Synthetic planetary detection rates using simulated radial velocity observations

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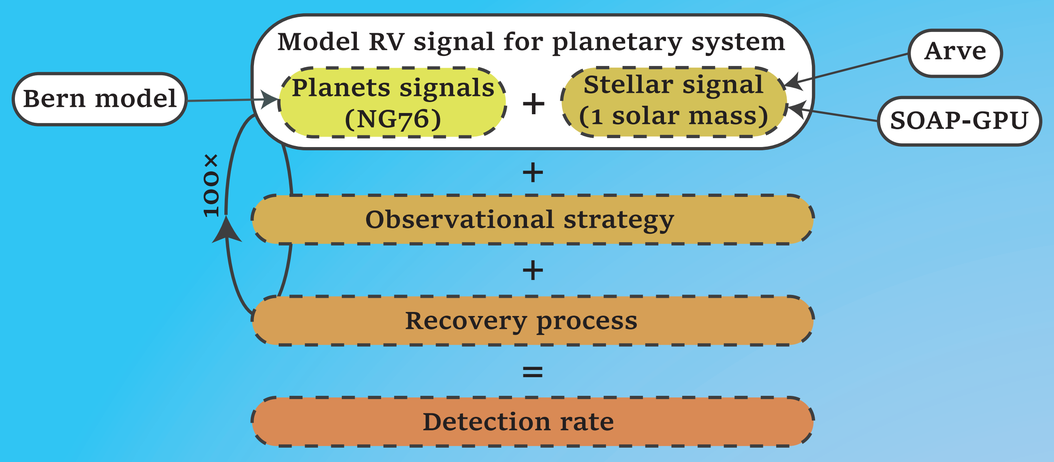
Objectives

Simulate realistic planetary systems and estimate the detectability of the planets using the radial velocity (RV) method.

Here is our general approach:



Methodology

1. Model planetary signals:

Use the Generation III Bern model to simulate the formation and evolution of the NG76 population, composed of 1000 systems of planets orbiting 1 solar mass stars.

2. Model stellar signal:

- The Arve[1] software was used to produces the stellar RV variation caused by:
  1) Oscillation
  2) Granulation
  3) Supergranulation
- The SOAP-GPU[2] software was used to produce the stellar RV variation caused by active regions:
  1) Photometric effect
  2) Convective effect.

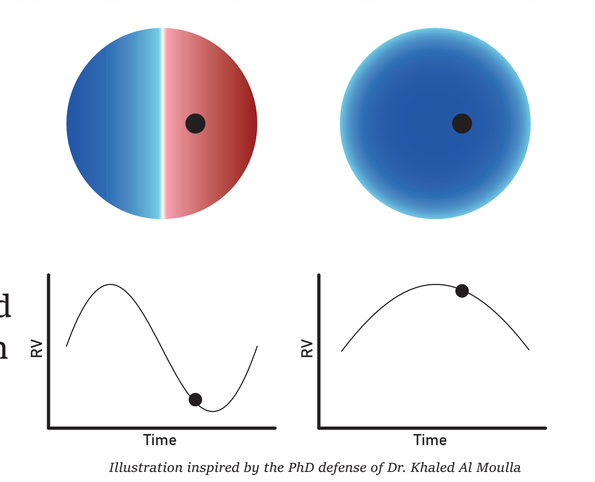


Illustration inspired by the PhD defense of Dr. Khaled Al Moulla

3. Observational strategy:

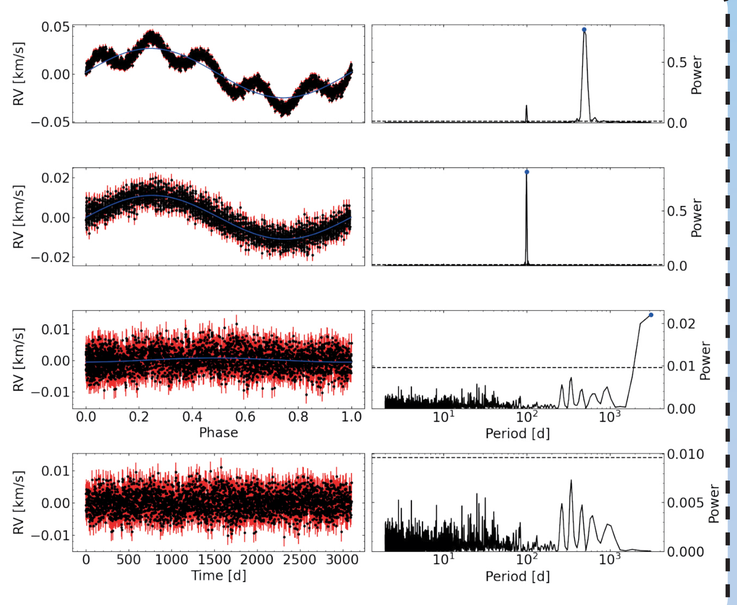
For each system, we first combine the stellar signal with the signals of its planets to obtain a total RV signal. Then, we generate 100 realisations of this signal by adding different photon noise each time. The resulting signals are binned following this strategy:

