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tau Herculids outburst on May 31, 2022 over the famous Kitt Peak Observatory in Arizona. 19 tau Herculids and 4 sporadic meteors were recorded. In the foreground the building of the Bok 2.3 meter telescope and behind it the building of the 4.0 meter Mayall Telescope. Recorded by Jianwei Lyu. The image has also become APOD

- Anti-helion outburst
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Contents

Near anti-helion meteor shower outburst recorded by Global Meteor Network

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An outburst near the anti-helion source has been registered by the cameras of the Global Meteor Network on 2022 August 15–16 and August 16–17. The shower meteors radiated from a very compact radiant centered at $\alpha = 325.3 \pm 0.4°$ an $\delta = -11.5 \pm 0.4°$ with a geocentric velocity $v_g = 23.9 \pm 0.3$ km/s, with M2022-Q1 as temporary identification, likely recorded before as the August delta Capricornids (ADC#00199). The flux plot indicates that the activity lasted ~15 hours with the main peak activity at $\lambda_O = 143.71°$ corresponding to 2022 August 16, 22^h04^m UT with a ZHR of about 10. The mean orbit could be derived from 123 very similar orbits. Another set of 5 paired meteors recorded by the RMS network in Ukraine confirms the orbit obtained by GMN. The observed outburst matches very well with the forecast by Mikhail Maslov who predicted that a young trail of comet 45P/Honda-Mrkos-Pajdusakova ejected in 1980 could encounter the Earth at 2022 August 16, at 23^h40^m UT.

1 Introduction

On 2022 August 17, amateur astronomer Ivan Sergei from Belarus sent me the following message: "*I just saw a concentration of an unclassified radiant near Capricorn with RA~21:42 DEC ~ –9 (lamda 179.8, beta 2.4 deg, Sol.long ~143.2), v_g ~ 24 km/s according to the CAMS video network. Perhaps a new meteor shower is emerging*", adding a screenshot of the CAMS website[1] (*Figure 1*).

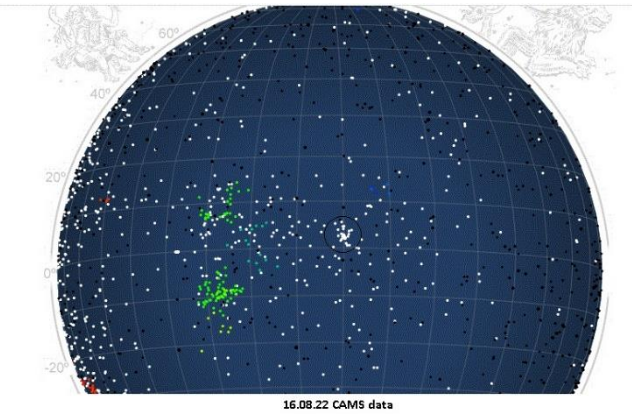


Figure – 1 Screenshot of the CAMS radiant plot that caught the attention of Ivan Sergei.

At that time Peter Jenniskens already had a CBET ready (Jenniskens, 2022a) to announce the shower outburst and the same day a report was published on MeteorNews (Jenniskens, 2022b). Already the next day a confirmation followed by the Japanese SonotaCo network (Sekiguchi, 2022).

The night of the outburst, August 16–17, much of Europe had a partially cloudy night after a long period with stable clear nights. Clouds hampered registration of meteors at many GMN camera stations but still a fair number of orbits could be recorded (*Figure 2*).

A planned migration of the server with the GMN data caused some delay in the processing of the new incoming data, but also the Global Meteor Network detected the outburst as a very compact radiant source (*Figure 3*).

Figure 2 – A –2 meteor of this meteor outburst at 2022 August 16, $21^h11^m30^s$ UT recorded by the GMN camera BE0007 in Genk, Belgium, paired with DE0005 and FR0006.

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

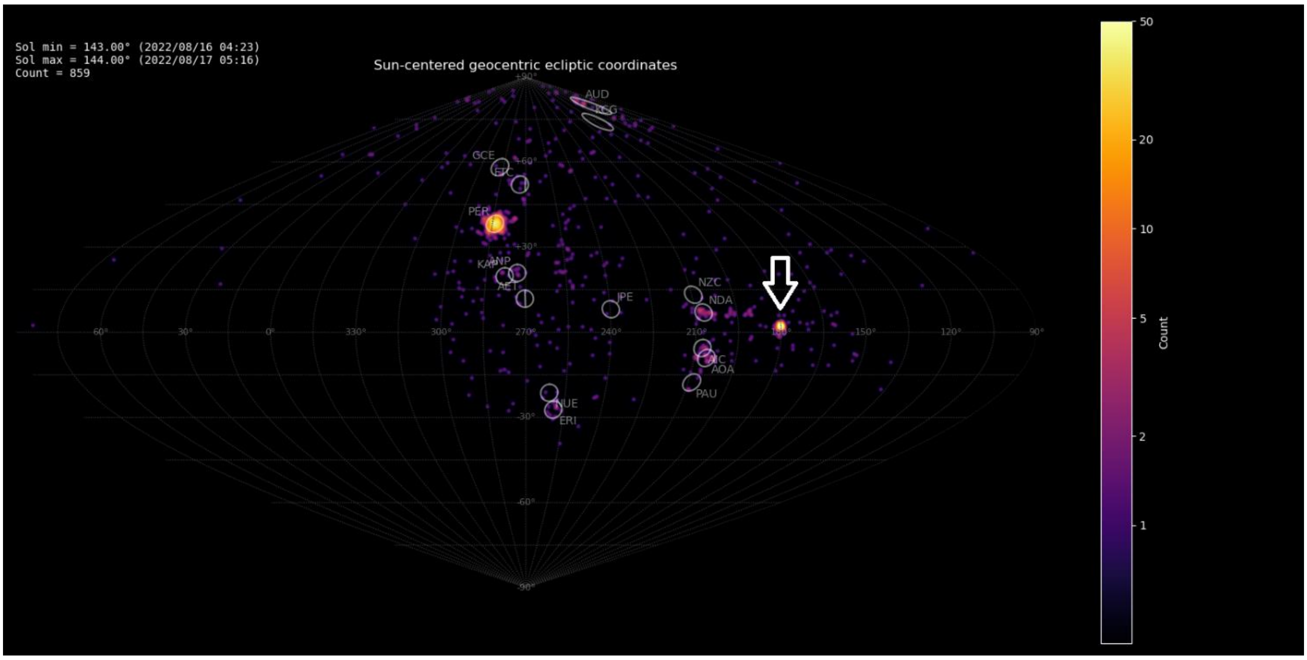


Figure 3 – The radiant density plot in Sun-centered geocentric ecliptic coordinates for the night August 16–17, 143°< $\lambda_{\odot}$ <144°.

2 Global Meteor Network data

When the data was processed for the suspect period, an extract was downloaded with all GMN orbits obtained after $\lambda_{\odot}$ = 142° (2022, August 15,03^{h}23^{m}04^s UT) until the latest data available at the time of the download, $\lambda_{\odot}$ = 144.772° (2022 August 18, 00^{h}35^{m}34^s UT). This dataset includes 2307 orbits and is publicly available for download from the GMN website[2].

The median values for the orbit published by Jenniskens (2022a; 2022b) were used as initial reference orbit to start an iterative search for the best fitting mean orbit for a concentration of similar orbits. The method used for this has been described before (Roggemans et al., 2019) and combines three classic discrimination criteria, considering different classes for the degree of similarity. The discrimination criteria used in this method are that of Southworth and Hawkins (1963), identified as D_{SH}, Drummond (1981), identified as D_D, and Jopek (1993), identified as D_H. The method to compute the mean orbit during the iteration process has been described by Jopek et al. (2006).

The position of the radiant of the outburst near the anti-helion source is a tricky region to look for orbit similarity because that area is full of sporadic Jupiter-family comets' orbits with $2.0 \leq T_J < 3.0$. This means there is a high risk for contamination with sporadic orbits that fit the similarity criteria by pure chance. In such a case it depends on the compactness of the outburst to distinguish orbits related to the outburst from the rich sporadic background. In this case the iteration procedure converted very quickly after few steps at a best fitting mean orbit for 123 very similar orbits with D_{SH} < 0.05, D_D < 0.02 and D_H < 0.05.

3 GMN results

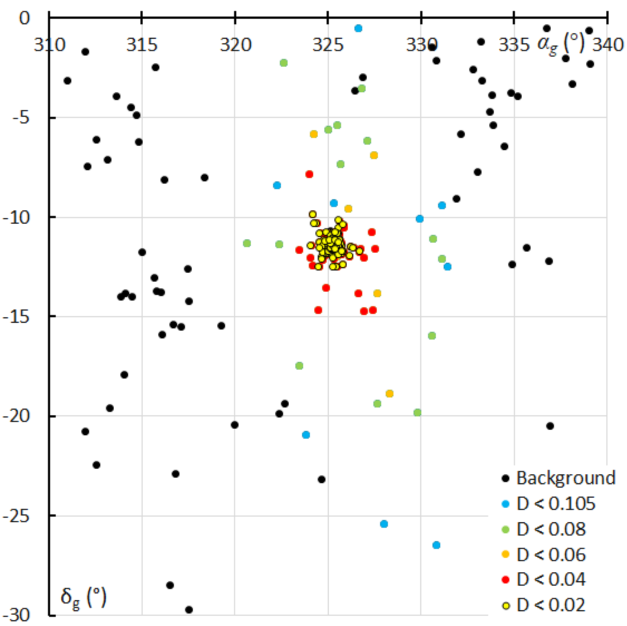


Figure 4 – The geocentric radiants in equatorial coordinates.

The median value for the geocentric radiant position is α = 325.3 ± 0.4° and δ = –11.5 ± 0.4°, with v_g = 23.9 ± 0.3 km/s, derived from the 123 most similar orbits obtained. *Figure 4* shows the radiant plot color coded for the different thresholds of similarity. If we consider the most tolerant criteria with D_{SH} < 0.25, D_D < 0.105 and D_H < 0.25, 169 orbits fit this criterion (blue dots). Using D_{SH} < 0.10, D_D < 0.04 and D_H < 0.10, still 139 orbits can be accepted (red dots). However, considering the risk for sporadic contamination near the anti-helion source which is rich in JFC meteor orbits, we focus on the strictest discrimination threshold with D_{SH} < 0.05, D_D < 0.02 and D_H < 0.05, visible

[2] https://globalmeteornetwork.org/data/traj_summary_data/

in *Figure 4* as the dense concentration of yellow dots. The lower threshold points marked in blue, green and orange appear very dispersed and are likely sporadics that fit the criteria by pure chance.

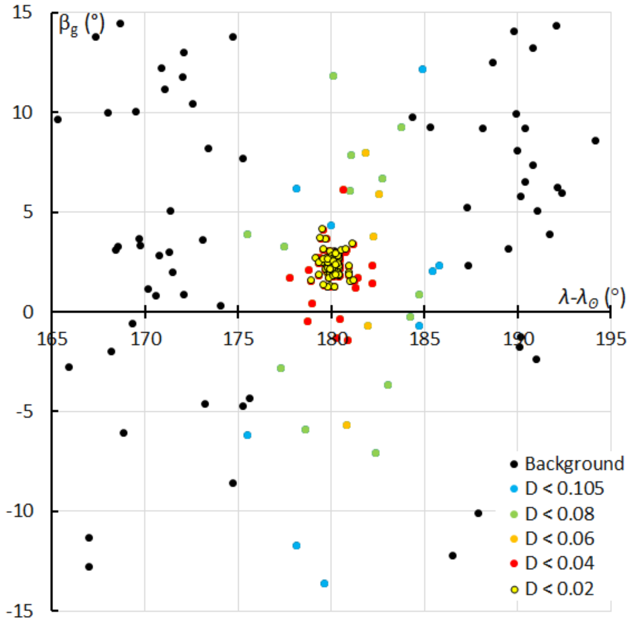


Figure 5 – The geocentric radiants in Sun-centered ecliptic coordinates.

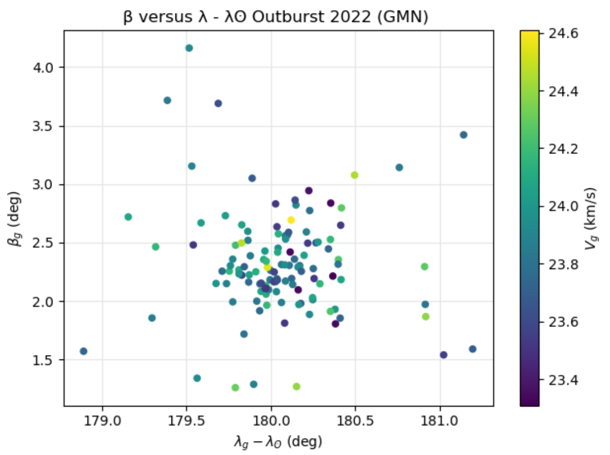


Figure 6 – The geocentric radiants in Sun-centered ecliptic coordinates, color coded for velocity.

Looking at the Sun-centered geocentric ecliptic radiant coordinates we see the same very dense concentration of radiant points (*Figure 5*). Within the small size radiant in Sun centered geocentric ecliptic coordinates color coded for velocity, we see no trend in variation in velocity (*Figure 6*). Checking if we find any trace of activity in past years, we applied the same stream search on all available orbits in the period 2019–2021 within the interval 142° < $\lambda_ʘ$ < 144.772°, a dataset with 6024 orbits. The result is shown in *Figure 7*, no concentration is found. The orbits that fit the discrimination criteria in previous years are likely sporadic orbits that fulfill the criteria by pure chance. Removing these from *Figure 7* would create an empty space in the plot.

Trying to establish the time of peak activity we compare the number of orbits associated with the outburst as a percentage relative to the number of orbits not related to the outburst, or the so-called background activity. We did not filter other meteor showers as these are relative stable during the short activity period. To avoid too small number statistics, we left out the time intervals with too few data. Unfavorable weather and poor coverage at some longitudes caused the gaps in the activity profile. Luckily the main peak activity occurred over Europe where the best coverage of GMN is situated. *Figure 8* shows the activity profile with the different thresholds of similarity. The dispersed low threshold orbits (blue, green and orange) can be ignored, the most relevant activity was caused by the very similar orbits (red and yellow). Peak activity occurred at $\lambda_ʘ$ = 143.71° corresponding to 2022 August 16, 22^{h}04^m UT. The total activity period covered about 24 hours with the first orbits being detected in the night of August 15–16. After the peak, the activity faded out within about 5 hours. Both the small radiant size and the narrow activity profile indicate an encounter with a very compact dust cloud. The flux plot is shown in *Figure 9*.

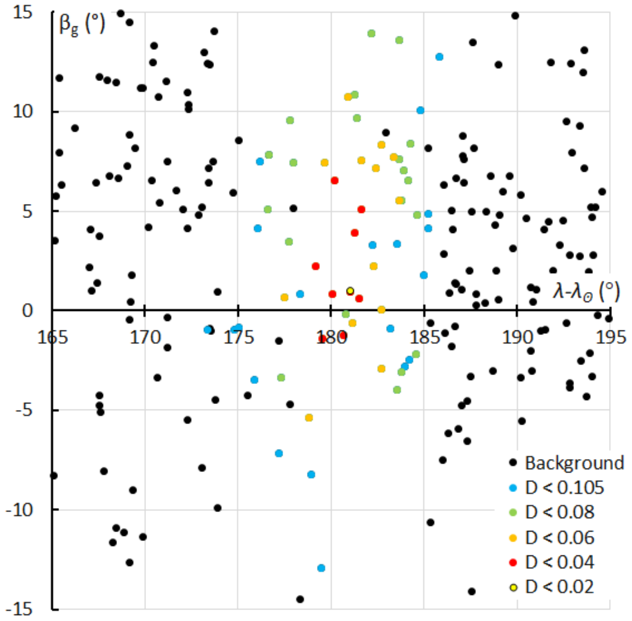


Figure 7 – Same plot as *Figure 5* but with GMN data from 2019, 2020 and 2021.

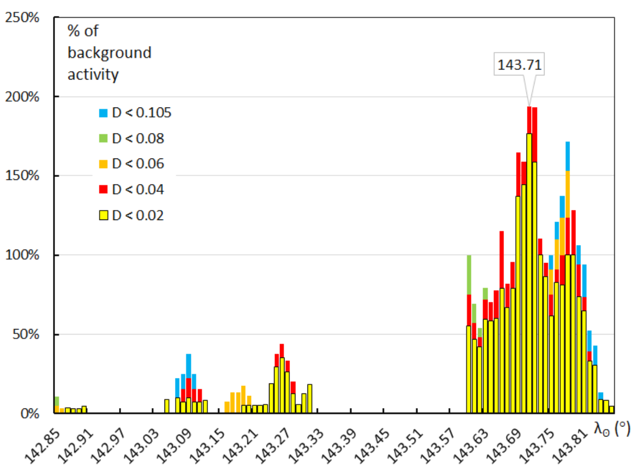


Figure 8 – The activity profile with the number of orbits caused by the outburst as a percentage relative to the number of orbits not associated with the outburst.

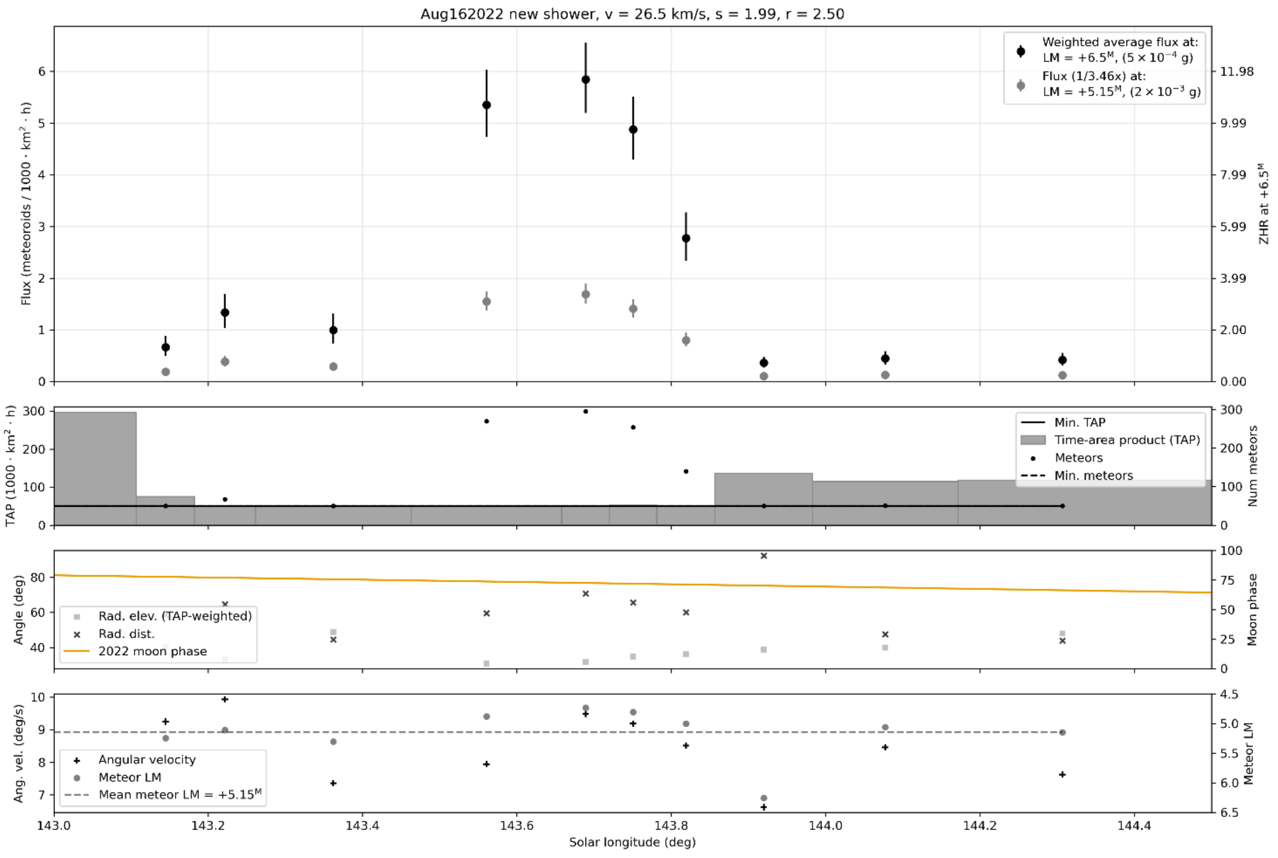
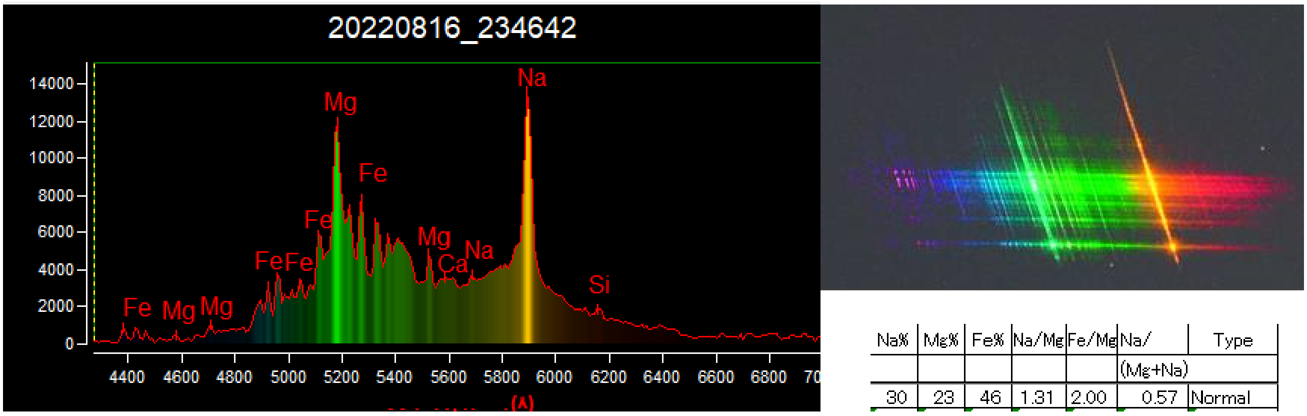


Figure 9 – The flux plot assuming a standard value of s = 2.0, the ZHR is about 10. The activity lasted only ~15 hours.

Figure 10 – Spectrum images of new shower members, α7s, 35mm, 600 gratings reduced to 4K30p ½, dispersion direction corrected. (SonotaCo Network, Japan, recording by Maeda).



Na%	Mg%	Fe%	Na/Mg	Fe/Mg	Na/ (Mg+Na)	Type
30	23	46	1.31	2.00	0.57	Normal

Figure 11 – Results of the spectral analysis of the new meteor shower with the identification of the emission lines, ratio of the emission lines and the type of classification.

The SonotaCo network in Japan obtained spectral data of meteors belonging to the new shower (*Figure 10*). The spectral analysis shows a normal type of spectrum rich in Iron (Fe 46%), Natrium (Na 30%) and Magnesium (Mg 23%) (*Figure 11*).

Table 1 – Comparing the orbit parameters obtained by GMN with those of CAMS (Jenniskens, 2022c) and SonotaCo.

	GMN	CAMS	SonotaCo
α (°)	325.3 ± 0.4	325.28 ± 0.06	324.9 ± 0.04
δ (°)	–11.5 ± 0.4	–11.40 ± 0.06	–11.9 ± 0.3°
v_g (km/s)	23.9 ± 0.3	24.12 ± 0.14	23.9 ± 0.5
H_b	98.1 ± 2.6	–	98.4
H_e	84.0 ± 4.2	–	79.9
$\lambda-\lambda_\odot$ (°)	180.04 ± 0.35	–	–
β (°)	+2.28 ± 0.45	–	–
a (AU)	2.91 ± 0.15	3.16	3.03
q (AU)	0.551 ± 0.005	0.547 ± 0.025	0.554 ± 0.005
e	0.811 ± 0.01	0.823 ± 0.069	0.816 ± 0.015
i (°)	1.81 ± 0.36	1.90 ± 1.30	1.61 ±0.19
ω (°)	270.9 ± 0.7	270.7 ± 2.3	270.5 ± 0.12
Ω (°)	143.75 ± 0.18	143.2 ± 0.7	143.4 ± 0.15
Π (°)	54.6 ± 0.7	–	–
T_j	2.66 ± 0.09	–	–
P (Y)	4.98 ± 0.39	–	–
N	123	137	4

The mean orbit (Jopek et al., 2006) for this new shower has been calculated using only orbits with $D_{SH} < 0.05$, $D_D < 0.02$ and $D_H < 0.05$. The result based on 123 orbits is listed in *Table 1* and compared with the results obtained by CAMS and SonotaCo.

The close-up of the orbit distribution with inclination i plotted against longitude of perihelion Π shows no trend in the velocity distribution. The small variation in velocity is within the error margins of the measured velocities (*Figure 12*).

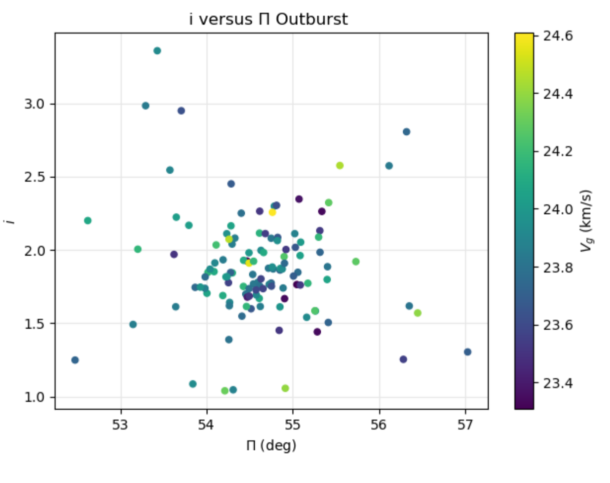


Figure 12 – Concentration of orbits with the inclination i plotted against the longitude of perihelion Π, color coded for velocity.

The distributions of the orbital elements plotted in *Figures 13, 14 and 15*, show the dense concentration of the 123 orbits used to compute the mean orbit (yellow dots). The more dispersed orbits marked in blue, green and orange may be likely sporadic orbits of the anti-helion source which accidently fit the similarity criteria. The dispersion of these orbits compared to the dense concentration (yellow) is also obvious in the histograms with the distributions of the eccentricity e, perihelion distance q, inclination i and the longitude of perihelion Π (*Figures 16, 17, 18 and 19*). The variation in geocentric velocity v_g varies within the measurement accuracy interval (*Figure 20*).

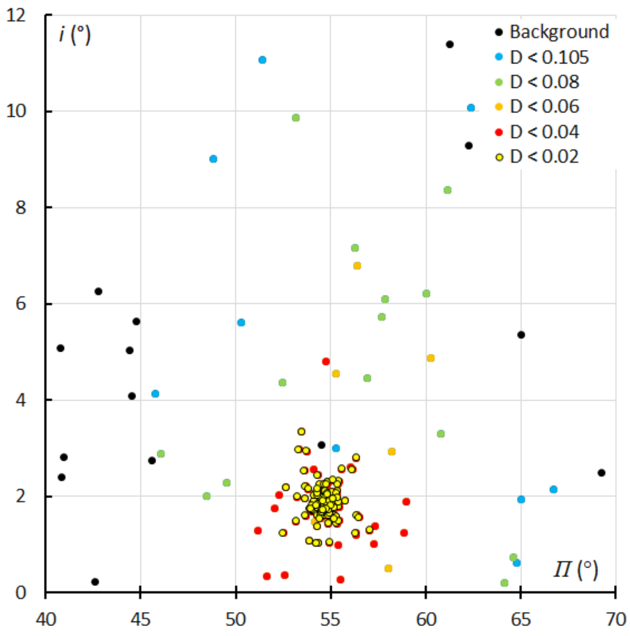


Figure 13 – Concentration of orbits with the inclination i plotted against the longitude of perihelion Π.

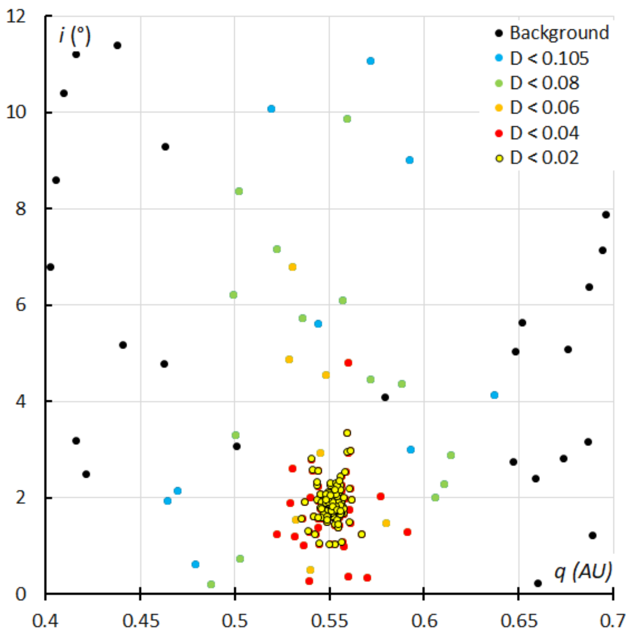


Figure 14 – Concentration of orbits with the inclination i plotted against the perihelion distance q.

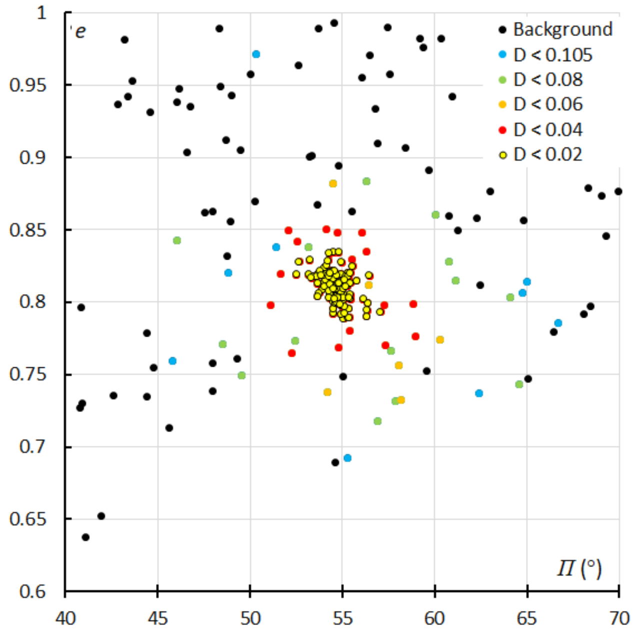


Figure 15 – Concentration of orbits with the eccentricity *e* plotted against the longitude of perihelion *Π*.

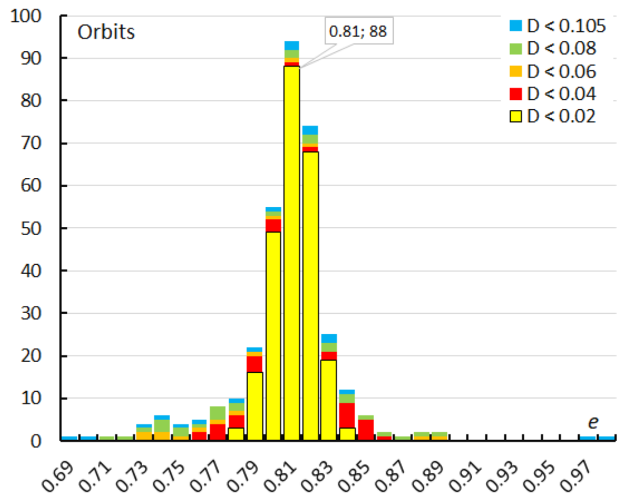


Figure 16 – The histogram with the distribution of the eccentricity *e* showing the spread for the different thresholds of similarity.

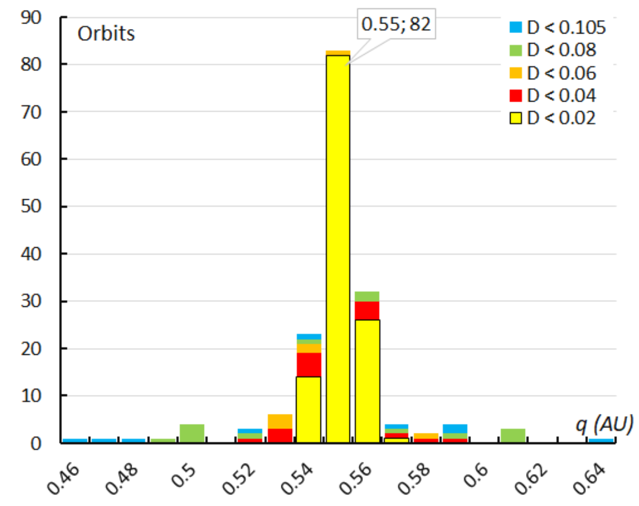


Figure 17 – The histogram with the distribution of the perihelion distance *q* showing the spread for the different thresholds of similarity.

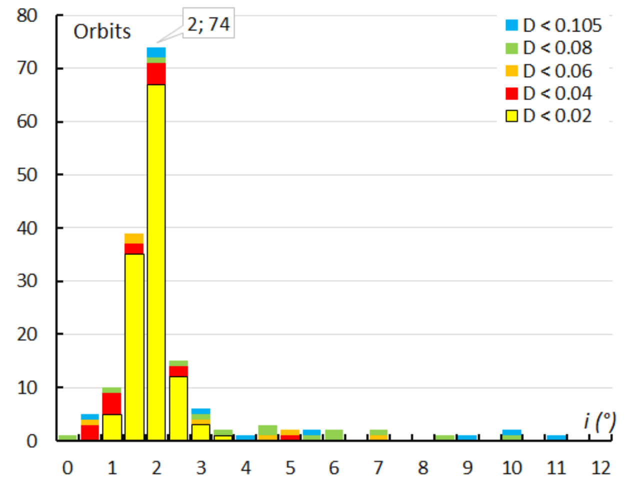


Figure 18 – The histogram with the distribution of the inclination *i* showing the spread for the different thresholds of similarity.

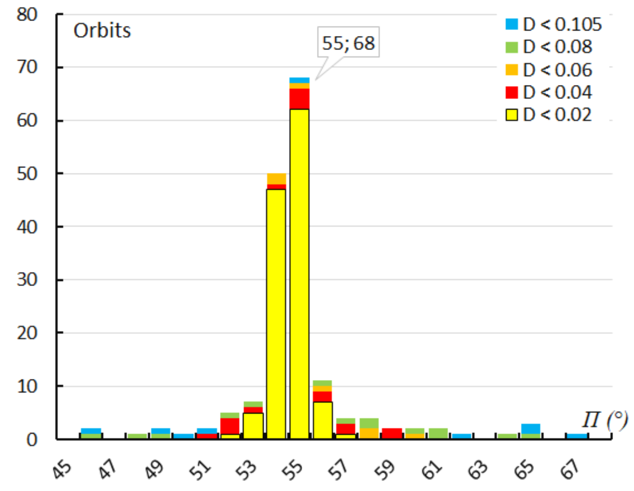


Figure 19 – The histogram with the distribution of the longitude of perihelion *Π* showing the spread for the different thresholds of similarity.

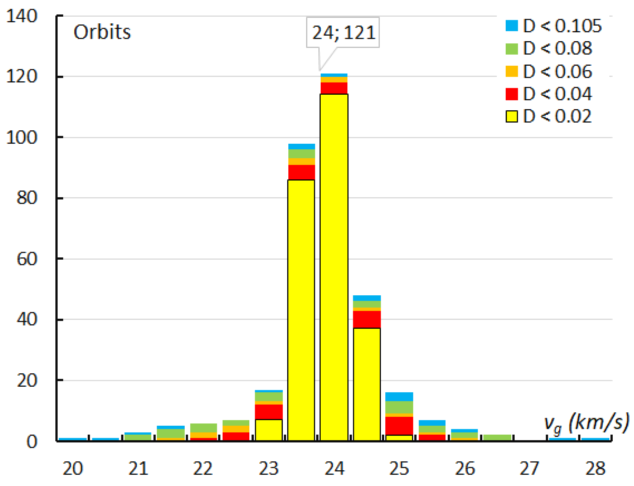


Figure 20 – The histogram with the distribution of the geocentric velocity v_g showing the spread for the different thresholds of similarity.

4 Confirmation by the Ukrainian RMS network

Despite the ongoing war, observers from Ukraine independently got the same results based on 5 paired meteors recorded by RMS cameras at the Ukrainian camera stations in the southwest of Ukraine. The mean orbit has been calculated using the method of Jopek et al. (2006). The Ukrainian results are listed in *Table 2* and in excellent agreement with the GMN, CAMS and SonotaCo results listed in *Table 1*. *Figures 21 and 22* display two meteors from the outburst. *Figure 23* shows a plot of the orbits.

Table 2 – The Orbit parameters obtained by the RMS network in Ukraine.

α (°)	325.6 ± 0.2
δ (°)	–11.6 ± 0.4
v_g (km/s)	23.3 ± 0.3
H_b	98.7 ± 2.5
H_e	83.6 ± 2.7
a (AU)	2.65 ± 0.13
q (AU)	0.555 ± 0.003
e	0.791 ± 0.01
i (°)	1.53 ± 0.36
ω (°)	271.3 ± 0.3
Ω (°)	143.76 ± 0.04
N	5

Figure 21 – Shower member recorded 2022 August 16, $22^h19^m29^s$ UT, at Odessa, Ukraine (photo Alex Angelsky).

Figure 22 – Shower member recorded 2022 August 16, $23^h46^m48^s$, at Odessa, Ukraine (photo Alex Angelsky).

[3] https://www.ta3.sk/IAUC22DB/MDC2007/Roje/pojedynczy_obiekt.php?kodstrumienia=00199&colecimy=0&kodmin=00001&kodmax=01180&sortowanie=0

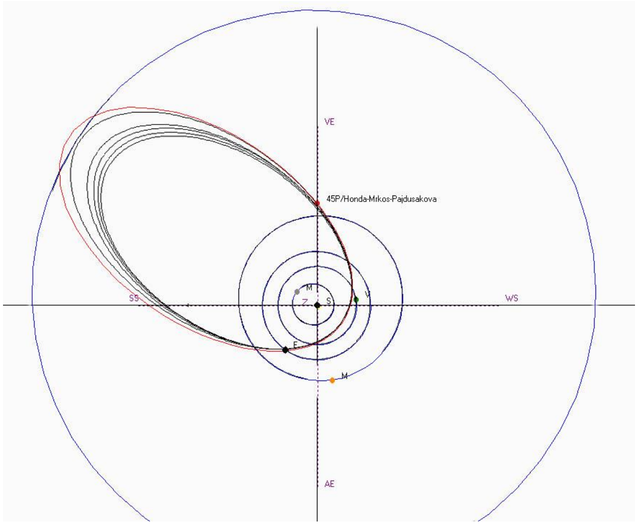


Figure 23 – The orbit of the parent body (red) and the 5 orbits recorded by the Ukrainian network.

5 New or already known shower?

In the IAU MDC meteor shower list, we find an entry listed as the August delta Capricornids (ADC#00199)[3] associated with parent body 45P/Honda-Mrkos-Pajdusakova, active at $\lambda_\odot = 146°$, with a radiant at $\alpha = 328.7°$ and $\delta = –16°$, $v_g = 21.6$ km/s with orbital elements $a = 2.414$ AU, $q = 0.597$ AU, $e = 0.753$, $i = 2.8°$, $\omega = 87.3°$ and $\Omega = 327°$, based on as few as 6 single orbits. The radiant is just south of the ecliptic in ecliptic latitude while our outburst radiant is just north of the ecliptic in ecliptic latitude.

This entry is based on a stream search on a set of over 1000 photographic fireball orbits of meteors brighter than magnitude –3 using only the Southworth and Hawkins criteria (Porubčan and Gavajdová, 1994). The photographic fireball data includes all-sky camera data which in general is less accurate and unsuitable for orbit determination apart from some properly investigated meteorite droppers. It is not clear which threshold has been used to avoid contamination by sporadics fitting the criteria by pure chance. The orbit listed for ADC#00199 should be regarded with caution as we do not know how it was obtained. Unfortunately, this cannot be verified anymore and we do not know the reliability of the fireball data used.

