

SEARCH FOR ASSOCIATIONS BETWEEN FIREBALL STREAMS AND ASTEROIDS

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Abstract. A procedure was applied to find associations between the fireball streams and the AAA asteroids known until July, 1994. The search is based on the orbital comparison considering D-discriminant, activity period, and the radiant. Possible associations are discussed.

Key words: Meteoroid streams, fireballs.

1. Introduction

More authors (Olsson-Steel, 1987; Drummond, 1991; Štohl and Porubčan, 1993) have been dealing with the problem of possible asteroidal origin of meteoroid streams in recent past. It is suggested that some of the streams may be associated with asteroids and in addition, with comets and some asteroids as is the case of the Taurid meteor complex (Porubčan et al, 1992).

The present paper deals with a search for possible associations between new fireball streams found by Porubčan and Gavajdová (1994) obtained on the basis of all precise photographic orbits available from the IAU Meteor Data Center in Lund (Lindblad, 1987, 1991). Data of the AAA asteroids known until July 28, 1994 are obtained from the Minor Planet Circulars/ Minor Planets and Comets published by Minor Planet Center, Smithsonian Astrophysical Observatory in Cambridge (compiled and kindly provided by Dr. D.I.Steel).

2. Procedure of the search for asteroid - fireball stream associations

The fireball streams which constitute the basis for the present analysis were found among the set of 1028 fireballs of photographic magnitude -3 and brighter (IAU Meteor Data Center catalogue) with their orbital elements, velocities and radiant positions (Porubčan and Gavajdová, 1994). The mean orbits of the streams are listed in Table 1.

For the evaluation of a similarity between the mean orbit of a fireball stream and the AAA asteroids, the Southworth-Hawkins D-criterion was used (Southworth and Hawkins, 1963). In the first step for each stream listed in Table 1, we looked for asteroids which are moving in similar orbits and might be associated

Table 1. Mean orbital parameters of the fireball streams with $M_{ph} \leq -3$ do not belonging to the known meteor streams.

No.	Shower	Period	α	δ	V_p	q	a	e	i	ω	Ω	π	n	N	N
														($D \leq 0.30$)	($D \leq 0.20$)
1	α Cancerids	13 Jan - 7 Feb	135.4	6.3	19.3	0.484	1.167	0.583	7.2	112.6	123.5	236.1	3	5	0
2	β Cancerids	31 Jan - 10 Feb	121.3	9.5	14.8	0.794	1.981	0.603	4.6	61.4	136.2	197.6	3	7	4
3	Lynxids	24 Feb - 7 Mar	123.5	50.3	9.4	0.962	1.965	0.511	7.4	204.1	339.4	183.5	3	9	4
4	March Cassiopeids	4 Mar - 21 Mar	359.6	50.6	13.4	0.930	2.322	0.600	15.2	146.3	350.5	136.8	4	11	2
5	α Coma Berenicids	7 Apr - 21 Apr	193.1	22.9	16.7	0.839	2.680	0.687	11.9	232.5	22.1	254.6	5	5	0
6	γ Corvids	14 Apr - 7 May	183.2	-15.5	13.9	0.867	2.262	0.617	5.0	50.0	212.7	262.7	5	14	1
7	β Librids	24 Apr - 3 May	226.8	-8.7	28.3	0.418	2.531	0.836	9.1	286.5	38.3	324.8	3	0	0
8	η Ursa Maiorids	21 Apr - 15 May	212.0	47.7	14.8	0.963	2.205	0.570	19.1	207.6	39.4	247.0	3	3	0
9	ν Ursa Maiorids	4 May - 26 May	180.6	35.3	8.2	1.006	1.976	0.491	7.2	189.6	53.7	243.3	3	9	2
10	β Cassiopeids	3 Jul - 19 Aug	352.9	58.8	50.4	0.995	18.194	0.962	89.1	192.1	125.5	317.6	6	0	0
11	λ Aquilids	14 Aug - 31 Aug	287.0	-3.8	8.6	0.956	1.795	0.466	4.5	215.2	149.5	2.7	4	22	8
12	δ Piscids	12 Sep - 19 Sep	7.0	7.0	30.4	0.272	1.977	0.862	5.2	305.2	172.6	117.8	3	2	0
13	Sept. ϵ Aquarids	12 Sep - 1 Oct	334.0	-13.8	12.8	0.884	2.564	0.654	1.0	45.2	369.8	45.0	3	8	4
14	λ Cygnids	20 Oct - 7 Nov	319.1	34.9	12.3	0.972	2.768	0.649	13.9	199.4	212.5	51.9	3	2	1
15	α Taurids	3 Dec - 18 Dec	66.6	15.6	15.2	0.738	1.901	0.602	2.8	67.0	78.9	145.9	4	9	0
16	December Aurigids	11 Dec - 31 Dec	84.9	35.5	19.5	0.668	2.279	0.695	7.2	257.7	270.0	167.7	5	6	4
17	τ Geminids (N)	19 Dec - 5 Jan	107.5	26.5	24.5	0.386	1.437	0.734	4.2	296.8	272.0	208.8	4	1	0
17	τ Geminids (S)	27 Dec - 16 Jan	108.4	16.4	23.0	0.529	2.010	0.735	4.5	94.9	104.2	199.1	6	6	0
18	December β Perseids	19 Dec - 6 Jan	43.3	41.6	11.3	0.926	2.545	0.625	7.1	212.0	273.0	125.0	3	12	3

with the streams. In the first approximation all asteroids with $D \leq 0.30$, with respect to the mean orbit of a given stream, from the set of 209 asteroids with $q \leq 1.1$, were chosen. Followingly, a stricter value of $D \leq 0.20$ was applied. The number of asteroids satisfying $D \leq 0.30$, and $D \leq 0.20$, respectively, with respect to a certain stream is presented in Table 1.

