Contrib. Astron. Obs. Skalnaté Pleso **43**, 135 – 141, (2013)

Meteoroids of 1P/Halley - the list of photographic orbits

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Received: August 1, 2013; Accepted: October 9, 2013

Abstract. The paper presents lists of 63 Orionids and 14 Eta Aquariids selected from the newest version of the IAU MDC database of photographic orbits. The selection was made by a method of indices described in detail by, e.g., Svoren et al. (2000) and Svoren et al. (2006). Published datasets should enable a more comprehensive study of the meteoroid stream of the Comet 1P/Halley, comparing the internal structure of the stream at two different locations in which it crosses the Earth's orbit.

Key words: Orionids – Eta Aquariids – photographic – orbits – meteors

1. Introduction

The Earth on its path around the Sun encounters a number of meteoroid streams. However, so far there has been only one known case of a meteoroid stream observable as two night meteor showers, where encounters both on pre-perihelion and post-perihelion arcs are realised. The meteoroid stream of the periodic comet 1P/Halley with its showers of Orionids and Eta Aquariids is such a case. Encounter of the Earth with the stream at two different locations, and thus different geometry, enables us a more comprehensive view of the internal structure of the stream.

Orionids are a known prolific autumn stream associated with 1P/Halley. The minimum distance of the Earth from the orbit of the parent comet is 23 million kilometers, resulting in a huge width of the stream. There is observed a double maximum in radar records, in response to long-term libration of the 1P/Halley orbit (Hajduk, 1985). This gives a good indication of a long-term stability of the internal structure of the stream. In terms of the need for an appropriate method is searching for an orbital link between the Orionids and their parent comet. Despite the visible similarity of the orbits, application of generally used Porter's method of calculating the theoretical radiant did not give satisfactory results. Only formulation of a method of ω-adjustment by Hasegawa (1990) allows an elegant and unambiguous assignment the Orionids shower and the comet 1P/Halley.

Eta Aquariids are a known meteor swarm which, like Orionids, is associated with Halley's comet. It is active in late April and early May. A width of the meteoroid stream reaches 56 million kilometers. Both Eta Aquariids and Orionids belong to fast showers with a geocentric velocity greater than 65 km/s. The first records on their observations are in Chinese, Korean and Japanese chronicles from the year 401 AD. At that time, the orbit of Halley's Comet passed much closer to the Earth's orbit as it is nowadays. Currently, the frequency is substantially lower, better observational conditions are from the southern hemisphere.

A selection of members of both parts of the stream of Halley's Comet enables a deeper study of the fine structure of the stream and its inter-comparisons at different geometry of encounters with the Earth.

2. Selection of Orionids and Eta Aquariids

The International Astronomical Union Meteor Data Center database (hereinafter IAU MDC database) of photographic orbits (Lindblad et al., 2003) was used to obtain the set of the Orionids' and Eta Aquariids' orbits. In accordance with previous results (Porubčan et al., 1995), 46 meteors of the IAU MDC database with heliocentric velocities greater than 48 kms^{-1} were not included in the analysis. Thus, the final set of database consisted of 4526 orbits. To select the Orionids and Eta Aquariids, we used the method of indices (described in details by, e.g., Svoreň et al., 2000; Svoreň et al., 2006). The method is based on a comparison of meteoroid orbits on the basis of their "indices" - set accordingly to the values of 5 orbital elements (perihelion distance q, eccentricity e, argument of perihelion ω, longitude of ascending node Ω, inclination i) and 3 geocentric parameters (right ascension α and declination δ of the radiant, and geocentric velocity v_g) of individual meteoroids.

In the selection, we assumed the same values of relative errors and ranges of individual parameters in Tab. 1 as in our previous work (Kaňuchová et al., 2005). The errors of 8 individual parameters were determined as the mean weight values calculated from primary errors derived for the 5 most numerous streams (Perseids, Geminids, Orionids, Quadrantids and Leonids).

