1 Sun-Jupiter System

1.1 Energy

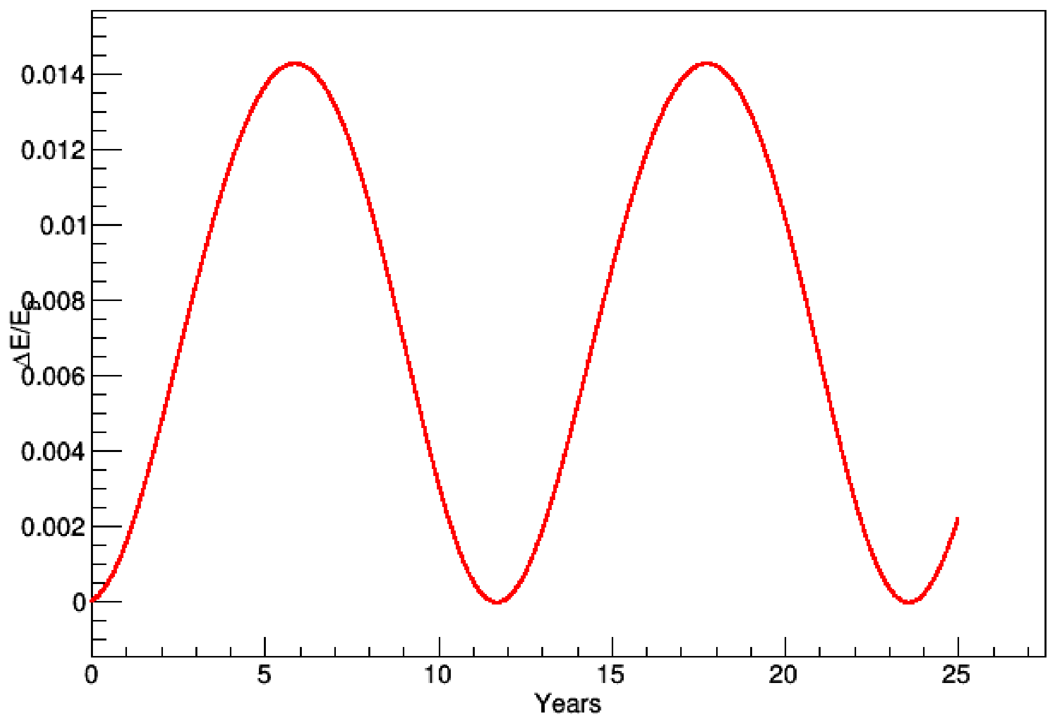


Figure 1: The Sun-Jupiter system's total energy relative error is plotted over 25 years from April 8, 1988. The error oscillates periodically and shows the total energy is conserved with a max error less than 1.5%.

