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Draconid fireball in evening twilight, with multiple brightness variations and fragmentation!
Photographed on October 8/9 2018
Canon 5D and Rokinon 24mm f/1.4 lens (at f/2.0), ISO 1600 (Pierre Martin).

- Ancient meteor in Morocco
- Lyrid case study
- CAMS reports
- Global Meteor Network
- Radio observations
- 10 October Hungarian Fireball

Contents

The discovery of mysterious petroglyphs suggests that a meteor has been observed in ancient times in Morocco

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The purpose of this paper is to make an exceptional discovery public. Three petroglyphs engraved with a never seen topic in Moroccan rock art were found in the province of Essaouira (Morocco). Astronomical and anthropomorphic figures were engraved by incision. The nature of the engraved subjects evokes, presumably, a testimony with a material document that a meteor occurred above Morocco in ancient times, thus contributing to the understanding of the ancient history of natural disasters in Morocco.

1 Introduction

Regardless of the cultures involved, observation of the sky and astronomical bodies has been of worldwide interest since prehistoric times. Petroglyphs have been found around the world and have been interpreted by researchers as signs of the Sun (Davis-Kimball and Martynov, 1993; Coimbra, 2009), the Moon (Olivera and Silva, 2010) and supernovas (Iqbal et al., 2009). However, very few have been interpreted as bolides (Coimbra, 2007) and meteors (Barreto, 2009; Iqbal et al., 2010. Coimbra 2017). It is not difficult to admit that these events could have been interpreted by the first societies as bad or good manifestations of the gods and thus carved on rocky surfaces to be admired by future generations (Sagan and Druyan, 1986). Indeed, Bailey (1995) argues that meteor and comet phenomena seem to have played an important role in the beliefs and social habits of most civilizations.

Our preliminary investigations, predict that a meteor occurred above Morocco in ancient times. The petroglyphs which we have studied seem to provide a new perspective on Amazigh archeoastronomy in Morocco, thus contributing to the understanding of the ancient history of the region.

2 Materials studied

The petroglyphs studied were found in the area of Tiwrare (rural village of Ida Oukazzou, coordinates: 30°59’49.7” N 9°32’10.9” W) about 100 km north of Agadir. The village Ida Oukazou is located on the western side of the High Atlas in the province of Essaouira on a rugged mountainous terrain with altitudes ranging from 800 to 1500 meters. The technical analysis performed with a binocular magnifier equipped with an integrated digital camera, revealed the mesoscopic characters to reconstruct the approach of the artisan (engraving technique, direction of movement of the tool, etc.). The geological materials chosen by the artist, three sandstones pebbles and quartz sandstones that we nicknamed *Ida 1*, *Ida 2* and *Ida 3*.

The characteristics for *Ida 1* and *Ida 2*: length 20 cm, width 17 cm, thickness 5 cm and length 18 cm, width 15 cm, thickness 5 cm respectively. These are two pebbles of melanocratic cryptocrystalline quartz sandstone of subcircular form and very flat. They show traces of corrosion and a surface calcification layer consisting of thin platelets of carbonates. After carefully cleaning *Ida 1* (brushing and vinegar), the only engraved side of this piece offers a spectacular scene of a man and a woman seemingly distraught by the fall of a meteor (*Figure 1*). Identically on *Ida 2*, not yet cleared of its gangue of clay and sand and under the secondary precipitation of carbonate layers, we can identify a scene that includes a fleeing anthropomorphic and a huge fireball (*Figure 2*).

Figure 1 – Overview of the Ida 1 petroglyph.

Figure 2 – Overview of the Ida 2 petroglyph.

Ida 3 (length 35 cm, width 27 cm, thickness 12 cm) is a thin, leucocratic sandstone pebble, rather flat and more or less square in shape. After cleaning, *Ida 3* symbolizes a scene that includes an anthropomorphic, two cattle of different sizes, a meteor and a figurative of the Sun with concentric circles in the center. To complete his ideogram, the artist has arranged two lines of inscriptions with Tifinagh characters with dull incised lines (*Figure 3*), thus showing an image-inscription association which is arranged in the empty interval where it integrates harmoniously. These Tifinagh inscriptions, difficult to translate, are quite old, it is impossible to date them accurately. A subsequent paper will be devoted to it.

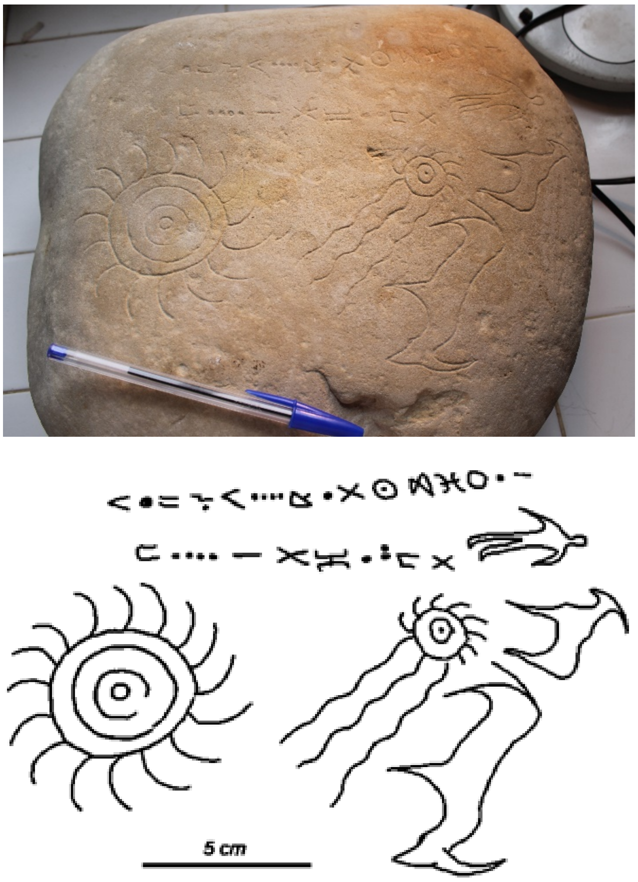

Figure 3 – Overview (before and after cleaning) and survey of the Ida 3 petroglyph.

3 Discussions and conclusions

The countless astronomical representations painted or engraved on rocks around the world, with different chronologies, seem to prove that one of the first concerns was to observe the sky. Indeed, the representation of astronomical bodies such as the Sun, the Moon and, less occasionally, the appearance of meteors, is an idea of the intellectual processes of these early societies. The three petroglyphs studied show concentric circles (in the center hollowed out for *Ida 1*) attached to a group of three undulating lines (four for *Ida 2*) that extend backward and that look like nothing else than a round object flying in the air and leaving behind a trail (*Figure 4*, A, B and C). These are the objects we propose to be meteors.

Figure 4 – View of meteor symbols, A: Ida 1, B: Ida 2 and C: Ida 3.

The typology of these objects is very similar to the meteor engraving of Toca do Cosmos (Bahia, Brazil) (Coimbra, 2009) and that of the rock painting in the Fouriesburg district (South Africa) (Woodhouse, 1986) (*Figure 5*). The lines engraved on the studied petroglyphs show long and wavy tails giving a luminous and very dynamic aspect of a flying object. Eyewitnesses of the Tissint meteorite fall in 2011 in the Tata region (Morocco) reported that the fireball appeared in the sky with a trail of smoke and continuous dust (Ibhi et al., 2013). Therefore, the wavy lines engraved on the petroglyphs can be interpreted as the smoke left behind a meteor.

The astronomical observations reveal that these sculptures are those of a meteor, the three petroglyphs seem to represent the impact of a great meteorite that has frightened the inhabitants and that the artist has certainly experienced this astronomical event spectacular enough to be recorded on the rock. There will certainly be future scientific investigations that must confirm or invalidate our hypothesis. We underline the preliminary character of this paper and one of our objectives is to encourage the debate between colleagues interested in Moroccan archeoastronomy, to participate in the development of scientific research in this field.

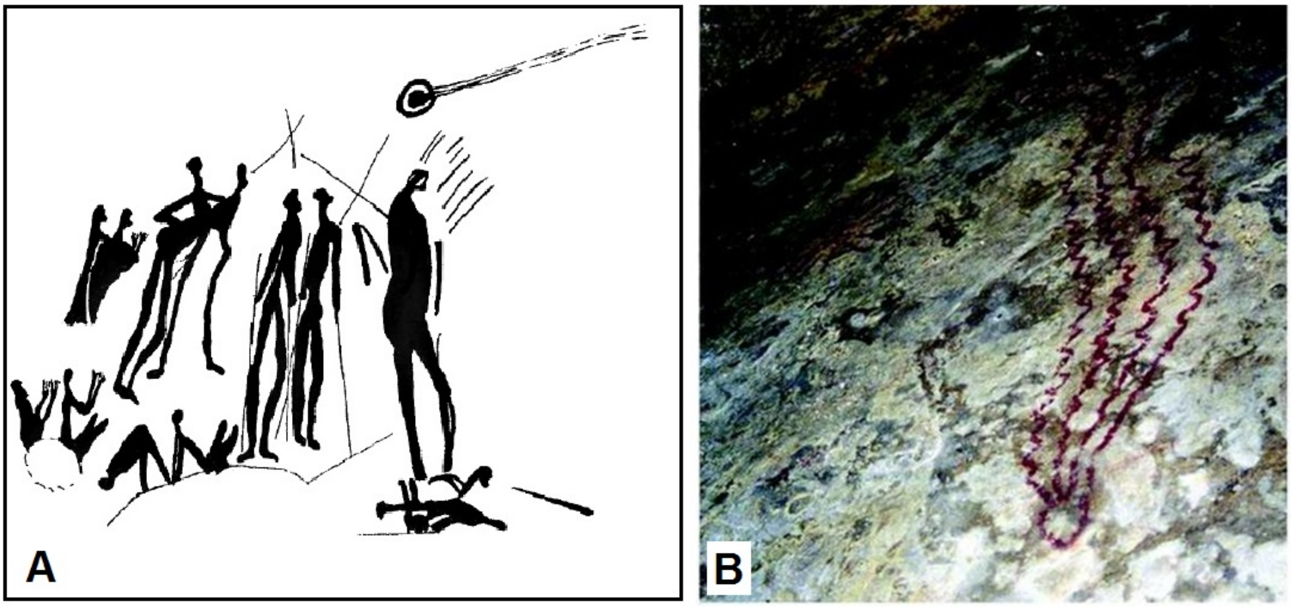

Figure 5 – Left (A): Meteor of Toca do Cosmos (Bahia, Brazil) (Coimbra, 2009). Right (B): Meteor of Fouriesbourg (South Africa) (Woodhouse, 1986).

Acknowledgment

The authors would like to thank Mr Ali Lamghari (meteorite hunter and inhabitant of the commune Ida Oukazou) and an anonymous person for their help in the discovery of the analyzed petroglyphs.

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The April Lyrids (LYR#006)

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A case study is presented on the April Lyrid meteor shower, based on 23083 orbits observed between solar longitude 20° and 45°. A reference orbit was derived by an iterative procedure resulting in 3220 Lyrid orbits that fulfil the low threshold D-criteria. The orbit concentration is very dense near the stream maximum with a compact radiant with more dispersed orbits at the edges of the activity period. The radiant drift was compared for different threshold classes of D-criteria. An activity profile was obtained, and the time of maximum was found to be at solar longitude 32.18 ± 0.05° instead of 32.3°. The stream shows a remarkable spread in inclination and geocentric velocities.

1 Introduction

The weather has been very favorable to observe the 2018 Lyrids by the CAMS BeNeLux network (Johannink and Roggemans, 2018) as well as by visual observers (Miskotte, 2018a, 2018b). The video results included 106 Lyrid orbits which fitted the high threshold criteria with $D_D < 0.04$ and these were used to calculate the Lyrid radiant drift. The results differed slightly from earlier results and also from an independent analysis on EDMOND and SonotaCo data.

The visual observations were used to investigate the activity profile and an attempt was made to pinpoint the time of maximum activity. The time of maximum activity differs from literature values, mainly due to a lack of visual data for several time bins.

With many Lyrid orbits available in public datasets it may be possible to consider these aspects more in detail and perhaps find an explanation for the differences between the 2018 and earlier results?

2 The available Lyrid orbit data

We have the following orbit data collected over 11 years, status as until July 2018, 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 257010 orbits (2007–2017). SonotaCo is an amateur video network with over 100 cameras in Japan (SonotaCo, 2009).
- CAMS with 111233 orbits (October 2010 – March 2013), (Jenniskens et al., 2011). For clarity, the CAMS BeNeLux orbits April 2013 – July 2018 are not included in this dataset because this data is still under embargo.

The methodology to detect associated orbits has been explained in previous analyses (Roggemans and Johannink, 2018; Roggemans, 2018; Roggemans and Campbell-Burns, 2018a, 2018b, 2018c, 2018d and 2018e). First of all, the outer limits within which Lyrid orbits may be detected were obtained as follows:

- Time interval: $20° < \lambda_{O} < 45°$;
- Radiant area: $259° < \alpha < 286°$ & $+25° < \delta < +43°$;
- Velocity: 40 km/s $< v_g < 52$ km/s.

In total 23083 orbits were available in the considered time interval; 3953 orbits had a radiant position and geocentric velocity within the range mentioned above.

The D-criteria used are these of Southworth and Hawkins (1963), Drummond (1981) and Jopek (1993). We consider five different 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: $D_{SH} < 0.05$ & $D_D < 0.02$ & $D_H < 0.05$.

The purpose of this case study is to compare results with the previously published results for CAMS. For this reason, the 'average' orbit of the stream is obtained in the same way as by Jenniskens et al. (2016), using an ordinary median value for each orbital element. The semi-major axis a and the eccentricity e are ignored in case of hyperbolic orbits. A reference orbit for the Lyrids was derived from the selection and a few sub datasets were generated for each class of threshold level as well as for the different sources of data. The results are compared in *Table 1* and *Table 2*. The results for the different datasets compare very well, except for the semi major axis a. The semi major axis is very sensitive for the measurement errors on velocity. The scatter on the semi major axis a for the individual orbits is very large and therefore these median values are not relevant. Both CAMS and UFOCapture are limited in accuracy to obtain the velocity of meteors, something that remains a challenge for even the most accurate observing techniques.

Table 1 – The median values for each sub-set of orbits that fulfill D_D<0.105, CAMS, SonotaCo and EDMOND and all combined orbits. The orbit from the literature is taken from Jenniskens et al. (2016).

	All	CAMS	SonotaCo	Edmond	Literature
$\lambda_{\odot}$	32.3°	32.3°	32.5°	32.2°	32.0°
α_g	272.1°	272.1°	272.5°	272.0°	272.0°
δ_g	+33.4°	+33.4°	+33.3°	+33.4°	+33.4°
v_g	46.4	46.7	46.7	46.2	46.7
a	12.5	14.0	15.5	11.4	10.8
q	0.920	0.921	0.921	0.918	0.921
e	0.938	0.953	0.952	0.928	0.956
ω	214.5°	214.0°	214.0°	214.8°	214.0°
Ω	32.3°	32.3°	32.5°	32.2°	32.3°
i	79.2°	79.4°	79.5°	79.0°	79.4°
N	3220	256	870	2094	258

Table 2 – The median values for the final selections of orbits for the five different threshold levels on the D-criteria.

	Low	Medium low	Medium high	High	Very high
$\lambda_{\odot}$	32.3°	32.3°	32.3°	32.3°	32.3°
α_g	272.1°	272.1°	272.1°	272.1°	272.1°
δ_g	+33.4°	+33.4°	+33.4°	+33.4°	+33.4°
v_g	46.4	46.4	46.4	46.5	46.4
a	12.5	13.2	13.9	15.5	15.1
q	0.920	0.920	0.919	0.919	0.919
e	0.938	0.940	0.941	0.942	0.939
ω	214.5°	214.5°	214.5°	214.5°	214.6°
Ω	32.3°	32.3°	32.3°	32.3°	32.3°
i	79.2°	79.2°	79.3°	79.3°	79.3°
N	3220	2890	2525	1892	803
%	*81%*	*73%*	*64%*	*48%*	22%

The results in *Tables 1 and 2* can be compared with the orbital elements of the parent comet C/1861 G1 (Thatcher) (Jenniskens et al., 2016):

- a = 55.7 AU
- q = 0.923 AU
- e = 0.984
- ω = 213.5°
- Ω = 31.9°
- i = 79.8°

The Lyrids are considered as a major annual shower, there is no doubt about its existence. Looking at the plot of inclination versus length of perihelion, the dense concentration of orbits is obvious with a gradual spreading away from the core of the stream with very high threshold orbits towards medium low and low threshold cases dispersed at the edges of the stream (*Figure 1*).

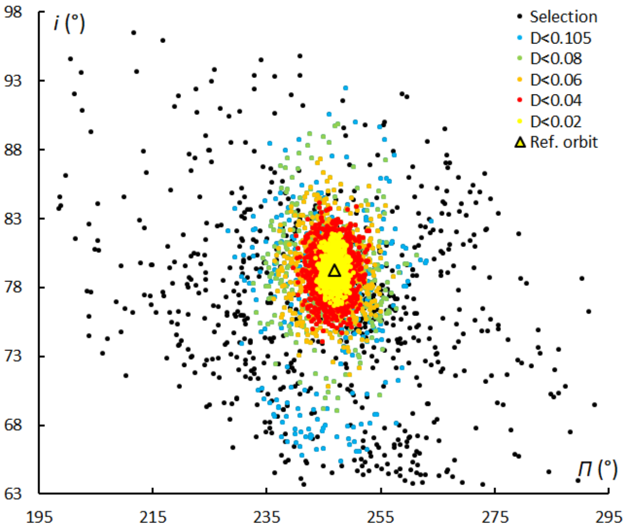

Figure 1 – The plot of inclination i (°) against the length of perihelion Π (°) for the 3953-selected possible LYR-orbits. The colors mark the different threshold levels of the D-criteria relative to the final reference orbit listed in Table 2.

About 19%, or 733 orbits of all 3953 Lyrid resembling orbits fail to fulfil the similarity criteria. Indeed, sporadic radiants are distributed all over the sky, also within the known meteor shower radiant areas. In *Figure 2* we plot these 733 sporadic radiants to make the sporadic background visible which is hidden behind the color-coded Lyrid radiants shown in *Figure 1*. Some concentration appears at the Lyrid position in the sporadic background which is likely due to Lyrids that failed in the similarity criteria due to inaccuracies, mainly the velocity registration.

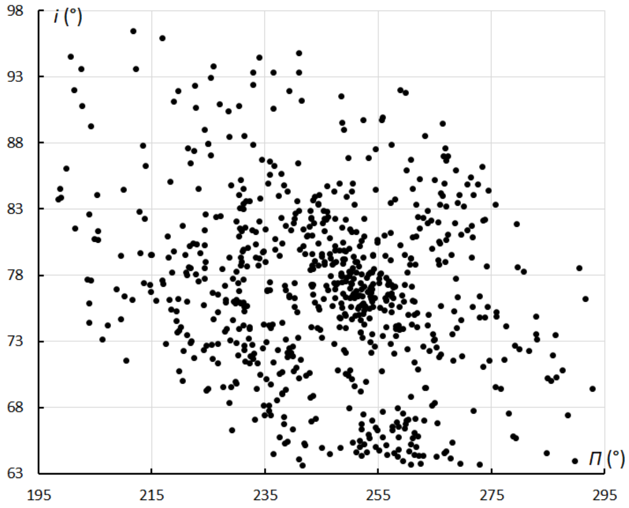

Figure 2 – The plot of inclination i (°) against the length of perihelion Π (°) for the 733- orbits from the selection that failed in the similarity criteria.

The Lyrid orbits display a large spread in orbital inclination. *Figure 3* shows a close up of *Figure 1* for all 3220 Lyrids with a color gradient to indicate the variation in velocity. The higher the inclination, the higher the geocentric velocity.

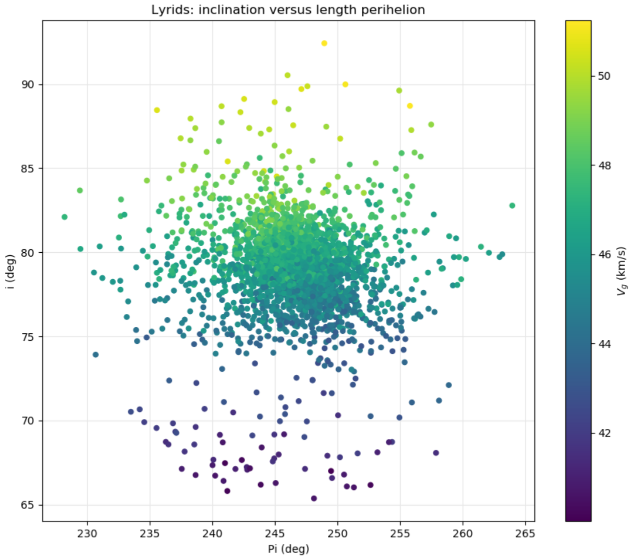

Figure 3 – Close up on the plot of inclination i (°) against the length of perihelion Π (°) for the 3220 Lyrid orbits that fulfill the low threshold similarity criteria with a color gradient to display the variation in the velocity v_g.

When we plot the geocentric velocity v_g versus inclination i for all 3220 Lyrid orbits the geocentric velocity v_g increases with 0.485 km/s per degree in inclination (*Figure 4*). This variation in velocity in function of the inclination is very well visible in *Figure 3*.

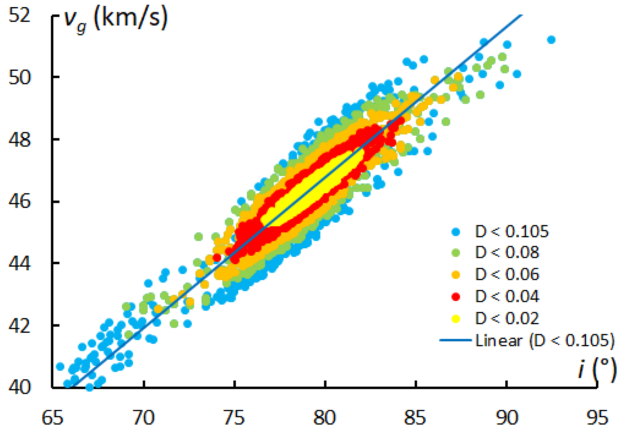

Figure 4 – Plot of the geocentric velocity v_g against the inclination i (°).

Kresák and Porubčan (1970) made a study about the dispersion of meteor orbits and the size of the radiants. For the Lyrids they found a rather small radiant area, but based on 7 Lyrid orbits only, which is too few to be statistically relevant. The dense concentration of orbits also appears in the 3220 radiant positions of this analysis, plotted in Sun centered ecliptic coordinates. The radiant is very concentrated for very high, high and medium high threshold orbits (*Figure 5*).

Kresák and Porubčan also calculated the variation of the orbital elements, e, q, i and ω in function of Ω. For instance, for the Lyrids they found $di/d\Omega = +0.24$, we find +0.25. However, the scatter on the data points requires great caution and for this reason we do not go into further detail on this point.

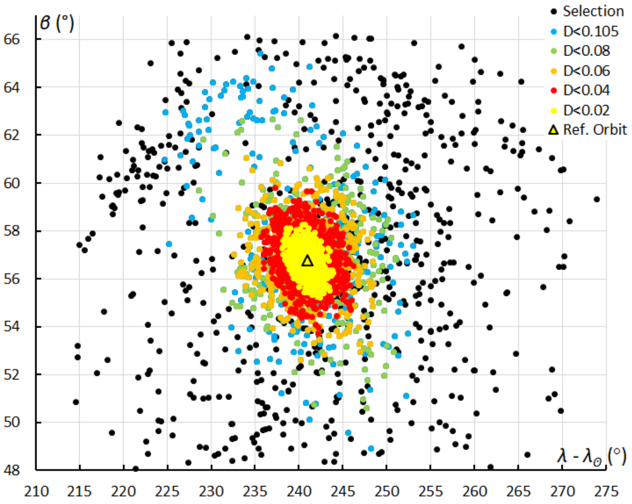

Figure 5 – Plot of the ecliptic latitude β against the Sun centered longitude $\lambda - \lambda_{\odot}$. The different colors represent the 5 different levels of similarity.

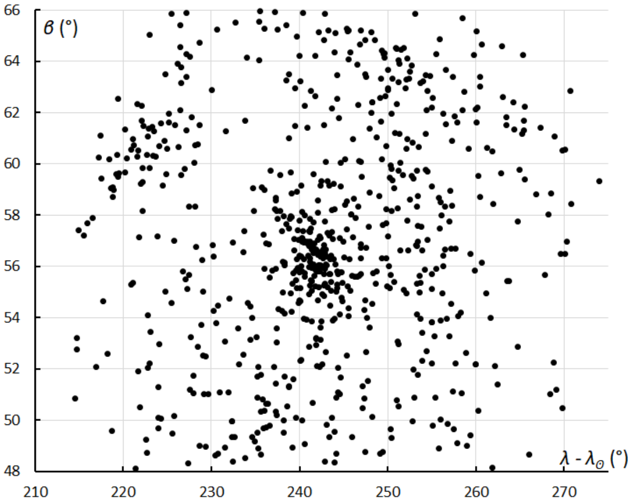

Figure 6 – Plot of the ecliptic latitude β against the Sun centered longitude $\lambda - \lambda_{\odot}$ for the 733- orbits from the selection that failed in the similarity criteria.

