New showers from parent body search across several video meteor databases

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This work was initiated by utilizing the latest complete set of both comets and NEOs downloaded from the JPL small-body database search engine. Rather than search for clustering within a single given database of meteor orbits, the method employed herein is to use all the known parent bodies with their individual orbital elements as the starting point, and find statistically significant associations across a variety of meteor databases (SonotaCo, 2013; CMN, 2013). Fifteen new showers possibly related to a comet or a NEO were found.

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1 Introduction

The Croatian Meteor Network (CMN) is in operation since 2007 and is described in Andreić & Šegon (2010) and Andreić et al. (2010). The catalogues of orbits for 2007 to 2009 are already published (Šegon et al., 2012; Korlević et al., 2013) and the catalogue for 2010, together with all previous ones, is available on the CMN download page (CMN, 2013). Simultaneously, the skies over Japan were monitored by the SonotaCo Meteor Network (SonotaCo, 2009; 2013). These database catalogues contain over one hundred thousand meteoroid orbits (114 280 SonotaCo from 2007 to 2011; 19 372 CMN from 2007 to 2010) that were obtained through multistation trajectory and orbital parameter estimation. In addition, the IMO video meteor database (IMO, 2012) contains nearly one and a half million single station records (1993–2012) that were used to provide further statistical relevance to a given shower's existence. Combined, these datasets cover radiants down to declination $-30°$.

The processing approach employed an extensive search for meteor orbit relationships to potential parent bodies (comets and NEOs) by applying several D-criteria restrictions with appropriate thresholds on shower membership. These are D_{SH}, D_D and D_H and were developed by Southworth & Hawkins (1963), Drummond (1981) and Jopek (1993) respectively. Each independent potential parent body was compared against every meteor orbit available, selecting orbits satisfying $D_{SH} \leq 0.15$, $D_H \leq 0.15$ and $D_D \leq 0.075$. The latest complete set of both comets and NEOs (Near-Earth Objects) was downloaded from the JPL small-body database search engine (JPL, 2013) for this purpose.

From that processing, a short list of parent bodies was obtained and the individual meteor orbits were analyzed in greater depth to evaluate the significance of each result. Thus in cases where the comet's or NEO's orbital parameters led us to the shower (using these quite strict threshold values for the D-criteria), we then searched for additional shower members by allowing a slightly larger threshold in D_{SH}. The final set of orbits for a particular shower candidate was then analyzed in more detail, including radiant plots, plots of orbital data as functions of solar longitude, mean value of D-criteria, etc. Last, single station observation data from IMO were analyzed in order to find out if the new showers could be detected in that dataset, too.

2 New showers

The file with all individual orbits of the new showers described in this article can be downloaded from the CMN download page mentioned before. The 15 showers were reported to the IAU, following the standard procedure (Jenniskens et al., 2009), and temporary shower numbers were obtained for them. The search method automatically produced the best possible parent body candidate. The orbital elements of showers discussed in this article are summarized in Table 15. Members of 13 showers discussed here were detected through analysis of the IMO single station observation database. The only 2 showers that were not found are 535 THC and 536 FSO.

2.1 γ Aquilids (531 GAQ) and C/1853 G1 (Schweizer)

A possible new meteor shower consisting of 27 meteors with mean orbit similar to C/1853 G1 (Schweizer). Shower mean orbit and comet orbit (see Table 1) are quite similar with $D_{SH} = 0.11$. This shower is active from April 27 to May 11, with peak activity around May 4. The mean daily motion of the radiant is about dRA = 0.66°, dDEC = 0.25°.

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NASA-ADS bibcode 2014JIMO...42...57S

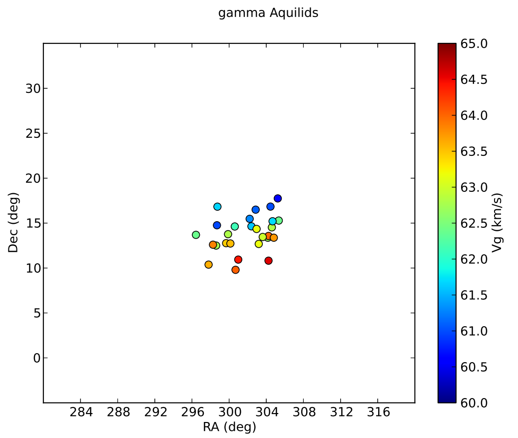

Figure 1 – Radiant plot of γ Aquilids.

