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Fireball recorded on 2024 April 14 at 0h35m21.0 ± 0.1s UT from the Calar Alto astronomical observatory. (credit: José Madiedo).

- Outburst of September psi-Cassiopeiids
- New meteor shower in Ursa Minor
- Meteor visualizing tool Meteorview
- MetLab software
- CAMS reports
- CARMELO report
- SWEMN fireball reports
- Dust trails of fireballs

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Contents

Possible new meteor shower in Ursa Minor

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A possible new meteor shower has been discovered on September 24, 2024 (at $\lambda_O = 181.9°$) by Belarusian and Ukrainian video meteor networks. The radiant at α = 238.4° and δ = +77.4° is situated in Ursa Minor, with a geocentric velocity v_g of 31.1 ± 1.1 km/s.

1 Observations

During the night of 24–25 September 2024, the Belarusian Meteor Network recorded activity from an unidentified radiant in the constellation of Ursa Minor near the star ζ UMi. Three paired meteors with very nearby radiants were captured. A day later, data from this night came from our Ukrainian colleague Alex Angelsky, who brought one more paired meteor. *Figure 2* shows images of all 4 meteors, which had a medium angular velocity and absolute magnitudes in the range –0.51m to +0.6m. All meteors were registered within the interval in solar longitude of 181.7996° to 182.0316°.

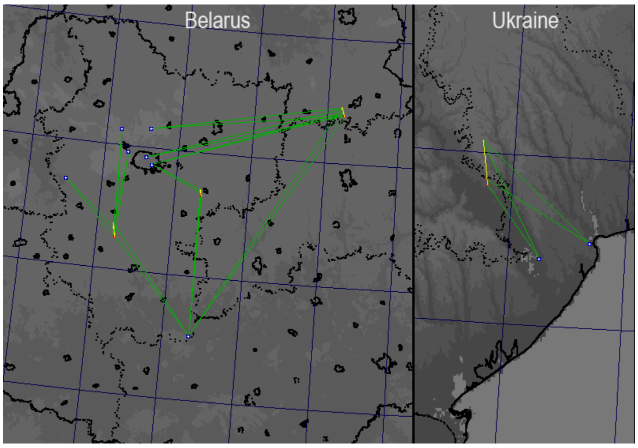

Figure 1 – Meteor trajectories from this unknown radiant in projected on the Earth's surface.

Figure 1 shows the projection of meteors onto the Earth's surface, two of these meteors were captured by four stations at once.

2 Results

The data were processed in UFOOrbit[1] (SonotaCo). *Table 1* shows the calculated individual parameters for each meteor on September 24, 2024.

The radiant parameters and orbital elements averaged for the four meteors are as follows:

- λ_O = 181.9261° ± 0.1226°
- α_g = 238.37° ± 1.32°
- δ_g = +77.35° ± 0.15°
- v_g = 31.08 ± 1.12 km/s
- a = 2.73 ± 0.41 AU
- q = 0.996 ± 0.001 AU
- e = 0.629 ± 0.055
- ω = 168.735° ± 0.676°
- Ω = 181.926° ± 0.123°
- i = 52.83° ± 1.39°

Figure 2 – Four meteors from the possible new meteor shower recorded during the night of 24–25 September 2024.

[1] www.sonotaco.com

Table 1 – The orbital parameters of the four meteors recorded from the possible new meteor shower.

Time, UT	$\lambda_\odot$	Mag_A	α_g	δ_g	λ_g	β_g	v_g	a	q	e	ω	Ω	i
17:09:52	181.80	0.59	238.74	77.14	118.45	75.97	29.65	2.261	0.9953	0.56	168.15	181.80	51.04
18:12:48	181.84	-0.51	237.76	77.46	117.81	75.62	32.37	3.263	0.9954	0.695	168.99	181.84	54.38
22:49:41	182.03	-0.01	240.02	77.45	116.72	76.03	30.99	2.663	0.9966	0.626	169.58	182.03	52.72
22:50:50	182.03	-0.11	236.95	77.33	118.6	75.53	31.31	2.722	0.9947	0.635	168.23	182.03	53.18

Figure 3 shows the distribution of the radiants at the celestial sphere near the star ζ UMi.

It should be noted that 6 degrees north of the unidentified meteor shower is the radiant of the minor meteor shower epsilon-Ursae Minorids (EPU), which was expected to have its maximum activity on this night according to the IAU MDC data[2]. It can be assumed that the new source may be dynamically related to the epsilon-Ursae Minorids.

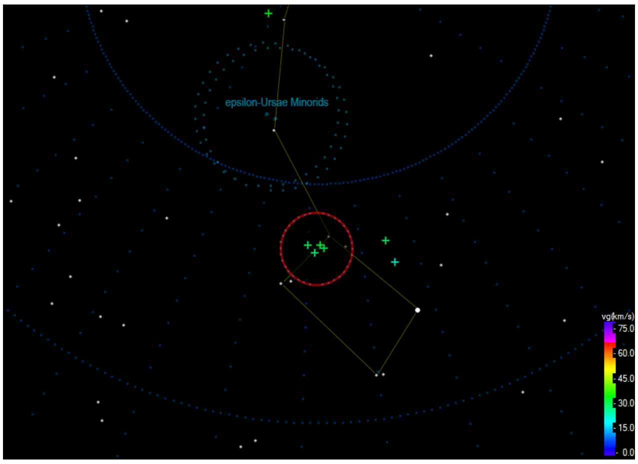

Figure 3 – Distribution of the radiants at the celestial sphere. The red circle indicates the radiant area of the possible new meteor shower.

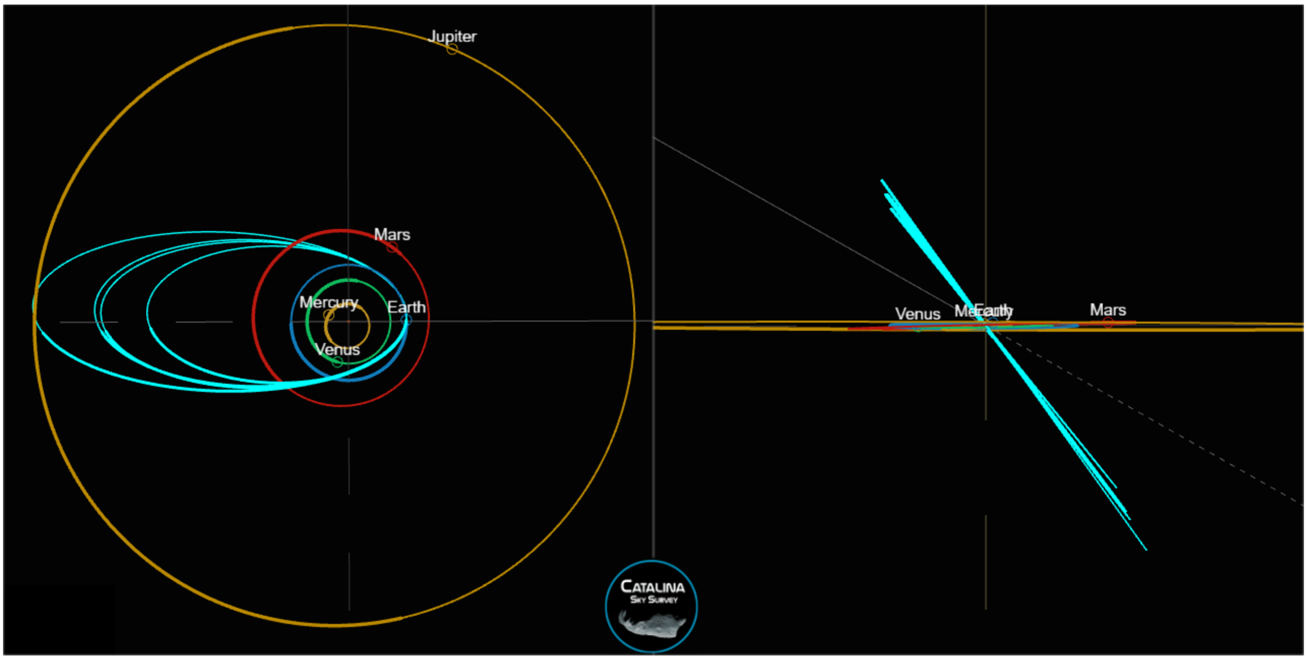

Figure 4 – The orbits of the meteoroids. The plotting of the orbits was made using the CSS Orbit View application[3].

Acknowledgment

The author would like to thank all operators and people involved in the Belarusian and Ukrainian meteor networks. We would especially like to thank our Ukrainian colleagues who continue to be involved in meteor astronomy during this difficult time for Ukraine. The author would also like to thank *Paul Roggemans* for his help in writing this report.

[2] https://www.ta3.sk/IAUC22DB/MDC2022/Roje/roje_lista.php?corobic_roje=0&sort_roje=0

[3] https://catalina.lpl.arizona.edu/css-orbit-view

2024 outburst of September psi-Cassiopeiids

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A meteor outburst was detected by low-light level video camera networks in Arizona and California on September 4, 2024. The outburst was of short duration. Past data show a weak annual shower at these coordinates, which stands out from the nearby sporadic meteors by having a slightly lower entry speed. The shower was in outburst before in 2014.

1 Introduction

Now the main annual showers have mostly been mapped (e.g., Jenniskens, 2023), ongoing meteoroid orbit surveys by low-light video camera networks aim to document unusual meteor shower activity. One such unexpected meteor outburst with a radiant in the constellation Cassiopeia was detected on 2024 September 4. The provisional name for the shower proposed here is September psi-Cassiopeiids (SPC).

2 Observations

The CAMS California network is managed by station operators *Eric Egland* (Fremont Peak Observatory), *Jim Albers* (Sunnyvale), *Bryant Grigsby* (Lick Observatory), *Jim Wray* (Foresthill), and *Tim Beck* (Windsor, Ukiah, and Kelseyville). The Windsor station was recently moved to a new location in Cotati, just south of Santa Rosa. At the time of the outburst, the Fremont Peak Observatory station was down for maintenance.

The Lowell Observatory CAMS network (LO-CAMS) consists of four stations at Lowell Observatory in Flagstaff, at the Lowell Discovery Telescope, at the Meteor Crater (*Nick Moskovitz*, *Sam Hemmelgarn*), and at the Embry Riddle Aeronautical University (ERAU) in Prescott. The ERAU CAMS station, operated by *Brian Rachford*, is down at the moment awaiting repairs. In addition, there are several 6-camera Global Meteor Network stations in the LO-CAMS network, located at Lowell Observatory and the Lowell Discovery Telescope (*Nick Moskovitz*, *Sam Hemmelgarn*), Prescott (*Megan Gialucca*), Window Rock (*Rob Schottland*), Sunizona (*Matt Francis*), Pine Top (*John Glitsos*), and Holbrook (*Bob Broffel*). These also report to the CAMS server.

The astrometry submitted to the CAMS server was downloaded and triangulated using the Coincidence software written by *Pete Gural*. The radiant positions are posted at the website4, as well as at the CAMS daily operations website.

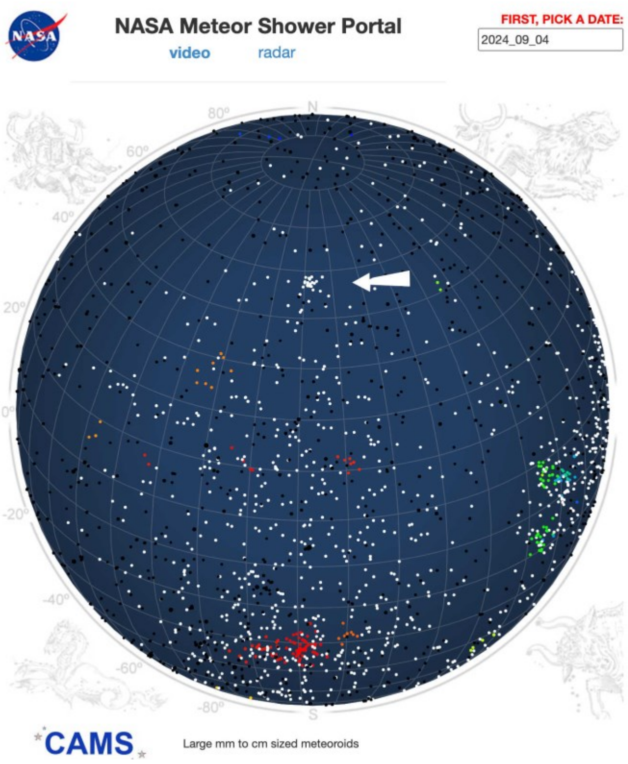

Figure 1 – CAMS daily shower map of 2024 September 4 (at the CAMS website[5]) with the meteor outburst marked by an arrow.

3 Results

The daily map for September 4 showed a distinct cluster of meteors in the northern apex source (*Figure 1*). The surface density of triangulated radiants is about 0.59 per square degree over the 4-degree diameter area surrounding the radiant, while the average sporadic background surface density in the northern apex region over the 20-degree diameter area surrounding but outside of that radiant is about 0.01 radiant per square degree. After isolating the orbits from the shower in radiant and speed, and removing one double report of what appears to be the same meteor, it was found that nine meteors of this previously unknown shower were triangulated by LO-CAMS and four meteors by CAMS California.

[4] https://meteorshowers.seti.org

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

Table 1 – The median orbital elements of the newly detected shower (Equinox J2000.0).

	September psi-Cassiopeiids 2024	September psi-Cassiopeiids 2014
$\lambda_\odot$ (°)	162.104 ± 0.005	162.11 ± 0.07
α_g (°)	20.6 ± 0.6	25.6 ± 0.7
δ_g (°)	+73.5 ± 0.2	+73.7 ± 0.2
v_g (km/s)	46.4 ± 0.3	45.9 ± 0.3
$\lambda - \lambda_\odot$ (°)	258.6 ± 0.3	260.6 +- 0.3
β (°)	+57.2 ± 0.2	+56.2 ± 0.2
a (AU)	5.3 ± 0.4	3.33 ± 0.29
q (AU)	0.987 ± 0.001	0.992 ± 0.001
e	0.812 ± 0.018	0.702 ± 0.018
ω (°)	197.8 ± 0.5	195.8 ± 0.5
Ω (°)	162.07 ± 0.04	162.11 ± 0.07
i (°)	82.4 ± 0.3	83.5 ± 0.3
Π (°)	359.6 ± 0.5	358.1 ± 0.5
T_j	1.15 ± 0.10	1.71 ± 0.10
N	13	11

The shower was of short duration. Based on these orbits, the shower was active between solar longitude 161.88 and 162.14 degrees (Equinox J2000), apparently centered on 162.104 degrees, with activity possibly continuing past morning twilight. The times of detection on September 4 were at 06^h25^m, 07^h01^m, 8^h21^m, 9^h28^m, 9^h35^m, 10^h27^m, 10^h55^m, 11^h42^m, 11^h53^m, 11^h55^m, 11^h58^m, 12^h06^m and 12^h42^m UTC. LO-CAMS observed from 2^h49^m to 12^h19^m UTC, during which a total of 432 meteors were triangulated, while CAMS California observed from 3^h09^m to 12^h51^m UTC, during which 86 meteors were triangulated.

Table 1 presents the median orbital elements and the standard error that defines the uncertainty of the median value. The geocentric radiant and speed are given, as well as the orbital elements in equinox J2000. The dispersion of the measured radiant and speed (including measurement errors) are ±2.2 deg in R.A., ±0.6 deg in Dec, and ±0.9 km/s in v_g.

The radiant is significantly further south from that of the episodic kappa-Cygnids at this time of year, which also did not return this year. The radiant is also significantly east of the diffuse shower 523, the August delta-Cepheids at R.A. = 358.9°, Decl. = +76.7°, peaking on August 28 (Jenniskens, 2023, p. 307).

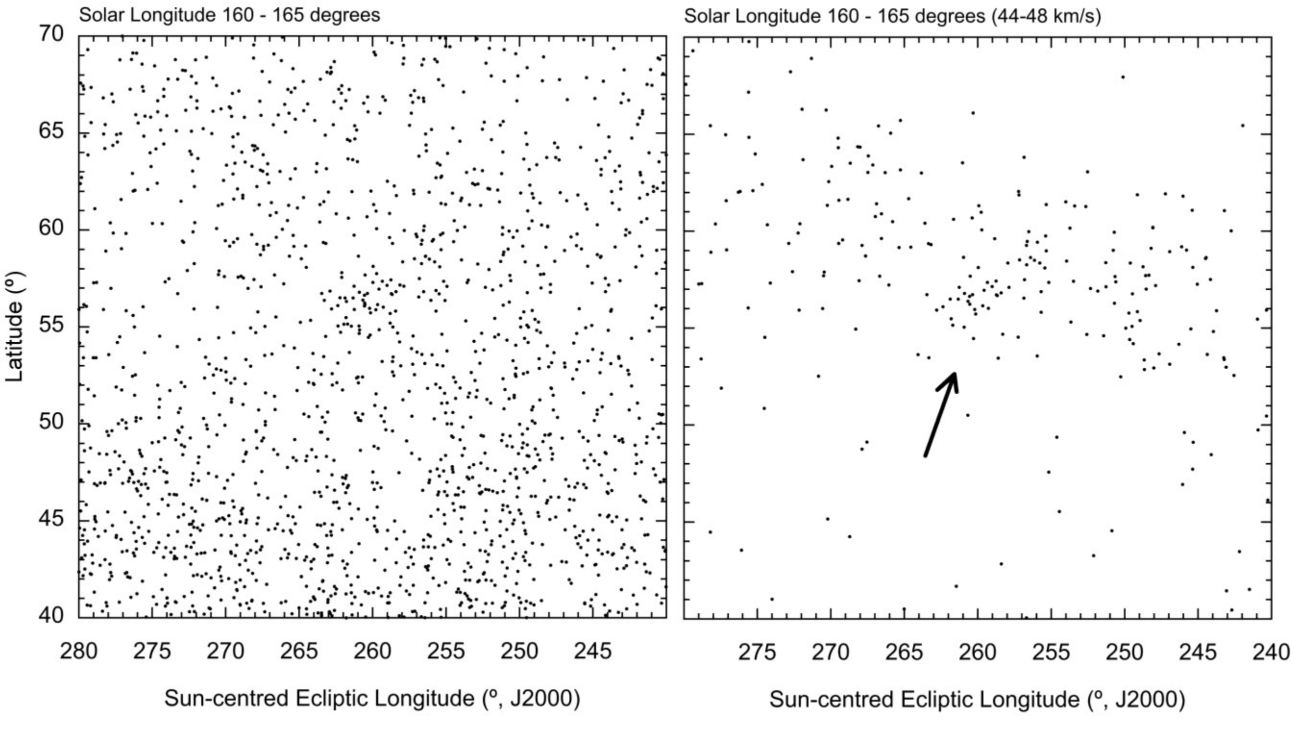

Figure 2 – Radiants of all video-detected meteors towards the northern apex source during the solar longitude interval 160–165° in the years 2010–2020.

4 Discussion

Looking back to the 2010–2020 data collected by the SonotaCo, CAMS and EDMOND programs during solar longitude 160 – 165 degrees (*Figure 2*), we find a weak shower at the radiant position of the September psi-Cassiopeiids. The density of radiants does not stand out well from the sporadic background. The shower did not make the threshold to be included in Jenniskens (2023). However, these meteors have an entry speed below that of most of the sporadic background in that direction (*Figure 2*, right panel). Extracting those orbits in radiant and speed results in the following number of detections starting in 2011: 0, 0, 2, 11, 2, 1, 1, 2, 3, and 3. These meteors appeared between solar longitude 161.0 and 163.0 degrees. The counts suggest that there is a low-level of annual shower activity and that the shower was previously in outburst in 2014.

In 2014, 7 meteors were triangulated by the EDMOND project (Kornos et al., 2013), 2 by CAMS California and 2 by CAMS-BeNeLux (network coordinator *Carl Johannink*). The shower was active from solar longitude 161.11 to 162.40 degrees. The median orbital elements are tabulated in *Table 1*. Compared to the return in 2024, the radiant position is slightly different in R.A., indicative of planetary perturbations. Modeling of this dynamical evolution is outside the scope of this paper.

The value of the Tisserand parameter with respect to Jupiter is more typical of Mellish-type showers (Jenniskens, 2023), but the semi-major axis of the orbit suggests that the parent body is a Jupiter-family comet. That comet remains undiscovered.

Acknowledgments

While only two of the CAMS networks captured the 2024 outburst, the detection was made possible by the concerted effort of all CAMS network and station operators as well as by efforts from *Dave Samuels* and *Steve Rau*, who continue to maintain the CAMS networks.

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Jenniskens P. (2023). Atlas of Earth's Meteor Showers, Amsterdam: Elsevier, 838 pp. (page 579).

Kornos L., Koukal J., Piffl R., Tóth J. (2013). "EDMOND Meteor Database". In *Proceedings of the International Meteor Conference*, Poznan, Poland, 22-25 August 2013. Eds.: Gyssens M., Roggemans P., Zoladek P., Mechelen: International Meteor Organization, pp. 23–25.

2024 outburst of September psi-Cassiopeiids by SonotaCo Network in Japan

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On 2024, September 4, a meteor outburst was detected by a video camera network in the United States. Therefore, we also looked into data from Japan's SonotaCo Network and other sources. There were six simultaneous meteors on the same day, and the outburst lasted about eight hours. One of these was recorded with a spectrum and had multiple echoes in radio observations. A weak annual meteor shower was also observed at this time in past data. In addition, when we look into the parent body candidates, we found that there is an asteroid 2010OA101 with a similar orbit.

1 Observations

Six simultaneous meteors have been recorded by video cameras in Japan's SonotaCo Network within the eight hours of the outburst duration (*Figure 1 and 2*). About 20 single station meteors were observed, some of which simultaneously. In addition, one spectrum was captured from the simultaneous meteors for which the orbit was determined. Multiple echoes of this meteor were also observed in radio observations[6].

Figure 1 – SPC meteor on September 4, $12^{h}51^{m}22^{s}$ UTC.

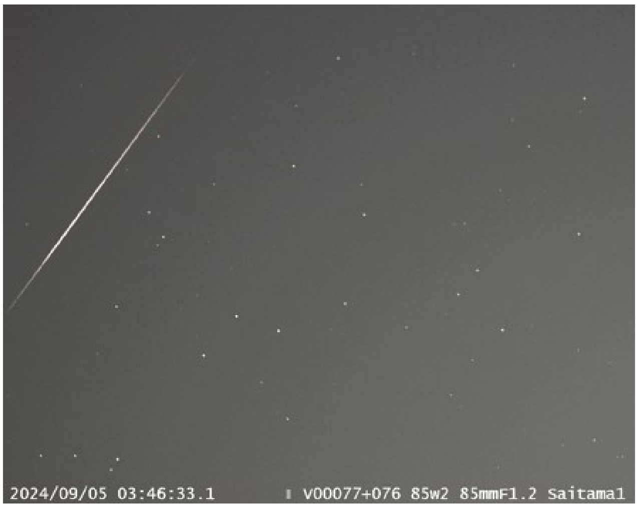

Figure 2 – SPC meteor on September 4, $18^{h}46^{m}33^{s}$ UTC.

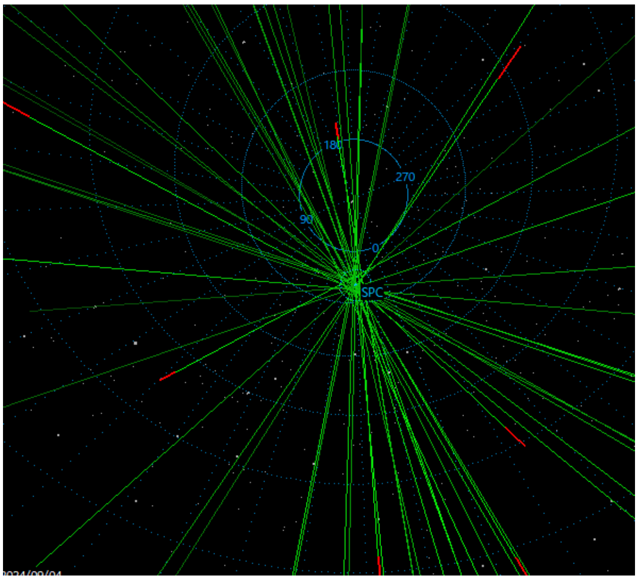

Figure 3 – Single SPC meteors and radiant.

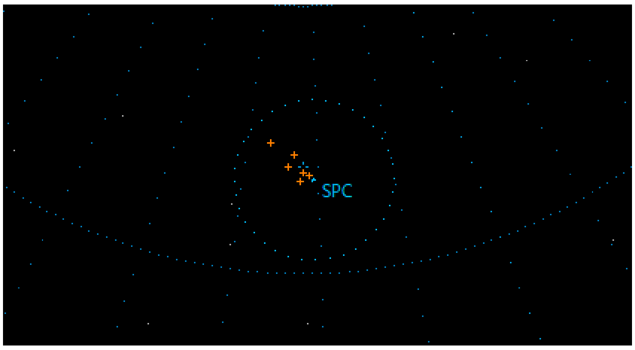

Figure 4 – SPC radiant map 2024, September 4.

2 Results

Similar to the American observation results (Jenniskens and Moskovitz, 2024a; 2024b) the meteor trail map on September 4 (UT) showed a clear cluster of meteors (*Figures 3 and 4*). The orbits from the meteor shower with the triangulated radiant and velocity were selected, and six meteors from this meteor shower were triangulated. The duration of the meteor shower was short. Based on these orbits, the meteor shower was active between solar

[6] https://cgi.iprmo.org/patio/patio.cgi?read=2939&ukey=1

longitudes 162.07 and 162.38 degrees (Equinox J2000), apparently centered at 162.14 degrees, and activity may have continued throughout the night. Detection times on September 4 are listed in *Table 1*. This table shows the orbital elements, geocentric radiant and velocity, and orbital elements for the vernal equinox J2000. The measured radiant was ±1.9degrees in right ascension, ±0.5degrees in declination, and the velocity ±0.4km/. These dispersions are common in meteor triangulations.

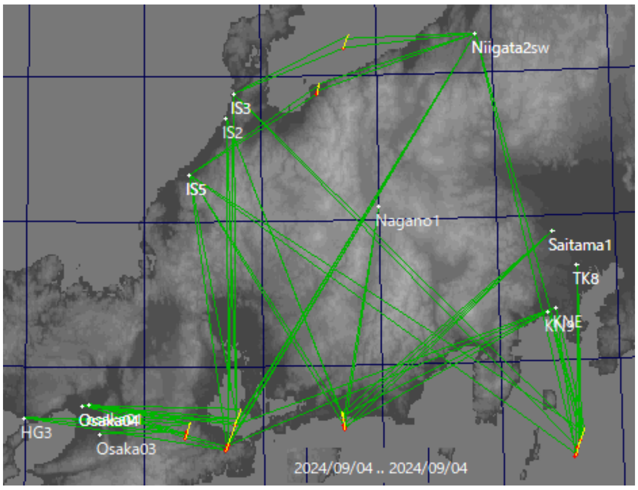

Figure 5 – SPC trajectory map 2024, September 4.

The spectrum obtained from the simultaneous meteor shows early release of sodium, indicating that the meteoroid is fragile (Vojáček et al., 2015). The spectral type is Normal (*Figures 6 and 7*).

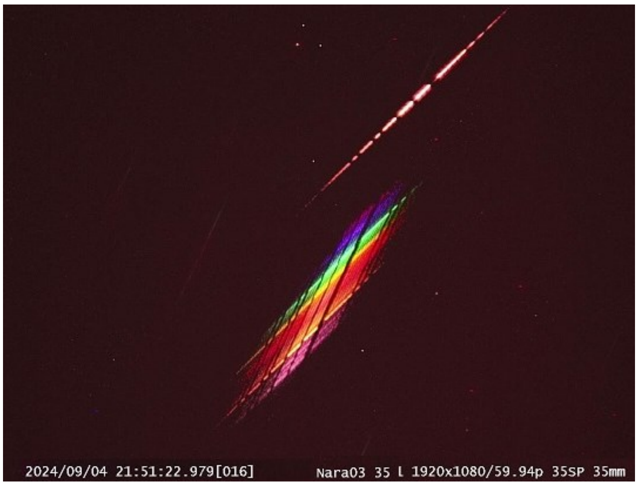

Figure 6 – SPC spectrum of the SPC at $12^h51^m22^s$.

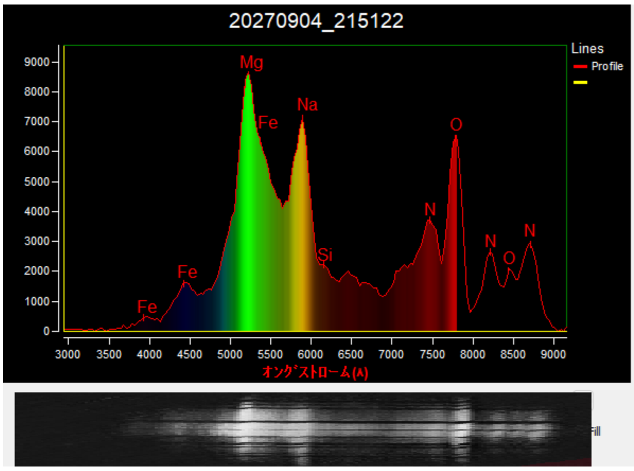

Figure 7 – Spectral analysis results. No sensitivity correction. Spectral type is Normal.

Table 1 – The orbital elements, geocentric radiant and velocity, and other orbital parameters.

Date (UT)	04/09/2024	04/09/2024	04/09/2024	04/09/2024	04/09/2024	04/09/2024	Average	SD
Time (UT)	$11^h06^m39^s$	$12^h12^m58^s$	$12^h51^m22^s$	$14^h31^m08^s$	$16^h02^m00^s$	$18^h46^m33^s$		
$\lambda_\odot$ (°)	162.07	162.12	162.14	162.21	162.27	162.38	162.198	±0.114
α_g (°)	22.45	24.02	22.00	21.15	26.67	23.12	23.23	±1.944
δ_g (°)	73.45	74.00	73.81	73.69	74.86	74.43	74.04	±0.522
v_g (°)	45.03	45.89	45.53	45.56	45.11	44.68	45.30	±0.44
a (AU)	3.08	3.71	3.60	3.71	3.10	3.04	3.37	±0.33
q (AU)	0.987	0.992	0.989	0.987	0.997	0.991	0.991	±0.004
e	0.679	0.733	0.725	0.734	0.679	0.674	0.704	±0.029
ω (°)	198.72	196.00	197.46	198.08	193.72	196.60	196.76	±1.785
Ω (°)	162.07	162.12	162.14	162.21	162.27	162.38	162.20	±0.114
ι (°)	82.01	82.87	82.21	82.10	82.14	81.27	82.10	±0.512
Mag_A	–1.8	–1.7	–2.4	0.7	–0.1	–1.2	–1.1	
Dur. (s)	0.3	0.5	0.9	0.4	0.3	0.4	0.5	
H_b (km)	98.1	107.3	115.8	106.2	105.6	105.3	106.4	
H_e (km)	90.9	93.0	87.3	93.9	95.9	89.8	91.8	
L (km)	12.5	23.7	44.6	17.1	12.5	20.3	21.8	
T_j	1.85	1.54	1.60	1.56	1.83	1.88	1.71	±0.16
λ_{II}	344.77	344.16	344.58	344.78	344.18	344.97	344.57	±0.336
β_{II}	–18.5	–15.9	–17.3	–17.9	–13.6	–16.4	–16.6	±1.762
D_{SH}	0.05	0.05	0.05	0.06	0.07	0.06	0.04	±0.01

Table 2 – Comparing CAMS orbit data and the parent body candidate orbital elements.

	N	$\lambda_{\odot}$ (°)	α_g (°)	δ_g (°)	v_g (km/s)	a (AU)	q (AU)	e	ω (°)	Ω (°)	ι (°)	T_j	λ_{II} (°)	β_{II} (°)	D_{SH}
CAMS2024	13	162.104	20.6	73.5	46.4	5.3	0.987	0.812	197.8	162.07	82.4	1.15	344.5	-17.64	0.12
CAMS2014	11	162.11	25.6	73.7	45.9	3.33	0.992	0.702	195.8	162.4	83.5	1.71	344.23	-15.7	0.03
Parent body 2010OA101						4.5	1.38	0.693	197.87	161.29	82.1	1.29	343.1	-17.78	0.39
RVO 9/4			26.1	72.6	46.2	3.22	0.989	0.693	197.9	161.9	84.4	1.72	343.71	-17.81	0.04

I tried to find a parent body candidate from the orbital elements. When I calculated it with RVO at the observation time, it came up as a candidate. there was an asteroid 2010OA101 with a similar orbit. See *Table 2 and Figure 8*.

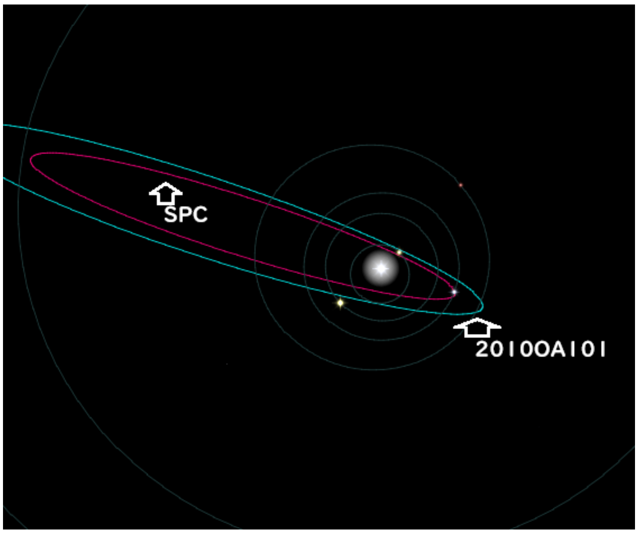

Figure 8 – Comparing the orbits of the SPC meteoroid stream with the possible parent body 2010OA101.

The meteoroid stream and the suggested parent body have a very large offset in space, the Southworth&Hawkins criterion with 0.39 raises doubts if there is an association. However, the high inclination, unusual for minor planets and other parameters show these orbits are remarkably parallel although at a large distance. This object may be an inactive cometary body and then the meteoroids encountered by Earth could be outliers of a dust trail barely intersecting with the Earth orbit. It would require an in-depth long-term orbit modelling to find out what the origin could be, but most likely this is a cometary meteoroid stream that may cause surprise outbursts in the future.

Acknowledgment

We would like to thank the SonotaCo network for providing the orbit calculation data for this study. We would also like to thank *Paul Roggemans* for his proofreading and advice.

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Vojáček V., Borovička J., Koten P., Spurný P., Štork R. (2015). “Catalogue of representative meteor spectra”. *Astronomy & Astrophysics*, **580**, A67, 1–31.

Meteor shower originating from asteroid 2024 RW1 (CAQTDL2) by SonotaCo Network in Japan

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Asteroid 2024 RW1 (CAQTDL2) entered the atmosphere as predicted, and a large fireball was seen from the Philippines. This is the ninth asteroid discovered before entry in the Earth’s atmosphere, following 2024 BX1 in January this year. After investigating whether there were any meteors associated with this, about 15 meteors with similar orbits were found by Japan’s SonotaCo network. Two of them were also photographed with a spectrum. The spectral type is Na rich. It was also found that asteroid 2024 RW1 has an orbit that is very similar to the SAQ#475 meteor shower in September, and it appears that there are three groups.

1 Observations

About 15 meteors possibly associated with asteroid 2024 RW1 (CAQTDL2) were simultaneously observed by Japan's SonotaCo Network between September 1 and September 7. Two of them were also photographed with a spectrum (*Figures 1 and 2*). The activity appeared from September 1st to around the 14th, with slightly more events on September 5–6 and 6–7. Single-station observations on Mauna Kea also revealed that a total of about 30 meteors of the same group were observed on September 4–5 and 5–6.

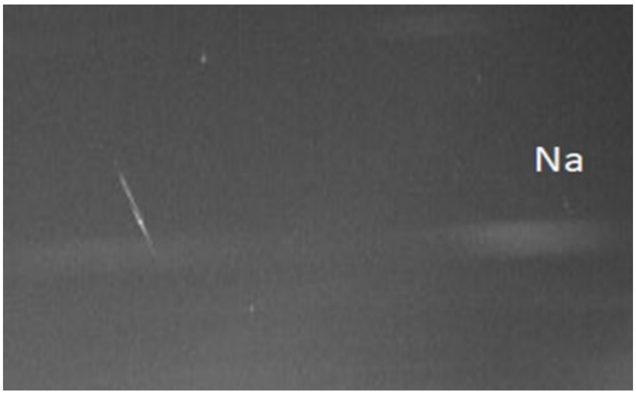

Figure 1 – The spectrum of 2024 September 5, $12^h17^m17^s$ UTC.

