# Influence of Jupiter-like Planets on Centaur Transits to the Inner Solar System

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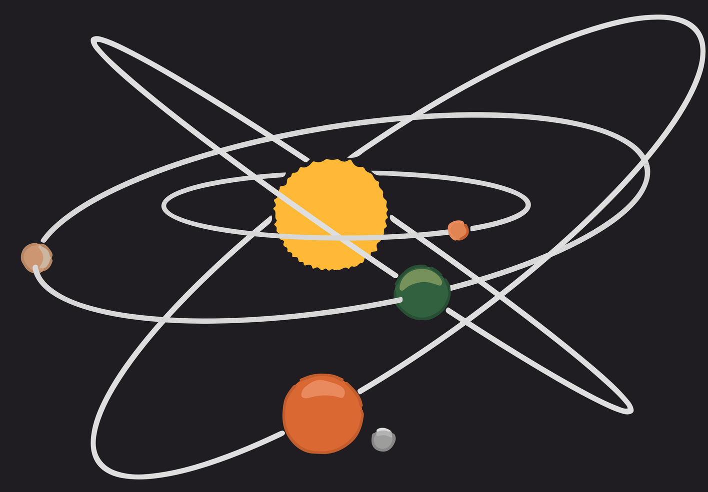


## Introduction

- A common belief is that Jupiter ‘protects’ Earth from asteroid impacts.
- A previous study done on this phenomenon, found that lighter Jupiter-like planets increased Earth impact rates [1].
- This project sought to validate these findings by examining Centaur transit rates into the inner solar system under varying Jupiter-like planet masses.

