Highlights of Astronomy, Volume 16
XXVIIIth IAU General Assembly, August 2012
T. Montmerle, ed.

doi:10.1017/S174392131401182X

The Near Earth Asteroid associations

Tadeusz J. Jopek

Astronomical Observatory Institute, Faculty of Physics, A.M. University, Poznan, Poland

Abstract. We have made an extensive search for grouping amongst the near Earth asteroids (NEAs). We used two D- functions and rigorous cluster analysis approach. We have found several new groups (associations) among the NEAs: the objects moving on similar orbits with small minimum orbital intersection distances (MOID) with the Earth trajectory. Reliability of some of these groups is quite high.
Keywords. minor planets, methods: data analysis

1. Introduction

The existence of the main belt asteroid families is beyond the doubts. However existence of groups among the NEAs, with members of common origin, suggested by similarity between their orbital parameters (Drummond (1991), Obrubov(1991), Fu *et al.*(2005), Jopek (2011), Schunová *et al.*(2012)) is not yet generally accepted. Many groups found by these authors might be attributed to chance alignments.

In this study we have searched for associations amongst 9004 NEA's osculating orbits (NEODyS, 2012) by two strict cluster analysis methods, similar to that used in Jopek (2011). Two D- functions were used: D_{SH} introduced in Southworth and Hawkins (1963) and D_H introduced in Jopek (1993). The orbital similarity thresholds corresponded to 1% probability that given group was found by chance alignment. The clusters were detected by a single neighbour linking technique.

2. Results and discussion

Using two searching methods we found 20 groups of ten or more members: 13 groups with the D_{SH} function and 9 groups using D_H function. Among 20 formally separated groups we have selected 10 associations. All but two has been found in both searches, however with different amount of members. Associations No 1 and 2 (SH -179 and SH-380) were detected only with D_{SH} function. Of course when the values of the similarity thresholds has been slightly increased, these groups were found also with D_H function. Associations No 3-7 were identified with both functions with considerable amount of members in common. In case of associations 8,9 and 10 the results shown to be more complicated: several overlapping subgroups were detected for which the common members were less numerous. In Table 1 we see that for all groups the mean orbital inclinations are smaller than 10 degrees. It is not unexpected, we should recall that all NEAs but two have $i < 75$ degrees, and for ~ 4500 orbits the inclinations are smaller than 10 degrees.

We have continued our study gradually decreasing thresholds. As was expected, amount of members of the group was decreasing; some groups were splitting and finally disappearing. Associations SH-306, SH-1385, H23 have proved to be the most robust one. On Figure 1, just for an example we have plotted the orbits of the members of association SH380.

In this study we have shown, that using similar rigorous method as for the meteoroid orbits, the NEA's associations can be found easily. However, to ensure about their common origin, the long term numerical integration is needed.

Table 1. The list of 10 NEAs associations of 10 or more members found in this study. The codes of the associations include the distance function tag and the ordinal number of the asteroid from the NEODyS list which was identified as a first group member. The name of this asteroid is also given. N is the amount of members in the group. In brackets the amount of the common members identified by both functions are given. Within each group the orbital elements were averaged by the method described in Jopek *et al.* (2006).

No	NEA	Code	N	a [AU]	q [AU]	e	i [deg]	ω [deg]	Ω [deg]
1	'13553' Masaakikiyama	SH-179	53	2.133	1.154	0.459	5.7	157.3	143.5
2	'89136' 2001US16	SH-380	24	1.375	1.025	0.254	1.0	16.0	227.3
3	'2368' Beltrovata	SH-35	77(74)	2.128	1.221	0.426	2.7	32.2	301.6
		H-35	101	2.137	1.222	0.428	3.0	31.2	305.6
4	'4660' Nereus	SH-77	63(40)	1.864	.936	0.498	1.2	37.2	82.1
		H-77	63	1.793	0.959	0.465	1.0	46.0	70.9
5	'8014' 1990MF	H-143	69	2.019	1.051	0.479	0.1	100.3	232.1
	'10860' 1995LE	SH-167	65(61)	2.135	1.111	0.480	1.3	160.9	167.4
6	'11054' 1991FA	H-168	68	1.513	0.984	0.350	0.9	84.7	349.1
	'190491' 2000FJ10	SH-866	25(23)	1.427	1.014	0.289	2.6	184.9	249.8
7	'36017' 1999ND43	SH-255	39(21)	1.425	1.012	0.290	2.6	148.5	227.1
	'256004' 2006UP	H-1050	35	1.421	1.013	0.287	2.8	157.4	217.0
8	'54509' YORP	H-295	78	1.045	1.031	0.013	1.0	321.6	224.2
	'65717' 1993BX3	SH-306	89	1.162	0.957	0.176	0.6	235.4	210.2
	'209215' 2003WP25	SH-910	23	1.082	0.926	0.144	0.8	95.9	188.8
9	'19356' 1997GH3	H-202	73	1.815	1.007	0.445	0.9	14.5	145.1
	'27002' 1998DV9	SH-236	27(21)	1.974	1.015	0.486	3.3	10.4	130.3
	'1994GV'	SH-1385	85	1.676	1.015	0.394	0.1	296.2	243.3
	'2003DW10'	H-2582	16	1.587	0.998	0.371	0.2	127.5	74.8
10	'136564' 1977VA	SH-423	17(1)	2.172	1.141	0.475	4.2	204.1	199.3
	'2061' Anza	H-23	181	2.202	1.046	0.525	0.2	201.2	182.1
	'4015' Wilson-Harrington	SH-60	196(134)	2.150	1.046	0.514	0.3	169.0	223.1

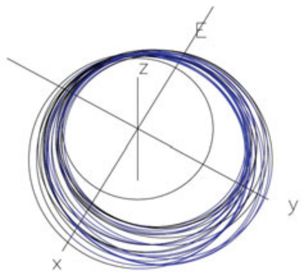

Figure 1. Association SH-380 plotted on the ecliptic plane. The orbits remarkably resemble a meteoroid stream. Association includes 24 NEAs: 89136, 26430 8,1994CJ1, 2003CC, 2003GA, 2004KG17, 2005HB4, 2005JT1, 2006HX30, 2006KL103, 2007HB15, 2008GR3, 2008LE, 2009DC12, 2009HG, 2009HH21, 2010CE55, 2011GR59, 2011GV9, 2011OK45, 2011OR5, 2011PU1, 2012GP1, 2012KT12. The Earth circular trajectory is seen inside the association.

References

Drummond, J. D. 1991, *Icarus* 89, 14

Drummond, J. D. 2000, *Icarus* 146, 453

Fu, H., Jedicke, R., Durda, D. D., Fevig, R., & Scotti, J. V., 2005, *Icarus* 178, 434

Jopek, T. J., 2011, *MemSAI* 82, 310

Jopek, T. J. 1993, *Icarus* 106, 603

Jopek, T. J., Rudawska, R., & Pretka-Ziomek, H., 2006, *MNRAS* 371, 1367

NEO Dynamic Site, 2012, August, http://newton.dm.unipi.it/neodys

Obrubov, Y. V., 1991, Complexes of Minor Solar System Bodies, *Soviet Astron.* 35, 531

Schunová, E., Granvik, M., Jedicke, R., Gronchi, G., Wainscoat, R., & Abe, S., 2012, *Icarus* 220, 1050

Southworth, R. B. & Hawkins, G. S., 1963, *Smithson. Contr. Astrophys.* 7, 261

https://doi.org/10.1017/S174392131401182X Published online by Cambridge University Press