N Body Problem

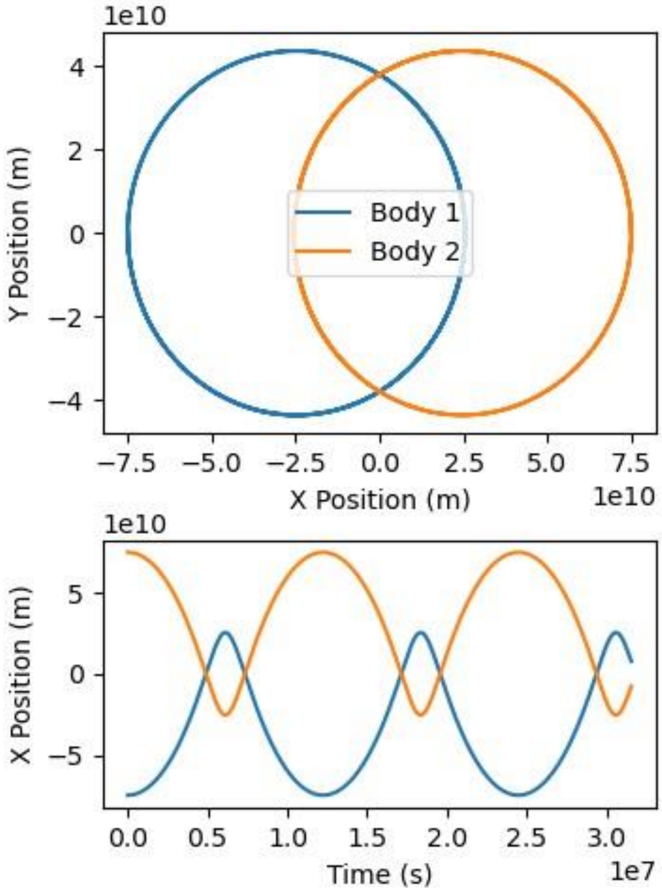

Figure 1: Basic 2 body test case. The top figure shows circular orbits anticipated from two bodies exerting equal and opposite gravitational forces on one another under the initial conditions specified in the test case. The figure underneath shows the evolution of both bodies x position over time. It is clear that both bodies have a periodic relation between their position and the x axis and that the average position of the bodies is approximately 0 at all times.

