Hunting exoplanets: detection limits due to starspots

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1. Introduction

Starspots are one of the main hindering factor when searching for exoplanets. This problem resides in the magnetic activity of the star and widely affects radial velocity measurements. Indeed, starspots alter the spectral line shapes leading to a radial velocity variation ("jitter") that might both drown the signal from the planetary companion and lead to erroneous determination of planetary parameters. Our aim is to investigate the limits the starspots pose to the detection of Earth-mass planets.

2. Stellar magnetic activity

- Local magnetic fields on stellar surface suppress convective overturn so they block or redirect the energy flow which leads to starspots.
- Starspots are tracers of the so called magnetic activity.
- Emission reversal in CaII H&K lines is a proxy for the chromospheric activity of the star.
- The contribution of the CaII H&K lines to the bolometric luminosity of the star is quantified by $\log R'_{\mathrm{HK}}$.

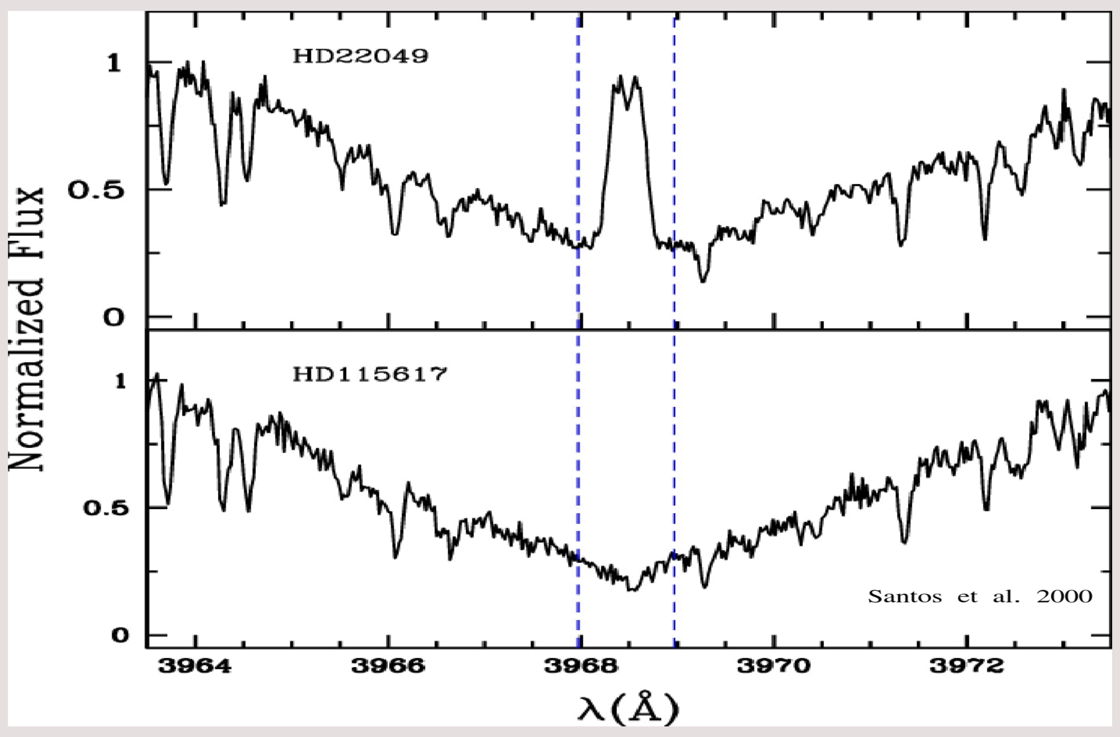


Fig. 1: *Top*: CaII H emission line for an active star. *Bottom*: Inactive star.

3. Catalogue of host stars

- We built a catalogue of chromospheric activity indexes for known exoplanets hosts, extending the ones found in the literature.
- The catalogue is composed by 210 stars ranging from F to M spectral type and spanning different activity levels.
- We extracted a sample based on specific constraints: main sequence stars, circular orbits and widest span in activity.

