CLOSE APPROACHES TO THE TERRESTRIAL PLANETS BY ASTEROIDS WHICH Q<1.667 AU

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In general there are computed and published close approaches to the Earth by asteroids or by comets, for example NASA Risk Page (http://neo.jpl.nasa.gov/risk/) or NEODYS www site (http://newton.dm.unipi.it/cgi-bin/neodys/neoibo). Computation are mainly referred to the Earth Impact Risk.

The main goal of this work is to show all of the possible close approaches of the asteroids which q<1.667 AU with all terrestrial planets, from Mercury to Mars and with Moon. In order to attain this the orbital elements of all known minor planets which orbits cross the orbits of terrestrial planets were extracted from Lowell catalogue (ftp://ftp.lowell.edu/pub/elgb/astorb.html) update to March 14th, 2003. The equations of motion of these selected asteroids and the planets with Moon treated as separated body were integrated 548 years (200,000 days) forward using Everhart's RA15 (RADAU) method from Mercury Integrator Package v. 6 by J. Chambers [1]. The starting orbital elements of planets were taken using ephemeredes DE405/WAW of prof. Grzegorz Sitarski from Space Research Center Polish Academy of Science in Warsaw [2].

The results of computation show the close approaches with the terrestrial planets. For example, in the forthcoming 548 years couple of minor planets can close approache Mercury and Venus even below 0.003 AU (450,000 km). The tables list, in order of increasing planet-centric distance, the closest known approaches to terrestrial planets by asteroids.

distance [AU]	distance [thousands of km]	year	minor planet	diameter [km]	arc length days	number of observations
MERCURY						
0.00158	237	2084	2000 DO1	0.4	24	215
0.00162	243	2183	2000 JG5	1.1	436	242
0.00199	299	2152	2000 JG5			
0.00251	377	2096	2001 CP36	0.2	7	142
0.00252	378	2340	2000 JG5			
0.00280	420	2201	2002 FB3	2.5	731	131
VENUS						
0.00054	81	2530	2000 KP44	0.8	16	62
0.00100	150	2231	2002 RW25	0.8	90	71
0.00106	159	2184	2000 YS134	0.1	60	19
0.00108	162	2201	1998 KJ9	0.6	5109	176
0.00122	183	2251	2000 EE104	0.4	1805	444
0.00136	204	2545	1998 KN3	1.0	8	53
0.00161	242	2538	2003 QB30	0.03	3	32
0.00170	255	2265	1996 GF17	0.6	2	18
0.00197	296	2259	2000 YS134	0.1	60	19
0.00219	329	2506	2002 JR100	0.1	16	36
0.00244	366	2096	2001 CA21	1.0	2	13
0.00271	407	2419	66146 1998 TU3	5.5	7686	507

EARTH (below 0.001 AU)

0.00058	87	2069	2000 SG344	0.05	507	31
0.00059	89	2003	2003 SQ222	0.1	4	18
0.00061	92	2544	2000 SZ162	0.01	8	30
0.00062	93	2335	1999 CQ2	0.01	6	16
0.00082	123	2002	2002 MN	0.08	53	90
0.00100	150	2003	2003 XJ7	0.02	1	35

MOON (below 0.0015 AU)

0.00069	104	2204	1993 KA	0.03	12	38
0.00079	119	2002	2002 MN			
0.0011	165	2002	2002 EM7	0.05	25	69
0.0011	165	2106	2000 SG344			
0.0013	195	2335	1999 CQ2			
0.0013	195	2003	2003 SQ222			
0.0013	195	2363	1991 VA	0.04	8	26
0.0014	210	2172	2000 SG344			

MARS (below 0.002 AU)

0.00047	71	2401	2003 SE41			
0.00076	114	2236	2001 BF10	0.1	713	35
0.00086	129	2461	2000 OG8	1.3	152	367
0.00156	234	2345	2002 HP11	0.4	26	65
0.00180	270	2309	5641 McCleese			

From this Table we can see that some asteroids have repeated close approaches to the terrestrial planets for example 2000 JG5 and Mercury.

