Searching for exoplanets with SKA

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Credit: ESO/M. Kornmesser

Introduction

Different methods for exoplanet search (and their biases)

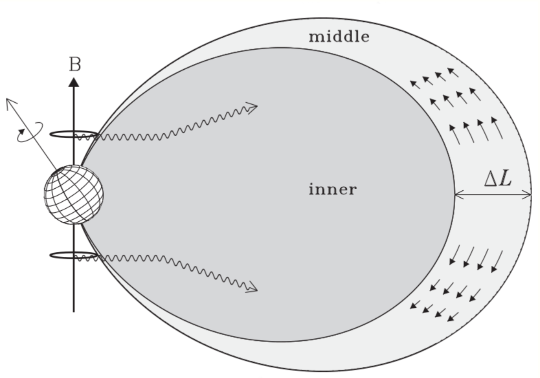
- Radial velocity:
  - more sensitive to massive close-in planets **(hot-Jupiters)**, needs sharp spectral lines and high stellar fluxes **(not suitable for very cool stars)**
- Transits:
  - more sensitive to large close-in planets in very low-inclination systems, needs high stellar fluxes **(not suitable for very cool dwarf stars)**

Radio advantages:

- No bias towards low-mass cool stars
- No bias towards planetary mass

Cyclotron maser instability

The main mechanism responsible for the solar system planet radio emission is the so-called **"cyclotron maser instability"** (CMI).



Leto et al. 2016

Cyclotron maser instability

CMI takes place when free electrons:

- are accelerated to ∼keV by:
  - magnetic reconnection in equatorial regions of the magnetosphere perturbed by the stellar wind
  - MHD shocks by magnetized orbiting bodies (dipolar inductors) or unmagnetized (unipolar inductors)
- interact with planetary magnetic field (migrating toward the magnetic poles)
- their energy distribution is inverted
  - pitch angle anisotropy
  - horseshoe distribution (?)

Auroral radio emission (ARE)

Accelerated electrons emit at the local cyclotron frequency ($\nu_B \propto B$) when they are reflected by magnetic mirroring. Since this emission originates close to magnetic poles, it is called Auroral Radio Emission (ARE).

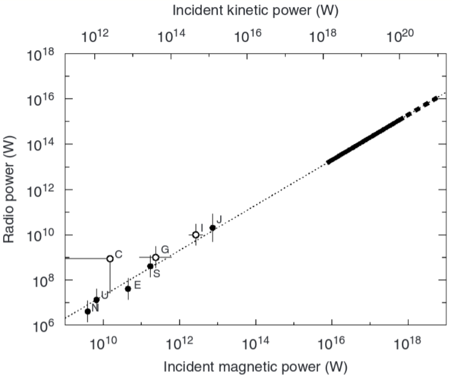
The ARE is characterized by:

- coherence
- circular polarization (up to 100%)
- time variability
- directivity

Scenario 1: ARE on a planet

The ARE can be observed on magnetized (exo)planets:

- interaction between stellar wind and planet magnetosphere



Zarka 2007

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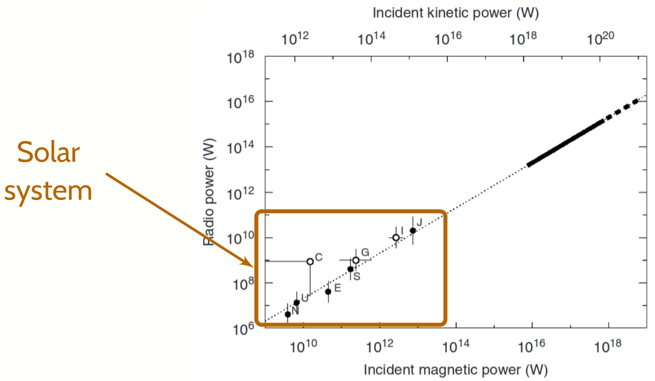

