
Influence of Hypothetical Planet 9 on Dwarf Planet Pluto

Baron L

Introduction

- Early 2016–Konstantin Batygin and Mike Brown suggested the existence of a “Planet 9”
 - Supported by irregular movements of objects in the Kuiper Belt

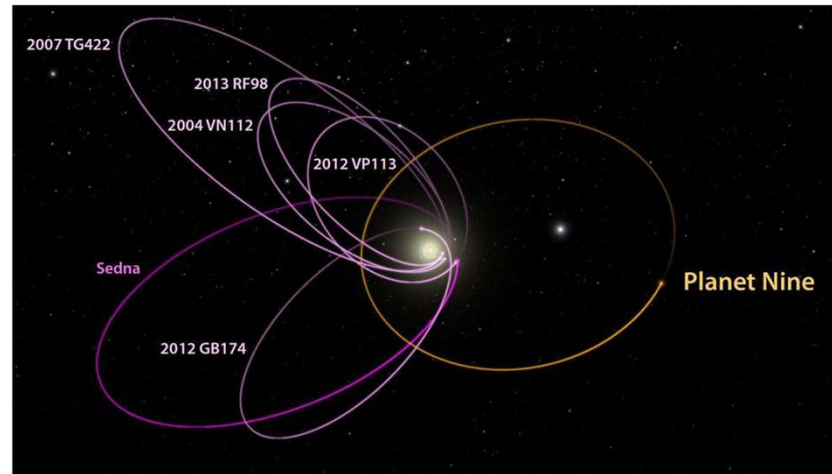


Fig 1: Hypothesized Orbit of Planet 9 Credit: R. Hurt (IPAC)/Caltech.

- This research aims to determine how a 9th planet would affect other objects in the Solar System.

Methods

- Used Newton's law of universal gravitation and Newton's second law of motion:

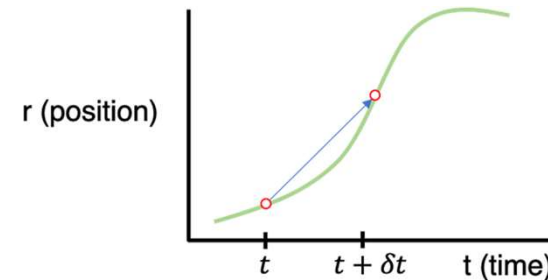
$$\vec{F}_i = \sum_{j \neq i}^N G \frac{m_i m_j}{r_{ij}^2} \hat{r}_{ij}$$

With acceleration $\vec{\alpha}_i = \frac{\vec{F}_i}{m_i}$

- Velocity Verlet was used in a Github Repository to simulate the Solar System with a new planet:

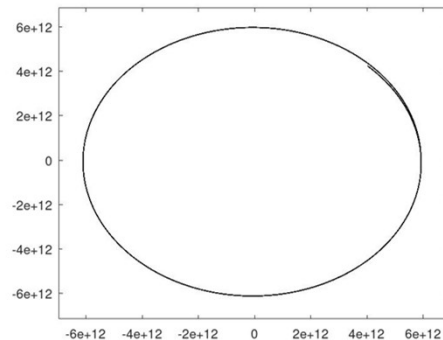
$$\vec{x}(t + \Delta t) = \vec{x}(t) + \vec{v}(t)\Delta t + \frac{1}{2}\vec{a}(t)\Delta t^2$$

$$\vec{v}(t + \Delta t) = \vec{v}(t) + \vec{a}(t)\Delta t$$



Methods (continued)

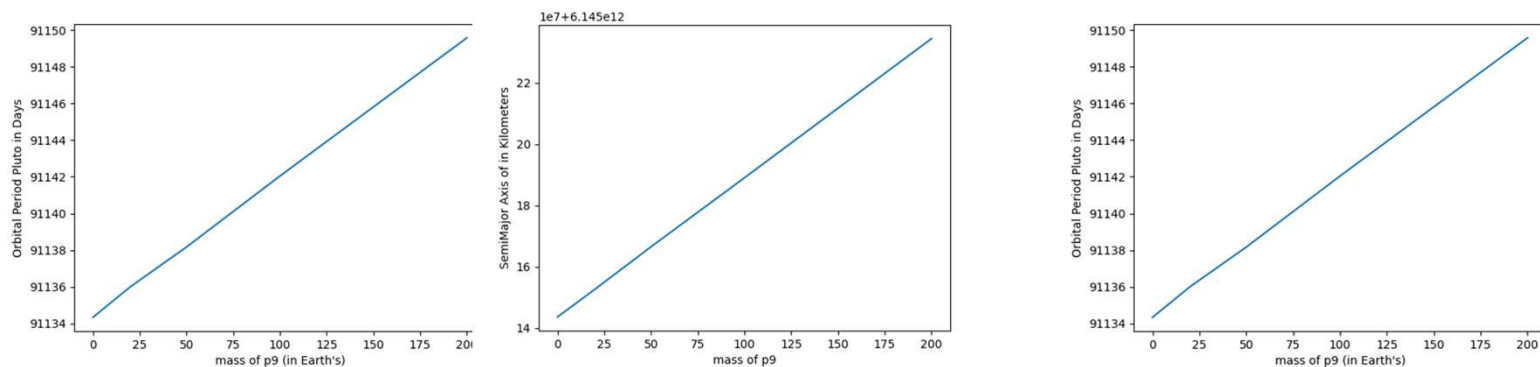
- We collected the data through a simulation—our control group was with 21 objects (the Sun, 8 planets, and some major moons).
- We chose to focus on Pluto for this study because it is far from the Sun, and has a small mass. We printed its position and velocity at each timestep.



