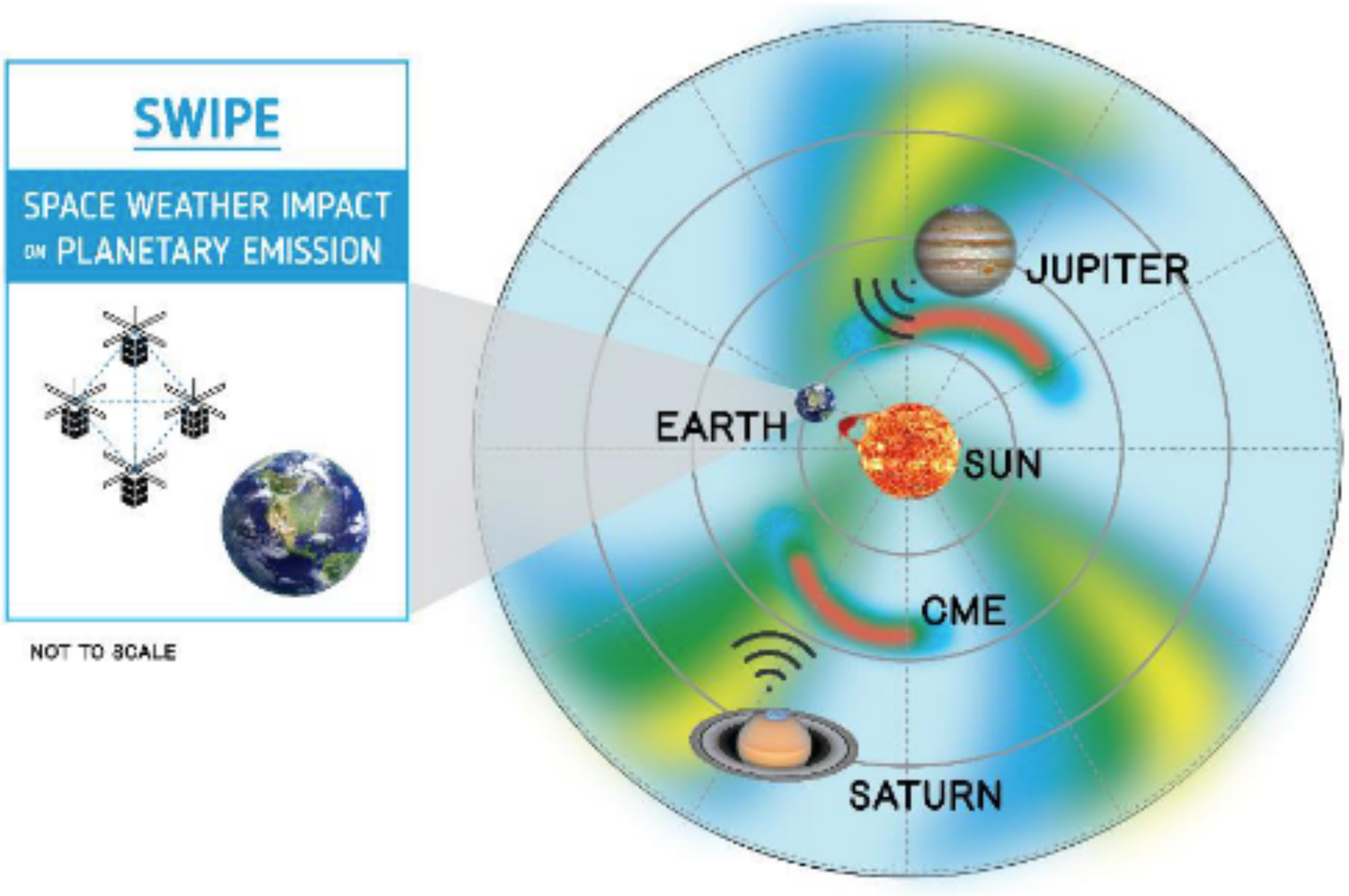
Space Weather Impacts on Planetary Emissions (SWIPE): an observatory for Solar System radio aurorae



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PRE X
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Why build a remote monitor for planetary radio emission?