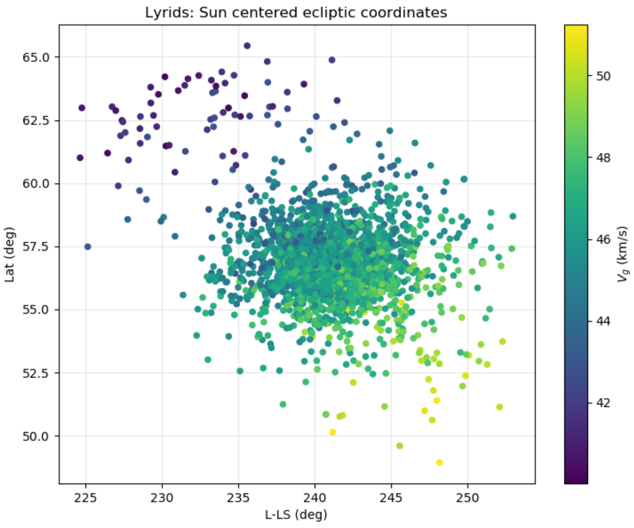

Figure 7 – Plot of the ecliptic latitude β against the Sun centered longitude $\lambda - \lambda_{\odot}$ (°) for the 3220 Lyrid orbits that fulfill the low threshold similarity criteria with a color gradient to display the variation in the velocity v_g.

We also show the plot of the ecliptic latitude β against the Sun centered longitude $\lambda - \lambda_{\odot}$ for the 733 sporadic orbits of the 3953 selected orbits (*Figure 6*). Mind that any single station observing method has no possibility to distinguish these sporadics from Lyrids! In *Figure 7* we see the 3220 Lyrid radiants with the variation in velocity. From *Figure 3* we know that the higher the velocity, the higher the inclination, hence the lower inclination Lyrid orbits are in the upper left corner, the higher inclination orbits in the bottom right corner of *Figure 7*.

Plotting the geocentric velocity v_g against the solar longitude, the velocity increases with 0.11 km/s per degree in solar longitude. Earth travers the Lyrid stream from the inner to the outer side, encountering first slower Lyrids and gradually slightly faster Lyrids.

The Lyrids do not display high hourly rates, unless in certain years when outbursts surprised observers. With its in general rather low hourly rates this shower is an interesting case to compare with the so-called minor showers, some of which reach comparable activity levels. Note that in *Table 2* as many as 81% of all possible Lyrids fulfil the low threshold D-Criteria. The Lyrids presence in the selected dataset is very distinct, something that makes the difference with most minor showers.

3 Radiant drift

The CAMS BeNeLux results of 2018 were used to derive the radiant drift (Johannink and Roggemans, 2018). The results differed slightly from past CAMS orbit data as well as from what was derived from past EDMOND and SonotaCo orbit data. The question arises why the results differ and how relevant the differences in resulting radiant drift really are. We therefore repeat the analysis using the Lyrid orbit selection in this case study and we do this for each of the D-criteria threshold classes.

Figures 8 and 9 display the Right Ascension and declination in function of time (solar longitude) for all different threshold classes of D-criteria. The slope of the linear regression through the datapoints is a good measure for the daily movement, or drift, of the radiant through the sky. The radiant drift is the result of the rotation of the Earth around the Sun relative to the orbit of the meteor stream and thus the direction from where the meteoroids enter the atmosphere.

When applying linear regression, the dispersion on the data points determines the relevance of the trend line. Linear regression makes no sense neither on too few datapoints, nor on a too short range. In our case *Figure 8* visualizes the number, the range and the spread of the datapoints for the drift in Right Ascension. The higher the threshold level, the closer we get to the core of the meteor stream, the smaller the range becomes. From a calculation point of view the low threshold points (blue) cover the largest range in solar longitude and provide the best linear regression. However, the low threshold datapoints represent the more dispersed orbits with the poorest association to the shower.

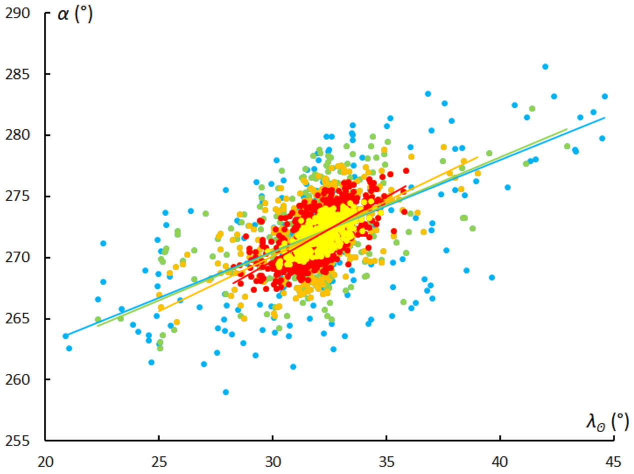

Figure 8 – Radiant drift in Right Ascension α against solar longitude $\lambda_{\odot}$. The different colors represent the 5 different levels of similarity, blue for $D_D < 0.105$, green for $D_D < 0.08$, orange for $D_D < 0.06$, red for $D_D < 0.04$ and yellow for $D_D < 0.02$.

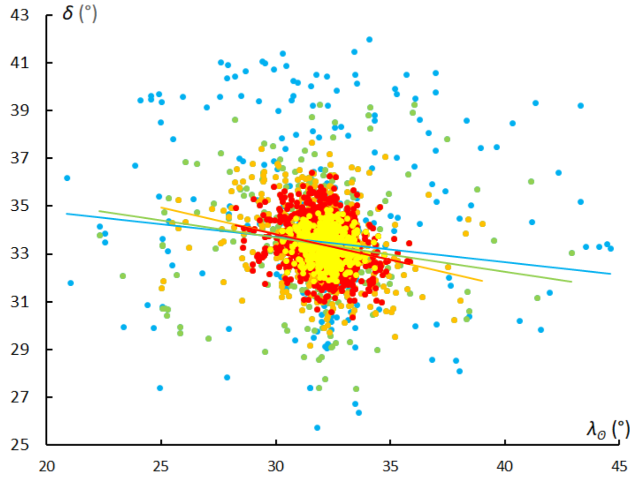

Figure 9 – Radiant drift in declination δ against solar longitude $\lambda_{\odot}$. The different colors represent the 5 different levels of similarity, blue for $D_D < 0.105$, green for $D_D < 0.08$, orange for $D_D < 0.06$, red for $D_D < 0.04$ and yellow for $D_D < 0.02$.

Table 3 – Radiant drift with ± σ for the Lyrids obtained from the orbits for each threshold level of the D-criteria and from the 2018 study (Johannink and Roggemans, 2018 (*)).

Threshold/source	LYR – 006	
	Δα / λ⊙	Δδ / λ⊙
Low	0.75 ± 0.02	–0.11 ± 0.02
Medium low	0.78 ± 0.02	–0.14 ± 0.02
Medium high	0.90 ± 0.03	–0.22 ± 0.02
High	1.04 ± 0.03	–0.21 ± 0.02
Very high	1.03 ± 0.04	–0.12 ± 0.03
Edmond&SonotaCo (*)	1.04 ± 0.03	–0.21 ± 0.02
Jenniskens et al. (2018)	0.66	+0.02
BeNeLux 2018 (*)	0.87 ± 0.08	–0.10 ± 0.11

Figure 9 shows a large spread in datapoints which is somehow problematic for a linear regression. If the datapoints would be equally distributed in *x*- and *y*-coordinates, the resulting trendline becomes meaningless. It is rather difficult to see any trend in the points in *Figure 9* especially for the high and very high threshold orbits. The

larger the spread on a cloud of points, the larger the uncertainty on the resulting trendline. Altogether the differences found for the radiant drift based on the different classes of threshold levels and the results found by Johannink and Roggemans (2018) listed in *Table 3* are normal because of the scatter on the radiant positions. In principle radiant drift is just the resultant of the movement of the Earth and the direction of the shower orbit. The scatter on the orbits due to measurement errors and the physical dispersion of particles explain the differences in radiant drifts between different analyzes. A standard deviation on the linear regression is not representative for the error margin due to the dispersion of the orbits.

One way to verify the effect of the differences in radiant drift is to just apply these radiant drift corrections to see to which extend the resulting pictures differ. *Figure 10* displays the uncorrected radiant positions for all 3953 orbits in the sample. The Lyrid radiant appears already very compact in this plot of uncorrected radiant position.

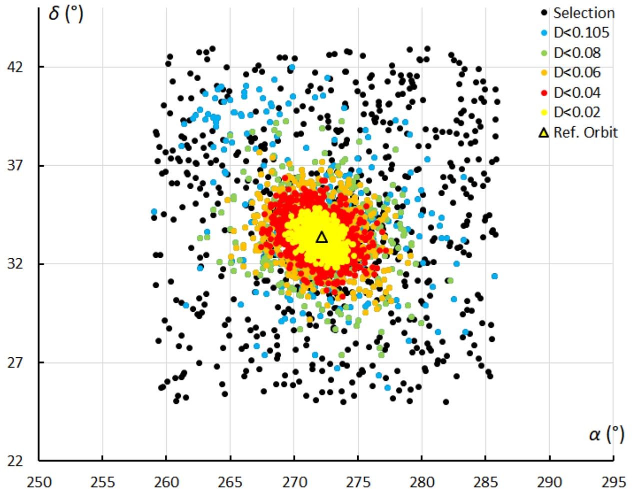

Figure 10 – Plot of the 3953 uncorrected radiant positions as selected. The different colors represent the 5 different levels of similarity according to different threshold levels in the D-criteria.

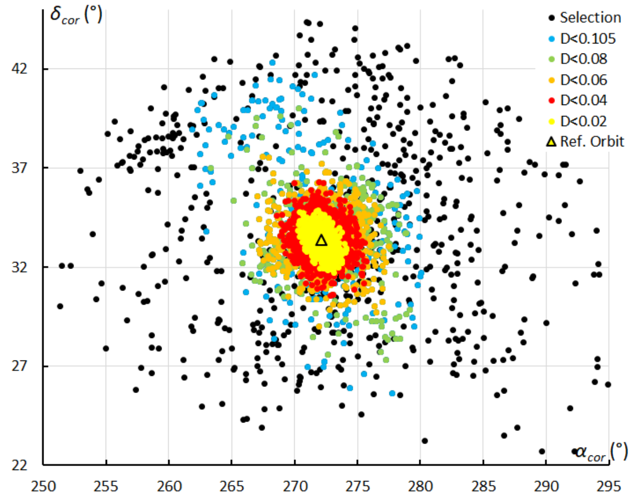

Figure 11 – The Lyrids radiant drift corrected in equatorial coordinates with $\Delta\alpha/\Delta\lambda_{\odot}$ = +0.9° and $\Delta\delta/\Delta\lambda_{\odot}$ = –0.22°.

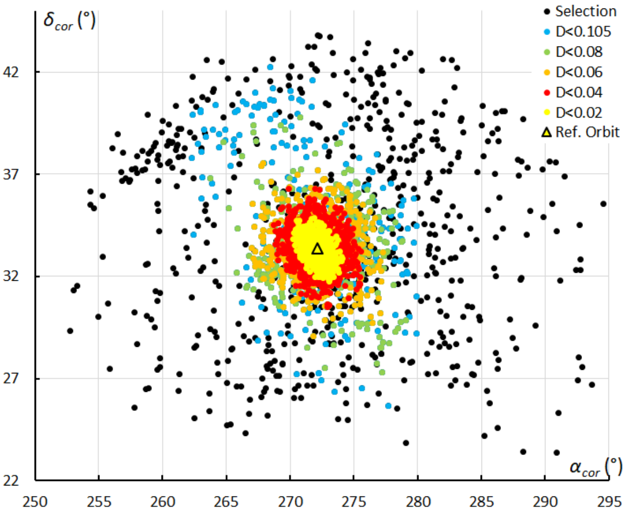

Figure 12 – The Lyrids radiant drift corrected in equatorial coordinates with $\Delta\alpha/\Delta\lambda_{\odot}$ = +0.78° and $\Delta\delta/\Delta\lambda_{\odot}$ = –0.14°.

We apply the radiant drift correction with $\Delta\alpha/\Delta\lambda_{\odot}$ = +0.9° and $\Delta\delta/\Delta\lambda_{\odot}$ = –0.22°, valid for the medium high threshold orbits in this analysis (*Table 3*, *Figure 11*). We do the same with $\Delta\alpha/\Delta\lambda_{\odot}$ = +0.78° and $\Delta\delta/\Delta\lambda_{\odot}$ = –0.14°, valid for the medium low threshold orbits in this analysis (*Table 3, Figure 12*), and $\Delta\alpha/\Delta\lambda_{\odot}$ = +0.66° and $\Delta\delta/\Delta\lambda_{\odot}$ = +0.02° according to Jenniskens et al. (2018) (*Table 3, Figure 13*).

In all three cases we see that the sporadic (black) radiant points get more dispersed as the radiant drift is not valid for these meteors. The radiants of the orbits that fit the D-criteria get more concentrated in a compact radiant, showing the validity of the radiant drift correction for these radiants. Many radiants of the low threshold orbits remain with a rather large dispersion which may indicate that the radiant drift is not valid for these radiants which may be sporadics. Therefore, in some cases it is recommended not to use the low threshold class radiants for radiant drift determination. In our case, all values listed in *Table 3* can be considered as a good approach of the theoretical radiant drift.

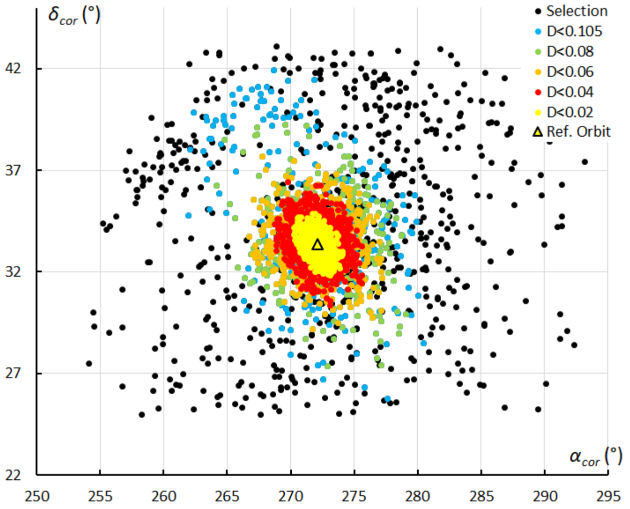

Figure 13 – The Lyrids radiant drift corrected in equatorial coordinates with $\Delta\alpha/\Delta\lambda_{\odot}$ = +0.66° and $\Delta\delta/\Delta\lambda_{\odot}$ = +0.02°.

4 The activity profile and maximum

The orbit sample has been collected over 11 years from 2007 until 2017. There is no indication for any outburst in these years. The percentage of Lyrid orbits compared to the non-Lyrid orbits remains stable, ~16.2% when we consider the entire Lyrid activity interval. In the period when mainly medium high threshold orbits or better are recorded ($27° < \lambda_{\odot} < 37°$) the number of Lyrid orbits reach one third (34.4%) of the number of non-Lyrid orbits. Also, the interval with the best Lyrid rates, $31.85° < \lambda_{\odot} < 33°$, appears very stable in strength from year to year. At the maximum the number of Lyrid orbits are 1.6 times (156.1%) the number of non-Lyrid orbits. The different relative activity levels are displayed in *Figure 14*.

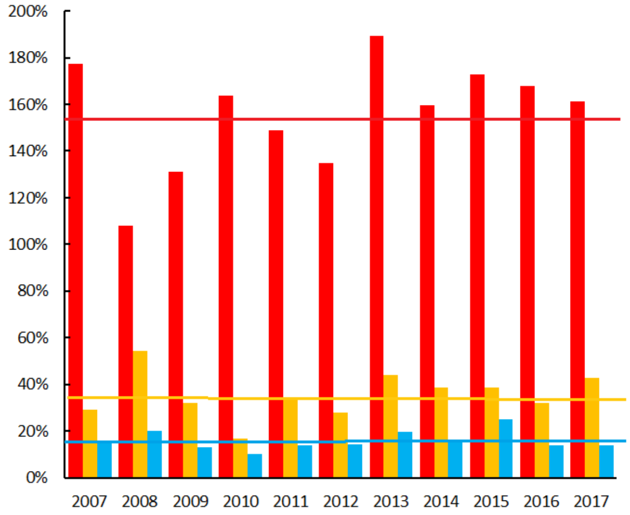

Figure 14 – The percentage of Lyrid orbits relative to the total number of non-Lyrid orbits obtained per year for different intervals of its activity period: Total activity period ($20° < \lambda_{\odot} < 45°$, blue), the main activity period ($27° < \lambda_{\odot} < 37°$, orange) and the bin with the maximum at $31.85° < \lambda_{\odot} < 33°$ (red).

The number of shower meteors per hour depends on the elevation of the radiant, the size of the unobstructed field of view and the limiting magnitude of the sky. The standard procedure for visual observers requires these data in order to calculate the Zenithal Hourly Rate or ZHR which should allow to compare the activity for observations done under different circumstances. With our orbit data we have only a total number of orbits obtained by cameras with different fields of view and different limiting magnitudes with the radiant at different elevations, no way to correct for any of these factors. With data collected over a wide range of radiant elevations, the influence on the total number of orbits per unit of time is likely to be averaged out. Video observations are much less sensitive to influences of moonlight and light pollution than visual observations. Moreover, these and other influences on the number of orbits per unit of time can be eliminated by comparing the proportion of shower orbits to the total number of non-shower orbits as the weather circumstances will affect both in the same manner. This way we can reconstruct an activity profile as a percentage of the shower orbits relative to the background activity or the total number of the remaining non-shower orbits collected in the same time interval.

Figure 15 shows the activity profile obtained from the number of orbits. The profile is the same for each threshold level.

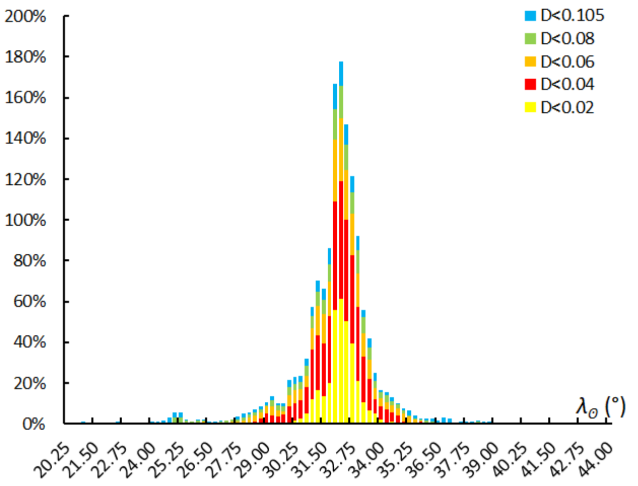

Figure 15 – The relative number of Lyrid orbits collected per 0.5° of solar longitude in steps of 0.25° during the years 2007–2017, with blue for $D_D < 0.105$, green for $D_D < 0.08$, orange for $D_D < 0.06$, red for $D_D < 0.04$ and yellow for $D_D < 0.02$, as percentage compared to the total number of non-Lyrid orbits collected in the same time span.

The activity is made up of mainly medium high and higher threshold level orbits. The low threshold orbits (blue) which represent outliers or perhaps sporadics that just fit the similarity criteria by pure chance, do not have any significant effect on the total activity level (*Figure 15*).

Koen Miskotte (2018), made an analysis of the Lyrid 2018 activity based on the available visual observations worldwide. Unfortunately, visual observing has been sadly neglected in recent years and the observational data is rather limited to Europe and few observers based in America. The theoretical maximum was not covered by observers and only some limited time spans got documented with ZHR values. To compare the 2018 ZHRs with our orbits-based activity profile we take one point from Koen Miskotte's ZHR profile and the relative activity at the very same instance on our activity profile to calibrate all ZHR values to the relative activity level. The datapoints for these ZHR values are shown in *Figure 16* and the corresponding times for the ZHR data are marked with A, B, C, D, E, F and G in *Figures 16 and 17*. The activity level of the visual ZHR at point 'A' is close to 40%, while 'B' is between 60% and 80%, the increase in activity is comparable in both curves, but the visual observations seem to identify more meteors as Lyrids than what we get from the orbit data.

The activity profile in *Figure 17* shows a shoulder in activity between 'B' and 'C' that lasts for about 0.8 days, ending with a dip. It is at this dip that Koen has another few hours of visual data available, marked with 'C'. Both the orbit data and the visual ZHR are close to 60%. It is not clear how to explain the scatter in ZHR values within this short interval of time. This may be due to too few observers or perhaps to some under correction of the ZHR.

From about $\lambda_\odot$ = 31.7° the Lyrid activity increases rapidly towards its maximum and half way this steep increase, Koen has another ZHR result at ‘D’. When the next time span with ZHRs is available at ‘E’, the Lyrid maximum was already over. Rendtel (2017) situates the Lyrid maximum between 32° and 32.45° in solar longitude with the time of maximum activity at $\lambda_\odot$ = 32.32° (red arrows in *Figure 17* activity period marked with 1–2, the maximum with 3). The activity profile obtained from the orbit data suggest the maximum to be rather at $\lambda_\odot$ = 32.20°.

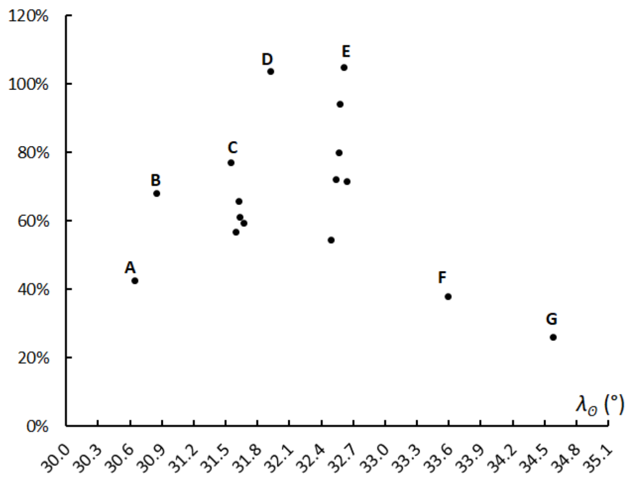

Figure 16 – The ZHRs from visual observations (Miskotte, 2018), normalized to compare with the relative activity of Lyrid orbits in function of time.

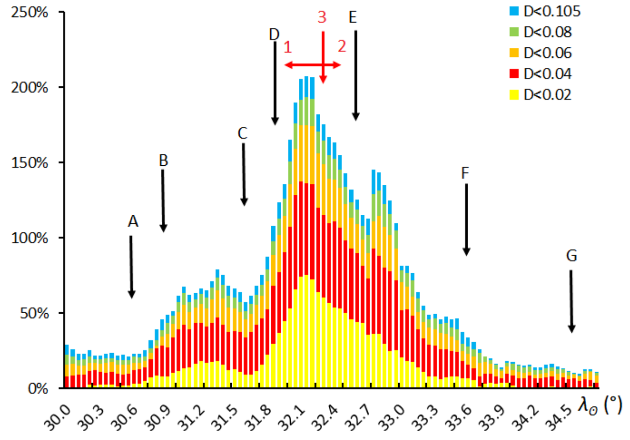

Figure 17 – The relative number of Lyrid orbits collected per 0.25° of solar longitude in steps of 0.05° based on the years 2007–2017, with blue for $D_D < 0.105$, green for $D_D < 0.08$, orange for $D_D < 0.06$, red for $D_D < 0.04$ and yellow for $D_D < 0.02$, as percentage of the number of non-Lyrid orbits collected in the same time span.

The orbit-based activity profile does not include any 2018 data and there is no reason to assume the Lyrid activity could not have displayed short-lived fluctuations in 2018. However, the ZHRs at points ‘D’ and ‘E’ look somehow underestimated. The scatter on the ZHRs at ‘E’ is remarkable and it might be worthwhile to check if these ZHR values could have been under corrected somehow. The ZHR values at ‘F’ compares well to the orbit data, while the ZHR at ‘G’ is more than twice what we expect from the orbit data. Since the 2018 visual data is based on a fractional coverage of the Lyrid activity, it would be interesting to combine data from different years into a single ZHR profile.

Looking at *Figure 17* we see that Lyrids display the best of their activity in about a week of time. Zooming in on the peak activity period, we see a shoulder (‘B’ to ‘C’) about a day ahead of the shower maximum. The main peak is skew, increasing steep from ‘C’ to the maximum, decreasing more slowly towards ‘E’, like a shoulder is imbedded on the profile. About 16 hours after the maximum another sub maximum appears on the activity profile (few hours after position ‘E’) and a final ‘shoulder’ is visible just before ‘F’. Such sub maxima, often merged in the activity profile as a ‘shoulder’, are produced by dust filaments that precede or follow the main core of the stream. Such features are typical for a layered dust distribution produced by the dynamic evolution of particles injected by the parent body at different revolutions and undergoing effects of planetary perturbations.

