Finding Past Interactions of our Sun Through Simulating Orbital Distributions of Trans-Neptunian Objects

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Introduction

Our Sun was formed in a star cluster. During that time, our Sun had multiple interactions with other stars. In the early history of the Sun, a group of low mass objects between 30–50 au from the Sun formed a belt known as the Kuiper belt. Because of their low mass, Kuiper belt objects, or KBOs, have low gravitational attraction with each other, so their orbital states are based primarily on their past interactions with objects outside the belt.

By understanding and studying how KBOs react, and comparing them to our known Kuiper belt distributions, we may be able to clarify the characteristics of interactions our Sun had after its formation.

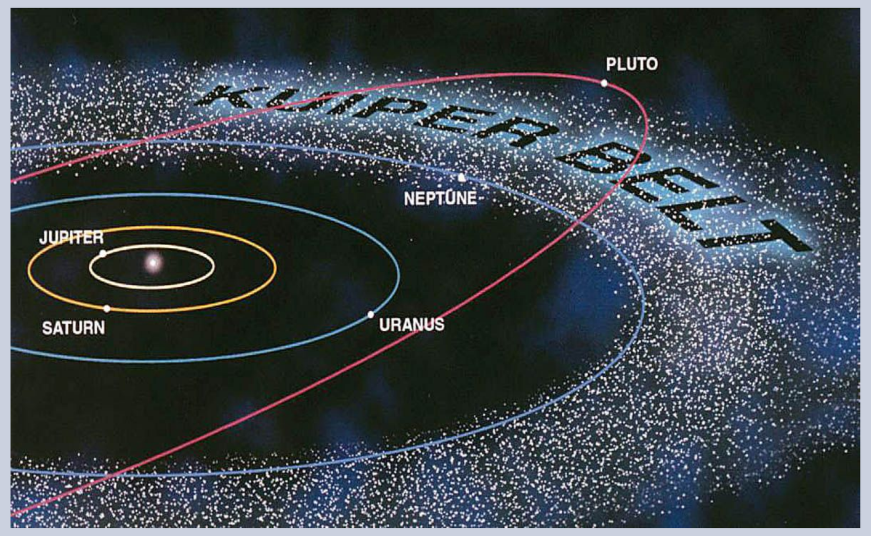

Figure 1.

Diagram of the location of the Kuiper Belt [2].

