All sky camera image between 20h08m40s – 20h09m40s UT at Wilderen, Belgium by Jean-Marie Biets

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October Ursae Majorids (OCU#333)

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The October Ursae Majorids caught attention with a significant number of orbits in the period 2006-2017. This study could identify 442 October Ursae Majorid orbits. The shower displays a compact radiant at R.A. 145° and dec. +64° and a velocity of 55.2 km/s. The velocity displays a significant dispersion with the faster particles at higher inclination and the slower particles at lower inclination. The shower activity displays a skew activity profile between solar longitude 201° and 206° with a sharp maximum at 202.05° ± 0.10°. The shower appears to be rich in bright meteors, including fireball events. The shower displays an annual activity without any indication for periodic outbursts.

1   Introduction

The nights 14–15 and 15–16 October 2018 had clear sky for the BeNeLux and apart from many Orionid and Taurid orbits, another less known shower caught attention, the October Ursae Majorids, listed as an established shower in the IAU Meteor Data Center, identified as OCU#333.
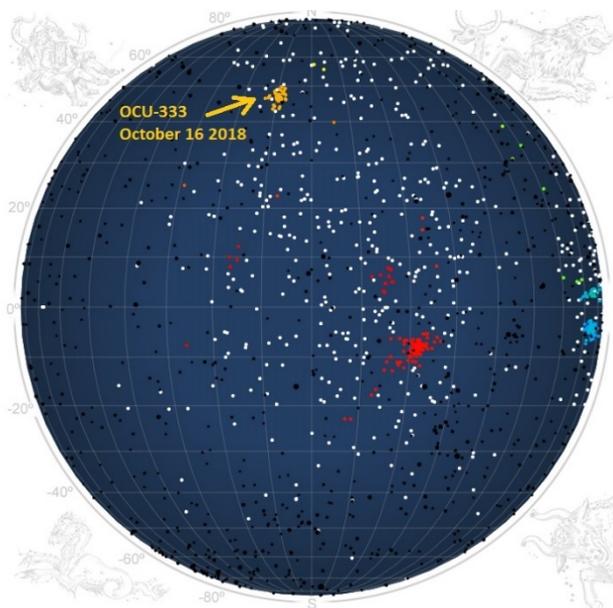

Figure 1 – Screenshot of the CAMS radiant plot for the night of 2018 October 16 with the compact radiants identified as October Ursae Majorids (OCU#333). The radiants of the Orionids (red near the center) and Taurids (blue at the edge at right) are more scattered.

Carl Johannink identified 83 orbits of the CAMS BeNeLux network in 2018 as October Ursae Majorids, slightly more than in 2017 when 73 orbits were identified as October Ursae Majorids. In total CAMS BeNeLux collected 211 October Ursae Majorids' orbits, the orbits derived from these are listed in *Table 5*. These are rather impressive

numbers of orbits and therefore the authors decided to dedicate a case study to this shower.

2   History of the October Ursae Majorids

The Japanese meteor observer, Satoshi Uehara, noticed the October Ursae Majorids on October 16, 2006 as some meteors radiated from a compact area at R.A. 144° and Dec. +64° (Uehara et al., 2006). SonotaCo (2009) continued investigations and found a few extra orbits. Their results are listed in *Table 5*.

Looking for older recorded orbits that might match the October Ursae Majorid orbits, we found 3 look alike orbits in the Photographic meteor orbit catalogue. Only one orbit fulfills our similarity test, an orbit recorded in the night 13–14 October 1958 with identification 022K1 (Dem'yanenko et al., 1964). This orbit is also listed in a list of meteor showers collected and documented by Dr. A.Terentjeva, published in 1966 where this shower was already recognized and listed as shower number 135, the σ-Ursa Majorids (σ-Урса-Майориды) (Terentjeva, 1966, 2017), which means Dr. Alexandra Terentjeva was the first to identify this shower. The Harvard radar meteor orbit catalogues 1961-1965 (Verniani, 1973; Sekanina, 1973) has no similar orbits and only two possible OCU orbits were found, both recorded in 1969 (Verniani, 1973; Sekanina, 1976).

CMOR data covering 2001–2008 (Brown et al., 2010) detected orbits of this shower during only 3 days. The shower appears in the meteor stream searches of CAMS, listed among the long periodic comet meteor streams (Jenniskens et al., 2016). Eight out of nine October Ursae Majorids were recorded in the night of October 15, 2012, while the shower was almost absent in 2011 under good observing circumstances. Therefore, the shower was assumed to be in outburst in 2012 and thus not an annual shower.

3 The methodology and 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 – October 2018 are not included in this dataset because this data is still under embargo.

In total 686073 video meteor orbits are publicly available, most of which can be excluded from any association with October Ursae Majorids by their position. Our methodology to detect associated orbits has been slightly modified compared to previous case studies. The current method works as follows.

The first step is to assess the outer limits in time, radiant position and velocity range within which orbits of this stream may be found. To establish these outer limits, we take one of the suspect orbits and check the similarity criteria on all 686073 orbits. This results in a set of orbits which serves only to find the outer limits in time, radiant position and velocity range within which similar orbits can be found. From this first preliminary selection it appears that any possible October Ursae Majorids should have their orbit, radiant position and velocity, within the following limits:

- Time interval: $189° < \lambda_\odot < 214°$;
- Radiant area: $123° < \alpha < 169°$ & $+56° < \delta < +72°$;
- Velocity: 49 km/s $< v_g <$ 61 km/s.

Then we select all orbits available within this time interval, regardless their radiant position or velocity. In total 65478 orbits were available in the considered time interval. This dataset will serve as source for the background activity. From this dataset we select all orbits with a radiant position and geocentric velocity within the range established above. Any possible October Ursae Majorids orbits will be among this selection. In this case 918 orbits had the radiant and velocity within the interval mentioned above. For any single station observer, either visual or video, all 918 orbits displayed meteors that appeared like perfect October Ursae Majorids, from the right radiant area with the right angular velocity.

Since we have the orbital elements we will verify if the orbits can be identified as October Ursae Majorids. We use the so-called similarity or discrimination criteria to accept or to reject the identification of an orbit as October Ursae Majorids. The similarity criteria consider the distance between some of the orbital elements combined with the angle between the orbital planes. The first numeric discrimination criterion was proposed by Southworth and Hawkins (1963), referred to as D_{SH}. Later Drummond (1981) introduced a slightly different criterion, referred as D_D. Jopek (1993) proposed another version D_H, based on the former criteria. We can apply all three criteria combined:

First, we determine Γ

$$\Gamma = \begin{cases} +1, & |\Omega_p - \Omega_m| \le 180º \\ -1, & |\Omega_p - \Omega_m| > 180º \end{cases}$$

Then we calculate ψ, the angle between the two orbital planes from

$$\psi = \arccos[\cos i_p \cos i_m + \sin i_p \sin i_m \cos(\Omega_p - \Omega_m)]$$

Next, we calculate Π, the angle between the perihelion points:

$$\Pi = \omega_p - \omega_m$$

$$+2\Gamma \arcsin\left(\cos\frac{i_p + i_m}{2} \sin\frac{\Omega_p - \Omega_m}{2} \sec\frac{\psi}{2}\right)$$

λ is the ecliptic longitude of the perihelion, with

$$\lambda = \Omega + \arctan(\cos i \tan \omega),$$

β is the ecliptic latitude of the perihelion, with

$$\beta = \arcsin(\sin i \sin \omega),$$

where λ has $180°$ added if $\cos \omega < 0$.

The angle θ between the two perihelion points on each orbit is given by the equation:

$$\theta = \arcos[\sin \beta_p \sin \beta_m + \cos \beta_p \cos \beta_m \cos(\lambda_p - \lambda_m)]$$

The three different discriminant criteria can now be calculated from the following equations, with D_{SH} for the Southworth Hawkins criterion, D_D for the Drummond criterion and D_H for the Jopek criterion:

$$D_{SH}^2 = (q_p - q_m)^2 + (e_p - e_m)^2 + \left(2\sin\frac{\psi}{2}\right)^2 + \left(\frac{e_p + e_m}{2} \cdot 2\sin\frac{\Pi}{2}\right)^2,$$

$$D_D^2 = \left(\frac{e_p - e_m}{e_p + e_m}\right)^2 + \left(\frac{q_p - q_m}{q_p + q_m}\right)^2 + \left(\frac{\psi}{180°}\right)^2 + \left(\frac{e_p + e_m}{2}\right)^2 \cdot \left(\frac{\theta}{180°}\right)^2,$$

$$D_H^2 = (e_p - e_m)^2 + \left(\frac{q_p - q_m}{q_p + q_m}\right)^2 + \left(2\sin\frac{\psi}{2}\right)^2 + \left(\frac{e_p + e_m}{2}\right)^2 \cdot \left(2\sin\frac{\Pi}{2}\right)^2.$$

The larger the values of ψ, Π or θ, the bigger the 'distances' between the orbits and the less the probability becomes for an association. Related orbits have values in the order of a few degrees. The final values for these similarity criteria are dimensionless numeric values, where 0 represents identical orbits. The smaller the D-values the higher the degree of similarity and the better the probability becomes for an association. The D criteria cannot be applied without caution. It remains a way to find similarity between different orbits, without providing any prove for some physical relationship between the orbits. It is an approach in the sense of best effort, while it must be applied with caution in certain circumstances.

The D-criteria that we use are these of Southworth and Hawkins (1963), Drummond (1981) and Jopek (1993) combined. We define five different classes with specific threshold levels of similarity:

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

These classes should allow to compare shower characteristics in function of the reliability of the shower identification. While the low threshold similarity class may include some sporadic orbits that fit the criteria by pure chance, the higher the threshold the less the risk for contamination with sporadic orbits.

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

|	CAMS	SonotaCo	Edmond	All	Literature
λ_O	203.2°	202.6°	202.4°	202.5°	202.0°
α_g	146.0°	145.2°	145.1°	145.3°	145.0°
δ_g	+64.3°	+64.1°	+64.0°	+64.1°	+64.8°
v_g	55.5	55.6	54.9	55.2	55.6
a	11.9	11.0	7.8	8.8	12.63
q	0.979	0.980	0.978	0.979	0.982
e	0.917	0.911	0.874	0.889	0.967
ω	164.6°	165.0°	163.8°	164.3°	165.9°
Ω	203.2°	202.6°	202.4°	202.5°	202.2°
i	100.8°	101.0°	100.6°	100.8°	100.6°
N	35	160	247	442	9

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. This way a reference orbit for the October Ursae Majorids was derived from the selection of 918 orbits. Then this reference orbit was used to recalculate all similarity criteria and new median values were calculated for the orbits that fulfilled

these criteria. This procedure was repeated 4 times until the iterations only influenced the insignificant decimals.

A few sub datasets were generated based on the final 442 probable October Ursae Majorids orbits 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 2 – The median values for the final selection of orbits with five different threshold levels on the D-criteria.

	Low	Medium low	Medium high	High	Very high
λ_O	202.5°	202.6°	202.5°	202.4°	202.2°
α_g	145.3°	145.4°	144.5°	145.4°	144.6°
δ_g	+64.1°	+64.1°	+64.2°	+64.2°	+64.2°
v_g	55.2	55.2	55.2	55.2	55.1
a	8.8	9.8	11.0	11.0	10.0
q	0.979	0.979	0.979	0.979	0.979
e	0.889	0.900	0.912	0.911	0.903
ω	164.3°	164.3°	164.2°	164.3°	164.2°
Ω	202.5°	202.6°	202.5°	202.3°	202.2°
i	100.8°	100.8°	100.6°	100.8°	100.4°
N	442	331	237	141	43
$\%$	*48%*	*36%*	*26%*	*15%*	*5%*
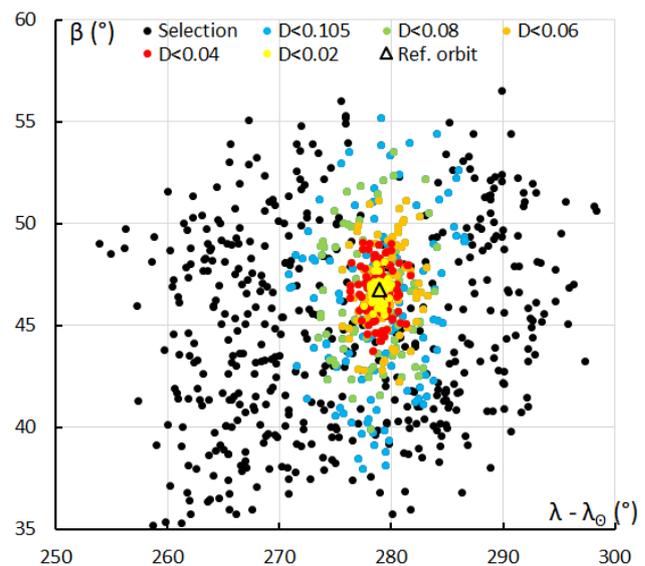
Figure 2 – Plot of the ecliptic latitude β against the Sun centered longitude $\lambda - \lambda_O$. The different colors represent the 5 different levels of similarity.

Plotting the ecliptic latitude β against the Sun centered longitude $\lambda - \lambda_O$ neutralizes the radiant drift due to the movement of the Earth around the Sun. The presence of a concentration of radiants with similar orbits is very clear in

Figure 2. The low threshold similarity orbits marked in blue display still a reasonable spread, but most of the October Ursae Majorids (OCU#333) orbits form a rather compact radiant.
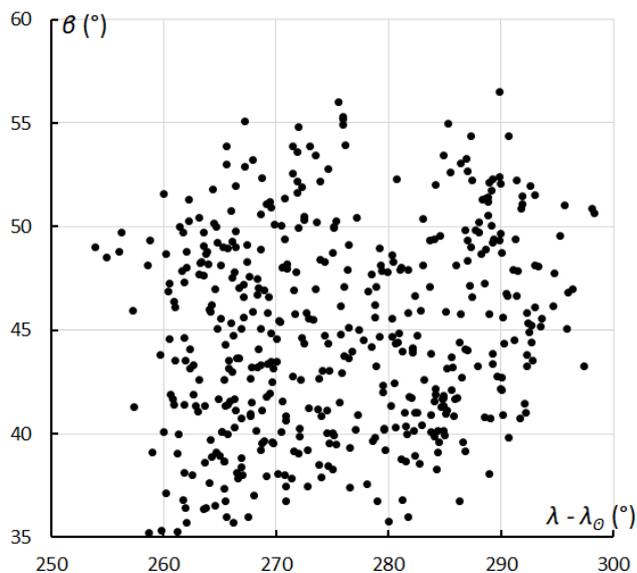

Figure 3 – Plot of the ecliptic latitude β against the Sun centered longitude λ – λ⊙ for the 476- orbits from the selection that failed in the similarity criteria.

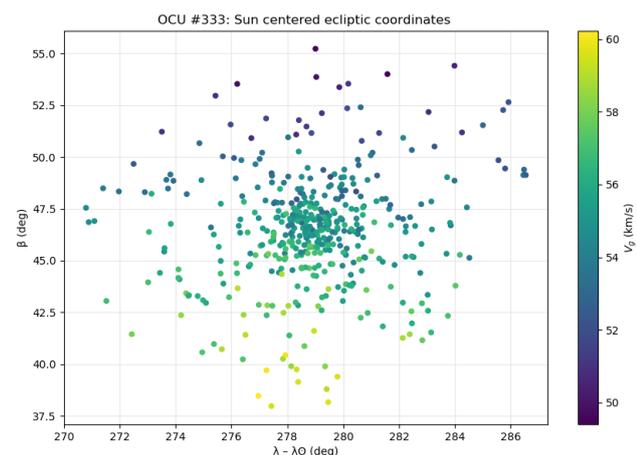*Figure 4* – Plot of the ecliptic latitude β against the Sun centered longitude λ – λ⊙ (°) for the 442 OCU orbits that fulfill the low threshold similarity criteria with a color gradient to display the variation in the velocity v_g.

If we remove all the radiants that were identified as October Ursae Majorids (OCU#333) based on their orbit, as many as 476 radiants remain for which the orbits fail in the similarity criteria (*Figure 3*). For any single station observer, either visual or video, all these meteors would be identified as October Ursae Majorids (OCU#333) because they appear from the radiant area with the right velocity. This means that single station data would have more than half of its shower meteors identified as OCU-333, while the orbits should be considered as sporadics. Of course, a contamination of the sample with 52% erroneously identified October Ursae Majorids makes statistics with such single station sample meaningless. To make the situation worse, single station data will have even more sporadic contamination due to meteors that line up with the assumed radiant position by pure chance as seen from a

given site, while its true radiant is somewhere else on its backwards produced path at the sky. Therefore, it makes no sense to do visual counts for low activity minor showers, or even major showers when the activity is still under a certain minimal level of statistical relevance. For visual observers plotting errors or estimation errors will make the situation even worse so that shower identification becomes more like gambling.
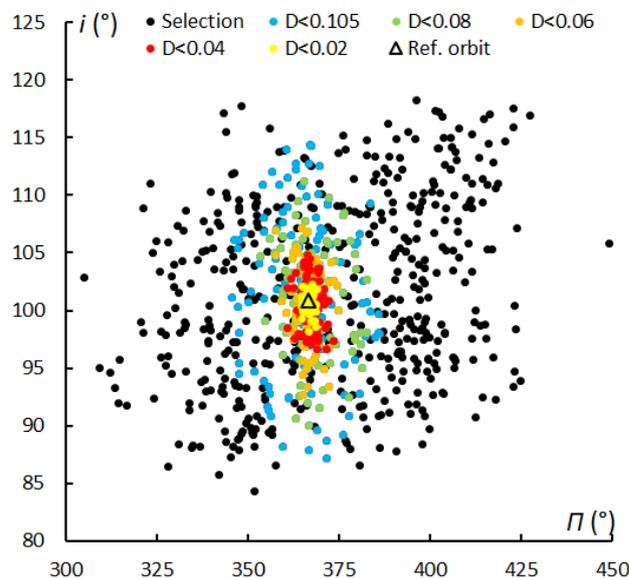

Figure 5 – The plot of inclination i (°) against the length of perihelion Π (°) for the 918-selected possible OCU-orbits. The colors mark the different threshold levels of the D-criteria relative to the final reference orbit listed in Table 2.
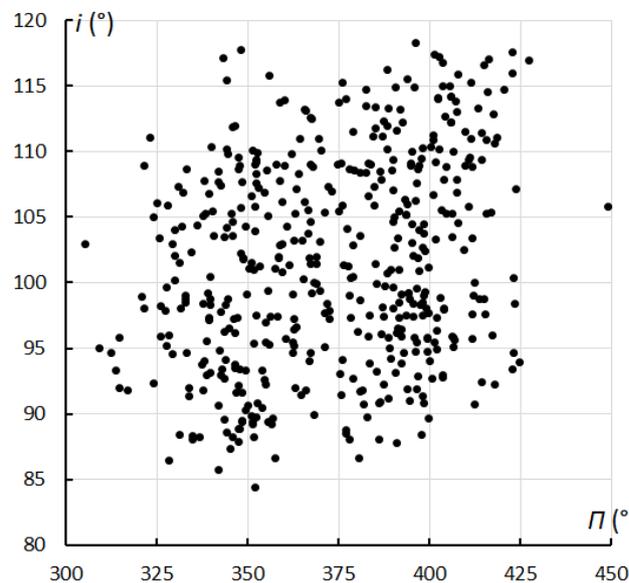

Figure 6 – The plot of inclination i (°) against the length of perihelion Π (°) for the 476 orbits from the selection that failed in the similarity criteria.

If we remove all sporadic orbits and take a close-up of the October Ursae Majorids with a color gradient to illustrate the spread in the geocentric velocity we see a remarkable distribution of the velocity. The slow velocity radiants appear at higher ecliptic latitude (top of *Figure 4*) with a gradual decrease in velocity over the core of the meteor stream towards the highest velocity at lower ecliptic latitude (bottom of *Figure 4*). This shows the orientation of the

dispersion of the particles in the stream. The presence of a concentration of similar orbits is also very well visible in the plot of the inclination i against the length of perihelion Π (*Figure 5*). The selection of 918 orbits, although each of these orbits produced a meteor that looked like October Ursae Majorids, includes a significant number of sporadic orbits, marked as black dots. Removing the shower orbits, we see the sporadic background radiant distribution in *Figure 6* hidden in *Figure 5*.
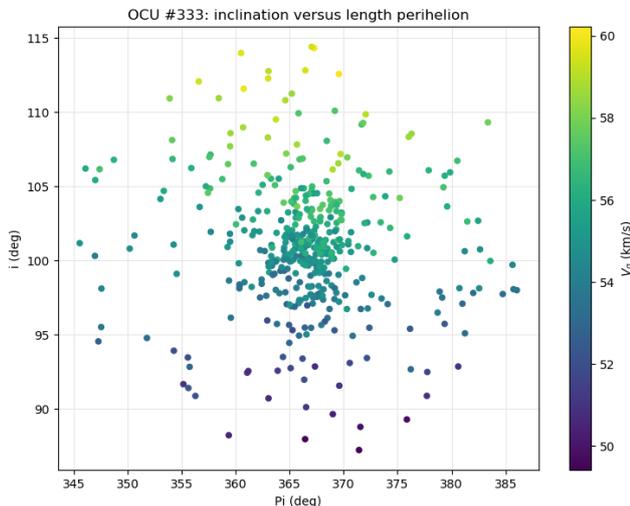

Figure 7 – Close-up on the plot of inclination i (°) against the length of perihelion Π (°) for the 442 OCU orbits that fulfill the low threshold similarity criteria with a color gradient to display the variation in the velocity v_g.
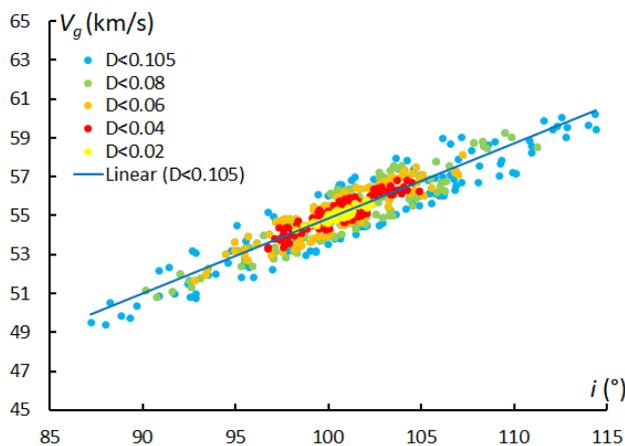

Figure 8 – Plot of the geocentric velocity v_g against the inclination i (°).

The dispersion of the velocity found in the Sun centered ecliptic coordinate plot also appears in the plot of the inclination i against the length of perihelion Π (*Figure 7*). When we plot the geocentric velocity v_g versus inclination i for all 442 OCU orbits the geocentric velocity v_g increases with 0.39 km/s per degree in inclination (*Figure 8*). The slower, lower energy particles, got at lower inclination, the faster, accelerated particles, got at higher inclinations. If we look at possible changes in inclination and in geocentric velocity in function of time (solar longitude $\lambda_\odot$), both the inclination i and the velocity v_g remain almost constant throughout the passage of the Earth through the stream. This means that Earth encounters the velocity dispersed particles

all along its passage through the October Ursae Majorid stream.

4 Radiant drift

The radiant of any shower moves eastwards in the sky due to the Earth moving on its orbit around the Sun. By pinpointing the radiant night by night, we can track this radiant drift. In equatorial coordinates the radiant drift in R.A. and declination may differ quite a bit depending upon the source of the data. Therefore, we list the radiant as derived from the different datasets according to the class of the similarity criteria threshold.

Table 3 – Radiant drift with $\pm$ σ for the October Ursae Majorids obtained from the orbits for each threshold level of the D-criteria compared with a reference from literature.

Threshold/source	OCU – 333	
	$\Delta\alpha$ / $\lambda_\odot$	$\Delta\delta$ / $\lambda_\odot$
Low	1.40 ± 0.06	−0.25 ± 0.03
Medium low	1.57 ± 0.08	−0.35 ± 0.04
Medium high	1.96 ± 0.11	−0.38 ± 0.06
High	1.68 ± 0.14	−0.40 ± 0.08
Very high	1.72 ± 0.23	−0.31 ± 0.12
Jenniskens et al. (2016)	1.39	−0.33

5 The activity profile and maximum

The orbit sample has been collected over 11 years from 2007 until 2017. To estimate the relative activity of the October Ursae Majorids relative to the background activity, we had a problem with the variable Orionid activity in the sample. Therefore, all Orionid orbits were removed. The background activity in each time bin includes all orbits except the OCU orbits and Orionid orbits. The background meteor activity should be as much as possible free of variable sources of activity to avoid to measure the shower activity level relative to a composite of different variable sources of activity. A method such as for meteor echo counts should be avoided as it makes no sense to compare a variable shower activity with a complex variable background.

October Ursae Majorid orbits were collected in each year during the activity period of 189° < $\lambda_\odot$ < 214° with on average 0.9% of all orbits. Focusing on the time bin with the shower maximum 201.5° < $\lambda_\odot$ < 202.5°, the relative activity on average reaches 7.1% of the background activity (*Figure 9*). Taking a narrower time bin around the time of the maximum, 201.75° < $\lambda_\odot$ < 202.25°, the relative activity reaches 8.3%. The variation from year to year in maximum activity can be explained by the rather poor coverage of the time bin around the maximum in some years. The peak maximum was missed completely in 2008. From the total number of orbits available for the time bin with the maximum 201.75° < $\lambda_\odot$ < 202.25°, we can see that only the years 2011, 2012, 2014 and 2015 had good coverage. The assumption proposed by Dr. Jenniskens (2016) that the OCU aren't annual because CAMS collected most OCU

orbits in 2012 and nothing in 2011, cannot be confirmed since OCU orbits were collected in all years based on our dataset which includes Japanese and European networks' data. Checking the CAMS data in detail, the reason why CAMS did have no OCU orbits in 2011 was mainly because the maximum night was missed in 2011 while for some reason most of the CAMS OCU orbits that fulfill our similarity criteria, even those with a very good similarity were not identified as OCU orbits in the CAMS data. It seems that the shower was not taken into account at all in 2011.
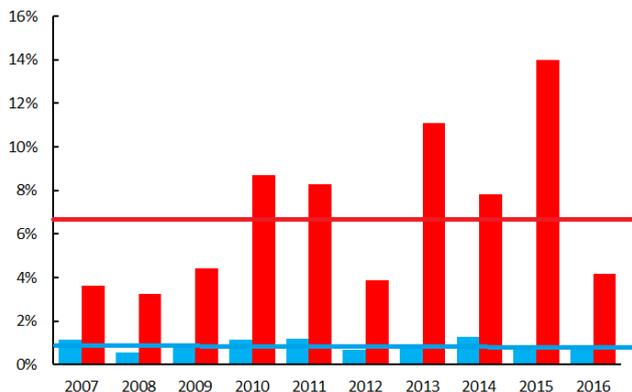

Figure 9 – The percentage of OCU orbits relative to the total number of non-OCU orbits obtained per year for different intervals of its activity period: Total activity period $189° < \lambda_\Theta < 214°$, blue and the bin with the maximum at $201.5° < \lambda_\Theta < 202.5°$ (red).

Unpublished CAMS BeNeLux results show a strong presence of OCU orbits in both 2017 and 2018 data. Unfortunately, the maximum and most of this shower activity was missed by the Japanese SonotaCo network due to bad weather in 2017. We wait for the release of 2017, 2018 EDMOND data and 2018 SonotaCo data to check if the OCU activity was higher than usual in 2017 and 2018.
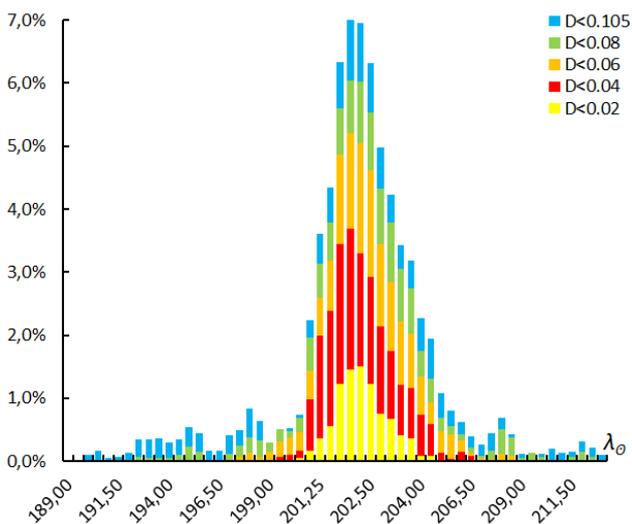

Figure 10 – The relative number of OCU orbits collected per 1° of solar longitude in steps of 0.5° during the years 2007–2017, with blue for $D_D < 0.105$, green for $D_D < 0.08$, orange for $D_D < 0.06$, red for $D_D < 0.04$ and yellow for $D_D < 0.02$, as percentage compared to the total number of non-OCU orbits without any Orionids, collected in the same time span.

The number of orbits available for each time bin depends on the weather circumstances, number of cameras running, the kind of optics used etc. All these factors are the same for the non-shower orbits as for the shower orbits. The number of shower orbits relative to the number of non-shower orbits as a percentage results in a fairly reliable activity profile. The number of shower orbits also depends on the elevation of the radiant above the local horizon. We do not attempt any correction for this. The composition of our sample of orbits is the result of a mixture of orbits collected at many different locations with the radiant at all possible elevations, this way we can consider the sample as representative for an average radiant elevation which remains approximately the same for all considered time bins.
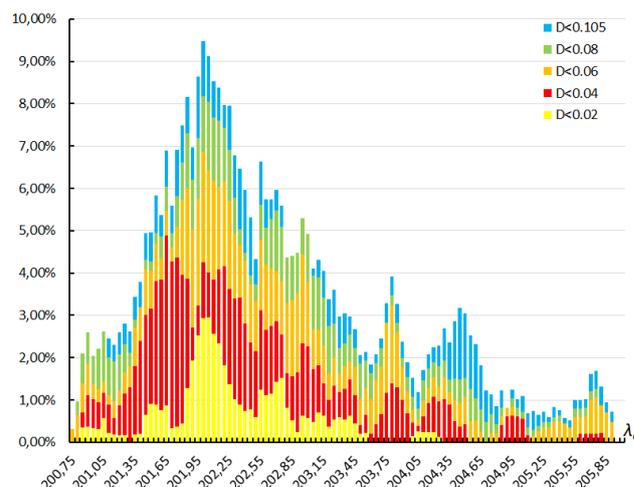

Figure 11 – The relative number of OCU orbits collected per 0.25° of solar longitude in steps of 0.05° based on the years 2007–2017, with blue for $D_D < 0.105$, green for $D_D < 0.08$, orange for $D_D < 0.06$, red for $D_D < 0.04$ and yellow for $D_D < 0.02$, as percentage of the number of non-OCU orbits collected in the same time span, with the Orionid orbits removed from the sample.

The activity is made up of mainly medium high and higher threshold level orbits. The low threshold orbits (blue) which represent outliers that may include sporadics that just fit the similarity criteria by pure chance, but these do not have much effect on the total activity level (*Figure 10*). The resulting activity profile shows a fast increase in activity from $\lambda_\Theta = 201.0°$ to the peak at $\lambda_\Theta = 202.0°$ with a slower decline until $\lambda_\Theta = 204.0°$, beyond the short period of 201.0° until 206.0° in solar longitude only very few OCU orbits have been collected. The skew shape or shoulder in the activity profile may hide some sub maxima caused by some layered structure of dust trails in the stream. Therefore, we look more in detail at the activity profile with a time bin of 0.25° moved forward in steps of 0.05° in solar longitude. The resulting activity profile in *Figure 11* shows some remarkable ups and downs with a dip at $\lambda_\Theta = 201.9°$ immediately before the maximum peak. The best rates are within the interval 201.95°– 202.15° and another dip occurs at $\lambda_\Theta = 202.45°$ followed by a kind of sub maximum around $\lambda_\Theta = 202.65°$. Future data may help to decide if the modest sub maxima at $\lambda_\Theta = 203.8°$ and $\lambda_\Theta = 204.3°$ are real or just spurious due to statistical scatter. The number of orbits

available requires some caution when considering details in the activity profile.

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 $\lambda_{\varnothing} = 202.05 \pm 0.1°$, while $\lambda_{\varnothing} = 202.5°$ is in fact the median value of the entire activity period which falls slightly after the peak of the activity due to the skewness of the activity profile.

6   Other shower characteristics

With a geocentric velocity of 52.2 km/s the October Ursae Majorids produce a luminous trajectory in the atmospheric layer between 115 and 95 km elevation. This is the same layer where the Perseids appear. Remarkable enough, although OCU meteors have a slightly lower velocity than the Perseids (59.1 km/s), the OCU meteors start a couple of kilometers higher in the atmosphere than Perseids. This could indicate a slightly different composition with more volatile fresh cometary material. The high layer in which the OCU meteors appear is favorable for video camera networks as these have their best overlap at this level.

Table 4 – Beginning and ending heights with ± σ for the October Ursae Majorid obtained for the trajectories from this study (1) and from CAMS BeNeLux (2) for each threshold level of the D-criteria.

Threshold level	OCU – 333	
	H_{beg}	H_{end}
Low (1)	110.6 ± 6.3 km	96.4 ± 6.1 km
Medium low (1)	111.2 ± 5.8 km	96.5 ± 6.0 km
Medium high (1)	111.4 ± 5.1 km	97.0 ± 5.9 km
High (1)	112.3 ± 4.6 km	97.3 ± 6.1 km
Very high (1)	112.1 ± 4.3 km	96.5 ± 6.8 km
Low (2)	110.0 ± 6.0 km	96.6 ± 5.2 km
Medium low (2)	111.2 ± 5.9 km	96.8 ± 5.4 km
Medium high (2)	113.1 ± 4.4 km	97.4 ± 4.9 km
High (2)	113.7 ± 4.4 km	97.0 ± 5.0 km
Very high (2)	114.1 ± 4.1 km	95.6 ± 5.1 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.

Our sample of 442 October Ursae Majorid orbits had an average absolute magnitude, brightest and faintest value of –1.3 [–9.6; +1.9]. The magnitude distribution as a percentage of the total number of October Ursae Majorids is shown in *Figure 12*. The shower is abundant in bright meteors and produced some very bright fireballs in the past. The shape of the magnitude profile in *Figure 12* indicates that the amount of data doesn't sufficiently cover the

magnitude range to attempt any population index calculation.

If we calculate the average absolute magnitude for each interval of 3.0° in solar longitude with a step of 0.5° solar longitude for all non-OCU meteors, without Orionids in the considered period and for all 442 OCU orbits, we see that the October Ursae Majorids are about 0.5 magnitude brighter than the overall meteor activity (*Figure 13*). Although the shower produced some very bright fireballs, the overall brightness is with 0.5 magnitude only slightly above that of the background activity, without Orionids. *Figure 13* suggests that the average shower produces more bright meteors during its maximum and less before and after the maximum. However, the number of OCU meteors is too small yet to draw any conclusions about these variations in average magnitude.
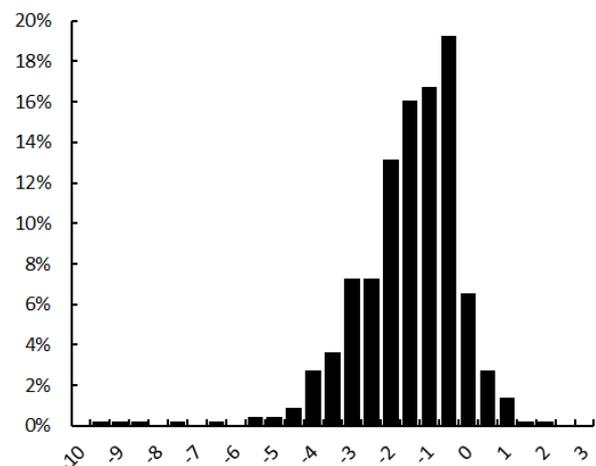
Figure 12 – Magnitude distribution per half magnitude class based on the absolute magnitudes of October Ursae Majorids.
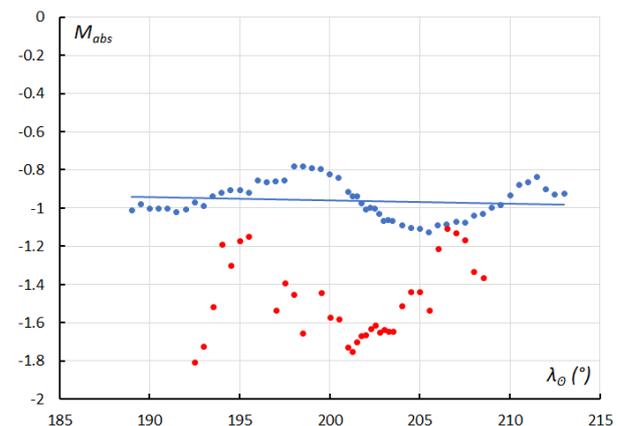
Figure 13 – Average absolute magnitude for the overall meteor activity (blue) and the October Ursae Majorids (red) per 3° in solar longitude with a step of 0.5° in solar longitude.

7   October Ursae Majorids orbits

In *Table 5* we list all relevant orbits for October Ursae Majorids (OCU#333) meteor stream. The orbital data published by the IAU Meteor Data Center, based on different stream searches, represents rather small numbers of orbits. It is often not clear which D-criteria were applied to determine the reference orbit. Therefore, for this case

study we list the reference orbits for the different threshold levels.

The orbits collected by CAMS BeNeLux which are still under embargo are not included in this case study, but the preliminary results for these OCU orbits are listed for each threshold level.

