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A population of co-orbital asteroids in the Main Belt

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Abstract

We show that many MBAs are presently in the 1:1 resonance ('co-orbitals') with dward planet Ceres and large MBA Vesta. They most likely represent a transient population; their dynamical evolution is similar to that of objects known to co-orbit with Earth and Venus. We discuss this population in terms of the longevity of co-orbital capture, its relation to encounters with the secondary and other massive asteroids and the existence of distant Quasi-Satellites of Ceres and Vesta.

1. Introduction

The co-orbital resonance allows two or more objects, at least one of which has appreciable mass (the 'secondary'), to co-exist in a stable orbital configuration around a planet or a star [3]. It serves as a gravitational anchor for long-lived populations of so-called Trojans at the orbits of planets [4].

More recently, the planets Earth and Venus were shown to host co-orbital populations of a new type [9, 10, 7, 8, 1]. Unlike Trojans, these have large eccentricities and inclinations - typical, in fact of NEAs - and exhibit a larger variety of libration modes. Stable transitions between different modes can occur as a result of the secular evolution of the orbital elements and moderately close approaches to the secondary.

We have searched for similar populations of Main Belt Asteroids (MBAs) co-orbiting with the large MBA Vesta and the dwarf planet Ceres. We were motivated by the fact that a few such objects are already known to exist [2] and the expectation that the productivity of asteroid surveys in the decade since then would lead to the discovery of a statistically significant population of new objects.

2. Results

Through improving the search criteria used in [2] and numerical integrations of candidate coorbitals, we have found approximately 51 (44) objects currently in co-orbital libration with Ceres (Vesta). These are of the transient variety; 129 (94) MBAs underwent episodes of co-orbital libration with Ceres (Vesta) within a 2Myr interval centred on the present. These lasted from $\sim 10^5$ yr to $> 10^6$ yr. Fig 1 shows an example of an MBA while a Trojan and horseshoe librator of Ceres. Several MBAs - mainly L4 and L5 Trojans - outlasted our 2 Myr integrations; they were later shown to exit the resonance within 10^7 yr. The variational properties of several objects were examined through the generation and integration of clones. It was found that their present states are well determined but knowledge of their state with respect to the secondary is lost after $\sim 2 \times 10^5$ years. Objects deeper into the coorbital zone maintain their coorbital state for longer.

During this presentation we will describe our search methodology, present our results and discuss their implications. In particular we will show examples of persistent Trojans and Horseshoes of Ceres and Vesta, as well as non-keplerian Quasi-Satellites around these bodies [5, 6]. We will identify similarities and differences with the much sparser population of known transient coorbitals of Earth and Venus and show how the coorbital resonance affects, and is affected by, encounters with both the secondary and other massive bodies. Finally, we will discuss the signatures these coorbitals may have left on the surface and environment of Ceres and Vesta.

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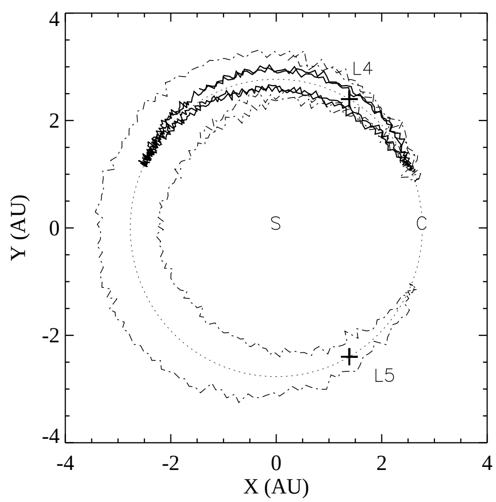

Figure 1: Evolution of main belt asteroid 157214 during episodes of tadpole (bold line) and horseshoe (dashed-dotted line) libration with respect to Ceres. These last for 2.4×10^5 yr and 1.6×10^5 yr respectively. The location of Ceres ('C') - averaged over one orbital period - and that of the Sun ('S') in a frame rotating with the mean motion of Ceres are indicated, as are the triangular equilibrium points L_4 and L_5.

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