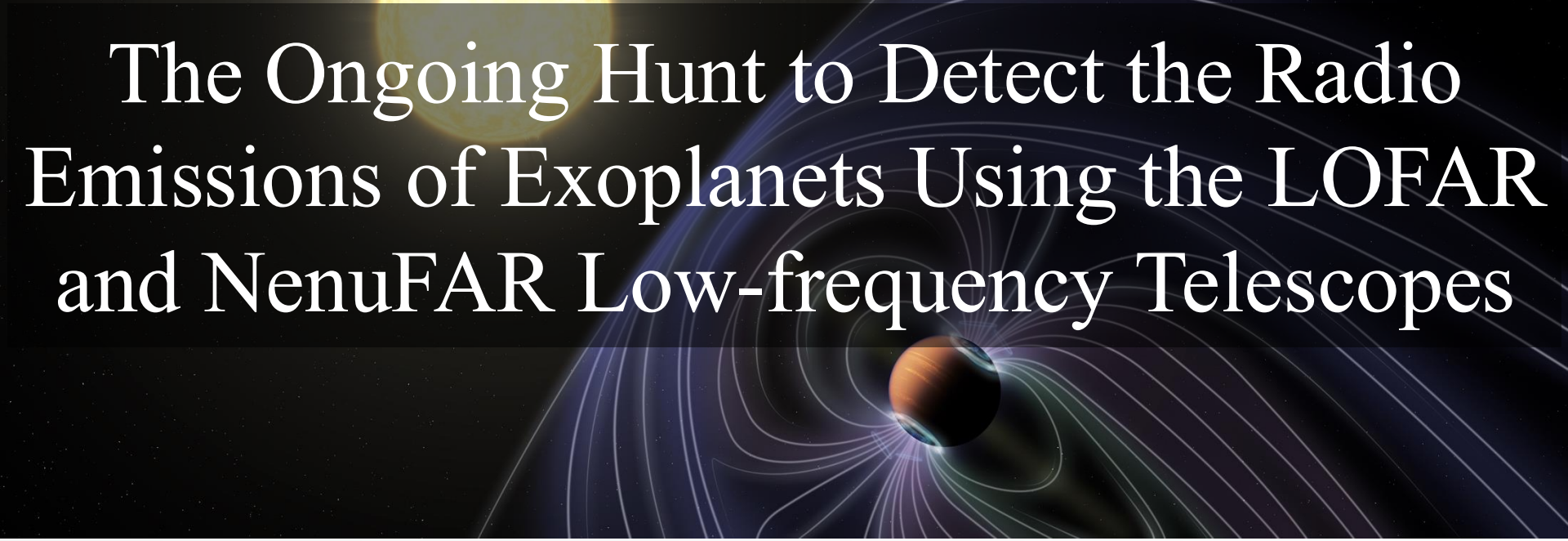
The Ongoing Hunt to Detect the Radio Emissions of Exoplanets Using the LOFAR and NenuFAR Low-frequency Telescopes



Jake D. Turner (he/him)

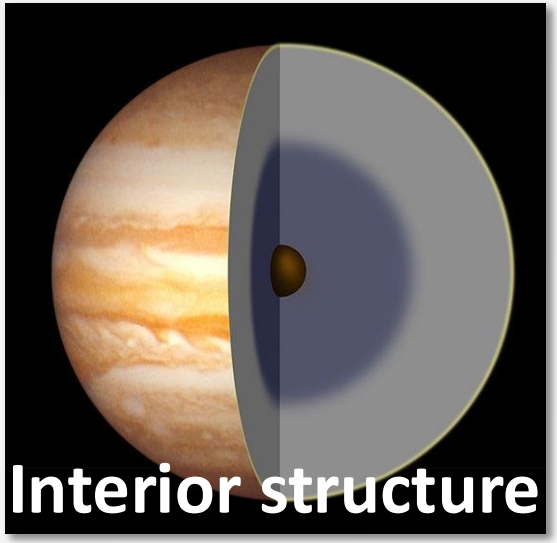
Cornell University and Carl Sagan Institute

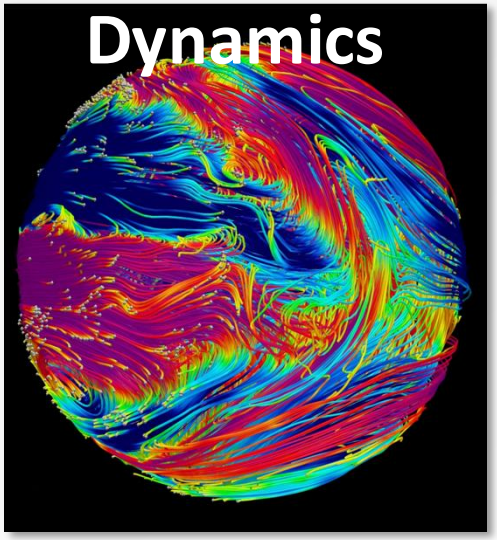
Ad ASTRA Workshop: September 1, 2026

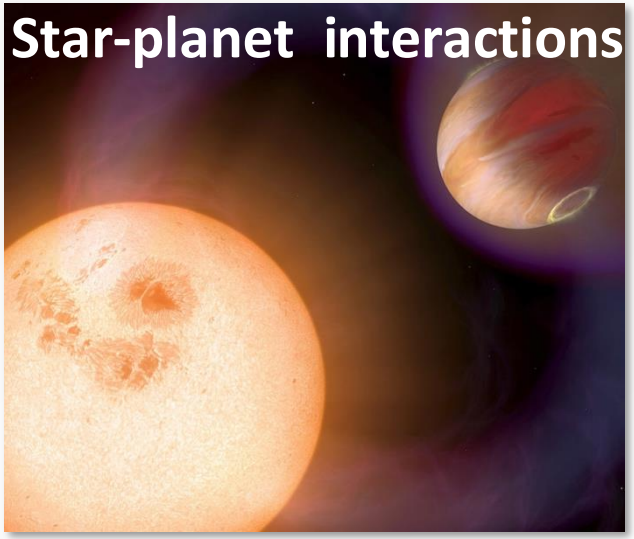
Collaborators: Philippe Zarka, Jean-Mathias Grießmeier, Xiang Zhang, Emilie Mauduit, & NenuFAR Exoplanets Team

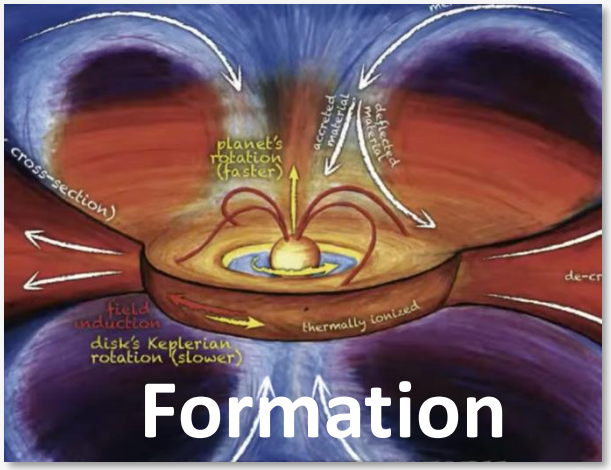
CARL SAGAN INSTITUTE

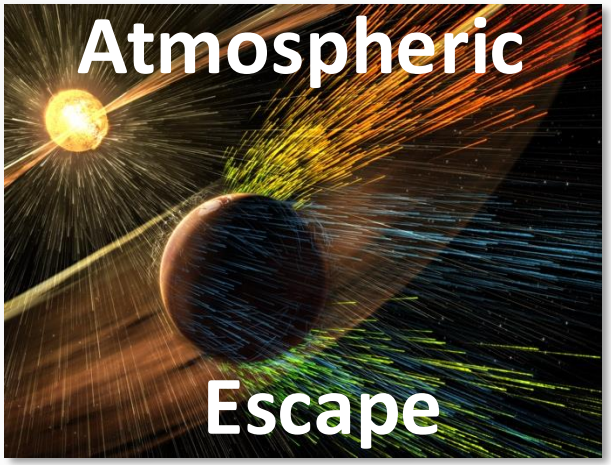
Why care about exoplanet magnetic fields?

