Analysis of co–orbital motion of real asteroid in a medium–term timescale*

Sara Di Ruzza[1 [0000−0003−3996−5232]], Alexandre Pousse[2 [0000−0003−3996−5232]], and Elisa Maria Alessi[2 [0000−0001−6693−0014]]

[1] Department of Mathematics, University of Palermo, via archirafi 34, 90123, Palermo, Italy
[2] Istituto di Matematica Applicata e Tecnologie Informatiche "E. Magenes", Consiglio Nazionale delle Ricerche (IMATI-CNR), Via Alfonso Corti 12, 20133, Milano, Italy

Abstract. The focus of this work is the current distribution of asteroids in co-orbital motion with Venus, Earth and Jupiter, under a quasi-coplanar configuration and for a medium-term timescale of the order of 900 years. A co-orbital trajectory is a heliocentric orbit trapped in a 1:1 mean-motion resonance with a given planet. The averaged planar circular restricted three-body problem is used as a tool to classify co-orbital dynamics, which can be quasi-satellite (QS), horseshoe (HS), tadpole (TP), according to the dynamical behavior. Transitions between different types of motion are analyzed as well as compound motions, which represent a coexistence of two dynamical regimes. The results provide a general catalog of co-orbital asteroids in the solar system, the first one to our knowledge, and an efficient mean to study transitions.

Keywords: Orbital resonances · Asteroid motions · Co-orbital dynamics.

1 Asteroids in co-orbital motions

Let us consider three bodies interacting by the gravitational force where two of them (e.g., a planet and an asteroid) orbit around a central more massive body (e.g., the Sun). We say that there exists a co-orbital motion between the two less massive bodies if they are trapped in a 1:1 mean-motion resonance, namely the ratio between the two orbital periods around the Sun is equal to 1. The system can be described by the restricted three-body problem if one of the bodies (the asteroid in our case) has negligible mass. We use results obtained from the averaged planar circular restricted three–body problem as a tool to classify different types of co-orbital motion (see [2]).

Many asteroids of the solar system have been seen to be trapped in co-orbital motion with planets. The aim of this work is to provide a tool to catalog these objects and easily recognize them (see [1]). In Fig 1, we provide a two-dimensional

* S.D.R. is supported by University of Palermo and A.P. and E.M.A. are supported by the project entitle "co-orbital motion and three-body regimes in the solar system", funded by Fondazione Cariplo through the program "Promozione dell'attrattività e competitività dei ricercatori su strumenti dell'European Research Council - Sottomisura rafforzamento"

map (independent from the planet) where it is possible to identify clearly the regions of the phase-space according to the co-orbital dynamics. In Fig. 2, we show real asteroids to be found in co-orbital motion with planets Venus, Earth, Jupiter, respectively. The motion of asteroids is given by the ephemerides computed through the JPL Horizon system for a time-span of 900 years around the current date.

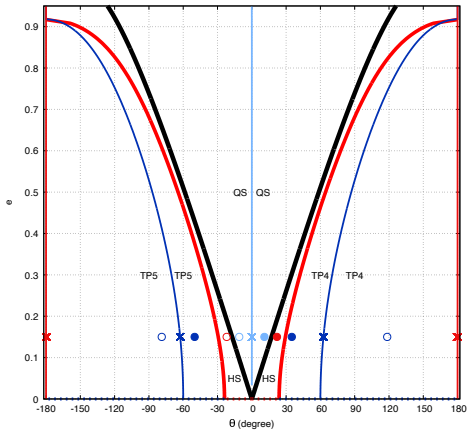

Fig. 1. Types of co-orbital motions in the two-dimensional map e versus θ, where e is the eccentricity of the asteroid and θ is the resonant angle measuring the 1:1 mean-motion resonance.

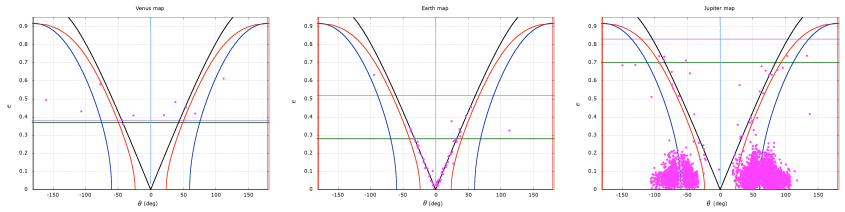

Fig. 2. Asteroids in the (e, θ)-maps for Venus, Earth, Jupiter, respectively, from left to right.

References

1. Di Ruzza S., Pousse A., Alessi E.M.: On the co-orbital asteroids in the solar system: medium-term timescale analysis of the quasi-coplanar objects, (2022) arXiv:2209.05219
2. Pousse A., Alessi, E.M.: Revisiting the averaged problem in the case of mean-motion resonances in the restricted three-body problem, Nonlinear Dynamics **108**, 959–985 (2022)