Hands-on Session: "Planet Hunt Challenge"

Resources:
- DACE introduction tutorial: https://dace.unige.ch/tutorials/?tutorialId=2
- RV measurement tutorial: https://github.com/bjfultn/sagan-2020/tree/master/tutorials/rv
- DACE page for 51 Peg: https://dace.unige.ch/radialVelocities/?pattern=51%20peg
- Advanced planet hunting tutorial using DACE: https://github.com/bjfultn/sagan-2020/tree/master/tutorials/DACE
- DACE "cheat sheet" http://obswww.unige.ch/~segransa/dacecheatsheet/

For the "planet hunt challenge", you will be provided with a real radial velocity dataset with known planets, but not told the star name or which planets to expect. You have to find and fit the planets using the DACE tools (either the online tools or the Jupyter notebook).

Your task is to (more details below):
1. Access the RV dataset using DACE
2. Identify all significant periodic signals in the RV dataset
3. Decide which signals are planets and which are activity
4. Model the system as a sum of Keplerian orbits
5. Fill out the Google forms with your results

Submit (via Google form) the following by Thursday, July 23, 5pm PDT:
- number of planets
- periods of the planets
- masses of the planets (give the stellar mass, too)
- any activity periods?

On Friday, July 24, 8:30-9:00 am PDT, the results will be compiled and discussed.

Step 1: Access a mystery RV dataset.

- We have compiled 5 datasets for you to analyze. They can be accessed using the DACE interface and each dataset will have it's own page.
   - https://dace.unige.ch/radialVelocities/?pattern=Sagan_system1
    - https://dace.unige.ch/radialVelocities/?pattern=Sagan_system2
    - https://dace.unige.ch/radialVelocities/?pattern=Sagan_system3
    - https://dace.unige.ch/radialVelocities/?pattern=Sagan_system4
    - https://dace.unige.ch/radialVelocities/?pattern=Sagan_system5

    You can also find these five systems by typing 'Sagan_system1', 'Sagan_system2'… 'Sagan_system5' in the « Radial velocity » field in DACE.
    To do this, go to: https://dace.unige.ch/dashboard/
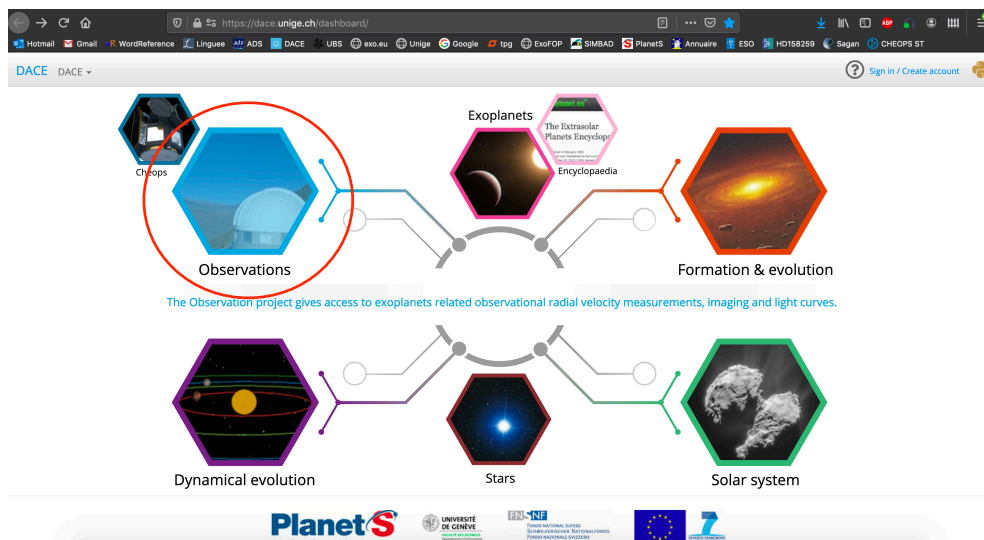
IN THE DACE WEBPAGE, CLICK ON « OBSERVATIONS »
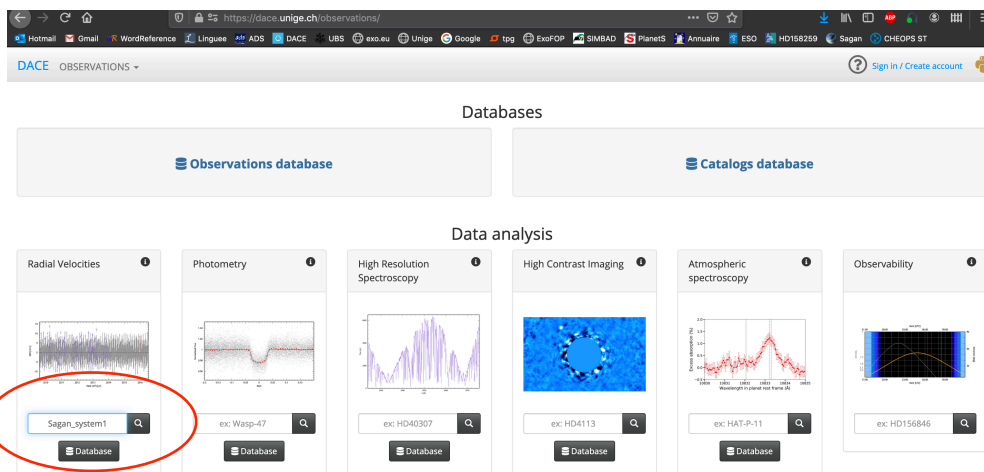
TYPE THE NAME OF THE SYSTEM YOU WANT TO ACCESS