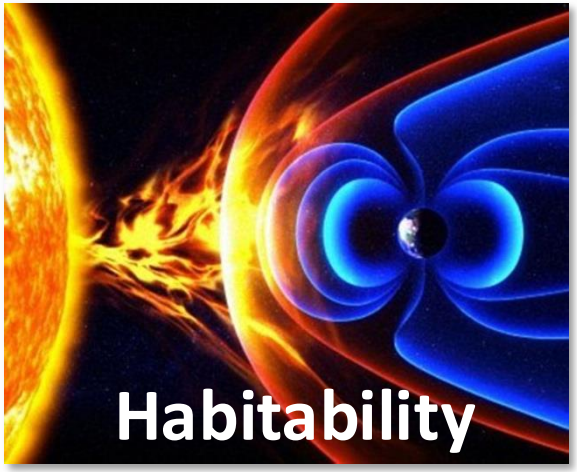












(e.g., Farrell+ 1999; Bastian+ 2000; Shkolnik+ 2003; Grießmeier+ 2005, 2015, 2017; Perna+ 2010; Rauscher & Menou 2013; Lazio+ 2016, 2019; Zarka+2015; Grießmeier+ 2018; Zarka 2018; McIntyre+ 2019; Ginzburg & Chiang 2020)

Ways to detect exoplanet magnetic fields

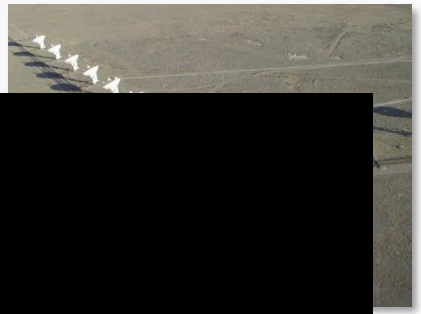
- Auroral radio observations are among the best methods to study planetary magnetic fields (Grießmeier 2015, Brain+ 2024)
- Many false positives for other techniques
  (e.g. Preusse+ 2006; **Turner+ 2016ab**, Gurumath+ 2018, Route 2019, **Meziani+ 2025**)

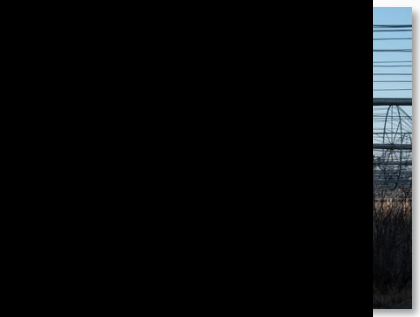
Observation	Section	Expected effect	False positives?	False negatives?	Suitable
Superflares	11.2.1	Weak or none	Yes	Yes	No
Planetary migration	11.2.2	Weak	Yes	Yes?	No
H_3^+ emission	11.2.3	Yes?	Yes	Yes	No
Gas giant mass loss	11.2.4	Yes	Yes	Yes	No
Chrom. emission	11.2.5	Yes	Yes	Yes	No
Early ingress	11.2.6	Yes	Yes	No?	No
Transit profiles (ENAs)	11.2.7	Yes	No?	No?	?
Radio emission	11.2.8	Yes	No	Yes	Yes
Atmospheric loss	11.3.1	Yes	Yes	Yes	No
Cosmic rays	11.3.2	Yes	Yes?	Yes?	No
Comet-like exosphere	11.3.3	Yes	No?	Yes	?

Grießmeier 2015

Past Exoplanet Radio studies

- Clark Lake [Yantis+ 1977]
- VLA [Winglee+ 1986; Bastian+ 2000; Farrell+ 2003;
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- WSRT [Stroe+ 2012]
- Arecibo [Route+ 2013, 2019, 2022, 2023, 2024]
- UTR-2 [Zarka+ 1997, 2011; Ryabov+ 2004; Vasylieva 2015]





Why?

- Too high frequency
- Too low of sensitivity
- Only partial orbit

- no confirmed detections

- NenuFAR [**Turner+ 2023, 2026**; **Zhang+ 2025**]
- LOFAR [**Turner+ 2017**; O'Gorman+ 2018; De Gasperin+ 2020, **Turner+ 2021, 2024**, Cordun+ 2025]

