e–Zine for meteor observers
meteornews.net

MeteorNews

ISSN 2570-4745
VOL 8 / ISSUE 2 / MARCH 2023

Meteorite dropping fireball predicted to strike Earth's atmosphere on 13 February at 3 am.
As seen and photographed from Netherlands by Gijs de Reijke

- Pulat Babadzhanov
- June Bootids
- omega-Carinids
- Global Meteor Network
- CAMS reports
- Radio meteor work

Contents

Obituary
Babadzhanov Pulat Babadzhanovich
(15 October 1930 – 10 February 2023)

Gulchehra Kokhirova and Firuza Rakhmatullaeva

Institute of Astrophysics, National Academy of Sciences of Tajikistan,
Ayni 299/5, Dushanbe, 734063, Tajikistan
`kokhirova2004@mail.ru`

Babadzhanov Pulat (2011)

Babadzhanov Pulat Babadzhanovich was born on October 15, 1930, in Tajikistan. Babadzhanov Pulat showed interest in the study of astronomy at the Faculty of Physics and Mathematics of the Leninabad State Pedagogical Institute, where he graduated with honors in 1949. He began his scientific activity in 1950 as a graduate student, first at the Stalinabad Astronomical Observatory of the Academy of Sciences of Tajikistan, and from 1951 at the State Astronomical Institute named after. P. K. Sternberg of the Moscow State University. In 1954 he defended his dissertation for the degree of Candidate in Physical and Mathematical Sciences at the Moscow State University. In 1970, he defended his dissertation for the degree of Doctor in Physical and Mathematical Sciences. In 1973 Babadzhanov Pulat was elected as academician of the Academy of Sciences of the Republic of Tajikistan and received the degree of professor.

Babadzhanov P. B. is an outstanding scientist in the field of interplanetary dust research. He is the author of more than 300 scientific papers and 8 monographs. His work covers the distribution of meteoroid dust in interplanetary space, the density of the meteoroid stream encountered by the Earth, the physics of meteor phenomena, the physical parameters of the Earth’s upper atmosphere determined by meteor observing methods, the evolution of meteoroid swarms and their relationship with comets and asteroids, as well as the development and implementation of new methods for studying meteor phenomena.

Based on photographic observations, Babadzhanov P. B. obtained a rich and unique collection on meteors brighter than the first magnitude, used to compile a catalog of orbits which was included in the Meteor Data Center of the International Astronomical Union (IAU). The results of photographic and radar observations of meteors made it possible to determine the density of the meteoroid flux and the influx of meteoric matter on the Earth, to reconstruct the spatial distribution of the atmospheric currents in the meteor layers of the atmosphere, and to establish a relationship between the phenomena of luminescence and ionization of meteors. Babadzhanov has developed and implemented the method of “instant exposures” for photographic and spectrographic observations of meteors, which made it possible for the first time in the world to obtain instantaneous images of hundreds of meteors and their spectra with exposures of 0.00056 sec and to establish the process of fragmentation of meteoroids in the atmosphere. This allowed to consider the physics of meteor events from qualitatively new perspectives. These new results made it possible to develop a theory of quasi-continuous fragmentation of meteoroids in the Earth’s atmosphere. On the basis of this theory, a method for analyzing the light curves of meteors was developed and put into practice, and the densities of meteoroids belonging to different streams as well as to the sporadic background were determined. Under the leadership of Babadzhanov Pulat, the Soviet Equatorial Meteor Expedition of the USSR Academy of

Sciences was organized, which conducted a two-year cycle of observations of meteors and the ionosphere in equatorial Africa (Somalia). Based on these observations, fundamental astronomical and geophysical results were obtained, which made it possible to establish the patterns of the global circulation of the Earth's atmosphere at altitudes of 80–120 km, to determine the distribution of radiants of sporadic meteors in the equatorial region of the sky, and to compile a catalog of the orbits of several thousand meteors.

Babadzhanov Pulat (2010)

Babadzhanov Pulat has carried out extensive studies of the evolution of meteoroid streams under the influence of gravitational and non-gravitational perturbations, as well as the evolution of the orbits of comets and asteroids. This made it possible to obtain completely new ideas about the shape and dynamics of meteoroid streams and to discover new meteor showers associated with comets and asteroids crossing the Earth's orbit. It has been shown that each meteoroid stream, as a rule, can generate up to four (and some up to eight) meteor showers, active at different times of the year from significantly different radiants. This fundamental result made it possible to resolve one of the contradictions which consisted in the significant predominance of the number of observable meteor showers compared to the number of known short-period comets. The existence of meteor showers associated with asteroids crossing the Earth's orbit and moving in comet-like orbits is an important criterion for establishing that such asteroids are extinct comets. The population of near-Earth objects, consisting of real asteroids, which are stony or iron, and extinct comets, which are a conglomeration of frozen gases and solid particles, poses a potential danger for collision with the Earth. Outwardly, primordial asteroids and nuclei of extinct comets, covered with a thick dusty mantle, do not differ from each other. Therefore, the aforementioned study by Babadzhanov Pulat was applied to separate them. Using this criterion more than 500 objects that are extinct comets have been identified among NEAs up to present and which can be chosen as a target for space missions. Fruitful scientific activity and valuable contribution of Babadzhanov Pulat to science made him one of the leading researchers of small bodies in the Solar system. Since 1959 Babadzhanov Pulat was a participant who made presentations at the General Assemblies of the International Astronomical Union in Moscow, Germany, Czech Republic, Great Britain, France, Canada, the Philippines, Greece, India, the Netherlands, Japan and USA, as well as at international conferences in Italy, Yugoslavia, Sweden, Finland, Slovakia, South Korea, etc. He was one of the coordinators of the meteor section of the International Halley Comet Research Program.

From 1960 to 1972 Babadzhanov Pulat was a member of the Astronomical Council of the Academy of Sciences of the USSR. Since 1961 - a member of the International Astronomical Union (IAU), a member of the Bureau of the Commission 22 "Meteors and Interplanetary Dust" of the International Astronomical Union, in 1985–1988 he was elected President of this commission. In 1972–1990 Babadzhanov Pulat coordinated meteor research in the USSR, being the Chairman of the working group of the Astronomical Council of the USSR Academy of Sciences "Meteoric substance". Since 1990 Babadzhanov Pulat is a member of the International Committee for Space Research (COSPAR). In 1994 Babadzhanov Pulat was elected a member of the Royal Astronomical Society of Great Britain for his leadership in astronomy.

The activity of Babadzhanov Pulat is also connected with the training of staff. His pedagogical talent manifested itself most fully when supervising the dissertations of graduate and doctoral students, and when he was the Rector of the Tajik State University.

Babadzhanov Pulat with Kokhirova Gulchehra, 2006

P. B. Babadzhanov's achievements, honors and awards

- 1954 – 1959 Senior Researcher, Head of the Department of Meteor Astronomy, Institute of Astrophysics Tajik SSR Academy of Sciences.
- 1959 – 1971 Director of the Institute of Astrophysics of the Tajik SSR Academy of Sciences.
- 1971 – 1982 Rector of the Tajik State University.
- 1982 – 2022 Head of the Department of Meteor Astronomy of the Institute of Astrophysics of the Tajik SSR Academy of Sciences.
- 1986 – 1989 Vice-President of the Tajik SSR Academy of Sciences.
- 1992 – 2002 Director of the Institute of Astrophysics of the Academy of Sciences of the Republic of

Tajikistan (now the National Academy of Sciences of Tajikistan (NAST)).

- 1999 – 2003 Head Department of Astronomy, Professor of the Department of Astronomy Tajik National University.
- 2003 – 2023 Counselor to the President of the National Academy of Sciences of Tajikistan and Honorary Director Institute Astrophysics NAST.

Babadzhanov Pulat with Cepleha Zdenek

Scientific direction

Physics and dynamics of small bodies of the Solar system (meteors and meteoroids, comets and asteroids), physics of the Earth's upper atmosphere:

- 1961 – … Member of the International Astronomical Union (IAU).
- 1994 – … Member of the Royal Astronomical Society (UK).
- 1998 – … Member of the International Space Research Committee.
- 1996 – … Member of the European Astronomical Society.
- 1998 – … Member of the Euro-Asian Astronomical Society.
- 1992 – … Member of the International Meteor Organization.

Babadzhanov Pulat with his birthday 15 October 2022

P. B. Babadzhanov has created a large school of astrophysicists in Tajikistan. Under his direct supervision and participation, 8 Doctor of Science and 23 Ph.D.'s theses were prepared and defended.

For merits in the development of science and training of personnel, Babadzanov Pulat was awarded by a few Tajikistan's and international Prizes, titles, etc. Minor planet 7164 "Babadzhanov" was named in honor of Babadzhanov Pulat.

Babadzhanov Pulat, Kholshevnikov Konstantin and staff of the Institute of Astrophysics of NAST, Dushanbe, 2015

Babadzhanov Pulat (2012)

Babadzhanov Pulat (2014)

June Bootids (JBO#170) in 2022 recorded by Global Meteor Network

Paul Roggemans[1], **Damir Šegon**[2] **and Denis Vida**[3]

[1] **Pijnboomstraat 25, 2800 Mechelen, Belgium**
paul.roggemans@gmail.com

[2] **Astronomical Society Istra Pula, Park Monte Zaro 2, 52100 Pula, Croatia**

[3] **Department of Earth Sciences, University of Western Ontario, London, Ontario, N6A 5B7, Canada**
denis.vida@gmail.com

The Global Meteor Network recorded a distinct concentration of June Bootid orbits with most of the orbits collected at $\lambda_{\odot}$ = 90.2°, or 2022, June 21 at 22^h UT. Visual hourly rates were very low with a ZHR ~0.5. The radiant plot shows a compact core of very similar orbits embedded within a very large radiant area with very dispersed radiants. Comparing with other networks in previous years suggests that a concentration of very similar orbits like in 2022 may have occurred in 2016 and 2010.

1 Introduction

The parent comet of the June Bootids, sometimes referred to as the iota Draconids, was discovered by Jean-Louis Pons, a French astronomer (1761 – 1831), in 1809 and found again in 1858 by Friedrich August Theodor Winnecke, a German astronomer (1835 – 1897). No meteor shower was known or associated to this comet until 1916 when the famous British meteor observer William Frederick Denning (1848 – 1931) observed an outburst of meteors on June 28 from a radiant between Boötes and Draco. Denning (1916) concluded that Pons-Winnecke's Comet of 1819-58 satisfied the conditions to be the parent body. The radiant was placed in the correct region and the date agreed. The shower was observed again in 1921 with moderately low hourly numbers except for one Japanese observer, Kaname Nakamura who observed this shower activity during several nights with best rates on July 3 with 153 meteors in 35 minutes. The shower activity consisted mainly in faint meteors with an average magnitude of +4.8. This observer was known to have an exceptional sensitive vision compared to other observers (Yamamoto, 1922).

King (1927) mentions a letter from Mr. V. Maltzev, the secretary of the meteor section of a Russian astronomy society about the observations of this shower in the Russian territories. More than 4000 meteor trails were recorded at Tashkent (todays capital of Uzbekistan) during end of June and beginning of July 1927. The maximum occurred on June 27 when hourly rates reached 500 from a radiant near ζ Ursa Major. 90% of these meteors were fainter than the 5th magnitude, confirming the observations made in 1921 at Kyoto in Japan.

Although attempts were made to observe this shower in later years, only very low rates were seen which could be explained as sporadic noise being lined up with the assumed radiant position. The comet orbit gradually evolved away from the Earth's orbit and nobody expected any June Bootid activity anymore when unexpectedly a strong outburst of the June Bootids was seen in 1998 on June 27 (Velkov, 1999) with a peak ZHR of 250 ± 50 at $\lambda_{\odot}$ = 95.69 ±0.01° (Jenniskens, 2006). Until then, no reliable orbit was known for the June Bootids, but two photographed meteors at Ondrejov Observatory in the Czech Republic allowed Pavel Spurny and Jiri Borovicka to compute a first accurate orbit on June 27.89102 UT. The obtained orbital parameters (all for equinox J2000.0) were:

- α_g = 222.88 ± 0.16°
- δ_g = +47.60 ± 0.06°
- v_g = 14.1 ± 0.4 km/s
- a = 3.3 ± 0.3 AU
- e = 0.69 ± 0.03
- q = 1.01577 ± 0.00005 AU
- ω = 183.65 ± 0.07°
- Ω = 96.04559 ± 0.00003°
- i = 18.4 ± 0.4°

This meteoroid was of the most fragile, typically cometary type IIIB (Spurny and Borovicka, 1998). The heliocentric orbit corresponds to a previous orbit of the comet 7P/Pons-Winnecke and is far off from the current parent body orbit (see *Table 1*).

Sergey Shanov and Sergey Dubrovsky predicted another return on 2004, June 23. Visual observers reported June Bootid activity from June 22, 20^h UT until June 23, 23^h UT with a peak activity and ZHR = 18 ± 2 at 10^h UT ($\lambda_{\odot}$ = 92.21°), in good agreement with the prediction (Jenniskens, 2006).

Mikiya Sato did dynamical simulations of the meteoroid stream until 2055 and showed that there will be no more future encounters with the stream (Jenniskens, 2006). It looked as there was no hope anymore to collect more orbit data for the June Bootids as the 1998 and 2004 returns came some years too early for the upcoming video camera networks. Or would the unpredictable nature of meteor showers bring some surprise in the future?

Table 1 – The dynamic evolution of 7P/Pons-Winnecke with the orbit at past returns[1] and June Bootids orbits.

Comet's return	*a* (AU)	*e*	*q* (AU)	*Ω* (°)	*ω* (°)	*i* (°)
1892	3.24	0.726	0.887	105.6	172.2	14.5
1898	3.24	0.715	0.924	102.2	173.4	17.0
1909	3.26	0.702	0.973	100.6	172.3	18.3
1915	3.26	0.702	0.971	100.5	172.4	18.3
1921	3.31	0.685	1.041	99.2	170.3	18.9
1927	3.31	0.686	1.039	99.1	170.4	18.9
1933	3.33	0.670	1.102	97.5	169.3	20.1
1939	3.33	0.670	1.101	97.5	169.4	20.1
…	…	…	…	…	…	…
2015	3.42	0.638	1.239	93.4	172.5	22.3
P. Spurny and J. Borovicka (1998)	3.30	0.690	1.016	96.0	183.7	18.4
This paper	3.11	0.674	1.014	89.5	185.6	18.2

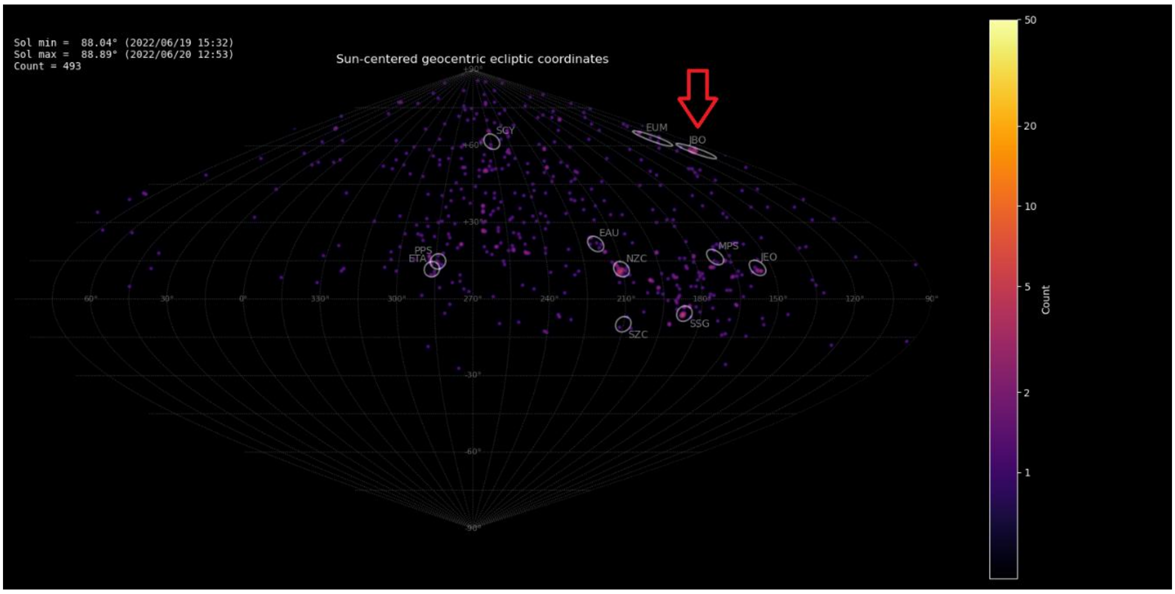


Figure 1 – The June Bootid radiant in Sun-centered geocentric ecliptic coordinates recorded by GMN during 88.04° < $\lambda_{\odot}$ < 88.89° (June 19–20).

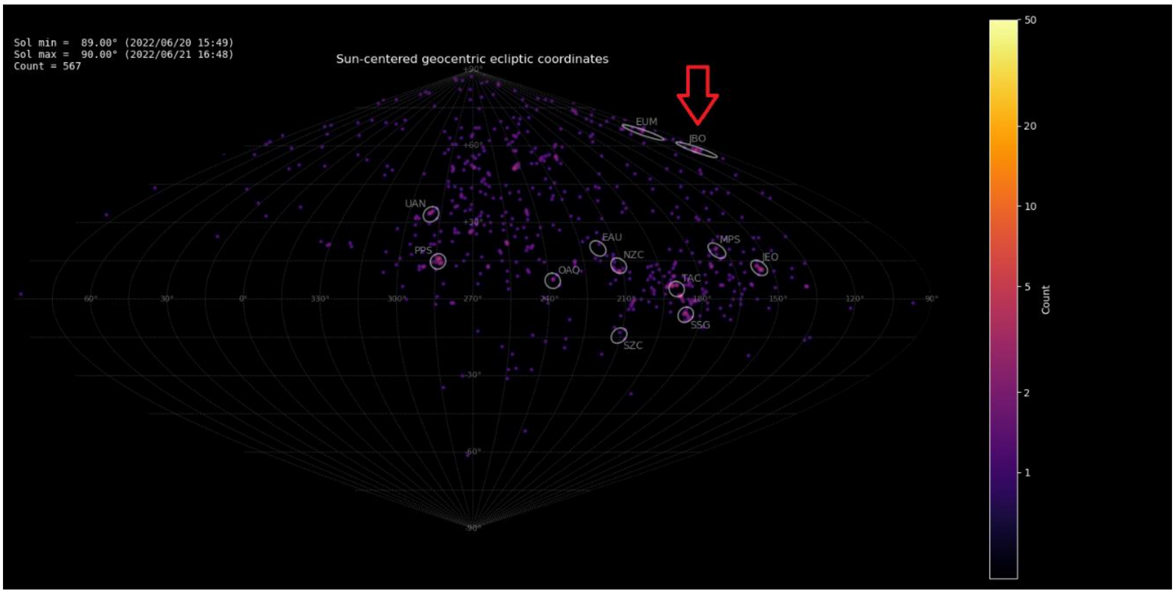


Figure 2 – The June Bootid radiant in Sun-centered geocentric ecliptic coordinates recorded by GMN during 89.00° < $\lambda_{\odot}$ < 90.00° (June 20–21).

---

[1] https://ssd.jpl.nasa.gov/tools/sbdb_lookup.html#/?sstr=7P

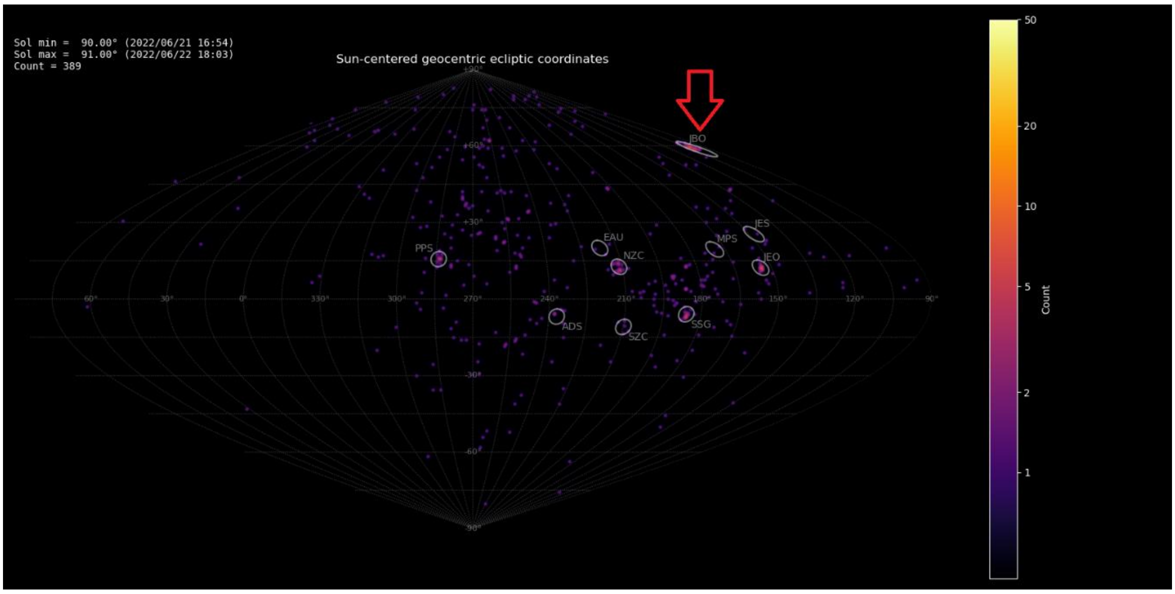


Figure 3 – The June Bootid radiant in Sun-centered geocentric ecliptic coordinates recorded by GMN during 90.00° < $\lambda_{\odot}$ < 91.00° (June 21–22).

2 The GMN data

The JBO-radiant shows up in GMN radiant plots during three nights, 19–20, 20–21 and 21–22 June, nothing earlier or later (*Figures 1, 2 and 3*). The Global Meteor Network collected 2436 orbits during the five nights of 2022 June 18–23 (87.00° < $\lambda_{\odot}$ < 92.00°) and identified 37 orbits as June Bootids (JBO#170) in 2022. A dense concentration of 31 orbits with $D_{SH} < 0.05$ alerted the authors that some unusual activity occurred and required a dedicated analysis (*Figure 4*).

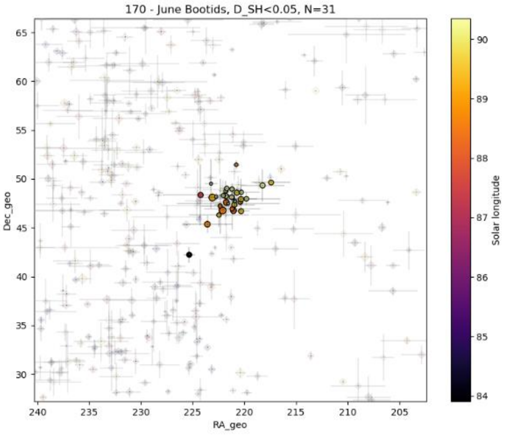


Figure 4 – Plot showing the concentration of radiants color coded in function of the solar longitude.

The initial identification by GMN has been made based on a list of known meteor showers (Jenniskens et al., 2018) for orbits recorded within 1° in solar longitude of the known activity period, with the radiant within 3° relative to the known radiant position and with a geocentric velocity v_g within an interval of 10% relative to the reference geocentric velocity (Moorhead et al., 2020). Details about the methodology, theory and results of the Global Meteor Network can be found in Vida et al. (2019; 2020; 2021).

Figure 5 – June Bootid recorded on 2022 June 21, $23^h45^m12^s$ on BE0005 at Grapfontaine, multi-station with BE0003 at Zillebeke, BE0008 at Genk and BE000C at Humain.

Most June Bootids were rather faint meteors, no really bright events. For instance, *Figure 5* shows one of the brighter June Bootids recorded in 2022. The number of orbits identified as June Bootids by GMN in previous years is almost negligeable with only 3 in 2021, 5 in 2020 and none in 2019. It is unlikely that any unusual June Bootid activity was missed due to weather circumstances or lack of cameras as GMN covered the suspect period in previous years with a total of 254 orbits collected in 2019, 1079 in 2020 and 827 in 2021.

Using orbit similarity criteria, we find many more candidate June Bootid orbits within the suspect period: 8 in 2019, 57 in 2020, 20 in 2021 and 137 in 2022, most of these from a very dispersed radiant in equatorial coordinates as well as in Sun-centered ecliptic coordinates. *Figure 6* shows the huge area at the sky where these widely dispersed radiants occur, most of them with very low or low similarity. Only in 2022 we have a distinct concentration of a statistically significant number of June Bootid orbits. The lower the velocity of a meteor shower, the larger the radiant tends to be. In such a case a dense concentration of radiants amid a widely spread radiant area indicates that Earth encountered some dust cloud of particles that didn't get dispersed yet.

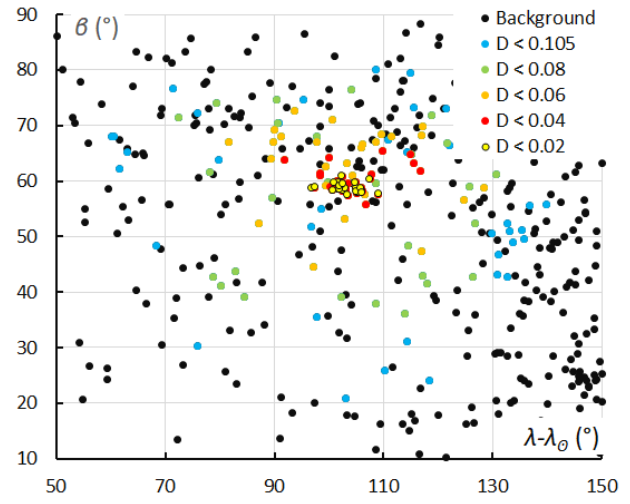


Figure 6 – The 2022 June Bootid radiants in Sun-centered geocentric ecliptic coordinates color coded for different classes of similarity.

Dispersed showers with large sized radiant areas are tricky to distinguish from the sporadic background and risk including sporadics. To eliminate these, we should look at the orbits after removing outliers that deviate too much from the mean orbit to avoid that the results get contaminated by 'noise'. To search for JBO orbits, we selected our sample within the following intervals:

- $87° < \lambda_\odot < 92°$
- $96° < \lambda - \lambda_\odot < 110°$
- $+54° < \beta < +64°$
- 11 km/s $< v_g < 16$ km/s

The radiant size considered corresponds to the concentration of very similar orbits in *Figure 6*. The GMN data[2] in total has 43 orbits within these intervals for 2022. By limiting our search sample within this range in time and radiant size, we deliberately ignore June Bootids that appeared sooner or later as well as all cases with outlier radiant positions that may physically belong to this meteoroid stream, but which cannot be distinguished from the background activity on a statistical relevant basis. It may be worthwhile mentioning that these 43 orbits include three orbits identified as epsilon-Ursae Majorids (EUM#186), a meteoroid stream with orbital parameters that are very similar to the June Bootids and could be somehow related to it.

This sample has been searched with an iterative procedure to locate the best fitting mean orbit for a concentration of similar orbits. The method used for this has been described before (Roggemans et al., 2019a) and combines three classic discrimination criteria, considering different classes for the degree of similarity. The discrimination criteria used in this method are that of Southworth and Hawkins (1963), identified as D_{SH}, Drummond (1981), identified as D_D, and Jopek (1993), identified as D_H. The method to compute the mean orbit during the iteration process has been described by Jopek et al. (2006).

We define five different classes with specific threshold levels of similarity:

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

These classes allow us to distinguish the degree of concentration and dispersion of the particles within the meteoroid stream. The iterative search identifies 42 orbits with low threshold similarity of which as many as 23 fit the very high threshold similarity. The mean orbits for each threshold class of similarity are listed in *Table 2*. These mean orbits were obtained for the sample limited to the core of the radiant shown in *Figure 6*. The values are almost identical regardless the class of similarity.

Table 2 – The mean orbits for the final selection of Global Meteor Network June Bootid orbits with five different threshold levels on the D-criteria.

	Low	Medium low	Medium high	High	Very high
$\lambda_\odot$	89.69°	89.71°	89.69°	90.22°	89.64°
α_g	221.6°	221.7°	221.6°	221.2°	221.5°
δ_g	+48.1°	+48.1°	+48.1°	+48.0°	+47.9°
v_g	13.9	13.9	13.9	13.9	13.9
$\lambda - \lambda_\odot$	102.3°	102.4°	102.4°	102.4°	102.5°
β	+59.1°	+59.2°	+59.0°	+58.9°	+58.8°
H_b	90.9	91.0	91.0	91.0	91.0
H_e	80.7	80.5	80.5	80.8	80.5
a	3.07	3.04	3.05	3.06	3.11
q	1.0140	1.0140	1.0141	1.0142	1.0141
e	0.6695	0.6659	0.6679	0.6688	0.6739
ω	185.3°	185.4°	185.4°	185.4°	185.6°
Ω	89.57°	89.58°	89.58°	89.70°	89.48°
i	18.2°	18.3°	18.3°	18.2°	18.2°
Π	274.9°	275.0°	275.0°	275.1°	275.1°
T_j	2.78	2.80	2.79	2.78	2.76
N	42	41	38	33	23

The number statistics are too small to compute a reliable meteor shower flux but based on the numbers and the calibrated time-area product, we can set an upper limit on the activity to a ZHR of ~0.5. We better look at the relative number of June Bootids as a percentage of the number of sporadic orbits in an interval of 0.2° in solar longitude (*Figure 7*). If we take all 137 possible JBO-orbits for 2022, including all these outliers obtained with the orbit similarity criteria, the result is heavily affected by these dispersed orbits (blue and green in *Figures 6 and 7*). There is a peak

---

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

at $\lambda_{\odot}$ = 90.2°, but this becomes more distinct when we limit our sample to the core of the radiant area where the orbit concentration appears (*Figure 8*). Most June Bootids were recorded at $\lambda_{\odot}$ = 90.2°, or 2022, June 21 at 22^{h} UT. In this interval alone, 9 of the 23 most similar JBO-orbits (yellow in *Figure 8*) were recorded. The number of sporadic orbits per time interval varied from 20 to 189 while some intervals had zero JBO-orbits recorded. Recalling the historic records of 1921 and 1927 when most meteors of the June Bootid outburst were +4 and fainter, it could be that our cameras captured only the brightest events as meteors of magnitude +4 and fainter are definitely below the detection limits of the cameras.

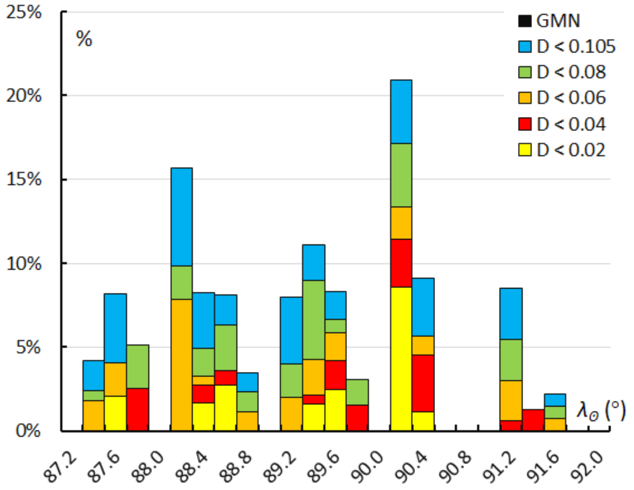


Figure 7 – The percentage of June Bootid orbits relative to the number of sporadic orbits in the a time interval of 0.2° in solar longitude for all possible JBO-orbits in 2022.

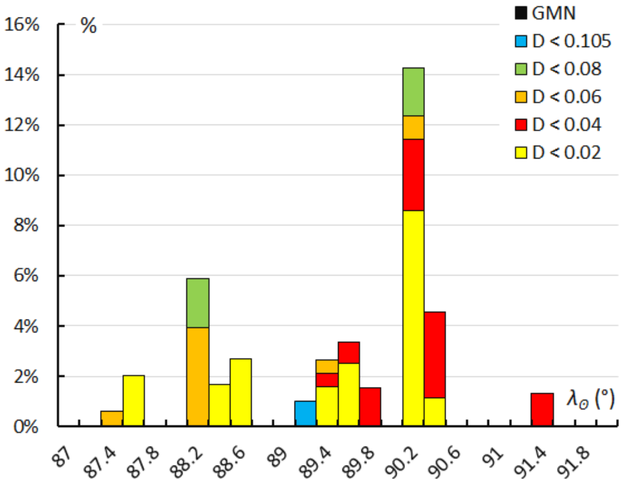


Figure 8 – The percentage of June Bootid orbits relative to the number of sporadic orbits in the a time interval of 0.2° in solar longitude for 2022 JBO-orbits with their ecliptic radiant within 96° < $\lambda - \lambda_{\odot}$ < 110° and +54° < β < +64°.

The compactness of the main concentration in the 2022 June Bootids is obvious in the radiant plot in geocentric equatorial coordinates (*Figure 9*). In Sun-centered ecliptic coordinates the radiants appear less concentrated (*Figure 10*) and the geocentric velocity v_g varies randomly within a rather small interval (*Figure 11*). Both diagrams of inclination i versus longitude of perihelion Π (*Figure 12*) and eccentricity e versus longitude of perihelion Π (*Figure 13*) show a very compact concentration of very similar orbits. *Figure 14* shows a clear variation with higher velocities for higher inclination orbits and *Figure 15* shows higher velocities for higher eccentricity.

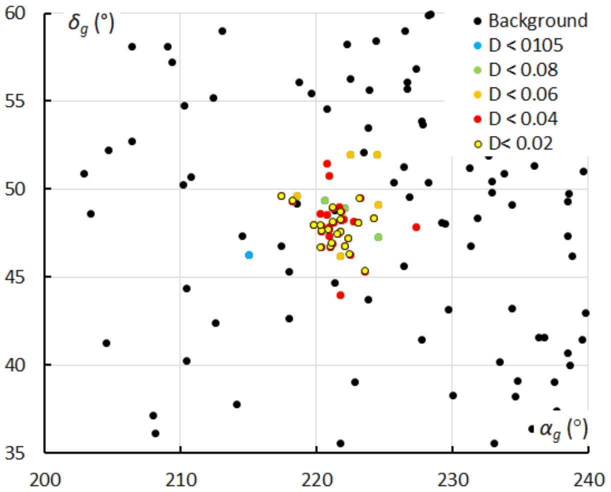


Figure 9 – The core of the 2022 June Bootid radiant in geocentric equatorial coordinates, color coded according to the similarity classes.

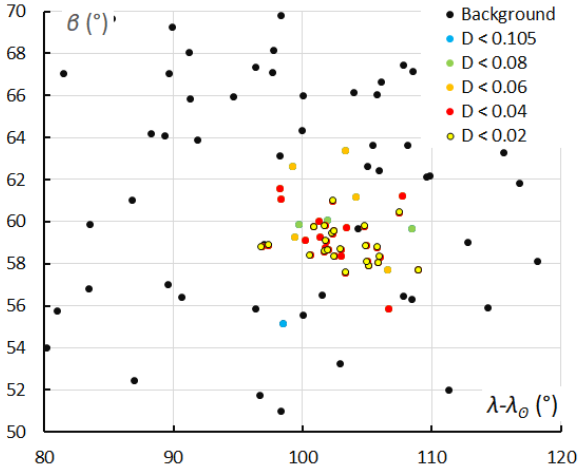


Figure 10 – The core of the 2022 June Bootid radiant in Sun-centered geocentric ecliptical coordinates, color coded according to the similarity classes.

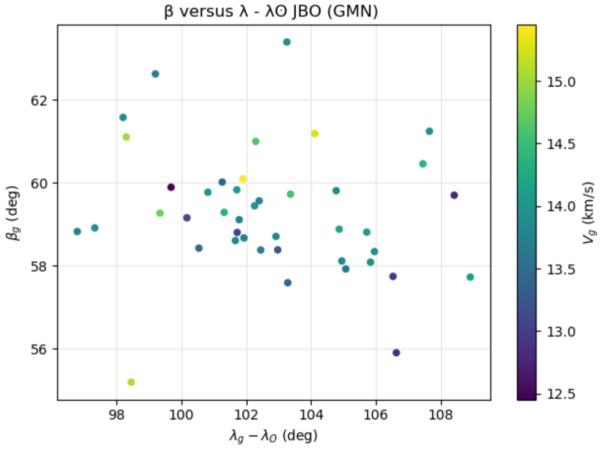


Figure 11 – The core of the 2022 June Bootid radiant in Sun-centered geocentric ecliptical coordinates, color coded according to the geocentric velocity.

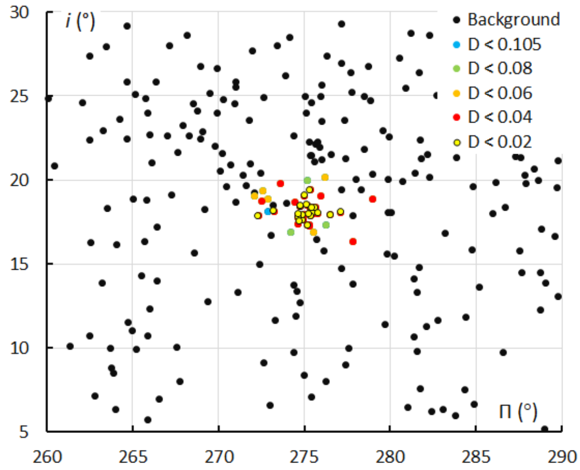


Figure 12 – Diagram of inclinination *i* against the longitude of perihelion *Π* for the core of the 2022 June Bootids, color coded according to the similarity classes.

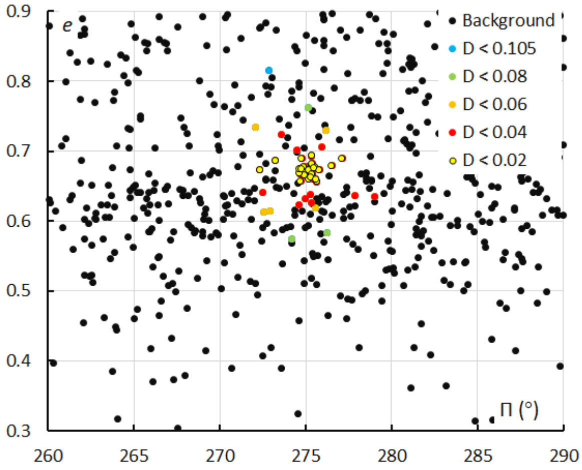


Figure 13 – Diagram of eccentricity *e* against the longitude of perihelion *Π* for the core of the 2022 June Bootids, color coded according to the similarity classes.

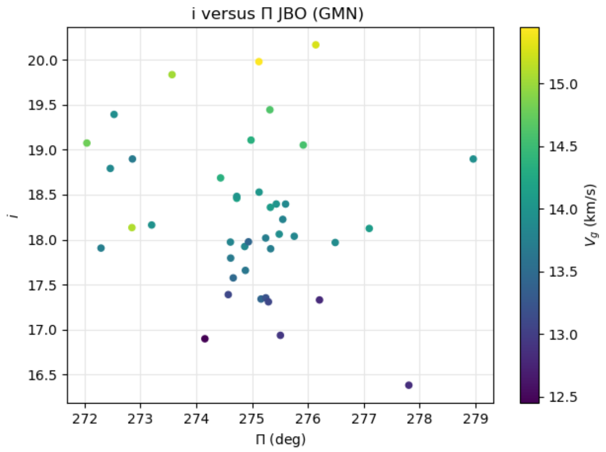


Figure 14 – Diagram of inclinination *i* against the longitude of perihelion *Π* for the core of the 2022 June Bootids, color coded according to the geocentric velocity.

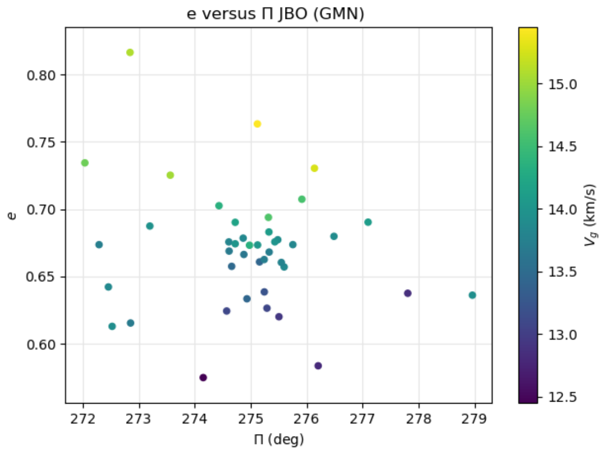


Figure 15 – Diagram of eccentricity *e* against the longitude of perihelion *Π* for the core of the 2022 June Bootids, color coded according to the similarity classes.

3 June Bootids in other years

EDMOND has the oldest collection of orbit data covering 2006–2016 (Kornoš et al., 2014). SonotaCo covers 2007–2021 but its data is limited to the longitudes covered from Japan (SonotaCo, 2009). CAMS made only data for 2010–2016 public (Jenniskens et al., 2011) and Global Meteor Network started collecting orbit data in October 2018.

We use our final mean orbit derived from the concentration of 23 very similar orbits (*Table 2*) as a reference to search the above-mentioned datasets without using any filter on the activity duration, radiant or velocity range. We find relatively many very dispersed look-alike June Bootid orbits for each dataset in each year, spread over more than two months. These can be regarded as noise or sporadics resembling the JBO-orbit. Low inclined, low velocity JFC-type meteor showers such as the June Bootids often appear problematic for identification using discrimination criteria. The results are listed in *Table 3*.

Because of the scatter we are only interested in the high and very high similarity classes with $D_{SH} > 0.10$ and $D_D > 0.04$ or better. Here we see mostly zero or very small numbers of orbits. EDMOND and SonotaCo had 8 orbits in 2010 that were very similar to our mean orbit. All six orbits of EDMOND occurred in the interval $92.20° < \lambda_{\odot} < 92.33°$, the two orbits of SonotaCo occurred at solar longitude 91.88° and 92.83°. In 2016 CAMS had 5 and EDMOND 2 very similar orbits. Four orbits by CAMS were recorded during the interval $89.94° < \lambda_{\odot} < 90.17°$, the last orbit at $\lambda_{\odot} = 97.93°$, the two orbits by EDMOND at solar longitude 88.92° and 89.91°. Small number statistics require caution, but the occurrence in 2010, 2016 and 2022, six years apart correspond to the periodicity of the parent body 7P/Pons-Winnecke. It is possible that some concentration of orbits, similar to the 2022 mean orbit, remained ignored in 2010 and 2016 as the camera coverage at that time was not comparable to 2022.

Table 3 – Number of orbits fulfilling the discrimination criteria with the mean orbit of 2022 as reference for the different similarity classes, for different networks in the period 2007–2022.

Year and Network	Low	Med. low	Med. high	High	Very high
2007 SonotaCo	8	2	0	0	0
2007 EDMOND	0	0	0	0	0
2008 SonotaCo	16	7	3	0	0
2008 EDMOND	2	0	0	0	0
2009 SonotaCo	22	8	4	2	0
2009 EDMOND	4	4	1	0	0
2010 SonotaCo	32	19	8	5	**2**
2010 EDMOND	43	28	21	14	**6**
2011 SonotaCo	13	3	1	0	0
2011 EDMOND	50	18	5	2	0
2011 CAMS	129	61	29	9	0
2012 SonotaCo	12	5	3	0	0
2012 EDMOND	49	18	4	0	0
2012 CAMS	129	61	29	9	0
2013 SonotaCo	18	7	1	0	0
2013 EDMOND	59	20	7	2	0
2013 CAMS	209	93	30	7	1
2014 SonotaCo	21	13	1	0	0
2014 EDMOND	80	30	6	2	0
2014 CAMS	339	151	58	14	0
2015 SonotaCo	19	12	2	0	0
2015 EDMOND	82	40	13	3	0
2015 CAMS	298	154	55	8	1
2016 SonotaCo	26	14	5	1	0
2016 EDMOND	101	49	20	7	**2**
2016 CAMS	250	146	62	25	**5**
2017 SonotaCo	35	14	5	0	0
2018 SonotaCo	26	8	2	0	0
2019 SonotaCo	33	11	3	2	0
2019 GMN	123	58	18	3	0
2020 SonotaCo	32	15	5	0	0
2020 GMN	516	251	84	31	3
2021 SonotaCo	28	12	4	1	0
2021 GMN	507	241	101	27	0
2022 GMN	2079	1461	205	61	**24**

The number of low, medium low and medium high threshold similarity orbits has been mentioned pro-memory in *Table 3*, as most of these are just look-alike June Bootids by pure chance. Caution is required when applying discrimination criteria, especially with this kind of JFC-type meteoroid streams.

4 Conclusions

The Global Meteor Network recorded a distinct concentration of June Bootid orbits with most of the orbits collected at $\lambda_{\odot} = 90.2°$, or 2022, June 21 at 22^h UT. The radiant plot shows a compact core of very similar orbits embedded within a very large radiant area with very dispersed radiants with a low threshold of similarity. It is statistically impossible to distinguish the dispersed look-alike JBO-orbits from the background noise as many may be as much sporadic fitting the similarity criteria by pure chance as these could be physically related to the meteoroid stream but too dispersed to be statistically identified.

Comparing with other networks in previous years suggests that a concentration of very similar orbits like in 2022 may have occurred in 2016 and 2010. The final mean orbits for 2010, 2016 and 2022 are compared in *Table 4*.

Table 4 – The mean orbits for the orbits that fulfilled $D_D < 0.02$ in 2010 (2 orbits by SonotaCo, 6 orbits by EDMOND) and 2016 (5 orbits by CAMS, 2 orbits by EDMOND), compared with the mean orbit obtained by Global Meteor Network for the June Bootids in 2022.

	2010	2016	2022
$\lambda_{\odot}$ (°)	92.2	90.1	89.64°
α_g (°)	223.4	220.1	221.5°
δ_g (°)	+47.3	+48.6	+47.9°
v_g (km/s)	14.0	13.8	13.9
$\lambda - \lambda_{\odot}$ (°)	102.5	100.4	102.5°
β (°)	+59.3	+59.1	+58.8°
H_b (km)	87.9	91.4	91.0
H_e (km)	80.3	82.9	80.5
a (AU)	3.11	3.05	3.11
q (AU)	1.0143	1.0149	1.0141
e	0.6739	0.6673	0.6739
ω (°)	185.6	183.8	185.6°
Ω (°)	92.27	91.02	89.48°
i (°)	18.5	17.9	18.2°
Π (°)	277.8	274.9	275.1°
T_j	2.76	2.79	2.76
N	8	7	23

Acknowledgment

The authors thank all the camera operators and people involved in the Global Meteor Network. Orbits for this shower analysis were obtained by GMN RMS cameras. The Global Meteor Network (GMN) data are released under the following license[3].

