Lab 4 - Modeling the Solar System (part II)

Thursday 21 September, 2006 - Due: Thursday 28 September

The aim of this lab is to continue development of the solar system model we started in lab3. In this lab we continue with our discussion in lecture by adding Jupiter into the mix. We will examine its effect on the Earth and a hypothetical planet we insert between Earth and Jupiter. At the end of the lab you will know why there is no such planet in the real solar system. *As always, please include in your writeup any sections of Python code you write.*

1 Orbital precession

Download the two codes `integrator.py` and `solar.py` available as links from the **LABS** page. You should save them to your I: drive for future reference. Notice that in `solar.py` the total momentum of the system is set to zero with the commands

```
# set total momentum of system to zero
momentum=vector(0,0,0)
for b in bodies:
    if (b!=sun):
        momentum=momentum+b.velocity*b.mass

sun.velocity=-1.0*momentum/sun.mass
```

The center of the scene is also fixed to the Sun's position in the final line of code

```
scene.center=sun.pos   #center the view on the sun}
```

In `solar.py` you will see a parameter `boost` which is initially set to unity. This allows one to increase the mass of Jupiter. For `boost=1` run the simulation.

- Capture a screen shot of the simulation. Is there any observable effect for long times on Earth's orbit ?
- Increase `boost` to 10.0. Again capture a screen shot of the resultant motion. What happens to the Sun ? What is the orbit of Jupiter now ?
- Run your simulation for larger values of the `boost` parameter and record what you see. At what value of `boost` does the system become unstable ?

2 PlanetX

Now add code to `solar.py` to create another planet - call it planetX with the Earth's mass and situated at some distance r_X from the Sun.

- Write down an equation relating the gravitational force to the radial acceleration for planetX if it is to orbit the Sun at radius R_X with speed v_X (neglect the gravitational effect of the other planets at this stage) Give your answer in terms of G and M_{Sun}.
- Hence find an expression for the velocity v_X which planetX must have to execute such a circular orbit around the Sun
- Create an sphere object representing planetX in `solar.py` and add it to the list of gravitating masses. Let its initial position be R_X.
- Choose $R_X = 2.5$, $R_X = 3.276$ AUs. Using your results from above set the initial velocities so that planetX would, in the absence of Jupiter, undergoe a circular orbit for each R_X.
- Run the simulation using `boost=10.0` to amplify the effects and record the resulting motion. For which value of R_X is the perturbation of the orbit due to Jupiter greatest ?
- In the case where the orbit is maximally affected what is the ratio of the orbital time of planetX with the orbital period of Jupiter. Comment. This is an example of resonance.
- Experiment with increasing the mass of Jupiter – this exaggerates the effect on the resonant orbit. You should be able to see cases where planetX is ejected from solar system

While there are many asteroids between Mars (radius 1.5AU) and Jupiter (radius 5.2 AU) there are essentially none at certain radii. These are called Kirkwood gaps and stem from a resonance phenomenon in which Jupiter's gravitational effects act coherently for objects orbiting at a rational fraction of Jupiter's orbital period.

Jupiter's gravity is so large that it has prohibited the formation of any planet in this region. The asteroid belt is thought to represent the material that would, in Jupiter's absence, have ordinarily clumped together to form another planet. The Kirkwood gaps represent regions where even asteroids are scarse due to a resonant amplification of the effects of Jupiter's gravity.