Bull. Astron. Belgrade № 145 (1992), 145 – 151

UDC 521.44-32
Preliminary report

CLOSE ENCOUNTERS BETWEEN MINOR PLANETS

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(Received. December 16. 1991)

SUMMARY: The values of mutual distances at moments of closest encounters, for the period of 1970-2010, between minor planets with diameters $D \geq 100\ km$ and other numerated minor planets, are calculated. The number of 94 close encounters have been found in all, with minimal mutual distances less than 0.01 AU, resp. 66 for the period 1970-1991 and 28 for 1992-2010. For the pair (81,767) the mutual distance of 0.00060 AU has been found, which represents the least registered mutual distance between minor planets.

1. INTRODUCTION

The orbits of minor planets are permanently modified due to the perturbing influence of major planets and can find themselves at very small mutual distances (cf Kuzmanoski, 1992). However, the possibility that minor planets find themselves at so small mutual distances is considerably less. It is particularly important to establish close encounters of minor planets, since it gives the possibility of the dynamical determination of their masses from their muttually perturbing effects. Besides the masses of three largest asteroids, determined from their temporary resonances (Schubart and Matson, 1979), Schol et al.(1987) have determined the mass of the fourth asteroid, (10) Hygiea, from a typical single close encounter. Hoffmann (1989) established 15 close encounters of minor planets for the period 1980-1988, with the upper limit of minimal mutual distances of 0.01 AU, but only three among them had diameters exceeding 100 km. In this paper we have determined the close encounters of large asteroids (with a diameter $D \geq 100$ km) with all remaining numerated asteroids (3859 asteroids in all, for the epoch of osculation JD 2447400.5). The basis for the determination of mutually close encounters of minor planets was provided by the minimal distances between their orbits, established with the help of the procedure given by Lazovic (1967), and already applied (Lazovic and Kuzmanoski, 1978).

2. RESULTS AND CONCLUSIONS

From the great number of pairs with minimal distances between their orbits, at first we have chosen the ones which admitted an effective mutual close encounter. Further, applying the calculus of perturbations, we established the least distances at which such minor planets are mutually close, taking into account only the pairs for which the least distances are inside the limit of 0.01 AU. The calculus of perturbations is applied to the ecliptic orbital elements with the help of Gauss-Enche method, with a step of integration of 5 days, without taking into account the perturbations which come from Mercury and Pluto. Obtained results are given on Table 1 for close encounters in the period 1970-1991 and on Table 3 for the period 1992-2010. In the first two rows are given the indexes j and k of the asteroids in the pair, and in the third one the diameter D_j of the first (larger) asteroid, taken from the TRIAD file. The asterisk (*) denotes the values of diameters taken from other sources, and in the brackets the ones from the TRIAD file having values less than 100 km. In the fourth row is given the moment of the closest position, in the fifth one the least mutual distance, in the sixth the relative velocity V_{rel} at the moment of the closest position (approach) and in the last one homocentric distance r_j of the first asteroid in the pair. On Tables 2 and 4 are given, for the same pairs: the great semiaxes a_j and a_k and their difference Δa, the eccentricities e_j and e_k and the difference Δe, the inclinations i_j and i_k and the mutual inclination I. The epoch of osculation of the orbital elements, because of the step of integration of 5 days, can differ from the given moment t by a maximum of 2.5 days. We can see, from Tables 1 and 3, that the number of pairs with close encounters for the period 1970-1991 is much greater than the one for the period 1992-2010. This fact could be fortuitous, but if some periodicity appears in further research, one could infer the possibility of existence of some kinematical characteristics of the motion of minor planets. Save the diameter and the mutual distance, on which the interaction mostly depends, an important characteristics is the relative velocity. The computing simulations show that for relative velocities of about 5 km/s (with other favourable conditions) one can expect interaction. We could add that the relative velocity depends, in the first place, on the mutual inclination of the orbits,as in the case of great inclination the mutual velocity of the asteroids would be much greater, the proper velocities remaining unchanged.Taking into account diameters, least distances and relative velocities, the most interesting pairs for further study are: (15,3591), (45,673), (81,767), (308,2296), (308,3661) and (19,3486). Let us remark that, for the pair (81,767) the minimal mutual distance established up to now is 0.00060 AU, the smallest ever registered. On Fig. 1 and 2 are given the histograms of the distribution of the eccentricity differences Δe and of the great semiaxes Δa with the data from Table 1 (continuous line), from Table 3 (dotted line) and the total distribution (thick line). The histograms show that close encounters are to be expected, before all, for the asteroids with orbits "similar" semiaxes and eccentricities.