The Global Meteor Network results were obtained thanks to the efforts of the following volunteers: *Richard Abraham, Victor Acciari, Rob Agar, Yohsuke Akamatsu, David Akerman, Daknam Al-Ahmadi, Jamie Allen, Alexandre Alves, Don Anderson, Željko Andreić, Martyn Andrews, Enrique Arce, Georges Attard, Chris Baddiley, David Bailey, Roger Banks, Hamish Barker, Jean-Philippe Barrilliot, Ricky Bassom, Richard Bassom, Alan Beech,*

---

[3] https://creativecommons.org/licenses/by/4.0/

Dennis Behan, Ehud Behar, Josip Belas, Alex Bell, Florent Benoit, Serge Bergeron, Denis Bergeron, Jorge Bermúdez Augusto Acosta, Steve Berry, Adrian Bigland, Chris Blake, Arie Blumenzweig, Ventsislav Bodakov, Robin Boivin, Claude Boivin, Bruno Bonicontro, Fabricio Borges, Ubiratan Borges, Dorian Božičević, David Brash, Stuart Brett, Ed Breuer, Martin Breukers, John W. Briggs, Gareth Brown, Peter G. Brown, Laurent Brunetto, Tim Burgess, Jon Bursey, Yong-Ik Byun, Ludger Börgerding, Sylvain Cadieux, Peter Campbell-Burns, Andrew Campbell-Laing, Pablo Canedo, Seppe Canonaco, Jose Carballada, Steve Carter, David Castledine, Gilton Cavallini, Brian Chapman, Jason Charles, Matt Cheselka, Enrique Chávez Garcilazo, Tim Claydon, Trevor Clifton, Manel Colldecarrera, Michael Cook, Bill Cooke, Christopher Coomber, Brendan Cooney, Jamie Cooper, Andrew Cooper, Edward Cooper, Paul Cox, Llewellyn Cupido, Christopher Curtis, Chris Dakin, Fernando Dall'Igna, James Davenport, Richard Davis, Steve Dearden, Christophe Demeautis, Bart Dessoy, Pat Devine, Miguel Diaz Angel, Paul Dickinson, Ivo Dijan, Pieter Dijkema, Tammo Dijkema Jan, Luciano Diniz Miguel, Marcelo Domingues, Stacey Downton, Stewart Doyle, Zoran Dragić, Iain Drea, Igor Duchaj, Jean-Paul Dumoulin, Garry Dymond, Jürgen Dörr, Robin Earl, Howard Edin, Ollie Eisman, Carl Elkins, Ian Enting Graham, Peter Eschman, Nigel Evans, Bob Evans, Bev M. Ewen-Smith, Seraphin Feller, Eduardo Fernandez Del Peloso, Andres Fernandez, Andrew Fiamingo, Barry Findley, Rick Fischer, Richard Fleet, Jim Fordice, Kyle Francis, Jean Francois Larouche, Patrick Franks, Stefan Frei, Gustav Frisholm, Jose Galindo Lopez, Pierre Gamache, Mark Gatehouse, Ivan Gašparić, Chris George, Megan Gialluca, Kevin Gibbs-Wragge, Marc Gilart Corretgé, Jason Gill, Philip Gladstone, Uwe Glässner, Chuck Goldsmith, Hugo González, Nikola Gotovac, Neil Graham, Pete Graham, Colin Graham, Sam Green, Bob Greschke, Daniel J. Grinkevich, Larry Groom, Dominique Guiot, Tioga Gulon, Margareta Gumilar, Peter Gural, Nikolay Gusev, Kees Habraken, Alex Haislip, John Hale, Peter Hallett, Graeme Hanigan, Erwin Harkink, Ed Harman, Marián Harnádek, Ryan Harper, David Hatton, Tim Havens, Mark Haworth, Paul Haworth, Richard Hayler, Andrew Heath, Sam Hemmelgarn, Rick Hewett, Nicholas Hill, Lee Hill, Don Hladiuk, Alex Hodge, Simon Holbeche, Jeff Holmes, Steve Homer, Matthew Howarth, Nick Howarth, Jeff Huddle, Bob Hufnagel, Roslina Hussain, Jan Hykel, Russell Jackson, Jean-Marie Jacquart, Jost Jahn, Nick James, Phil James, Ron James Jr, Rick James, Ilya Jankowsky, Alex Jeffery, Klaas Jobse, Richard Johnston, Dave Jones, Fernando Jordan, Romulo Jose, Edison José Felipe Pérezgómez Álvarez, Vladimir Jovanović, Alfredo Júnior Dal'Ava, Javor Kac, Richard Kacerek, Milan Kalina, Jonathon Kambulow, Steve Kaufman, Paul Kavanagh, Ioannis Kedros, Jürgen Ketterer, Alex Kichev, Harri Kiiskinen, Jean-Baptiste Kikwaya, Sebastian Klier, Dan Klinglesmith, John Kmetz, Zoran Knez, Korado Korlević, Stanislav Korotkiy, Danko Kočiš, Bela Kralj Szomi, Josip Krpan, Zbigniew Krzeminski, Patrik Kukić, Reinhard Kühn, Remi Lacasse, Gaétan Laflamme, Steve Lamb, Hervé Lamy, Jean Larouche Francois, Ian Lauwerys, Peter Lee, Hartmut Leiting, David Leurquin, Gareth Lloyd, Robert Longbottom, Eric Lopez, Paul Ludick, Muhammad Luqmanul Hakim Muharam, Pete Lynch, Frank Lyter, Guy Létourneau, Angélica López Olmos, Anton Macan, Jonathan Mackey, John Maclean, Igor Macuka, Nawaz Mahomed, Simon Maidment, Mirjana Malarić, Nedeljko Mandić, Alain Marin, Bob Marshall, Colin Marshall, Gavin Martin, José Martin Luis, Andrei Marukhno, José María García, Keith Maslin, Nicola Masseroni, Bob Massey, Jacques Masson, Damir Matković, Filip Matković, Dougal Matthews, Phillip Maximilian Grammerstorf Wilhelm, Michael Mazur, Sergio Mazzi, Stuart McAndrew, Lorna McCalman, Alex McConahay, Charlie McCormack, Mason McCormack, Robert McCoy, Vincent McDermott, Tommy McEwan, Mark McIntyre, Peter McKellar, Peter Meadows, Edgar Mendes Merizio, Aleksandar Merlak, Filip Mezak, Pierre-Michael Micaletti, Greg Michael, Matej Mihelčić, Simon Minnican, Wullie Mitchell, Georgi Momchilov, Dean Moore, Nelson Moreira, Kevin Morgan, Roger Morin, Nick Moskovitz, Daniela Mourão Cardozo, Dave Mowbray, Andrew Moyle, Gene Mroz, Brian Murphy, Carl Mustoe, Juan Muñoz Luis, Przemek Nagański, Jean-Louis Naudin, Damjan Nemarnik, Attila Nemes, Dave Newbury, Colin Nichols, Nick Norman, Philip Norton, Zoran Novak, Gareth Oakey, Perth Observatory Volunteer Group, Washington Oliveira, Jorge Oliveira, Jamie Olver, Christine Ord, Nigel Owen, Michael O'Connell, Dylan O'Donnell, Thiago Paes, Carl Panter, Neil Papworth, Filip Parag, Ian Parker, Gary Parker, Simon Parsons, Ian Pass, Igor Pavletić, Lovro Pavletić, Richard Payne, Pierre-Yves Pechart, Holger Pedersen, William Perkin, Enrico Pettarin, Alan Pevec, Mark Phillips, Anthony Pitt, Patrick Poitevin, Tim Polfliet, Renato Poltronieri, Derek Poulton, Janusz Powazki, Aled Powell, Alex Pratt, Miguel Preciado, Nick Primavesi, Paul Prouse, Paul Pugh, Chuck Pullen, Terry Pundiak, Lev Pustil'Nik, Dan Pye, Nick Quinn, Chris Ramsay, David Rankin, Steve Rau, Dustin Rego, Chris Reichelt, Danijel Reponj, Fernando Requena, Maciej Reszelsk, Ewan Richardson, Martin Richmond-Hardy, Mark Robbins, Martin Robinson, David Robinson, Heriton Rocha, Herve Roche, Paul Roggemans, Adriana Roggemans, Alex Roig, David Rollinson, Andre Rousseau, Jim Rowe, Nicholas Ruffier, Nick Russel, Dmitrii Rychkov, Robert Saint-Jean, Michel Saint-Laurent, Clive Sanders, Jason Sanders, Ivan Sardelić, Rob Saunders, John Savage, Lawrence Saville, Vasilii Savtchenko, Philippe Schaack, William Schauff, Ansgar Schmidt, Yfore Scott, James Scott, Geoff Scott, Jim Seargeant, Jay Shaffer, Steven Shanks, Mike Shaw, Jamie Shepherd, Angel Sierra, Ivo Silvestri, François Simard, Noah Simmonds, Ivica Skokić, Dave Smith, Ian A. Smith, Tracey Snelus, Germano Soru, Warley Souza, Mark Spink, Denis St-Gelais, James Stanley, Radim Stano, Laurie Stanton, Robert D. Steele, Yuri Stepanychev, Graham Stevens, Richard Stevenson, Thomas Stevenson, Peter Stewart, William Stewart, Paul Stewart, Con Stoitsis, Andrea Storani, Andy Stott, David Strawford, Claude Surprenant, Rajko Sušanj, Jeremy Taylor, Yakov Tchenak, John Thurmond, Stanislav Tkachenko, Eric Toops, Torcuill Torrance, Steve Trone, Wenceslao Trujillo, John Tuckett, *Sofia Ulrich, Jonathan Valdez Aguilar Alexis, Edson Valencia Morales, Myron Valenta, Jean Vallieres, Paraksh Vankawala, Neville Vann, Marco Verstraaten, Arie Verveer, Jochen Vollsted, Predrag Vukovic, Aden Walker, Martin Walker, Bill Wallace, John Waller, Jacques Walliang, Didier Walliang, Christian Wanlin, Tom Warner, Neil Waters, Steve Welch, Tobias Westphal, Tosh White, Alexander Wiedekind-Klein, John Wildridge, Ian Williams, Mark Williams, Guy Williamson, Graham Winstanley, Urs Wirthmueller, Bill Witte, Jeff Wood, Martin Woodward, Jonathan Wyatt, Anton Yanishevskiy, Penko Yordanov, Stephane Zanoni, Pető Zsolt, Dario Zubović, Marcelo Zurita, Rob de Corday Long, Pierre de Ponthière, Jocimar Justino de Souza, Erwin van Ballegoij, Raoul van Eijndhoven, Ivica Ćiković, Dino Čaljkušić, Damir Šegon, Marko Šegon* (list established 19 December 2022).

References

Denning W. F. (1916). “Remarkable Meteoric Shower on June 28”. *Monthly Notices of the Royal Astronomical Society*, **76**, 740–743.

Drummond J. D. (1981). “A test of comet and meteor shower associations”. *Icarus*, **45**, 545–553.

Jenniskens P. (2006). Meteor Showers and their Parent Comets. ISBN 0521853494. Cambridge, UK: Cambridge University Press. Pages 528–530.

Jenniskens P., Gural P. S., Grigsby B., Dynneson L., Koop M. and Holman D. (2011). “CAMS: Cameras for Allsky Meteor Surveillance to validate minor meteor showers”. *Icarus*, **216**, 40–61.

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

Jopek T. J. (1993). “Remarks on the meteor orbital similarity D-criterion”. *Icarus*, **106**, 603–607.

Jopek T. J., Rudawska R. and Pretka-Ziomek H. (2006). “Calculation of the mean orbit of a meteoroid stream”. *Monthly Notices of the Royal Astronomical Society*, **371**, 1367–1372.

King A. (1927). “Meteor notes. – The Pons-winneckids 1927”. *The Observatory*, **50**, 361–363.

Kornoš L., Matlovič P., Rudawska R., Tóth J., Hajduková M. Jr., Koukal J. and Piffl R. (2014). “Confirmation and characterization of IAU temporary meteor showers in EDMOND database”. In Jopek T. J., Rietmeijer F. J. M., Watanabe J., Williams I. P., editors, Proceedings of the Meteoroids 2013 Conference, Poznań, Poland, Aug. 26-30, 2013. A.M. University, pages 225–233.

Moorhead A., Clements T.D. and Vida D. (2020). “Realistic gravitational focusing of meteoroid streams”. *Monthly Notices of the Royal Astronomical Society*, **494**, 2982–2994.

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

SonotaCo (2009). “A meteor shower catalog based on video observations in 2007–2008”. *WGN, Journal of the IMO*, **37**, 55–62.

Southworth R. B. and Hawkins G. S. (1963). “Statistics of meteor streams”. *Smithsonian Contributions to Astrophysics*, **7**, 261–285.

Spurny P., Borovicka J. (1998). “June Bootid meteors 1998”. Central Bureau for Astronomical Telegrams, Circular No. 6973.

Velkov V. (1999). “The 1998 June Bootid Outburst Observed in Bulgaria”. In, Arlt R., Knöfel A., editors, *Proceedings of the International Meteor Conference*, Stará Lesná 20-23 August 1998. International Meteor Organization, Pages 84–96.

Vida D., Gural P., Brown P., Campbell-Brown M., Wiegert P. (2019). “Estimating trajectories of meteors: an observational Monte Carlo approach - I. Theory”. *Monthly Notices of the Royal Astronomical Society*, **491**, 2688–2705.

Vida D., Gural P., Brown P., Campbell-Brown M., Wiegert P. (2020). “Estimating trajectories of meteors: an observational Monte Carlo approach - II. Results”. *Monthly Notices of the Royal Astronomical Society*, **491**, 3996–4011.

Vida D., Šegon D., Gural P. S., Brown P. G., McIntyre 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.

Yamamoto I. (1922). “Observations in Japan of meteors probably connected with Pons Winnecke’s Comet”. *The Observatory*, **45**, 81–83.

2023 activity omega-Carinids (OCR#1033)

Damir Šegon[1], Denis Vida[2], Paul Roggemans[3], Jeff Wood[4], Mia Boothroyd[5], Ryan Fraser[6],
Graeme Hanigan[7], Derek Poulton[7], Geoff Scott[8], James Scott[5] and Christoph Zink[9]

[1] **Astronomical Society Istra Pula, Park Monte Zaro 2, 52100 Pula, Croatia**

[2] **Department of Earth Sciences, University of Western Ontario, London, Ontario, N6A 5B7, Canada**
denis.vida@gmail.com

[3] **Pijnboomstraat 25, 2800 Mechelen, Belgium**
paul.roggemans@gmail.com

[4] **Pioneer Drive, Bindoon WA, Australia**
rvball1@hotmail.com

[5] **University of Otago, Department of Geology, New Zealand**
boomi751@student.otago.ac.nz, james.scott@otago.ac.nz

[6] **Ardgowan School, New Zealand**
principal@ardgowan.school.nz

[7] **Astronomical Society of Victoria, Australia**
writeit@fastmail.com.au

[8] **Perth Observatory Volunteer Group, Australia**
scottastrophe@outlook.com

[9] **Fiordland College, New Zealand**
c.zink@fiordland.school.nz

Global Meteor Network cameras in Australia and New Zealand confirm the unusual activity of the omega-Carinids in 2023, centered at $\lambda_{\odot} = 290.79 \pm 0.13°$ which is 11 hours later than the activity reported by CAMS (Jenniskens, 2023). The geocentric radiant was determined as $\alpha_g = 153.8 \pm 1.6°$ and $\delta_g = -73.5 \pm 0.6°$, with a geocentric velocity $v_g = 40.9 \pm 0.5$ km/s. With a Tisserand relative to Jupiter of ~0.7 the omega-Carinid meteoroid stream has a long-period comet type orbit with unknown parent body.

1 Introduction

Peter Jenniskens (2023) announced the detection of unusual activity displayed by the omega-Carinids (OCR#1033) during a short time interval 2023, January 10, 2^h to 8^h UTC by the CAMS Chile network. Eleven meteors were triangulated during the interval $289.22° < \lambda_{\odot} < 289.48°$, centered on $\lambda_{\odot} = 289.35 \pm 0.03°$ (equinox J2000.0).

The omega-Carinid meteoroid stream has a long-period comet type orbit with unknown parent body. The median values for the 2023 orbit according to CAMS are:

- $q = 0.958 \pm 0.001$ AU
- $e = 0.986 \pm 0.062$
- $i = 66.9 \pm 0.7°$
- $\omega = 341.3 \pm 0.7°$
- $\Omega = 109.35 \pm 0.03°$

2 Global Meteor Network results

The GMN cameras also picked up the sudden activity of the omega-Carinids in Australia (*Figure 2*) and New Zealand, with a remarkable concentration of 5 very similar orbits in the time interval $290.63° < \lambda_{\odot} < 290.96°$ or 2023, January 11, between 11^h and 19^h UTC, centered on $\lambda_{\odot} = 290.79 \pm 0.13°$ (equinox J2000.0), almost half a day

Figure 1 – Omega-Carinid recorded at 2023 January 11, $16^h47^m29^s$ UTC on AU000H with a 16mm lens (top) and on AU0007 with a 4mm lens (bottom). (Credit Perth Observatory).

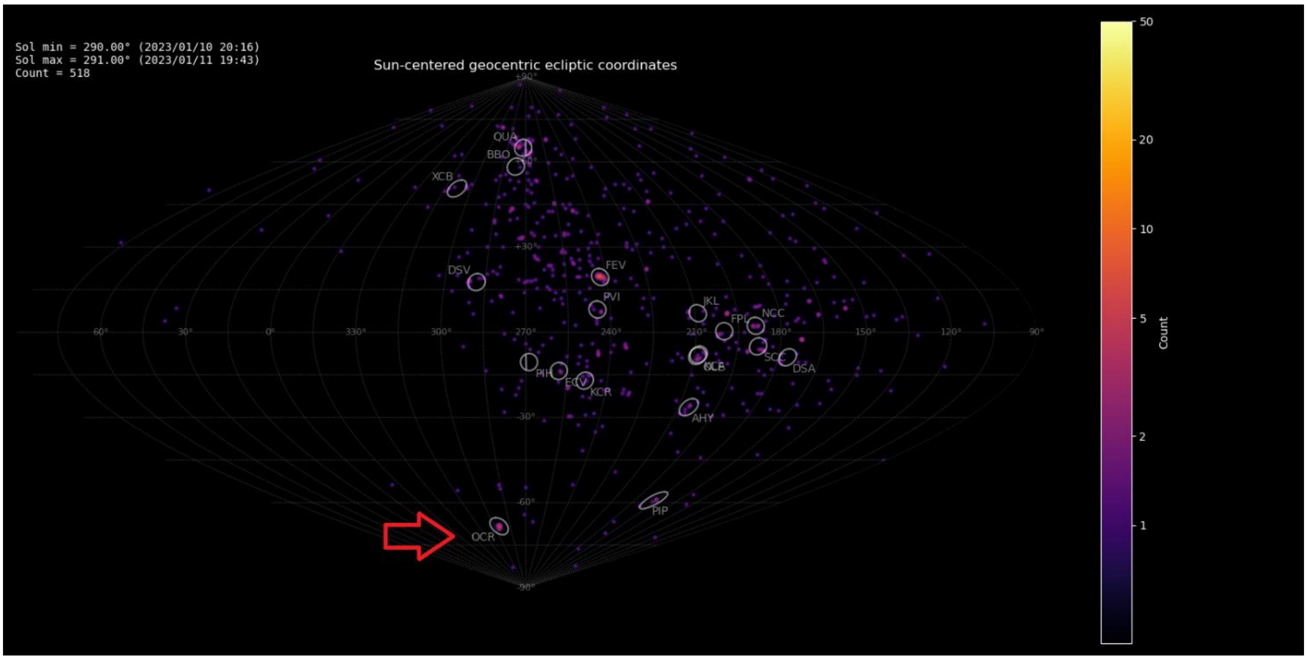


Figure 2 – Radiant plot of the Global Meteor Network for 2023 January 10–11 in Sun-centered geocentric ecliptic coordinates.

later than the activity given for the CAMS network. The explanation for this difference is probably due to the fact that GMN has better coverage in Australia and New Zealand than in South-America. The preliminary shower identification of GMN identified 8 meteors as OCR#1033. Applying D-criteria confirms all of these to belong to this shower with the earliest detected at $\lambda_{\odot} = 287.35°$ and the last one detected at $\lambda_{\odot} = 291.96°$. However, to compute the most relevant mean orbit, the selection was limited to the concentration of 5 very similar orbits mentioned above.

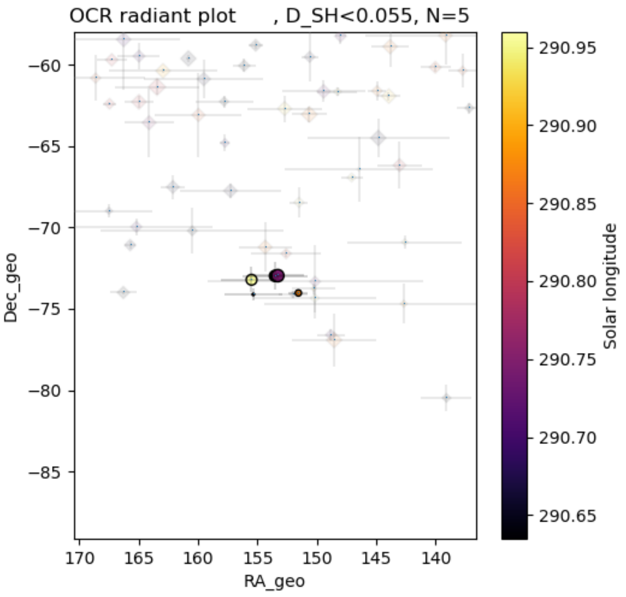


Figure 3 – The omega-Carinid radiant plot.

The following mean radiant (*Figure 3*) and orbit data has been calculated and is in excellent agreement with the CAMS result. The orbit has been reported and listed in the Working List of Meteor Showers of the IAU Meteor Data Center[4]:

- $\lambda_{\odot} = 290.79 \pm 0.13°$
- $\alpha_g = 153.8 \pm 1.6°$
- $\delta_g = -73.5 \pm 0.6°$
- $\lambda_g - \lambda_{\odot} = 295.4 \pm 1.5°$
- $\beta_g = -68.3 \pm 0.5°$
- $v_g = 40.9 \pm 0.5$ km/s
- $a = 46.9 \pm 45.5$ AU
- $q = 0.959 \pm 0.003$ AU
- $e = 0.959 \pm 0.030$
- $i = 66.4 \pm 0.7°$
- $\omega = 341.7 \pm 1.1°$
- $\Omega = 110.8 \pm 0.1°$
- $T_j = 0.71 \pm 0.16$

3 Search for previous occurrences

No omega-Carinids could be located in the previous years of GMN data (2019–2022). This is most likely because Southern hemisphere coverage by the Global Meteor Network was very limited until major extensions were deployed during 2022. No trace of this shower in EDMOND data (2006–2016) either for the obvious reason there was no coverage at the Southern hemisphere, same for the SonotaCo orbit dataset as the radiant is too far south for Japanese observers.

The only orbit dataset with earlier recorded OCR-orbits is the CAMS dataset with 5 possible orbits, 4 of which were recorded 2016 January 9, between 12^h31^m and 13^h59^m UTC by CAMS New Zealand. The mean values obtained for the 5 orbits from 2016 agree very well with the 2023 results,

---

[4] https://www.ta3.sk/IAUC22DB/MDC2022/Roje/pojedynczy_obiekt.php?lporz=01411&kodstrumienia=01033

but note the larger uncertainties for the 2016 data (equinox J2000.0):

- $\lambda_{\odot}$ = 288.50 ± 0.38°
- α_g = 159.3 ± 5.4°
- δ_g = –73.0 ± 1.3°
- $\lambda_g - \lambda_{\odot}$ = 297.7 ± 2.6°
- β_g = –68.7 ± 1.8°
- v_g = 41.4 ± 1.4 km/s
- a = 41.1 AU
- q = 0.951 ± 0.007 AU
- e = 0.977 ± 0.069
- i = 67.8 ± 2.2°
- ω = 339.5 ± 2.5°
- Ω = 108.4 ± 0.4°
- T_j = 0.58 ± 0.15

A detailed search through 19th and 20th century Southern hemisphere meteor data revealed no trace of any previously observed omega-Carinids in visual and other meteor observing reports.

4 Conclusion

Evidence was found for some unusual activity in 2023 of the poorly known long-period comet type meteoroid stream registered in the Working List of Meteor Showers of the IAU Meteor Data Center as omega-Carinids (OCR#1033). The short activity duration and the fact that the coverage of the Southern hemisphere could easily have missed any activity of this very southern radiant in past years may explain why the shower has been only detected in 2016 and 2023.

Acknowledgment

The authors thank all the camera operators and people involved in the Global Meteor Network. The Global Meteor Network (GMN) data are released under the following license[5].

Reference

Jenniskens P. (2023). “Omega Carinid meteor shower 2023”. CBAT 5207, Daniel W. E. Green, editor.

---

[5] https://creativecommons.org/licenses/by/4.0/

Global Meteor Network report 2022

Paul Roggemans[1], **Peter Cambell-Burns**[2], **Mark McIntyre**[3],
Damir Šegon[4] and **Denis Vida**[5]

[1] **Pijnboomstraat 25, 2800 Mechelen, Belgium**
`paul.roggemans@gmail.com`

[2] **UK Meteor Observaton Network, Cavendish Gardens, Fleet, Hampshire, United Kingdom**
`peter@campbell-burns.com`

[3] **UK Meteor Observaton Network and Tackley Observatory, United Kingdom**
`mark.jm.mcintyre@cesmail.net`

[4] **Astronomical Society Istra Pula, Park Monte Zaro 2, 52100 Pula, Croatia**

[5] **Department of Earth Sciences, University of Western Ontario, London, Ontario, N6A 5B7, Canada**
`denis.vida@gmail.com`

A status report is presented for the Global Meteor Network. Since the start of the network, 722311 orbits have been collected until end of 2022, 423 different meteor showers have been identified among these orbits. During 2022 more than 300 new GMN cameras were installed. 334668 orbits were collected in 2022. The development of the Global Meteor Network in different regions is described. The coverage of the camera fields of view is shown on maps.

1 Introduction

In the past 15 years many regional and some international video camera networks were created to obtain multi-station registrations in order to obtain meteor trajectories and orbits. Some of these networks are specialized in fireballs, others are dedicated to a fainter magnitude range comparable to what visual observers used to cover. The orbit data obtained by these networks brought a tremendous progress in our knowledge of meteoroid streams.

The Global Meteor Network is the most recent development in this domain but its success builds on many years of expertise as one of the pioneers in the field of video meteor observations was the Croatian Meteor Network which is at the origin of GMN (Gural and Šegon, 2009). Based on the significantly improved Raspberry Pi solution introduced by Zubović et al. (2015) and Vida et al. (2016), at the end of 2018 the Global Meteor Network emerged starting with 6 cameras located in New Mexico, using IP cameras controlled by a Raspberry with its own dedicated software and reduction pipeline (Vida et al., 2021). GMN became the fastest growing meteor video network with 73 operational cameras at the end of 2019, 155 at the end of 2020 and 341 by the end of 2021. The former EDMOND network was discontinued and GMN became a logic successor with most European amateur networks now building and installing RMS cameras. In this report we highlight the progress made during 2022 compared to previous years.

2 GMN camera coverage

The aim of the GMN is to cover all latitudes and longitudes to assure a global coverage of meteor activity in order to let no unexpected meteor event pass unnoticed. This is an ambitious goal especially for a project that depends for most efforts entirely on volunteers' work. In this report we describe the progress that was made by GMN during 2022 in different regions of the world. The status of the camera coverage is illustrated with maps showing the fields of view intersected at an elevation of 100 km in the atmosphere, projected and clamped to the ground. This way the actual overlap between the camera fields is shown without any effects of 3D perspectives. Where possible the camera ID has been mentioned on the plots. The status at the end of 2022 can be compared to the 2021 annual report (Roggemans et al., 2022).

Many RMS cameras with 4 mm optics have the horizon at the bottom of their field of view what results in a huge camera field at 100 km elevation. Rather few meteors will be bright enough to get registered near the horizon. The large distance between the camera station and the meteor also reduces the chances to obtain a useable triangulation. The number of paired meteors at the outskirts of these large camera fields is very small. However, cameras pointing so low towards the horizon turn out to be very useful regarding obtaining coverage at lower heights where meteorite dropping fireballs end their visible path. When looking for camera overlap, it is strongly recommended to look for an optimized overlap between cameras. An interesting study on this topic for the New Mexico Meteor Array has been published by Mroz (2021). Camera operators are encouraged to optimize their camera overlap.

The number of multi-station events mentioned per country corresponds to the number of orbits, unless an orbit was based on camera data from different countries, then it was counted once for each country. This can also be visualized on the MeteorMap[6] (Dijkema, 2022). The current camera coverage is presented per country or per region for reason of readability. To consider the real overlap for most European countries it is necessary to look at the camera coverage of neighboring countries.

2.1 Australia

The first 31 meteor orbits by Australian RMS cameras were registered in September 2021 when the first 5 cameras got ready to harvest meteors. By the end of 2021, 12 cameras managed to obtain 1871 orbits in the final 4 months of 2021. A real breakthrough was achieved in 2022 as the number of RMS cameras in Australia increased to 29, good for 12460 orbits in 2022. Most cameras were installed in West Australia. Three cameras overlap in Victoria and some lonely cameras in Queensland and New South Wales wait for multi-station partners. Australia being a very large country, there is a great potential for GMN to expand further.

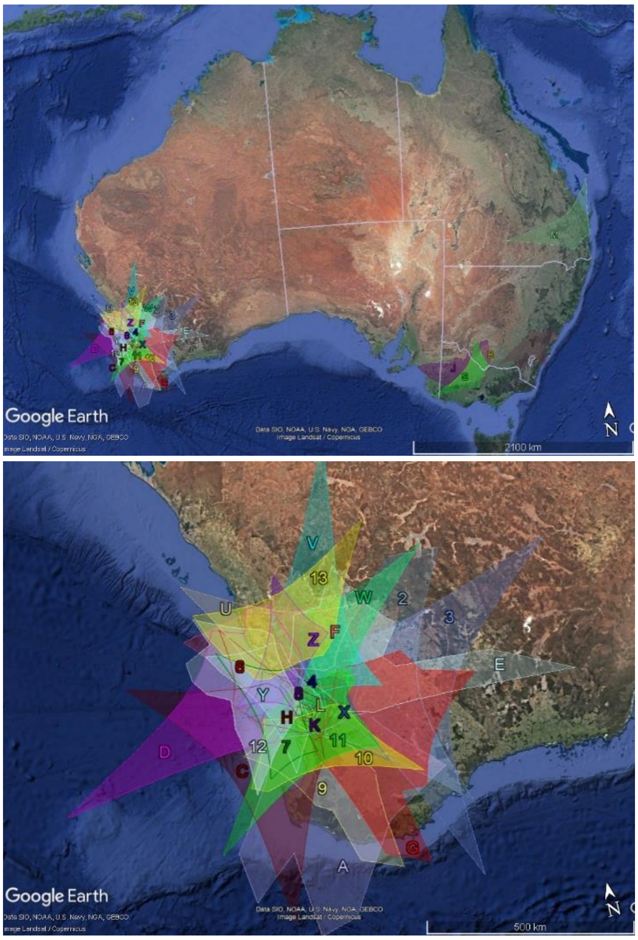


Figure 1 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Australia, global view on top and a close up for West Australia at bottom. The letter code refers to the camera ID, e.g., D = AU000D.

2.2 Belgium

Belgium had its first RMS cameras operational in early 2019. *Figure 2* shows the GMN coverage at the end of 2022 for Belgium. The map can be compared with the situation end of 2021 in the previous GMN annual report (Roggemans, 2022). The number of RMS cameras has doubled from 10 to 20, good for 23174 orbits in 2022 against 8582 orbits previous year.

Most of the Belgian RMS cameras are being installed for the reinforcement of the CAMS-BeNeLux network. For this purpose, the 6 mm lenses are preferred which have less distortion than the 3.6 mm. All cameras are pointed in function of an optimal geographic overlap. 2022 brought exceptional many clear nights and 2022 ended as the best year ever in 11 years for CAMS-BeNeLux, much thanks to the extra coverage created by the RMS cameras.

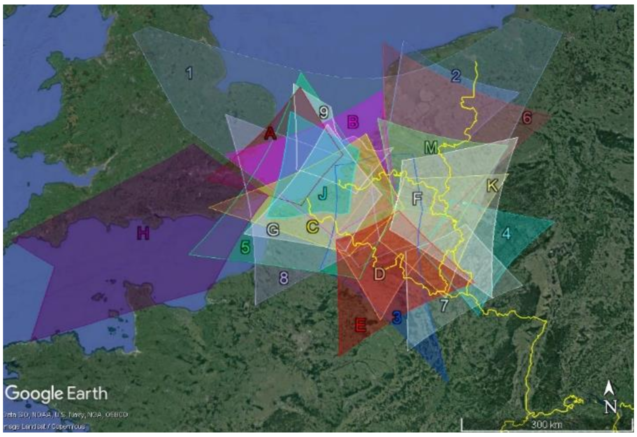


Figure 2 – GMN camera fields intersected at 100 km elevation, for 20 cameras installed in Belgium, status 2022. The letter code refers to the camera ID, e.g., M = BE000M.

2.3 Brazil

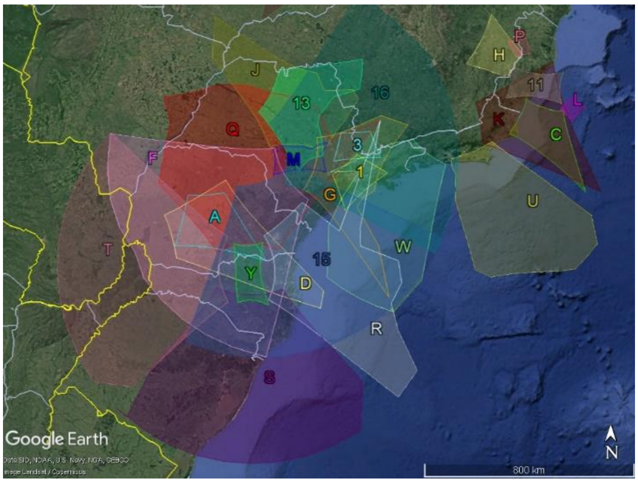


Figure 3 – GMN camera fields in 2022 intersected at 100 km elevation, for 20 cameras active in Brazil. The letter code refers to the camera ID, e.g., S = BR000S.

The BRAMON network had its first two RMS cameras getting paired meteors in October 2020 good for 40 orbits with two cameras in the last quarter of 2020. The network expanded to 13 operational cameras, good for 1645 orbits in 2021. In 2022 the number of cameras increased to 20 and 2760 orbits were obtained. The number of paired meteors will increase once the overlap of the camera FoVs will be optimized. Several cameras do not yet have overlap from

---

[6] https://tammojan.github.io/meteormap/

multi-station partners (*Figure 3*). One camera installed in the north (BR0010) is outside of the map.

2.4 Bulgaria

Bulgaria got its first RMS camera operational in June 2021 and got three cameras installed by the end of 2021 of which two had 419 multi-station events. In April 2022 a 4th RMS and in July 2022, two extra cameras were pointed. With 6 cameras in 2022, 3877 orbits could be collected. One camera, BG0006, was only active in July 2022 and is not included on the map (*Figure 4*).

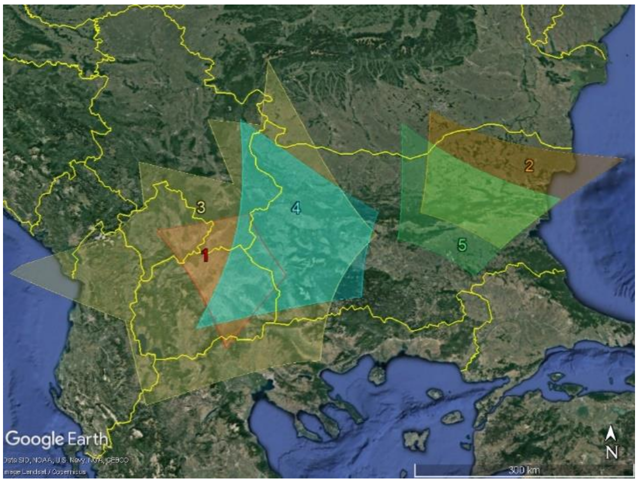


Figure 4 – GMN camera fields in 2022 intersected at 100 km elevation, for 5 cameras active in Bulgaria. The code refers to the camera ID, e.g., 4 = BG0004.

2.5 Canada

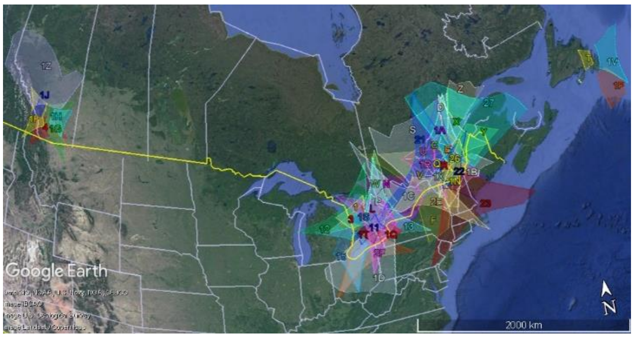


Figure 5 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Canada, overview.

The Canadian GMN network got its first 5 operational RMS cameras providing orbits in June 2019 and expanded to 11 cameras by the end of 2019, good for 3599 orbits. The number of cameras increased to 18 by the end of 2020 with 10815 orbits registered. During 2021, 15 new camera IDs appeared in the list and 8809 orbits were recorded with 29 cameras in 2021, less than the year before despite the extra cameras. The number of cameras doubled from 29 to 58 in 2022 resulting in 16232 orbits. Some cameras in New Found Land still wait for a multi-station partner (*Figure 5*). Most cameras are installed in Quebec and Southern Ontario, ideal for volunteers south of the Canadian border in the US (*Figure 6*). A small network in the Calgary region of Alberta had its first orbits in 2022 (*Figure 7*).

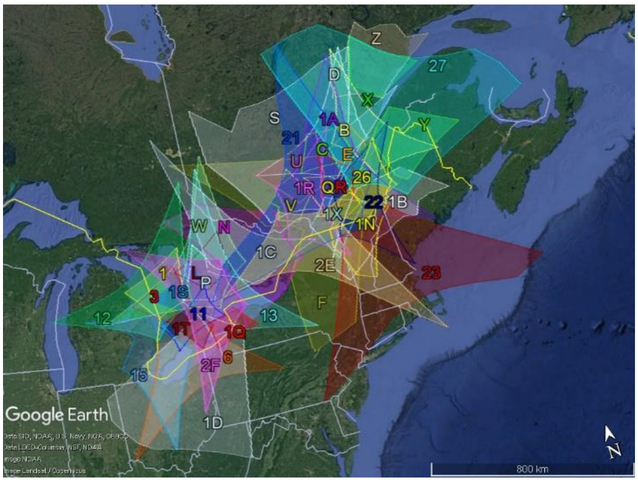


Figure 6 – GMN camera fields intersected at 100 km elevation, for cameras active in Canada, Quebec and Ontario. The letter code refers to the camera ID, e.g., 1D = CA001D.

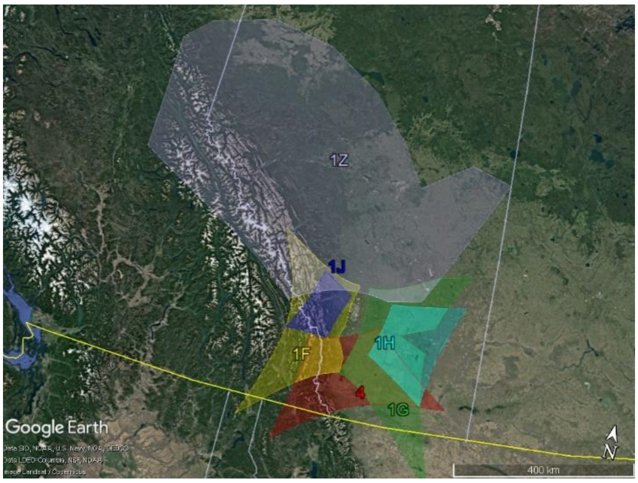


Figure 7 – GMN camera fields intersected at 100 km elevation, for cameras active in Canada, Alberta. The letter code refers to the camera ID, e.g., 1F = CA001F.

2.6 Croatia

Croatia was the first European country in May 2019 to harvest orbits with three RMS cameras. By the end of 2019 Croatia had already 23 cameras successfully contributing in triangulations, good for 12221 multi-station events. The number of cameras increased to 32 in 2020 resulting in 35099 orbits that year. 38370 multi-station events were recorded in 2021 with 48 cameras. Last year was slightly less successful with 31329 orbits and 45 operational cameras.

Croatia plays a major role in the coordination of GMN, maintaining the IStream website[7], offering RMS cameras plug & play for sale and providing technical assistance to participants in the GMN project worldwide. The Croatian cameras provide a huge overlap on the neighboring countries (*Figure 8*). A number of Croatian cameras have a very small FoV to register fainter meteors with higher

---

[7] http://istrastream.com/rms-gmn/

positional accuracy. For clarity, these camera fields are shown in close-up in *Figure 9*.

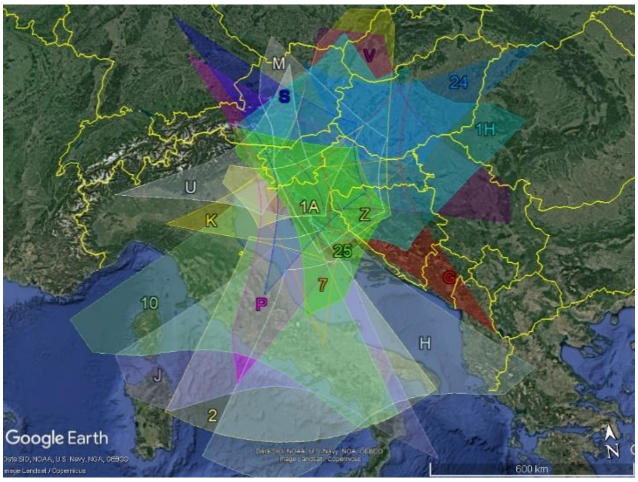


Figure 8 – GMN camera fields intersected at 100 km elevation, for cameras installed in Croatia, status 2022. The code refers to the camera ID, e.g., M = HR000M.

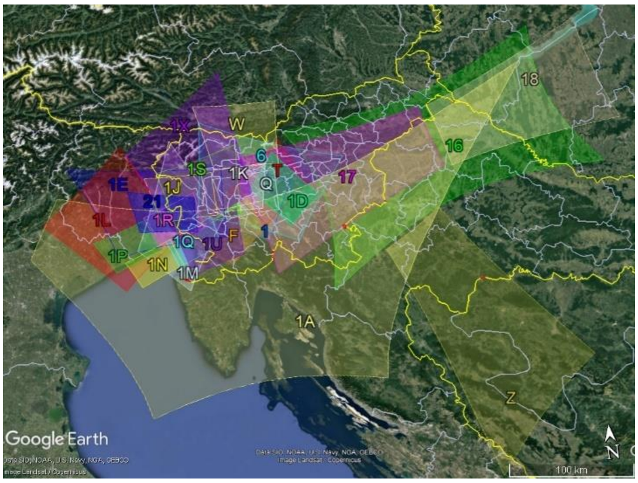


Figure 9 – Close-up for small GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Croatia.

2.7 Czech Republic

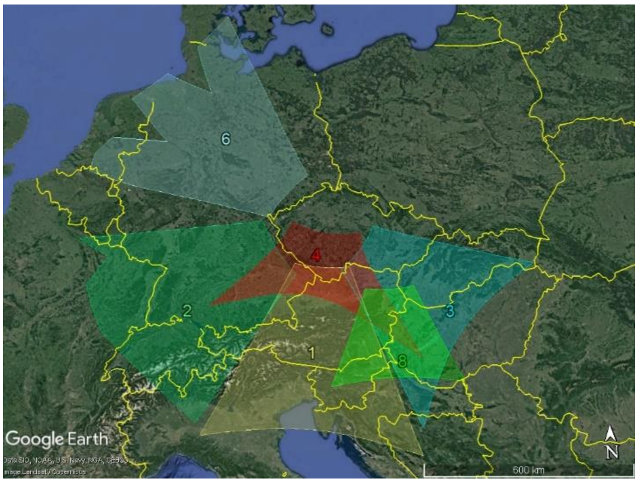


Figure 10 – GMN camera fields in 2022, intersected at 100 km elevation, for cameras active in the Czech Republic. The code refers to the camera ID, e.g., 1 = CZ0001.

The number of operational cameras in the Czech Republic increased from 4 in 2021 to 6 in 2022. In total 2490 orbits were collected in 2022 against 464 in 2021 and 163 in 2020 with 3 cameras. The central location of the country in Europe and the increasing number of cameras installed in neighboring countries determine to a large extend the number of paired meteors (*Figure 10*). The Czech Republic was the driving force behind the former EDMOND network and there is good hope to see a revival of video meteor work in this part of Europe.

2.8 Denmark

In October 2022 a first GMN camera got operational in Denmark, good for 55 orbits in 2022 with paired meteors mainly with German and Dutch cameras and occasionally some British and a Belgian camera (*Figure 11*).

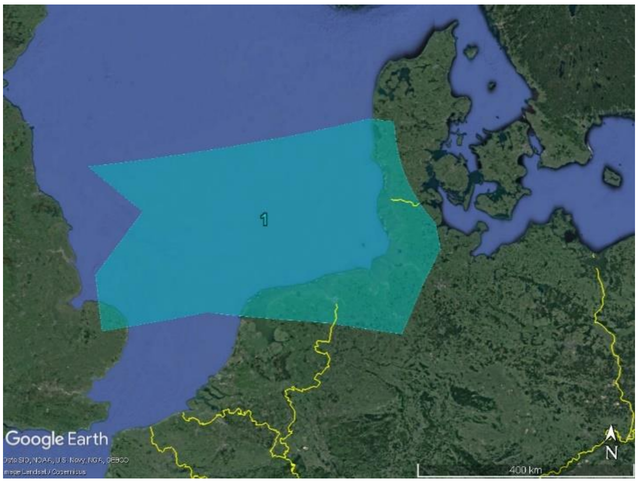


Figure 11 – GMN camera field in 2022 intersected at 100 km elevation, for cameras active in Denmark. The code refers to the camera ID, e.g., 1 = DK0001.

2.9 Finland

In October 2022 the first GMN cameras became operational at two sites in Finland, with 41 orbits as a first result (*Figure 12*). There is a long tradition in Finland with meteor photography and all-sky fireball surveys. Hopefully the video meteor work will continue this tradition.

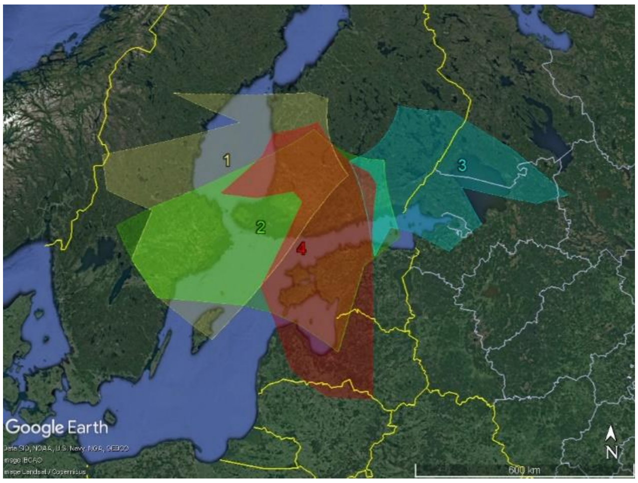


Figure 12 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Finland. The code refers to the camera ID, e.g., 3 = FI0003.

2.10 France

The number of French RMS cameras had increased from 10 to 14 devices in 2021, good for 5601 multi-station events in 2021 against 3176 events in 2020 with 10 cameras. In 2022 there were 16 RMS cameras in France which contributed 11990 orbits. In total 20 RMS cameras were installed since March 2020, but 4 of them did not function anymore in 2022. The Southwestern part of France so far got no GMN installed. Extra cameras in the west of France would benefit from the coverage by British sites and in the southwest from Spanish GMN cameras (*Figure 13*).

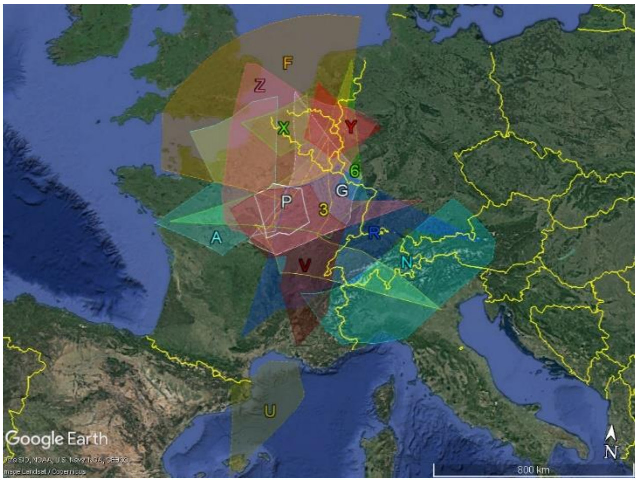


Figure 13 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in France. The code refers to the camera ID, e.g., P = FR000P.

2.11 Germany

The first GMN camera in Germany had its first orbits in August 2019 with Belgian GMN cameras. By end of 2019 there were 4 GMN cameras in Germany, good for 200 orbits. The number of cameras increased to 10 and the numbers of orbits to 3963 in 2020. With 12 cameras in 2021, 7009 orbits were collected. In 2022 some extra devices were installed, with 18 cameras 9128 orbits were collected. Some GMN cameras in the North-Western part of Germany also participate in the CAMS-BeNeLux network, supporting both GMN and CAMS (*Figure 14*).

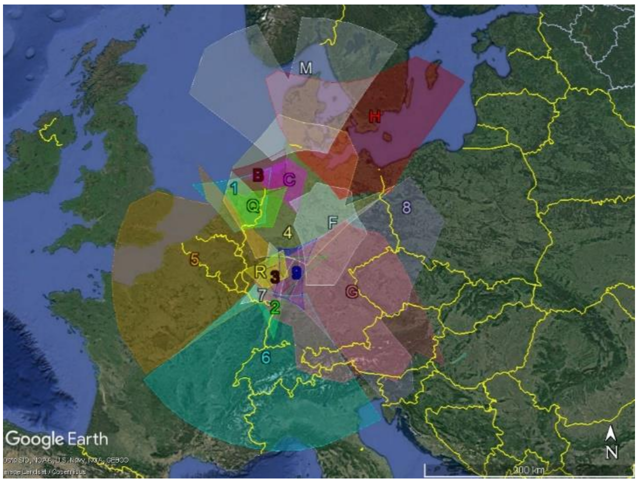


Figure 14 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Germany. The code refers to the camera ID, e.g., M = DE000M.

2.12 Greece

In September 2022 the first GMN camera got operational in Greece, ideally point to overlap with some Bulgarian GMN cameras, good for as many as 977 paired meteors in the 4 last months of 2022 (*Figure 15*).

Figure 15 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Greece. The code refers to the camera ID, e.g., 2 = GR0002.

2.13 Hungary

A first GMN camera got operational in March 2022 in Hungary and by end of 2022, two Hungarian cameras had obtained 2114 orbits, mainly multi-station events with Croatian cameras, but also with cameras in the Czech Republic and Slovenia. Hungary has a long tradition in meteor astronomy and hopefully more GMN camera sites will get installed (*Figure 16*).

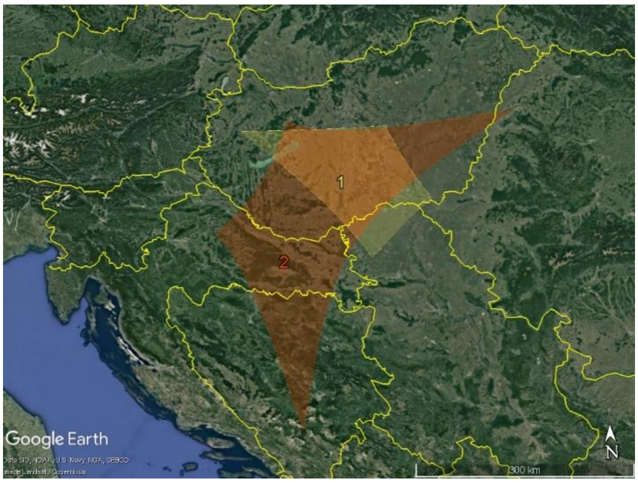


Figure 16 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Hungary. The code refers to the camera ID, e.g., 2 = HU0002.

