Preparing for FARSIDE: OVRO-LWA

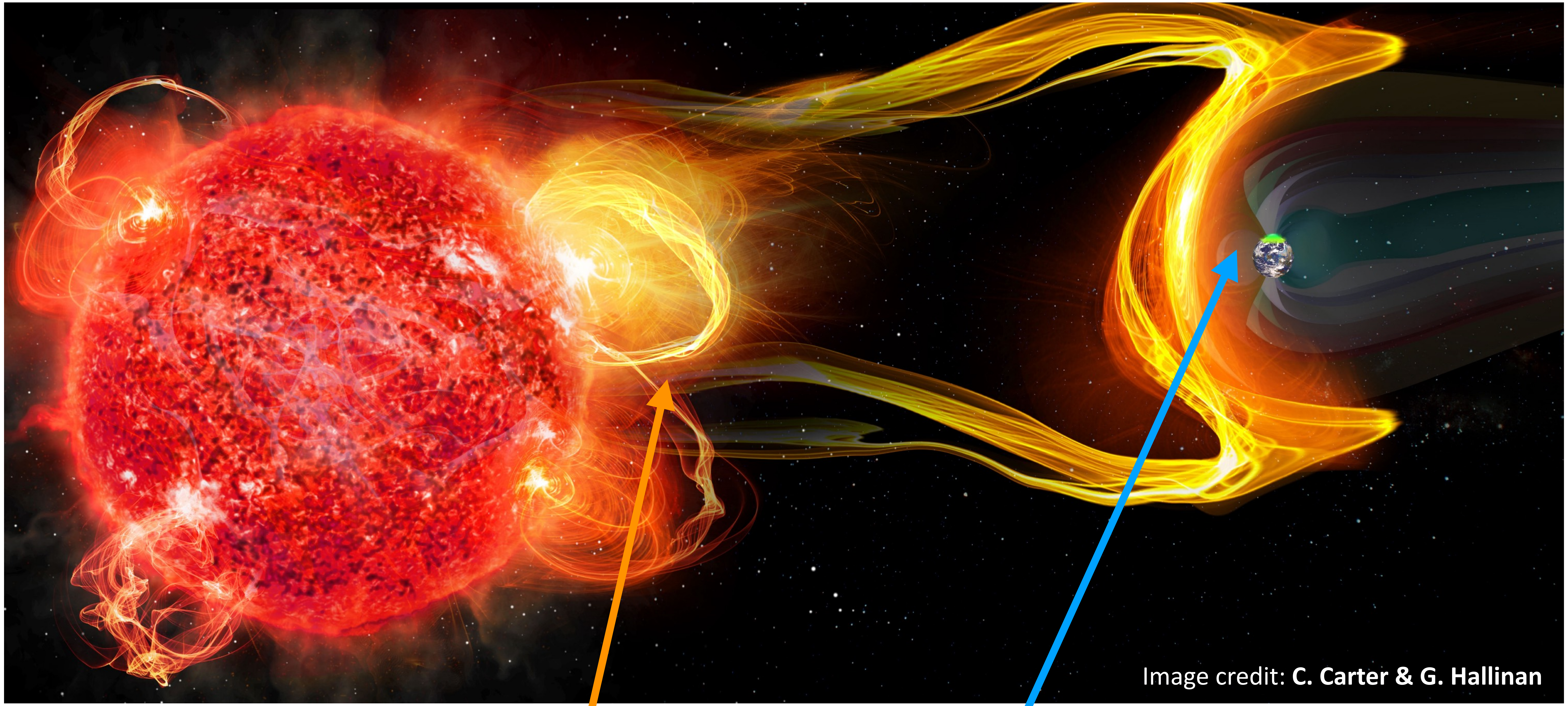
Marin M. Anderson
JPL, OVRO-LWA Project Scientist

NESS
Network for Exploration and Space Science

November 30, 2020
SSERVI NESS Site Visit

RICE | ASU | JPL Jet Propulsion Laboratory California Institute of Technology | Caltech | NJIT New Jersey Institute of Technology | LWA Long Wavelength Array | NSF | SIMONS FOUNDATION

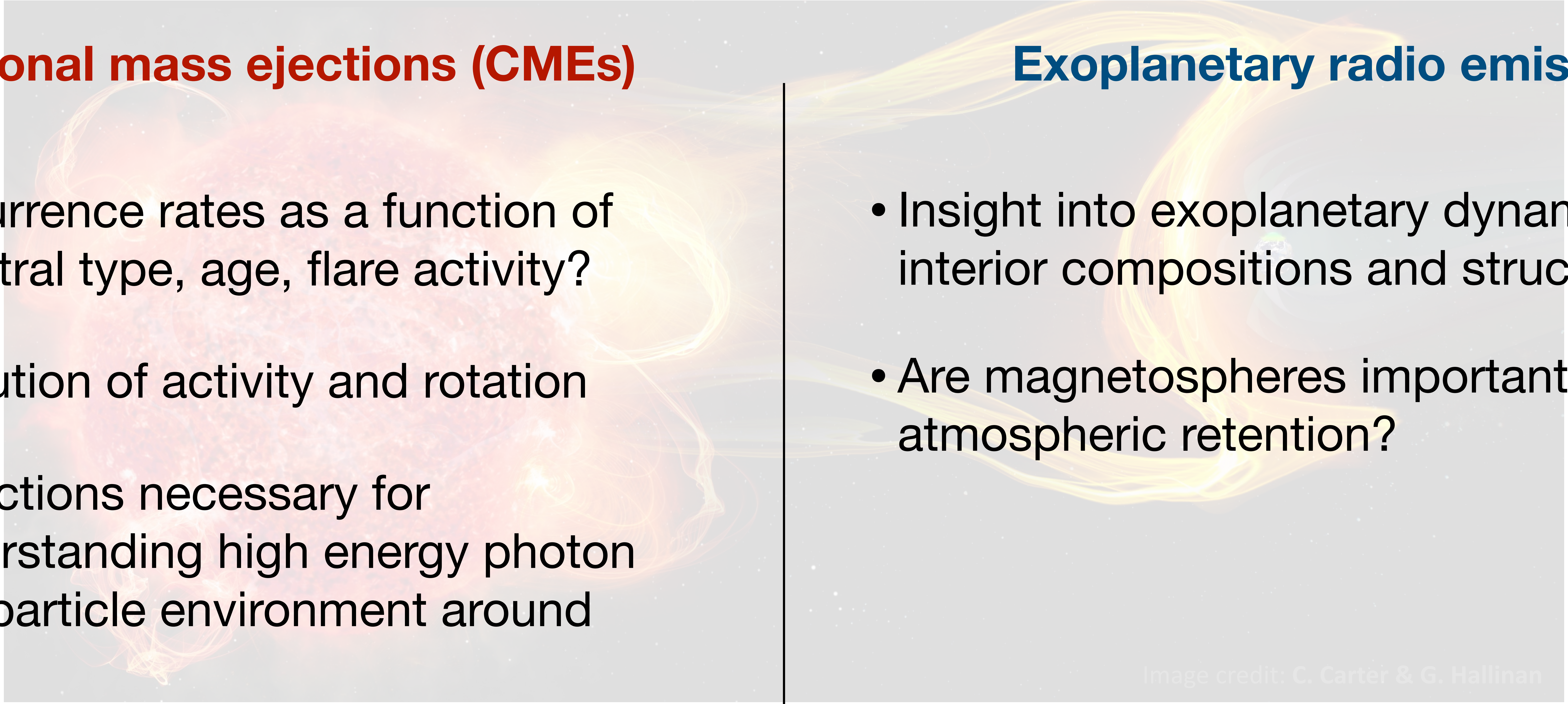
Measuring exoplanetary and stellar radio emission is critical for understanding how both the exoplanetary magnetosphere and the surrounding space weather environment influences habitability.



Coronal mass ejections (CMEs)

Earth's Auroral Kilometric Radiation (AKR)

Measuring exoplanetary and stellar radio emission is critical for understanding how both the exoplanetary magnetosphere and the surrounding space weather environment influences habitability.