1.2 Angular Momentum

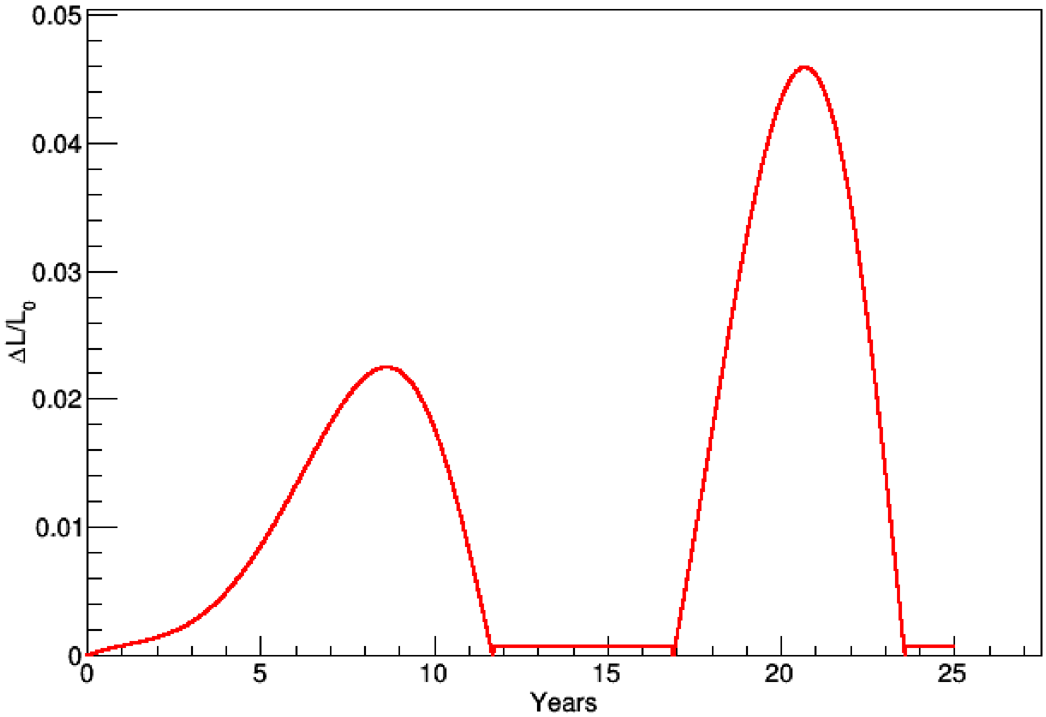
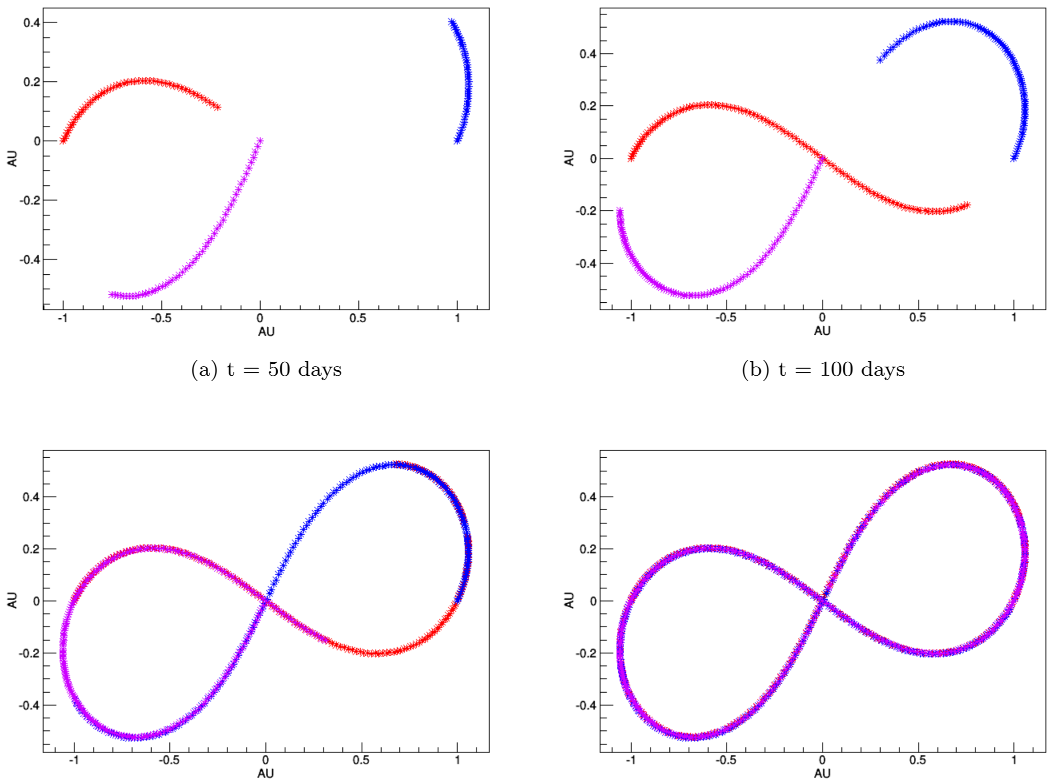


Figure 2: The Sun-Jupiter system's angular momentum relative error is plotted over 25 years from April 8,1988. The angular momentum is conserved with a max error less than 5% error.

