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The search for radio emission from the exoplanetary systems 55 Cnc, Upsilon Andromedae, and Tau Boötis using LOFAR beam-formed observations

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Abstract

The detection and characterization of exoplanetary radio emission would constitute a new and important field of exoplanet science. We present LOFAR low-frequency circularly polarized radio observations of the three exoplanetary systems 55 Cnc, Upsilon Andromedae, Tau Boötis. We find 20-30 MHz emission from both Upsilon Andromedae and Tau Boötis and constrain their magnetic fields to be $\sim$11 G. The detection of Tau Boötis is the most conclusive exoplanetary radio signal to date. However, follow-up observations are highly needed to confirm these detections.

1. Introduction

One of the most elusive hunts in exoplanet science today is the detection of exoplanetary magnetic fields. Observations of an exoplanet's magnetic field would allow constraints on planetary properties difficult to study such as their interior structure (composition and thermal state), atmospheric escape, and the physics of star-planet interactions ([7], [1], [8]). Additionally, the magnetic fields on Earth-like exoplanets might help contribute to their sustained habitability by deflecting energetic stellar wind particles, cosmic rays, and UV radiation ([1]).

Out of all the methods proposed to detect the magnetic fields of exoplanets, radio emission observations are considered to be the most promising since they are not susceptible to false positives [1]. Over the past few decades, a number of observational campaigns searching for exoplanetary radio emission have been performed (see [1] for an overview). None of these campaigns have achieved a confirmed radio detection yet. In parallel, a number of studies have attempted to estimate the radio flux density that can be expected for different types of exoplanets (e.g. [6]). Indeed, the most recent estimated flux densities are close to the sensitivity of modern low-frequency radio telescopes ([7], [1], [8]). In particular, [2] find that the flux densities of 15 exoplanets are above the theoretical detection limit of LOFAR as given by [3].

In this study, we analysis LOFAR LBA beam-formed observations of 3 exoplanetary systems (55 Cnc, Upsilon Andromedae, Tau Boötis) predicted to be ideal candidates ([2]) to search for exoplanet emission.

2. Method

We observe the exoplanetary systems 55 Cnc, Upsilon Andromedae, and Tau Boötis with the Low-Frequency Array (LOFAR; [5]) Low Band Antenna (LBA) in beam-formed mode. In all, 22 observations were taken with a total of 95 hours. In order to differentiate a physical signal from RFI, we use one ON-beam and two OFF-beams ([3]). In this study, we focus on the circularly polarized (Stokes-V) data. All data was ran through the BeamfORmEd AweSome (`BOREAS`) pipeline ([3]; [4]). The `BOREAS` pipeline performs RFI mitigation, finds the time-frequency (t-f) response function of the telescope, subtracts the data by this t-f function, and rebins the data in broader time and frequency bins. The post-processing part of the `BOREAS` pipeline consists of a series of observable quantities Q1 to Q4 that search for faint emission (see [4])

Next, to search for possible emission we first examined the observable plots by eye and then performed an automated search. In total, $\sim$19000 plots were examined. As an important benchmark, the two OFF beams were always compared to each other. Any supposed ON signal that was also detected when comparing the two OFF beams was considered a false-positive.

3. Results

We find possible detections for both Upsilon Andromedae and Tau Boötis in our data. The Tau Boötis detection was found by examining the time-series (Q1a) and integrated spectrum (Q1b) plots for one date (Figure 1). For the ON-beam points in Q1a, 100% of the points are above both OFF-beams by several sigma. The OFF-beams are exactly the same within 1 σ for both Q1a and Q1b highly suggesting that there is an additional signal in the ON-beam. Further examination of Q1b, determined that the bulk of the emission is coming from 21–30 MHz. We find that the probability of a false-positive detection for obtaining a signal that seen in Figure 1 is 1×10^{-11} or 6.8 σ. The Upsilon Andromedae detection was found by examining the Q4f observable for one observation from 20-30 MHz.

4. Summary and Conclusions

In this study, we obtain and analyze LOFAR LBA beam-formed Stokes-V observations of the exoplanetary systems 55 Cnc, Upsilon Andromedae, and Tau Boötis. We find possible Stokes-V emission from 20–30 MHz for both Tau Boötis (Figure 1) and Upsilon Andromedae. Under the assumption that the 2 OFF-beams fully-characterize the ON-beam, the Tau Boötis detection is the most conclusive of any exoplanet radio detection to date. Using these observations, the polar magnetic fields for both targets are constrained to be $\sim$11 G. The observed signal is 289 and 1300 mJy for Tau Boötis b and Upsilon Andromedae b, respectively. Follow-up observations from LOFAR and other low-frequency telescopes (e.g. UTR-2, LWA-OLWA, NenuFAR) are needed to confirm these detections. We find a 3σ upper limit for for the 55 Cnc system of 93 mJy. This study highlights the promise of using beam-formed observations to study exoplanetary radio emission.

References

[1] Grießmeier, J.-M. 2015, ASSL, 211, 213

[2] Grießmeier, J.-M. 2017, PRE VIII, 285–299

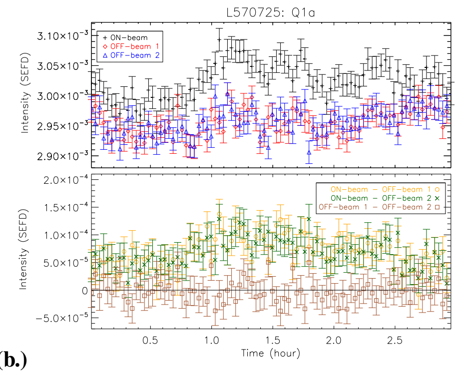
[3] Turner, J. D., et al. 2017, PRE VIII, 301–313

[4] Turner, J. D., et al. 2019, A&A, 624, A40

[5] van Haarlem, et al. 2013, A&A,556, A2

[6] Zarka, P., et al. 1997, PRE IV, 101

(a.)



(b.)

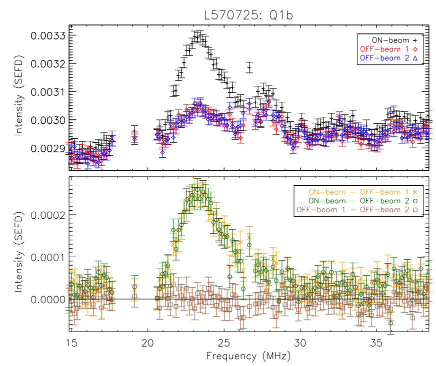


Figure 1: Time-series (*panel a*) and integrated spectrum (*panel b*) detection plots in Stokes-V for Tau Boötis. In *panel a*, the ON-beam shows excess signal at all times above both OFF-beams. In *panel b*, the signal in the ON-beam is concentrated between 21–30 MHz and is distinctly different than both OFF-beams. In all plots, the two OFF-beams are exactly the same within the errors.

[7] Zarka, P., et al. 2015, AASKA14, 120

[8] Zarka, P. 2018, Exoplanet Handbook, 22

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