1 Results

1.1 Euler and Verlet without oo

In order to make sure that our algorithm is running correctly, we will start solving the differential equation using both Euler's and Verlet's method without using object oriented(oo) code. The algorithms used to calculate the two are located in the following folders ((Euler) and (Verlet))

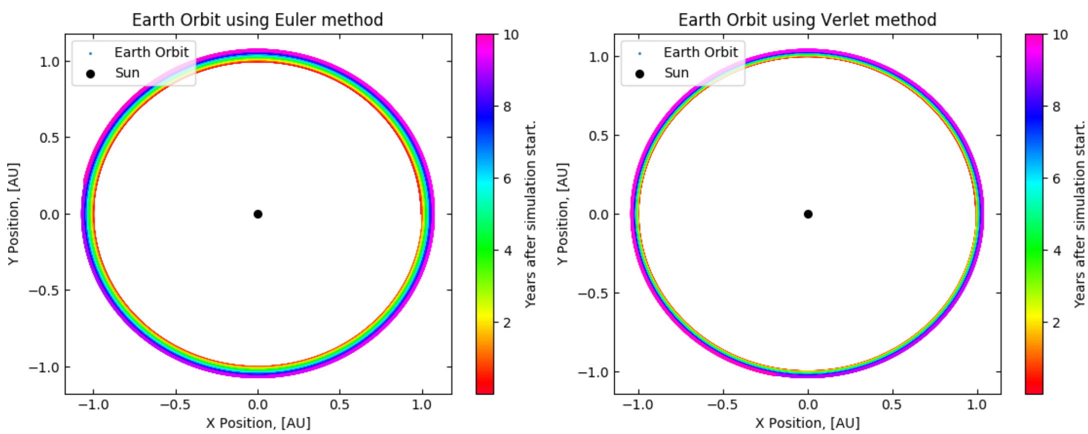

Figure 1: Earth orbit around the Sun using Eulers method and Verlets method respectively

1.2 Testing

1.2.1 Stability with varying timestep

In the figures below we plotted Earths orbit over a thousand years with different timesteps.

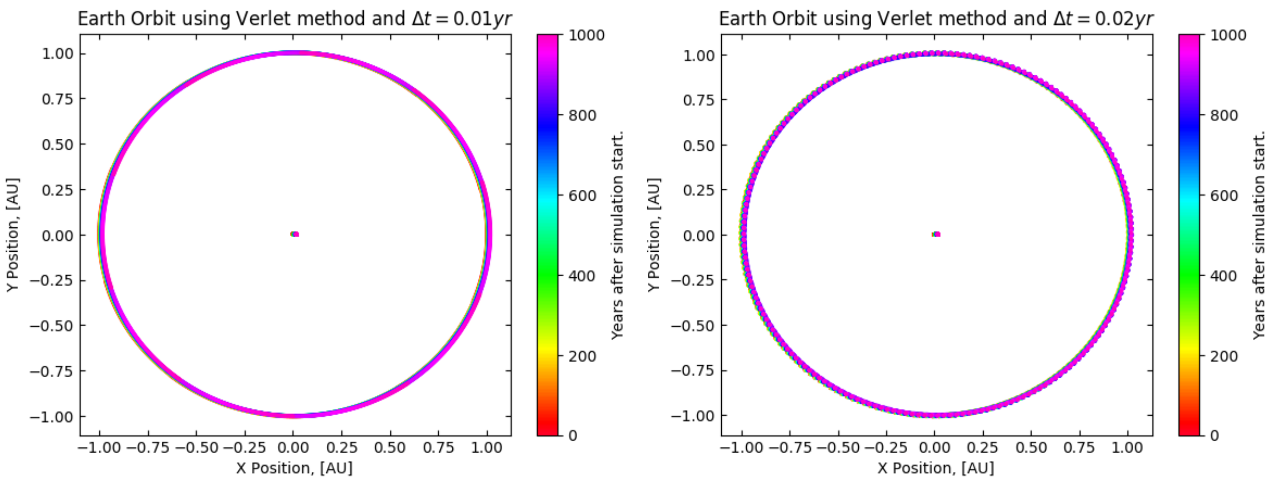

Figure 2: Earth orbit with time steps $\Delta t = 0.01$years and 0.02years respectively