2 Stable 3-body Problem



(a) t = 50 days

(b) t = 100 days

(c) t = 200 days

(d) t = 365 days

Figure 3: The stable 3-body problem requires equal masses, $M_1 = M_2 = M_3 = 1\ M_{\odot}$. The 3 masses display stable motions throughout a 1 year period as shown in figures 3.a, 3.b, 3.c, and 3.d. The initial position conditions are $\vec{x_1} = (-1, 0, 0)$, $\vec{x_2} = (0, 0, 0)$, and $\vec{x_3} = (1, 0, 0)$. The initial velocity conditions (AU/year) are $\vec{v_1} = (.347111, 0.532728, 0)$, $\vec{x_2} = (.347111, 0.532728, 0)$, and $\vec{x_3} = (-.694222, -1.065456, 0)$.

3 10-body Solar System

3.1 Orbital Motion of Solar System

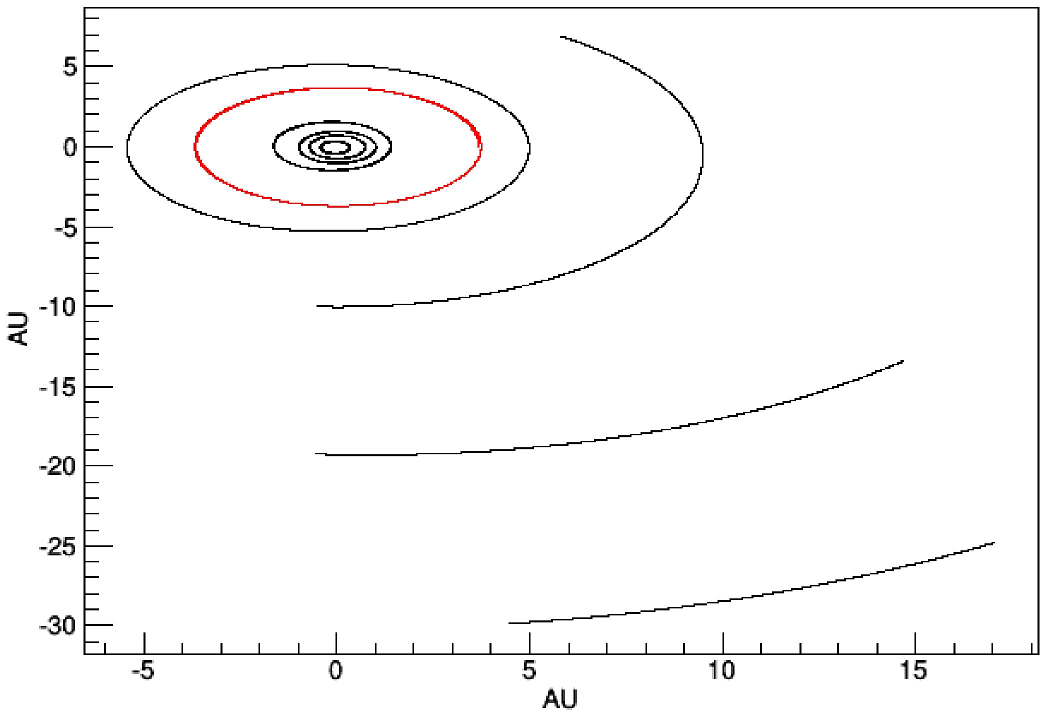
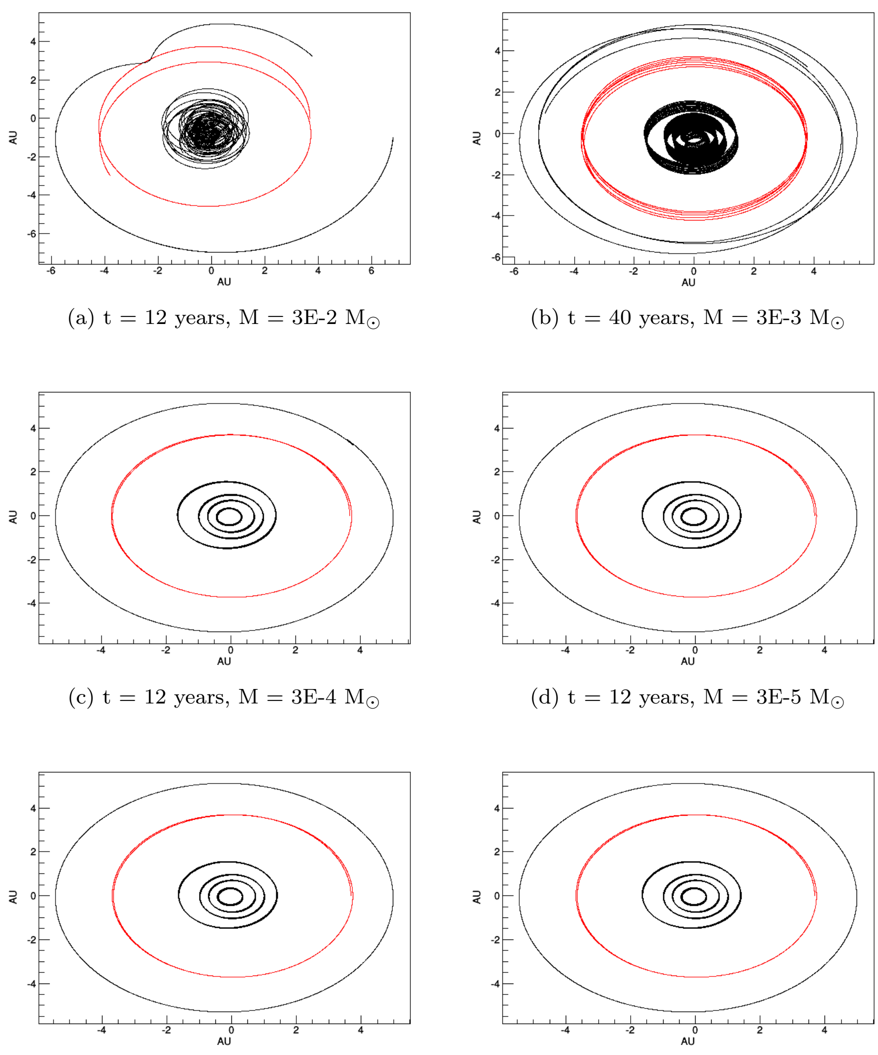