- We tested the data with Planet 9 being 20 times as far from the Sun as Neptune with a mass of: 20, 50, 100 and 200 times that of Earth.

Data Preprocessing

- We used code in order to process the data and figure out the relationships between the mass of Planet 9, and: the orbital period of Pluto, the eccentricity of Pluto, and the Semimajor Axis of Pluto.



- All the relationships were extremely close to being linear
- Given the Orbital Period curve, we can fit the data with linear regression (LMSE):

$$y = 454011.25x + 6.14514 \cdot 10^{12}$$

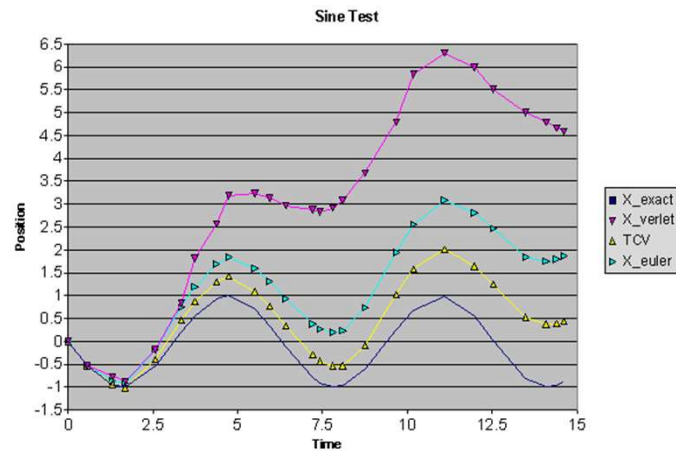
Conclusions

- We researched the effects of a hypothetical Planet 9 on the objects of the Solar System.
 - We used a simulation to collect data for our study and processed it to find Pluto's orbital period, eccentricity, and semimajor axis with 5 separate masses of Planet 9.
 - Our findings were that the mass of Planet Nine had a directly proportional relationship to the eccentricity, orbital period, and the Semi-Major axis of Pluto.
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- This research can help us redefine what we know about the solar system if the existence of a 9th planet is further considered or confirmed in the future.
 - Further study can also use a similar approach to identify the mass and distance of Planet 9, given the real-time ground truth orbital information of other planets in the Kuiper belt.
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Future Directions

Here is a list of some things that could be done to further this research :

- A more precise algorithm, such as Verlet Integration, can be used to calculate the movements of the Solar System objects.
- Add more objects to a simulation of the Solar System, such as the rest of the Kuiper Belt
- More accurate initial parameters should be added to the study, such as the z-axis.
- Use the ground truth of movements observed in our Solar System to reach further conclusions.



Works Cited

1. Batygin, Konstantin, and Michael E. Brown. "EVIDENCE for a DISTANT GIANT PLANET in the SOLAR SYSTEM." *The Astronomical Journal*, vol. 151, no. 2, 20 Jan. 2016, p. 22, arxiv.org/pdf/1601.05438.pdf, <https://doi.org/10.3847/0004-6256/151/2/22>.
2. Brown, Michael E, et al. "A Pan-STARRS1 Search for Planet Nine." *ArXiv (Cornell University)*, 31 Jan. 2024, <https://doi.org/10.48550/arxiv.2401.17977>. Accessed 30 Dec. 2024.
3. Naess, Sigurd, et al. "The Atacama Cosmology Telescope: A Search for Planet 9." *The Astrophysical Journal*, vol. 923, no. 2, 1 Dec. 2021, p. 224, <https://doi.org/10.3847/1538-4357/ac2307>. Accessed 25 May 2022.
4. aromanro. "SolarSystem/README.md at Master · Aromanro/SolarSystem." *GitHub*, 2016, github.com/aromanro/SolarSystem/blob/master/README.md.
5. Verlet, Loup. "Computer "Experiments" on Classical Fluids. I. Thermodynamical Properties of Lennard-Jones Molecules." *Physical Review*, vol. 159, no. 1, 5 July 1967, pp. 98–103, <https://doi.org/10.1103/physrev.159.98>.