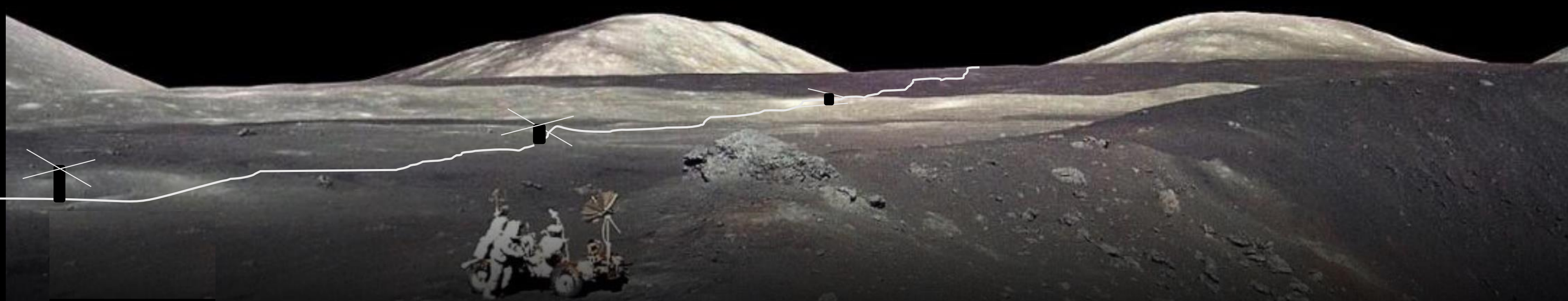
The Space Astrophysics Landscape for the 2020s and Beyond

FARSIDE



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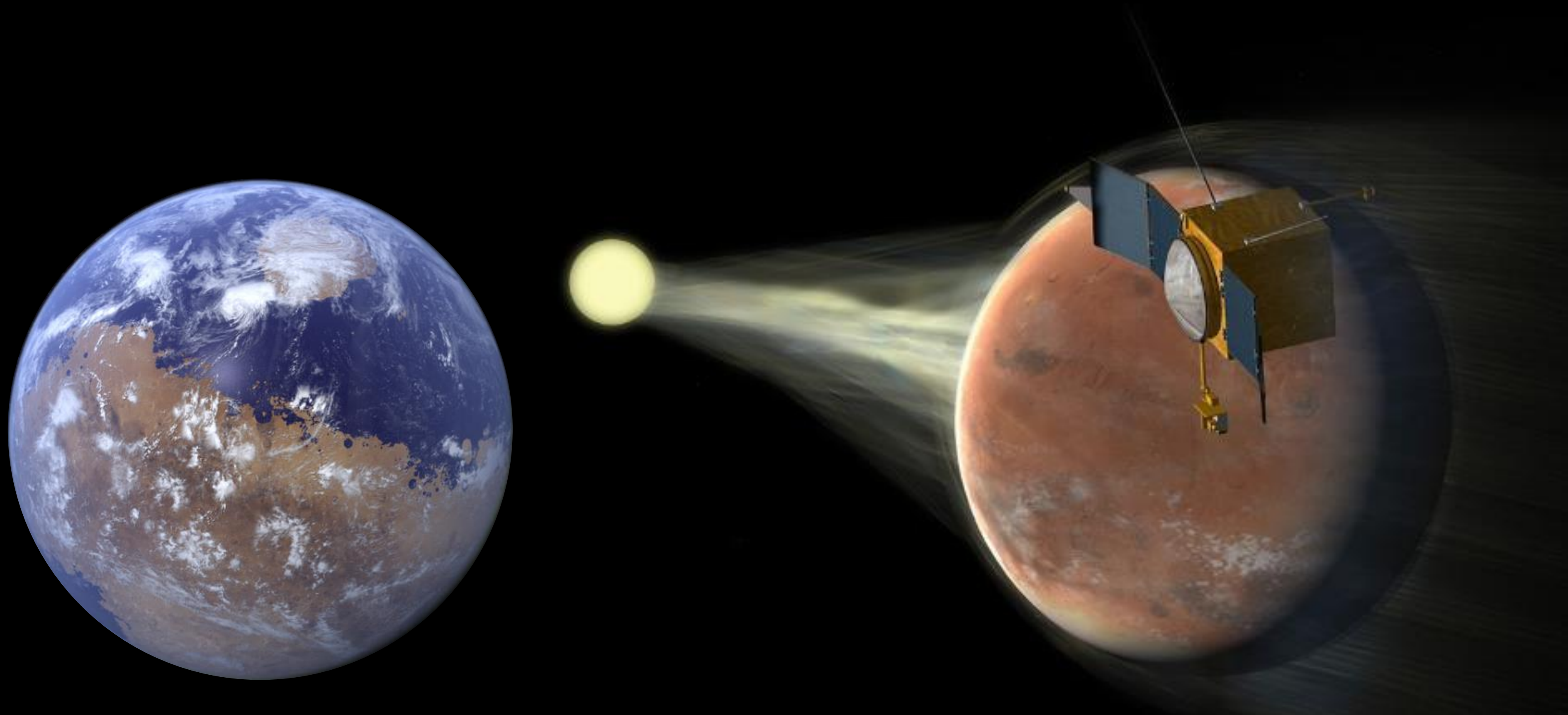
Magnetospheres and Space Environments of Habitable Planets

The Dark Ages and Cosmic Dawn

Simulation: Marcelo Alvarez

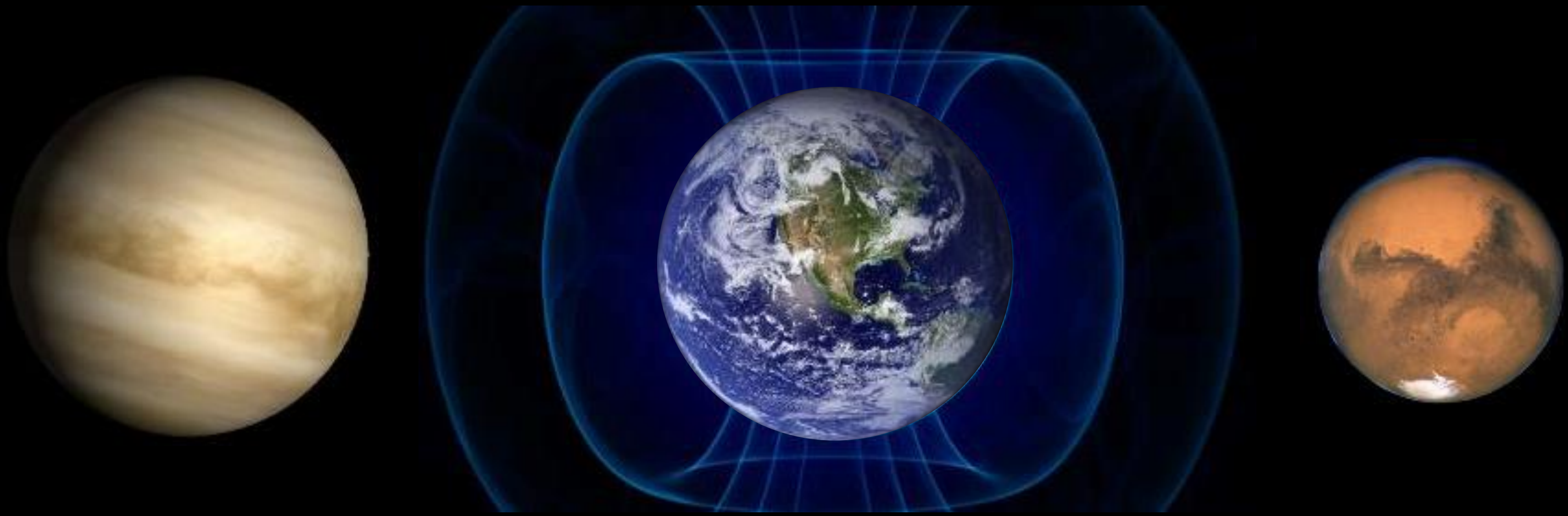


Young Mars was warmer and wetter

Mars atmosphere removed by coronal mass ejections from the young Sun (Jakosky et al. 2015)

Flares – higher X-ray and ultraviolet radiation flux –>
heating results in extended thermospheres (Lammer et al. 2003)

Coronal mass ejections (CMEs) – higher stellar wind flux –>
can erode atmosphere – eg. ion pick-up erosion (Kulikov 2007)