Based on the relative activity profile derived from the numbers of orbits collected on a global scale over 11 years of time, we can pinpoint the time of maximum at $\lambda_\odot$ = 32.18 ± 0.05°, while $\lambda_\odot$ = 32.3° is in fact the median value of the entire activity period. The different characteristics of the orbit-based activity profile are present in all classes of threshold of D-criteria and therefore pretty sure not just spurious effects.

5 Other shower characteristics

With a geocentric velocity of 46.4 km/s the Lyrids produce a luminous trajectory in the atmospheric layer between 105 and 90 km elevation. This is between the higher layer where fast meteors such as Leonids, Orionids or Perseids appear, and the lower level where slow meteors such as Taurids, Draconids, etc can be expected. This layer is very well covered by all camera networks optimized for 90 kilometers or lower.

Table 4 – Beginning and ending heights with ± σ for the Lyrids obtained from the trajectories for each threshold level of the D-criteria.

Threshold level	LYR – 006	
	H_{beg}	H_{end}
Low	104.8 ± 4.3 km	90.3 ± 6.3 km
Medium low	104.8 ± 4.2 km	90.2 ± 6.3 km
Medium high	104.9 ± 4.2 km	89.9 ± 6.3 km
High	105.0 ± 4.1 km	89.8 ± 6.3 km
Very high	105.2 ± 4.0 km	89.5 ± 6.1 km

Looking at the median values for the beginning and ending points for each class of threshold level in D-criteria, all results are in a very good agreement (*Table 4*). We assume that the data providers, CAMS, EDMOND and SonotaCo, list the values obtained from triangulations that represent the real begin, and ending heights. Anyway, by using median values any outliers have little or no influence.

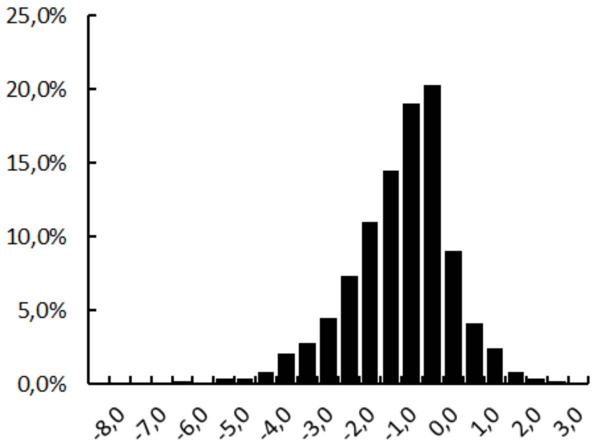

Figure 18 – Magnitude distribution per half magnitude class based on the absolute magnitudes of Lyrids.

Most orbits in this case study were obtained by the EDMOND and SonotaCo networks which use wide field of view optics and less sensitive cameras with a limiting magnitude for meteors of about +2.0. The CAMS networks use small field of view optics and mostly Watec H2 Ultimates, capturing meteors of up to magnitude +4.5. This explains why most orbits were obtained for relative bright meteors, compared to the range in brightness typically covered by a visual observer or by the CAMS video system. The magnitude range covered by CAMS data and the range covered by EDMOND and SonotaCo data is too different to just combine the data for further analyzes.

It might be tending to derive the population index from the the trend line through the linear segment of the histogram in *Figure 18* and perhaps look at different time bins to determine possible variation of the population index. However, the suitable range is limited to –4.0 to –0.5, which cannot be straightforward compared to values from classical visual observation which mostly cover a range of –4.0 to +5.0. Another concern is that the composition of the sample based upon data from a very diverse kind of optics may be unsuitable to derive population indices. This requires a more thorough evaluation of the use of the magnitude data obtained from such variety of video optics.

Although the Lyrids produce some nice numbers of bright meteors, exceptional bright Lyrid fireballs are missing, and the magnitude distribution is less abundant in bright meteors than for instance the ζ-Cassiopeiids (Roggemans and Cambell-Burns, 2018e). The Lyrids have a Long Periodic Comet type orbit and are associated with Comet C/1861 G1 (Thatcher) which moves in an orbit with a periodicity of about 415 years. This may be the reason why the smaller particles were better preserved and why the proportion bright Lyrids is less abundant than for other orbit types. Our sample of 3220 Lyrid orbits had an average absolute magnitude, brightest and faintest value of –1.1 [–7.2; +2.6]. The magnitude distribution as a percentage of the total number of Lyrids is shown in *Figure 18*.

If we calculate the average absolute magnitude for each interval of 0.5° in solar longitude with a step of 0.25° solar longitude for all 19840 non-Lyrid meteors in the considered period and for all 3220 Lyrid orbits, we see that the Lyrids are about 1 magnitude brighter than the overall meteor activity (*Figure 19*). The graph shows a trend that indicates the average Lyrid magnitude becomes brighter throughout the activity period. This could indicate some mass sorting meaning that Earth enters the Lyrid stream where it is richer in small particles and gradually encounters proportional more larger particles. This should be visible in an analyzes of visual observations as a decreasing value for the population index.

However, the geocentric velocity v_g shows a trend in function of the solar longitude $\lambda_{\odot}$, with slight slower speeds than the average when Earth enters the Lyrid stream, gradually increasing during the transit of the Earth through the stream. We see this velocity distribution very distinctly in the radiant plot (*Figure 7*) as well as in the plot of inclination i against the length of perihelion Π (*Figure 3*). The increase in brightness during the Lyrid activity can be partially explained by the increase in velocity as the faster a particle with a given mass moves, the more energy it has and the brighter the meteor will be. With an increase of 0.11 km/s per degree in solar longitude, the increase in velocity over the 9° in solar longitude as shown in *Figure 19* cannot explain the increase of 0.6 magnitude. The most likely explanation is some particle size sorting with the smaller particles being encountered first as these got towards the inner side of the stream due to the Poynting-Robertson drag. More research remains to be done to assess to which extent the increasing velocity accounts for the increase in brightness and how much is due to the particle size sorting. If the mass sorting effect can be estimated, it might be possible to get an idea of the age of the stream as how much time was needed to get at the current stage of mass sorting.

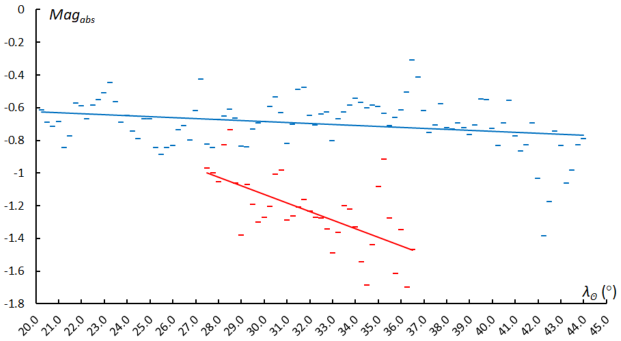

Figure 19 – Average absolute magnitude for the non-Lyrid meteor activity (blue) and the Lyrids (red) per 0.5° in solar longitude with a step of 0.25° in solar longitude.

6 Conclusion

In this case study the authors found that the differences in radiant drift in the 2018 Lyrid analyzes which puzzled the authors, are not a problem, all values are a good approach of the resultant of the movement of Earth and the direction of the shower orbit, within the uncertainty limits for the method to obtain the radiant drift. The statistical standard deviation which is found for the slope of the linear regression is rather small due to the large number of data points but not representative for the physical properties of the sample, including the error margins on the data points.

The ZHR curve for the 2018 Lyrids was very fragmentary due to a lack of global coverage. Converting the visual ZHR values to a percentage as a relative activity level allows to compare with the activity profile derived from the percentage of shower orbits per unit of time relative to the number of non-shower orbits. The 2018 visual observers had missed the hours with the Lyrid maximum, but the observed activity levels on different dates can be compared with the activity profile based on 11 years of orbital data. The time of maximum activity appears rather at $\lambda_{\odot} = 32.18 \pm 0.05°$ instead of $\lambda_{\odot} = 32.3°$ like mentioned in literature (Rendtel, 2017).

Contrary to other major showers, Lyrids are not abundant in bright and very bright events. The Lyrid stream contains still a large portion of small particles. During the transit of the Earth through the Lyrid stream, the average velocity and the average brightness of the particles increase.

Acknowledgment

We thank Denis Vida for providing us with a tool to plot a color gradient to show the dispersion in velocity and for his critical reviewing of this case study.

The authors are very grateful to Jakub Koukal for updating the dataset of EDMOND with the most recent data, to SonotaCo Network (Simultaneously Observed Meteor Data Sets SNM2007–SNM2017), to CAMS (2010–2013) and to all camera operators involved in these camera networks.

EDMOND[1] 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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[1] https://fmph.uniba.sk/microsites/daa/daa/veda-a-vyskum/meteory/edmond/

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Observation October 8–9, 2018 Draconids outburst from Indiana, U.S.A.

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A report is presented on the authors' observing expedition to observe the 2018 Draconids outburst.

1 Introduction

I have always been fascinated by the Draconids meteor shower from parent comet 21P/Giacobini-Zinner. During my teenage years, I remember having a big poster in my room of this comet; an artistic rendering of the International Cometary Explorer spacecraft passing through 21P's tail. As for the Draconids, part of my fascination with it is due to its erratic and elusive behavior. It is one of those meteor showers that produces nearly nothing on most years but can be intense and very spectacular on rare occasions. This can occur on years when the comet is close to perihelion. Most of its material (young and old dust trails) tend to hang around not too far behind the comet, and when we are lucky enough to pass through a concentration of dust, the Draconids become active. In 1933 and in 1946, meteor storms of 7000/hr and 20000/hr (respectively) occurred above Europe and North America. Those were some of the strongest meteor displays of the 20th century. During other perihelion years, such as 1952, 1985, 1998, 2011 and 2012, the Draconids produced strong outbursts of a few hundred per hour.

For 2018, the situation at first glance looked highly promising. The Earth would pass the node of comet 21P/Giacobini-Zinner only 22.7 days after the comet itself has passed by this same region of space. With only 0.017 AU of separation between the respective orbits of Earth and the comet, the analogue method of predicting meteors would suggest that a storm (more than 1000/hr) was possible. What's more, this would occur around 23-00 UT (7:00-8:00pm Eastern Daylight Time) favoring Eastern North America and Europe along with New Moon conditions. Yet, when meteor dynamicists looked at the situation, they found that the Earth would pass through a "gap" within the Draconids network of dust, perturbed and rarified by previous Earth encounters. As a result, activity was predicted to be low. The models from Vaubaillon and Maslov forecasted ZHR of only 10-20, while NASA's MEO indicated that activity would be "mild to moderate". Only a few individuals (Ye, Kastinen and Kero) predicted a stronger outburst but little details were known. A study by the UWO (Egal, Wiegert, Brown, Moser, Moorhead, Cooke) called for a strong meteor storm at the L2 region of space where the Gaia spacecraft is located, but their results at Earth again showed rates on the order of just a few tens per hour at best. One thing that was quite well agreed upon all forecasters was the time of maximum activity.

No matter the strength of this year's Draconids, this was still an excellent chance for me to see them – something that I had been pursuing for over 27 years now.

Figure 1 – Daytime image of the location and the 2018 Draconid observing site.

So, in early October (about a week prior to the Draconids), I began examining the weather forecasts. The closer we got to the peak night, the worse it looked for the Ottawa area. It appeared likely that I would have to hit the road and drive several hours to reach clear skies. First, I considered driving to the Canadian Maritimes (Nova Scotia, New Brunswick or PEI). The east coast was favored to be the best position in the world to witness the 2018 Draconids in full darkness and with a high radiant. The weather initially looked good for the Maritimes, but then it deteriorated. Then, I turned my attention to the high pressure building up into the U.S. that looked more promising. It showed a large stretch of clear skies from Indiana to Ohio and perhaps Lake Erie. Many parts of that high pressure had scattered clouds and appeared to be a warm air mass. I decided that north east Indiana had the best prospects of clear skies, so I started looking for a site to camp out and observe. With approximately 11 hours of driving, this was absolutely as far south-west as I wanted to go. Any further and I risked that much of the Draconids would be lost in bright evening twilight during the critical time.

Figure 2 – Daytime image of the location and the 2018 Draconid observing site.

Late on Sunday Oct 7th, I checked the weather once more… it was a GO… so I packed my car and off I went! I drove until late evening, which brought me past London (Ontario) and I stopped at a motel to sleep. The following day, I left early in the morning and drove all day to my destination: Lost Bridge State Area, Salamonie Lake in Indiana, an outdoor recreation MNR managed property. The temperature there was 30C (86F) – highly unusual to be this hot even for that area! I still had a thick sweater on! The friendly staff at the park greeted me and offered some possibilities for me to setup at night with a good open view of the sky. The park is huge (12000 acres) but at this time of the year, I was almost all alone, except for the friendly park staff. It was late afternoon, so I quickly scoped the area out. First, I explored the beach, and then I looked around the camping sites. There, I noticed a sign that indicated "wildlife viewing area" so I went for a closer look. Much to my delight, it was the perfect observing site! Not only was it completely wide open and secluded, but natural and surrounded by a low tree line towards my desired view point (north-west) … WOW!!! It reminded me of Bootland Farm with the wilderness all around and no people to worry about. Back at the office, the staff was happy to allow me to setup there with my chair and cameras. My camping site and car was still only a few hundred feet away, just a short walking distance. This worked out perfectly!

Figure 3 – Daytime image of the location and the 2018 Draconid observing site.

Setting up well before the sunset was crucial for this early evening event. I needed to be in my chair well before darkness, so my goal was to have everything ready and into position by 7:00pm EDT. I kept my setup simple (consisting of two cameras on fixed tripods, internal batteries and chemical hand warmers/socks acting as low-tech dew heaters for the lenses). The sleeping bag was completely unnecessary because it was 25C and very warm after sunset. It didn't take long for the mosquitoes to come out and they were ferocious. I was glad I remembered to bring my Thermacells! The noise from a variety of insects, birds and frogs was crazy loud — almost deafening!

Figure 4 – Daytime image of the location and the 2018 Draconid observing site.

Figure 5 – Daytime image of the location and the 2018 Draconid observing site.

As I watched the Sun set, I was all-set but a bit nervous. I questioned myself: "Did I travel too far in the wrong direction? Will it be all over by the time it gets dark?" But here I was, and at least the sky was all clear and looking great! At 7:30pm (all times in EDT), my cameras were activated, and I was in my chair looking up even though the sky was still too bright to see any meteors. I could only see Vega, Deneb and Arcturus. At 7:40pm, I spotted the ISS making a nice bright pass low in the north. At 7:45pm, the limiting magnitude was 3.0 (could see Polaris, Albireo and Cassiopeia). Still no meteors. At 7:50pm, I could start to make out mag 4.0 stars at the zenith (Epsilon Lyra) and the head of Draco was out. I started thinking that maybe I was cutting it too close by travelling south-west? But those doubts quickly evaporated. At 7:55pm, a short and very slow +2 meteor was seen across the zenith…… a DRACONID!!!!! There was no doubt about it! I took an "off the record" note of it as the sky was still not dark enough to begin a formal watch. Two minutes later, at 7:57pm, another short +2 Draconid was caught going through the tail of Draco. Then, at 7:59pm, a bright mag 0 Draconid flew near Lyra, and at 8:00pm a +3 Draconid went out to the north! Sky was now mag 4.5 and I still could not quite see the handle of the Little Dipper. Yet all these meteors were going by — no doubt a STRONG outburst was in progress beyond expectations! From 8:03-04pm, a burst of FIVE Draconids were seen in that one minute alone!

Figure 6 – Daytime image of the location and the 2018 Draconid observing site.

Figure 7 – Daytime image of the location and the 2018 Draconid observing site.

At last, the sky near the zenith reached mag 5.00 at 8:05pm, just barely good enough to "sign-on" for formal observing. I kept my field almost straight up where the sky was darkest. What I saw was a very strong activity of more than one meteor per minute on average. Sometimes, there was multiple Draconids within one minute! All of them moved very slowly, were usually very short, and many were seen near the radiant. Many of the Draconids were faint, but a few brighter ones appeared. At 8:11pm, a nice –1 flew near Mars, leaving a one sec train behind just as the brighter parts of the Milky Way began to show up. At 8:15pm, with the sky reaching 5.70, three Draconids (a +1, -1 and +2) all appeared a few seconds apart! The sky finally got to full darkness (mag 6.10) at 8:20pm. I noted many Draconids having the "fragile" appearance – meteors with brief flares and that seem to dissipate into a nebulous "fuzz". I have seen this effect with the Camelopardalids in 2014 and the June Bootids of 2004. However, not all Draconids appeared this way. Many of them had smooth paths that slowly came in and out.

The first hour (8:05-9:07pm EDT) was definitely very strong with 73 Draconids. It felt like I was watching one of the major showers!! The meteors came in waves, many times there would be several Draconids in a single minute! They calmed down around 8:45pm, only to rise up again at 9:00pm (01:00 UT) with multiple meteors per minute. What a great display!!!

The second hour (9:07-10:08pm EDT) was still strong with 51 Draconids. Between 9:30pm and 9:45pm, the rates were dropping but shortly after 10:00pm (02:00 UT), another flurry of Draconids occurred and surprised me! In just 13 minutes (from 9:59-10:12pm), I counted seventeen Draconids! After this flurry, the shower started declining more steadily.

The third hour (10:08-11:14pm EDT) produced 23 Draconids. The rates were declining but some bright meteors appeared during this hour. At 10:27pm, a magnificent –3 Draconid descended 35 degrees into Capricornus and fragmented into 3 pieces that continued some distance before fading away. It had the appearance of an earth-grazer… impressive and a nice contrast from most typical short DRAs!! Five minutes later, a mag 0 Draconid descended into Corona Borealis with a yellow-blue color – nice one too!!

The fourth hour (11:14pm-12:15am EDT) had just 5 Draconids.

During the fifth hour (12:15-1:25am EDT), the Draconids looked just about done as only 1 member of that shower was seen. At the end of of this hour, clouds started moving in. I decided to sign-off, pack up and go to sleep.

In all 5 hours of viewing, I saw 183 meteors (153 Draconids, 7 Southern Taurids, 2 October Camelopardalids and 21 sporadics). One very interesting aspect is that I noticed in both visual and in my photos that the radiant for this 2018 outburst was shifted by about 3 degrees towards the zenith from the traditional position. The radiant was very close to the star Grumium in Draco, and centered at near 17h49 (267) +56. This might not seem like much but the difference was quite noticeable.

It was certainly a very strong meteor display, consisting of very rare meteors! This outburst also lasted much longer that normal and had several sub-peaks! It was also very cool to see such a strong rate decline as the evening went by; it's almost like I could feel the Earth moving right out of the Draconids stream. I sure wish that the weather would have been more co-operative in North America to allow more observers to have seen this. According to the IMO's Visual Campaign, the ZHR exceeded 100/hr from 6:00-9:00pm EDT and had a peak of 157/hr shortly after 7:00pm EDT on October 8. These rates are several times stronger than what several forecasters were calling for. I took a chance by travelling a long distance and it was absolutely worth it! Witnessing a significant Draconids outburst has been a long-term life goal of mine. In 2018, not only did I observe 21P/Giacobini-Zinner for the first time, but I was fortunate enough to see its meteors in larger-than-expected numbers! It's definitely a year that I won't soon forget!

Figure 8 – Draconid fireball in evening twilight, with multiple brightness variations and fragmentation! Photographed on October 8/9 2018. Canon 5D and Rokinon 24mm f/1.4 lens (at f/2.0), ISO 1600.

Figure 9 – Daytime image of the location and the 2018 Draconid observing site.

2 The visual data

October 8/9 2018, 00:05-05:25 UT (20:05-01:25 EDT) Location: Lost Bridge State Recreation Area, Salamonie Lake, Indiana, USA. (Long: 85° 37' 42″ W; Lat: 40° 46′ 3″ N)

Observed showers:

- October Draconids (DRA) – 17:32 (263) +56
- October Capricornids (OCC) – 20:28 (307) –09
- Southern Taurids (STA) – 01:44 (026) +07
- October Camelopardalids (OCT) – 11:13 (167) +78

00:05-01:07 UT (20:05-21:05 EDT); 3/5 trans; F 1.00; LM 5.50; facing NW80 deg; t_{eff} 1.00 hr.

- DRA: seventy-three: -1(2); 0(2); +1(6); +2(7); +3(20); +4(23); +5(13)
- Sporadics: one: +3
- Total meteors: seventy-four

01:07-02:08 UT (21:07-22:08 EDT); 2/5 trans; F 1.00; LM 6.10; facing NW60 deg; t_{eff} 1.00 hr.

- DRA: fifty-one: +1(7); +2(8); +3(9); +4(15); +5(12)
- STA: one: +2
- OCT: one: +3
- Sporadics: seven: +3(3); +4(3); +5
- Total meteors: sixty

02:08-03:14 UT (22:08-23:14 EDT); 2/5 trans; F 1.00; LM 6.10; facing NW60 deg; t_{eff} 1.00 hr.

- DRA: twenty-three: -3; 0; +1(5); +2(2); +4(5); +5(9)
- STA: one: +4
- Sporadics: three: +3; +4(2)
- Total meteors: twenty-seven

03:14-04:15 UT (23:14-00:15 EDT); 2/5 trans; F 1.00; LM 6.10; facing NW60 deg; t_{eff} 1.00 hr.

- DRA: five: +4(3); +5(2)
- STA: three: +2; +4(2)
- Sporadics: three: +2; +4(2)
- Total meteors: eleven

04:15-05:25 UT (00:15-01:25 EDT); 2/5 trans; F 1.00; LM 6.00; facing NW60 deg; t_{eff} 1.16 hr.

- DRA: one: +2
- STA: two: +2; +3
- OCT: one: +3
- Sporadics: seven: +3(3); +4(2); +5(2)
- Total meteors: eleven

On my International Meteor Organization (IMO) report form[2] data is listed with shorter 5 minutes observing periods during the outburst.

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[2] https://www.imo.net/members/imo_vmdb/view?session_id=77633

Figure 10 – Composite image (digital combination) of 98 Draconid meteors captured on the night of October 8–9 2018. These were very slow moving meteors captured during a rare outburst. This wide-angle photo shows the radiant of the shower (the point in the sky where the meteors appear to trace back from if you drew an imaginary line behind them, due to perspective). Salamonie Lake, Indiana, USA. Canon 6D and Sigma Art 35mm f/1.4 lens (at f/2.0), ISO 1600.

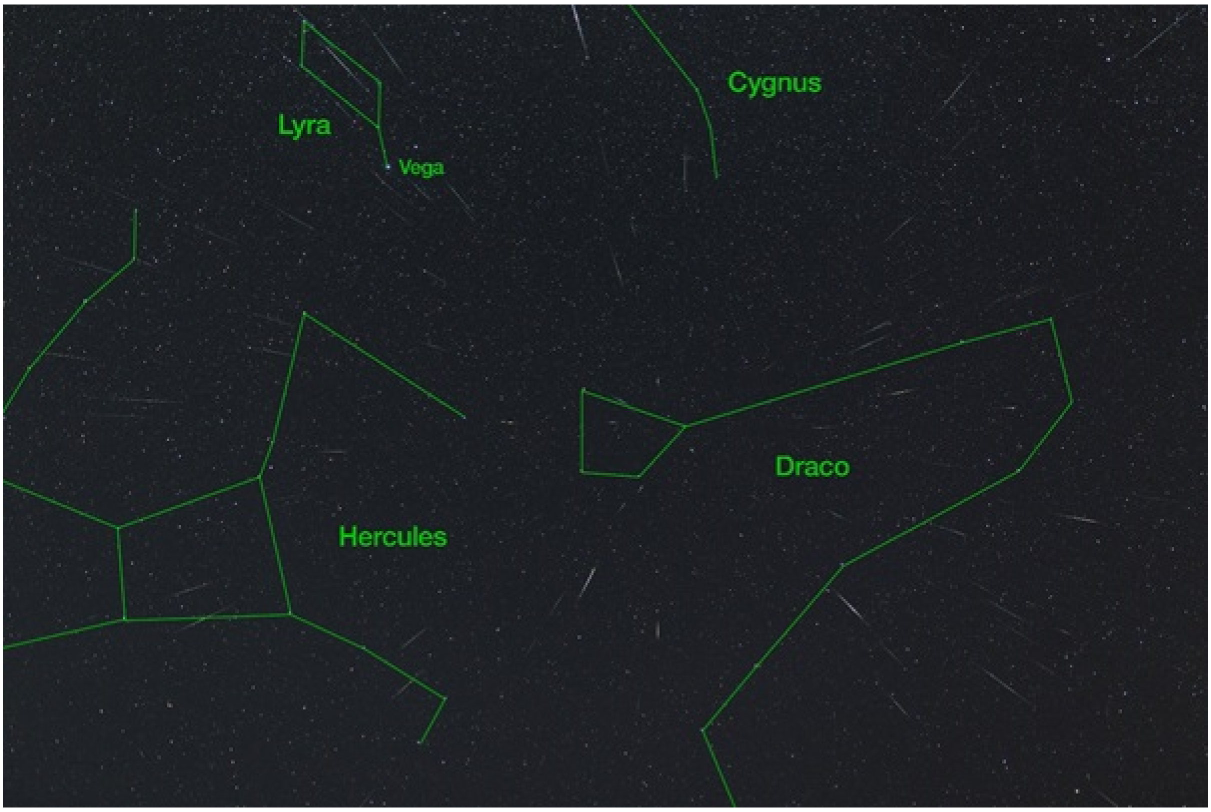

Figure 11 – Same image as in Figure 10 with constellation lines drawn in for reference.

