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Northern Lights and the Perseids, stacked photo composition made during the night of 12-13 August at Wânswert, in Friesland, the Netherlands. (credit: Gijs de Reijke).

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New meteor shower in Fornax

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A new meteor shower has been discovered by Global Meteor Network from a radiant at $\alpha = 44.0°$ and $\delta = -38.3°$, with a geocentric velocity of 51.7 ± 1.0 km/s within an activity period $97.3° < \lambda_O < 105.1°$ with a maximum at $\lambda_O = 102.78°$. The Tisserand parameter relative to Jupiter corresponds to a Long Period-type comet (LPC), in this case on a retrograde orbit. The new meteor shower has been registered in the Working List of Meteor Showers of the IAU MDC with the preliminary designation M2024-N1.

1 Introduction

The Global Meteor Network radiant map for July 3–4, 2024 (*Figure 1*) showed a remarkable concentration with a radiant in geocentric equatorial coordinates at $\alpha = 44.4°$ and $\delta = -38.2°$ in the constellation of Fornax. No known meteor shower was expected to display any activity from this part of the sky. The possible new meteor shower was noticed immediately when the orbit data were processed.

The method to analyze new meteor shower has been described in Šegon et al. (2023). The first search was done in a narrow observing window $102.3° < \lambda_O < 103.14°$ with the data available up to July 6. In first instance 28 similar meteoroid orbits were found which fit the D-criterion $D_D < 0.06$ (Drummond, 1981) for a mean orbit (Jopek et al., 2006) with:

- $q = 0.9887$ AU
- $e = 0.9384$
- $i = 92.7°$
- $\omega = 340.87°$
- $\Omega = 282.86°$

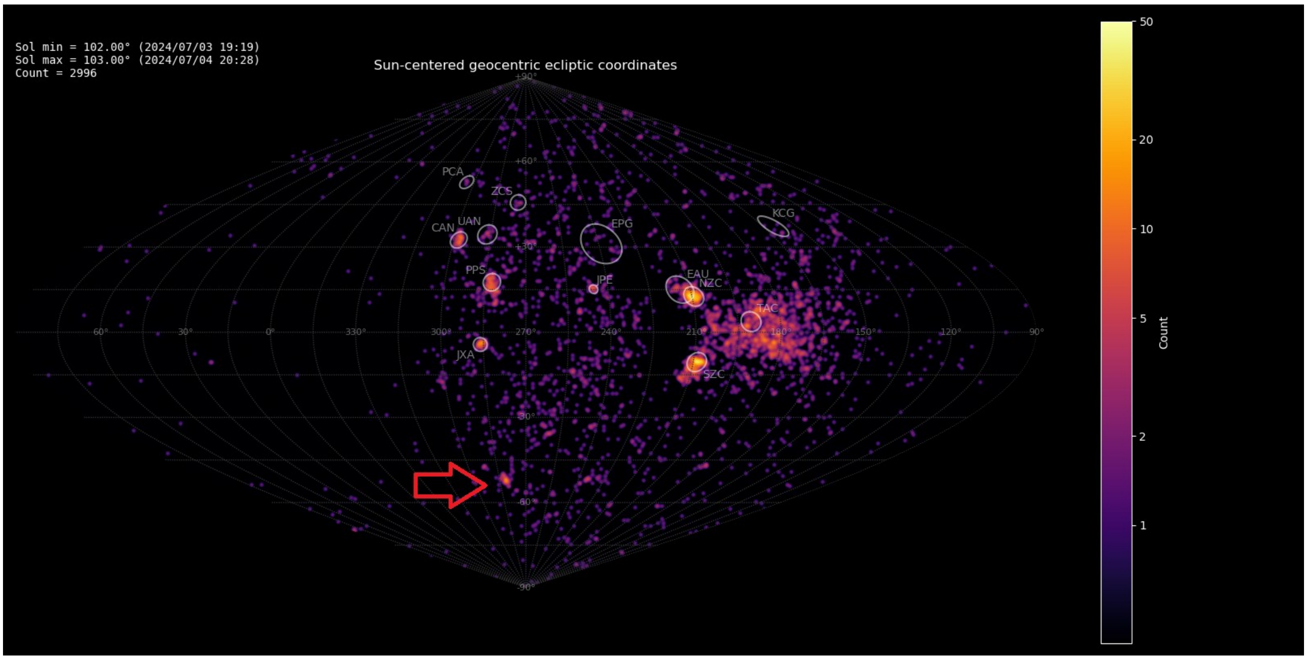

Figure 1 – Radiant plot of the Global Meteor Network data for 2024 July 3–4 in Sun-centered geocentric ecliptic coordinates. The new radiant is marked by a red arrow in an area without known meteor showers in the constellation of Fornax.

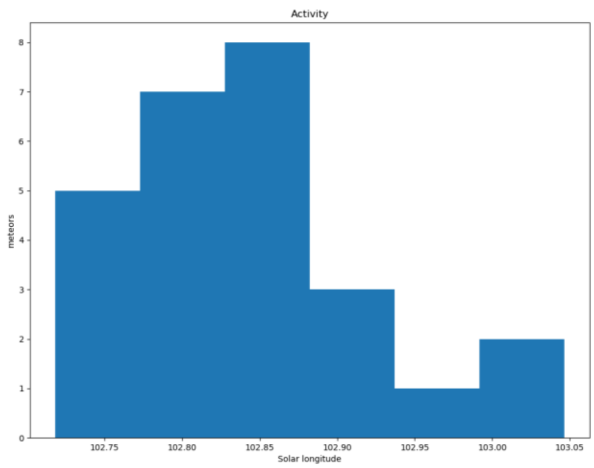

Figure 2 – The activity profile for the initial sample of similar orbits.

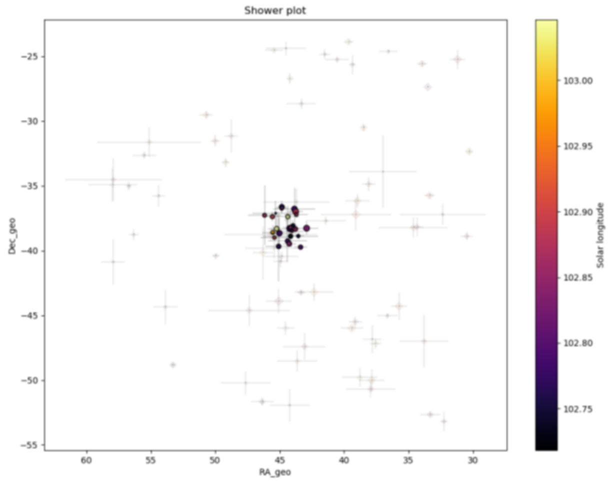

Figure 3 – The radiant positions in geocentric equatorial coordinates for the 28 meteoroids with similar orbits.

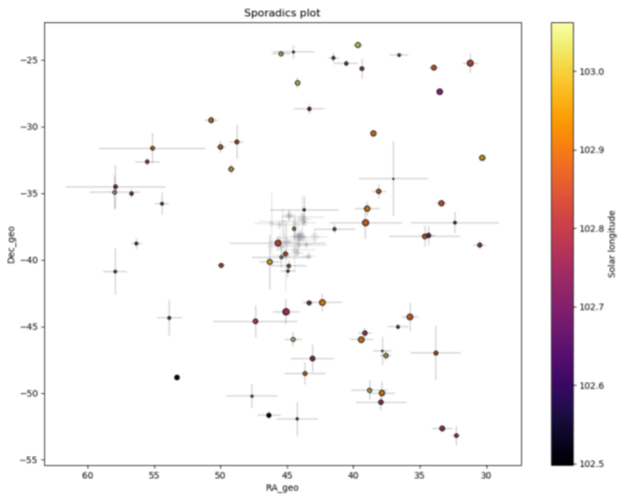

Figure 4 – The radiant positions in geocentric equatorial coordinates for the sporadics recorded from this part of the sky, with the new meteor shower radiants marked in grey.

No known meteor shower matches this orbit. *Figure 2* shows the activity profile and *Figure 3* shows the compact radiant obtained for the initial search. *Figure 4* presents the sporadic background near the new meteor shower radiant. *Figure 5* is the diagram of the inclination *i* against the longitude of perihelion *Π*, confirming the compact nature of this new meteoroid stream.

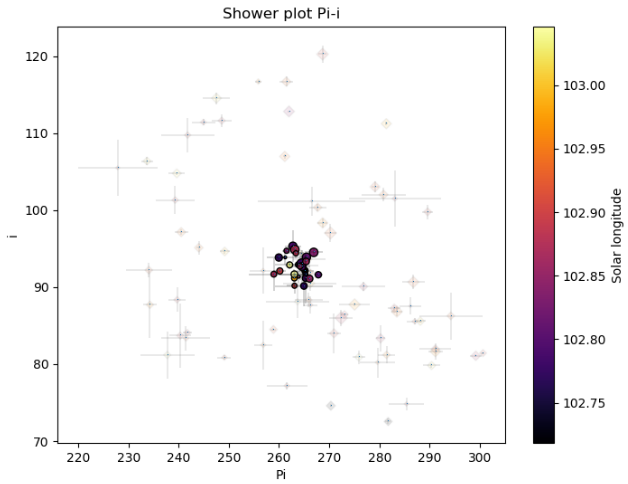

Figure 5 – The diagram of the inclination *i* against the longitude of perihelion *Π* for the 28 meteoroids with similar orbits.

At this date, July 6, no trace of this new shower was visible in the CAMS data online[1], and without such an independent confirmation it was decided to collect more data before reporting anything.

2 Another search

In order to establish the duration of this possible new meteor shower, a few more days of orbit data were collected before resuming this shower analysis. Another method has been applied to check this new meteor shower (Roggemans et al., 2019). The main difference with the method used for the first search is that three different discrimination criteria are combined in order to have only those orbits which fit different criteria (Drummond, 1981; Southworth and Hawkins, 1963; Jopek, 1993). Instead of using a cutoff value for the D-criteria these values are considered in different classes with different thresholds of similarity. Depending on the dispersion and the type of orbits, the most appropriate threshold of similarity is selected to locate the best fitting mean orbit as a result of an iterative procedure.

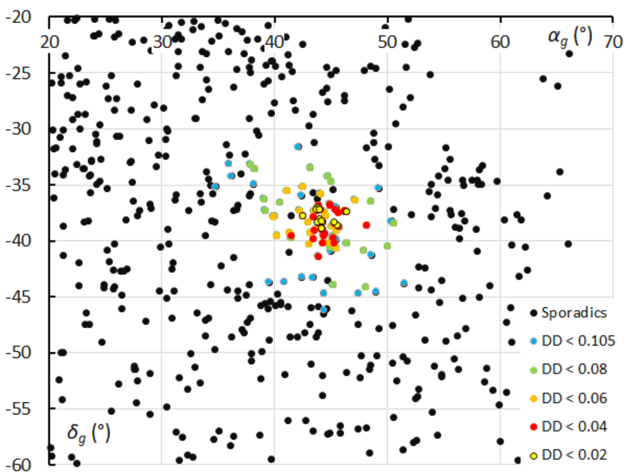

Figure 6 – Close up of the radiant points in geocentric equatorial coordinates for the new meteor shower in Fornax.

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

The search resulted in 51 orbits detected within the interval of $100° < \lambda_O < 104°$ with a maximum at $\lambda_O = 102.78°$. *Figure 6* shows the radiant distribution in equatorial coordinates. The radiants for orbits that fall within less strict D-criteria, $D_D < 0.105$ and $D_D < 0.08$ have been plotted too. To limit the risk of contamination by sporadic look-alikes, the mean orbit has been calculated for $D_D < 0.06$. The radiants appear like a concentration amidst the sporadic background. *Figure 7* shows the radiant concentration in Sun-centered geocentric ecliptic coordinates, the radiant concentration is very obvious. *Figure 8* is a close up of *Figure 7*, but color coded for the velocity v_g.

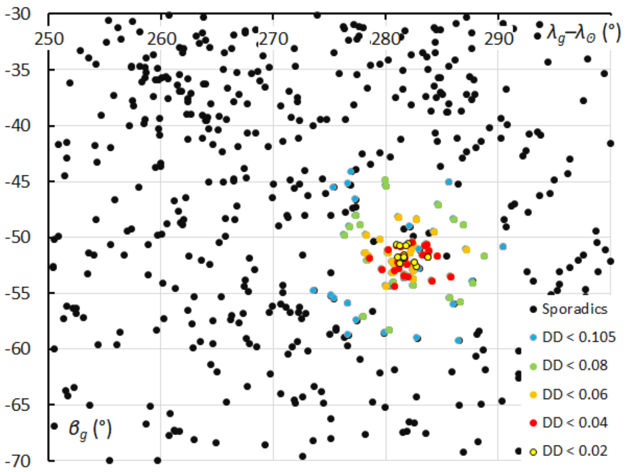

Figure 7 – The radiant distribution in Sun-centered ecliptic geocentric coordinates for the new meteor shower, color coded for the different classes of orbit similarity.

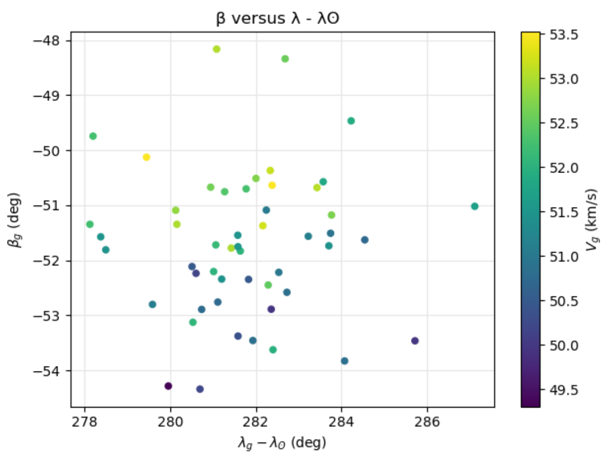

Figure 8 – Close up of the Sun-centered ecliptic geocentric coordinates for the new meteor shower color coded for the geocentric velocity v_g.

Figure 9 displays the diagram with the orbital elements inclination i against the longitude of perihelion Π and shows the concentration of very similar orbits, marked with red and yellow dots. *Figure 10* is a close up of *Figure 9*, with the new meteor shower orbits displayed color coded for the geocentric velocity v_g. Faster meteoroids have a higher inclination than slower particles.

Similar orbits with $D_D < 0.06$ could be detected during the activity interval of $100° < \lambda_O < 104°$ with a maximum at $\lambda_O = 102.78°$ (*Figure 11*). The empty intervals are due to a lack of camera coverage in the Southern hemisphere. It is possible that the actual maximum activity occurred slightly before $\lambda_O = 102.78°$.

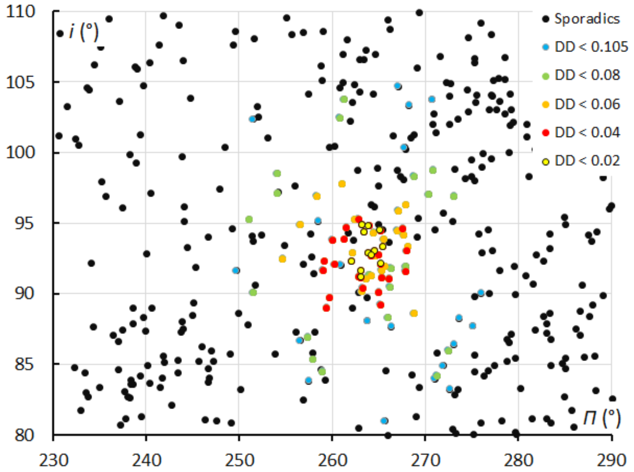

Figure 9 – Diagram of the inclination i against the longitude of perihelion Π for the new meteor shower, color coded for the different classes of similarity.

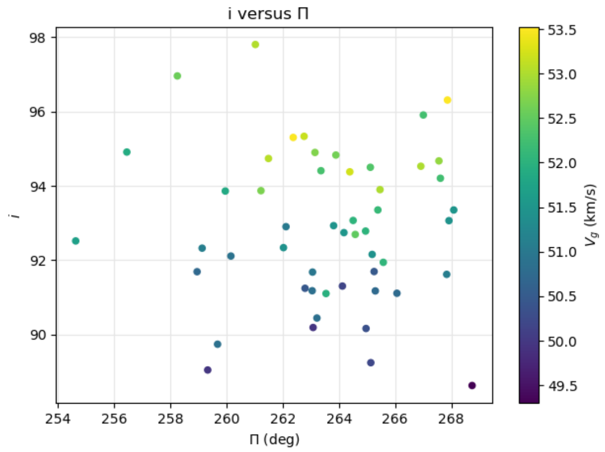

Figure 10 – Close up of the diagram of the inclination i against the longitude of perihelion Π for the new meteor shower color coded for the geocentric velocity v_g.

The mean orbit for the 51 members of this new meteor shower has a Tisserand parameter relative to Jupiter of $T_J = 0.3$ which corresponds to a Long Period-type comet (LPC) orbit, in this case on a retrograde orbit. The mean orbit parameters are listed in *Table 1*. This is a highly inclined very eccentric orbit probably related to an unknown long period comet.

Checking orbit data from before 2024, GMN had 5 orbits from this new meteor shower with $D_D < 0.06$ in 2022 during the period $100.4° < \lambda_O < 104.4°$ and 16 orbits in 2023 during the period $97.3° < \lambda_O < 105.1°$. It should be noted however that the southern hemisphere coverage for Global Meteor Network expanded year after year after 2021. Probably the meteor shower was there but awaited sufficient coverage of the southern sky to be detected. A search through the SonotaCo orbit dataset for 2007–2022 resulted in zero matching orbits, what can be explained by the fact this radiant is out of reach from the northern latitudes of this network.

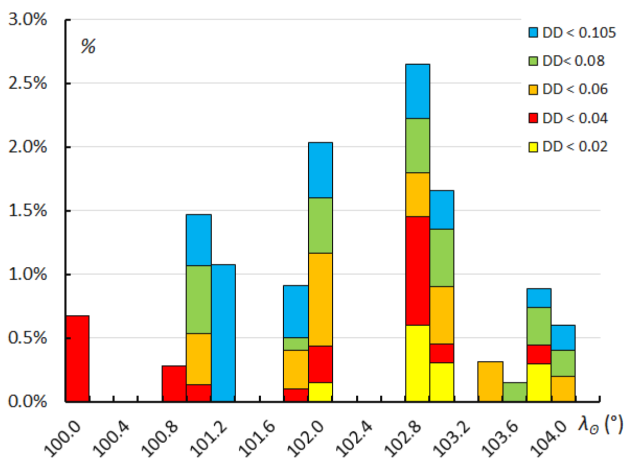

Figure 11 – The number of shower meteors per 0.2° in Solar longitude, as percentage of the total number of orbits collected during the corresponding time interval, for the different classes of similarity according to the D-criteria.

Table 1 – The mean orbit of the possible new meteor shower detected in the constellation of Fornax on July 4, 2024.

	M2024-N1
λ_O (°)	102.8
λ_{Ob} (°)	100
λ_{Oe} (°)	104
α_g (°)	44.0 ± 1.6
δ_g (°)	–38.3 ± 1.3
$\Delta\alpha_g$ (°)	–
$\Delta\delta_g$ (°)	–
v_g (km/s)	51.7 ± 1.0
λ (°)	24.2 ± 2.0
$\lambda_g - \lambda_O$ (°)	281.6 ± 1.8
β_g (°)	–51.7 ± 1.3
a (A.U.)	18.3
q (A.U.)	0.9880 ± 0.008
e	0.9460 ± 0.056
i (°)	92.7 ± 2.0
ω (°)	340.7 ± 3.0
Ω (°)	282.9 ± 0.8
Π (°)	263.9 ± 3.0
T_j	0.31 ± 0.31
N	51

On July 9, the new shower was reported with the required data and lookup table to the IAU MDC, following the official guidelines. On July 15, the IAU confirmed the GMN discovery and gave the new meteor shower a preliminary designation M2024-N1. The same day CBET 5415 appeared announcing the discovery of the psi Fornacids by CAMS (Jenniskens, 2024), without IAU authorization. A separate CBET was published on July 16 with the Global Meteor Network discovery data for this new meteor shower (Šegon et al., 2024), correcting the discovery record.

3 Conclusion

A new meteor shower was noticed in Global Meteor Network orbit data on July 3–4, 2024 with meteors radiating from a geocentric radiant at $\alpha = 44.4°$ and $\delta = -38.2°$ in the constellation of Fornax. The discovery was made in a narrow observing window of $102.3° < \lambda_O < 103.14°$. In the first instance 28 similar meteoroid orbits were found which fit the D-criterion $D_D < 0.06$.

A few days later when all camera data got uploaded and processed, a new search resulted in 51 orbits detected within the interval of $100° < \lambda_O < 104°$ with a maximum at $\lambda_O = 102.78°$. These 51 orbits were obtained from 35 meteors in New Zealand caught on 100 cameras, 15 in Australia on 34 cameras and 1 in Brazil on 2 cameras. The Tisserand parameter relative to Jupiter, $T_J = 0.3$ corresponds to a Long Period-type comet (LPC) orbit, in this case retrograde orbit. Earlier orbit data from GMN in 2022 and 2023 had similar orbits with $D_D < 0.06$ in the observing interval of $97.3° < \lambda_O < 105.1°$.

The new meteor shower has been registered in the Working List of Meteor Showers of the IAU MDC with the preliminary designation M2024-N1, the name psi Fornacids has been proposed by Peter Jenniskens.

The Global Meteor Network methodology, theory and results have been published in Vida et al. (2019, 2020 and 2021).

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2024 Perseid-season meteor outburst with a radiant in Capricorn

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A meteor outburst was detected during the Perseid shower season in 2024, radiating from near the star nu Cap. The shower was active from August 3 to 16, and was not seen in prior years. The origin is uncertain. The radiant is just below that of the alpha-Capricornids from 169P/NEAT at this time of year and further west from the radiant position of the August delta-Capricornids from 45P/Honda-Mrkos-Pajdusakova.

1 Introduction

Observers during this year's Perseid meteor shower, especially the ones with dark and clear skies, may have noticed something unusual: slow meteors from the south adding to the usual Perseid display of fast meteors from the north-east. Between August 10 and 15, slow meteors radiated from near the star nu Cap (Jenniskens, 2024). The meteors were visible to the naked eye, but mostly faint. This nu-Capricornids meteor shower is new to astronomers and was detected by low-light video cameras all over the globe[3]. The new shower is caused by a yet-to-be-identified comet or primitive asteroid that lost material in the recent past.

2 Observations

The shower was first noticed on August 10 as a dense cluster of radiants in the anthelion source[4]. The shower continued to stand out above the background until August 16. After extracting the orbits, the shower appears to have been first detected above the sporadic background on August 3, but rates stayed low in that first week. The shower spanned the solar longitude range of 131.3 to 143.5 degrees, centered on 139.05 degrees (equinox J2000), one day earlier than the peak of the Perseid shower.

In total, 130 orbits were measured by CAMS and Global Meteor Network stations. Sixty-two new shower meteors were triangulated by CAMS New Zealand (coordinated by J. Baggaley, University of Canterbury; and J. Scott, University of Otago), 24 by CAMS Australia (H. Devillepoix, Curtin University; D. Rollinson), 19 by CAMS-BeNeLux (C. Johannink, M. Breukers), 11 by LO-CAMS in Arizona (N. Moskovitz, Lowell Observatory), 6 by CAMS Namibia (T. Hanke, E. Fahl, R. van Wyk, HESS Collaboration), 3 by CAMS Chile (S. Heathcote and T. Abbott, NOIRLAB and Cerro Tololo; E. Jehin, University of Liège), 3 by the UAE astronomical Camera Network (M. Odeh, International Astronomical Center), one by CAMS Arkansas (L. Juneau), and one by CAMS California (J. Albers, B. Grigsby, E. Egland, and T. Beck).

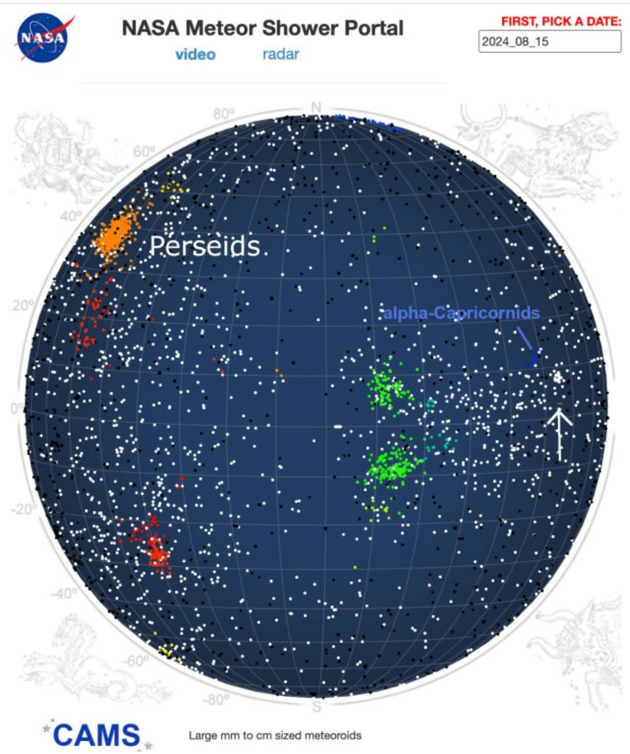

Figure 1 – Radiant map on August 15, 2024, with arrow marking the new shower.

Table 1 summarizes the median radiant, speed and orbital elements. The radiant drift was +0.40 deg/day in R.A. and +0.26 deg/day in Decl., while the orbital elements changed along the Earth's path at a rate of +0.006 AU/day in q, +0.03 deg/day in i, and –0.89 deg/day in the longitude of perihelion Π.

The results are compared to those for the annual epsilon-Aquariids from comet 169P/NEAT (Jenniskens, 2023), which are close to the position of the alpha-Capricornids in mid-August, and the 2022 outburst of August delta-Capricornids from comet 45P/Honda-Mrkos-Pajduskaova (Jenniskens, 2022a; 2022b; Roggemans et al., 2022).

[3] http://cams.seti.org/FDL/ for dates of August 10-15, 2024.

[4] http://cams.seti.org/FDL/ for date of 2024-08-10.

Table 1 – The median orbital elements (Equinox J2000.0) compared to nearby showers.

	nu-Capricornids 2024	epsilon-Aquariids (annual)	August delta-Capricornids 2022
$\lambda_\odot$ (°)	139.05	136.7	143.1
α_g (°)	306.65 ± 0.14	310.8	324.7 ± 0.2
δ_g (°)	–11.38 ± 0.09	-6.4	-11.6 ± 0.3
v_g (km/s)	18.34 ± 0.08	20.1	24.2 ± 0.3
$\lambda - \lambda_\odot$ (°)	166.74 ± 0.18	174.3	180
β (°)	+7.62 ± 0.07	11.2	2.3
a (AU)	2.94 ± 0.03	2.42	3.16
q (AU)	0.749 ± 0.02	0.665	0.547 ± 0.025
e	0.745 ± 0.003	0.728	0.823 ± 0.069
ω (°)	247.0 ± 0.3	259	270.9 ± 1.7
Ω (°)	139.1 ± 0.3	136.7	143.2 ± 0.4
i (°)	4.17 ± 0.04	7.16	1.9 ± 1.3
Π (°)	26.4 ± 1.2	36.4	54.5 ± 1.0
T_j	2.75 ± 0.19	3.08	2.58 ± 0.50
N	130	438	36

3 Discussion

At this point in time, it is unclear what may be the source of this shower. Another outburst with a radiant in Capricorn was observed in 2022, when meteoroids from comet 45P/Honda-Mrkos-Pajdusakova were intercepted by Earth (Sekiguchi, 2022). The radiant of the new shower this year was nearly 20 degrees further west and the geocentric velocity was lower by 6 km/s. The longitude of perihelion of the resulting orbit is lower by almost 30 degrees.

It is perhaps more likely that the shower is related to the alpha-Capricornids. However, the shower radiant was significantly below and to the west of that of the alpha-Capricornids at this time of year. This shower has a component slightly offset called the epsilon-Aquariids (*Table 1*). The longitude of perihelion of the new shower is 10 degrees below that of these showers associated with 169P/NEAT.

Acknowledgments

I thank the CAMS station and network operators for a successful 2024 Perseid shower campaign. Especially CAMS-BeNeLux had outstanding results. I thank *Dave Samuels* and *Steve Rau* for maintaining the CAMS operations. Many Global Meteor Network stations were established in and around CAMS networks and these contributed a majority of the results described here. I thank *D. Vida, P. Roggemans, N. Moskovitz, D. Rollinson* and *J. Scott* for making this possible.

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A note on meteor association with the orbit of P/2024 L4 Rankin

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Following the release of MPEC 2024-N106 declaring the newly discovered comet P/2024 L4 Rankin an immediate examination of GMN meteor orbits tested against this published orbit using a discrimination criterion was made revealing a potential, currently unknown, shower. Later on the same day IAUC CBET 5409 gave a more detailed and general announcement of the comet discovery as well as including a short note commenting on a potential association with the δ^1 Canis Minorids (DCN#1168). The published orbit for this shower was subsequently tested in the same way against the GMN orbits as the earlier examination had revealed no such connection with this shower. This independently showed that no connection of the latter shower with the comet orbit existed according to discrimination criterion and that there was only a small overlap in GMN meteor orbits with poor discrimination criterion values, and, that the few putative new shower orbits that matched the the δ^1 Canis Minorid shower orbit had no individual meteor orbit common to both showers. The names α Canis Minorids and Procyonids are given to the suggested new shower here.

1 Introduction and methodology

MPEC 2024-N106[5] was released on July 9th 2024 at 02^h49^m UT announcing the discovery details and preliminary orbital elements for P/2024 L4 Rankin. An examination of the orbit using the Jopek 1993 discrimination criterion variant (henceforth D_J), adopting a threshold value of 0.100 was made against Global Meteor Network data revealing a potential association with 112 meteor orbits. Much later on July 9th 2024 UT CBET 5409 was released also announcing P/2024 L4 Rankin[6] and including a note with respect to the potential association of the comet with the δ^1 Canis Minorids (DCN#1168) which has a radiant similar, but somewhat offset, in celestial coordinates and solar longitude to those that which can be predicted from the comet's orbit, with a similarly scaled offset in geocentric velocity (these being the most readily derived and primary measures of a meteor event from which other details are then derived when multi-station data are utilized).

Accordingly, the earlier analysis was repeated using the published orbital elements for this latter suggested shower as given in Jenniskens 2024. The Jopek 1993 variant, D_J, was again utilized and the δ^1 Canis Minorid orbital elements were tested against both the published comet orbit and the earlier potential new shower association that had been derived from GMN meteor orbits, as well as the full GMN dataset of meteor orbits, the latter resulting in 146 matched meteor orbits. A cross match of the Procyonid candidates was also made against these candidates leading to 13 objects from each being matched, however with poor D_J values and no meteor common to each.

2 Results

When the orbit for P/2024 L4 Rankin is tested against the complete Global Meteor Network (GMN) dataset up to and including July 2024 112 comets are found to be associated using $D_J < 0.100$, albeit with very few bettering the value of 0.08 or so, most of them being in the 0.09 to 0.10 range. These are referred to as the Procyonids here.

When the published orbital elements for P/2024 L4 Rankin are compared to those of the published δ^1 Canis Minorid orbital elements the D_J value returned is 0.172, where the published suggested threshold value for this criterion is 0.105 and 0.100 was used here. Given the tighter rein this criterion has compared to others and the fact that the value does not follow a linear relation this is quite a large offset demonstrating no similarity between the two orbits. Further the comet has a somewhat stable orbit with an aphelion well distanced from that of Jupiter and is not particularly perturbed by said (not significantly differently from any other general solar system object that is influenced by Jovian gravity). There is no evidence of connection between this shower and this comet based on their representative orbits nor any evidence of any perturbation upon the comet's orbit.

When the 112 putative Procyonid meteor orbits derived from GMN data using D_J against P/2024 L4 Rankin's published orbit are tested against the 146 δ^1 Canis Minorid meteor orbits derived from GMN data using D_J against their published orbit 13 matched objects are found for each shower, albeit predominantly with D_J values mostly well above 0.09, i.e. near the threshold value limit, giving a total

[5] https://minorplanetcenter.net/mpec/K24/K24NA6.html

[6] http://www.cbat.eps.harvard.edu/iau/cbet/005400/CBET005409.txt

of 26. None of these meteor orbits were common to both showers and only uniquely matched their shower neighbors, despite being matched when matched across showers via D_J, thus 13 meteors per shower could be shown to have a connection using this test but none were shown to be the same as any meteor in the other shower.

The resulting elements are given in *Table 1* for four orbits, the comet, the published δ^1 Canis Minorid orbit, the mean δ^1 Canis Minorid orbit derived from GMN data and the mean Procyonid orbit derived with GMN data (both with the 13 common orbits removed as an extra filtering), with the parenthetic values for P/2024 L4 being predicted from its orbital elements. The 13 matched orbits have been removed from the 112 meteor orbit Procyonid dataset as their relation to either shower cannot be affirmed, leaving 99 orbits, similarly the δ^1 Canis Minorid dataset had its 13 matched orbits removed and becomes reduced to 133 orbits.

It should be strongly noted, however, that no specific meteor orbit was common to both the 112 meteor Procyonid dataset and the 146 meteor δ^1 Canis Minorid dataset, potential connections only appearing due to the use of a discrimination criterion cross match of said datasets. That is, all GMN meteor orbits within each shower's dataset were unique to that particular dataset and no particular/specific meteor could be shown to associated with both showers.

Low inclination comet orbits within that of Jupiter can be problematic the nearer they are to the solar system's orbital plane, with unassociated meteors appearing related due to the assumed random background distribution not being valid the nearer to the orbital plane inclination becomes. For example, orbital inclinations of 5 or less degrees can be found to match with several Jupiter family comets and/or showers when using discrimination criteria. Accordingly, in order to assess this potential contamination, a handful of artificial orbits with the same elements and inclination as the comet but with the argument of perihelion and the ascending node reversed as well as those two elements randomly chosen but the same offset in values kept were also used to assess the situation, as given a sufficiently non-random distribution of orbits biased by perturbations by their proximity to the ecliptic plane any low inclination orbit, real or not, has the potential to find matches in meteor orbit datasets of sufficient size. Fortunately, these tests gave no such matches.

Table 1 – Particulars and orbital elements for P/2024 L4 Rankin the δ^1 Canis Minorids (DCN#1168) and the Procyonids.

Entity	*RA*	*Decl.*	λ_O	v_g	*q*	*e*	*i*	*ω*	*Ω*
P/2024 L4	(111.5)	(+6.5)	(297.1)	(19.9)	0.672	0.699	10.1	53.7	139.8
δ^1 CMi publ	110.6	–0.1	293.2	23.6	0.622	0.78	16.1	80.5	113.2
δ^1 CMi calc	110.9	–0.4	293.6	23.4	0.625	0.775	16.1	80.5	113.6
Procyonid	113.8	+6.2	303.5	19	0.715	0.705	9.1	70.1	123.5

Simple plotting of either radiant positions for each meteor orbit or graphical representations of the orbits themselves reveals distinct offsets in perihelion distance and inclination between the δ^1 Canis Minorids and both the proposed Procyonids and the P/2024 L4 Rankin orbit whilst the latter lies amongst the spread of Procyonid orbits quite well.

3 Discussion

Recent times have seen the latest guidelines from IAU working group for meteor shower nomenclature being ignored in publications with in some cases suggested names being given to showers instead of the recommended preliminary code, and in at least two cases names being suggested in publications by author(s) who are not the showers' discovery authors! Also, the IAU Meteor Data Centre has over time removed showers with no hint of reference to them on their webpages in some cases without full consideration of the role of nomenclature with respect to historic bibliographic linkage. That is some current mnemonic code identifiers used for some current showers that have been published have been used for showers published in the past that have now been rejected, which can cause confusion during literature searches and lead to much unneeded investigation into what is actually happening. In some cases, there is no record of the former rejected shower and/or designation given at IAU MDC.

In recent times Flamsteed numbers have been added to the naming conventions due to the increased number of showers discovered and/or difficulties in finding a near enough star for naming basis and/or a unique mnemonic/acronym, with in extreme cases variable star designations even being used for shower names! Meanwhile, comet identifiers are not allowed and in any case can no longer be used due to comets being able to cause more than one shower (e.g. 1P/Halley) and also because under current comet nomenclature regulations the named comets no longer have an ordinal number attached when the discoverer already has comets named after them (in other words, different showers could end up being the something Rankinids with no ready clarification as to which of the several Rankin comets that exist is the relevant one from that name, or in yet other words, comet Rankin has no ranking). Indeed, often the comet name is only used in the initial announcement with the comet being referred to in literature by its identifier (although bright ones announced to the general public are often identified by only their name, e.g. NEOWISE, although the press often invents nicknames instead, e.g. Green Comet and Devil Comet), and the use of P/2024 L4-ids is somewhat clumsy, if not very clumsy.

Proper names for stars in many instances predate even Bayer designations, and in many cases are as old as the proper names for constellation used in meteor shower nomenclature. What is more official star proper name lists compiled by the IAU exist.

Given the above points, and especially recent instances of showers being named by non-discoverers when the actual discovers neglected to give a suggested name for once the shower is confirmed I am left with no choice but to name this shower the Procyonids in this publication, its working identifier by regulation would be M2024 L1 utilizing the comet discovery date but M2024 N1 using this discovery shower and paper date.

4 Conclusion

The orbit of recently discovered comet P/2024 L4 Rankin is shown to have meteor orbits from the Global Meteor Network database to be associated with it. The comet has orbital elements, especially the aphelion distance, precluding any readily indicated perturbation due to Jupiter which could have led to past orbits and different resultant shower details. Examination of similar orbits against the full GMN dataset where only the argument of perihelion and the ascending node are changed for the comet orbit shows null results when inspecting whether the near ecliptic plane Jupiter family comet derived population of meteor orbits tested with the Jopek 1993 discrimination criterion can lead to false positives. This suggests some validity to the usage of that criterion for this comet's orbital association with meteors and a likely lack of false positives amongst the results.

CBET 5409 noted that an association with the unconfirmed published meteor stream the δ^1 Canis Minorids was a possibility, however utilizing GMN orbital data it can be shown that that shower is distinct from both the comet and the newly suggested shower detailed here, albeit with some relatively minor overlap between the two showers albeit only via discrimination criterion with no actual specific meteor being shown to be common to both showers. Accordingly, P/2024 L4 Rankin is not associated with the δ^1 Canis Minorids even though the comet has a potential associated meteor shower, and the potential associated meteor shower is similarly not associated with the δ^1 Canis Minorids.

Due to extenuating circumstances beyond the author's control the name Procyonids is used for this shower here, although the alternative name of α Canis Minorid shower (alpha-Canis Minorids) is unused and equally applicable upon any confirmation of this shower. If current somewhat half policed IAU nomenclature naming rules are followed the shower would receive the identifier M2024-N1 based on discovery date.

Since this paper was written the identifier M2024-N1 has already been used in a publication'.

Acknowledgments

The online data services for the Minor Planet Center at the Harvard and Smithsonian Center for Astrophysics were utilized for obtaining the comet orbit details. The GMN meteor survey group and especially their volunteers and operatives are expressly thanked not only for their work but for making their data not only public but in near real time and thus available for analytical examination by all in a timely manner when novel events occur.

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July gamma Draconids outburst in 1852?

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A short report in a Danish newspaper describing a meteor outburst on 1852 July 25 between 22^h15^m and 22^h45^m local time, corresponding to solar longitude 125.12° (2000.0) from a radiant west of Deneb in the constellation Cygnus, resembles in duration, intensity, time of appearance and radiant location to the July gamma Draconid outburst observed by CAMS-BeNeLux between July 27, 23^h56^m and July 28 00^h23^m UT ($\lambda_{\odot}$ = 125.13°).

1 Introduction

While checking old newspapers on the occurrences of astronomical events, the first author came across an interesting report published in the Danish journal “Fyens Stiftstidende” on 28. juli 1852[7] (*Figure 1*).

The original article in Danish reads as: “*Odense. (Meddelt.) I Søndags Aftes den 25de Juli, Kl. 10¼ til 10¾, blev her i Odense iagttaget en for denne Tid sjelden Mængde Stjerneskud: Indsenderen [*i.e. message was sent as a letter*] talte i Løbet af 3 a 4 Minuter nogle og tyve, men da Mængden forøgedes saaledes, at der i enkelte Øieblikke udskjød 3, 4 a 5 ad Gangen, kunde han ikke længere controllere Tallet. Særegenheder ved disse Stjerneskud, hvilke Indsenderen ikke tidligere har bemærket, vare, at de næsten alle udgik fra eet Sted paa Himmelhvælvingen, lidt vestlig for Deneb i Stjernebilledet Svanen (omtrent i Zenith), at alle de, som udgik fra dette Punkt, bevægede sig næsten parallelt imod S.S.O. med saa stor Hastighed og i saa korte synlige Baner og vare af saa forskjellig Farve og Glands, og tildeels saa smaa, at Øiet neppe kunde følge dem og det i enkelte Øieblikke saae ud, som om Stjernerne af 3die til 6te Rang i en liden Kreds foretog en Flytning* ***en masse****. Da man hidindtil har antaget de periodiske Stjerneskuds Tid kun at være fra 9de til 14de August samt 13de og 14de November og de her seete syntes for hyppige til at kunne henføres under de sporadiske, kunde denne lille notits maaskee, især dersom lignende Iagttagelser vare gjorte paa andre Steder, være af nogen Interesse.*”

The translation from Danish to English reads: “*Last Sunday evening, July 25, between 10:15 p.m. and 10:45 p.m., one - for the time of the year - unusual [unusually high] number of meteors were witnessed here in Odense: during some three to four minutes the contributor [the sender, the rapporteur] counted more than twenty [the Danish term usually means 22, 23, 24, or 25], but as the rate increased, so that in some instances three, four of five were emitted simultaneously, he could no longer be sure of the figure. Peculiarities of these meteors, which he has not noted prior, was, that almost all radiated from [were emitted from, emanated from] one single area [place, spot] on the celestial hemisphere, a little West from Deneb in the constellation The Swan (close to Zenith), that all those, which emitted from this point moved in almost parallel tracks towards SSE, with so great speed, and in so short tracks, and were of such different hue and brightness, and partially [to some extent] so small, that the eye could hardly follow them, and at some instances it appeared as if stars of 3rd to 6th magnitude in a small area [an area confined by a ring-like perimeter] moved ‘****en masse****’ [italics]. Since until now, the assumption has been that intervals of periodic [i.e. annually occurring] meteors were exclusively from August 9 to 14, and November 13 and 14 - and the here witnessed, seem too frequent to be referred to the sporadics - perhaps this little notice could - if similar observations are made elsewhere - be of some interest [i.e. to science]*”.

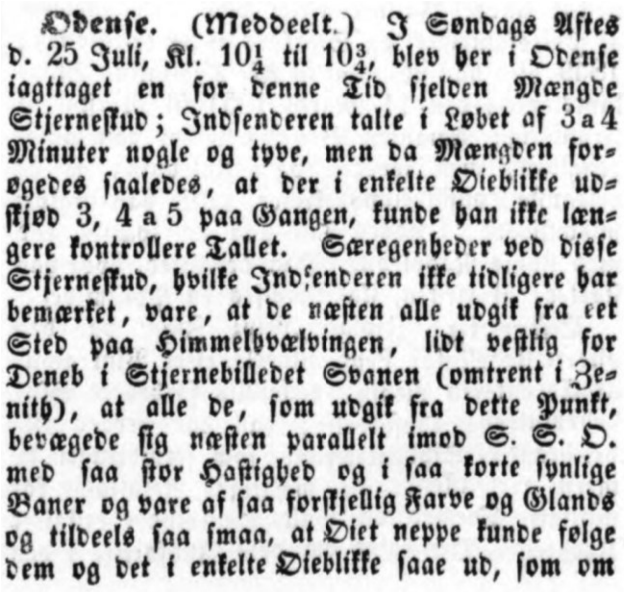
Odense. (Meddeelt.) I Søndags Aftes d. 25 Juli, Kl. 10¼ til 10¾, blev her i Odense iagttaget en for denne Tid sjelden Mængde Stjerneskud; Indsenderen talte i Løbet af 3 a 4 Minuter nogle og tyve, men da Mængden forøgedes saaledes, at der i enkelte Øieblikke udskjød 3, 4 a 5 paa Gangen, kunde han ikke længere kontrollere Tallet. Særegenheder ved disse Stjerneskud, hvilke Indsenderen ikke tidligere har bemærket, vare, at de næsten alle udgik fra eet Sted paa Himmelhvælvingen, lidt vestlig for Deneb i Stjernebilledet Svanen (omtrent i Zenith), at alle de, som udgik fra dette Punkt, bevægede sig næsten parallelt imod S. S. O. med saa stor Hastighed og i saa korte synlige Baner og vare af saa forskjellig Farve og Glands og tildeels saa smaa, at Øiet neppe kunde følge dem og det i enkelte Øieblikke saae ud, som om

Figure 1 – Part from the original publication printed in the old typesetting.

