General Relativistic Precession in Small Solar System Bodies

A. Sekhar (1, 2), S. C. Werner (1), D. J. Asher (2), J. Vaubaillon (3), M. Hajduková (4), G. Li (5),
(1) Centre for Earth Evolution and Dynamics, University of Oslo, Norway (aswin.sekhar@geo.uio.no), (2) Armagh Observatory, United Kingdom (3) IMCCE, Observatory of Paris, France (4) Astronomical Institute, Slovak Academy of Sciences, Slovakia (5) Harvard-Smithsonian Center for Astrophysics, United States of America

Introduction

One of the greatest successes of the Einstein's General Theory of Relativity (GR) was the prediction,[1], of the precession of perihelion of Mercury. The expression,[2], 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 (q) and semi-major axis (a). Minimum Orbit Intersection Distance (MOID) is a quantity which helps us to understand the closest proximity of two orbits in space. Hence evaluating MOID is crucial to understand close encounters and collision scenarios better. In this work, we look at the possible scenarios where a small GR precession in argument of pericentre (ω) can create substantial changes in MOID for small bodies ranging from meteoroids to asteroids.

Analytical Approach and Numerical Integrations

Previous works, [3][4], have looked into neat analytical techniques to understand different collision scenarios and we use those standard expressions to compute MOID analytically. We find that the nature of this function is such that a relatively small GR precession ($\Delta\omega \sim 10^{-1}$ degrees/10 kyr) can lead to drastic changes in MOID values (dMOID $\sim 10^{-3}$ AU) depending on the initial value of ω. Numerical integrations were done with package MERCURY incorporating the GR code to test the same effects. Numerical approach showed the same interesting relationship (as shown by analytical theory) between values of ω and the peaks/dips in MOID values. Previous works, [5][6], have shown that GR precession suppresses Kozai oscillations and this aspect was verified using our integrations. We find an overall agreement between both analytical and numerical methods.

Discussion

We find that GR precession could play an important role in the calculations pertaining to MOID and impact forecasts in the case of some small solar system bodies. Previous works, [7][8][9][10][11], have looked into impact probabilities and collision scenarios on planets from different small body populations. This work aims to find certain sub-sets where GR could play an interesting role. Certain parallels are drawn between the cases of asteroids, comets and small q meteoroid streams (similar to the one discussed in [12]).

References

[1] Einstein A. 1915, Preussische Akademie der Wissenschaften, Sitzungsberichte, 831.
[2] Weinberg S. 1972, Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity, Wiley, New York.
[3] Valsecchi G.B. 2006, Lect. Notes Phys., 682, 145.
[4] Valsecchi G.B., Milani A., Gronchi G.F. , Chesley S.R. 2003, Astron. Astrophys., 408, 1179.
[5] Naoz, S., Kocsis, B., Loeb, A., Yunes, N. 2013, ApJ, 773, 187.
[6] Li, G., Naoz, S., Kocsis, B., Loeb, A. 2014, ApJ, 785, 116.
[7] Werner S. C., Ivanov B. A., 2015, Exogenic Dynamics, Cratering and Surface Ages. In: Gerald Schubert (editor-in-chief), Treatise on Geophysics, 2nd edition, Vol. 10, Oxford: Elsevier, 327.
[8] Asher D. J., Bailey M. E., Emel'yanenko V. V., 1999, MNRAS, 304, L53.
[9] Vaubaillon J., Lamy P., Jorda L., 2006, MNRAS, 370, 1841.
[10] Sekhar A., Asher D. J., 2014, Meteorit. Planet. Sci., 49, 52.
[11] Hajduková, M., Rudawska, R., Kornos, L., Tóth, J. 2015, P&SS, 118, 28.
[12] Fox K., Williams I.P., Hughes D.W. 1982, MNRAS, 199, 313.