6 Parent body

Japanese observers concluded that the orbit of the new meteor shower resembled the low inclination orbit of comet 45P/Honda-Mrkos-Pajdusakova which is the most likely parent body responsible for the encounter with this dense dust cloud.

Accordingly orbits for 45P for the discovery apparition of 1948 onward were obtained from the IAU Minor Planet Center[4] and tested against the GMN orbit listed in *Table 1* using the D_H criterion (Jopek, 1993) with a detection threshold of 0.10. An interaction with Jupiter at a closest

[4] IAU Minor Planet Center https://minorplanetcenter.net/db_search/show_object?object_id=45P

distance of 0.11 AU (Astronomical Units) on 1983 March 26th decreased the comet's perihelion distance from roughly 0.58 to 0.54 AU and its inclination from around 13 to 4 degrees, as well as changes in other orbital elements, such that after the 1980 apparition the following apparitions would have somewhat different orbital parameters, as can be seen in the IAU MPC data. This would also likely include modifications to the orbits of any material ejected during the 1980 apparition and perihelion. Since that time the orbit has been more favorable to generating meteor streams impinging on Earth's orbit, and indeed the parent body itself has made relatively close approaches to Earth in 2011 and 2017. It will again return to a larger perihelion distance and inclination amongst other orbital element changes after a 0.17 AU Jupiter encounter in 2030 (e.g., Kinoshita, Kazuo[5]), although it should be noted that future orbit predictions are complicated by this comet having variable non-gravitational factors.

Table 3 – The criteria D_{SH}, D_D and D_H for the GMN orbit in comparison to the epoch year for the orbit of each perihelion passage of 45P from 1948 to 2032 are given with threshold limits of 0.15, 0.10 and 0.10 respectively. Any value in the table below that number can be considered a valid association, the lower the better, whilst any value above it cannot.

45P year	D_{SH}	D_D	D_H
1948	0.235	0.076	0.235
1954	0.236	0.076	0.236
1964	0.236	0.076	0.236
1969	0.236	0.076	0.236
1974	0.237	0.079	0.237
1980	0.237	0.08	0.237
1985	0.063	0.022	0.063
1990	0.063	0.023	0.063
1995	0.066	0.028	0.066
2001	0.068	0.03	0.067
2006	0.067	0.029	0.067
2011	0.067	0.029	0.067
2016	0.066	0.028	0.066
2022	0.066	0.022	0.066
2027	0.066	0.022	0.066
2032	0.218	0.092	0.214

Taking this into consideration it should be noted that the orbits from 1948 to 1980 inclusive did not pass the $D_H < 0.1$ threshold when tested against the GMN orbit, whilst the 1985 to current orbits do. The D_{SH}, D_D and D_H values for the GMN orbit tested against the orbits for the comet's apparitions from 1948 to 2032 are given in *Table 3*. Note that the standard threshold value for D_D appears to be too generous for very low inclination objects relative to the other two criteria. It should be further noted that only these orbits for 45P passed this threshold mark when a selection of 1170 cometary orbits (inclusive of multiple apparition orbits for some periodic comets) having perihelion distance less than 1.2 AU, including D/1770 Lexell, were similarly tested against the GMN orbit for this shower. Not one other of these comets matched the GMN orbit to better than $D_H = 0.10$, thus it can be taken from this that the Japanese team's suggestion of 45P being the potential parent body for the current outburst, and that despite the tendency of Jupiter Family Comets to have similar orbits such that at times many comets can be matched to one shower, no other comet can be shown to be a potential parent body to the outburst being analyzed. It also appears that the changes in the orbit of the comet will make it a potential continuing source for Earth crossing meteoroids for only around 50 years.

Moreover, some years ago this outburst had been computed by Mikhail Maslov. He predicted: "*On (2022) 16 August at 23^{h}40^m UT the Earth is expected to encounter the young trail of the comet 45P/Honda-Mrkos-Pajdusakova ejected in 1980. The parameters of the encounter are the following: minimum distance is 0.00377 AU, ejection velocity is 9.82 m/s, trail density is 373.2% of that for 1 rev. Leonid trail. While the computed minimum distance to the central axis of the 1980 trail is quite large, the rest encounter parameters (ejection velocity and trail density) are quite favorable. So far, some minor activity is possible around the given maximum time and observations for checking this forecast are recommended.*"[6]. It is obvious that this is what we encountered in the form of a very compact dust cloud, slightly earlier in time than predicted.

7 Conclusion

The Global Meteor Network has once again succeeded in achieving its objective, not to let any unexpected meteor shower pass unnoticed. A compact radiant centered at $\alpha = 325.3 \pm 0.4°$ an $\delta = -11.5 \pm 0.4°$, has been recorded. This is close to the radiant predicted by Mikhail Maslov at $\alpha = 326.8°$, $\delta = -15.1°$. The peak occurred at $\lambda_O = 143.71°$ or 2022 August 16, 22^{h}04^m UT, about 1.5 hours sooner than predicted with a *ZHR* of about 10. The outburst has been confirmed by the CAMS, SonotaCo and Ukrainian networks. The activity might have been strong enough to catch attention from visual observers.

Acknowledgement

The authors thank all the camera operators and people involved in the Global Meteor Network. Orbits for this shower outburst were obtained by GMN RMS cameras installed in: Australia, Belgium, Bulgaria, Canada, Croatia, France, Germany, Hungary, Israel, Italy, Poland, Russia, Slovakia, Slovenia, Spain, Switzerland, United Kingdom, and the United States. The Ukrainian RMS network provided independent evidence. The Global Meteor Network (GMN) data are released under the following license[7]. This research has made use of data and/or services

[5] https://jcometobs.web.fc2.com/pcmtn/0045p.htm
[6] http://feraj.ru/Radiants/Predictions/45p-ids2022eng.html
[7] https://creativecommons.org/licenses/by/4.0/

provided by the International Astronomical Union's Minor Planet Center.

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New radiant on Aquarius/Capricorn border by the SonotaCo Network

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On 2022, August 16, the SonotaCo Network Japan detected an outburst from a mean geocentric radiant position at R.A. = 324.9 ± 0.04 deg, Decl. = –11.9 ± 0.3 deg, at the anti-helion source, with geocentric velocity v_g = 24.4 ± 0.5 km/s (Equinox J2000). The shower was detected by the SonotaCo network in the Japan among the first data from August 16. The orbit has a low inclination and resembles that of comet 45P/Honda-Mrkos-Pajdusakova.

1 Introduction

The SonotaCo Network Japan have detected an ongoing outburst of meteors with a low inclined orbit in the anti-helion source. See the online discussion in Japanese[8].

2 Observations

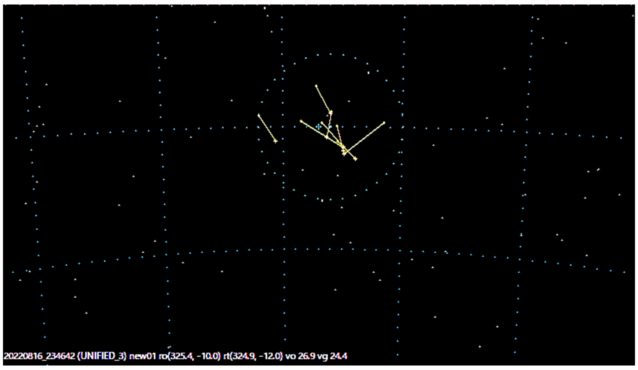
A total of 8 meteors were triangulated between 2022, Aug. 12, 13^{h}22^m and 2022, Aug. 16, 19^{h}14^m UT, but that does not mark the end of the shower activity as the activity is still ongoing when this report was written. The radiant around $\lambda_{\odot}$ = 143.4° was centered on the median geocentric position R.A. = 324.9 ± 0.04°, Decl. = –11.9 ± 0.3°, with a geocentric speed v_g = 24.4 ± 0.5 km/s (Equinox J2000). This is on the border of Aquarius and Capricorn (*Figure 1*). The median orbital elements based on four accurate meteors (*Table 1* and *Figure 2)* are:

- a = 3.03 AU,
- q = 0.554 ± 0.005 AU,
- e = 0.816 ± 0.015,
- i = 1.61 ±0.19°,
- ω = 270.5 ± 0.12°,
- Ω = 143.4 ± 0.15°.

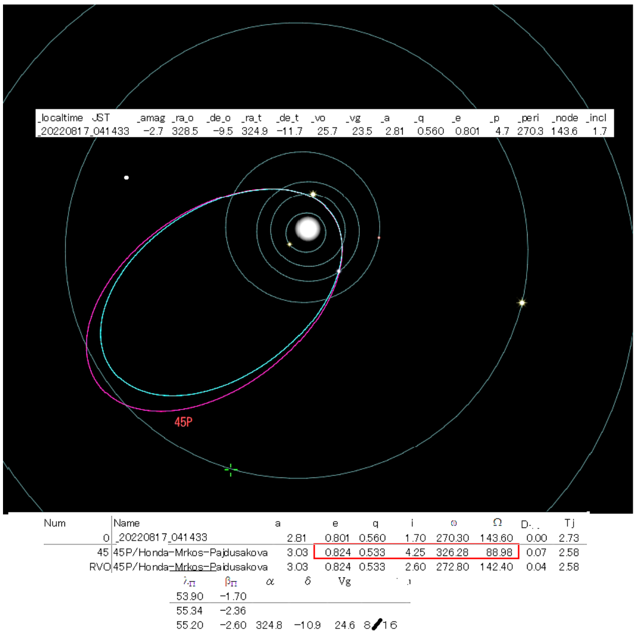
3 Parent body

Jenniskens P. (2022) suggested that this orbit resembles that of lost comet D/1770 L1 (Lexell), during its returns in 1770 and 1776 with a = 3.15 AU, q = 0.674 AU, e = 0.786, i = 1.55 deg, ω = 225.0°, and Ω = 134.5°. Mainly the argument of perihelion differs significantly. But comparing other orbits, there is another possible parent body matching the orbit better, which is 45P/Honda-Mrkos-Pajdusakova.

- a = 3.03 AU,
- q = 0.533 AU,
- e = 0.824,
- i = 2.60°,
- ω = 272.8°,
- Ω = 142.4°.



Fgure 1 – The radiants as spotted in 4 different nights.



Fgure 2 – Meteor shower orbit and the orbit of 45P.

Acknowledgment

SonotaCo Network Japan contributed to this report: 4 meteors were detected.

[8] https://sonotaco.jp/forum/viewtopic.php?t=5234

Table 1 – SonotaCo meteor orbits and the average orbit.

Local time−JST	*α* (°)	*δ* (°)	v_g (km/s)	*a* (AU)	*q* (AU)	*e*	*i* (°)	*ω* (°)	*Ω* (°)	M_A	H_b (km)	H_e (km)
20220816_193802	324.8	–12.2	23.7	2.87	0.556	0.806	1.4	270.5	143.2	–2.3	94.6	84.4
20220816_234642	324.9	–12.0	24.4	3.25	0.549	0.831	1.6	270.5	143.4	–4.3	104.9	77.1
20220817_013405	324.9	–11.7	24.3	3.16	0.550	0.826	1.8	270.6	143.5	–3.6	100.8	81.4
20220817_041433	324.9	–11.7	23.5	2.81	0.560	0.801	1.7	270.3	143.6	–2.7	93.5	76.5
Average	324.9	–11.9	23.9	3.03	0.554	0.816	1.6	270.5	143.4	–3.2	98.4	79.9
S.D.	0.0	0.3	0.5	0.22	0.005	0.015	0.2	0.1	0.1	0.9		

Reference

Jenniskens P. (2022). CBET 5159. Ed.: D. W. E. Green. Cambridge: Central Bureau for Astronomical Telegrams.

Ongoing outburst from a new radiant on Aquarius/Capricorn border

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On August 16, 2022, the global CAMS low-light video camera networks detected an outburst from a mean radiant position at geocentric position R.A. = 324.7 ± 0.2°, Decl. = –11.6 ± 0.3°, in the anti-helion source, with geocentric speed v_g = 24.2 ± 0.3 km/s (Equinox J2000). The new shower received the temporary designation M2022-Q1, and likely will be called 18-Aquariids. The shower was detected first mainly by the networks in the USA and Chile. However, the shower is ongoing, and may be increasing in activity, given that the first data from August 17 also shows the shower active. The orbit has a low inclination and resembles that of comet Lexell during its return in 1770 and 1776.

1 Introduction

The CAMS low-light video camera networks have detected an ongoing outburst of meteors with a low inclined orbit in the anti-helion source (c.f. see CAMS website[9] for the date of 2022 August 16). Now that the IAU Commission F1 has introduced a new meteor shower designation system, which assigns a temporary name based on the time of the report, this shower is called M2022-Q1. We don't know yet how to use such designations properly. The author preferred name is: 18-Aquariids.

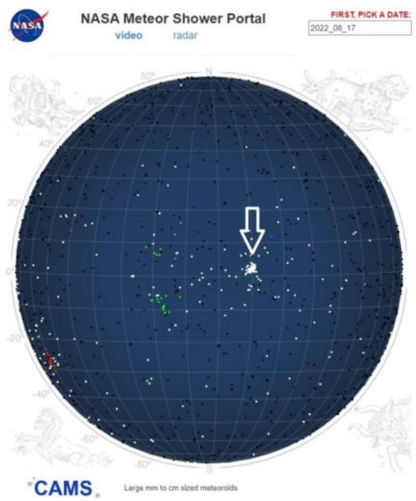

Figure 1 – As new observations are coming in, the activity on August 17 seems to be stronger than previous day. (See CAMS website[9], select the date as August 17)

Figure 2 – 18-Aquariid on August 16, $11^h09^m02^s$ UT, in video from CAMS California station Lick Observatory.

2 Observations

A total of 36 meteors were triangulated between 2022 Aug. 15, 20^h37^m and 2022 Aug. 16, 12^h02^m UT (Jenniskens, 2022), but that does not mark the end of the shower (e.g., see the CAMS website[1] for the date of 2022 Aug 17). The radiant around solar longitude 143.1° was centered on the median geocentric position R.A. = 324.7 ± 0.2°, Decl. = –11.6 ± 0.3°, with geocentric speed v_g = 24.2 ± 0.3 km/s (Equinox J2000). This is on the border of Aquarius and Capricorn. The median orbital elements are:

- a = 3.16 AU,
- q = 0.547 ± 0.025 AU,
- e = 0.823 ± 0.069,
- i = 1.90 ± 1.30°,
- ω = 270.7 ± 2.3°,
- Ω = 143.2 ± 0.7°.

Perhaps coincidentally, this orbit resembles that of lost comet D/1770 L1 (Lexell) during its returns in 1770 and 1776: a = 3.15 AU, q = 0.674 AU, e = 0.786, i = 1.55°,. ω = 225.0°, and Ω = 134.5°. Mainly the argument of perihelion differs significantly.

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

Figure 3 – 18-Aquariid of August 16, 11^{h}09^{m}02^s UT, from CAMS California station Windsor.

The following CAMS networks contributed to this report: 9 meteors were detected by LO-CAMS (coordinated by N. Moskovitz), 7 meteors were detected by CAMS California (station operators T. Beck, J. Albers, E. Egland, and B. Grigsby), 7 by CAMS Chile (S. Heathcote, E. Jehin), 5 by CAMS Florida (A. Howell), 3 by CAMS Texas (W. Cooney), 2 by CAMS Arkansas (L. Juneau), 2 by CAMS Namibia (T. Hanke), and 1 by CAMS South Africa (T. Cooper). C. Johannink also reports 2 detections from CAMS BeNeLux.

Reference

Jenniskens P. (2022a). "18-Aquariid meteor shower 2022". CBET 5159, published 2022, August 17. Ed.: D. W. E. Green. Cambridge: Central Bureau for Astronomical Telegrams.

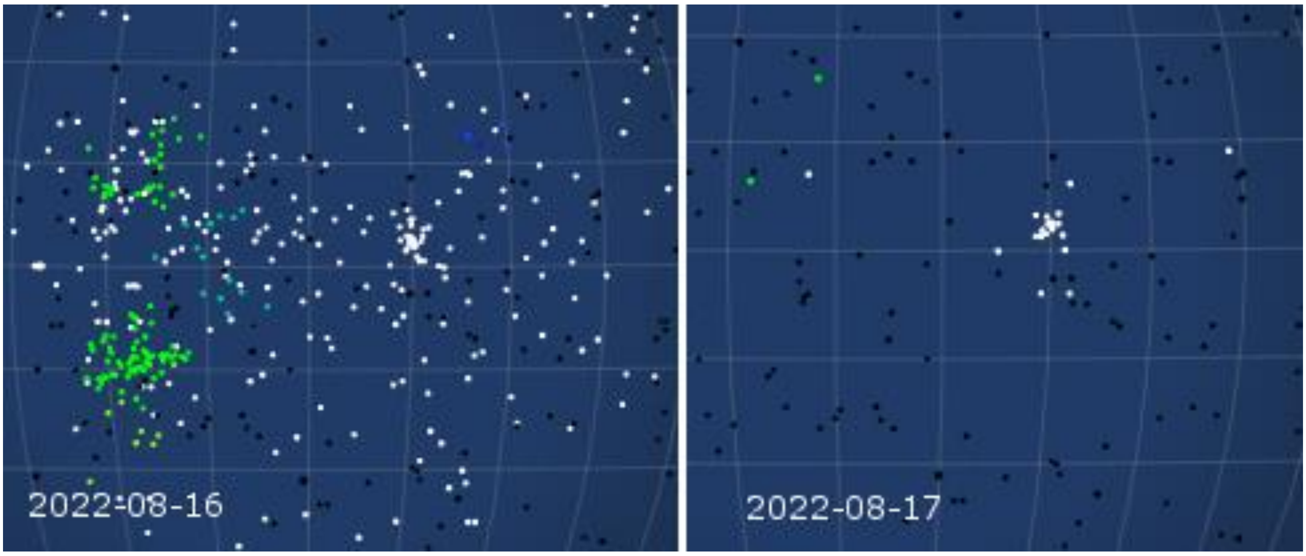

Figure 4 – The radiants as spotted in two different nights.

August delta Capricornids meteor shower 2022

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On August 16, 2022, the global CAMS low-light video camera networks detected a meteor outburst in the anti-helion source from a median radiant at geocentric position R.A. = 324.7 ± 0.2°, Decl. = –11.6 ± 0.3°, with geocentric speed v_g = 24.2 ± 0.3 km/s (Equinox J2000). The parent comet of this meteor shower is now identified as 45P/Honda-Mrkos-Pajdusakova. The shower previously associated with this comet from D-criterion searches among photographed orbits is IAU number 199, called the August delta Capricornids. The observations suggest that Earth crossed two dust trails, one trail being ejecta from the 1980 return of 45P.

1 Introduction

After a strong detection on August 17, 2022 (Jenniskens, 2022a), the new shower on the border of Aquarius and Capricorn was no longer detected on August 18 (see CAMS website[10] for the date of 2022 August 18 and the report in Jenniskens, 2022b). Sekiguchi (2022) pointed out that the longitude of perihelion of these meteoroid orbits, not just the shape of the orbit, agreed with that of comet 45P/Honda-Mrkos-Pajdusakova.

2 Observations

The following CAMS networks contributed to this report: 82 meteors were triangulated by CAMS Namibia (coordinated by T. Hanke), 11 by CAMS Chile (S. Heathcote, E. Jehin), 9 by LO-CAMS (N. Moskovitz), 9 by CAMS BeNeLux (C. Johannink), 7 by CAMS California (station operators T. Beck, J. Albers, E. Egland, and B. Grigsby), 5 by CAMS Florida (A. Howell), 5 by CAMS South Africa (T. Cooper), 4 by CAMS Arkansas (L. Juneau), 3 by CAMS Texas (W. Cooney) and 1 by the UAE Astronomical Camera Network (M. Odeh).

In all, 137 meteors were triangulated by the global CAMS networks, concentrated mainly during two brief time intervals. The first peak was centered on solar longitude 143.16 ± 0.02° (33 orbits), while the second stronger peak was centered on solar longitude 143.707 ± 0.008° (equinox J2000.0), corresponding to 2022 Aug. 16, 22^h00^m UTC (98 orbits). Six meteors were detected outside these intervals.

Table 1 – Median orbital elements of the shower 199 outburst in 2022.

a	3.16 AU
q	0.547 ± 0.025 AU
e	0.823 ± 0.069
i	1.90 ± 1.30°
ω	270.7 ± 2.3°
Ω	143.2 ± 0.7°
N	137

3 Discussion

That second outburst was predicted. Maslov[11] predicted an encounter with the 1980 dust of 45P on 2022 Aug. 16 around 23^h40^m UTC and put the radiant at R.A. = 326.8°, Decl. = –15.1°. The observed coordinates for the second peak were R.A. = 325.28 ± 0.06°, Decl. = –11.40 ± 0.06° with v_g = 24.12 ± 0.14 km/s. According to these calculations, Earth passed only 0.0038 AU from the center of the dust trail and encountered dust that was ejected at a modest speed of 9.8 m/s. To my knowledge, this is the first time an encounter with a dust trail of 45P has been confirmed.

A shower with similar radiant and speed is already listed in the IAU Working List of Meteor Showers as number 199, called the August delta Capricornids. That makes the name 18-Aquariids (Jenniskens, 2022a) a duplicate.

A difference in the orientation of the nodal line between the current comet orbit of 45P and the meteor shower assigns these as dissimilar using the usual D-criteria. That rotation of the nodal line is mostly a consequence of a close encounter of the comet with Jupiter in 1983. The observed meteoroids were ejected in the orbit prior to this encounter.

Reference

Jenniskens P. (2022a). "18-Aquariid meteor shower 2022". CBET 5159, published 2022, August 17. Ed.: D. W. E. Green. Cambridge: Central Bureau for Astronomical Telegrams.

Jenniskens P. (2022b). "August delta Capricornids meteor shower". CBET 5161, published 2022, August 26. Ed.: D. W. E. Green. Cambridge: Central Bureau for Astronomical Telegrams.

Sekiguchi T. (2022). "New radiant on Aquarius/Capricorn border by the SonotaCo network". *eMetN*, **7**, 302–303.

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

[11] http://feraj.ru/Radiants/Predictions/45p-ids2022eng.html

A meteor outburst caused by dust from comet 73P/Schwassmann–Wachmann: the tau Herculids, a visual analysis

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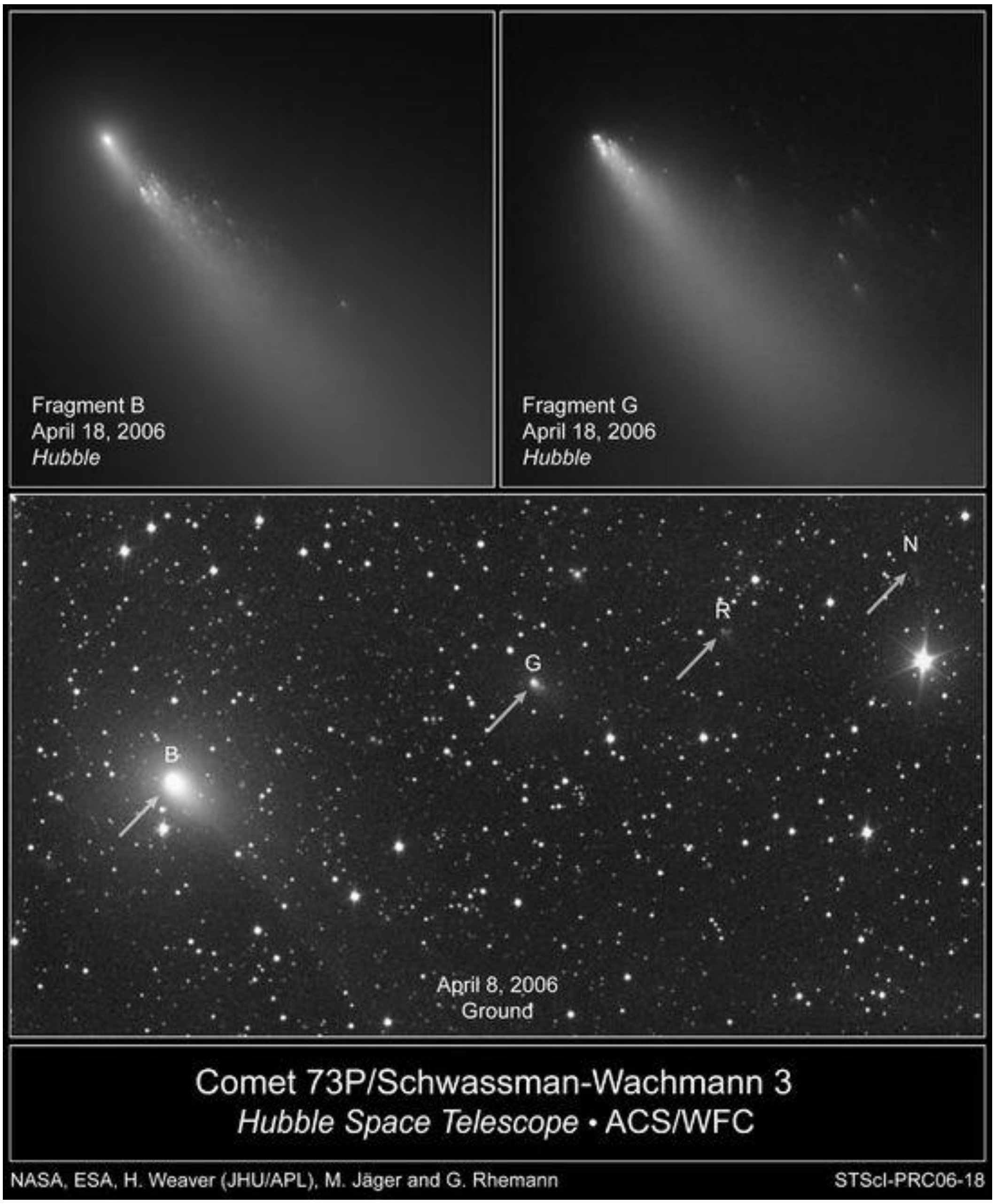
On the night of May 30–31, 2022, a beautiful meteor outburst caused by dust from comet 73P/Schwassmann–Wachmann has been observed from Europe and especially from America. This article is based on calculations from the visual observations reported to the International Meteor Organization. The results are also compared with CAMS and radio observations.

1 Comet 73P/Schwassmann–Wachmann

In 1930, astronomers Arnold Schwassmann and Arno Arthur Wachmann discovered a comet while searching for asteroids. The comet was then 9.3 million km from Earth and completes one orbit around the Sun in 5.4 years. However, after this discovery, the comet was not seen for a while. This may have been due to a bad geometry relative to the Earth during perihelion, but it could also have been missed. The comet was rediscovered in 1979, but then missed again in 1985. In the fall of 1995, the comet was sighted again and found to be in outburst. Shortly thereafter, instead of one nucleus, four distinct nuclei, named "A", "B", "C", and "D", were observed. Since fragment "C" was the largest, it is believed that this fragment was the original large cometary nucleus. The next (unfavorable) appearance of comet 73P/Schwassmann–Wachmann was in 2000–2001, only fragments "C" and "B" were observed, which were brighter than expected.

Figure 1 – Beautifully composed 2.5 hour image of the tau Herculids outburst on May 31, 2022 over the famous Kitt Peak Observatory in Arizona. 19 tau Herculids and 4 sporadic meteors were recorded. In the foreground the building of the Bok 2.3 meter telescope and behind it the building of the 4.0 meter Mayall Telescope. Recorded by Jianwei Lyu. The image has also become APOD[12].

[12] https://apod.nasa.gov/apod/ap220601.html



Figures 2 (top left), 3 (top right), and 4 (bottom) – These beautiful images from Hubble (above) and Michael Jäger and Gerald Rhemann shows the disintegration process of Comet 73P/Schwassmann–Wachmann.

The disintegrated comet made its next return to the inner regions of our solar system in 2006. It was a spectacular appearance that showed how comets come to an end. Initially, astronomers reported the two large fragments "B" and "C" and six smaller fragments "G", "H", "J", "M" and "N". But in the end 68 fragments were counted. Spectacular images from the Hubble and the Spitzer Space Telescope showed the fragmentation process in detail. Large and small pieces break off from the mother's body and the then smaller fragments fall apart again. During that appearance, the author was able to observe the comet visually and photographically on several dates with an 80 mm telescope[13].

2 Meteors from comet 73P/Schwassmann–Wachmann?

Because the comet's orbit is close to Earth, several astronomers independently made predictions for meteor activity from this comet. However, no real evidence of meteor activity has been found in the past from a radiant near the star tau Herculi. The first hopeful model calculations showed that a meteor storm could possibly occur on 2022, May 31 from a radiant northwest of the bright star Arcturus in Bootes (Lüthen, 2001). But some activity from the tau Herculids was also predicted for 2017, especially from the dust trail of 73P from 1941. Indeed, on the night of May 30–31, 2017, the CAMS BeNeLux network captured five tau Herculids within an hour exactly from the predicted radiant position by (Johannink, 2017). Also, visual observers active in late May early June

[13] Source: Kronk G., https://cometography.com/pcomets/073p.html

sometimes report very slow meteors from Bootes. This gave hope for a good activity in 2022. The initially predicted meteor storm in 2022 was later put into perspective by new model calculations: the expectations ranged from nothing at all to a few tens of tau Herculids per hour. However, due to the spectacular breakup of 73P/Schwassmann–Wachmann, some researchers expected (Rao, 2021) that there was a good chance for a meteor storm. It was mentioned that much would depend on the speed at which particles were released from the parent body 73P in 1995. The dust trail from 1995, the year of the first major break up of 73P/Schwassmann–Wachmann should be the largest supplier of activity, but also older dust trails could give some activity. Ultimately, the independent model calculations for the dust trail of 1995 yielded the following results as described in the IMO Meteor Shower Calendar (Rendtel, 2021):

- 2022 May 31, 04^h55^m UT ($\lambda_\odot = 69.44°$ with a minimum distance of +0.0004 AU (Jenniskens, 2006).
- 2022 May 31, 05^h17^m UT ($\lambda_\odot$ = 69.459° with a minimum distance of –0.00214 AU (Jenniskens, 2006).
- 2022 May 31, 05^h04^m UT ($\lambda_\odot$ = 69.451° with a minimum distance of –0.00041 AU (Sato, 2021).

These would mainly be weak meteors, because the tau Herculids have a very low entry speed of 16 km per second. The times mentioned were very favorable for Central and North America. In Europe the Sun is already above the horizon at the times mentioned, but it is possible that the rising flank of the outburst would be visible in Europe. Because there are multiple dust trails from the various fragments of 73P/Schwassmann–Wachmann near Earth, the IMO meteor calendar called for tau Herculid observations between May 28 and June 1. For example, two dust trails from 1892 and 1897 are mentioned that could give some activity on 2022 May 30, around 16^h UT and 2022 May 31, around 10^h UT respectively (Wiegert, 2005).

On 2022 May 30, Peter Jenniskens reported (Jenniskens, 2022a; 2022b) the first detections of tau Herculids on MeteorNews on 2022 May 27, by the CAMS global network. And, the GMN network and the CMOR radar clearly detected activity of the tau Herculids. Radio observations (Ogawa, 2022) also show distinct activity. Visual observers reported several to many tens of tau Herculids per hour in Europe and America (Martin, 2022; Miskotte, 2022). This article presents the results of an analysis based on visual meteor observations reported to IMO up to June 25, 2022. The data is also compared with CAMS and radio observations.

3 Visual analysis

Several European observers have taken the initiative to do observations from America, including *Thomas Weiland, Sirko Molau, Javor Kac* and *Francisco Ocaña González*.

Via the website of the International Meteor Organisation[14] the observational data could be checked on location and possible errors. When entering the observations, it was immediately checked whether the data met the known requirements. These requirements are:

- A good reliable *Cp* of the observer must be known, or there must be enough August data available from the previous year(s) to calculate a *Cp*.
- Only observations made with a limiting magnitude of 5.9 or higher are used for analysis.
- The minimum radiant height was set at 25 degrees.
- Only observations with cloud percentages of 10% or lower were used.
- Also 0 detection observations were used in this analysis.
- Next, the magnitude distributions were checked for the following requirement: The difference between the observed mean magnitude of the meteor shower and the limiting magnitude should not exceed 4 magnitudes.

4 Population index *r*

The astronomers' model calculations indicated that it would mainly involve many faint meteors. Indeed, many observers in the field noticed this. Nevertheless, a number of bright tau Herculids were also seen, as Mark Adams observing from Virginia counted two tau Herculids of –2 and one –3. Pierre Martin also saw a few bright tau Herculids from Canada: "*The tau Herculids seemed to be very fragile, delicate meteoroids – many extremely short paths. The brighter ones often had multiple flares and terminal flashes. The brightest tau Herculids reached –3 and displayed thick wakes that seemed "sparkly (fragmentation)*". Javor Kac was the only visual observer to observe a tau Herculid fireball, which had a magnitude of –6. Astronomer Pavel Spurny reports that the Czech all sky network has captured 16 tau Herculid fireballs, the brightest even at magnitude –15 (private com Betlem).

Table 1 – Population index *r*[–1;+5] of the tau Herculids

$\lambda_\odot$ (°)	*r*[–1;+5]
68.347	–
69.126	3.06 ± 0.44
69.206	3.07 ± 0.24
69.266	2.67 ± 0.62
69.306	3.07 ± 0.53
69.346	–
69.386	2.76 ± 0.15
69.426	2.75 ± 0.10
69.466	2.63 ± 0.12
69.506	2.84 ± 0.15
69.566	2.63 ± 0.33

[14] https://www.imo.net/members/imo_live_shower?shower=TAH&year=2022

The population index r calculations seem to confirm that most tau Herculids were faint. *Table 1* and *Figure 5* give the results of these calculations.

A cautious conclusion is that the tau Herculids had a slightly decreasing population index r between $\lambda_{\odot}$ 69.05° and 69.60°.

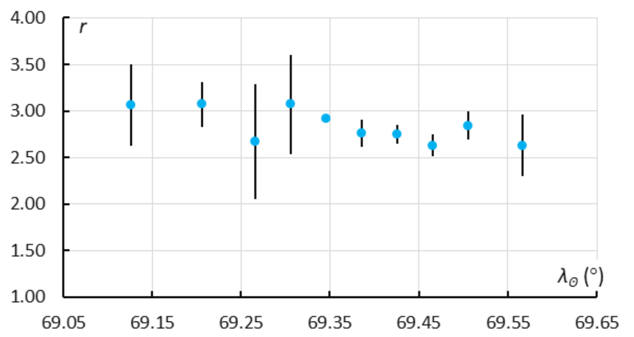


Figure 5 – Population index r of the tau Herculids between 2022 May 30, 20^h UT and 2022 May 31, 09^h UT.

5 Zenital Hourly Count (ZHR)

The ZHR was determined as follows:

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

In addition, the radiant zenith exponent was set as $\gamma = 1.0$. The ZHR could be calculated using the population index r. In view of the activity shown, half-hour counts were chosen. Depending on how the observer provided his data, overlapping half-hour counts were used as much as possible. This is possible if an observer provides 10 minutes counts. The disadvantage is that observers who only provided counts on one subsequent 30 minutes have a smaller percentage in the processing than those who provided ten minutes counts. But the observational data shows roughly the same results, so there is a lot of confidence in the end result. *Table 2* and *Figure 6* give the results of these calculations.

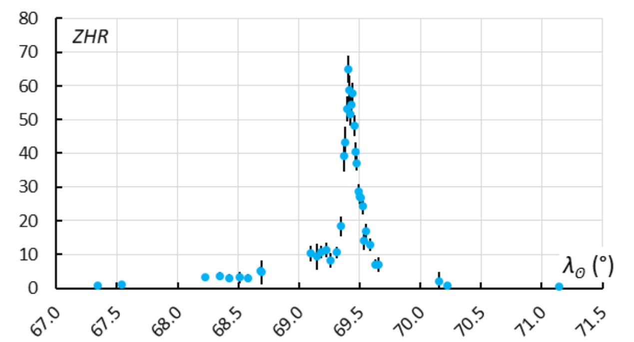


Figure 6 – ZHR of the tau Herculids between 2022 May 29 and June 2.

Figure 6 shows that there was clearly visually detectable activity in the nights around the maximum. The ZHR was always around 1 to 3. In *Figure 7* we zoom in on the maximum more in detail.

Table 2 – Zenital Hourly Rate of the tau Herculids in 2022.

Date	T_m UT	$\lambda_{\odot}$ (°)	Bins	Obs	TAH	*ZHR*
May 25	3.17	63.752	1	1	1	0.8 ± 0.8
May 29	0.37	67.342	5	3	4	0.7 ± 0.4
May 29	5.42	67.544	4	2	2	1.2 ± 0.8
May 29	22.50	68.227	4	1	11	3.2 ± 1
May 30	1.50	68.347	4	1	9	3.7 ± 1.2
May 30	3.43	68.424	2	2	2	2.8 ± 2
May 30	4.53	46.468	4	4	16	6.6 ± 1.7
May 30	5.70	68.515	2	2	9	3.2 ± 1.1
May 30	7.29	68.578	2	2	6	3 ± 1.2
May 30	9.98	68.686	1	1	2	5.1 ± 3.6
May 30	10.21	68.695	1	1	4	4.7 ± 2.3
May 30	20.17	69.093	1	1	7	10.3 ± 3.9
May 30	21.57	69.149	6	3	24	9.3 ± 1.9
May 30	22.39	69.182	6	4	25	10.6 ± 2.1
May 30	23.39	69.222	6	4	26	11.3 ± 2.2
May 31	0.43	69.264	6	5	22	8.3 ± 1.8
May 31	1.54	69.308	3	3	13	10.6 ± 2.9
May 31	2.58	69.350	3	3	16	18.4 ± 4.6
May 31	3.22	69.375	6	5	68	39.1 ± 4.7
May 31	3.38	69.380	11	6	129	43.2 ± 3.8
May 31	3.73	69.395	12	8	175	53.2 ± 4
May 31	3.95	69.404	14	9	244	65 ± 4.2
May 31	4.23	69.415	18	10	323	58.8 ± 3.3
May 31	4.46	69.425	20	10	383	51.5 ± 2.6
May 31	4.71	69.435	17	9	355	54.4 ± 2.9
May 31	4.95	69.444	16	8	352	57.9 ± 3.1
May 31	5.22	69.455	17	9	322	48.3 ± 2.7
May 31	5.55	69.468	24	12	365	40.5 ± 2.1
May 31	5.80	69.478	22	10	302	37 ± 2.1
May 31	6.19	69.494	15	8	157	28.6 ± 2.3
May 31	6.43	69.503	15	9	151	27.1 ± 2.2
May 31	6.66	69.513	12	8	116	26.8 ± 2.5
May 31	6.91	69.523	8	5	77	24.3 ± 2.8
May 31	7.20	69.534	6	4	45	14.1 ± 2.1
May 31	7.56	69.549	9	5	80	16.9 ± 1.9
May 31	8.59	69.589	5	3	88	12.8 ± 1.4
May 31	9.55	69.628	4	3	10	7.1 ± 2.2
May 31	10.25	69.656	3	3	6	6.9 ± 2.8
May 31	22.64	70.151	4	2	6	2 ± 0.8
June 1	0.49	70.225	3	2	2	0.8 ± 0.6
June 1	23.52	71.145	1	1	1	0.4 ± 0.4

In *Figure 7*, the European part of the data runs from $\lambda_{\odot}$ = 69.09° to 69.35°, this is 2022 May 30 from 20^h UT to 2022 May 31, 2^h30^m UT. During that period the ZHR was stable around *ZHR* = 10. At the end of the night in Europe on 2022 May 31, around 3^h UT, the onset to the peak was noticeable. Btw, this does not apply from the Canary Islands where it remained dark until just after 5^h00^m UT, where, among others, *Jürgen Rendtel* and *Rainer Arlt* observed the tau Herculids.

