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Life in the isolation
Tom Welland from Brighton, United Kingdom

- A lifetime observing
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Four decades of visual work: A lifetime of visual meteor observations

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December 2019 marks the end of a four-decade long period with visual meteor observations by the author. In those 40 years I was able to observe meteors during 1184 sessions. It resulted in 3413.23 hours of effective observing time and in total I observed 86542 meteors. A good time to look back on 40 years of meteor observations.

1 Overview 1980–2019

The first attempts to observe meteors were made in 1978 (Perseids) and 1979 (Lyrids, Perseids and Orionids). I made my first serious observations during the night of 4–5 August 1979. After a meeting of the Werkgroep Meteoren NVWS in March 1980, I founded the Delphinus Group with the aim to observe meteors together with friends and interested people. The location where we made our observations was a water tower. My father was working for the Waterleiding Maatschappij Gelderland (a water company) and so we got permission to do meteor observations at an almost 100-year-old water tower in the woods near Harderwijk. From this spot several memorable observing campaigns were organized with as highlights the Taurids 1981, Perseids 1983, Geminids 1983, Perseids 1989, Geminids 1991 and of course the unexpected Orionid outburst of 1993.

Figure 1 – The first real meteor observations I did together with Bauke Rispens during the night 4–5 August 1979.

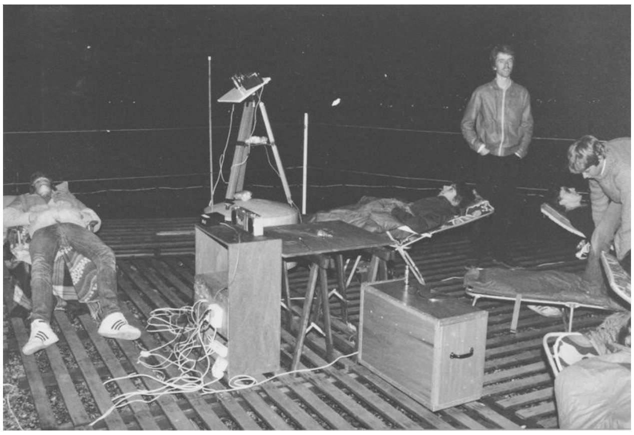


Figure 2 – Perseid 1983 observations with from left to right Olaf Miskotte, Richard Buijs, Koen Miskotte (standing), Jan Henk Maneschijn and Klaas Jan Homsma.

Figure 3 – Author’s first observing campaign abroad. From left to right. Rob Tille, Arlette Steenmans, Dany Cardoen, Carl Johannink, Marcel Lücht, Bauke Rispens and Koen Miskotte.

In 1983 we had a huge successful Perseid campaign at the water tower (*Figure 2*). Within two weeks we had nine clear nights, a rarity in the Netherlands. That year we used 15 reflex cameras, which we bought second hand. These were mainly Praktica LTL 3, Zenit B's and Pentor TL cameras and were equipped with Tri-X film. To keep the camera lenses dew-free, we used heating resistors that were powered by 24 Volt transformers.

During this period a number of observing campaigns were also organized in southern France at the little village of Puimichel (Provence) where Dany Cardoen and Arlette Steenmans had an observatory for amateur astronomers (*Figure 3*). In 1983 I read in the popular scientific astronomy magazine Zenit a report by a well-known Belgian amateur Leo Aerts entitled: “Dream nights in the Provence”. There he had observed under very dark starry skies in combination with many clear nights and little light pollution. In 1984 I visited the Provence together with Bauke Rispens and Carl Johannink. All observing campaigns there were very successful. Many thousands of meteors were observed, for instance during the summer campaigns in 1984 (with increased Capricornid activity), 1985 (the magnitude –10 sporadic fireball of August 12), 1986 (August 12–13 under a fierce mistral wind and lm 7.0 skies, *Figure 4*) and the Orionids/Taurids campaign in 1986. During these journeys, Carl Johannink, Bauke Rispens, Robert Haas and Arjen Grinwis were also present.

Figure 4 – August 13, 1986: Koen Miskotte at dawn after a very successful night with many Perseids. The photo was taken on the flat roof of the building (under construction) of the 1 meter telescope of Dany Cardoen.

Figure 5 – During a meeting of the Dutch Meteor Society we discussed about the visual archive of DMS. From left to right Marco Langbroek, Michiel van Vliet, Koen Miskotte, Peter Jenniskens en Michael Otten (Courtesy: Casper ter Kuile).

Figure 6 – 1993 August 11–12, three bright Perseids captured within 10 minutes with a Canon T70 and a Canon FD 50 mm F 1.8 lens (Courtesy: Casper ter Kuile).

In 1993 something changed, the Harderwijk team was rather small, including only Paul Bensing, Robert Haas and the author. But it was also becoming increasingly difficult to make observations from the water tower because of the increase of light pollution. In that year we observed the Perseids from Rognes, southern France. There, the expected Perseid outburst of 11–12 August (ZHR 300–400) was observed together with Robert Haas, Marco Langbroek and Casper ter Kuile (*Figure 6*). We were there as part of a large DMS expedition deploying four fully equipped photographic stations in the Provence (*Figure 7*). During the Perseid outburst we also observed many bright kappa Cygnids, amongst them a –8 KCG fireball (*Figure 8*).

Figure 7 – The author is programming the Canon T70 camera's before the night of the big Perseid outburst of 1993 (Courtesy: Casper ter Kuile).

Figure 8 – During the Perseid outburst we also observed many bright kappa Cygnids, amongst them this –8 KCG fireball (Courtesy: Casper ter Kuile and Robert Haas).

Following the successful collaboration in Rognes, Marco and Casper joined the group in 1994. At the same time, a new observing location was searched for and found near Biddinghuizen. There, in the meadows of the farm of the Appel family, it was still possible to observe under almost Provencal conditions. Even the zodiacal light was once observed there. Successful observing campaigns at Biddinghuizen were the Quadrantids 1995, SDA/CAP 1995, Orionids 1995, Lyrids 1996, Geminids 1996 and Perseids 1997. After the 1997 Perseid campaign, more observing campaigns were organized, but the weather wasn't cooperative.

2 Leonid campaigns

In 1994 the Leonids had their first outburst in the new series associated with the return of Comet 55P Tempel-Tuttle in the inner parts of our solar system. In addition, more time was spent on the organization of the Leonid expeditions that were organized by DMS. Almost all of these expeditions were successful. The first expedition from Spain in 1995 was a great success with observations of two meteor outbursts: the Leonids and alpha Monocerotids (the last one together with Peter Jenniskens). In 1996 we were able to observe a peak of weak Leonids on a broader background with bright Leonids. This happened after a long 600 km camper ride where we ended up near a small hamlet in northwestern France called Woignarue.

Figure 9 – The 1995 Leonid/alpha Monocerotid expedition. Some hours after the alpha Monocerotid outburst Peter Jenniskens is calculating ZHRs. From left to right Charlie Hasselbach, Peter Jenniskens, Koen Miskotte, Casper ter Kuile and Marco Langbroek (Courtesy: Robert Haas).

Figure 10 – Group picture of the DMS post Alcudia during the Leonid 1995 expedition at Alcudia de Guadix, Andalusia, Spain (Courtesy: Casper ter Kuile).

Figure 11 – Bam! The big Spanish fireball of November 17, 1995. It produced a sonic boom. The author observed this stunning fireball visually (Courtesy: Casper ter Kuile).

Figure 12 – Group photo of the Sino Dutch Leonid Expedition 1998, taken at the shores of the large saltlake of Quinhai. From left to right: Romke Schievink, Casper ter Kuile, our busdriver, Marc de Lignie, Marco Langbroek, Jos Nijland, Carl Johannink, Arnold Tukkers, Koen Miskotte and Robert Haas (Courtesy: Zhao Haibin and Casper ter Kuile).

In 1998 there was a hugely successful Leonid expedition to China under the name Sino Dutch Leonid Expedition 1998 (SDLE 1998) (*Figure 12*). That success was not so much due to the (disappointing) Leonid outburst on November 18, but more because of the unexpected occurrence of a fireball rain one night earlier (November 17). Under crystal clear skies we observed Leonid fireball after Leonid fireball. They always left persistent trains behind which were sometimes visible for tens of minutes. The brightest Leonid were a couple of magnitude –12! A –15 Leonid behind the mountains lit the sky up, bluish. At dusk a beautiful –12 Leonid was seen with many colors in the persistent train (*Figure 14*). Moreover, it was a beautiful location where we could observe, on the site of the radio observatory of the famous Purple Mountain Observatory near Delingha at the edge of the Gobi Desert in a valley at an altitude of 3000 meters! There we stayed between 13 and 20 November 1998 (*Figure 13*). Temperatures were very low, down to

Figure 13 – Another group photo with some equipment of the SDLE 1998 expedition in front of the Delingha Radio Observatory of the Purple Mountain Observatory in Quinhai, China (Courtesy: Casper ter Kuile and Robert Haas).

–23 degrees Celcius. The group consisted of Carl Johannink, Marco Langbroek, Jos Nijland, Arnold Tukkers, Robert Haas, Marc de Lignie and Romke Schievink.

Figure 14 – One of the many spectacular fireballs of the Leonid fireball shower of November 16, 1998. Camera: Canon T70 with a Canon FD 50 mm F 1.8 lens (Courtesy: Casper ter Kuile).

In 1999 we were able to observe the Leonids from Spain. It was the first meteor storm I could observe, with a maximum ZHR of 4200 (*Figure 15*). This time most Leonids were weak. Highest minute count reached 50 Leonids and sometimes I saw 5 or 6 Leonids at once! Sometimes we really had the impression that we were traveling at high speed towards the constellation of Leo.

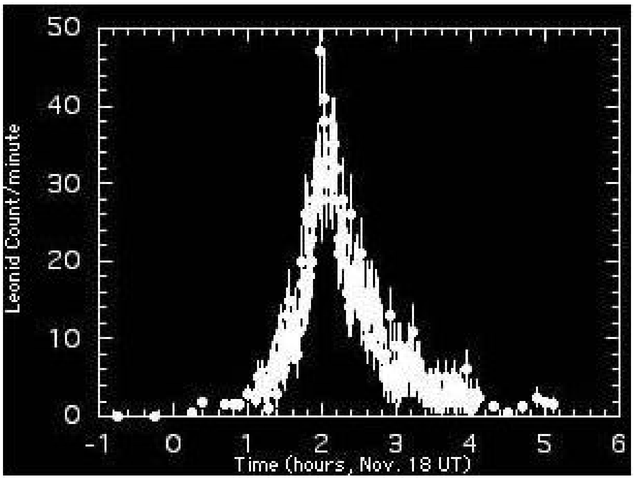


Figure 15 – Leonid counts made during the night of 17–18 November 1999 by Koen Miskotte.

Figure 16 – Carl Johannink, Koen Miskotte and Marco Langbroek at Almodovar, Portugal for the Leonids 2000 (Courtesy Carl Johannink).

In 2000 I flew with Marco Langbroek and Carl Johannink last-minute to Portugal, last minute because the weather forecast over western Europe was so bad (*Figure 16*). There, again we saw a beautiful Leonid outburst that showed several peaks with a maximum ZHR of 400.

Figure 17 – Composition of the Leonid meteor storm of November 19, 2001 taken at the optical observatory of XingLong, China. Camera: Canon T70 with a Canon FD 50 mm F 1.8 lens attached on a Vixen Photoguider. Film: Kodak Elite II, 400 ASA (Courtesy: Koen Miskotte).

In 2001 there was the second Leonid expedition to China (Sino Dutch Leonid Expedition 2001, *Figure 19*). This time we stayed five days at the largest optical observatory in China near Xing Long (150 km northeast of Beijing). There we again witnessed a beautiful outburst of the Leonids. This time it was the perfect (and my second!) meteor storm, the bright Leonids from 1998 and the activity of the 1999 Leonid Storm combined. Maximum ZHR around 3700. Many fireballs appeared; the author observed 169 Leonids from –3 to –10 that night (*Figures 17 and 18*). The finest was a magnitude –8 Leonid earthgrazer which left a drifting persistent train that was visually visible for more than 20 minutes. I observed on the flat roof of the building of the 1-meter Schmidt telescope together with Casper ter Kuile and Arnold Tukkers and 20 (occasional) Chinese observers.

Figure 18 – Composition of the Leonid meteor storm of November 19, 2001 at XingLong Observatory (Courtesy: Casper ter Kuile).

Figure 19 – For the sponsors of the Sino Dutch Leonid Expedition, this group photo was made in Ermelo a few weeks before leaving for China. From left to right: Michel Vandeputte, Sietse Dijkstra, Casper ter Kuile, Jos Nijland, Arnold Tukkers, Koen Miskotte and Robert Haas (Courtesy: Casper ter Kuile).

In 2002 I observed the Leonids together with Olga van Mil, Jaap van ’t Leven and Peter Bus from Moncarapacho, Portugal. Unfortunately, this was not a success, only between a few small clearings we could observe the increasing Leonid activity. In 2003 I was again in Moncarapacho with Jaap and Peter and this time we were able to observe the Leonids for four nights in a row.

3 Post Leonid period

After 2002 something changed again. The Delphinus team had its last campaign at the Cosmos observatory in Lattrop. After this, there were simply no more joint activities. The major Leonid campaigns were also history. Of course, my individual observational sessions always continued as usual. In 2003, the Southern delta Aquariids and Capricornids were observed from the south coast of Crete during a vacation. In 2004 there were some crash (=escaping bad weather) expeditions to Britzingen with Carl Johannink, Rita Verhoef and Romke Schievink (Perseid outburst ZHR 200) and Winterberg (observing the Geminids from the Kahler Asten).

Figure 20 – One hour after the Leonid 2006 outburst observed from Orchiva, Andalusia, southern Spain. From left to right Jaap van ’t Leven, Peter Jenniskens, Carl Johannink, Koen Miskotte, Peter Bus and Michel Vandeputte (Courtesy: Jaap van ’t Leven).

In 2006 there was a small and final Leonid expedition to Andalusia, Spain together with Jaap van 't Leven, Peter Bus, Michel Vandeputte, Carl Johannink and Peter Jenniskens (*Figure 20*). Casper ter Kuile and Robert Haas manned a small second station near the town of Basa. On the night of November 18–19 we observed a brief outburst of the Leonids with an ZHR of around 90.

In 2006, an unexpected Orionid outburst was also observed by the author. Increased Orionid activity was also observed in 2007, 2008, 2009 and 2010. The year 2007 being the most beautiful when the Orionids performed at Perseid strength (ZHR 90) with many bright meteors.

In 2007 and 2009 the Geminids were observed from Portugal. Both campaigns were very successful. Thanks to Felix Bettonvil’s involvement, I was able to observe for a week at the end of July 2008 together with Carl Johannink, Peter van Leuteren, Klaas Jobse and Michel Vandeputte on the Roque de Los Muchachos observatory on the Canary Island of La Palma. High quality data of the Southern delta Aquariids and Capricornids were collected. We were there internally at the observatory for eight days, what was a great experience!

Figure 21 – Koen Miskotte at the Hakos farm in Namibia during the Southern delta Aquariids expedition July–August 2011.

Following the successful 2008 SDA/CAP campaign from La Palma, we decided to observe the Southern delta Aquariids from Namibia in 2011 (*Figure 21 and 22*). And so, we were there for two weeks on the holiday observatory near the small town of Hakos. The darkest starry sky ever was seen there. With only a tiny light dome from Windhoek in the northeast. In the evening when the galaxy center was at the zenith, it wasn't completely dark either. The landscape was somewhat “fairy-tale like” illuminated by the galaxy. When it went down later in the night it really became obvious how dark it could be there. SQM 22.2. In addition, the bright zodiacal light was always visible in the evening and in the morning. Record numbers of SDAs and CAPs were seen. Company included Casper ter Kuile, Carl Johannink, Klaas Jobse, Michel Vandeputte, Inneke Vanderkerken and Peter van Leuteren.

Figure 22 – Long time friends and meteor observers in Namibia. From left to right Casper ter Kuile, Carl Johannink and Koen Miskotte (Courtesy: Peter van Leuteren).

Figure 23 – The magnificent Perseid outburst of 11–12 August 2016 (Courtesy: Koen Miskotte).

Figure 24 – Last night at Revest du Bion during the magical Perseid campaign 2016. Koen Miskotte and Michel Vandeputte (Courtesy: Michel Vandeputte).

From 2009 onwards the Perseids were also regularly observed from the south of France. The highlights were the Perseids 2010, 2015, 2016 and 2018. The night of 11–12 August 2016 in particular was historic: the Perseids showed several peaks in activity with ZHRs between 120 and 300! Some Perseids of –8 were seen (*Figures 24 and 25*). In 2018, the Geminids were observed from Tenerife. There we could observe on the terrain of the German solar telescope of the Del Teide observatory. This was arranged for us by the astronomer Jürgen Rendtel, who is also a very active meteor observer (*Figure 25*).

Partly due to health problems, 2019 was not such a successful year. No foreign campaigns were set up either.

Figure 25 – Group photo on the Del Teide Observatory at Tenerife during the Geminid maximum of 2018. From left to right. Peter van Leuteren, Carl Johannink, Koen Miskotte and Jürgen Rendtel. Bad weather conditions at that time, but an hour later sky would clear up and stay clear until dawn (Courtesy: Peter van Leuteren).

4 Overview 1980–2019

In *Table 1* an overview of the number of sessions, effective duration of the observation, number of observed meteors and number of observed fireballs (meteors of –3 or brighter) per year.

Table 1 – Overview 1980–2019.

Year	Sessions	Hours	Meteors	Fireballs
1980	8	19.72	103	0
1981	3	11.17	44	2
1982	8	28.07	77	2
1983	16	56.93	579	7
1984	47	158.43	2553	11
1985	36	141.58	3642	12
1986	34	137.42	4993	11
1987	0	0.00	0	0
1988	4	11.63	146	0
1989	5	15.38	373	3
1990	16	50.22	696	1
1991	34	89.80	1528	4
1992	19	53.87	736	4
1993	28	97.72	2358	30
1994	16	47.10	1061	15
1995	49	144.63	3165	17
1996	27	64.70	2152	20
1997	43	116.52	3102	16
1998	34	97.25	3094	112
1999	37	76.42	3186	14
2000	36	82.23	1734	10
2001	52	145.13	6898	180
2002	16	53.63	1326	7
2003	33	115.83	2709	7
2004	16	42.20	1827	25
2005	31	68.38	1110	10
2006	32	100.05	2508	13
2007	31	91.13	3486	32
2008	33	100.63	2949	15
2009	47	144.78	3617	27
2010	33	103.68	2650	22
2011	38	111.38	2836	12
2012	28	58.28	1104	9
2013	35	93.72	2550	22
2014	40	99.07	1529	5
2015	42	130.67	3322	30
2016	58	170.10	4272	45
2017	28	77.93	1808	13
2018	57	145.97	3857	23
2019	27	59.88	862	4
Total	1177	3413.23	86542	792

In terms of the number of sessions and effective observing time (T_{eff}) per year, 1984, 1995, 2009, 2016 and 2018 stand out. In terms of numbers of observed meteors, 1986, 2001 and 2016 are at the top. 2001 shows a distorted picture because 4109 meteors were seen during the night of November 18–19 as a result of the Leonid outburst (*Figures 26 and 27*). The number of fireballs is also distorted because of the two Leonid outbursts in 1998 and 2001.

Table 2 – The 10 best years in terms of effective observation time.

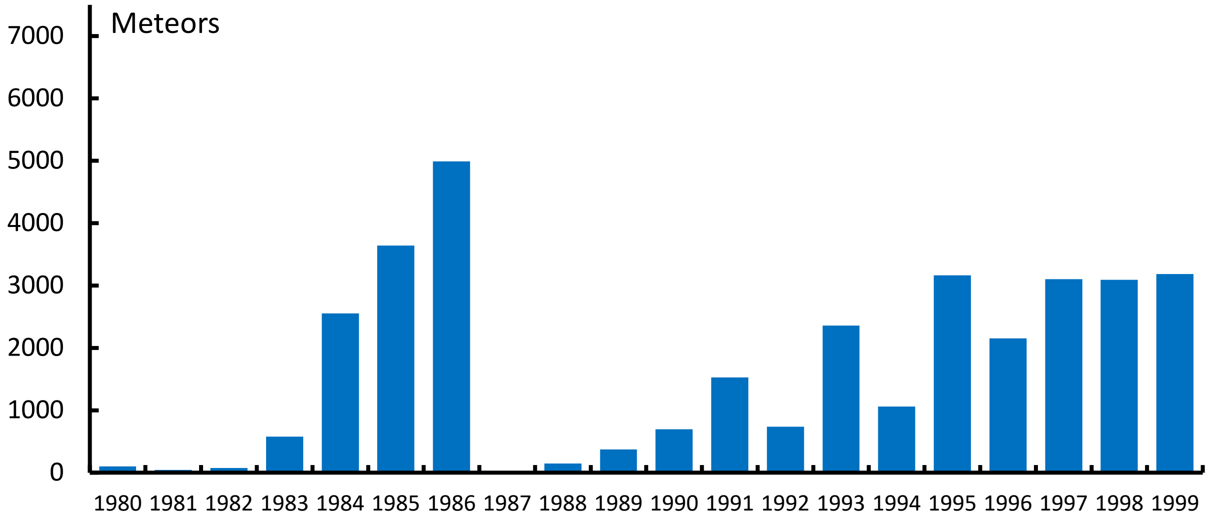
Nr.	Year	$T_{eff.}$	Locations	Successful campaigns
1	2016	170.10	FR, NL	PER
2	1984	158.43	FR, NL	PER, SDA, CAP
3	2018	145.97	NL, FR, SP	LYR, PER, LEO, GEM
4	2001	145.13	NL, CH, GR	LEO, SDA, GEM, LYR
5	2009	144.78	FR, NL, GE, PO	GEM, PER, QUA
6	1995	144.63	SP, NL	QUA, LEO, PER, ORI
7	1985	141.58	FR, NL	PER, SDA, ORI
8	1986	137.42	FR, NL	PER, TAU
9	2015	130.66	NL, GER, FR	PER, GEM
10	1997	116.52	NL	PER

Table 3 – The 10 best years in terms of numbers of observed meteors.

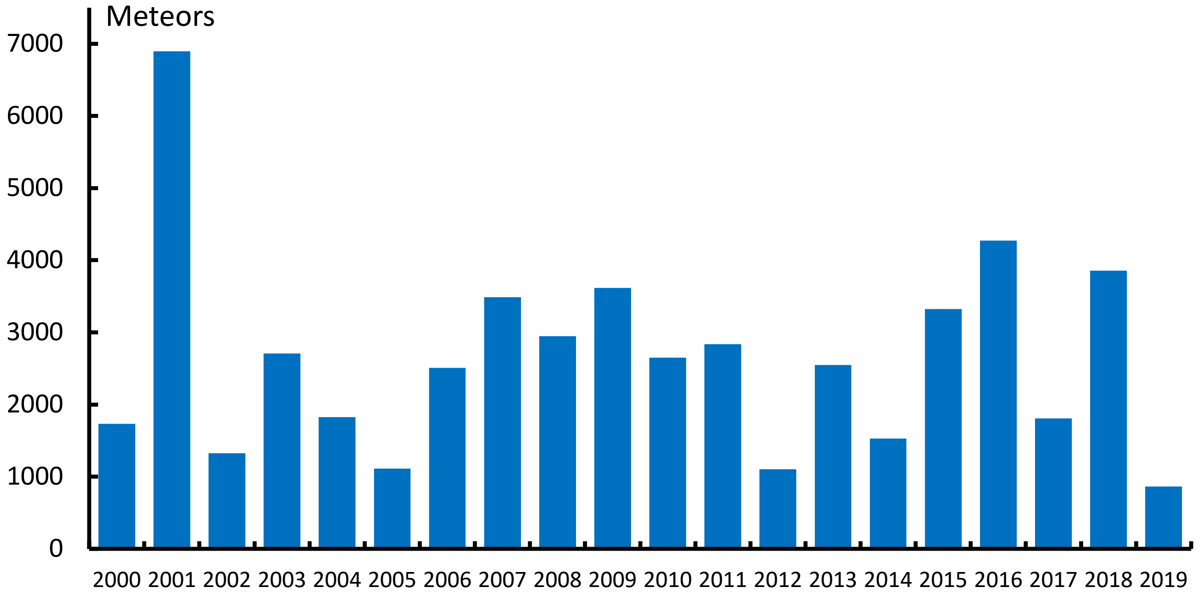
Nr	Year	Meteors	Successful campaigns
1	2001	6900	Leonid meteor storm (XingLong, China)
2	1986	4985	Successful PER and TAU campaign, FR
3	2016	4272	PER Revest du Bion, FR
4	1985	3639	PER Puimichel FR
5	2009	3617	PER (FR), GEM (PO)
6	2007	3486	PER, GEM (PO),
7	1999	3185	Leonid meteor storm (SP)
8	1995	3162	QUA, PER, LEO
9	1997	3097	Perseids Biddinghuizen (NL)
10	1998	3095	Leonid fireball shower China

Table 4 – The 10 best nights in terms of the numbers of meteors observed.

Nr	Date	Meteors	Remarks
1	18–19 Nov. 2001	4109	Leonids outburst
2	17–18 Nov. 1999	2203	Leonids outburst
3	13–14 Dec. 1996	1039	Geminids
4	13–14 Dec. 2004	1003	Geminids
5	13–14 Dec. 2009	992	Geminids
6	16–17 Nov. 1998	952	Leonids outburst
7	13–14 Dec. 2007	904	Geminids
8	12–13 Aug. 1986	830	Perseids
9	11–12 Aug. 1993	806	Perseids outburst
10	11–12 Aug. 2016	747	Perseids outburst



Figures 26 – Overview number of meteors observed by Koen Miskotte during the period 1980–1999.



Figures 27 – Overview number of meteors observed by Koen Miskotte during the period 2000–2019.

Table 5 summarizes the statistics for the decades.

Table 5 – Overview per decade.

Decade	$T_{Eff.}$ hours	Number of meteors	Fireballs [–3;–12]	Number of sessions
1980–1989	580.33	12510	48	161
1990–1999	838.23	21078	233	302
2000–2009	943.99	28164	326	335
2010–2019	1050.68	24790	185	386
1980–2019	3413.23	86542	792	1184

5 Expeditions

Several times the author was able to participate in often beautiful and memorable expeditions. Highlights were the SDLE 1998 and 2001 expeditions to China, but also the Perseids 1993 and 2016 and the SDA/CAP expeditions to the La Palma observatory and Namibia were unforgettable. These expeditions often lead to dark places where the air is much cleaner and there is much less light pollution than in the BeNeLux. It is also not surprising that of the 86542 observed meteors, 48145 were observed during these expeditions and vacations. *Table 6* lists an overview of the expeditions.

6 Observed meteor outbursts

The most interesting phenomenon for a meteor observer is the appearance of an expected or unexpected meteor outburst. These can occur when the Earth travels through a fresh dust trail left by a comet. Usually such a situation provides extra activity in numbers of meteors. Of course, how much extra also depends on the density or age of the dust trail, or at what distance the Earth travels along the dust trail or, on the contrary, pulls through such a dust trail.

Good example of an unexpected meteor activity were the Orionids of 1993 and the delta Cancrids of the same year. The author has experienced a meteor storm twice (1999 and 2001) with the observed ZHR above 1000. Taken altogether, the author has seen about 50 meteor outbursts, with ZHRs ranging from 5 to 4200! In *Table 7* a comprehensive overview is presented of all meteor outbursts observed by the author.

Table 6 – Overview of all the meteor expeditions of the author.

Year	Period	location	Type	Goal	Meteors
1984	22 July–5 August	Puimichel, Provence, France	Expedition	SDA, CAP, PER	1489
1985	6–22 August	Puimichel, Provence, France	Expedition	PER, CAP, SDA, KCG	2875
1986	3–16 August	Puimichel, Provence, France	Expedition	PER, CAP, SDA, KCG	3106
1986	26 Oct.–8 Nov.	Puimichel, Provence, France	Expedition	ORI, STA, NTA, LMI	1713
1993	8–15 August	Rognes, Provence, France	DMS expedition	PER outburst	1457
1995	12–22 November	Alcudia de Guadix, Spain	DMS expedition	LEO & AMO outbursts	881
1996	15–18 November	Woignarue, France	DMS Crash expedition	LEO outburst	197
1998	7–23 November	Deligha radio observatory, Quinhai, China	SDLE 1998 expedition	LEO outburst	2100
1999	14–20 November	Xalos Spain	DMS expedition	LEO outburst	2251
2000	16–19 November	Almodovar, Portugal	DMS Crash expedition	LEO outburst	761
2001	20 July–1 August	Chios island, Greece	Vacation	SDA, CAP, PER	823
2001	13–22 November	XingLong observatory, Hebei, China	SDLE 2001 expedition	LEO outburst	4824
2002	13–20 November	Moncarapacho, Portugal	Expedition	LEO outburst	45
2003	21 July–3 August	Ferma, Crete, Greece	Vacation	SDA, CAP, PER	1372
2003	14–22 November	Moncarapacho, Portugal	Expedition	LEO outburst	586
2004	10–12 August	Britzingen, Germany	DMS Crash expedition	PER outburst	442
2004	13–14 December	Kahler Asten, Germany	DMS Crash expedition	GEM	1003
2006	22 July-05 August	Entracasteux, Provence, France	Vacation	SDA, CAP, PER	1152
2006	14–21 November	Orchiva, Andalusia, Spain	DMS expedition	LEO outburst	773
2007	12–13 August	Grevesmühlen, Germany	DMS Crash expedition	PER maximum	367
2007	12–15 December	Evora, Portugal	DMS expedition	GEM maximum	1463
2008	25 July–1 August	Roque de los Muchachos Obs., La Palma, Spain	DMS expedition	SDA, CAP, PER	1532
2009	2–16 August	Vaison la Romaine, Provence, France	Vacation	PER, CAP, SDA, KCG	1111
2009	20–21 October	Grevesmühlen, Germany	DMS Crash expedition	ORI outburst	104
2009	12–15 December	Castelo de Vide, Portugal	DMS expedition	GEM maximum	1148
2010	7–14 August	Redortiers, Provence, France	DMS expedition	PER, CAP, SDA, KCG	954
2011	25 July–7 August	Hakos, Namibia	DMS expedition	SDA, CAP, PER	2010
2013	3–17 August	Revest du Bion, Provence, France	Vacation	PER, CAP, SDA, KCG	2126
2015	25 April–2 May	Buzancy, Chapagne-Ardenne, France	Vacation	LYR	18
2015	8–22 August	Revest du Bion, Provence, France	Vacation	PER, CAP, SDA, KCG	1877
2015	13–15 December	Oberied Hufgrund, Germany	DMS Crash expedition	GEM maximum	650
2016	2–14 August	Revest du Bion, Provence, France	Vacation	PER outburst	3035
2017	24 July–2 August	Agia Galini, Crete, Greece	Vacation	SDA, CAP, PER	1077
2018	1–14 June	Any Martin Rieux, Champagne-Ardenne, France	Vacation	SPO	70
2018	4–17 August	Abenas les Alps, Provence, France	DMS expedition	PER, CAP, SDA, KCG	1710
2018	12–14 December	Observatorio Del Teide, Tenerife, Spain	DMS expedition	GEM maximum	936
2019	30 April–5 May	Buzancy, Chapagne-Ardenne, France	Vacation	ETA, SPO	107
Total					48145

Table 7 – Summary meteor outbursts 1980–2019 observed by the author.

Nr.	Date	Time UT	Show.	ZHR Norm.	ZHR Obs.	Parent body	Remark (see below) and cause	
1	1981 Nov. 1–20	~	STA	5	10	2P Encke/Taurid complex	1)	Taurids trapped in 7:2 resonance with Jupiter
2	1984 Jul. 20–31	~	CAP	5	10-15	169P NEAT	2)	Unknown
3	1985 Aug. 10–15	~	KCG	2	5	2008 ED69	3)	Outburst with a period of 7/8 years
4	1988 Nov. 1–20	~	STA	5	10	2P Encke/Taurid complex	1)	Taurids trapped in 7:2 resonance with Jupiter
5	1992 Aug. 11	20^h00^m	PER	60	170	109P Swift-Tuttle	4)	1862 & 1610 & Filament
6	1993 Jan. 17	00^h36^m	DCA	2	25		5)	Unknown
7	1993 Aug. 11–12	22^h00^m	PER	70	170	109P Swift-Tuttle	6)	1862
7	1993 Aug. 11–12	~	PER	70	300	109P Swift-Tuttle	6)	Filament
8	1993 Aug. 10–15	~	KCG	2	5	2008 ED69	3)	Outburst with a period of 7/8 years
9	1993 Oct. 16–19	~	ORI	8	25	1P Halley	7)	13:2 mean motion resonance Jupiter?
10	1995 Nov. 1–20	~	STA	5	10	2P Encke/Taurid complex	1)	Taurids trapped in 7:2 resonance with Jupiter
11	1995 Nov. 18	~	LEO	12	35	55P Tempel-Tuttle	8)	Filament
12	1995 Nov. 22	~	AMO	5	600	Long period comet?	9)	Short outburst 50 minutes
13	1996 Sep. 9	00^h00^m	SPE	5	20	Long period comet?	10)	Unknown
14	1996 Nov. 18	~	LEO	12	140	55P Tempel-Tuttle	11)	Filament + dust trail?
15	1997 Aug. 12	23^h45^m	PER	80	120	109P Swift-Tuttle	12)	Unexpected!
16	1997 Nov. 17	12^h00^m	LEO	12	30	55P Tempel-Tuttle	13)	Filament, maximum above US: ZHR 140
17	1997 Nov. 18	12^h00^m	LEO	12	30	55P Tempel-Tuttle	13)	Filament, maximum above US: ZHR 140
18	1998 Oct. 08	18^h30^m	GIA	0-2	10	21P Giacobini-Zinner	14)	Background activity
19	1998 Oct. 19	02^h00^m	ORI	8	10-15	1P Halley	15)	Unknown
20	1998 Nov. 1–20	~	STA	5	?	2P Encke/Taurid complex	1)	Taurids trapped in 7:2 resonance with Jupiter
21	1998 Nov. 17	23^h00^m	LEO	12	250	55P Tempel-Tuttle	16)	Filament
22	1998 Nov. 18	~	LEO	12	200	55P Tempel-Tuttle	16)	1899 trail?
23	1999 Aug. 10–15	~	KCG	2	5	2008 ED69	3)	Outburst with a period of 7/8 years
24	1999 Nov. 18	02^h00^m	LEO	12	4200	55P Tempel-Tuttle	17)	Trails 1899 & 1932
25	2000 Nov. 1717	05^h00^m	LEO	12	30	55P Tempel-Tuttle	18)	Trail 1932 (7^h00 UT)
26	2000 Nov. 18	03^h00^m	LEO	15	350	55P Tempel-Tuttle	18)	Trails 1733 and 1866
27	2001 Nov. 1–20	~	STA	5	10	2P Encke/Taurid complex	1)	Taurids trapped in 7:2 resonance with Jupiter
	2001 Nov. 18		LEO	12	30	55P Tempel-Tuttle	19)	Unknown
28	2001 Nov. 19	17^h00^m	LEO	15	3400	55P Tempel-Tuttle	19)	Comb. of dust trails from 1866,1699,1666 & 1633
29	2002 Nov. 19	~	LEO	15	1500	55P Tempel-Tuttle	20)	1767 trail
30	2003 Jul. 29	00^h00^m	SDA	20-25	40	96P Machholz	21)	Unknown, not confirmed
31	2003 Nov. 18	05^h00^m	LEO	10	25	55P Tempel-Tuttle	22)	Unknown
32	2003 Nov. 19	03^h36^m	LEO	10	50	55P Tempel-Tuttle	22)	Unknown
33	2003 Nov. 20	03^h00^m	LEO	8	20	55P Tempel-Tuttle	22)	Unknown
34	2003 Nov. 20	05^h00^m	LEO	8	35	55P Tempel-Tuttle	22)	Unknown
35	2004 Aug. 11	20^h00^m	PER	80	170	109P Swift-Tuttle	23)	Peak faint meteors, trail 1862

Nr.	Date	Time UT	Show.	ZHR Norm.	ZHR Obs.	Parent body	Remark (see below) and cause	
36	2004 Aug. 12	00^h00^m	PER	80	120	109P Swift-Tuttle	23)	Filament
37	2005 Nov. 1–20	~	STA	5	15	2P Encke/Taurid complex	1)	Taurids trapped in 7:2 resonance with Jupiter
38	2006 Oct. 22	00^h00^m	ORI	20	50	1P Halley	24)	Dust trails from –1265 & –1197 & –910
39	2006 Nov. 19	04^h39^m	LEO	15	90	55P Tempel-Tuttle	25)	Dust trail 1932
40	2006 Nov. 20	~	LEO	15	25	55P Tempel-Tuttle	25)	Filament
41	2007 Oct. 20	00^h00^m	ORI	15	50	1P Halley	26)	Dust trail –1265
42	2007 Oct. 22	01^h30^m	ORI	20	90	1P Halley	26)	Dust trail –1197
43	2007 Oct. 23	02^h00^m	ORI	20	50	1P Halley	26)	
44	2007 Aug. 10–15	~	KCG	1	5	2008 ED69	3)	Outburst with a period of 7/8 years
45	2007 Nov. 18	04^h00^m	LEO	15	25	55P Tempel-Tuttle	27)	Unknown trail
46	2008 Aug. 13	00^h00^m	PER	80	135	109P Swift-Tuttle	28)	Possible disturbed old 441 trail
47	2008 Oct. 20	03^h00^m	ORI	20	40	1P Halley	29)	
48	2008 Oct. 22	02^h00^m	ORI	20	35	1P Halley	29)	
49	2008 Nov. 19	~	LEO	15	80	55P Tempel-Tuttle	30)	Dust trail 1466
50	2009 Jan. 3	04^h00^m	QUA	30	100	2003 EH1	31)	Above normal activity
51	2009 Aug. 12	21^h00^m	PER	80	135	109P Swift-Tuttle	32)	Dust trail 1348?
52	2009 Oct. 21	00^h00^m	ORI	20	35	1P Halley	33)	
53	2009 Dec. 13–14	~	HYD?	5	5		34)	3 very bright HYD fireballs within hours
54	2010 Oct. 21	03^h00^m	ORI	20	30	1P Halley	35)	
55	2010 Oct. 25	03^h00^m	ORI	15	25	1P Halley	35)	
56	2011 Oct. 8	19^h00^m	GIA	0-2	250	21P Giacobini-Zinner	36)	
57	2013 May 6	~	ETA	60	120	1P Halley	37)	Dust trails –1197 & –910
58	2013 Aug. 10–15	~	KCG	0-2	5	2008 ED69	3)	Outburst with a period of 7/8 years
59	2015 Aug. 11	21^h18^m	PER	90	120	109P Swift-Tuttle	38)	Trail 1862?
60	2015 Nov. 1–20	~	STA	5	15	2P Encke/Taurid complex	1)	Taurids trapped in 7:2 resonance with Jupiter
61	2016 Aug. 11	22^h38^m	PER	90	170	109P Swift-Tuttle	39)	Trail 1862 combined with trail 1479
62	2016 Aug. 11	23^h17^m	PER	90	330	109P Swift-Tuttle	39)	Trail 1479, very sharp peak!
63	2016 Aug. 12	$01–04^h$	PER	90	120-180	109P Swift-Tuttle	39)	Filament/old trails
64	2018 Aug. 11	20^h00^m	PER	90	110	109P Swift-Tuttle	40)	Filament
65	2018 Aug. 13–14		PER	40	90	109P Swift-Tuttle	41)	New feature?
66	2018 Oct. 8	22^h55^m	GIA	0–2	140	21P Giacobini-Zinner	42)	Trail 1953, disturbed

Remarks associated with the events listed in *Table 7*:

1) Taurids resonant swarm 1981, 1988, 1995, 1998, 2001, 2005, 2015 (ZHR 10–15). Occasionally, the southern Taurids (STA) exhibit increased activity. This is caused by a swarm of heavier meteoroids caught in a 7:2 resonance with the planet Jupiter. 1981 and 2005 were the most impressive due to the appearance of one or more very bright fireballs in the class –8 to –10 (Delphinus, 1981; Johannink and Miskotte, 2006a; Nijland, 1995; Miskotte, 1988; Miskotte and Johannink, 2005c; 2006a; 2006b).
2) Capricornids 1984 (ZHR 10–12). In 1984 I observed the Capricornids with Bauke Rispens and Carl Johannink from Puimichel, Provence, southern France (Miskotte et al., 1984; Miskotte and Johannink, 2005b; 2008a). The brightness and ZHR observed there clearly show an increased activity with ZHRs around 10–12, where normally the ZHR is around 5. There were also quite a few fireballs seen, including one –8 CAP.

