DO GENETICALLY RELATED COMET PAIRS AND GROUPS EXIST?

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Abstract. In connection with the discoveries of the new comets 1982b and 1982c, 1988e and 1988g, the orbits of which have the essentially similar elements, the problem of existence of the cometary groups with the similar orbits and their genetical relationship are considered. The similarity of the quasistationary parameters , and the Tisserand invariants Ti is used as a criterion for the selection of comets in the groups. This criterion has been verified on comets of the Kreutz' family and comets approaching closely the Jupiter. It is shown that this criterion is quite feasible one for selection of comet groups related genetically.

Key Words: Comet pairs, groups, genetical relations.

The idea on the genetical relations of some comets and their common origin was initially expressed by H.Kreutz (1888, 1891,1901) a hundred years ago, while investigating four comets with the similar orbits - 1843 I,1880 I, 1882 II and 1887 I, each of these 'grazing' the Sun by passing it at the distance from 7000 to 1200000 kms. Since that time, many investigators have put their attention to the problem of the existence of the genetically related comet groups. Using the different criteria, they tried to find all the possible groups of comets and to make their reality scientifically grounded.

In the fifties-sixties of the 20th century, J.Porter (1952,1963) discovered about 15 comet groups according to the similarity of the orbits. Porter assumed a great range of the comets' perihelion distances in these groups, which sometimes exceed 3.4 AU. The search for the family groups was based upon two criteria by E.Opik (1971): the Bernulli probability criterion and the statistic criterion on the basis of the visible orbits' similarity. Due to this approach, he succeeded in discovering of 97 comet groups, each including from two to seven comets with three inherent elements. According to the Opik's calculations, the probability of their random coincidence is not more than 10 . Such a large number of comet groups, selected from the Catalogue containing 472 comets, initiated F.Whipple (1977) to reconsider the question on the degree of their reality. Using the Monte Carlo method and the elementary theory of probability, he came to the conclusion that the degree of orbits' elements similarity in the groups selected by Opik (with the exception of solely several pairs) does not exceed the expected value in the random grouping of comets. In 1979, E.N.Kramer et al.(1979) made a search for the comet groups from the Catalogues of J.Porter (1961) and B.Marsden (1972), by using a well-known D-criterion of R.Southworth and G.Hawkins (1963). They found seven groups, in each of which the mutual phase distance D between the orbits satisfy the condition D. The authors did not exclude the possibility of a common origin of the comets belonging to the same group. L.Kresak (1982) and B.Lindblad (1985) quite independently considered a problem on the reality of the comet groups with the similar orbits. For this purpose, Kresak investigated the sample of 546 long-periodic comets and found 38 pairs with D as well as five groups containing three and four comets. In order to estimate the reality or the random appearing of such groups, Kresak also considered two random samples of the same volume. Discovering only slight prevalence of small values of D for the real comets as compared to the random samples, Kresak came to the conclusion on the absence of the comets' genetical relations existence in the groups with the similar elements. B.Lindblad (1985) investigated 599 long-periodic comets, and by using the D-criterion, he found five pairs and two groups with 4 and 7 comets each, including the Kreutz's family comets. The reality of these pairs and groups as well as Kresak's those was estimated by comparing with the groups found in the random samples. As a result, Lindblad has made a conclusion, that at the level reliability 2 σ, the groups of comets with the similar orbits are not found more often than in the samples with random orbits' distribution. The problem of the randomness of comets' combinations in pairs and groups seemed to raise no doubts and the hypothesis on the reality of physical and genetical relations of comets in groups had apparently to be burried and forgotten at long last. Only the Kreutz's family - universally recognized - was considered as an exception. However, the life sometimes presents us the sudden gifts. Such gift was embodied as a discovery of two new comets in 1988 - Levy (1988e) and Shoemakers-Halt (1988g) - with essentially similar orbits (see Table 1). As soon as the discovery was made, the problem again was facing the scientists: whether the wonderful coincidence of the comets' orbits was a random one, or there was a physical and genetical relation between them. Based upon a striking similarity of orbits' elements, and taking into account the fact, that the comets were at the angular distance of 20 degrees at the moments of the discovery, and passed the perihelion in 76 days one after another, Marsden (1988) suggested, that in this case there were two fragments of the same parent comet with a semimajor axis 750 AU. The comet was splitted during one of the previous perihelion passages. As our calculations have shown, the scatter velocity of these fragments are about to 9.7 m/s. We cannot exclude the possibility, that the parent comet was splitted into several fragments rather than into two ones (there is a sufficient number of examples) or that the separated fragments themselves may continue the splitting. As a result, these fragments might appear to the observers as some independent comets (as was the case with the fragments of the Biela's comet nucleus). Naturally, one may expect, that the orbital elements of such comets are to be distinctly similar and may be found in Catalogues. Indeed, in the "Catalogue of Comet Orbits" (Marsden,1986), there are some comets, the orbital elements which are close enough to those of the comets 1988e and 1988g (see Table 1). The similarity of the orbits may confirm the above mentioned suggestion on the common origin of some of them at least. A bit earlier, in 1982, two comets were discovered - 1982b and 1982c - which most probably are the fragments of the P/Du Toit comet nucleus (or together with it are fragments of another primary comet). In 1985, A.Carusi et al. (1985) made a suggestion on the relationship of two more comets - Van Biesbroeck and Neujmin 3. All the above-mentioned facts initiate us once more to return to the problem on the reality of existence and genetical relations comets with the similar orbits using the quite different criteria. In spatial twice restricted problem of three bodies, the system of equations of the motion of the perturbed body, assumes three integrals: - the semimajor axis remains constant

