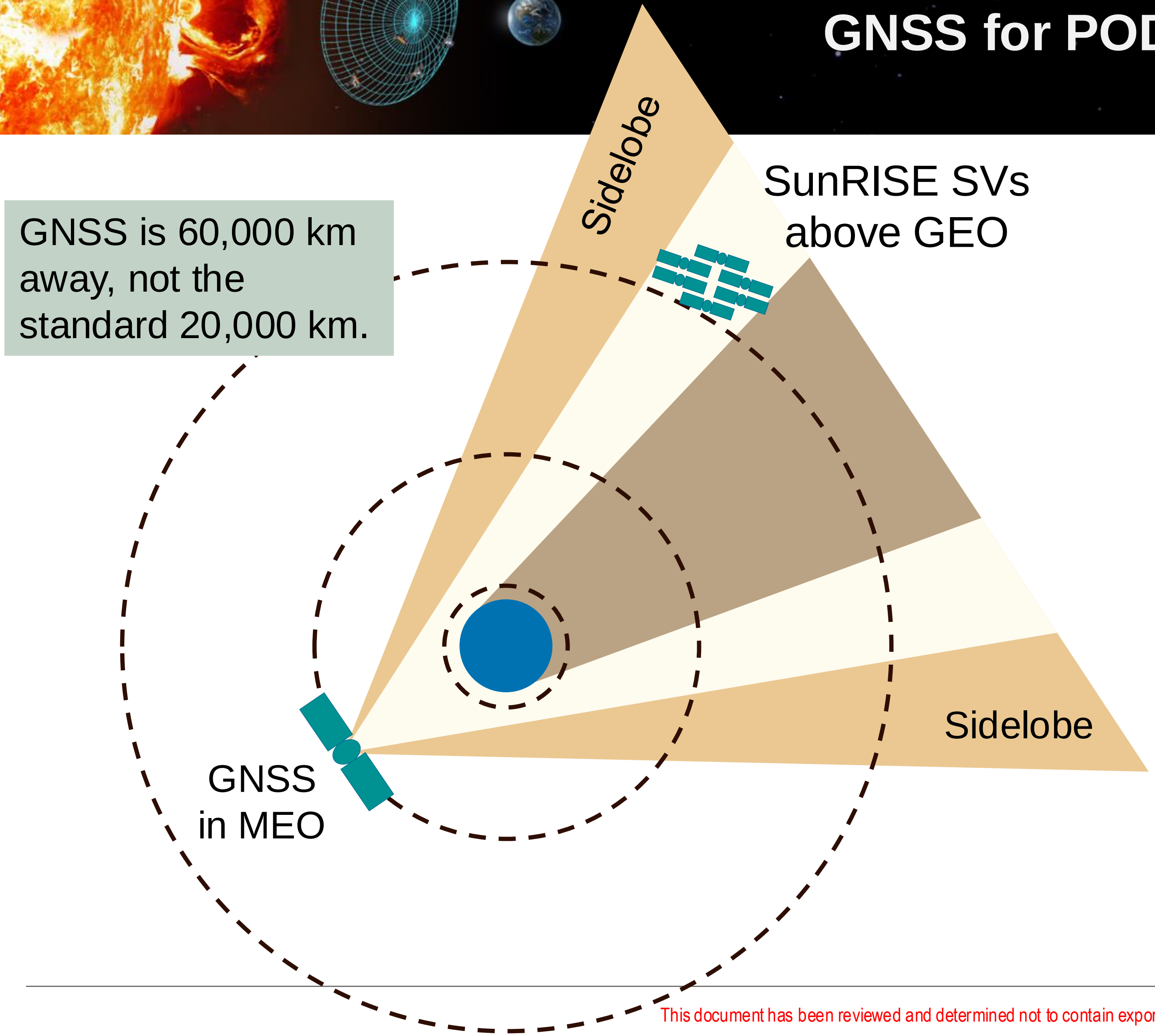
Each space vehicle carries two orthogonal 5.5-m dipoles to measure the DH signals.

Interferometry at these frequencies needs position and time knowledge to 1m and 1ns.

Frequencies below 23 MHz can be distorted by the ionosphere, so SunRISE flies just above GEO.

Orbital period is 3-4 months.

GNSS for POD



The GNSS signal chain achieves on-board knowledge of time (and position) to a microsecond. This allows all 6 space vehicles to take simultaneous DH measurements.

Post processing achieves higher accuracy Precision Orbital Determination (POD) solutions, which are used to determine the relative propagation delays between the space vehicle pairs in the interferometer.

POD is also used for navigation planning and Forward Orbit Prediction.

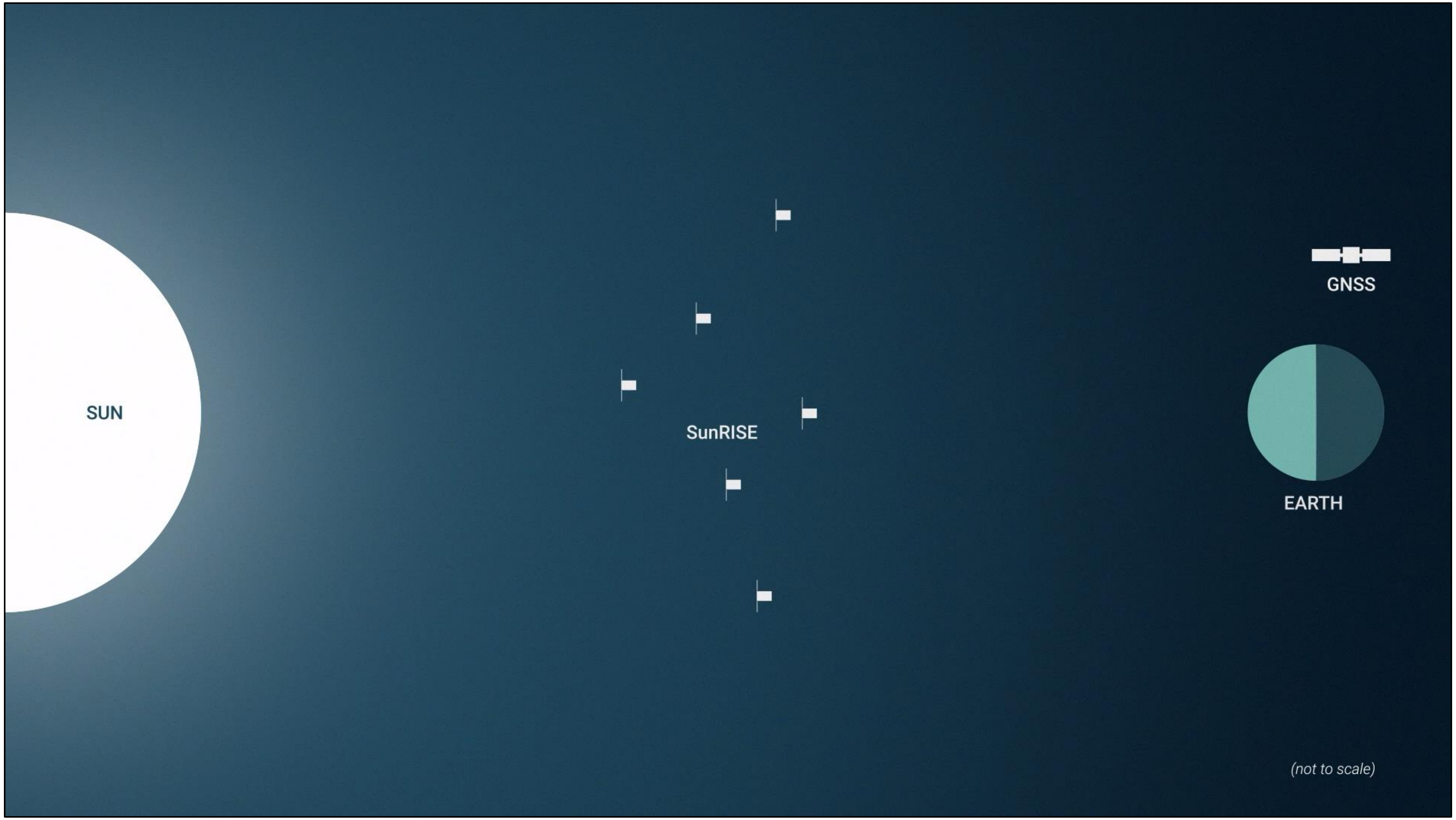
Observatory

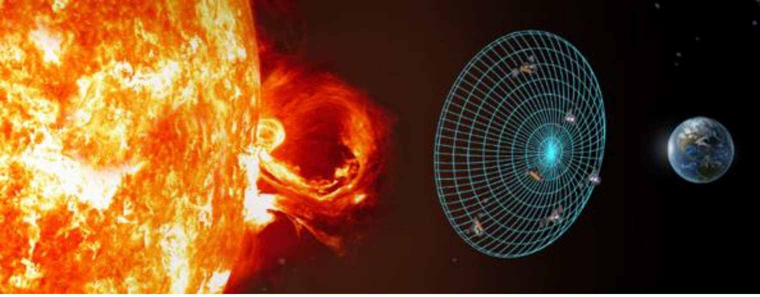
SUNRISE
SUN RADIO INTERFEROMETER SPACE EXPERIMENT

GNSS provides ~1 m position accuracy on each spacecraft.

Supersynchronous orbit 37,000 km altitude.

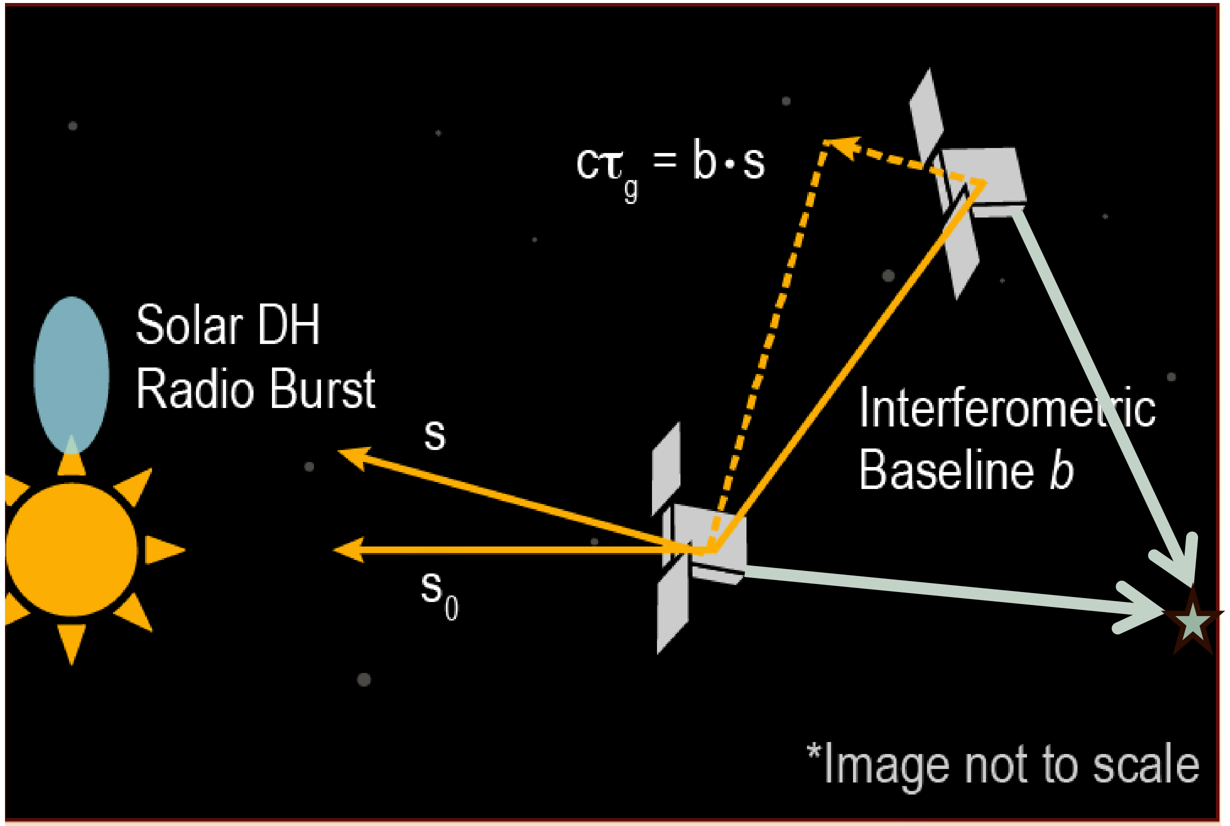
3-20 km spacecraft separations



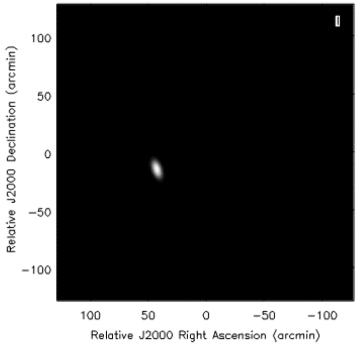


Interferometer for Imaging

SUNRISE
SUN RADIO INTERFEROMETER SPACE EXPERIMENT



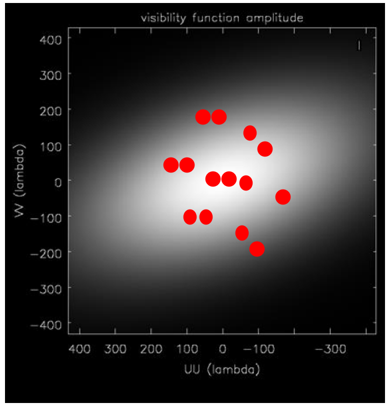
Basic Interferometric Element



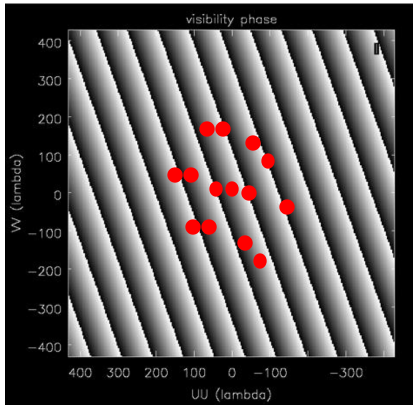
SunRISE combines visibilities from all uniqu baselines (15 for N=6)

Requires knowing position and time accurately (~1m, ~1ns)