Data/Results

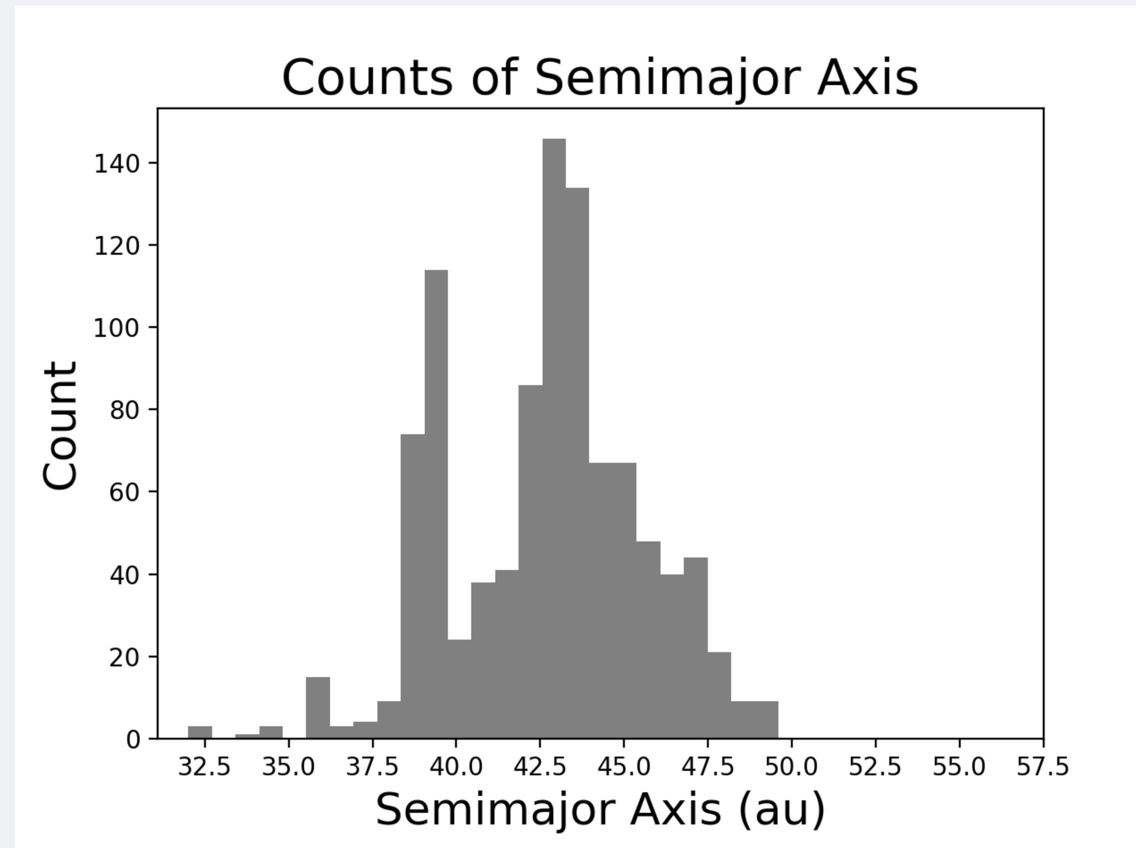

Figure 2.
Histogram of the Semimajor axis of the known KBOs [5].

The focus of the graph is the two peaks. The first are the Plutinos centered around 38-39 au and they should be ignored. The second is centered around 43-44 au which are the main KBOs being looked at.

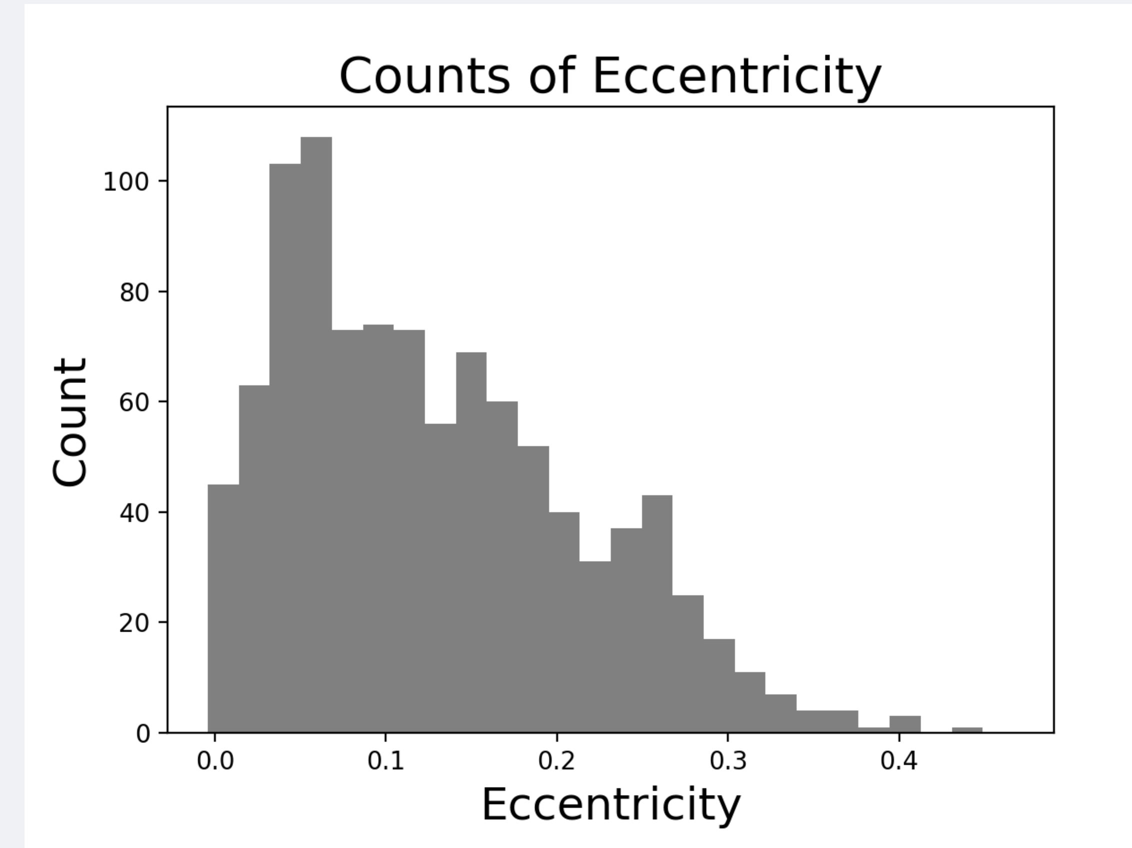

Figure 3.
Histogram of the Eccentricities of the known KBOs [5].