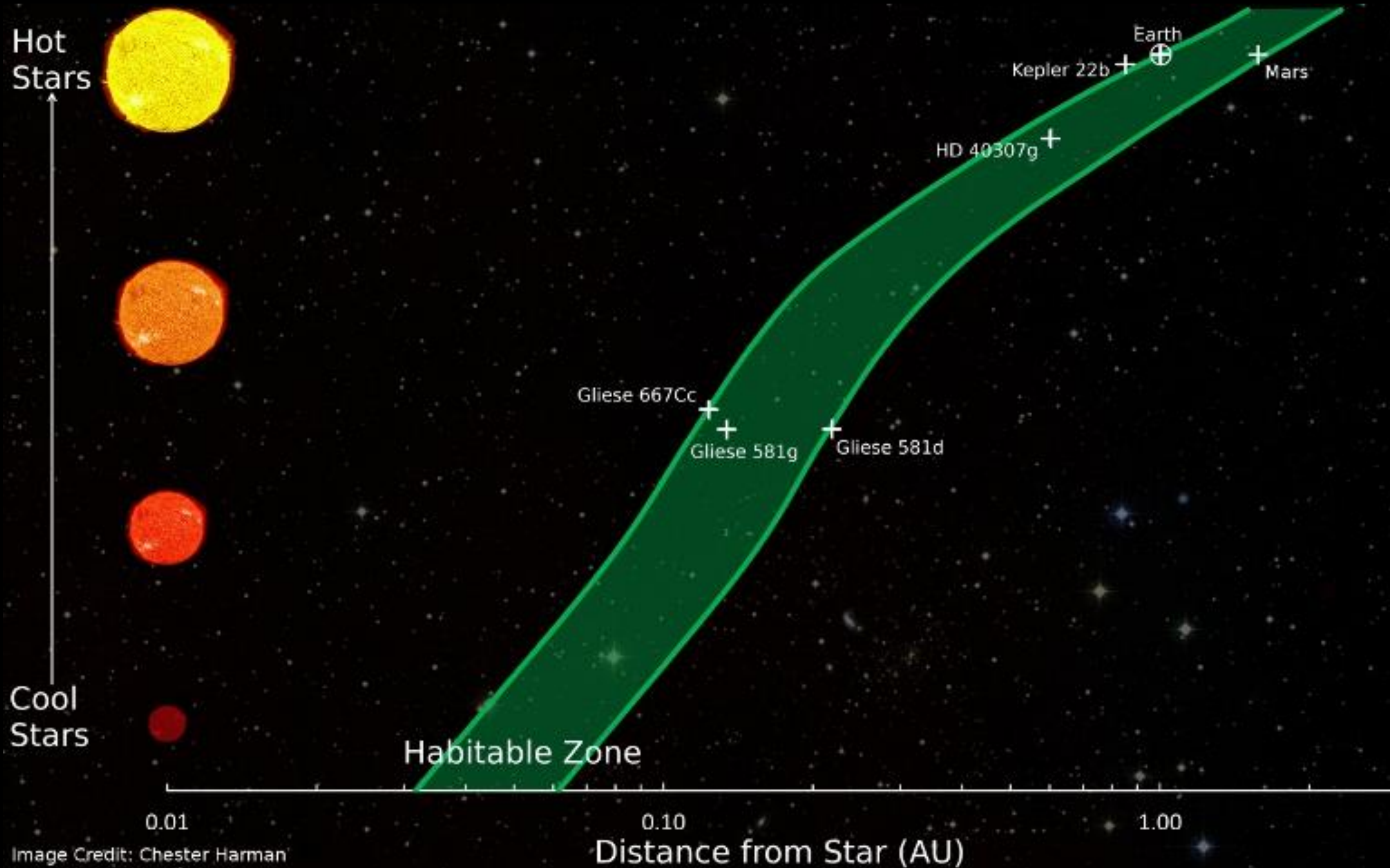


Magnetic activity can redefine habitability!

The M Dwarf Opportunity

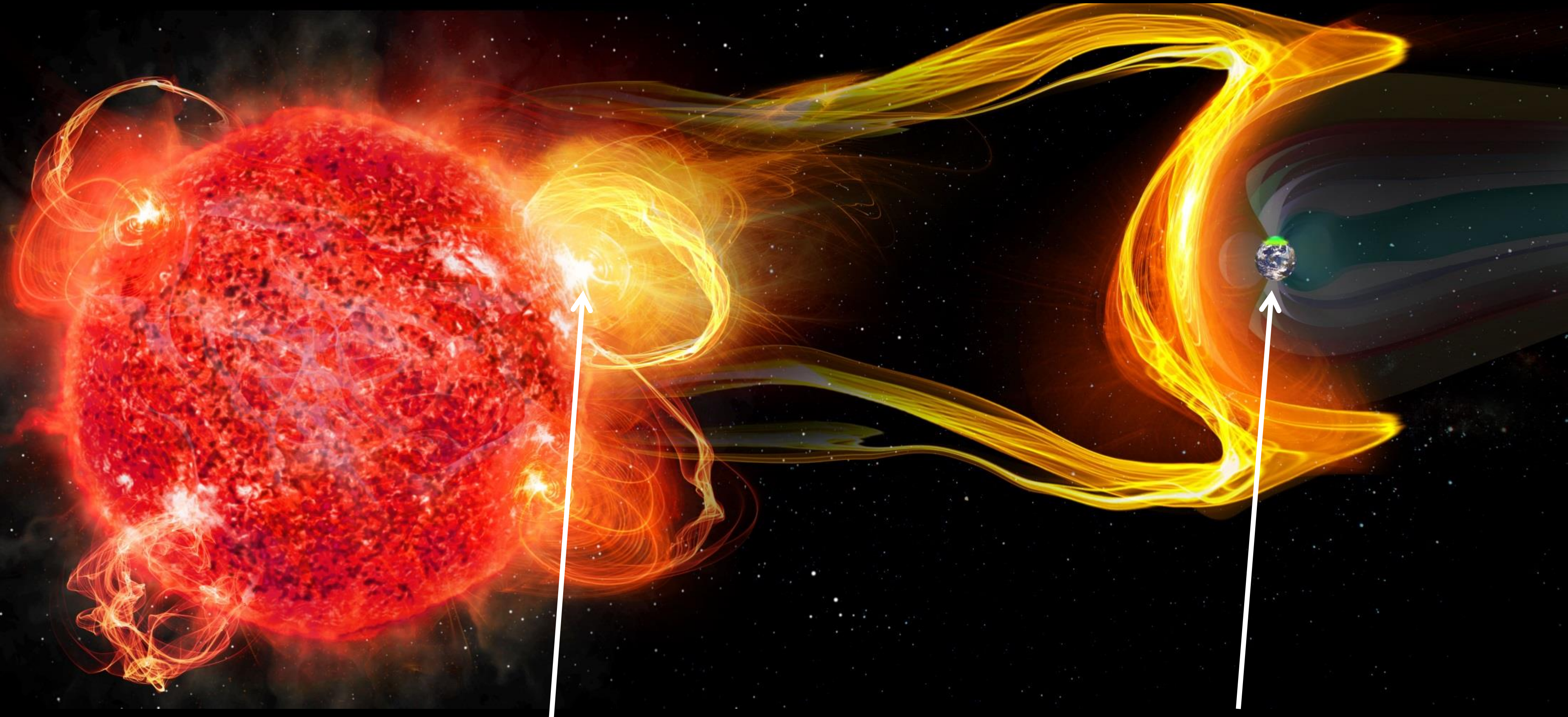
Rocky planets are particularly frequent around M dwarfs (Dressing & Charbonneau 2013, 2015)

The nearest "habitable" planet likely orbits an M dwarf within a few pc


Hot Stars
Cool Stars
Earth
Kepler 22b
Mars
HD 40307g
Gliese 667Cc
Gliese 581g
Gliese 581d
Habitable Zone
0.01
0.10
1.00
Distance from Star (AU)
Image Credit: Chester Harman