Fourier transform



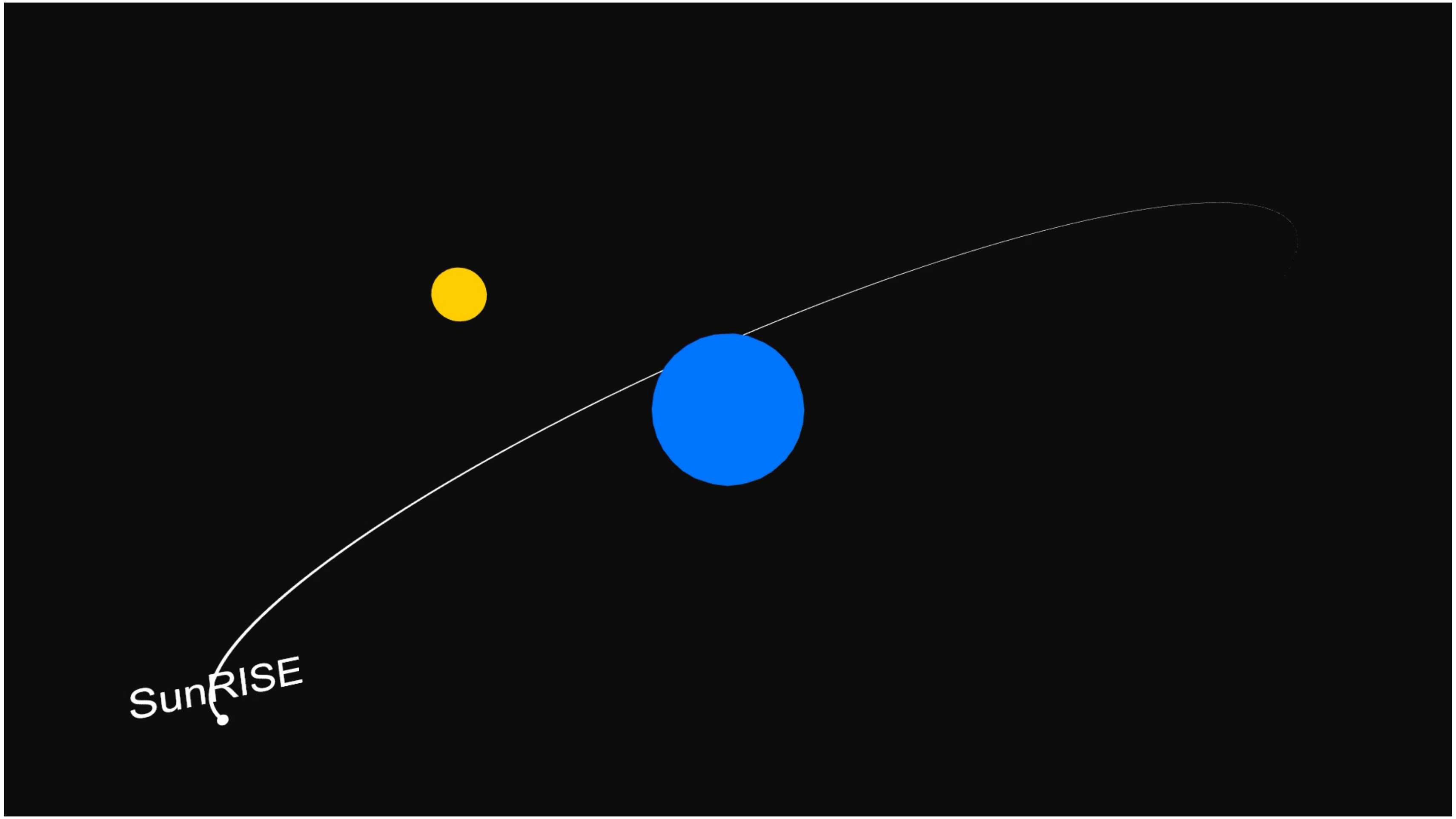
amplitude



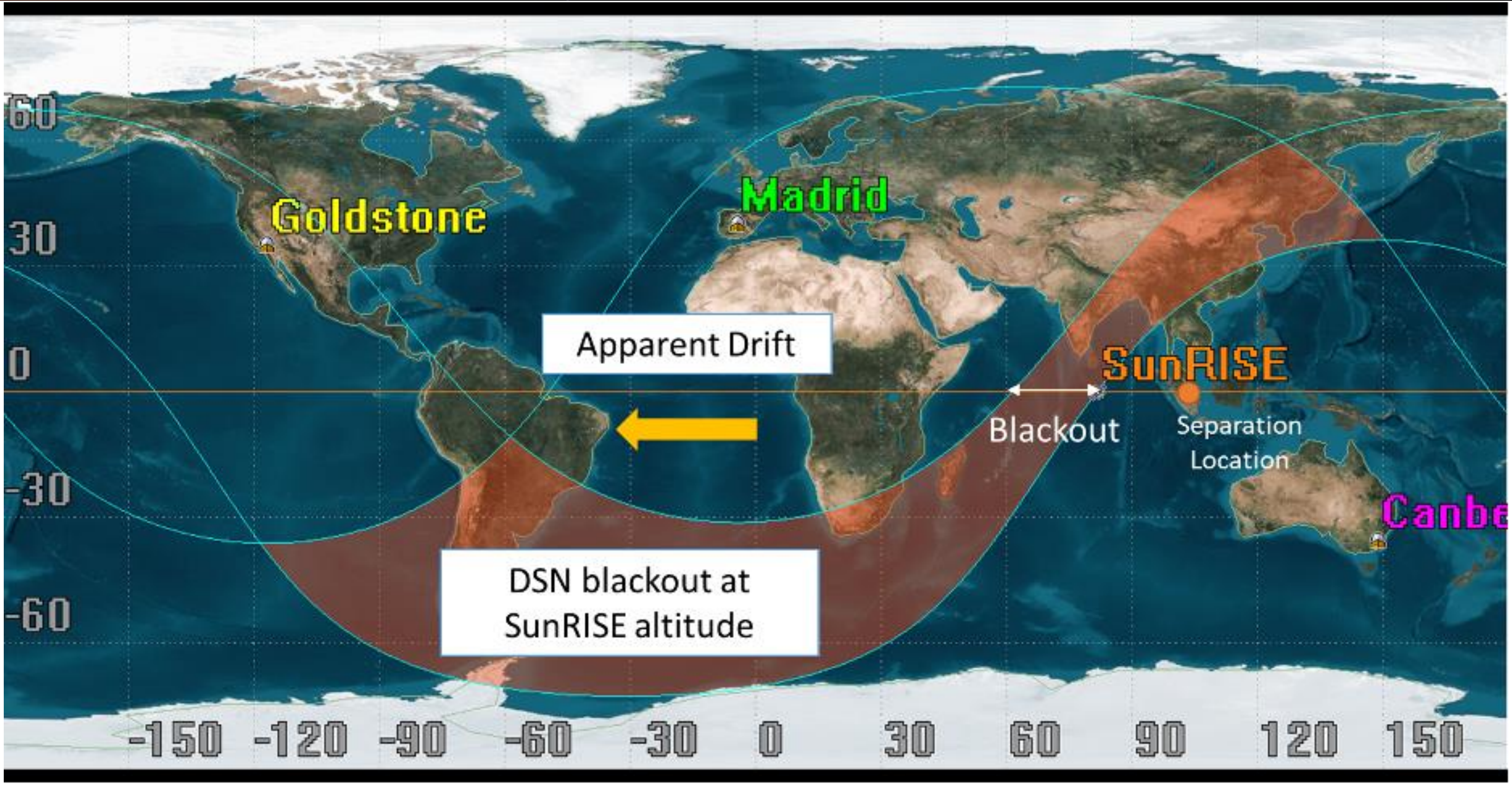
phase

Orbits and Baseline Coverage

- 6.5 km radius disk in the projected plane of the Sun
- SunRISE orbits are designed so that 2 orthogonal projected baseline lengths are >6.5 km.
- This enables the resolution needed.
- SunRISE is a digitally steerable radio telescope allowing for comparable resolution anywhere in the sky.



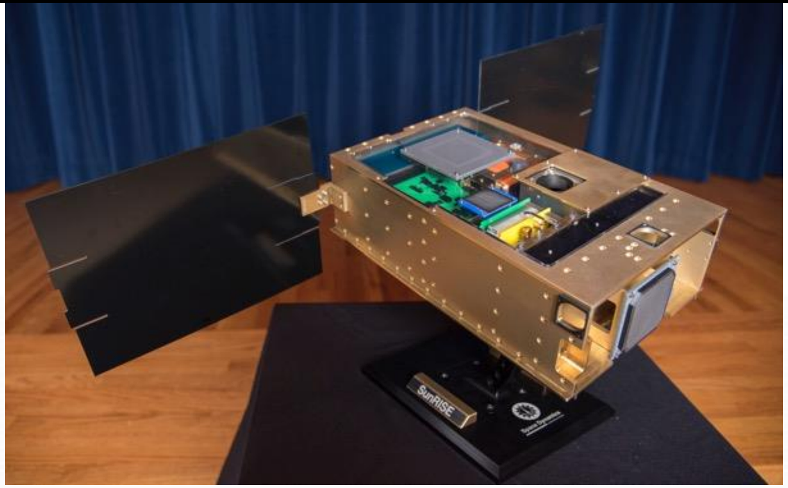
Ground Communications Coverage

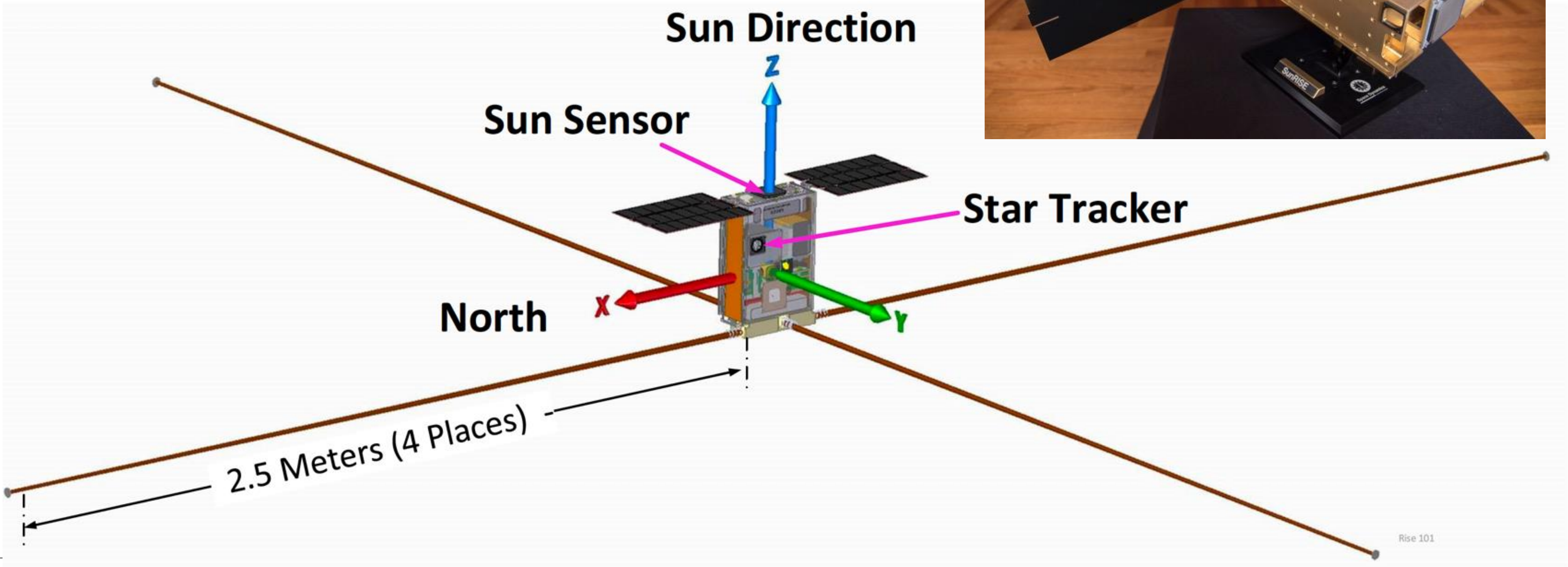


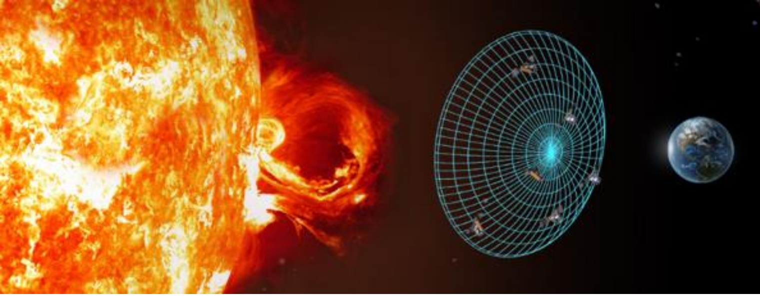
SunRISE Spacecraft

SUNRISE
SUN RADIO INTERFEROMETER SPACE EXPERIMENT

- Electrically short antenna for 0.1-25 MHz deca-hectometric (DH) receiver.
- Dual-polarized receiver.
- Integrated DH and GNSS receiver fits in 6U CubeSat form factor.