The focus of the graph is the concentration around 0-.1 and the gradual decline from .15-.4.

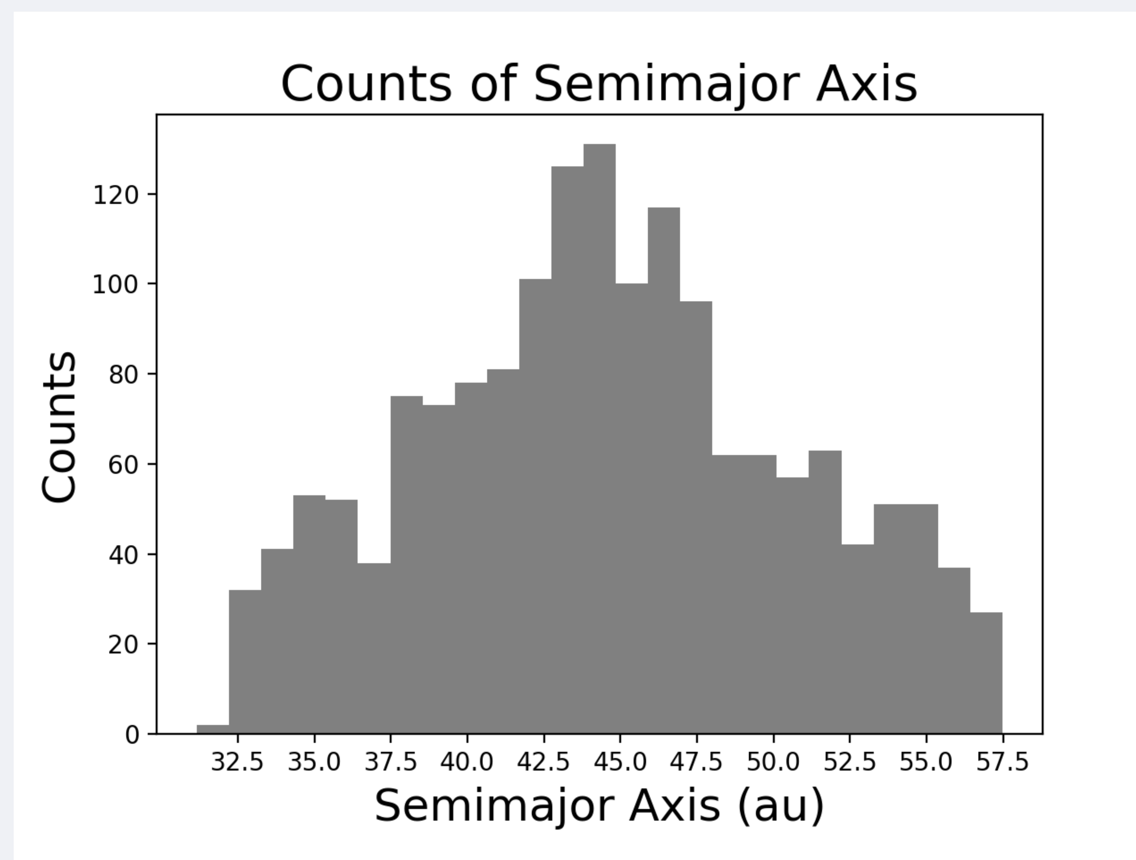

Figure 4.
Histogram of the semimajor axis of the created data.

The Semimajor axis was 50 au and the impact parameter was between 60–100 au. The Semimajor axis is concentrated around 42.5 au which resembles the known distribution (fig2), but it is more spread out.