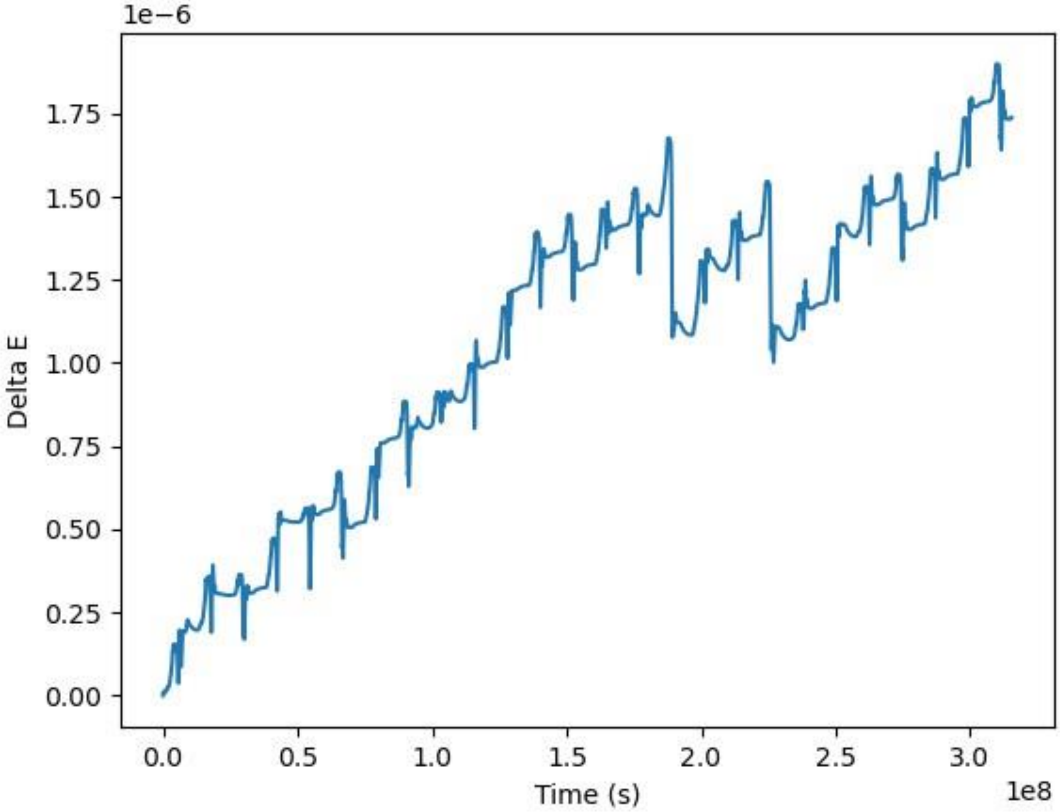

Figure 2: Plot of delta E against time. Delta E represents the change in energy of the system compared to its initial energy. As energy is conserved in an isolated system this change should be 0, however as time goes on it slowly increases implying a slight uncertainty in the system. This inaccuracy is due to the numerical integration methods used in this investigation.

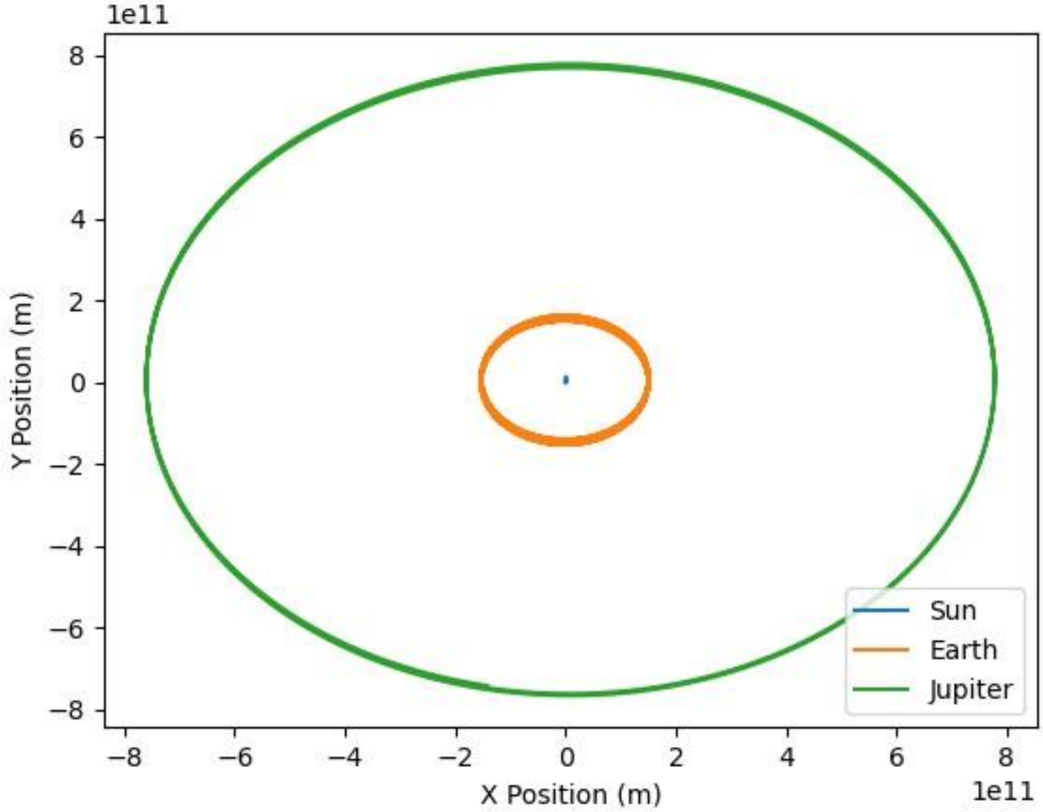

Figure 3: Sun – Earth – Jupiter system. This is a basic test case to see if the expected elliptical orbits will be reproduced by my model. As this was only a test case initial conditions were given in a similar manner to the two body system rather than with actual data.