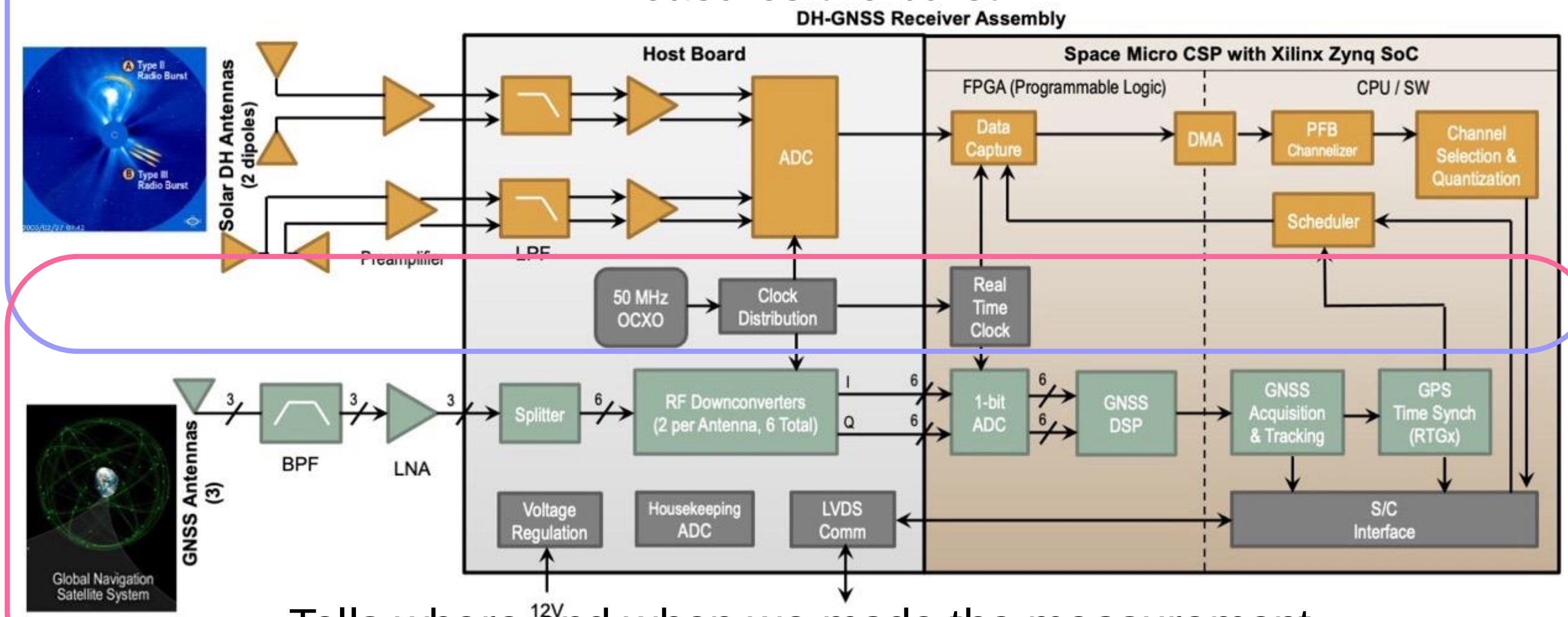




Science Payload

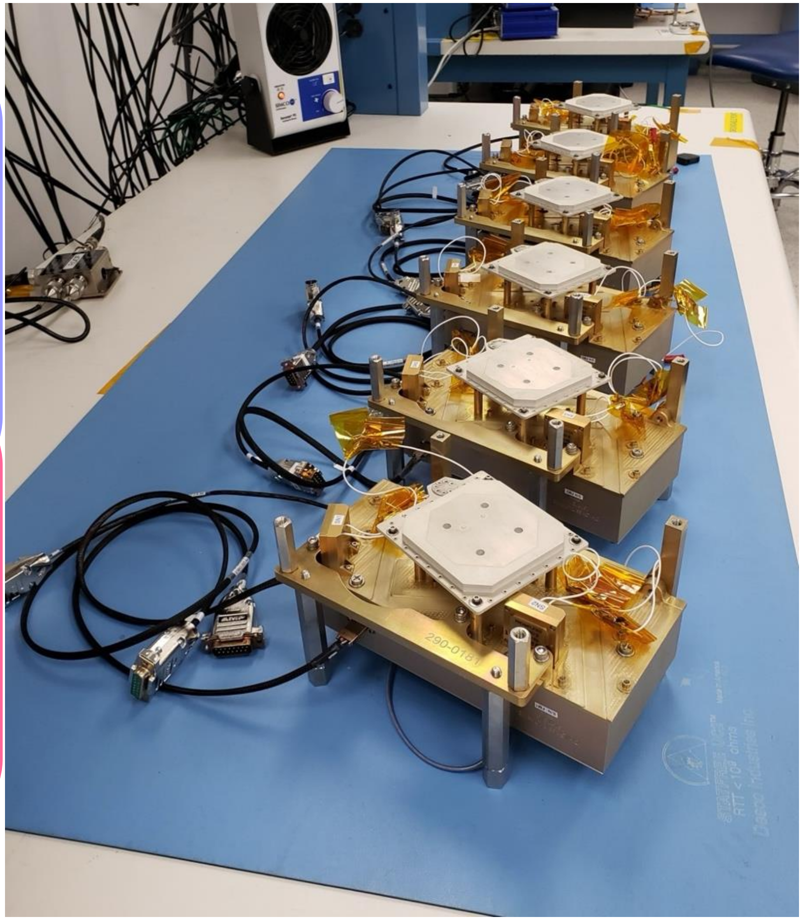
SUNRISE
SUN RADIO INTERFEROMETER SPACE EXPERIMENT

Measures the burst



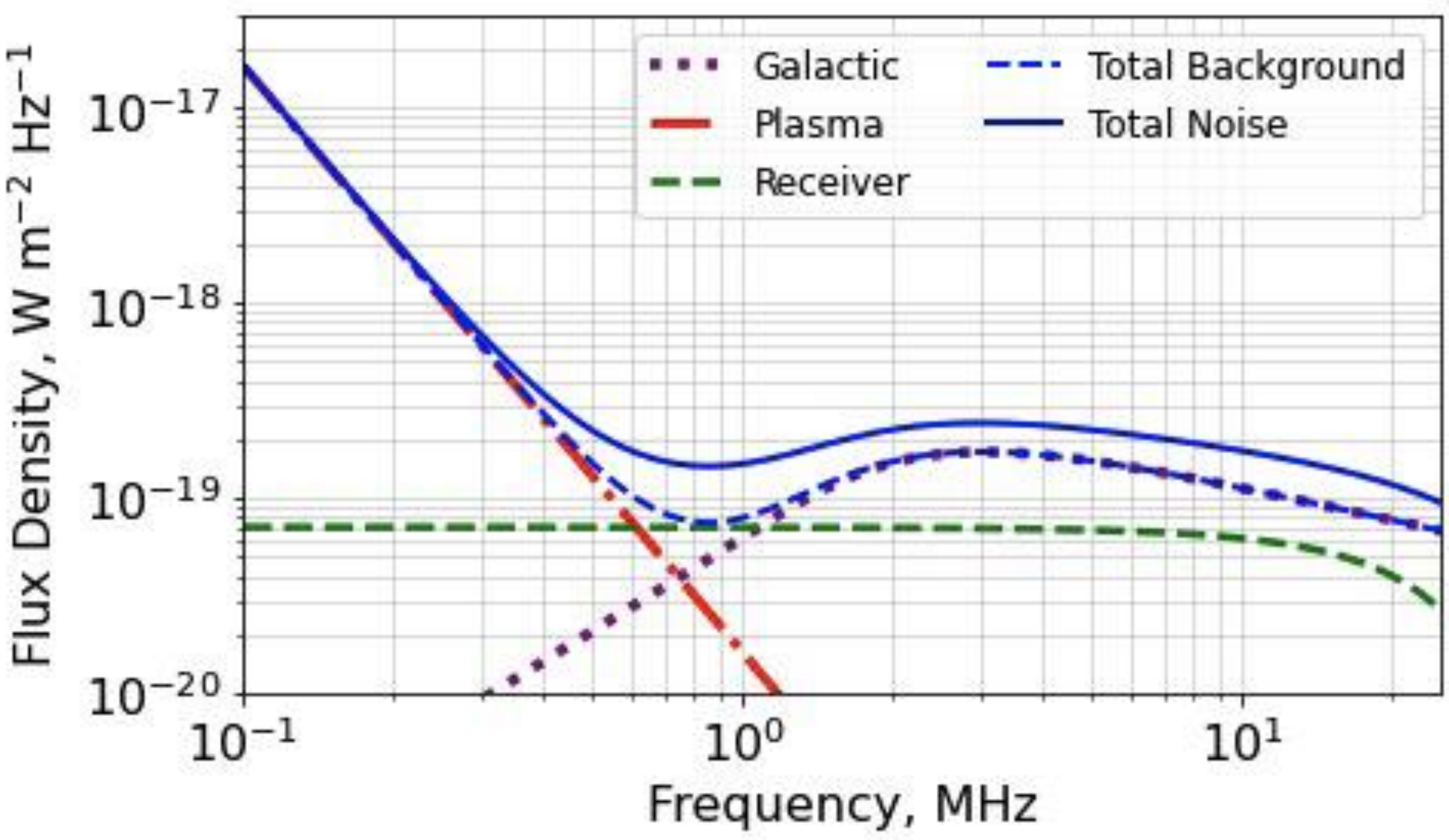
Tells where and when we made the measurement

Common clock for GNSS and DH measurements connects the measurement to a time and place

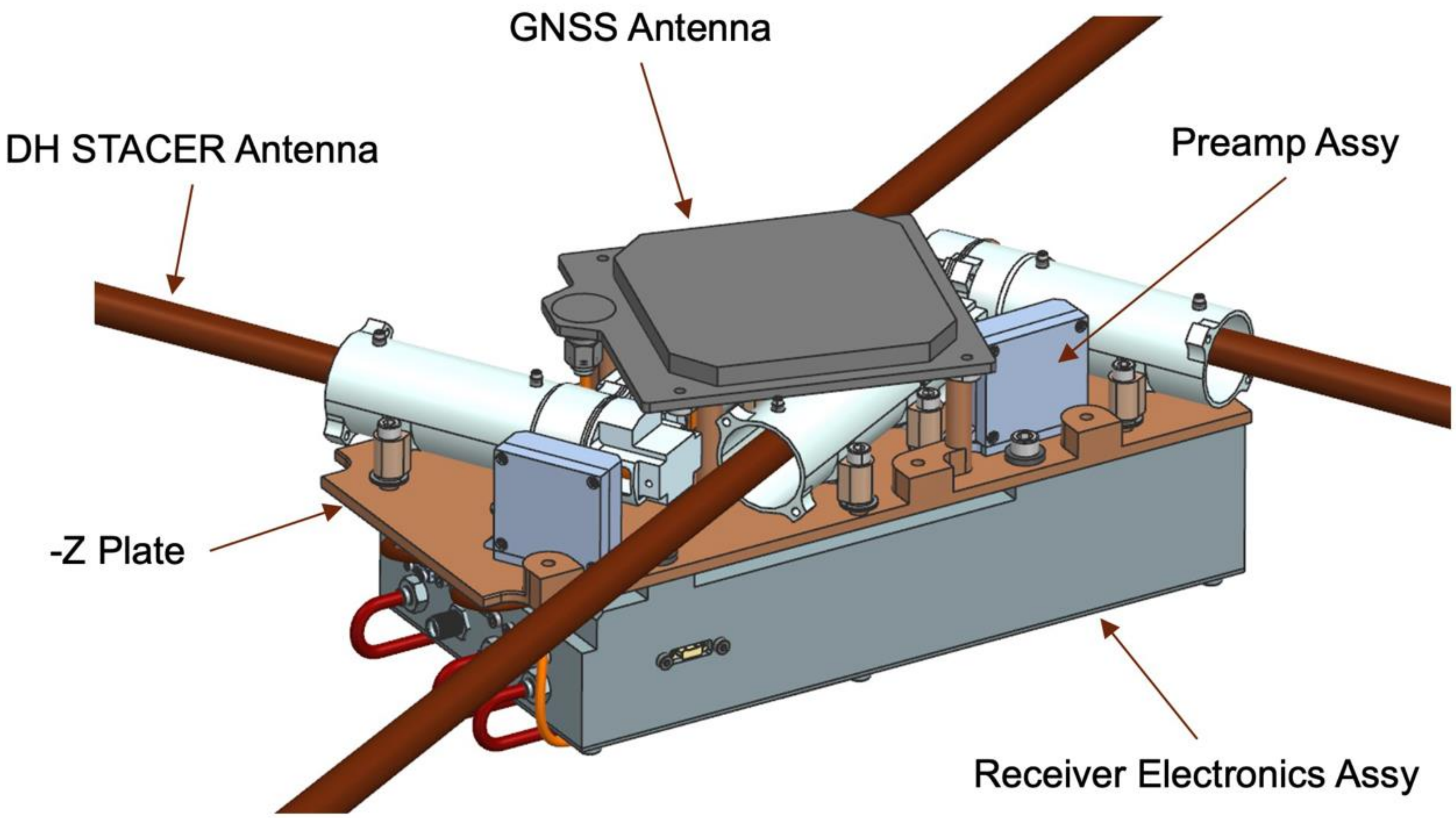


All six Payloads during Integration and Test (I&T)