Close approaches to the terrestrial planets and to Moon by asteroids are shown in below pictures.

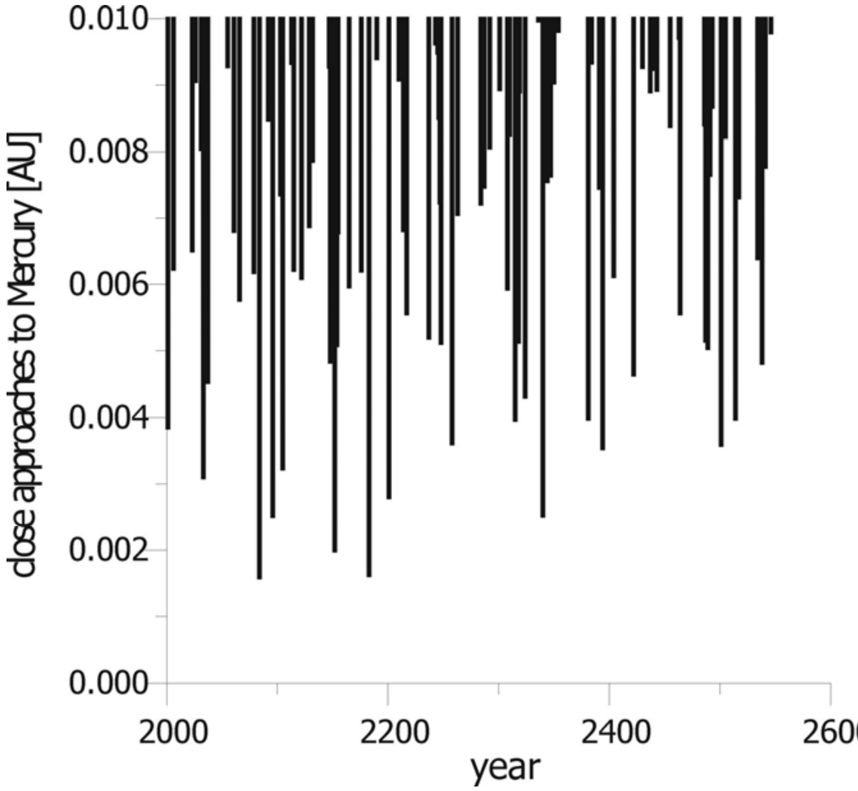
dose approaches to Mercury [AU]
0.010
0.008
0.006
0.004
0.002
0.000
2000
2200
2400
2600
year

Fig.1

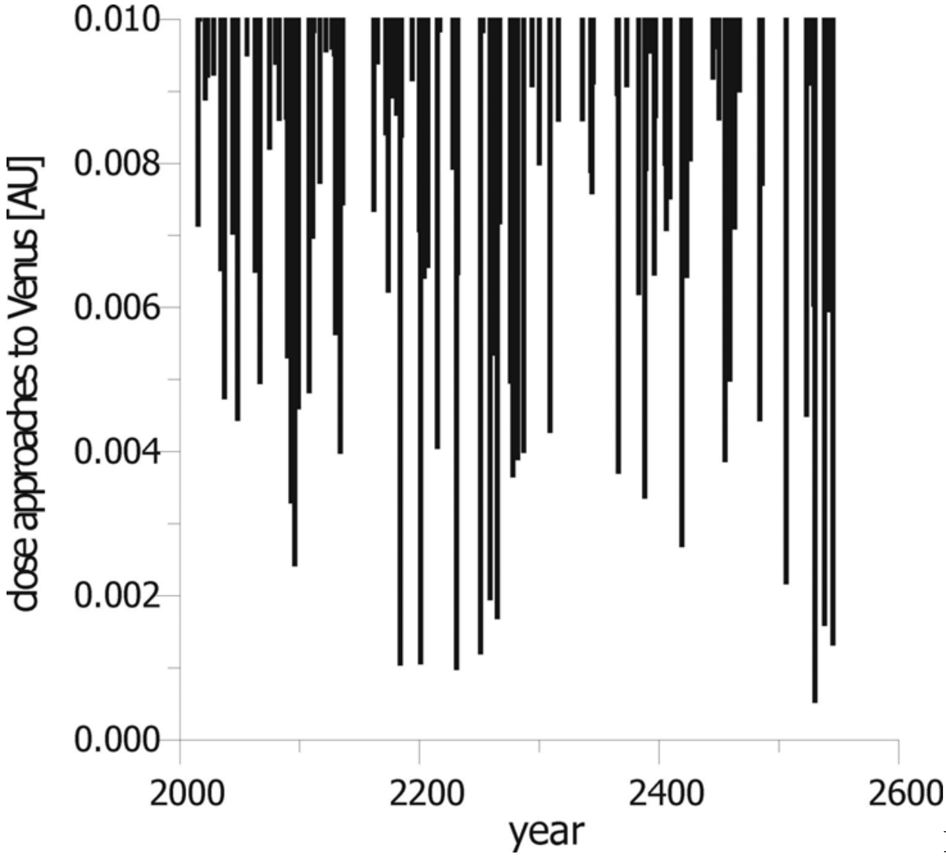
dose approaches to Venus [AU]
0.010
0.008
0.006
0.004
0.002
0.000
2000
2200
2400
2600
year