Motivation:

- We do not have radio instrumentation at all of the solar system planets all the time – **there are gaps in observations** (Saturn today)
- We **lack a consistent data set** of planetary auroral emission - same instrument, same viewing geometry
- We wish to study space weather impacts on planets within the solar system where comparison with in-situ measurements is possible – ***solar system planets as exoplanets***

Enablers:

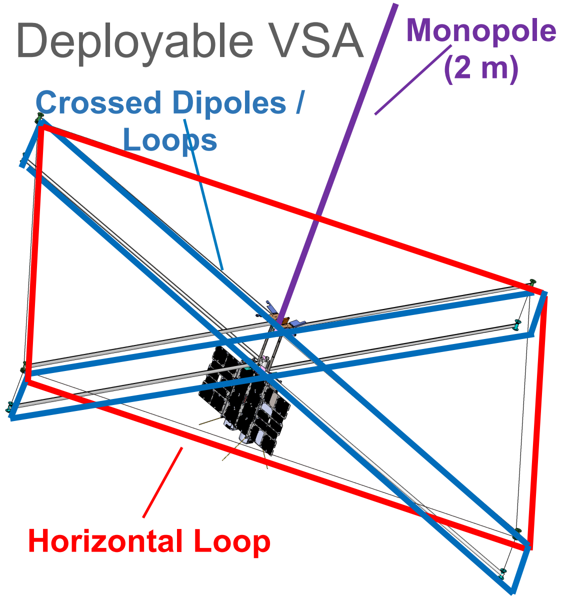
- CubeSats/smallsats – mature bus and component market
- Frequent, low cost secondary payload launches
- Maturing lasercom technology for returning high data volumes
- Vector sensor antennas

Vector sensor: a better broadband low frequency antenna

What is a vector sensor?

- 3 dipole antennas
- 3 loop antennas
- Electrically small → broadband
- Full polarization information
- Direction of arrival in single snapshot
- Originally developed for ground-based signal-finding
- Adapted for space-based all-sky imaging (see Knapp et al. 2016)

