Meteor shower search in the CMN and SonotaCo orbital databases

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The following article is a summarized version of a paper published for the *Meteoroids 2013* Conference on the topics of meteoroid-stream parent-body search and new stream discovery in which further details and published findings can be obtained (Šegon et al., 2014).

1 Introduction

By 2013, the ongoing collection of multi-station video meteor orbits had reached a point of statistical significance, to the extent that it was possible to revisit the association of minor meteoroid streams to potential new parent body candidates as well as to search for new minor streams in the meteor orbit databases. By utilizing the latest complete set of both comets and NEOs downloaded from the JPL small-body database search engine[1], a search could be made by starting with their orbital parameters as seed orbits and data mining several published meteor orbit databases for spatial correlations in their Keplerian parameters. The goal was to discover new associations between minor meteoroid streams that connected to either asteroidal or cometary bodies. A second search used each meteor independently as a seed orbit (parent body) to search for new minor streams amongst the other meteor orbits.

Since 2007, two independent video meteor camera networks have been monitoring the skies over Japan and Croatia, the SonotaCo Meteor Network and the Croatian Meteor Network (CMN), respectively. Between them, their database catalogues contain over one hundred thousand meteor orbits (114 280 from SonotaCo, 2007–2011; and 19 372 from CMN, 2007–2010) obtained through multi-station trajectory and orbital parameter estimation. In addition, the IMO Video Meteor Database 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 $-30°$.

[1] http://ssd.jpl.nasa.gov/sbdb_query.cgi.

The orbital correlation approach employed an extensive search for meteor orbit relationships to potential parent bodies by applying several D-criteria restrictions with appropriate thresholds on stream membership. These were developed by Southworth and Hawkins (1963); Drummond (1981); and Jopek (1993). Each independent parent body (comet, asteroid, or meteor) was compared against each meteor orbit available. After an initial assessment, refinements were made to extend the association in time to account for radiant drift, and additional sweeps through the databases were made. From that processing, a short list of parent bodies were obtained and the individual meteoroid orbits were analyzed in greater depth to evaluate the significance of each result.

2 Comet and asteroid search results

As was to be expected, the major meteor showers such as the Geminids, the Perseids, the Leonids, and several minor showers were connected to their known parent bodies. Of particular significance was that 11 new potential meteoroid streams were discovered through their similarity to orbits of known comets. These are listed in the *Meteoroids 2013* conference paper (Šegon et al., 2014) along with verification of the existing known comet and meteoroid stream associations. One example of a new comet/stream discovery is shown in Figure 2, as a plot of the meteoroid stream members connected to Comet C/1853 G1 Schweizer. The corresponding radiant plot is shown in Figure 2.

Almost 3000 asteroids tied to very low-flux meteoroid streams, including as many as 43 Near Earth Object

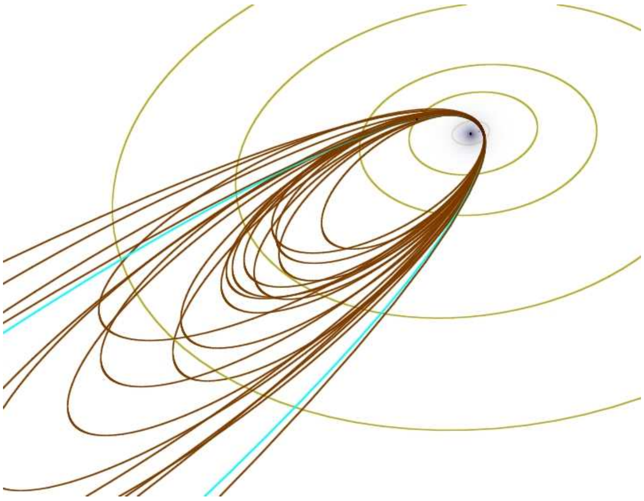

Figure 1 – Meteoroid orbit plot for the new stream members associated with Comet C/1853 G1 Schweizer. The Comet's orbit is the lighter curve.

