Calculating Planet Orbits

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(Dated: October 22, 2021)

We received data describing another solar system. We then used this data to calculate the orbits of the exo-planets, but with big margins for error, given that we chose to ignore the gravitational effect the planets have on each other.

I. INTRODUCTION

We recieved data from a solar system with 8 planets, 6 solid, and 2 gas planets. The star in this system was 14% smaller and 10% cooler than our sun. The data we received included the masses, radii, and positions and velocities at a given point in time.

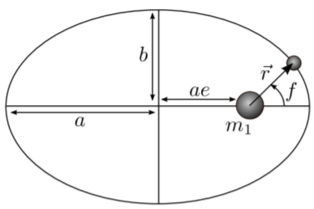

Figure 1.

II. METHOD

Our plan was to use the collected data to calculate the orbits of the planets using the Euler-Cromer method. We chose this method because it is a simple yet quite effective way of calculating Newtonian mechanics:

$$v_1 = v_0 + a_0 \Delta t \qquad (1)$$

$$x_1 = x_0 + v_1 \Delta t \qquad (2)$$

We take the initial velocity and add the initial acceleration times Δt, or in other words, the velocity gained in Δt, to get the velocity in the next time step. The same logic is then used to get to the next position, but to do so we needed to first find a fitting Δt.

We calculated the periods T of each planet by using Kepler's third law taken from [1]:

$$T = \sqrt{\frac{4\pi^2 a^3}{G m_1 m_2}} \qquad (3)$$

where G is the gravitational constant at 6.674×10^{-11}, a is the semi-major axis of the planet's orbit(as can be seen in figure 1), and m_1 and m_2 being the planet's and star's masses. Once we found the period to each planet, we then divided it with a chosen number of time-steps N.

Using the vectorized form of Newton's law of gravitation:

$$\vec{F} = -G\frac{m_1 m_2}{|\vec{r}|^3}\vec{r} \qquad (4)$$

($\vec{r}$ being the vector from the star to the specific planet, which in this case is just the position vector of the planet since the star is in the origin.) we calculated the force from the star on each planet. We then used the calculated force and newton's second law:

$$\vec{F} = m\vec{a}, \quad \vec{a} = \frac{\vec{F}}{m} \qquad (5)$$

to calculate the acceleration. We repeated this process N times.

After we had all of the orbits, we chose to then plot the star itself. We chose a size that fit our graph accordingly and then plotted the planets in their initial positions. We divided the planet's radius by the star's radius and used that number as a ratio to plot the planets in proper proportion to the star.

III. RESULTS

When plotting our data, we chose to go with $N = 1000$, we decided there wasn't any more resolution gained from increasing it past that. We ended up with very close to circular orbits, not unlike our solar system (see figure 2). The two most visible planets are the gas planets, the rest solid.

IV. DISCUSSION

When we calculated the acceleration, instead of first finding the force and then acceleration in two steps like we did, we could have just simply taken m_1 out of Newton's law of gravitation.

The fact that we didn't include the gravitational effect the planets had on each other or their star can't be forgotten, it's possible that these orbits do look quite different in reality, especially the 2 most visible planets that come relatively close to each other in their orbits.

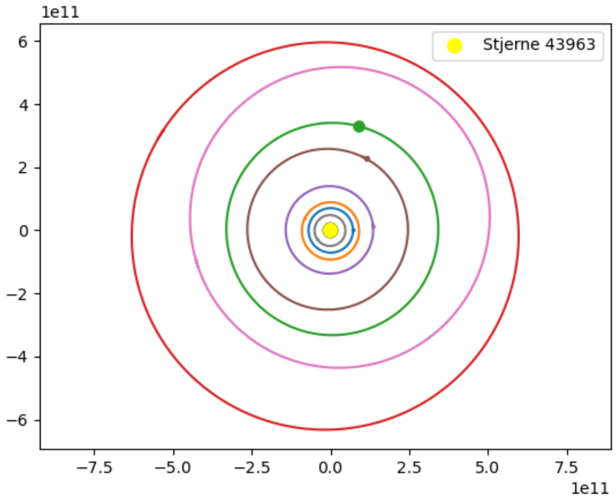

Figure 2.

V. CONCLUSION

In summary what we have done is use data collected from another solar system to simulate the orbits of the planets using the Euler-Cromer method and Newton's 2nd law, and his law of gravitation. We made an approximation by not including the gravitational effect all the planets would have on each other and the star.

REFERENCES

[1] Hansen, F. K., 2017, Forelesningsnotat 1b i kurset AST2000