In the next step, the date within which the asteroids approach to the Earth's orbit to within $r_0 = 0.15$ AU was calculated together with the corresponding theoretical meteor radiant. The results were compared with the period of the fireball streams activity and the streams radiants.

In the next step, for the asteroids obtained by this search, we repeated the search for fireballs which might be associated with the individual asteroids, again on the basis of the D discriminant ($D \leq 0.25$ and $D \leq 0.20$).

3. Results

We can conclude that in a total 8 asteroids have been found in the case of $D \leq 0.30$ for which an association with a fireball stream (Table 1) might be suggested. The results are summarized in Table 2.

Table 2 lists the fireball streams, the number of their members (Table 1), the asteroids with which they may be orbitally associated in the case of $D \leq 0.30$, the number of fireballs orbitally associated with the asteroid (for $D \leq 0.25$ and $D \leq 0.20$) and the number of fireballs orbitally associated both with the fireball

Table 2. The fireball streams orbitally related to the asteroids for $D \leq 0.30$

No.	Shower	n	Asteroid	N ($D \leq 0.25$)	N ($D \leq 0.20$)	N
1	α Cancrids	3	1993 VD	2	1	2
2	β Cancrids	3	1991 BA	5	3	1
3	γ Corvids	5	1987 SB	12	6	1
4	η Ursa Maiorids	3	1991 DG	5	1	1
5	ν Ursa Maiorids	3	1994 NK	4	3	2
6	λ Aquilids	4	1989 VB	10	7	4
7	Sept. ι Aquarids	3	6344 P-L	12	11	2
8	α Taurids	4	1994 GK	9	2	2

stream (Porubčan, Gavajdová, 1994) and with the asteroid. Asteroid representing a certain stream was chosen from the set of asteroids given in Table 1 (column 14), according to its D value. It means that in the first step we have chosen the asteroid with the lowest value of D with respect to the stream. Then the date within which the asteroid approaches to the Earth's orbit and the period of the fireball stream activity, as well as the radiants, were compared. If the data were not consistent, the next asteroid with the next lowest D-value was chosen and compared with the stream.

It is difficult to decide on a real association due to low numbers of potential stream members and not considering orbital evolution as the suggested stream members so the potential parent bodies. According to the number of fireballs found by the search procedure a certain degree of association has shown stream no. 6 - λ Aquilids with the asteroid 1989 VB. All members of this stream ($n=4$) belong to fireballs which can be orbitally related to the asteroid 1989 VB. They are designated by an asterisk in Table 3.

Table 3. Orbital elements and D values of the fireballs which can be orbitally related to the asteroid 1989 VB (* - fireballs originally found as members of the λ Aquilids)

No	q	a	e	i	ω	Ω	D
1989 VB	1.005	1.865	0.461	2.1	329.6	38.9	
39716*	0.959	1.736	0.447	6.7	214.0	140.5	0.18
00158*	0.922	2.035	0.547	4.7	221.3	147.4	0.17
39730*	0.965	1.877	0.486	4.4	210.3	154.1	0.12
39731	0.968	1.599	0.394	7.3	31.3	335.0	0.12
00037*	0.979	1.592	0.385	2.3	207.1	156.0	0.12
00167	1.008	1.580	0.363	3.5	4.4	338.3	0.21
39757	0.997	1.766	0.435	17.6	168.4	180.3	0.24
00028	0.985	2.350	0.580	3.0	165.8	205.4	0.15
40151	0.995	2.372	0.581	1.0	183.1	208.5	0.25
00059	0.956	2.530	0.622	2.0	204.9	225.0	0.18

Table 4 lists the fireball streams which might be associated with the asteroids if we consider a lower value of $D \leq 0.20$. In the columns 5 and 6 are given the numbers of fireballs orbitally associated with the asteroid for $D \leq 0.25$ and $D \leq 0.20$, respectively, and the last column contains the number of fireballs orbitally associated both with the fireball stream and with the asteroid ($D \leq 0.20$).

Table 4. The fireball streams orbitally related to the asteroids for $D \leq 0.20$

No.	Shower	<i>n</i>	Asteroid	<i>N</i> ($D \leq 0.25$)	<i>N</i> ($D \leq 0.20$)	<i>N</i>
1	β Cancrids	3	1991 BA	4	3	1
2	ν Ursa Maiorids	3	1994 NK	3	3	2
3	λ Aquilids	4	1989 VB	8	6	4
4	Sept. ι Aquarids	3	6344 P-L	11	10	2

We have to note that the associations of the fireball streams and the asteroids listed in this paper may be considered for only potential ones due to the fact that they are suggested on the basis of a comparison of their present orbits only. A further and more detailed analysis is necessary to be done to find out if they are only chance groups or if we can speak about real associations.

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