Coronal mass ejections (CMEs)

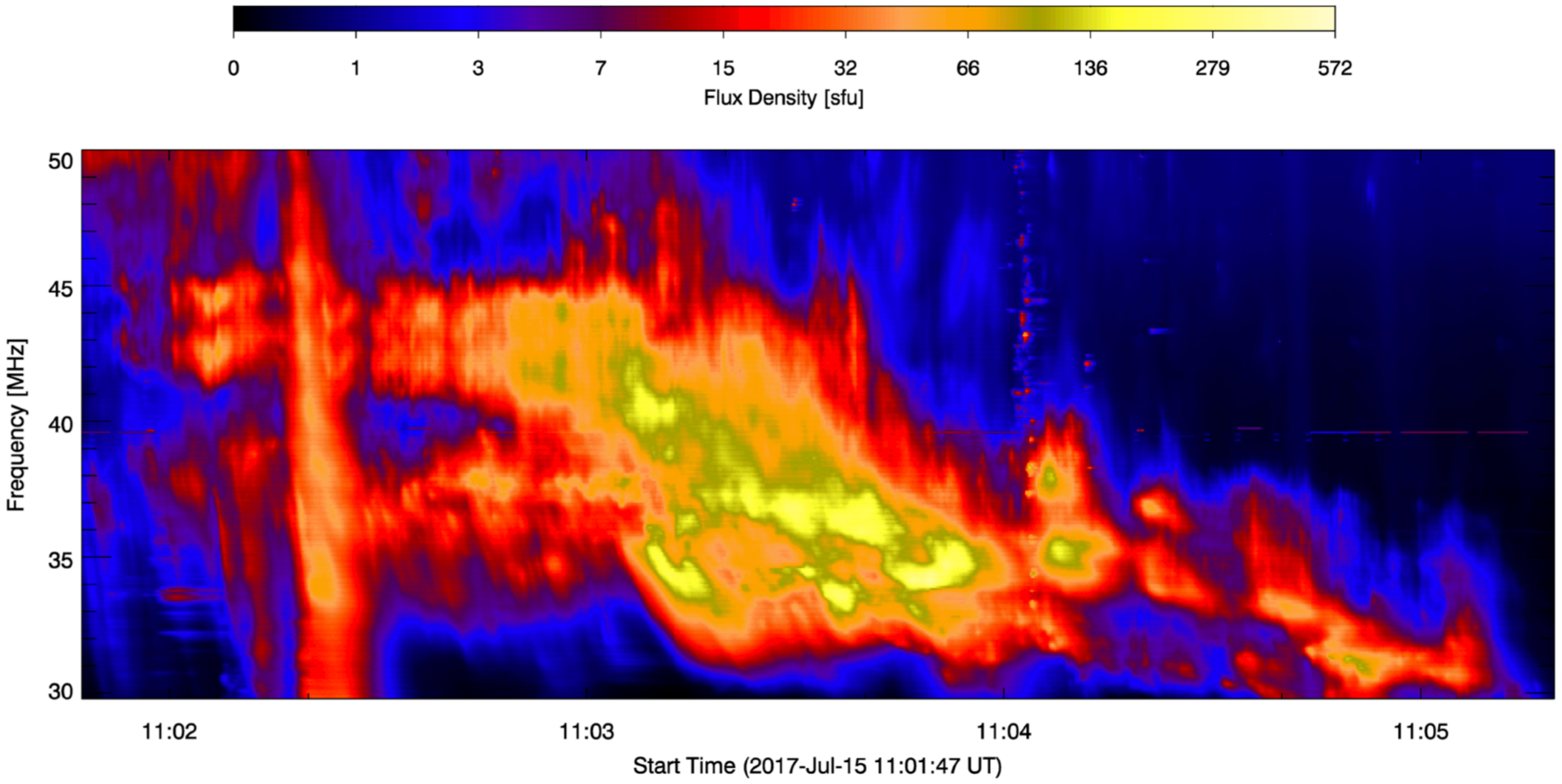
- Occurrence rates as a function of spectral type, age, flare activity?
- Evolution of activity and rotation
- Detections necessary for understanding high energy photon *and* particle environment around stars

Exoplanetary radio emission

- Insight into exoplanetary dynamos, interior compositions and structure
- Are magnetospheres important for atmospheric retention?

Coronal mass ejections (CMEs)

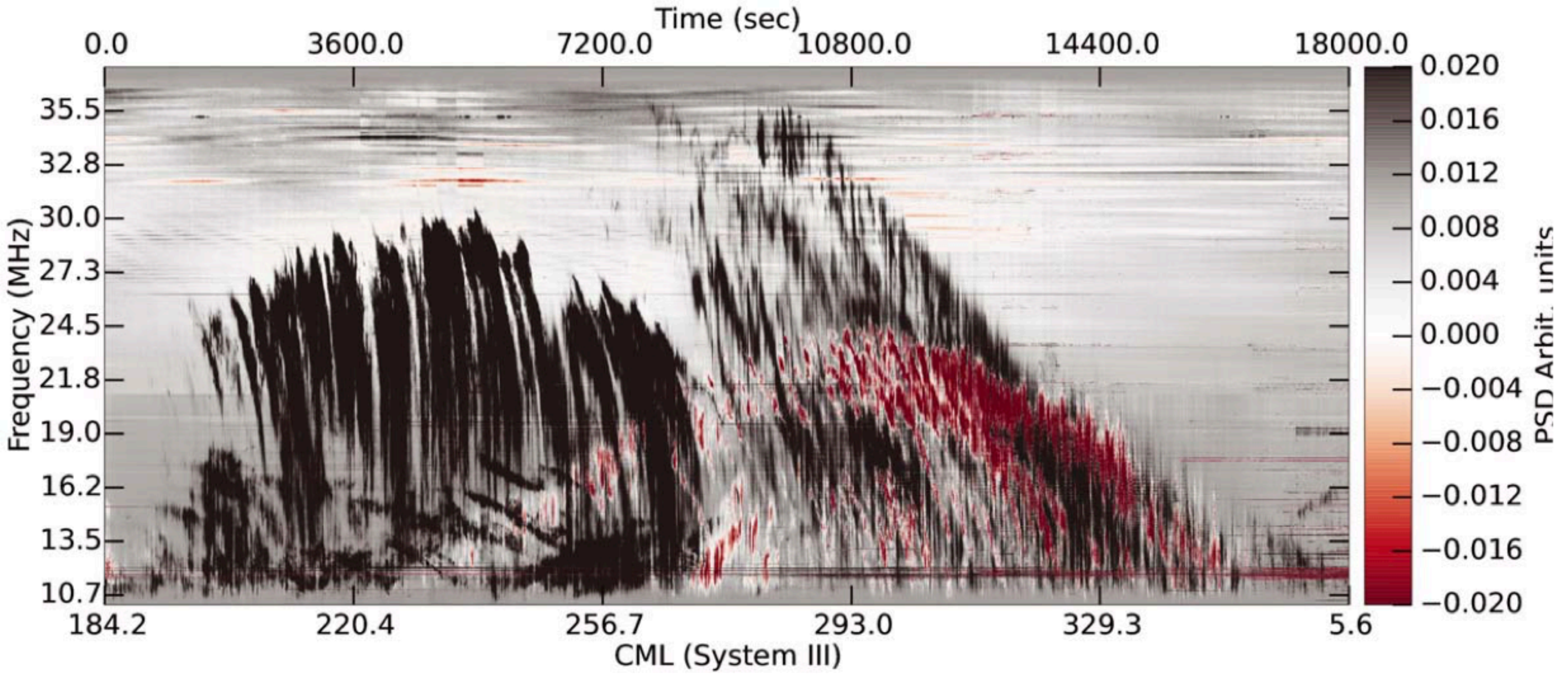
- Solar CMEs are associated with Type II radio bursts
- Langmuir waves —> plasma emission
- $\nu_p \propto \sqrt{n_e}$



Chrysaphi et al. 2020

Exoplanetary radio emission

- Electron cyclotron maser emission (ECME)
- $\nu_{\text{cyc}} \propto B$
- Emission is circularly polarized and beamed in a hollow cone with large opening angle along magnetic field



Clarke et al. 2017

How can we optimize the search for extrasolar space weather, and begin detecting and characterizing a wide range of systems en masse?

