HOW DEEP AND LOW CAN WE GO?
First radio image at 15 MHz

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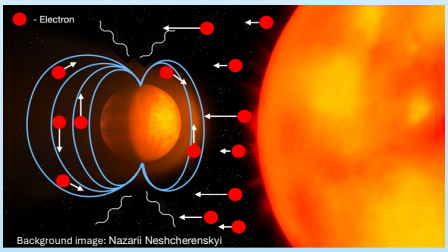
1. Why do we want to go deep and low?

Radio emission from an exoplanet is the only way to detect and measure its magnetic field.

Stars constantly eject **charged particles** into the interstellar medium (stellar wind), which can be **trapped** by the nearby **magnetic planet**. As a result, the electrons will move along the magnetic field lines in high energy states (**inversion**).



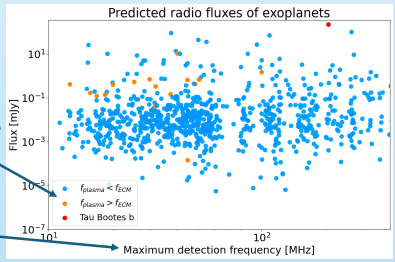
A **perturbation** in a small region results in a **cascade of photons** with similar energies, called electron cyclotron maser **(ECM) emission**, which is **coherent**, highly **circularly polarized** (Stokes V), and observable **below 40 MHz**.

2. What is the best planet candidate?

Proportional to the stellar wind intensity

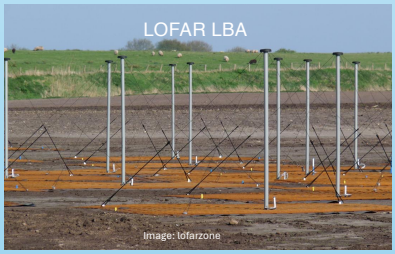
Escape condition for radio emission (the blue dots are detectable planets)

Proportional to the surface magnetic field



The brightest radio exoplanets are highly magnetized planets located close to the host star (Hot Jupiters). **Tau Bootes b** (red dot) is the best candidate up to date.

3. What instrument can go deep and lower than 40 MHz?

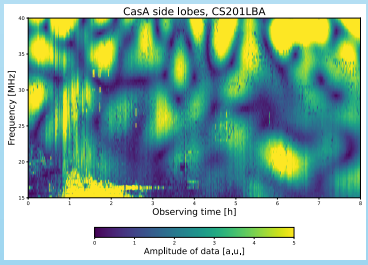


The Low-Frequency Array (LOFAR) is the ideal tool studying this type of emission because of its:

- high sensitivity (large collecting area)
- long baselines (aids with calibration)
- low-frequency band (the Low Band Antennas can observe between 10 and 100 MHz)

4. What are the challenges with low frequencies?

- Intense glare of bright off-axis sources (**sidelobe noise**)
- Human-made interference
- Ionospheric scintillations
- Cosmic noise from bright galactic background (700 kJy at 15 MHz)

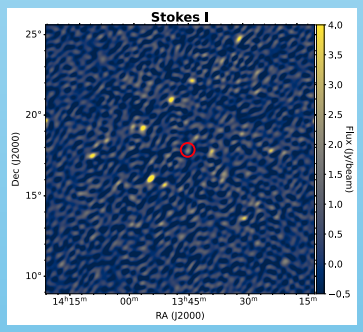


5. How low did we go?

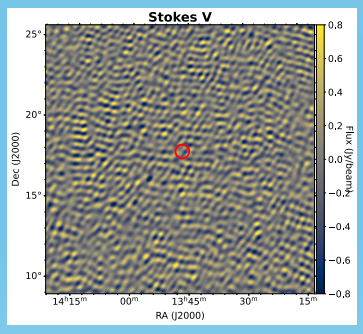
Targeted observation on Tau Bootes b: 8 datasets (7 usable), 8 hours per dataset, 15 – 40 MHz

We do not see any planet (location - red circle). We only show one dataset (8 hours). Ask me if you want to see the others

15.2 MHz
1 MHz bandwidth

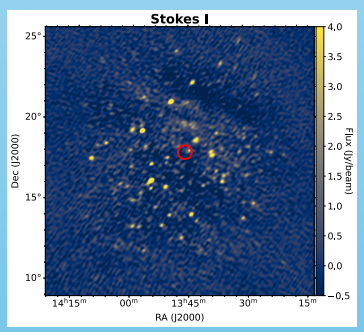


Noise: 445 mJy

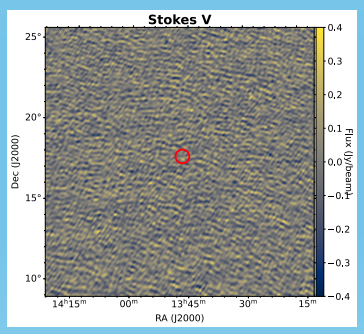


Noise: 225 mJy
3.5 times thermal level (50% flagged)

27.0 MHz
1 MHz bandwidth

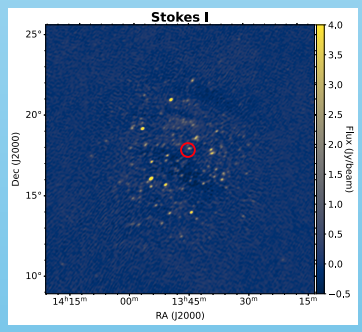


Noise: 190 mJy

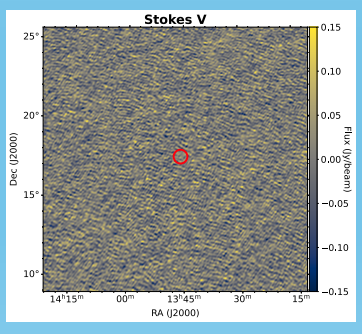


Noise: 80 mJy
3 times the thermal level

37.7 MHz
1 MHz bandwidth



Noise: 70 mJy



Noise: 40 mJy
2 times the thermal level

6. Will we go lower or deeper?

Deeper – yes, lower – no:

- 44 hours of new, more sensitive data on Tau Bootes b
- LOFAR will start its upgrade to **LOFAR 2.0**. The array will become up to **two times more sensitive**. New data will be taken after the upgrade
- Going lower is not feasible due to the ionospheric cutoff

7. Summary

- Low frequency imaging is essential for detecting exoplanets
- No confirmed detection of a radio exoplanet up to date
- Imaging below 40 MHz is challenging, but achievable
- No planet detected… yet

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