The Magnetospheres and Space Weather Environments of Extrasolar Planets

Optimized Strategies for Detecting Extrasolar Space Weather

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Sunspot AR2673
Severe storm conditions met at: 07/2350 UTC
- Flares – higher X-ray and ultraviolet radiation flux $\rightarrow$ photochemical reactions leading to significant atmospheric loss

- Coronal mass ejections (CMEs) – higher stellar wind flux $\rightarrow$ can erode atmosphere – eg. ion pick-up of a CO$_2$-rich atmosphere
Magnetic activity can redefine habitability!
Small planets dominate planetary demographics and favor smaller stars (Howard et al. 2012). Rocky planets are particularly frequent around M dwarfs (Dressing & Charbonneau 2013, 2015). The nearest habitable planet likely orbits an M dwarf at 2.6 +/- 0.4 pc.
Is magnetic activity important for defining habitability?
Can we directly detect CMEs and planetary magnetic fields?

Yes – with radio observations

Credit: KISS/Caltech
Low Frequency Radio Emission

Type II radio emission associated with CMEs

Planetary auroral radio emission
Strategy 1: Targeted Searches
Ongoing Searches for Stellar CMEs

Long bursts (>~1 hour)
Requires ongoing electron acceleration

Short bursts (sec - min)
Powered by individual flares?

AD Leo (M3.5)  UV Cet (M6)  YZ CMi (M4.5)

- Stellar dynamic spectroscopy a mature field (Bastian & Bookbinder 1987, Osten & Bastian 2006)
- Recent study – 21 bursts with ultra-wide bandwidth, no Type II bursts (Villadsen, GH et al. 2018)

- Need more sensitivity at lower frequencies!
Exoplanet Searches

- Searches have been ongoing for > 30 years
- No detections
- See Lazio et al. 2009 for review
New Kids on the Block

LOFAR: 10-240 MHz

MWA: 80-300 MHz

HERA: 50-250 MHz

LOFAR: 10-240 MHz

LWA: 10-90 MHz
Mostly detected with the VLA at GHz frequencies → kG magnetic fields
- see recent reviews by Pineda, GH and Kao 2017; Williams 2017
Radio Emission from a Candidate Free Floating Planet – SIMP0136

- Brightest T dwarf in the northern hemisphere (Artigau et al. 2006)
- Carina Near moving group association - age of 200 Myr (Gagne et al. 2017)

Estimated mass of $12.7 \pm 1.0$ Jupiter masses – first radio exoplanet?
Magnetic fields $\sim 3$ kG
Gaia will find many more candidates for the VLA...
- Long-term monitoring of nearest candidate habitable exoplanet hosts (e.g. Alpha Cen system)
- Can we detect solar-like CMEs on Alpha Cen AB and Proxima Centauri?
- Do M dwarfs produce radio bursts (and CMEs) as energetic as the Sun?
- Exoplanets detection via this method likely requires $>10^4$ dipoles
Strategy 2: Multiplexed Searches
Space Weather Is highly Variable

Gallagher & D’Angelo 1981

Li, Zhang & Feng 2016
The OVRO-LWA: An Extrasolar Space Weather Telescope
UV Ceti: M5.5 + M6 (2.7 pc)
Epsilon Eridani: K2 (3.2 pc)
GJ725: M3 + M3.5 (3.5 pc)
Ross 248: M3 (3.2 pc)
61 Cygni: K5 + K7 (3.5 pc)

288-antenna performance: 500 mJy (10 s); 50 mJy (1 hr)
352-antenna performance: 100 mJy (10 s); 5 mJy (1 hr); 1 mJy (1 day)
Monitors ~4,000 stellar/planetary systems out to 25pc

Anderson, GH et al. 2017
Planetary radio emission subject to scaling laws for magnetic field strength and input solar wind power (e.g. see Farrell et al. 1999)

Adapted from Burkhart & Loeb 2017

Proxima b

L-ROLS - 100 lunar-based dipoles

Adapted from Burkhart & Loeb 2017
Contextual Data in the Search for Biosignatures
Strategy 3: Triggered Searches for Biosignatures
Triggered Alerts from a Lunar Array

Simulated high-resolution spectrum of Proxima Cen b with 0.1 TW auroral emission at 5577 Å (Luger et al. 2017)
Understanding the impact of stellar activity and the presence of planetary magnetic fields is becoming increasingly important for defining planetary habitability.

Low frequency radio observations are key.

The long-term future is from the lunar far-side.

Targeted searches are computationally low-cost but limited.

Multiplexed searches require significant in-situ computational resources.

Triggered searches for biosignatures present an exciting possibility.