[7] http://hdl.handle.net/109.3.1/uuid:285c37c8-094f-4ed5-b37b-384858f68f86

Square brackets are the comments, alternatives suggested by the first author. At least eight other Danish newspapers copied the report, but adding no info. The Norwegian, Swedish and German newspaper archives were searched, but no similar report could be found.

2 July gamma Draconids outburst?

The report clearly describes a meteor outburst at an unusual time of the year not related to any known annual meteor shower like the Perseids or Leonids in the 19th century. The author gives a pretty precise hint where to look for the radiant: west of Deneb or alpha Cygnii near the zenith in Denmark on 1852 July 25 around 22^h30^m local time. The time of appearance corresponds to $\lambda_{\odot} = 125.12°$ (epoch 2000.0).

Looking for possible associations with known meteor showers, the July gamma Draconids (GDR#184)[8] appear to be a most likely candidate. This meteor shower produced a meteor outburst in 2016 at $\lambda_{\odot} = 125.13°$ from a radiant position at $\alpha = 279.9°$ and $\delta = +50.5°$, which is about 20° west from Deneb and near the zenith at the time mentioned for Denmark (*Figure 2*).

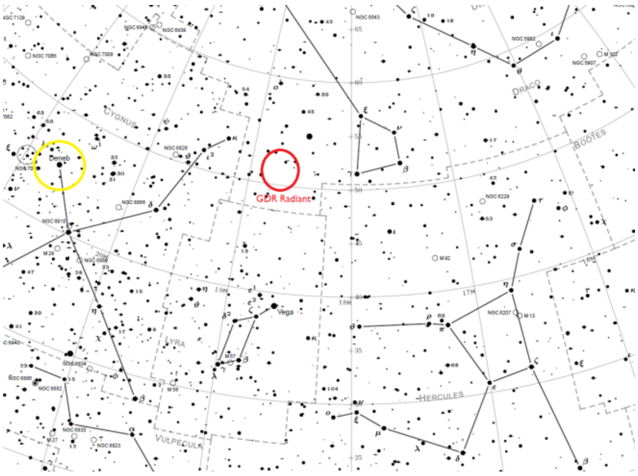

Figure 2 – Star map[9] with the GDR#184 radiant marked in red, 20° west of Deneb marked in yellow.

3 What do we know about this shower?

Pulat Babadzhanov (1963) is considered to be the first who mentioned this radiant at $\alpha = 278.5°$ and $\delta = +48.8°$ as an unknown meteor shower based on 4 photographed meteors recorded between June 1957 and December 1959 at two stations of the Institute of Astrophysics of the Academy of Sciences of Tadjikistan. He refers to a nearby radiant at $\alpha = 279°$ and $\delta = +55°$ which was listed in a Russian Astronomical Calendar by Maltsev (1930), but the authors were unable to verify this reference.

It is strange that this shower does not appear in the radiant catalogue compiled by W.F. Denning (1899), apart from one unverified entry with a radiant at $\alpha = 285°$ and $\delta = +52°$ observed by Konkoly (Hungary) during July 26–29 in 1875 listed in this work. The absence in Dennings's work, who systematically mapped meteor radiants from visual observations could be explained by its short-lived periodic outbursts. In the past most meteor shower outbursts were simply missed.

Alexandra Terentjeva listed a meteor shower with the name 13-Lyrids (Terentjeva, 1966; 2017, see pages 82 and 107 for shower entry 102), which corresponds to the current day known July gamma Draconids.

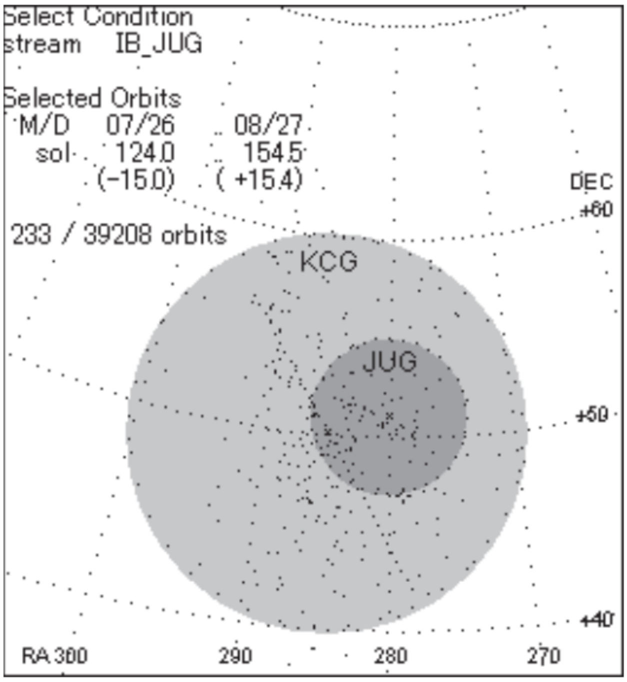

Figure 3 – The identification of the July gamma Draconids distinguished from the kappa Cygnid complex by SonotaCo (credit SonotaCo).

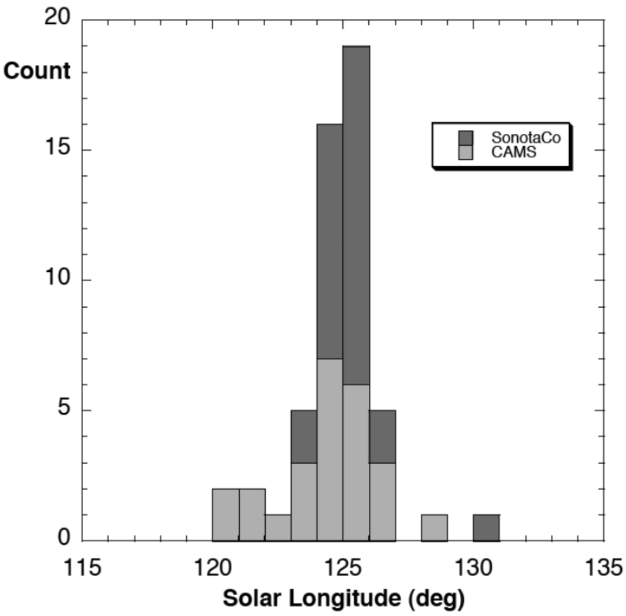

Figure 4 – The number of orbits identified as GDR#184 meteors in function of the solar longitude (credit CAMS, Holman & Jenniskens).

[8] https://www.ta3.sk/IAUC22DB/MDC2022/Roje/pojedynczy_obiekt.php?lporz=00458&kodstrumienia=00184&colecimy=0&kodmin=00001&kodmax=01224&lpmin=00001&lpmax=01713&sortowanie=0

[9] https://eyesonthesky.com/charts/free-star-charts/

Some sources refer to Cook's working list of meteor showers (Cook, 1973) with the o Draconids assumed to correspond to GDR#184, but the original publication by Cook et al. (1973b) clearly shows that this shower was based on only three isolated photographed meteors recorded on 6 and 16 July 1953 and 24 July 1952 all of which were very likely unrelated sporadic events, or perhaps early appearances of the kappa Cygnid complex. In the 1970ies until beginning of the 21st century meteor observers identified meteor activity from this area of the sky as the kappa Cygnid complex.

The meteor shower catalog based on 2007–2008 SonotaCo meteor orbits is in fact the very first publication that mentioned the July gamma Draconids based on 22 orbits from a radiant at $\alpha = 280.1°$ and $\delta = +51.1°$ with a maximum at $\lambda_{O} = 125.3°$ (SonotaCo, 2009). This cluster with 22 radiants was extracted from the diffuse radiant area identified as kappa Cygnids (*Figure 3*) and was initially added to the IAU MDC Working List of Meteor Showers as JUG#344. Later it was recognized as identical to the GDR#184 entry and listed as GDR#184 while JUG#344 was removed from the list.

The GDR#184 meteor shower was soon confirmed by CAMS observations in July 2011 with a mean radiant at $\alpha = 279.6°$ and $\delta = +50.4°$ (Holman and Jenniskens, 2012). The number of occurrences in function of time or solar longitude shows a very sharp activity profile at $\lambda_{O} = 125°$, see *Figure 4*.

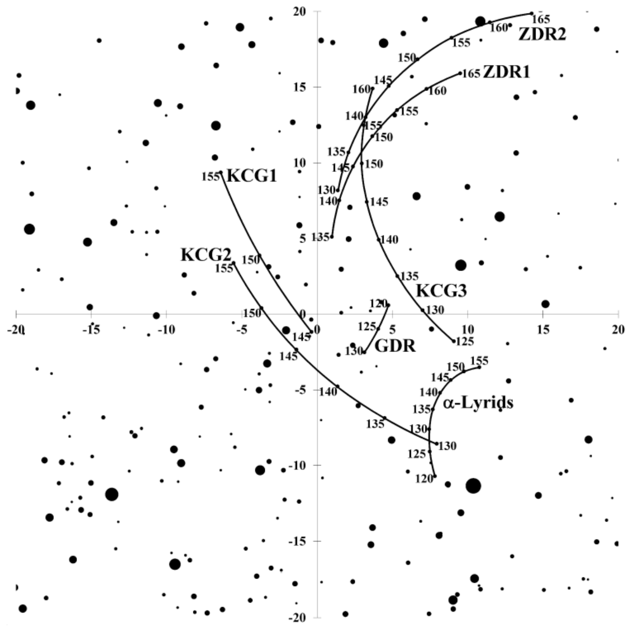

Figure 5 – The radiant drift of different components within the kappa Cygnid complex (credit Masahiro Koseki).

The availability of sufficient numbers of meteor orbit data made it possible to resolve the composition of the kappa Cygnid complex into separate branches with the July gamma Draconids as a distinct meteor shower. Masahiro Koseki (2014) analyzed and resolved the different components and distinguished the July gamma Draconids as group A in his study. The map with the radiant drift (*Figure 5*) shows the position of the GDR radiant very well west of Deneb. The GDR meteor shower was also described in Masahiro's work on 12 years of SonotaCo data (Koseki, 2021, see page 135).

The July gamma Draconids surprised observers with an outburst in 2016 during the night of July 27-28 with a sharp maximum between July 27, 23^h56^m and July 28 00^h23^m UT ($\lambda_{O} = 125.13°$). About half of all 126 single-station detected meteors, typically about +2 magnitude bright, radiated from this shower's radiant, as did 5 out of 9 multi-station meteors during this partly cloudy night. Beyond CAMS-BeNeLux this outburst was also confirmed by the meteor radar CMOR in Canada and different forward scatter meteor observers (Roggemans, 2016). The meteor shower characteristics were also described by Peter Jenniskens (2023).

4 Conclusions

The July gamma Draconids which produced a short-lived outburst in 2016 are the most likely source for a similar event described in a Danish newspaper in 1852. The timing corresponding to the same solar longitude and the location of the point of radiation at the zenith, west of Deneb, corresponds with the known meteor shower of the July gamma Draconids.

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Meteor shower data from video observation Part III Radiant point distribution map and activity profile

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The radiant distribution map gives the results of regression analysis for the radiant shift and shows the shape and spread of the radiant distribution.
The activity profile is based on meteors that fall within 3 degrees from the center of the radiant map. As shown in the example of the Orion group in part I, "Research methods and summary of survey results" (Koseki, 2024a). GMN data were strongly influenced by observation conditions in 2022, so we have avoided discussing the number of meteors themselves as much as possible. In addition, the *DR* used is changed as appropriate to avoid being affected by other meteor showers active in the surrounding area. Which *DR* or the meteor number itself was used, is shown in the graphs as the type of activity profile.
Basically, we use the ratio of meteors within 3 degrees from the center for each degree of solar longitude to meteors within, for example, 15 to 20 degrees (written as *DR3_20*). Naturally, this calculation considers the area of each range. This ratio is plotted as a moving average of 0.1 degrees in solar longitude. If the number of meteors that appear is small or the activity is irregular, a ratio is calculated from the number of meteors every 3 degrees in the solar longitude, and a moving average for a one-degree solar longitude bin has been calculated. In this case, it is written in lowercase letters, such as *dr3_20*.

1 Introduction

A brief explanation of each meteor shower is included. Cases that require detailed discussion, such as cases where the meteor shower classification differs from the IAUMDCSD's, are covered separately in part II "Meteor showers that need careful attention" (Koseki, 2024b). Radiant point distribution maps and activity curves are shown for the 118 meteor showers listed in *Tables 4 to 7* of part I, "Research methods and summary of survey results" (Koseki, 2024a).

Table 1 – Overview of the meteor showers discussed in this study. Click on the meteor shower code to consult the data.

Code	λ_O	Code	λ_O	Code	λ_O	Code	λ_O	Code	λ_O	Code	λ_O
BCO	13	JEC	82.6	SDA	126.9	OCT	192.55	NSU	241.7	KVE	274.9
ZCY_0	16	JRC	84	ERI	132.3	SAN	196.8	NOO	246.1	JLE	281.6
DHE	19.6	SSG	87	AXC	135.5	XIE	198.2	ORS	246.2	QUA	283.25
AED	20	JBO	90.3	PER	140.5	STA_SE	201.5	NAC	246.5	AHY	283.8
PSR	24.7	DPI	91.2	KCG	141.5	OCU	202.5	TPY_0	249.4	OLE	288.3
AVB	25	JEO	92	ADC	143.65	EGE	203.7	DKD	251	XCB	294.8
ZCY_1	31.5	JIP	94.1	AXD	147.2	LMI	209.2	PSU	251.5	XUM	298.6
LYR	32.3	FPE	95.8	NDA	149	TCA	209.5	DAD	253.5	GUM	299.8
HVI	39	PPS_0	98.5	ZDR	153.2	ORI	209.5	HYD	255.4	ACB	307.5
ARC	39.5	NZC	101	AGC	155.4	LUM	214.8	DRV	255.6	AAN	312.5
BAQ	44	MIC	101.3	AUR	158.4	SLD	221.5	EHY	256.2	FED	314.84
ETA	44.3	TCS	104.6	PSO	160.4	STA_SF	222.2	PUV	256.5	FHY	325.4
GAQ	48	CAN	105	OMG	163.2	KUM	222.8	MON	258.1	TTR	332.1
PCY	49.5	JPE	109.6	NUE	165.5	OER	223	GEM	261.85	DNO	334.2
ELY	50.2	ZCS	113.6	SPE	166.9	AND	224.5	XVI	262.8	TSB	343.7
MBC	55	JXA	115	NPI	167.2	RPU	226.2	DAB	263.1	XHE	351.9
TAH	69.45	XCS	116.3	SLY_0	169.5	NTA	226.5	TPY_1	264.3	EVI	358
PAN	72	PPS_1	117.5	CCY	173.4	LEO	235.4	COM	267.5	EOP	358.2
JMC	72	GDR	125.5	DSX	188.5	ACA	239.5	URS	270.65		
ARI	79.5	CAP	126.9	SLY_1	191.5	AMO	239.6	DSV	271.5		

0647BCO: beta-Comae Berenicids

$\lambda_\odot = 13°$, $\lambda - \lambda_\odot = 174.6°$, $\beta = 30.1°$,
$\alpha = 199.6°$, $\delta = 24.5°$, $v_g = 26.6$ km/s.

This group was not covered in the previous article and is not listed in SonotaCo net J14 list. IAUMDC only lists one CAMS observation. The number of meteors is not large, the radiant points are scattered, and the maximum is unclear, so BCO is close to the lower limit of this shower list.

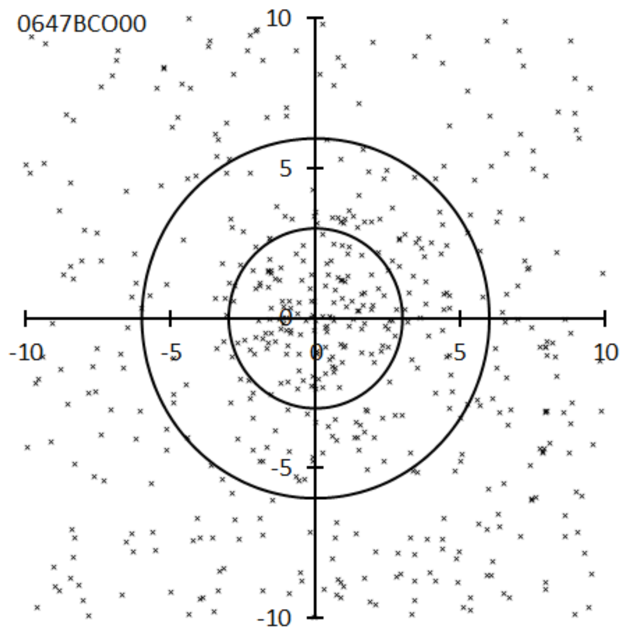

Figure 1 – Radiant point distribution map for the beta-Comae Berenicids.

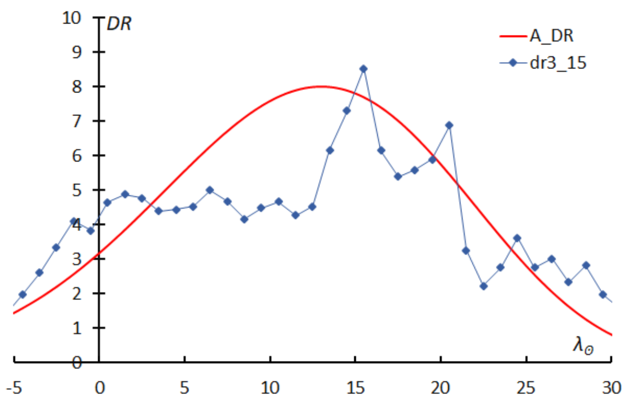

Figure 2 – Activity profile for the beta-Comae Berenicids.

0040ZCY_0: zeta-Cygnids

$\lambda_\odot = 16°$, $\lambda - \lambda_\odot = 300.4°$, $\beta = 59.1°$,
$\alpha = 299.2°$, $\delta = 40.2°$, $v_g = 43.5$ km/s.

0040ZCY and 0348ARC are described in detail in Part II. "Meteor showers that need careful attention" (Koseki, 2024b). As seen in the radiant distribution and activity profile shown in *Figures 3 and 4*, this is on the boundary between a coincidental increase in scattered meteor activity and what is recognized as meteor shower activity. Here, based on the activity curve, ZCY is divided into ZCY_0 around $\lambda_\odot = 15°$ and ZCY_1 around $\lambda_\odot = 30°$. None of these activities were covered in the previous article (Koseki, 2021), and they are not listed on SonotaCo net J14 list[10]. GMN[11] treats ZCY as a single meteor shower.

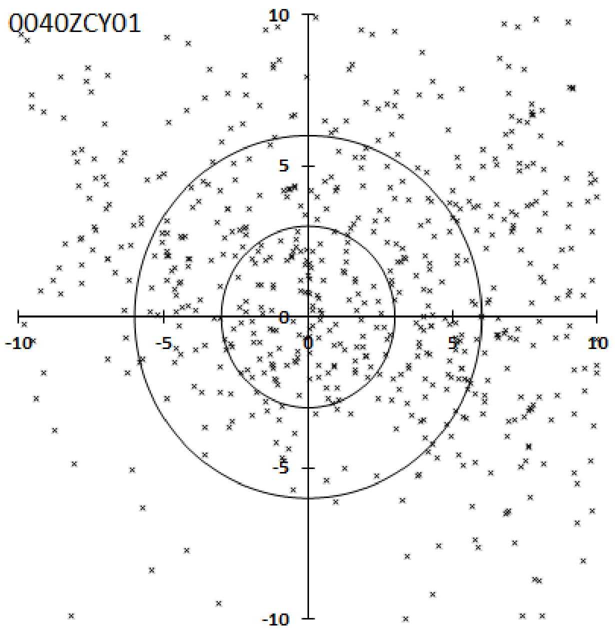

Figure 3 – Radiant point distribution map for the zeta-Cygnids.

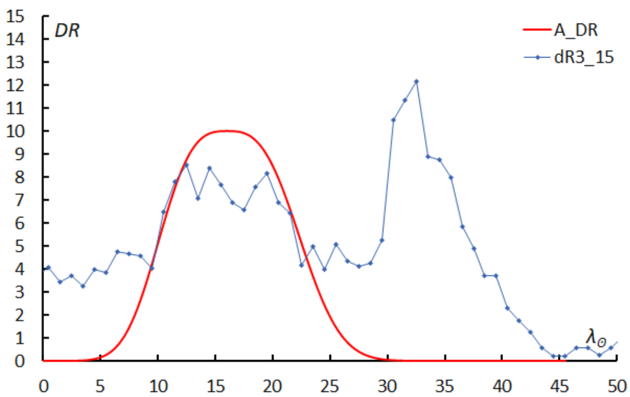

Figure 4 – Activity profile for the zeta-Cygnids.

0841DHE: delta-Herculids

$\lambda_\odot = 19.6°$, $\lambda - \lambda_\odot = 231.9°$, $\beta = 46.5°$,
$\alpha = 256.2°$, $\delta = 23.9°$, $v_g = 49.3$ km/s.

DHE was covered in the second report of CAMS (Jenniskens, et al., 2018b). DHE is an activity that was not covered in the previous article (Koseki, 2021) and is not listed on SonotaCo net J14 list. As seen in the activity profile, the period of activity is short and is one of the meteor showers in which the number of meteors observed by GMN is small. It will be difficult to detect unless it reaches a maximum.

[10] https://sonotaco.jp/doc/PDA/J14/

[11] https://globalmeteornetwork.org/projects/2023_gmn_shower_table

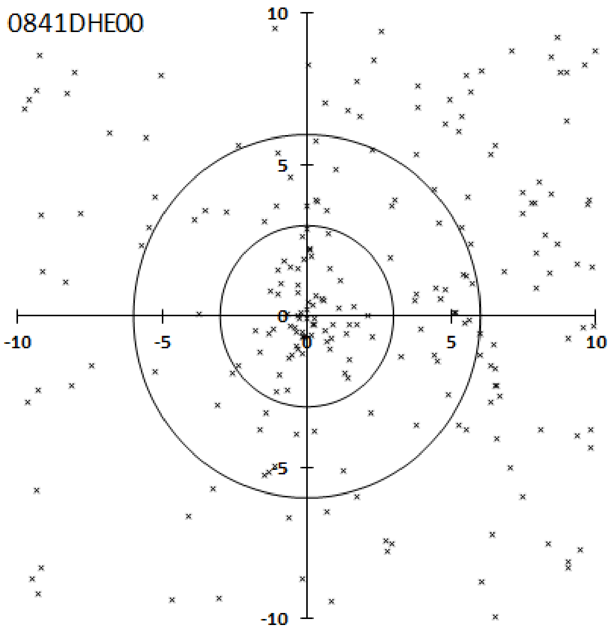

Figure 5 – Radiant point distribution map for the delta-Herculids.

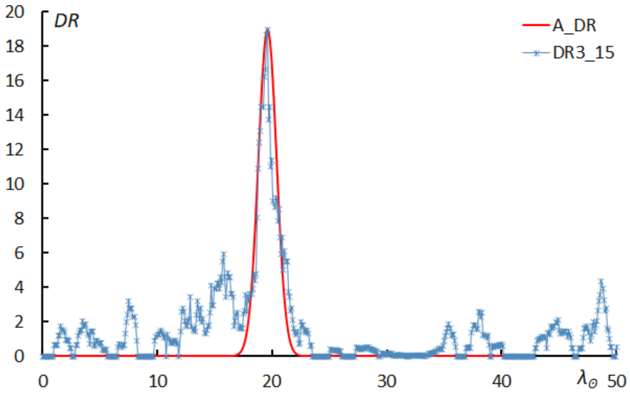

Figure 6 – Activity profile for the delta-Herculids.

0450AED: April epsilon-Delphinids

$\lambda_{\odot} = 20°$, $\lambda–\lambda_{\odot} = 293.1°$, $\beta = 30.1°$,
$\alpha = 307.2°$, $\delta = 12.0°$, $v_g = 60.6$ km/s.

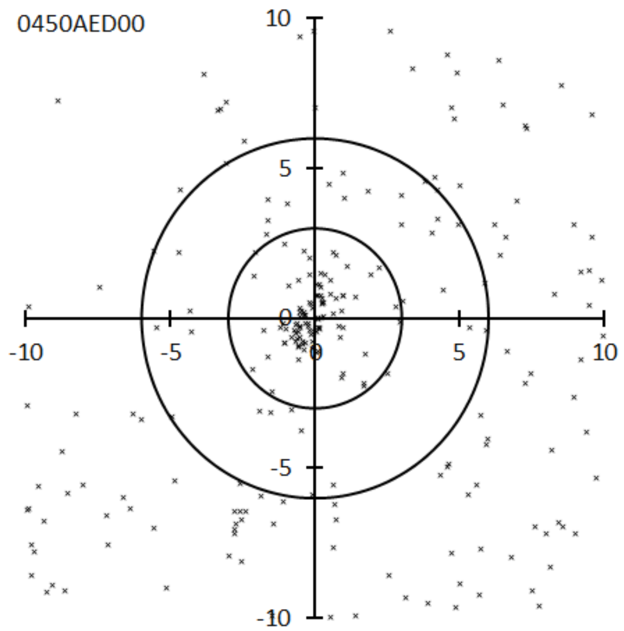

Figure 7 – Radiant point distribution map for the April epsilon-Delphinids.

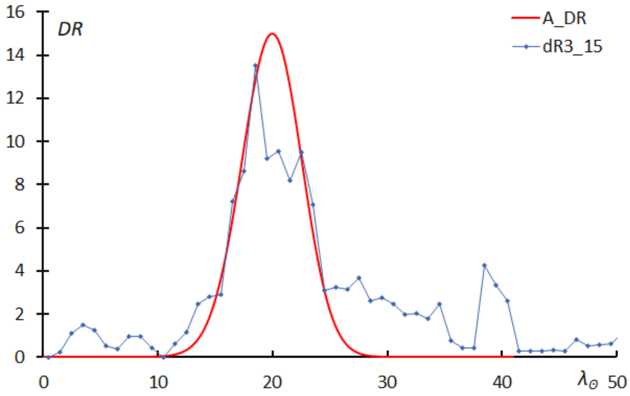

Figure 8 – Activity profile for the April epsilon-Delphinids.

This meteor shower was detected by combining SonotaCo net and CAMS data (Rudawska and Jenniskens, 2014). This group was covered in the previous article (Koseki, 2021) and is also listed on SonotaCo Net's J14 list and GMN. Although not many meteors appear, as the radiant point distribution map shows, they stand out from the surroundings, and the activity curve is clear.

0839PSR: phi-Serpentids

$\lambda_{\odot} = 24.7°$, $\lambda–\lambda_{\odot} = 211.4°$, $\beta = 34.7°$,
$\alpha = 241.7°$, $\delta = 14.6°$, $v_g = 45.1$ km/s.

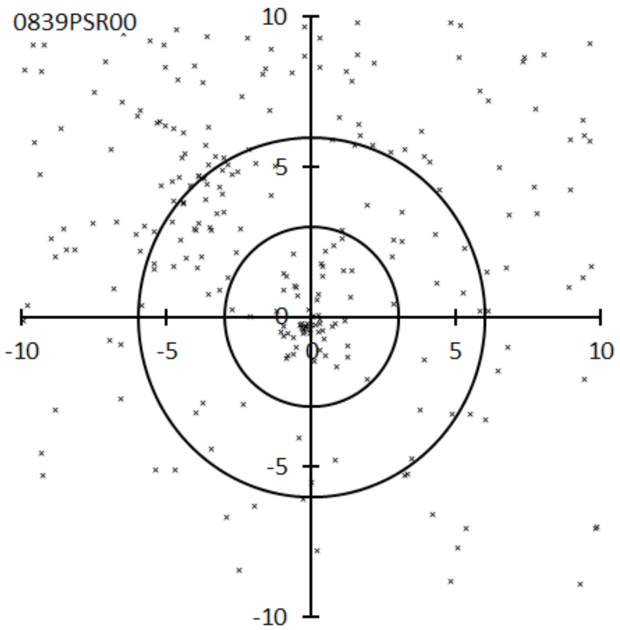

Figure 9 – Radiant point distribution map for the phi-Serpentids.

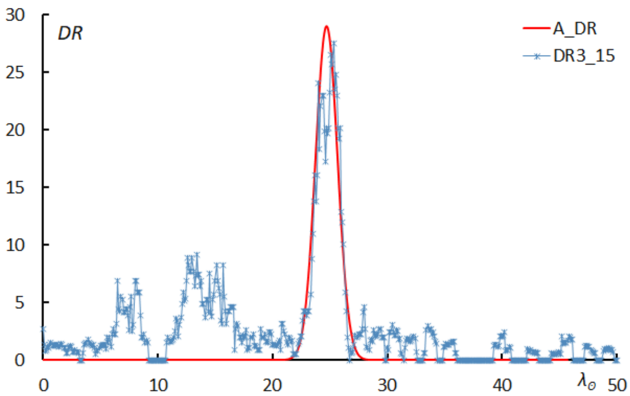

Figure 10 – Activity profile for the phi-Serpentids.

KSE03, which was discussed in the previous article (Koseki, 2021), has been deleted in the current IAUMDCSD. The relationship between KSE and PSR is described in detail in Part II, "Meteor showers that need careful attention" (Koseki, 2024b), so please refer to that for information on KSE03.

0021AVB: alpha-Virginids

$\lambda_{O} = 25°$, $\lambda\text{–}\lambda_{O} = 171.4°$, $\beta = 11.7°$,
$\alpha = 199.6°$, $\delta = 4.4°$, $v_g = 19.7$ km/s.

It is a different meteor shower activity than 0021AVB00, 0021AVB01, and 0021AVB02, which gave rise to the name AVB, and consists of 0021AVB03, 0021AVB04, 0021AVB06, and 0136SLE02 (Koseki, 2019).

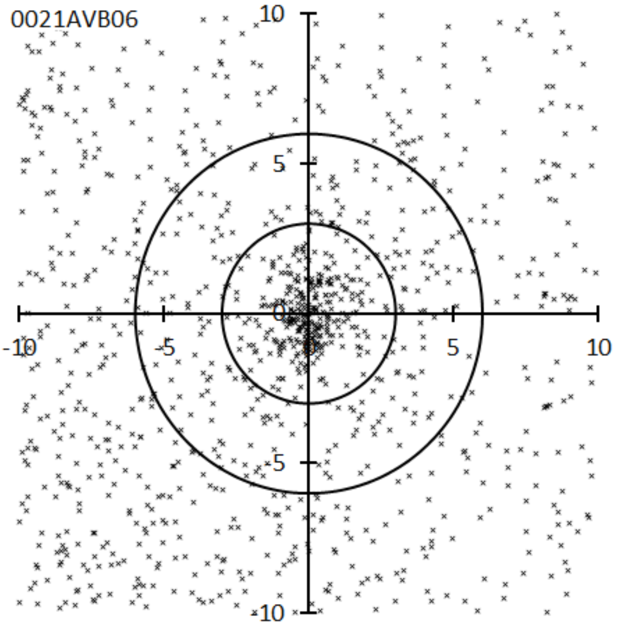

Figure 11 – Radiant point distribution map for the alpha-Virginids.

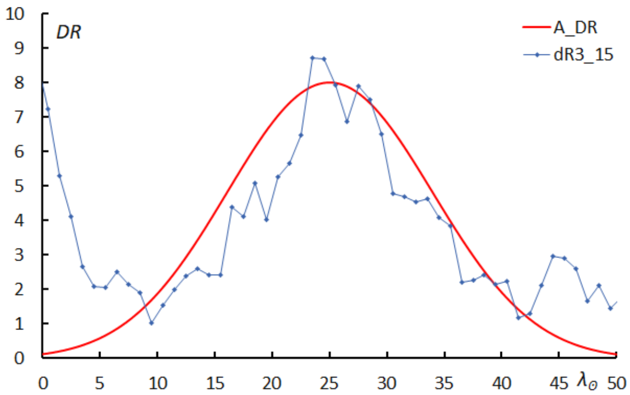

Figure 12 – Activity profile for the alpha-Virginids.

0040ZCY_1: zeta-Cygnids

$\lambda_{O} = 31.5°$, $\lambda\text{–}\lambda_{O} = 299.1°$, $\beta = 58.1°$,
$\alpha = 308.6°$, $\delta = 42.5°$, $v_g = 41.8$ km/s.

ZCY and ARC are described in detail in Part II, "Meteor showers that need careful attention" (Koseki, 2024b). This ZCY_1 activity shows a very clear maximum at $\lambda_{O} = 31.5°$. The graph below the activity profile shown in the second row was compiled by GMN. The activity period of ZCY is $\lambda_{O} = 1.6\text{\textasciitilde}33.9°$, and the activity near the maximum estimated in this paper is active.

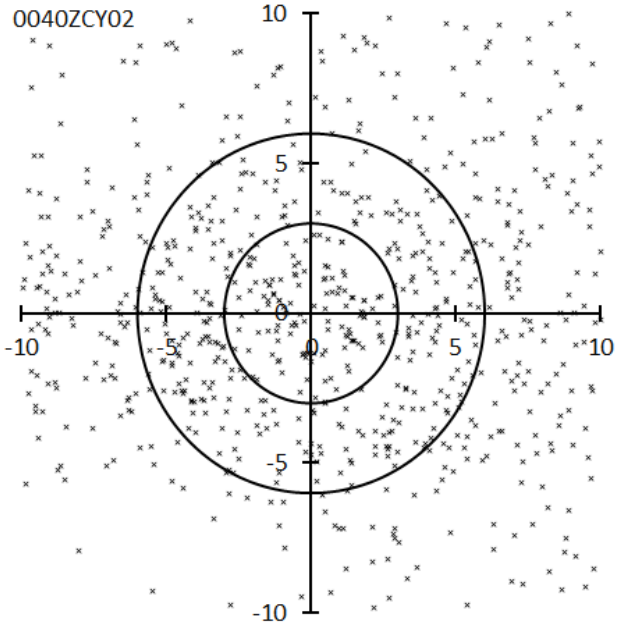

Figure 13 – Radiant point distribution map for the zeta-Cygnids.

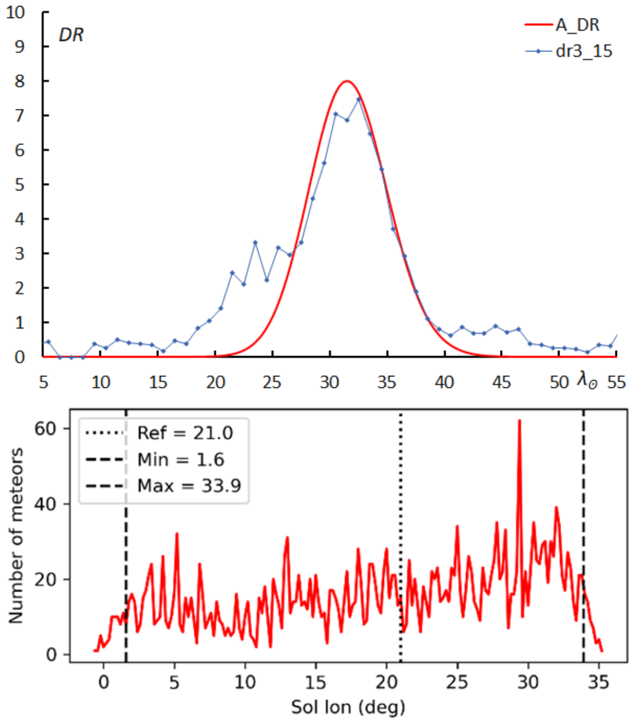

Figure 14 – Activity profile for the zeta-Cygnids (top), determed by GMN (bottom).

0006LYR: April Lyrids

$\lambda_{O} = 32.3°$, $\lambda\text{–}\lambda_{O} = 240.8°$, $\beta = 56.7°$,
$\alpha = 272.1°$, $\delta = 33.3°$, $v_g = 46.6$ km/s.

The period of LYR's activity was once thought to be quite long, but the SonotaCo net sets it as $\lambda_{O} = 27.60\text{\textasciitilde}35.86°$, and GMN also sets it as $\lambda_{O} = 30\text{\textasciitilde}34°$, which is quite short. A structure resembling the base of a spire can be seen in the activity curve, and this is also common to the previous results obtained from SonotaCo net data.

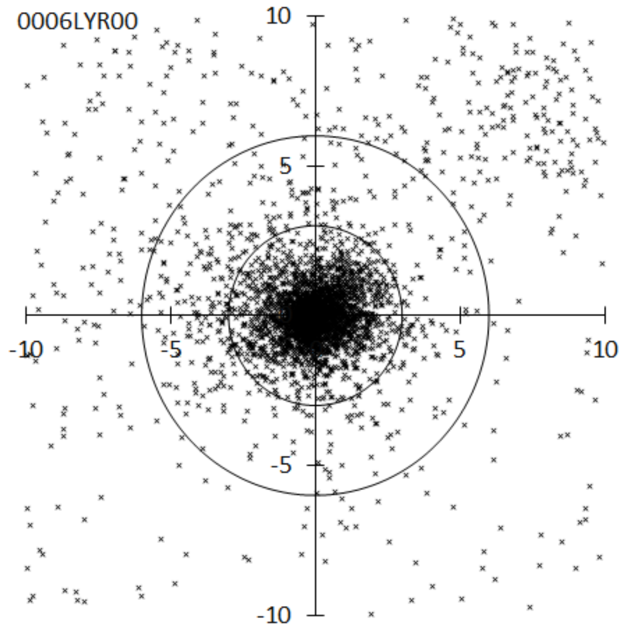

Figure 15 – Radiant point distribution map for the April Lyrids.

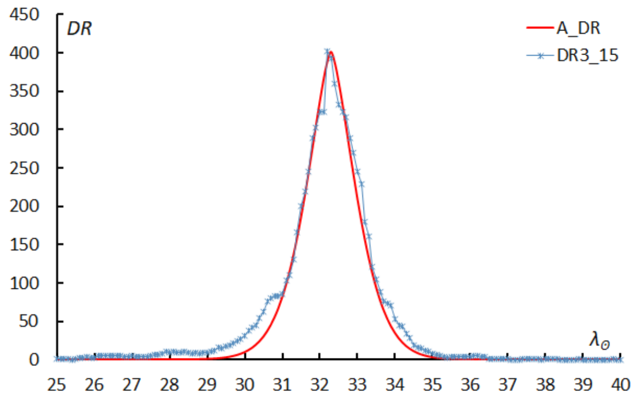

Figure 16 – Activity profile for the April Lyrids.

0343HVI: h-Virginids

$\lambda_\odot = 39°$, $\lambda–\lambda_\odot = 166.2°$, $\beta = –1.3°$,
$\alpha = 202.9°$, $\delta = –11.0°$, $v_g = 18.4$ km/s.

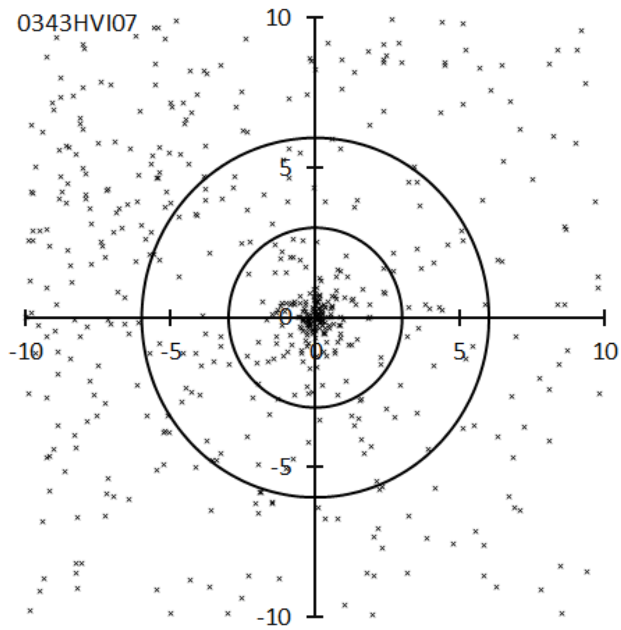

Figure 17 – Radiant point distribution map for the h-Virginids.

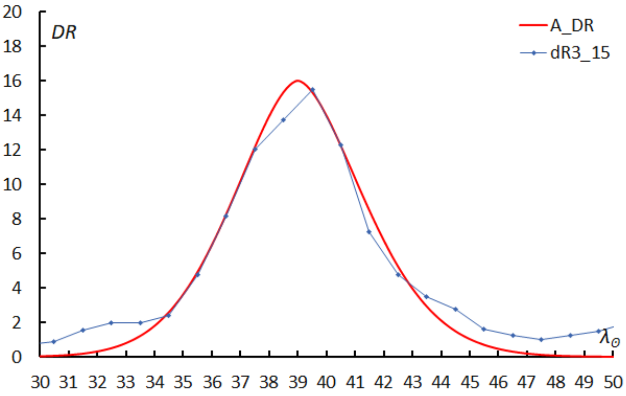

Figure 18 – Activity profile for the h-Virginids.

0343HVI01 is quite different from the other HVI in both, the position of the radiant point and the solar longitude and cannot be recognized as an observation of HVI. HVI's activity changes significantly from year to year, so observations by GMN are mostly limited to 2020.

0348ARC: April rho-Cygnids

$\lambda_\odot = 39.5°$, $\lambda–\lambda_\odot = 312.7°$, $\beta = 56.5°$,
$\alpha = 323.8°$, $\delta = 47.3°$, $v_g = 41.3$ km/s.

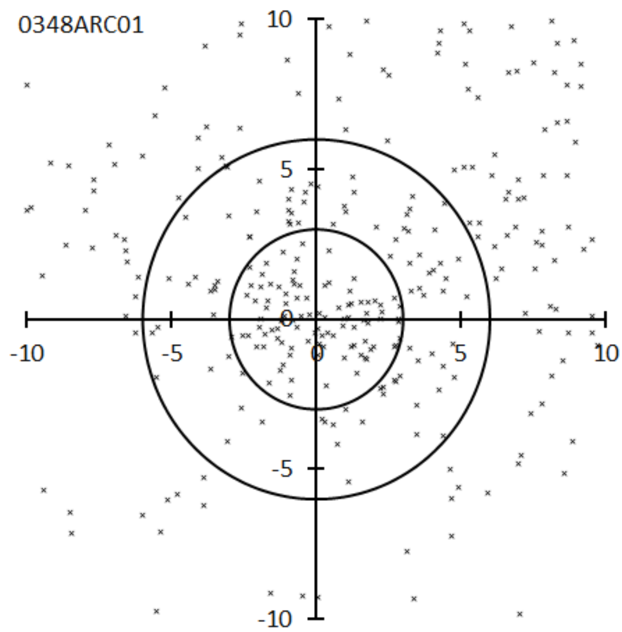

Figure 19 – Radiant point distribution map for the April rho-Cygnids.

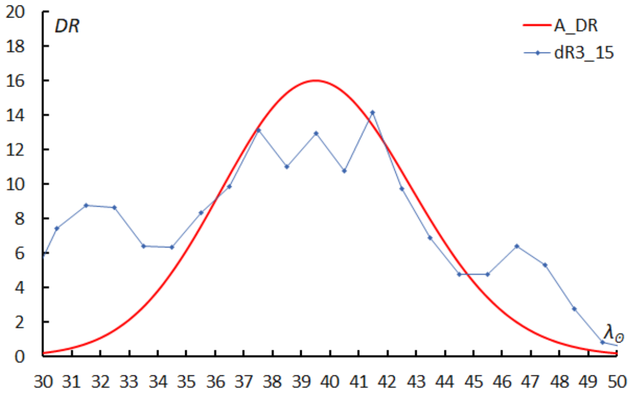

Figure 20 – Activity profile for the April rho-Cygnids.

ARC is adjacent to the active area of ZCY, and the activity around $\lambda_\odot = 30°$ is presumed to be due to the contamination of ZCY. For the relationship between ARC and ZCY, please refer to Part II, "Meteor showers that need careful attention" (Koseki, 2024b). Although the activity profile is not clear, the radiant shift is clear. This meteor shower was not covered in the previous article (Koseki, 2021) and is not even on the J14 list on SonotaCo net.

0519BAQ: beta-Aquariids

$\lambda_\odot = 44°$, $\lambda–\lambda_\odot = 279.3°$, $\beta = 13.3°$,
$\alpha = 321.3°$, $\delta = –1.2°$, $v_g = 68.3$ km/s.

This activity was detected by combining observations from Croatia and SonotaCo net (Andreić et al., 2013). Although the radiant points are well concentrated, they are few, so they are on the GMN list but not on the SonotaCo net J14 list. This meteor shower was not covered in the previous article (Koseki, 2021).