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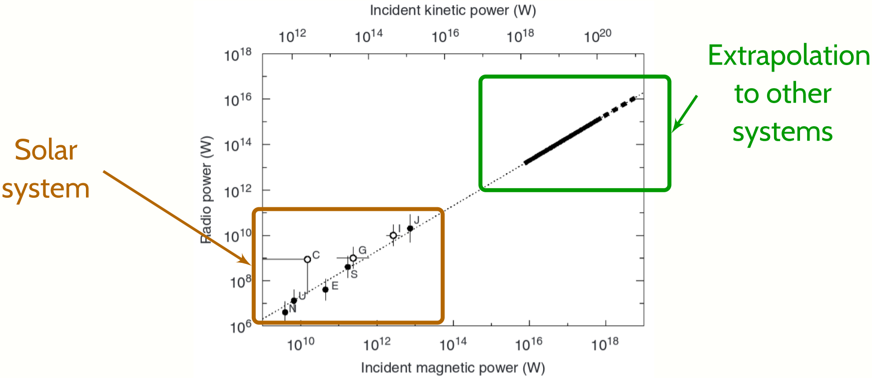
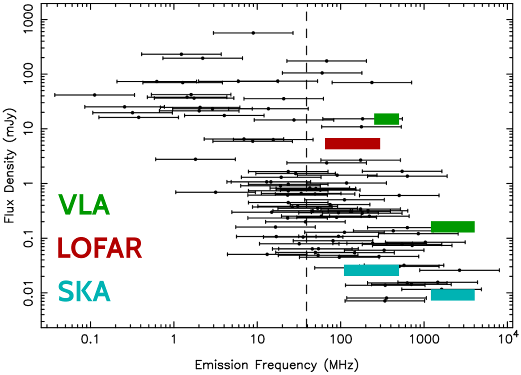


Zarka 2007

Scenario 1: ARE on a planet

ARE on planets:

- $\nu \sim 50$ - 100 MHz
- $S \sim 100$ μJy



Lazio et al. 2004

Observations possible only with the advent of SKA

Scenario 2: ARE on a star

The ARE can be observed in stars, and it is caused by:

- interaction between stellar wind and stellar magnetosphere
- induction due to planets

Being stellar magnetic field more intense than planet ones, stellar ARE is observed at higher frequencies.

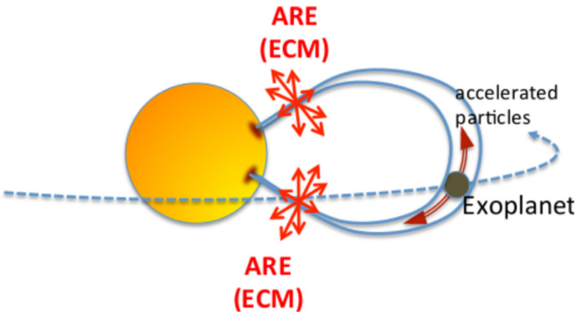
Stars where ARE has been observed

- MCP stars
- ultra cool dwarfs

Scenario 2: ARE on a star

ARE on stars induced by planets:

- typical frequencies: ∼1 GHz
- expected flux density: up to ∼100 mJy



Trigilio et al. 2018

What can we unveil?

Complementary information with respect to other methods:

- presence and intensity of a planetary magnetic field
- hint of internal structure
- presence of satellites

Current limitations

- For ARE on exoplanets high sensitivity ($\lesssim$100 μJy) required at low frequencies: unfeasible with current instruments!
- Only few systematic studies on stars: mitigated by SKA precursors' surveys.
- Difficult to observe for enough time to cover all the planet orbital period.

