LOFAR Searches for Radio Exoplanets

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Twitter: @Astro_journey
Exoplanet Magnetic Fields

Motivation

– Interior structure
– Star-planet interactions
– Ohmic dissipation
– Solar System comparison
– Habitability


“To be habitable, a planet needs warmth, water, and it needs to be sheltered from a young, violent sun.” Jose-Dias Nascimento (2016, APJL, 820, L15)
Radio Observations

- Best method to study planetary magnetic fields (Grießmeier 2015)
- Electron cyclotron emission

![Solar System Radio Spectrum](Image)

Zarka 1998

Normalized flux density at 1 AU, W m\(^{-2}\) Hz\(^{-1}\)

- Frequency, kHz
- Space
- Ionospheric cutoff
- Ground
Radio Flux & Frequency Predictions

Zarka+ 2015; Grießmeier+ 2011

Flux Density (Jy)

Frequency (MHz)

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LOFAR Observations

• 16-73 MHz
• IQUV
• 10 msec & 3 kHz
• 22 mJy sensitivity: 2 mins over full band

Observational Campaign:
• 3 Beams (ON & 2 OFF)
• 4 exoplanets so far
• Over full orbital coverage

Turner+ 2017
5.2.2. RFI Mitigation

We run RFI mitigation on the pre-processed data in slices. The mask, which is an array the same dimensions as the data of 0 (polluted pixels) and 1 (clean pixels) weight, is saved after each slice. To accomplish this task, we use the program RFI MITIGATE developed by Phillip Zarka and Iana (cite thesis). The program RFI MITIGATE consists of 4 main RFI mitigation techniques and has
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<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>40</td>
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<tr>
<td>40</td>
<td>30</td>
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<tr>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>60</td>
<td>10</td>
</tr>
</tbody>
</table>

Intensity (Arbitrary)

Response of telescope

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Dynamic Spectra

Sky: Stokes–I

Sky: Stokes–V

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55 Cnc Planetary System

- One of best targets for radio observations due small orbital distance, proximity (12.3 pc), and multiplicity (Grießmeier+ 2007).
- Emission from 55 Cnc e possible: tens of MHz with flux densities up to hundreds of mJy (Grießmeier+ 2007, Jardine+ 2008).
55 Cnc Results (Stokes-I)

- No emission from 55 Cnc in Stokes-I
- $3\sigma$ upper limit $\rightarrow$ 2.6 Jy (50x theoretical sensitivity!)

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No emission from 55 Cnc in Stokes-V

3σ upper limit $\rightarrow$ 100 mJy ($2x$ theoretical sensitivity)
Jupiter as an Exoplanet

- Scale Jupiter radio emission as if it was exoplanet
- Find an upper limit of detectability
- Guide in exoplanet search
Jupiter as an Exoplanet

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Detection Limits

- **Stokes-I**: $10^6 \times$ Jupiter max bursts @20 pc
- **Stokes-V**: $10^5 \times$ Jupiter max bursts @20 pc

Turner+ 2018 (submitted)

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Dynamic Spectra from Imaging

V830Tau

Loh+ 2017 (in prep)

Direction Dependent Calibration

Image curiosity of Alan Loh (LESIA)

LOFAR HBA (120-190 MHZ)

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Conclusions

• Stokes-I and Stokes-V LOFAR pipelines now done
• $3\sigma$ upper limit on 55 Cnc radio emission in Stokes-V of 100 mJy (2x thermal noise)
• Scaled Jupiter radio emission as if it was exoplanet (Jupiter as an exoplanet)
• Find upper limit of $10^5 \times$ Jupiter max bursts @20 pc (Stokes-V)

Questions?

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