$$a = \text{const}, \tag{1}$$

÷ the vector projection of an angular moment of the body on the normal to the plane of motion of a perturbative planet remains constant

$$\mu = [q(1+e)] \cos i = \text{const} \tag{2}$$

and the averaged perturbative function also remains constant (Moiseev, 1945)

$$[W] = \text{const.} \tag{3}$$

The latter equation, for the Hill's case, takes the following form (Lidov, 1961)

$$\nu = e^2 (0.4 - \sin^2 i \sin^2 \omega) = \text{const.} \tag{4}$$

From the Jacoby's integral, it also follows, that the Tisserand invariant Ti remains constant

$$\text{Ti} = (1-e)/q + 0.1686 [q(1+e)]^{1/2} \cos i = \text{const.} \tag{5}$$

It has been shown earlier (Kramer and Shestaka 1983, 1987), that the variations in μ and ν (under the influence of the secular perturbations and Pointing-Robertson effect) do not exceed 5-10 %.

Due to the constancy of μ, ν and Ti parameters, one can suggest, that the comets of the common origin should keep on the close values of these parameters during their evolution. Therefore, if among the well-known comets, there are the parent groups, but not the random ones, they should be expected to have the similar parameters of μ, ν and Ti.

In order to estimate a possible range of such a similarity, we have investigated the above parameters in the periodic comets, the orbital elements of which have changed drastically after the close approachings to Jupiter. In Table 2, we present the orbital elements and the μ, ν, Ti parameters for a number of comets for two moments: before their close approaches to Jupiter (upper line) and after such approaches (bottom line). As one may see from Table 2, even the considerable variations in the orbital elements may result in rather close quasistationary parameters μ and ν. The Tisserand invariant Ti practically not changing at all.

Thus, it seems justified, that the comets may be subdivided into the groups according to the similarity of all the quasistationary parameters μ, ν and Ti.

First of all, we have considered a well-known family of Kreutz comets, the genetic relations of which leave no doubts. Within a total number of known comets of this family - 23, the two groups have been selected consisting of 4 and 19 comets, with inherent close values of μ, ν, Ti (see Table 3). The first group includes 1843 I, 1882 II, 1963 V and 1965 VIII comets, the Tisserand invariant of which does not exceed 0.0060. The second group includes 1880 I, 1887 I, 1945 VII, 1970 VI, as well as 15 comets discovered with the board coronographs mounted at the spacecrafts SOLWIND and SMM (Marsden, 1989). The Tisserand invariant for this comets' group ranges from 0.0129 to 0.0214.

