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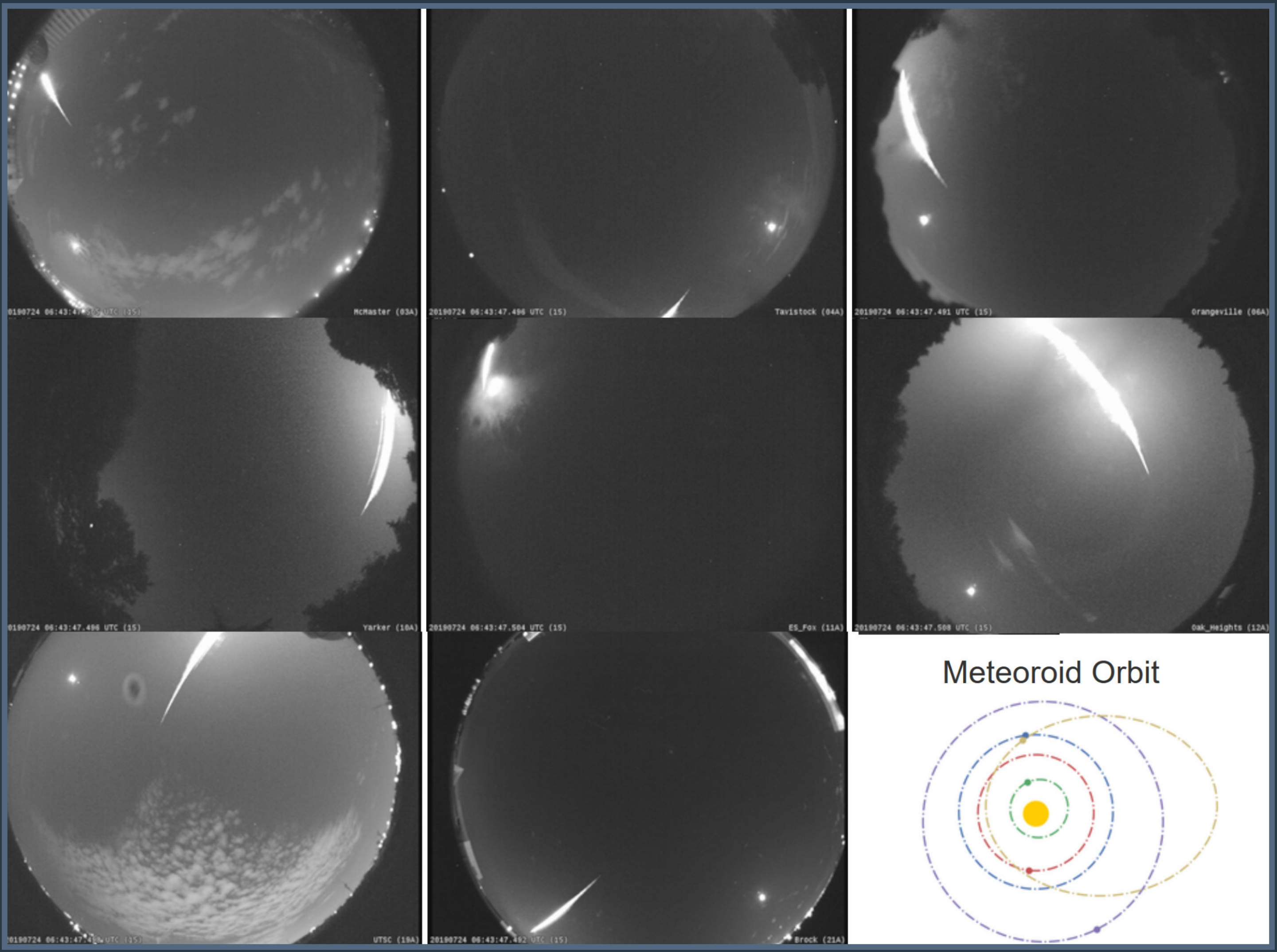

Images taken by the array of all-sky cameras belonging to the University of Western Ontario that recorded the 2019 July 24 at 06h43m40s UTC fireball

- Outburst 15 Bootids
- June epsilon Ophiuchids
- 2018 Geminids analysis
- Meteorite in Morocco
- Radio observations
- Fireballs

Contents

June epsilon Ophiuchids (JEO#459), 2019 outburst and an impactor?

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The recent enhanced activity of the June epsilon Ophiuchids (JEO#459) in 2019 June 19 to 24 and the case study on the available video meteor orbits for 2006-2018 provide sufficient evidence to add this shower as an established meteor shower. Annual activity has been registered during each year. The highest numbers of orbits in past years were recorded at solar longitude 87.5°, about 4.5 days earlier than the middle of the time span with enhanced activity recorded in 2019. A number of other minor showers may be associated and form a dispersed complex with the JEO#459 shower. A possible link with the impacting minor planet 2019 MO requires caution and remains to be proven.

1 Introduction

Checking regularly the radiant map of the global CAMS project[1] A remarkable concentration of radiants caught my attention on the nights around 21–22–23 June at the position of the yet unconfirmed minor meteor shower of the June epsilon Ophiuchids (JEO#459).

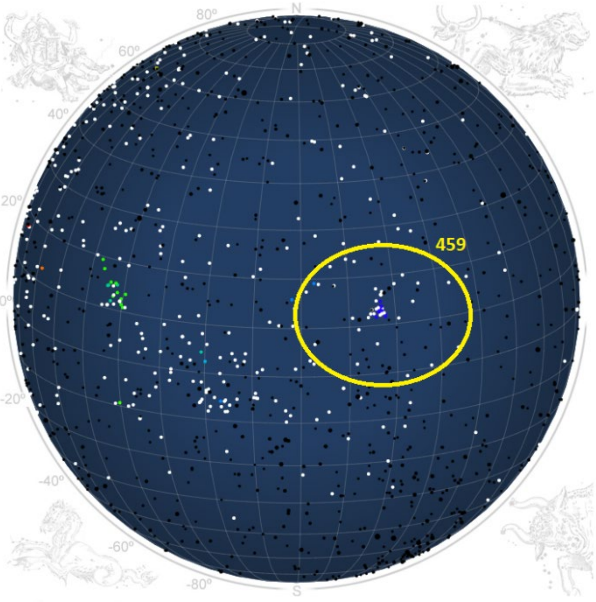

Figure 1 – Screenshot of the CAMS radiant plot for the night of 2019 June 23 with the blue radiants identified as June epsilon Ophiuchids (JEO#459). Some of the white dots may actually be shower members too, but that failed in the similarity criteria.

This shower was first detected in meteor stream searches on video meteor orbits (Rudawska and Jenniskens, 2014; Kornos et al., 2014). The shower was detected again in the CAMS data 2011–2012 (Jenniskens et al., 2016). The number of orbits, 11 was rather low. A new search on the larger CAMS dataset 2011–2016 had a total of 24 similar orbits (Jenniskens et al., 2018). The preliminary CAMS data for 2019 has more JEO#459 orbits than all previous years together. Therefore, it looks appropriate to look-up what we have about this shower from previous years.

The type of orbit with short period and low inclination in the ecliptic is rather tricky to identify with any discrimination criteria because of the dense dust concentration in this part of the Solar System. There are many meteoroids on very similar orbits which are just sporadics.

2 Available orbit data to search

We have the following orbit data collected over 12 years, status as until June 2019, available for our search:

- EDMOND EU+world with 317830 orbits (until 2016). EDMOND collects data from different European networks which altogether operate 311 cameras (Kornos et al., 2014).
- SonotaCo with 284138 orbits (2007–2018). SonotaCo is an amateur video network with over 100 cameras in Japan (SonotaCo, 2009).
- CAMS with 110521 orbits (October 2010 – March 2013), (Jenniskens et al., 2011). For clarity, the CAMS BeNeLux orbits since April 2013 are not included in this dataset because this data is still under embargo.

In total 712489 video meteor orbits are publicly available. Our methodology to detect associated orbits has been explained in a previous case study (Roggemans et al., 2019).

3 A preliminary search

In order to locate the position where a concentration of June epsilon Ophiuchids orbits can be found, we take some sample JEO orbits to determine the range in time, radiant

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

area and velocity interval where we can find these orbits within a low threshold similarity criterion. This results in:

- Time interval: $53° < \lambda_O < 210°$;
- Radiant area: $199° < \alpha_g < 267°$ & $-47° < \delta_g < +33°$;
- Velocity: 7 km/s $< v_g < 20$ km/s.

We have 1352 orbits that fit these selections. The D-criteria that we use are these 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: $D_{SH} < 0.05$ & $D_D < 0.02$ & $D_H < 0.05$.

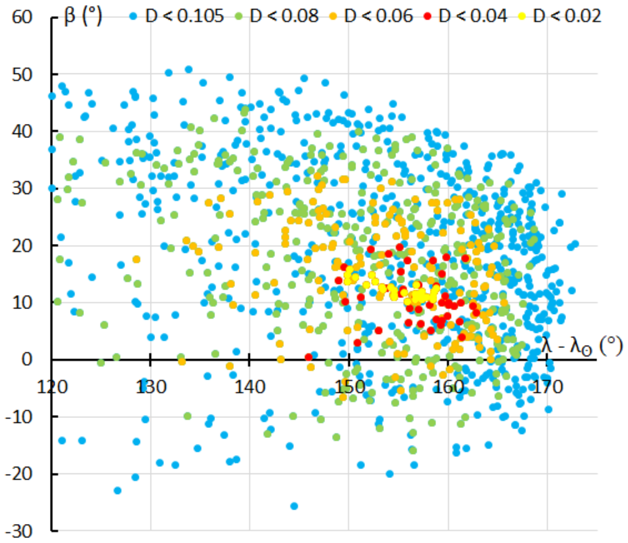

Figure 2 – Plot of the ecliptic latitude β against the Sun centered longitude λ – λ⊙. The different colors represent the 5 different levels of similarity.

Table 1– The average values for the preliminary selection of orbits for the four different threshold levels on the D-criteria, compared to a reference orbit from literature for the shower JEO#459.

	Low	Medium low	Medium high	High	Jenniskens et al. (2018)
λ_O	93.1°	89.7°	88.3°	87.7°	90.0°
α_g	244.2°	244.1°	244.4°	244.8°	245.0°
δ_g	–1.9°	–4.7°	–8.3°	–9.8°	–8.9°
v_g	14.0	14.0	14.3	14.3	13.9
a	2.4	2.4	2.4	2.47	2.50
q	0.883	0.881	0.872	0.865	0.877
e	0.632	0.637	0.643	0.650	0.649
ω	220.8°	224.7°	228.4°	231.2°	229.3°
Ω	98.2°	93.5°	90.3°	88.6°	90.1°
i	6.5°	5.9°	5.5°	4.6°	4.9°
N	1352	586	228	71	24

In a first approach we calculate the average orbit for this set, using the calculation method explained by Jopek et al. (2006). *Table 1* lists the resulting average orbit for each similarity threshold level in our preliminary sample of orbits. *Figure 2* shows the huge radiant scatter for these orbits in Sun centered ecliptic coordinates.

Both the time interval and the radiant area are huge, in fact too big to apply our method to locate a concentration of orbits. This type of short period orbits with low inclination near the ecliptic has a high risk to match with sporadic orbits that look similar by chance. Therefore, it is more appropriate to resample the range to search, but based on the high threshold similarity criterion, rather than on the low similarity criterion like done above.

4 Focus on the core of the shower

Sample orbits within the high threshold ($D_{SH} < 0.1$ & $D_D < 0.04$ & $D_H < 0.1$) occur within the following time interval, radiant position and velocity range:

- Time interval: $78° < \lambda_O < 102°$;
- Radiant area: $236° < \alpha_g < 251°$ & $-21° < \delta_g < -1°$;
- Velocity: 12 km/s $< v_g < 16$ km/s.

Selecting all orbits that we have for this interval in solar longitude we find 20952 orbits among our 712489 video meteor orbits. Only 121 orbits have the geocentric radiant position and geocentric velocity within the listed range.

Starting our shower search routine on this dataset with 121 orbits just two iterations are necessary to get a reference orbit averaged with the method of Jopek et al. (2006). The results are shown in *Table 2*. Only two orbits fail in the low threshold criteria.

Table 2– The average values for the final selection of orbits for the five different threshold levels on the D-criteria. The values can be compared to the orbit for the shower JEO#459 from literature listed in Table 1.

	Low	Medium low	Medium high	High	Very High
λ_O	87.4°	87.2°	87.2°	87.4°	87.0°
α_g	244.7°	244.7°	244.8°	244.8°	244.2°
δ_g	–10°	–10.2°	–10.2°	–9.9°	–9.9°
v_g	14.4	14.4	14.4	14.4	14.4
a	2.40	2.38	2.38	2.41	2.45
q	0.861	0.859	0.858	0.859	0.860
e	0.641	0.638	0.640	0.643	0.649
ω	232.0°	232.4°	232.7°	232.1°	232.3°
Ω	87.8°	87.5°	87.5°	87.9°	87.1°
i	4.1°	4.2°	4.2°	4.5°	4.6°
N	119	114	109	75	27

Figure 3 shows the radiant plot in Sun centered ecliptic coordinates. Even the high threshold orbits display a large scatter on the radiant positions which is typical for such low

velocity shower with this type of orbit. However, the position of the radiant for the averaged orbit of each threshold level are all five at about the same position (marked as triangles in *Figure 3*). The only significant difference with the orbit from literature is time related in solar longitude, ascending node and argument of perihelion.

The diffuse nature of this kind of radiants makes it difficult to detect any radiant drift. The plots in Sun centered ecliptic coordinates neutralizes the effect of the radiant drift for orbits obtained at a different time in solar longitude. The radiant size has more than 20° in diameter. *Figure 4* shows the same plot as *Figure 3*, but with a color gradient to mark the variation in geocentric velocity. The speed of the JEO meteoroids in *Figure 4* is slower at left and faster at right compared to the median value.

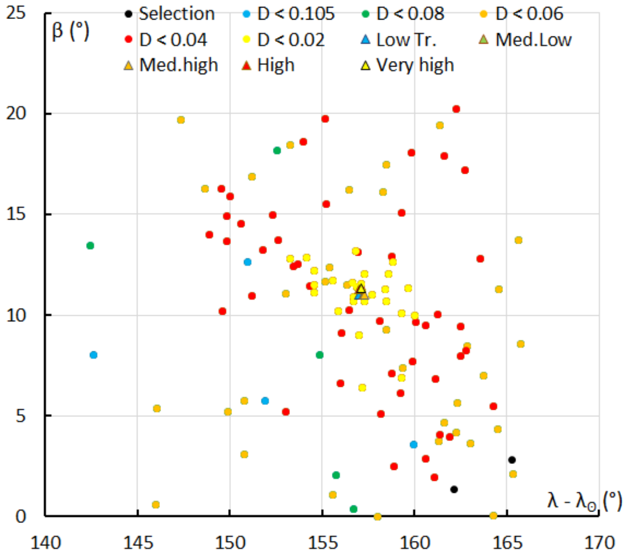

Figure 3 – Plot of the ecliptic latitude β against the Sun centered longitude $\lambda - \lambda_{\odot}$. The different colors represent the 5 different levels of similarity. The triangles mark the radiant for the average orbit of each threshold level.

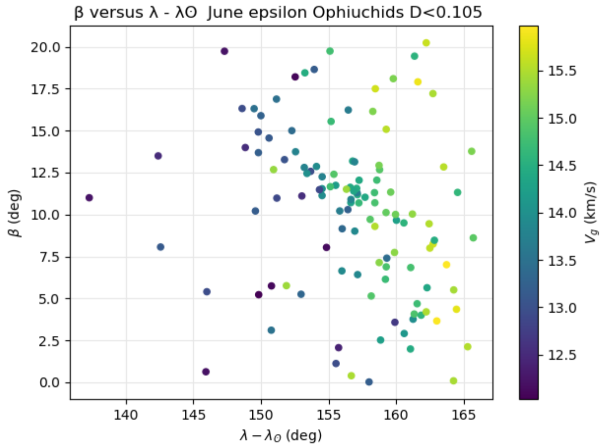

Figure 4 – Plot of the ecliptic latitude β against the Sun centered longitude $\lambda - \lambda_{\odot}$ (°) for the 119 JEO orbits that fulfill the low threshold similarity criteria with a color gradient to display the variation in the velocity v_g.

If we look at the number of orbits we have available for each year since 2006 in the time interval: $78° < \lambda_{\odot} < 102°$and the number of JEO#459 orbits per year, we can conclude from *Table 3* that the shower produces annual activity. Because of the small numbers of shower meteors there is no significant statistical variation in activity from year to year. On average 0.6% of all orbits collected during these nights fit the discrimination criteria for association with the JEO#459.

Table 3 – Number of orbits available for each year in the time interval: $78° < \lambda_{\odot} < 102°$, and the percentage of JEO#459 orbits.

Year	JEO orbits	All orbits	%
2006	1	26	3.8%
2007	2	277	0.7%
2008	1	454	0.2%
2009	6	641	0.9%
2010	8	880	0.9%
2011	24	3745	0.6%
2012	32	5650	0.6%
2013	8	1949	0.4%
2014	13	2074	0.6%
2015	6	1755	0.3%
2016	14	2482	0.6%
2017	2	567	0.4%
2018	2	452	0.4%
Total	119	20952	0.6%

Table 4 – Number of orbits available for each of the three contributing networks in the time interval: $78° < \lambda_{\odot} < 102°$.

Network	Total number of orbits	JEO orbits	%
SonotaCo	3957	24	0.6%
CAMS	6443	33	0.5%
EDMOND	10552	62	0.6%
Total	20952	119	

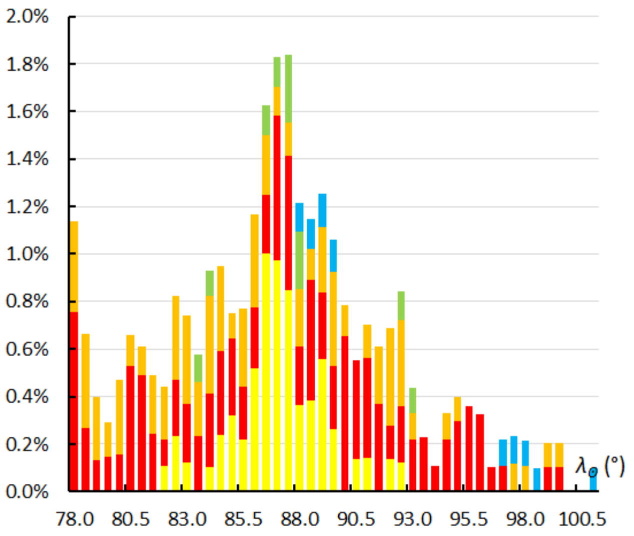

Figure 5 – The relative number of accumulated JEO orbits collected per 1° of solar longitude in steps of 0.5° during the years 2006–2018, with blue for $D_D < 0.105$, green for $D_D < 0.08$, orange for $D_D < 0.06$, red for $D_D < 0.04$ and yellow for $D_D < 0.02$, as percentage compared to the total number of non-JEO orbits, collected in the same time span.

When we look at the total number of available orbits for each of the three main networks we get at about the same percentage of 0.6% for each network (*Table 4*).

Although the numbers of JEO#459 orbits are rather small, we may try to pinpoint the time with the highest number of JEO#459 orbits as the most likely time of a shower maximum. *Figure 5* shows the distribution in time of the number of JEO-orbits collected for each degree in solar longitude during the period 2006 until 2018. Best numbers of orbits were recorded at about λ_O = 87.5° or 2019 June 19.4, 2.5 day before the maximum given in literature (Jenniskens et al., 2018) and 4.7 days earlier than half way the 4 days long enhanced activity of 2019.

Looking at the absolute magnitude of the 119 JEO#459 meteoroids in this case study, the shower was rather deficient in bright meteors with only 13 events with M_{abs} brighter than –3 with the brightest case $M_{abs} = –4.5$. In the past this shower was completely deficient in exceptional bright meteors.

5 The 2019 JEO outburst

Peter Jenniskens (2019) reported the unusual activity of the June epsilon Ophiuchids (JEO#459) between June 19^d08^h and 26^d05^h UT. Most activity was recorded between solar longitude 89.3° and 93.3°, centered around 92.1°. In total 88 JEO#459 orbits were collected by CAMS New Zealand (coordinated by *J. Baggaley*), CAMS South Africa (coordinated by *T. Cooper*), CAMS BeNeLux (coordinated by *C. Johannink*), CAMS Florida (coordinated by *A. Howell*), LO-CAMS in Arizona (coordinated by *N. Moskovitz*), and CAMS California (coordinated by *P. Jenniskens* and *D. Samuels*)[2]. This is an impressive number compared to the 24 orbits collected in the previous CAMS stream search on the data for the years 2011 until 2015. The 2019 CAMS orbits had the following median orbital elements:

- $\lambda_O = 92.11°$
- $\alpha_g = 245.2° \pm 1.3°$
- $\delta_g = –7.4° \pm 2.0°$
- $v_g = 14.2 \pm 1.1$ km/s
- $a = 2.69 \pm 0.52$ AU
- $q = 0.885 \pm 0.011$ AU
- $e = 0.671$
- $\omega = 227.3° \pm 1.9°$
- $\Omega = 92.2° \pm 1.1°$
- $i = 5.3° \pm 0.9°$
- $N = 88$

Also, the NASA fireball network registered enhanced activity of this shower with the ASGARD system with the June epsilon Ophiuchids being responsible for 50% of the fireball detections in the period June 22–24. In total 8 JEO's with an orbit were collected.

Peter Eschman and *Dimitrii Rychkov* of the Global Meteor Network also report registration of JEO#459 orbits. *Dimitrii Rychkov* at the Krasnodar Region, Russia listed 10 JEO#459 orbits recorded between solar longitude 92.75° and 92.9°.

No outburst was noticed by CMOR, but the slow velocity is not very radar friendly and it would require a special analysis to check if even weak activity can be found in the radar data (Brown, 2019).

6 JEO outburst related with impact?

A small asteroid was found by the Atlas Project Survey[3] on 2019 June 22.40. The Minor Planet Center attributed 2019 MO as official name to this object. *Davide Famocchia* at JPL mentioned that this object could impact at a position that coincides with the impact of a large bolide on 2019 June 22 at $21^h31^m54^s$ UT off the South coast of Jamaica as shared on Twitter and Facebook. It is only the 4th case an impacting body has been observed before the actual impact[4].

Denis Denisenko pointed the attention to the similarity between the JEO#459 meteor shower and the orbit of the asteroid 2019 MO. The match between the two orbits is not perfect, but this can be explained as the meteor shower appears to be very dispersed.

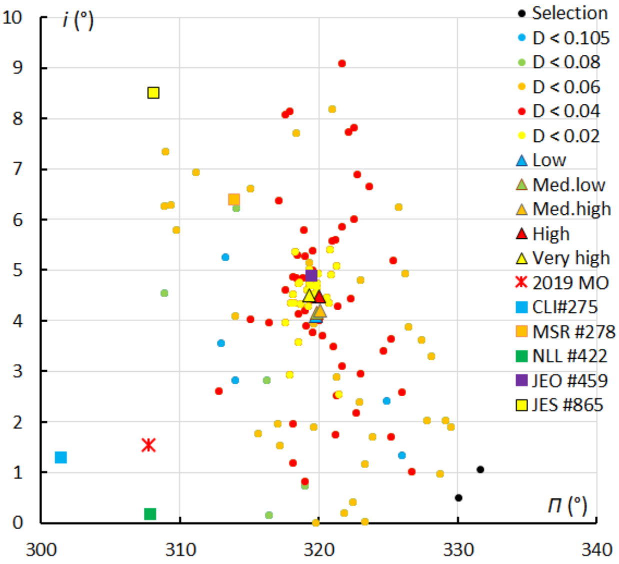

Figure 6 – The plot of inclination i (°) against the length of perihelion Π (°) for the 121-selected possible JEO-orbits. The colors mark the different threshold levels of the D-criteria relative to the final reference orbit listed in Table 2. The squares and * mark the positions of possible related sources.

Looking at the plot of the inclination *i* versus length of perihelion *Π* (*Figure 6*) with different colors for the similarity threshold classes the scatter is obvious, even for the high threshold similarity criteria. *Figure 6* also shows

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

[3] https://atlas.fallingstar.com/home.php

[4] https://remanzacco.blogspot.com/2019/06/small-asteroid-neocp-a10eom1-impacted.html

the positions for the orbit of the impactor 2019 MO as well as some possible related meteor showers active in this area. The position for 2019 MO is about 12° away from the concentration of JEO orbits. The position for the comet 300P/Catalina (formerly known as 2005 JQ5) is right on top of the concentration of the JEO-orbits. While writing the CBET 4642 text, *Dr. Peter Jenniskens* noticed that the Jupiter-family comet 300P/Catalina appears to be the parent body of the JEO #459 meteor shower (Jenniskens, 2019).

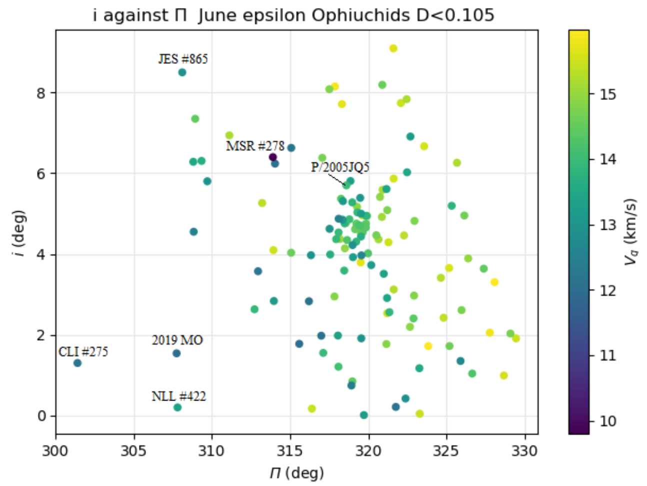

Figure 7 – Plot of inclination i (°) against the length of perihelion Π (°) for the 119 JEO orbits that fulfill the low threshold similarity criteria with a color gradient to display the variation in the velocity v_g. Positions of some possible associated meteor showers and objects are marked in the plot.

Figure 7 shows the same plot as *Figure 6*, but with a color gradient to show the variation in geocentric velocity. The faster particles tend to be at slightly higher inclination with a higher value for the length of perihelion.

A possible physical connection between the impact of 2019 MO and the JEO#459 outburst requires some caution. A cross reference search of the 2019 MO orbit with all orbits listed in the IAU Working List of Meteor showers identifies four other minor showers besides the JEO#459 shower that all fulfil our similarity criteria. The results of this search are listed in *Table 5*, with the values for the different D-criteria. The similarity criteria only provide us with an idea about the geometric similarity of the orbits, it says nothing about the physical relationship. This provides no evidence that the minor planet is related to any of these showers.

The showers CLI #275 and MSR #278 are both marked as from asteroidal source. The question is rather if there is a physical relationship between all the different sources listed in *Table 5*? These different minor showers, the impactor 2019 MO and comet 300P/Catalina may be remnants of one and the same parent body. More research is required to confirm or to decline this possibility.

7 Conclusion

The June epsilon Ophiuchids produced an exceptional level of activity between 2019 June 19 – 24, confirmed by different networks. A search on video meteor orbits of the period 2006 until 2018 confirmed annual activity. The obtained average orbits are in agreement with the published orbital data in literature.

The June epsilon Ophiuchids radiate from a very large scattered radiant area and may be related to a number of other minor showers that were identified, which could be earlier instances of the same meteor shower complex associated with Jupiter-family comet 300P/Catalina. In past years the June epsilon Ophiuchids were rather deficient in exceptional bright events, the brightest event being M_{abs} = –4.5. A possible connection with the impacting minor planet 2019 MO should be considered with caution as the orbital similarity may be just by chance.

The June epsilon Ophiuchids can be considered as an established meteor shower. The possible relationship with some other nearby meteor showers and the impactor 2019 MO requires further investigations.

Table 5 – Comparison between the orbit of 2019 MO and the IAU working list of meteor showers for the showers that fulfil our similarity criteria with for each shower the values of D_{SH}, D_D and D_H with the orbit of 2019 MO as reference orbit.

Object	$\lambda_{\odot}$ (°)	*R.A.* (°)	*Decl.* (°)	v_g km/s	*a* (AU)	*q* (AU)	*e*	*ω* (°)	*Ω* (°)	*i* (°)	D_{SH}	D_D	D_H
2019 MO	–	–	–	–	2.458	0.939	0.618	216.7	91.04	1.54	–	–	–
CLI #275	79.7	223.2	–20.4	12.2	3.484	0.898	0.742	46.2	255.2	1.3	0.16	0.10	0.16
MSR #278	112.2	240.8	+4.7	9.8	2.42	0.990	0.591	201.7	112.2	6.4	0.12	0.05	0.11
NLL #422	67.8	227.9	–17.4	13.3	1.845	0.834	0.548	239.9	67.9	0.2	0.13	0.08	0.09
JEO #459	89	244.7	–8.8	14.9	2.53	0.866	0.659	230.3	89.1	4.9	0.16	0.07	0.15
JEO #459	90	245	–8.9	13.9	2.5	0.877	0.649	229.3	90.1	4.9	0.16	0.06	0.15
JES #865	87.9	239.1	+4.5	12.9	2.51	0.924	0.631	220.1	88	8.5	0.12	0.04	0.12
P/2005JQ5					2.69	0.826	0.590	222.8	95.8	5.7	0.18	0.08	0.15

Acknowledgment

The author is very grateful to *Jakub Koukal* for maintaining EDMOND, to SonotaCo Network (Simultaneously Observed Meteor Data Sets SNM2007–SNM2018), to CAMS (2010–2013) and to all camera operators involved in these camera networks.

I thank *Denis Vida* for providing me with scripts to plot a color gradient to show the dispersion in velocity and to compute the average orbit according to the method of Jopek et al. (2006). I thank *Peter Jenniskens* for providing the recent CAMS data published in the CBET and I thank *Peter Brown* for his personal comments.

