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A NEW DYNAMICAL POPULATION OF ASTEROIDS

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RESUMEN

Hemos encontrado aproximadamente 1500 asteroides evolucionando en la resonancia exterior 1:2 con Marte. Si nos fijamos en el histograma de semiejes mayores de los asteroides del cinturón principal la población puede ser distinguida como un pico en $a \simeq 2.419$ UA. Aproximadamente 400 asteroides se encuentran librando alrededor de los centros de libración asimétricos y aproximadamente 700 están describiendo trayectorias tipo herradura. Una fuerte perturbación secular debida a Júpiter y debida a la evolución temporal de la excentricidad de Marte produce saltos entre los centros de libración y entre libraciones y trayectorias de herradura. A pesar de este fuerte efecto secular la población permanece vinculada a la resonancia por escalas de tiempo de $10^8 - 10^9$ años.

ABSTRACT

We have found approximately 1500 asteroids evolving in the exterior 1:2 resonance with Mars. Looking at the histogram of semimajor axes of the asteroids in the main belt the population can be distinguished as a peak at $a \simeq 2.419$ AU. Approximately 400 asteroids are librating around the asymmetric libration centers and about 700 are describing horseshoe trajectories. A strong secular perturbation due to Jupiter and due to Mars' eccentricity time evolution produces switching between libration centers and between librations and horseshoe trajectories. In spite of this strong secular effect the population remains linked to the resonance over time scales of $10^8 - 10^9$ years.

Key Words: celestial mechanics — minor planets, asteroids

1. THE RESONANT POPULATION

Mean motion resonances are present everywhere in the solar system, the fact that they show up or not is determined by their strength which depends on the planet, the particular resonance and the orbital elements of the asteroid's orbit (Gallardo 2006). The strength is associated with the stickiness of the resonance, that means, the ability of the resonance of retain minor bodies in the resonant regime (Lykawka & Mukai 2007).

We have recently found there is a numerous population of asteroids in the exterior mean motion resonance 1:2 with Mars at $a \simeq 2.419$ AU (Gallardo 2007). After a reanalysis of the orbital dynamics of the population of asteroids in the region $2.416 \leq a \leq 2.422$ AU and using the same dynamical model we increased our first estimation of resonant asteroids from 1000 to 1500 approximately. The analysis was donelooking at the time evolution of the critical angle:

$$\sigma = 2\lambda - \lambda_M - \varpi \,, \tag{1}$$

where the λ's are the mean longitudes of the asteroid and Mars and ϖ is the asteroid's longitude of

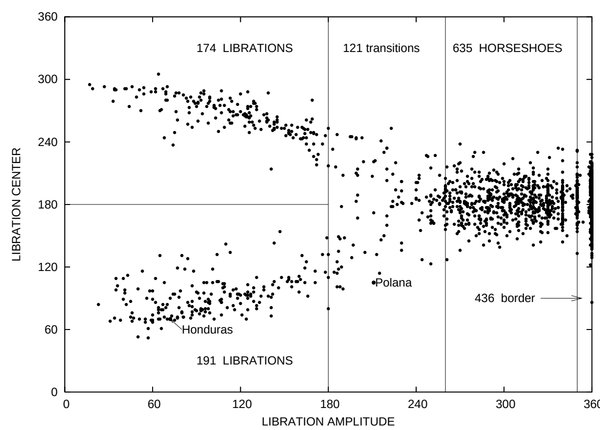

Fig. 1. The resonant population according to the firsts 10.000 years from present. The libration period is of the order of some 10^3 years. Polana with a diameter of 55 kms is the biggest asteroid.

the perihelion. Resonances usually have their critical angle librating around 0° or 180° but exterior resonances of the type 1:N have "asymmetric" libration centers which means that σ librates around a value which depends on the asteroid's eccentricity (Beaugé 1994).