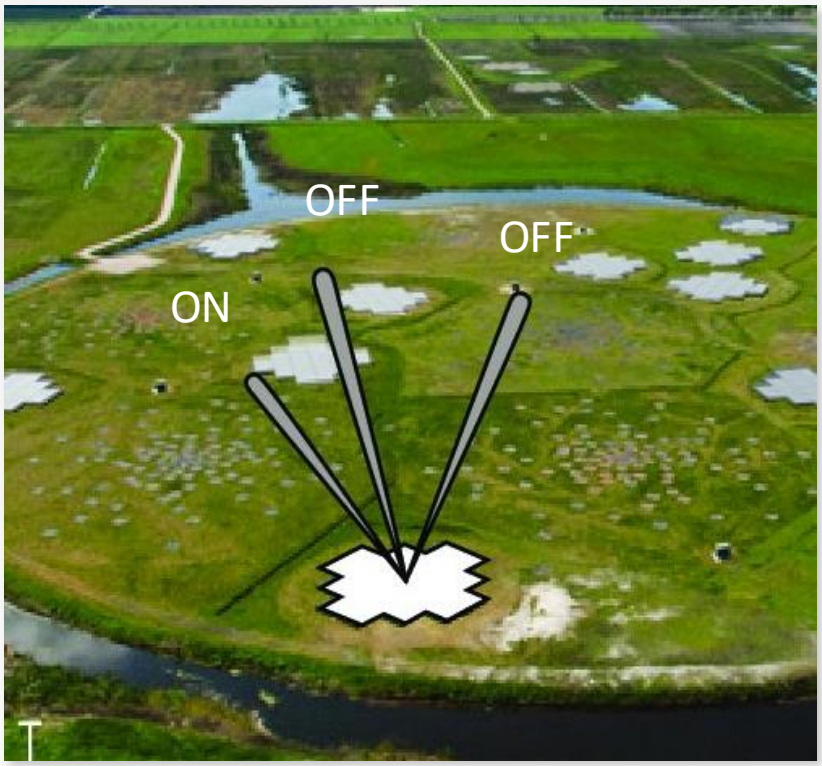
- Tentative detections

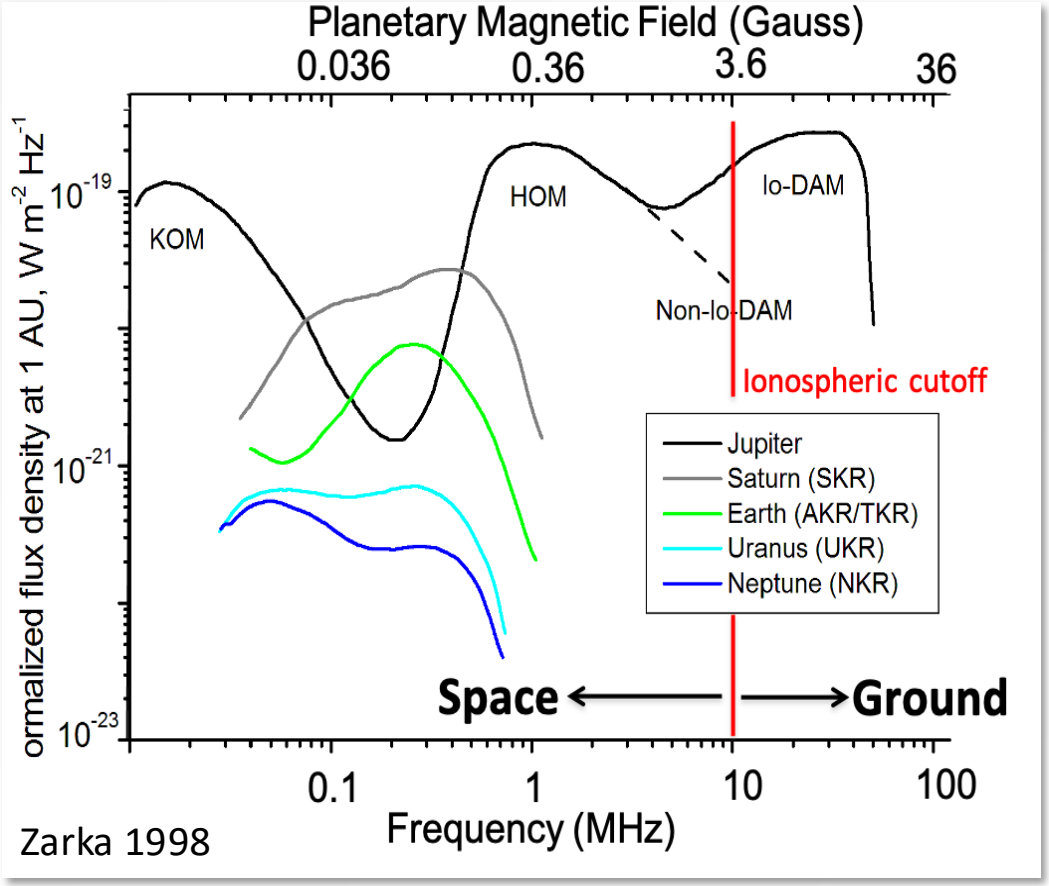
LOFAR

NenuFAR

Low-Frequency Observations

- 15 - 75 MHz, IQUV
- Beamformed (ON & 2/3 OFF) & imaging

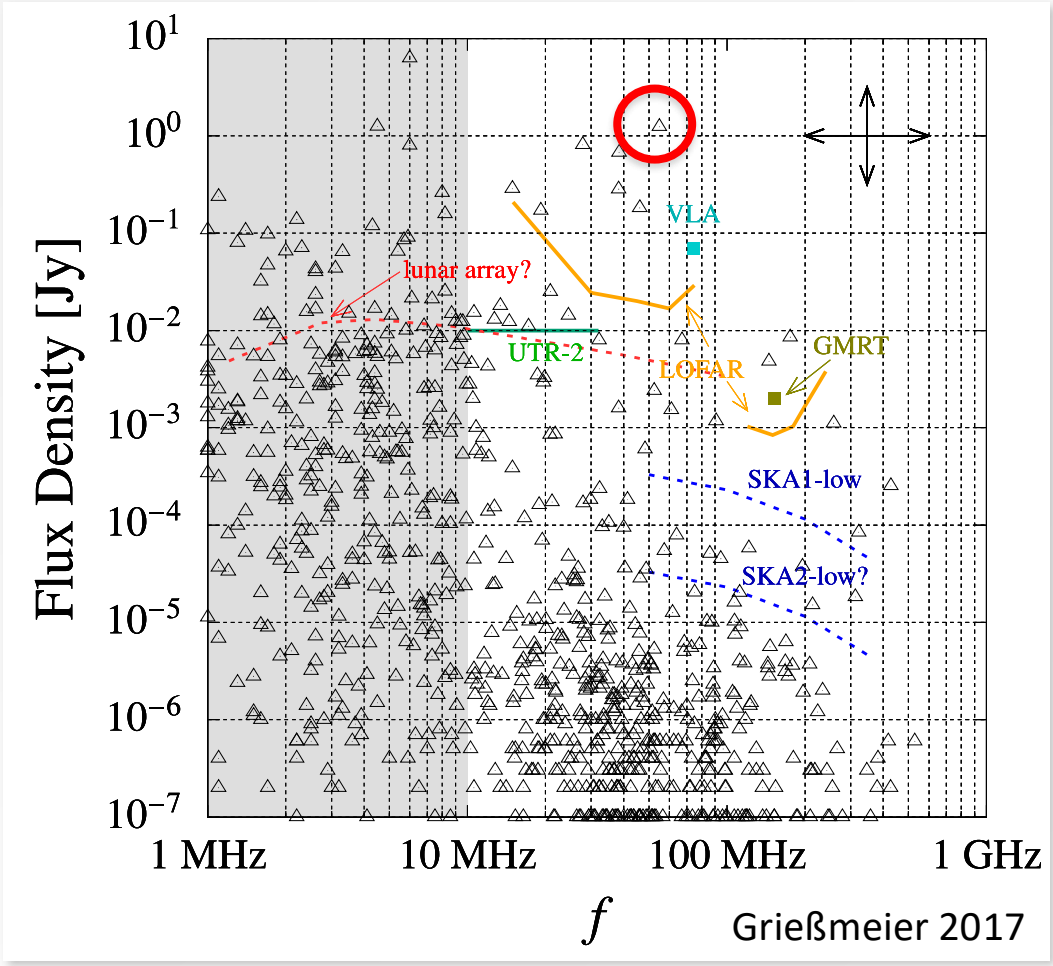




Tau Bootis b: Close-in hot-Jupiter

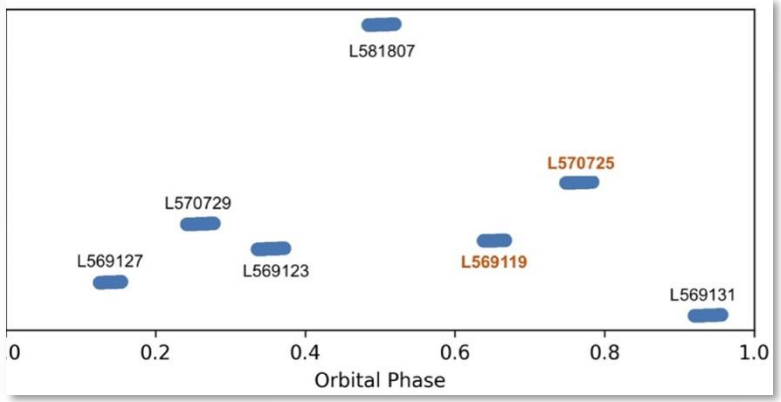
- Ideal target to observe in the radio

(e.g. Farrell+ 2003; Stevens 2005; Grießmeier+ 2007, 2017; Lynch+ 2018; **Ashtari+ 2022; Mauduit+ 2023**)