At λ_O = 69.40° (2022 May 31, just before 4^h00^m UT) a first early peak is observed, the ZHR is then around 65 ± 4. The activity then decreases slightly to around 50 around λ_O = 69.444° (2022 May 31, just before 5^h00^m UT), but then again had a peak with a *ZHR* of 58 ± 3. After the second peak, activity slowly decreased and from λ_O = 69.60° (2022 May 31, 09^h UT) the activity remained below a *ZHR* of 10. The rising edge of the peak is also somewhat steeper than the decreasing edge.

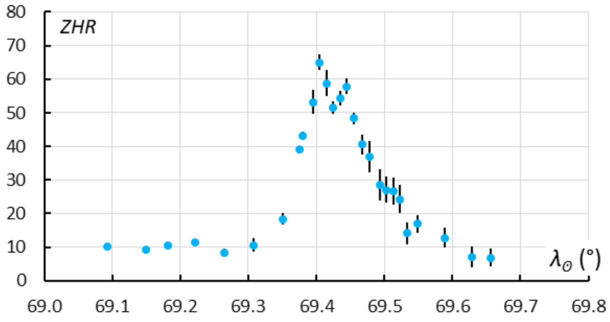


Figure 7 – *ZHR* tau Herculids between 2022 May 30, 20^h UT and 2022 May 31, 11^h UT.

If we compare the two peaks found with the predictions mentioned above, it is noticeable that the second peak with a *ZHR* of 58 coincides very nicely with the first prediction of Peter Jenniskens (2022 May 31, 04^h55^m UT), but of course it should be mentioned that all predictions were very close.

Finally, in *Figure 8* we give a comparison with the population index *r*. It is clear that the population index *r* begins to decrease as the outburst began.

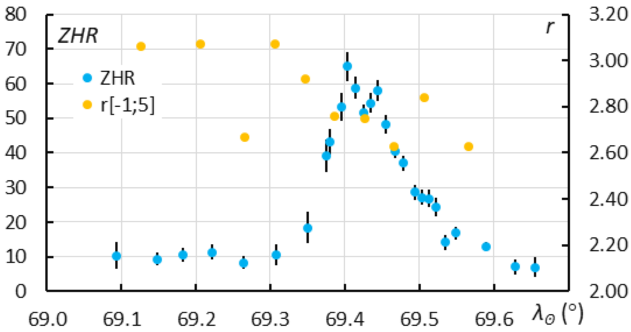


Figure 8 – *ZHR* and population index *r* in one graph.

6 Comparison with radio- and CAMS observations

In an article in Meteornews Hiroshi Ogawa (2022) published results of the worldwide radio observations of the tau Herculids. Here the radio observations are converted to activity profiles such as activity index and radio *ZHR*. Although the observation techniques are completely different, there is a possibility to (carefully) compare the radio *ZHR* with the visual *ZHR*. The method to estimate the radio ZHR is described in (Sugimoto, 2017). In (Ogawa, 2022, see *Figure 4*) a graph provides a detailed picture of the tau Herculids outburst. The author recognized two possible structures here, one small peak around λ_O = 68.9° falls in the time window in which dust from 1892 and/or 1897 meteors may be generated as predicted by Wiegert (2005). The largest activity (the second peak) comes from the dust from the big break up of 73P in 1995. The graph has been remade by the author (see *Figure 9*) and the visual ZHR curve has also been added. Unfortunately, the first (fainter) peak around λ_O = 68.9° cannot be confirmed visually, simply because there is no observational data from the period λ_O = 68.8° to 69.0°. The second peak in the radio data coincides nicely with the peak found from visual observations, although the visual level is much higher visually. Radio and visual meteor observations are always difficult to compare, but the broad outlies are usually there.

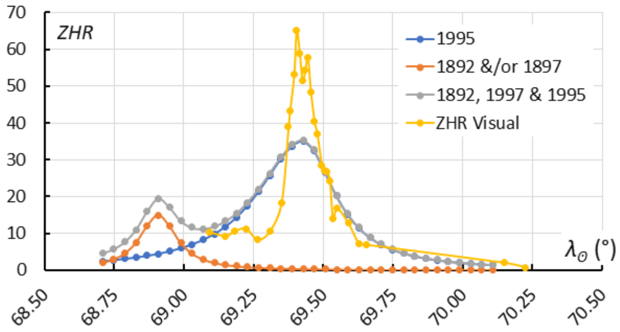


Figure 9 – Comparison between the activity of the tau Herculids estimated radio *ZHR* and visual *ZHR*.

CAMS observations (Jenniskens, 2022) show a maximum on 2022 May 31, at 04^h42^m UT ± 25 minutes. The second maximum found on 2022 May 31, at 04^h57^m UT in the visual analysis fits well in the period specified by Jenniskens.

7 Conclusion

The tau Herculids showed clearly observable activity in 2022. Based on visual observations, a maximum was found that appears an hour earlier than predicted. The *ZHR* was then 65 ± 4. A second slightly weaker peak with a *ZHR* of 58 ± 4 was found at the correct time. Comparison with radio and CAMS data gives comparable times for the maxima.

Acknowledgment:

First of all, of course, for all observers who have observed the tau Herculides. These are: *Mark Adams, Daniel Alcazar, Rainer Arlt, Orlando Benitez Sánchez, Tim Cooper, Howard Edin, Aldo Nicolas Frezzi, Christoph Gerber, Robert Harris, Jan Hattenbach, Carl Hergenrother, Glenn Hughes, Javor Kac, André Knöfel, Pete Kozich, Jens Lacorne, Anna Levin, Michael Linnolt, Robert Lunsford, Oleksandr Maidyk, Oscar Martin Mesonero, Pierre Martin, Marco Micheli, Russel Milton, Koen Miskotte, Sirko Molau, Edward Murphy, Basil Nikolau, Artyom Novichonok, Francisco Ocaña González, Sasha Prokofyev, Ina Rendtel, Jurgen Rendtel, Terrence Ross, Ivan Sergey, Wesley Stone, Fengwu Sun, Hanjie Tan, Austin Uhler, Michel Vandeputte,* *Alan Webb, Thomas Weiland, Frank Wächter, Sabine Wächter* and *Quanzhi Ye*.

In addition, a word of thanks to *Carl Johannink* and *Michel Vandeputte* for reading the article. Special thanks to *Hiroshi Ogawa* and RMOB for providing the radio data.

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The Andromedids (#0018AND)

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The Andromedids' outburst surprised meteor observers in 2021. The Andromedids were recovered by photographic observations and observed annually by video observations before $\lambda_{\odot} < 240°$. We compare former observations with the outburst and recognize this event has a unique maximum later than $\lambda_{\odot} > 245°$. This outburst is near the Great Andromedids in the 19th century but is clearly distinct from #0446DPC.

1 Introduction

Lovell classified the Andromedids as a lost stream (1954) and visual observers have not observed aby activity except occasionally by chance. Video observations can catch them annually now, but their daily rates are under 2 at their maximum. The Andromedids are called also Bielids by the name of their parent comet. 3D/Biela is the official name, it was broken up as 'D' means dead, and it had many close encounters to Jupiter. The prediction of the activity of the Andromedids is difficult because of Biela's history and, therefore, we were surprised by their sudden outburst in 2021. In this analysis, we study the unique character of this outburst using video observations.

2 Recovery of the Andromedids

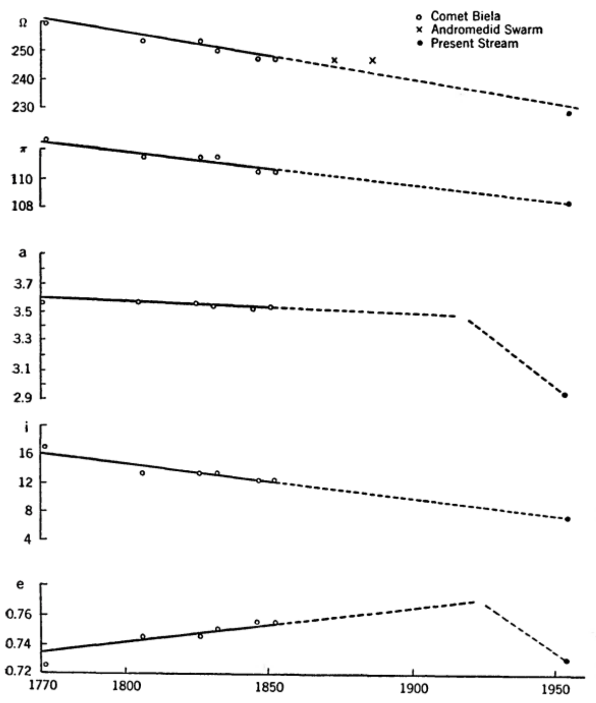

Figure 1 – 'The recovery of the Andromedids', Hawkins et al. (1958).

Hawkins et al. (1958) reported the Andromedids were recovered by photographic observations and suggested that their radiant moved southward; the inclination of the stream decreased (*Figure 1*). But we had to wait to certify the recovery until video observations had enough developed. SonotaCo found the Andromedids in Japanese video observations (2009)[15].

Koseki published the meteor shower catalog by using SonotaCo net results 2007–2018 observations (2021). *Figure 2* shows the result for the Andromedid activity and this shower is active for a full month. The meteor activity could be better expressed by the radiant density ratios (Koseki, 2019). The activity profiles indicate their maximum differently: $N_r \leq 3$ and DR10 suggest the maximum around $\lambda_{\odot} = 224°\sim226°$, DR = 3 and DR15 show their peak around $\lambda_{\odot} = 230°$, but there seems to be another one around $\lambda_{\odot} = 240°$ (see *Table 1* for the meaning of the abbreviations).

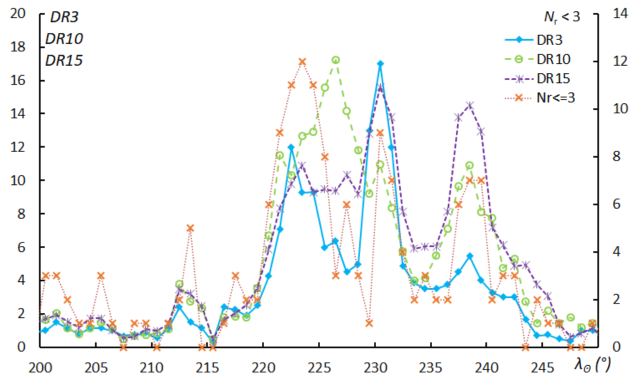

Figure 2 – The activity profiles of video Andromedids.

Figure 3 represents the radiant shift of the Andromedids (dotted line) and their path reaches the radiant of the Great Andromedids (left circle in *Figure 3* is for 1872 and the right circle is for 1885). The asterisk and the plus in *Figure 3* show the radiant of December psi Cassiopeiids (#0446DPC) by CMOR and CAMS respectively in 2011.

[15] See also "SonotaCo Network Simultaneously Observed Meteor Data Sets", http://sonotaco.jp/doc/SNM/

Table 1 – The abbreviations used in the activity profiles; *r* is the distance from the center in degrees, *S* is the area in which radiants are counted, in square degrees, *DR3~DR15* are calculated as $N1/S1/(N2/S2) = R*N1/N2$ using the sliding mean in 3 degrees $\lambda_{\odot}$ bins.

Abbriation	Base limit	Radiants	Area (*S1*)	Reference limit	Radiants	Area (*S2*)	*S2/S1 = R*
$N \le 3$	$r \le 3$	*N1*		–			
DR3	$r \le 3$	*N1*	28.3	$3 < r \le 6$	*N2*	84.7	2.997
DR10	$r \le 3$	*N1*	28.3	$6 < r \le 10$	*N2*	200.4	7.088
DR15	$r \le 3$	*N1*	28.3	$10 < r \le 15$	*N2*	389.5	13.778

Table 2 – Yearly number of the classified AND and DPC meteors during the period 2007–2018.

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
AND	7	12	20	23	6	12	6	11	17	20	17	16	167
DPC	0	1	0	0	20	1	2	1	1	2	1	1	30

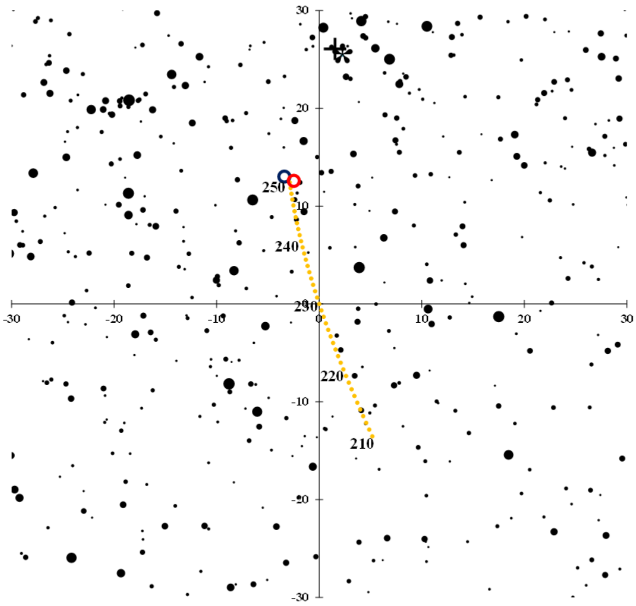

Figure 3 – The radiant shift derived by video observations.

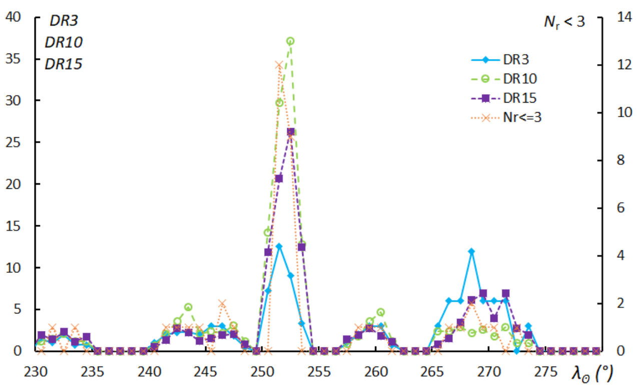

Figure 4 – The activity profiles of the December psi Cassiopeiids (0446DPC00) by Japanese video observations.

The December psi Cassiopeiids (#0446DPC) is listed in the IAUMDC meteor shower database (SD) with as its parent body 3D/Biela (the version of 2018 January 13, $20^{h}35^{m}17^{s}$ of the SD has been used[16]) but this shower is not a part of the annual Andromedid activity. Japanese video observations observed the 2011 outburst of the December psi Cassiopeiids (#0446DPC) (*Figure 4 and 5*). Both figures are not corrected for the radiant shift because the activity is quite short as *Figure 4* shows; #446DPC is not the late Andromedid activity because the latter seems to cease before the spike of the former activity occurs (*Figure 1*).

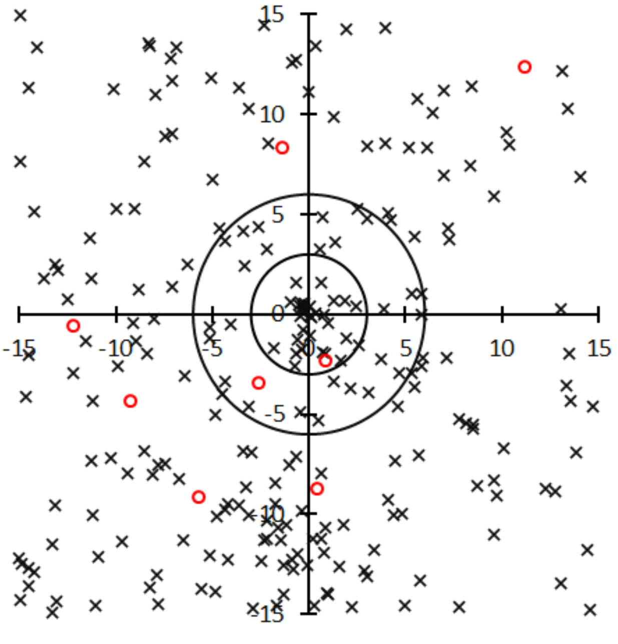

Figure 5 – The radiant distributions of the December psi Cassiopeiids (0446DPC00) by Japanese video observations.

The radiant of the December psi Cassiopeiids (#0446DPC) is very compact as shown in *Figure 5* and does not match the prolonged path of the annual Andromedids. We can add one more suggestion on the separation of #446DPC from the Andromedids by the yearly change in the observed number of meteors (*Table 2*). #446DPC has not been observed except for 2011 practically. But a photographic radiant (red circle) in *Figure 5* within the most inner circle is H4-9596 observed in 1956. It hits the maximum of

[16] IAUMDC SD, https://www.ta3.sk/IAUC22DB/MDC2007/index.php

#446DPC and suggests #446DPC has an annual or a recurrent nature.

We know now the Andromedids are not dead but can still produce meteor activity related to 3D/Biela.

3 Observations of Global Meteor Network (GMN) 2021

The Andromedids displayed a sudden outburst on November 28, 2021. The peak occurred around 5^h (UT) and favored observers in Europe and America. The Global Meteor Network collected many useful data (Roggemans et al., 2022). The data in GMN is increasing rapidly and it is not necessary to exclude observations before 2021 to investigate the Andromedids. We, therefore, used all GMN data (as available, downloaded on 2022-07-04 $00^h51^m26.021001^s$ UTC) and applied #0018AND00 ($\lambda_\Theta = 232°$, $\lambda - \lambda_\Theta = 162.6°$, $\beta = +20.8°$, $\Delta\lambda_\Theta = 25°$) as the startup data. We changed the startup because this outburst occurred later than the latest limit of the former study where we adopted #0018AND01 ($\lambda_\Theta = 228.6°$, $\lambda - \lambda_\Theta = 163.4°$, $\beta = +18.8°$, $\Delta\lambda_\Theta = = 10°$) as the startup (*Figure 2*). *Figure 6a* represents the radiant distributions centered at #0018AND00 and *Figure 6b* indicates the converged radiant distribution: the results of the iteration steps (see *Figure 9a~c*). The radiant distribution and the density from the center are shown in *Table 3* and *Figure 7*.

The density decreases rapidly with the distance from the center (r) and might be constant for $r > 10$. We can accept Density = 3 is the sporadic background. We can, therefore, classify radiants in $r = 3\sim4$ as Andromedids with 50% probability. It is clear that the radiant area of the Andromedids is compact.

Table 3 – The final radiant distribution density from the center. *r* is the distance from the center, *N* is the number of radiants between *r*–1 to *r*, the Area is represented in square degrees between *r*–1 to *r*, Density is calculated from *N* by dividing *N* by the Area.

r	*N*	*Area*	*Density*
1	640	3.1	203.7
2	398	9.4	42.2
3	202	15.7	12.9
4	121	22	5.5
5	135	28.2	4.8
6	140	34.5	4.1
7	144	40.8	3.5
8	183	47	3.9
9	181	53.2	3.4
10	160	59.4	2.7
11	233	65.6	3.6
12	237	71.8	3.3
13	216	77.9	2.8
14	260	84	3.1
15	270	90.1	3
16	261	96.2	2.7
17	317	102.2	3.1
18	300	108.3	2.8
19	345	114.2	3
20	344	120.2	2.9

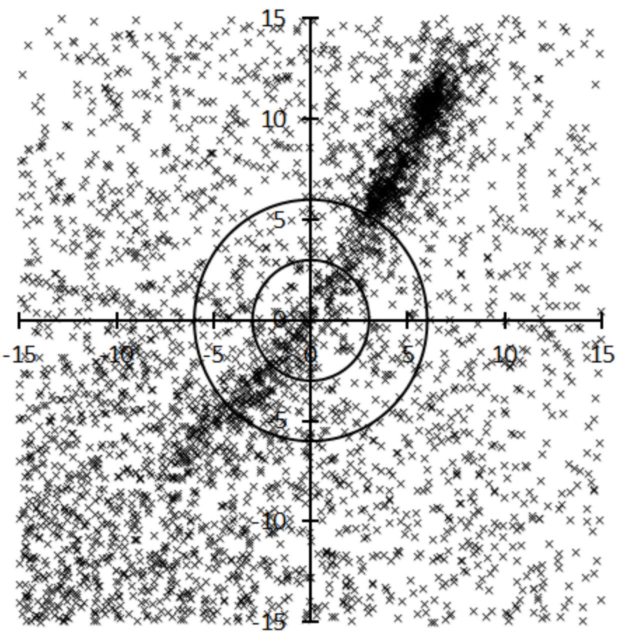

Figure 6a– The initial radiant distribution of the Andromedids (0018AND00).

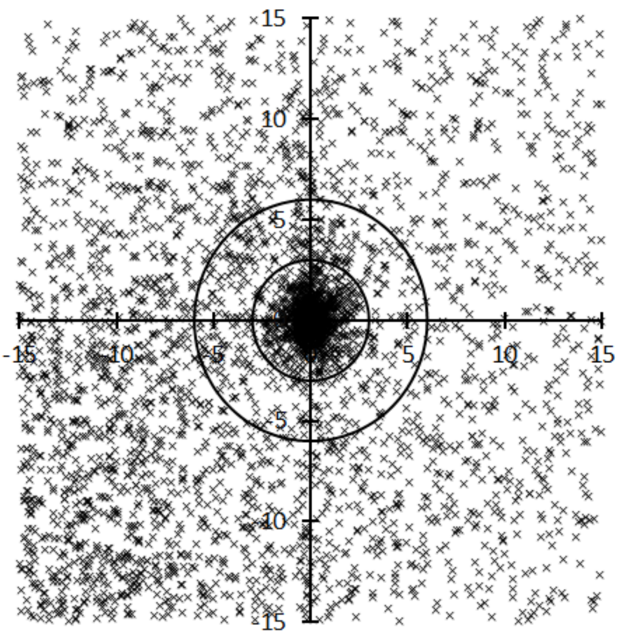

Figure 6b – The final radiant distribution through the iteration processes of the Andromedids. 0018AND00

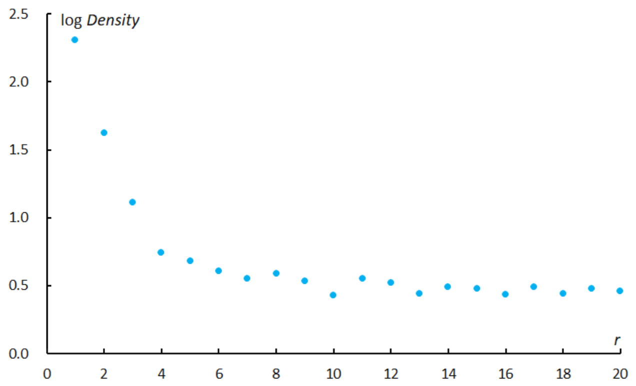

Figure 7 – The radiant density distribution from the center.

It is reasonable that we define the radiants within 3 degrees of the center as members of the Andromedids. The yearly number of the observed number of Andromedids is shown in *Table 4*. The Andromedids in 2021 are dominant because of the outburst of the Andromedids but also the rapid increase of the observations naturally. The following activity graphs are including 2019 and 2020 observations but this inclusion does not affect the conclusion. It is better to note that this regression study ignores the original classification in the GMN data. We omitted 113 Andromedids from the GMN data and included 98 sporadics and 34 DPC meteors from GMN (see *Table 5*); most of the omitted radiants were distributed between 3 to 6 degrees from the center of the figure or outside of the activity period considered in the GMN research.

Table 4 – Yearly number of the Andromedids observed by GMN.

Year	2018	2019	2020	2021	Total
N	0	64	114	1062	1240

Table 5 – The number of meteors classified as AND and DPC in GMN.

AND	DPC	sporadic	Total
1108	34	98	1240

Figure 8a shows the activity profiles of the Andromedids in the same manner as *Figures 2 and 4*. It is impressive that the 2021 outburst occurred after the annual activity of the Andromedids represented by Japanese 2007–2018 observations (*Figure 2*). *Figure 8b* gives the detailed graph by the moving mean with a 1-degree bin sliding with 0.1-degree steps. We can draw the transition more precisely by counting the periods between each 30 radiants on a time scale. We can calculate the number of radiants per 1 solar longitude easily by 30/(a time span of 30 radiants). *Figure 8c* clearly shows the condition; GMN catched meteors well between $\lambda_\odot = 245.5$~$245.9°$. It is very clear that the outburst is a short-lived one; the activity drops rapidly after $\lambda_\odot > 245.9°$. But we are uncertain whether the decrease occurred by the activity change itself or if the approaching twilight over Europe caused this. We will check this drop by using Japanese observations later.

Former Japanese observations suggest the Andromedids have several sub-maxima as shown in *Figure 2*. This indicates the annual Andromedids are composed of several segments including this outburst.

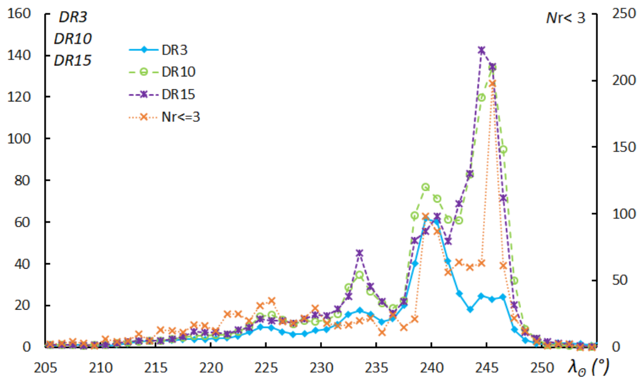

Figure 8a – The activity profiles of the Andromedids (0018AND00).

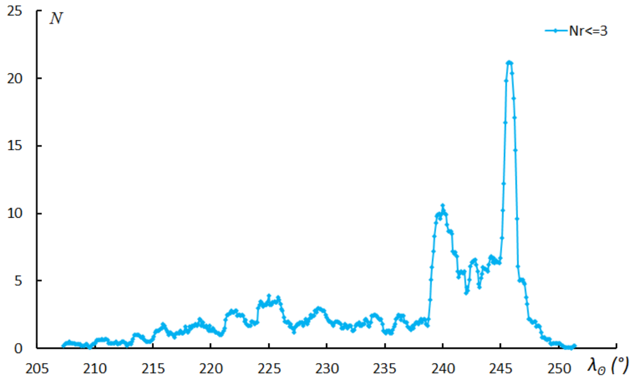

Figure 8b – The sliding mean of the radiants classified as Andromdids using 1 degree bins with 0.1-degree steps in $\lambda_\odot$.

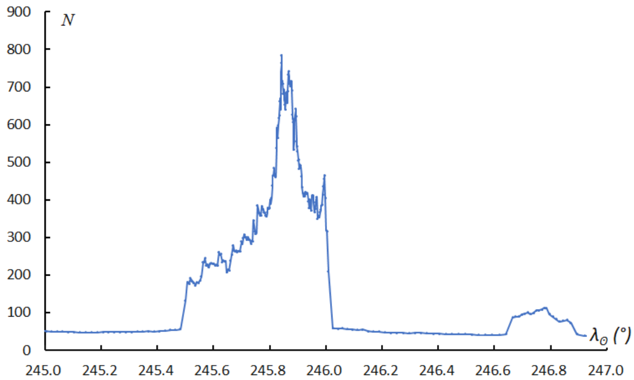

Figure 8c – The estimated activity progress using each time span of 30 Andromedids meteors.

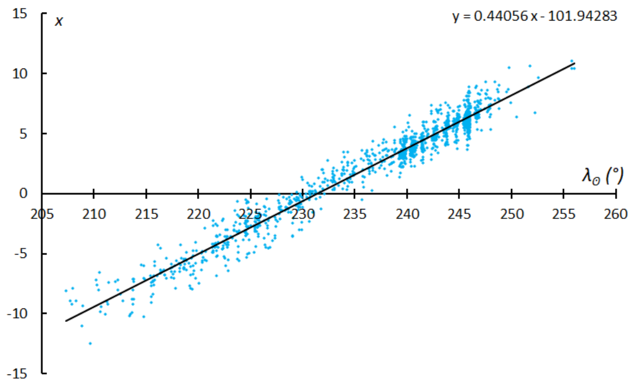

Figure 9a – The final regression results on *x* in the radiant distribution.

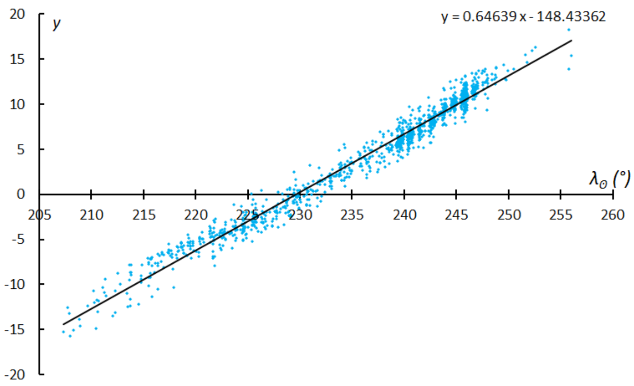

Figure 9b – The final regression results on *y* in the radiant distribution.

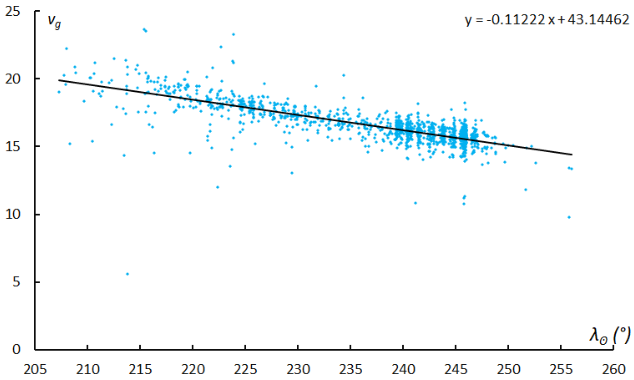

Figure 9c – The final regression results on the geocentric velocity (v_g) for the selected meteors in Figure 9a and 9b.

We used linear regression to get the conversion (*Figure 9a~c*); the dots in the graph express the radiants within the estimated center. The radiant shift in the *x*-axis (*Figure 9a*) might suggest the distribution bends around $\lambda_{\odot} = 230°$. Also, the radiant shift in the *y*-axis (*Figure 9b*) shows a rather clear bending around $\lambda_{\odot} = 230°$ and around $\lambda_{\odot} = 220°$. The geocentric velocity (v_g) does not indicate the bending around $\lambda_{\odot} = 230°$ but suggests the deviation from the line before $\lambda_{\odot} < 220°$. We will come back to this problem in the next section (concerning *Table 7b*).

4 Note on #0446DPC in GMN

The December psi Cassiopeiids (#0446DPC) were observed as a short-lived and compact activity (see *Figure 4 and 5*). According to the GMN classification #0446DPC have a longer activity period and a larger radiant area. *Figure 10 and 11a* are plotted based on the GMN's classification. The radiant distributions are shown centered at #0446DPC00, $\lambda_{\odot} = 252°$, $\lambda - \lambda_{\odot} = 152.8$, β = +44.8°, $\Delta\lambda_{\odot} = 10°$, DPC shower members are indicated with red circles. The crowd below the center represents the Andromedids. GMN's DPC radiants overlap with the Andromedids, and they are too elongated compared with the Andromedids' area. This classification distorts the activity graph (*Figure 11a*); the false peak appears before $\lambda_{\odot} < 245°$ because of the contamination by the Andromedids.

If we count the radiants within 3 degrees from the center, DPC's maximum would become clearer (*Figure 11b*). Radiants between the DPC and the Andromedids might be caused by sporadic activity; it would be a future work to investigate the relation between them.

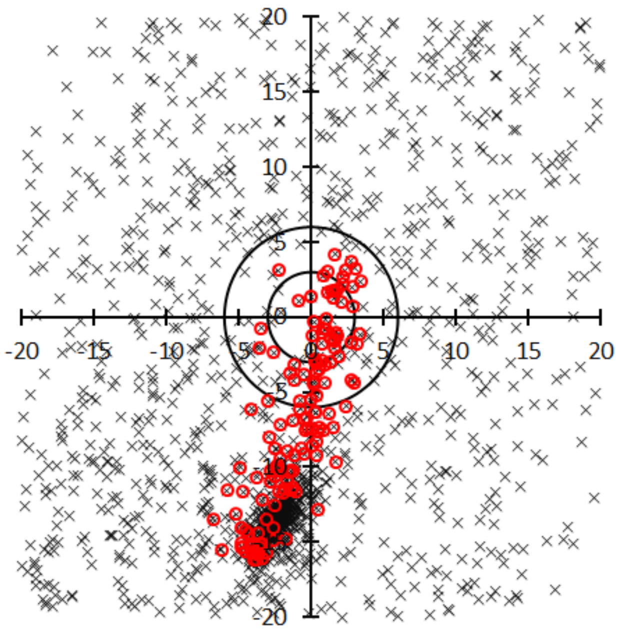

Figure 10 – The radiant distributions centered at DPC (0446DPC00) in $\lambda_{\odot}$ = 242~262°. Red circles are classified as DPC in GMN.

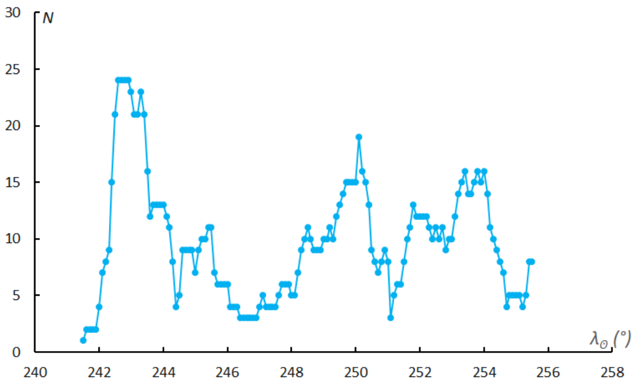

Figure 11a – The sliding mean of the radiants classified as DPC in GMN using 1 degree bins with 0.1-degree steps in $\lambda_{\odot}$.

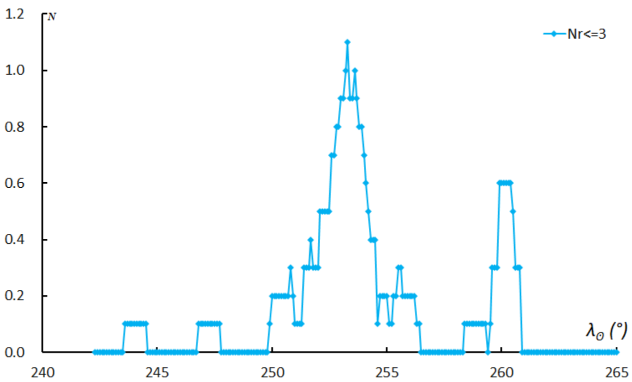

Figure 11b – The sliding mean of the number of radiants within 3 degrees from the center of Figure 10 using 1 degree bins with 0.1-degree steps in $\lambda_{\odot}$.

5 Observations of SonotaCo net extending to 2021

We analyzed the annual Andromedids using SonotaCo net data 2007–18 (*Figure 2* and Koseki, 2021). It seems to be better to extend the data to 2021 and rather not study 2021 data individually. We ignored the original classification as used in the former analysis but changed the startup because this outburst occurred later than the latest limit of the former study where we adopted #0018AND01 ($\lambda_O = 228.6°$, $\lambda - \lambda_O = 163.4°$, $\beta = +18.8°$, $\Delta\lambda_O = 10°$) as the startup (*Figure 2*). The data shown here are the results of #0018AND00 ($\lambda_O = 232°$, $\lambda - \lambda_O = 162.6°$, $\beta = +20.8°$, $\Delta\lambda_O = 25°$) as the startup data.

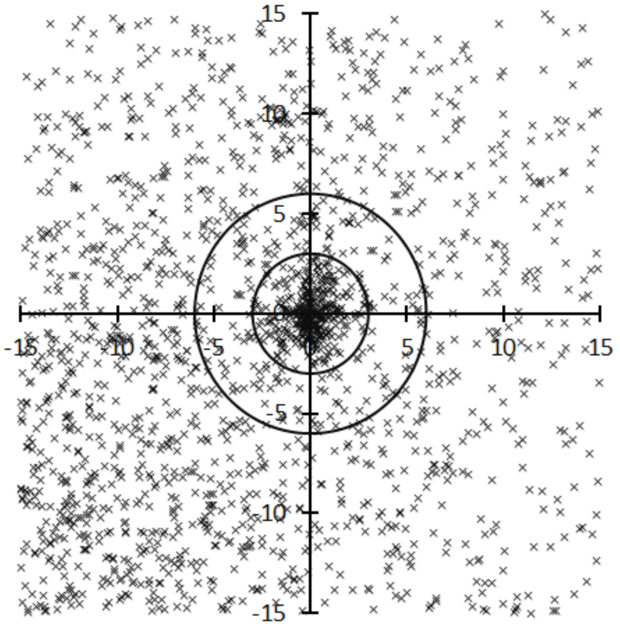

Figure 12 – The final regression results of the Andromedids (0018AND00) in SonotaCo net data.

The radiant distribution (*Figure 12*) resembles that of the GMN results (*Figure 6b*) though the December psi Cassiopeiids (#0446DPC) radiants can be recognized close to the 10°-mark on the *y*-axis because this figure is including 2011 observations. We can confirm here also that it is proper to use radiants within $r < 3°$ as Andromedids. *Table 6* gives the yearly number of the Andromedids and it is clear that the 2021 outburst was about ten times more active than the activity in regular years.

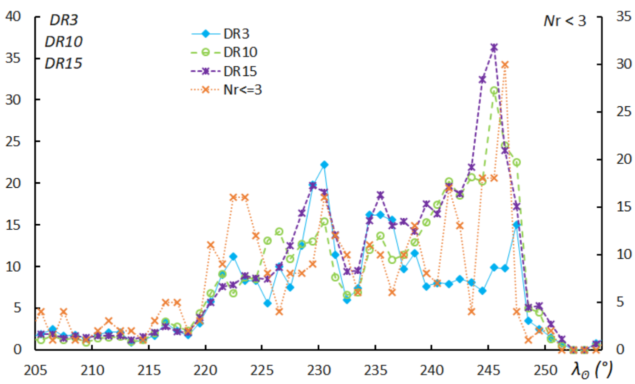

Figure 13a – The activity profiles of the Andromedids in 2007–2021 (0018AND00) by SonotaCo net.

The activity profiles represented in *Figure 13a* differ from GMN results (*Figure 8a*) because the profiles in *Figure 13a* are influenced by observations from before 2021. We can easily indicate the multi peaks of the activity like in *Figure 2* but the most intense peak is around $\lambda_O = 245°$ as GMN shows.

Figure 13b gives the detailed graph by the sliding mean with a 1-degree bin sliding by 0.1-degree steps. Japanese video observations started from $\lambda_O > 246.0°$ but the activity did not increase after the evening twilight ended. We can confirm the results of GMN; the outburst was a short-lived one and the activity dropped rapidly after $\lambda_O > 245.9°$.

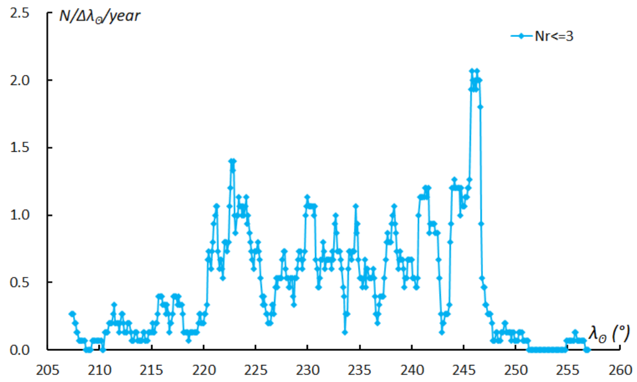

Figure 13b – The sliding mean of the classified radiants as Andromdids usng a 1 degree bin with 0.1-degree steps in λ_O.

The *y*-axis in *Figure 13b* gives the mean number of observed radiants per day but it is necessary to note that these profiles represent the mean values for 15 years while *Figure 8b* is based on almost 2021 data only. If the difference in number of observational years is considered, the observed number per day would be almost the same.