2.14 Ireland

Ireland got a first GMN operational in October 2020 and second one a month later, good for 120 orbits in 2020. With 3 cameras in 2021 the number of orbits increased to 424. The number of orbits increased a lot to 3490 in 2022 with 5 GMN cameras (*Figure 17*). Most of the paired meteors were obtained thanks to the overlap provided by GMN cameras in the UK. Many attributed GMN camera IDs don’t show up on the map yet as several new cameras are expected to get installed in 2023.

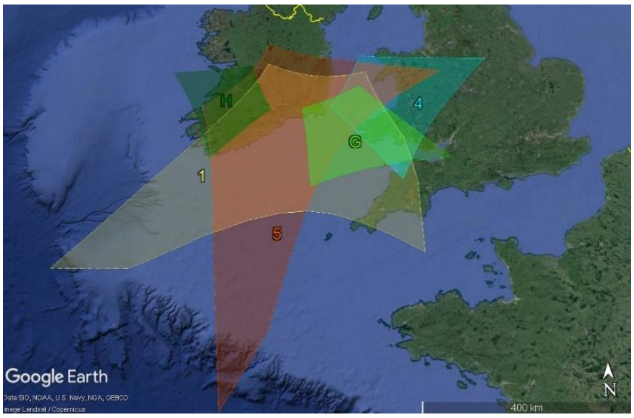


Figure 17 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Ireland. The code refers to the camera ID, e.g., G = IE000G.

2.15 Israel

Israel got its first 3 GMN cameras installed in November 2020, good for 553 orbits that year. In 2021 3 extra cameras got installed which collected 2009 orbits. In 2022 the cameras did not provide orbits during some time and one camera was discontinued. With 5 cameras still 975 orbits could be obtained (*Figure 18*).

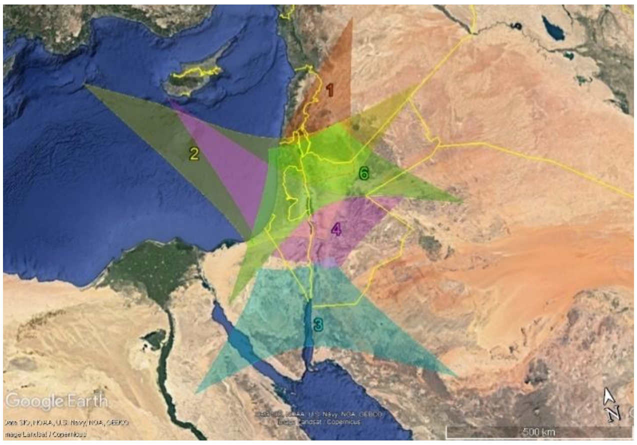


Figure 18 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Israel. The code refers to the camera ID, e.g., 3 = IL0003.

2.16 Italy

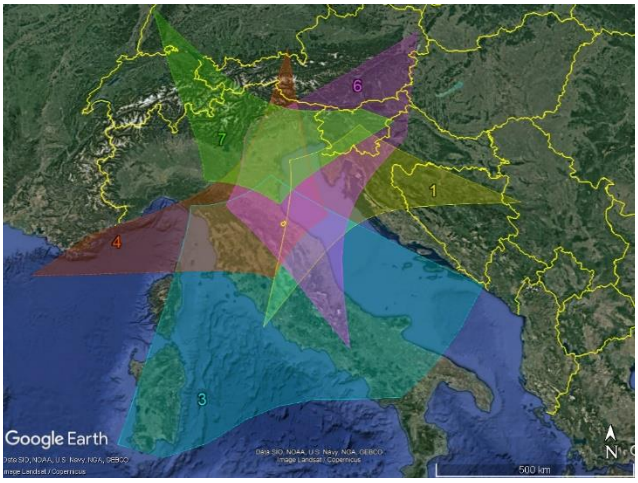


Figure 19 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Italy. The code refers to the camera ID, e.g., 3 = IT0003.

Italy got its first GMN camera installed and contributing to orbits in October 2019, good for 862 orbits in 2019. Italy remained with one GMN camera in 2020, which had as many as 5384 paired meteors with Croatian and Slovenian cameras. Italy increased its number of cameras from 1 to 5 and these cameras were involved in 5447 multi-station events in 2021. One camera IT0005 functioned only in September 2021. An extra camera was added in Bologna in 2022 and last year 5 GMN cameras collected 4943 orbits (*Figure 19*).

2.17 Japan

A first GMN camera got installed in Japan in 2022, waiting for some multi-station partners at suitable distance for triangulation. When more GMN cameras get installed in Japan, there is an interesting opportunity to obtain paired meteors with South Korean GMN cameras (*Figure 20*).

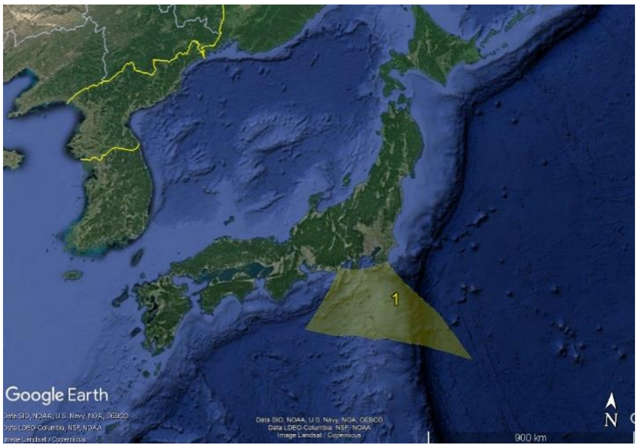


Figure 20 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Japan. The code refers to the camera ID, e.g., 1 = JP0001.

2.18 Korea (South)

A most impressive deployment of GMN cameras took place in 2022 in South Korea with a first few cameras obtaining orbits in September and as many as 47 GMN cameras installed in November and December 2022. The cameras were installed and pointed to obtain an optimal overlap (*Figures 21 and 22*), resulting in 7711 orbits!

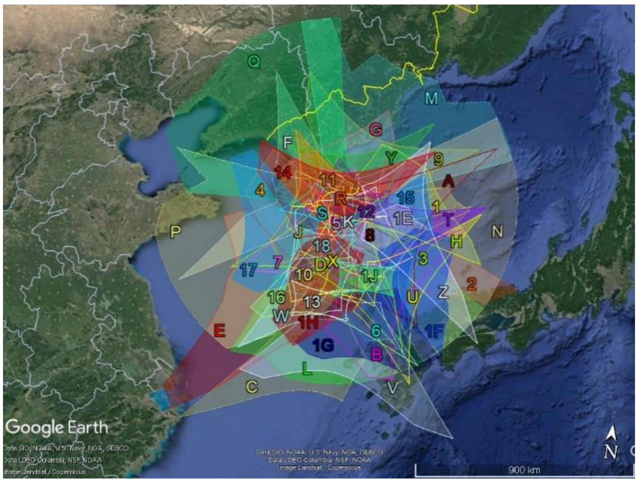


Figure 21 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in South Korea. The code refers to the camera ID, e.g., E = KR000E.

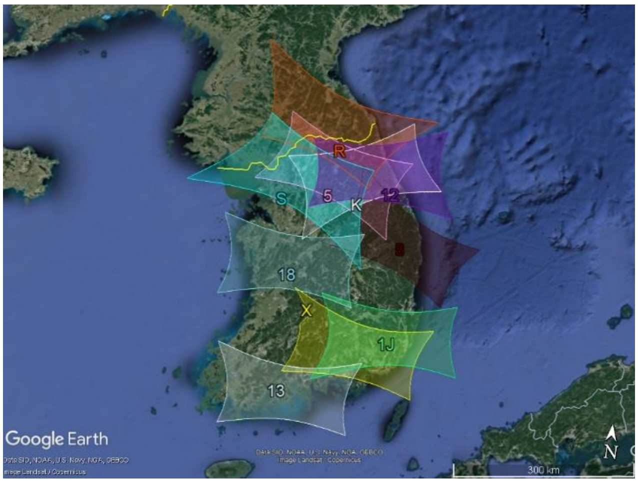


Figure 22 – Close-up for small GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Korea.

2.19 Luxembourg

In October 2022 a first GMN camera got installed in Luxembourg contributing to 622 orbits combining with Belgian, Dutch, French, German and even Czech GMN cameras (*Figure 23*).

Figure 23 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Luxembourg. The code refers to the camera ID, e.g., 1 = LU0001.

2.20 Mexico

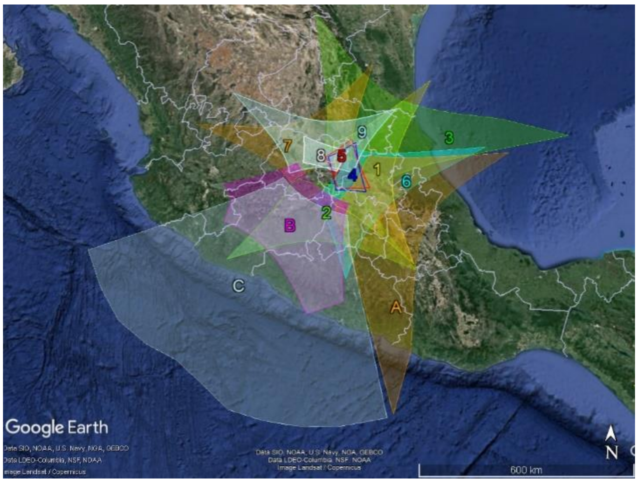


Figure 24 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Mexico. The code refers to the camera ID, e.g., C = MX000C.

An impressive deployment of GMN cameras took place in Mexico in 2022. The first few installed cameras obtained the first orbits in February 2022 and soon 12 cameras got installed with a good overlap (*Figure 24*). A total of 1769 meteor orbits could be collected.

2.21 Malaysia

A first GMN camera had been installed in Malaysia in 2021 waiting for coverage from cameras installed at a suitable distance to get good triangulations. Some extra cameras got installed in 2022 and in June 2022 the first orbits were obtained. With 3 cameras 50 orbits were obtained. With some extra camera coverage, the number of orbits will increase drastically.

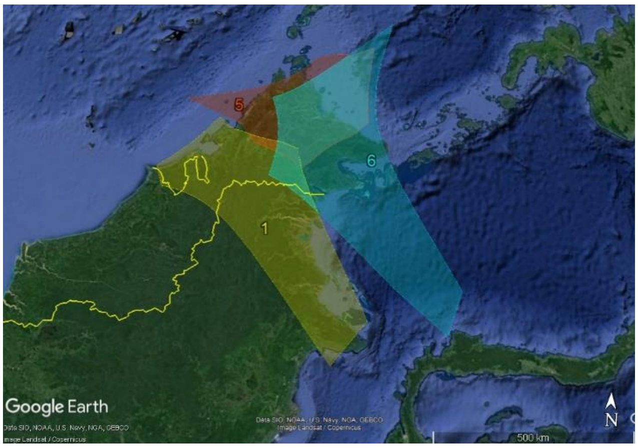


Figure 25 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Malaysia. The code refers to the camera ID, e.g., 5 = MY0005.

2.22 Netherlands

The Netherlands started collecting orbits within the GMN in August 2019 and had 278 orbits in its first year. The number of GMN cameras increased to 11 in 2020 with 4337 orbits as result. The number of cameras remained unchanged in 2021 but the better overlap from neighboring countries resulted in 7605 orbits. Some cameras dropped off in 2022 and few new got installed, resulting in 9139 orbits with 13 cameras (*Figure 26*). Dutch cameras get mainly multi-station coverage from cameras in Belgium, Germany, the UK and recently also Denmark.

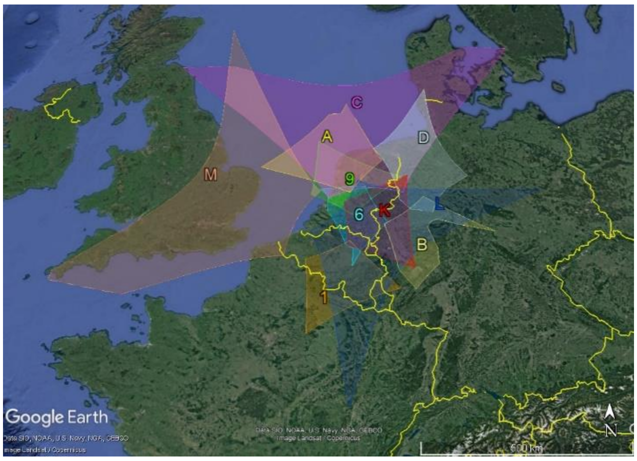


Figure 26 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in the Netherlands. The code refers to the camera ID, e.g., C = NL000C.

2.23 New Zealand

The first two GMN cameras got installed in July 2021 in New Zealand and 1146 orbits were obtained that year. From March 2022 more cameras got installed month by month with an impressive deployment of strategically placed well pointed cameras covering the huge surface of the country. With 28 active cameras at the end of 2022, 6280 orbits were recorded, making New Zealand one of the most important providers of orbit data for the Southern Hemisphere (*Figure 27*).

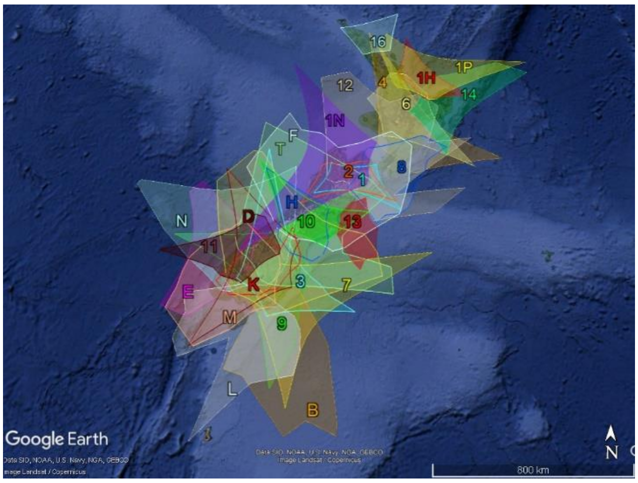


Figure 27 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in New Zealand. The code refers to the camera ID, e.g., 1P = NZ001P.

2.24 Poland

The first GMN camera got installed in September 2020 and remained long the only Polish GMN camera. In March 2022 two extra Polish GMN cameras got their first orbits. The cameras didn't function all the time but the number of orbits obtained increased from 67 in 2021 to 398 in 2022. Polish amateurs were major contributors to the former EDMOND network. Unfortunately, when EDMOND quit, also many former contributors quit. A revival in Poland of meteor video work combined with extra cameras in the Czech Republic and Germany would bring a major boost to the coverage of the atmosphere over Europe for the monitoring of meteor shower events within the European observing window (*Figure 28*).

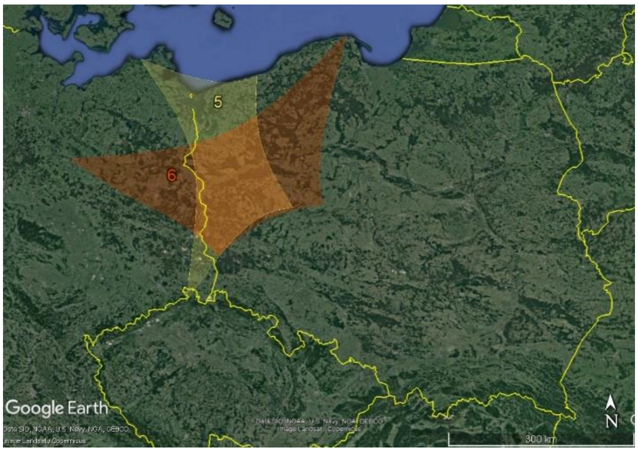


Figure 28 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Poland. The code refers to the camera ID, e.g., 5 = PL0005.

2.25 Portugal

A first GMN camera got its first orbits in September 2022 in Portugal. A vast coverage from GMN cameras in Spain guarantees many paired meteors (*Figure 29*). Any extra cameras installed in the western part of the Iberian Peninsula would significantly improve the multi-station coverage.

Figure 29 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Portugal. The code refers to the camera ID, e.g., 2 = PT0002.

2.26 Russia

The first two GMN cameras had orbits in July 2019. The first year had already 5715 orbits with 10 cameras. In 2020 the number of cameras increased to 21, good for as many as 13438 orbits. The number of RMS cameras having paired meteors remained stable at 21, but the number of orbits decreased to 6208 in 2021. Problems with the maintenance of some meteor stations reduced the number of paired observations. In 2022, 19 cameras in Russia had 5437 orbits. Some single RMS devices (*Figure 30*) got installed elsewhere in Russia, waiting for coverage from other RMS cameras at a suitable distance.

Two cameras are installed in the far east of Russia and were good for 1252 of the orbits recorded in 2022 (*Figure 31*).

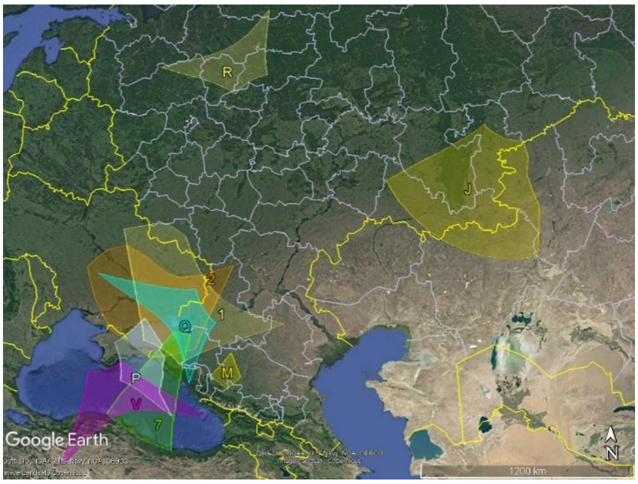


Figure 30 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Russia (West). The code refers to the camera ID, e.g., J = RU000J.

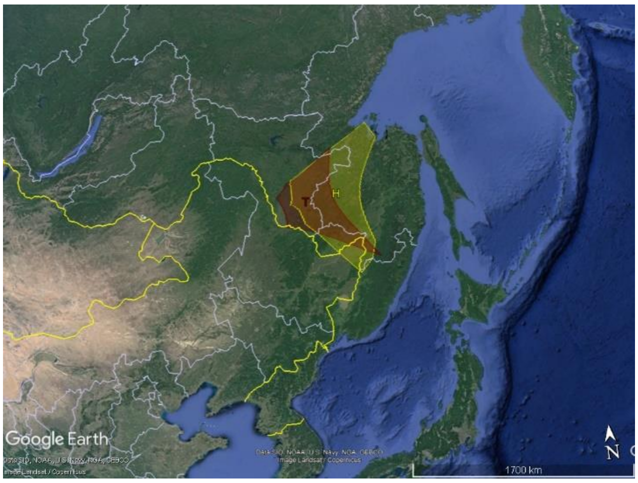


Figure 31 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Russia (far east). The code refers to the camera ID, e.g., T = RU000T.

2.27 Singapore

A first camera got installed in 2022 and is waiting for multi-station partners (*Figure 32*).

Figure 32 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Singapore. The code refers to the camera ID, e.g., 1 = SG0001.

2.28 Slovakia

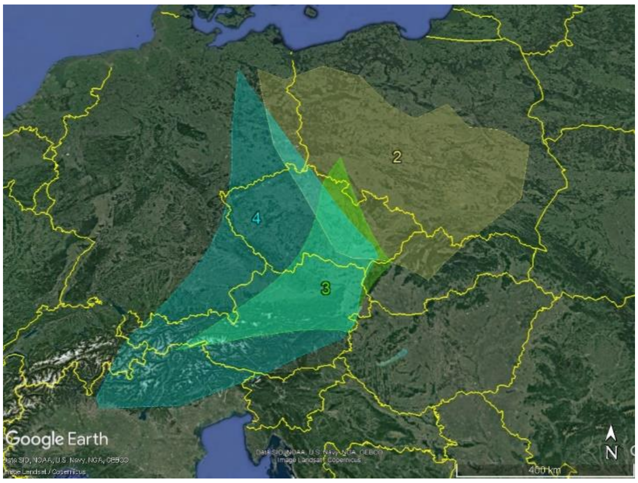


Figure 33 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Slovakia. The code refers to the camera ID, e.g., 3 = SK0003.

Slovakia got its first camera in November 2021 with 37 paired meteors. Meanwhile 3 GMN cameras got operational and 2022 had 2026 orbits for Slovakian cameras (*Figure 33*).

2.29 Slovenia

Slovenia got its first RMS contributing in August 2019 and a second RMS in August 2021. The coverage by cameras in neighboring Croatia resulted in 2753 orbits in 2019, 3999 in 2020 and 6001 in 2021. The two Slovenian cameras contributed to 5887 orbits in 2022 (*Figure 34*).

Figure 34 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Slovenia. The code refers to the camera ID, e.g., 1 = SI0001.

2.30 Spain

The GMN had its first orbits collected in Spain in April 2020. End of 2020, 8 GMN cameras had collected 1207 orbits. A lot of progress was made in Spain in 2021 when the number of cameras increased from 8 to 23. The 23 Spanish cameras were involved in 15113 multi-station events in 2021. The number of GMN cameras increased further to 30 in 2022 and resulted in 19301 orbits (*Figure 35*).

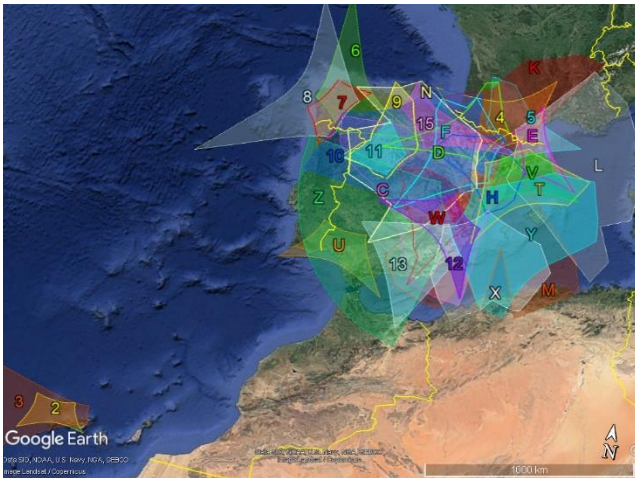


Figure 35 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Spain. The code refers to the camera ID, e.g., C = ES000C.

2.31 Switzerland

The first orbits were obtained in August 2021 but it took until May 2022 before extra cameras got installed and more orbits recorded. With 5 operational cameras 3439 orbits were obtained. The central location of Switzerland is ideal to obtain multi-station events with GMN cameras in the neighboring countries (*Figure 36*).

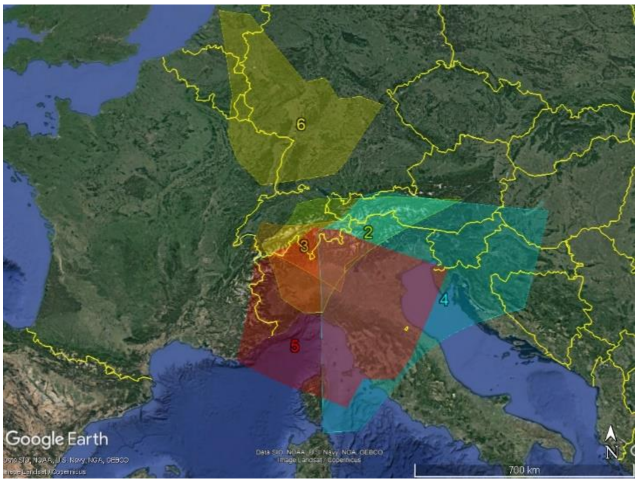


Figure 36 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in Switzerland. The code refers to the camera ID, e.g., 6 = CH0006.

2.32 United Kingdom

Cameras

During 2022 the number of active cameras in the UK grew from 97 in 2021 to 169 at the end of 2022 (*Figure 37*). The vast majority of these cameras are part of the UK Meteor Network which now provides complete coverage of the UK and Eire though some parts of the far West are covered by only one or two cameras.

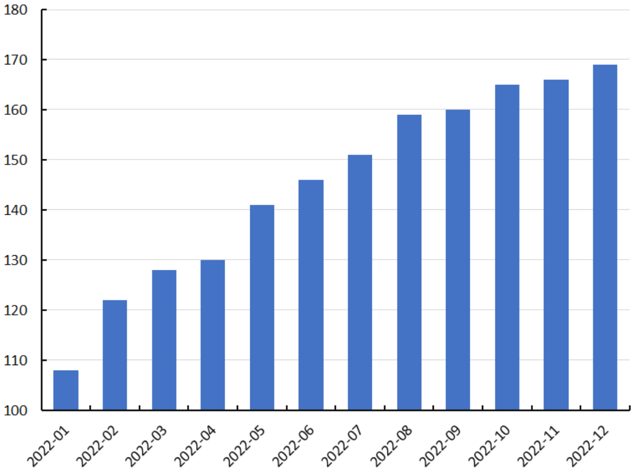


Figure 37 – The camera growth in the United Kingdom in 2022.

At 100 km UK camera coverage reaches as far as Shetland, Faroe, Norway, Western Germany, the Bay of Biscay and central France. Notable growth this year has been in Scotland which is now well covered, though the Western Isles are still not covered fully at lower altitudes. There is almost complete overlap with the BENELUX network. Maps showing coverage and camera overlaps are available on UKMON's website[8] (*Figure 38*).

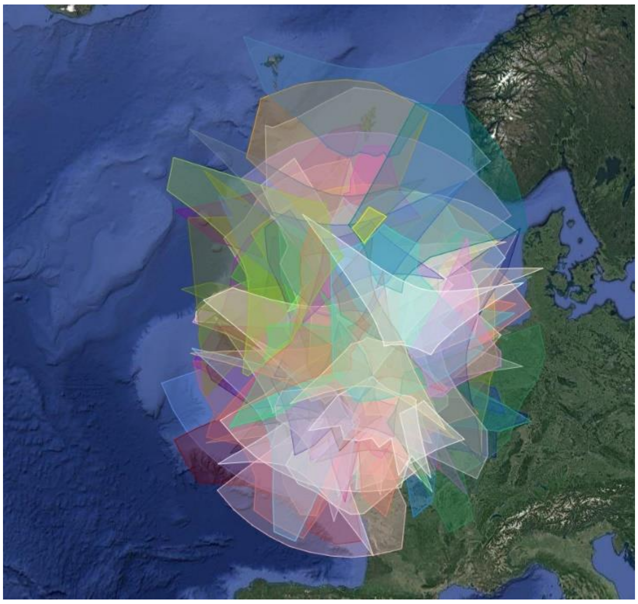


Figure 38 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in the United Kingdom. To check the camera IDs and positions, consult the link provided above.

Matches

UK cameras were involved in 78652 matched multi-station events compared to 27430 in 2021. One match was detected by 31 cameras, and 6809 were detected by ten or more stations, providing high levels of confidence in the data (though see next section). Over 1.5 million individual single-station detections were recorded, though this total includes non-meteoric events.

The furthest East match involving a UK camera was just south of Erfurt, Germany, while the furthest West was a few miles off the Dingle, Eire. The furthest north was near Shetland, Scotland and the furthest south was in the Bay of Biscay, about 150km south of Quimper, France. A fireball was also matched off the coast of Norway!

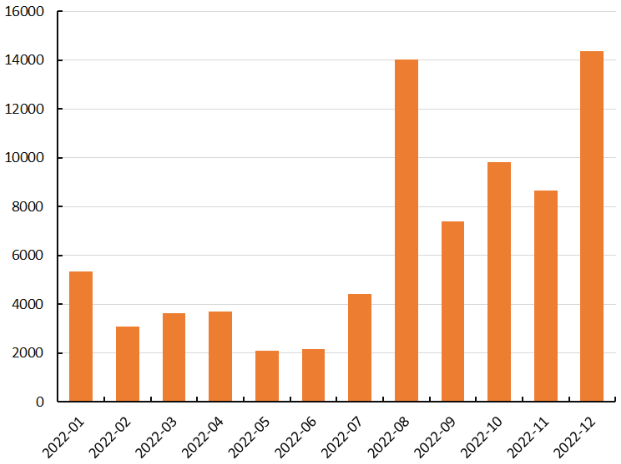


Figure 39 – The number of matches in the United Kingdom in 2022.

---

[8] https://archive.ukmeteornetwork.co.uk/latest/coverage-maps.html

Data volume issues

There are downsides to such large numbers of cameras. Firstly, multi-station matches take longer to solve, delaying overall GMN processing. Secondly, there is a much higher chance of two different meteors being detected within a 10 second window. This can sometimes lead to mismatching or even failures to match. To mitigate these issues, the GMN team is working on code changes to rank detections by quality, and then use only the best in solutions.

Showers

360 individual meteor showers were detected, accounting for 46% of all matches. As one might expect, the Perseids and Geminids dominate shower meteors, though other major showers were well represented. Relatively low numbers of Quadrantids and Lyrids are reflective of poor weather in January and April. The top ten showers are listed below. 2022 was a "Taurid Swarm" year, and so various flavors of Taurid meteors were detected in numbers – for example the s-Taurids feature in the list below.

PER	7207
GEM	6631
ORI	2342
STA	959
STS	794
QUA	716
COM	678
LEO	597
NTA	591
HYD	523

Fireballs

49 detections over the UK were marked as fireballs, with five probable meteorite dropping events. In the UK, when a potential meteorite dropper is detected, GMN works with the UK Fireball Alliance to effect press communications, engage with UK universities and museums, and organize ground searches where appropriate. Two ground searches were in fact conducted in 2022, and although no meteorites were recovered many valuable lessons were learned – notably, that searching in former coal mining areas and sheep fields is quite impractical as there are many "small black rocks" to confound the search! The three other likely meteorite-dropping events were over the sea.

Looking forward

The UK network continues to grow, with at least 30 additional cameras being commissioned. Over 7000 matches and three fireballs have already been detected in January 2023, and we look forward to a busy year!

2.33 United States

The American New Mexico Meteor Array was the pioneering network of the GMN as it started to harvest meteors in December 2018 with 6 cameras, and the first 497 orbits for GMN. It remained the only data provider for GMN until May 2019 when the first 3 Croatian cameras started to deliver orbits. At the end of 2019, the number of US cameras had increased to 20 when the network collected 27643 orbits that year.

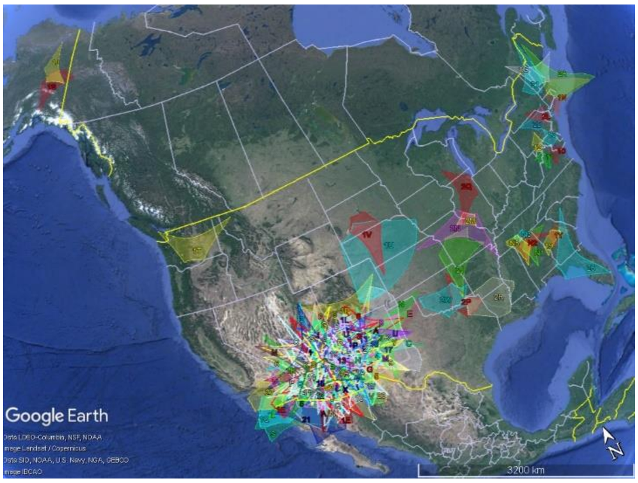


Figure 40 – GMN camera fields intersected at 100 km elevation, global view for cameras installed in the USA, status 2022.

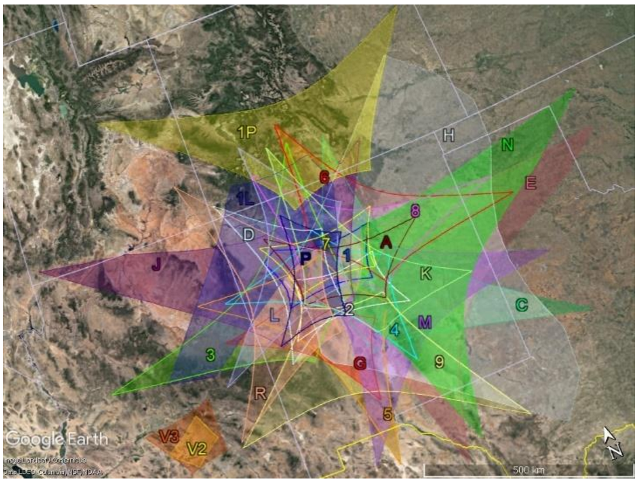


Figure 41 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras of the New Mexico Camera Array. The code refers to the camera ID, e.g., D = US000D.

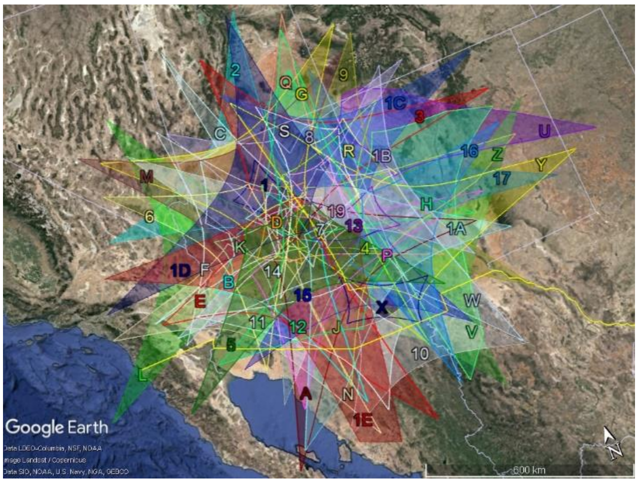


Figure 42 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras of the Lowell Observatory in Arizona. The code refers to the camera ID, e.g., D = USL00D.

Figure 40 shows the GMN status like it was end of 2022 with 100 GMN cameras in the US, most of which belong to the New Mexico Camera Array and the Lowell Observatory in Arizona. Both networks are independent in neighboring states but have a large overlap. *Figure 41* shows the situation for New Mexico and *Figure 42* for Arizona. The Lowell Observatory cameras also benefit coverage from other GMN cameras in the state as well as in California (*Figure 43*). In December 2020 the Lowell CAMS team at Lowell Observatory, Arizona, had added 9 GMN cameras to their CAMS network and another 14 GMN cameras got installed elsewhere in the US. The 33 operational cameras in the US collected as many as 50607 orbits in 2020.

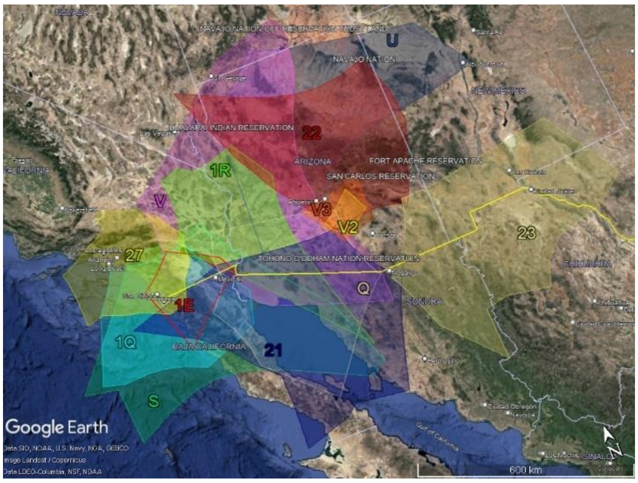


Figure 43 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras in California and Arizona. The code refers to the camera ID, e.g., Q = US000Q.

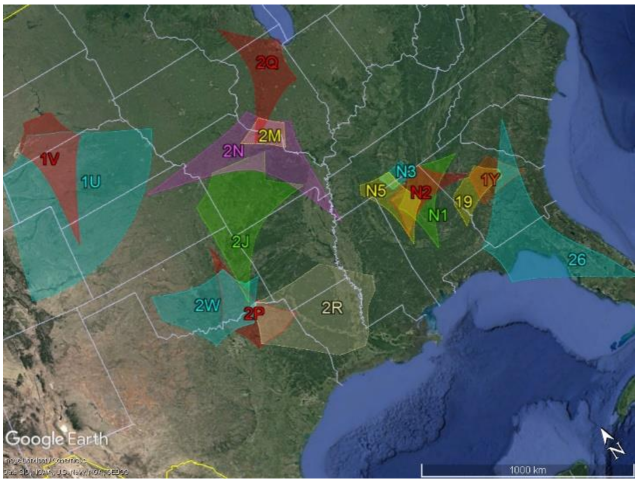


Figure 44 – GMN camera fields in 2022 intersected at 100 km elevation, several new networks in the US. The code refers to the camera ID, e.g., 2R = US002R.

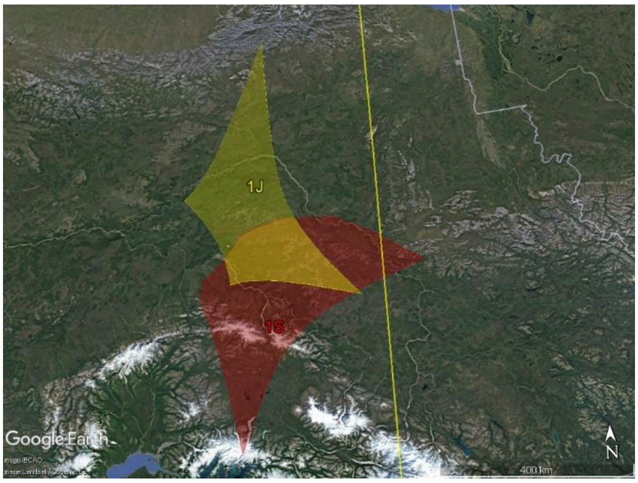


Figure 45 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras in Alaska. The code refers to the camera ID, e.g., 1J = US001J.

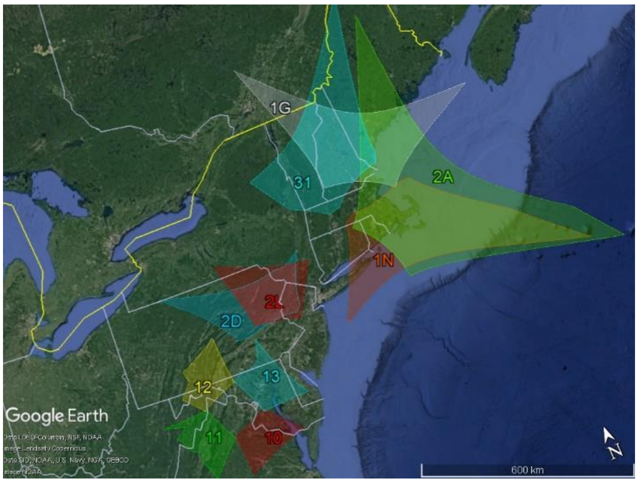


Figure 46 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras at the East Coast of the US. The code refers to the camera ID, e.g., 2A = US002A.

The Lowell team added another 27 GMN cameras to their CAMS network in 2021 and 12 cameras got installed in California and elsewhere in the US. With 72 RMS cameras registering paired meteors in the US, a total of 91901 orbits were obtained. The number of GMN cameras involved in orbit determinations increased to 100 in 2022, good for 114054 orbits.

The implementation of GMN cameras by the Lowell Observatory in Arizona made Lowell the most important orbit contributor for the CAMS project. While Lowell contributed 51425 orbits to GMN in 2021, it contributed 76232 orbits to CAMS. In 2022 Lowell contributed 106596 orbits to CAMS against 79647 to GMN. The GMN software provides CAMS compatible data and this way these cameras prove an excellent alternative for the outdated Watecs. Beyond the Lowell Observatory, CAMS benefits from GMN in its CAMS-BeNeLux network and in CAMS Australia, a win-win for both projects. GMN has more rigorous quality validation built-in for its trajectory solver than CAMS which explains why CAMS obtains more orbits from the same number of paired meteors.

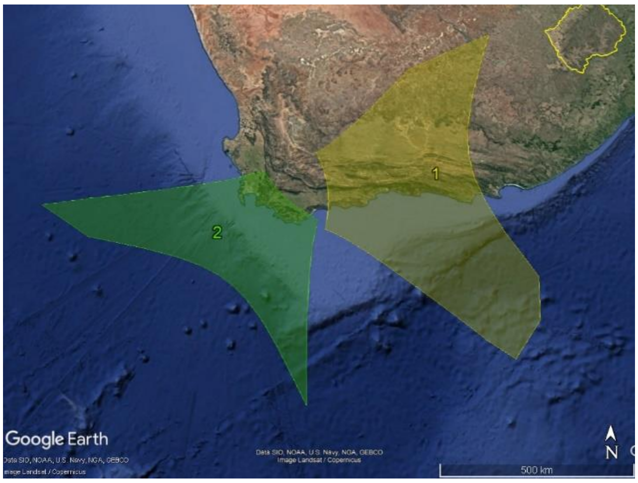


Figure 47 – GMN camera fields in 2022 intersected at 100 km elevation, for cameras active in South Africa. The code refers to the camera ID, e.g., 2 = ZA0002.

GMN camera networks are emerging at several other sites in the US (*Figure 44*). The network reaches till Alaska at 65° northern latitude (*Figure 45*). Several cameras installed near the East Coast, south of the Canadian border connect to the existing GMN network in Canada (*Figure 46*). The maps show where cameras in the US still wait for multi-station partners to set up cameras.

2.34 South Africa

The first two GMN cameras got installed and are waiting for multi-station partners (*Figure 47*).

3 GMN statistics 2022

When a first GMN status report got published, including all data until end October 2020, 140 operational cameras were involved and 144950 orbits had been collected (Roggemans, 2021). Meanwhile, we can compare 4 years of GMN work. *Figure 48* shows the accumulated number of orbits obtained and the number of contributing cameras during each calendar month. The rapid growth of the Global Meteor Network is obvious. The number of cameras involved in collecting orbits for GMN increased from 390 in 2021 to 700 in 2022.

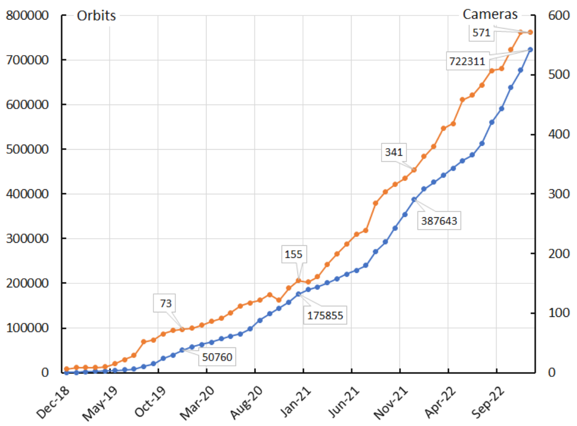


Figure 48 – The accumulated number of orbits (blue) and the actual number of operational cameras involved in triangulations (orange). The numbers at the end of each year are indicated.

Table 1 – Total number of orbits obtained by the Global Meteor Network cameras per calendar month.

	2018	2019	2020	2021	2022	Total
01	0	564	7539	9919	23727	41749
02	0	1284	5330	6529	14910	28053
03	0	537	5101	8767	15409	29814
04	0	876	7213	9655	15658	33402
05	0	1242	5654	10217	16951	34064
06	0	1523	5700	7954	13463	28640
07	0	1961	10973	11325	25226	49485
08	0	5387	19422	31292	47300	103401
09	0	6058	14012	21189	29984	71243
10	0	11978	13097	31501	48360	104936
11	0	7710	13228	30381	37895	89214
12	497	11143	17826	33059	45785	108310
	497	50263	125095	211788	334668	722311

Table 2 – Total number of operational cameras within the Global Meteor Network per calendar month.

	2018	2019	2020	2021	2022	Total
01		9	75	152	363	397
02		9	80	161	380	417
03		9	86	182	410	445
04		10	91	200	418	462
05		15	101	216	458	499
06		22	112	232	466	524
07		29	117	239	483	534
08		52	122	285	507	568
09		55	131	304	510	578
10		65	122	316	542	607
11		71	142	326	571	642
12	6	73	155	341	571	659
	6	76	173	390	700	729

Table 3 – Total number of multi-station events contributing to an orbit result, recorded in each country for each year.

	2018	2019	2020	2021	2022	Total
AU	0	0	0	1871	12460	14331
BE	0	921	5500	8582	23174	38177
BG	0	0	0	419	3877	4296
BR	0	0	40	1645	2760	4445
CA	0	3599	10815	8809	16232	39455
CH	0	0	0	3	3439	3442
CZ	0	0	163	464	2490	3117
DE	0	200	3963	7009	9128	20300
DK	0	0	0	0	55	55
ES	0	0	1207	15113	19301	35621
FI	0	0	0	0	41	41
FR	0	0	3176	5601	11990	20767
GR	0	0	0	0	977	977
HR	0	12221	35099	38370	31329	117019
HU	0	0	0	0	2114	2114
IE	0	0	120	424	3490	4034
IL	0	0	553	2009	975	3537
IT	0	862	5384	5447	4943	16636
KR	0	0	0	0	7711	7711
LU	0	0	0	0	622	622
MX	0	0	0	0	1769	1769
MY	0	0	0	0	50	50
NL	0	278	4337	7605	9139	21359
NZ	0	0	0	1146	6280	7426
PL	0	0	35	67	398	500
PT	0	0	0	0	327	327
RU	0	5715	13438	6208	5437	30798
SI	0	2753	3999	6001	5887	18640
SK	0	0	0	37	2026	2063
UK	0	0	1889	27430	78652	107971
US	497	27643	50607	91901	114054	284702

Table 4 – Total number of operational cameras in each country for each year. Inactive devices and cameras without orbits are not counted.

	2018	2019	2020	2021	2022	Total
AU	0	0	0	12	29	30
BE	0	4	4	10	20	20
BG	0	0	0	2	6	6
BR	0	0	2	13	20	21
CA	0	11	18	29	58	60
CH	0	0	0	1	5	5
CZ	0	0	3	4	6	6
DE	0	4	10	12	18	19
DK	0	0	0	0	1	1
ES	0	0	8	23	30	30
FI	0	0	0	0	4	4
FR	0	0	10	14	16	20
GR	0	0	0	0	1	1
HR	0	23	32	48	45	54
HU	0	0	0	0	2	2
IE	0	0	2	3	5	6
IL	0	0	3	6	5	6
IT	0	1	1	5	5	6
KR	0	0	0	0	47	47
LU	0	0	0	0	1	1
MX	0	0	0	0	12	12
MY	0	0	0	0	3	3
NL	0	2	11	11	13	15
NZ	0	0	0	2	28	28
PL	0	0	1	1	3	3
PT	0	0	0	0	1	1
RU	0	10	21	21	19	25
SI	0	1	1	2	2	2
SK	0	0	0	1	3	3
UK	0	0	13	97	191	191
US	6	20	33	72	100	100
	6	76	173	389	699	728

The details per month for the number of orbits are given in *Table 1* and the number of cameras is given in *Table 2*. Note in *Table 2* that for instance 571 cameras contributed with orbits in December, far less than the 700 cameras that contributed during the entire year of 2022. The explanation can be bad weather, technical issues or other problems which temporarily prevented cameras to score multi-station events. A number of formerly active cameras did not contribute in 2022. Installed cameras waiting for multi-station coverage are not included in these totals.

Table 3 lists the number of paired meteors that contributed to orbits counted per country. That meteors have no borders is obvious as the sum of all totals per country equals 812338 orbits while there were 722311 orbits in total in the GMN dataset at the end of 2022. The difference 90027 are orbits established by cameras in two or more countries for cross-border events and thus counted twice or more times.

Table 4 lists the number of different camera IDs that contributed to orbits in each country. Sometimes, cameras were not recording all year long and a number of active cameras from past years did no longer contribute data. For Canada cameras with country code CAWE (Western) were counted for CA, while CAWT (Tavistock) is not included as no orbits from these cameras were found in the GMN orbit dataset. US includes cameras and orbits identified as USL (Lowell) and USV (Arizona), but not USN (NASA stations) which has no orbits in the GMN dataset. One camera had been functioning with a preliminary country code XX.

4 Meteor showers covered by GMN

Using the Working List of Meteor Showers[9] (Jenniskens et al., 2020; Jopek and Kaňuchová, 2017; Jopek and Jenniskens, 2011; Neslušan et al., 2020) as a reference, 423 of the showers listed could be associated with orbits collected by the Global Meteor Network. The number of orbits recorded for each of these showers is listed in *Table 5* for each year since 2018.

The GMN meteor shower association has been based on the table of Sun-centered ecliptic shower radiant positions given in Jenniskens et al. (2018). Many entrees of the Working List of Meteor Showers have no matching orbits in the GMN database yet. Some of the showers are periodic and display only some activity once every few years, some showers have been detected only by radar in a fainter range of magnitudes than what GMN cameras cover and others are known as daylight meteor showers. While GMN is getting better coverage at the southern hemisphere, more of the low declination meteor showers will get covered. For a number of listed meteor showers their absence in the GMN orbit database may be explained because the evidence for the existence of the shower could be missing. One of the goals of the GMN project is to help to identify ghost meteor showers that should be removed from the Working List.

Table 5 serves as an inventory of what the GMN orbit database has available until end 2022. Of course, the number of shower members detected depends on the criteria used to associate a meteor with a known meteor shower radiant. The GMN shower association criterion assumes that meteors within 1° in solar longitude, within 3° in radiant, and within 10% in geocentric velocity of a shower reference location are members of that shower. Further details about the shower association are explained in Moorhead et al. (2020). This is a rather strict criterion since meteor showers often have a larger dispersion in radiant position and velocity. Therefore, using the orbit similarity criteria (Drummond, 1981; Southworth and Hawkins, 1963; Jopek, 1993) will certainly detect more shower candidates

---

[9] https://iaumeteordatacenter.org/

but at the risk of including sporadic orbits that fulfil similarity criteria by pure chance.

The main goal of the GMN, not to let any meteor shower activity pass unnoticed is being achieved. Whenever some unexpected meteor activity occurs, the Global Meteor Network has good chances to cover it.

Table 5 – Total number of orbits according to the meteor shower association (IAU number + code) for each year.