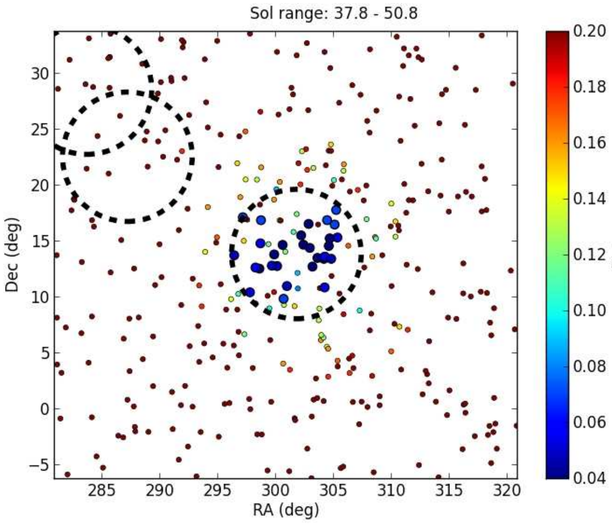

Figure 2 – Radiant plot for the new stream members associated with Comet C/1853 G1 Schweizer. Note that only meteors with D_C smaller than 0.075 are considered stream members.

(NEO) candidates at inclinations over 15°, were found. However, each NEO candidate will require further analysis and better statistical numbers to properly validate the associations. This is because many are low-inclination orbits which can cause confusion and mixing when using the D-criteria. It is hoped that with further multi-station meteor orbit database growth and the publication of the CAMS (Jenniskens et al., 2011) higher-accuracy meteoroid orbits, that the additional statistics will help establish these new asteroidal and meteoroid stream tie-ins.

3 New minor stream search results

The second search, which attempted to discover new meteoroid streams, employed a different methodology. Each single meteor orbit was used as a potential "parent body", and the meteoroid orbits databases were searched for meteoroid-to-meteoroid associations using the D-criteria on orbital similarity. An iterative approach was used to find the mean orbital parameters in a given solar longitude interval and the radiant drift extrapolated to extend the duration of the active shower associations. This approach reproduced 54 of the showers in the IAU MDC database (see Table 1) along with several hundred new groups that still wait to be analyzed in detail.

Once the groups were established, a search through the single-station IMO Video Meteor Database was made to associate a potential group's radiant, radiant proximity, and apparent velocity. An expression relating meteor mid-point height h_{mid} to the entry velocity (V_{inf}) had been published by Molau and SonotaCo (2008), but a linear function did not fit well for low values of V_{inf}. Thus, the following improved expression was derived from multi-station trajectory data for the single-station association analysis herein:

$$h_{\mathrm{mid}} = 82 + 0.39 V_{\mathrm{inf}} - \frac{2400}{V_{\mathrm{inf}}^3} - \frac{\langle \mathrm{entry} \rangle}{9} + M_{\mathrm{vis}},$$

where $\langle \mathrm{entry} \rangle$ is the entry angle of the meteoroid and M_{vis} the absolute magnitude of the meteor, all in the usual units. The single-station analysis will help to validate many of the groups found as well as provide for a better estimate on shower stream duration due to the higher statistical counts in the single station database.

4 Conclusions

The current analysis has resulted in the confirmation of existing relations between known meteor showers and parent bodies. The search procedure based on comparing a parent body orbit (comet, asteroid, or meteoroid) with the orbits of all meteors in a database, can indeed extract a large fraction of possible showers from a given meteor orbital database. This is verified in that the method recovers almost all known meteor showers and that the mean orbits of those streams determined by this method quite accurately reproduce the published mean orbits. The remaining groups of meteoroid streams found are most probably new minor showers, but further analysis and stream verification with dynamical modeling is needed for each group to confirm their reality.

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Table 1 – The list of all known showers (according to the IAU MDC database) that were found by our search.

