1.2 Lecture: Motion of the Planets and their Interactions

In this lecture I will review some theory of the laws that govern the motion of the planets in our solar system and explain how we can model their motion. There are analytical solutions for the 2-body problem. However, there is no general solution for the n-body problem. Hence we must use a computer to solve many coupled ordinary differential equations.

In the lecture I will explain that Newton's laws of Motion for 2-bodies predicts that the motion of planets around the sun are perfect ellipses (as observed by Kepler). However, when interactions between other planets are included the orbits develop a so-called 'precession' where the shape of the ellipse changes slightly over time. This is due to planets such as Jupiter and Saturn pulling the other planets slightly out of their orbits. Orbital precession is also known as the first Milankovitch cycle. Milankovitch cycles such as these may be responsible for ice ages and other changes to the Earth's climate.

We will run a solar system model and also plot out the orbits of the planets vs time. We will also discuss a way of performing time-series analysis known as Fourier analysis. As you will see Fourier analysis is a clever mathematical technique that allows us to quantify the frequencies that are present in an oscillation. For example we will be able to see that the main frequency present in a planets orbit is its orbital period (the time it takes to go around the Sun).

However, we shall also see that the presence of other planets can result in additional frequencies: an important one is Jupiter, whose orbital frequency of 11.8 years can be felt by most other planets in the solar system.

Analysis of these frequencies will also allow us to see effects such as the *'Great Conjunction'*, which is when Jupiter and Saturn are aligned in the sky: their alignment means that a large amount of mass is concentrated in one part of the sky and therefore, the gravitational pull of the the combined planets is stronger.

Lastly, we shall run the model and analyse the wobble of the Sun due to the gravitational pull of all of the planets. The wobble of stars is often used to identify exo-planets that are often too small to be seen. Rather that visually identify these planets we can often see that they cause the parent star to wobble.

1.2.1 Homework and reading

Background reading:

- Review the notes before the practical class.
- Ensure you know how to log into the server computer using a Terminal / CMD window.
- Have you completed the previous practical? If not, please do so.