Shower	2018	2019	2020	2021	2022	Total
SPOR#-1	188	27834	71186	115900	188413	403521
CAP#1	0	139	793	641	1563	3136
STA#2	0	1388	1645	3417	5171	11621
SIA#3	0	25	53	61	91	230
GEM#4	200	2664	7309	12163	17950	40286
SDA#5	0	350	1560	1570	4099	7579
LYR#6	0	46	733	1044	1431	3254
PER#7	0	1809	8615	14711	20480	45615
ORI#8	0	2771	3423	6900	12690	25784
DRA#9	0	4	3	10	10	27
QUA#10	3	139	919	1710	2172	4943
EVI#11	0	5	102	424	408	939
KCG#12	0	51	237	2554	305	3147
LEO#13	0	426	912	1598	2247	5183
URS#15	5	134	336	259	560	1294
HYD#16	7	557	778	2116	1994	5452
NTA#17	1	963	1332	2476	2803	7575
AND#18	0	61	126	1034	316	1537
MON#19	12	184	330	791	727	2044
COM#20	17	367	762	925	2183	4254
AVB#21	0	15	155	194	226	590
LMI#22	0	109	134	269	451	963
EGE#23	0	168	198	597	825	1788
NOA#25	0	145	170	234	330	879
NDA#26	0	203	687	894	1390	3174
KSE#27	0	3	17	45	46	111
SOA#28	0	180	324	663	354	1521
ETA#31	0	218	647	1607	2961	5433
NIA#33	0	108	187	292	351	938
ZCY#40	0	32	362	607	829	1830
DLI#47	0	7	99	73	203	382
TAH#61	0	0	0	1	1241	1242
GDE#65	0	1	5	22	27	55
SSG#69	0	31	87	113	161	392
SLY#81	0	15	98	149	101	363
ODR#88	0	4	20	21	53	98
PVI#89	0	1	41	114	189	345
NCC#96	1	45	153	197	451	847
SCC#97	1	81	223	227	584	1116
PIH#101	0	152	272	533	919	1876
ACE#102	0	0	0	0	39	39
AAN#110	0	3	26	19	94	142
DME#130	0	0	0	0	3	3
ELY#145	0	10	63	202	265	540
NOP#149	0	7	25	23	24	79
SOP#150	0	3	22	44	21	90
EAU#151	0	15	71	74	123	283
NOC#152	0	2	4	7	9	22
SSC#161	0	9	5	27	16	57
NZC#164	0	143	602	617	1321	2683
SZC#165	0	32	108	131	324	595
JBO#170	0	0	5	3	36	44
ARI#171	0	6	19	34	40	99
JPE#175	0	43	254	351	690	1338
PHE#176	0	2	1	24	109	136
OCY#182	0	1	19	19	36	75
PAU#183	0	9	55	73	89	226
GDR#184	0	10	140	84	214	448
EUM#186	0	1	12	5	21	39
PCA#187	0	11	45	63	127	246
XRI#188	0	0	1	0	0	1
BPE#190	0	11	52	60	174	297
ERI#191	0	88	232	321	596	1237
UCE#194	0	51	108	168	320	647
BIN#195	0	0	1	6	5	12
AUD#197	0	176	464	582	806	2028
AUR#206	0	58	152	259	336	805
SPE#208	0	196	422	813	854	2285
BAU#210	0	84	267	304	512	1167
KLE#212	0	2	4	10	8	24
NPI#215	0	71	120	138	254	583
SPI#216	0	20	47	38	79	184
NDR#220	0	39	123	125	157	444
DSX#221	0	7	4	27	46	84
SOR#225	0	71	114	228	364	777
XDR#242	0	33	60	165	158	416
ZCN#243	0	2	2	13	10	27
NHD#245	0	13	39	127	101	280
AMO#246	0	25	30	41	81	177
NOO#250	1	396	489	1340	1590	3816
ALY#252	0	2	5	9	15	31
CMI#253	1	65	96	166	320	648
ORN#256	8	172	185	380	560	1305
ORS#257	3	279	385	759	1066	2492
OCT#281	0	27	11	57	159	254
FTA#286	0	51	39	89	295	474
DSA#288	3	46	69	74	228	420
DNA#289	0	20	23	144	113	300
TPU#307	0	1	0	6	12	19
PIP#308	1	28	32	62	119	242
MVE#318	0	15	27	52	96	190
JLE#319	0	0	9	7	25	41

Shower	2018	2019	2020	2021	2022	Total
OSE#320	0	1	1	2	1	5
LBO#322	0	0	6	16	40	62
XCB#323	0	0	26	48	69	143
EPR#324	0	1	13	3	13	30
EPG#326	0	12	63	94	127	296
SSE#330	0	2	3	0	8	13
AHY#331	1	30	100	130	367	628
OCU#333	0	51	72	182	194	499
DAD#334	5	271	419	1068	1139	2902
XVI#335	1	68	95	145	207	516
DKD#336	1	129	54	385	182	751
NUE#337	0	403	786	1543	2290	5022
OER#338	0	243	272	612	779	1906
PSU#339	0	45	37	178	105	365
TPY#340	2	41	74	114	256	487
XUM#341	0	0	28	40	66	134
HVI#343	0	18	189	28	29	264
FHE#345	0	2	31	69	134	236
XHE#346	0	6	50	100	152	308
BPG#347	0	0	1	8	5	14
ARC#348	0	12	92	112	262	478
LLY#349	0	0	3	7	8	18
JMC#362	0	9	37	92	111	249
PPS#372	0	111	572	662	1601	2946
ALN#376	0	4	11	22	34	71
OLP#384	0	24	21	64	72	181
OBC#386	0	37	49	93	196	375
CTA#388	0	145	141	439	481	1206
THA#390	3	50	107	193	254	607
NDD#391	0	2	2	13	6	23
NID#392	0	37	76	167	138	418
ACA#394	1	35	26	75	124	261
GCM#395	2	34	65	61	157	319
GUM#404	0	0	35	29	84	148
DPI#410	0	3	12	17	59	91
CAN#411	0	31	222	317	632	1202
SIC#416	0	5	46	76	54	181
SOL#424	0	29	99	127	297	552
FED#427	0	1	7	5	31	44
DSV#428	5	87	194	337	602	1225
ACB#429	0	6	28	21	132	187
JIP#431	0	3	17	10	67	97
ZCS#444	0	34	193	330	531	1088
KUM#445	0	30	81	192	153	456
DPC#446	0	24	17	102	86	229
AAL#448	0	2	11	14	30	57
AED#450	0	3	26	42	60	131
CAM#451	0	4	1	2	6	13
MPS#456	0	57	159	259	351	826
JEC#458	0	5	44	74	48	171
JEO#459	0	41	16	3	43	103
LOP#460	0	0	0	3	0	3
AXC#465	0	7	31	74	116	228
AOC#466	0	0	15	30	34	79
LAQ#473	0	16	34	36	58	144
ICE#476	0	9	38	27	34	108
TCA#480	0	131	149	395	634	1309
NZP#486	0	11	30	26	76	143
NSU#488	0	13	21	25	59	118
DEL#494	0	39	59	207	170	475
DAB#497	0	4	15	23	51	93
FPL#501	0	1	31	51	43	126
DRV#502	2	58	81	186	235	562
AIC#505	0	69	186	262	439	956
FEV#506	0	14	127	196	478	815
UAN#507	0	25	121	170	434	750
JRC#510	0	1	19	54	64	138
RPU#512	0	17	53	71	96	237
OMC#514	0	0	18	24	48	90
OLE#515	0	31	73	138	278	520
FMV#516	0	6	81	90	208	385
ALO#517	0	1	5	29	52	87
AHE#518	0	1	13	4	20	38
BAQ#519	0	8	12	41	79	140
MBC#520	0	5	23	44	41	113
AGC#523	0	31	94	133	270	528
LUM#524	0	19	14	91	135	259
SLD#526	0	18	26	104	93	241
EHY#529	4	88	144	315	390	941
ECV#530	0	6	45	83	206	340
GAQ#531	0	11	43	107	120	281
JXA#533	0	15	61	90	191	357
THC#535	0	0	4	9	18	31
FSO#536	0	1	1	2	5	9
TTB#543	0	4	7	7	19	37
JNH#544	0	3	25	17	81	126
XCA#545	0	2	6	9	36	53
FTC#546	0	17	86	95	115	313
KAP#547	0	92	368	564	1083	2107
FAN#549	0	5	75	79	152	311
PSO#552	0	61	183	388	471	1103
OCP#555	0	23	32	83	148	286
PTA#556	0	16	13	65	110	204
SFD#557	0	100	125	309	344	878
MCB#559	0	10	18	28	56	112
SSX#561	1	10	33	40	94	178
DOU#563	3	38	59	46	171	317
SUM#564	0	14	23	17	53	107
OHY#569	0	16	48	65	225	354
FBH#570	0	6	19	16	81	122

Shower	2018	2019	2020	2021	2022	Total
TSB#571	0	1	11	14	31	57
SAU#575	0	7	19	23	40	89
CHA#580	0	16	53	37	120	226
NHE#581	0	11	103	166	235	515
JBC#582	0	3	23	49	108	183
GCE#584	0	22	56	86	153	317
THY#585	1	9	24	38	78	150
FNC#587	0	6	18	33	60	117
FCA#589	0	13	38	66	115	232
VCT#590	0	1	5	2	9	17
ZBO#591	0	3	30	40	69	142
PON#592	0	3	9	16	24	52
TOL#593	0	17	26	80	96	219
RSE#594	0	0	3	2	3	8
POS#599	0	8	96	190	351	645
ICT#601	1	4	5	7	17	34
KCR#602	0	0	5	27	51	83
FAR#608	0	4	14	35	39	92
TLY#613	0	5	19	90	61	175
THD#618	0	1	5	7	26	39
XCS#623	0	33	123	134	309	599
XAR#624	0	214	330	288	676	1508
LTA#625	0	43	123	98	298	562
LCT#626	0	171	53	340	563	1127
NPS#627	0	79	37	239	293	648
STS#628	0	175	134	415	3472	4196
ATS#629	0	126	170	220	464	980
TAR#630	0	183	164	611	521	1479
DAT#631	0	192	63	449	656	1360
NET#632	0	54	138	344	141	677
PTS#633	2	75	52	172	172	473
TAT#634	0	150	256	267	682	1355
ATU#635	0	67	388	665	337	1457
MTA#636	0	59	25	177	112	373
FTR#637	0	69	95	236	515	915
DZT#638	2	10	11	37	40	100
AOA#640	0	123	413	479	768	1783
DRG#641	0	1	10	4	5	20
JLL#644	1	39	60	83	147	330
BCO#647	0	10	61	114	137	322
TAL#648	0	18	188	265	478	949
OAV#651	0	27	65	144	237	473
OSP#652	0	4	18	35	48	105
RLY#653	0	6	63	67	155	291
APC#655	0	1	2	3	6	12
GSG#657	0	1	6	16	13	36
EDR#658	0	2	27	35	54	118
EPS#660	0	3	21	50	36	110
OTH#661	0	1	17	35	49	102
MXA#664	0	0	0	1	1	2
MUC#665	0	3	30	42	55	130
JMP#668	0	2	20	22	41	85
MCY#671	0	0	5	11	22	38
HNJ#672	0	2	5	22	11	40
FCL#677	0	0	0	5	4	9
MUA#679	0	10	19	41	53	123
JEA#680	0	7	10	13	24	54
OAQ#681	0	4	19	21	28	72
JTS#683	0	0	8	6	4	18
JPS#685	0	3	11	5	38	57
JRD#686	0	1	3	8	20	32
KDP#687	0	1	7	4	5	17
TAC#689	0	17	64	46	151	278
ZCE#691	0	1	2	20	42	65
EQA#692	0	32	165	331	518	1046
ANP#693	0	23	55	93	200	371
OMG#694	0	59	130	219	317	725
APA#695	0	9	13	12	36	70
OAU#696	0	8	30	41	73	152
AET#698	0	4	40	47	84	175
BCE#701	0	2	10	8	23	43
ASP#702	0	1	9	7	13	30
OAN#704	0	53	191	281	408	933
ZPI#706	0	28	59	110	162	359
BPX#707	0	0	1	3	16	20
RLM#708	0	0	2	18	32	52
FDC#712	0	3	16	14	28	61
CCR#713	0	2	12	10	17	41
RPI#714	0	56	120	167	318	661
ACL#715	0	145	363	641	945	2094
OCH#716	0	43	56	145	213	457
NGB#720	0	8	3	19	21	51
DAS#721	0	12	10	42	25	89
FLE#722	0	16	16	73	49	154
LAP#724	0	0	0	0	1	1
DEG#726	3	15	35	6	81	140
ISR#727	1	4	6	1	19	31
PGE#728	0	8	8	5	35	56
DCO#729	0	2	10	3	17	32
ATV#730	0	1	11	3	7	22
FGV#732	0	4	17	24	43	88
MOC#734	0	1	14	15	18	48
XIP#736	0	2	6	14	33	55
FNP#737	0	2	7	11	30	50
RER#738	0	1	11	28	46	86
LAR#739	0	3	12	31	61	107
OSD#745	0	22	41	81	128	272
EVE#746	0	19	24	202	373	618
JKL#747	0	13	44	87	192	336
JTL#748	0	6	32	44	176	258

Shower	2018	2019	2020	2021	2022	Total
NMV#749	0	13	84	113	193	403
SMV#750	0	20	122	178	358	678
KCE#751	0	38	83	91	150	362
AAC#752	0	0	0	0	2	2
MID#755	0	0	5	8	19	32
CCY#757	0	19	508	48	56	631
VOL#758	0	0	0	2	0	2
ZPH#768	0	0	0	0	11	11
SCO#771	0	1	0	4	8	13
ILU#783	0	0	1	0	3	4
KVE#784	0	0	5	43	155	203
TCD#785	0	0	0	10	53	63
SXP#786	0	2	4	1	15	22
MBE#792	0	0	0	2	3	5
KCA#793	0	0	8	6	28	42
SED#796	0	19	9	62	97	187
EGR#797	0	0	0	4	17	21
ADS#802	0	2	14	15	29	60
LSA#803	0	5	11	43	68	127
FLO#807	0	11	100	130	176	417
XCD#810	0	29	16	57	116	218
NAA#812	0	6	19	22	36	83
CVD#814	0	1	11	9	55	76
UMS#815	0	1	10	9	20	40
CVT#816	0	2	15	19	34	70
OAG#818	0	9	11	13	24	57
NUT#822	0	0	4	9	19	32
FCE#823	0	14	33	39	82	168
DEX#824	0	2	16	12	34	64
XIE#825	0	10	11	22	19	62
ILI#826	0	9	52	60	134	255
NPE#827	0	1	17	25	42	85
TPG#828	0	0	1	1	3	5
JSP#829	0	6	19	28	43	96
SCY#830	0	3	40	24	69	136
GPG#831	0	4	9	21	33	67
LEP#832	0	4	5	9	29	47
KOR#833	0	10	8	20	37	75
ACU#834	0	1	1	6	5	13
JDP#835	0	0	0	1	0	1
ABH#836	0	0	2	7	18	27
CAE#837	0	2	0	2	20	24
ODS#838	0	2	0	5	2	9
PSR#839	0	1	9	19	21	50
TER#840	0	0	4	9	3	16
DHE#841	0	1	7	26	58	92
CRN#842	0	0	0	6	27	33
DMD#843	1	9	9	9	21	49
DTP#844	0	17	8	60	42	127
OEV#845	0	0	1	1	0	2

Shower	2018	2019	2020	2021	2022	Total
TSC#846	0	0	0	0	2	2
BEL#847	0	4	1	15	12	32
OPE#848	0	2	5	4	11	22
SZE#849	0	1	15	19	23	58
MBA#850	0	0	2	8	7	17
BEC#851	0	0	0	0	1	1
AST#852	0	0	0	0	5	5
ZPA#853	0	0	0	0	3	3
PCY#854	0	3	28	49	98	178
ATD#855	0	0	3	11	9	23
EMO#856	0	6	12	14	29	61
EVO#857	0	0	0	0	1	1
FPB#858	0	8	34	36	163	241
MTB#859	0	2	8	22	49	81
PAN#860	0	0	4	14	32	50
JXS#861	0	3	7	3	7	20
SSR#862	0	1	12	28	62	103
TLR#863	0	0	5	12	13	30
JSG#864	0	0	1	9	9	19
JES#865	0	4	5	6	16	31
ECB#866	0	2	7	12	12	33
FPE#867	0	3	8	3	38	52
PSQ#868	0	1	4	2	8	15
UCA#869	0	0	16	8	28	52
JPG#870	0	0	12	9	13	34
DCD#871	0	0	6	5	11	22
ETR#872	0	1	10	15	29	55
OMI#873	0	3	7	12	18	40
PXS#874	0	8	36	38	60	142
TEI#875	0	12	11	25	40	88
ROR#876	0	9	11	15	35	70
OHD#877	0	6	9	26	29	70
OEA#878	0	3	4	4	8	19
ATI#879	0	6	8	26	39	79
YDR#880	0	16	22	45	74	157
TLE#881	0	3	1	15	17	36
PLE#882	0	3	8	9	14	34
NMD#883	0	1	6	3	0	10
NBP#884	0	0	3	2	17	22
DEV#885	0	4	12	8	20	44
ACV#886	2	2	7	18	63	92
DZB#887	0	7	12	10	23	52
SCV#888	0	0	2	7	8	17
YOP#889	0	0	1	2	8	11
ESU#890	0	1	3	5	8	17
FSL#891	0	6	30	29	90	155
MCN#892	0	0	0	3	9	12
EOP#893	0	0	21	37	59	117
JMD#894	0	3	18	25	21	67
OAB#895	0	0	0	1	3	4

Shower	2018	2019	2020	2021	2022	Total
OTA#896	0	8	20	12	48	88
OUR#897	0	9	2	22	27	60
SGP#898	0	5	12	24	10	51
EMC#899	0	1	0	5	20	26
BBO#900	0	2	28	61	173	264
TLC#901	0	1	5	5	15	26
DCT#902	0	11	18	30	48	107
OAT#903	0	8	13	9	25	55
OCO#904	0	2	4	13	6	25
MXD#905	0	0	4	8	6	18
ETD#906	0	4	26	22	59	111
MCE#907	0	0	8	19	27	54
SEC#909	0	0	1	6	6	13
BTC#910	0	3	30	24	63	120
TVU#911	0	3	18	39	75	135
BCY#912	0	0	30	58	77	165
FVI#913	0	0	0	0	1	1
AGE#914	0	0	3	0	2	5
DNO#915	0	0	0	2	2	4
ATH#916	0	0	0	0	4	4
OVI#917	0	1	1	2	1	5
TAG#918	0	4	7	14	32	57
ICN#919	0	0	1	1	3	5
XSC#920	0	5	10	28	47	90
JLC#921	0	3	21	8	27	59
PPE#922	0	1	2	2	9	14
FBO#923	0	0	1	1	5	7
SAN#924	0	1	3	21	5	30
EAN#925	0	3	3	3	15	24
OMH#926	0	0	0	1	2	3
ARD#1130	0	0	0	6	0	6
OZP#1131	0	0	0	14	8	22
	497	50263	125095	211788	334668	722311

5 Joining the Global Meteor Network

More information about this project can be found in Vida et al. (2019; 2020; 2021; 2022) and on the GMN website[10]. A nice video presentation about the Global Meteor Network project can be watched online[11]. Many sites and participants are still waiting to find partners to improve the coverage on their cameras. New participants are welcome to expand the network.

To obtain a camera for participation you can either buy it plug&play from Istream[12], or you buy the components and build your own camera for about 250 US$ or ~200 €. The RMS cameras are easy to build and operate. If you are interested in building your own camera you can find detailed instructions online[13].

The daily status of most (not all) meteor stations can be followed on a webpage[14]. The GMN results and data are publicly available and daily updated online[15]. The British UKMON maintains a nice archive[16] and daily update[17] which may inspire others. Their Wiki-page[18] may be helpful to people outside the UK as well as their github repos[19,20].

The meteor map[21] is an online tool for visualizing meteor cameras and ground tracks of observed meteors. Each participant can check the results obtained with each camera, check the location of the meteor trajectories and combinations with other camera stations. The tool has been described in an article (Dijkema, 2022).

As the static maps of camera FoVs presented in this report sometimes become overcrowded, the aggregated kml files valid for end of 2022 can be downloaded[22]. The individual up-to-date kml-files for all GMN cameras can be downloaded from the GMN website[23]. Camera operators are encouraged to point new cameras in function of optimal coverage with other cameras. Opening the kml files in Google Earth allows to toggle cameras on and off to get a better view on the actual coverage. Make sure to compare kml files at the same elevation (e.g. 100km) and prevent 3D perspective by changing the properties in the Google Earth graphical interface to "clamped to ground" instead of the default setting "absolute". A handy tool to check overlap between two cameras is available online[24].

If you have a dark site with a free view and if you are looking to make a scientifically useful contribution, with just 5 RMS cameras with 3.6 mm lenses (FoV 88° × 47°) pointed at azimuths 0° (North), 70°, 140°, 220° and 290°, between 35° and 40° elevation, you cover all the sky except your zenith. Avoid pointing a camera at the meridian (180° azimuth) as the transit of the Full Moon will take full effect in this position. Also do not point lower than 35° elevation: there are no meteors in the local scenery, trees or buildings. If you use 6 mm lenses, recommended where light pollution is an issue, you need 6 RMS to cover the sky with a royal overlap between the camera edges. 6 cameras with 6 mm lenses (FoV 54° × 30°) pointed at azimuths 30°, 90°, 150°, 210°, 270° and 330°, between 35° and 40° elevation, would make you a key video meteor hub in the network. Building the cameras at the cost of the purchased components, or

---

[10] https://globalmeteornetwork.org/
[11] https://www.youtube.com/watch?v=MAGq-XqD5Po
[12] https://globalmeteornetwork.org/?page_id=136
[13] https://globalmeteornetwork.org/wiki/index.php?title=Build_A_Camera
[14] http://istrastream.com/rms-gmn/
[15] https://globalmeteornetwork.org/data/
[16] https://archive.ukmeteornetwork.co.uk/
[17] https://ukmeteornetwork.co.uk/live/#/
[18] https://github.com/markmac99/ukmon-pitools/wiki
[19] https://github.com/markmac99/ukmon-pitools
[20] https://github.com/markmac99/UKmon-shared
[21] https://tammojan.github.io/meteormap/
[22] https://meteornews.s3-eu-central-1.amazonaws.com/downloads/kml_files_2022.zip
[23] https://globalmeteornetwork.org/data/kml_fov/
[24] http://www.davesamuels.com/cams/campointing/scripts/latlong.html

bought plug&play, both remain a low-cost project, affordable to many amateurs, observatories and societies.

Acknowledgment

This report is based on the data of the Global Meteor Network which is released under the CC BY 4.0 license[25]. We thank all the participants in the Global Meteor Network project for their contribution and perseverance, operators whose cameras provided the data used in this work and contributors who made important code contributions The Global Meteor Network results were obtained thanks to the efforts of the following volunteers: *Richard Abraham, Victor Acciari, Jorge Acosta Bermúdez Augusto, Rob Agar, Salvador Aguirre, Yohsuke Akamatsu, David Akerman, Daknam Al-Ahmadi, Jonathan Alexis Valdez Aguilar, Jamie Allen, Asociación Alta De Astronomía De Marina, Edison Álvarez José Felipe Pérezgómez, Alexandre Alves, Don Anderson, Željko Andreić, Martyn Andrews, Miguel Angel Diaz, Enrique Arce, Georges Attard, David Attreed, Chris Baddiley, Erwin van Ballegoij, David Bailey, Roger Banks, Hamish Barker, Jean-Philippe Barrilliot, Alejandro Barriuso, Ricky Bassom, Richard Bassom, Alan Beech, Dennis Behan, Ehud Behar, Josip Belas, Alex Bell, Florent Benoit, Denis Bergeron, Serge Bergeron, Steve Berry, Adrian Bigland, Jim Blackhurst, Chris Blake, Thomas Blog, Arie Blumenzweig, Ventsislav Bodakov, Claude Boivin, Robin Boivin, Bruno Bonicontro, Mia Boothroyd, Fabricio Borges, Ubiratan Borges, Dorian Božičević, David Brash, Stuart Brett, Ed Breuer, Martin Breukers, John W. Briggs, Gareth Brown, Peter G. Brown, Nial Bruce, Laurent Brunetto, Tim Burgess, Jon Bursey, Yong-Ik Byun, Ludger Börgerding, Sylvain Cadieux, Peter Campbell-Burns, Andrew Campbell-Laing, Pablo Canedo, Seppe Canonaco, Jose Carballada, Daniela Cardozo Mourão, Steve Carter, David Castledine, Gilton Cavallini, Brian Chapman, Jason Charles, Zhuoyang Chen, Matt Cheselka, Tim Claydon, Trevor Clifton, Manel Colldecarrera, Michael Cook, Bill Cooke, Christopher Coomber, Brendan Cooney, Tim Cooper, Edward Cooper, Andrew Cooper, Jamie Cooper, Marc Corretgé Gilart, Paul Cox, Llewellyn Cupido, Christopher Curtis, Ivica Ćiković, Dino Čaljkušić, Chris Dakin, Fernando Dall'Igna, Alfredo Dal'Ava Júnior, James Davenport, Richard Davis, Steve Dearden, Christophe Demeautis, Bart Dessoy, Pat Devine, Paul Dickinson, Ivo Dijan, Pieter Dijkema, Marcelo Domingues, Stacey Downton, Stewart Doyle, Zoran Dragić, Iain Drea, John Drummond, Igor Duchaj, Jean-Paul Dumoulin, Garry Dymond, Jürgen Dörr, Robin Earl, Howard Edin, Raoul van Eijndhoven, Ollie Eisman, Carl Elkins, Peter Eschman, Bob Evans, Nigel Evans, Bev M. Ewen-Smith, James Farrar, Seraphin Feller, Andres Fernandez, Louw Ferreira, Andrew Fiamingo, Barry Findley, Rick Fischer, Richard Fleet, Jim Fordice, Kyle Francis, Jean Francois Larouche, Patrick Franks, Stefan Frei, Gustav Frisholm, Pierre Gamache, Enrique Garcilazo Chávez, José García María, Mark Gatehouse, Ivan Gašparić, Chris George, Megan Gialluca, Kevin Gibbs-Wragge, Jason Gill, Philip Gladstone, Roel Tim Gloudemans Gloudemans, Uwe Glässner, Chuck Goldsmith, Hugo González, Nikola Gotovac, Colin Graham, Pete Graham, Ian Graham Enting, Neil Graham, Sam Green, Bob Greschke, Stephen Grimes, Daniel J. Grinkevich, Larry Groom, Perth Group Observatory Volunteer, Dominique Guiot, Tioga Gulon, Margareta Gumilar, Peter Gural, Nikolay Gusev, Kees Habraken, Alex Haislip, John Hale, Peter Hallett, Graeme Hanigan, Erwin Harkink, Ed Harman, Marián Harnádek, Ryan Harper, David Hatton, Tim Havens, Paul Haworth, Mark Haworth, Richard Hayler, Andrew Heath, Sam Hemmelgarn, Rick Hewett, Lee Hill, Nicholas Hill, Don Hladiuk, Alex Hodge, Simon Holbeche, Jeff Holmes, Steve Homer, Matthew Howarth, Nick Howarth, Jeff Huddle, Bob Hufnagel, Roslina Hussain, Jan Hykel, Anatoly Ijon, Russell Jackson, Jean-Marie Jacquart, Jost Jahn, Tihomir Jakopčić, Chris James, Rick James, Ron James Jr, Phil James, Nick James, Tammo Jan Dijkema, Ilya Jankowsky, Alex Jeffery, Klaas Jobse, Richard Johnston, Dave Jones, Fernando Jordan, Romulo Jose, Vladimir Jovanović, Javor Kac, Richard Kacerek, Milan Kalina, Jonathon Kambulow, Steve Kaufman, Scott Kaufmann, Paul Kavanagh, Ioannis Kedros, Jürgen Ketterer, Alex Kichev, Harri Kiiskinen, Jean-Baptiste Kikwaya, Sebastian Klier, Dan Klinglesmith, John Kmetz, Zoran Knez, Korado Korlević, Stanislav Korotkiy, Danko Kočiš, Josip Krpan, Zbigniew Krzeminski, Patrik Kukić, Reinhard Kühn, Remi Lacasse, Gaétan Laflamme, Steve Lamb, Hervé Lamy, Jean Larouche Francois, Ian Lauwerys, Peter Lee, Hartmut Leiting, Damien Lemay, David Leurquin, Gareth Lloyd, Rob Long De Corday, Robert Longbottom, Jose Lopez Galindo, Eric Lopez, Paul Ludick, Juan Luis Muñoz, José Luis Martin, Pete Lynch, Frank Lyter, Guy Létourneau, Anton Macan, Jonathan Mackey, John Maclean, Igor Macuka, Nawaz Mahomed, Simon Maidment, Mirjana Malarić, Nedeljko Mandić, Alain Marin, Bob Marshall, Colin Marshall, Gavin Martin, Andrei Marukhno, Keith Maslin, Nicola Masseroni, Bob Massey, Jacques Masson, Damir Matković, Filip Matković, Dougal Matthews, Michael Mazur, Sergio Mazzi, Stuart McAndrew, Lorna McCalman, Alex McConahay, Mason McCormack, Charlie McCormack, Robert McCoy, Vincent McDermott, Tommy McEwan, Mark McIntyre, Peter McKellar, Peter Meadows, Edgar Merizio Mendes, Aleksandar Merlak, Horst Meyerdierks, Filip Mezak, Pierre-Michael Micaletti, Greg Michael, Luciano Miguel Diniz, Matej Mihelčić, Simon Minnican, Wullie Mitchell, Georgi Momchilov, Dean Moore, Edson Morales Valencia, Nelson Moreira, Kevin Morgan, Roger Morin, Nick Moskovitz, Dave Mowbray, Andrew Moyle, Gene Mroz, Muhammad Muharam Luqmanul Hakim, Brian Murphy, Carl Mustoe, Przemek Nagański, Jean-Louis Naudin, Damjan Nemarnik, Attila Nemes, Dave Newbury, Colin Nichols, Nick Norman, Philip Norton, Zoran Novak, Gareth Oakey, Washington Oliveira, Jorge Oliveira, Angélica Olmos López, Jamie Olver, Christine Ord, Nigel Owen, Michael O'Connell, Dylan O'Donnell, Thiago Paes, Carl Panter, Neil Papworth, Filip Parag, Gary Parker, Ian Parker, Simon Parsons, Ian Pass, Igor Pavletić, Lovro Pavletić, Richard Payne, Pierre-Yves Pechart, Holger*

---

[25] https://creativecommons.org/licenses/by/4.0/

Pedersen, Eduardo del Peloso Fernandez, William Perkin, Enrico Pettarin, Alan Pevec, Mark Phillips, Alan Pickwick, Anthony Pitt, Patrick Poitevin, Tim Polfliet, Renato Poltronieri, Pierre de Ponthière, Derek Poulton, Janusz Powazki, Aled Powell, Alex Pratt, Miguel Preciado, David Price, Nick Primavesi, Paul Prouse, Paul Pugh, Chuck Pullen, Terry Pundiak, Lev Pustil'Nik, Dan Pye, Nick Quinn, Chris Ramsay, David Rankin, Steve Rau, Mike Read, Dustin Rego, Chris Reichelt, Danijel Reponj, Fernando Requena, Maciej Reszelsk, Ewan Richardson, Martin Richmond-Hardy, Mark Robbins, Martin Robinson, David Robinson, Heriton Rocha, Herve Roche, Paul Roche, Adriana Roggemans, Paul Roggemans, Alex Roig, David Rollinson, Marthinus Roos, Andre Rousseau, Jim Rowe, Nicholas Ruffier, Nick Russel, Dmitrii Rychkov, Robert Saint-Jean, Michel Saint-Laurent, Clive Sanders, Jason Sanders, Ivan Sardelić, Simon Saunders, Rob Saunders, John Savage, Lawrence Saville, Vasilii Savtchenko, Philippe Schaak, William Schauff, Ansgar Schmidt, Thomas Schmiereck, Geoff Scott, James Scott, Yfore Scott, Jim Seargeant, Jay Shaffer, Steven Shanks, Mike Shaw, Jamie Shepherd, Angel Sierra, Ivo Silvestri, François Simard, Noah Simmonds, Nikos Sioulas, Ivica Skokić, Ian A. Smith, Dave Smith, Ned Smith, Tracey Snelus, Costa Society Blanca Astronomical, Germano Soru, Warley Souza, Jocimar de Souza Justino, Mark Spink, Denis St-Gelais, James Stanley, Radim Stano, Laurie Stanton, Robert D. Steele, Yuri Stepanychev, Graham Stevens, Thomas Stevenson, Richard Stevenson, Peter Stewart, William Stewart, Paul Stewart, Con Stoitsis, Andrea Storani, Andy Stott, David Strawford, Claude Surprenant, Rajko Sušanj, Bela Szomi Kralj, Damir Šegon, Marko Šegon, René Tardif, Jeremy Taylor, Yakov Tchenak, John Thurmond, Steven Tilley, Stanislav Tkachenko, Christopher Tofts, Eric Toops, Torcuill Torrance, Steve Trone, Wenceslao Trujillo, John Tuckett, Sofia Ulrich, Myron Valenta, Jean Vallieres, Paraksh Vankawala, Neville Vann, Marco Verstraaten, Arie Verveer, Jochen Vollsted, Predrag Vukovic, Martin Walker, Aden Walker, Bill Wallace, John Waller, Jacques Walliang, Didier Walliang, Christian Wanlin, Tom Warner, Andrew Washington, Neil Waters, Steve Welch, Tobias Westphal, Tosh White, Alexander Wiedekind-Klein, John Wildridge, Phillip Wilhelm Maximilian Grammerstorf, Ian Williams, Mark Williams, Guy Williamson, Graham Winstanley, Urs Wirthmueller, Jan Wisniewski, Bill Witte, Jeff Wood, Martin Woodward, Jonathan Wyatt, Anton Yanishevskiy, Penko Yordanov, Stephane Zanoni, Bob Zarnke, Pető Zsolt, Dario Zubović, Marcelo Zurita (list established 27 February 2023).

The cameras in Dourbes and Humain (Belgium) have been funded by STCE (Solar Terrestrial Center of Excellence[26]).

References

Dijkema T. J. (2022). "Visualizing meteor ground tracks on the meteor map". *eMetN*, **7**, 73–75.

Drummond J. D. (1981). "A test of comet and meteor shower associations". *Icarus*, **45**, 545–553.

Gural P. and Šegon D. (2009). "A new meteor detection processing approach for observations collected by the Croatian Meteor Network (CMN)". *WGN, the Journal of the IMO*, **37**, 28–32.

Jenniskens P., Gural P. S., Grigsby B., Dynneson L., Koop M. and Holman D. (2011). "CAMS: Cameras for All-sky Meteor Surveillance to validate minor meteor showers". *Icarus*, **216**, 40–61.

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

Jenniskens P., Jopek T.J., Janches D., Hajduková M., Kokhirova G.I., Rudawska R. (2020). "On removing showers from the IAU Working List of Meteor Showers". *Planetary and Space Science*, **182**, id. 104821.

Jopek T. J. (1993). "Remarks on the meteor orbital similarity D-criterion". *Icarus*, **106**, 603–607.

Jopek T. J. and Jenniskens P. M. (2011). "The Working Group on Meteor Showers Nomenclature: A History, Current Status and a Call for Contributions". In Meteoroids: The Smallest Solar System Bodies, *Proceedings of the Meteoroids Conference* held in Breckenridge, Colorado, USA, May 24-28, 2010. Edited by W.J. Cooke, D.E. Moser, B.F. Hardin, and D. Janches, NASA/CP-2011-216469., 7–13.

Jopek T. J. and Kaňuchová Z. (2017). "IAU Meteor Data Center - the shower database: A status report". *Planetary and Space Science*, **143**, 3–6.

Moorhead A. V., Clements T. D., Vida D. (2020). "Realistic gravitational focusing of meteoroid streams". *Monthly Notices of the Royal Astronomical Society*, **494**, 2982–2994.

Mroz E. J. (2021). "Optimizing Camera Orientation for the New Mexico Meteor Array". eMetN, 6, 562–567.

Neslušan L., Poručan V., Svoreň J., Jakubík M. (2020). "On the new design othe IAU MDC portal". *WGN, Journal of the International Meteor Organization*, **48**, 168–169.

Roggemans P., Vida D., Šegon D. (2022). "Global Meteor Network report 2021". *eMetN*, **7**, 76–91.

---

[26] https://www.stce.be

Southworth R. R. and Hawkins G. S. (1963). “Statistics of meteor streams”. *Smithson. Contrib. Astrophys.*, **7**, 261–286.

Vida D., Zubović D., Šegon D., Gural P. and Cupec R. (2016). “Open-source meteor detection software for low-cost single-board computers”. In: Roggemans A. and Roggemans P., editors, *Proceedings of the International Meteor Conference*, Egmond, the Netherlands, 2-5 June 2016. International Meteor Organization, pages 307–318.

Vida D., Gural P., Brown P., Campbell-Brown M., Wiegert P. (2019). “Estimating trajectories of meteors: an observational Monte Carlo approach - I. Theory”. *Monthly Notices of the Royal Astronomical Society*, **491**, 2688–2705.

Vida D., Gural P., Brown P., Campbell-Brown M., Wiegert P. (2020). “Estimating trajectories of meteors: an observational Monte Carlo approach - II. Results”. *Monthly Notices of the Royal Astronomical Society*, **491**, 3996–4011.

Vida D., Šegon D., Gural P. S., Brown P. G., McIntyre 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.

Vida D., Blaauw Erskine R. C., Brown P. G., Kambulow J., Campbell-Brown M., Mazur M. J. (2022). “Computing optical meteor flux using global meteor network data”. *Monthly Notices of the Royal Astronomical Society*, **515**, 2322–2339.

Zubović D., Vida D., Gural P. and Šegon D. (2015). “Advances in the development of a low-cost video meteor station”. In: Rault J.-L. and Roggemans P., editors, *Proceedings of the International Meteor Conference*, Mistelbach, Austria, 27-30 August 2015. International Meteor Organization, pages 94–97.

December 2022 report CAMS-BeNeLux

Carl Johannink

Am Ollenkamp 4, 48599 Gronau, Germany
`c.johannink@t-online.de`

A summary of the activity of the CAMS-BeNeLux network during the month of December 2022 is presented. This month we collected a total of 26326 multi-station meteors resulting in 7680 orbits.

1 Introduction

Only under specific favorable circumstances the BeNeLux region can count on a longer series of clear nights in December. Meteor activity is very high this month, due to high sporadic activity and the visibility of meteoroid streams like the Geminids and the Ursids. Especially during clear nights during the Geminid maximum, this shower can produce large numbers of simultaneous meteors in our network. But chances for clear weather in this time of the year are rather low. However, it is interesting to see what this month has brought us.

2 December 2022 statistics

December started with gloomy conditions, as can be expected for our regions. Only 130 orbits could be collected during the first week, despite at least 74 cameras were active every night during this period.

But then the weather above western Europe evolved to a more winterly pattern, with clear skies most of the time around the Geminid maximum at December 13–14. Hence, it is no surprise that we could collect a large number of orbits then.

On December 14–15, 1743 orbits, and on December 12–13, 1946 orbits were recorded. The last number is an all-time record in the history of our network. During the maximum night, observations in the more southern parts of the BeNeLux were hampered by clouds. Despite the maximum activity of the Geminids, this night resulted in a drop-off to about ~700 orbits.

After this remarkable period, weather picked up the normal pattern, with more or less only clear spells during the nights. Only December 26–27 and 29–30 were completely clear nights. As a result, we could collect around 500 orbits during both nights.

On December 2–3, 4–5, 18–19 and 30–31 the skies remained completely cloudy over all of the BeNeLux. This month CAMS-BeNeLux collected a total of 26326 multi station meteors, resulting in 7680 orbits. 58% of all orbits were collected by at least 3 stations. Once again, like in October and November, this emphasizes good coverage of the skies over the BeNeLux. The network has been still expanding its number of cameras and participants.

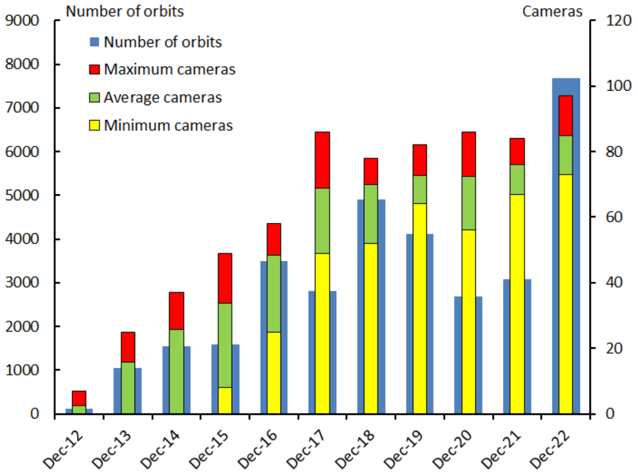


Figure 1 – Comparing December 2022 to previous months of December in the CAMS-BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras capturing in a single night, the green bars the average number of cameras capturing per night and the yellow bars the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

Table 1 – Number of orbits and active cameras in the BeNeLux during the month December for the period 2012–2022.

Year	Nights	Orbits	Stations	Max. Cams	Min. Cams	Mean Cams
2012	12	117	6	7	–	2.4
2013	23	1053	10	25	–	15.7
2014	19	1540	14	37	–	25.8
2015	27	1589	15	49	8	33.8
2016	25	3492	21	58	25	48.3
2017	25	2804	22	86	49	68.9
2018	23	4908	21	78	52	69.8
2019	28	4124	21	82	64	72.8
2020	24	2693	24	86	56	72.4
2021	25	3072	25	84	67	76.0
2022	27	7680	31	97	73	84.8
Total	258	33072				

Steve Rau installed a new RMS camera (3840) at the Observatory “Armand Pien” in Gent. This camera will be operated by *Tim Polfliet* as soon as everything works smoothly. In Luxemburg we could welcome a new station at the capital of this country. *Jan Thoemel* operates CAMS 3950 since December 13 and in the future CAMS 3951 will become operational.

At Winterswijk Woold *Hans Betlem* and the author added 5 Watecs to this station. A first step to increase the numbers of orbits from this part of the BeNeLux.

The mean number of active cameras this month was 84.8. At 31 stations at least 73 cameras were active every night this month. The highest number of active cameras was 97 on December 29–30. These numbers can be compared with last month. See *Figure 1* and *Table 1*.

3 Conclusion

The results for December 2022 are the best in the 11 years of the existence of the CAMS-BeNeLux network.

Acknowledgment

Many thanks to all operators in the CAMS BeNeLux network for their work and quick delivery of data. In December 2022 the CAMS-BeNeLux network was operated by the following volunteers:

Hans Betlem (Woold, Netherlands, CAMS 3071, 3072, 3073, 3074, 3075, 3076, 3077 and 3078), *Jean-Marie Biets* (Wilderen, Belgium, CAMS 379, 380, 381 and 382), *Ludger Boergerding* (Holdorf, Germany, RMS 3801), *Günther Boerjan* (Assenede, Belgium, RMS 3823), *Martin Breukers* (Hengelo, Netherlands, CAMS 320, 321, 322, 323, 324, 325, 326 and 327, RMS 319, 328 and 329), *Seppe Canonaco* (Genk, RMS 3818 and 3819), *Pierre de Ponthiere* (Lesve, Belgium, RMS 3816 and 3826), *Bart Dessoy* (Zoersel, Belgium, CAMS 804, 805 and 806), *Tammo Jan Dijkema* (Dwingeloo, Netherlands, RMS 3199), *Isabelle Ansseau, Jean-Paul Dumoulin, Dominique Guiot* and *Christian Walin* (Grapfontaine, Belgium, CAMS 814 and 815, RMS 3814 and 3817), *Uwe Glässner* (Langenfeld, Germany, RMS 3800), *Luc Gobin* (Mechelen, Belgium, CAMS 3890, 3891, 3892 and 3893), *Tioga Gulon* (Nancy, France, CAMS 3900 and 3901), *Robert Haas* (Alphen aan de Rijn, Netherlands, CAMS 3160, 3161, 3162, 3163, 3164, 3165, 3166 and 3167), *Robert Haas* (Texel, Netherlands, CAMS 811), *Kees Habraken* (Kattendijke, Netherlands, RMS 3780 and 3781), *Klaas Jobse* (Oostkapelle, Netherlands, CAMS 3030, 3031, 3032, 3033, 3034, 3035, 3036 and 3037), *Carl Johannink* (Gronau, Germany, CAMS 3100, 3101, 3102), *Reinhard Kühn* (Flatzby, Germany, RMS 3802), *Hervé Lamy* (Dourbes, Belgium, CAMS 395, RMS 3825), *Hervé Lamy* (Humain, Belgium, RMS 3821 and 3828), *Hervé Lamy* (Ukkel, Belgium, CAMS 393), *Koen Miskotte* (Ermelo, Netherlands, CAMS 3051, 353 and 354), *Pierre-Yves Péchart* (Hagnicourt, France, RMS 3902 and 3903), *Tim Polfliet* (Gent, Belgium, CAMS 396, RMS 3820 and 3840), *Steve Rau* (Zillebeke, Belgium, CAMS 3850 and 3852, RMS 3851 and 3853), *Paul and Adriana Roggemans* (Mechelen, Belgium, RMS 3830 and 3831, CAMS 3832, 3833, 3834, 3835, 3836 and 3837), *Jim Rowe* (Eastbourne, Great Britain, RMS 3829), *Philippe Schaack* (Roodt-sur-Syre, Luxemburg, RMS 3952), *Hans Schremmer* (Niederkruechten, Germany, CAMS 803), *Jan Thoemel* (Luxemburg, Luxemburg, CAMS 3950), *Erwin van Ballegoij* (Heesh, Netherlands CAMS 3148 and 3149).

Annual report 2022 CAMS-BeNeLux

Carl Johannink

Am Ollenkamp 4, 48599 Gronau, Germany
`c.johannink@t-online.de`

A summary of the activity of the CAMS-BeNeLux network during the year 2022 is presented. The year 2022 brought in general good conditions for astronomical observations. The best months were the months August and October. 61616 orbits could be collected during 345 different nights which corresponds to 94.5% of all 365 nights in 2022. The months March, July, August, October and December had the best scores ever for these months since the start of the network in 2012.

1 Introduction

The CAMS-BeNeLux network existed ten years in March 2022. After a strong growth of the network, especially in the years 2014 to 2017, the number of cameras and the number of participating camera stations has been quite stable since then. Some stations have stopped; others were added. In addition to the traditional Watecs H2 Ultimate, many RMS devices have been added to the network in recent years.

This year also saw the start of observations from two camera stations in Luxemburg, *Philippe Schaack* (Roodt-sur-Syre) participated with an RMS-camera since October, and *Jan Thoemel* (Luxemburg) participated with two Watecs since December. This means the network can now be called a real, BeNeLux-network. The number of cameras in France doubled when *Pierre-Yves Péchart* started to participate in August with two RMS-cameras in our network. Also, one camera station in England is participating now. *Jim Rowe* (Eastbourne, UK) is contributing with one RMS to the CAMS-BeNeLux network since June 2022.

Figure 1 – The locations of the sites participating in CAMS-BeNeLux in 2022. Most camera stations in the southern part are equiped with RMS cameras.

2 CAMS BeNeLux 2022 statistics

During the first two months we have had unstable variable weather. Clear nights were many times alternated with cloudy nights. As a consequence, the results for the months January and February were fairly average. Towards the end of February, the weather became more and more stable. These circumstances remained more or less stable for the rest of the year. As a consequence, results for each month from March until December were always one of the best in 10 years since the start of our network. *Table 1* shows that a record number of orbits has been collected in March, July, August, October and December. Especially August with ~14000 orbits caught attention (*Table 1*).

Table 1 – Overview of the number of orbits during each month of 2012, and the ranking of this month since 2012.

Month	#Orbits	Ranking
January 2022	1744	5th
February 2022	1939	4th
March 2022	3189	1st
April 2022	2543	3rd
May 2022	2160	3rd
June 2022	2228	2nd
July 2022	4499	1st
August 2022	14807	1st
September 2022	5446	3rd
October 2022	9749	1st
November 2022	5635	2nd
December 2022	7680	1st
Total 2022	61619	1st

In total, we have collected 61619 orbits, a new record (*Table 2*, *Figure 2*). It should be no surprise that the year 2022 was the sunniest year since the start of the measurements in 1901 (*Table 3*). Approximately 2200 hours of sunshine are normal for regions near Lyon in southern France, but this exceeds the normal amount of sunshine in our regions (~1700 hours) with more than 25%.

Table 2 – Number of orbits obtained by CAMS-BeNeLux since 2012.

Year	#Orbits
2012	1079
2013	5684
2014	11288
2015	17259
2016	25187
2017	35591
2018	49627
2019	42746
2020	45743
2021	45985
2022	61619
Total	341808

Table 3 – The sunniest years since 1901.

Year	Sunshine (hours)
2022	2208.7
2018	2044.9
2003	2021.7
1959	1986.1
2020	1957.6

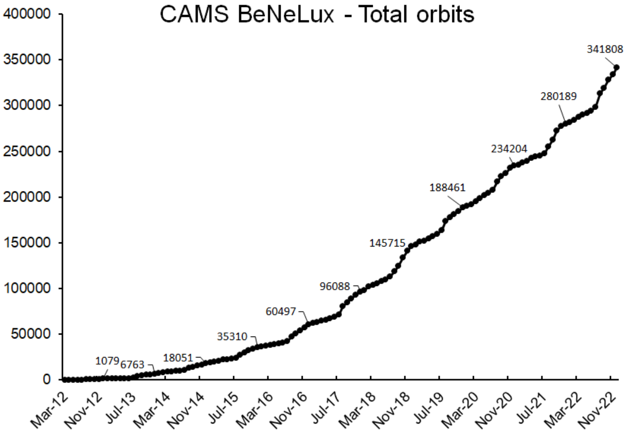


Figure 2 – The cumulative total number of orbits collected by CAMS-BeNeLux since 2012. Note the steep increase in the last months of 2022.

