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ON ASSOCIATIONS OF APOLLO ASTEROIDS WITH METEOR STREAMS

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Abstract

Potential associations of Apollo asteroids with meteor streams are searched on the basis of the orbital parameters comparison. From all Apollo asteroids discovered through 1991 June those are only selected for further analysis whose orbits approach to less than 0.1 AU to the Earth's orbit. Their orbits are compared with precise photographic orbits of individual meteors from the Meteor Data Center in Lund. Results on the associations of asteroids with meteor streams are presented and discussed.

Introduction

Since the time of the discovery of the asteroid 3200 Phaethon in 1983 and of its strong association with the Geminid meteor shower, earlier suggestions of the association of meteoroid streams with asteroids (cf. Sekanina, 1973, 1976; Drummond, 1982) have become more substantiated. Recently an attempt was made to find out asteroids-meteor streams associations on the basis of comparison of individual radar orbits of meteors determined by the Adelaide meteor orbit surveys with orbits of the Apollo asteroids (Olsson--Steel, 1988, 1990). Several asteroids have been proposed as very probable candidates for association with meteors. Similar search with the mean orbits of the Cook's working list of meteor streams lead Olsson-Steel to the same conclusions.

In the present paper a search for associations of asteroids with meteors is carried out on the basis of comparison between the orbits of asteroids and precise photographic meteor orbits available from the IAU Meteor Data Center in Lund.

Data and the association search

Through 1991 June there have been 174 orbits of Apollo, Amor and Aten asteroids available. Only those of them were included into our analysis, which approach the orbit of the Earth to less than 0.1 AU, their number being 90. For each of them the date of the closest approach to the Earth was calculated, together with the limiting ecliptical longitudes within which orbit of a particular asteroid is closer to the Earth orbit than 0.1 AU. These

longitudes were than accepted as limits for search of association of the particular asteroid with meteor orbits.

As a counterpart to the orbits of asteroids 3500 orbits of individual meteors from the IAU Meteor Data Center in Lund were searched. Orbit of each asteroid was compared with all meteor orbits falling within the longitudinal limits of 0.1 AU. For finding the asteroid-meteors associations the Southworth-Hawkins' D-criterion was applied (Southworth and Hawkins, 1963). As a limit for the orbital match the value D = 0.25 was taken into account, though for the association a stronger limit D = 0.20 was only accepted.

Among the 147 Apollo, Amor and Aten asteroids there were 84 cases for which no meteor orbit has been found matching their orbits within the limit of D = 0.25; for another 31 asteroids there were no meteor orbits found fulfilling the association criterion D = = 0.20. We have thus 59 asteroids, for which the association with meteor streams can be accepted with various degree of probability.

Asteroids-meteors associations and their discussion

In Table 1 general results of the search are presented in a concise form. Asteroids are somewhat arbitrarily divided into 4 groups according to the number of meteor orbits N.20 and N.25 matched to the orbits of particular asteroids within the limits, D = 0.20 and D = 0.25, respectively. The groups are chosen as follows: I - N.20 $\geq$ 8 or N.25 $>$ 13; II - N.20 $\geq$ 6 or N.25 $>$ 9; III - - N.20 $\geq$ 4 or N.25 $>$ 6; IV - N.20 $\leq$ 3. Total numbers of asteroids

Table 1. Associations of asteroids with meteors

Group	Number of asteroids	Asteroids
I. High	14 13P, 1M	(Cf. Table 2)
II. Medium	13 8P, 5M	1950 DA, 1983 LC, 1991 JX, 1 1991 FB, 1987 SF3, 4197 (1982 TA), 2061 Anza, 1990 UQ, 1990 MF, 3361 Orpheus, 3908 (1980 PA), 3757 (1982 XB), 1984 KB
III. Low	13 12P, 1M	1989 UP, 4486 Mithra, 1917 Cuyo, 1988 EG, 1989 DA, 4450 Pan, 1990 TG1, 4515 (1979 VA), 1990 UN, 1989 JA, 1988 VP4, Hermes
IV. Very low	19 15P, 2M 2T	1566 Icarus, 1862 Apollo, 2101 Adonis, 2340 Hathor, 2608 Seneca, 4034 (1986 PA), 4183 (1959 LM), 4581 (1989 FC), 4769 (1989 PB), 1983 TF2, 1987 OA, 1988 XB, 1989 QF, 1989 UQ, 1989 UR, 1990 SP, 1990 SS, 1991 GO, 1991 JR

falling into each group is given in Table 1, Col. 2, together with following specification of the asteroids: P-Apollo, M-Amor, T-Aten. The asteroids underlined have $V_G < 10$ km s^{-1}.

