CALIFORNIA STATE SCIENCE FAIR
2010 PROJECT SUMMARY

Name(s)
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Project Number
S1906

Project Title
Celestial Body Mass Estimation: A Study of the Accuracy of Using Orbital Elements to Determine the Central Body#' Mass

Abstract

Objectives/Goals
This project analyzes the variables that affect the accuracy of mass estimations using a method that relies on the relative distance and velocity of satellites of interest. The hypothesis is that the orbital eccentricity of the satellites is indirectly proportional to the accuracy of mass estimates using this method, and the accuracy of the velocity and relative distance of the satellite to the central object is directly proportional to the accuracy of mass estimates using this method.

Methods/Materials
Data for the velocities and object locations were collected from the NASA JPL HORIZONS Ephemeris. Data for the mean eccentricity of satellite orbits were obtained from NASA JPL Solar System Dynamics. The data sets included the distance and velocities of all the planets and Eris with respect to the sun, the Moon with respect to the Earth, and for Triton with respect to Neptune. A mass estimate for the central body was calculated for every point using the orbital speed equation solved for the mass of the orbital center using Excel and Maple. This was compared with modern measurements of the actual mass of the orbital center and a relative error and range of relative error were calculated. If the planets exhibiting the highest velocity and position accuracies and the lowest mean orbital eccentricity demonstrated a higher accuracy for a mass estimation, then the hypothesis would be supported.

Results
In the test of individual planets with respect to the sun, the planet that exhibited the lowest maximum relative error was Venus, at 7.097 E-3, and the planet that exhibited the highest maximum was Mercury, at 4.111 E-1. The overall lowest maximum relative error for any satellite was exhibited by Triton, at 3.506 E-5, and the highest maximum was exhibited by Eris, at 8.869 E-1. The maximum relative errors for Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and the Moon are, 1.750 E-2, 9.369 E-2, 4.956 E-2, 1.129 E-1, 5.769 E-2, 1.597 E-2, and 8.982 E-1, respectively.

Conclusions/Discussion
The data partially supported the hypothesis. While the orbital eccentricity was almost exactly proportional to the maximum relative error for each satellite, the accuracy of measurements of the satellite#s relative distance and velocity had almost no impact on the accuracy of the estimation of the mass of the orbital center, e.g., Mars and Jupiter exhibited a significantly larger maximum relative error than Neptune and Triton.

Summary Statement
To analyze the variables that affect the accuracy of mass estimations using a method that relies on the relative distance and velocity of satellites of interest.

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