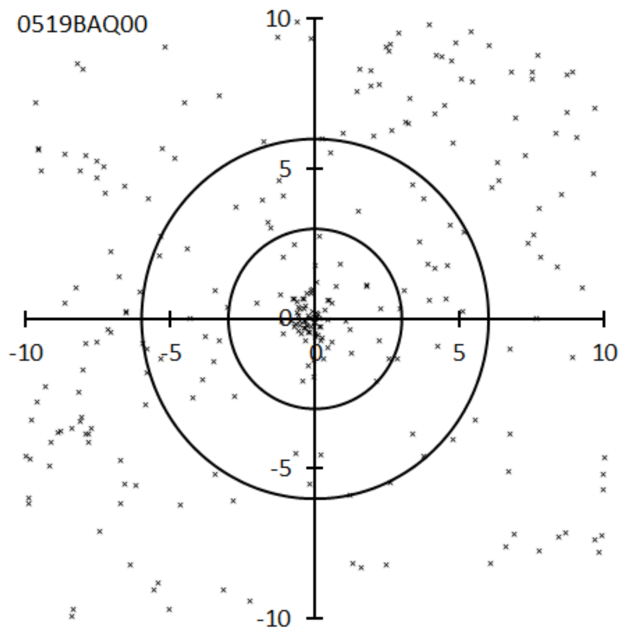

Figure 21 – Radiant point distribution map for the beta-Aquariids.

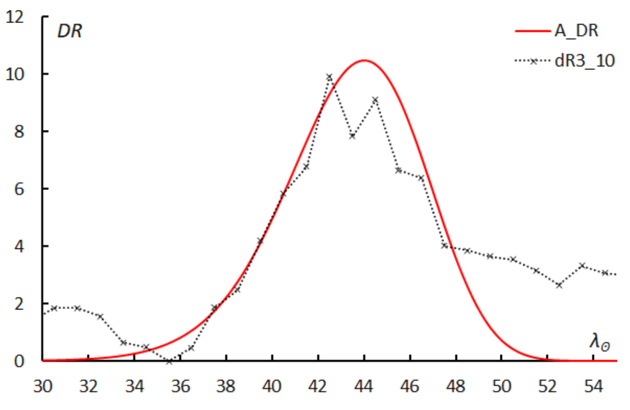

Figure 22 – Activity profile for the beta-Aquariids.

0031ETA: eta-Aquariids

$\lambda_\odot = 44.3°$, $\lambda–\lambda_\odot = 294.0°$, $\beta = 7.6°$,
$\alpha = 337.1°$, $\delta = –1.4°$, $v_g = 65.4$ km/s.

The radiant points are well concentrated. The activity curve is not symmetrical, and the activity period after the maximum is long. The activity after the maximum is up to $\lambda_\odot = 65.48°$ in the J14 list of SonotaCo net, and $\lambda_\odot = 66°$ in GMN. However, in GMN's meteor list, there are meteors that are classified to be ETA even if they are $\lambda_\odot = 95°$. For more details, as mentioned in Part II, "Meteor showers that need careful attention" (Koseki, 2024b), this may be meteor activity linked to the PPS.

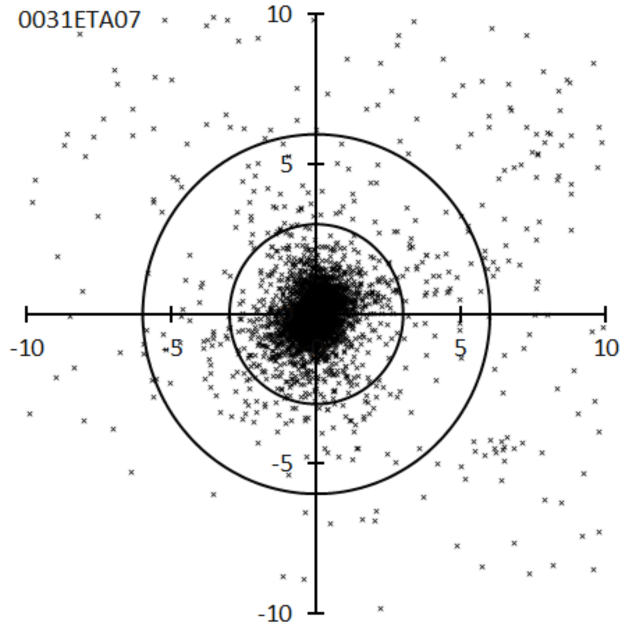

Figure 23 – Radiant point distribution map for the eta-Aquariids.

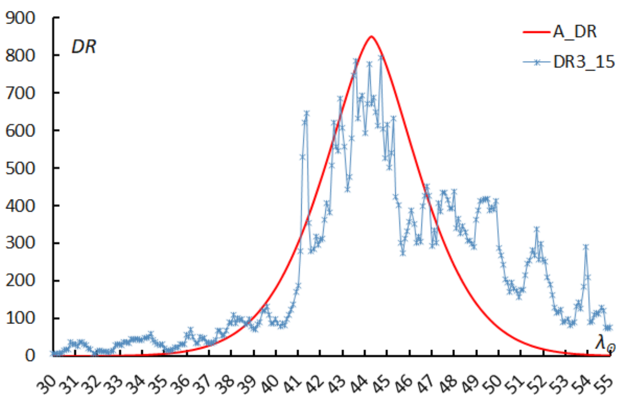

Figure 24 – Activity profile for the eta-Aquariids.

0531GAQ: gamma-Aquilids

$\lambda_\odot = 48°$, $\lambda–\lambda_\odot = 262.5°$, $\beta = 33.3°$,
$\alpha = 304.1°$, $\delta = 14.5°$, $v_g = 62.0$ km/s.

This was discovered during a search for the parent object by combining observations from Croatia and the SonotaCo network (Šegon et al., 2014), and it has been pointed out that it may be related to C/1853G1 (Schweizer). The activity period is set as $\lambda_\odot = 44.6$~$65°$ in GMN, but in the J14 list of SonotaCo net, it is shorter as $\lambda_\odot = 51.04$~$52.44°$, and moreover, it is in the latter period of the activity profile in *Figure 26*. This meteor shower was not covered in the previous article (Koseki, 2021).

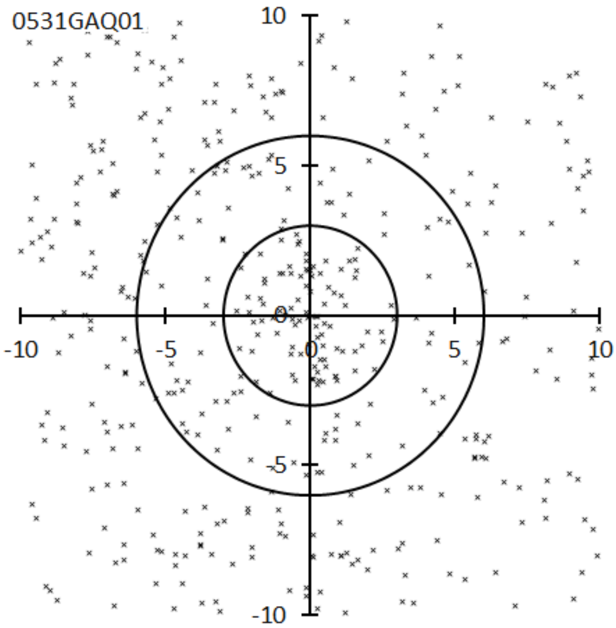

Figure 25 – Radiant point distribution map for the gamma-Aquilids.

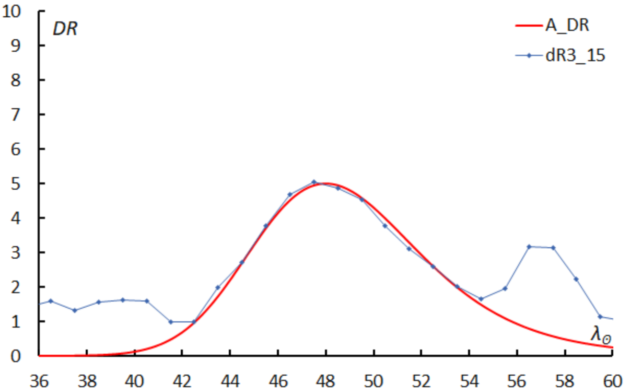

Figure 26 – Activity profile for the gamma-Aquilids.

0854PCY: psi-Cygnids

$\lambda_\odot = 49.5°$, $\lambda\text{–}\lambda_\odot = 278.1°$, $\beta = 71.5°$,
$\alpha = 296.6°$, $\delta = 53.4°$, $v_g = 39.4$ km/s.

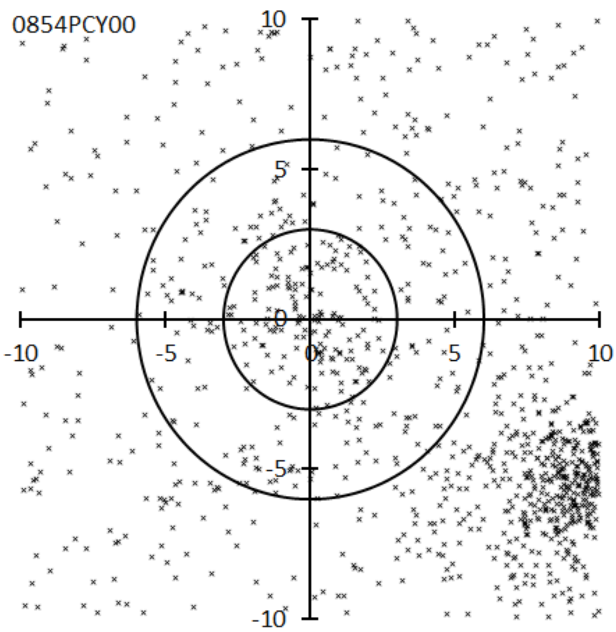

Figure 27 – Radiant point distribution map for the psi-Cygnids.

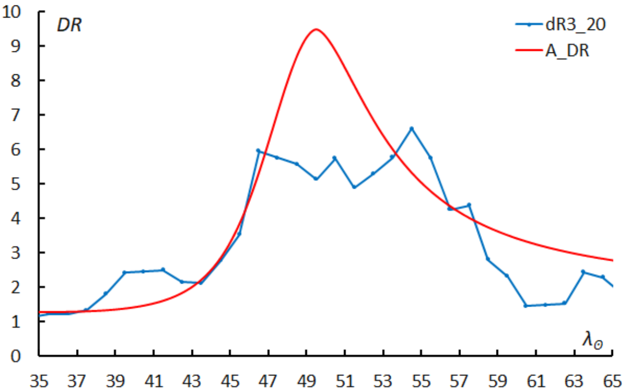

Figure 28 – Activity profile for the psi-Cygnids.

This meteor shower appears in the second report of CAMS (Jenniskens, et al., 2018b), but there are no other reports in IAUMDCSD. The activity at the bottom right of the radiant distribution is 0145ELY, which is only about 10 degrees away. The radiant point is somewhat diffused and the maximum is unclear. This meteor shower is not listed in the SonotaCo net J14 list and was not featured in the previous article (Koseki, 2021).

0145ELY: eta-Lyrids

$\lambda_\odot = 50.2°$, $\lambda\text{–}\lambda_\odot = 256.3°$, $\beta = 64.5°$,
$\alpha = 290.7°$, $\delta = 43.7°$, $v_g = 44.0$ km/s.

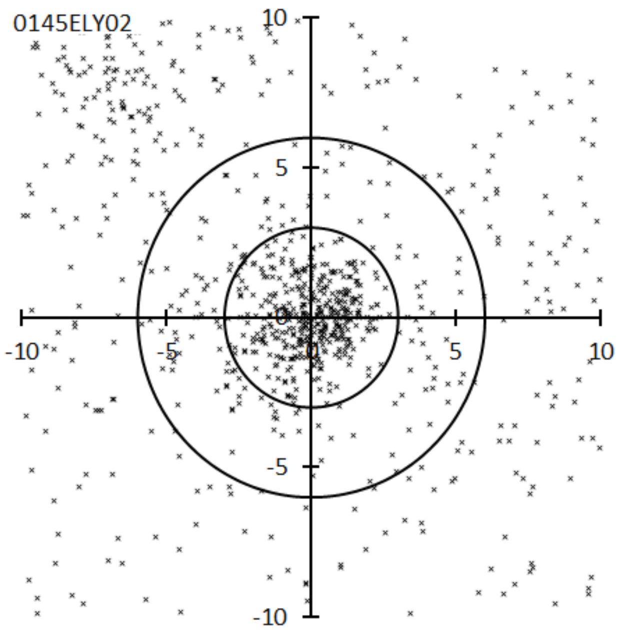

Figure 29 – Radiant point distribution map for the eta-Lyrids.

Although the current IAUMDCSD version mentions the SonotaCo net for the first time, the shower's existence has been known since shortly after C/1983 H1 (IRAS-Araki-Alcock) appeared. The author also presented it as a meteor shower related to this comet at the 1985 Japanese Meteor Conference (Koseki, 1985). Now SonotaCo's report is considered the first report on 0145ELY00, but formerly this was Jenniskens' 2006 book mentioned in the IAUMDCSD. Even if the IAUMDCSD is revised, it may be necessary to save and verify previous versions.

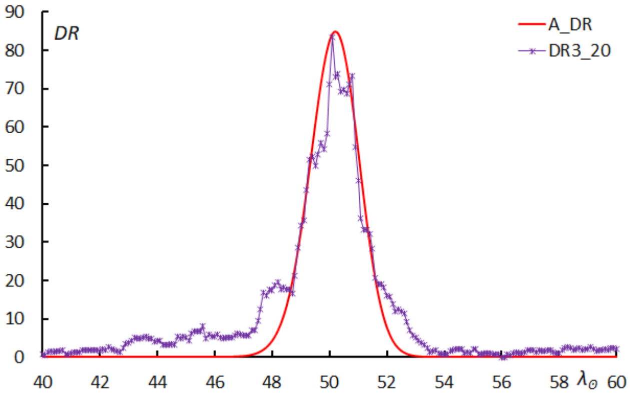

Figure 30 – Activity profile for the eta-Lyrids.

0520MBC: May beta-Capricornids

$\lambda_\odot = 55°$, $\lambda–\lambda_\odot = 245.8°$, $\beta = 4.8°$,
$\alpha = 302.0°$, $\delta = –15.3°$, $v_g = 65.7$ km/s.

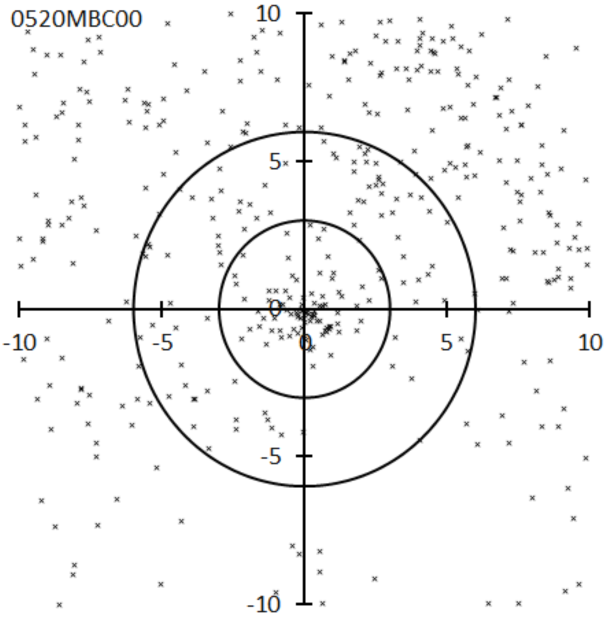

Figure 31 – Radiant point distribution map for the May beta-Capricornids.

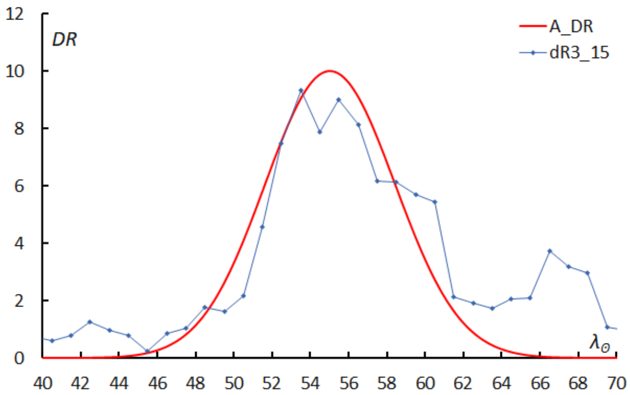

Figure 32 – Activity profile for the May beta-Capricornids.

This is also a meteor shower detected by combining observations from Croatia and SonotaCo Net (Andreić et al., 2013), but SonotaCo Net's J14 list only recognizes activity near the maximum of $\lambda_\odot = 53.72{\sim}54.38°$. This meteor shower was not discussed in the previous article (Koseki, 2021), but although the number of meteors observed is small, the radiant point plot and the activity curve are distinct.

0061TAH: tau-Herculids

$\lambda_\odot = 69.45°$, $\lambda–\lambda_\odot = 125.3°$, $\beta = 36.9°$,
$\alpha = 208.9°$, $\delta = 28.0°$, $v_g = 11.4$ km/s.

The data shown here is for the outburst in 2022. No meteors falling within 3 degrees of the radiant distribution map were observed from 2019 to 2021 in GMN observations. For more information, please refer to Part II, "Meteor showers that need careful attention" (Koseki, 2024b). This meteor shower was not mentioned in the previous article (Koseki, 2021) and is not on the SonotaCo net J14 list. GMN lists the observed values for 2022 as TAH, not the IAUMDCSD's data on TAH.

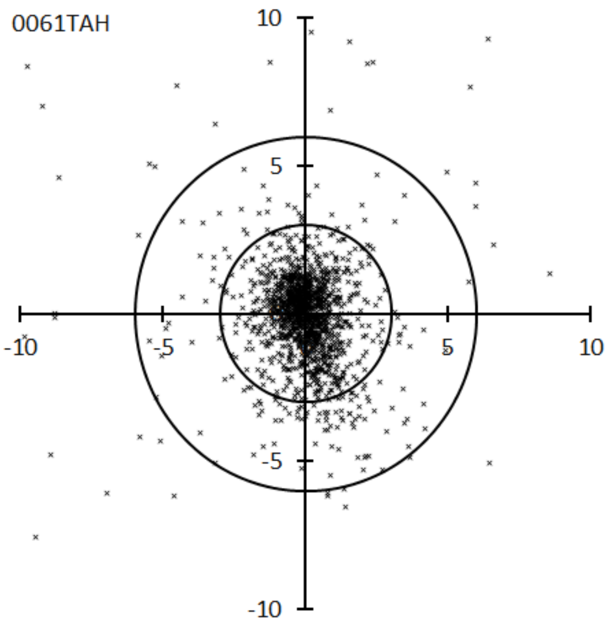

Figure 33 – Radiant point distribution map for the tau-Herculids.

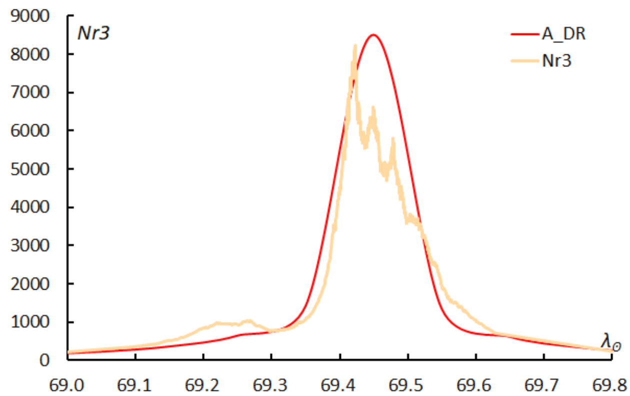

Figure 34 – Activity profile for the tau-Herculids.

0860PAN: psi-Andromedids

$\lambda_\odot = 72°$, $\lambda–\lambda_\odot = 307.1°$, $\beta = 43.6°$,
$\alpha = 355.3°$, $\delta = 46.6°$, $v_g = 50.4$ km/s.

This was first detected in the second CAMS observation report (Jenniskens et al, 2018b), and there are no other reports in the IAUMDCSD yet. Although the maximum is short and the number of meteors observed is small, the radiant points are well clustered. This was not mentioned in the previous article (Koseki, 2021).

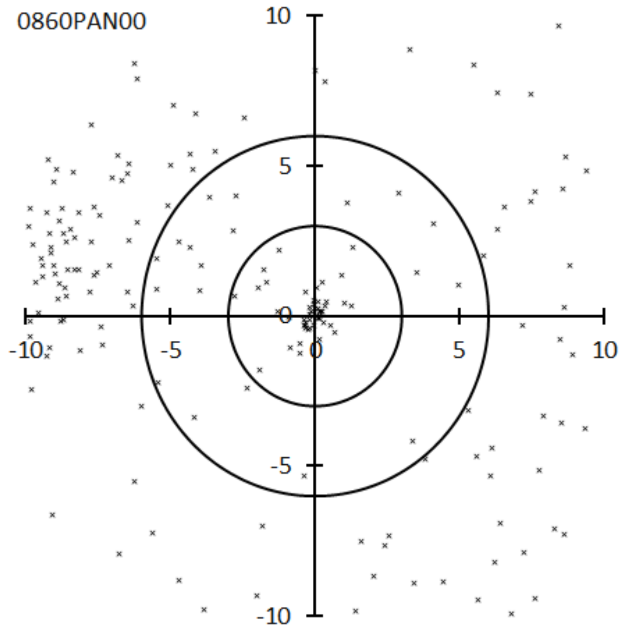

Figure 35 – Radiant point distribution map for the psi-Andromedids.

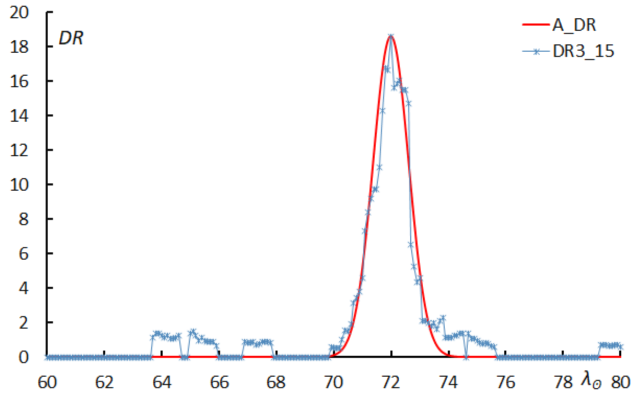

Figure 36 – Activity profile for the psi-Andromedids.

0362JMC: June mu-Cassiopeiids

$\lambda_\odot = 72°$, $\lambda–\lambda_\odot = 323.5°$, $\beta = 43.6°$,
$\alpha = 10.7°$, $\delta = 53.2°$, $v_g = 42.7$ km/s.

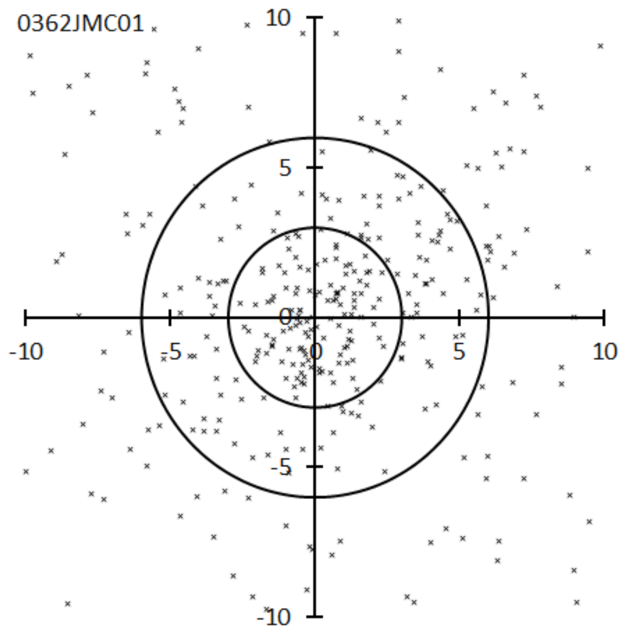

Figure 37 – Radiant point distribution map for the June mu-Cassiopeiids.

This meteor shower was first detected by CMOR2 radar observations (Brown et al., 2010), but there have also been multiple reports from video observations. The radiant points are diffuse, and the activity profile is not clear. It was not mentioned in the previous article (Koseki, 2021) and this shower is not on the SonotaCo net J14 list.

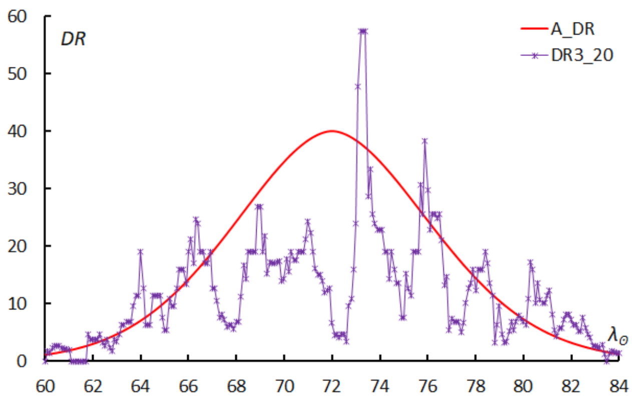

Figure 38 – Activity profile for the June mu-Cassiopeiids.

0171ARI: Daytime Arietids

$\lambda_\odot = 79.5°$, $\lambda–\lambda_\odot = 330.6°$, $\beta = 7.8°$,
$\alpha = 45.3°$, $\delta = 25.2°$, $v_g = 40.8$ km/s.

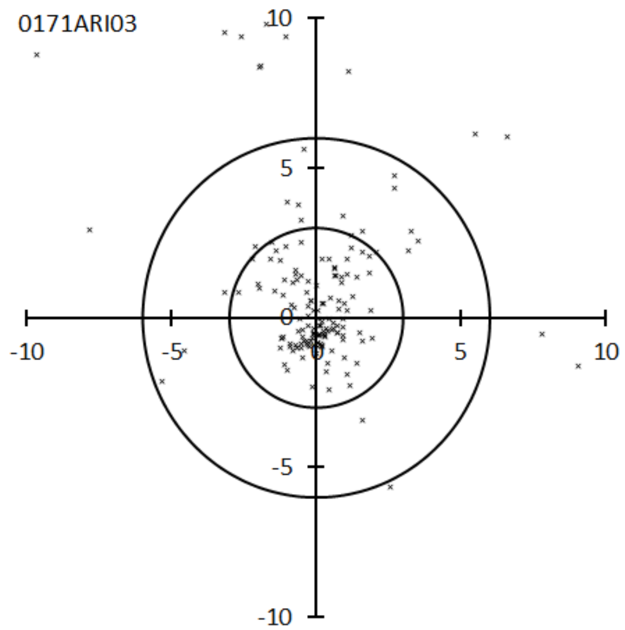

Figure 39 – Radiant point distribution map for the Daytime Arietids.

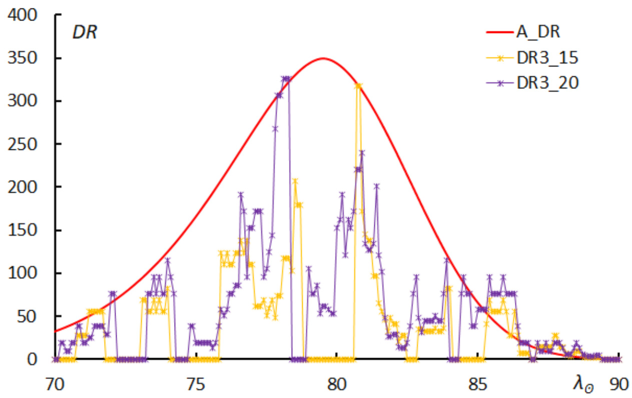

Figure 40 – Activity profile for the Daytime Arietids.

Although Sekanina’s radio observations are the first reports in the IAUMDCSD (Sekanina, 1976), ARI has been known since the early days of radio observations, and Lovell’s radio observations are well known (Lovell, 1954). Because it is relatively far from the Sun, these meteors can be seen by visual observers in the Northern Hemisphere. However, even with video observations, the number of meteors obtained is not large, so the activity profile is not clear.

0458JEC: June epsilon-Cygnids

$\lambda_{\odot} = 82.6°$, $\lambda\text{–}\lambda_{\odot} = 249.2°$, $\beta = 47.9°$,
$\alpha = 315.3°$, $\delta = 33.7°$, $v_g = 52.7$ km/s.

This meteor shower was detected by combining SonotaCo net and CAMS data (Rudawska and Jenniskens, 2014). Both the radiant point and the activity curve are clear. Because the width of the maximum is narrow, the number of meteors obtained tends to vary from year to year.

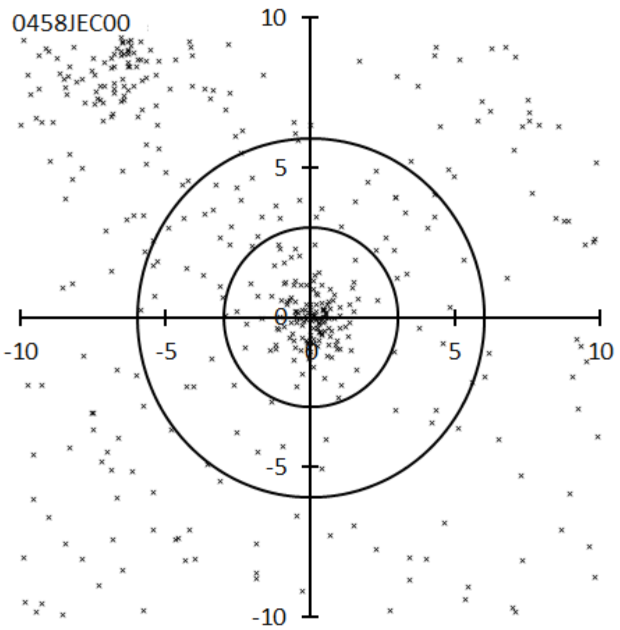

Figure 41 – Radiant point distribution map for the June epsilon-Cygnids.

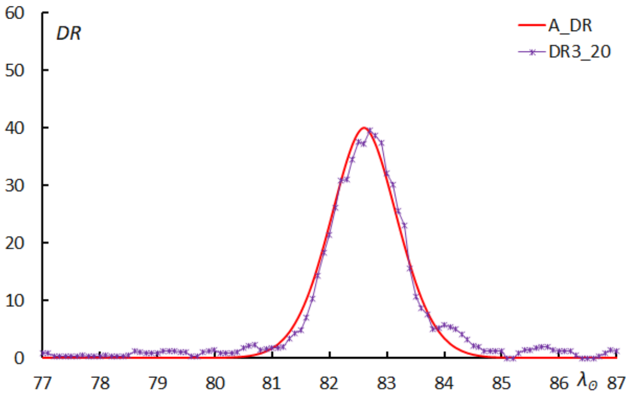

Figure 42 – Activity profile for the June epsilon-Cygnids.

0510JRC: June rho-Cygnids

$\lambda_{\odot} = 84°$, $\lambda\text{–}\lambda_{\odot} = 262.2°$, $\beta = 55.4°$,
$\alpha = 320.7°$, $\delta = 44.5°$, $v_g = 49.7$ km/s.

This meteor shower was detected by combining observations from Croatia and SonotaCo net (Šegon et al., 2013). 0458JEC is visible at the bottom right of the radiant point distribution. The activity period of this meteor shower is short, so it was not discussed in the previous article (Koseki, 2021).

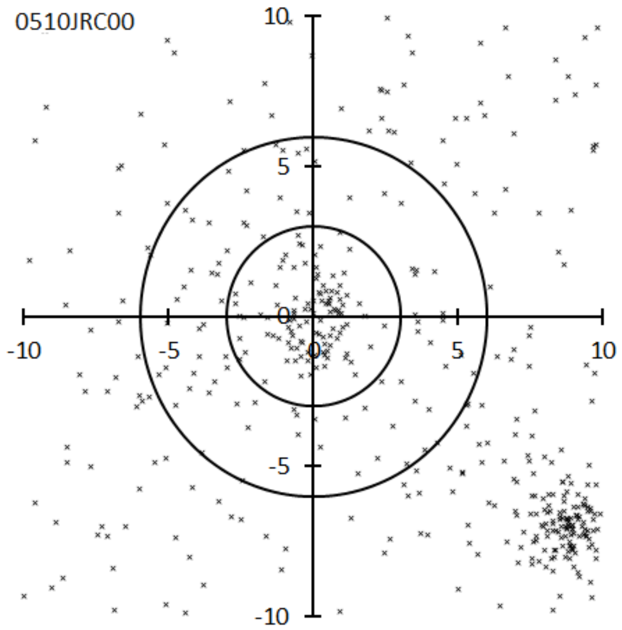

Figure 43 – Radiant point distribution map for the June rho-Cygnids.

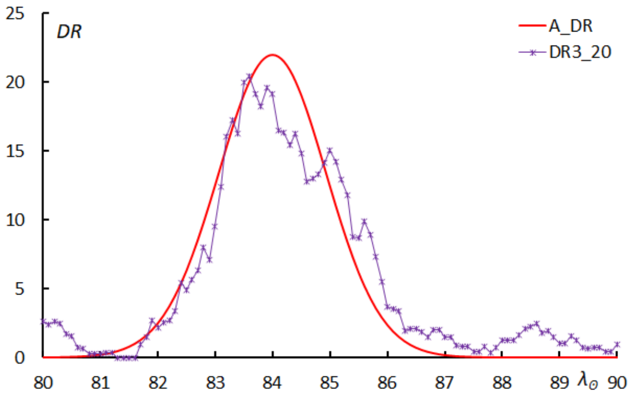

Figure 44 – Activity profile for the June rho-Cygnids.

0069SSG: Southern mu-Sagittariids

$\lambda_{\odot} = 87°$, $\lambda\text{–}\lambda_{\odot} = 186.7°$, $\beta = -6.5°$,
$\alpha = 274.2°$, $\delta = -29.9°$, $v_g = 25.2$ km/s.

The region between Scorpius and Sagittarius is known to be the active area of the ecliptical meteor showers based on visual observations, and various meteor showers have been proposed based on photographic observations also. The upper half of the radiant distribution map is the ANT region. Among them, SSG can be clearly distinguished from ANT activity by its radiant distribution and activity curve. 0069SSG00 is an activity determined from photographic meteors brighter than magnitude –3 (Porubcan and Gavajdova, 1994), and in the radiant distribution in *Figure 45*, it is located at the upper right, slightly outside the circle with a radius of 3 degrees from the center, and is close to ANT. SSG was not mentioned in the previous article (Koseki, 2021) and is not listed on the SonotaCo net J14 list.

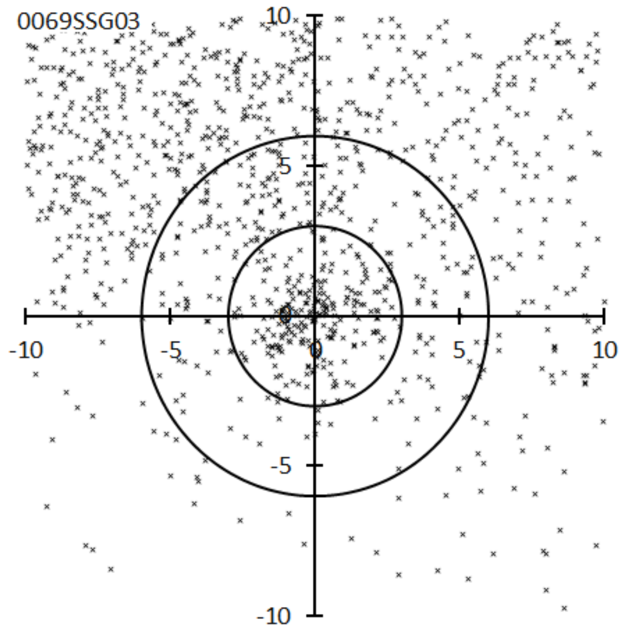

Figure 45 – Radiant point distribution map for the Southern mu-Sagittariids.

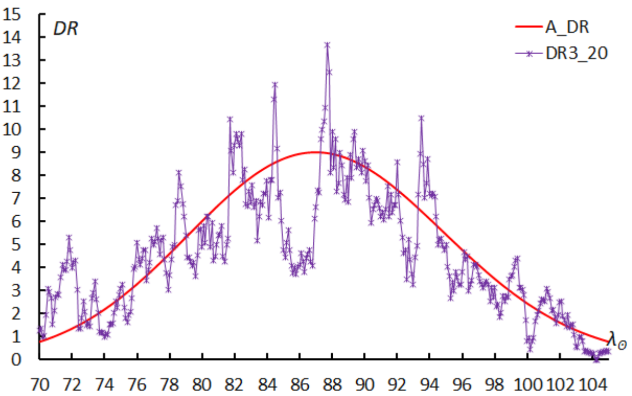

Figure 46 – Activity profile for the Southern mu-Sagittariids.

0170JBO: June Bootids

$\lambda_\odot = 90.3°$, $\lambda–\lambda_\odot = 101.2°$, $\beta = 59.4°$,
$\alpha = 221.1°$, $\delta = 48.5°$, $v_g = 14.0$ km/s.

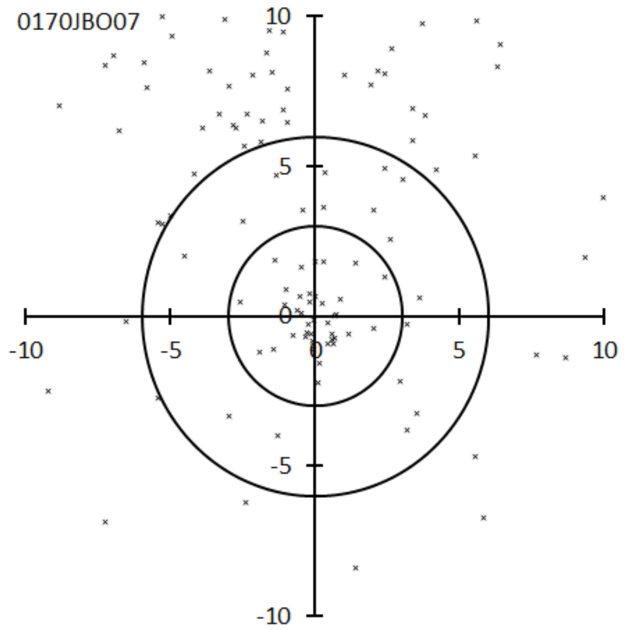

Figure 47 – Radiant point distribution map for the June Bootids.

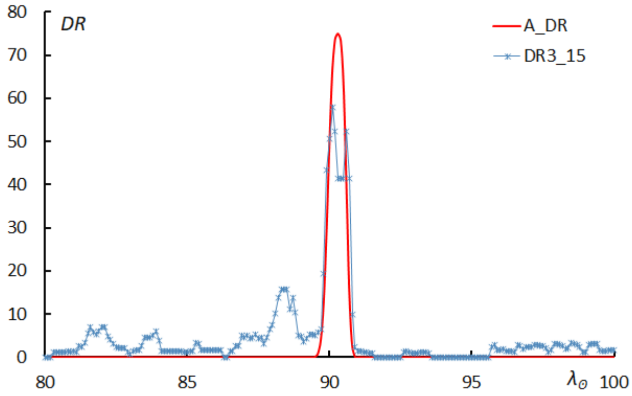

Figure 48 – Activity profile for the June Bootids.

It is well known as the meteor shower related to 7P/Pons-Winnecke, but in normal years it is almost hidden by sporadic meteor activity and cannot be detected. If GMN had not observed it in 2022, it would have been unconfirmed here as well. Prior to that, the only reliable orbit was one taken by the European Fireball Network in 1998 (Spurný, 1999); radar observation of 0170JBO00 is unreliable. Since then, observations every six years, in 2010, 2016 and 2022, have caught weak activities of JBO (Roggemans et al., 2023). JBO is not on the SonotaCo net J14 list and was not mentioned in the previous article (Koseki, 2021).

0410DPI: delta-Piscids

$\lambda_\odot = 91.2°$, $\lambda–\lambda_\odot = 280.4°$, $\beta = 1.0°$,
$\alpha = 10.2°$, $\delta = 5.5°$, $v_g = 69.8$ km/s.

This meteor shower was detected by IMO's video net (Molau and Rendtel, 2009). Although the number of meteors observed by GMN is small, the radiant distribution and activity curve are clear. DPI is not on the SonotaCo net J14 list and was not mentioned in the previous article (Koseki, 2021).

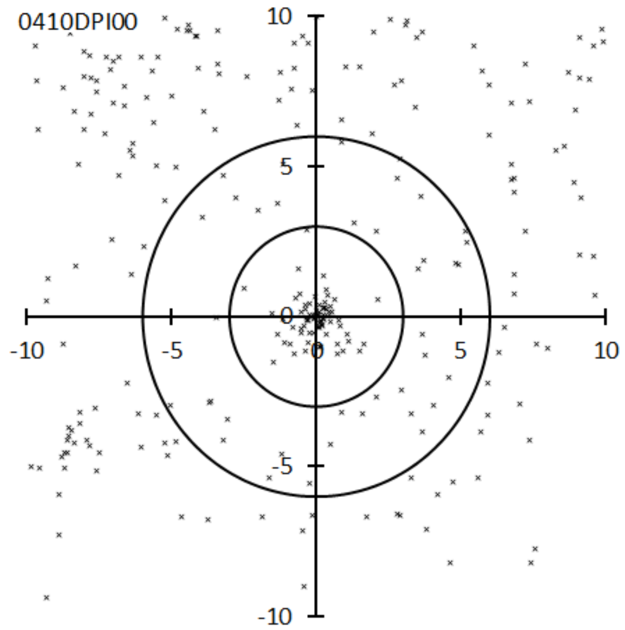

Figure 49 – Radiant point distribution map for the delta-Piscids.

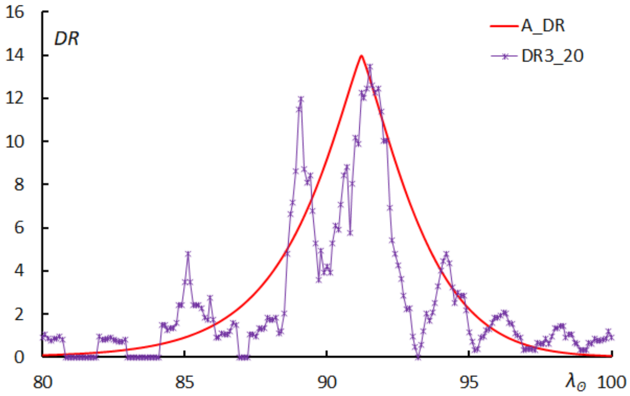

Figure 50 – Activity profile for the delta-Piscids.

0459JEO: June epsilon-Ophiuchids

$\lambda_\odot = 92°$, $\lambda - \lambda_\odot = 152.7°$, $\beta = 13.1°$,
$\alpha = 245.1°$, $\delta = -8.2°$, $v_g = 13.7$ km/s.

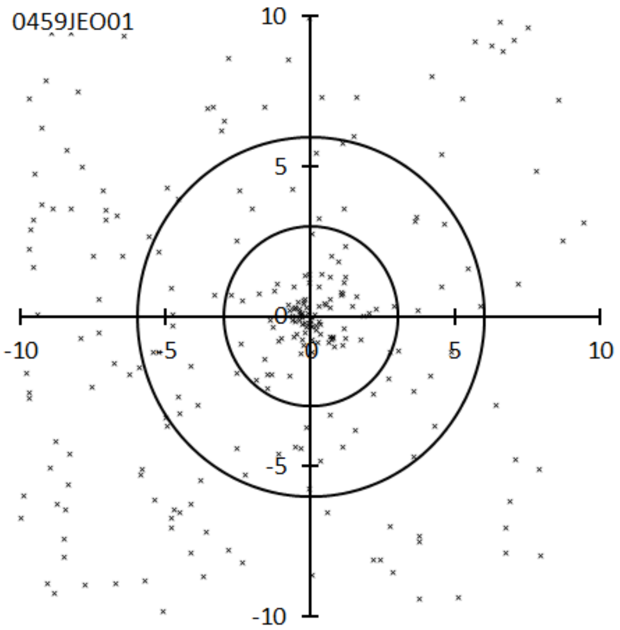

Figure 51 – Radiant point distribution map for the June epsilon-Ophiuchids.

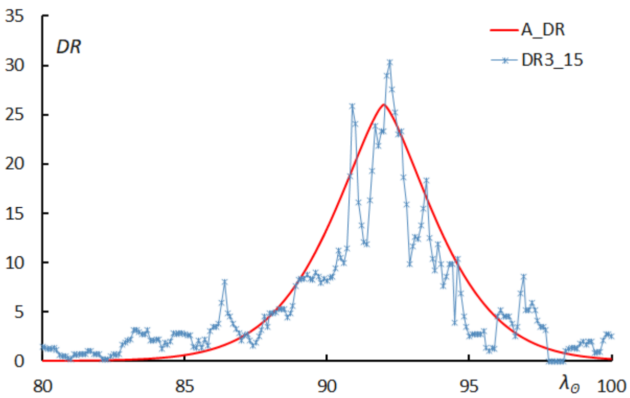

Figure 52 – Activity profile for the June epsilon-Ophiuchids.

This meteor shower was detected by combining SonotaCo net and CAMS data (Rudawska and Jenniskens, 2014). However, this 0459JEO00 is located in the upper left outside the circle with a radius of 6 degrees in the radiant point distribution map, and the maximum solar longitude of $\lambda_\odot = 84.1°$ is also difficult to call a representative value when considering the activity curve. JEO was not mentioned in the previous paper (Koseki, 2021).