3) Kappa Cygnids in 1985, 1993, 1999, 2007 and 2013 (ZHR 5). Just like the southern Taurids (STA), the kappa Cygnids (KCG) occasionally show more activity with a slightly higher ZHR, but especially more bright fireballs (Johannink, 2007b; Langbroek, 1993; Miskotte, 1985). The fireballs were particularly noticeable in 1993 and 2007. In 1985 and 2013, the numbers were somewhat higher, but no fireballs were seen.
4) Perseids (1992) from the Netherlands (ZHR 170). A spectacular outburst of the Perseids (ZHR 600) was reported from China, Eastern Europe and Switzerland. With a maximum around 19^h50^m UT not visible from the Netherlands, but when I started at 20^h15^m UT I immediately saw a number of bright Perseids in the twilight sky. A ZHR calculation resulted in a ZHR of 170. So, I may have seen the last minutes of this outburst (Miskotte, 1992).
5) Delta Cancrids (1993) from the Netherlands (ZHR 25). Over a period of 68 minutes, 8 delta Cancrids were seen, including a number of bright ones (Miskotte, 1993a). ZHR 12 for the entire period (Jenniskens, 2006a; Van Vliet, 1993), ZHR 25 in shorter intervals (Miskotte, private analyses).
6) Impressive Perseid outburst of 11–12 August 1993 (ZHR 300). As a participant of a large DMS expedition to the south of France, I witnessed the beautiful Perseid outburst of 11–12 August 1993 (Langbroek, 1993). A peak with a ZHR of 170 was seen around 22^h30^m UT caused by the 1 revolution dust trail of P 109 Swift-Tuttle and later that night a peak ZHR of 300 was caused by the “filament” (Jenniskens, 2006b). Many bright Perseids were seen that night.
7) Unexpected Orionid outburst on October 18, 1993 (ZHR 30). I was able to observe the nights 16–17, 17–18 and 18–19 October 1993, three nights in a row. The first night, despite disturbing clouds, gave rather high Orionid activity. The night of October 17–18 the activity was comparable to a good Orionid maximum with many bright meteors up to magnitude –5 (Jenniskens, 2006c; Miskotte, 1993b; Rendtel and Betlem, 1993)! Later on, this outburst was confirmed by Jürgen Rendtel and André Knöfel and a radio observer, Esko Lyytinen.
8) Leonid outburst November 18, 1995 (ZHR 35). In 1994 the first Leonid outburst in a new series was observed. In 1995, DMS organized an expedition to Andalusia in southern Spain. There, along with many other DMS members, I saw the second Leonid outburst with a ZHR of 35 caused by the Leonid filament (Jenniskens, 2006d; Langbroek, 1996a; Nijland, 1995).
9) Alpha Monocerotids outburst November 22, 1995 (ZHR 600). As a participant in the first DMS Leonid expedition, I also saw the 50-minute alpha Monocerotid outburst (Jenniskens, 2006e; Langbroek and Jenniskens, 1996; Nijland, 1995).
10) September Perseids (ZHR 30 and decreasing). On the verge of a detection and not noticed by other observers active at the same time (Miskotte, 1996).
11) Leonids outburst November 17, 1996 (ZHR 140). A crash expedition brought the team Delphinus to the northern French hamlet of Woignarue where we saw a beautiful Leonid return. On a background of bright Leonids (ZHR 80) we saw a peak of weak Leonids (ZHR 60). A nice campaign made with a rented camper (Langbroek, 1996b; Langbroek, 1999; Miskotte and ter Kuile, 1997).
12) Unexpected Perseid activity on August 12, 00^h UT (ZHR 135). During a regular Perseid maximum, a ZHR of 120 was briefly observed (Arlt, 1997; Langbroek, 1997; ter Kuile and Miskotte, 1997).
13) Leonids 17 and 18 November 1997 (ZHR 30–50). In that year I was able to observe the Leonids with other DMS members from the Cosmos Observatory near Lattrop (Miskotte et al., 1998). There we saw an increasing (November 17, 1997) and a decreasing activity (November 18) of the Leonid filament with relatively many bright Leonids in a moonlit sky (Jenniskens, 2006f).
14) Draconid activity on October 8, 1998 (ZHR 10). A major outburst of the Draconids (ZHR 800) was seen above East Asia on 8 October. When it became dark above western Europe, only some background activity remained visible (Langbroek, 1998).
15) Orionids on October 19, 1998 (ZHR 25). Possibly slightly increased Orionid activity that morning, similar to October 18–19, 1993 (one night after the outburst of 1993 when the activity was also enhanced
16) Leonids 17 and 18 November 1998 (ZHR resp. 250–200). As a participant in the Sino Dutch Leonid Expedition 1998 (SDLE) I observed the beautiful fireball rain on November 17 caused by the Leonid filament. On November 18 I observed a peak activity of Leonids caused by the dust trail from 1899. An unforgettable experience (Betlem, 1998; Betlem and Van Mil, 1999; Jenniskens, 2006f; 2006g; Miskotte, 1999a; Nijland, 1999; Tukkers, 1999).
17) My first Leonid meteor storm (ZHR 4200). Together with a large team of DMS members I saw my first Leonid storm from Andalusia in Spain. Minute counts up to 50 Leonids and sometimes 5 or 6 Leonids in a second! Only a few bright Leonids and many weak Leonids (Jenniskens, 2006g; Miskotte, 1999b). A nice encounter with a dust trail of 55P/Tempel-Tuttle from 1866.
18) Leonids 17 and 18 November 2000 (ZHR resp. 30 and 350). Together with Marco Langbroek and Carl Johannink I flew last-minute to southern Portugal where we could observe the Leonids on 17 and 18 November. On November 17 we had some increased activity leading up to the passage of the dust trail of 55P from 1932. On the morning of November, the 18th we observed several peaks in activity, associated with dust trails of 55P from 1733 and 1866 (Jenniskens, 2006g; Johannink, 2000).
19) November 19, 2001: my second Leonid storm (ZHR 3600). As a participant in the Sino Dutch Leonid Expedition, I witnessed the Leonid storm of November 19, 2001 from the optical observatory of XingLong,

China. The ideal meteor show: the bright Leonids of 1998 and the activity of the 1999 Leonid meteor storm combined (Miskotte, 2001; ter Kuile, 2001). The night before there was also increased Leonid activity (ZHR 30). The activity of the 18th was a combination of various dust traces left by 55P in 1866, 1699, 1666 and 1633.

20) A Leonid outburst (ZHR 2200). In November 2002 I was in southern Portugal with Peter Bus, Jaap van 't Leven and Olga van Mil. Unfortunately, the weather did not cooperate. We did not see much of the last Leonid storm of this series, the only thing we saw was the rising activity in tiny clearings in a moonlit sky (Bus, 2002; Jenniskens 2006g, Miskotte et al., 2002).
21) The Southern delta Aquariids July, 29, 2003 (ZHR 40). A 2-week holiday in Crete offered me the opportunity to do some observations night after night on the Southern delta Aquariids and Capricornids. On July 29, 2003, the SDAs showed high activity which I noticed during the observations (Miskotte, 2004).
22) Leonids 2003, multiple peaks (ZHR 30–50). A week in southern Portugal with Jaap van ’t Leven and Peter Bus yielded four clear nights. During the nights 17–18, 18–19 and 19–20, several brief peaks of the Leonid meteor shower were observed. The ZHRs ranged from 30–50 (Bus, 2004).
23) Perseid outburst August 11, 2004 (ZHR 200). After a tour through Germany together with Carl Johannink, Rita Verhoef and Romke Schievink we finally found a clear sky over Britzingen, Germany. There we observed a short outburst of faint Perseids as a result of the Earth moving through the 1 revolution dust trail of comet 109P/Swift-Tuttle from 1862. Later that night many bright Perseids appeared as a result of the filament (Jenniskens, 2006h; Miskotte and Johannink, 2004; 2005a).
24) Orionid outburst on October 21, 2006 (ZHR 60). Because the Earth moved through old dust trails from Comet 1P/Halley (–1265, –1197 and –910) I was able to observe clearly increased Orionid activity during a few major clear spells that night (Jenniskens et al., 2006a; Johannink and Miskotte, 2006b; Miskotte, 2006).
25) Leonid outburst November 19, 2006 (ZHR 90). A week in southern Spain, together with Jaap van 't Leven, Peter Bus, Michel Vandeputte, Carl Johannink, Robert Haas, Peter Jenniskens and Casper ter Kuile, resulted in a number of clear nights. A dust trail of 55P/Tempel-Tuttle from 1932 produced a short outburst with a maximum ZHR of 90. The next night, remarkably bright Leonids were seen as a result of the filament (Jenniskens et al., 2006b; Jenniskens et al., 2008; Johannink, 2007a; Vandeputte, 2007).
26) Orionid outburst October 2007 (ZHR 90). Again, due to old dust traces of comet 1P Halley from –1265 and –1197 beautiful Orionid activity. The highlight was the night 21–22 October from Lattrop with a large group of observers. Incredibly beautiful activity, comparable to a Perseid maximum (Johannink and Miskotte, 2008; Miskotte, 2008a;).
27) Leonid 2007 small outburst on November 18, 2007 (ZHR 25). A crystal-clear night from the Ermelo Heide (a heath) together with Jaap van 't Leven. Beautiful Leonid activity, also with bright Leonids up to magnitude –4 (Miskotte, 2008b; Miskotte and Johannink, 2008b).
28) Perseid outburst 12–13 August 2008 (ZHR 135). As a result of a possibly old and disturbed dust trail from comet 109P Swift-Tuttle from 441 a beautiful outburst of bright Perseids was observed, including a –10 Perseid. Observed from the Cosmos Observatory in Lattrop (Johannink, 2008; Johannink et al., 2008).
29) Orionid outburst in 2008 (ZHR 40). For the third year in a row an Orionid outburst, noticeable despite moonlight (Miskotte, 2008c; Miskotte and Johannink, 2009).
30) Leonid outburst on November 19, 2008 (ZHR 80). Despite a lot of moonlight, low radiant position and clouds I observed beautiful Leonid activity[1].
31) Quadrantids were very active (ZHR 100). Unexpectedly high Quadrantid activity in 2009, ZHR 90 instead of the normal ZHR 30–40. Nice and cold observing from the Ermelo Heide (Johannink and Miskotte, 2009; Vandeputte, 2009).
32) Perseid outburst August 12, 2009 (ZHR 135). Due to disturbances of the Perseid meteoroids by Saturn, the Earth moved through several dust trails of comet 109P. Possibly I saw the last part of an outburst caused by a dust trail from 1348. Beautiful bright Perseids made long tracks across the Provencal sky (Miskotte, 2009; Miskotte et al., 2009).
33) Orionids 2009 (ZHR 40). An Orionid outburst for the fourth year in a row.
34) Hydrid fireballs 13–14 December 2009. The observation of three very bright Hydrid fireballs from magnitude –4, –5 and –8 during the Geminid maximum of 2009 (Johannink et al., 2010; Van Leuteren and Miskotte, 2010).
35) Orionids outburst 2010 (ZHR 30). A crash expedition with Carl Johannink to Grevesmuhlen in northern Germany yielded a few hours of Orionid data with a ZHR of 30. Fifth year on a row with enhanced Orionid activity.
36) Draconid outburst October 8, 2011 (ZHR 300). Unfortunately, due to bad weather only a dozen Draconids were seen during short clear spells (Miskotte, 2012).
37) eta Aquariids outburst May 6, 2013 (ZHR 100). Despite very low radiant elevations, not less than 13 ETAs were seen during twilight from Ermelo, the Netherlands (Johannink et al., 2013; Miskotte, 2013).
38) Small Perseid outburst on August 12, 2015 (ZHR 120). Despite a low radiant position, I saw a somewhat higher PER activity from the Provence. Data from

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[1] http://www.astrorocker.nl/Meteors/Observations/storys/Leonids_2008.htm

Eastern Europe confirms this observation. Possibly a belated activity of the REV 1 trail from 1862 (Miskotte, 2016a; 2016b; Vandeputte and Miskotte, 2016).

39) The beautiful Perseid outburst of 11–12 August 2016 (ZHR 100–300). Fantastic Perseids outburst in this night, the most beautiful of all Perseid outburst that I have seen. No less than three peaks, the first of which was the most intense (ZHR 300). Never saw such a rapid decline in activity after this peak (Miskotte and Vandeputte, 2017a; 2017b; Vandeputte, 2016).
40) Enhanced Perseid activity on August 12, 2018 (ZHR 110). Strikingly many bright Perseids seen including a beautiful –4 earthgrazer that moved from the constellations of Cepheus to Sagittarius in the evening of August 11, 2018. Probably caused by the appearance of the Perseid filament (Miskotte, 2019a; 2019b; Vandeputte, 2018; 2019).
41) A second peak in Perseid activity on August 14, 2018 (ZHR 80). Surprise during the night August 13–14, 2018. A peak of Perseid activity observed together with Michel Vandeputte, Carl Johannink and Jos Nijland (Miskotte, 2019a; 2019b; Vandeputte, 2018; 2019).
42) Draconid outburst of October 8, 2018 (ZHR 140). Despite moderate weather conditions, this outburst has been properly observed (Miskotte 2018a; 2018b; 2019a; 2019b).

7 The coming decade

If health permits, I hope to add another decade of meteor observing. In addition to the visual meteor work, there is also the CAMS, visual reductions and all sky work that the author is working on. However, the visual work is still the most important thing for the author. Nothing can beat a nice active meteor night from a beautiful scenic and dark location!

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Phi Serpentids (PSR#839) activity enhancement

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A short-lived activity enhancement of the Phi Serpentids (PSR#839) allowed to calculate a reliable reference orbit for the 2020 return of this minor shower. The meteors and orbit identification of the Phi Serpentids caused confusion with the κ Serpentids (KSE#027) meteor stream for which the reference orbits were established before the PSR shower was known. The sudden activity with several orbits registered in a short time lapse from a very compact radiant is very likely related to an unknown long periodic comet. Attention should be paid to the PSR shower in the future as more dust may move ahead of the unknown parent body that may be on its way to return. The similarity between the KSE and PSR orbits suggests that these are both dust components of the same parent body.

1 Introduction

When a small compact cluster of radiants appeared on the daily CAMS report screen[2], it was obvious that one of the minor showers in this region of the sky had suddenly flared up. Peter Jenniskens identified the minor shower φ Serpentids (PSR#839) with the recorded orbits. This was somehow confusing as most camera operators got the κ Serpentids (KSE#027) suggested as possible shower identification. The KSE shower has been listed as an established shower for years, while PSR#839 was detected during a survey of the CAMS orbits as available until 2016 (Jenniskens et al., 2018).

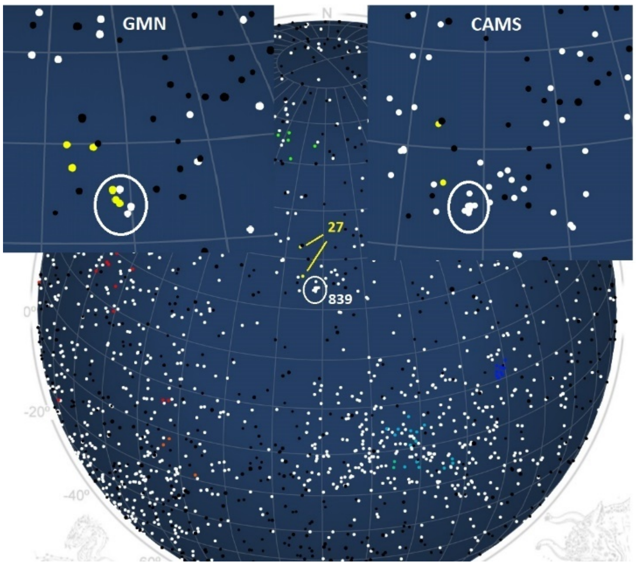

Figure 1 – The radiant map for CAMS for 2020 April 15 with some KSE radiants and the compact PSR radiant nearby. The inset at left shows the compact radiant according to GMN and the inset at right shows the radiant as found by CAMS.

The reference orbits from the IAU working list[3] of meteor showers are listed in *Table 1*. The velocity is about identical and the radiant positions are close to each other. *Figure 1* shows the situation as registered this year on April 15 by the CAMS networks. The insets compare the compact radiant for the Global Meteor Network with CAMS.

Table 1 – The reference orbits listed for the KSE#027 and PSR#839 as listed in the IAU working list of meteor showers.

	KSE#027 Cook 1973	KSE#027 Jacchia 1961	KSE#027 Jenniskens et al. 2016	PSR#839 Jenniskens et al. 2018
$\lambda_\odot$	15.7°	15.7°	20.0°	25.1°
α_g	230.6°	232.6°	240.2°	242.2°
δ_g	+17.8°	+15.4°	+16.8°	+14.0°
v_g	45 km/s	45.0 km/s	46.7 km/s	46.3 km/s
a	∞	41.7 AU	7.9 AU	∞
q	0.45 AU	0.417 AU	0.489 AU	0.435 AU
e	1.00	–	0.971	1.017
ω	275°	279.9°	273.4°	277.2°
Ω	15.7°	16.5°	20.1°	25.1°
i	65°	63.0°	72.5°	69.9°
N	4	1	21	5

The status of the κ Serpentids (KSE#027) as an established shower raises some questions. Cook (1973) obtained his data from four graphically reduced meteors (McCrosky and Posen, 1961), with limited accuracy. The second reference orbit (Jacchia and Whipple, 1961) is based on a single orbit, a rather questionable criterium to define a reference orbit for a meteor shower. The third reference orbit has been

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[2] http://cams.seti.org/FDL/

[3] https://www.ta3.sk/IAUC22DB/MDC2007/Roje/roje_lista.php?corobic_roje=0&sort_roje=0

obtained from the CAMS dataset 2010–2013. Looking at the 21 orbits on which the KSE reference orbit is based, some of these orbits fit better with the φ-Serpentids (PSR#839) reference orbit. When the 2016 reference orbit for the κ Serpentids (KSE#027) was calculated the φ-Serpentids (PSR#839) was not yet known. When we calculate the median values for all parameters of these 21 KSE-orbits, we find 242.7° as R.A. instead of the 240.2° listed in the IAU shower list. This orbit is remarkable similar to that of the φ-Serpentids (PSR#839). The only significant difference between both is the time of activity, reflected in the difference in the ascending node Ω.

It looks like we have a dispersed meteor shower with orbits that define the κ Serpentids (KSE#027) followed by a compact component known as the φ-Serpentids (PSR#839). The similarity of both orbits suggests both are somehow related, probably from the same parent body. May be this is an old dispersed shower (KSE#027) with a compact dust trail now observed as the φ-Serpentids (PSR#839) moving perhaps ahead of a parent comet that has still to be discovered? Future observations can learn us whether the enhanced activity in 2020 is just a lucky encounter with a dust concentration in the shower, or the beginning of a trail which will become more active year after year?

2 CAMS BeNeLux

April 14–15 had an almost complete clear night for the CAMS BeNeLux network. All the operational cameras were recording this night. The data of 63 cameras got collected within 24 hours when the next morning Peter Jenniskens reported that the CAMS Namibia network had recorded enhanced activity from a radiant in the top of the constellation Serpens. The next day, data of 73 cameras was available for analyses and yes, CAMS BeNeLux had also registered a few orbits of this meteor shower. The results for CAMS BeNeLux are listed in *Table 2*. The camera operators who were lucky to contribute to these orbits were: *Koen Miskotte* (CAMS 354, Ermelo, the Netherlands), *Adriana and Paul Roggemans* (RMS 3830, Mechelen, Belgium), *Hervé Lamy* (CAMS 394, Dourbes, Belgium), *Luc Gobin* (CAMS 390 and 808, Mechelen, Belgium), *Guiseppe Canonaco* (RMS 3815, Genk, Belgium) and *Tioga Gulon* (CAMS 3900, Nancy, France).

All CAMS BeNeLux and Namibia PSR orbits were recorded from a very compact radiant area in a short time interval within the range of $25.21° < \lambda_{\odot} < 25.39°$, which corresponds to about as little as 4 hours in time. All CAMS networks together had a total of 14 PSR orbits this year. The mean orbit for the 2020 PSR orbits is listed in *Table 5* and refers to a thusfar unknown long periodic comet according to Jenniskens (2020). The mean orbit obtained by the CAMS networks agrees very well with that obtained independently by the Global Meteor Network.

Figure 2 – The PSR#839 meteor of April 15, $0^h39^m27.7^s$ UT, registered by Luc Gobin in Mechelen, Belgium. Note at the top of the picture the CAMS software suggests KSE as possible shower association.

Table 2 – The three PSR orbits obtained by CAMS BeNeLux.

	14 April $22^h53^m47.8^s$	15 April $0^h39^m27.7^s$	15 April $0^h45^m18.5^s$
$\lambda_{\odot}$	25.17°	25.24°	25.25°
α_g	242.0 ± 0.2°	242.3 ± 0.0°	241.9 ± 0.2°
δ_g	+12.7 ± 0.3°	+14.1 ± 0.1°	+14.1 ± 0.2°
v_g	42.8 ± 0.3 km/s	44.8 ± 0.1 km/s	46.6 ± 0.1 km/s
H_b	101.2 km	107.2 km	105.5 km
H_e	92.9 km	85.8 km	90.8 km
a	4.26 AU	14.7 AU	∞
q	0.3908 AU	0.4308 AU	0.489 AU
e	0.9082	0.9707	1.0368
ω	286.41°	279.12°	276.01°
Ω	25.17°	25.24°	25.25°
i	65.1°	67.9°	69.6°
Camera	354–3830	394–390	808–3900–3815

3 Global Meteor Network

We checked the results of the Global Meteor Network for the night 14–15 April[4]. All the raw trajectory and orbit data are made available online after 24 hours. The GMN radiants can also be compared online[5]. We found 9 candidates, six were identified by the analyzing software as PSR, three were classified as KSE. Some of the PSR orbits recorded by the Global Meteor Network appeared several hours later than those recorded by CAMS BeNeLux and CAMS Namibia. The orbit identification was checked with the similarity criterion D_D of Drummond (1981) using the orbits given by Jenniskens (2016, 2018) as reference, listed in *Table 1*. The meteors and cameras involved are listed in *Table 3*.

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[4] https://globalmeteornetwork.org/data/traj_summary_data/daily/traj_summary_20200414_solrange_025.0-026.0.txt

[5] http://cams.seti.org/FDL/index-GMN.html

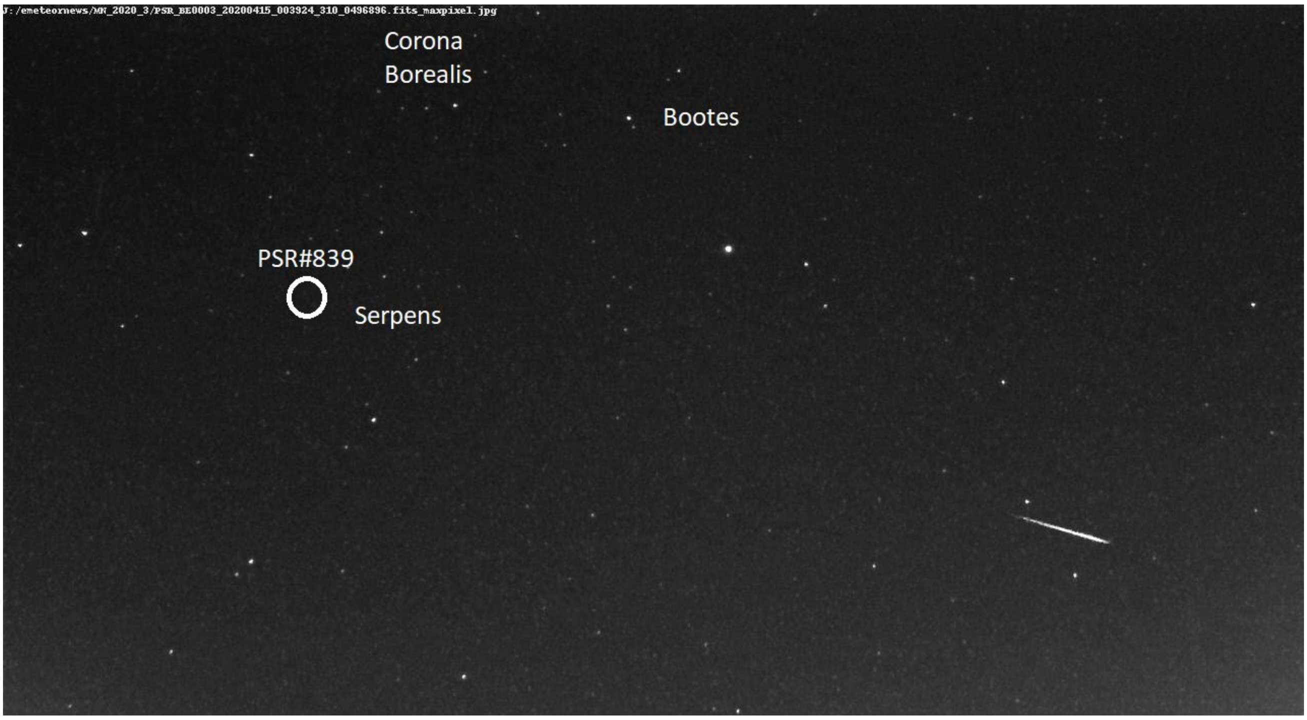

Figure 3 – The φ-Serpentids (PSR#839) meteor recorded on 15 April at $0^h45^m18.5^s$ by camera 003815 in Genk, Belgium (Adriana and Paul Roggemans).

The meteor of $01^h35^m02.2^s$ fails to fit the PSR reference orbit, the meteors of $05^h50^m48.0^s$ and $05^h50^m48.0^s$ have a best fit with the KSE reference orbit but also fit the PSR orbit. The meteor of $05^h43^m49.5^s$ is listed as best fit with PSR but also fits the KSE orbit.

The cameras marked with BE share a part of the same layers of the atmosphere with the cameras of the CAMS BeNeLux network. The PSR meteor on BE0003 at $23^h29^m23^s$ was not found at any other CAMS station, but on two French RMS cameras of GMN. The PSR meteor on BE0003 at $0^h45^m18^s$ (*Figure 3*) had no partner camera within the GMN. The PSR meteor on BE0001 and BE0002 at $03^h17^m54^s$ (*Figures 4 and 5*) for some reason did not pass the Coincidence procedure of CAMS. This proves how valuable complementary CAMS and GMN really work.

Table 3 – The Global Meteor Network candidate orbits for PSR shower association. The records marked (*) have better similarity with the KSE reference orbit.

Beginning	IAU	D_D	Participating
2020-04-14 $23^h29^m23.1^s$	839	0.01	BE3-FR6-FRG
2020-04-15 $01^h24^m00.9^s$	839	0.05	HRD-HR10-IT1
2020-04-15 $01^h35^m02.2^s$	27*	0.07	FR6-FRG
2020-04-15 $03^h17^m54.3^s$	839	0.02	BE1-BE2
2020-04-15 $05^h43^m49.5^s$	839	0.09	US6-US8
2020-04-15 $05^h50^m48.0^s$	27*	0.06	US7-US8-USA
2020-04-15 $06^h24^m20.6^s$	839	0.08	US7-US8-USA-USC-USE-USH
2020-04-15 $07^h52^m53.2^s$	839	0.06	CA6-CA9-CA15
2020-04-15 $09^h25^m26.5^s$	27*	0.02	US4-US5-USC-USD-USH

When we calculate the mean orbit based on the 6 certain PSR meteors using the method of Jopek et al. (2006), we find a mean orbit which is in good agreement with the result obtained by Peter Jenniskens based on the CAMS data, see *Table 5*.

Figure 4 – The φ-Serpentids (PSR#839) meteor recorded on 15 April at $3^h17^m54.3^s$ by camera BE0002 in Mechelen, Belgium (Adriana and Paul Roggemans).

Figure 5 – The φ-Serpentids (PSR#839) meteor recorded on 15 April at $3^h17^m54.3^s$ by camera BE0001 in Grapfontaine, Belgium (Adriana and Paul Roggemans).

4 SonotaCo Network Japan

The SonotaCo camera network found 6 candidate orbits:

- A: 2020 April 11 $18^h30^m27^s$ UT $mag_a = +1.0$
- B: 2020 April 14 $12^h05^m12^s$ UT $mag_a = –2.7$
- C: 2020 April 14 $12^h14^m55^s$ UT $mag_a = –0.1$
- D: 2020 April 14 $18^h55^m58^s$ UT $mag_a = +0.9$
- E: 2020 April 15 $15^h05^m31^s$ UT $mag_a = –1.7$
- F: 2020 April 15 $16^h29^m01^s$ UT $mag_a = +0.4$

Table 4 – The orbits obtained by the SonotaCo Network.

	A	B	C	D	E	F
$\lambda_{\odot}$	22.1°	24.7°	24.7°	25.0°	25.8°	25.9°
α_g	234.0°	241.8°	239.6°	242.3°	240.2°	236.9°
δ_g	+11.6°	+13.9°	+15.9°	13.4°	17.9°	12.7°
v_g	39.8	45.6	39.5	42.8	39.6	38.3
H_b	89.4	99.8	93.6	101.8	98.2	92.1
H_e	85.9	88.0	82.7	97.8	86.5	87.6
a	3.7	54.4	3.3	4.3	4.3	3.2
q	0.36	0.43	0.45	0.41	0.49	0.40
e	0.90	0.99	0.87	0.91	0.89	0.88
ω	290.6°	278.7°	281.4°	284.6°	275.0°	287.2°
Ω	22.1°	24.7°	24.7°	25.0°	25.8°	25.9°
i	54.1°	68.9°	58.0°	65.5°	57.8°	51.9°

Table 5 – Comparing the PSR orbits obtained by CAMS, by GMN and by SonotaCo Network.

	CAMS	GMN	SonotaCo
$\lambda_{\odot}$	25.2°	25.4°	25.2°
α_g	242.4 ± 0.4°	242.3 ± 0.7°	240.2°
δ_g	+13.9 ± 0.3°	+14.1 ± 0.8°	+14.8°
v_g	46.4 ± 0.5 km/s	44.5 ± 2.3 km/s	41.1 km/s
H_b	–	104.3 ± 2.1 km	97.1 km
H_e	–	90.7 ± 2.6 km	88.5 km
a	∞	72 AU	13.9 AU
q	0.432 ± 0.007 AU	0.432 ± 0.02 AU	0.4 AU
e	1.011 ± 0.034	0.994 ± 0.08	0.9
ω	277.6 ± 1.2°	277.92 ± 4.9°	281.4°
Ω	25.24 ± 0.13°	25.395°	25.2°
i	69.7 ± 0.7°	68.3 ± 3.1°	60.4°
N	12	6	5

The orbit of meteor B is very similar to the mean orbit obtained for the PSR#839 orbits by CAMS and GMN. The other orbits are more spread and all have a lower geocentric velocity v_g. As mentioned above the first alert came from orbits recorded in about 4 hours time. All PSR orbits from the compact radiant were collected in less than 24 hours of time. The meteor at April 14 $12^h05^m12^s$ UT detected by the SonotaCo Network may be one of the earliest meteors of the compact PSR return. Some of the meteors detected by the SonotaCo Network may belong to the more dispersed component. This could explain the lower velocity v_g, smaller eccentricity e and lower inclination i of the mean orbit.

5 The KSE#027 and PSR#839 confusion

Both KSE#027 and especially PSR#839 are poorly documented. No activity period is determined and while we got a reliable reference orbit for PSR#839 from a compact cluster of orbits, the reliability of the reference orbits for the obviously very dispersed κ Serpentid shower remains questionable. Two showers with nearby radiants, the same velocity and only 5° apart in solar longitude, how to identify these orbits correctly? Are both somehow related?

This confusing situation has been discussed before in a study by Masahiro Koseki (2019). Masahiro Koseki considers the positions of shower radiants in Sun centered ecliptic coordinates relative to the median value of the radiant position. By counting the number of radiants that occur within concentric circles and radiant density ratios in function of the time (solar longitude) the evidence for the existence of the shower can be evaluated. The study by Masahiro Koseki includes two other nearby minor showers, the April β Herculids (ABH#836) and the δ Herculids (DHE#841) with nearby radiants but significant higher geocentric velocities. The conclusion is that no clear concentration could be found for the κ Serpentid shower and the question then is how KSE got ranked as an established shower? The φ-Serpentids (PSR#839) displays a small but clear peak and its radiant position is close to that of KSE.

The available orbits may help to get a better picture of the situation. We have 1101924 orbits public available, 630341 combined for EDMOND and SonotaCo (2007–2019), 471583 for CAMS (2010–2016). We use the orbit given for KSE#027 by Jenniskens et al. (2016) as reference (*Table 1*) and for PSR#839 the orbit of Global Meteor Network as reference (see *Table 5*). These reference orbits are used to search for orbits that fulfil the D-criteria of Southworth and Hawkins (1963), Drummond (1981) and Jopek (1993) combined. We define five different classes with specific threshold levels of similarity:

- Low: $D_{SH} < 0.25$ & $D_D < 0.105$ & $D_H < 0.25$;
- Medium low: $D_{SH} < 0.2$ & $D_D < 0.08$ & $D_H < 0.2$;
- Medium high: $D_{SH} < 0.15$ & $D_D < 0.06$ & $D_H < 0.15$;
- High: $D_{SH} < 0.1$ & $D_D < 0.04$ & $D_H < 0.1$.
- Very high: $D_{SH} < 0.05$ & $D_D < 0.02$ & $D_H < 0.05$.

Working with the discrimination criteria requires caution. The results indicate only a degree of similarity between the orbits. D-criteria provide no prove for any physical relationship between the meteoroids. D-criteria can be very misleading, especially if applied on short period orbits with small eccentricity. In case of the KSE and PSR which have long period orbits with high eccentricity and high inclination the use of D-criteria is justified. However, the method should be applied unbiased and we must be confident that the orbits are based on reliable velocities.