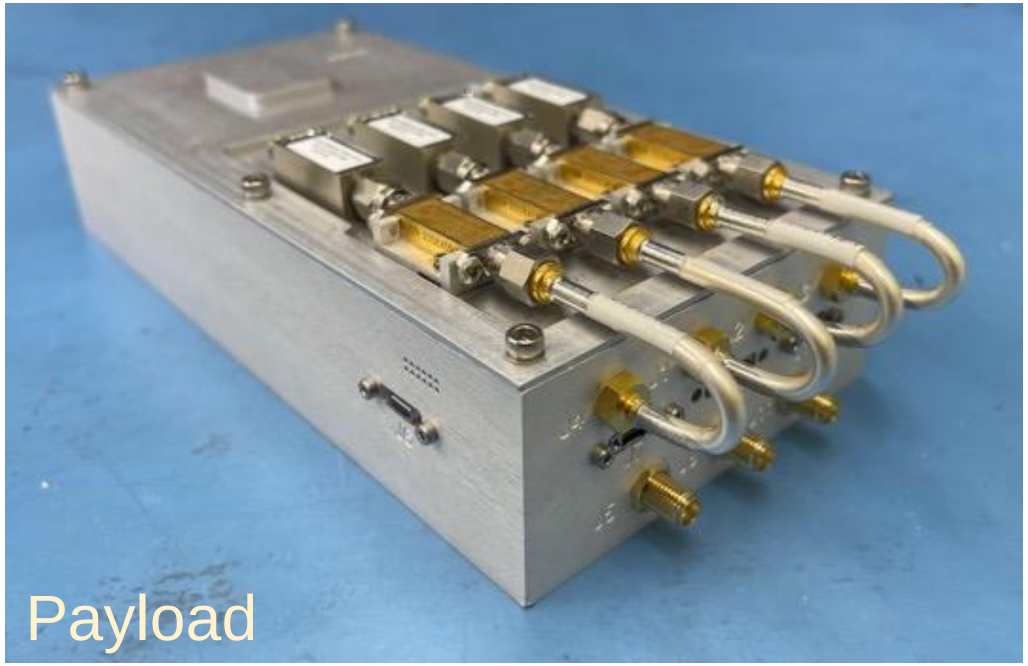
Payload Sensitivity

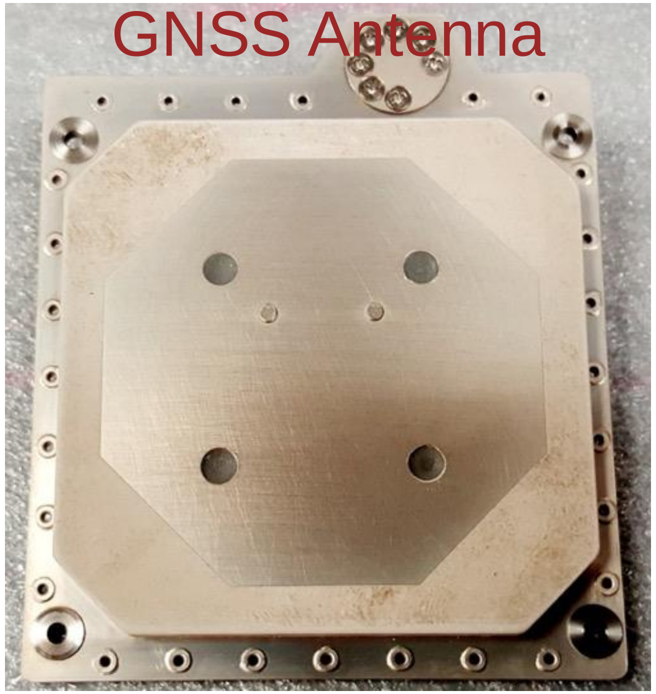


Payload

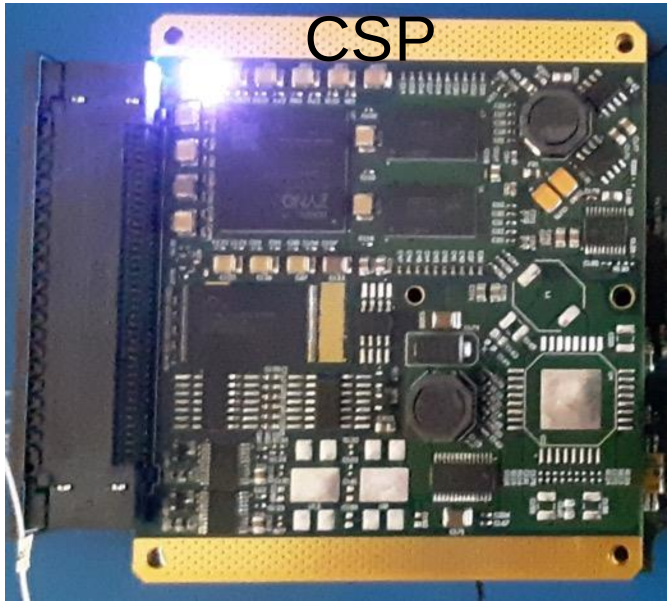

GNSS Antenna
DH STACER Antenna
Preamp Assy
-Z Plate
Receiver Electronics Assy

Payload Hardware



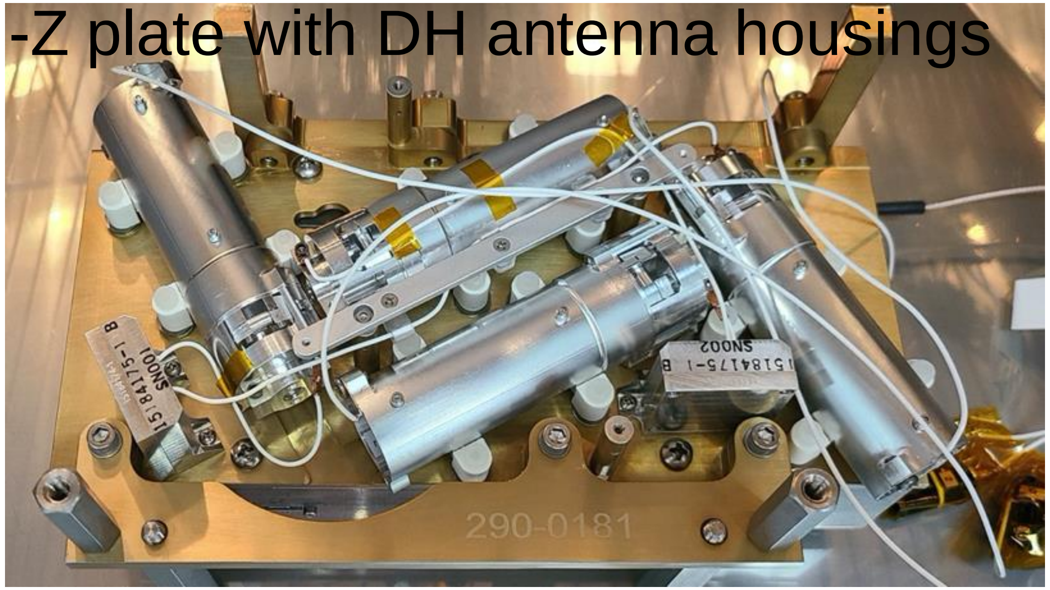


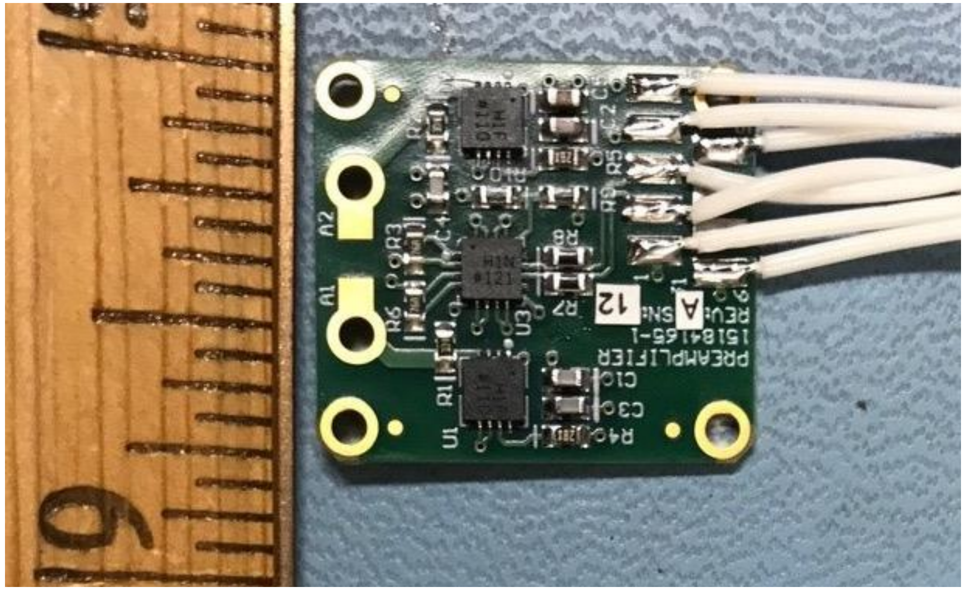
Payload Hardware

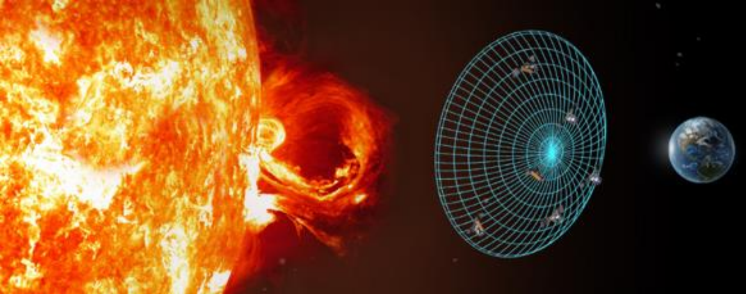


Payload Hardware

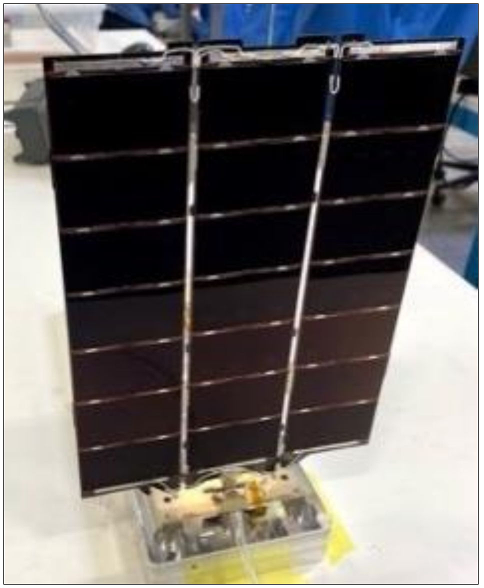
-Z plate with DH antenna housings







Flight System



Solar Panel (2x)

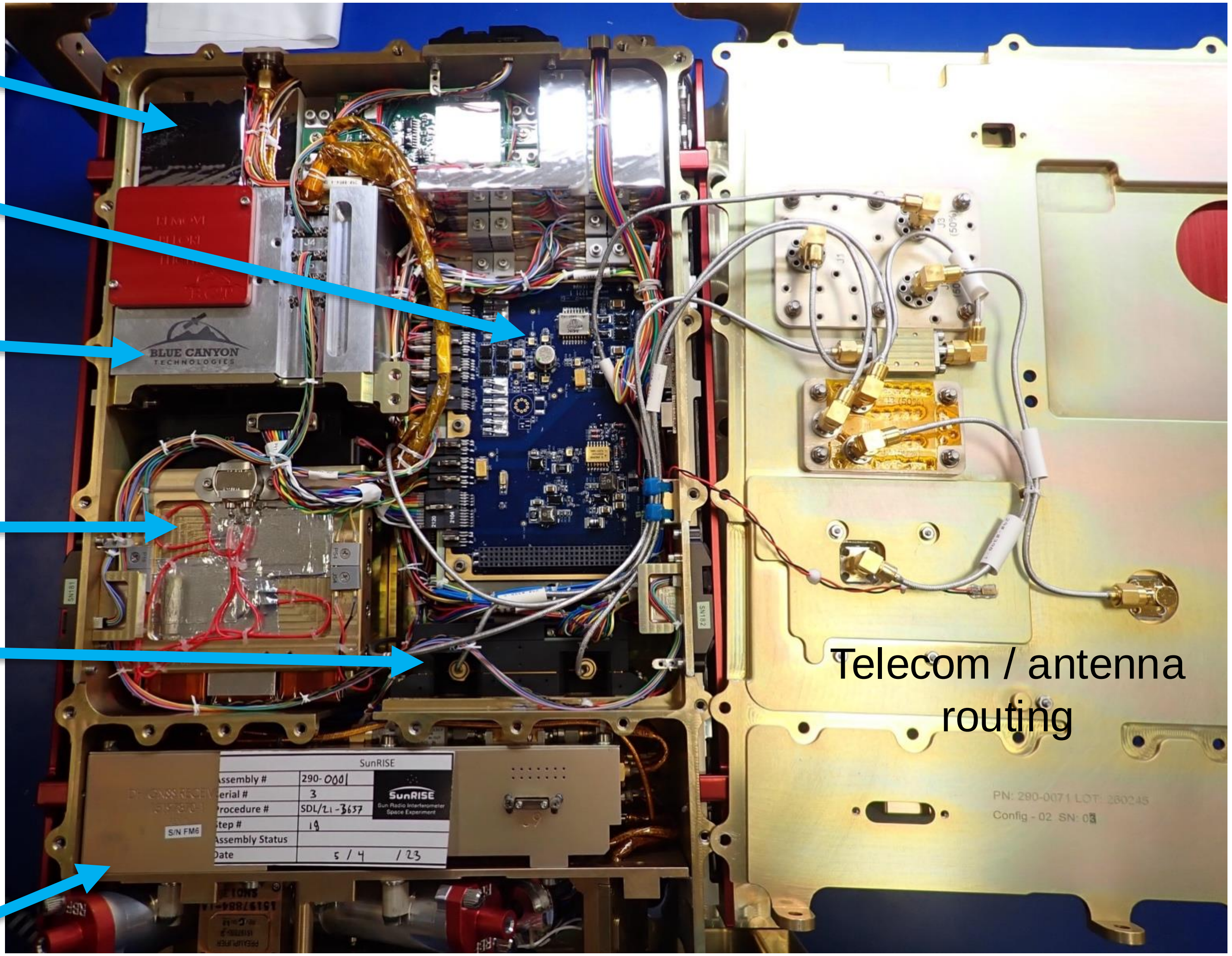
Propulsion

Avionics

Attitude Determination & Control

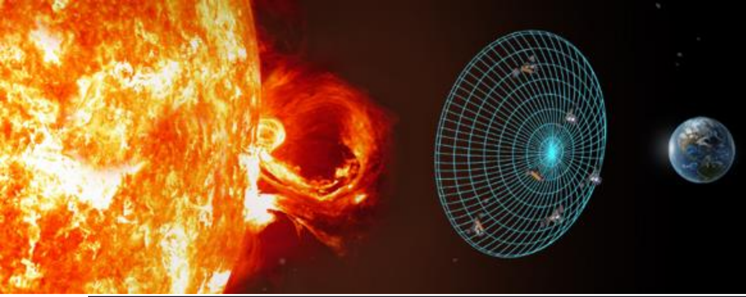
Battery Pack

Telecom Radio



Solar DH-GNSS Payload

About 12 kg in 6 liters is ~2g/cm^3
Compare Aluminum 2.7 g/cm^3
Like most cubesats, we run out of volume before we run out of mass
(Dispenser is max 14 kg allowable)



NASA’s 6-Pack of Mini-Satellites Ready for Their Moment in the Sun

SUNRISE
SUN RADIO INTERFEROMETER SPACE EXPERIMENT

Explore | Search... | NASA | News & Events | Multimedia | NASA+ LIVE

4 MIN READ

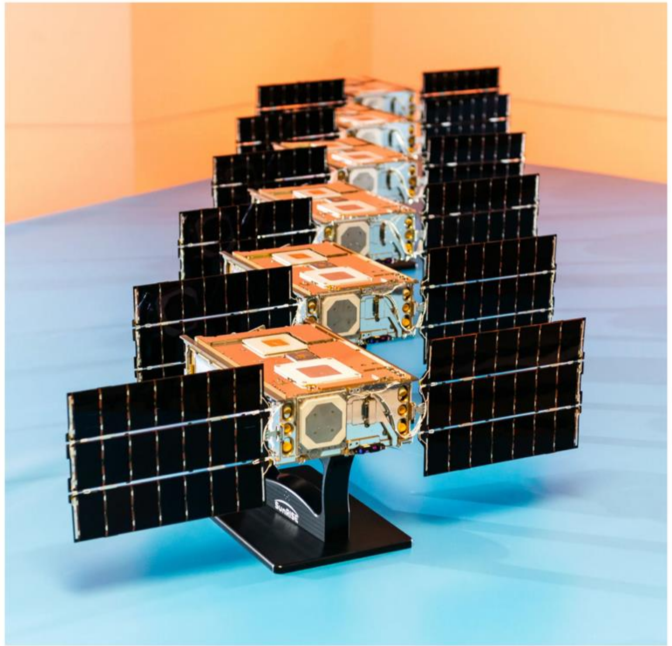
NASA’s 6-Pack of Mini-Satellites Ready for Their Moment in the Sun

Jet Propulsion Laboratory

NOV 30, 2023

ARTICLE

CONTENTS



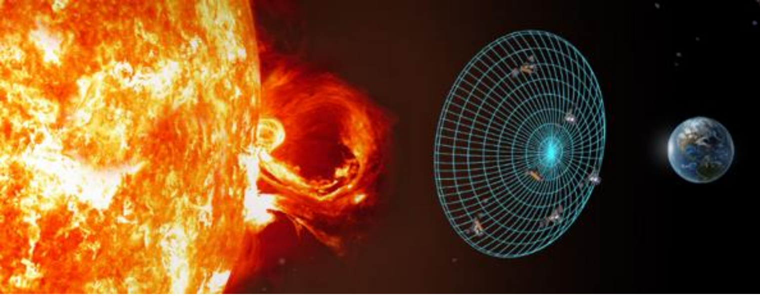
The six satellites that make up NASA’s SunRISE mission are each only about the size of a cereal box, flanked by small solar panels. This fleet of six SmallSats will work together to effectively create a much larger radio antenna in space.
Space Dynamics Laboratory/Allison Bills

Credit: SDL/Allison Bills

No, they do NOT fly this close together in space! 1km is a space! 1km is a “close approach”