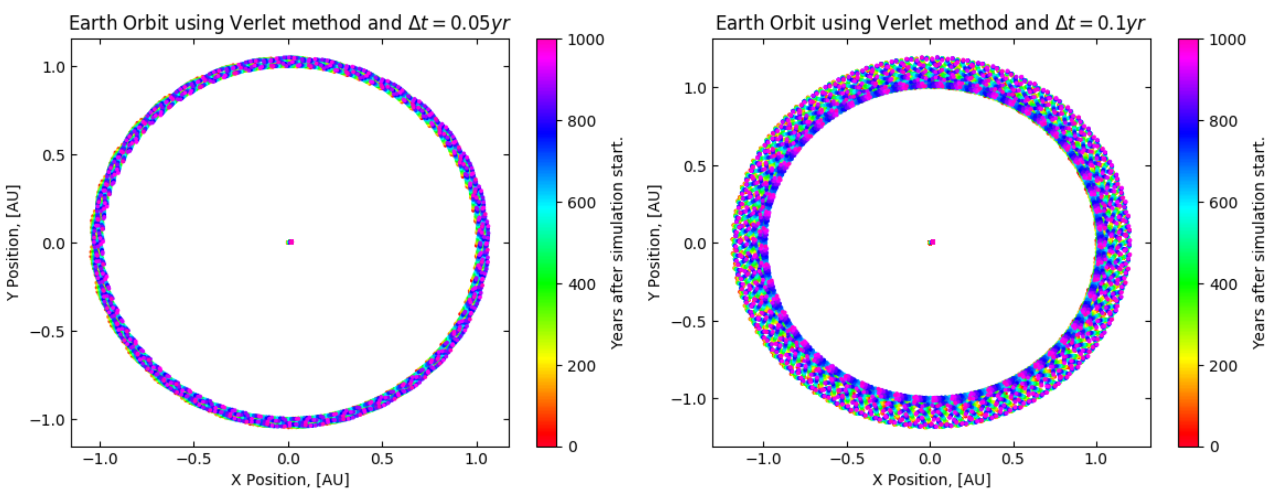

Figure 3: Earth orbit with time steps $\Delta t = 0.05$year and 0.1year respectively

1.2.2 Energy and angular momentum conservation

In the figures below, kinetic energy and potential energy is plotted as a function of time in the system. We chose to simulate over a thousand years with a timestep of $\Delta t = 0.01$, as this gives the most stable results.

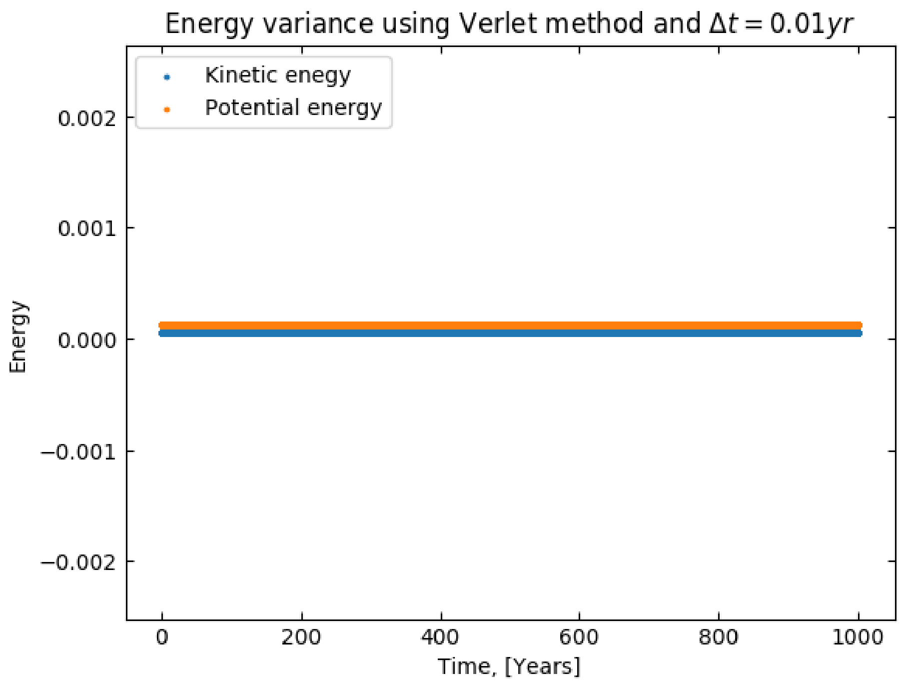

Figure 4: Kinetic and Potential energy with timestep $\Delta t = 0.01$year.