- 3 observations per night separated by 2 hours
- 10 minutes exposure
- 10 consecutive nights per month
- 8 consecutive months per year
- Over 10 years
- Remove 20% of the nights accounting for technical issues

4. Recovery process:

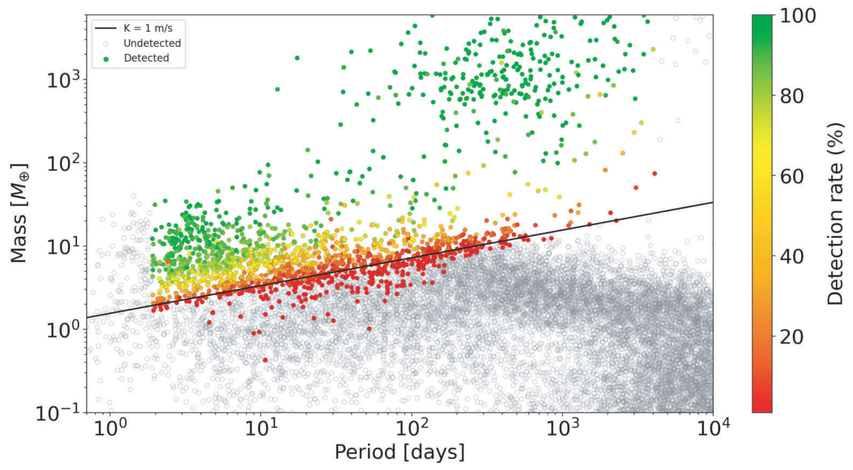
1. Compute periodogram from the data.
2. Identify the strongest peak (planet candidate).
3. Fit and subtract a sinusoid at this period.

Repeat steps 1-3 until no signal exceeds the FAP threshold.



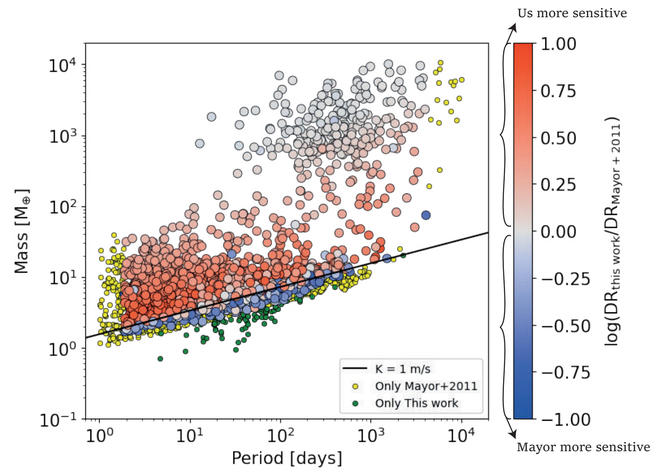
Results

5. NG76 population's detection rate:



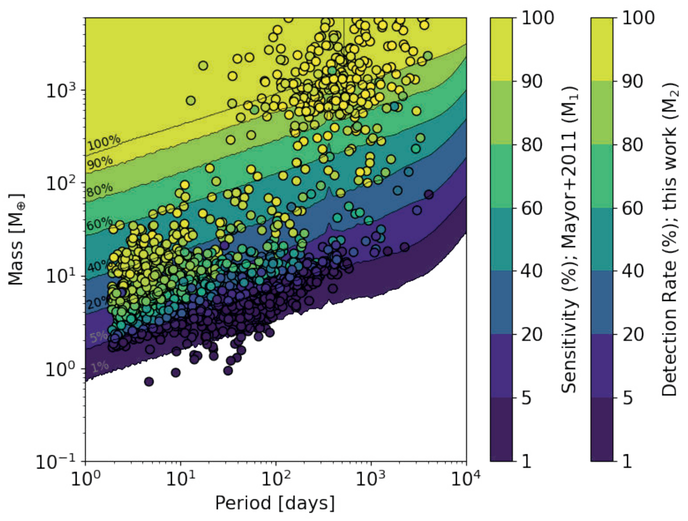
Comparison between Mayor's[3] and our method

Mayor's method used the same process as we did, but instead of simulating stellar signals, they used real RV data from HARPS and CORALIE. Known planetary signals were removed, leaving residuals dominated by stellar activity and undetected planets.



Comparison of detection performance:

Both approaches generally agree on which planets are detectable, but our method assigns higher detection rates, for massive and short-period planets.



Future prospects

- Use AI to recreate the detection rates[4]
- Include eccentric orbits
- Add stellar activity proxies and apply RV detrending techniques
- Test alternative observational strategies
- Expand planetary system diversity

References: Eltschinger, R. et al. in prep. - Al Moulla, K. et al. 2023 - [1]Al Moulla, K. in prep - [2]Zhao, Y. et al. 2023 - [3]Mayor, M. et al. 2011 - Emsenhuber, A. et al. in prep. - [4]Davoult, J. in prep.

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