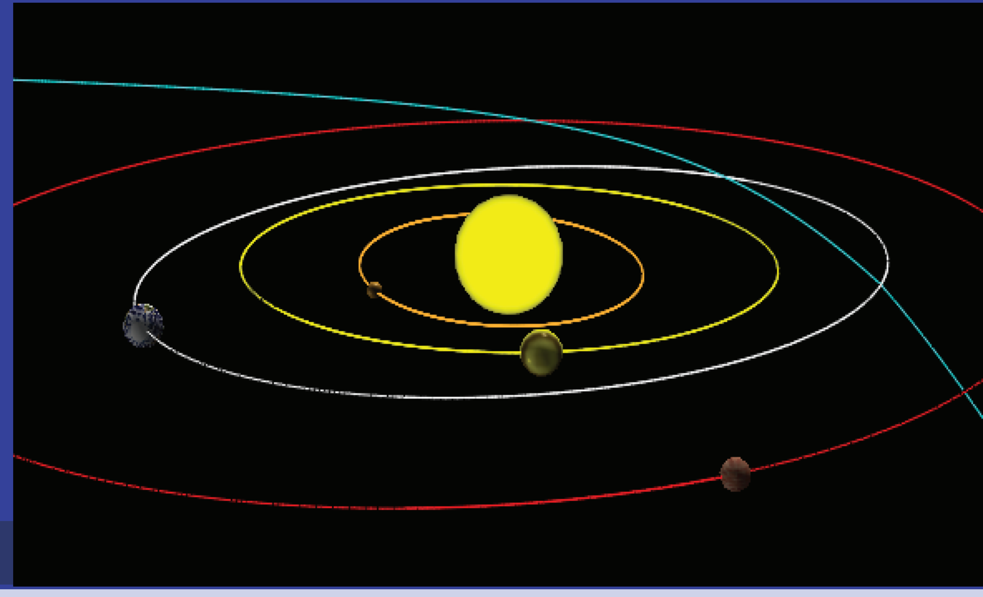
Rendezvous with Rama: Ramageddon!

Jordan Boyd, Ashley Mascareno, Andrew Winhold
Department of Physics, School of Earth and Space Exploration

Github URL: https://github.com/ASU-CompMethodsPhysics-PHY494/final-rendezvous-with-ramageddon



Abstract:

Near earth objects (NEOs) and the devastation they have caused Earth in the past continues to pose risks in the future. Should an extra-solar object following a hyperbolic trajectory graze too close to Earth, determining whether the Earth is on a potential collision course is vital.

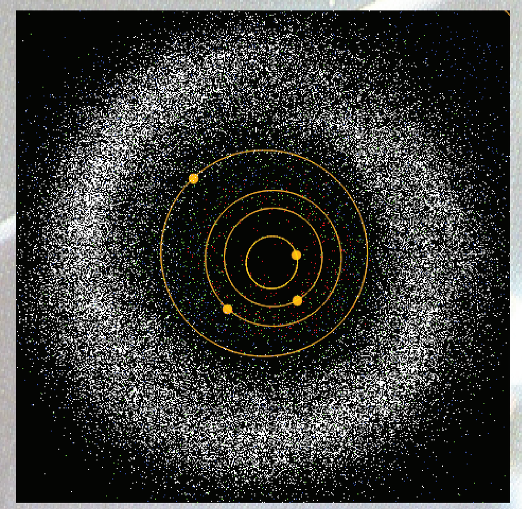
Inspired by Arthur C. Clarke's "Rendezvous With Rama", this Python-based simulation reenact the hyperbolic orbit of extrasolar object Rama, a 50km long, cylindrical alien starship on a trajectory through the inner solar system passes. The simulation scenario imagines what kind of threat Rama may pose if it was a bit closer to Earth.

Using Newtonian and Keplerian orbital mechanics coupled with the velocity verlet algorithm, the simulation computes the positions and velocities to make predictions about the orbits of Mercury, Venus, Earth, Mars, and Rama from a heliocentric frame of reference.