Figure 4: The placement of a earth-like mass M_1 = 3E-6 $M_\odot$ between Mars and Jupiter with initial conditions $\vec{x} = (3.680588, 0, 0)$ and $\vec{v}$ = (0,9E-03,0). The new planet's orbit is shown in red alongside the entire solar system over a time period of 12 years. It can be seen that the orbit is quite stable in these conditions.

3.2 Varying Planetary Mass and its Effect Mars' and Jupiters' Orbital Motion



(a) t = 12 years, M = 3E-2 $M_\odot$

(b) t = 40 years, M = 3E-3 $M_\odot$

(c) t = 12 years, M = 3E-4 $M_\odot$

(d) t = 12 years, M = 3E-5 $M_\odot$

(e) t = 12 years, M = 3E-6 $M_\odot$

(f) t = 12 years, M = 3E-7 $M_\odot$

Figure 5: The time period for the orbits and mass of planetary body are below each graph. The various masses show the orbital motion of Mercury, Venus, Earth, Mars, Jupiter, and the planetary mass, which is colored red. For larger masses, the orbital motion becomes unstable (figures a and b). The orbital motion of the system does become more stable as the mass decreases in magnitudes with minimal changes (figures c-f).

4 Binary Star System

4.1 Stable Motion and Orbit

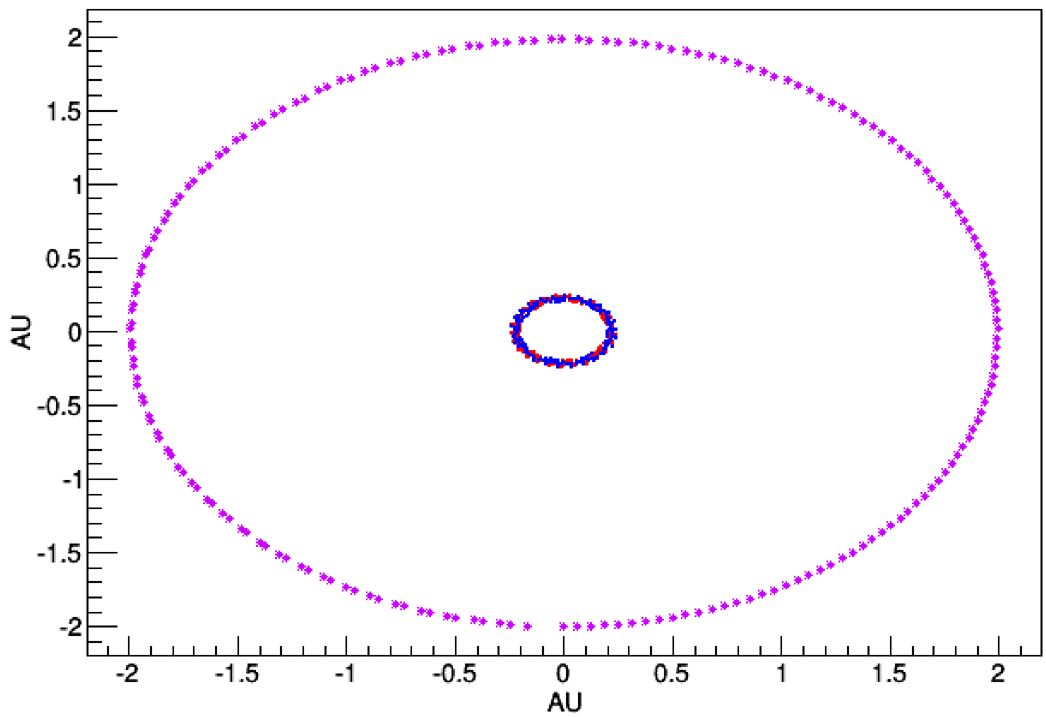


Figure 6: The motion of the binary star system requires a total angular momentum of zero in order to keep the stars in a stable motion around the origin. The system uses stars with masses $M_1 = M_2 = 1\ M_\odot$. The initial conditions, AU and AU/year, are $\vec{x_1}$ = (-.2,0,0), $\vec{v_1}$ = (0,-7.0,0) and $\vec{x_2}$ = (.2,0,0), $\vec{v_1}$ = (0,7.0,0). The stable orbit of a earth-sized body around a binary star system uses initial conditions M_3 = 3E-4 $M_\odot$, $\vec{x_3}$ = (0,-2.0,0), and $\vec{v_3}$ = (6.3,0,0).

4.2 Energy

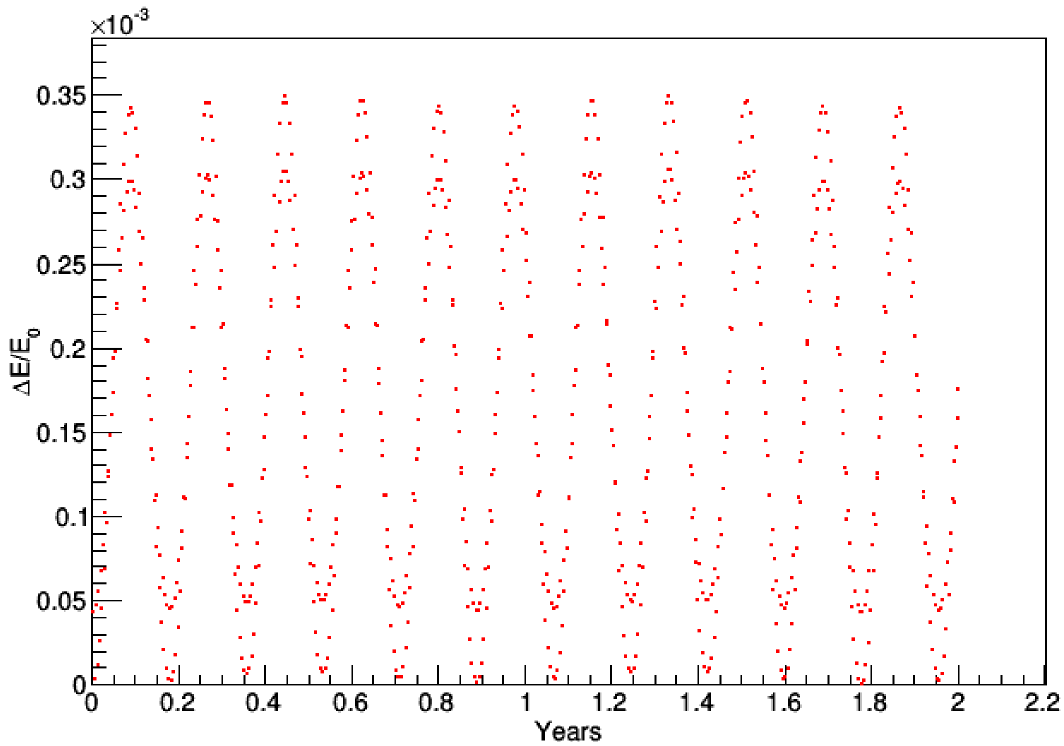
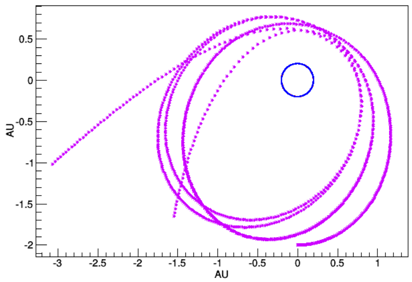
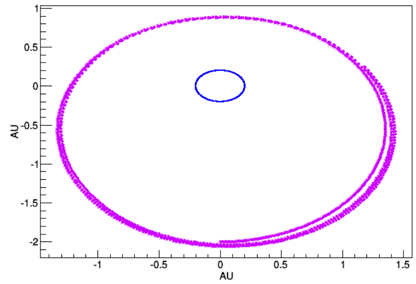