Figure 14 represents the distribution of the radiants taken from several interesting lists; background (cross): the showers in the SD, target (red box): the Andromedids showers in the SD, photo (circle): photographic observations, LIST (triangle: excluded meteor shower lists of the SD).

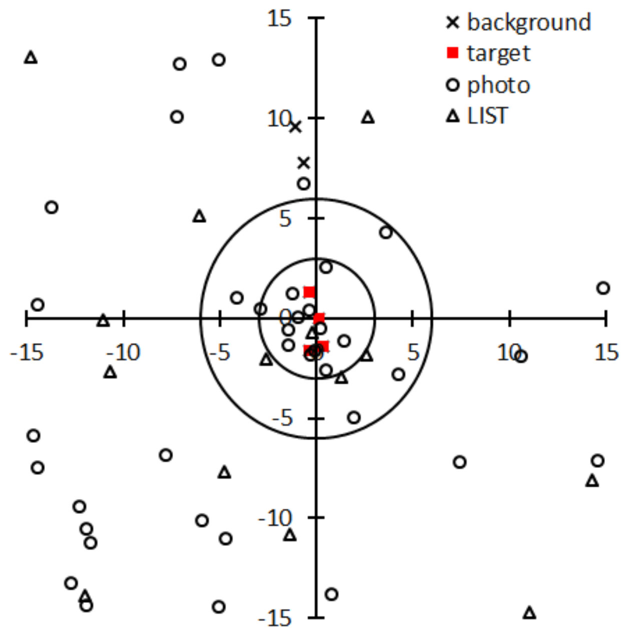

Figure 14 – The radiant distributions of several meteor shower sources.

Table 6 – The revised yearly number of the Andromedids extending to 2021.

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Tot.
N	7	16	22	17	6	14	5	12	18	20	15	13	14	33	143	355

Table 7a – The SD showers in *Figure 14*: background (cross) and target (red box) in *Figure 14*.

Code	$\lambda_\odot$	$\lambda - \lambda_\odot$	β	v_g	Distance	Angle	x	y
0018AND02	223	166.8	17.9	18.2	1.4	16	–0.4	1.3
0018AND01	228.6	163.4	18.8	17	1.5	194	0.4	–1.4
0018AND03	230.4	162.8	21.4	17.5	0.2	254	0.1	0
0018AND00	232	162.6	20.8	17.2	1.7	166	–0.4	–1.7
0446DPC01	250.4	153.1	42	16.5	7.8	5	–0.7	7.8
0446DPC00	252	152.8	44.8	16.5	9.7	7	–1.1	9.6

Table 7b – Possible Andromedids in photographic observations (within 6 degrees from the center of *Figure 14*).

Code	$\lambda_\odot$	$\lambda - \lambda_\odot$	β	v_g	Distance	Angle	x	y
D1-66	208.3	170.9	1.7	19.77	5.3	202	2	–5
H1-4977	208.7	175.6	7.4	22.4	2.9	81	–2.9	0.5
H1-4967	208.7	176.9	7.9	20.1	4.3	76	–4.2	1
H3-9172	221.1	166.8	12.6	22.46	2.7	190	0.5	–2.6
H4-11093b	211.2	172.9	9.8	20.68	1.7	45	–1.2	1.2
H4-12336	223.8	166.4	17.4	19.18	0.5	44	–0.4	0.4
H5-2622	225.1	165.5	16.3	18.8	1.6	178	–0.1	–1.6
H2-5337	225.3	166.9	16.7	17.4	2	133	–1.5	–1.4
H1-5335	225.7	165.5	16.5	17.7	1.9	170	–0.3	–1.8
H1-5339	225.7	161.3	22.6	17.3	5.6	320	3.6	4.3
K1-31	228.7	159.3	17.5	13.4	5.1	237	4.3	–2.8
H1-5392	230.7	162.6	21.1	18.1	0.6	203	0.2	–0.5
H1-5384	230.7	163.8	21.7	2.7	0.9	86	–0.9	0.1
H1-5382	230.7	161.3	20.5	17.4	1.8	232	1.4	–1.1
H4-11182	232.2	163.6	22.1	17.55	1.5	110	–1.4	–0.5
H3-9379	249.3	152.3	36.1	16.14	2.6	350	0.5	2.5

Table 7c – Meteor showers not listed in the SD (within 6 degrees from the center of *Figure 14*).

Code	$\lambda_\odot$	$\lambda - \lambda_\odot$	β	v_g	Distance	Angle	x	y
LE-512	211.7	168.8	7.1	20.8	3.2	235	2.6	–1.8
L1-129	228.2	164.2	19.3	21	0.8	164	–0.2	–0.7
LE-565	234.3	163.8	21.9	21.2	3.3	129	–2.6	–2.1
LE-630	243.2	154.9	26.8	19.9	3.2	204	1.3	–2.9

The Andromedids in the SD distribute well within 3 degrees from the center and the December psi Cassiopeiids are located about 10 degrees above the center as indicated in *Figure 12*.

We found 16 photographic meteors within 6 degrees from the center and confirm 'the recovery of the Andromedids'. It should be noted that photographic data suggest that the annual Andromedids reach their maximum around $\lambda_\odot = 225°$ as shown in *Figure 2* with Japanese video observations. The geocentric velocity of H1-5384 is extremely low but this is because of the graphical reduction.

We note there are three small camera observations; one is H5-2622 and two are former Soviet records (D1-66 and K1-31). This means that the annual Andromedids do not consist of faint, but rather bright meteors. We suggested that the regression graphs might bend at about $\lambda_\odot = 220°$ and $\lambda_\odot = 230°$ in the GMN observations (*Figure 9a~c*). The photographic meteors before $\lambda_\odot = 220°$ are faster than the later ones and seem to coincide with the GMN results (*Figure 9c*). The photographic maximum before $\lambda_\odot = 230°$ might indicate this activity comes from the different segments of the Andromedids after the $\lambda_\odot = 230°$ ones as *Figures 2 and 13b* suggest.

It is interesting that although one is a photographic survey (L1-129, Lindblad) the three others are radar observations (LE-512, LE-565, LE-630). The latter three are not independent observations because the radar operations at that time needed some maintenance period and the observations were interrupted; it seems that the three entries express one continual activity.

Acknowledgment

We appreciate the daily efforts of all meteor observers of the Global Meteor Network and SonotaCo net.

The author would like to give special thanks to Paul Roggemans. Though the database of GMN is open, the author failed to download it due to problems of Windows10; Windows says 'memory over' every time not because of the PC's memory. Paul kindly downloaded the GMN-dataset and sent it to me. The author is now free to use GMN data up to July 4, 2022. This offers a very nice opportunity to investigate other minor shower activities. Thank you very much Paul.

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Analysis of remarkable bolides observed between June and July 2022 in the framework of the Southwestern Europe Meteor Network

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Some of the bright bolides spotted in the framework of the Southwestern Europe Meteor Network from June to July 2022 are discussed here. These were observed from Spain. Their absolute magnitude ranges from –6 to –11. Fireballs included in this work were generated by different sources: the sporadic background, major meteoroid streams, and poorly known streams.

1 Introduction

We perform a systematic monitoring of meteor activity in the framework of the SMART project (Spectroscopy of Meteoroids by means of Robotic Technologies), which started operation in 2006 to analyze the properties of meteoroids ablating in our planet's atmosphere. This includes chemical data derived from the emission spectra of meteors generated by these particles of interplanetary matter. This survey, which is being conducted in the framework of the Southwestern Europe Meteor Network (SWEMN), employs an array of automated spectrographs deployed at meteor-observing stations in Spain (Madiedo, 2014; Madiedo, 2017). This allows to derive the luminous path of meteors and the orbit of their progenitor meteoroids, and also to study the evolution of meteor plasmas from the emission spectrum produced by these events (Madiedo, 2015a,b). SMART also provides important information for our MIDAS project, which is being conducted to study lunar impact flashes produced when large meteoroids impact the Moon (Madiedo et al., 2018; Madiedo et al. 2019; Ortiz et al., 2015).

In this work we focus on the preliminary analysis of five fireballs recorded by the SWEMN network between June and July 2022. This work has been fully written by AIMIE (acronym for Artificial Intelligence with Meteoroid Environment Expertise) from the records included in the SWEMN fireball database (Madiedo et al., 2021; Madiedo et al., 2022).

2 Equipment and methods

To record the events presented in this work we have used Watec 902H2 and Watec 902 Ultimate cameras. Their field of view ranges from 62 × 50 degrees to 14 × 11 degrees. we have also employed digital CMOS color cameras (models Sony A7S and A7SII) operating in HD video mode (1920 × 1080 pixels). These cover a field of view of around 70 × 40 degrees. A detailed description of this hardware and the way it operates was given in previous works (Madiedo, 2017). Besides digital CMOS cameras manufactured by ZWO, model ASI185MC were used. The atmospheric paths of the events were triangulated by employing the SAMIA software, developed by J. M. Madiedo. This program employs the planes-intersection method (Ceplecha, 1987).

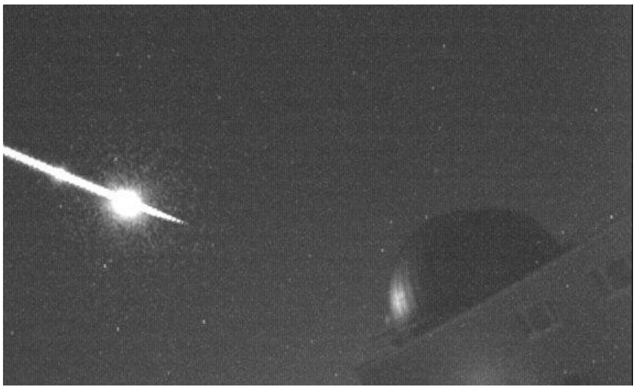

Figure 1 – Stacked image of the final part of the SWEMN20220610_001139 "Ardales" fireball as recorded from Sierra Nevada.

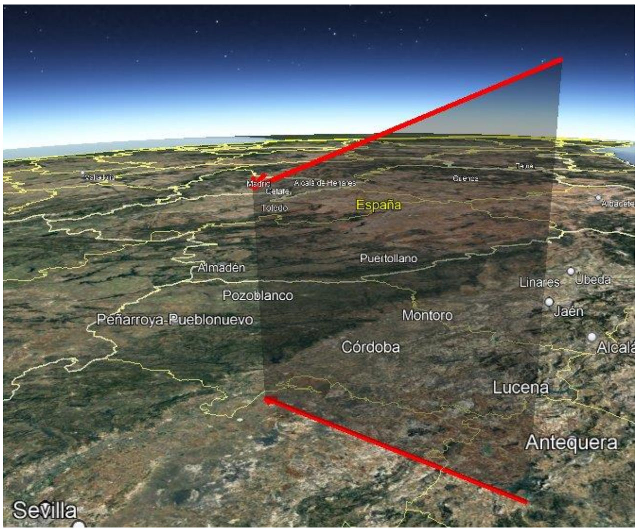

Figure 2 – Atmospheric path of the SWEMN20220610_001139 "Ardales" fireball, and its projection on the ground.

3 Description of the 2022 June 10 meteor

This bright fireball was spotted on 2022 June 10, at $0^h11^m39.0 \pm 0.1^s$ UT (*Figure 1*). The meteor, that showed different flares along its trajectory in the Earth's atmosphere, had a peak absolute magnitude of –9.0 ± 1.0. These flares took place because of the sudden disruption of the meteoroid. The code given to this event in the SWEMN database is SWEMN20220610_001139. A video showing images of the bolide and its atmospheric trajectory was uploaded to YouTube[17].

Atmospheric trajectory, radiant and orbit

This bright meteor overflew the provinces of Málaga and Sevilla (south of Spain). Its initial altitude was $H_b = 102.9 \pm 0.5$ km and the bolide penetrated the atmosphere till a final height $H_e = 64.4 \pm 0.5$ km. From the analysis of the atmospheric path we also found that the apparent radiant was located at the position $\alpha = 277.41°$, $\delta = –26.68°$. Besides, we deduced that the meteoroid hit the atmosphere with a velocity $v_\infty = 36.7 \pm 0.3$ km/s. *Figure 2* shows the obtained trajectory in our atmosphere of the fireball. *Figure 3* shows the orbit in the Solar System of its progenitor meteoroid.

Table 1 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	3.1 ± 0.1	ω (°)	127.74 ± 00.06
e	0.928 ± 0.005	Ω (°)	258.844369 ± 10^{-5}
q (AU)	0.227 ± 0.002	i (°)	9.32 ± 0.07

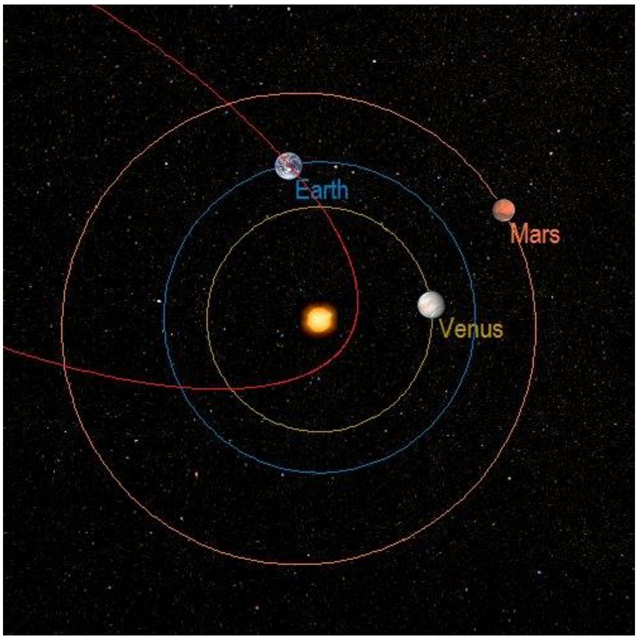

Figure 3 – Projection on the ecliptic plane of the orbit of the SWEMN20220610_001139 "Ardales" meteor.

The bolide was named "Ardales" since the event was located over this locality during its initial phase. *Table 1* shows the orbital parameters of the progenitor meteoroid before its encounter with our planet. The geocentric velocity of this meteoroid was $v_g = 34.9 \pm 0.3$ km/s. The Tisserand parameter referred to Jupiter ($T_J = 2.21$) indicates that the particle was moving on a cometary (JFC) orbit before colliding with the atmosphere. By taking into account this orbit and the radiant position, the event was produced by the lambda Sagittariids (IAU meteor shower code LSA#0803). This poorly known meteor shower peaks around June 4 (Amaral et al., 2020).

[17] https://youtu.be/qM3m-elQjhM

Figure 4 – Stacked image of the SWEMN20220630_215833 “Cacín” meteor as recorded from Sierra Nevada..

Figure 5 – Atmospheric path of the SWEMN20220630_215833 “Cacín” event, and its projection on the ground.

4 Analysis of the 2022 June 30 bolide

We spotted this bright meteor from the meteor-observing stations located at Huelva, La Hita, CAHA, Sierra Nevada (OSN), La Sagra, Sevilla, and El Aljarafe. The fireball was recorded on 2022 June 30, at $21^h58^m33.0 \pm 0.1^s$ UT. The peak luminosity the bright meteor, that exhibited different flares along its trajectory in the atmosphere, was equivalent to an absolute magnitude of -10.0 ± 1.0. These flares appeared as a consequence of the sudden break-up of the meteoroid. The code given to the fireball in the SWEMN meteor database is SWEMN20220630_215833. The bright meteor can be viewed on this video[18]. The fireball is shown in *Figure 4*. A wide number of casual observers saw how the bright meteor crossed the sky. These reported the event on social networks.

Atmospheric path, radiant and orbit

This bright meteor overflew the province of Córdoba (south of Spain). Its initial altitude was $H_b = 102.5 \pm 0.5$ km. The event penetrated the atmosphere till a final height $H_e = 66.0 \pm 0.5$ km. The position obtained for the apparent radiant correspond to the equatorial coordinates $\alpha = 276.26°$, $\delta = -20.81°$. The pre-atmospheric velocity found for the meteoroid yields $v_\infty = 28.2 \pm 0.3$ km/s. *Figure 5* shows the calculated trajectory in the Earth’s atmosphere of the bolide. The heliocentric orbit of the meteoroid is drawn in *Figure 6*.

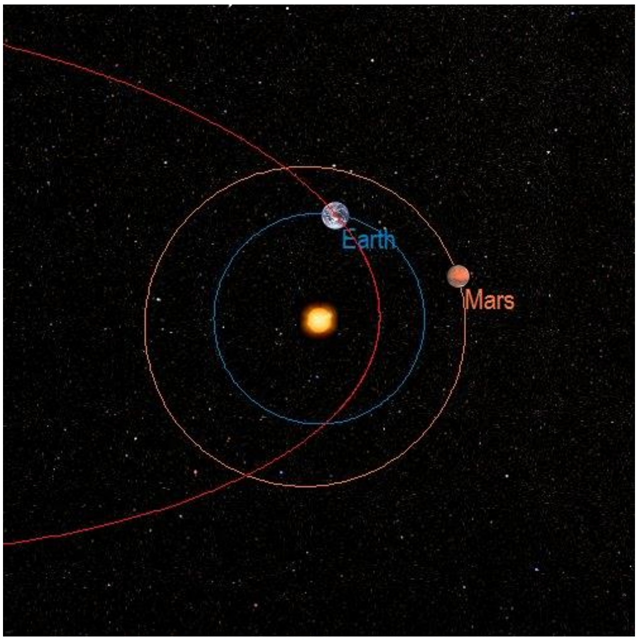

Figure 6 – Projection on the ecliptic plane of the orbit of the SWEMN20220630_215833 “Cacín” event.

We named this fireball “Cacín”, because the event was located over this locality during its initial phase. The orbital parameters of the progenitor meteoroid before its encounter with our planet have been included in *Table 2*. The geocentric velocity obtained for the particle yields $v_g = 25.8 \pm 0.3$ km/s. From the value obtained for the Tisserand parameter with respect to Jupiter ($T_J = 1.76$), we found that the particle was moving on a cometary (HTC) orbit before colliding with the Earth’s atmosphere. These parameters and the calculated radiant confirm that the bright meteor was produced by the sporadic background).

Table 2 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	6.2 ± 0.8	ω (°)	84.4 ± 00.1
e	0.90 ± 0.01	Ω (°)	279.336754 ± 10^{-5}
q (AU)	0.575 ± 0.002	i (°)	0.30 ± 0.05

[18] https://youtu.be/12FTod4YlMo

5 Analysis of the 2022 July 25 meteor

On 2022 July 25, at $23^h04^m20.0 \pm 0.1^s$ UT, SWEMN meteor stations captured this bright bolide (*Figure 7*). The maximum brightness the bright meteor, that exhibited a series of flares along its atmospheric trajectory, was equivalent to an absolute magnitude of –10.0 ± 1.0. These flares arose as a consequence of the sudden disruption of the meteoroid. It was added to the SWEMN meteor database with the code SWEMN20220725_230420. The fireball can be viewed on this YouTube video[19].

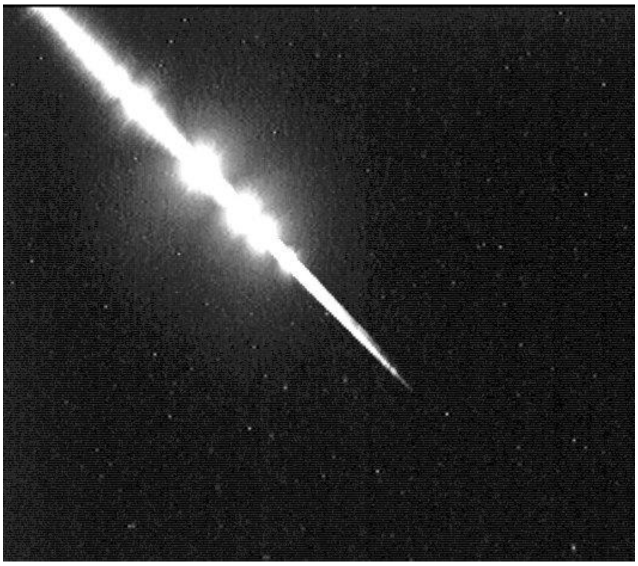

Figure 7 – Stacked image of the final part of the SWEMN20220725_230420 "Las Ventas" meteor as recorded from Sierra Nevada.

Atmospheric path, radiant and orbit

This fireball overflew the provinces of Jaén and Granada (south of Spain). The initial altitude of the meteor yields H_b = 103.5 ± 0.5 km, and ended at a height H_e = 26.8 ± 0.5 km. The equatorial coordinates found for the apparent radiant are α = 223.72º, δ = +39.50º. The pre-atmospheric velocity inferred for the meteoroid yields v_∞ = 15.7 ± 0.3 km/s. The calculated path in the atmosphere of the bright meteor is shown in *Figure 8*. The heliocentric orbit of the meteoroid is drawn in *Figure 9*.

We named this fireball "Las Ventas", since the event was located over this locality during its initial phase. *Table 3* shows the orbital parameters of the parent meteoroid before its encounter with our planet. The value calculated for the geocentric velocity was v_g = 11.5 ± 0.4 km/s. The Tisserand parameter with respect to Jupiter (T_J = 2.84) reveals that the particle was moving on a cometary (JFC) orbit before impacting the Earth's atmosphere. Radiant and orbital data do not match any of the meteoroid streams listed in the IAU meteor database. So, we concluded that this bolide was produced by the sporadic background.

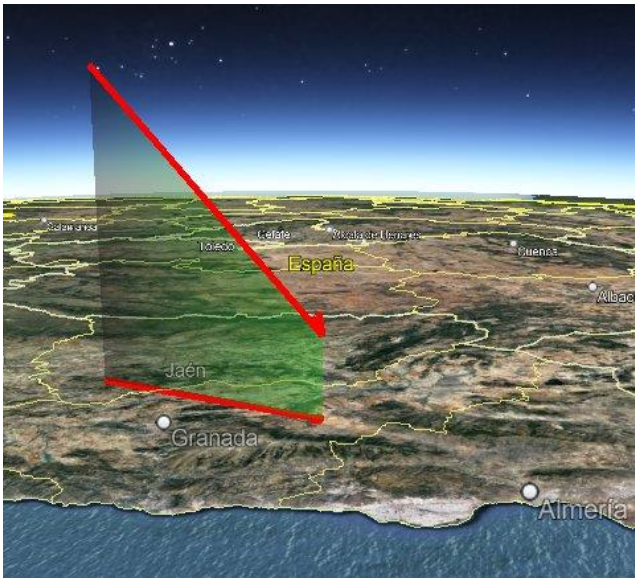

Figure 8 – Atmospheric path of the SWEMN20220725_230420 "Las Ventas" event, and its projection on the ground.

Table 3 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	3.0 ± 0.2	ω (º)	170.7 ± 00.2
e	0.66 ± 0.02	Ω (º)	122.662704 ± 10-5
q (AU)	1.0104 ± 0.0001	i (º)	12.1 ± 0.4

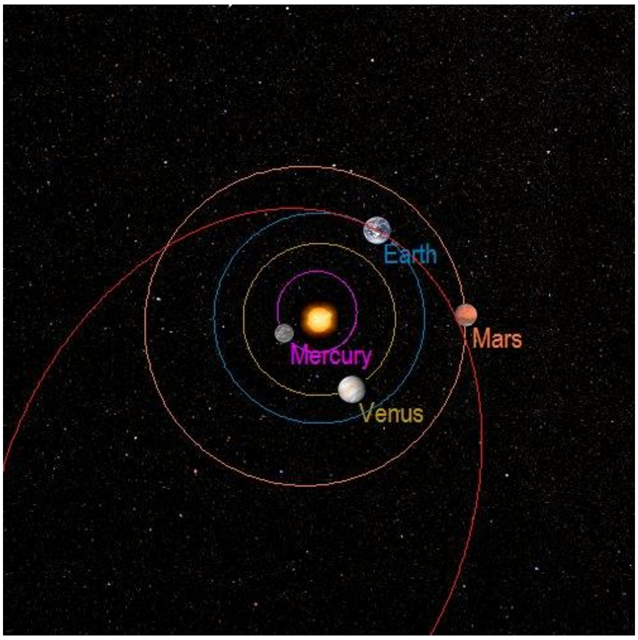

Figure 9 – Projection on the ecliptic plane of the orbit of the SWEMN20220725_230420 "Las Ventas" bolide.

6 Description of the 2022 July 26 event

On 2022 July 26, at $1^h09^m41.7 \pm 0.1^s$ UT, our devices captured this fireball. It had a peak absolute magnitude of –6.0 ± 0.5 (*Figure 10*). The code assigned in the SWEMN database to this bolide is SWEMN20220726_010941. The bright meteor can be viewed on YouTube[20].

[19] https://youtu.be/GbvuIGFLnqY

[20] https://youtu.be/mks-MJTsHOI

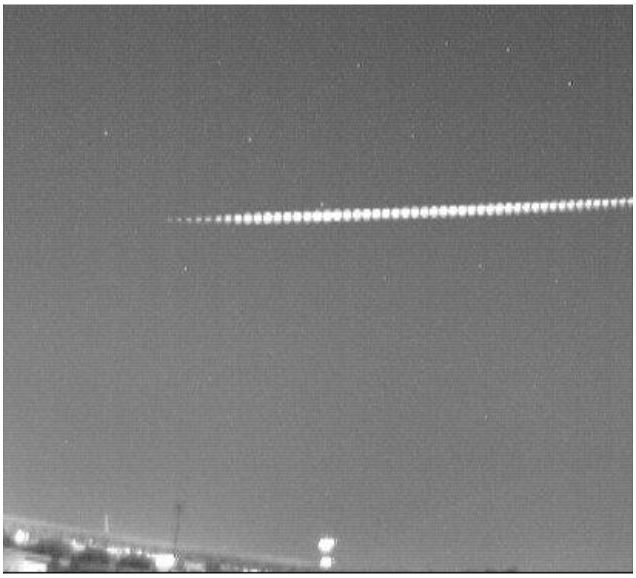

Figure 10 – Stacked image of the SWEMN20220726_010941 “Alpalhao” fireball as recorded from Sevilla.

Atmospheric path, radiant and orbit

This bright meteor overflew Spain and Portugal. Its initial altitude was H_b = 110.2 ± 0.5 km. The event penetrated the atmosphere till a final height H_e = 85.4 ± 0.5 km. The apparent radiant was located at the equatorial coordinates α = 61.33°, δ = +35.49°. The meteoroid stroke the atmosphere with an initial velocity v_∞ = 62.2 ± 0.0 km/s. The calculated trajectory in the Earth’s atmosphere of the fireball is shown in *Figure 11*.

Figure 11 – Atmospheric path of the SWEMN20220726_010941 “Alpalhao” bolide, and its projection on the ground.

Figure 12 shows the orbit in the Solar System of the parent meteoroid. The name given to the bright meteor was “Alpalhao”, because the event was located over this locality during its final phase. The parameters of the orbit of the parent meteoroid before its encounter with our planet have been included in *Table 4*, and the geocentric velocity derived in this case was v_g = 60.9 ± 0.0 km/s. The value derived for the Tisserand parameter referred to Jupiter (T_J = –0.16) indicates that the meteoroid followed a cometary (HTC) orbit before hitting our atmosphere. According to these data and the calculated radiant, the event was associated with the sporadic component.

Table 4 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	12.1 ± 0.2	ω (°)	72.04 ± 00.09
e	0.9701 ± 0.0007	Ω (°)	122.760711 ± 10-5
q (AU)	0.361 ± 0.001	i (°)	143.18 ± 0.04

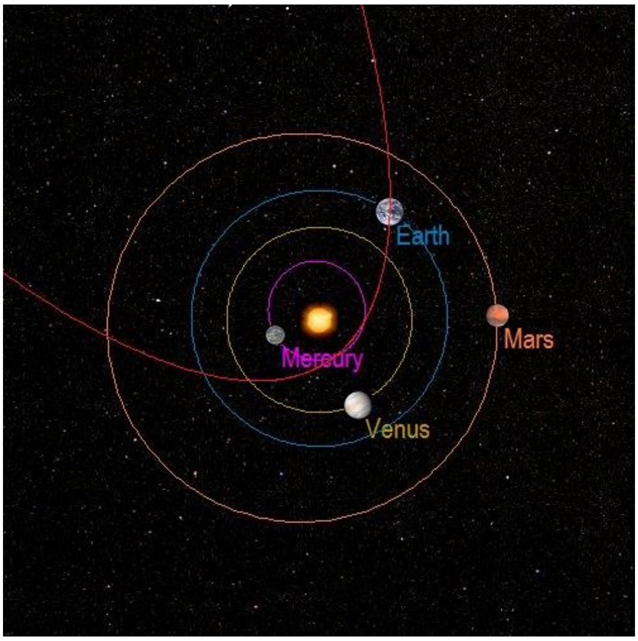

Figure 12 – Projection on the ecliptic plane of the orbit of the SWEMN20220726_010941 “Alpalhao” bolide.

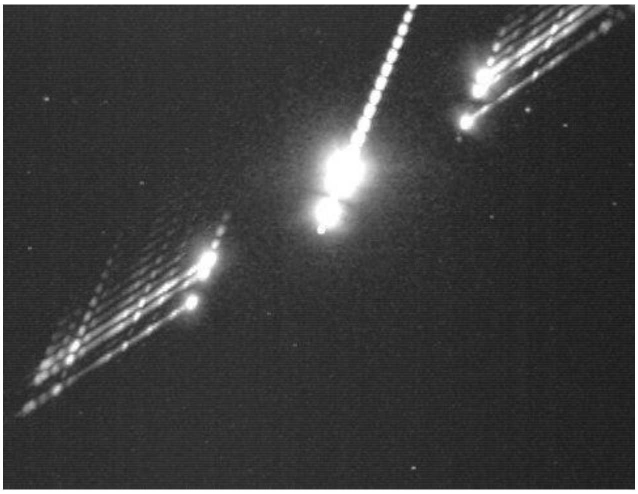

Figure 13 – Stacked image of the SWEMN20220728_022851 “Albolote” bolide as recorded from Calar Alto.

7 Analysis of the 2022 July 28 meteor

This notable bolide was spotted by our cameras at $2^h28^m51.0 \pm 0.1^s$ UT on 2022 July 28. The event, that presented various flares along its trajectory in the Earth’s atmosphere, had a peak absolute magnitude of –11.0 ± 1.0 (*Figure 13*). These flares arose as a consequence of the sudden break-up of the meteoroid. It was included in the SWEMN meteor database with the code

SWEMN20220728_022851. The event can be viewed on YouTube[21].

Atmospheric path, radiant and orbit

According to the analysis of the trajectory in our atmosphere of the fireball it was inferred that this bright meteor overflew the province of Granada (south of Spain). The luminous event began at an altitude H_b = 116.1 ± 0.5 km. The event penetrated the atmosphere till a final height H_e = 74.4 ± 0.5 km. The position inferred for the apparent radiant correspond to the equatorial coordinates α = 23.98º, δ = +53.39º. The entry velocity in the atmosphere found for the parent meteoroid was v_∞ = 59.1 ± 0.4 km/s. *Figure 14* shows the obtained atmospheric trajectory of the bright meteor. The orbit in the Solar System of the meteoroid is shown in *Figure 15*.

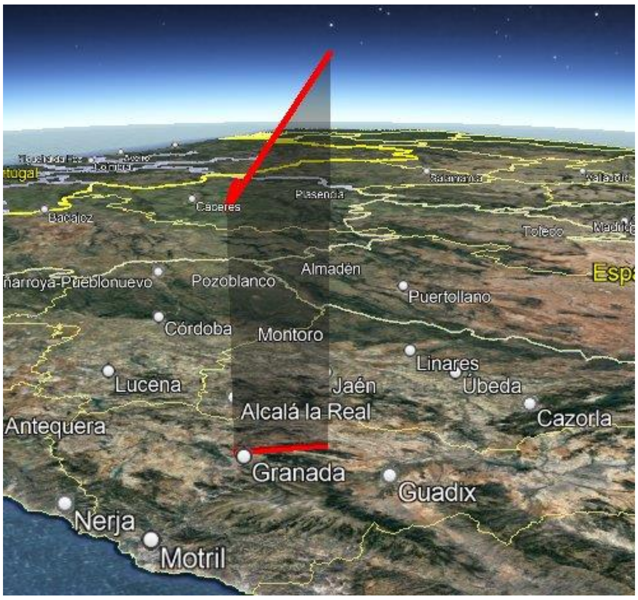

Figure 14 – Atmospheric path of the SWEMN20220728_022851 "Albolote" meteor, and its projection on the ground.

Table 5 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	8.9 ± 2.6	ω (º)	157.5 ± 00.4
e	0.89 ± 0.03	Ω (º)	124.721789 ± 10-5
q (AU)	0.9791 ± 0.0008	i (º)	111.0 ± 0.2

We named this bright meteor "Albolote", because the bolide overflew this locality during its final phase. The orbital parameters of the progenitor meteoroid before its encounter with our planet have been listed in *Table 5*. The geocentric velocity of the meteoroid was v_g = 57.9 ± 0.4 km/s. From the value calculated for the Tisserand parameter with respect to Jupiter (T_J = 0.15), we found that before colliding with the Earth's atmosphere the meteoroid was moving on a cometary (HTC) orbit. These parameters and the derived radiant confirm that the fireball was linked to the Perseids (IAU code PER#0007). The progenitor body of this shower, which peaks around August 12, is Comet 109P/Swift-Tuttle (Jenniskens et al., 2016).

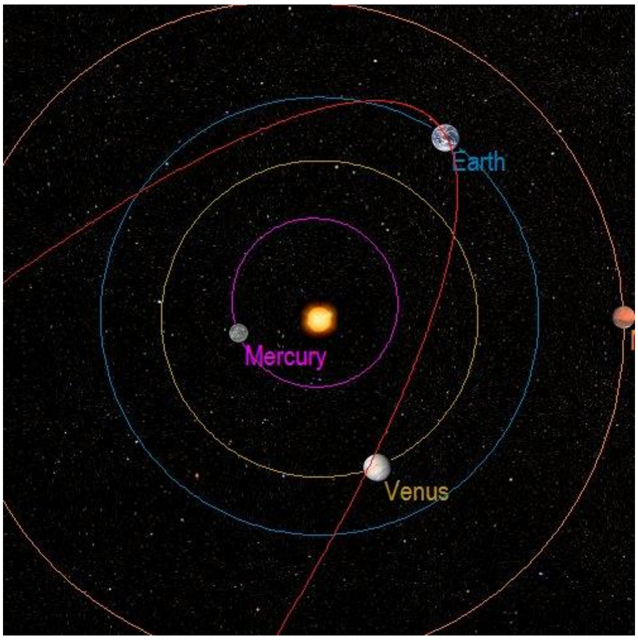

Figure 15 – Projection on the ecliptic plane of the orbit of the SWEMN20220728_022851 "Albolote" meteor.

8 Conclusions

We have presented in this work some of the most remarkable meteors captured by our meteor-observing stations during June and July 2022. Their maximum brightness ranges from mag. –6 to mag. –11.

The "Ardales" bolide was captured on June 10. It belonged to the poorly known stream of the lambda Sagittariids (LSA#0803). Its peak magnitude was –9.0 and overflew the south of Spain. The particle was moving on a cometary (JFC) orbit before hitting our atmosphere.

The next bolide discussed here was a bright meteor that was captured on June 30 named "Cacín". It reached a peak absolute magnitude of –10.0, and its progenitor meteoroid belonged to the sporadic component. This bolide overflew the provinces of Córdoba and Granada (south of Spain). The particle was moving on a cometary (HTC) orbit before colliding with the Earth's atmosphere.

The third event analyzed here was the "Las Ventas" bright meteor. This was captured on July 25. It reached a peak absolute magnitude of –10.0 and belonged to the sporadic background. This meteor event overflew the provinces of Jaén and Granada (south of Spain). The meteoroid was moving on a cometary (JFC) orbit before hitting our planet's atmosphere. This deep-penetrating meteor reached a terminal height of about 26 km.

Next, we have presented a sporadic bright meteor that was captured on July 26 named "Alpalhao". It reached a peak absolute magnitude of –6.0. This meteor overflew Spain and Portugal. The meteoroid was also moving on a

[21] https://youtu.be/6t6oVvFljaw

cometary (HTC) orbit before striking the Earth's atmosphere.

And the last event discussed here was the "Albolote" event, that was captured on July 28. Its peak magnitude was –11.0. The meteor event was produced by a Perseid (PER#0007) meteoroid from Comet 109P/Swift-Tuttle and overflew the province of Granada (south of Spain). This meteoroid was moving on a cometary (HTC) orbit before impacting the Earth's atmosphere.

Acknowledgment

We acknowledge support from the Spanish Ministry of Science and Innovation (project PID2019-105797GB-I00). We also acknowledge financial support from the State Agency for Research of the Spanish MCIU through the "Center of Excellence Severo Ochoa" award to the Instituto de Astrofísica de Andalucía (SEV-2017-0709). P.S-S. acknowledges financial support by the Spanish grant AYA - RTI2018 – 098657 – J - I00 "LEO-SBNAF" (MCIU / AEI / FEDER, UE). The first author is very grateful to Casa das Ciencias (Museos Científicos Coruñeses) for their helpful support in the setup and operation of the automated meteor-observing station located at their facilities in A Coruña.

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Fireball 2022, July 13 in Hungary

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At 1^h14^m (UT) on July 13, 2022, a fireball rivaling the brightness of the Full Moon moved through the Hungarian sky.

1 Introduction

Many people saw the phenomenon despite the early time, as its light cast a shadow in the dark night. In addition to the usual meteorological cameras, Bence Gucsik was lucky enough to catch our guest from space with a video camera (*Figure 1*). It can also be viewed on video[22].

Another lucky catch from Kaposfő (Hungary) is recorded by Rafael Schmall, who has a meteorological camera system to every direction from his place (*Figure 2*).

Figure 1 – Fireball from Sopron, Hungary (Recording of Bence Gucsik).

Figure 2 – The fireball on Kaposfő – North camera, recorded by Rafael Schmall.

2 Trajectory and orbit

I used – UFOAnalyser and UFOOrbit (Sonotaco, 2009) – four meteorological cameras' pictures to reconstruct the meteor trail. Based on the preliminary measurement, the meteor lit up at an altitude of 104 km – a little beyond the southwestern border of Hungary – above Croatia. The body that hit our atmosphere at an angle of 24 degrees traveled about 173 km at an average speed of 29.4 km/s, which is unfortunately high enough to not drop any meteorite. Its last crumbs were still shining at an altitude of 36 km above Márkó. There were no visible parts which could survive the atmospheric entry (*Figure 3*).

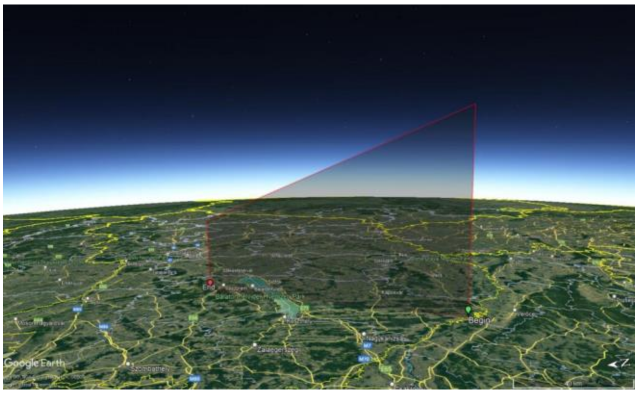

Figure 3 – The trajectory.

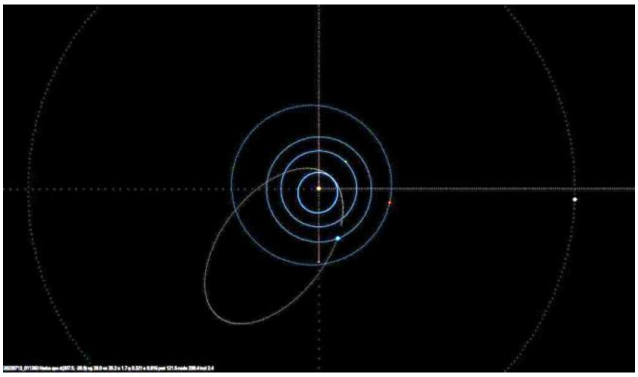

Figure 4 – The orbits.