4. Simulation sample

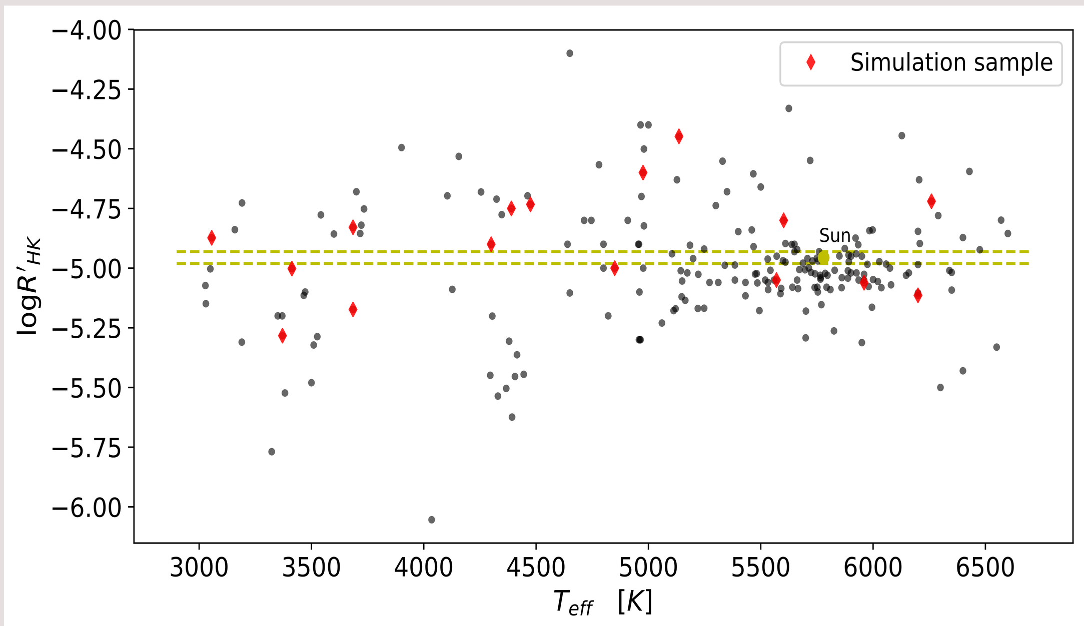


Fig. 2: Sample of host stars employed in the simulations.

5. Simulation parameters

We need specific stellar and planetary parameters in order to generate the synthetic spectra and the radial velocity datasets.

Star

- Surface temperature
- Spots temperature
- Filling factor
- Rotation period
- Active latitude
- Inclination

Planet

- Orbital period
- Orbital inclination
- Mass

As an example, we show how we estimated the filling factor for our sample of host stars.