Using the same similarity criterion of μ, ν; Ti parameters, we have selected some groups of comets from Marsden's (1979) Catalogue, which are shown at Table 4. In addition to the similarity of the above mentioned quasistationary parameters, we inferred, that the comets of the common origin, which underwent no close approaches to the big planets, must keep up the similar values of the perihelion distances and the orbital eccentricities. At Table 4, there are 14 groups containing from two to three comets. It is not impossible, that the comets entering these groups, are related genetically like the latter three groups: Du Toit-Hartley, Neujmin 3 -Van Biesbroeck and Levy- Shoemaker-Halt.

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Table 1. The orbital elements of comets of Levy's and Shoemakers-Halt's group

Comet	ω	Ω	i	e	q,
	(degrees, 1950.0)				a.u..
1988e	326.52130	288.06334	62.80479	0.9978636	1.1741402
1988g	326.47214	288.04196	62.79278	0.9969724	1.1736201
1889 IV	345.8705	287.0100	65.9895	0.997720	1.039727
1964 IX	20.6932	279.7444	67.9668	0.996452	1.259270
1968 V	353.9833	254.0145	61.7700	1.0	1.234003
1946 VI	320.4217	237.6345	56.9684	1.000794	1.136222

Table 2. The orbital elements and quasistationary parameters some comets after their close approaches to Jupiter

Comet	ω	Ω	i	e	q	μ	ν	Ti
	(degrees, 1950.0)				a.u.			
				Kojima				
1970 XII	198.11	291.14	4.09	0.515	1.631	1.57	0.11	0.5617
1978 X	348.36	154.08	0.89	0.393	2.399	1.83	0.06	0.5612
				Wolf				
1918 V	172.93	207.14	25.29	0.559	1.582	1.42	0.12	0.5182
1925 X	160.74	204.45	27.30	0.405	2.435	1.64	0.06	0.5216
				Harrington-Abel				
1969 III	338.08	145.89	16.84	0.524	1.773	1.57	0.11	0.5337
1983 XVII	138.58	336.72	10.16	0.539	1.785	1.63	0.11	0.5333
				Daniel				
1909 IV	3.50	71.54	19.45	0.603	1.382	1.40	0.15	0.5239
1978 XII	10.83	68.49	20.14	0.549	1.662	1.51	0.12	0.5253
				De Vico-Swift				
1844 I	278.93	65.05	2.91	0.617	1.186	1.38	0.15	0.5561
1965 VII	325.35	24.42	3.61	0.524	1.624	1.57	0.11	0.5578

Table 3. Two comets' groups of the Kreutz family

Comet	ω	Ω	i	e	q	μ	ν	Ti
	(degrees, 1950.0)				a.u.			
1843 I	82.64	2.83	144.35	0.9999	0.0055	-0.09	0.07	-0.0037
1882 II	69.59	346.96	142.00	0.9999	0.0078	-0.10	0.07	-0.0038
1965 VIII	69.59	346.30	141.58	0.9999	0.0078	-o.10	0.07	-0.0037
1963 V	86.16	7.24	144.58	0.9999	0.0051	-0.08	0.07	-0.0057
1880 I	82.25	7.08	144.66	1.0	0.0055	-0.09	0.07	-0.0144
1887 I	83.51	3.88	144.38	1.0	0.0048	-0.08	0.07	-0.0134
1945 VII	72.06	350.50	141.87	1.0	0.0075	-0.10	0.06	-0.0162
1970 VI	61.29	336.32	139.07	1.0	0.0089	-0.10	0.07	-0.0170
1979 XI	67.67	344.30	141.45	1.0	0.0048	-0.08	0.11	-0.0135
1981 I	65.43	341.41	140.67	1.0	0.0079	-0.10	0.07	-0.0164
1981 XIII	68.43	345.26	141.70	1.0	0.0061	-0.09	0.07	-0.0146
1981 XXI	77.68	356.87	143.84	1.0	0.0045	-0.08	0.07	-0.0129
1983 XX	78.58	357.98	143.98	1.0	0.0075	-0.10	0.07	-0.0167
1984 XII	56.67	329.74	136.38	1.0	0.0154	-0.13	0.07	-0.0214
1987 XXII	80.59	0.46	144.25	1.0	0.0054	-0.08	0.07	-0.0142
1987 XXV	82.63	2.96	144.46	1.0	0.0063	-0.09	0.07	-0.0153
1988 l	85.88	6.96	144.70	1.0	0.0052	-0.08	0.07	-0.0139
1988 m	82.25	2.50	144.43	1.0	0.0059	-0.09	0.07	-0.0149
1988 n	88.08	9.65	144.78	1.0	0.0051	-0.08	0.07	-0.0139
1988 q	86.14	7.28	144.71	1.0	0.0058	-0.09	0.07	-0.0148
1988 p	84.72	5.54	144.63	1.0	0.0056	-0.09	0.07	-0.0145
1989 q	91.80	14.20	144.78	1.0	0.0046	-0.08	0.07	-0.0132