- **Low frequency (< 100 MHz) observations**
- **Large field-of-view instruments**
- **Capitalize on characteristics of emission mechanisms (Stokes V)**

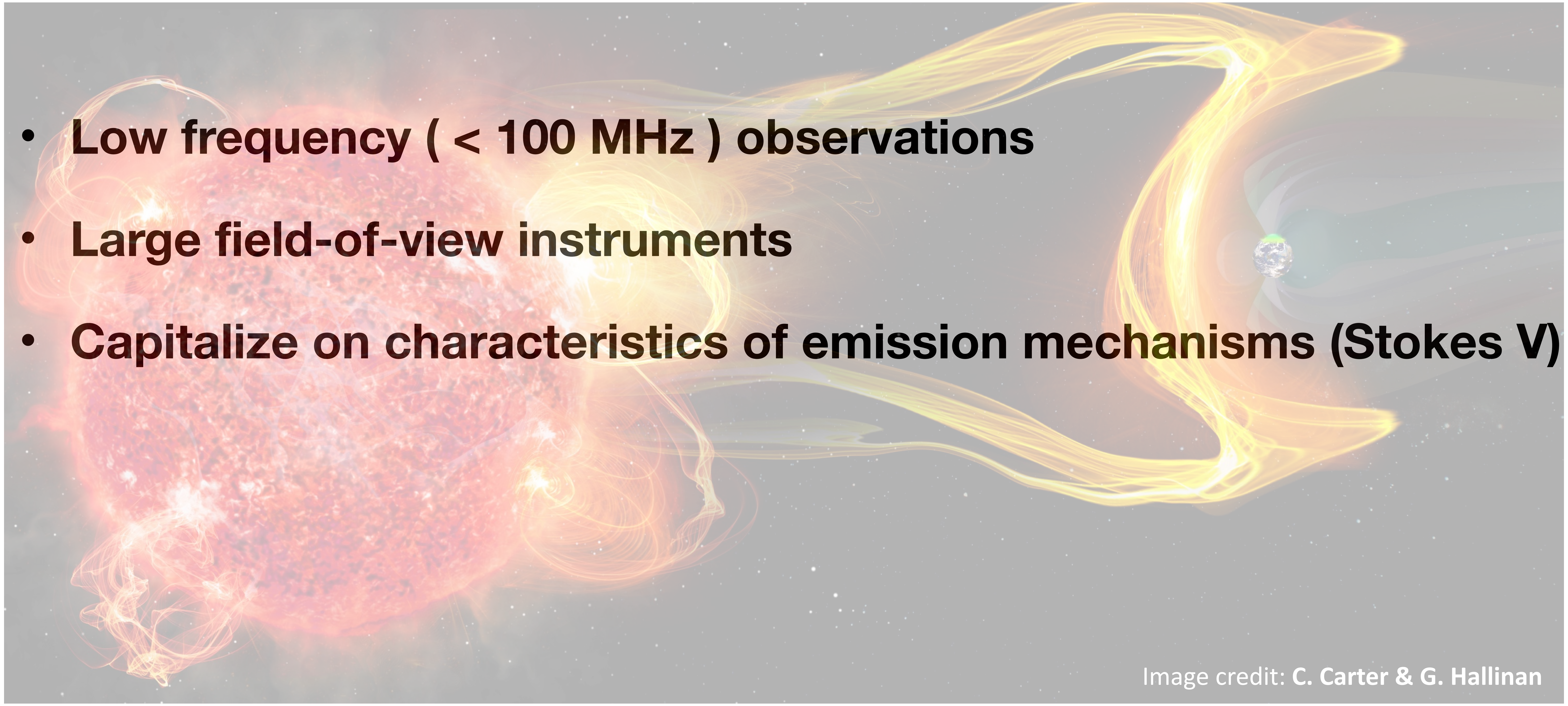
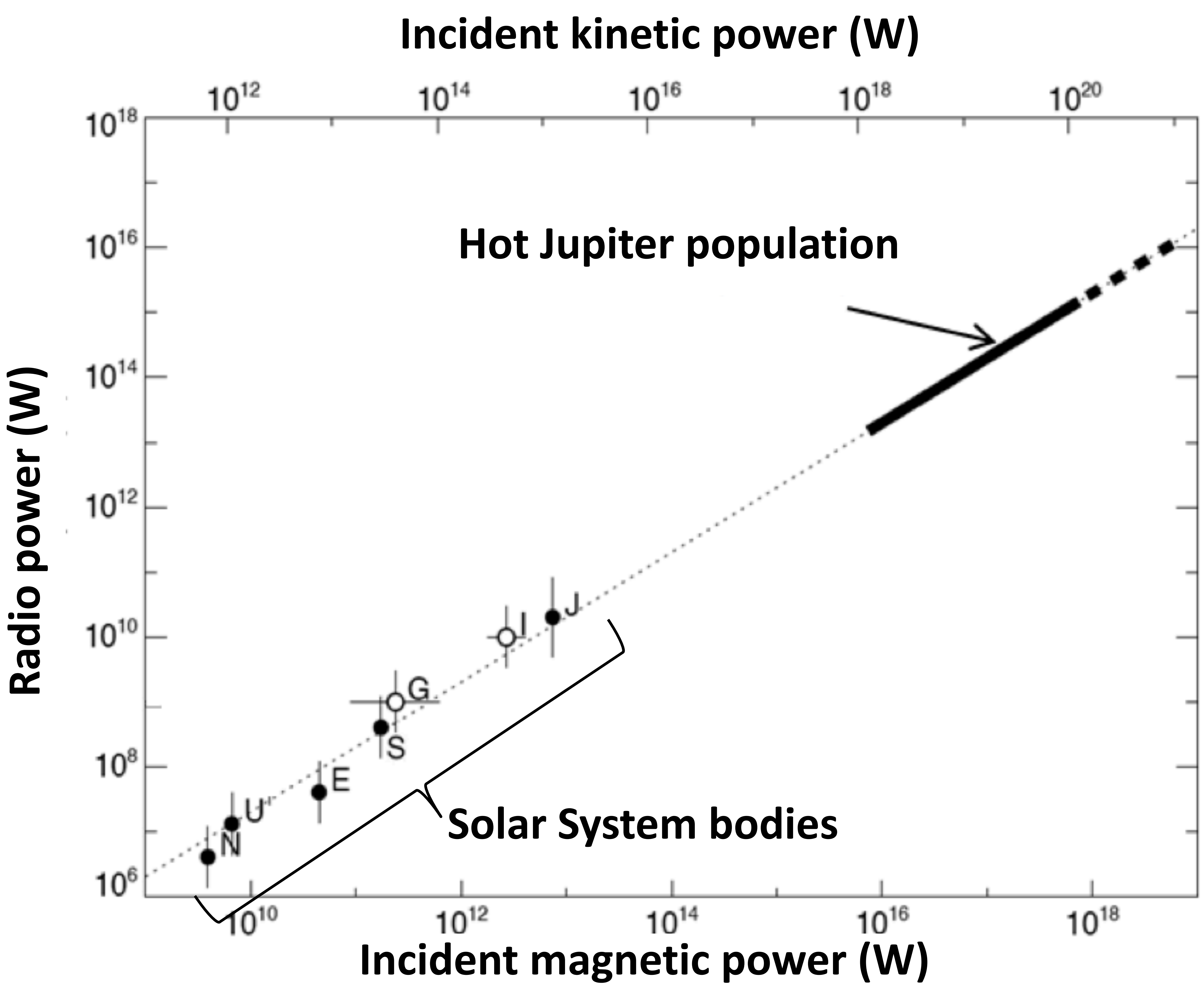
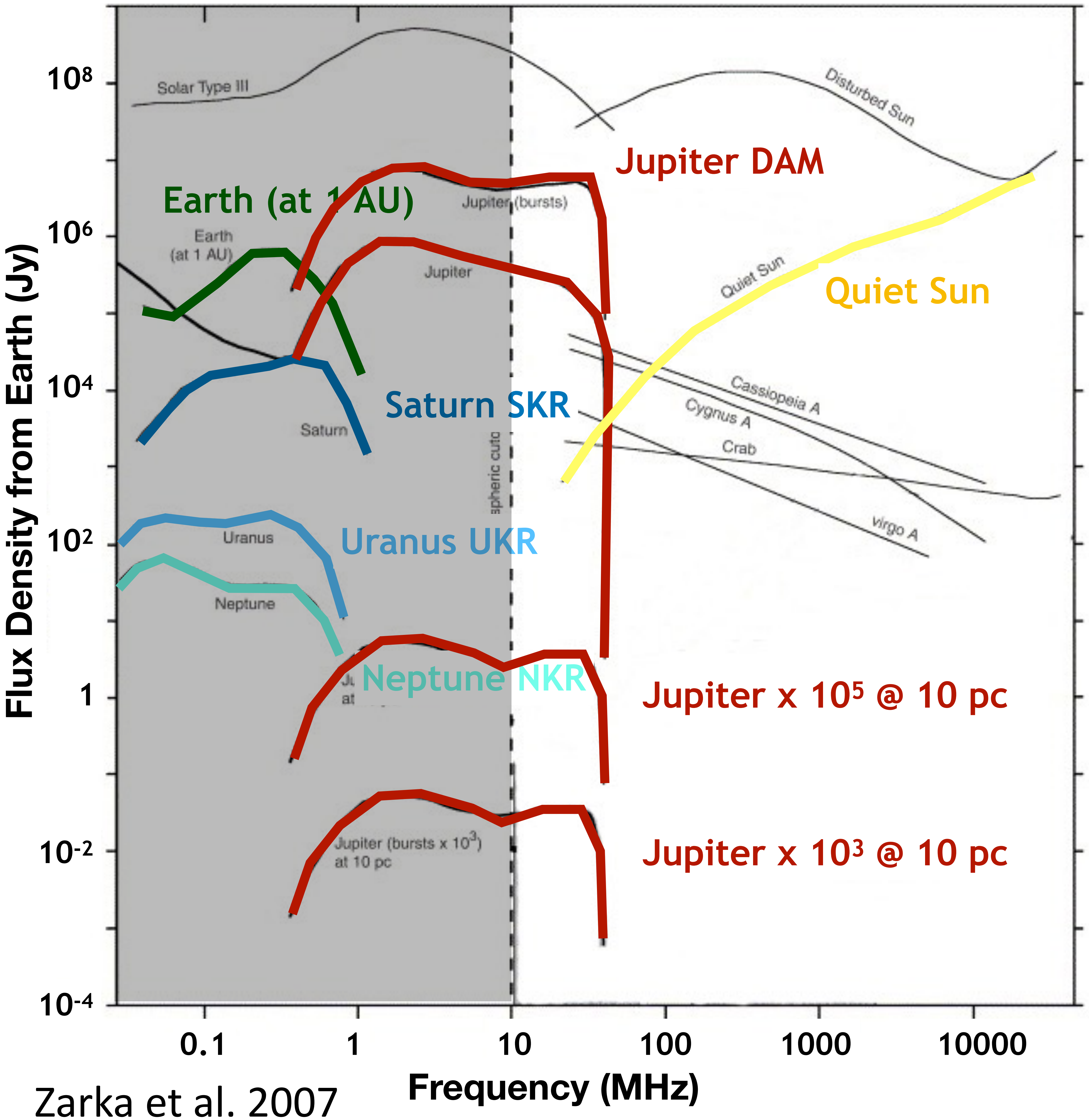