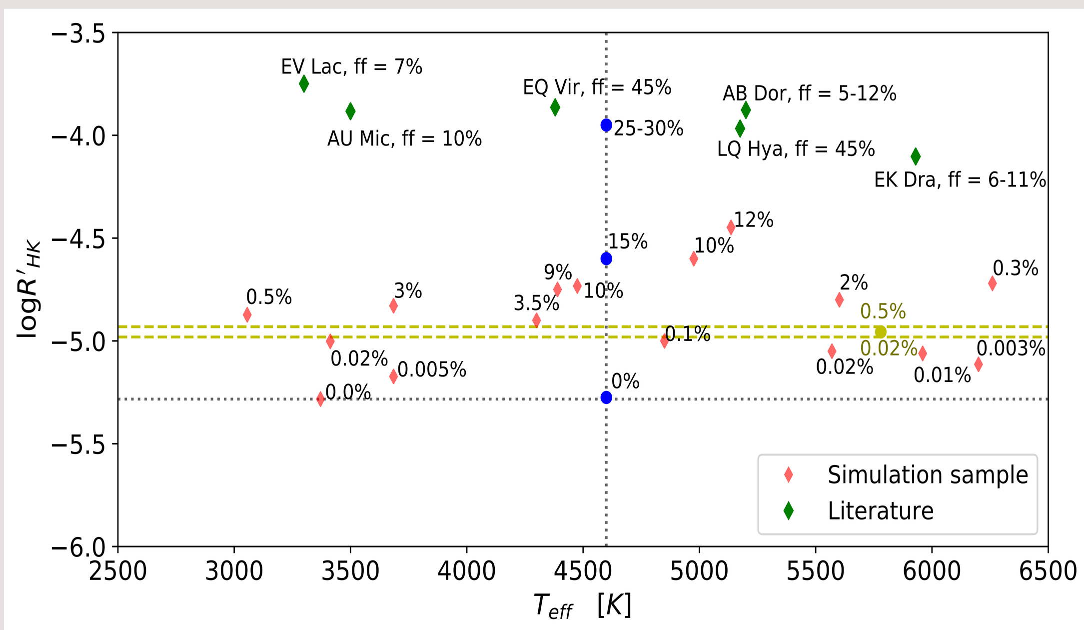
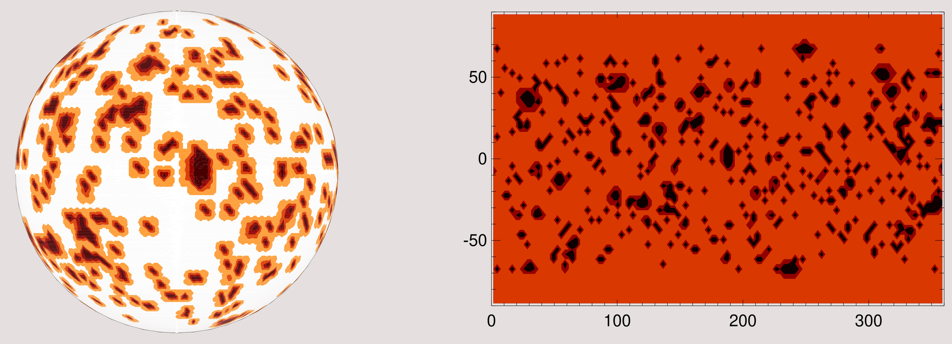
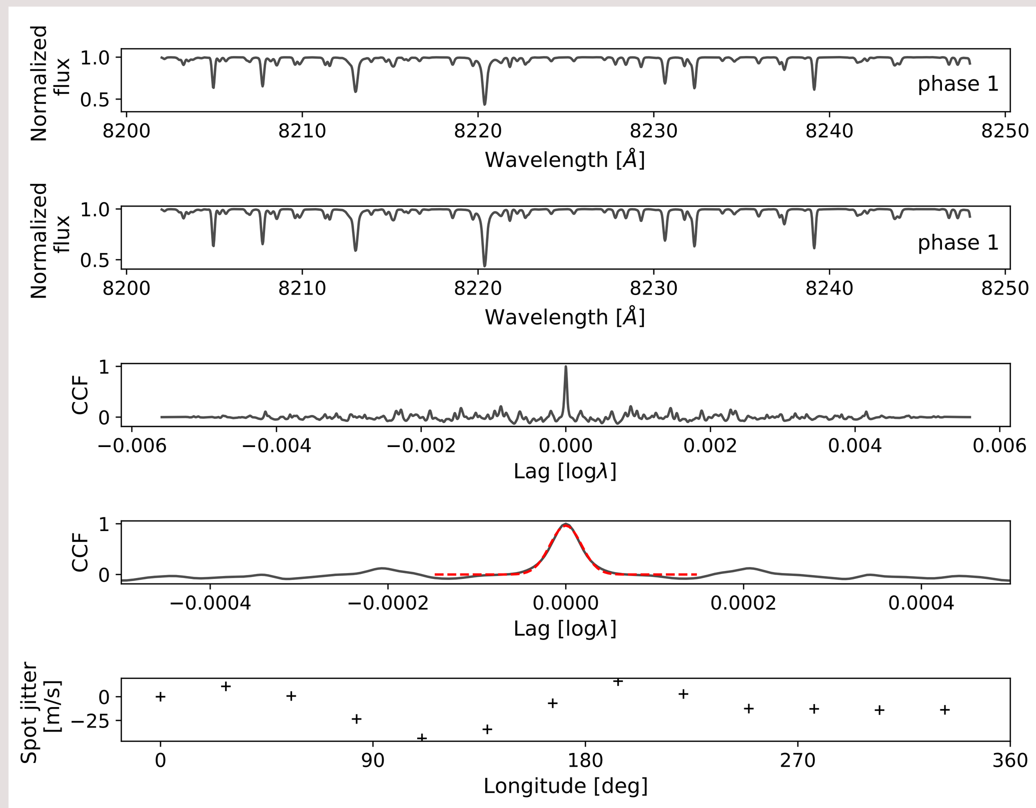


Fig. 3: Filling factor estimates for the host stars present in our sample.