Two case studies

Two stars recently investigated by our group:

- TVLM 513-46546 (Leto et al. 2017)
- α Centauri (Trigilio et al. 2018)

TVLM 513-46546

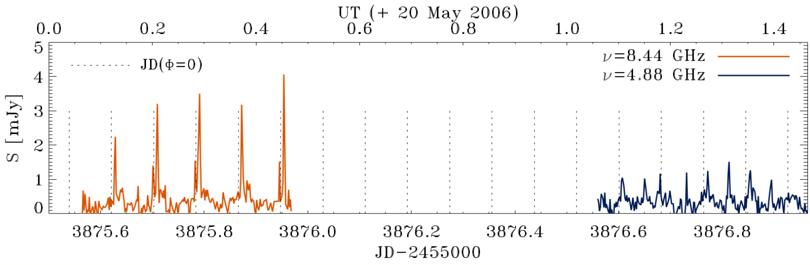
TVLM 513-46546 is a well-studied ultra-cool dwarf.

Stellar parameters:

- spectral type: M8.5V
- distance: ~ 10.8 pc
- rotation period: ~ 2 hours
- radius: $0.11\ R_\odot$
- mass: $0.07\ M_\odot$
- surface temperature: 2500 K
- No previous evidence of planets

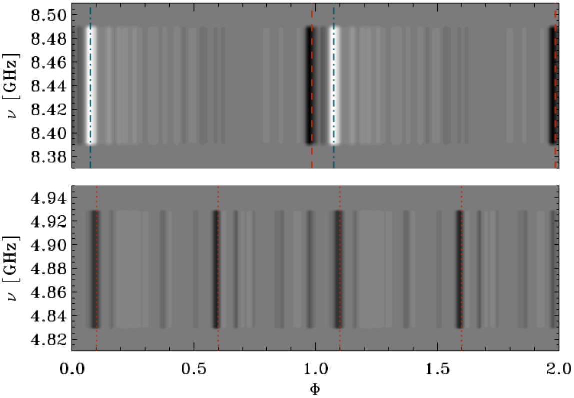
TVLM 513-46546

Radio observations carried out with VLA at 4.9 and 8.4 GHz during 2006 (Hallinan et al. 2007).



TVLM 513–46546

Phase-folded in Stokes *V*.



Leto et al. 2017

TVLM 513-46546

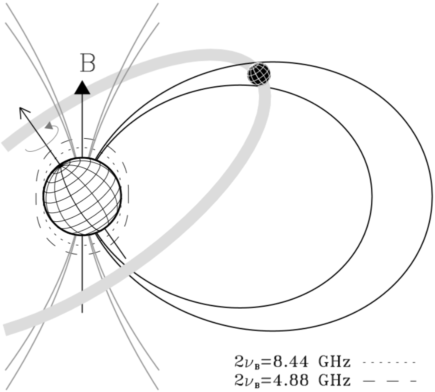
Still difficult to explain why 8.4-GHz emission is characterized by only one doubly-peaked pulse per stellar rotation.

Unless we suppose that it is constrained within a small range of magnetic longitudes.

This scenario is **very similar to the Jupiter-Io interaction**, which has been also proposed to explain the emission of other ultra-cool dwarfs (e.g. Hallinan et al. 2015).

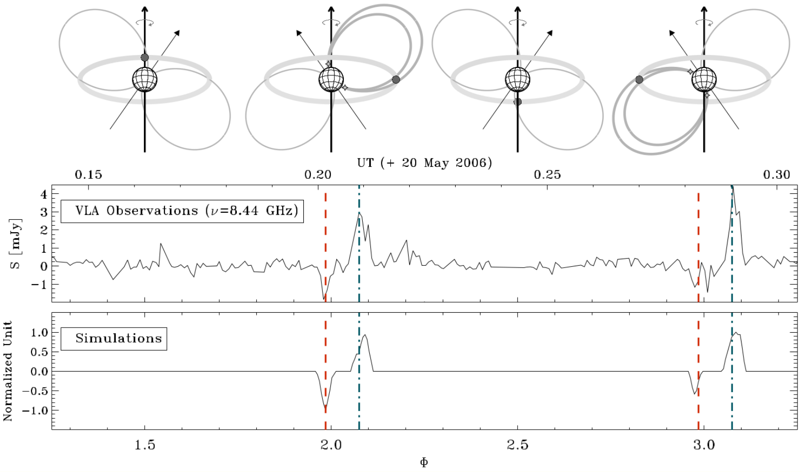
TVLM 513-46546

A possible model where 8.4-GHz emission is triggered by a planet.