EDMOND[5] includes: BOAM (*Base des 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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[5] https://fmph.uniba.sk/microsites/daa/daa/veda-a-vyskum/meteory/edmond/

The Geminids of 2018: an analysis of visual observations

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An analysis is presented of the visual observations of the Geminids gathered in December 2018. In 2017 there were two main peaks in the activity of the Geminids, a first at solar longitude 261.9° and the second at solar longitude 262.2° (Miskotte, 2018a; 2018b). The first peak has been seen also in the 2018 data although slightly later in time. The second peak was not observed as this time was not covered by observations in 2018.

1 Introduction

The year 2018 was an excellent year to observe the Geminids. With a Moon at its First Quarter on December 15, this only meant some moonlight in the evening sky. This article gives the results of the analysis of the Geminid activity in 2018, based on visual observations. In addition, this analysis is compared with the analysis from 2017 (Miskotte, 2018a; 2018b). The 2018 analysis is interesting because in the series of previous years 1994–2002 and 2010, the Moon still disturbed considerably. In that respect, 2018 is the best year in terms of moonlight compared to the years mentioned. In 2026 the Moon will not disturb the observations at all and we can map this series of years even better! See also *Table 1*. In this article, however, there is no comparison with this series of years as done in (Miskotte et al., 2010; Miskotte et al., 2011). The author will come back at this aspect separately in a forthcoming article.

Table 1 – Moon set during the Geminid campaigns of 1994–2002–2010–2018–2026 (situation in the Netherlands).

Date	Moon set at:
14 December 1994	03^h30^m UT
14 December 2002	01^h30^m UT
13 December 2010	23^h30^m UT
13 December 2018	21^h30^m UT
13 December 2026	17^h00^m UT

2 Collecting the data

All data was collected during spring 2019. Most observations were gathered from the IMO website[6], but the author also received observations from observers who did not report to IMO. Only data was used that met the following requirements:

- Only observations from observers with a known C_p were used;
- Only observations with limiting magnitudes 5.9 or higher were used;
- Only observations with a radiant height of at least 25 degrees were used;
- Extreme outliers were removed.

3 Population index r

The population index *r* could be calculated for several nights. The magnitude distributions of observers with a good C_p determination were examined. The rule here is: the difference between the average limiting magnitude and the average magnitude of the Geminids may not be greater than 4.5 magnitude. In the end, more than 5100 Geminids could be used to determine the population index *r*. *Table 2* and *Figure 1* give the result.

Table 2 shows that only the period 11 to 15 December provided enough data to calculate reliable population index *r*-values. The population index *r* on the magnitude range [–1; +5] has been used in the final ZHR calculations.

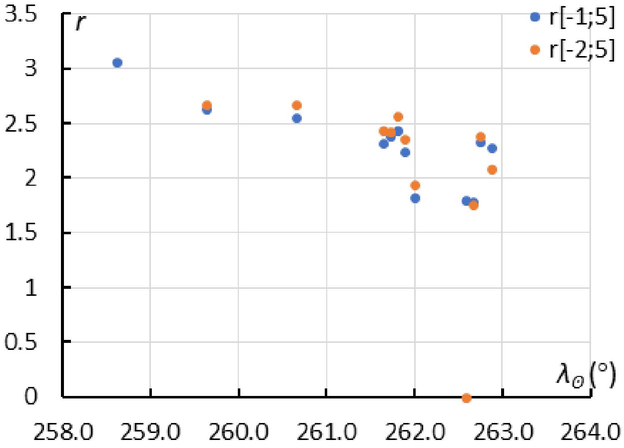

Figure 1 – Population index r [–2;+5] and r [–1;+5] from the Geminids between December 11, 2019 00^h00^m UT and December 15, 2019 06^h00^m UT. The low r value at $\lambda_\odot = 262.0°$ indicates that a lower population index r also occured after the first peak (more bright meteors). This is interesting enough to look at in the coming years to see if it is an annual phenomenon.

4 Zenithal Hourly Rate

The ZHRs are always calculated according to the method of *Peter Jenniskens* as described in (Miskotte et al., 2011):

$$ZHR = \frac{n \cdot F \cdot r^{6.5-LM}}{(\sin h)^{\gamma} \cdot C_p \cdot T_{eff}} \quad (1)$$

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[6] www.imo.net

Table 2 – Population index r Geminids 2018.

Date	$\lambda_{\odot}$	r [–2;+5]	nGEM	r [–1;+5]	nGEM
11-12-2018 00^{h}00^{m} UT	258.622	~	~	3.06	48
12-12-2018 00^{h}00^{m} UT	259.639	2.67	155	2.63	154
13-12-2018 00^{h}00^{m} UT	260.656	2.67	685	2.55	680
13-12-2018 23^{h}30^{m} UT	261.644	2.44	271	2.32	269
14-12-2018 01^{h}30^{m} UT	261.730	2.42	1305	2.39	1292
14-12-2018 03^{h}00^{m} UT	261.804	2.56	838	2.44	833
14-12-2018 05^{h}20^{m} UT	261.886	2.36	786	2.24	779
14-12-2018 07^{h}30^{m} UT	261.995	1.94	422	1.82	415
14-12-2018 21^{h}20^{m} UT	262.577	~	~	1.80	~
14-12-2018 23^{h}30^{m} UT	262.669	1.76	83	1.78	80
15-12-2018 01^{h}30^{m} UT	262.746	2.39	288	2.33	285
15-12-2018 04^{h}00^{m} UT	262.866	2.09	291	2.28	278
Total			5124		5113

Table 3 – ZHR of the Geminids in 2018.

2018 Dec. Day	UT	$\lambda_{\odot}$	Bins	Numb. of Gem	ZHR	±
3	9.50	251.914	1	5	5.9	2.6
4	22.67	252.471	7	17	3.5	0.9
5	10.42	252.970	1	7	7.9	3.0
6	3.50	253.690	2	6	3.9	1.6
8	5.25	255.795	3	23	9.2	1.9
9	3.02	256.717	11	78	6.7	0.8
10	2.28	257.702	7	51	7.3	1.0
11	2.76	258.728	15	126	10.2	0.9
11	22.27	259.565	16	108	22.4	2.2
12	2.66	259.752	21	208	27.5	1.9
12	20.51	260.508	3	16	42.9	10.7
12	21.26	260.539	3	17	38.9	9.4
12	22.51	260.593	7	57	35.1	4.7
12	23.56	260.637	6	61	38.1	4.9
13	0.58	260.680	7	110	37.9	3.6
13	1.44	260.716	13	172	58.5	4.5
13	2.49	260.761	13	192	68.3	4.9
13	3.46	260.802	14	210	51.8	3.6
13	4.49	260.846	12	140	37.8	3.2
13	5.50	260.889	5	63	41.1	5.2
13	6.45	260.929	5	71	57.3	6.8
13	7.75	260.984	2	47	74.2	10.8
13	8.36	261.010	6	80	57.2	6.4
13	9.27	261.048	4	53	51.8	7.1
13	10.52	261.101	3	40	53.0	8.4
13	11.13	261.127	1	5	41.2	18.4
13	19.60	261.486	3	26	62.8	12.3
13	20.57	261.527	11	134	76.7	6.6
14	0.49	261.693	38	789	99.5	3.5
14	1.55	261.738	44	1090	107.2	3.2
14	2.52	261.779	38	935	104.0	3.4
14	3.45	261.819	22	513	89.3	3.9
14	4.49	261.863	16	369	81.0	4.2
14	5.49	261.905	20	434	83.7	4.0
14	6.37	261.943	8	167	107.3	8.3
14	7.18	261.977	1	30	121.3	22.1
14	8.55	262.035	6	159	112.7	8.9
14	9.42	262.072	4	98	101.6	10.3
14	20.71	262.550	3	30	79.7	14.6
14	21.58	262.587	4	45	73.9	11.0
14	22.62	262.631	5	43	54.1	8.3
14	23.47	262.667	8	104	76.5	7.5
15	0.54	262.713	14	188	63.6	4.6
15	1.42	262.750	15	156	47.4	3.8
15	2.52	262.796	19	194	35.4	2.5
15	3.35	262.832	14	130	36.1	3.2
15	4.51	262.881	14	110	23.3	2.2
15	5.46	262.921	10	68	22.6	2.7
15	6.23	262.954	2	18	41.9	9.9
15	9.39	263.088	5	28	27.3	5.2
16	3.79	263.868	2	5	3.1	1.4

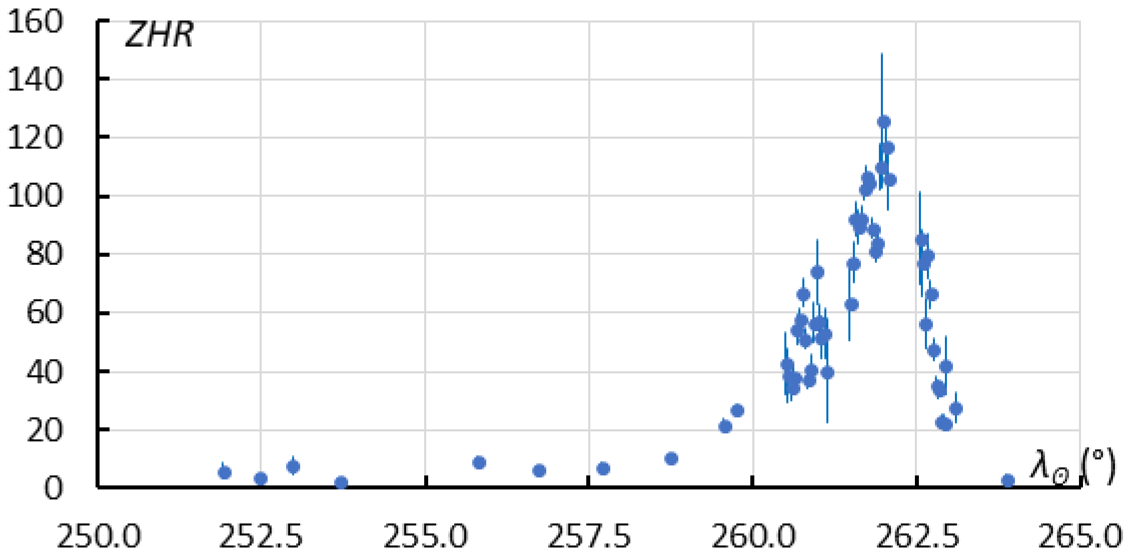

Figure 2 – Zenithal Hourly Rate of the Geminids between December 3 and 17, 2018.

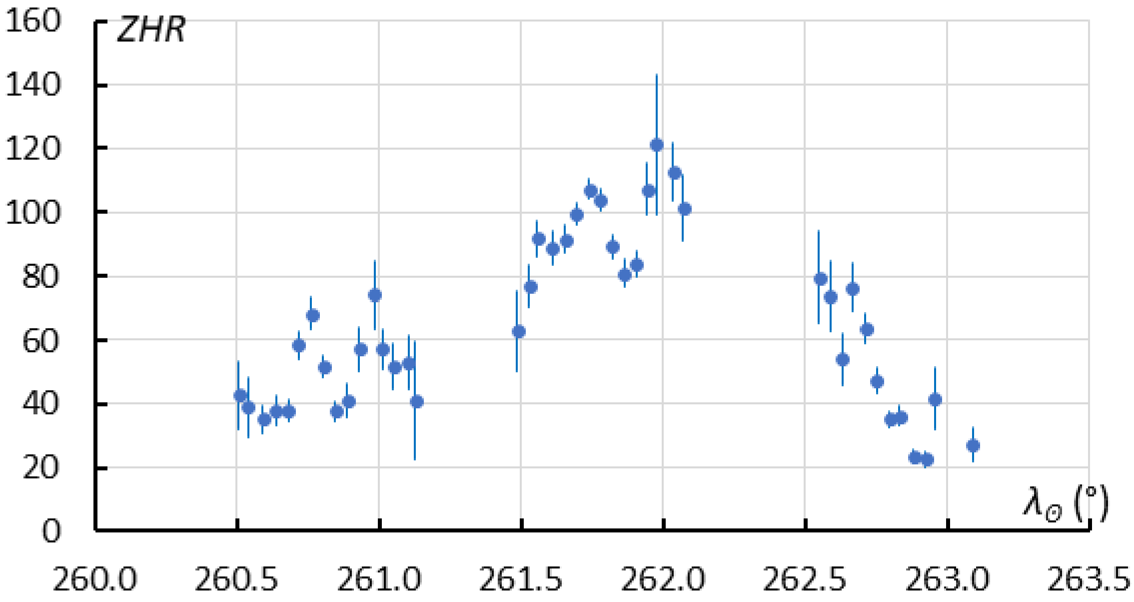

Figure 3 – ZHR of the Geminids between 12 and 15 December 2018.

However, the radiant height correction factor γ is set to 1.0 instead of 1.4. After all the data that met the criteria mentioned had been obtained, 8826 Geminids remained for processing. For the nights up to December 11, all ZHR values per night were calculated (weighted averages); for the night 11–12 December from the periods before and after 00^h UT, for the nights 12–13, 13–14 and 14–15 December the ZHR could be determined per hour over Europe and partly for America. The results are presented in *Table 3* and *Figure 2*.

Figure 2 shows that the build-up of the Zenithal Hourly Rate is rather flat between December 3 and 10, 2018, with the ZHR values ranging between 5 and 10. The night of December 11–12 gives ZHR values of 20–25 for Europe. The night December 12–13, 2018 in Europe gives ZHR values between 30–70 and over America the ZHRs varied between 50 and 70. The maximum night December 13–14, 2018 had ZHRs between 70 and 110 over Europe and above America the ZHRs rose to 100–130. The night of 14–15 December gives ZHRs (above Europe) decreasing from 60–80 to 20–30. Above America ZHRs varied between 40 and 30. One night later, the Geminid activity is almost gone. Below we zoom in on the nights 12–13, 13–14 and 14–15 December 2018 respectively, because there are quite a few comments to make here and there. *Figure 3* below gives a more detailed look of the Geminids ZHR in the period from 12 to 15 December 2018.

5 12–13 December 2018 for Europe and north America

For this night the author used 15–30 minutes counts to obtain a weighted average of the ZHR. *Figure 4* shows that this year two impressive sub maxima were observed above Europe and America. A first maximum took place above Europe on December 13 around 02^h30^m UT with a ZHR of 70 ± 5. This is followed by a decrease in activity to a ZHR 38 ± 3 around 4^h30^m UT. Then a second maximum follows around 7^h45^m UT with a ZHR of 75 ± 11 best visible above the eastern part of North America. After this peak the activity decreased back to ZHR 40–50. It is striking that both peaks show a clear increase and decrease that fall within the error margins. So, in other words these are two real peaks. Unfortunately, there is not enough data available from Asia so that we cannot say anything about the activity of the Geminids there.

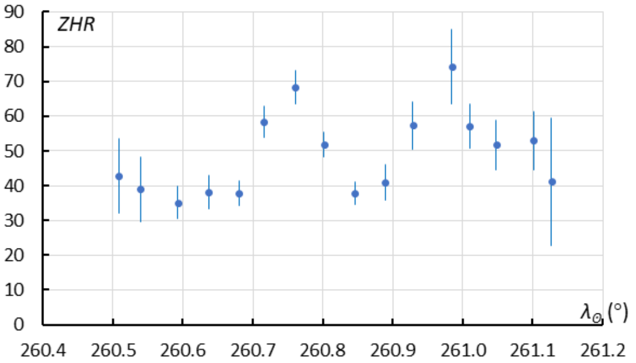

Figure 4 – Detailed view of Geminids ZHR in the period from December 12, 2018 $20^{h}00^{m}$ UT to December 13, $11^{h}00^{m}$ UT.

6 13–14 December 2018 for Europe and north America

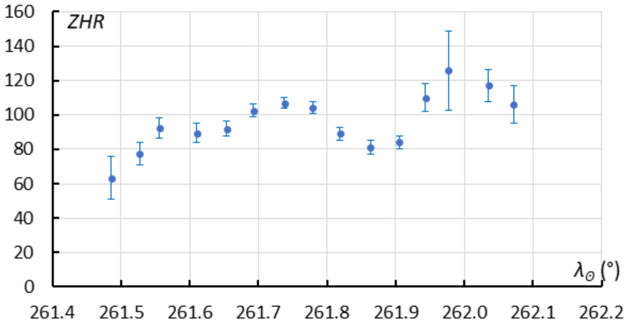

Figure 5 – Detailed view of the Geminid activity between December 13, 2018 $19^{h}00^{m}$ UT and December 14, 2018 $11^{h}00^{m}$ UT.

For this night, the ZHR was obtained from 10–20 minutes counts and a weighted average of the ZHR values was calculated. The first good data of the maximum night above Europe is available from $19^{h}00^{m}$ UT. *Figure 5* shows the result. We see an increasing ZHR from 62 ± 12 around $\lambda_{\odot}$ = 261.48° (= December 12, 2018 $19^{h}36^{m}$ UT) to ZHR 107 around $\lambda_{\odot}$ = 261.74° (= December 14, 2018 $1^{h}30^{m}$ UT). After that, the ZHR decreased to 80, to rise then again at the end of the night in Europe to ZHR 107 ± 8 around $\lambda_{\odot}$ = 261.94° (= December 14, 2018 $06^{h}20^{m}$ UT). The first data point from America is at $\lambda_{\odot}$ = 261.98° (= 14 December 2018 $07^{h}10^{m}$ UT) with a ZHR of 126. It should be noted that all data points from North America come from only one or two observers.

The data from 2018 was then compared with data from 2017 (Miskotte, 2018). See *Figure 6* for the result. This is to see whether the two peaks found in 2017 were again visible in the observational data of 2018.

If we look very closely at *Figure 6* at the first maximum of 2017 at $\lambda_{\odot}$ = 261.9°, it will fall slightly later in 2018. The ZHR in 2017 was 135 compared to ZHR 125 ± 9 in 2018. Subsequently, a decrease in activity was observed in both years. However, in 2017 the decrease was much sharper and much deeper than in 2018, although the data did not completely overlap in this period. A cautious conclusion is that the first maximum from 2017 is well observed in 2018, and that the second maximum was not observed in 2018.

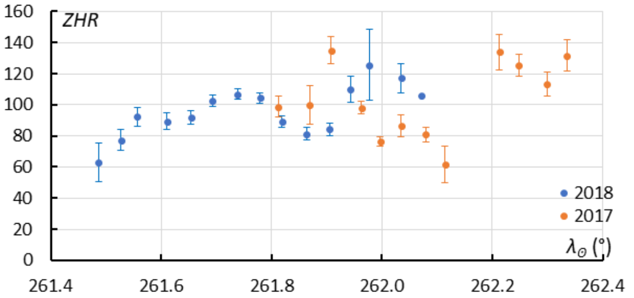

Figure 6 – Comparison between the ZHR of the Geminids in 2017 and in 2018.

7 14–15 December 2019 for Europe and north America

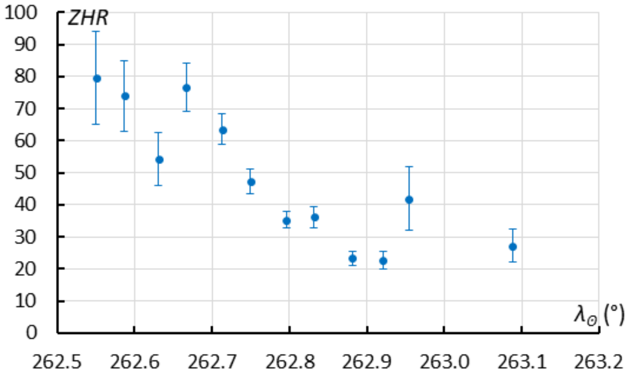

Figure 7 – Details of the ZHRs of the Geminids for 14–15 December 2018

As usual, a nice decreasing activity of the Geminids can be seen during the night December 14–15, 2018 (*Figure 7*). With ZHRs up to 80 ± 13 at the start of the night in Europe, at the end of the night the ZHR is close to 20 ± 4. *Figure 8* shows a comparison with 2017. This shows that the 2017 data is reasonably consistent with that of 2018.

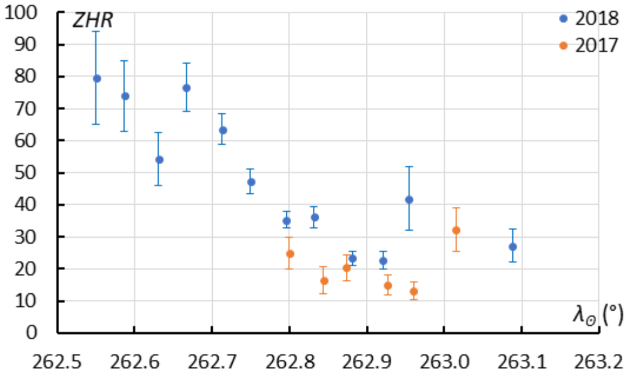

Figure 8 – Comparison between the ZHR of the Geminids from the night of December 14–15, 2017 and 2018.

Table 4 – Prospects for the Geminids in 2020 from different locations. In the column $\lambda_\odot$ in blue the expected solar longitudes for both maxima. At right 5 columns with the radiant elevations at specific locations. The blue numbers in bold indicate the maximum radiant height at that specific location. The good observing period is indicated in light blue, considering radiant rise and / or start / end of the twilight.

					Radiant elevation in degrees				
					Netherlands	France	Portugal	Tenerife	Oman
Year	Month	Day	UT	$\lambda_\odot$ (°)	5.4e 52.0n	6.0e 44.0n	7.9w 36.6n	16.5w 28.3n	56.3e 20n
2020	12	13	15	261.783	-4	-11	-20	-28	-7
2020	12	13	16	261.825	-1	-8	-18	-28	5
2020	12	13	17	261.868	4	-2	-14	-24	17
2020	12	13	18	261.910	11	6	-7	-18	29
2020	12	13	19	261.953	18	14	1	-10	42
2020	12	13	20	261.995	26	24	11	0	54
2020	12	13	21	262.037	35	34	21	11	66
2020	12	13	22	262.080	45	45	33	23	**75**
2020	12	13	23	262.122	54	55	44	35	75
2020	12	14	0	262.165	62	66	56	47	66
2020	12	14	1	262.207	69	75	68	60	54
2020	12	14	2	262.249	**71**	**79**	80	72	41
2020	12	14	3	262.292	67	72	**85**	**84**	29
2020	12	14	4	262.334	60	62	74	80	16
2020	12	14	5	262.377	51	52	62	68	4
2020	12	14	6	262.419	42	41	50	55	-7
2020	12	14	7	262.461	33	30	38	43	-17

8 Outlook for the 1st and 2nd Geminid maximum in 2020

In *Table 4* the author made predictions for both maxima of the Geminids. It has been assumed that the two maxima are always a recurring phenomenon. Furthermore, the first maximum is based on the value found in 2018 at $\lambda_\odot = 262.95°$. The first peak of 2017 was slightly earlier than in 2018. The second maximum is based on $\lambda_\odot$ = 262.2°. Therefore, this year is important, because we can more or less observe the two maxima from Europe for the first time. Between the maxima we will probably have the well-known dip in activity that went much deeper in 2017 than in 2018. So, be aware of some disappointing activity between both peaks (ZHR 60–100)! That observations of both peaks were not possible in 1994, 2002 and 2010 was because the 1st maximum always took place too early, so it was still not yet dark enough or the radiant height was too low.

If we look at *Table 4*, there are advantages and some disadvantages for all locations. Incidentally, it is worth mentioning that in the evening during the Geminid maximum (period) a beautiful conjunction is visible between the planets Jupiter and Saturn. The planet Venus will also be visible in the early morning hours.

From *the Netherlands*, we can observe a nice long period and both maxima will be observable. During the 1st maximum the radiant height is around 18–26 degrees. The 2nd maximum takes place during maximum radiant height. After that we can still see the decreasing branch with the bright Geminids for 4 to 5 hours! The disadvantage is that the chance to have a clear night in December in the Netherlands is only 10%.

From *France* (Provence) the same story, around the 1st maximum the radiant height is about 25 degrees, around the 2nd maximum the radiant height culminates at 79 degrees. However, the chances for clear weather are also not so great there (20–30%), sometimes with strong local differences.

From *Portugal*, the 1st maximum is barely visible because of a very low radiant height (only 10 degrees). The advantage is that after the 2nd maximum you can still enjoy the bright Geminids for 5 to 6 hours. In Portugal there is a better chance for clear weather than in France. In Portugal there is a 40–50% chance to have a clear night in December.

From *Tenerife*, the 1st maximum is not visible because the radiant is below the horizon at that moment, but the 2nd maximum is good with the big advantage that the decline in activity with many bright Geminids for 5 to 6 hours can be observed. Weather conditions are better than in southern France and Portugal with 50-70% or more chance for a clear night.

From *Oman* we can observe both maxima, with the 1st maximum there being the best perceptible in terms of radiant height (42–54 degrees) compared to the 4 other locations. The 2nd maximum can also be seen there with a reasonable radiant height, but the radiant height is the lowest compared to the 4 other locations (also 54 degrees high). The disadvantage is that the decreasing branch of the second maximum with bright Geminids can only be observed for two hours with a lower radiant height. Weather wise, little can go wrong here.

Acknowledgment

The author thanks *Paul Roggemans*, *Michel Vandeputte* and *Carl Johannink* for critically reading this article and for their advises. In addition, a huge word of thanks to all the observers who have observed the Geminids of 2018. The author knows from his own experiences how difficult that can be in terms of finding clear weather and/or cold weather conditions. It takes a lot of perseverance! Hope you are all active during the coming Geminid returns! The observers in 2018 were:

Alexandre Amorin, Pierre Bader, Benitez Sanchez Orlando, David Buzgo, Tim Cooper, Kelly de Lima Gleici, Katie Demetriou, Mayuresh Desai, John Drummond, Garry Dymond, Mohammad Iman Fotouhi, Kai Gaarder, Aldrin Gabuya, Carl Hergenrother, Gabriel Hickel, Glenn Hughes, Gerardo Jiménez López, Carl Johannink, Hansub Jung, Károly Jónás, Javor Kac, Omri Katz, Shubham Kawabe, Kajal (FC) Kesare, Roman Kostenko, Greet Lembregts, Jan Lembregts, Anna Levin, Ole Lit,Vincent Marik, Adam Marsh, Jemma Marsh, Pierre Martin, Fabrizio Melandri, Anushka Menon, Frederic Merlin, Koen Miskotte, Shai Mizrachi, István Mátis, Jos Nijland, Francisco Ocaña González, Lovro Pavletic, Jonas Plum, Tushar Purohit, Pedro Pérez Corujo, Venugopal Raskatla, Ina Rendtel, Jurgen Rendtel, Sina Rezaei, Filipp Romanov, Terrence Ross, Branislav Savic, Alex Scholten, Fengwu Sun, David Swain, Hanjie, Tamara Tchenak, Sonal Thorve, Peter van Leuteren, Hendrik Vandenbruaene, Michel Vandeputte, Ariel Westfried, Roland Winkler, Patrick Wullaert, Quanzhi Ye and *Negar Yeganeh*.

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Activity of the 15 Bootids (FBO#923) observed by CAMS BeNeLux

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During the routine observations on 2019, April 21 on 22 the CAMS BeneLux network captured 7 meteors from the minor shower 15-Bootids (FBO#923) between 22^{h}00^{m} – 01^{h}11^{m} UT. The United Arab Emirates CAMS network captured 4 meteors of this stream between 23^{h}00^{m} – 01^{h}12^{m} UT. No activity was observed from CAMS California. This stream, with a long periodic comet as its origin, showed also some activity in 2013.

1 Introduction

The nights around the traditional Lyrid maximum were clear in the BeNeLux. So also, the night of April 21–22 offered favorable weather circumstances. A total of 212 meteor orbits were recorded by the CAMS network during this night.

In *Figure 1* we see a plot of all radiant positions obtained in this night.

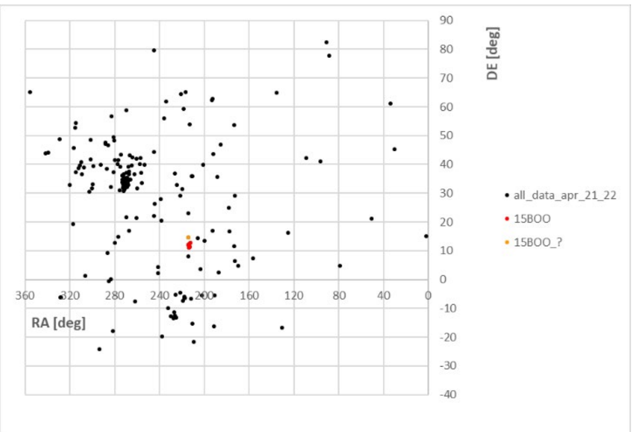

Figure 1 – Radiantpositions obtained by CAMS BeNeLux during the night of April 21–22.

2 Activity from Bootes

Compared to the past activity pattern obtained for the sky near Lyra, around $\alpha = 270°$ and $\delta = +32°$, *Peter Jenniskens* noticed a small group of meteors with almost identical radiant positions and orbital elements while processing the data. This group of meteors appeared to have a strong resemblance in terms of orbital elements with the minor shower 15-Bootids (FBO#923). In *Figure 1* the radiants of this group of meteors are marked with red and orange color. The shower was previously recorded in 2013 by CAMS (Jenniskens et al., 2018).

If we zoom in on the radiant positions of this meteor shower (*Figure 2*), the compact radiant size of these meteors is even more striking: there are two pairs of meteors in this close up, with a declination just above +11 degrees. In addition, three meteors with a slightly higher declination and one meteor at a more significant distance (orange dot).