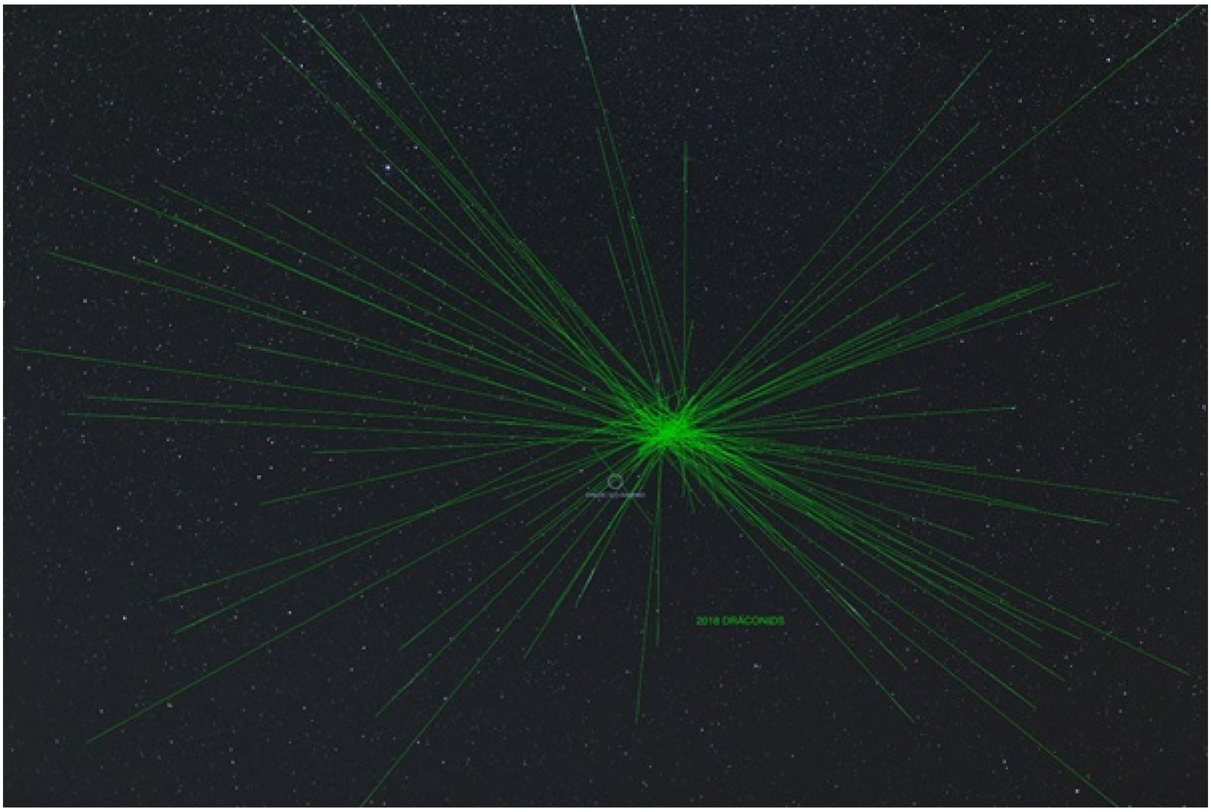

Figure 12 – Same image with lines drawn behind each meteors to show actual radiant compared to the predicted one.

Figure 13 – Same image with position of predicted radiant and 2018 radiant near 17h49 (267) +56.

Figure 14 – Composite image (digital combination) of 34 Draconid meteors captured on the night of October 8–9 2018. Canon 5D and Rokinon 24mm f/1.4 lens (at f/2.0), ISO 1600.

3 October 9–10, 2018

I was able to observe one more time after the Draconids outburst, to see if anything was going on before the long drive back home. I did not expect to see any but as always with meteors, we never know. After a very relaxing day, I decided to setup at the beach for a different view and also to try and get away from the mosquitoes. The beach area is very long and there is a massive parking lot area lit by just one dim security light. The local police was present with red cones all over the parking lot to practice driving maneuvers. I decided to setup on the far end (east side) of the beach in a quiet spot that gave a beautiful open view of the sky and shrubs blocked the light. Surprisingly, there were absolutely no mosquitoes at this spot. The temperature was again unusually warm and muggy at 24C and the sky was clear but below-average transparency. I could see the cirrus clouds in the west starting to rise so I knew that it would likely be a short session. Due to the low clouds, it was easier to see the distant light domes of Marion, Fort Wayne and Huntington, but they were not too bad.

I was able to observe for two hours (from 8:45-10:45pm EDT), with varying amounts of thin clouds (10-20%) that came in and out of my field of view. The first hour was very slow with only 3 sporadics. The second hour surprised me with 3 sporadics and 3 Draconids. This suggested that there was still a weak background activity. The Draconids seemed to radiate from about the same position near the star Grumium in Draco at 17h49 (267) +56. The brightest was a +1 low in the north but it was not so well seen due to the clouds.

October 9/10 2018, 00:45-02:45 UT (20:45-22:45 EDT) Location: Lost Bridge State Recreation Area, Salamonie Lake, Indiana, USA. (Long: 85° 37’ 42″ W; Lat: 40° 46′ 3″ N).

Observed showers:

- October Draconids (DRA) – 17:32 (263) +56
- October Capricornids (OCC) – 20:28 (307) -09
- Southern Taurids (STA) – 01:44 (026) +07
- October Camelopardalids (OCT) – 11:13 (167) +78

00:45-01:45 UT (20:45-21:45 EDT); 3/5 trans; F 1.13; LM 6.10; facing NW60 deg; t_{eff} 1.00 hr. (20% clouds from 01:10-01:45).

- DRA: none
- Sporadics: three: +3; +4(2)
- Total meteors: three

01:45-02:45 UT (21:45-22:45 EDT); 3/5 trans; F 1.10; LM 6.10; facing NW60 deg; t_{eff} 1.00 hr. (10% clouds from 01:45-02:20, 20% clouds from 02:35-02:45).

- DRA: three: +1; +3; +4
- Sporadics: three: +3; +4; +5
- Total meteors: six

Observation November 17–18, 2018

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A report is presented on the authors' 2018 Leonid observations.

1 Introduction

I went out this past Sunday morning to view the Leonids at the Fred Lossing Observatory (FLO) near Almonte to check out the 18" dob and then get comfortable in my winter sleeping bag for a predawn meteor watch. It was cold (–17C or +1F) so there is something to be said about having access to an observatory plus warm room, and not having to setup my own scope. Another RASC member, Dan, treated me to a very nice view of M42/43 with a closeup on the Trapezium among a few other sky objects. A near Leonid fireball of mag –3 was seen shooting high in the south, leaving a train persisting for several seconds! I was excited to find out what I would see once I settled down for a formal watch. Dan remarked that he had seen a few possible Leonids as well.

In the two hours that I watched until dawn, I saw 22 meteors (11 Leonids, 3 North Taurids, one Alpha Monocerotid and 7 sporadics).

It was off to a good start! Almost right away into my "formal" watch, I saw the brightest meteor of the night! It was a fabulous –4 Leonid fireball out of the radiant! It was blue-green with a terminal flash and left a train that remained visible for 50 seconds! This event brought back flashbacks of the amazing 2001 Leonid storm. Two minutes later, a pair of long North Taurids went by one after the other, including a nice 30 degrees long mag 0 NTA! Then, just one minute later, a blue-green –3 Leonid shot high near the zenith, leaving a 40 seconds persistent train!

After this initial excitement, the meteors settled down to a more evenly distributed rate, with a few lulls of inactivity. The Leonids did not appear to be more active as the radiant climbed. In fact, the rates were fairly low but included some bright meteors. My thick winter sleeping bag created a slight field obstruction. Near the end of the night, a bright –2 sporadic shot horizontally 40 degrees low in the east, a near earthgrazer.

It was a nice but frigid night for this time of the year.

2 2018 November 17–18 observations

November 17/18 2018, 08:48-10:50 UT (03:48-05:50 EDT) Location: Almonte, Ontario, Canada. (Long: 76° 15' 50" W; Lat: 45° 15' 2" N).

Observed showers:

- Northern Taurids (NTA) – 04:22 (065) +25
- Southern Taurids (STA) – 04:31 (068) +18
- November Orionids (NOO) – 05:20 (080) +16
- alpha Monocerotids (AMO) – 07:47 (117) +01
- Leonids (LEO) – 10:19 (155) +21

08:48-09:48 UT (03:48-04:48 EST); 3/5 trans; F 1.11; LM 6.10; facing S55 deg; t_{eff} 1.00 hr.

- LEO: six: -4; -3; +2(2); +4; +5
- NTA: three: 0; +3; +4
- Sporadics: three: +2(2); +4
- Total meteors: twelve

09:48-10:50 UT (04:48-05:50 EST); 3/5 trans; F 1.11; LM 6.10; facing S55 deg; t_{eff} 1.03 hr.

- LEO: five: -1; 0; +1; +2; +3
- AMO: one: +4
- Sporadics: four: -2; +3; +4; +5
- Total meteors: ten

The overview of the Global Meteor Network project and preliminary results of the 2018 Geminids

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The Global Meteor Network has now about 40 RMS systems in 11 countries. Some preliminary results of the Geminids 2018 are presented.

1 Introduction

The Raspberry Pi Meteor Station (RMS) is open-source software[3] for capture, detection, reduction and calibration of optical meteor data. The software was designed to run on cheap Raspberry Pi computers, but also has full functionality under Linux, and some parts of the codebase can also run under Windows.

The current default version of the system is using cheap IP cameras with either Sony IMX225 or IMX291 sensors and 3.6mm f/0.95 lenses. Such systems have a field of view of 87×45°, a resolution of 1280×720, and achieve a stellar limiting magnitude of +6.0 at 25 frames per second in decent sky conditions (varies from +5.2 under heavily light polluted skies, down to +6.5 in ideal conditions). Narrower lenses are supported as well, and an all-sky solution is being tested.

Figure 1 – Countries with RMS stations – December 2018.

A new project called the *Global Meteor Network*[4] (GMN) has been started with the motto "No Meteor Unobserved", whose goal is to cover a large range of longitudes and continents and make sure that there exists a record of all important events in meteor science, from meteor shower outbursts to meteorite falls. Long term monitoring of the meteoroid environment is one of the goals as well.

Currently, there are more than 40 systems in 11 different countries, and the expansion is progressing at a fast pace. *Figure 1* shows the map of countries (blue) participating in the project.

2 2018 Geminids observations

The software and the hardware have been in the 'beta' phase for about a year now. After much development and rigorous testing, we present the first large scale observations and demonstrate the capability of the system to produce high quality data in near real time.

At the end of every night the system produces fully calibrated (both astrometry and photometry) detections of meteors in CAMS and UFOOrbit formats. Meteor trajectory estimation can be performed using either CAMS or UFO tools, while our in-house software is under development.

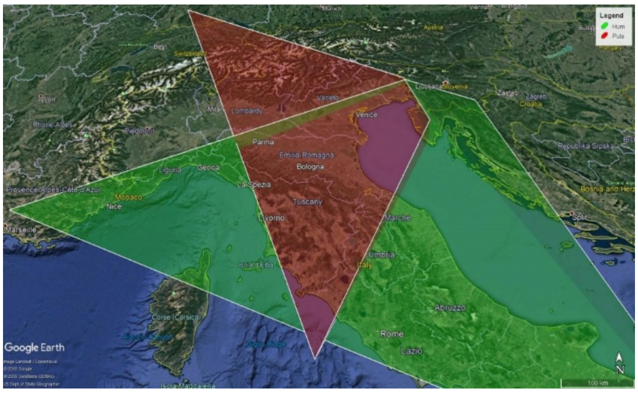

Figure 2 – FOVs of the cameras. Figure generated using Google Earth and Geert Barentsen's FOV3D code.

Here we present the results from two RMS stations in Croatia, one in Pula, other in Hum. *Figure 2* shows the locations and the volumes of the fields of view up 120 km in altitude.

The data was collected on the night of December 14 to 15, 2018. The Hum camera is in dark sky conditions and it detected more than 900 meteors that night, as shown in *Figure 3*. On the other hand, Pula is a city with a population of 100000 and it suffers from plenty of light pollution – this camera detected only 490 meteors (*Figure 4*).

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[3] https://github.com/CroatianMeteorNetwork/RMS

[4] https://gmn.duckdns.org/

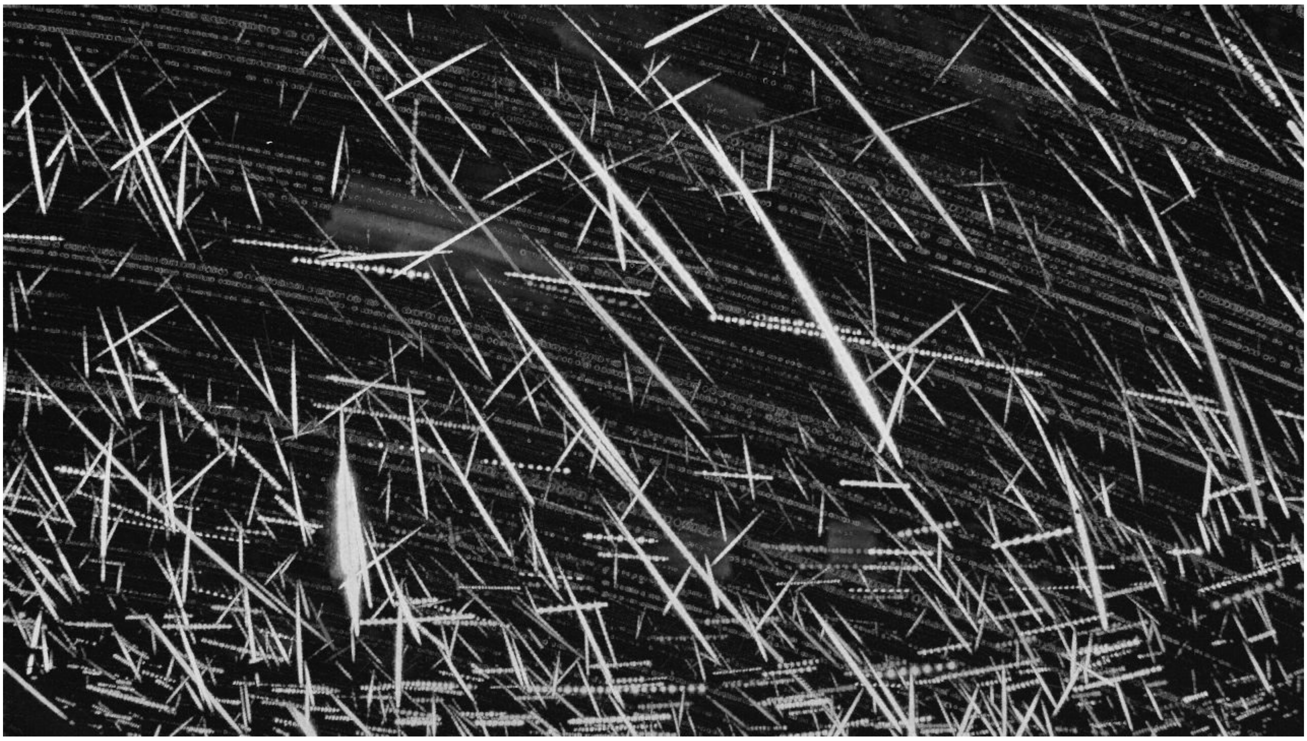

Figure 3 – Stack of more than 900 meteors detected from Hum.

Figure 4 – Stack of 490 meteors detected from Pula.

We used UFOorbit to estimate the trajectories of common meteors – due to the unfavorable geometry and non-optimal field of view overlap, there were only 155 meteors with the convergence angle Q_c larger than 10° (and about 250 common meteors with $Q_c > 5°$). *Figure 5* shows the ground projection of paired trajectories. Due to the high sensitivity of the system, meteors as far as 400 km away were observed.

The radiant scatter and the orbits are shown on *Figures 6 and 7*. The majority of meteors observed that night were Geminids, with only a handful of sporadics. The radiant spread is fairly tight, but as it can be seen, raising the convergence angle threshold to 15° decreases the radiant dispersion significantly, which indicates that the meteors with a lower threshold suffer from great uncertainty in estimated parameters.

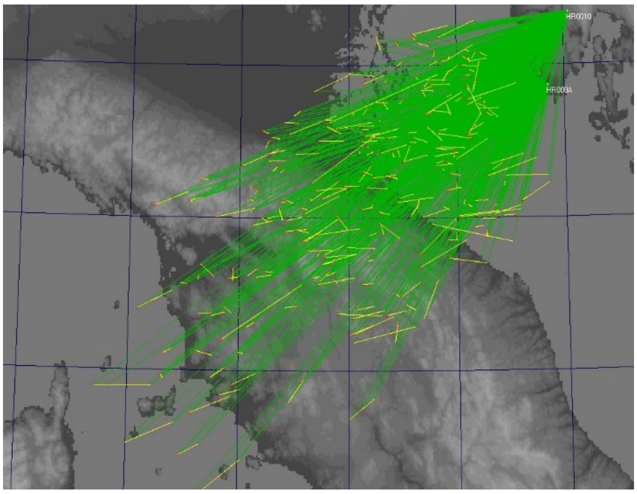

Figure 5 – UFOorbit ground map of paired trajectories.

Because UFOorbit uses a very simple two-point method of meteor trajectory estimation which disregards other points along the trajectory, the solution cannot be further improved by dynamical constraints. The RMS code even fits a great circle on the observed meteor and projects the first and the last point to it, which minimizes the error. Nevertheless, the low convergence angle Q_c is the dominant cause of the scatter, thus it is advised to use more advanced methods of meteor trajectory estimation. Such methods will become available in the near future and will be a part of the GMN processing pipeline.

Finally, we give all raw input data used to generate this short report (CAMS and UFO format), as well as the results in the UFOorbits format. Interested readers can download the data at this URL: 2018geminids_20181214_rms_data[5].

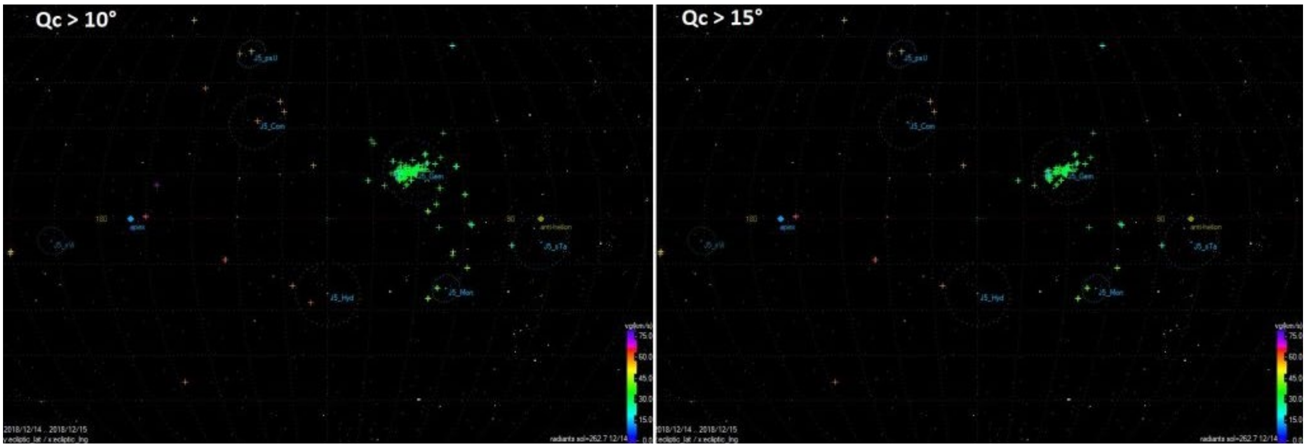

Figure 6 – Comparison of the radinat spread depending on the convergence angle.

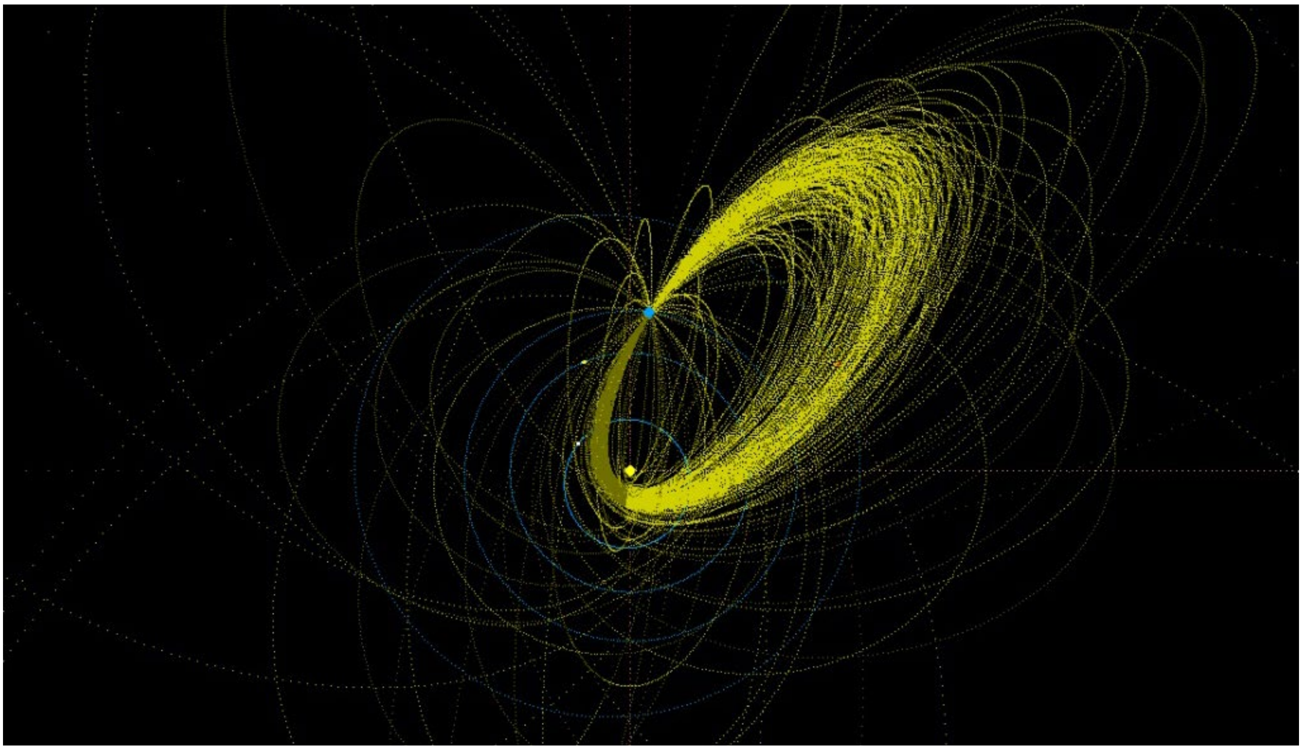

Figure 7 – Orbits of the observed meteors.

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[5] https://meteornews-assets.ams3.cdn.digitaloceanspaces.com/wp-content/uploads/2018/12/2018geminids_20181214_rms_data.zip

CAMS-Florida report: November 2018

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A summary report is presented on the CAMS-Florida results for November 2018.

1 Introduction

During November 2018, CAMS-Florida contributed 374 orbits to the NASA CAMS project led by Peter Jenniskens. Individual CAMS-Florida sites contributed as follows to the orbit counts:

- 230 (Gainesville) – 136
- 231 (New Smyrna Beach) – 193
- 232 (New Smyrna Beach) – 154
- 233 (Florida Tech) – 128
- 234 (Gainesville) – 110
- 5004 (Gainesville) – 8
- 5005 (Gainesville) – 130
- 5006 (Gainesville) – 44
- 5007 (Gainesville) – 2

Camera operators are *Barbara Harris* (New Smyrna Beach), *Vicky Jenne* (Florida Tech), *Matt Marquart* (Florida Tech) and *Andreas (Andy) Howell* (Gainesville).

Figure 1 – Andy Howell and Barbara Harris at her observatory in New Smyrna Beach. CAMS 232 is visible behind them on the hand railing.

Cameras 5004–5007 are part of the 8-camera CAMS setup in Gainesville. *Figure 2* shows the 8-camera enclosure on top of a pole that also supports CAMS 230 and CAMS 234. The eight cameras sit beneath a 10-inch acrylic dome, providing 360 degree coverage of the sky. An acrylic dome rather than flat glass plate is used, because it drains water better during summertime, when it rains every afternoon. The cameras are the Mallincam Micro-Ex that use the Sony ICX 672 CCD chip. Each camera is fitted with an 8mm f/1.0 lens that provides 26 degree × 35 degree sky coverage. Each of the two ethernet cables exiting the enclosure carries video signal from four cameras to the central computer. The faintest meteors imaged are magnitude 3–4 from a suburban location which has moderate light pollution.