Table 1. The mean errors (MEs) and the numbers of intervals of basic division.

parameter	q	e	ω	Ω	i	α	δ	v_g
ME	0.016	0.072	3.5	2.6	2.3	3.6	1.3	1.3
Range	1.1	1.6	360.0	360.0	180.0	360.0	148.0	76.0
range/ME/11.39	6.04	1.95	9.03	12.16	6.87	8.78	10.00	5.13
intervals	6	2	9	12	7	9	10	5

Table 1 lists:

– the parameters considered in the method of indices;

– the errors of the parameters - the weighted mean values calculated from the 5 most numerous streams – Perseids, Geminids, Orionids, Quadrantids and Leonids;

– the ranges - differences between the highest and lowest values of parameters for the whole IAU MDC database;

– the ratios of given ranges to the mean errors, the result moreover divided by the empirical value (11.39 in our case) fulfilling a condition of the minimal sum of squares of differences between the real values and the closest integers.

– The corresponding nearest integers serving as a basic set of numbers for the division of the parameters into equidistant intervals, are in the last row.

There were selected 63 Orionids and 14 Eta Aquariids from the IAU MDC Database. The selected Orionids cover an interval from October 2 to October 29, the selected Eta Aquariids an interval from May 3 to May 5. The ranges of parameters for both streams are listed in Tab. 2. As we can see, some Orionids with $e > 1$ were observed. In the case of meteoroids with a high geocentric velocity (as Orionids are), excentricity values greater than 1 could be achieved as a consequence of low precision of atmosferic velocity measurements. Thus, values of $e > 1$ represent a tail of their statistical distribution and cannot be considered as real (Hajduková, 2008).

Table 2. The ranges of parameters and the comparison of the 1P/Halley orbit (in the same precision as mean orbits of the meteors, although the cometary orbit is known with higher precision) with the mean orbits of the Orionids and Eta Aquariids. Comet data were taken from Marsden and Williams (1997) for epoch 1986 February 19.

parameter	q	e	ω	Ω	i
lowest value ORI	0.510	0.807	62.7	9.5	155. 9
highest value ORI	0.734	1.213	94.2	36.0	168.5
Orionids	0.579	0.972	81.4	28.3	163.5
	±0.046	±0.075	±6.21	±4.3	±1.7
lowest value ETA	0.545	0.885	91.5	43.1	162.8
highest value ETA	0.591	0.974	98.7	45.4	165.1
Eta Aquariids	0.569	0.935	95.6	44.6	163.7
	±0.013	±0.028	±2.2	±0.7	±0.7
Comet 1P/Halley	0.587	0.967	111.9	58.9	162.2

3. Selected Orionids and Eta Aquariids

A list of selected Orionids and Eta Aquariids is given in Tab. 3 and Tab. 4. Only the identification code, date and time of observation and the above-mentioned 8 parameters are listed in the tables. The Universal Time was used for all data. The reader can obtain all the other data characterizing the selected meteors from the electronic version of the IAU MDC database (Lindblad et al., 2003). The identification code is an easy way to find in the database the meteors here selected. The distributions of right ascension and declination of the radiants of the selected Orionids (Eta Aquariids), depending on the length of the ascending node, are plotted in Fig. 1 (Fig. 2, resp.).

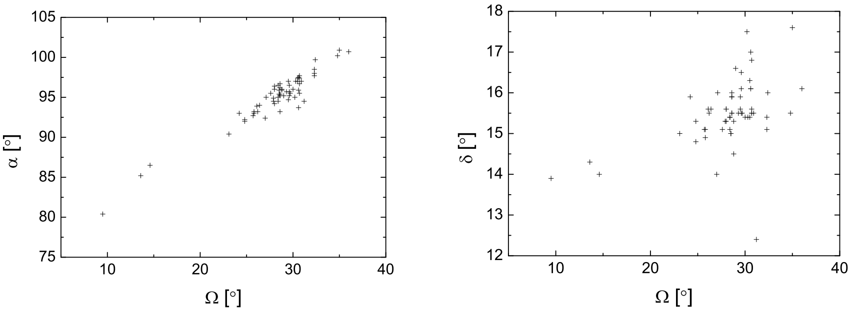

Figure 1. The distributions of right ascension (left) and declination (right) of the Orionids radiants depending on the length of the ascending node.