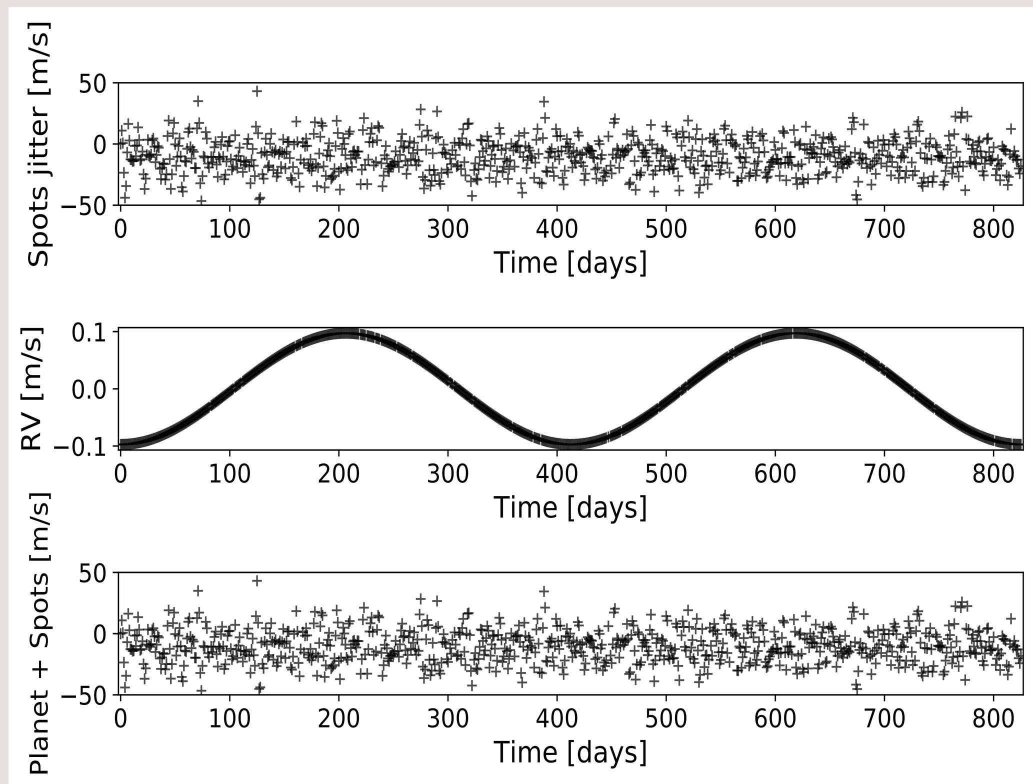
6. Code

By means of the codes SPOTSS and DIRECT7 we generate synthetic spectra which serve as input for our code and the figures below show the surface map and its mercator projection for ε Eri (our most active star) as an example.





The code cross-correlates the spectra at each rotational phase in order to calculate the spots induced jitter which is then added to the radial velocity variation due to the planet: the output of our code is composed both of planetary and spots contributions.



7. Project status and outlook

We perform a Lomb-Scargle period search in order to extract the planetary signal from the datasets we generated. We initially assume an Earth-mass planet. If the signal is completely drown by the starspots jitter, then we vary the planetary mass until we obtain a value at which the detection is successful. This analysis is still in progress; once it is performed for every host star in our sample, the next goal will be to quantify how successful the orbital period recovery is. To this end, we will carry out ten simulations (corresponding to different spots configuration evolutions) for several values of the planetary mass for each star. In this way, we will be able to determine the sensibility of the detection relative to the planetary mass when the spot jitter in the radial velocity data is taken into account.

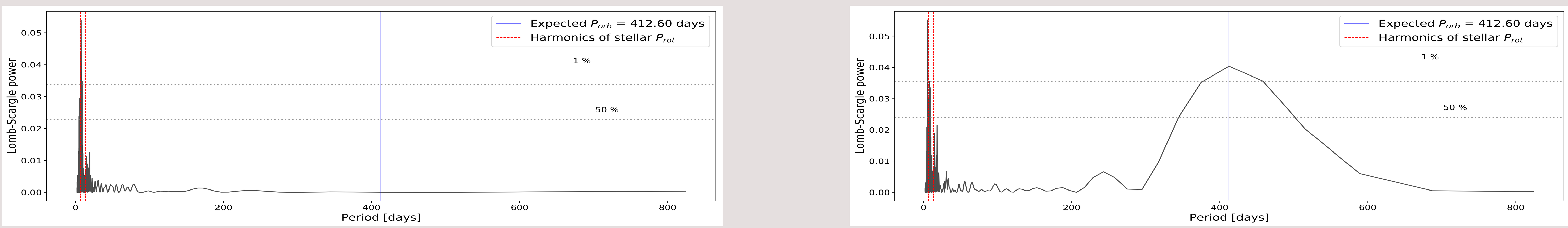


Fig. 8: *Left*: Lomb-Scargle periodogram when considering 1 $M_\oplus$ planet. *Right*: The same as the left panel but with a 39 $M_\oplus$ planet. FAP levels are shown as dotted lines.