The orbit of the October Ursae Majorids as well as the shower characteristics suggest a long periodic comet as parent body, perhaps a Halley type comet. The parent body remains to be discovered and perhaps the dust trail may provide some indications where and when to expect this comet at its perihelion, if it still exists. Any irregular annual activity of the OCU meteor stream may be a hint for the presence of a fresh dust trail related to the parent comet or its remnants. Careful annual monitoring is strongly recommended.
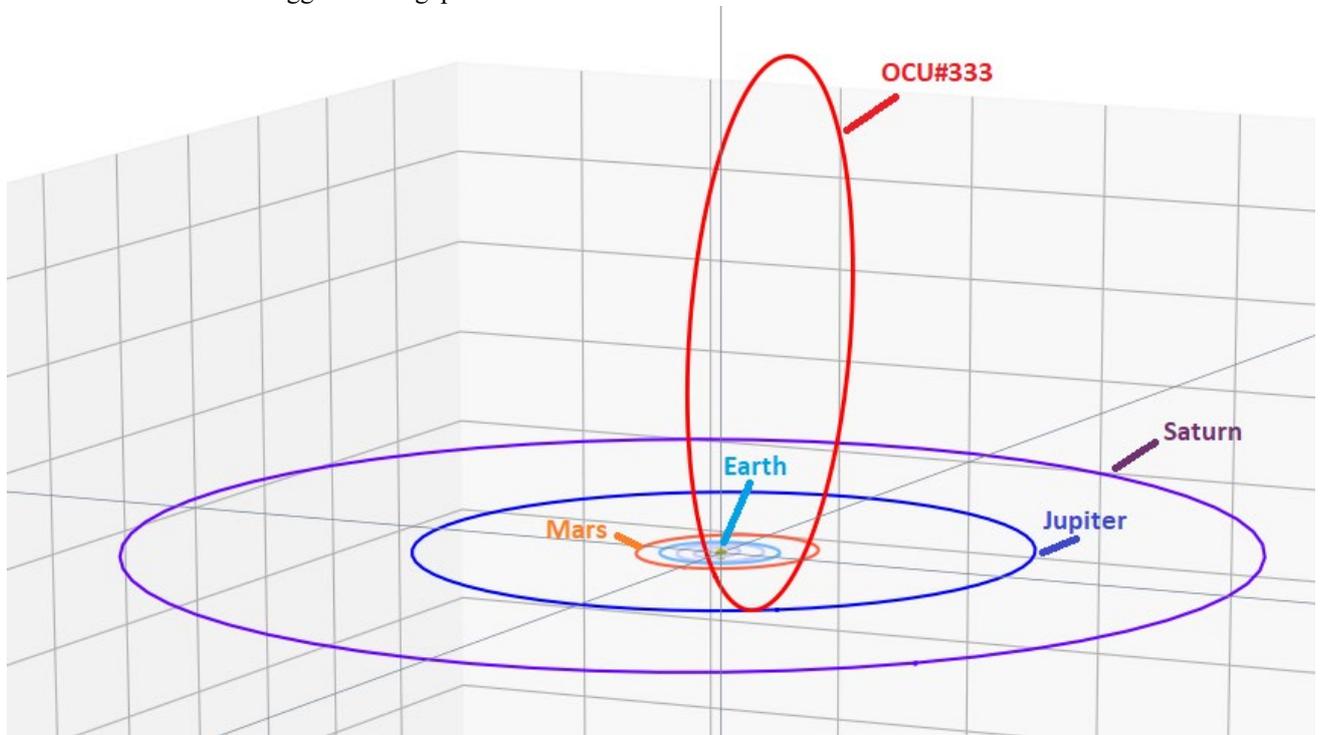

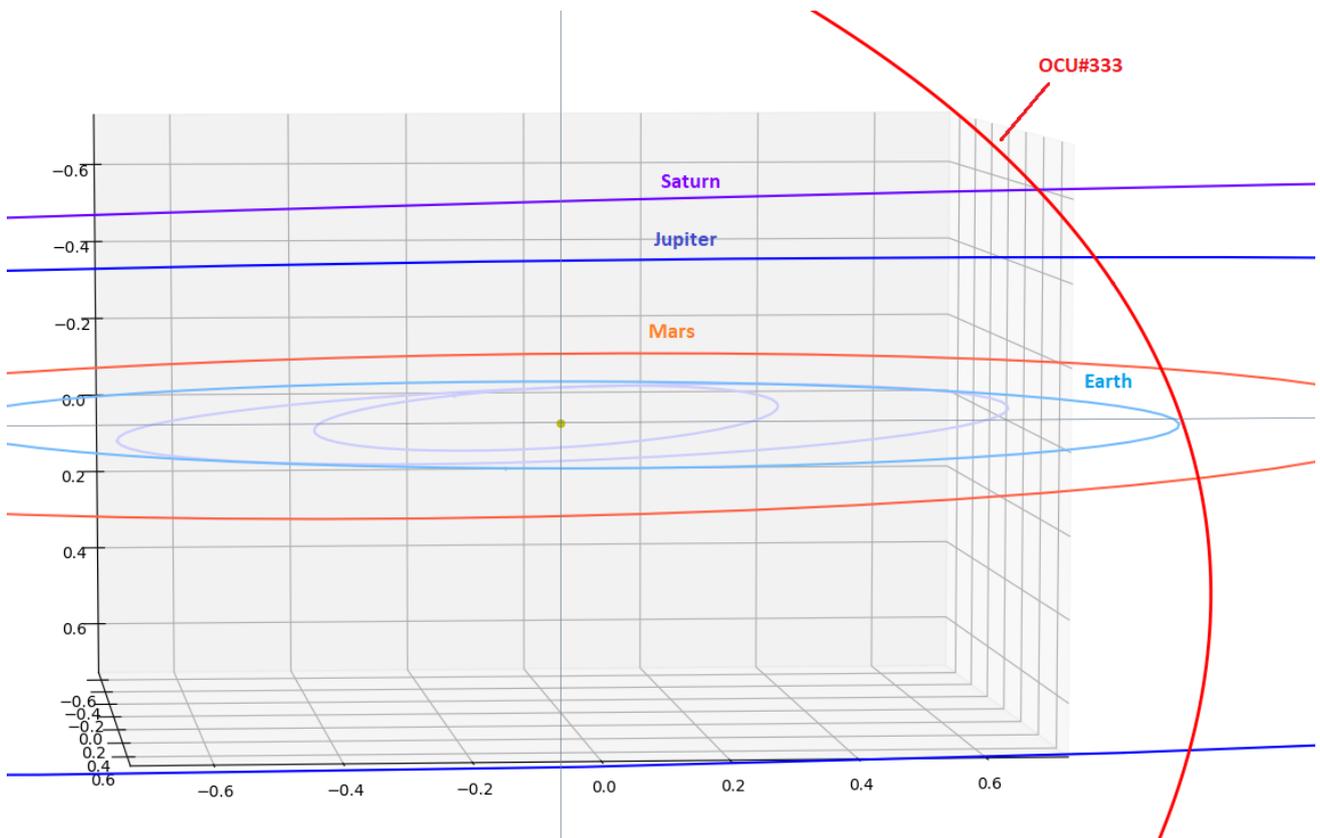*Figure 14* – The reference orbit from this study with D<0.04 in Table 5 as seen from North of the ecliptic plane.

Figure 15 – The reference orbit from this study with D<0.04 in Table 5 as seen near the Earth orbit.

Table – 5 The orbital data for the OCU #333 all J2000. The data marked with (*) refers to Jenniskens et al. (2018).

$\lambda_\odot$ (°)	α_g (°)	δ_g (°)	$\Delta\alpha$ (°)	$\Delta\delta$ (°)	v_g km/s	a AU	q AU	e	ω (°)	Ω (°)	i (°)	N	Source
200.6	137.8	67.7	–	–	54.2	9.1	0.994	0.891	173.5	200.6	98.2	1	022K1 (1958)
202	144.8	64.5	–	–	54.1	5.9	0.979	0.875	163.7	202.1	99.7	10	Uehara et al., 2006
204.7	147.6	64.0	0.13	0.09	54.4	–	–	–	–	–	–	15	SonotaCo, 2009
202	143.8	63.9	–	–	58.1	–	0.981	1.115	165.7	202.0	103.3	1223	Brown et al., 2010
202.0	145.0	64.8	1.39	-0.33	55.6	12.6	0.982	0.967	165.9	202.2	100.6	9	Jenniskens et al. (2016)
202.2	143.6	63.9	–	–	55.2	7.89	0.980	0.876	164.5	202.2	101.4	1	2015 (*)
202.6	146.0	63.7	–	–	55.5	13.1	0.976	0.925	163.2	202.6	101.1	6	2016 (*)
202.7	146.1	64.2	–	–	55.5	18.1	0.978	0.946	164.1	202.7	100.7	11	2014 (*)
202.8	146.0	64.0	–	–	55.6	18.1	0.977	0.946	163.9	202.8	100.8	69	Annual (*)
202.0	144.4	64.3	–	–	55.7	17.2	0.980	0.943	164.7	202.0	101.2	16	2013 (*)
202.24	144.8	64.3	–	–	55.9	14.1	0.979	0.930	164.4	202.2	101.2	211	*BeNeLux (<0.105)*
202.24	144.8	64.4	–	–	55.9	15.6	0.980	0.938	164.6	202.2	101.1	137	*BeNeLux (<0.08)*
202.22	144.9	64.5	–	–	55.8	17.1	0.979	0.942	164.4	202.2	100.8	101	*BeNeLux (<0.06)*
202.23	144.9	64.5	–	–	55.9	18.5	0.980	0.947	164.7	202.2	100.8	77	*BeNeLux (<0.04)*
202.18	144.6	64.6	–	–	55.9	30.8	0.981	0.968	165.3	202.2	100.7	25	*BeNeLux (<0.02)*
202.5	*145.3*	*64.1*	*1.40*	*-0.25*	*55.2*	*8.8*	*0.979*	*0.889*	*164.2*	*202.5*	*100.8*	*442*	*This study (<0.105)*
202.5	*145.4*	*64.1*	*1.57*	*-0.35*	*55.2*	*9.8*	*0.979*	*0.900*	*164.3*	*205.6*	*100.8*	*330*	*This study (<0.08)*
202.5	*145.6*	*64.2*	*1.96*	*-0.38*	*55.2*	*11.0*	*0.979*	*0.911*	*164.2*	*202.5*	*100.6*	*237*	*This study (<0.06)*
202.4	*145.4*	*64.2*	*1.68*	*-0.40*	*55.2*	*10.9*	*0.979*	*0.910*	*164.3*	*202.4*	*100.8*	*141*	*This study (<0.04)*
202.2	*144.6*	*64.2*	*1.72*	*-0.31*	*55.1*	*10.1*	*0.979*	*0.903*	*164.2*	*202.2*	*100.4*	*43*	*This study (<0.02)*

8   Conclusion

This case study confirms the October Ursae Majorids (OCU#333) meteor stream as annual minor meteor shower with a rather sharp maximum at $\lambda_\odot = 202.05 \pm 0.10°$. The skew activity profile rises steep to its maximum followed by a slower decline in activity. The activity profile displays dips and sub maxima which may be related to a layered structure of dust trails, but this requires more data to exclude statistical flutter on the profile. There is a significant spread in velocity with slower particles at lower inclination and the faster ones at higher inclination. The cause of this distribution remains to be explained. There is absolutely no indication for any periodicity in the shower activity which produces activity on annual bases. The shower is rich in rather bright meteors, including fireball events. The rather sharp peak activity can be easily missed in case of unfavorable weather therefore a global coverage with widely spread camera networks is recommended.

The October Ursae Majorids (OCU#333) should be investigated again when more data is available. Its orbit is typical for long periodic comets, but its parent body remains to be discovered. Future surprises with this shower are not excluded and require permanent attention.

Acknowledgment

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

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October Camelopardalids (OCT#281)

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CAMS BeNeLux collected 37 orbits of the October Camelopardalids in 2018. A stream search on all available video meteor orbits could identify 249 October Camelopardalids orbits. The shower has a compact radiant at R.A. 169° and declination +78° and a velocity of 45 km/s. The velocity displays a significant dispersion with the faster particles at higher inclination and the slower particles at lower inclination. The shower activity displays a very sharp activity profile between solar longitude 192.2° and 192.9° with a sharp maximum at solar longitude 192.55 ± 0.05° with a duration of less than one hour.

1 Introduction

CAMS BeNeLux had clear sky during the night 5–6 October 2018 and registered 37 orbits of the October Camelopardalids, listed as an established shower in the IAU Meteor Data Center as OCT#281. The shower is poorly known.

Carl Johannink identified 37 orbits of the CAMS BeNeLux network in 2018 as October Camelopardalids, slightly more than in 2017 when 16 orbits were identified as October Camelopardalids. These are rather impressive numbers of orbits and therefore the authors decided to dedicate a case study to this shower.
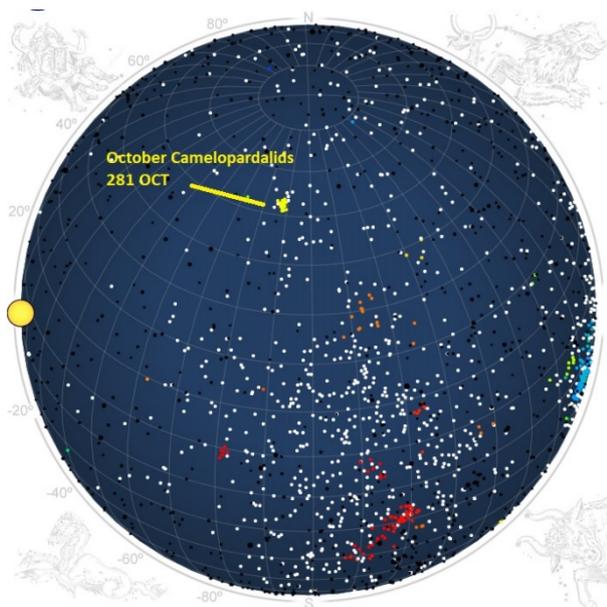

Figure 1 – Screenshot of the CAMS radiant plot for the night of 2018 October 6 with the compact radiants identified as October Camelopardalids (OCT#281). The radiants of the Orionids (red bottom right) and Taurids (blue at the edge at right) are more scattered.

2 History of the October Camelopardalids

The shower got little or no attention and was first documented by Jenniskens (2006) who lists the following likely early visual observations of this stream:

- 1902 October 4 ($\lambda_{\odot}$ = 192.01°) by G. Percy Bailey at Blackburn, United Kingdom, 50 light tracks behind clouds.
- 1942 October 5 ($\lambda_{\odot}$ = 192.7±0.1°) by Dr. Werner Sandner, with a significant meteor shower.
- 1976 October 5, 9:55–11:37 pm EST ($\lambda_{\odot}$ = 193.31–193.38°), E. Root reported 113 meteors moving from North to South.
- 2005 October 5, Jarmo Moilanen (Finland) detected 12 meteors by video with a compact radiant at R.A. = 164.1±2.0° and Decl. = +78.9±0.5°, confirmed by Esko Lyytinen and Illeka Yrjölä (Jenniskens et al., 2005).

Other lists with minor showers such as in Terentjeva (1966, 1968, 2017) do not contain any data about the October Camelopardalids. The IAU Photographic meteor catalogue (Lindblad et al., 2003) lists 4 orbits in 1952, 1954 and 1956 that fulfill our similarity criteria (all four orbits are listed in *Table 5*). The Harvard radar meteor orbit catalogue 1961–1965 (Verniani, 1973; Sekanina, 1973) has 3 similar orbits according to our criteria, all 3 in 1965. The Harvard radar meteor orbit catalogue 1968–1969 (Verniani, 1973; Sekanina, 1976) lists another 9 similar orbits, according to our D-criteria, all in 1969. We list the orbits that we obtained by our D-criteria as well as the original orbits published in 1973 and 1976. Sekanina (1973; 1976) applied the D-criterion with a very great tolerance with a high risk to include unrelated sporadic orbits. The radar observations were made in series of days with interruptions for some days and for this reason the shower maxima may have been

missed in some years. Unfortunately, Sekanina does not list any reference literature for the October Camelopardalids.

The October Camelopardalids were also detected in the meteor shower search on the SonotaCo data for 2007 and 2008 (SonotaCo, 2009) as well as in each year of the CAMS data since 2011, but remains absent in CMOR data.

3 The methodology and 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 – October 2018 are not included in this dataset because this data is still under embargo.

In total 686073 video meteor orbits are publicly available, most of which can be excluded from any association with October Camelopardalids by their position. Our methodology to detect associated orbits has been explained in a previous case study (Roggemans et al., 2019).

The first step is to assess the outer limits in time, radiant position and velocity range within which orbits of this stream may be found. To establish these outer limits, we take one of the suspect orbits and check the similarity criteria on all 686073 orbits. This results in a set of orbits which serves only to find the outer limits in time, radiant position and velocity range within which these orbits can be found. From this first preliminary selection it appears that any possible October Camelopardalids should have their orbit, radiant position and velocity, within the following range:

- Time interval: $179° < \lambda_{\odot} < 205°$;
- Radiant area: $102° < \alpha_g < 217°$ & $+70° < \delta_g < +88°$;
- Velocity: 40 km/s $< v_g <$ 52 km/s.

Then we select all orbits available within this time interval, regardless their radiant position or velocity. In total 52049 orbits were available in the considered time interval. This dataset will serve as source for the background activity. From this dataset we select all orbits with a radiant position and geocentric velocity within the limits listed above. Any possible October Camelopardalid orbits will be among this selection. In this case 791 orbits had the radiant and velocity within the interval mentioned above. For any single station observer, either visual or video, all 791 orbits displayed meteors that appeared like perfect October Camelopardalids, from the right radiant area with the right angular velocity.

Since we have the orbital elements we will verify if the orbits can be identified as October Camelopardalids. We use the so-called similarity or discrimination criteria to accept or to reject the identification of an orbit as October Camelopardalids. The similarity criteria consider the distance between some of the orbital elements combined with the angle between the orbital planes. The first numeric discrimination criterion was proposed by Southworth and Hawkins (1963), referred to as D_{SH}. Later Drummond (1981) introduced a slightly different criterion, referred as D_D. Jopek (1993) proposed another version D_H, based on the former criteria. We can apply all three criteria combined and we define five different classes with specific threshold levels of similarity:

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

Table 1 – The median values for each sub-set of orbits that fulfill $D_D<0.105$, CAMS, SonotaCo, EDMOND and all combined. The orbit from the literature is taken from Jenniskens et al. (2018).

	All	CAMS	SonotaCo	Edmond	Literature
$\lambda_{\odot}$	192.6°	193.9°	192.7°	192.55°	192.5°
α_g	169.1°	169.0°	168.4°	169.6°	170.0°
δ_g	+78.6°	+77.8°	+78.6°	+78.7°	+78.3°
v_g	44.9	45.0	45.6	44.6	45.8
a	9.3	6.8	11.9	9.2	25.6
q	0.991	0.991	0.991	0.991	0.989
e	0.893	0.853	0.917	0.892	0.961
ω	168.9°	168.8°	169.2°	168.9°	168.1°
Ω	192.6°	193.9°	192.7°	192.55°	192.5°
i	77.1°	76.8°	77.8°	76.3°	77.5°
N	249	18	59	172	14

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

	Low	Medium low	Medium high	High	Very high
$\lambda_{\odot}$	192.6°	192.6°	192.6°	192.6°	192.6°
α_g	169.1°	169.2°	169.2°	168.4°	168.7°
δ_g	+78.6°	+78.6°	+78.6°	+78.6°	+78.7°
v_g	44.9	45.0	45.0	45.1	45.0
a	9.3	9.2	10.2	10.0	9.2
q	0.991	0.991	0.991	0.991	0.991
e	0.893	0.892	0.903	0.901	0.892
ω	168.9°	168.7°	168.7°	168.7°	168.7°
Ω	192.6°	192.6°	192.6°	192.6°	192.6°
i	77.1°	77.1°	77.1°	77.4°	77.1°
N	249	154	107	53	21
$\%$	*31%*	*19%*	*14%*	*7%*	*3%*

These classes should allow to compare shower characteristics in function of the reliability of the shower identification. While the low threshold similarity class may include some sporadic orbits that fit the criteria by pure chance, the higher the threshold the less the risk for contamination with sporadic orbits.

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. This way a reference orbit for the October Camelopardalids was derived from the selection of 791 orbits. Then this reference orbit was used to recalculate all similarity criteria and new median values were calculated for the orbits that fulfilled these criteria. This procedure was repeated 4 times until the iterations only influenced the insignificant decimals.

A few sub datasets were generated based on the final 249 probable October Camelopardalids orbits for the different sources of data as well as for each class of threshold level. 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.

Plotting the ecliptic latitude β against the Sun centered longitude $\lambda - \lambda_\odot$ neutralizes the radiant drift due to the movement of the Earth around the Sun. The presence of a concentration of radiants with similar orbits is very clear in *Figure 2*. The low threshold similarity orbits marked in blue display still a reasonable spread, but most of the October Camelopardalids (OCT#281) orbits form a rather compact radiant.
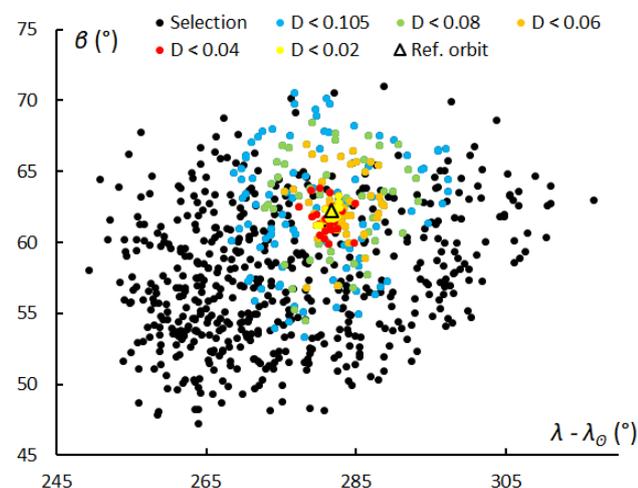

Figure 2 – Plot of the ecliptic latitude β against the Sun centered longitude λ – λ⊙. The different colors represent the 5 different levels of similarity.

If we remove all the radiants that were identified as October Camelopardalids (OCT#281) based on their orbit, as many as 542 radiants remain for which the orbits fail in the similarity criteria (*Figure 3*). For any single station observer, either visual or video, all these meteors would be identified as October Camelopardalids (OCT#281) because they appear from the radiant area with the right velocity. This means that single station data would have about two third of its shower meteors identified as OCT-281, while the orbits should be considered as sporadics. Of course, a contamination of the sample with 69% erroneously identified October Camelopardalids makes statistics with such sample meaningless.
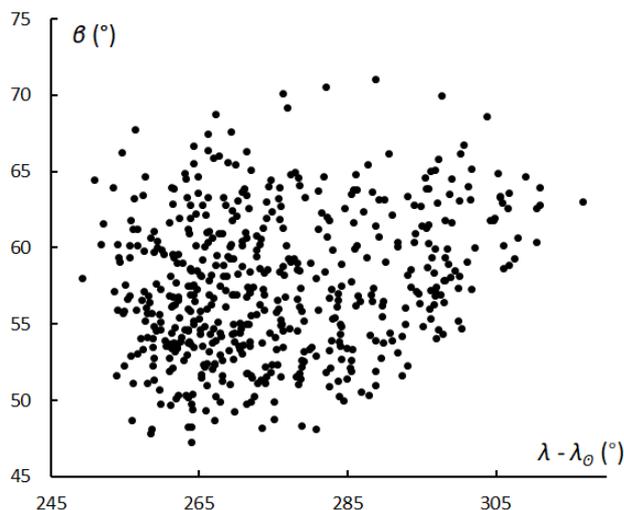

Figure 3 – Plot of the ecliptic latitude β against the Sun centered longitude λ – λ⊙ for the 542- orbits from the selection that failed in the similarity criteria.
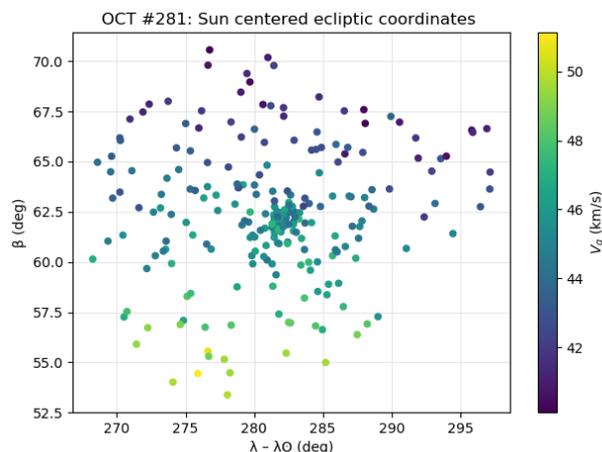

Figure 4 – Plot of the ecliptic latitude β against the Sun centered longitude λ – λ⊙ (°) for the 249 OCU orbits that fulfill the low threshold similarity criteria with a color gradient to display the variation in the velocity vg.

If we remove all sporadic orbits and take a close-up of the October Camelopardalids with a color gradient to illustrate the spread in the geocentric velocity, we see a remarkable distribution of the velocity. The slow velocity radiants appear at higher ecliptic latitude (top of *Figure 4*) with a gradual increase in velocity over the core of the meteor stream towards the highest velocity at lower ecliptic latitude (bottom of *Figure 4*). This shows the orientation of the

dispersion of the particles in the stream. The presence of a concentration of similar orbits is also very well visible in the plot of the inclination i against the length of perihelion Π (*Figure 5*). The selection of 791 orbits, although each of these orbits produced a meteor that looked like October Camelopardalids, includes a significant number of sporadic orbits, marked as black dots. Removing the shower orbits, we see the sporadic background radiant distribution in *Figure 6* which is partially hidden in *Figure 5*.
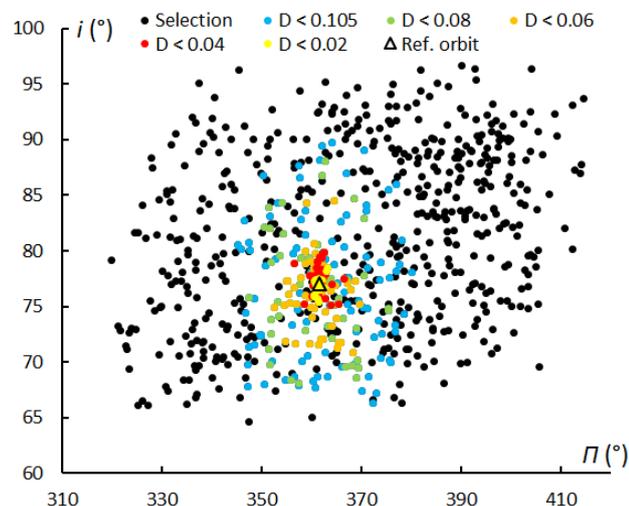
Figure 5 – The plot of inclination i (°) against the length of perihelion Π (°) for the 791-selected possible OCT-orbits. The colors mark the different threshold levels of the D-criteria relative to the final reference orbit listed in Table 2.
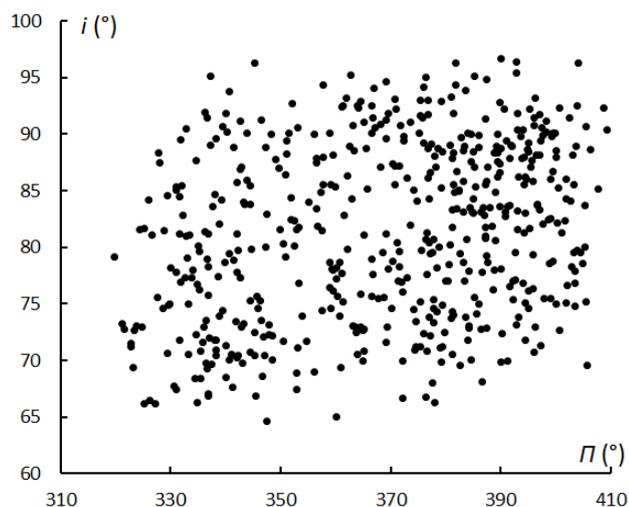
Figure 6 – The plot of inclination i (°) against the length of perihelion Π (°) for the 542- orbits from the selection that failed in the similarity criteria.

The dispersion of the velocity found in the Sun centered ecliptic coordinate plot also appears in the plot of the inclination i against the length of perihelion Π (*Figure 7*). When we plot the geocentric velocity v_g versus inclination i for all 249 OCT orbits the geocentric velocity v_g increases with 0.45 km/s per degree in inclination (*Figure 8*). The slower, lower energy particles, got at lower inclination, the faster, accelerated particles, got at higher inclinations. If we look at possible changes in inclination and in geocentric velocity in function of time (solar longitude $\lambda_\odot$), both the inclination i and the velocity v_g remain constant throughout

the passage of the Earth through the stream. This means that Earth encounters the velocity dispersed particles all along its passage through the October Camelopardalids stream.
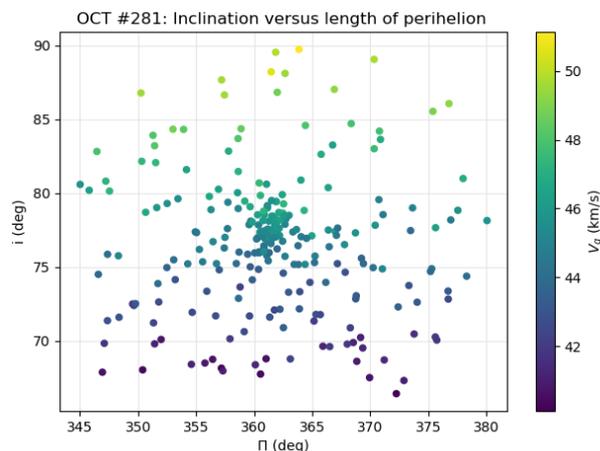

Figure 7 – Close-up on the plot of inclination i (°) against the length of perihelion Π (°) for the 249 OCT orbits that fulfill the low threshold similarity criteria with a color gradient to display the variation in the velocity v_g.
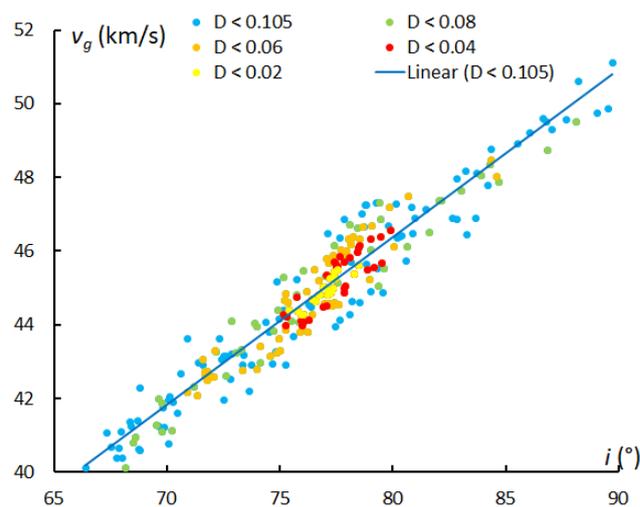

Figure 8 – Plot of the geocentric velocity v_g against the inclination i (°).

4   Radiant drift

The radiant of any shower moves eastwards in the sky due to the Earth moving on its orbit around the Sun. By pinpointing the radiant night by night, we can track this radiant drift. In equatorial coordinates the radiant drift in R.A. and declination may differ quite a bit depending upon the source of the data.

We list the radiant drift in *Table 3* as derived from the different datasets according to the class of the similarity criteria threshold. The compact nature of the radiant for the medium high and high threshold similarity criteria covers a too short range in solar longitude to make any reliable estimate of the radiant drift. In this case the values for the low and medium low similarity criteria will be the best estimate. Note that the OCT radiant position is at a high declination and that a small angle at the sky makes a large difference in R.A.

Table 3 – Radiant drift with ± σ for the October Camelopardalids obtained from the orbits for each threshold level of the D-criteria.

Threshold/source	OCT – 281	
	$\Delta\alpha / \lambda_\odot$	$\Delta\delta / \lambda_\odot$
Low	1.71 ± 0.24	–0.44 ± 0.03
Medium low	1.80 ± 0.29	–0.46 ± 0.05
Medium high	0.62 ± 0.43	–0.23 ± 0.05
High	0.98 ± 1.04	–0.05 ± 0.03

5   The activity profile and maximum

The orbit sample has been collected over 11 years from 2006 until 2016. For 2017 we have only data from the SonotaCo network which missed the OCT activity completely due to bad weather in 2017. In 2016 CAMS BeNeLux registered 4 OCT orbits, few hours after the expected maximum (Johannink, 2016). The CAMS data for 2013 to 2018 which is still under embargo and not included in this case study however confirms a distinct presence of OCT orbits, 1 in 2013, 1 in 2014, 5 in 2015, 8 in 2016, 16 in 2017 and 37 orbits in the 2018 data.

To estimate the activity of the October Camelopardalids relative to the background activity, all Orionid orbits were removed from the dataset. The background activity in each time bin includes all orbits except the Orionid and OCT orbits.
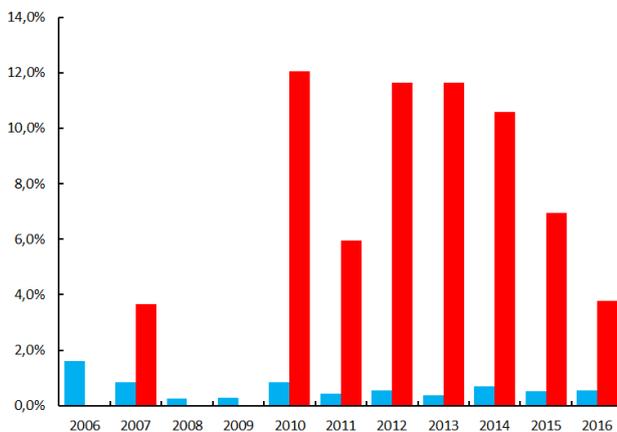

Figure 9 – The percentage of OCT orbits relative to the total number of non-OCT orbits obtained per year for different intervals of its activity period: The blue bars represent the total activity period, $179° < \lambda_\odot < 205°$, and the red bars stand for the bin with the maximum at $192° < \lambda_\odot < 193°$.

A weak October Camelopardalids activity has been detected during each year consisting of scattered orbits that fulfil the low and medium low threshold similarity criteria during the activity period of $179° < \lambda_\odot < 205°$ with on average 0.5% of all orbits being OCT orbits. A very sharp peak activity occurs between $192° < \lambda_\odot < 193°$, the relative activity reaches 12% of the background activity (*Figure 9*). The sharpness of the OCT peak activity means that this short time interval with the best OCT activity can be easily missed depending on the available capture capacity of camera networks and weather circumstances.

The absence of OCT activity in some years may feed the assumption that the shower is not annual but responsible for periodic outbursts. We find no indications neither for a periodic nature nor for any outbursts in the years covered by this analysis. The years without any OCT peak activity can be easily explained. 2006, 2008 and 2009 had no coverage during 12 hours around the OCT peak. If we look at a narrow window of 12 hours ($192.3° < \lambda_\odot < 192.8°$), the OCT activity made up to ~33% of the total activity in 2010, 2012 and 2015. Three other years with good coverage of the time of the OCT peak, 2011, 2014 and 2016 produced only OCT rates of ~12% of the total activity, while 2007 and 2013 had a relative activity level of ~20%. The OCT activity seems to be quite variable from year to year, but not to an extend that justifies speaking about outbursts. These results are not in line with the expectation according to the model proposed by Lyytinen (2016) but may help to finetune the assumptions used in the model. It is not excluded that the variable nature of this shower produced some outbursts that may explain the past poorly documented reports of 1902, 1942 and 1976.
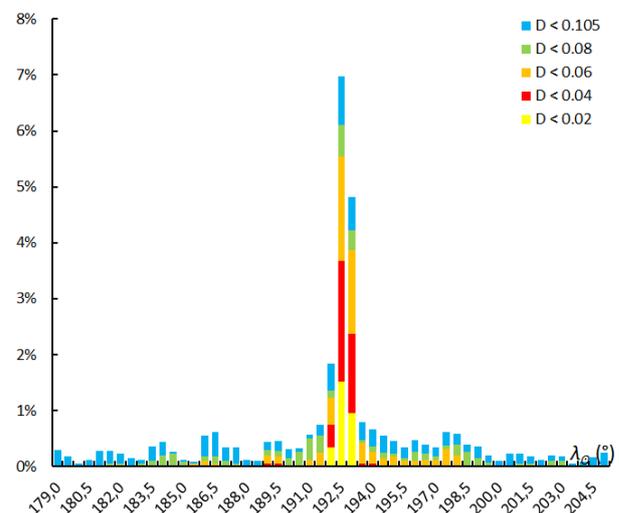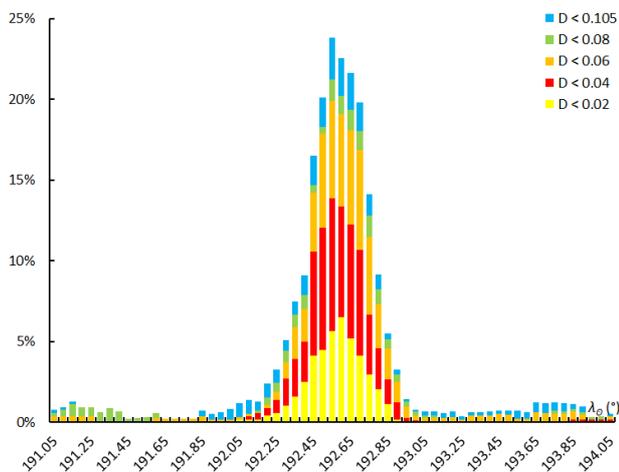

Figure 10 – The relative number of OCT orbits collected per 1° of solar longitude in steps of 0.5° during the years 2006–2016, with blue for $D_D < 0.105$, green for $D_D < 0.08$, orange for $D_D < 0.06$, red for $D_D < 0.04$ and yellow for $D_D < 0.02$, as percentage compared to the total number of non-OCT orbits without any Orionids, collected in the same time span.

The number of orbits available for each time bin depends on the weather circumstances, number of cameras running, the kind of optics used etc. All these factors are the same for the non-shower orbits as for the shower orbits. The number of shower orbits relative to the number of non-shower orbits as a percentage allows to create a reliable activity profile. The number of shower orbits also depends on the elevation of the radiant above the local horizon. We do not attempt any correction for this. The composition of our sample of orbits is the result of a mixture of orbits collected at many different locations with the radiant at all possible elevations, this way we can consider the sample as representative for an average radiant elevation which remains approximately the same for all considered time bins.

The low threshold orbits (blue) represent outliers and may include some sporadics that just fit the similarity criteria by pure chance. These orbits are detected each year (*Figure 10*). The resulting activity profile shows a fast increase in activity from $\lambda_\odot = 192.10°$ to the peak at $\lambda_\odot = 192.55°$ with high rates until $\lambda_\odot = 192.70°$, followed by a steep decline towards $\lambda_\odot = 192.95°$. Beyond this short period only very few OCT orbits can be collected. The OCT maximum occurs in a 6 hours' time span with peak activity during about one hour. *Figure 11* shows the activity profile with a time bin of 0.3° moved forward in steps of 0.05° in solar longitude. This is the best resolution we can afford with the available number of orbits. There are no indications for any sub maxima and the OCT shower appears to produce a single short duration sharp peak that can be easily missed in case of unfavorable observing circumstances.

Figure 11 – The relative number of OCT orbits collected per 0.3° of solar longitude in steps of 0.05° based on the years 2006–2016, 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-OCT orbits collected in the same time span, with the Orionid orbits removed from the sample.

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 $\lambda_\odot = 192.55 ± 0.05°$, with best rates limited to the interval 192.45° to 192.70°, about 6 hours, and the main OCT activity limited to the time bin of. 192.2° until 192.9°. Beyond this short interval only few dispersed OCT orbits can be detected. The time of maximum is exactly what Japanese radio observers obtained in 2016 (Ogawa, 2016) when a peak occurred that lasted less than half an hour. Single station video and visual observations in 2018 resulted in a maximum at $\lambda_\odot = 192.45 ± 0.05°$ (Rendtel and Molau, 2018). Single station data is rather tricky because of the small numbers of meteors which may be affected by sporadics with the right angular velocity but lined up by chance resulting in an activity profile of statistical flutter. However, these efforts by visual observers remain worthwhile to supervise if any real outburst would take place that could allow statistical relevant observations. It is of interest to know for sure that activity remained at or below detectability level while being vigilant for any unusual higher activity.

