1866 Sisyphus

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Variations Among the Clones

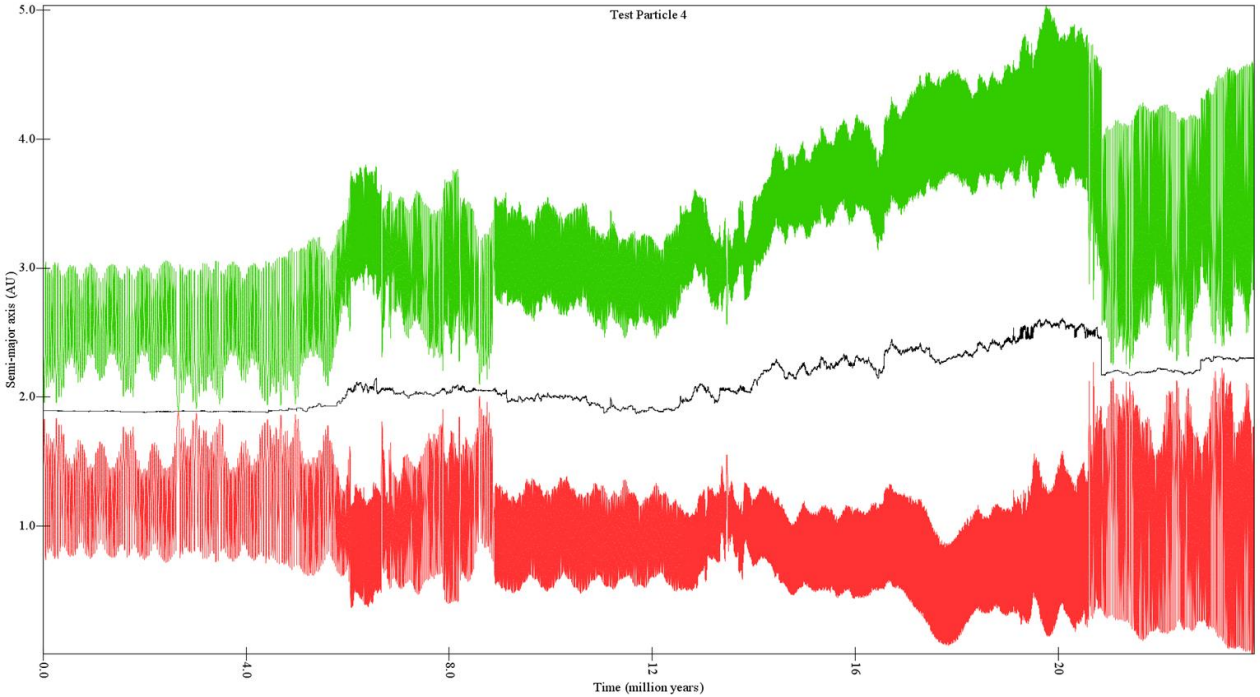
(factors to consider)

- Multiple factors to consider
  - x,y,z components of position and velocity vector
- Specific position of asteroid ⟿ unknown ⟿ margin of error exists
- Magnitude of error also unknown ⟿ manually input variations
- Keep one asteroid with the original calculated position/velocity
  - rest contains variations in position/velocity ranging from 10e-6 to 10e-10 magnitude

Fates of 1866 Sisyphus Clones...