Although the 2020 PSR activity suggests a very narrow concentrated shower, we cannot apriory exclude that more dispersed orbits are related to this shower. It should be understood that the low threshold class of similarity may be contaminated by sporadics that fulfil the criteria by pure chance. The purpose is to check if a shower concentration is confirmed by the high threshold classes with very similar orbits.

Table 6 – Number of low and high threshold KSE and PSR orbits per year.

Year	KSE Low	KSE High	PSR Low	PSR High
2007	5	1	5	1
2008	6	1	4	0
2009	12	0	3	1
2010	2	0	3	1
2011	28	2	17	1
2012	22	0	17	4
2013	47	0	31	7
2014	51	6	34	6
2015	52	2	36	5
2016	42	2	29	2
2017	11	0	7	1
2018	5	0	4	0
2019	10	0	6	2
Total	293	14	196	31

We find 293 KSE and 196 PSR orbits that fulfil at least the low similarity class mentioned above. This may be misleading somehow because of the risk for false positives. Therefore, we also list the number of orbits that fulfil the high threshold criteria in *Table 6*. Considering the high threshold class, the PSR shower emerges much stronger than the KSE which remains absent in most years. The number of high threshold PSR orbits registered in 2020 exceeds all previous years.

The number of orbits per year depends mainly on the number of available data. Before 2011 only EDMOND and SonotaCo Network orbits are available, after 2016 only SonotaCo Network orbits. There is no indication for any periodicity. Looking at the number of orbits in each class of similarity threshold we see that the KSE orbits appear very scattered while the PSR shower shows a distinct concentration of orbits (*Table 7*).

Table 7 – Number of KSE and PSR orbits per similarity class.

Class	KSE	PSR
Low	293	196
Medium low	147	99
Medium high	73	53
High	14	31
Very high	0	17

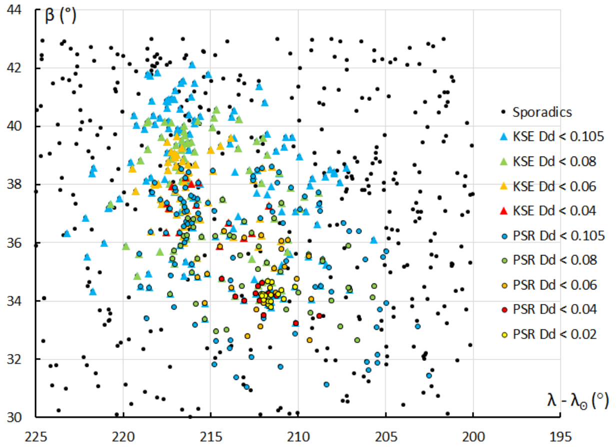

Figure 6 – Radiant positions for all KSE and PSR orbits in Sun centered ecliptic coordinates, color coded for the different similarity classes of the combined D-criteria.

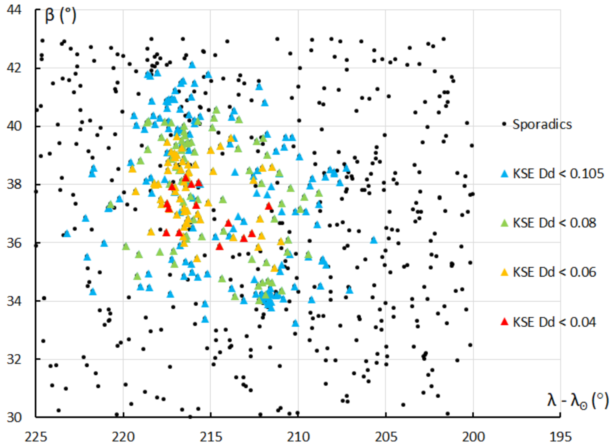

Figure 7 – Radiant positions for the KSE orbits in Sun centered ecliptic coordinates, color coded for the different similarity classes of the combined D-criteria.

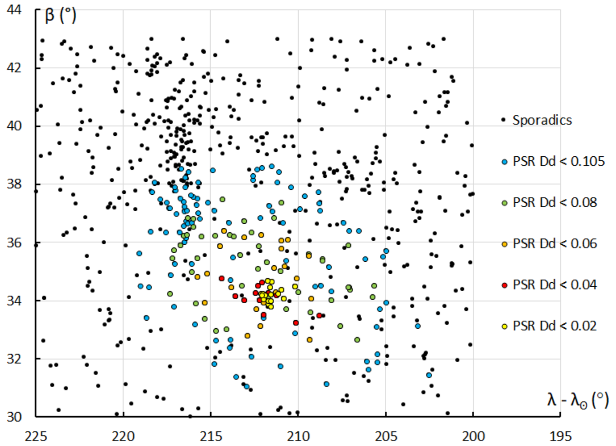

Figure 8 – Radiant positions for the PSR orbits in Sun centered ecliptic coordinates, color coded for the different similarity classes of the combined D-criteria.

The KSE orbits were detected in the time range $6.3° < \lambda_\odot < 33.5°$ for the low threshold, $16.8° < \lambda_\odot < 24.9°$ for the high threshold with not a single orbit fulfilling the very high threshold. For the PSR the time range was $12.8° < \lambda_\odot < 37.4°$ for the low threshold, $23.5° < \lambda_\odot < 27.0°$ for the very high threshold. These periods are a good indication for the activity periods of these showers. In a future case study, we may attempt to run an iterative search to locate orbit concentrations to determine independently new reference orbits.

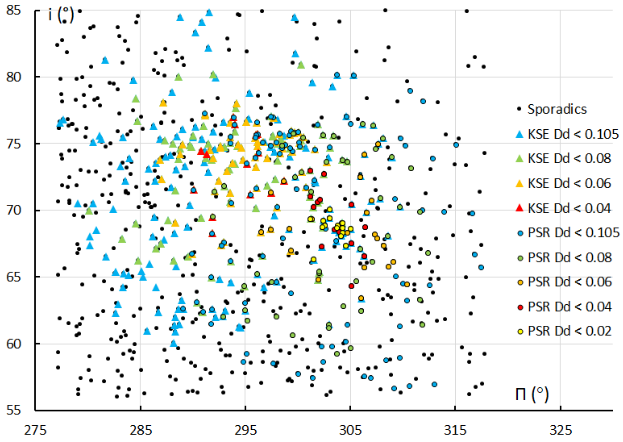

Figure 9 – Plot of inclination i against length of perihelion Π for all KSE and PSR orbits, color coded for the different similarity classes of the combined D-criteria.

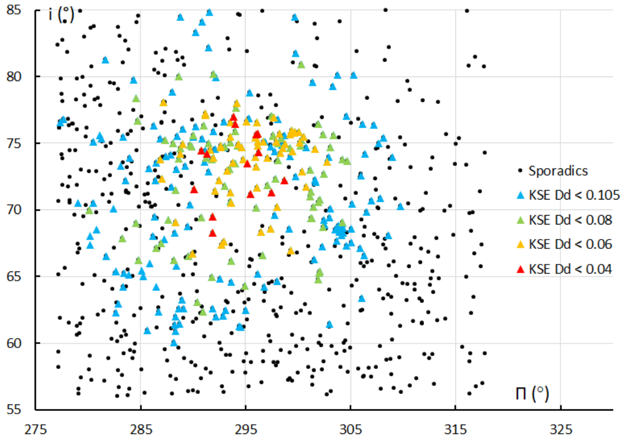

Figure 10 – Plot of inclination against length of perihelion Π for the KSE orbits, color coded for the different similarity classes of the combined D-criteria.

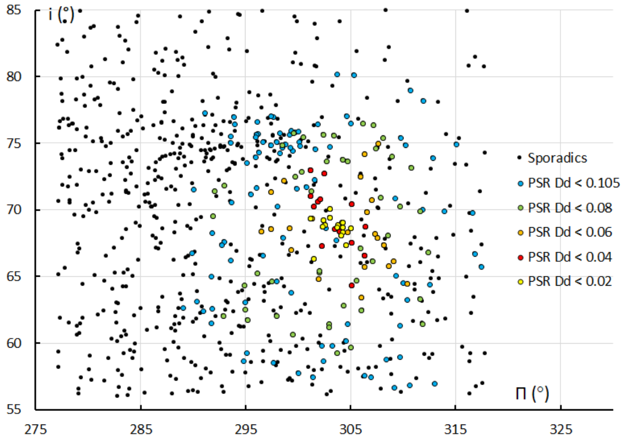

Figure 11 – Plot of inclination against length of perihelion Π for the PSR orbits, color coded for the different similarity classes of the combined D-criteria.

We consider the radiant distribution in Sun centered ecliptic coordinates to mark each radiant either as KSE or as PSR with a different color according to the threshold class of similarity. In *Figure 6* we see how complex the picture really is. KSE radiants appear mainly north and east from the PSR radiants, but a large number of the orbits fit the discrimination criteria for both shower reference orbits. This becomes better visible if we display only the radiants of orbits that fit the D-criteria for the KSE reference in *Figure 7* and only those that match the PSR reference in *Figure 8*. We see the PSR orbits (circles in *Figure 8*) fit the criteria for the KSE reference (triangles in *Figure 7*) and not only for the low threshold class. We make the same presentation in another distribution with the inclination *i* against the length of perihelion *Π* in *Figures 9, 10 and 11*.

The KSE radiants appear very dispersed and only the PSR radiants show a very distinct concentration. There seems to be no objective way to distinguish KSE and PSR associations. In *Figures 6, 7 and 8* we see a dispersed concentration (at left) and a more concentrated one a bit lower right of it. This looks like two showers, but when we take the D-criteria into account, it becomes obvious there is a lot of overlap with orbits that fit both shower associations. In *Figures 9, 10 and 11* the radiants also appear very dispersed, the best KSE associations appear to have a slightly higher inclination and lower value for the length of perihelion *Π* than the best PSR orbits.

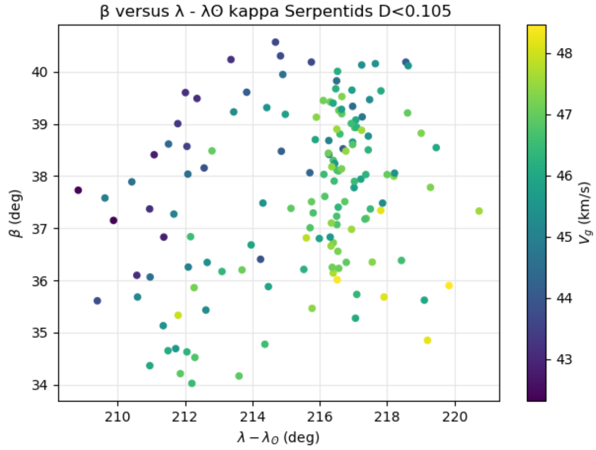

Figure 12 – Plot of the ecliptic latitude β (°) against the Sun centered longitude λ – λ⊙ (°) for the 147 KSE orbits that fulfill the medium low threshold similarity criteria with a color gradient to display the variation in the velocity v_g.

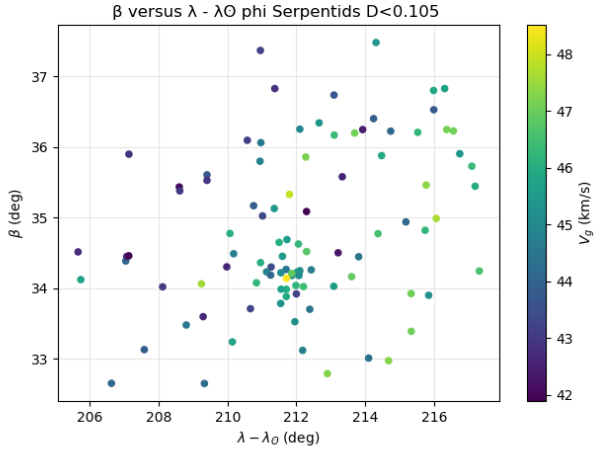

Figure 13 – Plot of the ecliptic latitude β (°) against the Sun centered longitude λ – λ⊙ (°) for the 99 PSR orbits that fulfill the medium low threshold similarity criteria with a color gradient to display the variation in the velocity v_g.

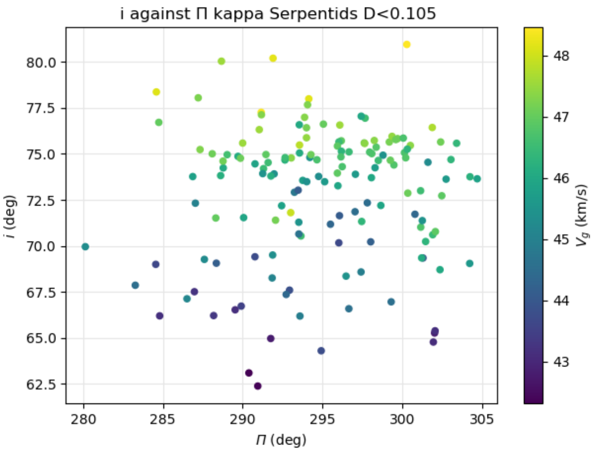

Figure 14 – Plot of inclination i (°) against the length of perihelion Π (°) for the 147 KSE orbits that fulfill the medium low threshold similarity criteria with a color gradient to display the variation in the velocity v_g.

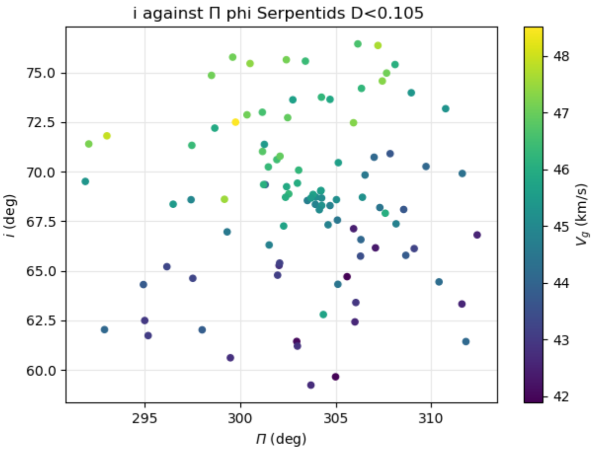

Figure 15 – Plot of inclination i (°) against the length of perihelion Π (°) for the 99 PSR orbits that fulfill the medium low threshold similarity criteria with a color gradient to display the variation in the velocity v_g.

In *Figures 12 and 13* we look at the velocity distribution in the Sun centered ecliptic coordinates. To reduce the number of false positives that may still be included in the low threshold class, we used the medium low class orbits. Here we see for both KSE and PSR associated radiants slower velocities for radiants in the western part (at left) and higher velocities in the eastern part (at right) towards the Apex. Note that both the dispersed KSE radiants and the concentrated PSR radiants appear in the same velocity range in both plots.

The same picture emerges in the plots of inclination *i* (°) against the length of perihelion *Π* (°) (*Figures 14 and 15*). Here the dispersed KSE orbits appear at slightly higher inclination with a higher velocity while the PSR concentration is situated at a bit lower inclination but within the same velocity range as the KSE orbits.

The question arises if the reference orbit for KSE we took from Jenniskens et al. (2016) is a good reference, this orbit may have been derived from a mixture of KSE and PSR orbits, as the PSR shower was not yet known when the 2016 mean orbits were calculated. The similarity between both KSE and PSR orbits makes it difficult, if not impossible to distinguish both with any degree of certainty.

6 Conclusion

A sudden short-lived activity enhancement of the φ-Serpentids (PSR#839) shower resulted in a number of orbits from a very narrow radiant concentration registered within a short time interval. The identification from simple radiant positions and velocities of the meteors caused confusion with the nearby κ Serpentids (KSE#027), an established but nevertheless poorly documented meteor stream. Looking up PSR and KSE orbits in our database with 1101924 public available orbits, both showers display considerable overlapping. This confirms an earlier detailed study by Masahiro Koseki (2019). While the φ-Serpentids (PSR#839) appear to be a very distinct concentration of similar orbits, the question arises if the available KSE reference orbits are relevant as these may be partially based on PSR orbits and perhaps some other nearby sources as the shower was not known when the KSE reference orbits were derived.

If we consider the φ-Serpentids (PSR#839) as a distinct minor shower, the KSE orbits may be related to it as a very dispersed component of this shower. The recent enhanced activity from the compact radiant of the φ-Serpentids is likely related to an unknown long periodic comet and could be caused by dust moving ahead of its parent body, announcing its return. Both the φ-Serpentids (PSR#839) and κ Serpentids (KSE#027) are very likely related and may have a common origin. It is highly recommended to keep an eye on the the φ-Serpentids activity in the future and it is very disrable to make a dedicated case study to check if a better representative reference orbit can be found for the KSE component.

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We used the data of the Global Meteor Network[6] which is released under the CC BY 4.0 license[7]. We thank the SonotaCo Network members in Japan who have been observing every night for more than 10 years, making it possible to consult their orbits. We thank the camera operators of the CAMS[8] networks[9]. And we thank the contributors to EDMOND[10], including: BOAM (Base des

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[6] https://globalmeteornetwork.org/data/

[7] https://creativecommons.org/licenses/by/4.0/

[8] http://cams.seti.org/

[9] http://cams.seti.org/FDL/

[10] https://fmph.uniba.sk/microsites/daa/daa/veda-a-vyskum/meteory/edmond/

Observateurs Amateurs de Meteores, France), CEMeNt (Central European Meteor Network, cross-border network of Czech and Slovak amateur observers), CMN (Croatian Meteor Network or HrvatskaMeteorskaMreza, Croatia), FMA (Fachgruppe Meteorastronomie, Switzerland), HMN (HungarianMeteor Network or Magyar Hullocsillagok Egyesulet, Hungary), IMO VMN (IMO Video Meteor Network), MeteorsUA (Ukraine), IMTN (Italian amateur observers in Italian Meteor and TLE Network, Italy), NEMETODE (Network for Meteor Triangulation and Orbit Determination, United Kingdom), PFN (Polish Fireball Network or Pracownia Komet i Meteorow, PkiM, Poland), Stjerneskud (Danish all-sky fireball cameras network, Denmark), SVMN (Slovak Video Meteor Network, Slovakia), UKMON (UK Meteor Observation Network, United Kingdom).

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Alpha Monocerotid outburst of 22 November 2019: an analysis of the visual data

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This analysis presents the results of the calculations on the visual observations of the alpha Monocerotid meteor shower of November 20,2019. A maximum activity with a ZHR of 160 ± 40 from this meteor outburst was obtained just before 5^{h} UT on November 22, 2019. A second peak with a ZHR of 70 in activity was found around $5^{h}20^{m}$ UT, thought there was not much data. After $05^{h}40^{m}$ UT all alpha Monocerotid activity had disappeared.

1 Introduction

Peter Jenniskens (2006) described that there would be a chance for activity of the alpha Monocerotids in 2019. However, new calculations by Lyytinen (Lyytinen and Jenniskens, 2020) indicated that there might be a better chance for activity than previously assumed. A few weeks before November 22nd, this was announced via MeteorNews. There was also a lot of attention in the press for this possible outburst, unfortunately this was often written “over the top” with high expectations for the numbers of meteors visible. One article even promised thousands of meteors! Meteor observers of course know that the short period in which it would all take place would ensure that at most a few dozens of alpha Monocerotids would be visible.

Unfortunately, the weather spoiled the opportunity in the BeNeLux. Only the southern part of the BeNeLux experienced some clear skies around the maximum activity. This resulted in one simultaneous Alpha Monocerotid for the CAMS BeNeLux network (Roggemans et al., 2020).

2 Method

First, the IMO website[11] was consulted to check how much data was available. Unfortunately, there was only few data available, mainly due to the bad weather. 25 observers reported 273 alpha Monocerotids. If we look at the “on-the-fly” graph with the so-called peak period, a maximum ZHR of 102 is found exactly at the expected time of the outburst (November 22, $04^{h}54^{m}$ UT, see *Figure 1*). This graph is based on 238 AMOs. For this graph, observations with a minimum limiting magnitude of 5.0 were used with an assumed population index r of 2.5.

It was remarkable that in first instance, observers reported that the visually counted numbers were disappointing, while the video systems that were active under good sky conditions nevertheless noticed good activity (Roggemans et al., 2020). This is probably largely due to the fact that in Europe the twilight started around the time of the expected maximum activity. The radiant heights were also unfavorable in Europe. Fortunately, three observers were also active on the Canary Islands and they were able to add a lot of data after $5^{h}15^{m}$ UT.

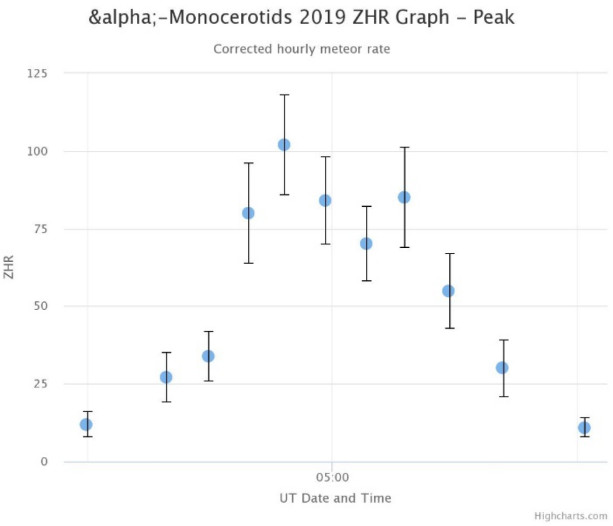

Figure 1 – ZHR curve AMOs from the IMO website[1].

Unfortunately, the author missed this alpha Monocerotid outburst and that is a pity. The author together with Peter Jenniskens, Marco Langbroek, Jos Nijland, Casper ter Kuile and Robert Haas were able to experience the beautiful outburst of 1995.

All data was carefully checked for the radiant heights (minimum 25 degrees elevation) and for the limiting magnitude. Also, the availability of a C_p determination was checked for the relevant observers. Minimum limiting magnitude was set at 5.6, which is 0.3 magnitude less than what the author normally sets as lower limit. This was necessary because otherwise too many observations could not be used because of the increasing twilight.

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[11] https://www.imo.net/members/imo_live_shower?shower=AMO&year=2019

It is unfortunate that most observers reported or counted in periods of three, five or more minutes. It is better to do 1-minute counts with this kind of very short intense meteor outburst. In this way, the analyst can determine the counting periods afterwards and calculate ZHR values in overlapping periods.

Another problem was that relatively few observers with a known C_p were active. The data of two observers without a known C_p were also used because they observed a respectable number of AMOs under good conditions. For one observer, the C_p was set to 1.0, his observations were pretty like those of other observers who were active at the same time. The same applied to a second observer whose C_p was set to 2.0, so that the ZHR values found also fit in line with observations from other observers around the same time.

3 Population index r

Unfortunately, because of the rather few visual observations, it was not possible to obtain a *r* value profile. Therefore, all observations between 03^h00^m and 06^h00^m UT with a minimum limiting magnitude of 5.6 rounded-off were used. The population index *r* could be determined based on 154 AMOs. See *Table 1* for the results. Since *r* [0; 5] contains the largest number of AMOs, it has been decided to set *r* at 3.00 ± 0.18 in the ZHR calculations.

Table 1 – Population index *r* for the alpha Monocerotids 2019.

Interval	r
r[0;4]	3.04 ± 0.18
r[0;5]	2.99 ± 0.18
r[1;5]	2.70 ± 0.18

4 Zenithal Hourly Rates

For these calculations, all observations were selected with a minimal radiant height of at least 25 degrees and the minimum limiting magnitude was set at 5.6. A total of 179 AMOs were used in this analysis.

As mentioned earlier, the observations were reported with 3, 5 or more-minute counts. The problem of three or more-minute counts with this kind of short, sharp outbursts is that in the last minute of a period the activity can be doubled or even more than at the time of the first minute. In addition, the mean time of the observations used is also a problem. Observations that are a few minutes apart can already make a significant difference in ZHR.

To tackle these problems somewhat, the period 04^h00^m to 05^h30^m UT was split into time bins of 6 minutes and the period 4^h36^m to 5^h15^m UT even into time bins of 3 minutes. All ZHR determinations that felt within one particular time bin were then averaged (weighted average). Ultimately, this work method resulted in *Table 2* and *Figures 2 and 3*.

Table 2 – ZHR Alpha Monocerotids 21–22 November 2019. First column is the time in hours on November 22.

Hour U.T.	$\lambda_\odot$ (°)	Bins	AMO	ZHR	±	Obs
2.758	239.217	1	0	0.0	0.0	1
3.583	239.252	1	0	0.0	0.0	1
3.908	239.266	1	0	0.0	0.0	1
4.000	239.270	1	1	3.7	3.7	1
4.183	239.277	1	1	0.0	0.0	1
4.270	239.281	3	1	6.7	6.7	3
4.352	239.285	5	3	5.8	3.3	4
4.447	239.289	3	2	7.7	5.4	2
4.525	239.292	5	4	10.6	5.3	4
4.619	239.297	4	3	11.3	6.5	3
4.668	239.297	5	5	12.6	5.6	4
4.730	239.300	5	7	34.6	13.1	4
4.776	239.302	6	10	26.3	8.3	6
4.833	239.305	6	19	120.0	27.5	4
4.873	239.306	5	17	70.0	17.0	5
4.927	239.309	5	17	157.5	38.2	4
4.962	239.310	6	28	140.7	26.6	6
5.031	239.313	6	8	69.6	24.6	5
5.079	239.315	4	14	50.8	13.6	4
5.119	239.317	5	13	63.0	17.5	4
5.175	239.319	2	7	62.9	23.8	2
5.229	239.321	2	7	62.9	23.8	2
5.325	239.324	1	3	67.4	38.9	1
5.383	239.328	2	3	25.2	14.5	2
5.421	239.330	2	1	3.9	3.9	2
5.479	239.332	2	2	19.1	13.5	2
5.586	239.336	3	2	4.9	3.5	3
5.642	239.339	1	0	0.0	0.0	1
5.742	239.342	2	0	0.0	0.0	2
5.842	239.347	2	1	2.4	2.4	2

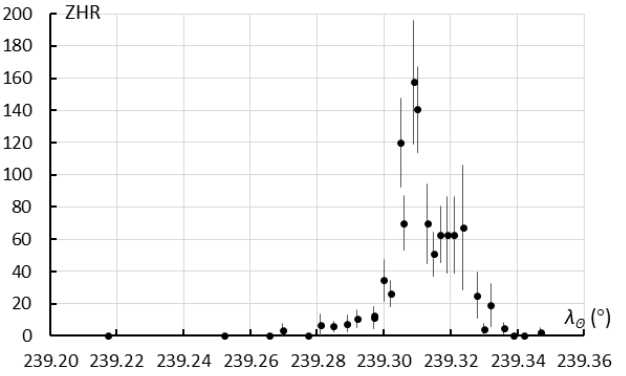

Figure 2 – ZHR profile of the Alpha Monocerotids 21–22 November 2019.

As can be seen in *Figures 2 and 3*, the real activity started around 4^h15^m UT and increased slowly from ZHR 6 to ZHR 12 around 4^h40^m UT, then started a rapid increase with a maximum just before 5^h00^m UT with a ZHR of 160 ± 40. After that the ZHR dropped to 50 around 5^h05^m UT and then remained stable for a few minutes at 60+. Finally, a small peak appeared around 5^h20^m UT with a ZHR of 70 and then rapidly faded to ZHR 10–20 around 5^h30^m UT. At 5^h40^m UT the activity seemed to be over, but the twilight set in.

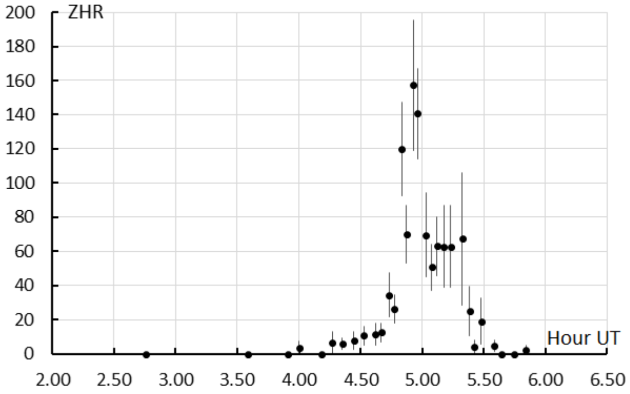

Figure 3 – ZHR profile of the Alpha Monocerotids 21–22 November 2019.

The night before and after the alpha Monocerotid outburst, some visual observers from Israel and Germany also reported activity from the AMOs. This is also confirmed by CAMS observations.

5 Conclusion

Even though not so much data was available for this analysis, this seems to be an acceptable result. Maximum activity just before 5^h00^m UT on November 22, 2019 with a ZHR of 160. A rapid increase followed by a slightly less rapid decrease.

Acknowledgment

A huge thank you to all observers who observed the alpha Monocerotids: *Alexandre Amorim, Orlando Benitez Sanchez, Riziele Correa da Silva, Michel Deconinck, Paul Gray, Ian Grech, Jan Hattenbach, Gabriel Hickel, Kamil Hornog, Javor Kac, Pete Kozich, Anna Levin, Alexandr Maidik, Pierre Martin, Koen Miskotte, Sirko Molau, Pedro Pérez Corujo, Ina Rendtel, Terrence Ross, Kai Schutze, Tamara Tchenak, Daniel Verde Van Ouytsel, Thomas Weiland, Roland Winkler* and *Oliver Wusk*.

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The Quadrantids in 2019: a great show

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The maximum of the Quadrantids meteor shower in 2019 was predicted on January 4 at 02h00m UT. This time is very favorable for Europe because the Quadrantids have only a short period with a lot of activity. Despite the fact that the weather in January is usually bad for meteor observations, an analysis was made based on the visual material available. Maximum activity was reached on January 4, 2020 at 02h20m UT with a ZHR of 120, very close to the predicted maximum.

1 Introduction

The Quadrantids are always the first active meteor shower of the year. The Quadrantids show a sharp maximum around January 4, which unfortunately only lasts a short time. As a result, the numbers of Quadrantids that are visible each year are very variable. If the maximum falls during the day, you will see much less in the nights before and after it than when the maximum falls in the second part of the night. And that can make a big difference in the numbers of observed meteors.

Furthermore, the Quadrantids also show varying maximum activity due to planetary disturbances. The Quadrantids usually peak with a ZHR of 80, but there have also been years when the ZHR was much higher. During the ice-cold and crystal-clear night 3–4 January 1995, the ZHR reached around 140 with the ZHR above 100 until dawn (ter Kuile, 1995; Van Vliet, 1995; Langbroek, 1995). The legendary DMS visual and photographic campaign from 1995 also produced a clue for the parent body of the Quadrantids 2003 EH1 (Jenniskens, 2004).

Also, in 2009, a ZHR of 140 was observed, this time from America (Johannink and Miskotte, 2009) and already the period before as observed from Europe it was obvious that the Quadrantids were more active than what you normally would expect (Vandeputte, 2009).

The astronomical circumstances for the Quadrantids in 2019 were particularly good for Europe with a predicted maximum on January 4 around 02^h00^m UT.

Unfortunately, the weather in January rarely cooperates. So, from the BeNeLux it was only possible to observe for a few hours in the evening when the radiant was still low in the north-west and north. Sky got cloudy after 23^h00^m UT due to an incoming front.

According to the live ZHR graph on the IMO website the Quadrantids in 2019 had a maximum ZHR of 116 on 4 January 2019 at 02^h20^m UT. After that the Quadrantids showed declining activity with a ZHR of 80 at 06^h00^m UT. A total of 35 observers reported 1993 Quadrantids to IMO, enough for a comprehensive analysis!

2 Collecting the visual data

The data was collected via the IMO site and immediately checked for limiting magnitude (at least 5.9) and whether a good C_p determination was available from the relevant observer. After entering all data, 1761 Quadrantids were used for the analysis. Once in the spreadsheet all data with lower radiant positions than rounded off 25 degrees were deleted. Fortunately, just a few meteors fell off. A total of 1749 Quadrantids remained available for the final analysis.

For both the population index *r* and ZHR, the data is checked on different criteria. That is also the reason why fewer meteors were used for the population index *r* than in the final ZHR calculations.

3 Population index *r*

To be able to make a good ZHR determination, the population index *r* must first be calculated. For this, the magnitude distributions of all observers were checked. The rule here is that the difference between the limiting magnitude and the average magnitude of the observed meteors may not be bigger than 4.0 magnitudes. After checking the data, 1283 Quadrantids were used to determine the population index *r*. The results of these calculations are shown in *Table 1*, *Table 2* and *Figure 1*.

Table 1 – Results for the population index r calculations; night 3–4 January 2019.

Time UT:	23^h00^m	01^h30^m	04^h30^m	10^h15^m
$\lambda_\odot$ (°):	283.016	283.122	283.250	283.494
r [–2;+5]	–	2.5	2.99	2.33
r [–1;+5]	2.66	2.55	3.15	2.52
r [–1;+4]	2.61	2.4	3.04	2.24
r [0;+4]	2.4	2.48	2.89	2.16
r [0;+5]	2.53	2.67	3.08	2.55
r [+1;+5]	2.57	2.82	3.4	3.06

The result is what you would expect for the Quadrantids, only the high population index *r* on 4 January 04^h30^m UT does not fit completely in the picture. The population index *r* is the lowest over America, something you would expect with the Quadrantids in 2019. The bright Quadrantids appear mainly after the maximum.

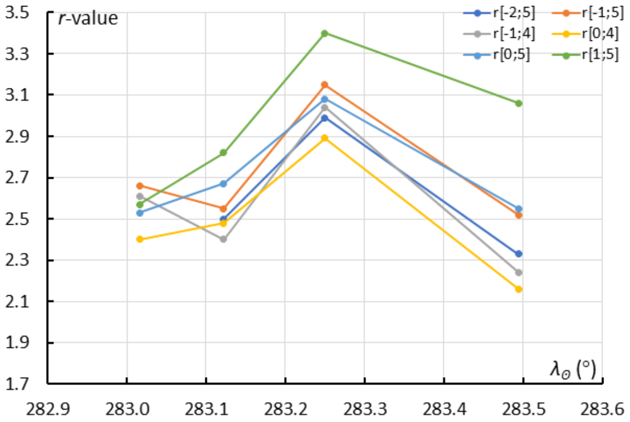

Figure 1 – Population index r gradient over the night 3–4 January 2019.

For the ZHR calculations a fixed *r* value was used for this night, determination based on *r* [–2;+5] and all Quadrantids observed between 3 January 2019 23^h UT and 4 January 2019 12^h UT. In total, a population index *r* = 2.73 ± 0.05 (Steyaert, 1981) was calculated from 1283 Quadrantids. Too few Quadrantids were observed during the night of 2–3 January to calculate a good population index *r*. The average magnitude that night was a bit lower than 3–4 January. For that reason, the population index *r* for that night was kept at *r* = 3.00.

Table 2 – Population index r for the period between January 3, 2019 23^h00^m UT and January 4, 2019 12^h00^m UT.

	r
r [–2;+5]	2.73 ± 0.05
r [–1;+5]	2.78 ± 0.05
r [–1;+4]	2.54 ± 0.06
r [0;+4]	2.52 ± 0.06
r [0;+5]	2.85 ± 0.05
r [+1;+5]	3.11 ± 0.05

4 Zenithal hourly Rate

The final ZHR calculation were made with population index *r* = 2.73 for the night 3–4 January and for the night 2–3 January an assumed population index *r* = 3.00 was used. A total of 1530 Quadrantids were used to calculate the ZHR. For the calculations 15 – 20-minute counts were used. Some observers sent in shorter counting periods; these were merged. The results of the calculations can be seen in *Table 3* and *Figure 2*.

Clearly a peak of the ZHR is visible at solar longitude 283.15°, which is on 4 January 2019 at 02^h05^m UT. This time is very close to the time of the on-the-fly curve on the IMO site. With a ZHR of 120 this is a good return of the Quadrantids and comparable to the returns from 1995 and 2009.

Table 3 – ZHR Quadrantids 2019.

$\lambda_{\odot}$ (°)	Bins	N	ZHR	r[–2;5]	Obs
282.173	2	8	5.0 ± 1.8	3.00	2
282.220	3	20	7.2 ± 1.6	3.00	2
283.088	7	78	94.9 ± 10.7	2.73	5
283.106	14	164	97.8 ± 7.6	2.73	6
283.125	16	281	109.5 ± 6.5	2.73	6
283.146	20	417	119.0 ± 5.8	2.73	6
283.167	24	504	110.2 ± 4.9	2.73	6
283.183	21	471	100.8 ± 4.6	2.73	6
283.208	18	448	92.3 ± 4.4	2.73	5
283.227	17	353	83.8 ± 4.5	2.73	5
283.250	18	369	86.8 ± 4.5	2.73	6
283.263	12	214	86.7 ± 5.9	2.73	4
283.337	3	30	70.6 ± 12.9	2.73	1
283.496	1	28	37.9 ± 7.2	2.73	1
283.537	1	13	17.3 ± 4.8	2.73	1

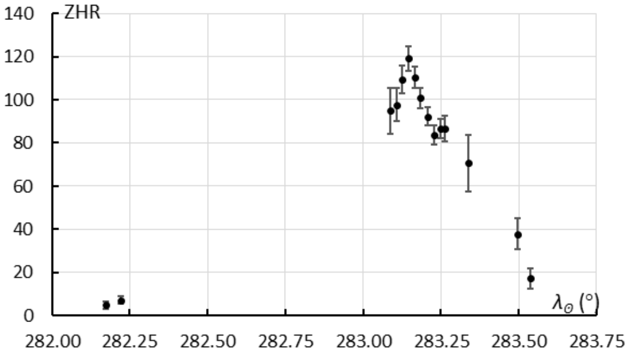

Figure 2 – ZHR Quadrantids on 3 and 4 January 2019.