1.2.3 Verlet vs. Euler

Table 1: Comparison of flops and time for the Verlet and Euler method for 100000 iterations over a period of 10 years

	Flops	**Timing**
Euler's method:	10N	2580 ms
Verlet's method:	6N	2875 ms

1.3 Escape velocity

By trail and error the escape velocity of planet Earth is somewhere between 2.8π and 2.85π, which is pretty close to the theoretical value calculated below. From section **??** using equation **??** to calculate the theoretical value

$$v_{esc-theoretical} = \sqrt{\frac{2 \cdot 4\pi^2 \cdot 1}{1}} = 2.83\pi$$

We also looked at what happens when changing the exponent of the denominator the force of gravity from 2 towards 3 with initial velocity $v_{initial,x} = 2.2\pi$. This is shown in the following plot.

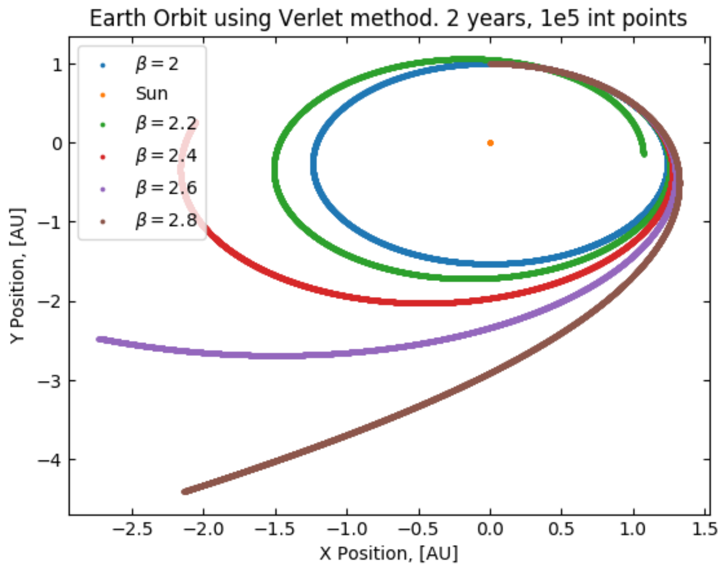

Figure 5: Escape velocity with increasing exponent of denominator of the gravitational force.

1.4 Three-body problem- Sun, Earth and Jupiter.

Stability Verlet solver with increased mass:

1.5 The Solar system

1.5.1 Real three body problem

In the previous section we studied the three body problem with the Sun fixed. In reality ? this is not the case. The Sun moves thoghether with all the other planets. Now, rather than having the origin in the position of the Sun, we set the center-off-mass of the three-body system(Sun, Earth and Jupiter) in the origion. The inital velocity of the Sun is set to ?? in order to have the total momentum of the system to exactly zero.

1.5.2 All planets in our Solar system

Finally we want to study the inpackt from all of the planets in our solar system on each other. This is simply done by adding the rest of the planets in our class and to set an initial velocity and position.