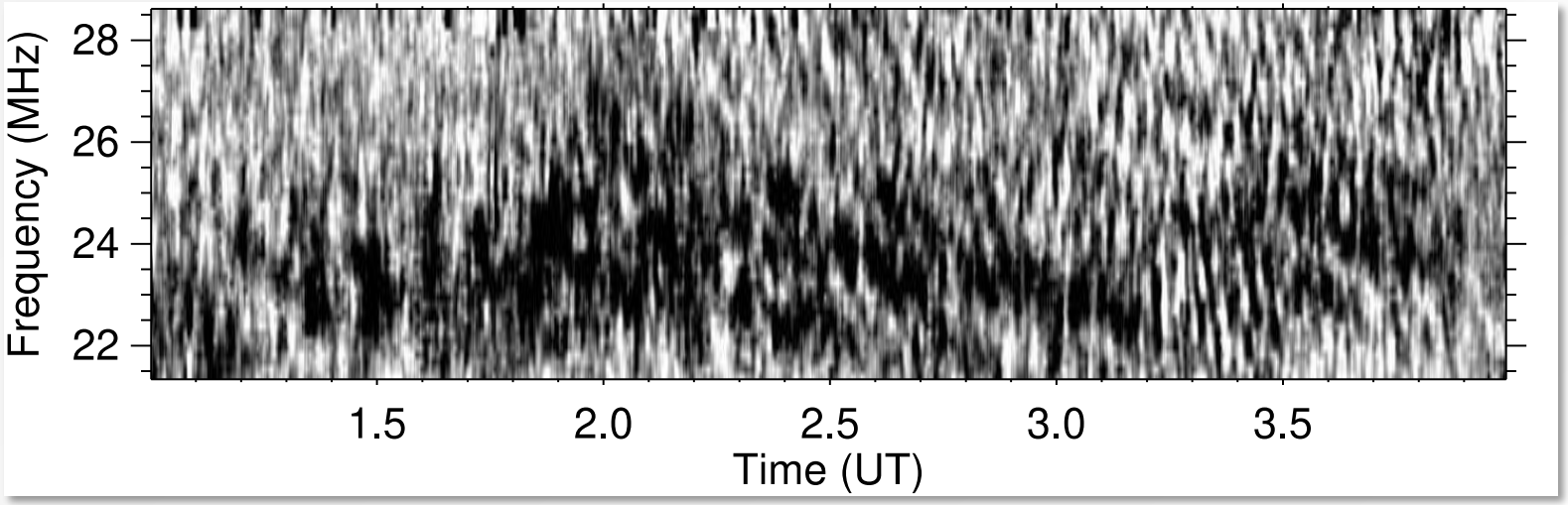
LOFAR Campaign

- 20 hrs (25% orbital coverage)
- ON & 2 OFF beams



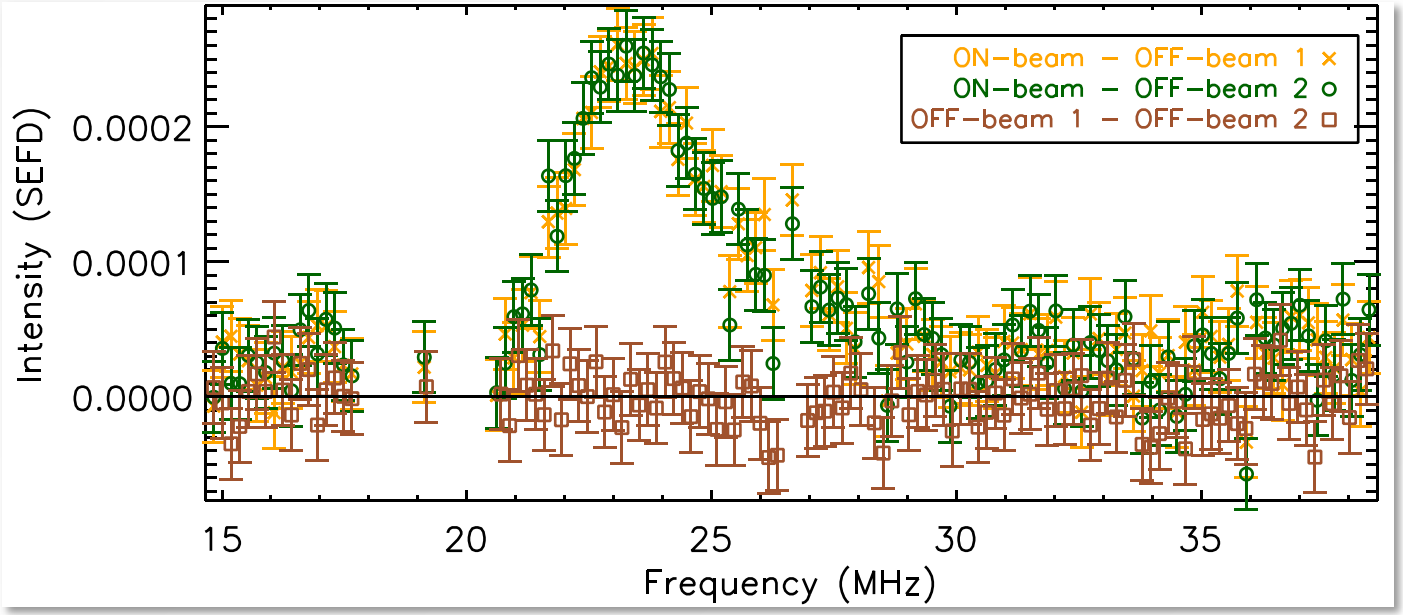
Turner+ 2021

Tentative detections from Tau Boo b



Phase 0.65
V+ (left)

8.6σ



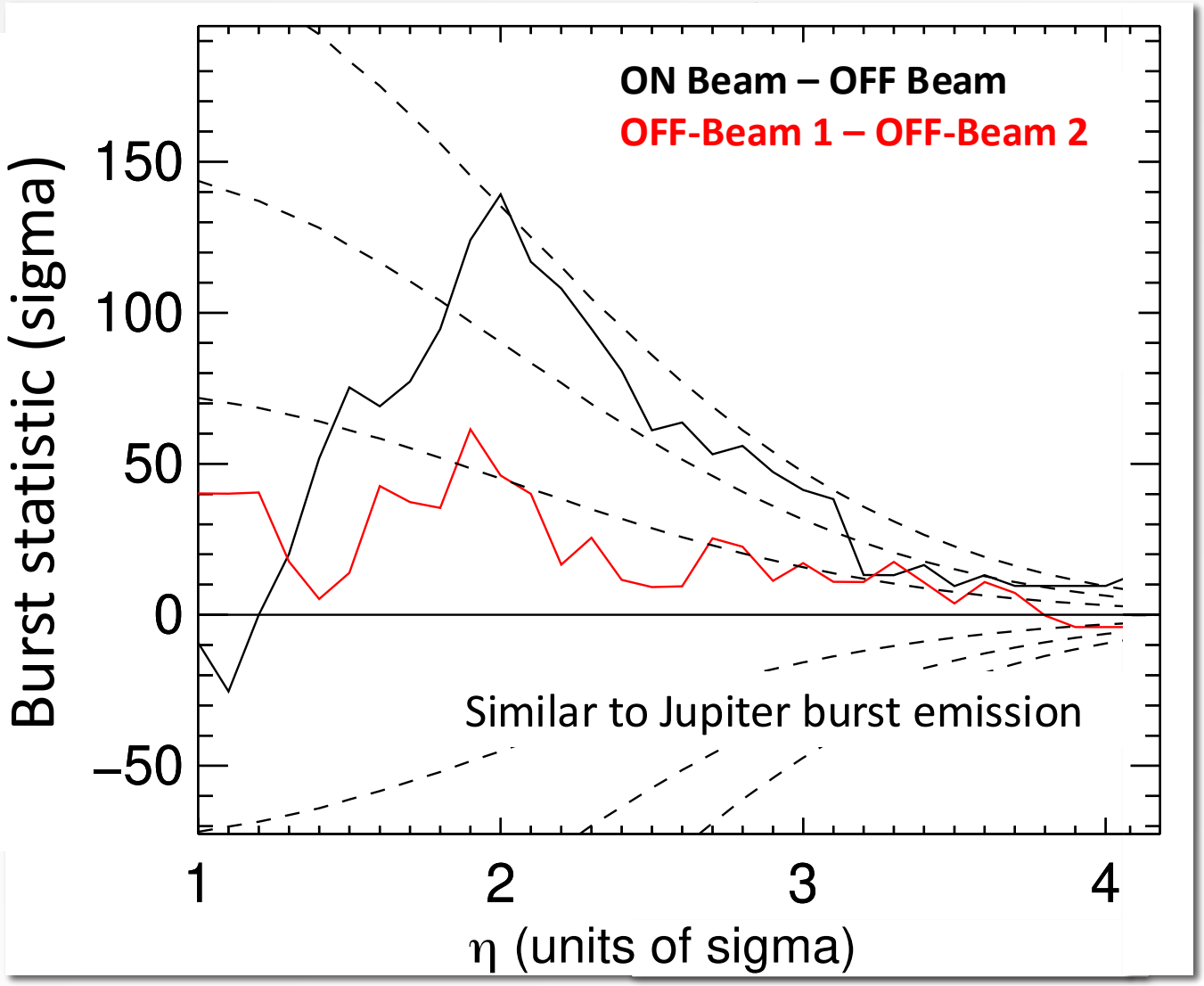
Turner+ 2021

Tentative detections from Tau Boo b

Bursty Emission: 1 sec bursts

Phase 0.80
V- (right)

