Solar System Dynamics
(Dinamica del Sistema Solare)
2023/2024

(second semester)

Teachers: Giacomo Lari and Giulio Baù

Introduction

Our Solar System is populated by a great variety of objects, like planets, satellites and asteroids, whose orbits show very interesting features. Indeed, even though in first approximation these bodies move on elliptic orbits, perturbations due to their mutual gravitational attraction affect greatly their motion over large timescales. For example, the distribution of asteroids of the main belt between Mars and Jupiter presents some clear gaps at certain distances from the Sun, suggesting the existence of a dynamical mechanism that allows to remove objects from these areas. Moreover, the orbital periods of many satellites around planets have integer ratios. Such peculiar configurations provide hints of dynamic orbital evolution of celestial bodies, often driven by dissipative processes. In a more general view, it is observed that often the architecture of planetary and satellites systems is organized around orbital configurations called resonances, which affects greatly their dynamics. Resonances are not limited only to the orbital motion of the bodies, but can involve also their rotation, as it is the case of the Moon which shows always the same face to the Earth. In this context, it is natural to wonder how the single objects, or more generally the whole Solar System, evolved up to their current states after their formation.

Highlights

We will study the gravitational N-body problem using Lagrangian and Hamiltonian formalism. As we are interested in the long-term (or secular) evolution of celestial bodies, we will formally introduce the operation of averaging, which allows to remove short-period terms from the dynamics' description. Then, we will present analytical models to study secular motion, mean-motion resonances and spin-orbit resonances between celestial bodies. We will also introduce dissipative effects acting in space, such as tidal dissipation which make satellites migrate and push them toward resonances.
During the course, we will also present some examples of dynamical evolution of celestial bodies obtained through numerical simulations (Fortran90 programs are available on the webpage of the course).

Practical information

The course will last 42 hours (6 CFU) and it will take place in the second semester. The exam will be a seminar on a topic present in the literature and agreed upon with the teachers of the course.
The prerequisites for this course are basic mathematical analysis, analytical mechanics and some fundamental of celestial mechanics. Moreover, some interest in space doesn't hurt!

Whoever is interested in knowing more about this course can visit the webpage `https://poisson.phc.dm.unipi.it/~lari/dss.html` or contact us via e-mail: giacomo.lari@unipi.it, giulio.bau@unipi.it.