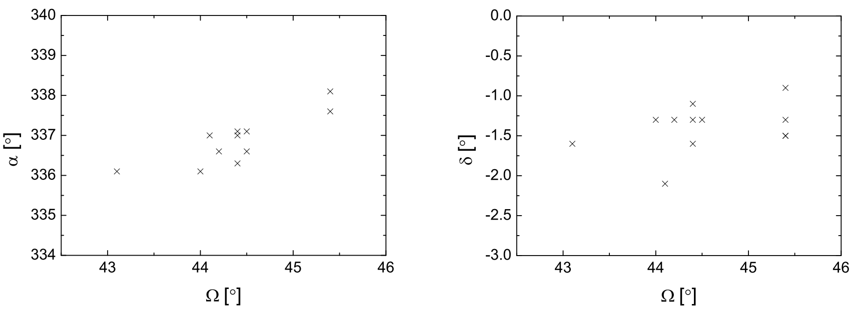

Figure 2. The distributions of right ascension (left) and declination (right) of the radiants of Eta Aquariids depending on the length of the ascending node.

Table 3. Selected Orionids - *IC* - identification code, *d.t.* - date (yymmdd.) and time (.ttttt), q - perihelion distance in AU, e - eccentricity, ω - argument of perihelion in degrees, Ω - longitude of ascending node and i - inclination of the plane of the meteor orbit to the ecliptic in degrees, α - right ascension and δ - declination of the radiant in degrees, v_g - geocentric velocity in km per second.

IC	*d.t.*	q	e	ω	Ω	i	α	δ	v_g
229P1	571002.36249	0.713	0.973	65.4	9.5	162.1	80.4	13.9	67.84
103C1	591007.01009	0.715	0.914	66.2	13.6	162.3	85.2	14.3	67.19
104C1	591008.06662	0.734	0.966	62.7	14.6	161.9	86.5	14.0	68.05
313P1	581016.41377	0.612	1.001	76.7	23.1	162.6	90.4	15.0	67.35
088O4	641017.06300	0.636	0.959	74.9	24.2	164.7	93.0	15.9	67.20
351B1	931018.07620	0.611	1.011	76.7	24.8	163.3	92.0	15.3	67.53
352B1	931018.12500	0.602	0.964	78.8	24.8	162.1	92.2	14.8	66.68
353B1	931018.95950	0.584	0.944	81.5	25.7	162.5	92.7	15.1	66.20
354B1	931019.05660	0.609	1.000	77.2	25.8	162.4	93.0	14.9	67.31
355B1	931019.07040	0.601	0.963	78.9	25.8	162.7	93.2	15.1	66.72
162W1	501019.37340	0.607	0.956	78.4	26.1	163.9	93.9	15.6	66.77
160W1	501019.50460	0.582	0.950	81.6	26.2	163.4	93.2	15.5	66.34
270H1	531019.42117	0.553	0.842	88.5	26.4	163.2	94.0	15.6	64.24
122N2	791020.75000	0.575	1.044	80.0	27.0	160.1	92.4	14.0	67.40
323P1	581020.46537	0.610	0.968	77.8	27.1	164.8	95.0	16.0	67.06
054N2	771020.77000	0.567	0.847	86.5	27.6	162.4	95.5	15.1	64.50
060B1	851021.13160	0.607	1.023	76.9	27.9	163.4	94.9	15.3	67.72
208S1	661021.31978	0.586	0.997	79.9	27.9	163.1	94.5	15.3	67.08
325P1	581021.34281	0.618	0.945	77.3	28.0	164.2	96.4	15.6	66.81
032B1	841020.95850	0.571	0.979	82.1	28.0	162.9	94.2	15.3	66.61
333P1	581021.36744	0.560	0.837	87.8	28.0	163.5	96.0	15.6	64.31
058D3	621021.80200	0.571	0.956	82.7	28.4	163.1	95.0	15.4	66.30
112D8	821021.89500	0.540	0.911	87.7	28.4	162.1	94.5	15.1	65.10
077O4	631022.04700	0.547	0.807	90.5	28.4	162.9	96.5	15.4	63.60
055N2	771021.70000	0.607	0.989	77.6	28.5	162.8	95.9	15.0	67.20
056N2	771021.73000	0.583	0.962	81.0	28.5	162.5	95.4	15.0	66.50
344J1	521021.34780	0.613	0.958	77.6	28.6	164.8	96.7	15.9	66.98
278H1	521021.43514	0.599	0.958	79.3	28.6	163.7	96.2	15.5	66.73
046T2	921021.68825	0.583	0.976	80.8	28.6	163.5	95.4	15.5	66.77
064O4	621021.91500	0.577	1.144	77.8	28.6	164.2	93.2	15.9	69.20
128D2	581021.97500	0.512	0.826	94.2	28.6	162.6	95.4	15.5	63.30
169B1	901022.10170	0.570	0.957	82.7	28.6	164.4	95.2	16.0	66.40
078O1	581022.09600	0.653	1.213	68.1	28.8	164.1	95.9	15.3	70.80
037N2	761021.71000	0.559	0.872	86.6	28.8	161.1	96.0	14.5	64.70
212N2	871022.77000	0.546	0.935	86.2	29.0	165.4	95.2	16.6	65.80
113D8	821022.79200	0.575	0.984	81.5	29.3	163.5	95.7	15.5	66.80
350J1	521022.31903	0.593	0.952	80.1	29.5	164.0	97.0	15.6	66.60
351J1	521022.33811	0.533	0.970	86.7	29.5	163.7	94.7	15.9	66.07
352J1	521022.37746	0.576	0.946	82.4	29.6	163.5	96.5	15.5	66.26