- You may use the online DACE interface to analyze the data, or download the data to your machine if you want to use other tools.

Step 2: Identify periodic signals.

- Utilize the techniques learned in the DACE introductory tutorial and/or the Advanced planet hunting tutorial to search for planets
- The basic idea is as follows:
    1. Calculate a periodogram of the RVs
    2. Identify peaks in the periodogram that stand out above the noise
    3. Fit a Keplerian model with the period of the peak identified in the periodogram
    4. Subtract that model from the RVs
    5. Repeat the process on the residuals until no significant peaks are found in the periodogram

Step 3: Decide which signals are planets

- After you are confident that you have identified all periodic signals in your dataset you need to decide which signals come from planets and which are caused by various sources of stellar variability
- There are infinite ways to do this and no one right answer, but here are some hints
    - Calculate periodograms of activity indicies – planets shouldn't show up here
    - Break up the dataset into several chunks and calculate periodograms for the data in those chunks to see if the signal is consistent over time
    - Analyze the dataset separately for each instrument if more than one present
    - Try models other than Keplerians (e.g. Gaussian Processes) to see if something that is not purely periodic is a better fit
    - Analyze other types of data where available (e.g. photometry). Planet signals should only show up in RVs, but activity signals often show up in multiple types of data.

Step 4: Model the full system

- Once you decide which signals should be included in the final model as Keplerians run an MCMC analysis to get the final parameters and uncertainties
- Again, the MCMC analysis can be performed using either the DACE online interface, the API, or any other tool that you would like to use (e.g. RadVel). If you use a tool other than DACE be prepared to describe your method.
- Compile the results into a table for easy reference. You'll want to record the following parameters, with uncertainties, for each planet (at a minimum) and also record the periods that you identified as activity:
    - Period
    - Eccentricity
    - Semi-amplitude
    - Semi-major axis – for simplicity lets all assume a stellar mass of 1.0 solar masses
    - Minimum mass (msini) – for simplicity lets all assume a stellar mass of 1.0 solar masses

Step 5: Publish your results

- Finally we will all submit our results using Google Forms so that we can compare our results.
    - Google Form for system 1
    - Google Form for system 2
    - Google Form for system 3
    - Google Form for system 4
    - Google Form for system 5