For our network, one of the most striking points was that we could collect orbits in every night between May 27 and October 12: a consecutive period of 139 nights with results!

During as few as 20 nights no orbits were obtained at all this year. So, we have achieved results in 94.5% of all nights in 2022. After a strong built-up of the network in 2017, we could collect orbits in ~89% of all nights in the years since then. This is a surprisingly high number, which means that our climate isn't that bad as is often thought (*Figure 3*). Of course, one can only draw this conclusion if the cameras are functioning 7 nights on 7.

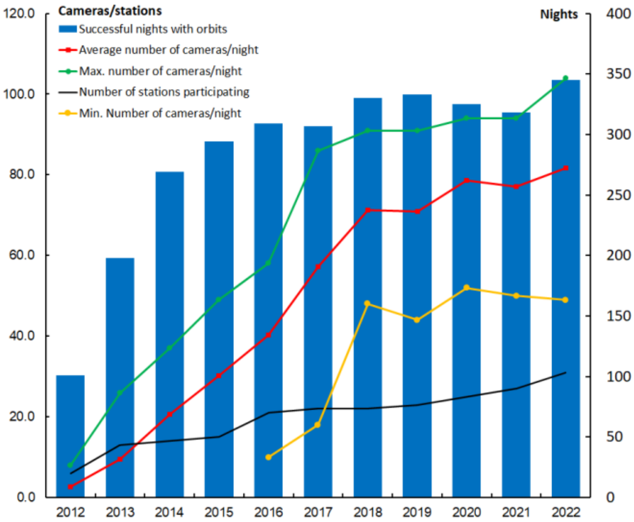


Figure 3 – The number of successful nights with orbits for each year (blue bars, right axis), the evolution of the minimum, average, maximum number of cameras and number of participating stations per year (left axis).

After a bit more than 10 years since the start of our network, we can conclude that expectations have been exceeded. As an example, the aim was to collect 100 orbits in every night of the year. Now, we see in *Table 4* that this is achieved in all nights except January 23–24.

On the other hand, we have collected more than 1000 orbits in more than 100 nights already (*Table 4*). "Expectations are exceeded" then looks like an understatement. Of course, it is no coincidence that during the activity of the Perseids and Geminids the number of orbits reaches the highest numbers. Unfortunately, a few stations in the northern parts of the Netherlands suffered technical problems most of the year, otherwise results could have been even better.

3 CAMS worldwide

CAMS is a global project in which different networks around the world participate all using the same software. Results for all networks are given in *Table 5*. CAMS-BeNeLux contributed almost 12% of the total score for 2022.

Since the start of the network 2500000 orbits were collected worldwide, of which 341808 orbits or 13.7% by CAMS-BeNeLux.

We are looking forward to the year 2023. Not only thinking of what kind of surprises this year may bring, but also because CAMS results up to spring 2021 will be published. These results are the content for a new book by Peter Jenniskens. (Jenniskens, 2023).

Table 4 – Cumulated daily tally with the total number of orbits obtained by CAMS-BeNeLux for each calendar date, period 2012–2022.

TOTAL	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26	26-27	27-28	28-29	29-30	30-31	31-01	
January	137	551	1382	537	571	316	607	556	406	302	143	237	353	265	460	329	640	676	867	984	580	178	28	162	242	243	237	244	407	296	147	13083
February	112	251	469	437	428	607	226	241	184	411	648	1109	948	480	933	418	625	468	134	566	646	700	862	1104	673	842	1065	374	169			16130
March	330	486	410	456	508	524	557	442	394	442	402	435	330	258	320	277	448	601	523	369	504	639	622	731	563	542	498	379	605	469	455	14519
April	466	252	439	414	418	355	283	473	466	565	643	506	468	532	653	698	818	699	1185	1308	1378	1552	852	378	435	594	489	274	269	327		18189
May	460	502	391	590	702	548	527	813	291	408	477	544	620	689	461	263	410	267	405	481	389	167	362	426	417	311	410	588	385	571	688	14563
June	590	293	224	196	250	427	221	305	439	342	403	442	544	337	451	456	329	493	246	548	559	508	356	468	483	366	527	639	650	382		12474
July	687	823	754	396	780	559	522	724	471	692	647	541	431	780	440	716	1219	1112	772	998	913	1160	944	792	745	566	792	880	1798	1491	1342	25487
August	1677	1806	1761	1347	2836	2974	2245	2347	2490	3505	3862	7909	5617	1875	2318	1042	1444	1914	936	1457	1218	1835	1783	2014	1268	1410	1191	1428	1235	1171	1558	67473
September	1860	1641	1200	1124	1502	1109	1445	1344	1663	1107	1271	1038	1649	1419	1115	1498	1731	1711	1532	1933	2172	1316	1109	1632	904	1438	1211	1675	1881	818		43048
October	884	1252	776	1786	1473	1119	1349	2891	1903	1683	1475	1331	1627	1282	1630	883	1302	1585	1398	1313	2141	1597	2156	1296	973	1527	2893	1514	1624	1802	1743	48208
November	1554	1540	1578	1593	1326	1644	2010	1116	1423	833	1147	1352	1652	867	920	1374	1547	845	1191	757	1188	1454	804	1134	1036	412	692	1127	931	515		35562
December	466	782	1040	1451	691	621	933	1090	1370	1246	1681	4208	2744	2734	1060	891	1000	837	564	1185	585	201	226	488	540	913	818	679	1280	399	349	33072
																																341808

Table 5 – Worldwide results of all CAMS networks in 2022.

CAMS network	2022	2021
LOCAMS (Arizona, USA)	106596	76232
Namibia	81197	99659
BeNeLux	61619	47023
California (USA)	52130	39683
Chile	49051	51350
Australia	38114	54893
UAE	32597	16294
Florida (USA)	26454	24554
New Zealand	16856	21661
Arkansas (USA)	18972	15868
Texas (USA)	19063	17449
South Afrika	7867	8726
Maryland (USA)	2384	5140
Turkey	1605	1323
Brazil	105	144
India	0	0
Total	514610	479999

Acknowledgments

Many thanks to all operators in the CAMS-BeNeLux network for their work and quick delivery of data. The CAMS-BeNeLux network was operated by the following volunteers in 2022:

Hans Betlem (Woold, Netherlands, Watec 3071, 3072, 3073, 3074, 3075, 3076, 3077 and 3078), *Jean-Marie Biets* (Wilderen, Belgium, Watec 379, 380, 381 and 382), *Ludger Boergerding* (Holdorf, Germany, RMS 3801), *Günther Boerjan* (Assenede, Belgium, RMS 3823 and 3824), *Martin Breukers* (Hengelo, Netherlands, Watec 320, 321, 322, 323, 324, 325, 326 and 327, RMS 319, 328 and 329), *Seppe Canonaco* (Genk, RMS 3818 and 3819), *Bart Dessoy* (Zoersel, Belgium, Watec 397, 398, 804, 805, 806, 3888 and RMS 3827), *Tammo Jan Dijkema* (Dwingeloo, Netherlands, RMS 3199), *Isabelle Ansseau*, *Jean-Paul Dumoulin*, *Dominique Guiot* and *Christian Walin* (Grapfontaine, Belgium, Watec 814 and 815, RMS 3814 and 3817), *Uwe Glässner* (Langenfeld, Germany, RMS 3800), *Luc Gobin* (Mechelen, Belgium, Watec 3890, 3891, 3892 and 3893), *Tioga Gulon* (Nancy, France, Watec 3900 and 3901), *Robert Haas* (Alphen aan de Rijn, Netherlands, Watec 3160, 3161, 3162, 3163, 3164, 3165, 3166 and 3167), *Robert Haas* (Burlage, RMS 3803 and 3804), *Robert Haas* (Texel, Netherlands, Watec 810,811, 812 and 813), *Kees Habraken* (Kattendijke, Netherlands, RMS 3780 and 3781), *Klaas Jobse* (Oostkapelle, Netherlands, Watec 3030, 3031, 3032, 3033, 3034, 3035, 3036 and 3037), *Carl Johannink* (Gronau, Germany, Watec 3100, 3101, 3102), *Reinhard Kühn* (Flatzby, Germany, RMS 3802), *Hervé Lamy* (Dourbes, Belgium, Watec 394 and 395, RMS 3825), *Hervé Lamy* (Humain Belgium, Watec 816, RMS 3821 and 3828), *Hervé Lamy* (Ukkel, Belgium, Watec 393), *Koen Miskotte* (Ermelo, Netherlands, Watec 3051, 3052, 3053 and 3054), *Jos Nijland* (Terschelling, Netherlands, Watec 841, 842, 843 and 844), *Pierre-Yves Péchart* (Hagnicourt, France, RMS 3902 and 3903), *Tim Polfliet* (Gent, Belgium, Watec 396, RMS 3820 and 3840), *Pierre de Ponthiere* (Lesve, Belgium, RMS 3816 and 3826) , *Steve Rau* (Zillebeke, Belgium, Watec 3850 and 3852, RMS 3851 and 3853), *Paul & Adriana Roggemans* (Mechelen, Belgium, RMS 3830 and 3831, Watec 3832, 3833, 3834, 3835, 3836 and 3837), *Jim Rowe* (Eastbourne, England, RMS 3829) , *Philippe Schaack* (Roodt-sur-Syre, Luxemburg, RMS 3952), *Hans Schremmer* (Niederkruechten, Germany, Watec 803) , *Jan Thoemel* (Luxemburg, Luxemburg, Watec 3950), *Erwin van Ballegoij* (Heesh, Netherlands Watec 3148 and 3149).

The cameras in Dourbes and Humain have been funded by STCE (Solar Terrestrial Center of Excellence[27]).

Reference

Jenniskens P. (2023). Atlas of Earth Meteor Showers (in press).

---

[27] https://www.stce.be

January 2023 report CAMS-BeNeLux

Carl Johannink

Am Ollenkamp 4, 48599 Gronau, Germany
`c.johannink@t-online.de`

A summary of the activity of the CAMS-BeNeLux network during the month of January 2023 is presented. This month had many cloudy nights due to a persistent moisty type of weather. A total of 6762 multi-station meteors were recorded, good for 2291 orbits.

1 Introduction

It is well known that January usually isn't a month with high scores for our network. Meteor activity is still at a fairly good level, but the weather isn't cooperating most of the time. 2023 wasn't an exception.

2 January 2023 statistics

January 2023 was again a very mild month for our region, with a mean temperature above 5 degrees Celsius. As in 2022, this is not a good sign for astronomical observations. Observations of our network were hampered by clouds during many nights. Complete clear nights were very rare this month for most parts of the BeNeLux.

We had 4 cloudy nights in a row from January 22–23 till 25–26. January 24–25 was completely overcast in the whole of the BeNeLux, with not a single captured meteor by all our cameras as a result.

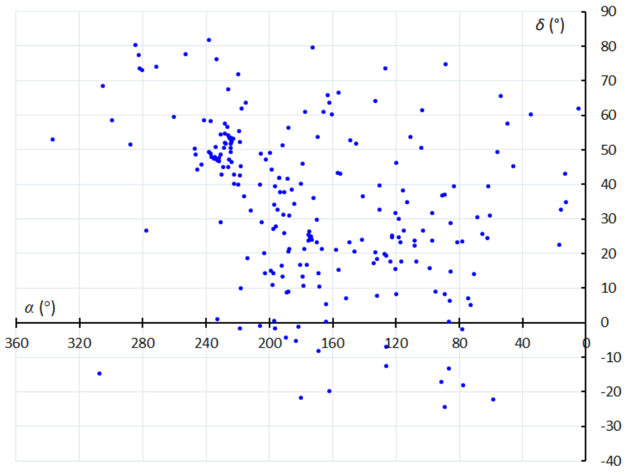


Figure 1 – Radiantplot in geocentric equatorial coordinates for the orbits obtained January 2–3, 2023 (data CAMS-BeNeLux).

The major stream Quadrantids was missed in bad weather: on January 3–4, when the highest meteor activity from this stream can be expected, we could add only 3 orbits to our database. The night before we could collect 256 orbits, but Quadrantid-activity always shows a sharp peak of short duration, so this stream wasn't very obvious during this night (*Figure 1*).

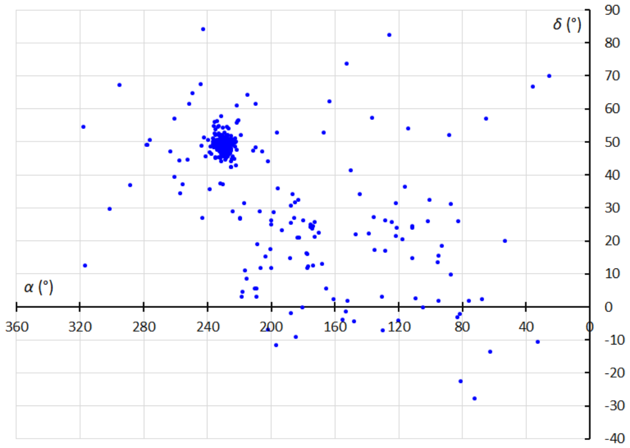


Figure 2 – Radiantplot in geocentric equatorial coordinates for the orbits obtained January 3–4, 2020 (data CAMS-BeNeLux).

What a contrast with for example 2020, when the night of January 3–4 was clear for most parts of the BeNeLux. That night we could collect 640 orbits. Quadrantid activity was abundant that night. (*Figure 2*).

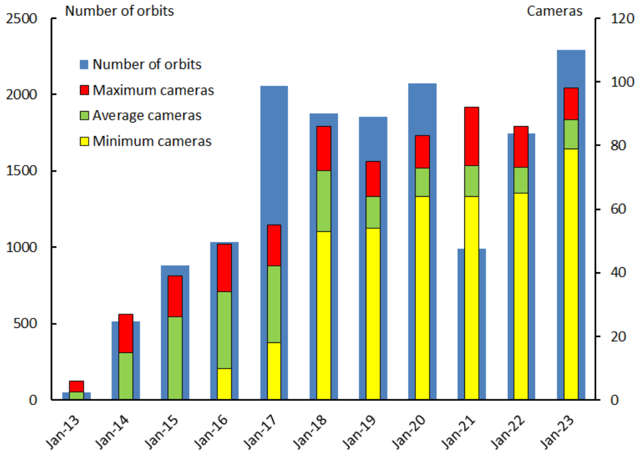


Figure 3 – Comparing January 2023 to previous months of January in the CAMS-BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras capturing in a single night, the green bars the average number of cameras capturing per night and the yellow bars the minimum number of cameras.

Table 1 – Number of orbits and active cameras in the BeNeLux during the month of January in the period 2013–2023.

Year	Nights	Orbits	Stations	Max. Cams	Min. Cams	Mean Cams
2013	7	49	6	6	–	2.6
2014	21	514	11	27	–	14.8
2015	22	880	14	39	–	26.1
2016	25	1037	15	49	10	34.0
2017	23	2058	18	55	18	42.3
2018	25	1878	22	86	53	72.0
2019	22	1857	20	75	54	64.0
2020	23	2075	21	83	64	72.9
2021	22	991	26	92	64	73.7
2022	28	1744	26	86	65	73.2
2023	25	2291	32	98	79	88.1
Total	243	15374				

Nevertheless, CAMS-BeNeLux collected 6762 multi-station meteors this month, resulting in a total of 2291 orbits. For January this is a new record, despite 6 nights this month with not a single orbit. The reason for this higher score is the increase in the number of cameras this month when compared to one year ago, as can be seen in *Table 1* and *Figure 3*.

Unfortunately, many stations in the northern parts of the Netherlands are still suffering problems. We hope that this situation improves in the course of this year.

3 Conclusion

The results for January 2023 are the best in the history of CAMS-BeNeLux.

Acknowledgment

Many thanks to all operators in the CAMS-BeNeLux network for their work and quick delivery of data. In January 2023 the CAMS-BeNeLux network was operated by the following volunteers:

Hans Betlem (Woold, Netherlands, CAMS 3071, 3072, 3073, 3074, 3075, 3076, 3077 and 3078), *Jean-Marie Biets* (Wilderen, Belgium, CAMS 379, 380, 381 and 382), *Ludger Boergerding* (Holdorf, Germany, RMS 3801), *Günther Boerjan* (Assenede, Belgium, RMS 3823), *Martin Breukers* (Hengelo, Netherlands, CAMS 320, 321, 322, 323, 324, 325, 326 and 327, RMS 319, 328 and 329), *Seppe Canonaco* (Genk, RMS 3818 and 3819), *Pierre de Ponthiere* (Lesve, Belgium, RMS 3816 and 3826), *Bart Dessoy* (Zoersel, Belgium, CAMS 804, 805 and 806), *Tammo Jan Dijkema* (Dwingeloo, Netherlands, RMS 3199), *Isabelle Ansseau, Jean-Paul Dumoulin, Dominique Guiot* and *Christian Walin* (Grapfontaine, Belgium, CAMS 814 and 815, RMS 3814 and 3817), *Uwe Glässner* (Langenfeld, Germany, RMS 3800), *Luc Gobin* (Mechelen, Belgium, CAMS 3890, 3891, 3892 and 3893), *Tioga Gulon* (Nancy, France, CAMS 3900 and 3901), *Robert Haas* (Alphen aan de Rijn, Netherlands, CAMS 3160, 3161, 3162, 3163, 3164, 3165, 3166 and 3167), *Robert Haas* (Texel, Netherlands, CAMS 811), *Kees Habraken* (Kattendijke, Netherlands, RMS 3780 and 3781), *Klaas Jobse* (Oostkapelle, Netherlands, CAMS 3030, 3031, 3032, 3033, 3034, 3035, 3036 and 3037), *Carl Johannink* (Gronau, Germany, CAMS 3100, 3101, 3102), *Reinhard Kühn* (Flatzby, Germany, RMS 3802), *Hervé Lamy* (Dourbes, Belgium, CAMS 395, RMS 3825 and 3841), *Hervé Lamy* (Humain, Belgium, RMS 3821 and 3828), *Hervé Lamy* (Ukkel, Belgium, CAMS 393), *Koen Miskotte* (Ermelo, Netherlands, CAMS 3051, 353 and 354), *Pierre-Yves Péchart* (Hagnicourt, France, RMS 3902 and 3903), *Tim Polfliet* (Gent, Belgium, CAMS 396, RMS 3820 and 3840), *Steve Rau* (Zillebeke, Belgium, CAMS 3850 and 3852, RMS 3851 and 3853), *Paul and Adriana Roggemans* (Mechelen, Belgium, RMS 3830 and 3831, CAMS 3832, 3833, 3834, 3835, 3836 and 3837), *Jim Rowe* (Eastbourne, Great Britain, RMS 3829), *Philippe Schaack* (Roodt-sur-Syre, Luxemburg, RMS 3952), *Hans Schremmer* (Niederkruechten, Germany, CAMS 803), *Jan Thoemel* (Luxemburg, Luxemburg, CAMS 3950), *Erwin van Ballegoij* (Heesh, Netherlands CAMS 3148 and 3149).

Photographic Geminid observations on 14 December 2022

Mikhail Maslov

skjeller@yandex.ru

A presentation is given with photographic records obtained during the 2022 Geminids.

1 Introduction

Here are the results of photographic Geminid observations on 14 December from 12^{h}17^m to 23^{h}33^m UT. The images were taken with a Pentax KP camera and 8.5 mm lens, without guiding. Most part of the night was with the gibbous waning Moon in the sky, only the first evening hours were dark, but with lower GEM radiant heights. Comparing to the previous night 13–14 December the detected Geminid activity was much higher, especially after 15^h UT, sometimes with more than 30 detected Geminid meteors per hour even despite moonlight. The increased number of bright meteors also took place.

The results are presented in the text form below and in the form of composite images for every hour of observations:

- 12^{h}17^m–13^{h}17^m UT – 12 GEM, 2 SPO, Geminids radiant altitude: 14°, Moon: below horizon.
- 13^{h}17^m–14^{h}17^m UT – 14 GEM, 1 SPO, Geminids radiant altitude: 22°, Moon: below horizon.
- 14^{h}17^m–15^{h}17^m UT – 13 GEM, 2 SPO, Geminids radiant altitude: 29°, Moon: below horizon.
- 15^{h}17^m–16^{h}17^m UT – 33 GEM, 1 SPO, Geminids radiant altitude: 38°, Moon: below horizon.
- 16^{h}17^m–17^{h}17^m UT – 22 GEM, Geminids radiant altitude: 46°, Moon: altitude 6°, phase a 66%.
- 17^{h}17^m–18^{h}17^m UT – 33 GEM, 2 SPO, Geminids radiant altitude: 55°, Moon: altitude 14°, phase 66%.
- 18^{h}17^m–19^{h}17^m UT – 24 GEM, 1 SPO, Geminids radiant altitude: 62°, Moon: altitude 22°, phase 65%.
- 19^{h}17^m–20^{h}17^m UT – 28 GEM, 1 SPO, Geminids radiant altitude: 67°, Moon: altitude 30°, phase 65%.
- 20^{h}17^m–21^{h}17^m UT – 30 GEM, 4 SPO, Geminids radiant altitude: 68°, Moon: altitude 37°, phase 64%.
- 21^{h}17^m–22^{h}17^m UT – 30 GEM, 1 SPO, Geminids radiant altitude: 64°, Moon: altitude 43°, phase 64%.
- 22^{h}17^m–23^{h}33^m UT – 20 GEM, 2 SPO, Geminids radiant altitude: 56°, Moon: altitude 47°, phase 64%.

2 The images

Figure 1 – 12^{h}17^m–13^{h}17^{m}m UT – 12 GEM, 2 SPO, Geminids radiant altitude: 14 degrees, Moon: below horizon.

Figure 2 – 13^{h}17^m–14^{h}17^m UT – 14 GEM, 1 SPO, Geminids radiant altitude: 22°, Moon: below horizon.

Figure 3 – 14^{h}17^m–15^{h}17^m UT – 13 GEM, 2 SPO, Geminids radiant altitude: 29°, Moon: below horizon.

Figure 4 – 15^h17^m–16^h17^m UT – 33 GEM, 1 SPO, Geminids radiant altitude: 38°, Moon: below horizon.

Figure 5 – 16^h17^m–17^h17^m UT – 22 GEM, Geminids radiant altitude: 46°, Moon: altitude 6°, phase a 66%.

Figure 6 – 17ʰ17ᵐ–18ʰ17ᵐ UT – 33 GEM, 2 SPO, Geminids radiant altitude: 55°, Moon: altitude 14°, phase 66%.

Figure 7 – 18ʰ17ᵐ–19ʰ17ᵐ UT – 24 GEM, 1 SPO, Geminids radiant altitude: 62°, Moon: altitude 22°, phase 65%.

Figure 8 – 19ʰ17ᵐ–20ʰ17ᵐ UT – 28 GEM, 1 SPO, Geminids radiant altitude: 67°, Moon: altitude 30°, phase 65%.

Figure 9 – 20ʰ17ᵐ–21ʰ17ᵐ UT – 30 GEM, 4 SPO, Geminids radiant altitude: 68°, Moon: altitude 37°, phase 64%.

Figure 10 – 21^{h}17^m–22^{h}17^m UT – 30 GEM, 1 SPO, Geminids radiant altitude: 64°, Moon: altitude 43°, phase 64%.

Figure 11 – 22^{h}17^m–23^{h}33^m UT – 20 GEM, 2 SPO, Geminids radiant altitude: 56°, Moon: altitude 47°, phase 64%.

Autumn 2022: visual meteor observations

Koen Miskotte

Dutch Meteor Society
`k.miskotte@upcmail.nl`

The author describes his observing experiences during September, October, November and December 2022.

1 Introduction

A number of meteor showers were on the agenda for autumn 2022. The Orionids under virtually moonless nights, the moonlit Taurids whose southern branch would give increased activity (2022 was a so-called Asher year), the Leonids and of course the Geminids. The latter would also be visible under moonlight conditions. The autumn in previous years did not excel in many clear nights. The last year in which relatively many observations were possible during autumn months was 2018. So, expectations were not high. After the extremely successful Perseid watches in the Netherlands, observations started again at the end of September.

2 Autumn observations

2022 September 21–22

A short session was possible from the meteor roof at home, observing between 22^h37^m and 01^h40^m UT. The sky had a somewhat light background with quite low numbers of meteors for September. In 3 hours effective observation time I counted 23 meteors of which 1 chi Cygnid and 4 southern Taurids. A few bright meteors were seen.

2022 September 28–29

Another session from the meteor roof, observing between 01^h00^m and 04^h08^m UT, 3.07 hours were observed with limiting magnitudes between 6.2 and 6.3. In total I saw 34 meteors including 2 delta Aurigids, 3 Southern Taurids and 2 possible Orionids. A very slow meteor in the second hour could be an early Draconid. The most beautiful meteor was a slow magnitude 0 sporadic meteor in the Big Dipper.

2022 October 02–03

This was a clear night just before my weekend. So, I prepared myself for a longer session from the Groevenbeekse Heide. Unfortunately, it turned out to be a lot of fog there, so I decided to try rather at home. There I have a big advantage, no fog as I am high up there and I could observe undisturbed for more than 3.5 hours. Observations were done between 00^h12^m and 04^h11^m UT. The first 1.5 hours there was low activity, the last two hours were quite good. A total of 39 meteors were counted, of which 4 delta Aurigids, 4 southern Taurids and 2 Orionids. Quite some bright meteors, including a magnitude 0 Orionid, a magnitude 0 sporadic meteor, an orange 0 magnitude delta Aurigid, and a –1 sporadic meteor.

2022 October 05–06

This was another clear morning with observations again from the meteor roof because of fog. This night, the obscure minor meteor shower of the October Camelopardalids (OCT#281) was active, possibly originating from a long-period comet. The meteor shower is barely active for a day, the maximum was expected on October 6 around 04^h00^m UT. Observations were carried out between 02^h09^m and 04^h20^m UT. Indeed, 4 OCT meteors (magnitudes +2, +3, +3, +4) were seen. CAMS BeNeLux also picked up these meteors. It is true that if you do not know about this meteor shower, you would easily miss it as a visual observer.

A total of 31 meteors were counted in 2.07 effective hours at a limiting magnitude of slightly above 6.2. In addition to the 4 OCT, 4 delta Aurigids, 1 Southern Taurid and 2 Orionids were also seen. A magnitude 0 sporadic meteor was the most beautiful appearance.

2022 October 18–19

Another clear night, with cirrus moving in from the south during the night. Observations took place between 22^h35^m and 01^h03^m UT. The author switched from a southern to a northern field of view in the last hour due to slowly advancing cirrus.

Radio observers report a radio peak from the Orionids on the evening of October 18, so there was a possibility to see something of this from Europe. It looked like the 1993 Orionid outburst which I could see in full regalia and which showed a lot of bright Orionids. This year, this was not apparent from the observations made by the author. With only 8 Orionids counted, most of them faint, which is what you would expect during a "normal" Orionid year. Unfortunately, the following nights were mostly cloudy in the Netherlands.

2022 October 23–24

Early morning clearings allowed me to observe between 03^h33^m and 04^h44^m UT with a limiting magnitude slightly below 6.3. There were some clouds between 04^h07^m and 04^h17^m UT. In 1.15 hour effective I saw 8 mostly faint

Orionids, 3 southern Taurids and 1 eta Geminid. The brightest meteor was a +1 sporadic meteor.

2022 October 30–31

The Taurids were eagerly awaited. Between roughly October 25 and November 15, the southern branch should produce more fireballs than usual. For the author, 1981 and 2005 were especially good years in which fireballs of –8 and –10 appeared. More southern Taurids were also seen in 1995, 1998, 2012 and 2015, but these years were not as impressive as 1981 and 2005.

Observations were only possible between 22^h11^m and 23^h05^m UT with a mean limiting magnitude of 6.2. Only 11 meteors were counted, including 3 southern and 1 northern Taurids. No bright ones.

The following nights were regularly clear, but often with cirrus. Indeed, relatively many beautiful Taurid fireballs were captured with the all-sky camera during this period, the brightest being a magnitude –12 Taurid.

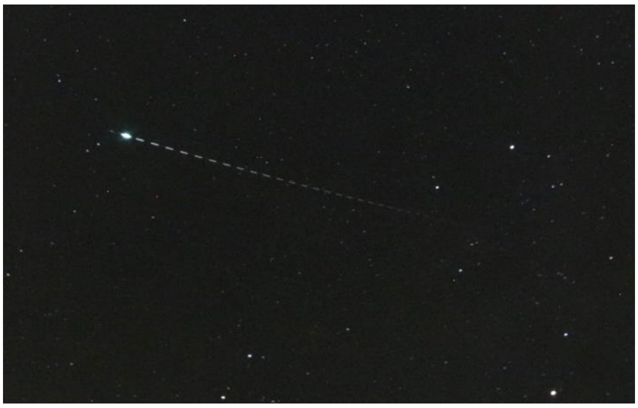


Figure 1 – A beautiful southern Taurid with a flare with magnitude –6 flare was captured on November 5, 2022 at $02^h54^m22^s$ UT. Camera: Canon 6D with Sigma 8 mm F 3.5 lens (LC shutter 16 breaks per second). Two other all-sky stations located at Bussloo and Woold captured this Taurid simultaneously.

2022 November 13–14

This observing session took place from the Groevenbeekse Heide. An early start was made because of the soon rising Moon. The observations were carried out between 18^h45^m and 21^h25^m UT. A slowly passing field of cirrus clouds caused a long pause between 19^h45^m and 20^h25^m UT. Only a few Taurids were seen, 2 northern and 3 southern Taurids. A +1 Southern Taurid was the brightest meteor. About halfway through the session, the author was quite shocked by a firework bomb that went off 100 meters away!

2022 November 19–20

This was a nice long session from the Groevenbeekse Heide where the temperature at ground level dropped to –11 degrees Celsius. I observed between 01^h30^m and 04^h45^m UT. The moon rose at about 3^h20^m UT, only 10% illuminated. Counts from the southern Taurids were again between 2 and 3 per hour, all faint meteors. The Leonids were quite active with hourly counts between 3 and 5. A total of 51 meteors were counted in 3.13 hours effective with a limiting magnitude 6.4, later declining slightly. Amongst them 14 Leonids, 3 alpha Monocerotids, 6 southern and 1 northern Taurid, and 1 possible Andromedid. Lots of beautiful meteors, two Leonids, with magnitude –2 and 0 left long-lasting persistent trains. A nice moment occurred around 3^h45^m UT when a yellow 0-magnitude Leonid with 1 second persistent train and a 0-magnitude sporadic meteor with 3 seconds persistent train appeared in quick succession.

Figure 2 – A beautiful magnitude –12 southern Taurid was captured in the night of 2022 November 10–11, with a lot of cirrus. Camera: Canon 6D with Sigma 8 mm F 3.5 lens (LC shutter 16 breaks per second). Several other all sky stations in the BeNeLux captured this one.

3 Geminids, only when it is freezing cold

The first weeks of December 2022 were rather chilly. Despite an almost Full Moon the period around the Geminid maximum was monitored to see if the weather allowed observations. Some freezing nights were expected in which the sky could clear up. Indeed, there was relatively much clear weather in the week around the Geminid maximum.

Given the expected moonlight and often bad conditions in December, I had not asked for a day off from work so the observations would be limited.

2022 December 12–13

This night had clear sky almost all night. Because the author had to work the next day, it remained a session with limited duration. The period was chosen when the radiant was the highest with the disadvantage of a lot of moonlight. I signed on at 00^h19^m UT on the meteor roof at home, and observations ended at 03^h20^m UT. Temperatures dropped to –9 degrees Celsius. Fortunately, a hot water bottle was very comfortable to keep my feet warm. The limiting magnitude first reached 5.7 and then dropping to 5.5. The transparency was very good, which resulted in a nice number of meteors, about 20 an hour. A total of 59 Geminids, 4 December Monocerotids, 4 sigma Hydrids, and 2 Antihelions (also called xi Orionids) were counted in an effective 3.02 hours. A pair of Geminids of magnitude –2 and –1 were the most beautiful meteors.

2022 December 13–14

This was a difficult night. A weak cold front with mainly cirrus would move across the Netherlands from north to south. Clear spells were expected in Ermelo around 3^h UT. Just before 0^h UT the first clear spells became visible on the all-sky images at low north. However, the southward movement of the front was very slow. The alarm went off around 01^h30^m UT. A look outside showed that the north had cleared but that the separation between clear sky and cirrus was right near the zenith. Within twenty minutes I was on the roof with the observation direction north (also because of the Moon of course). Without the cirrus the sky was nicely transparent with a limiting magnitude of 5.6. However, the cold front wobbled a bit, which sometimes caused parts of cirrus to cross my field of view. Under these varying and cold (again –9 degrees Celsius) conditions, observations were made between 01^h48^m and 03^h15^m UT. After this, more cirrus appeared from the west. But when I was cycling to work (4^h UT) the cirrus front had already descended a bit further south and it was almost completely clear.

A total of 48 meteors were counted, of which 41 Geminids, 2 December Monocerotids and 1 sigma Hydride. Two Geminids of –2 and –1 were the most beautiful meteors.

2022 December 14–15

Because a clear night was predicted for December 14–15, I planned a short working day so that I was home on time and could catch some sleep before the observations started. The next day, Thursday, was also a day off from work, so observations could be longer. However, I had obligations the next day so I couldn't observe the whole night.

Given the strongly decreasing activity of the Geminids after the maximum, I decided to start early in the evening. As early as 18^h02^m UT, the all sky captured a very nice Geminid Earth grazing fireball (*Figure 3*). And 18 minutes later the observations started. The sky was transparent, but unfortunately partly spoiled by the sports lighting of football fields (one kilometer east) so that the limiting magnitude was around 6.0. This lasted until after 20^h UT when the lights went out and the limiting magnitude suddenly jumped 3/10! A number of Geminid Earth grazers were seen.

Despite the lower limiting magnitude, nice numbers of Geminids were seen. The first hour it was still a bit low (because of the very low radiant position), but in the second hour more Geminids were visible. Meanwhile, the temperature reached –10 degrees Celsius! After 2.5 hours some clouds passed over and this was used to take a break and to provide the jug with hot water again. This was followed by another observation period of 2.5 hours. During that time about 30 Geminids were seen per hour despite the rising radiant, so indeed decreasing activity. Bright fireballs were not seen during this period, only two Geminids of magnitude –3. But the all-sky camera captured a very bright Geminid of –8 at 00^h58^m UT. In total the all-sky camera captured 16 Geminids this night.

Figure 3 – A beautiful Earth grazing Geminid appeared on December 14, 2022 at 18^h02^m UT. Camera: Canon 6D with Sigma 8 mm F 3.5 lens (LC shutter 16 breaks per second).

A total of 124 Geminids was seen in 5.03 hours effective observing time between 18^h20^m and 23^h40^m UT, along with 4 December Monocerotids, 2 sigma Hydrids, 4 Antihelions, 1 Ursid, and 26 sporadic meteors.

All in all, given the circumstances, this was a very successful Geminids campaign!

Figure 4 – Brightest Geminid captured from Ermelo on 2022 December 15, at 00^h58^m UT. Camera: Canon 6D with Sigma 8mm F 3.5 lens (LC shutter 16 breaks per second). In this image (and almost all other images from December 12–15) a small spider (above the star Sirius) can be seen making a web on the fisheye lens. Visible as bands of light in Orion. The web has since been removed.

Figure 5 – The last Geminid fireball captured this night from Ermelo: December 15, 2022 at 04^h33^m UT. Camera: Canon 6D with Sigma 8 mm F 3.5 lens (LC shutter 16 breaks per second).

The 2023 Quadrantidis

Lorenzo Barbieri

Associazione Astrofili Bolognesi (AAB)
`rambometeorgroup@gmail.com`

We present the report on the radio observation of the Quadrantid meteor shower recorded by the CARMELO (Cheap Amateur Radio Meteor Echoes LOgger) network.
As in the observations made in previous years, a complex structure is confirmed in which two secondary filaments are evident, before and after the main shower, the second of which appears to be composed of larger mass meteoroids.

1 Introduction

The Quadrantids are one of the most active of all the meteoroid streams the Earth encounters on its annual orbit around the Sun. This shower isn't as well-known as other showers, especially those which occur during the summer, due to the bad weather conditions that normally characterize observations in this part of the year. Because of this, radio observing can assume more importance by compensating the missing visual observations.

A further characteristic of this shower is that the progenitor body is most likely not a comet, but an asteroid: 2003 EH1. As it can be deduced from the name, this is a very recent discovery: before 2003, the Quadrantids parent body was unknown.

It is probably a fairly recent meteoroid stream: the first mentioning of the Quadrantids dates back to observations of 1835 and this would explain its relative compactness, given that the duration of the shower is approximately 24 hours.

Its orbit has a high inclination (> 70°) and the velocity of the meteors is 41 km/sec, an average value in the wide range of meteor velocities.

The observations were carried out with the CARMELO (Cheap Amateur Radio Meteor Echoes LOgger)[28] receivers' network, described before (Barbieri and Brando, 2022) which currently consists of some receivers placed in Europe and in the USA[29].

2 The observations

The graph in *Figure 1* shows both the hourly rates (in red) and the echo durations (in blue). The measurements have a time resolution of one hour.

It can be seen that the phenomenon begins on the evening of January 4th and ceases on the following evening.

The first peak begins at solar longitude 282.86°, the maximum occurs at solar longitude 283.25° while the last peak is at solar longitude 283.76°.

We note how the average duration of the meteoric echoes in the last filament is higher than in the previous two: an indication that suggests that the kinetic energy of these meteoroids is larger.

Since the particles speed is the same, we must therefore deduce that the meteoroids have a larger mass.

Wishing to compare these data with other observations in the past, we can refer to that of 2016 (Brando, 2016) even if it should be emphasized that it was collected by a single analog radio observer while those of this year, as mentioned above, are collected by digital receivers, with a greater number of devices and a greater territorial coverage.

The comparison shows a substantial correspondence between the two observations, both with respect to the number of filaments, their time location, and the increase in the mass index in the third and last filament.

References

Barbieri L., Brando G. (2022). "A global network for radio meteors observers". *eMetN*, **7**, 1, 34–45.

Brando G. (2016). "The 2016 Quadrantids". In Roggemans A. and Roggemans P., editors, *Proceedings of the International Meteor Conference*, Edmond, the Netherlands, 2-5 June 2016. IMO, pages 39–41.

---

[28] http://www.astrofiliabologna.it/static/file/carmelo/2022_emn.pdf

[29] http://www.astrofiliabologna.it/obs_on_line

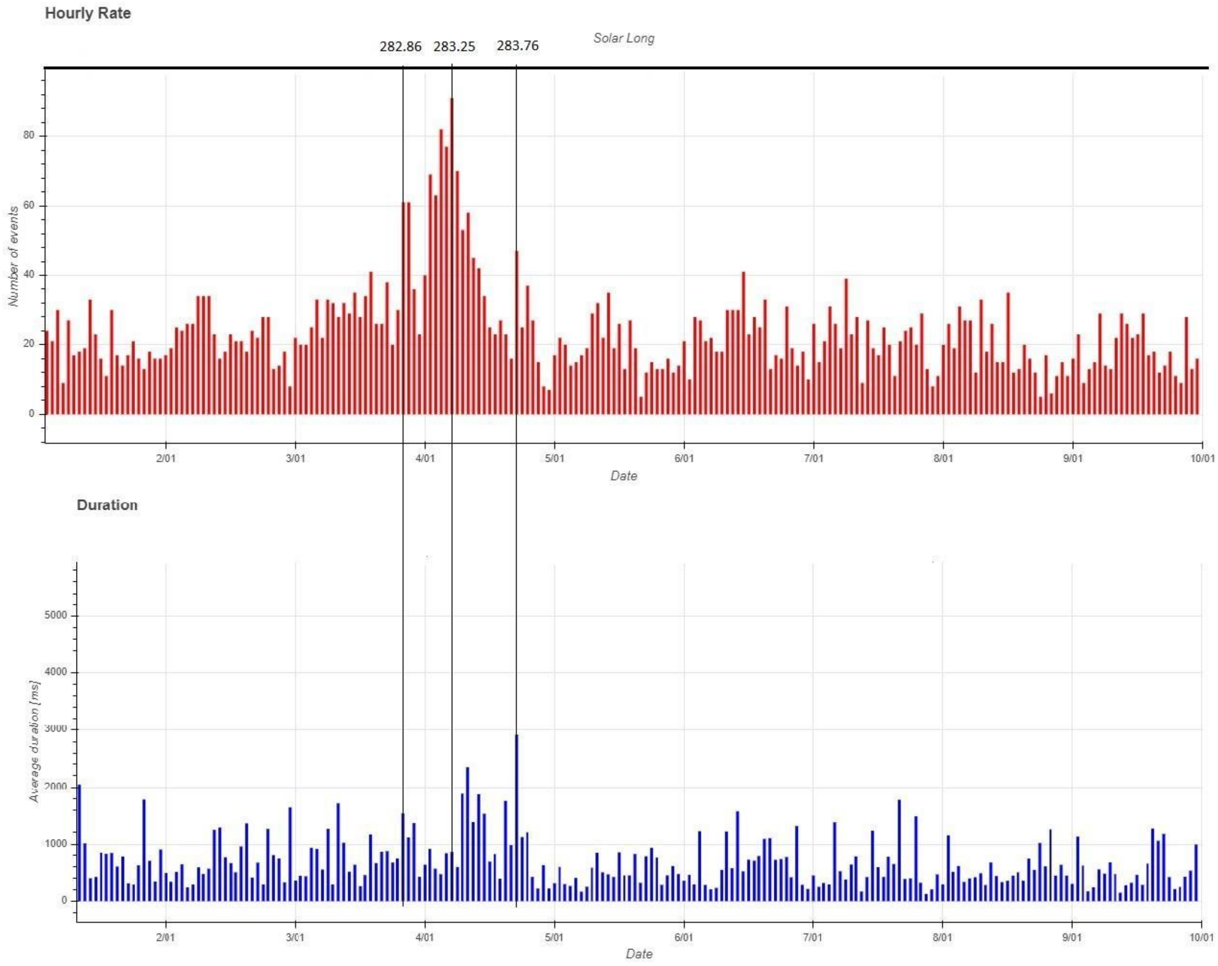


Figure 1 – Quadrantids 2023, the hourly rate (in red) and the echo durations (in blue). The measurements have a time resolution of one hour.

Radio observations of meteors in February–November 2022 (summary)

Ivan Sergei

Mira Str.40-2, 222307, Molodechno, Belarus
`seriv76@tut.by`

I present the results of counting radio meteor echoes on 88.6 MHz during the period from February to November 2022.

1 Introduction

The observations were carried out at a private astronomical observatory near the town of Molodechno (Belarus) at the place of Polyani. A 5 element-antenna directed to the west was used, a car FM-receiver was connected to a laptop with as processor an Intel Atom CPU N2600 (1.6 GHz). The software to detect signals is Metan (author – Carol from Poland). Observations are made on the operating frequency 88.6 MHz (the FM radio station near Paris broadcasts on this frequency). The "France Culture" radio broadcast transmitter (100 kW) I use is at about 1550 km from my observatory which has been renewed in 1997. The method of listening to a radiophone is more "sensitive" in terms of detecting meteor signals compared to the method of automatic detection, so it is more interesting. Regular (daily) observations 3–5 times a day are of scientific value, because they have uniformity being performed on the same equipment.

2 Counting radio echoes on 88.6 MHz

In order to save observation time and to increase the efficiency of listening for the radio meteor echoes in order to obtain a more complete observation series, I made a modification to the method with the introduction of a definition of "synthetic" hourly rate numbers (*Figure 1–7 and 10–12*).

Listening to the radio signals for 10 minutes with extrapolation of the data to 1 hour was done about 3 to 5 times a day. At the times of the maxima of the main meteoroid streams, the counting of meteor echoes was performed on average every 2–3 hours in order to get a better coverage of the observational series. This was done in order to control the level of the hourly rates as well as to distinguish between periods of tropospheric passage and other natural radio interference.

February is a rather quiet month in terms of meteor activity (*Figure1*). The month was even calmer until March 20, but after March 20 there was a monotonous increase in meteor activity. Most likely due to sporadic meteors, as there are no active showers with high activity (*Figure 2*).

April is a fairly active month. The maximum hourly numbers of about 170–180 signals were recorded on April 21–25 and apparently connected to the Lyrids (#0006), although no pronounced peak was observed (*Figure 3*).

The high hourly numbers from May 4 to 8 are probably due to the ETA peak (#0031). The peak on the morning of May 15 with 200 signals per hour may be due to meteoroids associated with asteroid 2006GY2. An unclassified peak appeared on May 27 with 150 signals per hour. The high activity on May 31 may be associated with the outburst of the minor shower of TAH (#0061) (*Figure 4*).

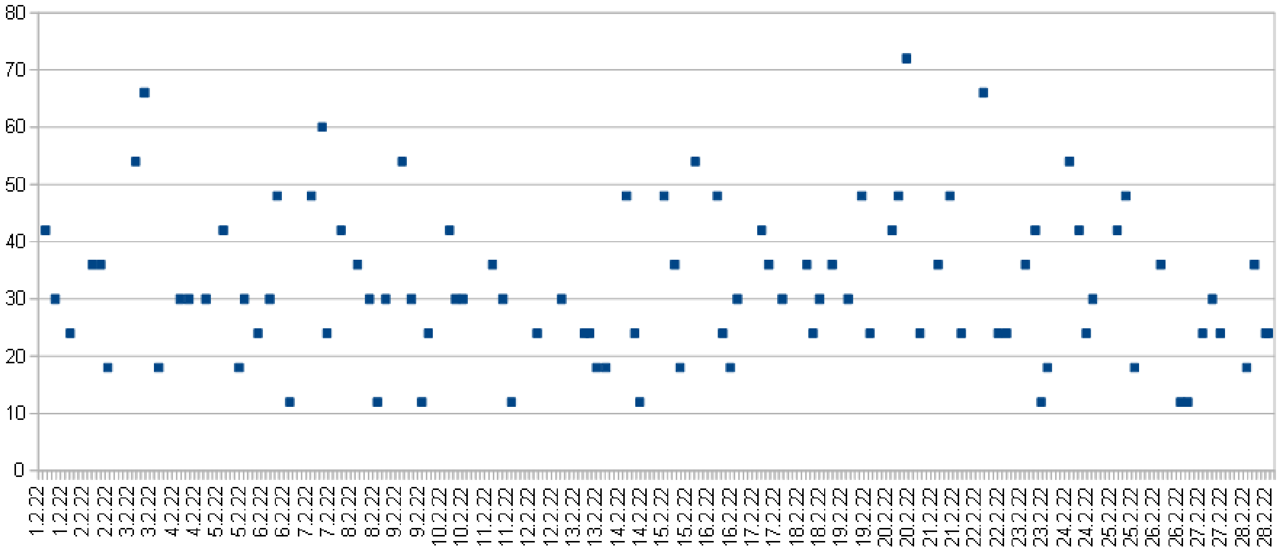


Figure 1 – The result with the calculated hourly numbers of meteor echoes by listening to the radio signals during February 2022.

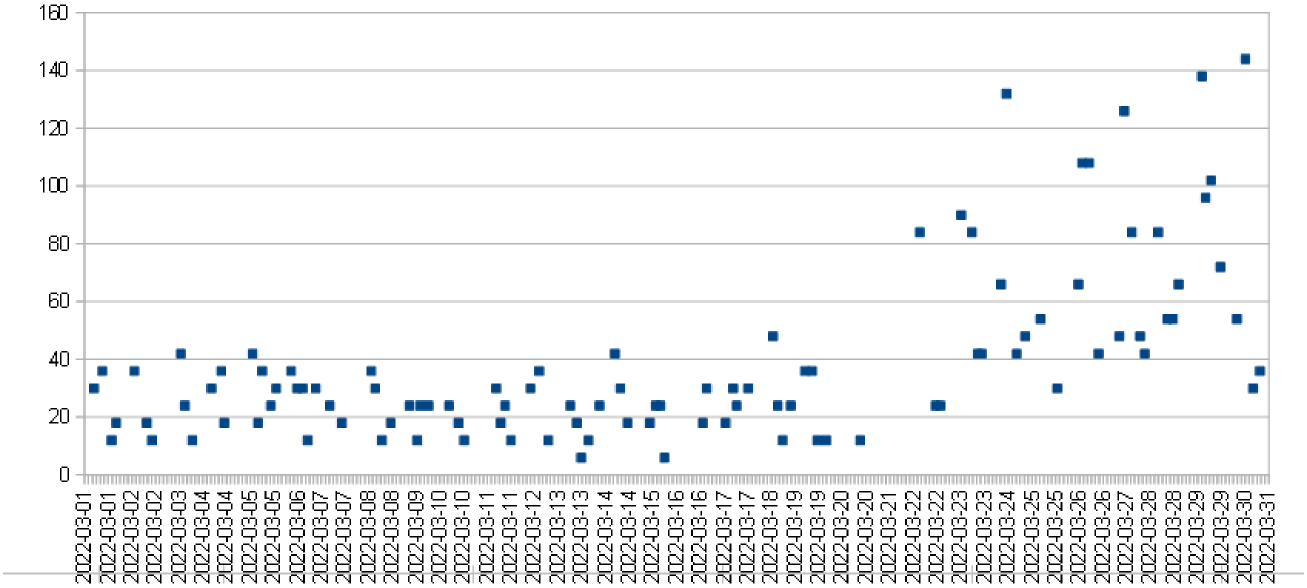


Figure 2 – The result with the calculated hourly numbers of meteor echoes by listening to the radio signals during March 2022.