Based on its trajectory, it came from beyond Mars from the main asteroid belt. It is interesting though that this small piece of stone ventured all the way to Mercury during its closest approach to the Sun (*Figure 4*).

Reference

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

[22] https://www.youtube.com/watch?v=2yI2ZUxQOec

Fireball 2022, July 26 with a sonic boom over Hungary

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On July 26, 2022, at 19^{h}19^m (UT), a sonic boom of a fireball was heard in Hungary.

1 Introduction

Barely two weeks after the previous fireball with a sonic boom, a bright meteor was reported by many people in Facebook groups, describing in detail the strongly fragmenting phenomenon crossing the sky. The most useful catch was made by Mónika Landy-Gyebnár this time (*Figure 1*). Her meteorological camera recorded the whole event (12.6 s) from the beginning to the end with 25 fps. This made possible also to calculate the fireball's deceleration through the atmosphere. The video can be seen online[23].

2 Trajectory and orbit

The measurement was made based on images from meteorological cameras which images were calibrated by UFOAnalyser (SonotaCo, 2009) The results then imported into UFOOrbit. (*Figure 2*) The meteoroid entering the atmosphere at an angle of 13.5°, glowed above Öcsöd at an altitude of 85.3 km. At an average speed of 16 km/s, it travelled about 200 km in our atmosphere, while the Earth's gravity bent the otherwise straight path by 758 meters. Based on the light curve, (*Figure 3*) the body began to disintegrate very high, at an altitude of 77 km, due to the forces induced by atmospheric drag, the pressure was only 0.006MPa there. (*Bronshten, 1981*) Its continuous explosive detachment of material lasted until around 50 km, where it finally broke into pieces. Based on the deceleration that can be determined from the recordings, we saw the ablation of the most resistant piece in the last moments. According to dynamic mass calculation, (Halliday et al., 1996) it was approx. 150 g. Unfortunately, this piece also barely slowed down to less than 10 km/s, so it did not reach the speed required for dark flight. Its final height, where its material was scattered, was 42.2 km, above Mocsa. (*Figure 4*).

Figure 1 – Fireball from Veszprém, Hungary (Recording of Mónika Landy-Gyebnár).

[23] https://www.youtube.com/watch?v=0PWlGjzQgnk

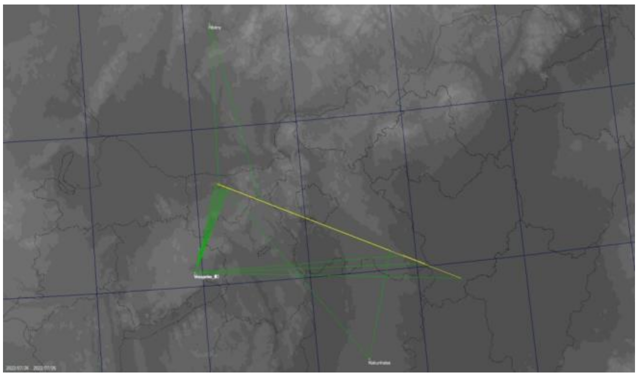

Figure 2 – The trajectory in UFOOrbit.

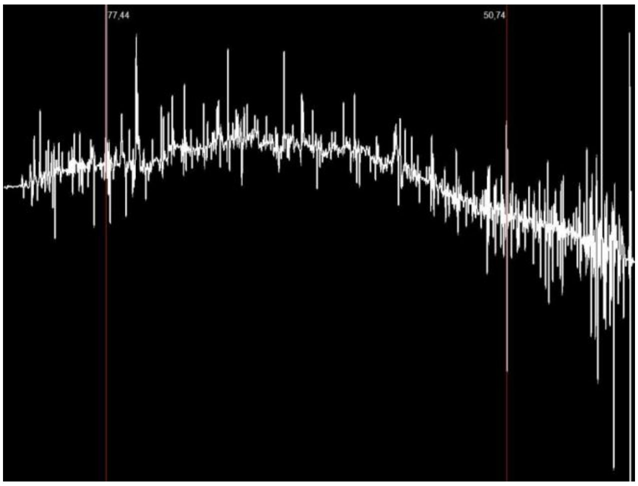

Figure 3 – The fireball's lightcurve.

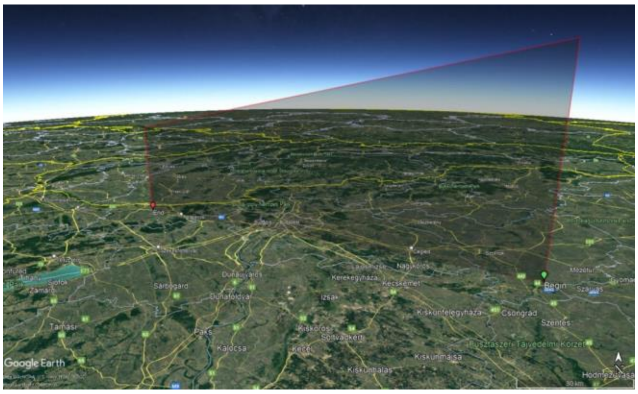

Figure 4 – 3d projection of the trajectory in Google Earth.

According to UFOOrbit, the radiant of the sporadic meteor is R.A. = 315.22° and Dec.= –7.51°. The orbit in the solar system unusually does not draw the ordinary material movement from beyond Mars. Instead, the meteoroid's orbit was in the near vicinity of the Earth's orbit in the main plane. (*Figure 5*) I determined the orbital elements based on the speed measured at the beginning of the trail (16.9 km/s) before the deceleration had happened.

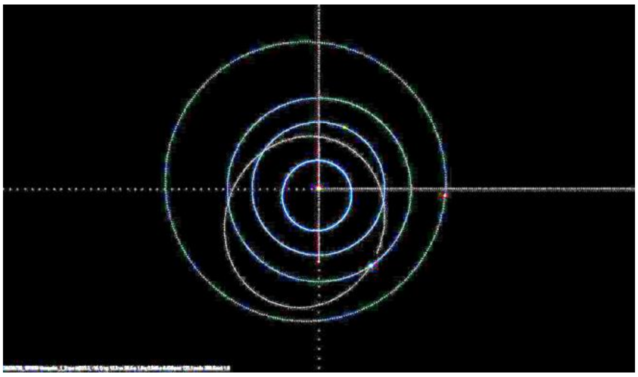

Figure 5 – The meteoroid's orbit.

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A notch in the Arietids radio data and a new so called in-line-effect

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Meteor showers of the daytime Arietids (ARI), the zeta Perseids (ZPE) and the daytime lambda Taurids (DLT) were observed as echoes with the GRAVES radar, France, from June 9 to June 19, 2022. According to CMOR radar, the Arietids were the dominant stream in this time window. Although the ARI radiant height should have its maximum at around 9^h UT, the meteor detection rate exhibited a second maximum at 12^h–13^h UT. A closer look at the detection rate reveals a notch in the rate around 11^h UT causing the measured rate to have two maxima. It turns out that the large echoes are mainly causing this dip. Unexpectedly, the small echoes show the opposite: a maximum appears at the minimum of the notch.

1 Introduction

In order to study meteor showers and sporadic meteors, I have developed a software that not only determines the rate but also the sizes of the meteor echoes[24]. The dots in *Figure 1* represent the measured echo sizes as a function of the time for June 9 as an example. About five orders of magnitude of echo size are resolved. 1461 echoes were counted. The yellow histograms in *Figure 2* show the rate and the red histograms show the rate weighted by the sizes of the meteor echoes. *Figure 3* shows a representation that makes it possible to view the rate development of the differently sized echoes over several days. In these diagrams, the sporadic meteors and the streams, if any, are superimposed. *Figure 2* shows beside the histogram of June 9 the rates of May 14 as an example, which mainly contain sporadic meteors. Since the radiant height of the Arietids is highest at 9^h UT, the sporadic and the Arietids should overlap to a more or less broad maximum at this time. Surprisingly, the bars in *Figure 2a* and the blue (large) echoes in *Figure 3* show local maxima at about 12^h UT, when there should not be a maximum at that time. An explanation for the maxima is given.

2 Setup

In order to measure the meteor echoes, I observe the GRAVES frequency 143.05 MHz. My main interest is studying the influence of the ionosphere on meteor echoes. Therefore, I use two almost identical receiving systems. They differ only in the antennas: They are a right hand circularly polarized 4-Element Cross-Yagi and a left hand circularly polarized 5-Element X-Quad. The antennas are mounted in the attic, so that the configuration can be easily changed. In addition, on June 19 I recorded the echoes for control purposes with a vertically polarized discone antenna. Low-noise preamplifiers with a frequency range of 140–150 MHz and a noise figure of 0.25 dB are connected directly to the phase lines of the antennas. The receivers are Icom IC-R8600. Spectrum-Lab[25] (SL) serves as the recording software. SL generates plots every 20 seconds with the appropriate date and time in the file name, which are evaluated later with a self-written image processing software based on Python3 and OpenCV. At the end of the paper two figures from SL and the software are shown. The histogram in *Figure 3* is smoothed with a (variable) Gaussian filter over up to 11 hours, while the histograms from *Figure 4* to the end are smoothed with a fixed Gaussian like filter with the coefficients 0.31, 0.74, 1.0, 0.74 and 0.31. After many tests I estimate the uncertainty on the rate to be < 5%. Unless otherwise noted, data are shown from the right hand circularly polarized antenna.

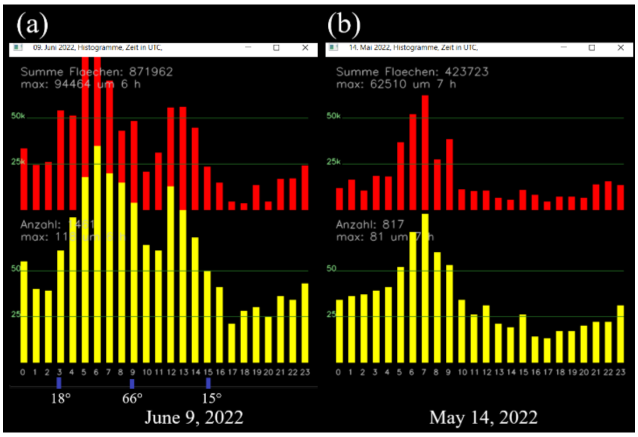

Figure 2 – (a) The yellow histogram shows the rate and the red histogram shows the rate weighted by the sizes of the meteors of June 9. Three radiant heights of Aries are indicated. The radiant was estimated using Stellarium Web[26] for Dijon in France, located close to the GRAVES radar. (b) The histogram shows the rates of May 14 as an example for comparison, which contains mostly sporadic meteors. The maximum of the sporadic meteors occurs if the position of the observer on Earth is in the direction of flight. Then most of the meteors are collected, like insects are collected on a windshield.

[24] https://forum.astronomie.de/threads/automatische-detektion-von-meteor-scatter-spektrogrammen.300615/

[25] https://www.qsl.net/dl4yhf/spectra1.html

[26] https://stellarium-web.org/

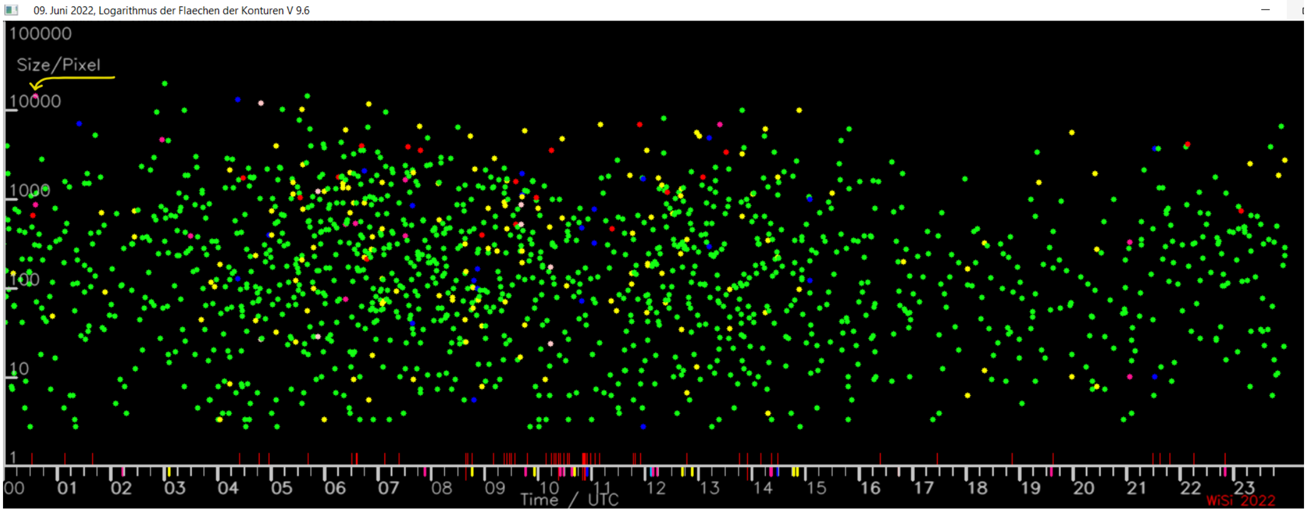

Figure 1 – Measured meteor sizes as a function of the time recorded on June 9. Each point represents an echo. 1461 echoes where logged. The program saves the echo sizes for further analysis in an intermediate file. A graphical representation of a relatively large example echo represented by the purple dot at the yellow arrow is shown in *Figures 11 and 12* as an example.

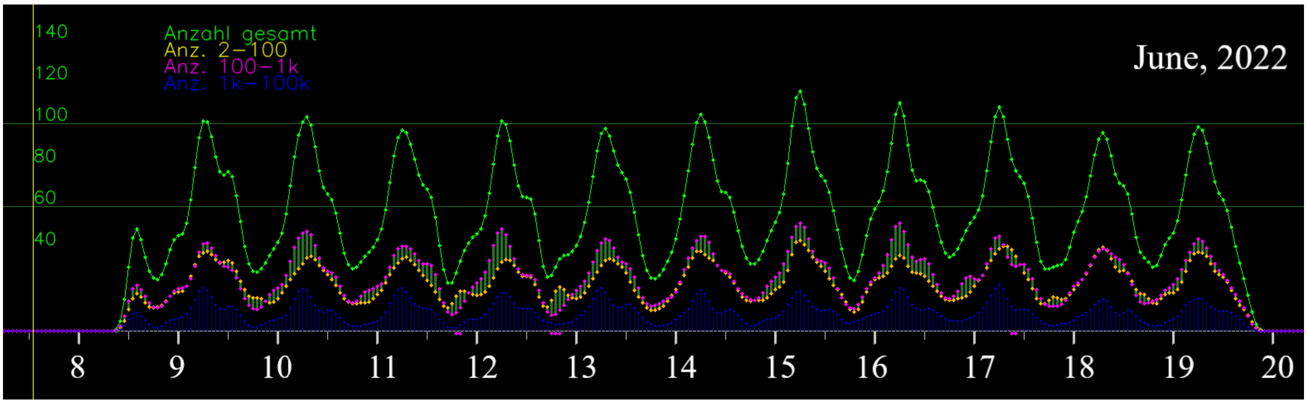

Figure 3 – Meteor detection rate for different echo sizes over about 10 days in June 2022. The blue lines represent the rate of large echoes (1k–100k pixels), the purple line shows the medium sized echos (100 to 1k) and the yellow line shows the small echoes (below 100 pixels). Finally, the green curve shows the rate of all sizes summed up. Large echoes (blue) show maxima at around 12^h UT, while small echoes (yellow) show a different behavior.

3 Results and discussion

Three radiant heights of ARI are shown in *Figure 2*. 66° at 9^h UT was the highest point. The radiant walks alongside the Sun. My finding is that the measured local maximum at 12^h UT is not a real maximum but that there is a notch with a minimum at 11^h UT superimposing the underlying distribution. A notch was earlier documented by Verbelen (2019). *Figure 4* shows a ten-minute histogram from three days. The relevant notches are marked. In *Figure 5*, the echoes from the right hand circularly polarized and the left hand circularly polarized antennas from June 9 and June 10 are plotted for comparison purposes. While there are differences, the notches are reproduced by both systems.

The data could be explained by the following hypothesis: The meteors appear from the direction of the Sun. GRAVES emits its main lobe in opposite direction to the south. My receiving system is located in the north of GRAVES. When the radiant passes in front of the transmitting antenna, a meteor trail will eventually run in the direction of the radar beam. Then the ionized area that reflects the radio waves is smaller than when the trail is hit more from the side. Statistically distributed, less signal is received if the flight direction is more in the direction of the beam. The optimal cancellation or the minimum of the notch occurs when the radar direction and the direction of flight are in a line. The large echoes are particularly affected: As can be seen from the hourly histogram in *Figure 2a*, the red bars, the size-weighted rate, have decreased more than the yellow bars, which represent the rates. Furthermore, the large echoes, shown as blue trace in *Figure 3*, show maxima or at least shoulders around 12^h UT, while the small echoes, shown as yellow trace, often show no dip. Small meteors should be affected by this effect only a little bit or not at all because it does not matter if they are lit from the front or from the side. To confirm this, I plotted the small echoes (< 30 pixels), intermediate sized ones (< 100 pixels) and large echoes (up to 100000 pixels) separately, see *Figures 6 and 7*. The plots confirm, that only the large echoes cause the dip. Sometimes the small echoes even show an increase at the notch, see *Figure 7*, for example. This is probably because large echoes look like small ones when viewed straight ahead. This effect is somewhat more pronounced with the right hand circularly polarized antenna than with the left hand circularly polarized antenna, see *Figure 6* compared with *Figure 7*.

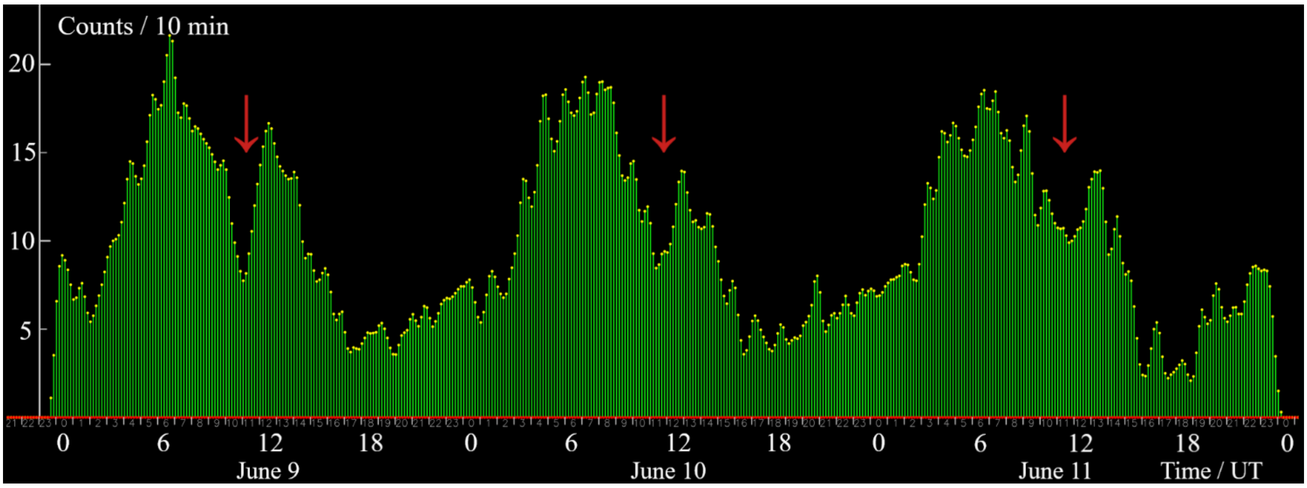

Figure 4 – The meteor detection rate in bins of ten minutes over three days clearly shows notches at about 11^h UT.

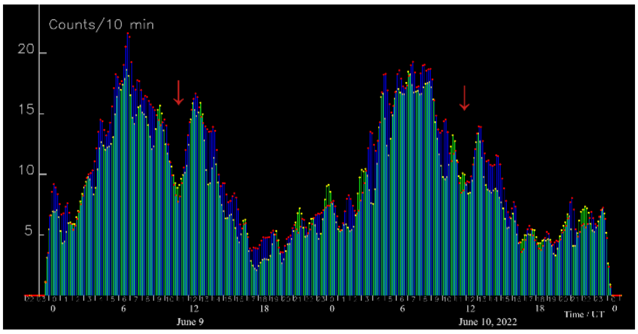

Figure 5 – The meteor detection rate recorded with two different antennas. The histogram with the red dots and blue lines is from the right hand circularly polarized antenna Cross Yagi, the histogram with the yellow dots and green lines is from the left hand circularly polarized X-Quad antenna. While there are differences, the notches are reproduced by both systems, see the red arrows.

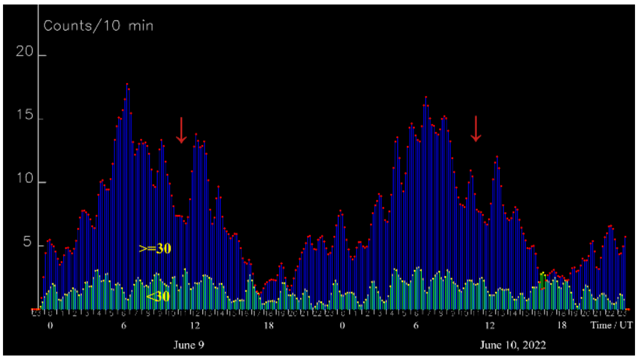

Figure 6 – Meteor detection rate for small echoes (< 30 pixel) and large ones (≥ 30 to 100k pixels). Only the rate of large echoes exhibits dips. No notch is observed in the detection rate of small echoes at the dip. The data are from the left hand circularly polarized antenna.

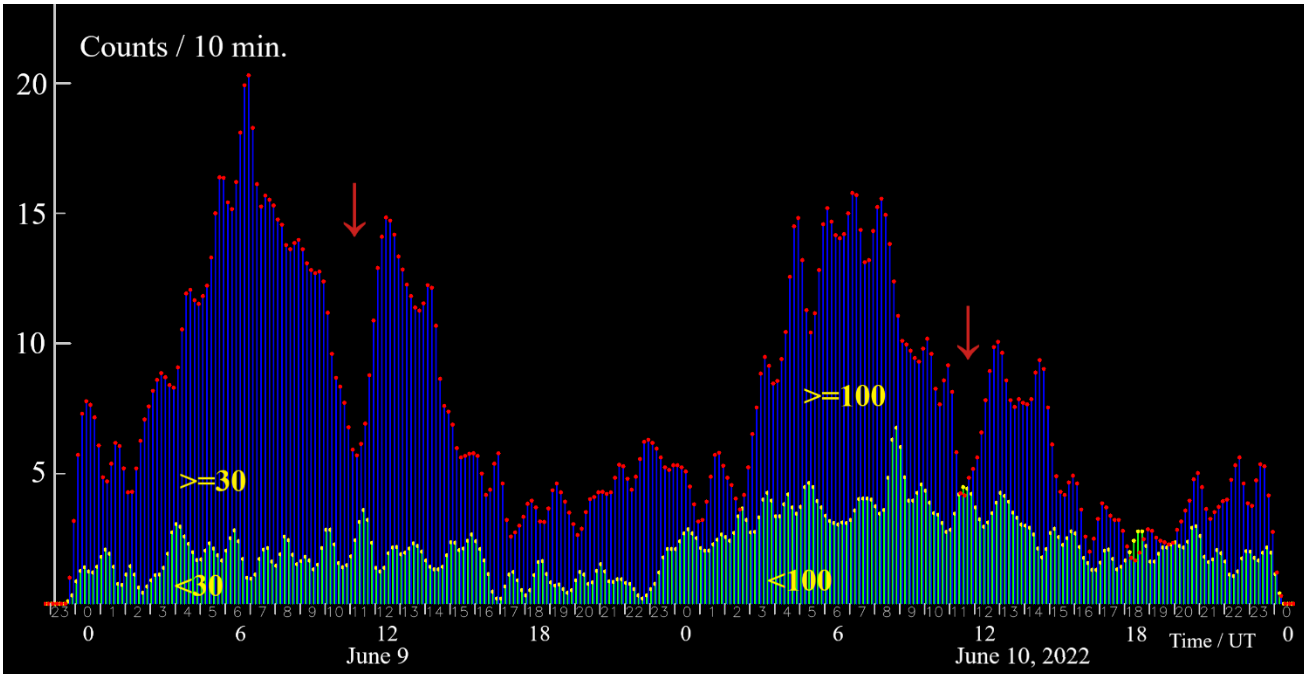

Figure 7 – Meteor detection rate for small echoes (< 30 or < 100 pixel) and large ones (≥ 30 or ≥ 100 to 100k pixels). The data are from the right hand circularly polarized antenna. The small echoes show an increase at the notch, see text. Basically, it makes no difference whether the threshold is 30 or 100 pixel.

Rate and size-weighted rate have notches of different widths.

In *Figure 8* the rate and the rate weighted by the sizes of June 9 and June 10 are shown in bins of ten minutes. The notch of the size-weighted rate is much wider than the notch of the rate. In theory, the rate shouldn't have a notch because the numbers don't change as the radiant passes in front of the antenna. Only the sizes change due to the changing the viewing angle. However, if the echoes are too small when viewed from an acute angle, they fall below the threshold. A result is the dip of the rate, however with a different width. This behavior fits perfectly with the hypothesis discussed here. Furthermore, the image shows a nice detail, the peak at the bottom of the notch of the size-weighted rate, see the yellow arrow. This peak is small but belongs probably to the effect discussed above. It was also seen in Geminids 2021 data. The Geminids data are not shown here because it would go beyond the scope of this article, but will be reexamined in December.

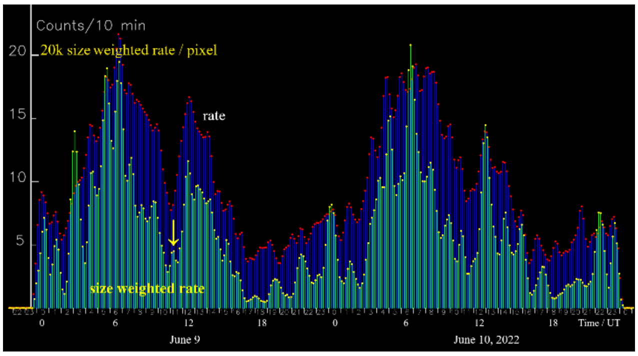

Figure 8 – Histograms of the rate and of the size-weighted rate have notches of different widths, shown in bins of ten minutes of June 9 and June 10. This is the case in all cases examined. The peak at the yellow arrow is probably due to the postulated In-Line-Effect, see text.

Test with a discone antenna

On June 19 I recorded for control purposes the echoes with a vertically polarized discone antenna. Because of the less sensitive discone and because ARI is decreasing, the notch is weak. However, both the notch in the large echoes and the local maximum of the small echoes are clearly visible, see *Figure 9*.

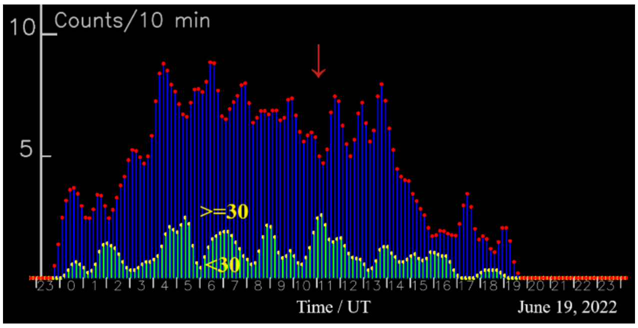

Figure 9 – Comparison of the small echoes with the large ones on June 19. Due to the less sensitive discone and the decreasing ARI, the notch is weak. The peak and the notch are indicated by the red arrow.

The so called In-Line-Effect

The increase in small echoes is somewhat reminiscent of the opposition effect. I will call it the in-line-effect. The opposition effect (also Seeliger effect) in visual optics works of course differently. *Figure 10* shows the shadow of my copter on a grain field. In the direction of the rays of the sunlight and the line of sight, the culms cover their own shadow, so that a light stripe is created for the viewer who is exactly on the line. Further outwards, the shadows become visible again and the image becomes darker as a result. In both cases, the observed objects hide something: the culm hides its shadow, the head of the meteor hides its trail. This comparison also explains that statistical effects are involved in both cases. Future investigations will have to show why and whether echoes are amplified by the in-line arrangement.

The sporadic meteors are also affected, of course, but it is not visible. Overall, however, the effects lead to an underestimation of the sporadic meteors and of the streams.

Figure 10 – The image shows the shadow of my copter on a crop field and bright areas around it caused by the opposition effect. The contrast of the image is enhanced.

What does the software look like?

Finally, I would like to show how the spectrograms and the program look like: *Figure 11* is an original output from Spectrum Lab and *Figure 12* shows how the evaluation software sees the echoes. Two differently sized echoes are recognized, and the sizes are determined.

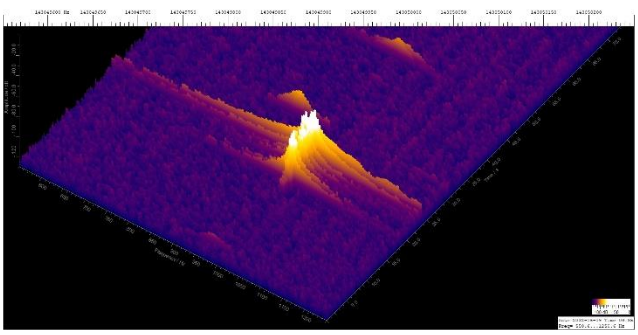

Figure 11 – Original Spectrum Lab output from 00^h35^m UT on June 9, 2022. Three echoes (above the threshold) are visible.

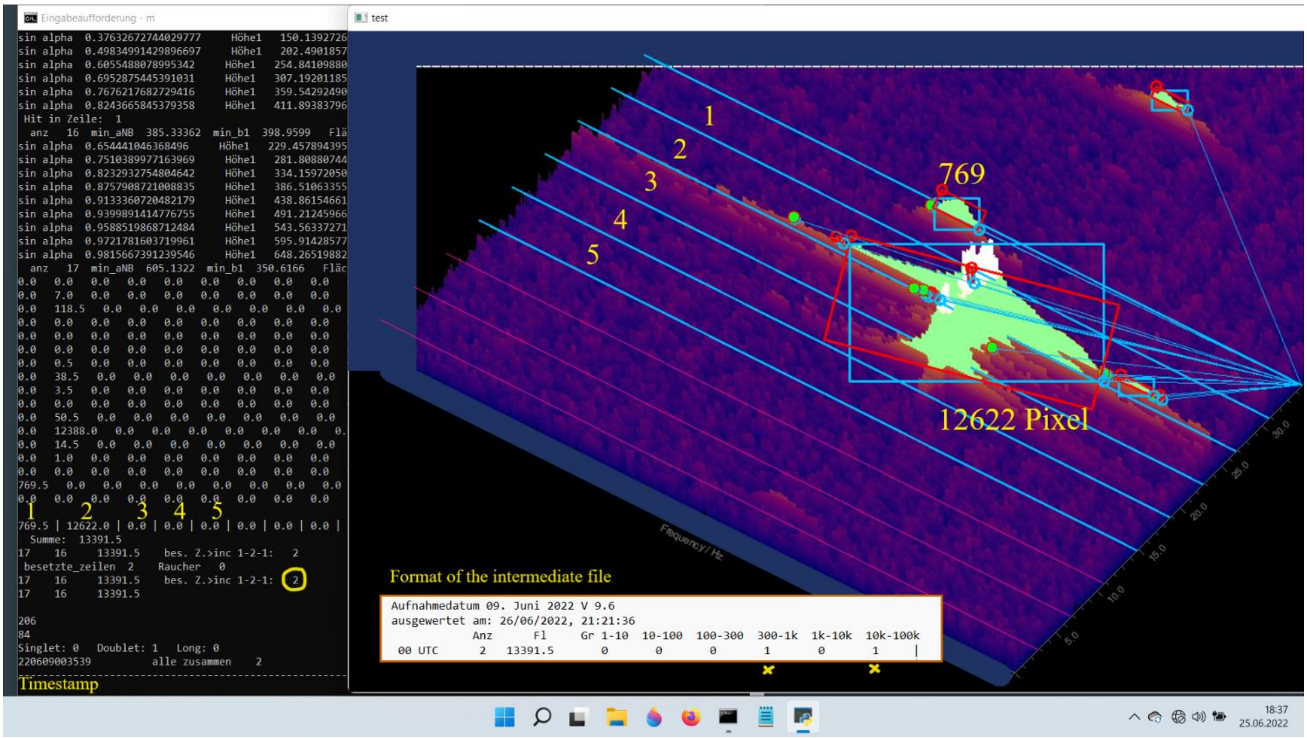

Figure 12 – Screenshot of the evaluation software output in debug mode. Only two echoes instead of three from Figure 11 are being detected because they fall within the 20-second evaluation window. This area is divided into five sections. Echoes can be detected separately in each section. If multiple echoes or fragments fall within one of the five 4-second ranges, they are summed up as one echo. The large echo is indicated in Figure 1. Finally, the values are saved in an intermediate file, see the inset.

Acknowledgment

Many thanks to Eva for the proofreading.

Reference

Verbelen F. (2019). “Meteor velocity derived from head echoes obtained by a single observer using forward scatter from a low powered beacon”. *WGN, Journal of the International Meteor Organization*, **47**, 49–54.

Radio meteors June 2022

Felix Verbelen

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An overview of the radio observations during June 2022 is given.

1 Introduction

The graphs show both the daily totals (*Figure 1 and 2*) and the hourly numbers (*Figure 3 and 4*) of "all" reflections counted automatically, and of manually counted "overdense" reflections, overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during the month of June 2022.

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

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

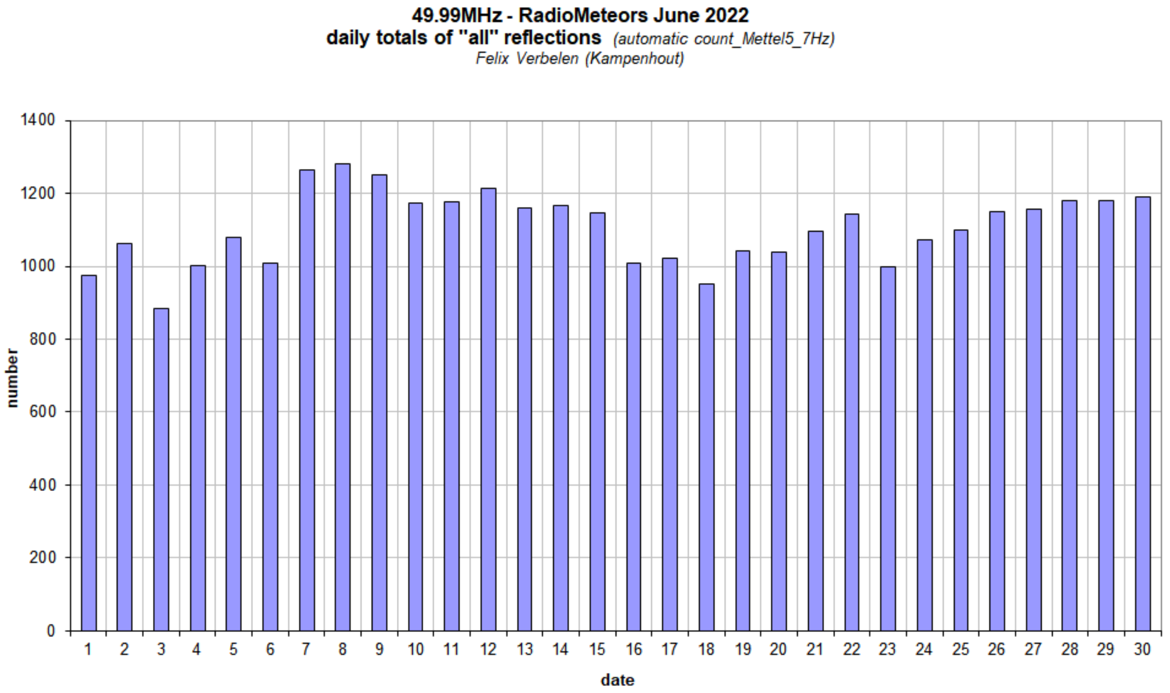
Local interference and unidentified noise remained moderate to low for most of the month, but observations were sometimes difficult due to intense lightning activity (on 9 different days) and near-daily strong solar eruptions and even noise storms. This solar activity was obviously interesting in itself.

The general meteor activity was quite high, with the well-known daytime showers during the whole month which showed a clear maximum with the Arietids on June 8th in terms of overdense reflections.

This month, 13 reflections of more than 1 minute were observed. SpecLab-pictures of a selection of these and some other interesting reflections are attached. (*Figures 5 to 15*). In addition to the usual graphs, you will also find the raw counts in cvs-format[27] from which the graphs are derived.

The table contains the following columns: day of the month, hour of the day, day + decimals, solar longitude (epoch J2000), counts of "all" reflections, overdense reflections, reflections longer than 10 seconds and reflections longer than 1 minute, the numbers being the observed reflections of the past hour.

[27] https://www.meteornews.net/wp-content/uploads/2022/07/202206_49990_FV_rawcounts.csv



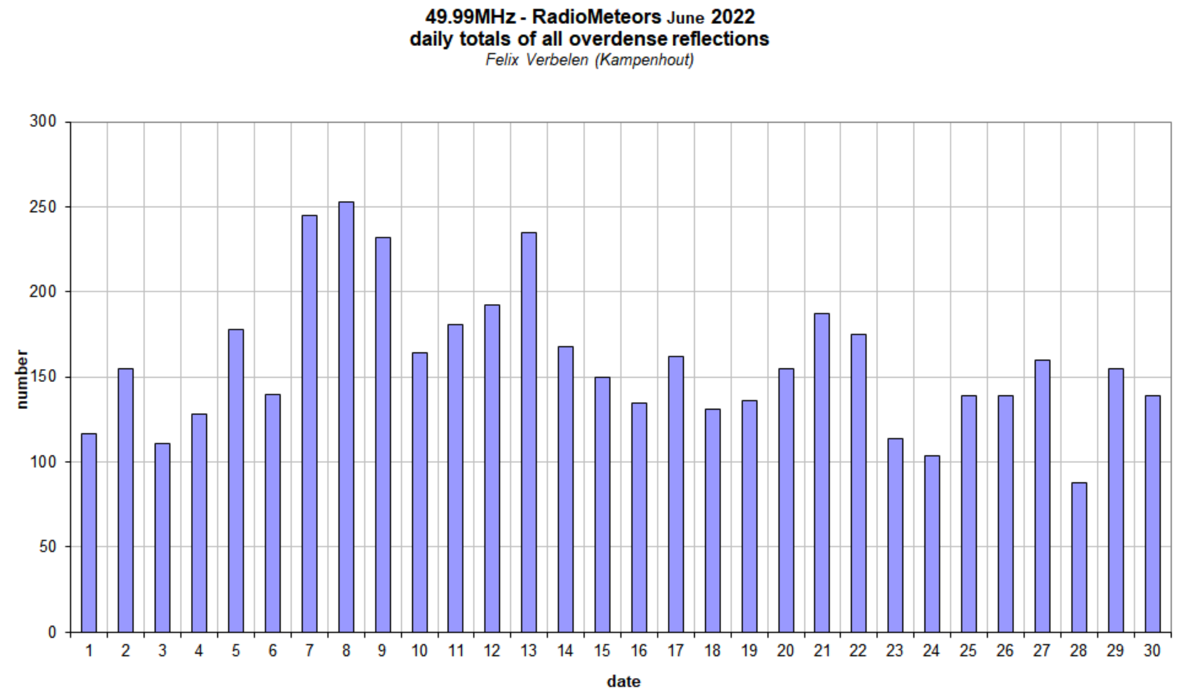
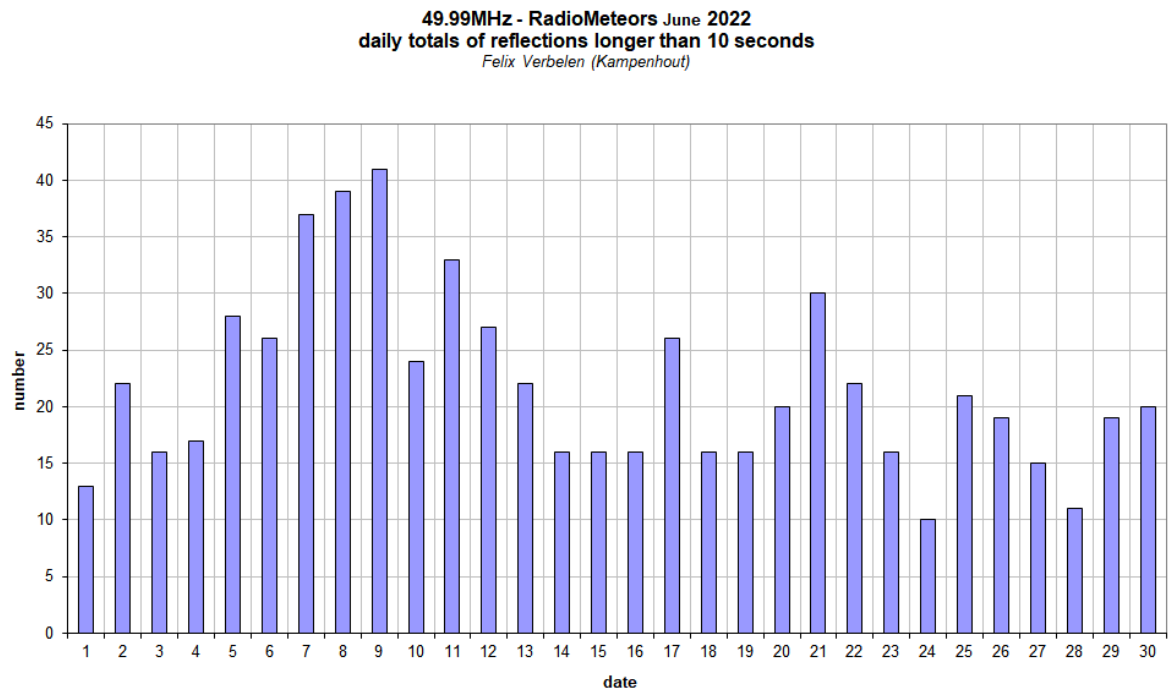


Figure 1 – The daily totals of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during June 2022.