6 Other shower characteristics

With a geocentric velocity of 45 km/s the October Camelopardalids produce a luminous trajectory in the atmospheric layer between 110 and 93 km elevation. 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.

The velocity of the October Camelopardalids is comparable to the April Lyrids. Remarkable enough, although OCT meteors have a slightly lower velocity than the Lyrids (46.1 km/s), the OCT meteors start slightly higher in the atmosphere and end several kilometers sooner than the Lyrids. This could be an indication for a different composition with the October Camelopardalids being composed of more fragile fresh cometary material. This and the short sharp activity profile may indicate a young cometary dust trail left by a yet undiscovered long periodic comet.

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

Threshold level	OCT – 281	
	H_{beg}	H_{end}
Low	105.0 ± 4.9 km	93.3 ± 6.5 km
Medium low	106.0 ± 4.6 km	94.2 ± 6.1 km
Medium high	106.8 ± 4.3 km	95.0 ± 5.7 km
High	107.6 ± 3.0 km	94.9 ± 5.1 km
Very high	108.5 ± 2.3 km	96.0 ± 3.4 km
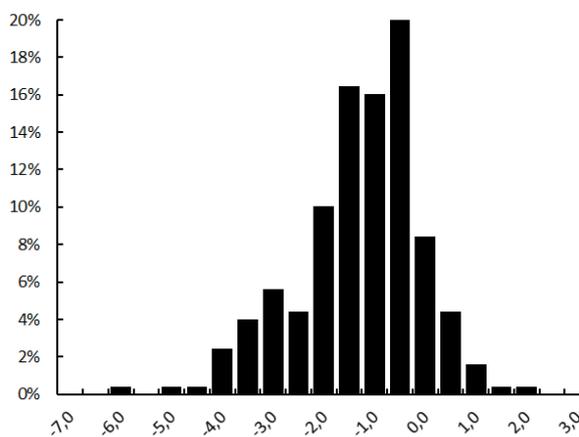
Figure 12 – Magnitude distribution per half magnitude class based on the absolute magnitudes of October Camelopardalids.

Our sample of 249 October Camelopardalids orbits had an average absolute magnitude, brightest and faintest value of –1.1 [–5.8; +2.1]. The magnitude distribution as a percentage of the total number of October Camelopardalids is shown in *Figure 12*. There are no exceptional fireballs included and there is no evidence for any exceptional

brightness or anything that could point to a fireball stream. Nothing excludes that this shower produced outbursts with many bright meteors in the past, but the data covered here has no indication for this.
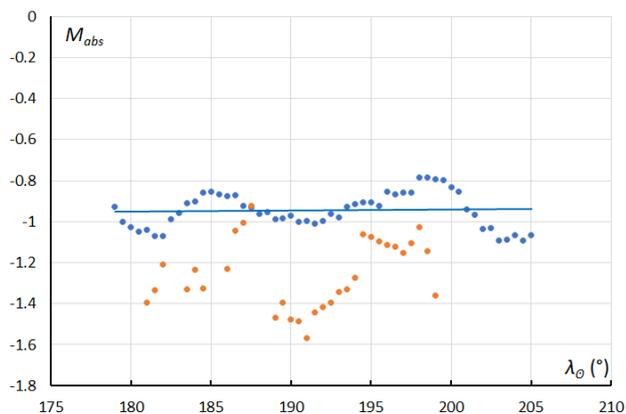

Figure 13 – Average absolute magnitude for the overall meteor activity (blue) and the October Camelopardalids (orange) per 3° in solar longitude with a step of 0.5° in solar longitude.

If we calculate the average absolute magnitude for each interval of 3.0° in solar longitude with a step of 0.5° solar longitude for all non-OCT meteors, without Orionids in the considered period and for all 249 OCT orbits, we see that the October Camelopardalids are about 0.3 magnitude brighter than the overall meteor activity (*Figure 13*). The best average brightness occurs near the shower maximum. Away from the core of the shower the OCT meteors are just slightly brighter on average than the background activity.

7 October Camelopardalids orbits

Table 5 lists all the relevant orbits that we could find for the October Camelopardalids (OCT#281) meteor stream. In most cases it is not clear which similarity criteria were applied to establish the orbit. Therefore, for this case study we list the reference orbits for the different threshold levels.
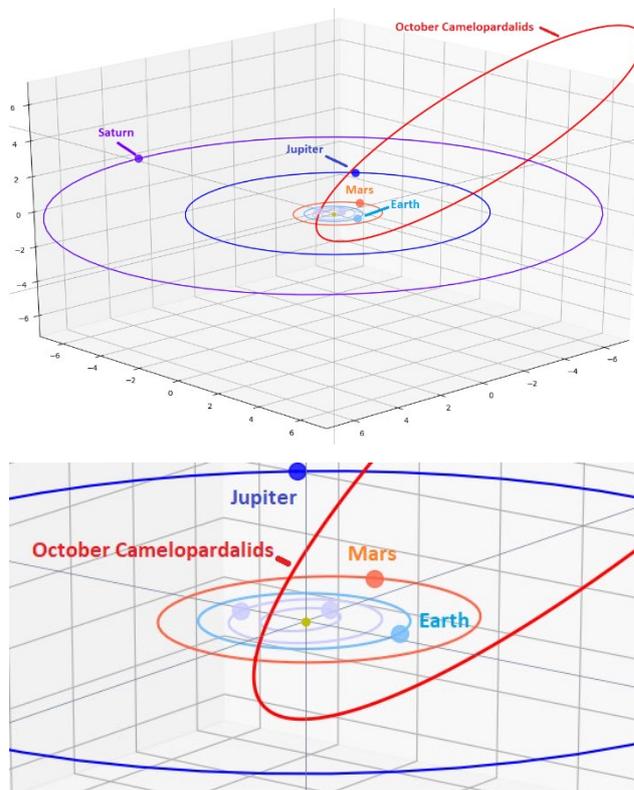

Figure 14 – The October Camelopardalid orbit (This study <0.04) as seen from north of the ecliptic, overview (top) and close-up near the Earth orbit (bottom).

The orbit of the October Camelopardalids suggests a long periodic comet as parent body, perhaps a Halley type comet. The parent body remains to be discovered and perhaps the dust trail may provide some indications where and when to expect this comet at its perihelion, if it still exists. The shower characteristics indicate relative fresh volatile cometary material. Any irregular annual activity of the OCT meteor stream may be a hint for the presence of a fresh dust trail related to the parent comet or its remnants. Careful annual monitoring is strongly recommended.
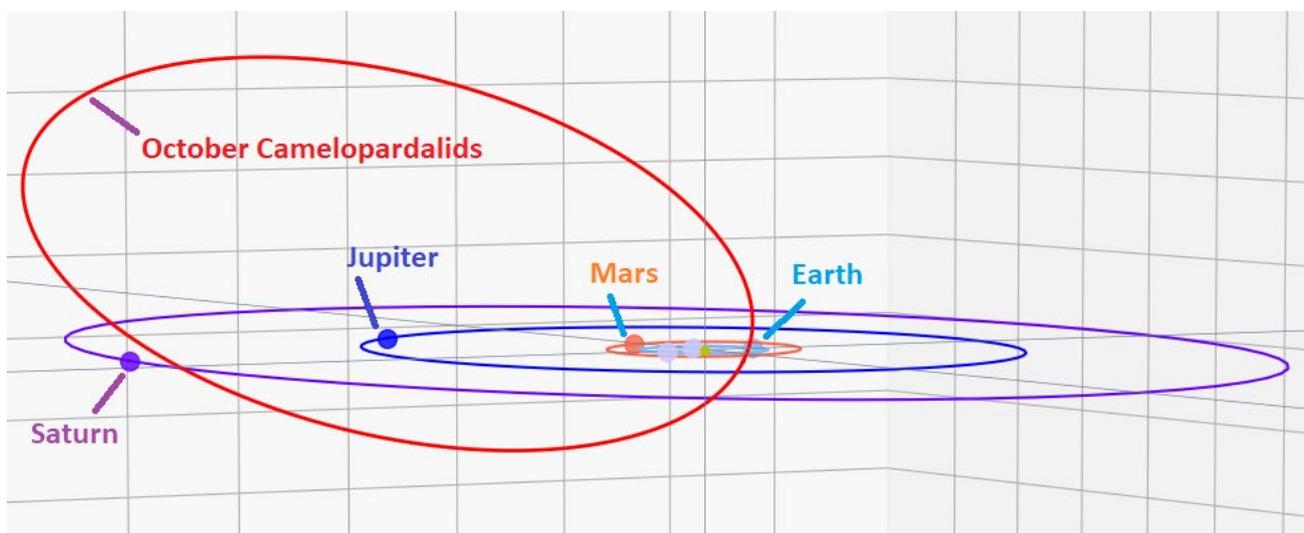

Figure 15 – The October Camelopardalid orbit (This study <0.04) as seen from above the orbital plane of the shower.

Table – 5 The orbital data for the OCT #281 all J2000. The data marked with (*) refers to Jenniskens et al. (2018), (°) refers to Lindblad et al. (2003), (!) are references with epoch 1950.0.

λ_Θ (°)	α_g (°)	δ_g (°)	$\Delta\alpha$ (°)	$\Delta\delta$ (°)	v_g km/s	a AU	q AU	e	ω (°)	Ω (°)	i (°)	N	Source
199.4	182.4	+81.0	–	–	42.1	5.5	0.998	0.818	179.4	199.4	72.0	P	254H1 (1952) (°!)
192.8	132.9	+77.7	–	–	48.6	7.4	0.999	0.863	178.1	192.8	85.5	P	065D1 (1954) (°!)
198.4	179.1	+73.0	–	–	46.2	44.8	0.973	0.978	161.6	198.4	77.7	P	011P1 (1956) (°!)
200.5	188.5	+80.5	–	–	42.7	9.9	0.997	0.899	179.0	200.5	72.0	P	313S1 (1956) (°!)
195.6	189.7	+79.2	–	–	38.0	2.5	0.992	0.610	169.7	195.6	67.1	22	Sekanina (1973)(!)
195.2	168.5	+81.0	–	–	42.9	4.7	0.997	0.786	176.6	195.2	74.4	15	Sekanina (1976)(!)
195.7	196	+79	–	–	42.5	5.4	0.989	0.810	171.1	195.7	70.2	3	Radar 1965 (!)
194.0	163	+81	–	–	46.1	5.7	0.996	0.825	173.1	194.0	78.1	9	Radar 1969 (!)
193	166.0	+79.1	–	–	46.6	368	0.993	–	170.6	192.57	78.6		Jenniskens (2006)
197.1	163.3	+76.7	-0.93	-0.13	45.3							10	SonotaCo (2009)
192.6	170.0	+79.5	–	–	45.3	17.5	0.993	0.943	170.6	192.6	76.8	1	2013 (*)
192.7	167.8	+78.7	–	–	45.8	21.2	0.991	0.953	169.3	192.6	77.8	6	2014 (*)
192.6	168.1	+79.0	–	–	46.8	–	0.992	1.026	170.2	192.6	78.5	13	2015 (*)
192.5	170.0	+78.3	–	–	45.8	25.6	0.989	0.961	168.1	192.5	77.5	14	2016 (*)
192.7						347	0.994	0.997	171.4	192.66	78.7	1	Lyytinen (2016)
192.6	*169.1*	*+78.6*	*1.72*	*-0.44*	*44.9*	*9.3*	*0.991*	*0.893*	*168.9*	*192.6*	*77.1*	*249*	*This study (<0.105)*
192.6	*169.2*	*+78.6*	*1.80*	*-0.46*	*45.0*	*9.2*	*0.991*	*0.892*	*168.7*	*192.6*	*77.1*	*154*	*This study (<0.08)*
192.6	*169.2*	*+78.6*	*0.62*	*-0.23*	*45.0*	*10.2*	*0.991*	*0.903*	*168.7*	*192.6*	*77.1*	*107*	*This study (<0.06)*
192.6	*168.4*	*+78.6*	*0.99*	*-0.05*	*45.1*	*10.0*	*0.991*	*0.901*	*168.7*	*192.6*	*77.4*	*53*	*This study (<0.04)*
192.6	*168.7*	*+78.7*	*–*	*–*	*45.0*	*9.2*	*0.991*	*0.892*	*168.7*	*192.6*	*77.1*	*21*	*This study (<0.02)*

8   Conclusion

This case study confirms the October Camelopardalids (OCT#281) meteor stream as annual minor meteor shower with a very sharp maximum at λ_Θ = 192.55 ± 0.05° which may last less than 1 hours. The activity profile rises steep to its maximum and most of the activity is limited to the time bin in solar longitude from 192.2° until 192.9°. There is a significant spread in velocity with slower particles at lower inclination and the faster ones at higher inclination. The cause of this distribution remains to be explained.

The October Camelopardalids (OCT#281) orbit is typical for long periodic comets and its parent body remains to be discovered. This shower should be monitored on annual bases.

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The outburst of the Draconid meteor shower in 2018: an analysis

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The available visual observations of the 2018 Draconids outburst were analyzed, a population index r = 3.3 was found. The ZHR profile proves that the activity level was much higher than expected according to the predictions. The shape of the ZHR profile is remarkable without any real sharp peak but with a plateau leveled maximum activity that lasted for about 6 hours.

1   Introduction

On the evening of October 8th, 1933, *Dirk Teunissen* (the now deceased father-in-law of the author and at that moment 13 years old) was cycling home from the Ambachtschool Over-Veluwe in the small city of Harderwijk to the village of Ermelo. Outside Harderwijk on what now is called the Harderwijkerweg, he saw an uncommon phenomenon. The clear sky was filled with many shooting stars. He saw them wherever he looked. Most of the shooting stars were weak and very slow. Sometimes several appeared at once! After watching this spectacle for a while, he cycled to home, wondering about the phenomenon. When he arrived at home he told what he had seen to the family members who also went outside to watch. Meanwhile, the numbers were much less but it was still a beautiful sight.

Dirk witnessed the impressive Draconid meteor shower of 1933. The ZHR rose that year to 6000–10000 (Jenniskens, 2006). The parent body of the Draconids is comet 21P/Giacobini-Zinner which has a period of 6.6 years. In 1933 and 1946, the Draconids caused impressive meteor showers. In later years more Draconid outbursts were detected but they never reached the level of 1933 and 1946. The outbursts almost always occurred in the years of the perihelium passage of Comet 21P/Giacobini-Zinner, among others in 1985 when an outburst (ZHR 700) was observed above Japan, as well as in 1998 (ZHR 500). On 8 October 2011, an outburst was observed from Europe. For example, Dutch and Belgian observers observed the outburst from Denmark, Germany and Portugal (Langbroek et al., 2012; Bus, 2011; Vandeputte, 2012). The ZHR reached 350 (Miskotte, 2012) that year. The period of 6.6 years of 21P is also the reason that a large outburst occurred every 13 years and smaller ones every 6 or 7 years in between. In 2005, a small outburst (ZHR 35) was observed from the Draconids, but this took place just before the end of the evening twilight in the Netherlands.

Also, in the years after the bigger outbursts some low Draconid acitvity could be observed: in 1999 Marco Langbroek witnessed unexpected Draconid activity with a ZHR 10 to 20 (Langbroek, 1999) and in 2012 the CMOR radar showed a very high activity of the Draconids, but almost all of them were very weak Draconids. In the off-season period of the Draconids, usually a few Draconids are seen, but the activity is very low or even nihil.

2   Predictions for 2018

Several astronomers made predictions for the Draconids in 2018 (Rendtel, 2017). *Mikiya Sato* found a close approach of the Earth to the dust trail of 21P/Giacobini-Zinner from 1953. Due to the 1985 approach to the Earth, the dust might have been dispersed, but even then, there should be something observable with a ZHR of 20–50 around 9 October 2018 at 00^h14^m UT ($\lambda_\odot$ = 195.406°). *Jérémie Vaubaillon* found a possible maximum on 8 October 2018 at 23^h31^m UT ($\lambda_\odot$ = 195.374°) with an expected ZHR of 15. *Mikhail Maslov* found several dust trails, but none of them came close enough to the Earth to expect high activity. He expected a ZHR of 10–15 around 23^h34^m UT on 8 October 2018. An overview of all the predictions can be found in *Table 1* (source Egal et al.,2018).

Table 1 – Predictions for the Draconids 2018 (Egal et al.,2018).

| Modeller	Trail	$\lambda_\odot$ (°)	ZHR	Comment
Egal	Multiple	195.327	10 s	[1]
Maslov	1953	195.354-195.395	10-20	Dispersed, little activity
Vaubaillon	~	195.374	15	
Maslov	1953	195.378	10-15	
Egal	Multiple	195.390	10s	[2]
Ye	~	195.4	~	Nodal footprint offset, activity like 2012?
Kastinen & Kero	~	195.4	~	Possibly 2x higher activity than in 2011
Sato	1953	195.406	20-50	Dispersed dust
Vaubaillon	Multiple	195.415	15	
NASA MEO	Multiple	195.416	~	Weak to modest activity
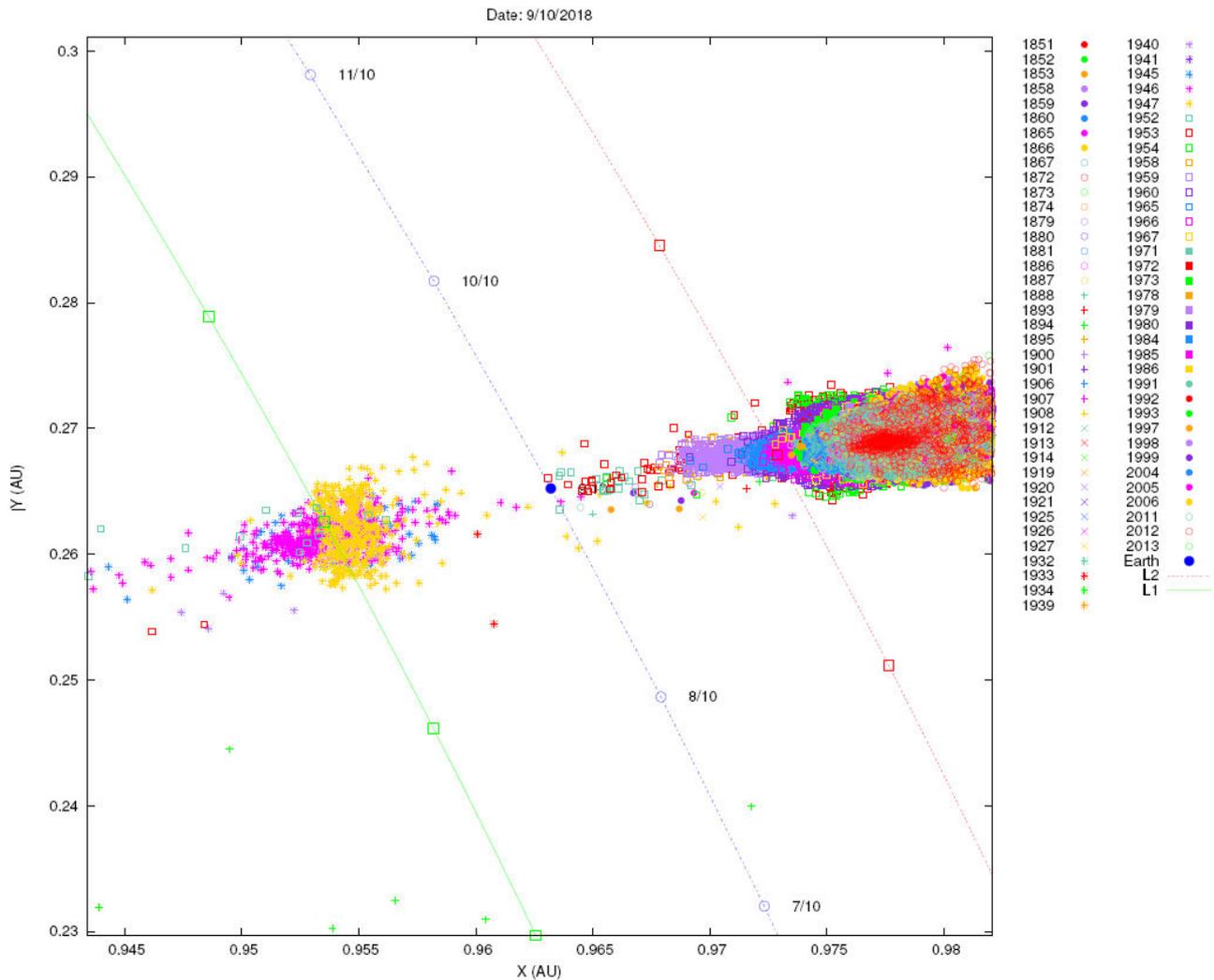
Figure 1 – Draconid meteoroid nodal crossings close to the Earth's orbital plane on 8–9 of October 2018. Each symbol indicates a particles ejection epoch (legend) while the Earth's path is shown in blue with L1 in green and L2 in red. Figure and text from (Egal et al.,2018).

Interesting is the prediction of Egal et al. She states that the Earth moves through a hole in the denser parts of the Draconids that was struck by the passage of the Earth through the dust trail in 1985 (see *Figure 1*).

For these reasons, the expectations were not very high. Nevertheless, a few observers decided, if necessary, to travel great distances to be able to observe something. The reason for this was that the comet had its perihelion a month earlier on September 10, 2018. That gave some hope for higher activity than had been predicted. And they were not disappointed!

3   8–9 October 2018

As the night falls over Europe, the already active observers observed low but clearly detectable Draconid activity. The ZHR during the first hours was around 10. Just after 21^h UT the activity started to rise. A rapid increase that continued until just before 23^h UT. Most observers then reported considerable activity, even though the radiant was already low in the northwestern sky. Some reports from the field:

Jure Atanakov from Slovenia: "*Observed 22:40-00:44 UT under mediocre conditions, LM about 6.5 and variable cloud cover (0-40%). Peak seemed to be around 23:00-23:20 UT. Rates were probably >100/h, even with the radiant below 30 degrees. Will be surprised if peak ZHR is not around several hundred. Possible secondary peak around 00:00 UT.*"

Michel Vandeputte from Belgium: "*A lot of faint stuff; but also, nice events, sometimes nice very white appearances with flares: the typical 'fragile' Draconid. The activity remained long time stable and modest until suddenly activity started to pick up; a period when about one per minute appeared. The outburst had materialized well in advance of the predicted observing window. However, it did not remain with just short pulses. The activity increased further out of nothing, multiple meteors were seen per minute, even two or three at the same instance! Yes, this was going hard: probably getting at a ZHR of about 100, certainly considering the low position of the radiant! Everywhere nice long meteor trails appeared at the sky thanks to the decreasing radiant position. Not only faint stuff, but sometimes very nice meteors up to –2, even one small fireball!*"

Kai Gaarder from Germany: "*A short update from me before heading for the train station: 7 hours and 15 min of observations under variable, but quite good observing conditions. 300 meteors observed, among them 191 Draconids. Clearly a good outburst from 21:00 onwards, with uncorrected hourly rates of 34, 57 and 53 the next 3 hours! This was real fun, and a big success!*"

When the night falls over America, high Draconid activity is visible, also thanks to the high radiant level. Well-known meteor observers such as *Paul Jones*, *Bruce McCurdy* and *Pierre Martin*[3] see impressive numbers of Draconids that decrease over time (Martin, 2019). And when it finally gets dark on the west coast of America (including *Wesley Stone* observations), the activity has virtually disappeared.

Figure 2 – Five bright Draconids captured with CAMS 354 camera. All these Draconids showed fragmentation (flares). CAMS 354 camera (CAMS Benelux network) is located at Ermelo, the Netherlands and is operated by the author. The picture shows the constellation of Auriga.

Figure 3 – Draconid outburst in full progress! These Draconids were captured on 8 October 2018 between 22^{h}00^m-00^{h}00^m UT with CAMS 351 camera (CAMS Benelux network), located at Ermelo, the Netherlands and is operated by the author. The bright star in the middle is Kochab (beta Ursa Minor).

4   Processing of the data

The author obtained a lot of data via the IMO website. The author also received a lot of data from a few observers who do not report to IMO. The ZHR curve shown on the IMO website[4] is based on 2074 Draconids collected by 39 observers. For the determination of the population index *r* many observations could be used, as well as for the ZHR values.

5   Population index r

After an extensive check of the magnitude distributions supplied by the observers, a total of 1075 Draconids remained that could be used to determine the population index *r*. An attempt has been made to obtain the evolution of the population index *r* during the period of 8 October 2018, 18^{h}00^m UT until 9 October 2018 06^{h}00^m UT. For this evaluation *r*[0;5] was the most suitable magnitude range. This resulted in *Table 2*. No real trend emerges from the result but rather a slightly variable *r* value.

Table 2 – Population index r Draconids 8/9 October 2018.

Period UT		r[0;5]
08/10/2018	18^h – 22^h	3.47
08/10/2018	22^h – 00^h	3.14
09/10/2018	00^h – 02^h	3.39
09/10/2018	02^h – 06^h	3.09
Mean		3.3

6   ZHR

The ZHR was determined with a mean r value of 3.3. For this purpose, counting periods of 10–15 minutes were used and these were always calculated in overlapping periods. A total of 2763 Draconids have been used for the ZHR analysis. This resulted in *Figure 4*.
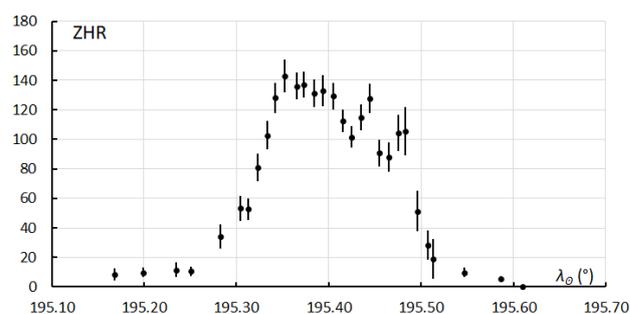
Figure 4 – ZHR profile for the Draconid outburst of 8–9 October, based on a population index r = 3.3 and zenith attraction γ = 1.0.

What is clearly noticeable in the graph is the fast but gradual increase in activity to the maximum around $\lambda_{\odot}$ = 195.35° (8 October 2018 just before 23^h UT). After that, a flat activity follows until 0^{h}15^m UT, after which the activity with two strong sub-peaks drops back to $\lambda_{\odot}$ = 195.44° (9 October 01^{h}07^m UT) and $\lambda_{\odot}$ = 195.48° (9 October 2018, 02^{h}09^m UT). Then the ZHR drops quickly to 10. Impossible to explain what has caused these subpeaks. The predictions from *Table 1* were expected in the period from $\lambda_{\odot}$ = 195.35°

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[3] https://www.meteornews.net/2018/11/13/observation-october-8-9-2018-draconids-outburst-from-indiana-u-s-a/

[4] https://www.imo.net/members/imo_live_shower?shower=DRA&year=2018

to $\lambda_{\odot}$ = 195.42°. That is exactly the period with the 1st peak followed by the flat ZHR.

In addition, a few Draconids were observed visually as well as with CAMS in the night before (Europe) and after (Europe and US).
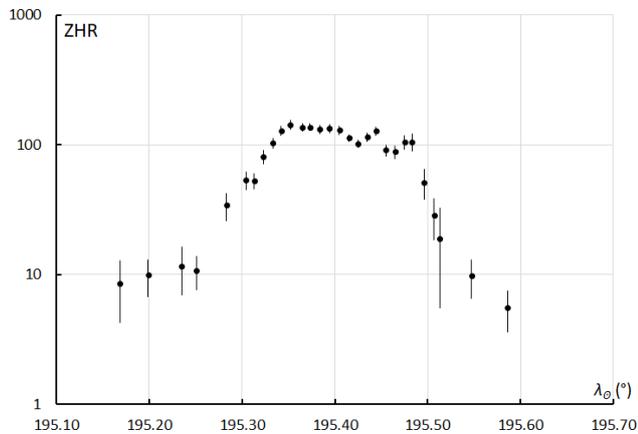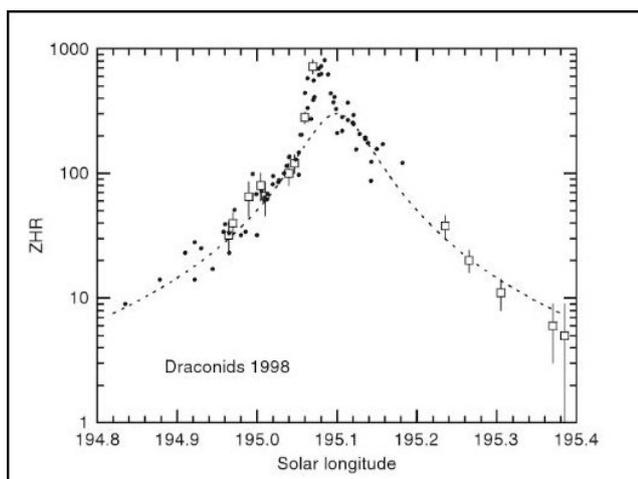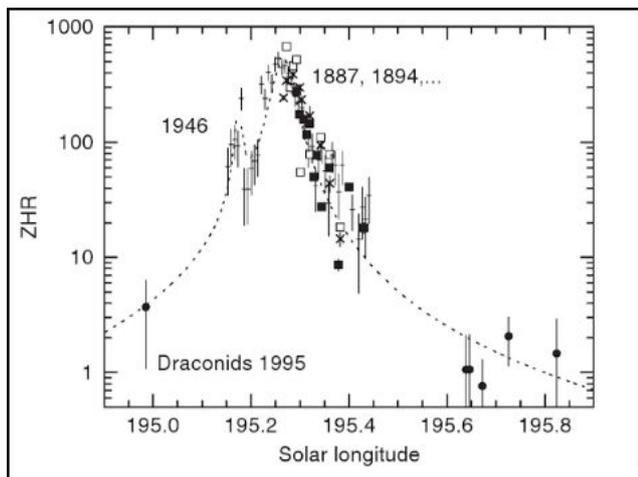

Figure 5 – The same profile as Figure 2 of the Draconids ZHR in 2018, but on a logarithmic scale to compare the ZHR with figures 6a and 6b

Figures – 6a and 6b ZHR graphs of the Draconid outbursts in 1985 (top) and 1998 (bottom) from (Jenniskens, 2006).

What is striking about this curve is that we are looking at a ZHR curve with a nice increasing wing between $\lambda_{\odot}$ = 195.27° to $\lambda_{\odot}$ = 195.35° and a nice decreasing wing between $\lambda_{\odot}$ = 195.44° and $\lambda_{\odot}$ = 195.52°. In between we see a rather slightly variable activity. Comparing this graph with that of 1985 and 1998 *(Figures 6a and 6b* from Jenniskens, 2006), a clear peak is visible in both graphs for 1985 and 1998. The graph from 2018 *(Figures 4 and 5)* clearly shows a "capped" ZHR curve without a sharp peak. So here we see the result of the passage of the Earth through the dust trail of 21P in 1985! The activity curve is the sum of the activity of the various disturbed and thus thinned dust trails.

This analysis seems to be supported by the observations of the CAMS BeNeLux network. We see a large diffuse radiant here *(Figure 7)*. An extensive analysis of the CAMS data may perhaps bring more clarity about the possible dust trails that caused this outburst.
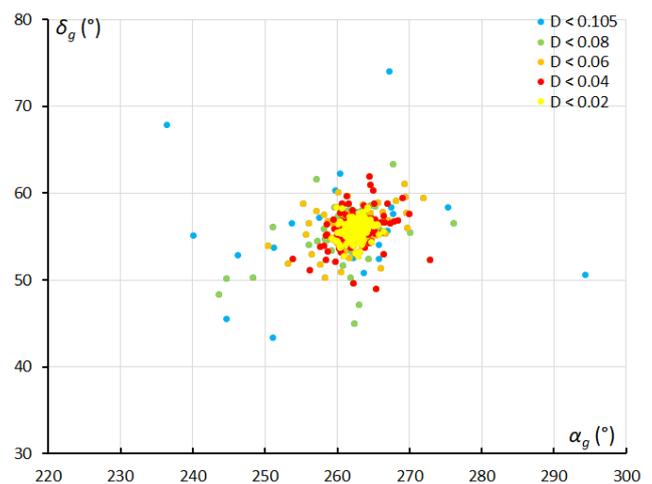
Figure 7 – All radiant positions of the Draconids 2018 outburst as recorded by CAMS BeNeLux network.

7   Conclusion

The Draconids showed a nice outburst in 2018. The activity was much higher than predicted. The resulting ZHR curve shows a rather irregular activity of the Draconids during the outburst, as a result of the passage of the Earth through the dust trail in 1985!

Acknowledgment

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The η-Aquariids (ETA#031)

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In this article we find 1073 Eta Aquariid meteor orbits obtained by CAMS BeNeLux in 2018 combined with the public CAMS data 2011-2012, that fulfil the low threshold D-criteria. We find 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.

1   Introduction

Exceptional good conditions around the maximum of the η-Aquariids resulted in a rich collection of η-Aquariids at our rather northern latitude. There was not a single night in the entire month of May without multiple station meteors.

Around the maximum of the shower, the number of multiple station events collected by our network was on average about 165 per night in 9 nights of the first decade, with the night 9–10 May as exception. In that night only 20 multiple station events were recorded.

As the month of April already had a lot of clear nights, this was a great opportunity to establish the radiant drift of this shower using the data that CAMS BeNeLux collected in 2018 together with the data that can already be found in the CAMS database (Jenniskens et al., 2016).

2   Available data

The CAMS database (2010 – March 2013) and data from CAMS BeNeLux were selected for the analysis from April 15 to June 1. In total, 17223 orbits were available during this period.

The orbital elements from Jenniskens et al. (2016) were used as reference orbit for the η-Aquariids.

Next, the discrimination criterion of Drummond (1981) determined which orbits could be considered as η-Aquariids. In total we found 1073 orbits with $D_D < 0.105$, and another 504 orbits within the following intervals:

- $320° < \alpha_g < 360°$;
- $-10° < \delta_g < +10°$;
- 55 km/s $< v_g < 75$ km/s.

The orbits of the η-Aquariids were divided into five D-criterion classes:

- low ($0.08 < D_D < 0.105$)
- medium ($0.06 < D_D < 0.08$)
- medium high ($0.04 < D_D < 0.06$)
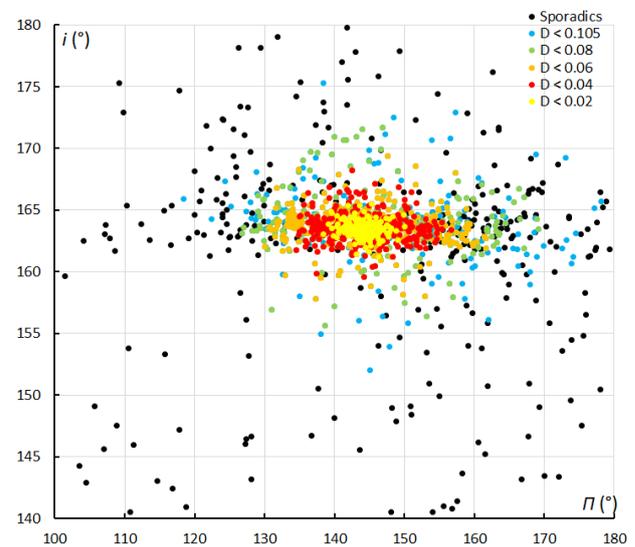
- high ($0.02 < D_D < 0.04$)
- very high ($D_D < 0.02$)

Figure 1 – Plot of the inclination i versus length of perihelion Π for the 1073 η-Aquariids and 503 non η-Aquariids.

If we look at the plot of Π versus i of these 1073 orbits (*Figure 1*), divided into these five classes, we see a concentration of orbits in the center with $D_D < 0.02$ with an increase of orbits outwards with lower D-criterion classes. A gradual smearing out of the shower orbits with the sporadic orbits seem to occur.

In that light it is interesting to see if there is a link between the D_D-value of an η-Aquariid and the Solar Longitude $\lambda_\odot$ at which this meteor appeared. In *Table 1* these data are shown for the 5 D_D classes.

Those meteoroids with higher values of the D-criterion were probably long ago released by the comet, and by planetary perturbations, and for the smaller dust particles effects of the solar wind, drifting further away from the parent body, resulting in increasing differences in orbital elements. This process continues until the particles can no longer be distinguished from the random sporadic background.

For a meteor stream with low inclinations this will probably occur fairly quickly, but for the ETAs the speed is quite distinctive due to the retrograde orbit, so that visual observers can still identify them, even relatively far from the maximum activity.

Table 1 – Number of η-Aquariids per D$_D$-class, per degree of solar longitude.

$\lambda_\odot$ ±0.5°	<0.105 >0.08	<0.08 >0.06	<0.06 >0.04	<0.04 >0.02	<0.02
31.5	1	0	0	0	0
32.5	0	0	0	0	0
33.5	0	0	0	0	0
34.5	0	0	0	0	0
35.5	1	0	0	0	0
36.5	1	1	0	0	0
37.5	1	2	3	0	0
38.5	0	3	5	0	0
39.5	5	6	7	2	0
40.5	4	10	9	7	0
41.5	6	8	19	15	0
42.5	7	11	20	22	2
43.5	7	12	17	37	11
44.5	8	11	10	20	16
45.5	16	20	22	50	39
46.5	15	13	24	47	59
47.5	12	11	15	20	24
48.5	12	6	12	13	10
49.5	2	12	18	33	5
50.5	8	3	19	31	0
51.5	10	11	11	16	0
52.5	3	6	12	4	0
53.5	2	1	9	2	0
54.5	1	8	10	0	0
55.5	5	7	9	0	0
56.5	0	2	1	0	0
57.5	6	4	1	0	0
58.5	3	7	0	0	0
59.5	0	4	0	0	0
60.5	7	2	0	0	0
61.5	0	0	0	0	0
62.5	3	1	0	0	0
63.5	4	0	0	0	0
64.5	1	0	0	0	0
65.5	1	0	0	0	0
66.5	0	0	0	0	0
67.5	0	0	0	0	0
68.5	1	0	0	0	0
69.5	0	0	0	0	0

3   The radiant drift

For the η-Aquariid orbits we found the following numbers in each D_D -class:

- $D_D < 0.020$;   165 orbits
- $D_D < 0.040$;   485 orbits
- $D_D < 0.060$;   737 orbits
- $D_D < 0.080$;   920 orbits
- $D_D < 0.105$; 1073 orbits

For each of the η-Aquariids in these classes, both the right ascension and the declination were plotted against the solar longitude. Subsequently, by means of the least-squares method, a best linear fit was determined through the points with corresponding standard deviation (Doom and Bouma, 2018).