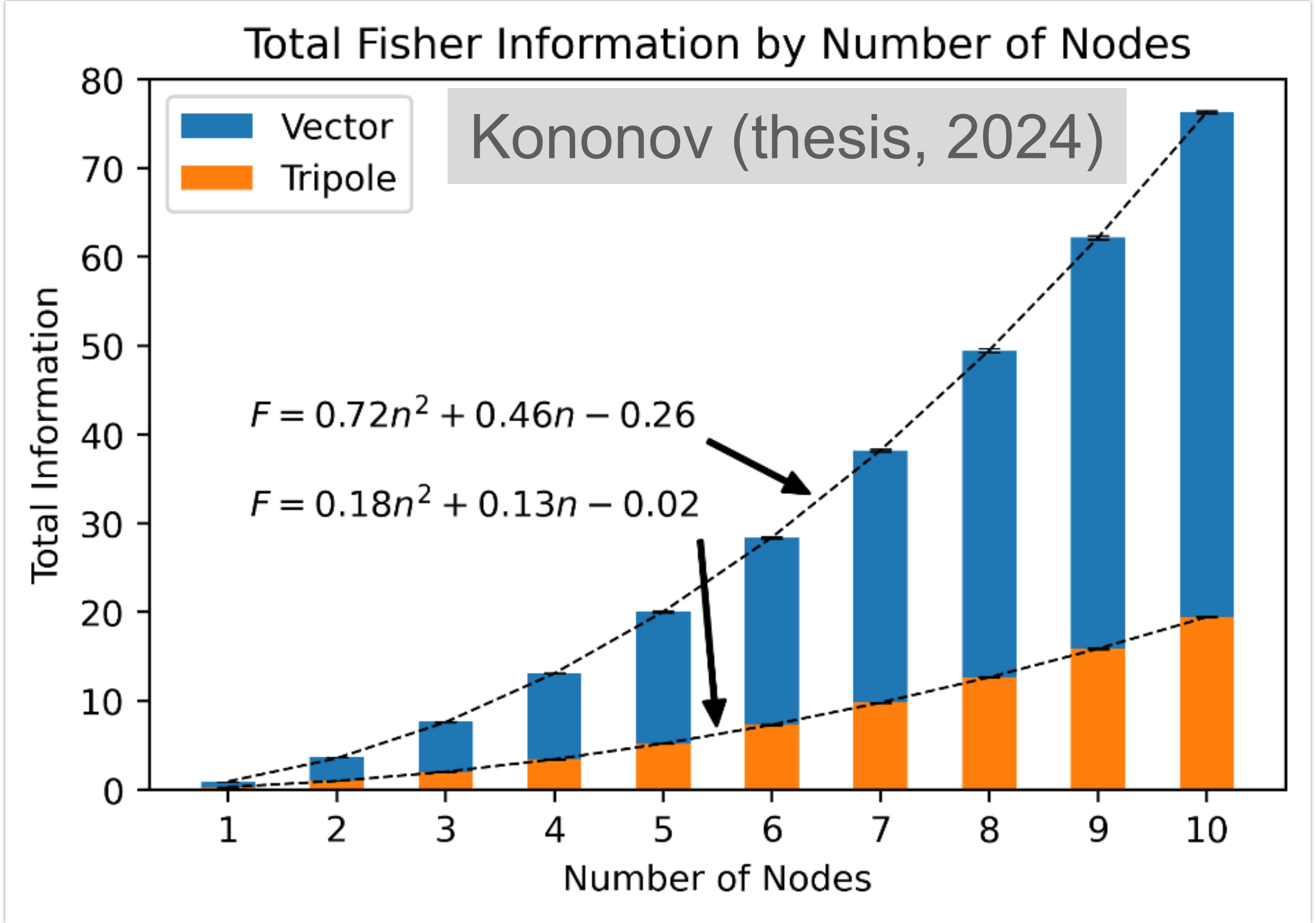
Vector sensor antenna: 3 orthogonal dipoles, 3 orthogonal loops



Learn more about AERO-VISTA antenna

Vector sensor: a better broadband low frequency antenna

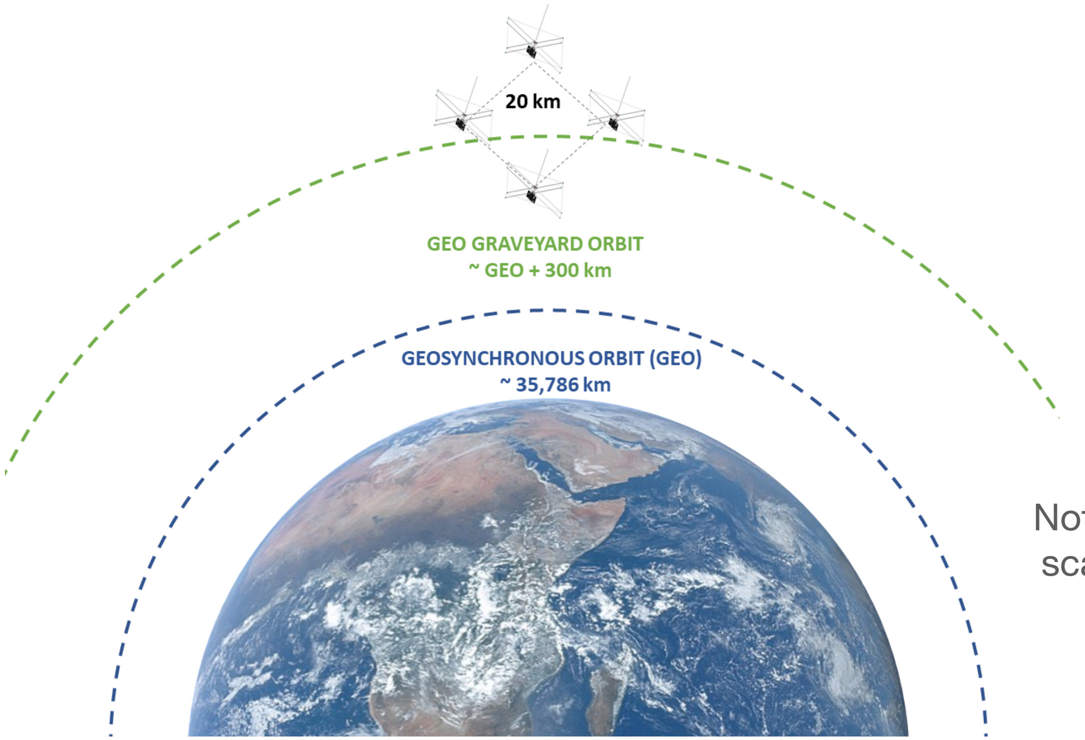
Vector sensors deliver more information per number of nodes than tripoles; are up to 2x more sensitive