More 8-camera installations are planned to join CAMS-Florida during 2019. These will enable CAMS-Florida to contribute many more coincident orbits to the CAMS project.

Figure 2 – The 8-camera enclosure on top of a pole that also supports CAMS 230 and CAMS 234.

April 2018 report CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month of April 2018 is presented. The month started with mainly cold cloudy weather which improved just in time with a stable favorable situation to cover the April Lyrid activity period. 11328 meteors were recorded, 5529 of which proved multiple station, or 49%. In total 1929 orbits were collected during this month, including 203 orbits identified as Lyrid orbits.

1 Introduction

First two weeks of April 2018 were characterized by the same unstable and unfavorable weather pattern which continued since the last week of March. Most of the nights remained cloudy with no more than clear gaps. With only two nights with partial clear sky at most stations resulting in a reasonable number of over 100 orbits, April 2018 seemed to become another disappointing month. Luckily, by mid-April, the cold mainly overcast weather ended. The sudden weather improvement brought much warmer and dry weather with excellent transparent sky. The poor start of April was compensated by a week-long favorable weather covering most of the activity period of the April Lyrid meteor shower, most nights were clear from 16 until 23 April.

2 April 2018 statistics

CAMS BeNeLux collected 11328 meteors of which 5529 or 49% were multi-station, good for 1929 orbits. This is the highest number of orbits ever for the month of April. The statistics of April 2018 are compared in *Figure 1* and *Table 1* with the same month in previous years since the start of CAMS BeNeLux in 2012.

A new extra camera, 328, was added by *Martin Breukers* at his CAMS station in Hengelo, the Netherlands. The CAMS station Oostkapelle, the Netherlands, with 8 cameras, a cornerstone of the CAMS network, remained out of service during April for renovation works. The CAMS station at Alphen a/d Rijn, the Netherlands, solved a problem with the time synchronization which was at the origin of a failure to identify multiple station events during almost 4 weeks in March. CAMS station Texel, the Netherlands, was down for 11 nights due to technical problems. Finally, CAMS station Terschelling encountered a problem with the time synchronization, producing no multiple station events since 26 March until 22 April, missing most of the favorable Lyrid activity. The unavailability of both most northern CAMS stations, Terschelling and Texel, reduced the chances for capturing multiple station meteors for the remaining cameras pointed at the northern region of the network.

The success of April 2018 was mainly due to the exceptional good weather during the week of the April Lyrid activity. The CAMS network had to do without the 8 cameras of the strategic important station Oostkapelle, this way April was covered with 83 cameras at best, against 91 operational cameras in March. Thanks to AutoCAMS 59 cameras were all nights operational, more than ever before. This way on average 88.3% of the available cameras were active, only February 2018 had a better score with 89.8%.

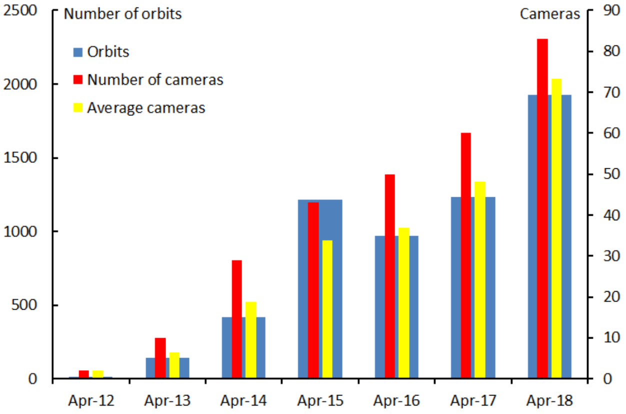

Figure 1 – Comparing April 2018 to previous months of April in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the yellow bar the average number of cameras running per night.

Table 1 – April 2018 compared to previous months of April.

Year	Nights	Orbits	Stations	Max. Cams	Min Camas	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	37.0
2017	28	1235	20	60	32	48.2
2018	27	1929	21	83	59	73.3
Total	152	5919				

As many as 203 orbits of the 1929 orbits collected in April were identified as Lyrids. A detailed report on the Lyrid activity 2018 has been published by Johannink and Roggemans (2018). The exceptional circumstances during the 2018 Lyrids allowed extensive visual observations too (Miskotte, 2018a, 2018b).

During the Lyrid meteor shower activity, several orbits caught attention identified as ζ-Cygnids (ZCY–040). The presence of these orbits in the 2018 data inspired a detailed case study on this shower and the probably associated shower, the April ρ-Cygnids (ARC–348) (Roggemans and Campell-Burns, 2018).

3 Conclusion

April 2018 started with poor and cold weather until a sudden weather improvement brought much warmer and dry weather, well timed to cover most of the Lyrid activity. The favorable Lyrid activity period and the many extra cameras available compared to previous years explain the record number of orbits collected for this month of April.

Acknowledgment

Many thanks to all participants in the CAMS BeNeLux network for their dedicated efforts. Thanks to *Carl Johannink* for providing all the data on which this report is based. The CAMS BeNeLux team was operated by the following volunteers during the month of April 2018:

Hans Betlem (Leiden, CAMS 371, 372 and 373), *Felix Bettonvil* (Utrecht, CAMS 376 and 377) , *Jean-Marie Biets* (Wilderen, CAMS 380, 381 and 382), *Martin Breukers* (Hengelo, CAMS 320, 321, 322, 323, 324, 325, 326, 327 and 328), *Bart Dessoy* (Zoersel, CAMS 397, 398, 804, 805 and 806), *Franky Dubois* (Langemark, CAMS 386), *Jean-Paul Dumoulin / Christian Wanlin* (Grapfontaine, CAMS 814 and 815), *Luc Gobin* (Mechelen, CAMS 390, 391, 807 and 808), *Robert Haas* (Alphen aan de Rijn, CAMS 3160, 3161, 3162, 3163, 3164, 3165, 3166 and 3167), *Robert Haas / Edwin van Dijk* (Burlage, CAMS 801, 802, 821 and 822), *Robert Haas* (Texel, CAMS 810, 811, 812 and 813), *Carl Johannink* (Gronau, CAMS 311, 312, 313, 314, 315, 316, 317 and 318), *Hervé Lamy* (Dourbes / Ukkel, CAMS 394 and 395/ 393), *Koen Miskotte* (Ermelo, CAMS 351, 352, 353 and 354), *Piet Neels* (Ooltgensplaat, CAMS 340, 341, 342, 343, 344 and 345, 349, 840), *Piet Neels* (Terschelling, CAMS 841, 842, 843 and 844), *Tim Polfliet* (Gent, CAMS 396), *Steve Rau* (Zillebeke, CAMS 385 and 387), *Paul Roggemans* (Mechelen, CAMS 383, 384, 388, 389, 399 and 809), *Hans Schremmer* (Niederkruechten, CAMS 803) and *Erwin van Ballegoij* (CAMS 347 and 348).

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May 2018 report CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month of May 2018 is presented. The month started with exceptional dry weather and clear nights just in time to cover the Eta Aquariid activity period. 13630 meteors were recorded, 7310 of which proved multiple station, or 54%. In total 2426 orbits were collected during this month, including many Eta Aquariid orbits.

1 Introduction

After the final few nights of April suffered from unstable cloudy sky, a period with exceptional stable weather offered excellent observing circumstances during the first 10 nights of May, providing excellent coverage of the Eta Aquariid activity. A record number of orbits for the month of May were collected, mainly during these first 10 nights.

2 May 2018 statistics

CAMS BeNeLux collected 13630 meteors of which 7310 or 54% were multi-station, good for 2426 orbits. This was the best month of May since 2012 without any single night with zero orbits. The statistics of May 2018 are compared in Figure 1 and Table 1 with the same month in previous years since the start of CAMS BeNeLux in 2012.

The CAMS station Oostkapelle with 8 cameras, a cornerstone of the CAMS network, remained out of service during May. The CAMS station at Wilderen, Belgium encountered technical problems which affected camera 380 and 381 during a series of nights. All other stations could function without major technical problems.

Less bad luck with technical problems than previous months and the general favorable weather explain the success of May 2018 with a very good coverage of the Eta Aquariids activity. The best nights occurred during the first 10 nights of May, while the next 3 weeks offered only partial clear nights as well as several nights with mostly cloudy skies. During the best nights up to 84 cameras were operational. Thanks to AutoCAMS 64 cameras were all nights operational, more than ever before. On average 91.2% of the available cameras were active, the best efficiency rate ever. This explains the high ratio of multiple station events; as many as 54% of all detected meteors were multiple station with a good orbit solution. 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. The exceptional dry weather in May, blessed with a lot of clear sky got close to February 2018 which had similar circumstances combined with much longer nights (Roggemans, 2018).

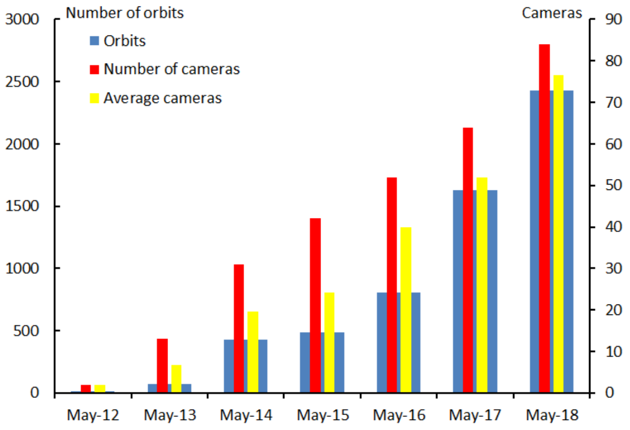

Figure 1 – Comparing May 2018 to previous months of May in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the yellow bars the average number of cameras running per night.

Table 1 – May 2018 compared to previous months of May.

Year	Nights	Orbits	Stations	Max. Cams	Min. Camas	Mean Cams
2012	5	13	4	2		2.0
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
Total	146	5852				

3 Conclusion

May made a brilliant start with overall very good nights during the first 10 nights, a perfect timing for an optimal coverage of the Eta Aquariids. May 2018 will likely remain the best month of May in the history of the

BeNeLux CAMS network, unless mother nature has more pleasant surprises to offer in future years.

Acknowledgment

Many thanks to all participants in the CAMS BeNeLux network for their dedicated efforts. Thanks to Carl Johannink for providing all the data on which this report is based. The CAMS BeNeLux team was operated by the following volunteers during the month of May 2018:

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June 2018 report CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month of June 2018 is presented. The month was characterized by many cloudy nights and rather few nights with clear sky. 8218 meteors were captured, 3864 of which proved multiple station, or 47%. A total of 1425 orbits were collected during this month.

1 Introduction

After the rather poor last two weeks of May, June continued with the same kind of weather pattern, dry but mostly cloudy sky. 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. Could June 2018 offer better results than previous years?

2 June 2018 statistics

CAMS BeNeLux collected 8218 meteors of which 3864 or 47% were multi-station, good for 1425 orbits. June is the most difficult month for CAMS BeNeLux because of the short observing window of barely 5 hours dark sky each night. June 2018 brought mediocre weather conditions although the lack of rain caused serious problems of drought for agriculture, the sky remained cloudy on many nights resulting in rather low numbers of orbits for most nights. Two nights remained without any double station meteors. Only 5–6 June and the last week of June brought clear nights. The statistics of June 2018 are compared in *Figure 1* and *Table 1* with the same month in previous years since the start of CAMS BeNeLux in 2012.

A great catastrophe happened at Ooltgenplaat on 6–7 June as an overheated PC caused a fire in the observatory of CAMS member *Piet Neels*, destroying all the electronic and optical equipment. Since then CAMS station Ooltgenplaat with its 10 cameras could no longer function. A tragedy for Piet Neels but also a huge loss for the CAMS BeNeLux network as a whole. Piet Neels and his CAMS station was one of the first two stations to start with the CAMS BeNeLux network and was one of the cornerstones of the network providing coverage to about three quarter of all cameras at other stations. The disaster at Ooltgenplaat happened while the nearby CAMS station Oostkapelle with 8 cameras, another cornerstone of the CAMS network, remained out of service for ongoing renovation work. As a result, the coverage of the atmosphere over the entire South-western region of the network and Belgium in particular became very thin, reducing the chances to get double station meteors for many other cameras.

To make things worse several other stations encountered technical problems, mainly failing dongles that had to wait for replacement Cameras 347 and 348 at Heesch went down for a series of nights, the 822 at Burlage had to be switched off for a long time, the 394 and 395 in Dourbes remained out of service for a week while almost no double station meteors were recorded on other nights by these cameras.

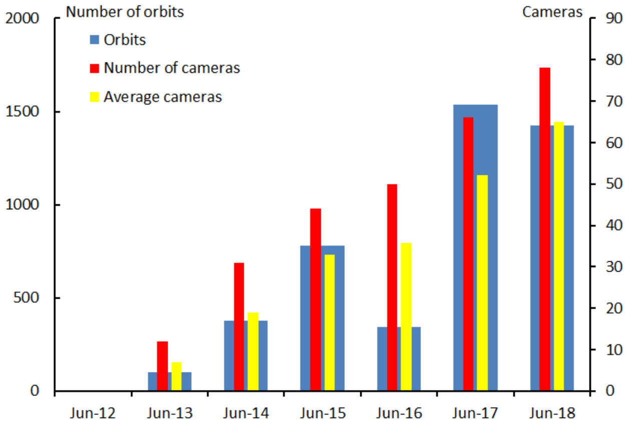

Figure 1 – Comparing June 2018 to previous months of June in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the yellow bar the average number of cameras running per night.

Table 1 – June 2018 compared to previous months of June.

Year	Nights	Orbits	Stations	Max. Cams	Min. Camas	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
Total	131	4566				

These technical problems and the rather poor weather explain the rather modest results of June 2018. During the best nights up to 78 cameras were operational. Thanks to AutoCAMS 52 cameras were all nights operational. On average 83% of the available cameras were active. As many as 47% of all detected meteors were multiple station with a good orbit solution. 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.

3 Conclusion

June 2018 was a month of bad luck for the CAMS BeNeLux network, with the fire at Piet Neels observatory in Ooltgenplaat destroying one of the most important CAMS stations and several less problematic technical issues at other stations. Since the weather was not favorable at all, we hope for a better month of June next year.

Acknowledgment

Many thanks to all participants in the CAMS BeNeLux network for their dedicated efforts. Thanks to *Martin Breukers* for providing all the data on which this report is based. The CAMS BeNeLux team was operated by the following volunteers during the month of June 2018: *Hans Betlem* (Leiden, CAMS 371, 372 and 373), *Felix Bettonvil* (Utrecht, CAMS 376 and 377) , *Jean-Marie Biets* (Wilderen, CAMS 380, 381 and 382), *Martin Breukers* (Hengelo, CAMS 320, 321, 322, 323, 324, 325, 326, 327 and 328), *Bart Dessoy* (Zoersel, CAMS 397, 398, 804, 805 and 806), *Franky Dubois* (Langemark, CAMS 386), *Jean-Paul Dumoulin / Christian Wanlin* (Grapfontaine, CAMS 814 and 815), *Luc Gobin* (Mechelen, CAMS 390, 391, 807 and 808), *Robert Haas* (Alphen aan de Rijn, CAMS 3160, 3161, 3162, 3163, 3164, 3165, 3166 and 3167), *Robert Haas / Edwin van Dijk* (Burlage, CAMS 801, 802, 821 and 822), *Robert Haas* (Texel, CAMS 810, 811, 812 and 813), *Carl Johannink* (Gronau, CAMS 311, 312, 313, 314, 315, 316, 317 and 318), *Hervé Lamy* (Dourbes / Ukkel, CAMS 394 and 395/ 393), *Koen Miskotte* (Ermelo, CAMS 351, 352, 353 and 354), *Piet Neels* (Ooltgensplaat, CAMS 340, 341, 342, 343, 344 and 345, 349, 840), *Piet Neels* (Terschelling, CAMS 841, 842, 843 and 844), *Tim Polfliet* (Gent, CAMS 396), *Steve Rau* (Zillebeke, CAMS 3850 and 3852), *Paul Roggemans* (Mechelen, CAMS 383, 384, 388, 389, 399 and 809), *Hans Schremmer* (Niederkruechten, CAMS 803) and *Erwin van Ballegoij* (CAMS 347 and 348).

July 2018 report CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month of July 2018 is presented. July 2018 offered exceptional many clear nights resulting in 21446 meteors being recorded;11717 of which proved multiple station, or 55%. A total of 4098 orbits were collected during this month.

1 Introduction

People associate July with nice good weather because it is a summer month, but for astronomical observations July proves often rather disappointing with few clear nights. Nighttime is still the shortest of the year, the number of hours to capture video meteors is limited to 5 up to 6 hours. The total meteor activity increases significantly in July compared with the low activity period in May and June. Some major showers such as Perseids, Delta Aquariids South and Alpha Capricornids display many extra meteors on top of the minor shower activity and rich sporadic background activity. Weather circumstances were unfavorable during July in past years, except for 2017 when 2644 orbits could be collected. What would July 2018 bring?

2 July 2018 statistics

CAMS BeNeLux collected 21446 meteors of which 11717 or 55% were multi-station, good for 4098 orbits. These are the best results ever for a month of July.

July 2018 offered more nights and hours with clear sky than any previous month of July since 2012. About half of all July nights were almost completely clear nights for the network, with most of the other nights offering reasonable chances to collect multiple station meteors under partial clear sky. All nights allowed to register meteors and only 9–10 July was too bad to have any single orbit. With only 9 orbits on 20–21 July and 13 orbits on 29–30 as poorest nights all other nights performed better. 22 nights had more than 100 orbits, 5 nights had more than 200 orbits. This way July 2018 was a most successful month for the network. The statistics of July 2018 are compared in *Figure 1* and *Table 1* with the same month in previous years since the start of CAMS BeNeLux in 2012. In 7 years, 161 July nights allowed to obtain orbits with a grand total of 10501 orbits collected during July in all these years.

The success of July 2018 masks the fact that the CAMS BeNeLux functioned, missing two of its major cornerstones, Ooltgenplaat with its 10 cameras and Oostkapelle with 8 cameras. The non-availability of these two strategic important camera stations had a major impact on the coverage of the meteor layer in the atmosphere for many other cameras at other CAMS stations. Hardware problems at some other stations also reduced the chances to get multiple station meteors. The cameras 394 and 395 at Dourbes recorded remarkable few multiple station events since weeks and were shut down on 2 July. Camera 822 in Burlage, Germany remained unavailable due to technical problems. Martin Breukers added a 10th camera at his CAMS station in Hengelo, the Netherlands.

Altogether at best 72 cameras were available in July, 59 of which functioned all nights thanks to AutoCams. On average 94% of all operational cameras were active, a record efficiency of the functional hardware.

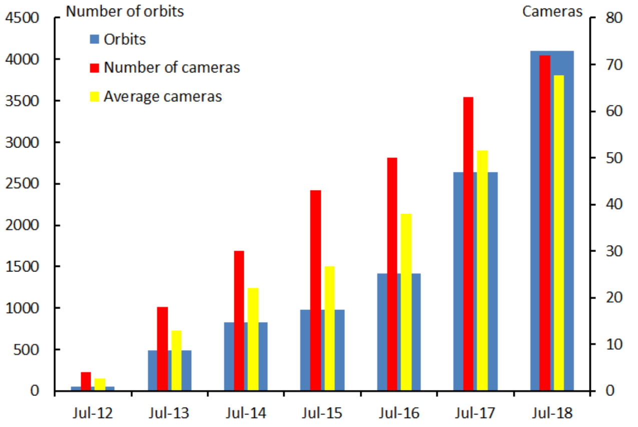

Figure 1 – Comparing July 2018 to previous months of July in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the yellow bar the average number of cameras running per night.

Table 1 – July 2018 compared to previous months of July.

Year	Nights	Orbits	Stations	Max. Cams	Min. Camas	Mean Cams
2012	7	49	4	4	-	2.6
2013	22	484	10	18	-	12.9
2014	19	830	14	30	-	22.0
2015	28	976	15	43	-	26.7
2016	28	1420	18	50	10	37.9
2017	27	2644	20	63	30	51.6
2018	30	4098	19	72	59	67.7
Total	161	10501				

3 Conclusion

July 2018 became the most successful month of July in the CAMS BeNeLux history because of an exceptional large number of completely clear nights and many hours of clear sky during partial cloudy nights.

Acknowledgment

Many thanks to all participants in the CAMS BeNeLux network for their dedicated efforts. Thanks to *Martin Breukers* for providing all the data on which this report is based. The CAMS BeNeLux team was operated by the following volunteers during the month of July 2018:

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August 2018 report CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month of August 2018 is presented. The time around the Perseid maximum had rather poor weather. 27917 meteors were recorded;15286 of which proved multiple station, or 55%. A total of 5403 orbits were collected during this month.

1 Introduction

August is the most popular month among meteor observers because of the Perseid meteor shower that contributes many meteors on top of several other shower activities and a strong sporadic background. A good month of August often makes the year. August 2017 had a record number of orbits, a challenge to do better. What did August 2018 bring us?

2 August 2018 statistics

CAMS BeNeLux collected 27917 meteors of which 15286 or 55% were multi-station, good for 5403 orbits. This is significant less than previous year when a record number of 8738 orbits were recorded. The main reason for the modest number of orbits is the poor weather during the best Perseid nights.

August 2018 started with several clear nights in the first week but weather deteriorated and most of the Perseid activity was lost due to poor observing conditions. The second half of August continued with variable sky conditions. Meteorologically August 2018 was exceptional dry, with a lot of sunshine and high temperatures, but clouds interfered during many nights limiting the number of double station meteors. The statistics of August 2018 are compared in *Figure 1* and *Table 1* with the same month in previous years since the start of CAMS BeNeLux in 2012. In 7 years, 189 August nights allowed to obtain orbits with a grand total of 26409 orbits collected during August during all these years together.

Apart from the weather the scores for August 2018 also suffered from the unavailability of several CAMS stations. The two major CAMS stations Ooltgenplaat and Oostkapelle remained out of service as well as Dourbes with its two cameras. Camera 386 at Langemark stopped functioning on 20 August. Both Gronau with 8 cameras and Ermelo with 4 cameras remained non-active for two weeks because of the summer holidays. Most camera operators use AutoCams with remote control to keep their cameras functioning during the summer holidays which is a great help to keep sufficient coverage of the atmosphere. While August 2017 had a maximum of 82 cameras, 69.9 on average available, August 2018 had to do with a maximum of 72 cameras, 62.4 on average. With less cameras and less favorable weather during the richest Perseid nights, the score of 5403 orbits is still a very nice result mainly thanks to the generalized use of AutoCAMS at most CAMS stations. It was the first time that the CAMS BeNeLux network had less cameras available than one year earlier.

For the first time in a while the CAMS BeNeLux network could welcome a new participant, *Marco Van der weide* in Hengelo with CAMS 3110.

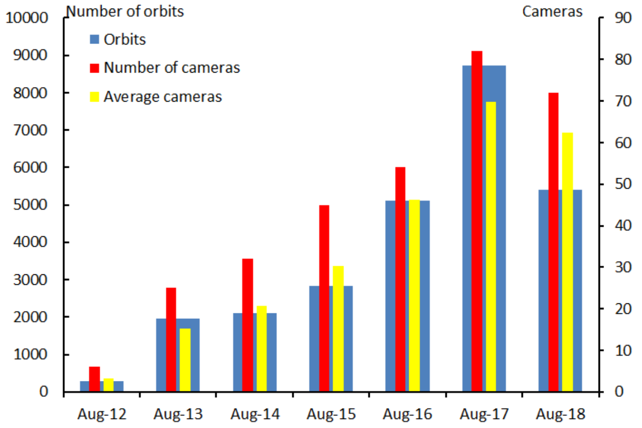

Figure 1 – Comparing August 2018 to previous months of August in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the yellow bar the average number of cameras running per night.

Table 1 – August 2018 compared to previous months of August.

Year	Nights	Orbits	Stations	Max. Cams	Min. Camas	Mean Cams
2012	21	283	5	6		3.2
2013	27	1960	13	25		15.3
2014	28	2102	14	32		20.8
2015	25	2821	15	45		30.4
2016	30	5102	20	54	15	46.2
2017	28	8738	21	82	45	69.9
2018	30	5403	19	72	56	62.4
Total	189	26409				

3 Conclusion

August 2018 ended with a nice new collection of orbits in spite of less favorable weather during the Perseid maximum and the unavailability of a significant number of cameras. Auto CAMs proved to be a great help to insure the availability of cameras during the summer holidays while the camera owners enjoy their vacation.

Acknowledgment

Many thanks to all participants in the CAMS BeNeLux network for their dedicated efforts. Thanks to *Martin Breukers* for providing all the data on which this report is based. The CAMS BeNeLux team was operated by the following volunteers during the month of August 2018:

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September 2018 report CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month of September 2018 is presented. September 2018 counted many clear nights. 29160 meteors were recorded,15833 of which proved multiple station, or 54%. A total of 5606 orbits were collected during this month.