3.2σ

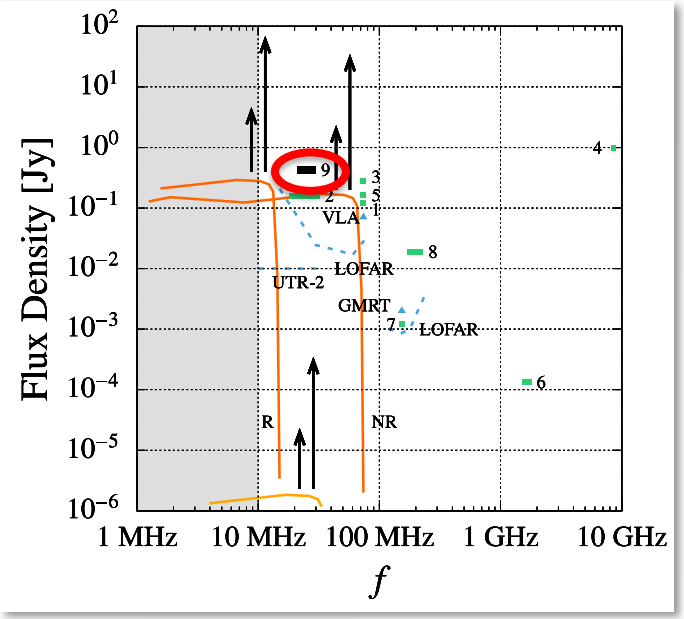


Turner+ 2021

First Possible Exoplanet Radio Detection

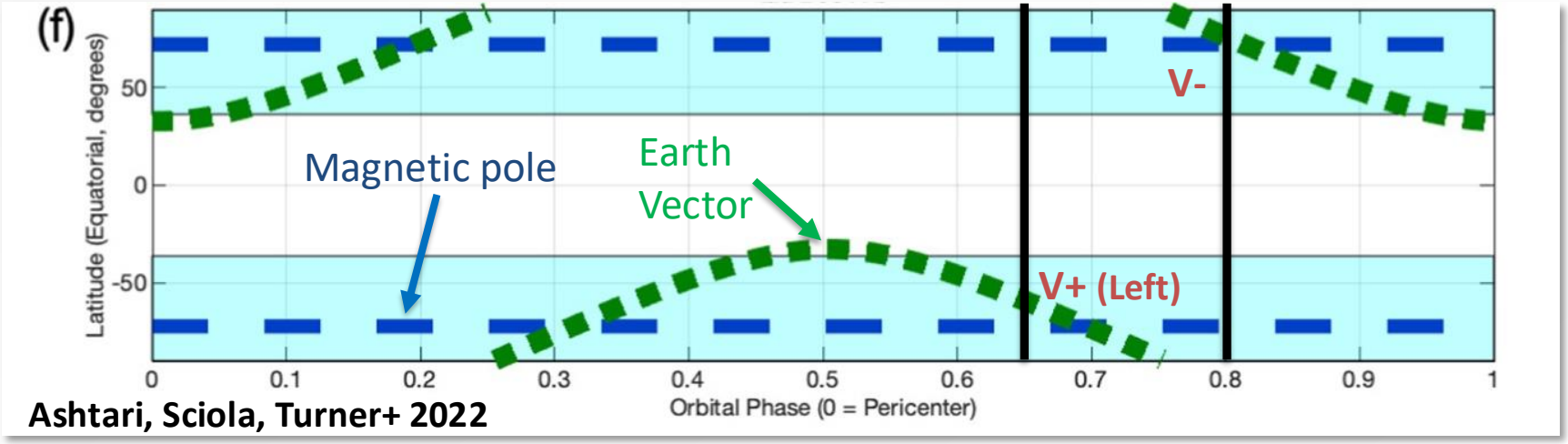
- B-field: 5-11 G, 0.94 m_{Jup}
- Consistent (B-field, flux, phase, handedness) with theoretical predictions

  (e.g., Grießmeier+ 2007b, 2017, **Ashtari+ 2022, Mauduit+ 2023**)
- Follow-up needed



Turner+ 2021

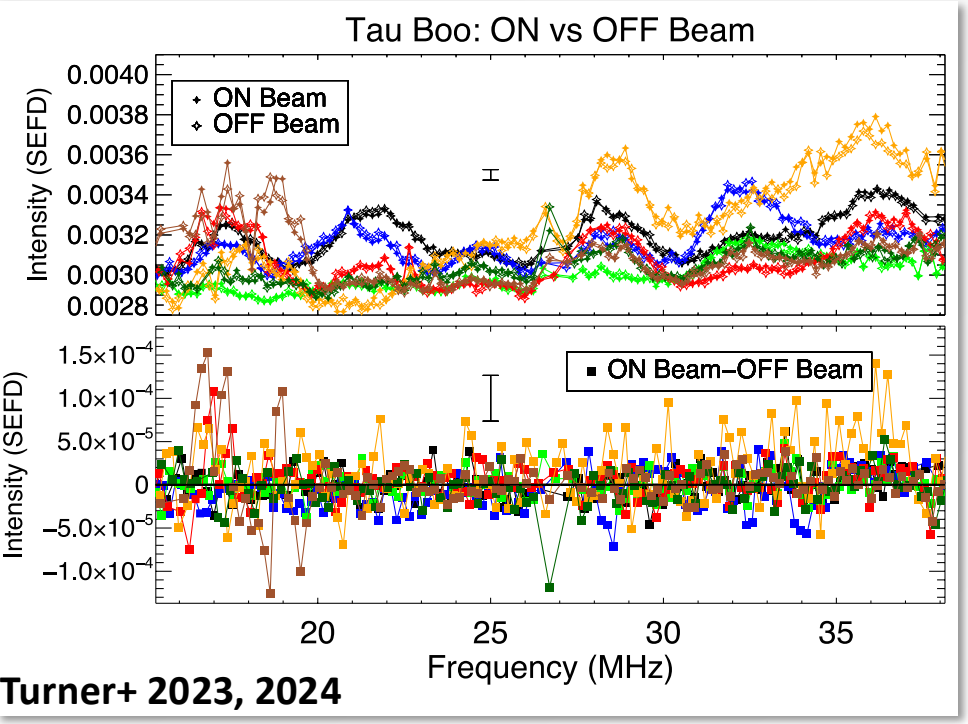
Observed phases & handedness



Ashtari, Sciola, Turner+ 2022

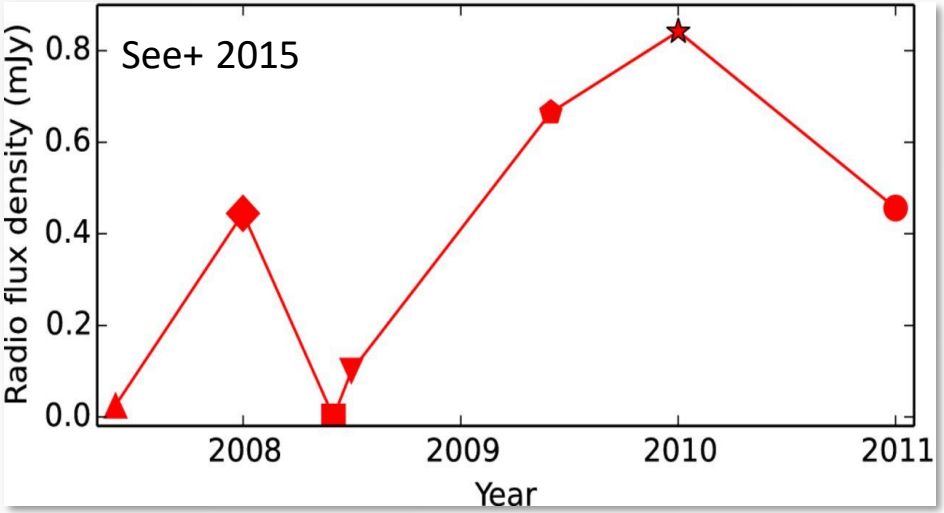
Signs of variability?

Follow-up LOFAR and NenuFAR Observations



Turner+ 2023, 2024

Predicted radio flux of τ Boo b



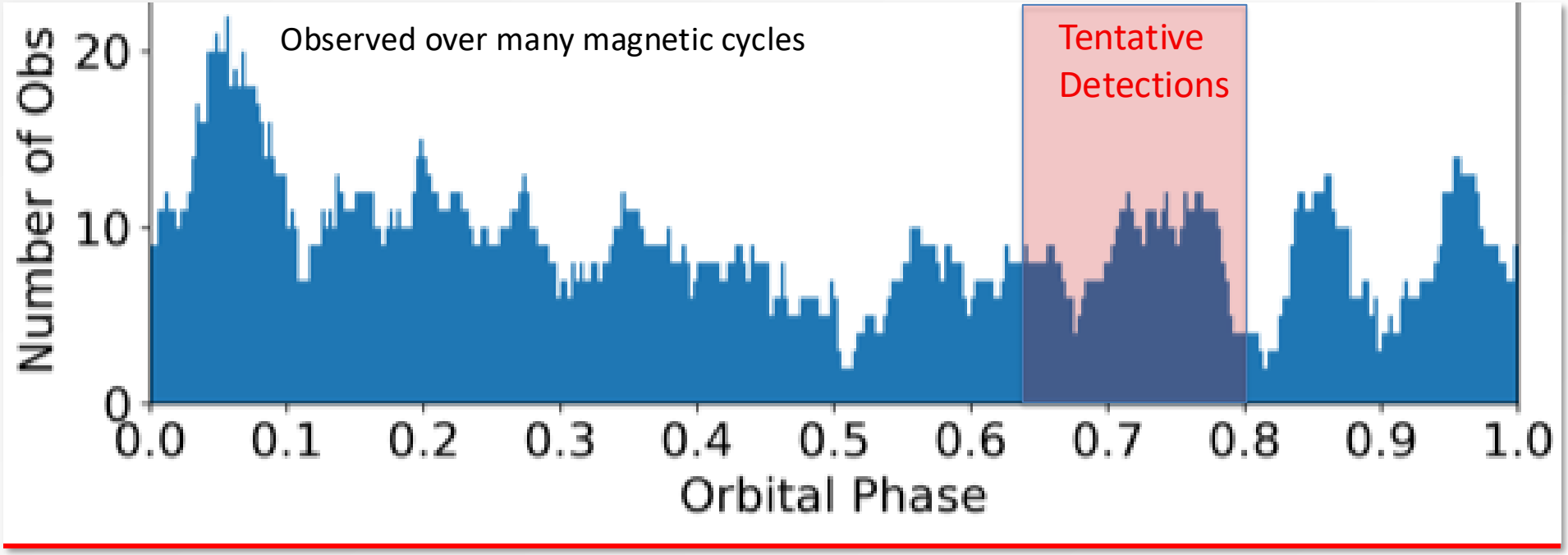
See also Elekes & Saur 2022

Imaging: Cordun+ 2025

- Stellar variability
  - For τ Boo b its radio flux "variability only occurs on the time-scale of the magnetic cycle." (See+ 2015)