Table 1 – Comparison of orbital elements of γ Aquilids (mean orbit) and the orbit of comet C/1853 G1 (Schweizer). The quantity n. dist. is nodal distance of the comet orbit from the Earth, at the node associated with the shower.

parameter	531 GAQ	C/1853 G1
q	0.988	0.909
e	0.957	0.989
ω	196.2	199.2
Ω	44.5	43.0
i	123.4	122.2
D_{SH}	0.11	
n. dist.	0.07	

2.2 May λ Draconids (532 MLD) and 209P/LINEAR

A possible new meteor shower consisting of 23 meteors with mean orbit similar to 209P/LINEAR. Shower mean orbit and comet orbit (see Table 2) differ by only $D_{SH} = 0.12$. This shower is active from April 24 to June 4, with peak activity around May 12. The mean daily motion of the radiant is about dRA $= -1.87°$, dDEC $= -0.08°$.

When we did this search, some meteor showers listed in IAU MDC database had no orbital parameters listed, not even geocentric (or any other) velocity data, but just information on mean solar longitude activity and RA, Dec. One of those showers was the 8-member shower 451 CAM, Camelopardalids, for which only $\lambda_\odot = 39.1°$, RA $= 172.6°$ and DEC $= 83.7°$ were listed. During the matching phase (between existing and possible new showers) of our search, this shower seemed to be distant from 532 MLD since the difference in solar longitude found was 13° (corresponding to almost two weeks), and radiant distances were separated by well over 10°. However, the data on this shower were updated lately and we found out that the connection with comet 209P has been claimed as well. When orbital parameters of 451 CAM and 532 MLD are compared, we may see that those two showers most probably are the same, with $D_{SH} = 0.13$ between their mean orbits.

Table 2 – Comparison of orbital elements of May λ Draconids (mean orbit) and the orbit of comet 209P/LINEAR.

parameter	532 MLD	209P
q	0.987	0.912
e	0.651	0.689
ω	164.8	149.7
Ω	51.9	66.5
i	18.7	19.2
D_{SH}	0.12	
n. dist.	0.03	

More observational data should help in finding better orbital parameters for this shower. Moreover, calculations made by Vaubaillon (2013a) suggest that meteors from comet 209P are about to produce an outburst on 2014 May 24 at $\lambda_\odot = 62.9°$, having radiant positions around RA $= 120°$, DEC $= 79°$.

2.3 July ξ Arietids (533 JXA) and C/1964 N1 (Ikeya)

A possible new meteor shower consisting of 61 meteors with mean orbit similar to C/1964 N1 (Ikeya). Shower mean orbit and comet orbit (see Table 3) are quite similar with $D_{SH} = 0.10$. This shower is active from July 4 to August 12, with peak activity around July 21. Due to the sufficient number of known orbits it is possible to accurately determine the mean daily motion of the radiant dRA $= 0.66°$, dDEC $= 0.25°$.

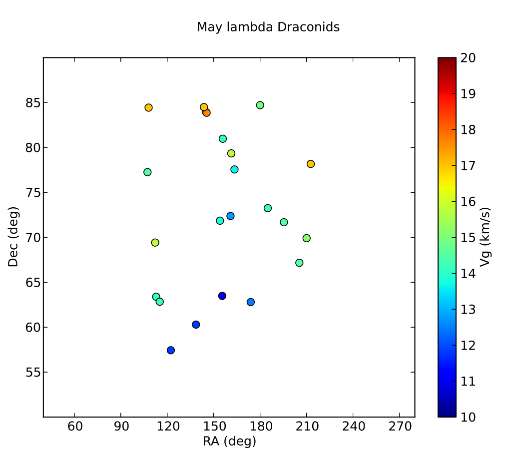

Figure 2 – Radiant plot of May λ Draconids.

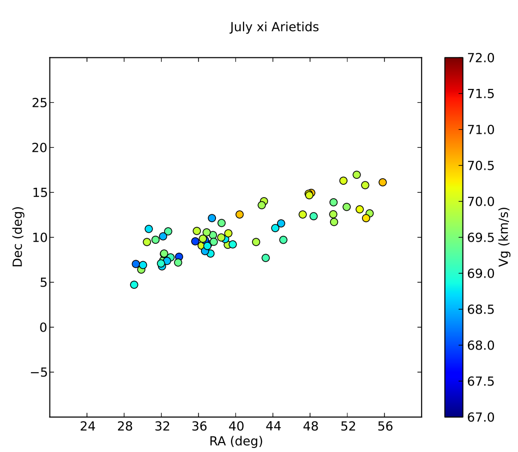

Figure 3 – Radiant plot of July ξ Arietids.