Image credit: **C. Carter & G. Hallinan**

Extrapolation from our own solar system suggests it is necessary to go below 100 MHz to directly detect exoplanetary radio emission.



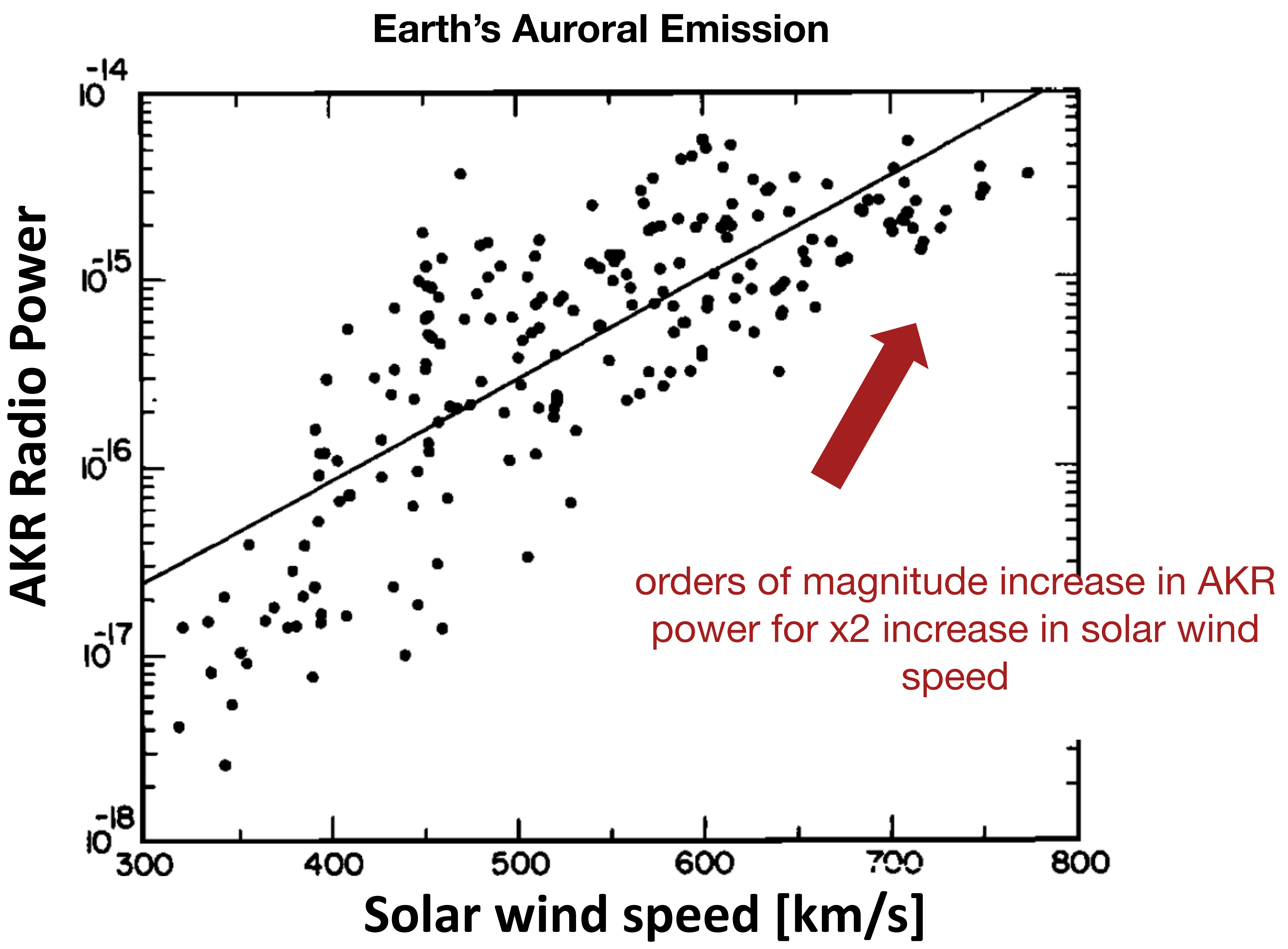
Zarka 2001



Zarka et al. 2007

Capture a large fraction of the sky in order to simultaneously monitor a large sample of objects.

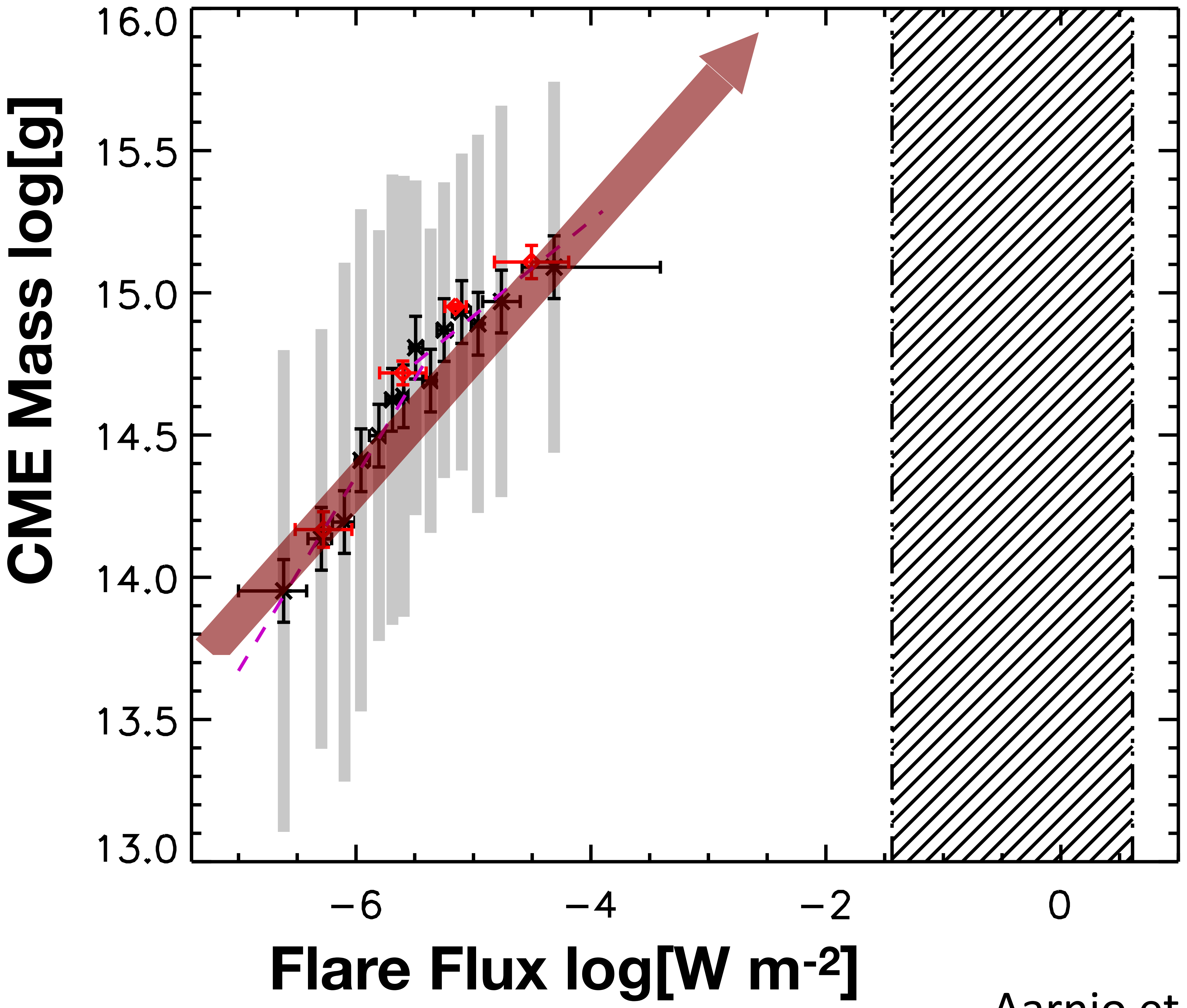
- Sensitive to rare CME-driven events that can increase the output power in exoplanetary radio emission by orders of magnitude.