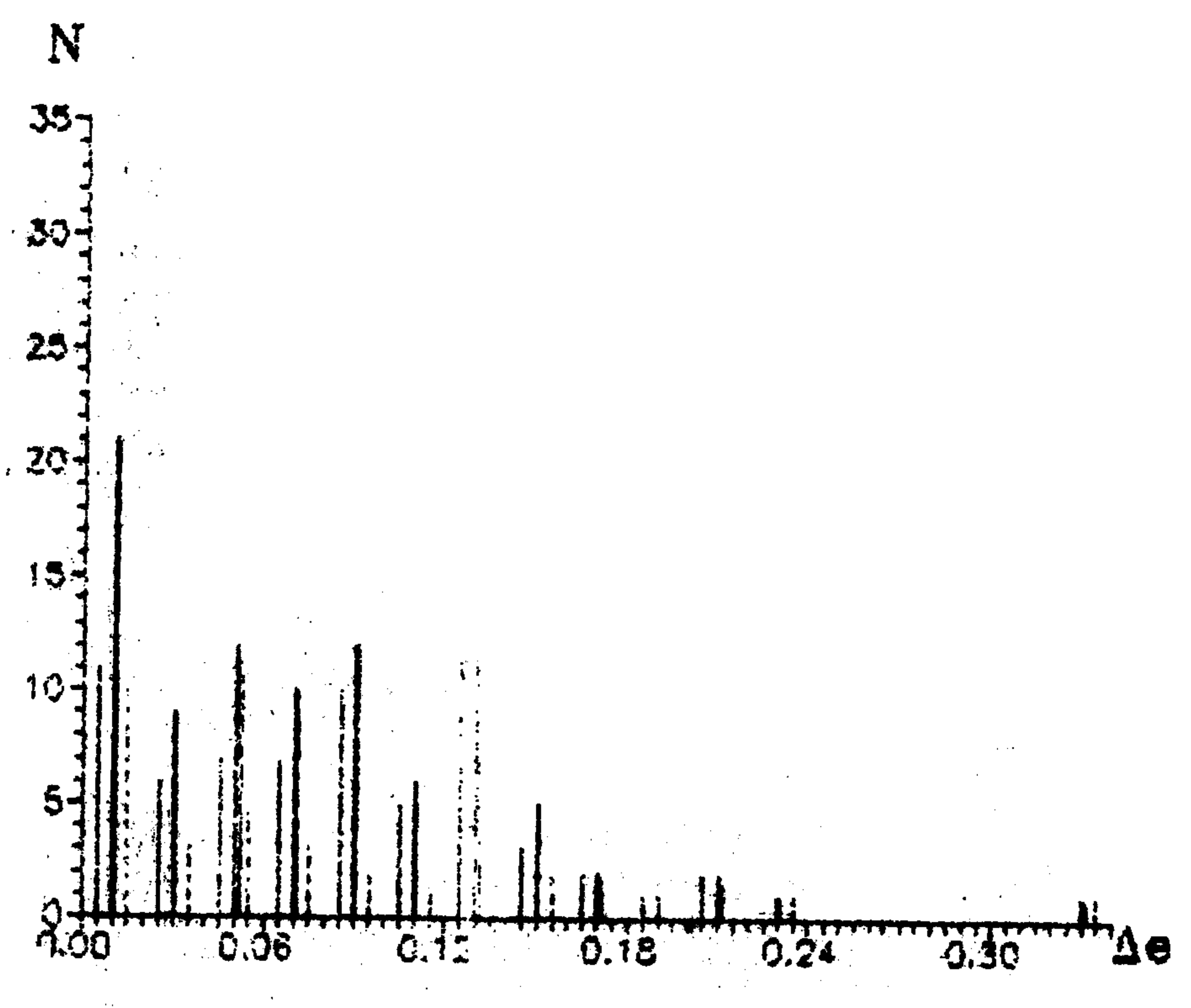

Fig. 1.