1 Introduction

September is a month with the richest meteor activity without any major shower contributing. Nights get longer and allow easily up to eight and more hours of capture. Most years September has stable and in general favorable weather for astronomy in the BeNeLux region. Past few years the network obtained impressive numbers of orbits during this month. Would 2018 confirm the reputation of the month September?

2 September 2018 statistics

CAMS BeNeLux collected 29160 meteors of which 15833 or 54% were multi-station, good for 5606 orbits. This is a new record for the month of September. The exceptional dry weather that dominated 2018 since mid-April continued in September. This month counted as many as 19 nights with more than 100 orbits. The best September night was 28–29 with as many as 498 orbits in a single night. Only two nights remained without any orbits. The statistics of September 2018 are compared in *Figure 1* and *Table 1* with the same month in previous years since the start of CAMS BeNeLux in 2012. In 7 years, 180 September nights allowed to obtain orbits with a grand total of 19404 orbits collected during September during all these years together.

The strategic important CAMS station Oostkapelle was back operational end September after about 6 months of renovation work. Another cornerstone of the network, Ooltgenplaat, remained non-active as well as Dourbes and Langemark. Technical problems with some cameras at different stations could be solved within few days. While September 2017 had a maximum of 83 cameras, 70.2 on average available, September 2018 had 80 cameras at best and 65.4 on average. The record number of orbits was the result of the exceptional number of clear nights combined with the use of AutoCams at almost all stations.

On 4 September camera 3900 had its first orbits. This new camera operated by *Tioga Gulon* is installed in Nancy, France and has a large overlap with many other cameras. Whenever Nancy has clear sky, impressive numbers of orbits are obtained. During its first few weeks as many as 446 orbits were obtained, the highest score of all cameras.

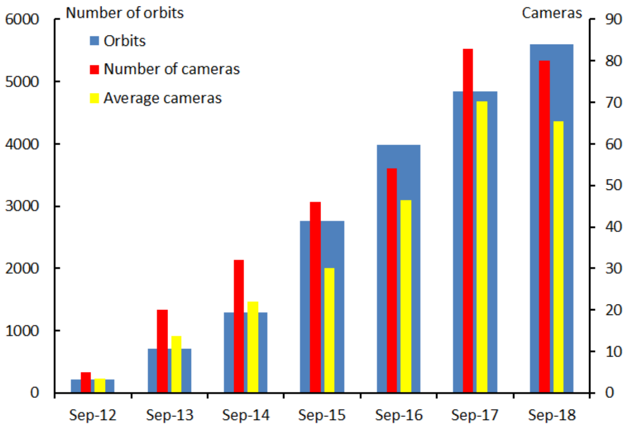

Figure 1 – Comparing September 2018 to previous months of September in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the yellow bar the average number of cameras running per night.

Table 1 – September 2018 compared to previous months of September.

Year	Nights	Orbits	Stations	Max. Cams	Min. Camas	Mean Cams
2012	18	209	5	5	-	3.4
2013	19	712	9	20	-	13.7
2014	27	1293	14	32	-	22.0
2015	29	2763	15	46	-	30.0
2016	30	3982	19	54	32	46.5
2017	29	4839	22	83	47	70.2
2018	28	5606	20	80	57	65.4
Total	180	19404				

3 Conclusion

September 2018 confirmed the reputation of this month with a very rich background meteor activity and favorable weather. Even with less cameras more orbits were collected than in 2017.

Acknowledgment

Many thanks to all participants in the CAMS BeNeLux network for their dedicated efforts. Thanks to *Martin Breukers* for providing all the data on which this report is based. The CAMS BeNeLux team was operated by the following volunteers during the month of September 2018:

Hans Betlem (Leiden, CAMS 371, 372 and 373), *Jean-Marie Biets* (Wilderen, CAMS 380, 381 and 382), *Martin Breukers* (Hengelo, CAMS 320, 321, 322, 323, 324, 325, 326, 327, 328 and 329), *Bart Dessoy* (Zoersel, CAMS 397, 398, 804, 805 and 806), *Jean-Paul Dumoulin / Christian Wanlin* (Grapfontaine, CAMS 814 and 815), *Luc Gobin* (Mechelen, CAMS 390, 391, 807 and 808), *Tioga Gulon* (Nancy, France, CAMS 3900), *Robert Haas* (Alphen aan de Rijn, CAMS 3160, 3161, 3162, 3163, 3164, 3165, 3166 and 3167), *Robert Haas / Edwin van Dijk* (Burlage, CAMS 801, 802, 821 and 822), *Robert Haas* (Texel, CAMS 810, 811, 812 and 813), *Klaas Jobs* (Oostkapelle, 3030, 3031, 3032, 3033, 3034, 3035, 3036 and 3037), *Carl Johannink* (Gronau, CAMS 311, 312, 313, 314, 315, 316, 317 and 318), *Hervé Lamy* (Ukkel, CAMS 393), *Koen Miskotte* (Ermelo, CAMS 351, 352, 353 and 354), *Piet Neels* (Terschelling, CAMS 841, 842, 843 and 844), *Tim Polfliet* (Gent, CAMS 396), *Steve Rau* (Zillebeke, CAMS 3850 and 3852), *Paul Roggemans* (Mechelen, CAMS 383, 384, 388, 389, 399 and 809), *Hans Schremmer* (Niederkruechten, CAMS 803), *Erwin van Ballegoij* (CAMS 347 and 348) and *Marco Van der weide* (CAMS 3110).

October 2018 report CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month of October 2018 is presented. October 2018 counted many clear nights. 51332 meteors were recorded, 28032 of which proved multiple station, or 55%. A strong Draconid outburst, the October Camelopardalids with a modest outburst, the October Ursae Majorids with a surprisingly good activity and some of the Orionid top nights all with clear nights resulted in a total of 9611 orbits collected during this month.

1 Introduction

October is in general the month that the last few warm days remind us of the past summer, with 10 hours long nights and unfortunately often much humidity at night. Any lucky chance to have some clear nights this time of the year means great numbers of orbits. Since the CAMS BeNeLux network got started in 2012 weather in October has been rather uncooperative. Would October 2018 bring us more luck?

2 October 2018 statistics

CAMS BeNeLux collected the absolute record of 51332 meteors of which 28032 or 55% were multi-station, good for 9611 orbits. This is a great new record for the month of October. The exceptional dry weather that dominated 2018 since mid-April continued throughout October. This month counted as many as 22 nights with more than 100 orbits. The best October night was 08–09 with as many as 1391 orbits in a single night, thanks to the Draconid outburst. Only two nights remained without any orbits. The statistics of October 2018 are compared in *Figure 1* and *Table 1* with the same month in previous years since the start of CAMS BeNeLux in 2012. In 7 years, 170 October nights allowed to obtain orbits with a grand total of 22141 orbits collected during October during all these years together.

Unfortunately, a cornerstone of the network, Ooltgenplaat, remained non-active as well as Dourbes and Langemark. Technical problems with some cameras at different stations could be solved within few days. While October 2017 had a maximum of 87 cameras, 74.4 on average available, October 2018 had 82 cameras at best and 73.0 on average.

The record number of orbits was the result of the exceptional number of clear nights combined with the use of AutoCams and the exceptional outburst of the October Camelopardalids in the night of 5–6 October, followed few days later by a far much stronger outburst than anyone expected of the Draconids, alias Giacobinids, and as cherry on the cake another strong activity of the October Ursae Majorids in the night of 14-15-16 October. The broad Orionid maximum activity is a most rewarding observing period for meteor workers and 2018 offered some partial clear nights during this Orionid activity. A favorable weather for Orionids is a once in a five years festivity which we did not enjoy since the testing period of CAMS in the BeNeLux after the Draconid 2011 project, months before the official start of the CAMS BeNeLux network. Better than this, nobody can expect a month of October to be. October 2018 so far is the best month ever in the CAMS BeNeLux history and this while the network had less cameras available than one year earlier.

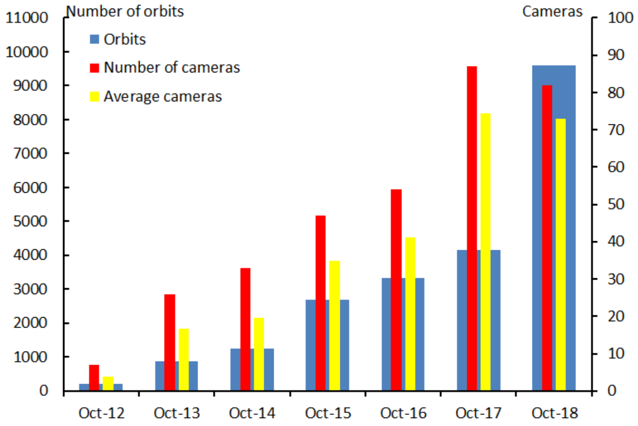

Figure 1 – Comparing October 2018 to previous months of October in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the yellow bar the average number of cameras running per night.

Table 1 – October 2018 compared to previous months of October.

Year	Nights	Orbits	Stations	Max. Cams	Min. Camas	Mean Cams
2012	16	220	6	7		3.9
2013	20	866	10	26		16.8
2014	22	1262	14	33		19.7
2015	24	2684	15	47		34.8
2016	30	3335	19	54	19	41.3
2017	29	4163	22	87	45	74.4
2018	29	9611	21	82	52	73.0
Total	170	22141				

3 Conclusion

October 2018 exceeded all expectations with the strong Draconid outburst, the October Camelopardalids with a modest outburst, the October Ursae Majorids with a surprisingly good activity and some of the Orionid top nights, all with favorable weather.

Acknowledgment

Many thanks to all participants in the CAMS BeNeLux network for their dedicated efforts. Thanks to *Carl Johannink* for providing all the data on which this report is based. The CAMS BeNeLux team was operated by the following volunteers during the month of October 2018:

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Full Moon bright bolide over Hungary

Kővágó Gábor

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On 10 October, 2018 at 3:58:59 UT a Full Moon bright bolide exploded high above Hungary. One of my meteor cameras successfully caught the phenomenon from begin to end. Because this was my brightest capture in the last five years, I decided to collect data and calculate its trajectory and orbit as precise as I can. The preliminary calculation shows that this was likely an Orionid fireball and that it ablated totally in the atmosphere.

1 Introduction

On that morning – as always – I checked my cameras uploaded pictures on their homepage[6] and surprisingly realized an oversaturated image among the others. I immediately downloaded the data which was automatically analyzed by the system (SonotaCo, 2009).

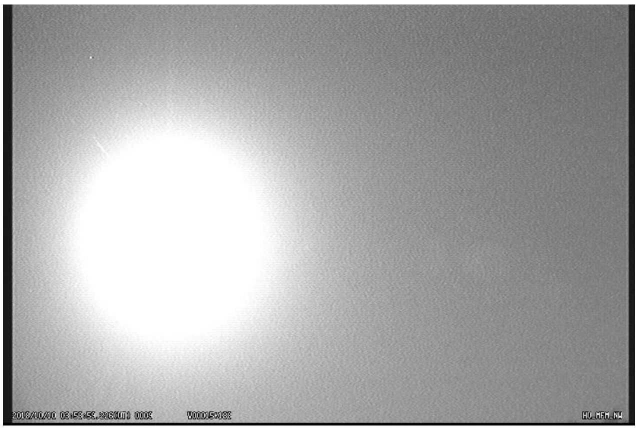

Figure 1 – The bolide's snapshot on the north-west camera from Budapest, Hungary.

2 Detailed story

I collected every reachable picture about this event. Unfortunately, the Hungarian Video meteor Network's online reachable cameras had been stopped operating before the bolide because the sunrise's time was very close to the falling. This early hour also caused that we haven't any visual observation. So, I turned to the online meteorological cameras and luckily, we have hundreds spread across the country and there were a dozen among them which had taken pictures of it. But these are just still images and these have to be manually calibrated all of them one by one with UFOAnalyzer. That's why I chose only four of them – the easiest ones all around the meteor trajectory – in addition to my dedicated meteor camera's data.

I tried to widen the search and I found many pictures about the drifted trail on Austrian meteorological pages. The Czech meteorological cameras also managed to catch the meteor's trail immediately after the fall. I put a post on the EDMOND facebook page to find more observations and Jiri Srba contacted me and sent their (Observatory Valasske Mezirici, Czech Republic) data[7]. It also contains a spectral recording but it is probably affected by the trees (large patches in place of dots/lines on both visual ends) and contains no zero order, so it would be hard to analyze properly.

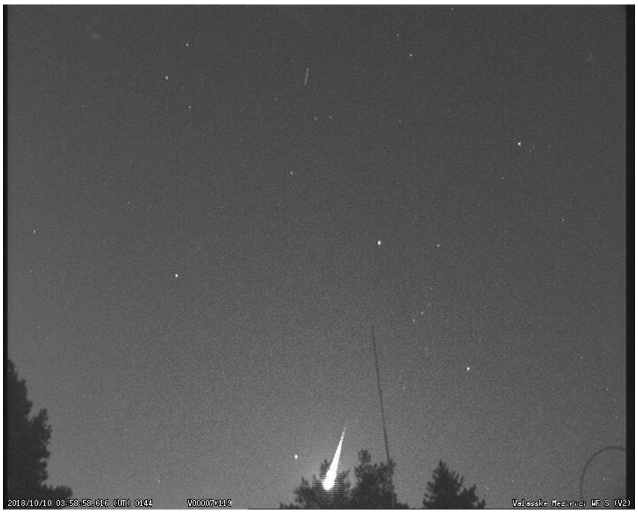

Figure 2 – The bolide's snapshot from Valasske Mezirici, Czech Republic.

3 Trajectory

I have six observations all around the meteor trajectory, four of them are calibrated manually and two dedicated meteor cameras.

Table 1 – Overview of the 6 observations used in this analyzes.

Site Name	Resolution (pixel)	Field of view (degree)	Max. Error (degree)
(HU) Bp. Kelenföld	720×480	57.3	0.07
(HU) Hajdúszoboszló	1920×1440	69.6	0.15
(HU) Bp. Megyer	2688×1520	81	0.12
(HU) Zselic	640×480	Allsky	0.3
(HU) Barlahida	1920×1080	78.6	0.12
(CZ) Valasske Mezirici	720×576	74.6	0.06

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[6] http://videometeor.co.nf - The only Hungarian video meteor system based on UFOTools.

[7] https://www.astrovm.cz/cz/ Observatory Valasske Mezirici, Czech Republic.

I also had to manually measure begin- and endpoints in UFOAnalyzer, because the software calculation depends on detection's thresholds omitting frames especially from the beginning of a fall. I used UFOOrbit's (SonotaCo, 2009) import function to deal with the measured points.

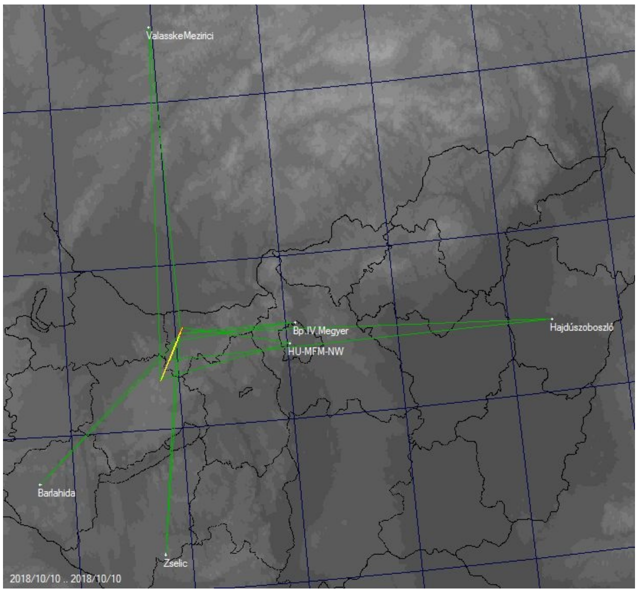

Figure 3 – UFOOrbit calculated trajectory based on six calibrated observations.

The meteor started its luminous path very early at 137 km with an angle of 60 degree to the Earth surface. At 90 km high in the atmosphere it began to ablate heavily and after 10 km along the trajectory it reached its peak brightness in a great explosion at 81 km high. The thickest part of the plasma cloud was more than 2 km wide. During slightly more than one second the meteor went from Borzavár to Nagyigmánd (80km distance) with an enormous speed of 66.7 km/s (*Figure 3*). A tiny piece of the original mass could survive the detonation and continued its flight for about another 10 km where it died out at 72.2 km high.

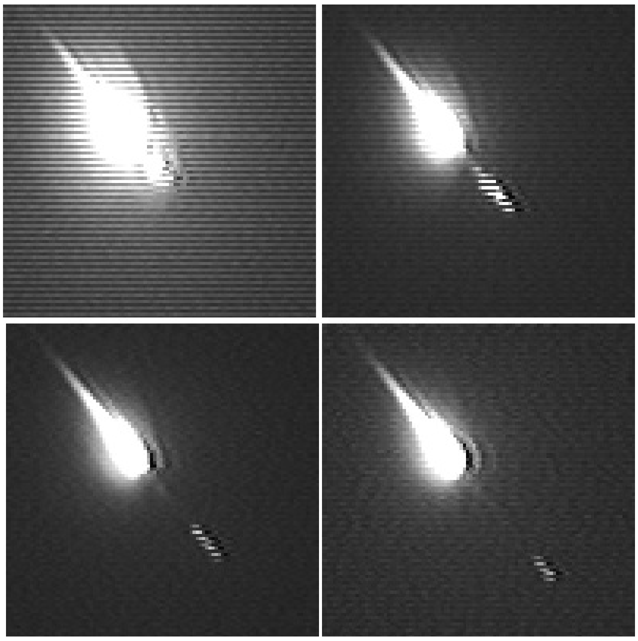

Figure 4 – The remaining piece after the main explosion, the camera was quick enough to adjust its aperture frame by frame, so the brightness was affected by that.

4 Orbit and origin

I don't have any velocity information from the meteorological camera's detections because they are just still images. The other two are dedicated meteor cameras with exact timing frame by frame. The orbital elements are calculated from these two observations taking into consideration the velocity changes. Because of that I used only the first third part of the trajectory. I draw the attention to the fact that without error range calculations the resulting orbit is just a rough estimate.

Table 2 – The orbital elements of the fireball compared to the Orionids and their parent comet P/Halley.

Orbital elements	Fireball	Orionids	Comet Halley
a (AU)	11.8	15.1	18
q (AU)	0.517	0.571	0.587
e	0.956	0.962	0.967
ω (°)	89.2	82.5	110.7
Ω (°))	16.5	28	56.8
i (°)	172	163.9	162.3

All the orbital elements (Cook, 1973) are near the Orionids ephemerides and they are in between the error boundaries of the stream, except the inclination which is 10 degree away. It is five times more than the greatest acceptable distance. The fireball's radiant was very close (RA. 81° and dec.+9.5°) to the Orionids radiant (RA.80.97° and dec.14.37° – daily motion corrected values) but far enough to be rather an individual debris then part of the main stream (*Table 2, Figure 5*).

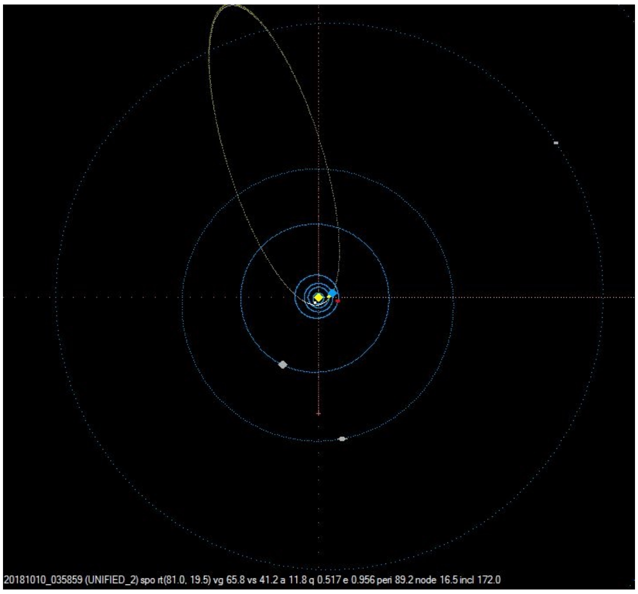

Figure 5 – UFOOrbit (SonotaCo, 2009) calculated orbits with subtle differences – rarely accurate – between the observations.

5 Light and mass

Programs like UFOCapture (SonotaCo, 2009) aren't the finest tools to measure precise light curves for meteors. In this case before the brightest flash – at around –5 magnitude

– the software couldn't fallow the meteor's trajectory and calculate its brightness because the highly saturated images. I have to estimate its peak brightness with the aid of an old picture about the Full Moon. It was definitely in the same category from Budapest (*Figure 6*).

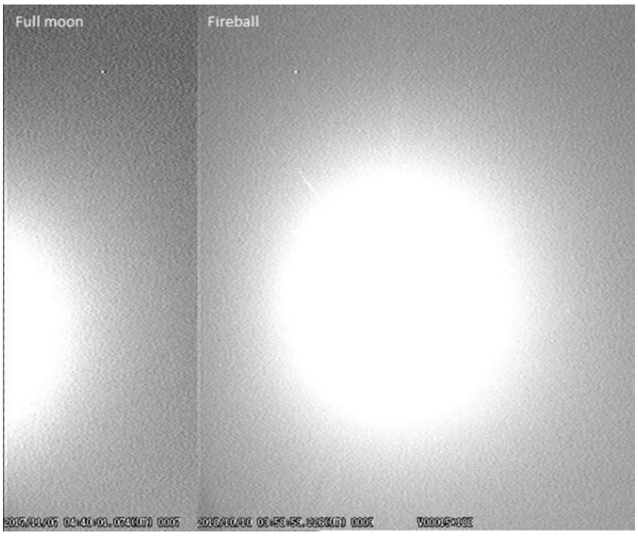

Figure 6 – Full Moon compared to the fireball.

I calculated the photometric mass from the basic parameters of the event, absolute magnitude, velocity and zenith angle. (Jones et al., 1989) The original mass was 7.2 kg (±1.4 kg) which corresponds to a 16 cm diameter spherical body assuming a density of ordinary chondrites. Only a 3 mm diameter (0.05g) small grain survived the great explosion and continued its flight for the last 10 km. This could be the toughest part of the original body maybe just one chondrule.

6 Unusual observation

During the frame by frame measurement of the beginning of the meteor something odd caught my attention. A little fuzzy dot appeared and disappeared (two frames long event) on the same trajectory while the main event got brighter and brighter (*Figure 7*). I tried to find it on the other video (from the Czech Republic) but without any luck, it was too faint from that far. Likely it was part of the original body and was separated early by the Earth gravitational field. Assuming the same trajectory, this pebble had 1.2 mm diameter and 0.003 g with its absolute magnitude of 2. The distance between the two bodies was 3 km. This observation would be impossible without video meteor networks which are capable at such speed.

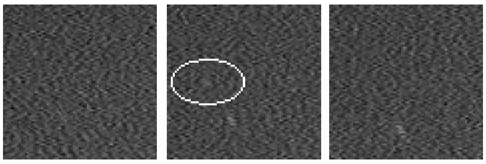

Figure 7 – It is difficult to see this tiny object on still images but it is clearly visible stepping the frames.

References

SonotaCo (2009). "A meteor shower catalog based on video observations in 2007-2008". *WGN, Journal of the International Meteor Organization*, **37**, 55–62.

Cook A. F. (1973). "A working list of Meteor Streams". In Curtis L. Hemenway, Peter M. Millman, and Allan F. Cook, editors, Evolutionary and physical properties of Meteoroids, *Proceedings of IAU Colloq. 13*, held in Albany, NY, 14-17 June 1971. NASA SP-319, Washington DC, 183–191.

Jones J., McIntosh B. A. and Hawkes R. L. (1989). "The age of the Orionid meteoroid stream". *Monthly Notices of the Royal Astronomical Society*, **238**, 179–191.

Fireball events

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An overview is presented of exceptional fireball events by the meteor observing stations operated by the SMART Project (University of Huelva) from Sevilla and Huelva during the period November–December 2018.

1 Stunning Taurid fireball on 2018 November 3

This impressive North. Taurid meteor event[8] was spotted over southern Spain on 2018 Nov. 3, at 0:46 local time (23:46 UT on Nov. 2). The fireball was brighter than the full Moon, and it was produced by a large meteoroid from Comet Encke that hit the atmosphere at about 110000 km/h. The event overflew the Mediterranean Sea and the province of Almeria (Andalusia, Spain). It began at an altitude of about 122 km and ended at a height of around 63 km. This meteor was recorded in the framework of the SMART project (University of Huelva) from the meteor-observing stations located at the astronomical observatories of La Hita (Toledo), Sierra Nevada (Granada), La Sagra (Granada) and Sevilla.

Figure 1 – Fireball 2018 November 3, 23h46m UT.

2 Bright Taurid over central Spain on 2018 November 4

This impressive meteor event[9] was spotted over central Spain on 4 Nov. 2018 at 4:54 local time (3:54 universal time). It was brighter than the full Moon (absolute magitude: -13). It was a North Taurid bolide produced by a fragment from Comet 2P/Encke that hit the atmosphere at about 100,000 km/h. The event overflew the province of Albacete. It began at an altitude of about 113 km and ended at a height of around 51 km. The meteor was recorded in the framework of the SMART project (University of Huelva) from the meteor-observing stations located at La Hita (Toledo), Calar Alto (Almeria), Sierra Nevada (Granada), La Sagra (Granada) and Sevilla.