Figure 2 – The spectrum of 2024 September 2, $15^h42^m44^s$ UTC.

2 Results

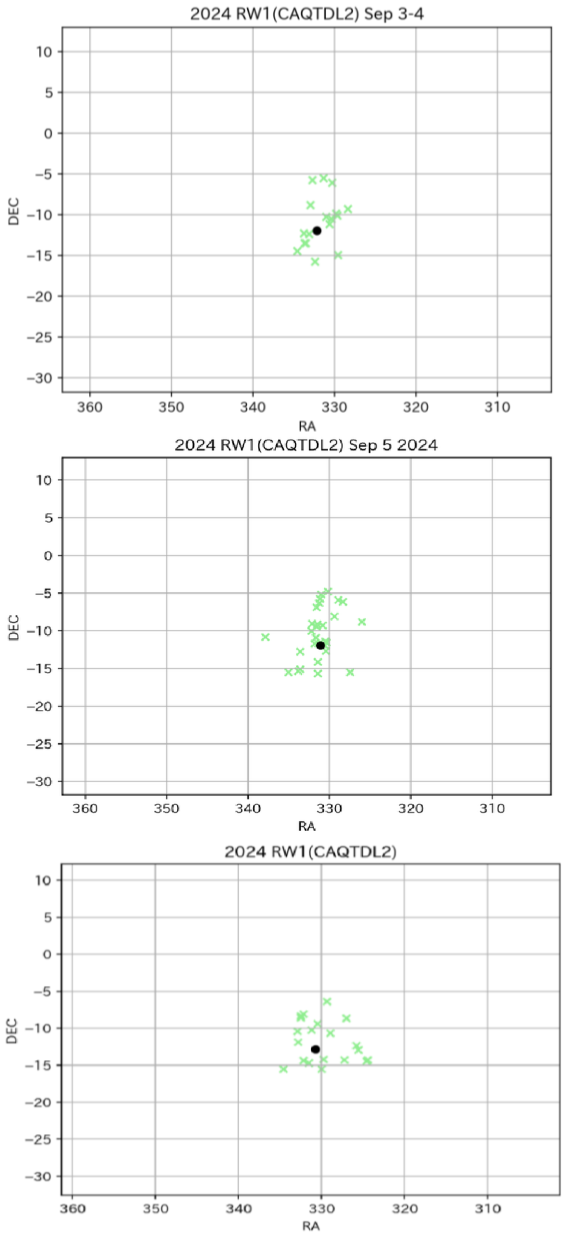

Figure 3 – Radiant map from Mauna Kea Live.

According to Hasegawa, radiants were determined on September 3rd to 5th from single station meteor trails from a live video of Mauna Kea[7]. The radiant points are dispersed, but concentrated enough (*Figure 3*). To find the radiant point from a single meteor, first extract meteors that pass within a certain range (radius of 5 degrees) of the expected radiant point, then find the poles of the great circles of the meteor trails (two points). If they are from the same group, the great circle made by the poles of the paths will be on a great circle with the radiant point as its pole, so the pole of that great circle determined using the least squares method becomes the coordinates of the radiant point.

The distribution of the radiants from simultaneous observations by SonotaCo Net is shown in *Figure 4*. As with the single station data, there is a spread, but they can be divided into three groups (*Figure 4*).

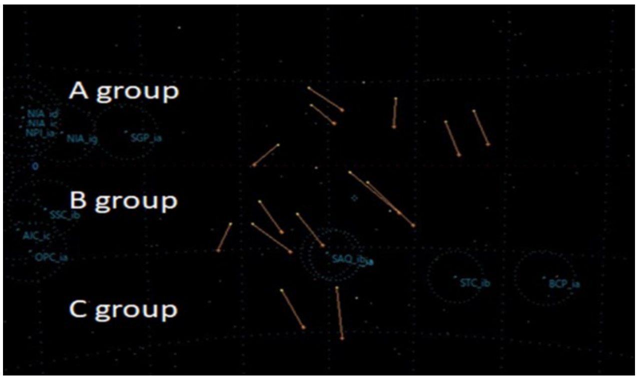

Figure 4 – Radiant map from SonotaCo Net. The yellow points are the apparent radiant points (Ro) and the orange + is the true radiant point (Rt).

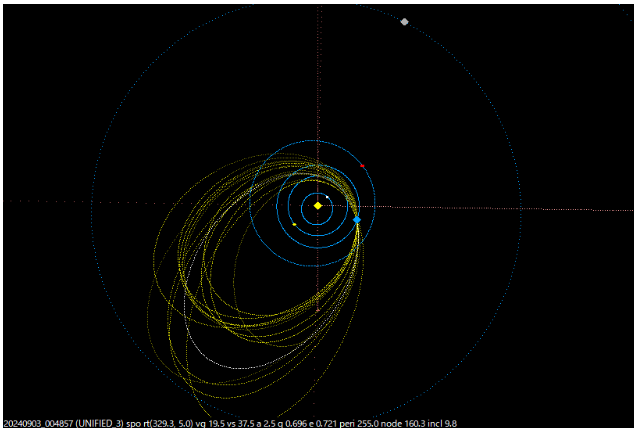

Figure 5 – Plot of the orbits from SonotaCo Net.

The plot of the orbits also shows a spread, but it is divided into two groups (*Figure 5*).

Furthermore, by calculating the average orbit from the orbital elements, it was found to be divided into three groups (*Table 1*).

Groups A and B are north-south groups. Group C has a difference of 180 degrees in ω and Ω. The map of simultaneous meteor tracks from August 23 to September 23 shows three groups that appear to be related to the SAQ meteor shower (*Figure 6*). Furthermore, what seems to be the part of the same group appears to have a dispersion into three groups.

In addition, it was found that both of the two meteors in the spectrum were richer in Na than Mg. *Figure 2* has a poor dispersion direction, but we managed to analyze it (*Figure 7*). The type is normal, but Na is more abundant than Mg, and a lot of iron seems to have been released during the explosion.

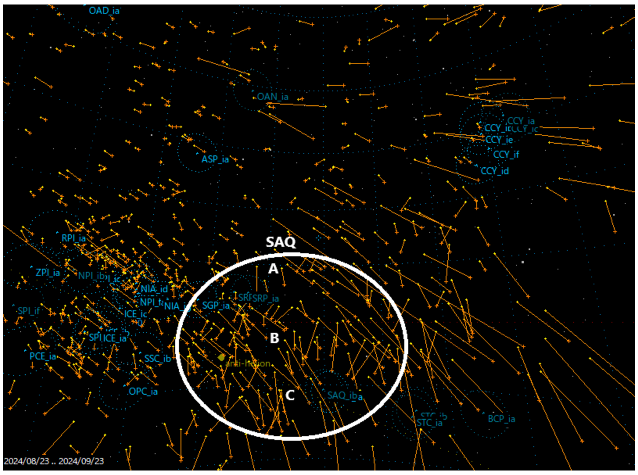

Figure 6 – Radiant map from August 23rd to September 23rd.

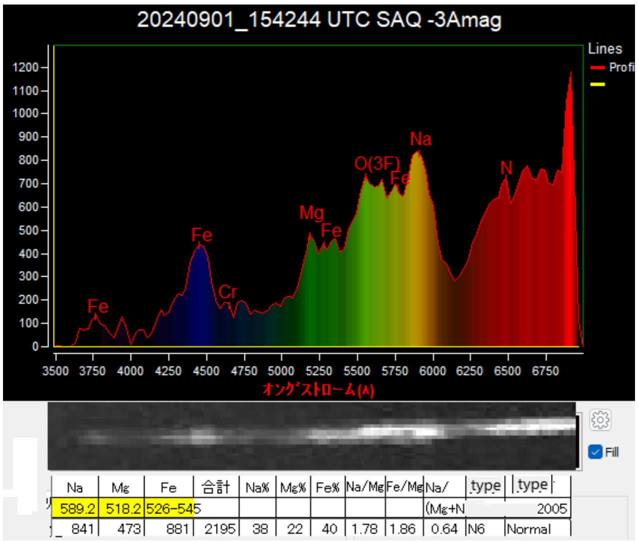

Figure 7 – Spectral analysis results. No sensitivity correction was applied. Spectral type is Normal.

3 Parent body

As shown in *Table 2*, there is a candidate parent body for the three groups. Groups A and B are related to asteroid 2024 RW1. Group C is related to asteroid 2022BM2. It is thought that these two asteroids once split off from the same asteroid.

The asteroid is considered to be a parent body of this group because it has been determined to be related to the SAQ#475, or September Aquariids meteor shower. However, this meteor shower has been removed from the active working list of the IAU MDC because of its low

[7] https://x.com/KinHase/status/1834770018435056024

reliability. The radiant points are widely dispersed, but the slow speed for the activity of the three groups, and because of the similarities in their orbits it is thought that this asteroid is the parent body of these associated meteor showers (*Figure 8*). From January 2nd to September 10th of last year, there were nearly 20 simultaneous meteors with D_{SH} values of 0.2 or less. As expected, they are split into two groups, and the radiant points are dispersed.

Table 1 – The orbital elements, geocentric radiant and velocity, and other orbital parameters.

Group	$\lambda_{\odot}$ (°)	α_g (°)	δ_g (°)	v_g (km/s)	a (AU)	q (AU)	e	ω (°)	Ω (°)	i (°)	M_A	dur (sec)	H_B (km)	H_E (km)	D_{SH}	λ_{Π}	β_{Π}
	159.35	330.71	-9.80	17.09	2.19	0.727	0.668	252.41	159.33	1.07	-3.2	0.9	80.3	68.3	0.05	51.7	-1.02
	159.46	334.43	-10.46	20.57	2.96	0.662	0.777	257.67	159.16	0.08	-0.1	1.3	89.6	79.6	0.12	56.8	-0.08
A	160.34	320.19	-7.27	14.23	2.29	0.830	0.638	236.99	160.33	3.23	-0.4	2.1	84.2	61.4	0.21	37.3	-2.71
	162.24	335.46	-8.09	17.81	2.17	0.700	0.677	255.94	162.22	1.10	-3.5	1.4	73.0	52.7	0.09	58.2	-1.07
	163.26	321.82	-5.78	13.92	2.27	0.838	0.631	235.72	163.25	3.51	-0.3	2.0	82.8	61.6	0.20	38.9	-2.9
	160.32	329.31	5.04	19.49	2.50	0.696	0.721	255.00	160.32	9.82	1.0	1.1	96.4	76.6	0.17	55.1	-9.48
	160.40	328.39	6.69	20.00	2.72	0.699	0.743	253.75	160.39	11.11	-0.2	1.8	89.1	64.9	0.19	53.9	-10.7
B	162.15	315.09	1.23	13.26	2.25	0.868	0.615	230.68	162.15	6.54	0.4	0.5	80.4	72.4	0.29	32.7	-5.06
	163.00	338.46	0.10	22.51	3.01	0.606	0.799	264.17	163.00	6.18	0.1	1.6	99.9	83.2	0.27	67.1	-6.15
	163.09	322.48	4.63	14.18	1.99	0.820	0.588	240.29	163.09	7.62	-0.8	0.6	77.0	68.2	0.22	43.2	-6.61
	163.11	311.94	2.52	13.35	2.53	0.886	0.650	226.12	163.10	7.21	0.5	0.9	89.4	75.4	0.33	29.0	-5.19
	160.18	342.59	-10.01	20.95	2.07	0.584	0.718	90.51	340.19	1.72	-0.4	0.2	85.6	83.1	0.28	70.7	1.72
C	161.20	328.45	-20.66	15.05	2.34	0.807	0.654	60.30	341.21	3.26	-0.5	1.0	81.5	69.3	0.17	41.5	2.84
	162.24	333.03	-19.44	18.06	3.11	0.756	0.757	65.30	342.25	4.12	-0.1	1.0	90.3	77.9	0.11	47.5	3.74
	164.19	344.09	-22.74	21.89	4.01	0.675	0.832	74.15	344.19	9.75	1.0	0.6	86.1	78.4	0.23	58.1	9.38
A	160.93	328.52	-8.28	16.72	2.38	0.751	0.678	247.75	160.86	1.80	-1.5	1.5	82.0	64.7			
B	162.01	324.28	3.37	17.13	2.50	0.763	0.686	245.00	162.01	8.08	0.2	1.1	88.7	73.5			
C	161.95	337.04	-18.21	18.99	2.88	0.706	0.740	72.56	341.96	4.71	0.0	0.7	85.9	77.2			

Table 2 – Orbit data and orbital elements of the parent body candidate.

Name	a (AU)	e	q (AU)	i (°)	ω (°)	Ω (°)	D_{SH}	T_J	λ_{Π}	β_{Π}	α_g (°)	δ_g (°)	v_g (km/s)
2024 RW1	2.51	0.707	0.735	0.53	249.62	162.46	0.00	3.06	52.08	-0.50	332.5	-10.3	17.5
A	2.51	0.678	0.738	1.80	247.75	160.86	0.06	3.21	48.60	-1.67	328.5	-8.3	16.7
B	2.30	0.686	0.723	8.08	245.00	162.01	0.15	3.12	46.79	-7.32	324.3	3.4	17.1
C	2.51	0.710	0.720	3.03	72.03	341.22	0.11	2.88	54.46	4.49	337.0	-18.2	19.0
2022BM2	2.51	0.706	0.738	0.88	71.74	346.14	0.03	3.05	57.88	0.84	336.7	-11.4	18.4

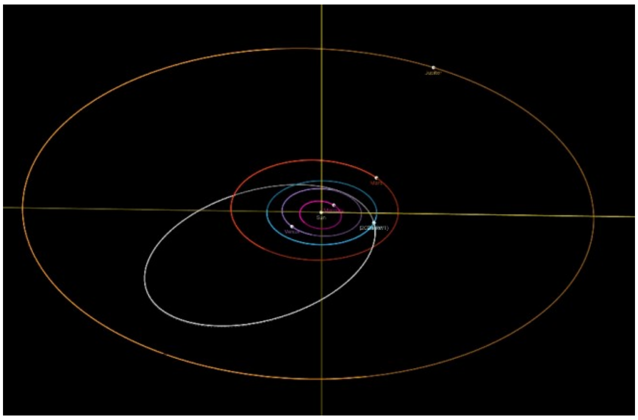

Figure 8 – Plot of the orbit of 2024RW1.

Acknowledgment

We would like to thank the SonotaCo network for providing orbital calculation data for this study. We would also like to thank *Paul Roggemans* for proofreading and advice.

Meteorview – new meteor visualizing tool for the Global Meteor Network

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A new tool for visualizing meteor trajectories, generated by the Global Meteor Network solver has been described. Various filtering and displaying options are thoroughly described including the screenshots. The new GUI allows to study all GMN meteor trajectories back to 2021, when the solver started to officially calculate and archive the data.

1 Introduction

There are a couple of tools for visualizing meteor orbits, produced by the Global Meteor Network (Vida et al., 2021), namely Tammo Jan's Meteormap (Dijkema, 2022). After using this amazing tool for some time, I have decided to implement some new features, however, by using another platform, capable to process a larger amount of data. Finally, I ended up using SQL database, serving the panel/bokeh based engine on the external python hosting service, providing enough network bandwidth.

The application is available online[8].

Besides the meteor ground plots, the substantial addition is the radiant map, enabling to visualize selected data on the sky map and focus on the particular time or the sky map region of interest.

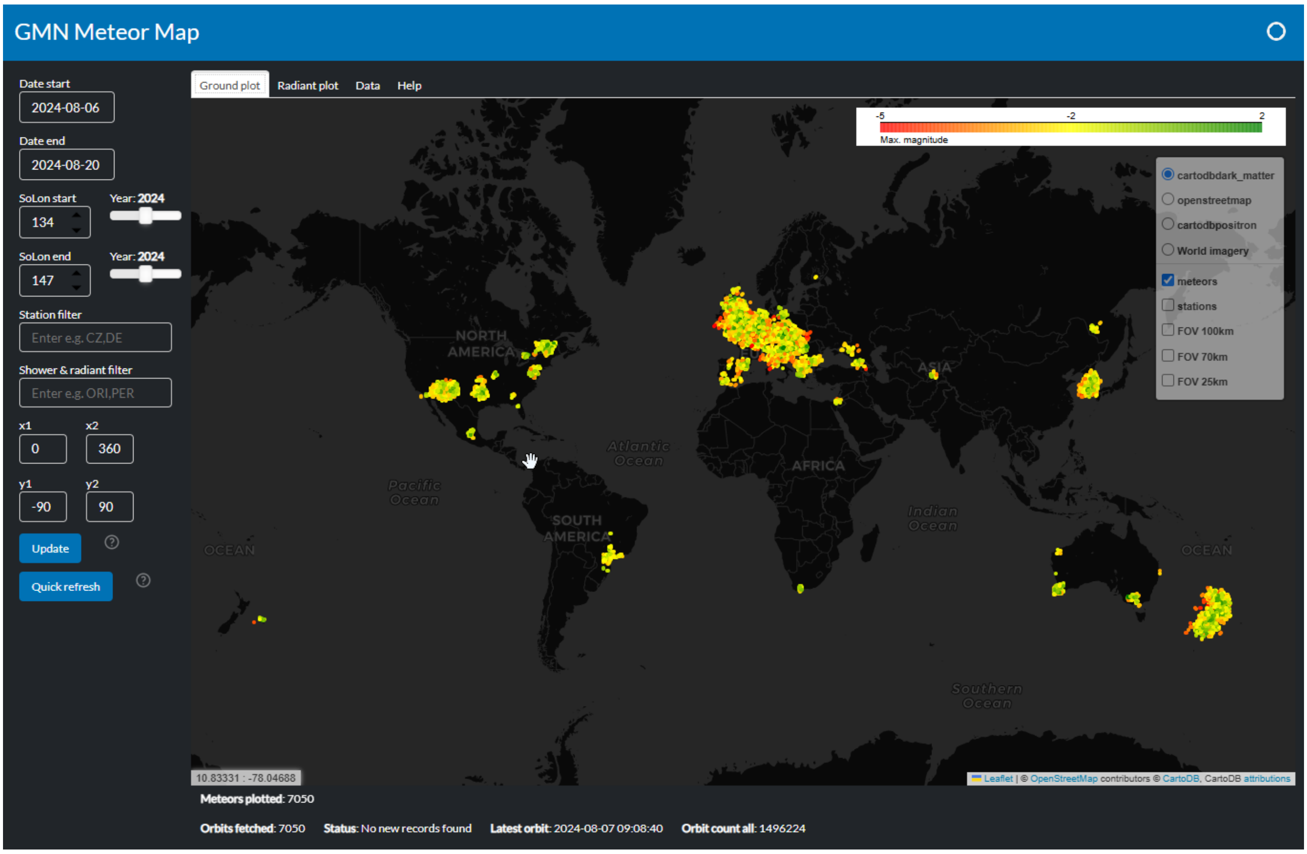

Figure 1 – Screenshot of the MeteorView visualizing tool.

[8] https://www.meteorview.net

2 Basic features

- All GMN data since 2021 available;
- Worldwide meteor ground plot with several basemap options;
- GMN station locations colored by a current status;
- Field of View (altitude of 100, 75, 25km) for each station;
- Filtering by date (solar longitude), station ID, shower, radiant coordinates;
- Radiant plot visualizing computed radiant, colored by selectable dimension;
- Rasterize option for large data display.

3 Background operation

The Meteorview meteor database is instantly refreshed by pulling the data from the GMN server, to keep up-to-date information about:

- Calculated orbits;
- Station list – add new stations if needed;
- Station status – displayed color determines the station status;
- Station FOVs at 25, 75 and 100 km.

Periodically, the Meteorview updates the all the camera station status, which is then used by coloring the station marker.

4 GUI description – Ground plot

When the main page is loaded, the date and time of the last calculated meteor/orbit is determined. The meteors of the last 2 days are loaded, by default.

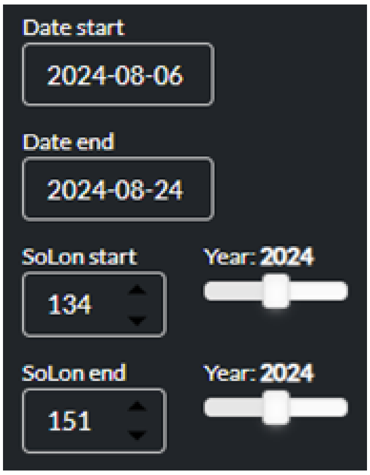

Figure 2 – Time interval selection.

The beginning and end date can be customized, either by the calendar widget, or by a solar longitude selection. Upon a change, the corresponding control is updated.

Data can be filtered by a station and shower name, both by a pattern, consisting from a few leading characters, separated by a comma.

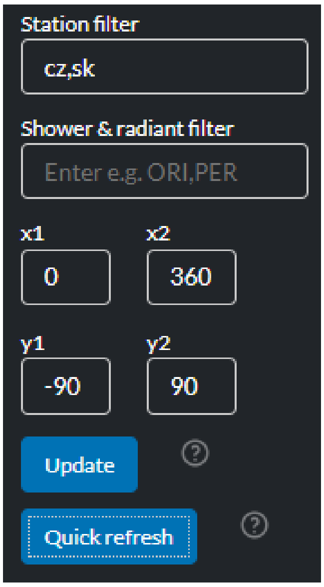

Figure 3 – Selection of station(s) and/or meteor shower(s).

In addition, the filter can be furthermore enhanced by radiant coordinates (in units currently selected on the radiant tab).

UPDATE button – simple submitting the above parameters.

Quick refresh button – instant download of the last 2 daily summary files from the GMN server, adding them to the database.

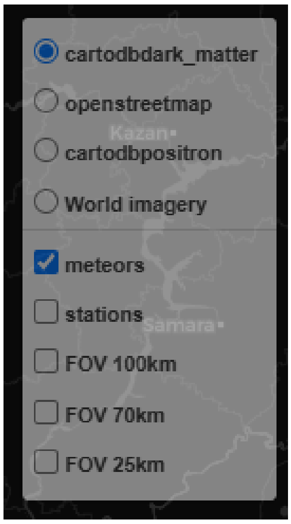

Figure 4 – Selection of map and objects.

There are a few basemaps available as a background. These can be used for various purposes, providing optimal brightness and contrast, when rendering the meteor ground plots and FOV polygons.

Meteors, station markers and FOV polygons can be switched on/off as independent layers. FOV polygons for each station are generated for heights of 25, 50 and 100 km above the ground.

Meteors are plotted as lines, colored by an apparent magnitude, starting from 2 (green) to –5 (red).

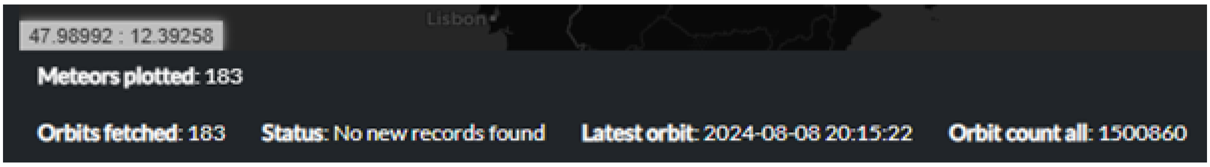

Figure 5 – The status bar.

The status bar displays some valuable information:

- Coordinates of the mouse cursor;
- Total number of meteors shown on the map;
- Current status of the last GUI action;
- Latest orbit calculated by the GMN solver3;
- Total number or orbits since 2021.

There are a few features, linked to the users' mouse action.

- Mouse over – depending on the object, some corresponding information is shown:
  - Meteor – date & time, shower code, peak magnitude, list of stations;
  - Station marker – station ID, when last seen by the GMN server, status description;
  - FOV – station ID.
- Mouse click:
  - Meteor – detailed information, including orbit parameters;
  - Station marker – station ID and a link to a corresponding GMN weblog.

A mouse click elsewhere on the map returns the station list, covering that point on the map, using the FOV polygons at 100 km height. This is useful especially in order to find out which stations could have recorded the meteor spotted at that location. The coordinates of that point are shown next to the station list.

5 GUI description – Radiant plot

The radiant plot is another kind of plot. Unlike the ground plot, it is displaying the sky map along with meteor/orbit markers positioned according to their calculated radiant coordinates.

The meteors are colored by a dimension, selected on the left side selection bar. By default, this is the meteor shower, as shown in *Figure 6*. The color palette is randomly generated.

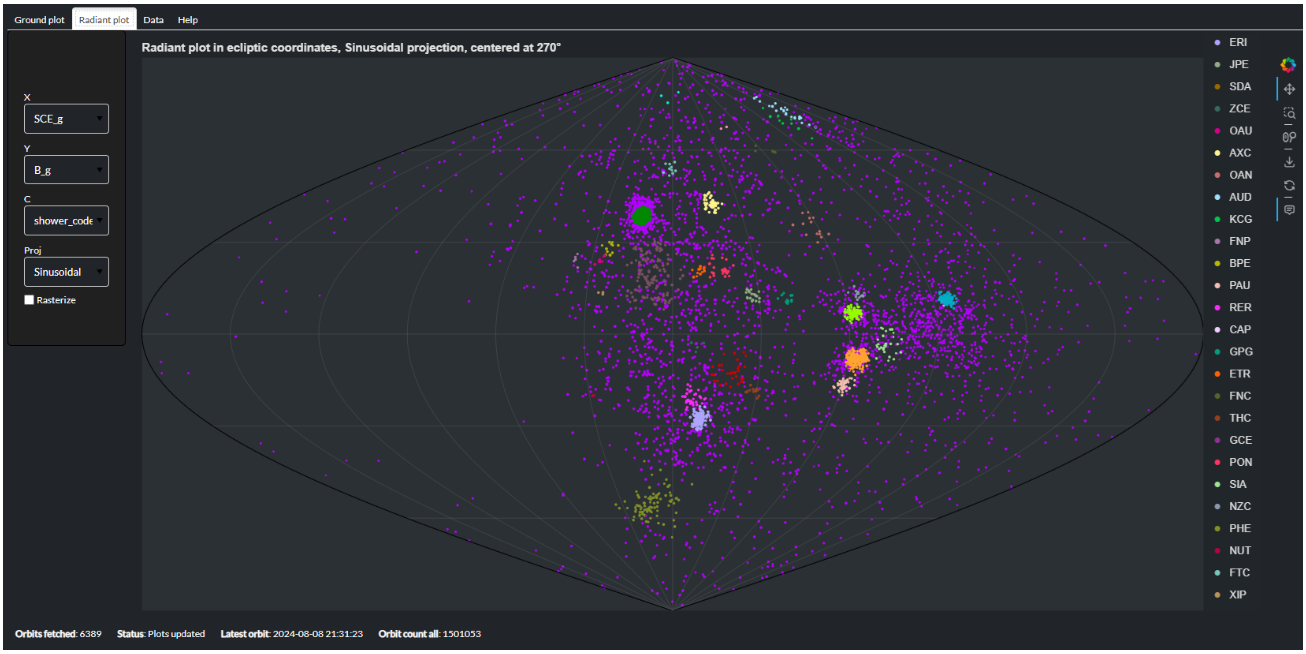

Figure 6 – The radiant map with the selection bar at right and color coded meteor showers at right.

On the left-hand side in *Figure 6*, there is a selection bar.

The units used for the sky map coordinates (X, Y) can be the geocentric Sun-centered ecliptic coordinates (default), Sun-centered heliocentric ecliptic coordinates, or simple geocentric equatorial or ecliptic coordinates. A diagram with longitude of perihelion *Π*, against inclination *i* or eccentricity *e* is also possible.

The C is the dimension used for the Z-axis (coloring). There is a number of continuous dimensions available, the default is categorical (shower code).

There are two projections available – sinusoidal (equal-area, default) or the Platecarree (equi-rectangular). Both projections exhibit different (dis)advantages.

The radiant plot is capable to process large amounts of data. In order to utilize the full display capacity, the Rasterize option dramatically decreases the marker size, to make the large data display possible.

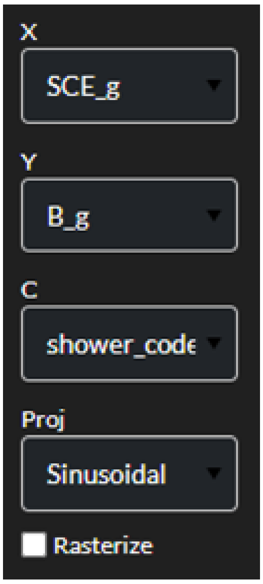

Figure 7 – The selection bar for the radiant map.

The bar on the right enables to switch on-off the controls on the radiant plot:

- Pan;
- Box zoom;
- Mouse wheel zoom;
- Save the plot as a picture;
- Undo;
- Hover on/off.

Figure 8 – Switching on and off controls.

Similar to the ground plot, a simple mouse over shows some basic information about the meteor/orbit.

6 GUI description – Data

This tab contains the simple paged table of data, as they were extracted from the database by a given filter. The button below can be used to download them as a CSV text file.

7 Backend details

The core of the application is Panel, part of the Holoviz open-source library, featuring the Folium map. The data is stored in the SpatiaLite database.

The code runs on the dedicated python hosting, using the NGINX server and a balancer.

The source code is available online[9].

This project is not maintained on the daily basis.

I appreciate any suggestions regarding the features and bugs, or even a pull request.

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Vida D., Šegon D., Gural P. S., Brown P. G., McIntyre M. J. M., Dijkema T. J., Pavletić L., Kukić P., Mazur M. J., Eschman P., Roggemans P., Merlak A., Zubrović D. (2021). "The Global Meteor Network – Methodology and first results". *Monthly Notices of the Royal Astronomical Society*, **506**, 5046–5074.

[9] https://github.com/satmonkey/GMN_meteormap

The MetLab software

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In this article I present my biggest aid in computations around a meteor phenomenon, Metlab. It is a software which can transform coordinates, visualize light curves, calculate trajectory parameters and if there is any remaining mass, simulate dark flight. I use it every day not exclusively for events above Hungary but neighboring countries either. My more distant goal is to further expand the knowledge of the program by creating a tool that can be used for all phases of the meteor phenomenon.

1 Introduction

Each nation has its own program for performing calculations of meteor phenomena, with particular reference to dark flight. Such as the Spanish – Amalthea (Madiedo, 2006[10]), the Finnish – MC (Gritsevich et al., 2014), the Russian – Meteor Toolkit (Dmitriev et al., 2018) or the Japanese – Fireball Inspector. (SonotaCo, 2010) I would like to introduce the program I wrote – MetLab – which is constantly being developed since 2015. The purpose of this article is not to present the operation of the program in detail, it merely provides a comprehensive picture of its current (2024) status. I do not plan to publish the program for the time being, it is only intended for personal use. It was also an essential tool for the calculations I published so far, and it will be more and more so in the future.

2 Beginnings

I started writing the program in 2015 using the Delphi programming language. At first, the goal was just to be able to convert between the many different coordinate formats with it. The information arrives in any format (Ra. – Dec.; Alt. – Az.; degrees/minutes – hours/minutes…etc.) I can calculate with them; these data must be saved / read back and can be converted with one click into the readable format for UFOOrbit. (SonotaCo, 2009). At that time, I began to deal more seriously with the calculation of the dark flight of fireballs, since there was no program available for this (not since then), neither free nor paid. In one year, I delved so much into the subject – among other things based on Ceplecha's article (Ceplecha, 1987) – that I managed to

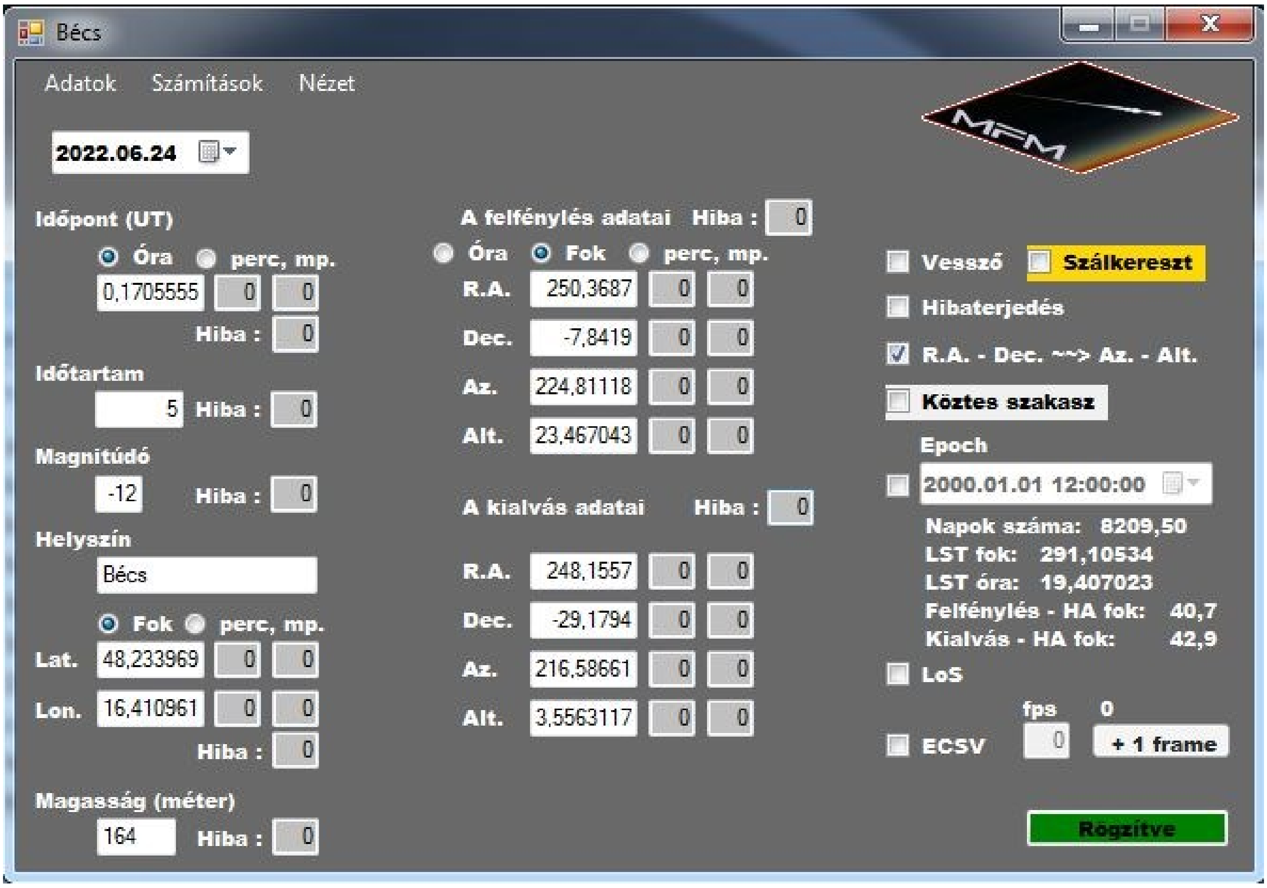

Figure 1 – Basic data window displaying one observation from Vienna, 2022 June 24, a fireball above Austria.

[10] http://www.meteoroides.net/e_metobs_software.html

program the first version of the dark flight calculation module in Delphi. Here I would like to point out that, as an amateur astronomer, I can only dedicate a small amount of my free time to meteoritics, which I have persistently done since the mid-90s. In 2020, I rewrote the entire program into C#, at which time I also rethought the user interface based on my experience so far. Many small new functions of the program have already been completed on the new interface, such as the light curve display, dynamic mass calculation or the calculation and display of track parameters in 2D/3D.

3 The MetLab program

The program's functions open separate windows, so it's easy to customize exactly what you're working with, and arrange it on the screen as you like.

Basic data window – coordinate conversion

This is the main window (*Figure 1*) of the program, which opens first and the main data of the meteor fall can be entered, the conversion takes place, and the other functions can be accessed from here via the main menu. The time, duration, brightness of the fall, data on the location of the observation, the celestial coordinates of the start and the celestial coordinates of the end can be recorded. The program automatically handles and transforms if the data is entered with a dot or a comma-decimal separator. To accurately read the celestial coordinates, a crosshair can be activated, which remains active even outside the program window. The cursor can be moved pixel by pixel with the help of arrow keys and the environment of the reticle is displayed enlarged in a separate pop-up window, thus a pixel-accurate reading is available. By default, the coordinate calculations are made with the J2000 epoch, but this can also be changed. The calculated or uploaded data of the window can be transferred to other windows in one move, e.g. for the trajectory display to calculate the data of an intermediate section or for the trajectory calculation module (LoS) which is still under development. The basic and calculated data are changed dynamically if we prepare ECSV export step by frame for WMPL. (Vida et al., 2019).

