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The Near-Earth Asteroid Streams

Tadeusz J. Jopek
Inst. Astr. Observatory UAM, Poznan, Poland (jopek@amu.edu.pl)

1. Introduction

The concept of the MB asteroid families is accepted beyond the doubt since the work by Hirayama. Simimlarity between the orbits of the NEAs was discovered 20 years ago by Drummond and Obrubov, [5, 17]. In [6] among 708 NEAs, Drummond found 14 NEA associations of $4-25$ members. However, he estimated that many groups found by him, might be attributed to chance alignments.

The computer searches among the meteoroids and NEAs lead to many hypotheses of the possible associations between these objects, e.g.: [22, 19, 21, 20, 8].

In this study we have made similar search using significantly larger asteroidal orbital set and restrictive cluster analysis approach.

2. Data and the method

4097 photographic meteors were extracted from the IAU Meteor Data Center [15] and supplemented by 5518 NEAs (the NeoDys website) and by 579 cometary orbits (with eccentricities $e < 1$)selected from [16] catalogue. The cometary set was increased by the orbit of comet 169P/NEAT.

As a quantitative measure of the orbital similarity we have used the D_{SH} and D_V functions introduced in [23] and [12], respectively. The thresholds of the dynamical similarity were found by the method given in [10, 11] with the reliability level 99%. Hence, in this study, probability that any single group was indetified by chance, was equal to 1% only. As a cluster analysis algorithm we have used a single neighbour linking technique, the same as in [13].

3. Results and disscussion

Seven major meteoroid streams and their parent bodies were found: Perseids and the comet Swift-Tuttle; Geminids and the NEA '3200' (Phaethon); Orionids and η Aquariids and the comet Halley; Quadrantids and the asteroid 2003EH1; Leonids and the comet Tempel-Tuttle; December Monocerotids and comet Mellish; Lyrids and the comet Thatcher. Also we have detected κ Cygnids and the N. and S. δ Aquariids. However, no parent body was fond for these streams.

Table 1: Association of the NEOs and the Taurids meteoroid complex deceted in this study.

NEO	D-	Ref.	NEO	D-	Ref.
2005 UR	SH, V	-	2004 TG10	SH, V	[20, 8]
2005 TB15	SH, V	-	2003 WP21	SH, V	[20, 9]
2006 SO198	SH, V	-	2007 RU17	SH, V	[4]
2002 MX	SH	-	2007 UL12	SH, V	[4]
2003 UV11	SH	-	2201 Oljato	V	[1, 2, 19]
2005 NX39	V	-	2005 TF50	V	[20]
2005 UY6	V	-	2P/Encke	V	-

All above results are consistent with the information given for these streams in [7]. Therefore we claim that our searching method, its actual implementation works very well.

The next results, the Taurids and α Capricornids complexes are difficult for interpretation. Here we will disscuss the case of Taurids only. With D_{SH} we found two groups of Taurids. The first one of 14 members consisted with S. Taurids only; no parent body was conected with this group. The second group included 174 Taurids (N. and S. branches) and 9 NEA's. With D_V we found 134 N. and S. Taurids, and 12 parent bodies: 11 NEA's and one comet, see Table 1. Inclusivly, 14 parent bodies of the Taurids stream has been detected, 7 of them were found in both searches. Associations among the NEA's and Taurids were known earlier, and we confirmed some of them, see references in Table 1. However, in this search no association was found between Taurids and: (4179) Toutatis [19]; 5055-PL [18, 19, 2]; 1984 KB (6063 Jason) [1, 19].

Table 2: The NEA streams detected in this study. N_M and N_A are the numbers of meteoroids and NEA's identified with D_{SH} and D_V functions.

Group name	D_{SH}		D_V	
	N_M	N_A	N_M	N_A
Association 228			5	33
Association 694			6	34
Association 1821			1	38
Association 4266			0	20
Association 495	8	19	6	27
Association 657			5	25
Association 177			15	63
Association 796	11	25		
Association 1612	3	12		
Association 43	5	17	53	449

Table 3: The members of the association 694.

7480	36017	99799	1997WB21	1998VS
2001QF96	2001SZ169	2001WH49	2001XP88	2002CY58
2002RO28	2003BQ35	2003QU5	2003TK1	2004RW2
2004SU55	2005QA5	2005SD71	2005UN	2005VS
2006SK61	2006SV5	2006UA216	2006UL	2006UN
2006UP	2006WZ184	2007BF72	2007PQ9	2007TA23
2007TT24	2007VV6	2007WZ4	2008PG1	

We found ten associations consisting mainly of the NEAs (see Table 2) mostly using D_V function.

Association 43 proved to be very sensitive on the similarity threshold applied in the cluster analysis. Using thresholds coresponding to the reliability 99%, this association merged into a hudge group with many members of α Capricornids Complex. Using more restrictive approach the hudge group decreased considerably.

Associations 228, 1821, 4226 are new ones, their members were not mentioned in [5, 6]. Using more rigorous approach they were not detected.

Association 694 is a new group: 6 meteoroids and 34 NEA's, the orbits of all members are very similar, see Figure 1. The group was detected also with more rigorous approach — 15 members were found, all but one were asteroids.

Association 177 we found with D_V function: 49 meteoroids and 198 NEAs. Using D_{SH} function, this group was detected in form of two branches: association 796 and association 1612, see Table 2. 16 members of the association 796 and 11 of the association 1612 are members of the association 177. Inside associations 177, we have noticed several members of associations A4, A8, A9, A10 and A13 identified in [6]. Using more rigorous approach, associations 796 and 1612 have dissapeared, the association 177 survived with less number of members.

Association 495 was found with D_{SH}, and more in number with D_V. 11 objects of this group one can see in the list of 13 SEA's asteroid given in [3]. Inside this association we found several meteoroid orbits very similar to the Earth orbit. Such meteoroids called "Cyclids" has been identified earlier in [23, 14, 10]. The members of the association 657 also have small eccentricities and semi-major axes close to 1 AU. They are very similar to the "Cyclids" group. Indeed, when the search was repeated using a bit less rigorous approach all members of association 657 have bound together with association 495.

4. Conclusions

In this study we have made extensive and very rigorous search for grouping among photographic meteoroids, comets and asteroids. Ten associations were found mainly consisted of minor planets, Table 2. The common origin of the members of these groups is an open question. At the moment, we want to pay attention on the remarkable orbital similarity of the members of the association 694. Also we have detected two groups of object (associations 495 and 657) moving on the orbits very similar to the Earth trajectory. Following an earlier discoveries we called this group "Cyclids".

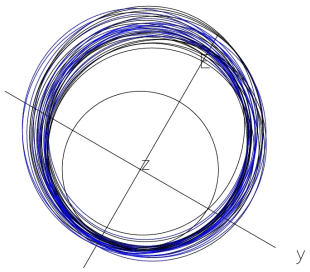

Figure 1: Association 694 plotted on the ecliptic plane. The orbits have low inclination and remarkably resemble a meteoroid stream. The Earth circular trajectory is seen inside the associaton.

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