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Front cover photo

A pair of magnitude −3 Capricornids, shot from Hakos Guestfarm, Namibia. See page 87 for observing report. Photo courtesy: Carl Johannink.

Writing for WGN This Journal welcomes papers submitted for publication. All papers are reviewed for scientific content, and edited for English and style. Instructions for authors can be found in WGN **31:4**, 124–128, and at `http://www.imo.net/articles/writingforwgn.pdf` .

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Editorial

Javor Kac

The June WGN comes out with about a week delay due to prolonged editorial handling. Nonetheless, I hope you will find it a good read. In this issue the Dutch Meteor Society members are presenting observing results of the Capricornids. A long-lasting fireball was analysed by Alastair McBeath. The Croatian Meteor Network is presenting their first year of meteor orbits, a valuable resource for future work. The daytime Arietids have been linked to Marsden sunskirters based on the CAMS data. Finally, the IMO Meteor Network observing reports for February and March are presented.

The International Meteor Conference at La Palma is nearing. About 80 participants from 21 countries have registered by the time of writing this editorial.

The early-bird registration deadline has passed, but it is still possible to register until August 20. However, you may want to reserve your flight to Canary Islands soon. I hope to see many of our members at La Palma.

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Letter — Leonids 2011

Alastair McBeath [1]

We read in the IMO Video Meteor Network's review of November 2011 (Molau et al., 2012, quote from p. 49) that, "There were no predictions for unusual Leonid rates in 2011." This is a surprising remark given that I went to the trouble of including a full discussion of the Leonid shower in 2011 in the IMO Meteor Shower Calendar (McBeath, 2010, pp. 16–17), despite the fact the shower would be very badly affected by moonlight, precisely because there were no less than four different maximum timing predictions spread between 2011 November 16 and 18, including one for potential ZHRs of order 200!

This oversight in the IMO Video report, and the consequent lack of detail in the Leonid discussion there, was particularly unfortunate, as the visual results, available online at `www.imo.net/live/leonids2011/`, were hampered by some extremely poor weather conditions during the Leonids last year. Thanks to this, they were only able to hint at a possible maximum, with ZHRs of order 22, on November 17/18, contrary to the video results, which suggested instead a peak on the next night.

I have recently completed an examination of the radio results collected by the SPA Meteor Section during the shower, primarily data published in Radio Meteor Observation Bulletins 220 and 221 for 2011 November and December respectively (available at `www.rmob.org`). Even these gave incomplete coverage, since with observers based primarily in central-western Europe and western North America, the Leonid radiant was effectively unobservable due to being below the horizon for all locations, from about 20^{h}–21^{h} until 00^{h}–01^{h} UT daily, a period into which fell three of the four predicted maximum timings.

A detailed hour-by-hour examination of the radio information from November 16 to 20, concentrating on when the Leonid radiant was observable from each site, showed no distinct brief maxima on any of these dates, but activity probably due to the Leonids seemed to have been somewhat stronger than normal on November 17, between roughly 02^{h}–13^{h} UT, and was at its strongest on November 19 from about 01^{h}–14^{h} UT. (Remembering that these intervals do not give true peaks, but indicate instead the better-detectable daily period for radio Leonid meteors from the two main geographic regions represented.)

Overall, this radio meteor pattern supported the findings of the IMO video observers much better than those from the visual reports, and implied the better shower activity could have occurred on November 18/19, significantly later than any of the advance predictions had anticipated. In all cases, shower rates were apparently fairly unremarkable, which would in turn infer quite typical Leonid ZHRs had taken place, probably of the order of 15–20 or so at best, much as the visual data found.

However, it seems important that any further results from elsewhere which could plug the gaps in the data should be communicated without further delay, in case anything unusual did occur in time to any of the late-evening-UT predictions.

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Note that the radio meteor results given here were previously published online on the SPA's Observing Forum "Leonids 2011" topic, at `www.popastro.com/phpBB2/viewtopic.php?t=16368`.

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Authors' response: We agree with Alastair that our statement was inaccurate. It rather meant "There were no predictions for significantly enhanced rates for visual and video observers."

From the Treasurer—How can you support your organization?

Marc Gyssens [1]

1 Supporting members 2011

The following people have paid at least double the normal membership fee for 2011:

Karl Antier	Lars Bakmann	Luc Bastiaens	Felix Bettonvil
Mihail Bidnichenko	Peter Brown	Luis Bellot Rubio	David Entwistle
Marc Gyssens	Detlef Koschny	Sirko Molau	Dragana Okolić
Tom Roelandts	Hans-Georg Schmidt	René Scurbecq	Joseph Simpson
Walter Soto	Casper ter Kuile	Mihaela Triglav-Čekada	Jan Verbert

We are very grateful to the people above for their support. At the same time, however, it must be emphasized that many other people contributed to the IMO. For instance, many members gave gifts smaller than the regular membership fee; of course, these gifts are equally appreciated. Also, several members contribute by providing a gift membership to a friend, or by paying a friend's or colleague's registration fee for the International Meteor Conference, or by a direct gift to the IMO Support Fund. We mention in particular David Asher, Jonathan Mc Auliffe, Marc Gyssens, and Casper ter Kuile, who made very generous gifts. We also received a much appreciated gift from the Japanese account.

The annual International Meteor Conference plays a very important role in the international meteor work as it is the primary forum where meteor workers can physically meet. In particular, it helps hard-working meteor workers that were not yet in touch with the international meteor community to break out of their relative isolation, improve on their observing methods, and learn which problems have been solved already and which questions still beg for an answer.

Thanks to the generosity of our members, the IMO was able to provide support for the 30th International Meteor Conference in Sibiu, Romania, to 2 participants from Belarus, 1 participant from Greece, 1 participant from Moldova, and 1 participant from Sri Lanka. This support was given based on formal applications, which were subsequently judged by the Council.

In one of the upcoming issues of WGN, you will also learn about a new initiative of the IMO Council. It was felt that the International Meteor Conference, however important it is, is too narrow a focus for IMO Support. While we will continue to offer the possibility to request support for participating in an International Meteor Conference, we will also offer our members in the very near future the possibility to request support for scientific projects. As mentioned, details will follow shortly.

Therefore, we encourage our members to continue providing support to our Organization in one of the many ways possible: supporting membership, smaller donations, gift memberships, private support to IMC participants, or a direct gift to the IMO Support Fund. The international meteor community will be very grateful for it!

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Ongoing meteor work

The Capricornids observed from Namibia

Koen Miskotte [1] *and Carl Johannink* [2]

During a δ-Aquariids expedition to Namibia by the Dutch Meteor Society (DMS) 793 Capricornids were recorded from 2011 July 25 till August 7. The activity profile shows a low but steady activity with a maximum of 6 Capricornids per hour near solar longitude 128° ($\lambda_\odot$ 2000.0). The higher ZHRs observed in 1984 were not confirmed in 2011.

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1 Introduction

A number of observers of the Dutch Meteor Society (DMS) travelled to Namibia to observe the Southern δ-Aquariids (SDA) in the period from 2011 July 25 till August 7. The analysis of this stream has been published (Johannink & Miskotte, 2011). Apart from a record number of Southern δ-Aquariids another record number of Capricornids were recorded (Table 1). Indeed it was not a surprise that record numbers of shower meteors were seen. The Capricornid radiant gets up to 78 degrees above the Northern horizon in Namibia compared to 51 degrees above the Southern horizon in La Palma. Moreover the longer effective observing time in Namibia favoured the high number of meteor totals. The transparency of the sky in Namibia at the zenith was a little bit better but at lower altitude the quality of the sky was much better in Namibia.

These extraordinary transparent nights resulted in fine hourly rates for the Capricornids during their maximum. While we saw up to 9 Capricornids per hour at maximum on La Palma, this number got between 12 and 15 per hour in Namibia. Capricornids are often beautiful meteors to be seen. Aside from a nice number of fireballs we also saw a rather rare phenomenon on July 31 with the simultaneous appearance of two Capricornids of magnitude −3 parallel to each other.

Figure 1 – A −5 magnitude Capricornid photographed by Peter van Leuteren on 2011 August 1 at $01^h51^m18^s$ UT.

2 History

Let us start with an overview of successful Capricornid campaigns. The first such year was 1984 when three DMS observers Carl Johannink, Koen Miskotte and Bauke Rispens observed from the region of Provence in France (Johannink et al., 1984). A relative large number of fireballs of this stream were recorded. A first analysis was made by Rudolf Veltman (Veltman, 1984). More observations were done from Southern France in later years, but these happened mostly around the Perseid maximum and therefore after the Capricornid maximum.

This changed in 2001 when Koen Miskotte took holidays on the Greek island of Chios where he could observe during eight nights (Miskotte, 2001). Carl Johannink made observations from Tuscany, Italy in the same year. Remembering the observations of 1984 a lot was expected but it was a disappointment. A first unpublished analysis by Koen Miskotte yielded maximum ZHR values of about 4 and contrary to 1984 no fireballs were noticed.

Another observing project from a Southern European location was conducted in 2003 from the Greek island of Crete by Koen Miskotte. Although some more bright Capricornids were seen, the ZHRs were comparable with 2001 with maximum ZHRs of 4 to 5. These results were also published (Miskotte & Johannink, 2005; Miskotte & Johannink, 2008). These analyses included confirming observations from 1984, made by Paul Roggemans from Florida, USA. The authors concluded that 1984 was an exceptional Capricornid year with many bright meteors and double the usual ZHR values.

Thanks to Felix Bettonvil, the observers Klaas Jobse, Carl Johannink, Peter van Leuteren, Koen Miskotte and Michel Vandeputte could observe a week from the Roque de Los Muchachos observatory at La Palma, Spain in 2008 (van Leuteren, 2008; Miskotte et al., 2009). The results for this expedition were published in (Miskotte & Johannink, 2009). Slightly higher ZHR

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Table 1 – Overview of the observing data as collected in Namibia.

Sessions	T_{eff}	SDA	CAP	PAU	ANT	KCG	PER	SPO	Total
9	31.60	350	90	37	56	0	28	779	1340
10	50.08	970	248	66	140	5	32	870	2331
11	41.64	775	155	26	78	4	27	945	2010
11	57.02	1381	300	54	43	7	58	1189	3032
31	180.34	3476	793	183	317	16	145	3783	8713

values were found compared to 2001 and 2003, with a maximum ZHR of 6. This difference can be explained by the better transparency of the atmosphere at La Palma because of its height of over 2000 meter above the sea level.

3 ZHR analyses

First of all the population index r was derived from the data set and determined to be 2.00. The procedure used has been described in the analyses for the Southern δ-Aquariids (Johannink & Miskotte, 2011). The value of 2.00 is exactly the same as found in 2008. In a next step the data was verified on very small hourly periods, outliers in ZHR-values and radiant elevations of less than 30 degrees were filtered out. As the Capricornid radiant only descends below 30 degrees at the end of the night, very few data had to be removed. Of the 793 observed Capricornids, 785 could be used in this analysis. This is about 99% of all data, a score that was never achieved

Figure 2 – A magnitude −7 Capricornid in the zenith photographed by the all sky camera of Peter van Leuteren on 2011 July 26 at $20^{\mathrm{h}}11^{\mathrm{m}}$ UT. Casper ter Kuile and Koen Miskotte were outdoors when this Capricornid appeared and they saw the landscape twice intensely illuminated.

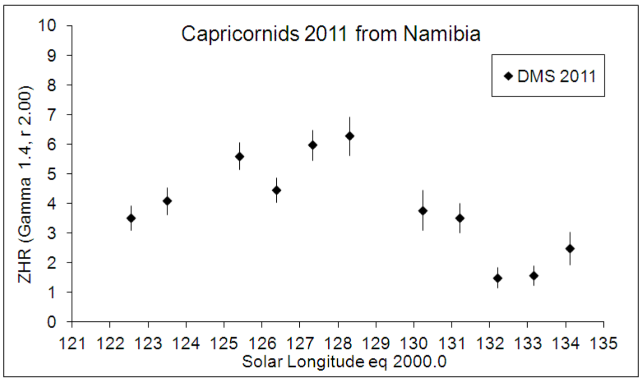

Figure 3 – ZHR profile for the Capricornids 2011. A maximum ZHR of 6 was found for both nights 2011 July 30–31 and July 31 – August 1. The profile is based on 785 Capricornids.

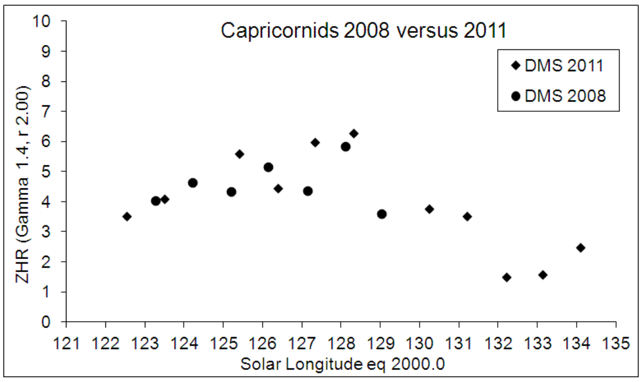

Figure 4 – Comparison between two good Capricornid years: 2008 and 2011. Both years yield a maximum ZHR of 6. These ZHR profiles are based on 503 Capricornids for 2008 and 785 Capricornids for 2011.

before in our meteor stream analyses. The results of these calculations are shown in Figure 3. Further a second graph was made with the ZHR values of 2008. During both years observations took place under very good circumstances. For both years a maximum ZHR of 6 was found.