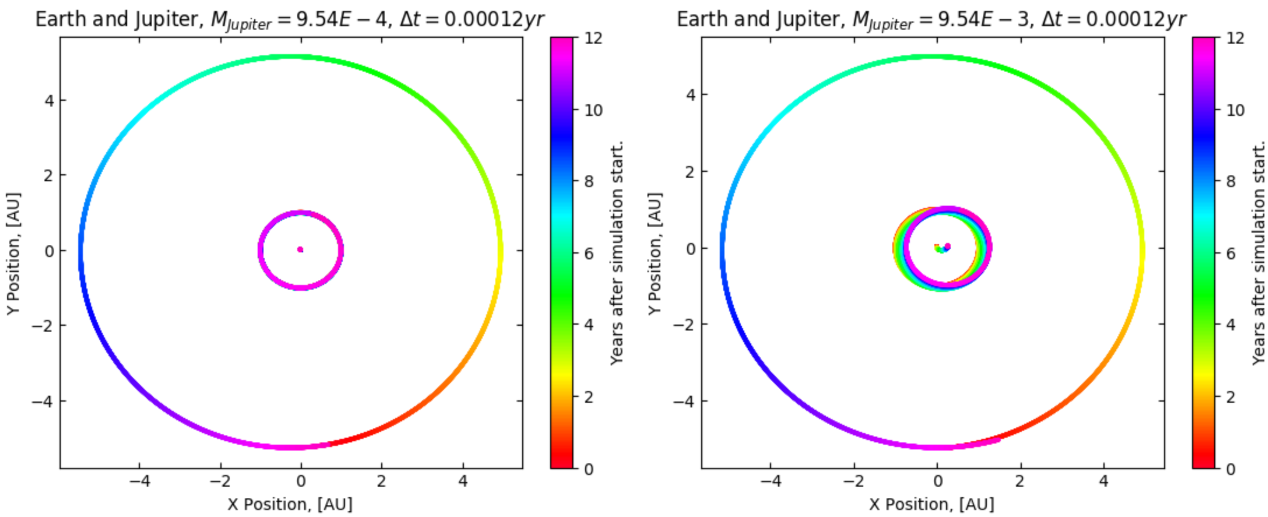

Figure 6: Positions of Sun in the middle, Earth second and outermost Jupiter calculated using the velocity Verlet method with with original mass of Jupiter and an increase of mass of a factor of 10 respectively

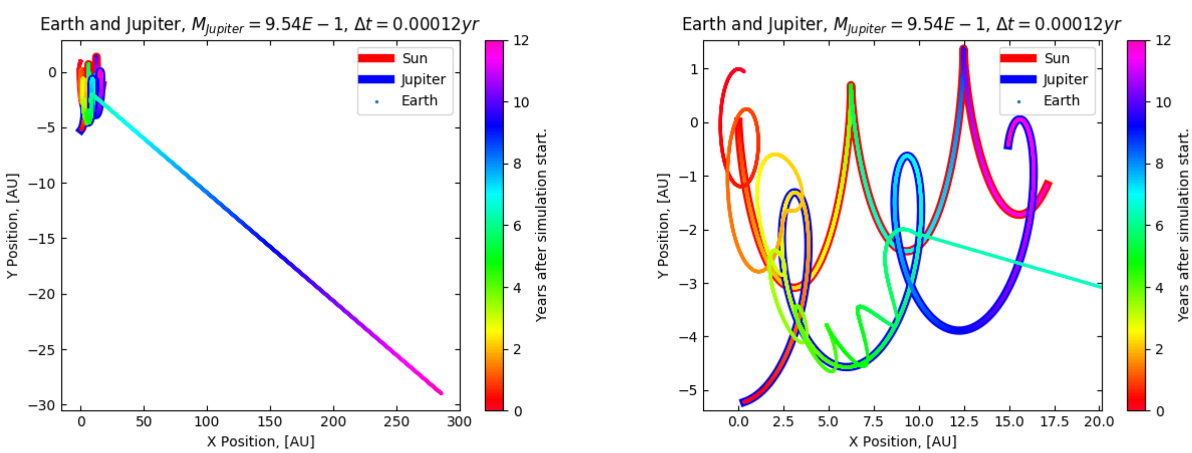

Figure 7: Positions of Earth and Jupiter using the velocity Verlet method with an increase of mass with a factor of 1000. The Sun starts at approximately (0,0)???, Jupiter starts at (0.0,-5)??? and Earth starts at (??????????). After som time, t$\approx$ 7years Earth escapes the system. Picture to the right is a zoomed version of the first plot.

Sammenlign resultetene med de tidligere.

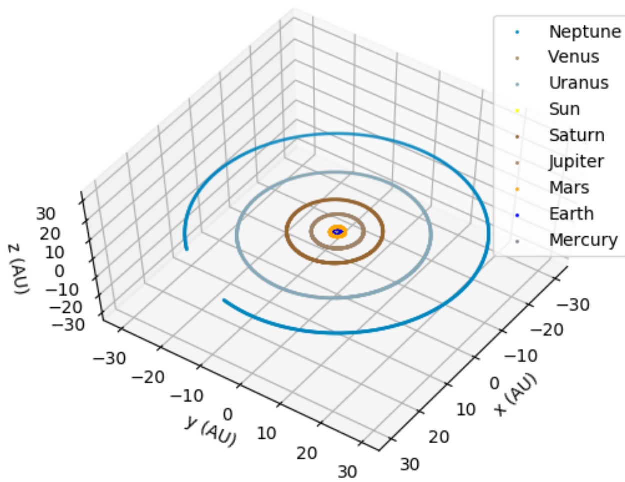

Figure 8: All planets in The Solar System. Due to the large orbits of the outer planets, it is hard to plot the orbit of the inner planets, the Sun, Venus and Mercury without loosing information from the outermost planets.

1.6 The perihelion precession of Mercury