See Kononov (thesis, 2024), **left**, for Fisher information analysis; Kononov et al. (2024), **right**, for vector sensor sensitivity

Mission design

- Frequency band: 100 kHz – 15 MHz
- Instrument: vector sensor antenna, FPGA-based 6-channel receiver, CSAC + GPS
- Number of spacecraft: 4 (3 minimum)
- Spacecraft size: 12U (20 x 20 x 30 cm)
- Location: near-geostationary
- Propulsion: Cold gas thrusters
- Communication: Lasercom for science data (raw voltages), X-band for command/telemetry
  - Correlation/beamforming on the ground for maximum resolution/flexibility
- Launch: rideshare in ESPA-class dispenser

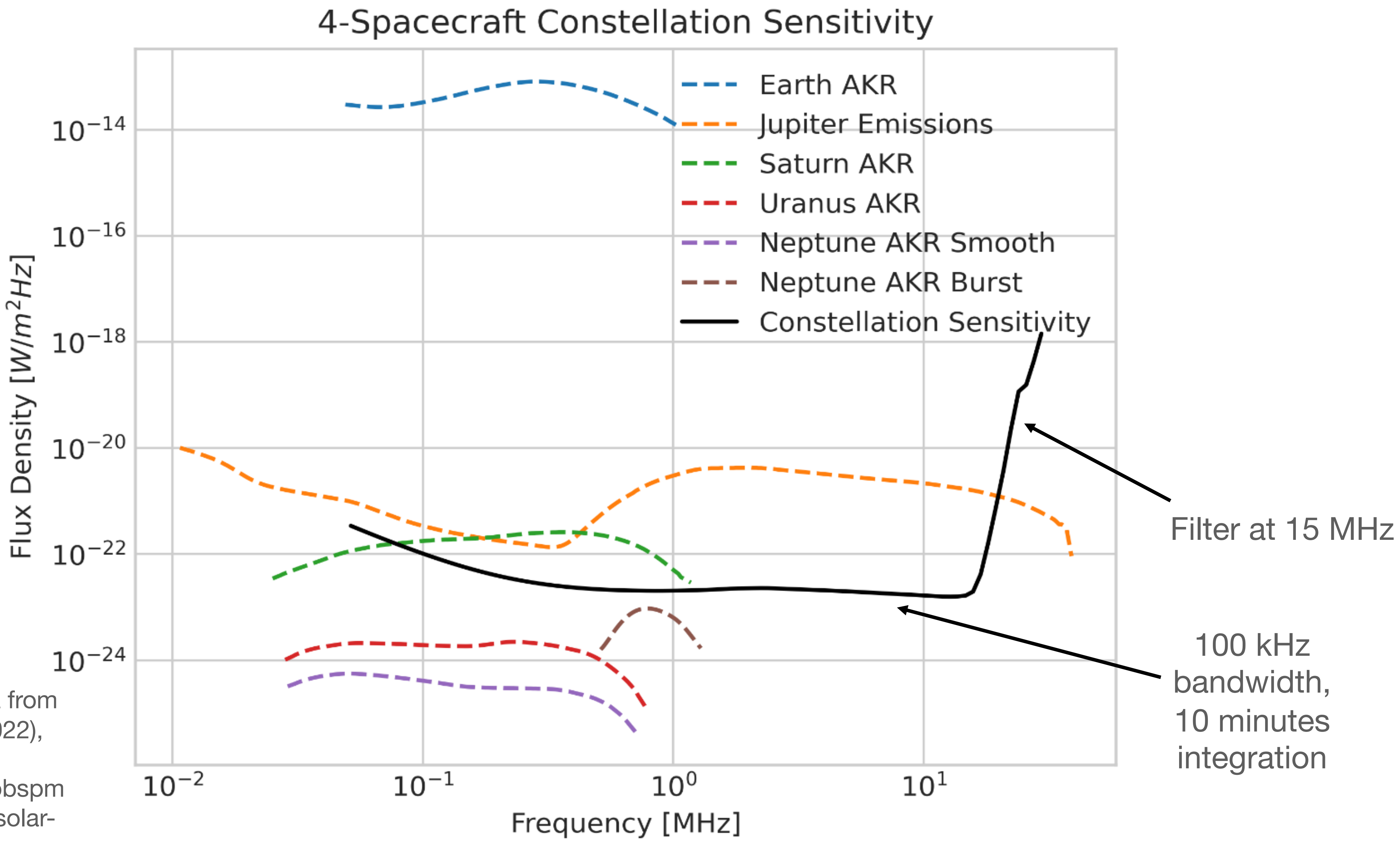


Not to scale

Image Source: MIT Haystack

See next talk!

Science Goal	Science Questions	Investigation Objective Requirements			Future Mission, Top Level Requirements
		Measurement	Requirement	Projected Performance	
NASA Heliophysics Science Objective 2: Advance our understanding of the Sun's activity, and the connections between solar variability and Earth and planetary space environments, the outer reaches of our solar system, and the interstellar medium **SWIPE science goal: Observe the effects of solar weather (solar wind, CMEs, SIRs) on planetary auroral radio emission over time**	Do solar wind models accurately (~15% error similar to Earth) **predict the arrival times** (and transit time across magnetosphere) **of CMEs** and SIRs at Jupiter and Saturn?	