Finally data from 1984, 2001 and 2003 were added in Figure 5. Remarkably similar ZHRs were found in 2001 and 2003 with maximum ZHRs of 4 to 5. For 2008 and 2011 maximum ZHRs of 6 were found. The difference might be explained by the observing circumstances as in 2001 and 2003. The sky was indeed very good but at lower elevation the transparency was a bit less. In both 2008 and 2011 the transparency at lower elevations was very good at both sites since the observations took place at about 2000 meter above sea level. The year 1984 remains an exception with maximum ZHRs above 10 and relatively many fireballs.

4 Conclusions

This analysis indicates that the Capricornids have an annual maximum ZHR of 5 to 6. Reliable observations are only possible from southern latitudes, in Europe this includes Spain, Portugal, Southern Italy, the islands south of Greece and further south. The 1984 shower remains a remarkable outlier.

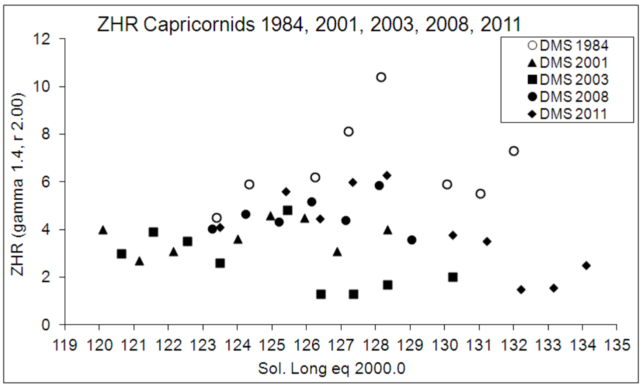

Figure 5 – All ZHR values combined in one graph. It is remarkable that for the years 2001 and 2003, and for the years 2008 and 2011 identical maximum ZHRs were found. The ZHR values correlate well before the maximum but after the maximum the ZHR values are more scattered.

5 Acknowledgement

A word of thanks to all observers who made their data available for this analysis. We thank Paul Roggemans for translating this article.

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Handling Editor: Paul Roggemans
This paper has been typeset from a LaTeX file prepared by the authors.

Figure 6 – A Capricornid of −6 photographed by Peter van Leuteren on 2011 July 31 at $00^h38^m25^s$ UT. On this picture we see the constellations of Aquila, Lyra and Delphinus up-side-down in the North-North-West.

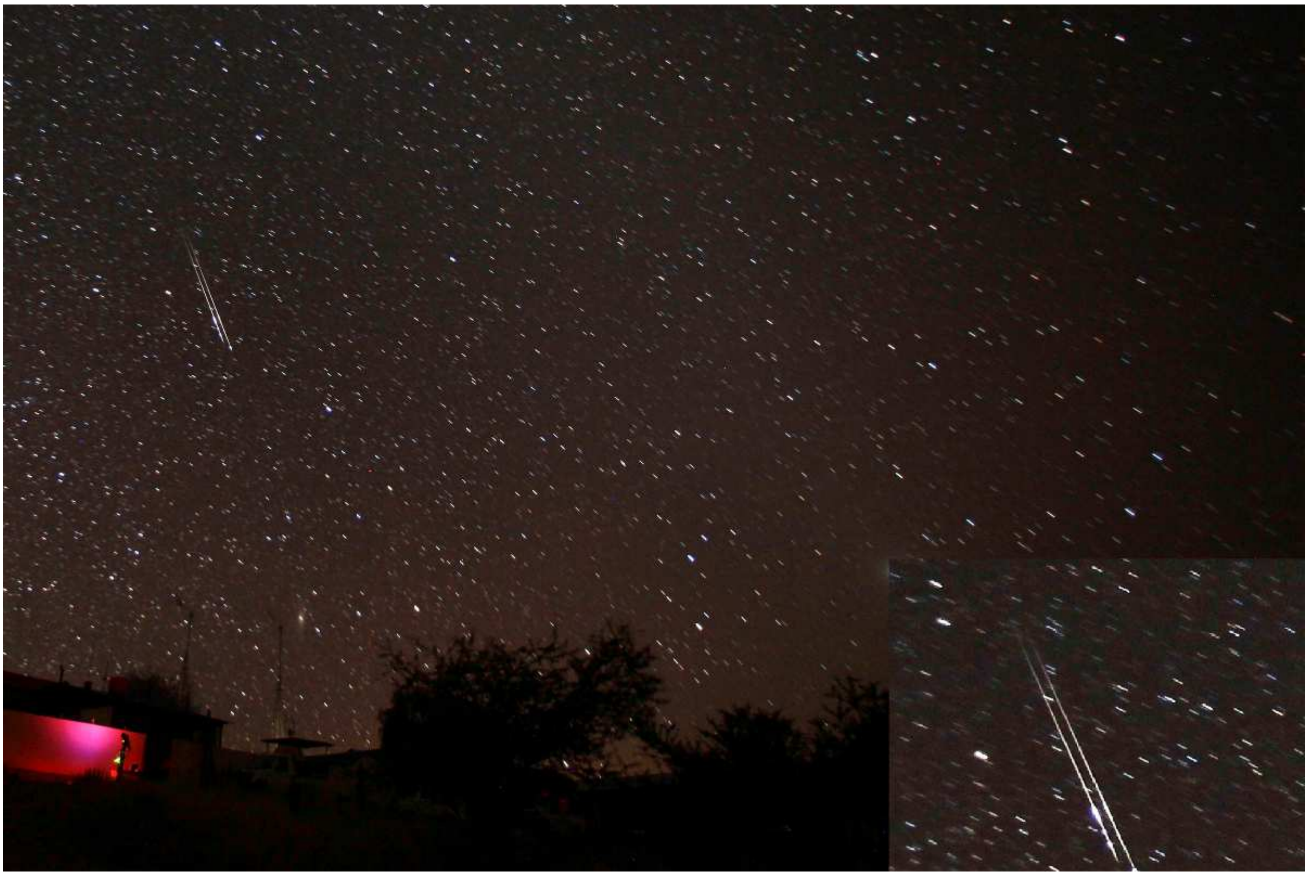

Figure 7 – Two Capricornids of −3 parallel as a double Capricornid photographed on 2011 July 29 by Carl Johannink.

SPA Meteor Section Results: Unusual Long-Lived Fireball, 2012 March 3, 21^{h}41^m–21^{h}42^m UT

Alastair McBeath[1]

An analysis based on 376 eye-witness reports and details from 15 images and videos is presented of a remarkably persistent natural fireball which was widely-observed from the British Isles on 2012 March 3. The meteor survived for about 45 ± 15 s, and likely ended around 62 km altitude near Bozeat, Northamptonshire in southeast England. Simultaneous sounds were reported from seventeen places associated with the fireball, which probably peaked in the magnitude −9 to −15 range. Notes on six other fireball-class meteors reported from the UK on March 3–4 are given too.

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1 Introduction

As has been noted before in this journal in reports of the SPA Meteor Section, the past two decades have seen a substantial rise in the number of casual fireball observations sent to the Section from the British Isles and places nearby, whereas dedicated meteor observing sessions away from nights close to the maxima of the major showers have shown a similarly marked decline. While problematic from the perspective of attempts to scientifically monitor shower activities away from such peaks in activity, the opportunity has been created to better examine individual fireball-class meteors, while the continued, rising, supply of such sightings has helped confirm a generally healthy level of interest in matters meteoric among society overall, from casual first-time witnesses to experienced meteor observers. Here, I have examined a particularly unusual event from 2012 March 3, which despite being a natural meteoric fireball, persisted for much longer than the vast majority of meteors ever do, resulting in its being seen and imaged from much of the UK, creating national and international media interest. Some comments are also provided on six other fireballs which were reported from March 3–4 partly because of the publicity generated by the more widely-seen meteor.

2 March 3, 21^{h}41^m–21^{h}42^m UT fireball

Excluding duplicates, a total of 376 reports, including 15 videos or images of part of the trail, were probably of this "main" fireball event on March 3–4. As Figure 1 demonstrates, witnesses of it stretched from Wick in northern Scotland (plus an unlocated observer somewhere on the Isle of Lewis off the northwest Scottish coast; not shown) to Somerset, Hampshire and Essex in southern England, with several sightings from northeast Wales. Of the 353 observers whose locations could be identified, 116 were in Scotland, 168 in northern England (north of roughly 53° N latitude, somewhat variable to allow for county boundaries), 9 in Wales, and 60 in southern England.

Dots on Figure 1 represent places where at least one observer was situated, although they frequently indicate multiple witnesses at or near the same site, particularly for the city centres (up to a maximum of 24 people in and near central Manchester). On the electronic colour version, black dots show visual or imaging locations, red dots where simultaneous sounds associated with the meteor were reported, blue dots where sounds heard some time after the meteor ended were

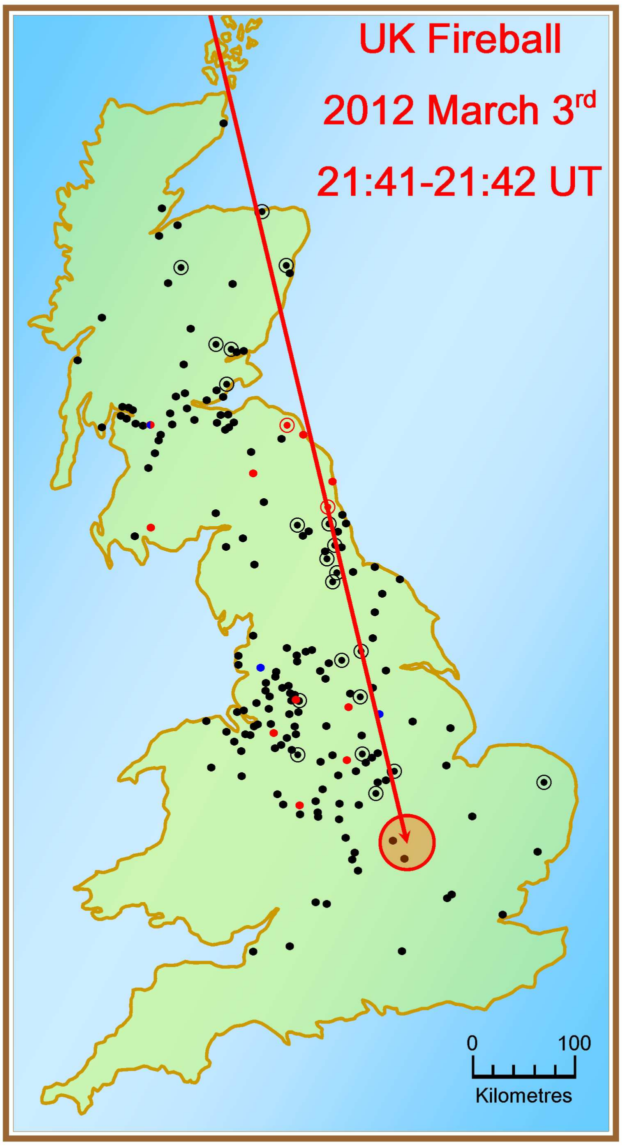

Figure 1 – A sketch map of mainland Britain showing details for the March 3, 21^{h}41^m–21^{h}42^m UT fireball.

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noted, and circled dots where the meteor was claimed as having passed overhead or nearly so. The half-blue, half-red dot in Scotland is in central Glasgow, where both simultaneous and delayed sounds were claimed as detected possibly linked to this fireball. The arrowed line shows the more probable projected surface track for the fireball, and the circle around the arrow the area in which the meteor most likely finished its visible flight.

It was difficult to confirm some of the reports as being of this meteor due to differences in the estimated timings for the fireball, and where in the sky the object was claimed to have been seen. Outlying estimates for the occurrence time of what was plausibly this fireball ranged from 21^h00^m to 22^h35^m UT, for instance! However, 80% fell within ten minutes of $21^h41^m30^s$ UT, while the fireball most probably happened between 21^h41^m and 21^h42^m judging by the more accurate estimates by amateur astronomers and an automated meteor video camera timing. Further complications in the timing estimates resulted from the fireball's exceptional longevity. While no witnesses saw both the start and end of its flight, and all images were of merely part of the trail, drawing on the more plausible estimates and extrapolating from those to what seemed reasonable for the entire event, the fireball's full visible duration was probably around 45 ± 15 s. This in turn restricted the possibilities for more precisely-determining the time it appeared.

The most likely start area for the meteor's flight could be only vaguely defined, as very few people seemed to have witnessed it. It was plausibly between the Faeroe, Shetland and Orkney Islands, perhaps within 100 km of $3\overset{\circ}{.}9$ W, $60\overset{\circ}{.}5$ N, assuming a start height range between 140–90 km, but it may have been some way west or north of this zone. The end area was far more closely-confined thanks to more observers seeing it, and especially as at least two still-images were secured which probably included this point. The end was thus likely within 25 km of $0°45\overset{'}{.}3$ W, $52°13\overset{'}{.}3$ N, with a best-estimated average for its final visible height of 61.6 ± 8.5 km. The centre of this zone on the ground was close to the village of Bozeat, Northamptonshire, in southeast England.

Using this relatively fixed end-point with the data from those observers who suggested the meteor had passed overhead, or very nearly so (and excluding a few outliers) would imply the meteor's direction of travel across the British Isles was towards azimuths 165° to 170°. There was a small majority in favour of the $\sim 170°$ line, which is that shown on Figure 1.

Assuming this path to have been roughly correct, the fireball's intra-atmospheric trajectory would have been between 1060 and 900 km long, descending at between 5° to 2° from the horizontal, so was literally skimming the meteor layer in the upper atmosphere. Using the proposed 30–60 s full-flight duration converted to an atmospheric velocity range of the order of 25 ± 10 km/s, with no allowance for atmospheric deceleration.