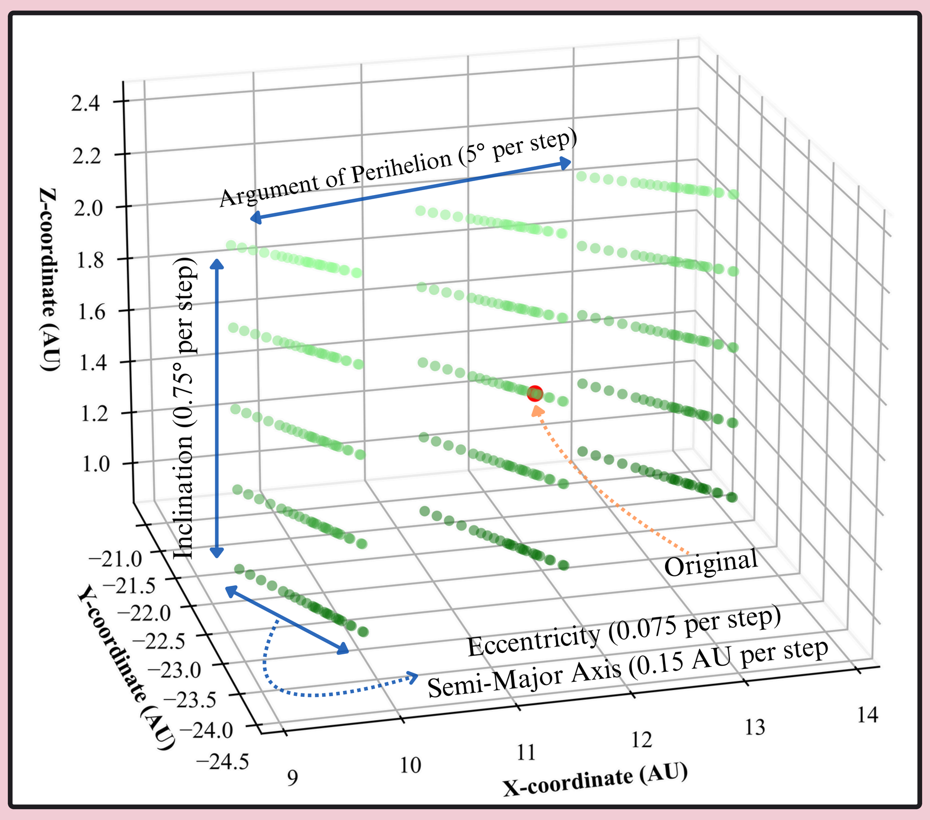
## Research Question

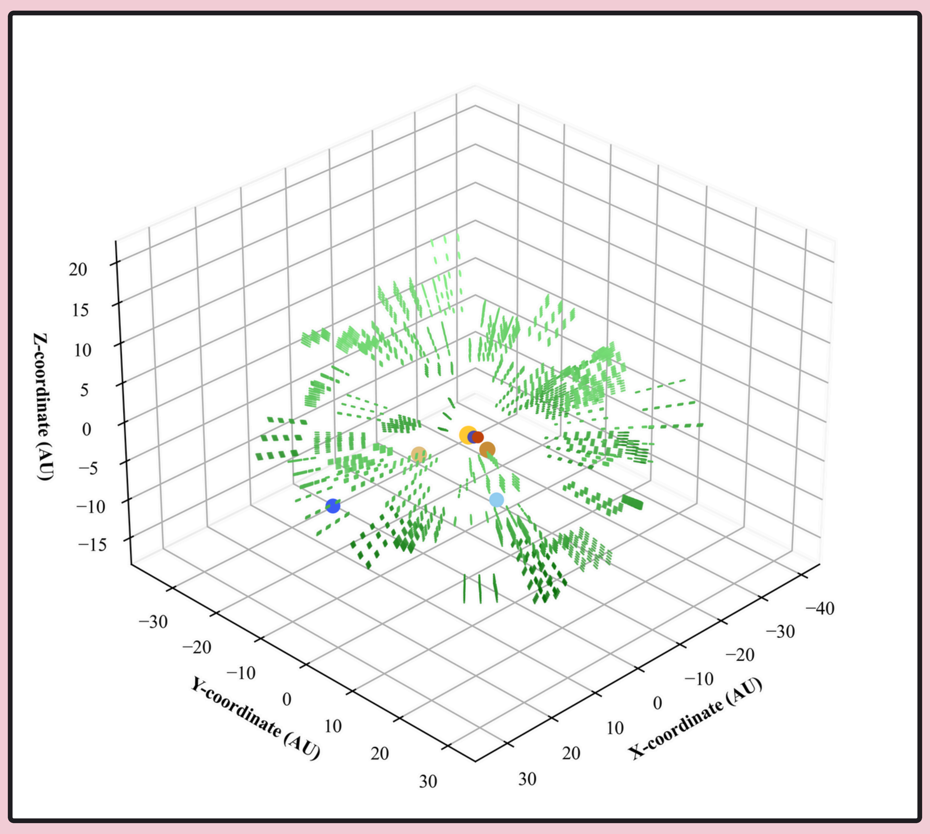
How does the mass of a Jupiter-like planet affect the amount of Centaur-like objects entering the inner region of the solar system?

## Method

N-body simulation of major objects in the solar system and Centaurs (small solar system body that orbits between Jupiter and Neptune). 65 original Centaur objects were cloned into a total of 24375.

**Cloning Process**




Only Newtonian gravity was used to simulate the system :

$$\vec{a} = \frac{\vec{F}_g}{m} = -\frac{GM}{r^3}\vec{r}$$

This results in the following coupled ODE:

$$\frac{d\vec{v}}{dt} = -\frac{GM}{r^3}\vec{r}$$

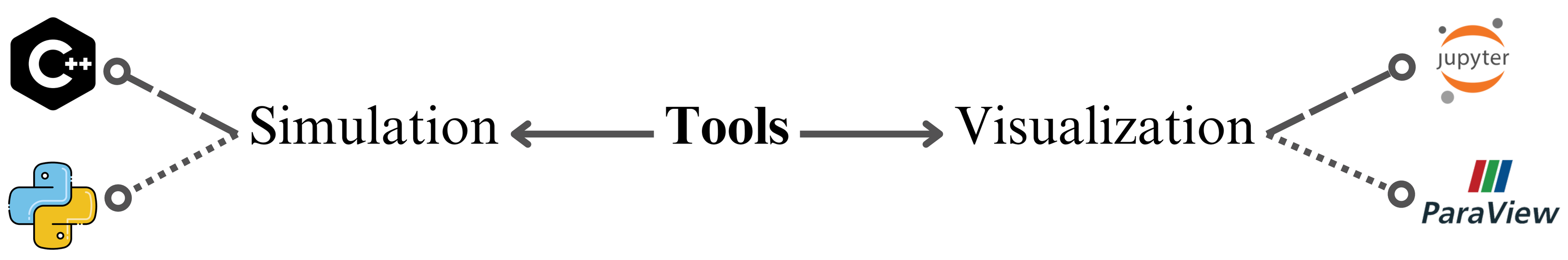
$$\frac{d\vec{r}}{dt} = \vec{v}$$

In the simulation this was approximated using the velocity Verlet algorithm.