Functions available from the main menu:

Data:

- New data: Opens another basic data form window – in addition to keeping the original – if the main page is filled out, it automatically fills in the detection time data.
- Loading: loading previously saved data.
- Save: save entered / calculated data.
- R91 export: creating a file that can be read directly into UFOOrbit.
- ECSV export: creating a file that can be read into WMPL.
- Save / load location data: faster handling of detection location data.

Calculations:

- Trajectory: opens the meteor trajectory data window.
- Image analysis: you can work on the light curve of a meteor in this window.
- Mass: opens the meteor fall mass calculation window.
- Dark flight: the data of the dark flight of a meteorite fall can be entered in this window.
- Line of sight: trajectory calculation (under development) (Borovička J. 1990).

View:

- Enables switching between light and dark mode, which changes the colors of the user interface to colors that are easier for the eyes.

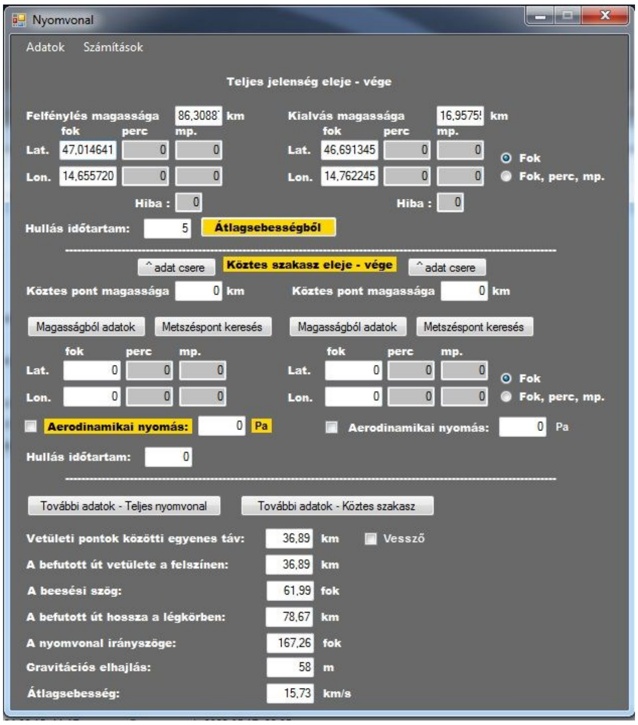

Figure 2 – Trajectory window showing the data of 2022 June 24 fireball above Austria.

Trajectory window

Here you can enter the data of the start and end point of the fall (*Figure 2*), the duration of the fall, from which the following parameters can be calculated:

- The length of the straight line between projection points.
- Length of distance traveled on the surface.
- Angle of incidence.
- Distance traveled in the atmosphere.
- Trajectory azimuth.
- Gravitational deflection.
- Average speed.

At a specified height, it can calculate the coordinates of an intermediate point and the aerodynamic pressure (Bronshten, 1981) acting on the body there. The intermediate point can be recorded not only on the entered path, but also beyond it, e.g. thus a trail can be extended…

The program can search for the intersection of a detection entered in the Basic data window with the trajectory entered here.

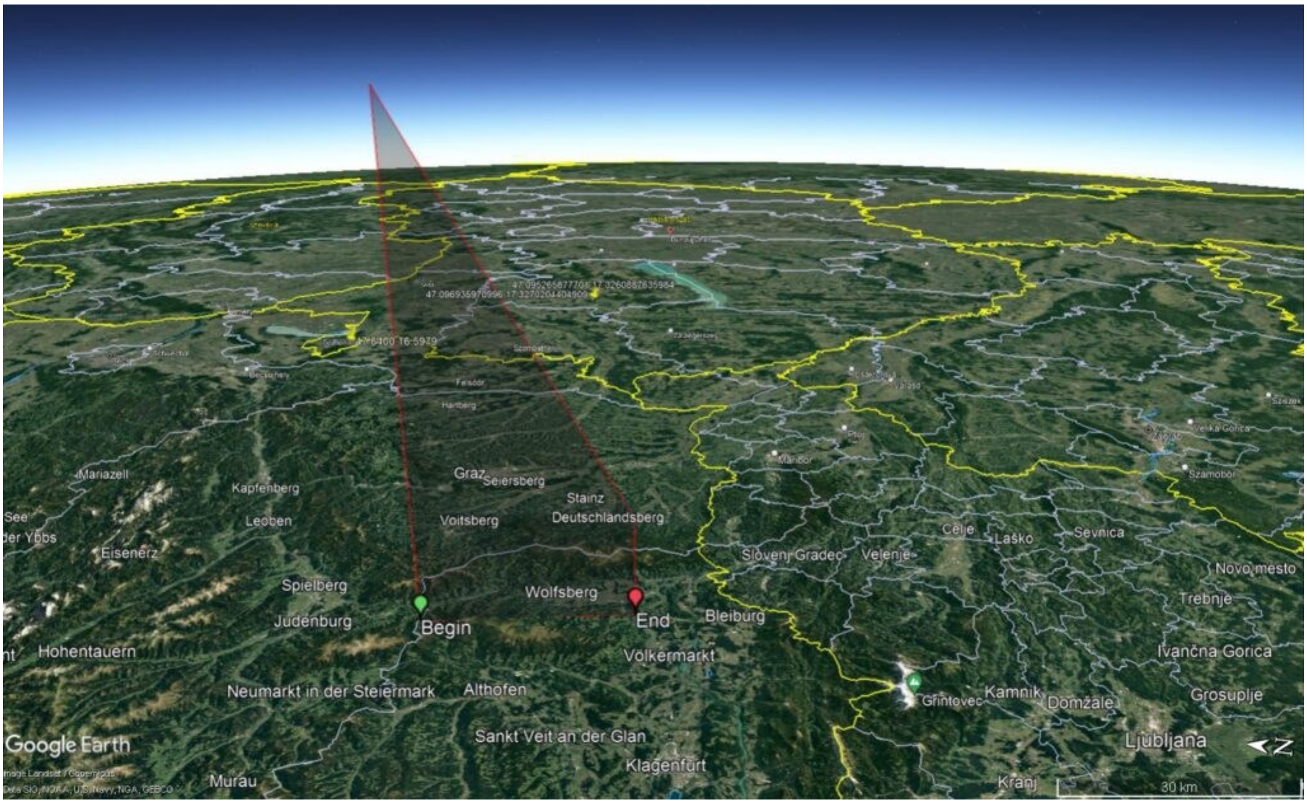

Figure 3 – 2022 June 24 Austrian fireball trajectory in 3D.

All recorded or calculated data can be transferred to the dark flight calculation window with the press of a button.

The data can be saved in KML format: in 2D, it displays the surface projection in Google Earth, and in 3D, it represents the track in the atmosphere (*Figure 3*).

Image analysis

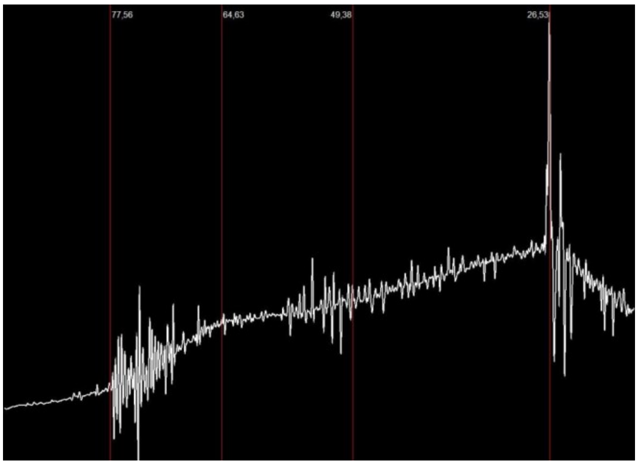

Figure 4 – The lightcurve of the 2022 June 24 Austrian fireball, height is in km.

The meteor photo can be processed in this window. By selecting the meteor in the image, the program creates a pixel database that can be read and converted under different conditions. The data read out pixel by row can be displayed in a light curve, at different points of which the height of the meteor can be displayed. The created light curve can be saved. The light curve can be calculated by subtracting the background lighting, highlighting the differences and stretching the axes to show each detail more accurately (*Figure 4*).

Mass calculation

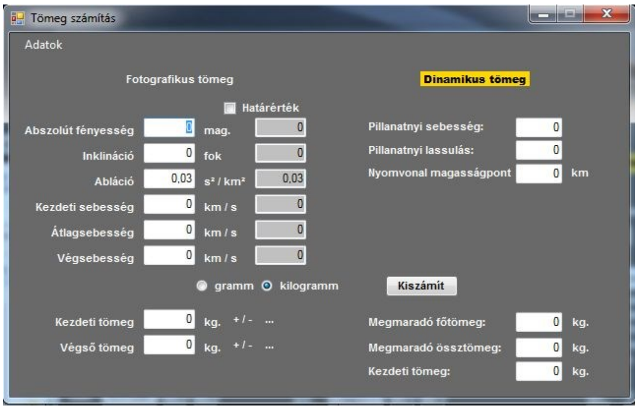

Figure 5 – The mass calculation window.

Based on the entered values, the mass of smaller meteors can be estimated by photographic mass calculation. (Jones et al., 1989). By entering the values read from the videos frame by frame, the dynamic mass of larger fireballs can be calculated (Halliday et al., 1996) (*Figure 5*).

Dark flight

By entering the parameters calculated at the end of the trajectory, the dark flight of the remaining mass can be modeled, further fragmentation is not yet calculated by the program. The stochastic simulation is performed using the Monte Carlo method with the specified limit values, in several thousand iteration steps down to the specified surface. It can start the pieces from a given point, a flat area, a given part of the space around the trajectory or a section of the trajectory. One of the most important parameters for performing the calculation is the upper atmospheric wind. The program can calculate from balloon wind measurements from one place or even interpolate the results of wind measurements from several places in space. Sounding data provided by University of Wyoming-Department of Atmospheric Science[11]. However, the most accurate results can be obtained with data from satellites refined with meteorological models. (GFS / NCEP / US National Weather Service) The program can calculate with all three methods at the same time, even with the weighting of these input data. The calculation result can be written out in CSV, in detail, for all the calculated data of each interpolation step in the case of 1 calculation. Only the data lines containing the final results, for each calculated piece are included in the CSV. The most frequently used option is that the program saves the results in KML, which can be viewed immediately in Google Earth. The entire strewn field with all calculated data can also be exported to GPX, which can be loaded into a GPS to help on-site searches. (*Figures 6 and 7*).

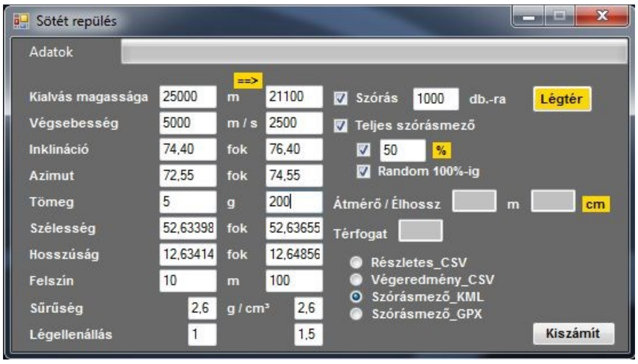

Figure 6 – The dark flight calculation window showing the data of 2024 January 21 German fireball above Ribbeck.

Figure 7 – The calculated strewn field with the initial data above. Blue – white ; higher or lower starting point, cube / circle resembles the shape of the meteorite.

4 Vision – ongoing developments

The next important step is to program the trajectory calculation using the LoS method. This in itself would not be important, as there are programs available for free on the Internet. However, none of the programs deal with error propagation, which is essential for determining the standard deviation of the final results.

The graphical representation of the histogram and the RGB values read from the pixels will provide additional help for the analysis of the light curve. Another interesting thing could be the reading of a light curve using the current method, but from video material, frame by frame.

For a more complete picture of the strewn field, the simulation of further fragmentation during dark flight is also necessary.

I am constantly developing the program as I learn new formulas or more accurate data files.

[11] http://weather.uwyo.edu/upperair/sounding.html

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August 2024 report CAMS-BeNeLux

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A summary of the activity of the CAMS-BeNeLux network during the month of August 2023 is presented. This month was good for 43080 multi-station meteors resulting in 12074 orbits.

1 Introduction

In August, of course, all attention goes to the Perseid meteor shower, peaking around August 12. Little moonlight this year in the first half of the month offered favorable conditions. It was going to be a very successful month.

2 August 2024 statistics

The month of August was by far the sunniest and warmest summer month in 2024. Since the start of CAMS in 2012, it has only been sunnier in August in 2022. But even the less sunny days were often followed by a (partially) clear night this month. There was not a single night this month without simultaneous meteors. This has happened before since the start of this project in the BeNeLux, but never before have the lowest scores in one night been so high during an entire month. Only in two nights did we collect less than 100 orbits: 80 orbits in the night of August 3–4 and 31 orbits in the night of August 17–18. More than 1000 orbits were collected in 5 nights (August 5–6 and in all nights from August 9–12). The nights around the Perseid maximum were the highlights when 2761 (August 11–12) and 2882 orbits (August 12–13) were collected under clear sky conditions.

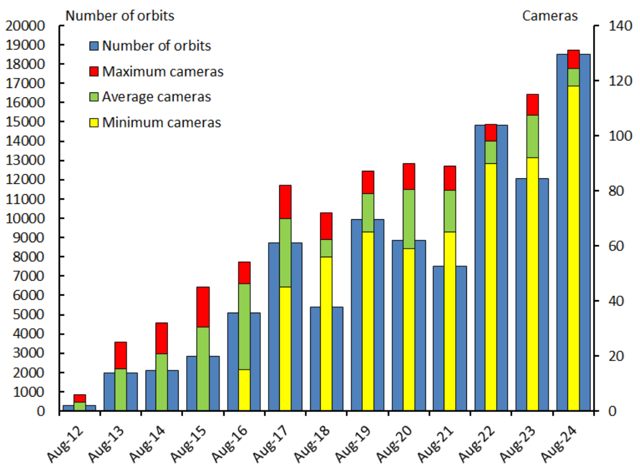

Figure 1 – Comparing August 2024 to previous months of August in the CAMS-BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras capturing in a single night, the green bars the average number of cameras capturing per night and the yellow bars the minimum number of cameras.

All cameras in CAMS-BeNeLux captured a total of 133634 meteors this month. Of these, 69684 were simultaneous. In the end, this resulted in a total of no less than 18522 orbits. This is by far the best result for August since 2012 (*Figure 1* and *Table 1*). 59.7% of all orbits were collected from more than two stations.

Table 1 – Number of orbits and active cameras in CAMS-BeNeLux during the month of August in the period 2012–2024.

Year	Nights	Orbits	Stations	Max. Cams	Min. Cams	Mean Cams
2012	21	283	5	6	–	3.2
2013	27	1960	13	25	–	15.3
2014	28	2102	14	32	–	20.8
2015	25	2821	15	45	–	30.4
2016	30	5102	20	54	15	46.2
2017	28	8738	21	82	45	69.9
2018	30	5403	19	72	56	62.4
2019	29	9916	23	87	65	79.0
2020	31	8845	24	90	59	80.6
2021	29	7496	27	89	65	80.2
2022	31	14807	31	104	90	98.1
2023	31	12074	37	115	92	107.3
2024	31	18522	52	131	118	124.5
Total	371	98069				

Part of this great result is also due to a significant expansion of our network with stations in the East of England. Seven RMS cameras in this country started to provide camera data to our project. *Nick Russell* (Seaford, UK), and *Alan Maunder* (Catherington, UK) started their contributions with 1 and 2 RMS cameras respectively on August 9. *Nick James* (Chelsford, UK) delivers his data to our network since August 11. *Jamie Olver* (Redhill, UK) since August 12. *Steve Carter* (Welwyn Garden City, UK) made his first contributions on August 16. Finally, contributions by *Miles Eddowes* (Reading, UK) are available since August 20. Together with data of the other UK cameras of *Andy Washington* and *Jim Rowe*, who are contributing already for several months, these stations have already contributed to a total of 1992 simultaneous meteors during the month of August. In the Netherlands, *Rob Smeenk* placed another RMS-camera in Assen on August 11. The number of captured meteors by this camera is already considerable: no less than 910 meteors of his total number of meteors this month were simultaneous.

The atmosphere over the southwest of the Netherlands is now better covered with cameras, since the station in Oostkapelle unfortunately stopped running, at least for some months, in June. The cameras of *Steve Rau* (Zillebeke, Belgium) have also been switched off since 23 August due to renovation work. Restart of these cameras will probably follow in November.

During the Perseid maximum, we were also treated to the activity of a new meteor shower. Peter Jenniskens called this new meteoroid stream the 'nu Capricornids' (Jenniskens, 2024a; 2024b). CAMS-BeNeLux collected no less than 19 meteor orbits of this new meteoroid stream. On average, 124 cameras were active every night this month. This high number is of course also a result of the expansion of our network this month. A minimum of 118 cameras and a maximum of 131 cameras were active each night (*Figure 1* and *Table 1*).

3 Conclusion

In August 2024 we have captured a record number of meteors, resulting in a new record of orbits for this month, thanks to excellent weather and a significant expansion of our network, especially in the United Kingdom.

Acknowledgement

Many thanks to all participants in the CAMS-BeNeLux network for their dedicated efforts. The CAMS-BeNeLux team was operated by the following volunteers during the month of August 2024:

Stéphane Barré (Colombey-Les-Belles, France, RMS 3907), *Hans Betlem* (Woold, Netherlands, Watec 3071, 3072, 3073, 3074, 3075, 3076, 3077 and 3078) , *Felix Bettonvil* (Utrecht, Netherlands, CAMS 377), *Jean-Marie Biets* (Engelmanshoven, Belgium, Watec 3180, 3181, 3182 and 3183), *Ludger Boergerding* (Holdorf, Germany, RMS 3801), *Günther Boerjan* (Assenede, Belgium, RMS 3823), *Martin Breukers* (Hengelo, Netherlands, Watec 320, 321, 322, 323, 324, 325, 326 and 327, RMS 319, 328 and 329), *Jean Brunet* (Fontenay le Marmion, France, RMS 3911), *Seppe Canonaco* (Genk, RMS 3818 and 3819), *Steve Carter* (Welwyn Garden City, England, RMS 3706), *Pierre de Ponthiere* (Lesve, Belgium, RMS 3816 and 3826), *Bart Dessoy* (Zoersel, Belgium, Watec 398, 805 and 806 and RMS 3827), *Jürgen Dörr* (Wiesbaden, Germany, RMS 3810, 3811 and 3812), *Isabelle Ansseau, Jean-Paul Dumoulin, Dominique Guiot* and *Christian Wanlin* (Grapfontaine, Belgium, Watec 814, 815, RMS 3817, 3843, 3844 and 3845), *Miles Eddowes* (Reading, England, RMS 3709), *Uwe Glässner* (Langenfeld, Germany, RMS 3800), *Roel Gloudemans* (Alphen aan de Rijn, Netherlands, RMS 3197), *Luc Gobin* (Mechelen, Belgium, Watec 3890, 3891, 3892, 3893 and 3894), *Tioga Gulon* (Nancy, France, Watec 3900 and 3901), *Tioga Gulon* (Chassignolles, France, RMS 3910), *Robert Haas* (Alphen aan de Rijn, Netherlands, Watec 3160, 3161, 3162, 3163, 3164, 3165, 3166 and 3167), *Robert Haas* (Burlage, Germany, RMS 3803 and 3804), *Kees Habraken* (Kattendijke, Netherlands, RMS 3780, 3781, 3782 and 3783), *Erwin Harkink* (Elst, Netherlands, RMS 3191), *Nick James* (Chelmsford, England, RMS 3710), *Carl Johannink* (Gronau, Germany, Watec 3100, 3101, 3102), *Reinhard Kühn* (Flatzby, Germany, RMS 3802), *Hervé Lamy* (Dourbes, Belgium, Watec 394 and 395, RMS 3825, 3841, 3895, 3896, 3897 and 3898), *Hervé Lamy* (Humain, Belgium, RMS 3821 and 3828), *Hervé Lamy* (Ukkel, Belgium, Watec 393 and 817), *Hartmut Leiting* (Solingen, Germany, RMS 3806), *Arnoud Leroy* (Gretz-Armainvielliers, France, RMS 3909), *Alan Maunder* (Catherington, England, RMS 3707-3708), *Horst Meyerdierks* (Osterholz-Scharmbeck, Germany, RMS 3807), *Koen Miskotte* (Ermelo, Netherlands, Watec 3051, 3052, 3053 and 3054), *Jamie Olver* (Redhill, England, RMS 3705), *Pierre-Yves Péchart* (Hagnicourt, France, RMS 3902, 3903, 3904, 3905, 3906 and 3908), *Holger Pedersen* (Otterup, Denmark, RMS 3501), *Eduardo Fernandez del Peloso* (Ludwigshafen, Germany, RMS 3805), *Tim Polfliet* (Gent, Belgium, Watec 396, RMS 3820 and 3840, *Tim Polfliet* (Grimbergen, Belgium, RMS 3846), *Steve Rau* (Oostende, Belgium, RMS 3822), *Steve Rau* (Zillebeke, Belgium, Watec 3850 and 3852, RMS 3851 and 3853), *Paul and Adriana Roggemans* (Mechelen, Belgium, RMS 3830, Watec 3832, 3833, 3834, 3835, 3836 and 3837), *Jim Rowe* (Eastbourne, England, RMS 3703), *Nick Russell* (Seaford, England, RMS 3704), *Philippe Schaack* (Roodt-sur-Syre, Luxemburg, RMS 3952), *Romke Schievink* (Bruchhausen Vilsen, Germany, RMS 3808 and 3809), *Hans Schremmer* (Niederkruechten, Germany, Watec 803), *Rob Smeenk* (Assen, Netherlands, RMS 3190 and 3196), *Rob Smeenk* (Kalenberg, Netherlands, RMS 3192, 3193, 3194 and 3195), *Erwin van Ballegoij* (Heesh, Netherlands Watec 3148 and 3149), *Andy Washington* (Clapton, England, RMS 3702).

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September 2024 report CAMS-BeNeLux

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A summary of the activity of the CAMS-BeNeLux network during the month of September 2024 is presented. This month was good for 32379 multi-station meteors resulting in 9921 orbits.

1 Introduction

Sporadic meteor activity in September is already fairly high. Major meteor streams are absent this month, but nevertheless September can be very enjoyable for meteor observers due to this sporadic activity.

2 September 2024 statistics

The weather in September was very changeable. This month ended with the rare combination of both sunshine and amount of rain above average. As a result, our network could record some wonderful nights and also a few nights with only a meager result.

Thanks to the expansion of our network with some stations in the UK last month, not a single night passed without any result. The worst case was September 25–26, when only three orbits could be collected with 118 cameras active this night.

Thanks to very clear nights in the period September 11–15 and September 28, the number of collected orbits in these nights got above 700, with up to 884 during September 28–29. Like in 2023 this month got only five nights with less than 100 orbits collected.

CAMS-BeNeLux collected data of 32379 multi-multaneous meteors from all stations. As a result, a total of 9221 orbits was collected. The second-best result for a September month so far. 53.6% of all orbits were captured from more than two stations. This percentage is lower than last months.

An extra RMS camera has been installed this month by *Erwin van Ballegoij* at Heesch (Netherlands). This camera gives a better coverage for the northwestern parts of the Netherlands and the adjacent parts of the North Sea.

On average 121 cameras were active every night. At least 112 cameras and at most 128 cameras were active this month (*Figure 1* and *Table 1*).

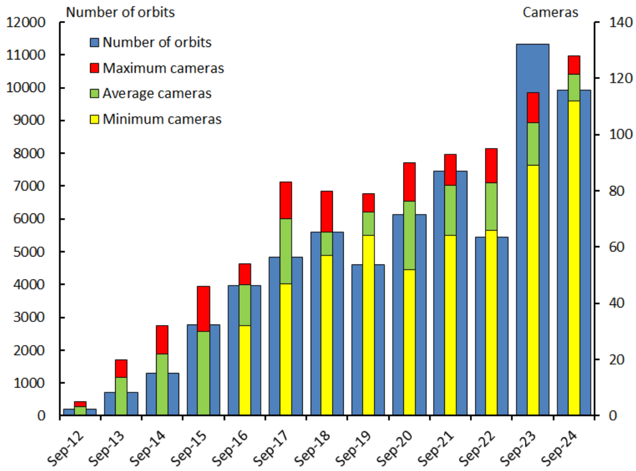

Figure 1 – Comparing September 2024 to previous months of September in the CAMS-BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras capturing in a single night, the green bars the average number of cameras capturing per night and the yellow bars the minimum number of cameras.

Table 1 – Number of orbits and active cameras in CAMS-BeNeLux during the month of September in the period 2012–2024.

Year	Nights	Orbits	Stations	Max. Cams	Min. Cams	Mean Cams
2012	18	209	5	5		3.4
2013	19	712	9	20		13.7
2014	27	1293	14	32		22.0
2015	29	2763	15	46		30.0
2016	30	3982	19	54	32	46.5
2017	29	4839	22	83	47	70.2
2018	28	5606	20	80	57	65.4
2019	29	4609	20	79	64	72.3
2020	26	6132	24	90	52	76.2
2021	30	7457	26	93	64	82.0
2022	30	5446	30	95	66	82.8
2023	30	11331	37	115	89	104.1
2024	30	9921	49	128	112	121.5
Total	355	64300				

3 Conclusion

The month of September 2024 managed to generate a high number of orbits for a September month, partly thanks to some very clear nights and the substantial expansion towards the UK since last month.

Acknowledgement

Many thanks to all participants in the CAMS-BeNeLux network for their dedicated efforts. The CAMS-BeNeLux team was operated by the following volunteers during the month of September 2024:

Stéphane Barré (Colombey-Les-Belles, France, RMS 3907), *Hans Betlem* (Woold, Netherlands, Watec 3071, 3072, 3073, 3074, 3075, 3076, 3077 and 3078), *Jean-Marie Biets* (Engelmanshoven, Belgium, Watec 3180, 3181, 3182 and 3183), *Ludger Boergerding* (Holdorf, Germany, RMS 3801), *Günther Boerjan* (Assenede, Belgium, RMS 3823), *Martin Breukers* (Hengelo, Netherlands, Watec 320, 321, 322, 323, 324, 325, 326 and 327, RMS 319, 328 and 329), *Jean Brunet* (Fontenay le Marmion, France, RMS 3911), *Seppe Canonaco* (Genk, RMS 3818 and 3819), *Steve Carter* (Welwyn Garden City, England, RMS 3706), *Pierre de Ponthiere* (Lesve, Belgium, RMS 3816 and 3826), *Bart Dessoy* (Zoersel, Belgium, Watec 398, 805 and 806 and RMS 3827), *Jürgen Dörr* (Wiesbaden, Germany, RMS 3810, 3811 and 3812), *Isabelle Ansseau, Jean-Paul Dumoulin, Dominique Guiot* and *Christian Wanlin* (Grapfontaine, Belgium, Watec 814, 815, RMS 3817, 3843, 3844 and 3845), *Miles Eddowes* (Reading, England, RMS 3709), *Uwe Glässner* (Langenfeld, Germany, RMS 3800), *Roel Gloudemans* (Alphen aan de Rijn, Netherlands, RMS 3197), *Luc Gobin* (Mechelen, Belgium, Watec 3890, 3891, 3892, 3893 and 3894), *Tioga Gulon* (Nancy, France, Watec 3900 and 3901), *Tioga Gulon* (Chassignolles, France, RMS 3910), *Robert Haas* (Alphen aan de Rijn, Netherlands, Watec 3160, 3161, 3163, 3164, 3165, 3166 and 3167), *Robert Haas* (Burlage, Germany, RMS 3803 and 3804), *Kees Habraken* (Kattendijke, Netherlands, RMS 3780, 3781, 3782 and 3783), *Erwin Harkink* (Elst, Netherlands, RMS 3191), *Nick James* (Chelmsford, England, RMS 3710), *Carl Johannink* (Gronau, Germany, Watec 3100, 3101, 3102), *Reinhard Kühn* (Flatzby, Germany, RMS 3802), *Hervé Lamy* (Dourbes, Belgium, Watec 394 and 395, RMS 3825, 3841, 3895, 3896, 3897 and 3898), *Hervé Lamy* (Humain, Belgium, RMS 3821 and 3828), *Hervé Lamy* (Ukkel, Belgium, Watec 393 and 817), *Hartmut Leiting* (Solingen, Germany, RMS 3806), *Arnoud Leroy* (Gretz-Armainvielliers, France, RMS 3909), *Alan Maunder* (Catherington, England, RMS 3707-3708), *Horst Meyerdierks* (Osterholz-Scharmbeck, Germany, RMS 3807), *Koen Miskotte* (Ermelo, Netherlands, Watec 3051, 3052, 3053 and 3054), *Jamie Olver* (Redhill, England, RMS 3705), *Pierre-Yves Péchart* (Hagnicourt, France, RMS 3902, 3903, 3904, 3905, 3906 and 3908), *Holger Pedersen* (Otterup, Denmark, RMS 3501), *Eduardo Fernandez del Peloso* (Ludwigshafen, Germany, RMS 3805), *Tim Polfliet* (Gent, Belgium, Watec 396, RMS 3820 and 3840, *Steve Rau* (Oostende, Belgium, RMS 3822), *Paul and Adriana Roggemans* (Mechelen, Belgium, RMS 3830, Watec 3832, 3833, 3834, 3835, 3836 and 3837), *Jim Rowe* (Eastbourne, England, RMS 3703), *Nick Russell* (Seaford, England, RMS 3704), *Philippe Schaack* (Roodt-sur-Syre, Luxemburg, RMS 3952), *Romke Schievink* (Bruchhausen Vilsen, Germany, RMS 3808 and 3809), *Hans Schremmer* (Niederkruechten, Germany, Watec 803), *Rob Smeenk* (Assen, Netherlands, RMS 3190 and 3196), *Rob Smeenk* (Kalenberg, Netherlands, RMS 3192, 3193, 3194 and 3195), *Erwin van Ballegoij* (Heesh, Netherlands Watec 3148 and 3149, RMS 3189), *Andy Washington* (Clapton, England, RMS 3702).

August 2024 CARMELO report

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The CARMELO network (Cheap Amateur Radio Meteor Echoes LOgger) is a collaboration of SDR radio receivers aimed at detecting meteor echoes. This report presents the data for August 2024, particularly during the Perseid meteor shower, observed by 14 receivers located in Italy, the UK, Croatia, and the USA. A notable increase in meteor activity was recorded from August 11 to 13, in agreement with predictions of Earth's encounter with ancient debris from comet Swift-Tuttle. The high speed of Perseid meteors led to oversaturated echoes and fragmentation events. The analysis of the echoes, including head echoes and Doppler effects, allowed some estimations of meteoroid size and trajectory. The network's findings support current meteor shower predictions and demonstrate the potential for expanding the network to improve data collection.

1 Introduction

The CARMELO network consists of SDR radio receivers. In them, a microprocessor (Raspberry) performs three functions simultaneously:

1. By driving a dongle, it tunes the frequency on which the transmitter transmits and tunes like a radio, samples the radio signal and through the FFT (Fast Fourier Transform) measures frequency and received power.
2. By analyzing the received data for each packet, it detects meteoric echoes and discards false positives and interference.
3. It compiles a file containing the event log and sends it to a server.

The data are all generated by the same standard, and are therefore homogeneous and comparable. A single receiver can be assembled with a few devices whose total current cost is about 210 euros.

To participate in the network read the instructions on this page[12].

2 August data

In the graphs that follow, all available at this page[13], the abscissae represent time, which is expressed in UT (Universal Time), and the ordinates represent the hourly rate, calculated as the total number of events recorded by the network in an hour divided by the number of operating receivers.

The Perseid meteor shower reaches its peak activity every year before the middle of August, of which it becomes the real main character. This shower is caused by the debris left behind by comet Swift-Tuttle, which, entering Earth's atmosphere at a speed of 61 km/s, disintegrate to create the characteristic light trails.

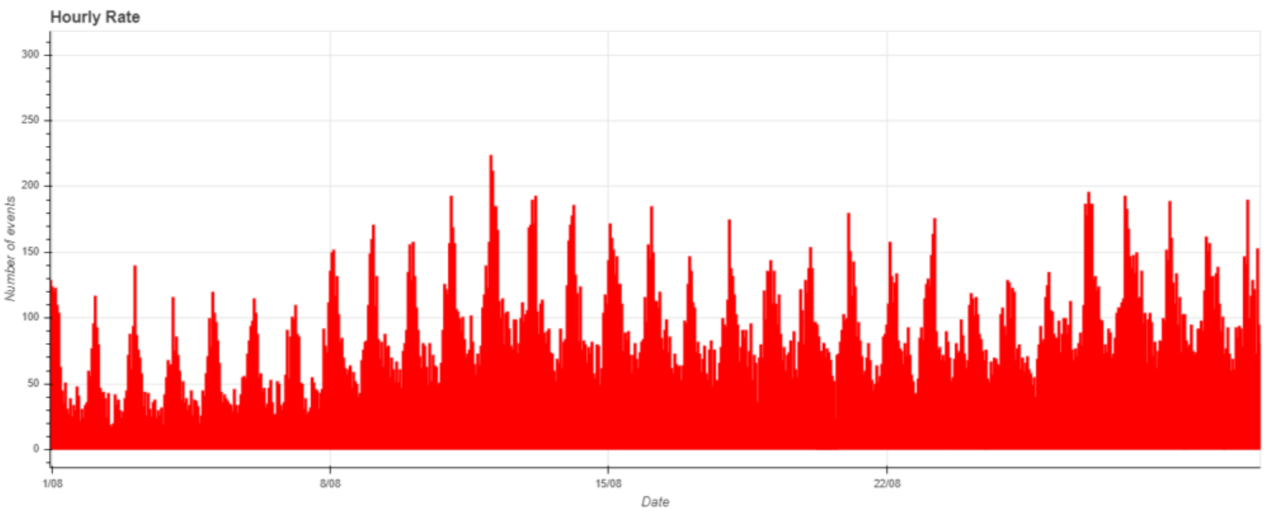

Figure 1 – August data trend from the CARMELO network.

[12] http://www.astrofiliabologna.it/about_carmelo

[13] http://www.astrofiliabologna.it/graficocarmelohr

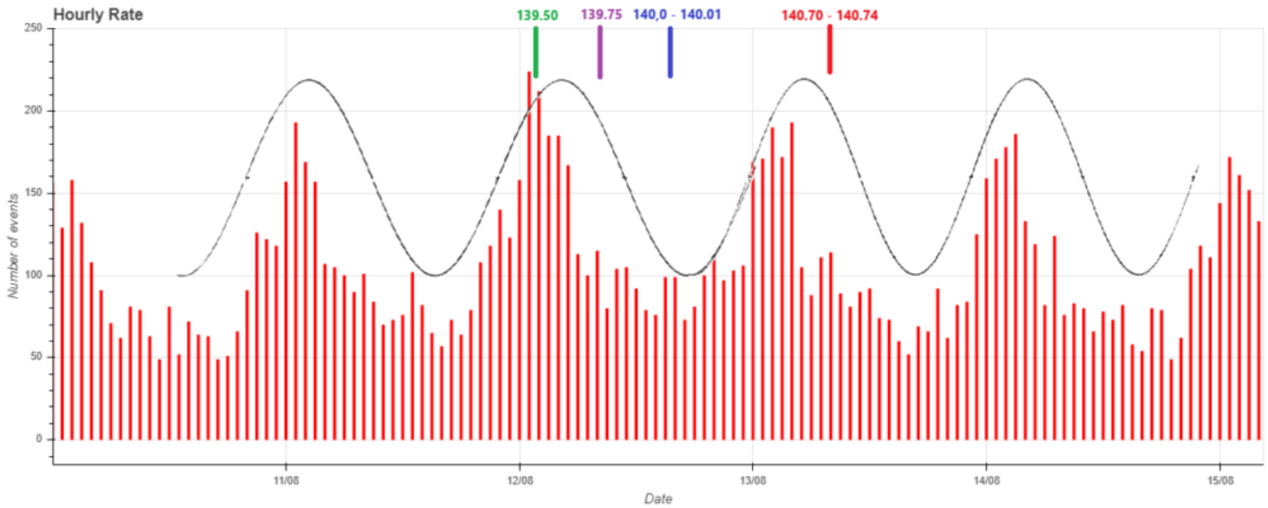

Figure 2 – Details of the three days from August 11 to 13.