Credit: Chuck Carter / Caltech

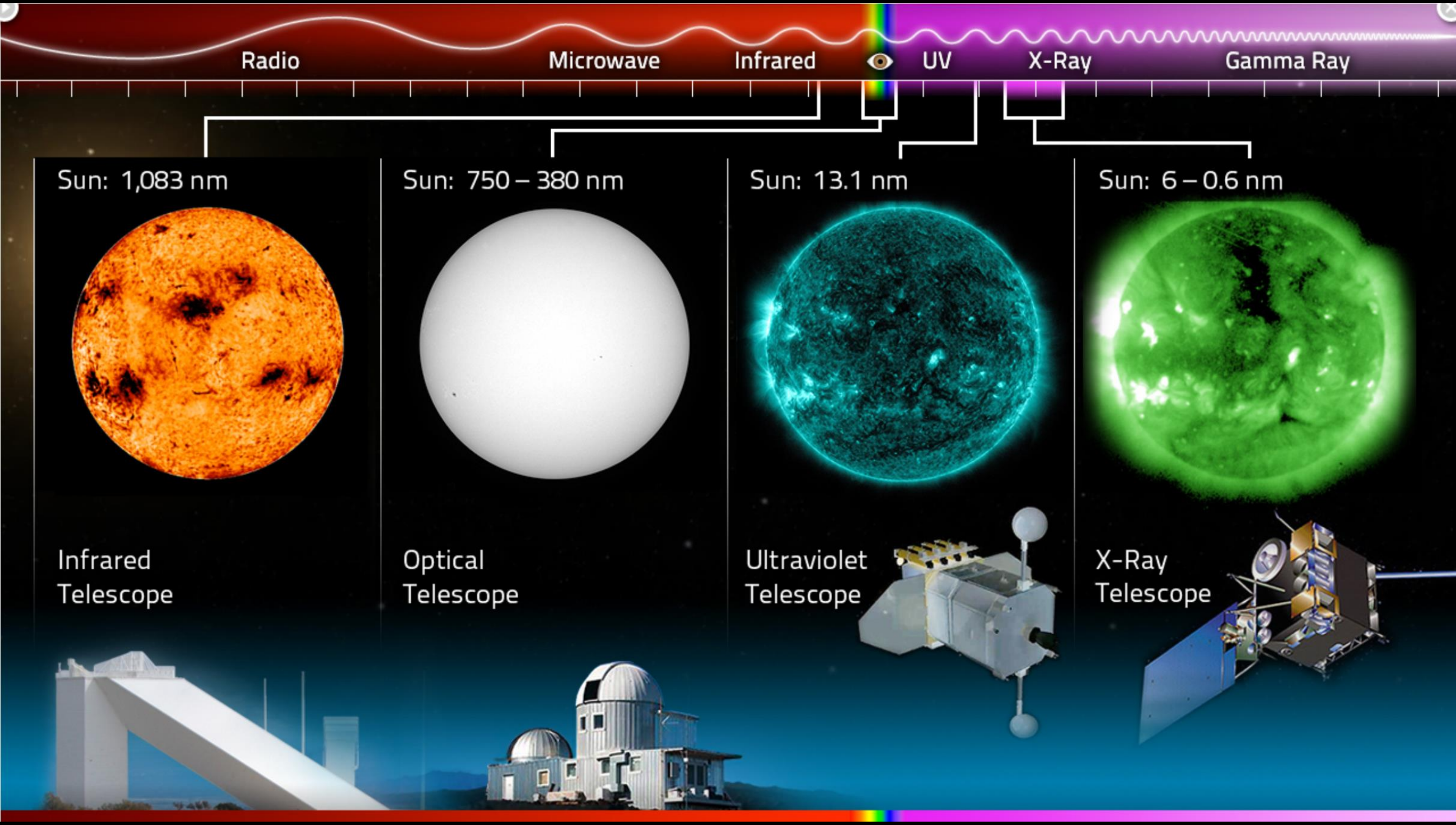
Low Frequency Radio Emission

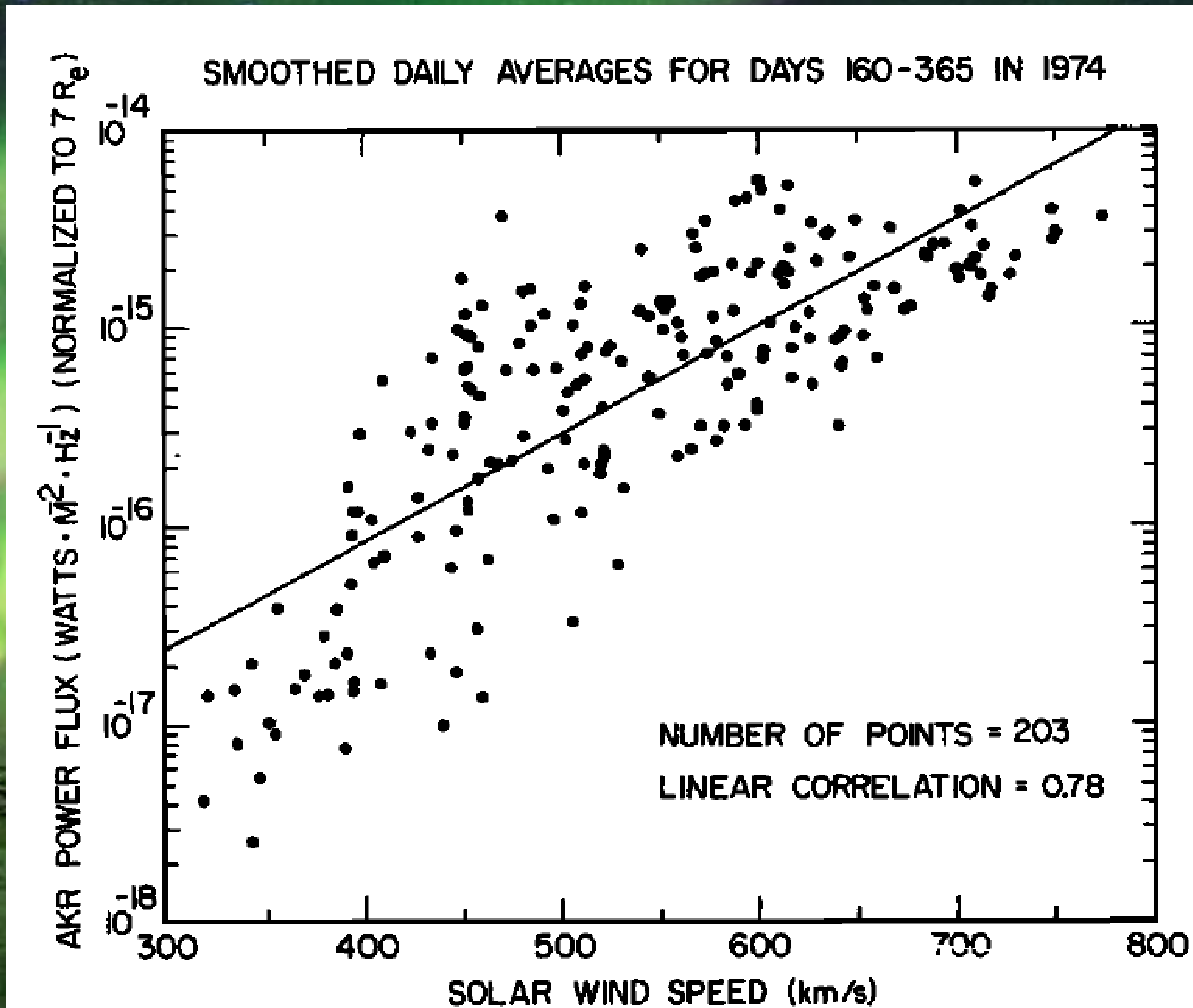


Type II radio bursts
traces density at CME shock

Auroral radio emission
measures magnetic fields

Paradigm Shift





Gallagher & D’Angelo 1981

Requirements

Need many km^2 of collecting area…

in space…

that can monitor 1000s of stellar systems simultaneously

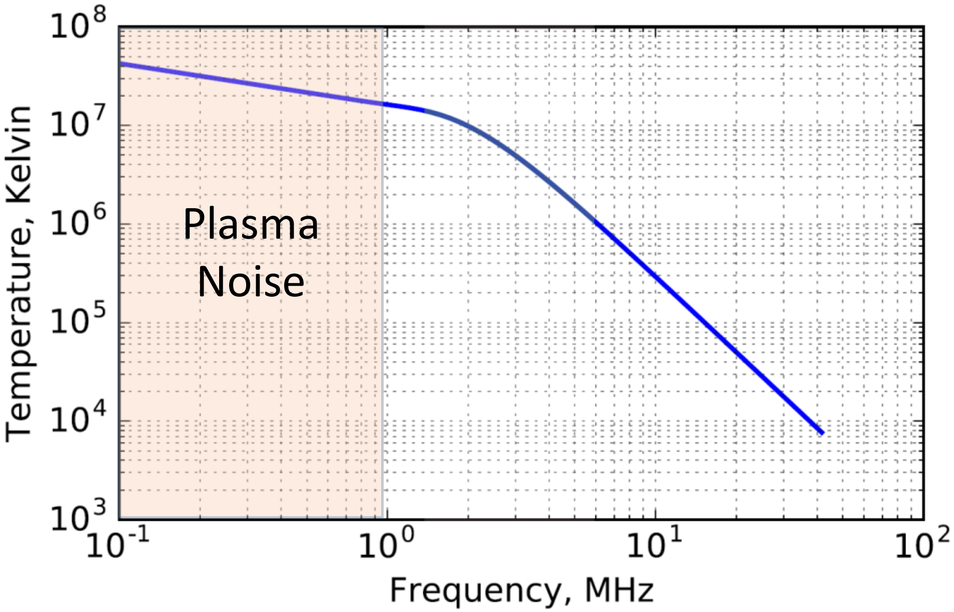
EASY!

The Lunar Far-side

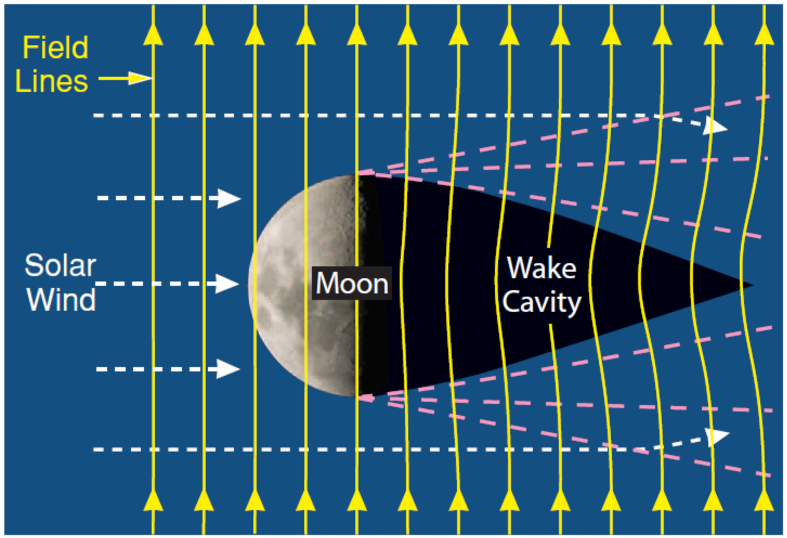
Jim Bridenstine: "we'll be putting pieces of wire on the moon"