An unusually large range of estimated brightnesses were suggested by different witnesses, from magnitude -1 to brighter than the Sun, the more extreme brightness estimates probably due to surprise at seeing such an amazing meteor, rather than its actual brilliance. The more reliable estimates averaged circa magnitude -12, with the likely brightest parts of the trail probably falling in the range from magnitude -9 to -15. The object seemed to have been about at its brightest during its passage between approximately Aberdeenshire in northeast Scotland to North Yorkshire in northern England. Judging by the descriptions (albeit with an unavoidable degree of subjectivity, as not everyone agreed what happened) it may have begun breaking up or shedding small sparkling fragments from about the time it crossed the Northumberland coast in England onwards, or perhaps a little before then. The degree of fragmentation overall seemed to have been relatively slight and fairly gentle however, with people often reporting a train or tail with and/or after the meteor. There was also some confusion about the difference between the persistent train left after the meteor had gone, and the tail seen behind the head of the meteor while still in-flight, making determining just what took place quite difficult. Some of the videos supported that minor fragmentation had happened during the later flight at least.

Sounds potentially associated with the fireball were reported from seventeen places, twelve of those simultaneous with the meteor's flight or almost so, five some time afterwards. The simultaneous sounds were mostly of the kind expected from previous events of this kind, described here as often quite faint, but distinct rustling, hissing, sizzling, crackling or popping. Two witnesses, one each in Derby and Wolverhampton had their attention drawn to the fireball by hearing the sound, which has also occurred before. One report from Dumfries & Galloway (also the most distant place from the projected surface track to have reported a sound associated with the meteor) suggested a boom was heard a couple of seconds after the meteor vanished, much too soon for ordinary acoustic waves to have arrived at that site, but which might still have been linked to the event, although a more earthly explanation could not be ruled-out. Another witness in Manchester mentioned sounds like the whirring and banging from a helicopter were noted during the meteor's appearance. Again, a man-made cause nearby could not be excluded. Four reports of simultaneous sounds from Northumberland and the Borders were almost directly beneath the probable line-of-flight, which provided further support for such a trajectory, with eight of the twelve within 70 km of that projected ground line.

Of the five reports of sounds after the meteor ended, two were of sonic booms from unidentified locations (one possibly in either Derbyshire or Staffordshire), and another was of a similar boom from Worksop in Nottinghamshire between 60–120 seconds after the meteor vanished, another place almost directly beneath the flight-path. The remaining two reports were from Glasgow, one of a double shotgun-like detonation an unspecified time after the meteor had disappeared, and Preston in Lancashire, of a rumbling noise barely audible above the local traffic about ten minutes after the meteor. Both the latter seemed more likely to have had local causes. Whether any of these delayed noises were genuinely linked to the meteor was uncertain, since assuming the fireball's estimated trajectory was correct, it would likely have been too high to have generated such noises audibly at the surface.

Various contrasting colours were suggested as seen in the meteor, with some people differentiating between hues noticed in the head and tail. Of those who reported colours in the head, most preferred red, orange or yellow (65.5%) or white (24%) with the remaining 10.5% made up of green, blue or violet.

Apart from numerous sightings received directly by the SPA, many of the reports came from the American Meteor Society (AMS; 161), with grateful thanks to Bob Lunsford and Mike Hankey who made those sightings freely available to the SPA for this analysis. See the AMS website's fireball archives page for 2012 fireball 322 via `www.amsmeteors.org`. Another substantial batch of sightings was extracted from the BBC News webpage at `www.bbc.co.uk/news/world-17248959`, where there were also links to some of the video recordings. Further notes were taken from Twitter by Assistant SPA Meteor Director Tony Markham. Links to these sources and others, with an earlier online version of this report, can be found on the SPA's Observing Forum, at `www.popastro.com/phpBB2/viewtopic.php?t=16810`.

3 Other fireballs reported from March 3–4

Of these additional fireballs, the earliest on March 3 was in daylight (BBC News webpage report 305), unfortunately at an unspecified time as seen from North Yorkshire. The witness gave no details other than that the object was moving roughly south to north.

After nightfall, the next fireball was around 19^h10^m–19^h15^m UT, a slow, orange meteor seen in the western sky moving southeast according to one unlocated witness, with another possible witness in Hampshire, southern England (BBC webpage reports 159 & 269).

Following the $\sim 21^h41^m$ event, at some stage within half an hour either side of 22^h UT a bright yellow or white possible fireball was spotted from Exeter in Devon southwest England (AMS report 322fc). The witness recorded it at about 45° elevation to the southeast. If correct, and this was a genuine meteor, it would have been likely high above the Channel off the south or southwest coast of England. As the 45° elevation angle meant any object would have to have been exactly as high above the surface as it was horizontally from the observer, this cannot have been another sighting of the 21^h41^m–21^h42^m UT fireball, plus it was visible for less than two seconds and had a very short path.

Within roughly five minutes of 22^h25^m UT, a magnitude -5 to -12 event was seen from at least three places, Dublin in Eire, Lancashire and Manchester in northwest England. Details from the observers suggested this fireball had plausibly occurred over the northern Irish Sea, and was likely red, orange or yellow in colour, visible for a few seconds (AMS reports 322fh, fi & fj). Three other reports, one from Manchester and two from Glasgow were perhaps timed between 22^h30^m–22^h35^m, but from the descriptions, they seemed more likely to have been mistimed observations of the $\sim 21^h41^m$ meteor instead (AMS reports 322fm, fn & fo).

Another bright meteor between 23^h00^m–23^h15^m UT was spotted possibly from North Yorkshire and Kent. The Kent witness indicated the fireball – assuming both reports were of just the one meteor – had likely ended above the Channel to the south-southeast of Kent, or possibly over the French coast (BBC reports 104 & 227).

The final March 3–4 fireball event reported to the SPA probably took place between 00^h05^m–00^h15^m UT, according to six reports (BBC numbers 87, 244, 259, 263, 273 & 372), although there were uncertainties in the timing of some of these. Those observers who mentioned their locations were in North Yorkshire, Norfolk, Cambridgeshire and near London, with most describing a steeply-descending meteor which may have ended over East Anglia or the nearby North Sea.

4 Conclusion

The excitement and interest generated by the leading March 3 fireball and the number of reports received of it, far outstripped anything the SPA Meteor Section had had to handle previously. The power of the Internet to create such an effect is very clear, and something that as amateur astronomers we should both be aware of and be prepared to take advantage of to help spread good-quality information about the type of data most useful to report from fireball sightings, and to provide rapid feedback to the lucky witnesses. For example, it was possible to provide online news from the fireball's analysis, including a preliminary trajectory estimate which has remained largely unchanged still, within 48 hours of its occurrence, thanks to the large number of rapidly-submitted reports and images. On a personal note, this fireball provided a suitable final major event for my time as Meteor Director, as I shall retire from that post at the end of 2012 April, after almost thirty years, making its analysis my last significant act in that role. As always, I am indebted to the people named already for their assistance in making this analysis possible, but most especially to the many observers who freely provided their data so rapidly on this remarkable meteor.

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Meteor science

Croatian Meteor Network Catalogue of Orbits for 2007

Damir Šegon[1], *Željko Andreić*[2], *Korado Korlević*[3], *Filip Novoselnik*[4] *and Denis Vida*[5]

The Croatian meteor Network (CMN) was started in 2007. Here we describe the catalogue of meteor orbits that resulted from data gathered by CMN during 2007. Out of 15 189 meteor trails, 1 211 orbits were obtained, out of which 358 orbits of meteors from known streams and 853 orbits of sporadics. The catalogue can be accessed on the CMN web page.

Received 2012 March 30

1 Introduction

Year 2007 was the first year of operation of the Croatian Meteor Network (CMN). The network uses 1004X surveillance cameras for night sky imaging. They are build around Sony 1/3" EXView HAD CCD chip and achieve sensitivity of 3 mLux with a $f/1.2$ objective lens. They provide black and white images at standard 25 frames per second, which allows for simple coupling with a PC: almost any frame-grabber PC card, or PC-TV card works with this camera. Readily available 4 mm $f/1.2$ objective lenses were used on most cameras. They provide a good compromise between sensitivity (the faintest meteors recorded with this objective are around 3.5 magnitude) and image scale (which in this case is around 10'/px). The hardware of the camera is modified so that the video signal gain is fixed to about 90% of the maximal gain. The CMN is in more detail described in (Andreić & Šegon, 2010) and (Andreić et al., 2010). The list of cameras that were in operation in 2007 is given in the Table 1 and the sky coverage at height of about 100 km is shown in Figure 1.

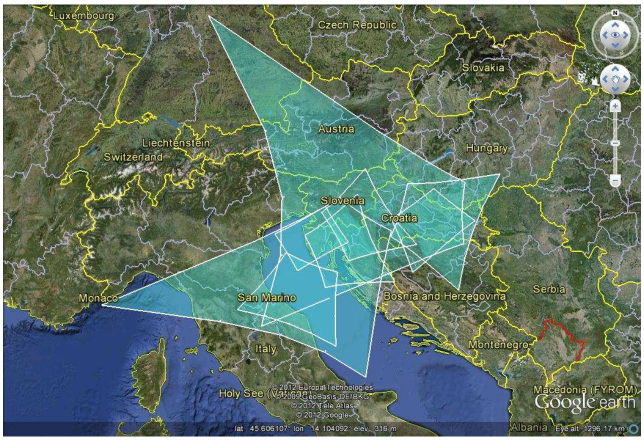

Figure 1 – Locations of CMN cameras that were in operation in 2007, and their fields of view at typical meteor height of 100 km.

2 Data reduction

SKYPATROL program (Vornhusen, 2003) was used for image acquisition. It is freeware and very simple to use. Once set, it will run the camera automatically. The program produces still images in BMP 24-bit color format, usually in 384×288 pixel size and with the nonstandard color coding. The camera produces black and white images that are stored in the blue color channel of the BMP file. The other two color channels are used for storing data about the time of maximal brightening of any given pixel. Thus, although the resulting image is a still image, accurate data about appearance of bright objects are stored in it. The program can "integrate" for several minutes of time, but for CMN the integration time of 1 minute is adopted. In this case the still image is an integration of 1500 frames. This makes images less cluttered with moving objects of which meteors are the rarest; airplanes, satellites, even birds lit by light pollution are recorded most of the time. There is only one, although small disadvantage of this program: it makes an average "dark frame" at the beginning of each integration, so the first two seconds are lost from the integration. Actually, the program records events even during this time, but only at 5 fps.

The time stamp of any given image sequence is determined from the `logfile.txt` output file provided by the SKYPATROL, which, in turn, is based on the computer system clock.

Images were reduced afterwards, with the help of software written especially for this purpose by Peter Gural. This software is described in detail in (Gural & Šegon, 2009), so we will provide only a brief description here:

The software automatically scans through the images from a given night collected by SKYPATROL. Each BMP image represents a single maximum intensity image combined with its associated temporal information. Although the images were originally obtained at video frame rates, only the maximum value in time and its associated frame number are stored for each pixel. The

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Table 1 – List of CMN cameras that were operable in 2007. The last two cameras, labeled with an "∗" were used only occasionally. First two columns give CMN camera label, its location and principal operator. Coordinates of camera location are provided in the next three columns. Number of nights with at least one detected meteor follows, together with the total number of meteors detected by the particular camera in the 2007.

code	location and operator	longitude	latitude	z (m)	no. nights	no. meteors
CMN_BJA	Rovišće, Denis Štogl	16°7313	45°9464	134	121	1769
CMN_MEA	Merenje, Željko Andreić	15°7825	45°9581	194	94	1339
CMN_OSA	Osijek, Dario Klarić	18°6167	45°5693	84	159	2076
CMN_PUA	Pula, Damir Šegon	13°8520	44°8691	15	258	4931
CMN_RIA	Rijeka, Ivica Ćiković	14°3705	45°3472	98	164	2715
CMN_ZGR	Zagreb, Željko Andreić	15°9640	45°8071	117	192	2082
CMN_PUB∗	Pula, Damir Šegon	13°8463	44°8655	28	10	222
CMN_TIA∗	Tićan, VSA 2007 meteor group	13°7494	45°2908	330	2	55

bit-mapped files are encoded in such a way, so that the red and green channels contain the frame number (red plus green times 100) and the blue channel contains the maximum brightness value across time over the duration of the entire exposure. To take advantage of the temporal information contained within the images, the Maximum Temporal Pixel (MTP) Meteor Detector algorithm and software package was developed for the CMN. The MTP software interfaces to the MeteorScan "detection" modules to take advantage of combined space-time processing for the detection of meteors (Gural, 1999). A separate driver program and file input/output interface module was built around MeteorScan to handle the unique format of the CMN data sets yet still utilize the spatial-temporal processing advantages of MeteorScan's Hough transform and matched filter detector. The MTP driver program scans through an entire night's collected data in a single sweep automatically and provides frame-by-frame focal plane positions of each meteor track. It also estimates positions of stars in each BMP for astrometric calibration and it can operate under partly cloudy conditions. All data gathered is stored in appropriate data files that are used in the next processing step.

Distortion correction and astrometric calibration of each detected meteor point are made using all the stars detected during the entire night. The procedure is in detail described in a previous article (Šegon, 2009), so just a brief summary is given here. In the calibration procedure, up to 20 000 stellar positions across a given camera's focal plane are used for the FOV calibration of a single station camera. This method allows FOV calibration down to a mean error of 3' when using a 4 mm $f/1.2$ lens ($64° \times 48°$ FOV). This is equivalent to a subpixel accuracy of 0.3 pixels.