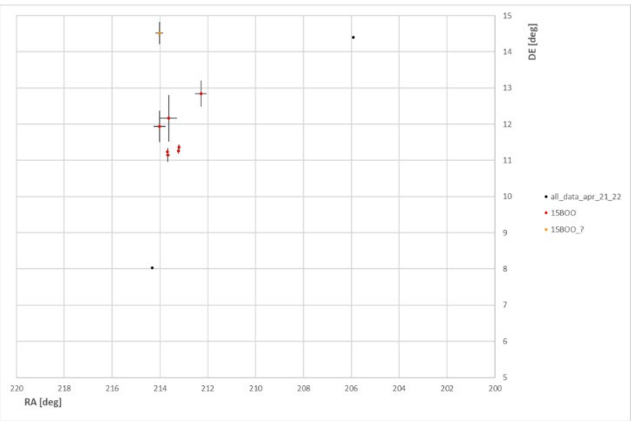

Figure 2 – Detail of the radiant positions from Figure 1; the very compact radiant makes it possible to distinguish four of the seven 15-Bootids in terms of individual radiant positions.

It is doubtful whether this (orange) meteor can be associated with this meteor shower. Activity from this region has also been noted by the UAE network. A total of four FBO#923 meteors were recorded by this network.

The compactness in radiant position is also reflected in the orbital elements. *Figure 3* shows a plot of the length of perihelion *Π* versus inclination *i* for all 212 meteors recorded in this night.

Also, here we see that we really have to zoom in (*Figure 4*) to be able to distinguish six of the seven individual 15-Bootids.

The rightmost point, with the largest value for *Π*, are in fact two meteors (see below in *Table 1* meteors 31 and 88).

Finally, in *Table 1 and 2*, the radiant position, geocentric velocity and the values of the various orbital elements of the seven 15-Bootids observed by CAMS BeneLux are listed. Also, the corresponding median values and reference values are mentioned in *Tables 1 and 2* (Jenniskens et al., 2016).

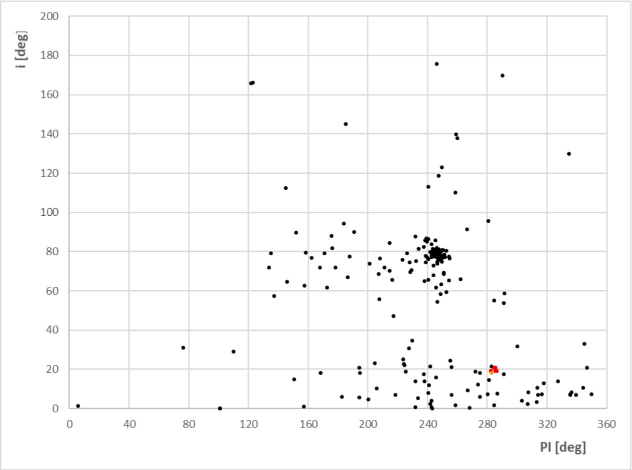

Figure 3 – Plot of the length of perihelion Π versus inclination i. Here too, the compact structure of the 15-Bootids (FBO#923) meteor shower is most striking.

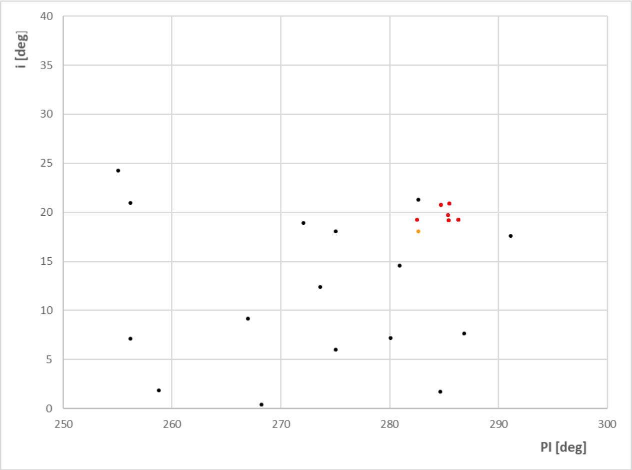

Figure 4 – Close up of Figure 3.

Table 1 – Time, radiant position and geocentric velocity of the seven 15-Bootids (FBO#923) meteors. The last column lists the cameras that have recorded these meteors.

N°	Observed date	Begin Time (UT)	α_g (°)	δ_g (°)	v_g (km/s)	λ_Θ (°)	Contributing
17	21-04-2019	$21^h29^m09.14^s$	212.3±0.2	+12.8±0.4	27.38±0.13	31.2268	00312_003162_003830
24	21-04-2019	$22^h01^m07.51^s$	214.0±0.3	+11.9±0.4	29.52±0.16	31.2492	000322_003030
31	21-04-2019	$22^h22^m30.80^s$	213.7±0.0	+11.2±0.0	27.73±0.00	31.2637	000397_000393
39	21-04-2019	$22^h49^m50.48^s$	213.2±0.1	+11.4±0.1	27.95±0.02	31.2822	000807_000815_000397 003037_000393
43	21-04-2019	$22^h58^m13.64^s$	214.0±0.2	+14.5±0.3	27.84±0.10	31.2878	_000311_000325
57	21-04-2019	$23^h18^m50.71^s$	213.6±0.4	+12.2±0.6	29.36±0.24	31.3018	_000351_003160
64	21-04-2019	$23^h31^m43.36^s$	213.2±0.1	+11.3±0.1	28.88±0.04	31.3105	_00303_000322_00352 _003167_003167
88	22-04-2019	$00^h11^m59.42^s$	213.7±0.1	+11.1±0.2	27.88±0.07	31.3378	_003037_000397_000391 _000393
Median			213.7	11.7	27.9	31.3	
Jenniskens et al. (2016)			213.1	11.2	27.5	30.9	

Table 2 – The orbital elements for Table 1.

	q (AU)	$1/a$ (1/AU)	e	i (°)	ω (°)	Ω (°)	Π (°)
17	0.665±0.003	0.01±0.01	0.9934±0.0079	19.26±0.28	251.295±0.42	31.2343±0.0007	282.529±0.421
24	0.630±0.004	–0.074±0.01	1.0466±0.0092	20.92±0.33	254.255±0.583	31.2562±0.0007	285.511±0.583
31	0.637±0.000	0.04±0.00	0.9718±0.000	19.244±0.00	255.0.23±0.00	31.2716±0.0000	286.295±0.000
39	0.641±0.001	0.013±0.002	0.9914±0.0014	19.208±0.06	254.117±0.102	31.2905±0.0001	285.408±0.103
43	0.664±0.003	0.003±0.01	0.9932±0.0057	21.32±0.20	251.34±0.436	31.2905±0.0004	282.635±0.436
57	0.637±0.007	–0.08±0.02	1.0506±0.0136	20.75±0.47	253.42±0.898	31.31±0.0008	284.73±0.898
64	0.635±0.001	–0.05±0.003	1.031±0.0018	19.70±0.07	254.044±0.107	31.3193±0.001	285.363±0.107
88	0.637±0.002	0.033±0.006	0.9789±0.0036	19.26±0.13	254.957±0.257	31.3472±0.0002	286.304±0.257
Med.	0.637		0.993	19.5	254.1	31.3	285.4
Ref.	0.640		0.964	18.9	254.9	30.9	285.8

According to the orbits of these meteors, the parent body appears to be a long-term comet. According to Jenniskens (2019), the candidate is the bright comet C / 539 W1.

Acknowledgment

The author thanks *Reinder Bouma* for his critical comments on this article. Thanks a lot, to all CAMS station operators in our network, especially to those who have recorded meteors from this meteor shower: *Martin Breukers, Bart Dessoy, Luc Gobin, Robert Haas, Klaas Jobse, Hervé Lamy, Koen Miskotte, Adriana Roggemans* and *Paul Roggemans*.

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Jenniskens P., Baggaley J., Crumpton I., Aldous P., Pokorny P., Janches D., Gural P. S., Samuels D., Albers J., Howell A., Johannink C., Breukers M., Odeh M., Moskovitz N., Collison J. and Ganjuag S. (2018). “A survey of southern hemisphere meteor showers”. *Planetary Space Science*, **154**, 21–29.

Jenniskens P. (2019). “CAMS BeNeLux detected an outburst of 15 Bootids (shower IAU#923)”. CBET 4624: 20190510.

Outburst 15 Bootids (FBO#923)

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CAMS BeNeLux recorded 7 orbits in a two hours' time lapse that were identified as 15 Bootids (FBO#923) orbits. A stream search to assess activity of this stream in earlier years failed to confirm annual activity. Instead of a confirmation of the FBO#923 activity, the stream search converged to a dominant number of orbits that are similar to the orbit of the MPV#454 shower, a meanwhile removed entry in the IAU meteor shower working list. This justifies a reconsideration of the presence of some source related to the removed MPV#454 shower.

1 Introduction

During the night of April 21–22 the CAMS BeNeLux network registered 7 orbits that were identified as belonging to the unconfirmed shower of the 15 Bootids (FBO#923). All seven meteors were registered in a short time span of two hours. The mini outburst was confirmed by the CAMS network of the United Arab Emirates where 4 more orbits of the shower were registered during the same two-hour interval (Johannink, 2019).

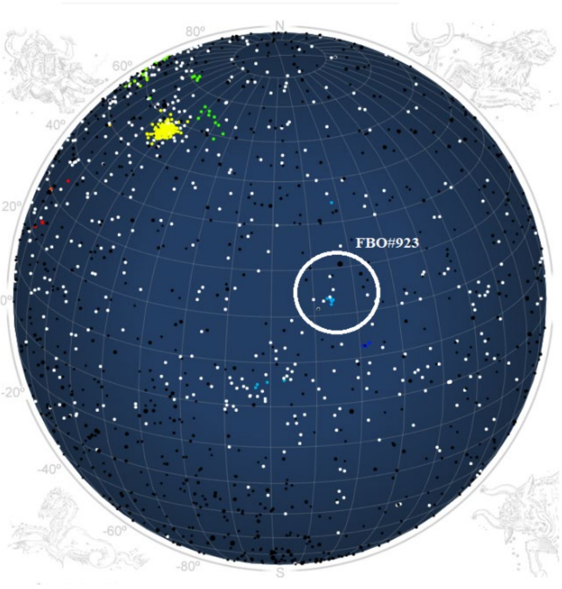

Figure 1 – Screenshot of the CAMS radiant plot for the night of 2019 April 21–22 with the blue radiants identified as 15 Bootids (FBO#923).

This weak barely detectable shower was first noticed during the stream search on the CAMS dataset 2010–2016 (Jenniskens et al., 2018). The shower remained unnoticed before; hence this is a good opportunity to check if and what we can find about this shower in the EDMOND and SonotaCo orbit databases.

2 Available orbit data to search

We have the following orbit data collected over 12 years, status as until June 2019, available for our search:

- EDMOND EU+world with 317830 orbits (until 2016). EDMOND collects data from different European networks which altogether operate 311 cameras (Kornos et al., 2014).
- SonotaCo with 284138 orbits (2007–2018). SonotaCo is an amateur video network with over 100 cameras in Japan (SonotaCo, 2009).
- CAMS with 110521 orbits (October 2010 – March 2013), (Jenniskens et al., 2011). For clarity, the CAMS BeNeLux orbits since April 2013 are not included in this dataset because this data is still under embargo.

In total 712489 video meteor orbits are publicly available. Our methodology to detect associated orbits has been explained in a previous case study (Roggemans et al., 2019).

3 A preliminary search

To locate the position where a concentration of 15 Bootids (FBO#923) orbits may be found, we take some sample FBO orbits to determine the range in time, radiant area and velocity interval where we can find these orbits within a low threshold similarity criterion. This first test results in:

- Time interval: $13° < \lambda_O < 51°$;
- Radiant area: $197° < \alpha_g < 229°$ & $0° < \delta_g < +23°$;
- Velocity: 22 km/s $< v_g < 32$ km/s.

The D-criteria that we use are these 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: $D_{SH} < 0.05$ & $D_D < 0.02$ & $D_H < 0.05$.

In total we have 37223 orbits available within the time span in solar longitude of 13° until 51°. 331 of these orbits have their radiant position and velocity within the above-mentioned range.

In a first approach we calculate the average orbit for this set, using the calculation method explained by Jopek et al. (2006). *Table 1* lists the resulting average orbit for each similarity threshold level in our preliminary sample of orbits. *Figure 2* shows the radiant scatter for these orbits in Sun centered ecliptic coordinates.

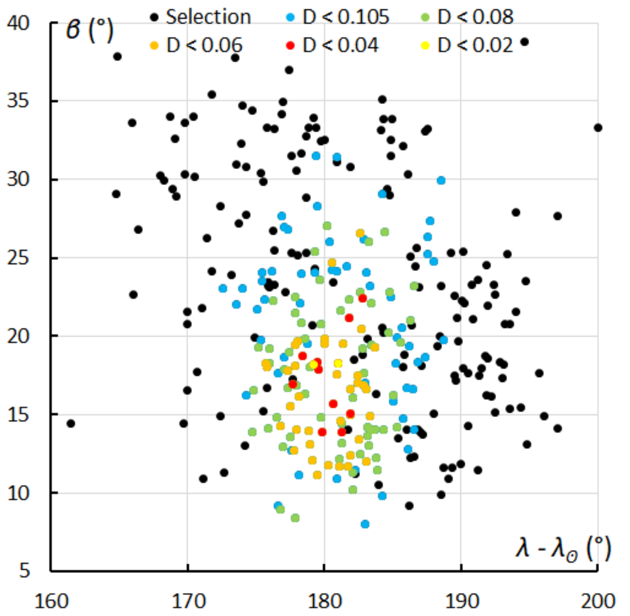

Figure 2 – Plot of the ecliptic latitude β against the Sun centered longitude $\lambda - \lambda_{\odot}$. The different colors represent the 5 different levels of similarity relative to the final average orbit.

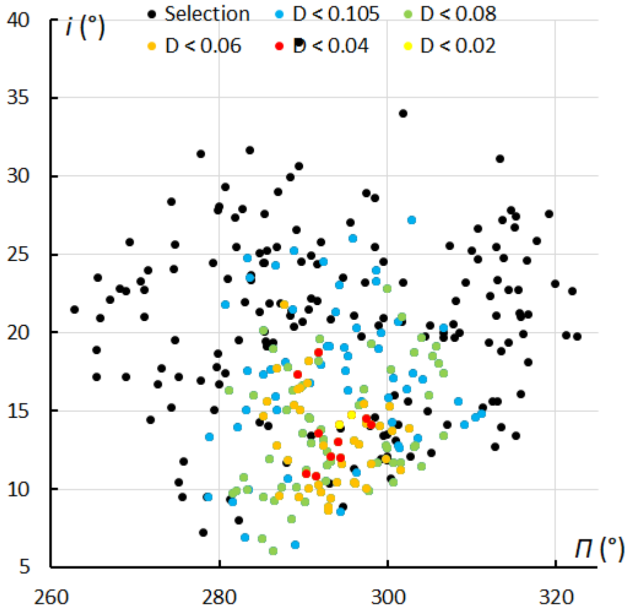

Figure 3 – The plot of inclination i (°) against the length of perihelion Π (°) for the 331-selected orbits. The colors mark the different threshold levels of the D-criteria relative to the final average orbit.

However, the search for a concentration of orbits in this dataset of 331 orbits does not converge to the expected FBO#923 orbit. After a number of iterations, the search ends with a complete different average orbit. The cause is with a dominant number of orbits with lower geocentric velocity, lower inclination and smaller eccentricity. It looks like another group of similar orbits exists in this region. A check through the IAU working list of meteor showers has a positive match with medium low values for the discrimination criteria for the May phi Virginids (MPV#454). However, this shower has been removed meanwhile from the IAU working list of meteor showers. The motivation for the removal was that this meteor stream (MPV#454) did not show up in a later meteor shower search when more CAMS data was available.

The question arises as whether or not the removal of this shower was justified. Our pre-selection on activity period, radiant area and velocity range was derived from a sample of FBO#923 orbits and this will definitely not be a perfect sample to search for MPV#454 orbits. Our selection may contain only part of such similar MPV-orbits. It might be useful to reconsider the MPV#454 case based on another specific selection for this stream.

Table 1– The average values for the preliminary selection of orbits for the four different threshold levels on the D-criteria, compared to a reference orbit from literature for the shower MPV#454.

	Low	Medium low	Medium high	High	Rudawska & Jenniskens (2014)
$\lambda_{\odot}$	26.0°	26.1°	26.2°	26.5°	41.6°
α_g	212.7°	211.1°	210.8°	211.7°	220.2°
δ_g	+6.2°	+4.9°	+4.5°	+4.9°	+0.3°
v_g	24.4	24.0	24.0	24.1	21.7
a	2.69	2.61	2.71	2.66	2.6
q	0.586	0.588	0.588	0.593	0.652
e	0.782	0.775	0.783	0.777	0.744
ω	265.7°	266.2°	266.5°	266.2°	259.7°
Ω	27.9°	27.3°	26.7°	27.3°	41.6°
i	15.0°	13.7°	13.3°	13.9°	10.4°
N	164	107	49	12	12

The plot of the Sun centered ecliptic coordinates (*Figure 2*) indicates that likely more similar orbits can be found with more southern radiant positions. The plot of the inclination *i* against the length of perihelion *Π* in *Figure 3* suggests more similar orbits may be found with lower inclination and larger length of perihelion.

Whatever sample orbit we take to start our stream search, the iterative search routine ends with the orbit type as listed in *Table 1*. The population with orbits similar to MPV#454 is too dominant in this region and makes it impossible to pin-point any other weaker source in this area. The only alternative to look for FBO#923 orbits in this region is to use the average orbit for the 2019 outburst of the FBO#923 (Jenniskens, 2019):

- $\lambda_{\odot} = 31.24° – 31.34°$
- $\alpha_g = 213.7° \pm 0.2°$
- $\delta_g = +11.3° \pm 0.2°$
- $v_g = 27.7 \pm 0.3$ km/s
- $a = 25$ AU
- $q = 0.634 \pm 0.004$ AU
- $e = 0.975 \pm 0.038$
- $\omega = 254.2° \pm 0.5°$
- $\Omega = 31.3° \pm 0.2°$
- $i = 19.8° \pm 0.5°$

Only 56 orbits of our 712489 video meteor orbits fulfill the low threshold similarity criterion with the above orbit as reference. *Table 2* lists the averaged orbits for each threshold level. The extreme low number of similar orbits, together with the presence of a more dominant source explain why this shower escaped attention in many older meteor stream searches.

Table 2– The average values for the selection of FBO-orbits for the five different threshold levels on the D-criteria.

	Low	Medium low	Medium high	High	Very high
$\lambda_{\odot}$	31.0°	31.0°	31.0°	31.0°	31.0°
α_g	215.6°	214.0°	213.4°	213.3°	213.3°
δ_g	+11.6°	+11.5°	+11.5°	+11.5°	+11.4°
v_g	26.9	27.5	27.8	27.8	27.7
a	7.2	8.8	17.5	23.4	27.8
q	0.640	0.642	0630	0.633	0.640
e	0.911	0.927	0.964	0.973	0.977
ω	255.3°	255.0°	256.1°	255.5°	254.6°
Ω	31.7°	31.8°	20.5°	30.3°	30.9°
i	20.6°	20.3°	20.0°	20.0°	19.6°
N	56	27	11	9	5

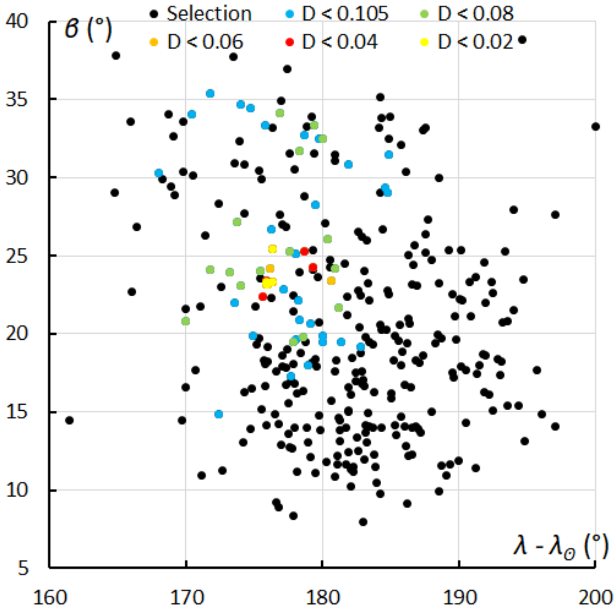

Figure 4 – Plot of the ecliptic latitude β against the Sun centered longitude λ – λ⊙. The different colors represent the 5 different levels of similarity.

Using similarity criteria to identify orbits requires caution as similarity does not prove any physical relationship. When looking at the number of FBO orbits per year, there is no convincing proof for annual activity. Years with a single or few possible FBO orbits may be explained by sporadic orbits which are similar by chance. Looking at the radiant plot in *Figure 4* and the plot of inclination *i* in function of the length of perihelion *Π* in *Figure 5* there is a considerable spread while the 2019 FBO orbits displayed a very compact radiant.

A short, two hours long activity period can have been easily missed in the past. Until few years ago the global coverage was still poor and events such as the 2019 FBO activity could be easily missed.

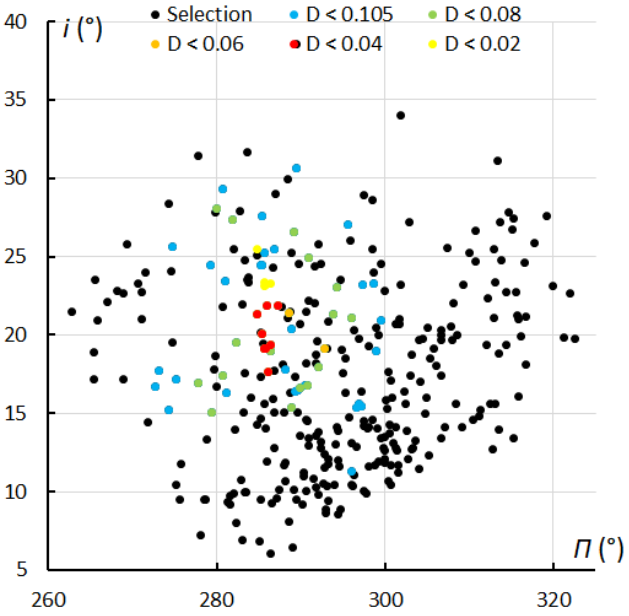

Figure 5 – The plot of inclination i (°) against the length of perihelion Π (°) for the 331-selected orbits. The colors mark the different threshold levels of the D-criteria relative to the average orbit of the FBO 2019 outburst.

Table 3 – Number of possible FBO#923 orbits and total number of orbits available per year within the time interval 13° < $\lambda_{\odot}$ < 49°.

Year	FBO orbits	Total orbits	%
2006	0	31	0.0%
2007	1	664	0.2%
2008	1	974	0.1%
2009	2	1821	0.1%
2010	1	1851	0.1%
2011	7	5335	0.1%
2012	9	5647	0.2%
2013	7	3646	0.2%
2014	4	3969	0.1%
2015	7	4180	0.2%
2016	12	3864	0.3%
2017	4	1705	0.2%
2018	1	1202	0.1%

4 Conclusion

Our attempt to identify past FBO#923 orbits in the public available video meteor orbits did not provide convincing proof for some annual activity. Our meteor stream tool does not detect the FBO#923 shower. Each search iterates towards an average orbit that is similar to the MPV#454, a meanwhile removed meteor shower from the IAU working list. The selection interval is definitely not optimal to search for MPV#454 orbits, but the dominant presence of similar orbits seems to indicate the presence of many similar orbits in this region and time range. Perhaps the initial determined reference orbit of the MPV#454, based on an early available CAMS dataset wasn't representative and reason why this shower was not found in later stream searches? Another possible explanation is the presence of a large number of unrelated sporadic orbits in this rich area near the ecliptic.

A possible association with comet C/539 W1 remains to be proven. The orbital elements of this comet were:

- $q = 0.16$ AU
- $e = 1.0$
- $\omega = 246°$
- $\Omega = 33°$
- $i = 19°$

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I thank *Denis Vida* for providing me with scripts to compute the average orbit according to the method of Jopek et al. (2006).

EDMOND[7] includes: BOAM (*Base des 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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[7] https://fmph.uniba.sk/microsites/daa/daa/veda-a-vyskum/meteory/edmond/

EDMOND and SonotaCo net

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EDMOND and SonotaCo net use UFO software commonly but their published data show slight differences. This paper gives the basic comparison between EDMOND and SonotaCo net results. The SonotaCo net data for 2007-2018 covers the whole year around except for bad weather conditions. The early EDMOND data covered only major shower periods. SonotaCo net favors faster meteors than EDMOND does and on the other hand SonotaCo net seems to perform weaker for slow meteors. The most important difference is the shower identification; both use different shower definition tables. It is recommended to know their characteristics to use them for shower search and orbit analyses.

1 Introduction

The European viDeo MeteOr Network Database (EDMOND) consists of the following regional networks:

- BOAM (Base des Observateurs Amateurs de Meteores, France);
- BosNet (Bosnia);
- 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 (Hungarian Meteor 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).

We can get their results online[8,9]. The results of SonotaCo net are published also on the web[10].

The EDMOND data are based on UFO Orbit v2.41 and MetRec data has been converted by SonotaCo's INF2MCSV. Both published data are, therefore, the same format and the comparison between them is very easy.

2 The data distributions around the year

Figure 1 shows the total recorded number of orbits for each bin of one degree in solar longitude with EDMOND 2001–2016 (top) and SonotaCo net 2007–2018 (bottom). The general views seem very similar, but the details are different between them, especially year by year.

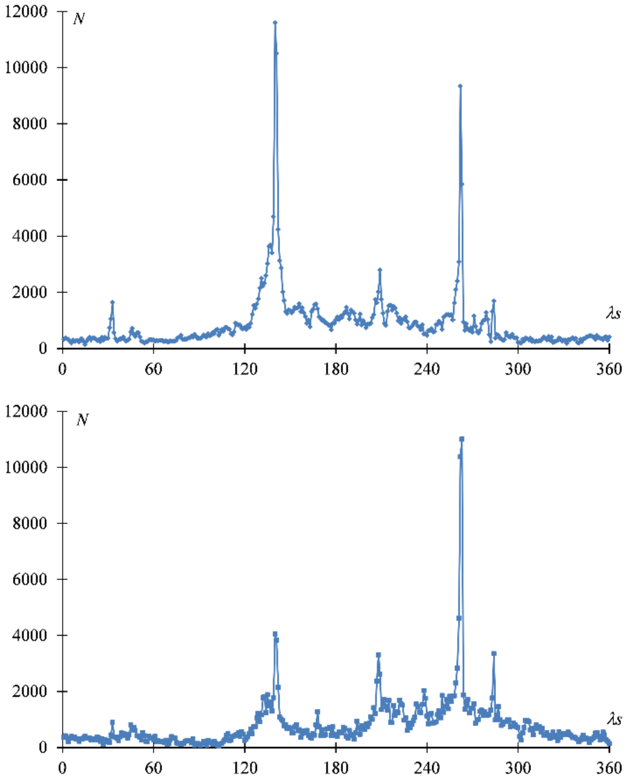

Figure 1 – Recorded number of meteor orbits in function of the solar longitude for all years. EDMOND (top) and SonotaCo net (bottom).

SonotaCo net has published the results of all the year round for 2007 to 2018 but the early EDMOND years are limited to the observations of the major shower period. *Figure 2* compares 2007 observations. Prior to 2007 EDMOND data are scarcer than in 2007. We recommend checking the

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[8] https://www.meteornews.net/edmond/edmond/edmond-database/

[9] https://fmph.uniba.sk/en/microsites/daa/division-of-astronomy-and-astrophysics/research/meteors/edmond/

[10] http://sonotaco.jp/doc/SNM/

observational year when making a survey on meteor shower activity (*Table 1*).

Table 1 – The annual totals of meteor orbits stored by EDMOND and SonotaCo net.

Year	EDMOND	SonotaCo
2001	251	–
2002	71	–
2003	113	–
2004	34	–
2005	82	–
2006	532	–
2007	2279	19274
2008	5583	19436
2009	8275	25940
2010	19618	25858
2011	36413	23772
2012	34732	27231
2013	41295	26514
2014	43546	22078
2015	57439	18723
2016	67426	22170
2017	–	26149
2018	–	27128
Total	317689	284273

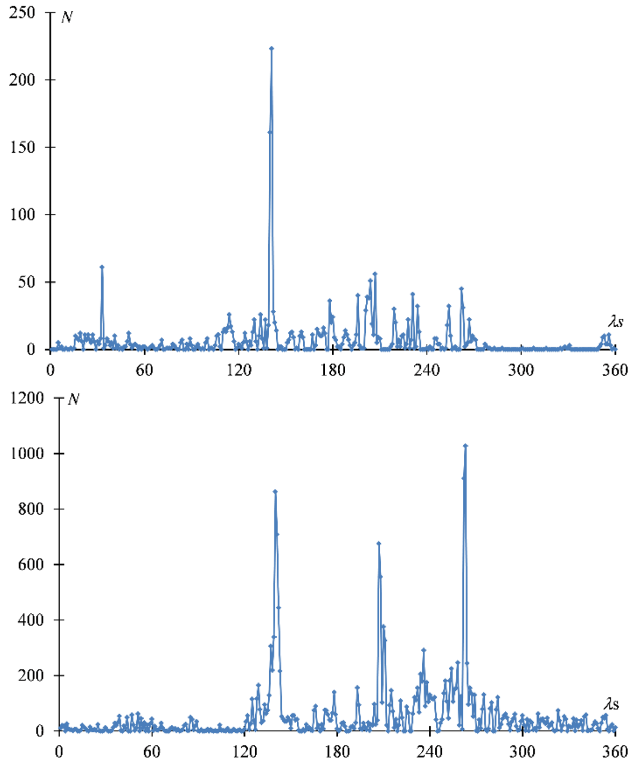

Figure 2 – Recorded number of meteor orbits in function of the solar longitude for the year 2007 only. EDMOND (top) and SonotaCo net (bottom).