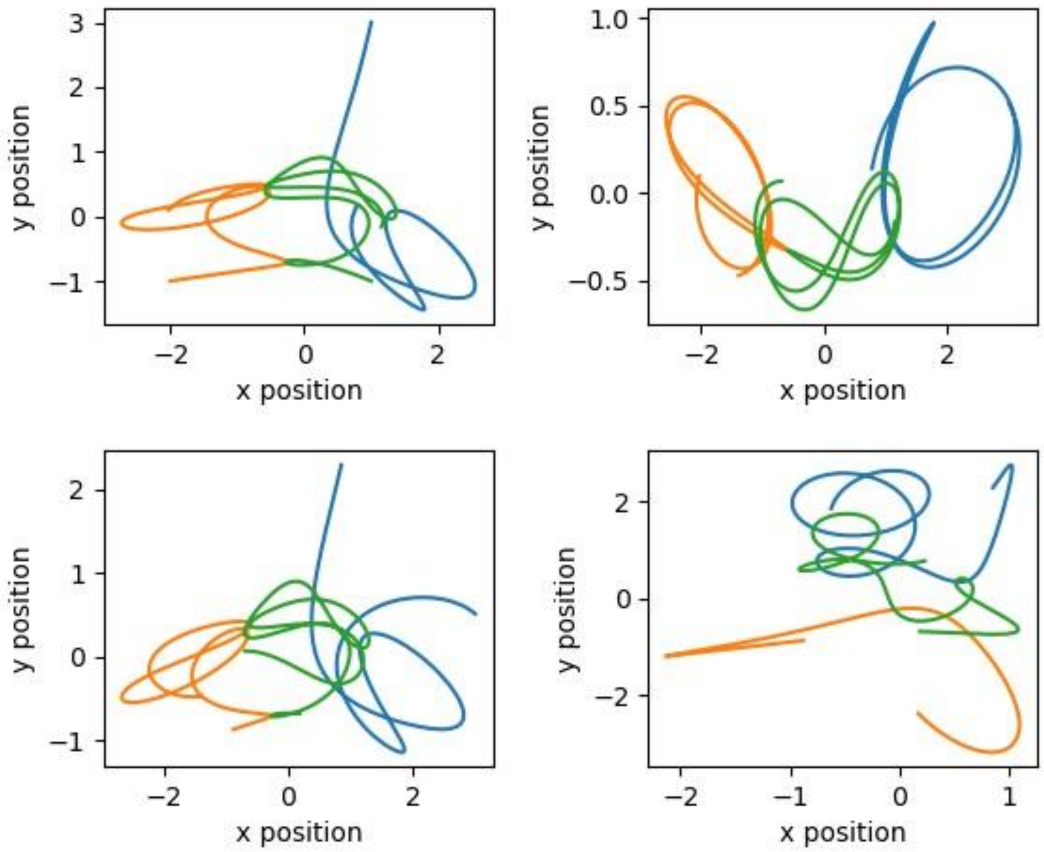

Figure 4: Burraus problem from t=0 to t=40. Graphs show x vs y plots of the position of the 3 bodies in arbitrary units. The top left shows motion from time t = 0 to t = 10, the top right shows motion from t = 10 to t = 20, the bottom left shows motion from t=20 to t=30 and finally the bottom right shows from t=30 to t=40. All bodies appear to follow the expected trajectories from literature showing that the simulator is capable of dealing with close encounters using rtol and atol.

