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Supplementary Catalogue I of Original and Future Comet Orbits

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This is the first continuation of the General Catalogue of Original and Future Comet Orbits, published in 1966. Seven new original and 16 future orbits are included, published or derived in the course of 1966 to 1968 (February). Fundamental data on both original and future orbits are now available for 86 nearly-parabolic comets with rigorously derived osculating orbits. The Supplementary Catalogue is arranged exactly in the same way as the General Catalogue. The statistical relations, however, studied in the 1966 paper, are not repeated, because the supplementary data can change the earlier conclusions in no substantial way. Instead of this, cometary splits and possible interference effects of the non-gravitational phenomena in comet motions are briefly mentioned, as apparently impairing the original and future values derived from the "gravitational" osculating orbits.

I. Introduction

This is the first supplement to the General Catalogue of Original and Future Comet Orbits, published by the writer two years ago (Sekanina 1966).

New original orbits for 7 comets and new future orbits for 16 comets have been computed since. Of the 7 original orbits, six have been derived by Marsden (1968) and one by Yanovitskaya (1967). Of the 16 future orbits, 9 have been computed by the writer (Sekanina 1967a), 6 by Marsden (ibid.) and one by Yanovitskaya (ibid.). The new original and future orbits for Arend-Roland 1957 III replace, respectively, the earlier approximate original value included in the General Catalogue, and the future value, involved in the supplementary list enclosed to the Catalogue. The nine future orbits by the writer fill the empty spots in the General Catalogue: they refer to those comets, for which the General Catalogue has given the original orbit only. At present there is only a single comet with the original orbit available, but its future orbit unknown: the Great September Comet 1882 II. However, this comet does not belong to the group of comets with extremely distant aphelion distances, and its future orbit is of no interest from our point of view. Omitting this comet, the General Catalogue with its first Supplementary Catalogue includes fundamental data on the original and future orbits for 86 nearly-parabolic comets at present.

2. Comments on the Supplementary Catalogue I

The arrangement of the presented Supplementary Catalogue is exactly the same as that of the General Catalogue itself: it consists of six parts, described in Section 9 of the General Catalogue. Only those data are included in the Supplementary Catalogue, which complete the General Catalogue, or which replace the out-of-date data of the General Catalogue. Hence, for example, this supplement gives Comet 1957 V only in Part F (future orbits), since its osculating and original orbits remain unchanged, as published in the General Catalogue.

No statistical discussion of the extended material is included. The writer prefers to postpone the re-discussion of the conclusions from Sections 3 to 6 and 10 to 11 of the General Catalogue till the time when the number of comets exceeds at least 100. The probability parameters of the interstellar character of the new original and future orbits, however, are included in Tables 1 and 2. They are computed from (26) of the General Catalogue and complete its Tables 14 and 15, respectively.

The list of references of the Supplementary Catalogue includes among others also Strömgren's pioneer paper from 1914, many times referred to in the General Catalogue, but omitted by mistake in its reference list.

3. Determination of the original and future orbits and the existence of non-gravitational phenomena in comet motions

The writer has recently suggested that the non-gravitational impulses upon comet nuclei, originated by the explosive activity of cometary materials, can impair the determinacy of the original and future orbits. Cometary splits are a telling demonstration of the existence of detectable non-gravitational forces. As a matter of fact, the original orbit should be integrated backward from the moment just before the non-gravitational mechanism starts acting, the future orbit forward from the moment just after the mechanism stops acting.

The major axis of the orbit is affected by the component of the non-gravitational forces along the orbital-velocity vector. Denoting the respective component of the comet's velocity increment w_V (in m/s), positive if directed in the same sense as the orbital velocity, negative if directed in the opposite sense, the contribution of a non-gravitational effect to the change in the inverse semi-major axis is given by (Sekanina 1967b):

$$\Delta_n \left(\frac{1}{a}\right) = -95 \frac{w_V}{\sqrt{r_n}} 10^{-6} \text{ AU}^{-1}, \tag{1}$$

where r_n is the solar distance of action of the non-gravitational mechanism (in AU). Numerical data available show that $\Delta_n \left(\frac{1}{a}\right)$ can in some cases reach values comparable in order with those of $(1/a_b)_{orig}$ or $(1/a_b)_{fut}$, and, consequently, should be taken into account whenever possible.