Fig.2

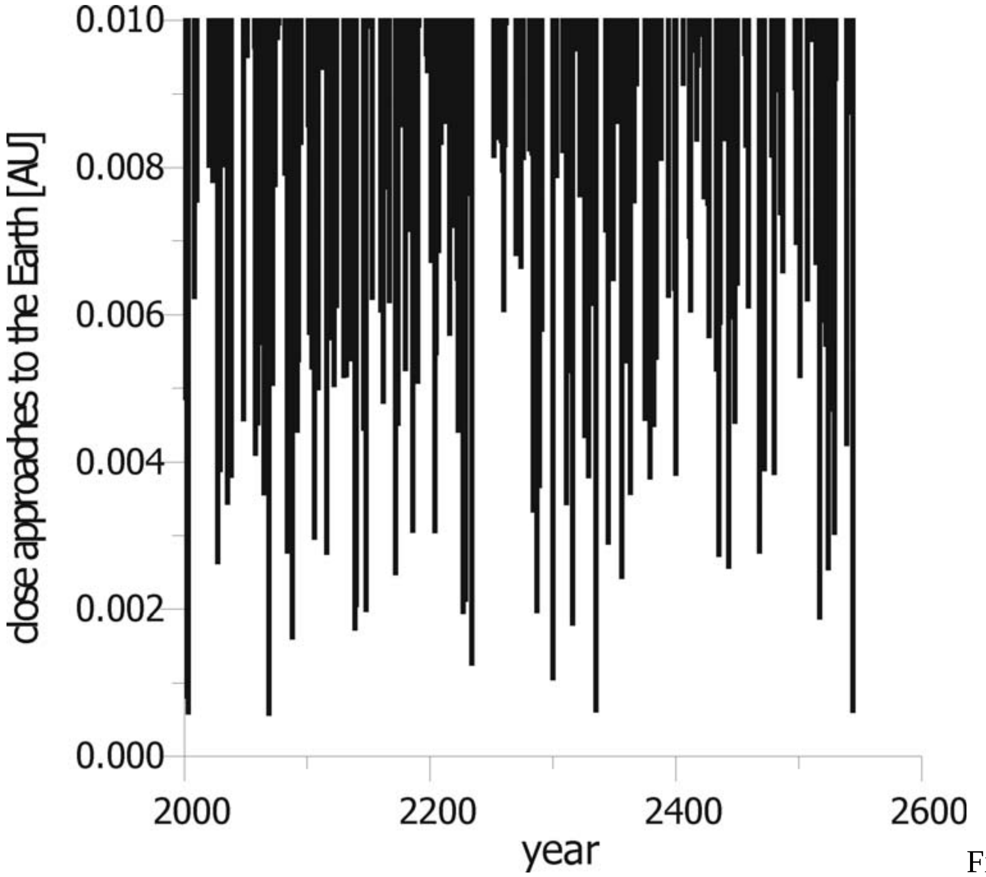
0.010
0.008
0.006
0.004
0.002
0.000
dose approaches to the Earth [AU]
2000
2200
2400
2600
year