Sensitivity of a dipole ∝ collecting area / system temperature

$\propto \lambda^2$ **$\propto \lambda^{-2.6}$**



Credit: Andres Romero-Wolf

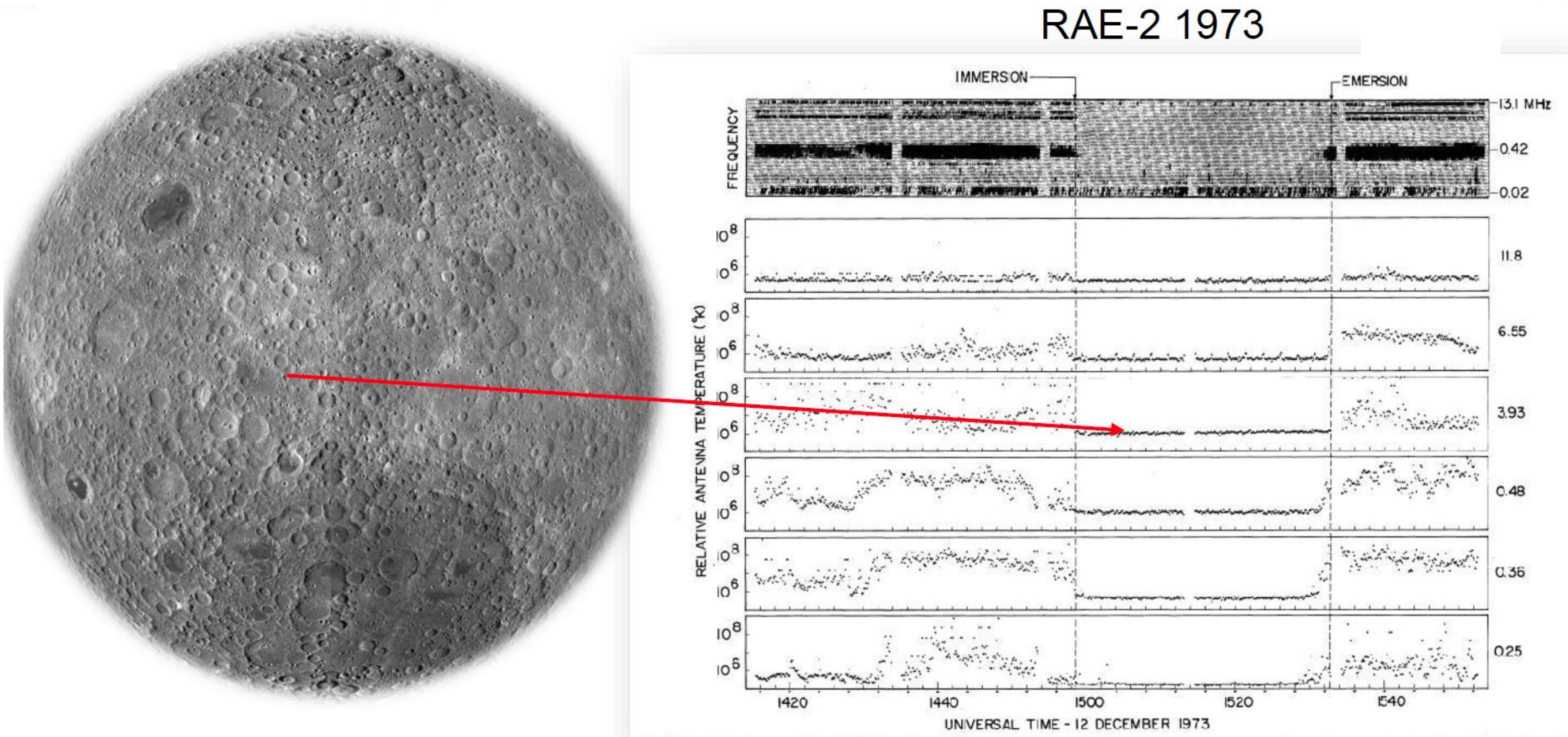


Credit: Steve Bartlett

A dipole of a few meters length on the moon has a collecting area of ~0.3 km^2 at 300 kHz

A dipole at 300 kHz is 20x more sensitive than at 30 MHz

Radio-frequency Environment of the Lunar Far-side



RAE-2 occultation of Earth in 1972

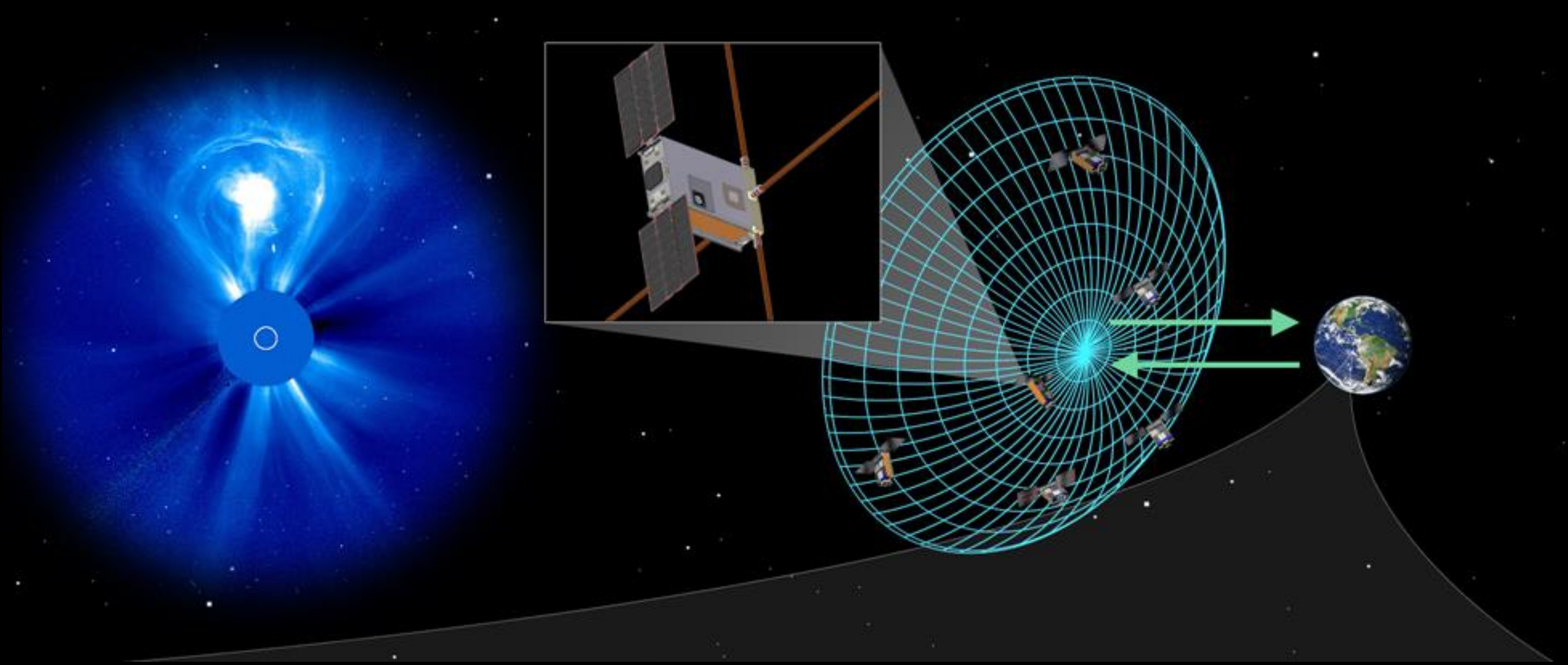
FARSIDE Probe Study

- Science Drivers:
  - The Magnetospheres and Space Environments of Candidate Habitable Exoplanets
  - The Dark Ages and our Cosmic Dawn

- Assumptions:
  - i) Lunar Gateway in operation (available as a communication relay)
  - ii) $1 billion cost cap and 500 kg mass cap [for deployed hardware]

- Timeline:
  - Nov 2018: Directed probe study commenced
  - Mar 2019: Overall architecture selected [Team X]
  - Apr 2019: Follow up mission and instrument studies planned
  - Jun 2019: Initial report completed
  - Sep 2019: Engineering Concept Definition Package

Sun Radio Interferometer Space Experiment (SunRISE)



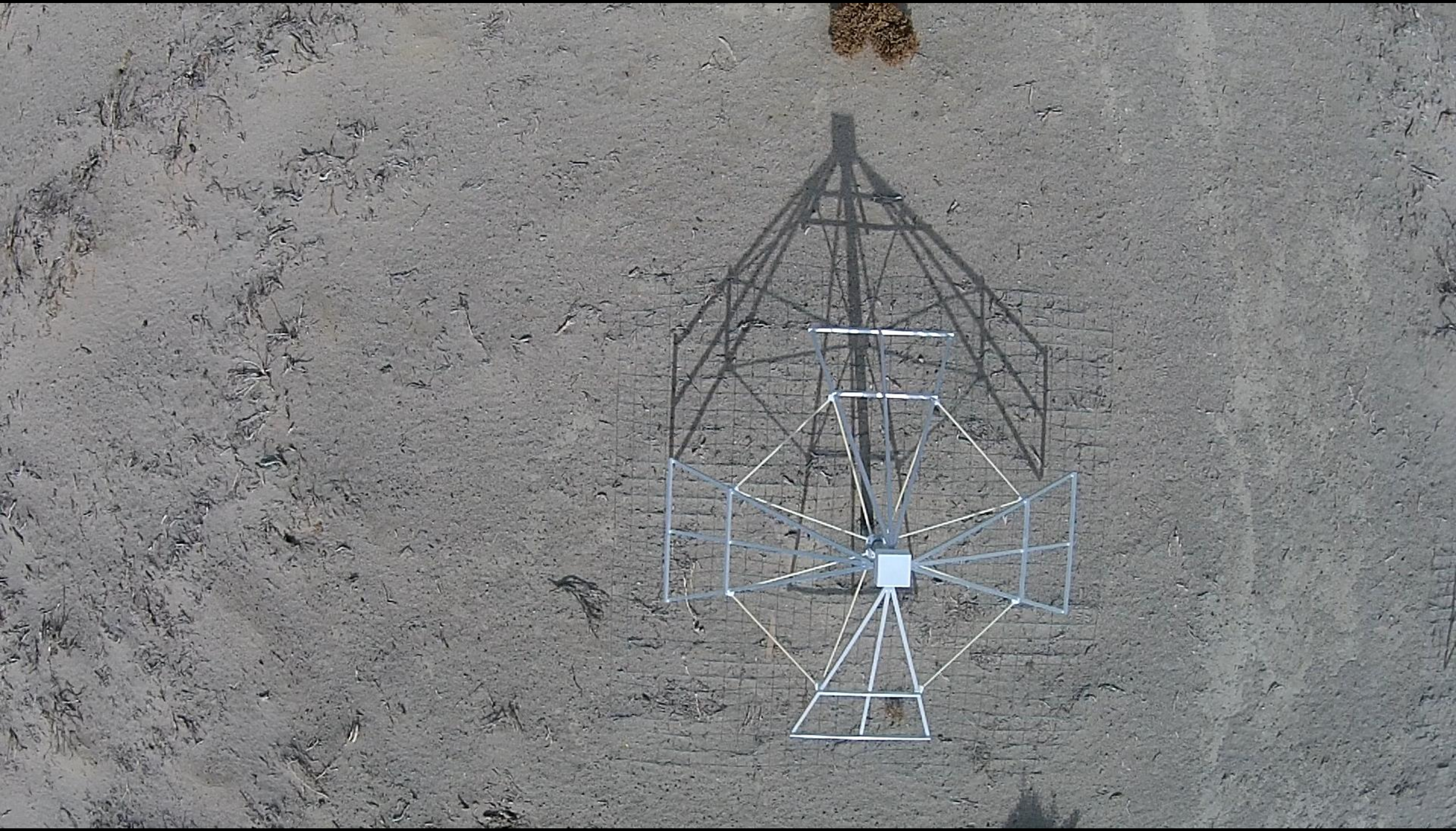
Loose formation of six 6U form factor smallsats in 10 km sphere