Together with the presented Supplementary Catalogue I, the General Catalogue includes now 4 split comets with the original aphelion distances greater than 10,000 AU. The possible effect of the splitting forces on the total orbital energy of three of them,

Table 1

Comet	Probability of interstellar original orbit				Note
	$H = 0.48$ pc	$H = 0.97$ pc	$H = 2.4$ pc	$H = \infty$	
1947 I	0.00	0.00	0.00	0.00	
1947 VI	0.00	0.00	0.00	0.00	
1954 VIII	0.00	0.00	0.00	0.00	
1957 III	1.00	1.00	1.00	1.00	$(1/a_b)_{orig} = —0.000106 \pm 0.000005$
	0.82	0.73	0.66	0.62	$(1/a_b)_{orig} = —0.000010 \pm 0.000033$
1957 VI	0.16	0.00	0.00	0.00	
1959 IV	0.00	0.00	0.00	0.00	
1959 X	0.00	0.00	0.00	0.00	

Table 2

Comet	Probability of interstellar future orbit				Note
	$H = 0.48$ pc	$H = 0.97$ pc	$H = 2.4$ pc	$H = \infty$	
1863 I	0.00	0.00	0.00	0.00	
1882 I	0.00	0.00	0.00	0.00	
1905 VI	0.00	0.00	0.00	0.00	
1910 III	0.00	0.00	0.00	0.00	
1941 VIII	0.00	0.00	0.00	0.00	
1944 I	1.00	1.00	1.00	1.00	
1947 I	0.00	0.00	0.00	0.00	
1947 VI	1.00	1.00	1.00	1.00	
1954 V	0.39	0.20	0.12	0.08	
1954 VIII	0.05	0.03	0.02	0.02	
1955 IV	0.00	0.00	0.00	0.00	
1957 III	1.00	1.00	1.00	1.00	
1957 V	0.00	0.00	0.00	0.00	
1957 VI	0.00	0.00	0.00	0.00	for both nuclei
1959 IV	1.00	1.00	1.00	1.00	
1959 X	0.00	0.00	0.00	0.00	

Swift 1899 I, Kopff 1905 IV and Mellish 1915 II, have recently been discussed by the writer (Sekanina 1967b). The fourth comet is Wirtanen 1957 VI, the osculating orbit of which has been studied by the writer (Sekanina 1968a). The pre-split orbit of this comet is very uncertain, and no trustworthy original value can be deduced from it. However, the few pre-split observations of the comet can be satisfactorily linked with the post-split positions of nucleus *A* (the brighter one), indicating that this nucleus was exposed to nearly no detectable impulse during the process of separation. On the other hand, nucleus *B* — the weak companion — was expelled from the primary nucleus at a measurable velocity, but in the direction nearly perpendicular to the orbital-velocity vector, producing thus just a small change in $1/a$.

Supplementary Catalogue I of Original and Future Comet Orbits. Part A

Comet's Designation			T_{osc}	T	ω	Ω	i	q	e
definitive	preliminary	nominal							
					°	°	°		
1947 I	1946k	Bester	1947 Oct. 2.0 E	1947 Feb. 7.3279	348.6094	34.8579	108.1690	2.407528	1.000589
1947 VI	1947h	Wirtanen	1948 Feb. 9.0	1947 July 18.34942	9.3835	311.0975	97.3268	2.827986	1.000836
1954 VIII	1954f	Vozárová	1954 Sept. 5.0 E	1954 June 1.93512 E	357.2284	122.1253	116.1590	0.677112	1.000069
1957 III	1956h	Arend-Roland	1957 May 2.0 E	1957 Apr. 8.03194 E	308.7808	215.1590	119.9494	0.316054	1.000249
1957 VI	1956c	Wirtanen	1957 Jan. 2.0 E	1957 Sept. 2.23100 E	13.2414	232.9507	33.1998	4.447594	1.003024
1959 IV	1959e	Alcock	1959 Aug. 20.0 E	1959 Aug. 17.60754 E	124.7062	159.2257	48.2628	1.150354	1.000919
1959 X	1960e	Humason	1960 Dec. 2.0 E	1959 Dec. 11.35975 E	46.5088	306.5762	125.4695	4.267868	1.000040