The differences between all five classes are small for the drift in right ascension as for the drift in declination. All the values are mentioned in *Table 2*.

Table 2 – Radiant drift with ± σ for the η-Aquariids obtained from the orbits for each threshold level of the D-criteria compared with a reference from literature.

Threshold/source	ETA – 031	
	$\Delta\alpha / \lambda_\odot$	$\Delta\delta / \lambda_\odot$
Low	0.72 ± 0.01	+0.33 ± 0.01
Medium low	0.71 ± 0.01	+0.32 ± 0.01
Medium high	0.71 ± 0.01	+0.32 ± 0.01
High	0.72 ± 0.01	+0.32 ± 0.01
Very high	0.76 ± 0.02	+0.34 ± 0.02
Jenniskens et al. (2016)	0.92	+0.37

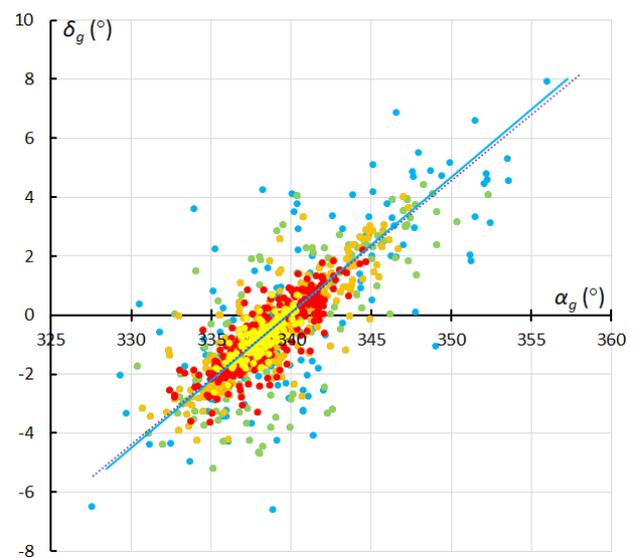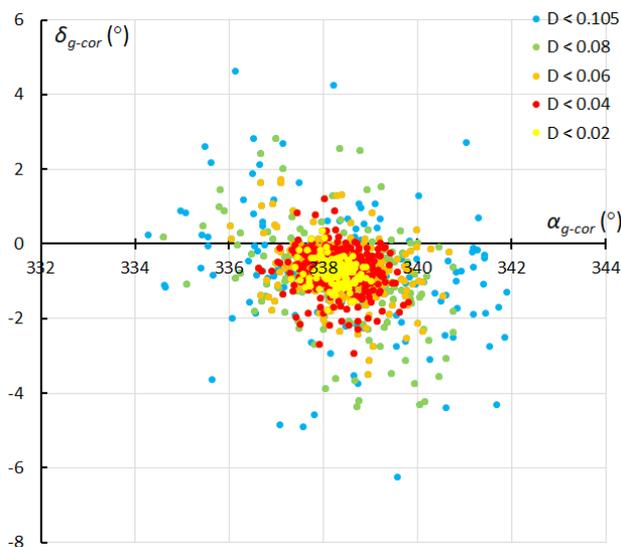*Figure 2* – The radiant positions of the η-Aquariids orbits in equatorial coordinates. The colors indicate the similarity class like in Figure 1. The linear regression for the radiant drift for all orbits with D$_D$ < 0.105 is plotted in blue, for D$_D$ < 0.02 as a dotted line.

The radiant positions of the η-Aquariids orbits in equatorial coordinates are plotted in *Figure 2* together with the linear

regression line for the low similarity class (blue line) and for the very high similarity class (dotted line).

The radiant drift corrected positions for all η-Aquariids are plotted in *Figure 3*. Also, here we see the concentration of orbits with $D_D < 0.02$ as mentioned above, in the center, with more orbits of the lower similarity classes towards the edges.

If we select all 1073 η-Aquariids plotted in *Figure 1*, adding a color gradient to show the variation in geocentric velocity, we see a remarkable concentration of slower η-Aquariids at left and another distinct concentration with faster η-Aquariids at right (*Figure 4*). We don't have yet an explanation for these slower and faster η-Aquariids concentrations. This point may need further investigation.

Figure 3 – The radiant drift corrected positions for the η-Aquariids orbits in equatorial coordinates.
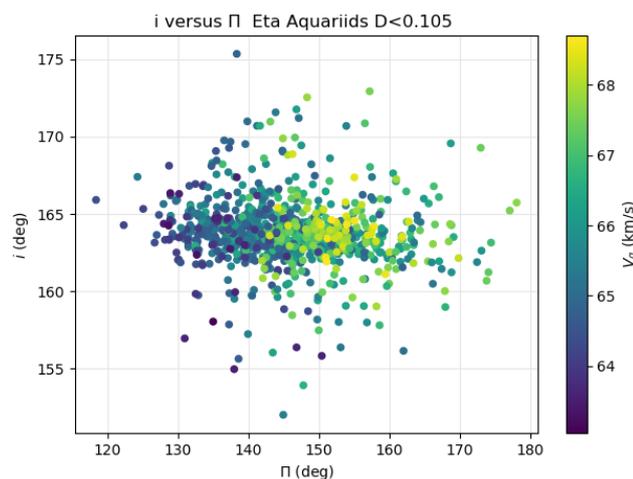
Figure 4 – The inclination i against the length of the perihelion Π with a color gradient to show the spreading on the geocentric velocity.

4   Conclusion

We find a radiant drift $\Delta\delta / \lambda_\odot$ of 0.34° in good agreement with the values obtain by Jenniskens et al. (2016). For the drift in Right Ascension we find a slightly smaller value than Jenniskens et al., $\Delta\alpha / \lambda_\odot = 0.76$°.

Far ahead of and far behind the maximum activity we find barely any more orbits with a similarity value of $D_D < 0.04$.

These are probably particles that got further away from the parent body due to planetary perturbations, with as a consequence increasingly deviating orbital elements.

Two remarkable concentrations of slower and faster η-Aquariids need further investigation to find an explanation.

Acknowledgment

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Overview of meteor observations in 2018

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An overview is given of the author's meteor observing activities in 2018 and the expectations for 2019.

Figure 1 – A sporadic fireball of magnitude –6 was captured on 8 October 2018 at 00:30:34 UT (timing CAMS Benelux). Camera: Canon 6D. Lens: Sigma 8 mm F 3,5 fish eye. The Liquid Crystal Shutter was set at 12 breaks per second.

1   Overview 2018

For 2018 I can look back on a very successful year. I could observe the following meteor showers: the Lyrids, eta Aquariids, Perseids, Draconids, Leonids and Geminids. There are only few years in which that was possible in the Netherlands.

Besides the many observations in Ermelo, the Netherlands, I could also observe from dark locations in northern and southern France (respectively Any Martin Rieux in June and Aubenas Les Alps in August) and in Spain (Geminids from Observatorio Del Teide, Tenerife).

All these activities resulted in 57 different sessions in which 145.97 hours were observed. In total I counted 3857 meteors in 2018, making this a far above average year. I saw 23 fireballs (meteors of magnitude –3 or brighter), the brightest a Geminid of –8.

Highlights were the pre-maximum night of 13/14 August 2018 when we saw more than normal numbers of Perseids and the Geminids I observed from the Del Teide observatory together with *Carl Johannink*, *Peter van Leuteren* and *Jürgen Rendtel*. But the Draconid outburst of 8/9 October was also a pleasant surprise!

The all sky camera and CAMS systems also recorded many fireballs and thousands of meteors in 2018.

2   Plans for 2019

2019 will be a quieter year in terms of visual observations. After all, most meteor shower activity peaks around Full Moon (except the Bootids). 2019 is therefore a great year to recharge the batteries for 2020!

In 2019 I will stop making eRadiant due to an increasing lack of time. Fortunately, at my request *Hans Betlem* will take over this work. He was the founder and editor of the old paper Radiant (1979-2002), Journal of the Dutch Meteor Society. However, I will certainly continue to make meteor shower activity analyzes: the Draconids 2018 have just been completed and I am already well on the way with the Perseids 2018. There will also be extensive analyzes for the Leonids 2018 and the Geminids 2018. These will be published in eRadiant (Dutch language) and eMeteornews (English language).

I wish all observers many clear skies and a healthy and successful 2019!

Perseid campaign at Aubenas Les Alpes, Haute Provence

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An activity report is presented about the 2018 Perseid observing expedition in southern France.

1 Introduction

The year 2018 will enter the books as a peculiar weather year. High pressure areas reigned very long over northern Europe with great drought and real heat waves as a result. The corner in the southeast of France was just clamped in the 'saddle area' between the high pressure from the Azores and northern Europe. This generated rather a changeable weather type with episodes of unstable heat including a lot of thunderstorms and showers. In between also quieter moments when high pressure had more influence on the Provence region. The big drought and heat, as we were confronted in 2017 (including severe forest fires) in the Provence, was not at all an issue this year. Yet we were once again lured to the Provence thanks to the extremely favorable observation conditions at astronomical level: New Moon on 11 August.

2 First week

Present at Aubenas les Alpes for a stay between 4 and 17 August 2018: *Carl Johannink*, *Casper ter Kuile*, *Karin and Jos Nijland*, *Koen Miskotte*, *Michel Vandeputte* and his family. Our rented house, 'les Escauffiers' is located at an altitude of 600m and towers above the valley of the river 'le Largue'. A very comfortable and spacious gantry equipped with the necessary cooling (pool!) to get through the warm days comfortably. In the field of nocturnal darkness, Aubenas les Alpes has exceeded our expectations by far. After all, the surrounding hills formed a perfect buffer for the limited light pollution of the neighboring villages of Reillane, Vacheres and St. Michel l'Observatoire (and at a safe distance of the larger towns of Forcalquier and Manosque). Also, Aubenas clearly had less trouble with

Figure 1 – The beautiful accommodation of the group of observers near Aubenas Les Alps. It was not until 10 August that the sky finally got that distinctive deep blue Provencal color!

orographic clouds triggered by the larger mountain ranges (Mont Ventoux and the Montagne de Lure) which form the barrier between the Provence and the inland.

Our first confrontation with the Provençal landscape was unusually green in 2018! And it became clear to us quite quickly how that came about. We knew in advance that the first week was going to be rather unstable and that the probability of doing observations might well be disappointing. But we lived on hope: around 10 August we expected a stabilization in the weather with nice opportunities for 11–12 August (the pre-maximum night). The maximum night itself bothered us a lot with bad weather predictions.

Figure 2 – Our rented house as seen from the observation site about a few hundred meters away of the house. We had an all sky view on the heaven on that place!

The first 2 evenings we had heavy thunderstorms. Somewhere this was a relief if you came from a Benelux heat wave … Unfortunately, these storms also had an impact on the night sky. For example, 05–06 August was completely lost in the remaining clouds after a heavy thunderstorm. On the night, 06–07 August, after the thunderstorm the sky gradually opened but was saturated with moisture. Nevertheless, we did some observations for a few hours until the moonlight was reflected too much over the humid air layers. The meteor activity was normal. Also, on 7 August the heat dominated the weather. And that again generated heavy thunderstorms above the mountain ranges of France. After the storms another 'soggy' sultry night sky followed (07–08 August). A true feast for the mosquitoes and other insects! This night we observed briefly. The observation conditions were very moderate, especially down to the horizon. Observations were therefore stopped quickly after moonrise. August 8 hardly scored better: sultry day with the formation of violent storms in the afternoon/evening. The result…once again a moist night

sky after solving the remaining clouds. And during this session even formation of low clouds in the valley which sometimes came up to the height of the cottage (600m). The light domes of the surrounding villages betrayed the bad observation conditions even more. Fortunately, it was still acceptable at a higher altitude in the night sky, with some observations done until the moonrise. Can the weather be worse in Provence? Yes, it can! 9 August was an unusual weather day during which an 'episode of Mediterranean' took place. This is a regional 'heavy weather' phenomenon which occurs normally in the autumn and winter when warm, unstable air from the Mediterranean Sea collides with cooler continental air from above the southern French relief (mainly the Cévennes, but also the Ardèche and the Provencal Alps). This results in stationary storms that gradually emerge as a curve over the entire southeastern (Mediterranean) part of France. The precipitation amounts can sometimes assume catastrophic proportions with heavy flooding. In this 'Episode' especially the Ardèche got it hard to endure with precipitation amounts of up to 200mm in a 24-hour period! In Aubenas it began to rain continuously from the late morning until midnight at varying intensity. From August 10, a temporary improvement in the weather was expected under the favorable influences of a spur of the high-pressure area of the Azores. Our weather forecasts were therefore fortunate …

Figure 3 – Groupphoto of the Perseid 2018 team. F.l.t.r. Casper ter Kuile, Rientje, Koen Miskotte, Boris, Inneke Vanderkerken, Karin Nijland, Jos Nijland, Michel Vandeputte and Carl Johannink (photo-credit).

3   Aubenas Les Alps at its best!

Fortunately, it was not all trouble in the Provence … In the night from 09 to 10 August there was a slight Mistral wind. It blew away all the clouds and opened the entire sky in a short period of time, in which we were able to observe unexpectedly! An excellent night sky awaited us; finally, the night sky that we wanted to see from Aubenas! The Milky Way and the zodiacal light popped out at SQM values rising to 21.5. Due to the amount of humidity some lower clouds were formed in the valley for a while; but with one small attempt, this mess was hanging down nicely, partly under pressure from the deploying Mistral wind. Many meteors were seen. The Perseids showed also many bright meteors up to the magnitude –4 class. No interference of the moon this night, because moonrise was during the morning twilight. The good intentions regarding the weather were also prolonged during the day on 10 August: sunny, a deep blue Provençal sky with a tight Mistral wind on top. The night of 10 to 11 August then also went completely cloudless and crystal clear with SQM values again rising to 21.5. We were able to observe for a longer time for the first time during our stay, an undisturbed meteor session until the morning twilight arrived. The Perseids activity had increased further; but especially rich in weak meteors and a rather gusty activity. Exactly what you can expect at this time in August. Of course, also a few nice meteors were seen up to magnitude –4.

Figure 4 – This beautiful Capricornid of magnitude –3 was observed on 12 August 2018 around 02ʰ03ᵐ UT. Camera: Canon 6D. Lens: Canon 8-15 mm F 4.0 zoom fish eye lens. ISO: 2500, F: 5.0, 8 mm, Exposure time 58 sec.

Also, August 11 was a beautiful summer day at temperatures rising to 30° and a moderate Mistral to give the necessary cooling. We also had good weather during the night 11 on 12 August. We started observations early because we knew that the maximum night would more than likely become a fiasco. Unfortunately, the wind started to linger as the night progressed. This slightly reduced the quality of the night sky compared to the two previous nights. The SQM values stayed around 21.3, at the end of the session a bit better. Of course, everyone went for a longer observation session and observed a beautiful, once again gutsy, Perseid activity. In the morning a lot of meteors were visible with on average one Perseid per minute (roughly ZHR ~ 50 to 60). There were also several bright meteors up to –4 with a cluster in the period 23ʰ00ᵐ – 23ʰ30ᵐ UT. The Capricornids also managed to produce a nice, long meteor of magnitude –3. There were very satisfied faces after this session!

4   An eventful maximum night!

The weather during daytime on 12 August did not really suggest that the maximum night would go down in the clouds. This Sunday was very warm and sunny with some classic shallow cloud turrets in the afternoon. This gave us a little hope: but the satellite images told another story. There was an immense cold front approaching from a British depression that reached to the south of Spain. August 12–13 approached. The sultry wind continued further from the southern corner and yet the night seemed to start with a clear sky! We did not hesitate for a minute to start from the twilight in the evening. At 19ʰ58ᵐ UT (!), when hardly any stars were visible, a first beautiful Perseid earth-grazer appeared through Pegasus. At 20ʰ02ᵐ UT an extremely long and very beautiful magnitude –4 Perseid earth-grazer appeared with an extremely long path between Cassiopeia to the northern parts of Sagittarius. Everyone screamed! In that first early hour (20ʰ00ᵐ – 21ʰ00ᵐ UT) several earth-grazers of negative magnitude followed. It quickly became dark: SQM increased to almost 21.5. But we could not escape the cirrus which now resolutely made its advance from the west. This announced the approaching

cold front on which a violent storm had formed over the southern French departments of Herault and the Gard. That thunderstorm slowly moved towards the Haute Provence. The stroboscopic storm increased dramatically in intensity. *Jos* observed a 'sprite' with the naked eye above the gigantic anvil over the western horizon. The eastern and northern sky remained the longest free, so we could even observe until 23ʰ UT. An unexpected three-hour session during this maximum night. This was a very peculiar experience. The Perseids activity increased strongly in force in the clear sky over the north and east while it flashed very bright on all other sides. After 23ʰ UT the last clearings disappeared to the east and we could go to sleep. The whole night long there was intense lightning; but it was not until the morning that the active system passed with rain and thunder. In the morning we were all equally awakened by two huge booms …

5   A Big Surprise during the post maximum night!

August 13. During the day it soon became drier with varying clouds. In the evening the clouds increased again with approaching new storm cells over the southwest of France and cells over the Alps. We did not expect making observations that night. We were rather looking forward to the first clearings by the morning: putting an alarm here was the message. Although the author sleeps very frequently in waking mode, from his window he saw the stars of the Big Bear sparkling in the night sky just before midnight. WOW: it had become completely clear! Not immediately a top sky such as 10–11 and 11–12 August, there was still too much moisture in the lower air layers. But we could immediately start the observations! Fifteen minutes after midnight local time, *Koen* and the author lay under the clear sky with another 5 hours of observing pleasure ahead of them. *Jos* and *Carl* started a bit later. The Mistral wind blew weakly at the start of the session. Then it lay down for a while and from 02ʰ UT onwards, literally started to blow violently from scratch and thus creating top conditions in the end of this session.

Figure 5 – The spectaculair earth-grazing Perseid of 12 August 2018 20ʰ02ᵐ UT in an even light sky. Visually, the meteor was already noticed in Cepheus and moving to the northern parts of Saggitarius! Camera: Canon 6D. Lens: Canon 8-15 mm F 4.0 zoom fish eye lens. ISO: 2500, F: 5.0, 8 mm, B = 58 sec.

The Perseids were quite active. The first hour was almost normal; but then the Perseids started to appear more and more! They came in strong gusts with sometimes multiple meteors per minute. In fact, this even went unusually hard for a post maximum night! Most of the meteors were relatively weak, but a nice –5 Perseid appeared in the Big Dipper. Everyone observed a lot of meteors! For example, the author had a top quarterly count between 02ʰ15ᵐ and 02ʰ30ᵐ UT with a whopping 39 Perseids and counted 102 Perseids in the last hour before dusk. In total, almost 400 Perseids were counted in 5 hours observation time! This quantity you only see in a good regular maximum night! Preliminary ZHR calculations show that the activity peaked at 90 to 100 in this night which is a remarkable amount for a post maximum night. This nice activity was also confirmed internationally by other observers from the European continent. 03ʰ15ᵐ UT: the morning twilight came fast now. Very clear sky, the first winter constellations already appeared above the eastern horizon … a fresh Mistral wind … everyone turned into bed very satisfied. We had enjoyed such a beautiful meteor activity so much! Moreover, we were lucky to be present in Aubenas. After all, many low – orographic – clouds had formed over the mountain massifs north of us; a typical local phenomenon when sometimes a hard Mistral wind blows. A stay in Revest had more than likely been a less successful story …

6 Beautiful final nights from Aubenas

August 14, the combination of the Azores high pressure and a small Genoa depression over Italy also created top conditions in the night of 14–15 August. The Mistral, which came out hard during the day, gradually started to linger. Without any headaches regarding the weather we could observe meteors to our heart's content. And a lot was seen! The Perseids activity was still quite worthwhile with a rather gutsy activity: quiet moments sometimes alternated with nice and firm activity.

Figure 6 – The best capture of this Perseid expedition. This Perseid of –6 appeared on August 16, 2018 at 00ʰ02ᵐ UT. Camera: Canon 6D. Lens: Canon 8-15 mm F 4.0 zoom fish eye lens. ISO: 2500, F: 5.0, 8 mm, Exposure time 58 sec.

We also had beautiful observation conditions in the night of 15–16 August, which was opened greatly to Jos and Koen with a beautiful –6 Perseid fireball. Unfortunately, in the morning, from the north, there were some orographic high clouds, because of which the

observations had to be aborted prematurely. Also, in our last night (16–17 August), three hours were observed for the morning twilight under very good observing conditions. The Perseids declined further in strength. And for the last time we went with all our equipment (Koen's all sky camera, field beds, sleeping bags and other things) from our observation area towards the house, enjoying the morning twilight for the last time. Saying goodbye to Perseus and his Perseids, the rising winter constellations and a weak Mistral wind which whispered in our ear: you will return to Provence anyway?

Figure 7 – Composition of images shot between 00ʰ27ᵐ and 01ʰ27ᵐ UT on 14 August 2018. The brightest meteors are magnitude –4. Camera: Canon 6D. Lens: Canon 8-15 mm F 4.0 zoom fish eye lens. ISO: 2500, F: 5.0, 8 mm, exposure time 58 sec.

Table 1 – Overview of all individual observations made from Aubenas Les Alps, Haute-Provence, France.

Date	Observer IMO-code	Period UT Start	Period UT End	T_{eff}	Mean Lm	PER	SDA	CAP	KCG	ANT	SPO	Total
06–07	JOHCA	21:12	23:12:	2.00	6.5	8	4	0	–	–-	17	29
	MISKO	21:20	00:31	3.08	6.6	31	7	1	–	1	34	74
	VANMC	21:35	01:35	4.00	6.6	39	2	3	1	–	45	90
07–08	NIJJO	23:00	01:18	1.82	6.3	18	3	0	1	–	22	44
	VANMC	23:25	01:25	2.00	6.5	28	3	0	2	–	31	64
08–09	JOHCA	22:45	00:30	1.75	6.5	16	4	2	–	–	17	39
	MISKO	23:00	02:12	2.73	6.5	33	4	3	0	1	29	70
	NIJJO	23:20	01:18	1.83	6.3	16	1	1	1	–	17	36
	VANMC	22:55	02:15	3.00	6.5	34	0	2	3	–	25	64
09–10	MISKO	00:54	03:15	2.29	6.7	54	4	1	0	2	40	101
	VANMC	00:45	03:15	2.50	6.8	59	2	0	1	–	59	121
10–11	JOHCA	23:00	02:15	3.08	6.5	60	7	3	–	–	51	121
	MISKO	22:51	03:15	4.20	6.7	129	2	1	2	4	56	195
	NIJJO	22:53	22:53	0.14	6.6	120	2	3	10	–	74	209
	VANMC	22:45	03:15	4.50	6.7	128	1	2	8	–	84	223
11–12	JOHCA	23:23	02:53	3.50	6.5	95	4	2	–	–	78	179
	MISKO	22:49	03:18	4.37	6.7	234	4	3	2	–	46	292
	NIJJO	22:49	03:15	4.32	6.5	162	3	4	17	–	64	250
	VANMC	22:15	03:15	5.00	6.6	236	4	2	5	–	53	300
12–13	JOHCA	20:15	23:00	1.63	6.5	44	4	0	1	–	34	83
	MISKO	20:02	23:00	2.52	6.5	71	0	2	2	0	29	104
	NIJJO	20:10	22:45	2.00	6.4	56	1	3	6	–	29	95
	VANMC	20:00	23:00	3.00	6.5	128	0	1	1	–	22	152
13–14	JOHCA	01:55	03:10	1.25	6.5	65	3	1	0	–	23	92
	MISKO	22:20	03:20	4.93	6.7	365	4	3	3	0	65	440
	NIJJO	23:20	03:24	4.07	6.7	316	1	5	20	–	93	435
	VANMC	22:15	03:15	5.00	6.7	393	–	1	7	–	60	461
14–15	JOHCA	23:55	02:45	2.83	6.5	62	2	2	0	–	52	116
	MISKO	23:14	03:18	4.00	6.7	125	3	0	8	3	61	198
	NIJJO	23:08	03:20	4.17	6.7	128	2	5	18	–	81	234
	VANMC	23:10	03:10	4.00	6.7	134	–	3	9	–	78	224
15–16	MISKO	23:15	02:50	3.52	6.6	72	2	3	4	3	53	137
	NIJJO	23:44	02:50	3.00	6.4	42	4	3	18	–	50	117
	VANMC	00:10	02:10	2.00	6.6	41	–	1	0	0	40	82
16–17	MISKO	00:19	03:20	3.00	6.6	45	2	3	3	3	43	99
	VANMC	00:16	03:16	3.00	6.7	36	–	4	4	–	75	119
Totals	**4**			**110.03**		**3623**	**89**	**73**	**157**	**17**	**1730**	**5689**

Draconid observations 8–9 October 2018

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An overview is given of the author's observations of the Draconids in 2018, including the outburst.

1   Introduction

Modelers expected some low but detectable activity from the Draconids for 2018. However, the comet passed through perihelion a few weeks earlier and perhaps there was more to see than predicted. I had not asked for a couple of free days from work because no exceptionally high activity was predicted. I was able to do a first short Draconid session on Sunday evening 7 October.

2   October 7, 2018

In the evening of 7th of October the sky was filled with cirrus clouds. But they disappeared after a while and in the period of 19^{h}32^m until 20^{h}32^m UT I could visually observe meteors. My four CAMS cameras (CAMS 351, 352, 353 and 354) and the all sky camera already were taking movies and pictures of the sky. I observed from the flat roof of my dormer. In an effective observing time of 60 minutes I counted 7 meteors. The sky was of moderate quality with a decreasing limiting magnitude from 6.1 to 5.7 and some incoming cirrus (F = 1.05).

Figure 1 – Composition of two CAMS recordings of the Draconid of 7 October 2018 at 20^{h}16^{m}16^s UT.

I was observing just a few seconds when at 19^{h}32^{m}37^s UT a nice slow magnitude +1 meteor appeared from Cepheus to Cassiopeia. Immediately I thought of a Draconid, but after carefully examining the path between the stars, I dismissed the idea. This meteor was also multi-station captured by some CAMS BeNeLux stations and after calculations carried out by our network

coordinator *Carl Johannink* it appears that this was indeed not a Draconid.

A second bright meteor did have the correct characteristics of a Draconid. At 20^{h}16^{m}16^s UT, an orange +2 meteor slowly moved slightly from the right of Polaris towards the star Capella. Direction and speed were correct, so I recorded it as a Draconid. The nice thing was that this meteor appeared in the image field of CAMS 353 on two consecutive registrations. This meteor was also recorded by other CAMS BeNeLux stations and the obtained orbital elements were tested with the D criterion, which clearly showed that this was a Draconid meteor.

The third fine meteor appeared at 20^{h}24^{m}38^s UT. I classified this magnitude 0 meteor as a southern Taurid (STA). The meteor moved from the constellation Perseus to Camelopardalis. This meteor was also captured with one of my CAMS cameras (354) and from other CAMS BeNeLux stations. Although the calculated radiant position is very close to the position of the STA, a comparison with the D-criterion shows that this was not a STA. Classifying such meteors visually is of course very difficult!

Figure 2 – Composition of two CAMS recordings of the "fake" Southern Taurid of 7 October 2018 at 20^{h}24^{m}38^s UT.

A total of 7 meteors were observed, 1 Draconid, 1 Delta Aurigid and 5 sporadic meteors[5]. Thanks to the beautiful meteors this was a nice session. After this session, I set the alarm twice to see if the starry sky was clear enough. Unfortunately, the cirrus clouds remained present

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[5] https://www.imo.net/members/imo_vmdb/view?session_id=77626

throughout the night. The CAMS and all-sky systems did run all night. A thank you to Carl Johannink for doing the calculations cited above.

3   8–9 October 2018

Again, the observations were made from the flat roof of my dormer. A night with every now and then a lot of cirrus. Yet several observing attempts were made. The first session was from 18h28m to 19h33m UT[6]. After 19h33m UT the cirrus became too thick to do useful observations. Clearly detectable Draconid activity was seen during that period despite the moderate conditions. The *lm* increased from 5.9 to 6.0 decreasing again to 5.7. SQM did not exceed 19.57. Yet I observed 6 Draconids of resp. +3, +4, +2, +3, +4 and +4.

After this short session I took a short sleep and set the alarm at 23h00m UT.

23h UT: a quick look outside: the sky was "clear". There was some cirrus but the *lm* was pretty good: 6.0. As soon as I started the observations at 23h15m UT[7] the first Draconids were seen. Despite the low limiting magnitude and the thin cirrus, the Draconids were clearly active!

Although the cirrus was variable, just like the *lm* (between 5.8 and 6.1) I could observe until 01h46m UT. In those 2.50 effective observing time I saw 48 DRA, 3 DAU, 3 STA and 18 SPO (a total of 72 meteors). Not the numbers of other known observers, but that says a lot more about the bad circumstances at Ermelo that night. Draconids are beautiful meteors, they look fragile, sometimes with multiple flares and fragmentation. The most beautiful Draconids were of course the brighter ones. For example, a beautiful –1 Draconid was observed by me and captured by CAMS 354 (*Figure 2*).

Looking back at this, I could have started a little earlier, but this was the maximum feasible given the fact that I had to work again the 9th October during the day. It is a nice feeling that I have seen the Draconid outburst of 2018.

Figure 3 – The Draconid outburst in full progress! These Draconids were captured on October 8, 2018 between 22h and 00h UT.

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[6] https://www.imo.net/members/imo_vmdb/view?session_id=77627

[7] https://www.imo.net/members/imo_vmdb/view?session_id=77628

Observations December 12–13, 2018
Geminids pre-maximum night

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A report is presented on the author's observations of the Geminids 2018.

1   Introduction

Observing sessions can occasionally be a big test of patience and bound to fail from time to time! I attempted two meteor sessions in early December, but they were both a bust due to poor weather. The first was for the possible Andromedids activity on December 5/6; I drove two hours out of Ottawa to the L&A Dark Sky Site in an attempt to get some clear skies. It was more than halfway cloudy when I arrived, but I was still able to casually see two nice Geminids (but no Andromedids). Before long, the sky clouded over entirely, and no formal observations were possible.

Figure 1 – Geminid meteors meet Comet 46P/Wirtanen. Composite image of 6 Geminids. December 12/13 2018. Blue Sea, Quebec. Canon 5D, ISO 1600, Canon 70-200 f/4.0 (set at 135mm).
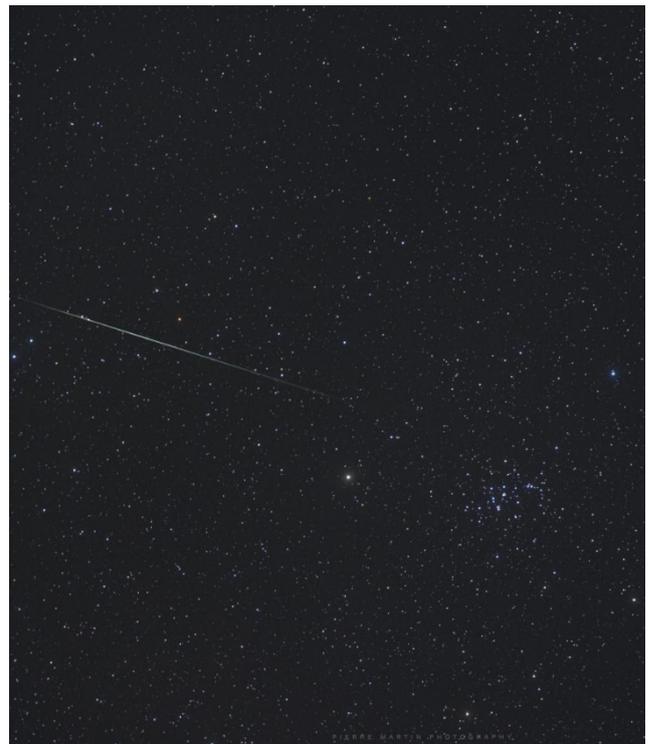
Figure 2 – Geminid and the Beehive Cluster (M44). December 12/13 2018. Blue Sea, Quebec. Canon 5D, ISO 1600, Canon 70-200 f/4.0 (set at 135mm).

On December 10, I drove to the RASC's Fred Lossing Observatory near Almonte late at night to start observing the Geminids. The weather predicted a good clearing sky after midnight but unfortunately this never did happen. I napped inside the warm room and checked on the sky once in a while, but it stayed completely solid overcast. It wasn't until I started driving home before dawn that the sky cleared, it was too late.

The weather finally looked much more promising for the night of December 12/13, just one night before the Geminids peak! Raymond Dubois joined me for a road trip north of Ottawa, where the prospect for a good transparency was best. We drove about 1.5 hours north, stopping for dinner in Gracefield and then on to the Blue Sea Lake area. We checked out a potential observing site at a public parking lot, but it was brightly lit and that was a no-go. We

drove a bit further and found a boat ramp overlooking Lac Morissette with a perfect view of the southern sky! We setup right there on the frozen lake. It was a frigid night with a forecast low of –26C (–15F), so we took our time getting many layers of warm clothes on and then setup our cameras. The sky was nice and clear with the exception of some ice fog and distant high cirrus. Overhead, the winter stars and Milky Way were beautiful — and the Geminids were active! After two "false start" sessions, it was nice to finally get a clear sky!

Figure 3 – Geminids in the winter sky, above Lake Morisette. Composite image of 21 Geminids captured on the night of December 12/13 2018. Blue Sea region, Quebec. Canon 6D, ISO 1600, Rokinon 24mm f/1.4 (set at f/2.0). Some cirrus and sky fog created slight halo effects around the brighter stars.

I got my Star Adventure mount tracking with my two DSLR cameras on top (one equipped with a 24mm f/1.4 lens and the other with a 70-200mm f/4). I settled down into my lawn chair and winter sleeping bag out onto the frozen lake. It was eerie hearing the cracks, pops and other strange sounds emitted by the ice underneath me, due to the cold. Raymond opted to watch from closer to the dock than where I was positioned. At one point, I felt the whole ice settle down with a THUMP and it had me a tad bit nervous. But all was well as long as nothing cracked underneath me. I pulled my 9×63 binocs to take a look at Comet 46P/Wirtanen near its best. It was very easy to pick up the concentrated fuzz ball in the 9x63mm binocs, and then I was able to just barely make it out to the unaided eyes.
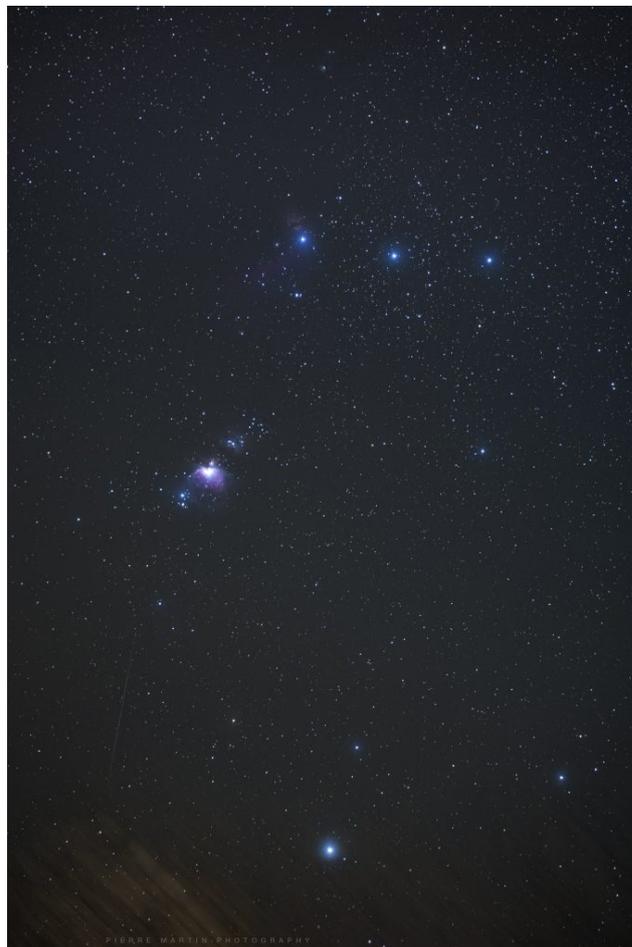
Figure 4 – Faint Geminid in Orion. December 12/13 2018. Blue Sea, Quebec. Canon 5D, ISO 1600, Canon 70-200 f/4.0 (set at 135mm).

I signed on for meteors at 12:40am EST and went on until 6:15am. I took a number of breaks during the night (to attend cameras mostly), so the actual session was nearly four and a half hours of effective time. During that time, I saw 256 meteors (210 Geminids, 8 Monocerotids, 7 Hydrids, 4 December Leo Minorids, 3 Antihelions, 3 December Alpha Draconids and 21 sporadics). It was indeed a very active night, with higher than expected numbers. My hourly rates for the Geminids were 48, 67, 47 and 42. The second hour was especially great as the radiant crossed the meridian. Many of the meteors were on the faint side (typical during the pre-peak night). There was many mag +2s, +3s and +4s, however the final hour of the night produced some brighter meteors. The most impressive was a –3 Geminid at 3:11am EST that scooted through the head of Hydra and left a 2 sec train. Brighter Geminids were typically white, slightly bluish or yellowish. Only 2% of Geminids left a visible train.

All in all, a really good, productive … but cold night!! It was nice having Raymond along for company, but we were quite frozen when we left. The last hour was very humid with the kind of cold that went right through our parkas and through the bones. Unfortunately, the peak night of the Geminids was completely clouded out. So I was glad that we made a good effort to go out on this night. The green "Christmas comet" was a treat too

Figure 5 – Comet 46P/Wirtanen late at night. December 12/13 2018. Blue Sea, Quebec. Canon 5D, ISO 1600, Canon 70-200 f/4.0 (set at 135mm).