During this period, the hourly rate of observed meteors showed a significant increase. The graph for the month of August (*Figure 1*) clearly shows this increase, particularly between August 11 and 13, due to the increased density of meteoroids in the regions crossed by Earth on those days.

3 Perseids hourly rate

Analyzing the days from August 11 to 13 in detail, we seethe activity displayed in *Figure 2*. In this graph, the black sinusoidal line represents the height of the radiant, or the point in the sky where the meteors appear to come from, corresponding to the direction from which the Earth passes through the dust trail. The radiant depends on location, because its position with respect to the horizon varies with latitude and time of the day, affecting the number of meteors observable in that area, and thus the hourly rate. The graph shows the trend for an average Italian location.

An increase in the hourly rate can be seen at the expected peak, when the solar longitude reaches 140.0° to 140.1° (indicated by the blue arrow). However, this peak, which is the time when the largest number of meteors is expected during a meteor shower, occurred precisely when the radiant was at its lowest position on the horizon, at the time of minimum observability.

We can also see a correspondence between the increase in the hourly rate of meteors and the predictions of Jürgen Rendtel and Jérémie Vaubaillon (Rendtel and Vaubaillon, 2024), who predicted the encounter of the Earth with some very old dust trails. The first occurred at solar longitude 139.50° (on August 12 at 04^h50^m UT), indicated in the graph with a green line. The second occurred at solar longitude 139.75° (on August 12 at 07^h19^m UT), marked with a line arrow. The third at solar longitude 140.70°–140.74° (on August 13 between 07^h00^m and 08^h00^m UT). These dust trails come from ancient passages of comet Swift-Tuttle, and contributed to the increase in the observed number of meteors. According to the authors, they are very old: dating back to passages more than 1300 years ago.

To make an approximate assessment of the diameter of these filaments, consider the Earth speed in its motion in the Solar System, which is 107000 km/h. A filament such as the first, at which the increase in the hourly rate we detected is about two hours, could therefore have a diameter greater than or equal to 200000 km by considering it, in an arbitrary and coarse manner, to be cylindrical in shape.

4 Meteoroid mass and saturation

Analyzing the duration of the echoes, we see that the average durations tend to increase around 11^h to 12^h UT on August 12, thus ahead of the peak hourly rate by about 5 to 6 hours. This fact, if we consider that longer duration of the echoes is associated with larger meteoroids, suggests that the largest fragments of the Perseids shower could be encountered by the Earth about 500000 km before the peak time of the shower, preceding the peak (*Figure 3*).

5 Perseids speed

The Perseids are one of the fastest meteor showers. The result of this was the high number of “oversaturated” meteor echoes, i.e., signals that were particularly intense in terms of both the duration of the echoes and the intensity of the radio signal received.

We had to increase the scale of the graphs representing the intensity of the signals, since some of them were significantly louder, exceeding the levels recorded during the rest of the year by several decibels.

Precisely because of the great speed of the meteors, it was also easier to observe the leading echoes, which are the signals reflected from the front of the ionization cylinder created by the meteors in their trajectory. Because velocity affects the way the ionization trail moves, head echoes can show obvious Doppler effects, thus shifts in signal frequency, due to the meteoroid’s fast movement through the atmosphere.

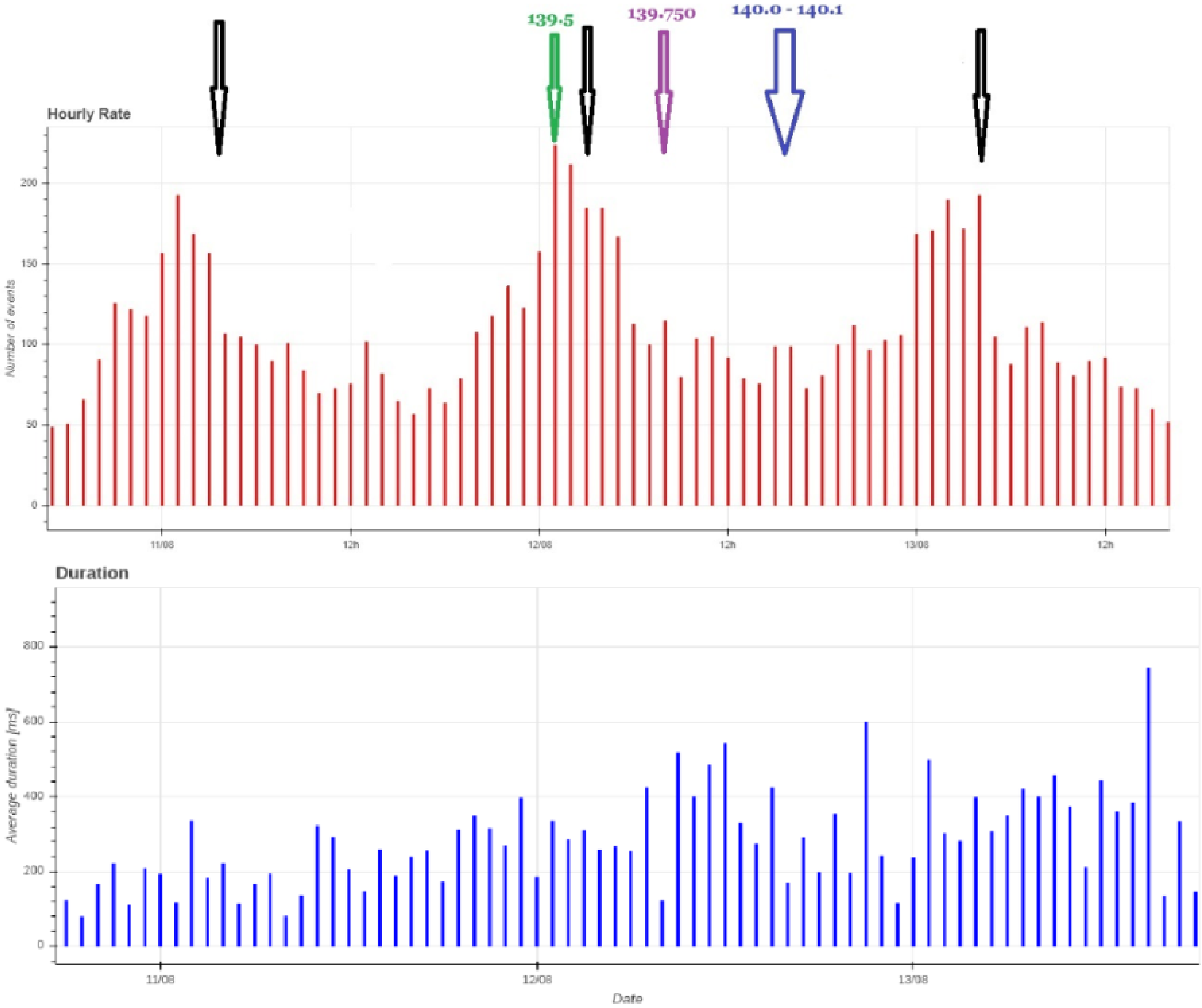

Figure 3 – Comparison of echoes hourly rate and duration.

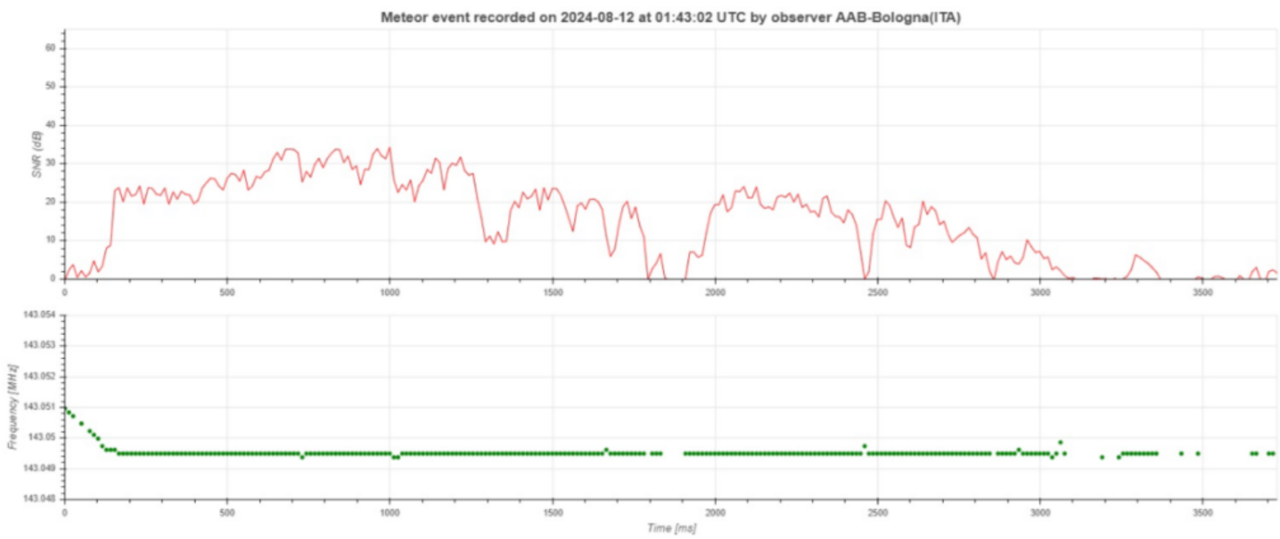

Figure 4 – Head echoes preceding specular reception.

6 Fragmentations

Again, because of the large kinetic energy of these meteors, many more signals from fragmentations were recorded during the shower period.

Figure 5 shows the echoes from fragmented meteor. The variation in amplitude can be explained by the sum of the contributions of echoes from two or more fragments, which, depending on their distance from each other, provide different echoes that add up to different phases.

In *Figure 5* one of many echoes from fragmented meteors is displayed. The physics of this phenomenon are described by Elford and Campbell (2001).

We also noted two cases of head echoes from a fragment that most likely belonged to a "train" of fragments: one of these two cases is shown in *Figure 6*.

Such signals had never appeared in two years of CARMELO network observations, but during the Perseids 2024 meteor shower we saw two of them.

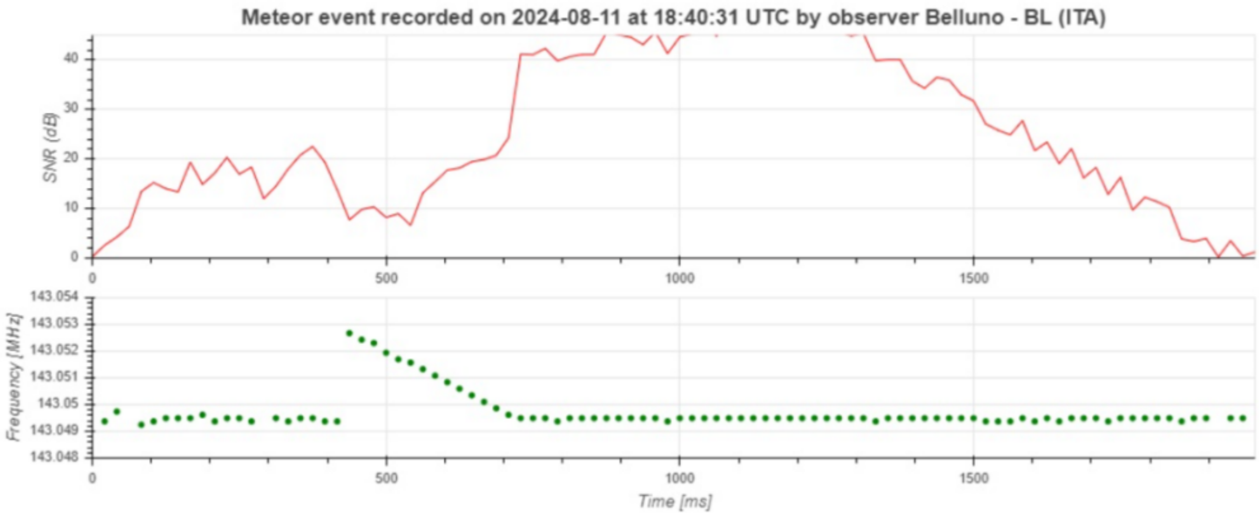

Figure 6 – In the first 400 milliseconds the echo of the specular reception of a first fragment is seen. Then the echo is overlaid by the leading echo and the following specular reception of a larger fragment, which follows the first one.

7 The CARMELO network

The network currently consists of 14 receivers, 13 of which are operational, located in Italy, the UK, Croatia and the USA. The European receivers are tuned to the Graves radar station frequency in France, which is 143.050 MHz. Participating in the network are:

- Lorenzo Barbieri, Budrio (BO) ITA
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- Associazione Astrofili Pisani, Orciatico (PI) ITA
- Gruppo Astrofili Persicetani, San Giovanni in Persiceto (BO) ITA
- Roberto Nesci, Foligno (PG) ITA
- MarSEC, Marana di Crespadoro (VI) ITA
- Gruppo Astrofili Vicentini, Arcugnano (VI) ITA
- Associazione Ravennate Astrofili Theyta, Ravenna (RA) ITA
- Akademsko Astronomsko Društvo, Rijeka CRO
- Mike German a Hayfield, Derbyshire UK
- Mike Otte, Pearl City, Illinois USA

The authors' hope is that the network can expand both quantitatively and geographically, thus allowing the production of better-quality data.

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Rendtel J., Vaubaillon J. (2024). "Observing the Perseid maximum in 2024". *WGN Journal of the International Meteor Organization*, **52**, 27–28.

Elford W.G., Campbell L. (2001): "Effects of meteoroid fragmentation on radar observations of meteor trails". *Proceedings of the Meteoroids 2001 Conference*, 6 – 10 August 2001, Kiruna, Sweden. Ed.: Barbara Warmbein. ESA SP-495, Noordwijk: ESA Publications Division, ISBN 92-9092-805-0, 2001, pp. 419–423.

September 2024 CARMELO report

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The CARMELO network (Cheap Amateur Radio Meteor Echoes LOgger) is a collaboration of SDR radio receivers aimed at detecting meteor echoes. This report presents the data for September 2024.

1 Introduction

The month of September 2024 offered some interesting radio meteor observations, with activity produced mainly by the ε-Perseids (SPE#208) meteor shower. This bulletin from the CARMELO (Cheap Amateur Radio Meteor Echoes Logger) network presents an analysis of events detected through radio receivers distributed among Italy, Croatia, England and the United States, particularly during the ε-Perseids (208 SPE) peak, which characterized the early part of the month.

The bulletin examines the trend of meteoric activity during the month. It also discusses some of the effects of the recent May 2024 geomagnetic storm, which affected the surveys, offering some insights and possibilities for future studies.

2 Methods

The CARMELO network consists of SDR radio receivers. In them, a microprocessor (Raspberry) performs three functions simultaneously:

1. By using a dongle, it tunes the frequency on which the transmitter transmits and tunes like a radio, samples the radio signal and through the FFT (Fast Fourier Transform) measures frequency and received power.
2. By analyzing the received data for each packet, it detects meteoric echoes and discards false positives and interference.
3. It compiles a file containing the event log and sends it to a server.

The data are all generated by the same standard, and are therefore homogeneous and comparable. A single receiver can be assembled with a few devices whose total current cost is about 210 euros.

To participate in the network read the instructions on this page[14].

3 September data

In the graphs that follow, all available at this page[15], the abscissae represent time, which is expressed in UT (Universal Time), and the ordinates represent the hourly rate, calculated as the total number of events recorded by the network in an hour divided by the number of operating receivers.

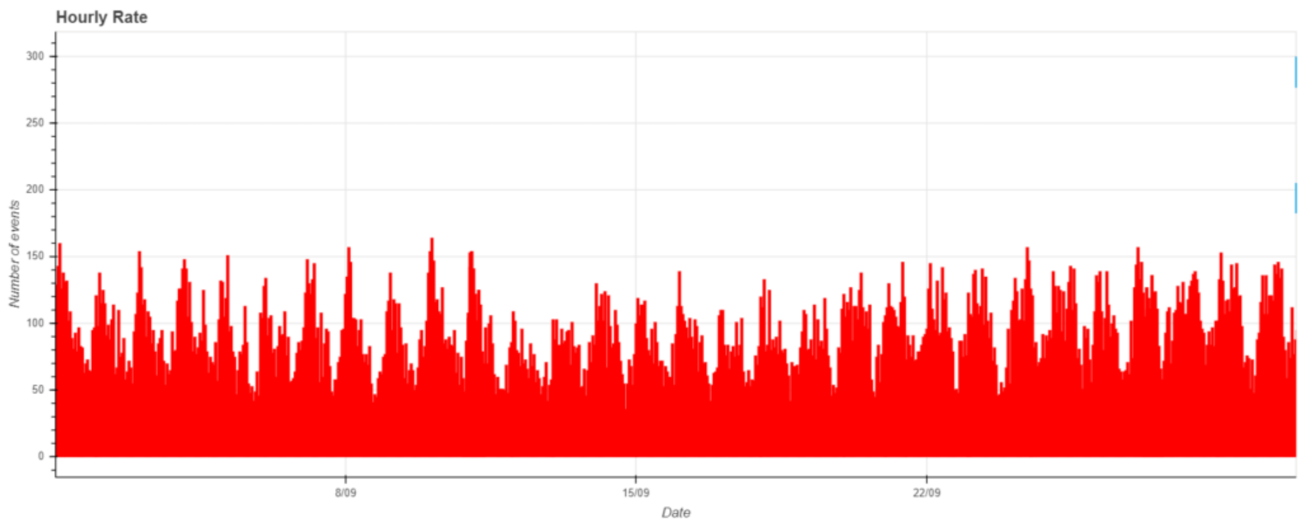

Figure 1 – September data trend from the CARMELO network.

[14] http://www.astrofiliabologna.it/about_carmelo

[15] http://www.astrofiliabologna.it/graficocarmelohr

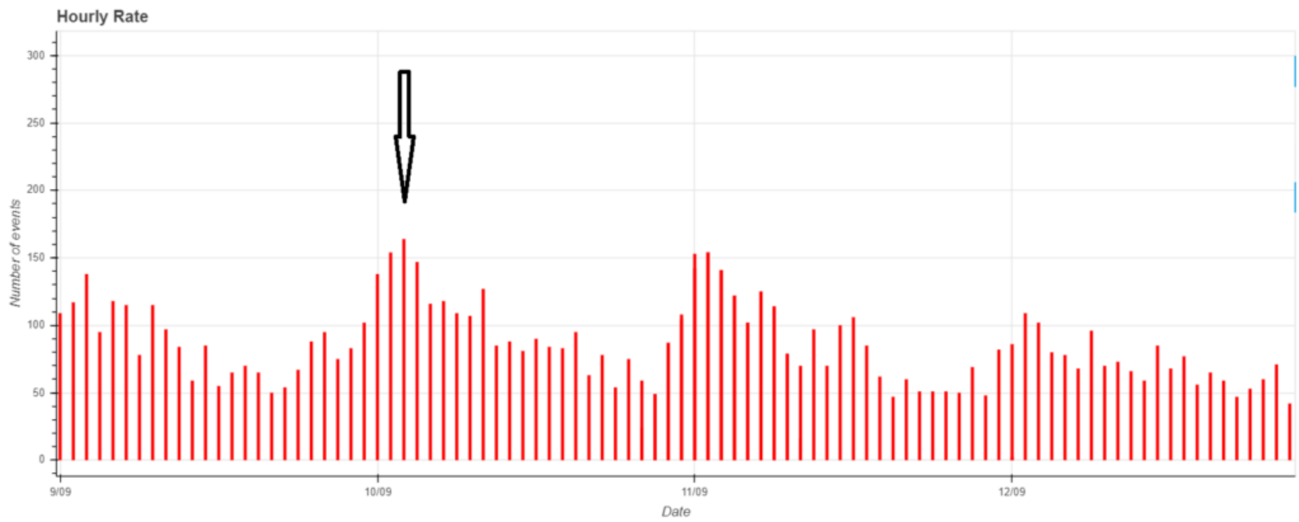

Figure 2 – Signals received by the CARMELO network between September 9 and 13, 2024.

Figure 1 shows the hourly rate of radio meteor detections for the month of September 2024. The main event corresponds to the ε-Perseid (208 SPE) meteor shower, active between late August and mid-September[16]. The shower peaked on September 10.

4 ε-Perseids

September's ε-Perseids are less well known than major meteor showers such as the August's Perseids or December's Geminids. The peak produces a maximum activity of about 5–10 meteors per hour under dark sky conditions. The shower has its radiant, or the point in the sky from which the meteors appear to radiate, in the constellation of Perseus, which, in the northern hemisphere, is particularly high on the horizon in the pre-dawn hours.

The graph shows a slight increase in the number of events detected in the days up to Sept. 11. In *Figure 2*, a zoom-in shows the trend during this time of the month.

After the peak, the graph shows a decline and finally a relatively constant background level of meteor detections, with small fluctuations mainly due to sporadic or contributions from other meteor showers.

5 May 2024 auroral radio emissions and interference

During the International Meteor Conference 2024 (IMC2024) Sept. 19-22 in Kutná Hora, Czech Republic, Hervé Lamy of the Belgian Institute for Space Aeronomy gave a presentation titled "Radio emissions of auroral origin observed by the BRAMS network during the Mother's Day geomagnetic storm", during which he presented a study of geomagnetic activity during geomagnetic storms and its impact on radio detection networks such as the Belgian BRAMS (Lamy, 2024).

Geomagnetic storms, such as the particularly intense one that occurred between May 10 and 12, 2024, occur when coronal mass ejections (CMEs) interact with the Earth's magnetic field, causing changes in the ionosphere that affect radio transmission. Radio emissions associated with the aurora, mainly at VLF frequencies (3–30 kHz), but also HF and VHF (between 30 and 300 MHz), disrupt radio wave propagation[17] (Sigh et al., 2018).

In addition, in conjunction with strong coronal mass emissions, it is conceivable that the degree of ionization of the ionosphere increases implying the presence of more free electrons. It can be hypothesized that the ionization efficiency due to the meteor phenomenon is therefore lower, resulting in fewer detected meteors.

During the geomagnetic storm of May 10–12, 2024, the BRAMS network detected a reduction in meteor signals, as illustrated by Lamy. We checked the behavior of the CARMELO network from days before to days after the May storm to see if it was in agreement with what Lamy reported. *Figure 3* shows the trend of signals detected during that period.

It shows a reduction in the number of signals received on May 11 at 3^h UT at the peak of the storm.

Auroral radio emissions, however, as pointed out in a 2023 study by James LaBelle (2023), still present both theoretical and experimental open challenges, including understanding their frequency, temporal structure, and relationship to auroral phenomena. Key parameters such as source heights or generation mechanisms remain uncertain. However, technological advances, such as the use of cubesats and dedicated missions, are paving the way for improved remote sensing and understanding of auroral emissions, providing new opportunities to monitor the ionosphere and improve the sensitivity of radio receiver networks, such as CARMELO.

[16] https://www.iaumeteordatacenter.org/

[17] https://www.swpc.noaa.gov/impacts/hf-radio-communications

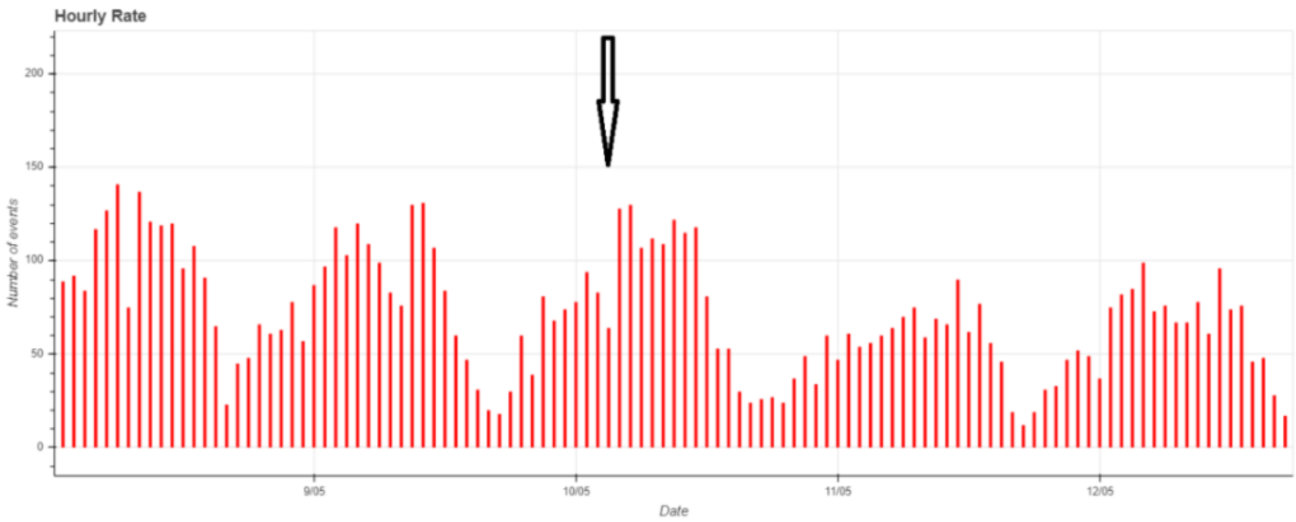

Figure 3 – Trend of signals detected between May 8 and May 14, 2024.

6 The CARMELO network

The network currently consists of 14 receivers, 13 of which are operational, located in Italy, the UK, Croatia and the USA. The European receivers are tuned to the Graves radar station frequency in France, which is 143.050 MHz. Participating in the network are:

- Lorenzo Barbieri, Budrio (BO) ITA;
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The authors' hope is that the network can expand both quantitatively and geographically, thus allowing the production of better-quality data.

References

Lamy H. (2024). "Radio emissions of auroral origin observed by the BRAMS network during the Mother's Day geomagnetic storm". International Meteor Conference 2024, to be published.

Sigh S. B., Patel K., Sigh A. K. (2018). "Effect of geomagnetic storms on VHF scintillations observed at low latitude". *Journal of Astrophysics and Astronomy*, **39**, n°36.

LaBelle J. (2023). "Radio emissions of auroral origin observable at ground level: outstanding problems". *Frontiers in Astronomy and Space Sciences*, vol.10.

Radio meteors August 2024

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An overview of the radio observations during August 2024 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 August 2024.

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 generally remained low, while weak to moderate lightning activity was recorded on only 3 days. However, there were multiple, fairly strong solar flares per day, the vast majority of type III.

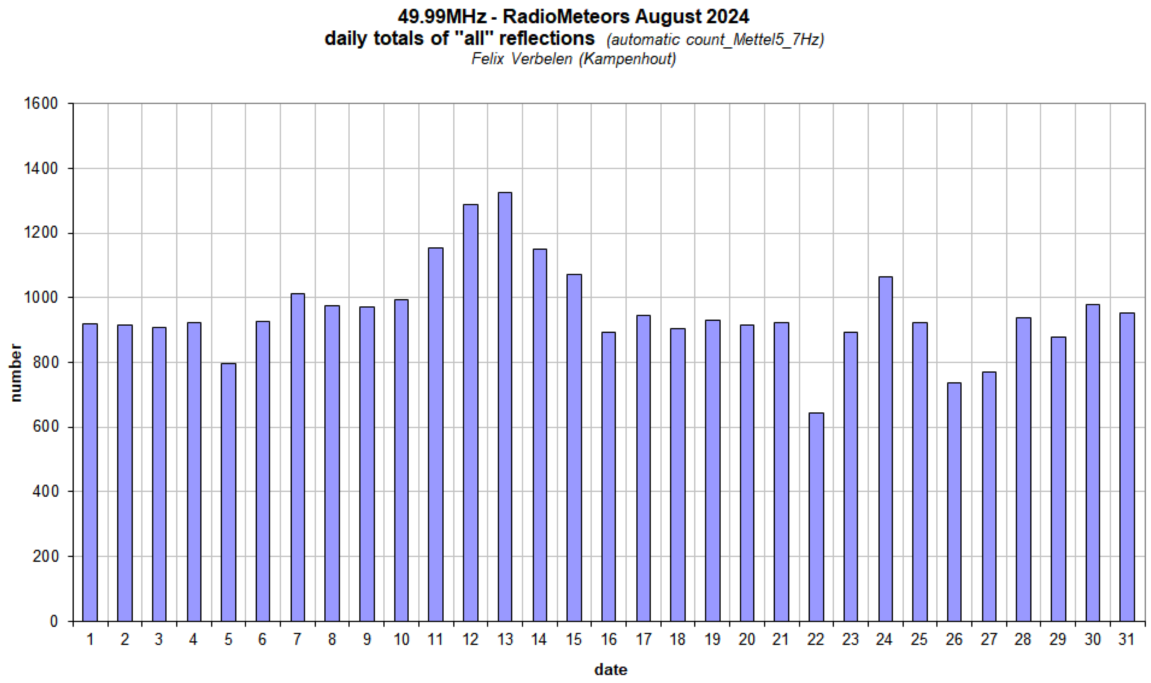
Remarkable was the reflection of the beacon signal on August 6 between approximately 09^h30^m UT and 10^h37^m UT, when the reflection abruptly stopped. This reflection was observed by many stations and at various frequencies. Further research and comparison with both geophysical observations and amateur radio connections showed that it was due to strong "sporadic E" (Es). The registration here in Kampenhout between 10^h00^m UT and 10^h40^m UT is shown in *Figure 5*.

The highlights of the month were undoubtedly the Perseids, with numerous long-duration reflections as every year. After a ramp-up period with increased activity in the first part of the month, the shower reached the predicted maximum on August 12–13. Reflections with a duration of more than 1 minute showed a clear maximum on August 13.

Over the entire month, 68 reflections longer than 1 minute were recorded here. A selection of these, along with some other interesting reflections is included (*Figures 6 to 31*). More of these are available on request.

In addition to the usual graphs, you will also find the raw counts in cvs-format[18] 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.

[18] https://www.emeteornews.net/wp-content/uploads/2024/09/202408_49990_FV_rawcounts.csv



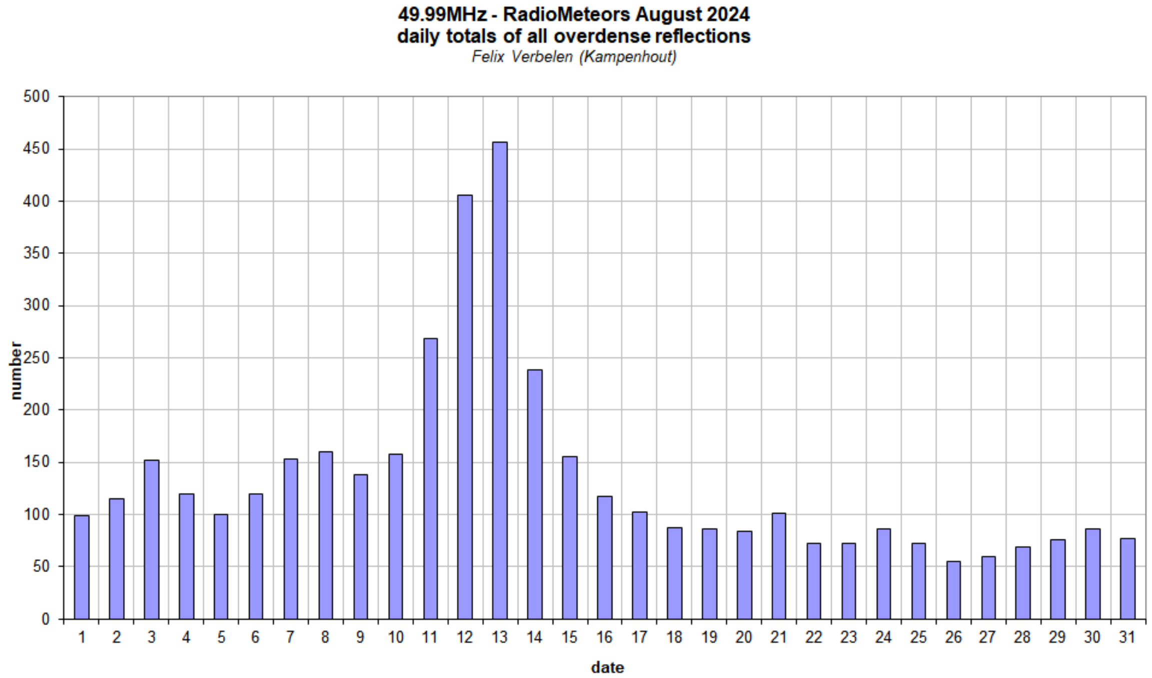
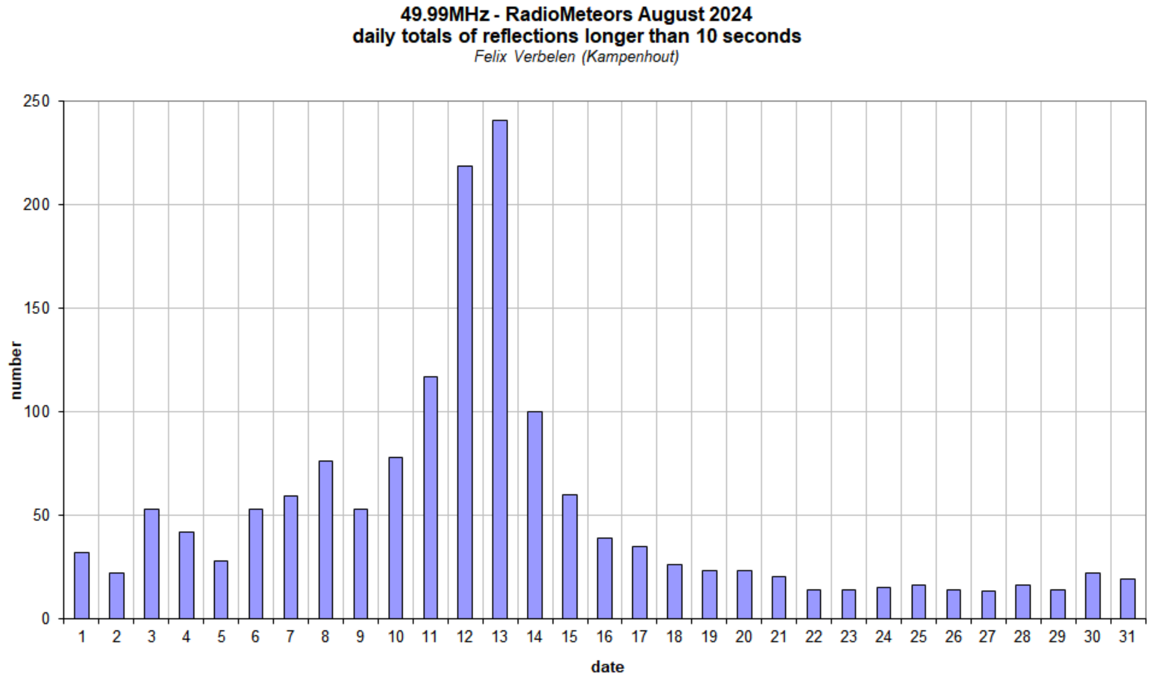


Figure 1 – The daily totals of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during August 2024.



