SPECIFIC STUDY OF THE GRAVITATIONAL EFFECTS OF CERES, PALLAS AND VESTA ON MARS AND THE EARTH'S ORBITAL PARAMETERS

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ABSTRACT. The drastic evolution of computing tools and the necessity to take into account small effects has led the specialists of ephemerides to include a large number of asteroids in their computations. For this reason it looks appropriate to model in details the individual specific effects of these asteroids (at least the largest ones). In this paper we present our work (Souchay et al., in prep.) concerning the effects of Ceres, Pallas and Vesta on the orbital parameters of the Earth Moon Barycenter (EMB) and Mars , as well as on the longitude and distance of Mars with respect to the EMB , which are important in term of space navigation. A least-square analysis has been carried out to model in details the effects of the asteroids, thus allowing a precise determination of the largest sinusoidal terms, at the level of the kilometer.

1. INTRODUCTION

The construction of modern ephemeris as the recent INPOP (Fienga et al.,2008), EPM2006 (Pitjeva,2007) and DE414 (Konopliv et al.,2006) requires to take into account the gravitational effects of a large number of asteroids. Considering up-to-date space navigation, a lot of asteroids (about three hundreds) have enough mass to perturb significantly terrestrial planets such as Mars and the Earth. Nevertheless, because of the large uncertainty on the determination of the asteroids' mass, it is difficult, or impossible, to evaluate the effect with enough accuracy. An important step to evaluate the accuracy limits in the ephemerides of the four inner planets was made by Standish and Fienga(2002) carrying out a Monte Carlo analysis and adjusting the ephemerides to fit the observational data with a suitable set of asteroid masses. In addition, to clearly understand the influence of a given asteroid in the orbital motion of a terrestrial planet, an interesting way consists in determining the differences of motion when considering or not this asteroid in the computations. In a recent study (Souchay et al., A & A in prep.) we restricted our attention on the three largest asteroids Ceres, Pallas and Vesta.

2. COMPUTATIONS AND RESULTS

Our work is similar but to previous calculations done by Williams (1984), but with an extended analysis of the effects of asteroids . At first we integrate a classical N-bodies problem for the solar system, by taking 9 bodies into account (the Sun and the eight planets). Then we carry out the same integration, but by the sole addition of the perturbing asteroid (Ceres, Pallas or Vesta). Subtracting the two signals gives a direct determination of the effect of the single asteroid considered on the EMB or Mars.

We have carefully investigated the effects of each of the 3 asteroids on the 6 orbital parameters (a,e,i, Ω,$\tilde{\omega}$, L) of the 2 bodies (EMB and Mars), which are consequently represented by 36 curves at total. The effects on the EMB are naturally much smaller than for Mars, for two reasons : the comparatively small mass of the planet and its proximity to the asteroids. In addition we have also investigated the influences of Ceres, Pallas and Vesta on the distance and the longitude of Mars which are important in astrometry and space navigation. As an example, we show in **Fig.1** the variations of Mars distance with respect to the EMB due to each of the three asteroids. It is possible to model the total curve (obtained by summing the effects) as a sum of Fourier and Poisson components in the form : $\Delta d_{EMB-Mars} = \sum_i A_i \sin \omega t + B_i \cos \omega_i t + C_i \times t \sin \omega t + D_i \times t \cos \omega_i t$, where the frequencies ω_i are obtained through a Fast Fourier Transform (FFT), and the amplitudes A_i etc... are obtained by least mean squares analysis. The 7 leading components are shown in Table 1. The signal is dominated by

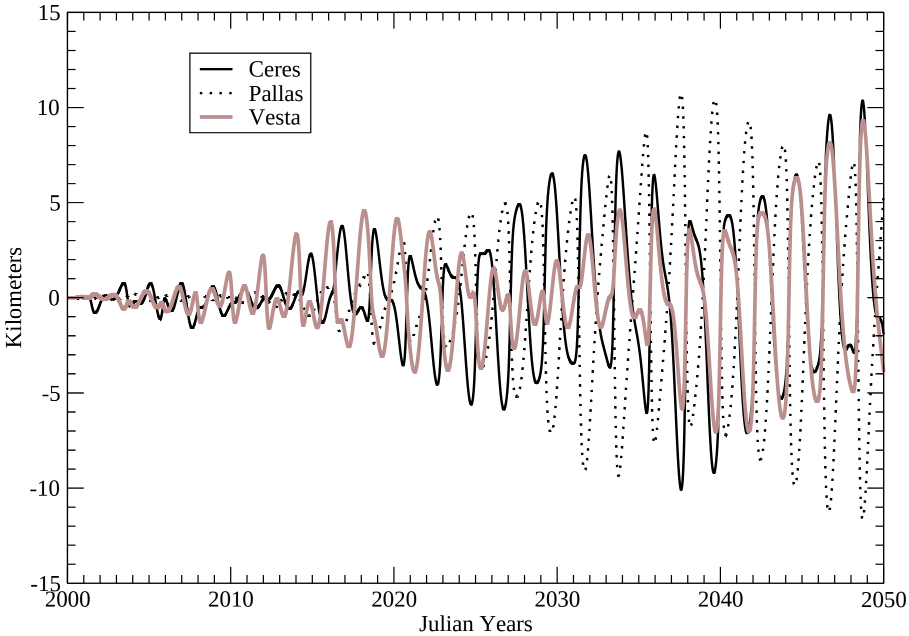

Figure 1: Variations of Mars distance from the Earth Moon Barycenter (EMB) due to Ceres, Pallas and Vesta

Poisson terms reaching 18 km peak to peak in a 100 years time span. This can be explained by the fact that the linear trend of Δe, Δi etc... are gradually affecting the amplitudes of the components of Mars orbital motion.

Table 1: Leading sinusoidal components (Fourier and Poisson terms) in the distance between the Earth-Moon barycenter and Mars, due to the influence of the combined effects Ceres, Pallas and Vesta

Period (day)	A_j $\sin\omega t$ (m)	B_j $\cos\omega t$ (m)	Amplitude total (m)	C_j $t \times \sin\omega t$ (m)	D_j $t \times \cos\omega t$ (m)	Amplitude total (m)
1170.0	56.05	-115.07	127.99	-715.23	1095.97	1308.70
891.0	-217.55	-302.32	372.45	2263.06	709.70	2371.73
777.8	250.44	735.28	776.76	-2374.90	-17534.05	17746.06
687.0	. 78.82	-473.69	480.21	-4781.23	857.05	4857.44
389.5	417.46	-304.41	516.66	-27.93	5781.76	5781.83
356.0	25.37	737.52	737.95	3081.31	-6485.06	7179.86
315.0	-127.92	153.02	199.44	1211.37	-1665.16	2059.17

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