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PHYS 305 Final Project: Predicting the Existence of Planet X through the Orbital Dynamics of the Goblin (2015 TG387)

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ABSTRACT

The discovery of the dwarf planet 2015 TG387, also known as the Goblin, provided compelling evidence for the existence of a hypothetical ninth planet, Planet X, located in the outer regions of the Solar System. This project simulates the gravitational interactions between the Sun, the Goblin, and Planet X using numerical methods based on Newtonian mechanics. The simulations reveal how the Goblin's highly elliptical orbit is influenced by the gravitational pull of Planet X. Using realistic orbital parameters combining with verified constraints from Sheppard et al. (2019) and Brown & Batygin (2016); the results demonstrate stable orbital configurations consistent with observational data. These findings support the hypothesis of Planet X's existence and its significant gravitational influence on trans-Neptunian objects.

1. INTRODUCTION

The existence of a ninth planet, often referred to as Planet X, has been hypothesized to explain the peculiar orbital characteristics of extreme trans-Neptunian objects (ETNOs), including 2015 TG387 (the Goblin). The Goblin, discovered by Sheppard et al. (2019), has a highly elliptical orbit ($e = 0.945 \pm 0.003$) with a semi-major axis of approximately 65 AU, which appears to be influenced by an unseen massive body. Brown & Batygin (2016) suggested the existence of a hypothetical planet approximately 300 AU from the Sun, with a mass about 10 times that of Earth, to account for these orbital anomalies. This project investigates whether the Goblin's orbit, as observed, could predict the gravitational influence of Planet X.

2. METHODS AND PROCEDURES

This paper used numerical simulations to model the gravitational interactions between the Sun, the Goblin, and Planet X. The governing equations are based on Newtonian mechanics:

$$\mathbf{F} = -G\frac{m_1 m_2}{r^3}(\mathbf{r}_2 - \mathbf{r}_1), \tag{1}$$

where G is the gravitational constant, m_1 and m_2 are the masses, and $\mathbf{r}_1$ and $\mathbf{r}_2$ are position vectors.

2.1. *Simulation Configurations*

Three simulations were conducted to examine the gravitational effects of Planet X and compare them to the influence of outer planets (Uranus, Neptune, and Pluto for convenience):

1. **Simulation 1:** Includes both the outer planets (treated as stationary point masses) and Planet X to examine their combined effect on the Goblin.
2. **Simulation 2:** Excludes Planet X, keeping only the outer planets stationary to evaluate their influence.
3. **Simulation 3:** Includes Planet X but excludes the outer planets to determine its significance relative to other gravitational sources.

The results were analyzed to assess the Goblin's orbital parameters, including eccentricity (e) and semi-major axis (a), compared to observed values: $e \approx 0.9$ and $a \approx 120$ AU by Sheppard et al. (2019).

2.2. *Numerical Integration Techniques*

The simulation applied two numerical integration methods that we have learned throughout the semester to solve the equations of motion:

- **Forward Euler:** Despite its potential numerical instability over long time steps, this method surprisingly yielded results more consistent with observed orbital parameters compared to Runge-Kutta. The reason for this discrepancy remains unknown. Given the accuracy of the results, this method will be chosen as the primary numerical integration technique for the simulation.
- **Fourth-Order Runge-Kutta (RK4):** This method, while typically accurate, produced results that deviated from observational data for reasons that are unclear.

2.3. *Assumptions and Limitations*

The following assumptions and limitations were made to simplify the simulation:

- All bodies are assumed to orbit on the same plane (2D approximation).
- Outer planets were modeled as stationary, similar to the Sun, to minimize computational complexity while preserving their effects on the Goblin.
- Relativistic effects were not included in the calculations.
- Planet X and the Goblin were treated as point masses.
- Numerical errors from the integration methods may accumulate over long simulation times.

These constraints are important because real-world orbital dynamics involve three-dimensional motion and interactions with multiple celestial bodies, which could alter the results.

3. RESULTS

The simulation reveals the gravitational interactions between the Sun, the Goblin, and Planet X. The results for each configuration are summarized below:

- **Simulation 1 (Outer planets and Planet X):** The Goblin's orbit exhibited parameters consistent with observations ($e \approx 0.9$, $a \approx 120$ AU), confirming the significant influence of Planet X.