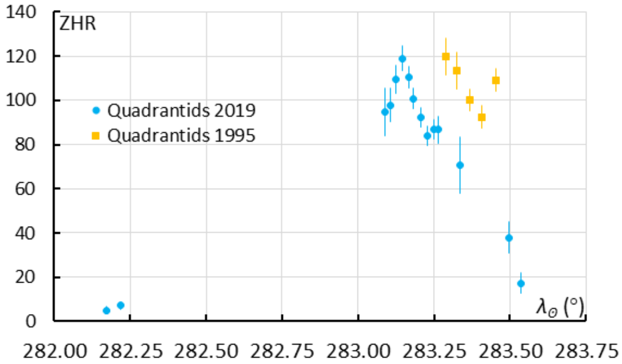

Figure 3 – Quadrantids ZHR profiles from 1995 and 2019.

In *Figure 3* the curve from 1995 has been added (own analysis 2009). Even though the 1995 Quadrantid curve was determined on the basis of 1 hour counts and that of 2019 on the basis of 20 minutes there is some agreement. The peak in 1995 was a bit later in solar longitude.

5 Conclusion

2019 was a good Quadrantid year, with a maximum ZHR of around 120. The time of the maximum was almost at the predicted time of January 4, 2019 around 02^h00^m UT. It is recommended for the Quadrantids during their maximum to observe in counting periods of 5 minutes.

Acknowledgment

A big thank you to all observers who observed the 2019 Quadrantids. These observers are: *Orlando Benitez Sanchez, Larry Black, Martin Davies, Michel Deconinck, Sietse Dijkstra, Kai Gaarder, Gerardo Jiménez López, Károly Jónás, Javor Kac,Omri Katz, André Knöfel, Selma Koelers, Anna Levin, Ole Lit, Pierre Martin, Fabrizio Melandri, Shai Mizrachi, Arash Nabizadeh Haghighi, Francisco Ocaña González, Jonas Plum, Pedro Pérez Corujo, Ella Ratz, Jurgen Rendtel, Branislav Savic, Kai Schultze, Costantino Sigismondi, Ulrich Sperberg, Hanjie Tan, István Tepliczky, Shigeo Uchiyama, Peter van Leuteren, Hendrik Vandenbruaene, Michel Vandeputte, Valentin Velkov , Thomas Weiland, Ariel Westfried, Patrick Wullaert* and *Sabine Wächter*.

Also, a word of thanks to *Carl Johannink*, *Paul Roggemans* and *Michel Vandeputte* for the useful comments on this article.

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Results of spectral observations of the Geminids meteor shower in December 2019

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In December 2019, 208 Geminids spectra were obtained. The absolute magnitude ranged from -5 to +1 magnitude. The analyses of the spectra of the Geminids in 2019 showed that the Geminid activity was roughly divided into three types. This was also seen in 2018. For 2019, we can say that the normal type meteoroids were the most frequent among the three types. There were also many normal types near the local maximum. This is probably because the observations were done after the maximum in Japan. The occurrence of each type in the order of appearance time and solar longitude was clearly understood. According to the triangular diagram showing the absolute line intensities of Na, Mg, and Fe, with the absolute magnitude distribution, the depletion of Na in the Geminids tends to be higher for fainter meteors. In the fireball class, the proportion of iron tends to be high. By plotting the relationship between Na / Mg and some orbital elements, and between orbital elements, you can get a glimpse of the dust trail.

1 Observing equipment

The equipment to register spectra consists of a single-color SONY alpha 7s camera with a 50 mm f 1.4 lens with a transmission diffraction grating film of 500 lines per mm as spectrometer and seven black and white cameras; four Watec Neptune 100+ with CBC 6 mm lenses, one with a 12 mm f 0.8 lens, and two Watec 902H2U with CBC lenses of 6 mm and 8 mm with f 0.8. Some cameras with spectrometer are shown in *Figure 1*. The coverage of all eight cameras is displayed in *Figure 2*.

Figure 1 – Transmission type diffraction grating film with 500 lines per mm, 5 units (Top), transmission blazed diffraction grating with 600 lines per mm, 2 units (Bottom).

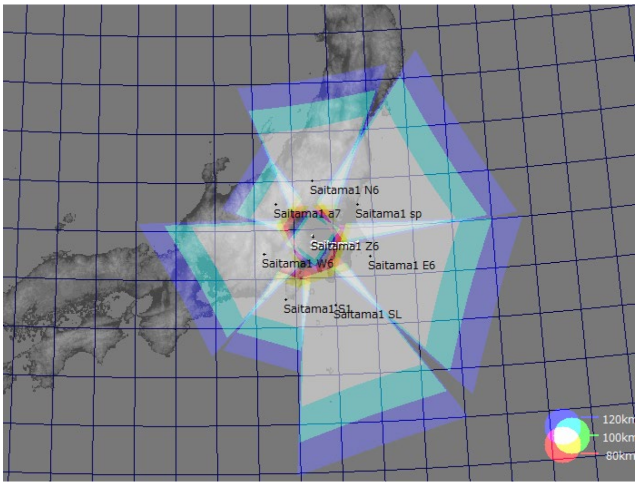

Figure 2 – The field of view coverage of the cameras for intersection layers at 80, 100 and 120 km elevation.

2 Observing and orbital calculation software

The author uses the software UFOCaptureV2 – UFOAnalyzer V2 and UFOOrbitV2[12]. These programs identify identical events and performs the triangulation calculations on SonotaCo net's meteor data.

3 Spectral analysis software

The Japanese version of the spectral analysis software Rspec[13] has been used.

In each spectrum analysis, a triangular diagram is created with the peak ratios including rotation, tilt correction, background correction and sensitivity correction.

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[12] http://sonotaco.com/

[13] https://www.rspec-astro.com/

4 Triangular diagrams

The software CKTriangle[14] is used to create the triangular or ternary diagrams. The spectral observations of the Geminid meteor shower in December, 2019 resulted in 208 spectra captured by eight cameras. The distribution of Na (5892 Å), Mg (5182 Å) and Fe (5269–5441 Å) is displayed by a triangle diagram.

We refer for the classification to the article by J. Borovička (2005):

- *Na-free* meteoroids are defined as those without the Na line but not classified as Irons. They fall into the region close to the left edge of the ternary diagram (e.g. *Figure 3*).
- *Normal* meteoroids are mainstream meteoroids lying near the expected position for chondritic bodies in the Mg–Na–Fe diagram or with somewhat lower Fe intensity.
- *Na-poor* meteoroids are mainstream meteoroids with the Na line significantly weaker than expected for the given speed but still reliably visible.
- *Fe poor* meteoroids are mainstream meteoroids having the expected Na/Mg ratio but with Fe lines too faint to be classified as normal meteoroids.

However, Fe poor were not classified in this study. The normal type represents about half and the Na free and Na poor make up the other half (see *Figure 3*).

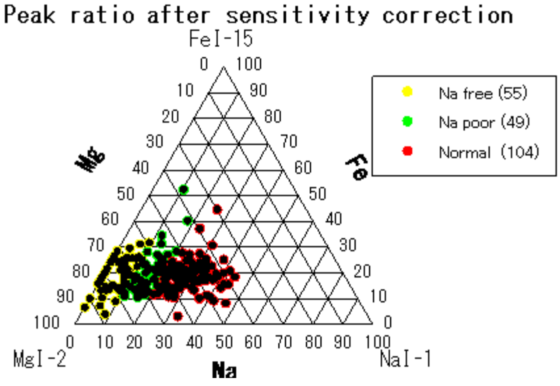

Figure 3 – The triangle diagram displaying the relative line intensities of Na, Mg and Fe for the 208 Geminid spectra of 2019.

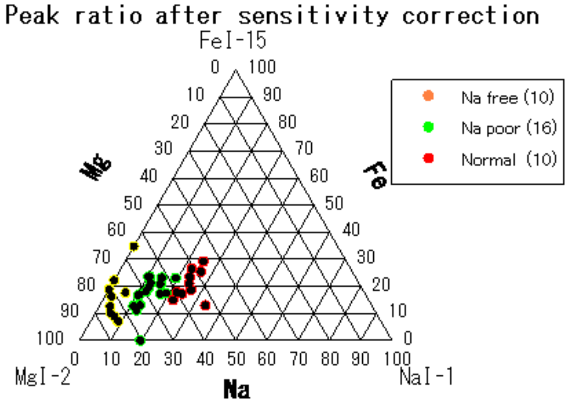

Figure 4 – The triangle diagram displaying the relative line intensities of Na, Mg and Fe for the 36 Geminid spectra of 2018.

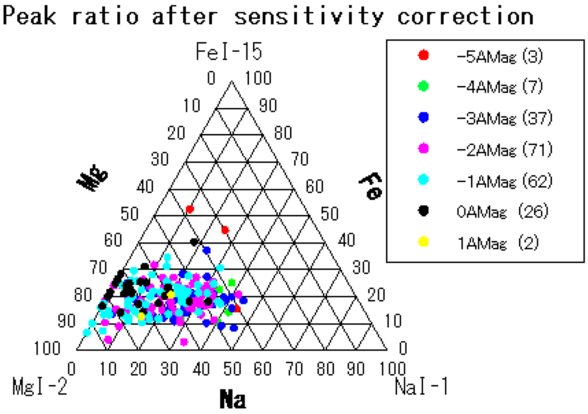

Figure 5 – The triangle diagram indicating the absolute line intensities for Na, Mg and Fe based on the 208 Geminid spectra of 2019, and the absolute magnitude distribution.

5 Occurrences per type near maximum

Table 1 – Number of appearance times of all Geminids in 2019 by spectrum type.

Time U.T.	Na free	Na poor	Normal	Total
Dec. 13–14, 15h	2	1	0	3
Dec. 13–14, 16h	0	0	0	0
Dec. 13–14, 17h	1	1	0	2
Dec. 13–14, 18h	0	0	0	0
Dec. 13–14, 19h	2	1	0	3
Dec. 13–14, Total	5	3	0	8
Dec. 14-15, 10h	1	1	0	2
Dec. 14-15, 11h	0	2	3	4
Dec. 14-15, 12h	2	3	2	7
Dec. 14-15, 13h	3	5	3	11
Dec. 14-15, 14h	3	6	10	19
Dec. 14-15, 15h	6	6	17	29
Dec. 14-15, 16h	8	4	9	21
Dec. 14-15, 17h	9	2	14	25
Dec. 14-15, 18h	5	6	11	22
Dec. 14-15, 19h	2	3	10	15
Dec. 14-15, 20h	1	2	5	8
Dec. 14-15, Total	40	39	84	163
Dec. 15–16, 11h	0	0	1	1
Dec. 15–16, 12h	2	0	3	5
Dec. 15–16, 13h	0	0	0	0
Dec. 15–16, 14h	0	0	3	3
Dec. 15–16, 15h	1	0	1	2
Dec. 15–16, 16h	1	0	1	2
Dec. 15–16, 17h	0	1	1	2
Dec. 15–16, 18h	0	1	0	1
Dec. 15–16, 19h	2	0	3	5
Dec. 15–16, Total	6	2	13	21

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[14] https://clikington-saito.com/CKTriangle/CKTriangle.html

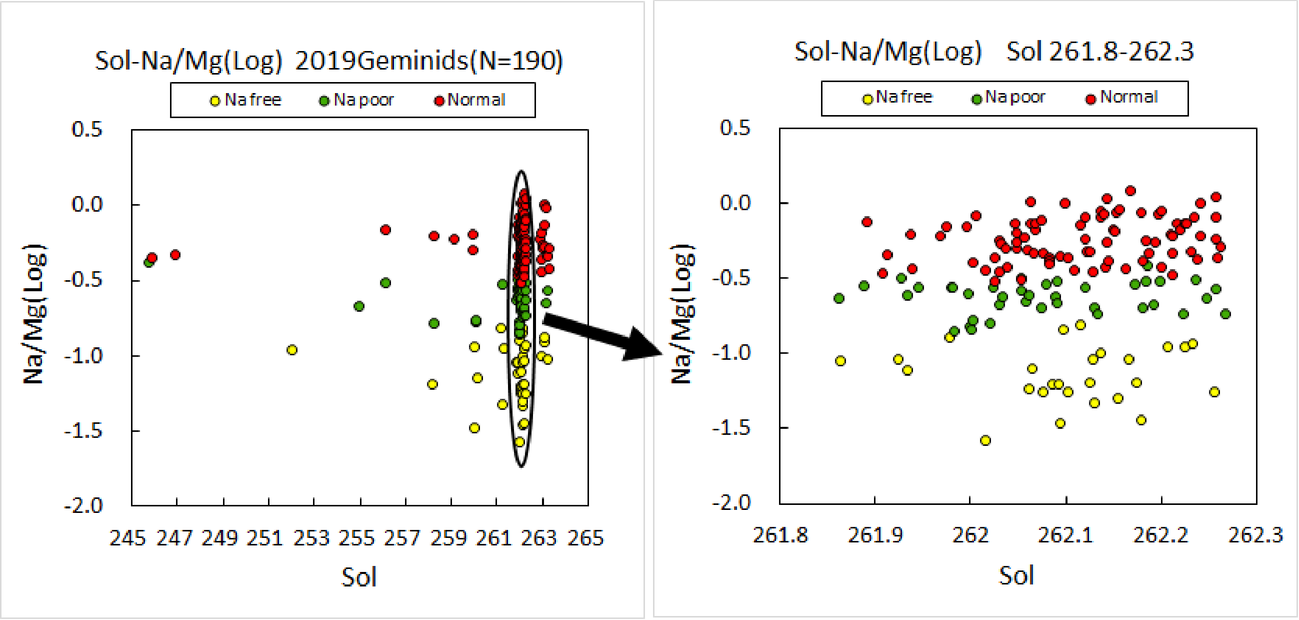

Figure 6 – The Na / Mg ratio (Log) plotted in function of solar longitude for the 190 Geminids 2019.

Many normal types appear concentrated near the time of maximum activity. Similarly, the Na free and Na poor also increased from 13^h00^m to 20^h00^m on December 14 (Universal Time), marked with yellow background in *Table 1*.

The change in appearance for each type has been plotted for the Na / Mg ratio (Log) plotted in function of solar longitude. There are rather few data points before and after the maximum. The time bin with the maximum is enlarged and displayed at right. At the center of the maximum, it seems that Na free and the normal type appear more abundant at the middle of the maximum activity (*Figure 6*).

6 Measured Na/Mg line intensity ratio

The Na/Mg line intensity ratio in function of the geocentric velocity v_g has been plotted in *Figure 7*. The data points are concentrated at $v_g = 33.5$ km/s. The normal type is the most abundant. In 2018 the Na poor type were slightly more numerous, although that year only a single camera was used (*Figure 8*).

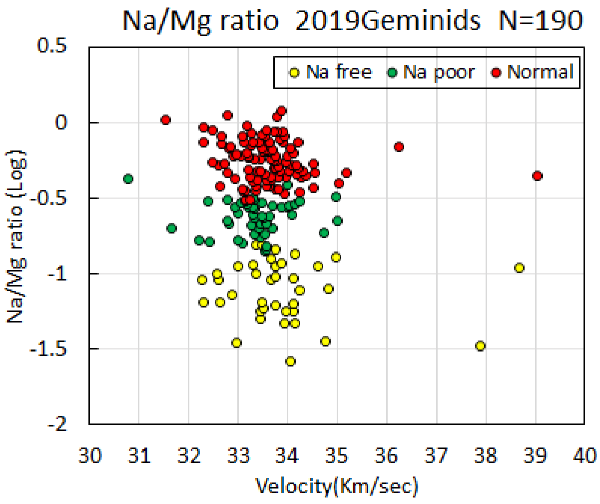

Figure 7 – The Na / Mg ratio (Log) plotted in function of the geocentric velocity for the 2019 Geminids.

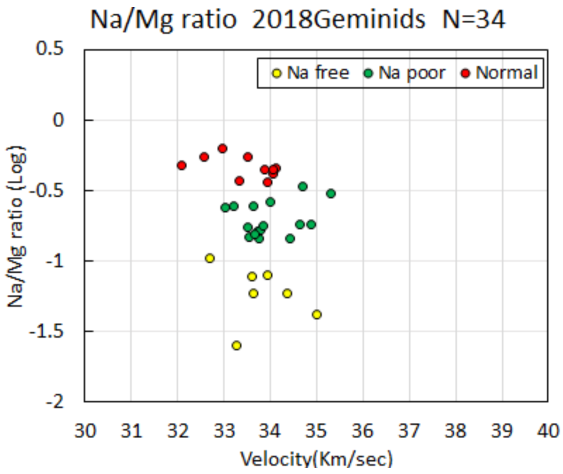

Figure 8 – The Na / Mg ratio (Log) plotted in function of the geocentric velocity for the 2018 Geminids.

7 Measured O/Mg line intensity ratio

The O / Mg line intensity ratio in function of the geocentric velocity v_g (Vojáček et al., 2015) has been plotted in *Figure 9*, obtained with a black and white camera. In particular, no tendency was observed depending on the type.

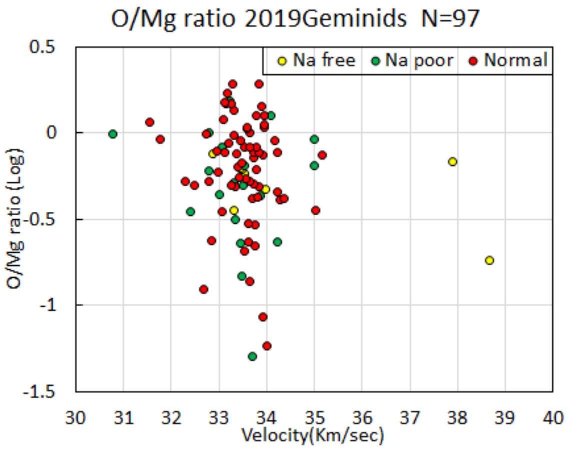

Figure 9 – O / Mg ratio (Log) in function of the geocentric velocity for the 2019 Geminids.

8 Relationship with orbital elements

Finally, we consider the relationship with the orbital elements. The Tisserand parameter relative to Jupiter,

$$T_J = \frac{a_J}{a} + 2\cos i \sqrt{\frac{a(1-e^2)}{a_J}}$$

where $a_J = 5.2\,AU$ is the semimajor axis of Jupiter, a is the semimajor axis of the meteoroid, and e is the eccentricity of the meteoroid. *Figure 10* shows the Na distribution against the inclination i and the Tisserand parameter relative to Jupiter, T_J. There is a clear concentration of mainly normal type meteoroids around inclination $i = 23°$ and $T_J = 4.5$.

Figure 11 shows the relative line intensity distribution of Na / Mg (Log) in function of the inclination *i*. The concentration of each type seems to be different for the same inclination. *Figure 12* shows the Aphelion Q (A.U.) against perihelion q (A.U.). *Figure 13* shows the relative line intensity distribution of Na / Mg (Log) in function of the perihelion q. The distribution of Q against q shows a similar spread as the distribution of T_J against i.

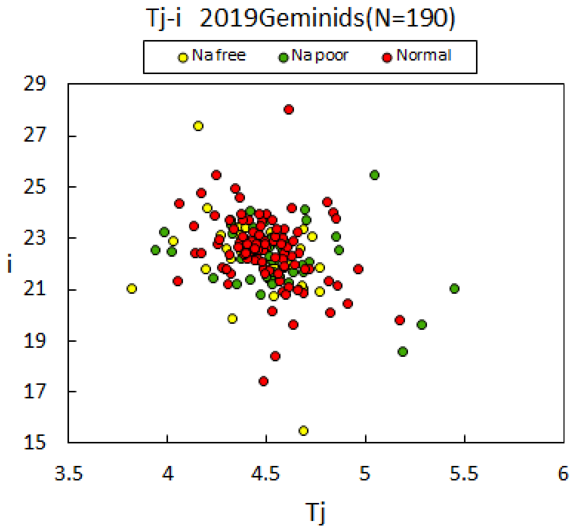

Figure 10 – Na distribution against i and Tj.

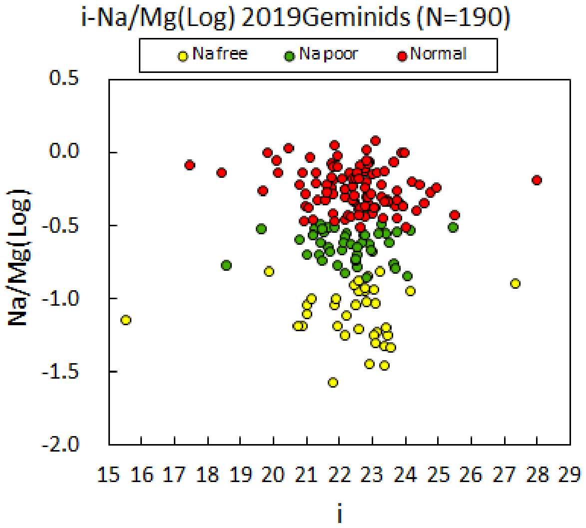

Figure 11 – Na / Mg ratio (Log) plotted in function of the inclination i.

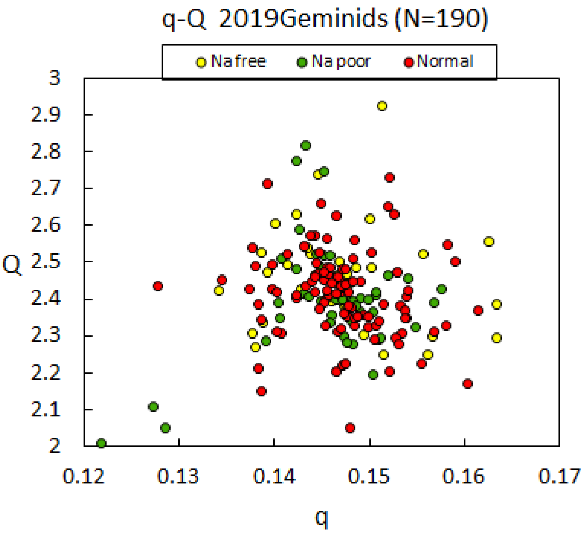

Figure 12 – Na distribution against q and Q.

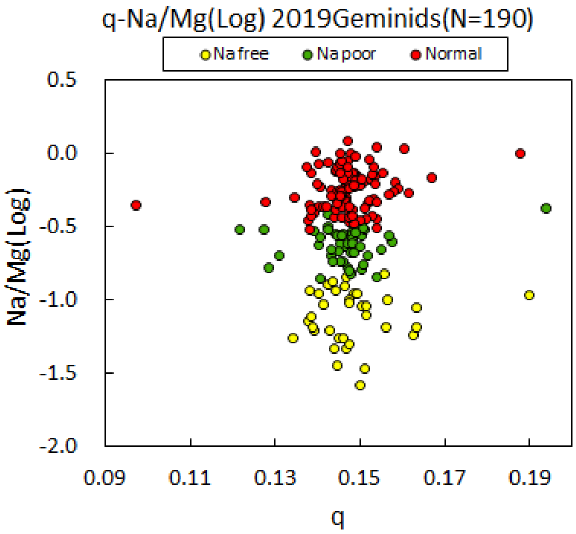

Figure 13 – Na / Mg ratio (Log) plotted in function of the perihelion q.

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February 2020 report CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month February 2020 is presented. This month was severely hampered by bad weather and remained without any single complete clear night. In total 7665 meteors were recorded, 3141 of which proved multiple station, or 41%. In total 1215 orbits were collected during this month. The number of operational cameras in February increased from 74 in 2019 to 84 in 2020.

1 Introduction

Winter months, in general, are very unfavorable for astronomy in the BeNeLux and so is February. However, both February in 2018 and in 2019 were exceptional favorable months for CAMS. As January 2020 ended as a really disappointing month for the network, the question was if we would be lucky again with February 2020?

2 February 2020 statistics

Unfortunately, weather got worse instead of better compared to January. Storms dominated the weather week after week with mainly overcast sky with some clear spells at best. Most CAMS stations did not have any single complete clear night. Only three nights had over 100 orbits, while February 2019 had eight nights with more than 200 orbits, 2018 even had eleven nights with over 200 orbits. February 2020 became one of the worst months for CAMS BeNeLux.

CAMS BeNeLux managed to collect 7665 meteors (against 17784 in 2019 and 23439 in 2018) with a maximum of 84 cameras capturing at 22 participating stations. 3141 or 41% of these meteors were multi-station meteors, good for 1215 orbits (against 3485 in 2019 and 4147 in 2018). With the 2020 results the total number of orbits for February obtained by CAMS BeNeLux is 12055 orbits collected in 164 successful nights. The statistics for February 2020 are compared in *Table 1* with all previous February months since the start of the CAMS BeNeLux network. Although more cameras were available than in 2019, the harvest in orbits remained far less due to the hopeless poor weather.

On average 72.6 of the available 84 cameras were capturing per night (68.8 of 74 in 2019). Especially in the first years, before AutoCams was available in the BeNeLux, many cameras remained switched off when the weather did not look good in the evening. This way the chances to obtain double station meteors for those cameras that remained active were rather small. Luckily, almost all camera stations function 7 on 7 now. This way only five nights remained without any orbit registered and not a single night remained without any meteor recording. AutoCAMS kept a minimum of 62 cameras active on all nights, even on completely overcast nights. On as many as 24 nights orbits have been collected. *Figure 1* shows that the camera capacity got restored compared to 2019, but the network did not yet get back at its strength of February 2018.

A new camera started to contribute, the Global Meteor Network RMS DE0001, alias CAMS 3800, installed at Langenfeld, Germany, owned by *Uwe Glässner*.

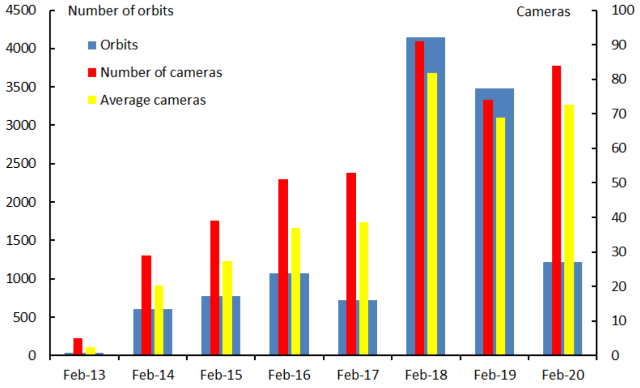

Figure 1 – Comparing February 2020 to previous months of February in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the yellow bars the average number of cameras running per night.

Table 1 – February 2020 compared to previous months of February.

Year	Nights	Orbits	Stations	Max. Cams	Min. Cams	Mean Cams
2013	9	38	6	5	–	2.3
2014	21	601	12	29	–	20.3
2015	21	777	14	39	–	27.4
2016	24	1075	17	51	13	36.9
2017	16	717	18	53	20	38.6
2018	26	4147	22	91	48	81.7
2019	24	3485	18	74	50	68.8
2020	23	1215	22	84	62	72.6
Totals	164	12055				

3 Conclusion

February 2020 was a month without any single complete clear night. It is a huge achievement that still 1215 orbits were collected under such poor weather conditions.

Acknowledgment

Many thanks to all participants in the CAMS BeNeLux network for their dedicated efforts. The data on which this report is based has been taken from the CAMS website[15]. The CAMS BeNeLux team is operated by the following volunteers:

Hans Betlem (Leiden, Netherlands, CAMS 371, 372 and 373), *Jean-Marie Biets* (Wilderen, Belgium, CAMS 379, 380, 381 and 382), *Martin Breukers* (Hengelo, Netherlands, CAMS 320, 321, 322, 323, 324, 325, 326 and 327, RMS 328 and 329), *Guiseppe Canonaco* (Genk, RMS 3815), *Bart Dessoy* (Zoersel, Belgium, CAMS 397, 398, 804, 805, 806 and 888), *Jean-Paul Dumoulin and Christian Walin* (Grapfontaine, Belgium, CAMS 814 and 815, RMS 003814), *Uwe Glässner* (Langenfeld, Germany, RMS 3800), *Luc Gobin* (Mechelen, Belgium, CAMS 390, 391, 807 and 808), *Tioga Gulon* (Nancy, France, CAMS 3900 and 3901), *Robert Haas* (Alphen aan de Rijn, Netherlands, CAMS 3160, 3161, 3162, 3163, 3164, 3165, 3166 and 3167), *Robert Haas* (Texel, Netherlands, CAMS 810, 811, 812 and 813), *Robert Haas / Edwin van Dijk* (Burlage, Germany, CAMS 801, 802, 821 and 822), *Klaas Jobse* (Oostkapelle, Netherlands, CAMS 3030, 3031, 3032, 3033, 3034, 3035, 3036 and 3037), *Carl Johannink* (Gronau, Germany, CAMS 311, 313, 314, 315 and 316), *Hervé Lamy* (Dourbes, Belgium, CAMS 394 and 395), *Hervé Lamy* (Humain Belgium, CAMS 816), *Hervé Lamy* (Ukkel, Belgium, CAMS 393), *Koen Miskotte* (Ermelo, Netherlands, CAMS 351, 352, 353 and 354), *Tim Polfliet* (Gent, Belgium, CAMS 396), *Steve Rau* (Zillebeke, Belgium, CAMS 3850 and 3852), *Paul and Adriana Roggemans* (Mechelen, Belgium, CAMS 383, 384, 388, 389, 399 and 809, RMS 003830 and 003831), *Hans Schremmer* (Niederkruechten, Germany, CAMS 803) and *Erwin van Ballegoij* (Heesch, Netherlands,CAMS 347 and 348).

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[15] http://cams.seti.org/FDL/index-BeNeLux.html

March 2020 report CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month of March 2020 is presented. 17983 meteors were reported of which 10301 were multiple station events, good for 3026 orbits, collected with a maximum of 93 operational cameras at 25 different CAMS stations. March 2020 was a record month for the number orbits, maximum number of operational cameras and number of participating camera stations.

1 Introduction

March used to be a rather unfavorable month for astronomy in the BeNeLux area. It is no surprise that March remains about the poorest month of the year for the network. Without any significant activity from any of the minor meteor showers, hourly rates remain low. March 2020 marked the 8th anniversary of the CAMS BeNeLux network as the first stations of the network collected the first orbits in the night of 14–15 March 2012. Would March 2020 finally bring a favorable month of March for the network?

2 March 2020 statistics

The weather continued the very unfavorable pattern we got since autumn 2019 with mainly overcast sky and some clear gaps at best. February 2020 passed without any single complete clear night and the first two weeks of March did no better. Such a long time without some clear nights did not occur since the early years of the network. Four nights remained without any single orbit, all during the first two weeks. A major weather improvement occurred from 15–16 March onwards with a series of excellent clear nights from 21–22 till the end of the month. The night of 22–23 March with 283 orbits in a single night marks a new record for this month, previous record for March was 165 orbits registered in a single night on 29–30 March 2019.

In total 17983 meteors were reported by all stations, 10301 of these meteors proved multi-station good for 3026 orbits, a new record number for the month of March. In March 2019, 3540 multi-station detections resulted in 1217 orbits, which was comparable to the numbers of 2018. At best 93 cameras were active in March 2020 (78 in March 2019), which is also a new record as never before CAMS BeNeLux had so many of its cameras operational in a same night. Previous record was in February and March 2018 when 91 cameras were active. The minimum of 66 cameras capturing each night is also a new record. The average of 81.7 operational cameras per night equals the record of February 2018. The network had reached its highest capacity in operational cameras in February–March 2018, but bad luck at some stations reduced this capacity for most of 2018 and entire 2019.

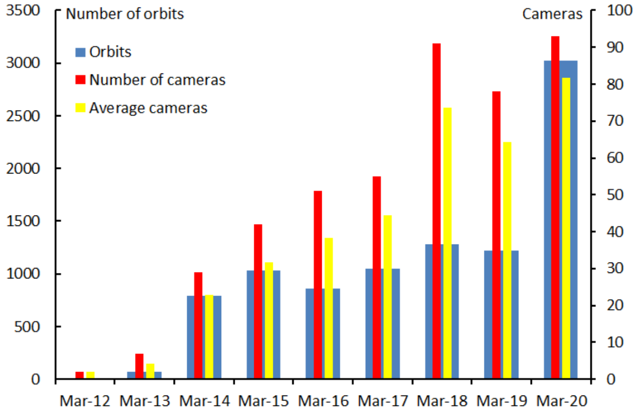

Figure 1 – Comparing March 2020 to previous months of March in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the yellow bars the average number of cameras running per night.

Figure 1 shows that the decline in camera capacity since 2018 has been undone. More cameras, more stations and better weather resulted in the best month of March ever.

Table 1 – March 2020 compared to previous months of March.

Year	Nights	Orbits	Stations	Max. Cams	Min. Cams	Mean Cams
2012	2	12	2	2	–	2.0
2013	10	69	6	7	–	4.2
2014	24	793	12	29	–	22.8
2015	23	1033	14	42	–	31.7
2016	23	856	16	51	12	38.2
2017	26	1048	19	55	20	44.4
2018	25	1280	22	91	53	73.5
2019	29	1217	20	78	54	64.4
2020	27	3026	25	93	66	81.7
Totals	189	9334				

As many as 25 different camera stations contributed to the network, also a record number. The network could welcome *Kees Habraken* as new participant with his RMS NL0009, alias CAMS 000378 at Kattendijke, Netherlands. Contributing CAMS data since 21-22 March, this new camera helped to determine as many as 271 orbits in its first 10 successful nights. *Jos Nijland* managed to restart CAMS station Terschelling with two cameras.

In total CAMS BeNeLux collected 9334 orbits during 189 March nights accumulated during 9 years. The statistics for March 2020 are compared in *Table 1* and *Figure 1* with all previous months of March since the start of the CAMS BeNeLux network.

3 Conclusion

March 2020 became a record month of March for the network with a new record for the number of orbits for this month, maximum number of operational cameras and number of participating stations.

Acknowledgment

Many thanks to all participants in the CAMS BeNeLux network for their dedicated efforts. The data on which this report is based has been taken from the CAMS website[16]. The data reduction and orbit calculation for all stations is coordinated by *Carl Johannink*. The CAMS BeNeLux team is operated by the following volunteers:

Hans Betlem (Leiden, Netherlands, CAMS 371, 372 and 373), *Felix Bettonvil* (Utrecht, Netherlands, CAMS 376 and 377), *Jean-Marie Biets* (Wilderen, Belgium, CAMS 379, 380, 381 and 382), *Martin Breukers* (Hengelo, Netherlands, CAMS 320, 321, 322, 323, 324, 325, 326 and 327, RMS 328 and 329), *Guiseppe Canonaco* (Genk, RMS 3815), *Bart Dessoy* (Zoersel, Belgium, CAMS 397, 398, 804, 805, 806 and 888), *Jean-Paul Dumoulin, Dominique Guiot and Christian Walin* (Grapfontaine, Belgium, CAMS 814 and 815, RMS 003814), *Uwe Glässner* (Langenfeld, Germany, RMS 3800), *Luc Gobin* (Mechelen, Belgium, CAMS 390, 391, 807 and 808), *Tioga Gulon* (Nancy, France, CAMS 3900 and 3901), *Robert Haas* (Alphen aan de Rijn, Netherlands, CAMS 3160, 3161, 3162, 3163, 3164, 3165, 3166 and 3167), *Robert Haas* (Texel, Netherlands, CAMS 810, 811, 812 and 813), *Robert Haas / Edwin van Dijk* (Burlage, Germany, CAMS 801, 802, 821 and 822), *Kees Habraken* (Kattendijke, Netherlands, RMS 000378), *Klaas Jobse* (Oostkapelle, Netherlands, CAMS 3030, 3031, 3032, 3033, 3034, 3035, 3036 and 3037), *Carl Johannink* (Gronau, Germany, CAMS 311, 313, 314, 315, 316, 317, 318, 3000, 3001 and 3002), *Hervé Lamy* (Dourbes, Belgium, CAMS 394 and 395), *Hervé Lamy* (Humain Belgium, CAMS 816), *Hervé Lamy* (Ukkel, Belgium, CAMS 393), *Koen Miskotte* (Ermelo, Netherlands, CAMS 351, 352, 353 and 354), *Jos Nijland* (Terschelling, Netherlands, CAMS 841 and 842), *Tim Polfliet* (Gent, Belgium, CAMS 396), *Steve Rau* (Zillebeke, Belgium, CAMS 3850 and 3852), *Paul and Adriana Roggemans* (Mechelen, Belgium, CAMS 383, 384, 388, 389, 399 and 809, RMS 003830 and 003831), *Hans Schremmer* (Niederkruechten, Germany, CAMS 803) and *Erwin van Ballegoij* (Heesch, Netherlands, CAMS 347 and 348).

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[16] http://cams.seti.org/FDL/index-BeNeLux.html

2020 1st quarter report, CAMS Florida, USA

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A summary report is presented with the statistics for the CAMS Florida Network during the months of January, February and March 2020.

1 Introduction

CAMS Florida began operation with two cameras in 2014. It has grown to twenty-nine cameras at five sites in 2020. The cameras provide excellent coverage of northern Florida. Areas that are currently outside coverage are the panhandle (western Florida) and south Florida.

