EPSC Abstracts
Vol. 11, EPSC2017-270-2, 2017
European Planetary Science Congress 2017

GR Precession and Kozai Mechanism in Asteroid-Comet Continuum

A. Sekhar (1,2), D. J. Asher (2), A. Morbidelli (3), S. C. Werner (1), J. Vaubaillon (4), G. Li (5)
(1) Centre for Earth Evolution and Dynamics, Faculty of Mathematics and Natural Sciences, University of Oslo, Norway (2) Armagh Observatory and Planetarium, Northern Ireland, United Kingdom, (3) Laboratoire Lagrange, Universite de Nice Sophia-Antipolis, CNRS, Observatoire de la Cote d'Azur, Nice, France (4) IMCCE Observatory of Paris, France (5) Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States (aswin.sekhar@geo.uio.no)

Abstract

1. Introduction

Two well known phenomena associated with low perihelion distance bodies in orbital dynamics are general relativistic (GR) precession and Kozai oscillations.

The accurate prediction of the perihelion shift [17] of Mercury in accord with real observations is one of the signicant triumphs of the general theory of relativity [3]. Past works have looked into the GR precession in perihelion in different types of solar system bodies like planets, asteroids [14][13], comets [15][13] and meteoroid streams [4][12][5]. More recently some works have explored the cases of GR precession in exoplanetary systems [8].

In its purest form the Lidov-Kozai mechanism involves three bodies, namely a central body, test particle and perturber [7]. In real situations such as the solar system, the perturber is mainly Jupiter and the Kozai-like oscillations have a significant role in the orbital evolution [2][9] of many small bodies in the solar system.

In this work, we are interested to identify solar system bodies evolving in the near future (i.e. thousands of years in this case) into rapid sungrazing and sun colliding phases and undergoing inclination flips, due to Kozai-like oscillations and being GR active at the same time thus forming a GR-Kozai continuum phase space.

2. GR Precession and Kozai Mechanism Dynamics

We find that Kozai mechanism leads to secular lowering of perihelion distance which in turn leads to a huge increase in GR precession of the argument of pericentre depending on the initial orbital elements. This in turn gives feedback to the Kozai mechanism as the eccentricity, inclination and argument of pericentre in Kozai cycles are closely correlated. In this work, we find real examples of solar system bodies which show rapid enhancement in GR precession rates due to Kozai-like oscillations and there are cases where GR precession rate peaks to about 60 times that of the GR precession of Mercury thus showing the strength and complementary nature between these two dynamical phenomena. Comet 96P/Machholz 1 stands as a unique example in many of these aspects especially because its orbital connection [10][11] with two sungrazing comet families (Marsden and Kracht) and low perihelion distance meteoroid streams like Daytime Arietids and Southern Delta Aquariids . The orbital evolution of the body 322P/SOHO (can be considered as part of the asteroid-comet continuum) which was investigated in an interesting study[6] recently is also discussed.

An analytical treatment [9] is done on some solar system bodies to understand the difference in their orbital evolution in the context of Kozai mechanism with and without GR precession term by incorporating suitable Hamiltonian dynamics. Suitable conditions in phase space for sun colliding trajectories are found for cases evolving with and without GR precession to see the difference in the nature of their dynamical evolution. This result is subsequently matched using numerical integrations to find direct correlations for bodies which form the GR-Kozai continuum.

3. Summary and Discussion

Real solar system bodies showing both GR precession and Kozai-like oscillations are identified using compiled observational records from IAU-Minor Planet Center, Cometary Catalogue, IAU-Meteor Data Center by performing analytical plus numerical tests on them.

This intermediate state (where GR and Kozai effects

are comparable and co-exist forming a GR-Kozai continuum) brings up the interesting possibility of drastic changes in GR precession rates during orbital evolution due to sungrazing and sun colliding phases induced by the Kozai-like mechanism. Both these phenomena complementing and co-existing at the same time has interesting implications in the nodal geometry [1][16] and long term impact studies [18] on Earth from small bodies in general and the fate of small bodies ending up colliding with the sun.

Acknowledgements

Sekhar and Werner acknowledge the Crater Clock project (235058/F20) based at Centre for Earth Evolution and Dynamics (through the Centres of Excellence scheme project number 223272 (CEED) funded by the Research Council of Norway).

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