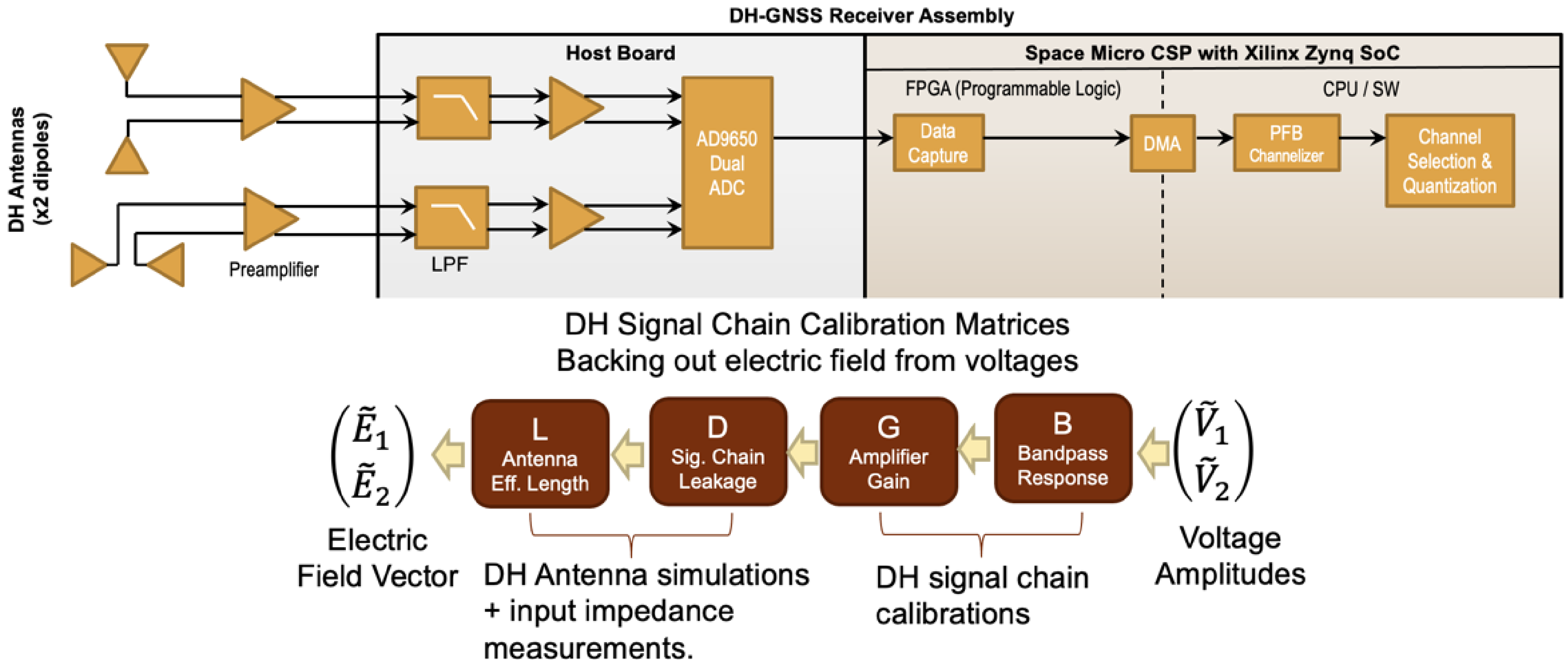
All the SVs snug in their storage

Launch No Earlier Than Sep 2024
More likely in mid-late 2025



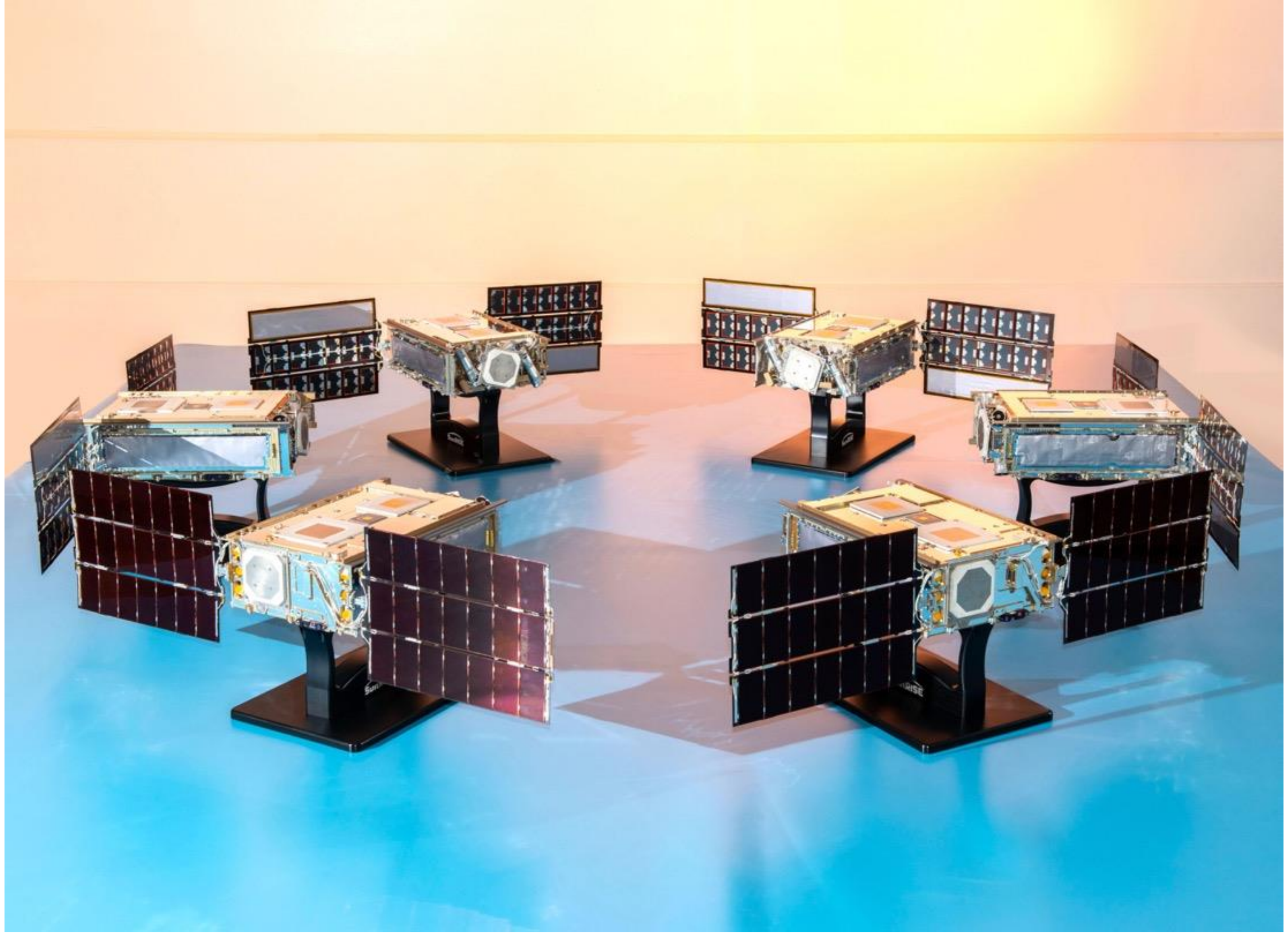
Measurements

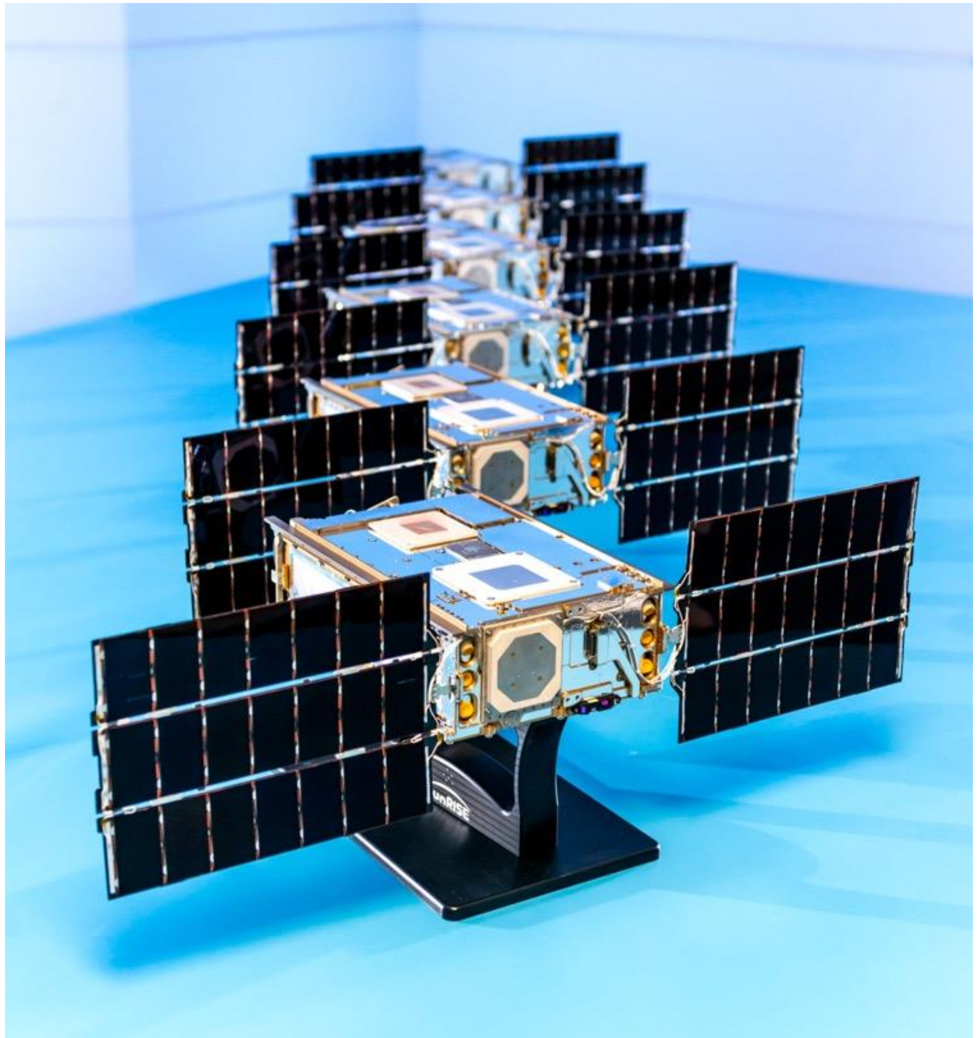
SUNRISE
SUN RADIO INTERFEROMETER SPACE EXPERIMENT

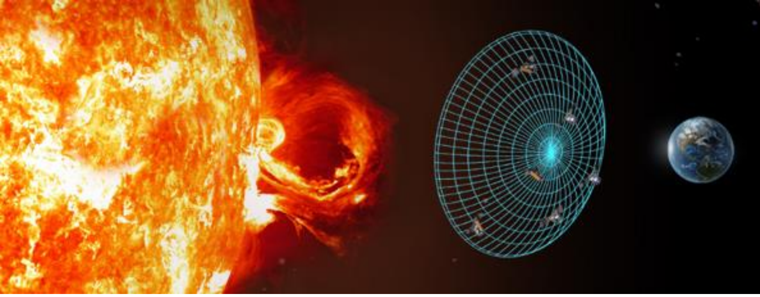


- DH signal chain acquires at a rate of 10 Hz with 6.1 kHz channels.
- End-to-end signal chain calibration for antenna effective length, signal chain leakage, gain, and bandpass.
- DH + GNSS data telemetered to ground for interferometric processing

SunRISE Ready to Go





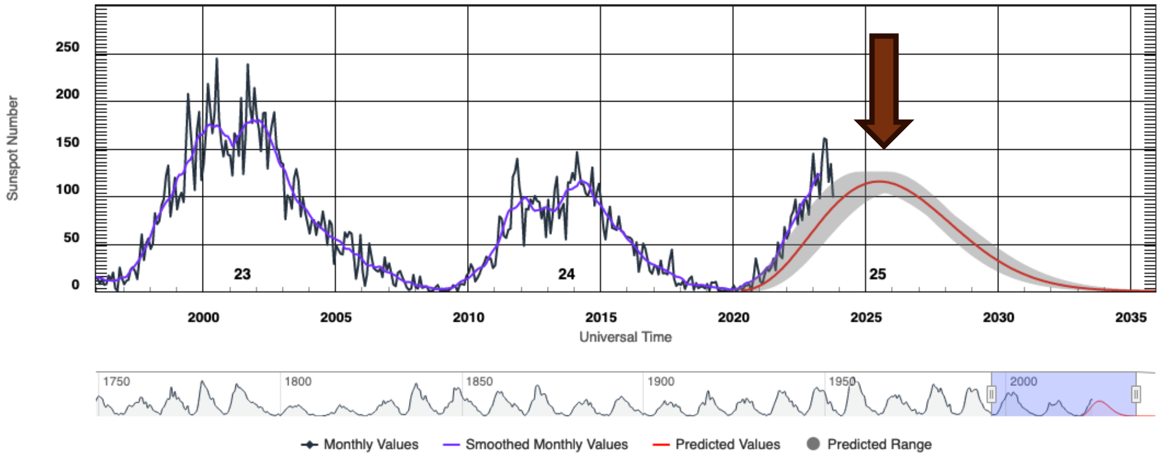


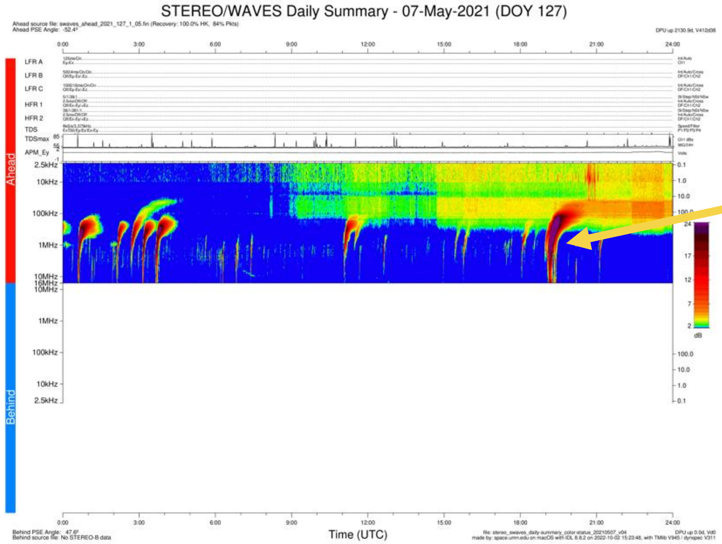
Solar Cycle 25
CME-Associated Type II Bursts

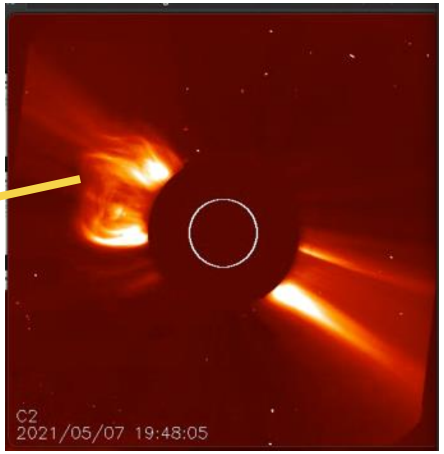
SUNRISE
SUN RADIO INTERFEROMETER SPACE EXPERIMENT

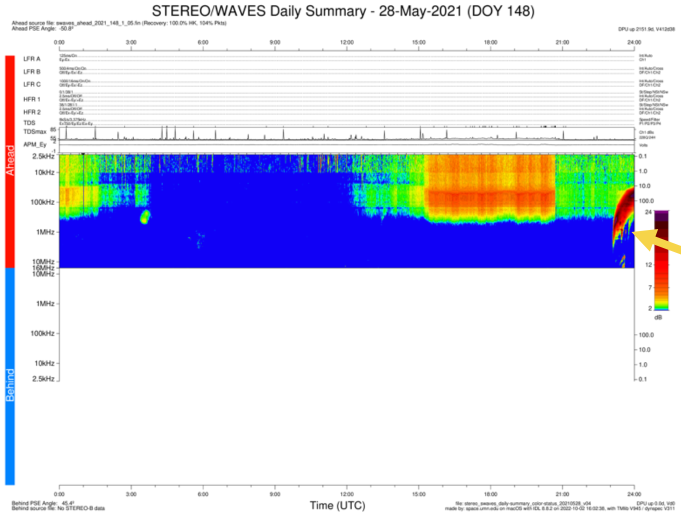
Launch is about here
And we operate for a year

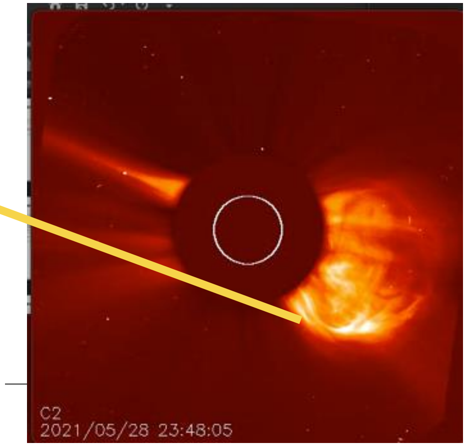
https://www.swpc.noaa.gov/products/solar-cycle-progression

