The Vesta Asteroid Family: Study of the family and close encounters with terrestrial planes and dynamical influences by (1) Ceres and (4) Vesta.

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The Vesta family is the largest asteroidal family known in the inner asteroid belt. Most of the identified members which belong to this family are V-type asteroids and are regarded as a source for Near-Earth Asteroids (NEAs). They are also thought to be the source of the HED (Howardite Eucrite Diogenite) meteorites, in particular these are supposed to come from the crust of the asteroid (4) Vesta (Cochran et al. [2004]). They are mainly perturbed by Jupiter, drifting in three-body and weak secular resonances until they are captured in the strong z_2 resonance (Carruba et al. [2005]).

1 We first confirm their membership, using the AstDys data base of proper elements provided by Knežević and Milani [2003], and by using the classical HCM algorithm. We redefine the family, compare the results with previous ones and give the borders of the family with respect to the invariable plane (Souami and Souchay [2011]).

2 We proceed to a long-term statistical dynamical study, by integrating a sample of 350 bodies inside the identified family over 100 Myrs and reporting their minimum perihelium distance. We integrate for an additional 100 Myrs, those which reached the border of the Hungaria group (2.03 AU, Galiazzo and Bazsó [2011]) and check the drift towards terrestrial planets. We reiterate the previous study, by taking into account the gravitational influences of (1) Ceres and (4) Vesta. In both cases, we proceed to a second integration over 100 Myrs. We define a pseudo metric on the set of osculatory elements (a,e,i), as follows:

$$d = \sqrt{\left(\frac{a}{\bar{a}}\right)^2 + \left(\frac{e}{\bar{e}}\right)^2 + \left(\frac{\sin i}{\sin \bar{i}}\right)^2} \qquad (1)$$

where $\bar{a}, \bar{e}, \bar{i}$ are proper elements. A threshold value (cut off distance) is introduced as follows:

$$d_{cutoff} = \frac{a_{max} - a_{min}}{2} + \sigma_{mean} \qquad (2)$$

a_{min}, a_{max} being the borders of the sample (osculatory semi-major axis). Selecting the asteroids with a distance $d > d_{cutoff}$, we analyse their drift towards Mars.

3 In addition to this sample we consider a synthetic population with a random distribution in the limits of the Vesta family and close to the J3:1 Mean Motion Resonance (MMR) with Jupiter (similar to Migliorini et al. [1997]). We also integrate this population over 100 Myrs. Using a Lie-Series-integrator (Hanslmeier and Dvorak [1984] and Eggl and Dvorak [2010]), we investigate their orbital drift towards terrestrial planets and their role in the supply of NEAs. We also study possible close encounters and impacts with Mars, the Earth and Venus.

Close encounters and impacts with terrestrial planets

We investigate the close encounters and possible impacts of the asteroids, considered as massless, with the terrestrial planets. We compute the angle of deflection, the encounter velocities, the possible dimension of the craters and the energy releases in the case of impacts (Galiazzo and Bazsó [2011] and Galiazzo [2012]). Comparison of the frequencies of encounters with the terrestrial planets and probabilities of impact are also being investigated.

Preliminary Results

The dynamical family we found is similar to that given in Nesvorny (Nesvorny, D., Nesvorny HCM Asteroid Families V1.0. EAR-A-VARGBDET-5-NESVORNYFAM-V1.0. NASA Planetary Data System, 2010.). In proper element space $(\bar{a}, \bar{e}, \bar{i})$, this family is dynamically constrained $(2.218 : 2.486 A.U, 0,074 : 0.133, 5.267° : 7.868°)$. Our sample of Vestians, ranges in osculatory semi-major axis from 2.3271 to 2.3955 A.U., and is subject to MMRs. Moreover we note a significant presence of future NEAs and consequently a relevant possibility to have an impact from asteroids that come from the Vesta family region, even if the probability of impact is lower than the asteroids coming from the Hungaria region (Galiazzo [2012]). If we consider only gravitational effects we find that for over 200 Myrs of integration the drift towards the inner part of Solar System is about $(0.4 \div 0.7) \cdot 10^{-10}$AU/ 1 Myr. This means by extrapolation that 1.6 to 2.6 Gyrs (fig.1) are necessary to reach the Earth without experiencing any close encounters.

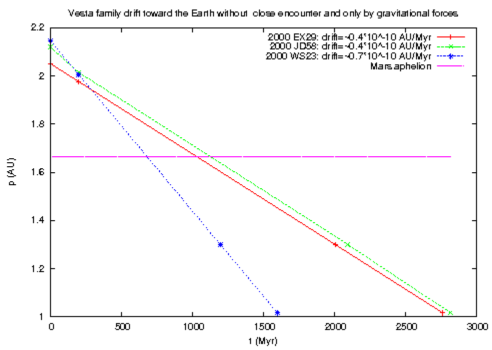

Figure 1: Drift of 2 vestian asteroids towards the Earth.

We compare also the consequences of Vestian impacts on the Earth, with those of the Hungarias (with a diameter twice smaller in average).

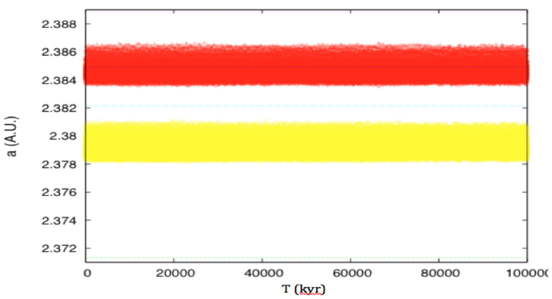

Figure 2: MMRs around 2 stable clones of 1997 RK3 from epoch+ 100 Myr to epoch+ 200 Myr. J13:4 (at 2.3713 AU), J29:9 (at 2.3849 AU), V1:6 (at 2.3884 AU) and U23:1 (at 2.3822). Resonaces J29:9 and U23:1 do not give any strong perturbation at least for 200Myr.

The presence of (4) Vesta and (1) Ceres makes some interesting differences in selecting which asteroids can be ejected from the family, even if the frequency of close encounters is not so important - at least over 100 Myr. However, it plays a certain role in changing the way by which these asteroids approach the terrestrial planets and in particular the Earth. Thus, we show that the number of bodies going towards the Earth is larger when considering the dynamical perturbation of (4) Vesta and (1) Ceres.

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