2   Visual data:

December 12/13 2018, 05:40-11:15 UT (00:40-06:15 EST) Location: Blue Sea Lake, Quebec, Canada. (Long: -76.11° W; Lat: 46.22° N)

Observed showers:

- Antihelions (ANT) – 06:08 (092) +32
- Monocerotids (MON) – 07:04 (106) +08
- alpha Hydrids (AHY) – 07:21 (110) -04
- Geminids (GEM) – 07:41 (115) +32
- sigma Hydrids (HYD) – 08:48 (132) +01
- December Leonis Minorids (DLM) – 10:22 (156) +32
- December sigma Virginids (DSV) – 13:30 (203) +05

05:40-6:45 UT (00:40-01:45 EST); 3/5 trans; F 1.00; LM 6.43; facing S50 deg; t_{eff} 1.08 hr, temp –18C

- GEM: forty-eight: 0(3); +1(2); +2(11); +3(9); +4(11); +5(12)
- ANT: two: +3(2)
- MON: two: +3(2)
- DLM: one: +4
- Sporadics: five: +3(2); +4(3)
- Total meteors: Fifty-eight

07:25-08:25 UT (02:25-03:25 EST); 3/5 trans; F 1.00; LM 6.48; facing SSW50 deg; t_{eff} 1.00 hr, temp –20C

- GEM: Sixty-seven: –3; 0(4); +1(5); +2(19); +3(11); +4(20); +5(7)
- MON: two: +3(2)
- DAD: two: +2(2)
- HYD: one: +3
- DLM: one: +4
- Sporadics: three: +1; +5(2)
- Total meteors: Seventy-six

08:25-09:50 UT (03:25-04:50 EST); 3/5 trans; F 1.00; LM 6.50; facing SSW50 deg; teff 1.00 hr, temp -22C

- GEM: forty-seven: 0; +1(4); +2(11); +3(6); +4(16); +5(9)
- HYD: four: 0; +3; +4(2)
- MON: three: +2; +4(2)
- DLM: two: +2; +3
- ANT: one: +2
- DAD: one: +3
- Sporadics: four: +2; +4(3)
- Total meteors: Sixty-two

09:50-10:55 UT (04:50-05:55 EST); 3/5 trans; F 1.00; LM 6.50; facing SSW50 deg; t_{eff} 1.00 hr, temp –24C

- GEM: forty-two: –1; 0; +1(10); +2(9); +3(12); +4(5); +5(4)
- HYD: two: +1; +4
- MON: one: +2
- Sporadics: seven: +1; +4(3); +5(3)
- Total meteors: Fifty-two

10:55-11:15 UT (05:55-06:15 EST); 3/5 trans; F 1.00; LM 6.30 (morning twilight); facing SSW50 deg; t_{eff} 0.33 hr, temp –26C

- GEM: six: +1; +2(2); +3(3)
- Sporadics: two: +4(2)
- Total meteors: Eight

Observations December 22–23, 2018

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A report is presented about the author's observations of the Ursids 2018.

1 Introduction

I went out on the morning of December 23 to look for Ursids. A cold front had just swept through, moving clouds away but not without strong winds. It was –10C, and the east-end looked favored, so I chose Johnston road, a quiet place out past the village of Bourget. Todd Weeks introduced me to this location several years ago. It has decently dark skies for only a 25 minutes' drive from my house. I quite enjoy the tranquility of this location and very rarely does a car go by.

This time, the sky was brightly lit by the nearly Full Moon but it was transparent enough that Ursa Minor could be seen in its entirety. I setup on the side of the road, and the wind was howling, but the thick forest behind me did a wonderful job blocking just about all of it. What makes this location unique are the trees acting as a wind shield and also hiding some of the city light pollution, but the other directions still feature excellent horizons.

Meteor activity was low. In fact, the entire first hour of observing had zero meteors. I cannot remember the last time that I had experienced such a long lull. At the end of this hour, I felt fatigue, so I called a break and went for a snooze. About 20 minutes later, I woke up more refreshed and I decided to try a second hour. I finally saw a few meteors! :) The count was four sporadics and a single Ursid. There was certainly no indication of any unusual Ursids rates (although my session was several hours after the predicted enhanced rates).

2 The observations

December 22/23 2018, 07:35-10:00 UT (02:35-05:00 EST) Location: Bourget, Ontario, Canada (Long: -75.104° W; Lat: 45.434° N)

Observed showers:

- Anthelion (ANT) – 06:52 (103) +23
- Monocerotids (MON) – 07:26 (112) +07
- December Leonis Minorids (DLM) – 10:44 (161) +29
- Coma Berenicids (COM) – 11:36 (174) +18
- Ursids (URS) – 14:24 (216) +75
- Quadrantids (QUA) – 14:56 (224) +53

07:35-08:38 UT (02:35-03:38 EST); 3/5 trans; F 1.00; LM 5.00; facing NE60 deg; t_{eff} 1.00 hr

- Total meteors: None seen

09:00-10:00 UT (04:00-05:00 EST); 3/5 trans; F 1.00; LM 5.00; facing NE60 deg; t_{eff} 1.00 hr

- URS: one: +4
- Sporadics: four: +2(2); +3; +4
- Total meteors: Five

Observations January 3–4, 2019

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A report is presented on the author's observations of the Quadrantids 2019.

1   Introduction

For the Quadrantids peak night on Friday morning January 4th, I was ready to write it off due to very poor weather. I checked the clouds forecast at 1:30am (local time) just in case the situation might have improved, and it still looked very bad near Ottawa (i.e. a snowstorm outside) but it was possibly better south-west of Ottawa out past Kaladar. So, I very quickly got ready and left as a strong snowfall was in progress. Along the way, I saw some accidents due to the treacherous driving conditions but traffic was light at that time of the night. By the time I reached Perth along Highway 7, snow had not occurred there, and the roads were in much better shape. I arrived at the Lennox & Addington Dark Sky Site at 4:30am and the sky was more than halfway clear and improving! Almost right away, I saw Quadrantid meteors left and right! I watched casually the next 15 minutes and enjoyed what I saw. The sky continued to improve, so I took out my chair and sleeping bag to setup in the snow next to the car. It was very mild, only 0C (32F) – quite unusual for a clear sky in January.

At 4:50am EST, it was all clear and I signed on for formal watch!! It was a beautiful dark sky, and with the radiant high up, "Quads" were coming down in different parts of the sky. Some were quite bright (up to –2 and –1) typically blue-white or yellowish. The rates were quite decent in the first hour with 28 "Quads" (the peak was several hours earlier). I watched for another 54 minutes until morning dawn (6:42am EST), and things were quieter with just 13 "Quads". The Earth was clearly moving out of the main part of the dust stream. The highlight was a –4 Coma Berenicid fireball split the sky like a green lightning bolt!

The total count in those two hours was 55 meteors (41 Quadrantids, 4 Coma Berenicids, 3 January Leonids, 2 December Leo Minorids and 5 sporadics).

Seeing the Quadrantids at their best involves a lot of luck and good timing. The peak is sharp and short lived but well worth chasing, as it is often as strong as the Perseids or Geminids, and occasionally even better! In all my meteor observing years, I've only seen the Quadrantids at full tilt a

small handful of times. In 2009, they were strong with an hourly rate count reaching 107 — it was a wonderful display! The timing for this year was not favorable here in North America as the peak came early in the evening while the radiant was low. It would have been still interesting to watch earlier anyway, for earth-grazers especially. But, I'm glad I was able to see something of this year's shower despite the iffy weather. I had some luck!!! :)

2   The observations

January 3/4 2019, 09:48-11:42 UT (04:48-06:42 EST)
Location: L&A County Public Dark Site, Ontario, Canada
(Long: -77.116 West; Lat: 44.559 North)

Observed showers:

- Quadrantids (QUA) – 15:24 (231) +49
- Anthelion (ANT) – 07:52 (118) +21
- alpha Hydrids (AHY) – 08:14 (130) -09
- December Leonis Minorids (DLM) – 11:38 (175) +23
- Coma Berenicids (COM) – 12:07 (182) +14

09:48-10:48 UT (04:48-05:48 EST); 3/5 trans; F 1.02; LM 6.40; facing N50 deg; t_{eff} 1.00 hr

- QUA: Twenty-eight: -2; -1; 0(3); +1(2); +2(4); +3(3); +4(9); +5(5)
- COM: three: +2; +3; +4
- DLM: two: +4(2)
- JLE: one: +3
- Sporadics: three: +2; +3; +5
- Total meteors: Thirty-seven

10:48-11:42 UT (05:48-06:42 EST); 3/5 trans; F 1.00; LM 5.95; facing N60 deg; t_{eff} 0.90 hr

- QUA: thirteen: 0; +1(2); +2(4); +3(3); +4(3)
- JLE: two: +3; +4
- COM: one: -4
- Sporadics: two: +3; +5
- Total meteors: Eighteen

November 2018 report CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month of November 2018 is presented. November 2018 was the most successful month of November so far. 38556 meteors were recorded, 20535 of which proved multiple station, or 53%. In total 6916 orbits were collected during this month.

1   Introduction

The month of November is characterized by frequent bad weather with a lot of clouds and humidity. Clear nights tend to be rather exceptional this period of the year, reason why the CAMS BeNeLux network scored rather modest numbers of orbits this time of the year. The long winter months with 13 to 14 hours of dark sky often cover variable weather circumstances with short periods with clear sky, while predictions and the situation at the start of the night appear hopeless. For such circumstances the use of AutoCams proves the best tool. Instead to keep the cameras switched off, expecting no clear sky, practice proves that it is recommended to keep cameras running in order not to miss the unpredictable changes in the weather pattern.

2   November 2018 statistics

CAMS BeNeLux collected 38556 meteors of which 20535 or 53% were multi-station, good for 6916 orbits. This is again a new record for the month of November. The exceptional dry weather that dominated 2018 since mid-April remained during much of November until about the Leonid activity. This month counted as many as 16 nights with more than 100 orbits. Six nights produced more than 500 orbits in a single night. The best November night was 17–18 with as many as 4038 meteors registered, 2464 of which were multi-station, good for 790 orbits in this single night. Only two nights remained without any orbits. Weather deteriorated after this record night and we got into the usual typical poor autumn weather with a lot of clouds and rain. The statistics of November 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, 152 November nights allowed to obtain orbits with a grand total of 16558 orbits collected during November during all these years together.

Three CAMS-stations, Ooltgenplaat, Dourbes and Langemark remained non-active this month. While November 2017 had a maximum of 88 cameras, 74.2 on average available, November 2018 had 85 cameras at best and 75.3 on average.

Never in the CAMS-BeNeLux history November offered such favorable opportunity to cover the rich meteor activity this period of the year. Especially the Leonid activity produced many Leonid orbits in 2018. Although most nights of November 2018 allowed observations, remarkable few fireballs were recorded, while previous years with less favorable weather had several bright fireball events.
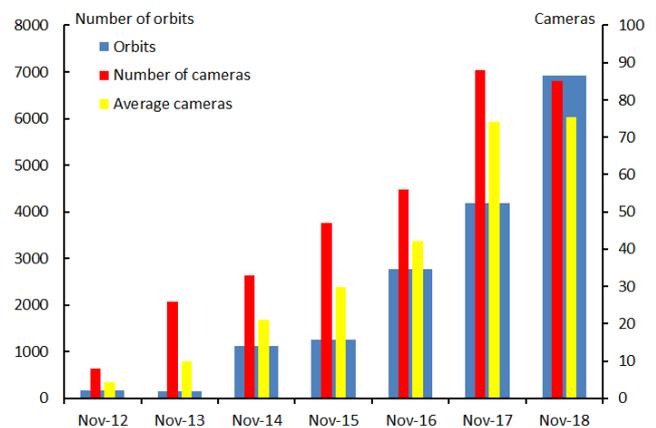
Figure 1 – Comparing November 2018 to previous months of November in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the yellow bar the average number of cameras running per night.

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

Year	Nights	Orbits	Stations	Max. Cams	Min. Cams	Mean Cams
2012	14	165	6	8	-	4.4
2013	13	142	10	26	-	9.8
2014	24	1123	14	33	-	21.1
2015	23	1261	15	47	10	29.8
2016	24	2769	19	56	19	42.2
2017	26	4182	22	88	57	74.2
2018	28	6916	21	85	59	75.3
Total	152	16558				

3   Conclusion

November 2018 was the best month of November in the history of the CAMS-BeNeLux network. The large number of orbits collected in 2018 confirms the exceptional rich meteor activity level during this month.

Acknowledgment

December 2018 report CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month of December 2018 is presented. December 2018 ended as the poorest month of 2018. 25912 meteors were recorded, 13220 of which proved multiple station, or 51%. Weather turned into the worst-case scenario with just a bit luck for good coverage of the best Geminid activity nights.

1   Introduction

December is one of the winter months with the worst weather circumstances for astronomy in BeNeLux. While the nighttime allows for more than 14 hours of astronomical observing and meteor activity is very rich this month, results are often very disappointing. Any clear night yields large numbers of orbits, question is if we will be lucky and get some clear nights and if so, how many?

2   December 2018 statistics

CAMS BeNeLux collected 25912 meteors of which 13220 or 51% were multi-station, good for 4908 orbits. This is a record for the month of December. The exceptional favorable weather we got most of 2018 was over and December suffered the usual poor weather pattern for this time of the year. This month counted 9 nights with more than 100 orbits but also as many as 8 nights without any orbits. For 3 nights not any single meteor could be recorded. The nice score in orbits for this month comes mainly from a lucky coincidence that some of the very few clear nights happened during the best Geminid activity nights. The best night was December 12–13 when as many as 6949 meteors were recorded, 4037 of which were multiple station and produced 1396 orbits in this single night. Without this little luck during the Geminid activity, the score in number of orbits would have been significantly less than in previous couple of years.

The statistics of December 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, 154 December nights allowed to obtain orbits with a grand total of 15503 orbits collected during December during all these years together.

Unfortunately, Ooltgenplaat, remained non-active as well as Ermelo and Langemark. Camera 395 could be restarted in Dourbes while the 394 waits for a next maintenance mission at the remote-controlled station to get focused. While December 2017 had a maximum of 86 cameras, 68.9 on average available, December 2018 had 78 cameras at best and 69.8 on average.

Auto-Cams proved to be crucial to take advantage of the unpredictable nature of the weather during the long winter nights. In the past when camera operators decided on sight to switch on their CAMS system, many unforeseen periods with clear sky were lost. Practical experience proves that the number of nights without any single meteor being detected are less than 10% of all nights. The unpredictable nature of meteor activity requires permanent alertness while the unpredictable nature of the weather keeps cameras switched off during clear nights. This is a pity because rare events may pass unnoticed, while all is available to monitor these events.
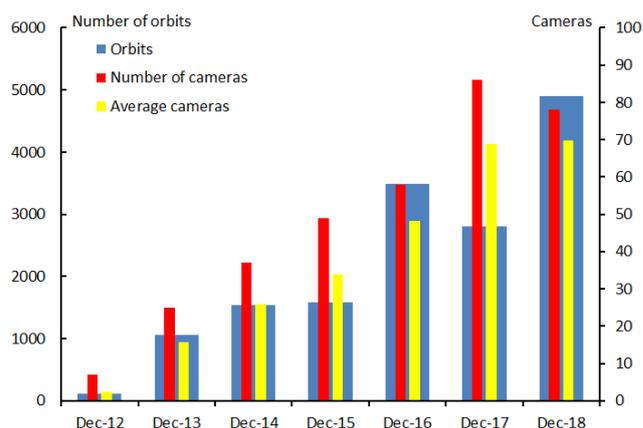
Figure 1 – Comparing December 2018 to previous months of December in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the yellow bar the average number of cameras running per night.

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

Year	Nights	Orbits	Stations	Max. Cams	Min. Camas	Mean Cams
2012	12	117	6	7	-	2.4
2013	23	1053	10	25	-	15.7
2014	19	1540	14	37	-	25.8
2015	27	1589	15	49	8	33.8
2016	25	3492	21	58	25	48.3
2017	25	2804	22	86	49	68.9
2018	23	4908	21	78	52	69.8
Total	154	15503				

3 Conclusion

December 2018 in general was the worst month for CAMS BeNeLux of the entire year 2018. A little luck during the Geminid nights saved the month with a new record number of orbits for December.

Acknowledgment

Annual report 2018 CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the year 2018 is presented. The year 2018 offered unusual good weather for astronomical observations with clear nights during most major shower events. The network recorded 272248 meteors of which 142507 proved multiple station, or 52%. 49627 orbits could be computed during 330 different nights which corresponds to 90% of all 365 nights in 2018. The exceptional weather resulted in record numbers of orbits for 9 months of 2018.

1   Introduction

CAMS BeNeLux depends 100% on volunteers, amateur astronomers who dedicate some of their free time to operate cameras, taking care of the daily task to confirm real meteors, deleting false detections and to report the meteor data to the CAMS network coordinator. The network functions without any financial subsides which means that participants purchase the required equipment with their own money, something that goes with a much stronger motivation than what often happens at observatories where expensive equipment bought with public money remains unused because of a rather poor personal commitment. The CAMS BeNeLux project is the most successful amateur project ever for the BeNeLux region based on a truly highly efficient international team work.

The CAMS BeNeLux network results are submitted to the Global CAMS project scientist Dr. P. Jenniskens at the Seti Institute. Results are published in refereed papers, presented at scientific conferences and results are online available[8]. The CAMS software is made available to all participating networks and technical support is provided by Steve Rau to implement the CAMS software and to configure Auto-Cams. The CAMS software developer, Pete Gural, keeps in touch and provides feedback to the networks involved to adapt the software for new developments.

2   CAMS BeNeLux 2018 statistics

The CAMS BeNeLux network expanded with about 50% in number of cameras since the summer of 2017. Setting up remote stations in Burlage, Grapfontaine, Terschelling and Texel allowed to expand the size of the network significantly. More stations switched to use Auto-Cams to keep the cameras as often as possible operational and the directions of the individual cameras were optimized to have an optimal common volume in the meteor rich layers of the atmosphere. 2018 would be the first year that the CAMS BeNeLux network could function at full strength. Never before the network had more cameras available than at the start of 2018, in theory 92 operational cameras could function from 22 different stations.

The large number of cameras also meant greater risks for malfunctioning equipment. The EzCap dongles proved to be rather unsuitable for intensive use like with Auto-Cams and disabled many cameras for some time until the dongle could be replaced. Other sources of malfunctioning were due to the unreliability of Windows as operating system, especially Windows 10 which is probably the worst Windows version for using CAMS. Finally, quite a bit of data could not be processed due to mistakes in the data communicated: failing clock synchronization, incorrect calibration file reporting, problematic numbers of dropped frames that cause sectored meteors, etc. To avoid such unfortunate loss of data, it is recommended to check daily if the time synchronization is okay, to check if the calibration files are valid for the night, to check that all required files are sent correctly.

Table 1 – Total numbers of nights (*D*) with orbits, number of orbits, number of camera stations (*S*), maximum of cameras available (M_x), minimum of cameras available (M_i), average number of cameras (M_m), total number of meteors and percentage of multiple station meteors.

M	D	Orbits	S	M_x	M_i	M_m	Meteors	%
Jan	25	1878	22	86	53	72.1	11986	41%
Feb	26	4147	22	91	48	81.7	23439	55%
Mar	25	1280	22	91	53	73.5	9324	36%
Apr	27	1929	21	83	59	73.3	11328	49%
May	31	2426	21	84	64	76.6	13630	54%
Jun	28	1425	21	78	52	64.9	8218	47%
Jul	30	4098	19	72	59	67.7	21446	55%
Aug	30	5403	19	72	56	62.4	27917	55%
Sep	28	5606	20	80	57	65.4	29160	54%
Oct	29	9611	21	82	52	73	51332	55%
Nov	28	6916	21	85	59	75.3	38556	53%
Dec	23	4908	21	78	52	69.8	25912	51%
	330	49627					272248	52%

The network could run at its full capacity during the first months of 2018 apart from some minor technical problems

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with some cameras. In March 2018 CAMS station Oostkapelle, a cornerstone with 8 cameras in the network, was shut down for 6 months for renovation work. In June 2018 a disaster at CAMS station Ooltgenplaat destroyed the equipment at the observatory of *Piet Neels*, a great personal loss for Piet but also a great loss for the network. Ooltgenplaat is a cornerstone in the same part of the network as Oostkapelle. With both stations missing, many other camera fields at other stations suddenly got much less coverage. Especially all cameras pointed above the western and southern part of the network got badly affected. With a few cameras being unavailable elsewhere, the network dropped at about 80% of the capacity of end 2017. This is visible in *Figure 1*, as a drop in the maximum (green line) and the average number (red line) of cameras available each month. The exceptional favorable weather and the use of Auto-Cams at most stations resulted in record numbers of orbits although up to 20% of all cameras weren't available.
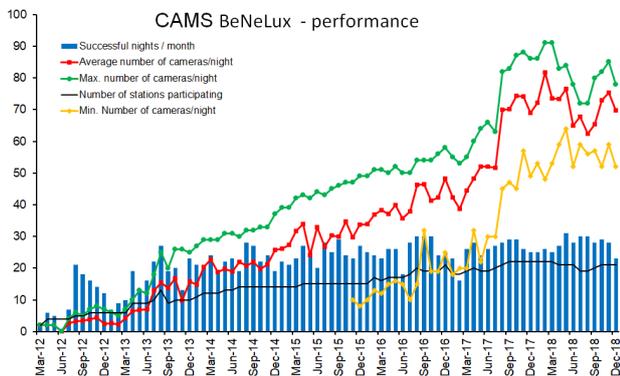
Figure 1 – Cams BeNeLux performance at a glimpse. The blue bars represent the number of nights with orbits for each month. The black line is the number of operational Cams stations, the green line the maximum number of operational cameras, the red line the average number of operational cameras and the yellow line the minimum number of operational cameras.

January 2018 started with mediocre weather circumstances, but February offered an exceptional number of clear nights. Some complete clear nights in February allowed to collect more than 300 orbits in a single night. Such high numbers of orbits show how rich meteor activity is this time of the year although no major showers are active.

Weather deteriorated in March but still a record number of orbits were collected this month. A major weather improvement happened in April, just in time for the coverage of the Lyrids. Also, the Eta Aquariids benefitted many clear nights. Although the weather remained dry and warm, a lot of clouds occurred at night from about 10 May until late June. A period with exceptionally many clear nights characterized the period from end of June until just before the Perseids. The Perseid maximum night was ruined by bad weather with rather poor circumstances during much of August. September brought many clear nights, some nights allowed to collect over 400 orbits a night. Stable good weather remained for most of October with 1391 orbits collected during the 2018 Draconids outburst 8 on 9 October. Several October nights had over 500 orbits per

night. October ended as the best month for CAMS ever with 9611 orbits.

The long period with clear nights continued through much of November. Some November nights allowed to collect more than 700 orbits in a single night. After the Leonids weather turned back into a more normal pattern for our climate with a lot of clouds and rain. Most of December suffered of exceptional bad weather, except for a lucky coincidence with the best nights of December during the rich Geminid activity, 12–13 December alone was good for as many as 1396 orbits. Apart from the lucky Geminid nights, December was the worst month weather-wise for CAMS. *Figure 2* shows the monthly scores in numbers of orbits.

Only 6 new cameras were added during 2018 including 2 at a strategic position in Nancy, France, by *Tioga Gulon*, an ideal location to give large coverage over the south eastern part of the CAMS network. *Marco van der Weide* also joined the network at Hengelo with an extra camera.
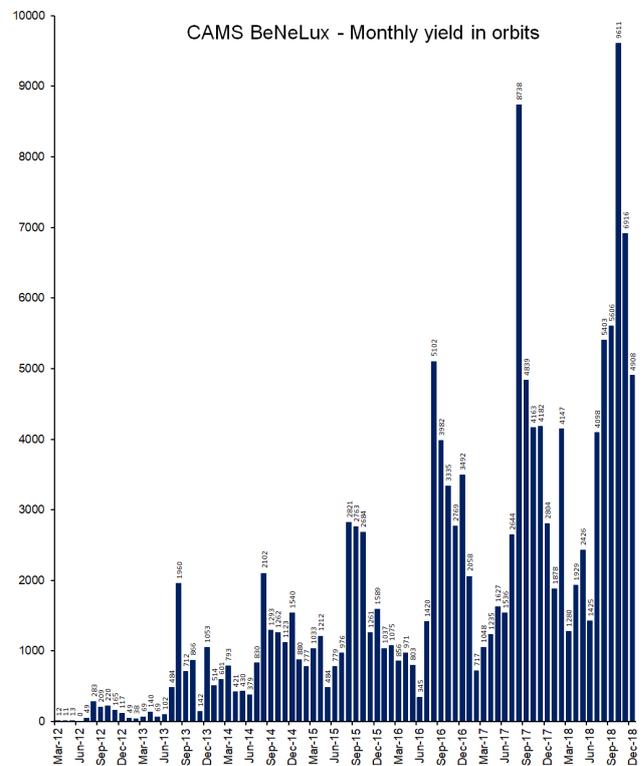
Figure 2 – The total number of orbits collected per month. October 2018 has the record with 9611 orbits in a single month.

3   2018 compared to previous years

Figure 3 shows the cumulated number of orbits. With 49627 orbits a record number of orbits were added to the collection of CAMS BeNeLux, bringing the total score at 145715 orbits. The total numbers of orbits are far higher than the most optimistic estimates anybody had expected in the past. The good result for 2018 is mainly due to the overall exceptional number of clear nights this year, combined with the use of Auto-CAMS and the still large number of operational cameras, although up to 20% of the equipment was unavailable during much of 2018.

CAMS BeNeLux - Total orbits
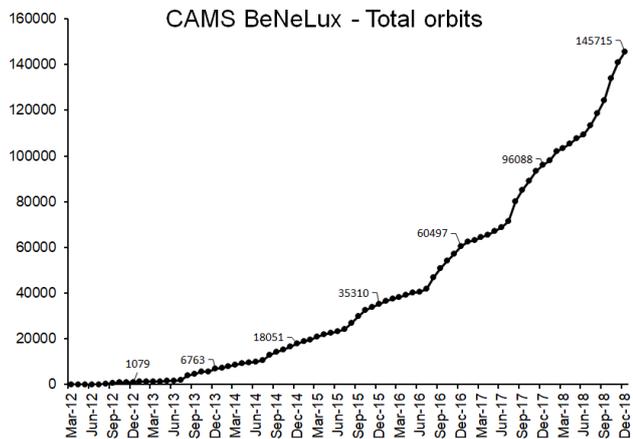
Figure 3 – The evolution of the number of orbits collected by the CAMS BeNeLux network.

Comparing 2018 with previous years the highest average number of nights/month with orbits, 27.5, was better than ever before. 330 of the 365 nights of 2018 allowed to collect orbits, only 10% of all nights had zero orbits. The total number of orbits obtained in 2018 is far above what normally can be expected for the network with its current capacity. The success is mainly a result of exceptional good weather. Some statistics are shown in *Table 2* and in *Figure 4*. Auto-Cams was introduced in November 2015.

Table 2 – Total numbers per year: average number of nights with orbits per month (D$_m$), orbits, average number of cameras per month (C$_m$), maximum number of operational cameras, number of operational stations and total number of nights with orbits.

Year	D$_m$	Orbits	C$_m$	Cameras	Stations	Nights
2012	10.1	1079	2.6	8	6	101
2013	16.5	5684	9.5	26	13	198
2014	22.4	11288	20.6	37	14	269
2015	24.5	17259	30.1	49	15	294
2016	25.8	25187	40.3	58	21	309
2017	25.6	35591	57.2	86	22	307
2018	27.5	49627	71.3	91	22	330
		145715				1478

CAMS BeNeLux - performance
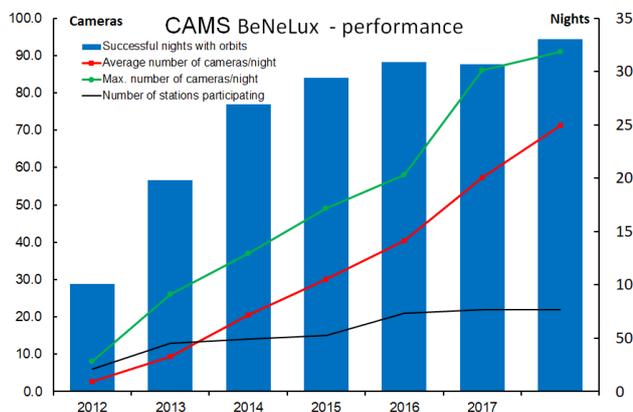
Figure 4 – The performance of the CAMS BeNeLux network from year to year. The blue bars represent the average number of nights per month that produced orbits. The black line is the number of Cams stations, the green line the maximum number of cameras available and the red line the average number of cameras available.

Figure 5 – Day-by-day tally of the cumulated number of orbits per day collected by CAMS-BeNeLux. Top: the overview up to 31 December 2017, bottom: the situation on 31 December 2018.

At the start of the CAMS project, almost 10 years ago, the purpose of the project was to collect at least a hundred orbits for each calendar date to detect unknown minor showers caused by weak dust trails. This initial target proved to be too modest as meanwhile the BeNeLux Cams network alone almost accomplished this purpose. CAMS proved much more successful than ever expected and meanwhile as many as over 1000 orbits are available for most of each degree in solar longitude for the global CAMS project. CAMS BeNeLux represents ~20% of all CAMS orbits.
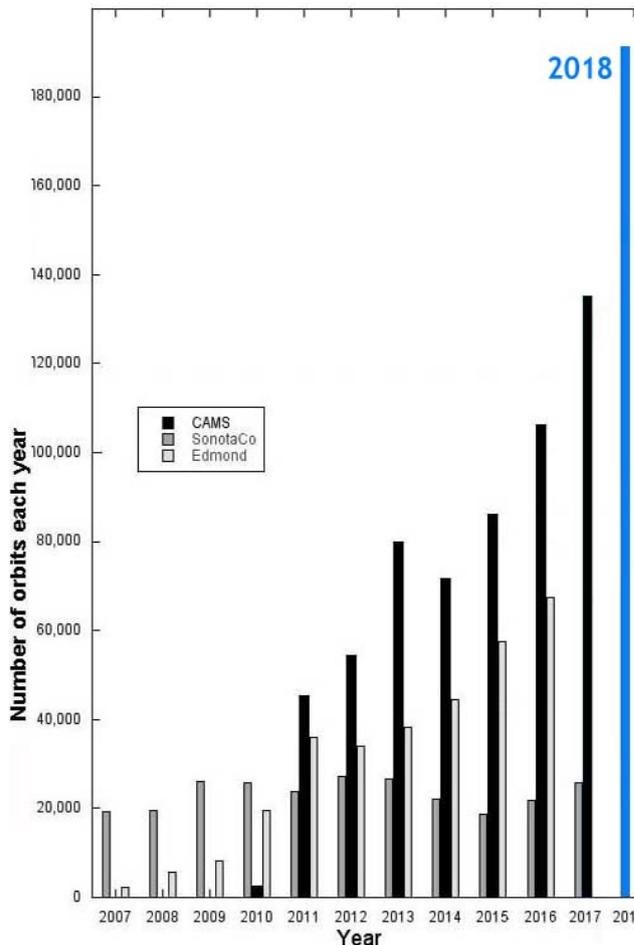
Figure 6 – CAMS BeNeLux within the global CAMS project compared to the other major video networks.

4   CAMS BeNeLux in the world

CAMS is a global project in which different networks around the world participate all using the same CAMS software. The 16th century emperor Charles V claimed that the Sun never set in his empire, the opposite is true for CAMS. The Sun never rises as there is always some network with nighttime allowing to collect video meteor orbits 24/24 if weather permits. Altogether the CAMS networks collected about 186500 orbits in 2018 with the following numbers of orbits for the different networks (raw data):

- CAMS Arkansas 2595
- CAMS BeNeLux 49627
- CAMS California 68329
- EXOSS (Brasilia) 400
- CAMS Florida 5654
- LOCAMS 45230
- CAMS New Zealand 3201
- CAMS Northern California 818
- UACN 10583
- Total ~186500

CAMS BeNeLux made its best contribution ever. Since the start of the CAMS project more than 765000 video meteor orbits have been collected of which 145715 orbits by CAMS BeNeLux. This is currently the largest collection of optical orbits and the project is expected to be continued for years with more networks involved than previous years.

5   Future plans

Figure 7 – Location of all the CAMS BeNeLux stations and cameras as until end 2018.

Figure 7 displays the positions of all CAMS stations of CAMS BeNeLux status end 2018, including few currently inactive stations. To guard the atmosphere over the entire region covering the meteor rich layer between 80 and 120 km at least 100 cameras with 30° x 22° FoV optics are required distributed over the different stations. The unavailability of some cameras for different reasons justifies some overcapacity to compensate temporarily inactive stations and cameras.

In December 2018 tests were started with RPi meteor cameras designed for the Global Meteor Network. The output from this system can be used for CAMS. In principle these cameras can provide coverage for CAMS if installed within 200 km from the CAMS BeNeLux region.

Acknowledgment

January 2019 report CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month of January 2019 is presented. January 2019 was a typical winter month with a limited number of hours with clear sky. 10943 meteors were recorded, 5124 of which proved multiple station, or 47%, good for 1857 orbits.

1   Introduction

After a long favorable weather period over the North Western part of Europe in 2018 the normal weather pattern returned since the second half of November. December 2018 was a typical wet and cloudy winter month. Would January 2019 bring any surprises?

2   January 2019 statistics

To keep a video camera network functioning the volunteers who operate the cameras need to be motivated. A regular feedback with results proves an efficient way to encourage people to report their data on time. Most participants report their data immediately the day after the registrations. Some people report their data a little bit later but within one week. This way no red tape occurs with the data reduction pipeline.

So far, all months of January in the short history of CAMS BeNeLux brought the usual cloudy winter weather without any year with an exceptional favorable January for astronomical observations. The first month of 2019 continued this tradition with mainly unfavorable weather and just one really clear night. All other nights brought clear gaps of variable length between the clouds and as many as 9 nights ended without any single orbit.

CAMS BeNeLux managed to collect 10.943 meteors with 75 operational cameras at 20 participating stations, with 5124 or 47% multi-station meteors good for 1857 orbits. This is a remarkable good result, taking into account the unfavorable weather. Although less stations and significant fewer cameras participated compared to last year, almost the same total score in orbits was obtained. This is likely due to AutoCAMS being applied at more stations to get more out of each moment with clear sky. This proves the remarkable efficiency of the CAMS BeNeLux system.

At best 75 of the 88 operational cameras were active during nights in January 2019. On average 64.0 cameras were capturing per night. Only one night did not have any meteor registered. Thanks to AutoCAMS the surveillance of the BeNeLux sky was guaranteed with a minimum of 54 active cameras on all nights. On 22 nights orbits have been collected. The long winter nights may often start with an overcast sky looking hopeless to get anything like clear sky,

but nights with up to 14 hours of dark sky may surprise with some unexpected clear sky. Casual observers often remain unaware of such clear periods, while the AutoCAMS observers get happily surprised when confirming unexpected meteors. A substantial part of the January 2019 orbits comes from this permanent alertness provided by AutoCAMS. *Figure 1* and *Table 1* show the evolution compared to the previous months of January.
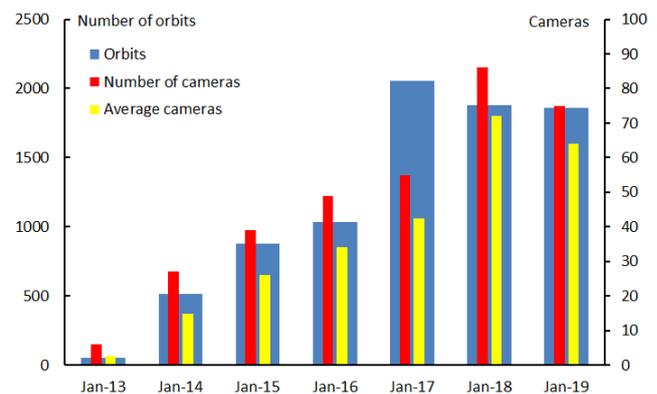
Figure 1 – Comparing January 2019 to previous months of January in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the yellow bar the average number of cameras running per night.

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

Year	Nights	Orbits	Stations	Max. Cams	Min. Cams	Mean Cams
2013	7	49	6	6	-	2.6
2014	21	514	11	27	-	14.8
2015	22	880	14	39	-	26.1
2016	25	1037	15	49	10	34.0
2017	23	2058	18	55	18	42.3
2018	25	1878	22	86	53	72.0
2019	22	1857	20	75	54	64.0
Tot.	145	8273				

Since the major expansion of the network in 2017, the number of stations and cameras remained stable since end of 2017. Bad luck and technical issues interfered at several stations keeping a number of cameras unavailable for some

time. Especially the EzCap 116 framegrabbers proved rather unreliable and responsible for most of the technical failures.

3   Conclusion

The team members spent a lot of efforts to get some results out of mostly cloudy nights. Despite the bad weather still a very nice result has been obtained. The variable weather combined with long winter nights produces often some short intervals with clear skies. In many cases no chances for clear sky exist in the evening and therefore AutoCAMS is recommended to have all cameras running whenever unexpected clear sky occurs.

Acknowledgment

Geminids – Albuquerque NM, UTC 20181214

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The first test results of the Global Meteor Network RMS cameras in New Mexico, USA, are presented.

1 Introduction

We are bringing up a network of RMS cameras in New Mexico, USA. We were fortunate to have seven cameras installed in time to catch one clear night of this year's Geminid meteor shower. Four of the cameras are in the Albuquerque area (us0001, 2, 6, and 7). Cameras us0008 and 9 are located a bit south in Los Lunas, NM, and our southernmost station (so far) is us0003 in Socorro, NM. Some of our cameras are quite close to the Albuquerque airport, so a lot of plane tracks can show up along with meteors. I have filtered out the worst of the plane tracks, and created stacked composite images of our night-long recordings.

2 Camera setup

These cameras are operating at around 1500m elevation, so sky glow is not nearly as bad as might be expected with the large population in the Albuquerque metro area. All-in-all, we are very impressed with our RMS IMX291 cameras fitted with 4mm f0.95 lenses.

The *Table 1* below shows all information about the cameras.

Table 1 – Number of fits files stacked and discarded due to plane or "bug" tracks, station owner and location. (* some plane track remained).