Gallagher & D'Angelo 1981

It remains an open question whether the Solar flare–CME relation can be extrapolated to higher flare energies and more magnetically active stars.

Relationship between CME mass and flare flux for the Sun



Aarnio et al. 2010

Owens Valley Radio Observatory
Long Wavelength Array (OVRO-LWA)

Stage I OVRO-LWA (2013-2014)

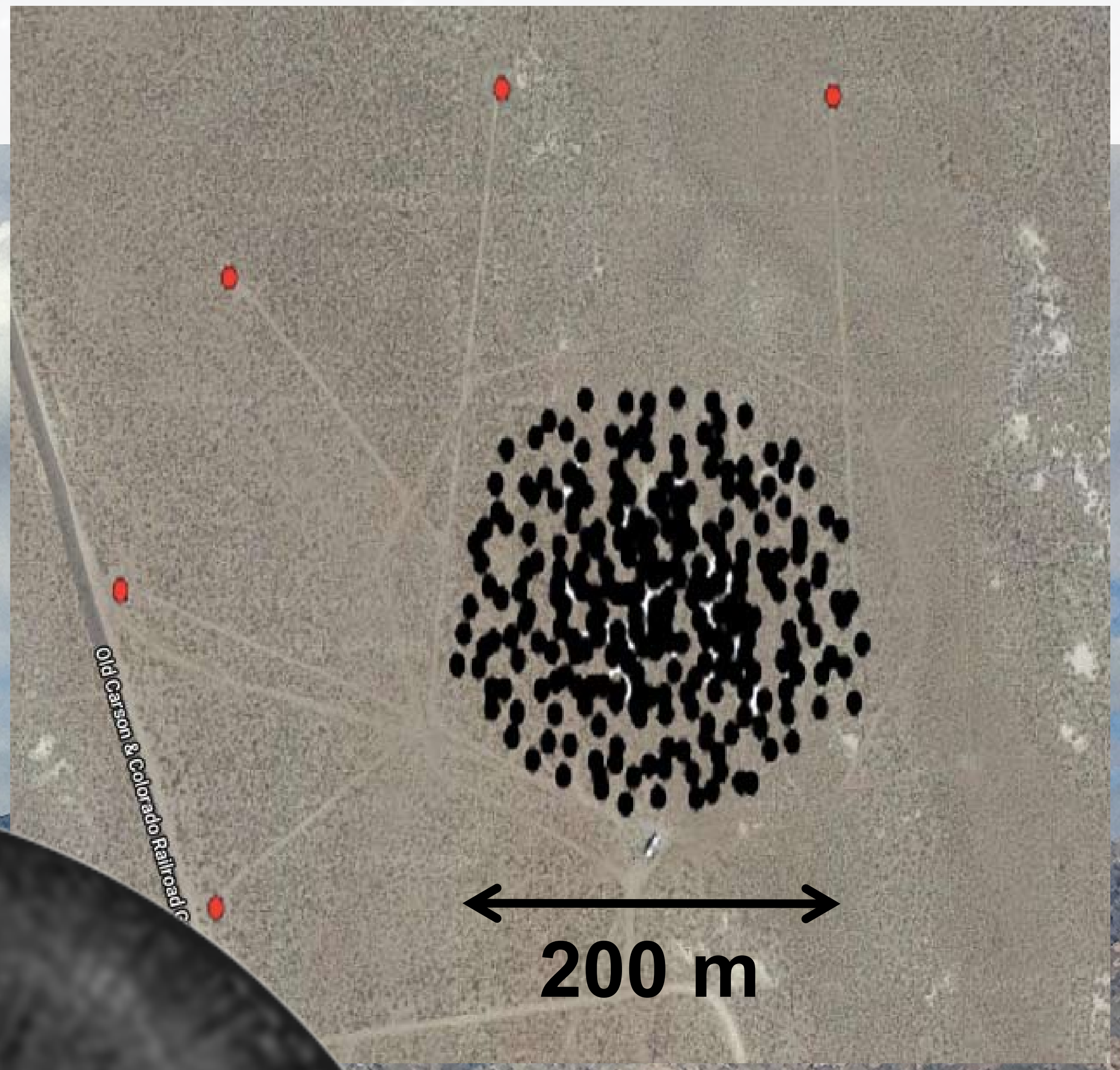
Stage II OVRO-LWA (2015-2016)

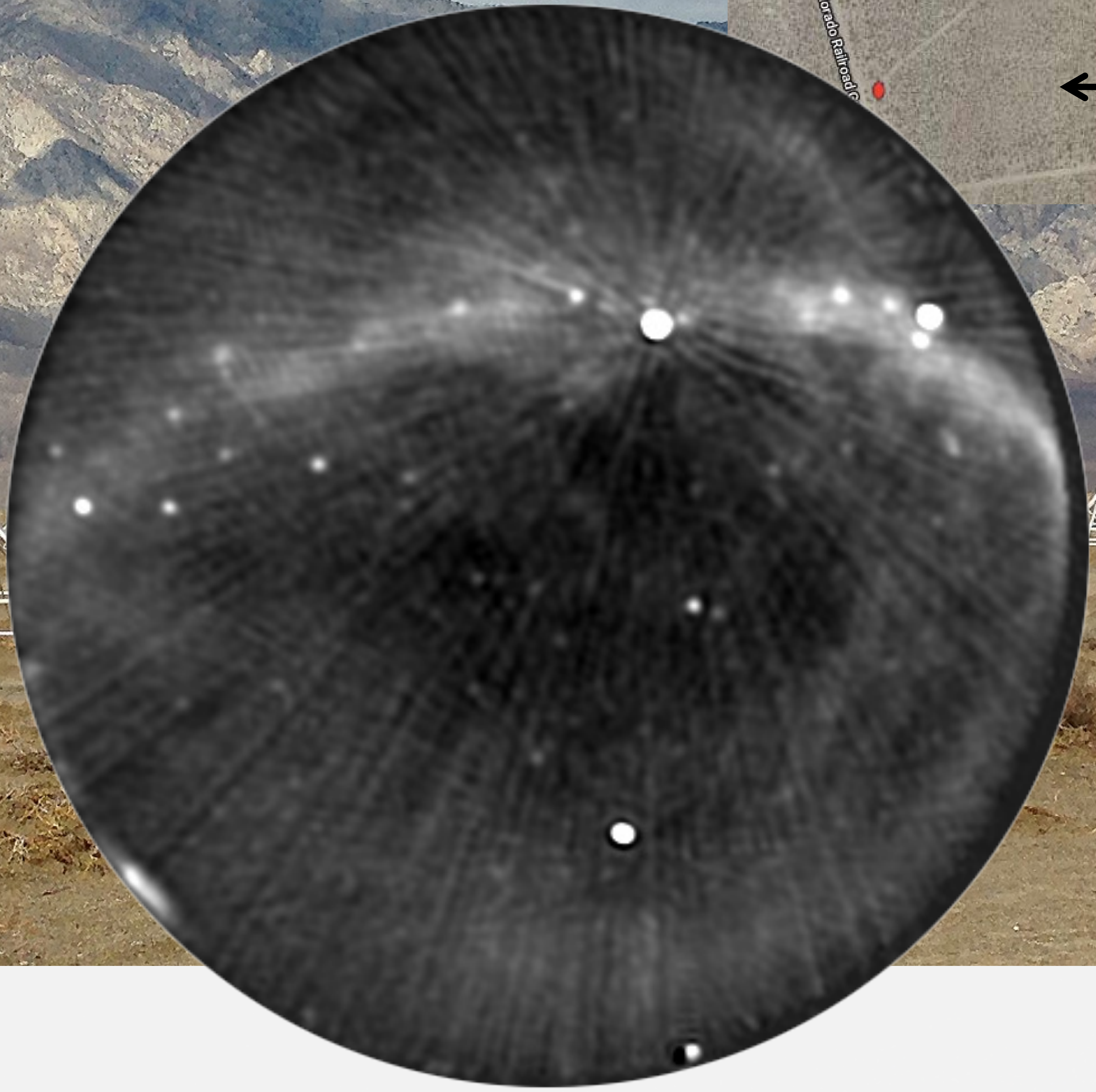
Stage III OVRO-LWA-352 (2019-)

