MULTI-STATION METEOR PHOTOGRAPHY IN THE NETHERLANDS

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INTRODUCTION

During the period 1982—1987 about 100 bright meteors have been photographed by two or more stations in the Netherlands; orbital data for the 70 best orbits are presented in this paper. Similar compilations of meteor orbits have been reported in literature — among others — by Ceplecha *et al* (1964), and Babadzhanov and Kramer (1965). The orbits have been used to investigate the cometary and asteroidal origin of meteoroids and to compare them with numerical models describing meteor stream evolution.

The present orbits have been obtained in a continuing program organized by the Dutch Meteor Society (DMS), an amateur organization which was founded in 1979. Several observing groups, equipped with large batteries of cameras, participate in this program. The activity of these groups is concentrated in the weeks around the maxima of the major meteor streams. In addition, six fully automated 'all-sky' cameras are operative during every clear night as part of the European Network under the directorship of Z. Ceplecha at Ondřejov Observatory, Czechoslovakia.

The majority of the meteors was photographed with cameras with either f/1.8–50 mm standard lenses and 35 mm film, or with f/4–75 mm lenses and 60 mm film. A panchromatic emulsion with a sensitivity of 400 ASA (Kodak Tri-X, Ilford HP5) was used. The limiting magnitude of these cameras is about 0 magnitude. The 'all-sky' cameras have f/2.8–16 mm or f/5.6–8 mm fish-eye lenses and also use 400 ASA 35 mm film. The limiting magnitude of these cameras is about -3 magnitude. At present all cameras are equipped with synchronously driven rotating shutters, which use the 50 Hz mains frequency. The chopping frequency of such shutters has been measured to be accurate within 0.2% (Mostert 1989). The distances between the various photographic stations vary between 20 and 150 km. The time of appearance of the photographed meteors is recorded by photo-sensitive equipment, utilizing a photo-multiplier tube (Mostert 1982). In some cases time recordings by experienced visual observers are used.

All negatives have been measured on a 'Jena Astrorecord', resulting in typical positional accuracies of 1 minute of arc for the negatives obtained with standard lenses and 3 minutes of arc for those obtained with fish-eye lenses. Further data reduction has been carried out using the Czechoslovakian 'FIRBAL' computer program (Ceplecha 1987), which computes the atmospheric trajectories and the orbital elements.

Table 1: *Orbital elements of photographic multi-station meteors obtained by DMS between 1981 and 1987 (Equinox 2000.0).*

DMS ref.no.	v_g (km/s)	v_h	q (AU)	a (AU)	e	i	ω (degrees)	Ω	Shower
81001	10.6	36.0	0.950	1.96	0.514	8.8	215.9	125.1	Spo
81002	23.4	38.0	0.585	2.94	0.801	7.1	267.3	127.9	α-Cap
81003	22.1	37.3	0.602	2.49	0.758	7.3	266.8	128.0	α-Cap
81004	59.5	41.4	0.970	21.86	0.956	113.8	156.0	140.5	Per
82002	58.8	41.7	0.956	74.61	0.987	111.0	152.3	139.1	Per
82003	59.0	40.9	0.963	11.02	0.913	113.6	153.5	139.2	Per
82006	58.1	40.9	0.937	11.27	0.917	111.1	147.3	139.2	Per
83002	18.0	37.8	0.974	2.75	0.646	26.0	205.8	137.0	Cyg
83003	59.1	42.4	-0.956	18.60	1.051	110.0	152.7	137.1	Per
83021	58.9	41.1	0.951	14.32	0.934	112.8	150.8	138.0	Per
83004	59.0	41.3	0.949	20.27	0.953	112.7	150.5	138.9	Per
83005	18.0	37.2	1.013	2.41	0.579	28.3	178.9	139.0	Spo
83006	60.5	42.9	0.957	-9.66	1.099	112.9	153.3	139.0	Per
83008	60.0	42.6	-0.988	14.25	1.069	111.9	162.1	140.0	Per
83011	58.1	40.5	0.953	7.80	0.878	111.9	150.9	140.0	Per
83013	59.1	40.8	0.952	10.64	0.911	114.2	150.8	140.0	Per
83015	59.3	41.2	0.939	15.68	0.940	114.1	148.1	141.9	Per
83016	59.3	41.1	0.937	14.86	0.937	114.1	148.2	142.8	Per
83018	33.6	33.9	0.163	1.36	0.880	24.3	321.4	262.2	Gem
83019	34.5	34.0	0.142	1.38	0.897	23.5	324.1	262.8	Gem
83020	30.2	37.7	0.980	2.33	0.580	51.3	188.4	262.8	Spo
84002	47.0	41.3	0.927	15.22	0.939	80.5	213.1	34.1	Lyr
84003	59.6	41.0	0.957	12.98	0.926	115.6	151.8	130.2	Per
84005	66.6	41.8	0.569	26.06	0.978	163.1	82.3	28.0	Ori
84006	23.5	40.1	0.972	4.89	0.801	35.0	197.5	220.7	Spo
84007	33.9	33.3	0.136	1.28	0.894	21.2	325.8	263.5	Gem
85001	16.5	35.2	1.004	1.69	0.405	27.8	184.1	31.0	Spo
85002	14.4	37.6	0.870	2.51	0.653	6.4	228.8	31.1	Spo
85003	46.1	40.8	0.917	8.76	0.895	79.3	215.5	31.1	Lyr
85004	25.5	38.9	0.547	3.81	0.856	8.1	270.1	121.3	α-Cap
85005	17.6	40.2	0.991	6.74	0.853	21.4	161.2	122.2	Spo
85006	58.8	41.4	0.965	23.72	0.959	111.7	154.4	138.4	Per
85007	22.8	39.4	0.974	4.42	0.780	33.8	204.3	138.4	κ-Cyg
85008	59.6	45.7	0.917	-2.64	1.350	103.4	146.5	138.4	Per
85009	59.5	40.8	0.953	9.88	0.904	115.8	151.0	138.4	Per
85010	59.5	40.9	0.982	11.01	0.911	115.1	159.1	138.5	Per
85011	58.7	41.0	0.969	12.41	0.922	112.4	155.2	138.5	Per
85012	58.5	41.6	0.959	42.68	0.978	110.3	153.1	139.5	Per
85014	58.7	41.7	0.934	76.86	0.988	110.9	147.3	139.5	Per
85016	59.3	41.5	0.938	33.17	0.972	112.9	148.1	139.5	Per