Figure 7: The total energy relative error is shown for time t = 2 years for the binary star system. The error is periodic, and the total energy is shown to be very conserved with errors much less than 1%. The initial conditions are the same as figure 5.

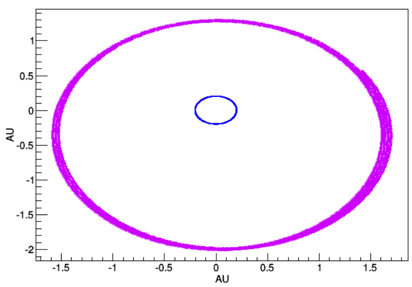
4.3 Effects of varying initial velocity on the planetary body



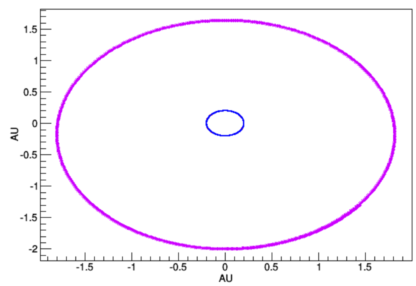
(a) $\vec{v_3}$ = (4.5,0,0), t = 2 years



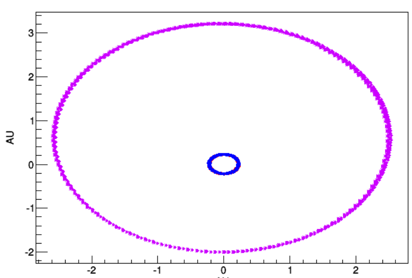
(b) $\vec{v_3}$ = (5.0,0,0), t = 2 years



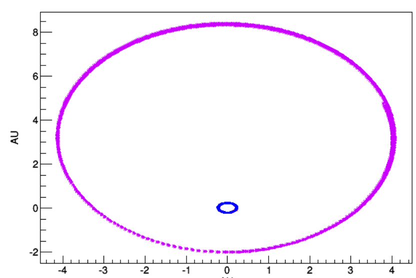
(c) $\vec{v_3}$ = (5.6,0,0), t = 2 years



(d) $\vec{v_3}$ = (6.0,0,0), t = 2 years



(e) $\vec{v_3}$ = (7.0,0,0), t = 3 years



(f) $\vec{v_3}$ = (8.0,0,0), t = 8.4 years

Figure 8: All motions use Δt = $\frac{1}{365}$ years and are plotted over a time frame listed under each plot. The orbit of the body shows stability with increasing initial velocities, especially when $v_x \geq 6$ AU per year. The binary stars relatively remain in the center of the orbit with velocities around $\vec{v_x} = 6.3$ but drift up or down the y-axis with lower or higher velocities, respectively. At lower velocities the orbit becomes unstable with a lower period. At larger velocities the orbit becomes larger with a longer period. Figures 7.d, 7.e, and 7.f are plotted for a full period. Figures 7.a, 7.b, and 7.c are not plotted for full periods.