OVRO-LWA Stage I (2013–2014)

- 251 LWA crossed-dipole antennas, in 200 m diameter core
- 5 LEDA antennas — total power measurements (**Price+2018**)
- 28-84 MHz band, 24 kHz resolution
- full cross-correlation with 512-input LEDA correlator (**Kocz+2015**)
- 1 deg resolution

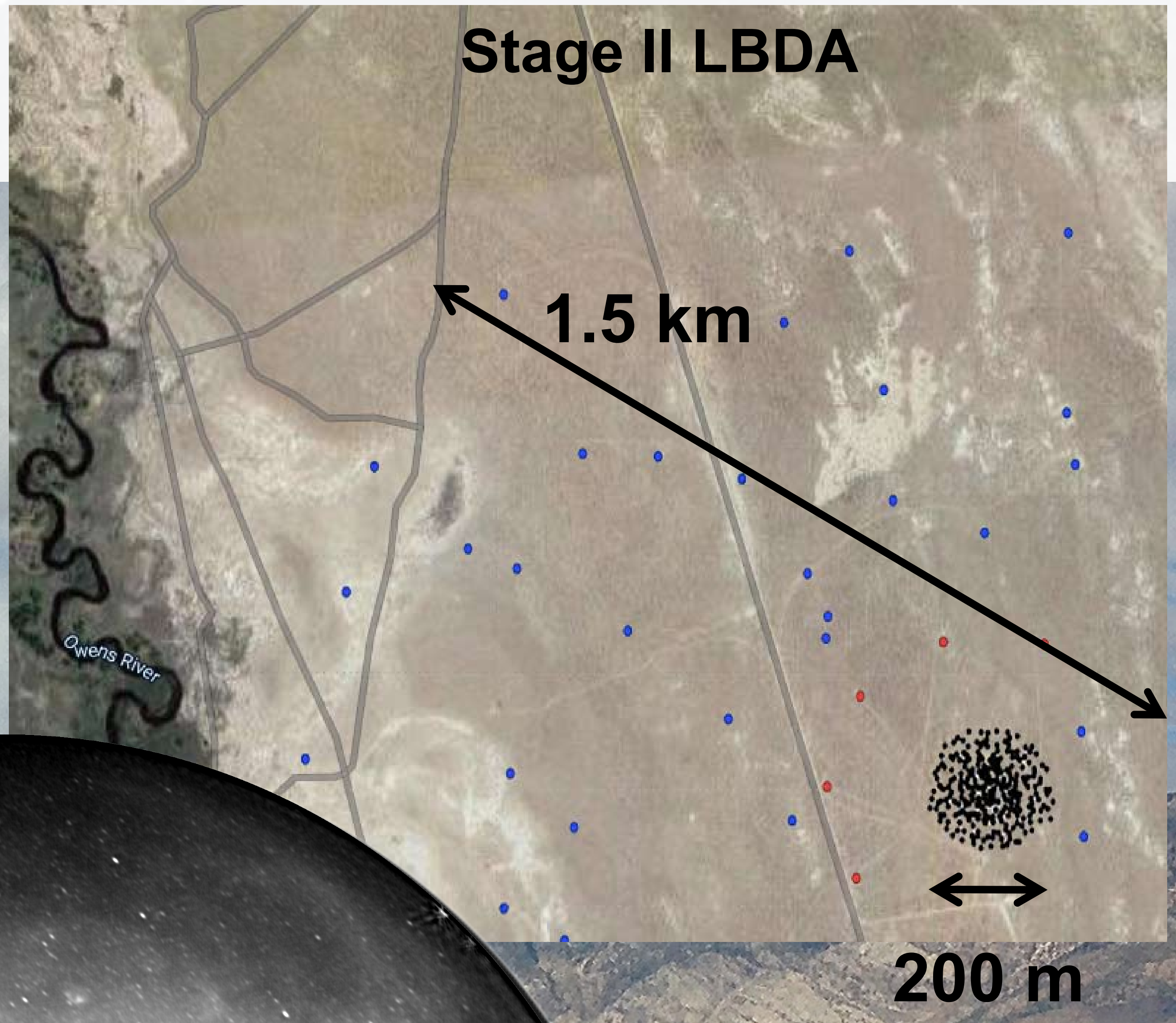
Stage I Core Array

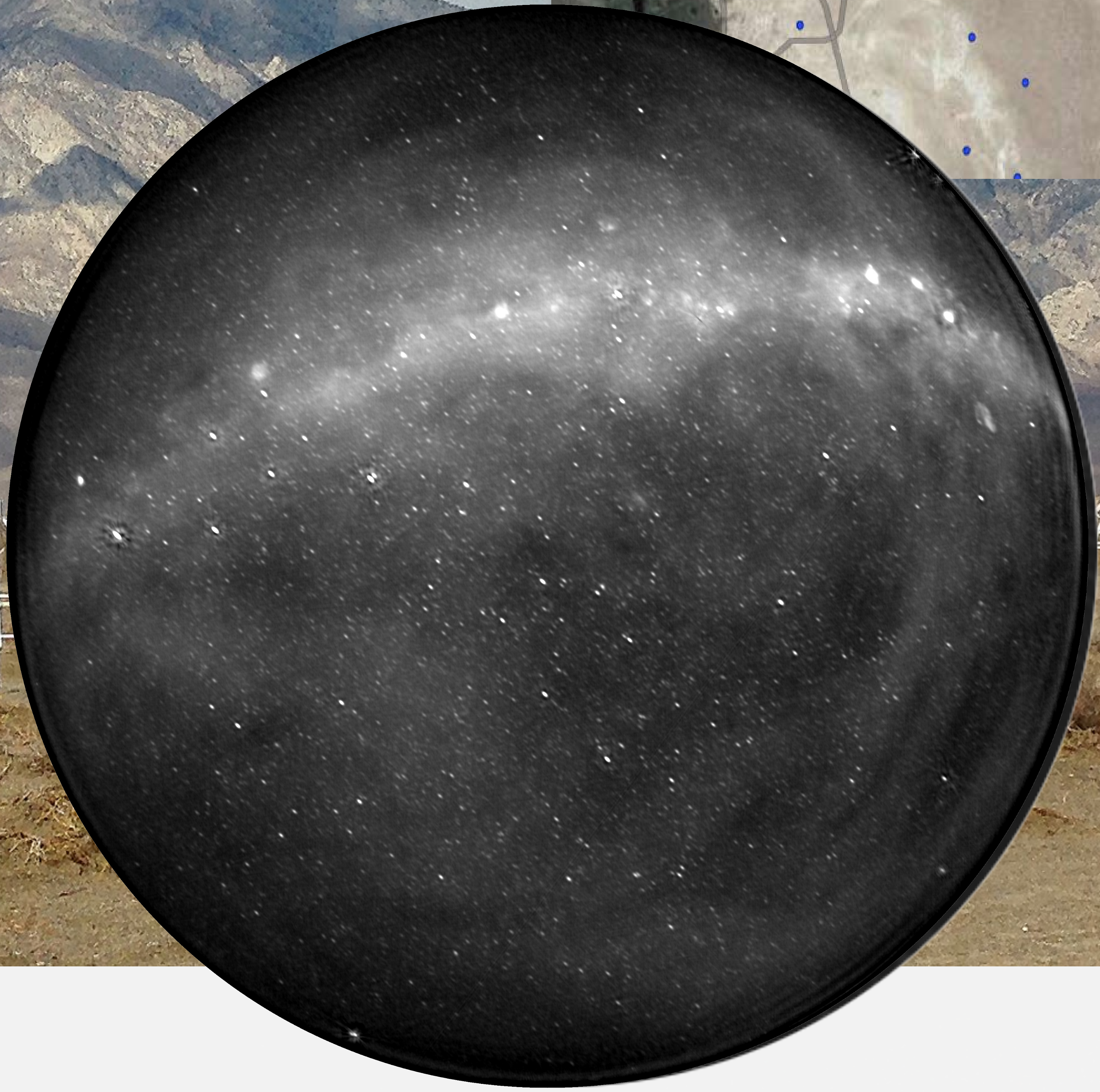




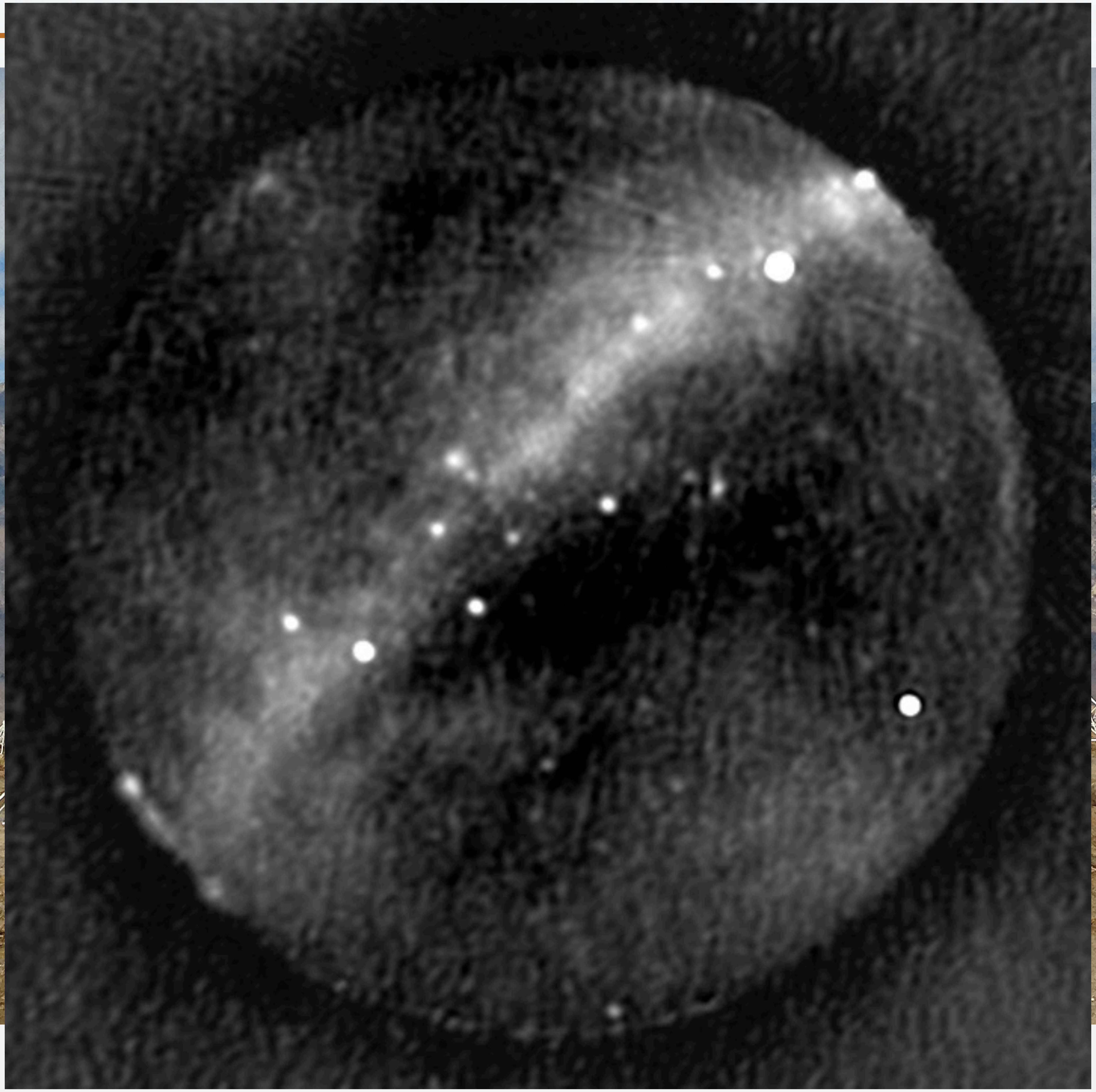
OVRO-LWA Stage II (2015–2016)

- 32 additional antennas out to 1.5 km (Long Baseline Demonstrator Array)
- RF signal transport over optical fiber