Group I with the largest number of meteor orbits associated with the asteroids is presented in Table 2 in more details. For each asteroid following data are given: Δr_{min} - minimum distance of the asteroidal orbit from the Earth orbit in AU, Date - the date at which Δr_{min} occurs, Δt - number of days when $\Delta r < 0.1$ AU, V_G - the geocentric velocity of the asteroid corresponding to Δr_{min}, δ - declination of the expected radiant, N - total number of meteor orbits within Δt, N_{sh} - number of meteor orbits belonging to various showers as was determined be original authors of the orbits, N.25 and N.20 - number of meteor orbits associated with the asteroid within the limits D = 0.25 and 0.20, respectively.

As was expected, the association of 3200 Phaethon with meteors, in this case belonging to the Geminid shower, is the most prominent. On the other hand, there are several other asteroids, for which the number of matched meteors is much higher than might be expected from random coincidences. They include asteroids which had been proposed by several authors as being associated with the Taurid meteor complex (5025 P-L, 2201 Oljato, 4197-1982 TA, 1984 KB) or with some minor showers (3671 Dionysius-1984 KD - τ Herculids, 1983 LC - Scorpiids, 1917 Cuyo - $\varkappa$ Cygnids, 2061 Anza - Northern ι Aquarids, 1950 DA - May Ursids, 3757-1982 XB - δ Leonids, 1986 JK - Lybrids etc.). Closer inspection of individual meteor orbits found to be matched with the orbits of asteroids reveals other close associations of asteroids with known meteor showers. Such is the case with the Delta Arietids (Kronk, 1988) which we suppose to be associated with 1990 HA showing moreover that the activity of this minor shower extends from November 26 till December 15 at least. Some of the asteroids

Table 2. Most probable associations of asteroids with meteors

Asteroid	Δr_{min}	Date	Δt	V_G	δ	N	N_{sh}	N.25	N.20
3200 Phaethon	0.025	14 Dec	6	33.6	+32	312	212	210	203
4179 Toutatis	0.007	24 Sep	58	11.9	-14	639	133	32	18
5025 P-L	0.082	8 Nov	6	28.5	+24	81	28	26	15
1990 HA	0.062	4 Dec	20	15.9	+11	437	242	23	14
3671 Dionysius	0.029	17 Jun	40	11.2	+33	186	2	15	11
1989 VB	0.016	10 Oct	86	6.4	-34	905	194	14	10
1986 JK	0.007	4 Jan	49	13.4	-9	211	3	13	10
1990 OS	0.009	15 Aug	67	9.6	-25	1349	684	14	9
1991 BA	0.001	17 Jan	21	18.0	+19	83	3	10	9
1990 UA	0.012	18 May	28	14.8	-14	111	1	12	8
4660 1982 DB	0.021	11 Dec	59	6.3	+23	696	329	19	7
1980 AA	0.054	10 Jan	56	5.2	+32	527	247	15	7
2201 Oljato	0.009	21 Dec	17	20.2	+20	305	180	13	7
1988 TA	0.026	13 May	31	12.8	-20	137	14	14	6

from Groups I-III are included in the Drummond's associations I-IV (Drummond, 1991).

It should be emphasized that the number of meteor orbits matched to the orbit of an asteroid by itself is not a sufficient measure of the reality of an association. There are several factors by which this number can be overestimated (random coincidences) or underestimated (especially low geocentric velocity which can reduce the observed number of meteors to 1-2 orders).Confirmation or refusal of the reality of the proposed associations demands therefore a careful elimination of all these effects.

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