The differences in the weather conditions between Europe and Japan affect the profiles. The base line of the profile (excluding the shower peak) tends to rise around autumn for EDMOND an around winter for SonotaCo net (*Figure 1*).

The maximum occurs at the Perseids activity period for EDMOND and at the Geminids for SonotaCo net. Many of the EDMOND cameras are located at higher latitudes than those of SonotaCo net. However, the morning twilight hinders European observers a lot. The number of recorded Perseids in Europe is much higher than for Japan (see also 'Shower classification').

As observers are staying fixed on Earth, they cannot record the real shower maximum every year as we encounter the different parts of meteoroid streams every 0.25 degree in solar longitude year after year. This influences the value for the peak of the shower activity a lot.

3 Magnitude distribution

Magnitude distributions for meteors classified as sporadics by the definition of each network are shown in *Figure 3*; the absolute magnitude is used here because the early EDMOND data do not give the observed magnitude.

SonotaCo net data seems to display a slightly steeper ascent; with a magnitude ratio r = 3.48 for SonotaCo (mag. = –10 to –3) and r = 3.34 for EDMOND (mag. = –7 to –1). These magnitude ratios look good for sporadics.

If we extend these ratios to fainter magnitudes, we could get their observability on the magnitude separately (*Table 2*).

Can EDMOND systems record fainter meteors than SonotaCo's? But, if we extend these ratios to the brighter range we see a strange situation. EDMOND has an excessive number of bright meteors (*Table 3*).

Table 2 – Estimated perception coefficient.

Magnitude	EDMOND	SonotaCo
–4 ~ –3	–	1.000
–3 ~ –2	–	0.787
–2 ~ –1	1.000	0.440
–1 ~ 0	0.656	0.170
0 ~ +1	0.039	0.036
+1 ~ +2	0.002	0.004

Table 3 – EDMOND's super fireball rates.

Magnitude	Estimated	Observed	Est./Obs.
–11 ~ –10	0.7	65	98.8
–10 ~ –9	2.2	29	13.2
–9 ~ –8	7.4	39	5.3
–8 ~ –7	24.6	73	3.0

EDMOND has recorded bolides of magnitudes –11 to –10 about one hundred times more frequently than expected by the magnitude ratio. Either the magnitude ratio for the fireball range (mag. = –7 to –1) should not be applied for super fireballs, or the magnitude distribution of EDMOND is affected by measuring problems? EDMOND data seem to be excessive in 0th magnitude meteors. 'Super fireballs' have been only observed in the interval 2007–2011. We cannot confirm that the perception of EDMOND is better than that of SonotaCo's.

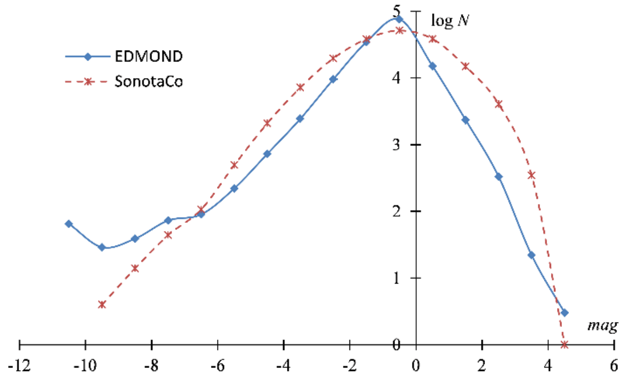

Figure 3 – Magnitude distributions.

4 Velocity distribution

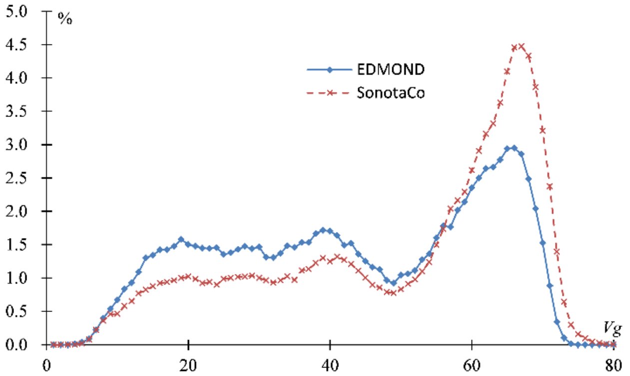

Figure 4 – Velocity distribution of sporadics.

Figure 4 shows the velocity distribution: the x-axis is geocentric velocity v_g in km/s bin and the y-axis is the percentage of the total number of sporadics. It is clear that EDMOND can capture slower meteors and SonotaCo net faster ones. The reason for the difference is still unknown, though the difference in recording of the fainter meteors (positive magnitude) might affect this (*Figure 5*).

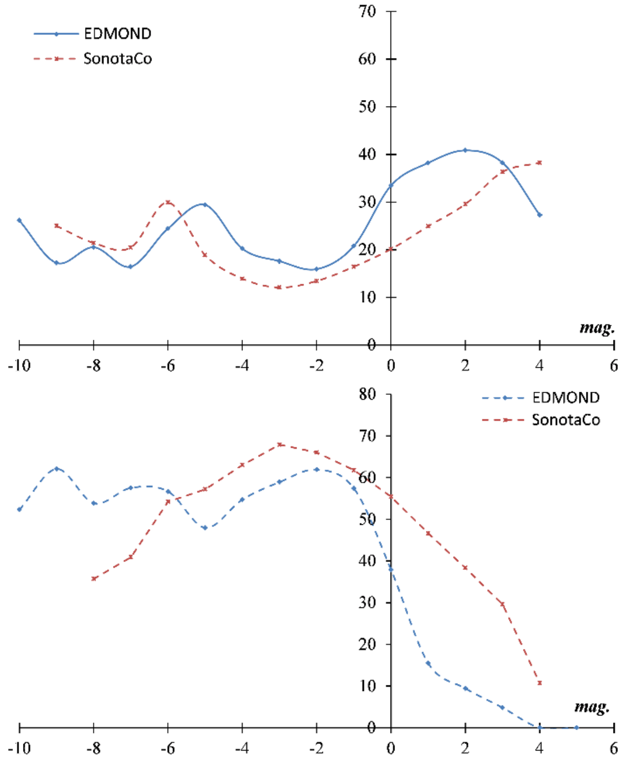

Figure 5 – Magnitude distributions: $v_g = 20 \sim 40$ km/s (top) and $v_g = 50 \sim 70$ km/s (bottom).

5 Radiant density distribution along the elongation from the apex

The radiant density (radiant/square degree) shows the difference of these two systems (*Figure 6*). The difference in the elongation between 60 and 90 degree is caused by slower meteors (see former section), i.e. ANT. However, the dip in the SonotaCo net data near the apex is curious. This may be caused by the shower classification (see next section).

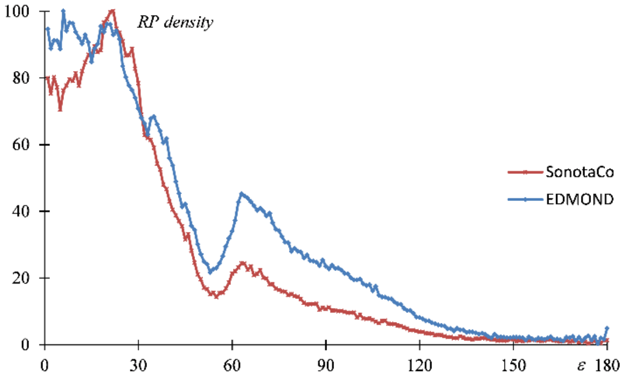

Figure 6 – Radiant density distributions.

6 Shower classification

The definition tables used to classify meteors are different for both networks. The definition table of EDMOND contains 621 IAUMDC showers and that of SonotaCo net has 311 IAUMDC showers with different entries together with the original list. SonotaCo net uses the '*all_shower_names*' file as their definition but the details of EDMOND's are not clear. The author asked the EDMOND network to send the definition, but he did not receive an answer yet.

Table 4 shows the most recognized meteor shower top 20 of each database based on their original classification. The shower code (*_stream*) is self-explanatory but _J5_bPi in SonotaCo net means NDA in the IAUMDC list. We note that some showers are missing in the list; _J8_SIA, _J8_ZCS and _J8_ZTA are not found in the SonotaCO list, and _J5_daD, _J5_bPi and _J5_Eri are not listed in EDMOND. The reason for the three missing showers in SonotaCo's list is obvious; they are less observed by EDMOND. But, the three EDMOND's showers are not recognized in SonotaCo's at all and, moreover, J8_ZCS is not listed in their definition table. It is very interesting that the ratios of sporadics and other showers are quite different. It is necessary to investigate what causes these differences.

7 Capricornids and Leonids

It is interesting to compare the Capricornids with the Leonids because of the difference in observability of the velocity between EDMOND and SonotaCo net.

Table 4 – Shower classification top 20.

EDMOND _stream	%	SonotaCo _stream	%
_J8_PER	14.17	_J5_Gem	8.95
_J8_GEM	6.07	_J5_Per	6.18
_J8_ORI	2.46	_J5_Ori	4.42
_J8_STA	1.98	_J5_Com	1.87
_J8_NTA	1.27	_J5_sTa	1.86
_J8_COM	0.92	_J5_Hyd	1.53
_J8_SIA	0.92	_J5_Leo	1.39
_J8_HYD	0.91	_J5_nTa	1.38
_J8_QUA	0.85	_J5_etA	0.97
_J8_ZCS	0.82	_J5_sdA	0.87
_J8_LYR	0.7	_J5_Qua	0.85
_J8_CAP	0.66	_J5_daD	0.81
_J8_KCG	0.58	_J5_noO	0.51
_J8_LEO	0.55	_J5_Mon	0.42
_J8_SPE	0.54	_J5_Lyr	0.4
_J8_ETA	0.43	_J5_Cap	0.38
_J8_SDA	0.38	_J5_sPe	0.35
_J8_ZTA	0.38	_J5_bPi	0.27
_J8_NOO	0.34	_J5_Eri	0.23
_J8_Mon	0.3	_J5_kCg	0.22
others	20.35	others	4.67
_spo	44.41	_spo	61.48

Figure 7 clearly shows the difference between the activity profiles of the Capricornids and the Leonids. The slower meteor shower, Capricornids, is twice as strongly recorded in EDMOND compared to SonotaCo net, while the faster Leonids are twice as strong in SonotaCo net compared to EDMOND. These results are mainly influenced by weather conditions; the early Capricornids are hindered by the Japanese rainy season. However, the difference is not fully explained by the weather, because the late Capricornids are not observed by SonotaCo net with the same strength.

On the contrary, Leonids are abundant in SonotaCo net data. The difference in the weather conditions is not enough to explain for the discrepancy in this case. The most likely answer for these different observabilities is the disparity of the treatment/recognition of fainter (positive magnitude) meteors in slower/faster velocity.

We can present one more reason for the difference. The difference in the shower definition table has a strong effect. EDMOND limits the activity period shorter than SonotaCo's (*Figure 7*). *Figure 8 and 9* suggest the difference in the table on the extent and the shift of the showers, although this explanation is not fully explanatory. These four maps are drawn in the azimuthal equidistant projection in ecliptic coordinates; the line $\lambda - \lambda_\odot = 180$ (*Figure 8*) or 272 (*Figure 9*) runs along the y-axis. These maps allow us to show that the radiant shift is slower than in the ordinary (α, δ) coordinates as well as the radiant distribution. The difference in the extent and the shift looks not so large for explaining the discrepancy.

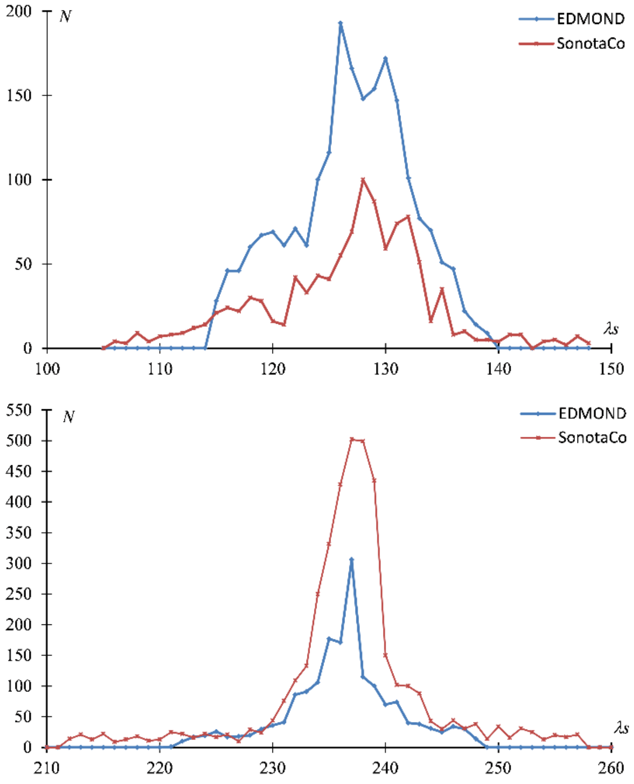

Figure 7 – Activity profiles: Capricornids (top) and Leonids (bottom).

8 Conclusions

EDMOND and SonotaCo net data are not completely equal. The observability in function of the velocity and the shower definition tables are different. We should be cautious when we search meteor showers combining both datasets.

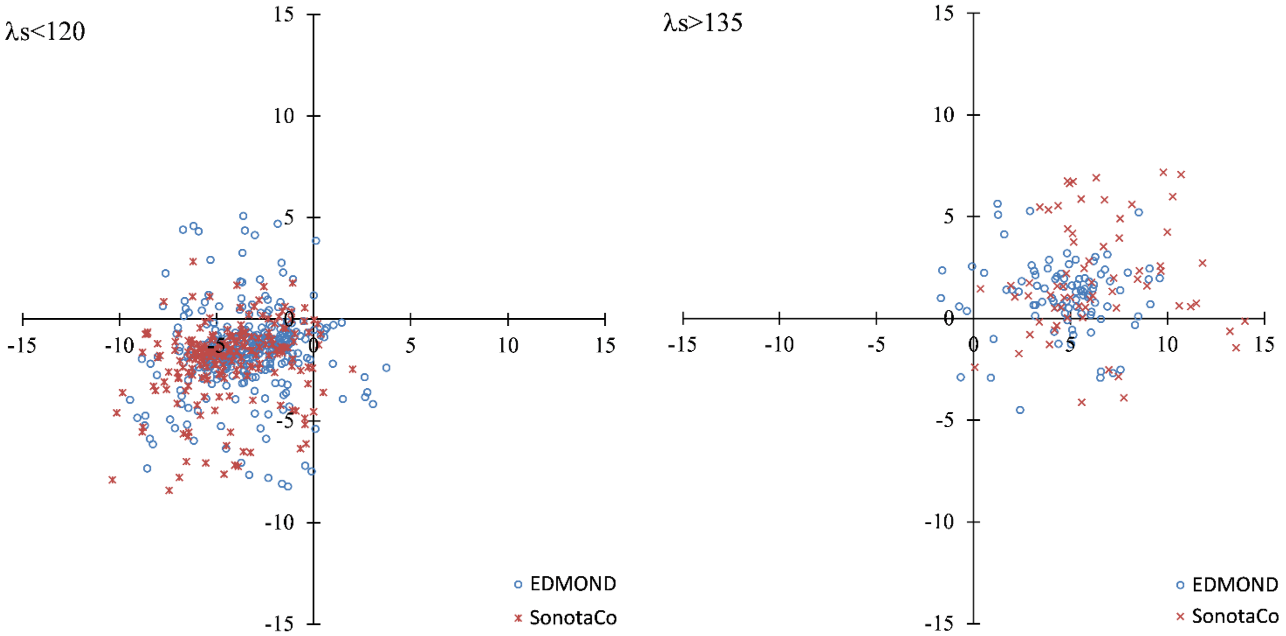

Figure 8 – Radiant distribution of the Capricornids centered at (λ – λ⊙, β) = (180°, 10°).

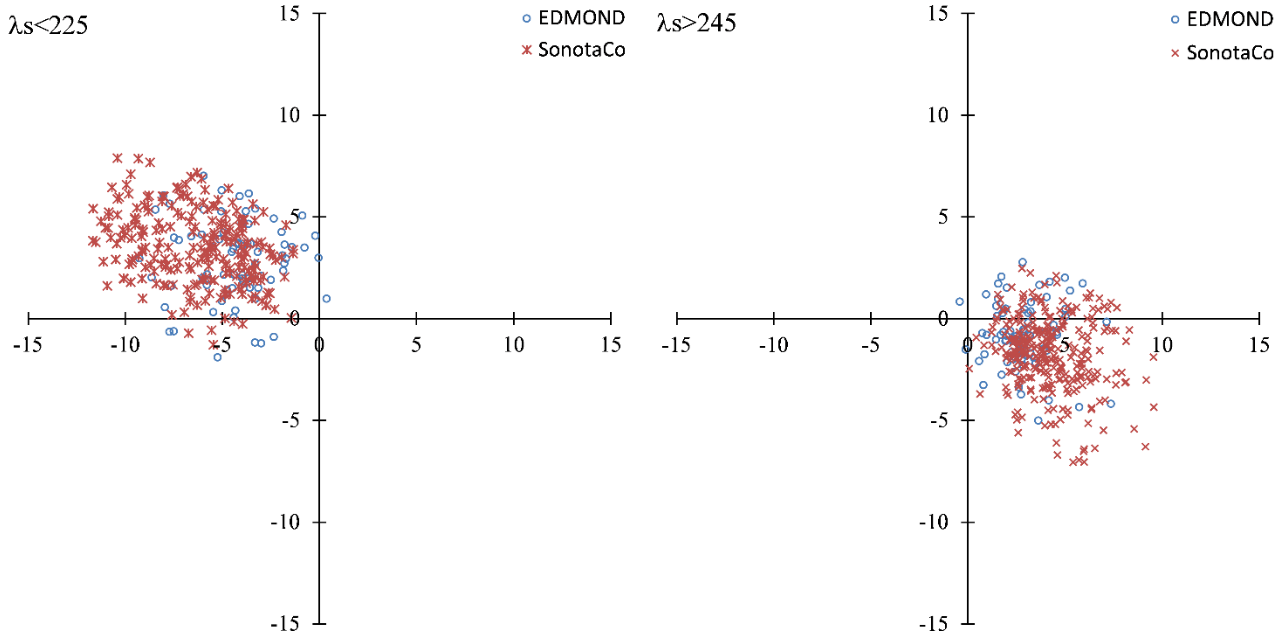

Figure 9 – Radiant distribution of Leonids centered at (λ – λ⊙, β) = (272°, 10°).

Large meteorite (H_{4-5}) exploded over the region of Zag (Morocco)

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Hundreds of meteorite hunters have arrived at the place where the fireball disappeared. They roam the desert in the oppressive heat, on foot or in an off-road car, hoping to find a fragment of this gift that has fallen from the sky.

1 Introduction

A big meteor appeared Thursday, June 27, 2019 at about 17h (local time), at the sky over Morocco (region of the city of Zag, Lhmada region exactly in the rural municipality of Lhtiba). Eyewitnesses of the spectacle of the entry in the Earth’s atmosphere confirm that: “*a ball of fire was first orange-blue in color before turning red, illuminating the whole area and breaking into pieces after a large explosion, leaving behind a trail of white smoke*”. The fireball was seen by residents of towns and villages more than 150 km from the site of the fall, but its precise speed was not achieved; however, on average, meteorite dropping fireballs move in the atmosphere at a maximum speed of 15 km/s.

2 The meteorite dropping

Figure 1 – The location where the first fragments were found near the rural municipality of Lhtiba.

Thousands of people from surrounding towns and villages have moved to the site. The first fragments of the meteorite were recovered the next day very early in the morning, near the rural municipality of Lhtiba (*Figure 1*). Most of the found fragments were quickly identified as meteorites because they had a conspicuous melting crust covering part of their surface. The largest mass recorded was about 1300 g, with a total estimated mass of 17 kg. A fragment of the “Lahtiba” meteorite (as it has been tentatively named) about 30 mm in diameter and 20 mm thick was presented to researchers at Ibn Zohr University in Agadir (*Figure 2*). The measurement of the magnetic sensibility (denoted χ_m, a dimensionless quantity) on this fragment is of the order of 10.4 and has shown that “Log χ m^3 / kg” is of the order of 5.33 with a density of 3.29. The density of chondrites in this meteorite is estimated to be between 4 and 5. These values correspond well to the range of chondrites of the type H_{4-5} (Folco et al., 2006), thus revealing that it is about an ordinary chondrite from the asteroid belt. It is a sample that did not undergo a large shock (S1–2) and does not represent any degree of terrestrial contamination (W0). Chondrites are the oldest materials in the solar system and are the main source of information for scientists on the conditions of the Sun and planet formation. It is for this reason that they are so interesting to study.

Figure 2 – Professor Abderrahmane Ibhi during the investigation of the June 27 meteorite sample.

Morocco is one of the most important countries in the world for meteorite falls. The supervision on meteorite falls is essentially provided by nomads living and crossing the Moroccan desert all year round. These people are a real network of live cameras. The observations and recovery of these meteorite falls are very interesting for several reasons. The materials from the falls observed have not been submitted to terrestrial contamination, making it a better sample for scientific studies. Southern Morocco is world famous for its meteorites. *More than half of the scientific publications on extraterrestrial rocks are made on the basis of Moroccan meteorites*. Anyway, the Lhtiba-2019 meteorite of the Zag region is added to the list of meteorite falls in Morocco. Over the past eighty years, twenty-two meteorite falls have been recorded in Morocco, of which nineteen are well-documented. A short list with the names;

- Douar Mghila (1932);
- Oued el Hadjar (1986);
- Zag (1998);
- Itqiy (1990);
- Bensour (2002);
- Oum Dreyga (2003);
- Benguerir (2004);
- Tamdakht (2008);
- Tissint (2011);
- Izrzar (2012);
- Aoussred (2012);
- Oum Drayga (2013);
- Mahbas Arraid, (2013);
- Tighert (2014);
- Tinajdad (2014);
- Sidi Ali Ou Azza (2015);
- Oudiat Sbaa (2016);
- Kheng Ljouad (2017);
- Ksar El Gorrane (2018);
- Geltat zemmour (2018).

Finally, this year Morocco has experienced two meteorite falls. This justifies considering seriously the creation of a national museum to preserve this heavenly heritage, since Morocco is a country of meteorites. The few Moroccan meteorites that remain in the country are part of some private collections. The largest collection of meteorites in Morocco is owned by the University Museum of Meteorites in Agadir.

Acknowledgments

We are very gratefull to *Mr. Bachikh Mouloud* (Es Smara), *Mr. Bekkar Mohamed* (Guelmim), *Mr. Leyreloup Christian* (Imouzzer Kander), *Mr. Amouri Hmad* (Erfoud) and *Mr. El Jarmouni Mohamed* (Casa) for their help in collecting all information and the samples.

References

Luigi Folco, Pierre Rochette, Jérôme Gattacceca, and Natale Perchiazzi (2006). “In situ identification, pairing, and classification of meteorites from Antarctica through magnetic susceptibility measurements”. *Meteoritics & planetary science*, **41**, 343–353.

Radio meteors May 2019

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An overview of the radio observations during May 2019 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 May 2019.

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 our registrations were quite often affected by moderate local interference, on 8 days by "sporadic E" (Es) and on 6 days by lightning activity. The automatic countings were manually corrected in order to eliminate as much as possible the effects of these disturbances.

Highlights of the month were as expected the Eta Aquariids that peaked on May 5th, and which produced several radio echoes lasting more than 1 minute.

Several other showers were quite active, with also a number of eye-catching long duration reflections. SpecLab pictures of a selection of these are attached.

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

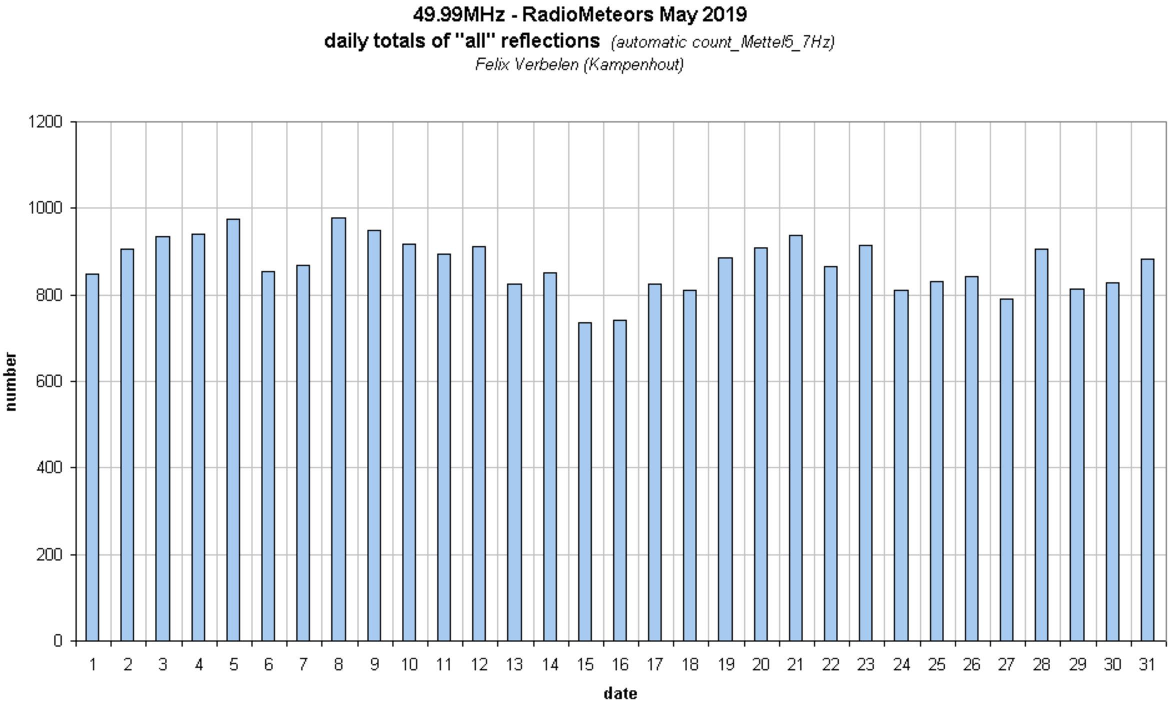
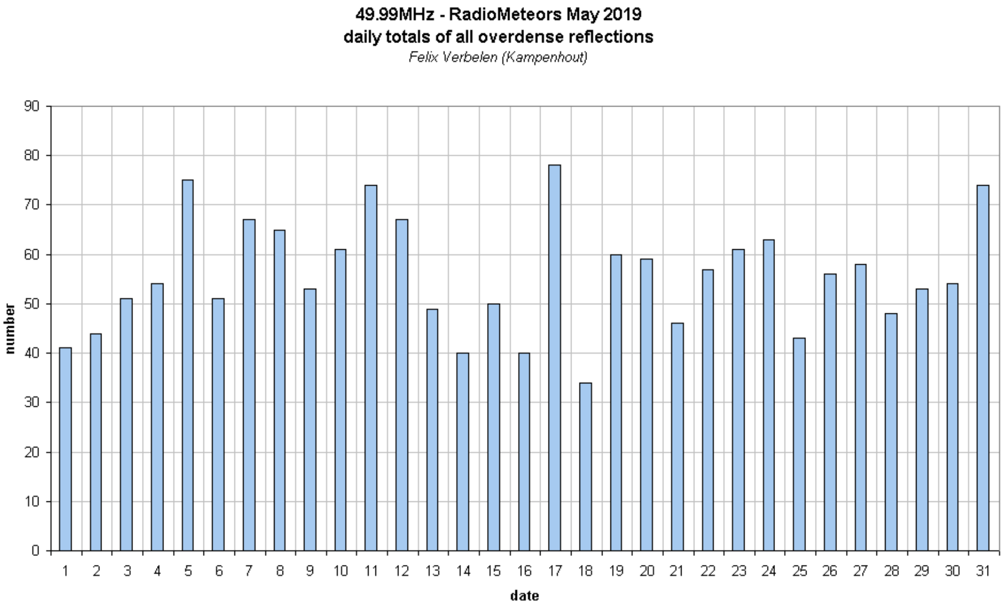
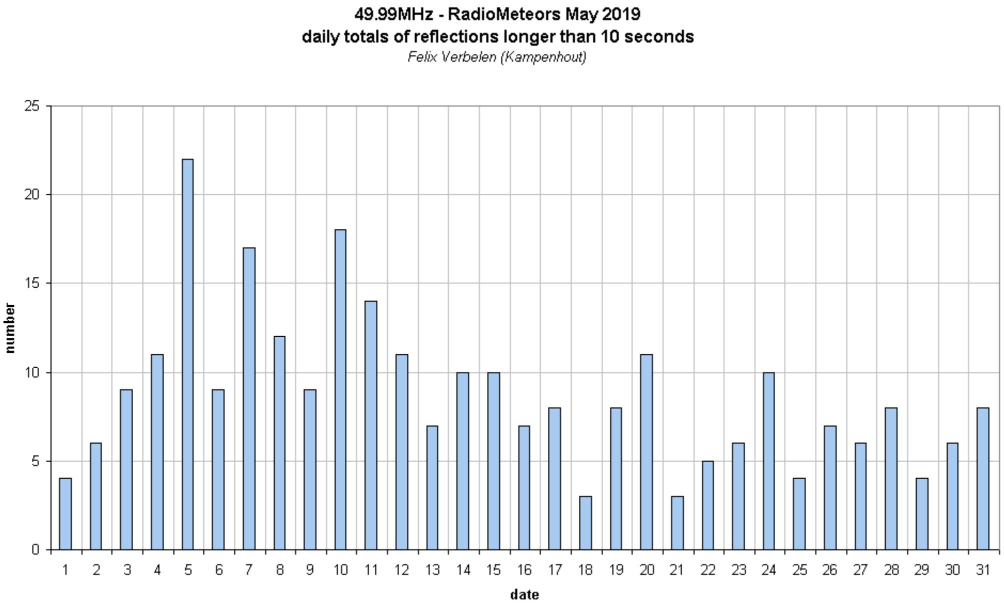


Figure 1 – The daily totals of "all" reflections counted automatically as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during May 2019.