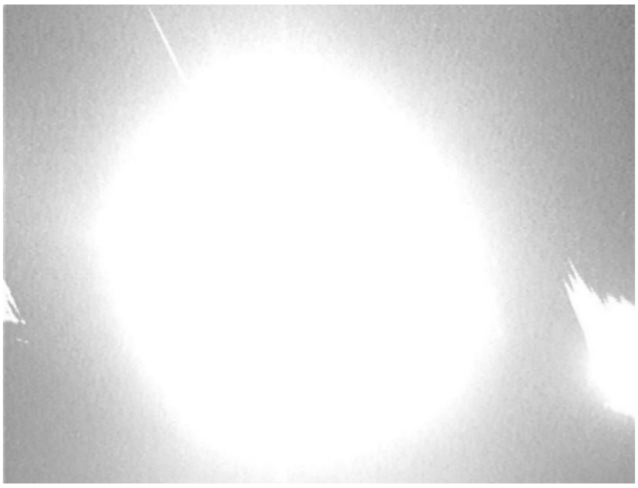

Figure 2 – Fireball 2018 November 4, 3h54m UT.

3 Geminids as seen from Toledo

This video[10] shows images of the Geminid meteor shower during its peak activity in 2018. This meteor shower produced stunning fireballs last night. Footage was recorded in the framework of the SMART project (University of Huelva) from La Hita Astronomical Observatory (Toledo).

Figure 3 – Stacked image of the Geminids.

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[8] https://youtu.be/UScQelOSXkQ

[9] https://youtu.be/QzbaAPJ3tkE

[10] https://youtu.be/DIXX4IvGKuI

Radio meteors – November 2018

Felix Verbelen

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`felix.verbelen@skynet.be`

An overview of the radio observations during November 2018 is given.

1 Introduction

The graphs show both the daily totals (*Figure 4 and 5*) and the hourly numbers (*Figures 6 and 7*) 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 November 2018.

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

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

During this month there were few local disturbances, no registered "sporadic E" (Es) nor was there lightning activity.

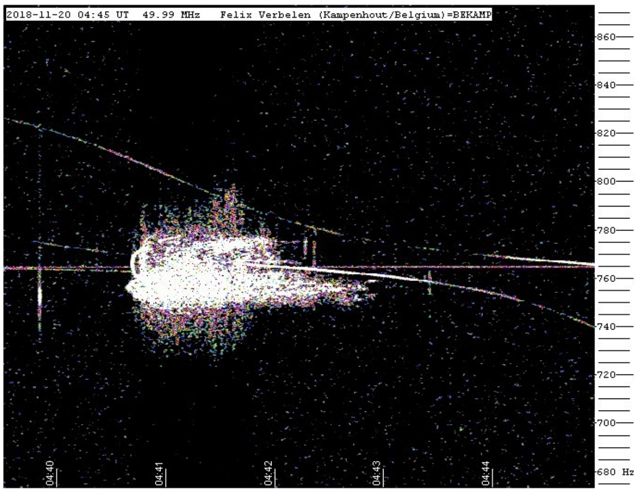


Figure 1 – Radio echoes lasting more than 1 minute, the most spectacular on 20181112_04:45 UT.

Highlights of the month were the Leonids. The number of underdense reflections of this swarm remained relatively low, but the overdense echoes were particularly numerous, with many reflections longer than 10 seconds. Remarkable was that the shorter overdense echoes had a maximum on November 19th, while the longer, and especially the overdenses longer than 1 minute, showed a clear maximum on November 20th. Attached are a few examples of the strongest reflections.

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

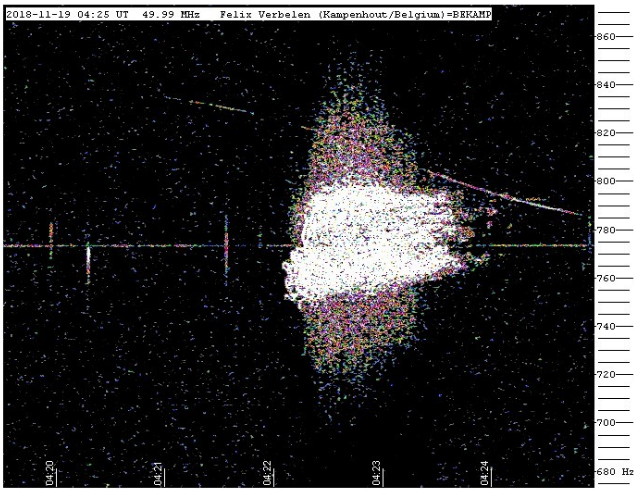


Figure 2 – Radio echoes lasting more than 1 minute, the most spectacular on 20181119_04:25 UT.

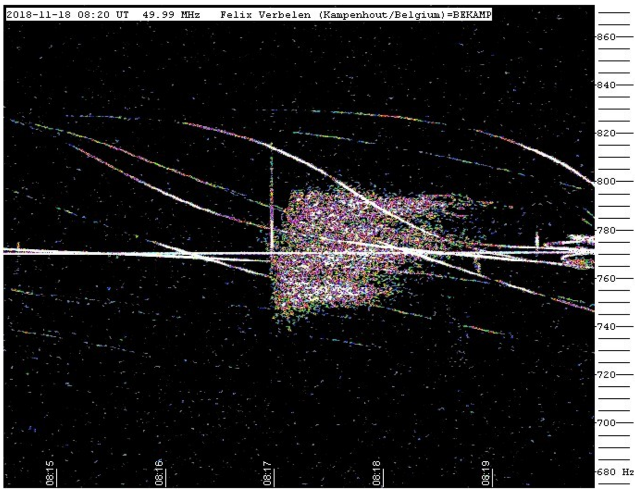


Figure 3 – Radio echoes lasting more than 1 minute, the most spectacular on 20181118_08:20 UT.

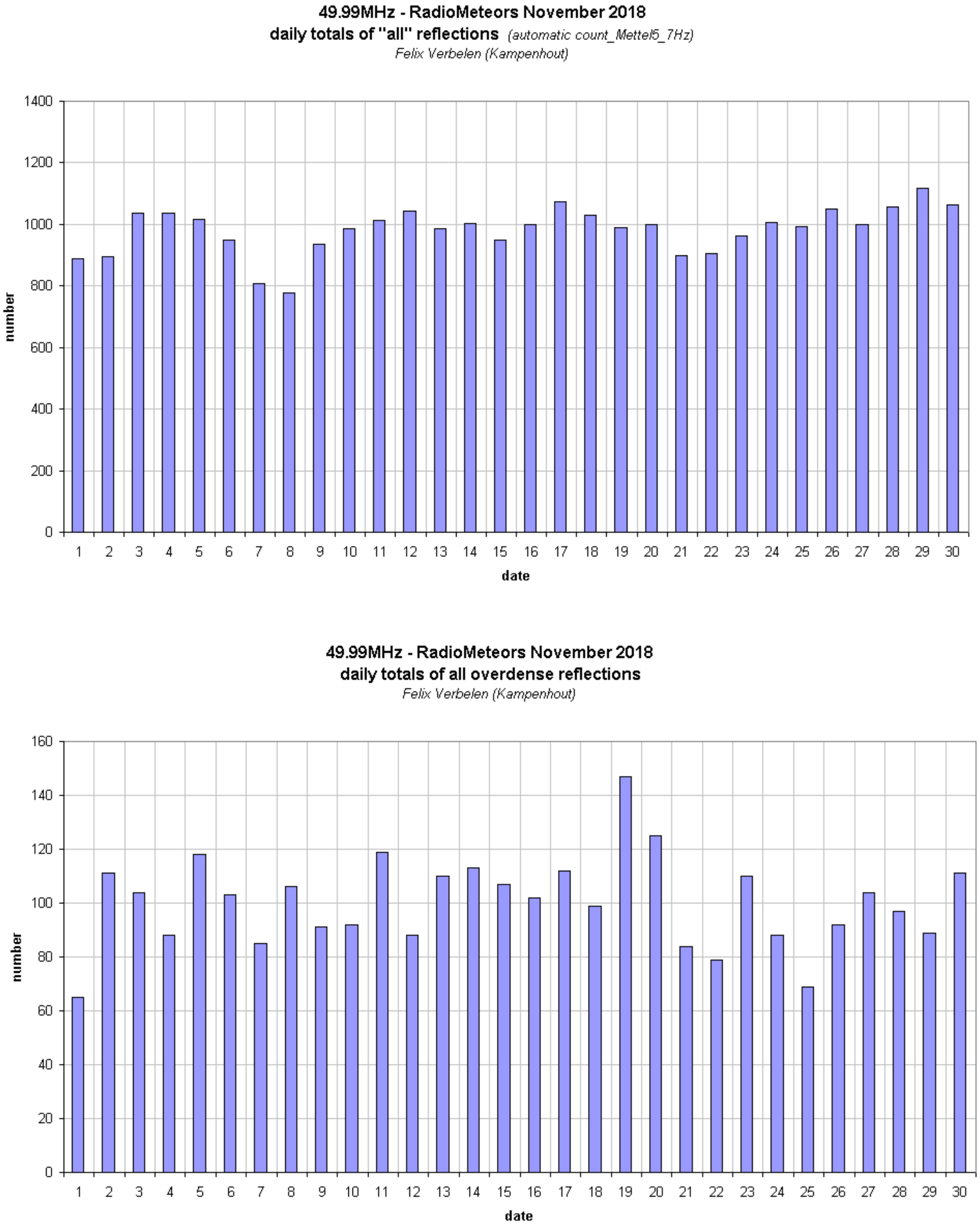


Figure 4 – The daily totals of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during November 2018.

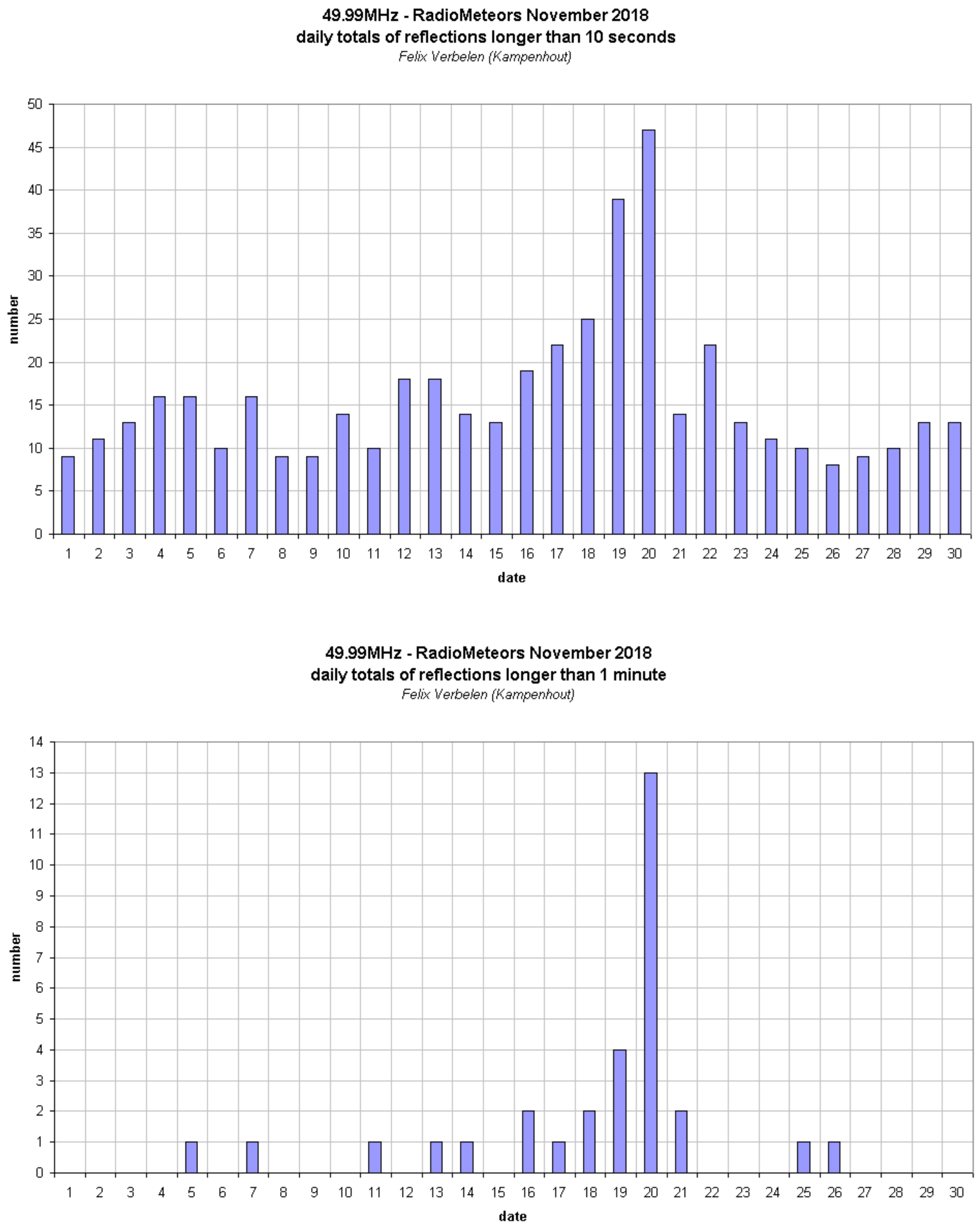


Figure 5 – The daily totals of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during November 2018.

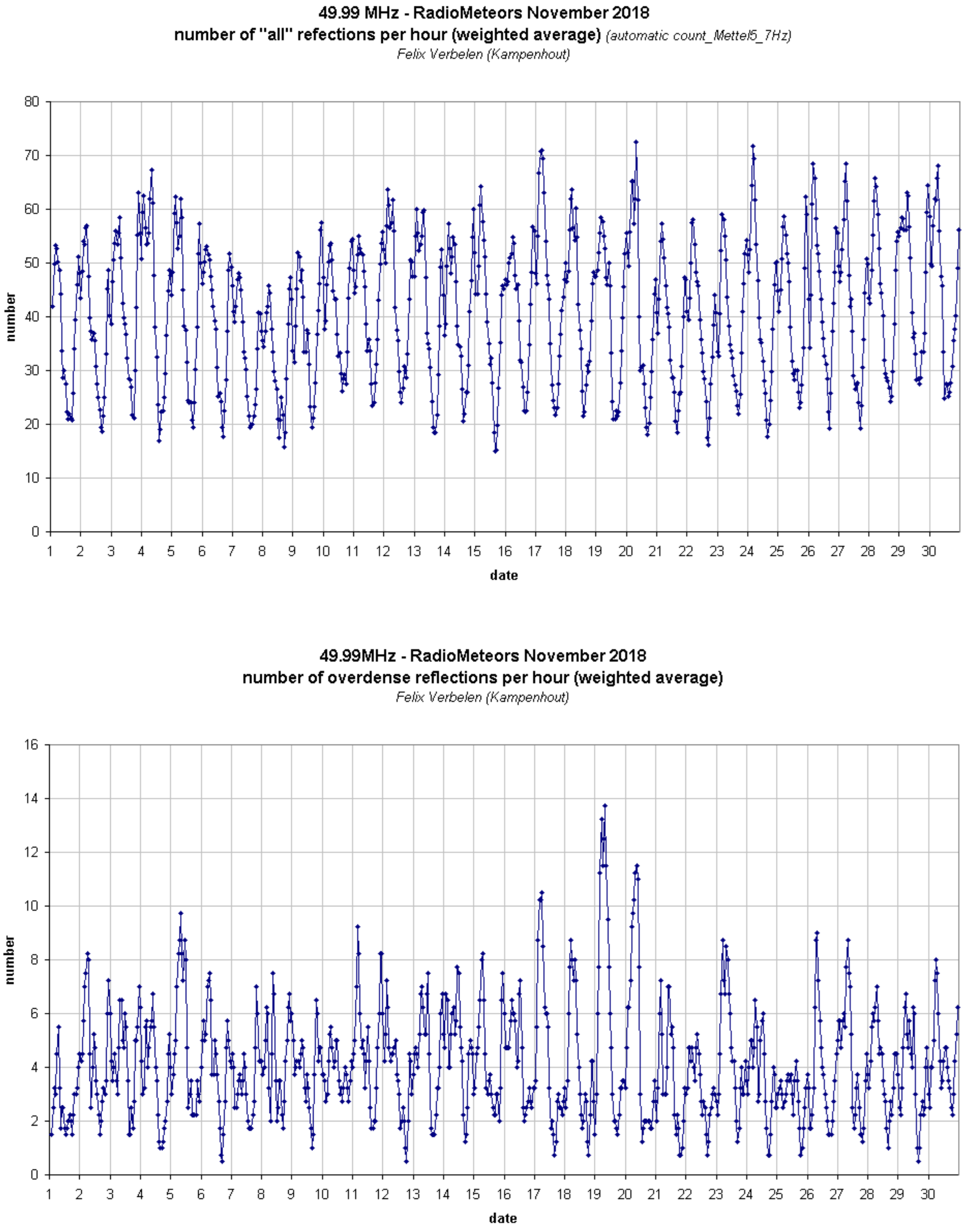
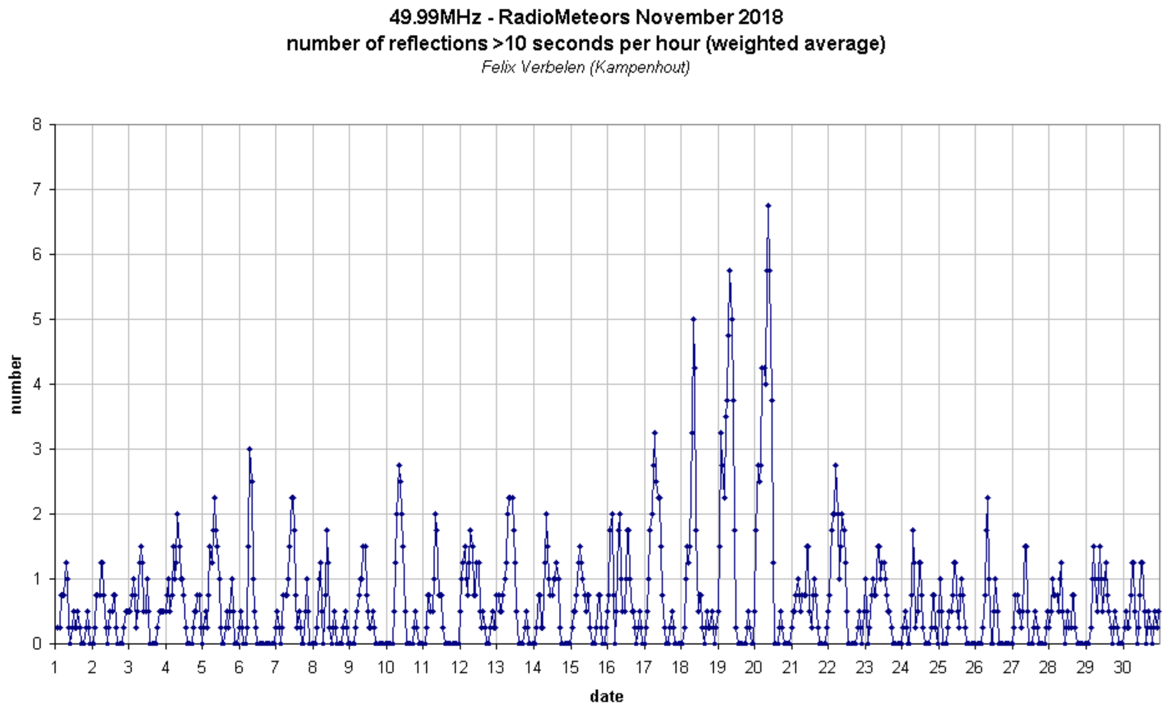


Figure 6 – The hourly numbers of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during November 2018.



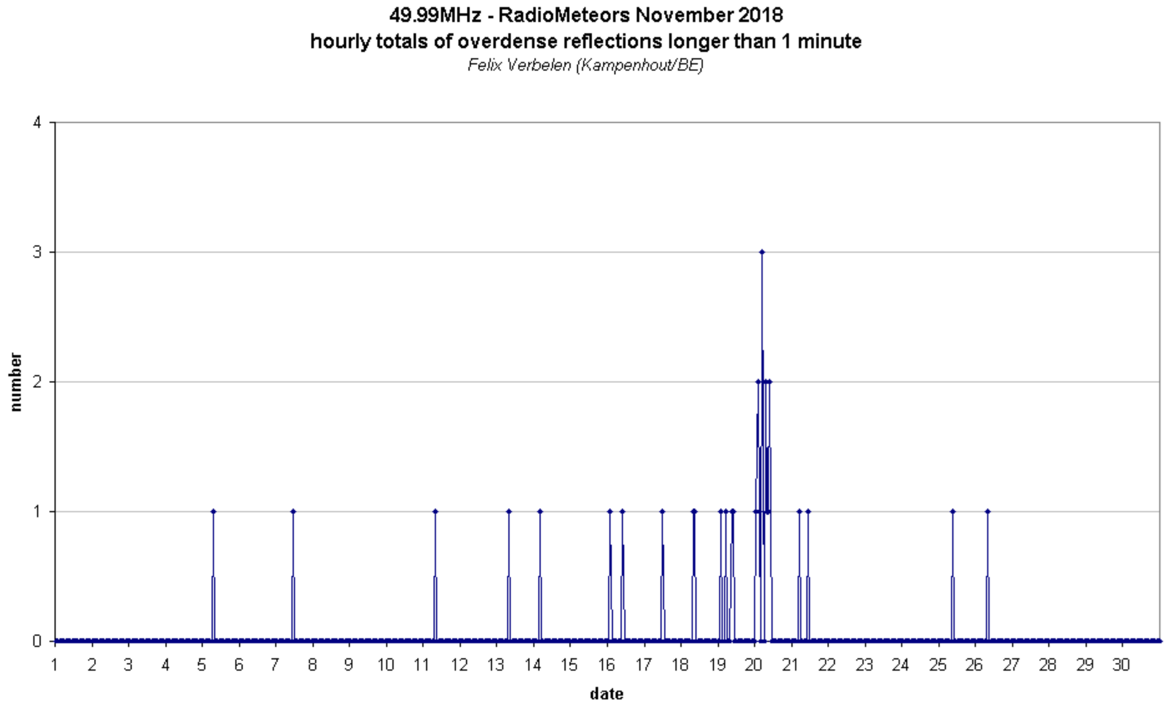


Figure 7 – The hourly numbers of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during November 2018.

Radio meteors – December 2018

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

During this month there were few local disturbances, no registered “sporadic E” (Es) nor was there lightning activity.

Highlights of the month were of course the Geminids. – see also *Figure 8* for the period 7-17 December 2018. The shower was very interesting, with as expected a large number of underdense and short overdense echoes, but with a rather unexpected outburst of longer overdenses on December 14/15th. *Figures 1, 2 and 3* are typical examples of both.

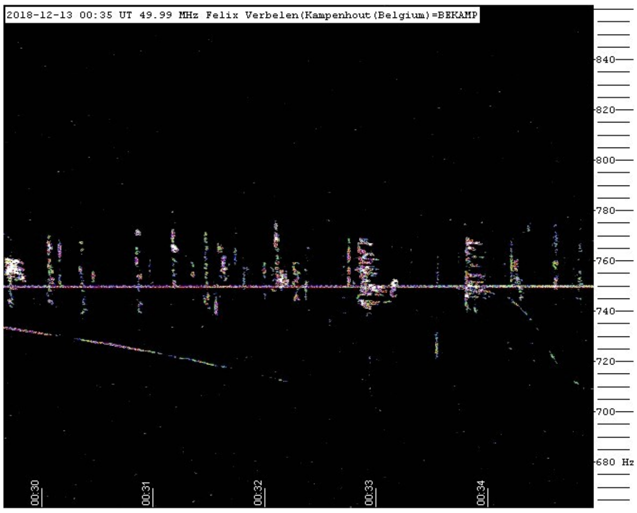


Figure 1 – Example of typical Geminid underdense and overdense echos, night of December 12-13 2018.

The Ursids were certainly interesting but much less numerous than e.g. in 2017, with as usually an fair number of overdense echoes which is mainly reflected in the daily totals.

Also, the beginning of the month was rich in reflections, both underdense and overdense, but these will have to be investigated further along with the rest of the month.

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

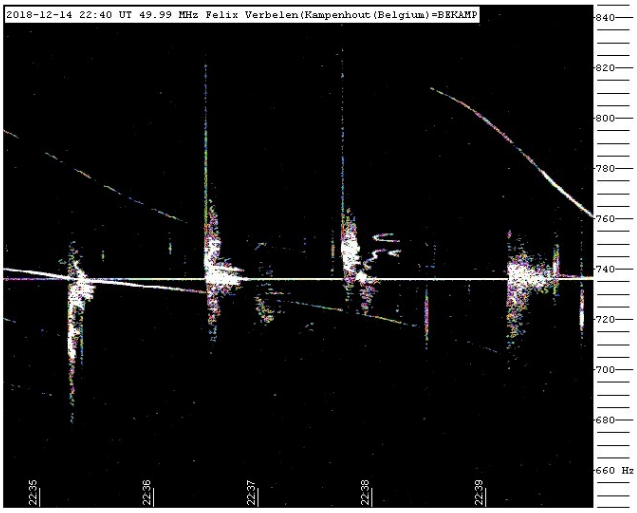


Figure 2 – Example of the outburst of overdense echos from the Geminids in the night of December 14-15, 2018.