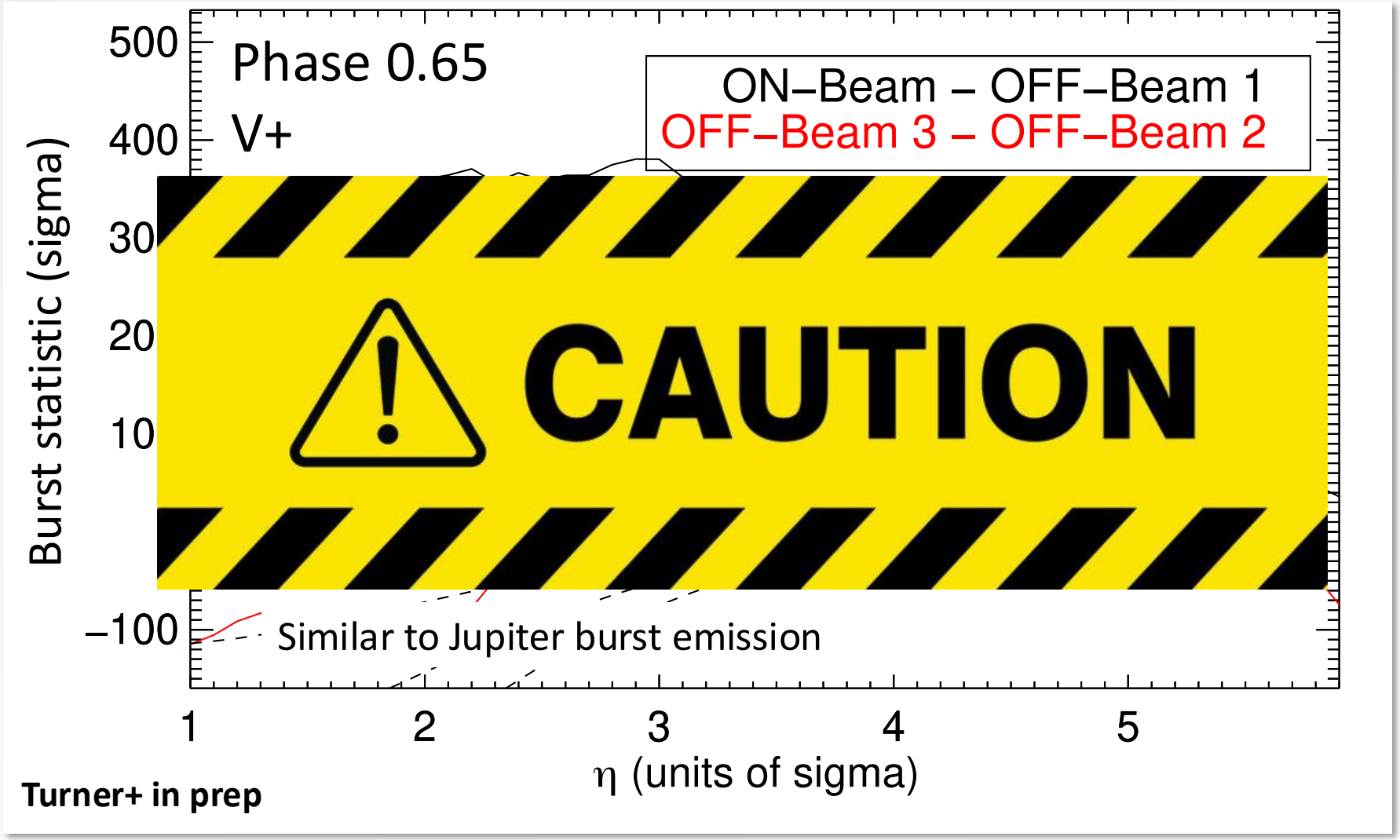
NenuFAR Follow-up Campaign

~800 hours of observations



- Magnetic maps of star with NeoNarval/CFHT

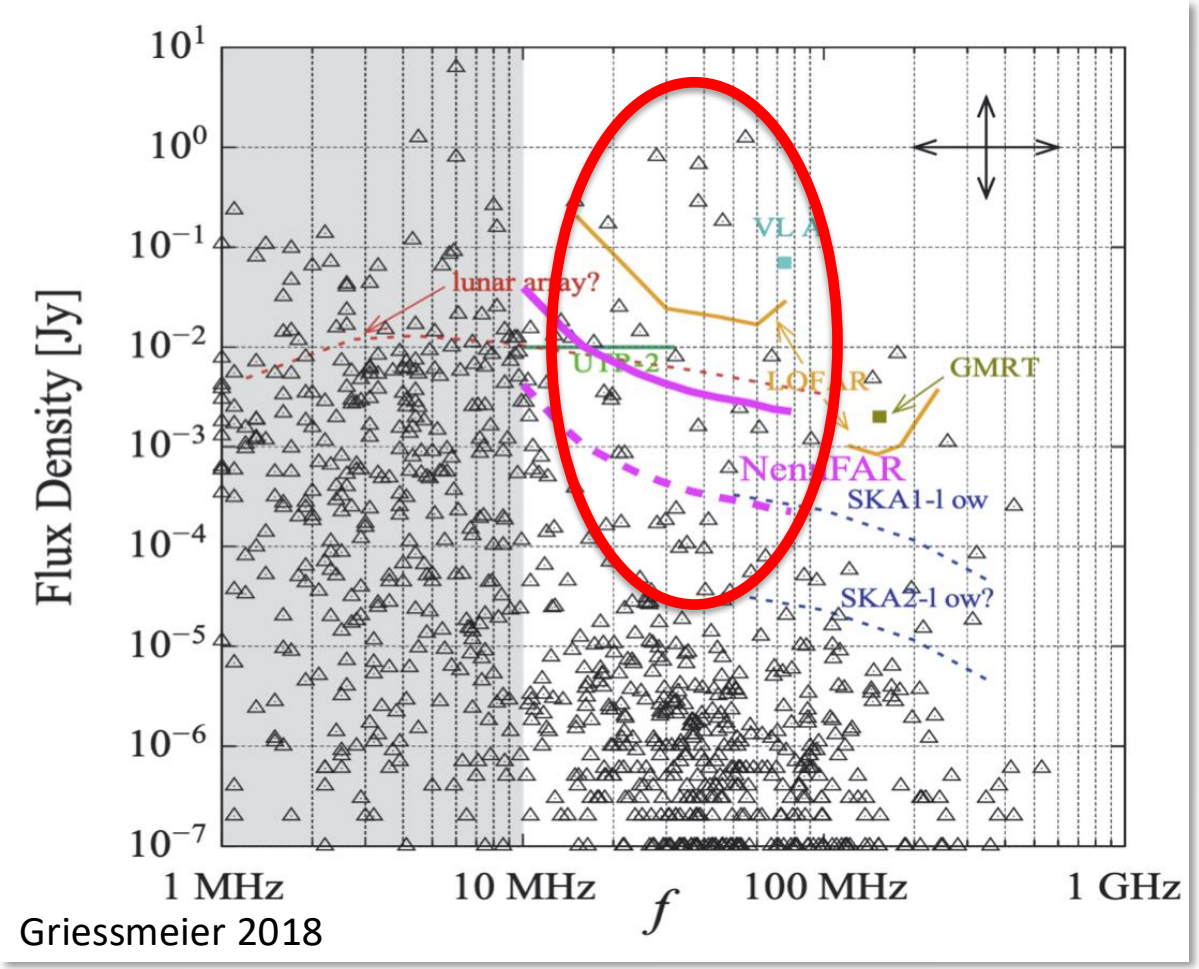
Possible Tau Boo Re-Detection



Very preliminary! So stay tuned

NenuFAR Radio Survey

- Targeted survey of 100s of gas giant exoplanets
- Statistically test theoretical models for the 1st time



Griessmeier 2018

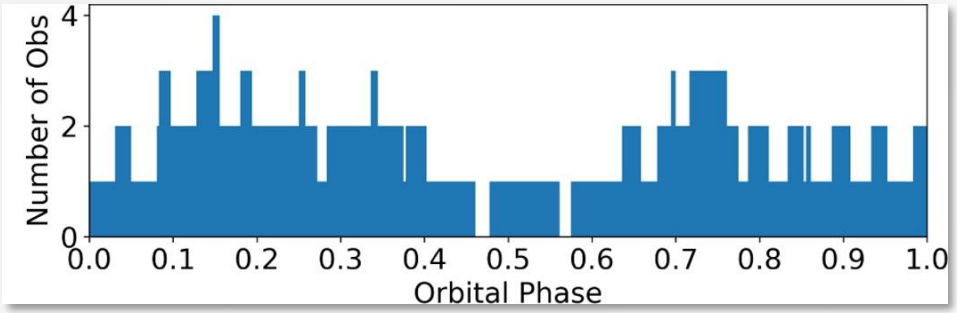
Updated predictions with *PALANTIR* **(Mauduit+ 2023, 2024)**