Station ID	#fits files	Discards	Owner / Location
us0001	1235	144	P.Eschman Albuquerque, near airport
us0002	639	54	P.Eschman Albuquerque, near airport
us0003	948	64	D.Klinglesmith / Socorro,NM
us0006	576	82	S.Kaufman / Albuquerque, NE Heights
us0007	838	51	R.Hufnagle / Albuquerque, North
us0008	139	0*	S. Welch / Los Lunas, NM
us0009	1070	94	S. Welch / Los Lunas, NM
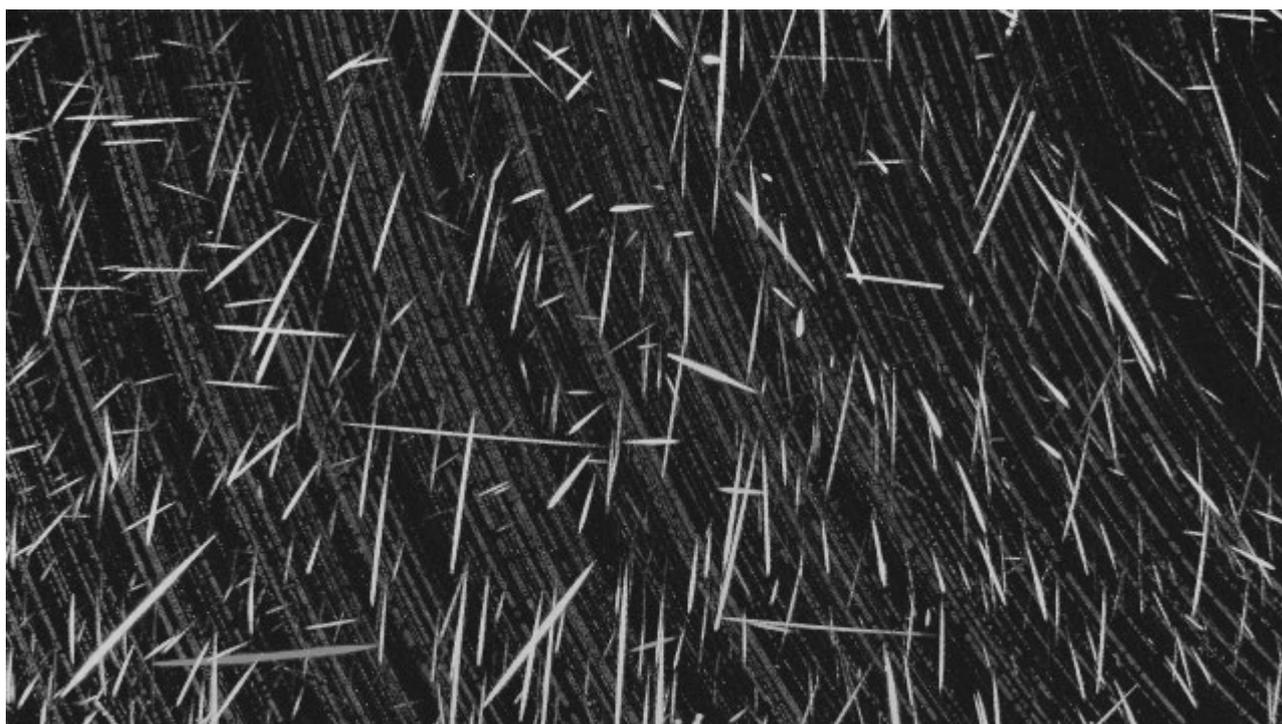
Figure 1 – Composite images from us0001.
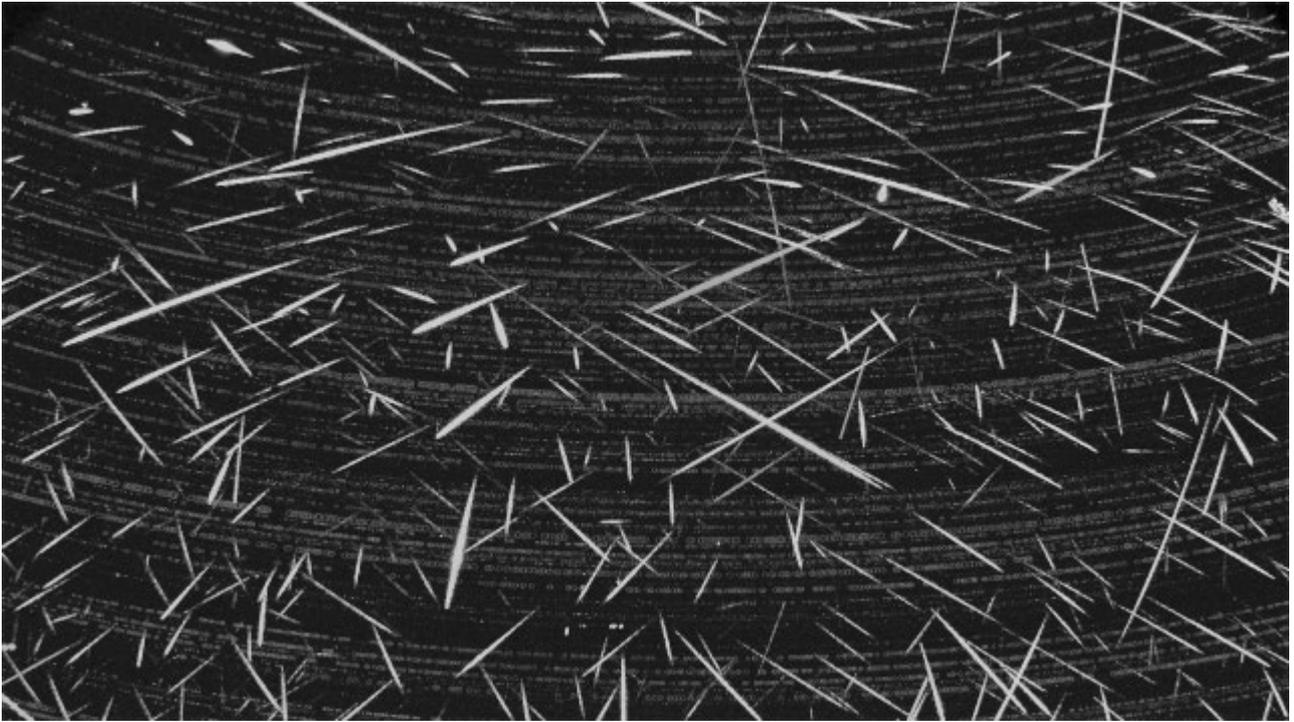
Figure 2 – Composite images from us0002.
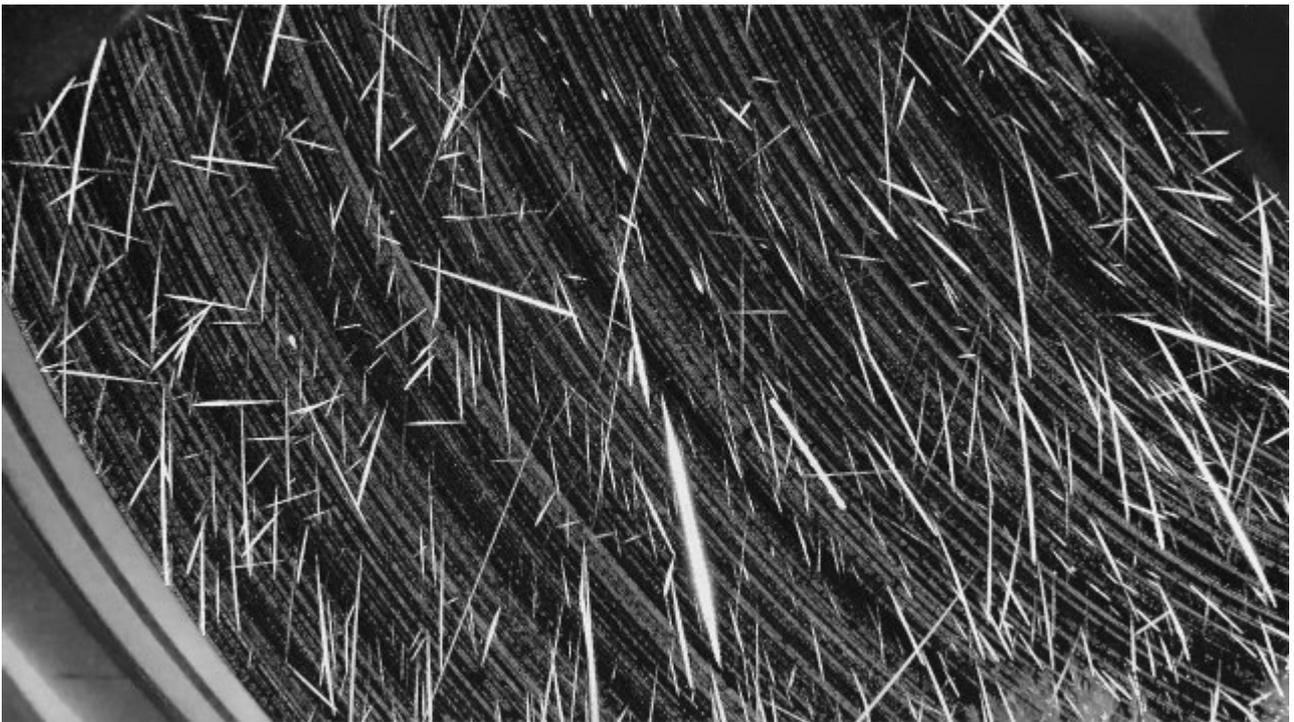
Figure 3 – Composite images from us0003.

Figure 4 – Composite images from us0006.

Figure 5 – Composite images from us0007.
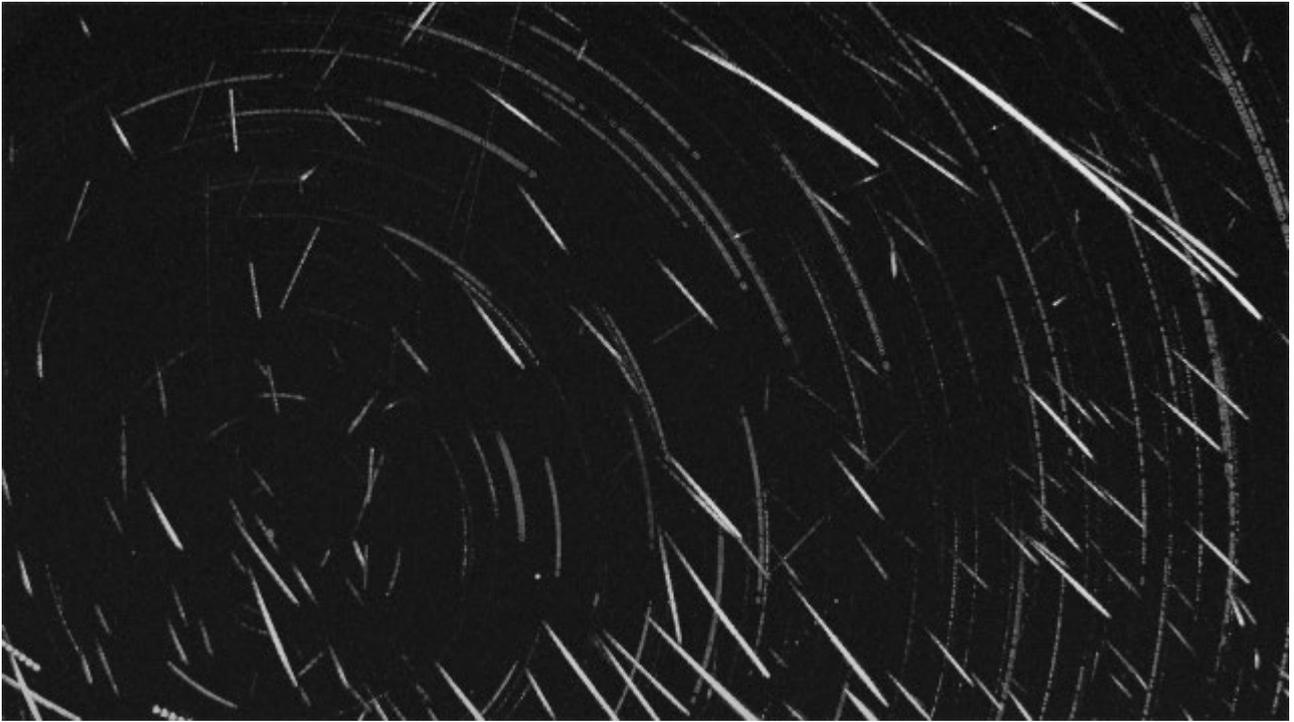
Figure 6 – Composite images from us0008.
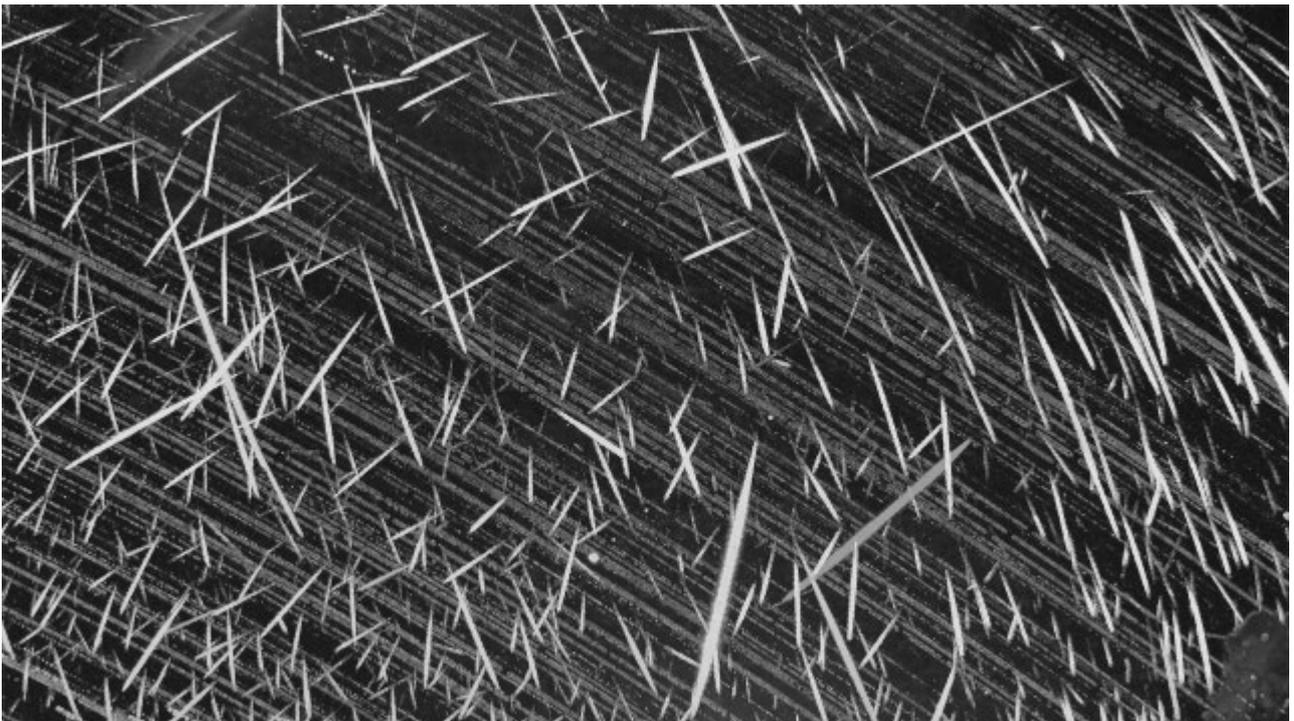
Figure 7 – Composite images from us0009.

Global Meteor Network
in Belgium, Germany and Netherlands

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The first triangulation results of the Global Meteor Network Cameras in Belgium, Germany and the Netherlands are described. Between 2019 February 11 and 16, 28 trajectories and orbits were obtained. A particular fireball was associated with the DSE#034 meteor shower, removed from the IAU meteor shower working list. This requires further investigation if any meteor source is active at this position.

1   Introduction

Some years ago, the Croatian team presented at the meteor conference in Austria the developments of a low costs video meteor camera to allow a wide coverage of the atmosphere (Zubović et al., 2015). Contrary to many other similar presentations at such conference these efforts were not idle talk and were developed further on (Vida et al., 2016). When the first results were published, the project caught wide attention among the meteor community (Vida et al., 2018a, 2018b).

When one of the authors was invited in March 2018 to participate in the project, the answer was immediately yes!

Figure 1 – The components of the RPi camera.

2   The RPi Meteor System

To be of interest to amateur astronomers any meteor video camera system should be easy to use and affordable since amateurs have only a limited amount of free time and budget to spend on a hobby. The advantage of the system is that this has been developed for amateurs, well aware of the typical concerns for the amateur community. All software is open source and user-friendly tutorials are provided online[9].

The first camera for Belgium, BE0001 arrived in November 2018 completely assembled and configured. It only needed to be mounted on the wall and get connected to the control unit, power supply and internet. The components shown in *Figure 1* were already assembled so that first light was just a matter of plug and play. Once the system was installed a number of software updates and modification were applied remotely by *Denis Vida* to get access to the RPi via the home network. Clear sky during the nights 9–10, 10–11, 11–12, 12–13 and 13–14 December with the Geminid activity, provided an excellent opportunity to test the system.

3   The Global Meteor Network

The mission statement of the project is well covered by its name: as many as possible cameras pointed at the sky to get a global coverage of the atmosphere. Too often in recent history meteor events such as outbursts or short-lived activity escaped from any visual coverage. The Global Meteor Network should help to avoid such sad loss of data about unique meteor shower happenings.

Developing the hardware and setting up such network requires huge efforts, lots of time and a great expertise. We strongly recommend to read background history of this project, documented on the GMN website[10].

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[9] https://globalmeteornetwork.org/?p=452

[10] https://globalmeteornetwork.org/?p=363

The scientific mission statement of the Global Meteor Network according to the GMN website[11]:

- *Providing the meteor community with near real-time awareness of near-Earth meteoroid environment by publishing orbits of all observed meteors from all around the globe every morning.*
- *Observing meteor showers, computing their flux, mass indices and orbits to constrain meteor shower prediction models.*
- *Observing meteorite producing fireballs to increase the number of meteorites with known orbits (only ~35 at the end of 2018, more info[12]) and help constrain meteorite source regions.*

4   GMN cameras for triangulation

Soon after the start of BE0001 at Mechelen Belgium, NL0006 and NL0008 were installed and tested at Hengelo, the Netherlands as well as DE0001 at Langenfeld, Germany. Three GMN locations at a suitable distance for multiple station work inspired the three authors to point the cameras in such a way that meteors could be registered from the three locations. The weather was not very cooperative but a major improvement in the weather pattern brought several clear nights in February.

Between 2019 February 11 and 16, the authors started with simultaneous observations of meteors. In about one week of time 28 trajectories were obtained by *Martin Breukers*, using the Ufo Orbit software from Sonotaco.com to process the observations. The trajectory plots are shown in *Figure 2*, the radiant distribution in *Figure 5*. This is a nice and encouraging first result.
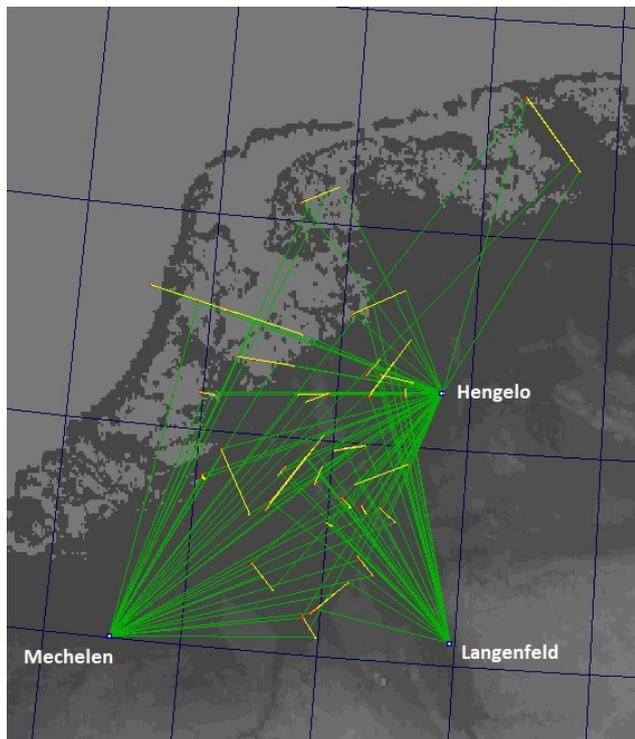
Figure 2 – The first 28 trajectories obtained by the GMN cameras in Hengelo, Langenfeld and Mechelen.
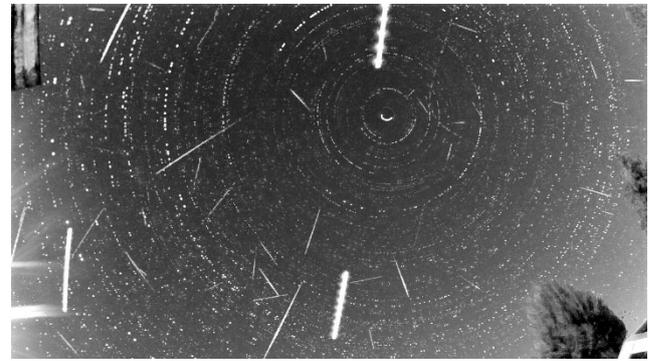
Figure 3 – Stacked image with 47 meteors and some planes registered by camera NL0008 at Hengelo the Netherlands in the night of 14–15 February 2019.

5   One of the first hits: a fireball!

The second simultaneous meteor was a –4 fireball that appeared on 2019 February 11 at 4^{h}33^{m}37^s UT, recorded on NL0008 at Hengelo and BE0001 at Mechelen where it appeared very low above the horizon. The trajectory of the fireball was above Northern Germany, the most northern path plotted on the map shown in *Figure 2*. *Figure 7 and 8* show the images as recorded by both cameras.
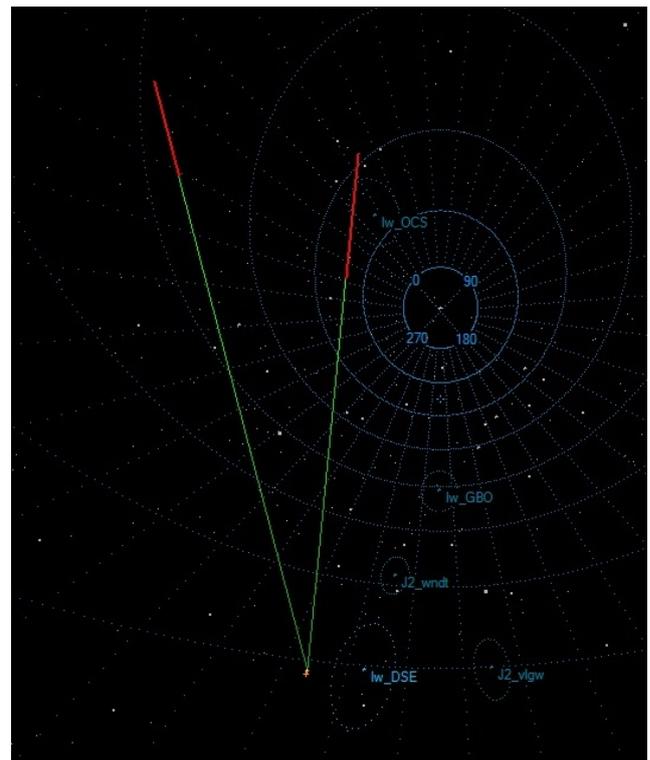
Figure 4 – The plots of the fireball of 2019 February 11 at 4^{h}33^{m}37^s UT and its radiant on the hemisphere.

The UFOCapture software associates our fireball with the minor shower δ-Serpentids (DSE#34), however this shower has meanwhile been removed from the IAU Meteor Data Center for reason of lack of evidence. Also, our own tool to verify orbit similarity rejects the shower association, using all three discrimination criteria of Southworth and Hawkins (1963), Drummond (1981) and Jopek (1993).

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[11] https://globalmeteornetwork.org

[12] http://www.meteoriteorbits.info/
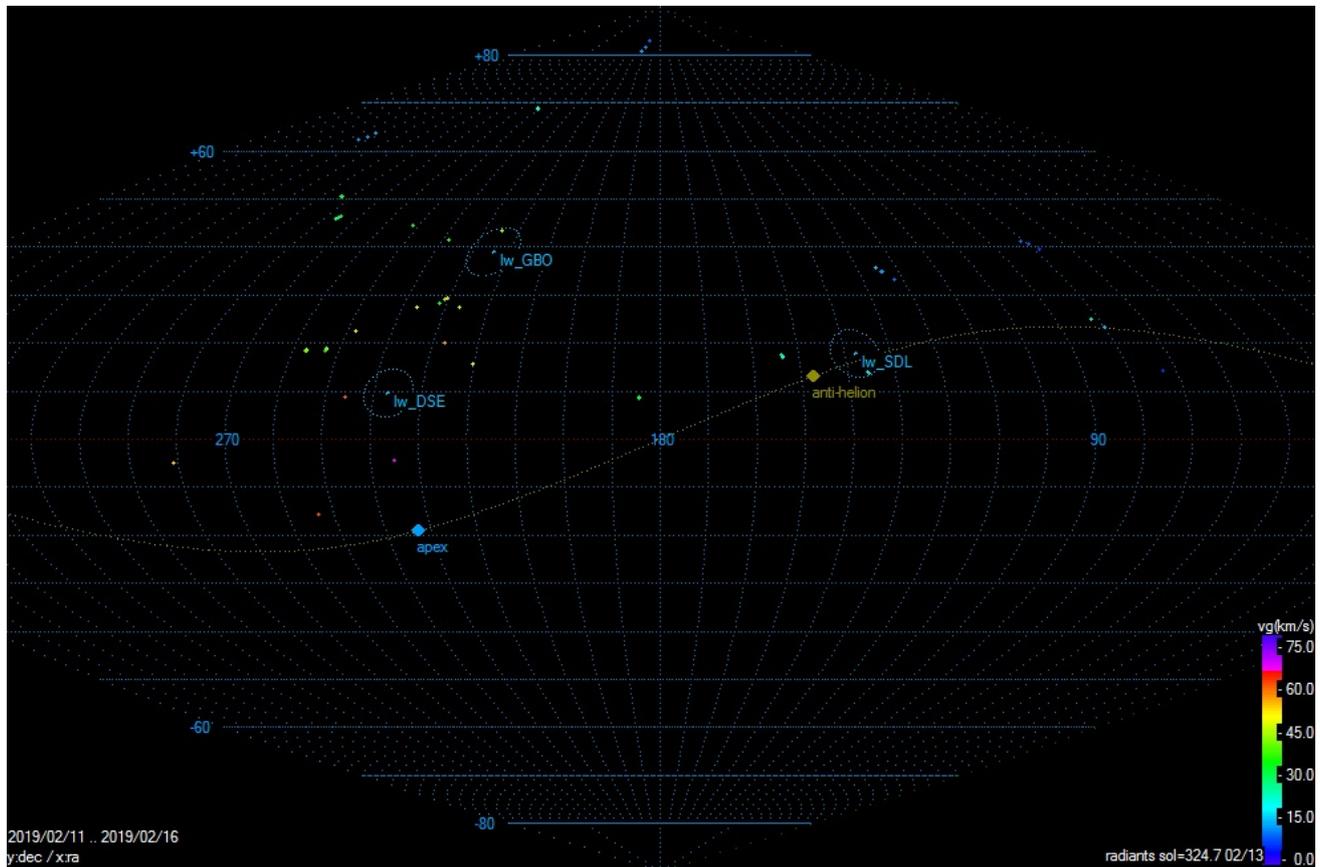
Figure 5 – The radiant plot for all 28 GMN multiple station meteors.

Table 1 – The orbital elements of the fireball of 2019 February 11 at 4ʰ33ᵐ37ˢ UT compared to the meteor shower DSE#034 that was removed from the IAU working list of meteor showers.

	IAU list DSE#034	GMN
α_g (°)	237	246
δ_g (°)	+9.6	+8.7
v_g (km/s)	65	61.4
a (AU)	9.2	3.3
q (AU)	0.986	0.910
e	0.893	0.724
i (°)	130.5	126.0
ω (°)	184.7	144.5
Ω (°)	324.1.	321.9

It is not clear how the shower DSE#034 got into the IAU meteor working list as the reference is missing. A parent body is mentioned as 1947 F2 (Becvar), but without any references. *Figure 6* shows the orbit plot, *Table 1* compares these with the data for DSE#034. That D-criteria fail on a similarity check is no surprise when the large difference in argument of perihelion ω is considered. Meteor orbits change with time and ω may have changed until a point that similarity criteria fail to indicate possible associations unless the evolution of the orbit can be reconstructed. This erroneous shower association by the SonotaCo software proves once more how tricky it is to associate meteors with

showers looking no further than radiant and velocity. This case also proves the need to invest in multiple station work in order to obtain orbits and not just single station meteor trails. Making statistics based on single station meteor work for showers with activity levels below a certain detection level will always result in some numbers, but the results will vary randomly within the statistical flutter.
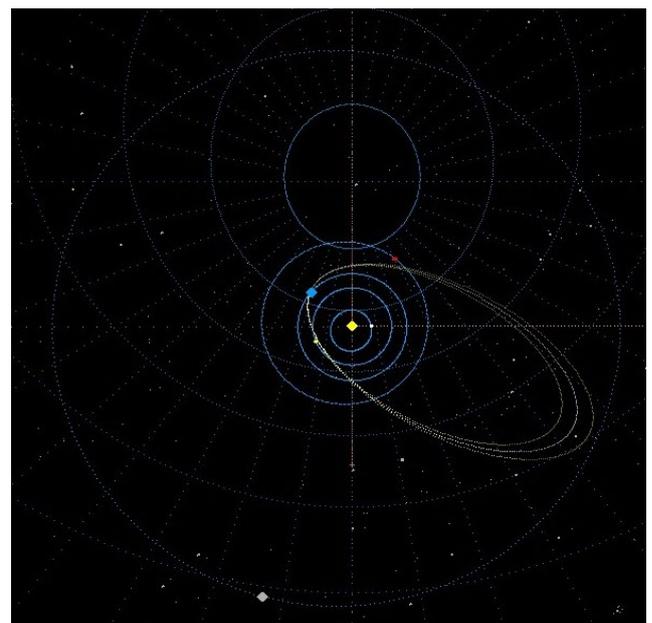
Figure 6 – The orbit plot for the fireball of 2019 February 11 at 4ʰ33ᵐ37ˢ UT.

/home/pi/RMS_data/ArchivedFiles/BE0001_20190210_231749_025697/FF_BE0001_20190211_043329_110_0462848.fits_maxpixel.jpg
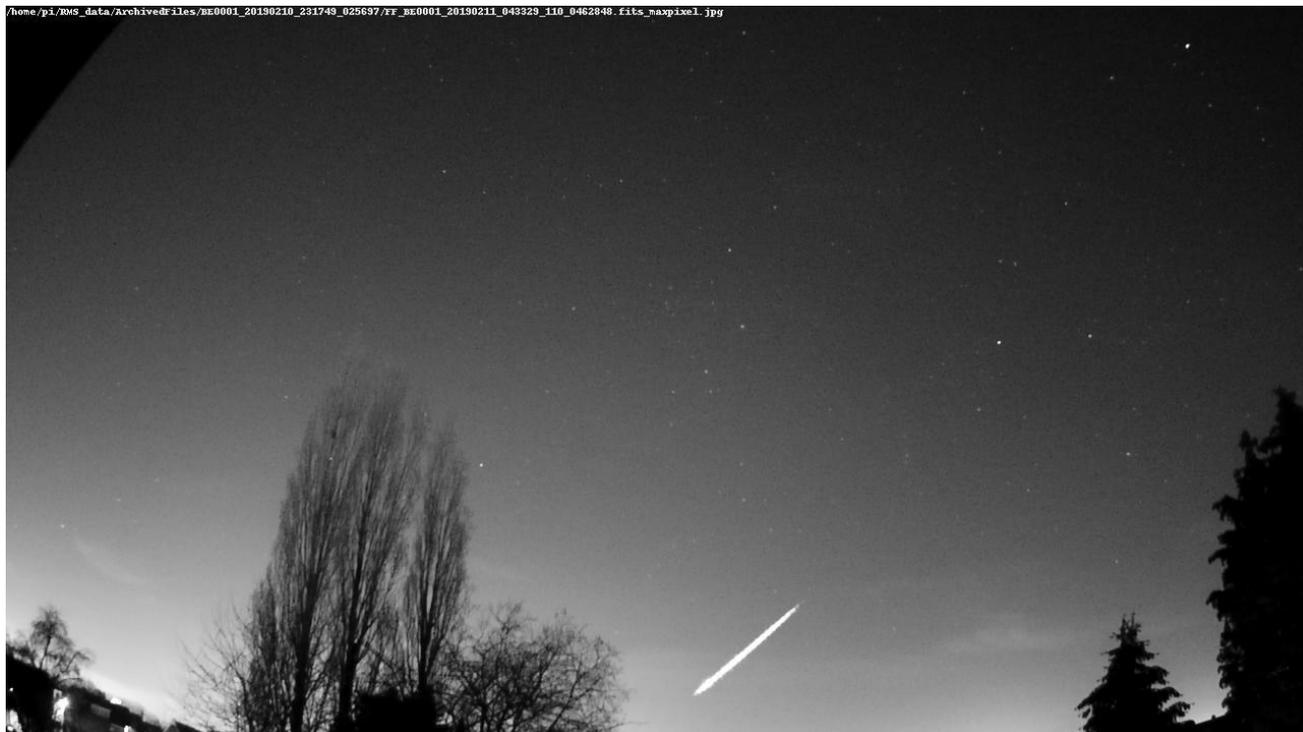
Figure 7 – The fireball of 2019 February 11 at 4^{h}33^{m}37^s UT as recorded by BE0001 at Mechelen, Belgium.

Figure 8 – The fireball of 2019 February 11 at 4^{h}33^{m}37^s UT as recorded by NL0008 at Hengelo, the Netherlands.

May be some source may be active as minor shower at this position. This may be a nice target for a minor shower case study on the large datasets of meteor orbits available, if we can find the time for this.

6   Future plans

The Global Meteor Network's goal is to have a yearly average of 1000 orbits per night. To achieve this there are still some hundreds of extra cameras required spread across our planet. A project like this is a life time project comparable to missions to explore the outer regions of our

Solar System, but nevertheless just concerns our own planet. The dust and bigger fragments that bomb our atmosphere causing shooting stars, dropping meteorites and hurting our dear planet with craters, needs monitoring.

The modest contribution of the authors is to run our cameras. The BE0001 will be moved to the south-east of Belgium near the French-Luxembourg border under perfect dark skies. A new GMN camera will be installed in Mechelen to be directed at optimal overlap with NL0008 and DE0001.

If there are other RPI users in France, Germany or the UK who want to join us, please contact us.

We would also like to encourage other stations to find a partner for data collection. Multiple station work has so much more to offer. It is worth it! Never before amateurs had such an opportunity to make their contribution to the understanding of the dust in our Solar System, the remnants of disintegrated comets that our ancestors failed to detect, famous known comets and yet to discover comets, but also all these near-Earth objects that dump debris into an orbit that sooner or later hits our planet.

There is so much to discover, to verify and to document, if you feel like ready to make a real contribution, then join us and set-up your meteor video camera!

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Radio observations of the Quadrantids 2019

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A summary report is presented covering the Quadrantid activity on 3 and 4 January 2019 as observed by radio at 49.99 MHz from Kampenhout, Belgium.

1 Introduction

This year, the Quadrantids again produced a great show, with here at Kampenhout (BE) a maximum of more than 230 counted reflections per hour around 05:00 h UT on January 4th.

Figures 1, 2 and *3* show the hourly totals of "all" reflections counted automatically, and of manually counted "overdense reflections" and "overdense reflections longer than 10 seconds" on the frequency of our VVS-beacon near Ieper (49.99 MHz), from 3 Jan 2019 00:00 UT till 5 Jan 2019 00:00 UT.

The shown hourly totals are weighted averages derived from:

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

The graphs also show for comparison the hourly activity for the years 2015, 2016, 2017 and 2018. It seems that this year's activity resembles strongly that of 2016, but with less overdense reflections.

For reference the hourly elevation of the Quadrantids' radiant here at Kampenhout is shown as well (*Figure 4*).

If you are interested in the actual figures, please send me an e-mail: felix.verbelen at skynet.be. I'll send you the underlying excel file.

Figure 1 – Weighted averages of all reflections on 49.99 MHz during the Quadrantids 3 to 4 January 2019.

QUA2019_49.99MHz_03+04 January
Overdense reflections (weighted averages)
Felix Verbelen (Kampenhout/BE)
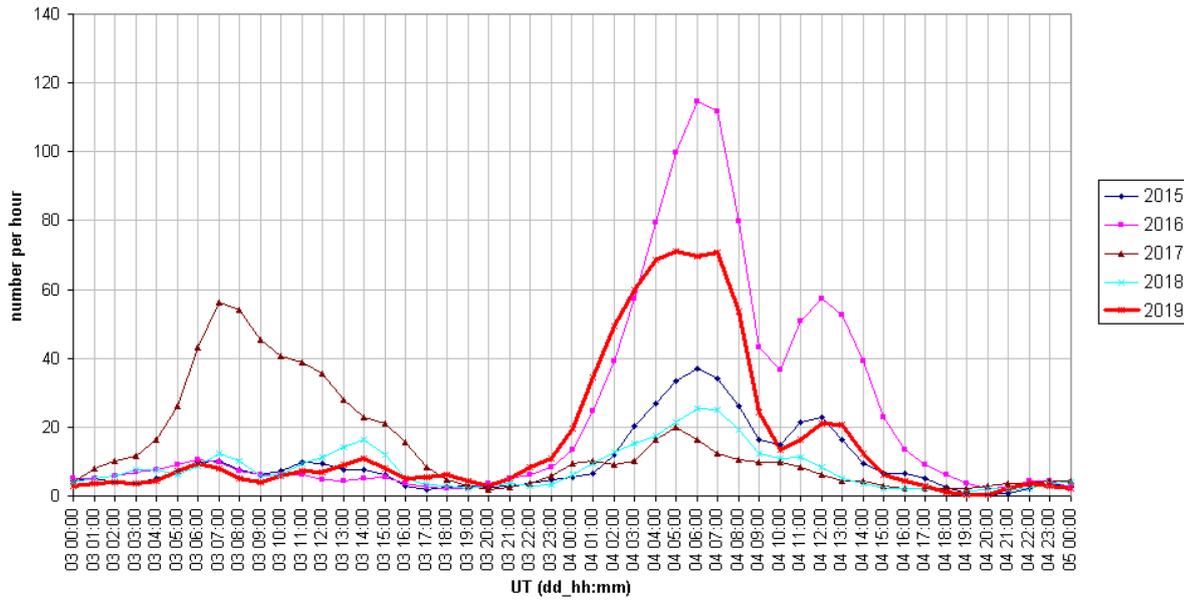
Figure 2 – Weighted averages of overdense reflections on 49.99 MHz during the Quadrantids 3 to 4 January 2019.

QUA2019_49.99MHz_03+04 January 2019
Overdense reflections longer than 10 seconds (weighted averages)
Felix Verbelen (Kampenhout/BE)
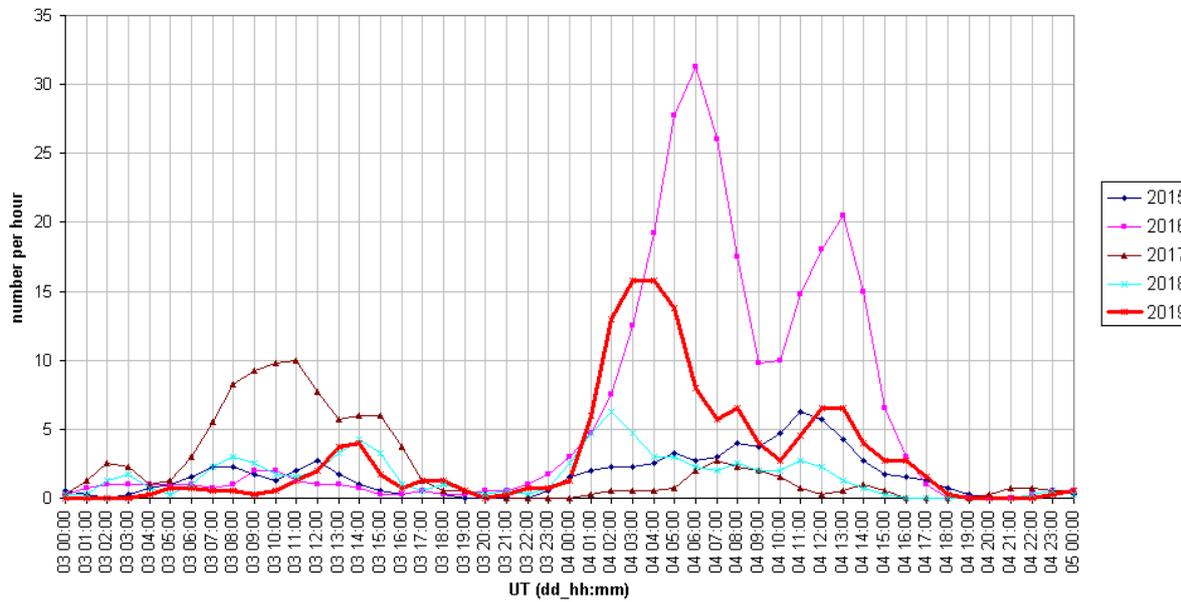
Figure 3 – Weighted averages of overdense reflections longer than 10 seconds on 49.99 MHz during the Quadrantids 3 to 4 January 2019.