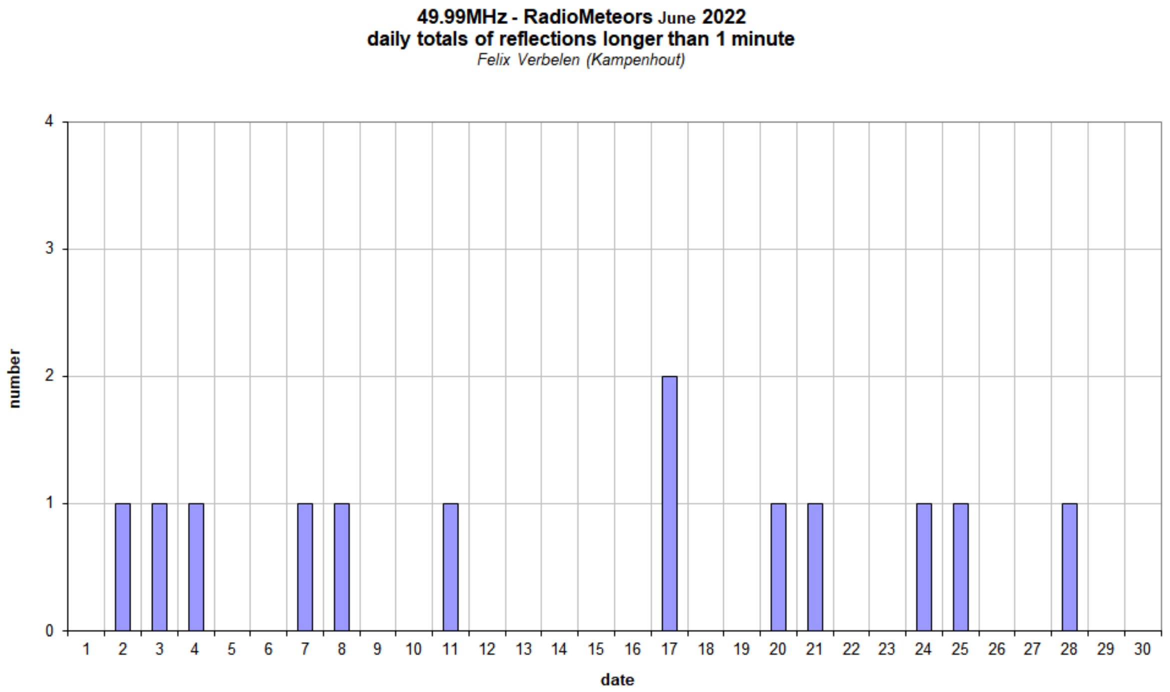
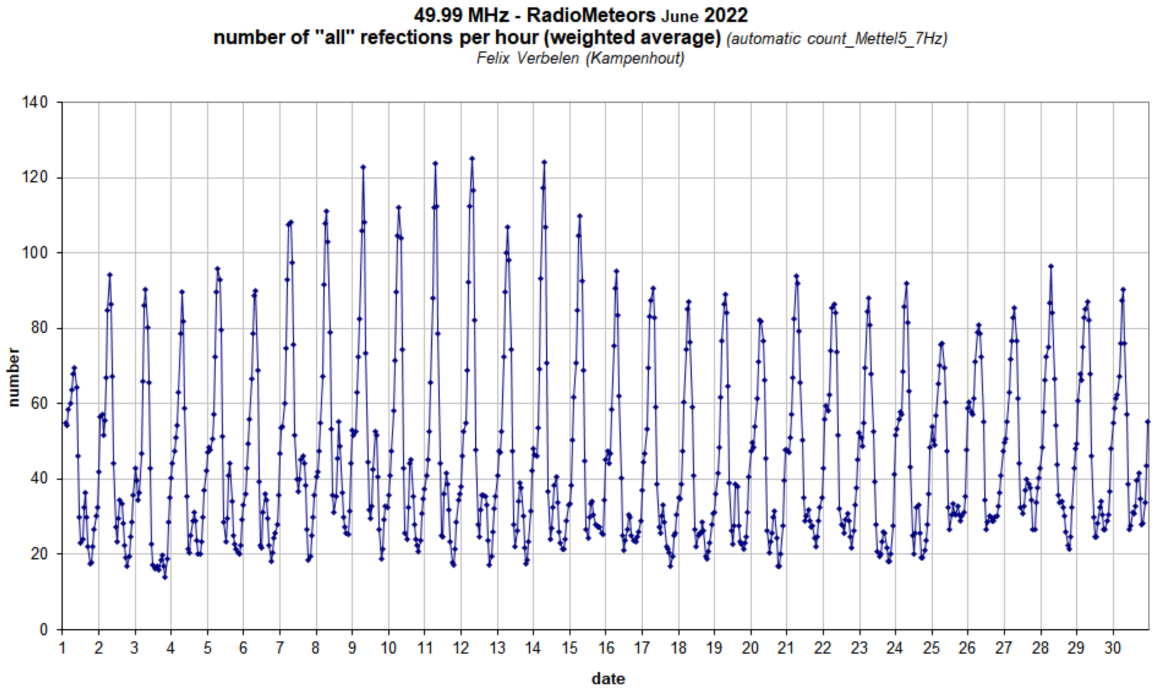


Figure 2 – The daily totals of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during June 2022.



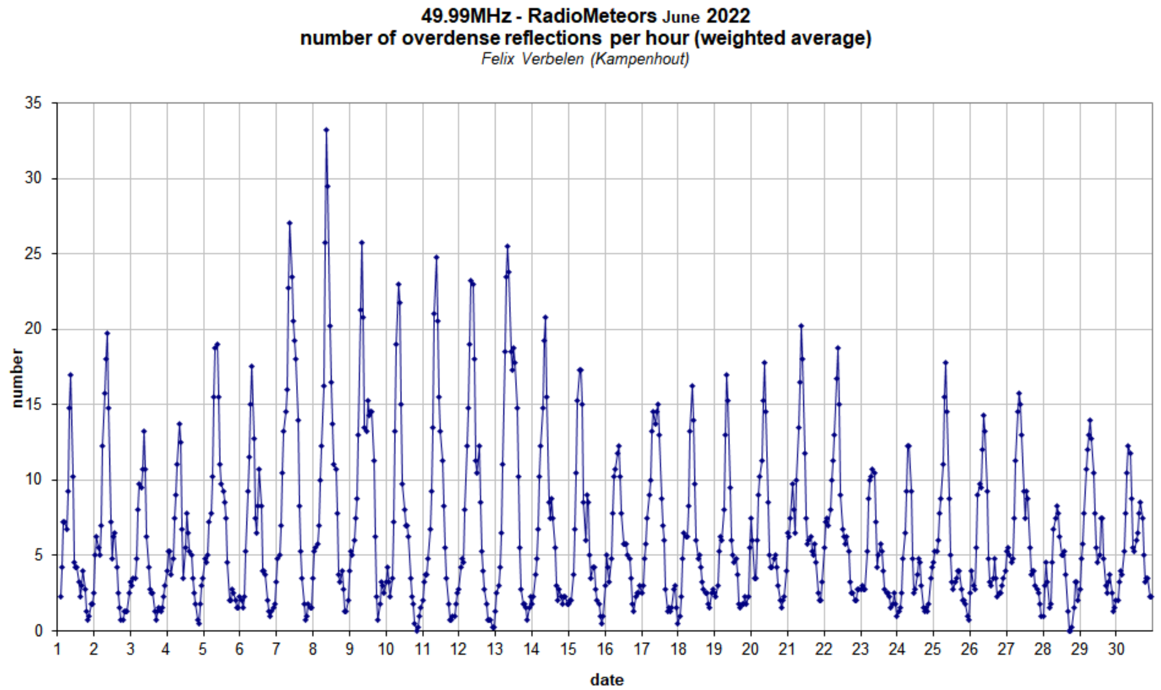
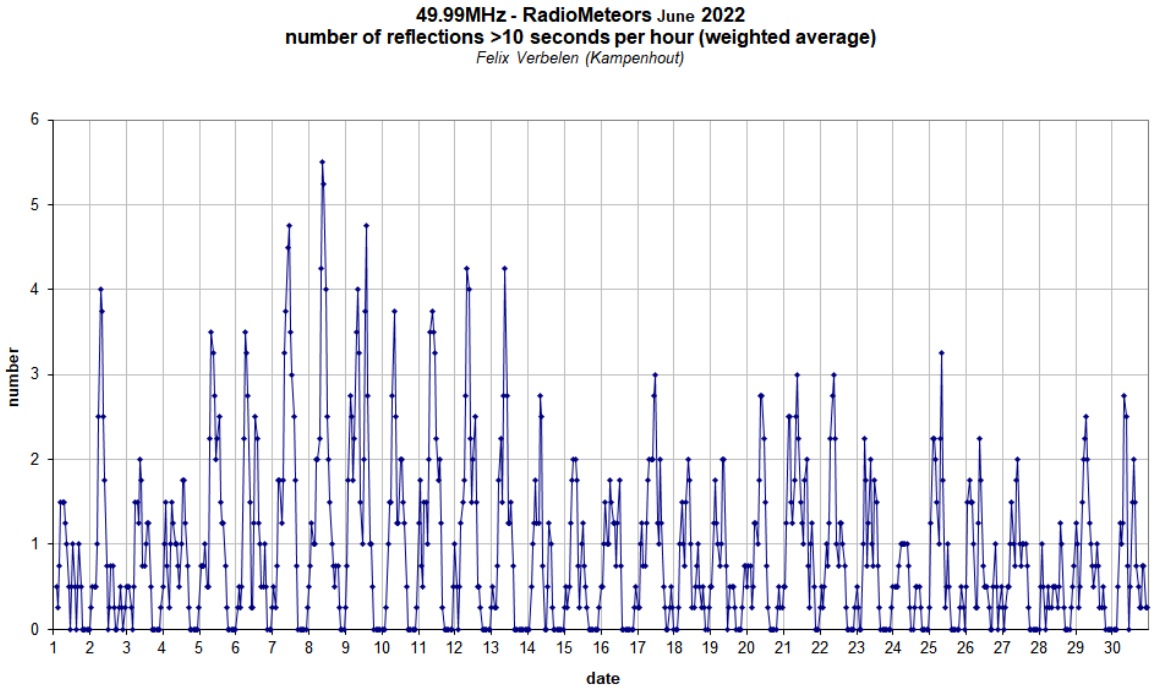


Figure 3 – The hourly numbers of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during June 2022.



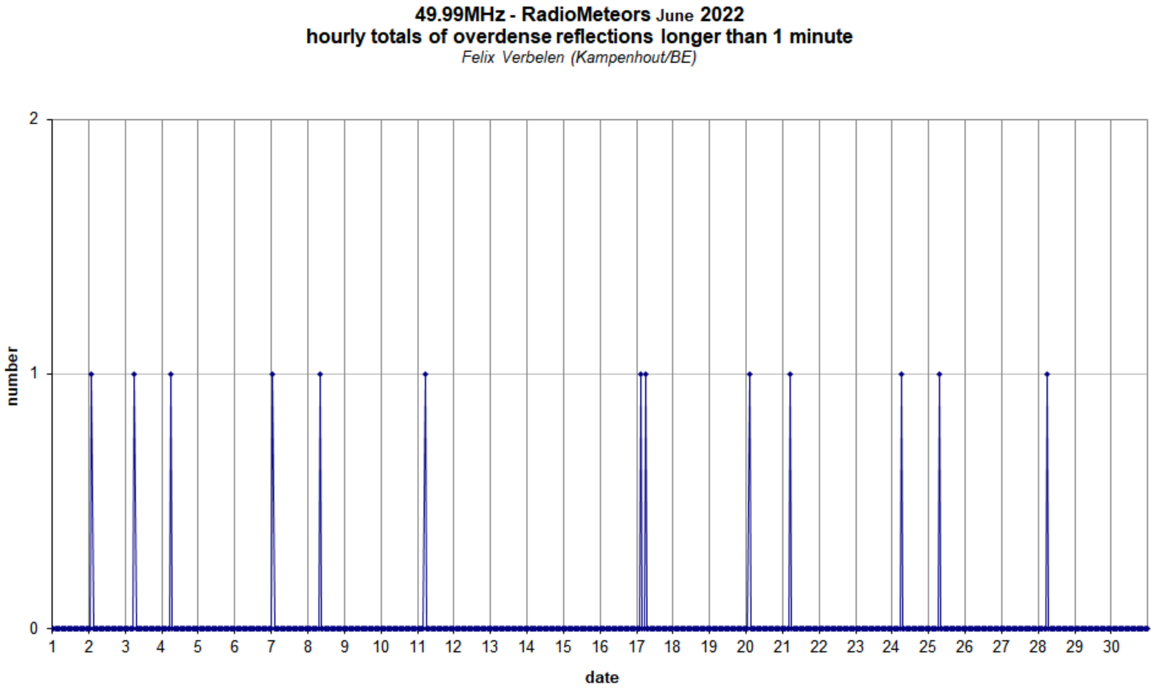


Figure 4 – The hourly numbers of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during June 2022.

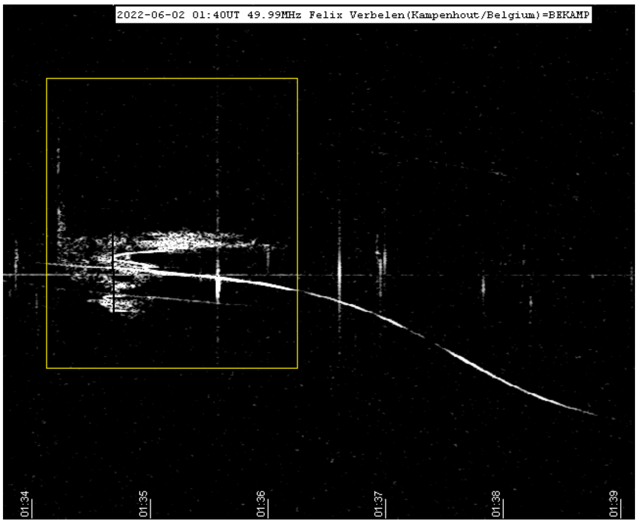


Figure 5 – Meteor reflection 2 June 2022, 01^h40^m UT.

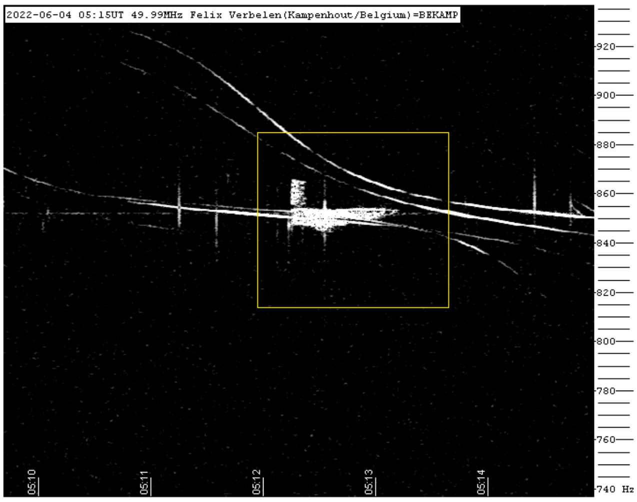


Figure 6 – Meteor reflection 4 June 2022, 05^h15^m UT.

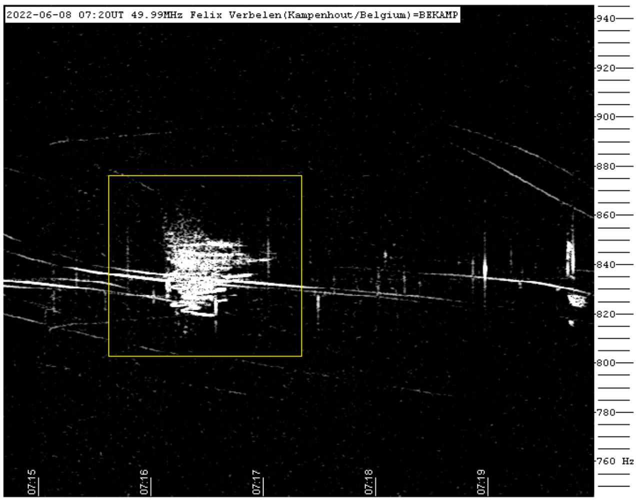


Figure 7 – Meteor reflection 8 June 2022, 07^h20^m UT.

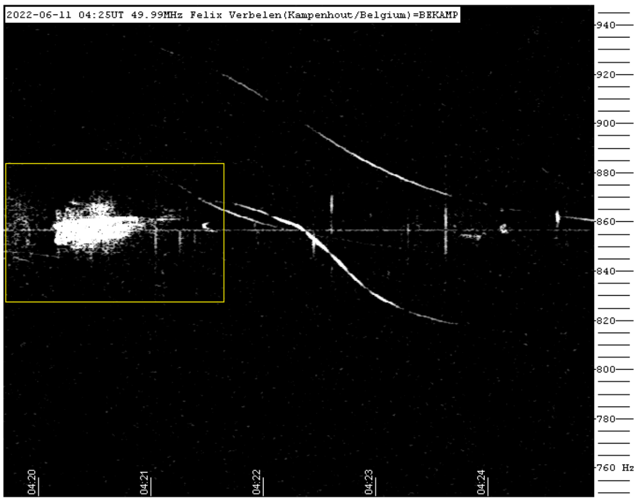


Figure 8 – Meteor reflection 11 June 2022, 04^h25^m UT.

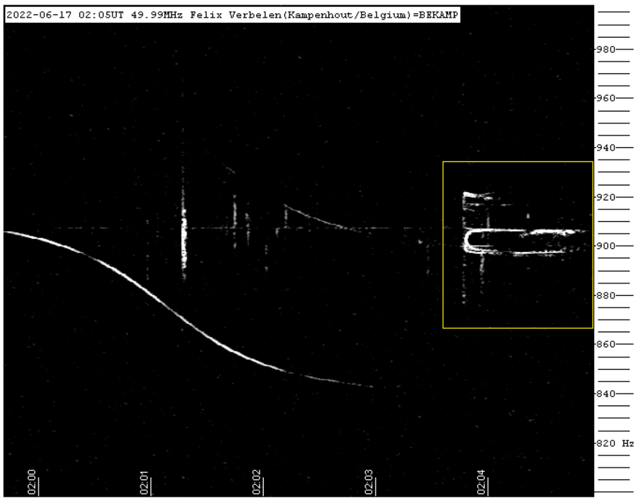


Figure 9 – Meteor reflection 17 June 2022, 02^h05^m UT.

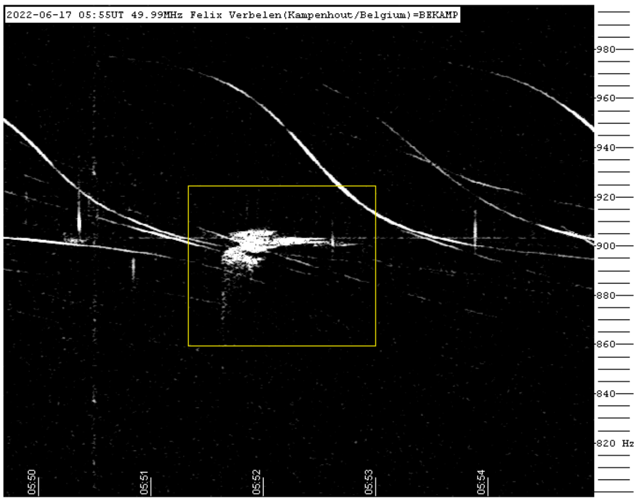


Figure 10 – Meteor reflection 17 June 2022, 05^h55^m UT.

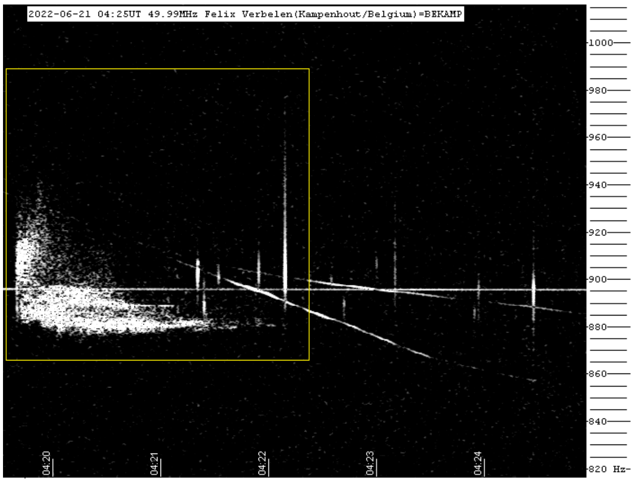


Figure 11 – Meteor reflection 21 June 2022, 04^{h}25^m UT.

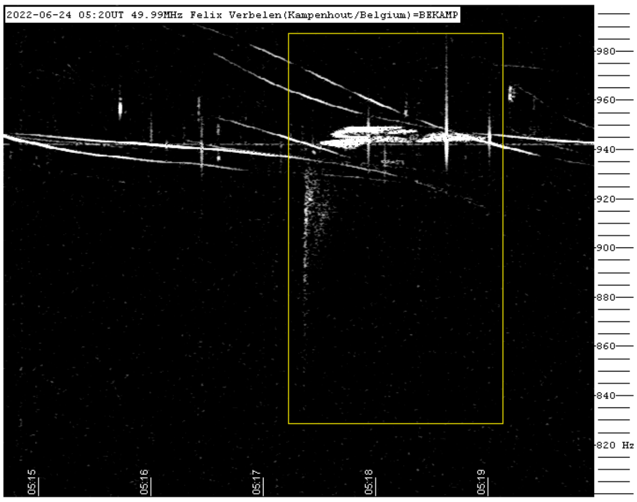


Figure 12 – Meteor reflection 24 June 2022, 05^{h}20^m UT.

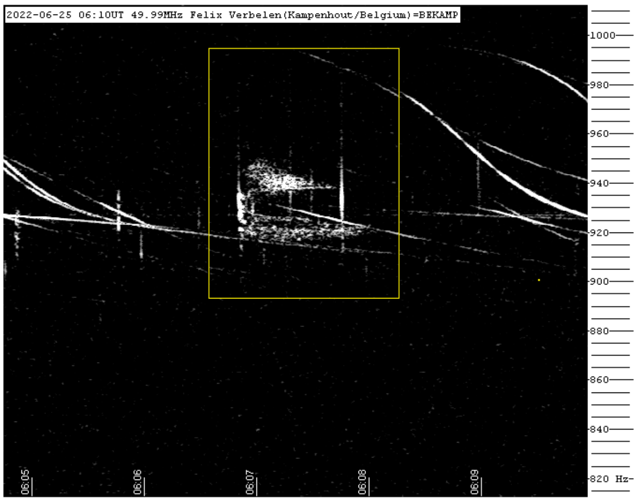


Figure 13 – Meteor reflection 25 June 2022, 06^{h}10^m UT.

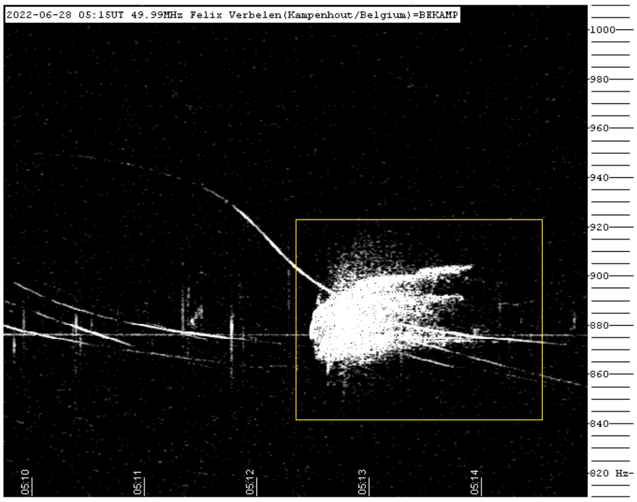


Figure 14 – Meteor reflection 28 June 2022, 05^{h}15^m UT.

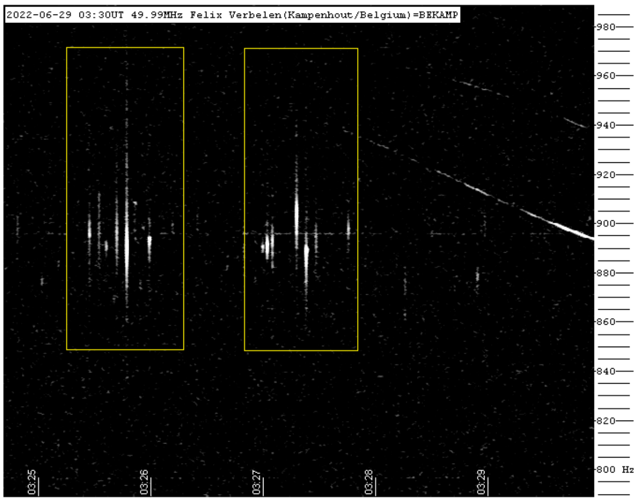


Figure 15 – Meteor reflection 29 June 2022, 03^{h}30^m UT.

Radio meteors July 2022

Felix Verbelen

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An overview of the radio observations during July 2022 is given.

1 Introduction

The graphs show both the daily totals (*Figure 1 and 2*) and the hourly numbers (*Figure 3 and 4*) of "all" reflections counted automatically, and of manually counted "overdense" reflections, overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during the month of Jujy 2022.

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

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

Local interference and unidentified noise remained moderate to low for most of the month. Lightning activity was observed on just 1 day (July 20th). Especially in the first half of the month intense solar eruptions often caused considerable noise (see i.e. *Figure 5*). Surprisingly, for the rest of the month, there were only a few faint solar outbursts despite the numerous sunspots and prominences that could be observed visually.

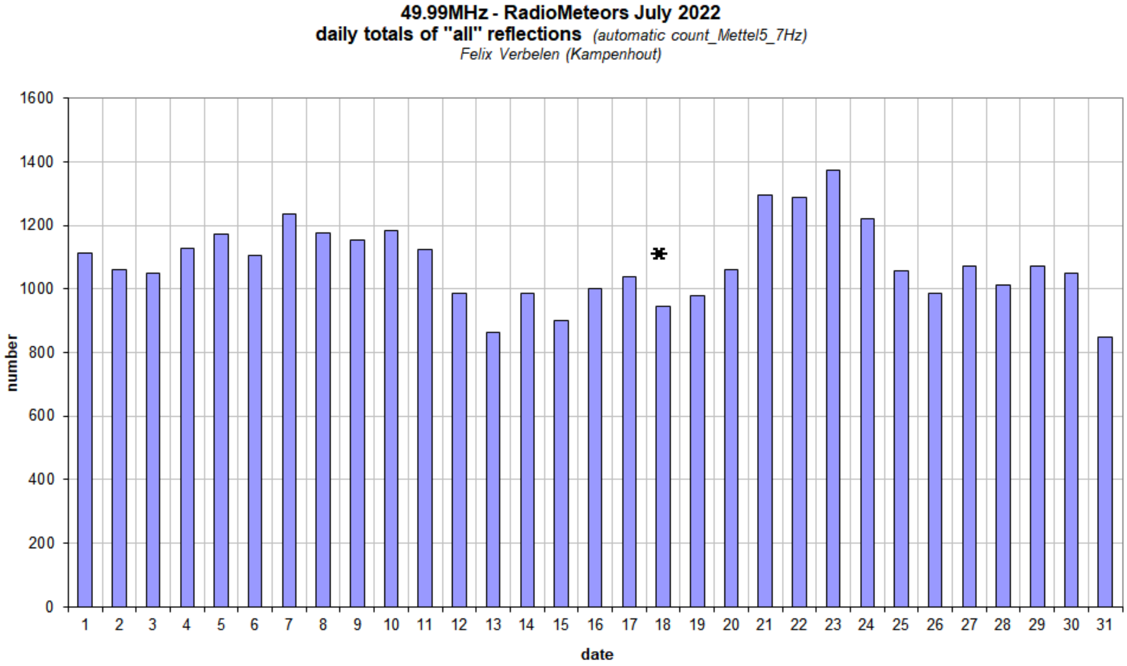
Overall meteor activity was quite high, with radiants mainly in the direction of the constellations Pegasus and Andromeda and surrounding areas. The steady increase of long-lasting (> 10 sec) reflections was also quite striking.

This month, 14 reflections lasting more than 1 minute were observed.

SpecLab images of some interesting reflections have been added (*Figures 6 to 15*). In addition to the usual graphs, you will also find the raw counts in cvs-format[28] from which the graphs are derived.

The table contains the following columns: day of the month, hour of the day, day + decimals, solar longitude (epoch J2000), counts of "all" reflections, overdense reflections, reflections longer than 10 seconds and reflections longer than 1 minute, the numbers being the observed reflections of the past hour.

[28] https://www.meteornews.net/wp-content/uploads/2022/08/202207_49990_FV_rawcounts.csv



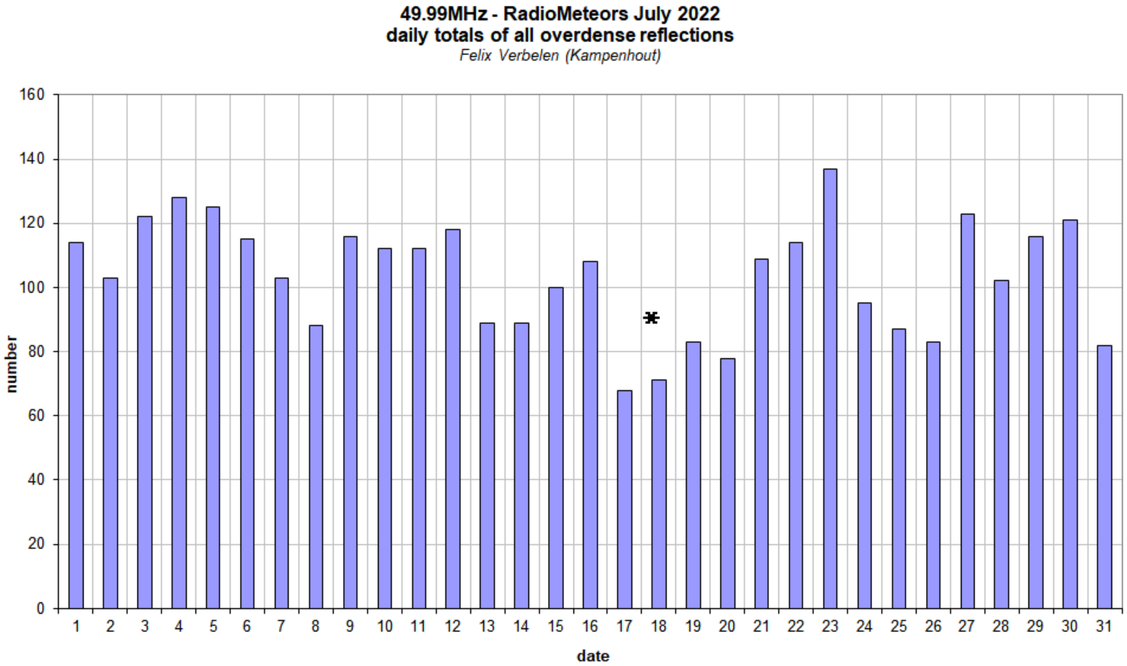


Figure 1 – The daily totals of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during July 2022.

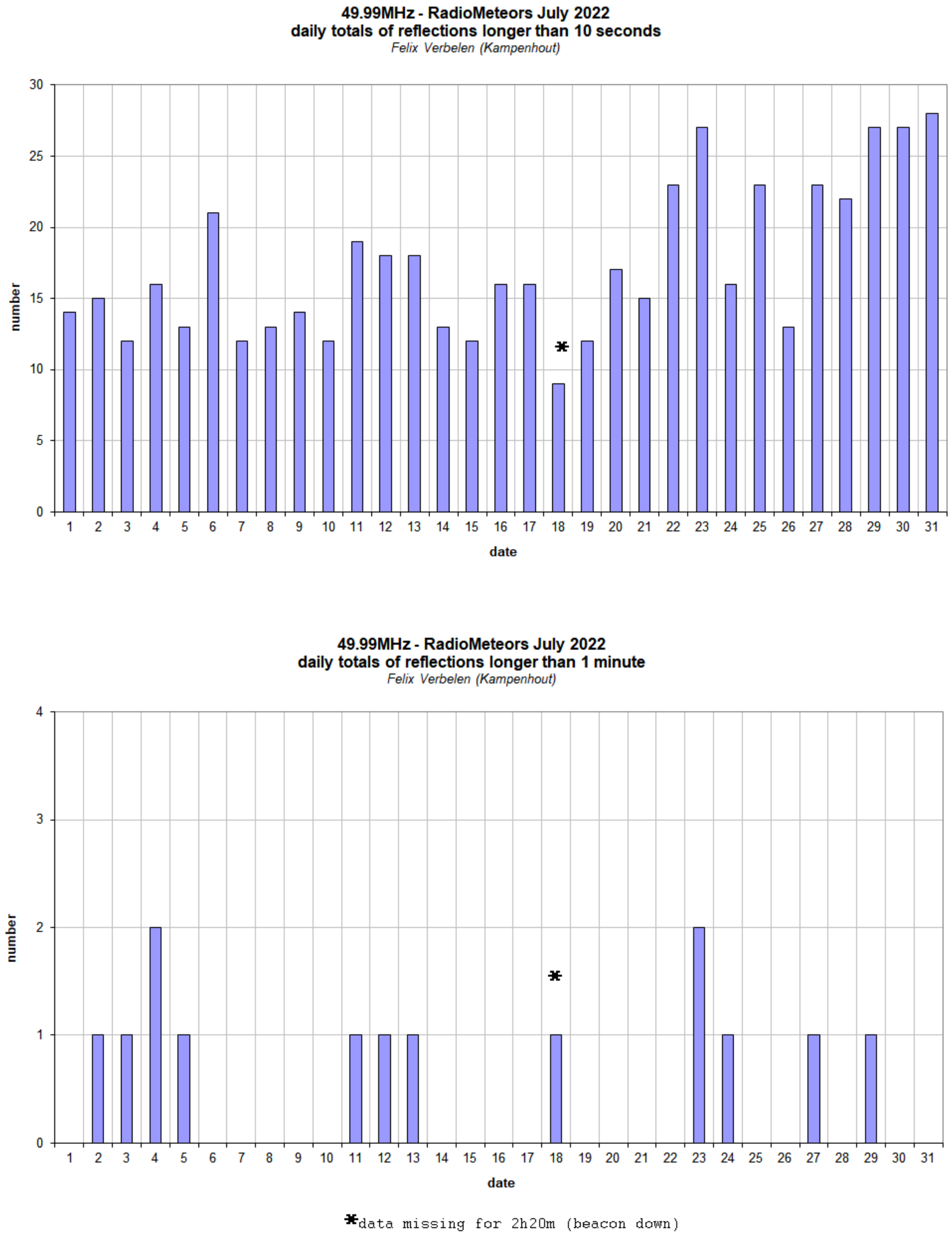
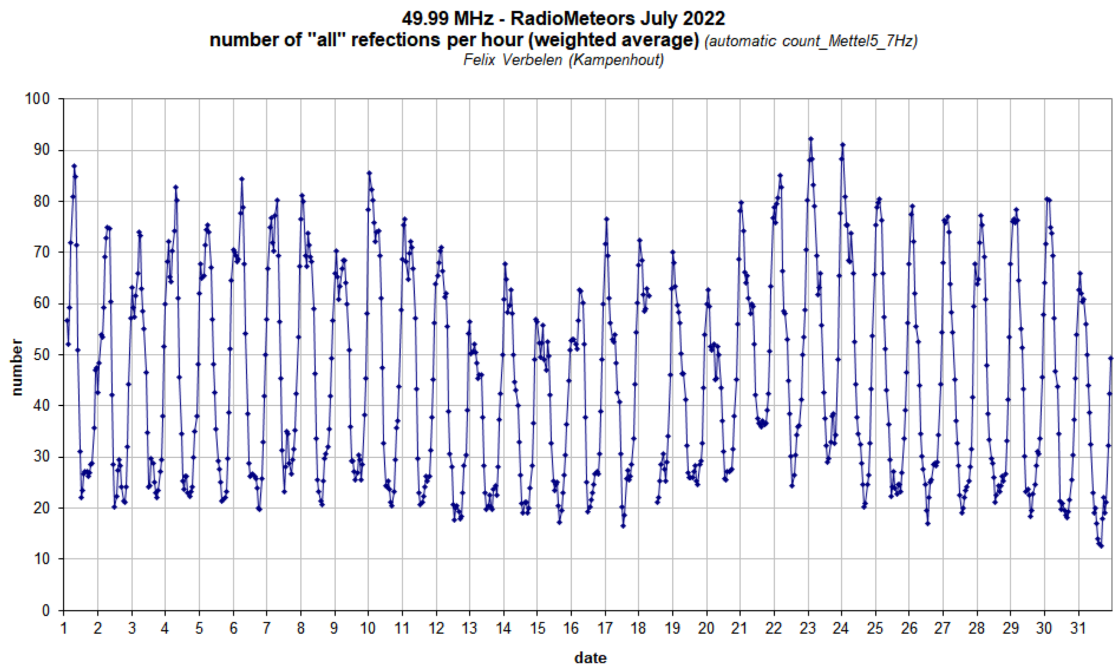


Figure 2 – The daily totals of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during July 2022.