0431JIP: June iota-Pegasids

$\lambda_\odot = 94.1°$, $\lambda - \lambda_\odot = 252.4°$, $\beta = 37.8°$,
$\alpha = 331.7°$, $\delta = 29.3°$, $v_g = 58.5$ km/s.

This is one of four meteor activities identified by Greaves (2012) in the UK using SonotaCo net data. The radiant points are well concentrated, and the activity curve is sharp and clear.

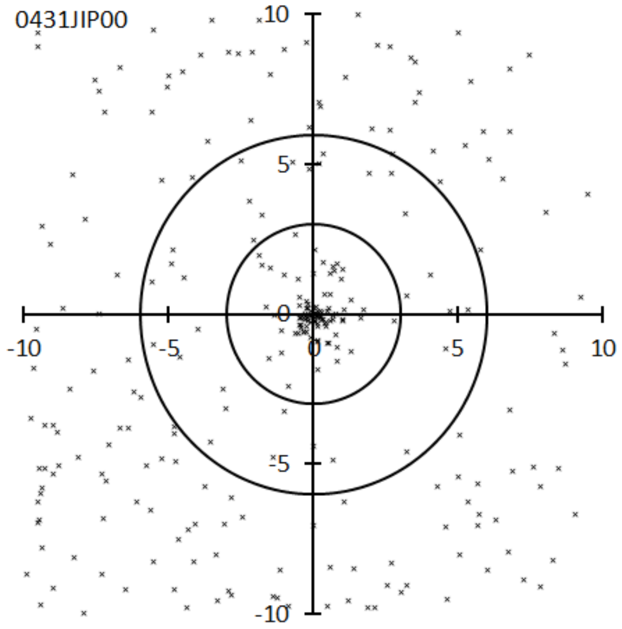

Figure 53 – Radiant point distribution map for the June iota-Pegasids.

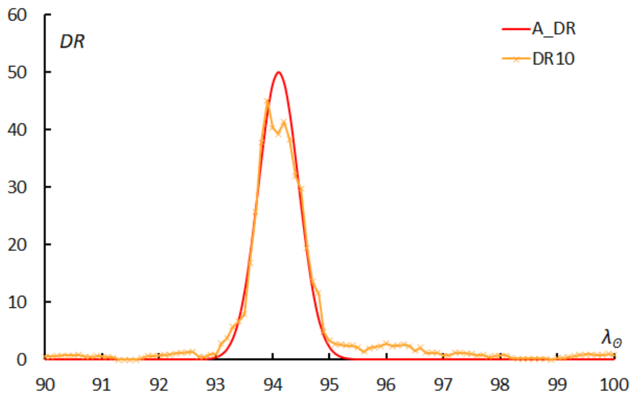

Figure 54 – Activity profile for the June iota-Pegasids.

0867FPE: 52-Pegasids

$\lambda_\odot = 95.8°$, $\lambda - \lambda_\odot = 254.9°$, $\beta = 15.9°$,
$\alpha = 345.2°$, $\delta = 11.0°$, $v_g = 66.7$ km/s.

This meteor shower appeared in the second CAMS report (Jenniskens et al., 2018b). Although the number of meteors obtained by GMN is small, the radiant points are well-grouped, and the activity profile is clear. FPE is not on the SonotaCo net J14 list and was not mentioned in the previous article (Koseki, 2021).

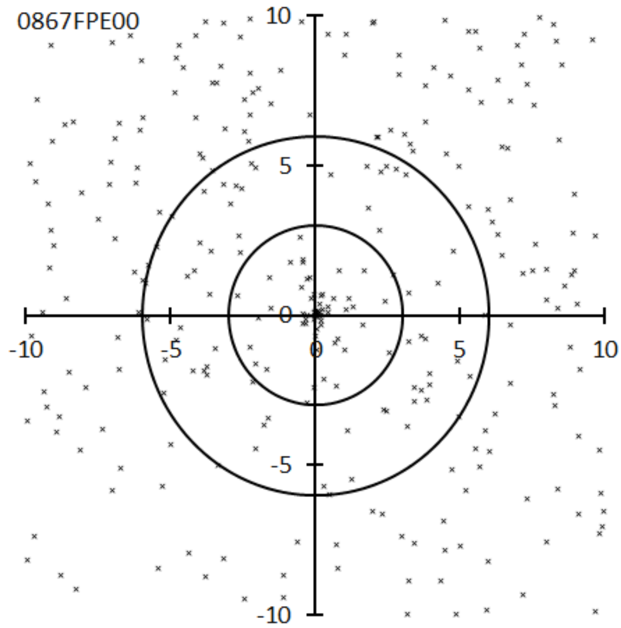

Figure 55 – Radiant point distribution map for the 52-Pegasids.

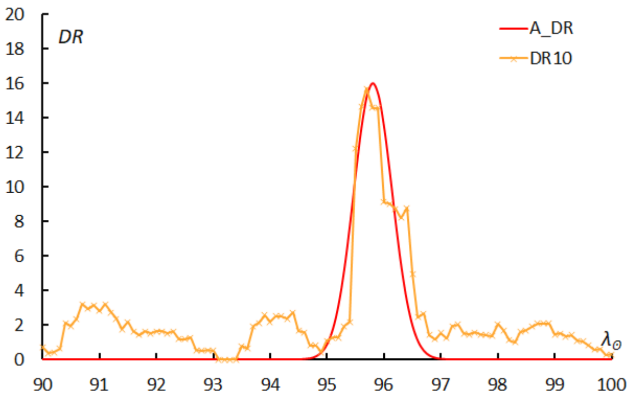

Figure 56 – Activity profile for the 52-Pegasids.

0372PPS_0: phi-Piscids

$\lambda_{\odot}$ = 98.5°, λ–$\lambda_{\odot}$ = 282.9°, β = 16.1°,
α = 13.3°, δ = 23.2°, v_g = 66.3 km/s.

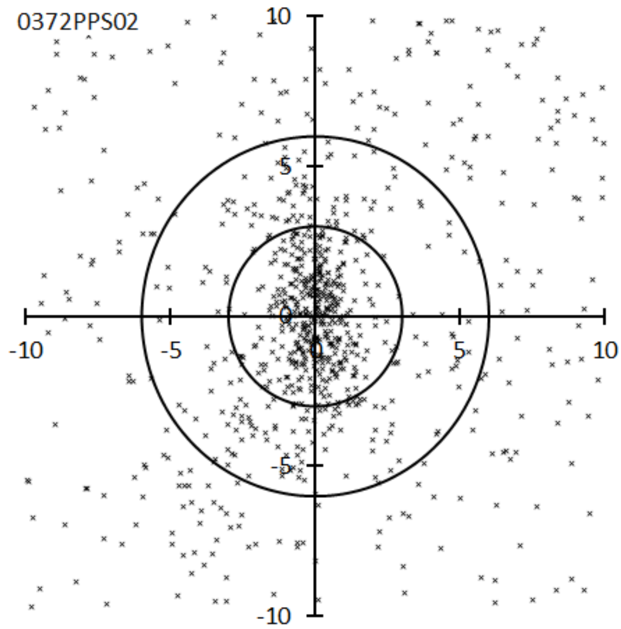

Figure 57 – Radiant point distribution map for the phi-Piscids.

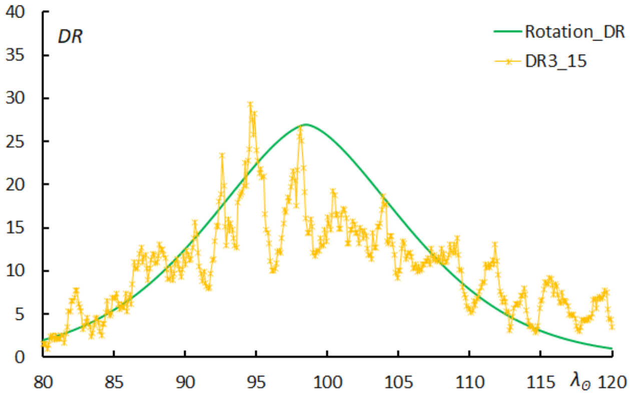

Figure 58 – Activity profile for the phi-Piscids.

This meteor shower was detected by radar observation by CMOR2 (Brown et al., 2010). Meteor activity around PPS is complicated, so we refer for the details to Part II, "Meteor showers that need careful attention" (Koseki, 2024b). The SonotaCo net J14 list states that the active period is $\lambda_{\odot}$ = 91.68~98.20°, but GMN sets it as $\lambda_{\odot}$ = 89~132.7° and actually extends further to both sides. The J14 list only deals with the pre-maximum period of PPS activity, and GMN seems to be taking the late activity period too long.

0164NZC: Northern June Aquilids

$\lambda_{\odot}$ = 101°, λ–$\lambda_{\odot}$ = 209.5°, β = 12.4°,
α = 309.6°, δ = –5.6°, v_g = 38.9 km/s.

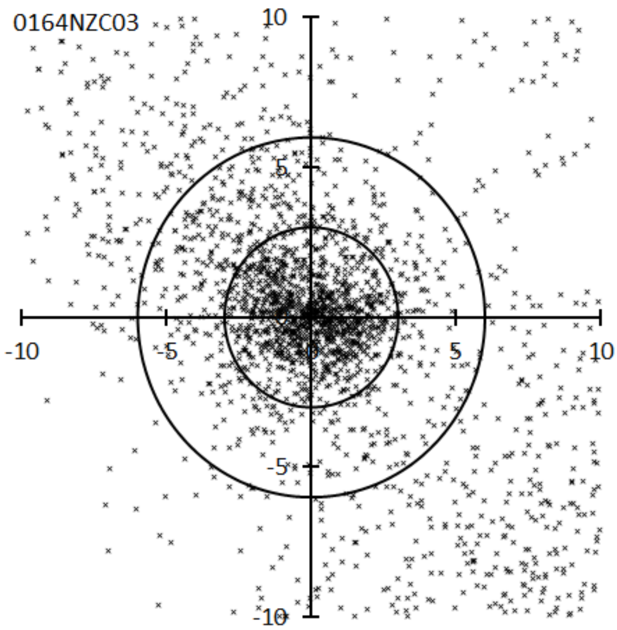

Figure 59 – Radiant point distribution map for the Northern June Aquilids.

0164NZC00 is a radar observation by Sekanina (1976), and NZC01 is also a radar observation by CMOR1 (Brown et al., 2008). The radiant points are scattered as seen in the distribution map, and are located in a continuous area of meteor activity from the upper left to the lower right. It is necessary to note that the SonotaCo net J14 list uses the abbreviation AQI of 1111AQI, which they proposed to the IAUMDCSD for NZC. Regarding the activity period, in J14, $\lambda_{\odot}$ = 92.55~96.10°, which is a short period before the maximum of the activity curve in *Figure 60*, whereas in GMN, on the other hand, $\lambda_\odot = 80.8{\sim}148.2°$. The GMN period is suspected to be influenced by the meteor activity area mentioned above.

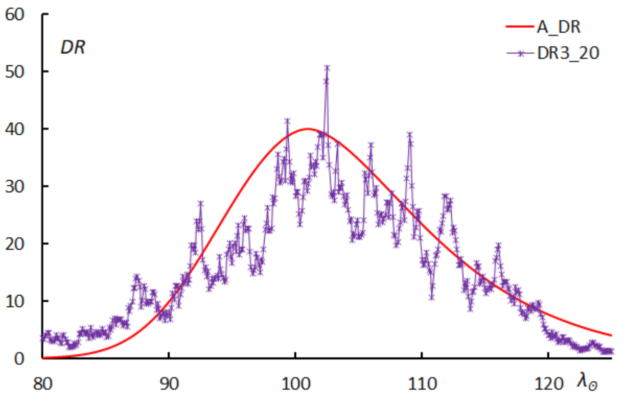

Figure 60 – Activity profile for the Northern June Aquilids.

0370MIC: Microscopiids

$\lambda_\odot = 101.3°$, $\lambda{-}\lambda_\odot = 208.8°$, $\beta = -10.3°$,
$\alpha = 315.7°$, $\delta = -27.6°$, $v_g = 40.0$ km/s.

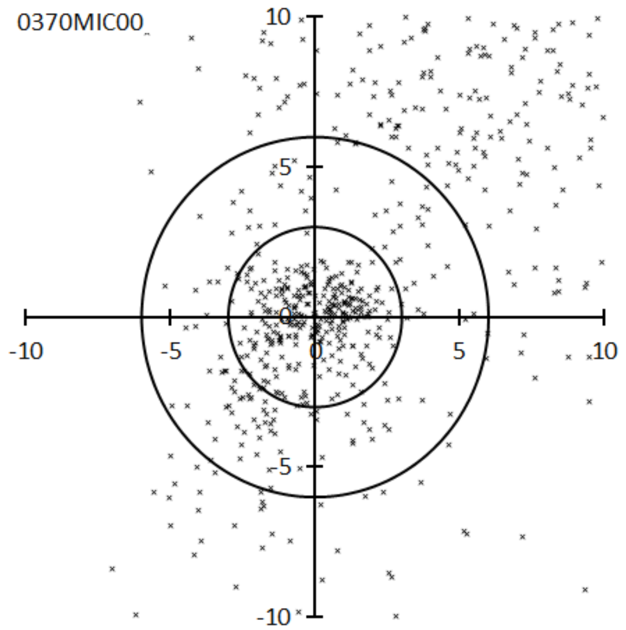

Figure 61 – Radiant point distribution map for the Microscopiids.

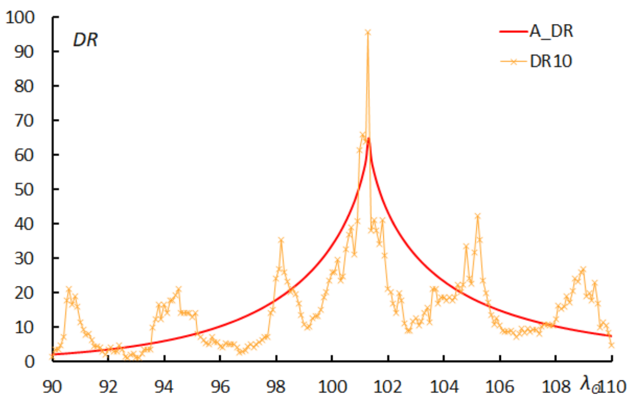

Figure 62 – Activity profile for the Microscopiids.

As pointed out in the previous article (Koseki, 2021) and mentioned in Part II, "Meteor showers that need careful attention" (Koseki, 2024b), the IAUMDC's SZC includes two different meteor showers. SZC00 and SZC01 should be called SZC, but both are radio observations and are hardly captured by video observations. SZC02 and SZC04 are video observations that should be considered as MIC. The meteor shower, which was referred to as "SZC" due to the confusion, will now be referred to by its original name, MIC. In the previous article (Koseki, 2021), it was called SZC, but it has been changed to MIC.

1133TCS: 32-Cassiopeiids

$\lambda_\odot = 104.6°$, $\lambda{-}\lambda_\odot = 303.6°$, $\beta = 52.7°$,
$\alpha = 13.7°$, $\delta = 65.4°$, $v_g = 46.3$ km/s.

This shower appears in the IAUMDCSD with the third report of CAMS (mentioned as '2022 submitted' in the IAUMDCSD). Although it is close to 0187PCA00 and PCA02, it is TCS that is active. The SonotaCo net J14 list has neither, but it is listed as PCA on GMN. PCA00 has $\lambda_\odot = 114.40°$, and PCA02 has $\lambda_\odot = 119°$, but as seen in the activity profile in *Figure 64*, TCS activity has ceased at that time. This activity was not discussed in the previous paper as either PCA or TCS (Koseki, 2021).

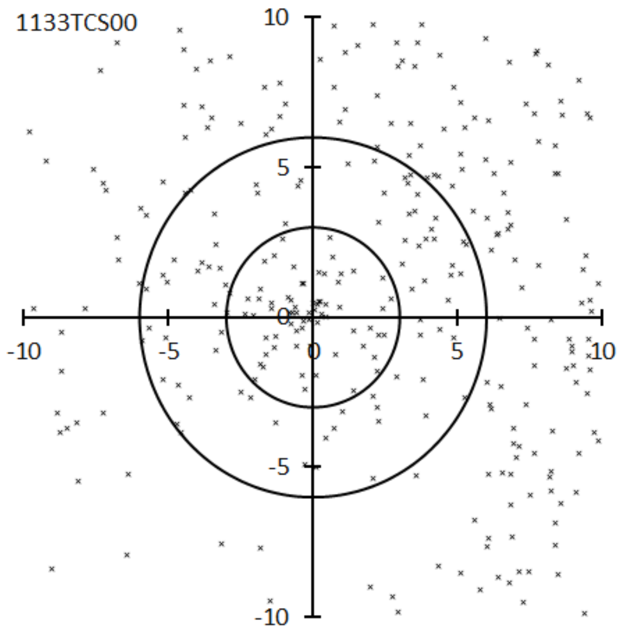

Figure 63 – Radiant point distribution map for the 32-Cassiopeiids.

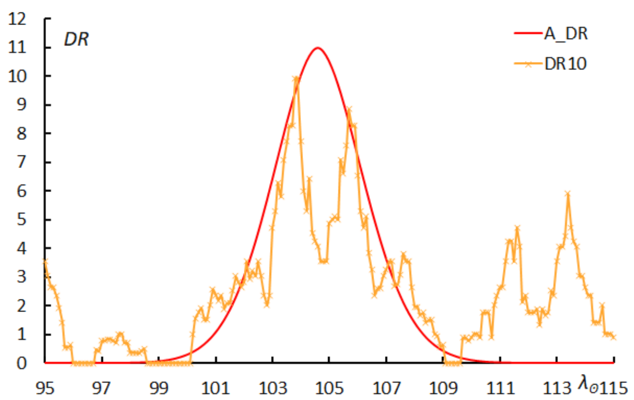

Figure 64 – Activity profile for the 32-Cassiopeiids.

0411CAN: c-Andromedids

$\lambda_\odot = 105°$, $\lambda–\lambda_\odot = 298.1°$, $\beta = 32.8°$,
$\alpha = 27.0°$, $\delta = 46.5°$, $v_g = 57.1$ km/s.

This meteor shower was detected by IMO's video network (Molau and Rendtel, 2009). The SonotaCo net J14 list gives the activity period as $\lambda_\odot = 108.62$~$113.18°$, which corresponds to the latter half of the activity profile in *Figure 66*. This activity profile is not the raw number of meteors observed but is corrected based on the number of meteors observed in the surrounding area. If the number of meteors is used to express activity, the activity will look different depending on the observation conditions; The weather during the first half of CAN's activities was bad in Japan.

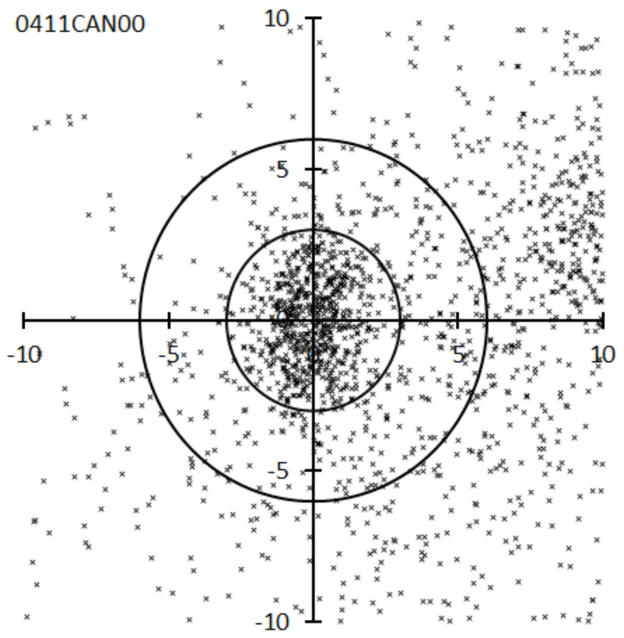

Figure 65 – Radiant point distribution map for the c-Andromedids.

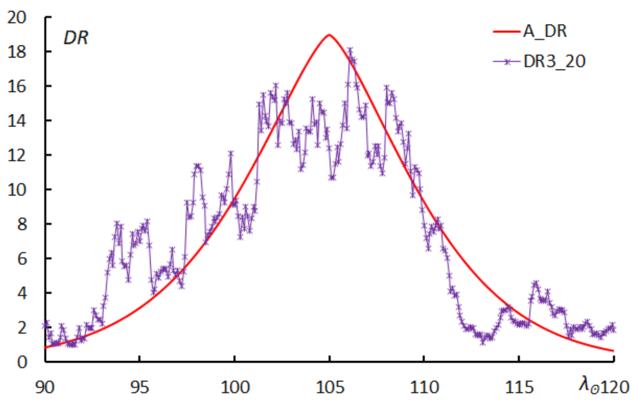

Figure 66 – Activity profile for the c-Andromedids.

0175JPE: July Pegasids

$\lambda_\odot = 109.6°$, $\lambda–\lambda_\odot = 244.6°$, $\beta = 14.6°$,
$\alpha = 348.8°$, $\delta = 11.1°$, $v_g = 63.8$ km/s.

According to Kronk (2013), JPE began to attract attention in 1987 when Olsson-Steel announced it as a predicted radiant point for C/1979 Y1 (Bradfield), C/1771 A1. Kronk's book cites Ueda's data as having clarified the orbit. Jennikens' famous book used to be JPE00 (Jenniskens, 2006), but IAUMDCSD's AdNo has been changed from the previous version. Currently, the IMO video observation by Molau and Rendtel (2009) is designated as JPE00, and the report by Jenniskens became JPE01. Although the current edition has added a publication date and time column, care must be taken when comparing AdNo with previous editions. 0507UAN00 is identified as JPE.

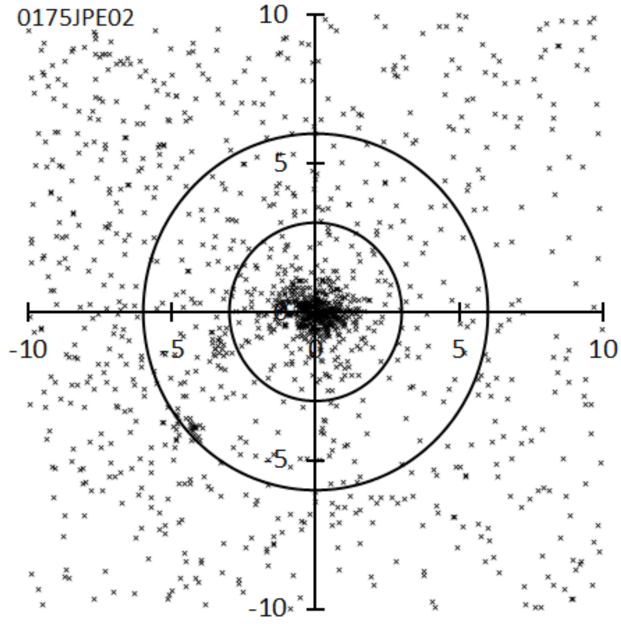

Figure 67 – Radiant point distribution map for the July Pegasids.

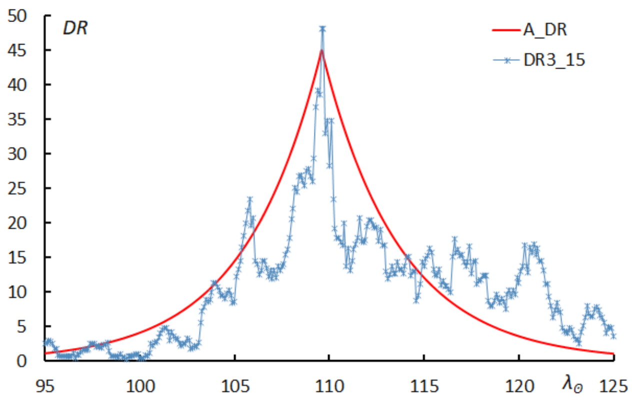

Figure 68 – Activity profile for the July Pegasids.

0444ZCS: zeta-Cassiopeiids

$\lambda_\odot = 113.6°$, $\lambda–\lambda_\odot = 277.9°$, $\beta = 42.7°$,
$\alpha = 7.5°$, $\delta = 50.8°$, $v_g = 57.1$ km/s.

The first report on IAUMDC's record was made by observers in Poland and Croatia in 2012 (Zoladek and Wisniewski, 2012, Segon et al., 2012). However, visual observations have long shown that the activity of the Perseid progenitor begins around July 10 (Denning, 1899), and there has been some debate as to whether this is a separate shower activity. Polish observers used observations from the SonotaCo network to reach their conclusions, and advances in video observations led to the conclusions for the progenitor. In the activity profile (*Figure 70*), the increase after $\lambda_\odot > 117°$ is due to the activity of the Perseids.

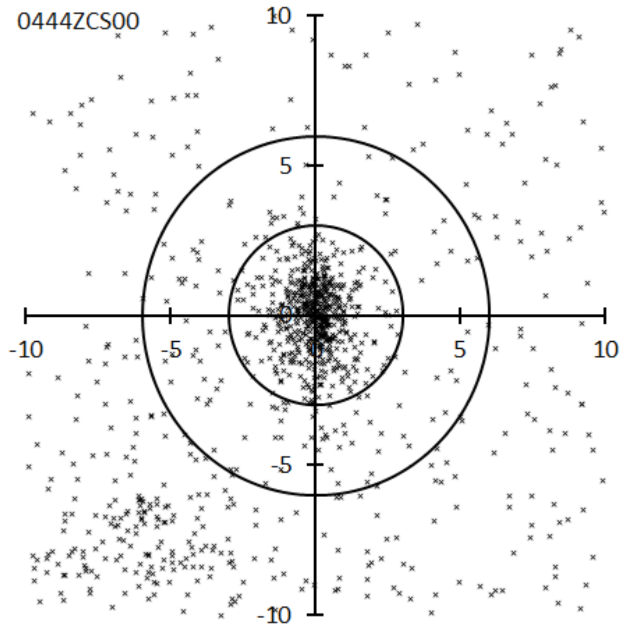

Figure 69 – Radiant point distribution map for the zeta-Cassiopeiids.

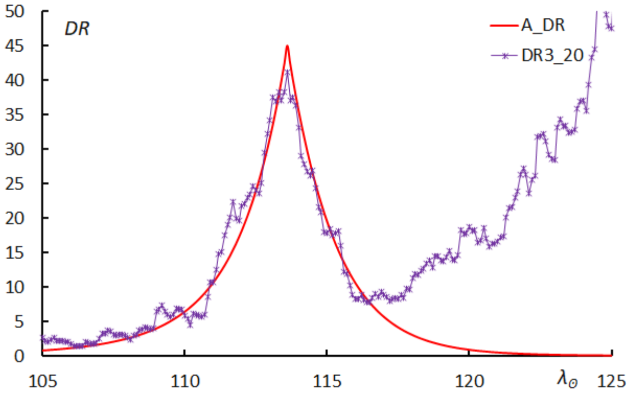

Figure 70 – Activity profile for the zeta-Cassiopeiids.

0533JXA: July xi-Arietids

$\lambda_\odot = 115°$, $\lambda–\lambda_\odot = 283.2°$, $\beta = –5.5°$,
$\alpha = 37.7°$, $\delta = 9.0°$, $v_g = 68.8$ km/s.

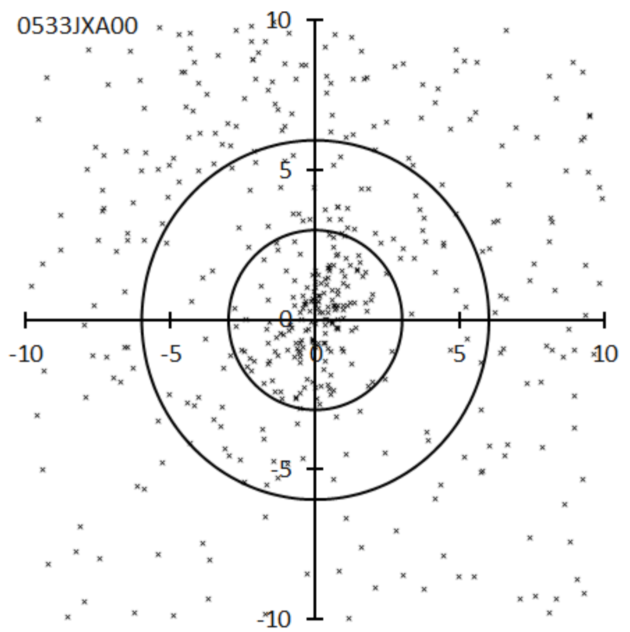

Figure 71 – Radiant point distribution map for the July xi-Arietids.

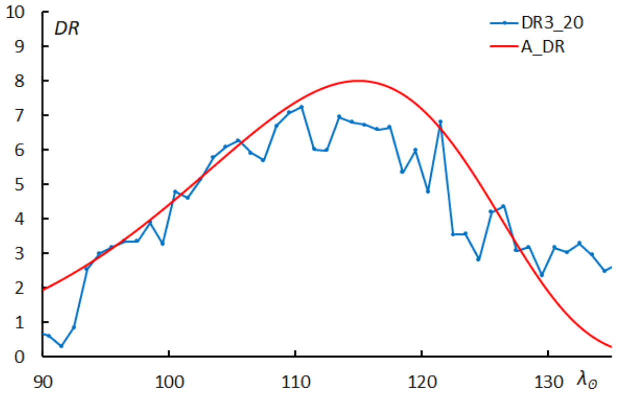

Figure 72 – Activity profile for the July xi-Arietids.

JXA was registered in IAUMDC in 2014 based on observations from Croatia and EDMOND, and observations from SonotaCo net are also utilized here (Šegon et al., 2014). In the SonotaCo net J14 list, a short period before the maximum is listed, $\lambda_\odot = 104.67$~$107.29°$, while GMN has a long period of $\lambda_\odot = 94.1$~$123.8°$. It seems to be a general trend that the GMN list is longer than the J14 list.

0623XCS: xi2-Capricornids

$\lambda_\odot = 116.3°$, $\lambda–\lambda_\odot = 185.1°$, $\beta = 8.4°$,
$\alpha = 301.8°$, $\delta = –11.7°$, $v_g = 25.1$ km/s.

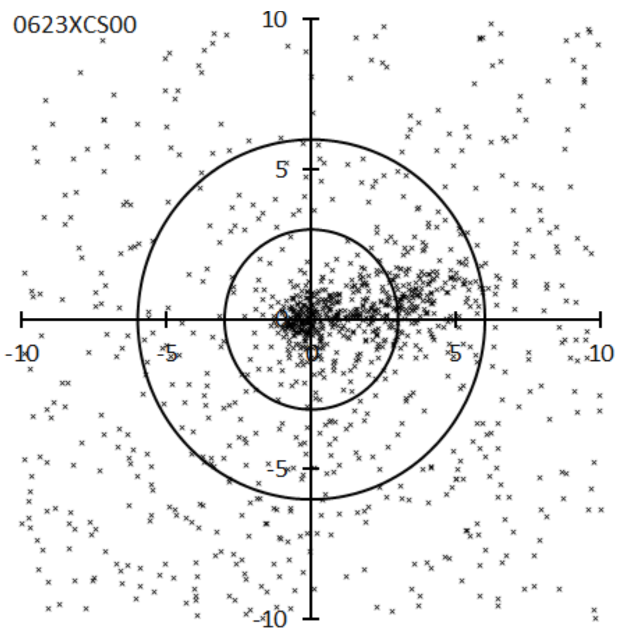

Figure 73 – Radiant point distribution map for the xi2-Capricornids.

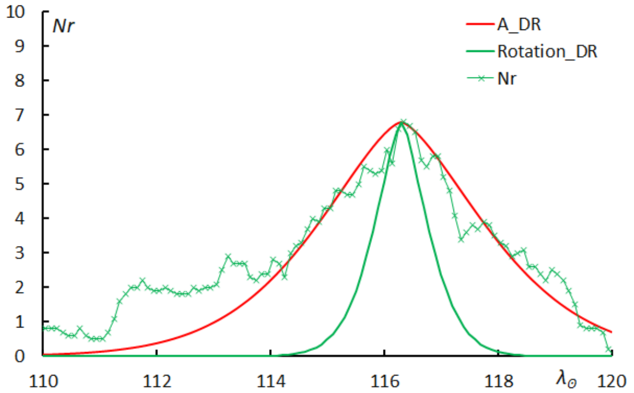

Figure 74 – Activity profile for the xi2-Capricornids.

This activity has only been published in the first report of CAMS in IAUMDCSD (Jenniskens et al., 2016a). The spread of radiant points extending to the right from the center in the radiant distribution in *Figure 73* is 0001CAP, and XCS is only 3 to 5 degrees away from CAP. However, the author also pointed out that the geocentric velocity of XCS is slightly higher by about 2 km/s, and that it should be distinguished from CAP (Koseki, 2018). The SonotaCo net J14 list treats XCS as part of CAP, but GMN distinguishes it.

0372PPS_1: phi-Piscids

$\lambda_\odot = 117.5°$, $\lambda–\lambda_\odot = 280.5°$, $\beta = 17.7°$,
$\alpha = 29.1°$, $\delta = 30.8°$, $v_g = 66.1$ km/s.

As in the previous paper (Koseki, 2021), PPS is divided into two activities. As mentioned in Part II, "Meteor showers that need careful attention" (Koseki, 2024b), it is estimated that the radiant movement paths of the previously mentioned PPS_0 and this PPS_1 intersect around $\lambda_\odot = 115°$. The radiant distribution in *Figure 75* is for the period $\lambda_\odot = 115\text{~}125°$, and the upper left side of the 3-degrees circle corresponds to the terminal activity of PPS_0. PPS_0 moves to the upper right and PPS_1 moves to the lower right.

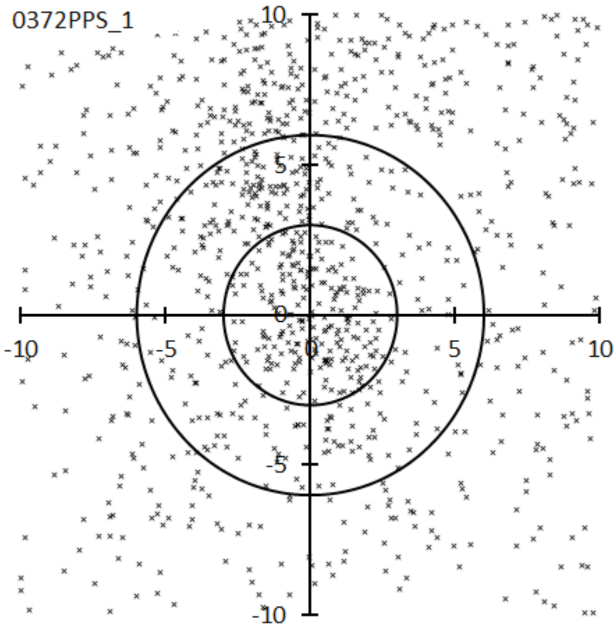

Figure 75 – Radiant point distribution map for the phi-Piscids.

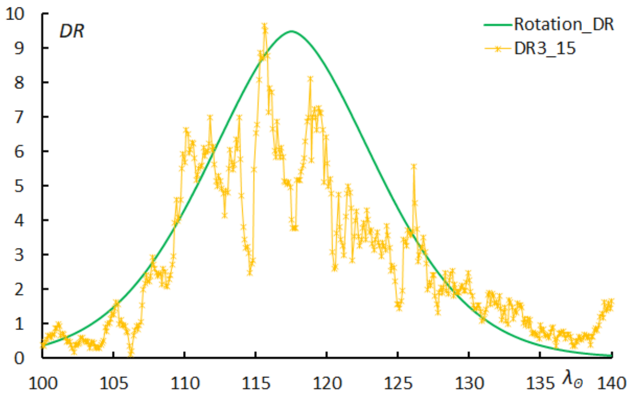

Figure 76 – Activity profile for the phi-Piscids.

0184GDR: July gamma-Draconids

$\lambda_\odot = 125.5°$, $\lambda–\lambda_\odot = 167.3°$, $\beta = 73.4°$,
$\alpha = 280.1°$, $\delta = 50.7°$, $v_g = 27.6$ km/s.

0184GDR00, as reported by the SonotaCo net (SonotaCo, 2009), is a meteor shower that has been attracting attention since the era of photographic observation, beginning with Babadzhanov's observations in the 1950s (Babadzhanov and Kramer, 1967). In the radiant distribution, the band of sparse radiant points extending from the upper left to the lower right is the early activity of 0012KCG, which was confused in visual observations. However, the geocentric velocity of GDR around $\lambda_\odot = 125°$ is nearly 10 km/s faster than that of KCG, so it is possible to distinguish them by careful visual observation.

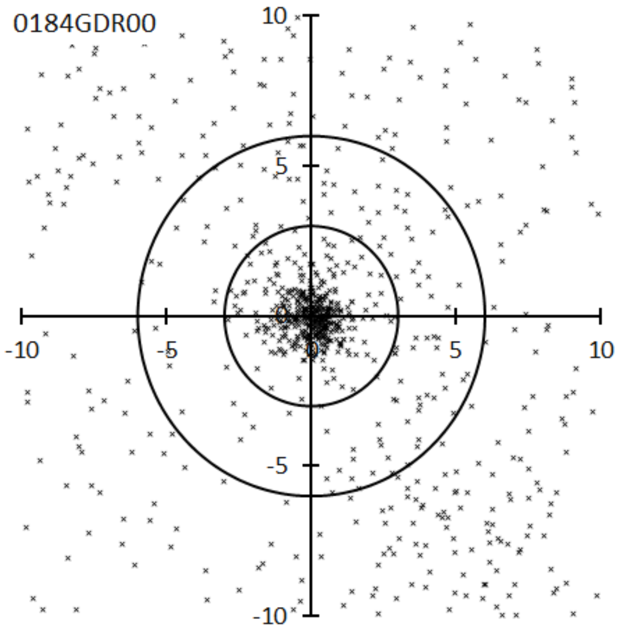

Figure 77 – Radiant point distribution map for the July gamma-Draconids.

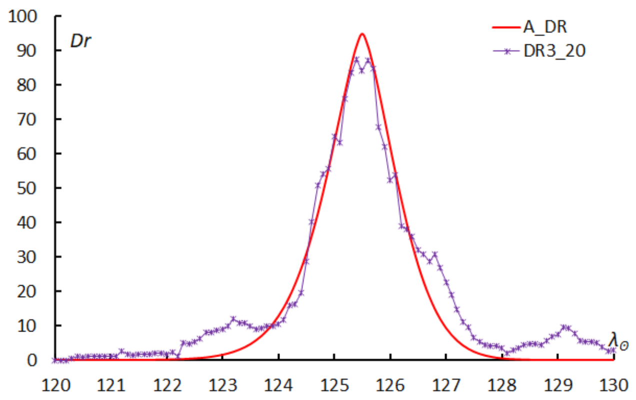

Figure 78 – Activity profile for the July gamma-Draconids.

0001CAP: alpha-Capricornids

$\lambda_\odot = 126.9°$, $\lambda–\lambda_\odot = 178.6°$, $\beta = 9.9°$,
$\alpha = 305.4°$, $\delta = –9.3°$, $v_g = 22.1$ km/s.

This meteor shower has been known since the earliest visual observations. As an ecliptical meteor shower, the radiant distribution is highly concentrated and the activity profile is clear. 692EQA00 seems to be part of CAP's final stage activities.

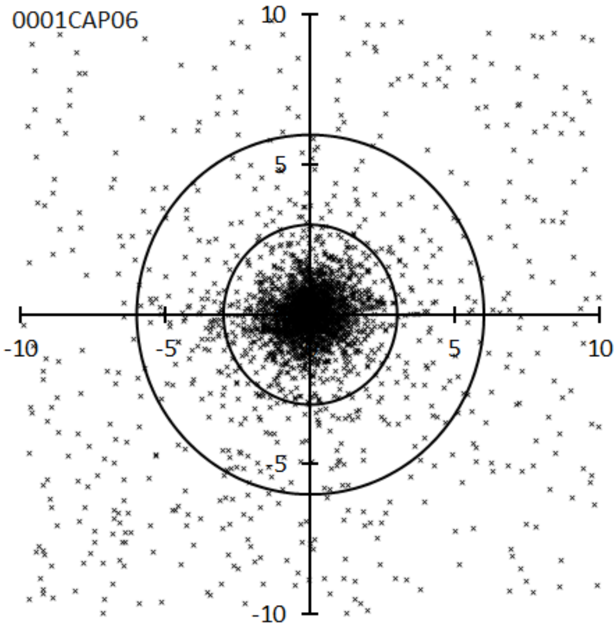

Figure 79 – Radiant point distribution map for the alpha-Capricornids.

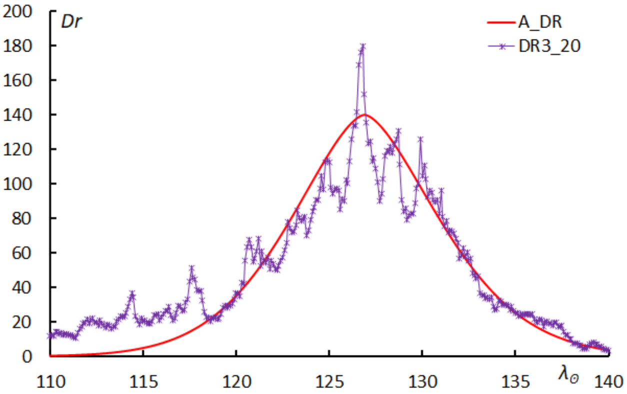

Figure 80 – Activity profile for the alpha-Capricornids.

0005SDA: Southern delta-Aquariids

$\lambda_{\odot} = 126.9°$, $\lambda\text{–}\lambda_{\odot} = 208.4°$, $\beta = –7.4°$,
$\alpha = 340.0°$, $\delta = –16.4°$, $v_g = 40.4$ km/s.

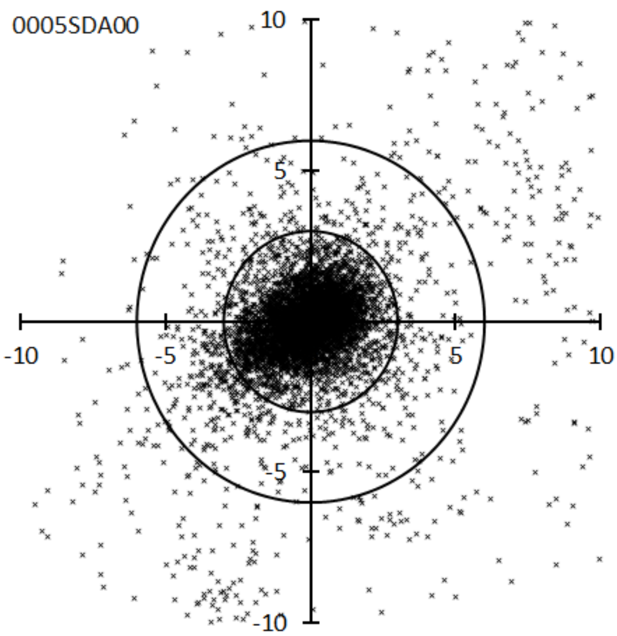

Figure 81 – Radiant point distribution map for the Southern delta-Aquariids.

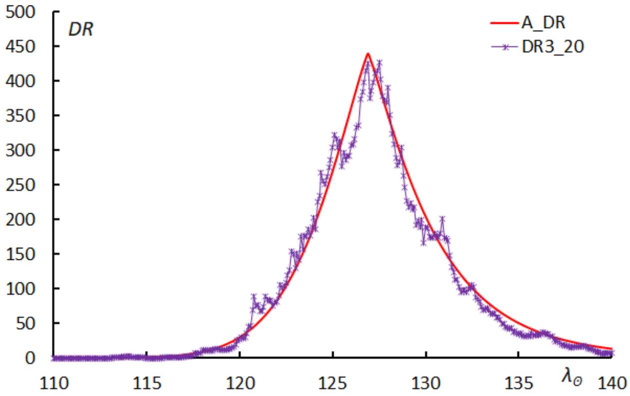

Figure 82 – Activity profile for the Southern delta-Aquariids.

This meteor shower has been known for a long time also. Compared to CAP, the radiant distribution shows more diffused, especially in the latter half of the activity, showing an elongated oval shape. 0003SIA01, 0640AOA00 are considered part of SDA. Regarding the activity profile, the increase before the peak was rapid in the previous paper (Koseki, 2021) because the data from the SonotaCo network were not fully compensated for the decrease in observed amount due to the rainy season, but the GMN data shows that it is almost symmetrical.

0191ERI: eta-Eridanids

$\lambda_{\odot} = 132.3°$, $\lambda\text{–}\lambda_{\odot} = 260.0°$, $\beta = –27.4°$,
$\alpha = 39.5°$, $\delta = –13.5°$, $v_g = 64.2$ km/s.

