EPSC Abstracts
Vol. 13, EPSC-DPS2019-1174-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Threat from the Within: Excitation of Venus's co-orbitals into Earth-crossing Orbits

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Abstract

There are currently 5 known co-orbitals, objects in the 1:1 mean motion resonance (MMR), of Venus: 2001 CK_{32}[1], 2002 VE_{68}[2], 2012 XE_{133}[3], 2013 ND_{15}[4] and 2015 WZ_{12} [5], and each is currently crossing the orbit of Earth. Low eccentricity Venus's co-orbitals have been suggested to be stable for the age of the solar system [6], while their Earth crossing cousins are not dynamically stable. A recent study investigating the origin of Venus's co-orbital dust ring suggested that asteroids in the 1:1 MMR with Venus are the only possible explanation [7]. The same study also showed that approximately 8% of Venus co-orbitals remain in a stable 1:1 mean-motion resonance with Venus for the age of the solar system.

In our contribution we explore the scenario that the Venus's co-orbitals we observe today are a proxy for a more abundant, yet unobserved, source population. Following the dynamical evolution of asteroids that are trapped in the 1:1 MMR with Venus, our simulations show that a fraction of asteroids acquire eccentricities large enough to push their aphelion distance beyond 1 au and become Earth-crossers while still maintaining their co-orbital regime with Venus. These orbits are generally only stable for thousands of years with several exceptions lasting more than 50 kyr.

We use the transport efficiency of Venus co-orbitals to Earth crossing orbits obtained from our simulation and currently observed population of such bodies to estimate the current mass of Venus's co-orbiting asteroid population assuming a range of different size-frequency distributions. Furthermore, we use the dynamical population decay of Venus's co-orbital population from [7] to estimate the range of masses of Venus's co-orbitals 4 billion years ago.

Additionally, we estimate the rate of excitation of originally stable Venus co-orbitals into Earth crossing orbits and follow them even after they leave the 1:1 MMR with Venus. Our simulation suggests that $\sim 3\%$ of all Venus co-orbitals can evolve into Earth crossing orbits and remain in such configurations for millions of years, posing a potential threat from currently poorly observed regions of the solar system.

Acknowledgements

P.P. and M.J.K. were supported by NASA Solar System Workings grant NNH14ZDA001N-SSW.

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