Supplementary Catalogue I of Original and Future Comet Orbits. Part B

Comet	$\left(\frac{1}{a}\right)_{osc}$	P	Perturbing planets	v_1	v_2	int v	int obs.	N	ε	Reference
				°	°	°			″	
1947 I	—0.000245 ± 0.000003		VEMJSUN	—34	+104	138	700	108	±0.26	van Biesbroeck (1967)
1947 VI	—0.000295 ± 0.000004		VEMJSUNP	+1	+84	83	437	41	±0.39	van Biesbroeck (1965)
1954 VIII	—0.000101 ± 0.000041		VEMJSUN	+87	+125	38	143	57	±1.31	Hasegawa (1966)
1957 III	—0.000789 ± 0.000005[2])		MeVEMJSUN	—141	+152	293	520	472	±2.04	Sekanina (1968d)
1957 VI	—0.000680 ± 0.000003[3])		VEMJSUN	—63	+76	139	1266	103	±1.17	Sekanina (1968a)
1959 IV	—0.000799 ± 0.000043		MeVEMJSUN	+12	+63	51	59	69	±3.3	Yanovitskaya (1968)
1959 X	—0.000009 ± 0.000003		VEMJSUN	+29	+67	38	349	34	±1.20	van Biesbroeck (1968)[4])

Supplementary Catalogue I of Original and Future Comet Orbits. Part C

Comet	P_x	P_y	P_z	Q_x	Q_y	Q_z	R_x	R_y	R_z
1947 I	+0.769212	+0.635051	+0.070877	+0.336769	—0.497161	+0.799636	+0.543046	—0.591220	—0.596288
1947 VI	+0.632878	—0.759003	—0.152906	—0.201993	—0.352508	+0.913749	—0.747439	—0.547406	—0.376408
1954 VIII	—0.549204	+0.782925	+0.292237	+0.347211	—0.104309	+0.931968	+0.760144	+0.613309	—0.214554
1957 III	—0.287967	—0.354050	—0.889788	—0.817386	—0.393237	+0.421006	—0.498955	+0.848536	—0.176156
1957 VI	—0.433513	—0.868602	—0.239994	+0.788088	—0.494586	+0.366473	—0.437017	—0.030266	+0.898944
1959 IV	+0.338240	—0.898796	+0.278852	+0.903075	+0.226672	—0.364796	+0.264670	+0.375213	+0.888350
1959 X	+0.072048	—0.972302	+0.222346	—0.753025	+0.093154	+0.651365	—0.654036	—0.214362	—0.725456

Supplementary Catalogue I of Original and Future Comet Orbits. Part D

Comet	α_π	δ_π	λ_π	β_π	l_π^{II}	b_π^{II}	α_p	δ_p	λ_p	β_p	l_p^{II}	b_p^{II}
	°	°	°	°	°	°	°	°	°	°	°	°
1947 I	39.54	+4.06	38.45	—10.82	167.17	—48.97	312.57	—36.60	304.86	—18.17	6.67	—39.36
1947 VI	309.82	—8.80	309.89	+9.31	37.88	—28.46	216.22	—22.11	221.10	—7.33	330.47	+35.34

1954 VIII	125.05	+16.99	123.35	—2.49	207.24	+27.61	38.90	—12.39	32.13	—26.16	187.25	—60.90
1957 III	230.88	—62.85	247.01	—42.49	319.63	—5.33	120.46	—10.15	125.16	—29.95	230.67	+11.07
1957 VI	243.48	—13.89	244.09	+7.21	359.93	+25.42	183.96	+64.02	142.95	+56.80	129.02	+52.99
1959 IV	290.62	+16.19	295.36	+37.84	51.18	+0.24	54.80	+62.67	69.23	+41.74	141.20	+6.23
1959 X	274.24	+12.85	275.12	+36.22	40.95	+12.88	198.15	—46.51	216.58	—35.47	307.22	+15.90