This report summarizes CAMS Florida activity during January 1 – March 31, 2020. UFOOrbit was used to generate summary data from the detection files produced each night using CAMS 2.0 software. NASA reported orbits are 5–10% higher, probably because it uses a more refined algorithm for coincidence detection.

2 Statistical Report

During the first three months (91 nights) of 2020, CAMS Florida made 13424 observations of multi-station meteors. These observations contributed to a total of 5226 orbits. On average, 2.6 sites contributed to each orbital determination. Following are the specific contributions by each of the five CAMS Florida sites:

- **Gainesville** (CAMS Florida HQ)
    - cameras =10
    - orbits = 4697
    - orbits/camera = 470
    - orbits/camera/night = 5.2
- **New Smyrna Beach** (BarJ Observatory)
    - cameras = 2
    - orbits = 918
    - orbits/camera = 459
    - orbits/camera/night = 5.0
- **Melbourne** (Florida Institute of Technology)
    - cameras = 1
    - orbits = 268
    - orbits/camera = 268
    - orbits/camera/night = 2.9
- **Ocala** (College of Central Florida)
    - cameras = 8
    - orbits = 3716
    - orbits/camera = 465
    - orbits/camera/night = 5.1
- **Ocklawaha**
    - cameras = 8
    - orbits = 3825
    - orbits/camera = 478
    - orbits/camera/night = 5.3
- **Totals**
    - cameras = 29
    - orbits determined = 13424
    - orbits/camera = 463
    - orbits/camera/night = 5.1

3 CAMS Florida Site Notes

Barbara Harris operates two cameras at her rooftop observatory near New Smyrna Beach. This system began operation in 2014, when CAMS Florida was established. At Florida Institute of Technology (Florida Tech) in Melbourne, *Csaba Palotai* and *Ashley Hughes* manage the camera that is on the roof of the Physical Sciences Building. Because Florida Tech is close to Kennedy Space Center, CAMS has an excellent view of space launches! At College of Central Florida in Ocala, physics professor *Erika Kisvarsanyi* oversees operation of eight cameras on the rooftop of the science building. These cameras have worked flawlessly for over one year with 100% uptime! The newest addition to CAMS Florida is operated by *Jerry Cheney* from the back yard of his home in Ocklawaha. The only thing that worries him are the wild hogs that get curious about CAMS equipment during mating season.

4 Radiant Plot of Meteors

The plot in *Figure 1* shows the radiants of all 5226 meteoroids for which orbits were determined during the first three months of 2020. About 95% of the radiants are from sporadic meteors, while the other 5% coming from known showers. The concentration of radiants (colored green) in the upper left portion is from the Quadrantids (#10, QUA). The Coma Berenicids (#20, COM) comprise a more diffuse radiant above the image’s center.

95% sporadic meteors is too high! Let’s continue our work to discern more meteor showers in the flux of interplanetary meteoroids.

Acknowledgments

CAMS Florida would not be possible without the following volunteers:

- *Jerry Cheney* (Ocklawaha, CAMS 5040-5047)
- *Barbara Harris* (BarJ Observatory, CAMS 231, 232)
- *J. Andreas (Andy) Howell* (Gainesville, CAMS 230, 234, 5000-5007)
- *Ashley Hughes* and *Csaba Palotai* (Florida Institute of Technology, CAMS 233)
- *Erika Kisvarsanyi* (College of Central Florida, CAMS 5020-5027)
- *Dave Samuels*, CAMS Operations Coordinator

Many thanks are due them for their efforts in support of the Cameras for All-Sky Meteor Surveillance (CAMS). We also thank *Dr. Peter Jenniskens*, principal investigator of the CAMS project.

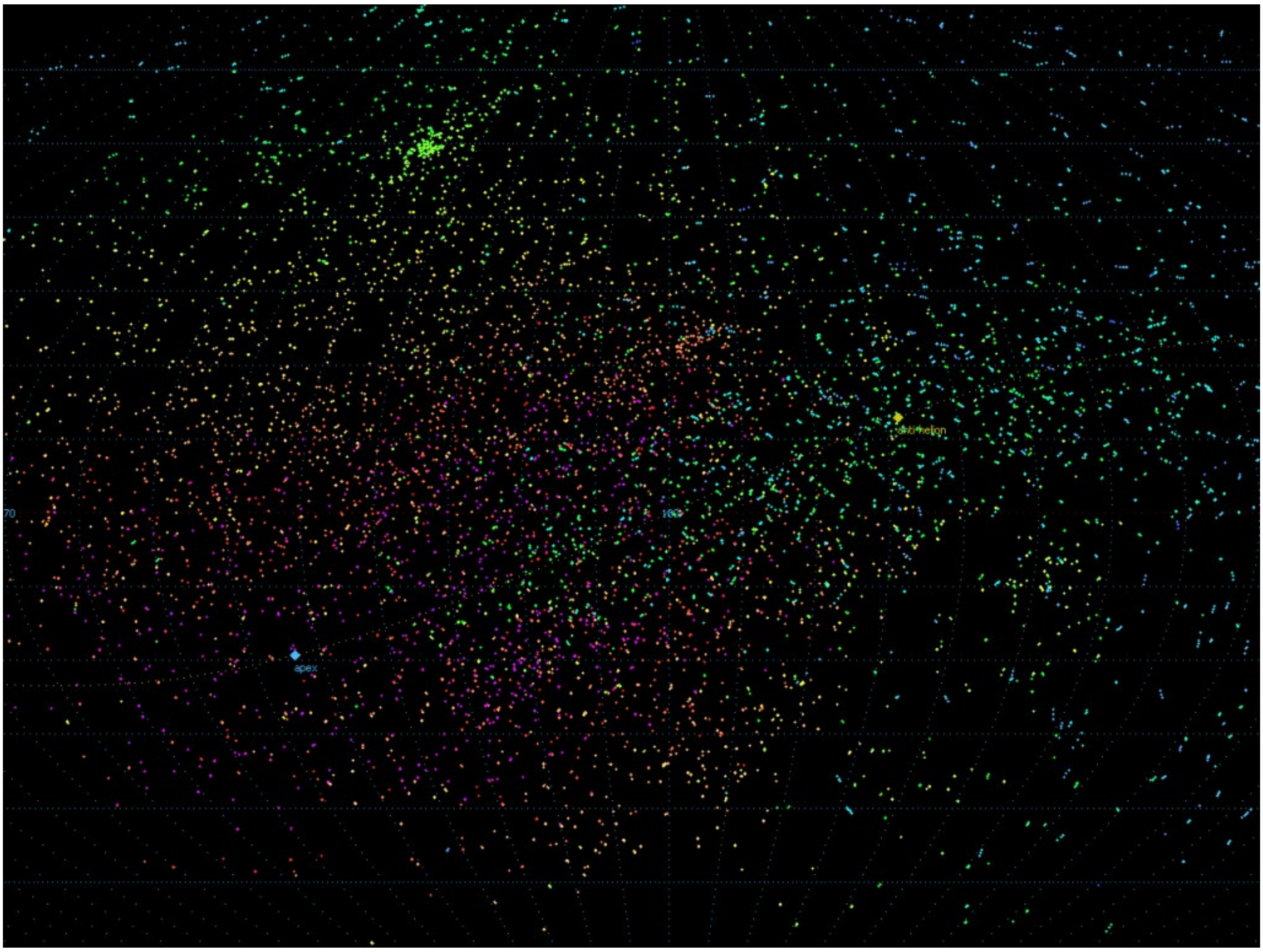

Figure 1 – Radiant distribution color coded for the velocity. The concentration of radiants (colored green) in the upper left portion is from the Quadrantids (#10, QUA). The Coma Berenicids (#20, COM) comprise a more diffuse radiant above the image's center.

Lyrids 2020 – Visual observation report from Norway

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Exceptional favorable observing circumstances in Norway allowed visual observations of the ascending phase of Lyrid activity during seven perfect clear nights on a row. The Lyrid activity proved normal with rather low hourly rates.

1 Introduction

A New Moon on April 23, and a stable high-pressure system over the north Atlantic, gave a rare opportunity for a close study of the Lyrids this year. In the period from April 15 to April 21, the author was able to observe the Lyrids under almost perfect clear skies for 7 nights in a row. This gave a unique opportunity to observe the ascending phase of Lyrid activity this year. A total of 186 meteors were observed visually, among these 44 Lyrids, in a total of 21.95 hours. Lyrid activity were detected from April 15 – 16 onwards, with less than one meteor an hour towards April 18 – 19. From April 19 – 20, a slight increase in rates was observed, continuing to increase in the night of April 20 – 21 towards the maximum. The highest rates were observed in a short 40-minute period between 22^h58^m and 23^h38^m on April 21 – 22, with 9 Lyrids observed. Rates then started to decline towards the morning twilight on April 22.

2 Observations April 15 – 16

After a long period with no meteor observations, I really looked forward to a night under clear skies. April is also the last chance to do serious meteor observations at these northern latitudes, before the bright summer nights sets in. The weather forecast looked promising, except for some medium high clouds that should pass by early in the evening. My plan was to start observations 21^h45^m UT, when the Lyrid radiant had reached an elevation of 30 degrees. After a 2-hour nap in the early evening, I packed my observation gear and walked up to a logging field 300 meters from my house. This place provides a totally undisturbed environment, with no direct light pollution from sources nearby. The only problem is the lights from the city of Oslo and Gardermoen airport, that makes the Lm drop sharply towards the horizon in south-eastern direction. The approaching bright summer nights also makes for a bright horizon to the north-west. Only in the north-eastern direction, the sky was pretty dark towards the horizon. High in the north-eastern sky, I was able to find a field of view with a Lm between 6.1 and 6.2.

When reaching the logging field, some clouds had moved in from west, making serious meteor observations impossible. I was not able to start observations until 22^h15^m UT. When I could start still 10 to 15 percent cloud cover occurred in my field of view. These conditions remained until 23^h45^m UT, and the period also includes a 12 minutes break due to clouds. The most notable in this period, was a beautiful, red, slow moving sporadic meteor low on the western horizon observed during the break. It was also interesting to note a clear activity from the antihelion region, with 2 long pathed, slow moving meteors. No Lyrids were seen during this period.

22^h15^m–23^h45^m: T_{eff}: 1.30, F: 1.16, Lm: 6.11

- Spo: 2(2), 3(2), 5 – Total of 5 meteors
- Ant: 2, 3 – Total of 2 meteors
- Lyr: 0 meteors

After 23^h45^m the last of the clouds disappeared, and I was able to make observations under perfectly clear skies until 01^h00^m. After 15 minutes I was really happy to see my first Lyrid meteor! This was a +4 mag in Cassiopeia, right in the middle of my view, and a perfect shower candidate regarding direction, speed and length of the trail. 5 minutes before the end of my observation, I saw another good candidate, a +5 mag Lyrid moving from Lyra into Draco. The sporadic activity also picked up during this period, with 11 meteors seen. When packing down my observation gear, I was really happy to have been able to get an observation period under perfectly clear skies, and to have witnessed my first Lyrid meteors of 2020.

23^h45^m–01^h00^m: T_{eff}: 1.25, F: 1.00, Lm: 6.18

- Spo: 1, 2, 3(2), 4(3), 5(3), 6 – 11 meteors
- Ant: 4 – 1 meteor
- Lyr: 4, 5 – 2 meteors

3 Observations April 16 – 17

Excited to see what the next night would bring, I started observations under perfectly clear skies 21^h50^m UT. After 12 minutes I became aware of a movement in the outskirts of my field of view. I turned around in time to see a beautiful, slow moving, –1 mag sporadic meteor that lasted for about 2 seconds in the western sky. Another highlight came 35 minutes later, when a +1 mag, yellow antihelion meteor slowly glided through the middle of my field of view near the zenith. Then a long period with mostly faint meteors came, before a +1 mag, yellow sporadic meteor found its way from Vega towards zenith at 00^h15^m UT. The sporadic rates this night varied between 4 – 9 meteors an hour. Only one good Lyrid candidate was seen, so no increase in activity from the night before was detected.

21^h50^m–22^h50^m: T_{eff}: 1.00, F: 1.00, Lm: 6.11

- Spo: -1, 0, 1, 2 – 4 meteors
- Ant: 1 – 1 meteor
- Lyr: 0 meteors

22^h50^m–23^h50^m: T_{eff}: 1.00, F: 1.00, Lm: 6.18

- Spo: 2(2), 3(2), 4(2), 5(3) – 9 meteors
- Ant: 0 meteors
- Lyr: 5 – 1 meteor

23^h50^m–01^h00^m: T_{eff}: 1.08, F: 1.00, Lm: 6.18

- Spo: 1(2), 4(2), 5 – 5 meteors
- Ant: 3 – 1 meteor
- Lyr: 0 meteors

4 Observations April 17 – 18

This night some medium high, drifting clouds became a problem the first hour again. Despite this, 9 meteors were seen, among them 1 Antihelion and 1 Lyrid. After only 4 minutes of observation, a –2 mag, reddish, slow moving sporadic lit up in Boötes, continuing for nearly 2 seconds in a south-westerly direction. After nearly an hour, another nice +1 mag sporadic was seen and photographed near Deneb. A good Lyrid candidate of mag +4, was seen shortly after this. After the first hour of observation, the sky became totally clear again, and I was hoping for some good activity after the first promising hour. I have to admit I got disappointed! Only 2 meteors were seen the next hour under good observing conditions, a +3 mag sporadic, and a +5 mag Lyrid. During such dull hours, you start to doubt your own perception, but I think the lack of activity was real. The following period of 1.25 hours again gave a good count of 10 sporadics, 2 Lyrids, and 1 antihelion. There was a lack of bright meteors this hour, with a +2 mag Lyrid in Draco as one of the finest.

21^h35^m–22^h35^m: T_{eff}: 1.00, F: 1.11, Lm: 6.06

- Spo: -2, 1, 2, 3, 4(2), 5 – 7 meteors
- Ant: 4 – 1 meteor
- Lyr: 4 – 1 meteor

22^h35^m–23^h35^m: T_{eff}: 1.00, F: 1.00, Lm: 6.17

- Spo: 3 – 1 meteor
- Ant: 0 meteors
- Lyr: 5 – 1 meteor

23^h45^m–01^h00^m: T_{eff}: 1.25, F: 1.00, Lm: 6.17

- Spo: 2(2), 3(4), 4(2), 5, 6 – 10 meteors
- Ant: 3 – 1 meteor
- Lyr: 2, 5 – 2 meteors

5 Observations April 18 – 19

On April 18, the weather forecast promised another perfect clear night, and I was eager to see if I could observe any increase in Lyrid activity. It was a quiet night with no wind, and temperatures around +2 degrees. A wonderful night to lay under the stars and listen to the sound of the forest! At one time a moose came a little too close before noticing me, and I could hear its hoofbeats as it ran away into the forest again. This night stood out with its lack of bright meteors. In 3.16 hours of observation the two brightest meteors were of mag +1 and +2! Sporadic rates were between 4 and 9, and only 1 Lyrid meteor was seen during the whole night. So, the conclusion to my question, was that no increase in Lyrid activity was visually observable!

21^h45^m–22^h45^m: T_{eff}: 1.00, F: 1.00, Lm: 6.17

- Spo: 1, 3, 4, 5(2), 6 – 6 meteors
- Ant: 0 meteors
- Lyr: 0 meteors

22^h45^m–23^h45^m: T_{eff}: 1.00, F: 1.00, Lm: 6.17

- Spo: 3, 4, 5, 6 – 4 meteors
- Ant: 3 – 1 meteor
- Lyr: 4 – 1 meteor

23^h45^m–01^h00^m: T_{eff}: 1.17, F: 1.00, Lm: 6.17

- Spo: 2, 3(3), 4(2), 5(2), 6 – 9 meteors
- Ant: 3, 4 – 2 meteors
- Lyr: 0 meteors

6 Observations 19 – 20 April

Weather forecast was again good, also indicating clear skies the following nights towards maximum. Could I really hope for clear skies 7 nights in a row towards the Lyrid maximum? It seemed too much to ask for in Norway during any time of the year, but a high-pressure system lay firmly on the north Atlantic, blocking the usual pattern of low-pressure systems towards the coast of Norway. Again, I headed out to my observation site hoping to see an increase in Lyrid activity. After only 7 minutes of observation my hopes were rising, as a +3 mag Lyrid gently streaked across Cepheus. 20 minutes later a nice 0 mag sporadic was seen low in the eastern sky, breaking the record from the show of faint meteors from the night before. 5 minutes before the end of the first hour, another Lyrid of mag +5 was seen close to the radiant in Lyra. Again 7 minutes into the next hour, another Lyrid of mag +4 glided with medium speed between Cepheus and Draco. 45 minutes later a short, slow moving, white Lyrid appeared in Hercules. The hour was rounded off with another nice 0 mag sporadic meteor. The next 1.17 hours of observations also generated 2 Lyrids of mag +4, making the total Lyrid count for the night 6 meteors. The highlight of the night came 13 minutes before the end of the observation. A –2 mag Antihelion lit up in Hercules, yellow/red in color, and slowly moving with several flares towards the eastern horizon. This one I also caught on camera, except from the final flares at the end of the meteors path. All in all, this was a memorable night, with a first observed slightly increase in Lyrid activity.

21^{h}35^m–22^{h}40^m: T$_{eff}$: 1.050, F: 1.00, Lm: 6.11

- Spo: 0, 3(2), 4, 5
- Ant: 0 meteors
- Lyr: 3, 5 – 2 meteors

22^{h}40^m–23^{h}45^m: T$_{eff}$: 1.083, F: 1.00, Lm: 6.17

- Spo: 0, 3, 4(3), 6 – 6 meteors
- Ant: 2, 5 – 2 meteors
- Lyr: 2, 4 – 2 meteors

23^{h}45^m–01^{h}00^m: T$_{eff}$: 1.166, F: 1.00, Lm: 6.11

- Spo: 3, 4, 5(2), 6 – 5 meteors
- Ant: -2 – 1 meteor
- Lyr: 4(2) – 2 meteors

7 Observations April 20 – 21

The night before maximum, and the weather was still looking good! What could be expected of activity this night? Eager to find out, I headed out to the logging field to start observations at 21^{h}35^m. The temperature was around 7 degrees, and never falling under 4 degrees during the night. This made observations really comfortable and pleasant, a rare event in the observing season from mid-August to late April. 16 minutes into the period the first Lyrid appeared, a nice +2 mag in Corona Borealis. At 22^{h}26^m a splendid, yellow, –1 mag Lyrid lit up in the southern parts of Cygnus, followed by another nice Lyrid of mag +1 seven minutes later. A bright surprise from the Lyrids the first 1.050 hour! The next 1.083 hour yielded 4 Lyrids, with the brightest one being of mag +1. This was also caught on camera as it appeared in the middle of my camera field in Draco. The final period of 1.167 hours also gave 4 Lyrids, the brightest one being a +2 mag in Ursa Major. This gave a total Lyrid count for the night of 11, a noticeable increase from the night before.

21^{h}35^m–22^{h}40^m: T$_{eff}$: 1.050, F: 1.00, Lm: 6.17

- Spo: 3(2), 4, 5(2), 6 – 6 meteors
- Ant: 0 meteors
- Lyr: -1, 1, 2 – 3 meteors

22^{h}40^m–23^{h}45^m: T$_{eff}$: 1.083, F: 1.00, Lm: 6.17

- Spo: 2, 3, 4(2), 5(2), 6 – 7 meteors
- Ant: 0 meteors
- Lyr: 1, 2, 4, 6 – 4 meteors

23^{h}45^m–01^{h}00^m: T$_{eff}$: 1.167, F: 1.00, Lm: 6.17

- Spo: 2, 3(2), 4, 5(3), 6 – 8 meteors
- Ant: 0 meteors
- Lyr: 2, 4(2), 5 – 4 meteors

8 Observations April 21 – 22

When I woke up this morning I got terrified! The weather forecast from "*Yr*", provided by the Norwegian Meteorological Institute, showed a high amount of high clouds in my observing window between 21^{h}30^m and 01^{h}00^m the coming night. Was it all too good to be true? Should I miss the 2020 maximum of the Lyrids in the last minute? In desperation I searched other meteorological sites. Both "*Storm*" and "*Meteoblue*" predicted still clear skies, so I became a little more relieved. As evening approached, there was no sign of high incoming cloud, and I went to bed early to get a couple of hours of sleep before observations. When I woke up, I quickly looked out of my bedroom window, and was relieved to see a crystal clear, darkening sky in the west. This night I also got company! I had already made an appointment with my daughter Marte to join me, and the day before I got a telephone from my nephew, asking about the Lyrids. He wondered if he, his girlfriend, her sister and son aged 6, could join me for a meteor watch after hearing about the Lyrids in the news. After warning them about that the rates may not exceed 10 meteors, and that no white lights or cellphones were allowed, they all joined me for the maximum of the Lyrids under crystal clear skies!

Well down in our sleeping bags, it took about 10 minutes before the first meteor appeared. A +3 mag sporadic in Cassiopeia was good enough for widespread cheers and applause! 4 minutes later the first Lyrid appeared, followed by 4 more the remaining hour, all between mag +2 and +4. In the next hour the activity was on the rise, and some bright meteors also started to appear. At 22^{h}58^m I saw a 0 mag Lyrid low in the northern horizon, unfortunately out of the field of view for the rest of the group. 12 minutes later a –1 mag Lyrid flashed its way through Draco, right in the middle of everyone's view! This meteor made the highlight of the night, except for the youngest boy who was well asleep at this time…The period between 22^{h}58^m and 23^{h}38^m was the most intense, with 9 Lyrids in 40 minutes! After this I had a feeling that activity declined. In the period between 23^{h}45^m and 01^{h}00^m, (T$_{eff}$ 1.167), only 5 Lyrids were seen, even as the radiant reached a higher elevation. A nice –1 mag Lyrid in Draco at 00^{h}14^m, made another highlight of the night, before a +1 Mag Lyrid from Hercules towards Ophiuchus ended the show.

The next night clouds finally came in, almost as a relief, to a very tired and satisfied observer. The unlikely event of 7 observing nights in a row under the Lyrids, had materialized! I do not think this will happen again anytime soon, so the Lyrids of 2020 will be a good and lasting memory in my mind.

21^{h}35^m–22^{h}40^m: T$_{eff}$: 1.050, F: 1.00, Lm: 6.11

- Spo: 3(3), 5 – 4 meteors
- Ant: 3 – 1 meteor
- Lyr: 2(2), 3(2), 4 – 5 meteors

22^h40^m–23^h45^m: T_{eff}: 1.083, F: 1.00, Lm: 6.17

- Spo: 1, 3, 4(2), 5(3), 6 – 8 meteors
- Ant: 1, 4 – 2 meteors
- Lyr: –1, 0(2), 2(3), 4(2), 5 – 9 meteors

23^h45^m–01^h00^m: T_{eff}: 1.167, F: 1.00, Lm: 6.11

- Spo: 0, 3, 4(2), 5, 6 – 6 meteors
- Ant: 0 meteors
- Lyr: –1, 1, 2, 5(2) – 5 meteors

Figure 1 – The picture is taken 00^h53^m on April 22 with a Nikon D3100, and a Samyang 16mm F 2.0 lens. Exposure time is 20 seconds with ISO 1600 settings. The bright star in the upper right is Vega, and a Lyrid meteor can also be seen in the upper right corner. The sky is starting to get brighter towards the horizon due to morning twilight.

Observing experiences with radio meteors

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A description is given of the observing method and the different applications of the radio observations made at the Venice Planetarium.

1 Introduction

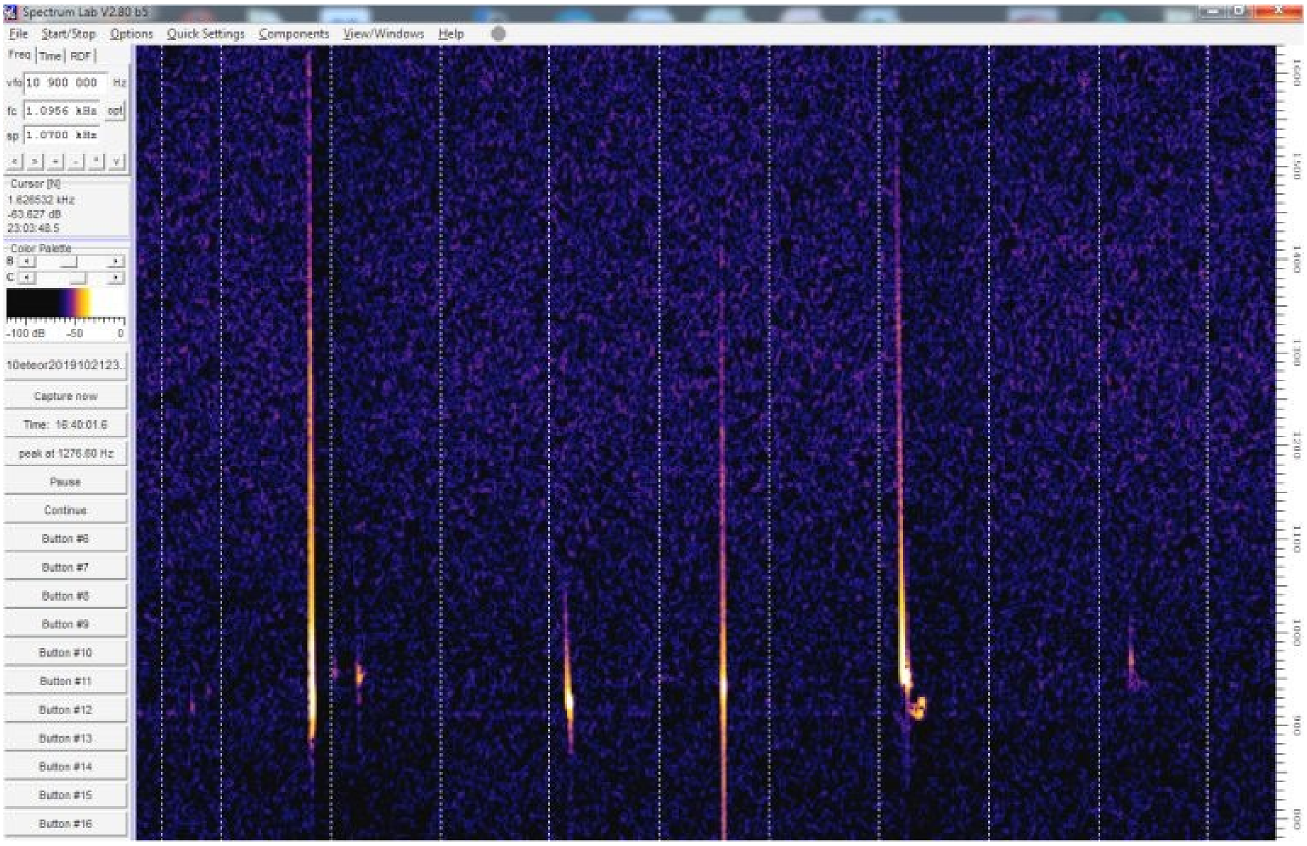
Radio observations of meteors entering the atmosphere can offer a lot of useful information, but a certain amount of theoretical knowledge is necessary to correctly interpret the recorded data. The following is a briefly illustrated approach that our association has taken in this regard.

2 Our observing method

Since 2013 the local association of amateur astronomers has installed a radio station for the reception of meteor echoes in the atmosphere at the Planetarium of Venice with satisfactory results. This choice was motivated by the interest to expand the study of meteors already widely developed for years in the video domain by many members.

The station, activated thanks also to the help of some amateur radio operators, consists of a Yaesu FT 817 receiver, a Yagi 6 element antenna and the Spectrum Lab software installed on a Pentium PC with Windows XP. The signals transmitted on the frequency 143.050 MHz by the French radar Graves (Tx) at a distance of 573 km from the receiving station (Rx) in the Planetarium, are received when they are reflected on the ionized layers left by the meteors.

After a period of testing and experimenting with different software (*Hrofft*, *SpectrumLab*), the most appropriate configuration for the system used was established with *Spectrum Lab*. This software analyzes in real time the audio input of all events, selecting those apparently of meteoric origin. The listening frequency of the radio receiver was tuned just outside the carrier frequency to obtain a tone instead of the mute carrier signal.

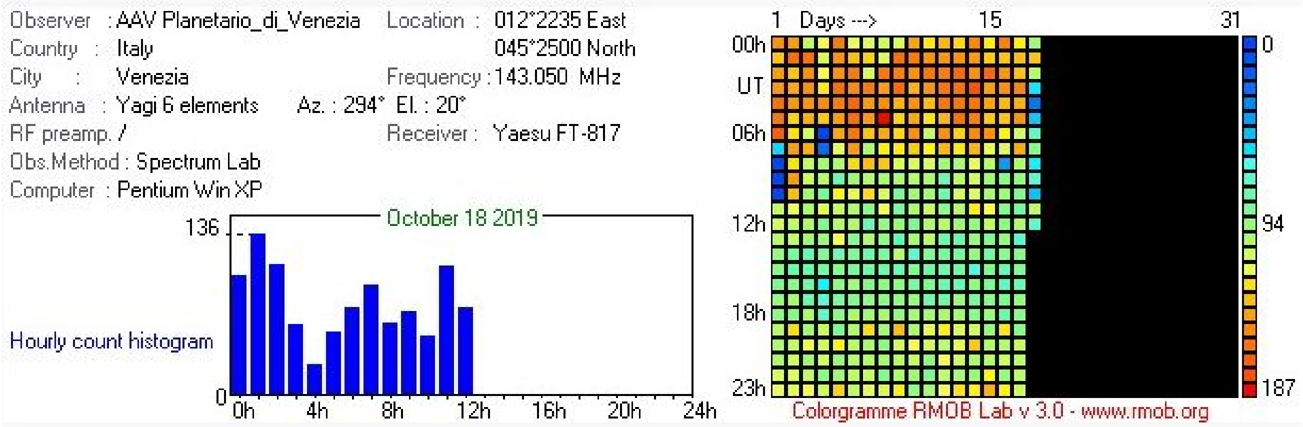


vfo 10 900 000 Hz
fc 1.0956 kHz
sp 1.0700 kHz

Cursor [N]
1.626532 kHz
-63.627 dB
23:03:48.5

10eteor2019102123...
Time: 16:40:01.6
peak at 1276.60 Hz

Figure 1 – Radio Spectrogram with some meteor events. The almost vertical lines correspond to the reflected echoes of the mobile plasma surrounding the meteor.



Observer : AAV Planetario_di_Venezia
Location : 012°2235 East
045°2500 North
Country : Italy
City : Venezia
Frequency : 143.050 MHz
Antenna : Yagi 6 elements
Az. : 294° El. : 20°
RF preamp. /
Receiver : Yaesu FT-817
Obs.Method : Spectrum Lab
Computer : Pentium Win XP

Figure 2 – Hourly radio echo count.

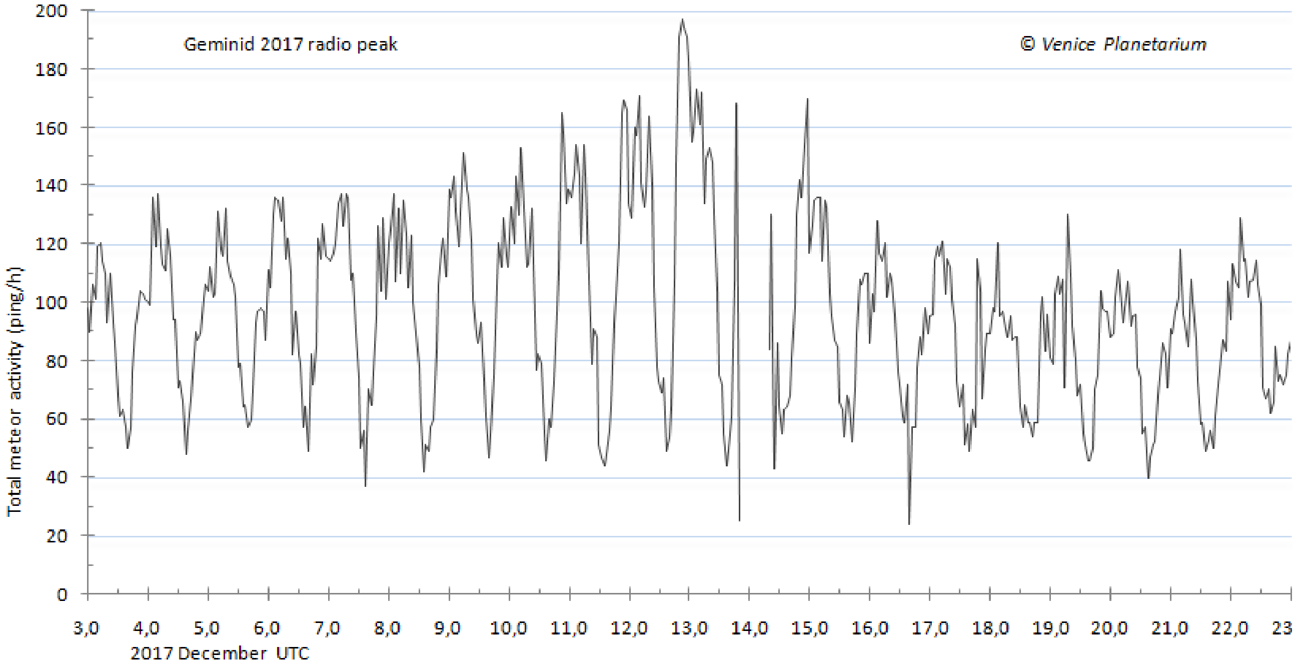


Figure 3 – Daily radio echo trend.

A nice example of reception is shown in the spectrogram (*Figure 1*) where some meteor events are visible: the yellow red color is an indication for the signal strength at a given frequency and the echo amplitude (meteoric "ping") shows the doppler displacement of the signal sent by the radar.

For each event, not only the statistical information (intensity, timing, frequency, duration, etc.) is saved, but also the audio input from which the software derives the spectrogram.

A correct reception obviously shows that the frequency of events varies according to the season and time of the day with a maximum in the early morning and a minimum in the afternoon (*Figure 2*).

It must be kept in mind that the registered signals are not only due to meteors, but also to the passage of satellites, planes, as well as thunderstorms and disturbances of various kinds (solar radiation, discharges, etc.). The collected data also shows that in some cases a statistical count is not possible, for instance in cases with significant meteoric activity (outburst), because the detection software may show saturation problems when recording too many received signals. In order to obtain reliable meteor data, an attempt was made to manually filter out all false detections as far as possible, primarily by setting a precise frequency scan interval in order to limit the count to a precise range.

All statistical observing data are shared on the network almost instantly and made public via the Radio Meteor Observing Bulletin[17].

Figure 3 shows the graph of all hourly echo rates recorded over a period of about 20 days. When analyzing the events, it is not possible to discriminate shower meteors and sporadics, as the count shows all meteors as a total, i.e. those of all active meteor streams and sporadic meteors together. Some radio echoes are also not physically recorded when they fail to emerge from the background noise or if there are persistent, overlapping disturbances in the reception. In order to obtain information on the actual meteor flux of a

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[17] Radio Meteor Observing Bulletin - http://www.rmob.org

given shower at a given time it is therefore necessary to evaluate the data singularly and then to subtract the hourly rate of the non-shower meteors, obtained the days before and after when only the sporadic background was active. To detect the real activity of the shower, it is necessary to take into account the variation of the observability function, which depends on various factors including, above all, the transmitter-meteor-receiver geometry (only meteors perpendicular to the Tx-Rx line are detected) and the height of the radiant. In this way it is possible to accurately determine the moment of maximum frequency, while the number of echoes will depend on the equipment used (*Figure 4*).

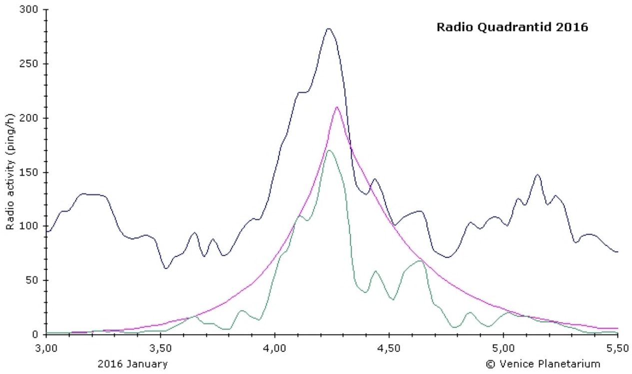

Figure 4 – Profiles of observed data, shower (without background) and the real shower curve. If the echo count is cleaned of the background and corrected for the observability function, a reliable measurement of the meteoric flux is obtained.

The meteor activity has also been analyzed using the different durations of radio echoes which depend on the persistence of ionized meteoric trails in the atmosphere (*Figure 5*).

Signal duration is more important than signal intensity, because it is related to the magnitude of the meteor and the population index of the meteor shower. Obviously in such a case, a preliminary careful check of the records to eliminate all false detections due to disturbances was a prerequisite to obtain a good result *(Figure 6*).