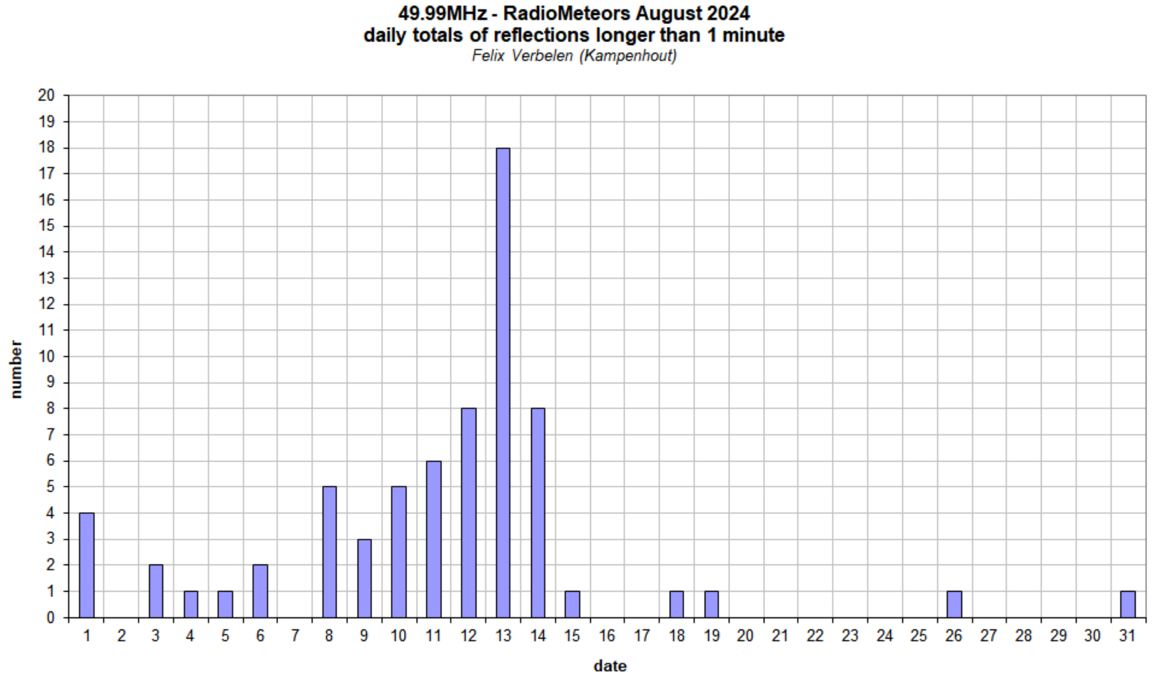
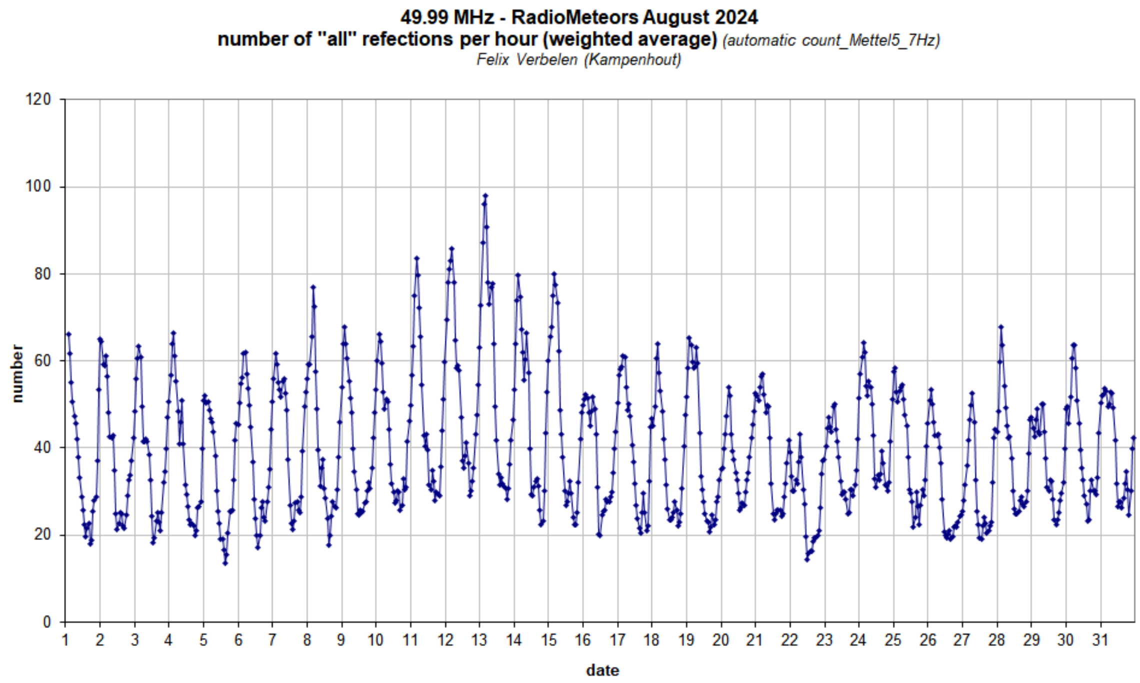


Figure 2 – The daily totals of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during August 2024.



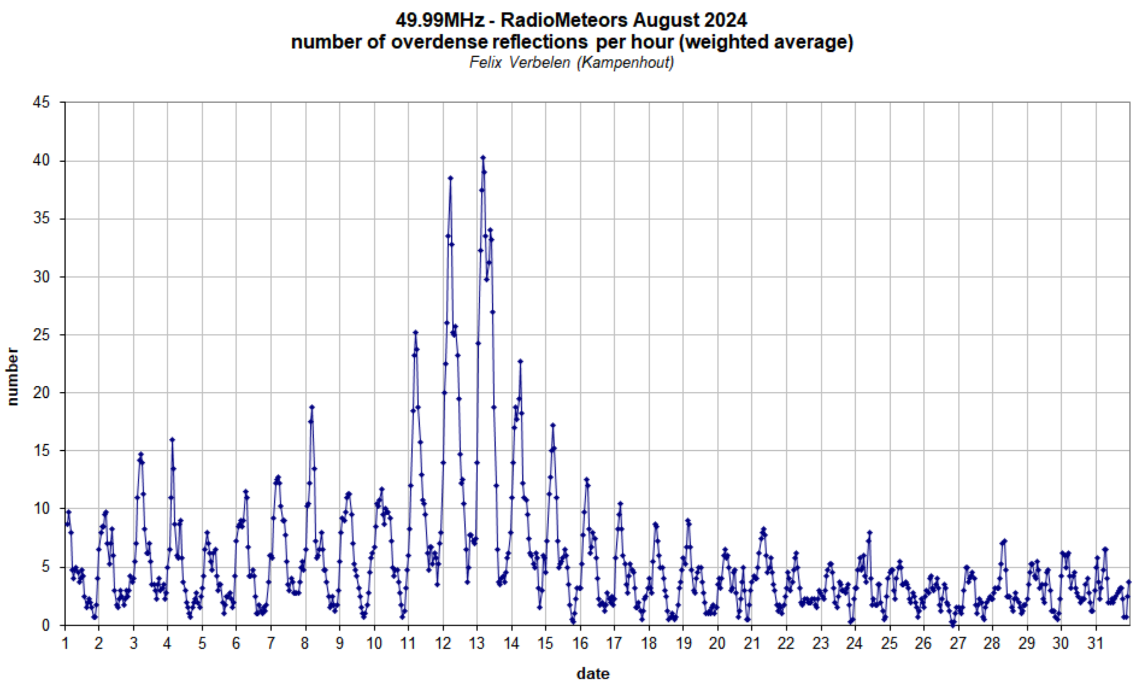
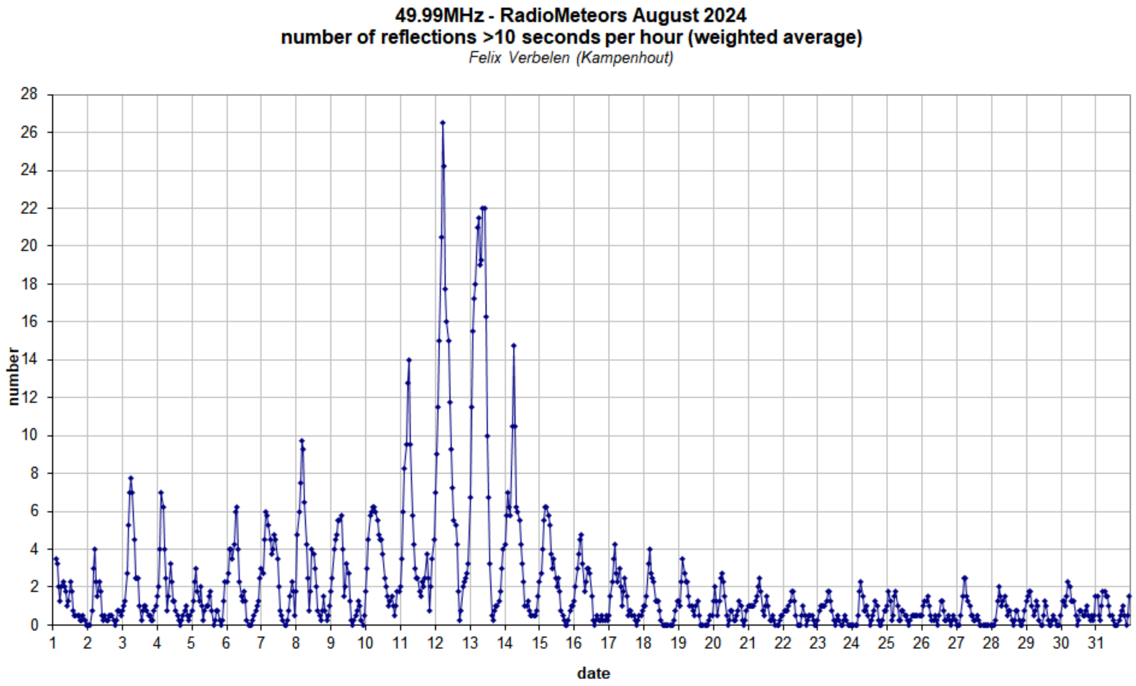


Figure 3 – The hourly numbers of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during August 2024.



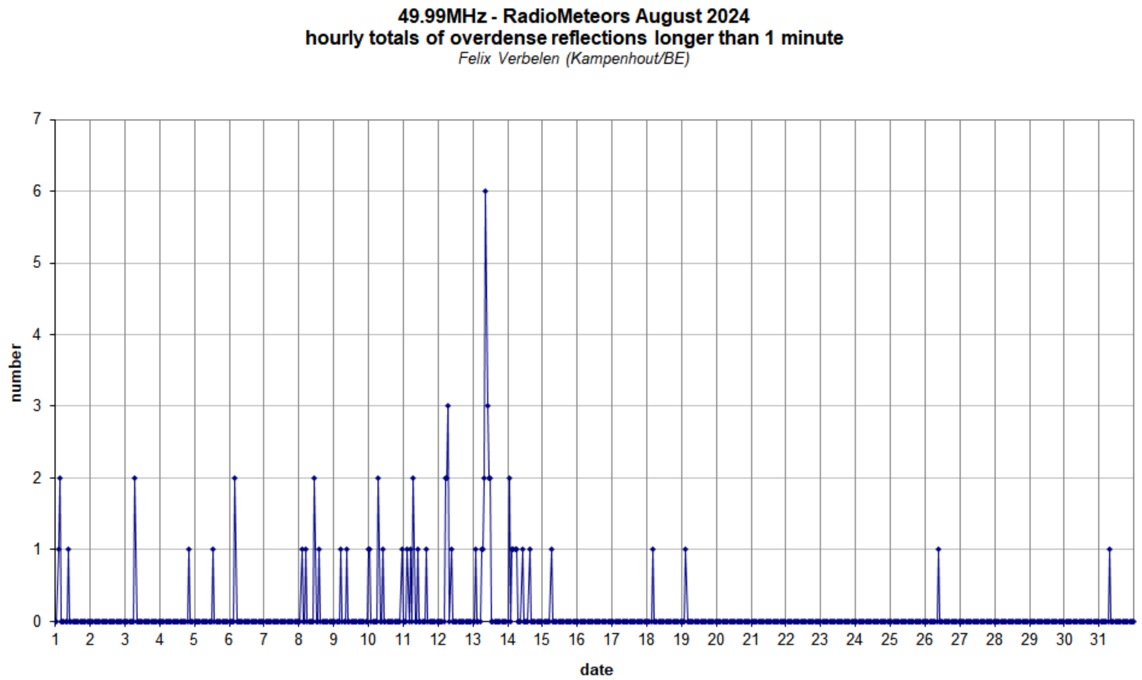


Figure 4 – The hourly numbers of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during August 2024.

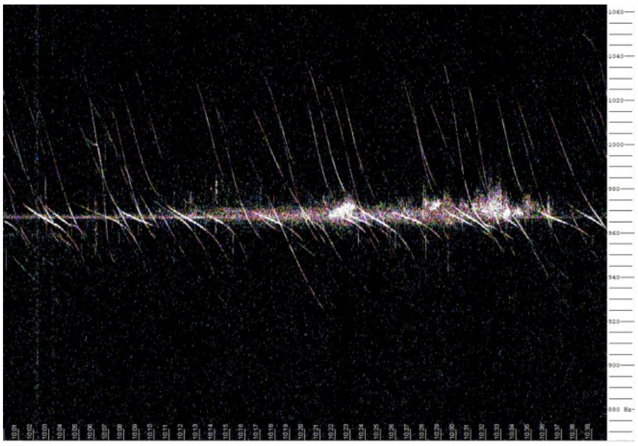


Figure 5 – Strong “sporadic E” (Es). The registration here in Kampenhout between 10^h00^m UT and 10^h40^m UT.

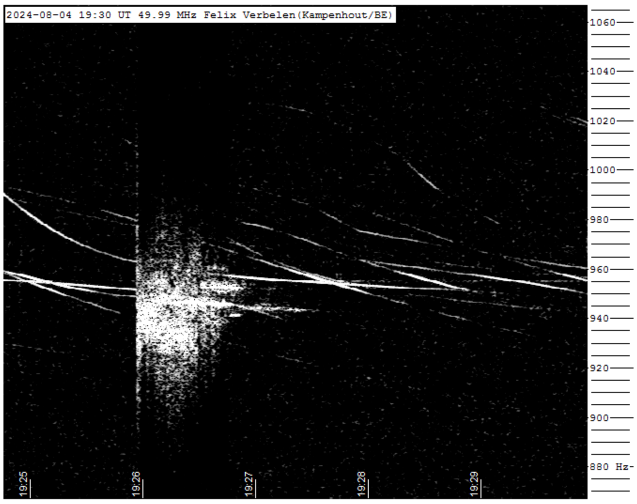


Figure 6 – Meteor echoes August 4, 19^h30^m UT.

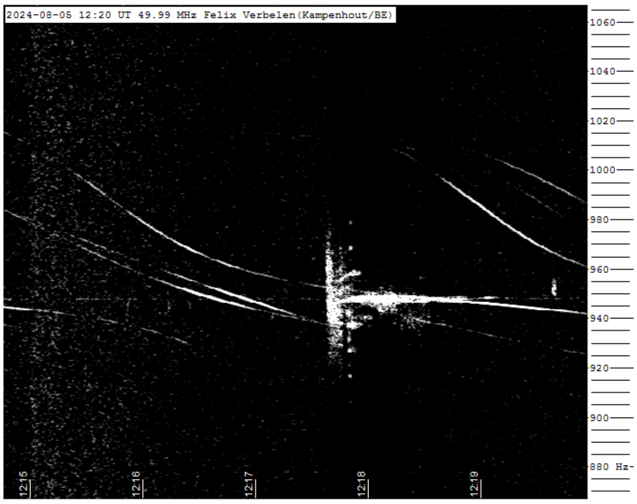


Figure 7 – Meteor echoes August 5, 12^h20^m UT.

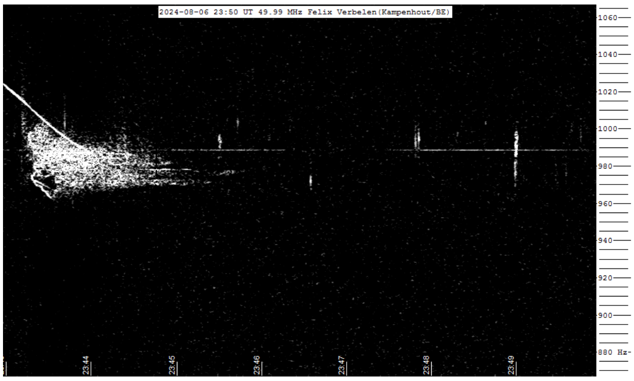


Figure 8 – Meteor echoes August 6, 23^h50^m UT.

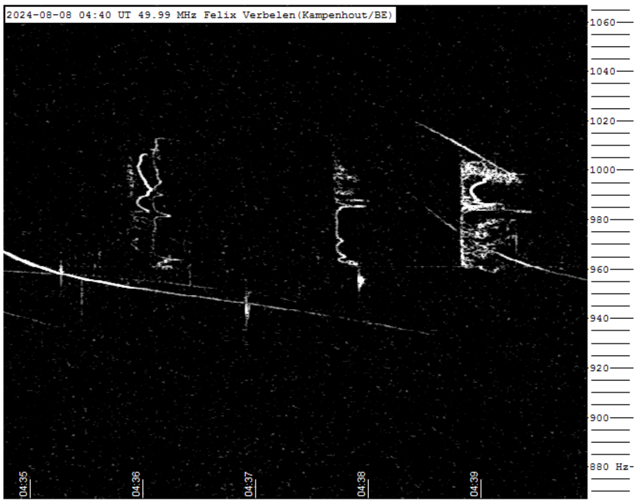


Figure 9 – Meteor echoes August 8, 04^h40^m UT.

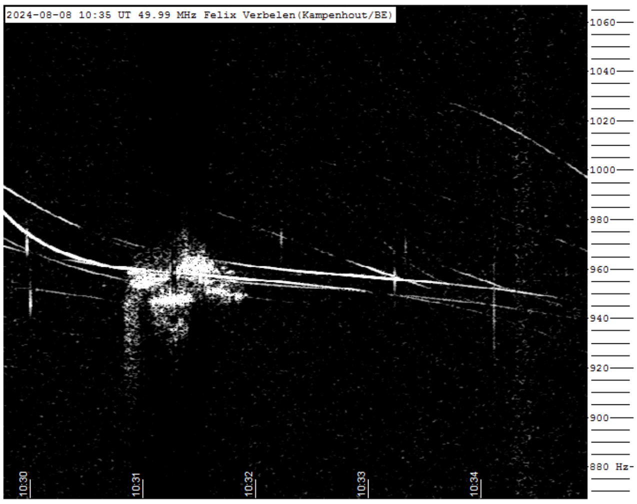


Figure 10 – Meteor echoes August 8, 10^h35^m UT.

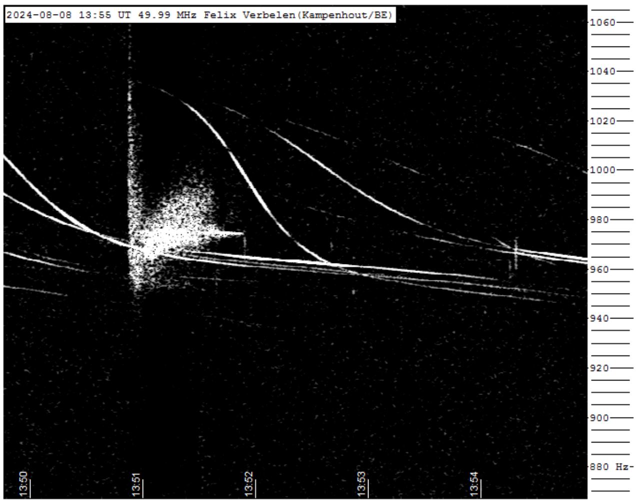


Figure 11 – Meteor echoes August 8, 13^{h}55^{m} UT.

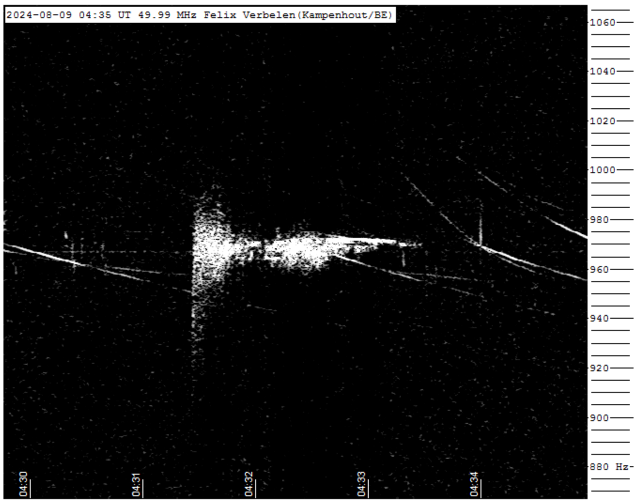


Figure 12 – Meteor echoes August 9, 04^{h}35^{m} UT.

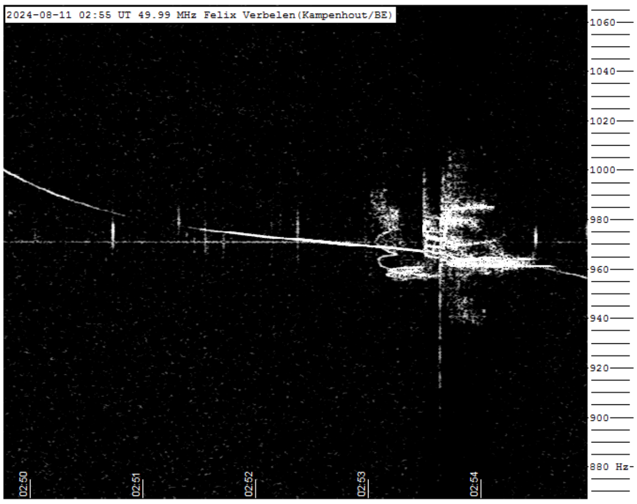


Figure 13 – Meteor echoes August 11, 02^{h}55^{m} UT.

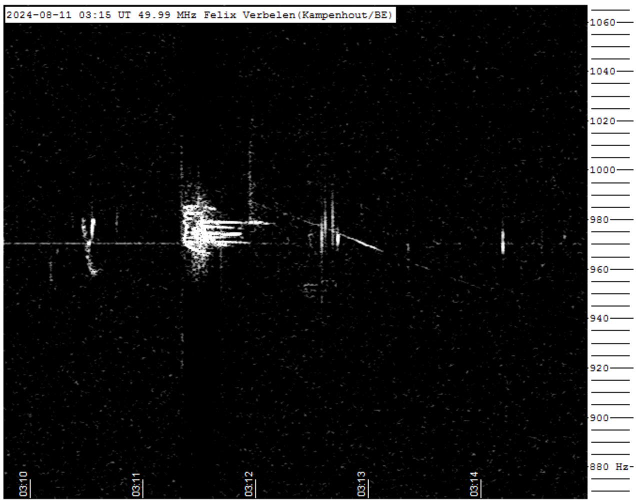


Figure 14 – Meteor echoes August 11, 03^{h}15^{m} UT.

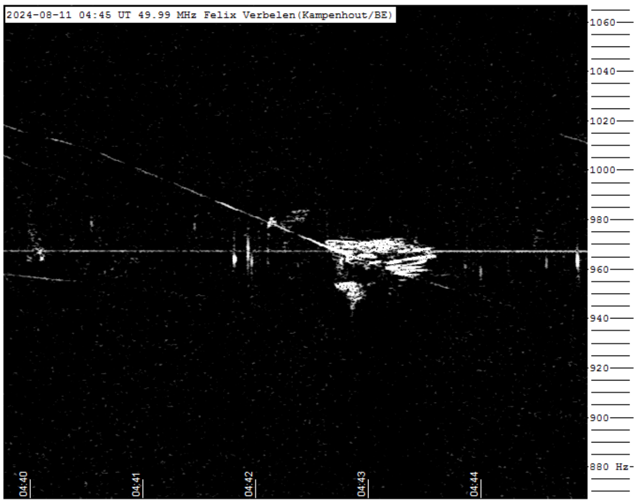


Figure 15 – Meteor echoes August 11, 04^{h}45^{m} UT.

Figure 16 – Meteor echoes August 11, 06^{h}30^{m} UT.

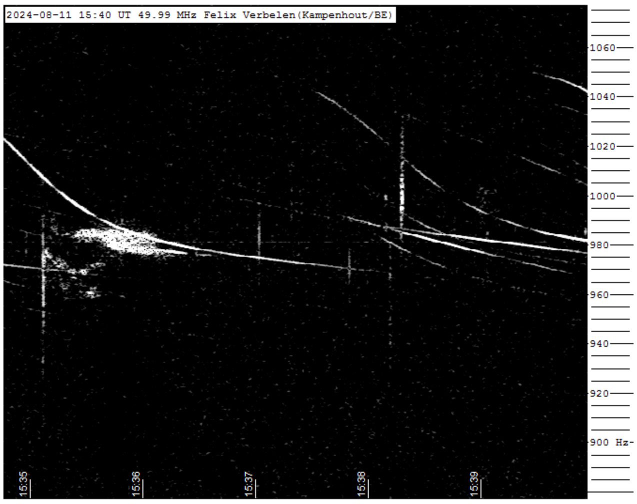


Figure 17 – Meteor echoes August 11, $15^{h}40^{m}$ UT.

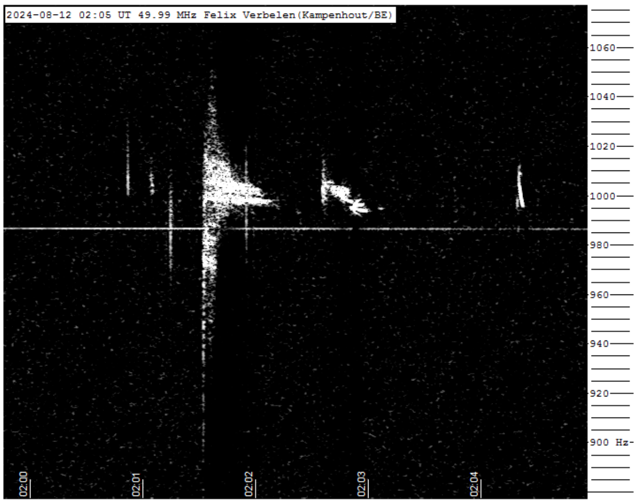


Figure 18 – Meteor echoes August 12, $02^{h}05^{m}$ UT.

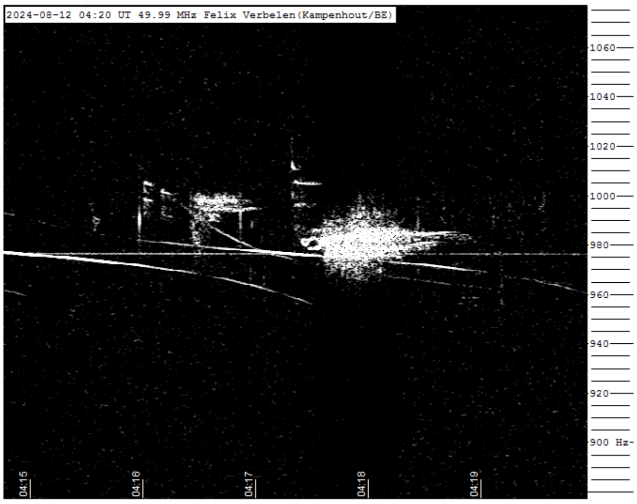


Figure 19 – Meteor echoes August 12, $04^{h}20^{m}$ UT.

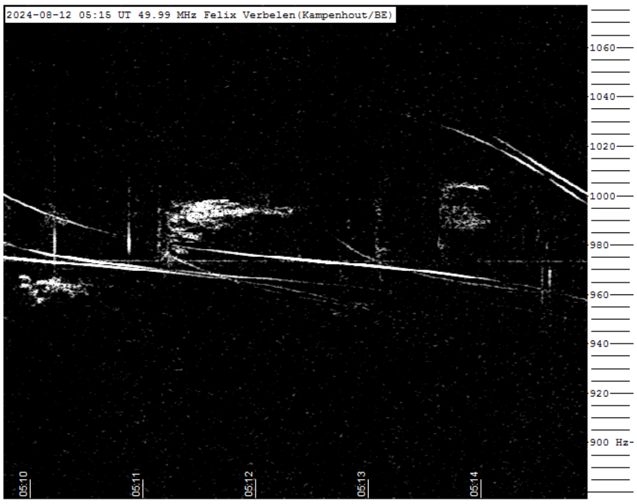


Figure 20 – Meteor echoes August 12, $05^{h}15^{m}$ UT.

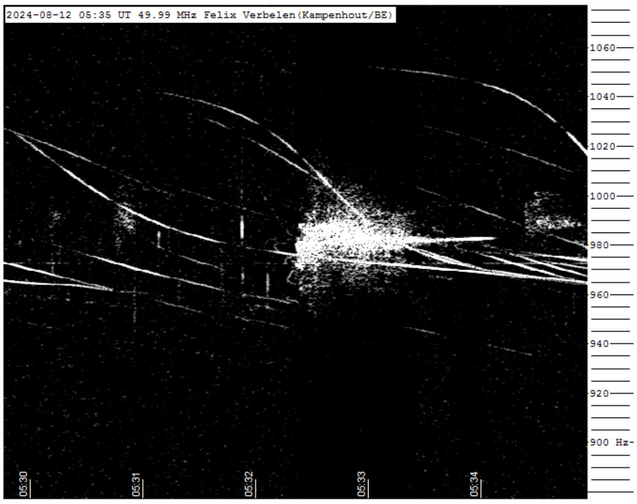


Figure 21 – Meteor echoes August 12, $05^{h}35^{m}$ UT.

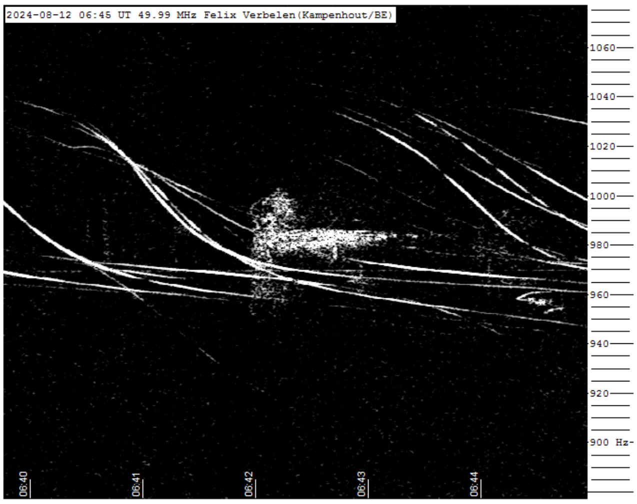


Figure 22 – Meteor echoes August 12, $06^{h}45^{m}$ UT.

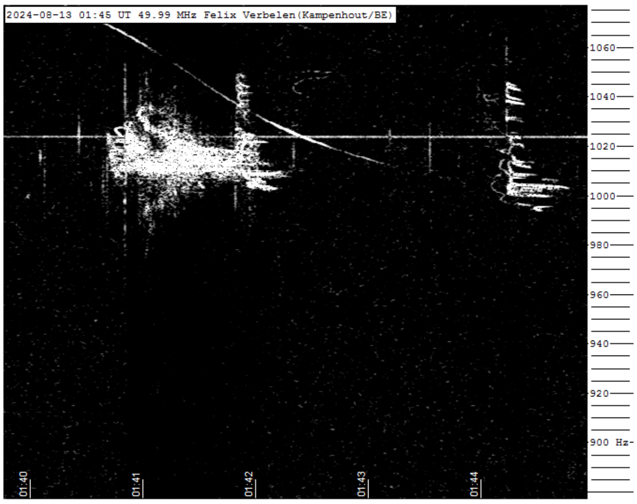


Figure 23 – Meteor echoes August 13, 01ʰ45ᵐ UT.

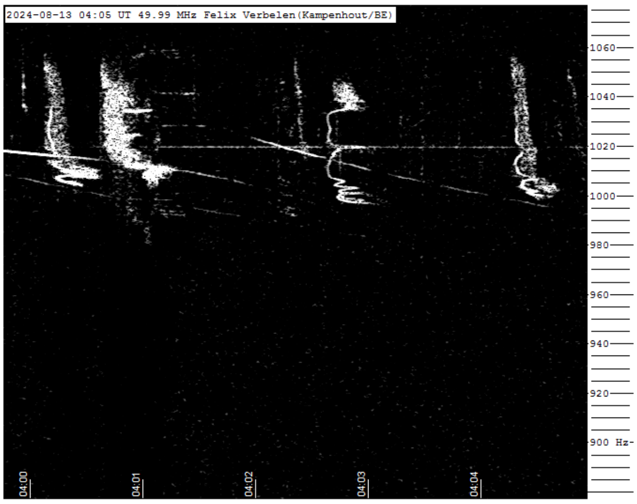


Figure 24 – Meteor echoes August 13, 04ʰ05ᵐ UT.

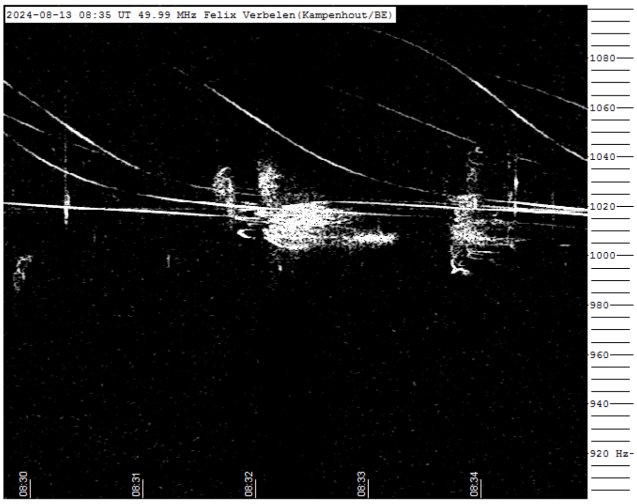


Figure 25 – Meteor echoes August 13, 08ʰ35ᵐ UT.

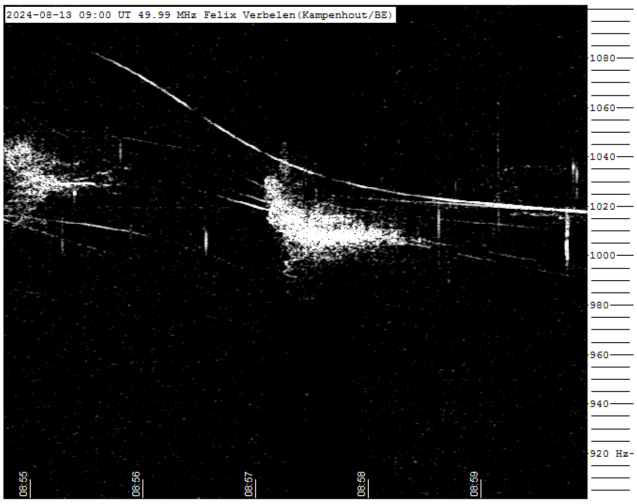


Figure 26 – Meteor echoes August 13, 09ʰ00ᵐ UT.

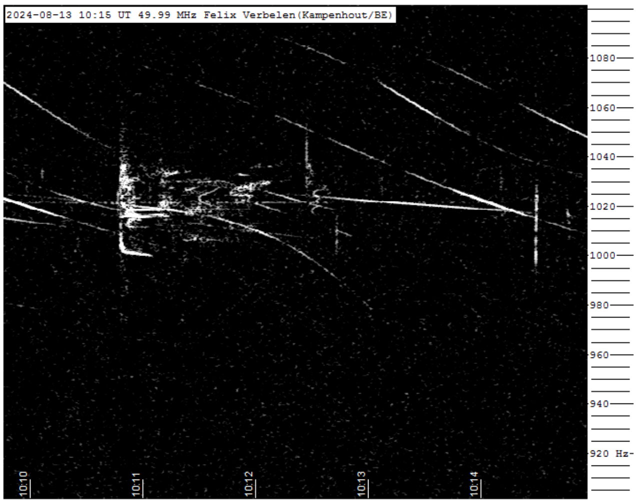


Figure 27 – Meteor echoes August 13, 10ʰ15ᵐ UT.

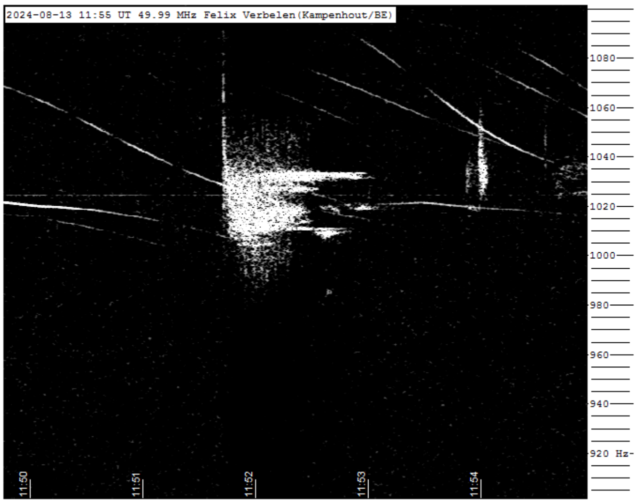


Figure 28 – Meteor echoes August 13, 11ʰ55ᵐ UT.

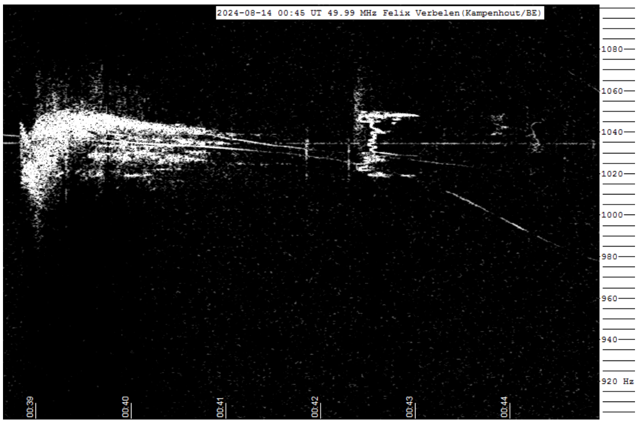


Figure 29 – Meteor echoes August 14, 00^h45^m UT.