- 7 arcmin resolution at top of band
- >10,000 point sources in single 13 s snapshot
- ~800 mJy snapshot sensitivity



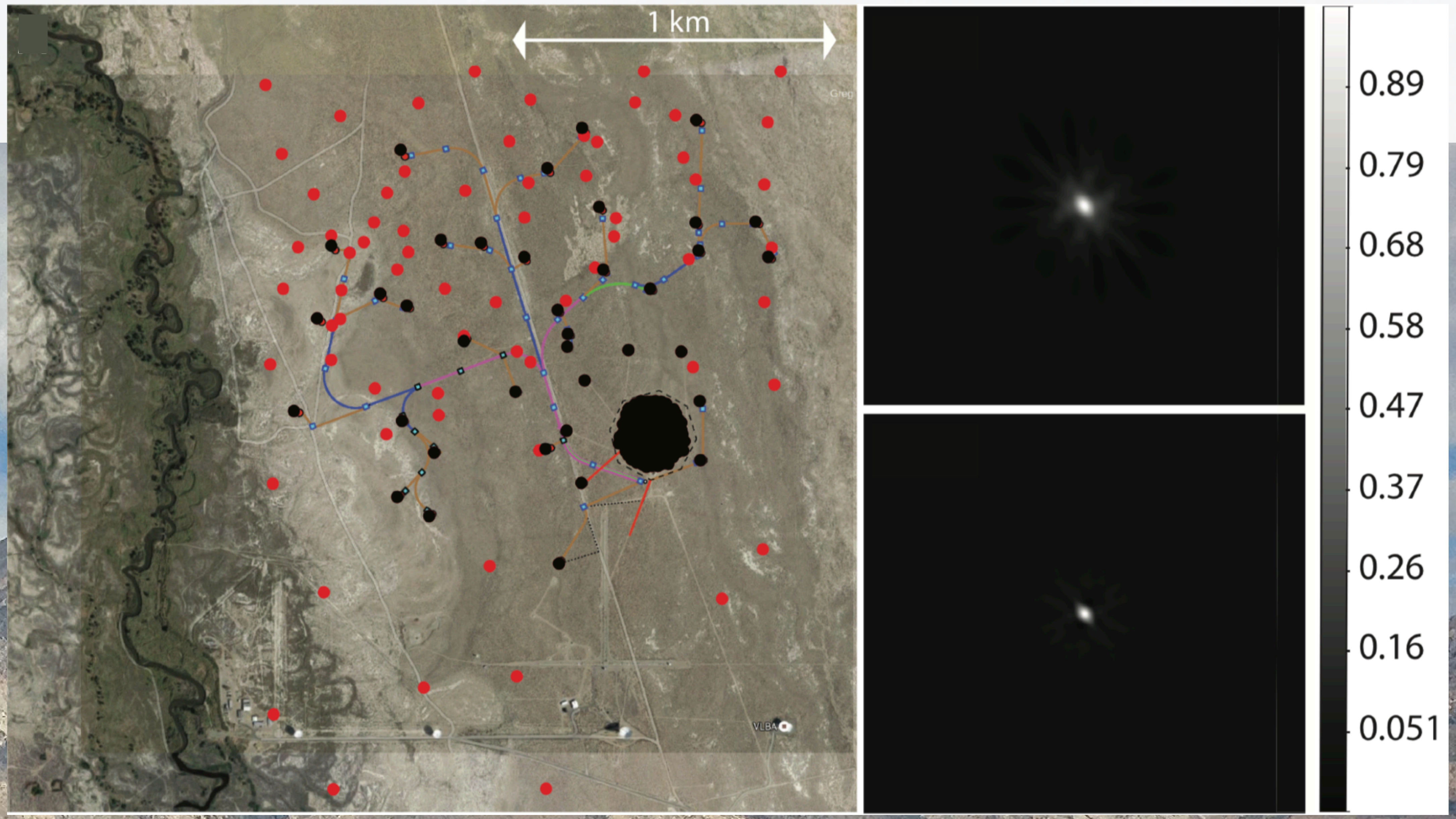


OVRO-LWA Stage II (2015–2016)



OVRO-LWA-352 (2019–)

- Additional 64 antennas **out to 2.6 km**, for a **total of 352**
- Complete redesign of the analog receiver boards
- Digital backend redesign, next-gen correlator (maintaining the FPGA/GPU architecture of the existing 512-input LEDA), with **704 inputs and 70 MHz BW**
- Upgraded calibration and imaging cluster, **3 PB usable storage and 4 TB RAM**



Simultaneous!