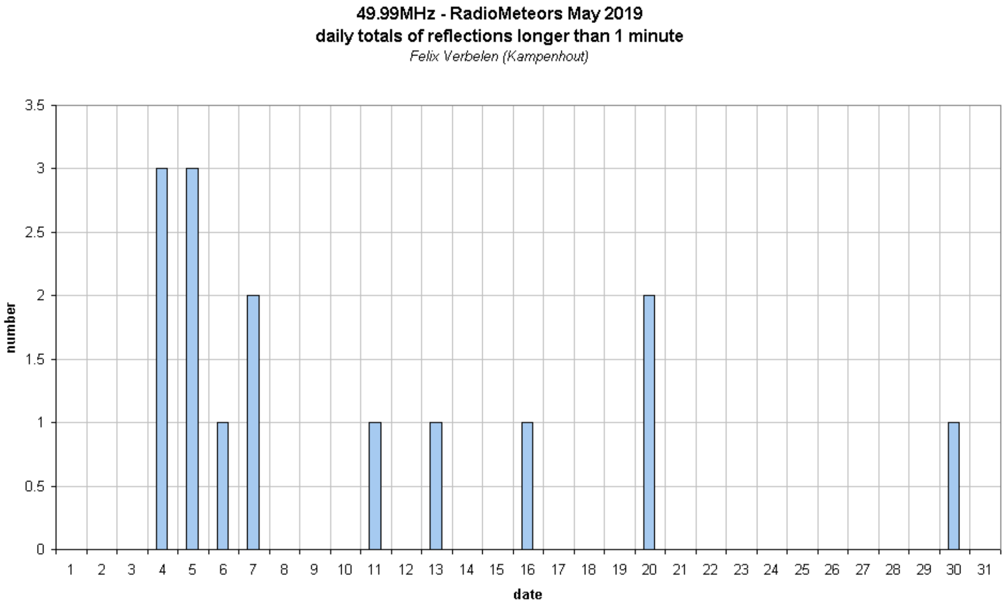
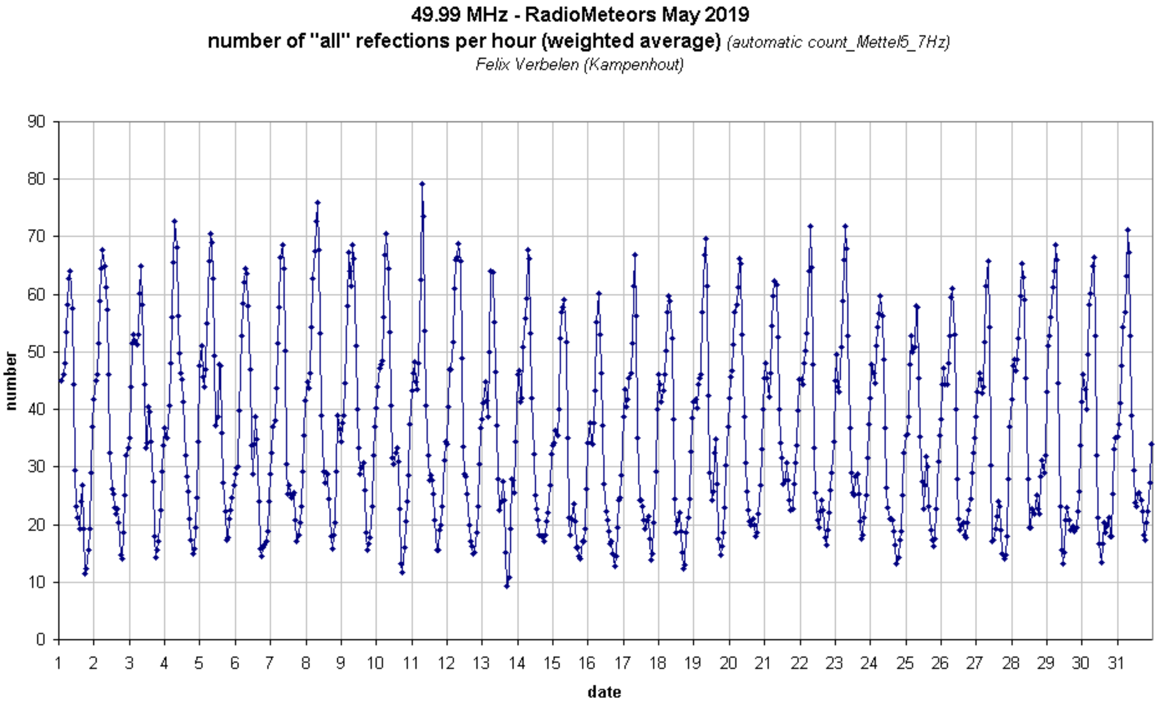


Figure 2 – The daily totals of manually counted "overdense" reflections, overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during May 2019.



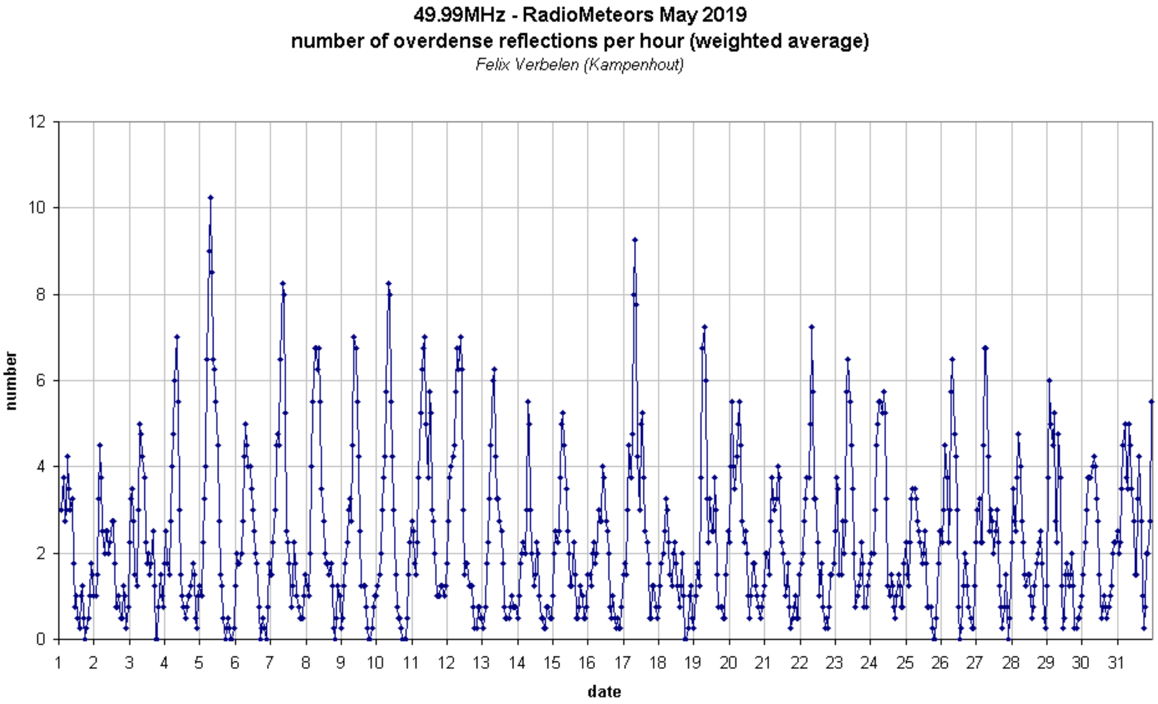
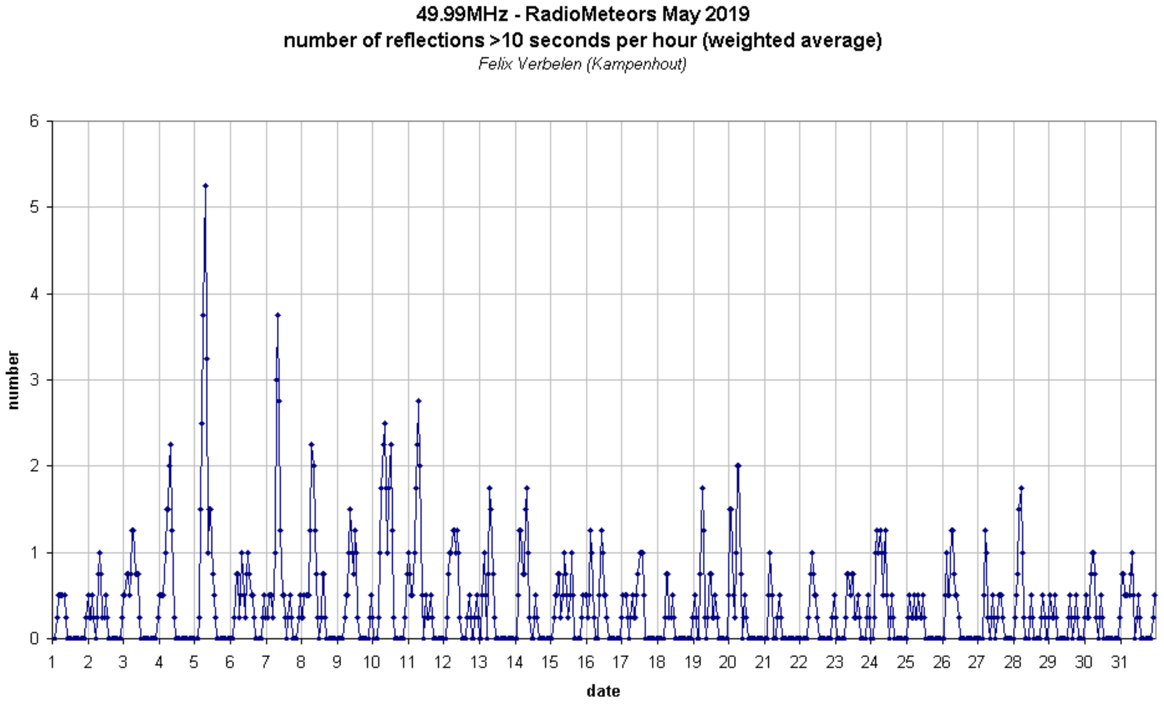


Figure 3 – The hourly numbers of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during May 2019.



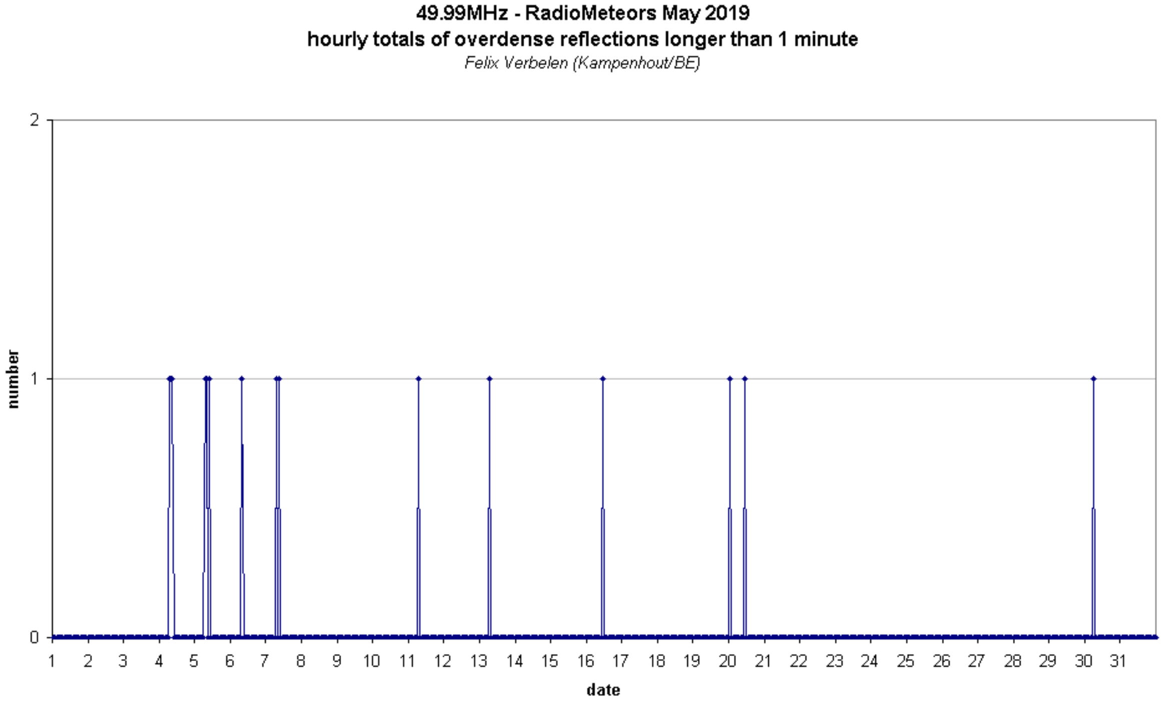


Figure 4 – The hourly numbers of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during May 2019.

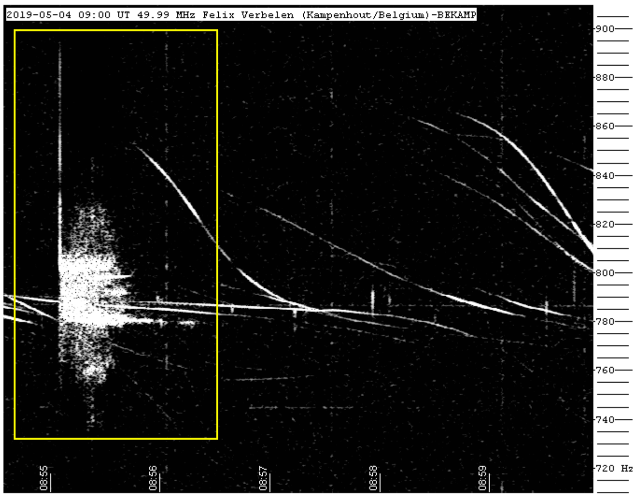


Figure 5 – Echo registered on 4 May 2019 at 09^h00^m UT.

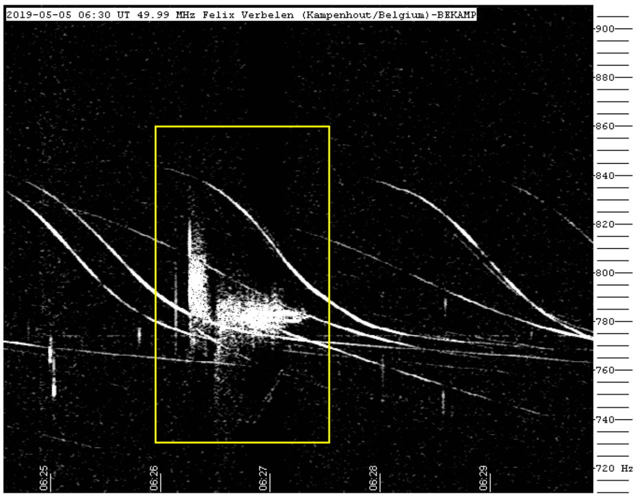


Figure 6 – Echo registered on 5 May 2019 at 06^h30^m UT.

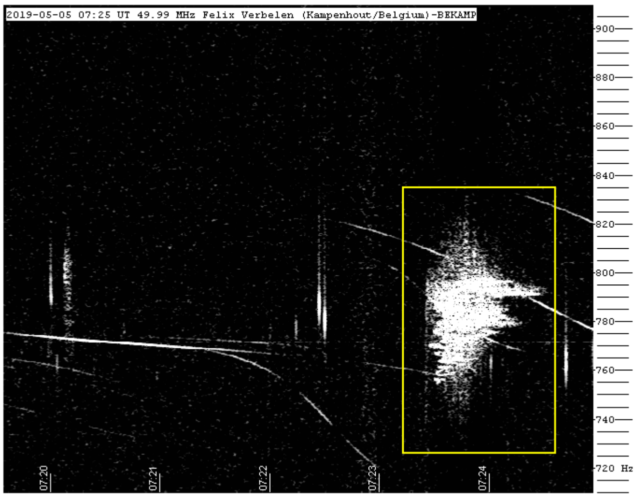


Figure 7 – Echo registered on 5 May 2019 at 07^h25^m UT.

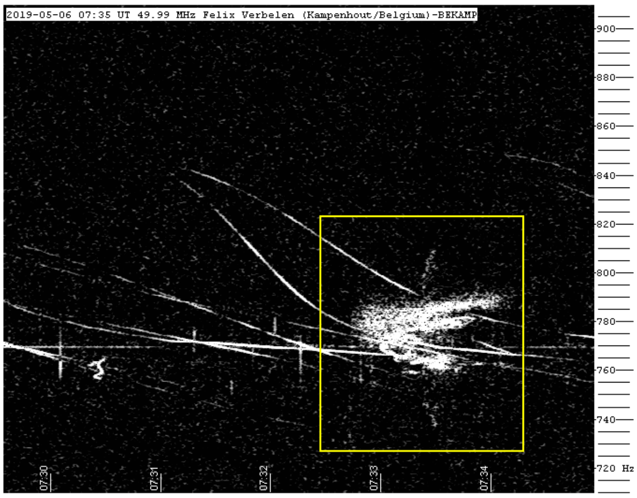


Figure 8 – Echo registered on 6 May 2019 at 07^h35^m UT.

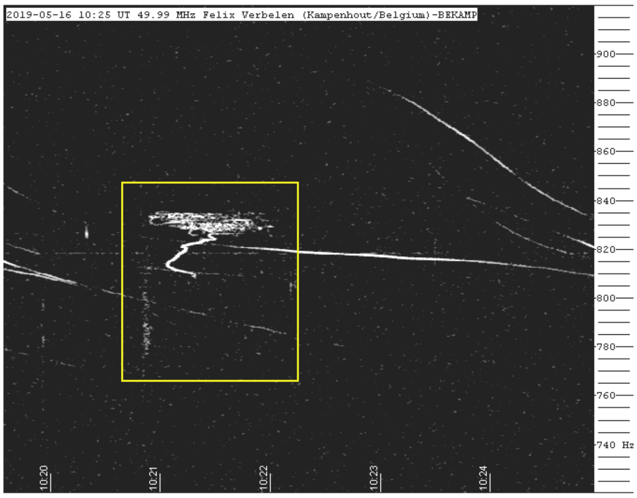


Figure 9 – Echo registered on 16 May 2019 at 10^h25^m UT.

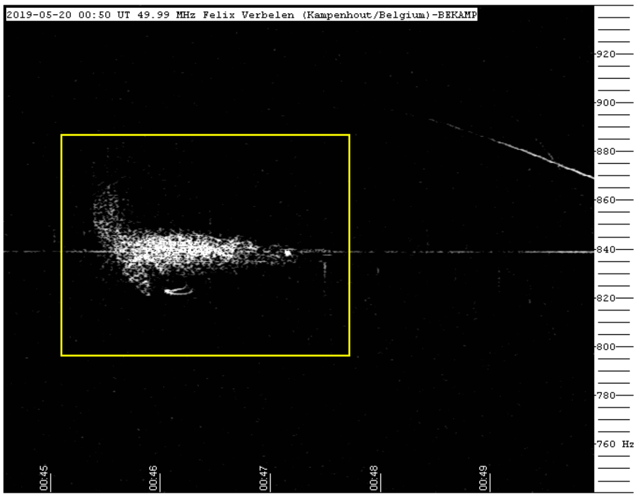


Figure 10 – Echo registered on 20 May 2019 at 00^h50^m UT.

Radio meteors June 2019

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An overview of the radio observations during June 2019 is given.

1 Introduction

The graphs show both the daily totals (*Figure 2*) and the hourly numbers (*Figure 3*) 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 June 2019.

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

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

Counting "all" reflections was at times very difficult, if not impossible, due to strong local noise and other interference, and also during periods of intense lightning activity. Especially when thunderstorms occurred in the vicinity of our beacon, counting underdense reflections was practically impossible, since the lightnings showed reflections mostly identical to that of some normal underdense reflections. *Figure 1* shows an example of how the SpecLab screen was filled with lightning reflections during one of these thunderstorms near Ieper.

Highlights of the month were as expected the daytime showers that peaked during the first half of the month, while long-lasting reflections were more numerous in the second half. SpecLab pictures of a selection of these are attached.

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

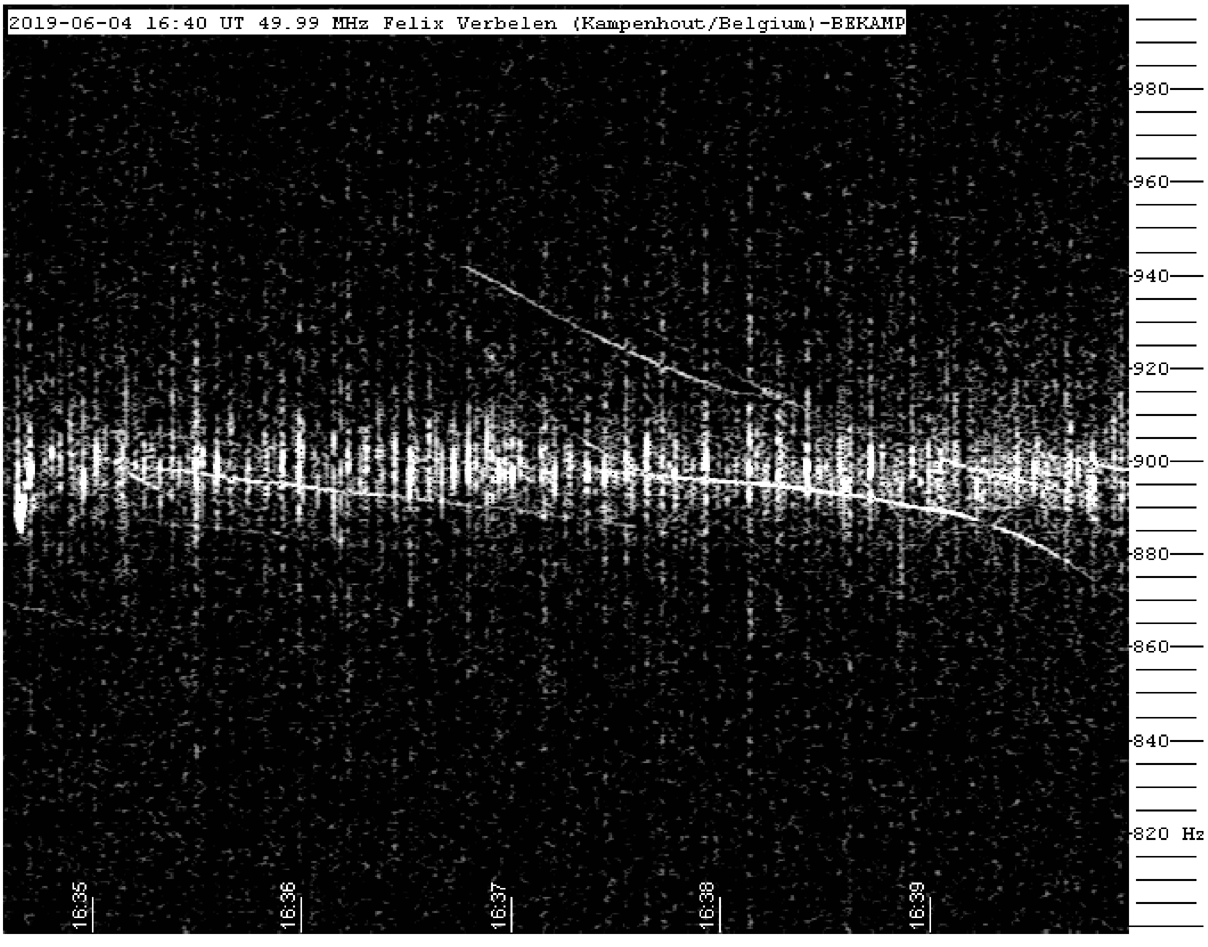
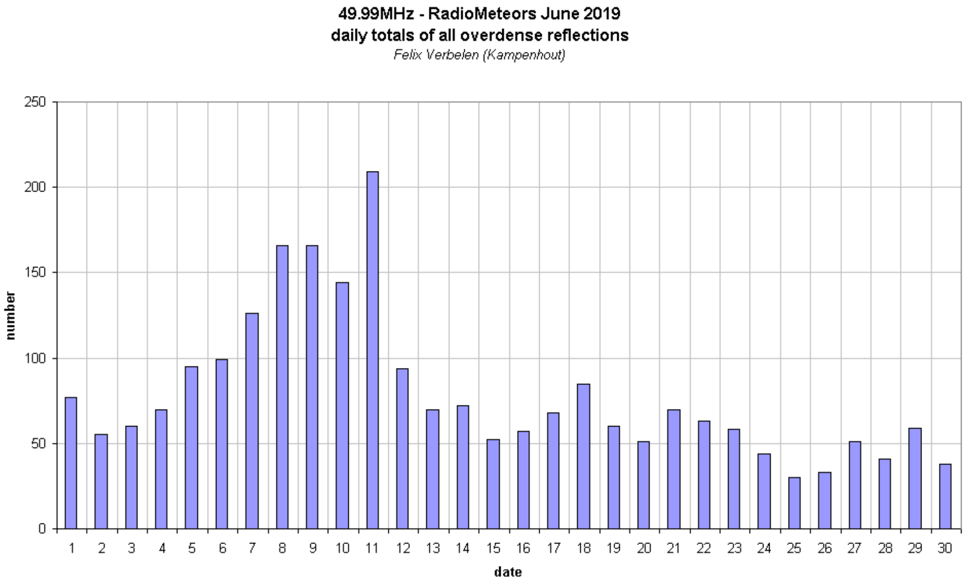
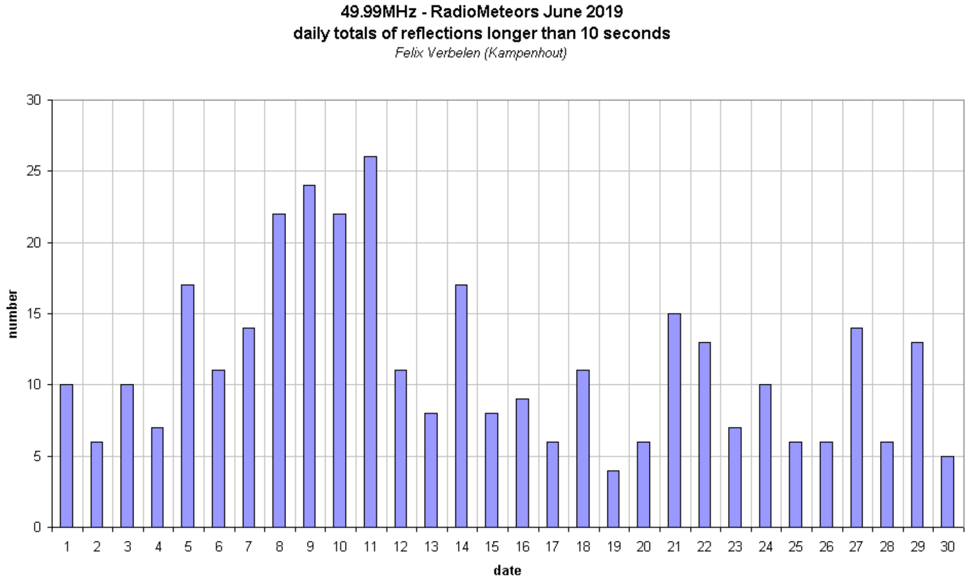


Figure 1 – Example how the SpecLab screen was filled with lightning reflections during one of these thunderstorms near Ieper.