Code	No.	Meteor shower	Meteors	Code	No.	Meteor shower	Meteors
GEM	4	Geminids	7612	CAN	411	c-Andromedids	36
PER	7	Perseids	6289	ACB	429	α-Coronae Borealids	35
ORI	8	Orionids	4710	MLE	438	μ-Leonids	34
LEO	13	Leonids	1119	SSS	168	South. σ-Sagittariids	33
QUA	10	Quadrantids	996	AMO	246	α-Monocerotids	33
NTA	17	North. Taurids	895	NAS	483	November α-Sextantids	32
HYD	16	σ-Hydrids	888	ZCY	40	ζ-Cygnids	29
COM	20	Comae Berenicids	814	LUM	524	λ-Ursae Majorids	29
STA	2	South. Taurids	682	GAQ	531	γ-Aquilids	29
ETA	31	η-Aquariids	488	NIA	33	North. ι-Aquariids	28
SDA	5	South. δ-Aquariids	439	ZAR	193	ζ-Arietids	28
FTA	286	ω-Taurids	409	OUI	241	October Ursae Minorids	28
CAP	1	α-Capricornids	351	TPY	340	θ-Pyxidids	28
MON	19	December Monocerotids	319	NSA	67	North. μ-Sagittariids	27
SPE	208	September ε-Perseids	280	CTA	388	χ-Taurids	27
LYR	6	April Lyrids	270	THA	390	November θ-Aurigids	27
URS	15	Ursids	258	AUP	415	August Piscids	27
KCG	12	κ-Cygnids	232	FPL	501	February π-Leonids	27
NOO	250	November Orionids	226	XHE	346	x-Herculids	26
JCO	90	January Comae Berenicids	156	BAR	434	β-Arietids	26
ORN	256	North. χ-Orionids	146	GBO	104	γ-Bootids	25
EGE	23	ε-Geminids	142	BCN	232	Daytime β-Cancrids	25
ZCS	444	ζ-Cassiopeiids	135	GUM	404	γ-Ursae Minorids	25
AND	18	Andromedids	132	FMV	516	February μ-Virginids	25
ERI	191	η-Eridanids	120	UUM	527	υ-Ursae Majorids	25
DSV	428	December σ-Virginids	113	UAN	507	υ-Andromedids	24
EHY	529	η-Hydrids	113	FLY	511	15-Lyncids	24
DKD	336	December κ-Draconids	112	FOA	534	51-Andromedids	24
XVI	335	December χ-Virginids	104	BAQ	519	β-Aquariids	22
BCD	268	β-Cancrids	101	DAB	497	December α-Bootids	21
JPG	462	July γ-Pegasids	92	DSE	34	δ-Serpentids	20
LMI	22	Leonis Minorids	89	PDF	45	φ-Draconids	20
NUE	337	ν-Eridanids	89	OCT	281	October Camelopardalids	18
OER	338	o-Eridanids	78	AIC	505	August ι-Cetids	18
AHY	331	α-Hydrids	75	OLE	515	o-Leonids	18
HVI	343	h-Virginids	75	ALO	517	April λ-Ophiuchids	18
PPS	372	φ-Piscids	73	FHE	345	f-Herculids	17
NDA	26	North. δ-Aquariids	70	MPR	435	μ-Perseids	17
DAD	334	December α-Draconids	70	AED	450	April ε-Delphinids	17
POR	430	September π-Orionids	66	XCB	323	ξ-Coronae Borealids	16
KUM	445	κ-Ursae Majorids	65	ARC	348	April ρ-Cygnids	16
DRV	502	December ρ-Virginids	65	CVN	403	Canum Venaticids	16
ECV	530	η-Corvids	64	JIP	431	June ι-Pegasids	16
AUR	206	Aurigids	63	JEC	458	June ε-Cygnids	16
NPI	215	North. δ-Piscids	63	DEL	494	December Lyncids	16
PSU	339	ψ-Ursae Majorids	63	JLE	319	January Leonids	15
DXL	204	Daytime χ-Leonids	61	THC	535	θ-Cetids	15
DLI	47	μ-Virginids	55	TAH	61	τ-Herculids	14
GDR	184	July γ-Draconids	53	KSE	27	κ-Serpentids	13
JRH	463	July ρ-Herculids	52	XLI	140	April χ-Librids	13
TCA	480	τ-Cancrids	52	MIC	370	Microscopiids	13
ELY	145	η-Lyrids	50	RPU	512	ρ-Puppids	13
JBO	170	June Bootids	49	UCE	194	υ-Cetids	12
SLY	81	September Lyncids	48	SCA	179	σ-Capricornids	11
BAU	210	β-Aurigids	48	SPI	216	South. δ-Piscids	11
DPI	410	δ-Piscids	47	OMO	227	October Monocerotids	11
DMH	498	December μ-Hydrids	47	GCM	395	γ-Canis Majorids	11
ICY	525	ι-Cygnids	46	NBO	432	ν-Bootids	11
NHY	121	ν-Hydrids	45	NZT	485	November ζ-Taurids	11
KAU	537	κ-Aurigids	45	MBC	520	May β-Capricornids	11
PIH	101	π-Hydrids	44	DSX	221	Daytime Sexantids	10
DCL	443	December Leonids	44	AAL	448	April α-Librids	10
AGC	523	August γ-Cepheids	44	FFA	538	55-Arietids	10
ASC	55	α-Scorpiids	43	AAN	110	α-Antliids	9
OCU	333	October Ursae Majorids	41	SSA	237	σ-Arietids	9
XUM	341	January ξ-Ursae Majorids	38	DCM	398	December Canis Majorids	9
NLY	437	November Lyncids	38	JMC	362	June μ-Cassiopeiids	8
AXC	465	August ξ-Cassiopeiids	38	AHE	518	April 102-Herculids	7

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Željko Andreić during his Friday afternoon presentation. (Credit Bernd Klemt.)