The prediction for the velocity Rama needed to maintain a hyperbolic orbit was found to be 41.7 km/s, and the smallest distance between Earth and Rama for the duration of the trajectory was found to be 39,127 km. The eccentric anomalies for the inner planets were found to converge at tolerance $1{\times}10^{-5}$. The code is available at https://github.com/ASU-CompMethodsPhysics-PHY494/final-rendezvous-with-ramageddon.

Background:

NEO: Near Earth Objects



+ Defined to be asteroids or comets that have orbits around the Sun that bring them close to Earth.
+ Criterion is a perihelion distance of < 1.3 AU
+ Approximately 800 NEOs ≤ 1 km wide
+ At 1km wide, NEOs can cause catastrophic local damage.

In Clarke's novel, Italy was destroyed by a NEO

Objectives:

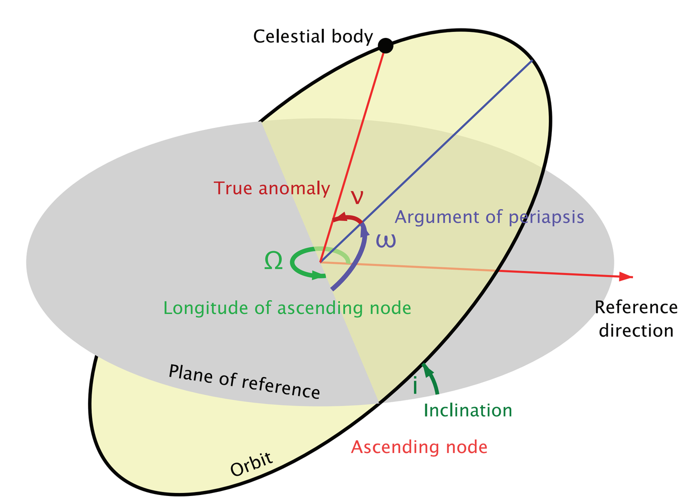
+ Initialize and propagate a simple model of Mercury, Venus, Earth, and Mars from a heliocentric frame.

+ Use observations of Rama to predict an accurate trajectory through the inner Solar System

+ Analyze the relative position of both Earth and Rama over time to consider whether there is a potential collision in the future.

+ Calculate the relative distance between Earth and Rama over time.

Methods:

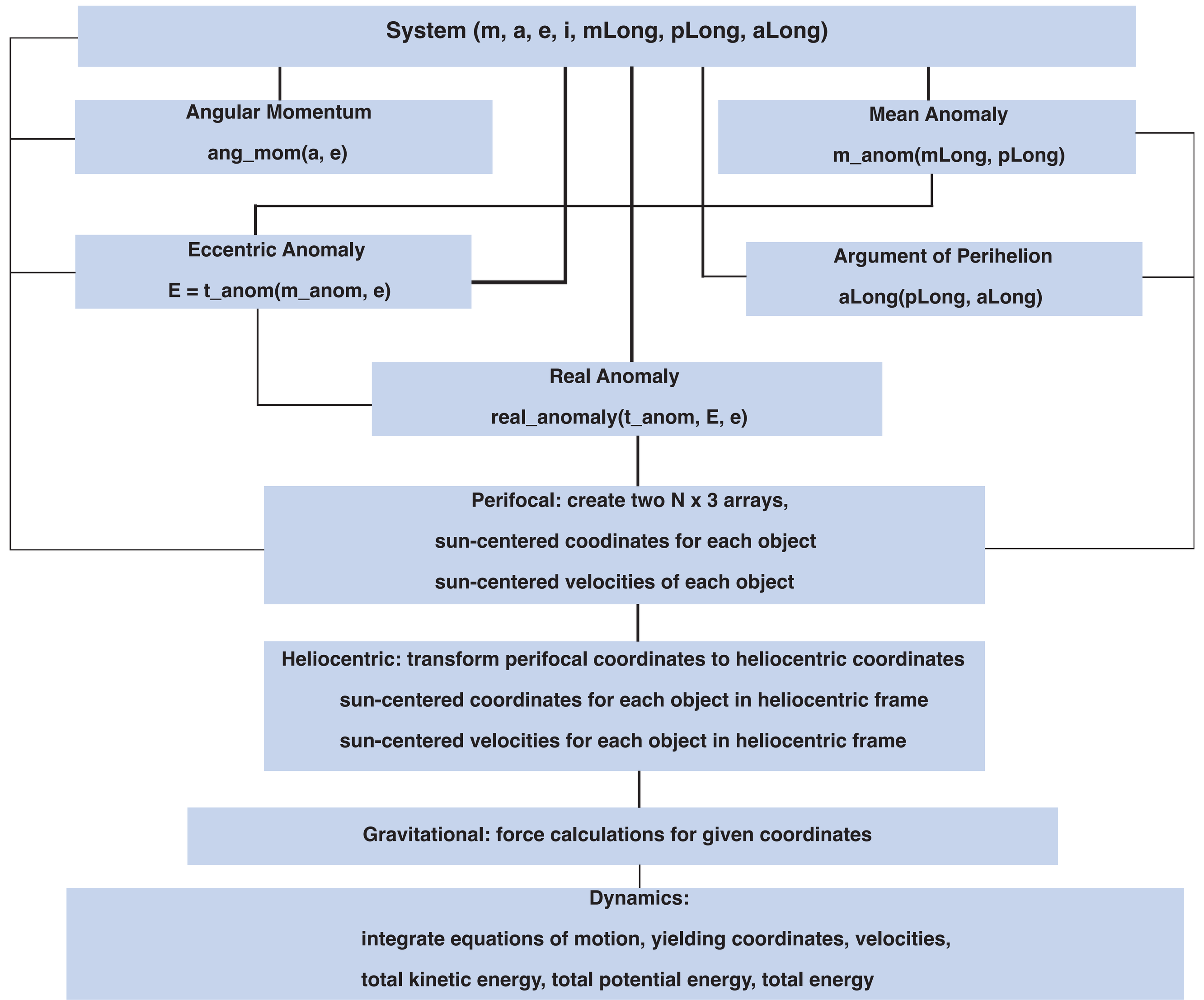


Coordinates:

At a given time, 6 variables are needed to describe the state in 3D translational motion (position + velocity):

+ Semi-major axis, a
+ Eccentricity, e
+ Inclination, i
+ Right Ascension of ascending node, ohm
+ Argument of perigee, w
+ Mean anomaly, M

Newtonian and Keplerian Heirarchy:



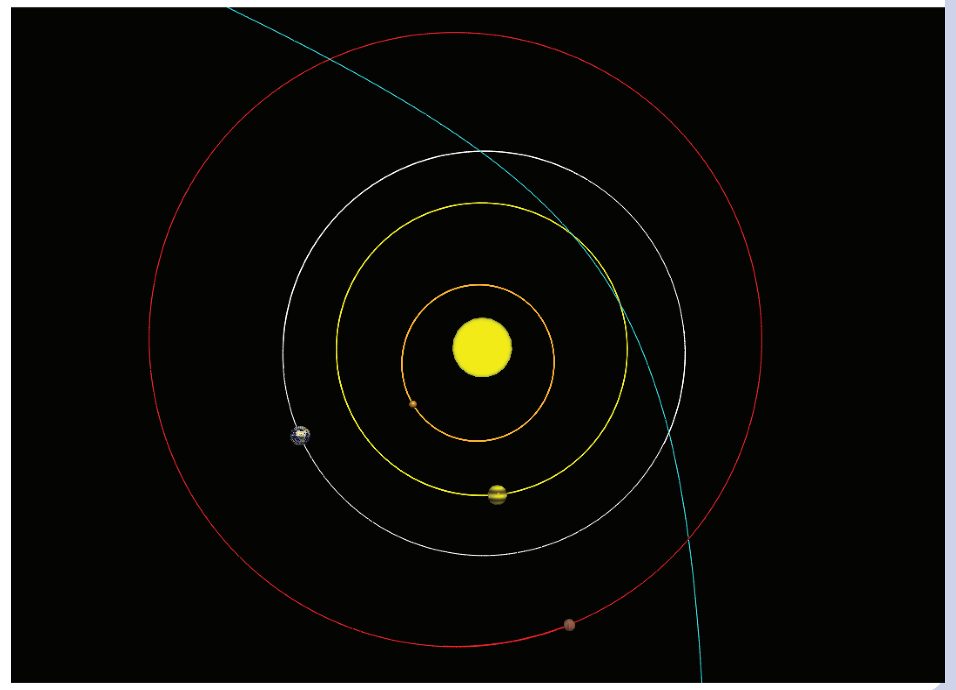
Algorithms:

Velocity Verlet

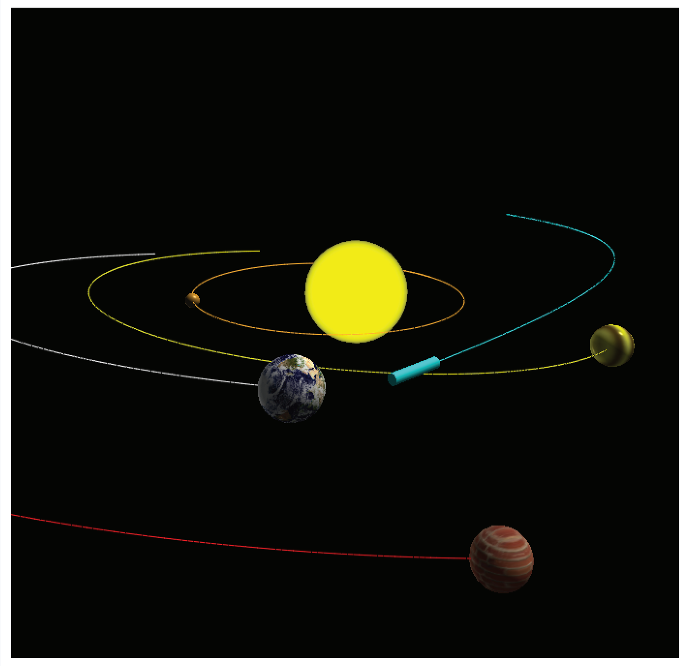
$$x(t+\Delta t)= x(t)+ v(t)\Delta t+1/2\, a(t)\Delta t^2$$

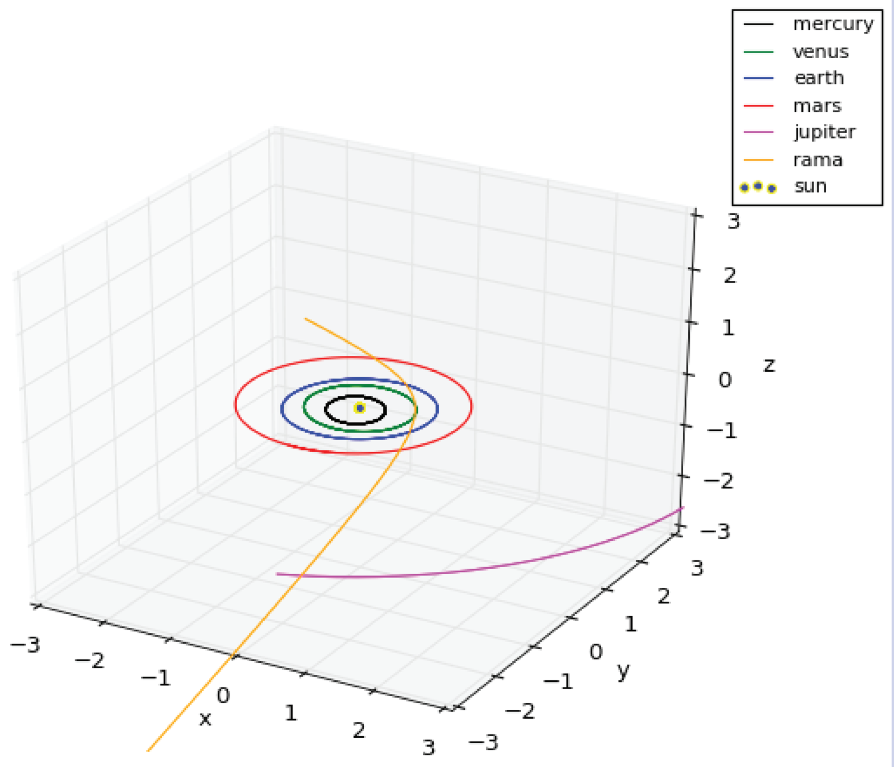
$$v(t+ \Delta t)= v(t)+ (a(t)+a(t+ \Delta t))/2\, \Delta t$$