Fig.3

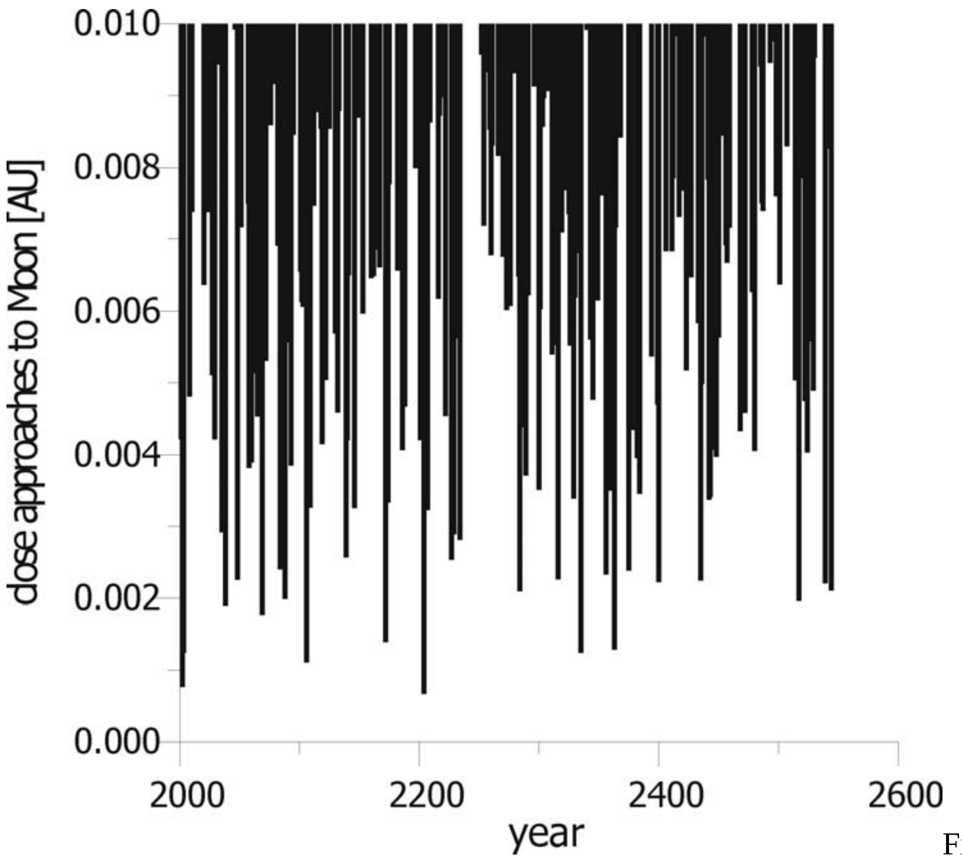
0.010
0.008
0.006
0.004
0.002
0.000
dose approaches to Moon [AU]
2000
2200
2400
2600
year