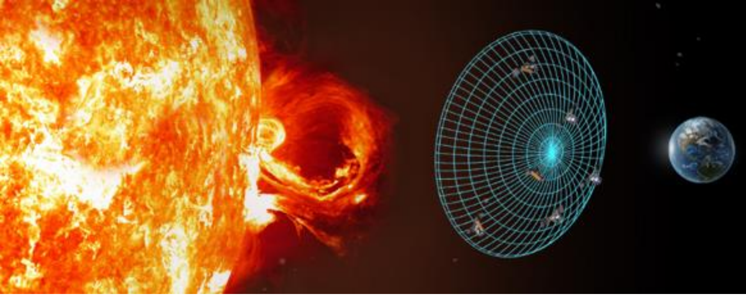






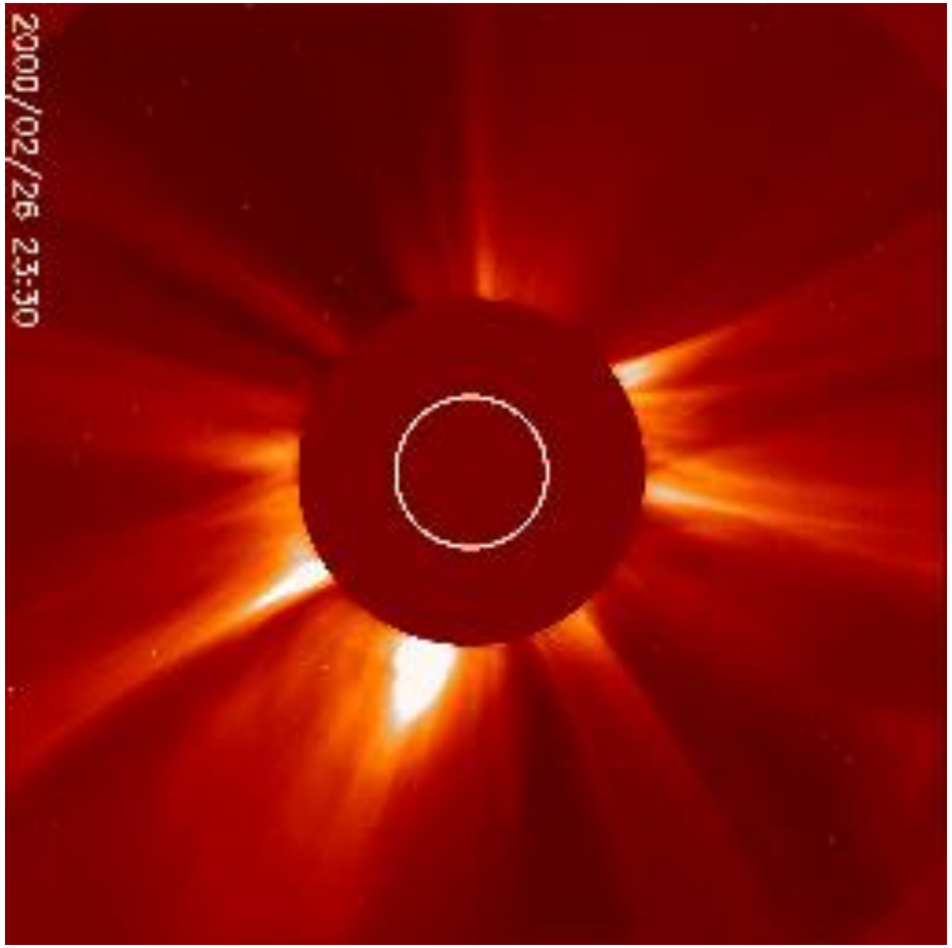


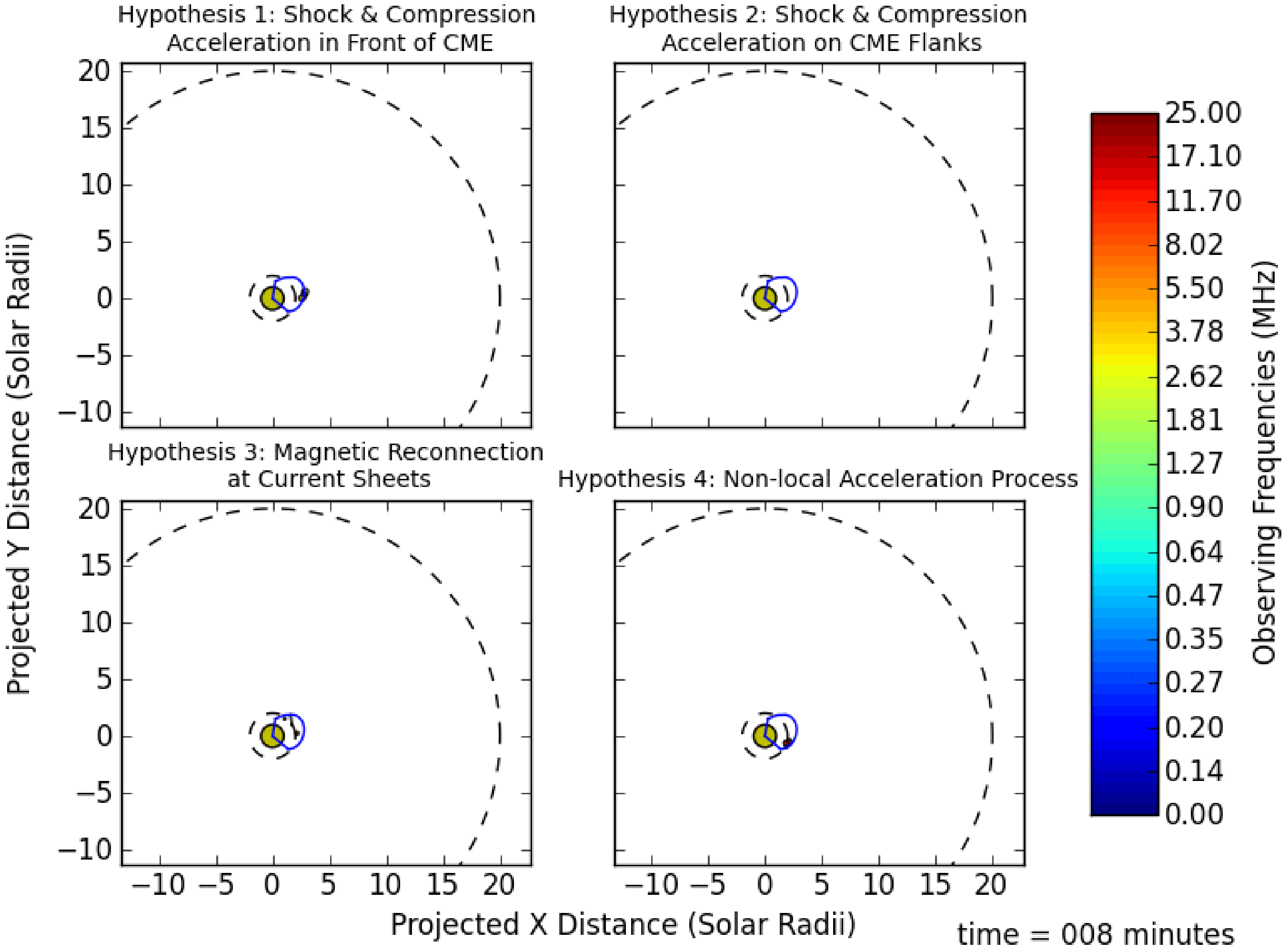




Determining the Particle Acceleration Sites of CMEs

SUNRISE
SUN RADIO INTERFEROMETER SPACE EXPERIMENT

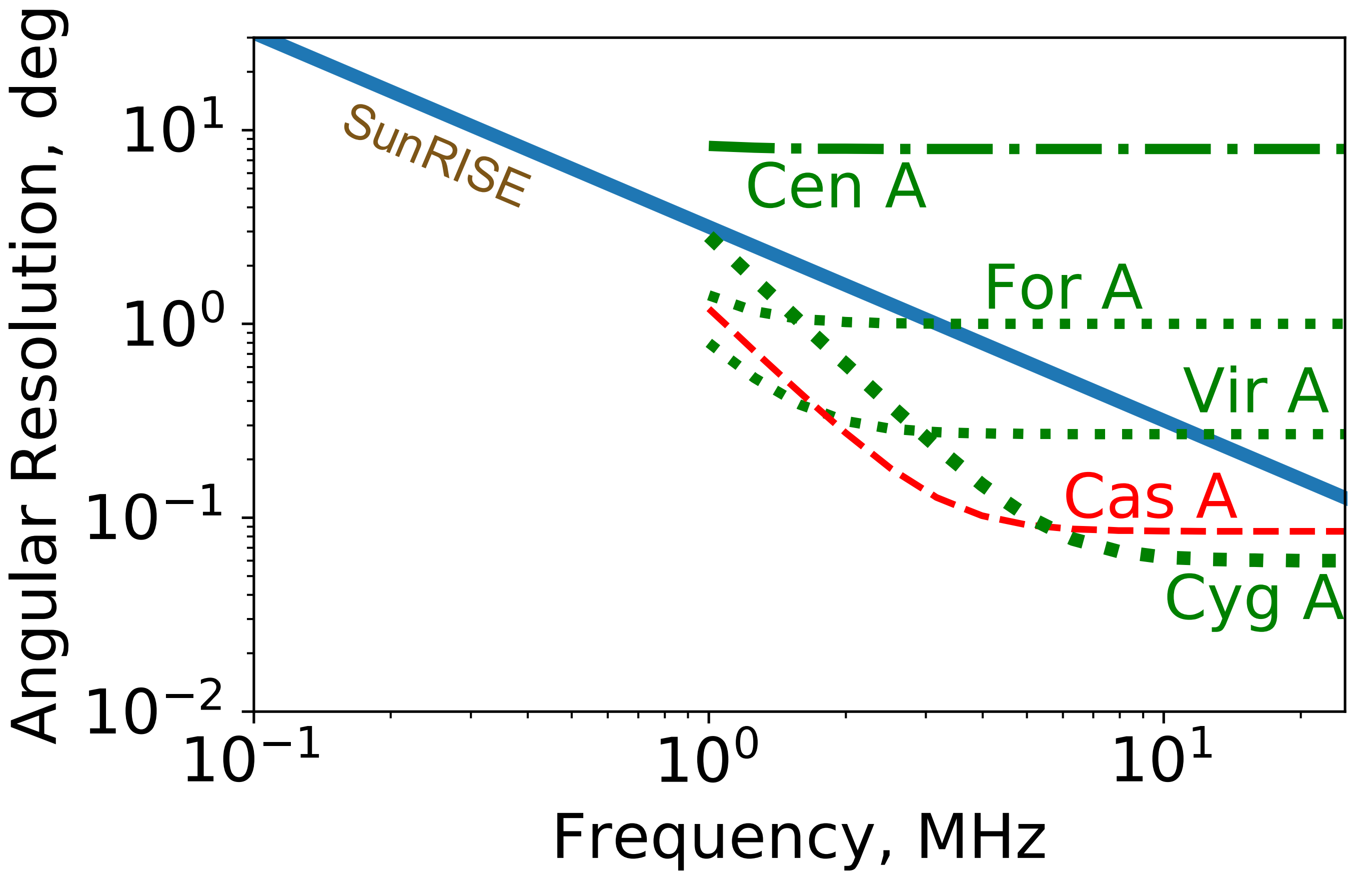




- SunRISE angular resolution tuned for localization of solar radio bursts.

- Examples of easily detectable sources are shown for comparison (there may be other sources as well)

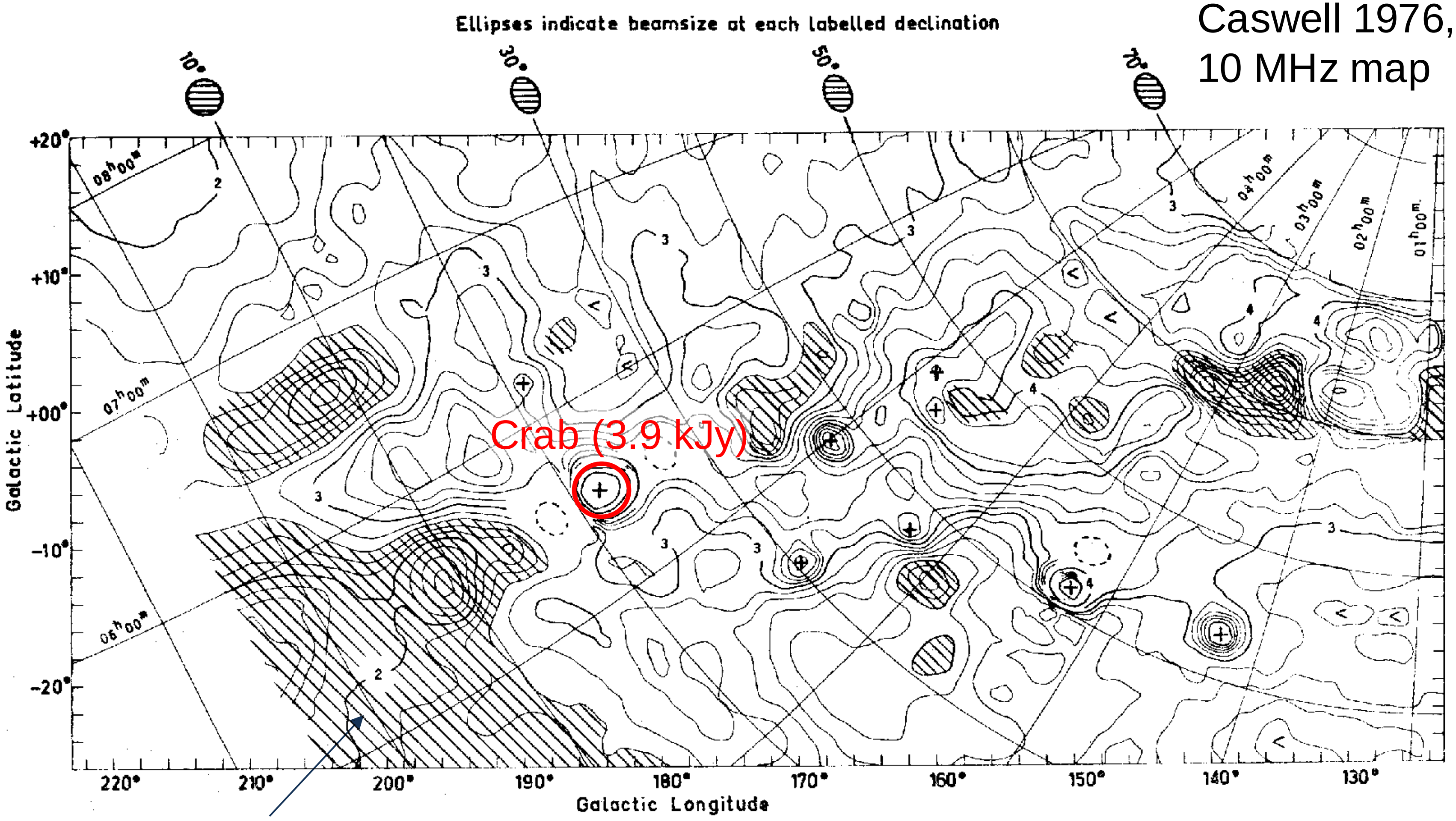
- Galactic free-free absorption becomes an issue for low Galactic latitude sources (e.g., Cas A and Cyg A) below about ~1 MHz.



All-Sky Maps

SunRISE could potentially produce all-sky maps with ~order of magnitude improvement in angular resolution from previous maps of Caswell 1976 (10 MHz) and Cane & Whitman 1976 (3.7 – 16.5 MHz).