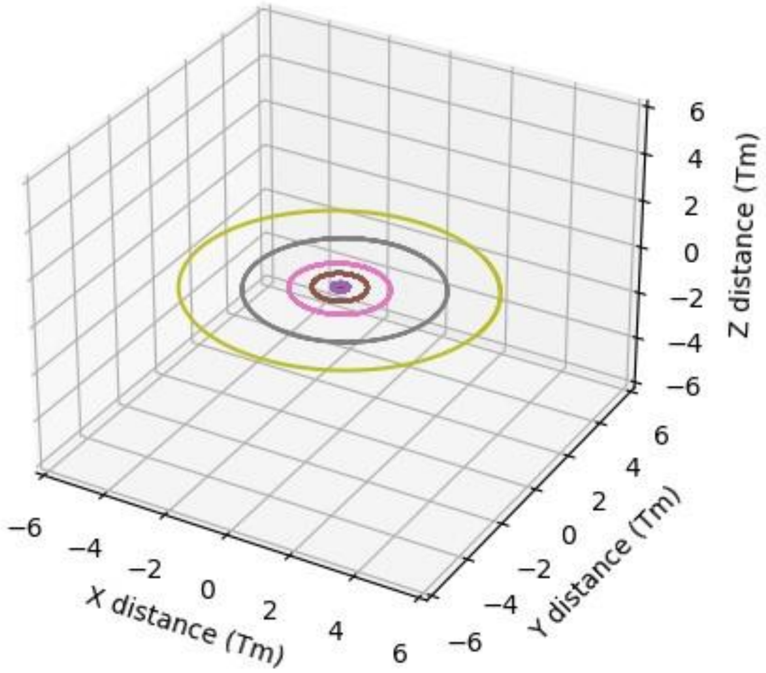

Figure 5: Model of the solar system in three dimensions. All distances given in Tm. Data for this model was taken from the Nasa horizons website, meaning that it is created using real data. All planets orbits end at the same place they started suggesting stability in the solar system. The inner planets orbits are unclear here due to the relatively small spacing between them compared to those of the outer solar system.