IC	$d.t.$	q	e	ω	Ω	i	α	δ	v_g
281H1	521022.40394	0.563	0.983	82.9	29.6	164.6	95.7	16.1	66.72
353J1	521022.43449	0.546	0.980	85.0	29.6	165.2	95.2	16.5	66.50
076C1	581023.07780	0.585	1.069	78.4	29.7	163.6	95.5	15.5	68.18
124W1	461023.29000	0.535	0.916	88.1	30.0	162.8	96.0	15.4	65.18
021E1	681023.09177	0.520	0.979	88.0	30.2	167.1	95.0	17.5	66.26
059D3	631023.94000	0.582	0.983	80.6	30.3	163.4	97.0	15.4	66.90
283H1	521023.32858	0.579	0.973	81.2	30.5	165.3	97.4	16.3	66.84
065O4	621023.90800	0.630	1.188	71.0	30.5	164.1	97.0	15.4	70.30
285H1	521023.38440	0.577	0.973	81.4	30.6	166.8	97.5	17.0	66.91
066O4	621023.96100	0.526	1.109	84.0	30.6	164.1	93.7	16.1	68.20
284H1	521023.37987	0.573	1.080	79.4	30.6	164.8	95.9	16.1	68.31
287H1	521023.45794	0.510	0.949	90.0	30.7	165.5	95.5	16.8	65.55
290H1	521023.49375	0.556	0.967	84.1	30.7	163.3	96.7	15.5	66.32
286H1	521023.45296	0.590	1.004	79.2	30.7	163.8	97.4	15.5	67.32
291H1	521023.49586	0.596	1.005	78.4	30.7	164.1	97.7	15.6	67.44
125W1	391024.40000	0.548	0.942	85.8	30.9	163.2	97.0	15.5	65.82
239P1	571024.31730	0.522	1.032	86.3	31.2	155.9	94.5	12.4	66.28
243P1	571025.34235	0.517	0.866	92.0	32.3	162.1	98.5	15.1	64.07
244P1	571025.38052	0.559	1.000	82.8	32.3	163.3	98.0	15.4	66.89
105E1	791026.05052	0.515	0.915	90.5	32.3	162.7	97.7	15.4	64.90
013G1	761025.31900	0.555	0.882	86.8	32.4	164.7	99.7	16.0	65.10
113I1	781028.30100	0.541	0.986	85.2	34.8	163.6	100.2	15.5	66.50
019O1	571028.10300	0.572	1.068	79.7	35.0	168.5	100.9	17.6	68.40
020O1	571029.09800	0.516	0.982	88.2	36.0	164.7	100.7	16.1	66.20