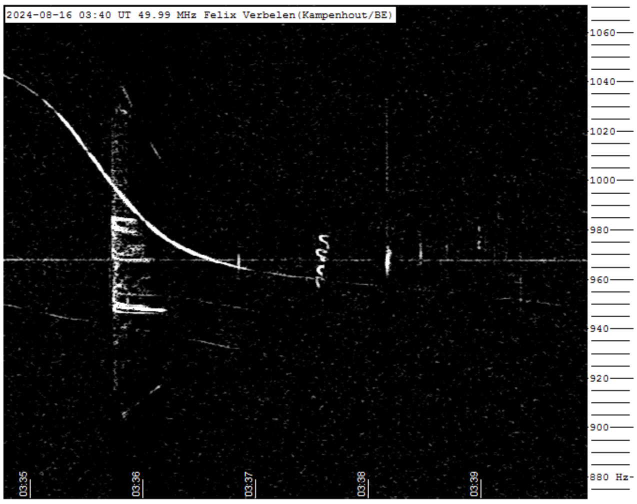


Figure 30 – Meteor echoes August 16, 03^h40^m UT.

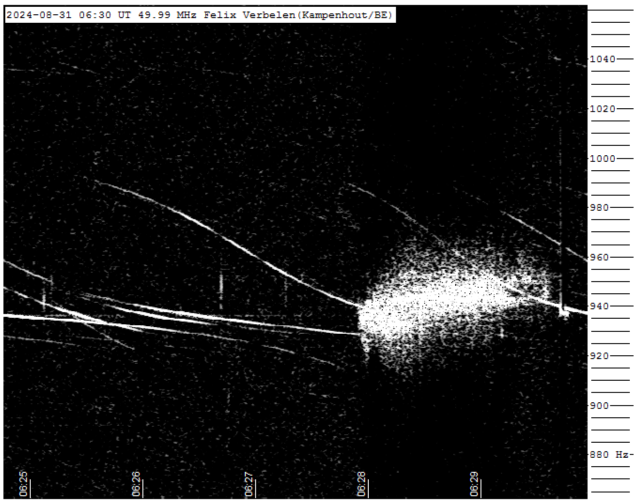


Figure 31 – Meteor echoes August 31, 06^h30^m UT.

Radio meteors September 2024

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An overview of the radio observations during September 2024 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 September 2024.

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 generally remained low, weak lightning activity was recorded on 6 days, while very strong activity was recorded on September 5th.

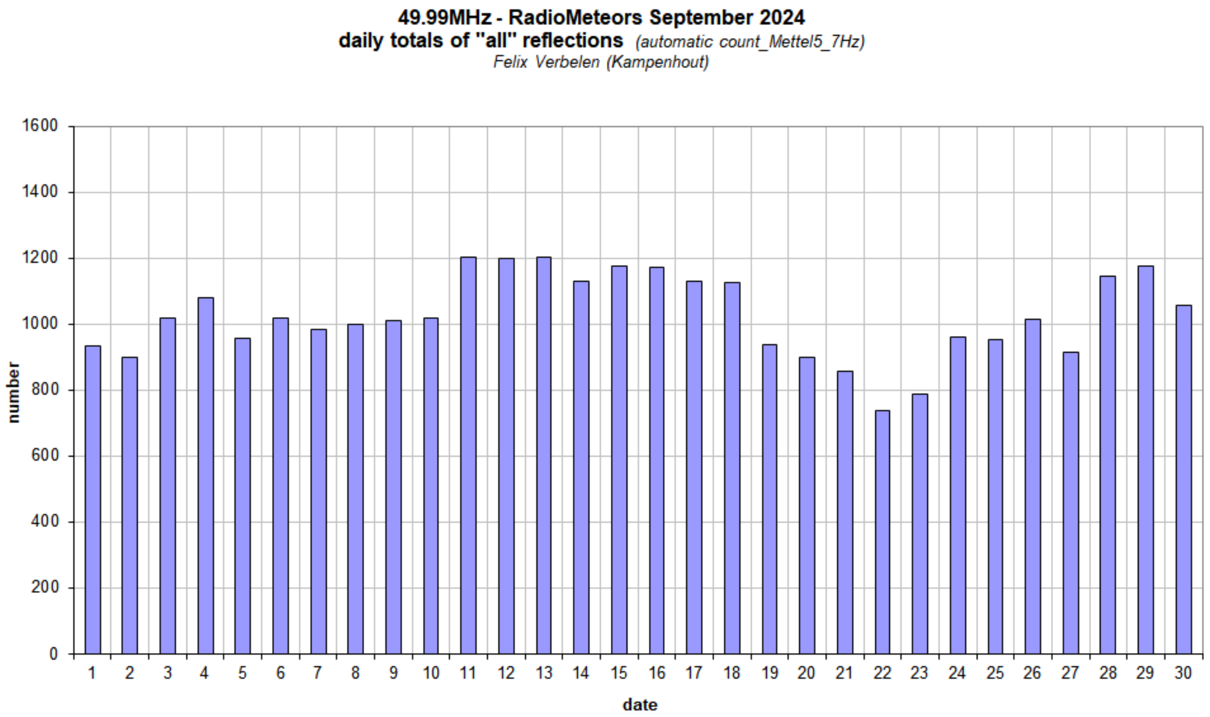
Solar activity continued to be strong. *Figure 5* is an exemple of a series of type III outbursts on September 14th.

During this month no real eye-catching showers were active, but nonetheless the activity remained interesting, showing both a number of minor showers and a fair number of long reflections.

Over the entire month 17 reflections longer than 1 minute were recorded here. A selection of these, along with some other interesting reflections is included (*Figures 6 to 21*). More of these are available on request.

In addition to the usual graphs, you will also find the raw counts in cvs-format[19] 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.

[19] https://www.emeteornews.net/wp-content/uploads/2024/10/202409_49990_FV_rawcounts.csv



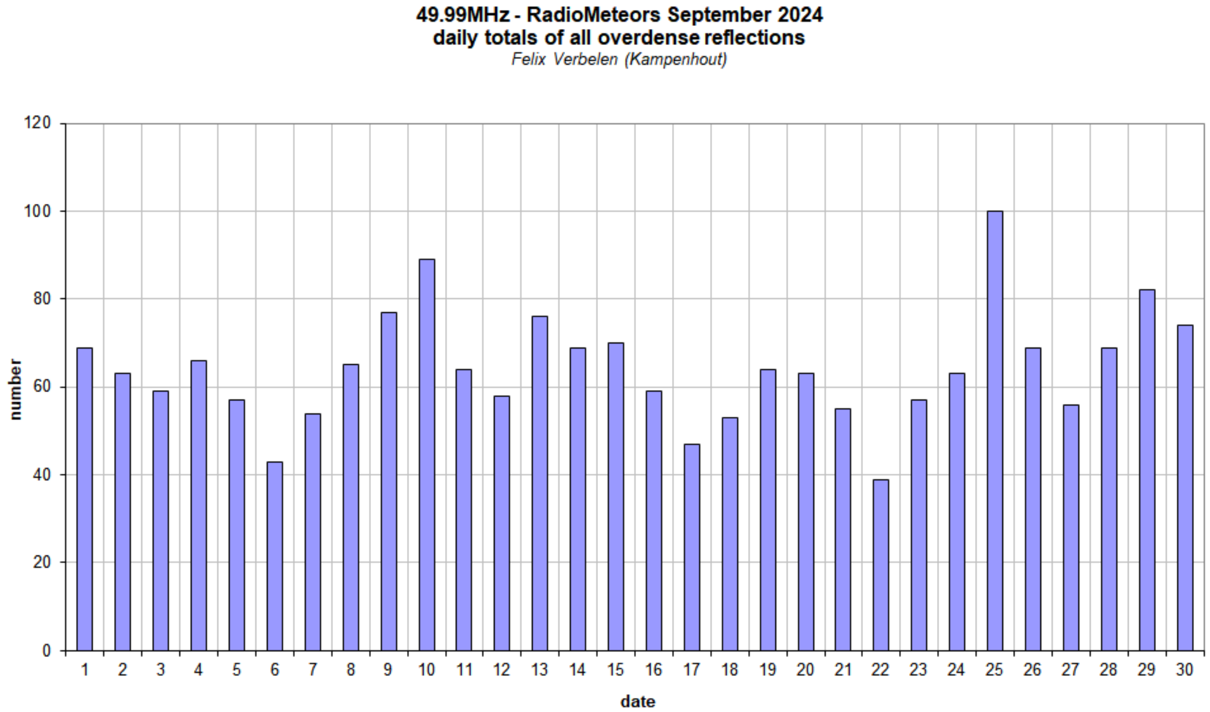
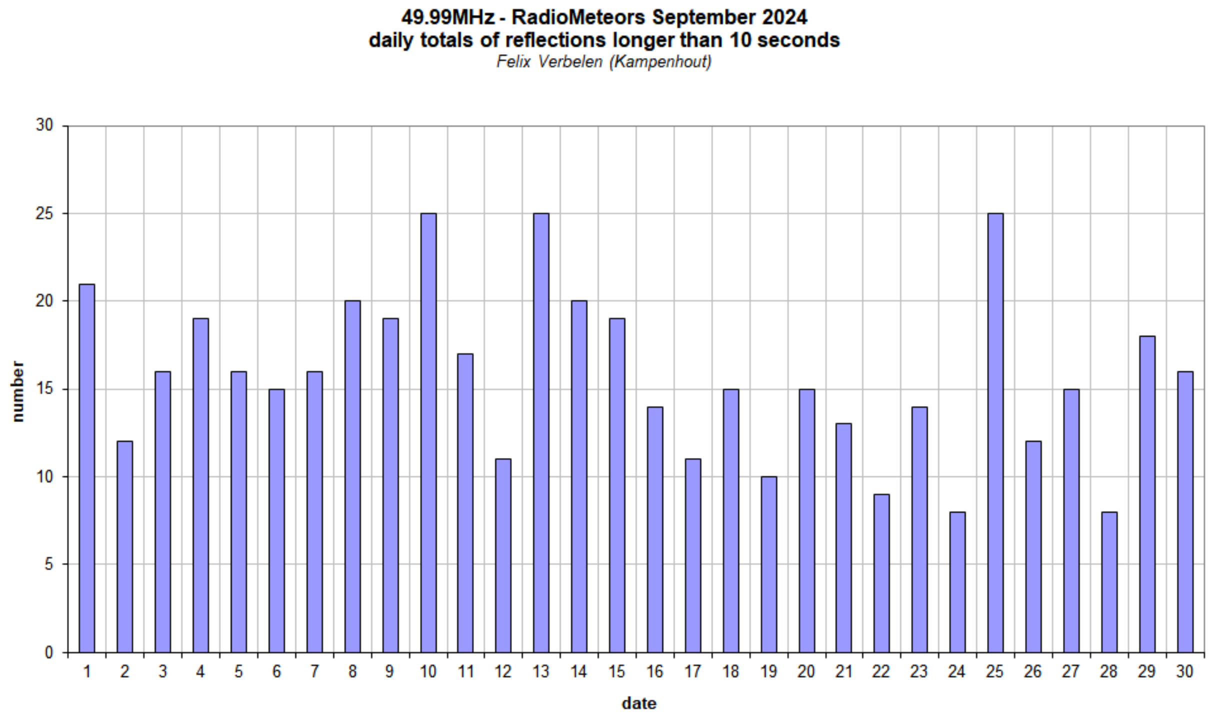


Figure 1 – The daily totals of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during September 2024.



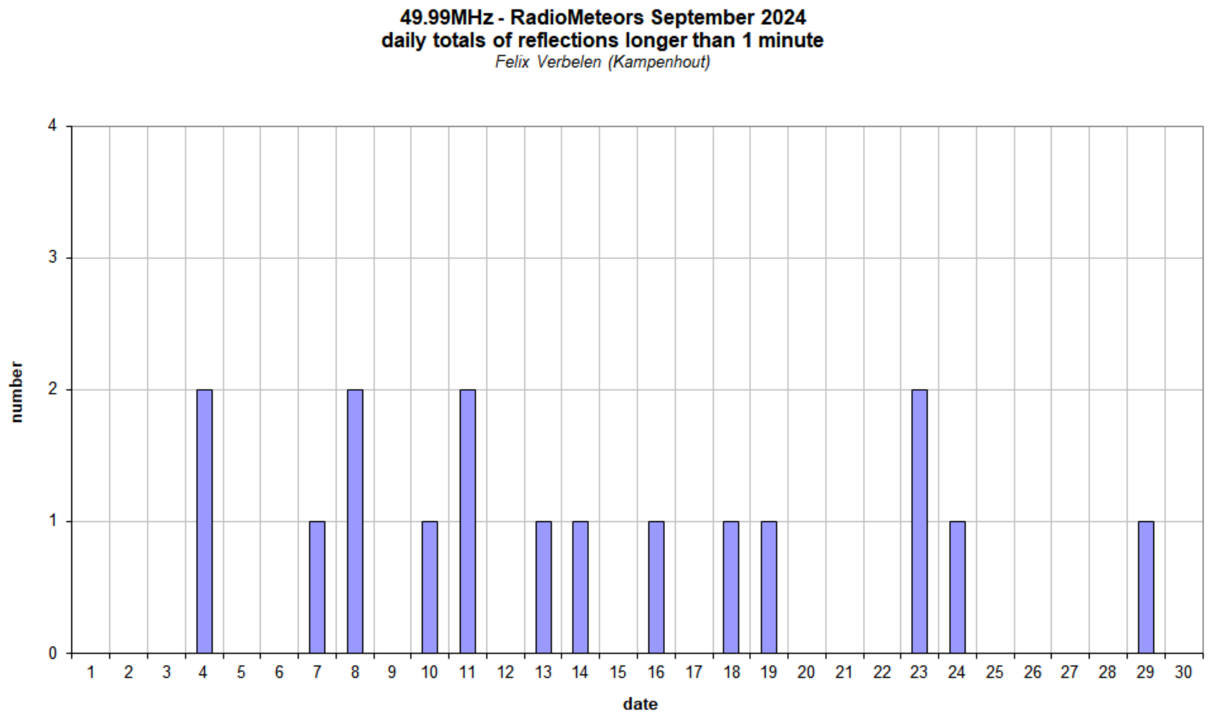
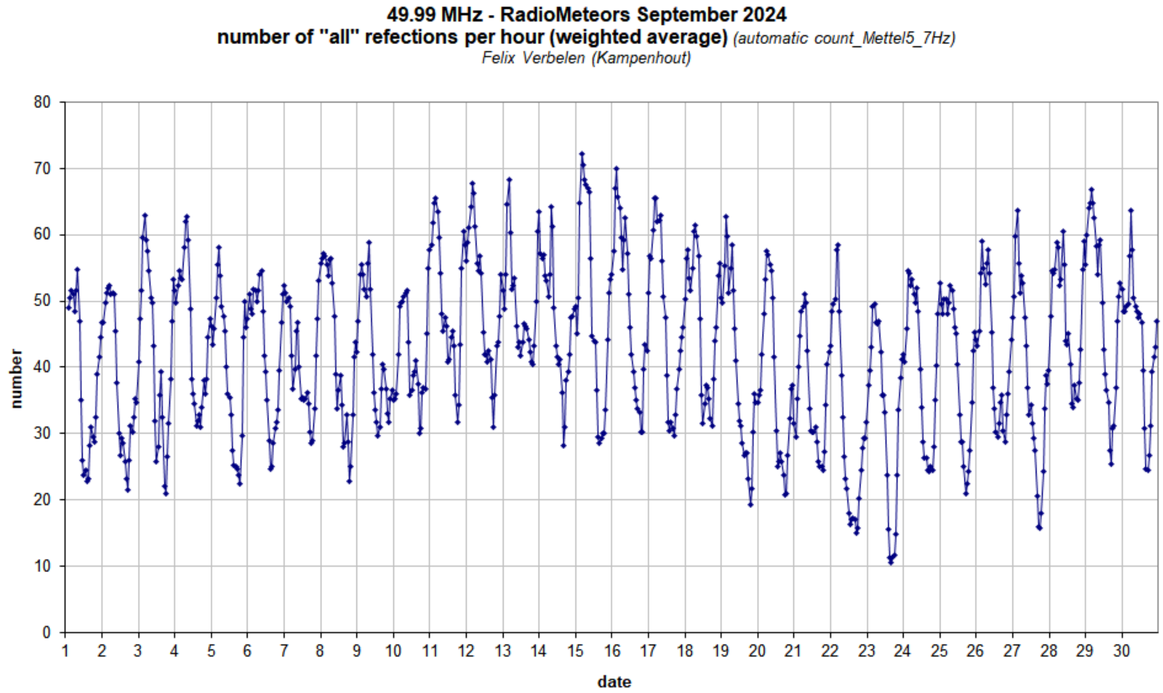


Figure 2 – The daily totals of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during September 2024.



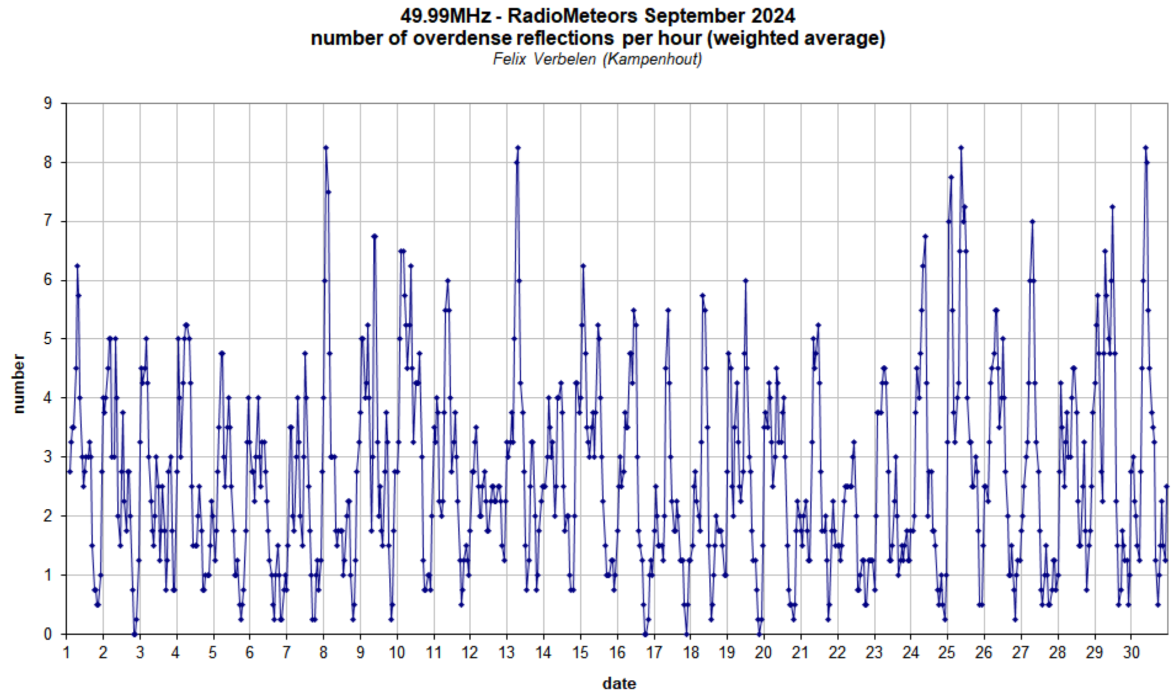
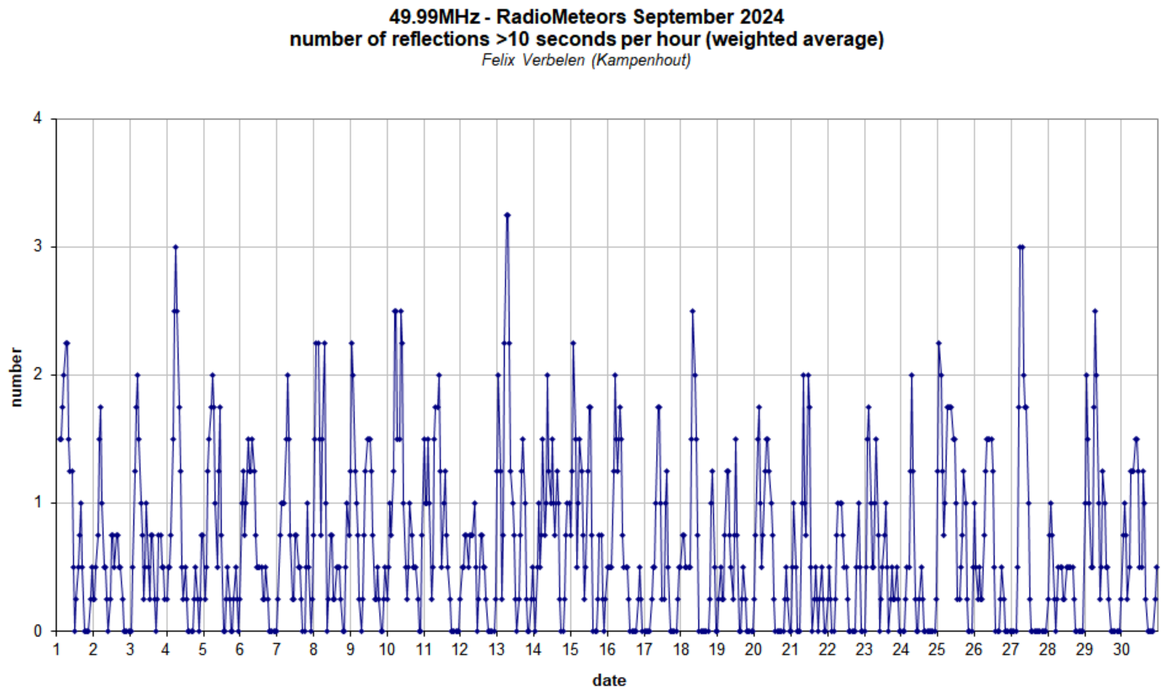


Figure 3 – The hourly numbers of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during September 2024.



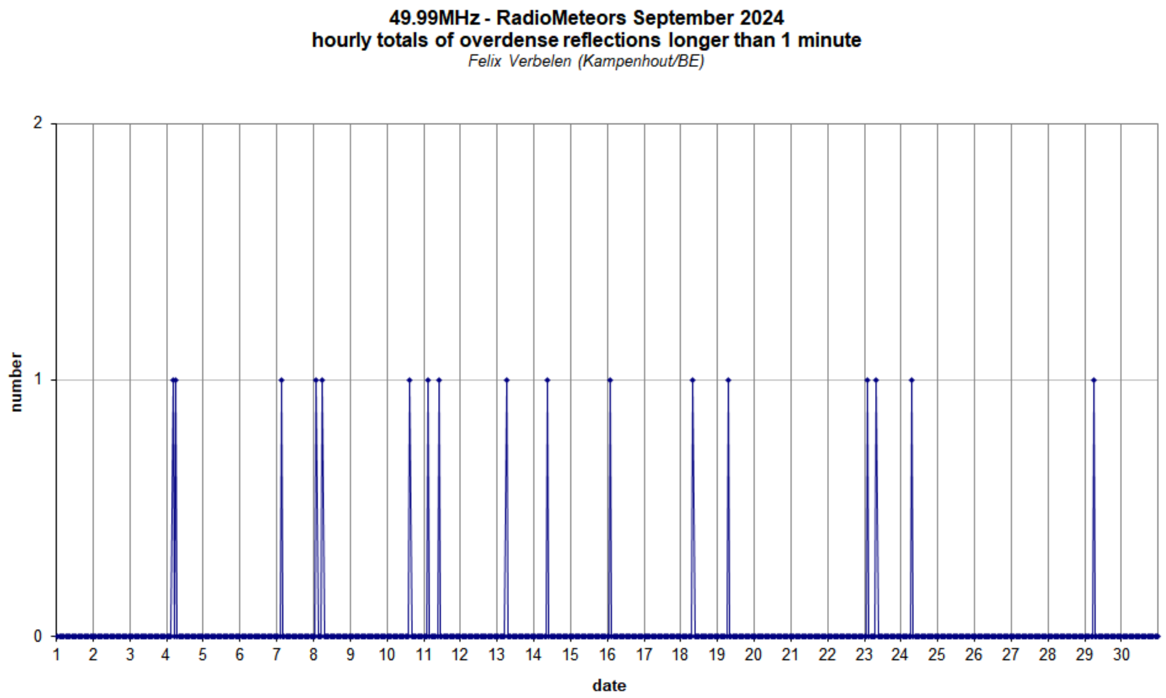


Figure 4 – The hourly numbers of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during September 2024.

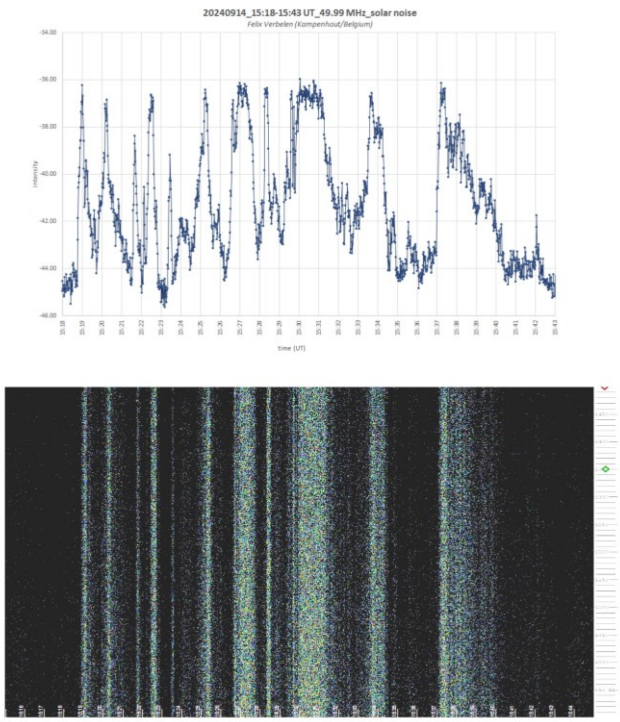


Figure 5 – A series of type III outbursts on September 14th.

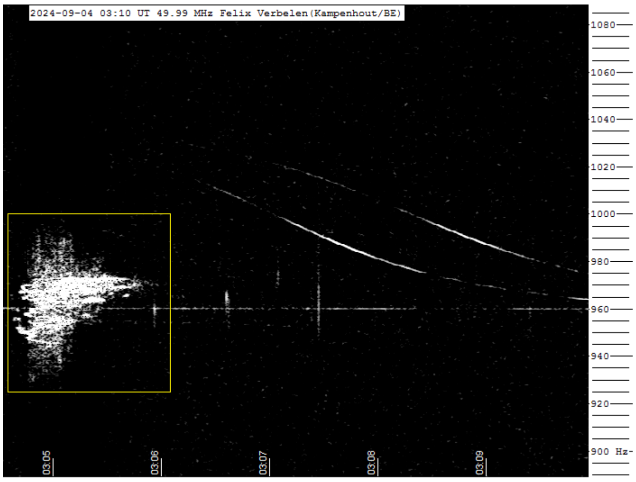


Figure 6 – Meteor echoes September 4, 03h10m UT.

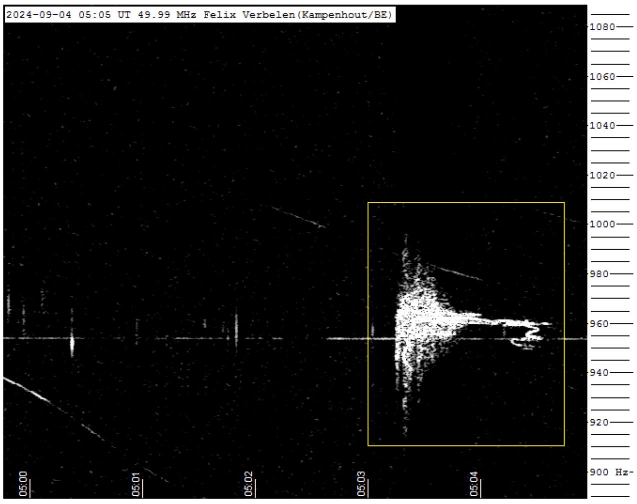


Figure 7 – Meteor echoes September 4, 05h05m UT.

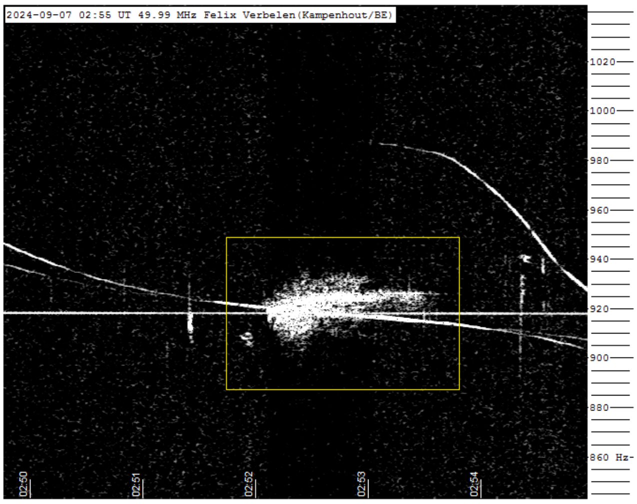


Figure 8 – Meteor echoes September 7, 02h55m UT.

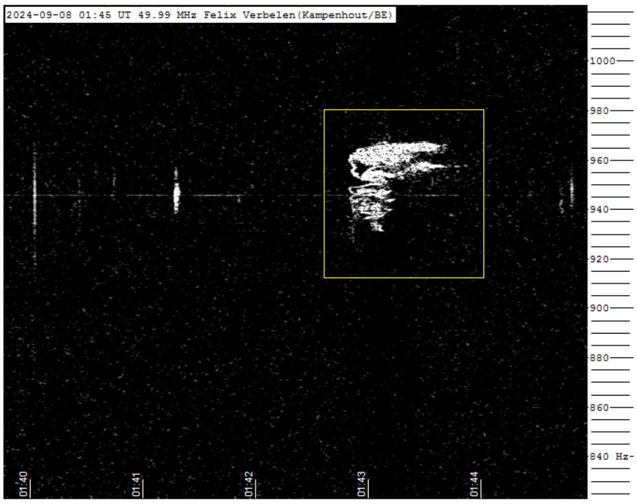


Figure 9 – Meteor echoes September 8, 01h45m UT.

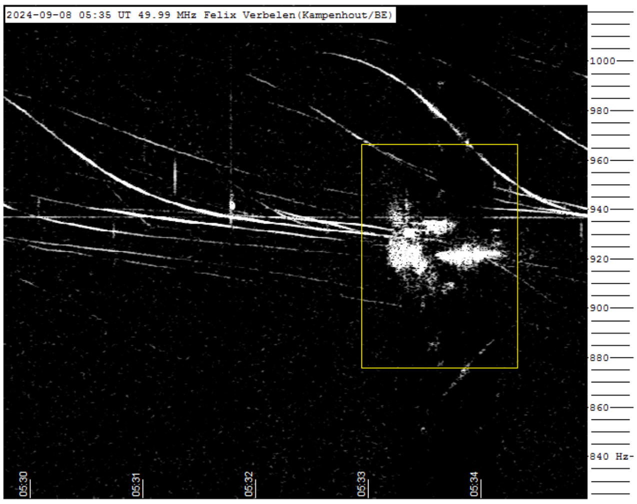


Figure 10 – Meteor echoes September 8, 05h35m UT.

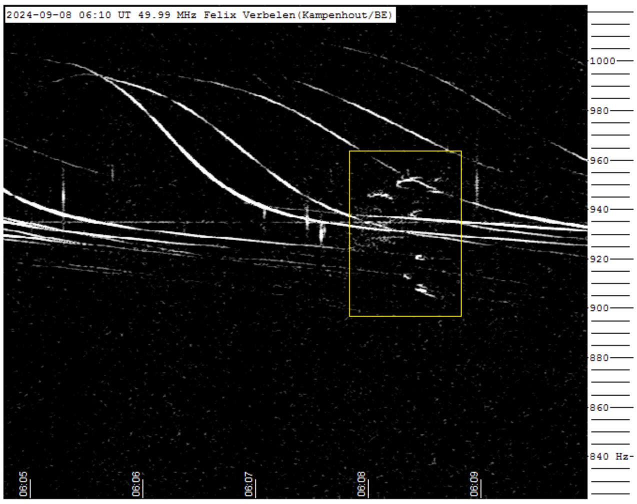


Figure 11 – Meteor echoes September 8, 06^h10^m UT.

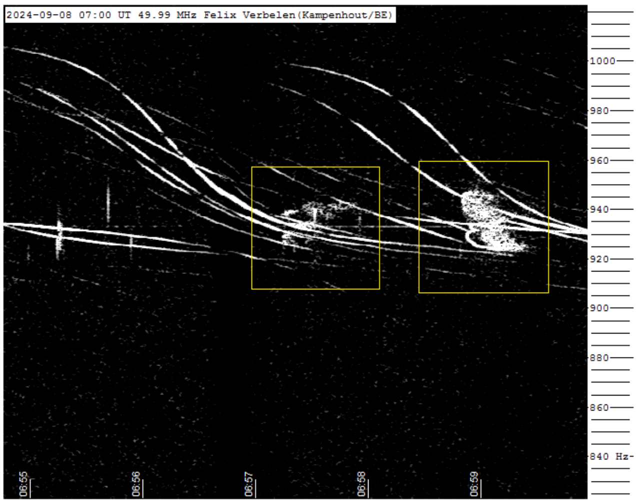


Figure 12 – Meteor echoes September 8, 07^h00^m UT.

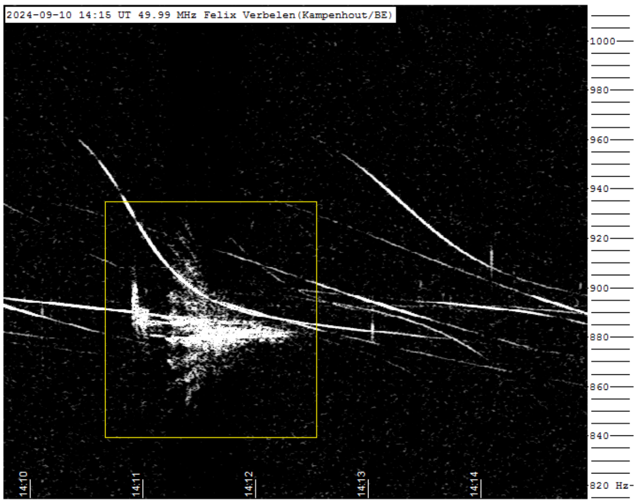


Figure 13 – Meteor echoes September 10, 14^h15^m UT.

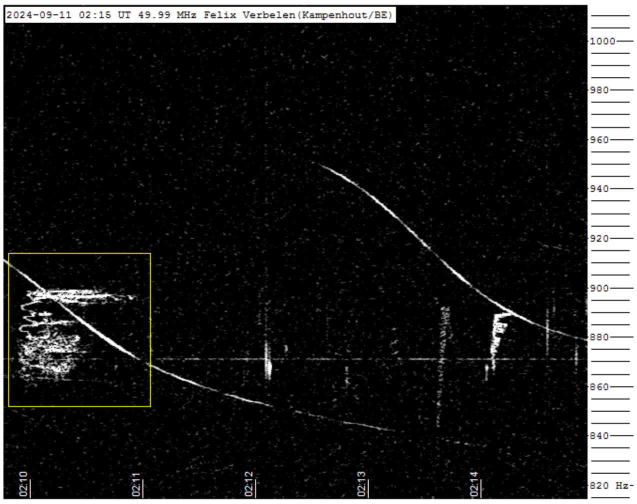


Figure 14 – Meteor echoes September 11, 02^h15^m UT.

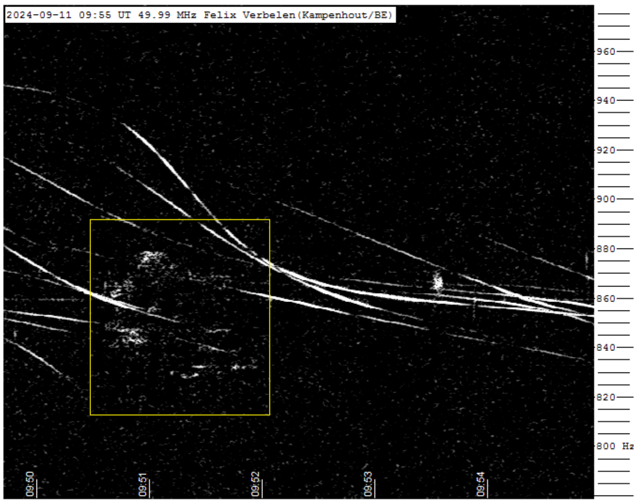


Figure 15 – Meteor echoes September 11, 09^h55^m UT.