Supplementary Catalogue I of Original and Future Comet Orbits. Part E

Comet	$\left(\frac{1}{a_b}\right)_{orig}$	Perturbing planets	v_{orig}	r_{orig}	int pert.	Reference	Catalogue Values $\left(\frac{1}{a_b}\right)_{orig}$	Catalogue Values $\left(\frac{1}{a_b}\right)_{orig} - \left(\frac{1}{a}\right)_{osc}$
			°					
1947 I	+0.000097	MeVEMJSUNP	—154.1	48.0	27.4	Marsden (1968)	+0.000097 ± 0.000003	+0.000342
1947 VI	+0.000273	MeVEMJSUNP	—148.8	39.1	20.8	Marsden (1968)	+0.000273 ± 0.000004	+0.000568
1954 VIII	+0.000352	MeVEMSJUNP	—166.6	50.0	27.4	Marsden (1968)	+0.000352 ± 0.000041	+0.000453
1957 III	—0.000106[5])	MeVEMSJUNP	—169.9	41.0	19.9	Marsden (1968)	—0.000106 ± 0.000005[5])	+0.000683
1957 VI	+0.000023[6])	MeVEMJSUNP	—145.5	50.6	29.7	Marsden (1968)	+0.000023 ± 0.000003[6])	+0.000703
1959 IV	+0.000595	MeVEMJSUN	—162.4	48.3	26.2	Yanovitskaya (1967)	+0.000595 ± 0.000043	+0.001394
1959 X	+0.000117	MeVEMJSUNP	—147.2	53.4	33.6	Marsden (1968)	+0.000117 ± 0.000003	+0.000126

Supplementary Catalogue I of Original and Future Comet Orbits. Part F

Comet	$\left(\frac{1}{a_b}\right)_{fut}$	Perturbing planets	v_{fut}	r_{fut}	int pert.	Reference	Catalogue Values $\left(\frac{1}{a_b}\right)_{fut}$	Catalogue Values $\left(\frac{1}{a}\right)_{osc} - \left(\frac{1}{a_b}\right)_{fut}$	Catalogue Values $\left(\frac{1}{a_b}\right)_{orig} - \left(\frac{1}{a_b}\right)_{fut}$
			°						
1863 I	+0.000766	VEJSUNP	+170.5	116.9	95.6	Sekanina (1967a)	+0.000767 ± 0.000060	—0.000826	—0.000239
1882 I	+0.000781	VEJSUNP	+177.3	107.4	83.7	Sekanina (1967a)	+0.000782 ± 0.000021	—0.000692	—0.000638
1905 VI	+0.000363	VEJSUNP	+167.3	106.9	84.1	Sekanina (1967a)	+0.000364 ± 0.000050	—0.000506	+0.000274
1910 III	+0.000280	VEJSUNP	+161.3	73.9	49.6	Sekanina (1967a)	+0.000281 ± 0.000006	—0.000186	+0.000191
1941 VIII	+0.000188	VEMJSUNP	+168.9	94.3	69.3	Sekanina (1967a)	+0.000188 ± 0.000007	—0.000467	—0.000106
1944 I	—0.001993	VEMJSUNP	+168.3	95.7	68.3	Sekanina (1967a)	—0.001993 ± 0.000381	—0.001031	—0.000355
1947 I	+0.000124	MeVEMJSUNP	+154.6	49.6	27.4	Marsden (1968)	+0.000124 ± 0.000003	—0.000369	—0.000027
1947 VI	—0.000194	MeVEMJSUNP	+155.0	60.4	36.9	Marsden (1968)	—0.000194 ± 0.000004	—0.000101	+0.000467
1954 V	+0.000025	VEMJSUNP	+153.6	87.4	64.0	Sekanina (1967a)	+0.000025 ± 0.000018	—0.000362	+0.000117
1954 VIII	+0.000086	MeVEMJSUNP	+167.2	54.3	30.3	Marsden (1968)	+0.000086 ± 0.000041	—0.000187	+0.000266
1955 IV	+0.004260	VEMJSUNP	+166.3	83.8	62.2	Sekanina (1967a)	+0.004260 ± 0.000046	—0.000143	+0.000094
1957 III	—0.000612[3,7])	MeVEMJSUNP	+169.9	41.2	19.9	Marsden (1968)	—0.000612 ± 0.000005[6,7])	—0.000177	+0.000506
1957 V	+0.003093	VEMJSUNP	+173.0	87.3	63.1	Sekanina (1967a)	+0.003094 ± 0.000018	—0.001264	—0.001056
1957 VI	+0.000154[8])	MeVEMJSUNP	+144.2	47.0	28.0	Marsden (1968)	+0.000154 ± 0.000007[8])	—0.000832[9])	—0.000131
1959 IV	—0.000476	MeVEMJSUN	+158.8	34.8	16.1	Yanovitskaya (1967)	—0.000476 ± 0.000043	—0.000323	+0.001071
1959 X	+0.000073	MeVEMJSUNP	+143.8	44.3	24.1	Marsden (1968)	+0.000073 ± 0.000003	—0.000082	+0.000044

