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Letter to the Editor

The evection resonance in trojan configuration

Giuppone, C. A.[1,2], Roig, F.[3] and Saad-Olivera, X.[3]

[1] Universidad Nacional de Córdoba, Observatorio Astronómico, IATE, Laprida 854, 5000 Córdoba, Argentina
[2] CIDMA, Departamento de Física, Universidade de Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal
[3] Observatório Nacional, Rio de Janeiro, 20921-400, RJ, Brazil

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ABSTRACT

Context. The stability of satellites in the Solar System is affected by the so called evection resonance. The moons of Saturn, in particular, exhibit a complex dynamical architecture in which coorbital configurations occur, especially close to the planet where this resonance is present.
Aims. To address the dynamics of the evection resonance, with particular focus in the Saturn system, and to compare the known behavior of the resonance for a single moon to that of a pair of moons in coorbital trojan configuration.
Methods. We develop an analytic expansion of the averaged Hamiltonian of a trojan pair of bodies, including the perturbation from a distant massive body. We also perform numerical N-body simulations to construct dynamical maps of the stability of the evection resonance in the Saturn system, and to study the effects of this resonance under the migration of trojan moons due to tidal dissipation.
Results. The structure of the phase space of the evection resonance for trojan satellites is similar to that of a single satellite, differing in that the libration centers are displaced from their standard positions by an angle that depends on the periastrons difference $\varpi_2 - \varpi_1$ and on the mass ratio m_2/m_1 of the trojan pair. In the Saturn system, the inner evection resonance, located at $\sim 8\,R_{\rm S}$, may capture pair of trojan moons by tidal migration; the stability of the captured system depends on the assumed values of the dissipation factor Q of the moons. On the other hand, the outer evection, located at $> 0.4\,R_{\rm Hill}$, cannot exist at all for trojan moons, because trojan configurations are strongly unstable at distances from Saturn longer than $\sim 0.15\,R_{\rm Hill}$.
Conclusions. The effect of the evection resonance during early evolution of Saturn's moons would be relevant to determine whether these moons may have had trojan companions destabilized by this resonance. This might impose constraints to the production of craters on their surfaces from collisions with these former companions, as well as to the tidal dissipation factor of the planet.

Key words. celestial mechanics – methods: analytical – methods: N-body simulations – planets and satellites: dynamical evolution and stability – planets and satellites: individual: Saturn

1. Introduction

In studying the dynamics of satellites in the Solar System, it is important to establish whether the bodies are bounded to the planets or may escape to heliocentric orbits. Therefore, the Sun's perturbation is a key issue to address the stability of these satellites. In the case of the Moon, the development of Hill's Lunar theory allowed to identify the so called evection term (Brouwer & Clemence 1961) as the largest periodic correction to the Moon's mean longitude. For any satellite, the evection term is associated to the harmonic $\cos(2\lambda_\odot - 2\varpi)$, where $\lambda_\odot$ is the mean longitude of the Sun and ϖ is the longitude of the pericenter of the satellite. The evection resonance arises when the precession rate of ϖ equals the solar mean motion, causing the angle $\lambda_\odot - \varpi$ to librate around an equilibrium point. In the classical evection, the pericenter precession is driven by the solar perturbation itself, but in principle any other perturbation inducing a pericenter precession may originate an evection resonance.

In the restricted three-body problem, Henon (1969, 1970) showed that the classical evection resonance appears as a bifurcation of a family of simple periodic orbits, at a value of semi-major axis $a = 0.45\,R_{\rm Hill}$. Hamilton & Krivov (1997) showed that in the case of prograde orbits, the evection resonance appears at $a = 0.53\,R_{\rm Hill}$ and is characterized by the resonant angle $\lambda_\odot - \varpi$ librating either around 0° or 180°. This alignment/anti-alignment of the satellite pericenter with the Sun direction induces cumulative perturbations that may cause the escape of the satellite (Nesvorný et al. 2003), which might be relevant for the stability of bodies that are migrating due to tidal evolution or gas drag.

Indeed, the evection resonance plays an important role in sculpting the architecture of the satellite systems. Nesvorný et al. (2003) studied the orbital and collisional evolution of satellites and found that prograde satellite orbits with large semi-major axes are unstable due to the effect of the evection resonance. Ćuk & Gladman (2009) explored the fate of fictitious objects trapped in the lunar trojan points after the formation of the Moon, and found that these bodies can survive the Moon's tidal migration until they get to 38 Earth radii, where the evection resonance ejects them from the system. Ćuk et al. (2016) also studied the past evolution of the Tethys-Dione system, and found that the evection resonance perturbing a pair of mid-sized moons is the most likely mechanism for triggering insta-