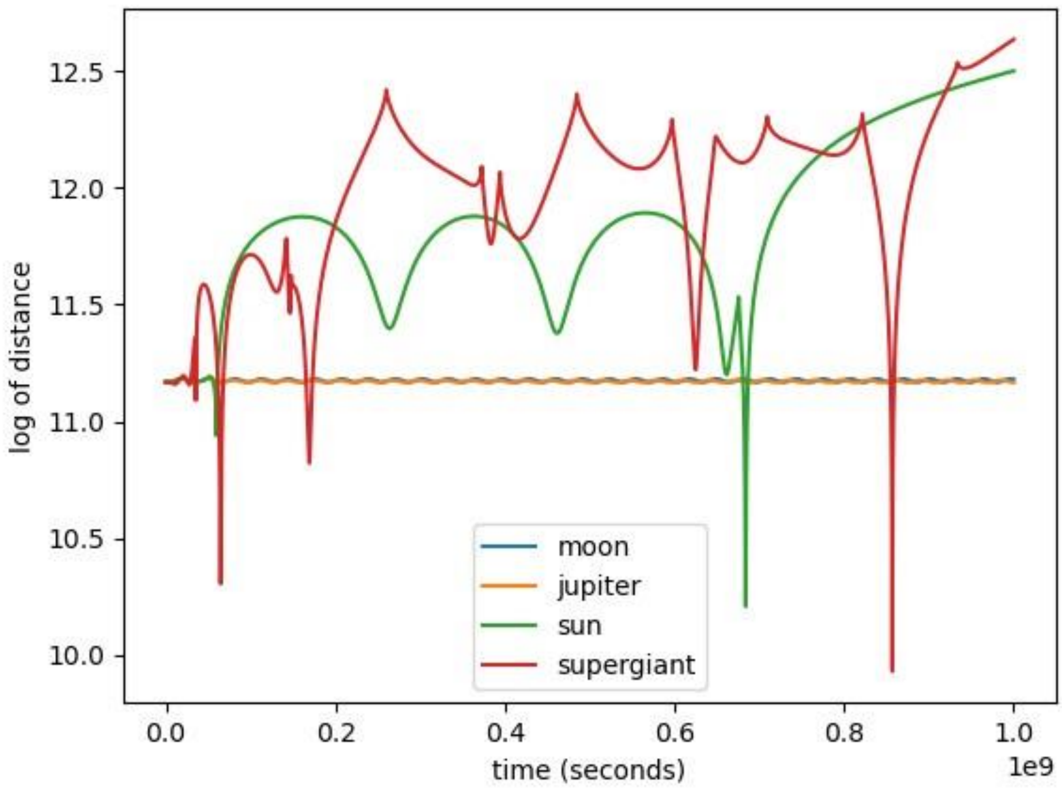

Figure 6: This figure shows the log of the distance between the Earth and the Sun with different bodies passing through the inner solar system with initial conditions of x and y = 1Tm, while vx and vy = -10 and -9 km/s respectively. It can be seen that if an object with the mass of the moon or even Jupiter underwent this path Earth would be unaffected (provided the bodies didn't get too close to Earth). The object with a mass of the Sun appears to initially create a periodic cycle before eventually the Earth is ejected into outer space. The supergiant mass object creates a chaotic relationship between the Earth and the Sun throughout.

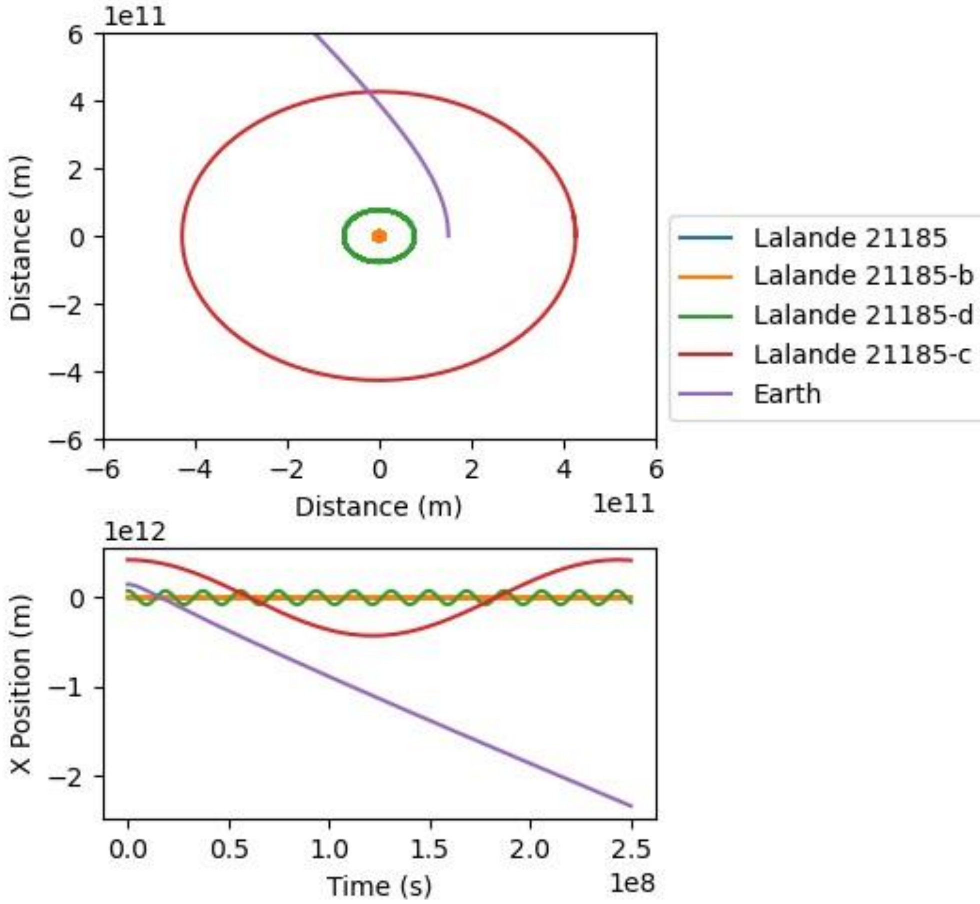

Figure 7: The Earth in an exoplanetary system. The top figure shows a 2d view of the *Lalande 21185* system, with Earth inserted at its current velocity and distance from the star. while all other planets in the system show stable elliptical orbits the earth has far to much velocity relative to the now smaller mass of its host star and is ejected from the system. The bottom figure shows the Earths X-position relative to the system and confirms the stability of the other planets which take on the expected sinusoidal curve while the (absolute) X-position of the Earth relative to the system increases linearly.