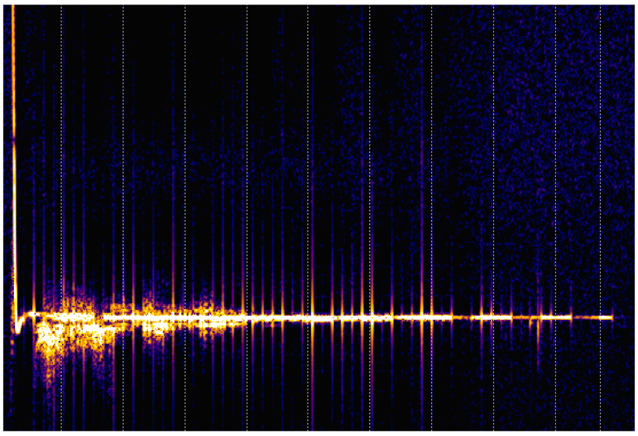

Figure 6 – Radio spectrogram of a hyperdense meteor with head echo. The mobile plasma echo is followed by the diffuse part of the trail turbulence. In this case a strong spurious disturbance signal is superimposed on the persistence of the trail.

In addition to this, one of the objectives that radio observation and video observation of meteors have in common is the search for simultaneous events (*Figure 7*). In order to reach this study objective, we tried to involve other Italian radio stations and the video stations of the Italian Meteor Group[18], in order to create a database from which the events observed in common could be identified.

Lastly, it happened every now and then that passages of satellites, or rather sections of their path, are detected when the reflection geometry of the signals becomes possible for the receiving station (*Figure 8 left*) and this with the same system with which the meteor echoes are recorded. A further interesting application of the radio meteor detection was the study of the transits of satellites during the re-entry phase[19], in order to obtain information on the flight speed and their status (*Figure 8 right*).

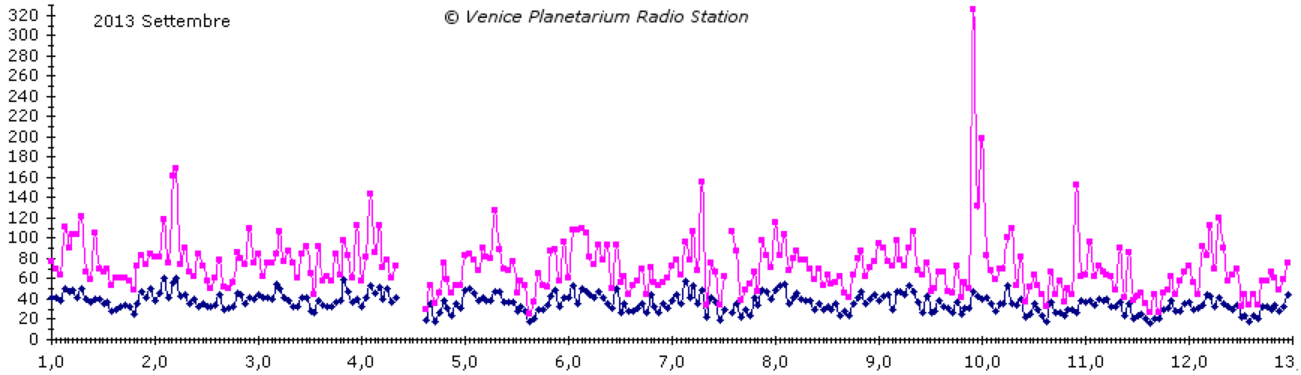

Figure 5 – Evidence for the outburst of the epsilon Perseids on 10 September 2013 using hourly rate data of persistence duration meteors.

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[18] http://meteore.uai.it/

[19] http://www.astrovenezia.net/radio_meteore/2018/20180325_0124_soyuz_reentry.htm

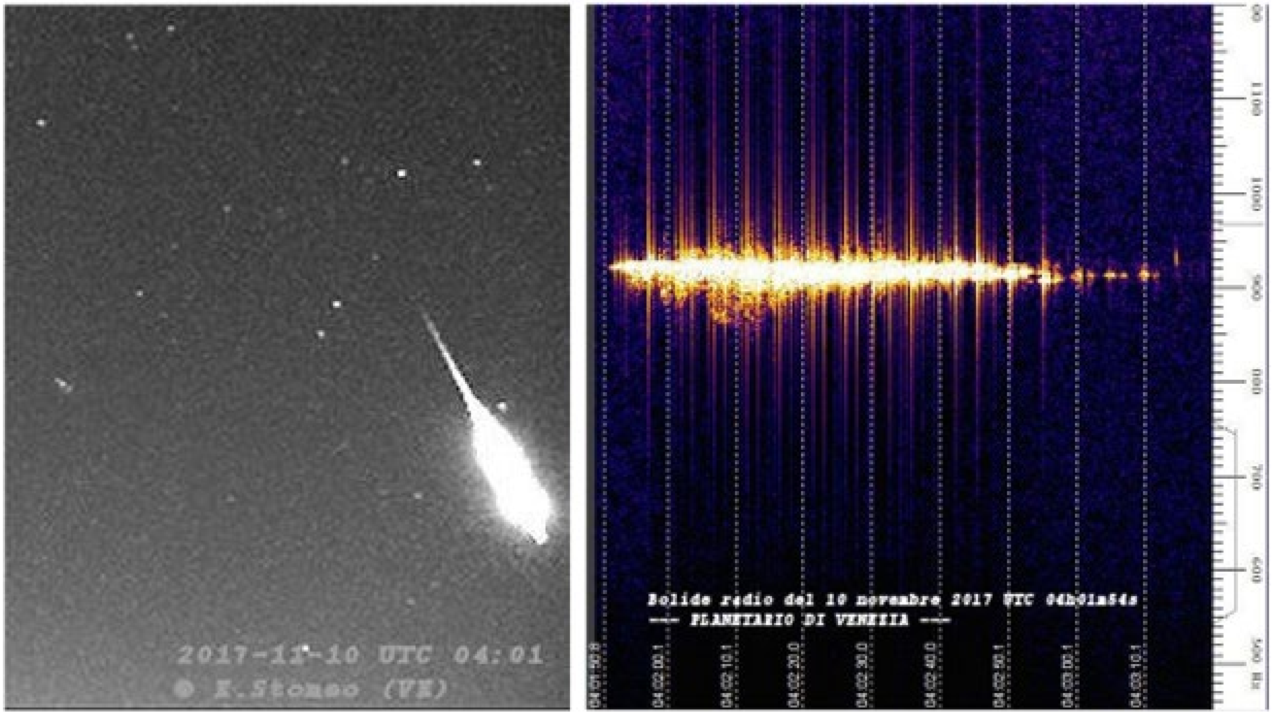

Figure 7 – Bolide recorded on November 10, 2017, resulting in a radio echo persisting for several seconds in the atmosphere.

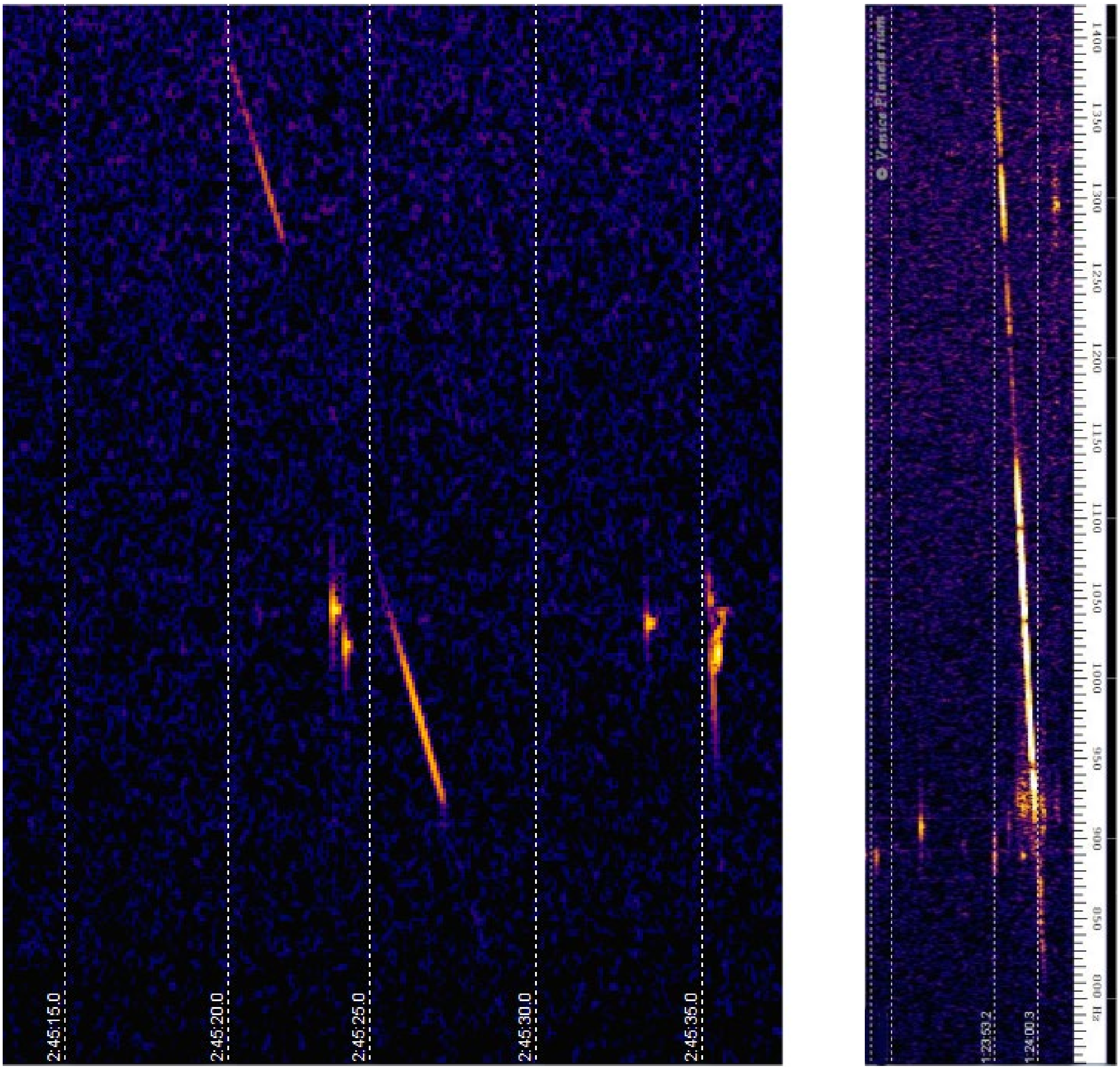

Figure 8 – Left : Radio recording of some meteor pings and the passage of the International Space Station (ISS). The inclined track of the ISS is indicative of its low speed. Right : Radio recording of the re-entry of a stage of the Soyuz MS-08 vector rocket.

Radio meteors February 2020

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An overview of the radio observations during February 2020 is given.

1 Introduction

The graphs show both the daily totals (*Figure 1 and 2*) and the hourly numbers (*Figure 3 and 4*) of "all" reflections counted automatically, and of manually counted "overdense" reflections, overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during the month of February 2020.

The hourly numbers, for echoes shorter than 1 minute, are weighted averages derived from:

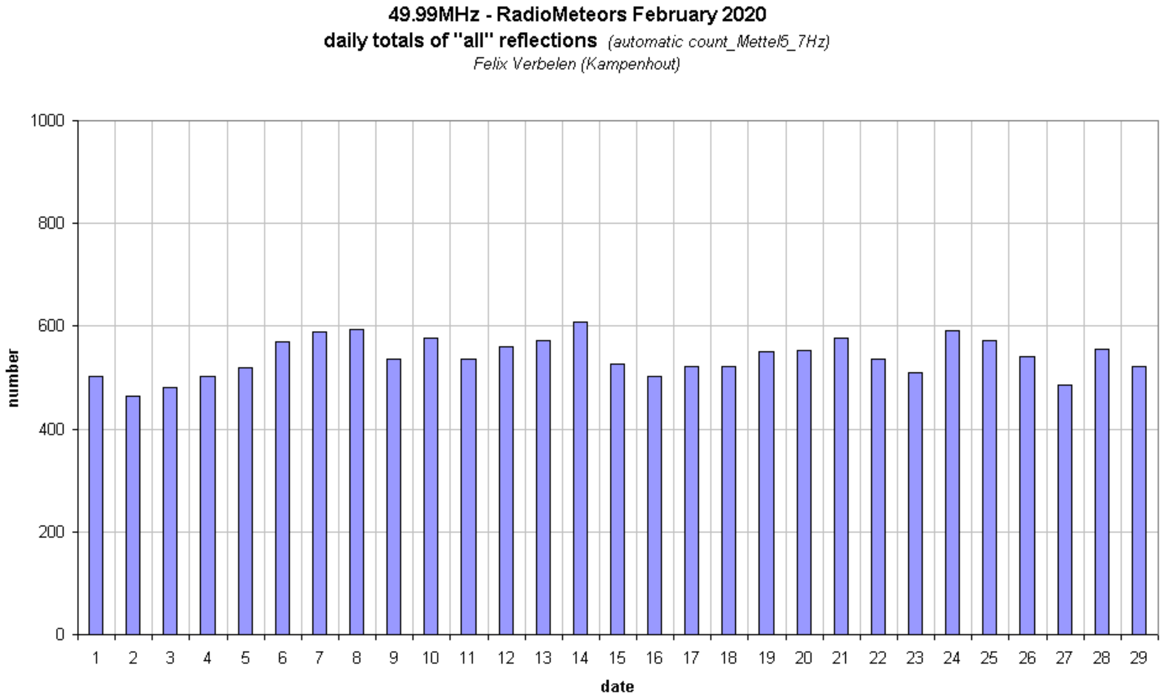
$$N(h) = \frac{n(h-1)}{4} + \frac{n(h)}{2} + \frac{n(h+1)}{4}$$

During this month there were few local disturbances, no registered "sporadic E" (Es) but quite strong light activity on several days (especially on 4, 10, 25 and 26 February).

This month there were no eye-catching showers, but several minor ones showed interesting activity, as can be seen in the graphs of overdense reflections.

Attached are also a few examples of the strongest reflections (*Figures 5 to 8*).

If you are interested in the actual figures, please send me an e-mail: felix.verbelen at skynet.be.



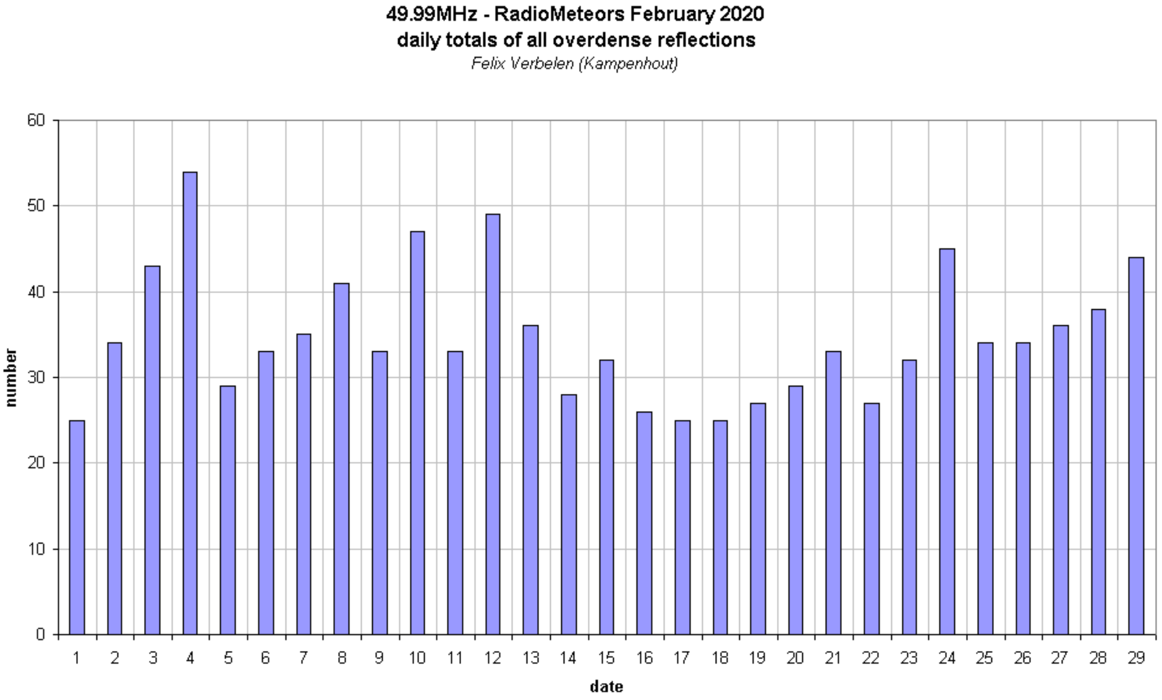
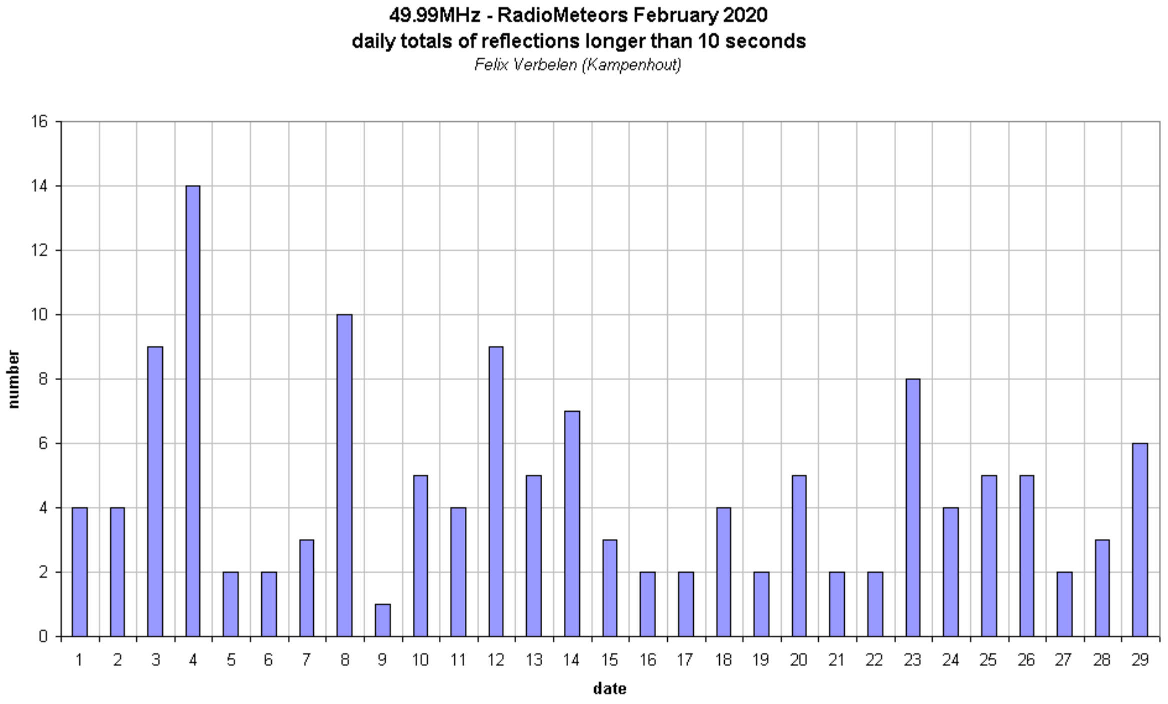


Figure 1 – The daily totals of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during February 2020.



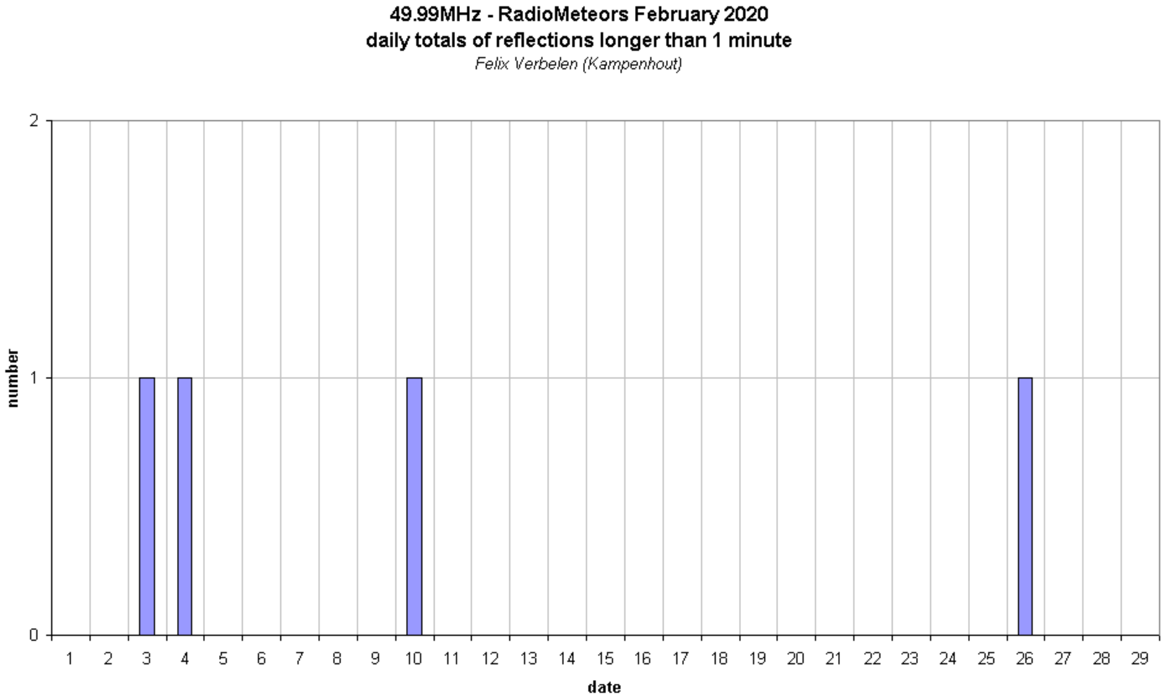
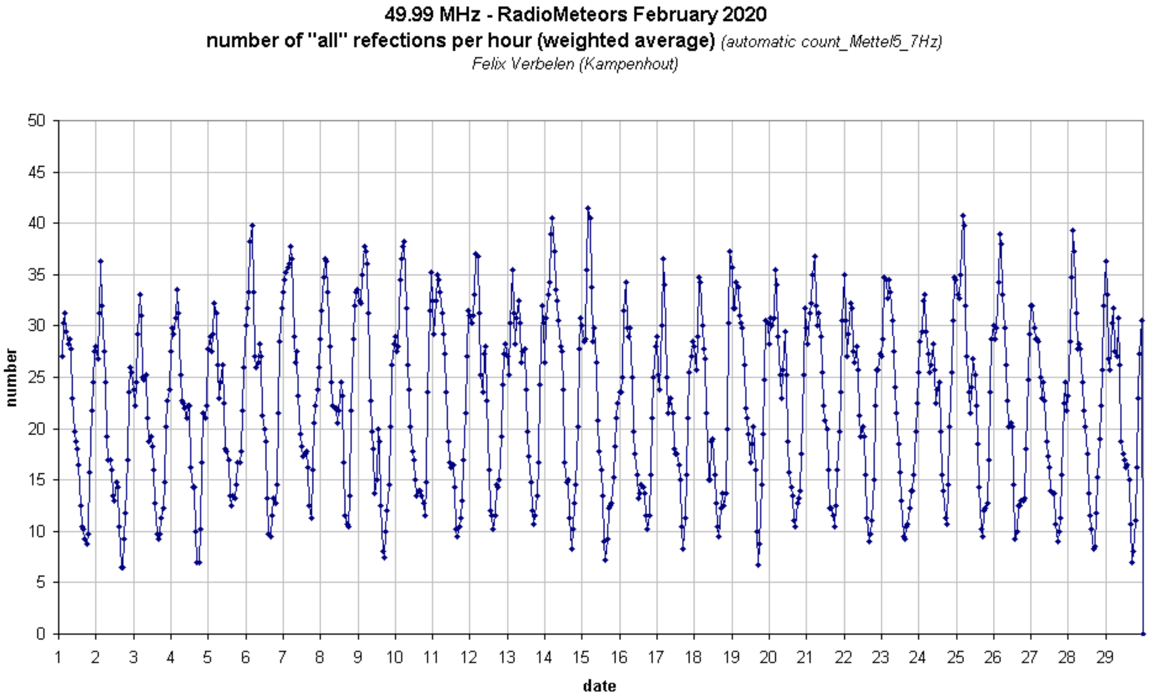


Figure 2 – The daily totals of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during February 2020.



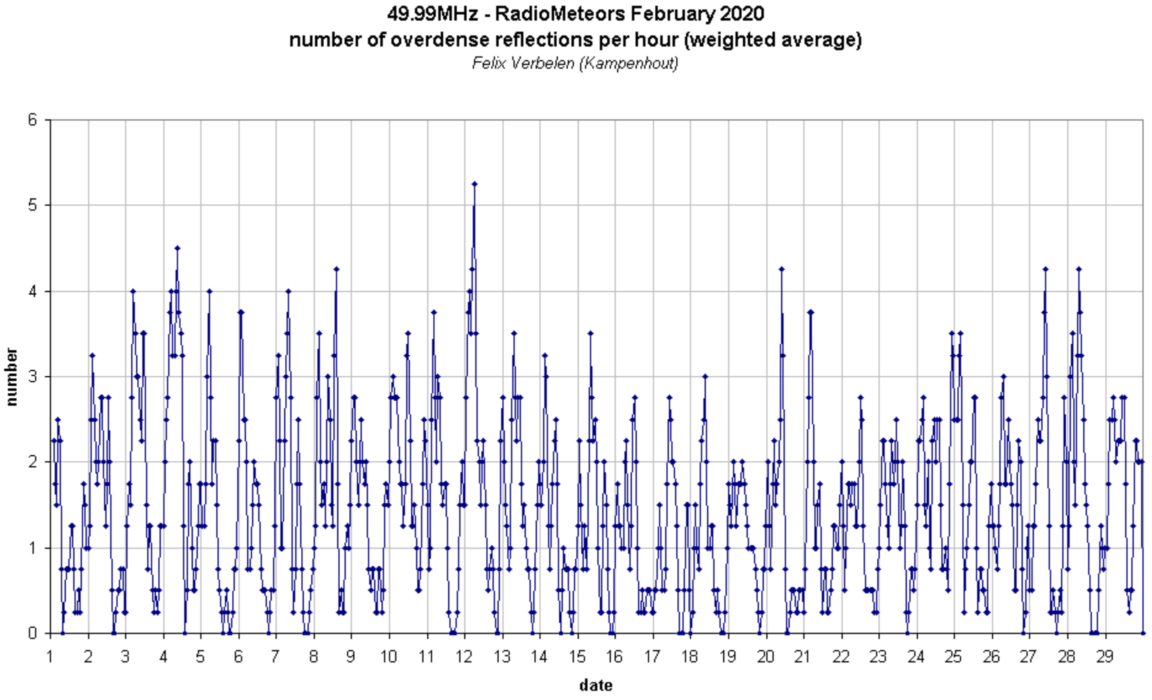
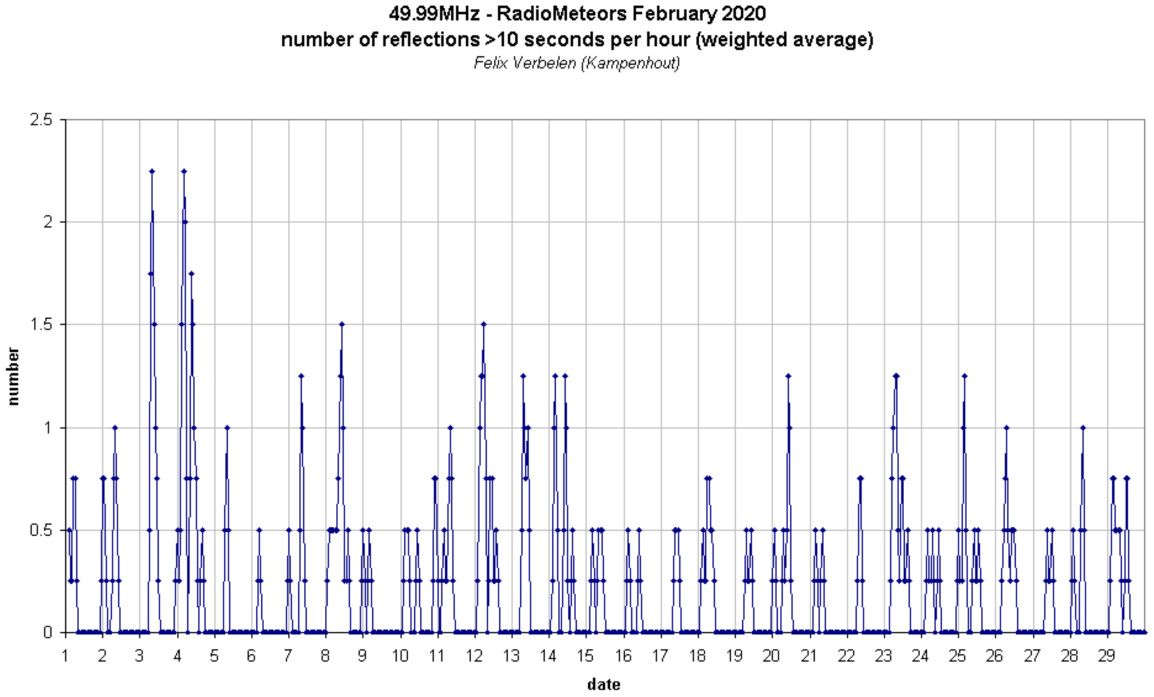


Figure 3 – The hourly numbers of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during February 2020.



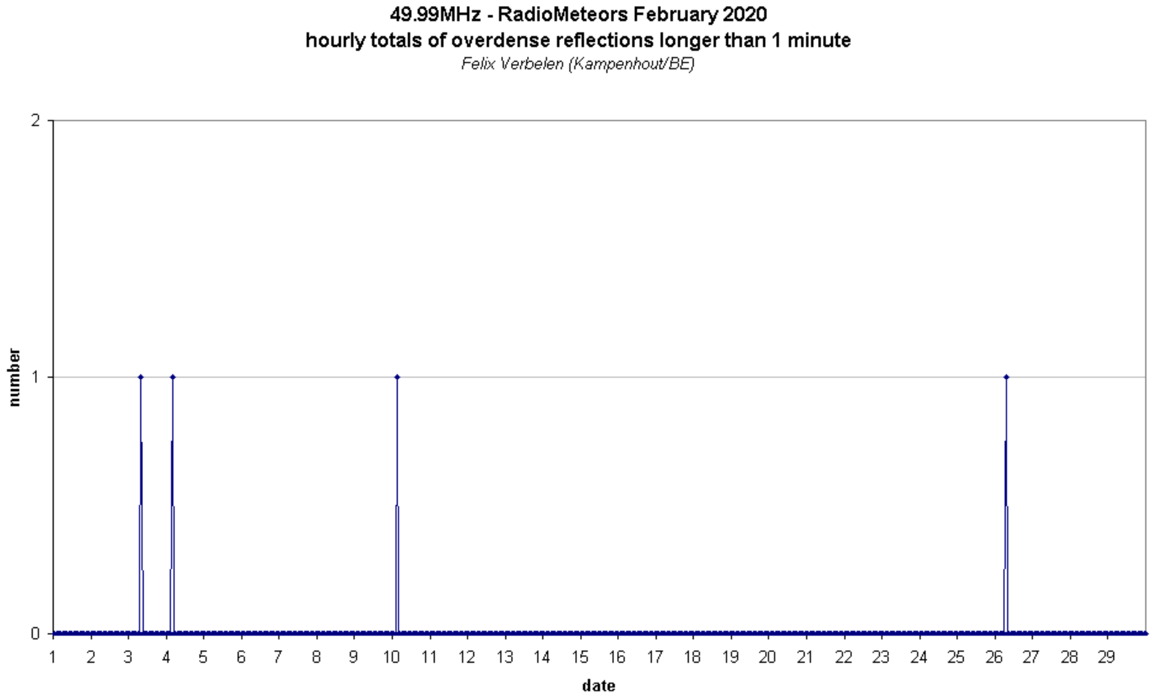


Figure 4 – The hourly numbers of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during February 2020.

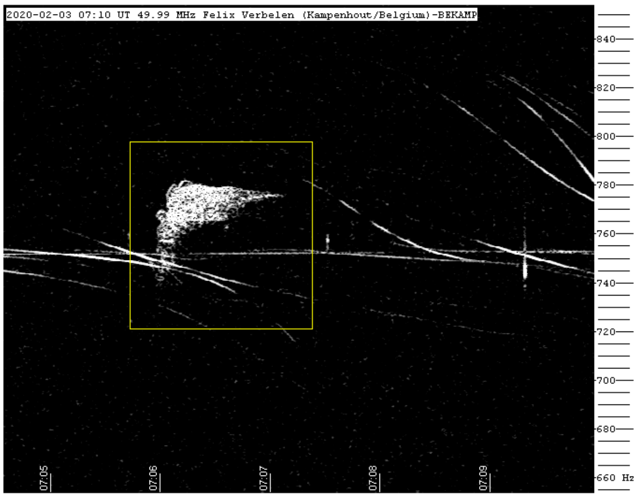


Figure 5 – 2020 February 03 at 07^{h}10^m UT.

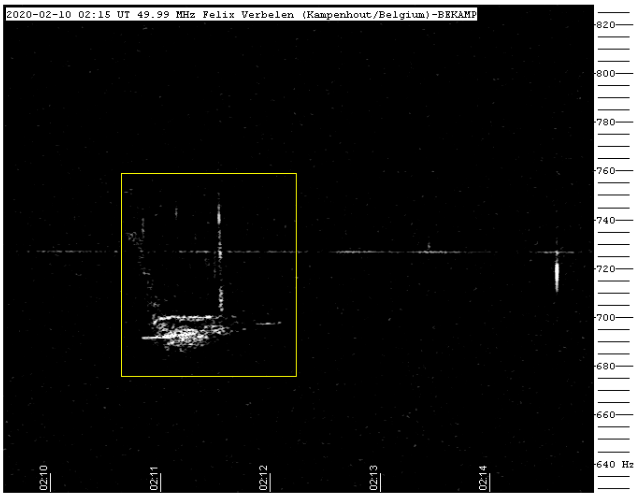


Figure 6 – 2020 February 10 at 02^{h}15^m UT.

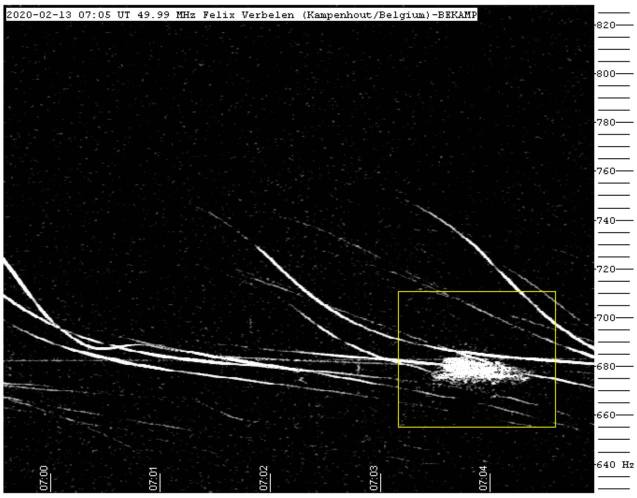


Figure 7 – 2020 February 13 at 07^{h}05^m UT.

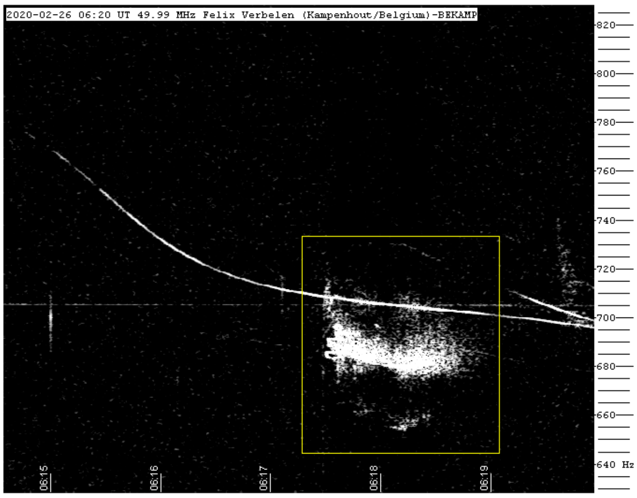


Figure 8 – 2020 February 26 at 06^{h}20^m UT.

Radio meteors March 2020

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An overview of the radio observations during March 2020 is given.

1 Introduction

The graphs show both the daily totals (*Figure 1 and 2*) and the hourly numbers (*Figure 3 and 4*) of "all" reflections counted automatically, and of manually counted "overdense" reflections, overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during the month of March 2020.