Figure 4 – Elevation of the Quadrantid radiant at Kampenhout (BE), 4.59° East and 50.95° North, for 3-4 January 2019.

Figure 5 – A 5-minutes SpecLab picture obtained in Kampenhout (BE) during a rich display with hundreds of radio reflections on the frequency of our VVS-radio beacon (49.99 MHz).
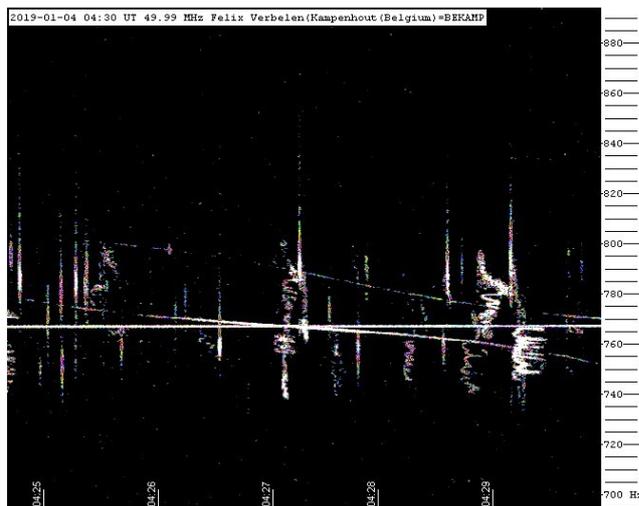
Figure 7 – A 5-minutes SpecLab picture obtained in Kampenhout (BE) during a rich display with hundreds of radio reflections on the frequency of our VVS-radio beacon (49.99 MHz).
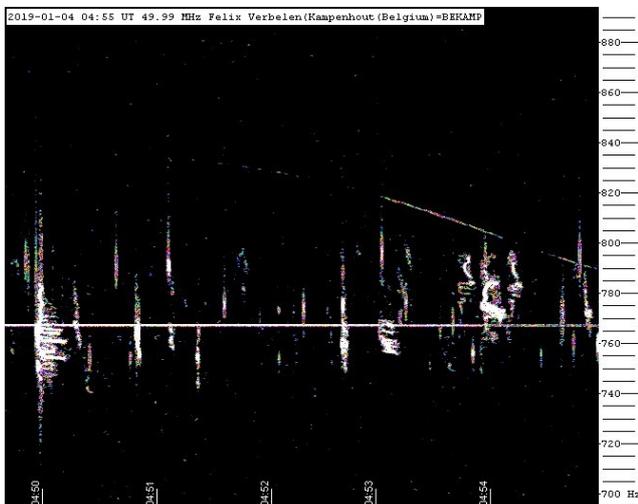
Figure 6 – A 5-minutes SpecLab picture obtained in Kampenhout (BE) during a rich display with hundreds of radio reflections on the frequency of our VVS-radio beacon (49.99 MHz).
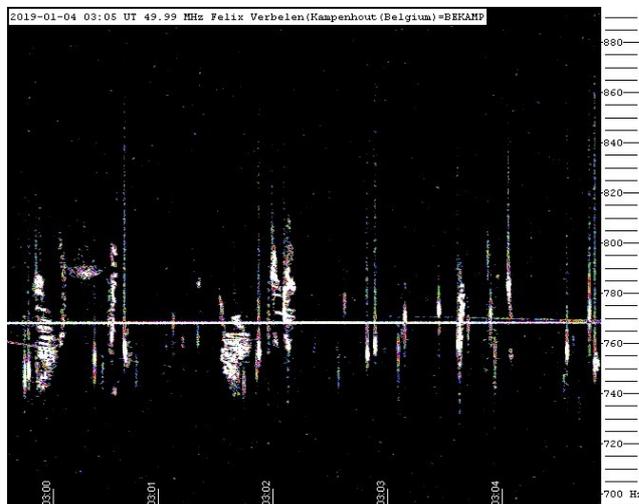
Figure 8 – A 5-minutes SpecLab picture obtained in Kampenhout (BE) during a rich display with hundreds of radio reflections on the frequency of our VVS-radio beacon (49.99 MHz).

Annual report 2018 radio meteors

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The annual report is presented with the results of the radio observations in 2018, with the relative activity of meteor showers in three categories of all overdense duration. The 2018 activity is compared with the average activity 2008-2017.

1   Introduction

The observations were carried out here at Kampenhout (BE) on 49.99 MHz, the frequency of our VVS beacon that is hosted by the colleagues of AstroLab-IRIS at Zillebeke (Ypres/BE). This beacon has been active since April 2005. Permanent monitoring of the forward scatter observed at Kampenhout started at the same time.

Both the beacon and the receiving installation remained practically unchanged for the entire period until now, and fortunately suffered only minimal problems or interruptions.

The activity graphs show only the number of overdense reflections, subdivided into 3 categories: "all overdense reflections", "all overdense reflections lasting more than 10 seconds", "all overdense reflections longer than 1 minute". Counts were all done manually, based on 5 minutes screen dumps obtained with the excellent program "SpecLab".

The presented charts indicate respectively:

- a global annual overview for each of the 3 categories showing the relative importance of the meteor shower in each category (*Figure 1*).
- a similar overview, but then per trimester (*Figures 2, 3, 4* and *5*).

2   The major meteor showers in 2018

Comparison of the three categories gives a good indication of the composition of the different meteor showers. It is i.e. striking that the Quadrantids (QUA) (*Figure 2*) and the Geminids (GEM) (*Figure 5*), that yield, as we know, a lot of reflections and are therefore considered, together with the Perseids (*Figure 4*), as the main annual showers, show little or no reflections with a duration of more than 1 minute.

3   Comparing 2018 activity with 2008–2017

Comparing 2018 to the 10-year average of the period 2008–2017, 2018 was a fairly normal meteor year, with the following exceptions:

- the Quadrantids (QUA) were much less active than average in the three considered categories (*Figure 2*);
- the Lyrids (LYR) were also less active than in previous years (*Figure 3*);
- the surprise of the year were the Leonids (LEO), producing an unusual number of long lasting reflections (*Figure 5*);
- the Ursids (URS) were less active than on some previous occasions (*Figure 5*).

The activity of the other "big" showers (i.e. Eta Aquariids, daytime showers including the Arietids, Perseids, Draconids, Orionids) was pretty well in line with the 10-year average.

Smaller and weaker showers showed some variations in 2018 compared to their average activity, but these should be further investigated on the basis of the hourly averages and certainly also taking into account the "underdense" reflections.
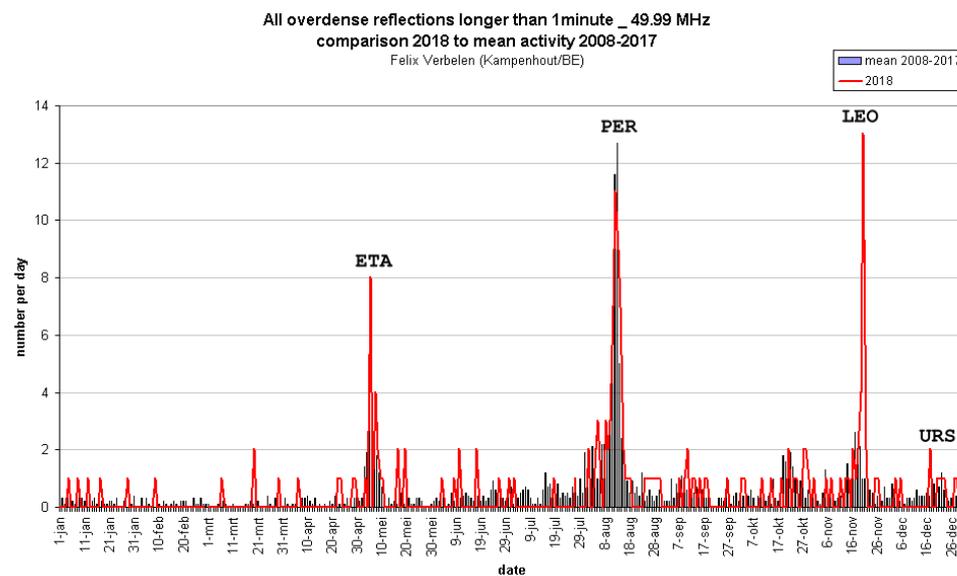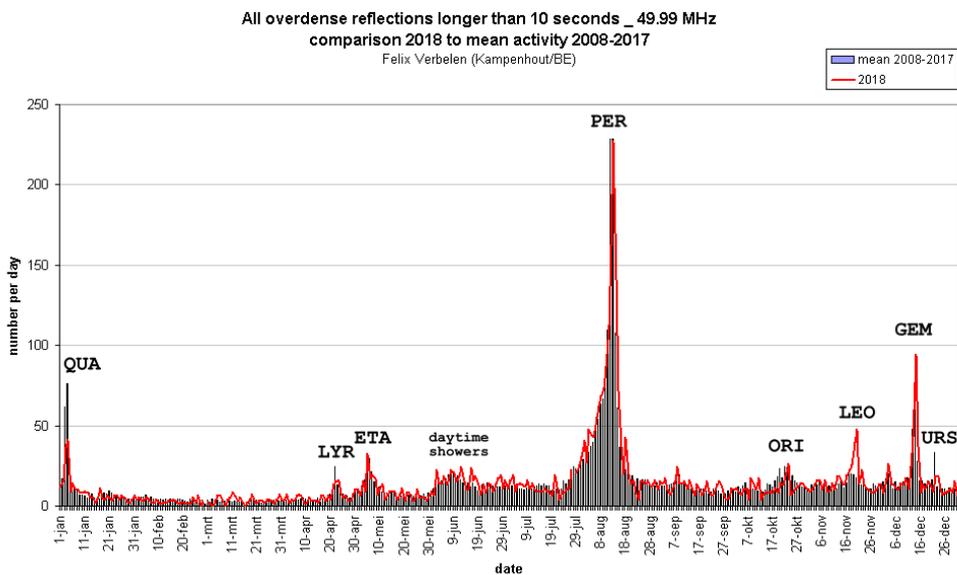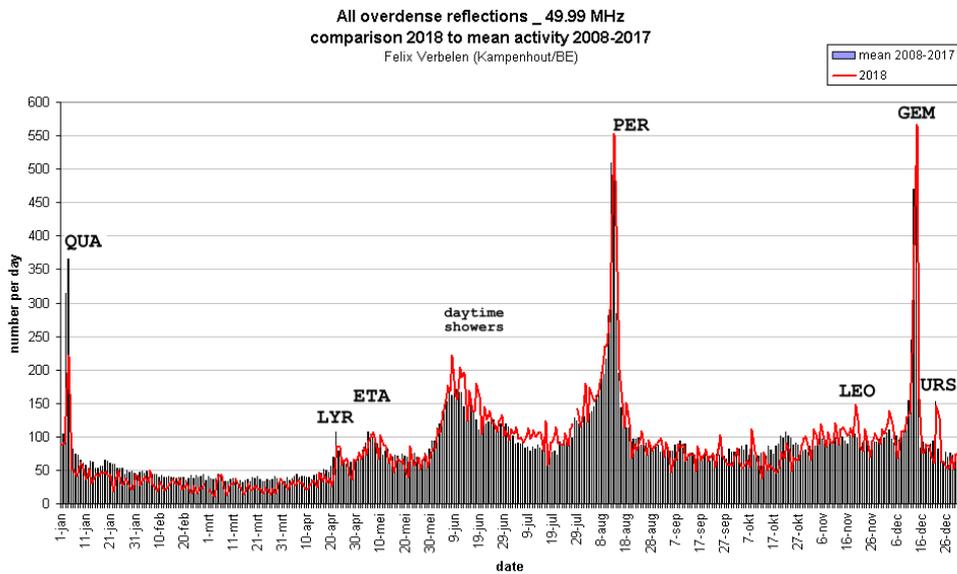
Figure 1 – Global annual overview for each of the 3 categories: "all overdense reflections", "all overdense reflections lasting more than 10 seconds", "all overdense reflections longer than 1 minute". This shows the relative importance of the meteor shower in each category. The daily meteor activity in 2018 is compared to the average daily activity during the period 2008–2017.
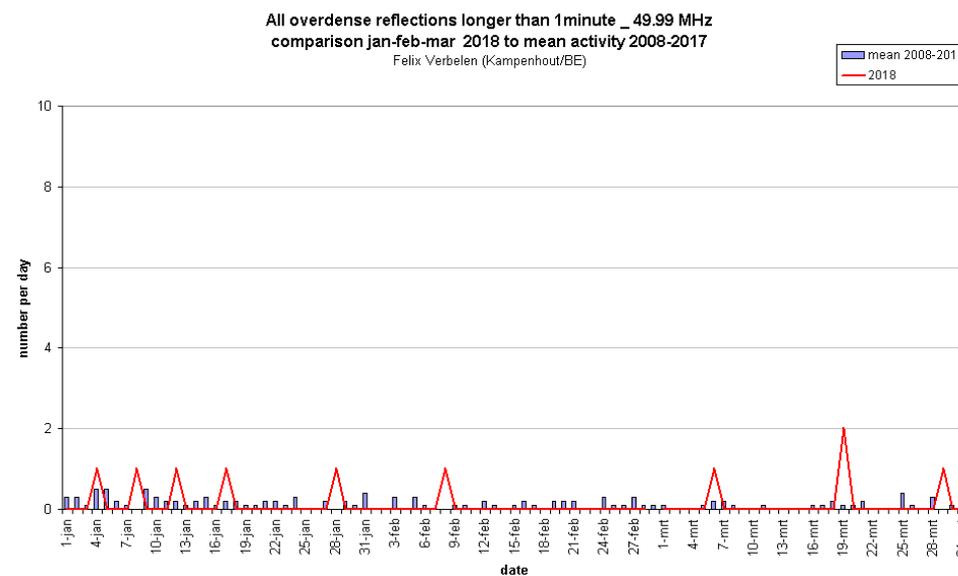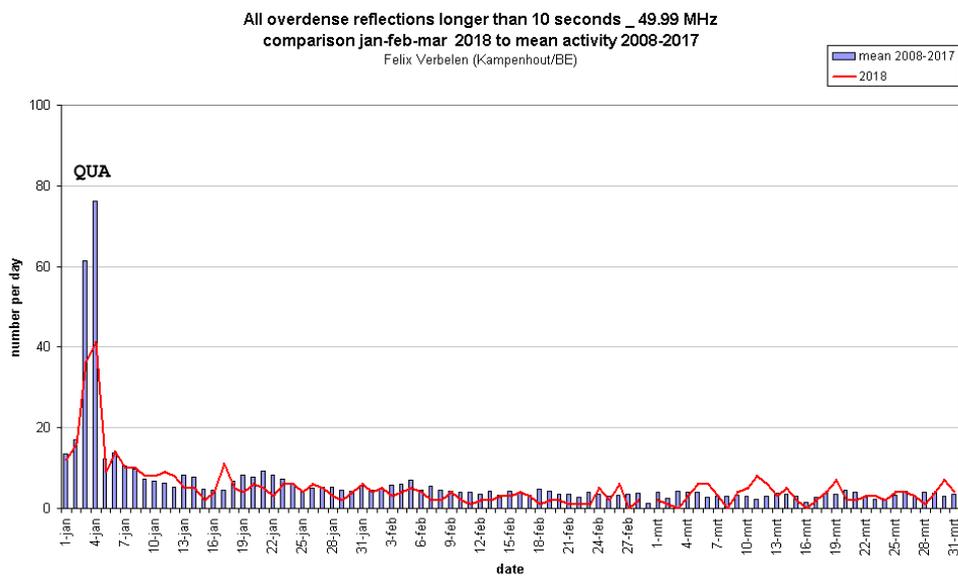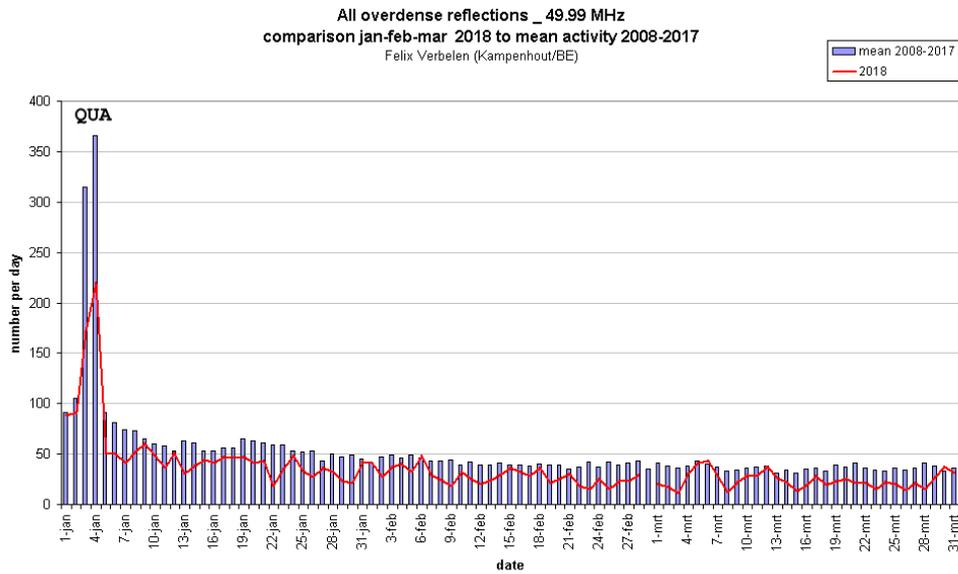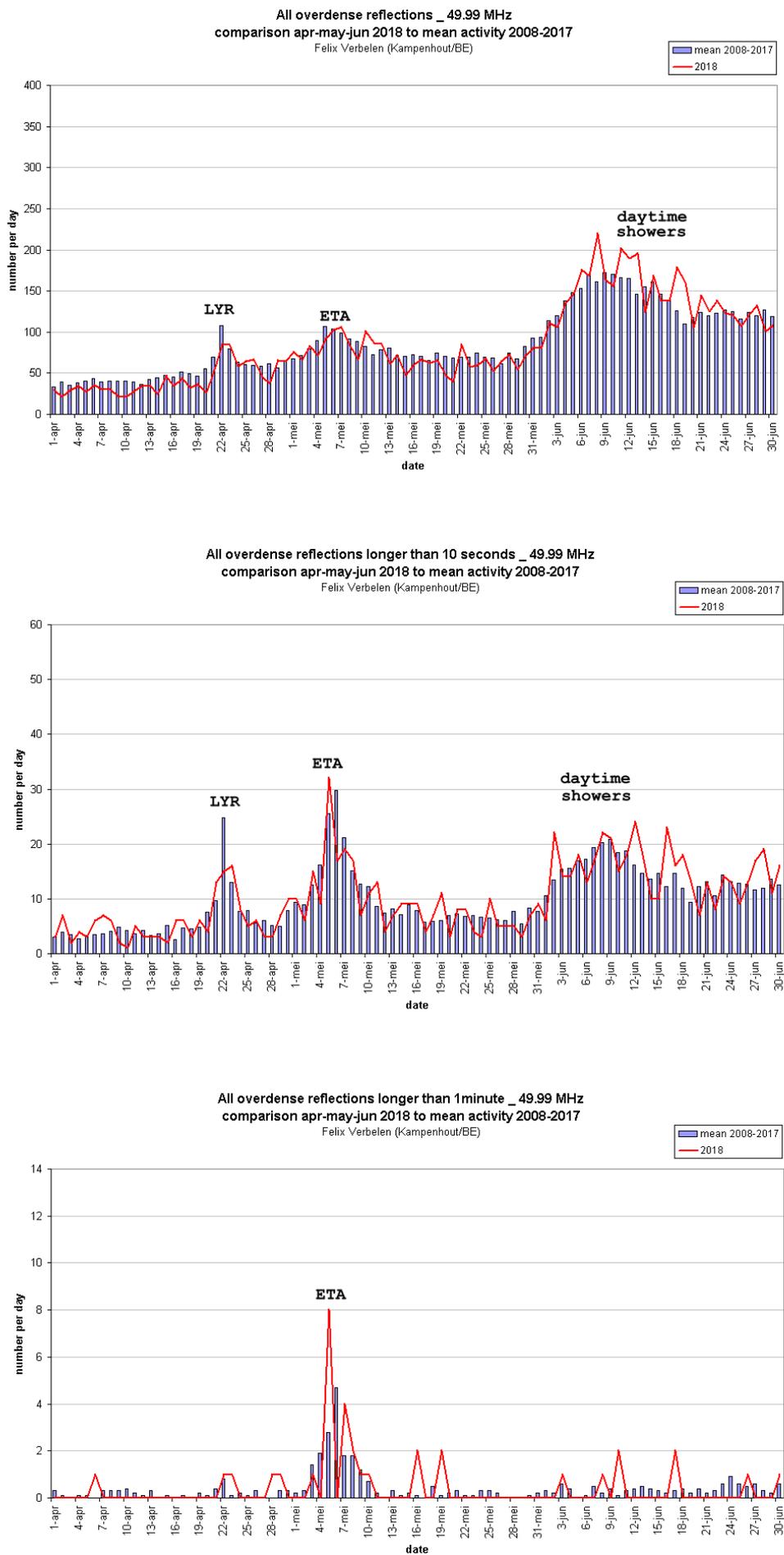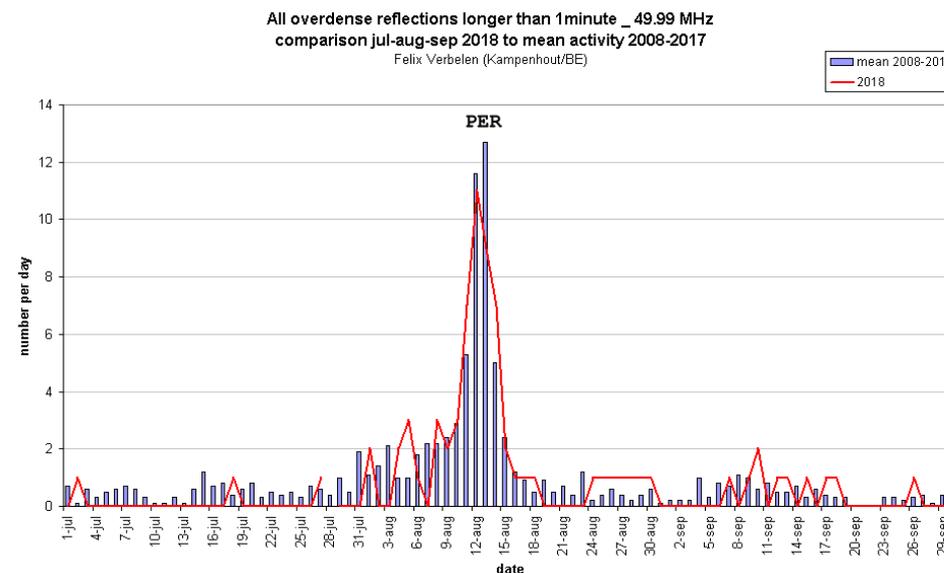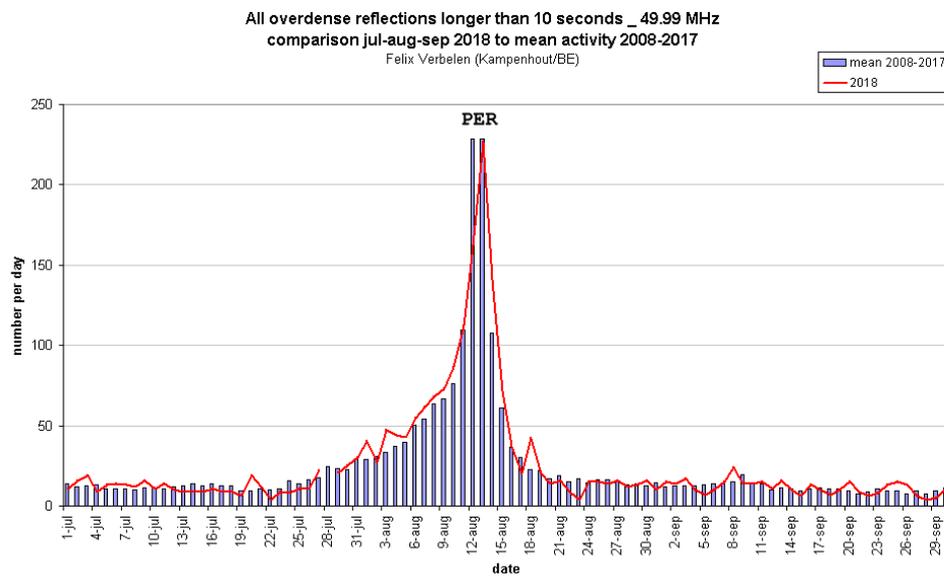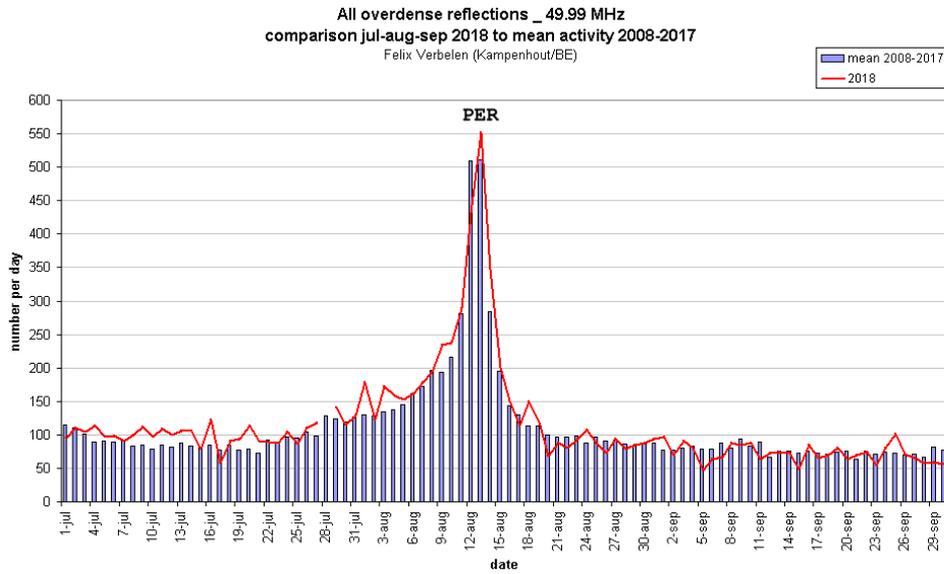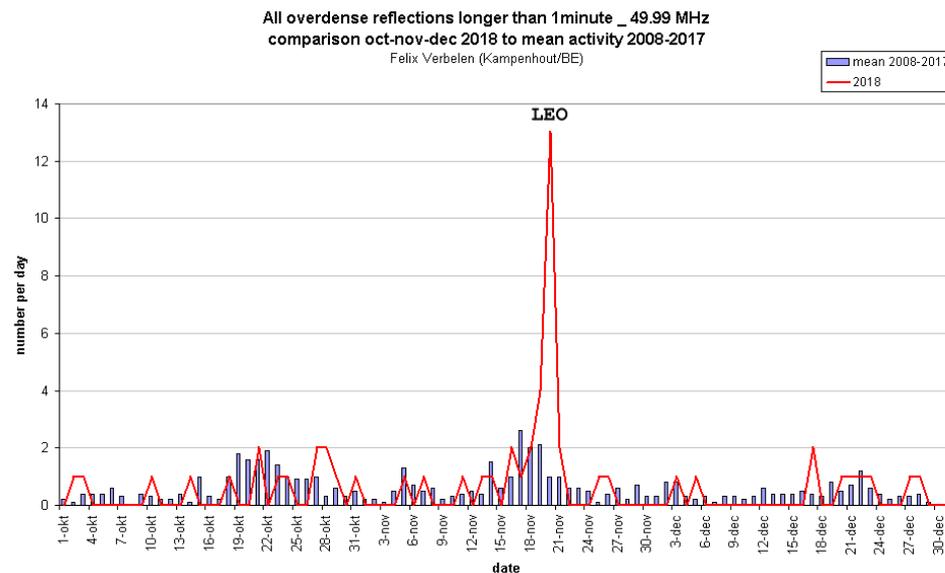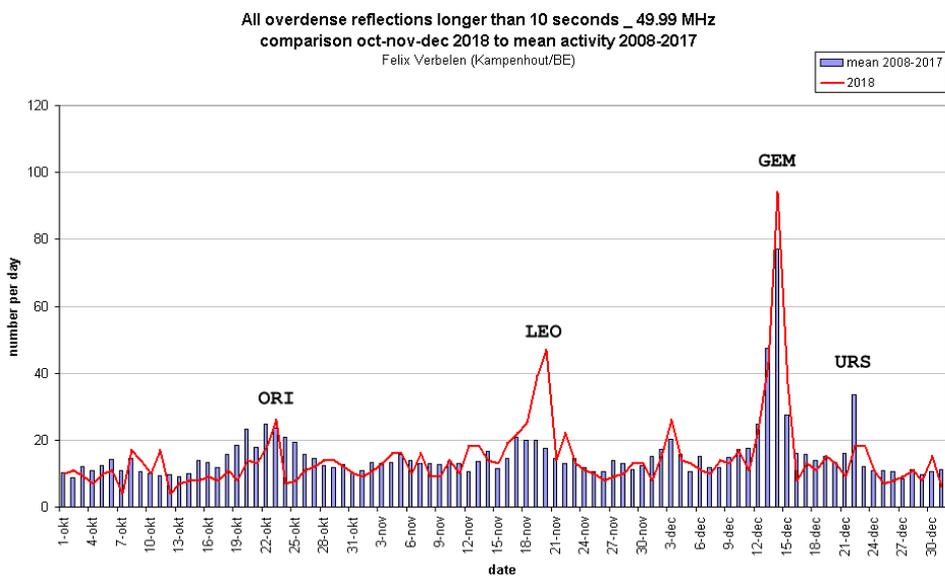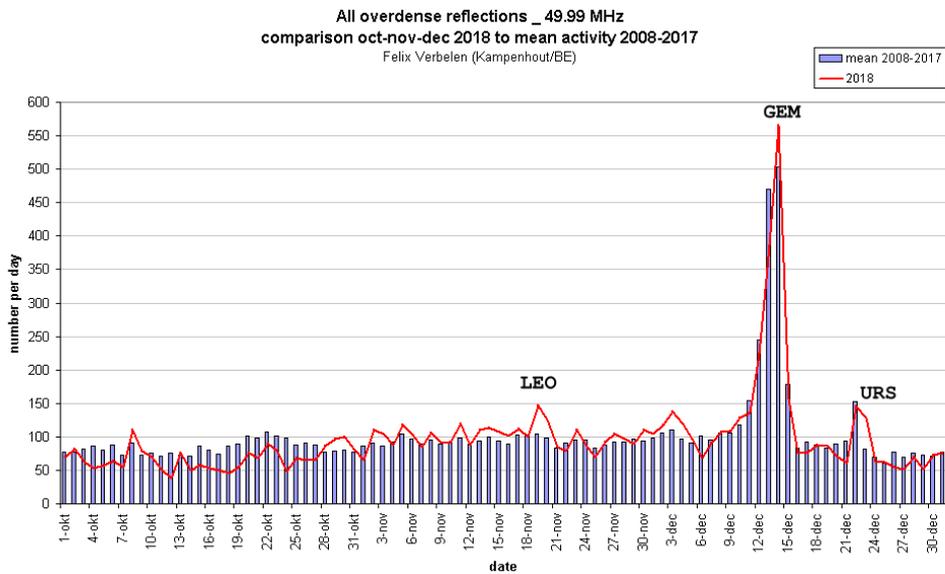
Figure 2 – First quarter 2018 overview for each of the 3 categories: "all overdense reflections", "all overdense reflections lasting more than 10 seconds", "all overdense reflections longer than 1 minute". This shows the relative importance of the meteor shower in each category. The daily meteor activity in 2018 is compared to the average daily activity during the period 2008–2017.

All overdense reflections _ 49.99 MHz
comparison apr-may-jun 2018 to mean activity 2008-2017
Felix Verbelen (Kampenhout/BE)

All overdense reflections longer than 10 seconds _ 49.99 MHz
comparison apr-may-jun 2018 to mean activity 2008-2017
Felix Verbelen (Kampenhout/BE)

All overdense reflections longer than 1minute _ 49.99 MHz
comparison apr-may-jun 2018 to mean activity 2008-2017
Felix Verbelen (Kampenhout/BE)

Figure 3 – Second quarter 2018 overview for each of the 3 categories: "all overdense reflections", "all overdense reflections lasting more than 10 seconds", "all overdense reflections longer than 1 minute". This shows the relative importance of the meteor shower in each category. The daily meteor activity in 2018 is compared to the average daily activity during the period 2008–2017.

Figure 4 – Third quarter 2018 overview for each of the 3 categories: "all overdense reflections", "all overdense reflections lasting more than 10 seconds", "all overdense reflections longer than 1 minute". This shows the relative importance of the meteor shower in each category. The daily meteor activity in 2018 is compared to the average daily activity during the period 2008–2017.

Figure 5 – Last quarter 2018 overview for each of the 3 categories: "all overdense reflections", "all overdense reflections lasting more than 10 seconds", "all overdense reflections longer than 1 minute". This shows the relative importance of the meteor shower in each category. The daily meteor activity in 2018 is compared to the average daily activity during the period 2008–2017.

Radio meteors January 2019

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

1   Introduction

The graphs show both the daily totals (*Figures 5 and 6*) and the hourly numbers (*Figure 7 and 8*) 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 January 2019.

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

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

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

Highlights of the month were of course the Quadrantids. For this I published an overview in MeteorNews (this issue). The rest of the month was fairly calm, but with nevertheless a number of nice smaller meteor showers (to be analyzed in detail) and with a few spectacular "radio fireballs" (see *Figures 1, 2, 3* and *4*).

If you are interested in the actual figures, please send me an e-mail: felix.verbelen at skynet.be.
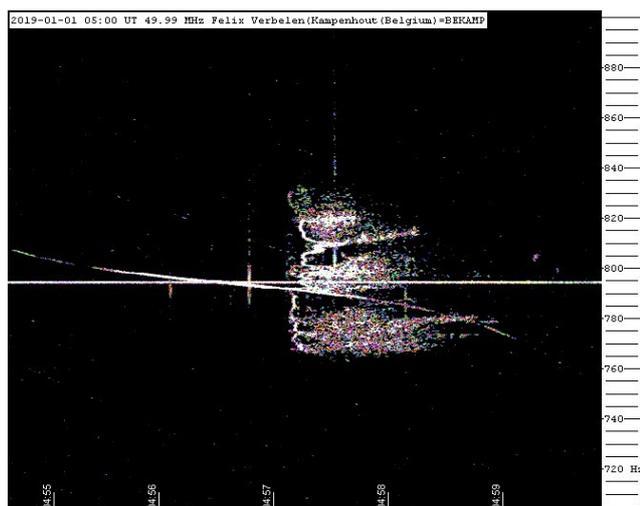
Figure 1 – 1 January 2019, 05h00m UT

Figure 2 – 5 January 2019, 14h30m UT.

