Modeling Fast-Moving Objects as They Travel through Crowded Astronomical Neighborhoods

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Introduction

The movements of a certain set of traveling interstellar objects can be discovered without directly observing them. One can do this by modeling the objects using either Gravitational Particle Dynamics or (for a broader scale) Smoothed Particle Hydrodynamics, commonly referred to as SPH. I intend to apply both of these through the course of this project, but on two different objects.

The first object I will analyze is known as ‘Oumuamua. This object is speculated to be a large chunk of metal and rock that came to our solar system by chance from the distant star Vega.[1] ‘Oumuamua is currently difficult to directly view due to the distance between it and the Earth. It will be modeled through the application of Gravitational Particle Dynamics to constrain the several theories concerning its origins. The first of these theories is that ‘Oumuamua is not made of metal, but of a type of N_2 ice similar to what is found on the surface of Pluto. This theory explains ‘Oumuamua's movements based on the non-gravitational acceleration caused by N_2 ice. Furthermore, N_2 gas is difficult to detect, and the red color and sloping surface of ‘Oumuamua are similar to that found on Pluto. ‘Oumuamua's odd shape could be a result of mass loss the ice suffered as a result of coming too close to the Sun.[6] A second theory is that ‘Oumuamua is a light sail, or an object that was blown by the solar winds of the sun. This theory hypothesizes that ‘Oumuamua was a comet-like object that approached too close to the Sun and was compressed by the sun's gravity before being blown away by the solar winds. A question regarding this theory is whether or not the solar winds of the Sun are powerful enough to counteract the strong gravitational force that had compressed ‘Oumuamua before it was blown away. The third theory concerning ‘Oumuamua's origins is that it is an alien spaceship, sent to examine the Sun.[8] A question regarding this theory is that an object moving at the rate of ‘Oumuamua may take a long amount of time to reach the Sun from another star system.

The second object I propose to model is called CWISE J1249+3621. CWISE J1249+3621 is a brown dwarf, moving through the Milky Way Galaxy at high speeds, independent of any stable star system.[2, 3] It is also difficult to directly observe, and will be modeled using SPH. There are several theories as to what CWISE J1249+3621's origins are; the first of these claims that CWISE J1249+3621 is the surviving companion of a type Ia Supernova. In other words, it shared a star system with a white dwarf that turned Supernova, ejecting CWISE J1249+3621 from the system. The authors of the theory[3] do mention that there are no remnants of a supernova in the direction CWISE J1249+3621 is theorized to have come from. Another theory concerning CWISE J1249+3621's origins is that it was ejected from a globular cluster. CWISE J1249+3621 may have received a large velocity 'kick' from a low mass object local to its globular cluster and been thrust out of the cluster and into space; this theory is equally as unlikely as the supernova theory, as there are no possible clusters in the brown dwarf's former direction from which it could have been 'kicked'.[3] A third theory concerning CWISE J1249+3621's origins is that it was an extragalactic star (a star from outside of the Milky Way galaxy). There is only one galaxy remotely in the range of CWISE J1249+3621's alignment, and it was only aligned in that way 6 billion years ago. Due to constantly changing factors throughout the space of 6 billion years, there is no way of eliminating the extragalactic star theory entirely.[3] One final theory on CWISE J1249+3621's origins is that it was ejected from the orbit of the Galactic Center (the black hole that lies at the center of the Milky Way). While the angle at which CWISE J1249+3621 travels and its inward trajectory do not suggest that it could have been ejected from the Galactic Center, several other stars similar to CWISE J1249+3621 have been identified in the general area from which it came.[3]

Plan

I intend to model the motions of CWISE J1249+3621, 'Oumuamua, and their surroundings by the means of Gravitational Particle Dynamics and SPH (Smoothed Particle Hydrodynamics). To run SPH, I will be using Gadget 2, a code that uses a hierarchical tree algorithm to model cosmological simulations.[4] I will program the equations needed to depict the motions of 'Oumuamua and the Solar System using the language C. After this process, I will load the results into Paraview[10] to provide a visual depiction of my objects' motions.

Progress

For my progress in the project, I have subscribed to the online coding course CodeAcademy to learn the language C. I have downloaded Gadget 2, and have explored its interface. I have been studying a book on computer simulation methods by Harvey Gould, Jan Tobochnik and Wolfgang Christian, particularly chapter five, which expounds upon gravitation.[9] I have identified the NASA JPL Horizons Database[5] as a source for data on 'Oumuamua, and I am still searching for data on CWISE J1249+3621. I have researched theories on the origins of my chosen objects, which are stated in the introduction.

Expected Outcomes

I expect to have a model of the movements of my chosen objects, and I anticipate that these models can:

A) limit the range of possibilities concerning 'Oumuamua's origin;

B) limit the range of possibilities concerning CWISE J1249+3621's origin;

C) give a hypothesis as to where each of these objects is headed next.

References

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[6] Desch, S. J., and Jackson, A. P. (2021).1I/'Oumuamua as an N2 ice fragment of an exo-Pluto surface II: Generation of N 2 ice fragments and the origin of 'Oumuamua. Journal of Geophysical Research: Planets, 126, e2020JE006807. https://doi.org/10.1029/2020JE006807.

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[9] Gould, Harvey, Jan Tobochnik, Wolfgang Christian, "An Introduction to Computer Simulation Methods: Applications to Physical Systems, Revised Third Edition", CreateSpace Independent Publishing Platform, 2017.

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