Radio receiver (0.1 – 20 MHz) with crossed 5 m dipole antennas

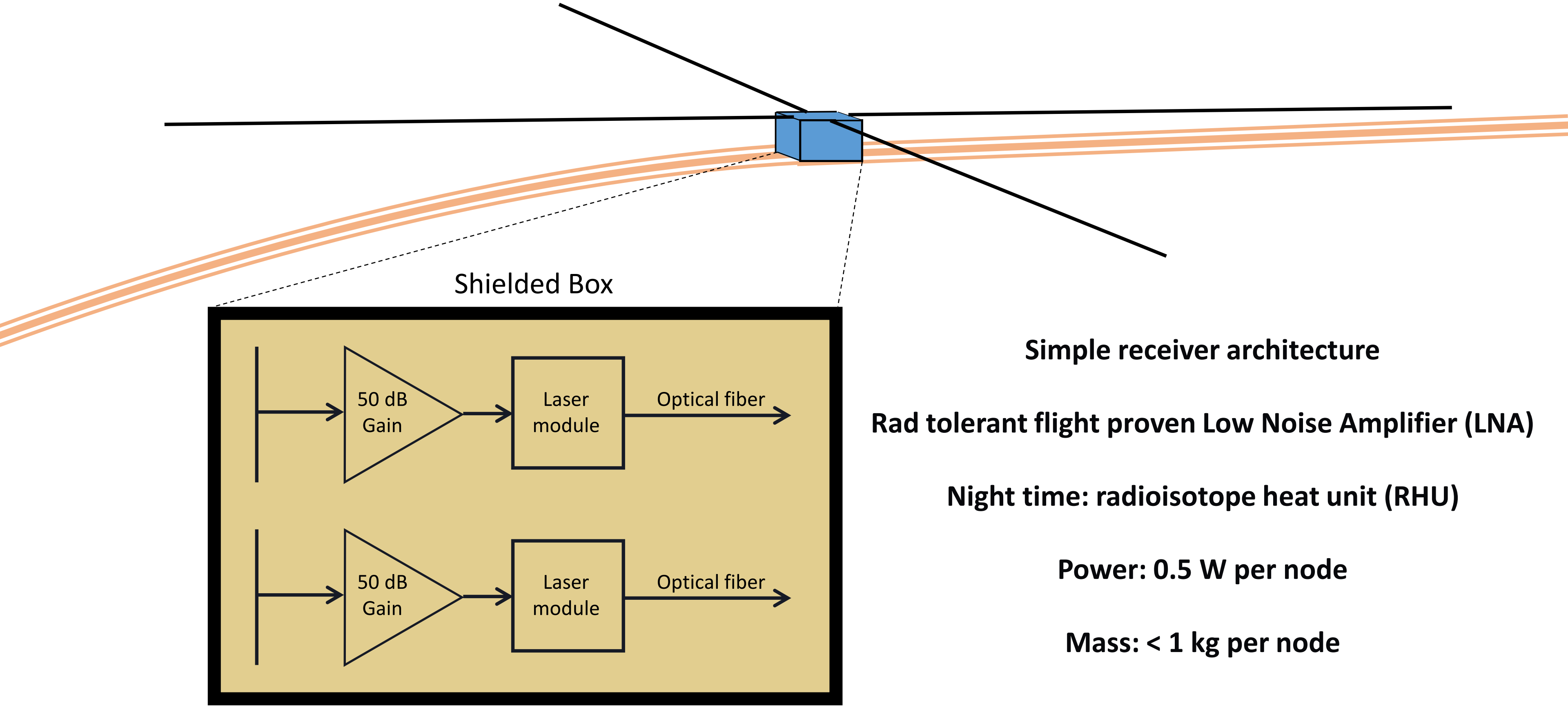
Currently in Extended Phase A Study

Courtesy of Justin Kasper & Joe Lazio

The OVRO-LWA



FARSIDE Antenna Node



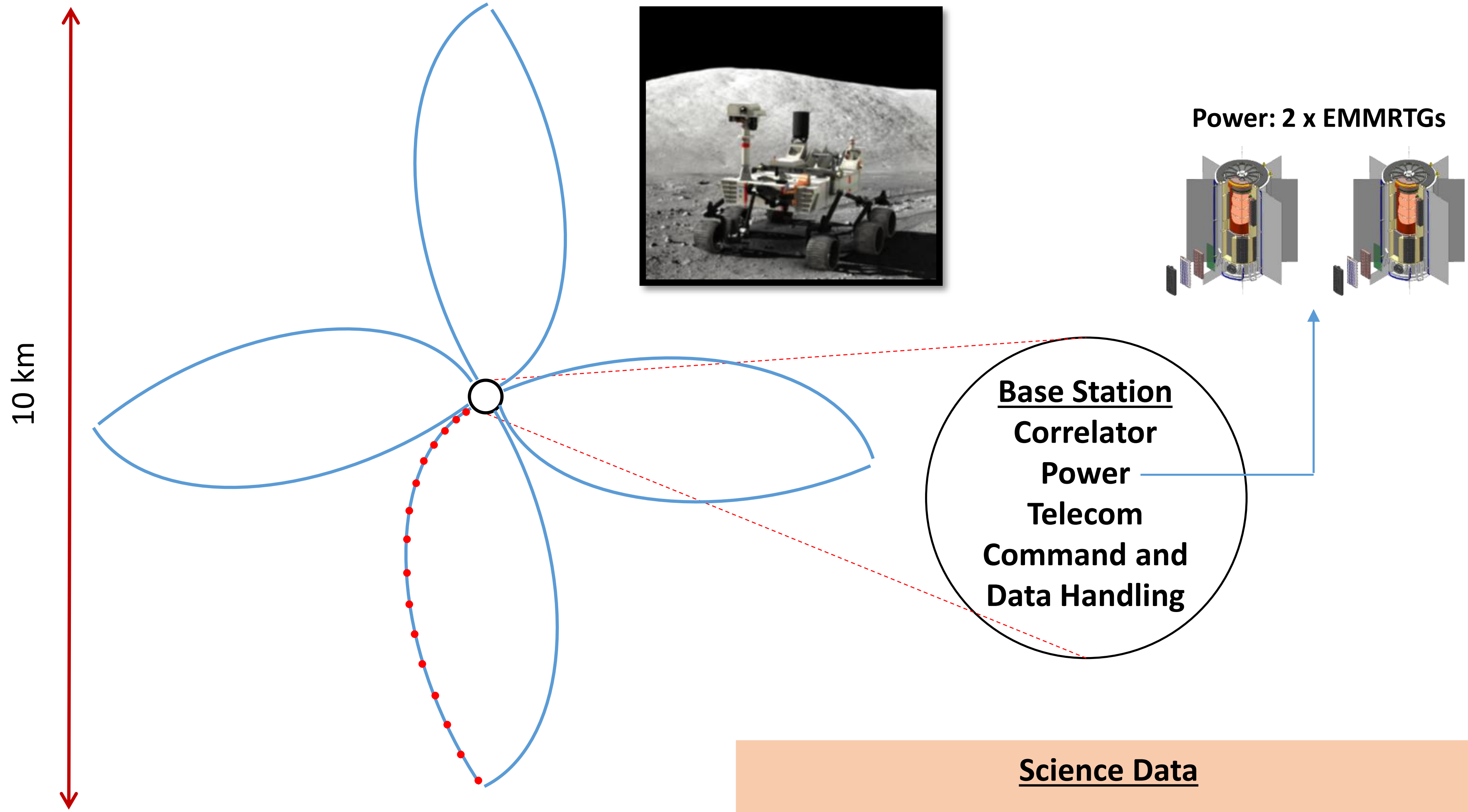
Simple receiver architecture

Rad tolerant flight proven Low Noise Amplifier (LNA)

Night time: radioisotope heat unit (RHU)

