Project-Jupiter and Asteroids

February 13, 2022

This project investigates the seemingly mysterious absence of asteroids at certain distances from the Sun, in the region between Mars and Jupiter (so-called 'Kirkwood Gaps'). Asteroids in this region are influenced by Jupiter, in addition to the influence of the Sun on them.

1. First, simulate the orbit of Jupiter. Given the relatively small eccentricity of Jupiter's orbit (about 0.05), simulate a circular orbit. Start with the expression for the acceleration of Jupiter under the influence of the Sun. Express lengths in units of Jupiter's distance r_0 from the Sun (assumed constant) and time in units of the time period T_0 of a circular orbit of radius r_0. Write down the expression for the (dimensionless) acceleration in terms of the dimensionless coordinates. What is the (dimensionless) speed of Jupiter in the circular orbit numerically? Using the leapfrog algorithm, compute and plot the orbit by running the code for large values of dimensionless time (a few thousand). Check for conservation of both energy and angular momentum by plotting them as functions of time.

2. Next, include an asteroid. Write an expression for the acceleration of the asteroid in presence of both the Sun and Jupiter. Express it in dimensionless form using the same length and time scales as before. Using data, find the ratio of the mass of Jupiter to that of the Sun (this should be relevant to the acceleration of the asteroid). Given that the mass of Jupiter is orders of magnitude greater than the mass of any asteroid, make reasonable assumptions to simultaneously determine the orbit of both Jupiter and the asteroid (use initial conditions that generate circular orbits only, for simoplicity). Run the code for large values of dimensionless time (several thousand). Do not bother checking for conservation of energy and angular momentum. Plot the orbits of Jupiter and the asteroid together, for different values of the asteroid orbital radius. For definiteness, scan the range of orbital radii from 2.3 AU to 3.7 AU (an AU is the mean orbital distance of the Earth from the Sun) in small steps. Can you explain the observations?