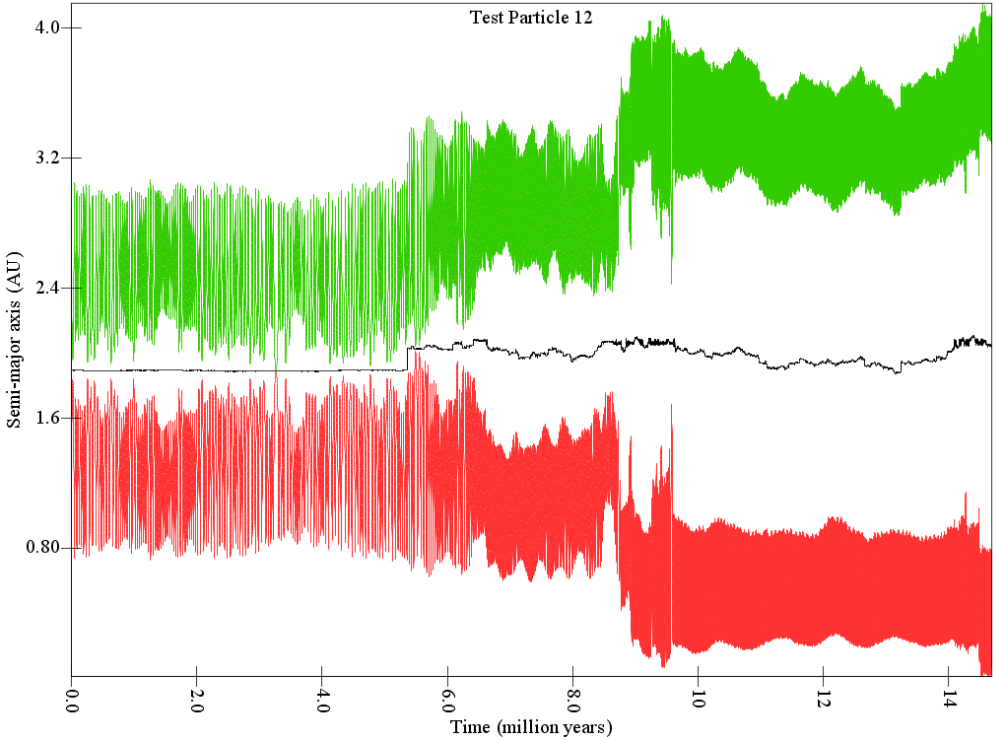
Outcome	Number of Particles	Percentage
Collided with the sun	18	33.3%
Collided with Venus	3	5.5%
Collided with Earth	0	0%
Collided with Mars	0	0%
Ejected from the solar system	1	1.8%
Survived the simulation (50Myr)	32	59.4%

Collision with the Sun



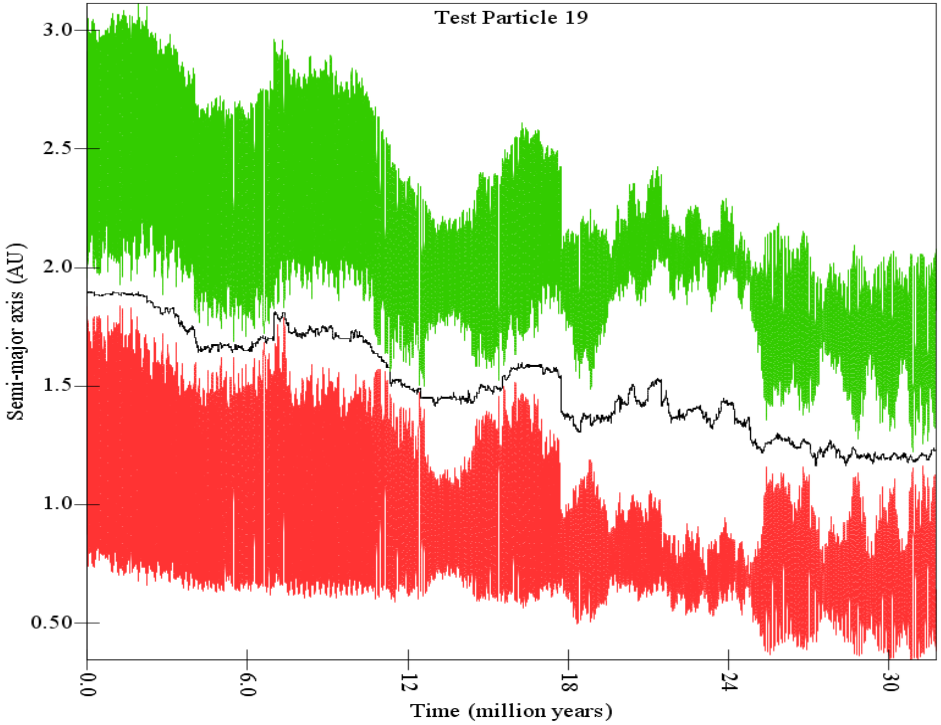
The perihelion and aphelion oscillate more and more, until the perihelion oscillates into the radius of the sun. The semimajor axis is actually larger at sun collision than at the beginning.

