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

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**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 $\omega$-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 km$s^{-1}$ 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 $\omega$, longitude of ascending node $\Omega$, inclination $i$) and 3 geocentric parameters (right ascension $\alpha$ and declination $\delta$ 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 | $q$ | $e$ | $\omega$ | $\Omega$ | $i$ | $\alpha$ | $\delta$ | $v_g$ |
|---|---|---|---|---|---|---|---|---|
| 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 | $q$ | $e$ | $\omega$ | $\Omega$ | $i$ |
|---|---|---|---|---|---|
| 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.).

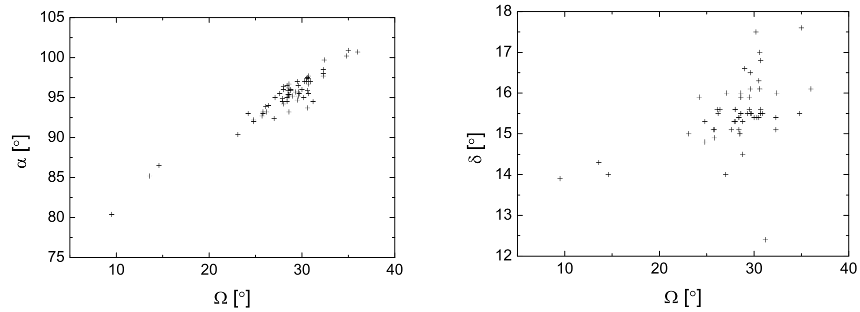


**Figure 1.** The distributions of right ascension (left) and declination (right) of the Orionids radiants depending on the length of the ascending node.

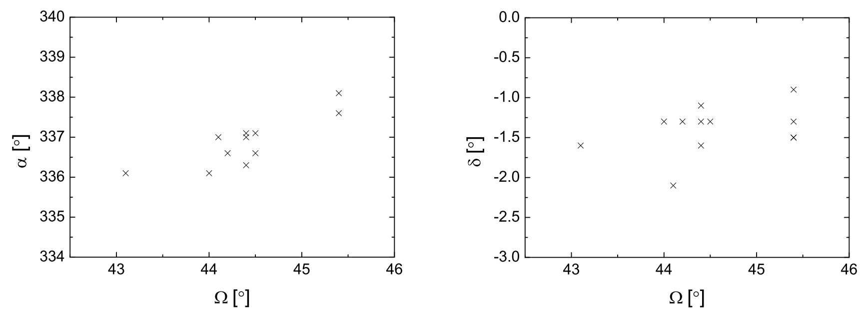


**Figure 2.** The distributions of right ascension (left) and declination (right) of the radiants of Eta Aquariids depending on the length of the ascending node.

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

| *IC* | *d.t.* | $q$ | $e$ | $\omega$ | $\Omega$ | $i$ | $\alpha$ | $\delta$ | $v_g$ |
|---|---|---|---|---|---|---|---|---|---|
| 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 |

| $IC$ | $d.t.$ | $q$ | $e$ | $\omega$ | $\Omega$ | $i$ | $\alpha$ | $\delta$ | $v_g$ |
|---|---|---|---|---|---|---|---|---|---|
| 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, $\omega$ - argument of perihelion in degrees, $\Omega$ - longitude of ascending node and $i$ - inclination of the plane of the meteor orbit to the ecliptic in degrees, $\alpha$ - right ascension and $\delta$ - declination of the radiant in degrees, $v_g$ - geocentric velocity in km per second.

| $IC$ | $d.t.$ | $q$ | $e$ | $\omega$ | $\Omega$ | $i$ | $\alpha$ | $\delta$ | $v_g$ |
|---|---|---|---|---|---|---|---|---|---|
| 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.* | $q$ | $e$ | $\omega$ | $\Omega$ | $i$ | $\alpha$ | $\delta$ | $v_g$ |
|---|---|---|---|---|---|---|---|---|---|
| 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.

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