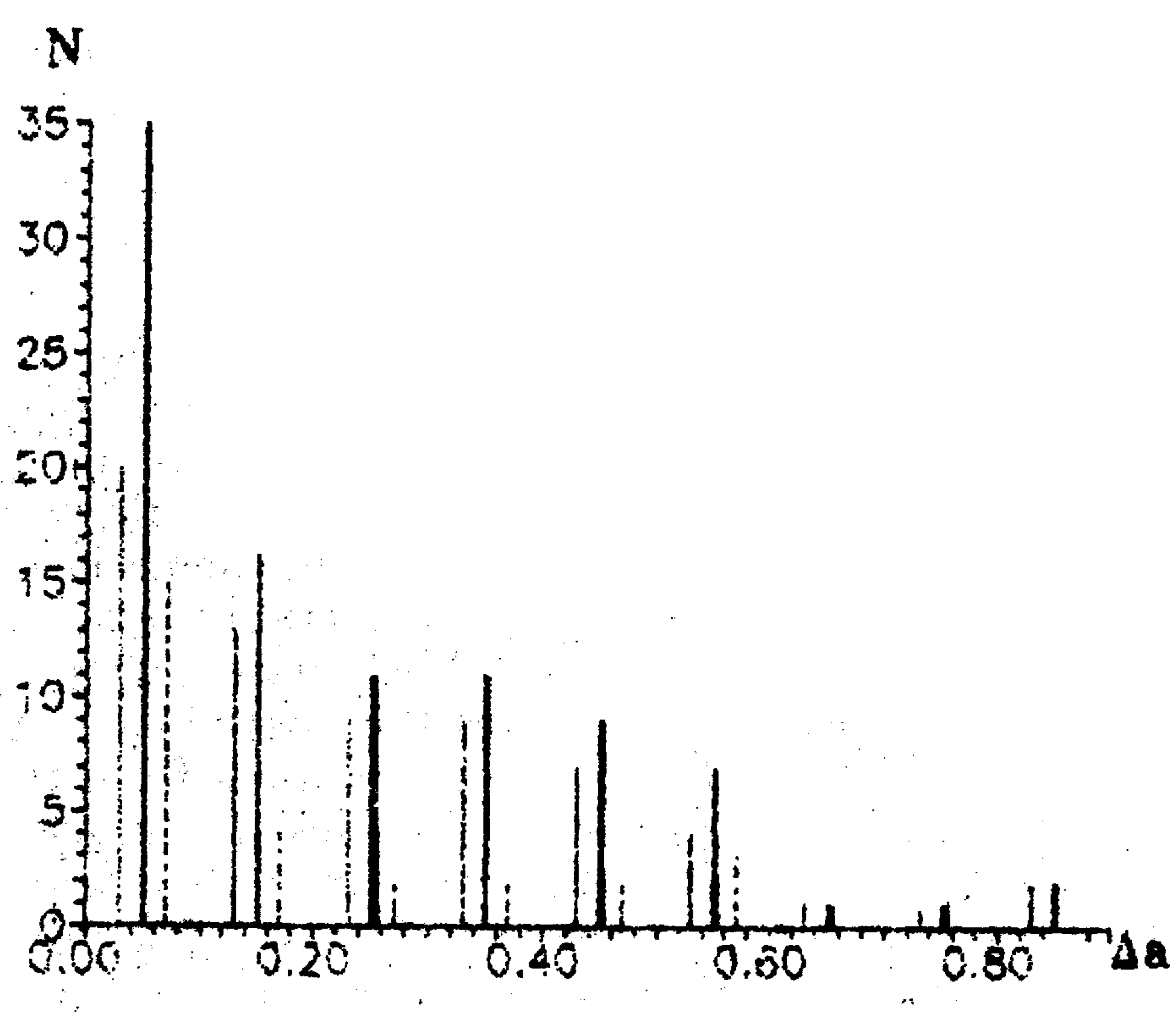

Fig. 2.