Table 3 – Comparison of orbital elements of July ξ Arietids (mean orbit) and the orbit of comet C/1964 N1 (Ikeya).

parameter	533 JXA	C/1964 N1
q	0.838	0.822
e	0.975	0.985
ω	310.3	290.8
Ω	288.9	269.9
i	171.5	171.9
D_{SH}	0.10	
n. dist.	0.21	

2.4 51 Andromedids (534 FOA) and C/1870 K1 (Winnecke)

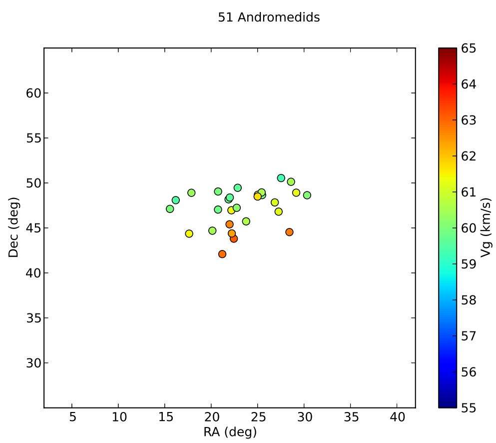

Figure 4 – Radiant plot of 51 Andromedids.

A possible new meteor shower consisting of 28 meteors with mean orbit similar to C/1870 K1 (Winnecke). Shower mean orbit and comet orbit (see Table 4) differ by D_{SH} = 0.17. This shower is active from August 1 to August 15, with peak activity around August 8. The mean daily motion of the radiant is about dRA = 0.90°, dDEC = 0.27°.

The comet C/1870 K1 (Winnecke) has a parabolic orbit, but this is just a best-fit orbit to the positional data, so the possibility that it is actually a long period comet on a highly eccentric elliptical orbit is quite real.

Table 4 – Comparison of orbital elements of 51 Andromedids (mean orbit) and the orbit of comet C/1870 K1 (Winnecke).

parameter	534 FOA	C/1870 K1
q	0.997	1.009
e	0.876	1.000
ω	194.7	198.2
Ω	136.0	143.6
i	120.7	121.8
D_{SH}	0.17	
n. dist.	0.03	

2.5 θ Cetids (535 THC) and C/1939 H1 (Jurlof-Achmarof-Hassel)

A possible new meteor shower consisting of 15 meteors with mean orbit similar to C/1939 H1 (Jurlof-Achmarof-Hassel). Shower mean orbit and comet orbit (see Table 5) are very similar, with D_{SH} = 0.07 only. This shower is active from July 31 to August 19, with peak activity around August 9. The mean daily motion of the radiant is roughly: dRA = 0.82°, dDEC = 0.37°.

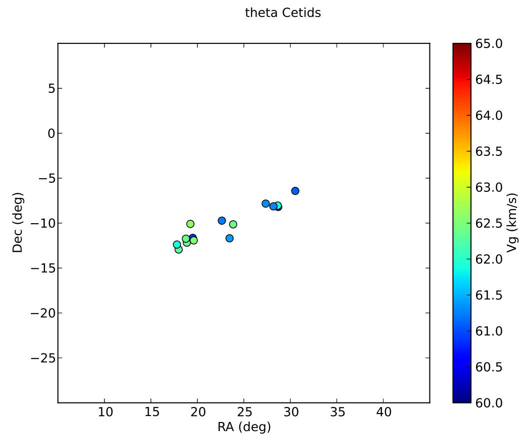

Figure 5 – Radiant plot of θ Cetids.

Table 5 – Comparison of orbital elements of θ Cetids (mean orbit) and the orbit of comet C/1939 H1 (Jurlof-Achmarof-Hassel). This comet comes near Earth's orbit at both nodes.

parameter	535 THC	536 FSO	C/1939 H1
q	0.499	0506	0.528
e	0.969	0.979	0.998
ω	91.8	90.9	89.2
Ω	316.8	319.7	312.3
i	138.0	137.6	138.1
D_{SH}	0.07	0.11	
n. dist.	0.04	0.07	

The search also found 3 meteors that may be the second shower associated with this parent body, the 47 Ophiuchids (536 FSO, also shown in Table 5). Very roughly this second shower is active from January 31 to February 13, with a very rough estimation of daily motion of dRA = 0.8°, dDEC = 0.0°.