The meteor brightness was determined by comparing the instantaneous meteor image to the averaged images of stars detected that night. Use of averaged star images significantly reduces the flickering noise and provides a larger database of comparison star images. It also reduces problems in case of partially cloudy conditions. The meteor brightness is instrumental, and no attempt was made to correct for the spectral type of comparison stars. The correction for angular velocity of the meteor was performed according to (Gural & Jenniskens, 2000). For brightness above −1.5 mag the meteor brightness has to be extrapolated and no corrections for detector saturation are done. For that reasons brightness estimations of very bright meteors are not very accurate.

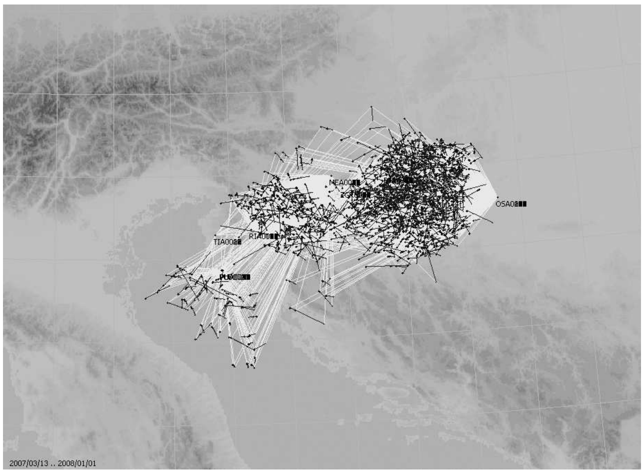

Figure 2 – Plot of ground tracks of meteors from the CMN Catalogue of Orbits for 2007.

3 The CMN Catalogue of Orbits for 2007

The data reduction process starts by combining together data obtained from individual cameras and identifying meteors recorded by two or more cameras. During this procedure the clock error of each camera is determined and accounted for. For more details, see (Vida & Novoselnik, 2011).

In the next step, the path of each meteor is calculated from all detected points of the meteor trail using the least-square method. The distance of each point from the calculated path is calculated next, and if a point deviates more than two standard deviations from the path, it is projected on the path. After that, the ideal meteor's path is recalculated, and used to determine coordinates of meteor start and end points. The duration of the meteor is determined in such a way that the time of appearance of the beginning point is calculated proportionally from distances between first two points and the next two points of detections. The time of disappearance of the end point is calculated in the

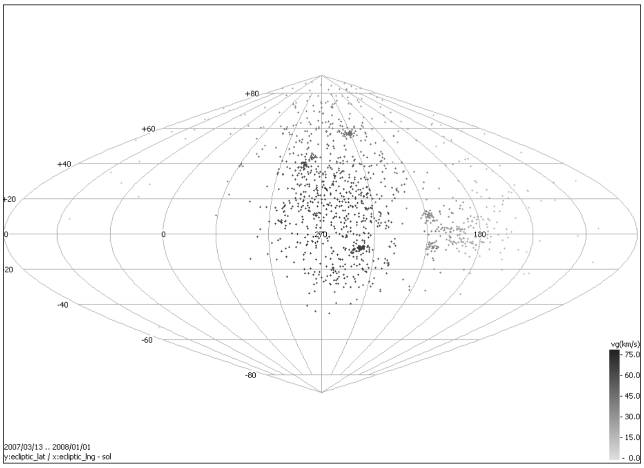

Figure 3 – Radiant plot of orbits from the CMN Catalogue of Orbits for 2007, in ecliptic coordinates. Longitude is given relative to the sun. Geocentric velocities are color coded.

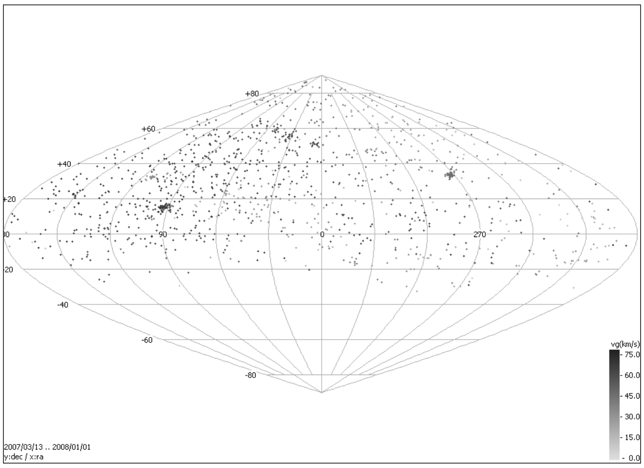

Figure 4 – Radiant plot of orbits from the CMN Catalogue of Orbits for 2007, in equatorial coordinates. Geocentric velocities are color coded.

same manner. At the end, the observations are extracted and processed with the help of UFO software package (SonotaCo, 2008). The calculated meteor paths are stored in `*.csv` R80 format that is described in detail in the UFOOrbit User manual, and meteoroid orbits are calculated from this data by the UFO orbit software.

All orbits obtained this way are gathered in the CMN Catalogue of Orbits for 2007 (CMN CAT 2007), which is available for free download on CMN web pages at `http://hmm.homeip.net/home/hmm/downloads/downloads.html`. As it was already said, this catalogue is in the standard R80 format of UO2, with the only difference being that the column "LocalTime" is used for storing the CMN meteor identification code, not the local time of meteor appearance.

The ground tracks of meteors in the catalogue are show in Figure 2, and radiant plots in ecliptic and equatorial coordinates are shown in Figures 3 and 4.

Last, but not least, the shower statistics of the meteors in the catalogue is summarized in the Table 2. Out of 1 211 orbits in the catalogue, 358 orbits can be identified as orbits belonging to known streams with the remaining 853 orbits left in the sporadics group.

Acknowledgements

Our thanks go to all members of Croatian Meteor Network, as listed in the Table 1. Also, to Peter Gural for MTP detection software and it's adaptation to CMN images and for extensive discussions about all aspects of video meteor detections, to Igor Terlević for many contributions to CMN software suite and to Filip Lolić for hardware modifications of CMN cameras.

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Table 2 – Double station stream statistics for 2007. The first column gives the number of determined meteor orbits for a particular meteor stream, and the following two columns identify the stream by its code and name.

stream name	IAU stream no.	UO2 code	meteors
α Hydrids	331	J5_aHy	1
Andromedids Annual	18	J5_And	1
August β Piscids	342	J5_bPi	1
α Capricornids	1	J5_Cap	3
Dec. Comae Berenicids	20	J5_Com	5
December α Draconids	334	J5_daD	5
η Lyrids	145	J5_eLy	3
η Eridanids	191	J5_Eri	2
η Aquariids	31	J5_etA	6
Geminids	4	J5_Gem	31
h Virginids	343	J5_hVi	1
σ Hydrids	16	J5_Hyd	11
κ Cygnids	12	J5_kCg	4
December κ Draconids	380	J5_kDr	1
Leonids	13	J5_Leo	10
Leonis Minorids	22	J5_Lmi	1
April Lyrids	6	J5_Lyr	44
Dec. Monocerotids	19	J5_Mon	3
Nov. Orionids	250	J5_noO	1
North. Taurids	17	J5_nTa	10
October Ursae Majorids	333	J5_ocU	4
o Eridanids	338	J5_oEr	1
Orionids	8	J5_Ori	79
Perseids	7	J5_Per	30
ψ Ursae Majorids	339	J5_psU	2
South. δ Aquariids	5	J5_sdA	7
September Perseids	208?	J5_sPe	5
South. Taurids	2	J5_sTa	18
θ Pyxidids	340	J5_tPy	1
December χ Virginids	335	J5_xVi	1
Dayt. Arietids	171	Ie_ARI	1
Aurigids	206	Ie_AUR	2
ϵ Geminids	23	Ie_EGE	7
Dayt. α Canis Majorids	231	Iw_ACM	1
August δ Capriconids	199	Iw_ADC	1
Sept. α Orionids	211	Iw_AOR	1
β Aurigids	210	Iw_BAU	6
δ Aquilids	131	Iw_DAL	3
October δ Aurigids	224	Iw_DAU	2
ϵ Eridanids	209	Iw_EER	1
γ Camelopardalids	277	Iw_GCA	1
λ Virginids	148	Iw_LVI	3
ν Aurigids	229	Iw_NAU	1
ν Draconids	220	Iw_NDR	1
Nov. Hydrids	245	Iw_NHD	1
October Cygnids	83	Iw_OCG	1
October Lyncids	228	Iw_OLY	3
October Monocerotids	227	Iw_OMO	3
ψ Aurigids	244	Iw_PAR	1
φ Bootids	273	Iw_PBO	1
σ Capriconids	179	Iw_SCA	1
September β Cassiopeiids	207	Iw_SCS	1
September Lyncids	81	Iw_SLY	2
South. σ Sagittariids	168	Iw_SSS	1
South. March Virginids	124	Iw_SVI	1
ζ Cygnids	40	Iw_ZCY	3
July ζ Draconids	73	Iw_ZED	1
S25	—	sm_025	4
S26	—	sm_026	9
S95	—	sm_095	2
Sporadic Meteors	—	spo	853

Daytime Arietids and Marsden Sunskirters (ARI, IAU #171)

Peter Jenniskens[1], *Heather Duckworth*[2] *and Bryant Grigsby*[3]

During routine low-light level video observations with CAMS (Cameras for All-sky Meteor Surveillance) in June of 2011, four Daytime Arietid meteors were triangulated during the hour before dawn. The measured orbital elements are in good agreement with the linked orbit of the Marsden Sunskirter group comet C/1999 J6 = C/2004 V9 = P/2010 H3. Unlike results from past radar observations of this daytime shower, and prior less accurate multi-station video observations, there is no longer a discrepancy in semi-major axis. This result firmly establishes the association of the Daytime Arietids with the Marsden Sunskirter group of comets.

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1 Introduction

The Daytime Arietids (ARI, IAU#171) are a daytime shower with a radiant only ∼ 30° from the Sun. Nevertheless, a visual observer can observe the shower in the early morning in the first three weeks of June, in the hour before dawn, with rates of 1 − 2 per hour at best. Because of that, the shower can also be targeted in video observations (Fujiwara et al., 2004).

The Daytime Arietids have been associated with the Marsden group of "sunskirter" comets (Seargent, 2002; Sekanina & Chodas, 2005; Jenniskens, 2006), currently with ∼ 38 known comet members. These have orbits that come as close as 0.025 AU from Earth orbit. Most of these small, tens of meter sized comets are only seen when they are very close to the Sun and cross the field of view of the SOHO and STEREO satellites. However, some apparitions have been linked, by predicting the return of the comet successfully. It is now known, that ∼ 35 meter sized Marsden group comet C/1999 J6 broke into C/2004 V9 and C/2004 V10 (Marsden, 2004), and that the brighter C/2004 V9 re-appeared as C/2010 H3 (Marsden, 2010b; Marsden, 2010a). From that we know that the orbital period of this comet is 5.5 years (semi-major axis 3.117 AU).

The proposed association had, until now, a glaring problem: radar observations of the Daytime Arietids claimed a much shorter orbit for the meteoroids than is measured for the comet fragments. The Harvard Radar Project measured a mean semi-major axis of 1.750 AU (Sekanina, 1973) and 1.376 AU (Sekanina, 1976) based on 55 and 48 meteors, respectively. More recently, CMOR radar observations (Campbell-Brown, 2004) measured a semi-major axis decreasing from $a = 2.2$ AU at 70° solar longitude to 1.6 AU at 86°.

If the meteoroids were formed at the same time that the Marsden sungrazer parent comet broke into the family of objects now observed by SOHO and STEREO, then the meteoroids should have a semi-major axis similar to those of the comet fragments (Ohtsuka et al., 2003). Jupiter perturbs the orbit near aphelion, but does not easily change the semi-major axis. If the meteoroids originated from an earlier fragmentation event that left comet 96P/Machholz, then the meteoroid orbits might be more dispersed from planetary perturbations over time, but should still have a semi-major axis not much different than those of the remaining comet fragments.

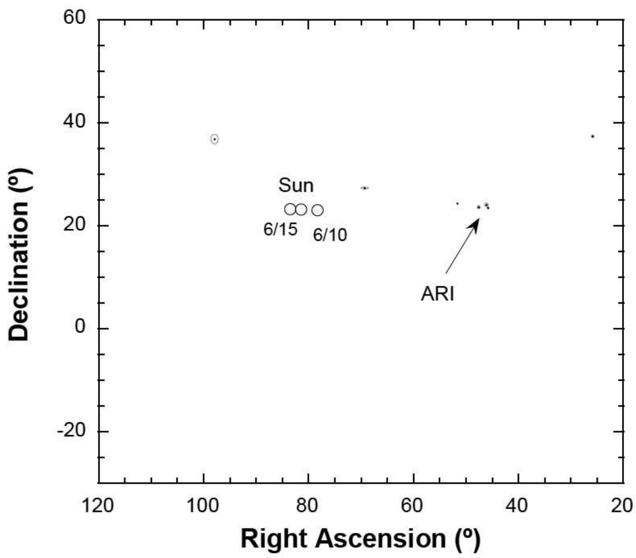

Figure 1 – Radiant position of CAMS meteors in the daytime sky during 2011 June 2–15. Arrow marks the Daytime Arietids.

2 CAMS: Cameras for All-sky Meteor Surveillance

CAMS is a three-station 60-camera meteor surveillance using Watec Wat902 H2 Ultimate cameras with f1.2/12-mm focal length lenses. During June 2011, the CAMS network stations were located at Fremont Peak Observatory, at Lick Observatory, and at a rural location near Lodi, California. The CAMS methods have been described in detail in previous work (Jenniskens et al., 2011), and more information about the CAMS network can be found on the web-site `http://cams.seti.org`.