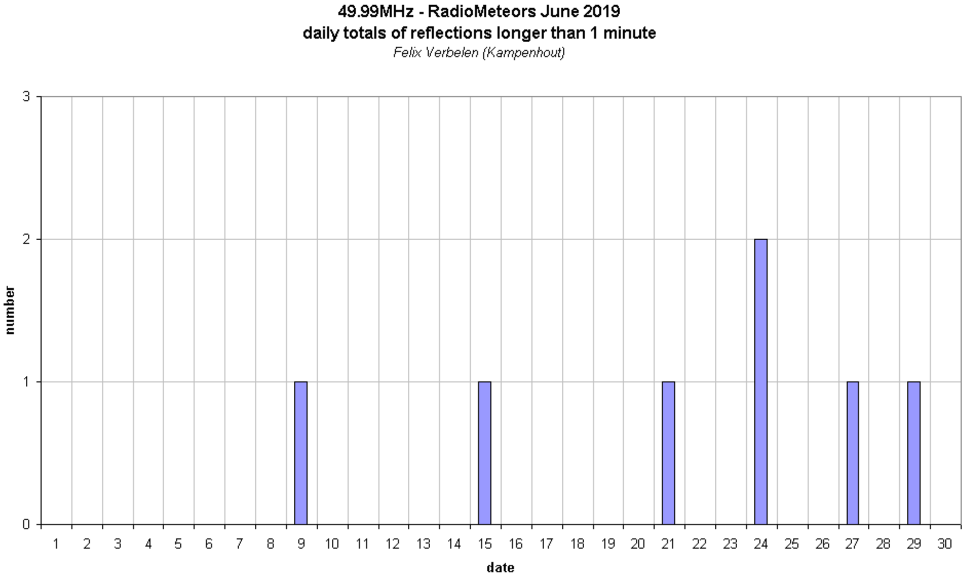
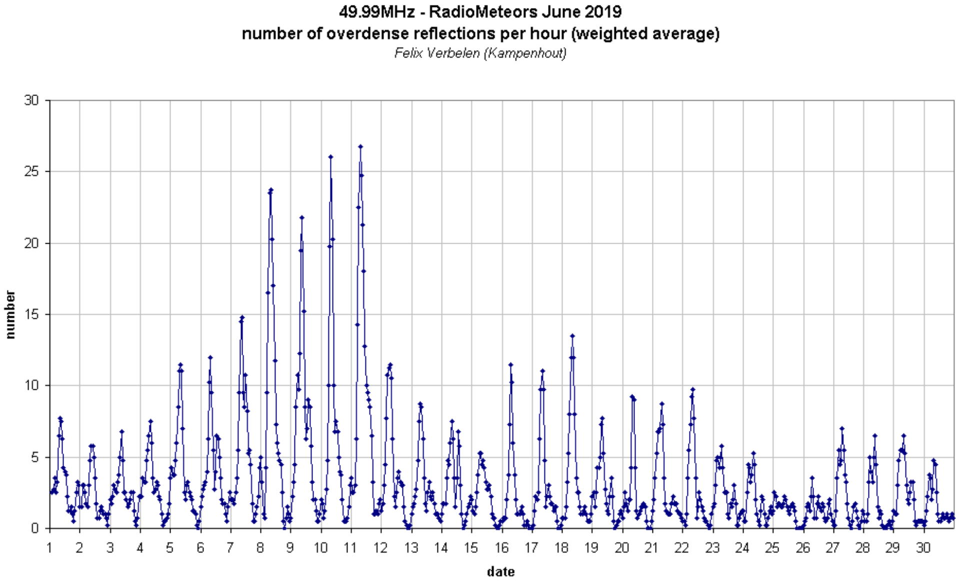
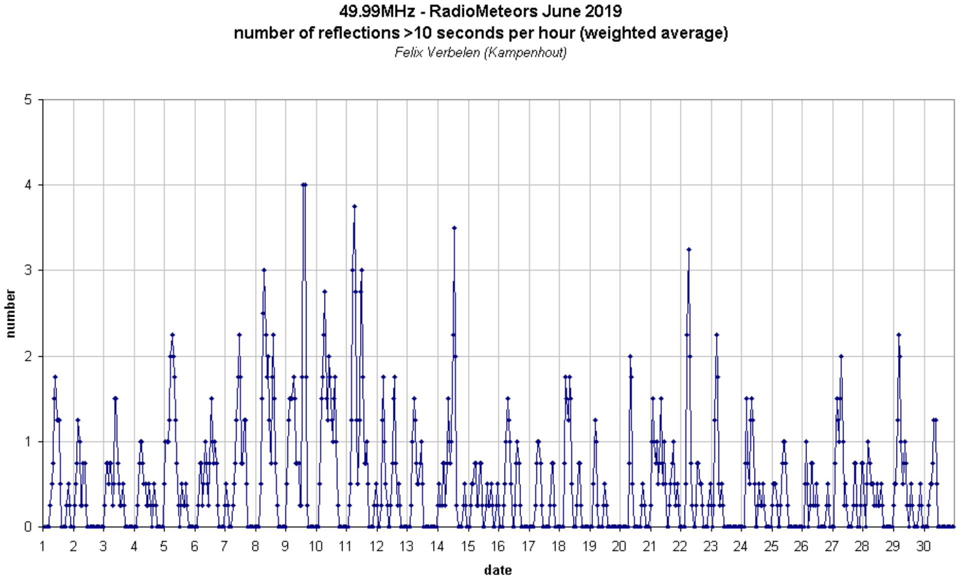


Figure 2 – The daily totals of manually counted "overdense" reflections, overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during June 2019.





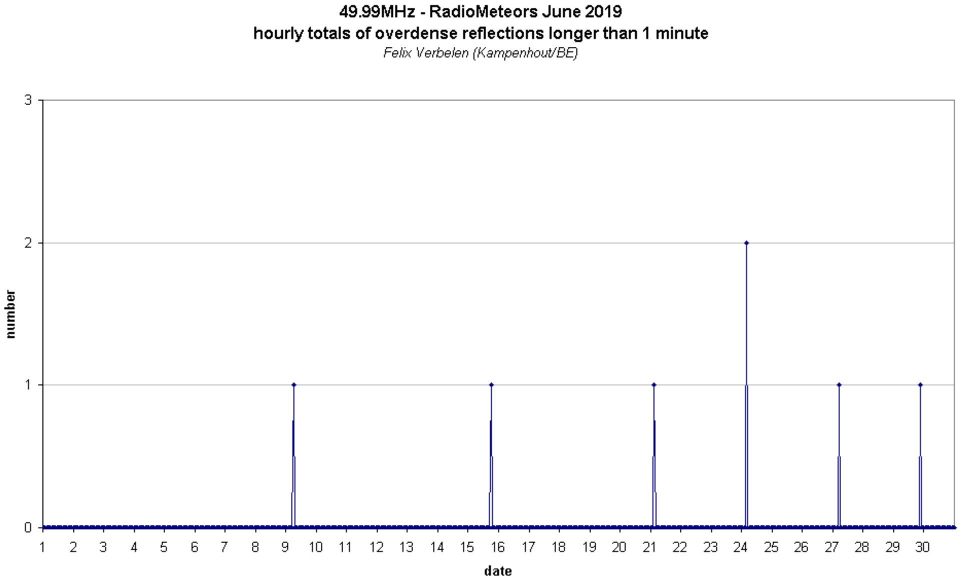


Figure 3 – The hourly numbers of manually counted "overdense" reflections, overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during June 2019.

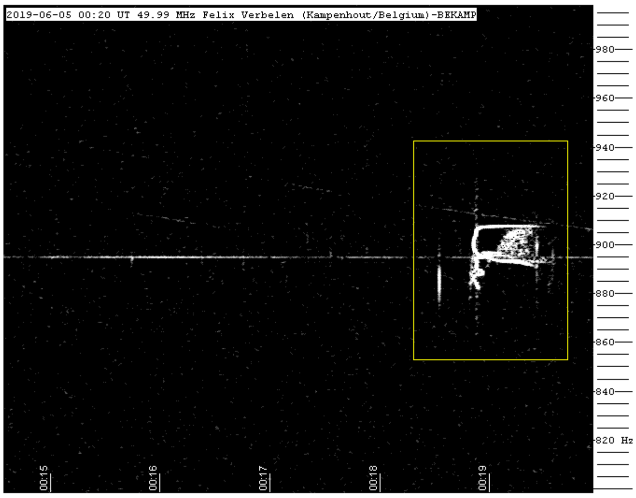


Figure 4 – Echo registered on 5 June 2019 at 00^{h}20^{m} UT.

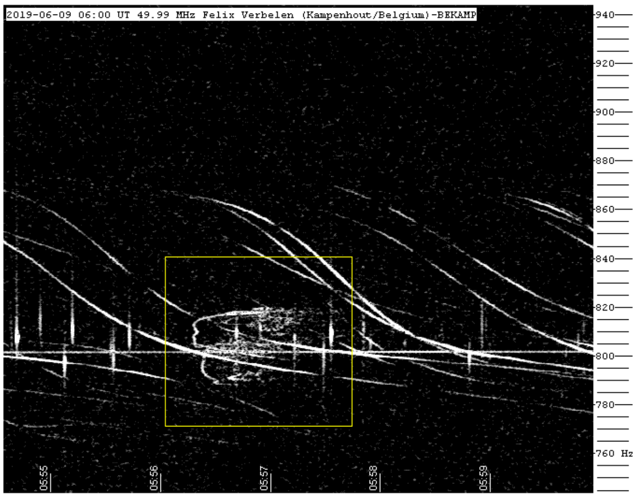


Figure 5 – Echo registered on 9 June 2019 at 06^{h}00^{m} UT.

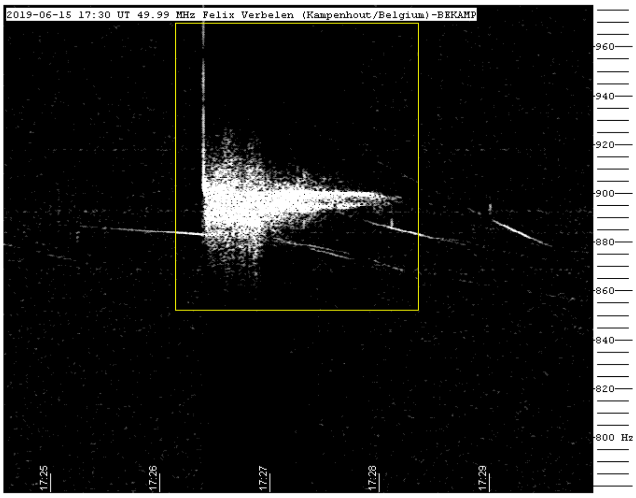


Figure 6 – Echo registered on 15 June 2019 at 17^{h}30^{m} UT.

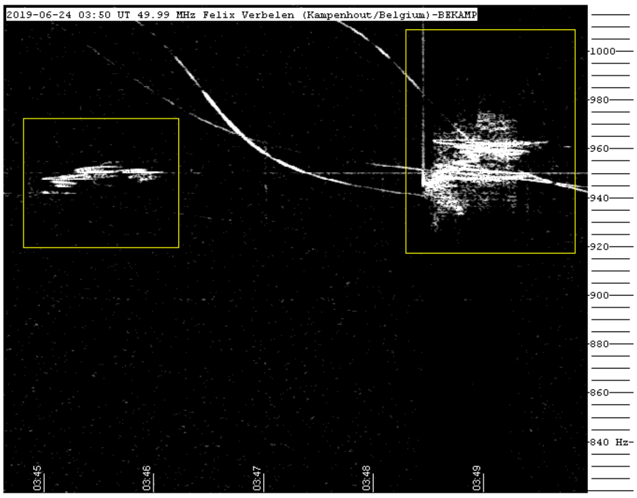


Figure 7 – Echo registered on 24 June 2019 at 03^{h}50^{m} UT.

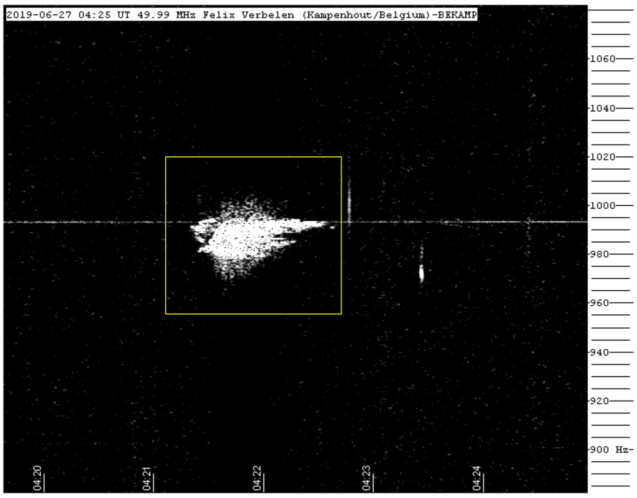


Figure 8 – Echo registered on 27 June 2019 at 04^{h}25^{m} UT.

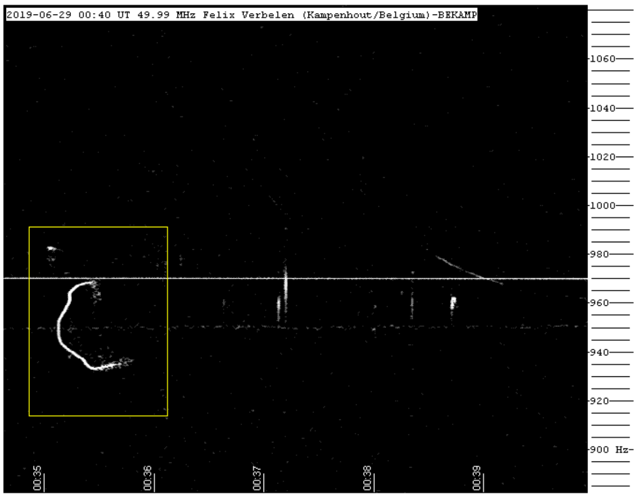


Figure 9 – Echo registered on 29 June 2019 at 00^{h}40^{m} UT.

Spring 2019: observations

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An overview is given with the observations by the author during the first quarter of 2019.

1 Introduction

After the very successful year 2018 regarding visual meteor observations, we can now look forward to 2019. Unfortunately, the Moon will be a major disturbance factor for almost all major meteor showers. In addition, from mid-2019 my time will be very limited due to an extensive renovation of the ground floor of our house.

The year started of course with the Quadrantids, but unfortunately the weather did not cooperate. The idea was to do some observations in the morning hours of January 4th. In the evening it was crystal clear in Ermelo for two hours and I should have better observed in that period, because the rest of the night showed a lot of clouds.

2 January 20–21, 2019

The night of January 20–21 was supposed to be cloudless and there was also a total lunar eclipse planned for this night! Because I have seen many total lunar eclipses since 1979, I decided to do something else. I wanted to observe meteors during the totality and do some SQM (Sky Quality Meter) measurements and limiting magnitude estimates. Observational location was the Groevenbeekse Heide a heath just south of Ermelo. There I regularly observe meteors and during very clear nights the SQM can rise to 20.65.

Around 2^h15^m UT I walked into the heath. The sky was very clean but very bright because of the Full Moon. You could clearly see that the penumbral phase of the eclipse had begun. It was very cold by the way; it was already freezing more than 6 degrees at 2^h00^m UT. I then installed my equipment in the middle of the heath with the moon behind a tree.

I brought with me a digital voice recorder, a Unihedron Sky Quality Meter, my sleeping bag, deck chair, tripod and camera with lens (I also wanted to take some photos of the lunar eclipse). During the meteor observations I looked eastward with the Moon behind me. The meteor observation started at 3^h35^m UT, when the partial eclipse of the central shadow began. Every fifteen minutes, halfway the period, the limiting magnitude and SQM was determined. I always kept the SQM meter on a small table slightly east of the zenith. Of course, I paused twice for 5 minutes to view the Moon when the partial eclipse was already well under way and during the maximum of the eclipse. After the 5-minute breaks, the limiting magnitude and SQM were again measured at the start and end of the quarter, as the limiting magnitude improved rapidly as the partial eclipse progressed. The SQM was always measured 4 times and the 2nd, 3rd and 4th measurements were averaged. The first measurement is always too high. The limiting magnitude was determined in several counting fields and also averaged. *Figure 1* is the result of all measurements.

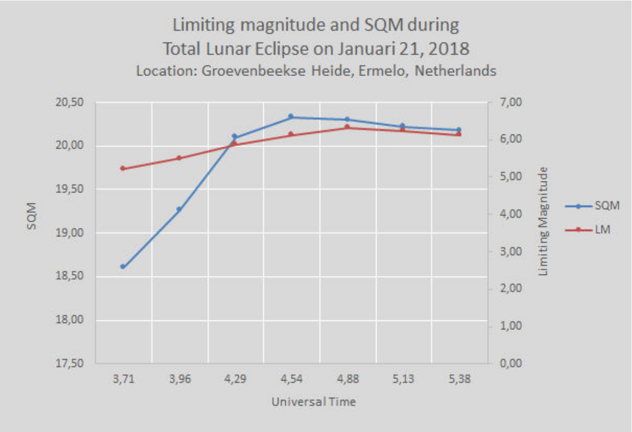

Figure 1 – Limiting magnitude estimations and SQM measurements during the total lunar eclipse of January 21, 2019. The highest achieved limiting magnitude was 6.32 and the highest SQM value was 20.36.

What a beautiful sight that lunar eclipse! Just before the end of the eclipse I stopped observing meteors (5^h30^m UT) because the twilight was increasing. The temperature had dropped from –6 to –10 Celsius at 1.5 meter. In total I counted 13 meteors during 1.75 hours effectively. A +1 sporadic meteor in Cepheus was the brightest one.

3 February 23–24, 2019

A short evening session before the Moon rose again. I could observe between 20^h25^m and 22^h56^m UT. A very clear night in which the limiting magnitude increased to 6.4. Still the SQM measurements were a bit disappointing. The very clear sky had no effect on the numbers of observed meteors, which remained very low. A total of 16 meteors, including 4 Antihelions, were seen. A very slow orange-red +1 sporadic meteor at the start of the session was the most beautiful meteor.

4 March 31 – April 1, 2019

A beautiful clear night in which the limiting magnitude increased to 6.4 and SQM to 20.43 maximum. Despite the good observing circumstances, rather variable activity.

Observations were done between 00^h06^m and 03^h37^m UT (effectively 3.50 hours). A total of 31 meteors were counted, including 4 Antihelions. A +1 sporadic meteor was the highlight, furthermore mainly weak meteors were seen.

5 All sky camera EN-98

This camera captured only three fireballs in the period of January – March 2019.

Figure 2 – Februari 15, 2019 at $20^h08^m59^s$ UT. Camera: Canon 6D. Lens: Sigma 8 mm F 3.5. Liquid Crystal Shutter set at 10 breaks/second.

Figure 3 – Februari 27, 2019 at 23^h19^m UT. Camera: Canon 6D. Lens: Sigma 8 mm F 3.5. Liquid Crystal Shutter set at 10 breaks/second.

The Lyrids of 2019 in a moonlit sky

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An overview is presented of the author’s observations during the Lyrids 2019.

1 Introduction

In 2019 most of the maxima of many meteor showers are in combination with the Moon. This was not different for the Lyrids. A Full Moon on April 19 meant moonlight all night long around the Lyrid maximum. Because the maximum was over the Easter weekend, I decided to make observations during two nights: 21–22 and 22–23 April.

According to IMO, the maximum was expected around $\lambda_{\odot} = 32.32°$, corresponding to the date of April 23, 2019 just after $00^{h}00^{m}$ UT ($02^{h}00^{m}$ hour local time). That was a good thing, because fairly soon after the maximum some brighter Lyrids appear. Therefore, also the choice for 21–22 and 22–23 April, this to see the difference between these two nights (the weak Lyrids versus the bright Lyrids).

I decided to observe from the meteor roof of my dormer. The advantage there is that the Moon (which is low in the south around Full Moon during this time of the year) remains hidden behind the eaves. In addition, a bike ride to the nearby Groevenbeekse Heide (a heath) will not lead to a darker sky just because of the Moon.

2 April 21–22, 2019

A start was made under a moonlit sky at $0^{h}09^{m}$ UT. The brightest stars of the constellation Ursa Minor were clearly visible and in star count area 1 I got no further than 10 stars (*lm* = 5.25). The sky background was quite bright, *SQM* = 18.98 and this remained so the whole session. Unfortunately, there was little to be seen, so little that I stopped after 90 minutes. In those 90 minutes I counted 4 Lyrids and 3 sporadic meteors. Only weak meteors as expected, the brightest meteor was a +2 Lyrid in the “Big Dipper”.

3 April 22–23, 2019

A clear night was predicted by the meteorological institute KNMI, but with occasional fields of cirrus passing by: deadly for observations in combination with moonlight. An alarm clock was set at $23^{h}35^{m}$ UT just in case…. A look outside: bright clear skies but also some patches of cirrus. A glance at SAT24: hmm, after an hour the cirrus might disappear temporarily. I decided to go outside despite the cirrus.

Start of observations at $23^{h}57^{m}$ UT. I worked in 15-minute count periods and determined every period the limiting magnitude, SQM and if necessary, the cloud percentage.

Period $23^{h}57^{m}$-$00^{h}12^{m}$ UT, Lm 5.66, $T_{eff.}$ 0.25 hours, F 1.20

- 2 meteors: a Lyrid of +4, sporadic meteor +3.

Period $00^{h}12^{m}$-$00^{h}27^{m}$ UT, Lm 5.58, $T_{eff.}$ 0.25 hours, F 1.15

- 2 meteors: 2 Lyrids are seen, a +3 and +4.

Period $00^{h}27^{m}$-$00^{h}42^{m}$ UT, Lm 5.49, $T_{eff.}$ 0.25 hours, F 1.15

Yes, activity was increasing! Some beautiful meteors in this quarter! The first one appeared at $00^{h}33^{m}$ UT (in the corner of my field of view): a beautiful magnitude –2 meteor that appeared to come from the Lyrid radiant shot through Cygnus. However, I almost immediately doubted whether this could be a Lyrid. The meteor seemed a bit too slow and started almost in the Lyrid radiant. I therefore classified it as a sporadic meteor and that turned out to be the right choice: the CAMS BeNeLux also recorded this meteor and indeed it turned out to be a sporadic meteor.

Figure 1 – CAMS 354 recorded this sporadic meteor on April 23, 2019 at $00^{h}33^{m}$ UT.

Shortly after this meteor a beautiful long blue +2 sporadic meteor appeared moving from Draco to Cygnus with a short persistent train. At $00^{h}41^{m}$ I saw something bright in the corner of my eye: a –4 Lyrid near Arcturus! Well, that was quite an underestimate: the all sky recording showed a –6 Lyrid. A –3 Lyrid was also recorded on the same recording: WOW! I had not seen the latter visually. Sometimes it happens to me that I estimate meteors that appear in the edge of my field of view too conservative… So, in total I counted 2 Lyrids and 2 sporadic meteors this quarter.

Figure 2 – These two Lyrids of magnitude –6 and –3 were captured in a short period on April 23, 2019 between $00^h41^m30^s$ and $00^h42^m58^s$ UT. Camera: Canon 6D. Lens: Sigma 8 mm F 3.5. The Liquid Crystal Shutter was set at 20 breaks/second.

Period 00^h42^m–00^h57^m UT, Lm 5.49, $T_{eff.}$ 0.25 hours, F 1.10

A little disappointment after the previous period. Despite improving conditions, only 2 Lyrids were seen of magnitude +3 and +2.

Period 00^h57^m–01^h12^m UT, Lm 5.60, $T_{eff.}$ 0.25 hours, F 1.05

Again, only two meteors, both Lyrids. The most beautiful was a Lyrid of –1 at 01^h09^m UT in the Big Dipper with a short persistent train. The limiting magnitude gently improved as the clear sky approached.

Figure 3 – CAMS 354 camera captured this bright Lyrid in the constellation of Cygnus.

Period 00^h12^m–01^h27^m UT, Lm 5.72, $T_{eff.}$ 0.25 hours, F 1.15

The sky was now improving visibly, only a band with cirrus was slowly moving from south to north through my field of view, but beyond that the limiting magnitude was getting better. No less than 5 Lyrids were seen in this period: respectively magnitudes +4, +3, +1, +2 and +1. Some of these were also recorded by CAMS. In addition to these 5 Lyrids, a sporadic meteor was also seen, so a total of 6 meteors during this quarter.

Figure 4 – This bright magnitude –4 Lyrid was captured with CAMS 351 camera on April 23, 2019 at 02^h53^m UT. Stars of Ursa Major are visible.

Period 01^h27^m–01^h42^m UT, Lm 5.72., $T_{eff.}$ 0.25 hours, F 1.05

The cirrus band slowly moved away from my field of view. The transparency was good, despite the moonlight. However, only two Lyrids were seen: +4 and +5.

Period 01^h42^m–01^h57^m UT, Lm 5.72, $T_{eff.}$ 0.25 hours, F 1.00

This period I counted 2 Lyrids and 1 sporadic meteor. A beautiful magnitude 0 Lyrid was observed at 01^h52^m UT in the constellation of Draco.

Period 01^h57^m–02^h12^m UT, Lm 5.72, $T_{eff.}$ 0.25 hours, F 1.00

Once again, a good period with more meteors, in these 15 minutes I counted 5 Lyrids and 2 sporadic meteors. Some bright meteors:

- 01^h58^m UT: +1 LYR
- 02^h01^m UT: +2 LYR
- 02^h02^m UT: +1 LYR

I saw a magnitude –2 Lyrid very low in eastern direction.

Period 02^h12^m–02^h27^m UT, Lm 5.66, $T_{eff.}$ 0.25 hours, F 1.00

The first signs of twilight were visible in the east. Unfortunately, this would be my last fifteen-minute count, because I had to go to work soon. 4 Lyrids were seen: a nice –1 at 02^h18^m UT and a +1 at 02^h26^m UT. The CAMS observations showed that a –2 and a –4 Lyrid appeared quite soon after the visual observations were stopped.

All in all, a very nice session. Observing with moonlight can be fun! The atmosphere in such a night is also completely different from a moonless night.

Figure 5 – These two Lyrids of magnitude –6 and –3 were captured in a short period on April 23, 2019 between 00^{h}41^{m}30^s and 00^{h}42^{m}58^s UT. Camera: Canon 6D. Lens: Sigma 8 mm F 3.5. The Liquid Crystal Shutter was set at 20 breaks/second.

Meteor observations from the very dark village Buzancy in northern France

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Everyone knows the beautiful starry skies of the Provence. However, you can also see such dark skies much closer to the Netherlands. In 2015 I was on holiday with my wife Lizzie near the town of Buzancy in the Champagne-Ardennes region (Miskotte, 2015) in northern France. Unfortunately, I was only able to observe once. In 2017 and 2018 I had a one- and two-week period of vacation (Miskotte, 2017; 2018) respectively in Any Martin Rieux (roughly 60 km north-west of Buzancy, 10 km east-southeast of Hirson). There I could do respectively 2 and 3 meteor sessions. Although the weather in Champagne-Ardennes is worse than in the Provence, the starry skies are even a bit darker than in southern France!

1 Introduction

Between Sunday 28 April and Sunday 5 May, I stayed with Lizzie and our four dogs again in Buzancy at the camping site “La Samatiraine”. We rented a small house there. This period coincided with the activity period of the eta Aquariids, remnants of the famous Comet 1P Halley. Although doing meteor observations was not a main objective, I naturally kept an eye on the weather ...

Observing the eta Aquariids is a challenge in Northwestern Europe (Langbroek, 1995). The nights during early May are getting short. And when de radiant of the eta Aquariids appears above the horizon, dawn begins. After that there is about a one-hour window to see one, two or three eta Aquariids in the brightening sky. Observations from eta Aquariids done from northern Europe are not useful, radiant elevation and limiting magnitude are too low to do serious analyses. But it is fun and a “sport” to see some eta Aquariids during dusk. I hope one day I can see this meteor shower from very southern locations such as Namibia.

Another meteor shower is also active in this period: the eta Lyrids. This meteor shower is a remnant of the Comet C/1983 H1 (IRAS-Araki-Alcock).

A high-pressure area above Scandinavia ensured a calm weather type in which a weak front moved from the northeast to the southwest. On April 30 the sky cleared slowly during the day. However, the sky was not deep blue, but a little hazy. This improved slightly as the day progressed. In 2015 I observed from a meadow surrounded by trees and bushes behind the campsite. Because fog might occur, I decided to look for a more open location where the weak northeast wind had more strength. I found such a location at 500 meters from our house next to a lake. The view proved perfect from the west over the south to the east. I had the lake and a number of large trees behind me.

2 April 30 – May 1, 2019

After a short sleep in the evening alarm went off at 22^h UT. Next, I walked to the location across the illuminated camping site and into the darkness. I found a nice place in the grass near the lake and so the observations could start. Towards the east the sky was a bit brighter, perhaps from Buzancy, but I didn't see any direct lighting in that direction.

Although the sky was a bit hazy at a lower altitude, the sky was breathtakingly beautiful. A very dark sky background. After the first *SQM* measurement I could not believe my eyes: *SQM* = 21.80 ... That is better than what Michel Vandeputte ever measured in Revest du Bion (Provence)! There we measured an *SQM* maximum of 21.65. Gradually the *SQM* rose slightly to 21.85 during the night.

This session was a very nice one. At night there were first the noises of the frogs and ducks, sometimes together with a dog or cow barking. Then I heard a Cuckoo in the morning, and after 1^{h}30^m UT when dusk sets in, the bird sounds were rapidly increasing. A bat regularly flew through my field of view, a few times in the distance a car passed. It is so nice to observe under these circumstances, what a joy! Such conditions are no longer to be found in most parts of the Netherlands! And the choice for this location was correct, because further on towards Buzancy and the pasture where I observed in 2015 were filled with fog. The weak breeze had prevented the fog to appear at my location.

I was able to observe between 22^{h}30^m and 2^{h}36^m UT, effectively exactly 4.00 hours. Limiting magnitude started at 6.7 but dropped slightly when the haze appeared. Thanks to the dark starry sky, quite a few meteors were seen, a 59 in total! That is an average of 15 per hour and for me a record for May! Most meteors were weak, most of them were magnitude +4 or +5. The brightest ones were some meteors of +1 and +2. Attention was paid to meteors from Comet 1983/D Iras-Aracki-Alcock: the eta Lyrids (ELY), Antihelions (ANT) and the eta Aquariids (ETA, which radiant appeared at 01^{h}30^m UT). As many as 5 possible

ELYs were seen, 7 ANT and 1 ETA. The latter appeared at 2^{h}12^m UT, a fast and long +4 ETA in Ophiuchus.

When I ended the session, the temperature was 0 degrees Celsius. A short time after the session I enjoyed the peace and quietness and birdsongs. Then I cleaned up my stuff and walked back to the campsite.

3 May 4–5, 2019

The weather remained calm and warm until Thursday, but it was often (partly) cloudy at night. Cold air would then gain ground over large parts of Europe. This was accompanied by a lot of clouds and some rain. Clearings were expected after a cold front moving by during the course of Saturday evening. The predictions of the HIRLAM model indicated that it would get completely clear just after 23^h UT. So, I set the alarm clock at that time and then looked outside: wow…. The sky was very clear! Very low southeast Antares and Jupiter were bright! There was no mist or fog and there was a northwestern wind. When I walked to the location I still saw some clouds hanging low east: they stood out black against the clear starry sky... A few minutes later these disappeared too.

It was now extremely quiet outside, there was no traffic at all this Sunday morning. However, during the entire period I heard a bird that whistles cheerfully all night long. A beautiful ambiance with the dark starry sky! The temperature this night was –3 degrees Celsius and my sleeping bag was covered white with frost.

Period 23^{h}23^m-00^{h}24^m UT: limiting magnitude 6.70, *SQM* 21.67, $T_{eff.}$ 1 hour.

At first, I was a bit surprised by the *SQM* measurements, which were lower than the previous night while the starry sky was much brighter at a lower altitude! This can be explained, towards Buzancy there was now some lighting visible that during the previous session was apparently blocked by fog and/or haze. It did not disturb at that distance (more than 1 km), but the *SQM* meter still picked it up. The big difference was this night at a lower altitude, where the starry sky was much brighter than in the previous night.