2.6 κ Aurigids (537 KAU) and C/1957 U1 (Latyshev-Wild-Burnham)

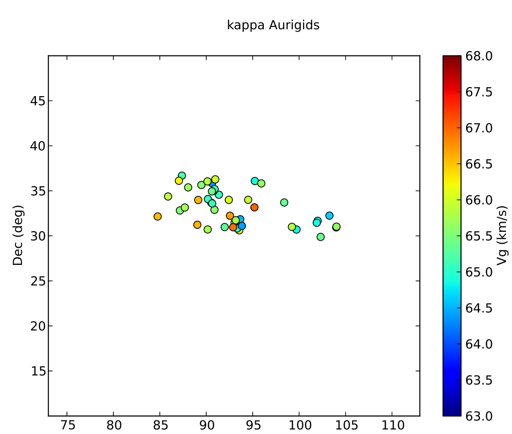

Figure 6 – Radiant plot of κ Aurigids.

A possible new meteor shower consisting of 45 meteors with mean orbit similar to C/1957 U1 (Latyshev-Wild-Burnham). Shower mean orbit and comet orbit (see Table 6) are very similar, with $D_{SH} = 0.07$ only. This shower is active from October 11 to October 31, with peak activity around October 20. Due to the sufficient number of known orbits it is possible to determine the mean daily motion of the radiant accurately: dRA = 1.03°, dDEC = −0.19°.

Again, the nominal orbit of comet C/1957 U1 (Latyshev-Wild-Burnham) is parabolic, but the possibility that it actually is a long period comet on a highly eccentric elliptical orbit is quite real.

Table 6 – Comparison of orbital elements of κ Aurigids (mean orbit) and the orbit of comet C/1957 U1 (Latyshev-Wild-Burnham).

parameter	537 KAU	C/1957 U1
q	0.543	0.539
e	0.958	1.000
ω	266.0	277.6
Ω	207.5	210.9
i	158.8	156.7
D_{SH}	0.07	
n. dist.	0.05	

2.7 55 Arietids (538 FFA) and C/1948 L1 (Honda-Bernasconi)

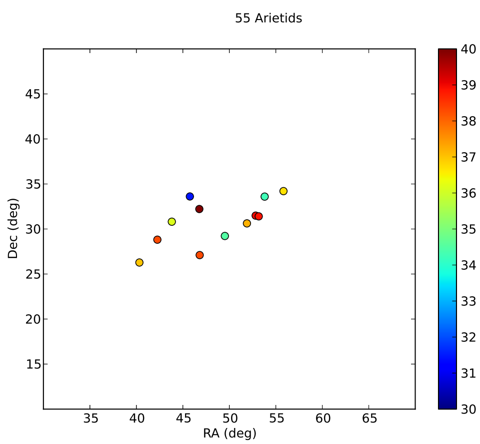

Figure 7 – Radiant plot of 55 Arietids.

A possible new meteor shower consisting of 12 meteors with mean orbit similar to the orbit of C/1948 L1 (Honda-Bernasconi). Shower mean orbit and comet orbit (see Table 7) are similar, with $D_{SH} = 0.10$. This shower is active from October 19 to November 3, with peak activity around October 27. An estimation of the mean daily motion of the radiant is about: dRA = 0.98°, dDEC = 0.22°.

This is another case of a long period comet with eccentricity very close to 1. The nodal distance is at the moment very large, but it is quite possible that the meteors observed recently are ejected a sufficiently long time ago so that orbital evolution eventually brought them into collision with Earth.

Table 7 – Comparison of orbital elements of 55 Arietids (mean orbit) and the orbit of comet C/1948 L1 (Honda-Bernasconi).

parameter	538 FFA	C/1948 L1
q	0.213	0.208
e	0.942	0.99987
ω	308.5	317.1
Ω	214.0	203.8
i	24.2	23.1
D_{SH}	0.10	
n. dist.	0.55	

2.8 α Cepheids (539 ACP) and 255P/Levy

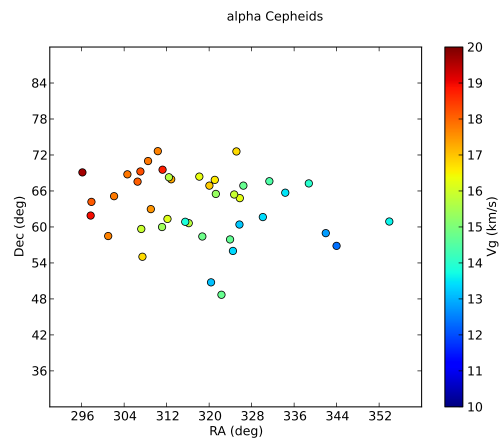

Figure 8 – Radiant plot of α Cepheids.