The situation at present as defined by the libration center and libration amplitude ($\sigma_{\max} - \sigma_{\min}$) is

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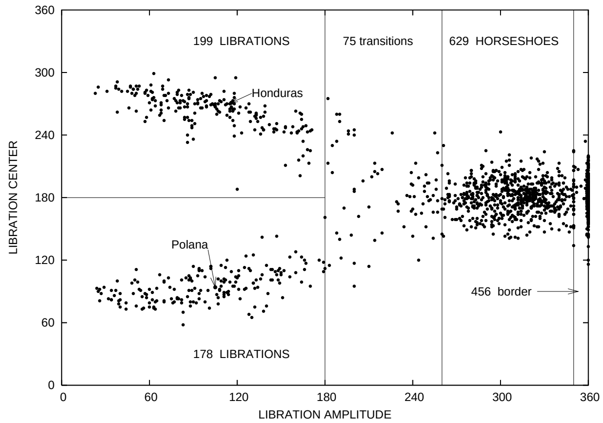

Fig. 2. The resonant population after one million years from present.

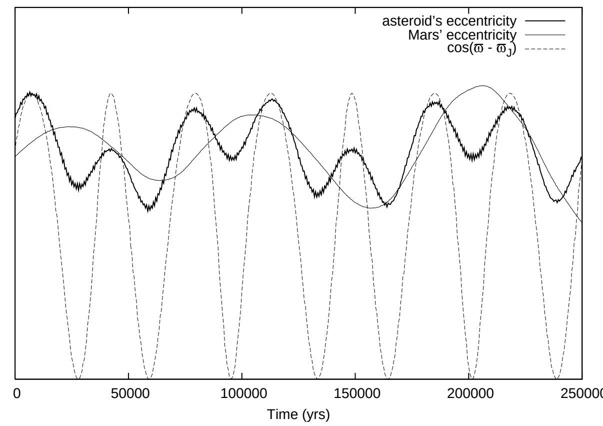

Fig. 3. The secular evolution of a particular asteroid.

showed in Figure 1. Approximately 400 asteroids are librating, 600 are in horseshoe trajectories, 100 are in transition between both regimes and finally there are about 400 asteroids in the boundary region. After one millon years the situation is globally the same (Figure 2) but several asteroids have interchanged their positions in the plot. For example, (11055) Honduras has switched its libration center and (142) Polana, the biggest asteroid of the population, has evolved from a transition zone to a libration regime.

2. SECULAR DYNAMICS

We have found a complex secular evolution inside the resonance. There are two main contributions in the long term evolution: a secular perturbation due to Jupiter and a forced mode due to the time evolution of Mars' eccentricity. As an example we show in Figure 3 the evolution of the eccentricity of one of the asteroids. Superimposed is Mars' eccentricity and the evolution of the difference between the perihelion's longitudes of the asteroid and Jupiter ($\varpi - \varpi_J$).

It is evident that the eccentricity is driven by a secular effect by Jupiter and also is modulated by Mars' eccentricity. This secular behavior generates a strong periodic perturbation in the resonant regime and is the cause of the continuous transitions between libration, horseshoe and circulation regime we have observed.

While Jupiter's effect is different for each asteroid because it depends on ϖ, Mars' effect is qualitatively the same for all the population. In consequence the mean eccentricity of the population follows Mars' eccentricity and librations are globally perturbed according to Mars' eccentricity evolution as we have found before (Gallardo 2007; Figure 2).

We have followed by some hundreds millon years the time evolution of an aleatory sub-sample of 50 asteroids in order to estimate the mean lifetime of the resonant population. In spite of the strong perturbations by Jupiter and Mars, we have found the population remains linked to the resonance over very long time-scales, of the order of 10^8 to 10^9 years.

3. CONCLUSIONS

A population of around 1500 asteroids is confirmed to be evolving inside the resonance 1:2 with Mars, 400 of them showing asymmetric librations. The concentration of asteroids in the space of semimajor axes in this resonance is one of the highest over all the solar system due to the strength and stickiness of the resonance. A complex secular evolution is driven by Jupiter and Mars in spite of which the population remains associated with the resonance over long time-scales.

Two numerous population of resonant asteroids are well known in the Solar System: Trojans and Hildas. This new resonant population is not so stable as them but anyway it is an intersting point that a small mass planet like Mars could dominate over long time scales a numerous population of asteroids by means of a resonant regime.

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