Power: 0.5 W per node

Mass: < 1 kg per node



128 antennas total

Arranged in a "petal" configuration

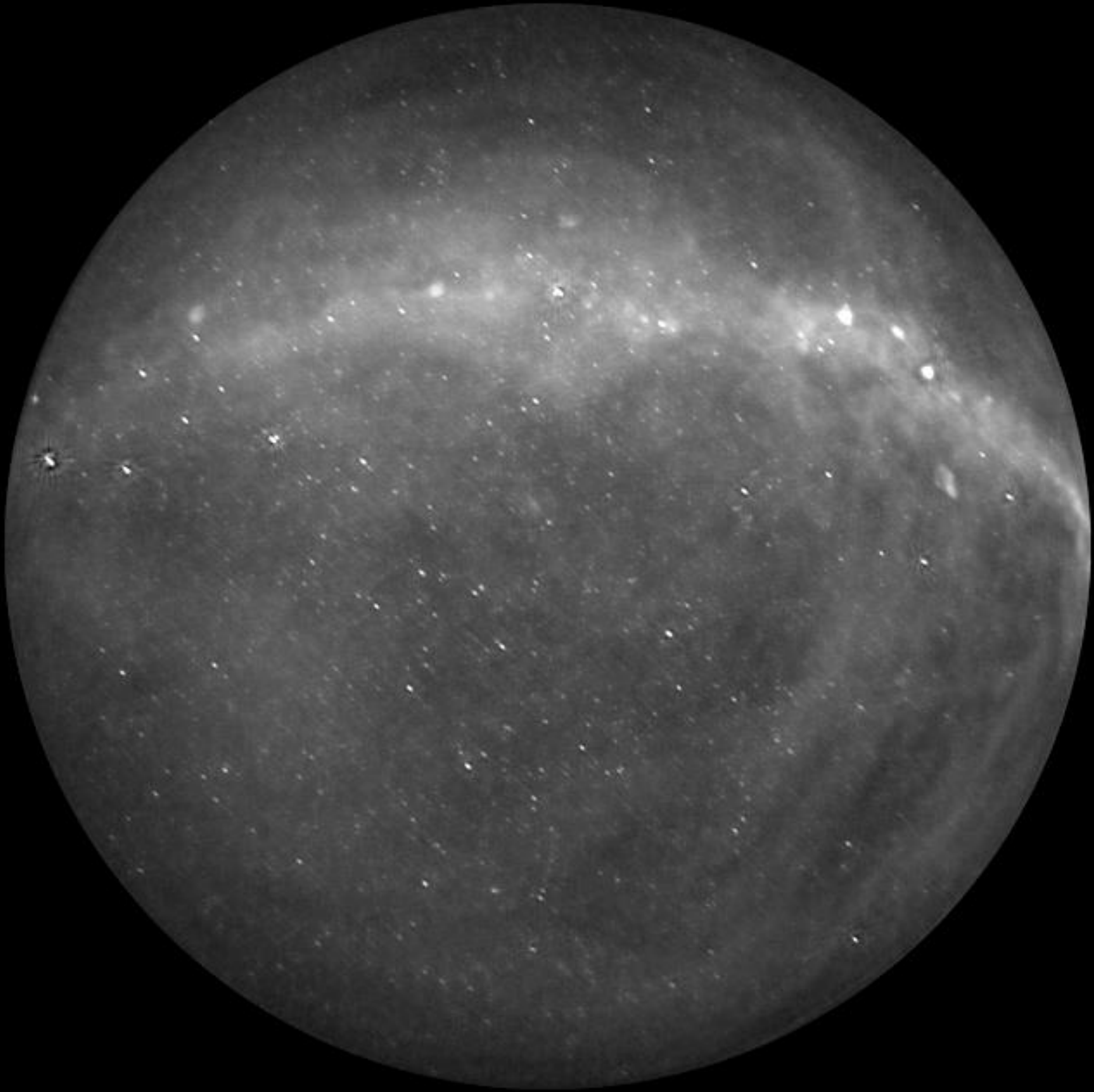
16 antennas per spoke (20 kg)

Rover covers <50 km in one single lunar day

Science Data

Frequency range: 0 – 25 MHz (1400 channels)
Integration time: 60 s
All visibilities: 65 GB/day
All-sky imaging every 60 seconds (Stokes I and V)
Deep all-sky imaging every lunar day

Monitors ~4,000 stellar/planetary systems out to 25 pc

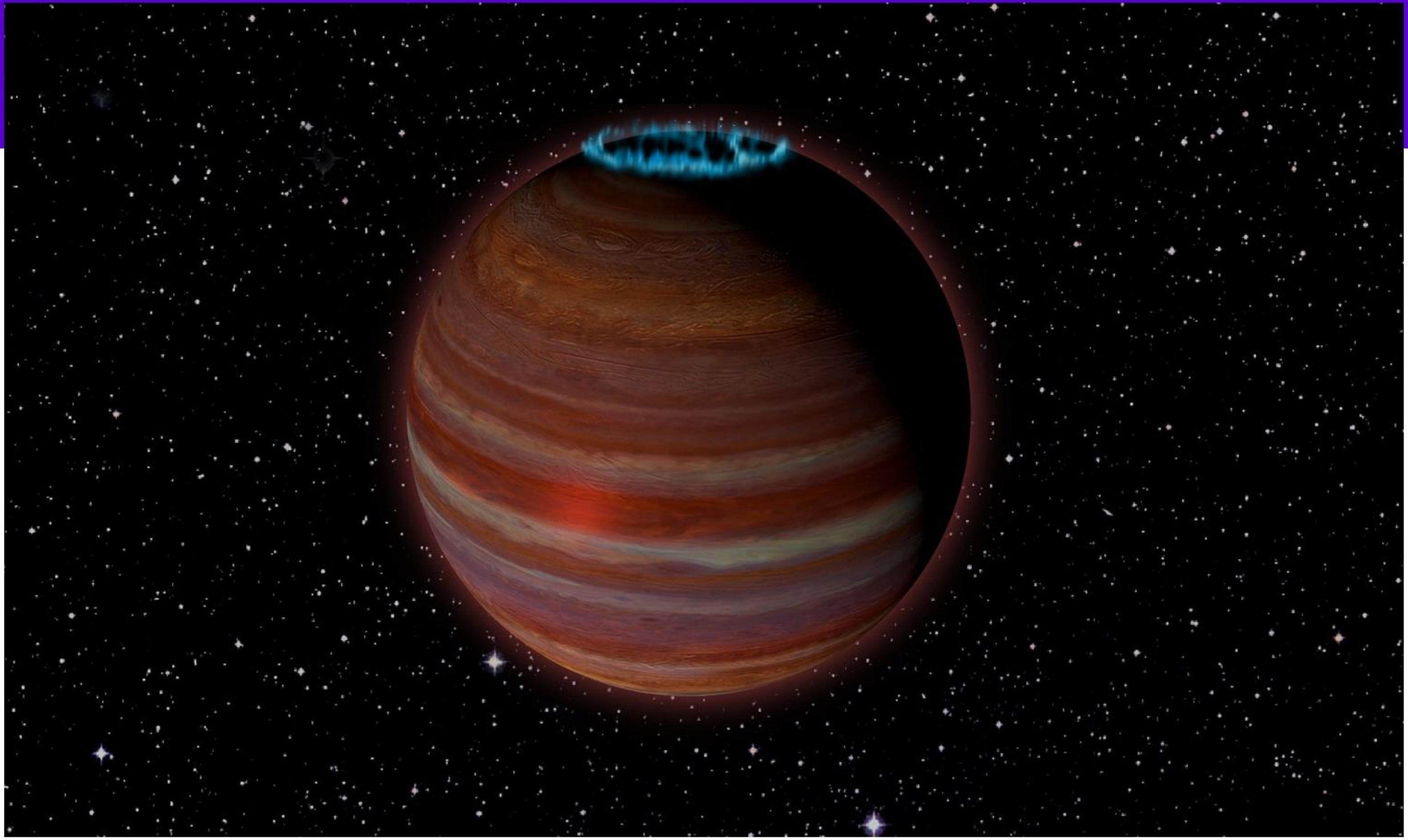


OVRO-LWA - 25-85 MHz, 10-second integrations

Anderson et al. 2018

Huge rogue 'planet' has magnetic field scientists can't explain

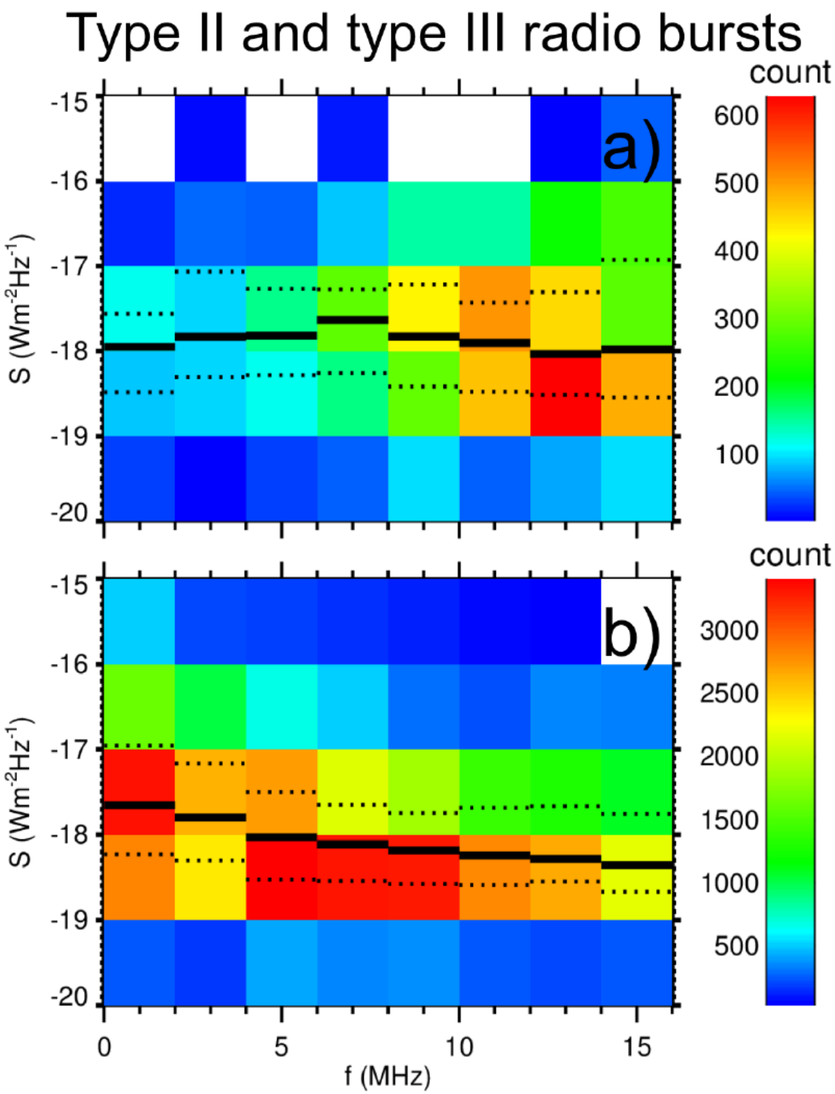
How this celestial object can maintain a field so strong is still unclear.