A possible new meteor shower consisting of 41 meteors with mean orbit similar to the orbit of 255P/Levy. Shower mean orbit and comet orbit (see Table 8) are similar, with $D_{SH} = 0.10$. This shower is active from December 16 to January 17, with peak activity around January 2. Due to the sufficient number of known orbits it is possible to determine the mean daily motion of the radiant: dRA = −0.45°, dDEC = −0.32°.

The connection of a meteor shower to the comet 255P/Levy was predicted by Vaubaillon (2013b). He linked this comet's theoretical shower to the December

Table 8 – Comparison of orbital elements of α Cepheids (mean orbit), the orbit of comet 255P/Levy and radiant data.

parameter	539 ACP	255P/Levy	Vaubaillon
max.	Jan. 2		Dec. 31
RA	318		332.8
DEC	64		55.8
v_g	15.9		13.5
q	0.979	1.008	
e	0.635	0.668	
ω	181.7	179.7	
Ω	281.0	279.7	
i	22.9	18.3	
D_{SH}	0.10		
n. dist.	0.01		

ϕ Cassiopeiids (446 DPC) from the IAU MDC database. However, the two showers (539 ACP and 446 DPC) are clearly unrelated, as the radiants are separated by about 60° in RA and moreover, the maximum activity of 446 DPC falls almost a month earlier, at December 5. The radiant of 539 ACP is much closer to the theoretical comet radiant, but still about 15° from Vaubaillon's prediction. However, the spread of the 539 ACP radiant is quite large and the radiant of the shower predicted by Vaubaillon falls inside the radiants of individual meteors of 539 ACP. Also, the maximum activities of the two differ by less than 3 days.

2.9 θ Craterids (540 TCR) and C/2012 C2 (Bruenjes)

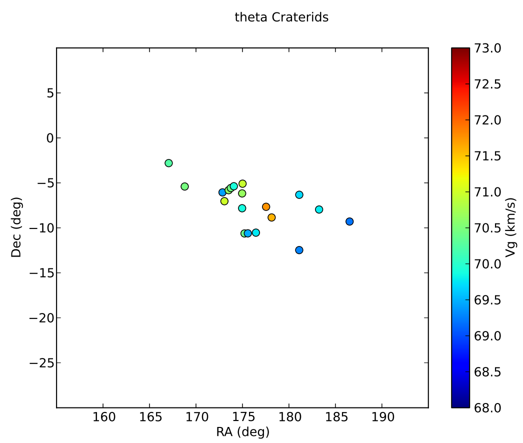

Figure 9 – Radiant plot of θ Craterids.

A possible new meteor shower consisting of 19 meteors with mean orbit similar to C/2012 C2 (Bruenjes). Shower mean orbit and comet orbit (see Table 9) are very similar, with $D_{SH} = 0.07$ only. This shower is active from December 20 to January 17, with peak activity around January 4. The mean daily motion of the radiant is about dRA = 0.70°, dDEC = −0.28°.

Table 9 – Comparison of orbital elements of θ Craterids (mean orbit) and the orbit of comet C/2012 C2 (Bruenjes).

parameter	540 TCR	C/2012 C2
q	0.821	0.802
e	0.971	1.003
ω	48.1	62.7
Ω	103.3	118.0
i	164.5	162.8
D_{SH}	0.07	
n. dist.	0.10	

2.10 66 Draconids (541 SSD) and 2001 XQ

A possible new meteor shower consisting of 43 meteors with mean orbit similar to 2001 XQ. Shower mean orbit and asteroid orbit (see Table 10) are quite similar with $D_{SH} = 0.09$. This shower is active from November 23 to December 21, with peak activity around December 7.

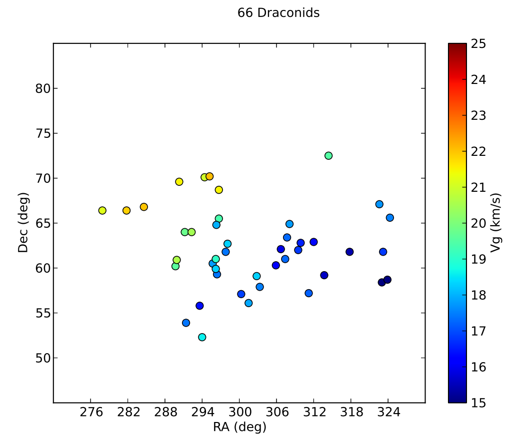

Figure 10 – Radiant plot of 66 Draconids.