During this observing period, I counted 2 eta Lyrids, 2 Antihelions and 10 sporadic meteors. Of course, a lot of weak meteors, the brightest meteor was a slow meteor of +2 coming from the north (Cepheus).

Period 00^{h}24^m-01^{h}25^m UT: limiting magnitude 6.70, *SQM* 21.63, $T_{eff.}$ 1 hour.

A busy period! In total I counted 2 eta Lyrids, 2 Antihelions and 15 sporadic meteors. As expected most meteors were weak. At 1^{h}17^m UT I saw something moving fast in the corner of my eye from Cygnus to Pegasus with a short fierce flare of –2. A +4 meteor with a long trail shot through Ophiuchus, perhaps an APEX meteor. A fluctuating +2 Antihelion was also nice to see.

Period 01^{h}25^m-02^{h}26^m UT: limiting magnitude 6.58, *SQM* 21.49, $T_{eff.}$ 1 hour.

Figure 1 – The observation field of the author. To the left behind the trees, the small village of Buzancy is 1 km away. The photo was taken towards the east. Facing south gives a full view of the sky.

The Milky Way is getting higher and now it is very impressive: from Cassiopeia I could follow it beautifully through Cygnus, Aquila (with the dark dust band) and the bright parts in Sagittarius with Jupiter in it. To the left of it was Saturn. The Milky Way was now comparable to what it looks like in the Provence. And just above the horizon in the south I saw the two stars G and λ Scorpio (both about magnitude +2). In my home town Ermelo they do not rise above the horizon!

Fewer meteors this period. From 2^h UT the twilight also became noticeable, after 2^h15^m UT it went faster. In total I observed 1 eta Lyrid, 2 Antihelions, 1 eta Aquariid and 9 sporadic meteors. A number of beautiful meteors: a +2 Antihelion meteor, at 01^h57^m UT a fast, sporadic meteor of +1 in Ophiuchus with a 1 second persistent train. Then a +3 eta Aquariid and at 02^h23^m UT the most beautiful meteor of this session: a fast blue-yellow magnitude –1 APEX meteor shot through the constellations of Ophiuchus, Hercules and Corona Borealis with a persistent train of 2 seconds.

At 2^h22^m UT the ISS appeared just above Jupiter. It then moved slowly through the “star-cloud” of Scutum to the east.

Period 02^h26^m-02^h43^m UT, limiting magnitude 6.20, $T_{eff.}$ 0.267 hours.

Twilight appeared faster now! Only two meteors were seen during this period, a +3 eta Aquariid with persistent train and one sporadic meteor. The limiting magnitude dropped from 6.3 to 6.0. Nature was waking up in the meantime, many birds were audible with the Chuckoo and an Oriole as the most striking attendees.

I concluded this session and quickly walked back to our rented house. After two hours of sleep, we packed up our stuff and returned to the Netherlands. I am really pleased with these two beautiful sessions from this dark location in northern France.

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Observation May 23-24 2019
Return of the May Camelopardalids (CAM#451)

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A report is presented on the observations made by the author at the occasion of the possible enhanced May Camelopardalids activity predicted for 2019.

1 Introduction

Meteor dynamicist *Mikhail Maslov*[11] predicted that the May Camelopardalids would re-appear in 2019. In his abstract, he writes: "After an outburst of Camelopardalids shower in 2014, the next interesting year is 2019, when two small outbursts are possible. The first one with ZHR up to 10 is expected from the 1939 trail of the comet 209P/LINEAR at 7^h44^m UT on 24 May, the second with ZHR up to 5 could be produced by the 1994-2009 trails around 11^h UT on 24 May." (Maslov, 2017).

2 The observations

I ventured out on the predicted peak night to a dark sky site south-west of Ottawa. Unfortunately, the rising gibbous Moon and occasional cloudy periods interfered with observations. I observed for 2.5 hours, with periods of clear and some clouds (up to 20% in field of view). Occasionally, the entire sky would cloud over and force me to stop observing, only to clear up a short while later. Despite the less than ideal night, I saw three Camelopardalids. The first one was seen almost immediately when I started observing; a long very slow +2 meteor that climbed from Ursa Minor to Draco. It had a yellow-orange color and became "nebulous" along its path, much like the CAMs that I saw in 2014! The direction, path length and velocity all were in good agreement! Near the end of the first hour, a fainter +4 CAM was seen. None were seen in the second hour, but a +2 appeared near Kochab at the end of the night.

Although, three meteors from a shower in a session is a small sample, the very slow velocity of the CAMs make them easy to recognize. Furthermore, the Canadian Meteor Orbit Radar (CMOR) clearly detected the activity during the night of May 23–24 at the expected radiant labelled as MCM (see images below). It appears that the CAMs were indeed active but weaker than they were in 2014, with just a few visible meteors per hour at most.

May 23–24 2019, 05^h00^m-08^h10^m UT (01^h00^m-04^h10^m EDT)

Location: L&A County Public Dark Site, Ontario, Canada (Long: -77.116° West; Lat: 44.559° North)

Observed showers:

- May Camelopardalids (CAM) – 08:08 (122) +79
- tau Herculids (TAH) – 14:56 (224) +39
- Anthelion (ANT) – 17:08 (257) -23
- June mu Cassiopeiids (JMC) – 00:12 (003) +51

05^h00^m-06^h00^m UT (01^h00^m-02^h00^m EDT); clear; 3/5 trans; F 1.05; LM 6.10; facing NNE50 deg; T_{eff} 1.00 hr, temp +12C

- CAM: two: +2; +4
- ANT: one: +3
- Sporadics: three: 0; +2; +4
- Total meteors: Six

06^h00^m-07^h05^m UT (02^h00^m-03^h05^m EDT); clear; 2/5 trans; F 1.10; LM 5.83; facing NNE60 deg; T_{eff} 1.08 hr, temp +11C

- ANT: one: +3
- Sporadics: one: +4
- Total meteors: Two

07^h36^m-08^h10^m UT (03^h36^m-04^h10^m EDT); clear; 2/5 trans; F 1.05; LM 5.55; facing NNE70 deg; T_{eff} 0.40 hr, temp +11C

- CAM: one: +2
- Sporadics: none
- Total meteors: One

Break from 07^h43^m-07^h53^m due to clouds

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[11] http://feraj.ru/Radiants/Predictions/209p-ids2019eng.html

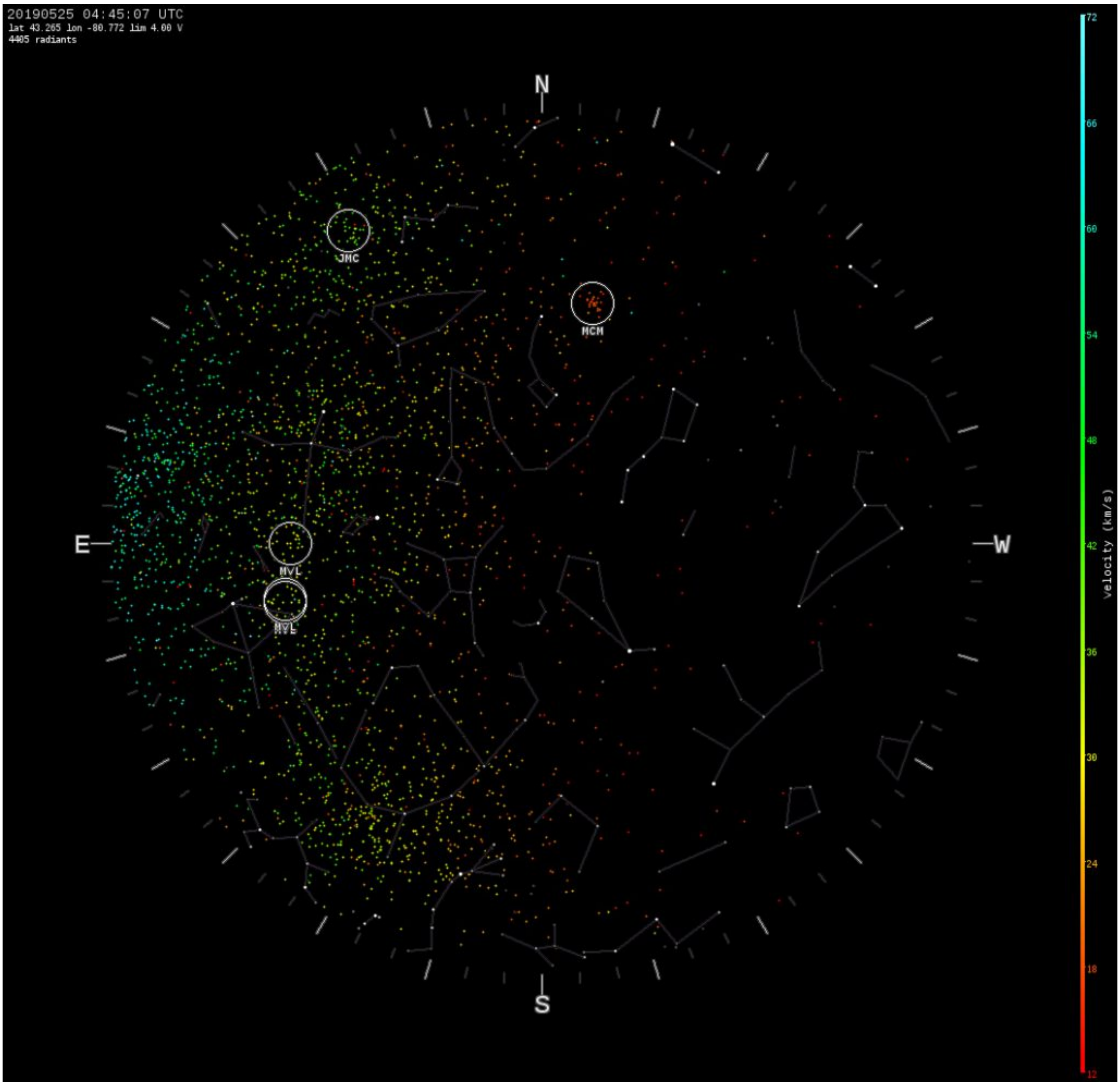

Figure 1 – The CMOR radiant map for May 25 with a clear mark of the Camelopardalids activity marked as MCM (credit: Canadian Meteor Orbit Radar, CMOR).

March 2019 report CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month of March 2019 is presented. 1217 orbits were collected during 29 nights with a maximum of 78 operational cameras at 20 different CAMS stations. The annual CAMS meeting took place on 10 March at the Observatory Mira in Grimbergen, Belgium.

1 Introduction

Past few years March had the typical weather pattern for this month without many favorable nights for astronomical observations. Meanwhile it is several years ago that March brought exceptional good weather but then the CAMS BeNeLux network had considerably less cameras available. Would March 2019 be better than what we got in March during previous years?

2 March 2019 statistics

The weather followed a similar pattern as previous year during this month with rather unfavorable weather. The first half of the month was very poor while only few clear nights occurred in the second part of the month. Only 5 nights had more than 100 orbits and only two nights remained without any orbit.

Table 1 – March 2019 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
Total	162	6308				

CAMS BeNeLux captured 3540 multi-station detections that resulted in 1217 orbits. March 2018 had more (1280) orbits with less detections (3391) although March 2019 counted 29 nights with orbits against March 2018 with 25 nights with orbits. At best 78 cameras were active, a minimum of 54 cameras capturing each night with an average of 64.4 operational cameras per night at 20 stations. In March 2018 we had as many as 91 cameras at best with an average of 73.5 each night at 22 stations. Reason for the decline in camera capacity is the loss of the strategic important CAMS station at Ooltgenplaat, the Netherlands that had 8 cameras and the CAMS station Terschelling with 4 cameras where the CAMS PC crashed months ago.

In total CAMS BeNeLux collected 6308 orbits during 162 March nights accumulated during the past 8 years. The statistics for March 2019 are compared in *Table 1* with all previous months of March since the start of the CAMS BeNeLux network.

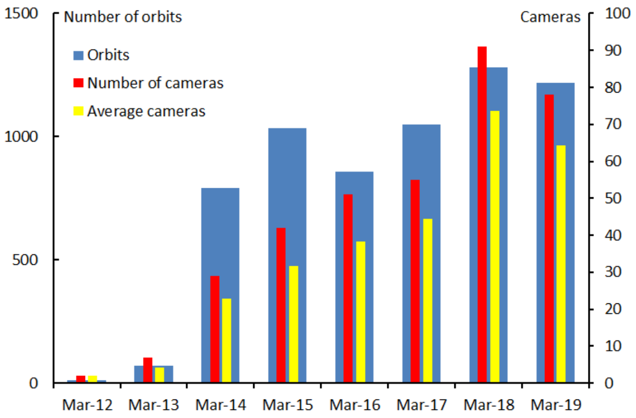

Figure 1 – Comparing March 2019 to previous months of March in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the yellow bars the average number of cameras running per night.

Figure 1 shows the decline in camera capacity compared to 2018. This combined with slightly better weather circumstances than in 2018 resulted in just a little fewer orbits than what we had last year.

3 CAMS meeting 10 March 2019

Since 2013 the CAMS BeNeLux participants come together to meet in person to discuss technical issues, results and future plans. The 2019 meeting was planned at the Public Observatory Mira in Grimbergen, Belgium.

The CAMS BeNeLux network coordinator *Carl Johannink* welcomed everybody and presented the program for the day with some short announcements about CAMS.

Figure 2 – CAMS meeting March 10 at the Observatory Mira, Grimbergen, Belgium. At left from front to back: Jean-Marie Biets, Carl Johannink, Luc Gobin, Uwe Glässner, Robert Haas, Jos Nijland, Tioga Gulon, Jan Pelgrims, Peter Pelgrims. At right from front to back: Paul Roggemans, Adriana Roggemans, Hervé Lamy, Steve Rau, Ian Rau, Tim Polfliet, Marco van der Weide, Martin Breukers, Erwin van Ballegoij and Ann Schroyens.

After this introduction each CAMS station operator shortly described the situation, technical problems encountered and future plans at each CAMS station. The advantage of this open discussion is that problems at one station are often quickly solved thanks to the solutions applied at other stations. Since the rapid expansion of the network in 2017, several technical issues often prevent some stations to fully participate.

Hervé Lamy gave a talk about BRAMS, the network for radio meteor observations. The first attempts were done to match radio echo results obtained by BRAMS with the video data obtained by CAMS. Contrary to radar work, single station radio observations don’t tell us anything about the radiant or exact position of meteor trajectories. Too many variables remain unknown for the complex ionization process, while most of these variables are known from the CAMS data. The meteor radio echoes of BRAMS and the video meteors captured by CAMS share a large part of the atmosphere above the BeNeLux. This allows to study statistically significant samples of CAMS trajectories that match with BRAMS radio echoes.

Paul Roggemans presented the method used to find meteor orbit concentrations and how meteor shower characteristics can be derived from large numbers of meteor orbits. Orbits are the best way to do meteor shower identifications, avoiding the controversy that is often raised with single station data where the shower identification is based on assumptions only. To understand the necessity to work with orbit data instead of single station data, the complex nature of the evolution of dust streams in the solar system was explained.

A lunch had been reserved at the local restaurant Fenikshof in the Monastery of Grimbergen, origin of the famous Belgian beer with the same name. After the lunch the results of different case studies on meteor showers based on orbital data were presented.

Jean-Marie Biets presented some results of a recent fireball event over Belgium on 15 February 2019. An overview of all the images was presented together with the results obtained by CAMS and by the all-sky data reduced by *Pavel Spurny*.

Another typical topic at CAMS meetings are the pointing directions of the individual cameras. If enough cameras are available, the atmosphere can be guarded from different sites in a way that even partial cloud cover cannot prevent that many meteors are being recorded from at least two stations. The many small FoV cameras are pointed in such a way that optimal coverage of the atmosphere is achieved from different sites. Viewed in Google Earth this looks like colorful puzzle of intersecting camera fields.

The new RMS cameras were shortly discussed. The first of these cameras were installed to test and such a RMS camera was brought to the meeting to show how it looks like. The current CAMS network is equipped with Watec H2 Ultimate cameras with Pentax 1.2/12mm lenses, EzCap dongles are used as framegrabbers. It is getting difficult to purchase this hardware which is all more than 10-year-old technology. The CAMS BeNeLux network risks to run out of spare parts. The RMS cameras developed by the Croatian ISTRA Stream can serve as a good alternative for future purchases of cameras. The results of these RMS cameras are 100% compatible with our CAMS standards, while for the small field optics of the RMS, the resolution is much better with 1.8 arc/pixel against 2.8 arc/pixel for our Watecs. The calibration is done for each detection which improves the positional accuracy. First tests with these cameras result in a much better score in number of orbits than with any of the Watecs.

The final talk was given by *Steve Rau* who discussed the most frequent technical problems reported by the CAMS camera operators. An overview was given of all bugs that were solved in 2018 and a number of technical advices were given.

Before the CAMS meeting was closed by *Carl Johannink*, a present was offered to *Steve Rau* for his technical support to the CAMS stations, distribution of the CAMS software and installation of AutoCAMS. The AutoCAMS provided by *Steve Rau* is to a large extend responsible for the impressive number of orbits collected by the network. Finally, *Carl Johannink* and *Martin Breukers* both got a bottle of wine offered to thank them for their continues efforts to collect and to reduce the CAMS data on a very regular bases, preventing delays in data reduction.

After the official CAMS meeting which ended a bit sooner than foreseen, a number of participants stayed few hours longer in Grimbergen to have a drink in a local pub and a dinner in a local Chinese restaurant.

4 Conclusion

March in general is a rather poor month for astronomical work and March 2019 was no exception. Although that the number of operational cameras decreased compared to last year still a very nice result could be obtained.

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[12]. 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 380, 381 and 382), *Martin Breukers* (Hengelo, Netherlands, CAMS 320, 321, 322, 323, 324, 325, 326 and 327, RMS 328 and 329), *Bart Dessoy* (Zoersel, Belgium, CAMS 397, 398, 804, 805, 806 and 888), *Jean-Paul Dumoulin and Christian Walin* (Grapfontaine, Belgium, CAMS 814 and 815), *Luc Gobin* (Mechelen, Belgium, CAMS 390, 391, 807 and 808), *Tioga Gulon* (Nancy, France, CAMS 3900), *Robert Haas* (Alphen aan de Rijn, Netherlands, CAMS 3360, 3361, 3362, 3363, 3364, 3365, 3366 and 3367), *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, 3037, 3038 and 3039) , *Carl Johannink* (Gronau, Germany, CAMS 311, 312, 313, 314, 315, 316, 317 and 318), *Hervé Lamy* (Dourbes, Belgium, CAMS 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), *Hans Schremmer* (Niederkruechten, Germany, CAMS 803) and *Erwin van Ballegoij* (Heesch, Netherlands,CAMS 347 and 348).

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

April 2019 report CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month of April 2019 is presented. 2534 orbits were collected during 29 nights with a maximum of 84 operational cameras at 20 different CAMS stations. Favorable weather circumstances during the Lyrid activity allowed to monitor the April Lyrid activity for a second year in a row.

1 Introduction

Already since 2013 the month of April tends to be more favorable for astronomical observations than previous winter months. 2018 had been very favorable during the Lyrid activity. Could it be possible to have two years in a row with favorable weather circumstances?

2 April 2019 statistics

The weather improved a lot in April compared to March. As many as 8 nights had more than 100 orbits, 3 nights with more than 200 and one night had as many as 367 orbits. Only one single night remained without any orbits. For a second year in a row, the CAMS BeNeLux network enjoyed clear sky during much of the Lyrid activity and 322 orbits could be identified as Lyrids (Johannink, 2019).

Table 1 – April 2019 compared to previous months of April.

Year	Nights	Orbits	Stations	Max. Cams	Min. Cams	Mean Cams
2012	6	11	4	2		2.0
2013	19	140	9	10		6.5
2014	19	421	12	29		18.8
2015	27	1212	15	43		33.9
2016	26	971	17	50	15	37
2017	28	1235	20	60	32	48.2
2018	27	1929	21	83	59	73.3
2019	29	2534	20	84	44	67.7
Total	181	8453				

CAMS BeNeLux captured 14667 meteors of which 7894 or 54% proved multiple station which resulted in 2534 orbits. This is the best score ever for the month of April in terms of orbits and clear nights. The maximum of 84 cameras available compares well with April 2018 (83 cameras), but the minimum number of cameras dropped from 59 in 2018 to 44 in April 2019. This was mainly due to a number of technical incidents at CAMS stations with AutoCAMS. On average 67.7 cameras were operational against 73.3 in April 2018.

In total CAMS BeNeLux collected 8453 orbits during 181 April nights accumulated during the past 8 years. The statistics for April 2019 are compared in *Table 1* with all previous months of April since the start of the CAMS BeNeLux network.

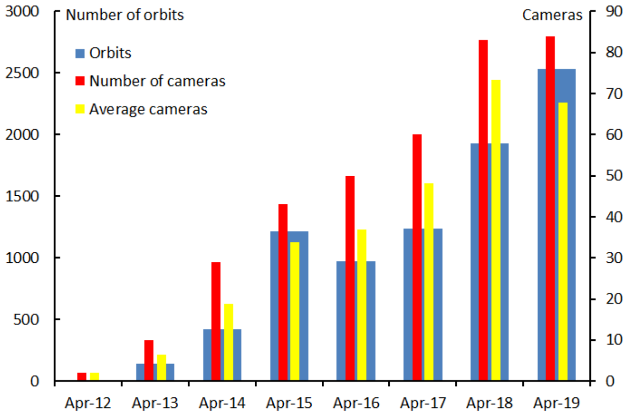

Figure 1 – Comparing April 2019 to previous months of April in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the yellow bars the average number of cameras running per night.

Figure 1 shows the decline in average operational cameras compared to 2018. This combined with considerable better weather circumstances than in 2018 resulted in a record number of orbits for the month of April.

On April 22 CAMS BeNeLux detected an outburst of 15 Bootids (#923). 7 orbits of this shower were registered during a two-hour period. The United Arab Emirates CAMS network confirmed this event and detected 4 more orbits during the same two-hour interval.

3 Conclusion

April 2019 brought exceptional favorable weather for the CAMS BeNeLux network. Just like in 2018 clear nights during much of the Lyrid activity period resulted in a record number of Lyrid orbits.

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[13]. The CAMS BeNeLux team is operated by the following volunteers:

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Johannink C. (2019). “CAMS BeNeLux results April 2019”. *eMetN*, **4**, 193–184.

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

May 2019 report CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month of May 2019 is presented. 1825 orbits were collected during 29 nights with a maximum of 84 operational cameras at 20 different CAMS stations.

1 Introduction

The first weeks of May offer nice levels of meteor activity with the eta Aquariids in the early morning hours. The last couple of weeks get shorter nights while the meteor activity decreases to the lowest level of the year. With short nights, low activity and often poor weather this time of the year remains a challenge to collect orbits.

2 May 2019 statistics

May 2019 was a reasonably good month although the first week with the Eta Aquariids activity had less luck with the weather. As many as 7 nights resulted in 100 or more orbits, not bad at all considering the limited number of dark hours at the BeNeLux latitudes this month. Only two nights remained without any orbits.

Table 1 – May 2019 compared to previous months of May.

Year	Nights	Orbits	Stations	Max. Cams	Min. Cams	Mean Cams
2012	5	13	4	2		2
2013	13	69	9	13		6.8
2014	22	430	13	31		19.7
2015	25	484	15	42		24.2
2016	26	803	17	52	16	39.9
2017	24	1627	19	64	22	52.0
2018	31	2426	21	84	64	76.6
2019	29	1825	20	84	53	72.4
Total	175	7677				

The statistics for May 2019 are compared in *Table 1* with all previous months of May since the start of the CAMS BeNeLux network. The maximum number of operational cameras remained stable at 84 but the number of cameras that remained operational all nights with AutoCAMS dropped from 64 in May 2018 to 53 in May 2019, also the average number of operational cameras decreased a bit. As many as 5886 of the detected meteors proved multiple station, good for 1825 orbits. This is still a very nice result although less than what the record month of May in 2018 offered with exceptional favorable weather.

A new RMS camera of the Global Meteor Network had been installed in Grapfontaine, Belgium and when all technical issues got solved, the camera got fully operational from May 15 onwards. The larger field of view combined with a much higher resolution results in 3.8 arc/pixel against 2.8 arc/pixel for an ordinary Watec camera with a 1.2/12mm lens. Pointed low to the NNW, this single camera intersects with as many as 62 other cameras at many other stations. The yield in multiple station meteors is impressive, outnumbering all other cameras except for the 003830 in Mechelen, also an RMS camera.

Since the start of CAMS BeNeLux 175 nights in May allowed to collect as many as 7677 orbits in May.

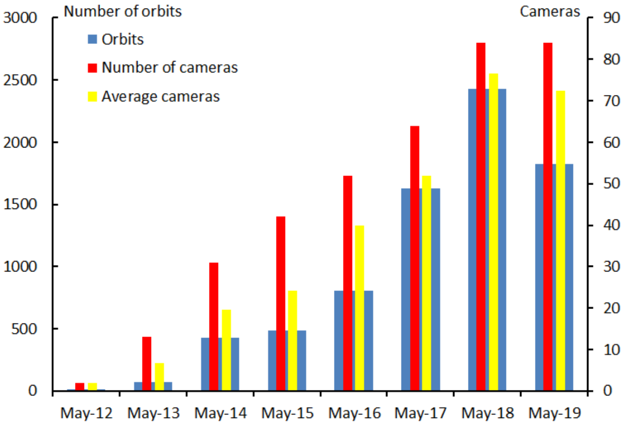

Figure 1 – Comparing May 2019 to previous months of May in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the yellow bars the average number of cameras running per night.

Figure 1 shows the decline in average operational cameras compared to 2018. The multiple station coverage of the atmosphere was slightly worse than in 2018 due to the loss of the CAMS station at Ooltgenplaat where 8 cameras were used 7/7 with AutoCams.

3 Conclusion

May 2019 was in general a normal month of May with several clear nights, but less favorable during the Eta Aquariids activity. The exceptional month of May 2018 remains the best month of May ever.

Acknowledgment

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

June 2019 report CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month of June 2019 is presented. The month was characterized by many clear nights and in general very favorable circumstances. 7817 multiple station meteors were captured which allowed to calculate 2457 orbits which is a new record for the month of June.

1 Introduction

The shortest nights of the year are a challenge to collect orbits at the latitudes of the CAMS BeNeLux network, also because the overall meteor activity is about at its minimum level first weeks of June. Would 2019 offer us a better month of June than previous years?

2 June 2019 statistics

June is the most difficult month for CAMS BeNeLux because of the short observing window of barely 5 hours dark sky each night. June 2019 brought better weather conditions than usually this time of the year. Only two nights remained without any double station meteors. As many as 13 nights resulted in more than 100 orbits in spite of the short duration of these nights, two nights got over 200 orbits each! The statistics for June 2019 are compared in *Figure 1* and *Table 1* with the same month in previous years since the start of CAMS BeNeLux in 2012.

Table 1 – June 2019 compared to previous months of June.

Year	Nights	Orbits	Stations	Max. Cams	Min. Cams	Mean Cams
2012	0	0	4	0		0.0
2013	16	102	9	12		7.0
2014	23	379	13	31		19.0
2015	20	779	15	44		32.9
2016	18	345	17	50	15	35.7
2017	26	1536	19	66	30	52.1
2018	28	1425	21	78	52	64.9
2019	28	2457	20	84	63	75.6
Total	159	7023				

This month it is one year ago that a disaster ruined the CAMS station of *Piet Neels* at Ooltgenplaat, the Netherlands. A great personal loss for Piet but also a huge drawback for the entire CAMS BeNeLux network. The role of Ooltgenplaat in the network became obvious once the station ceased functioning. Large areas covered by the CAMS BeNeLux network suddenly suffered poor coverage especially below 90 km altitude in the atmosphere over the western and southern areas of the network. Ooltgenplaat had 8 cameras functioning 7/7 with AutoCams. While all CAMS stations in Belgium operate 7/7 with AutoCams, Ooltgenplaat was the only station North of Belgium which provided 7/7 coverage on most of the southern part of the network. The impact of the reduced coverage has been masked by the overall better than usual observing circumstances. The loss of Ooltgenplaat illustrates well what a difference that 7/7 AutoCams makes for a meteor camera network.

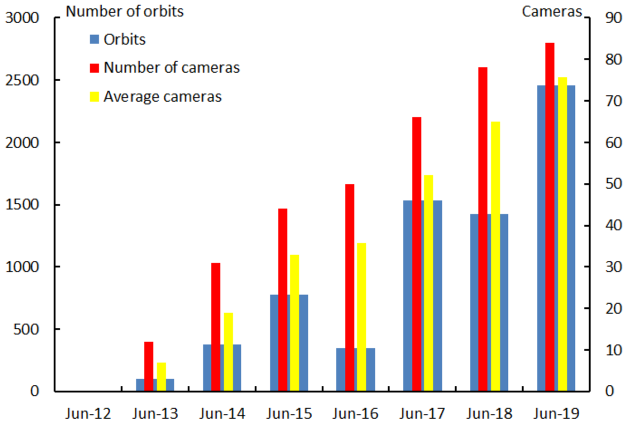

Figure 1 – Comparing June 2019 to previous months of June in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the yellow bar the average number of cameras running per night.

Compared to one year ago less technical failures occurred keeping more cameras operational. During the best nights up to 84 cameras were operational (78 in June 2018). Thanks to AutoCAMS at least 63 cameras were all nights operational (52 in June 2018). On average 90% of the available cameras were active. One issue remains a problem at some stations: shuttered meteors caused by an interruption with dropped frames that make the duration uncertain and affects the velocity determination making the registration unusable for orbit determination. The ratio of multiple station coincidences depends on the number of stations with clear sky during the same time span. The more stable the weather conditions are network wide and the less technical problems, the better the chances to catch a meteor from at least two stations.