Table 4. The comets' groups selected with criterion of closeness of parameters μ, ν, Ti

Comets	ω	Ω	i	e	q	μ	ν	Ti
	(degrees, 1950.0)				a.u.			
1905 II	352.35	77.38	30.48	0.615	1.395	1.29	0.15	0.4941
1975 IV	358.01	84.66	30.08	0.581	1.398	1.29	0.13	0.5166
1895 II	167.77	177.06	3.00	0.652	1.298	1.46	0.17	0.5147
1897 II	174.01	147.11	15.70	0.627	1.326	1.41	0.16	0.5197
1873 II	185.19	121.98	12.75	0.553	1.344	1.41	0.12	0.5702
1886 IV	176.85	54.47	12.67	0.571	1.338	1.41	0.13	0.5597
1906 VI	199.49	195.12	14.62	0.584	1.632	1.56	0.13	0.5172
1910 V	199.53	206.78	10.57	0.565	1.655	1.58	0.13	0.5296
1973 V	209.13	59.13	9.50	0.500	1.560	1.51	0.10	0.5749
1981 X	214.61	75.35	5.57	0.507	1.615	1.55	0.10	0.5670
1933 IV	190.56	188.80	10.21	0.348	2.497	1.81	0.05	0.5655
1981 XVII	183.46	215.53	6.66	0.408	2.362	1.81	0.07	0.5560

Table 4. (Continue). The comets' groups selected with criterion of closeness of parameters μ, ν, Ti

Comets	ω	Ω	i	e	q a.u.	μ	ν	Ti
	(degrees, 1950.0)							
1916 II	354.81	114.36	15.53	0.546	1.558	1.50	0.12	0.5435
1951 IX	343.00	127.79	16.35	0.515	1.664	1.52	0.10	0.5483
1958 V	187.03	254.23	18.48	0.540	1.605	1.49	0.09	0.5385
1970 XII	198.11	291.14	4.09	0.515	1.631	1.57	0.11	0.5617
1975 III	169.76	273.19	5.42	0.537	1.568	1.55	0.12	0.5556
1937 V	114.83	58.73	146.41	0.9997	0.803	-1.09	0.15	-0.1841
1956 III	81.01	226.03	147.46	1.0	0.842	-1.09	0.12	-0.1844
1819 IV	350.22	79.15	9.11	0.699	0.892	1.21	0.20	0.5424
1902 II	350.27	221.27	8.30	0.736	0.753	1.13	0.22	0.5409
1792 II	147.18	285.47	131.00	0.906	0.966	-1.39	0.40	-0.2303
1862 II	27.19	327.76	172.10	1.0	0.981	-1.37	0.40	-0.2231
1864 II	151.38	96.78	178.13	0.996	0.909	-1.35	0.40	-0.2340
1982 II	251.67	308.58	2.94	0.601	1.196	1.38	0.14	0.5666
1982c	251.62	308.59	2.94	0.602	1.195	1.38	0.14	0.5660
1982b	254.28	308.45	2.92	0.59	1.179	1.37	0.14	0.5783
1929 III	140.73	158.50	3.69	0.585	2.042	1.79	0.14	0.5059
1954 IV	134.98	148.98	6.59	0.550	2.414	1.92	0.12	0.5104
1988e	326.52	288.06	62.80	0.998	1.174	0.70	0.16	0.1197
1988g	326.47	288.04	62.79	0.997	1.174	0.70	0.16	0.1206