Table 1.

j	k	D_j (km)	t (JD)	ρ (AU)	V_{rel}	r_j
3	1767	244	2445334.0	.00646	4.54	2.75
6	1700	192	2446273.6	.00973	5.43	2.67
8	2540	141	2442114.3	.00784	3.24	2.31
9	1936	* 151	2447485.7	.00867	5.59	2.68
9	2478	* 151	2445400.4	.00809	3.66	2.10
11	2849	162	2445806.6	.00738	2.84	2.60
13	3408	215	2443043.5	.00825	7.71	2.56
15	3591	272	2447584.6	.00380	5.55	2.66
17	3616	*(109)	2446929.5	.00804	2.27	2.74
20	356	151	2445525.7	.00948	3.48	2.45
21	84	*(115)	2446765.7	.00951	3.37	2.80
24	809	* 234	2446564.6	.00730	3.74	2.72
29	1224	219	2447652.9	.00789	3.62	2.73
38	886	120	2447628.4	.00398	8.46	3.09
40	1216	111	2446249.2	.00498	4.00	2.35
40	3775	111	2446996.2	.00958	3.50	2.16
45	673	214	2448116.7	.00338	2.55	2.79
65	526	245	2445876.0	.00593	3.33	3.42
68	3403	127	2442270.0	.00532	4.63	2.39
70	521	127	2446064.8	.00546	7.44	2.22
71	1517	*(115)	2440957.9	.00493	8.75	2.61
81	767	124	2446095.9	.00060	4.57	2.54
85	3268	157	2446693.6	.00992	2.49	2.22
86	618	127	2446199.2	.00690	4.76	2.97
89	534	159	2446585.6	.00740	6.15	2.79
92	2950	132	2446402.9	.00261	3.09	3.40
93	485	146	2446714.6	.00974	9.20	2.71
96	2387	174	2446068.5	.00683	6.74	2.79
98	2337	109	2441818.6	.00625	6.13	2.27
98	2984	109	2445197.6	.00782	5.96	2.20
114	3379	103	2445626.4	.00985	1.99	2.35
137	1686	150	2447877.8	.00646	4.07	3.18
159	2152	131	2445811.4	.00858	5.95	3.40
165	57	160	2448173.0	.00926	6.52	3.26
176	2292	125	2446332.4	.00270	5.01	2.73
176	3226	125	2446216.6	.00791	7.87	2.67
192	3116	107	2445326.4	.00259	3.34	2.51
203	2288	120	2445196.3	.00162	5.72	2.85
216	2903	140	2445991.4	.00809	4.63	2.71
233	1275	108	2445043.8	.00569	3.03	2.92
268	821	142	2447269.1	.00897	2.72	3.35
308	2296	148	2446806.9	.00218	3.33	2.77
308	3661	148	2446789.6	.00307	2.32	2.77
324	1939	242	2447891.1	.00715	7.97	3.07
324	3075	242	2445587.0	.00898	4.41	2.38
345	809	100	2447481.6	.00985	4.94	2.18
345	817	100	2443615.1	.00743	5.73	2.18
354	1486	162	2441607.1	.00765	6.49	2.47
356	615	135	2443802.3	.00764	6.71	2.58
361	436	149	2446609.1	.00812	3.43	3.26
386	3636	173	2446847.6	.00941	8.23	2.46
426	166	134	2447227.7	.00674	11.36	2.65
488	300	158	2444720.6	.00788	4.65	3.26
514	1002	110	2448503.9	.00887	3.38	3.17
521	70	121	2446064.8	.00547	7.44	2.22
521	1050	121	2448135.9	.00527	6.52	2.47
532	2669	231	2448294.2	.00795	10.58	2.56
532	2733	231	2443789.8	.00666	3.12	2.62
537	3370	*(136)	2446012.1	.00280	4.31	2.46