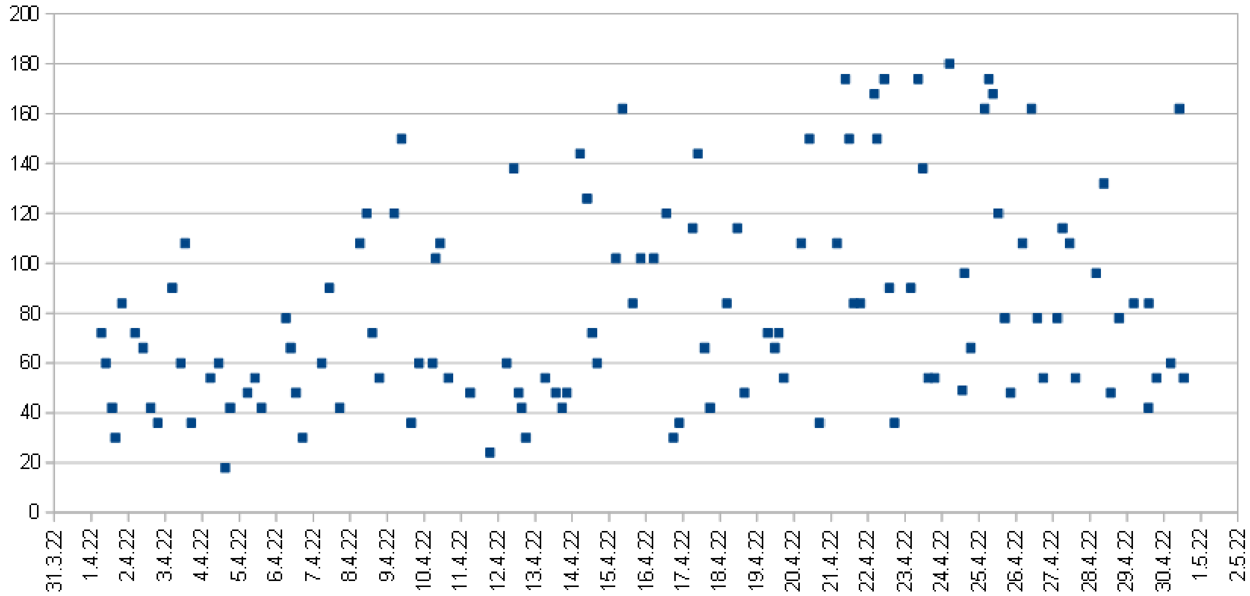


Figure 3 – The result with the calculated hourly numbers of meteor echoes by listening to the radio signals during April 2022.

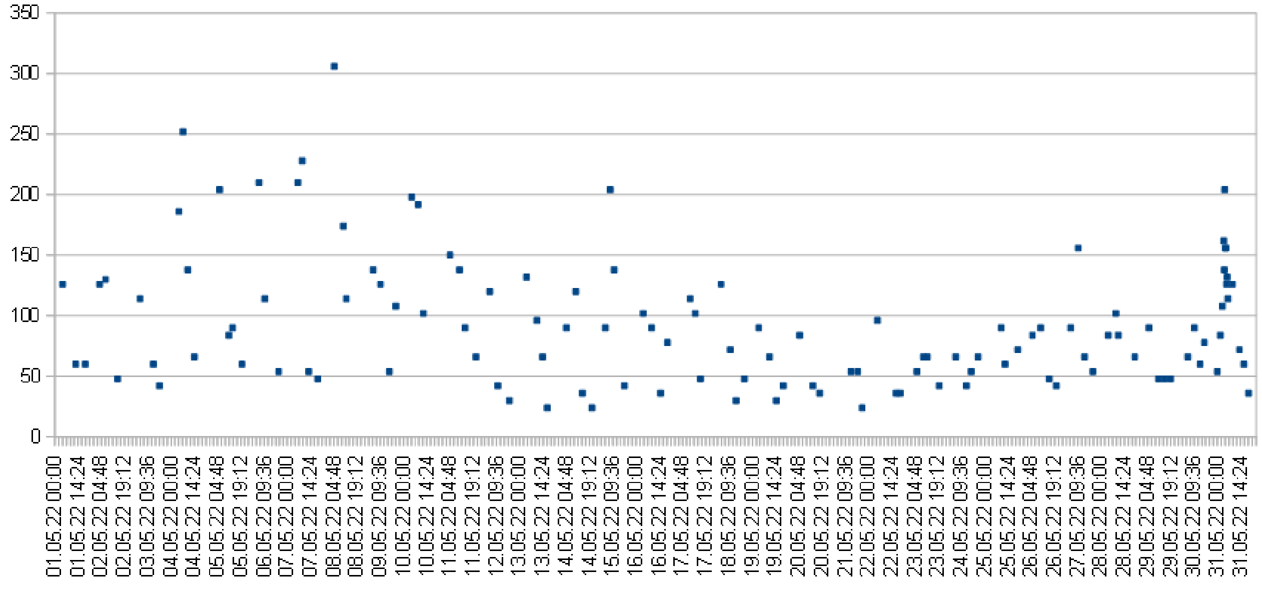


Figure 4 – The result with the calculated hourly numbers of meteor echoes by listening to the radio signals during May 2022.

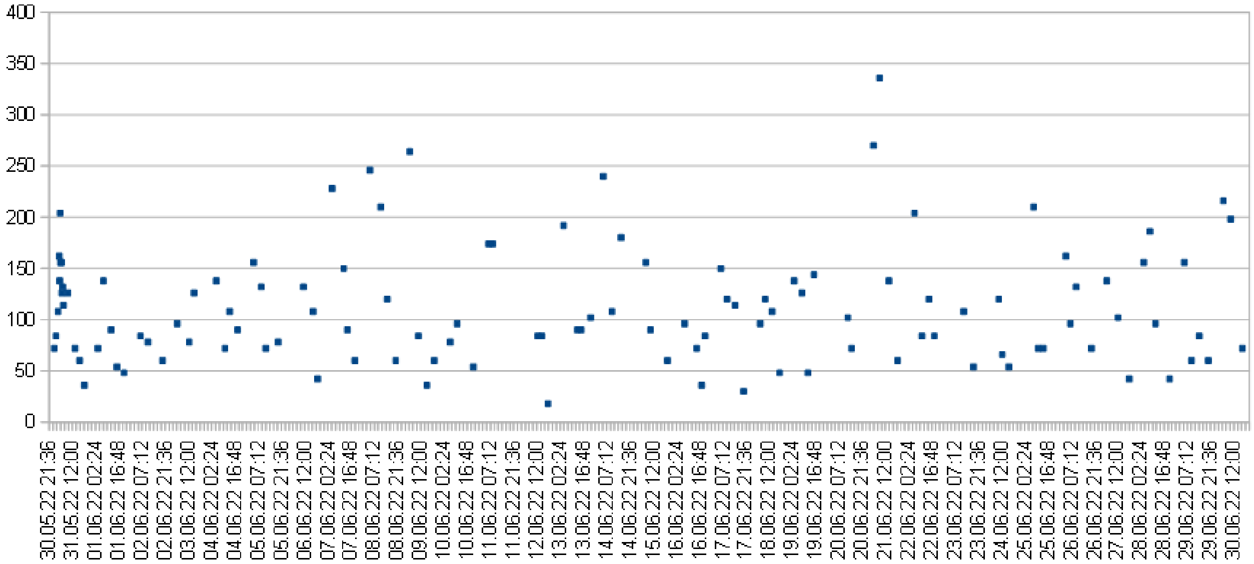


Figure 5 – The result with the calculated hourly numbers of meteor echoes by listening to the radio signals during June 2022.

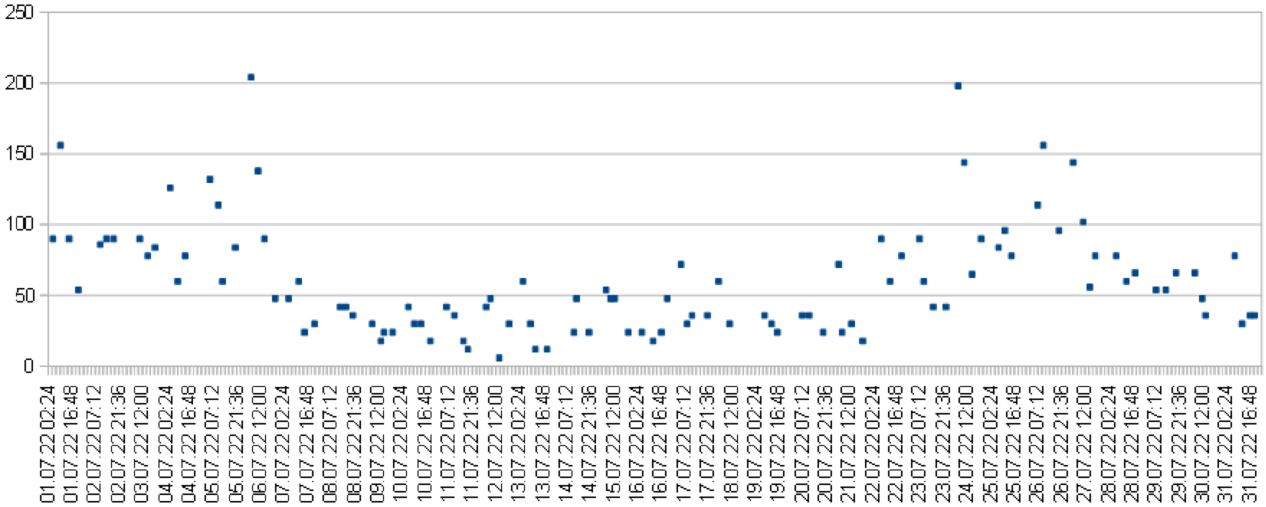


Figure 6 – The result with the calculated hourly numbers of meteor echoes by listening to the radio signals during July 2022.

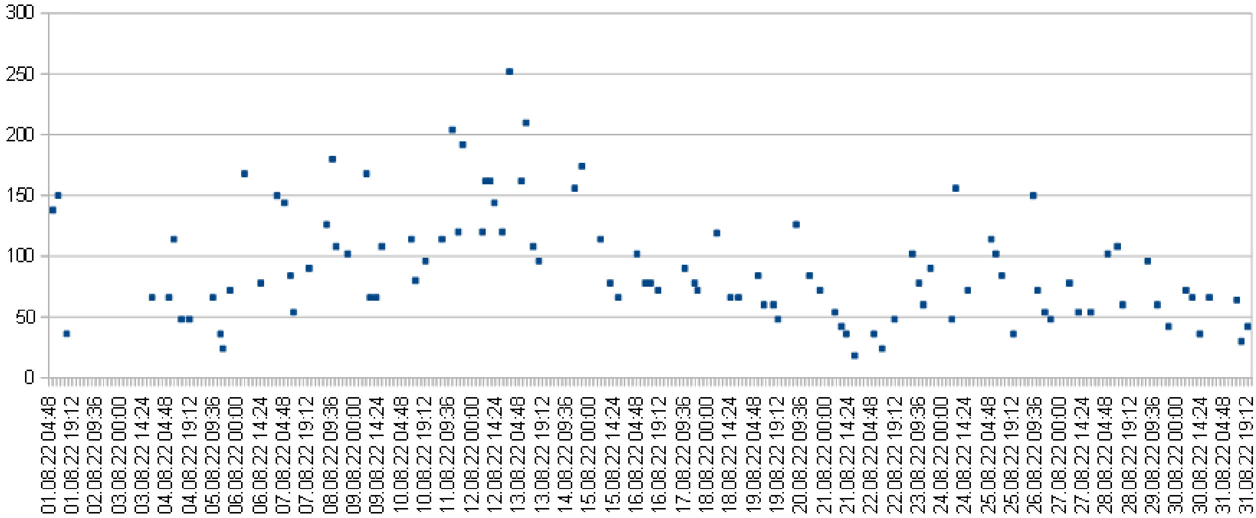


Figure 7 – The result with the calculated hourly numbers of meteor echoes by listening to the radio signals during August 2022.

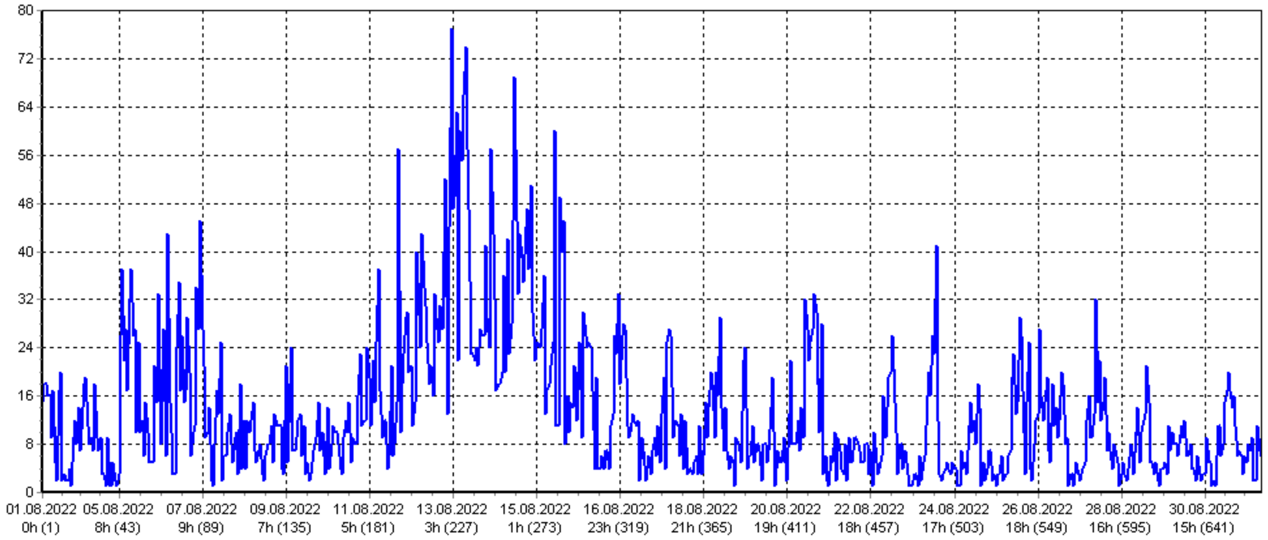


Figure 8 – Radio meteor echo counts at 88.6 MHz during August 2022.

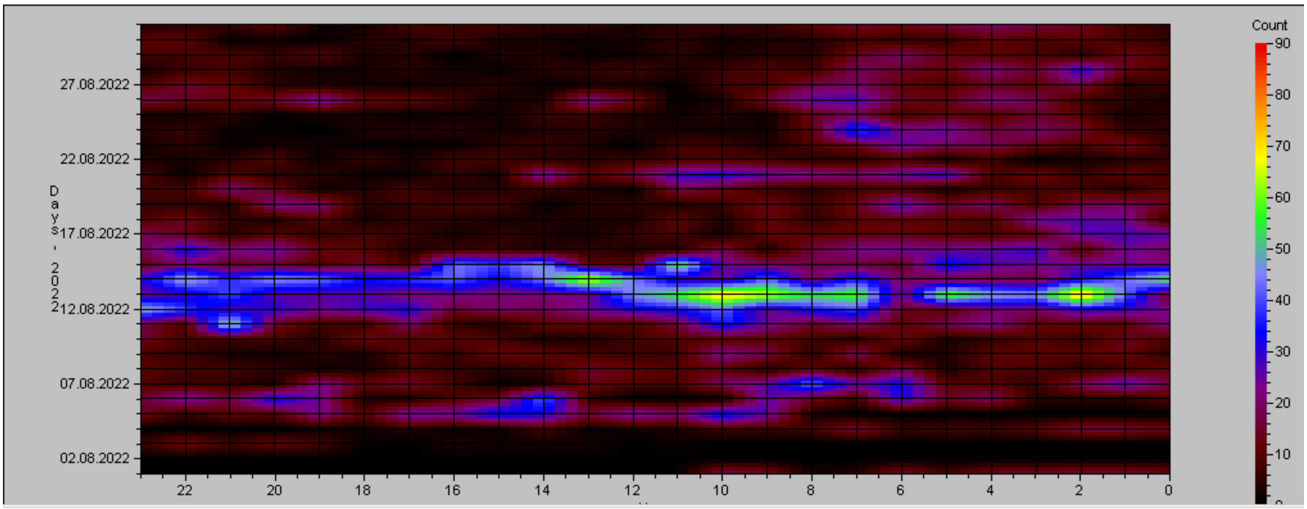


Figure 9 – Heatmap for radio meteor echo counts at 88.6 MHz for August 2022.

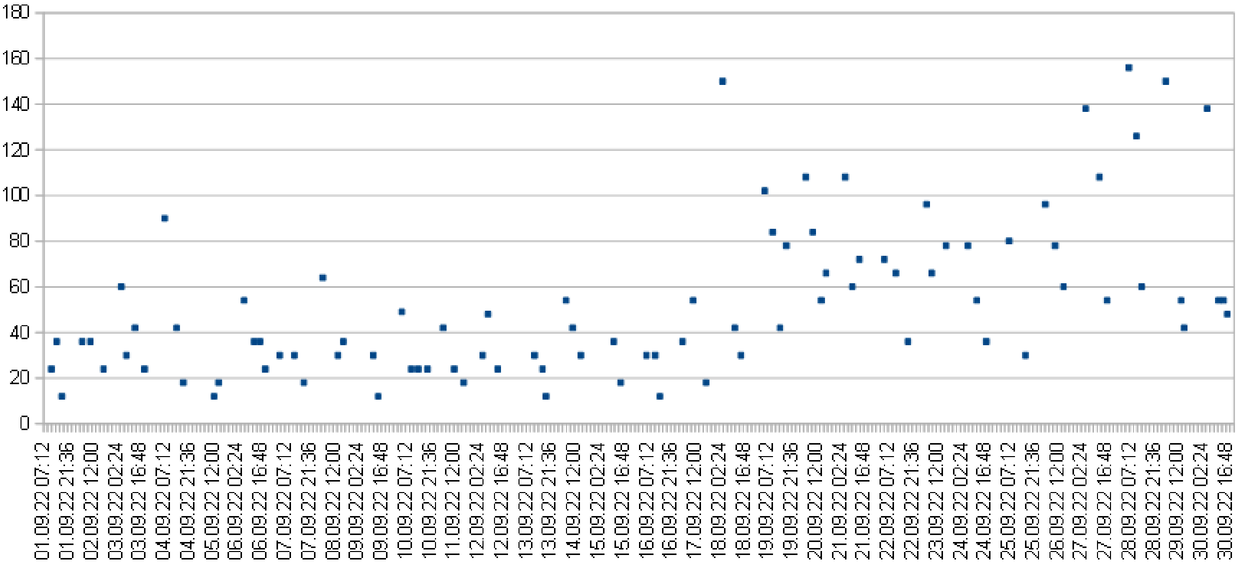


Figure 10 – The result with the calculated hourly numbers of meteor echoes by listening to the radio signals during September 2022.

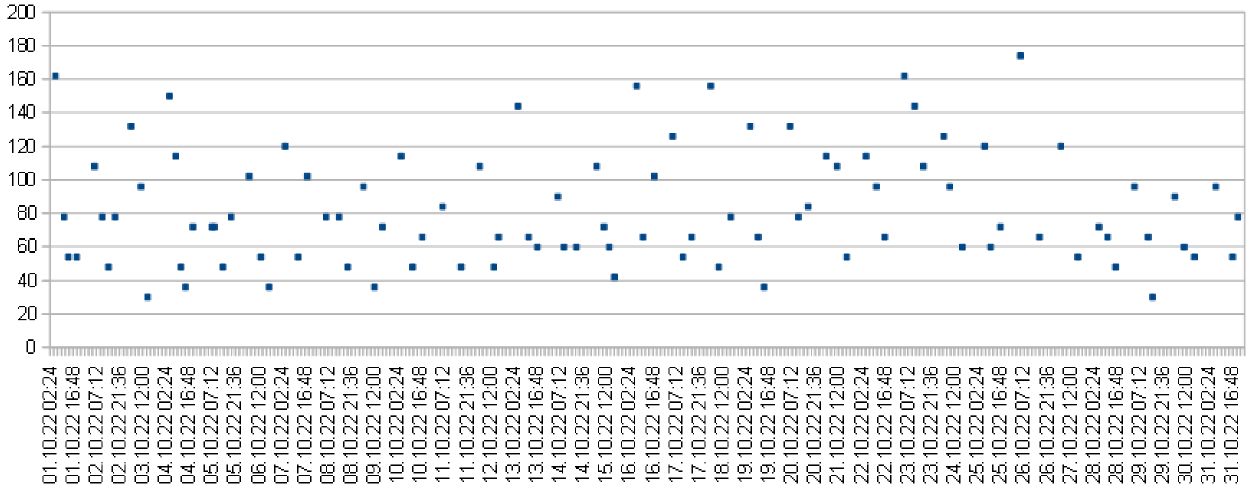


Figure 11 – The result with the calculated hourly numbers of meteor echoes by listening to the radio signals during October 2022.

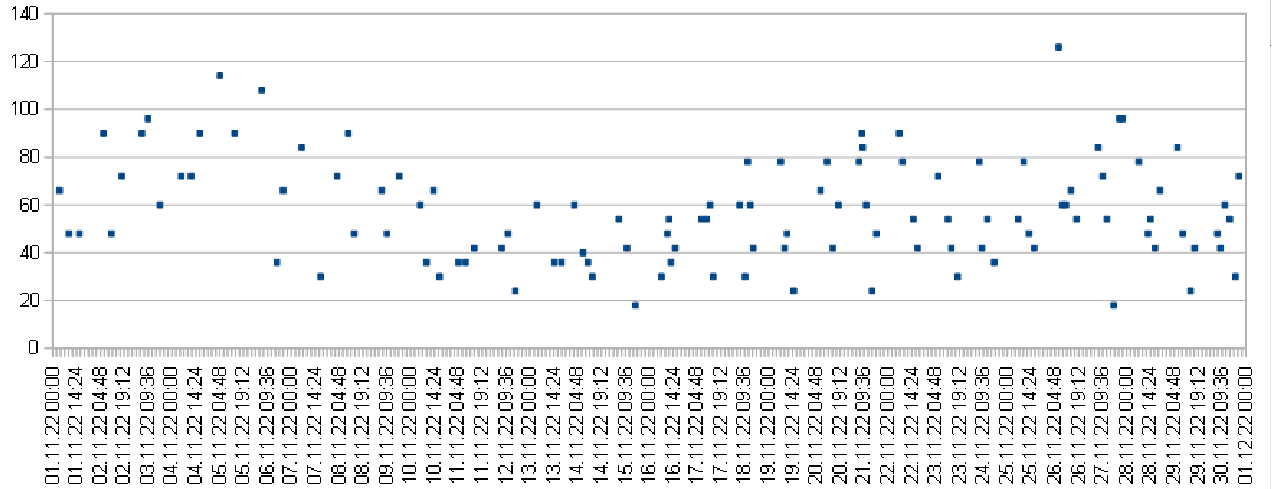


Figure 12 – The result with the calculated hourly numbers of meteor echoes by listening to the radio signals during November 2022.

On June 7–8, a peak caused by the daylight Arietid activity can be seen. June 13–14 there was an unclassified increased activity and on 21–22 a strong unclassified activity peak can be seen (*Figure 5*).

The peak of activity at the end of the month July is interesting, probably due to the minor showers SDA, CAP, and maybe PAU showing up. The peak in early July is interesting and not yet classified by me (*Figure 6*).

Figures 8 and 9 show the results of automatic observations for August 2022. The maximum hourly numbers reached at 2^h UT and around 9^h–10^h UT on August 13, correspond to a solar longitude of 140.02° and 140.3°. This coincides with the onset date of the traditional peak at solar longitude 140° (about 01^h UT on August 13). Perseids showed rather modest activity, only about 200–250 signals per hour. Very interesting is the broad peak of the shower, almost half a month wide (*Figure 7*).

The increase in overall activity after September 18 and up to the end of the month is very interesting. I have no idea what (which) showers may explain this (*Figure 10*).

Draconids displayed very weak activity and do not stand out from the general trend of activity. For the Orionids, there was a slight increase in activity on October 23, though the traditional peak of October 21 did not show anything (*Figure 11*).

The peak in early November is most likely due to the end of Orionid activity and the overlapping activity of a number of minor showers. The unclassified peak in the morning of November 26 is interesting. Perhaps it was caused by the November Orionids (NOO) that were active? The Leonids were so weak that they were not even visible in the profile (*Figure 12*).

3 Conclusion

The method of counting the radio meteor echoes by listening is about 3 times more sensitive than the method using automatic detection of meteor echo signals with music or speech. Experiments are underway to increase the sensitivity of the Metan software for automatic detection of meteor signals. The method of listening to the radio echoes is very interesting, because it allows you to "scan" the dynamics of the total meteor background over a long time, to identify periods of low activity, periods of high activity, as well as outbursts and the peak activity of the most prominent meteoroid streams.

Acknowledgment

I would like to thank *Sergey Dubrovsky* for the software he developed for data analysis and processing of radio observations (software Rameda). I thank *Carol* from Poland for the Metan software. Thanks to *Paul Roggemans* for his help in the lay-out and the correction of this article.

References

Rendtel J. (2021). "Meteor Shower Calendar". IMO.

Radio observations in December 2022

Ivan Sergei

Mira Str.40-2, 222307, Molodechno, Belarus
`seriv76@tut.by`

This article presents the results of radio observations made in December 2022.

1 Introduction

The observations were carried out at a private astronomical observatory near the town of Molodechno (Belarus) at the place of Polyani. A 5 element-antenna directed to the west was used, a car FM-receiver was connected to a laptop with as processor an Intel Atom CPU N2600 (1.6 GHz). The software to detect signals is Metan (author – Carol from Poland). Observations are made on the operating frequency 88.6 MHz (the FM radio station near Paris broadcasts on this frequency). The "France Culture" radio broadcast transmitter (100 kW) I use is at about 1550 km from my observatory which has been renewed in 1997. In December I began experiments to increase the sensitivity of the radio meteor installation (increasing the sensitivity of the Metan software by reducing the trigger for weak meteor signals). The purpose of the experiment is to obtain hourly numbers of meteor echo signals comparable to the hourly numbers obtained by listening for the radio reflections.

2 Counting radio echoes on 88.6 MHz

In order to save observation time and to increase the efficiency of counting the radio meteor echoes in order to obtain a more complete observation series, I made a modification to the method with the introduction of a definition of a "synthetic" hourly rate numbers (see *Figure 1*).

Listening to the radio signals for 10 minutes with an extrapolation of the data to 1 hour was done about 3 to 5 times a day. This was done in order to control the level of the hourly rates as well as to distinguish between periods of tropospheric passage and other natural radio interference. The total effective counting time was 145 synthetic hours.

The Geminid peak occurred on the morning of December 14 around 6^h to7^h UT with hourly numbers at 440 signals per hour at solar longitude ~261.9°, i.e., earlier than the traditional peak at solar longitude 262.2°.

The maximum hourly numbers for the Ursids (URS, #0015) were reached in the morning of December 22 around 9^h UT (solar longitude ~270.16°) at 110 signals per hour. At the traditional maximum, around 22^h UT (solar longitude 270.7°), hourly numbers with 60–70 signals per hour were recorded.

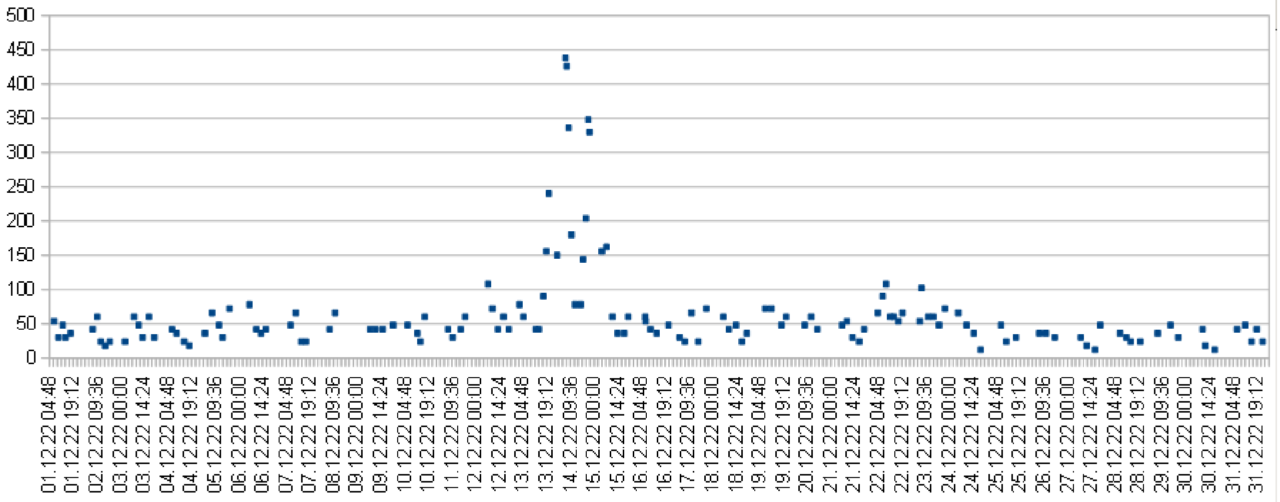


Figure 1 – Results plotted as "synthetic" hourly numbers counted for meteor echoes in December 2022.

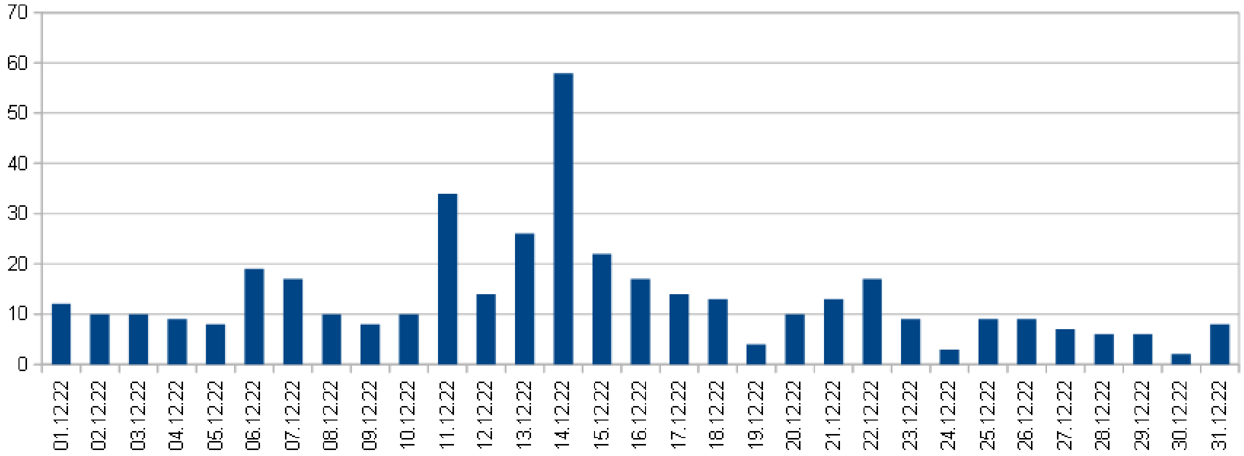


Figure 2 – Daily activity of radio fireballs in December 2022.

3 Fireballs

In order to quickly search for signals of the radio fireballs, the program SpectrumLab was running in parallel to the Metan program. Screenshots were saved every 10 minutes. The search for fireball events was performed visually by viewing many thousands of screenshots obtained over a month.

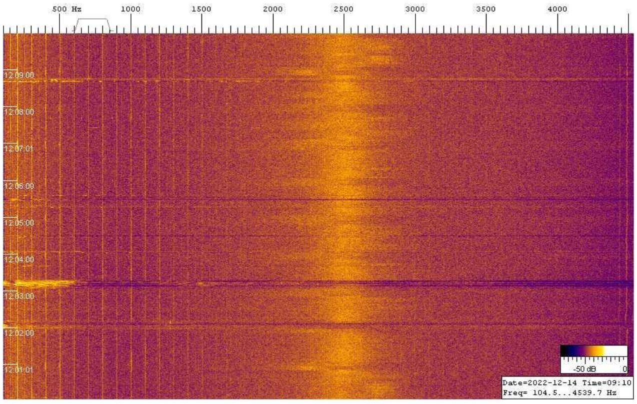


Figure 3 – Radio fireball recorded by SpectrumLab on December 14 at $09^{h}03^{m}$ UT.

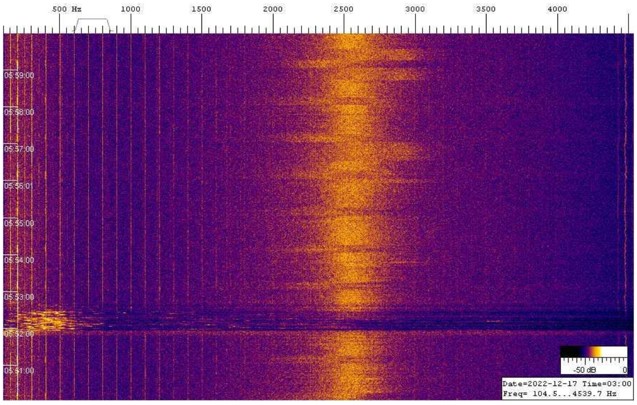


Figure 4 – Radio fireball recorded by SpectrumLab on December 17 at $02^{h}52^{m}$ UT.

For the selection of fireballs, I selected the longest phenomena (wide bands on spectrograms more than 10 seconds). Then each event was viewed by the log files of the program Metan. However, because of the experiment with increasing the sensitivity of the program, not all log files were good or even some did not exist (if a radio signal is detected and at this point the program should save its log file, it could happen that it may not be saved. This is one of the unpleasant features of this software).

Figure 2 shows the daily activity of the fireball radio signals. *Figures 3 to 5* display some of the fireball radio echoes.

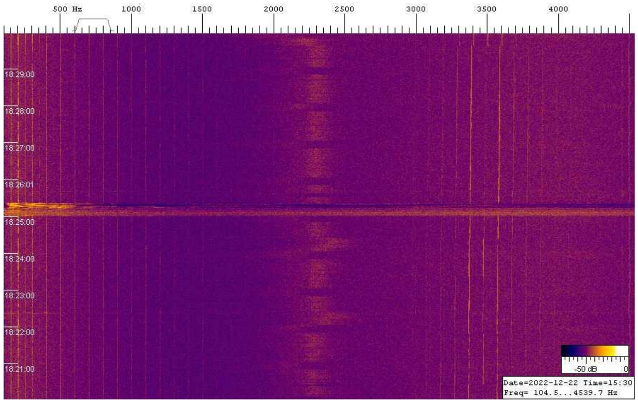


Figure 5 – Radio fireball recorded by SpectrumLab on December 22 at $15^{h}25^{m}$ UT.

Acknowledgment

I would like to thank *Sergey Dubrovsky* for the software he developed for data analysis and processing of radio observations (software Rameda). I thank *Carol* from Poland for the Metan software. Thanks to *Paul Roggemans* for his help in the lay-out and the correction of this article.

References

Rendtel J. (2022). "Meteor Shower Calendar". IMO.

Radio meteors December 2022

Felix Verbelen

Vereniging voor Sterrenkunde & Volkssterrenwacht MIRA, Grimbergen, Belgium
`felix.verbelen@skynet.be`

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

1 Introduction

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

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

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

No lightning activity was observed and local interference and unidentified noise remained moderate to low during this month.

The eye-catchers were of course the Geminids, which reached their peak in the period December 13-15, with the long-lasting overdenses clearly peaking later than the underdense.

The Ursids were also interesting, with a maximum on December 22.

Over the entire month, 13 reflections longer than 1 minute were observed here, among which the remarkable more than 5 minutes lasting reflection of December 3th. A selection of long reflections is shown in *Figures 5 to 12.*

In addition to the usual graphs, you will also find the raw counts in cvs-format[30] 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.

---

[30] https://www.meteornews.net/wp-content/uploads/2023/02/202212_49990_FV_rawcounts.csv

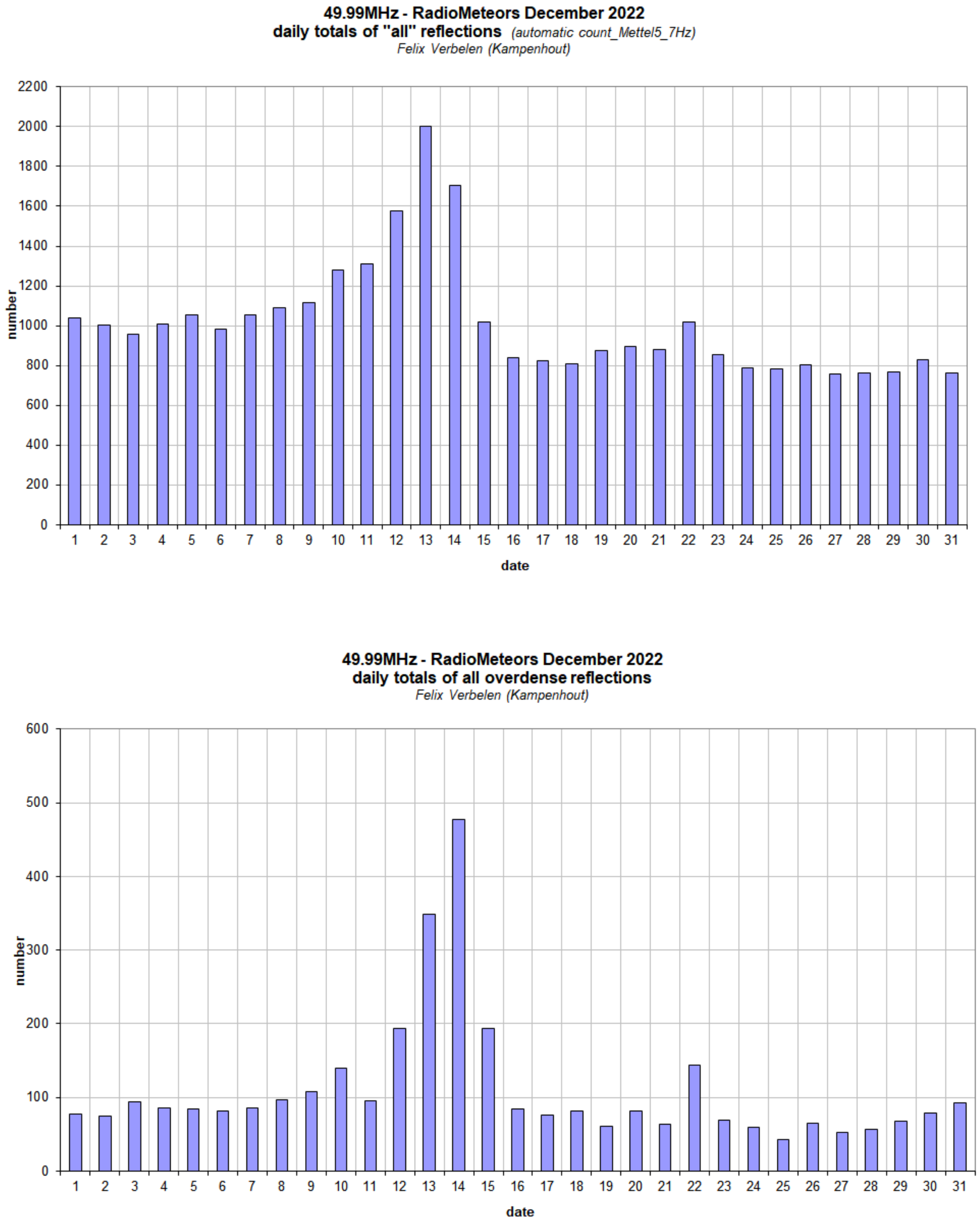
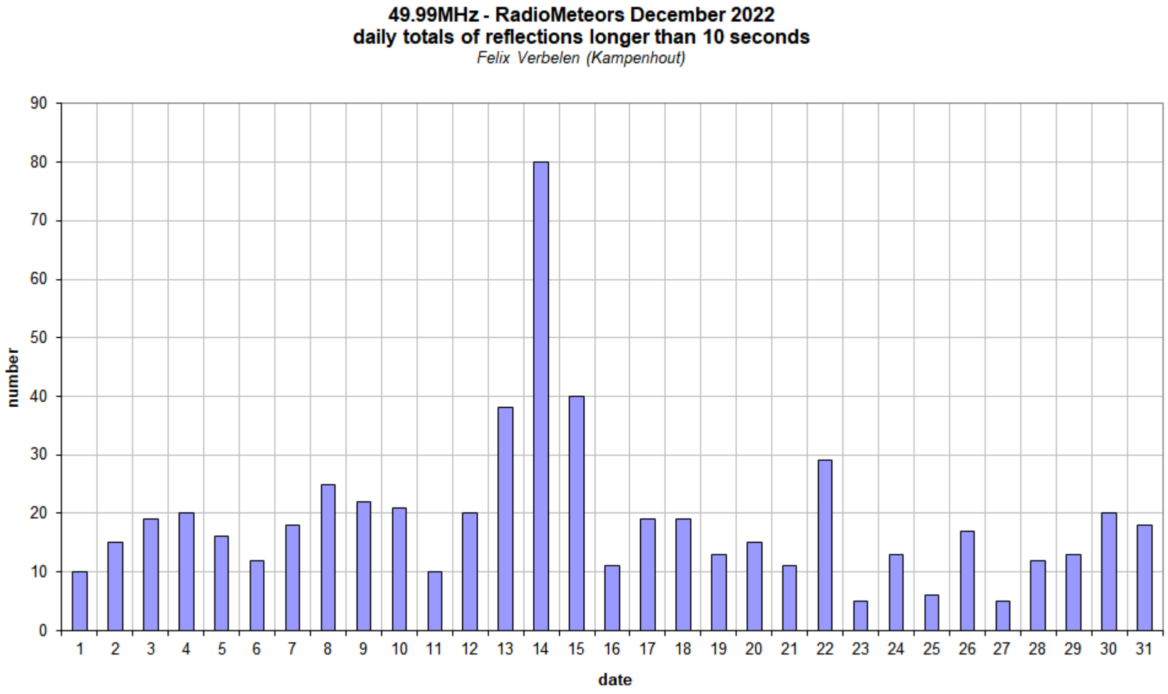


Figure 1 – The daily totals of “all” reflections counted automatically, and of manually counted “overdense” reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during December 2022.



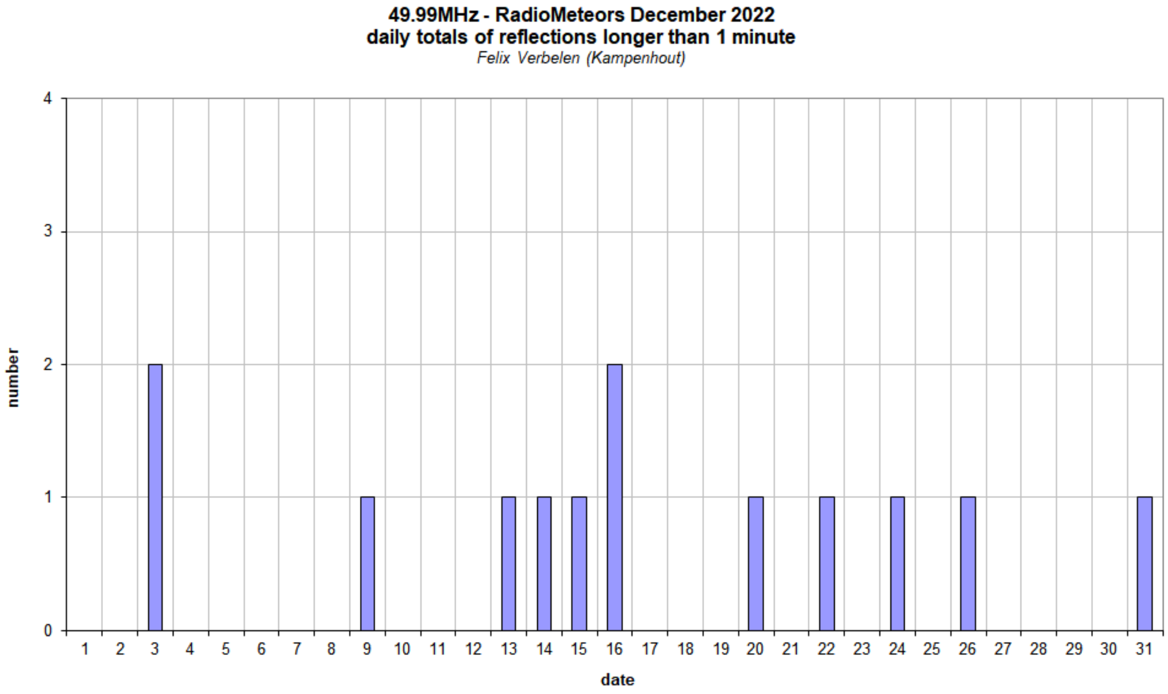
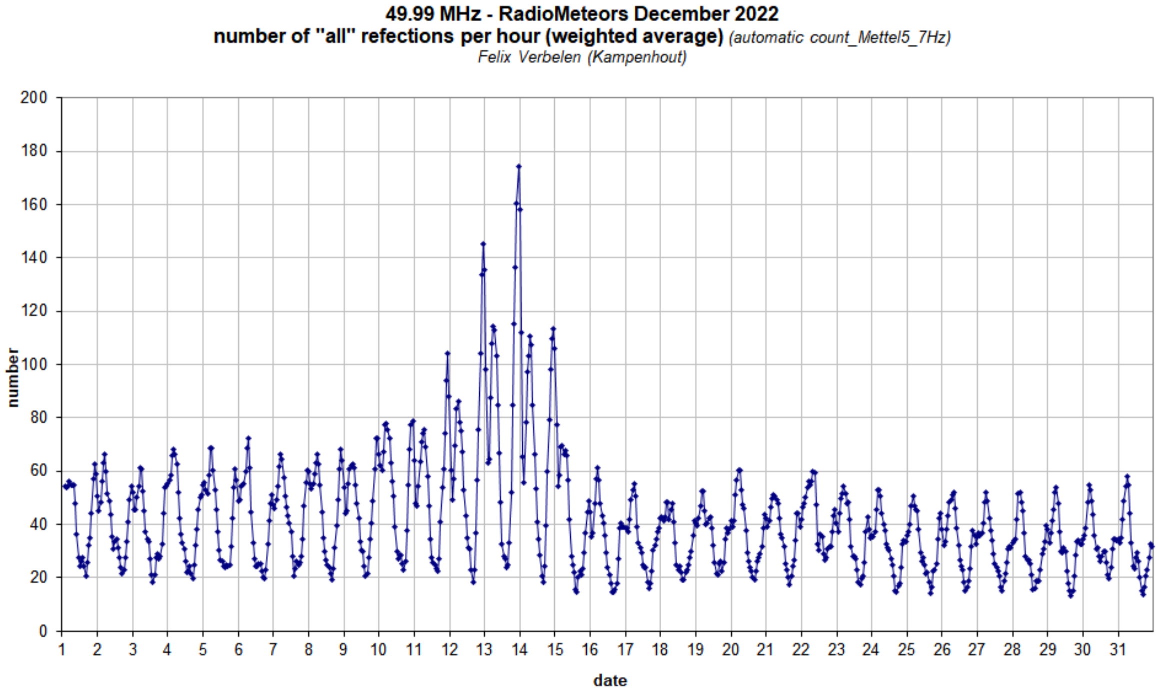


Figure 2 – The daily totals of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during December 2022.