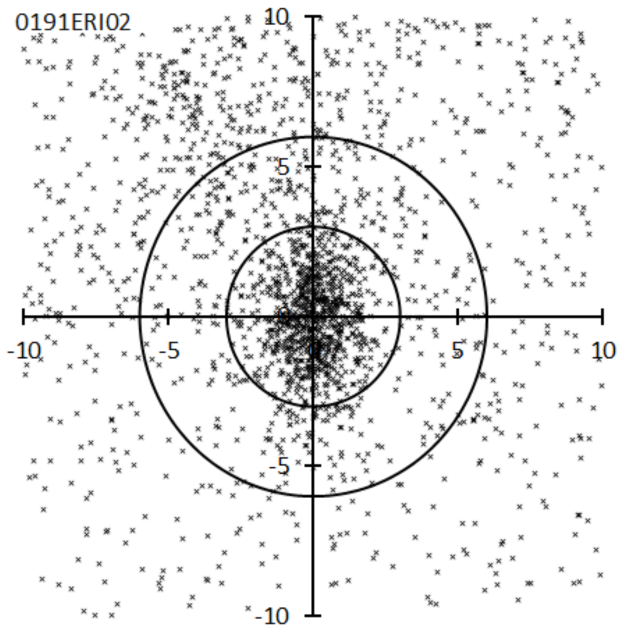

Figure 83 – Radiant point distribution map for the eta-Eridanids.

This activity was detected by Ohtsuka and his team using a combination of visual observation, photography, etc. (Ohtsuka et al., 2001). It appears to be the tail end of the so-called "the tail of Orionids" and Jenniskens notes that it is a member of it in the IAUMDCSD. The radiant distribution extends vertically, which roughly matches the direction of "the tail of Orionids". In the previous paper (Koseki, 2021), we set the maximum as $\lambda_{\odot} = 137.5°$, which is about 5 degrees different from the estimate in this paper.

Despite the large number of meteors obtained, the activity profile has many irregularities, and there appears to be a maximum between $\lambda_{\odot} = 135°$ and 140° in the activity profile (*Figure 84*).

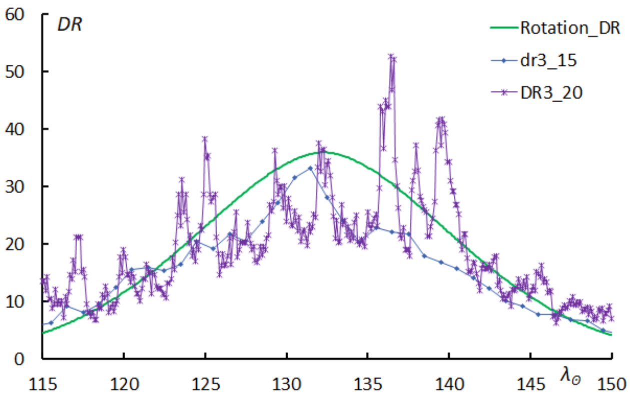

Figure 84 – Activity profile for the eta-Eridanids.

0465AXC: August xi-Cassiopeiids

$\lambda_{\odot} = 135.5°$, $\lambda - \lambda_{\odot} = 252.1°$, $\beta = 42.6°$,
$\alpha = 3.8°$, $\delta = 49.1°$, $v_g = 55.5$ km/s.

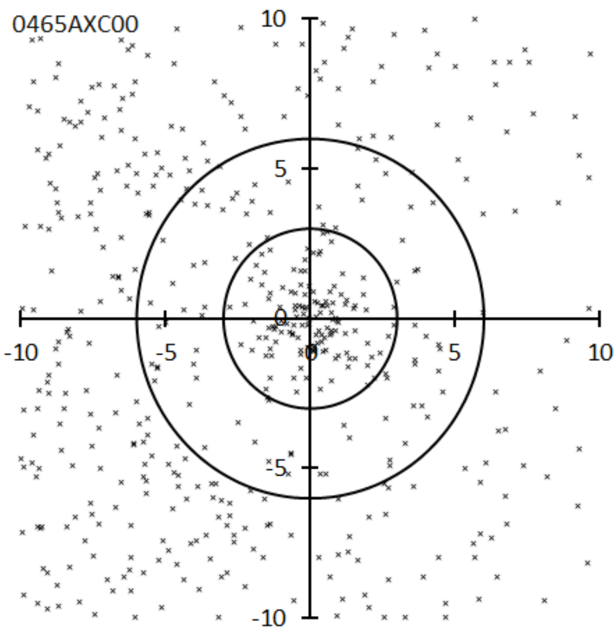

Figure 85 – Radiant point distribution map for the August xi-Cassiopeiids.

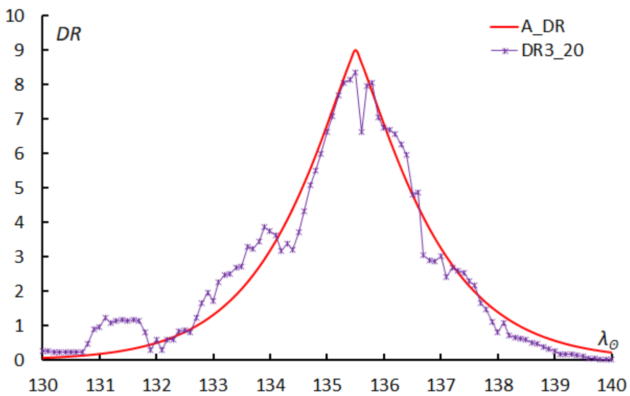

Figure 86 – Activity profile for the August xi-Cassiopeiids.

This meteor shower was detected by combining SonotaCo net and CAMS data (Rudawska and Jenniskens, 2014). However, it is not on the SonotaCo net J14 list and was not mentioned in the previous article (Koseki, 2021). Although the number of meteors obtained is only a fraction of that of ERI, the activity profile is clear (*Figure 86*).

0007PER: Perseids

$\lambda_{\odot} = 140.5°$, $\lambda - \lambda_{\odot} = 283.4°$, $\beta = 38.3°$,
$\alpha = 49.2°$, $\delta = 58.1°$, $v_g = 58.8$ km/s.

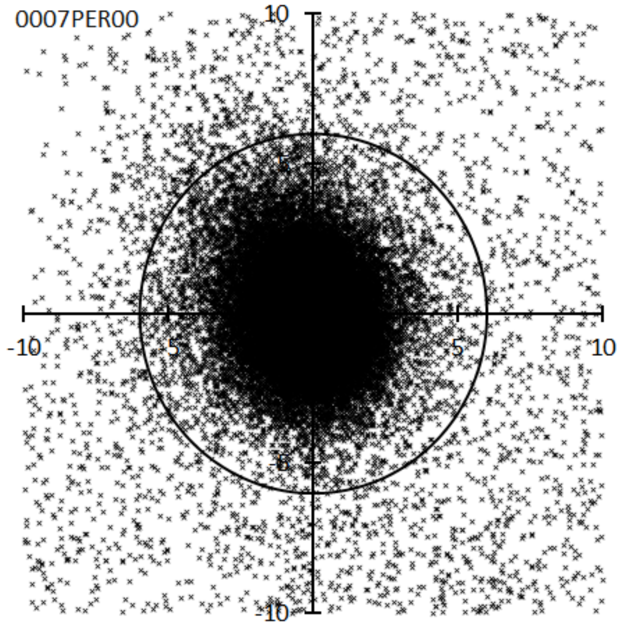

Figure 87 – Radiant point distribution map for the Perseids.

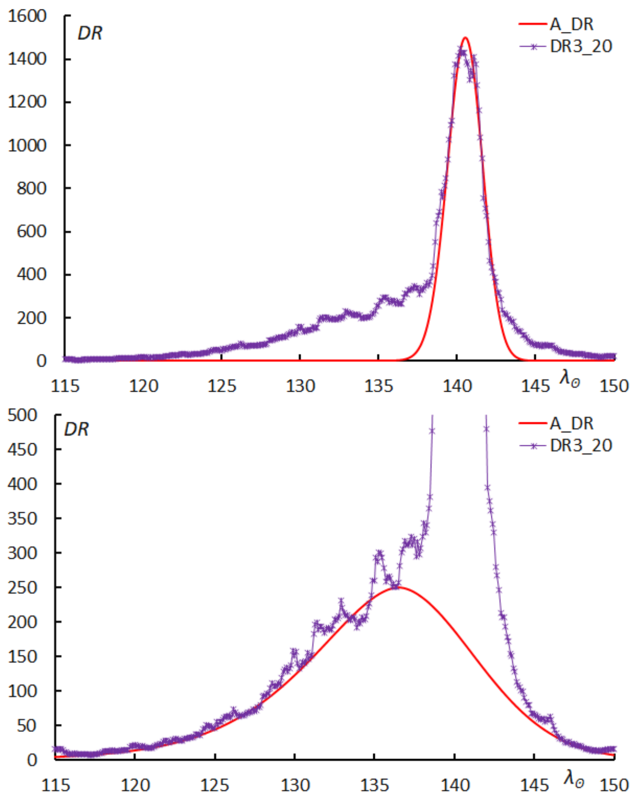

Figure 88 – Activity profile for the Perseids.

Expressed in coordinates ($\lambda - \lambda_{\odot}$, β), the radiant of the Perseids is almost stationary, but its distribution is elliptical and spreads upward like the tail of a comet. Furthermore, after the maximum, the distribution of radiants rapidly becomes blurred. As is known, the activity profile has a double structure of a pedestal and a tower (*Figure 88*). At $\lambda_{\odot} < 130°$, which corresponds to the pedestal in the activity profile, the radiant shift also seems to change. At the start of the activity, considering the distinction from ZCS, both the SonotaCo net J14 list and GMN are close to $\lambda_{\odot} = 115°$. Regarding the end of activity, J14 sets $\lambda_{\odot} = 156.36°$, and GMN sets $\lambda_{\odot} = 150.0°$, but GMN actually judges some meteors with $\lambda_{\odot} > 165°$ as PER.

0012KCG: kappa-Cygnids

$\lambda_{\odot} = 141.5°$, $\lambda–\lambda_{\odot} = 162.9°$, $\beta = 71.1°$,
$\alpha = 286.4°$, $\delta = 49.6°$, $v_g = 22.4$ km/s.

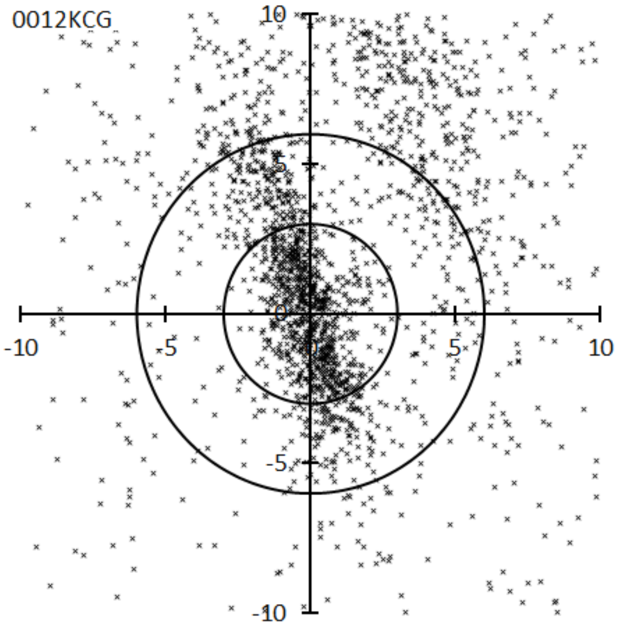

Figure 89 – Radiant point distribution map for the kappa-Cygnids.

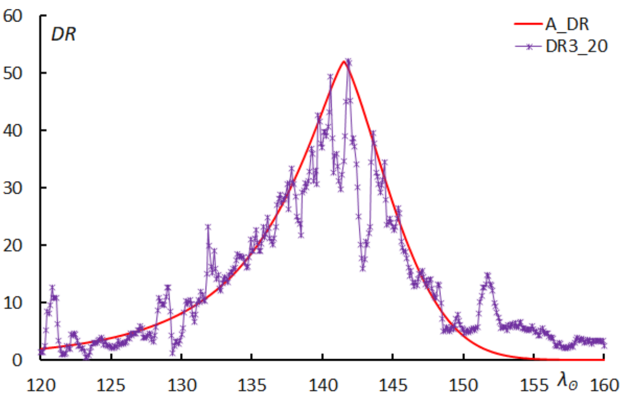

Figure 90 – Activity profile for the kappa-Cygnids.

This meteor shower gained attention due to photographic observations by Whipple (1954). The activity seen in the upper right corner of the radiant distribution is sometimes treated as KCG in normal years, so it is necessary to distinguish it from KCG. KCG activity increases every seven years, GMN observations began in 2019 and were lucky enough to capture the periodic activity in 2021. The activity curve in *Figure 90* can be said to represent the activity in 2021. While the SonotaCo net J14 list sets the active period to $\lambda_{\odot} = 136.55°$ to $150.34°$, GMN sets the active period to $\lambda_{\odot} = 93.1°$ to $167.1°$, which seems extremely long. We discussed this problem in Part II, "Meteor showers that need careful attention" (Koseki, 2024b), please refer to this article.

0199ADC: August delta-Capricornids

$\lambda_{\odot} = 143.65°$, $\lambda–\lambda_{\odot} = 180.1°$, $\beta = 2.2°$,
$\alpha = 325.3°$, $\delta = –11.5°$, $v_g = 23.8$ km/s.

0190ADC00 is an activity detected from photographic meteors brighter than –3 magnitude (Porubcan and Gavajdova, 1994). The radiant of the ADC is located 5 degrees lower right from the center of the radiant distribution in *Figure 91*, and $\lambda_{\odot} = 147.70°$. The activity profile in *Figure 92* is extremely sharp, suggesting that the activity captured in this paper is different from ADC. ADC is not listed on SonotaCo net J14 list or GMN. Most of the meteors captured by GMN were in 2022, so it seems better to think that this activity happened to appear suddenly near 0190ADC00. ADC01 is a report based on CAMS data for this activity (Jenniskens, 2022), and Sekiguchi announced that it was also detected by the SonotaCo net (Sekiguchi, 2022). Instead of calling it as ADC, it should be given a different number and name.

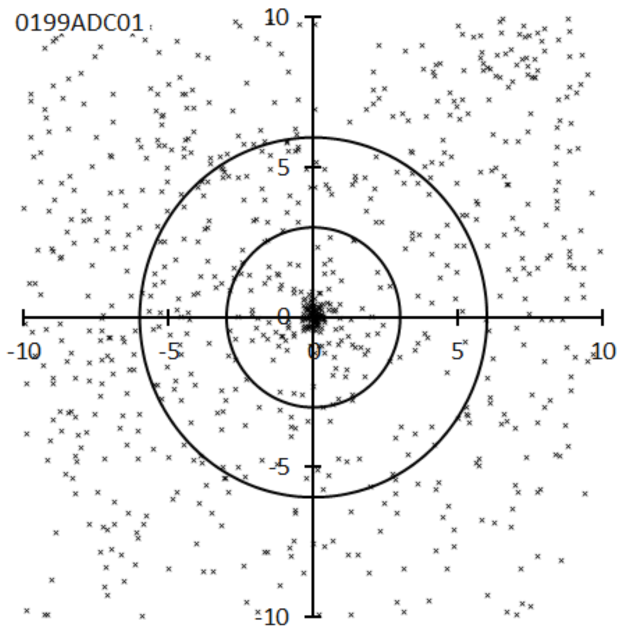

Figure 91 – Radiant point distribution map for the August delta-Capricornids.

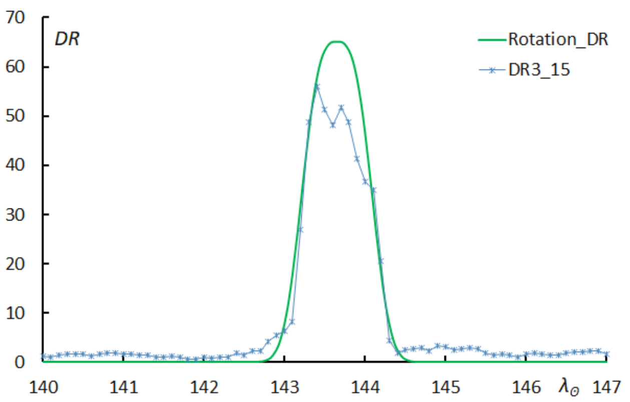

Figure 92 – Activity profile for the August delta-Capricornids.

AXD: August xi-Draconids

$\lambda_\odot = 147.2°$, $\lambda - \lambda_\odot = 140.6°$, $\beta = 82.8°$,
$\alpha = 274.3°$, $\delta = 59.7°$, $v_g = 21.8$ km/s.

This activity is tentatively named AXD (August xi Draconids) in this paper, and the activity at the bottom left of the radiant distribution in *Figure 93* is KCG. Although the activity is clearly distinguishable, it is also confusing in the IAUMDCSD, as detailed in Part II, "Meteor showers that need careful attention" (Koseki, 2024b). As seen in the estimation of the activity profile, the activity is thought to end rapidly at $\lambda_\odot > 150°$ and should be distinguished from the activity observed after that point.

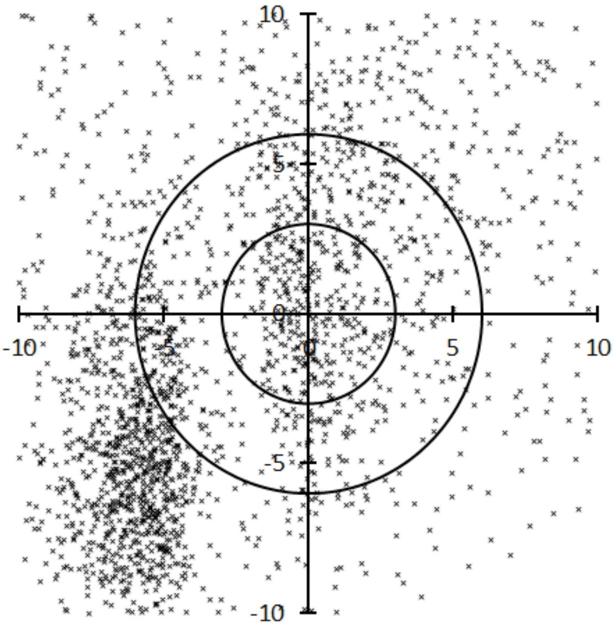

Figure 93 – Radiant point distribution map for the August xi-Draconids.

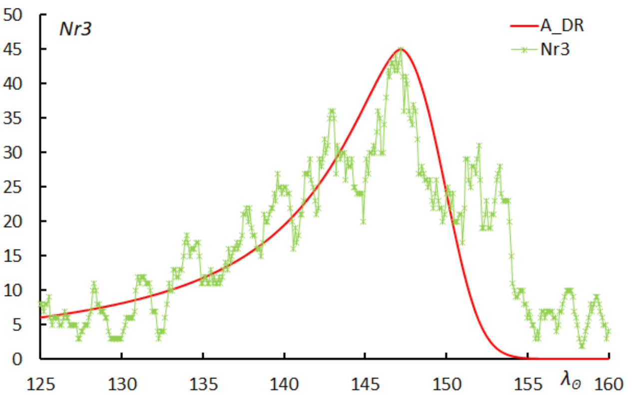

Figure 94 – Activity profile for the August xi-Draconids.

0026NDA: Northern delta-Aquariids

$\lambda_\odot = 149°$, $\lambda - \lambda_\odot = 206.8°$, $\beta = 7.0°$,
$\alpha = 353.4°$, $\delta = 4.8°$, $v_g = 37.9$ km/s.

The NDA remarks have the annotation "Member of 297/DAQ" except for NDA10, but the DAQ data is empty and $s = 2$, which means it is poor data. NDA04 (SonotaCo net observation) is annotated with "the name is 342/BPI August beta-Piscids", and NDA06 and NDA07 have "Previously considered as 508/TPI". It is difficult to determine when the term NDA first appeared for the meteor shower activities in this section. NDA was used to correspond to 0005SDA and was used for activities around $\lambda - \lambda_\odot = 130°$ (Wright et al., 1957), but gradually it has been called NDA for activities that occurred later. BPI would be a more appropriate name than NDA. GMN calls this activity NDA, but the SonotaCo net J14 list calls it BPI.

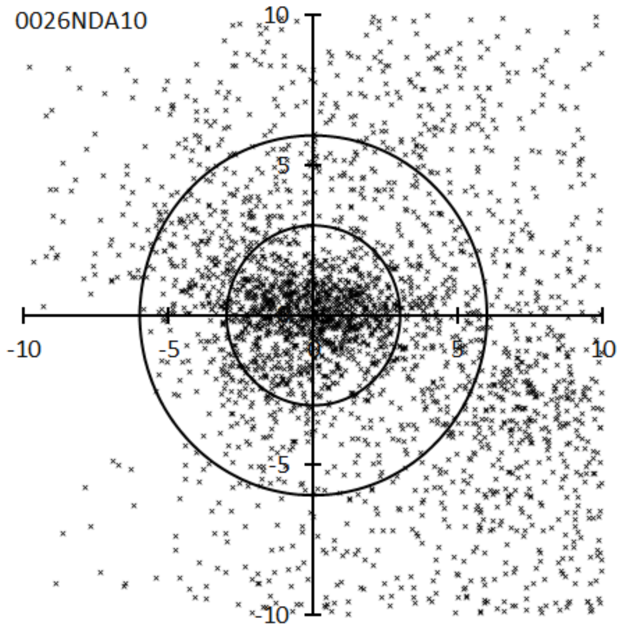

Figure 95 – Radiant point distribution map for the Northern delta-Aquariids.

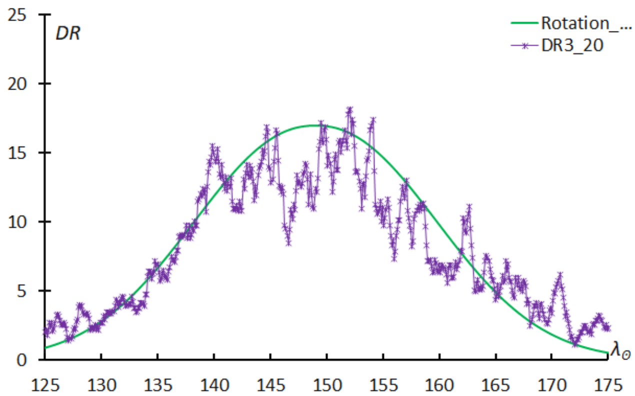

Figure 96 – Activity profile for the Northern delta-Aquariids.

ZDR: zeta-Draconids

$\lambda_\odot = 153.2°$, $\lambda - \lambda_\odot = 52.7°$, $\beta = 84.6°$,
$\alpha = 258.9°$, $\delta = 63.8°$, $v_g = 21.9$ km/s.

Including GMN, there have recently been cases where this activity is combined with AXD to form AUD. In the previous article (Koseki, 2021), we referred to this activity as AUD, following the IAUMDC, but we will appropriately refer to this activity as ZDR in this article. For more information on the relationship with ZDR in IAUMDC, please refer to Part II, "Meteor showers that need careful attention" (Koseki, 2024b). Since ZDR intersects with the path of AXD near $\lambda_\odot = 145°$, a spurious maximum occurs as a side effect in the activity curve.

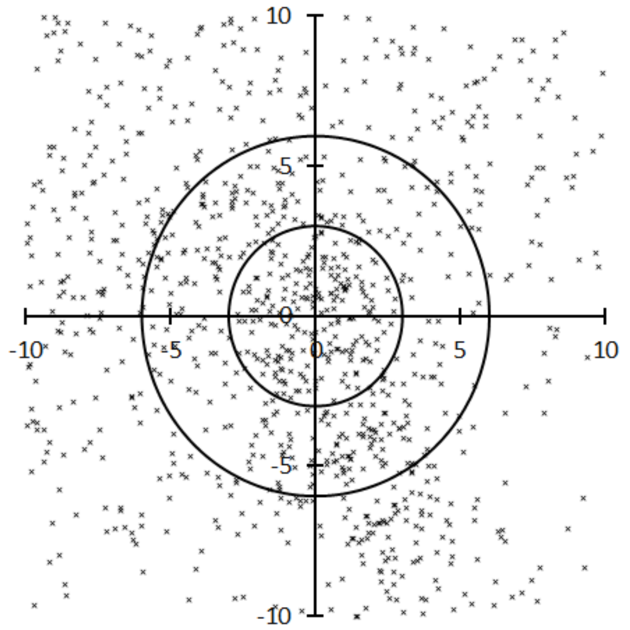

Figure 97 – Radiant point distribution map for the zeta-Draconids.

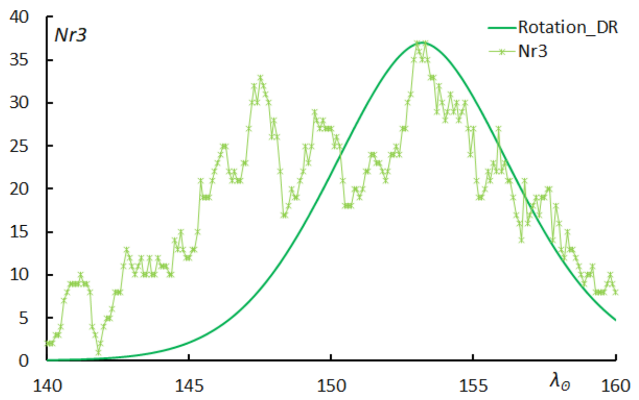

Figure 98 – Activity profile for the zeta-Draconids.

0523AGC: August gamma-Cepheids

$\lambda_\odot = 155.4°$, $\lambda–\lambda_\odot = 263.2°$, $\beta = 63.6°$,
$\alpha = 358.0°$, $\delta = 76.6°$, $v_g = 43.9$ km/s.

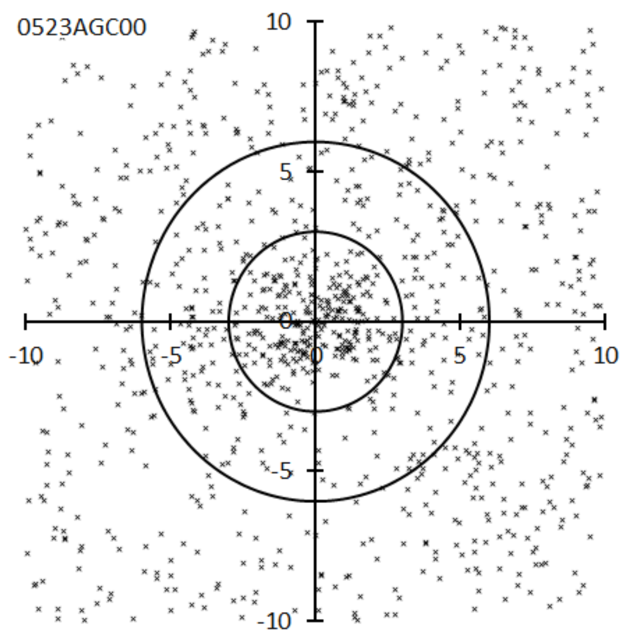

Figure 99 – Radiant point distribution map for the August gamma-Cepheids.

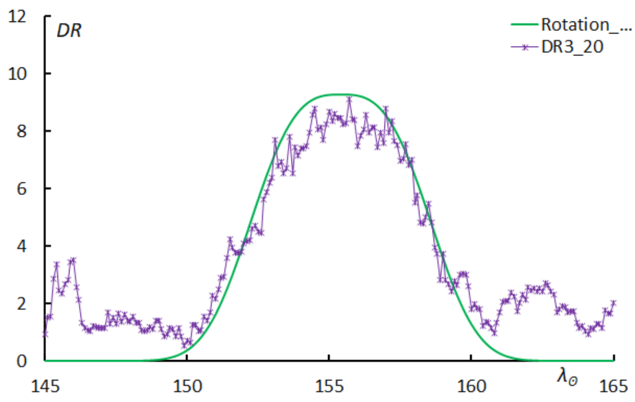

Figure 100 – Activity profile for the August gamma-Cepheids.

This is also a meteor shower detected by combining observations from Croatia and the SonotaCo net (Andreić et al., 2013). AGC seems to have a stable activity every year, and the SonotaCo net J14 list and GMN match well. The orbit of AGC is that of a long-period comet, intersecting the Earth's orbit at an almost perpendicular angle almost at perihelion, but since the direction of perihelion moves along the ecliptic plane, the period of activity is relatively long.

0206AUR: Aurigids

$\lambda_\odot = 158.4°$, $\lambda–\lambda_\odot = 292.6°$, $\beta = 15.8°$,
$\alpha = 91.2°$, $\delta = 39.2°$, $v_g = 65.5$ km/s.

Since Hoffmeister caught a sudden appearance in 1935 (Hoffmeister, 1948), several outbursts have been observed, however now this meteor shower is confirmed to be active every year. As seen in the activity curve, there also appears to be weak activity before and after the sharp maximum. However, as seen in the radiant distribution (*Figure 101*), there are many sporadic meteors in the surrounding area, so it would be better to limit the period of activity.

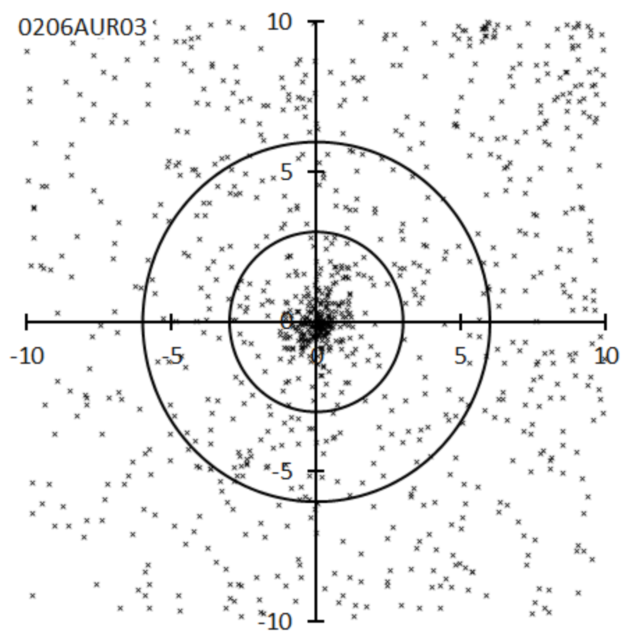

Figure 101 – Radiant point distribution map for the Aurigids.

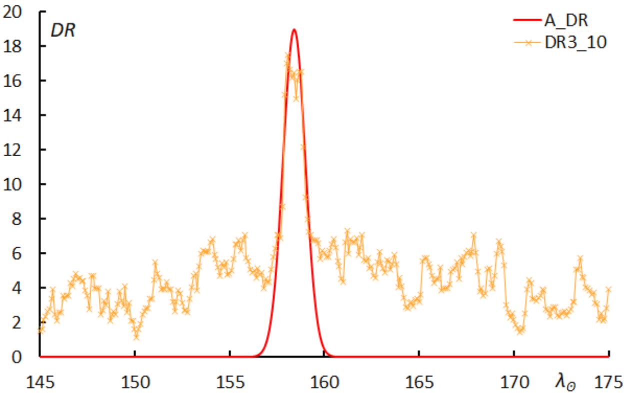

Figure 102 – Activity profile for the Aurigids.

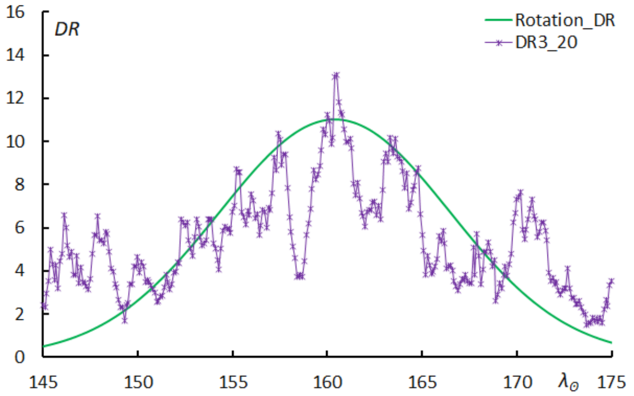

Figure 105 – Activity profile for the pi6-Orionids.

0552PSO: pi6-Orionids

$\lambda_{\odot} = 160.4°$, $\lambda–\lambda_{\odot} = 267.4°$, $\beta = –24.3°$,
$\alpha = 69.8°$, $\delta = –2.4°$, $v_g = 65.5$ km/s.

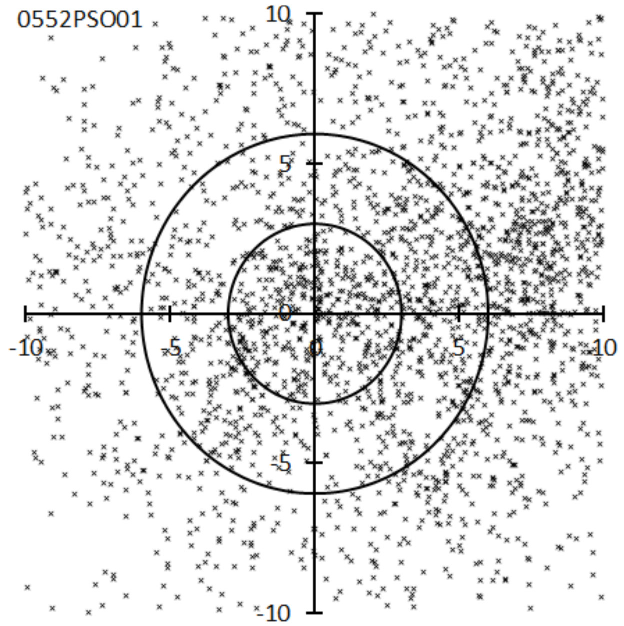

Figure 103 – Radiant point distribution map for the pi6-Orionids.

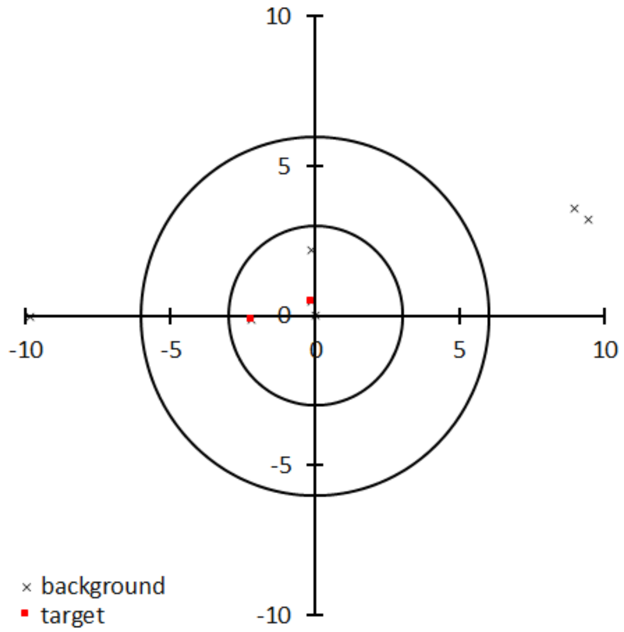

Figure 104 – The IAUMDCSD meteor showers corresponding to the radiant distribution for the pi6-Orionids.

This is also a meteor shower detected by combining observations from Croatia and the SonotaCo net (Šegon et al., 2014). The IAUMDCSD meteor showers corresponding to the radiant distribution are shown in *Figure 104*. The Croatian group reported 0337NUE at the same time as this PSO, and the cross on the far right indicates this. The other two crosses are also considered NUE in the IAUMDCSD. Jenniskens' PSO is the left filled box (PSO01) and he regards it a part of "the tail of Orionids". The radiant distribution shows that it is quite difficult to distinguish between meteor showers and sporadic meteors or the "the tail of Orionids" in this region.

0694OMG: omicron-Geminids

$\lambda_{\odot} = 163.2°$, $\lambda–\lambda_{\odot} = 307.1°$, $\beta = 17.1°$,
$\alpha = 115.2°$, $\delta = 38.8°$, $v_g = 58.1$ km/s.

Although it appears in the first CAMS report (Jenniskens et al., 2016d), there have been no subsequent confirmation observations. The position of 0695APA00 ($\lambda_{\odot} = 146°$, $\lambda–\lambda_{\odot} = 308.39°$, $\beta = 18.75°$) is extremely close to the position estimated from the movement of the OMG radiant point $\lambda_{\odot} = 146°$, $\lambda–\lambda_{\odot} = 310.4°$, $\beta = 18.6°$). Both may be the same activity. The right side of the radiant distribution is the Apex area, and OMG is located at the eastern edge of it.

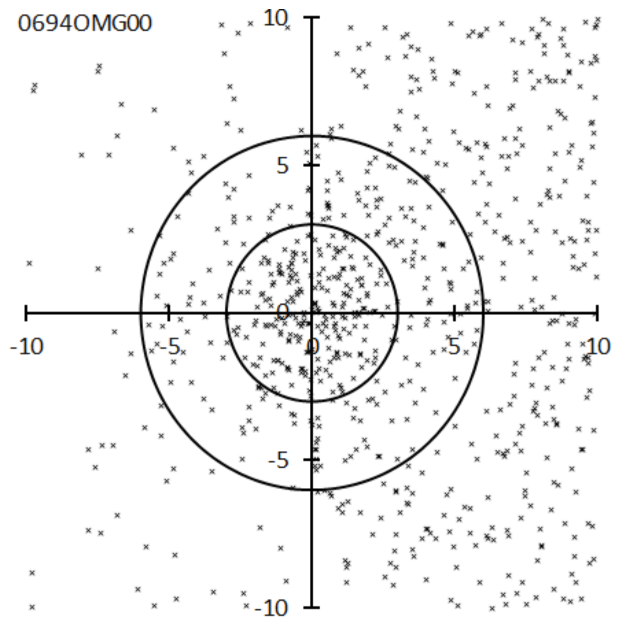

Figure 106 – Radiant point distribution map for the omicron-Geminids.

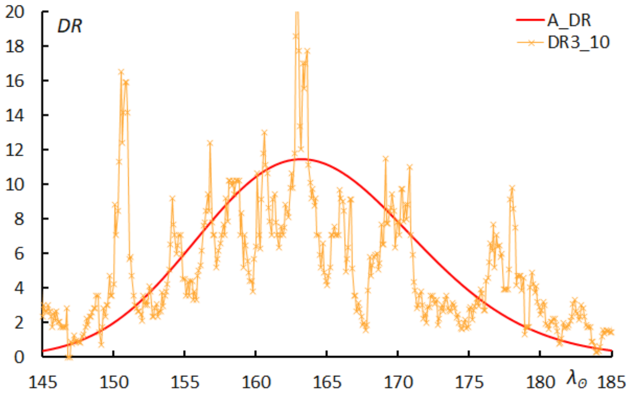

Figure 107 – Activity profile for the omicron-Geminids.

0337NUE: nu-Eridanids

$\lambda_\odot = 165.5°$, $\lambda–\lambda_\odot = 259.1°$, $\beta = –21.3°$,
$\alpha = 66.4°$, $\delta = 0.1°$, $v_g = 65.4$ km/s.

The first detection of NUE was made by SonotaCo net (SonotaCo, 2009). It is the second most active region after 0191ERI in the activity region of “the tail of Orionids”, but it is diffuse as seen in the radiant distribution. The part that looks like a tail branch extending to the left is 0552PSO. The area on the far right where radiant points are concentrated is the activity of 0583TTA00 and 1142SNT00, which are mentioned in Part II, “Meteor showers that need careful attention” (Koseki, 2024b). Even considering the radiant drift, the NUE activity profile is unclear. Regarding the period of activity, the SonotaCo net J14 list is limited to $\lambda_\odot = 160.50°\sim171.46°$, while GMN’s is $\lambda_\odot = 147.6°\sim232°$. The graph of the number of observed meteors published by GMN is shown below the activity profile in *Figure 109*, and it clearly shows including multiple activities.

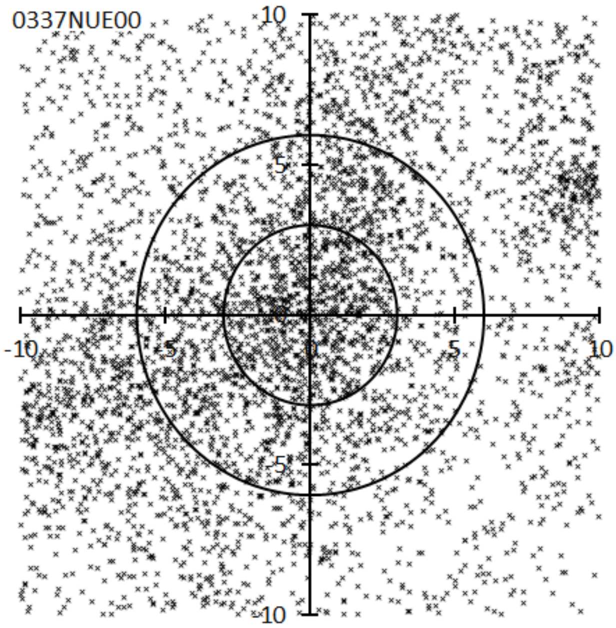

Figure 108 – Radiant point distribution map for the nu-Eridanids.

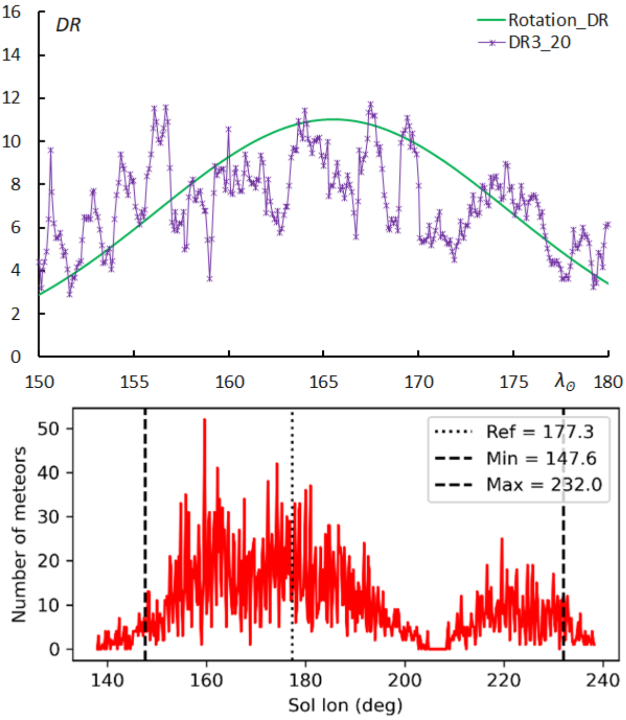

Figure 109 – Activity profile for the nu-Eridanids (top), determed by GMN (bottom).

0208SPE: September epsilon-Perseids

$\lambda_\odot = 166.9°$, $\lambda–\lambda_\odot = 249.1°$, $\beta = 21.1°$,
$\alpha = 47.4°$, $\delta = 39.6°$, $v_g = 64.0$ km/s.

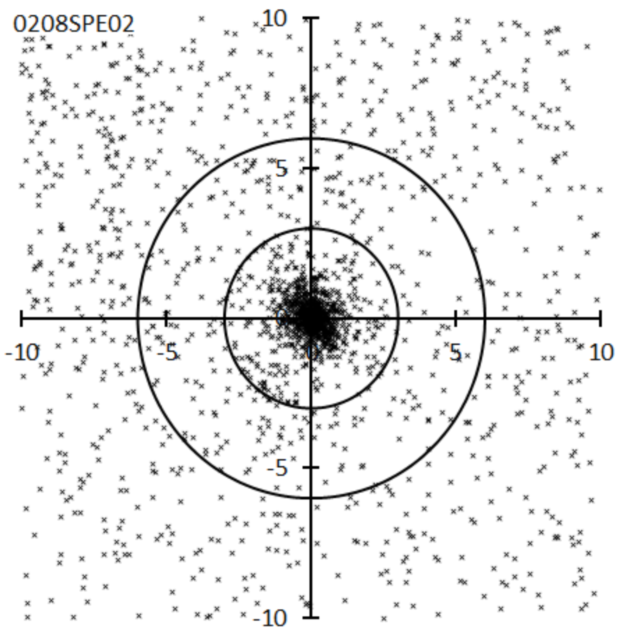

Figure 110 – Radiant point distribution map for the September epsilon-Perseids.

The existence of the September Perseids has been known since the era of visual observations, but even with the advent of photographic and radio observations, no clear conclusions could be reached. Jenniskens gave it the name SPE in his famous book (Jenniskens, 2006), but the data were disorganized and did not provide a clear conclusion. The decisive blow was given by the SonotaCo net report listed as SPE00 (SonotaCo, 2009). This initial report called it "September-Perseids", but Jenniskens identified it as SPE. Currently, SPE is one of the most prominent meteor showers in video observations.

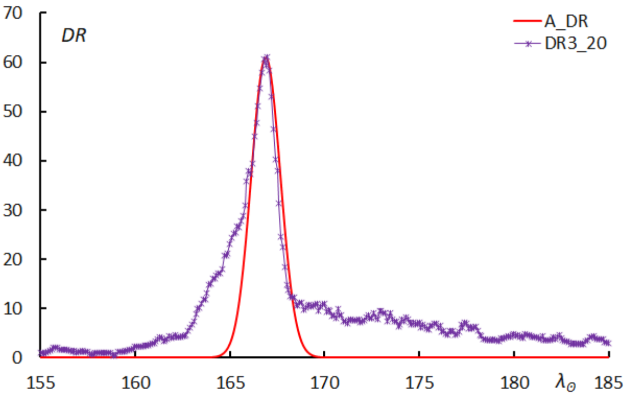

Figure 111 – Activity profile for the September epsilon-Perseids.