Tabele 1. (continued)

j	k	D_j (km)	t (JD)	ρ (AU)	V_{rel}	r_j
618	86	124	2446199.2	.00690	4.76	2.97
626	3452	104	2445751.2	.00383	9.97	2.09
690	1191	140	2446821.0	.00526	8.74	2.92
779	703	*(108)	2448020.6	.00634	5.44	2.15
804	411	161	2441307.7	.00855	7.33	3.22
804	775	161	2443472.4	.00592	4.70	3.03
804	1002	161	2445051.9	.00466	1.30	3.18

Table 2.

j	k	a_j	a_k	Δa	e_j	e_k	Δe	i_j	i_k	I
3	1767	2.67	3.02	.35	.26	.09	.16	13.0	9.8	5.4
6	1700	2.43	2.36	.06	.20	.22	.02	14.8	4.5	18.5
8	2540	2.20	2.20	.00	.16	.05	.10	5.9	1.3	5.6
9	1936	2.39	2.67	.29	.12	.14	.02	5.6	10.2	15.7
9	2478	2.39	2.23	.16	.12	.07	.05	5.6	4.1	9.6
11	2849	2.45	2.57	.11	.10	.01	.09	4.6	6.8	7.6
13	3408	2.58	2.37	.20	.09	.23	.14	16.5	2.9	16.7
15	3591	2.64	3.15	.51	.18	.16	.03	11.8	1.2	11.9
17	3616	2.47	2.60	.13	.14	.12	.02	5.6	12.8	7.3
20	356	2.41	2.76	.35	.15	.24	.09	.7	8.2	8.8
21	84	2.44	2.36	.07	.16	.24	.07	3.1	9.3	10.9
24	809	3.13	2.28	.85	.13	.19	.06	.8	7.1	7.5
29	1224	2.55	2.30	.25	.07	.20	.13	6.1	7.9	10.6
38	886	2.74	3.18	.44	.15	.27	.12	7.0	16.6	21.4
40	1216	2.27	2.23	.03	.05	.18	.13	4.3	7.6	4.3
40	3775	2.27	2.79	.52	.05	.23	.18	4.3	8.2	7.4
45	673	2.72	2.82	.09	.08	.01	.07	6.6	2.9	6.7
65	526	3.43	3.12	.31	.11	.14	.03	3.6	2.2	1.6
68	3403	2.78	2.41	.37	.19	.20	.01	8.0	4.6	12.4
70	521	2.61	2.74	.13	.18	.28	.09	11.6	10.6	7.9
71	1517	2.75	2.72	.04	.18	.04	.14	23.3	5.3	25.3
81	767	2.85	3.12	.26	.21	.19	.02	7.8	2.4	7.7
85	3268	2.65	2.35	.31	.19	.13	.07	12.0	6.4	6.3
86	618	3.11	3.19	.08	.21	.09	.13	4.8	17.0	12.8
89	534	2.55	2.88	.33	.18	.06	.12	16.1	3.3	18.8
92	2950	3.20	2.76	.44	.09	.26	.18	9.9	9.6	1.7
93	485	2.76	2.75	.00	.14	.19	.05	8.6	13.9	22.4
96	2387	3.05	3.02	.03	.14	.08	.06	16.0	11.0	19.5
98	2337	2.69	2.59	.09	.19	.17	.02	15.6	14.4	11.0
98	2984	2.69	2.47	.22	.19	.13	.05	15.6	3.1	15.7
114	3379	2.68	2.35	.32	.14	.13	.01	4.9	2.8	2.4
137	1686	3.11	3.16	.04	.22	.17	.06	13.4	.6	14.0
159	2152	3.10	3.14	.04	.11	.21	.10	6.1	13.9	17.6
165	57	3.13	3.15	.02	.07	.12	.04	11.2	15.2	20.9
176	2292	3.19	2.62	.57	.16	.24	.08	22.6	14.5	11.9
176	3226	3.19	2.87	.31	.16	.07	.09	22.6	3.1	23.4
192	3116	2.40	2.23	.17	.25	.20	.05	6.8	5.5	9.2
203	2288	2.74	2.91	.17	.06	.16	.10	3.2	14.6	14.8
216	2903	2.80	2.56	.23	.25	.06	.19	13.1	14.4	4.3
233	1275	2.66	2.68	.02	.10	.17	.07	7.7	12.9	7.7
268	821	3.11	2.78	.33	.12	.21	.08	2.4	5.4	5.9
308	2296	2.75	3.18	.43	.04	.17	.13	4.4	1.3	5.4
308	3661	2.75	2.93	.18	.04	.06	.02	4.4	2.0	6.3
324	1939	2.68	3.12	.44	.34	.13	.21	11.1	.9	10.9
324	3075	2.68	2.27	.41	.34	.13	.21	11.1	10.0	1.6