Another Collision with Sun

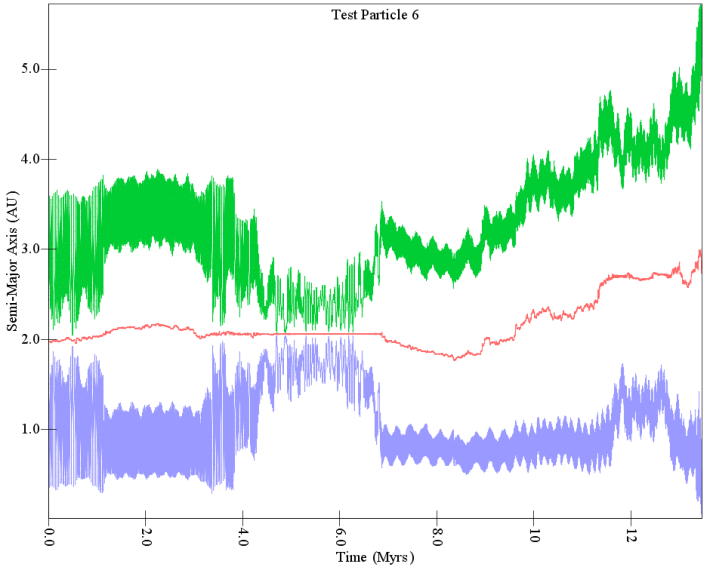


For this particle, the perihelion and aphelion trend relatively steadily towards the sun (within their range of oscillation). Semimajor axis remains nearly constant until a close encounter with another planet at 5.5Myr makes the orbit more eccentric and larger.

Collision with Venus

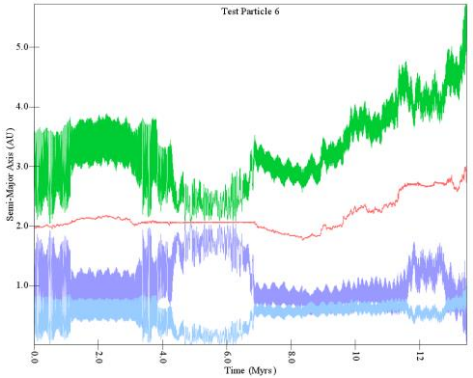


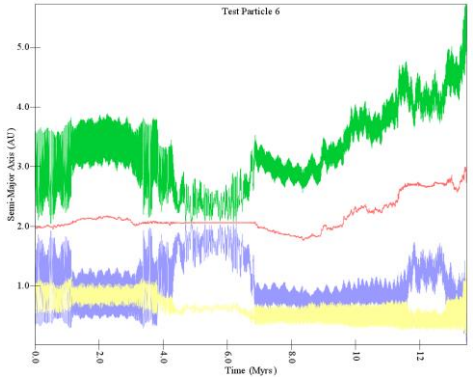
The perihelion and aphelion both fall until they reach the orbit of venus, where they remain for ~8Myr before collision.



(eccentricity = blue)

(inclination = yellow)