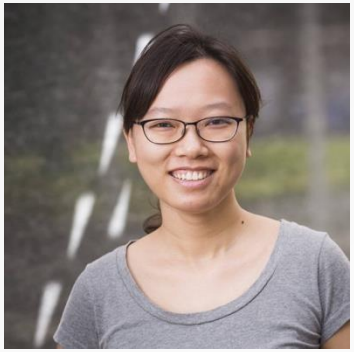
Emilie Mauduit

(PHD @ Paris Observatory)

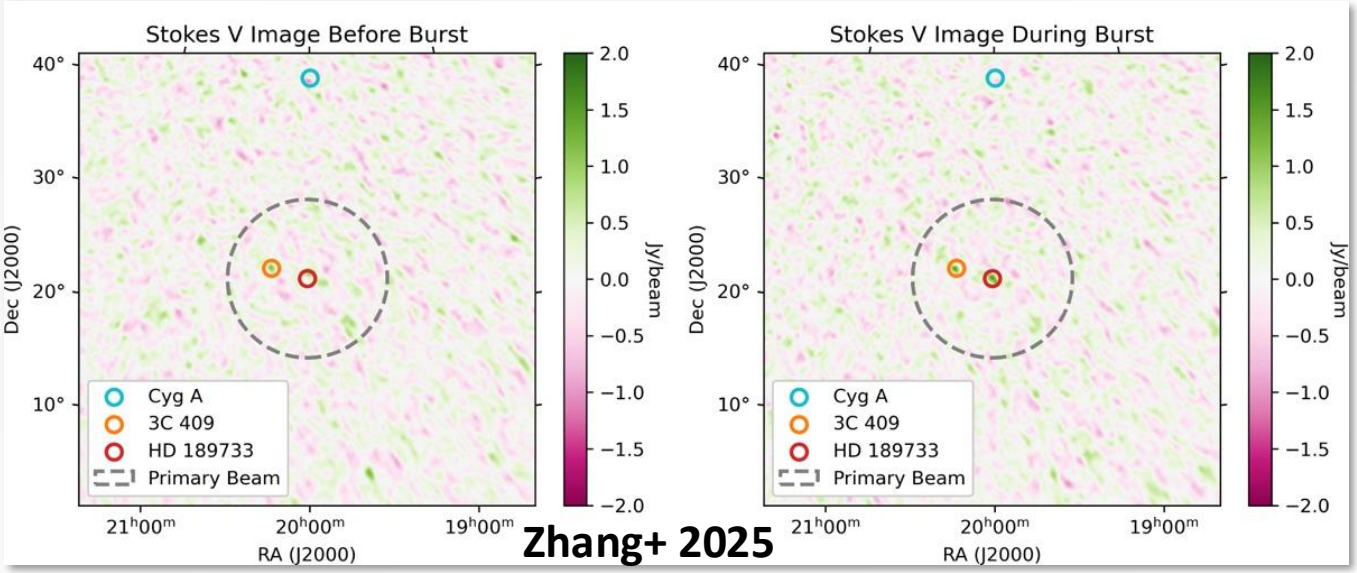
NenuFAR Pilot Study: HD 189733

- 100 hours: simultaneous imaging & beamformed mode





Imaging pipeline developed by Dr. Xiang Zhang (Paris Obs)



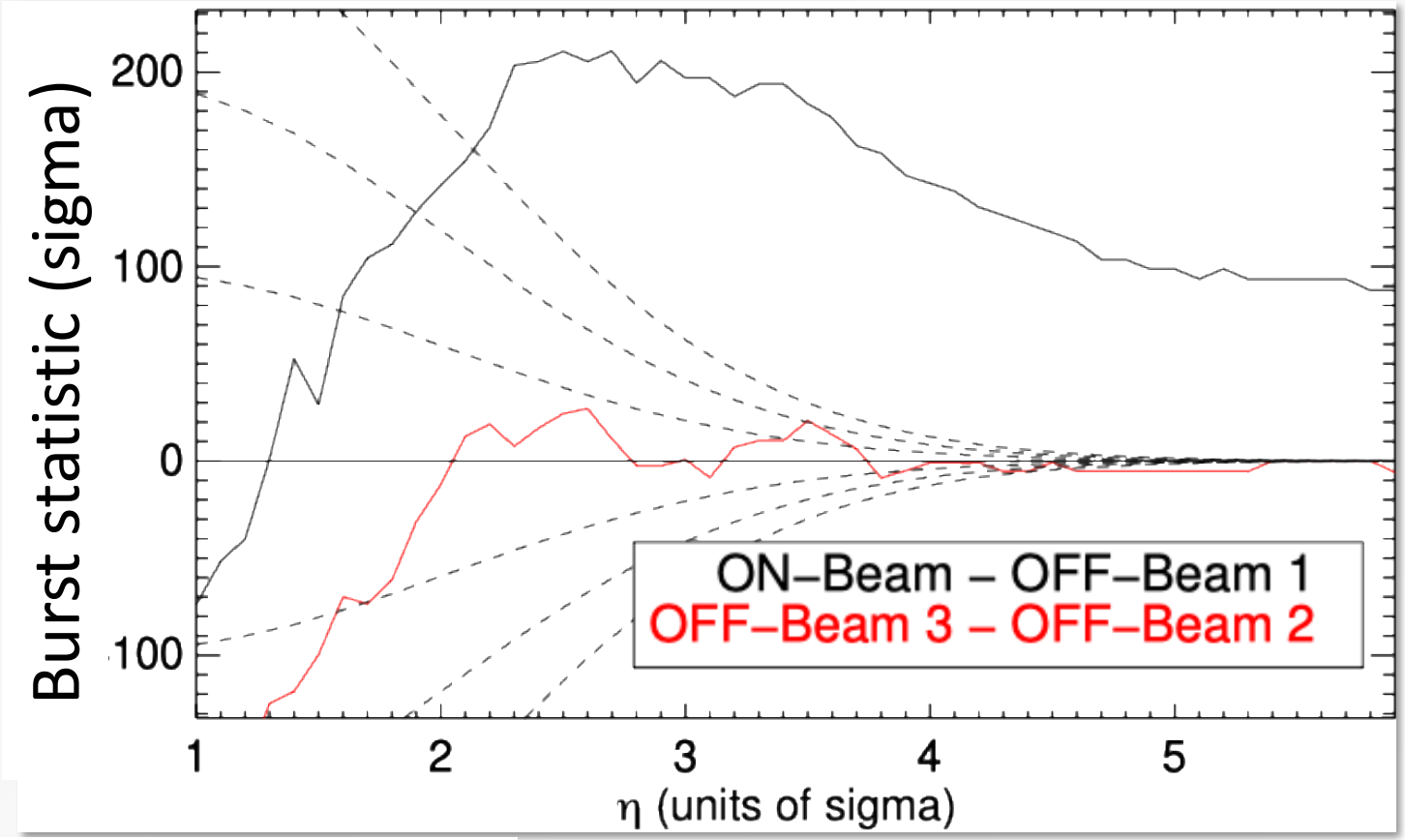
Zhang+ 2025

Phase: 0

6σ

HD 189733: Beamformed Detection

10σ



Similar to Jupiter burst emission

Turner+ 2026

- Both: Consistent with planetary auroral emissions
- More observations are needed to search for periodicity

Summary

- Tentative detections from Tau Boo b from LOFAR
  - Follow-up observations show possible variability, caused by the magnetic cycle?
  - Possible re-detection with NenuFAR (stay tuned)
- Detection of HD 189733 in simultaneous imaging and beamformed data from NenuFAR
  - Follow-up observations are ongoing
- The future of ground-based studies is bright (NenuFAR, LOFAR 2.0, OVRO-LWA)
  - Results greatly inform the best practices for future space-based radio telescopes

Thanks!