Caswell 1976, 10 MHz map

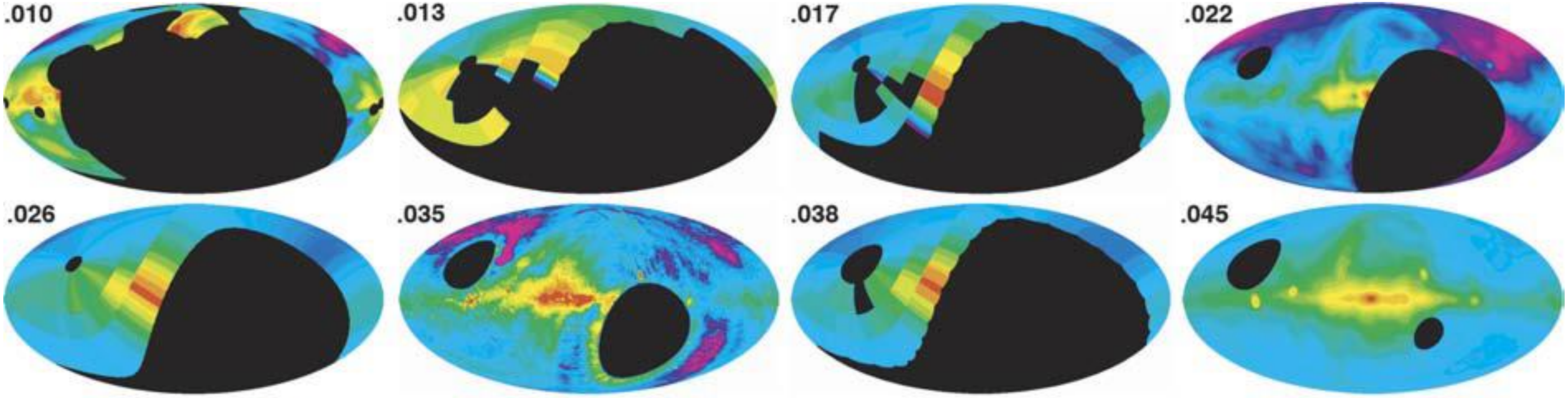


Hatched areas indicate absorption features corresponding to large-diameter H II regions. 20,000 K contours, contour labels in units of 100,000 K.

Low-Frequency Sky Maps (Ground-Based)

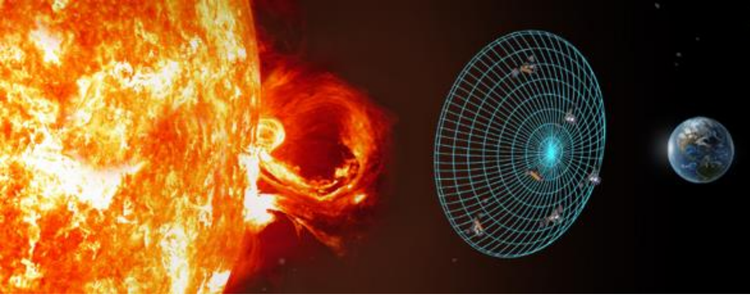
10 MHz

22 MHz



45 MHz

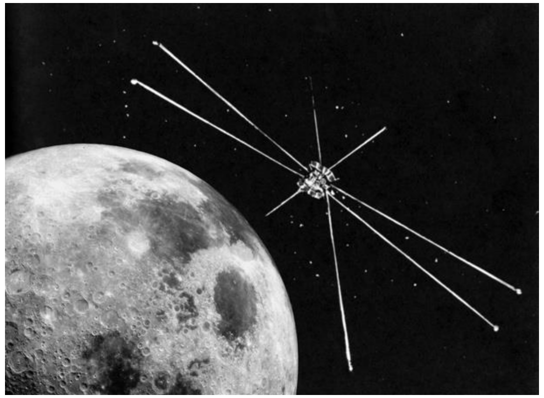
de Oliveira-Costa+ (2008)

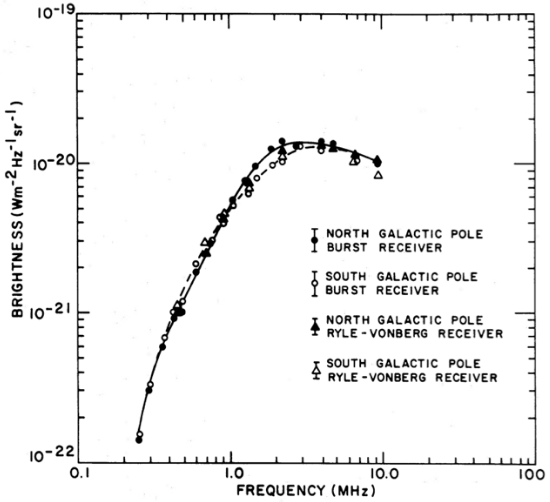


Low-Frequency Sky Maps (Space-Based)

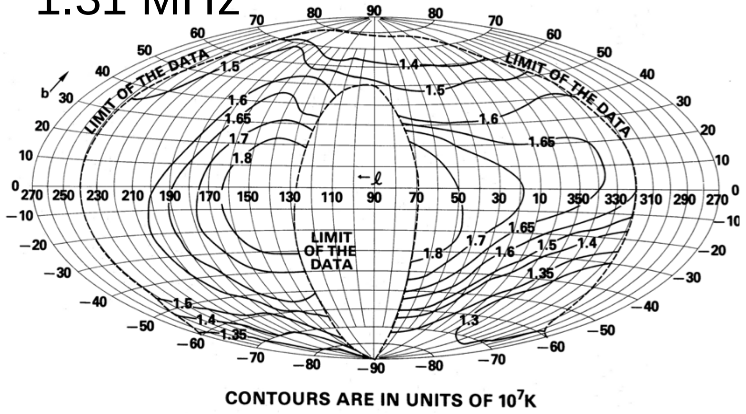
SUNRISE
SUN RADIO INTERFEROMETER SPACE EXPERIMENT

Radio Astronomy Explorer-2 Mission 1973-1977

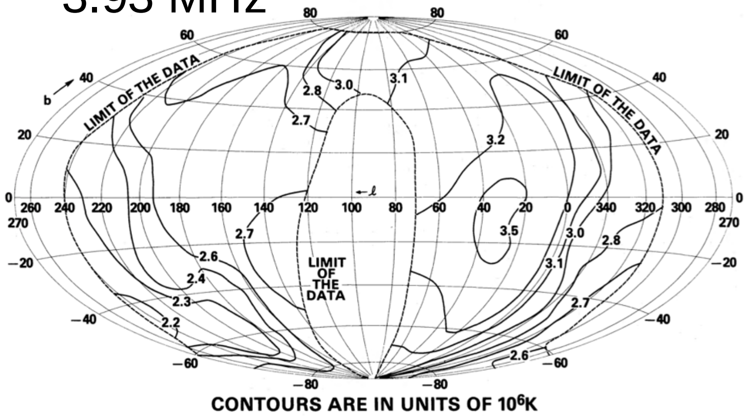




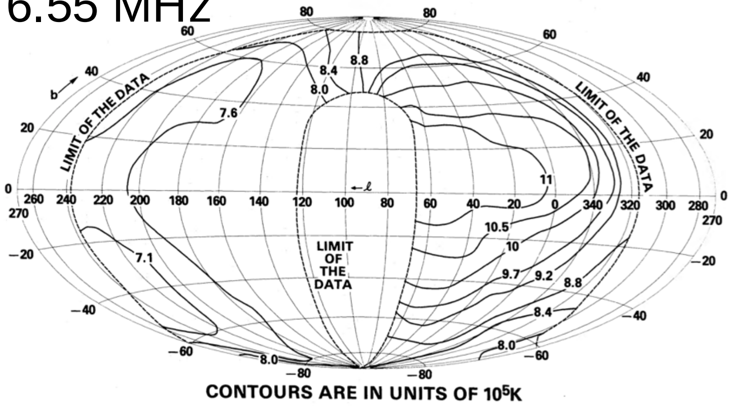
1.31 MHz



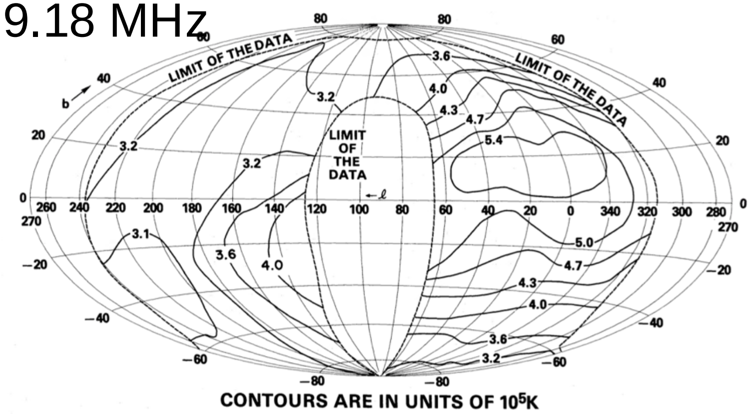
3.93 MHz



6.55 MHz



9.18 MHz

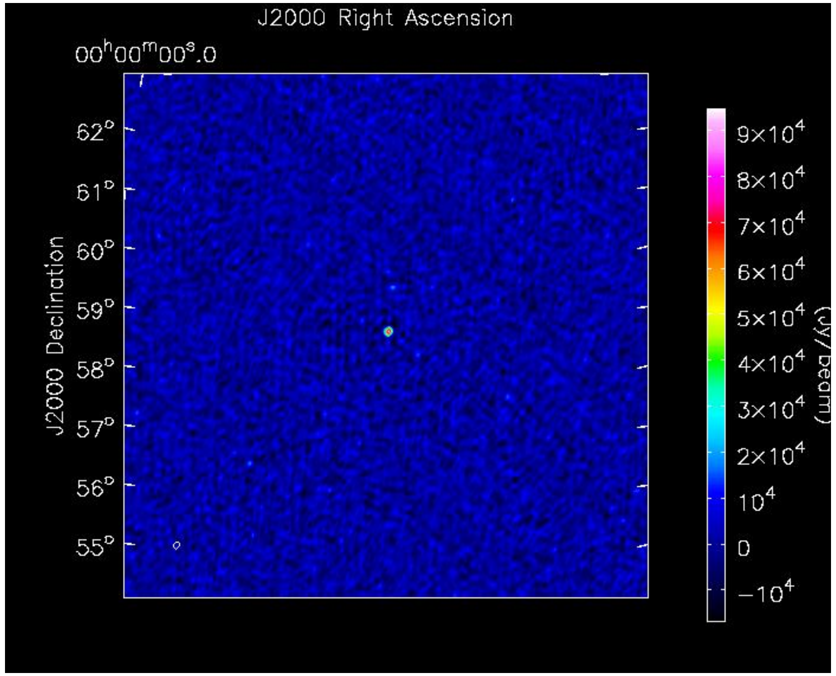


Novaco & Brown (1978)

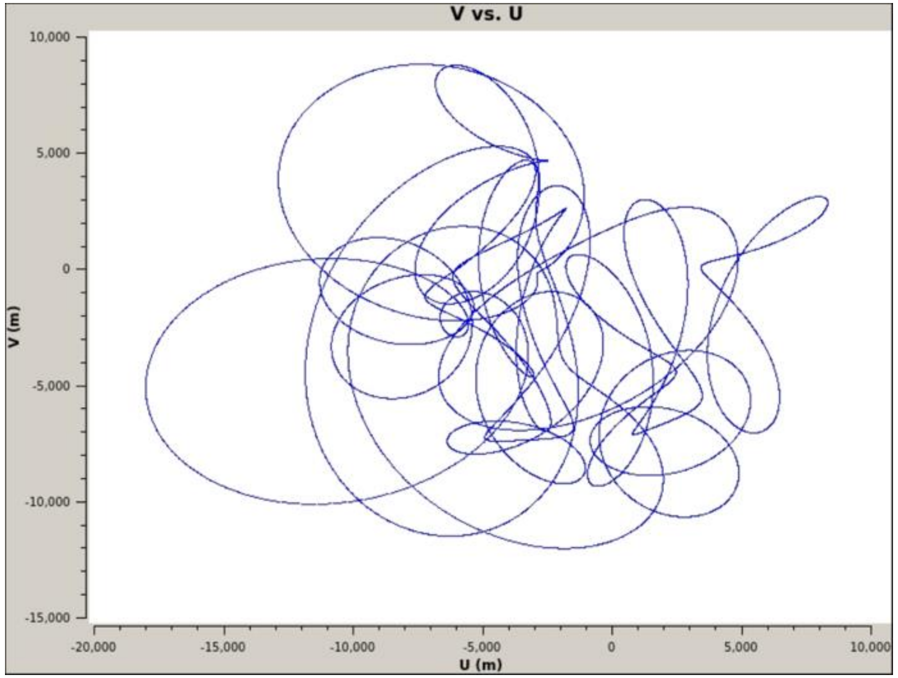
Spatial Resolution

UV plane coverage sufficient for imaging bright point-like sources.

Noisy Cas A Image (10 MHz)



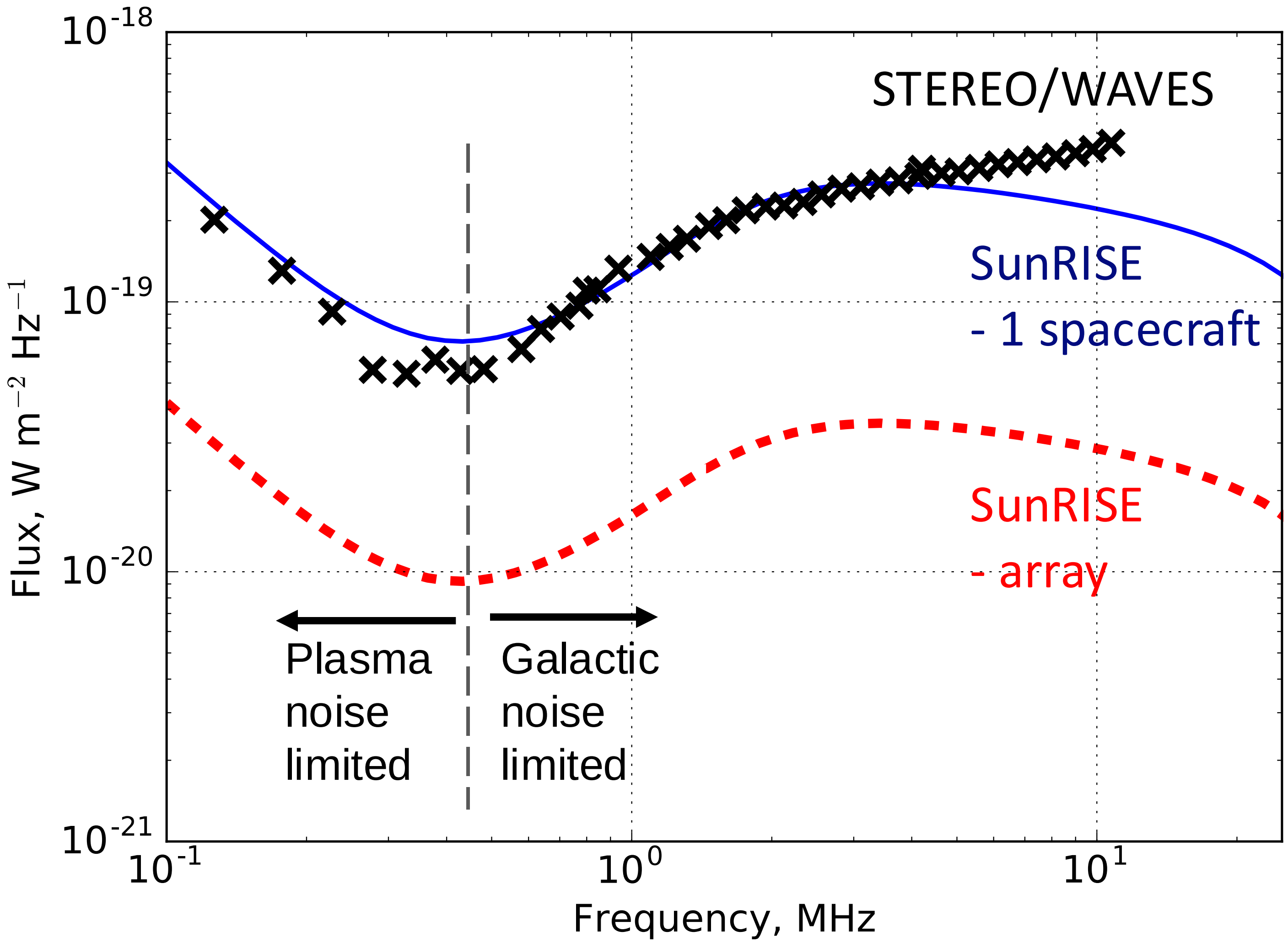
UV Coverage



Repeats every 25 days.