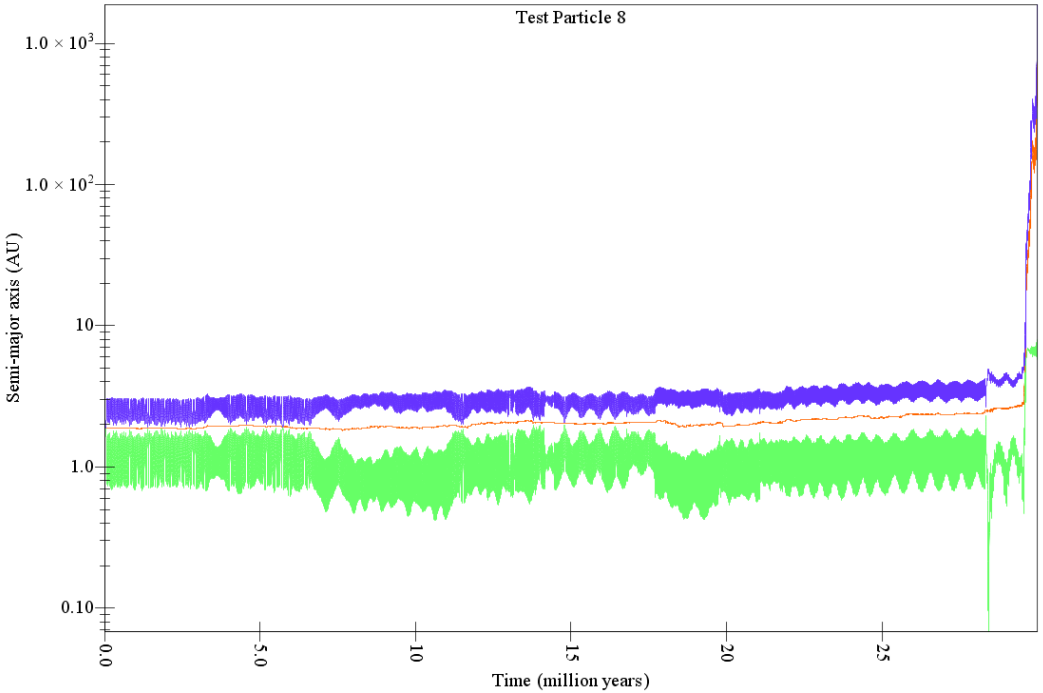




Interaction with Jupiter

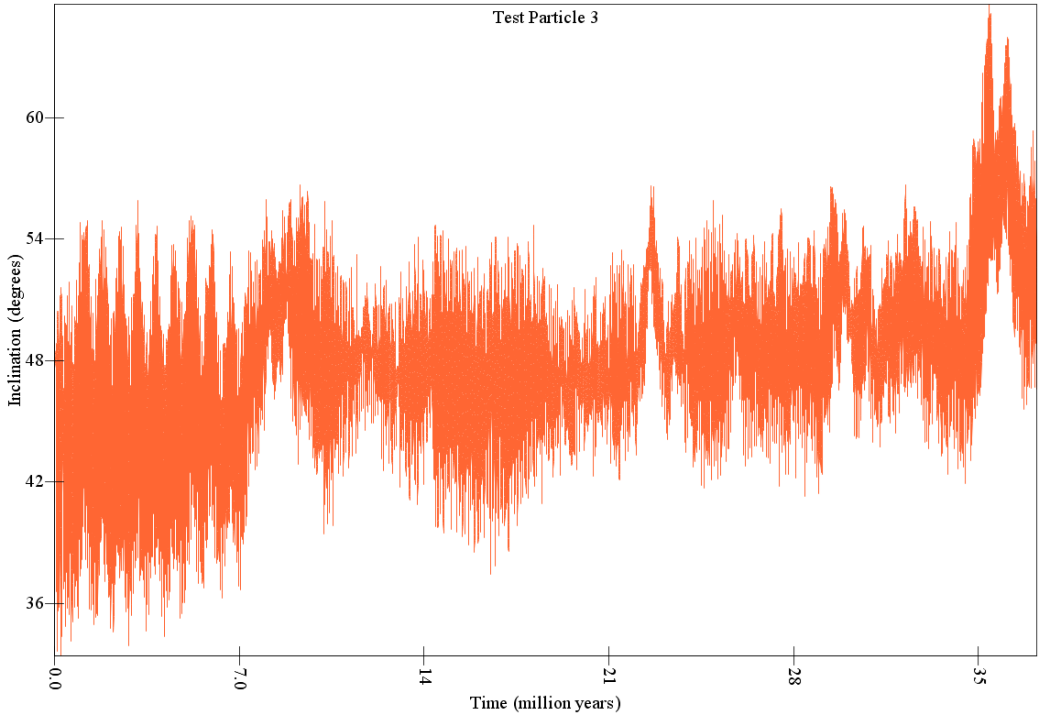
- Semi-major axis undergoes an increase starting from around 6.5 Myrs, resulting in a larger value than initially
- Magnitude of change in eccentricity grows until perihelion approaches zero
  - collision with the sun
- Last place detected was Jupiter
  - interaction with Jupiter's gravitational field led to clone's orbit being stretched in the final million years (small jump in eccentricity)
  - magnitude of change in inclination increases (more violent oscillations as approach Jupiter)