Leto et al. 2017

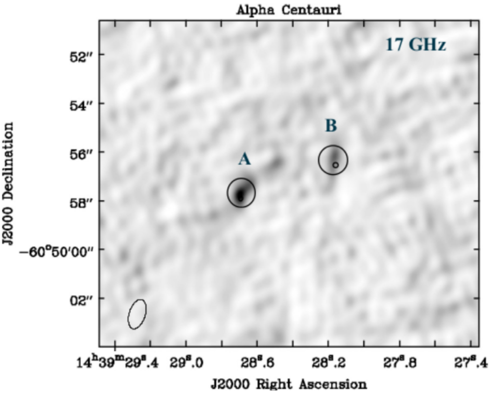
TVLM 513-46546



Leto et al. 2017

α Centauri

Solar-type stars are difficult to detect at centimeter wavelengths because of very low flux densities.



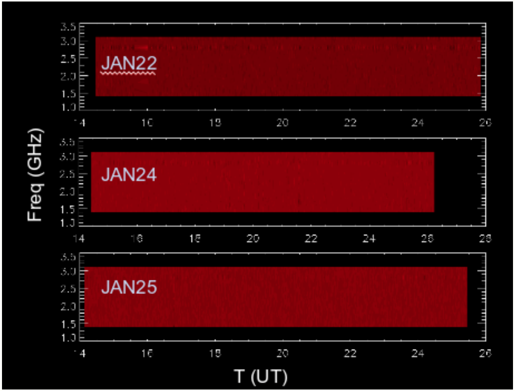
First detection ever at 17 GHz

- $S(A) = 161 \pm 17$ μJy
- $S(B) = 105 \pm 16$ μJy

Trigilio et al. 2018

α Centauri

Is there a planet around α Centauri B?
(proposed by Dumusque et al. 2012, disputed by Rajpaul 2016)



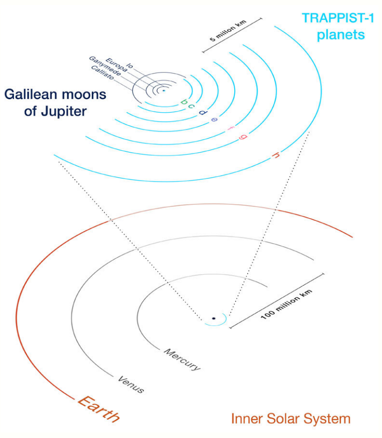
Trigilio et al. 2018

No radio evidence:

- Wrong frequency? (Different *B* intensity)
- Not favorable system geometry?
- Non-dipolar *B* topology?
- No planet at all?

What's next?

Observations of **Trappist-1** (PI C. Trigilio - under reduction)



What’s next?

Future observations:

- Targeted observations on a wider and wider sample of known exoplanetary system
- Galactic surveys with SKA precursors (**EMU**, ...)

Impact on SKA science and commensalities:

- SKA SWG: “Our Galaxy”
- SKA SWG: “Cradle of Life”

Conclusion

The auroral radio emission can supply a complementary method for searching and characterizing exoplanets.

A promising field is represented by the auroral radio emission induced by planets on stars.

The light curves of TVLM 513-46546 can be well reproduced by the presence of a planet in close-in orbit.

We posed upper limits on the presence of a planet around α Cen B.

Observations of Trappist-1 are under reduction.

The advent of SKA will allow a great expansion of the possible targets and to search for ARE directly on exoplanets.