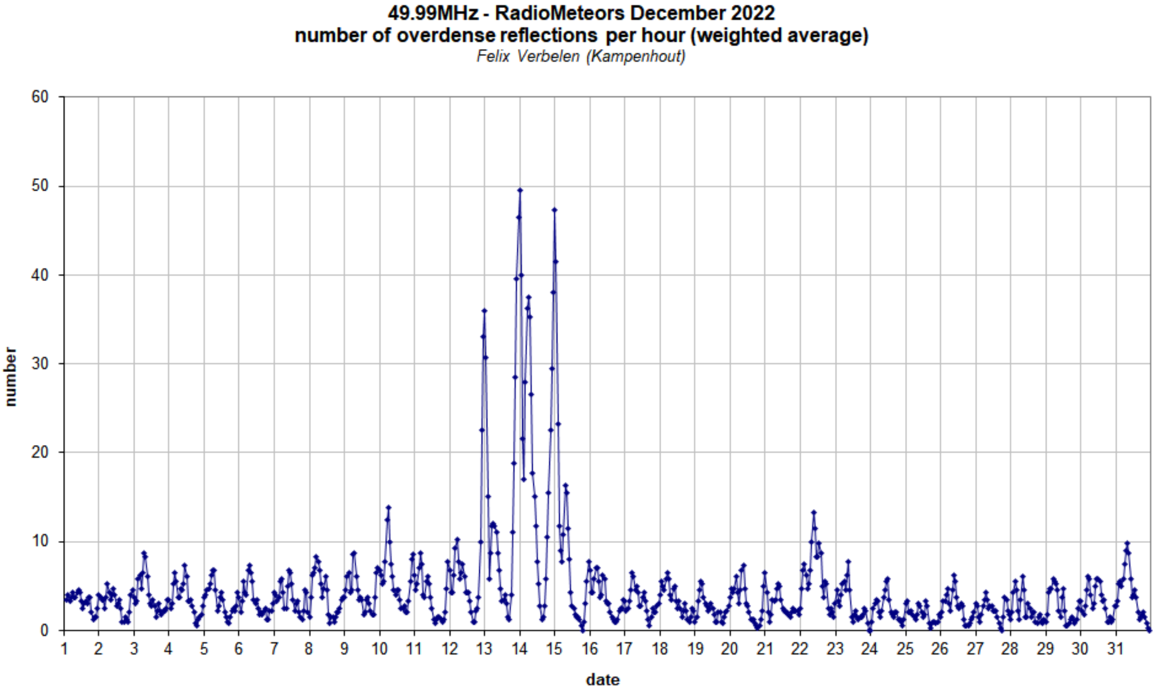
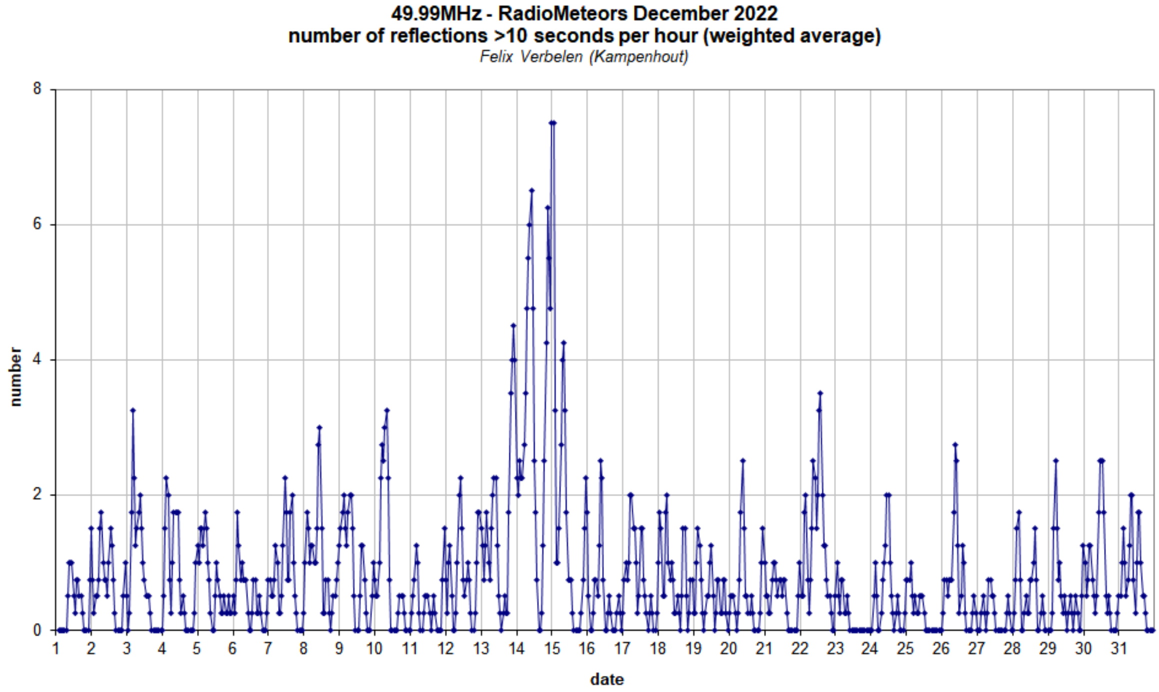


Figure 3 – The hourly numbers of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during December 2022.



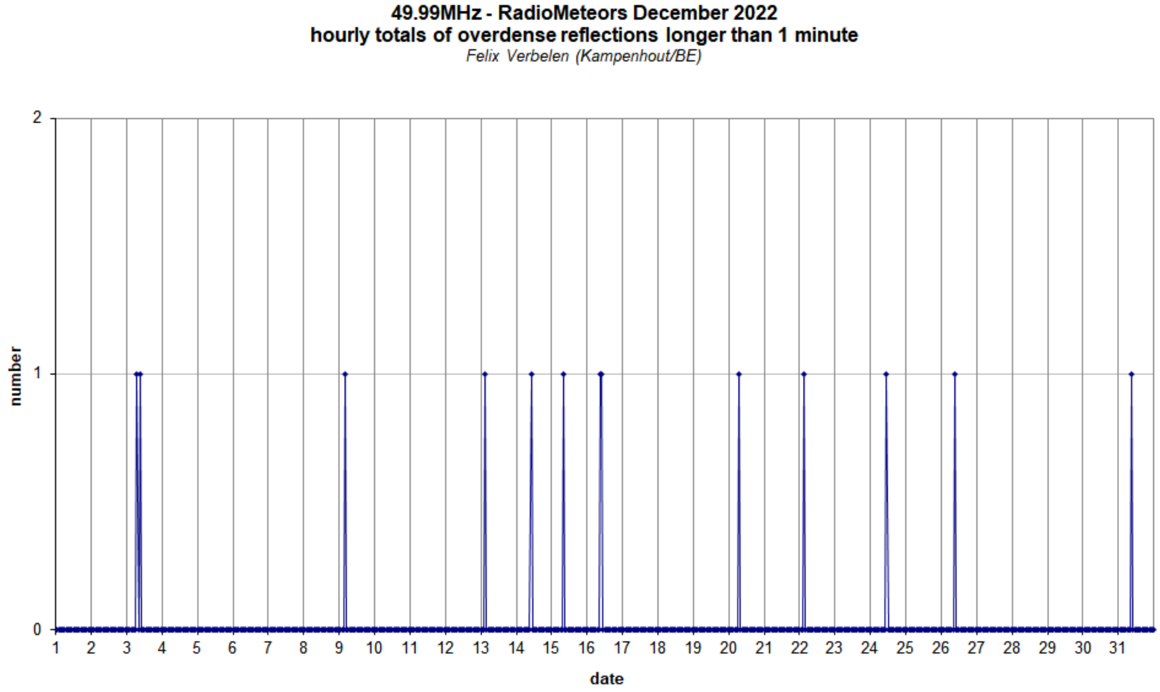


Figure 4 – The hourly numbers of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during December 2022.

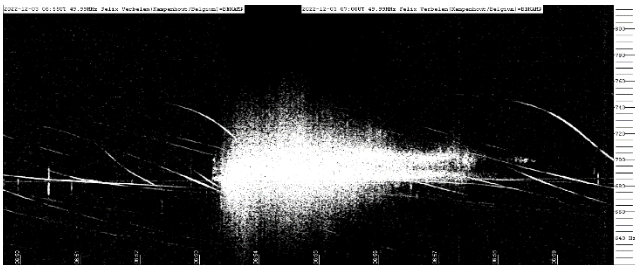


Figure 5 – Meteor echo 03 December 2022, 06^{h}55^m UT.

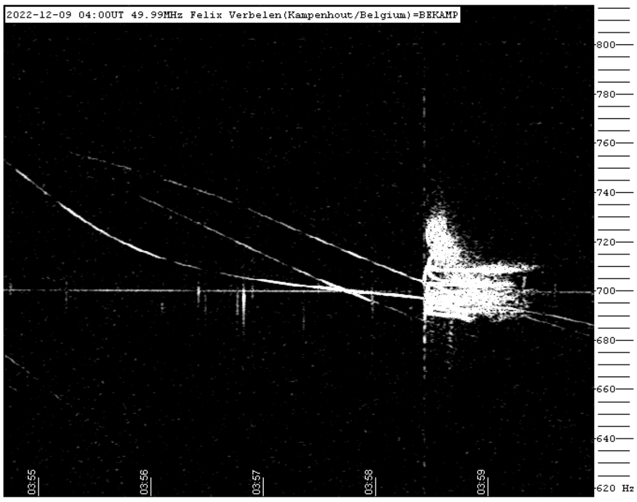


Figure 6 – Meteor echo 9 December 2022, 04^{h}00^m UT.

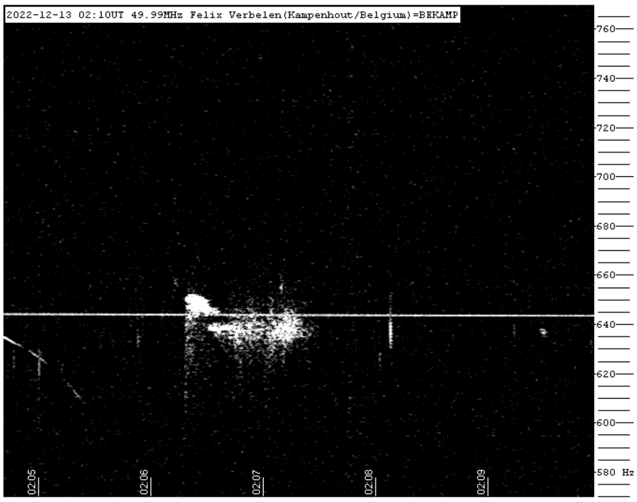


Figure 7 – Meteor echo 13 December 2022, 02^{h}10^m UT.

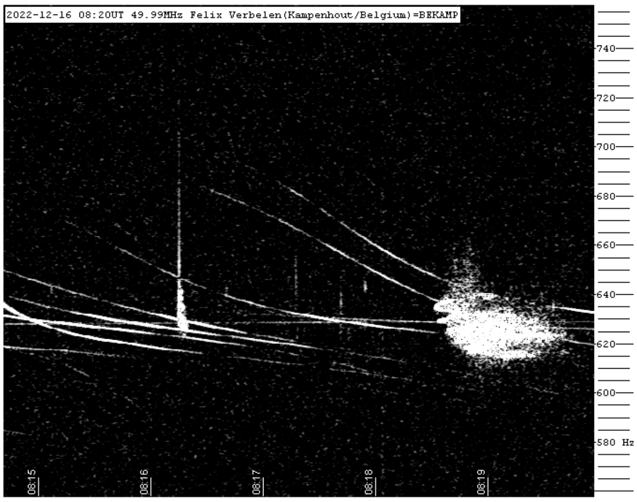


Figure 8 – Meteor echo 16 December 2022, 08^{h}20^m UT.

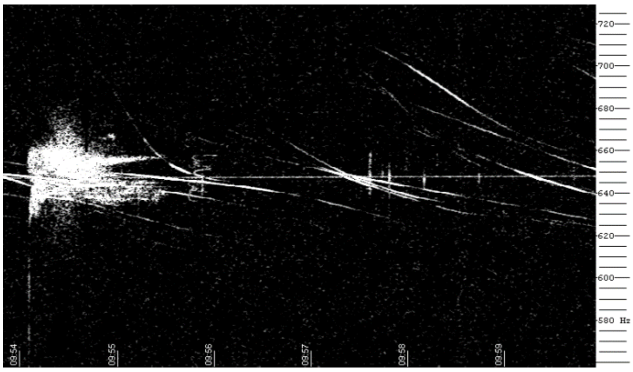


Figure 9 – Meteor echo 16 December 2022, 10^{h}00^m UT.

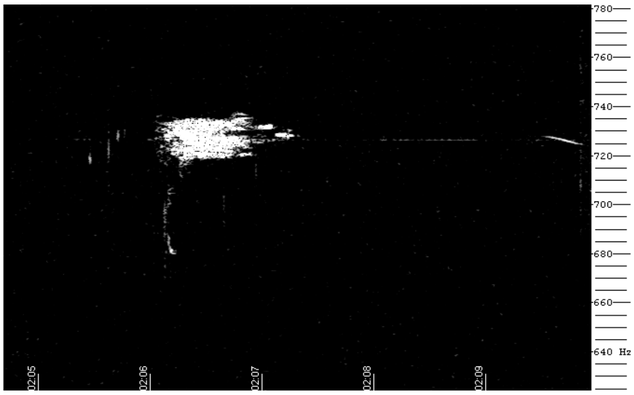


Figure 10 – Meteor echo 22 December 2022, 02^{h}10^m UT.

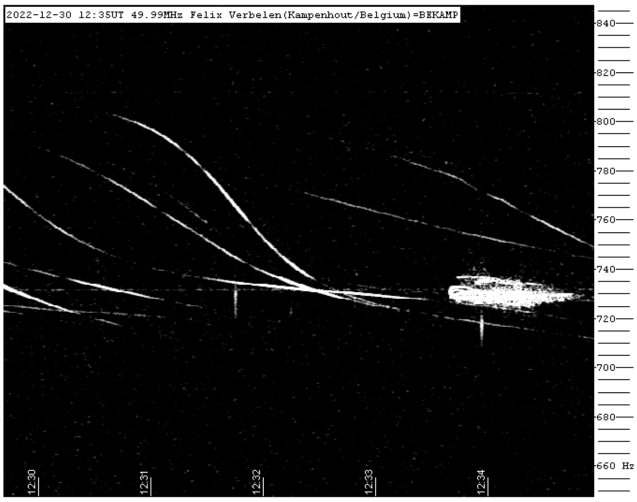


Figure 11 – Meteor echo 30 December 2022, 12^{h}35^m UT.

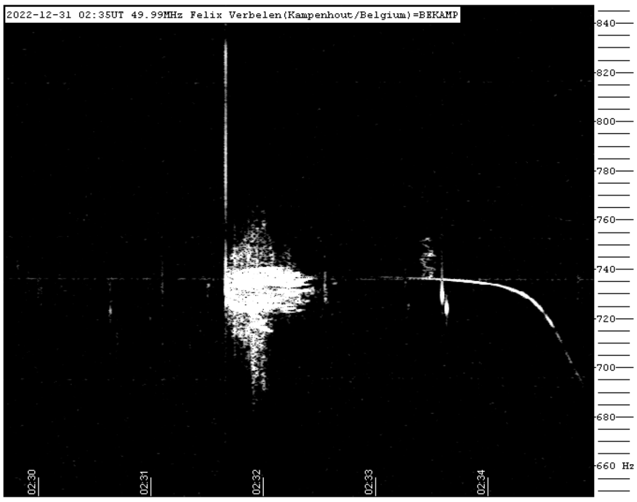


Figure 12 – Meteor echo 31 December 2022, 02^{h}35^m UT.

Radio meteors January 2023

Felix Verbelen

Vereniging voor Sterrenkunde & Volkssterrenwacht MIRA, Grimbergen, Belgium
`felix.verbelen@skynet.be`

An overview of the radio observations during January 2023 is given.

1 Introduction

The graphs show both the daily totals (*Figure 2 and 3*) and the hourly numbers (*Figure 4 and 5*) 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 January 2023.

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

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

No lightning activity was observed and local interference and unidentified noise remained moderate to low during this month.

The eye-catchers were of course the Quadrantids/Boötids, reaching their peak on January 4th. *Figure 1* shows the activity compared to the radiant's elevation.

Although the general activity was, as expected, quite low during the remainder of the month, several minor showers and brief outbursts as i.e., on January 26th (*Figure 6*) were observed.

Over the entire month, 7 reflections longer than 1 minute were observed. A selection of these, together with a number of interesting "epsilons" are attached (*Figures 7 to 16*). Many more are available on request.

In addition to the usual graphs, you will also find the raw counts in cvs-format[31] 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.

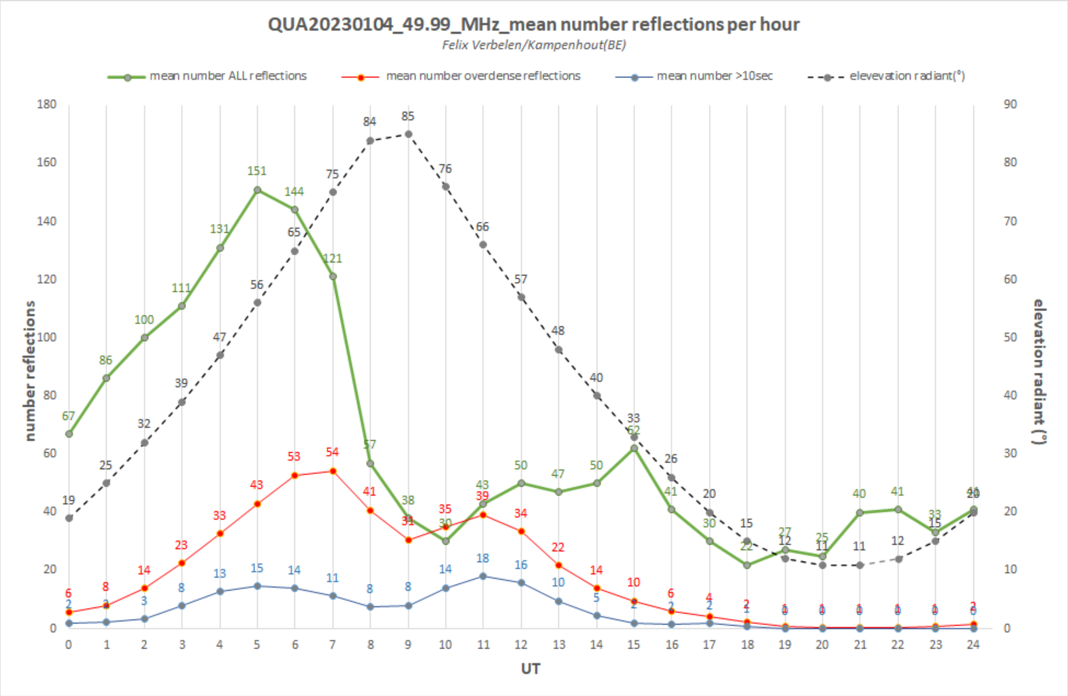


Figure 1 – The Quadrantid activity 2023 and the radiant elevation.

---

[31] https://www.meteornews.net/wp-content/uploads/2023/02/202301_49990_FV_rawcounts.csv

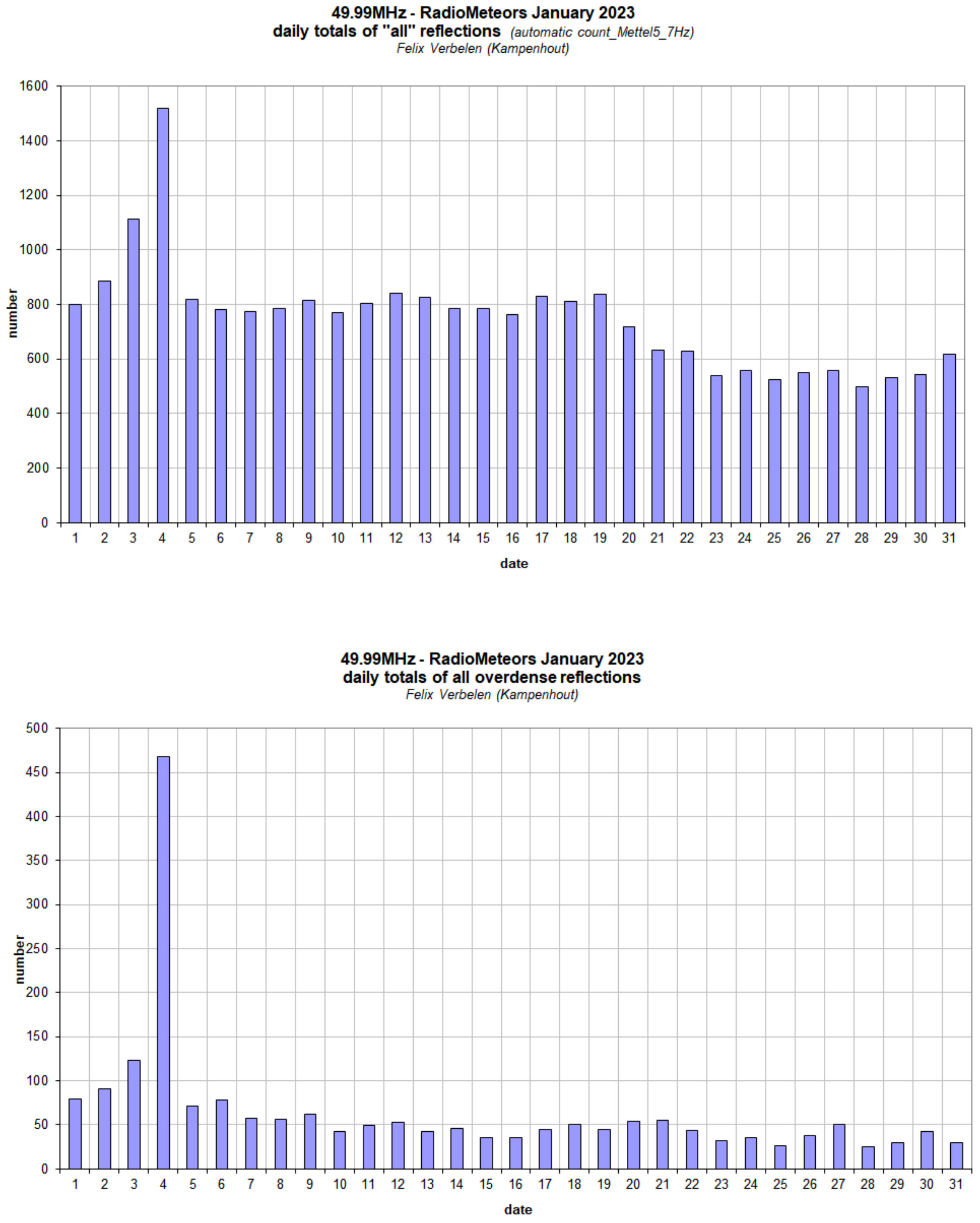
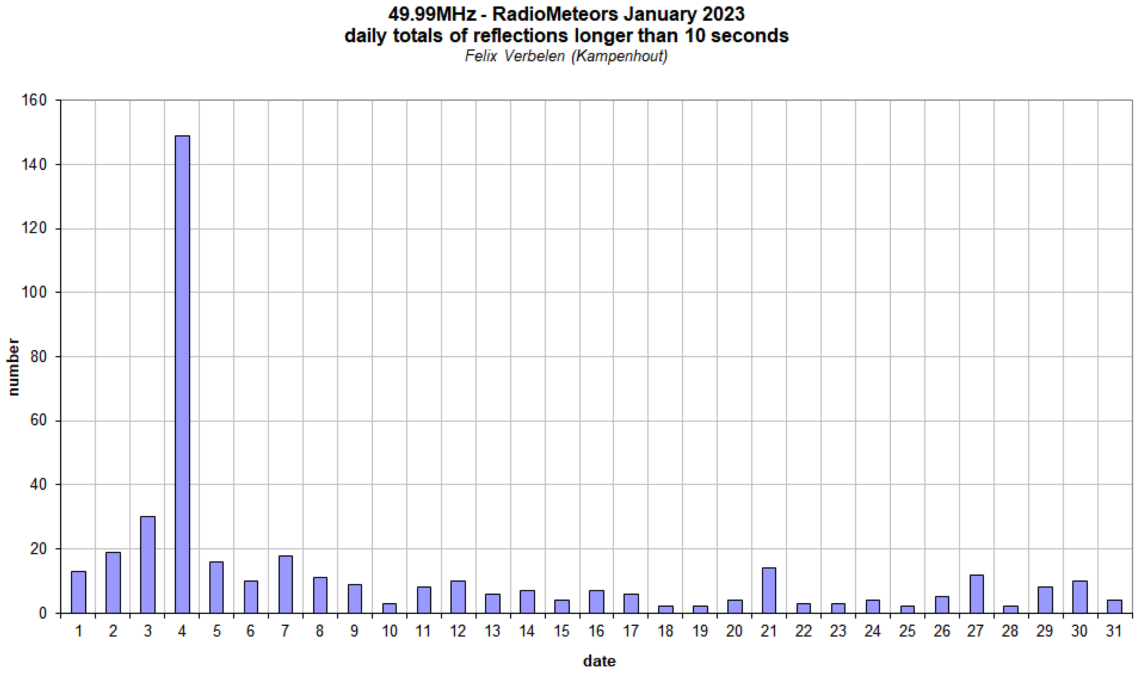


Figure 2 – The daily totals of “all” reflections counted automatically, and of manually counted “overdense” reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during January 2023.



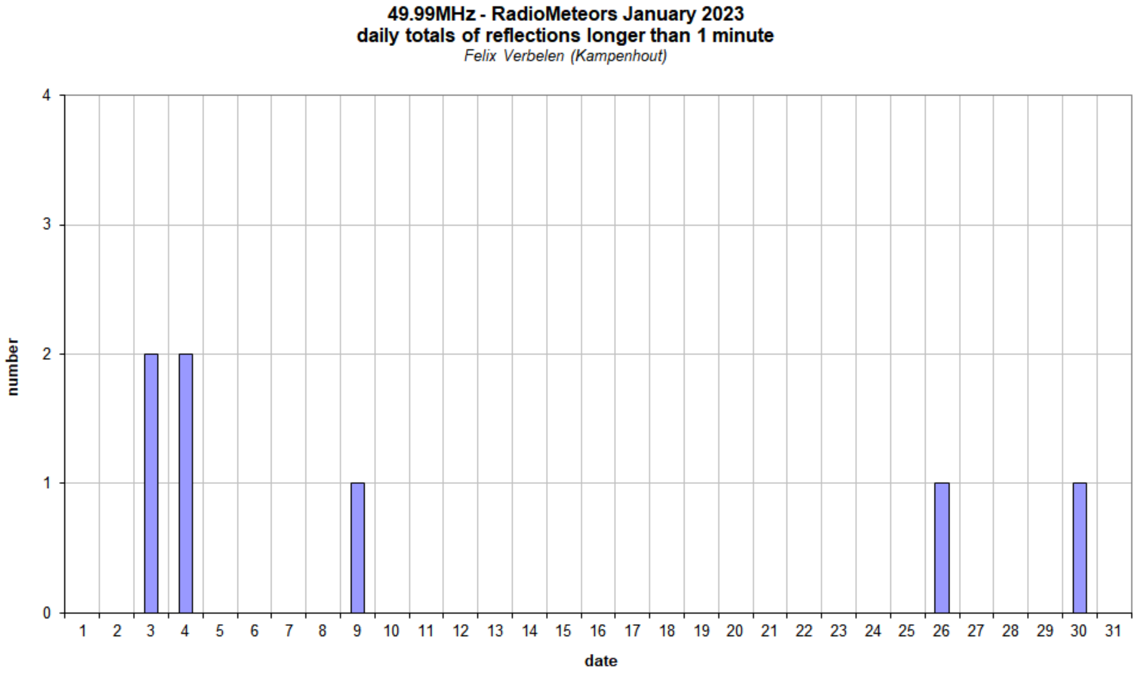
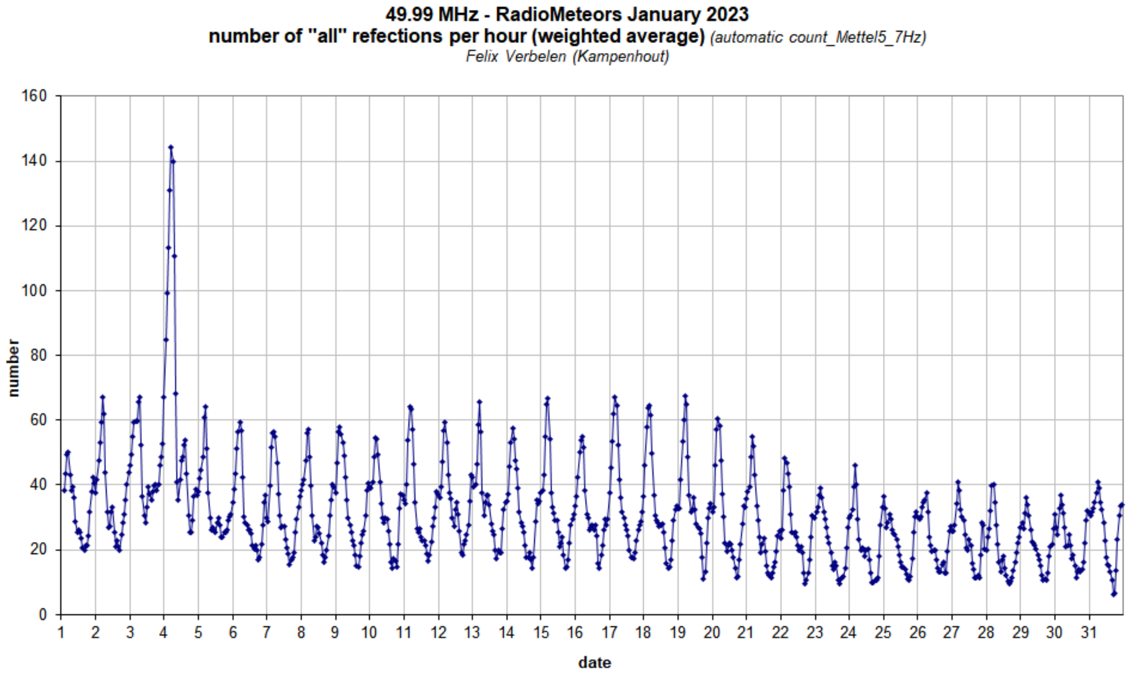


Figure 3 – The daily totals of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during January 2023.



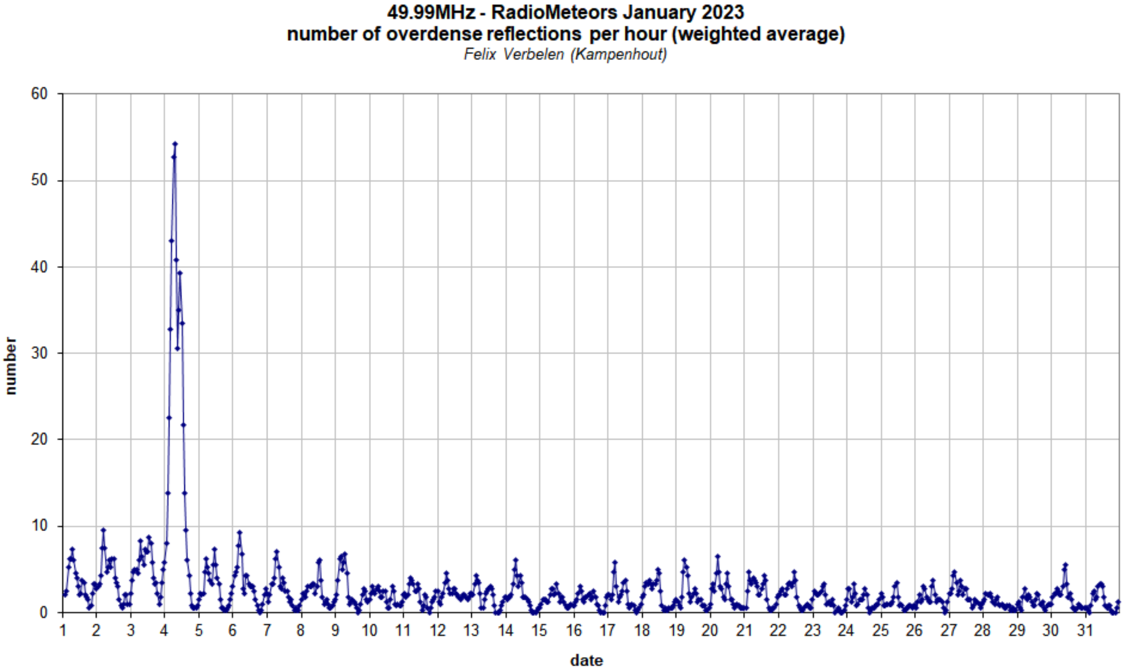


Figure 4 – The hourly numbers of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during January 2023.

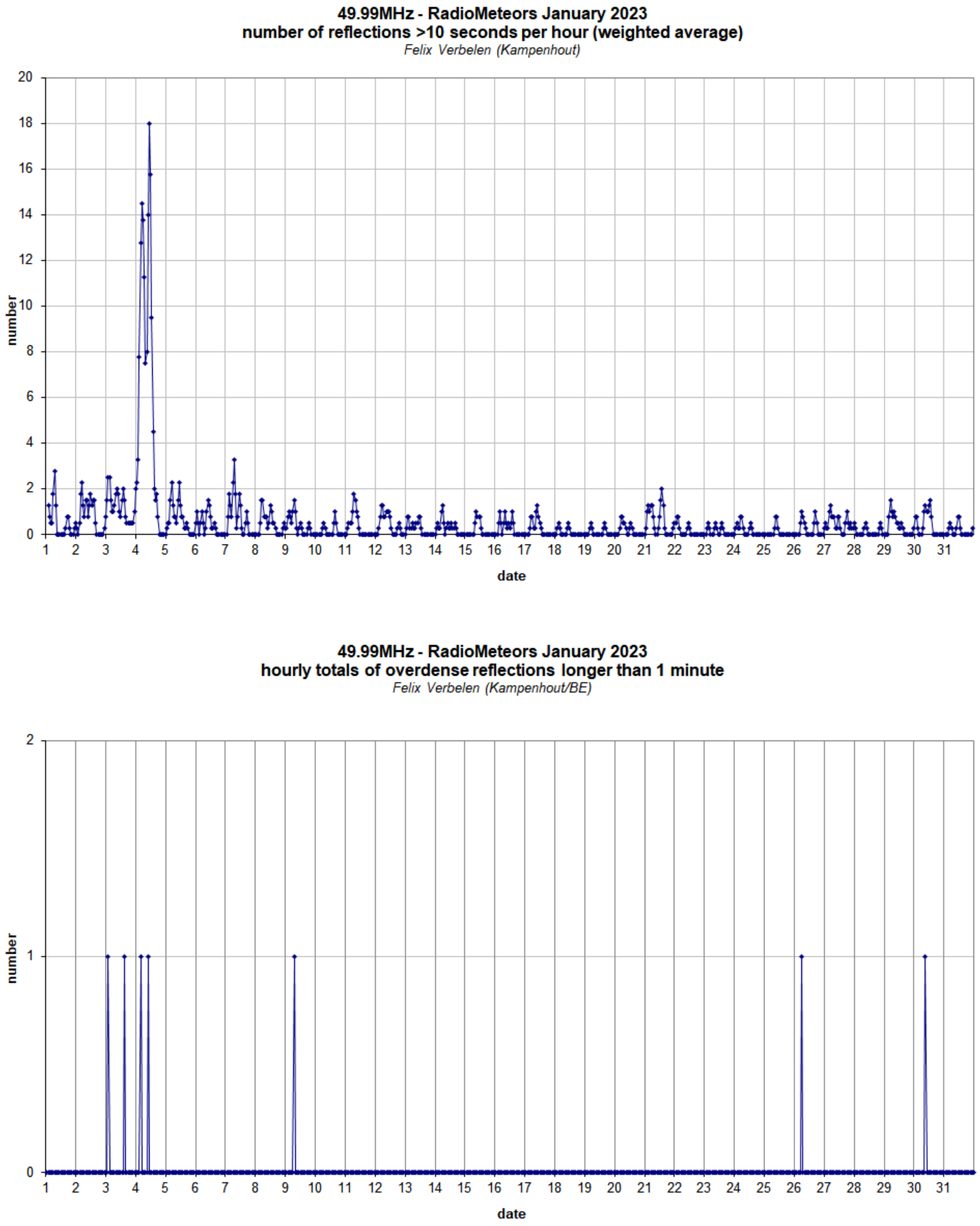


Figure 5 – The hourly numbers of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during January 2023.

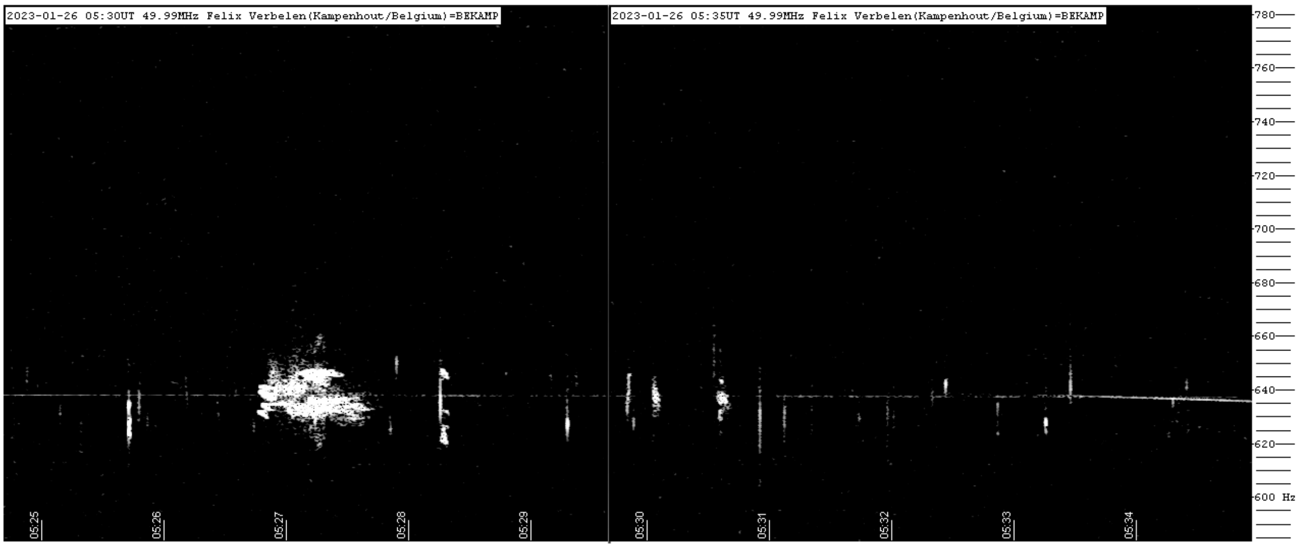


Figure 6 – Enchanced activity from an unknown source on 2023 January 26.

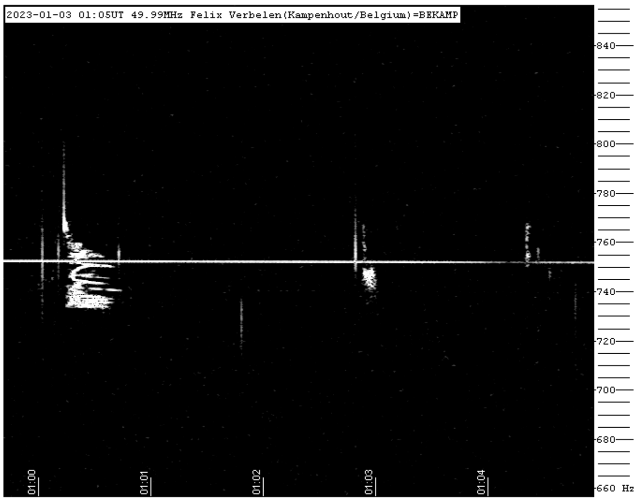


Figure 7 – Meteor echo 3 January 2023, 01^{h}05^m UT.

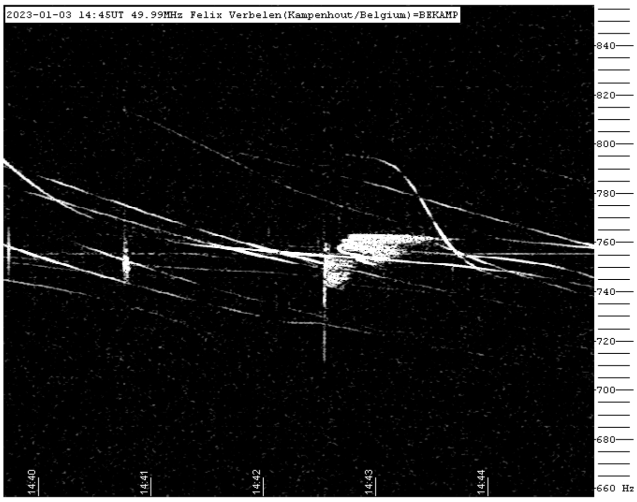


Figure 8 – Meteor echo 3 January 2023, 14^{h}45^m UT.

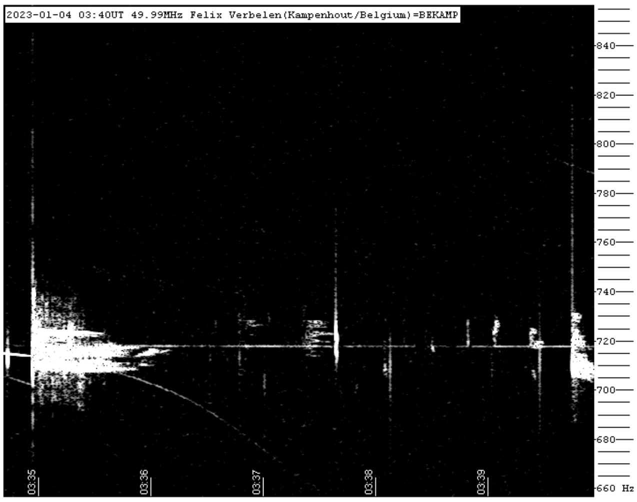


Figure 9 – Meteor echo 4 January 2023, 03^{h}40^m UT.

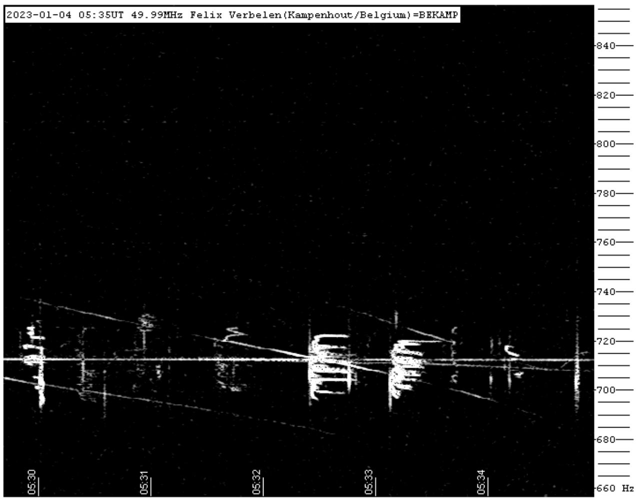


Figure 10 – Meteor echo 4 January 2023, 05^{h}35^m UT.

Figure 11 – Meteor echo 5 January 2023, 06^{h}10^m UT.

Figure 14 – Meteor echo 26 January 2023, 05^{h}30^m UT.

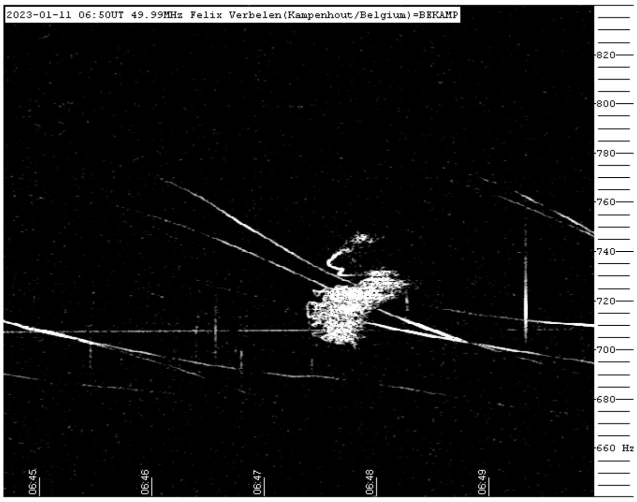


Figure 12 – Meteor echo 11 January 2023, 06^{h}50^m UT.

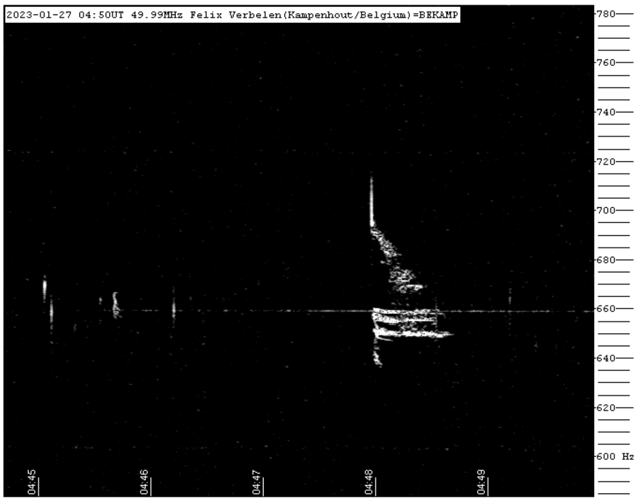


Figure 15 – Meteor echo 27 January 2023, 04^{h}50^m UT.

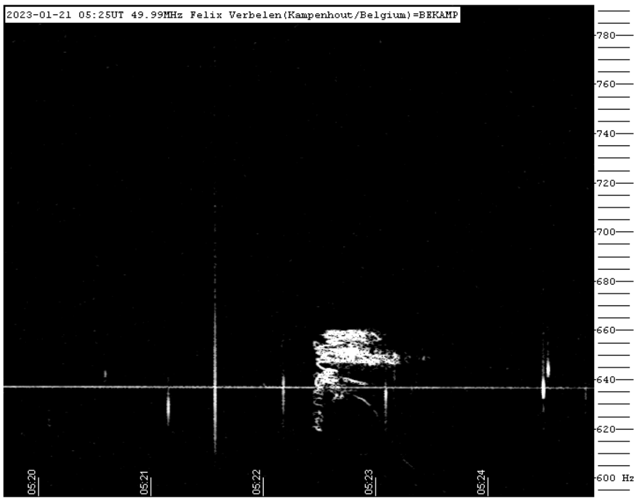


Figure 13 – Meteor echo 21 January 2023, 05^{h}25^m UT.

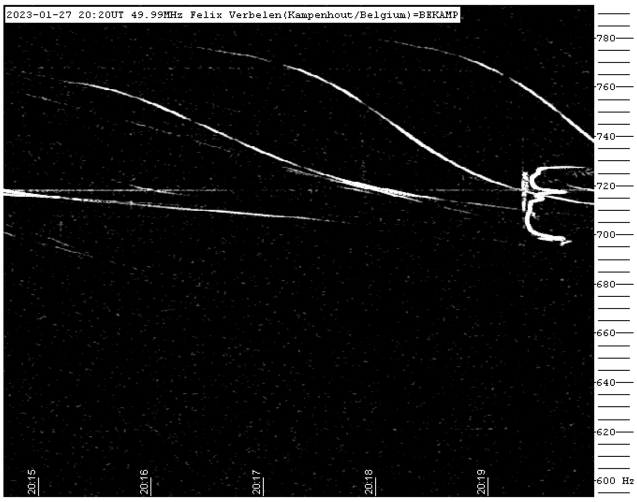


Figure 16 – Meteor echo 27 January 2023, 20^{h}20^m UT.

The Southwestern Europe Meteor Network: notable meteors spotted between December 2022 and January 2023

J.M. Madiedo[1], J.L. Ortiz[1], J. Izquierdo[2], P. Santos-Sanz[1], J. Aceituno[3], E. de Guindos[3], P. Yanguas[4], J. Palacián[4], A. San Segundo[5], D. Ávila[6], B. Tosar[7], A. Gómez-Hernández[8], Juan Gómez-Martínez[8], Antonio García[9], and A.I. Aimee[10]

[1] **Departamento de Sistema Solar, Instituto de Astrofísica de Andalucía (IAA-CSIC), 18080 Granada, Spain**
`madiedo@cica.es, ortiz@iaa.es, psantos@iaa.es`

[2] **Departamento de Física de la Tierra y Astrofísica, Universidad Complutense de Madrid, 28040 Madrid, Spain**
`jizquierdo9@gmail.com`

[3] **Observatorio Astronómico de Calar Alto (CAHA), E-04004, Almería, Spain**
`aceitun@caha.es, guindos@caha.es`

[4] **Departamento de Estadística, Informática y Matemáticas e Institute for Advanced Materials and Mathematics, Universidad Pública de Navarra, 31006 Pamplona, Navarra, Spain**
`yanguas@unavarra.es, palacian@unavarra.es`

[5] **Observatorio El Guijo (MPC J27), Galapagar, Madrid, Spain**
`mpcj27@outlook.es`

[6] **Estación de Meteoros de Ayora, Ayora, Valencia, Spain**
`David_ayora007@hotmail.com`

[7] **Casa das Ciencias. Museos Científicos Coruñeses. A Coruña, Spain**
`borjatosar@gmail.com`

[8] **Estación de Registro La Lloma, Olocau, Valencia, Spain**
`curso88@gmail.com`

[9] **Estación de Meteoros de Cullera (Faro de Cullera), Valencia, Spain**
`antonio.garcia88@joseantoniogarcia.com`

[10] **Southwestern Europe Meteor Network, 41012 Sevilla, Spain**
`swemn.server@gmail.com`

We present in this report the analysis of some of the notable meteors registered in the framework of the Southwestern Europe Meteor Network between December 2022 and January 2023. These were recorded from Spain. Their peak brightness ranges from mag. –7 to mag. –10. The emission spectrum of one of them is also presented. Bright meteors included here were produced by different sources: the sporadic background, major meteoroid streams, and poorly-known streams.

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).

We include in this report a preliminary analysis of a series of notable fireballs recorded from Spain in the framework of the SWEMN network along December 2022 and January 2023. This work has been fully written by AIMEE (acronym for Artificial Intelligence with Meteoroid Environment Expertise) from the records included in the SWEMN fireball database (Madiedo et al., 2021; Madiedo et al., 2022).

2 Equipment and methods

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 paths 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).

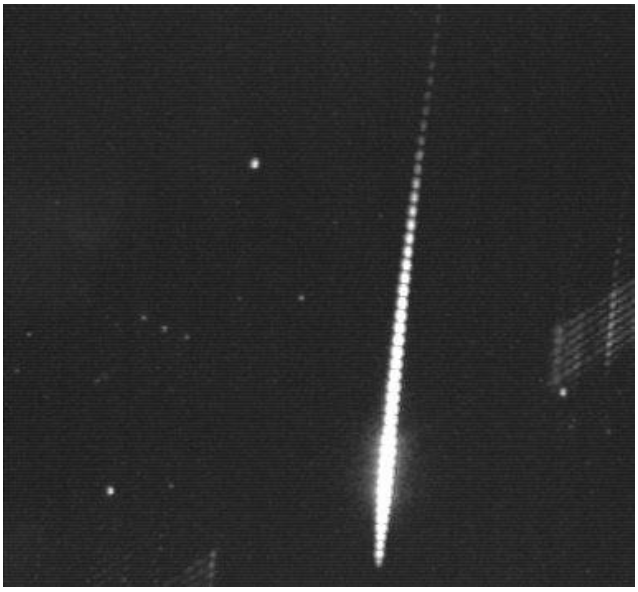


Figure 1 – Stacked image of the SWEMN20221215_033111 meteor.