The planet-size object, SIMP J01365663+0933473, has 12.7 times the mass of Jupiter but a magnetic field 200 times more powerful than Jupiter's. Chuck Carter / NRAO/AUI/NSF

Kao et al. 2018

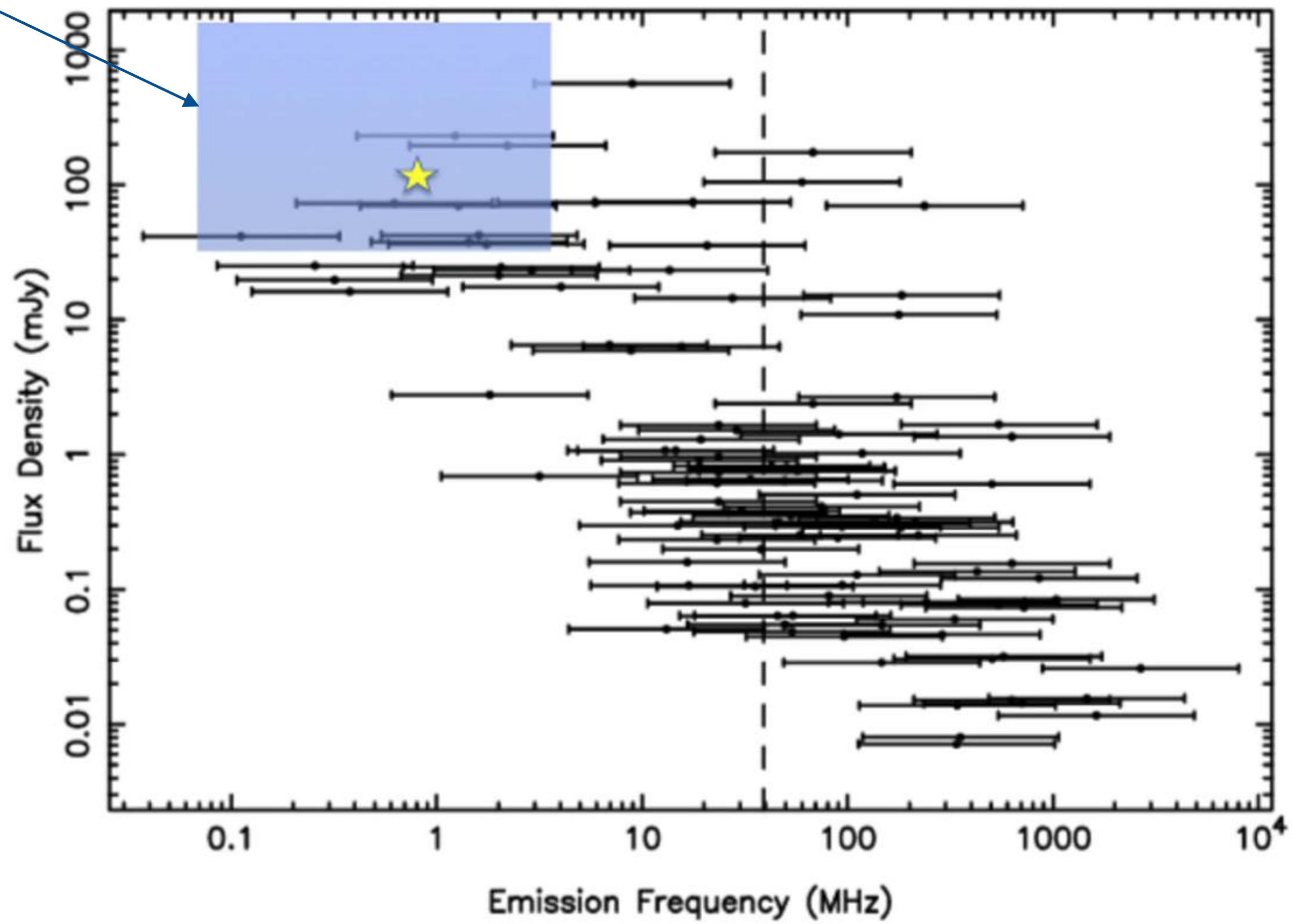
Solar-like Type II and Type III Events out to 10 pc



Krupar & Szabo (2018)

Constraints on the Magnetic Fields of the Nearest Habitable Planets

Proxima b

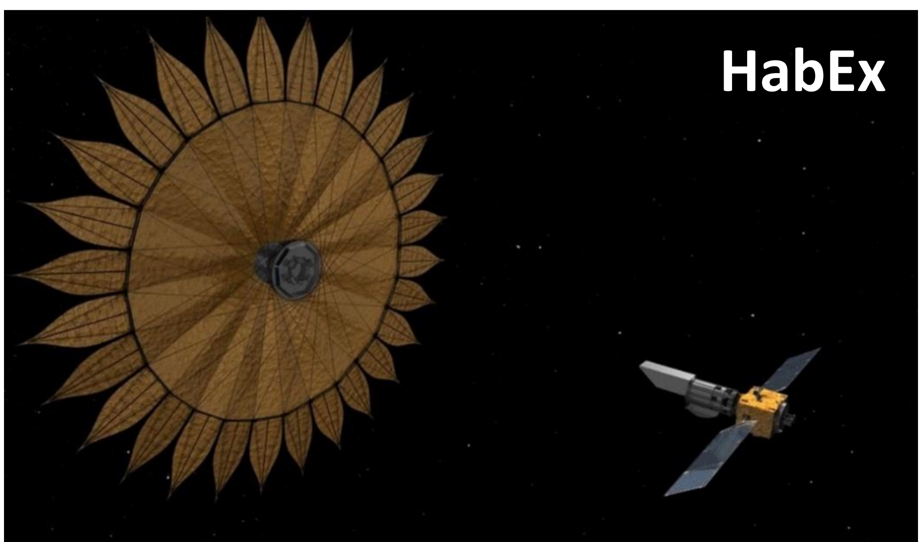


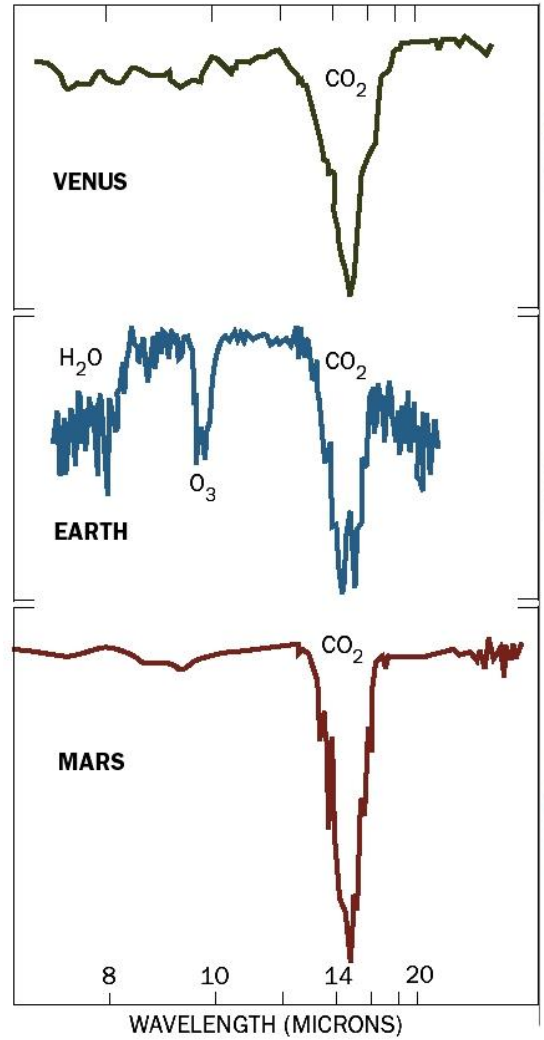
FARSIDE @ 300 kHz
1σ in 1 hour: 100 mJy

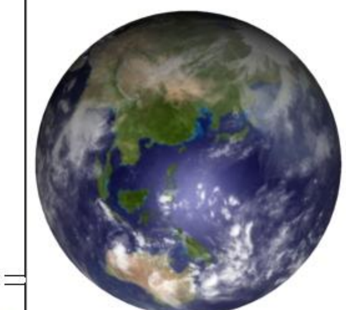
FARSIDE @ 300 kHz
1σ in 1 lunar night: 5 mJy