Tabele 2. (continued)

j	k	a_j	a_k	Δa	e_j	e_k	Δe	i_j	i_k	I
345	809	2.33	2.28	.04	.06	.19	.13	9.7	7.1	8.5
345	817	2.33	2.59	.26	.06	.18	.12	9.7	11.4	14.5
354	1486	2.80	2.20	.60	.12	.12	.01	18.4	.1	18.5
356	615	2.76	2.63	.13	.24	.11	.13	8.2	2.8	5.7
361	436	3.95	3.21	.74	.22	.06	.16	12.7	18.5	9.3
386	3636	2.90	2.28	.62	.17	.18	.01	20.3	4.1	23.6
426	166	2.89	2.68	.20	.10	.21	.11	19.5	12.0	31.5
488	300	3.14	3.21	.06	.18	.04	.14	11.5	.7	11.0
514	1002	3.05	2.79	.26	.04	.15	.11	3.9	10.8	10.4
521	70	2.74	2.61	.13	.28	.18	.09	10.6	11.6	7.9
521	1050	2.74	2.63	.12	.28	.18	.10	10.6	12.5	18.6
532	2669	2.77	2.78	.01	.18	.22	.04	16.4	7.8	24.1
532	2733	2.77	2.35	.43	.17	.14	.04	16.3	10.4	6.7
537	3370	3.06	2.22	.84	.24	.11	.13	9.9	7.1	4.5
618	86	3.19	3.11	.08	.09	.21	.13	17.0	4.8	12.8
626	3452	2.57	2.27	.31	.24	.08	.16	25.4	2.3	24.9
690	1191	3.14	2.89	.25	.18	.05	.14	11.3	18.5	25.7
779	703	2.67	2.18	.49	.23	.14	.09	14.6	2.5	13.9
804	411	2.84	2.94	.10	.14	.11	.03	15.4	15.3	26.5
804	775	2.84	3.01	.18	.14	.07	.07	15.4	9.3	11.7
804	1002	2.84	2.79	.05	.14	.15	.01	15.4	10.8	4.7

Table 3.

j	k	D_j (km)	t (JD)	ρ (AU)	V_{rel}	r_j
7	2346	203	2450442.1	.00777	3.75	2.73
8	967	141	2450697.0	.00428	4.44	1.92
8	3137	141	2450983.5	.00971	3.28	2.06
9	343	* 151	2448938.6	.00753	2.80	2.63
11	17	162	2450452.2	.00532	2.36	2.21
19	3486	* 215	2450217.1	.00211	2.30	2.82
24	1442	* 234	2450901.6	.00896	3.44	2.99
38	2558	120	2453545.8	.00521	5.37	2.34
53	467	119	2451640.0	.00993	3.69	2.92
70	3373	127	2451840.0	.00481	6.62	2.49
81	473	124	2449426.7	.00708	4.24	2.95
83	3409	*(123)	2448772.3	.00702	2.62	2.62
120	1637	178	2449321.2	.00893	3.13	2.92
130	3556	189	2449257.1	.00838	7.23	3.13
134	376	122	2451945.7	.00384	5.93	2.38
145	3688	155	2449188.9	.00753	7.63	2.98
194	779	174	2450404.5	.00622	7.39	3.23
203	1245	120	2448839.6	.00793	2.07	2.66
212	1828	140	2452020.3	.00329	4.80	3.26
230	3172	113	2449977.0	.00179	5.28	2.48
240	77	108	2449713.8	.00891	1.85	2.62
345	1791	100	2449297.6	.00822	3.30	2.44
346	3143	110	2453585.6	.00961	1.96	2.70
349	1400	143	2449724.8	.00284	7.55	3.17
393	336	106	2451913.6	.00616	5.68	2.33
554	2098	*(101)	2451285.5	.00398	4.29	2.15
663	772	104	2449264.6	.00582	14.83	2.74
772	663	123	2449264.6	.00582	14.83	2.74