3 Detection of the Daytime Arietids

Here, we report on the detection of four Daytime Arietids during routine observations on June 10, 13 and 15, 2011. The meteors were captured in the hour before dawn. Weather permitted observations in that time

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Table 1 – Daytime Arietid radiant (α, δ), speed (V_g), deceleration parameters (a_1, a_2), beginning and end height (H_b, H_e), peak absolute visual magnitude (m_V), and lightcurve asymmetry parameter (F).

Time (UT)	Date m/d/y	α (°)	δ (°)	V_g (km/s)	a_1 (km/s²)	a_2 (/s)	H_b (km)	H_e (km)	m_V (magn.)	F
$11^h34^m42^s$	6/10/11	45.85	+23.50	42.06	0.000	0.174	103.6	95.8	+0.8	0.49
		±0.22	±0.24	±0.03	±0.03	±0.034	±0.09	±0.16		
$11^h51^m32^s$	6/10/11	46.12	+24.09	41.49	0.000	0.034	98.4	95.7	+3.4	0.17
		±0.39	±0.38	±0.18	±0.01	±0.089	±0.06	±0.07		
$12^h03^m42^s$	6/13/11	47.60	+23.63	43.73	0.201	3.068	97.1	87.4	+1.1	0.41
		±0.33	±0.30	±0.33	±0.12	±0.68	±0.22	±0.21		
$11^h34^m06^s$	6/15/11	51.68	+24.33	40.91	0.001	5.156	101.6	90.1	+0.2	0.46
		±0.07	±0.07	±0.04	±0.000	±0.26	±0.03	±0.05		

Table 2 – Orbital elements of Daytime Arietids ($J2000$).

Time (UT)	$\lambda_\odot$ (°)	a (AU)	q (AU)	e (°)	i (°)	ω (°)	Ω (°)	Π (°)
$11^h34^m42^s$	79.114	2.992	0.0588	0.980	25.950	25.43	79.120	104.55
			±0.0017	0.001	0.94	0.43	0.000	0.43
$11^h51^m32^s$	79.125	2.835	0.0664	0.977	26.11	26.92	79.132	106.06
			±0.0040	0.001	1.08	0.93	0.000	0.93
$12^h03^m42^s$	82.000	3.513	0.0422	0.988	30.57	21.77	82.005	103.78
			±0.0034	0.001	0.97	0.92	0.001	0.82
$11^h34^m06^s$	83.891	2.608	0.0663	0.975	21.19	26.62	83.898	110.52
			±0.0007	0.001	0.12	0.15	0.000	0.15
CAMS	81.0	3.0	0.0584	0.980	26.0	25.1	81.0	106.2
$\sigma(N=4)$	(±4)		±0.0114	±0.003	±3.8	±2.3	±2.3	±3.0
CMOR:	78.5	1.6	0.088	0.94	29	27	78.5	105.5
σ	(±3)	±0.4	±0.003	±0.03	±6	±4	±3	±4
SonotaCo:	82.2	2.1	0.064	0.967	31.1	24.9	82.2	107.1
$\sigma(N=8)$	±3.5	±0.6	±0.013	±0.014	±7.6	±2.5	±3.5	±1.6
Fujiwara:	77.8	2.6	0.073	0.97	32.0	27.0	77.8	104.9
$\sigma(N=3)$	±2.2	±0.8	±0.006	±0.01	±3.3	±0.2	±2.2	±2.1
Marsden group comet:								
C/1999 J6	78.4	3.117	0.0478	0.9847	23.964	25.019	78.359	103.378

interval also on June 9 and 14, but without further detections.

The trajectory data of these four meteors are listed in (Table 1). The time and date of each meteor is given, as well as the geocentric radiant position and speed (equinox J2000), the deceleration parameters a_1 and a_2, where deceleration as a function of time equals $a = a_1 \exp(a_2 t)$, the beginning and end height, the absolute visual magnitude of the peak of the light curve and the light curve asymmetry parameter F. For definitions, see (Jenniskens et al., 2011).

In total, 512 meteors were triangulated between June 1 and 15. The four Daytime Arietids stand out well as a tight cluster of three radiants in the daytime sky and one slightly to higher right ascension Figure 1. The cluster of three CAMS Daytime Arietids has a mean radiant of $\alpha = 46.5 \pm 0.^\circ 9$, $\delta = +23.7 \pm 0.3$, and $V_g = 42.4 \pm 1.2$ km/s. All of the other 508 radiant positions fall outside of Figure 1.

The orbital elements calculated from the radiant and speed are given in (Table 2). Based on the calculated error bars, there is significant dispersion in perihelion distance (q), eccentricity (e), inclination (i), argument of perihelion (ω), and longitude of perihelion (Π).

4 Discussion and conclusion

Table 1 compares our results to the mean of the three Daytime Arietid orbits measured with intensified video cameras published by Fujiwara et al. (Fujiwara et al., 2004) and orbits reported by the SonotaCo network (SonotaCo, 2009) with mostly wider field low-light level cameras. Eight meteors in the SonotaCo database (2007 – 2009) are marked "Arietids". Another meteor marked "sporadic" is likely also an Arietid. One of these, however, has a 10° lower longitude of perihelion and may not be a member of the stream. With the exception of this meteor, the radiant position and speed are in general agreement with our data, but more widely scattered. Unlike our data, the geocentric speed correlates only weakly with semi-major axis, for unknown reason. The speeds are not corrected for deceleration.

Our new orbits have semi-major axis in the range $a = 2.6 - 3.5$ AU, higher than previously reported. When taking all low-light-level video orbits together, and after excluding three outlayers with low declination and speed, the mean geocentric speed is still higher than the 35.7 km/s quoted in the IAU database, higher even than the 39.4 km/s derived from the CMOR results after correction for deceleration. The radiant drift is $+0.87°$ per degree solar longitude (instead of $+0.70°$) in R.A. and $+0.07°$ (instead of $+0.60°$) in Declination. The velocity does not significantly change with solar longitude. During the peak of the shower at 78.5° solar longitude (Campbell-Brown, 2004), the CAMS measured radiant would be at $\alpha = 44.3°$, $\delta = +23.5°$, $V_g = 42.4$ km/s.

It is unclear why the radar observations show a much smaller semi-major axis on average than our optical observations. It is possible that the deceleration of the meteoroids was not accurately taken into account. The deceleration correction in the radar observations is based on a mean behavior for other showers with known speed (Campbell-Brown, 2004).

On the other hand, the decelerations measured for the four CAMS Daytime Arietids are not unusual, perhaps even on the low side (Table 1). For comparison, all 512 meteors detected by CAMS in this time period had a mean $a_1 = 0.17 \pm 0.85$ km/s^2, and $a_2 = 2.1 \pm 5.3$ /s (1 sigma variation).

All optical observations together show q decreasing with -0.0026 AU/° and ω decreasing with -0.59 °/° (between solar longitude 76° and 86°). Other parameters do not vary significantly. Some of that variation may be related to particle density, as the beginning height of the meteors also decreases with -0.56 km/°, while the mean magnitude stays constant. CMOR results (Campbell-Brown, 2004) also showed a decrease of perihelion distance (-0.001 AU/°) and decrease of argument of perihelion with solar longitude (-0.6 °/°), the most striking variations.

In Table 2, the CAMS results are compared to the linked orbit of Marsden group comet C/1999 J6 = 2004 V9 = 2010 H3 (for Epoch 2010), calculated by Syuichi Nakano (Nakano, 2008). There is good agreement between the CAMS orbital data and the linked Marsden group comet within the error bars calculated from the measurement uncertainty. This establishes the proposed association of the Daytime Arietids with the Marsden Sungrazer group. It is now possible that the meteoroids are debris from the breakup that created the Marsden group family of comets, or derived from an earlier fragmentation that left 96P/Machholz.

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Preliminary results

Results of the IMO Video Meteor Network — February 2012

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The IMO Video Meteor Network cameras operated in all 29 nights of 2012 February. More than 15 000 meteors were recorded by 67 cameras in over 7 400 hours of effective observing time. New showers recently reported by other authors are examined. The February η-Draconids were detected already in the 2009 analysis and are further confirmed by this analysis containing data up to 2012. The flux density profile in 2012 is presented for that shower. The December σ-Virginids are also confirmed based on the Network data up to 2011. The α-Coronae Borealids and June ι-Pegasids were also detected already in the 2009 analysis. This analysis based on data until 2011 confirms the shower. The July γ-Draconids that were recently reported confirmed were already confirmed in the 2009 analysis.

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1 Introduction

In February, the weather differed significantly at the individual observing sites. In the first half of the month, the observers in north-western Europe were preferred, whereas there were only little clear skies in the south-east of Europe. In the second half, the situation reversed. Now the Hungarian and Slovenian observers were more successful, whereas in Germany the weather was poor. Only the southern European observers enjoyed perfect observing conditions all month long. An overall of 16 cameras recorded meteors in twenty or more nights, which is about one quarter of all active cameras.

With 7 400 hours of effective observing time (Table 7 and Figure 1), the 2011 (Molau et al., 2011) result was more than doubled. The number of meteors, however, grew only by about 40%. Now you may ask, whether the low average of only 2.1 meteors per hour is real (last year it was 3.4 meteors per hour) or whether there was some other reason. Our analysis shows that the mean in 2010 and 2011 was well above 3.0, but more like 2.5 before that. In the last two years, we used a different method to determine observing breaks caused by clouds. Apparently this method was too pessimistic, so that in the absence of meteors many clear sky intervals were marked as clouded.

In February we could welcome a new observer in the IMO Network. Francisco Ocaña Gonzalez—Paco for short—has been dealing with video meteors already for quite some time. Now he started to operate his own camera FOGCAM in the city of Madrid. We are knocking on wood that the camera name is not a bad omen.

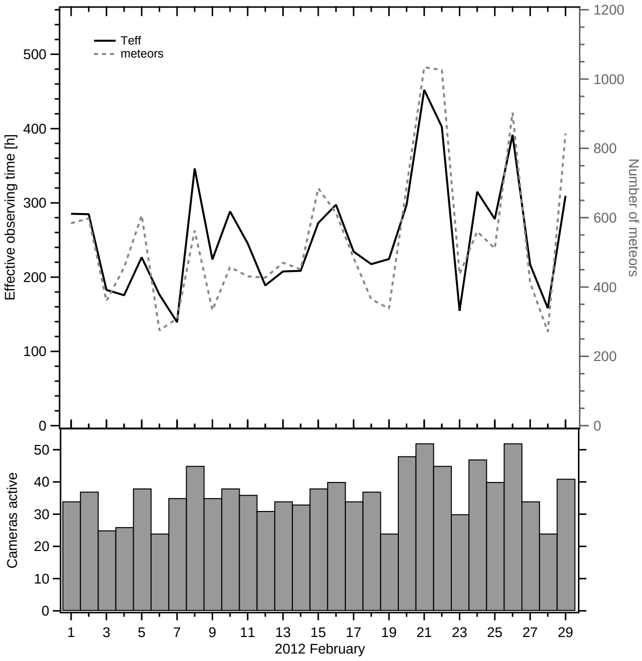

Figure 1 – Monthly summary for the effective observing time (solid black line), number of meteors (dashed gray line) and number of cameras active (bars) in 2012 February.

2 Recent shower reports

At this point let us have a look at observing results. In the previous months, there were a number of reports in *WGN* about discoveries of new meteor showers from multi-station video observations. Unfortunately, observations from the IMO Video Meteor Network and our analysis results were either ignored or incorrectly interpreted. That is a pity, because we have proven in the past that precise meteor shower parameters can also be derived from single-station data. In particular thanks to the long history and the comprehensive size, the IMO Video Meteor Database yields a better coverage than any other meteor database in the optical domain. In

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2009, for example, when SonotaCo analyzed the data of the SonotaCo Network and published ten new meteor showers in *WGN* (SonotaCo, 2009), we could confirm each of these in advance based on our own data (Molau & Rendtel, 2009b).

Before we look at the latest examples, we will first scrutinize the differences between double-station and single-station observations in more detail, and how that affects the calculation of meteor shower parameters.

It is not possible to determine the radiant or trajectory of the meteoroid from a single meteor recording. You only see a projection of the meteor against the sky background and you do not know then entry angle at which the meteoroid entered the Earth atmosphere.

In case of double-station observations the same meteor is observed from two different viewing angles. The apparent radiant can be derived from the backward prolongation of the meteor trails. By triangulation, the trajectory of the meteoroid is obtained, which in turn yields the entry velocity. A prerequisite is that the stations are located in a favorable angle with respect to the meteor trail. The connecting line between both stations should at best be perpendicular to the plane of the meteoroid. If the meteoroid moves in parallel to the connecting line, the meteor trail shifts along the direction of meteor motion and an analysis is hardly possible.

In case of single-station analysis, the meteor is not observed from two stations, but the analysis is based on two meteors of the same shower recorded by one station. Also in this case, the geometry must fit. The radiant can be determined by backward prolongation most precisely if both meteor trails are oriented orthogonal to each other. If the meteor trails are nearly parallel, however, the point of intersection cannot be computed properly. The derivation of the meteor velocity is not directly possible from single-station data. The altitude of the atmospheric entry point must be known to determine the entry velocity from the apparent angular velocity and the position of the meteor relative to the radiant.

Thus, there are two principal problems in single-station data analysis. On the one hand you cannot know for sure if two meteors belong to the same shower and have exactly the same radiant, and on the other hand assumptions about the entry point altitude need to be made. Both problems are tackled by statistics. That is feasible because there are typically an order of magnitude more meteors available in single-station analysis than from double-station observations.