Table 10 – Comparison of orbital elements of 66 Draconids (mean orbit) and the orbit of asteroid 2001 XQ.

parameter	541 SSD	2001 XQ
q	0.981	1.035
e	0.657	0.716
ω	184.8	190.1
Ω	255.2	251.4
i	27.2	29.0
D_{SH}	0.094	
n. dist.	0.04	

The mean daily motion of the radiant is dRA = −0.54°, dDEC = −0.30°, but the fit to actual data is poor.

2001 XQ is classified as an asteroid, but the body is on an orbit typical of the Jupiter family of comets opening the possibility that it is actually a dormant or extinct comet, which was active in the recent past, rather than an asteroidal body.

2.11 δ Sextantids (542 DES) and C/1943 R1 (Daimaca)

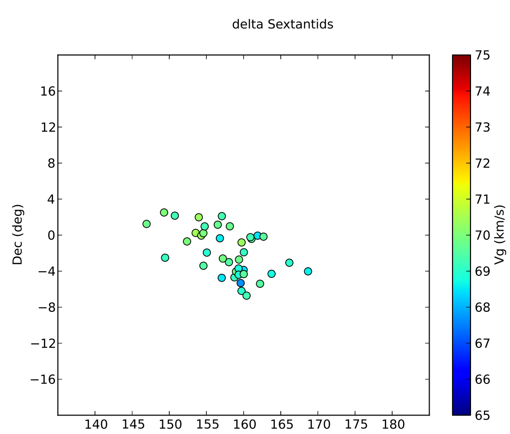

Figure 11 – Radiant plot of δ Sextantids.

39 meteors with mean orbit similar to C/1943 R1 (Daimaca) were found by our search. Shower mean orbit and comet orbit (see Table 11) are similar with $D_{SH} = 0.21$. Although this value is a little above the

maximum we allowed when identifying parent-stream associations (the limit is set to $D_{SH} = 0.20$), we included this comet as small inaccuracies in the mean orbit of the shower (or the orbit of the comet itself) could shift the D_{SH} under, or above, the preset limit. For sure, this case should be studied in more detail before further conclusions can be drawn.

This shower is active from November 29 to December 29, with peak activity around December 15. The mean daily motion of the radiant is dRA = 0.72°, dDEC = −0.29°.

This is another case of a comet on a nominally parabolic orbit, but using the same line of argument as before, we cannot exclude the possibility that it is in reality a long period comet.

Table 11 – Comparison of orbital elements of δ Sextantids (mean orbit) and the orbit of C/1943 R1 (Daimaca).

parameter	542 DES	C/1943 R1
q	0.835	0.758
e	0.920	1.000
ω	46.7	36.4
Ω	83.3	83.4
i	161.0	161.3
D_{SH}	0.21	
n. dist.	0.16	

2.12 22 Bootids (543 TTB) and C/1793 A1 (Gregory)

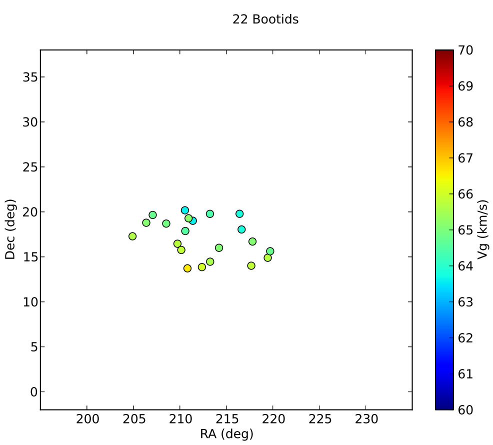

Figure 12 – Radiant plot of 22 Bootids.

21 meteors with mean orbit similar to C/1793 A1 (Gregory) were found. Shower mean orbit and comet orbit (see Table 12) are quite similar with $D_{SH} = 0.14$. This shower is active from December 25 to January, 14, with peak activity around January 5. The mean daily motion of the radiant is dRA = 0.75°, dDEC = −0.21°.

This is another case of a comet on a parabolic orbit, but using the same line of argument as before, it may well be a long period comet.