Another comet of interest is Arend-Roland 1957 III. This comet gives a well-defined interstellar original orbit, with the hyperbolic excess more than 20 times as large as the error involved. The distribution of the position residuals from the osculating orbit, however, is not quite satisfactory, indicating a progressive change in the osculating value of the major axis. If the original orbit is derived from the pre-perihelion arc of orbit only, the interstellar character of the comet's origin becomes doubtful in view of the possible action of stellar perturbations (Sekanina 1968c).

Earlier, a similar anomaly, but opposite in sign, was mentioned by van Biesbroeck and Marsden (1963) for Comet Burnham 1960 II. Its anomalous motion has recently been confirmed by the writer (Sekanina 1968b). Unfortunately, the observed arc of orbit is too short to give definitive values for the comet's original and future $(1/a_b)$'s with the non-gravitational corrections involved. In light of what has just been said, however, the original and future orbits of this comet, given in the General Catalogue, are very uncertain.

All the data, included in the Supplementary Catalogue, which are derived from the compiled values (Parts C and D completely, some columns of Parts B, E and F) as well as the data in Tables 1 and 2 have been computed on a Minsk 22 computer of the Centre for Numerical Mathematics, Prague.

The writer thanks to Drs Marsden, van Biesbroeck and Yanovitskaya for sending him their results in advance of publication.

The second supplement to the General Catalogue is planned to appear about 1971. The writer repeats his request (published on Circular IAU No 2041) to computers of original and future orbits that they send him their results as soon as possible in the future.

Notes on the Supplementary Catalogue

[1]) Some columns have been completed thanks to the data Dr van Biesbroeck kindly gave at my disposal.
[2]) This value has been derived from all the observations available. The pre-perihelion positions give separately $(1/a)_{osc} = -0.000692 \pm 0.000033$, the post-perihelion observations $(1/a)_{osc} = -0.000796 \pm 0.000019$. The late 1957 and 1958 observations yield even a stronger hyperbolic excess, suggesting a systematic non-gravitational increase in the comet's orbital energy throughout the observed arc of orbit.
[3]) This value has resulted from the linkage of the pre-split observations with the nucleus A positions after the separation. For the nucleus A orbit I have found $(1/a)_{osc} = -0.000678 \pm 0.000007$, for the nucleus B orbit $(1/a)_{osc} = -0.000672 \pm 0.000008$.
[4]) I thank to Dr Marsden for his kind calling my attention to van Biesbroeck's determination of this orbit and to him and Dr van Biesbroeck for sending some details on the resultant orbit.
[5]) The pre-perihelion osculating elements lead to the original value of -0.000010 ± 0.000033.
[6]) This value has resulted from the osculating orbit tabulated in Parts A and B.
[7]) The post-perihelion observations lead to the future value of -0.000620 ± 0.000019 or even a more hyperbolic one.
[8]) This value refers to nucleus A. It has been derived from the respective osculating orbit mentioned in Note[3]). For nucleus B we find $(1/a_b)_{fut} = +0.000160 \pm 0.000008$.
[9]) This difference refers to the osculating $(1/a)$ mentioned in Note [3]) (for nucleus A), not in Part B.

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