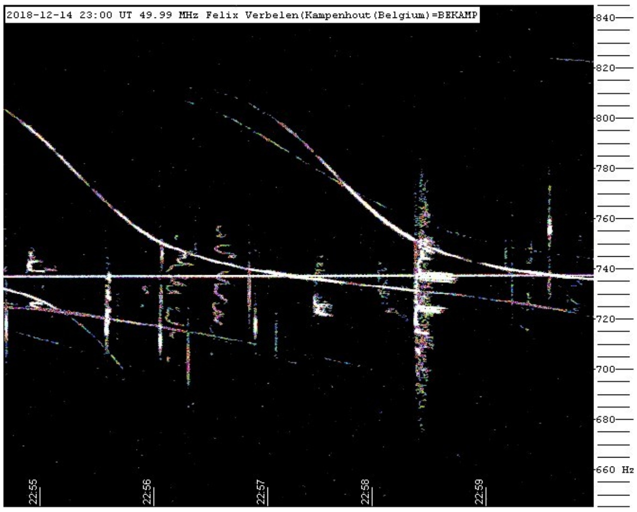
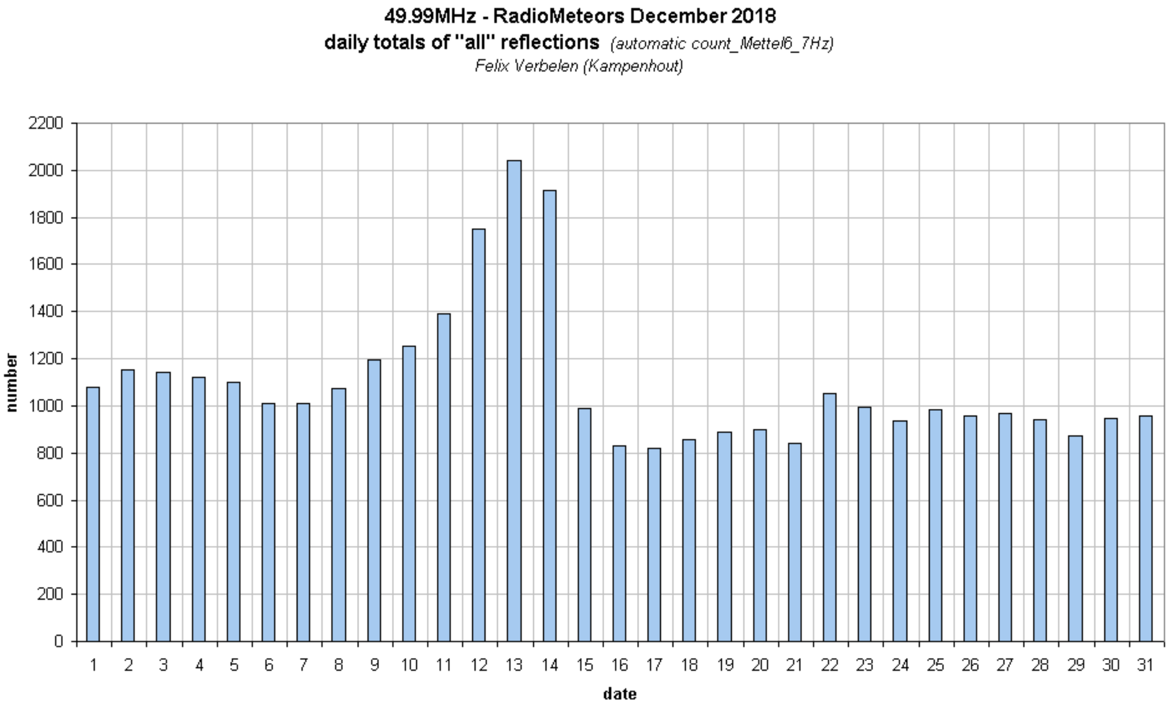


Figure 3 – Example of the outburst of overdense echos from the Geminids in the night of December 14-15, 2018.



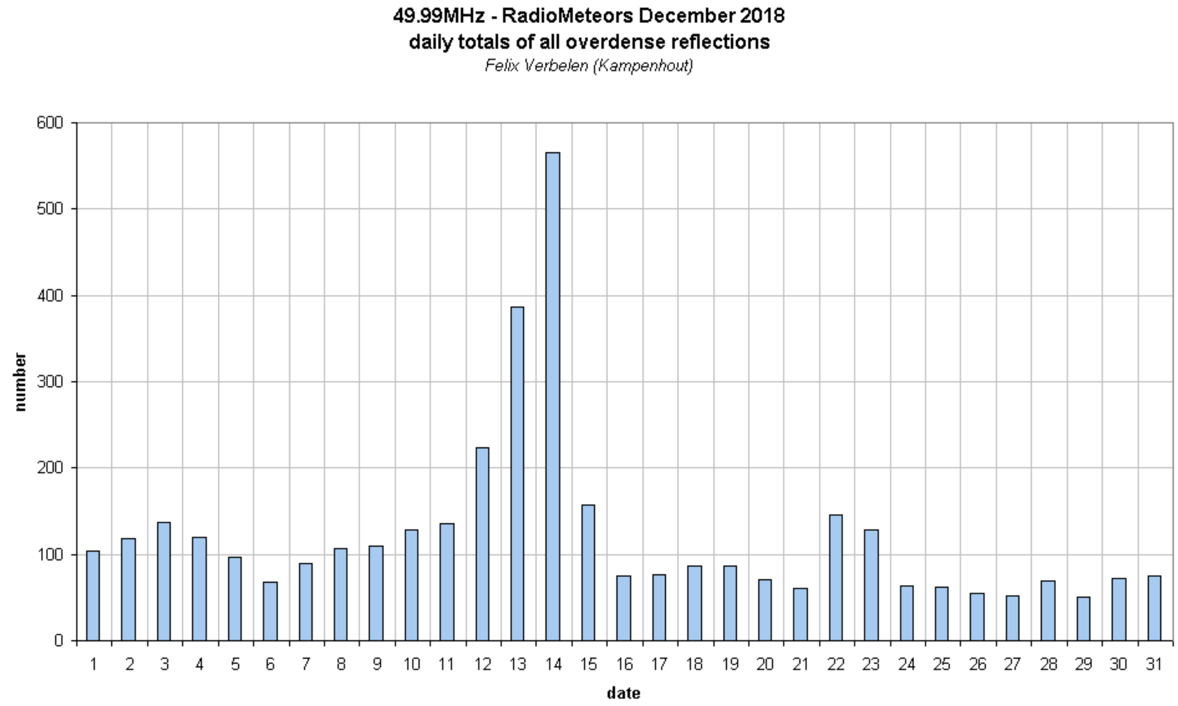


Figure 4 – The daily totals of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during December 2018.

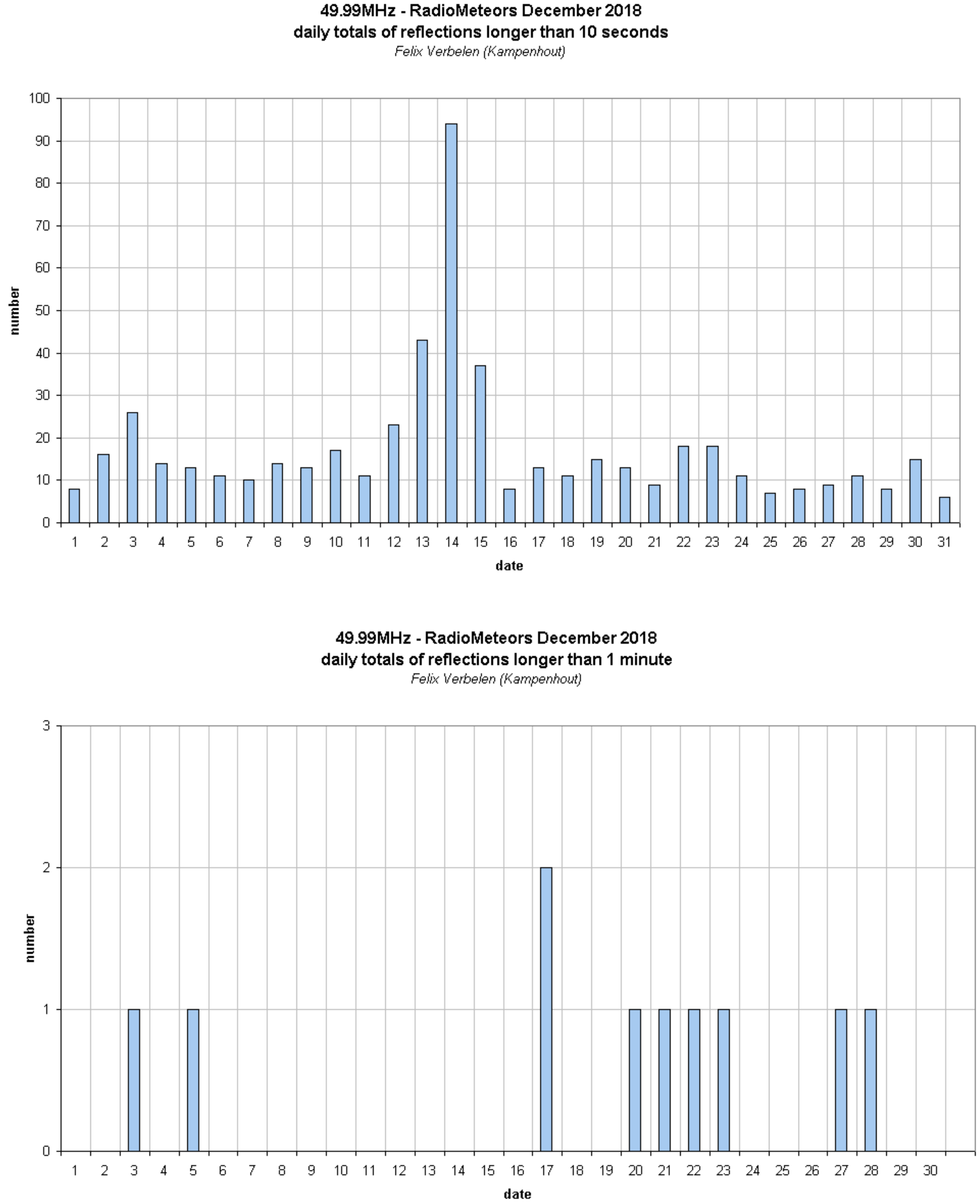


Figure 5 – The daily totals of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during December 2018.

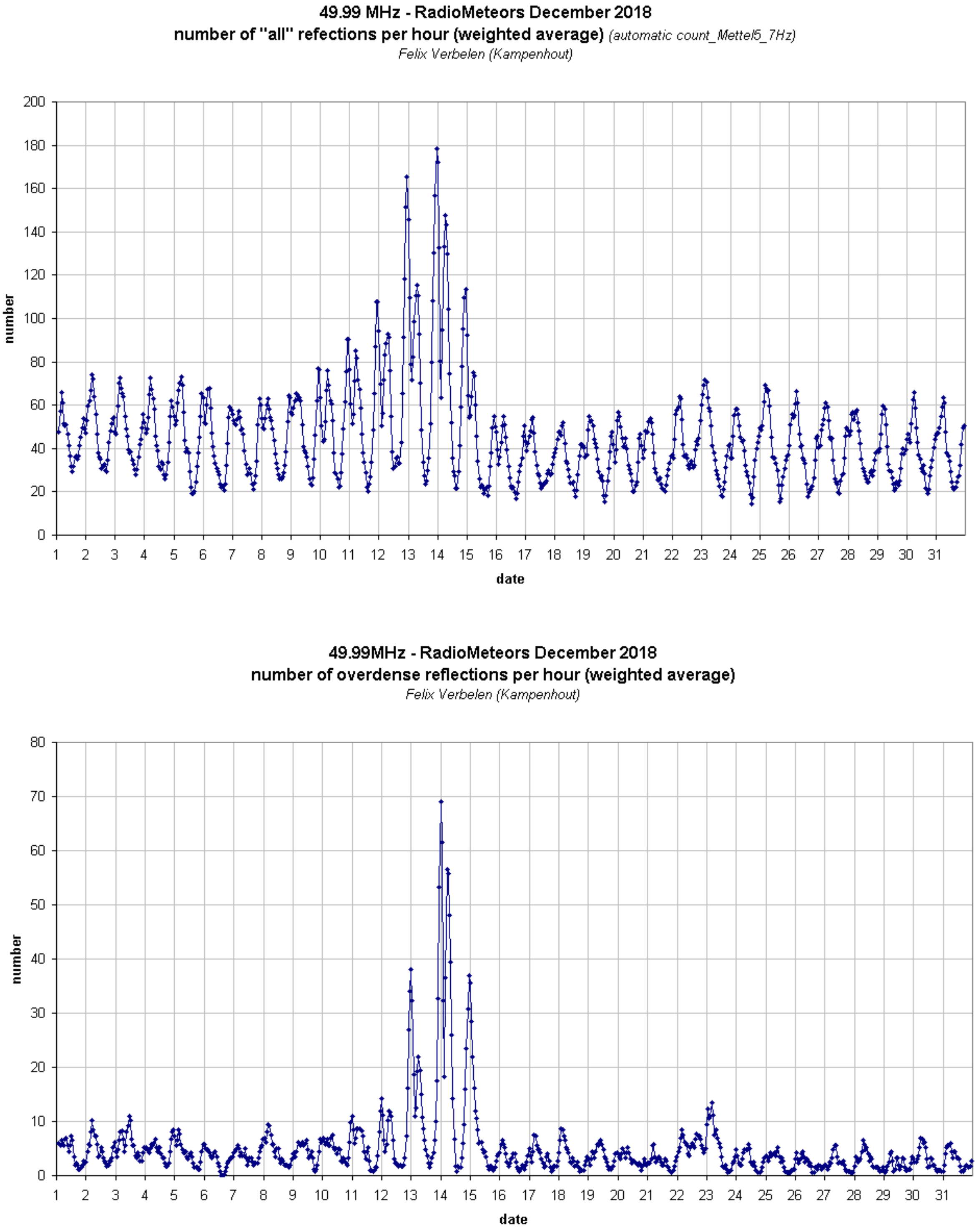
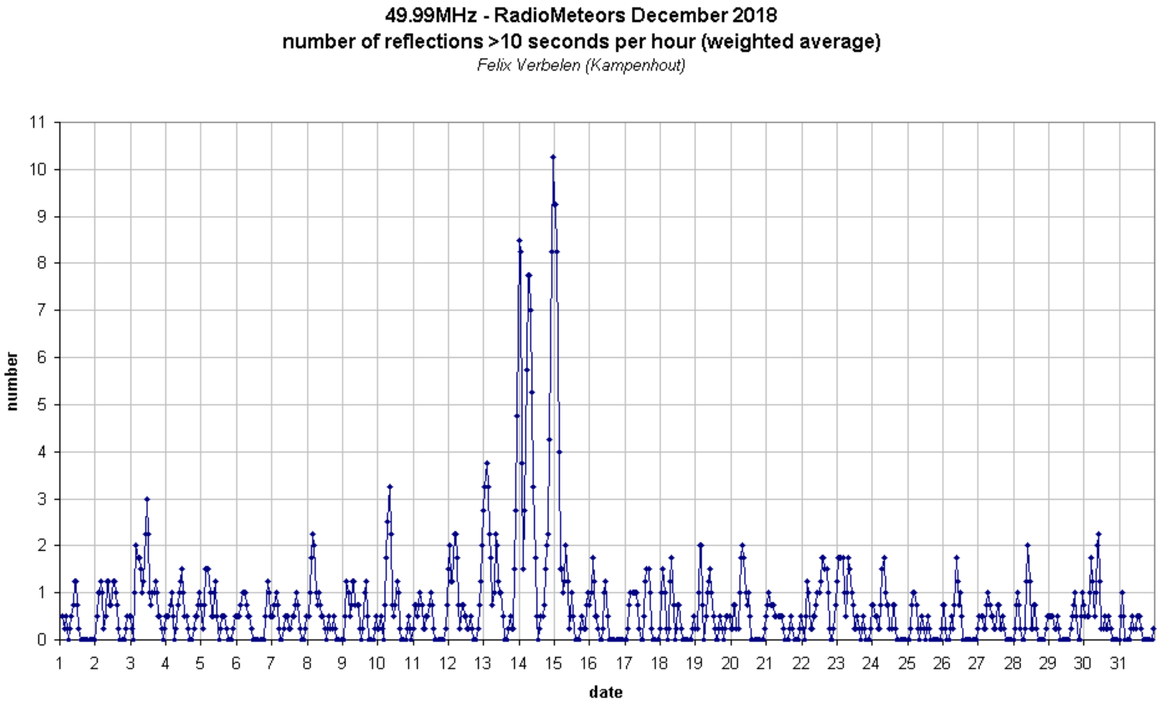


Figure 6 – The hourly numbers of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during December 2018.



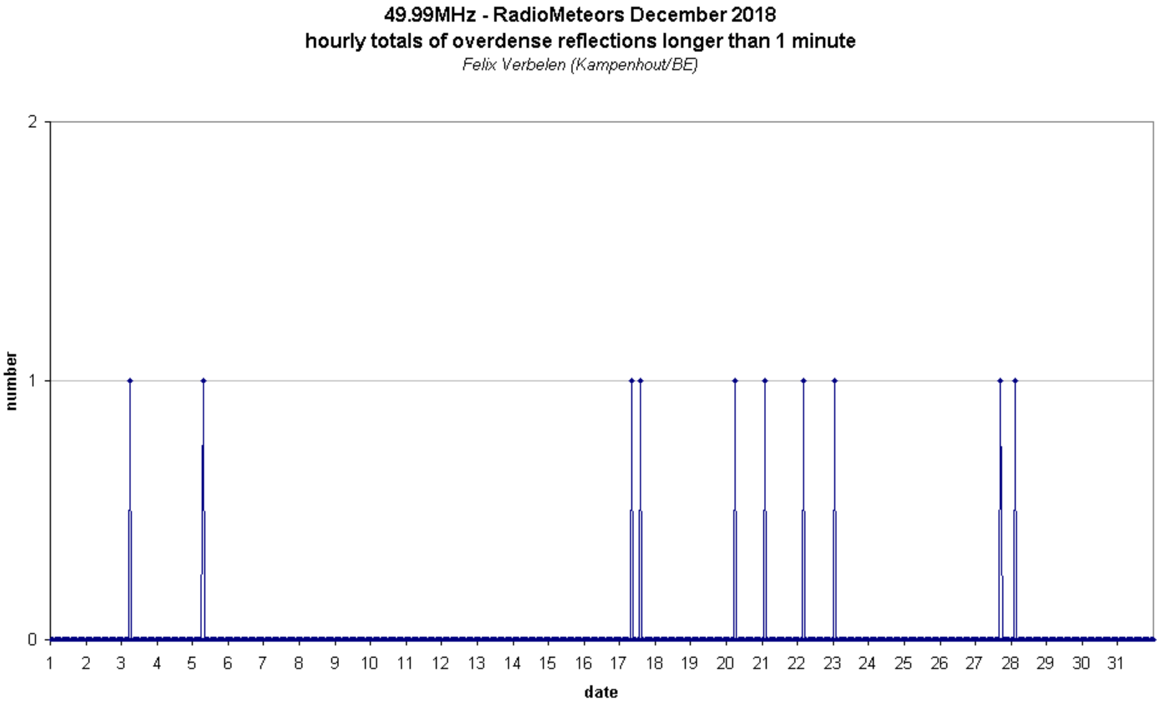
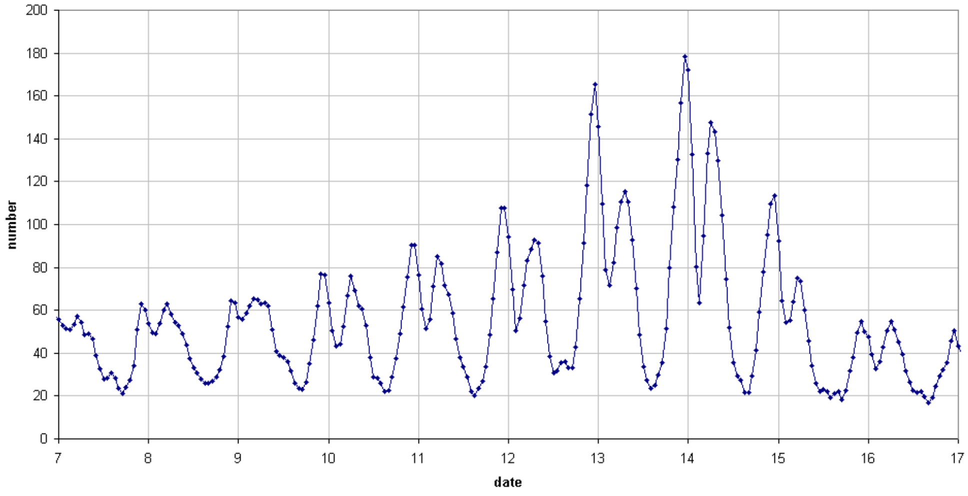
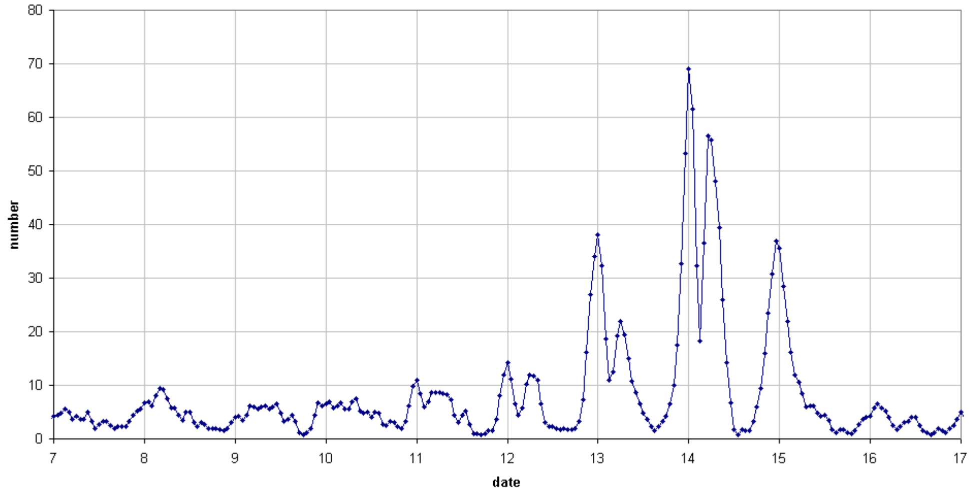


Figure 7 – The hourly numbers of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during December 2018.

49.99 MHz - GEMINIDS December 2018
number of "all" refections per hour (weighted average) (automatic count_Mettel6_7Hz)
Felix Verbelen (Kampenhout)



49.99MHz - GEMINIDS December 2018
number of overdense reflections per hour (weighted average)
Felix Verbelen (Kampenhout)



49.99MHz - GEMINIDS December 2018
number of reflections >10 seconds per hour (weighted average)
Felix Verbelen (Kampenhout)

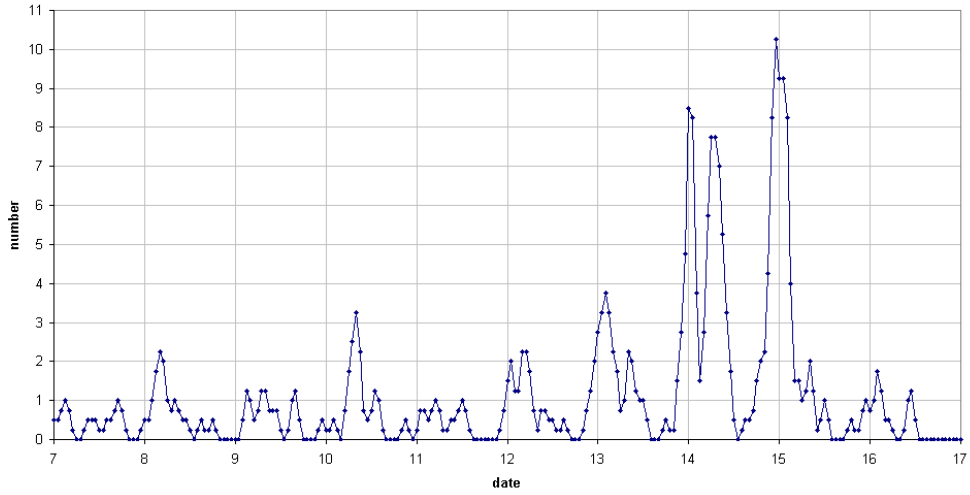


Figure 8 – The Geminids 2018 activity.

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