Table 12 – Comparison of orbital elements of 22 Bootids (mean orbit) and the orbit of C/1793 A1 (Gregory).

parameter	543 TTB	C/1793 A1
q	0.928	0.966
e	0.922	1.000
ω	152.3	147.2
Ω	284.1	286.2
i	130.3	131.0
D_{SH}	0.14	
n. dist.	0.05	

2.13 January ν Hydrids (544 JNH) and C/1787 G1 (Mechain)

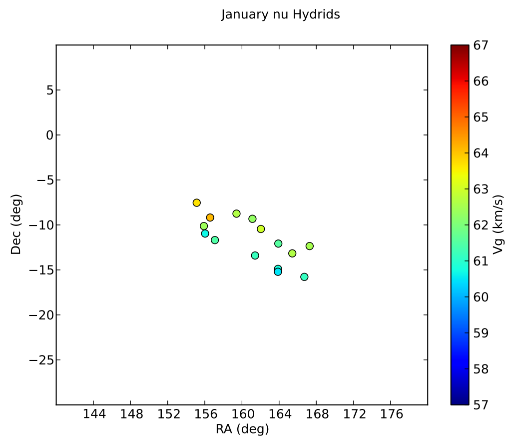

Figure 13 – Radiant plot of January ν Hydrids.

A possible new meteor shower consisting of 15 meteors with mean orbit similar to C/1787 G1 (Mechain). Shower mean orbit and comet orbit (see Table 13) are quite similar with $D_{SH} = 0.09$. This shower is active from January 2 to January 17, with peak activity around January 10. The mean daily motion of the radiant is dRA = 0.69°, dDEC = −0.36°.

Yet another case of a comet with a parabolic orbital elements, that may actually be a long period comet.

Table 13 – Comparison of orbital elements of January ν Hydrids (mean orbit) and the orbit of C/1787 G1 (Mechain).

parameter	544 JNH	C/1787 G1
q	0.417	0.349
e	0.976	1.000
ω	99.6	99.2
Ω	109.6	109.9
i	135.1	131.7
D_{SH}	0.094	
n. dist.	0.17	

2.14 ξ Cassiopeiids (545 XCA) and C/1871 V1 (Tempel)

A possible new meteor shower consisting of 13 meteors with mean orbit similar to C/1871 V1 (Tempel). Shower mean orbit and comet orbit (see Table 14) are quite similar with $D_{SH} = 0.12$. This shower is active from August 20 to August 30, with peak activity around

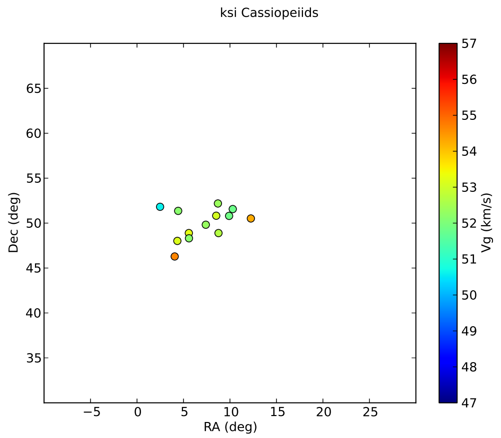

Figure 14 – Radiant plot of ξ Cassiopeiids.

Table 14 – Comparison of orbital elements of ξ Cassiopeiids (mean orbit) and the orbit of C/1871 V1 (Tempel).

parameter	545 XCA	C/1871 V1
q	0.727	0.691
e	0.990	0.996
ω	244.2	242.9
Ω	154.3	148.9
i	94.9	98.3
D_{SH}	0.12	
n. dist.	0.05	

August 27. The mean daily motion of the radiant is dRA = 0.72°, dDEC = 0.51°.

3 Discussion and conclusions

Using the latest complete set of both comets and NEOs downloaded from the JPL small-body database search engine as a starting point, we searched across a variety of meteor databases for orbits similar to the orbit of a particular comet/NEO. Statistically significant associations were found in 15 cases, which may represent hitherto unknown minor meteor streams. Additionally, the method automatically provides the best possible parent body candidate for the stream in question.

