



HAL
open science

The Vesta Asteroid Family: Study of the Family and Close Encounters with Terrestrial Planes and Dynamical Influences by (1) Ceres and (4) Vesta

M. A. Galiazzo, Damya Souami, Siegfried Eggl, Jean Souchay

► To cite this version:

M. A. Galiazzo, Damya Souami, Siegfried Eggl, Jean Souchay. The Vesta Asteroid Family: Study of the Family and Close Encounters with Terrestrial Planes and Dynamical Influences by (1) Ceres and (4) Vesta. 43rd Lunar and Planetary Science Conference, Mar 2012, The Woodlands, Texas, United States. hal-03809685

HAL Id: hal-03809685

<https://hal.science/hal-03809685>

Submitted on 2 Nov 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

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

Mattia A. Galiazzo^{1,2}, Damya Souami^{3,4}, Siegfried Egg1¹ and Jean Souchay⁴, ¹Department of Astronomy of Vienna and ²Department of Lithospheric Research, Univ. of Vienna, Austria; (mattia.galiazzo@univie.ac.at), ³ Université Pierre & Marie Curie, 75252 Paris cedex 5, France ; (damya.souami@obspm.fr) and ⁴SYRTE, Observatoire de Paris, CNRS UMR 8630, UPMC, Paris, France.

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 Ast-Dys 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 Bazzó [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:

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

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

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

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 Egg1 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 Bazzó [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 ($2.218 : 2.486 A.U., 0, 074 : 0.133, 5.267^\circ : 7.868^\circ$). 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.

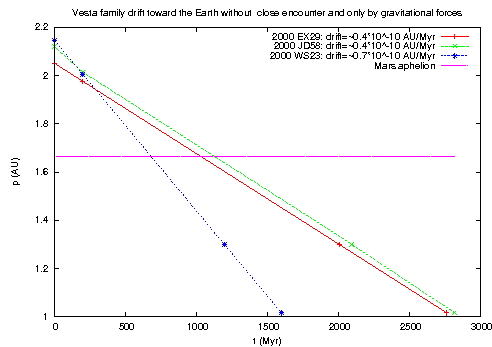


Figure 1: Drift of 2 vestian asteroids towards the Earth.

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

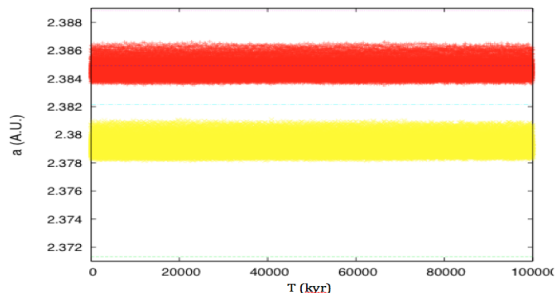


Figure 2: MMRs around 2 stable clones of 1997 RK3 from epoch+ 100 Myr to epoch+ 200 Myr. J13:4 (at 2.3713 AU), J29:9 (at 2.3849 AU), V1:6 (at 2.3884 AU) and U23:1 (at 2.3822). Resonances J29:9 and U23:1 do not give any strong perturbation at least for 200Myr.

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.

References

- Anita L. Cochran, Faith Vilas, Kandy S. Jarvis, and Michael S. Kelley. Investigating the Vesta-vestoid-HED connection. *Icarus*, 167:360–368, feb 2004. doi: 10.1016/j.icarus.2003.10.007. URL <http://tinyurl.com/84qn6nu>.
- Valerio Carruba, T. A. Michtchenko, F. Roig, Sylvio Ferraz-Mello, and David Nesvorný. On the V-type asteroids outside the Vesta family. I. Interplay of nonlinear secular resonances and the Yarkovsky effect: the cases of 956 Elisa and 809 Lundia. *aap*, 441:819–829, oct 2005. doi: 10.1051/0004-6361:20053355. URL <http://tinyurl.com/84z4hra>.
- Zoran Knežević and Andrea Milani. Proper element catalogs and asteroid families. *aap*, 403:1165–1173, June 2003. doi: 10.1051/0004-6361:20030475. URL <http://tinyurl.com/72u8xho>.
- Damya Souami and Jean Souchay. The Invariable Plane of the Solar system: a natural reference frame in the study of the dynamics of solar system bodies. In *Proceedings of the "Journées 2011 Systèmes de Référence Spatio-temporels"*, 2011.
- Mattia Galiazzo and Akos Bazsó. The Hungaria Asteroids: Resonances and Close encounters with terrestrial planets. *submitted to CEMDA*, 2011.
- Fabio Migliorini, Alessandro Morbidelli, Vincenzo Zappalá, Brett J. Gladman, Mark E. Bailey, and Alberto Cellino. Vesta fragments from v6 and 3:1 resonances: Implications for V-type NEAs and HED meteorites. *Meteoritics and Planetary Science*, 32:903–916, November 1997. doi: 10.1111/j.1945-5100.1997.tb01580.x. URL <http://tinyurl.com/7edsfud>.
- Arnold Hanslmeier and Rudolph Dvorak. Numerical integration with lie series. *aap*, 132:203, March 1984. URL <http://tinyurl.com/72awfqs>.
- Siegfried Eggl and Rudolph Dvorak. An introduction to common numerical integration codes used in dynamical astronomy. In J. Souchay & R. Dvorak, editor, *Lecture Notes in Physics, Berlin Springer Verlag*, volume 790 of *Lecture Notes in Physics, Berlin Springer Verlag*, pages 431–480, March 2010. doi: 10.1007/978-3-642-04458-8_9. URL <http://tinyurl.com/85df528>.
- Mattia Galiazzo. Impacts to the terrestrial planets by the Hungaria Asteroids. *in submission*, 2012.