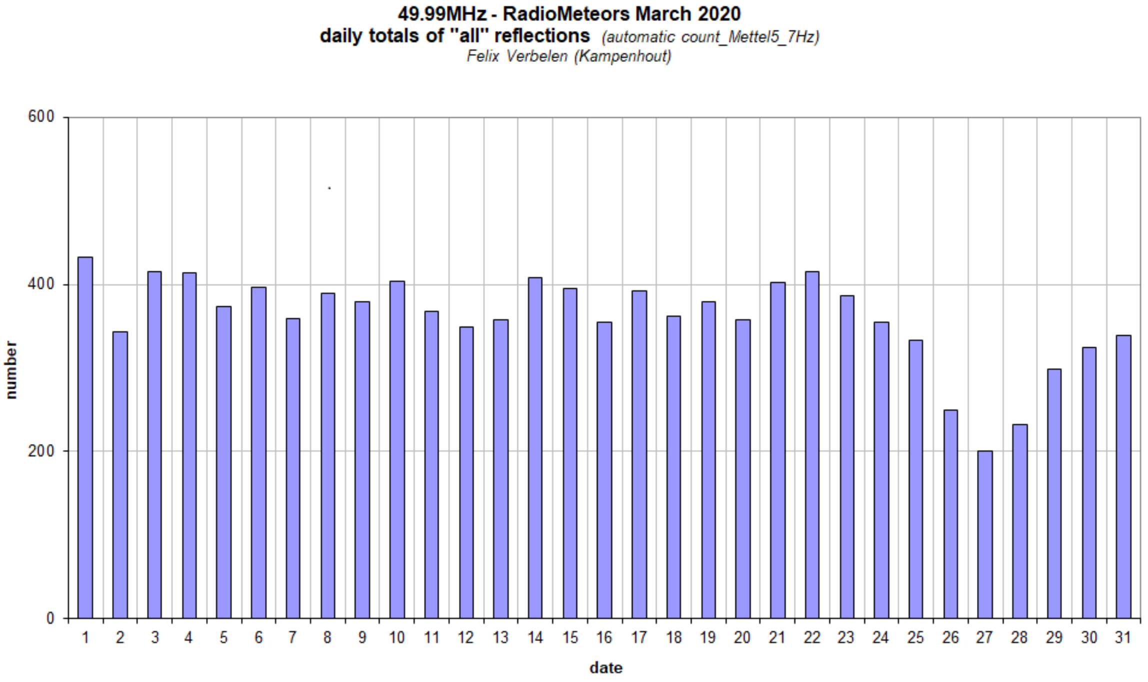
The hourly numbers, for echoes shorter than 1 minute, are weighted averages derived from:

$$N(h) = \frac{n(h-1)}{4} + \frac{n(h)}{2} + \frac{n(h+1)}{4}$$

During this month there were quite some local disturbances, but no registered "sporadic E" (Es) nor light activity. As expected, general activity was low, without eye-catching showers, but with nonetheless several interesting minor showers as shown by the graphs of overdense reflections.

Attached are also a few examples of the strongest reflections (*Figures 5 to 9*).

If you are interested in the actual figures, please send me an e-mail: felix.verbelen at skynet.be.



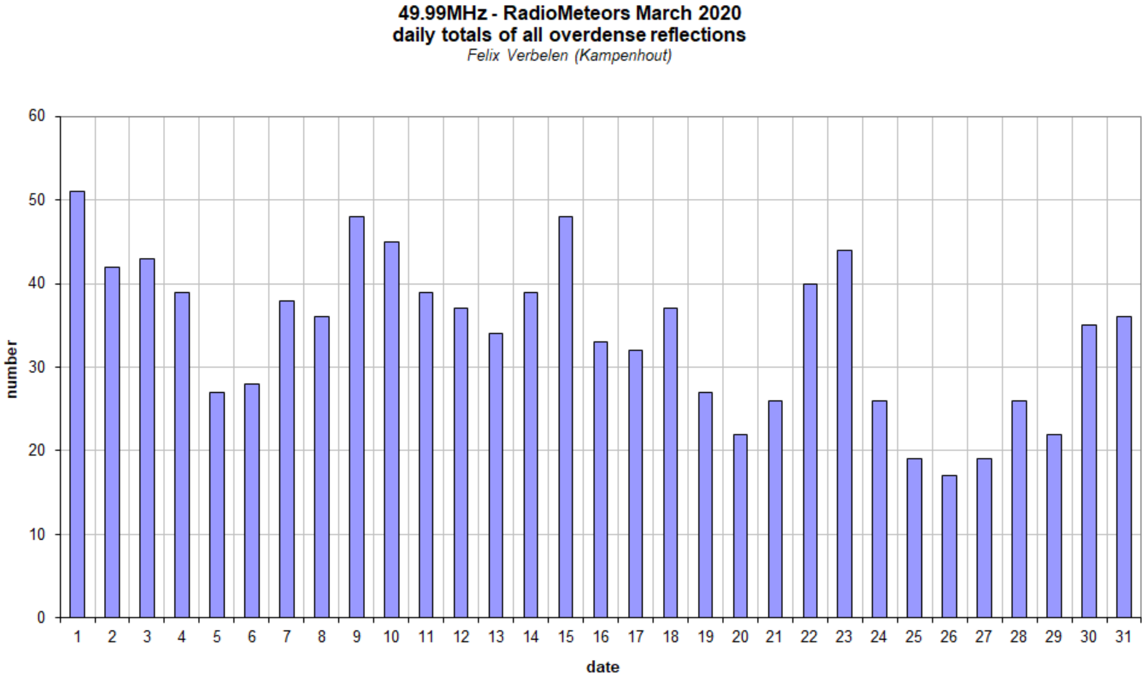
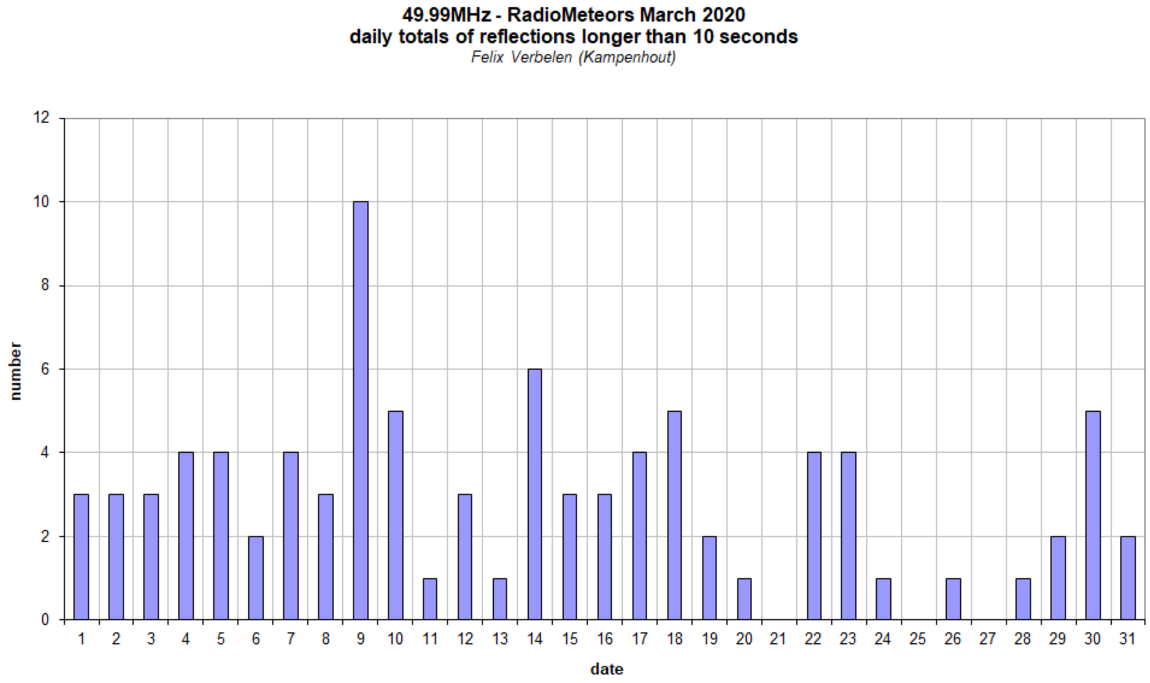


Figure 1 – The daily totals of “all” reflections counted automatically, and of manually counted “overdense” reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during March 2020.



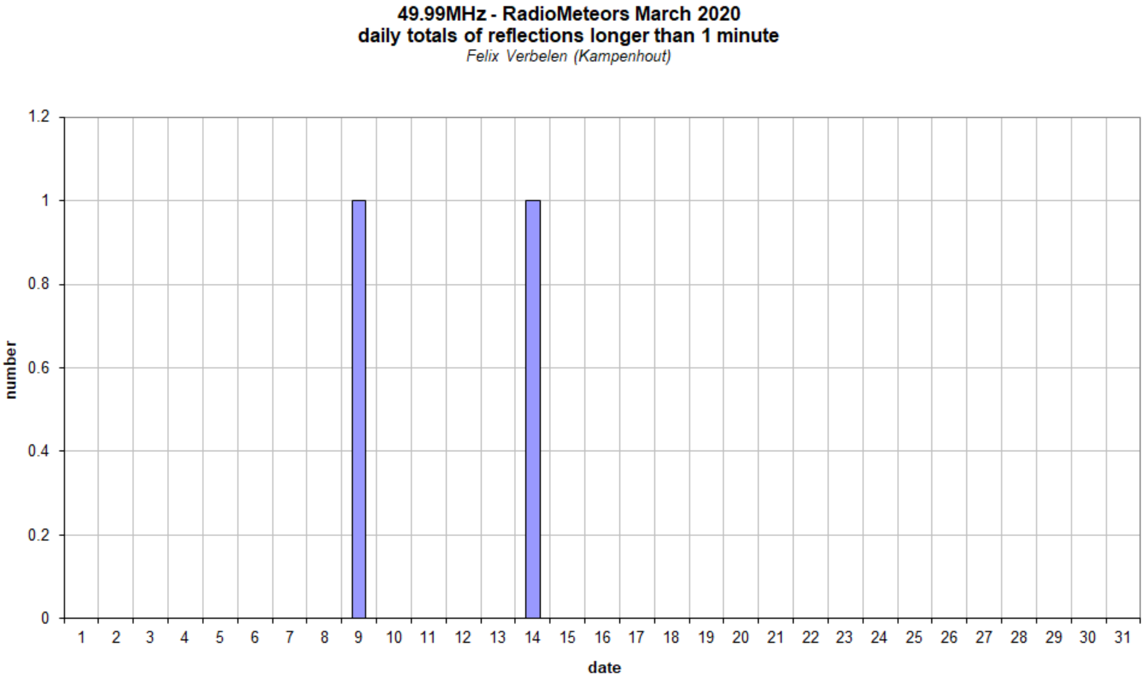
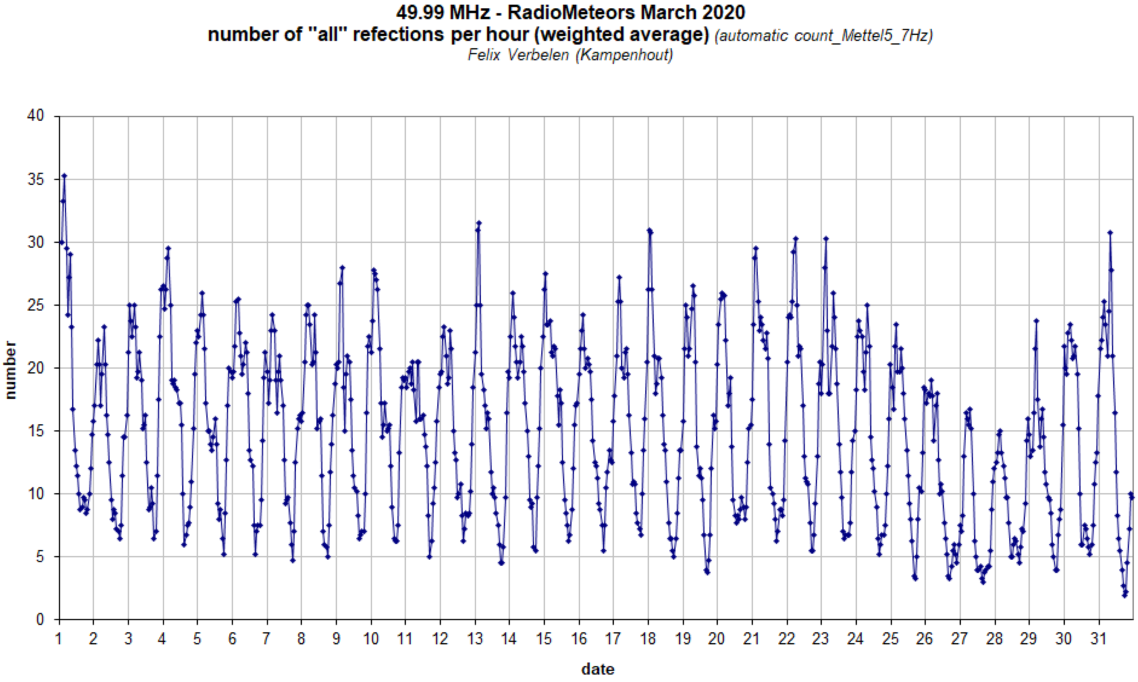


Figure 2 – The daily totals of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during March 2020.



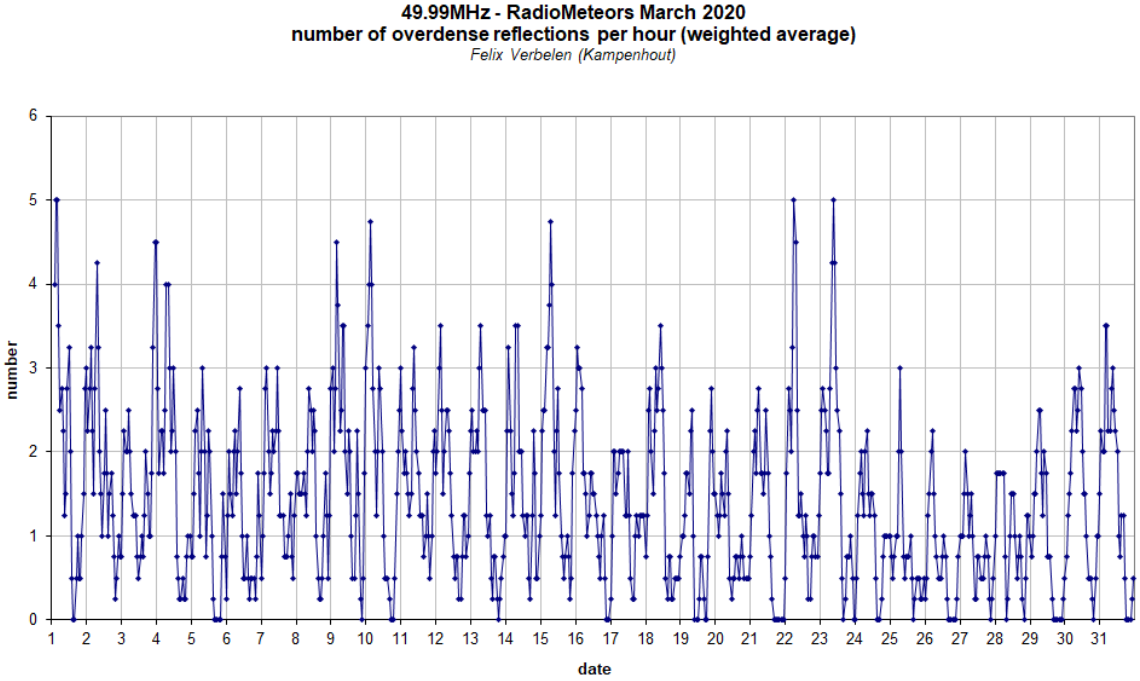
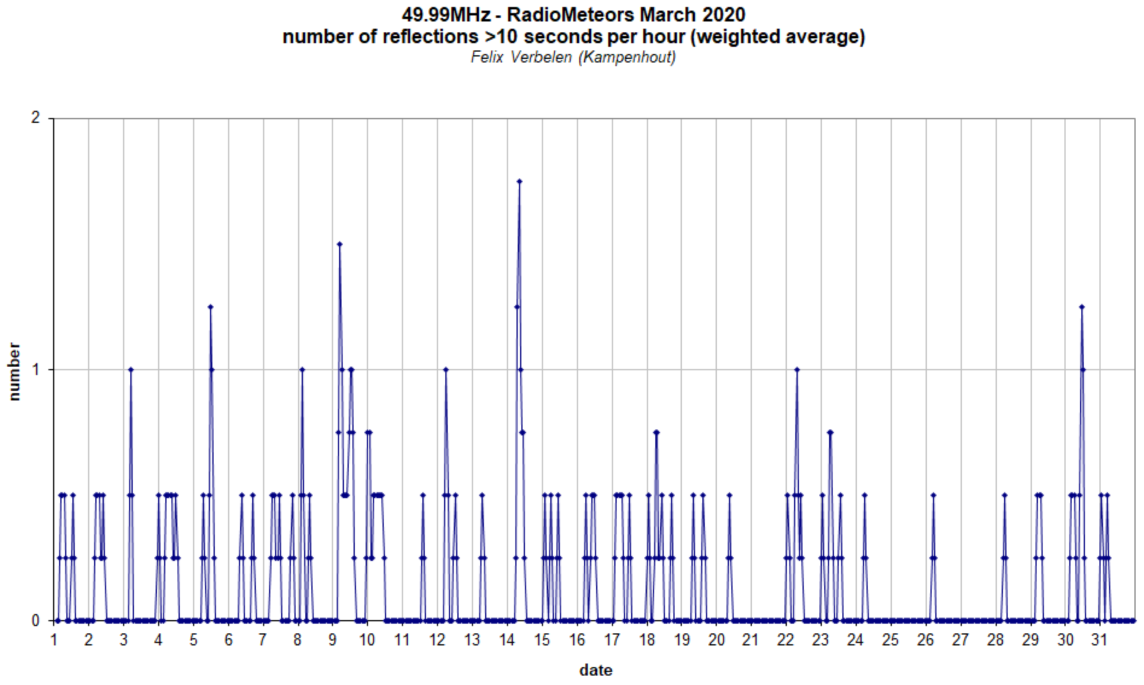


Figure 3 – The hourly numbers of “all” reflections counted automatically, and of manually counted “overdense” reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during March 2020.



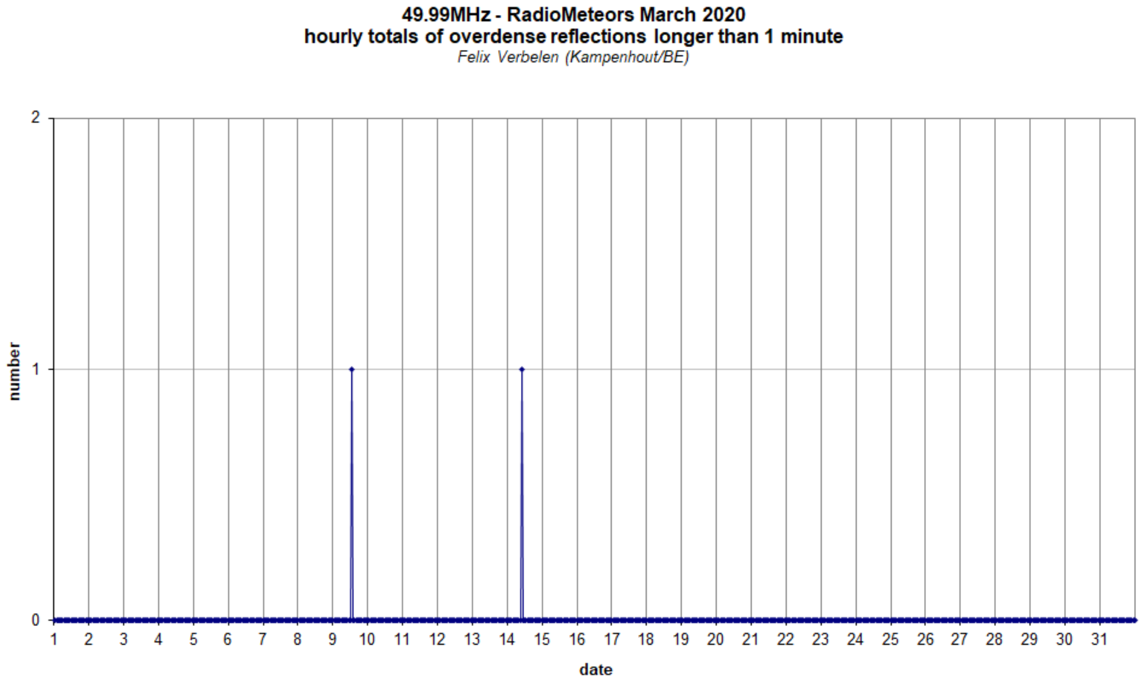


Figure 4 – The hourly numbers of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during March 2020.

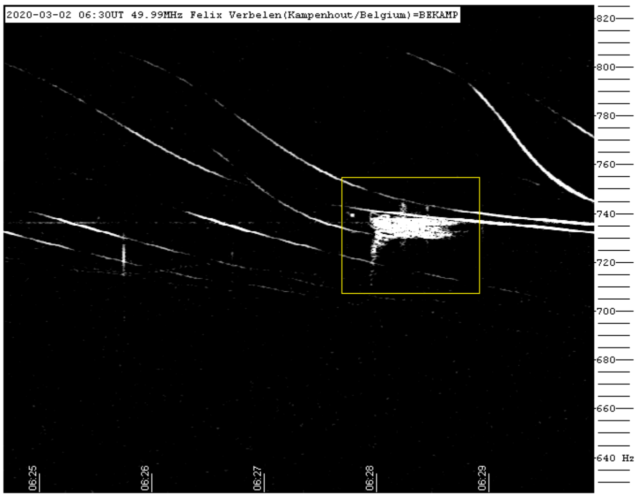


Figure 5 – 2020 March 02 at 06^{h}30^m UT.

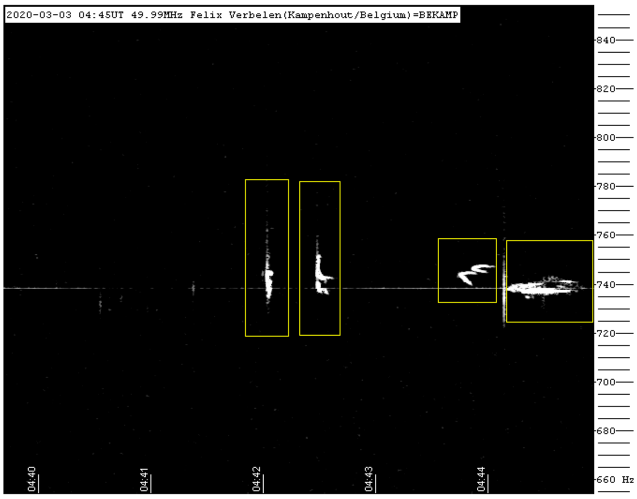


Figure 6 – 2020 March 03 at 04^{h}45^m UT.

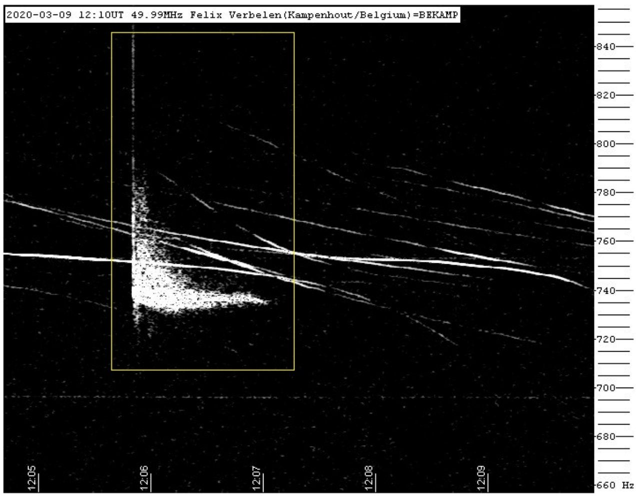


Figure 7 – 2020 March 09 at 12^{h}10^m UT.

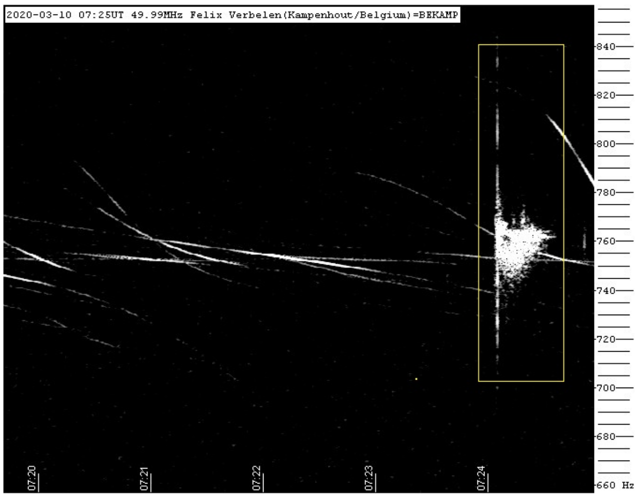


Figure 8 – 2020 March 10 at 07^{h}25^m UT.

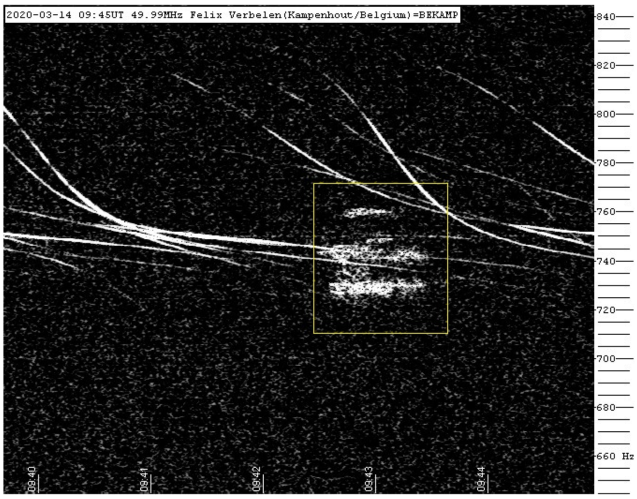


Figure 9 – 2020 March 14 at 09^{h}45^m UT.

Belgian fireball of 2020 March 18

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A fireball of magnitude -6 appeared above the Belgian Ardennes on 18 March 2020 at 02h03m52.9s UT and was registered by cameras of the BeNeLux CAMS network, the Global Meteor Network and FRIPON. A trajectory and orbit could be computed. The orbit does not fit with any known meteor stream and therefore the fireball is a sporadic. The aphelion is situated just outside the orbit of planet Mars.

1 Introduction

A very slow –6 magnitude fireball appeared 18 March 2020 at 02^{h}03^{m}52.9^{s} UT and was about 6 seconds visible at the sky. The event has been recorded by four stations of the CAMS BeNeLux network (*Figures 1, 2, 5 and 6*) and by two all-sky cameras of the FRIPON network at Brussels and at Liège (*Figures 3 and 4*). The night was clear for most parts of Belgium. The fireball passed almost unnoticed for casual watchers because of the time of the night, with most Belgian residents being at home due to the Covid-19 lock-down measures and almost nobody on the road.

Figure 1 – Fireball of 18 March 2020 at 02^{h}03^{m}52.9^{s} UT, registered at Nancy, France on CAMS 003901 (Watec, f1.2/12mm lens, courtesy: Tioga Gulon).

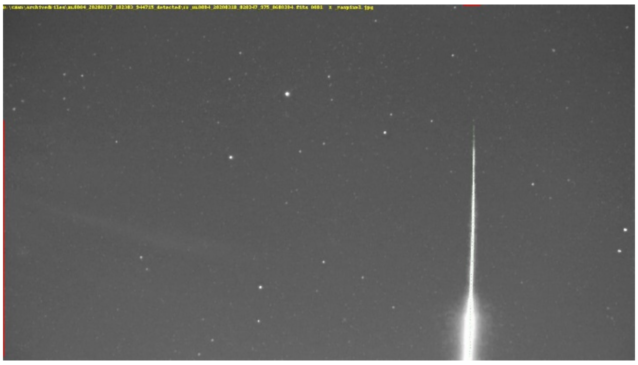

Figure 2 – Fireball of 18 March 2020 at 02^{h}03^{m}52.9^{s} UT, registered at Mechelen, Belgium on CAMS 003831 (RMS, f1.0/8mm lens, Adriana and Paul Roggemans).

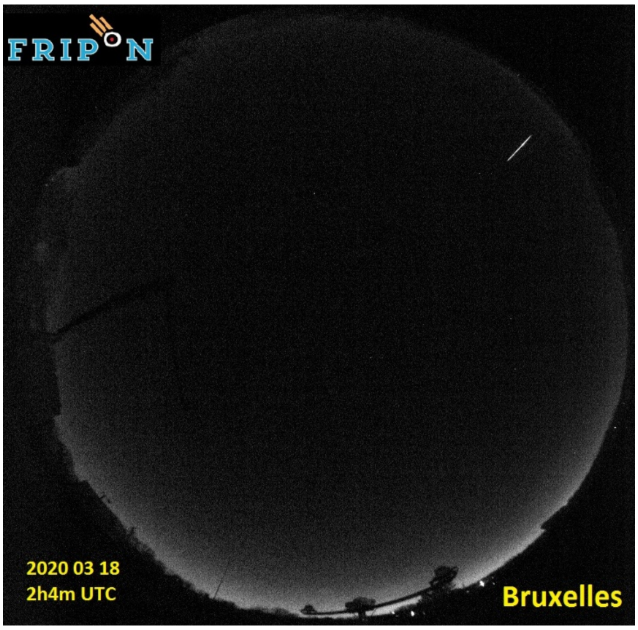

Figure 3 – Fireball of 18 March 2020 at 02^{h}03^{m}52.9^{s} UT, registered at Brussels, Belgium by FRIPON (courtesy François Colas).

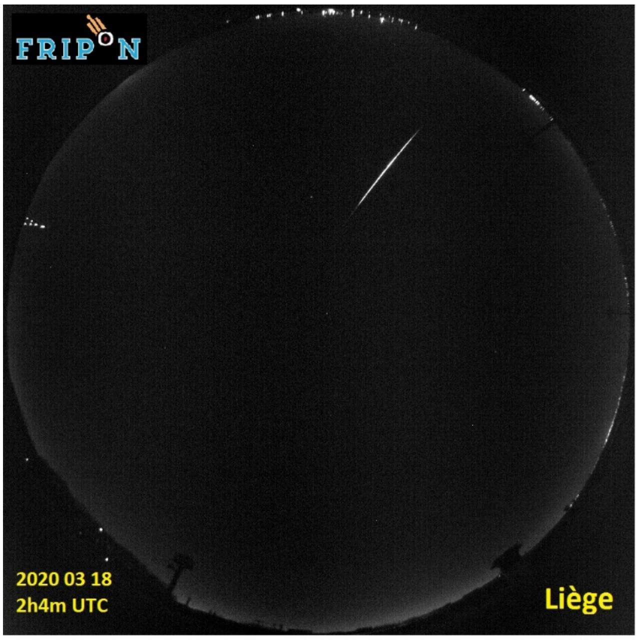

Figure 4 – Fireball of 18 March 2020 at 02^{h}03^{m}52.9^{s} UT, registered at Liège, Belgium by FRIPON (courtesy François Colas).

Figure 5 – Fireball of 18 March 2020 at $02^{h}03^{m}52.9^{s}$ UT, registered at Observatoire Centre Ardenne, Grapfontaine, Belgium on RMS BE0001 (CAMS 003814, f 0.95/3.6mm lens, Adriana and Paul Roggemans).

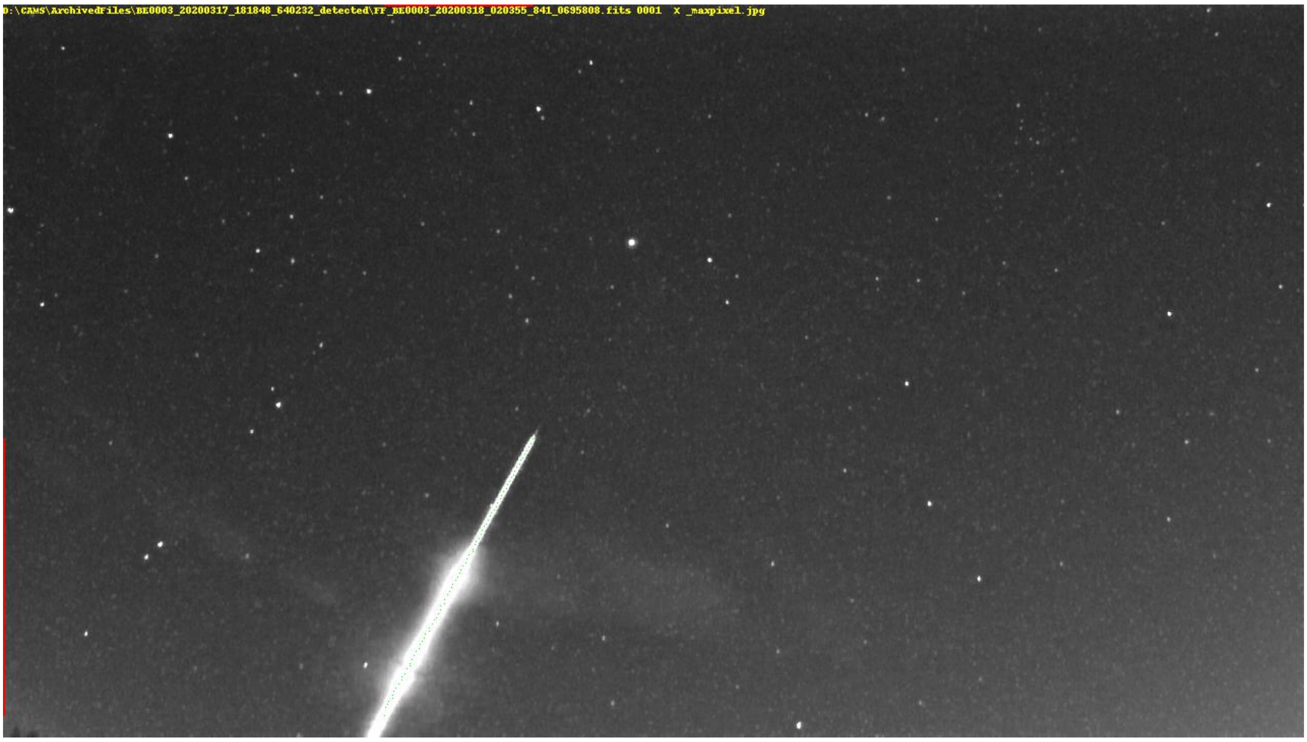

Figure 6 – Fireball of 18 March 2020 at $02^{h}03^{m}52.9^{s}$ UT, registered at Cosmodrome, Genk, Belgium on RMS BE0003 (CAMS 003815, f 0.95/3.6mm lens, Adriana and Paul Roggemans).

2 Trajectory and orbit

The fireball was registered at Nancy, France by CAMS 3901 (Tioga Gulon), at Cosmodrome, Genk, Belgium on RMS BE0003 (CAMS 003815), at Observatoire Centre Ardenne, Grapfontaine, Belgium on RMS BE0001 (CAMS 003814) and at Mechelen, Belgium on CAMS 809 and RMS BE0004 (CAMS 003831). *Figure 7* has a different color for each camera that contributed to establish the trajectory in the atmosphere and all fit well. The event started very deep in the atmosphere at less than 85 km elevation. For this reason, some cameras missed the event because it happened too low out of reach for some cameras.

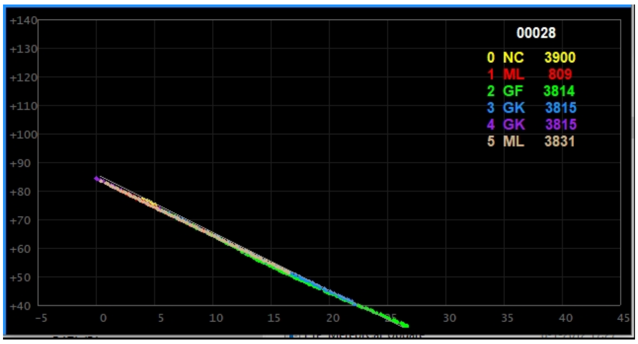

Figure 7 – The altitude and ground projection profile from CAMS Coincidence with different colors for each contributing camera (courtesy Carl Johannink).

The FRIPON all-sky cameras are less sensitive than the small FoV cameras used for CAMS, therefore FRIPON detected the fireball a bit later when it was deeper in the atmosphere and bright enough to be detected (*Figure 8*). The meteoroid encountered Earth at a very low pre-atmospheric velocity of about 12.1 km/s and suffered a very strong deceleration into the deeper layers of the atmosphere (*Figure 9*).

The trajectory as derived from the CAMS BeNeLux data has been plotted in Google Earth, combined with the trajectory obtained independently by FRIPON (*Figure 10*).

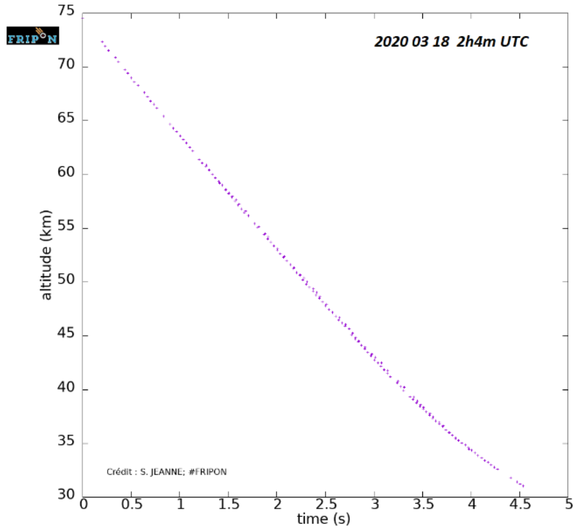

Figure 8 – The altitude in function of time as derived from the FRIPON data (courtesy François Colas).