Two RMS cameras produced the best scores in terms of orbits of all cameras in the CAMS BeNeLux network. There is no competition to nominate any most successful camera in the network, but in this case, it is interesting to see how the RMS performs compared to the Watecs. Certain cameras are pointed at regions where the chances for multiple station events is simply significant less, for instance towards the borders of the camera network coverage. However, to illustrate the order of difference for these RMS cameras, it is necessary to compare these numbers with what the most successful Watecs obtained.

Table 2 – The ten cameras of the CAMS BeNeLux network with the best score in terms of orbits during June 2019.

Camera	Total orbits	Total nights
003814 (RMS Grafontaine - B)	361	26
003830 (RMS Mechelen - B)	286	30
000395 (Dourbes - B)	186	30
000391 (Mechelen - B)	182	30
000394 (Dourbes - B)	178	30
000816 (Humain - B)	167	30
000384 (Mechelen - B)	166	30
000814 (Grapfontaine - B)	162	30
000390 (Mechelen - B)	155	30
000393 (Uccle - B)	152	30

3 Conclusion

June 2019 was the best month of June ever in the 8 years since 2012. The total number of orbits for the month of June rose to 7023 in 159 June nights that allowed to collect orbits. This way the month of March becomes the poorest covered month of the year for CAMS BeNeLux with ‘only’ 6308 orbits collected during 162 usable nights since 2012.

Acknowledgment

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

CAMS-Florida acquired orbits of 854 meteoroids during 1-27 June 2019

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CAMS-Florida acquired orbits of 854 meteoroids during 1-27 June 2019. The four sites that comprise CAMS-Florida contributed 2164 data tracks, for an average of 2.53 tracks per meteoroid.

1 Introduction

The four sites that comprise CAMS-Florida contributed 2164 data tracks, for an average of 2.53 tracks per meteoroid.

- Gainesville (10 cameras): 1079 tracks;
- BarJ Observatory (2 cameras): 265 tracks;
- College of Central Florida (8 cameras): 736 tracks;
- Florida Institute of Technology (1 camera): 84 tracks.

2 Some results

The map produced using UFO-Orbit shows the ecliptic running from left to right through the map's center. On the map are plotted the distribution of meteor radiants and their velocities observed by CAMS-Florida during June. For reference, the mean position of the Sun (solid circle), the apex of Earth's motion (X), and the anti-hellion (open circle) are plotted. The radiants are color-coded to indicate geocentric velocity. "Hot" colors (red and purple) signify high velocity whereas "Cold" colors (blue) signify low velocity.

Meteoroids with the highest geocentric velocity (up to about 75 km/sec) are clustered around the apex (direction) of Earth's motion. At the apex, Earth is running head first into meteoroids that it encounters. 90 degrees from the apex, the radiants are color-coded mostly green, indicating geocentric velocities of about 45 km/sec. A ring of blue points near the margins of the map are meteoroids with the lowest geocentric velocities, about 15 km/sec relative to Earth. This makes sense, because trailing meteoroids have to "catch up" with an Earth that is speeding away from them.

Earth orbits the Sun with a speed of approximately 30 km/sec. If the average heliocentric velocity of a meteoroid is 45 km/sec, then the maximum encounter velocity should be about 45 km/sec + 30 km/sec = 75 km/sec. On the other hand, an "average" meteoroid encountering Earth from behind would have a relative velocity of 45 km/sec – 30 km/sec = 15 km/sec.

One reads about these interesting facts in textbooks. However, it's even more fun to get the results first-hand using equipment built and operated by your team!

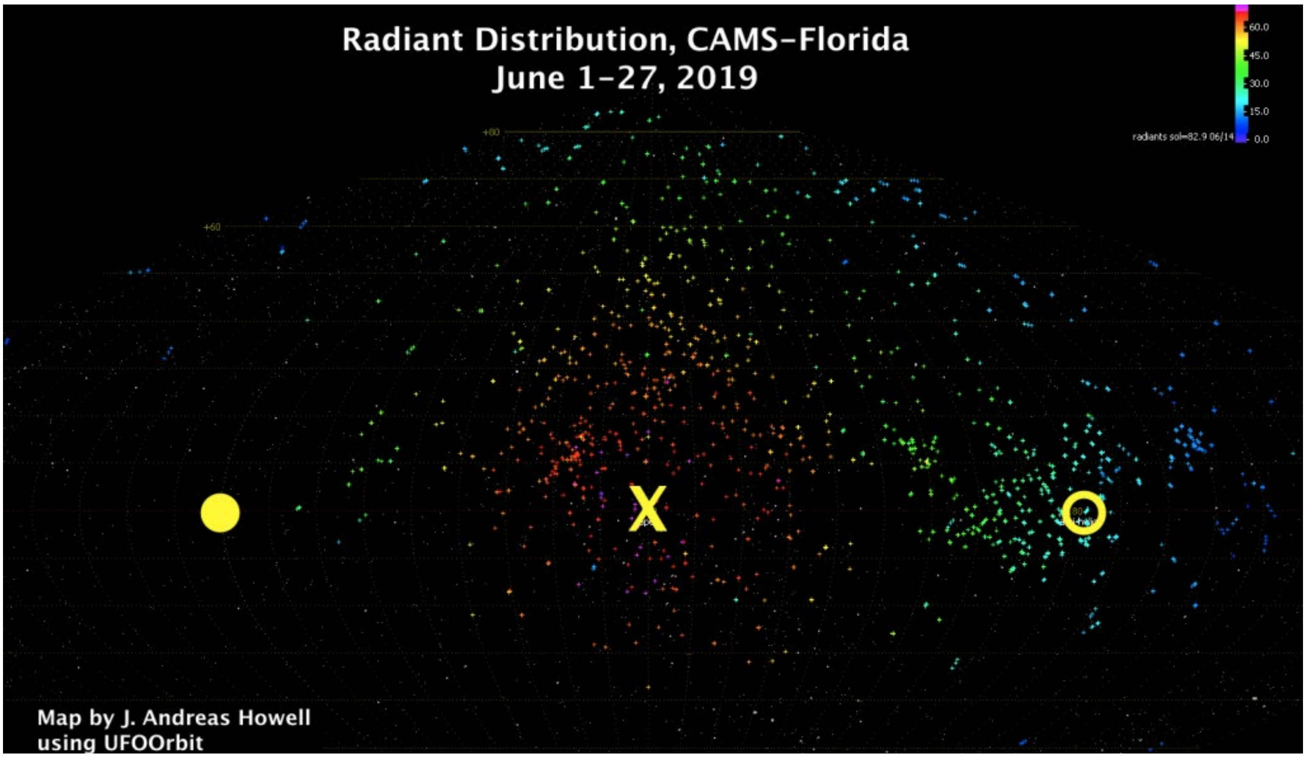

Figure 1 – The radiant map obtained for the 854 orbits collected by CAMS-Florida during June 2019.

CAMS observed an outburst of the June epsilon Ophiuchid meteors (JEO#459)

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A summary is given of the detection of an outburst of the JEO#459 meteor shower.

Electronic Telegram No. 4642 dated 29 June 2019 from the Central Bureau of Astronomical Telegrams (CBAT) reports an outburst of the June epsilon Ophiuchids Meteor Shower (IAU shower 459, code JEO). Peter Jenniskens of the SETI Institute and NASA Ames Research Center reports that the outburst lasted from 2019 June $19^{d}08^{h}$ until 2019 June $26^{d}05^{h}$ UTC, with a total of 88 June epsilon Ophiuchids having been detected. Most activity was centered on 92.11 degrees solar longitude (J2000.0), according to Jenniskens.

The following CAMS networks contributed to the observations: CAMS New Zealand (coordinated by *J. Baggaley*), CAMS South Africa (coordinated by *T. Cooper*), CAMS BeNeLux (coordinated by *C. Johannink*), CAMS Florida (coordinated by *A. Howell*), LO-CAMS in Arizona (coordinated by *N. Moskovitz*), and CAMS California (coordinated by *P. Jenniskens* and *D. Samuels*).

According to the CBAT telegram, the shower's orbital elements are similar to the Jupiter-family comet 300P/Catalina. It concludes that "the outburst confirms the existence of this otherwise minor shower and offers evidence of past activity of this body."

Bright fireball over Spain on 2019 July 6

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An overview is presented of the exceptional fireball events by the meteor observing stations operated by the SMART Project from Sevilla and Huelva during May, June and July 2019.

1 Fireball 2019 July 6

This bright fireball overflew Spain on 2019 July 6 at 22^h59^m UT (equivalent to 0^h59^m local time on July 7). It was generated by a meteoroid following an asteroid-like orbit that hit the atmosphere at about 54000 km/h. The preliminary analysis of this event shows that It began over the province of Ciudad Real at an altitude of about 85 km, and ended at a height of around 25 km.

The fireball was recorded in the framework of the SMART project, operated by the Southwestern Europe Meteor Network (SWEMN), from the meteor-observing stations located at the astronomical observatories of La Hita (Toledo), La Sagra (Granada), and Sevilla.

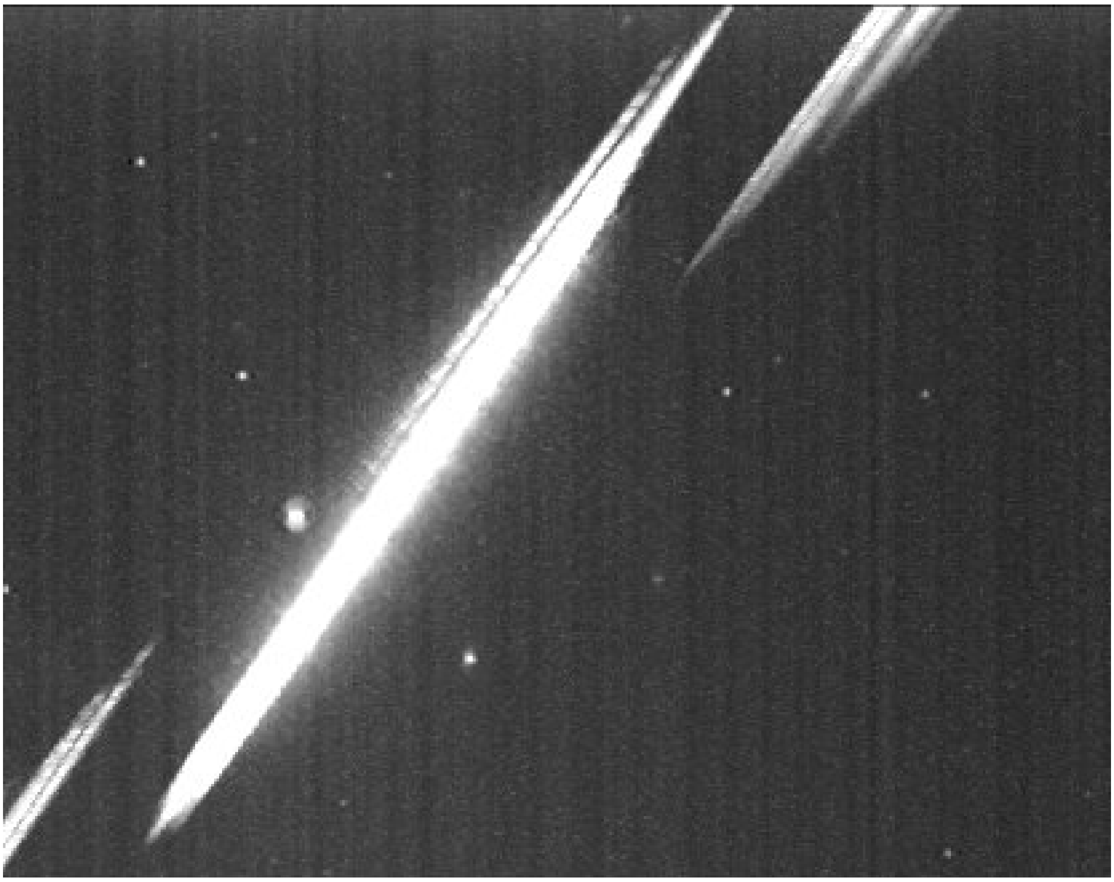

Figure 1 – Fireball overflew Spain on 2019 July 6 at 22^h59^m UT.

Spectacular fireball over Canada 20190724-064340 UTC

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A large fireball appeared right above the all sky camera network of the University of Western Ontario, Canada on 2019 July 24 at $06^h43^m40^s$ UTC. The fireball was as bright as the Full Moon with a magnitude of -12. It is expected that meteorites were dropped, scattered across the countryside near Bancroft, Ontario.

1 Introduction

According to NASA analyses the fireball was caused by a small asteroid with a diameter of about 30 centimeters. The velocity obtained from the camera data was 20.2 km/s. The meteor trajectory was about 130 km long and reached deep into the atmosphere ending at 28.9 km. Therefore, it is very likely that meteorites landed on the Earth surface[16],[17].

Further investigations are coordinated by *Prof. Peter Brown* of the University of Western Ontario. A call is made to the public to report any suspicious rock that may be from this event. You may contact Kim Tait of the Royal Ontario Museum at ktait at rom.on.ca.

A very nice video animation about this event made by *David Clark* can be seen online[18].

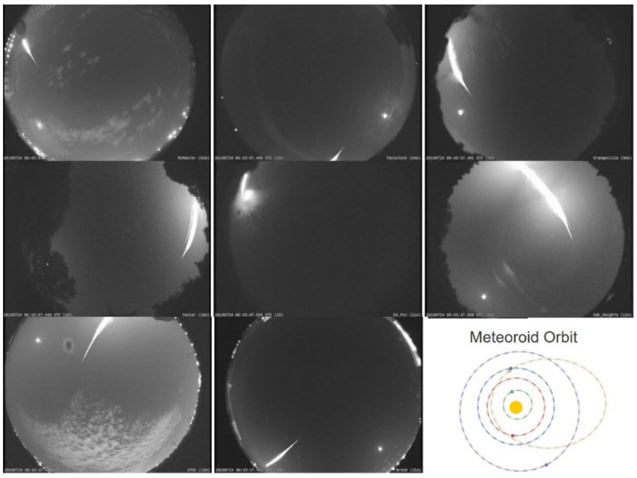

Figure 1 – Images taken by the array of all-sky cameras belonging to the University of Western Ontario that recorded the fireball.

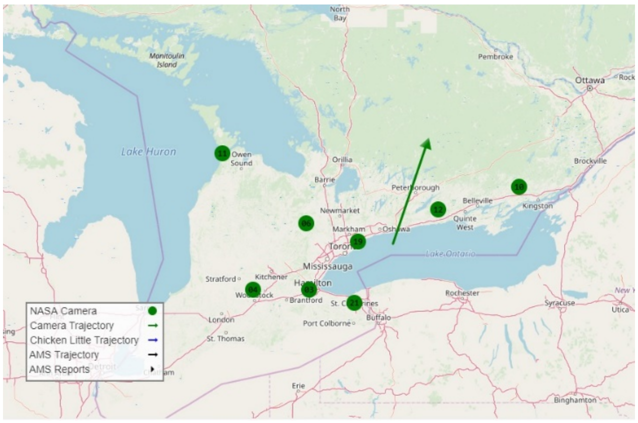

Figure 2 – The fireball trajectory relative to the all-sky cameras of the University of Western Ontario.

Figure 3 – The region where meteorites may have been dropped.

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[16] http://spaceweather.com/archive.php?view=1&day=25&month=07&year=2019

[17] https://fireballs.ndc.nasa.gov/skyfalls/events/20190724-064340

[18] https://youtu.be/gnybQHcOHMI

Meteoroids 2019 conference, a report

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A summary report is presented about the 10th Meteoroids conference which took place from 16 until 21 June 2019 in Bratislava, Slovakia.

1 Introduction

Meteoroids 2019 in Bratislava, Slovakia, was the 10th conference on meteor astronomy since the first Meteoroids conference was organized in Smolenice, Slovakia in July 1992. The 2019 event was organized by the Comenius University in Bratislava with assistance by the colleagues of the Astronomical Institute of the SAS. 129 participants registered for this conference.

Sunday, June 16, participants started to arrive at the conference site at Hotel Tatra in Bratislava. Registrations started with a welcome drink that offered excellent circumstances to talk with many people about the latest news and challenges in the meteor world (*Figure 1*).

A conference is more than just a series of oral and poster presentations, most of the time is spent on informal contacts and private discussions with meteor specialists. In this report we give a short overview of the different sessions.

The program with all presentations with links to the abstracts in PDF can be found online[19].

Figure 1 – Sunday evening welcome reception (credit LOC Meteoroids).

2 Monday, June 17

The conference was opened by the dean of Faculty Mathematics, Physics and Informatics, Comenius University in Bratislava. The President of IAU commission F1, *Diego Janches* (*Figure 2*) and *Juraj Toth*, Head of the LOC welcomed everyone to the 10th meeting of Meteoroids. At this occasion some memories were refreshed with photographs of the very first Meteoroids conference that took place 27 years ago in Smolenice during July 1992, also in Slovakia.

Figure 2 – The President of IAU commission F1, Diego Janches during his opening speech of the 10th Meteoroids conference (Credit LOC Meteoroids).

Figure 3 – Galina Ryabova informed the audience about the status of the Meteoroids book (crecit LOC Meteoroids).

Galina Ryabova (*Figure 3*) announced the publication of a new standard work on meteor astronomy which can be temporary ordered with a 20% reduction. More about this Meteoroids book can be found on MeteorNews[20].

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[19] https://fmph.uniba.sk/en/microsites/daa/division-of-astronomy-and-astrophysics/meteoroids-2019/program/

[20] https://www.meteornews.net/2019/06/17/meteoroids-sources-of-meteors-on-earth-and-beyond/

Iwan Williams (*Figure 4*) presented a first invited lecture about the history of meteor astronomy and astronomers at the Slovak Institutes of Astronomy.

Figure 4 – Iwan Williams with the invited lecture about astronomy and astronomers at the Slovak Institutes of Astronomy (credit LOC Meteoroids).

Figure 5 – Peter Jenniskens during his talk about asteroid Vesta and the source of 22-Ma clan HED meteorites (credit LOC Meteoroids).

Figure 6 – The conference room of Meteoroids 2019 (credit LOC Meteoroids).

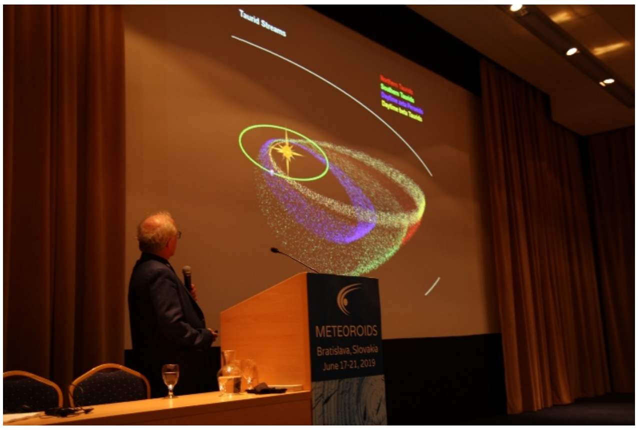

Figure 7 – David Clark of the University of Western Ontario in Canada presented "2019 observing opportunity for Taurid Swarm NEOs".

Figure 8 – The Meteoroids 2019 group photo in front of the Presidential Palace (credit LOC Meteoroids).

The first session “Meteoroid sources” was chaired by *Maria Hajdukova* and *Robert Jedicke*. This session focused on meteoroid parent bodies and the release of meteoroids. Junichi Watanabe presented some reports about short lived locally observed meteor hurricanes and David Clark (*Figure 7*) pointed the attention to the opportunities in 2019 to observe NEOs associated with the Taurid swarm. Before the lunch everybody was invited to walk in front of the Presidential Palace for the group photo (*Figure 8*).

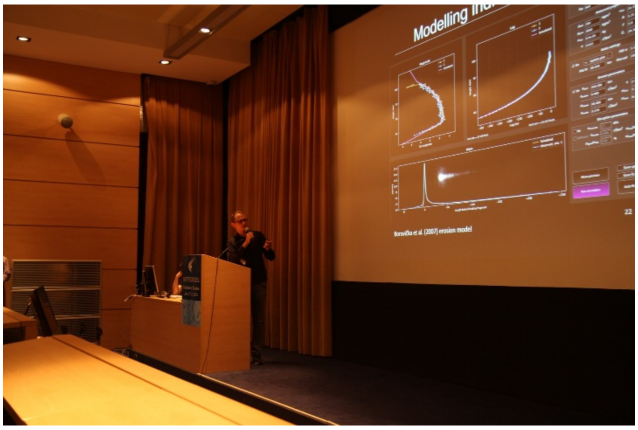

Figure 9 – Denis Vida of the University of Western Ontario, Canada presented “Ultra high precision meteor trajectories obtained using the Canadian Automated Meteor Observatory tracking system” (credit LOC Meteoroids).

The second session “Future Methods and Techniques” was chaired by *Galina Ryabova* and *Peter Veres*. This session covered all aspects of improvements in measurements, instruments and tools with several presentations of ongoing efforts to improve the meteor observing methods. *Denis Vida* (*Figure 9*) presented an impressive talk about Ultra high precision meteor trajectories obtained using the Canadian Automated Meteor Observatory tracking system”.

3 Tuesday, June 18

The third session “Meteor Physics and Chemistry” was chaired by *Jiří Borovička* and *Diego Janches*. This session focused on the physics of a meteoroid flight in the atmosphere. The talks covered a wide variety of topics about laboratory experiments, fireball characteristics, crater structures on other planets and meteor modelling. One of the talks covered a very interesting topic of simultaneous optical and specular radar measurements of low speed meteors by *Peter Brown*.

The fourth session “Influx of Interplanetary and Interstellar Matter” was chaired by *Margaret Campbell-Brown* and *Aswin Sekhar*. This session was dedicated to models, observations, constraints on shower, sporadic, and interstellar meteoroids and dust. *Mária Hajduková Jr.* of the Astronomical Institute, Slovak Academy of Sciences gave a very interesting presentation about “Interstellar Meteors”. The 2018 Draconid outburst got attention by *Margaret Campbell-Brown* of the University of Western Ontario presenting “Radar fluxes of Draconid meteor outbursts”. Then, *Pavel Koten* of the Astronomical Institute in the Czech Republic presented “Different masses of Draconids”. The profile presented by *Pavel Koten* compares very well with the analyses of visual data (Miskotte, 2019).

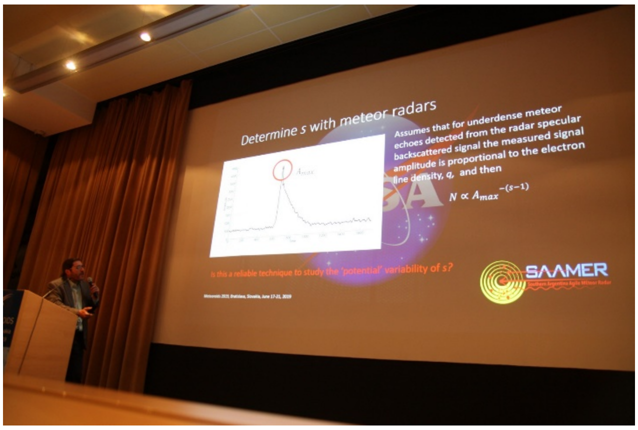

Figure 10 – Diego Janches of the GSFC/NASA during his talk “A Decade of Sporadic Meteoroid Mass Distribution Indices in the Southern Hemisphere Derived from SAAMER’s Meteor Observations” (credit LOC Meteoroids).

The session and the program for the day ended with a commented video by *Vladimír Porubčan* (*Figure 11*) of the Comenius University in Bratislava about the very first Meteoroids conference in Smolenice 1992. It was a pleasant souvenir to see those who participated in 1992, all 27 years younger as well as to remember those who passed away since this historic event in 1992.

Figure 11 – Vladimír Porubčan commented the video about the first Meteoroids conference at the castle of Smolenice in July 1992 (credit LOC Meteoroids).

4 Wednesday, June 19

The fifth session “Dynamical Evolution” was chaired by *Althea Moorhead* and *Jeremie Vaubaillon*. This session covered all aspects of dynamical evolution of meteoroids and meteoroid streams in space. The first talk by *Auriane Egal* of the Western University “Modelling meteor showers: future Draconid outbursts” was of particular interest to amateur meteor observers.

James Kinsman presented “Orbital dynamics of highly probable but rare Orionid outbursts possibly observed by the ancient Maya”. An interesting research on old Maya records that described meteor outbursts.

The sixth session “Planetary Defense” was chaired by *Althea Moorhead* and *Jeremie Vaubaillon*. This session focused on super-bolides, airbursts, craters, and impact hazard mitigation.

Wednesday afternoon was reserved for socializing with a boat trip on the Danube river. After a short walk through the historic part of Bratislava, all participants got on board of a ship for a trip along the river with as main destination the Devin castle situated at the confluence of the Danube and Morava rivers (*Figures 12 to 16*).

Figure 12 – Sightseeing along the border between Slovakia and Austria on the Danube river (credit LOC Meteoroids).

Figure 13 – The warm weather was perfectly timed to enjoy the boat trip in open air (credit Adriana Roggemans).

Figure 14 – Old and less old borders, in front a monument for those who died when trying to escape socialist rule, in the background a tower of the castle at a strategic position (credit LOC Meteoroids).

Figure 15 – The guided tour at the Devin castle (credit LOC Meteoroids).

Figure 16 – A view on the confluence of the Morava river into the danube (credit LOC Meteoroids).

Figure 17 – The conference organizer, Juraj Toth and The President of IAU commission F1, Diego Janches (credit LOC Meteoroids).

Figure 18 – Opening of the conference dinner on the tunes of Star Wars (credit LOC Meteoroids).

Figure 19 – From left to right: Chie Tsuchiya, Yasunori Fujiwara, Takumi Sato, Masa-yuki Yamamoto and Paul Roggemans (credit Adriana Roggemans).

Figure 20 – The Slovak team with the members of the LOC (credit LOC Meteoroids).

Figure 21 – From left to right Hadrien Devillepoix, Auriane Egal, Jean-Louis Rault, Mária Hajduková and Galina Ryabova (credit LOC Meteoroids).

After the excursion everybody enjoyed the conference dinner which started on the tunes of Star Wars performed by a quartet on strings (*Figures 17 to 21*).

5 Thursday, June 20

The seventh session "Composition and Physical Properties" was chaired by *Olga Popova* and *Robert Macke*. This session was dedicated to measurements and models of the physical properties of meteoroids, meteorites, micrometeorites and dust particles. This session had several interesting talks. *Solvay Blomquist* of the Lowell Observatory presented "Analysis of Meteor Light Curves from LO-CAMS Detections". A topic of particular interest for people involved with CAMS. *Jiří Borovička* of the Astronomical Institute of the Czech Academy of Sciences presented another very interesting study on "Physical properties of Taurid meteoroids of various sizes".

The eight session and very short session with only two talks "Dust Particles and Clouds in the Solar System and Beyond" was chaired by *Olga Popova* and *Robert Macke*. This session focused on dust particles in the Solar System and stellar systems.

The ninth session "Meteoroid Impact Physics and Meteorite Recoveries" was chaired by *Robert Weryk* and *Shinsuke Abe*. This session focused on meteoroids striking natural objects. *Pavel Spurný* of the Astronomical Institute of the Czech Academy of Sciences, Ondrejov gave a summary of some recent meteorite recoveries "The Hradec Králové (CZ) and Renchen (DE) meteorite falls – recovery of meteorites exactly according to prediction based on records taken by the European Fireball Network".

Figure 22 – Hadrien Devillepoix of the Curtin University in Australia during his talk "A Global Fireball Observatory" (credit LOC Meteoroids).

6 Friday, June 21

The tenth session "In-situ Experiments and Spacecraft Anomalies" was chaired by *Eleanor Sansom* and *Jiří Šilha*. This session focused on meteoroids striking spacecraft.

The eleventh session "Future Methods and Techniques" was chaired by *Eleanor Sansom* and *Jiří Šilha*. This session covered all recent or planned improvements in meteor measurements, including instrumentation, observations, and data analysis. A very interesting talk was presented by *Tomoko Arai* of the Chiba Institute of Technology in Japan with "METEOR: Space-based meteor observation project". Also, *Georgy Sambarov* (*Figure 23*) had an interesting talk about the evolution of the Quadrantid meteor stream.

Figure 23 – Georgy Sambarov of the Research Institute of Applied Mathematics and Mechanics, Tomsk State University in Russia presented “Analysis of the dynamical evolution of the Quadrantid meteor stream between AD 1760 and 2020” (credit LOC Meteoroids).

Figure 24 – A look in the poster room (credit LOC Meteoroids).

Figure 25 – Peter Gural presented “Advances in the Meteor Image Processing Chain using Fast Algorithms, Deep Learning, and Empirical Fitting” (credit LOC Meteoroids).

The twelfth session “Future Methods and Techniques” was chaired by *Danielle Moser* and *Junichi Watanabe*. This session covered recent or planned improvements in meteor measurements, including instrumentation, observations, and data analysis. *Pete Gural* (*Figure 25*) highlighted recent developments in meteor image processing. *Michael Hankey* gave an impressive overview of the multitude of possibilities his new system is offering with his talk “The All-Sky-6 and Video Meteor Archive System of the AMS Ltd.”.

The final talk of the conference was given by *Ryou Ohsawa* of the University of Tokyo in Japan “Radar and optical simultaneous observations of faint meteors with MU radar and Tomo-e Gozen”.

Figure 26 – Juraj Toth and Diego Janches closing the 10th Meteoroids conference (credit LOC Meteoroids).

A Conference summary was presented, and the Conference closed by *Diego Janches* (SOC) and *Juraj Toth* (LOC). The participants thanked the organizers with a warm applause for their great efforts and excellent organization of this most interesting conference.

The next Meteoroids conference will be organized in 2022 in Alabama, USA.

References

Miskotte K. (2019). “The outburst of the Draconid meteor shower in 2018: an analysis”. *eMetN*, **4**, 74–78.

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