Table 4.

j	k	a_j	a_k	Δa	e_j	e_k	Δe	i_j	i_k	I
7	2346	2.39	2.37	.01	.23	.16	.07	5.5	5.9	1.5
8	967	2.20	2.23	.02	.16	.17	.01	5.9	5.4	2.8
8	3137	2.20	2.40	.20	.16	.19	.03	5.9	2.5	8.4
9	343	2.39	2.41	.02	.12	.23	.11	5.6	3.3	3.2
11	17	2.45	2.47	.02	.10	.14	.04	4.6	5.6	1.0
19	3486	2.44	2.43	.01	.16	.18	.02	1.6	3.2	4.7
24	1442	3.13	2.87	.25	.13	.08	.06	.8	1.3	2.0
38	2558	2.74	2.22	.53	.15	.16	.00	7.0	5.1	10.0
53	467	2.62	2.94	.32	.20	.11	.09	5.2	6.4	11.6
70	3373	2.62	2.25	.37	.18	.13	.05	11.6	3.2	13.8
81	473	2.85	2.66	.19	.21	.11	.10	7.8	12.9	7.2
83	3409	2.43	2.86	.42	.08	.08	.00	5.0	1.4	6.4
120	1637	3.12	3.07	.05	.06	.05	.01	7.0	14.1	9.9
130	3556	3.11	3.15	.03	.22	.23	.02	22.9	9.3	25.4
134	376	2.56	2.29	.28	.12	.17	.05	11.6	5.4	8.5
145	3688	2.67	3.22	.55	.15	.48	.33	12.6	2.6	11.5
194	779	2.62	2.67	.05	.24	.22	.01	18.5	14.6	29.2
203	1245	2.74	2.89	.16	.06	.08	.02	3.2	2.9	6.0
212	1828	3.11	3.06	.05	.11	.11	.00	4.3	14.3	17.3
230	3172	2.38	2.43	.04	.06	.22	.16	9.4	3.6	12.9
240	77	2.66	2.67	.00	.21	.13	.07	2.1	2.4	3.8
345	1791	2.33	2.75	.42	.06	.14	.08	9.7	5.4	4.7
346	3143	2.80	2.85	.05	.10	.08	.02	8.8	3.1	5.8
349	1400	2.93	3.11	.19	.09	.24	.16	8.3	15.6	23.8
393	336	2.78	2.25	.53	.33	.09	.24	14.9	5.7	9.9
554	2098	2.38	2.42	.05	.15	.13	.03	2.9	6.5	4.8
663	772	3.06	3.00	.06	.16	.10	.06	17.9	28.8	46.5
772	663	3.00	3.06	.06	.10	.16	.06	28.8	17.9	46.5

The presentation of the results is not to be considered as definitive, since the calculus applied is naturally "sensible", in particular for small values of mutual distances, so that small differences in orbital elements can provoke sensible differences of the mutual distances. Changes in the orbital elements appear when one includes new observational data for the detemination of the osculatory orbits of numerated minor planets, but the method applied in the calculus of perturbations probably also includes some errors. So, for the use of further data it would be recommendable to repeat the calculations with newest osculatory orbital elements and to control the calculus of perturbations by the application of several methods.

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БЛИСКИ ПРИЛАЗИ ИЗМЕЂУ МАЛИХ ПЛАНЕТА

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УДК 521.44-32
Претходно саопштење

За период 1970 - 2010 израчунати су блиски прилази између малих планета са пречницима $D \geq 100\ km$ и осталих нумерисаних малих планета. Нађено је укупно 94 блиских прилаза са међусобним минималним даљинама мањим од 0.01 AU и то 66 за период 1970 - 1992 и 28 за период 1992 - 2010. За пар (81, 767) нађена је међусобна минимална даљина од 0.00060 AU што је до сада најмања регистрована минимална даљина између две мале планете.