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Close Encounter and Impact Scenarios on Earth from Small Solar System Bodies

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Abstract

1. Introduction

One of the greatest successes of the Einstein's General Theory of Relativity (GR) was the correct prediction [5] of the precession of perihelion of Mercury. The closed form expression [18] to compute this precession tells us that substantial GR precession would occur only if the bodies have a combination of both moderately small perihelion distance and moderately small semi-major axis [13].

Minimum Orbit Intersection Distance (MOID) is a quantity in celestial mechanics which helps us to understand the closest proximity of two orbits in space[15]. Hence evaluating MOID is crucial to understand close encounters and collision possibilities better[16]. In this work, we look at the possible scenarios where a small GR precession in argument of pericentre can create substantial changes in MOID for small bodies ranging from meteoroids, comets and asteroids and thereby leading to changes in close encounter and impact scenarios.

2. Methods and Techniques

Previous works have looked into neat analytical techniques [15] [16] to understand different collision scenarios and we use those standard expressions to compute MOID analytically. We find the nature of this mathematical function is such that a relatively small GR precession can lead to drastic changes in MOID values depending on the initial value of argument of pericentre. These cases are analysed for various examples of asteroids, comets and meteoroid stream particles. Past works [1][2][4][8][9][14][17][19] have looked into various interesting encounter geometries and impact cases on Earth and other planets from different classes of small body population. Recent works[6][7][10][12][13] have shows that GR effects can play an important role in the evolution of small bodies in solar system as well as exoplanetary systems.

Numerical integrations were done with package MERCURY [3] incorporating the GR code to look at the nature of their orbital evolution and double check the same effects. Numerical approach showed the same interesting relationship (as shown by analytical theory) between values of argument of pericentre and the peaks or dips in MOID values. There is an overall agreement between both analytical and numerical methods in understanding the pattern of MOID evolution for asteroids, comets and meteoroid stream particles which undergo measurable GR precession. Orbital elements are taken from IAU-Minor Planet Center, JPL-Horizons, Cometary Catalogue [11] and IAU-Meteor Data Center.

3. Summary and Discussion

We find that GR precession could play an important role in the calculations pertaining to MOID and close encounter scenarios in the case of certain small solar system bodies (depending on their initial orbital elements) when long term impact risk possibilities are considered. Previous works have looked into impact probabilities and collision scenarios on planets from different small body populations and this work aims to see how such contributions get affected by the role of GR in certain small bodies orbiting close to the sun.

Certain parallels in this GR influence are drawn between the cases of asteroids, comets and small perihelion distance meteoroid streams in the context of close encounter and impact scenarios on Earth.

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