In practice, meteors are not evaluated pairwise, but individually. For each meteor, the probability of radiants along the backward prolongation is calculated and accumulated over all meteors. Sporadic meteors yield a smooth background probability if they are numerous enough. If there is an active meteor shower, however, the accumulated probability will be highest at the intersection point of the backward prolongations and the proper shower velocity.

The entry point altitude required for the calculation is derived beforehand as a function of the meteor shower velocity. The real altitude of individual meteors will differ from the mean, but on average they will fit to the value determined beforehand.

What other differences are there between double-station and single-station analyses?

In case of double-station, each meteor yields a single radiant position and entry velocity. The challenge is to find those clusters from the cloud of sporadic radiants that belong to one shower. The orbital elements are typically determined for each meteor individually, and averaged over all meteors. That is somehow dangerous, as only in case of symmetric probability distributions the arithmetic mean yields the expectation value. In case of other distribution types, the expectation value should be derived differently.

In case of single-station, averaging is inherent to the analysis process. The procedure yields exactly one average radiant and velocity for a shower, that fits best to all data. From these values, a set of mean orbital elements can be derived. From the shape and size of the probability distribution, the radiant size and velocity distribution can be deduced, but it is more complicated than in case of double station observations. However, also in case of double-station observations it is not sufficient to treat each radiant as punctiform. The observing error needs to be considered as well. In the end, a probability distribution for radiant position and velocity should be obtained which resembles the distribution derived from single-station data.

To sum: The main disadvantage of single-station observation is the combination of different meteors from the same shower, and the estimate of the meteor altitude. On the other hand, the data set is typically larger and both the search for shower radiants in the sporadic background and averaging meteor shower radiants and the orbital parameters happens automatically.

Before we start to discuss detailed examples, we want to repeat briefly how the single-station analysis in the IMO Video Meteor Network is performed. In the first step, the active radiants (i.e. pairs of radiant position and velocity) are calculated for each solar longitude interval. Then a search for radiants with similar parameters in adjacent intervals is performed. The result is a list of meteor showers as published last time in *WGN* in 2009 (Molau & Rendtel, 2009b). Due to the required activity in several solar longitude intervals, the confidence is improved, but short-term meteor showers are missed by this type of analysis. For this reason, we published also the original list of individual radiants per solar longitude interval in the internet at `http://www.imonet.org/wgn09/radiants.html` (Molau & Rendtel, 2009a). Anyone can easily check there whether a certain radiant stands out from the sporadic background at a given time or not.

Now you may get the impression, that among those up to hundred radiants per solar longitude interval, there will always be chance alignments with real meteor showers, but that is not the case. On the one hand, we focus on the first ten radiants or so on the list. On the other hand, the probability to guess a radiant that deviates no more than 10° and 10 km/s from a given shower

Table 1 – Parameters of the February η-Draconids from the analysis of Jenniskens and Gural (2011), and from IMO Network analyses in 2009 (Molau & Rendtel, 2009a) and 2012 (this work).

Source	$\lambda_\odot$ [°]	Rank	α [°]	δ [°]	V_∞ [km/s]
Jenniskens & Gural (2011)	315.1	—	239.9	+62.5	37.3
IMO 2009	315	1	239.3	+61.0	34
IMO 2012	315	2	241.3	+61.0	33

can be estimated. The hemisphere contains more than 40 000 square degrees and the relevant velocity interval ranges from 10 to 70 km/s, which gives of the order of $7 \times 400 = 2\,800$ possible radiants. So the probability to have a fluke among the ten most active radiants is about 1/280. If you allow only 5° and 5 km/s deviation, it is even about 1/2 240 only.

After these theoretical considerations, we will now address the aforementioned publications.

2.1 February η-Draconids

In *WGN* **39:4**, Peter Jenniskens and Peter Gural report on the discovery of the February η-Draconids (Jenniskens & Gural, 2011). On 2011 February 4 they observed six similar meteoroid orbits from a hitherto unknown meteor shower in a time interval of roughly seven hours. As the shower could not be observed in the night before and thereafter, and also the data of the Japanese SonotaCo Network between 2007 to 2009 showed no hint of this shower, the authors assumed a unique outburst originating from the dust trail of a long-periodic comet.

That is a pity, because when the authors would have had a look at the above-mentioned radiant list (Molau & Rendtel, 2009a), they would have recognized immediately, that it was not a unique outburst. The most active radiant at solar longitude 315° found in our 2009 analysis is based on 36 meteors and fits well to the parameters derived by Jenniskens and Gural (2011). The figures are summarized in Table 1, whereby the velocities are transformed according to the formula $V_\infty = \sqrt{V_{geo}^2 + 125}$, and rank is the position of the radiant in the list which is sorted by accumulated probability.

As our analysis was based on data until 2009 it is clear that the February η-Draconids must have been active before 2011. We can confirm the short duration of the shower, because already in the adjacent solar longitude intervals the radiant is not detected anymore.

Based on the observation from the IMO Video Meteor Network until the end of 2011, a new analysis was conducted now. The new values derived from 70 shower members deviate only slightly from the previous ones. An additional analysis with higher temporal resolution showed that particularly many meteors were observed between 314.°7 and 315.°0 solar longitude, but also in a few intervals before and thereafter. Most February η-Draconids were recorded in 2007, 2008 and 2011 so far. The reason is, that in these years we obtained more observations in the corresponding solar longitude interval than in others. Since 2000, an average of 4% of all meteors recorded between 314° and 316° solar longitude belonged to this shower. It indicates that the February η-Draconids are active every year. In 2012, we recorded 20 shower meteors in the nights of February 3/4 and 4/5 (Figure 2).

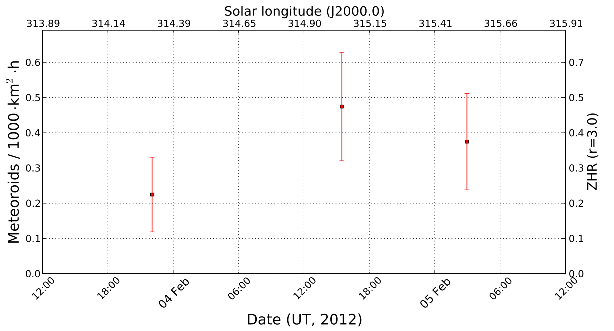

Figure 2 – Flux density of the February η-Draconids in February 2012.

In *WGN* **40:1**, John Greaves presented four new meteor showers that he had found in the SonotaCo Network data (Greaves, 2012).

2.2 December σ-Virginids

The first shower are the December σ-Virginids, derived from 22 meteoroid orbits at a mean solar longitude of 267.°4. This shower was identified by comparing the meteoroid orbits with orbits of known comets. Earlier SonotaCo had assigned all these 22 orbits to the sporadic background. Checking the radiant list given above (Molau & Rendtel, 2009a), no radiant at solar longitude 267° and 268° fits.

However, a new analysis of all data until 2011 draws a different picture. Here we find in all intervals between 263° and 267° solar longitude a radiant that agrees well with the parameters given by Greaves (2012). In fact, the activity interval could still reach beyond these limits. Thus, also this weak shower can be confirmed by us at least when using the more comprehensive data set of 2012.

2.3 α-Coronae Borealids

For the second shower, the α-Coronae Borealids, Greaves (2012) determined a radiant from 15 meteoroids at a mean solar longitude of 309.°9. In our 2009 radiant list, the strongest radiant both at solar longitude 308° and 309° fits well to the values given by Greaves (Table 3). The only reason why this shower with 75 members was not identified in the IMO analysis of 2009 was the inactivity in the solar longitude intervals before and thereafter. Hence, the activity was too short for the analysis procedure at that time.

A new analysis based on all data including 2011 is supporting the result, since now the radiant is also on top at solar longitude 307° and 310°, even though with slightly different declination and velocity.

Table 2 – Parameters of the December σ-Virginids from the analysis of Greaves (2012) and from the IMO Network analysis in 2012 (this work).

Source	$\lambda_\odot$ [°]	Rank	α [°]	δ [°]	V_∞ [km/s]
Greaves (2012)	267.4	—	205.0	+5.5	66.9
IMO 2012	263	18	202.4	+5.5	69
	264	10	202.8	+5.0	68
	265	6	202.9	+5.5	71
	266	5	203.4	+5.5	71
	267	7	204.6	+6.0	71
	268	7	205.3	+5.0	69
	269	11	207.0	+4.0	70
	270	7	207.4	+3.5	68
	271	8	207.9	+3.5	68
	272	9	208.4	+3.5	70
	273	5	209.5	+4.0	69
	274	4	209.9	+3.5	69
	275	5	212.0	+4.0	69
	276	7	212.4	+3.5	69

Table 3 – Parameters of the α-Coronae Borealids from the analysis of Greaves (2012) and from IMO Network analyses in 2009 (Molau & Rendtel, 2009a) and 2012 (this work).

Source	$\lambda_\odot$ [°]	Rank	α [°]	δ [°]	V_∞ [km/s]
Greaves (2012)	309.9	—	233.3	+27.0	59.1
IMO 2009	308	1	231.0	+28.0	59
	309	1	232.3	+27.0	58
IMO 2012	307	1	231.5	+29.0	55
	308	1	232.4	+26.5	58
	309	1	232.4	+26.5	58
	310	1	232.8	+23.5	58
	311	4	234.6	+22.0	64

2.4 September π-Orionids

Even more interesting is the third candidate from Greaves (2012), the September π-Orionids. Here he obtains a mean radiant from 13 meteoroid orbits at 178°.4 solar longitude. Also this shower is clearly confirmed in our 2009 data – the third strongest radiants at 177° and 178° solar longitude fits well to the data of Greaves (Table 4). But more than this: In our analysis, these radiant were assigned to a shower as well! In 2009, we could trace the ν-Eridanids between solar longitude 158° an 181°. In that time, the radiant drifted in right ascension from 68° to 74° and in declination from −2° to +4°. Between 177° and 181° solar longitude, however, declination jumped to values between +7° and +9°. For this reason, we only had used the interval from 162° to 165° in our analysis, where the position and velocity showed the smallest scatter.

A new analysis based on all data till 2011 returned a similar picture. Between 175° and 181°, the right ascension is increasing by an average of +0°.8 per day, and the declination values range from +4° to +6°. Only at solar longitude 179° and 180° it jumps again to +9°.

Our assumption is that the π-Orionids and the ν-Eridanids are not two showers nearby in time and space, but that they are in fact the same meteor shower.

Table 4 – Parameters of the September π-Orionids from the analysis of Greaves (2012) and from IMO Network analyses in 2009 (Molau & Rendtel, 2009a) and 2012 (this work).

Source	$\lambda_\odot$ [°]	Rank	α [°]	δ [°]	V_∞ [km/s]
Greaves (2012)	178.4	—	74.9	+8.4	68.9
IMO 2009	177	3	74.6	+7.0	66
	178	3	76.6	+7.5	65
IMO 2012	175	1	74.1	+3.5	65
	176	2	75.2	+4.0	66
	177	1	75.8	+5.0	68
	178	3	76.7	+4.5	68
	179	4	77.5	+9.0	71
	180	4	78.0	+9.0	69
	181	2	79.4	+6.0	67

Table 5 – Parameters of the June ι-Pegasids from the analysis of Greaves (2012) and from IMO Network analyses in 2009 (Molau & Rendtel, 2009a) and 2012 (this work).

Source	$\lambda_\odot$ [°]	Rank	α [°]	δ [°]	V_∞ [km/s]
Greaves (2012)	94.5	—	332.6	+29.2	60.0
IMO 2009	94	3	331.6	+29.0	57
IMO 2012	93	1	331.6	+29.0	60
	94	1	331.6	+29.0	60

2.5 June ι-Pegasids

Finally we can also confirm the fourth shower discovered by Greaves (2012). For the June ι-Pegasids, Greaves had found 9 orbits at a mean solar longitude of 94°.5. In our 2009 analysis, the third strongest radiant at solar longitude 94° is based on 41 meteors and fits well to the parameters given by Greaves. Also in the preceding interval the radiant is traceable, but not before and thereafter. The latest analysis including all data until 2011 confirms the result. Here, the radiant is on top of the list at solar longitude 93° and 94°, but untraceable at 92° and 95°.

2.6 July γ-Draconids

The last example are the July γ-Draconids. This shower was postulated in 1963 based on only three meteor photographs, and it could also be found in the SonotaCo Network data. In *WGN* **40:1**, David Holman and Peter Jenniskens (2012) report on the confirmation of this shower, after they derived 25 fitting meteoroid orbits with the CAMS network between 2011 July 24 and August 1. Furthermore the two authors report that this shower was not present in the IMO video analysis of 2009. Unfortunately they made a mistake here, as the July γ-Draconids were clearly identified by us between solar longitude 120° and 127°. Based on 428 shower members, we had derived parameters in 2009 that agree well with the results of SonotaCo and the CAMS network (Table 6). In fact, we even presented an activity graph in 2009 which confirms the maximum date of solar longitude 125° given by Holman and Jenniskens (2012).

Table 6 – Parameters of the July γ-Draconids from the analyses of Holman and Jenniskens (2012), SonotaCo (2009), and from IMO Network analyses in 2009 (Molau & Rendtel, 2009b) and 2012 (this work).