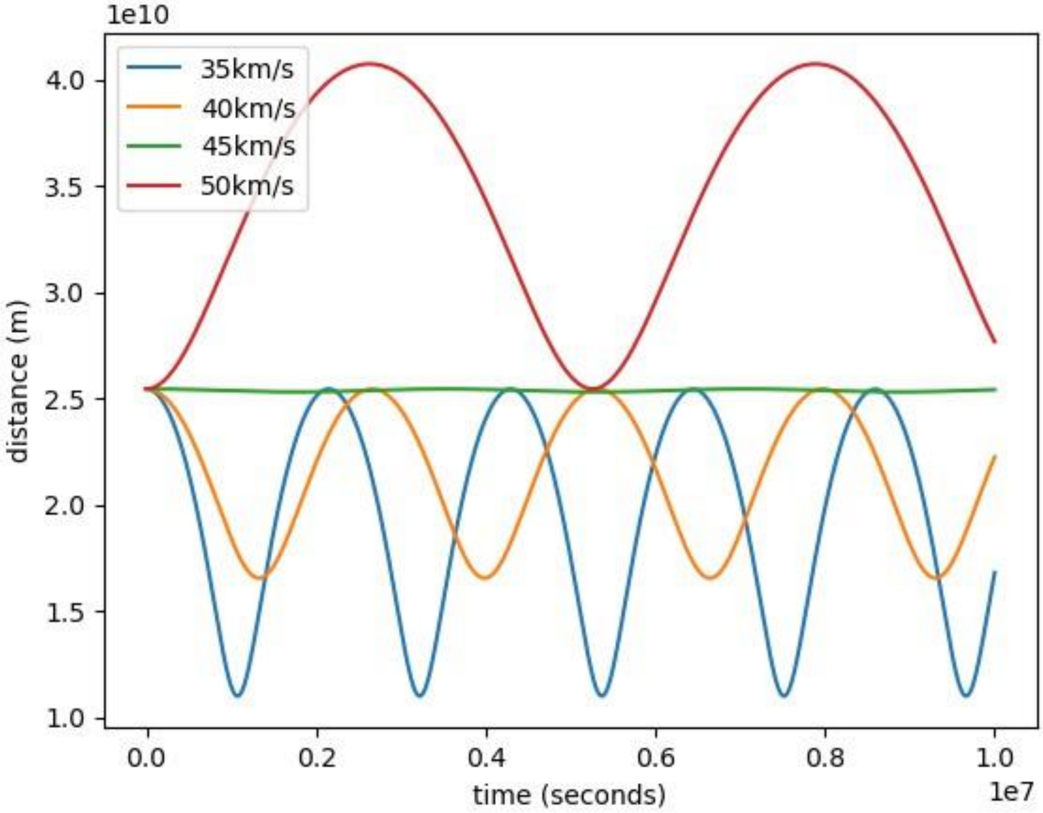

Figure 8: Distance of a 'Goldilocks Earth' from the central star of the *Lalande 21185* system. The habitable zone of this planet ranges from 1.65×10^{10}m (0.11 AU) to 3.59×10^{10}m (0.24 AU) from its host star. This chart shows a planet of earth mass at an initial distance of 2.54×10^{10}m from the star with different initial velocities. All of the velocities form stable periodic relationships with their stars with 45km/s coming very close to a circular orbit. The more elliptical orbits (35km/s and 50km/s) leave the habitable zone during their orbits and 40km/s coming right to the inside of the habitable zone. Incidentally 48km/s is the highest integer velocity that also lies within the habitable zone.