0215NPI: Northern delta-Piscids

$\lambda_\odot = 167.2°$, $\lambda\text{–}\lambda_\odot = 196.7°$, $\beta = 3.8°$,
$\alpha = 2.1°$, $\delta = 5.1°$, $v_g = 28.7$ km/s.

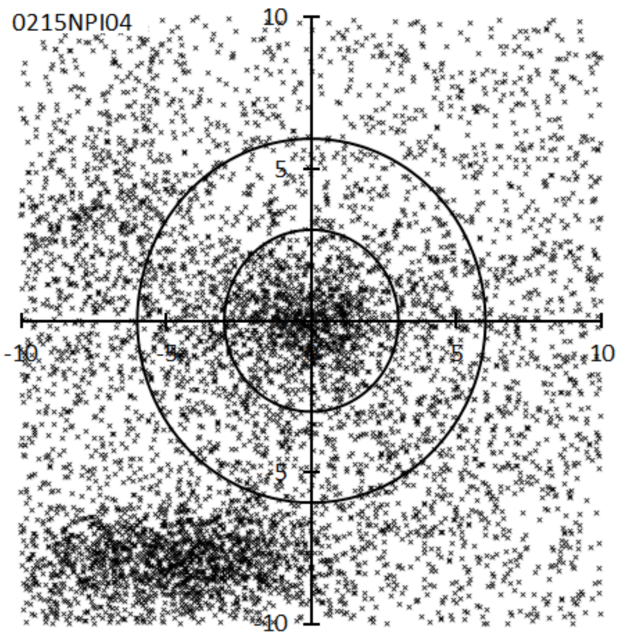

Figure 112 – Radiant point distribution map for the Northern delta-Piscids.

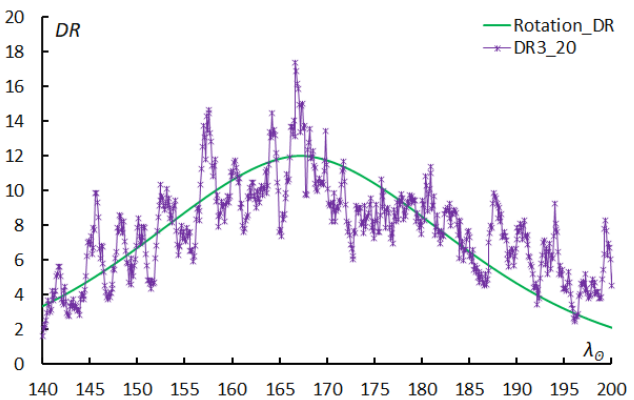

Figure 113 – Activity profile for the Northern delta-Piscids.

The combination of 0033NIA and 0215NPI is called NPI here, but in the previous article (Koseki, 2021), the same activity was called NIA. For more information on the reason, please refer to Part II, "Meteor showers that need careful attention" (Koseki, 2024b) (7. 0033NIA and 0215NPI). Both the SonotaCo net J14 list and GMN distinguish between NIA and NPI activities, and the NPI activity is in the latter half of the activity curve (*Figure 113*), especially in the J14 list, where the activity is extremely limited at $\lambda_\odot = 181.79°\sim184.37°$. The activity at the bottom left of the radiant distribution is sometimes called SPI, and this can almost be considered the early activity of the STA. As a side note, regarding NIA, the IAUMDCSD refers to empty data called "Member of 298/IAQ complex", but this is a remnant of an old version.

0081SLY_0: September Lyncids

$\lambda_\odot = 169.5°$, $\lambda\text{–}\lambda_\odot = 294.9°$, $\beta = 33.5°$,
$\alpha = 111.7°$, $\delta = 55.8°$, $v_g = 58.7$ km/s.

As mentioned in detail in Part II, "Meteor showers that need careful attention" (Koseki, 2024b), two different activities are registered as SLY in the IAUMDC. 0705UYL00 should be identified with this SLY_0. The SonotaCo net J14 list calls this activity as UYL.

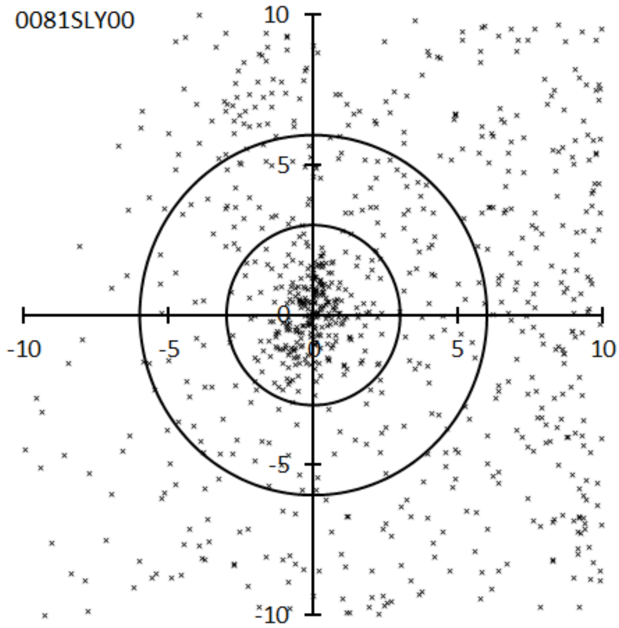

Figure 114 – Radiant point distribution map for the September Lyncids.

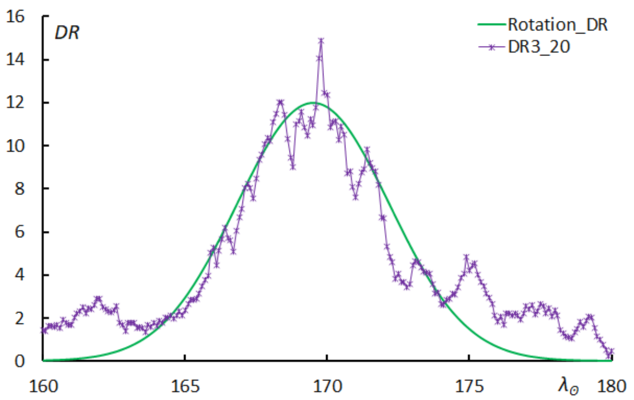

Figure 115 – Activity profile for the September Lyncids.

0757CCY: chi-Cygnids

$\lambda_\odot = 173.4°$, $\lambda–\lambda_\odot = 140.1°$, $\beta = 52.6°$,
$\alpha = 300.2°$, $\delta = 33.6°$, $v_g = 14.7$ km/s.

An outburst was captured by CAMS (Jenniskens, 2015) and observers in Europe in 2015 (Koukal et al., 2016). Shiba immediately pointed out the five-year activity periodicity (Shiba, 2015) and the author confirmed this using data from SonotaCo Net, CAMS, EDMOND, and GMN (Koseki, 2022b). The radiant distribution and activity profile in *Figures 116 and 117* are based on GMN observations in 2020. The next return will be in 2025. There seems to be a tendency for activity to increase each time, but confirmation is required (Koseki, 2022b). Naturally, it was not mentioned in the previous article (Koseki, 2021), and it is not in the SonotaCo net J14 list.

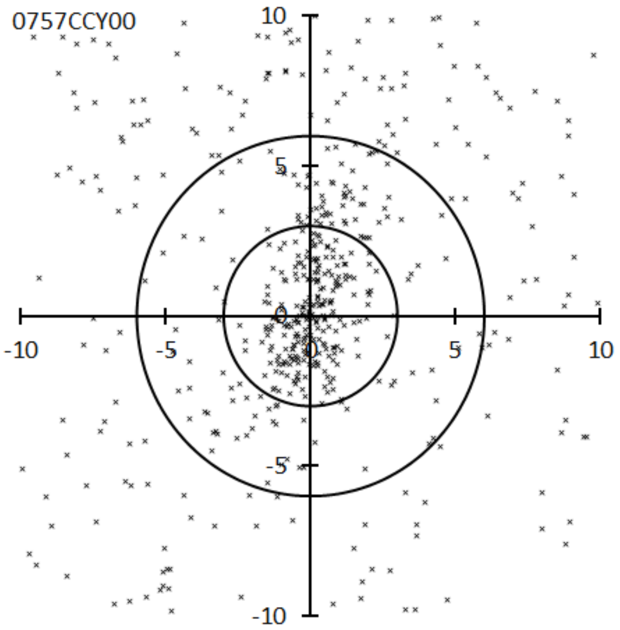

Figure 116 – Radiant point distribution map for the chi-Cygnids.

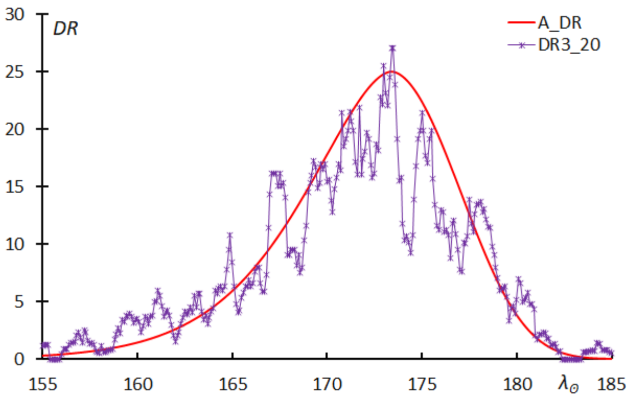

Figure 117 – Activity profile for the chi-Cygnids.

0221DSX: Daytime Sextantids

$\lambda_\odot = 188.5°$, $\lambda–\lambda_\odot = 330.6°$, $\beta = –11.5°$,
$\alpha = 156.5°$, $\delta = –2.5°$, $v_g = 32.3$ km/s.

IAUMDCSD uses "Galligan and Baggaley, 2002" for 0221DSX00, but this should refer to Nilsson, who first detected it through radar observations in 1961 at Adelaide (Nilsson, 1964). It is thought that they may have a twin relationship with Geminids. With the development of video observation, it became a target for optical observation.

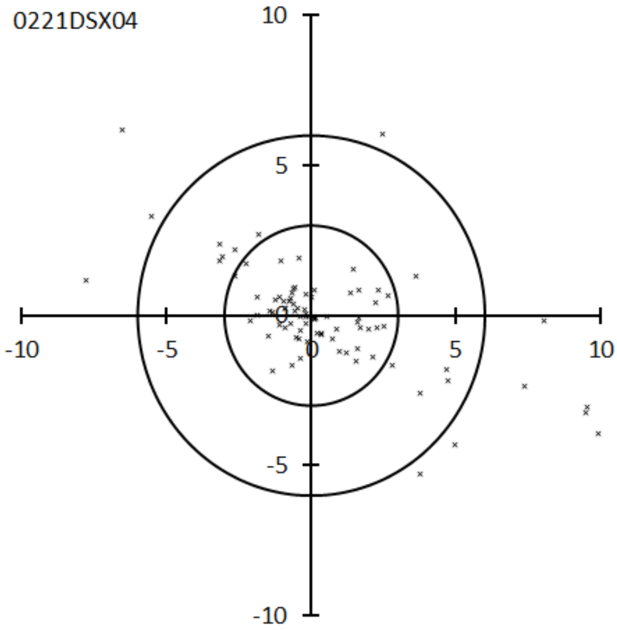

Figure 118 – Radiant point distribution map for the Daytime Sextantids.

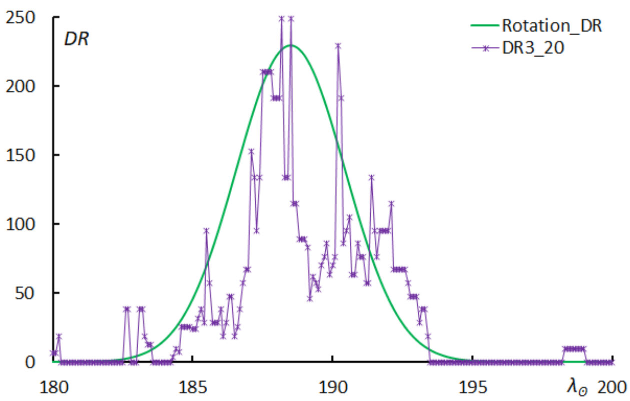

Figure 119 – Activity profile for the Daytime Sextantids.

0081SLY_1: September Lyncids

$\lambda_\odot = 191.5°$, $\lambda–\lambda_\odot = 277.5°$, $\beta = 23.9°$,
$\alpha = 115.2°$, $\delta = 45.7°$, $v_g = 66.3$ km/s.

0424SOL00 should be identified as this activity, as described in detail in Part II, "Meteor showers that need careful attention" (Koseki, 2024b). It appears to be a chance association of sporadic meteors, but the one listed as "Lyncids" in Lindblad's list (Lindblad, 1971) corresponds to SLY_1. SLY01 is not featured in the SonotaCo net J14 list. On the other hand, GMN treats SLY_1 as SOL.

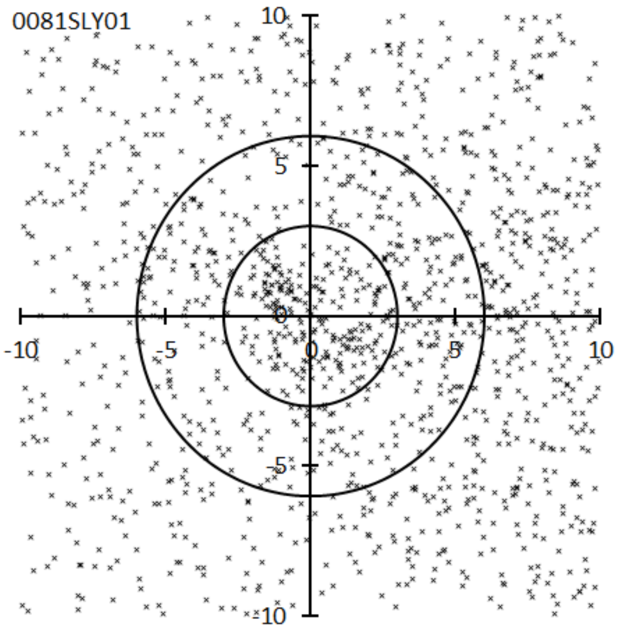

Figure 120 – Radiant point distribution map for the September Lyncids.

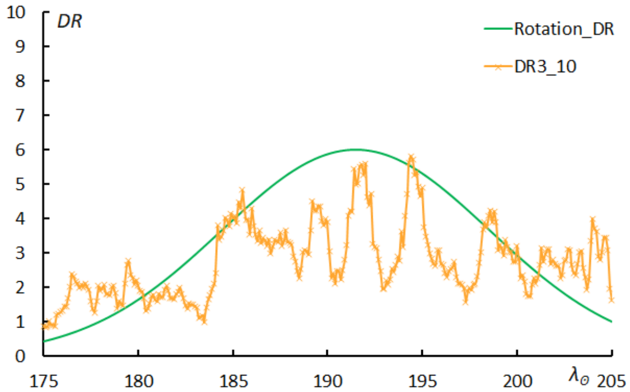

Figure 121 – Activity profile for the September Lyncids.

0281OCT: October Camelopardalids

$\lambda_\odot = 192.55°$, $\lambda – \lambda_\odot = 281.6°$, $\beta = 62.0°$,
$\alpha = 167.6°$, $\delta = 78.6°$, $v_g = 45.8$ km/s.

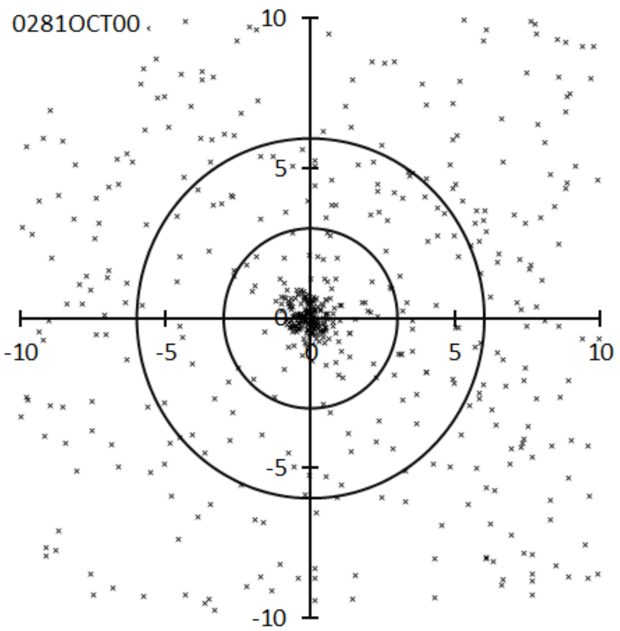

Figure 122– Radiant point distribution map for the October Camelopardalids.

An outburst was captured in Europe in 2005 (Jenniskens et al., 2005), but observations by the SonotaCo network later confirmed that it was an annual meteor shower (SonotaCo, 2009). As can be seen from the activity profile in *Figure 123*, the period of high activity is limited to approximately one day, so it seems to be a matter of whether the observation point is blessed with the conditions to encounter the maximum. The density of radiant points is also high (*Figure 122*), and if one encounters the maximum, it will be noticeable.

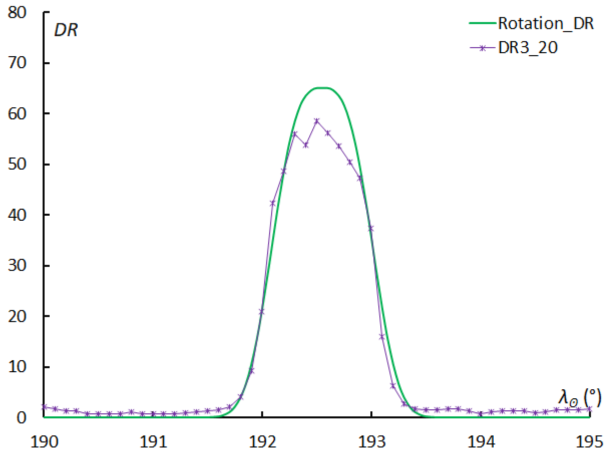

Figure 123 – Activity profile for the October Camelopardalids.

0924SAN: 62-Andromedids

$\lambda_\odot = 196.8°$, $\lambda – \lambda_\odot = 214.4°$, $\beta = 29.8°$,
$\alpha = 37.9°$, $\delta = 46.5°$, $v_g = 16.9$ km/s.

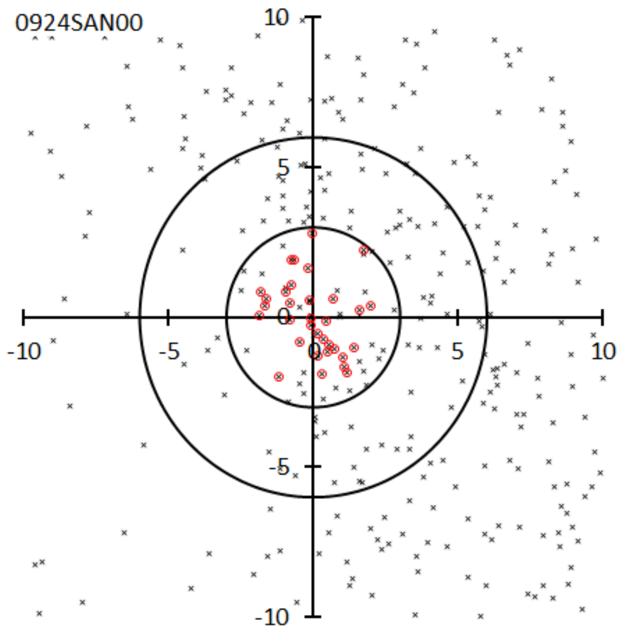

Figure 124– Radiant point distribution map for the 62-Andromedids (red circled crosses), others are sporadics.

This activity appeared in the second report of CAMS (Jenniskens et al., 2018b), was not covered in the previous article (Koseki, 2021), and is not on the SonotaCo net J14 list. This is a very unique meteor shower; in the geocentric velocity distribution shown in *Figure 126*, the lower cluster is SAN, and the upper cluster are sporadic meteors. In the radiant distribution, the circled crosses are the SAN under the geocentric velocity distribution, and the surrounding crosses can be regarded as sporadic meteors.

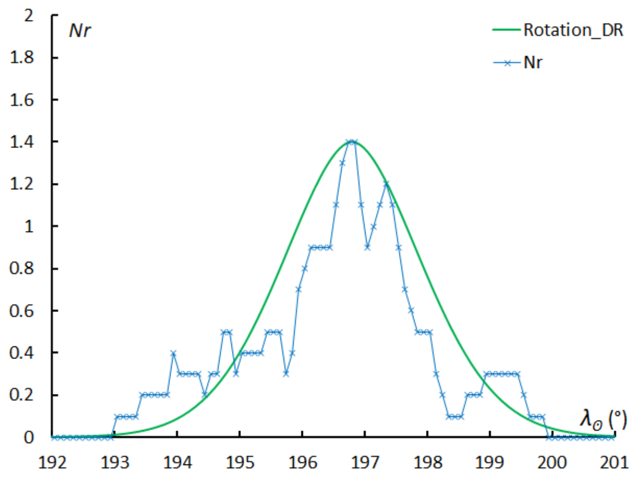

Figure 125 – Activity profile for the 62-Andromedids.

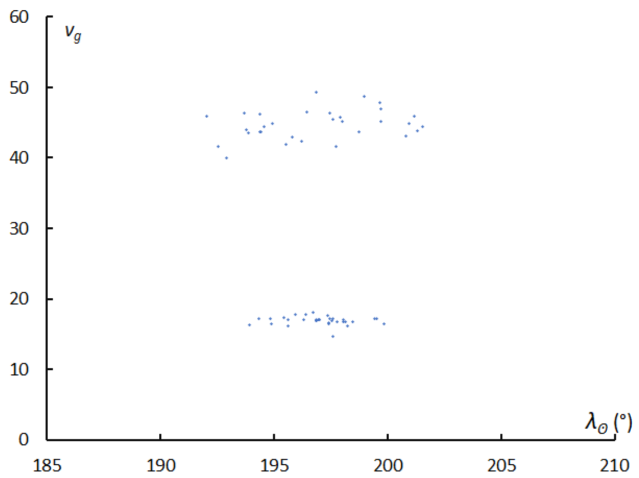

Figure 126 – The velocity distribution in function of time, upper concentration are sporadic meteors, lower concentration are SAN meteors.

0825XIE: xi-Eridanids

$\lambda_\odot = 198.2°$, $\lambda–\lambda_\odot = 228.1°$, $\beta = –27.8°$,
$\alpha = 69.1°$, $\delta = –6.1°$, $v_g = 54.2$ km/s.

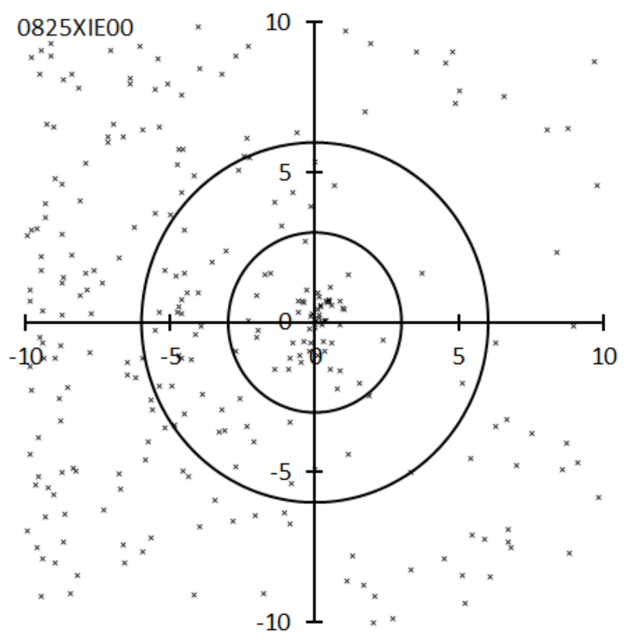

Figure 127 – Radiant point distribution map for the xi-Eridanids.

The second CAMS report is the first detection of this meteor shower (Jenniskens et al., 2018b). XIE was not mentioned in the previous article (Koseki, 2021), and it is not in the SonotaCo net J14 list. Due to the small number of observed meteors, the status of activity is not clear. In GMN, the activity period is set at $\lambda_\odot = 190.8°\text{~}200.8°$, and the maximum is set slightly earlier at $\lambda_\odot = 196.5°$.

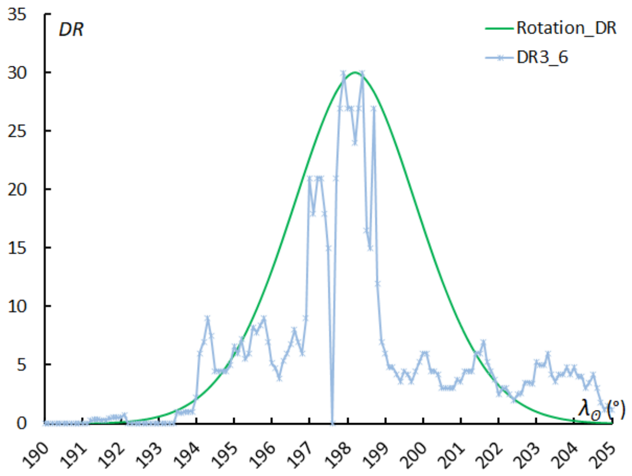

Figure 128 – Activity profile for the xi-Eridanids.

0002STA_SE: Southern Taurids_SE

$\lambda_\odot = 201.5°$, $\lambda–\lambda_\odot = 195.8°$, $\beta = –4.4°$,
$\alpha = 36.4°$, $\delta = 9.8°$, $v_g = 28.8$ km/s.

As mentioned in detail in Part II, "Meteor showers that need careful attention" STA must be considered separately into October Arietids (STA_SE) and Taurids in November (STA_SF). The increase seen in the activity curve after $\lambda_\odot > 210°$ is due to STA_SF (*Figure 130*). Since the radiant points are close and the geocentric velocities are almost the same, the only way to distinguish these two activities is to simply assume that the October maximum is STA_SE and the November maximum is STA_SF. Although the activity of STA_SF changes greatly from year to year, the activity of this STA_SE is almost constant every year.

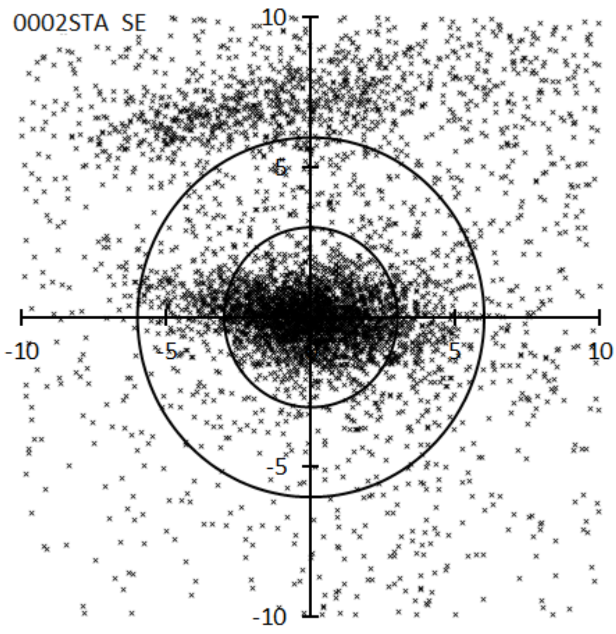

Figure 129 – Radiant point distribution map for the Southern Taurids_SE.

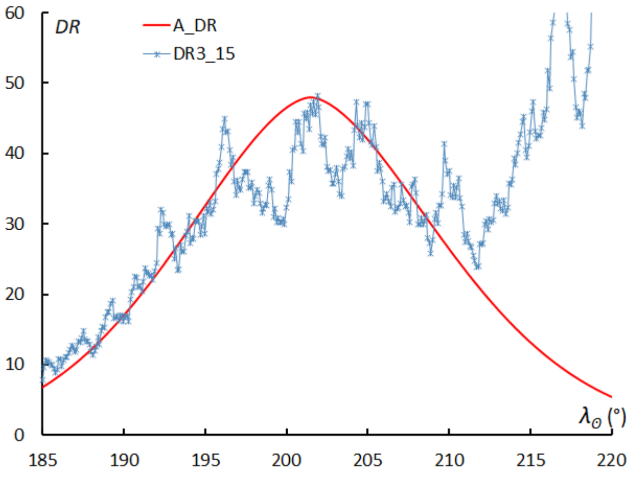

Figure 130 – Activity profile for the Southern Taurids_SE.

0333OCU: October Ursae Majorids

$\lambda_\odot = 202.5°$, $\lambda–\lambda_\odot = 279.1°$, $\beta = 46.8°$,
$\alpha = 145.7°$, $\delta = 64.2°$, $v_g = 55.5$ km/s.

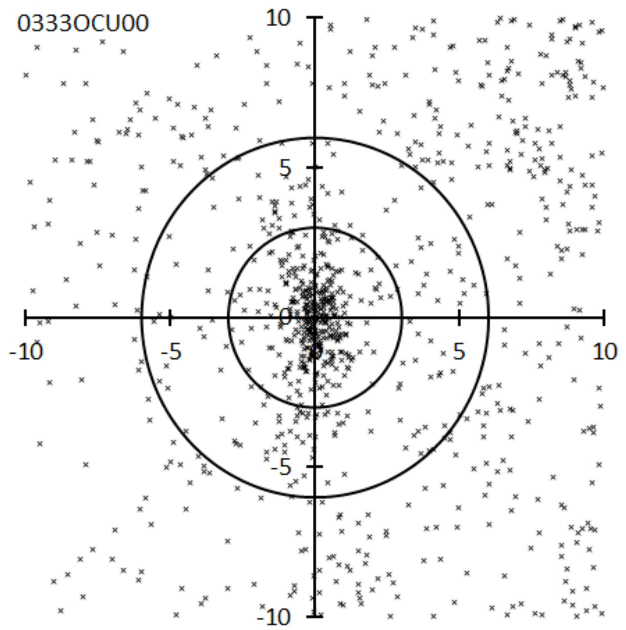

Figure 131 – Radiant point distribution map for the October Ursae Majorids.

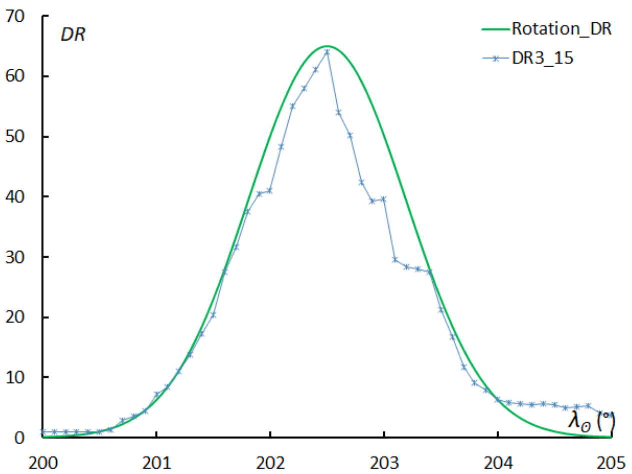

Figure 132 – Activity profile for the October Ursae Majorids.

The first detection were video observations by Uehara and his colleagues (Uehara et al., 2006), which was the result of the activities of the predecessor of the SonotaCo net. The radiant points are densely packed (*Figure 131*), and the activity profile is sharp (*Figure 132*). The number of meteors obtained appears to differ depending on the year, depending on whether a maximum is encountered. In 2006, when it was first detected, 14 OCU meteors were observed, but in 2007 and 2008, only 3 and 5 OCU meteors were observed by the SonotaCo net, respectively.

0023EGE: epsilon-Geminids

$\lambda_\odot = 203.7°$, $\lambda–\lambda_\odot = 254.9°$, $\beta = 5.1°$,
$\alpha = 99.7°$, $\delta = 28.3°$, $v_g = 68.7$ km/s.

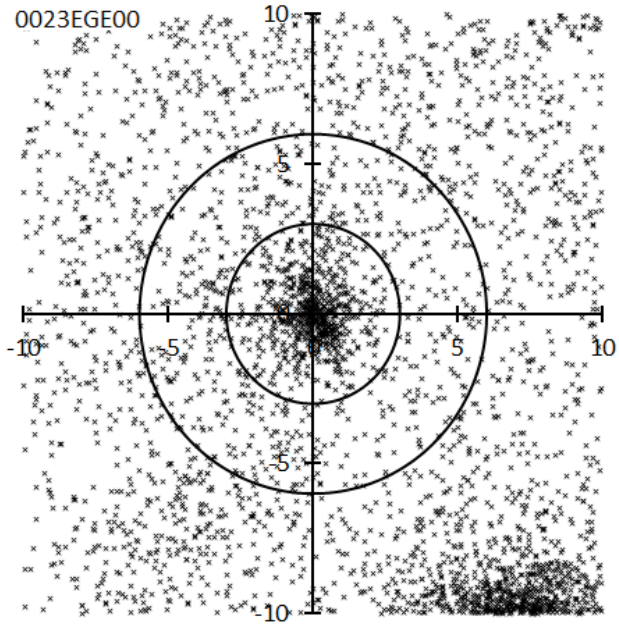

Figure 133 – Radiant point distribution map for the epsilon-Geminids.

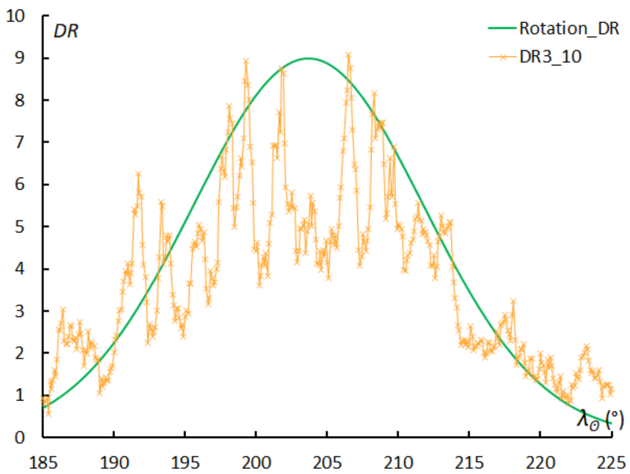

Figure 134 – Activity profile for the epsilon-Geminids.

Its existence has been known since the days when it was treated as a sub radiant point of the Orionids. The Orionids are at the bottom right of the radiant distribution, and there are many sporadic meteors around it (*Figure 133*). The activity profile fluctuates so much that the maximum could be anywhere from $\lambda_\odot = 198°$ to 208° (*Figure 134*). This is because activities vary greatly from year to year. The raw observed meteor counts (not *DR*) exhibit maximums in

2019 at $\lambda_\odot = 211.4°$, in 2020 at $\lambda_\odot = 205.6°$, in 2021 at $\lambda_\odot = 202.1°$, and in 2022 at $\lambda_\odot = 208.1°$, with an average of $\lambda_\odot = 211.4°$. The IAUMDCSD also has a range of $\lambda_\odot = 198°$ to 209.70°, and $\lambda_\odot = 203.7°$ shown in this paper (*Table 7* of Part I "Research methods and summary of survey results", see also *Table 5* in Part I, Koseki, 2024a) is also a reference value.

0022LMI: Leonis Minorids

$\lambda_\odot = 209.2°$, $\lambda - \lambda_\odot = 298.0°$, $\beta = 26.2°$,
$\alpha = 160.3°$, $\delta = 36.8°$, $v_g = 61.3$ km/s.

This is a meteor shower discovered through photographic observation using Super Schmidt at Harvard (McCrosky and Posen, 1959). Despite being active during the Orionids maximum, it is rarely detected visually. Although it borders the Apex region, surrounding meteor activity is low, making it a conspicuous meteor shower in photographic and video observations. CMOR radar observations[12] also capture weak but steady activity every year.

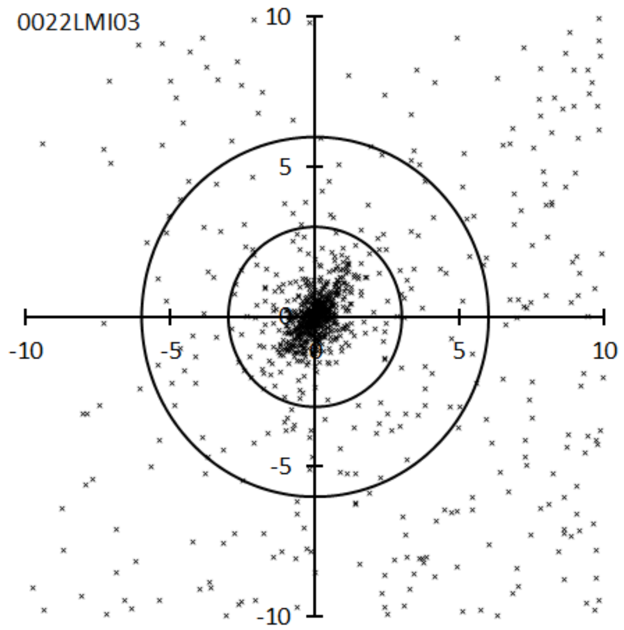

Figure 135 – Radiant point distribution map for the Leonis Minorids.

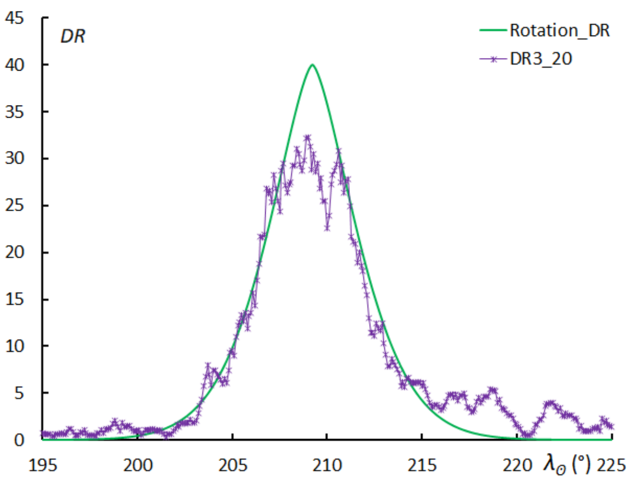

Figure 136 – Activity profile for the Leonis Minorids.

0480TCA_OML: tau-Cancrids_October mu-Leonids

$\lambda_\odot = 209.5°$, $\lambda - \lambda_\odot = 283.4°$, $\beta = 13.4°$,
$\alpha = 139.7°$, $\delta = 29.8°$, $v_g = 67.0$ km/s.

For details, as mentioned in Part II, "Meteor showers that need careful attention" (Koseki, 2024b), TCA and 0481OML are treated as one single activity. In the previous paper (Koseki, 2021), we only focused on TCA, but the activity profiles obtained in the previous and this paper are almost the same.

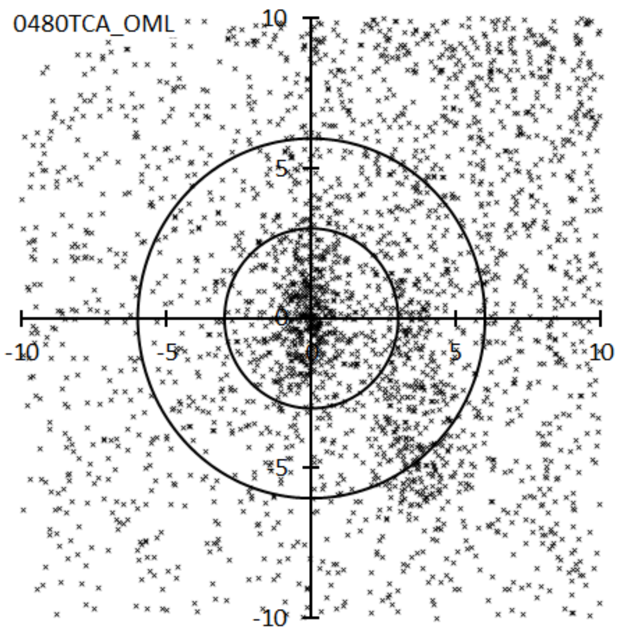

Figure 137 – Radiant point distribution map for the tau-Cancrids_October mu-Leonids.

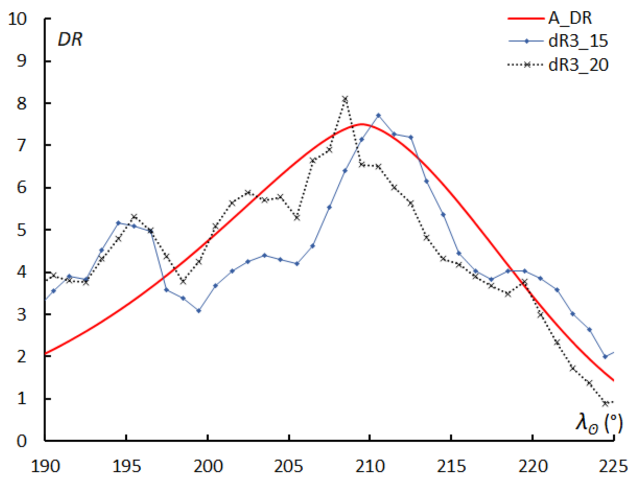

Figure 138 – Activity profile for the tau-Cancrids_October mu-Leonids.

0008ORI: Orionids

$\lambda_\odot = 209.5°$, $\lambda - \lambda_\odot = 246.6°$, $\beta = -7.5°$,
$\alpha = 96.3°$, $\delta = 15.8°$, $v_g = 65.5$ km/s.

In Part I, "Research methods and summary of survey results" (Koseki, 2024a), we gave a detailed explanation of the Orion group as an example, and in Part II, "Meteor showers that need careful attention" (Koseki, 2024b), we wrote about the "tail of Orionids" so please refer to those

[12] https://fireballs.ndc.nasa.gov/cmor-radiants/earth.html

as well. SonotaCo net observations include 2007–2009 (Koseki, 2021), when the Orion group was active, but the activity profile shown in *Figure 139* corresponds to the previous period 2010–2018 (normal year).

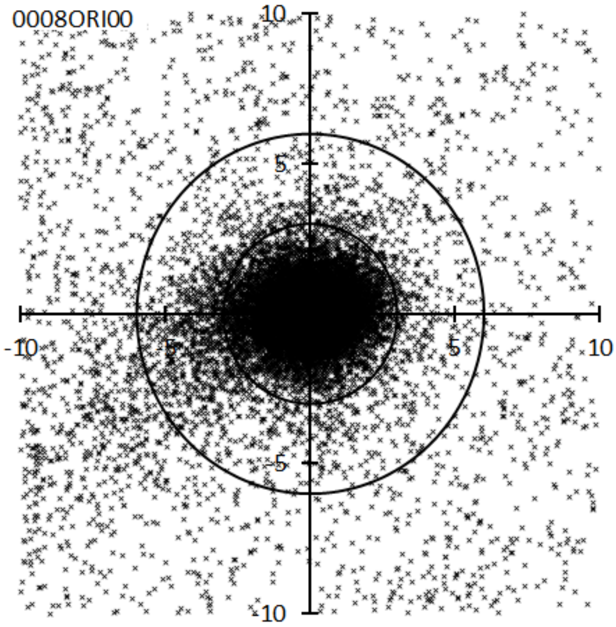

Figure 139 – Radiant point distribution map for the Orionids.

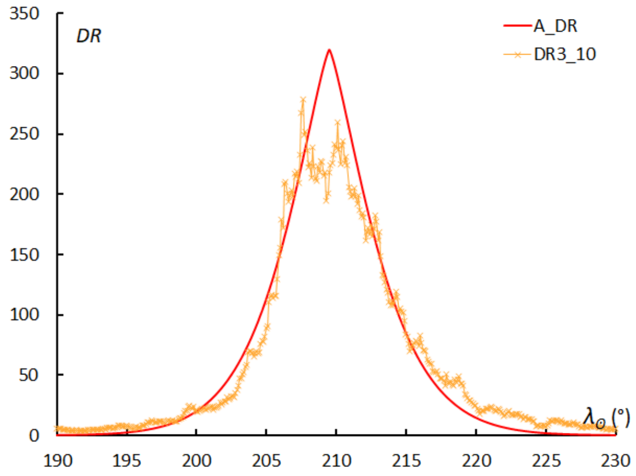

Figure 140 – Activity profile for the Orionids.

0524LUM: lambda-Ursae Majorids
$\lambda_\odot = 214.8°$, $\lambda–\lambda_\odot = 284.4°$, $\beta = 36.8°$,
$\alpha = 158.2°$, $\delta = 49.2°$, $v_g = 60.5$ km/s.

This activity was detected by combining observations from Croatia and SonotaCo net (Andreić et al., 2013). The orbit is such that the perihelion rotates along the ecliptic plane, and the radiant point of such meteor showers does not move much on the coordinates ($\lambda–\lambda_\odot$, β). Activity is stable every year, and the SonotaCo net J14 list and GMN's numbers match well.