**Reducing Complexity**

To reduce time complexity the gravitational pull of the Centaurs was ignored.

To reduce necessary simulation time the orbit of the Centaurs were destabilized by reducing initial velocity by 40%.




## Parameters

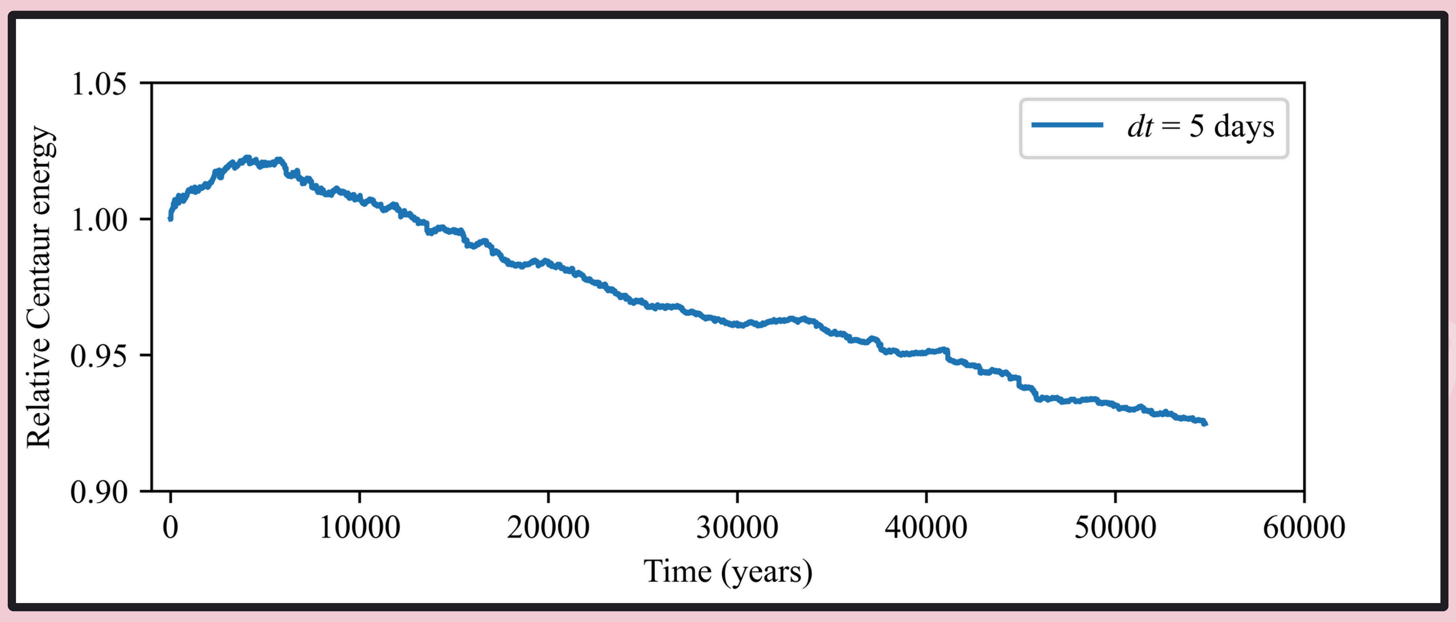
| | |
|---|---|
| Start date: | 01-01-2025 |
| Time span: | ~ 54757 years |
| Time step: | 5 days |
| Inner boundary: | 2 AU |