standard correlation mode
beamforming mode (12 beams)
cosmic ray detection

Extrasolar space weather monitoring with the OVRO-LWA

Triggered follow-up observations

- Data pulled from buffer in response to detection of flare
- 2 X-ray triggers from MAXI on RS CVns

AR Lac

- 2019-11-26 03:00–06:00 UTC
- 27.3–53.5, 56.1–85 MHz
- 43 pc, G2+K0

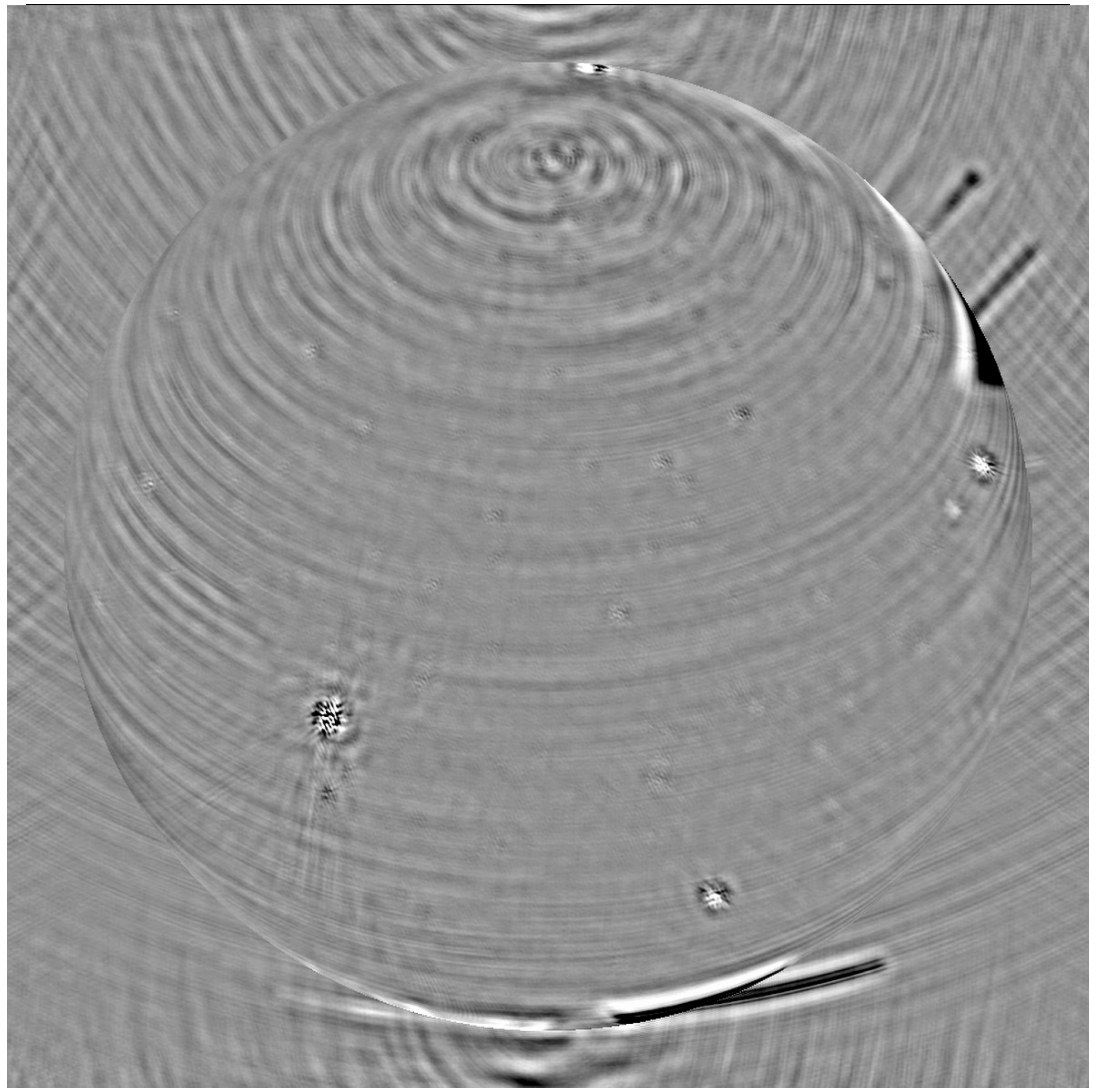
HR 1099

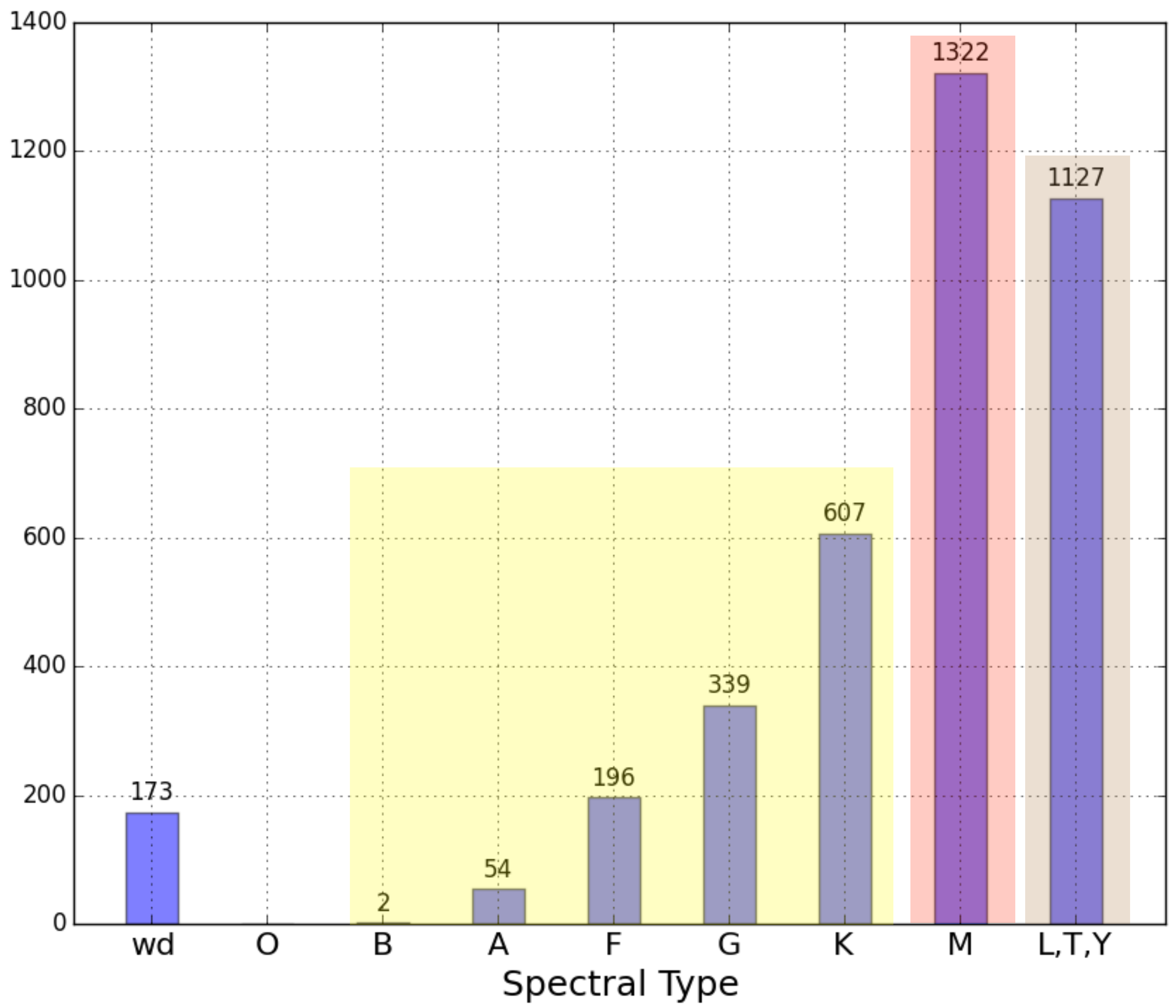
- 2020-02-11 22:00 – 01:00 UTC
- 27.3–48.3, 50.9–85 MHz
- 30 pc, K2+G5

1000-hour dataset

- 1082 hours collected (mostly continuous)
- Subbands 02–07: 33–48 MHz
- Science with the 1000-hour dataset includes
  - Epsilon Eridani monitoring
  - Search for radio emission associated with TESS flares
  - Hot Jupiter sample
  - 25-pc sample

Extrasolar space weather monitoring with the OVRO-LWA





- Volume-limited sample of nearly 4000 systems.
- Search for signatures of space weather across a broad range of stellar ages and spectral types.