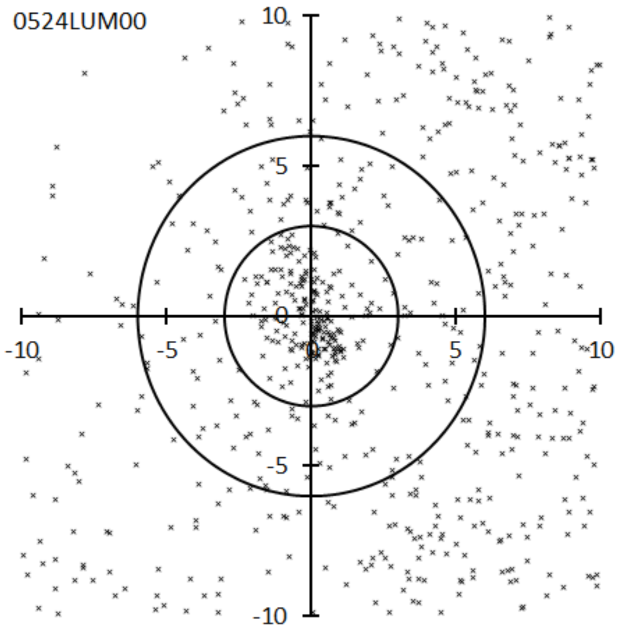

Figure 141 – Radiant point distribution map for the lambda-Ursae Majorids.

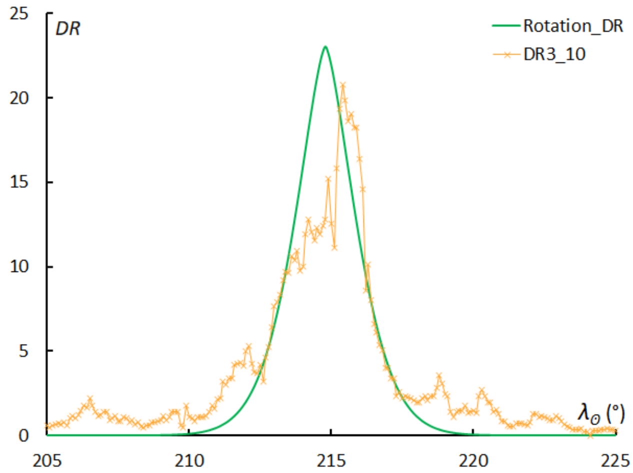

Figure 142 – Activity profile for the lambda-Ursae Majorids.

0526SLD: Southern lambda-Draconids
$\lambda_\odot = 221.5°$, $\lambda–\lambda_\odot = 265.2°$, $\beta = 53.5°$,
$\alpha = 161.6°$, $\delta = 68.0°$, $v_g = 48.9$ km/s.

Like 0524LUM, this activity was detected by combining observations from Croatia and SonotaCo net (Andreić et al., 2013). Although it is close to the active area of toroidal region such as 0387OKD and 0392NID, but LUM and SLD are not clearly seen in CMOR[13], and vice versa, OKD and NID are not clearly seen in the video. Although the orbit is similar both Jupiter family comet type, its plane intersects the ecliptic plane almost perpendicularly.

[13] https://fireballs.ndc.nasa.gov/cmor-radiants/earth.html

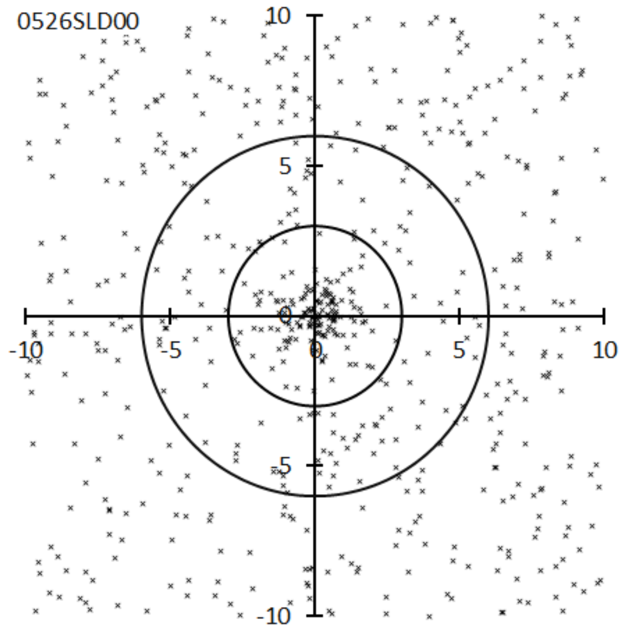

Figure 143 – Radiant point distribution map for the Southern lambda-Draconids.

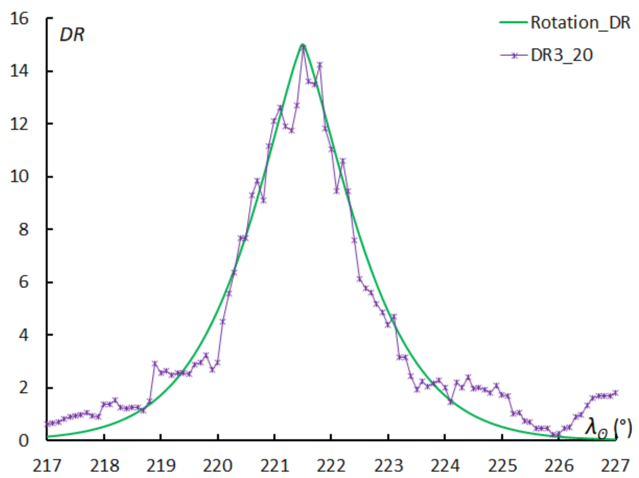

Figure 144 – Activity profile for the Southern lambda-Draconids.

0002STA_SF: Southern Taurids_SF

$\lambda_\odot = 222.2°$, $\lambda–\lambda_\odot = 192.3°$, $\beta = –4.5°$,
$\alpha = 53.2°$, $\delta = 14.5°$, $v_g = 28.5$ km/s.

We have discussed the details in Part II, "Meteor showers that need careful attention" (Koseki, 2024b) but we would like to reiterate that this is an activity that should be distinguished from STA_SE. In years when activity is strengthened, the number of meteors increases significantly. The radiant point distribution map in *Figure 145* and activity curve in *Figure 146* are mostly based on the activity in 2022, when the activity was enhanced.

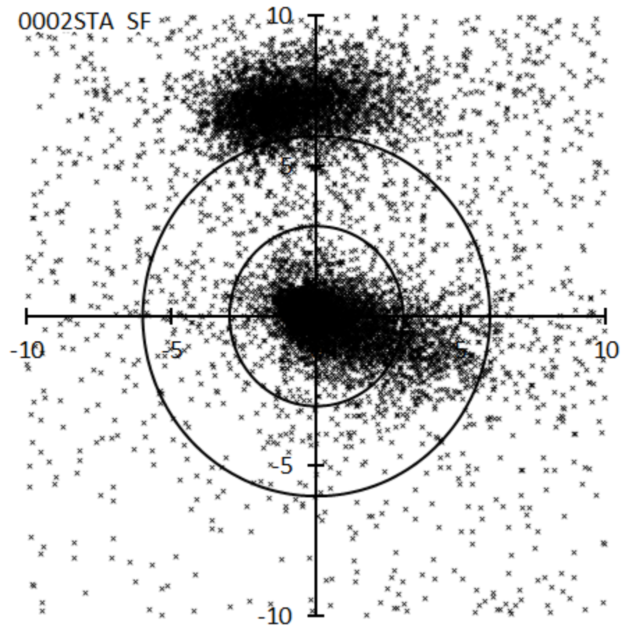

Figure 145 – Radiant point distribution map for the Southern Taurids_SF.

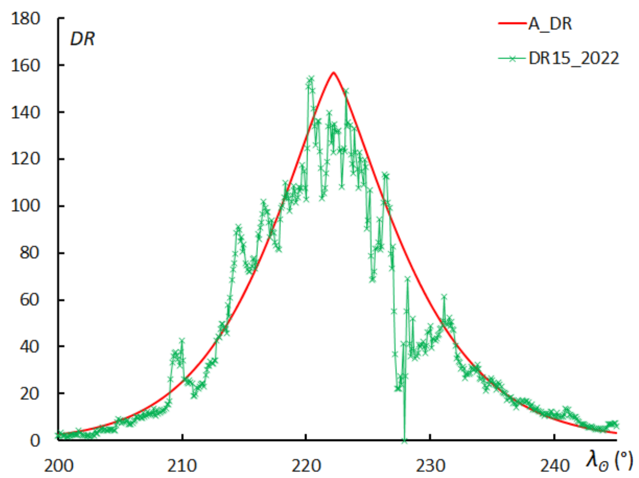

Figure 146 – Activity profile for the Southern Taurids_SF.

0445KUM: kappa-Ursae Majorids

$\lambda_\odot = 222.8°$, $\lambda–\lambda_\odot = 268.0°$, $\beta = 29.7°$,
$\alpha = 144.4°$, $\delta = 45.8°$, $v_g = 64.8$ km/s.

Although this meteor shower appeared in the first report of CAMS (Jenniskens et al, 2016a), there are no other reports in IAUMDCSD. Activities are stable every year, and the SonotaCo net J14 list and GMN list match well. It intersects the Earth's orbit almost at perihelion, and its orbital inclination is high, so its activity period is short.

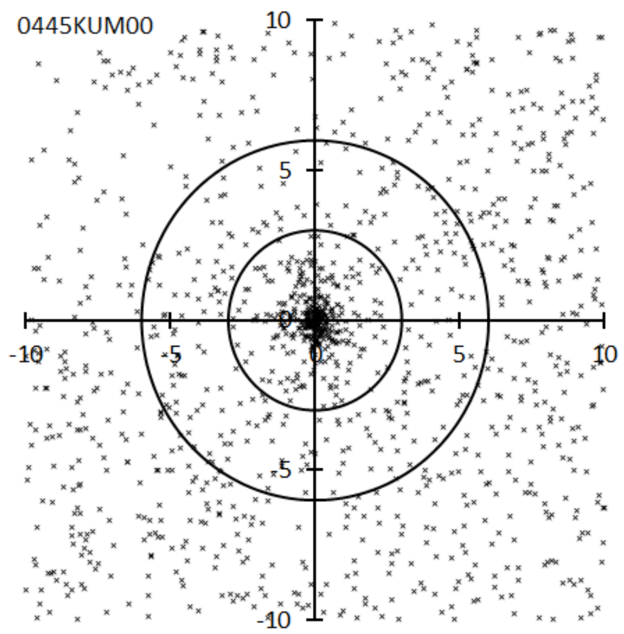

Figure 147 – Radiant point distribution map for the kappa-Ursae Majorids.

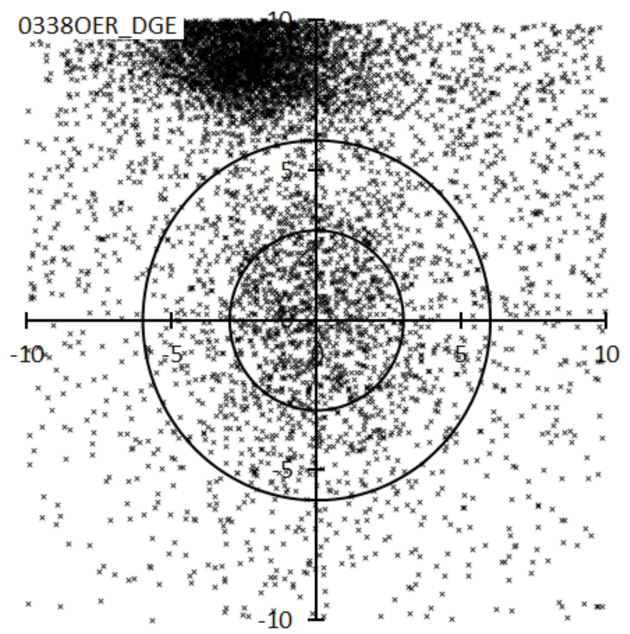

Figure 149 – Radiant point distribution map for the omicron-Eridanids_ December delta-Eridanids.

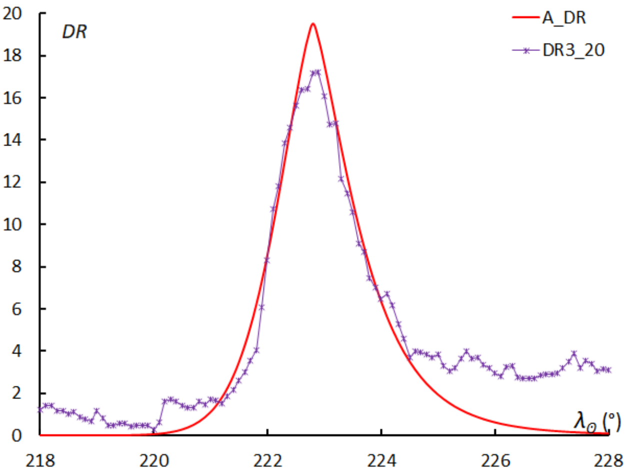

Figure 148 – Activity profile for the kappa-Ursae Majorids.

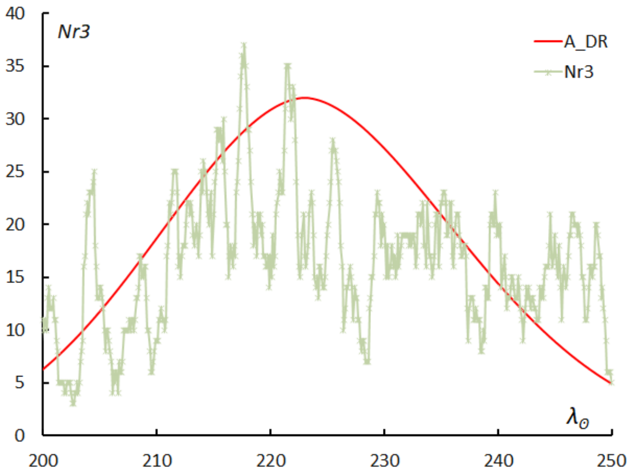

Figure 150 – Activity profile for the omicron-Eridanids_ December delta-Eridanids.

0338OER_DGE: omicron-Eridanids_ December delta-Eridanids

$\lambda_\Theta = 223°$, $\lambda–\lambda_\Theta = 187.1°$, $\beta = –18.7°$,
$\alpha = 52.6°$, $\delta = –0.3°$, $v_g = 28.7$ km/s.

0338OER00 was discovered by SonotaCo net (SonotaCo, 2009), and 0490DGE00 was detected by combining SonotaCo net and CAMS data (Rudawska, and Jenniskens, 2014). 0338OER appears to move its radiant point from the southern end of STA, as if branching out (*Figure 149*, top left is STA), and connect with 0490DGE01. After that, even weaker activity seems to extend southward, leading to 0709LCM. As mentioned in detail in Part II, "Meteor showers that need careful attention" (Koseki, 2024b), 0490DGE00 is part of this weak activity moving southward. DGE01 appears in the first report of CAMS (Jenniskens and Nénon, 2016c). Here we will only integrate OER and DGE, but this also includes 1115NXE00. Like the radiant distribution, the activity curve is unclear, and the maximum can only be seen in the range of $\lambda_\Theta = 215°\sim235°$ (*Figure 150*).

0018AND: Andromedids

$\lambda_\Theta = 224.5°$, $\lambda–\lambda_\Theta = 165.9°$, $\beta = 18.2°$,
$\alpha = 21.2°$, $\delta = 28.5°$, $v_g = 18.1$ km/s.

The Andromedids had an outburst in 2021, but its maximum was $\lambda_\Theta = 245.8°$, a time when no activity is observed in normal years. However, the position of the radiant point at the time of a sudden event corresponds exactly to the extension of the radiant point shift in normal years (Koseki, 2022a). *Table 7* in Part I (Koseki, 2024a) does not list the radiant points, etc. at the time of the outburst, so they are listed here: $\lambda_\Theta = 245.8°$, $\lambda–\lambda_\Theta = 155.0°$, $\beta = 30.4°$, $\alpha = 25.9°$, $\delta = = 43.5°$, $v_g = 15.4$ km/s, $e = 0.705$, $q = 0.864$ A.U., $i = 12.3°$, $\omega = 225.5°$, $\Omega = 245.8°$, $\lambda_\Pi = 110.7°$, $\beta_\Pi = –8.7°$, $a = 2.93$ A.U. Even in normal years, the activity profile is uneven, indicating that the distribution of meteoroids in orbit is uneven. The outburst in 2021 is probably an extreme example of a normal year activity. The SonotaCo net J14 list gives the active period as $\lambda_\Theta = 231.79°\sim232.48°$, but the Andromedids are active for a much longer period. It is characteristic that the radiant point moves northward at a fairly high speed.

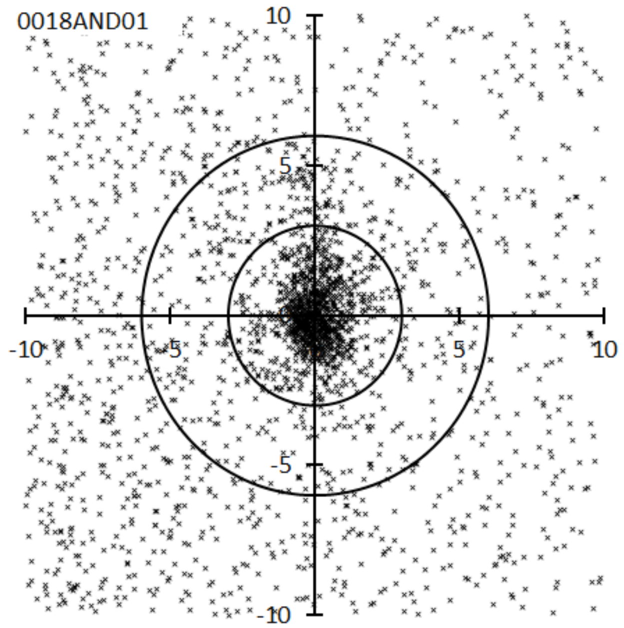

Figure 151 – Radiant point distribution map for the Andromedids.

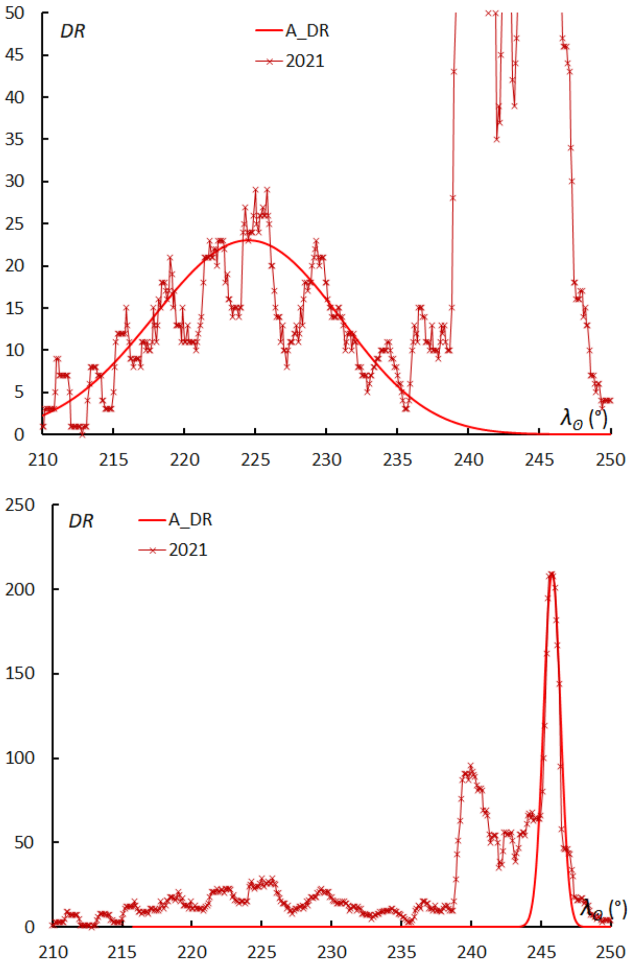

Figure 152 – Activity profile for the Andromedids, top, the usual annual activity, bottom with a *DR* scale to fit the 2021 peak.

0512RPU: rho-Puppids

$\lambda_{\odot} = 226.2°$, $\lambda\text{–}\lambda_{\odot} = 269.6°$, $\beta = –43.5°$,
$\alpha = 125.1°$, $\delta = –25.5°$, $v_g = 57.5$ km/s.

This is also an activity detected by combining observations from Croatia and the SonotaCo net (Šegon et al., 2013). The spread of the radiant points is somewhat large (*Figure 153*), and the activity curve is also uneven (*Figure 154*). It also appears that the maxima in 2021 and 2022 are different. The reason why the information obtained is ambiguous is because the period of activity is rather long, so the number of meteors per day is small compared to the total observed number of shower meteors.

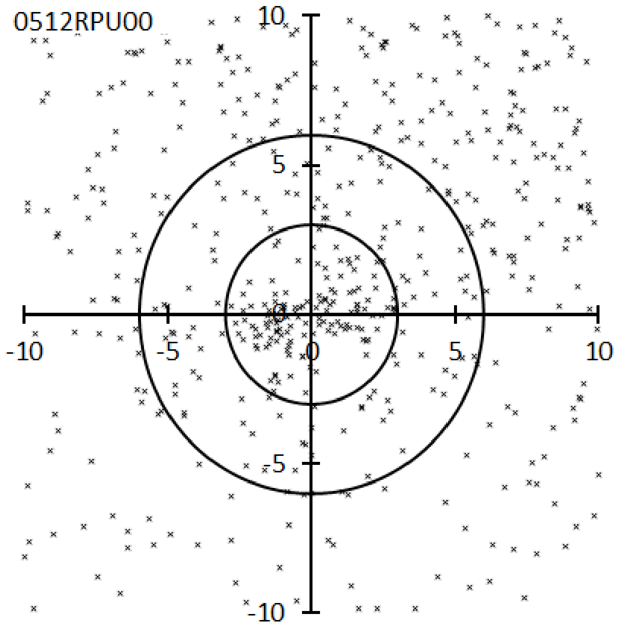

Figure 153 – Radiant point distribution map for the rho-Puppids.

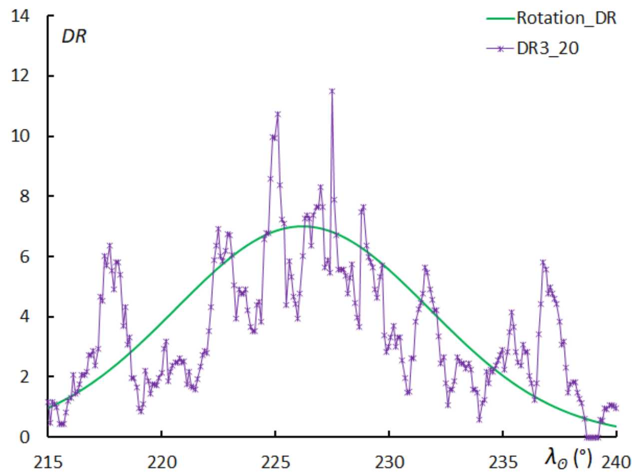

Figure 154 – Activity profile for the rho-Puppids.

0017NTA: Northern Taurids

$\lambda_{\odot} = 226.5°$, $\lambda\text{–}\lambda_{\odot} = 192.1°$, $\beta = 2.4°$,
$\alpha = 55.8°$, $\delta = 22.2°$, $v_g = 28.3$ km/s.

As mentioned in detail in Part II, "Meteor showers that need careful attention" (Koseki, 2024b) GMN subdivides NTA. Judging from the radiant distribution and activity profile in *Figures 155 and 156*, it is better to treat it as a single meteor shower activity. The dip in the activity profile around $\lambda_{\odot} = 227.5°$ seems to be due to poor observation conditions for GMN in 2022 and is thought to be a sham.

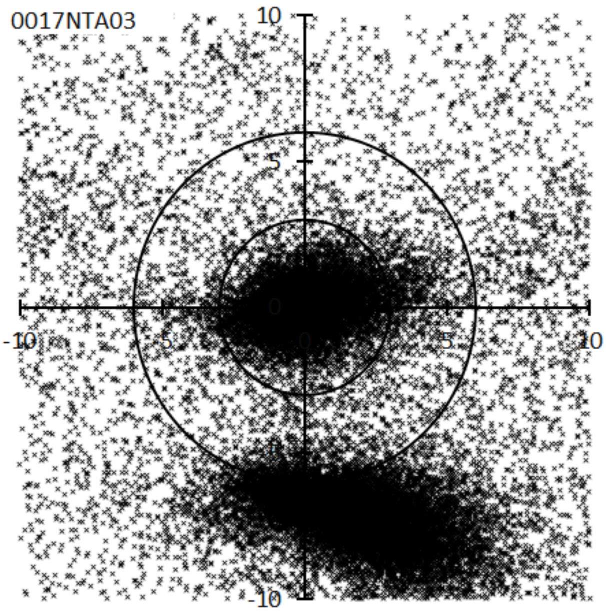

Figure 155 – Radiant point distribution map for the Northern Taurids.

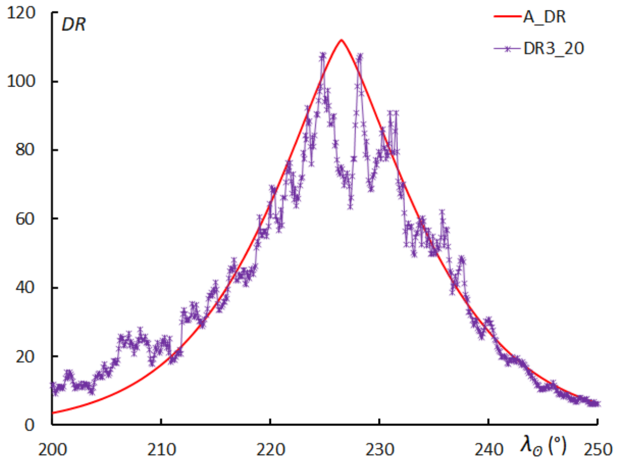

Figure 156 – Activity profile for the Northern Taurids.

0013LEO: Leonids

$\lambda_{\odot} = 235.4°$, $\lambda\text{–}\lambda_{\odot} = 272.5°$, $\beta = 10.3°$,
$\alpha = 153.9°$, $\delta = 21.8°$, $v_g = 69.7$ km/s.

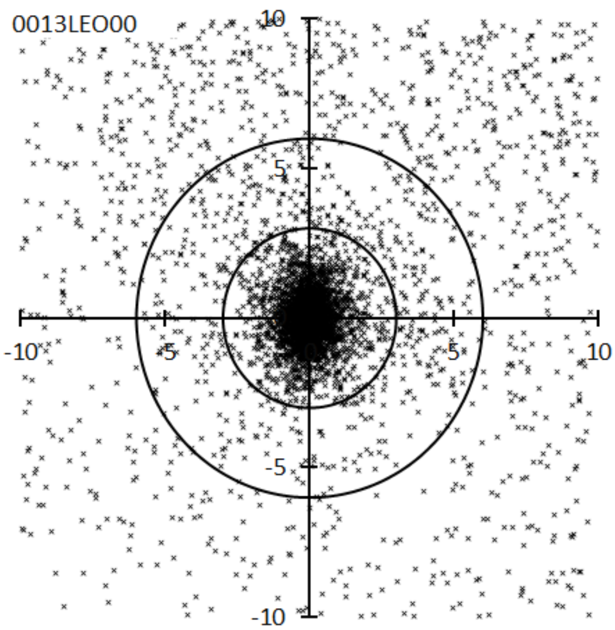

Figure 157 – Radiant point distribution map for the Leonids.

In the activity profile, the peak at $\lambda_{\odot} = 229°$ is a phenomenon unique to 2021, and the peak at $\lambda_{\odot} = 239°$ is a phenomenon unique to *DR3_10*, which does not appear in other years or in other estimated curves. Overall, the trend appears to be roughly along the Rotation_*DR* curve.

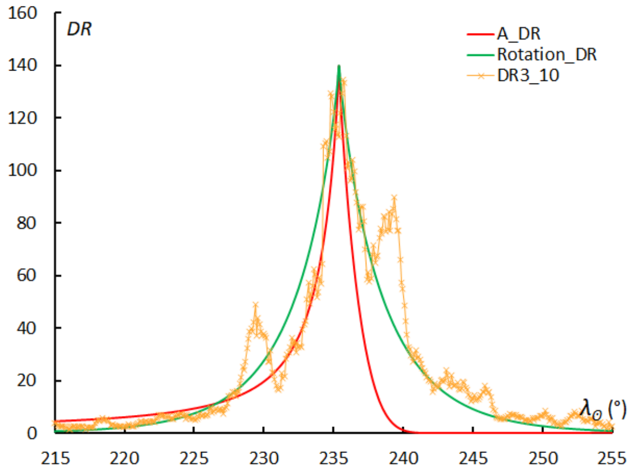

Figure 158 – Activity profile for the Leonids.

0394ACA: alpha-Canis Majorids

$\lambda_{\odot} = 239.5°$, $\lambda\text{–}\lambda_{\odot} = 216.8°$, $\beta = -41.8°$,
$\alpha = 95.0°$, $\delta = -18.5°$, $v_g = 43.7$ km/s.

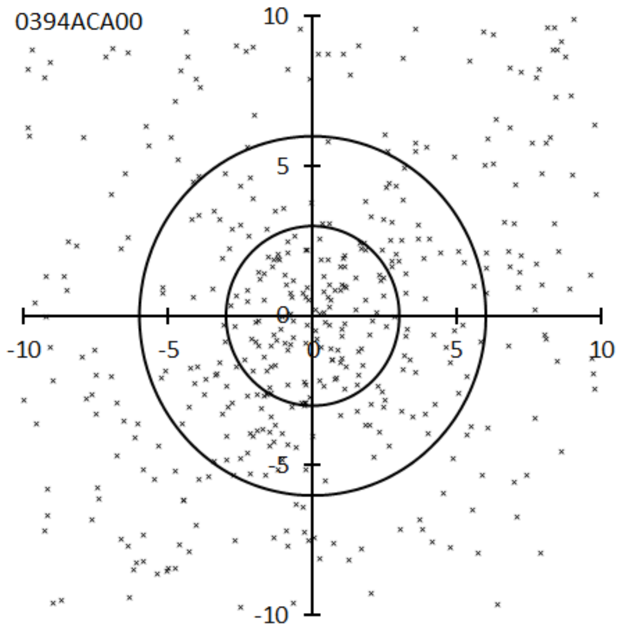

Figure 159 – Radiant point distribution map for the alpha-Canis Majorids.

This activity was detected by radar observation by CMOR2 (Brown et al., 2010). It was not mentioned in the previous article (Koseki, 2021) and is not on the SonotaCo net J14 list. In the radiant distribution, 0559MCB00 is on the lower left side of a circle with a radius of 3 degrees, and 0395GCM00 is on the upper right side of the circle. GCM is an observation of CMOR2 (Brown et al., 2010), but the radiant point distribution extends from the bottom left to the top right, so both MCB and GCM can be considered part of the ACA activity.

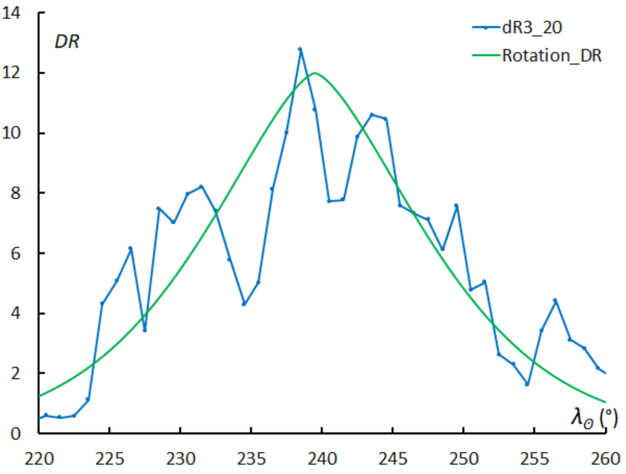

Figure 160 – Activity profile for the alpha-Canis Majorids.

0246AMO: alpha-Monocerotids

$\lambda_\odot = 239.6°$, $\lambda–\lambda_\odot = 239.5°$, $\beta = –19.9°$,
$\alpha = 117.2°$, $\delta = 0.8°$, $v_g = 61.7$ km/s.

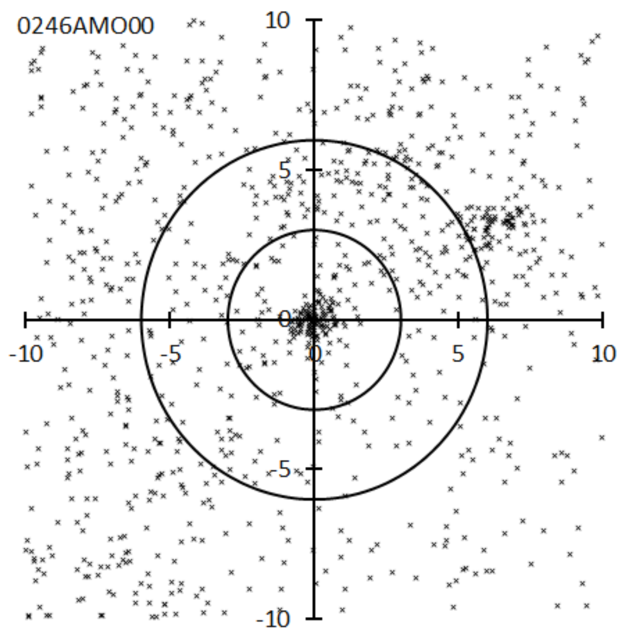

Figure 161 – Radiant point distribution map for the alpha-Monocerotids.

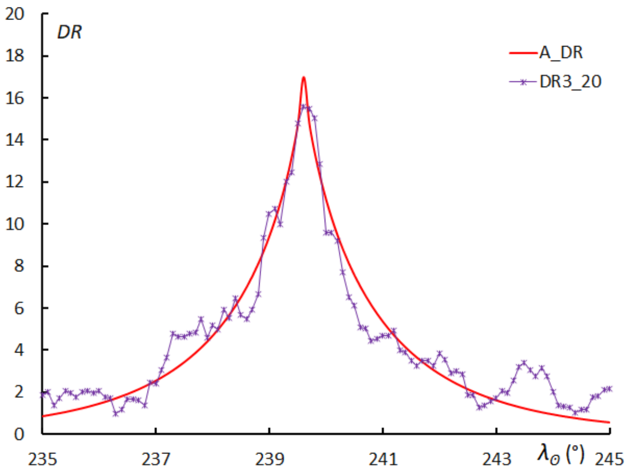

Figure 162 – Activity profile for the alpha-Monocerotids.

After its sudden appearance in the United States in 1925 and India in 1935, AMO was not recorded in photographs or radio observations in the 1950s and 1960s and was not detected until it was observed in the United States in 1985; the detailed history is written by Jenniskens (2006) and Kronk (2013). After that, a sudden outbreak was seen in 1995 (Jenniskens et al., 1997), and a 10-year cycle of activity was expected, but since then no activity has been seen as expected. However, the widespread use of video observations has revealed that AMO activity is observed every year, albeit in small numbers. IAUMDCSD annotates the first photo observation report of AMO by DMS as "*No reference*", but it should be supplemented with appropriate materials[14] and classified as AMO00. AMO's orbit has a period of several decades or more, and the 10-year period appears to be spurious due to the approach of the trail.

0488NSU: November sigma-Ursae Majorids

$\lambda_\odot = 241.7°$, $\lambda–\lambda_\odot = 245.1°$, $\beta = 43.2°$,
$\alpha = 148.9°$, $\delta = 59.4°$, $v_g = 54.4$ km/s.

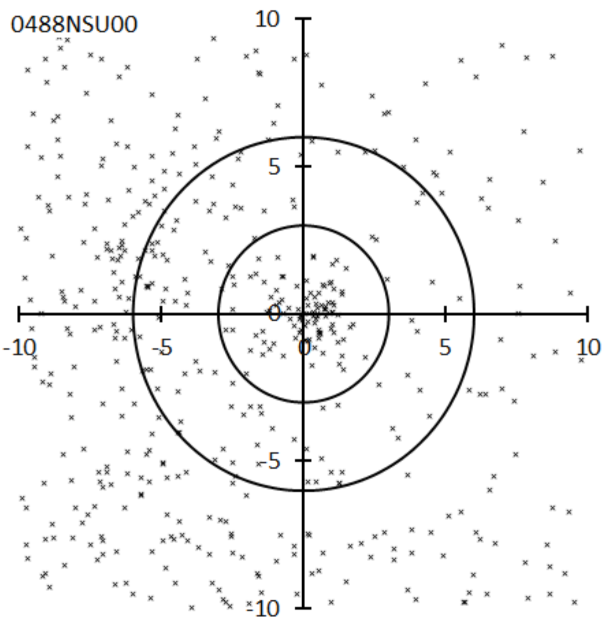

Figure 163 – Radiant point distribution map for the November sigma-Ursae Majorids.

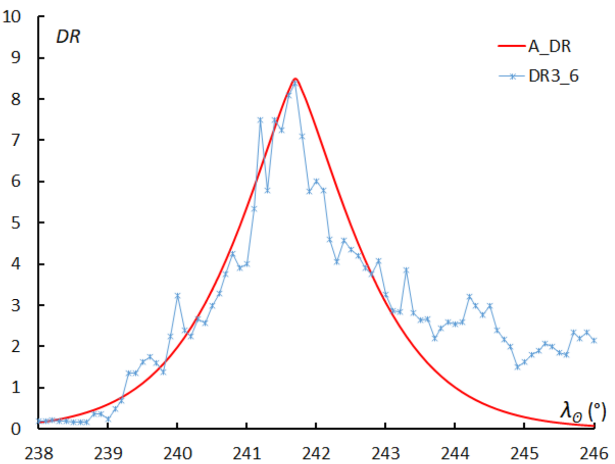

Figure 164 – Activity profile for the November sigma-Ursae Majorids.

[14] https://www.dutch-meteor-society.nl/meteor-databases/ or https://ceres.ta3.sk/iaumdcdb/home/catalog/photo

This meteor shower was detected by combining SonotaCo net and CAMS data (Rudawska and Jenniskens, 2014). Although the period of activity is short, the radiant points are well clustered and show stable activity every year. 0527UUM00 should be included in NSU.

0250NOO: November Orionids

$\lambda_\odot = 246.1°$, $\lambda–\lambda_\odot = 204.0°$, $\beta = –7.9°$,
$\alpha = 90.1°$, $\delta = 15.5°$, $v_g = 42.9$ km/s.

0019MON appears in the lower left of *Figure 165*. This activity has been known since the days of visual and photographic observation, and was sometimes collectively referred to as the "Monocerotids" together with the MON (Sekanina, 1976). It seems that NOO and MON began to be clearly distinguished after Jenniskens's famous book (Jenniskens, 2006). The activity profile is asymmetric, with a faster decline in the second half.

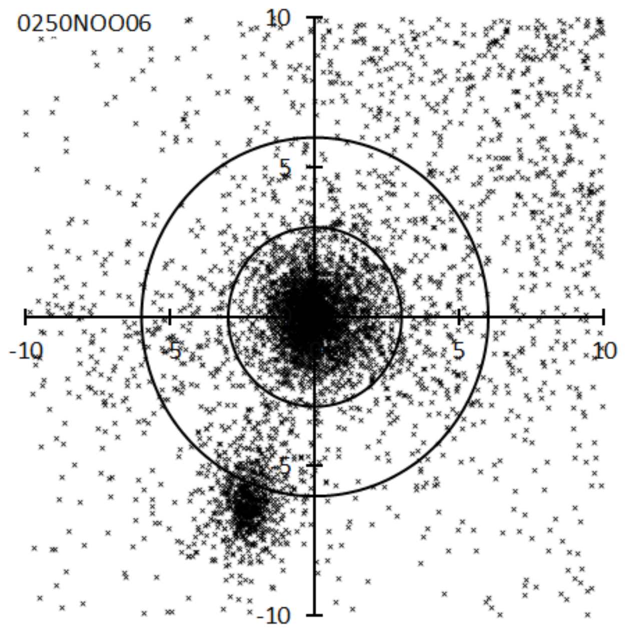

Figure 165 – Radiant point distribution map for the November Orionids.

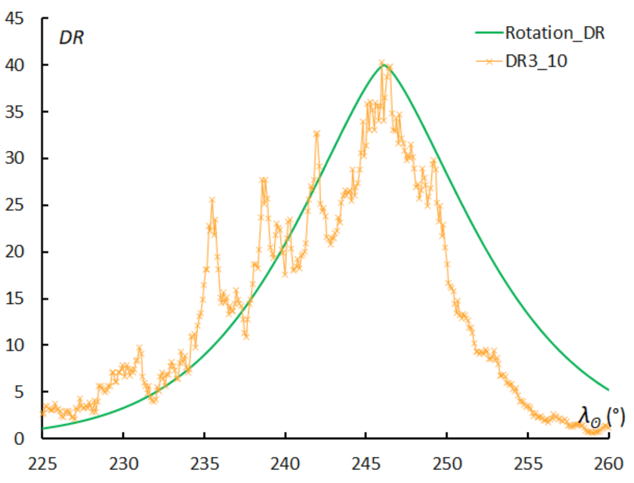

Figure 166 – Activity profile for the November Orionids.

0257ORS: Southern chi-Orionids

$\lambda_\odot = 246.2°$, $\lambda–\lambda_\odot = 190.1°$, $\beta = –4.7°$,
$\alpha = 75.6°$, $\delta = 18.0°$, $v_g = 27.4$ km/s.

Although the current IAUMDCSD number is missing, the classification 0014XOR (χ-Orionids) has existed since the Harvard photographic observation. Since Lindblad's survey of the meteor shower, it has been divided into northern and southern branches (Lindblad, 1971), and Jenniskens gave them the codes 0256ORN and 0257ORS (Jenniskens, 2006). ORS is barely distinguishable from STA, as seen in the radiant distribution and activity profile in *Figures 167 and 168*, but ORN has not been confirmed. In the J14 list of SonotaCo net, it is treated as part of STA, and in GMN, the end of its activities is considered as long as $\lambda_\odot = 275.2°$.

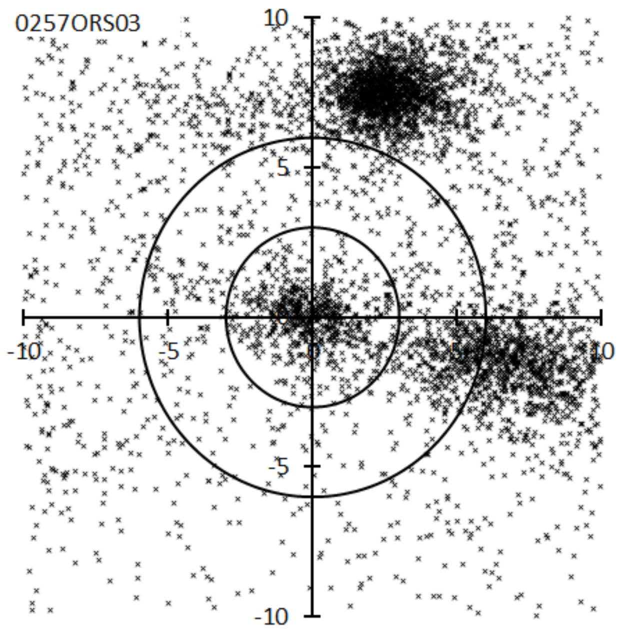

Figure 167 – Radiant point distribution map for the Southern chi-Orionids.

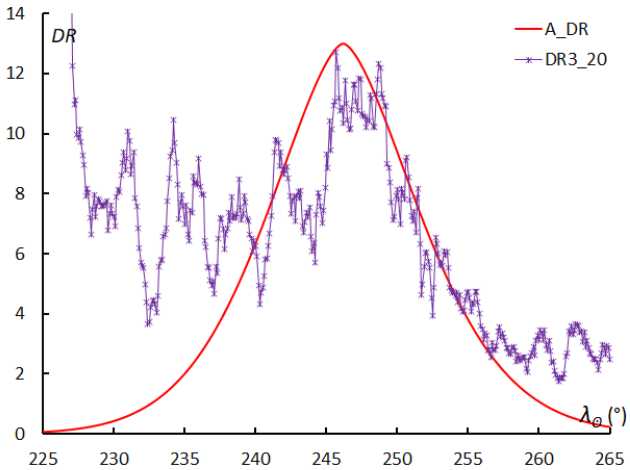

Figure 168 – Activity profile for the Southern chi-Orionids.

1096NAC: November alpha-Corvids

$\lambda_\odot = 246.5°$, $\lambda–\lambda_\odot = 286.2°$, $\beta = –20.5°$,
$\alpha = 165.0°$, $\delta = –16.0°$, $v_g = 66.6$ km/s.

This is a new meteor shower appearing for the first time in IAMDCSD with the third CAMS report (mentioned '2022 submitted' in the IAUMDCSD). Naturally, it was not mentioned in the previous article (Koseki, 2021), and it is not on SonotaCo net J14 list or GMN. The upper right of the radiant distribution is the Apex region (*Figure 169*), and NAC can barely be distinguished from its activity.

