CTA200 RV Project

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In this project you will use the publically availale NBody dynamics code `REBOUND` to simulate the radial velocity (RV) curve we might find when observing an exoplanetary system. The radial velocity curve is a measure of the relative motion of the star due to gravitational interactions with orbiting planets. For some background on the radial velocity method, this review provides some good background (see section 2 in particular).

1 Using `REBOUND`

The first step of this project is to get familiar with simulating planetary systems using the publically available NBody simulation code `REBOUND`. You can see the code at `https://github.com/hannorein/rebound`. If you are using the CITA machines, `REBOUND` is already installed, just load the Python module and you can import it. If you are using your own machine, install it using pip.

1. Go to the documentation for `REBOUND`. Find the Quick Start Guide and follow the instructions for running your first simulation.
2. By default the units are set such that $G = 1$ (a common choice by people in the planetary NBody and planetary disk community, though not one I am a huge fan of). Search the documentation to find how to set the units to ('yr', 'AU', 'Msun'). Make sure you set the new units before adding any particles to the simulation.
3. Modify the setup from the example in the quick start guide so that you are simulating two planets with the following parameters: $(m_1, a_1, e_1) = (10^{-3}M_\odot, 5.2AU, 0.05)$ and $(m_1, a_1, e_1) = (3 \times 10^{-4}M_\odot, 9.6AU, 0.05)$ around a $1M_\odot$ star. Run the simulation to a time of 500 years.
4. Plot the orbital trajectories of both planets on the same plot. Also make a plot of the semi-major axis and eccentricities of each planet as a function of time.

2 Making a Synthetic RV Curve and Understanding RV

In this section you will use `REBOUND` to simulate what an RV curve might look like for a certain planet configuration.

1. Make a simulation with a single planet of mass $10M_\oplus$ orbiting a $0.1M_\odot$ star on a circular orbit at 0.1 AU. Run the simulation for 30 orbital periods of the planet.
2. Plot the radial velocity of the star as a function of time (Hint: choose the direction to the observer such that it lies either along the x or y axis, think about what this means for the radial velocity). Make sure you have at least 10 data point per orbit.

3. Separately vary the mass of the star, the mass of the planet and the semi major axis. How does the radial velocity curve depend on each of these?
4. Repeat the simulation with $e = 0.3$. Make another plot of the RV curve. What changes?

3 Fitting RV data using `REBOUNDND` and `emcee`

In this part, you will build on the synthetic RV modelling you did already to try to fit the orbital parameters of real RV data. To do this, you will sample different sets of orbital parameters using the MCMC sampler `emcee` and will compare the synthetic RV with the real data for each realization. You will use the data and methods from Rein & Silburt (2017) and try to reproduce their fits.

1. Step by step instructions for this section coming soon.