Table 1: *Continued.*

DMS ref.no.	v_g (km/s)	v_h	q (AU)	a (AU)	e	i	ω (degrees)	Ω	Shower
85017	59.1	41.1	0.952	14.91	0.936	113.3	151.0	140.3	Per
85018	60.0	41.7	0.953	62.89	0.985	114.7	151.7	140.4	Per
85019	59.6	40.9	0.936	11.48	0.919	115.8	147.2	140.4	Per
85021	59.1	41.3	0.970	18.40	0.947	112.7	156.0	140.4	Per
85022	58.6	40.7	0.948	9.44	0.900	113.0	149.7	140.4	Per
85023	42.8	25.2	0.043	0.79	0.946	133.6	165.9	320.4	Spo
85024	59.3	41.4	0.944	22.45	0.958	113.5	149.3	140.5	Per
85025	59.0	41.2	0.945	16.70	0.943	113.0	149.6	140.5	Per
85026	59.1	40.9	0.959	11.22	0.915	114.1	152.6	140.5	Per
85027	23.8	36.0	0.468	1.83	0.743	8.5	104.2	19.9	Spo
85028	67.7	42.6	0.606	-27.04	1.022	163.6	76.9	27.9	Ori
85029	26.2	40.0	0.977	5.99	0.837	39.9	202.8	139.4	κ-Cyg
85030	21.4	35.6	0.998	1.82	0.452	36.8	197.9	140.4	Cyg
86001	37.0	40.5	0.813	7.80	0.896	57.8	125.6	140.0	Spo
86002	58.9	40.6	0.946	8.87	0.893	114.4	148.9	130.5	Per
86005	40.4	36.7	0.067	2.21	0.970	26.1	333.8	135.4	N-Aqr
86006	38.0	36.9	0.123	2.30	0.947	25.4	143.9	316.4	S-Aqr
86007	59.1	41.3	0.951	18.97	0.950	113.1	150.9	138.2	Per
86008	60.2	41.5	0.943	29.89	0.968	116.1	149.3	140.1	Per
86009	59.0	41.0	0.953	13.03	0.927	113.4	151.3	140.1	Per
86010	8.6	36.7	0.995	2.20	0.547	5.3	198.1	140.1	Spo
86011	59.8	41.3	0.957	18.27	0.948	115.3	152.3	140.1	Per
86013	59.9	42.0	0.959	-58.79	1.016	113.4	153.4	140.2	Per
86015	59.8	41.3	0.961	19.26	0.950	115.1	153.4	140.3	Per
86016	56.0	41.1	0.898	13.35	0.933	104.7	139.9	143.1	Per
86018	22.7	35.8	0.663	1.75	0.621	27.7	262.2	226.7	Spo
87001	18.7	38.3	0.932	2.59	0.641	26.2	210.6	312.6	Spo
87002	59.3	41.7	0.948	77.23	0.988	112.5	150.7	143.7	Per
87004	22.2	38.8	0.962	3.20	0.699	33.9	203.4	208.2	Spo
87005	20.5	35.5	0.651	2.01	0.676	5.1	80.7	90.8	Spo

RESULTS

The resulting orbits are shown in Table 1. Only a reference number, of which the first two digits denote the year in which the meteor was photographed, the geocentric and heliocentric velocity, the orbital elements (equinox 2000.0) and a stream assignation are listed; the complete data on these meteors will be published elsewhere. A preliminary list of 30 orbits has already been published (Betlem 1985).

The typical error in the coordinates of the calculated radiants (not listed) amounts to 0.2°. The typical relative error in the observed velocity amounts to 1%, depending on the duration and brightness of the meteor. These errors are derived from those meteors for which three or more recordings are available. In one case (DMS 85027) a sporadic fireball was photographed by four Dutch stations as well as by four German stations of the European Network (Betlem and de Lignie 1985). Independent reduction in Leiden and Ondřejov gave good agreement (Ceplecha 1986).

Since most of the observing time has been concentrated to periods of stream maxima, 80% of the listed orbits belong to the major meteor streams (60% are perseids). Since for some streams only a few orbits are known in literature, the present orbits may be a valuable addition.

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REFERENCES

Babadzhanov P.B. and Kramer E.N. (1965). *Smiths. Contr. to Astroph.* **11**, 67.

Betlem H. (1985). *Radiant* **7**, 73.

Betlem H. and Lignie M.C. de (1985). *Radiant* **7**, 126.

Ceplecha Z., Ježková M., Novák M., Rajchl J., Sehnal L. and Davies J.G. (1964). *Bull. Astron. Inst. Czech.* **15**, 144.

Ceplecha Z. (1986). Private communication.

Ceplecha Z. (1987). *Bull. Astron. Inst. Czech.* **38**, 222.

Mostert H.E. (1982). *Radiant* **4**, 78.

Mostert H.E. (1989). Private communication.