Ejected from the Solar System



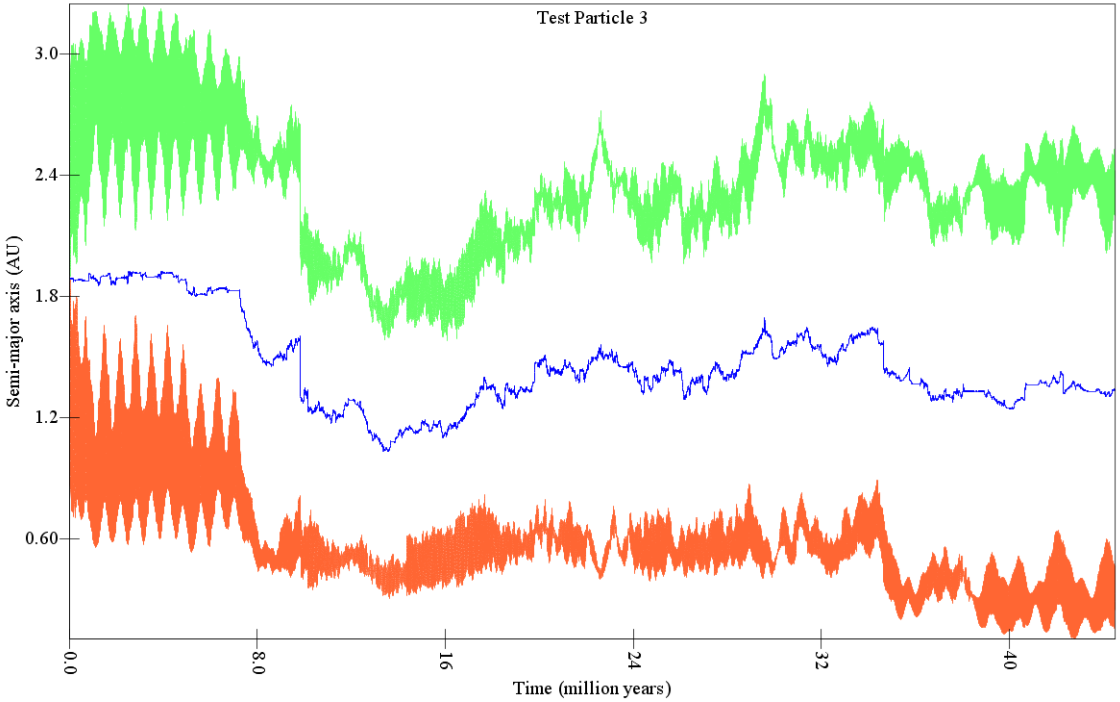
Due to the extreme range in semi-major axis of this test particles, a logarithmic scale is used to display the graph. The test particle last encountered Saturn, whose gravity sent the semi-major axis of the clone near 1000 AU.

Inclination



This asteroid's inclination changed more than most. With a starting inclination of 41 degrees, this asteroid's inclination fluctuated like that of the other test particles. However, at around 35 million years, the gravitational influence of a planet caused a larger than typical change in the particle's inclination.

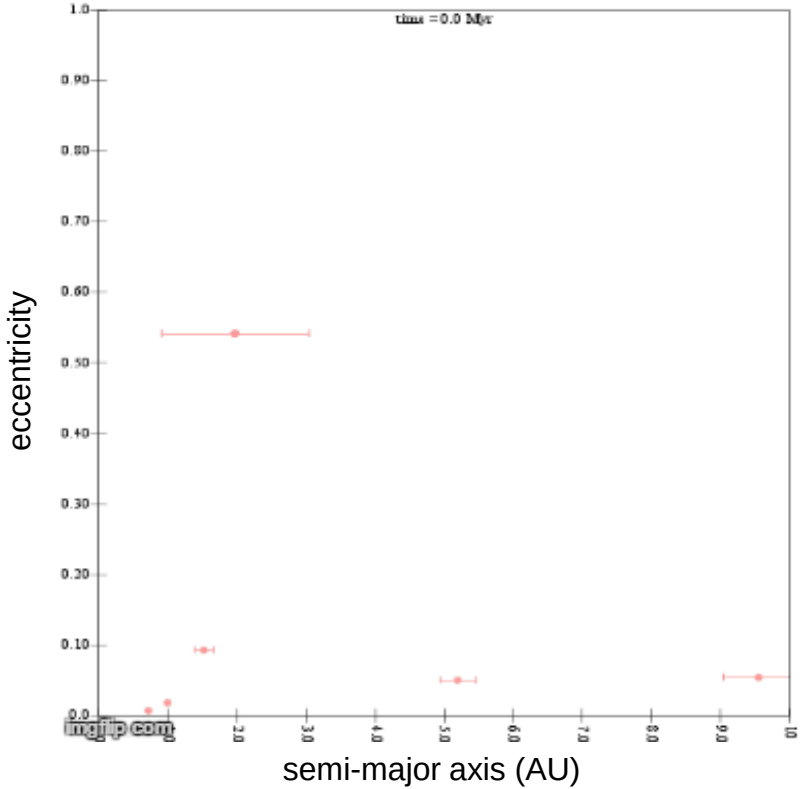
Inclination-2



Occurring at roughly the same time as the change in inclination, the semi-major axis of this test particle dipped. Prior to this dip, the semi major axis of test particle 3 was near that of the semi major axis. Due to the particle's high eccentricity at the time, it cannot be concluded that Mars caused the change, but it appears somewhat likely, even if Earth of Venus may have have been the cause.

Finding Lyapunov Time

- Approximate Lyapunov time is 20,000 yrs (point at which individual clones' data points in graph begin diverging)
- Stimulation time span is 50 Myr, the Lyapunov time of the solar system



vPython orbit visualization at t=41Myr (14 tp)