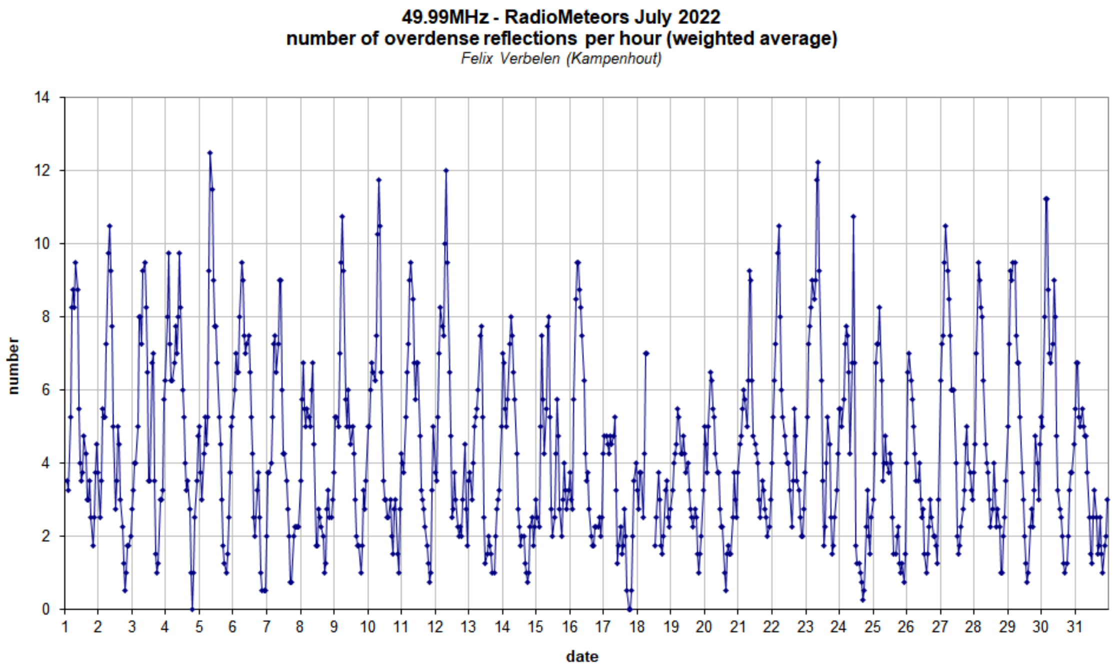
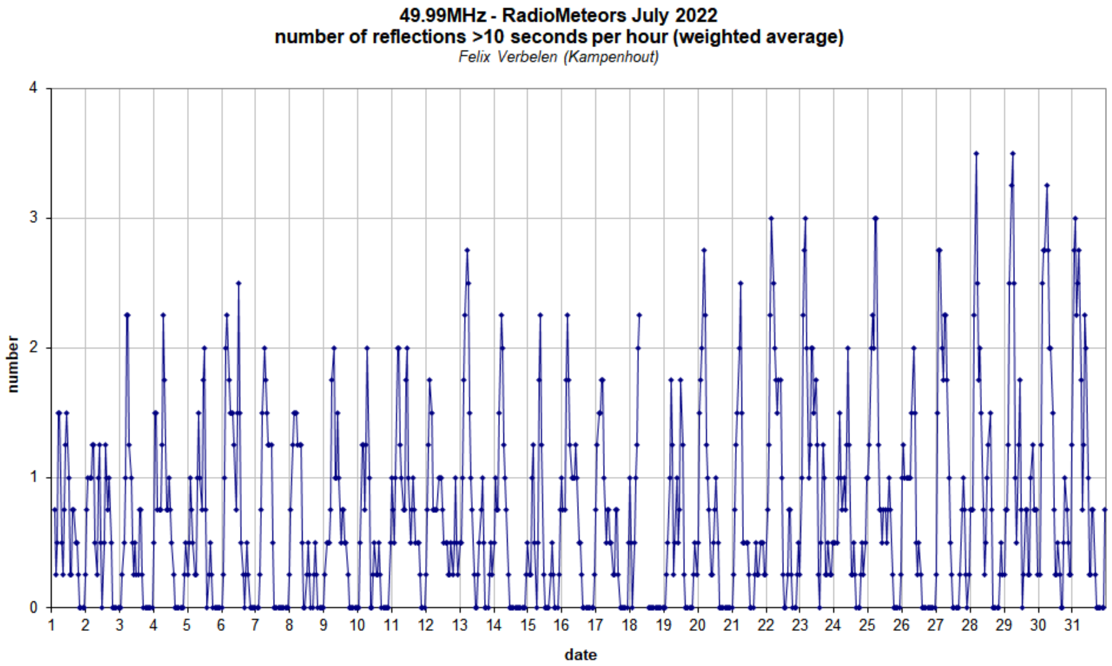


Figure 3 – The hourly numbers of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during July 2022.



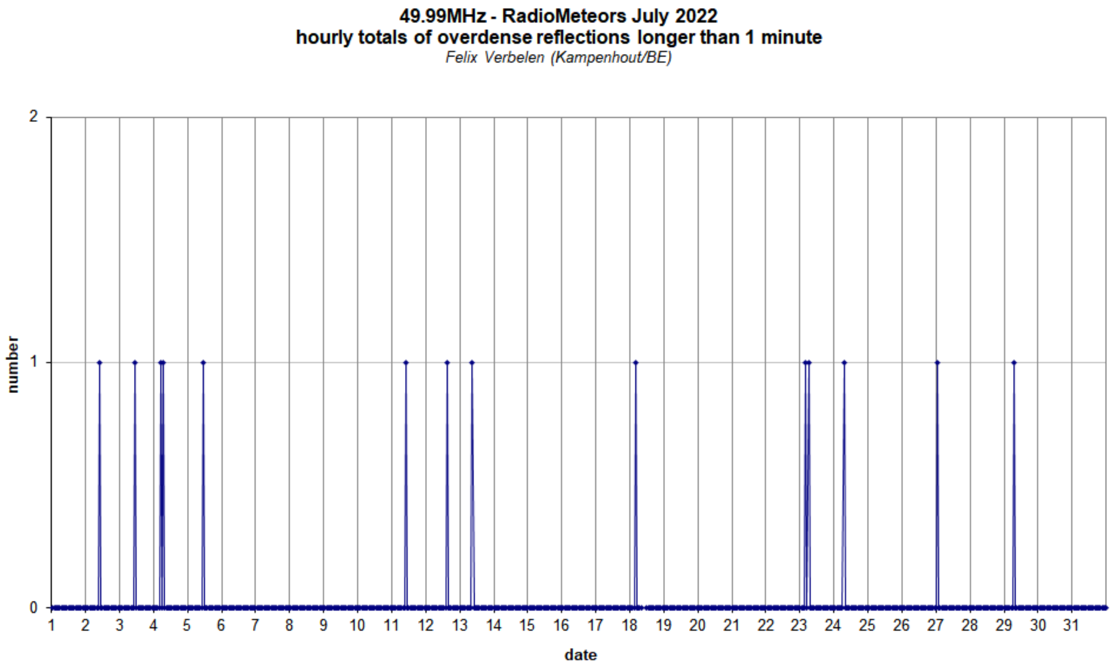


Figure 4 – The hourly numbers of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during July 2022.

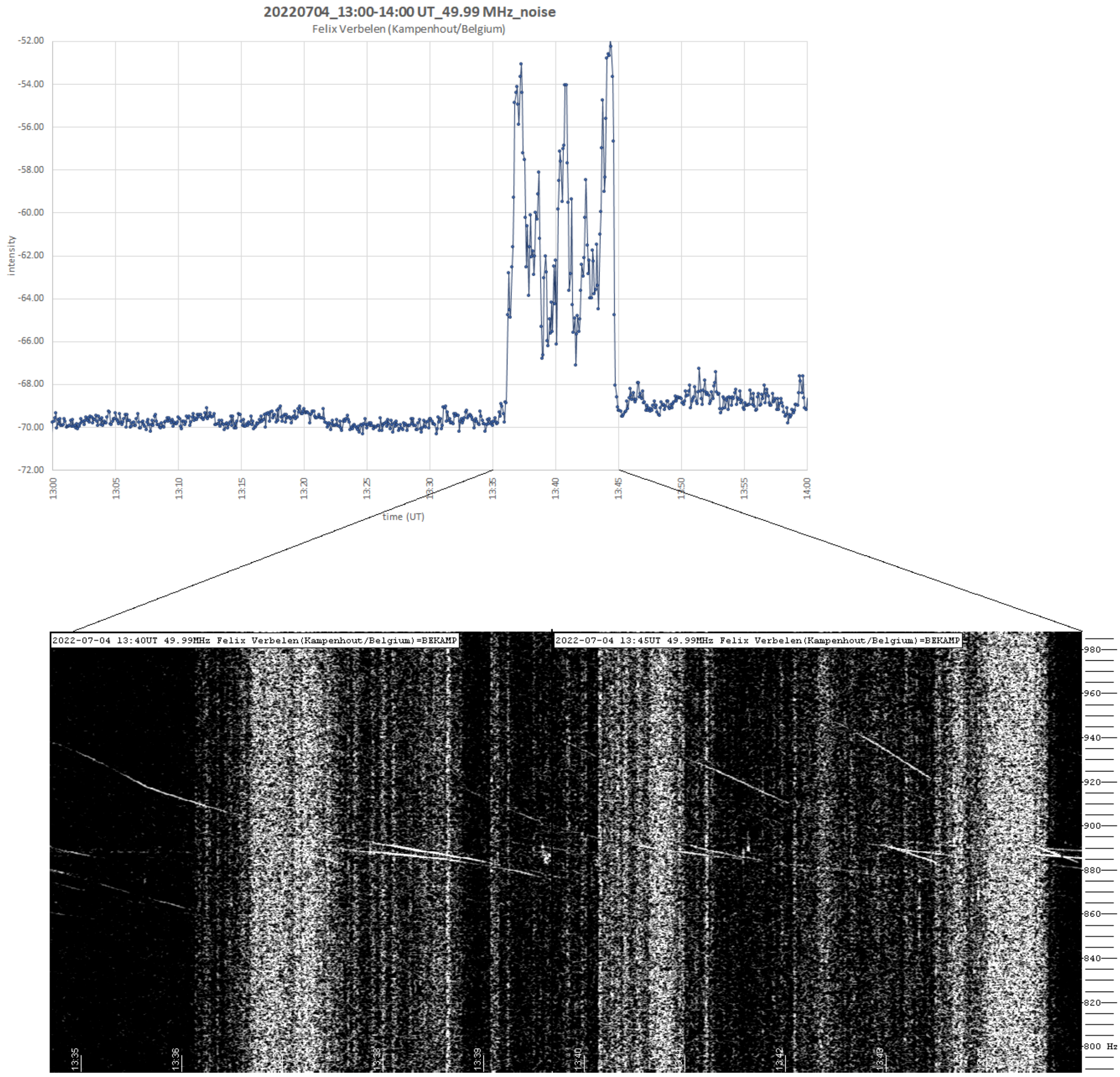


Figure 5 – Solar eruptions often caused considerable noise.

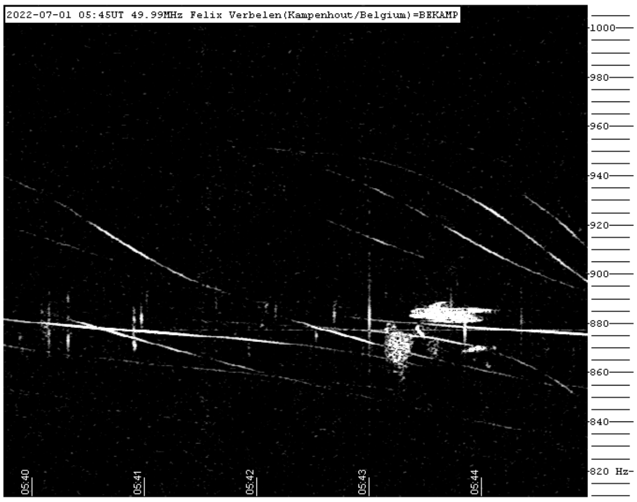


Figure 6 – Meteor reflection 1 July 2022, 04^h50^m UT.

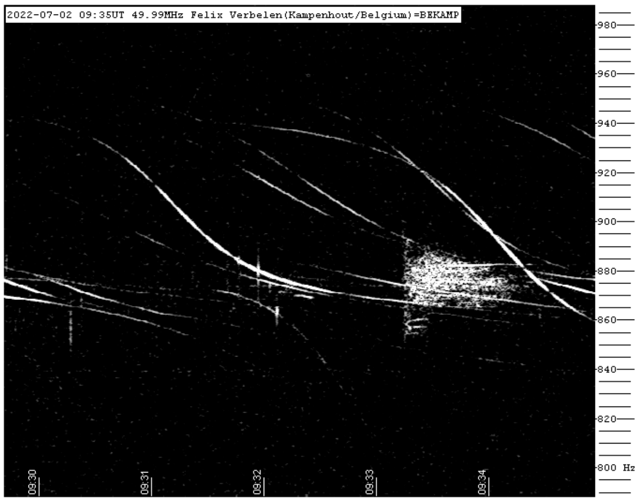


Figure 7 – Meteor reflection 2 July 2022, 09^h35^m UT.

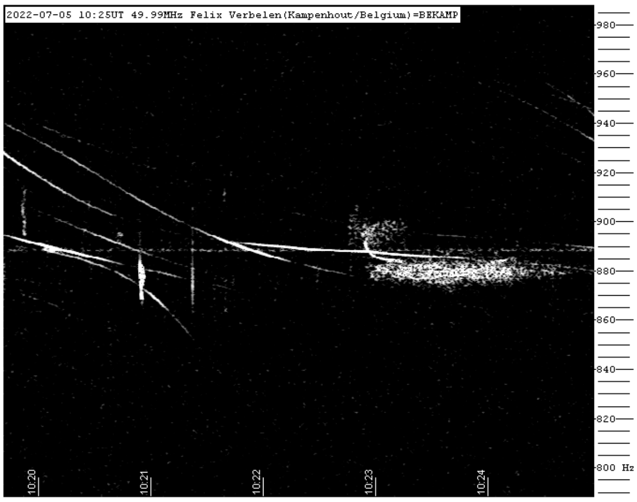


Figure 8 – Meteor reflection 5 July 2022, 10^{h}25^{m} UT.

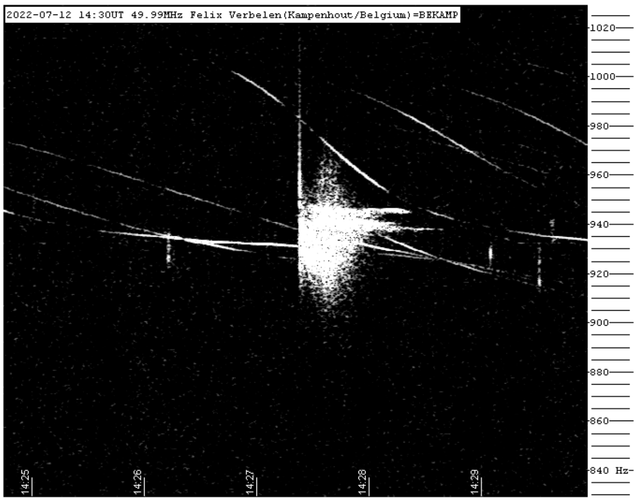


Figure 9 – Meteor reflection 12 July 2022, 14^{h}30^{m} UT.

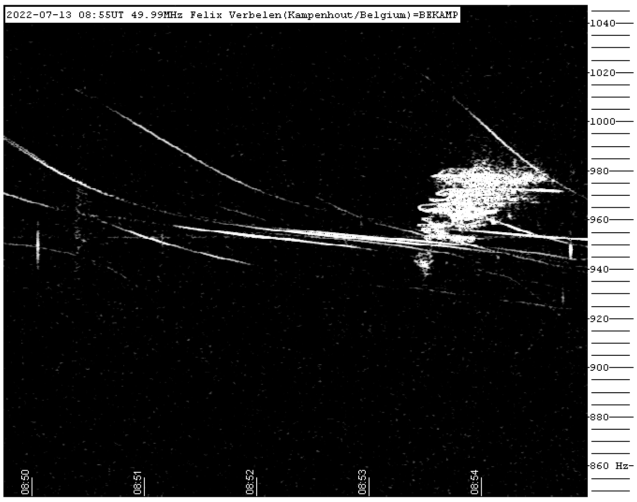


Figure 10 – Meteor reflection 13 July 2022, 08^{h}55^{m} UT.

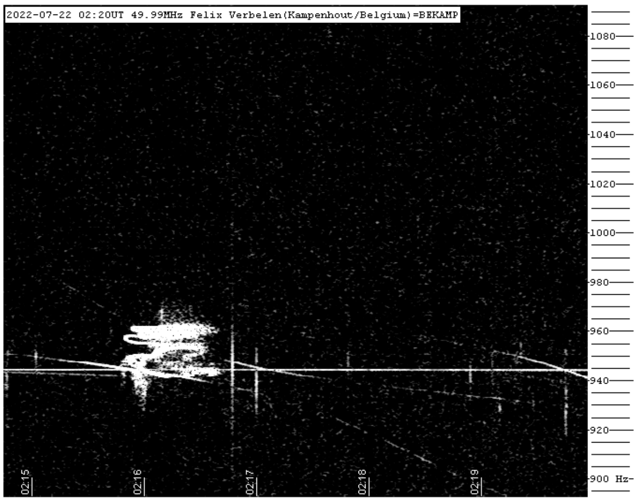


Figure 11 – Meteor reflection 22 July 2022, 02^{h}20^{m} UT.

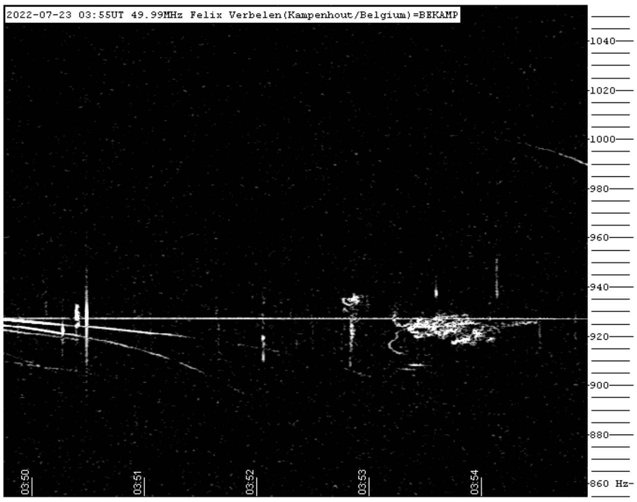


Figure 12 – Meteor reflection 23 July 2022, 03^{h}55^{m} UT.

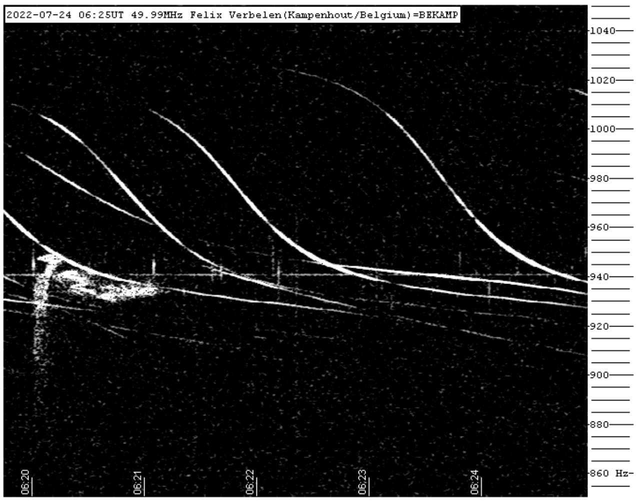


Figure 13 – Meteor reflection 24 July 2022, 06^{h}25^{m} UT.

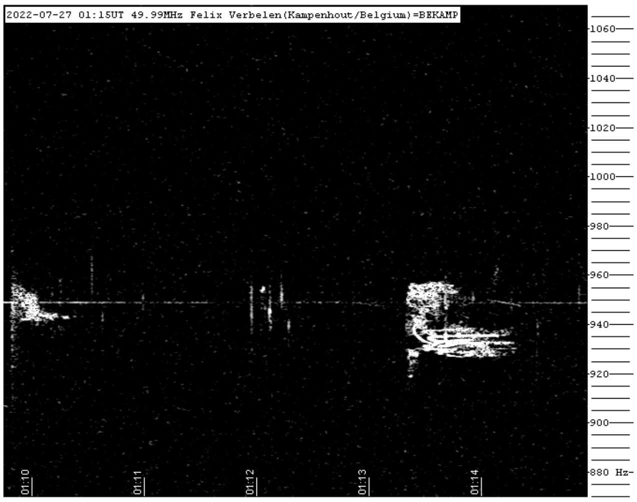


Figure 14 – Meteor reflection 27 July 2022, 01^{h}15^{m} UT.

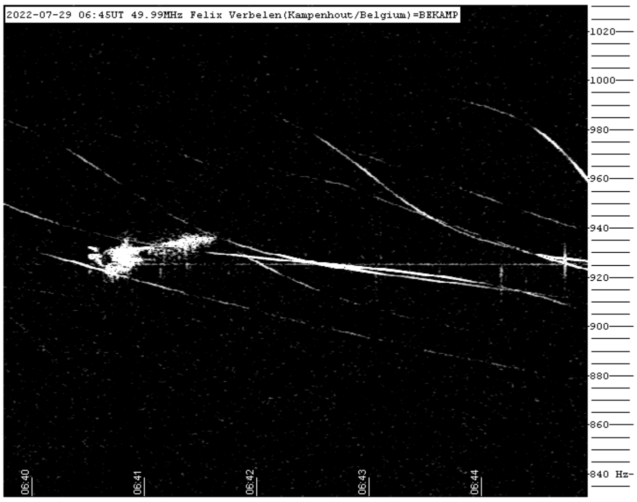


Figure 15 – Meteor reflection 29 July 2022, 06^{h}45^{m} UT.

Meteor observations May–June 2022 from Any Martin Rieux Northern France

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An overview of visual meteor observations made by the author from Any Martin Rieux (Northern France) in late May and early June is presented. Among other things, extra attention was paid to the meteor shower tau Herculids, which was expected to show a possible outburst during the night of May 30–31, 2022.

1 Overview of visual observations done

Every year in May or June my wife Lizzie and I take a 14-day vacation. Usually we stay in Northern France, in Buzancy or Any Martin Rieux. Both addresses are very convenient for us, because our 5 dogs are also welcome there. This year we were in Any Martin Rieux at the Chambres Hotes Bel Any. A very small-scale holiday park. In addition to the large house of the owners, there are three small 2-person houses and an outbuilding where several rooms are rented out. The site is very large and beautifully maintained with plenty of space. The complex is located on the edge of Any Martin Rieux. The village has approximately 500 inhabitants and is located about 10 km east of the larger town of Hirson. In addition to being ideal for our dogs, it is also a dark location. The streetlights are reasonably well shielded and switched off after 22^h local time. It is also very quiet, only the many birds provide a beautiful musical setting.

The weather forecast for those two weeks was reasonable. The weather would be a bit cooler with a few rain showers now and then. Well, it is no high meteor activity season so no problem. It is also primarily a holiday. But the date of May 30–31 was marked red on the calendar, the tau Herculids could show some activity as a result of the breakup of comet 29P/Schwassmann–Wachmann in 1995. The weather cooperated perfectly: out of 13 nights, 6 nights could be observed, an excellent score for western Europe. This makes this location far better compared to my hometown Ermelo, as witnessed by the remote all sky there, which only recorded one night completely clear. Some nights that were clear in Any Martin Rieux were completely cloudy in Ermelo. In *Table 1* an overview is given with all clear nights and observations.

Figure 1 – The rented house on the property of Chambres Hotes Bel Any, in Any Martin Rieux.

Table 1 – Overview of the author's observations from Any Martin Rieux, Northern France.

Date	Period UT	Max SQM	T_{eff}	Max Lm	TAH	ANT	SPO	Total	Remark
24–25 May	21^h50^m–00^h57^m	21.24	3.05	6.6	0	4	27	31	
27–28 May	21^h30^m–01^h06^m	21.32	3.52	6.7	0	5	28	33	T = –2° C
28–29 May	21^h50^m–01^h04^m	21.34	3.18	6.6	2	5	25	32	
30–31 May	23^h15^m–01^h00^m	21.10	1.75	6.5	7	2	7	16	
31–01 May	21^h43^m–01^h06^m	21.25	3.21	6.6	5	5	28	38	T = –3° C
01–02 May	22^h00^m–01^h02^m	21.23	2.90	6.5	1	3	23	27	
6 sessions			17.61		15	24	138	177	

Figure 2 – ISS passage in the night of 24–25 May 2022. The last clouds are moving away in a southwest direction.

2 The first cloudless night was 2022 May 24–25

After a consciously chosen break on visual meteor observations, this was also the first session of 2022. During the day a lot of cumulus clouds were present, but these started to dissolve by sunset. It was clear for a while, but later clouds moved in from the west again. After 21^h45^m UT the clouds had disappeared and the observations started at 21^h50^m UT. Incidentally, the observation spot became a path up the hill north of Bel Any, a five-minute walk. From there I had a beautiful view in all directions and a beautiful starry sky stretched out. After half an hour a nice ISS passage was also seen in the south. However, the conditions were not quite top and in the last hour there was some ground fog. The SQM reached a maximum of 21.20. In total, I counted 31 meteors during 3.05 hours, of which 4 meteors from the Antihelion region. Tau Herculids were also considered, but they were not yet visible. As expected in this kind of transparent conditions relatively many faint meteors. It was also a restless night, it started after half an hour when I was startled by a loud scream, repeated several times after ten seconds. The thought was with a bird of prey, also because the sound moved quickly from northeast of me to west of me. After a few minutes a farmer had apparently had enough of the screaming and a loud gunshot sounded. The noise then gradually diminished. But beyond this, more gunshots and bangs could be heard at a greater distance. During the daytime, research revealed that surprisingly the sound did not come from some bird of prey but from a fox. Never thought they could scream so loud.

3 2022 May 27–28 and 28–29

After two cloudy nights, the sky was clear again during the nights 27–28 and 28–29 May 2022. Both nights were characterized by very nice conditions with the limiting magnitude almost touching 6.7. Just before the observations started on the night of May 27–28, there was another beautiful ISS apparition low on the southwestern horizon. A few fireball class satellites were also observed. The first tau Herculids were observed on the second night. At first, I was skeptical because these were short slow meteors far from the radiant. Later it turned out that they were clearly tau Herculids. Now finally some more bright meteors were seen, three sporadic meteors of +1 and a nice orange yellow of 0 in Bootes were the most beautiful. The SQM value reached a maximum of 21.34 this night.

I was eagerly looking forward to 30–31 May. Unfortunately, the night before was completely cloudy as several observers reported more Tau Herculids this night. The CAMS networks had also already detected tau Herculids from May 27.

4 2022 May 30–31: tau Herculids active!

After the cloudy previous night, the evening of May 30 didn't look good either, with the weather and radar app showing clouds over Any Martin Rieux all night, with possible clearings between 00^h and 01^h UT. I also had a severe hay fever attack that afternoon, but luckily my eyes became calm again during the evening. Despite the bad prospects, I walked up just before 22^h UT. It was mostly cloudy, only very low south stars remained visible. Sometimes a bright star would pop through the clouds, but I couldn't do anything. Short naps were the result and once I was rudely awakened by the screaming fox. Things changed around 23^h UT, the clearings got a bit bigger and from 23^{h}15^m UT it was partly cloudy with nice clearings in between (Lm 6.4/6.5). This ~50% cloud period continued until 23^{h}55^m UT. Then the clouds started to disappear until it was completely clear from 00^{h}10^m UT. In the period 23^{h}15^m–00^{h}10^m UT I saw, surprisingly enough, 6 meteors of which 3 tau Herculids under partly cloudy conditions. A +2, +4 and a +1 respectively. All were short, including those that appeared further away from the radiant. The brightest tau Herculids also showed an increasing brightness and then an abrupt end.

The sky was completely clear in my field of view from 00h10m to 01h00m UT. In the north, however, the sky remained cloudy below the polar star. I counted nine meteors in this period, of which 4 TAH and 2 Antihelions. Distribution TAH: +5, +3, 0 and +3. That 0 tau Herculid was a very nice one, was white in color, appeared in the small constellation of Lyra and had a short flare at the end. Only a few sporadic meteors were observed. From 00^{h}55^m UT it started to close completely again, but by moving my field of view to the east I could observe until 01^{h}00^m UT. So, I'm glad I was able to see something of this phenomenon.

5 2022 May 31–1 June

This night was again completely clear. Observations could be done between 21^{h}43^m and 01^{h}06^m UT. A total of 39 meteors were seen, of which 5 Antihelion and 5 tau Herculids. The tau Herculids showed 1 or 2 meteors every hour. A beautiful moment was at 00^{h}18^m and 00^{h}19^m UT, first a beautiful +1 ANT and then a beautiful blue-yellow magnitude 0 APEX meteor moving from Delphinus to Corona Borealis. That was the highlight of the night.

6 2022 June 1–2

The following night in June 2022 was also clear, but there was more moisture high in the atmosphere. Maximum SQM 21.20 and lm 6.6 at maximum. I was also a bit tired this night, which resulted in fewer meteors.

7 Summarized

These observations yielded 177 meteors over 6 nights (effective 17.61 hours). Unfortunately, no meteors were captured by the travel all-sky camera. Perhaps also because there are relatively many trees on the Bel Any site. All in all, a successful period. Let's hope the weather cooperates in the upcoming observational events.

Figure 3 – My travel all sky camera in the field on the property of Bel Any guarded by the owners' dog

Figure 4 – Star trails image from the night of May 28–29, 2022. A bright satellite of –6 moved quite high in the southeastern sky and was also seen visually. The all-sky camera was located on another site on the property of Bel Any with more obstruction from trees.

Observations from Agios Pavlos, Crete

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A summary is presented of the series visual observations carried out by the author in 2022, July and August, at Agios Pavlos, Crete, Greece.

1 Introduction

After two successful observing campaigns in 2018 and 2019, I decided to go back to the south of Crete in 2022 to observe the maxima of the Southern delta Aquariids and the Alpha Capricornids. The place Agios Pavlos was chosen because of the dark sky and the stable weather in the south of Crete, shielded from clouds by the mountain range that cover the central parts of the island. Only hundred meters from my rented apartment, I could make observations away from direct light sources under a very dark sky with *Lm* between 6.7 and 6.8.

2 2022 July 23–24

The first night of observation, I decided to start early to monitor the activity from the Alpha Capricornids and the July gamma Draconids, with radiants already at a suitable elevation. I quickly became aware of a problem with severe wind gusts blowing up sand particles from the ground into my face. These gusts of wind could be heard before they hit, so I was somehow able to protect my face during the short intervals they lasted. After about an hour, the wind calmed, and I could observe uninterrupted throughout the night.

Observations were made for 4 hours, between 20^h15^m and 00^h20^m UT. The sky was clear, with a limiting magnitude of 6.72. Stable sporadic rates between 8 and 11 were recorded. The SDA activity was very low, with only 3 meteors seen in four hours. It must be noted though, that the radiant was very low in the sky the first two hours. Two possible candidates for the GDR shower were detected. At 20^h59^m, a +4 magnitude GDR appeared near the radiant in Draco, slowly gliding towards the border of Lyra. At 23^h31^m another beautiful GDR of magnitude +1 glided slowly through Cygnus. Three early Perseids were also detected the last two hours, but the best shower of the night was undoubtedly the Alpha Capricornids! Rates varied between 1 and 5, with a beautiful, slow moving, orange meteor that moved from about the position of Saturn in Capricornus, towards the position of Jupiter in Cetus as a highlight!

A total of 59 meteors were observed in 4 hours. Of these were 37 SPO, 10 CAP, 3 SDA, 3 PER, 4 ANT and 2 GDR.

Observed showers:

- Alpha Capricornids (001 CAP)
- Southern delta Aquariids (005 SDA)
- Perseids (007 PER)
- July gamma Draconids (184 GDR)
- Anthelion Source (ANT)

$20^h15^m – 21^h15^m$. T_{eff}: 1.00, *F*: 1.00, *Lm* 6.72, RA: 255, Dec: +20

- SPO: 9 meteors. +1(2), +2, +3(2), +4(2), +5, +6
- CAP: 1 meteor. +4
- SDA: 0 meteors.
- PER: 0 meteors.
- GDR: 1 meteor. +4
- ANT: 1 meteor. +3

$21^h15^m – 22^h15^m$. T_{eff}: 1.00, *F*: 1.00, *Lm* 6.72, RA: 270, Dec: +20

- SPO: 9 meteors. +0, +2(2), +3, +4(3), +5(2)
- CAP: 1 meteor. +6
- SDA: 0 meteors.
- PER: 0 meteors.
- GDR: 0 meteors.
- ANT: 0 meteors.

$22^h15^m – 23^h15^m$. T_{eff}: 1.00, *F*: 1.00, *Lm* 6.72, RA: 285, Dec: +20

- SPO: 11 meteors. +1, +3, +4(3), +5(5), +6
- CAP: 5 meteors. –1, +1, +3(2), +5
- SDA: 2 meteors. +1, +2
- PER: 1 meteor. +4
- GDR: 0 meteors.
- ANT: 1 meteor. +5

$23^h15^m – 00^h20^m$. T_{eff}: 1.033 (3 minutes break), *F*: 1.00, *Lm* 6.72, RA: 300, Dec: +20

- SPO: 8 meteors. +1, +2, +3, +4(2), +5(2), +6
- CAP: 3 meteors. +4(2), +6
- SDA: 1 meteor. +3
- PER: 2 meteors. +4(2)
- GDR: 1 meteor. +1
- ANT: 2 meteors. +3, +4

3 2022 July 24–25

This was my second night observing from the dark site of Agios Pavlos in southern Crete. Like the previous night conditions were warm and windy, with some powerful gusts of wind making some minor problems with sand particles hitting my face. Away from that, observing conditions were good, with clear and transparent sky with a limiting magnitude of 6.77. It was a stunning experience to view the south-eastern sky, with the bright stars in Sagitta and Sagittarius that can't be seen from Norway. They surrounded the rich parts of the Milky Way that glowed with a reddish tint all the way down into the black Libyan Sea. Also, the planets Saturn and Jupiter made up for some good views during the observation.

The Southern delta Aquariids proved to be a little more active than the previous night, reaching an hourly rate of 4 the last observing hour. Their best appearance was a yellow, –1 mag SDA, right in the densest part of the Milky Way. The Capricornids seemed less active with only 5 meteors seen for 4 hours, the best one being a +1 mag in Aquila. The Perseids reached an hourly rate of 4 the last two hours with high radiant elevation, the brightest being a –1-mag low in the northern horizon. Possible activity from the July gamma Draconids was also detected, with 3 meteors seen during 4 hours of observation. The sporadic activity was on the weak side this night, with rates varying between 4 and 8.

A total of 57 meteors were observed in 4 hours. Of these were 26 SPO, 5 CAP, 10 SDA, 9 PER, 3 GDR and 4 ANT.

Observed showers:

- Alpha Capricornids (001 CAP)
- Southern delta Aquariids (005 SDA)
- Perseids (007 PER)
- July gamma Draconids (184 GDR)
- Anthelion Source (ANT)

20^h45^m – 21^h45^m. T_{eff}: 1.00, F: 1.00, Lm: 6.77, RA: 255, Dec: +20

- SPO: 8 meteors. +0, +3(3), +4(3), +6
- CAP: 1 meteor. +2
- SDA: 1 meteor. +4
- PER: 0 meteors.
- GDR: 0 meteors.
- ANT: 0 meteors.

21^h45^m – 22^h45^m. T_{eff}: 1.00, F: 1.00, Lm: 6.77, RA: 270, Dec: +20

- SPO: 6 meteors. –1, +0, +1, +2, +3, +5
- CAP: 1 meteor. +2
- SDA: 2 meteors. +2, +5
- PER: 1 meteor. +4
- GDR: 2 meteors. +4, +6
- ANT: 1 meteor. +2

22^h45^m – 23^h45^m. T_{eff}: 1.00, F: 1.00, Lm: 6.77, RA: 285, Dec: +20

- SPO: 4 meteors. +3, +5(2), +6
- CAP: 2 meteors. +1, +5
- SDA: 3 meteors. –1, +2, +4
- PER: 4 meteors. +1, +3(2), +5
- GDR: 0 meteors.
- ANT: 1 meteor. +3

23^h45^m – 00^h45^m. T_{eff}: 1.00, F: 1.00, Lm: 6.77, RA: 300, Dec: +20

- SPO: 8 meteors. +2(3), +3, +5(3), +6
- CAP: 1 meteor. +5
- SDA: 4 meteors. +2, +3, +5(2)
- PER: 4 meteors. –1, +3, +4, +5
- GDR: 1 meteor. +3
- ANT: 2 meteors. +3, +4

4 2022 July 25–26

The third night of observations from Agios Pavlos started as a warm and windless night, with a small hint of haze near the horizon. With a temperature of 28 degrees Celsius, there was no need for any extra clothes or sleeping bags during the observation. A very strange experience for an observer from the cold north! After an hour of observation, the severe wind gusts started to appear again, clearing the sky for the remaining haze, but making the problems with flying particles of sand alive again. I now decided to look for a more protected observing site the next night.

The activity level of the Southern delta Aquariids was about the same as last night, culminating with 4 meteors an hour, and two +0 Mag meteors as highlights. The Capricornids produced steady rates between 1 and 3, with a couple of meteors reaching +0 mag. Perseid activity reached 3 the last two hours, but with no meteor brighter than +2. After a dull start with only 3 sporadic meteors the first hour, rates improved and stabilized between 9 and 12 the next 3 hours. No candidates for the July gamma Draconids were seen this session.

A total of 63 meteors were seen in 4 hours of observing time. Of these were 33 SPO, 8 CAP, 11 SDA, 8 PER, and 3 ANT.

Observed showers:

- Alpha Capricornids (001 CAP)
- Southern delta Aquariids (005 SDA)
- Perseids (007 PER)
- July gamma Draconids (184 GDR)
- Anthelion Source (ANT)

20^h45^m – 21^h45^m. T_{eff}: 1.00, F: 1.00, Lm: 6,71, RA: 255, Dec: +20

- SPO: 3 meteors. +3, +4, +5
- CAP: 2 meteors. +0, +1

- SDA: 2 meteors. +2, +4
- PER: 0 meteors.
- GDR: 0 meteors.
- ANT: 0 meteors.

21^h45^m – 22^h45^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.77, RA: 270, Dec: +20

- SPO: 9 meteors. +1, +3(2), +4, +5(3), +6(2)
- CAP: 2 meteors. +4, +6
- SDA: 3 meteors. +0, +3, +5
- PER: 2 meteors. +2(2)
- GDR: 0 meteors.
- ANT: 1 meteor. +3

22h45^m – 23^h45^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.77, RA: 285, Dec: +20

- SPO: 12 meteors. +1, +2, +3(4), +4(5), +5
- CAP: 3 meteors. +1, +4(2)
- SDA: 2 meteors. +4, +5
- PER: 3 meteors. +3(2), +6
- GDR: 0 meteors.
- ANT: 0 meteors.

23^h45^m – 00^h45^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.77, RA: 300, Dec: +20

- SPO: 9 meteors. +1, +2(3), +4, +5(3), +6
- CAP: 1 meteor. +0
- SDA: 4 meteors. +0, +2, +3(2)
- PER: 3 meteors. +2(2), +3
- GDR: 0 meteors.
- ANT: 2 meteors. +4(2)

5 2022 July 26–27

Trying to avoid the problems with flying sand from the previous nights, I had found a rockier ground to make observation from. This fourth night of observation in my 2022 SDA campaign, started regardless out as calm and windless. The wind gusts were replaced by another nuisance named mosquitoes. Luckily, I was well prepared with a mosquito repellent deodorant in my pocket, which had to be used every hour to keep the mosquitoes away. The bats were also quite active this night, flying over my camping bed.