Source	$\lambda_\odot$ [°]	Rank	α [°]	δ [°]	V_∞ [km/s]
Holman & Jenniskens (2012)	124.7	—	279.6	+50.4	29.7
SonotaCo (2009)	125	—	280.1	+51.1	29.6
IMO 2009	125	—	280.9	+50.7	27.3
IMO 2012	122	6	280.6	+50.5	27
	123	5	279.7	+51.0	26
	124	4	281.4	+50.5	26
	125	4	280.6	+50.5	27
	126	4	280.5	+51.0	27
	127	5	280.5	+51.0	26

A new analysis based on all data including 2011 is refining the result. This time, the shower was identified between 122° and 127° solar longitude, with the maximum between 125° and 126° and virtually no radiant drift.

3 Conclusions

From these six examples we draw two main conclusions.

Meteor shower and their parameters can be derived reliably from single station data, whereby the radiant position is currently more precisely derived than the velocity. For each hypothesized new meteor shower it is worth to check briefly at `http://www.imonet.org/wgn09/radiants.html` whether single-station observations of the IMO Video Meteor Network had derived a radiant with similar parameters. If that is the case, you have immediate confirmation for your own hypothesis. If not, you should double-check your results.

In addition, more showers are waiting for their discovery in the above-mentioned radiant list, which slipped our 2009 analysis because of their short duration.

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Table 7 – Observers contributing to 2012 February data of the IMO Video Meteor Network. Eff.CA designates the effective collection area.

Code	Name	Place	Camera	FOV [°²]	Stellar LM [mag]	Eff.CA [km²]	Nights	Time [h]	Meteors
BASLU	Bastiaens	Hove/BE	Urania1 (0.8/3.8)*	4545	2.5	237	1	4.5	1
BERER	Berko	Ludányhalászi/HU	Hulud1 (0.95/3)	2256	4.8	1540	18	92.3	328
			Hulud2 (0.75/6)	4860	3.9	1103	15	57.9	168
			Hulud3 (0.75/6)	4661	3.9	1052	17	51.4	121
BOMMA	Bombardini	Faenza/IT	Mario (1.2/4.0)	5794	3.3	739	13	108.3	86
BREMA	Breukers	Hengelo/NL	Mbb3 (0.75/6)	2399	4.2	699	11	98.9	143
			Mbb4 (0.8/8)	1470	5.1	1208	9	69.2	89
BRIBE	Brinkmann	Herne/DE	Hermine (0.8/6)	2374	4.2	678	16	135.7	186
		Bergisch Gladbach/DE	Klemoi (0.8/6)	2286	4.6	1080	15	130.1	167
CASFL	Castellani	Monte Baldo/IT	Bmh1 (0.8/6)	2350	5.0	1611	21	99.2	263
			Bmh2 (1.5/4.5)*	4243	3.0	371	21	57.9	299
CRIST	Crivello	Valbrevenna/IT	Bilbo (0.8/3.8)	5458	4.2	1772	23	185.8	531
			C3P8 (0.8/3.8)	5455	4.2	1586	22	158.0	305
			Stg38 (0.8/3.8)	5614	4.4	2007	24	184.8	692
CSISZ	Csizmadia	Zalaegerszeg/HU	Huvcse01 (0.95/5)	2423	3.4	361	12	49.3	62
ELTMA	Eltri	Venezia/IT	Met38 (0.8/3.8)	5631	4.3	2151	20	170.3	308
GONRU	Goncalves	Tomar/PT	Templar1 (0.8/6)	2179	5.3	1842	26	274.0	763
			Templar2 (0.8/6)	2080	5.0	1508	28	282.2	648
			Templar3 (0.8/8)	1438	4.3	571	28	271.4	442
GOVMI	Govedič	Središče ob Dravi/SI	Orion2 (0.8/8)	1447	5.5	1841	17	101.1	211
			Orion3 (0.95/5)	2665	4.9	2069	13	60.9	72
			Orion4 (0.95/5)	2662	4.3	1043	14	100.3	83
HINWO	Hinz	Brannenburg/DE	Acr (2.0/35)*	557	7.4	4954	7	49.7	255
IGAAN	Igaz	Baja/HU	Hubaj (0.8/3.8)	5552	2.8	403	20	89.5	174
		Debrecen/HU	Hudeb (0.8/3.8)	5522	3.2	620	15	128.9	242
		Hódmezővásárhely/HU	Huhod (0.8/3.8)	5502	3.4	764	15	90.6	93
		Budapest/HU	Hupol (1.2/4)	3790	3.3	475	18	95.5	43
		Sopron/HU	Husop (0.8/6)	2031	3.8	460	21	89.6	226
KACJA	Kac	Kostanjevec/SI	Metka (0.8/8)*	1372	4.0	361	7	57.7	83
		Ljubljana/SI	Orion1 (0.8/8)	1402	3.8	331	20	142.7	166
		Kamnik/SI	Cvetka (0.8/3.8)	4914	4.3	1842	19	130.7	387
			Rezika (0.8/6)	2270	4.4	840	18	121.6	486
			Stefka (0.8/3.8)	5471	2.8	379	15	117.5	281
KERST	Kerr	Glenlee/AU	Gocam1 (0.8/3.8)	5189	4.6	2550	12	60.5	474

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KOSDE	Koschny	Noordwijkerhout/NL	Lic4 (1.4/50)*	2027	6.0	4509	12	99.5	142
LERAR	Leroy	Gretz/FR	Saphira (1.2/6)	3260	3.4	301	17	127.3	71
MACMA	Maciejewski	Chelm/PL	Pav35 (1.2/4)	4383	2.5	253	14	63.4	63
			Pav36 (1.2/4)*	5732	2.2	227	16	70.0	76
			Pav43 (0.95/3.75)*	2544	2.7	176	13	8.7	37
MARGR	Maravelias	Lofoupoli-Crete/GR	Loomecon (0.8/12)	738	6.3	2698	9	54.7	110
MOLSI	Molau	Seysdorf/DE	Avis2 (1.4/50)*	1776	6.1	3817	12	75.0	374
			Mincam1 (0.8/8)	1477	4.9	1084	18	142.7	225
		Ketzür/DE	Remo1 (0.8/8)	1467	6.0	3139	19	135.8	559
			Remo2 (0.8/3.8)	5613	4.0	1186	8	56.2	103
MORJO	Morvai	Fülöpszállás/HU	Huful (1.4/5)	2522	3.5	532	18	90.5	99
OCAFR	Ocaña Gonzáles	Madrid/ES	Fogcam (1.4/8)	1890	3.9	109	4	22.6	23
OTTMI	Otte	Pearl City/US	Orie1 (1.4/5.7)	3837	3.8	460	16	112.7	232
PERZS	Perko	Becsehely/HU	Hubec (0.8/3.8)*	5498	2.9	460	18	102.7	430
PUCRC	Pucer	Nova vas nad Dragonjo/SI	Mobcam1 (0.75/6)	2398	5.3	2976	23	175.4	326
ROTEC	Rothenberg	Berlin/DE	Armefa (0.8/6)	2366	4.5	911	7	39.1	58
SARAN	Saraiva	Carnaxide/PT	Ro1 (0.75/6)	2362	3.7	381	28	266.6	400
			Ro2 (0.75/6)	2381	3.8	459	27	266.4	342
			Sofia (0.8/12)	738	5.3	907	26	272.0	265
SCALE	Scarpa	Alberoni/IT	Leo (1.2/4.5)*	4152	4.5	2052	19	144.7	206
SCHHA	Schremmer	Niederkrüchten/DE	Doraemon (0.8/3.8)	4900	3.0	409	15	114.8	104
SLAST	Slavec	Ljubljana/SI	Kayak1 (1.8/28)	588	—	—	1	3.0	5
STOEN	Stomeo	Scorze/IT	Min38 (0.8/3.8)	5566	4.8	3270	19	165.9	510
			Noa38 (0.8/3.8)	5609	4.2	1911	20	166.6	376
			Sco38 (0.8/3.8)	5598	4.8	3306	19	172.6	569
STRJO	Strunk	Herford/DE	Mincam2 (0.8/6)	2362	4.6	1152	6	48.5	26
			Mincam3 (0.8/12)	728	5.7	975	15	109.2	135
			Mincam5 (0.8/6)	2349	5.0	1896	14	108.6	161
TEPIS	Tepliczky	Budapest/HU	Humob (0.8/6)	2388	4.8	1607	15	116.3	243
TRIMI	Triglav	Velenje/SI	Sraka (0.8/6)*	2222	4.0	546	16	68.6	208
YRJIL	Yrjölä	Kuusankoski/FI	Finexcam (0.8/6)	2337	5.5	3574	14	37.0	103
ZELZO	Zelko	Budapest/HU	Huvcse02 (0.95/5)	1606	3.8	390	3	21.2	9
			Huvcse03 (1.0/4.5)	2224	4.4	933	5	25.9	26
						Overall	29	7 402.2	15 494

* active field of view smaller than video frame

Results of the IMO Video Meteor Network — March 2012

Sirko Molau[1], *Javor Kac*[2], *Erno Berko*[3], *Stefano Crivello*[4], *Enrico Stomeo*[5], *Antal Igaz*[6] *and Geert Barentsen*[7]

Preliminary results for 2012 March are presented of the IMO Video Meteor Network data, obtained by 62 video systems. More than 17 500 meteors were recorded in almost 9 000 hours of effective observing time. The IMO Video Meteor Database now contains over one million meteors. The database was analysed with RadFind to search for new showers and confirm showers on the IAU MDC working list. The χ-Herculids were confirmed and radiant parameters refined with respect to parameters reported at discovery. The f-Herculids were again found to be ill-defined and this shower remains questionable. The η-Virginids, λ-Virginids, Northern March Virginids and ζ-Serpentids could be partly confirmed, however a large scatter in RA, Dec and velocity was found. Hints about two possible new showers are presented but the dataset for them is too weak therefore they are not yet reported to MDC.

Received 2012 May 24

1 Introduction

In March, 33 observers participated in the camera network with 62 video systems. Even though some cameras had to pause because of relocation and reconstruction, the outcome was notable. In the first half of the month, only observers in southern and eastern Europe enjoyed great weather. Later almost all observers were lucky and, thus, there were once more a number of nights with more than fifty video systems active in parallel. At least 37 video systems observed in twenty observing nights and the effective observing time accumulated to 9 000 hours (Table 6 and Figure 1), which is the third best monthly total in the video network to date. The hourly meteor rate fell to the annual minimum of only two meteors per hour – in October the hourly rate is thrice as high! Still, those 17 500 meteors recorded in March are a fine result.

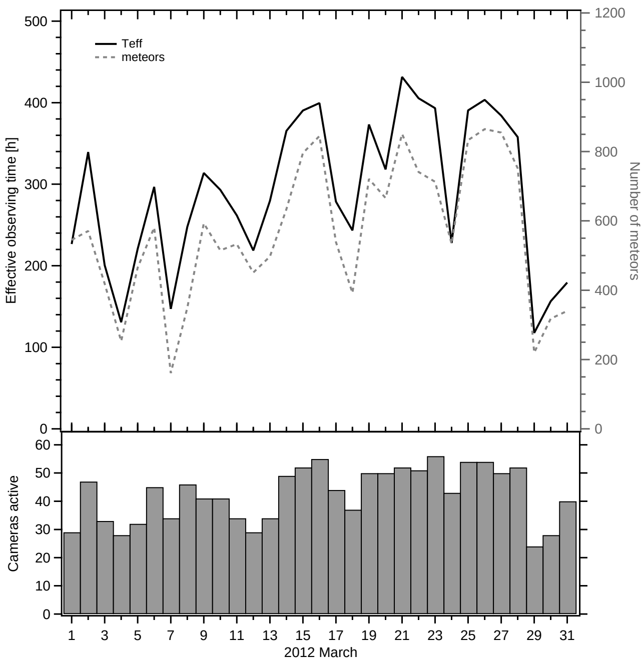

Figure 1 – Monthly summary for the effective observing time (solid black line), number of meteors (dashed gray line) and number of cameras active (bars) in 2012 March.

2 March minor showers

You may think that March has nothing to present with respect to meteor showers. That is true for major showers, but looking at minor showers the situation is not that bad.

Already in the February report (Molau et al., 2012) we checked and confirmed a number of new minor showers that were detected recently by different researchers. Whereas the time-consuming radiant calculations were only carried out for selected solar longitude intervals then, we now analysed the full IMO Video Meteor Database with over a million meteors until the end of 2011. The analysis software RadFind was left almost unchanged compared to the last major analysis of 2009 (Molau & Rendtel, 2009). Further improvements in the code will be implemented soon.

At the current size of the database, the computation time to accumulate the radiant probabilities amounts to about one CPU year on a powerful Windows server. Fortunately we could temporarily employ three servers with 24 CPU cores each, so that the computation was done in less than a week. As a preliminary result, the list of radiants was now made available online, so that everyone can check his meteor shower hypothesis against the IMO Video Meteor Database. The list can be found at `http://www.imonet.org/radiants` (Molau, 2012).

A detailed analysis of the radiant list is still pending. However, a first search for showers with the default settings of StrmFind identified almost a hundred showers

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[4]Via Bobbio 9a/18, 16137 Genova, Italy. Email: `stefano.crivello@libero.it`
[5]via Umbria 21/d, 30037 Scorze (VE), Italy. Email: `stom@iol.it`
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NASA-ADS bibcode 2012JIMO...40..108M

Table 1 – Parameters of the χ-Herculids from the analysis of Greaves (2012) and data of the IMO Network in 2008 (Molau & Kac, 2009) and 2012 (Molau, 2012).

Source	$\lambda_\odot$ [°]	α [°]	δ [°]	V_∞ [km/s]
IMO 2008	352	254	+48	36
Greaves (2012)	351.8	252.9	+50.1	35.8
IMO 2012	352	255.5	+48.1	37

Table 2 – Parameters of the f-Herculids from the IMO Network data in 2008 (Molau & Kac, 2009) and 2012 (Molau, 2012).