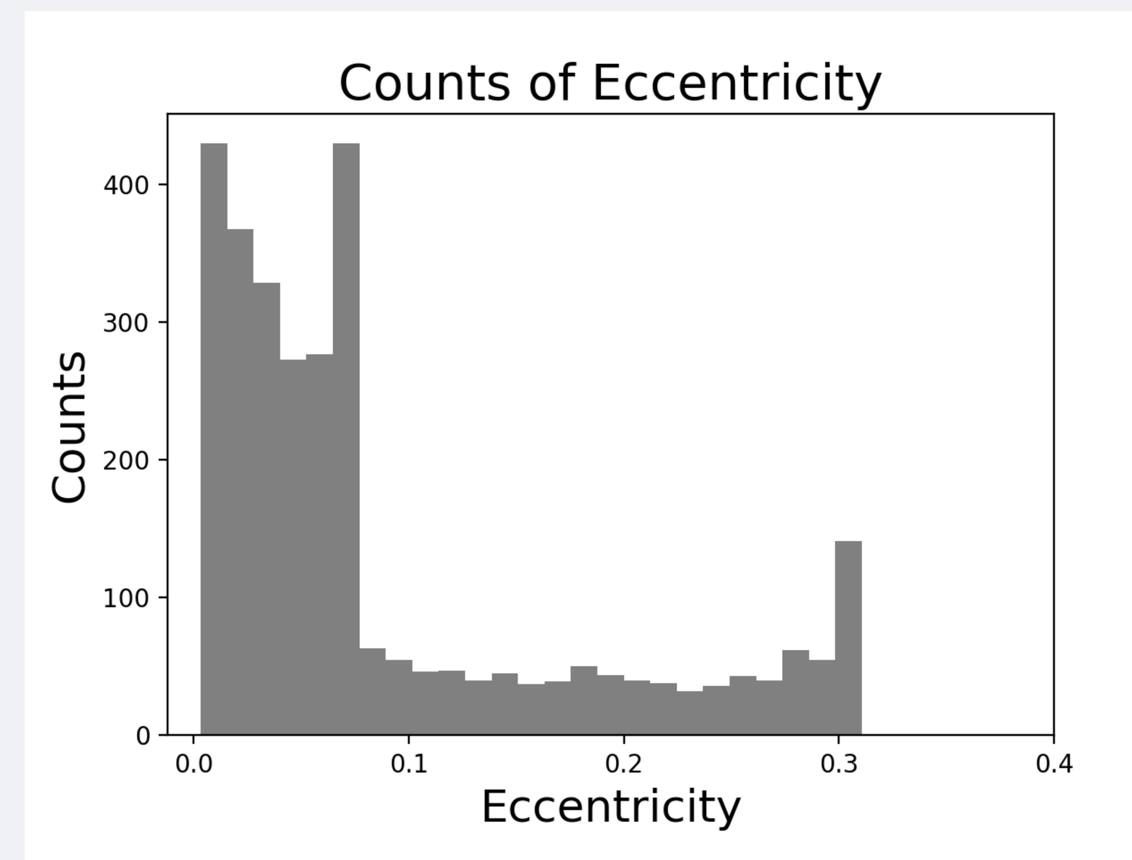

Figure 5.
Histogram of the eccentricities of the created data.

The semimajor axis was 40 au and the impact parameter was between 140–100 au. The graph shows the increase in concentration around .1 and a cut-off around .3. However, the amount of KBOs in the 0-.1 range is significantly larger than the known distribution (fig3).

Methods

By using the AMUSE [5] framework and Huayno [3] integrator, we created simulations consisting of our Sun, an incoming star, and, because they are gravitationally independent, a single KBO.

The parameters for the KBO and the incoming star were controlled for each simulation. The KBO was initialized with a semimajor axis of 5 au increments in the interval of 35–50 au, the eccentricity was set at zero, and the inclination was set at zero. The position of orbit of the KBO was initialized randomly. The incoming star was started and ended at a distance of 1000 au, the impact parameter was initialized in 20 au increments in the interval of 0–210 au, and the incoming speed was 3 kms.

Conclusion/Future Work

No trends were found within the distributions of the generated data. The most promising distribution was given above in Figure 4. However, the resulting eccentricity distribution for the initial conditions did not match. No conclusion can reasonably be drawn based on data created by the described initialization methods.

Because of time restraints, only a set number of parameters were able to be studied. With enough time, the entire parameter space would be studied in full as well as with more variation.

References

[1] Hut, Piet, and Bahcall, John N. " Binary-single star scattering. I - Numerical experiments for equal masses." *Astrophysical Journal, Part 1*, vol. 268, May 1, 1983, p. 319-341.
[2] *Kuiper Belt*. NASA Science. 2019
[3] "List of Transneptunian Objects". IAU Minor Planet Center. Harvard University and Smithsonian. 2019.
[4] Pelupessy, Federico I.; Jänes, Jürgen; Portegies Zwart, Simon, New Astronomy, Volume 17, Issue 8, p. 711-719
[5] Zwart, Simon, and Steve McMillan. *Astrophysical Recipes The Art of AMUSE*. IOP Publishing Ltd, 2018.

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