Localize radio emission to location of solar system planet Onset time of observed auroral radio emission change	Monitor planetary radio emission for sufficient time to observe 5 CME and 10 SIR passages at each planet	Mission lifetime: 18 months	Number of spacecraft: 4 Mission lifetime: 18 months Orbit: near-GEO (e.g. graveyard) Angular resolution: 1 degree at 1 MHz Sensitivity: $1*10^{-22}$ W/m^2/Hz Bandwidth: 100 kHz – 15 MHz Full polarization (Stokes IQUV)
			Monitor planetary radio emission with high-duty cycle in 2-week period around predicted CME arrival	Up to 20% observing duty cycle	
	What is the **relationship between CME properties (e.g., speed and duration) and planetary auroral radio emission response**? Can we infer interactions between CMEs and/or other structures in the interplanetary medium from the corresponding planetary auroral response?	Localize radio emission to location of solar system planet Measure as a function of time: • Auroral radio intensity (flux) • Spectral shape • Polarization	Angular resolution: 1 degree at 1 MHz	Sensitivity: $5*10^{-23}$ W/m^2/Hz	
			Sensitivity: $1*10^{-22}$ W/m^2/Hz	Bandwidth: 100 kHz – 15 MHz (AERO-VISTA current performance)	
			Frequency range: 100 kHz – 5 MHz		
			Ability to measure circular polarization (Stokes V)	Full polarization (Stokes IQUV)	
	How does each planet respond to the passage of the same SIR? How does auroral emission change with successive rotations of a single SIR?		Monitor planetary radio emission for 3 solar rotations (81 days)	Mission lifetime: 18 months	



