A STUDY OF METEOR ORBITS OBTAINED IN JAPAN

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ABSTRACT. A list of 325 two-station photographic meteor orbits obtained with 35 mm cameras has recently been published by Japanese amateur groups. The present study analyzes the data and concludes that the orbits are of high quality and very useful for scientific purposes.

Introduction

The first double station observations of meteors in Japan were made at the Tokyo Observatory in the 1950:s (Hirose, Kako and Tomita 1950, Hirose and Tomita 1950, 1955). In the 1960:s several amateur groups started to make double station observations of meteors using equatorially mounted 35 mm cameras equipped with rotating shutters. Exact timing of the meteor was accomplished by visual observers. The resulting orbits were originally published in various reports of the Nippon Meteor Society (Ochai 1984, Ochai, Ohtsuka and Sekiguchi 1989). A summary list containing 325 radiants and orbits, in the following denoted NMS data, has recently appeared in the scientific literature (Koseki 1990, Koseki, Sekiguchi and Ohtsuka 1990). The author become aware of these observations a few years ago and has used the orbital data in two recent publications (Lindblad 1990a, b). The purpose of the present paper is to search the NMS data set for meteor streams and to compare the mean stream orbits with those of other investigators. Various data checks are also applied to the NMS data sample.

Meteor Stream Search

In the present study a computer program based on the D-criterion of Southworth and Hawkins (1965) is used for identifying meteor streams. The computer program searches for similar orbits and groups them into streams at a specified level of orbital similarity D_s. The appropriate level D_s to be used in a computer search depends on sample size (Lindblad 1971a, b). For a sample of 325 orbits the appropriate rejection level is $D_s=0.20$. The computer search at this level identified 14 streams with two or more members in the NMS sample; comprising in all 269 stream members. Streams with only one member in the sample are not recognized by the program. It follows that at least 83% of the listed NMS meteors are in streams. The results of the stream search (which entirely confirmed the shower classifications previously made by Koseki et al.) are

A.C. Levasseur-Regourd and H. Hasegawa (eds.), Origin and Evolution of Interplanetary Dust, 299–302.

Table 1. Mean orbital elements of meteor streams (35 mm cameras)

Name	N	α	δ	V_G	q	a	e	i	ω	Ω
α Capric.	4	310	-23	19	0.727	2.682	0.729	2.8	70.8	317.4
N χ Orion.	3	87	24	30	0.425	2.492	0.830	0.1	284.7	259.7
S χ Orion.	3	79	18	26	0.572	2.647	0.785	4.1	87.8	80.1
Taurids	3	51	13	32	0.343	2.327	0.852	6.5	115.0	39.9
Geminids	100	113	33	35	0.149	1.246	0.878	23.2	324.8	261.3
κ Cygnids	4	285	42	23	0.955	3.378	0.717	29.1	207.9	139.7
Monoc.	5	102	7	43	0.202	11.223	0.981	35.3	127.4	80.8
Quadr.	24	231	49	43	0.983	2.964	0.668	71.8	169.0	282.5
Lyrids	2	272	34	47	0.913	13.934	0.935	78.8	215.9	31.3
Perseids	79	46	57	59	0.940	7.770	0.877	113.0	148.6	139.2
Hyp. Pers.	17	-	-	-	0.955	12.484	1.224	115.4	154.5	139.0
Orionids	6	95	15	65	0.556	5.099	0.892	163.2	85.6	27.8
Eta Aq.	13	335	-2	65	0.590	8.354	0.933	163.9	95.1	44.0
Leonids	3	154	21	72	0.985	19.531	0.950	163.5	170.7	235.6

Note. Mean semi major axis is calculated as $a = 1/\overline{1/a}$, other mean elements are arithmetic means.

Table 2. Mean orbital elements of meteor streams in search in IAU data

Name	N	α	δ	V_G	q	a	e	i	ω	Ω
α Capric.	18	307	-9	25	0.576	2.386	0.758	7.3	270.2	126.9
N χ Orion.	4	103	26	29	0.463	1.995	0.768	4.1	282.7	274.2
S χ Orion.	-									
Taurids	140	47	15	31	0.370	2.048	0.821	3.1	112.3	37.8
Geminids	84	111	32	37	0.140	1.389	0.899	23.5	324.3	260.2
κ Cygnids	7	289	55	27	0.985	4.257	0.769	38.2	199.8	147.7
Monoc.	2	102	8	44	0.183	65.789	0.998	37.1	129.1	80.3
Quadr.	14	230	49	43	0.978	3.028	0.677	71.9	171.1	282.4
Lyrids	5	273	34	48	0.920	21.552	0.957	79.4	214.4	31.9
Perseids	182	45	58	60	0.947	25.641	0.964	113.1	150.2	138.3
Hyp. Pers.	4	43	57	68	0.971	-	1.690	117.6	159.1	137.8
Orionids	27	94	16	68	0.575	11.487	0.951	164.3	82.7	28.2
Eta Aq.	-									
Leonids	7	152	22	72	0.985	14.265	0.931	162.3	172.1	234.5