Source	$\lambda_\odot$ [°]	α [°]	δ [°]	V_∞ [km/s]
IMO 2008	346	268	+41	44
IMO 2012	348	266.5	+35.6	45

Table 3 – Parameters of the η-Virginids from the MDC working list and the IMO Network data in 2012 (Molau, 2012).

Source	$\lambda_\odot$ [°]	α [°]	δ [°]	V_∞ [km/s]
MDC	354	182	+2.6	31.3
IMO 2012	354	188.7	+0.0	33

Table 4 – Parameters of the ζ-Serpentids from the MDC working list and the IMO Network data in 2012 (Molau, 2012).

Source	$\lambda_\odot$ [°]	α [°]	δ [°]	V_∞ [km/s]
MDC	5	266.3	−6.3	68.3
IMO 2012	8	257.9	−6.1	65

from the working list of the IAU Meteor Data Center (MDC). For sure there will be more surprises in the data set!

Let us start with March showers. Three years ago we presented two new shower candidates in Hercules, which resulted from the 2008 data set and analysis (Molau & Kac, 2009). From the MDC they got the designation f-Herculids (345 FHE) and χ-Herculids (346 XHE). In the subsequent more thorough analysis at the 10th anniversary of the IMO network (Molau & Rendtel, 2009), neither of the two showers was confirmed even though the data set had further grown.

2.1 χ-Herculids

In the latest issue of *WGN*, John Greaves (2012) analysed once more the data set of the SonotaCo network and confirmed four showers with MDC "working list" status – one of them being the χ-Herculids. That was a good reason to check whether the shower can now be found in the latest data set of the IMO Network with over a million meteors. Indeed, the analysis yields a well-fitting chain of radiants from 350° to 355° solar longitude with more than 280 meteors. The basic parameters are given in Table 1 and compared with our 2008 data (Molau & Kac, 2009) and the results of Greaves (2012).

2.2 f-Herculids

Apparently, Greaves (2012) could not confirm the f-Herculids with the SonotaCo network data. In our 2012 data set, this shower is detected again with 280 meteors (Table 2). However, similar to the analysis three years ago, the f-Herculids show strong daily variations in the meteor shower velocity and an unusually high drift in declination (decrease by more than one degree per day). Hence, this shower remains questionable.

2.3 Radiants in Virgo

Beside showers listed above, the MDC list contains in March some radiants in Virgo, which could be partly confirmed by our current analysis.

First of all there are the η-Virginids (11 EVI), which have the MDC status "established". Our current analysis yields a chain of radiants between 335° and 10° solar longitude based on roughly 1 600 meteors, which fits to the η-Virginids. However, when looking at the data in detail there remain doubts whether this is indeed a single shower, or if there are several sub-radiants in close spatial and temporal vicinity. Neither in right ascension or declination did we find a consistent drift (in that interval, the radiant rather drifts in different directions), nor is the meteor shower velocity reasonably stable. Between the end of February and the end of March, it is decreasing from over 45 to below 30 km/s. Table 3 compares the mean parameters from MDC with our current analysis.

The λ-Virginids (49 LVI) and Northern March Virginids (123 NVI) both have "working list" status at MDC. Our current analysis shows for both showers a possible counterpart in the IMO Network data. Once more, there is no uniform radiant drift in both cases, and also the calculated meteor shower velocity shows large variations. The Virginid complex is presumably a diffuse, large radiation area. This allows two interpretations for the variable radiant positions given the type of analysis employed here:

- at different solar longitudes, different sub-radiants may become strongest
- if there is only little variation in the accumulated radiant probability over a larger area, the determined maximum will be affected by random variations.

2.4 ζ-Serpentids

Finally there is another MDC "working list" shower in March away from the Virginid complex, which can be found in our data. 300 meteors create a chain of radiants between 3° and 13° solar longitude, which reasonably fits to the ζ-Serpentids (43 ZSE, Table 4). Unfortunately, this shower also has no uniform radiant drift and has large variations in the meteor shower velocity.

2.5 Possible new showers detected

Finally we want to present two candidates for hitherto unknown meteor showers. At this time, we consciously refrain from a report to MDC, as both hypothethi-

Table 5 – Parameters of two possible new meteor showers in March from the IMO Network data in 2012 (Molau, 2012).

Solar longitude interval [°]	Mean $\lambda_\odot$ [°]	α [°]	δ [°]	V_∞ [km/s]
338–343	340.5	244.2	+43.6	41
349–356	352.5	152.9	+4.4	20

cal showers should first be confirmed by independent sources (e.g. by SonotaCo network data).

On the one hand there is a chain of radiants between 338° and 343° solar longitude in northern Hercules. It shows only little scatter in the radiant position and meteor shower velocity. Overall 170 meteors are assigned to that chain.

A few days later, about 190 meteors between 349° and 356° solar longitude create a chain of radiants south of Leo. It shows a larger scatter in position, but all radiants have a remarkably low meteor shower velocity.

The average parameters of both shower candidates are given in Table 5. If there is independent confirmation for these, please contact the first author so that we can formally register the showers with MDC.

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Table 6 – Observers contributing to 2012 March data of the IMO Video Meteor Network. Eff.CA designates the effective collection area.

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BERER	Berko	Ludányhalászi/HU	Hulud1 (0.95/3)	2256	4.8	1540	25	155.6	428
			Hulud2 (0.75/6)	4860	3.9	1103	26	112.0	261
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OCHPA	Ochner	Albiano/IT	Albiano (1.2/4.5)	1971	—	—	5	2.9	19
OTTMI	Otte	Pearl City/US	Orie1 (1.4/5.7)	3837	3.8	460	23	133.8	217
PERZS	Perko	Becsehely/HU	Hubec (0.8/3.8)*	5498	2.9	460	29	160.3	623
PUCRC	Pucer	Nova vas nad Dragonjo/SI	Mobcam1 (0.75/6)	2398	5.3	2976	30	250.2	322
ROTEC	Rothenberg	Berlin/DE	Armefa (0.8/6)	2366	4.5	911	14	107.1	138
SARAN	Saraiva	Carnaxide/PT	Ro1 (0.75/6)	2362	3.7	381	20	145.1	154
			Ro2 (0.75/6)	2381	3.8	459	23	170.4	201
			Sofia (0.8/12)	738	5.3	907	19	158.4	117
SCALE	Scarpa	Alberoni/IT	Leo (1.2/4.5)*	4152	4.5	2052	29	202.5	265
SCHHA	Schremmer	Niederkrüchten/DE	Doraemon (0.8/3.8)	4900	3.0	409	21	139.3	121
SLAST	Slavec	Ljubljana/SI	Kayak1 (1.8/28)	588	—	—	19	30.5	72
STOEN	Stomeo	Scorze/IT	Min38 (0.8/3.8)	5566	4.8	3270	27	230.1	641
			Noa38 (0.8/3.8)	5609	4.2	1911	27	231.3	504
			Sco38 (0.8/3.8)	5598	4.8	3306	27	241.2	740
STRJO	Strunk	Herford/DE	Mincam2 (0.8/6)	2362	4.6	1152	16	113.6	97
			Mincam3 (0.8/12)	728	5.7	975	17	130.1	125
			Mincam5 (0.8/6)	2349	5.0	1896	17	125.3	178
TEPIS	Tepliczky	Budapest/HU	Humob (0.8/6)	2388	4.8	1607	27	206.4	453
TRIMI	Triglav	Velenje/SI	Sraka (0.8/6)*	2222	4.0	546	25	68.8	168
YRJIL	Yrjölä	Kuusankoski/FI	Finexcam (0.8/6)	2337	5.5	3574	17	82.2	213
						Sum	31	8 992.5	17 548

* active field of view smaller than video frame

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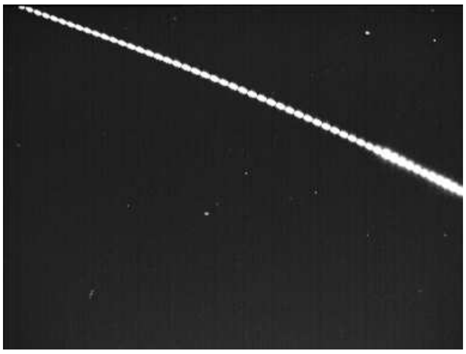
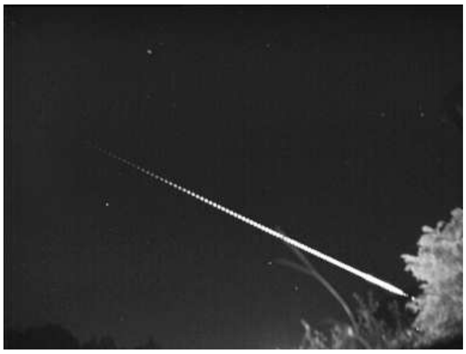
Long fireball over the Adriatic Sea

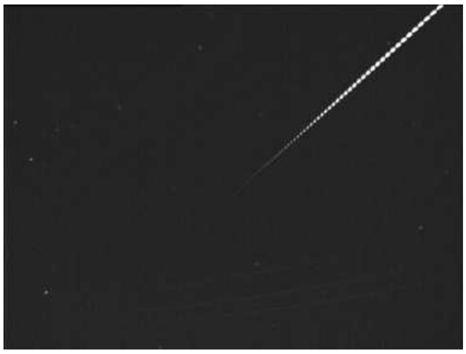

Pula_A (PUA): Damir Šegon


Duino (DUI): Mark Sylvester


Merenje (MEA): Željko Andreić


Rijeka_B (RIB): Ivica Ćiković


Ferrara: Ferruccio Zanotti


Visnjan_B (VIB): Denis Vida,
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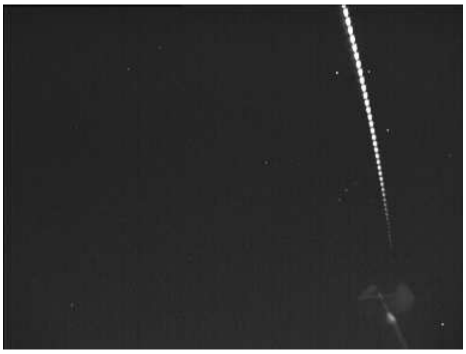
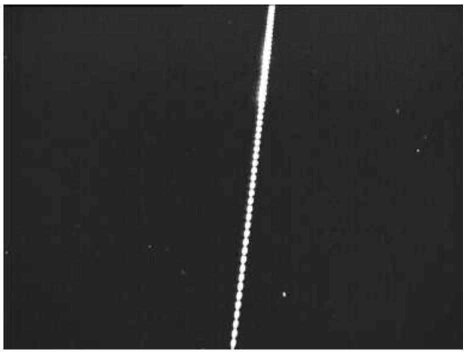
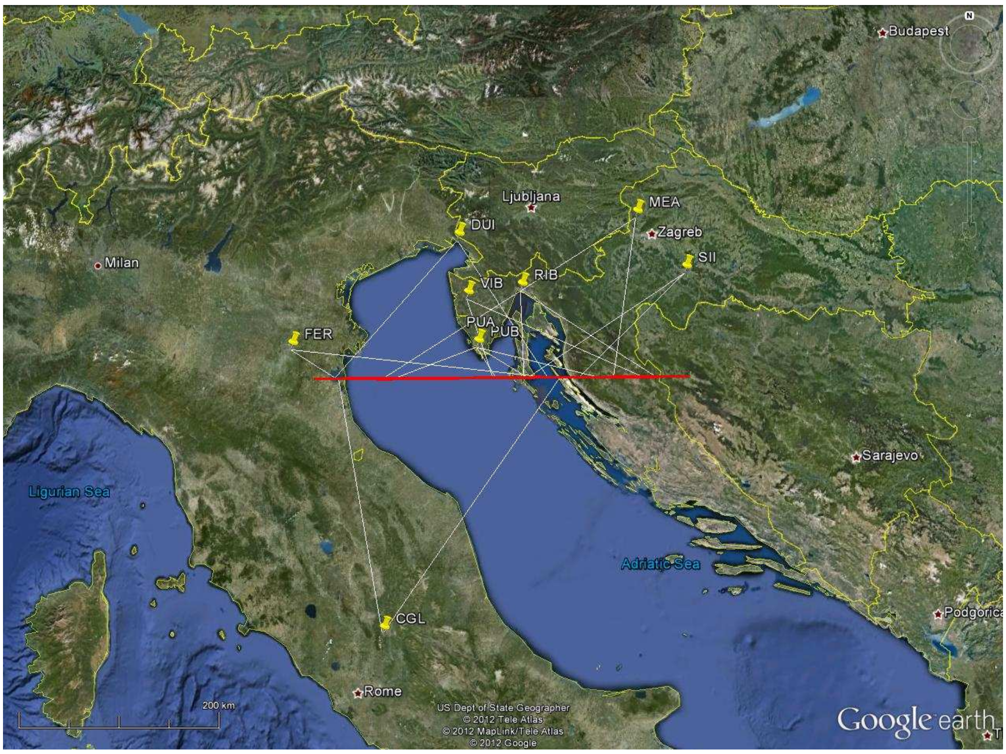

Pula_B (PUB): Sandi Šegota


Lazio: Diego Valeri


Mali_Losinj (MLA): Dorian Božičević



This 304.4 km long fireball was recorded by eight CMN and two IMTN cameras on 2012 June 20 at $01^h37^m24^s$ UT. The fireball's entry angle was 10.2°, a 129.7 km begin height and a 79.0 km end height, and a velocity of 64.0 km/s. Several other cameras in the region also recorded the event but are not included in this calculation.