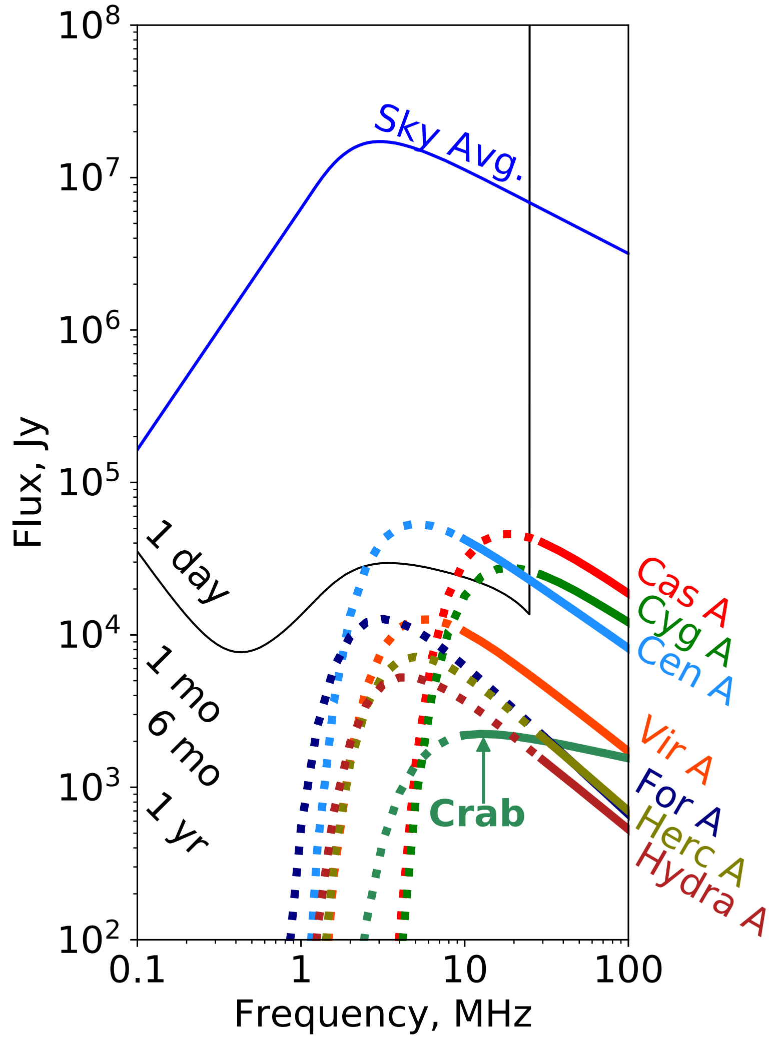
Sensitivity

- Each “snapshot” (0.66 ms integration time, 6.1 kHz bandwidth) is background noise limited.
- SunRISE sensitivity is comparable to Wind/WAVES and the STEREO/WAVES receivers.
- Array: 6 spacecraft, 2 polarizations improves the sensitivity by a factor of 8.5.



Sensitivity

- SunRISE integrated sensitivity would be capable of imaging the A-team sources at frequencies below the ionospheric cutoff.
- Cas A and Cyg A expected to be absorbed at frequencies <10 MHz due to low Galactic latitudes.

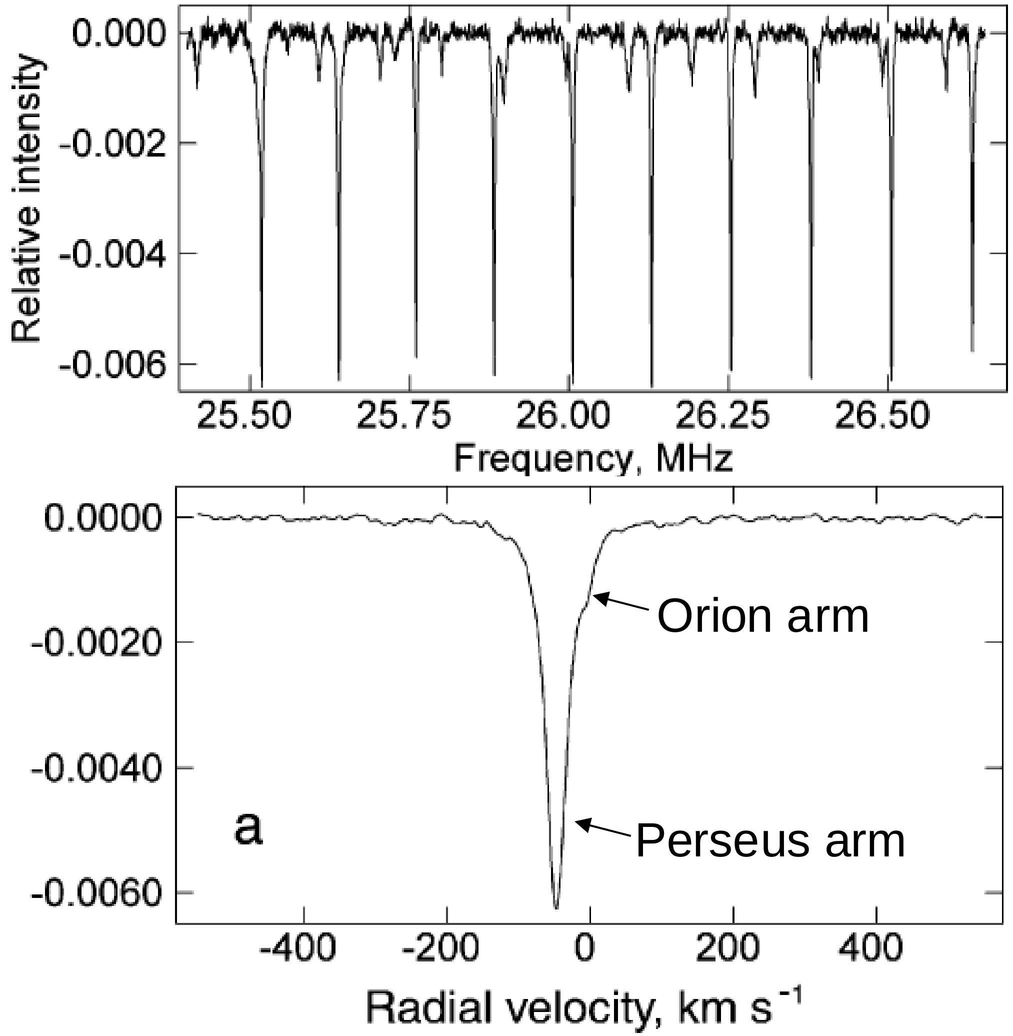


Radio Recombination Lines

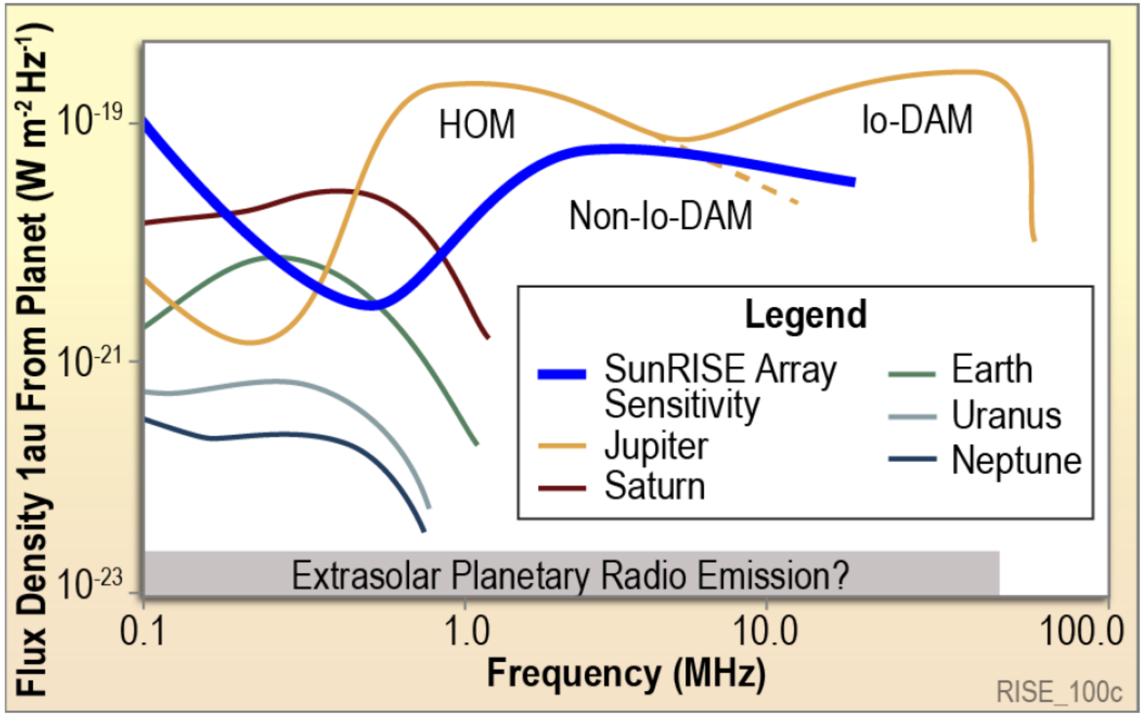
SUNRISE
SUN RADIO INTERFEROMETER SPACE EXPERIMENT

- SunRISE would search for radio recombination lines at frequencies below 25 MHz.

- Using Cas A as an illumination source and stacking the comb structure of radio recombination lines could enable a 5 σ detection of line depths of $\gtrsim$ 2.5×10^{-3} or greater.



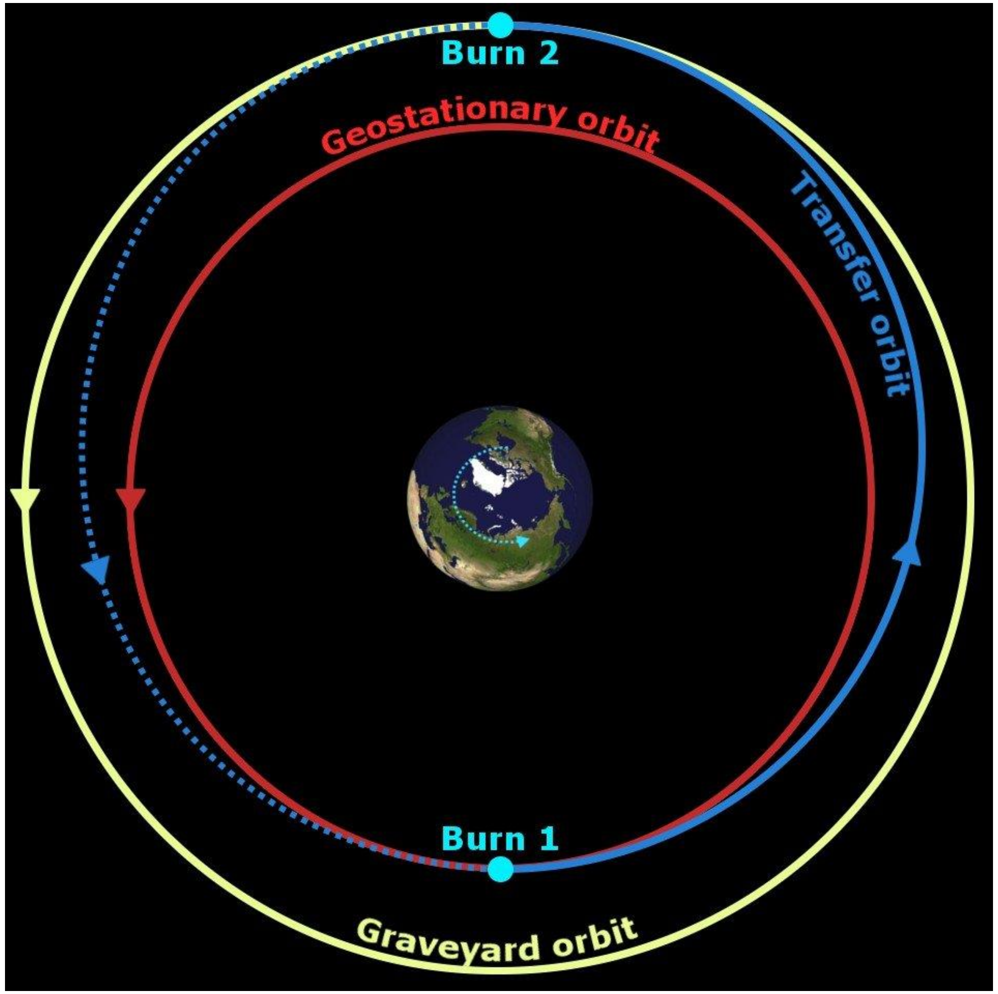
Planetary Science

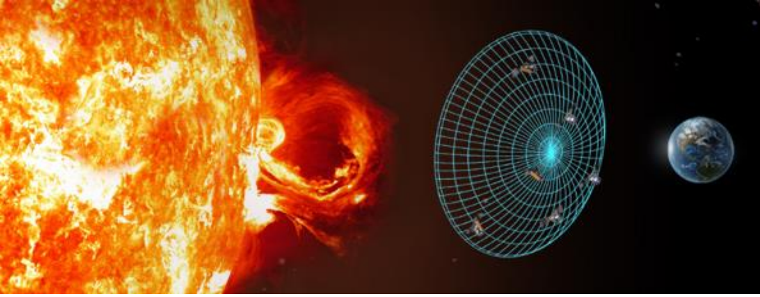


- Typical planetary radio emission seen from 1 au distance compared to SunRISE sensitivity in 1 second, 1 Hz measurement. Ten minute, 2 MHz integrations would be up to10,000x more sensitive
- Jupiter should be detectable most of the time
- Saturn, Uranus, and Neptune are a stretch but would be very exciting if detected

Observing with Ground-Based Radio Telescopes

- SunRISE is in a ~37,000 km altitude Supersynchronous orbit (a.k.a. GEO graveyard orbit).
- 25 hour period means SunRISE shifts 0.6° / hour with respect to a point on the ground.
- Potential for synchronized observations with ground based telescopes.
- Data type is an amplitude and phase with 6.1 kHz bandwidth acquired every 100 ms.





Summary

- SunRISE is in a ~37,000 km altitude Supersynchronous orbit (a.k.a. GEO graveyard orbit).
- 25 hour period means SunRISE shifts 0.6° / hour with respect to a point on the ground.
- Potential for synchronized observations with ground based telescopes.
- Data type is an amplitude and phase with 6.1 kHz bandwidth acquired every 100 ms.

SunRISE

SUN RADIO INTERFEROMETER SPACE EXPERIMENT