The Southern delta Aquariids started out as the previous nights, with rates approaching 4 the second hour. In the fourth hour a “burst” of activity occurred, with rates reaching 9, making out the first sign of rising activity towards the maximum. The meteors were on the faint side, with the brightest SDA being of magnitude +2. The Capricornids were also doing well with steady rates of 4, except for a dip to 1 in the third hour. A couple of bright Capricornids is worth mentioning. The first one being a yellow, slow moving, –2 magnitude CAP with fragments gliding into Ophiuchus. The second one was a bluish –2 magnitude in Andromeda. Perseid rates were as the previous nights, reaching 3 the last two hours with high radiant elevation. The sporadic rates climbed steadily from 6 the first hour, to 15 the last hour before dawn. At 22^h18^m UT a yellow, slow moving sporadic meteor of magnitude –1 glided into Aquarius. At 23^h20^m another yellow, slow moving meteor of magnitude –2 appeared in Bootes.

A total of 83 meteors were seen in 4 hours. Of these were 43 Sporadic, 13 CAP, 15 SDA, 8 PER, 1 GDR and 3 ANT.

Observed showers:

- Alpha Capricornids (001 CAP)
- Southern delta Aquariids (005 SDA)
- Perseids (007 PER)
- July gamma Draconids (184 GDR)
- Anthelion Source (ANT)

20^h45^m – 21^h45^m. T_{eff}: 1.00, *F*:1.00, *Lm*: 6.72, RA: 255, Dec: +20

- SPO: 6 meteors. +0, +3(2), +4, +5, +6
- CAP: 4 meteors. +1(2), +3, +4
- SDA: 0 meteors.
- PER: 0 meteors.
- GDR: 1 meteor. +3
- ANT: 0 meteors.

21^h45^m – 22^h45^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.77, RA: 270, Dec: +20

- SPO: 9 meteors. –1, +0, +2, +3(3), +4, +6(2)
- CAP: 4 meteors. –2, +0, +5(2)
- SDA: 4 meteors. +4(3), +5
- PER: 2 meteors. +1, +4
- GDR: 0 meteors
- ANT: 1 meteor. +5

22^h45^m – 23^h45^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.77, RA: 285, Dec: +20

- SPO: 13 meteors. –2, +2(3), +3(2), +4(3), +5(3), +6
- CAP: 1 meteor. +3
- SDA: 2 meteors. +4, +5
- PER: 3 meteors. +2(2), +6
- GDR: 0 meteors.
- ANT: 1 meteor. +5

23^h45^m – 00^h45^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.77, RA: 300, Dec: +20

- SPO: 15 meteors. –1, +1, +2, +3(4), +4(3), +5(4), +6
- CAP: 4 meteors. –2, +2, +4, +5
- SDA: 9 meteors. +2(2), +3(2), +4(4), +5
- PER: 3 meteors. +3, +4, +5
- GDR: 0 meteors.
- ANT: 1 meteor. +4

6 2022 July 27–28

Walking out to my fifth night of observations from Agios Pavlos, I was happy to see a clear and transparent sky, without the severe wind gusts that haunted me in some of the previous nights. I was eager to see if the SDA could keep up the rates that had started to climb in the last hour of the previous night. With the mosquitoes as my only annoyance, I was ready for four hours of hopefully rising meteor activity under an almost perfect night sky!

The first hour of observation hinted that the SDA had taken a leap in the activity level from the previous nights. 5 meteors were seen the first hour, with the radiant still quite low in the sky. The next three hours the rates increased further, with counts of 10, 9 and 11 respectively. A couple of bright meteors of magnitude –1 and +0 were also seen. The first hour also saw quite impressive CAP rates of 6, but declining throughout the night with rates of 3, 2 and 0 the last 3 hours. The Perseids were also quite active, with rates reaching 5 in the last hour with high radiant elevation. The best Perseid was a beautiful, yellow meteor that streaked into Pegasus at 22^h34^m UT. Sporadic rates between 9 and 16 added to the shower activity and kept me busy throughout the night!

A total of 110 meteors were seen in four hours of observation. Of these were 50 SPO, 11 CAP, 35 SDA, 11 PER, 1 GDR, and 2 ANT.

Observed showers:

- Alpha Capricornids (001 CAP)
- Southern delta Aquariids (005 SDA)
- Perseids (007 PER)
- July Gamma Draconids (184 GDR)
- Anthelion Source (ANT)

21^h00^m – 22^h00^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.77, RA: 270, DEC: +20

- SPO: 12 meteors. +0, +2, +3(3), +4(4), +5, +6(2)
- CAP: 6 meteors. +0, +1, +2(2), +3, +5
- SDA: 5 meteors. +1, +3, +4(2), +5
- PER: +2, +3
- GDR: 1 meteor. +2
- ANT: 1 meteor. +4

22^h00^m – 23^h00^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.77, RA: 285, DEC: +20

- SPO: 16 meteors. +0, +2(2), +3(3), +4(3), +5(5), +6(2)
- CAP: 3 meteors. +1(2), +4
- SDA: 10 meteors. +0, +1, +2, +3, +4(2), +5(2), +6(2)
- PER: 1 meteor. -1
- GDR: 0 meteors.
- ANT: 0 meteors.

23^h00^m – 00^h05^m. T_{eff}: 1.00 (5 minutes break), *F*: 1.00, *Lm*: 6.77, RA: 300, DEC: +20

- SPO: 9 meteors. +0, +2, +3, +4(4), +5, +6
- CAP: 2 meteors. +2, +4
- SDA: 9 meteors. –1, +1(2), +2, +3(3), +5(2)
- PER: 3 meteors. +3, +4, +5
- GDR: 0 meteors.
- ANT: +5

00^h05^m – 01^h05^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.77, RA: 315, DEC: +20

- SPO: 13 meteors. –1, +0, +1(2), +3, +4(4), +5(3), +6
- CAP: 0 meteors.
- SDA: 11 meteors. +1, +2(2), +3(2), +4(2), +5(2), +6(2)
- PER: 5 meteors. +3, +4, +5(3)
- GDR: 0 meteors.
- ANT: 0 meteors.

7 2022 July 28–29

My 6th night of observation started out with unusually high sporadic rates. The first hour I counted 17 sporadic meteors, and a high number of the meteors seemed to originate from the Cassiopeia region of the sky. The next hour the sporadic rates declined noticeably to 7, before they again rose to 15 and 11 the two last hours.

I was eager to see if the Southern delta Aquariids could keep up the good rates from the previous night but was a little disappointed to see rates of only 3 and 4 the two first hours. The next two hours rates were more comparable to the night before, with 10 and 8 meteors seen. Most of the Southern delta Aquariids seen this night were quite faint, with no meteors brighter than +1.

Like most of the previous nights, the Capricornids showed steady rates between 2 and 5, with a couple of nice +0 mag meteors. Except from this, most of the Capricornids seen this night was in the magnitude range +3 to +5.

The Perseids was a joy to observe this night with rates reaching 5 the two last hours, and with some nice meteors! At 23^h54^m UT a yellow –2 mag Perseid streaked into Draco, leaving a bright smoke train for about 5 seconds. Only 8 minutes later another yellow –2 mag Perseid flared up in Pegasus!

A total of 107 meteors were seen during 4 hours of observation this night. Of these were: 50 SPO, 13 CAP, 25 SDA, 13 PER, 4 GDR, and 2 ANT.

Observed showers:

- Alpha Capricornids (001 CAP)
- Southern delta Aquariids (005 SDA)
- Perseids (007 PER)
- July gamma Draconids (184 GDR)
- Anthelion Source (ANT)

21^h00^m – 22^h00^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.77, RA: 270, DEC: +20

- SPO: 17 meteors. +0, +1(2), +2(2), +3(2), +4(5), +5(4), +6
- CAP: 5 meteors. +0, +2, +3, +4, +5
- SDA: 3 meteors. +4, +5(2)
- PER: 0 meteors.

- GDR: 1 meteor. +2
- ANT: 0 meteors.

$22^h00^m – 23^h00^m$. T_{eff}: 1.00, F: 1.00, Lm: 6.77, RA: 285, DEC: +20

- SPO: 7 meteors. –1, +0, +1, +2, +3, +5, +6
- CAP: 2 meteors. +0, +4
- SDA: 4 meteors. +2, +4, +5, +6
- PER: 3 meteors. +1, +2, +4
- GDR: 1 meteor. +3
- ANT: 0 meteors.

$23^h00^m – 00^h00^m$. T_{eff}: 1.00, F: 1.00, Lm: 6.77, RA: 300, DEC: +20

- SPO: 15 meteors. +1(2), +2(3), +3(2), +4(3), +5(4), +6
- CAP: 4 meteors. +1, +3, 5(2)
- SDA: 10 meteors. +1, +3(4), +4(2), +5(2), +6
- PER: 5 meteors. –2, +2(2), +3, +6
- GDR: 0 meteors.
- ANT: +6

$00^h00^m – 01^h00^m$. T_{eff}: 1.00, F: 1.00, Lm: 6.77, RA: 315, DEC: +20

- SPO: 11 meteors. +2(2), +3(2), +4(5), +5(2)
- CAP: 2 meteors. +3, +6
- SDA: 8 meteors. +1, +2, +3(2), +4(2), +5(2)
- PER: 5 meteors. –2, +0(2), +5(2)
- GDR: 2 meteors. +3, +4
- ANT: 1 meteor. +3

8 2022 July 29–30

This was my 7th night in a row with observations from Agios Pavlos. The night was calm and warm, and I was excited to see if SDA activity would pick up as we were getting close to the expected maximum.

The session was up to a rather slow start, with only 8 meteors observed the first hour. Only 1 of these was considered to belong to the SDA shower. With rising radiant elevation, SDA rates reached 5 the next hour. I was hoping for some more action the last two hours, but rates came in at 8 and 7, with mainly faint meteors. It was interesting to note that this was the second night of declining SDA rates since the night of July 27–28!

The Capricornids showed steady rates of 2 to 3 meteors the 3 first hours, with a short, slow radiant meteor as a highlight. The last hour activity seemed to kick off, with 6 meteors counted, and a couple of bright meteors of mag –1 and +0!

It was also interesting to note the strong Perseid activity the last hour. 9 meteors were seen, among them a couple of nice +0 mag meteors! Together with a high sporadic rate of 16, this last hour kept me busy with 40 meteors altogether!

A total of 94 meteors were seen during 4 hours of observation this night. Among these were: 41 SPO, 14 CAP, 21 SDA, 14 PER, 1 GDR and 3 ANT.

Observed showers:

- Alpha Capricornids (001 CAP)
- Southern delta Aquariids (005 SDA)
- Perseids (007 PER)
- July gamma Draconids (184 GDR)
- Anthelion Source (ANT)

$21^h00^m – 22^h00^m$. T_{eff}: 1.00, F: 1.00, Lm: 6.77, RA: 270, DEC: +20

- SPO: 5 meteors. +2, +3, +4(2), +5
- CAP: 2 meteors. –1, +3
- SDA: 1 meteor. +5
- PER: 0 meteors.
- GDR: 0 meteors.
- ANT: 0 meteors.

$22^h00^m – 23^h00^m$. T_{eff}: 1.00, F: 1.00, Lm: 6.77, RA: 285, DEC: +20

- SPO: 9 meteors. +1(2), +2, +3, +4(3), +5(2)
- CAP: 3 meteors. +2(2), +5
- SDA: 5 meteors. +2, +3, +4(2), +5
- PER: 3 meteors. +2(2), +5
- GDR: 1 meteor. +2
- ANT: 0 meteors.

$23^h00^m – 00^h00^m$. T_{eff}: 1.00, F: 1.00, Lm: 6.77, RA: 300, DEC: +20

- SPO: 11 meteors. +2(2), +3(2), +4, +5(4), +6(2)
- CAP: 3 meteors. +2, +3, +4
- SDA: 8 meteors. +3(2), +4(3), +5(2), +6
- PER: 2 meteors. –1, +3
- GDR: 0 meteors.
- ANT: 1 meteor. +4

$00^h00^m – 01^h00^m$. T_{eff}: 1.00, F: 1.00, Lm: 6.77, RA: 315, DEC: +20

- SPO: 16 meteors. +1, +2(3), +3(5), +4(3), +5(3), +6
- CAP: 6 meteors. –1, +0, +2(2), +3, +5
- SDA: 7 meteors. +1, +2(2), +3, +4, +5, +6
- PER: 9 meteors. +0(2), +2(3), +4, +5(3)
- GDR: 0 meteors.
- ANT: 2 meteors. +0, +2

9 2022 July 30–31

Finally, the night I considered being the maximum of both the Southern delta Aquariids and the Capricornids had arrived! I had decided to do one more hour of observing, to follow the SDA activity into the morning sky. It was a calm and warm night with a transparent sky with a *Lm* of 6.77. After 2 nights of decreasing activity, I was wondering if the SDA could come up with some decent maximum rates!

I started out 15 minutes earlier than the previous night, with the SDA radiant still low in the sky. Only 2 SDA meteors were seen the first hour, but with rising radiant elevation, the meteors seemed to flow more frequently. The second hour gave the best rates so far during my SDA campaign, with 14 meteors seen. The third hour rates improved further to 19 meteors, with a beautiful, yellow, –1 magnitude SDA in Pegasus as a highlight! The fourth hour saw a noticeable drop-in activity to 10 meteors an hour, before increasing again to 15 meteors the last hour of observation. All in all, a decent SDA maximum, comparable to the observed activity seen under my SDA campaigns in 2017 and 2019.

In many ways the Capricornids stole the show this night! A very strong maximum was seen, with stable rates at a much higher level than the previous nights. The first hour of observation gave the best rate so far during the campaign, with 7 Capricornids seen. Rates continued to increase into the second hour, that ended with a record-breaking count of 10 meteors an hour! The third hour rates slid back to 6, but the shower was still keeping me busy with its characteristic, slow moving meteors. Well into the fourth hour, a stunning blue Capricornid with one giant flare, lit up the sky low in the star-rich area of the Milky Way. I find it hard to estimate such bright magnitudes, but I reported the meteor as a –6 mag. I was taking photographs with my DSLR camera, but the meteor was unfortunately slightly out of my 16mm camera field. Looking at the picture taken the moment the meteor appeared, the background color changes from black to light blue, lighted up by the final flare of the meteor outside of the camera field. The –6 estimate is probably too low, and may have been closer to the about –8? Another nice –1 mag CAP was seen this hour in Pegasus, and the hourly rate came in at 7 meteors. Only the final hour of the night, CAP rates fell to 3, with the radiant quite low in the sky.

Perseid rates were around 3 for most of the night, with the exception of the fourth hour, where 9 meteors were seen! The brightest Perseid this night was a +0-magnitude meteor in Pegasus. 2 nice sporadic meteors were also seen this night. The first one was a yellow slow-moving meteor with fragments low in the western sky. The second one was a yellow, fast moving –3 magnitude meteor in Aquila.

A total of 167 meteors were seen in 5.03 hours of observation. Of these were: 48 SPO, 33 CAP, 60 SDA, 20 PER, 1 GDR and 5 ANT.

Observed showers:

- Alpha Capricornids (001 CAP)
- Southern delta Aquariids (005 SDA)
- Perseids (007 PER)
- July gamma Draconids (184 GDR)
- Anthelion Source

20^h45^m – 21^h45^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.77, RA: 255, DEC: +20

- SPO: 6 meteors. +1(2), +2(3), +3
- CAP: 7 meteors. +1, +2(2), +3(2), +4, +5
- SDA: 2 meteors. +1, +5
- PER: 2 meteors. +1, +3
- GDR: 0 meteors.
- ANT: 1 meteor. +3

21^h45^m – 22^h45^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.77, RA: 270, DEC: +20

- SPO: 7 meteors. +2, +3(2), +4(2), +5, +6
- CAP: 10 meteors. +0(2), +1, +2(3), +4(2), +5(2)
- SDA: 14 meteors. +1(3), +2(2), +3(5), +4, +5(3)
- PER: 3 meteors. +2(2), +3
- GDR: 0 meteors.
- ANT: 2 meteors. +3, +5

22^h45^m – 23^h50^m. T_{eff}: 1.033 (3 minutes break), *F*: 1.00, *Lm*: 6.77, RA: 285, DEC: +20

- SPO: 11 meteors. –1, +1(2), +2(2), +3(2), +4, +5, +6(2)
- CAP: 6 meteors. +1, +2, +3(2), +5, +6
- SDA: 19 meteors. –1, +1, +2(4), +3(8), +4(3), +5(2)
- PER: 3 meteors. +0, +3, +5
- GDR: 0 meteors.
- ANT: 0 meteors.

23^h50^m – 01^h00^m. T_{eff}: 1.00 (10 minutes break), *F*: 1.00, *Lm*: 6.77, RA: 300, DEC: +20

- SPO: 9 meteors. –3, +0, +2, +3(2), +4(3), +5
- CAP: 7 meteors. –6, –1, +1, +2(2), +3(2)
- SDA: 10 meteors. +0, +2(2), +3(3), +5(2), +6(2)
- PER: 9 meteors. +1, +2(4), +3(3), +5
- GDR: 0 meteors.
- ANT: 2 meteors. +1, +3

01^h00^m – 02^h00^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.65, RA: 315, DEC: +20

- SPO: 15 meteors. –1, +0, +2(4), +3(2), +4(4), +5, +6(2)
- CAP: 3 meteors. +1, +3, +4
- SDA: 15 meteors. +1(2), +2(3), +3(2), +4(5), +5(2), +6
- PER: 3 meteors. +3, +4(2)
- GDR: 1 meteor. +3
- ANT: 0 meteors.

10 2022 July 31– August 01

After doing observations for 8 nights in a row, I was starting to dream about a full night of sleep, but that would have to wait for a couple of more nights! Again, the night was calm and clear with a very transparent sky with *Lm* 6.8. Soon the meteors started to flow, and I was in for another 5 hours of observations under excellent conditions.

It soon became clear that the Capricornids were less active than the previous night which yielded surprisingly high rates. Between 2 and 4 Capricornids could still be counted every hour throughout the night. No fireballs were seen from the shower this night, and most meteors were in the magnitude range between +2 and +5.

The Southern delta Aquariids still produced good rates between 7 and 12 meteors an hour, except for the first hour when the radiant was low in the sky. I soon noticed that the shower was richer in bright meteors than the previous nights. A beautiful, yellow –2 mag SDA was seen low in the eastern sky at 01^h19^m UT. Also 4 more meteors in the magnitude range –1 to +0 were seen during the night.

The Perseids produced stable rates around 5 throughout the night, with the exception of the first hour. A stunning, yellow, –2 mag in Cygnus was a memorable moment at 00^h19^m UT. The sporadic rates varied between 7 and 11 most of the night but peaking with a rocketing 18 meteors an hour in the morning sky!

A total of 134 meteors were seen during 5 hours of observation this night. Of these were: 52 SPO, 16 CAP, 40 SDA, 21 PER, 1 GDR, and 4 ANT.

Observed showers:

- Alpha Capricornids (001 CAP)
- Southern delta Aquariids (005 SDA)
- Perseids (007 PER)
- July gamma Draconids (184 GDR)
- Anthelion Source (ANT)

20^h45^m – 21^h45^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.80, RA: 285, DEC: +20

- SPO: 11 meteors. +0, +1(2), +2, +3(4), +4, +5(2)
- CAP: 3 meteors. +3, +4, +5
- SDA: 1 meteor. +3
- PER: 2 meteors. +3(2)
- GDR: 0 meteors.
- ANT: 1 meteor. +2

21^h45^m – 22^h45^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.80, RA: 300, DEC: +20

- SPO: 7 meteors. +0, +1, +2(2), +3, +4(2)
- CAP: 2 meteors. +1, +2
- SDA: 7 meteors. –1, +1, +3, +4(2), +5(2)
- PER: 5 meteors. +2(2), +4(2), +6
- GDR: 1 meteor. +0
- ANT: 1 meteor. +4

22^h45^m – 23^h45^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.80, RA: 315, DEC: +20

- SPO: 9 meteors. +1, +2(3), +3(2), +4(3)
- CAP: 3 meteors. +1, +2, +4
- SDA: 11 meteors. +0(2), +2(3), +3, +4(2), +5(3)
- PER: 5 meteors. +1, +2, +5(2), +6
- GDR: 0 meteors.
- ANT: 0 meteors.

23^h45^m – 00^h55^m. T_{eff}: 1.00 (10 minutes break), *F*: 1.00, *Lm*: 6.80, RA: 330, DEC: +15

- SPO: 7 meteors. +2, +3(2), +4, +5(3)
- CAP: 4 meteors. +3, +4, +5(2)
- SDA: 9 meteors. +1, +2(2), +3(2), +4(2), +5, +6
- PER: 4 meteors. –2, +1, +3, +5
- GDR: 0 meteors.
- ANT: 1 meteor. +0

00^h55^m – 01^h55^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.70, RA: 345, DEC: +15

- SPO: 18 meteors. +0, +1, +2(2), +3(5), +4(3), +5(4), +6(2)
- CAP: 4 meteors. +0, +2, +5(2)
- SDA: 12 meteors. –2, –1, +1, +2(3), +3(2), +4(3), +5
- PER: 5 meteors. +2(2), +3, +4(2)
- GDR: 0 meteors.
- ANT: 1 meteor. +3

11 2022 August 1– 2

My final night with observations from Agios Pavlos, emerged as a calm and clear night with very transparent sky! The observation started out with good sporadic activity, and only 5 minutes into the observation a brilliant, yellow –2 mag Capricornid with fragments and a final flare, glided into Ophiuchus. 4 more Capricornids were seen the first hour, before the rates stabilized around 3 for the rest of the night.

The Southern delta Aquariids showed a modest rate of 2 the first two hours. The next three hours with higher radiant elevation gave counts of 7, 12, and 6 respectively. The meteors were not so bright as the previous night, but still some nice +0 and +1 mags were seen.

The Perseids showed variable activity between 0 and 5 throughout the night, with a couple of nice +0 mag meteors seen.

This was my first night including the kappa Cygnid radiant. One obvious candidate of mag +2 was seen at 23^h55^m UT, as it slowly glided from a radiant north in Lyra into Cygnus. Stable sporadic rates between 8 and 15 meteors persisted throughout the night.

This concludes my observations from Agios Pavlos with 10 nights of observation in a row. It was now time to have some rest and enjoy the sun the last days of my vacation, although it was very hard to leave the beautiful night sky alone for the remaining time in Crete.

A total of 123 meteors were seen during 5 hours of observation this night. Of these were: 55 SPO, 16 CAP, 29 SDA, 14 PER, 0 GDR, 1 KCG, and 8 ANT.

Observed showers:

- Alpha Capricornids (001 CAP)
- Southern delta Aquariids (005 SDA)
- Perseids (007 PER)
- July gamma Draconids (184 GDR)
- kappa Cygnids (012 KCG)

- Anthelion Source (ANT)

20^{h}45^m – 21^{h}45^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.80, RA: 285, DEC: +20

- SPO: 10 meteors. +1, +2(2), +3(3), +4, +5(2), +6
- CAP: 5 meteors. –2, +1, +3(2), +4
- SDA: 2 meteors. +2, +3
- PER: 0 meteors.
- GDR: 0 meteors
- KCG: 0 meteors.
- ANT: 2 meteors. +2, +3

21^{h}45^m – 22^{h}45^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.80, RA: 300, DEC: +20

- SPO: 9 meteors. +1, +2(2), +3(3), +4, +6(2)
- CAP: 3 meteors. +4(3)
- SDA: 2 meteors. +1, +4
- PER: 5 meteors. +0, +1, +3, +4, +5
- GDR: 0 meteors.
- KCG: 0 meteors
- ANT: 1 meteor. +3

22^{h}45^m – 23^{h}45^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.80, RA: 315, DEC: +20

- SPO: 8 meteors. +0, +1, +2, +4, +5(3), +6
- CAP: 3 meteors. +1, +2, +3
- SDA: 7 meteors. +0, +1, +2, +3, +4(2), +5
- PER: 1 meteor. +3
- GDR: 0 meteors.
- KCG: 0 meteors
- ANT: 1 meteor. +5

23^{h}45^m – 00^{h}55^m. T_{eff}: 1.00 (10 minutes break), *F*: 1.00, *Lm*: 6.80, RA: 330, DEC: +15

- SPO: 15 meteors. +0(2), +1, +2(3), +3(3), +4(4), +5, +6
- CAP: 3 meteors. +3, +4(2)
- SDA: 12 meteors. +1(2), +2(3), +3(2), +4, +5(3), +6
- PER: 3 meteors. +2, +4(2)
- GDR: 0 meteors.
- KCG: 1 meteor. +2
- ANT: 1 meteor. +1

00^{h}55^m – 01^{h}55^m. T_{eff}: 1.00, *F*: 1.00, *Lm*: 6.70, RA: 345, DEC: +15

- SPO: 13 meteors. +2, +3(5), +4(3), +5(3), +6
- CAP: 2 meteors. +0, +5
- SDA: 6 meteors. +2(3), +3, +4(2)
- PER: 5 meteors. +0, +2(2), +4, +5
- GDR: 0 meteors.
- KCG: 0 meteors.
- ANT: 3 meteors. +1(2), +4

June 2022 report CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month of June 2022 is presented. 14179 meteors were registered of which 7739 multiple-station events, resulting in 2228 orbits. June 2022 was the second best month of June in the 11 years of the network.

1 Introduction

The first weeks of June display very low meteor activity while we get the shortest nights of the year with between 7 hours and less than 6 hours of capture time. Therefore, no spectacular numbers of orbits are to be expected. Collecting orbits under these circumstances remains a challenge. What did June 2022 bring us?

2 June 2022 statistics

June is the most difficult month for CAMS BeNeLux because of the short observing window of barely 5 to 6 hours dark sky each night. June 2022 was an exceptionally favorable month for astronomy with many clear nights and nights with partial clear sky. 14179 meteors were registered, 7739 of which were multi-station events good for 2228 orbits. Not a single night remained without any orbits (8 without orbits in June 2021, 3 in June 2020). Ten nights resulted in more than 100 orbits in spite of the short duration of these nights (3 in June 2021, 8 in June 2020). This is an excellent result but not as good as in 2019 when 13 nights had more than 100 orbits and two nights had even more than 200 orbits. The best night for June 2022 was June 27–28 with 182 orbits. The statistics for June 2022 are compared in *Figure 1* and *Table 1* with the same month in previous years since the start of CAMS BeNeLux in 2012.

Table 1 – June 2022 compared to previous months of June.

Year	Nights	Orbits	Stations	Max. Cams	Min. Cams	Mean Cams
2012	0	0	4	0	–	0.0
2013	16	102	9	12	–	7.0
2014	23	379	13	31	–	19.0
2015	20	779	15	44	–	32.9
2016	18	345	17	50	15	35.7
2017	26	1536	19	66	30	52.1
2018	28	1425	21	78	52	64.9
2019	28	2457	20	84	63	75.6
2020	27	1834	24	93	60	83.1
2021	22	1389	26	81	54	73.3
2022	30	2228	30	94	74	85.2
Total	238	12474				

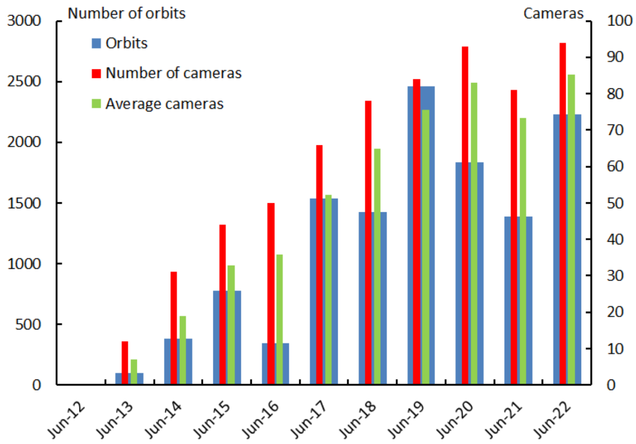

Figure 1 – Comparing June 2022 to previous months of June in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the green bar the average number of cameras running per night.

During the best nights 94 cameras were operational (81 in June 2021 and 93 in 2020). Thanks to Auto-CAMS for Watecs and the fully automated RMS cameras, at least 74 cameras were all nights operational (54 in 2021 and 60 in 2020). On average 85.2 of all available cameras were active, which is much better than the 73.3 of last year.

A new 6mm RMS camera (3824) got operational at the observatory "De Polderster" at Boekhoute on 11 June. Unfortunately, 8 nights later a local problem with the electric power made its sd-card crash as well as that of its twin RMS camera (3823) which was already operational since April. A British 4mm RMS camera (UK0004) operated by Jim Rowe in Eastbourne started to deliver data to CAMS BeNeLux since 21 June with CAMS id 3829.

The total number of orbits collected for the month of June since 2012 reached 12474 in 238 nights of June that allowed to collect orbits. This way the month of June remains the poorest month of the year in number of orbits collected for CAMS BeNeLux, mainly because of the short duration nights. But it isn't bad when compared to January for which we got 13083 orbits collected in spite of much longer nights and more rich meteor activity. So far, June counts already 7 calendar nights with more 500 orbits collected.

Table 2 – The twenty cameras of the CAMS BeNeLux network with the best score in terms of orbits during the month of June 2022, with the scores within GMN for the RMS cameras.

Camera	Total orbits CAMS	Total orbits GMN	Total nights
Dourbes (RMS 003825)	282	294	30
Humain (RMS 003821)	280	270	30
Lesve (RMS 003826)	253	190	30
Grapfontaine (RMS 003814)	200	132	30
Lesve (RMS 003816)	180	117	30
Zillebeke (RMS 003853)	176	101	30
Zillebeke (RMS 003851)	151	106	30
Grapfontaine (RMS 003817)	148	174	30
Zoersel (RMS 003827)	140	116	30
Mechelen (003837)	134	–	30
Genk (RMS 003818)	130	76	30
Mechelen (003891)	130	–	29
Zoersel (000805)	128	–	30
Zoersel (000806)	123	–	30
Wilderen (000380)	120	–	30
Genk (RMS 003819)	119	146	30
Grapfontaine (000814)	116	–	29
Grapfontaine (000815)	116	–	29
Mechelen (003834)	116	–	30
Mechelen (RMS 003831)	115	83	30

With comparable weather in 2022, we concluded June with about 10% less orbits than in 2019 although we had 10 cameras more than in 2019. The most likely explanation for this is that since a while the CAMS trajectory solver, Coincidence, rejects all meteors detected lower than 25° above the horizon. The reason for this blind cut-off is to reduce the number of poor triangulations due to large distances between the cameras and meteors although this also rejects the good triangulations at lower altitude. With the RMS cameras we see that the GMN trajectory solver in general rejects more combinations than CAMS but still has a reasonable number of good quality triangulations at lower than 25° elevation. Since the CAMS trajectory solver is less advanced than that of GMN, it was decided to reject all low altitude meteors as CAMS cannot handle these properly.

The Belgian part of the network got 10 new RMS cameras installed since summer 2021 to improve the coverage on this region. Looking at the scores in terms of orbits for all cameras, the RMS cameras outnumber the Watecs in numbers of paired meteors (see *Table 2*). With a larger field of view, better astrometric calibration and a superior detection algorithm, the RMS cameras are a real game changer. The scores in the GMN for the RMS cameras are listed in *Table 2* for comparison. CAMS Watec data is not accepted by GMN because the quality does not meet the GMN standards. With about half of the Dutch camera station not functioning each night, the epicentrum of the network moved south. The June 2022 trajectories can be visualized on MeteorMap[29].

3 Conclusion

June 2022 was an excellent month for CAMS BeNeLux with the second-best score in number of orbits after 2019.

Acknowledgment

The data on which this report is based has been taken from the CAMS website[30]. The CAMS BeNeLux team was operated by the following volunteers during June 2022: *Hans Betlem* (Woold, CAMS 3071, 3072 and 3073), *Jean-Marie Biets* (Wilderen, Belgium, CAMS 379, 380, 381 and 382), *Ludger Boergerding* (Holdorf, Germany, RMS 3801), *Günther Boerjan* (Assenede, Belgium, RMS 3823 and 3824), *Martin Breukers* (Hengelo, Netherlands, CAMS 320, 321, 322, 323, 324, 325, 326 and 327, RMS 319, 328 and 329), *Seppe Canonaco* (Genk, RMS 3818, RMS 3819), *Pierre de Ponthiere* (Lesve, Belgium, RMS 3816 and 3826), *Bart Dessoy* (Zoersel, Belgium, CAMS 397, 398, 804, 805, 806, 888 and RMS 3827), *Tammo Jan Dijkema* (Dwingeloo, Netherlands, RMS 3199), *Isabelle Ansseau*, *Jean-Paul Dumoulin*, *Dominique Guiot* and *Christian Walin* (Grapfontaine, Belgium, CAMS 814 and 815, RMS 3814, RMS 3817), *Uwe Glässner* (Langenfeld, Germany, RMS 3800), *Luc Gobin* (Mechelen, Belgium, CAMS 3890, 3891, 3892 and 3893), *Tioga Gulon* (Nancy, France, CAMS 3900 and 3901), *Robert Haas* (Alphen aan de Rijn, Netherlands, CAMS 3160, 3161, 3162, 3163, 3164, 3165, 3166 and 3167), *Robert Haas* (Texel, Netherlands, CAMS 810,811, 812, 813), *Robert Haas* (Burlage, Germany, RMS 3803, 3804), *Kees Habraken* (Kattendijke, Netherlands, RMS 378), *Klaas Jobse* (Oostkapelle, Netherlands, CAMS 3030, 3031, 3032, 3033, 3034, 3035, 3036 and 3037), *Carl Johannink* (Gronau, Germany, CAMS 3100, 3101, 3102, 3103 and 3104), *Reinhard Kühn* (Flatzby, Germany, RMS 3802), *Hervé Lamy* (Dourbes, Belgium, CAMS 394 and 395, RMS 3825), *Hervé Lamy* (Humain Belgium, CAMS 816, RMS 3821), *Hervé Lamy* (Ukkel, Belgium, CAMS 393), *Koen Miskotte* (Ermelo, Netherlands, CAMS 3051 and 3052), *Jos Nijland* (Terschelling, Netherlands, CAMS 841, 842, 844), *Tim Polfliet* (Gent, Belgium, CAMS 396, RMS 3820), *Steve Rau* (Zillebeke, Belgium, CAMS 3850, 3852, RMS 3851, RMS 3853), *Paul* and *Adriana Roggemans* (Mechelen, Belgium, RMS 3830 and 3831, CAMS 3832, 3833, 3834, 3835, 3836 and 3837), *Jim Rowe* (Eastbourne, UK, RMS 3829), *Hans Schremmer* (Niederkruechten, Germany, CAMS 803), *Erwin van Ballegoij* (Heesch, Netherlands, CAMS 3148).

[29] https://tammojan.github.io/meteormap/cams?
[30] http://cams.seti.org/FDL/index-BeNeLux.html

July 2022 report CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month of July 2022 is presented. July 2022 allowed to register 29558 meteors of which 15972 multiple-station meteors, with a total number of 4499 orbits. A maximum of 100 cameras was operational at 30 camera stations during this month.

1 Introduction

Although a summer month, the weather in July is often unfavorable for astronomy in the BeNeLux area. The short nights with only about 6 hours of observing time are easily ruined by bad weather. The overall meteor activity increases significantly during this month with some well-established showers late July while Perseid activity becomes clearly visible. July 2018, 2019, and 2020 were all excellent months of July for our CAMS network, July 2021 was a very poor month. What would July 2022 bring?

2 July 2022 statistics

CAMS BeNeLux collected 29558 meteors of which 15972 were multi-station meteors, good for 4499 orbits (against 7125 multi-station meteors and 2525 orbits in July 2021). This is with distance the very best month of July ever for the network.

July 2022 brought plenty of clear nights while July 2021 got only few complete clear nights. Not a single night had zero orbits, while last two years July had each year three nights ending without any single orbit. 24 nights had more than 100 orbits (11 in 2021, 14 in 2020), 9 nights had more than 200 orbits (2 in 2021, 6 in 2020). July 29–30 was the most successful night with 385 orbits, which is still much less than the record July night of 30–31 July 2020 with 542 orbits or July 29–30 in 2019 with 504 orbits. The statistics of July 2022 are compared in *Figure 1* and *Table 1* with the same month in previous years since the start of CAMS BeNeLux in 2012. In 11 years, 278 July nights allowed to obtain orbits with a grand total of 25487 orbits collected during this month in all these years.

A new RMS camera (BE000D) has been installed by Steve Rau at Astropolis in Ostend, Belgium. The status of the network improved a lot compared to July 2021 when as many as 25 cameras at several CAMS stations in the Netherlands and Germany were not available for various reasons. In a video camera network, the success of each participant depends on the availability and goodwill of all others involved in order to obtain multi-station events. When a number of camera locations have no cameras running, this reduces the number of paired meteors.

A record number of 100 cameras were operational at best with on average 91.7 operational cameras and a minimum of 80. With more cameras available than ever before in July and exceptional good weather, a record number of meteors and orbits were obtained, although meteors detected below 25° were still taken into account in previous years but rejected by CAMS since 2022.

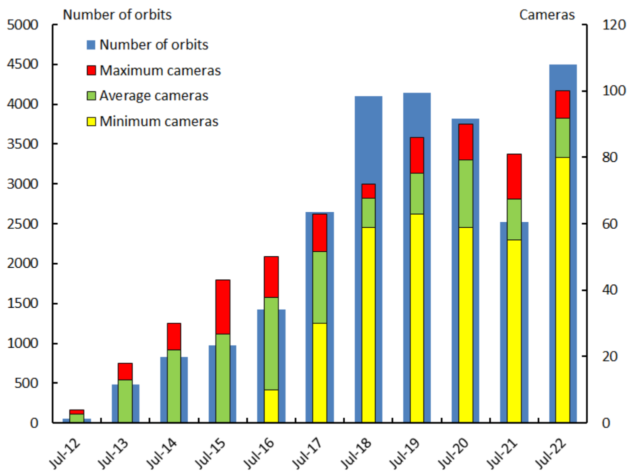

Figure 1 – Comparing July 2022 to previous months of July in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras capturing in a single night, the green bar the average number of cameras capturing per night and the yellow bar the minimum number.

Table 1 – July 2022 compared to previous months of July.

Year	Nights	Orbits	Stations	Max. Cams	Min. Cams	Mean Cams
2012	7	49	4	4	–	2.6
2013	22	484	10	18	–	12.9
2014	19	830	14	30	–	22.0
2015	28	976	15	43	–	26.7
2016	28	1420	18	50	10	37.9
2017	27	2644	20	63	30	51.6
2018	30	4098	19	72	59	67.7
2019	30	4139	21	86	63	75.2
2020	28	3823	24	90	59	79.1
2021	28	2525	27	81	55	67.3
2022	31	4499	30	100	80	91.7
Total	278	25487				

Table 2 lists the 20 best performing cameras in the network in terms of orbits. Note the scores of the RMS cameras. Note the difference in scores between CAMS and GMN, with the GMN trajectory rejecting more unfavorable geometrics than CAMS, but not blindly rejecting everything below 25° elevation.

Table 2 – Comparing RMS cameras among the twenty cameras of the CAMS BeNeLux network with the best score in terms of orbits during July 2022.

Camera	Orbits CAMS	Nights CAMS	Orbits GMN
003825 RMS, Dourbes, B	695	30	643
003821 RMS, Humain, B	690	30	665
003826 RMS, Lesve, B	561	31	403
003814 RMS, Grapfontaine, B	531	31	336
003853 RMS, Zillebeke, B	413	31	271
003816 RMS, Lesve, B	379	30	233
003817 RMS, Grapfontaine, B	376	31	522
003851 RMS, Zillebeke, B	296	31	225
003827RMS, Zoersel, B	275	31	226
003818 RMS, Genk, B	271	31	126
003819 RMS, Genk, B	269	31	329
003833 Watec, Mechelen, B	261	31	–
000805 Watec, Zoersel, B	258	31	–
003837 Watec, Mechelen, B	245	31	–
000814 Watec, Grapfontaine, B	243	31	–
003834 Watec, Mechelen, B	241	31	–
003832 Watec, Mechelen, B	232	31	–
000395 Watec, Dourbes, B	230	31	–
000815 Watec, Grapfontaine, B	230	30	–
003890 Watec, Mechelen, B	229	29	–

3 Conclusion

July 2022 became the most successful month of July in the CAMS BeNeLux history with a record number of meteors recorded and orbits obtained.

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

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