Fig.4

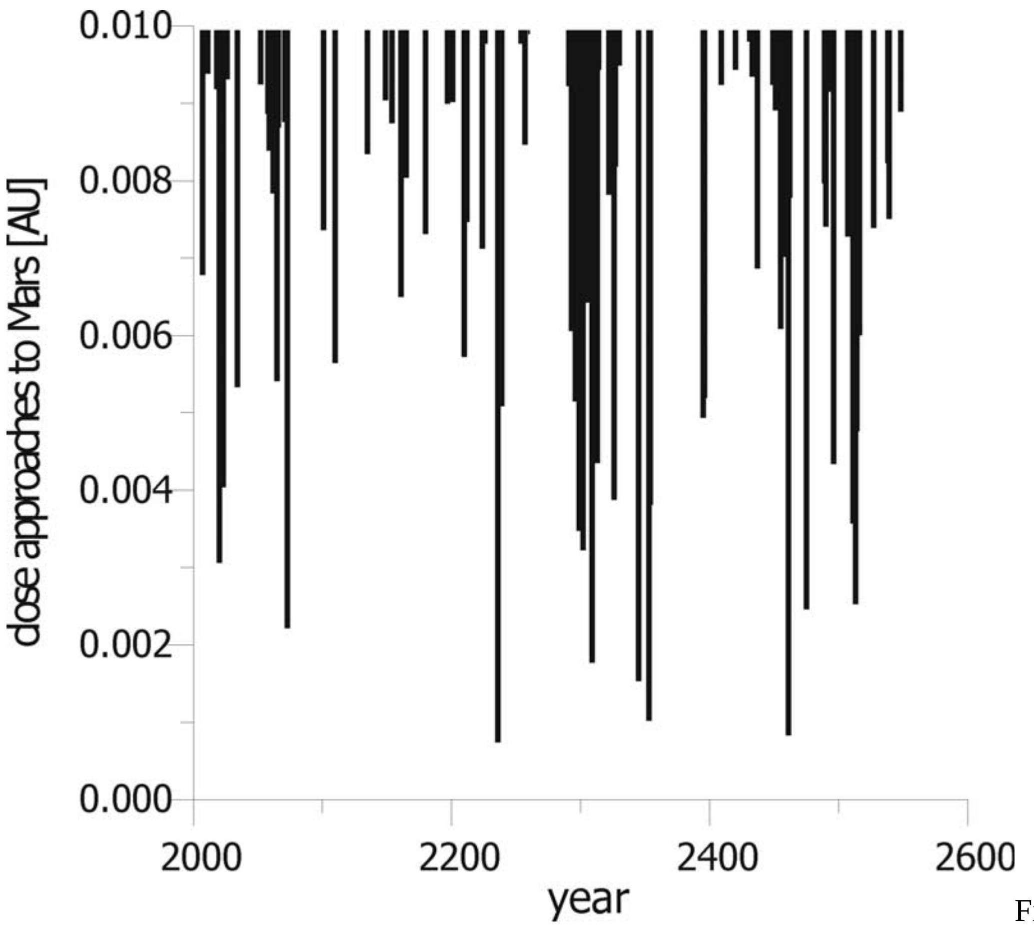

Fig.5

We can see in these pictures that the close approaches are random.
Because of the chaotic motion of these asteroids we can not predict theirs behavior for a time-span more than several hundreds years. In [3] I have computed for some asteroids so called time of stability. From that paper it is clear that starting orbital elements of the asteroids are computed with some errors and time evolution of those “infected” set of orbits which differ in orbital elements by the error of calculating of one orbital elements differs considerably. Difference of the mean anomalies of that two starting orbits of a minor planet grows rapidly with time. This means that it is almost impossible to predict behavior of minor planets on the orbit outside the period of time called the time of stability in my work.
For some minor planets the time of stability is astonishingly short, about several hundreds year only. In [4] I have published my results of investigation of time of stability for Atens, Apollos and Amor over 300,000 years. 33% of the calculated times of stability was shorter than 1000 years. Therefore, in first investigation I limited my computation to about 600 years forward.
Presented results of close approaches to the terrestrial planets by asteroids are only the first approximation of the problem. I have computed only nominal orbit which are burdened with errors of their determination. But at the same time there are only quality results because of the chaotic motion of these asteroids. For longer intervals of time the results will differ if we take into account still incoming astrometric observations and new computed orbits of these selected minor planets.

[1] G. Sitarski, Acta Astron. 2002, 52

[2] J. E. Chambers, MNRAS, 1999, 304, 793
[3] I. Wlodarczyk, Acta Astron. 2001, 51, 357
[4] I. Wlodarczyk, In „Proceedings of the US-European Celestial Mechanics Workshop in Poznan, July 2000", Poznan, 2001