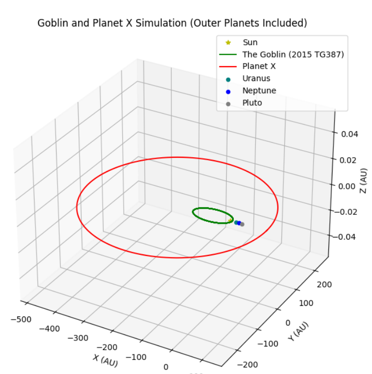

Figure 1. Simulated orbits of the Sun, Goblin, and Planet X, with outer planets stationary. The Goblin's orbit is highly elliptical, consistent with observational data.

- **Simulation 2 (Outer planets only):** The Goblin's eccentricity clearly decreased as its orbit became more circular. Based on my own speculation, the approximate eccentricity is around $e \approx 0.6$, inconsistent with observed data. This suggests that Planet X plays a critical role in maintaining its high eccentricity.

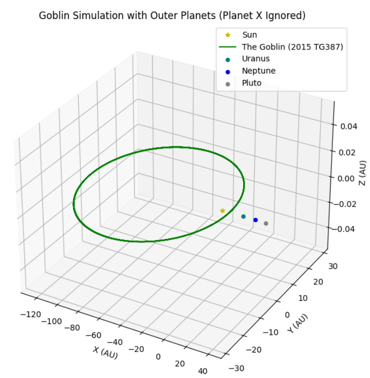

Figure 2. Simulated orbits of the Goblin without Planet X. The orbit's reduced eccentricity is inconsistent with observations.

- **Simulation 3 (Planet X only):** Results were consistent with Simulation 1, demonstrating that the outer planets have a minimal effect on the Goblin compared to Planet X.

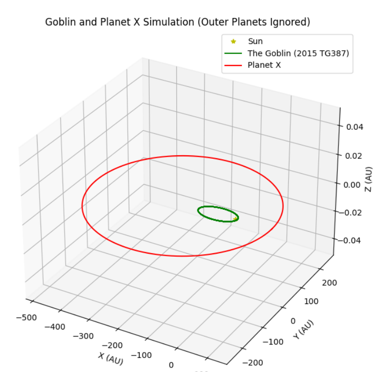

Figure 3. Simulated orbits of the Goblin with Planet X only. Results closely match the first simulation and observed parameters, suggesting minimal influence from outer planets.

4. DISCUSSION AND CONCLUSION

The results demonstrate that the Goblin's orbit is significantly influenced by the gravitational force of Planet X. Simulations without Planet X fail to reproduce the high eccentricity observed, emphasizing Planet X's vital role in shaping the orbital dynamics of extreme trans-Neptunian objects.

While these findings strongly support the hypothesis of Planet X's existence, the simulations are far from perfect. Assumptions such as planar motion and stationary outer planets, along with the exclusion of relativistic effects, limit the model's accuracy. This study does not provide definitive proof of Planet X; however, it adds further evidence to prior research, whose findings align with its gravitational influence.

Future work should extend beyond the current limitations by incorporating three-dimensional motion, dynamic interactions with outer planets, and additional trans-Neptunian objects to refine the analysis. While my coursework constraints (and my laptop's desire not to become a toaster) have prevented me from tackling these challenges, this project has demonstrated the immense value of numerical simulations in celestial mechanics. This project has been an enjoyable opportunity to apply the knowledge gained in PHYS305. This experience has enhanced my understanding of the Solar System's outer regions and also demonstrated the practical application of simulation and numerical integration techniques I have learned. It is exciting to show the extension of my classroom knowledge to real-world problems.

Looking ahead, I propose taking this work to new cosmic heights by simulating the "Goblin Galaxy." Unlike our humble Goblin, this elusive ghost galaxy operates on a level of interstellar grandeur that defies casual comprehension. Its gravitational impact on its surroundings is nothing short of phenomenal (or, at least, that's what the very esteemed Dr. Gupta, a lead scientist in the field of cosmic goblin presented at a conference in Steward Observatory Astronomy Club last year).

In all seriousness (or as much seriousness as this project allows), this experience has deepened my appreciation for the complexities of the Solar System's outer reaches while showcasing the practical applications of simulation and numerical integration techniques. It's thrilling to extend classroom concepts to explore the frontier of celestial mechanics.

Finally, I want to thank Dr.Wolgemuth for a fun semester. This project may not prove my genius, but it certainly proves that I can pretend to be one for a few pages of LaTeX. I hope to see you as orbit around PAS for another semester (pun intended)!

REFERENCES

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