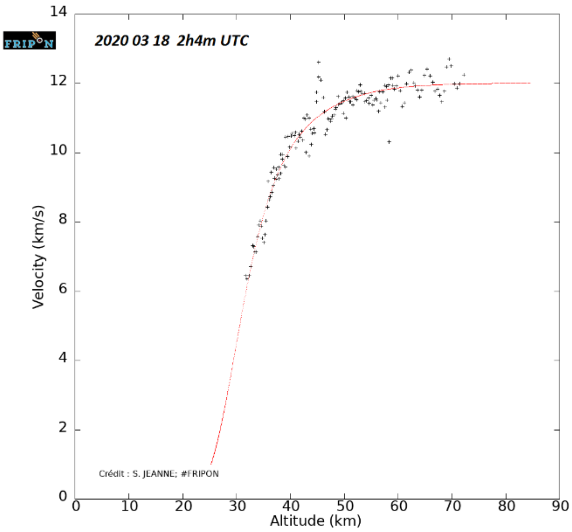

Figure 9 – The velocity in function of the altitude as derived from the FRIPON data (courtesy François Colas).

Although a –6 bright fireball in general is too bright for the cameras of the BeNeLux network because of the inaccuracy of the positions measured in the overexposed parts of the meteor, the resulting trajectory is very close to that obtained by FRIPON. If we zoom in on the projected ground track there is a small tilt that makes a difference of less than 200 meter with the begin and end point of FRIPON (*Figure 11*). CAMS detected the meteor when it was about magnitude +5 at 84 km altitude, it brightened to about –1 at 75 km where FRIPON detected it and reached maximum brightness at 60 km, where the overexposure generated pure

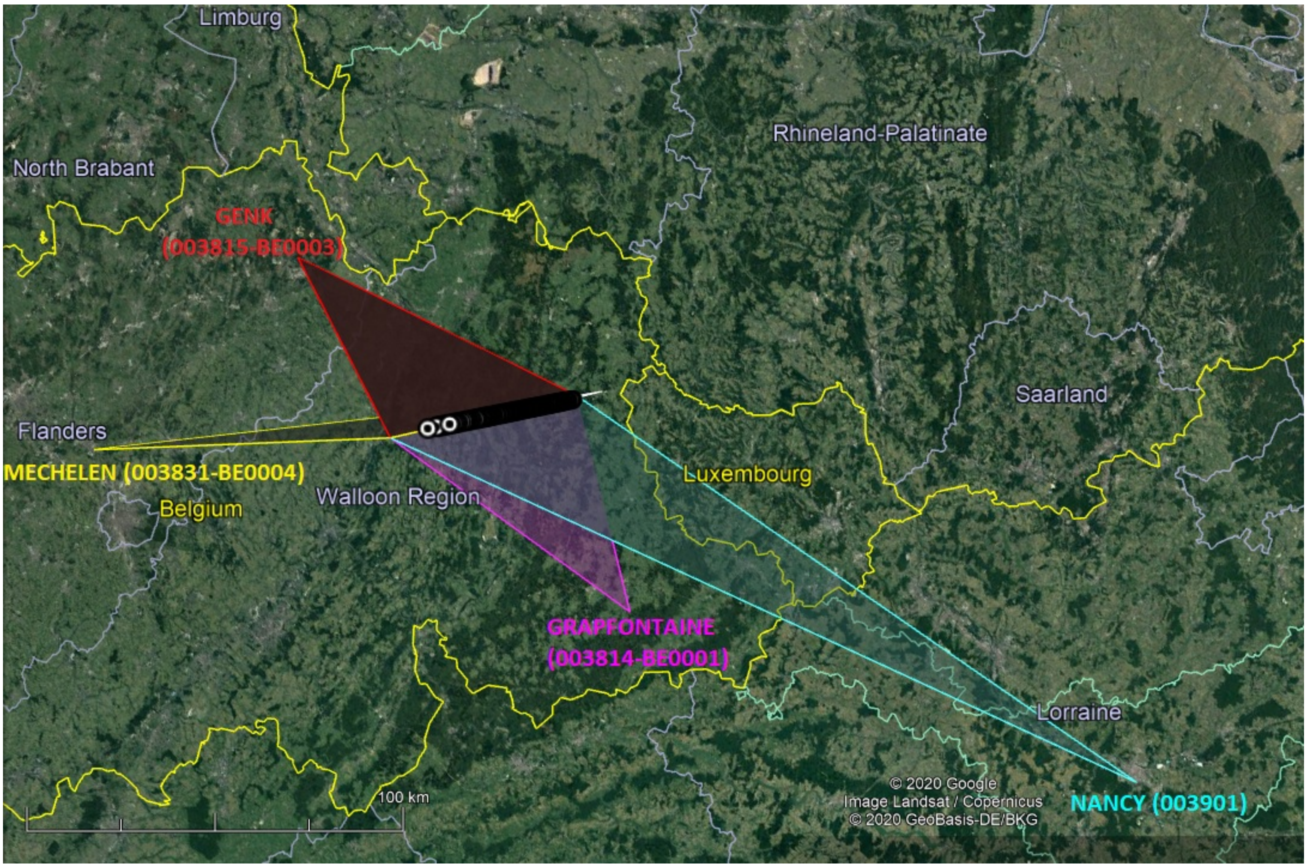

Figure 10 – The trajectory as seen from the four CAMS stations. The black line is the trajectory according to FRIPON.

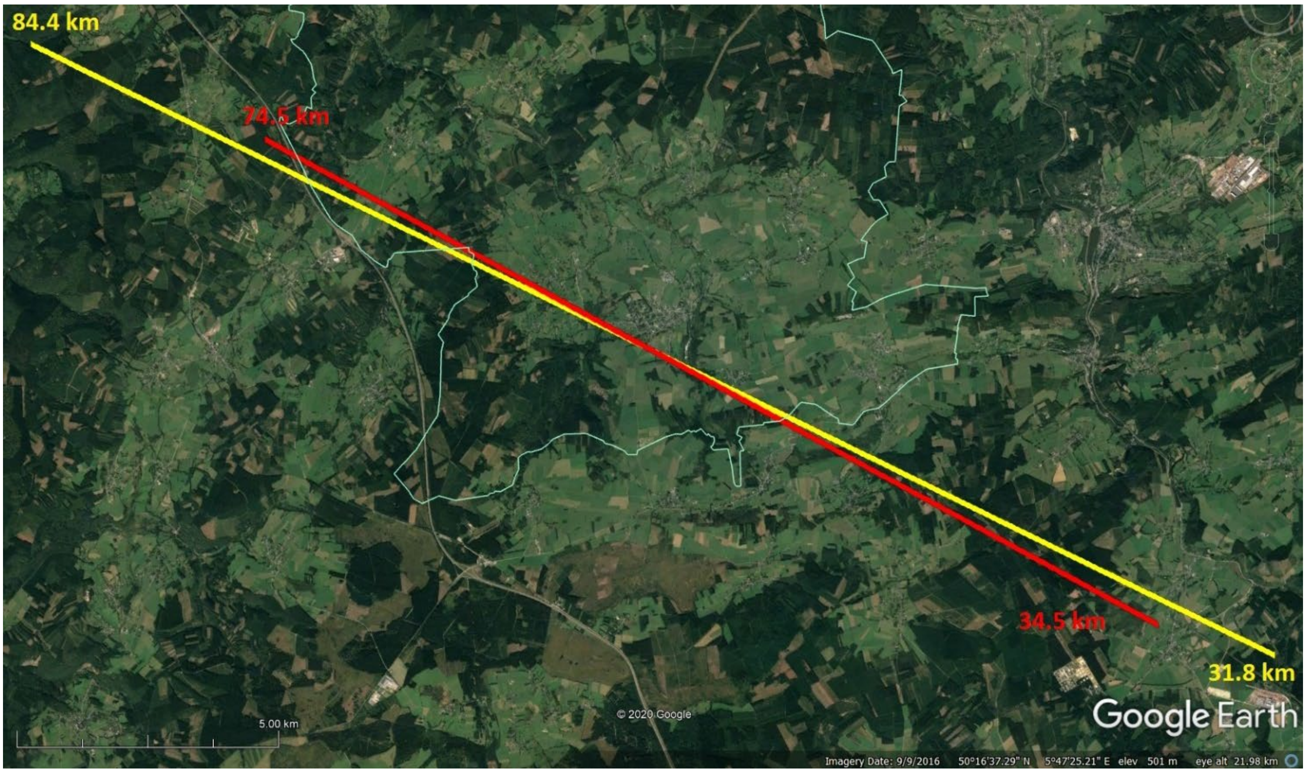

Figure 11 – The ground plot of the trajectory, the yellow according to CAMS, red according to FRIPON.

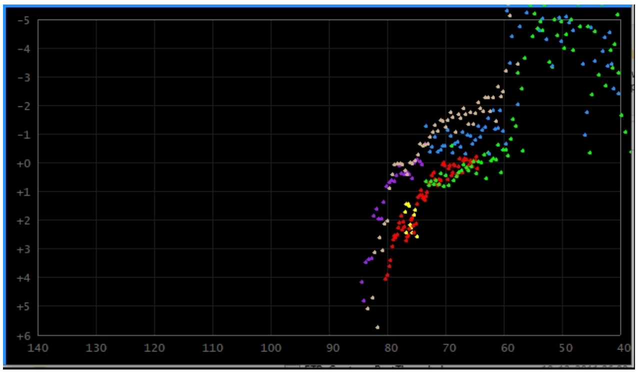

Figure 12 – Luminosity profile for CAMS with the colors corresponding to the cameras as identified in Figure 7 (courtesy Carl Johannink).

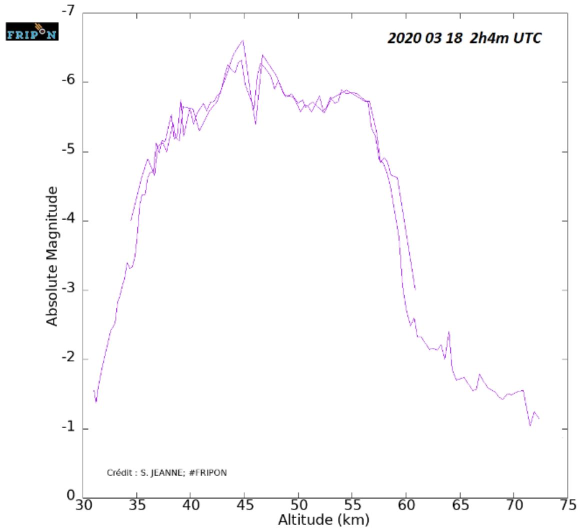

Figure 13 – Absolute magnitude profile obtained by FRIPON (courtesy François Colas).

scatter on the images of the CAMS network (*Figure 12*). The more suitable FRIPON camera for such bright events has a more reliable luminosity profile for the brightest part of the fireball path (*Figure 13*).

Table 1 summarizes the orbit data for this event. Initially, the preliminary CAMS results differed quite a lot from those of FRIPON. According to Carl Johannink this happens when partial data is used in a hurry. When all data was available the final result compares excellent to FRIPON. The Global Meteor Network rejected the event from automatic orbit calculations because of the too bright luminosity and therefore too poor accuracy of the positional measurement. The fireball is a sporadic as the orbit does not fit with any known shower.

Table 1 – Orbit of the fireball of 18 March 2020 at 02^{h}03^{m}52.9^s UT CAMS BeNeLux orbit (Carl Johannink) compared to FRIPON (François Colas).

	CAMS BeNeLux	FRIPON
α_g	144.99 ± 0.09°	–
δ_g	+57.15 ± 0.04°	–
H_b	84.4 km	74.5 km
H_e	31.8 km	34.5 km
v_∞	12.11 km/s	12.02 km/s
v_g	4.8 ± 0.01 km/s	–
a	1.28 A.U.	1.28 ± 0.01 A.U.
q	0.9877 A.U.	0.9877 ± 0.0002°
e	0.2282	0.2281 ± 0.0041
ω	196.56 ± 0.06°	196.58 ± 0.29°
Ω	357.69°	357.89 ± 0.007°
i	5.41 ± 0.01°	5.40 ± 0.06°

First of April fireballs above Belgium

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Two fireballs appeared above Belgium within a time period of 36 minutes on 2020 April 1, at 22h57m20.8s and 23h33m26.7s UT. Both were registered by cameras of the CAMS BeNeLux network, the Global Meteor Network, the FRIPON all-sky network and radio stations of the BRAMS network. The orbits did not fit with any known stream and the similarity between both orbits indicate that these were two independent sporadic events.

1 Introduction

The stacked image of RMS camera BE0001 installed in Grapfontaine at Observatoire Centre Ardenne (OCA) showed two bright parallel meteor trails that caught immediate attention (*Figure 1*, bottom). Seen from a single station such parallel appearance is often just an effect of perspective. When the results of RMS camera BE0003 installed in Genk at Cosmodrome showed the same two fireballs also parallel to each other (*Figure 1*, top), it was obvious the trajectories were really parallel in our atmosphere and thus had their radiant close to each other.

The first fireball appeared at $22^h57^m20.8^s$ UT, the second one at $23^h33^m26.7^s$ UT, about 36 minutes apart. Although the trajectories of the fireballs occurred within a small part of our atmosphere, the pre-atmospheric particles were far apart in space as Earth moved about 65000 km on its orbit in between the two times of appearances.

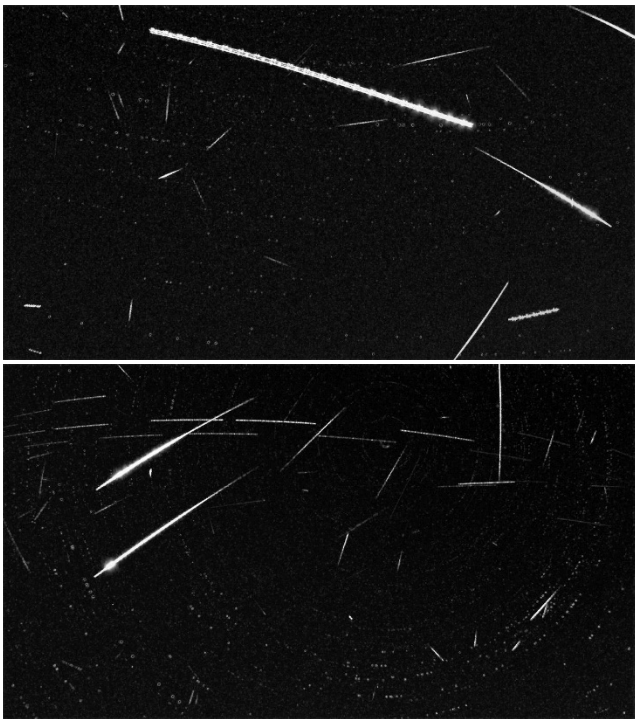

Figure 1 – The stacked images of RMS camera BE0003 (top) and BE0001 (bottom). The first fireball ($22^h57^m20.8^s$ UT) is at right middle on BE0003 and the upper one at left on BE0001, the second fireball ($23^h33^m26.7^s$ UT) is in the upper right corner on BE0003 and the lower one at left on BE0001.

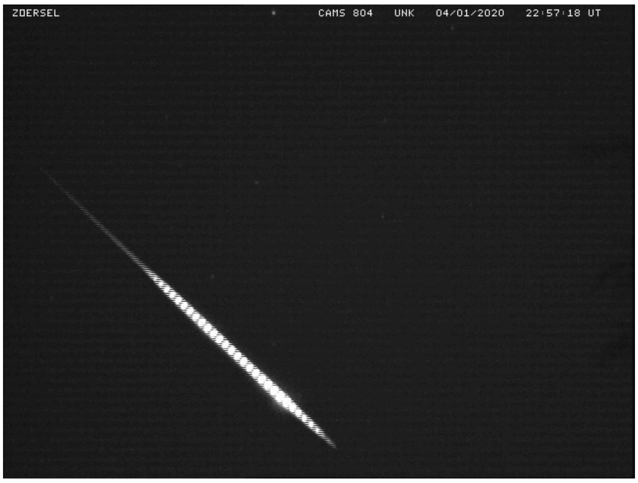

Figure 2 – The fireball of $22^h57^m20.8^s$ UT as registered on CAMS 804 in Zoersel, Belgium (credit Bart Dessoy).

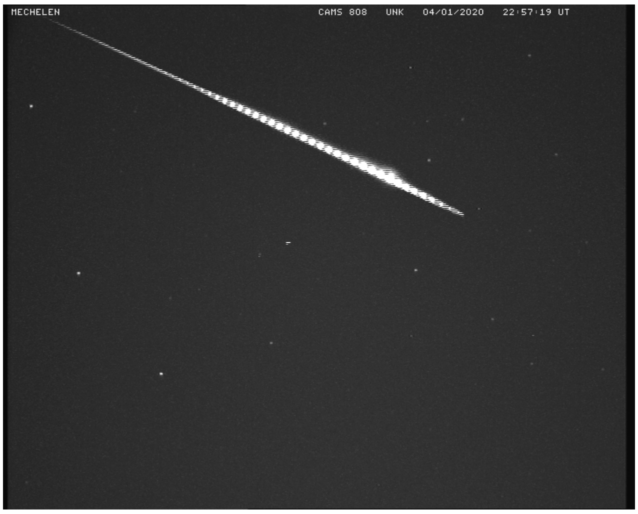

Figure 3 – The fireball of $22^h57^m20.8^s$ UT as registered on CAMS 808 in Mechelen, Belgium (credit Luc Gobin).

2 Trajectory and orbit

The event at $22^h57^m20.8^s$ UT was also registered by four FRIPON all-sky cameras at Rouen (FRNO05), Oostkapelle (NLWN02), Liège (BEWA01) and Brussels (BEBR01). The second event at $23^h33^m26.7^s$ UT was registered by three FRIPON all-sky cameras at Brussels (BEBR01), Oostkapelle (NLWN02) and Liège (BEWA01). The orbital elements obtained by FRIPON are compared with those obtained by CAMS and the Global Meteor Network in *Table 1* and *Table 2*.

Figure 4 – The fireball of $22^h57^m20.8^s$ UT as registered on CAMS 3814 in Grapfontaine, Belgium (Adriana and Paul Roggemans).

Figure 5 – The fireball of $22^h57^m20.8^s$ UT as registered on CAMS 3815 in Genk, Belgium (Adriana and Paul Roggemans).

The RMS cameras 3814 and 3815 also serve as BE0001 and BE0003 in the Global Meteor Network for which the trajectories and orbits are calculated independently. The results obtained by the GMN can be consulted online[20]. The first fireball appeared nicely in the FoV of both BE0001 in Grapfontaine and BE0003 in Genk, while the second fireball was caught entirely on BE0001 but only partially in the corner of the FoV of BE0003.

GMN has a very decent orbit for the first fireball of $22^h57^m20.8^s$ UT, while the $23^h33^m26.7^s$ UT event resulted in a hyperbolic orbit. The less accurate result for the second can be explained as a result of the unfavorable registration in the corner of the FoV on one camera. Although the CAMS orbits are based on positional data from several cameras at different stations, CAMS coincidence results for both fireballs in a hyperbolic orbit. (See *Table 1* and *Table 2*).

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[20] https://globalmeteornetwork.org/data/

Figure 6 – The fireball of $23^h33^m26.7^s$ UT as registered on CAMS 3914 in Grapfontaine, Belgium (Adriana and Paul Roggemans).

Figure 7 – The fireball of $22^h57^m20.8^s$ UT as registered on CAMS 3900 in Nancy, France (credit Tioga Gulon).

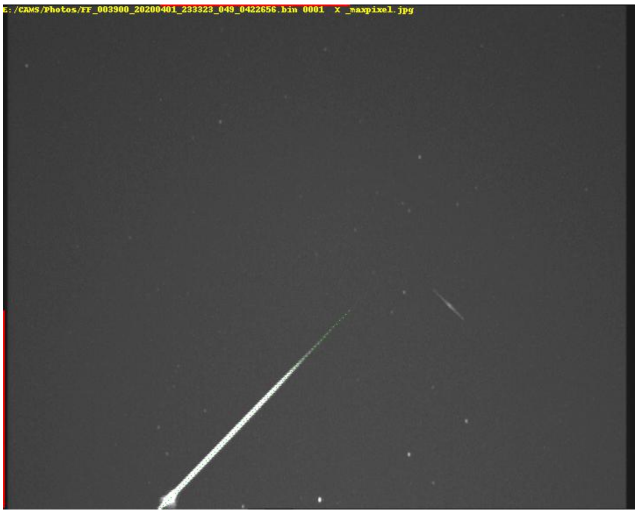

Figure 8 – The fireball of $23^h33^m26.7^s$ UT as registered on CAMS 3900 in Nancy, France (credit Tioga Gulon).

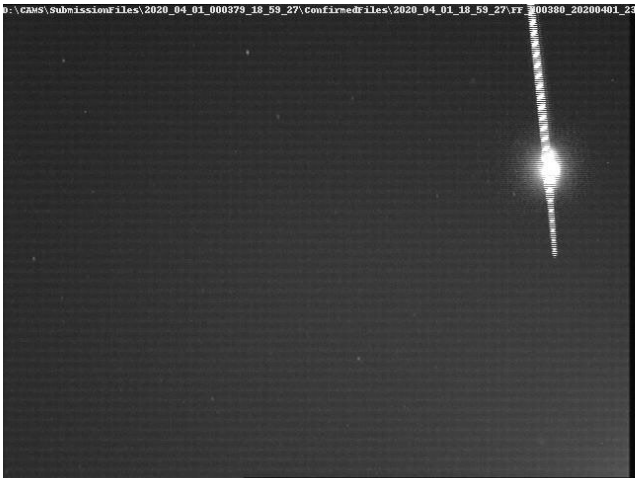

Figure 9 – The fireball of $23^h33^m26.7^s$ UT as registered on CAMS 380 in Wilderen, Belgium (credit Jean-Marie Biets).

Figure 10 – The fireball of $22^h57^m20.8^s$ UT as registered on CAMS 814 in Grapfontaine, Belgium.

Figure 11 – The fireball of 22^{h}57^{m}20.8^{s} UT as registered on CAMS 815 in Grapfontaine, Belgium.

Figure 12 – The fireball of 23^{h}33^{m}26.7^{s} UT as registered on CAMS 815 in Grapfontaine, Belgium.

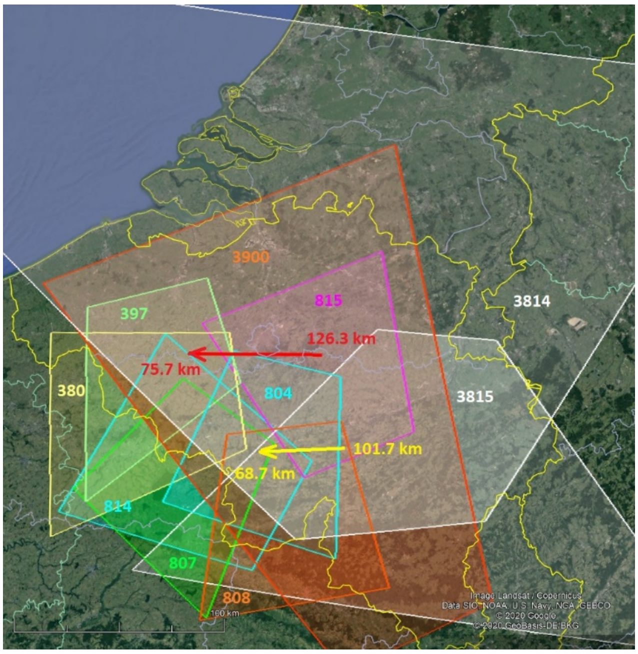

Figure 13 – The trajectories of both fireballs projected on the ground, the 22^{h}57^{m}20.8^{s} UT event is marked in yellow, the 23^{h}33^{m}26.7^{s} UT event is marked in red. The FoV for the 10 cameras involved have been intersected at 90 km elevation and projected to the ground.

Table 1 – Orbits of the fireball of 1 April 2020 at 22^{h}57^{m}20.8^{s} UT as obtained by CAMS BeNeLux (Carl Johannink) compared to GMN (Denis Vida) and FRIPON (François Colas).

	CAMS	GMN	FRIPON
α_g	245.1°	245.7°	245.2°
δ_g	+29.9°	+30.0°	+30.4°
H_b	101.7 km	99.8 km	–
λ_b	4.9438° E	4.9158° E	–
φ_b	50.3745° N	50.3711° N	–
H_e	68.74 km	70.1 km	–
λ_e	4.3746° E	4.3902° E	–
φ_e	50.3566° N	50.3509° N	–
v_∞	47.8 km/s	46.7 km/s	–
v_g	46.5 km/s	45.1 km/s	46 km/s
a	∞	19.9 A.U.	12.6 A.U.
q	0.7563 A.U.	0.7559 A.U.	0.7550 A.U.
e	1.0448	0.9620	0.940
ω	238.41°	239.81°	240.33°
Ω	12.3977°	12.3997°	12.400°
i	74.81°	73.88°	73.47°
T_J	–	0.56	0.71

Table 2 – Orbits of the fireball of 1 April 2020 at 23^{h}33^{m}26.7^{s} UT as obtained by CAMS BeNeLux (Carl Johannink) compared to GMN (Denis Vida) and FRIPON (François Colas).

	CAMS	GMN	FRIPON
α_g	252.7°	252.8°	252.7°
δ_g	+27.4°	+27.2°	+27.3°
H_b	126.25 km	119.4 km	–
λ_b	4.7686° E	4.6445° E	–
φ_b	50.7757° N	50.7724° N	–
H_e	75.67 km	78.5 km	–
λ_e	3.8518° E	3.8849° E	–
φ_e	50.7815° N	50.7771° N	–
v_∞	51.5 km/s	51.2 km/s	–
v_g	50.3 km/s	49.7 km/s	51 km/s
a	∞	∞	83.97 A.U.
q	0.8085 A.U.	0.8032 A.U.	0.8030 A.U.
e	1.0511	1.002	0.990
ω	231.17°	232.58°	232.78°
Ω	12.424°	12.424°	12.424°
i	84.85°	84.6°	84.98°
T_j	–	–	0.16

Although the ground projections of the trail appear remarkable parallel to each other (*Figure 13*) and also the entrance angle differed only few degrees, the orbits as listed in *Table 1* and *Table 2* do not fit well for the similarity criteria. With D_D ~0.1 and D_{SH} ~0.24 the criteria are at the very limit of what could point at a common origin. None of both orbits fit with any known stream in the IAU meteor shower list. The two fireballs are likely sporadics which appeared by pure chance within a small portion of the atmosphere in a time range of 36 minutes.

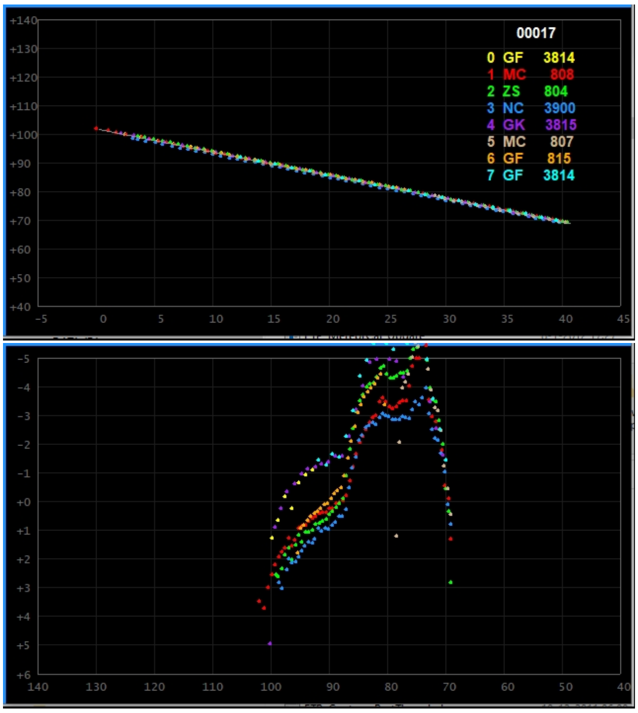

Figure 14 – The CAMS height profile (top) and intensity profile (bottom) for all the cameras involved with the fireball of $22^{h}57^{m}20.8^{s}$ UT.

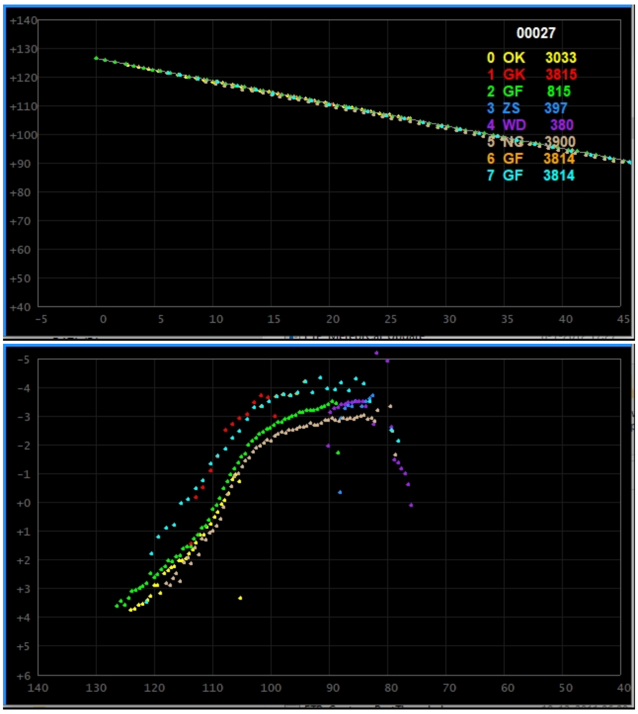

Figure 15 – The CAMS height profile (top) and intensity profile (bottom) for all the cameras involved with the fireball of $23^{h}33^{m}26.7^{s}$ UT.

The velocity of both fireballs is close to the hyperbolic limit, in such case the slightest inaccuracy on the measured duration and or position can make the difference between a high eccentric ellipsoid and a hyperbolic orbit. *Figures 14 and 15* display the height profiles and intensity profiles with all measured points for both fireballs for each camera involved. These profiles agree very well and reveal no significant mistakes.

3 The radio echo data

The fireballs were also detected by the radio observers network BRAMS. The event at $22^{h}57^{m}20.8^{s}$ produced only a weak overdense echo which was only detected by stations in the eastern part of Belgium, barely visible for stations in the center and nothing at all at stations in the western part of Belgium (*Figure 16*). The $23^{h}33^{m}26.7^{s}$ event caused a much stronger echo, saturating some receivers and registered by most BRAMS stations except for those in the west of Belgium (*Figure 17*) (source Hervé Lamy).

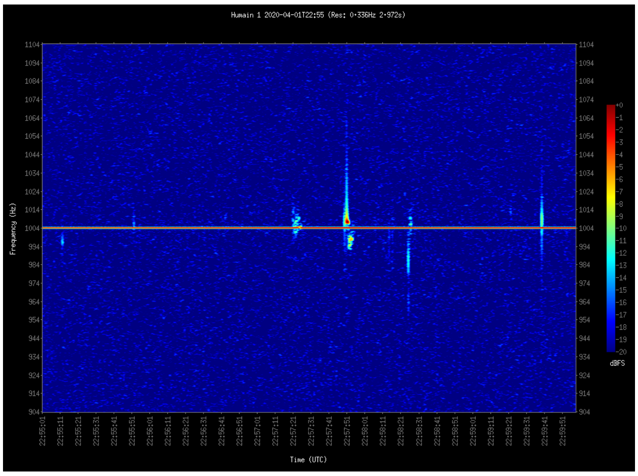

Figure 16 – Spectrogram of the BRAMS station in Humain with the echo of the $22^{h}57^{m}20.8^{s}$ UT event in the middle (just left from the strongest one) (credit Hervé Lamy).

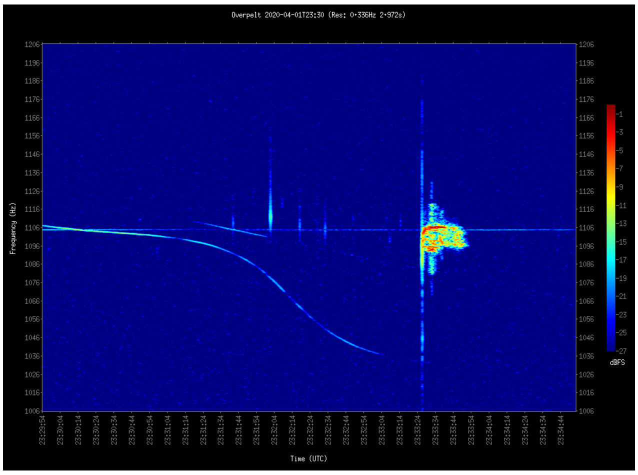

Figure 17 – Spectrogram of the BRAMS station in Overpelt with the echo of the $23^{h}33^{m}26.7^{s}$ UT (credit Hervé Lamy).

Acknowledgment

The author wishes to thank *François Colas* for providing the FRIPON data, *Hervé Lamy* for providing the BRAMS data, *Carl Johannink* for providing the CAMS data, *Denis Vida* for making available the Global Meteor Network orbit data and last but not least all the participating camera operators in the BeNeLux CAMS network who contributed to this result.

CAMS and Skysentinel observe April fool's day bolide in Florida

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A fireball was registered above Florida, US on 1st of April at 04h31m42.879s UT and its trajectory and orbit could be calculated.

1 Introduction

CAMS and Spalding All-Sky Network ("SkySentinel") low-light light level video cameras in Florida captured a bolide on 1 April 2020 (April Fool's Day) brighter than the first-quarter moon. Witnessed by eighteen sky watchers in Florida and Georgia, American Meteor Society tagged this event as #1532-2020.

Figure 1 – CAMS 5000 (Gainesville, Florida) registered the April 1 fireball at $04^h31^m42.880^s$ UT.

SkySentinel Node 10 (Newberry, Florida) all-sky camera saw the entire trajectory of the bolide, from first appearance until terminal explosion. The object first appeared at $04^h31^m42.879^s$ and remained in view until its explosion at $04^h31^m44.008^s$ UT. The bolide's terminal explosion was brighter than the first-quarter moon, which was then sitting in the western sky.

CAMS 5000 (Gainesville, Florida) also tracked the bolide during the early part of its trajectory. The bolide appeared at $04^h31^m42.880^s$, staying inside the field of view until $04^h31^m43.280^s$ UT. Three-quarters of a second after exiting the camera's field of view, the sky flash of the exploding bolide illuminated the camera's field of view.

Video cameras at other CAMS-Florida sites also saw the sky flash of the exploding bolide. These included BarJ Observatory (New Smyrna Beach), College of Central Florida (Ocala), Florida Institute of Technology (Melbourne) and CAMS-Ocklawaha.

CAMS 5042 (Ocklawaha, Florida) briefly saw what was left of the bolide after it exploded. The bolide remnant entered the camera's field of view (through clouds) at $04^h31^m44.181^s$, disappearing one-tenth of a second later at $04^h31^m44.298^s$.

2 Trajectory and orbit

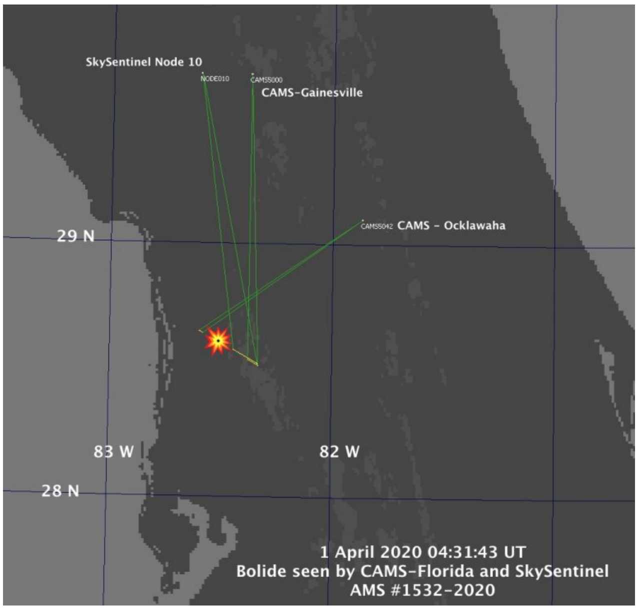

Figure 2 – The fireball trajectory relative to the camera stations.

From start to finish, the bolide's duration was 1.42 seconds. This was a sufficient duration to calculate the bolide's trajectory using UFOOrbit software:

- $q = 0.317$
- $a = 2.12$ AU
- $e = 0.850$
- $i = 21.51°$
- $\omega = 299.11°$
- $\Omega = 11.643°$
- Epoch (JD) = 2458940.688691

The orbit was checked with all known meteor streams and appears to be sporadic.

On a scale of 0 to 1, the quality parameter of the computed orbit was QA = 0.508. Because the longitude of the object's ascending node was in the same direction as the Sun, it is apparent that the bolide was descending through the ecliptic plane when it collided with Earth.

To simulate the meteoroid's pre-impact orbit, its orbital parameters were entered into Starry Night Pro Plus 8 planetarium software. With a calculated period of 3.08 years, it had nearly a 4:1 commensurability with Jupiter, coming within 2–3 AU of the giant planet in 1991, 2003, and 2015. Jupiter's gravity may have shifted the object's orbit, putting it on a collision course with Earth.

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