## Data

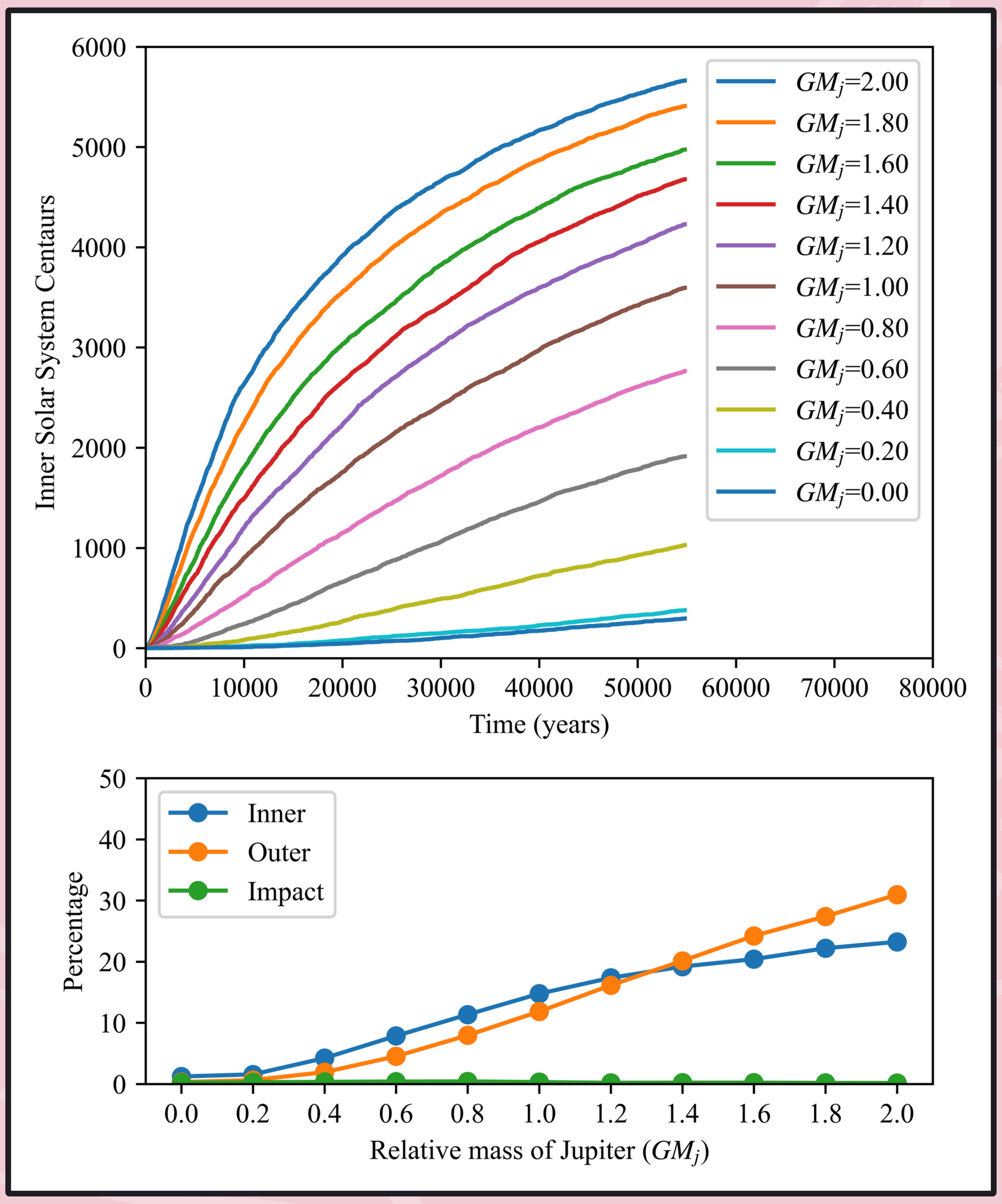
| | |
|---|---|
| Planet data: | JPL Horizons [2] |
| Centaur data: | JPL Horizons [2] |

## Validation

To validate the model we looked at the total energy of the centaurs in the system relative to the ‘true’ system energy, since in our model their energy should be conserved.




## Results




The upper graph shows the evolution of the amount of inner Centaurs over time for various relative masses of Jupiter ($GM_j$). The lower graph shows the final number of inner, outer and impact Centaurs for various $GM_j$.

## Conclusion

Our simulation shows a linear increase in the amount of Centaurs that enter the inner solar system as Jupiter’s mass increases. We believe this effect to occur because, as Jupiter’s mass increases, the total pulling force exerted on the Centaurs also increases, thus destabilising their orbits further. These results, however, do not explain the findings by Horner and Jones [1]. In fact, it could be interpreted as evidence against their claims. This discrepancy could be explained by the difference in simulation time and choice of integrator.

## References


[1] J. Horner and B. W. Jones, “Jupiter – friend or foe? II: the Centaurs,” International Journal of Astrobiology, vol. 8, no. 2, pp. 75–80, Dec. 2008, doi: 10.1017/s1473550408004357.

[2] NASA Jet Propulsion Laboratory, "JPL Horizons System," California Institute of Technology, Pasadena, CA, 2023. [Online]. Available: https://ssd.jpl.nasa.gov/horizons/ [Accessed: January. 2025].