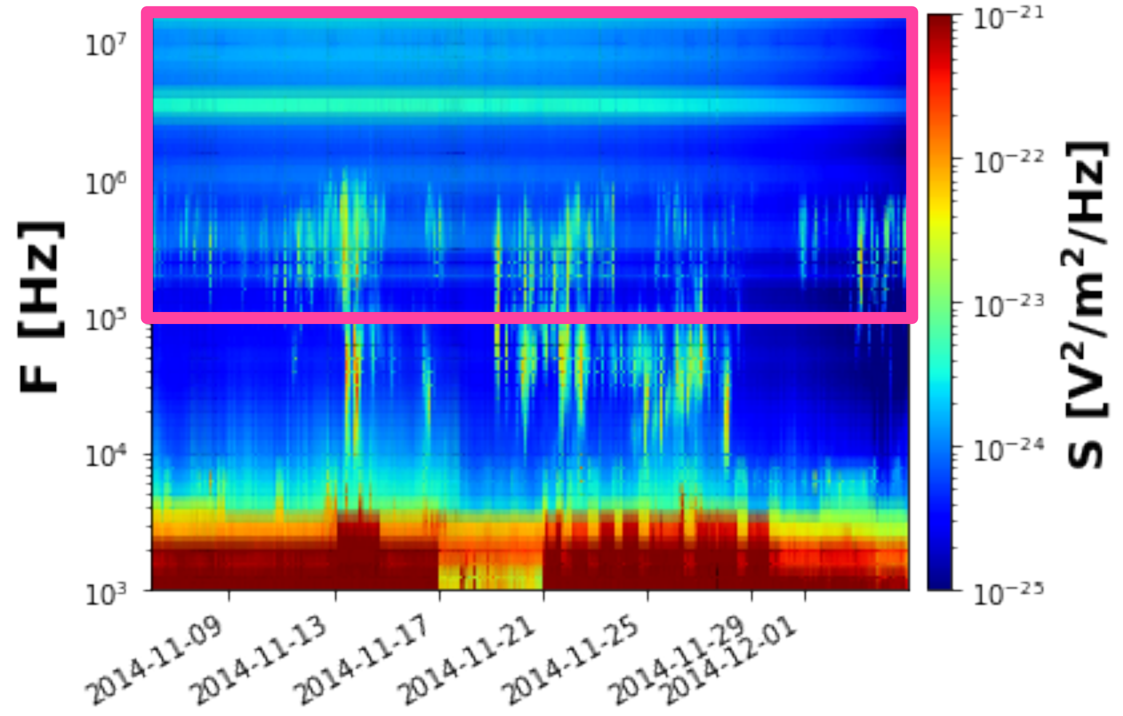
Planetary radio data from Zarka & Cecconi (2022), available from https://maser.lesia.obspm.fr/publications/doi/solar-system-low-frequency-radio.html

Work in progress: simulator

Goal: simulate what SWIPE would see for Saturn CME interactions observed by Cassini

Inputs:

- Cassini measurements of CME passages from 2012, 2014
- Positions of planets during these events
- Constellation positions



Cassini survey data for 2014 CME impact

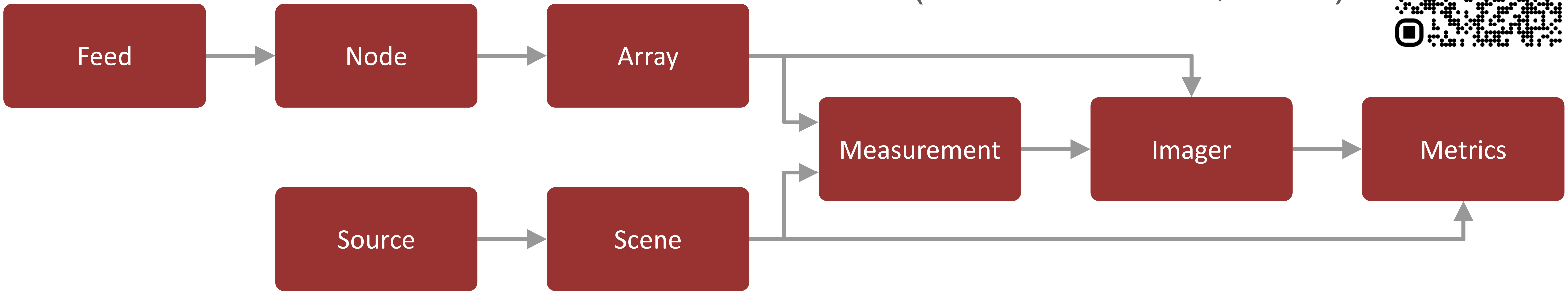
Work in progress: simulator

Simulator components:

- ✓ Scaling Cassini data based on planet positions
- ✓ Background sky map (ULSA, Cong et. al 2021)
- ✓ Calculation of measurement, beamformer output for each time/frequency bin

- ☐ Earth AKR
- ☐ Jovian bursts
- ☐ Earth RFI
- ☐ Nulling beamformer

Simulator architecture
(Kononov thesis, 2024)

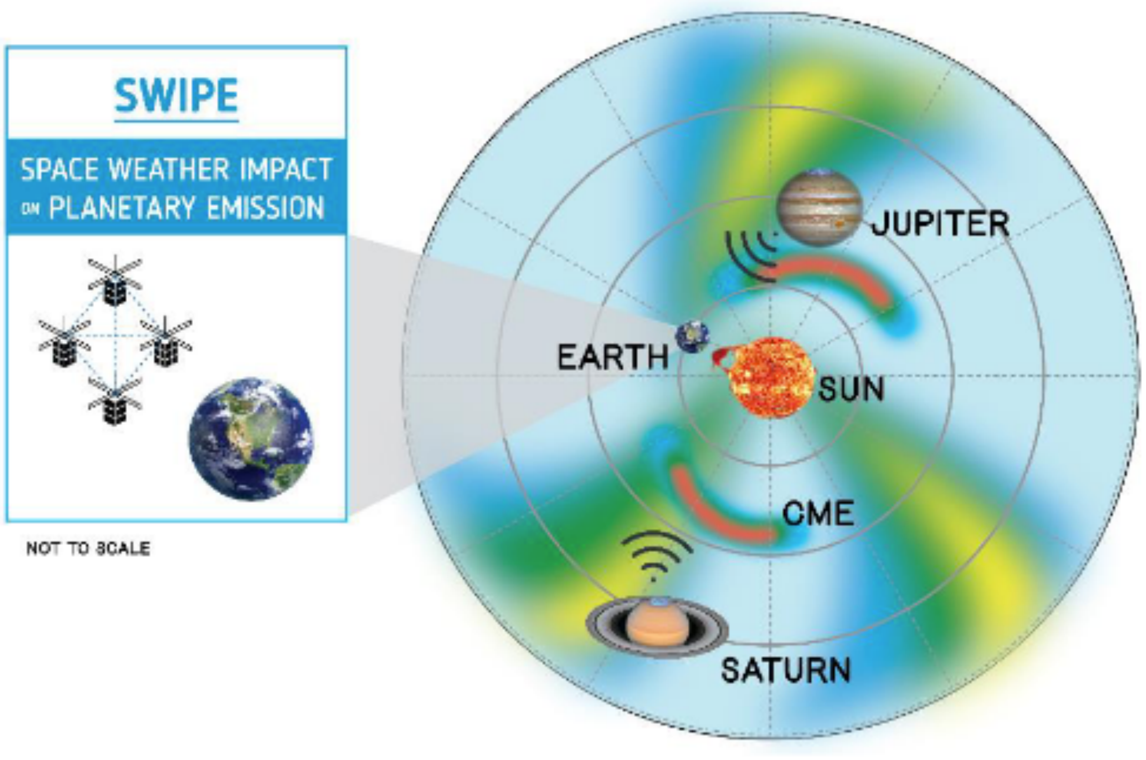


Let’s talk!

SWIPE is a new way to study planetary radio emission, but…

The current funding situation in the US makes it very difficult to pursue this mission, at least in the near term.

Let’s talk about collaboration and other ways to move forward with a remote planetary radio emission constellation.



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