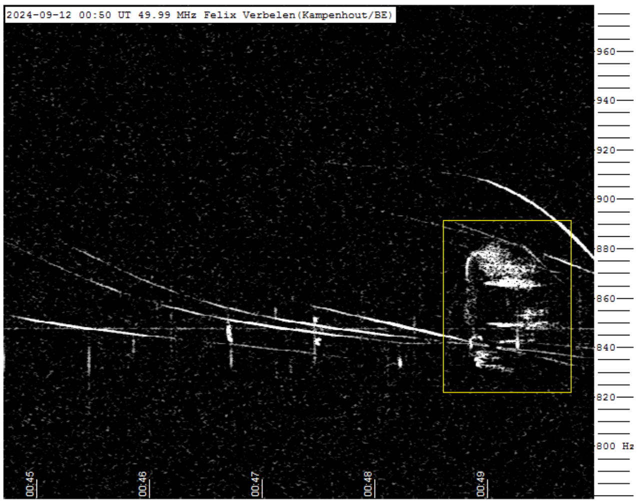


Figure 16 – Meteor echoes September 12, 00^h50^m UT.

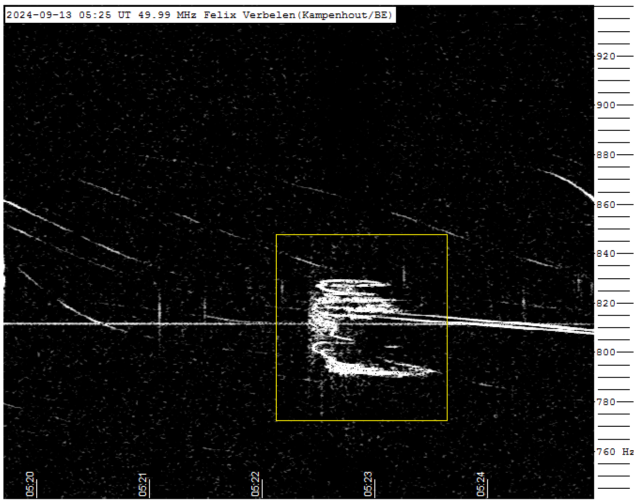


Figure 17 – Meteor echoes September 13, 05^h25^m UT.

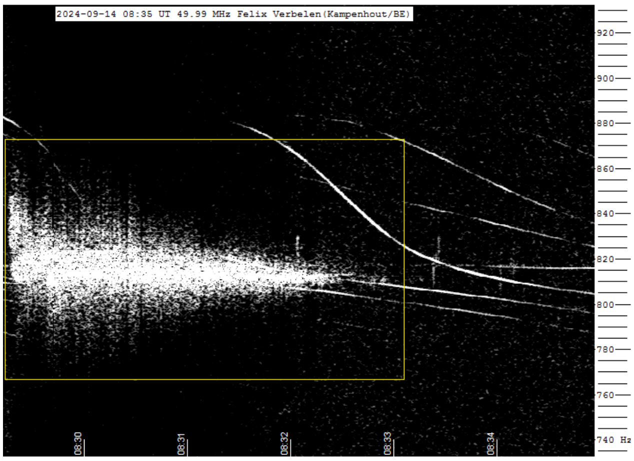


Figure 18 – Meteor echoes September 14, 08^h35^m UT.

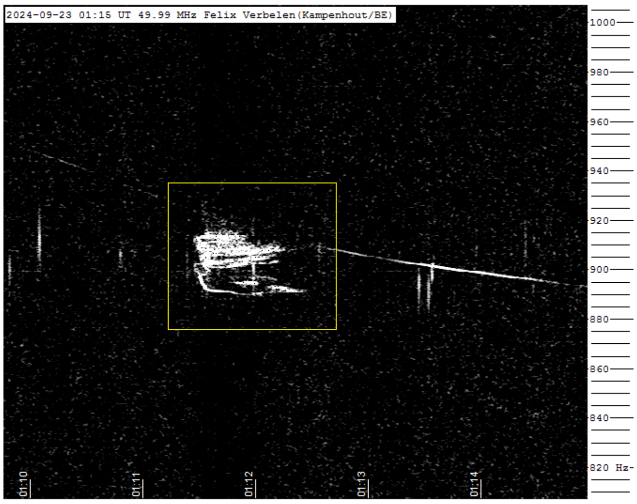


Figure 19 – Meteor echoes September 23, 01^h15^m UT.

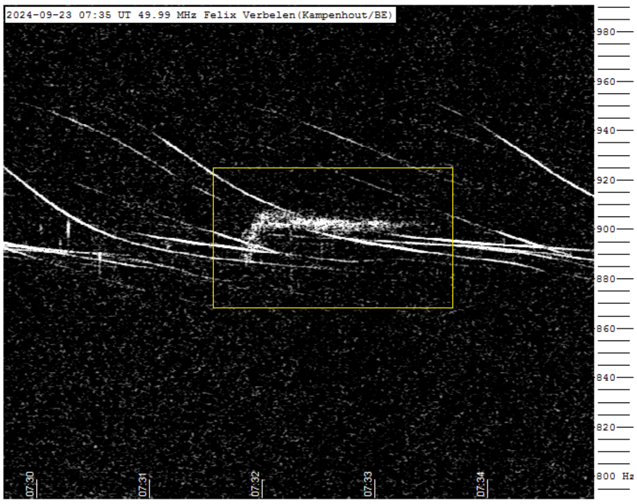


Figure 20 – Meteor echoes September 23, 07^h35^m UT.

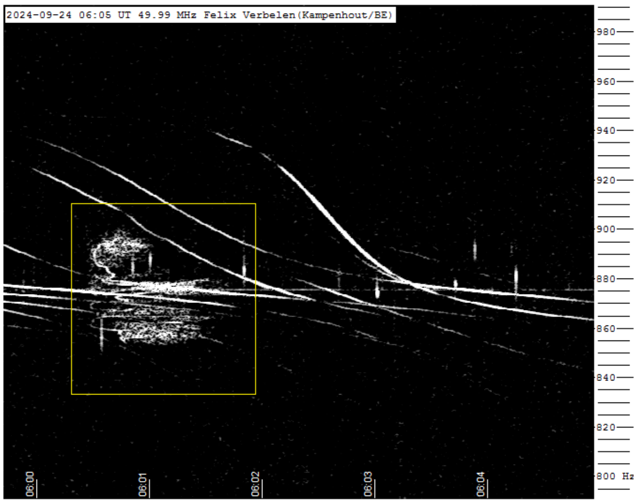


Figure 21 – Meteor echoes September 24, 06^h05^m UT.

Daytime fireball on August 4, 2024 by SonotaCo Network in Japan

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A daytime fireball was observed simultaneously at three sites on August 4, 2024 at $3^h18^m11^s$ UTC by SonotaCo Network in Japan. Orbital calculations determined that it was a sporadic meteor, but the parent body candidate is 2022QX4, a near-Earth object belonging to the Aten group. In some areas, vibrations were reported along with an explosion a few minutes later, which may have been caused by a meteorite dropping.

1 Observations

The observations were obtained at one site of the SonataCo Network and another, external high-sensitivity camera. The fireball was rather faint because it was daytime, but it was well captured. In some areas, an explosion was reported a few minutes later.

2 Measurement

The measurements could not be automatically analyzed with UFOAnalyzerV4, so the positions were derived from measurements of the still images taken at night and the still images of the fireball were measured manually.

Figure 1 – August 4, $3^h18^m11^s$ UTC. SonataCo Network[20].

Figure 2 – August 4, $3^h18^m11^s$ UTC. External[21].

3 Results

The orbit calculation based on three sites resulted in a deviation of the radiant point of 1.5 degrees. At two sites with a slightly smaller convergence angle, the difference in altitude was as much as 5 km. The difference in velocity was about 3 km/s. The orbit has a small dispersion. The duration of the event was just over 2 seconds.

Figure 3 – August 4, $3^h18^m11^s$ UTC. External[22].

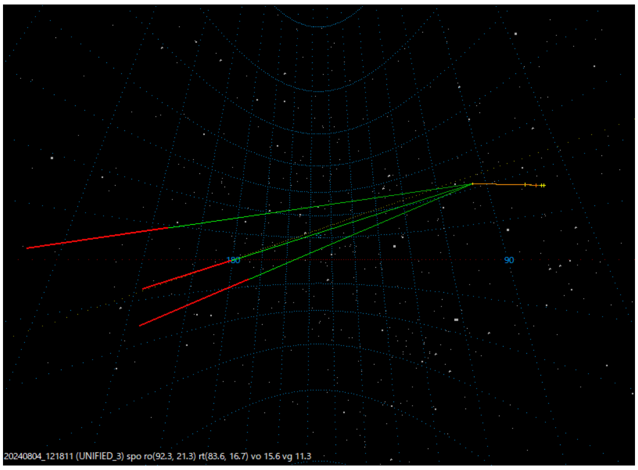

Figure 4 – The meteor trail plot of 2024 August 4.

[20] https://x.com/i/status/1820042457591013872
[21] https://sonotaco.jp/forum/download.php?id=101952
[22] https://sonotaco.jp/forum/download.php?id=101951

Table 1 – The trajectory data, observed radiant and velocity, height and other parameters.

No	Local time	*ID1*	*ID2*	RA_o	Dec_o	v_o	shower	*Mag*	Q_o	*Dur.*	H_b	H_e
1	20240804031811	knb	tks4	92.25	21.34	15.06	spo	–10	17.1	2.36	60.195	35.688
2	20240804031811	tks4	knb	92.25	21.34	16.55	spo	–5	24.8	2.59	59.109	29.563
3	20240804031811	yama1	knb	92.25	21.34	15.17	spo	–5	19.7	2.00	54.914	33.989
all	20240804031811	UNIFIED		92.25	21.34	15.59	po	–6.7	24.8	2.59	59.109	29.563

Table 2 – The orbital elements, geocentric radiant and velocity, and other parameters.

Name	a	e	q	i	ω	Ω	D_{sh}	T_j	λ_Π	β_Π	α	δ	v_g	Date
20240804	0.71	0.522	0.339	3.50	199.50	311.90	0.00	7.96	151.37	–1.17	83.6	16.7	11.3	8/4
RVO 8/4	0.72	0.505	0.354	0.20	200.00	311.80	0.06	7.91	151.80	–0.07	84.0	23.0	10.8	8/4
2022QX4	0.68	0.505	0.337	0.15	176.18	335.61	0.06	8.26	151.79	0.01	74.5	22.2	9.2	8/15

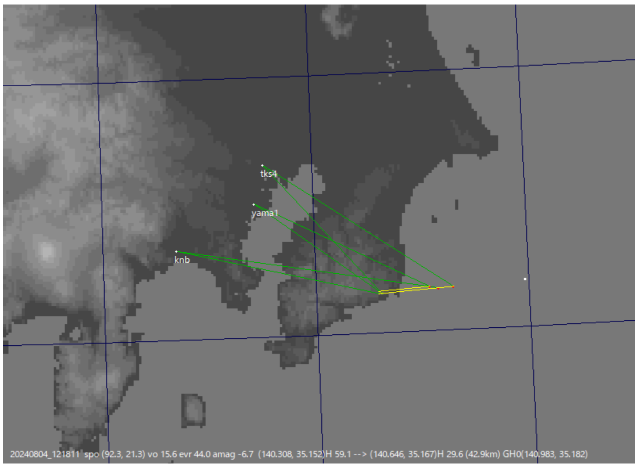

Figure 5 – Trajectory map of 2024 August 4.

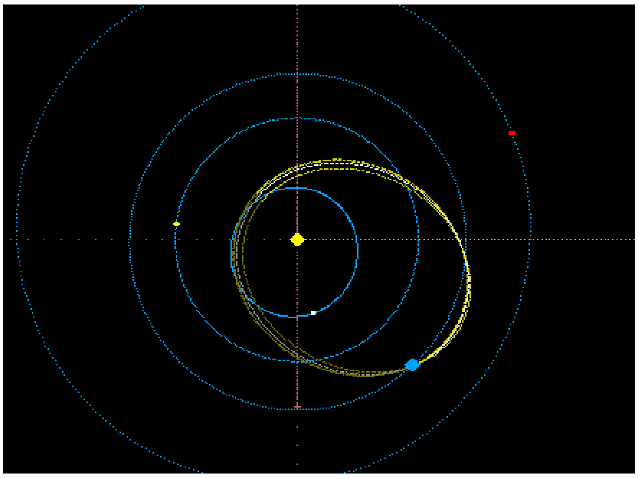

Figure 6 – Orbit plot 2024 August 04, $03^h18^m11^s$ UTC.

4 Parent body

When I looked for a candidate parent body, I found that it was 2022QX4, a near-Earth object belonging to the Aten group. The D_{SH} matched well with 0.06. 2022 QX4 is a Tunguska meteorite-sized asteroid classified as a near-Earth object belonging to the Aten group with a diameter of about 40 meters. It was discovered by the Asteroid Earth Impact Last Warning System on August 24, 2022, at a distance of 0.03 astronomical units (4.5×10^6 km) from Earth. On September 4, 2022, it was listed as having a 1 in 109 chance of impacting Earth on the Torino Scale 1 at 00^h52^m UTC on September 4, 2068, after an 8-day observation window. A nominal close approach is expected to occur on August 28, 2068. Its closest approach to Earth in 2022 occurred on August 29, 2022, at a distance of about 1.8 million kilometers. The short 17-day observation track indicates that the 2022 QX4 may have passed close to 5400 kilometers from Earth in early September 1977. Source: Wikipedia, the free encyclopedia[23]

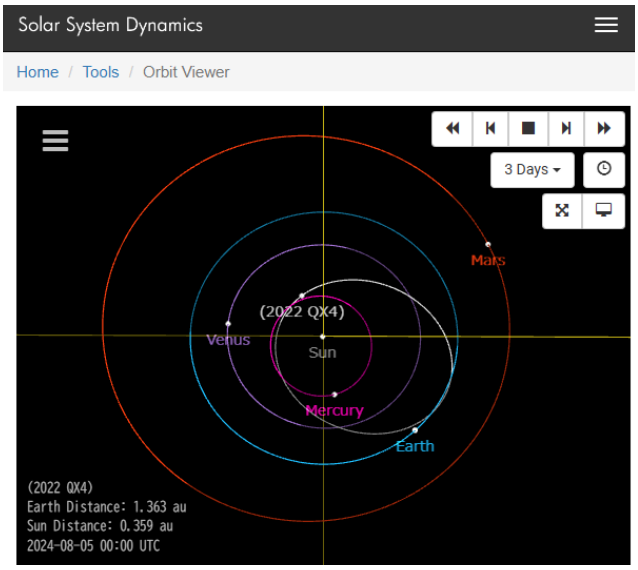

Figure 7 – Orbit plot 2022QX4.

Acknowledgment

I would like to thank the SonotaCo network for providing orbital calculation data for this study. I would also like to thank *Paul Roggemans* for his proofreading and advice.

[23] https://ja.wikipedia.org/wiki/2022_QX4

On dust trails of fireballs

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A meteor dust trail is a very rare natural phenomenon. Its occurrence requires penetration of a large meteoroid body deeply enough into the atmosphere. There is only one dust trail per 250 persistent gas trails in the personal archive of I. S. Astapovich (1956). Dust trails, as a rule, indicate meteorite falls.

1 Introduction

"The dust trail of a meteor is a rare phenomenon of nature", writes I. S. Astapovich (1956). "Unlike gas trails, visible only at night, dust trails are visible only in the daytime or at dusk. They appear during the flight of large fireballs, which penetrated low in the atmosphere. Against a light sky background, they, like ordinary clouds, can look both light and dark, depending on the illumination by sunlight. Projected against the background of evening glow, they will look almost black if they lie in the shadow of the Earth, or extremely bright, as if burning hot, if these trails are illuminated by the direct rays of the Sun at the heights where they are located. If at this time the Sun is below the observer's horizon and twilight has come, their light may be so bright as to produce shadows from terrestrial objects. In a few seconds, the initially straight-line trail seems jagged under the influence of air currents and then more and more curved, resembling a frozen lightning, until it is scattered away by winds. At the same time the trail expands, spreads, fades, turns into one or more shapeless clouds, sometimes stretched in the direction of their movement, and takes 30–60 minutes, or sometimes several hours, to dissipate completely".

The most thorough study of gas and dust trails of meteors is presented in the works by I. S. Astapovich (1956, 1958, 1966, etc.), which apparently remain little known or completely unknown to the Western reader. I. S. Astapovich gives an extensive series of his own observations of meteor trails coming from systematic year-round observations in 1942–1960. The observations were made in Ashkhabad, near Firyuza (38 km from Ashkhabad) and in Odessa. A total of 150 meteor trails were found during 1377 hours of observations. It is interesting that for 250 persistent gas trails in the personal archive of I. S. Astapovich there is only one dust trail, and even then, found outside the observation program (Astapovich, 1956). Therefore, it is impossible to make systematic natural observations of dust trails at any point, as the number of such trails will be one or zero for several decades.

2 On some exceptional dust trails

Speaking about the history of study of dust trails, I. S. Astapovich (1956) gives a number of remarkable examples. Some of them are worth highlighting. A remarkable specimen of a dust trail was given by the Boguslavka meteorite, which fell on 5/18 October 1916 in the Primorskaya region near the Chinese Eastern Railway station Grodekovo-Khorvatovo. "On the horizon ... a thick black cloud of smoke. This trail was visible 350 kilometers away in China ... The trail was quite impressive. As the fireball travelled, jets of fire could be seen bursting now and then through the thick misty trail. The found meteorites, two of which are in the collection of the USSR Academy of Sciences, and the third is in Japan, with a total weight of more than a quarter of a ton, were iron. Thus, dust trails are produced not only by stone, but also iron meteorites".

An exceptionally intense dust trail was left behind by a bright fireball –15m, which was visible over an area of six regions from Moscow to Penza. It occurred on 24 September 1948. In 20 minutes, air currents already gave it the appearance of a line of double curvature. In some places it was projected into the sky shaped as a giant number "3". The trail attracted the attention of numerous witnesses. A detailed processing of observations of this interesting fireball was made by V. V. Fedynsky (1955) from the materials of the Committee on Meteorites of the Academy of Sciences of the USSR. Its trajectory in the atmosphere and its orbit were determined accurately enough. The meteoroid body with a mass of 250 kg moved along an elliptical orbit slightly inclined to the ecliptic plane (i = 7.5°). The small geocentric velocity of the meteoroid body, which was catching up with the Earth, accounted for a relatively low altitude of the emergence of the fireball (85 km). The mass of the meteoroid body completely vaporized and dispersed above 62 km, which explains the absence of sounds and meteorite fallout.

Figure 1 – Corresponding Member of the USSR Academy of Sciences Vsevolod Vladimirovich Fedynsky (1908–1978). (Photo from the personal archive of A. K. Terentjeva).

Finally, we will briefly mention a particularly interesting trail of the famous Sikhote-Alin iron meteorite on 12 February 1947. "The trail stretched to the very surface of the Earth, as the meteorite had a large mass and hit the ground at a speed of 0.5–1 km/s with a stream of pieces... Its trail was broad, smoky, bubbling and curling and lasted until evening, that is about 8 hours" (Astapovich, 1956).

In 1907, Trowbridge began to study meteor trails. He showed that gas trails appear above 82 km while dust trails mainly at 64 km or lower. They are especially frequent at the altitude of 40 km and rare above 64 km (up to 80 km) (Astapovich, 1956).

3 Conclusion

By special observations in the glowing sky in 1955 in Ashkhabad (Terentjeva, 1956) it was found that ordinary meteors do not produce dust trails. "This is both because of their low mass and because they transform into meteor gas but not into dust. To make a dust trail, a meteor body must be large enough (a fireball) to penetrate rather dense layers of the atmosphere. Therefore, as a rule, dust trails emerge in meteorite falls", I. S. Astapovich wrote in his monograph (1958).

Thus, based on everything stated above, we can say that dust trails indicate meteorite falls. Hence, meteor observers having detected a dust trail should calculate the geographic coordinates of the ground point in the vicinity of which a meteorite or its fragments may have fallen.

We take this opportunity to present in this article a photograph of the outstanding scientist, Corresponding Member of the USSR Academy of Sciences, Laureate of the USSR State Prize V.V. Fedynsky (*Figure 1*). His main works relate to the field of exploration geophysics, gravimetry, Earth physics and meteor astronomy. In meteor astronomy he contributed to the organization of systematic photographic, spectral, and radar observations of meteors in the USSR. A submarine ridge in the Indian Ocean and the minor planet No. 1984 are named after him.

Corr. member V. V. Fedynsky had a long-standing friendship with Prof. I. S. Astapovich. Visiting I. S. Astapovich at his flat in Kiev, V. V. Fedynsky said: "Forty years of friendship were not overshadowed by anything". Both remarkable scientists were born in the same year of 1908 (the fall of the Tunguska meteorite) and passed away almost simultaneously (V. V. Fedynsky died two years after I. S. Astapovich).

Acknowledgment

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Analysis of remarkable bright meteors spotted from March to September 2024 by the Southwestern Europe Meteor Network

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This report focuses on the analysis of some of the fireballs recorded by the Southwestern Europe Meteor Network from March to September 2024. They have been observed from the Iberian Peninsula. Their maximum absolute brightness ranges from mag. –7 to mag. –14. Some of these bright meteors were potential meteorite-producing fireballs.

1 Introduction

The Southwestern Europe Meteor Network (SWEMN) conducts the SMART project (Spectroscopy of Meteoroids by means of Robotic Technologies), which started operation in 2006 to analyze the physical and chemical properties of meteoroids ablating in the Earth's atmosphere. For this purpose we employ an array of automated cameras and 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, 2015b). SMART also provides important information for our MIDAS project, which is being conducted by the Institute of Astrophysics of Andalusia (IAA-CSIC) to study lunar impact flashes produced when large meteoroids impact the Moon (Madiedo et al., 2015; Madiedo et al., 2018; Madiedo et al. 2019; Ortiz et al., 2015).

In this work we present the preliminary analysis of 12 bolides observed in the framework of the SWEMN network. This report has been fully written by AIMEE (acronym for Artificial Intelligence with Meteoroid Environment Expertise) by using as an information source the records listed in the SWEMN fireball database (Madiedo et al., 2021; Madiedo et al., 2022).

2 Equipment and methods

The events presented here have been recorded by using Watec 902H2 and Watec 902 Ultimate cameras. Their field of view ranges from 62 × 50 degrees to 14 × 11 degrees. To record meteor spectra we have attached holographic diffraction gratings (1000 lines/mm) to the lens of some of these cameras. 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 path of the events were triangulated by means of the SAMIA software, developed by J.M. Madiedo. This program employs the planes-intersection method (Ceplecha, 1987).

3 Analysis of the 2024 March 16 event

This fireball was spotted on 2024 March 16, at $1^h54^m07.0 \pm 0.1^s$ UT. The peak luminosity of the bolide was equivalent to an absolute magnitude of –14.0 ± 1.0 (*Figure 1*). The images clearly revealed that the meteoroid was fragmented along the meteor trajectory. The code given to the event in the SWEMN meteor database is SWEMN20240316_015407.

Figure 1 – Stacked image of the SWEMN20240316_015407 meteor.

Atmospheric trajectory, radiant and orbit

This event overflew Portugal. Its luminous phase began at an altitude $H_b = 89.0 \pm 0.5$ km. The fireball penetrated the atmosphere till a final height $H_e = 18.9 \pm 0.5$ km. The equatorial coordinates concluded for the apparent radiant are $\alpha = 161.52°$, $\delta = 16.15°$. The meteoroid impacted the atmosphere with an initial velocity $v_\infty = 16.9 \pm 0.3$ km/s. The calculated trajectory in our atmosphere of the event is shown in *Figure 2*. *Figure 3* shows the orbit in the Solar System of the progenitor meteoroid.

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

a (AU)	2.15 ± 0.09	ω (°)	229.4 ± 00.3
e	0.59 ± 0.01	Ω (°)	355.681082 ± 10^{-5}
q (AU)	0.864 ± 0.004	i (°)	0.3 ± 0.1

We named this event "Monte da Macarra", since the bolide was located over this locality during its final phase. The parameters of the orbit in the Solar System of the parent meteoroid before its encounter with our planet are listed in *Table 1*, and the geocentric velocity yields $v_g = 13.1 \pm 0.4$ km/s. According to the value estimated for the Tisserand parameter referred to Jupiter ($T_J = 3.45$), before impacting our planet's atmosphere the meteoroid was moving on an asteroidal orbit. These values and the calculated radiant coordinates confirm the sporadic nature of the meteor.

As a result of the analysis of the trajectory it was found that the meteoroid was not totally ablated in the atmosphere. So, part of it survived and reached the ground as a meteorite in Portugal.

Figure 2 – Atmospheric path of the SWEMN20240316_015407 event, and its projection on the ground.

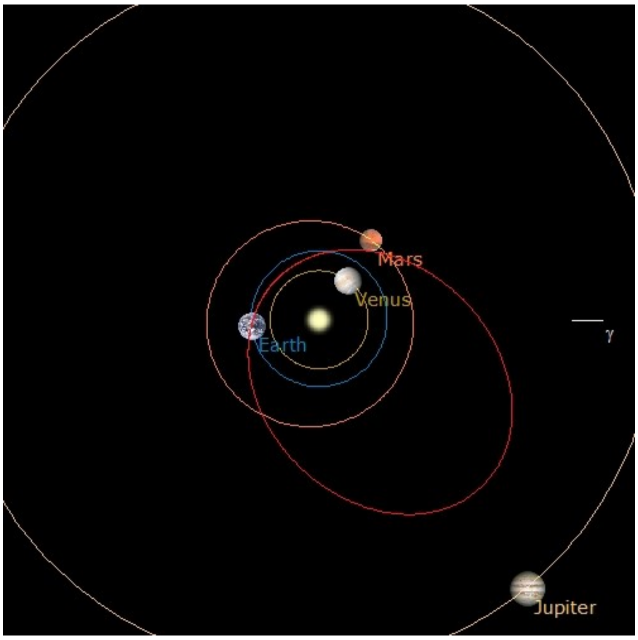

Figure 3 – Projection on the ecliptic plane of the orbit of the progenitor meteoroid of the SWEMN20240316_015407 event.

4 Description of the 2024 March 22 event

On 2024 March 22, at $1^h05^m16.0 \pm 0.1^s$ UT, our cameras recorded this bright event (*Figure 4*). Its peak brightness was equivalent to an absolute magnitude of –10.0 ± 1.0. The meteor was included in our meteor database with the code SWEMN20240322_010516.

Figure 4 – Stacked image of the SWEMN20240322_010516 event.

Figure 5 – Atmospheric path of the SWEMN20240322_010516 event, and its projection on the ground.

Atmospheric path, radiant and orbit

It was inferred following the analysis the luminous path of the bolide that this fireball overflew the province of Castellón (eastern Spain). It began at an altitude $H_b = 83.5 \pm 0.5$ km, and the event penetrated the atmosphere till a final height $H_e = 32.2 \pm 0.5$ km. The equatorial coordinates inferred for the apparent radiant are $\alpha = 191.28°$, $\delta = -0.08°$. The pre-atmospheric velocity deduced for the meteoroid yields $v_\infty = 30.7 \pm 0.2$ km/s. *Figure 5* shows the obtained atmospheric trajectory of the bolide. The heliocentric orbit of the meteoroid is drawn in *Figure 6*.

The bright meteor was named "Casa-Lluna", because the event was located over this locality during its initial phase. The parameters of the heliocentric orbit of the parent meteoroid before its encounter with our planet are listed in *Table 2*. The geocentric velocity obtained for the particle yields $v_g = 28.7 \pm 0.2$ km/s. The Tisserand parameter referred to Jupiter ($T_J = 2.73$) suggests that before hitting our atmosphere the meteoroid was moving on a cometary (JFC) orbit. By taking into account this orbit and the radiant position, the bolide was associated with the η-Virginids (IAU shower code EVI#0011). This meteor shower reaches its peak around March 14 (Jenniskens et al., 2016).

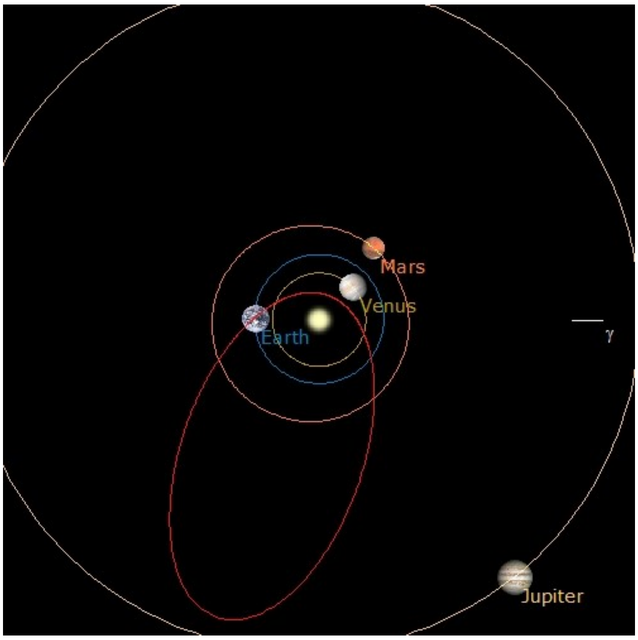

Figure 6 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20240322_010516 meteor.

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

a (AU)	2.64 ± 0.08	*ω* (°)	287.04 ± 00.01
e	0.846 ± 0.005	Ω (°)	1.571184 ± 10^{-5}
q (AU)	0.405 ± 0.002	*i* (°)	2.95 ± 0.04

5 The 2024 April 14 bolide

This remarkable fireball was spotted on 2024 April 14 at $0^h35^m21.0 \pm 0.1^s$ UT from the meteor-observing stations located at Huelva, La Hita (Toledo), Calar Alto, Sierra Nevada, La Sagra (Granada), and Sevilla (*Figure 7*). It had a peak absolute magnitude of –14.0 ± 1.0. The unique identifier given to the event in the SWEMN meteor database is SWEMN20240414_003521.

Figure 7 – Stacked image of the SWEMN20240414_003521 bolide.

Figure 8 – Atmospheric path of the SWEMN20240414_003521 fireball, and its projection on the ground.

Atmospheric path, radiant and orbit

It was deduced by analyzing the trajectory in the Earth's atmosphere of the fireball that this bolide overflew the provinces of Málaga and Jaén (southern Spain). Its initial altitude was H_b = 89.7 ± 0.5 km. The fireball penetrated the atmosphere till a final height H_e = 25.8 ± 0.5 km. The position found for the apparent radiant corresponds to the equatorial coordinates α = 177.59º, δ = –14.64º. The entry velocity in the atmosphere concluded for the parent meteoroid was v_∞ = 17.9 ± 0.0 km/s. The calculated luminous path of the event is shown in *Figure 8*. The orbit in the Solar System of the progenitor meteoroid is shown in *Figure 9*.

We named this event "Fuente Leiva", since the fireball was located over this locality during its final phase. The orbital parameters of the parent meteoroid before its encounter with our planet are listed in *Table 3*, and the geocentric velocity yields v_g = 14.3 ± 0.0 km/s. According to the value estimated for the Tisserand parameter with respect to Jupiter (T_J = 3.26), the particle followed an asteroidal orbit before striking the Earth's atmosphere. These parameters and the calculated radiant coordinates do not match any of the streams included in the IAU meteor database. Consequently, it was concluded that the bright meteor was linked to the sporadic background.

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

a (AU)	2.3374 ± 0.0009	*ω* (º)	48.107 ± 00.007
e	0.6258 ± 0.0001	Ω (º)	204.240364 ± 10^{-5}
q (AU)	0.87466 ± 0.00002	*i* (º)	8.967 ± 0.008

From the analysis of the atmospheric trajectory, it was deduced that the meteoroid was not totally ablated in the atmosphere. As a consequence of this, a part of it reached the ground as a meteorite, but with a mass of just about a few grams.

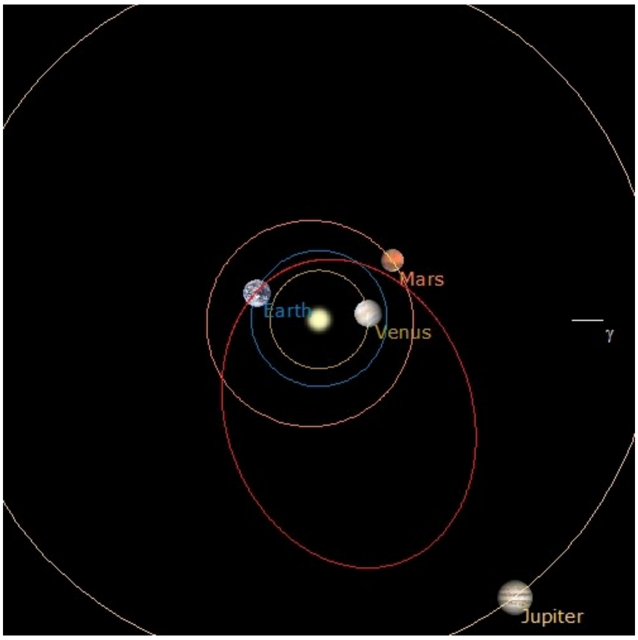

Figure 9 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20240414_003521 event.

6 Description of the 2024 May 29 bolide

On 2024 May 29, at $21^h03^m11.0 \pm 0.1^s$ UT, SWEMN cameras spotted this bolide. Its peak luminosity was equivalent to an absolute magnitude of –13.0 ± 1.0 (*Figure 10*). It was listed in the SWEMN meteor database with the code SWEMN20240529_210311. Casual observers saw the event crossing the sky, and these reported it on social networks.

Figure 10 – Stacked image of the SWEMN20240529_210311 bolide.

Atmospheric path, radiant and orbit

This bolide overflew the province of Cuenca (eastern Spain). The meteoroid started ablating at a height H_b = 83.2 ± 0.5 km, with the terminal point of the luminous phase located at a height H_e = 21.6 ± 0.5 km. From the analysis of the atmospheric path, we also obtained that the apparent radiant was located at the position $\alpha = 214.31°$, $\delta = +27.44°$. Besides, we deduced that the meteoroid hit the atmosphere with a velocity $v_\infty = 15.8 \pm 0.0$ km/s. The calculated trajectory in the Earth's atmosphere of the bolide is shown in *Figure 11*. The heliocentric orbit of the meteoroid is drawn in *Figure 12*.

Figure 11 – Atmospheric path of the SWEMN20240529_210311 event, and its projection on the ground.

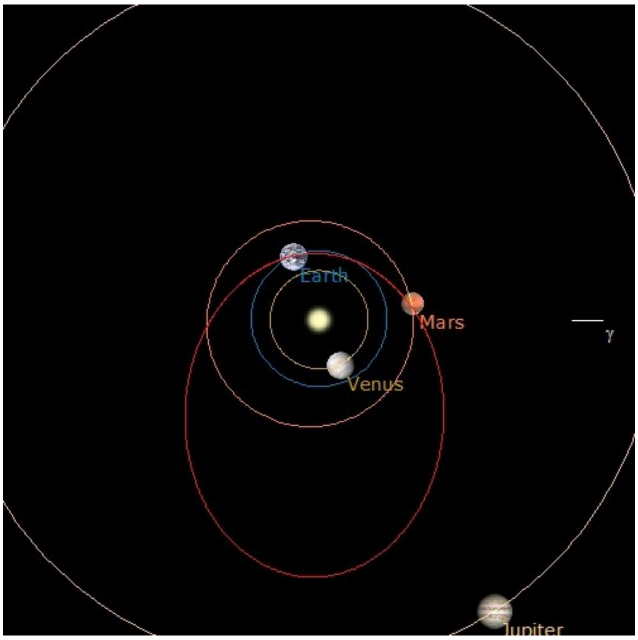

Figure 12 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20240529_210311 meteor.