Table 4. Selected Eta Aquariids - IC - identification code, $d.t.$ - date (yymmdd.) and time (.ttttt), q - perihelion distance in AU, e - eccentricity, ω - argument of perihelion in degrees, Ω - longitude of ascending node and i - inclination of the plane of the meteor orbit to the ecliptic in degrees, α - right ascension and δ - declination of the radiant in degrees, v_g - geocentric velocity in km per second.

IC	$d.t.$	q	e	ω	Ω	i	α	δ	v_g
125J1	540503.45107	0.562	0.954	95.4	43.1	163.3	336.1	-1.6	65.49
211N2	870504.80000	0.569	0.913	95.0	44.0	162.8	336.1	-1.3	64.90
008U1	860504.72081	0.567	0.944	95.6	44.1	165.1	337.0	-2.1	65.50
009U1	820504.77232	0.584	0.970	98.4	44.2	163.4	336.6	-1.3	66.00
215N2	890504.77000	0.591	0.953	98.7	44.4	162.8	336.3	-1.1	65.80
217N2	890504.78000	0.563	0.925	94.7	44.4	164.1	337.0	-1.6	65.10
216N2	890504.78000	0.577	0.974	97.7	44.4	163.7	337.1	-1.3	66.00
220N2	890504.81000	0.545	0.894	91.5	44.5	163.3	337.1	-1.3	64.30
221N2	890504.82000	0.567	0.944	95.6	44.5	163.6	337.1	-1.3	65.40
222N2	890504.83000	0.556	0.885	92.6	44.5	163.1	336.6	-1.3	64.30
224N2	890505.76000	0.560	0.927	94.3	45.4	164.7	338.1	-1.5	65.10

IC	*d.t.*	q	e	ω	Ω	i	α	δ	v_g
223N2	890505.76000	0.587	0.964	98.6	45.4	164.2	337.6	-1.3	66.00
226N2	890505.77000	0.577	0.932	96.5	45.4	164.5	337.6	-1.5	65.40
225N2	890505.77000	0.563	0.911	94.2	45.4	163.1	337.6	-0.9	64.80

4. Access to the data in a digital form

The lists of selected Orionids and Eta Aquariids (Tab. 3 and Tab. 4) are available in a digital form as a plain ASCII files from the web address:
http://www.astro.sk/caosp/Eedition/FullTexts/vol43no2/pp135-141.dat/.
Please, feel free to use catalogue data, provided that this paper is quoted in each official usage of the catalogue, or its part.

Acknowledgements. This research was supported by VEGA - the Slovak Grant Agency for Science (grant No. 2/0022/10).

References

Hajduk, A.: 1986, in *Dynamics of Comets: Their Origin and Evolution*, eds.: A. Carusi and G.B. Valsecchi, Reidel Publ. Comp., Dordrecht, 399-403

Hajduková, M.: 2008, *Earth, Moon, Planets* **102**, 67-71

Hasegawa, I.: 1990, *Astron. Soc. Japan* **42**, 175-186

Kaňuchová, Z., Svoreň, J., Neslušan, L.: 2005, *Contrib. Astron. Obs. Skalnaté Pleso* **35**, 135-162

Lindblad, B.A., Neslušan, L., Porubčan, V., Svoreň, J.: 2003, *Earth, Moon, Planets* **93**, 249-260

Marsden, B.G., Williams, G.V.: 1997, *Catalogue of Cometary Orbits 1997, IAU CBAT MPC* , Cambridge

Porubčan, V., Svoreň, J., Neslušan, L.: 1995, *Planet. Space. Sci.* **68**, 471-478

Svoreň, J., Kaňuchová, Z., Jakubík, M.: 2006, *Icarus* **183**, 115-121

Svoreň, J., Neslušan, L., Porubčan, V.: 2000, *Planet. Space Sci.* **48**, 933-937