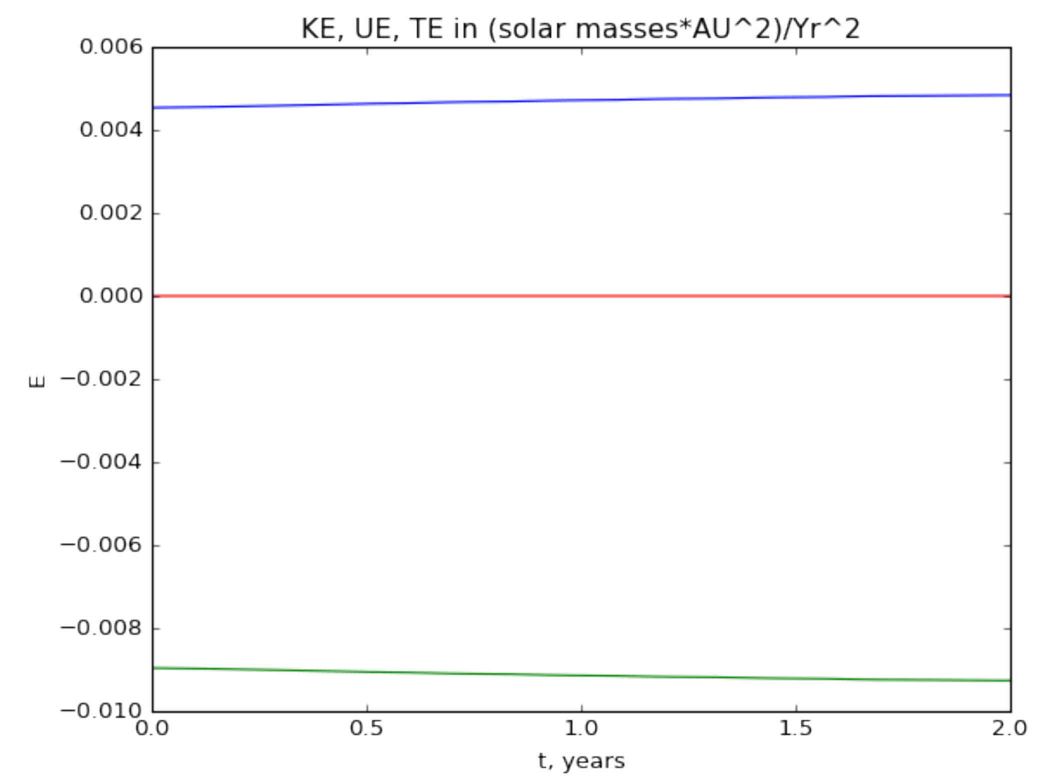
The velocity and position are calculated at the same value as the time variable



Results:







Conclusions:

1. Using what we know about Newtonian and Keplerian mechanics, as well as appropriate algorithms, one can make a rather accurate simulation of the inner solar system.

2. An extrasolar object following a hyperbolic orbit was successfully reproduced, and brought as close as 39,127 km to Earth at a blazing speed of 41.7 km/s

References:

+ Curtis, H. D. (2005). Orbital mechanics for engineering students. Amsterdam: Elsevier Butterworth Heinemann.

+JPL Solar System Dynamics. (n.d.). Retrieved April 20, 2016, from http://ssd.jpl.nasa.gov/