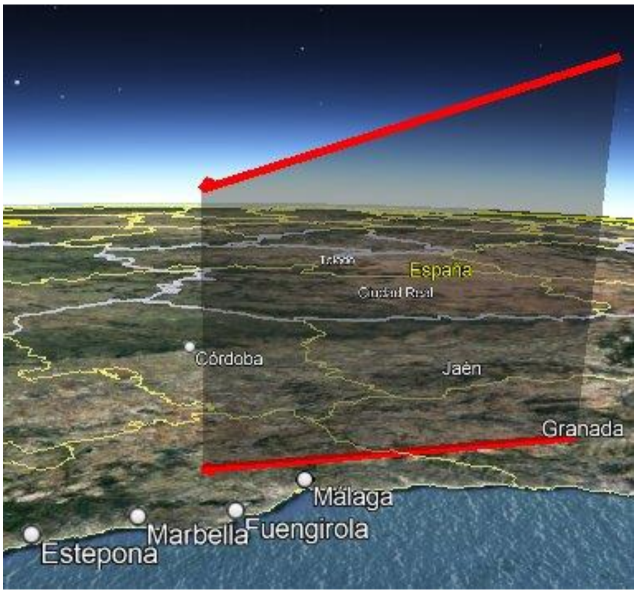


Figure 2 – Atmospheric path of the SWEMN20221215_033111 event, and its projection on the ground.

3 Description of the 2022 December 15 fireball

On 2022 December 15, at $3^h31^m11.0 \pm 0.1^s$ UT, SWEMN meteor stations captured this bright bolide (*Figure 1*). The peak luminosity of this bright meteor was equivalent to an absolute magnitude of –8.0 ± 1.0. It was included in the SWEMN meteor database with the code SWEMN20221215_033111.

Atmospheric trajectory, radiant and orbit

According to our analysis, this event overflew the provinces of Granada and Málaga (south of Spain). The initial altitude of the meteor yields $H_b = 107.0 \pm 0.5$ km, and the fireball ended at a height $H_e = 74.6 \pm 0.5$ km. The equatorial coordinates of the apparent radiant yield $\alpha = 216.52^o$, $\delta = +19.32^o$. Besides, we deduced that the meteoroid collided with the atmosphere with a velocity $v_\infty = 59.2 \pm 0.3$ km/s. *Figure 2* shows the calculated atmospheric path of the bright meteor and its projection on the ground. *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)	99.5 ± 246	ω (°)	98.1 ± 00.8
e	0.99 ± 0.01	Ω (°)	262.810958 ± 10^{-5}
q (AU)	0.562 ± 0.003	i (°)	108.5 ± 0.2

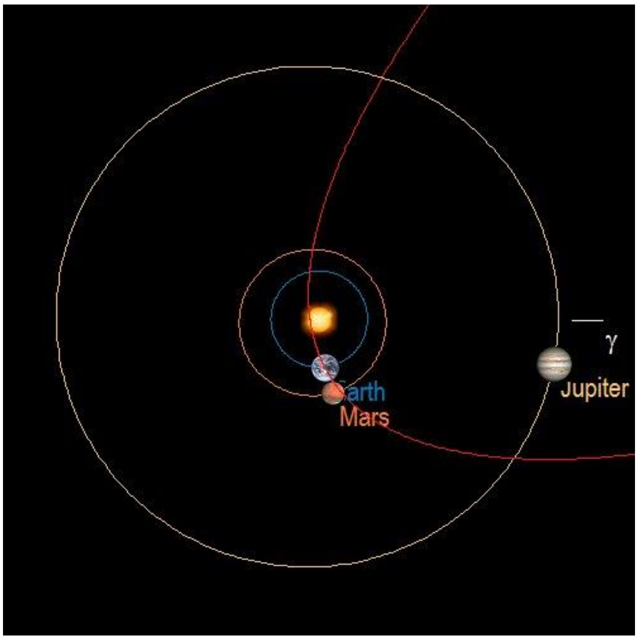


Figure 3 – Projection on the ecliptic plane of the orbit of the progenitor meteoroid of the SWEMN20221215_033111 event.

We named this fireball "Alora", since the event was located over this locality during its final phase. The orbital parameters of the parent meteoroid before its encounter with our planet are included in *Table 1*. The geocentric velocity of the meteoroid was $v_g = 57.8 \pm 0.3$ km/s. The Tisserand parameter with respect to Jupiter ($T_J = –0.24$) suggests that the particle followed a cometary (HTC) orbit before impacting our atmosphere. By taking into account these orbital data and the radiant position, it was deduced that the bolide was generated by a sporadic meteoroid.

Figure 4 – Stacked image of the SWEMN20221217_225012 event.

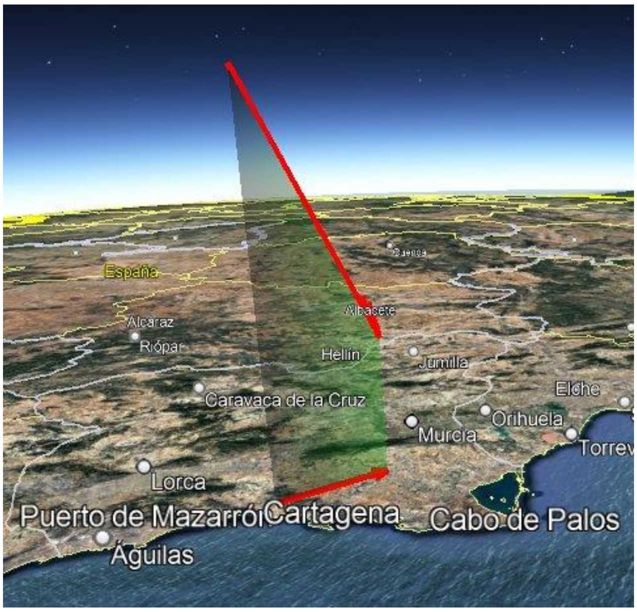


Figure 5 – Atmospheric path of the SWEMN20221217_225012 event, and its projection on the ground.

4 The 2022 December 17 meteor

This bright fireball was spotted on 2022 December 17 at $22^h50^m12.0 \pm 0.1^s$ UT from the meteor-observing stations located at Huelva, La Hita (Toledo), Calar Alto, Sierra Nevada, La Sagra (Granada), and Sevilla (*Figure 4*). It had a peak absolute magnitude of –9.0 ± 1.0. The code given to the bolide in the SWEMN meteor database is SWEMN20221217_225012. A video containing images of the event and its atmospheric trajectory was uploaded to YouTube[32]. The fireball was also witnessed by a wide number of casual observers who reported it on social networks.

Atmospheric path, radiant and orbit

It was concluded having analyzed the atmospheric trajectory of the bolide that this event overflew the region of Murcia (southeast of Spain). Its initial altitude was $H_b = 86.0 \pm 0.5$ km. The fireball penetrated the atmosphere till a final height $H_e = 30.4 \pm 0.5$ km. From the analysis of the atmospheric path, we also concluded that the apparent radiant was located at the position $\alpha = 45.61°$, $\delta = +15.06°$. The meteoroid hit the atmosphere with an initial velocity $v_\infty = 14.8 \pm 0.3$ km/s. The calculated atmospheric path of the bright meteor is shown in *Figure 5*. The heliocentric orbit of the meteoroid is drawn in *Figure 6*.

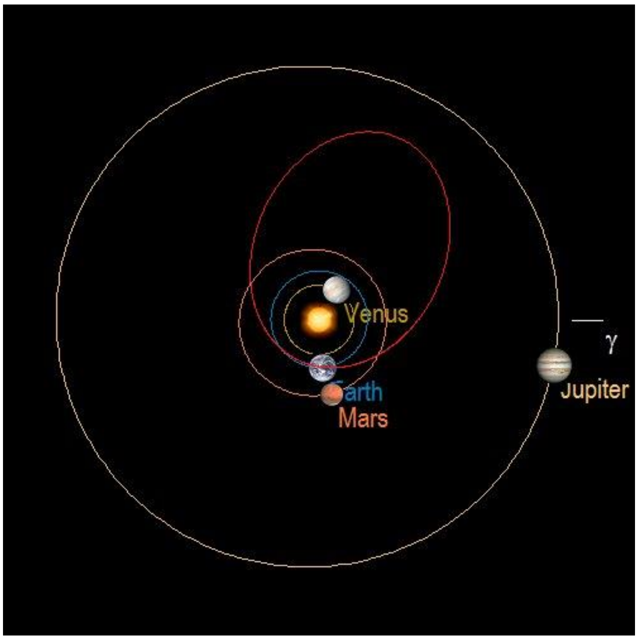


Figure 6 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20221217_225012 meteor.

The bright meteor was named “Molino de Carrasco”, since the bolide overflew this locality during its initial phase. *Table 2* shows the orbital parameters of the parent meteoroid before its encounter with our planet. The value calculated for the geocentric velocity was $v_g = 10.0 \pm 0.4$ km/s. The value found for the Tisserand parameter with respect to Jupiter ($T_J = 3.14$) suggests that the meteoroid followed an asteroidal orbit before colliding with the Earth’s atmosphere. These parameters and the derived radiant do not match any of the streams listed in the IAU meteor database. Consequently, it was concluded that the bright meteor was linked to the sporadic background.

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

a (AU)	2.5 ± 0.1	ω (º)	28.0 ± 00.4
e	0.62 ± 0.02	Ω (º)	85.545184 ± 10^{-5}
q (AU)	0.939 ± 0.002	i (º)	1.41 ± 0.02

5 The 2022 December 22 fireball

We recorded this bright fireball from the meteor-observing stations located at Huelva, La Hita (Toledo), Calar Alto,

---

[32] https://youtu.be/In5Q2bLeGeI

Sierra Nevada, La Sagra (Granada), and Sevilla. The bright meteor was captured on 2022 December 22, at $5^h35^m10.0 \pm 0.1^s$ UT. The event, that showed various flares along its trajectory in the atmosphere, had a peak absolute magnitude of –7.5 ± 0.5 (*Figure 7*). These flares appeared as a consequence of the sudden disruption of the meteoroid. The code given to the fireball in the SWEMN meteor database is SWEMN20221222_053510. A video showing images of the bright meteor and its luminous path was uploaded to YouTube[33].

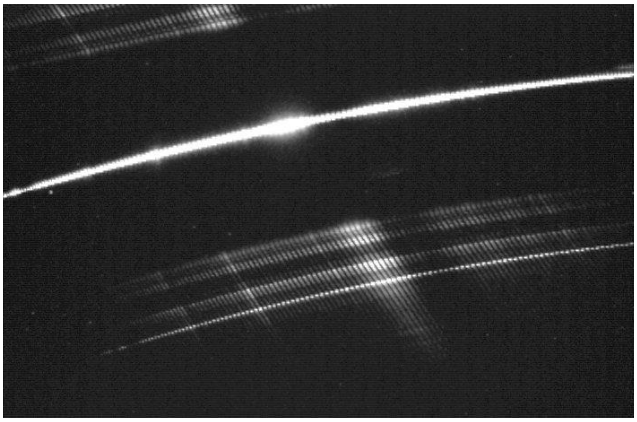


Figure 7 – Stacked image of the SWEMN20221222_053510 bolide.

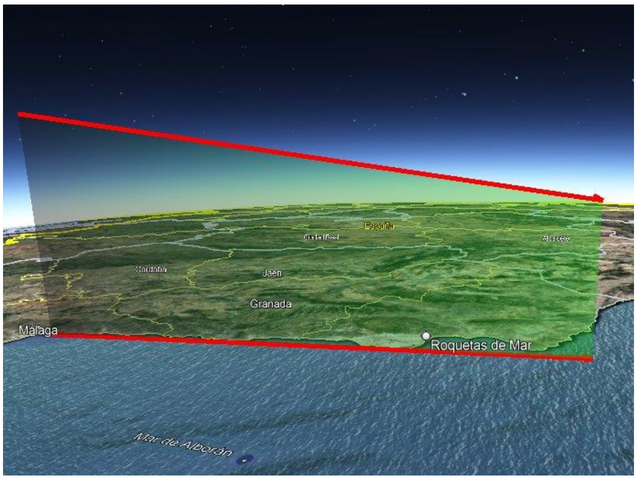


Figure 8 – Atmospheric path of the SWEMN20221222_053510 fireball, and its projection on the ground.

Atmospheric path, radiant and orbit

It was found from the calculation of the luminous path of the fireball that this event overflew the Mediterranean Sea. Its initial altitude was $H_b = 89.5 \pm 0.5$ km. The bolide penetrated the atmosphere till a final height $H_e = 54.6 \pm 0.5$ km. The position found for the apparent radiant corresponds to the equatorial coordinates $\alpha = 87.53°$, $\delta = +6.64°$. The entry velocity in the atmosphere obtained for the parent meteoroid was $v_\infty = 20.2 \pm 0.3$ km/s. The obtained trajectory in the atmosphere of the bright meteor is shown in *Figure 8*. The heliocentric orbit of the meteoroid is shown in *Figure 9*.

Table 3 shows 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 $v_g = 17.3 \pm 0.4$ km/s. From the value obtained for the Tisserand parameter referred to Jupiter ($T_J = 3.28$), we found that before colliding with the Earth's atmosphere the particle was moving on an asteroidal orbit. Radiant and orbital data do not match any of the meteoroid streams in the IAU meteor database. So, we concluded that this meteor was also produced by the sporadic background.

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

a (AU)	2.24 ± 0.06	ω (°)	64.6 ± 00.4
e	0.66 ± 0.01	Ω (°)	90.008927 ± 10^{-5}
q (AU)	0.759 ± 0.005	i (°)	11.0 ± 0.1

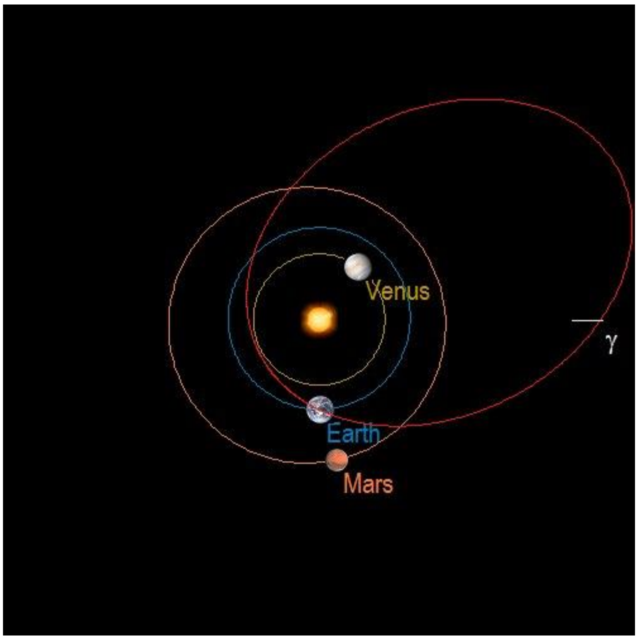


Figure 9 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20221222_053510 event.

6 Description of the 2023 January 4 event

This bright fireball was captured on 2023 January 4, at $6^h12^m18.0 \pm 0.1^s$ UT (*Figure 10*). Its peak brightness was equivalent to an absolute magnitude of –9.0 ± 1.0. It displayed a bright flare at the terminal point of its trajectory in the Earth's atmosphere as a consequence of the sudden break-up of the meteoroid. The code given to the bolide in the SWEMN meteor database is SWEMN20230104_061218.

Atmospheric path, radiant and orbit

By analyzing the trajectory in the Earth's atmosphere of the event it was inferred that this bright meteor overflew the province of Granada (Spain). The meteoroid started ablating at a height $H_b = 108.3 \pm 0.5$ km, and the terminal point of the luminous path was located at a height $H_e = 65.5 \pm 0.5$ km. The equatorial coordinates of the apparent radiant yield $\alpha = 227.78°$, $\delta = +47.67°$. The meteoroid stroke the atmosphere with an initial velocity

---

[33] https://youtu.be/7ViH_OJHTtw

v_∞ = 42.9 ± 0.3 km/s. *Figure 11* shows the calculated path in the atmosphere of the event. The heliocentric orbit of the meteoroid is drawn in *Figure 12*.

This bright meteor was named “Rambla del Agua”, because the bolide overflew this location during its final phase. The parameters of heliocentric orbit of the parent meteoroid before its encounter with our planet can be found in *Table 4*, and the geocentric velocity yields v_g = 41.3 ± 0.3 km/s. According to the value derived for the Tisserand parameter referred to Jupiter (T_J = 2.48), the particle was moving on a cometary (JFC) orbit before impacting the atmosphere. These values and the calculated radiant position confirm that the bolide was linked to the Quadrantids (IAU shower code QUA#0010). The proposed parent body of this shower is 2003 EH1 (Jenniskens et al., 2016).

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

a (AU)	2.3 ± 0.1	ω (º)	171.9 ± 00.1
e	0.59 ± 0.01	Ω (º)	283.297723 ± 10^{-5}
q (AU)	0.97973 ± 0.00007	i (º)	73.6 ± 0.3

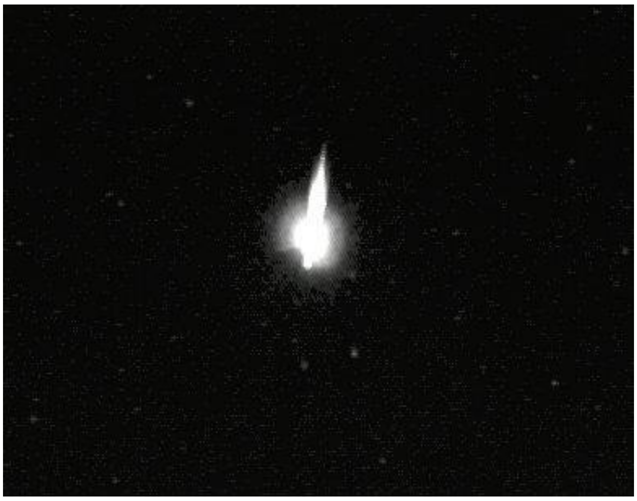


Figure 10 – Stacked image of the SWEMN20230104_061218 bolide.

Figure 11 – Atmospheric path of the SWEMN20230104_061218 event, and its projection on the ground.

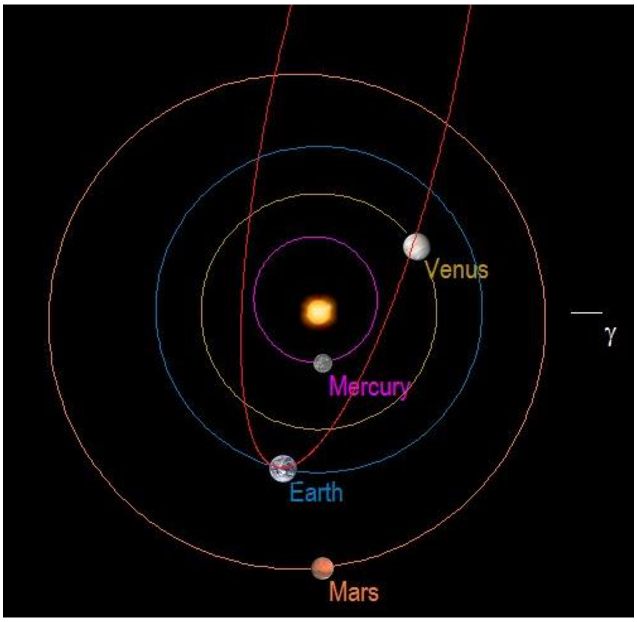


Figure 12 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20230104_061218 meteor.

Emission spectrum

The emission spectrum of the fireball was also recorded by employing the video spectrographs operated by the SWEMN network. This signal was calibrated in wavelength by employing typical lines appearing in meteor spectra, and then corrected by taking into account the sensitivity of the recording device. *Figure 13* shows the calibrated spectrum and the most remarkable contributions identified in it.

The majority of these contributions correspond to neutral iron (Fe I), which is typical in meteor spectra (Borovička, 1993; Madiedo, 2014). In this case, several multiplets of Fe I have been identified. The most important ones are Fe I-4 at 393.3 nm, Fe I-43, Fe I-42, Fe I-41, Fe I-21, and Fe I-15. The most important contributions, however, correspond to the H and K lines of Ca II-1, which appear blended in the signal. The emission lines of the Na I-1 doublet (588.9 nm) and the Mg I-2 triplet (516.7 nm) are also very significant. The analysis of the relative intensities of these lines will provide key information about the nature of the meteoroid.

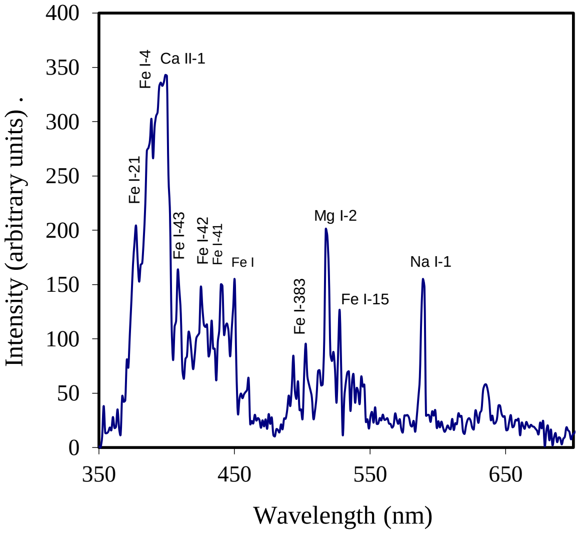


Figure 13 – Emission spectrum of the SWEMN20230104_061218 event.

7 The 2023 January 11 event

This bright event was captured on 2023 January 11, at $2^h17^m04.0 \pm 0.1^s$ UT. Its maximum luminosity was equivalent to an absolute magnitude of –9.0 ± 1.0 (*Figure 14*). The code assigned to the bright meteor in the SWEMN meteor database is SWEMN20230111_021704. The bolide can be viewed on this YouTube[34] video.

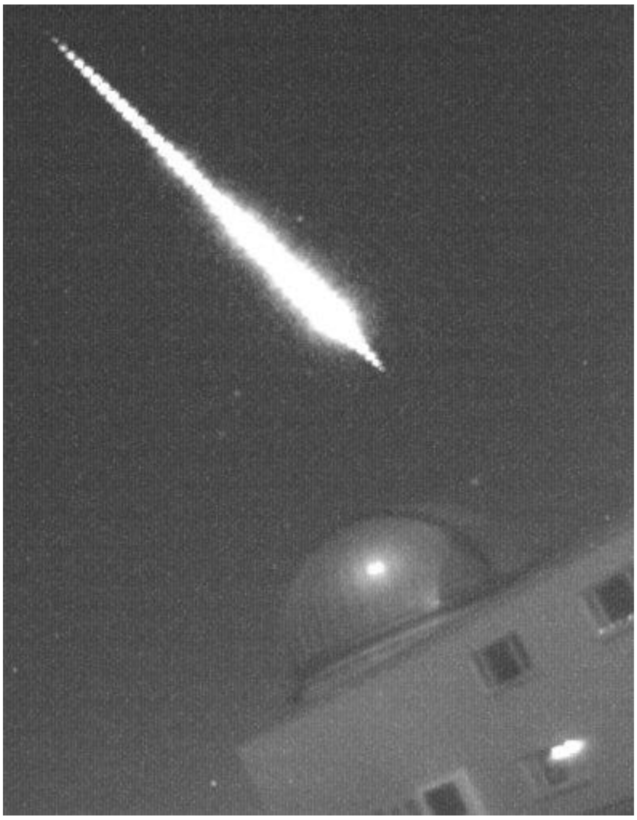


Figure 14 – Stacked image of the SWEMN20230111_021704 bolide.

Figure 15 – Atmospheric path of the SWEMN20230111_021704 meteor, and its projection on the ground.

Atmospheric path, radiant and orbit

This bolide overflew the provinces of Córdoba and Jaén (south of Spain). The luminous event began at an altitude H_b = 95.7 ± 0.5 km. The meteor penetrated the atmosphere till a final height H_e = 41.4 ± 0.5 km. The position found for the apparent radiant corresponds to the equatorial coordinates $\alpha = 136.84^\circ$, $\delta = +20.15^\circ$. The meteoroid impacted the atmosphere with an initial velocity v_∞ = 35.1 ± 0.3 km/s. The obtained atmospheric trajectory of the fireball is shown in *Figure 15*. The orbit in the Solar System of the meteoroid is shown in *Figure 16*.

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

a (AU)	1.63 ± 0.04	ω (°)	316.8 ± 00.2
e	0.888 ± 0.004	Ω (°)	290.294840 ± 10^{-5}
q (AU)	0.183 ± 0.003	i (°)	5.2 ± 0.1

This bolide was named “Baena”, because the event was located over this locality during its initial phase. *Table 5* shows the orbital parameters of the progenitor meteoroid before its encounter with our planet. The geocentric velocity of the meteoroid was v_g = 33.3 ± 0.3 km/s. From the value derived for the Tisserand parameter referred to Jupiter (T_J = 3.69), we found that the particle followed an asteroidal orbit before colliding with our atmosphere. These data and the calculated radiant position confirm that the event was produced by the zeta Cancrids (IAU code ACZ#0604). The proposed progenitor body of this shower, which peaks around January 2, is asteroid 2011YX62 (Segon et al., 2014).

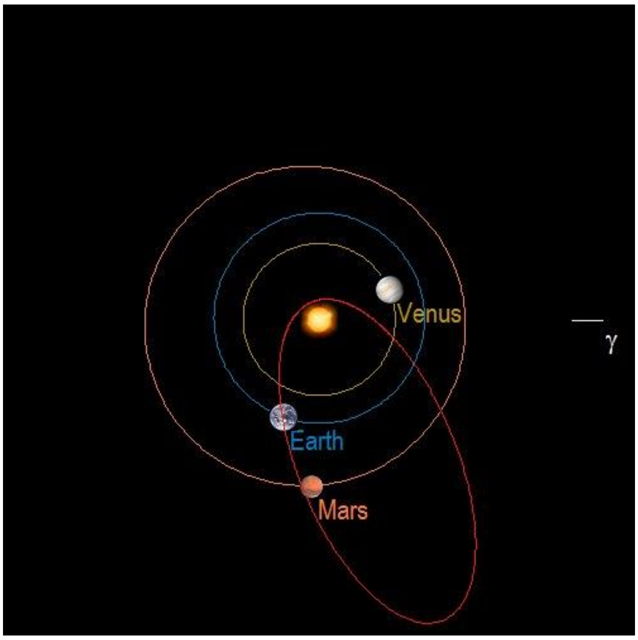


Figure 16 – Projection on the ecliptic plane of the orbit of the SWEMN20230111_021704 event.

---

[34] https://youtu.be/Gfpj8yf_fcc

Figure 17 – Stacked image of the SWEMN20230115_215222 event.

8 Analysis of the 2023 January 15 event

On 2023 January 15, at $21^h52^m22.0 \pm 0.1^s$ UT, SWEMN meteor stations spotted this bright meteor (*Figure 17*). The peak luminosity the bolide was equivalent to an absolute magnitude of –8.5 ± 0.5. Its code in the SWEMN meteor database is SWEMN20230115_215222. A video containing images of the bolide and its luminous path was. uploaded to YouTube[35].

Figure 18 – Atmospheric path of the SWEMN20230115_215222 bolide, and its projection on the ground.

Atmospheric path, radiant and orbit

It was concluded as a result of the analysis of the luminous path of the event that this fireball overflew Spain and the Gulf of Cádiz. The luminous event began at an altitude $H_b = 73.7 \pm 0.5$ km. The event penetrated the atmosphere till a final height $H_e = 39.1 \pm 0.5$ km. The equatorial coordinates inferred for the apparent radiant are $\alpha = 113.39°$, $\delta = +21.68°$. The pre-atmospheric velocity found for the meteoroid yields $v_\infty = 23.8 \pm 0.3$ km/s. The obtained atmospheric trajectory of the bolide is shown in *Figure 18*. The orbit in the Solar System of the meteoroid is shown in *Figure 19*.

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

a (AU)	2.3 ± 0.1	ω (°)	81.86 ± 00.04
e	0.73 ± 0.01	Ω (°)	114.908219 ± 10^{-5}
q (AU)	0.627 ± 0.003	i (°)	0.59 ± 0.01

We named this bolide “Puente Carrera”, because the event overflew this location in Spain during its final phase. The parameters of the heliocentric orbit of the progenitor meteoroid before its encounter with our planet are included in *Table 6*. The geocentric velocity of the meteoroid was $v_g = 20.9 \pm 0.3$ km/s. From the value calculated for the Tisserand parameter with respect to Jupiter ($T_J = 3.11$), we found that before entering our atmosphere the particle was moving on an asteroidal orbit. By taking into account these values and the derived radiant location, the event was linked to the ρ-Geminids (IAU meteor shower code RGE#0094) (Madiedo, 2015b). Since the ρ-Geminids reach their peak on January 16, this fireball was captured during this activity peak.

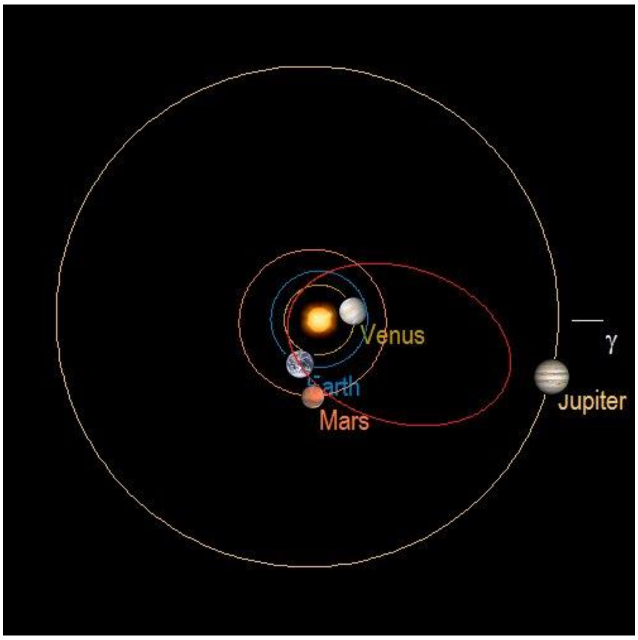


Figure 19 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20230115_215222 bolide.

9 Analysis of the 2023 January 20 event

This bright event was captured on 2023 January 20 at $23^h42^m24.0 \pm 0.1^s$ UT from the meteor-observing stations located at Huelva, La Hita (Toledo), Calar Alto, Sierra

---

[35] https://youtu.be/_N6tlXAY06g

Nevada, La Sagra (Granada), Sevilla, and El Aljarafe (Sevilla). The bright meteor had a peak absolute magnitude of –10.0 ± 1.0 (*Figure 20*). The event was included in our meteor database with the code SWEMN20230120_234224. The bolide can be viewed on this YouTube[36] video.

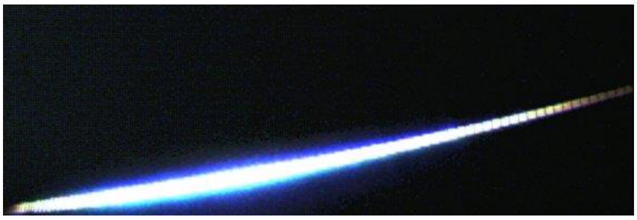


Figure 20 – Stacked image of the SWEMN20230120_234224 meteor.

Atmospheric path, radiant and orbit

This fireball overflew the province of Badajoz (Spain). The luminous event began at an altitude $H_b = 93.6 \pm 0.5$ km. The bright meteor penetrated the atmosphere till a final height $H_e = 29.5 \pm 0.5$ km. The equatorial coordinates of the apparent radiant yield $\alpha = 119.08^\circ$, $\delta = +11.98^\circ$. The entry velocity in the atmosphere obtained for the parent meteoroid was $v_\infty = 24.5 \pm 0.3$ km/s. *Figure 21* shows the obtained trajectory in the atmosphere of the bolide and its projection on the ground. The orbit in the Solar System of the progenitor meteoroid is shown in *Figure 22*.

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

a (AU)	2.5 ± 0.1	ω (°)	81.85 ± 00.09
e	0.75 ± 0.01	Ω (°)	120.318450 ± 10^{-5}
q (AU)	0.620 ± 0.003	i (°)	7.16 ± 0.07

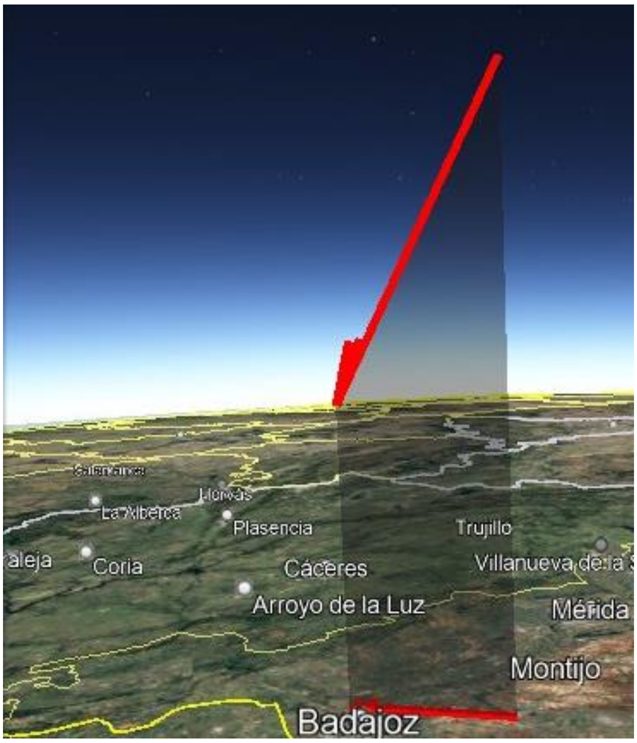


Figure 21 – Atmospheric path of the SWEMN20230120_234224 meteor, and its projection on the ground.

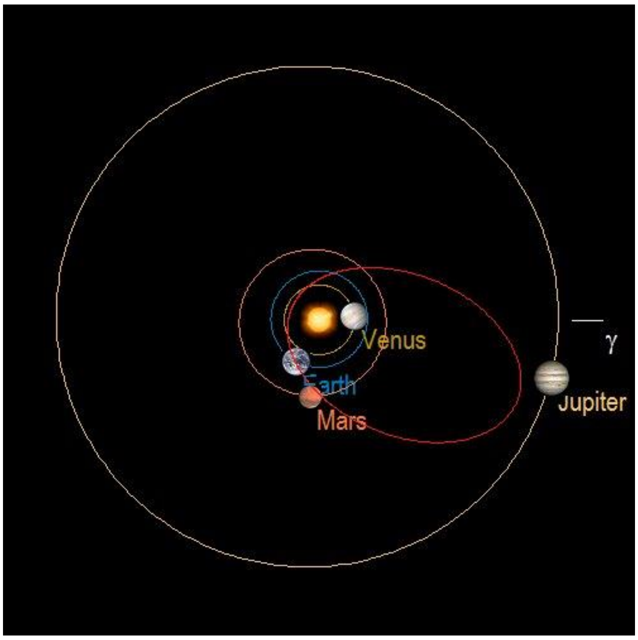


Figure 22 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20230120_234224 meteor.

We named this bolide “La Albuera”, because the fireball was located near the zenith of this locality during its initial phase. The orbital data of the meteoroid before its encounter with our planet are listed in *Table 7*. The geocentric velocity obtained for the particle yields $v_g = 21.9 \pm 0.3$ km/s. The value calculated for the Tisserand parameter with respect to Jupiter ($T_J = 2.95$) suggests that before entering our atmosphere the particle was moving on a cometary (JFC) orbit. Radiant and orbital data do not match any of the meteoroid streams in the IAU meteor database. So, we concluded that this bolide was produced by the sporadic background.

10 Conclusions

Here we have discussed some of the most important fireballs recorded by our meteor-observing stations along December 2022 and January 2023. Their maximum brightness ranges from mag. –7 to mag. –10.

The “Alora” fireball was recorded on December 15. Its peak absolute magnitude was –8.0. The fireball was produced by a sporadic meteoroid and overflew the provinces of Granada and Málaga (south of Spain). Before colliding with our planet’s atmosphere, the particle was moving on a cometary (HTC) orbit.

Next, we have discussed the “Molino de Carrasco” fireball. This was recorded on December 17 and its peak absolute magnitude was –9.0. The meteor was also produced by a sporadic meteoroid and overflew the region of Murcia (southeast of Spain). Before striking our planet’s atmosphere the meteoroid was moving on an asteroidal orbit. At the terminal stage of its luminous phase, this deep-penetrating fireball was located at an altitude of about 30 km.

---

[36] https://youtu.be/YYjZuF5qR9c

The third event analyzed in this report was a bright meteor recorded by our meteor-stations on December 22. It was associated with the sporadic component. With a peak absolute magnitude of –7.5, it overflew the Mediterranean Sea. Before striking our atmosphere, the meteoroid was moving on an asteroidal orbit.

The fourth fireball discussed here was a bolide recorded on January 4 which was named "Rambla del Agua". This Quadrantid (QUA#0010) meteor event had a peak absolute magnitude of –9.0 and overflew the province of Granada (south of Spain). The analysis of the emission spectrum of the meteor was also performed. This spectrum exhibits the contributions generated by Na I-I, Mg I-2, Ca II-1 and several Fe-I multiplets.

Next, we have analyzed the "Baena" event, which was recorded on January 11. This zeta Cancrid (ACZ#0604) bolide had a peak absolute magnitude of –9.0 and overflew the provinces of Córdoba and Jaén (Spain). The meteoroid followed an asteroidal orbit before impacting the Earth's atmosphere. At the final stage of its luminous phase this deep-penetrating meteor was located at an altitude of about 41 km. This suggests an asteroidal nature for this poorly-known meteoroid stream.

The next bolide analyzed in this report was an event which was recorded on January 15 named "Puente Carrera". This ρ-Geminid (RGE#0094) meteor had a peak absolute magnitude of –8.5 and overflew Spain and the Gulf of Cádiz. The particle was moving on an asteroidal orbit before hitting our planet's atmosphere. The ending altitude of this deep-penetrating bolide was of about 39 km.

The last meteor presented in this work was the "La Albuera" event, which was recorded on January 20. This sporadic meteor had a peak absolute magnitude of –10.0 and overflew the province of Badajoz (Spain). The meteoroid was moving on a cometary (JFC) orbit before impacting our planet's atmosphere. The terminal altitude of this deep-penetrating bolide was of about 29 km.

Acknowledgment

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

References

Borovička J. (1993). "A fireball spectrum analysis". *A&A*, **279**, 627–645.

Ceplecha Z. (1987). "Geometric, dynamic, orbital and photometric data on meteoroids from photographic fireball networks". *Bull. Astron. Inst. Cz.*, **38**, 222–234.

Jenniskens P., Nénon Q., Albers J., Gural P. S., Haberman B., Holman D., Morales R., Grigsby B. J., Samuels D. and Johannink C. (2016). "The established meteor showers as observed by CAMS". *Icarus*, **266**, 331–354.

Madiedo J. M. (2014). "Robotic systems for the determination of the composition of solar system materials by means of fireball spectroscopy". *Earth, Planets & Space*, **66**, 70.

Madiedo J. M. (2017). "Automated systems for the analysis of meteor spectra: The SMART Project". *Planetary and Space Science*, **143**, 238–244.

Madiedo J. M. (2015a). "Spectroscopy of a κ-Cygnid fireball afterglow". *Planetary and Space Science*, **118**, 90–94.

Madiedo J. M. (2015b). "The ρ-Geminid meteoroid stream: orbits, spectroscopic data and implications for its parent body". *Monthly Notices of the Royal Astronomical Society*, **448**, 2135–2140.

Madiedo J. M., Ortiz J. L., Organero F., Ana-Hernández L., Fonseca F., Morales N. and Cabrera-Caño J. (2015). "Analysis of Moon impact flashes detected during the 2012 and 2013 Perseids". *A&A*, **577**, A118.

Madiedo J. M., Ortiz J. L. and Morales N. (2018). "The first observations to determine the temperature of a lunar impact flash and its evolution". *Monthly Notices of the Royal Astronomical Society* **480**, 5010–5016.

Madiedo J. M., Ortiz J. L., Morales N. and Santos-Sanz P. (2019a). "Multiwavelength observations of a bright impact flash during the 2019 January total lunar eclipse". *Monthly Notices of the Royal Astronomical Society*, **486**, 3380–3387.

Madiedo J. M., Ortiz J. L., Izquierdo J., Santos-Sanz P., Aceituno J., de Guindos E., Yanguas P., Palacian J., San Segundo A., and Avila D. (2021). "The Southwestern Europe Meteor Network: recent advances and analysis of bright fireballs recorded along April 2021". *eMetN*, **6**, 397–406.

Madiedo J. M., Ortiz J. L., Izquierdo J., Santos-Sanz P., Aceituno J., de Guindos E., Yanguas P., Palacian J., San Segundo A., Avila D., Tosar B., Gómez-Hernández A., Gómez-Martínez J., and García A. (2022). "The Southwestern Europe Meteor Network: development of new artificial intelligence tools and remarkable fireballs observed from January to February 2022". *eMetN*, **7**, 199–208.

Ortiz J. L., Madiedo J. M., Morales N., Santos-Sanz P. and Aceituno F. J. (2015). "Lunar impact flashes from

Geminids: analysis of luminous efficiencies and the flux of large meteoroids on Earth”. *Monthly Notices of the Royal Astronomical Society*, **454**, 344–352.

Segon D., Andreic Z., Gural P., Skokic I., Korlevic K., Vida D., Novoselnik F. and Gostinski D. (2014). “Results of CMN 2013 search for new showers across CMN and SonotaCo databases III”. *WGN, Journal of the International Meteor Organization*, **42**, 227–233.

The meteorite of Saint Valentine

Roberto Gorelli

A.R.A., Osservatorio Astronomico Virginio Cesarini,
Via Vaschetta n. 1 -02030 Frasso Sabino (RI), Italy
`md6648@mclink.it`

A description is given of the recent meteorite dropping fireball on 2023 February 14, 17h58m UTC and the recovery of the meteorites on 18 February.

1 Introduction

From the oldest times mankind saw stones falling from the sky but only from the 26 April 1803, when a meteorite fell dropping 3000 fragments in the fields around the village of L'Aigle (France), science accepted the existence of this natural phenomena.

In a few years at the end of 18th century and the beginning of 19th century a certain number of events occurred that brought a revolution in astronomy: the discovery of Uranus the 13th of March 1781 by William Herschel, the discovery of 1 Ceres the 1st of January 1801 by Giuseppe Piazzi and the fall of the meteorites of L'Aigle in France that occurred the 26th of April 1803.

During this thrilling period for astronomy two books were published in the same year, 1794, one by Ernst Chladni: "*Über den Ursprung der von Pallas gefundenen und anderer ihr ähnlicher Eisenmassen und über einige damit in Verbindung stehende Naturerscheinungen*" (in German) and another one by Soldani: "*Sopra una Pioggietta di sassi accaduta nella sera de' 16 giugno, 1794, in Lucignano d'Asso nel Territorio sanese*" (in Italian), both treating the revolutionary topic for that epoch, the fall of stones from the sky.

In fact, it was some decades already that scientists such as the German Ernst Chladni, the Italian Ambrogio Soldani, the French Antoine Lavoisier and some others believed that stones could fall from the sky. Such as was the case with the fall on 26 May 1751 at Hraschina (Croatia), the fall on 13 September 1768 at Lucé (France), the fall on 17 May 1791 at Castel Berardenga (Italy), the fall on 24 July 1790 at Barbotan (France), the fall on 16 June 1794 at Siena (Italy), the fall on 13 December 1795 at Wold Cottage (United Kingdom) and the iron meteorite found near Krasnoyarsk studied in 1772 by the German Peter Simon Pallas.

After the fall of L'Aigle, it took many years before this reality was accepted by all scientists, for example the fall of Weston (Connecticut, USA) on the 14th of December 1807 required a lot of time to be accepted.

In Italy this topic was accepted almost immediately and lists of stones which had fallen from the sky were soon described for events from B.C. The first meteorite fall after 1803 was that of Gerace and Cutro (Reggio Calabria) on the 14th of March 1813, but the first accepted case was that of Renazzo (Ferrara) which fell on the 15th of January 1824. This was a rare carbonaceous chondrite. The list of Italian meteorites from the 19th century corresponds to an average of one meteorite once in each 3 years. Remarkably, in the 20th century the number of cases decreased. Following the theoretical calculations, there should be 3 meteorite falls each year in Italy. We can consider that many of these are missed, but proportional this is one of the best results in the world thanks to the high density of the population and the high percentage of people with good educational qualifications.

2 Latest meteorites in Italy

In the last years the number of bolides observed has increased since more attention is given to this type of phenomenon. So far, we have now two meteorites in the last three years, the one of the Cavezzo (Modena) fall on the 1st of January 2020 which was found on 4 January (*Figure 1*) and now we had the fall at Contrada Rondinelle e Contrada Serra Paducci (some km North of city of Matera) which fell on the 14th of February (Saint Valentine) and which was found on the 18th February.

Figure 1 – The two fragments of the fireball that fell on New Year's Eve and which were found in the Modena area. (Credits: Prisma/Inaf).

According to the newpapers *Corriere della Sera*, *Il Messaggero* and the TV channel RAI, the bolide was accompanied by a roaring sound following immediately after the appearance (*Figure 2*). A big noise was heard on the house where the meteorite impacted (*Figure 3*) but only some days later it was noticed that an object had damaged a tile of a terrace (*Figure 4*) and a solar panel. A meteorite was found, broken in many pieces for a total weight of around 70 gram (*Figures 5 and 6*). The meteorite is not a solid stone, has a grey color and no chondrules are visible. It is possible that more pieces are somewhere on the ground in the same area.

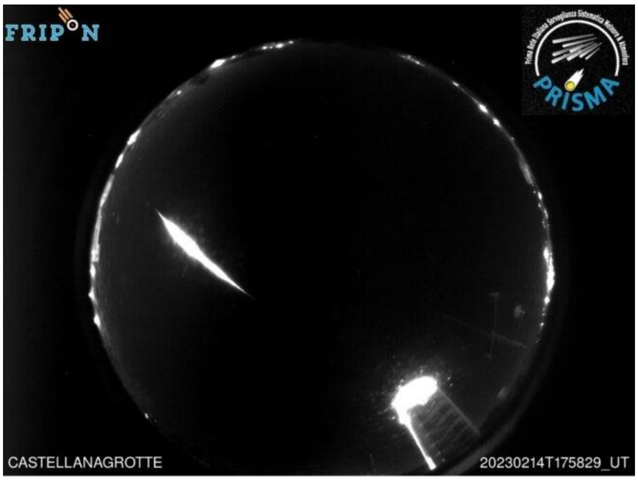


Figure 2 – The Valentine’s fireball recorded by the Prisma camera of Castellana Grotte. (Credits: Prisma/Inaf).

Figure 3 – The strewn field associated with the Valentine’s fireball determined by the Prisma team. (Credits: Prisma/Inaf).

Figure 4 – The tile of the balcony damaged by the impact of the meteorite. (Credits: Prisma/Inaf).

Figure 5 – The fragments of the meteorite that fell on the evening of Valentine’s Day in the northern area of Matera. (Credits: Prisma/Inaf).

Figure 6 – Collection of fragments found so far. Prisma experts do not rule out that there may also be other pieces in the area. (Credits: Prisma/Inaf).

These two events show that the networks of all-sky cameras may record all, or almost all, meteorites that fall in the future. This should permit to determine the real frequency of the number of meteorites that fall on the Earth.

The mission of MeteorNews is to offer fast meteor news to a global audience, a swift exchange of information in all fields of active amateur meteor work without editing constraints. MeteorNews is freely available without any fees. To receive a notification: https://www.meteornews.net/newsletter-signup/.

You are welcome to contribute to MeteorNews on a regular or casual basis, if you wish to. Anyone can become an author or editor, send an email to us. For more info read: https://meteornews.net/writing-content-for-emeteornews/

MeteorNews account manager: Richard Kacerek rickzkm@gmail.com.

The running costs for website hosting are covered by a team of sponsors. We want to thank the 2022-2023 sponsors: Anonymous (3x), Mikhail Bidnichenko, Gaetano Brando, Trevor C, Nigel Cunnington, Kevin Heider, Paul Hyde, K. Jamrogowicx, Dave Jones, Richard Kacerek, Richard Lancaster, Joseph Lemaire, Mark McIntyre, Hiroshi Ogawa, Paul Mohan, Stan Nelson, Lubos Neslusan, BillR, Whitham D. Reeve, John Schlin, Ann Schroyens and Denis Vida.

Financial support is still needed and welcome:
https://www.justgiving.com/crowdfunding/meteor-news?utm_term=JJBjmJpzV

Contributing to this issue:

- Aceituno J.
- Aimee A.I.
- Ávila D.
- Barbieri L.
- Boothroyd M.
- Cambell-Burns P.
- de Guindos E.
- Fraser R.
- García A.
- Gómez-Hernández A.
- Gómez-Martínez J.
- Gorelli R.
- Hanigan G.
- Izquierdo J.
- Johannink C.
- Kacerek R.
- Kokhirova G.
- Madiedo J.M.
- Maslov M.
- McIntyre M.
- Miskotte K.
- Ortiz J.L.
- Palacián J.
- Poulton D.
- Rakhmatullaeva F.
- Roggemans P.
- San Segundo A.
- Santos-Sanz P.
- Scott G.
- Scott J.
- Šegon D.
- Sergei I.
- Tosar B.
- Verbelen F.
- Vida D.
- Wood J.
- Yanguas P.
- Zink C.

ISSN 2570-4745 Online publication https://meteornews.net

Listed and archived with ADS Abstract Service: https://ui.adsabs.harvard.edu/search/q=eMetN

MeteorNews Publisher:

Valašské Meziříčí Observatory, Vsetínská 78, 75701 Valašské Meziříčí, Czech Republic

---