The event was named "Casa de la Vega", since the bright meteor passed near the zenith of this locality during its final phase. The orbital parameters of the parent meteoroid before its encounter with our planet are listed in *Table 4*, and the geocentric velocity derived in this case was $v_g = 11.2 \pm 0.0$ km/s. From the value calculated for the Tisserand parameter with respect to Jupiter ($T_J = 3.25$), we found that the meteoroid followed an asteroidal orbit before impacting the Earth's atmosphere. By taking into account this orbit and the radiant position, the bolide was also linked to the sporadic background.

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

a (AU)	2.394 ± 0.009	ω (°)	204.0 ± 00.1
e	0.590 ± 0.001	Ω (°)	68.619089 ± 10^{-5}
q (AU)	0.9809 ± 0.0002	i (°)	10.39 ± 0.03

7 The 2024 July 3 bolide

This bright fireball was captured on 2024 July 3 at $2^h29^m41.0 \pm 0.1^s$ UT from the meteor-observing stations located at Huelva, La Hita (Toledo), Calar Alto, Sierra Nevada, La Sagra (Granada), and Sevilla (*Figure 13*). Its peak brightness was equivalent to an absolute magnitude of –8.0 ± 1.0. The identifier given to the fireball in the SWEMN meteor database is SWEMN20240703_022941. A video about this event can be viewed on this YouTube[24] video.

Figure 13 – Stacked image of the SWEMN20240703_022941 bolide.

Atmospheric path, radiant and orbit

This event overflew the province of Murcia (southeast of Spain) and the Mediterranean Sea. The ablation process of the meteoroid began at a height $H_b = 86.8 \pm 0.5$ km, and the bright meteor penetrated the atmosphere till a final height $H_e = 33.9 \pm 0.5$ km. The equatorial coordinates inferred for the apparent radiant are $\alpha = 254.35°$, $\delta = +44.52°$. The meteoroid collided with the atmosphere with an initial velocity $v_\infty = 19.1 \pm 0.3$ km/s. The obtained luminous path of the fireball is shown in *Figure 14*. The orbit in the Solar System of the meteoroid is shown in *Figure 15*.

This bolide was named "Los Muñoces", because the bright meteor was located over this locality during its initial phase. The parameters of the heliocentric orbit of the parent

[24] https://youtu.be/YaPqepX9JXA

meteoroid before its encounter with our planet are listed in *Table 5*, and the geocentric velocity yields v_g = 15.8 ± 0.4 km/s. The value calculated for the Tisserand parameter with respect to Jupiter (T_J = 2.79) indicates that the particle was moving on a cometary (JFC) orbit before entering the atmosphere. These values and the derived radiant coordinates confirm that the event was produced by the sporadic background.

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

a (AU)	3.0 ± 0.1	*ω* (º)	197.75 ± 00.06
e	0.66 ± 0.01	Ω (º)	101.326651 ± 10^{-5}
q (AU)	0.9973 ± 0.0004	*i* (º)	21.7 ± 0.4

Figure 14 – Atmospheric path of the SWEMN20240703_022941 meteor, and its projection on the ground.

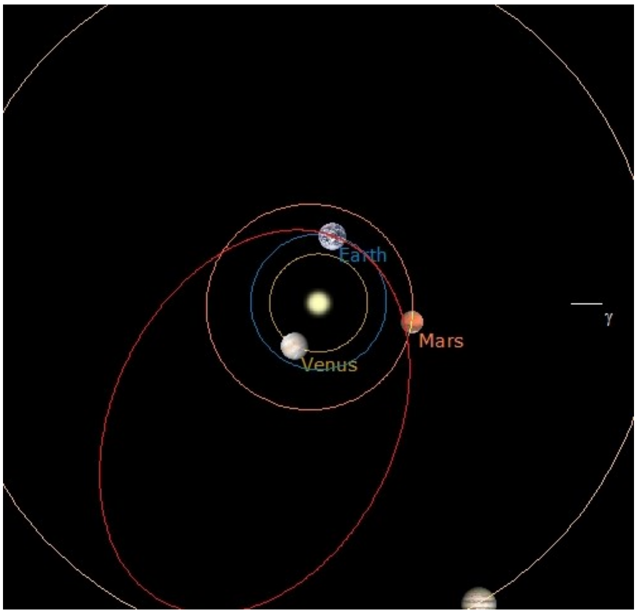

Figure 15 – Projection on the ecliptic plane of the orbit of the SWEMN20240703_022941 event.

[25] https://youtu.be/8NGEJ4ni4ik

8 The 2024 July 12 meteor

On 2024 July 12, at $0^h43^m10.0 \pm 0.1^s$ UT, SWEMN meteor stations recorded this bright meteor (*Figure 16*). Its peak brightness was equivalent to an absolute magnitude of –7.0 ± 1.0. The code given to the bolide in the SWEMN meteor database is SWEMN20240712_004310. The bolide can be viewed on this YouTube video[25].

Figure 16 – Stacked image of the SWEMN20240712_004310 event.

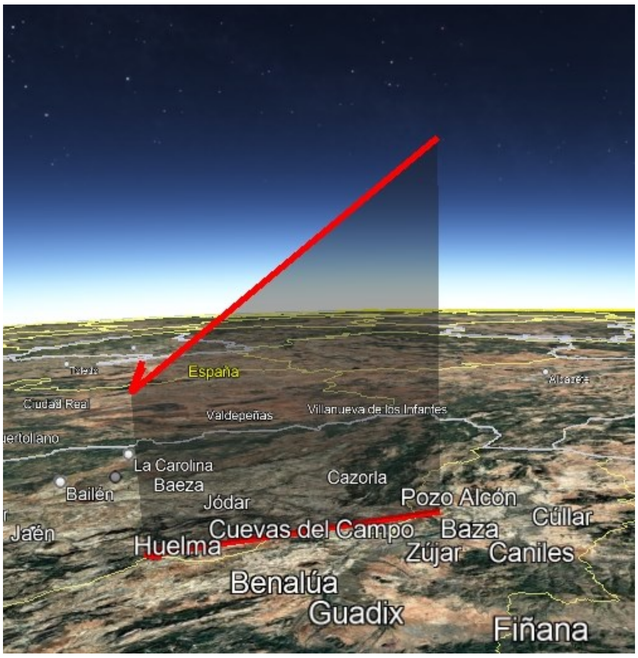

Figure 17 – Atmospheric path of the SWEMN20240712_004310 bolide, and its projection on the ground.

Atmospheric path, radiant and orbit

This bright meteor overflew the provinces of Granada and Jaén (southern Spain). Its initial altitude was H_b = 79.1 ± 0.5 km. The event penetrated the atmosphere till a final height H_e = 32.6 ± 0.5 km. The equatorial coordinates concluded for the apparent radiant are α = 359.27º, δ = +26.31º. The pre-atmospheric velocity inferred for the meteoroid yields v_∞ = 12.4 ± 0.2 km/s. The obtained trajectory in our atmosphere of the fireball is shown in *Figure 17*. The orbit in the Solar System of the meteoroid is shown in *Figure 18*.

We named this fireball "Arbuniel", because the bolide was located over this locality during its final phase. The parameters of the heliocentric orbit of the parent meteoroid before its encounter with our planet are included in *Table 6*. The geocentric velocity of the meteoroid was $v_g = 4.8 \pm 0.5$ km/s. The Tisserand parameter referred to Jupiter ($T_J = 7.44$) indicates that the meteoroid was moving on an asteroidal orbit before entering the atmosphere. These data and the calculated radiant location do not correspond with any of the meteoroid streams contained in the IAU meteor database. So, it was concluded that the event was produced by a sporadic meteoroid.

Table 6 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	0.77 ± 0.01	ω (°)	0.5 ± 00.3
e	0.30 ± 0.02	Ω (°)	109.740412 ± 10^{-5}
q (AU)	0.53 ± 0.03	i (°)	1.6 ± 0.4

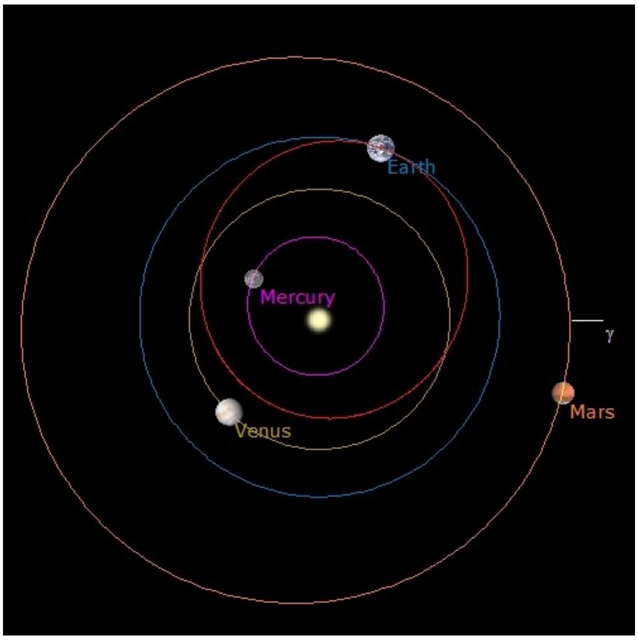

Figure 18 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20240712_004310 meteor.

9 Analysis of the 2024 July 25 meteor

This bright event was captured on 2024 July 25 at $23^h50^m36.0 \pm 0.1^s$ UT from the meteor-observing stations located at Huelva, La Hita (Toledo), Calar Alto, Sierra Nevada, La Sagra (Granada), and Sevilla (*Figure 19*). Its maximum luminosity was equivalent to an absolute magnitude of –7.0 ± 1.0. Its code in the SWEMN meteor database is SWEMN20240725_235036. A video about this bolide can be viewed on YouTube[26].

Figure 19 – Stacked image of the SWEMN20240725_235036 meteor.

Atmospheric path, radiant and orbit

The calculation of the trajectory in the Earth's atmosphere of the event led to the conclusion that this fireball overflew Jaén and Albacete. The meteoroid started ablating at a height $H_b = 76.5 \pm 0.5$ km, and ended at a height $H_e = 41.7 \pm 0.5$ km. The equatorial coordinates obtained for the apparent radiant are $\alpha = 267.81°$, $\delta = –5.90°$. The entry velocity in the atmosphere concluded for the progenitor meteoroid was $v_\infty = 14.8 \pm 0.3$ km/s. *Figure 20* shows the obtained atmospheric path of the bolide. The orbit in the Solar System of the progenitor meteoroid is shown in *Figure 21*.

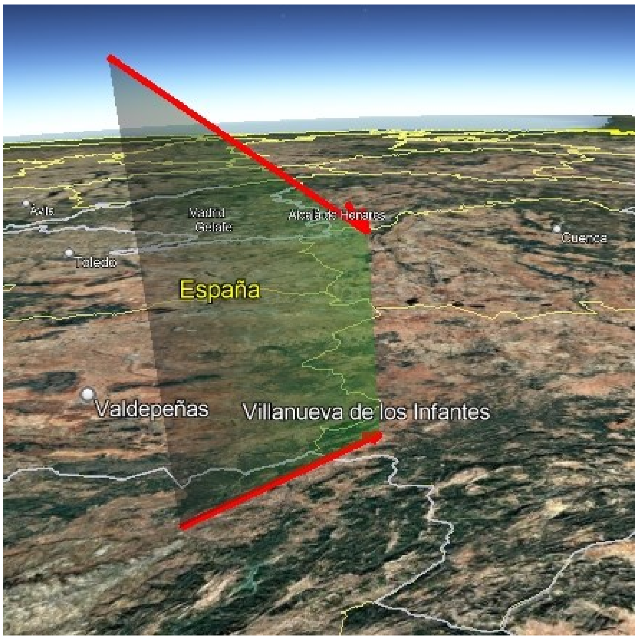

Figure 20 – Atmospheric path of the SWEMN20240725_235036 meteor, and its projection on the ground.

[26] https://youtu.be/DP-Sy0fGx20

Table 7 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	2.3 ± 0.1	*ω* (º)	210.8 ± 00.3
e	0.59 ± 0.02	Ω (º)	123.097318 ± 10⁻⁵
q (AU)	0.962 ± 0.002	*i* (º)	2.0 ± 0.2

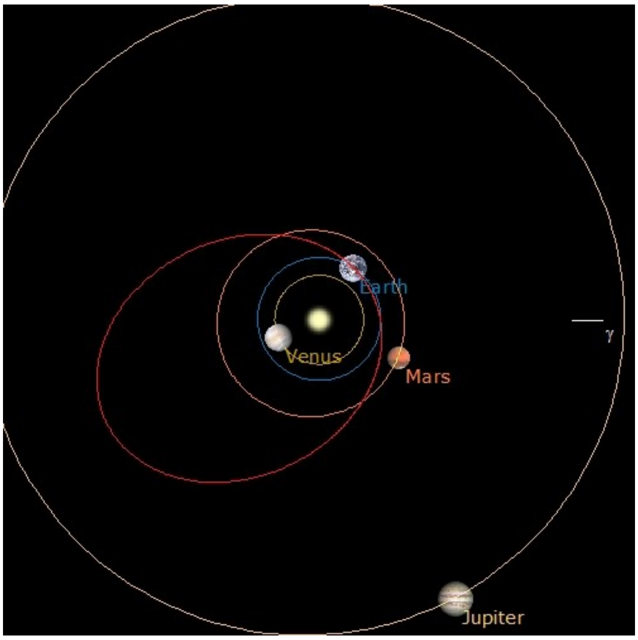

Figure 21 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20240725_235036 meteor.

The name given to the fireball was "Venta Cabrera", since the bright meteor overflew this locality during its initial phase. The parameters of the heliocentric orbit of the parent meteoroid before its encounter with our planet can be found in *Table 7*. The value calculated for the geocentric velocity was $v_g = 10.1 \pm 0.4$ km/s. The Tisserand parameter with respect to Jupiter ($T_J = 3.26$) indicates that the meteoroid was moving on an asteroidal orbit before impacting the Earth's atmosphere. These values and the calculated radiant coordinates suggest the sporadic nature of the event.

10 The 2024 July 26 fireball

This bright event was captured on 2024 July 26, at $2^h38^m57.0 \pm 0.1^s$ UT (*Figure 22*). The bolide, which showed a bright flare at the final part of its luminous path, had a peak absolute magnitude of –8.0 ± 1.0. This flare occurred as a consequence of the sudden disruption of the meteoroid. The code assigned to the event in the SWEMN meteor database is SWEMN20240726_023857. The bolide can be viewed on YouTube[27].

Atmospheric path, radiant and orbit

It was deduced from the calculation of the trajectory in our atmosphere of the fireball that this bolide overflew the province of Córdoba (southern Spain). The luminous event began at an altitude $H_b = 97.5 \pm 0.5$ km. The bright meteor penetrated the atmosphere till a final height $H_e = 73.9 \pm 0.5$ km. The equatorial coordinates obtained for the apparent radiant are $\alpha = 306.17º$, $\delta = –6.63º$. Besides, we deduced that the meteoroid collided with the atmosphere with a velocity $v_\infty = 25.4 \pm 0.3$ km/s. *Figure 23* shows the calculated trajectory in the atmosphere of the event. The orbit in the Solar System of the progenitor meteoroid is shown in *Figure 24*.

Figure 22 – Stacked image of the SWEMN20240726_023857 meteor.

Figure 23 – Atmospheric path of the SWEMN20240726_023857 meteor, and its projection on the ground.

Table 8 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	2.6 ± 0.1	*ω* (º)	269.27 ± 00.09
e	0.77 ± 0.01	Ω (º)	123.263516 ± 10⁻⁵
q (AU)	0.576 ± 0.004	*i* (º)	8.0 ± 0.1

[27] https://youtu.be/oFdec0qUuoo

Table 8 contains the parameters of the orbit in the Solar System of the progenitor meteoroid before its encounter with our planet. The value calculated for the geocentric velocity was $v_g = 23.1 \pm 0.3$ km/s. According to the value derived for the Tisserand parameter with respect to Jupiter ($T_J = 2.87$), the meteoroid was moving on a cometary (JFC) orbit before hitting the atmosphere. By taking into account this orbit and the radiant coordinates, the fireball was generated by the α-Capricornids (IAU meteor shower code CAP#0001). The proposed parent body of this meteor shower, which reaches its maximum around August 1, is 169P/NEAT (2002 EX12) (Jenniskens et al., 2016).

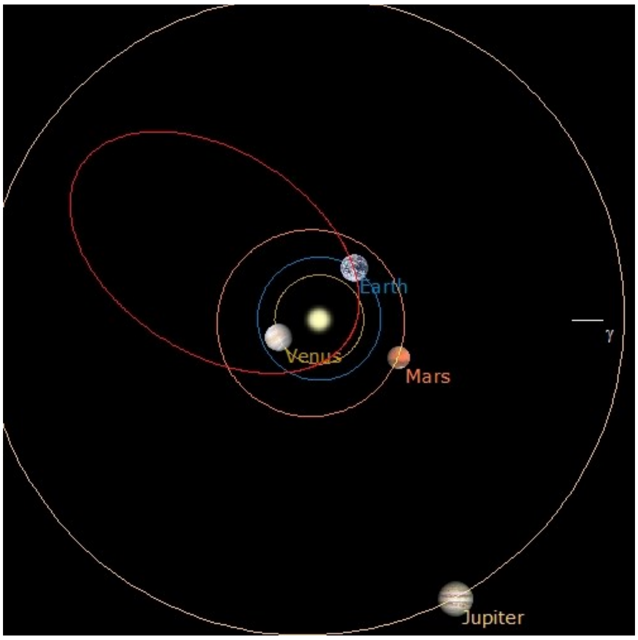

Figure 24 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20240726_023857 meteor.

11 Description of the 2024 August 1 bolide

This bright meteor was spotted by our cameras at $20^h57^m19.0 \pm 0.1^s$ UT on 2024 August 1. The event, that exhibited a series of flares along its trajectory in the atmosphere, had a peak absolute magnitude of –9.0 ± 1.0 (*Figure 25*). These flares took place as a consequence of the sudden disruption of the meteoroid. Its unique identifier in the SWEMN meteor database is SWEMN20240801_205719. The bolide was witnessed by a wide number of casual observers.

Atmospheric path, radiant and orbit

This event overflew the provinces of Málaga and Sevilla (southern Spain). The meteoroid ablation process began at a height $H_b = 143.7 \pm 0.5$ km, and ended at a height $H_e = 75.4 \pm 0.5$ km. The equatorial coordinates found for the apparent radiant are $\alpha = 293.38°$, $\delta = –6.76°$. The entry velocity in the atmosphere concluded for the parent meteoroid was $v_\infty = 25.0 \pm 0.3$ km/s. The calculated path in the atmosphere of the bright meteor is shown in *Figure 26*. The orbit in the Solar System of the progenitor meteoroid is shown in *Figure 27*.

Figure 25 – Stacked image of the SWEMN20240801_205719 meteor.

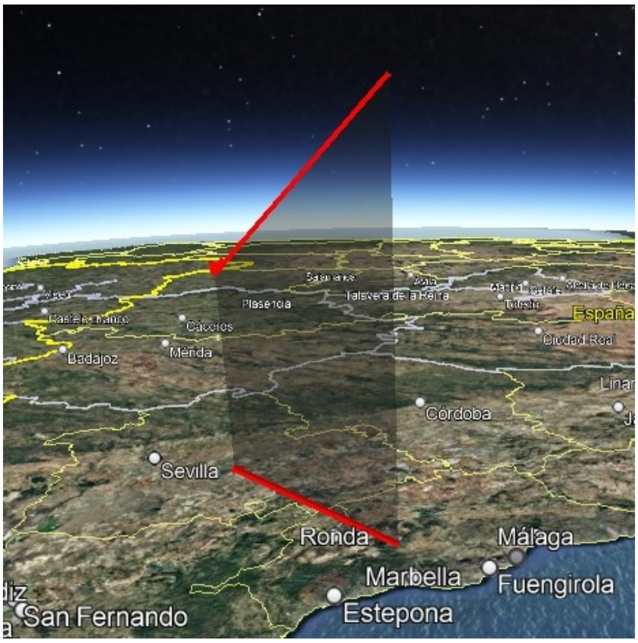

Figure 26 – Atmospheric path of the SWEMN20240801_205719 meteor, and its projection on the ground.

Table 9 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	36.3 ± 30.	*ω* (°)	241.84 ± 00.04
e	0.97 ± 0.01	Ω (°)	129.729233 ± 10^{-5}
q (AU)	0.749 ± 0.002	*i* (°)	7.4 ± 0.1

The name given to the event was "Yunquera", because the fireball overflew this locality during its initial phase. *Table 9* shows the parameters of the orbit in the Solar System of the parent meteoroid before its encounter with our planet. The geocentric velocity of the meteoroid was $v_g = 22.2 \pm 0.3$ km/s. According to the value found for the Tisserand parameter with respect to Jupiter ($T_J = 1.20$), the meteoroid was moving on a cometary (HTC) orbit before entering the atmosphere. These data and the derived radiant coordinates do not correspond with any of the streams included in the IAU meteor database. Consequently, it was concluded that the fireball was linked to the sporadic background.

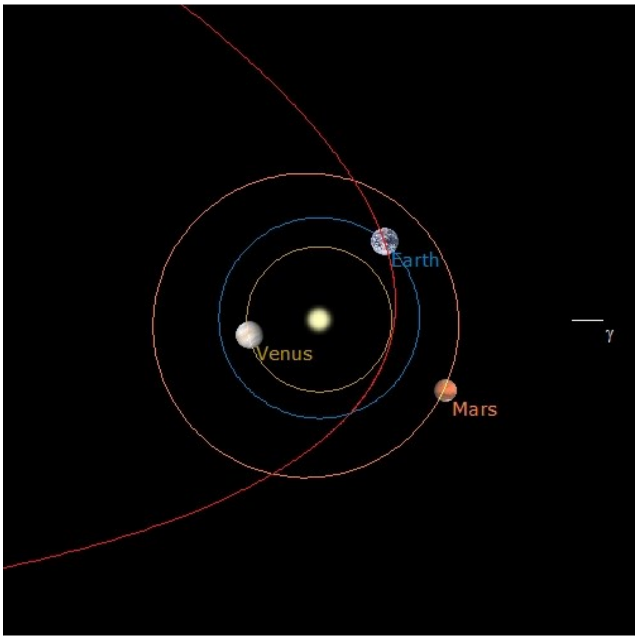

Figure 27 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20240801_205719 meteor.

12 The 2024 August 21 meteor

This bright meteor was captured by our cameras at $20^h28^m05.0 \pm 0.1^s$ UT on 2024 August 21 (*Figure 28*). Its maximum brightness was equivalent to an absolute magnitude of –7.0 ± 1.0. Its identifier in the SWEMN meteor database is SWEMN20240821_202805. A video containing images of the fireball and its atmospheric trajectory was uploaded to YouTube[28].

Figure 28 – Stacked image of the SWEMN20240821_202805 meteor

Atmospheric path, radiant and orbit

This bright meteor overflew Portugal and the Atlantic Ocean. Its initial altitude was $H_b = 124.4 \pm 0.5$ km. The event penetrated the atmosphere till a final height $H_e = 87.4 \pm 0.5$ km. The position deduced for the apparent radiant corresponds to the equatorial coordinates $\alpha = 22.85°$, $\delta = +45.16°$. The meteoroid collided with the atmosphere with an initial velocity $v_\infty = 57.2 \pm 0.0$ km/s. The calculated atmospheric path of the bolide is shown in *Figure 29*. The orbit in the Solar System of the progenitor meteoroid is shown in *Figure 30*.

Table 10 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	2.338 ± 0.007	*ω* (°)	245.1 ± 00.1
e	0.6678 ± 0.0009	Ω (°)	148.925122 ± 10^{-5}
q (AU)	0.776 ± 0.001	*i* (°)	116.65 ± 0.05

Figure 29 – Atmospheric path of the SWEMN20240821_202805 meteor, and its projection on the ground.

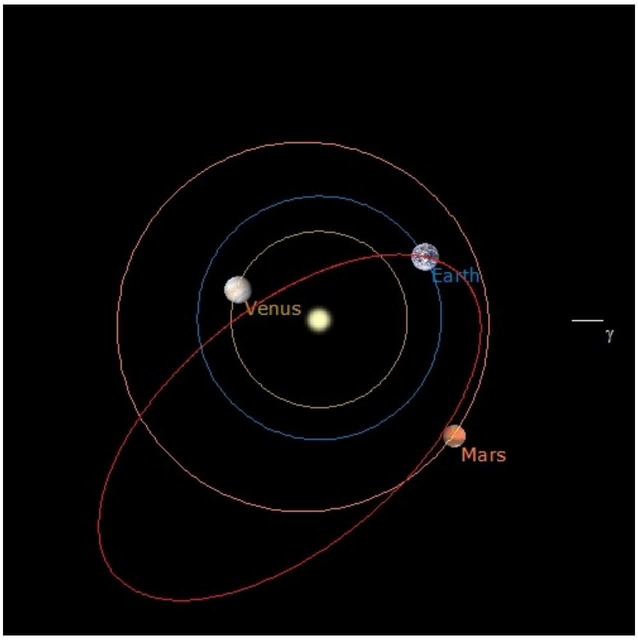

Figure 30 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20240821_202805 meteor.

The name given to the bolide was “Lobeira de Cima”, since the fireball passed near the zenith of this locality during its

[28] https://youtu.be/3QYY33WG8dI

initial phase. The parameters of the heliocentric orbit of the progenitor meteoroid before its encounter with our planet are listed in *Table 10*. The geocentric velocity of the meteoroid was v_g = 55.8 ± 0.0 km/s. According to the value found for the Tisserand parameter with respect to Jupiter (T_J = 1.78), the particle was moving on a cometary (HTC) orbit before entering our atmosphere. These parameters and the calculated radiant coordinates do not match any of the streams included in the IAU meteor database. Consequently, it was concluded that the bright meteor was linked to the sporadic background).

13 The second fireball on 2024 August 21

On 2024 August 21, at 20^{h}33^{m}47.0 ± 0.1^s UT, our cameras spotted this event (*Figure 31*). Its peak luminosity was equivalent to an absolute magnitude of –13.0 ± 1.0. It presented different flares along its trajectory in the Earth's atmosphere as a consequence of the sudden disruption of the meteoroid. The fireball was included in our meteor database with the unique identifier SWEMN20240821_203347. Casual observers saw the bolide crossing the night sky.

Figure 31 – Stacked image of the SWEMN20240821_203347 meteor.

Atmospheric path, radiant and orbit

By calculating the trajectory in the Earth's atmosphere of the event it was deduced that this bolide overflew the province of Sevilla (southern Spain). The initial phase of the luminous path of the event yields H_b = 81.2 ± 0.5 km, with the terminal point located at a height H_e = 32.0 ± 0.5 km. The apparent radiant was located at the equatorial coordinates α = 302.91º, δ = +10.20º. The entry velocity in the atmosphere found for the progenitor meteoroid was v_∞ = 22.0 ± 0.2 km/s. The calculated path in the atmosphere of the bright meteor is shown in *Figure 32*. The orbit in the Solar System of the progenitor meteoroid is shown in *Figure 33*.

Table 11 contains the parameters of the orbit in the Solar System of the progenitor meteoroid before its encounter with our planet, and the geocentric velocity derived in this case was v_g = 18.9 ± 0.2 km/s. From the value calculated for the Tisserand parameter with respect to Jupiter (T_J = 1.93), we found that before entering our atmosphere the particle was moving on a cometary (HTC) orbit. By taking into account these orbital data and the radiant position, it was found that the fireball was generated by a sporadic meteoroid.

Table 11 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	5.9 ± 0.5	*ω* (º)	230.79 ± 0.05
e	0.85 ± 0.01	Ω (º)	148.92128 ± 10^{-5}
q (AU)	0.839 ± 0.001	*i* (º)	13.6 ± 0.1

Figure 32 – Atmospheric path of the SWEMN20240821_203347 meteor, and its projection on the ground.

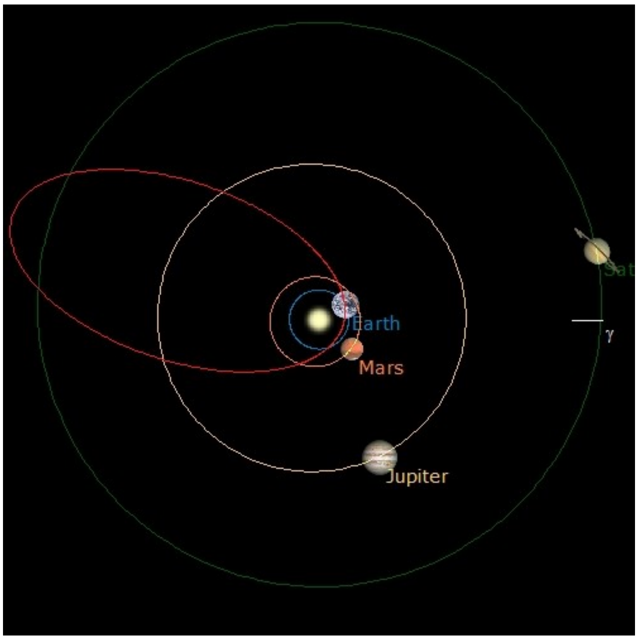

Figure 33 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20240821_203347 meteor.

14 The 2024 September 15 bolide

This bright fireball was captured by our devices at $21^h06^m14.0 \pm 0.1^s$ UT on 2024 September 15 (*Figure 34*). It had a peak absolute magnitude of –10.0 ± 1.0, and exhibited various flares along its luminous path as a consequence of the sudden disruption of the meteoroid. It was listed in the SWEMN meteor database with the unique identifier SWEMN20240915_210614. The bright meteor can be viewed on YouTube[29]. A wide number of casual observers saw how the fireball crossed the sky.

Figure 34 – Stacked image of the SWEMN20240915_210614 meteor.

Figure 35 – Atmospheric path of the SWEMN20240915_210614 meteor, and its projection on the ground.

Atmospheric path, radiant and orbit

This bright meteor overflew the provinces of Toledo and Madrid. The initial phase of the luminous path of the event yields $H_b = 80.2 \pm 0.5$ km, and the terminal point was located at a height $H_e = 38.1 \pm 0.5$ km. From the analysis of the atmospheric path we also obtained that the apparent radiant was located at the position $\alpha = 305.81°$, $\delta = –16.04°$. Besides, we deduced that the meteoroid collided with the atmosphere with a velocity $v_\infty = 13.9 \pm 0.2$ km/s. The obtained trajectory in our atmosphere of the bolide is shown in *Figure 35*. The orbit in the Solar System of the progenitor meteoroid is shown in *Figure 36*.

Table 12 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	2.2 ± 0.1	ω (°)	21.8 ± 00.1
e	0.56 ± 0.02	Ω (°)	353.178857 ± 10^{-5}
q (AU)	0.979 ± 0.001	i (°)	2.35 ± 0.07

The parameters of the heliocentric orbit of the parent meteoroid before its encounter with our planet are listed in *Table 12*. The geocentric velocity obtained for the particle yields $v_g = 8.4 \pm 0.3$ km/s. The value derived for the Tisserand parameter with respect to Jupiter ($T_J = 3.41$) reveals that the particle was moving on an asteroidal orbit before striking the Earth's atmosphere. These parameters and the calculated radiant coordinates confirm that the fireball was linked to the sporadic background.

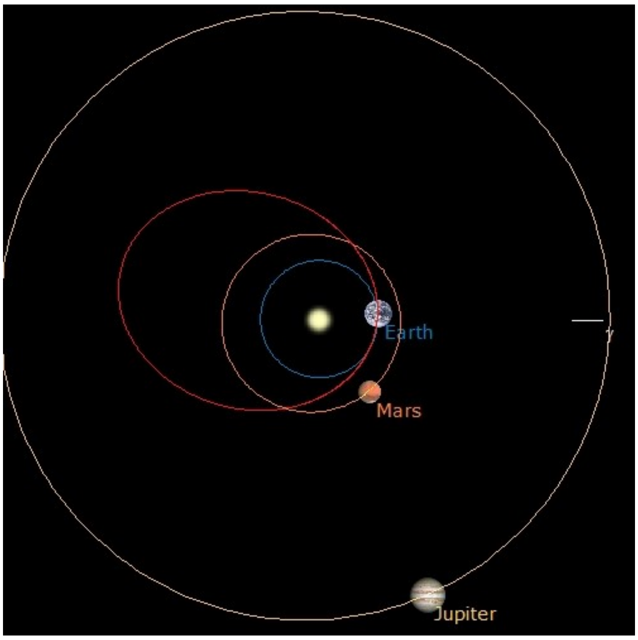

Figure 36 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20240915_210614 meteor.

15 Conclusions

We have discussed here some of the most notable fireballs captured by our meteor-observing stations from March to September 2024. They had a maximum luminosity ranging from mag. –7 to mag. –14.

The first event presented in this report was the "Monte da Macarra" fireball, which was captured on March 16. Its progenitor meteoroid belonged to the sporadic component. Its peak magnitude was –14.0 and it overflew Portugal. The meteoroid was moving on an asteroidal orbit before colliding with the Earth's atmosphere. At the final stage of its luminous phase this deep-penetrating bolide was located

[29] https://youtu.be/MqDQ7f1BG-g

at a height of about 18 km. According to our results, this meteor was a potential meteorite-producer.

The second fireball described here was a bright meteor captured on March 22 that was named “Casa-Lluna”. Its peak magnitude was -10.0. The meteor event was produced by an η-Virginid (EVI#0011) meteoroid and overflew the province of Castellón. This particle followed a cometary (JFC) orbit before entering the Earth’s atmosphere. At the final stage of its luminous phase this deep-penetrating fireball was located at a height of about 32 km.

Next, we have analyzed an event captured on April 14 that was named “Fuente Leiva”. The peak magnitude of this sporadic, which overflew the provinces of Málaga and Jaén (southern Spain), was –14.0. The particle was moving on an asteroidal orbit before impacting our planet’s atmosphere. The terminal altitude of this deep-penetrating meteor event was of about 25 km. From the analysis of the ending point of the luminous path we concluded that the bolide was a potential meteorite-producer, but with a very small terminal mass.

The next event presented here was a fireball captured on May 29 that was named “Casa de la Vega”. It reached a peak absolute magnitude of –13.0, and was associated with the sporadic component. This meteor overflew the province of Cuenca (Spain). The meteoroid was moving on an asteroidal orbit before impacting our planet’s atmosphere. The ending altitude of this deep-penetrating meteor event was of about 21 km.

The fifth fireball analyzed here was a bright meteor captured on July 3 that we named “Los Muñoces”. Its peak magnitude was –8.0. The event was produced by a sporadic meteoroid and overflew the province of Murcia (southeast of Spain) and the Mediterranean Sea. This meteoroid followed a cometary (JFC) orbit before hitting the atmosphere. This deep-penetrating meteor reached an ending altitude of about 33 km.

The next bright meteor analyzed here was the “Arbuniel” bolide, that was captured on July 12. It was also associated with the sporadic background. Its peak magnitude was –7.0 and overflew the provinces of Granada and Jaén (southern Spain). The meteoroid followed an asteroidal orbit before hitting the Earth’s atmosphere. The terminal altitude of this deep-penetrating meteor event was of about 32 km

We have also analyzed a bright meteor captured on July 25 named “Venta Cabrera”. It belonged to the sporadic component. Its peak magnitude was –7.0 and overflew the provinces of Jaén and Albacete (southern Spain). Before entering our planet’s atmosphere the meteoroid was moving on an asteroidal orbit. The ending height of this fireball was of about 41 km.

A mag. –8 α-Capricornid (CAP#0001) was spotted on July 26. Its peak magnitude was –8.0 and overflew the province of Córdoba.

The next fireball analyzed here was the “Yunquera” meteor, that was captured on August 1. It was associated with the sporadic component. Its peak magnitude was –9.0 and overflew the provinces of Málaga and Sevilla (southern Spain). Before entering the atmosphere, the progenitor meteoroid was moving on a cometary (HTC) orbit.

The “Lobeira de Cima” event was recorded on August 21. The peak magnitude of this sporadic, which overflew Portugal and the Atlantic Ocean, was –7.0. Before striking our atmosphere, the meteoroid was moving on a cometary (HTC) orbit.

Next, we have described another bright meteor captured also on August 21. Its peak magnitude was –13.0. This fireball was produced by a sporadic meteoroid and overflew the province of Sevilla (southern Spain). Before striking the atmosphere, the particle was moving on a cometary (HTC) orbit. The ending altitude of this deep-penetrating bolide was of about 32 km.

And the last bright meteor discussed here was captured on September 15. Its peak magnitude was –10.0. The bolide was produced by a sporadic meteoroid and overflew the provinces of Toledo and Madrid. The parent meteoroid followed an asteroidal orbit before striking the atmosphere. The ending altitude of this deep-penetrating meteor event was of about 38 km.

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