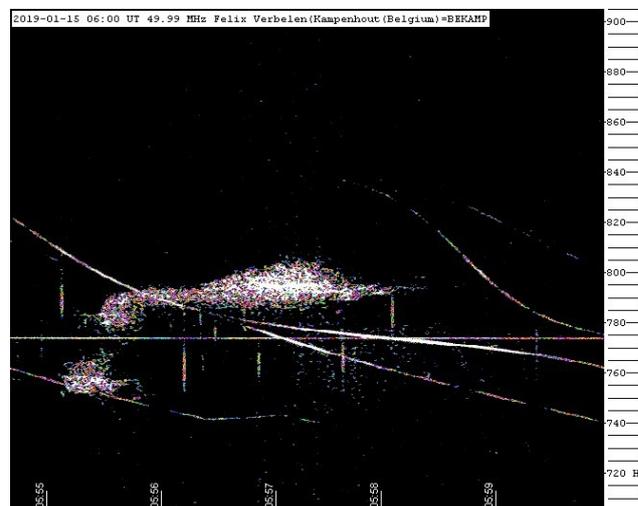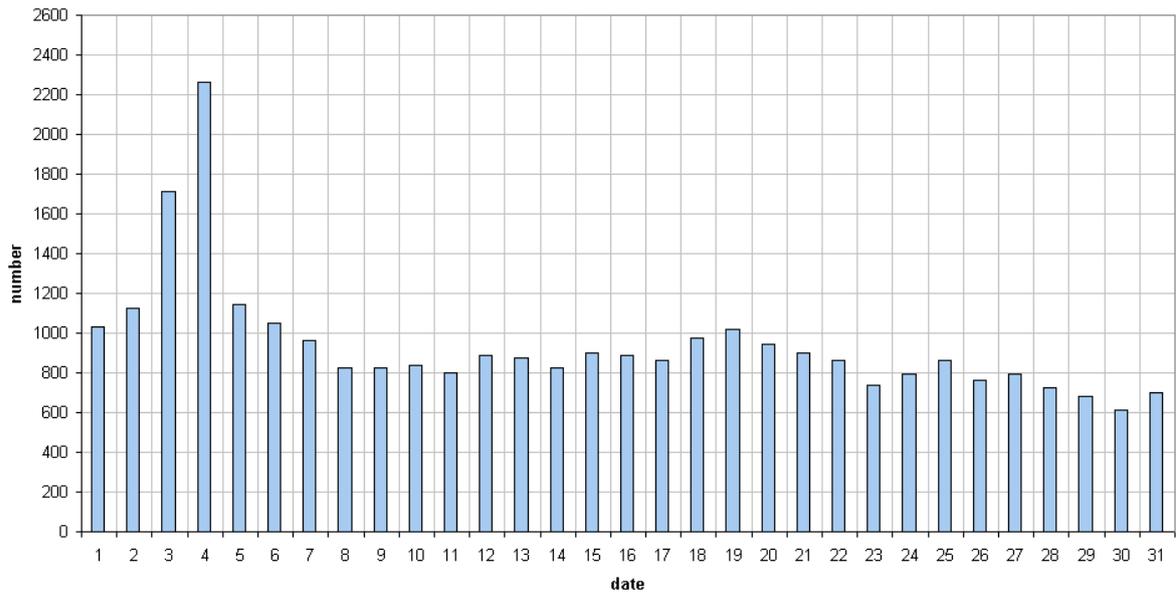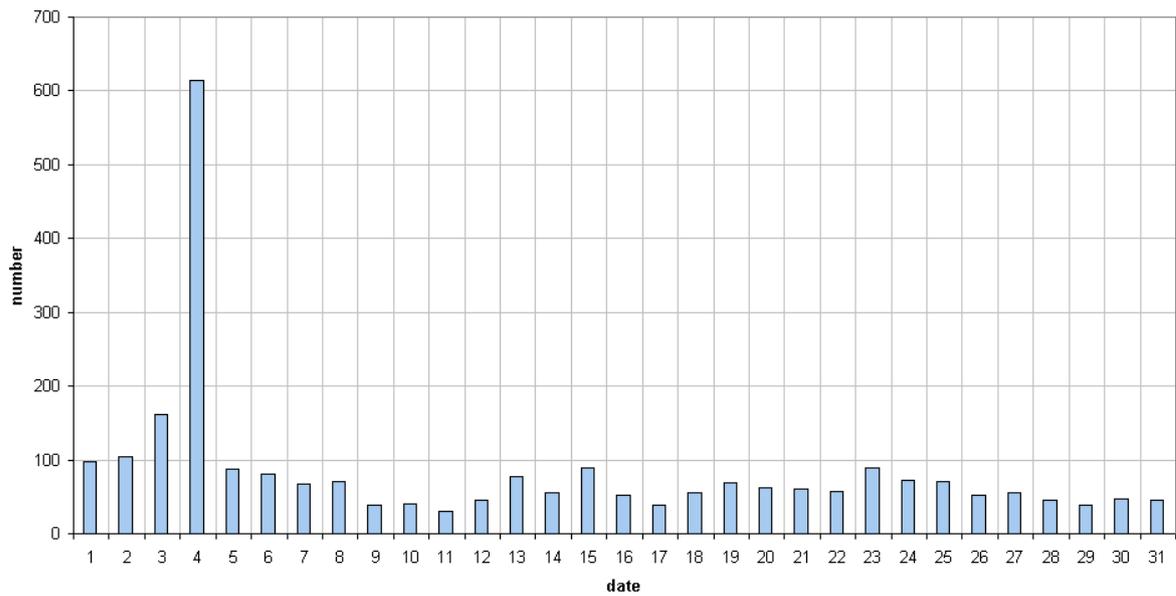*Figure 3* – 15 January 2019, 03h55m UT.

Figure 4 – 15 January 2019, 06h00m UT.

49.99MHz - RadioMeteors January 2019
daily totals of "all" reflections *(automatic count_Mettel5_7Hz)*
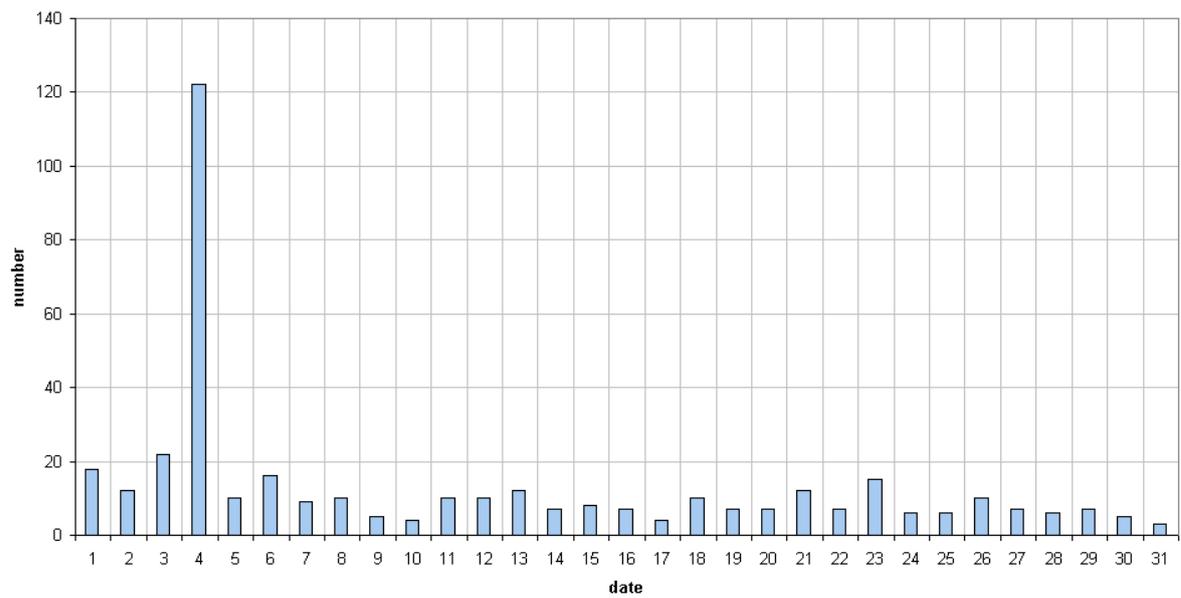*Felix Verbelen (Kampenhout)*

49.99MHz - RadioMeteors January 2019
daily totals of all overdense reflections
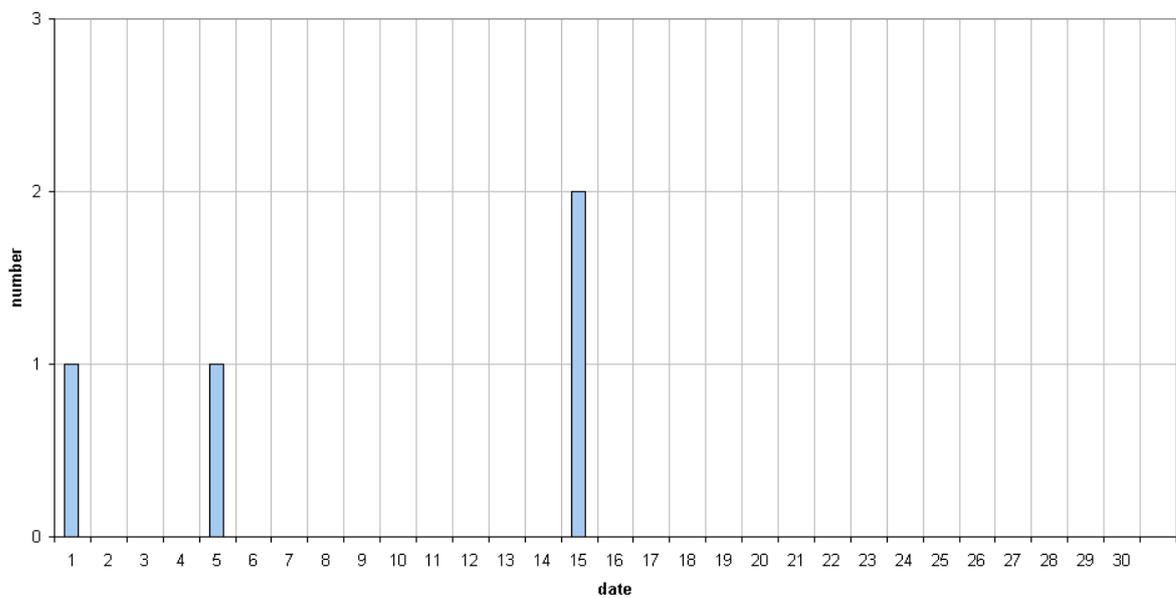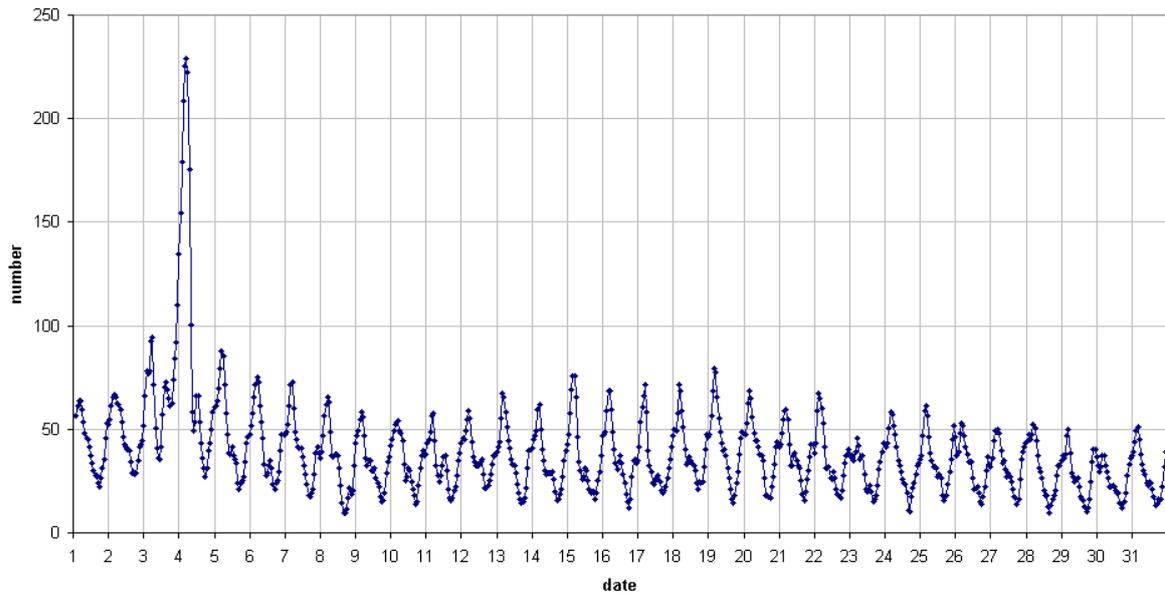*Felix Verbelen (Kampenhout)*

Figure 5 – 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 January 2019.

49.99MHz - RadioMeteors January 2019
daily totals of reflections longer than 10 seconds
Felix Verbelen (Kampenhout)

49.99MHz - RadioMeteors January 2019
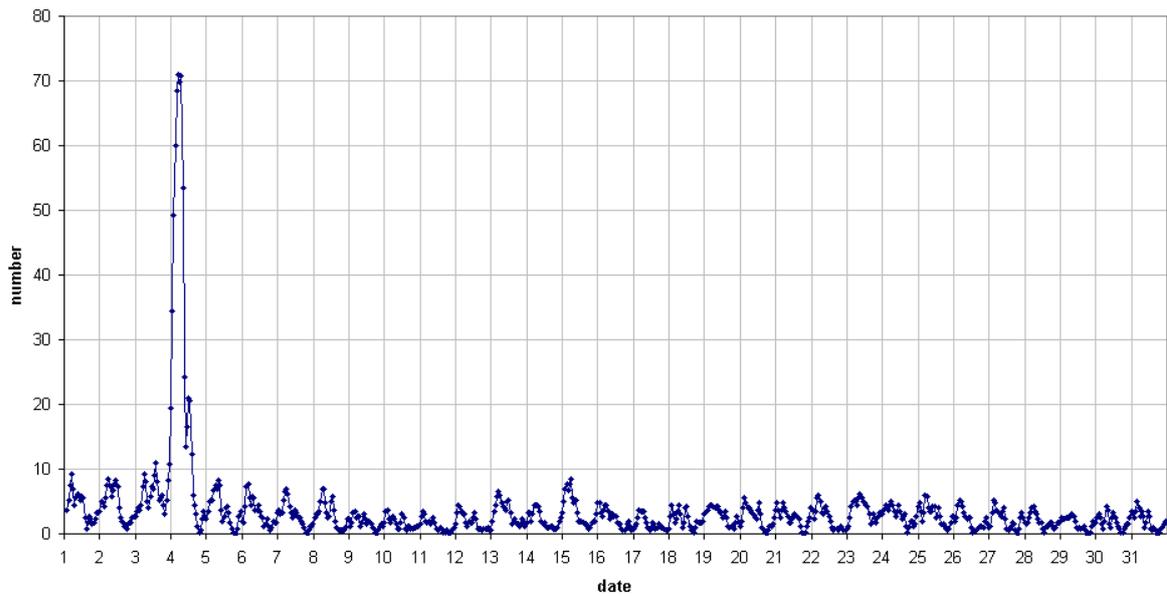### daily totals of reflections longer than 1 minute
Felix Verbelen (Kampenhout)

Figure 6 – 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 January 2019.

49.99 MHz - RadioMeteors January 2019
number of "all" refections per hour (weighted average) *(automatic count_Mettel5_7Hz)*
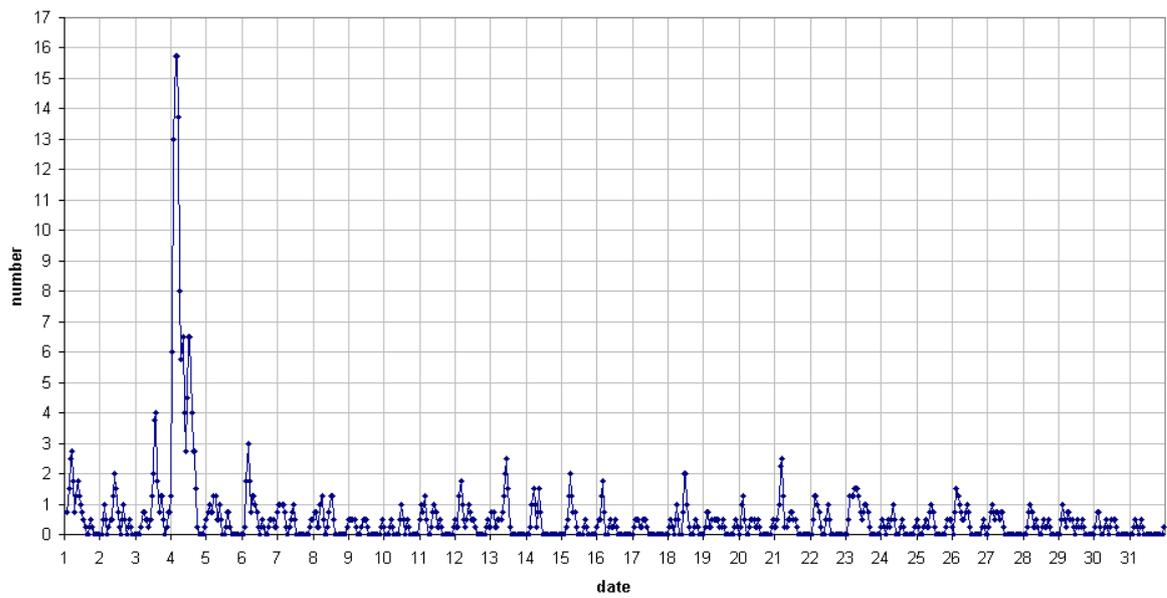*Felix Verbelen (Kampenhout)*

49.99MHz - RadioMeteors January 2019
number of overdense reflections per hour (weighted average)
*Felix Verbelen (Kampenhout)*

Figure 7 – 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 January 2019.

49.99MHz - RadioMeteors January 2019
number of reflections >10 seconds per hour (weighted average)
Felix Verbelen (Kampenhout)

49.99MHz - RadioMeteors January 2019
hourly totals of overdense reflections longer than 1 minute
Felix Verbelen (Kampenhout/BE)
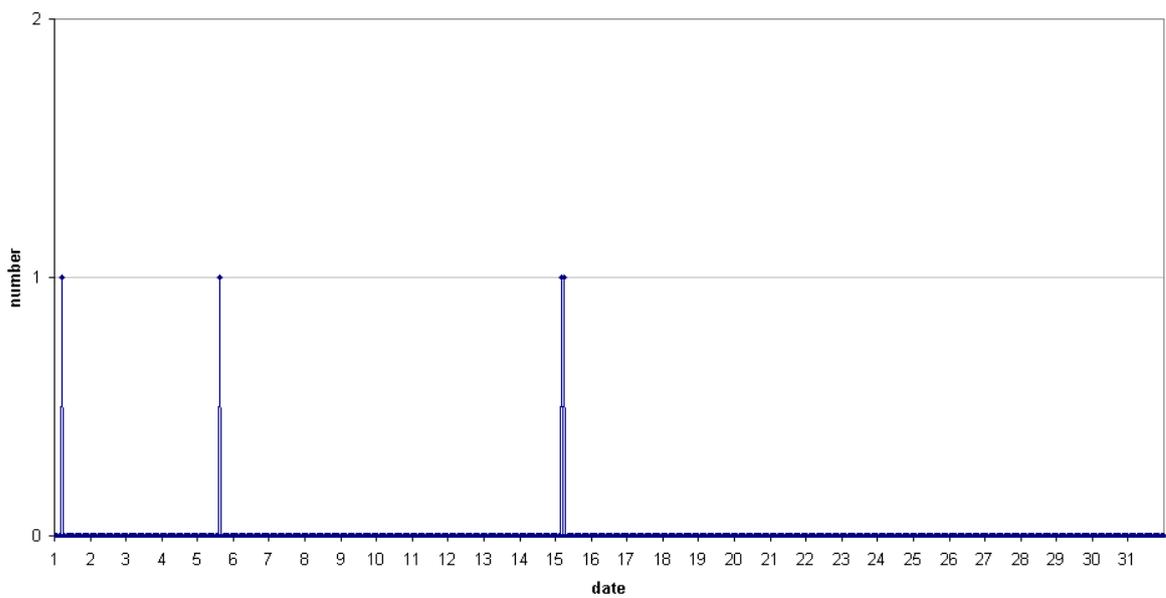
Figure 8 – The hourly numbers of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during January 2019.

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 January–February 2019.

1   Sporadic fireball over Spain on 2019 January 26

A bright fireball was spotted over Spain on 2019 January 26 at $23^h22^m27^s$ UT. This sporadic event was generated by a cometary meteoroid that hit the atmosphere at about 80000 km/h. It began over the province of Albacete at an altitude of around 97 km and ended at a height of about 65 km. It exhibited several bright flares along its atmospheric path.

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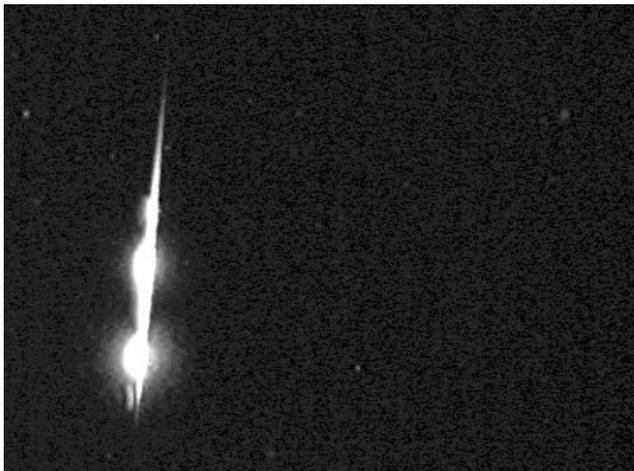

Figure 1 – Fireball 2019 January 26, $23^h22^m27^s$ UT.

2   Stunning fireball over the Mediterranean Sea

This fireball was recorded over the Mediterranean Sea on 2019 February 6 at 0^h33^m UT. It was generated by a meteoroid from an asteroid that hit the atmosphere at about 72000 km/h. It began at an altitude of about 116 km over the sea, and ended at a height of around 58 km. The event was brighter than the Full Moon.

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

Figure 2 – Fireball 2019 February 6, 0^h33^m UT.

Fireball over Belgium
2019 February 15, 20h09m UT

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An overview is presented of the images, trajectory and orbit of the fireball. The orbit may be associated with an earlier identified fireball stream listed as the January nu Orionids (JNO#267).

1   Introduction

A slow-moving fireball occurred on 2019 February 15 over Belgium at 20h09m UT at a perfect clear sky. The event was witnessed by many thousands of people that were out after an exceptional warm 15th of February. Most common descriptions were the slow appearance and a green color reported by many people. Luckily many meteor cameras are active in this region which could capture the event and allow reliable positional measurements.

Already at 20h25m UT, *Casper ter Kuile* shared a post in the CAMS BeNeLux Facebook group from an AstroForum published within 4 minutes after the appearance of the fireball. Many casual witnesses enjoyed the natural phenomenon. The camera data from all-sky stations and CAMS came early the next morning when the cameras ended the capture of the night.

2   The available data

Figure 1 – All sky camera image between 20h08m40s – 20h09m40s UT at Wilderen, Belgium, by Jean-Marie Biets.

Jean-Marie Biets (*Figure 1*) was the first to mention this event on the BeNeLux meteor mailing list. Soon more all-sky pictures were posted by Franky Dubois (*Figure 2*), Koen Miskotte (*Figure 3 and 4*), Klaas Jobse (*Figure 5*), Peter van Leuteren and Mark Jaap ten Hove. The CAMS network collected several more detailed registrations of the fireball: Jean Marie Biets (CAMS 380, Wilderen, Belgium, *Figure 6*), Jean-Paul Dumoulin and Christian Wanlin (CAMS 815, Grapfontaine, Belgium, *Figure 7*), Bart Dessoy (CAMS 397,398, 804; Zoersel, Belgium, *Figure 8*), Luc Gobin (CAMS 390, 807, Mechelen, Belgium, *Figure 9 and 10*), Steve Rau (CAMS 3852; Zillebeke, Belgium) and Klaas Jobse (CAMS 3034, Oostkapelle, Netherlands).
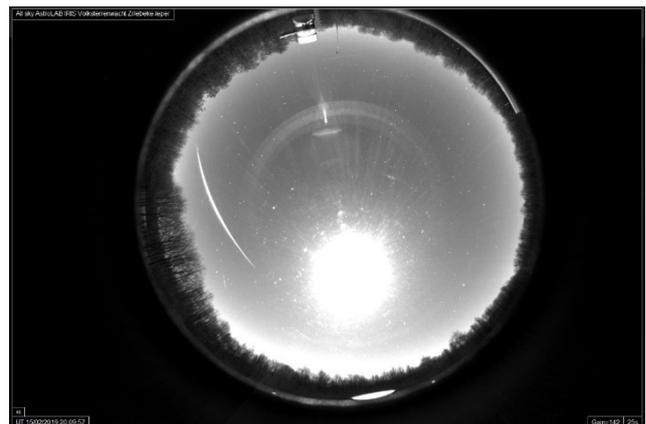

Figure 2 – All-sky image of the observatory Astro-Lab, Iris, at Zillebeke, Belgium, by Franky Dubois.

Figure 3 – The fireball as recorded by the all-sky camera EN-98 at Ermelo, the Netherlands by Koen Miskotte.

Figure 4 – Close-up of the All-Sky camera EN-98 at Ermelo, the Netherlands by Koen Miskotte.
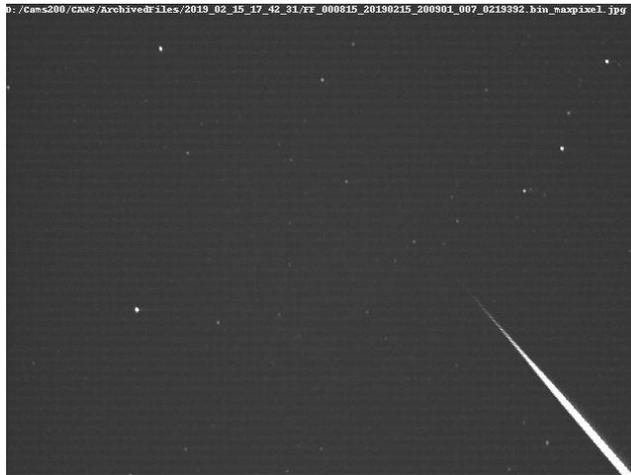

Figure 5 – The fireball recorded at Oostkapelle, the Netherlands by Klaas Jobse. The inset on the top shows the fireball as recorded by the CAMS 3034 Watec, also at Oostkapelle, the Netherlands.
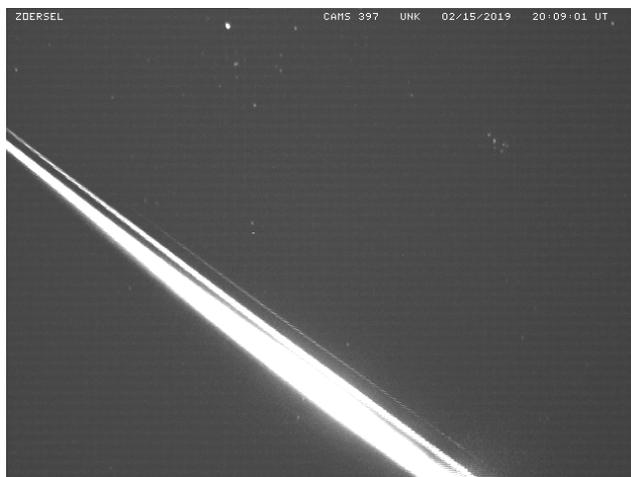

Figure 6 – Image from CAMS 380 at Wilderen, Belgium by Jean-Marie Biets.

Figure 7 – The fireball as seen from Grapfontaine, Belgium on CAMS 815, operated by Christian Wanlin and Jean-Paul Dumoulin.

Figure 8 – CAMS 397 image by Bart Dessoy at Zoersel, Belgium, with the fireball and its reflections in the glass of the window in front of the camera.

Figure 9 – The start of the fireball close to Orion as registered by CAMS 807 at Mechelen, Belgium by Luc Gobin.
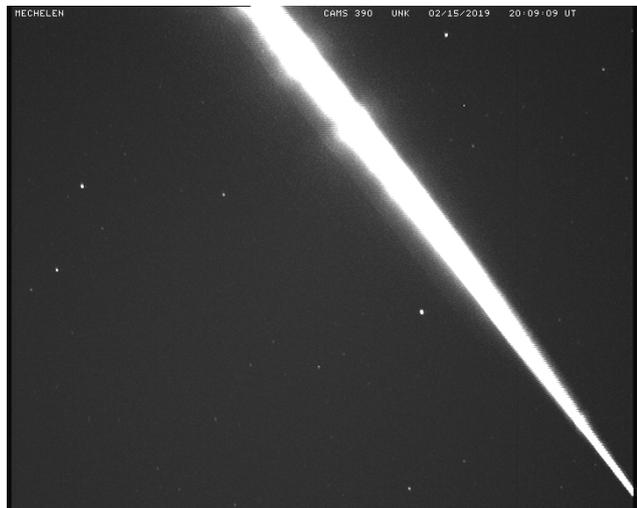
Figure 10 – The main part of the fireball registered by CAMS 390 at Mechelen, Belgium by Luc Gobin.

Figure 11 – The fireball registered by the UKMON camera at Blackfield in England.

The fireball was also recorded by several cameras of the French FRIPON network at Brussels, Eastbarnet, Maubeuge, Wimereux and Orsay, but remarkably enough not by all FRIPON cameras that had clear sky and should have registered this fireball. A likely explanation is that the slow angular velocity as seen from certain stations was too slow to be detected as a meteor.

At least one camera of the British UKMON video meteor network also captured this fireball from Blackfield in England (*Figure 11*).

3   The trajectory

The fireball started close to the Belgian-French border, south-east of the Belgian city Mons at 90 km height in the atmosphere. The endpoint was just across the Belgian-Dutch border, between the Belgian city Zelzate and the Dutch city Terneuzen. The ground path of the fireball shown in *Figure 12* is based on the CAMS network data calculated by *Carl Johannink*. The cameras of the CAMS network registered the begin of the fireball which wasn't bright enough for the all-sky cameras. The all-sky data was analyzed and calculated by *Pavel Spurný* at Ondrejov,

Czech Republic. The ground path as obtained from the all-sky cameras differs slightly from the result obtained from the CAMS data. In *Figure 13* the path according to CAMS is shown in white, the path according to the all-sky data is shown in yellow. The all-sky cameras registered the fireball from where it got bright enough, then at 78.8 km height in the atmosphere.

Table 1 – The trajectory data of the fireball of 2019 February 15, 20^h09^m UT, for the all-sky data calculated by Pavel Spurný and the CAMS data calculated by Carl Johannink.

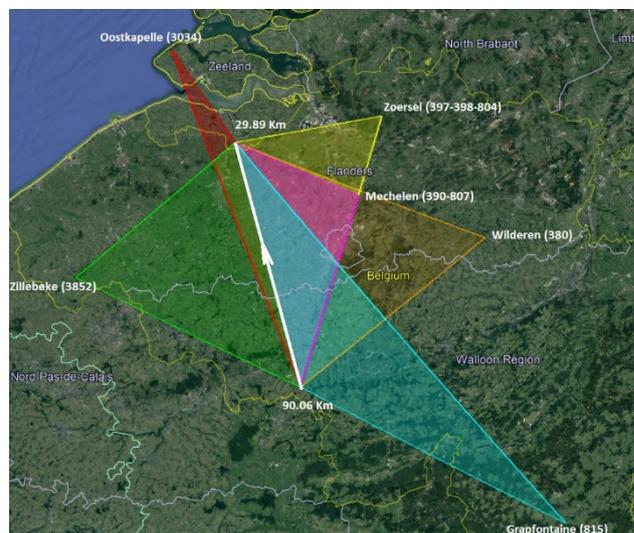|	All-sky	CAMS
λ_b (°)	4.0428 ± 0.0006	4.0708 ± 0.0001
φ_b (°)	50.5319 ± 0.0003	50.3757 ± 0.0001
H_b (km)	78.79	90.06
λ_e (°)	3.8162 ± 0.0006	3.8421 ± 0.0001
φ_e (°)	51.2293 ± 0.0002	51.2324 ± 0.0001
H_e (km)	30.37	29.89

Figure 12 – The ground path of the fireball of 2019 February 15, 20^h09^m UT based on the data of the CAMS stations plotted on the map, calculations done by Carl Johannink.
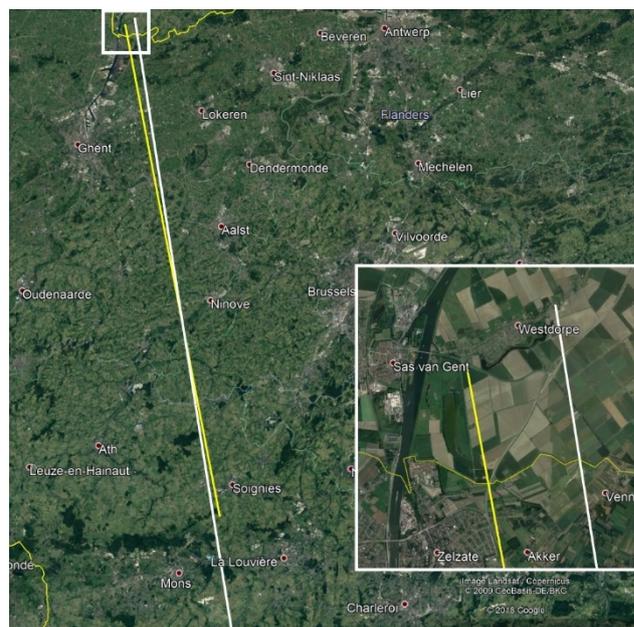

Figure 13 – The ground path of Figure 12 compared to the path calculated by Pavel Spurný with close up of the end points.

The all-sky data was worked out in the Czech Republic based on the images from Wilderen (*Figure 1*), Oostkapelle (*Figure 5*), Ermelo (*Figure 3 and 4*) and Borne. Jean-Marie Biets et al. (2019) concluded in their report that the accuracy of the result is insufficient for further scientific work. The cause mentioned by the authors is the too poor quality of the optics. Pavel Spurný has explained at several occasions at which details amateurs need to pay more attention if they want their data to be of scientific use. For instance, at the IMC in June 2016 at Egmont, the Netherlands, a long evening session was spent entirely to this topic by Dr. Pavel Spurný.

In this case there is no indication that anything survived the transit through the atmosphere, but if this had been the case the close-up of the difference between the ending points projected on the ground between CAMS and the All-sky, shown in *Figure 13* gives an idea about the consequences to locate a possible strew field to search for meteorites.

However, it can be much worse for the accuracy. *Figure 14* shows the trajectory obtained by the IMO[13] based on casual witness reports. This path is so far away from the reality, a huge distance in kilometers, that it is completely of no use. Some people still claim this kind of trajectories are of scientific use, suggesting this is a valid alternative when no camera data is available. Also, for previous fireball events over the BeNeLux these casual reports produced ground plots far away from reality. It can be fun and a nice way to keep people busy about fireballs for outreach and educational purposes. However, these casual witness reports are absolutely no alternative for camera networks. If we want to learn anything about fireball events, we need good quality and well calibrated cameras. For this reason, we never use such casual witness reports. This fireball has also been registered by the FRIPON network, unfortunately no results were yet available at the moment this report was written.
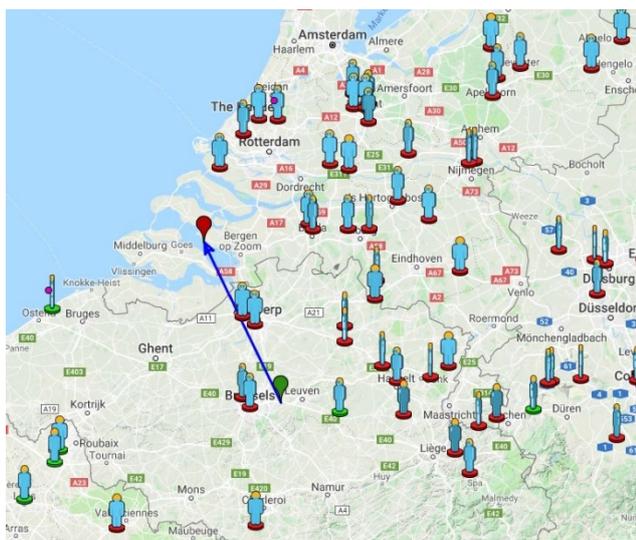
Figure 14 – The ground path of the fireball of 2019 February 15, 20^h09^m UT according to the IMO fireball report form.

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4   The orbit

The orbit based on the BeNeLux CAMS network was calculated by *Carl Johannink*, the orbit based on the all-sky data was calculated by *Dr. Pavel Spurný*. The results are listed in *Table 2*.

Table 2 – The trajectory data of the fireball of 2019 February 15, 20^h09^m UT, for the all-sky data calculated by Pavel Spurný and the CAMS data calculated by Carl Johannink.

	All-sky	CAMS
α_g (°)	–	100
δ_g (°)	–	-17
v_g (km/s)	–	12
α_ω (°)	101.76 ± 0.05	99.11 ± 0.01
δ_ω (°)	-7.38 ± 0.02	-6.64 ± 0.01
v_ω km/s	15.61 ± 0.03	15.64 ± 0.00
a (AU)	1.987 ± 0.003	2.1
e (AU)	0.5209 ± 0.0007	0.5472 ± 0.0003
q (AU)	0.9520 ± 0.0002	0.9542 ± 0.00003
i (°)	11.44 ± 0.02	11.227 ± 0.009
ω (°)	25.56 ± 0.06	25.233 ± 0.01
Ω (°)	146.5987 ± 0.0000	146.5914 ± 0.0000
Π (°)	172.16	171.82

First, no meteor shower association could be made. The meteor shower association tool which combines three orbit similarity criteria used for the case studies of meteor streams based on orbit data (Roggemans, 2019) resulted in a positive match for both the CAMS and the all-sky data orbits compared with all orbits listed in the IAU Meteor Data Center[14]. For the CAMS orbit a similarity with acceptable discrimination values was found with a shower named January nu Orionids (JNO#267), with D-criteria $D_{SH} = 0.19$, $D_D = 0.078$ and $D_H = 0.169$. For the all-sky data the association with this shower had $D_{SH} = 0.19$, $D_D = 0.075$ and $D_H = 0.17$.

This shower has been identified by Dr. A. K. Terentjeva (1989) in a study of complexes of large meteor bodies. The data for this meteor shower has been listed in *Table 3*. The large difference in radiant position may mask possible shower association but is normal for ecliptical or nearly ecliptical fireball showers with slow moving meteors. In her original publication Dr. A. K. Terentjeva identified this shower as the Mu-Orionids active between 1 January until 4 February. However, this activity period is only indicative and does not exclude orbital associations beyond this period. The IAU working list mentions 2003 AC23 as possible asteroidal parent body. Both the pre-atmospheric velocity v_ω (= 16.4 km/s) and the geocentric velocity v_g (= 12 km/s) agree very well with the CAMS data.

The all-sky data had a second match with $D_{SH} = 0.18$, $D_D = 0.093$ and $D_H = 0.18$. with the meteor shower chi2

Orionids (CHO#990) based on 24 orbits and listed in the IAU working list of meteor showers pro tempore. This shower just scores beyond the upper limit for D_D (= 0.105) with 0.112 for the CAMS orbit. The shower orbit is listed in *Table 3*. The activity of this shower is more than one month later than our fireball and may represent a similarity by pure chance. The large difference in the ascending node and argument of perihelion is not a problem if we look at the length of perihelion Π.

Table 3 – The orbital elements for the January nu Orionids (JNO#267) and the chi2 Orionids (CHO#990).

	JNO#267	CHO#990
α_g (°)	88	91
δ_g (°)	+12	+20
v_g (km/s)	12	6.65
v_∞ km/s	16.4	–
a (AU)	1.866	1.81
e (AU)	0.524	0.45
q (AU)	0.854	0.99
i (°)	4.1	2.7
ω (°)	51.7	348.66
Ω (°)	112.5	182.15
Π (°)	164.2	170.81

Unfortunately, the reference listed as "Amaral et al., 2018, WGN to be sub." Seems not to exist as never anything was submitted for publication. This way no sources can be checked. It is somehow a mystery how this information got into the IAU Meteor Data Center and who decided about the shower name and data verification.

5   Conclusion

The trajectory and orbit for the fireball of 2019 February 15, 20^h09^m UT could be calculated based on CAMS BeNeLux data and all-sky data. The orbit may be associated with an earlier identified fireball stream listed as January nu Orionids (JNO#267) another possible association with chi2 Orionids (CHO#990) is less likely and uncertain because the references cannot be verified.

Acknowledgment

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Biets J.-M., Johannink C. and Spurný P. (2019). "De vuurbol van 15 februari 2019". *Radiant*, **41**, 22–25.

Roggemans P., Johannink C. and Cambell-Burns P. (2019). "October Ursae Majorids (OCU#333)". *eMetN*, **4**, 55–64.

Terentjeva A. K. (1989). "Fireball streams". *WGN, Journal of the International Meteor Organization*, **17**, 242–245.

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- *Peter Eschman*
- *Uwe Glässner*
- *Carl Johannink*
- *Richard Káčerek*

- *José María Madiedo*
- *Pierre Martin*
- *Koen Miskotte*
- *Paul Roggemans*
- *Michel Vandeputte*
- *Felix Verbelen*