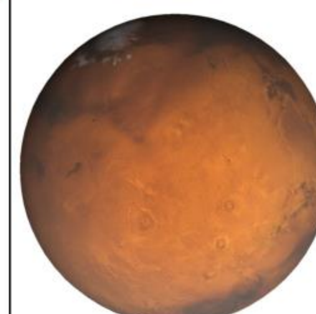
Burkhart & Loeb 2017

Comparative Planetology









Additional Science

- First constraints on Dark Ages 21-cm power spectrum (ruling out exotic models)

- Heliophysics: [poster of Bob MacDowall]

- Monitoring of auroral processes and lightning at Jupiter, Saturn, Uranus and Neptune

- Searches for unknown large magnetized bodies in our solar system (e.g. Planet 9)

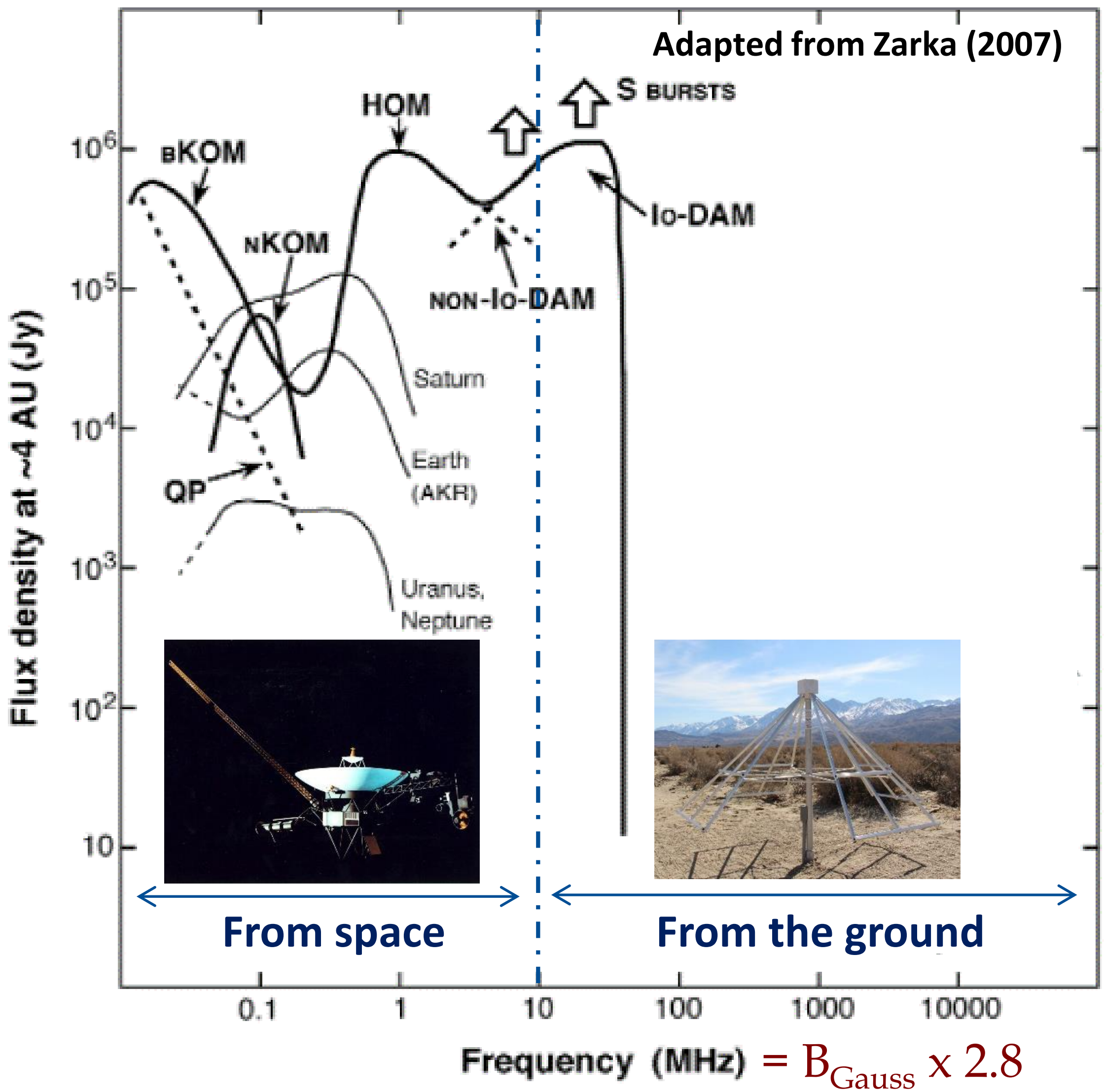
- Tomography of the ISM

- SETI

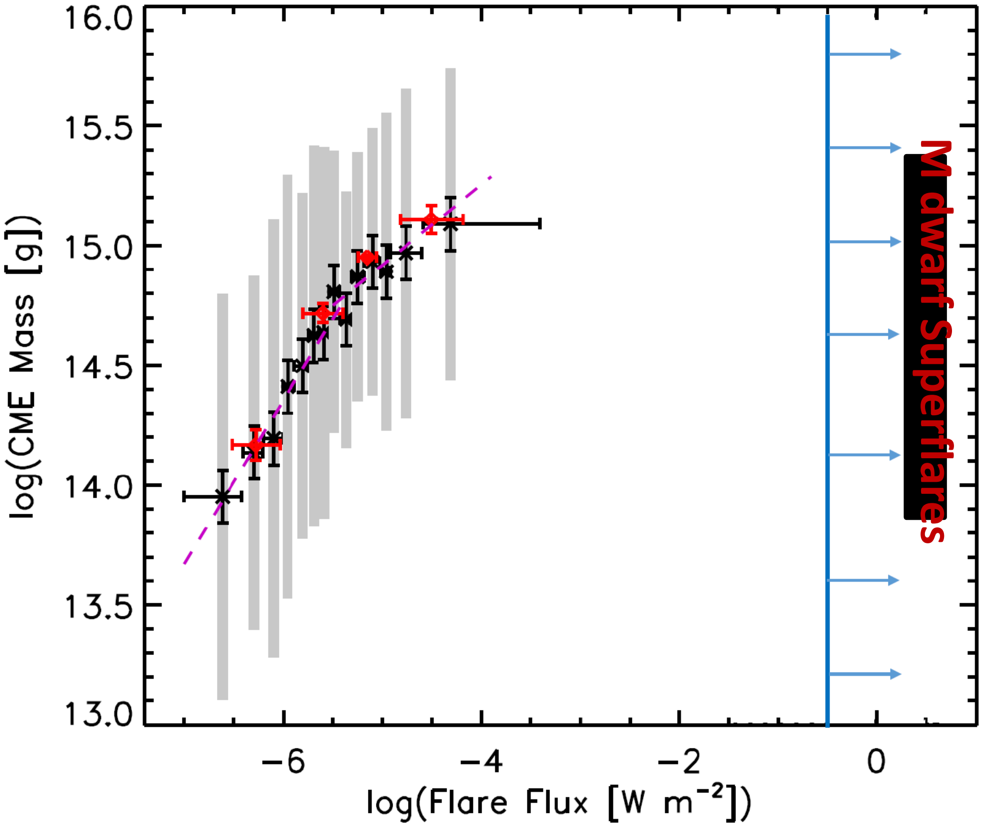
- Serendipitous!

Radio Emission from Solar System Planets

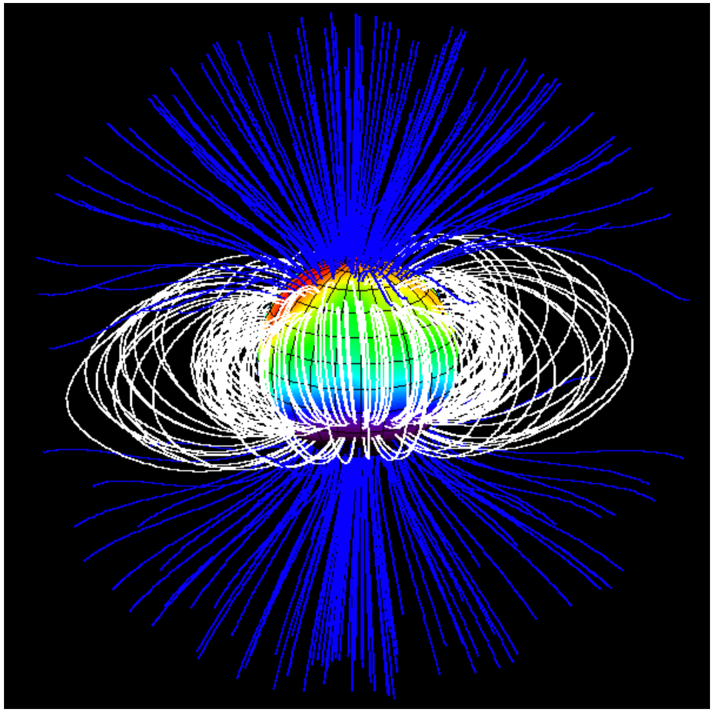
- All gas giants and Earth have strong auroral radio emission
- Electron cyclotron maser emission – coherent, highly circularly polarized



Stellar CMEs



Adapted from Aarnio et al. 2012



Donati et al. 2006

No direct evidence of CMEs on any star other than the Sun to date

Magnetic field configuration may be play an important role (Alvarado-Gómez et al. 2018)