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 $D = 0$. 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 $N.25 \geq 13$; 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>
<thead>
<tr>
<th>Group</th>
<th>Number of asteroids</th>
<th>Asteroids</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. High</td>
<td>14</td>
<td>(Cf. Table 2)</td>
</tr>
</tbody>
</table>
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 $V_G < 10 \text{ km s}^{-1}$.

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: $\Delta r_{\text{min}}$ - minimum distance of the asteroidal orbit from the Earth orbit in AU, Date - the date at which $\Delta r_{\text{min}}$ occurs, $\Delta t$ - number of days when $\Delta r < 0.1$ AU, $V_G$ - the geocentric velocity of the asteroid corresponding to $\Delta r_{\text{min}}$, $\varphi$ - declination of the expected radiant, $N$ - total number of meteor orbits within $\Delta t$, $N_{\text{sh}}$ - number of meteor orbits belonging to various showers as was determined by 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 - Κ Herculis, 1983 LC - Scorpiids, 1917 Cuyo - Ω Cygnids, 2061 Anza - Northern Ω Aquarids, 1950 DA - May Ursids, 3757-1982 XB - Ω 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

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