Also, in most cases the number of stream orbits was sufficient to determine the daily motion of the radiant with good accuracy. It is interesting to note that in the case of three showers (532 MLD, 539 ACP and 541 SSD) the daily motion dRA turned out to be negative. It seems that this is the combined effect of high declination of the radiant (all three radiants lie at declinations between 62° and 73° and show a large dispersion of radiants of individual meteors, so the obtained values of the daily motion are rather uncertain), small geocentric (and thus also entry) velocities, and possible short-term perturbations of parent bodies by Jupiter. The individual meteor radiants have been calculated without accounting for meteor deceleration, so the initial velocity could be a little different and consequently the orbital parameters also. The small difference in entry velocity at such small velocities may cause quite significant differences in true radiant positions due to zenith attraction. Last, but not least, the possible parent bodies are short-period comets and an asteroid on Jupiter family comets orbit, so they are constantly being perturbed, mainly by Jupiter, but possibly also by Earth and Mars. Thus the resulting coordinates of the radiant for observed meteors may differ a lot depending on the exact moment of the ejection of the particular meteoroid and the following perturbations by major planets.

In the case of one shower (535 THC) three meteors were found that may represent its twin shower, i.e. shower with a very similar orbit but different radiant and activity period, suggesting that the particular stream orbit intersects Earth's orbit in two points. This "three meteor shower" was thus also reported to the IAU MDC and bears the temporary designation 536 FSO.

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Table 15 – Mean orbits of the new showers. ID and name are the IAU identification and name of the shower, $\lambda_\odot$ solar longitudes of the activity period, $\overline{\lambda_\odot}$ average solar longitude, RA and DEC are coordinates of the mean radiant, v_g is geocentric velocity, q perihelion distance, e eccentricity, ω argument of perihelion, Ω longitude of ascending node, i inclination and N is the number of known orbits. The ± values are standard deviations. In the case of RA and DEC there is a contribution of the daily motion to the dispersion of the radiants.

ID	name	$\lambda_\odot$	$\overline{\lambda_\odot}$	RA	DEC	v_g	q	e	ω (peri)	Ω (node)	i	N
531 GAQ	γ Aquilids	38–51	45	301.8±3	13.8±2	62.7±1.1	0.988±0.007	0.957±0.048	196.2±3.3	44.5±4	123.4±3	27
532 MLD	May λ Draconids	35–74	52	155.0±33	73±9	14.4±1.8	0.987±0.024	0.651±0.040	165±13	52±11	18.7±4	23
533 JXA	July ξ Arietids	103–140	119	40.1±8	10.6±2.8	69.4±0.7	0.883±0.047	0.965±0.047	318±8	299±10	171.6±2.6	61
534 FOA	51 Andromedids	130–143	136	23.3±4	47.3±2.1	60.8±1.1	0.997±0.01	0.876±0.058	195±5	136±4	120.7±3	28
535 THC	θ Cetids	129–147	137	23.0±5	−10.2±2.1	61.8±0.6	0.499±0.032	0.969±0.032	92±4	317±5	138.0±1.1	15
536 FSO	47 Ophiuchids	311–325	320	259.0±6	−4.1±0.3	63.3±0.4	0.506±0.031	0.979±0.006	90.9±4	320±7	137.6±0.5	3
537 KAU	κ Aurigids	198–218	208	93.1±5	33.2±2.0	65.5±0.7	0.543±0.035	0.958±0.041	266±4	208±5	159±4	45
538 FFA	55 Arietids	206–221	214	48.6±5	30.8±2.5	36.9±2.5	0.213±0.014	0.942±0.044	308.5±3.1	214±5	24±4	12
539 ACP	α Cepheids	265–297	281	318.0±13	64±6	15.9±1.9	0.979±0.004	0.635±0.040	182±9	281±9	22.9±3.7	41
540 TCR	θ Craterids	269–297	283	175.9±5	−7.4±2.4	70.2±0.7	0.821±0.036	0.971±0.062	48±6	103±6	164.5±3.4	19
541 SSD	66 Draconids	242–270	255.2	302±12	62±4	18.2±2.0	0.981±0.006	0.657±0.044	184.8±7	255.2±7	27.2±4	43
542 DES	δ Sextantids	248–278	263.3	158±4	−1.9±2.6	69.4±0.6	0.835±0.033	0.920±0.047	46.7±6	83.3±6	161.0±4	39
543 TTB	22 Bootids	274–294	284.1	212.5±4	17.1±2.2	65.0±0.9	0.928±0.018	0.922±0.039	152.3±5	284.1±5	130.3±3	21
544 JNH	January ν Hydrids	281–297	289.6	161±4	−11.7±2.4	62.0±1.1	0.417±0.030	0.976±0.031	99.6±3	109.6±6	135.1±4	15
545 XCA	ξ Cassiopeiids	148–157	154.3	7.1±2.5	49.9±1.8	52.7±1.1	0.727±0.021	0.990±0.044	244.2±37	154.3±3	94.9±3	13