summarized in Table 1. Table 1 lists the numbers of members in each stream, mean values of radiant, geocentric and heliocentric velocity and orbital elements (referred to the mean equinox of 1950). For comparison the corresponding mean values obtained by the author in a computer search in a sample of 1827 precisely reduced photographic orbits from various professional programs are shown in Table 2 (Lindblad 1971c, 1987). Only streams represented in the NMS data are listed in Table 2.

Since the NMS sample included many long-period meteor streams the mean semi major axis is computed in Tables 1 and 2 as $a = 1/\overline{1/a}$. Mean radiant and geocentric velocity are computed by the program. All other orbital elements are arithmetic means. Inspection of the data shows that there is good agreement between the two sets. With the exception of the streams identified by the author as α Capricornids and κ Cygnids (which are very complex and the identification of which are doubtful), the differences in radiant position are of the order of 1 degree. Agreement in the orbital elements is also very good. This shows that the NMS data set is very useful for statistical studies. It is interesting to note that several minor meteor streams (S χ Orionids, Monocerotids and Eta Aquarids) are better represented in the Japanese amateur sample than in the much larger sample obtained by professional astronomers! The main difference between the two data sets is that the professional data in general show slightly higher values of velocity V_G and semi-major axis (Table 3). The discrepancy is most likely caused by a neglect of the correction for atmospheric deceleration in most of the NMS data.

Table 3. Derived values of semi-major axis

Stream	a_{NMS} (a.u.)	a_{1827} (a.u.)
Geminids	1.248	1.389
Perseids	7.770	25.641
Quadrantids	2.964	3.028

Checks of Consistency

Various routine checks of the consistency of the orbital elements of individual orbits have been made. These checks are based on the following equations:

$$D1 = q - a(1 - e) \qquad (1)$$

$$D2 = R - q(1 + e)/1 + e \cos \omega \qquad (2)$$

$$D3 = 1/a - (2/R - c \cdot V_h^2) \qquad (3)$$

where R is the radius vector of the Earth's orbit in a.u., V_h is the heliocentric velocity of the meteor in km/s, c is a conversion factor and q, a, e and ω are the meteoroid's orbital elements. If the data are consistent, then D1, D2 and D3 $\simeq$ 0. Checks in the NMS data based on eq. (1) always gave D1 = 0. The data sample was next divided into four subsets as shown in Table 4 and checks based on eqs. (2) and (3) were made. Since there is some overlap between the subset designations of Koseki et al. the subsets were selected in the order TN, * and +.

Table 4.

Data sample subsets	Designation in Koseki et al.	Total no.	s.d. of $\Delta(1/a)$	No. of approx. solutions R = 1
Tokyo network	TN	16	0.0021	0
Re-reduced orbits	*	46	0.0098	2
Amended orbits	+	86	0.0076	3
Remaining orbits		177	0.0197	74

Here $\Delta(1/a)$ = D3 is the difference between the published value of 1/a and the value computed from the heliocentric velocity. The s.d. of this value in each subset is a measure of the errors in the semi major axis. Table 4 shows that the re-reduced data sets marked TN, *, or + in Koseki (1990) and Koseki et al. (1990) are practically error free. Of the remaining 177 orbits about half exhibit minor discrepancies in eqs. (2) and (3). A further study showed that the orbit calculation had been based on the approximation $R=1$, i.e. a circular earth orbit. This approximation is sometimes used in studies of radio meteors, but it should be avoided in precise photographic meteor studies. The assumption $R=1$ implys that the errors in the orbital elements will vary slightly with date, being largest at the Earth's aphelion and perihelion points. It would be desirable to recompute these orbits. However, for most of these objects the films and original measurements are not available any more. We have therefore instead introduced two different quality classes for the data, depending on whether or not the exact value of R was used.

Conclusion

The NMS meteor data is of high quality and is very useful for statistical studies. This new data set represents a significant increase in the total number of precisely reduced photographic orbits available to the meteor scientist. The sample will be included in the official IAU meteor data center file.

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