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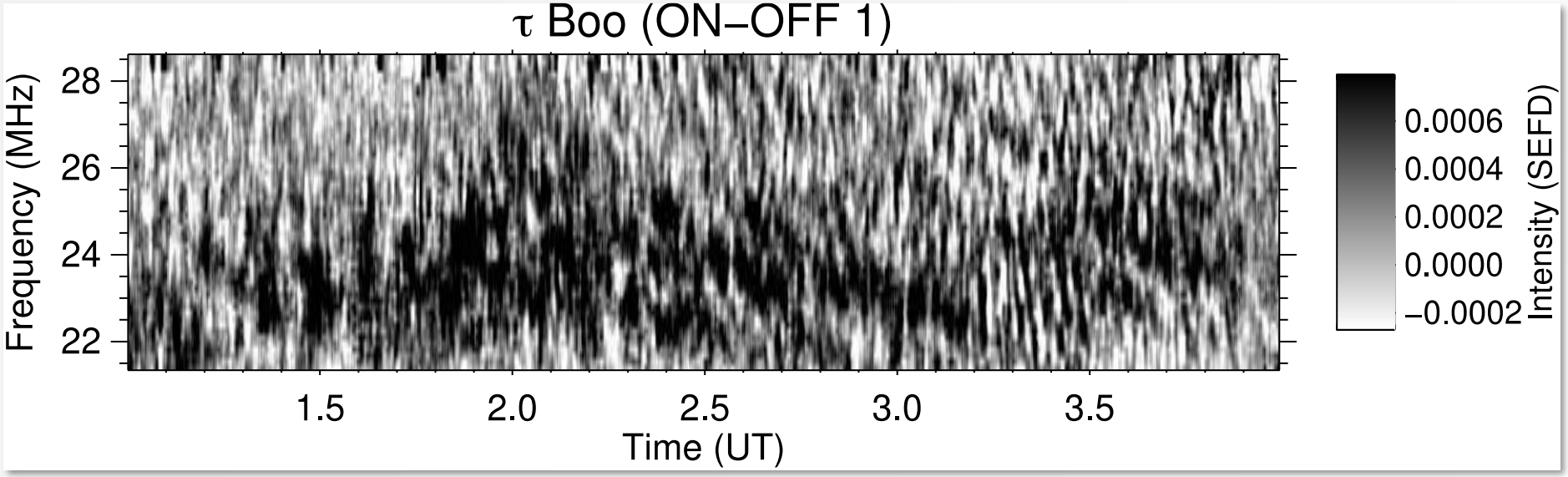
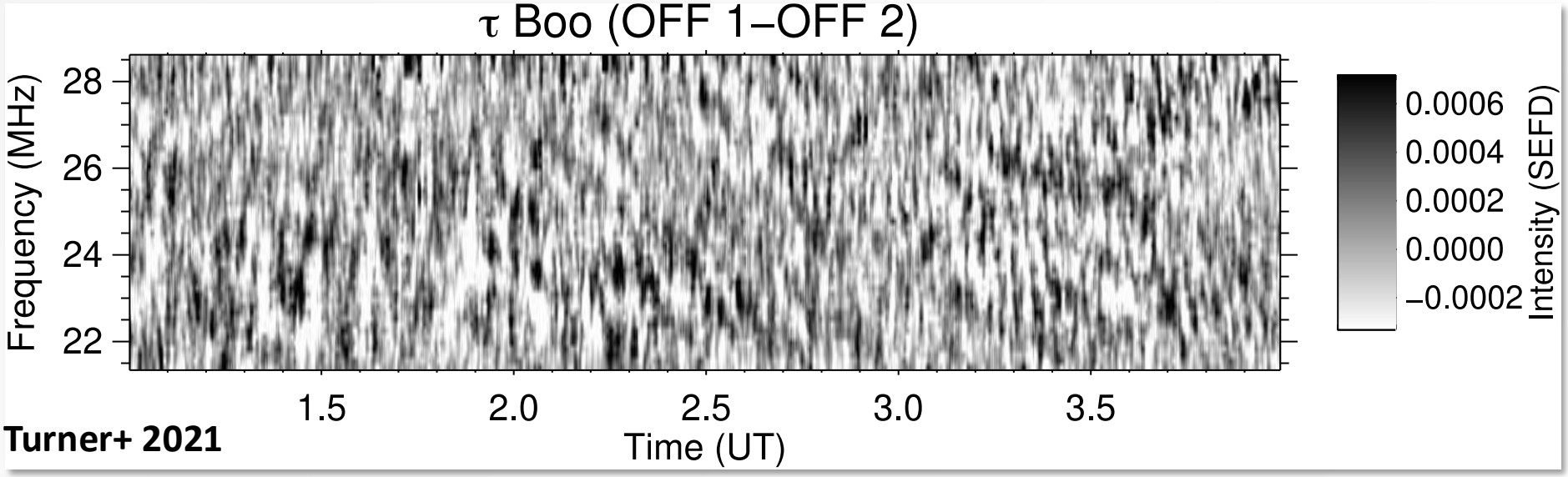
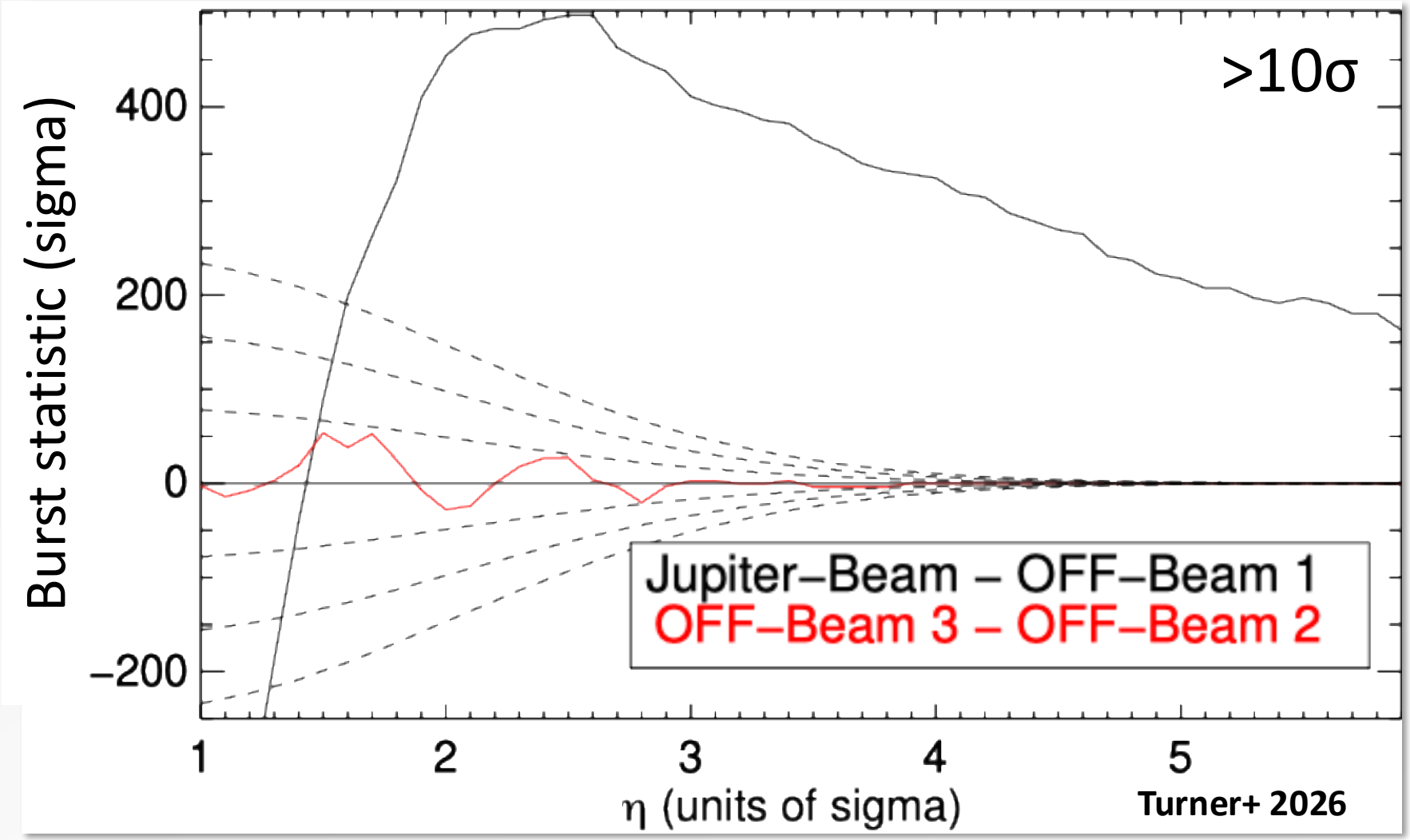
Backup Slides

Tau Boo: Dynspec of Detection





Turner+ 2021

Jupiter as an Exoplanet