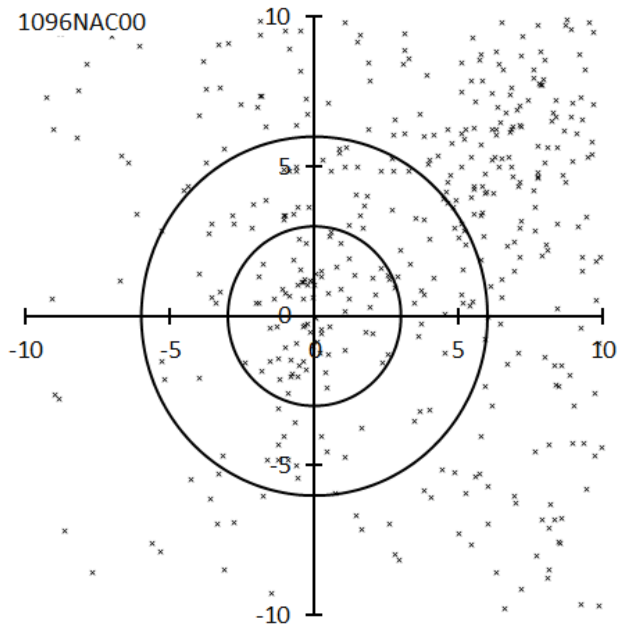

Figure 169 – Radiant point distribution map for the November alpha-Corvids.

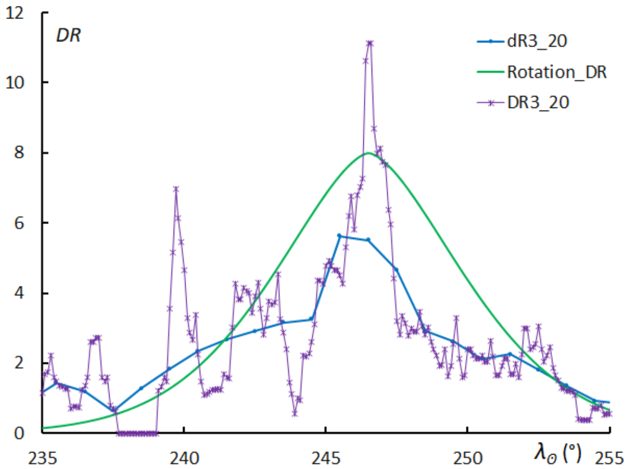

Figure 170 – Activity profile for the November alpha-Corvids.

0340TPY_0: theta-Pyxidids

$\lambda_{\odot} = 249.4°$, $\lambda\text{–}\lambda_{\odot} = 261.2°$, $\beta = –39.3°$,
$\alpha = 138.3°$, $\delta = –25.5°$, $v_g = 60.1$ km/s.

The group was detected by the SonotaCo network (SonotaCo, 2009), but as detailed in Part II, "Meteor showers that need careful attention" (Koseki, 2024b), there is confusion at IAUMDCSD, and two activities are in TPY. Here, they are distinguished as TPY_0 and TPY_1. It should be noted that GMN considers this activity to be DTP.

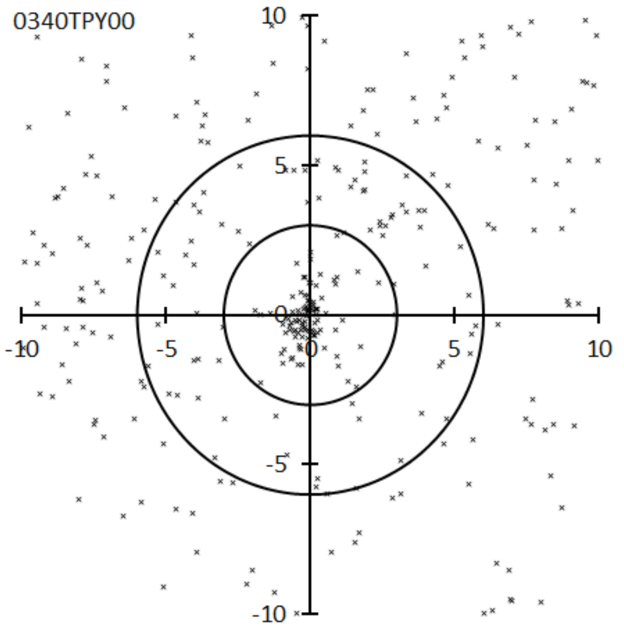

Figure 171 – Radiant point distribution map for the theta-Pyxidids.

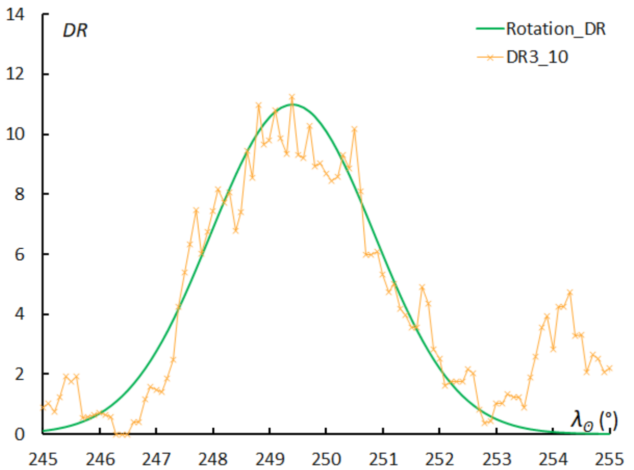

Figure 172 – Activity profile for the theta-Pyxidids.

0336DKD: December kappa-Draconids

$\lambda_{\odot} = 251°$, $\lambda\text{–}\lambda_{\odot} = 243.0°$, $\beta = 61.5°$,
$\alpha = 186.1°$, $\delta = 70.5°$, $v_g = 43.8$ km/s.

DKD was detected by SonotaCo net observations (SonotaCo, 2009). This activity was originally listed as KDR when it was published in WGN, but IAUMDCSD gave the CMOR2 observation (Brown et al., 2010) the name 0380KDR and designated this activity as 0336DKD. It should be noted that the J14 of the SonotaCo net remains KDR.

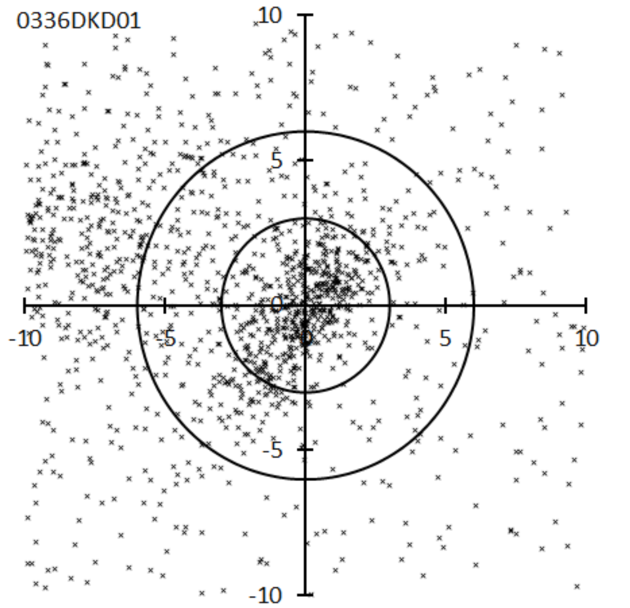

Figure 173 – Radiant point distribution map for the December kappa-Draconids.

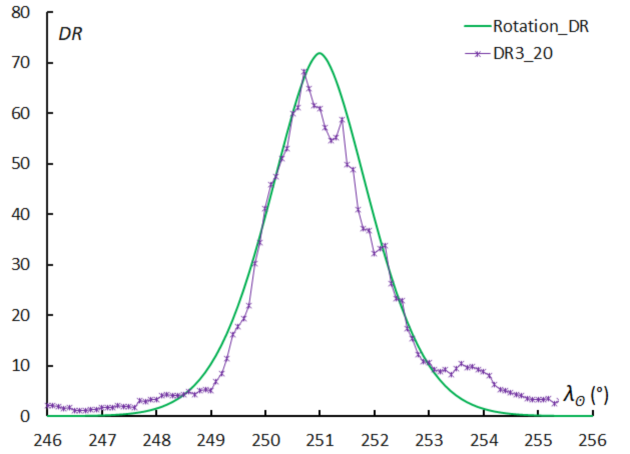

Figure 174 – Activity profile for the December kappa-Draconids.

0339PSU: psi-Ursae Majorids

$\lambda_\odot = 251.5°$, $\lambda–\lambda_\odot = 258.0°$, $\beta = 35.6°$,
$\alpha = 168.1°$, $\delta = 44.2°$, $v_g = 60.9$ km/s.

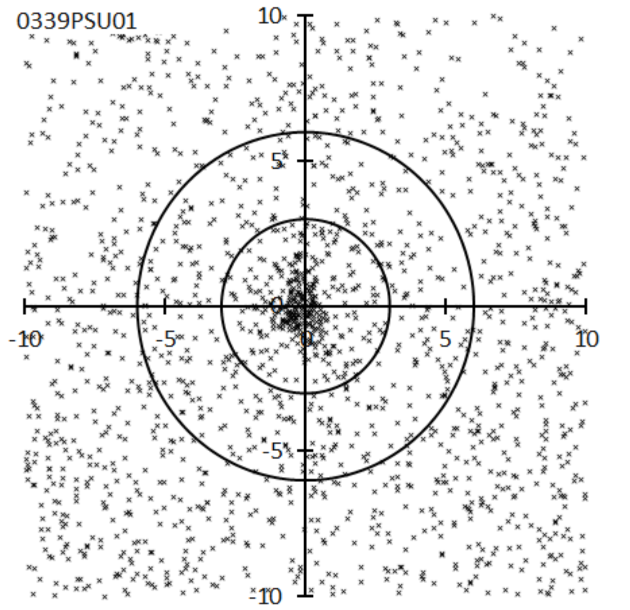

Figure 175 – Radiant point distribution map for the psi-Ursae Majorids.

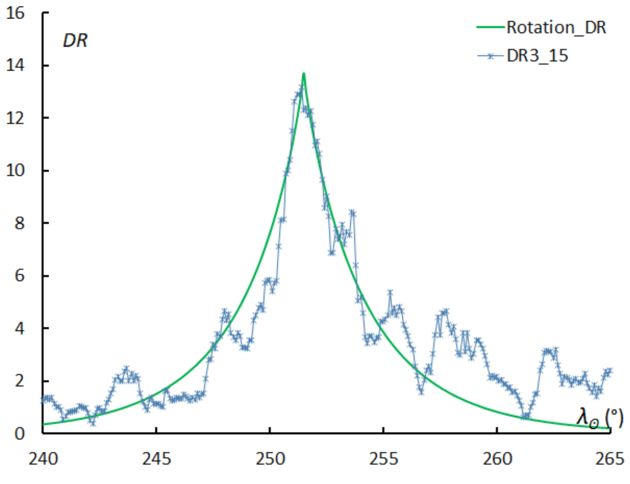

Figure 176 – Activity profile for the psi-Ursae Majorids.

This is also an activity detected by SonotaCo net observations (SonotaCo, 2009). GMN typically observed more meteors in 2022 than in 2021, but the number of PSU meteors in 2021 is 1.6 times that of 2022. Similarly, the SonotaCo net observations used in the previous paper showed large fluctuations in activity from year to year (Koseki, 2021), and whether there is any periodicity is a point of interest for future observations.

0334DAD: December alpha-Draconids

$\lambda_\odot = 253.5°$, $\lambda–\lambda_\odot = 264.2°$, $\beta = 62.7°$,
$\alpha = 204.6°$, $\delta = 62.2°$, $v_g = 40.6$ km/s.

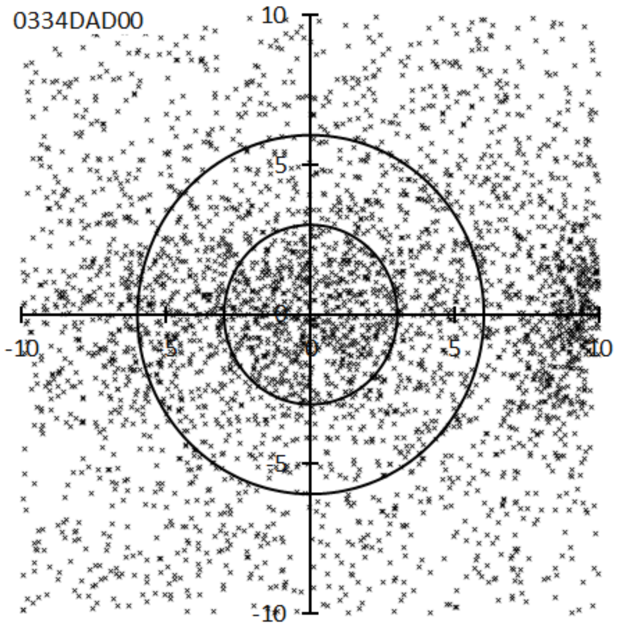

Figure 177 – Radiant point distribution map for the December alpha-Draconids.

This activity was also first detected by SonotaCo net (SonotaCo, 2009). The radiant points are spreading, and the activity profile is also widening. In the radiant distribution in *Figure 177*, 0392NID01 is on the left inner side of the circle with a radius of 3 degrees, and 0392NID00 is on the slightly outer left side of the circle with a radius of 6 degrees. NID is considered a "to be established shower" by IAUMDCSD, but there is room for consideration. If the radiant shift is not considered, DAD03 and 0753NED00 will be sandwiched between NID00 and NID01. There are many unknowns about DAD's activities, and it may be broken down into several parts.

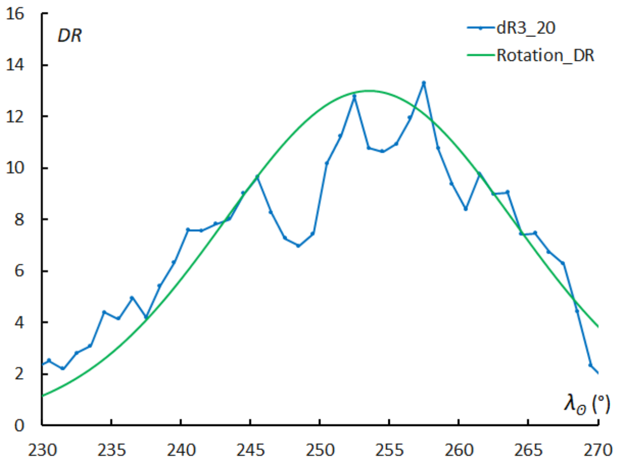

Figure 178 – Activity profile for the December alpha-Draconids.

0016HYD: sigma-Hydrids

$\lambda_O = 255.4°$, $\lambda–\lambda_O = 231.0°$, $\beta = –16.5°$,
$\alpha = 124.7°$, $\delta = 2.7°$, $v_g = 58.8$ km/s.

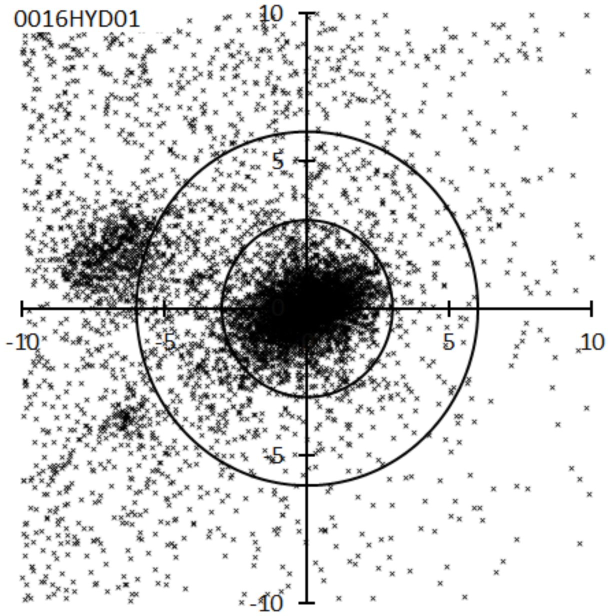

Figure 179 – Radiant point distribution map for the sigma-Hydrids.

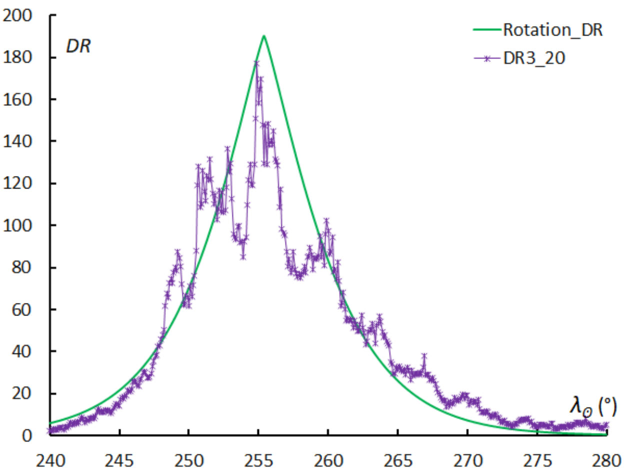

Figure 180 – Activity profile for the sigma-Hydrids.

Despite its radiant distribution and activity profile are very clear, it was unknown until it was detected in photographic observations at Harvard (McCrosky and Posen, 1961). The earliest visual observation of NMS (The Nippon Meteor Society) was in 1961 (Koseki, 1971). The magnitude ratio is not particularly low (Koseki, 2023), so it is not a meteor shower suitable for photography or video. According to visual observations, this level of activity corresponds to HR=1–2, which means visual observers will miss it if they are not careful.

0502DRV: December rho-Virginids

$\lambda_O = 255.6°$, $\lambda–\lambda_O = 286.0°$, $\beta = 15.0°$,
$\alpha = 187.5°$, $\delta = 13.1°$, $v_g = 68.2$ km/s.

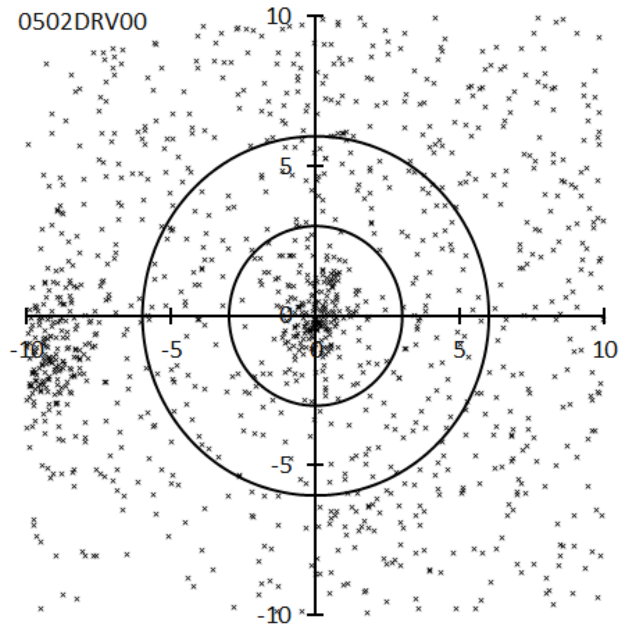

Figure 181 – Radiant point distribution map for the December rho-Virginids.

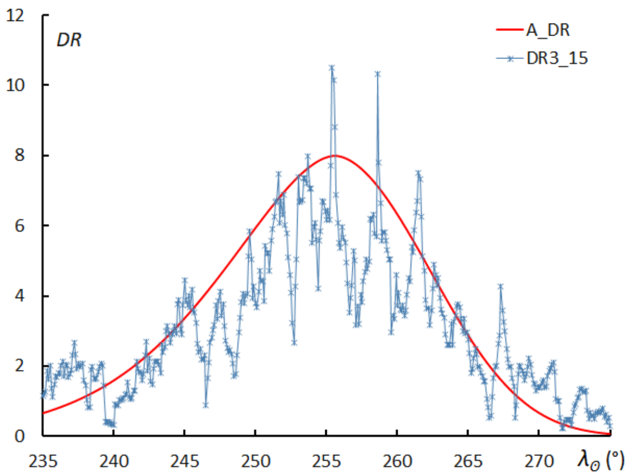

Figure 182 – Activity profile for the December rho-Virginids.

This meteor shower was detected by combining SonotaCo net and CAMS data (Rudawska and Jenniskens, 2014). 1116NFL00 should be included in DRV. The period of activity for this meteor shower is shorter in the SonotaCo net J14 list, and longer in GMN.

0529EHY: eta-Hydrids

$\lambda_\odot = 256.2°$, $\lambda - \lambda_\odot = 237.8°$, $\beta = -14.8°$,
$\alpha = 132.2°$, $\delta = 2.4°$, $v_g = 62.1$ km/s.

This is also an activity detected by combining the SonotaCo net and Croatian observations (Šegon et al., 2013). Looking at the number of meteors themselves, the maxima in 2021 and 2022 are $\lambda_\odot = 252.3°$ and $\lambda_\odot = 263.3°$, respectively, a difference of 10 degrees. This is probably due to differences in observation conditions, not changes in activity itself. However, even in the observation of the SonotaCo net used in the previous paper (Koseki, 2021), the maximum is not clear, and it would be better to think of the maximum as being in the range of $\lambda_\odot = 255°$ to 265°.

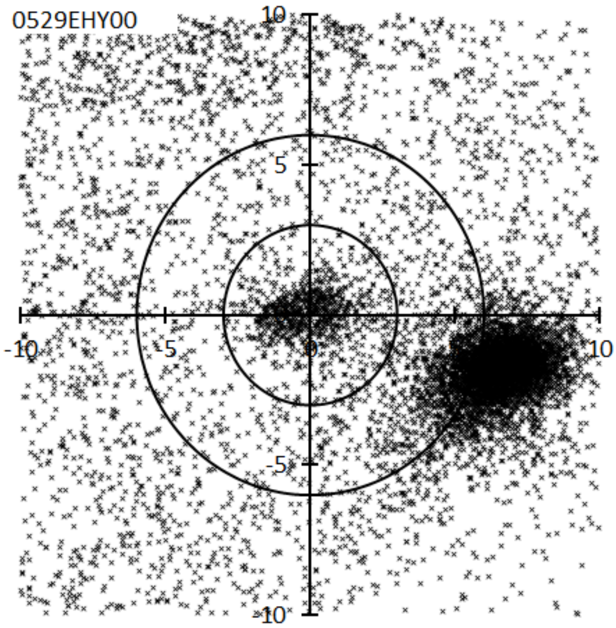

Figure 183 – Radiant point distribution map for the eta-Hydrids.

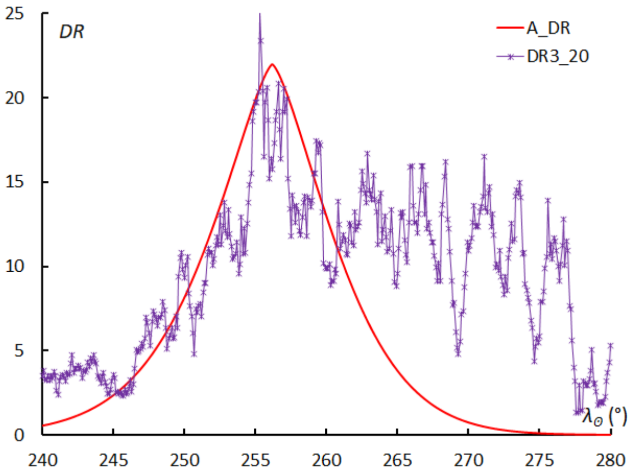

Figure 184 – Activity profile for the eta-Hydrids.

0255PUV: Puppid-Velid I Complex

$\lambda_\odot = 256.5°$, $\lambda - \lambda_\odot = 268.3°$, $\beta = -61.6°$,
$\alpha = 134.7°$, $\delta = -49.2°$, $v_g = 41.6$ km/s.

During this period, the following activities are expected in this area: 0255PUV, 0300ZPU, 0301PUP00, 0302PVE00, and 0746EVE00. As seen in the radiant distribution in *Figure 185*, the radiants are diffuse and the location is difficult to observe from the Northern Hemisphere, so future observations from the Southern Hemisphere are expected. When they will develop successfully, there may be a debate as to whether the name PUV is appropriate. PUV was set by Jenniskens from visual observations in the Southern Hemisphere (Jenniskens, 2006), but IAUMDCSD has made it a candidate for deletion due to insufficient data. Although it was not mentioned in the previous article (Koseki, 2021), it is listed as EVE in the SonotaCo net J14 list and in GMN.

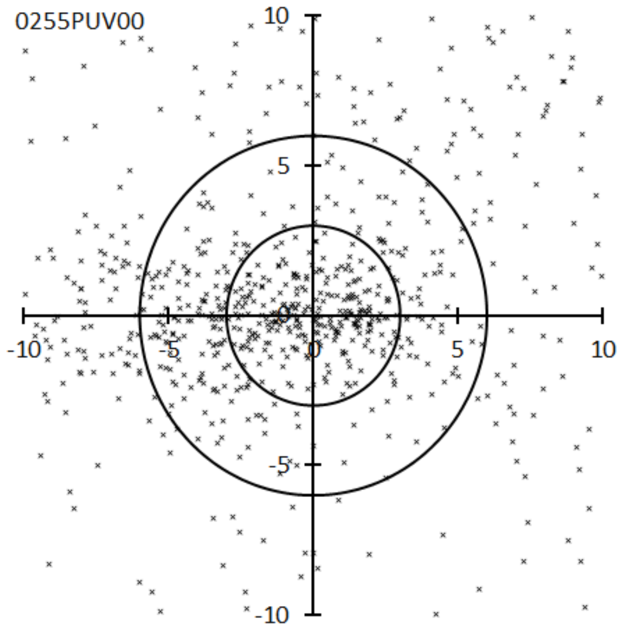

Figure 185 – Radiant point distribution map for the Puppid-Velid I Complex.

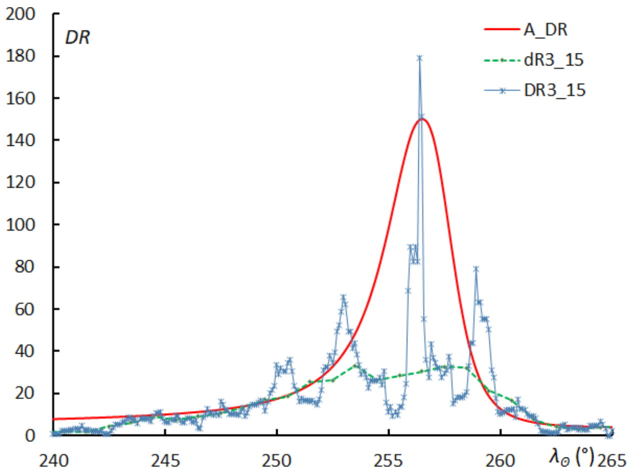

Figure 186 – Activity profile for the Puppid-Velid I Complex.

0019MON: December Monocerotids

$\lambda_\odot = 258.1°$, $\lambda - \lambda_\odot = 202.5°$, $\beta = -14.8°$,
$\alpha = 100.4°$, $\delta = 8.3°$, $v_g = 41.4$ km/s.

Though the first report of MON came from small cameras at Harvard (Whipple, 1954), it is relatively new that this MON has come to be clearly distinguished from the NOO located above the MON in *Figure 187*. Although the activity is stable from year to year, the difference in maximum is $\Delta\lambda_\odot = 12°$, and the positions are close to each other as shown in the radiant distribution, so it is difficult to distinguish them by visual observation.

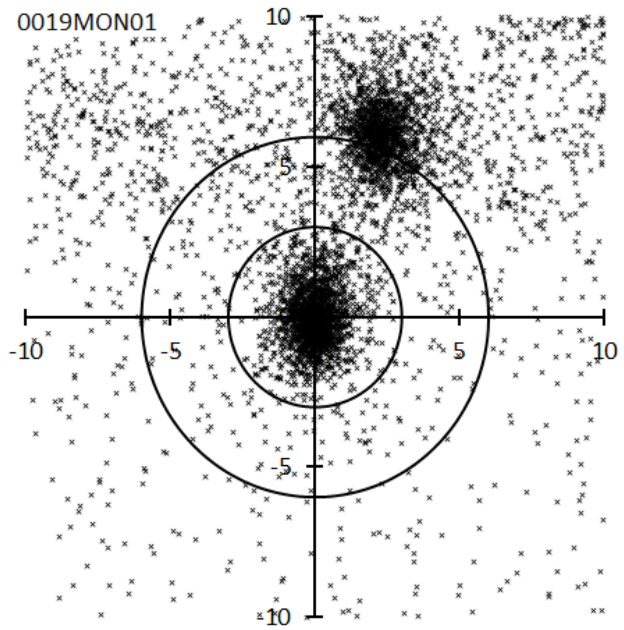

Figure 187 – Radiant point distribution map for the December Monocerotids.

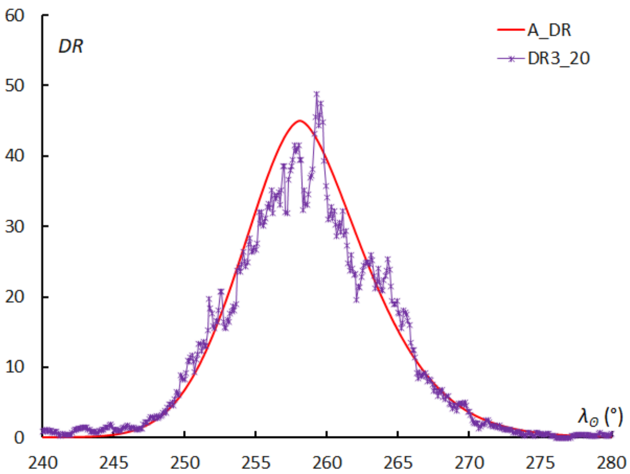

Figure 188 – Activity profile for the December Monocerotids.

0004GEM: Geminids

$\lambda_{\odot} = 261.85°$, $\lambda–\lambda_{\odot} = 208.0°$, $\beta = 10.5°$,
$\alpha = 113.3°$, $\delta = 32.4°$, $v_g = 33.8$ km/s.

As shown in *Figure 190*, the activity profile is asymmetric, and after the maximum, the activity quickly stops. The first report of CAMS (Jenniskens et al., 2016a) claims that there is an activity called 0641DRG00 whose radiant point almost coincides with GEM, and whose geocentric velocity is about 5 km/s faster than GEM, but there is no confirmed report. 0390THA is a confirmed group of IAUMDCSD and is also described in GMN, but it is difficult to distinguish it from the earliest activity of GEM. In the previous SonotaCo net settings (J5; used in SonotaCo data before 2019), the late activity was long enough to include 0644JLL and 0747JKL, but in the J14 list, it was up to $\lambda_{\odot} = 265.38°$. GMN lists JLL's activity period as $\lambda_{\odot} = 246.8°$~$280.2°$, which is different from $\lambda_{\odot} = 288°$ (or $\lambda_{\odot} = 288.1°$) published in IAUMDCSD. The radiant points from THA to JLL and JKL follow the radiant drift of GEM, and it remains to be seen whether they are related to the activities of GEM.

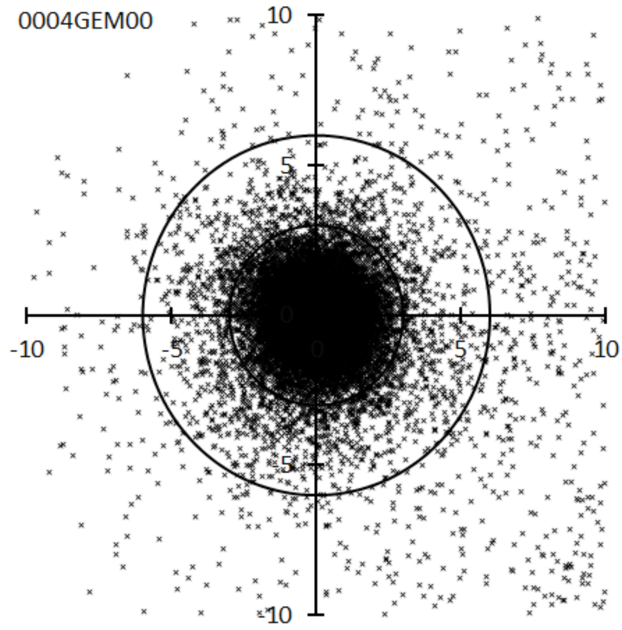

Figure 189 – Radiant point distribution map for the Geminids.

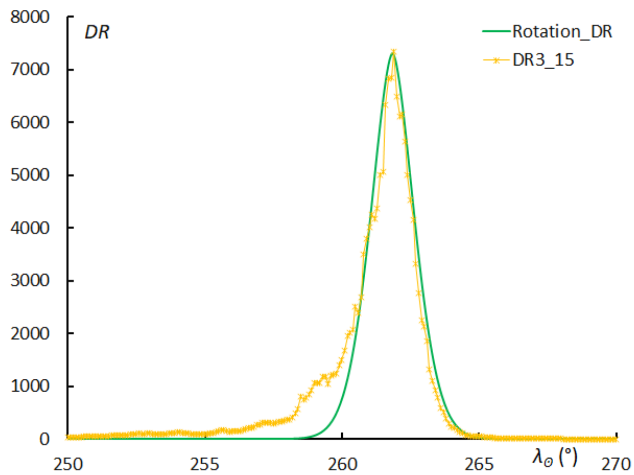

Figure 190 – Activity profile for the Geminids.

0335XVI: December chi-Virginids

$\lambda_{\odot} = 262.8°$, $\lambda–\lambda_{\odot} = 291.6°$, $\beta = –5.2°$,
$\alpha = 191.3°$, $\delta = –10.5°$, $v_g = 68.1$ km/s.

XVI was first detected through observations by the SonotaCo net (SonotaCo, 2009). However, there is a report from SonotaCo net of 1117NEV00, which can be the initial activity of XVI. Although the radiant points are well concentrated, the activity profile is not clear, and the maximum is not clear. The unevenness of the activity curve in *Figure 192* is due to changes in activity from year to year.

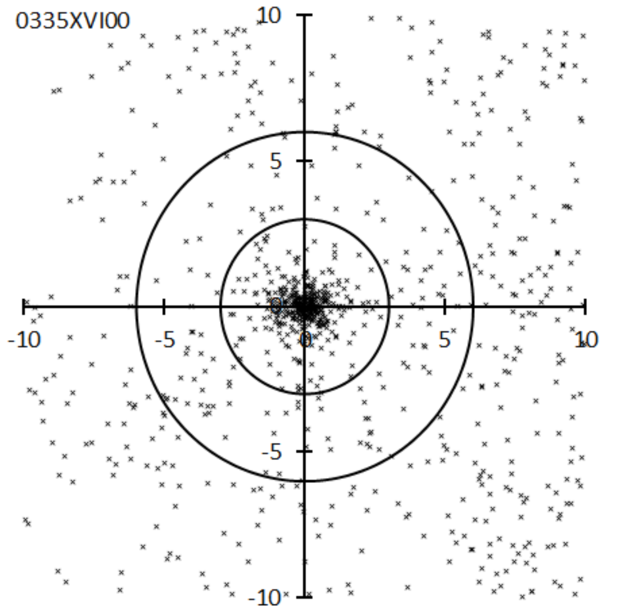

Figure 191 – Radiant point distribution map for the December chi-Virginids.

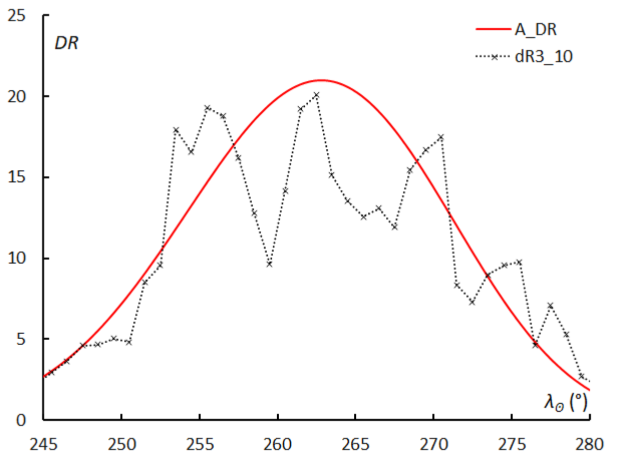

Figure 192 – Activity profile for the December chi-Virginids.

0497DAB: December alpha-Bootids

$\lambda_\odot = 263.1°$, $\lambda–\lambda_\odot = 298.1°$, $\beta = 32.6°$,
$\alpha = 212.1°$, $\delta = 21.9°$, $v_g = 59.4$ km/s.

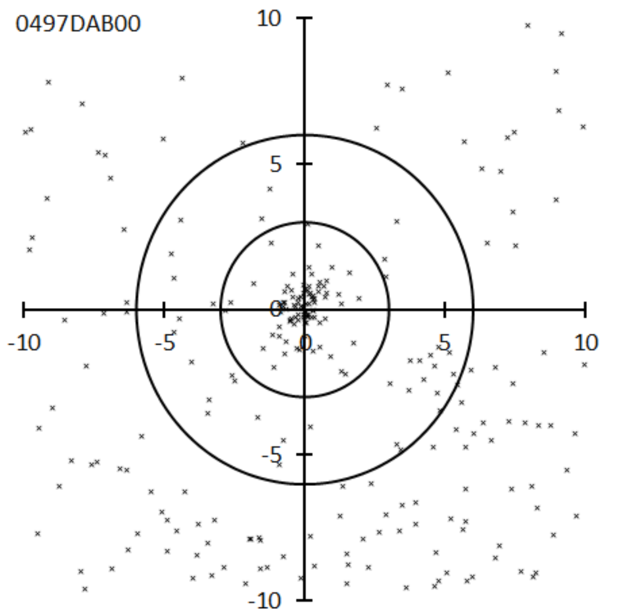

Figure 193 – Radiant point distribution map for the December alpha-Bootids.

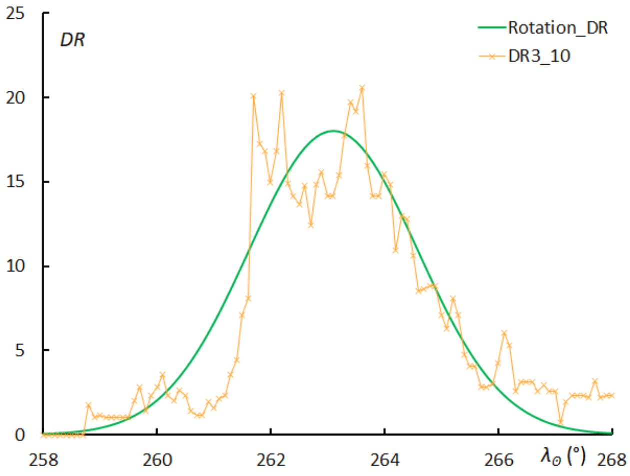

Figure 194 – Activity profile for the December alpha-Bootids.

This meteor shower was detected by combining SonotaCo net and CAMS data (Rudawska and Jenniskens, 2014). The two protrusions in the activity profile are due to the difference of the maximum in the solar longitudes in 2021 and 2022.

0340TPY_1: theta-Pyxidids

$\lambda_\odot = 264.3°$, $\lambda–\lambda_\odot = 259.6°$, $\beta = –32.9°$,
$\alpha = 152.0°$, $\delta = –23.9°$, $v_g = 63.0$ km/s.

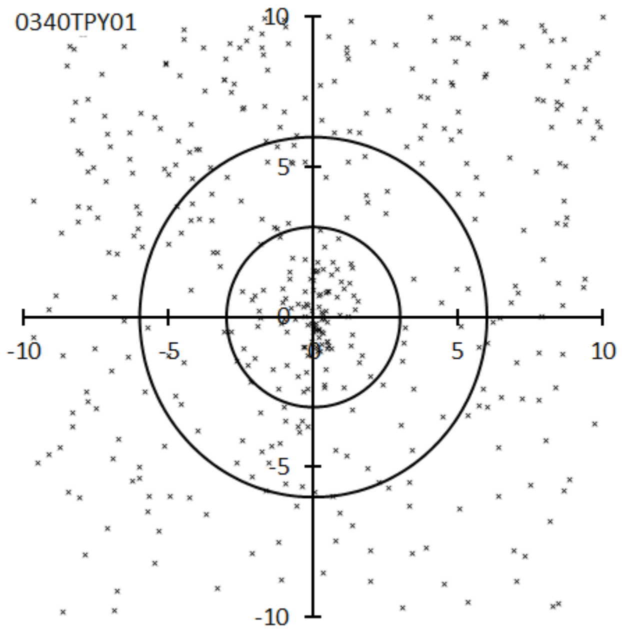

Figure 195 – Radiant point distribution map for the theta-Pyxidids.

This activity was detected in CAMS's first report (Jenniskens et al., 2016b). As mentioned in Part II, "Meteor showers that need careful attention" (Koseki, 2024b), for more details, confusion arose because it was classified as TPY. It should have been given a different name instead of the already existing TPY. GMN calls this TPY, but it would be appropriate to call it DMH, just like the SonotaCo net J14 list. However, if CAMS suggests another name for TPY01, it is better to use that name.

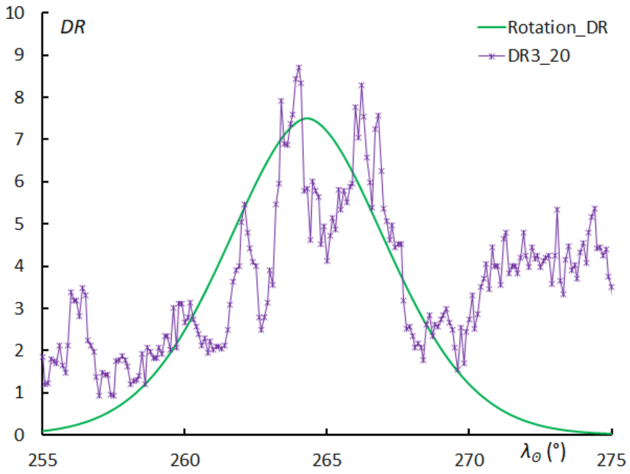

Figure 196 – Activity profile for the theta-Pyxidids.

0020COM: Comae Berenicids

$\lambda_{\odot} = 267.5°$, $\lambda–\lambda_{\odot} = 242.9°$, $\beta = 21.1°$,
$\alpha = 161.0°$, $\delta = 30.9°$, $v_g = 62.8$ km/s.

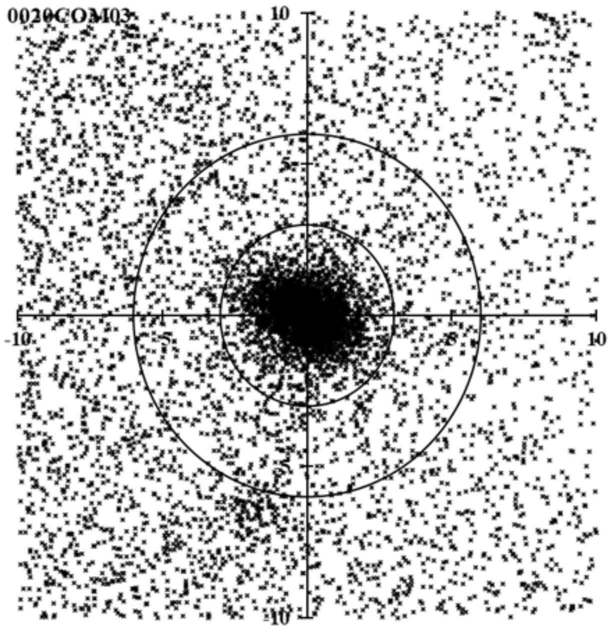

Figure 197 – Radiant point distribution map for the Comae Berenicids.

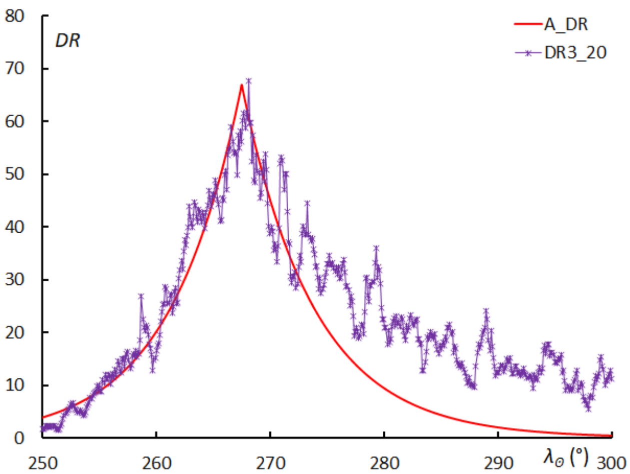

Figure 198 – Activity profile for the Comae Berenicids.

"Comae Berenicids" here includes 0020COM, 0032DLM, 0090JCO, and 0506FEV. FEV is classified as a definite group, but it is an extension of the radiant drift of the "Comae Berenicids" and cannot be distinguished even on the activity profile. FEV is not treated as an independent activity in the SonotaCo net J14 list but is a separate group in GMN. Considering the location of the radiant point and the maximum solar longitude, December Leonis Minorids (DLM) is a more appropriate name.

0015URS: Ursids

$\lambda_{\odot} = 270.65°$, $\lambda–\lambda_{\odot} = 218.8°$, $\beta = 72.1°$,
$\alpha = 219.4°$, $\delta = 75.4°$, $v_g = 33.1$ km/s.

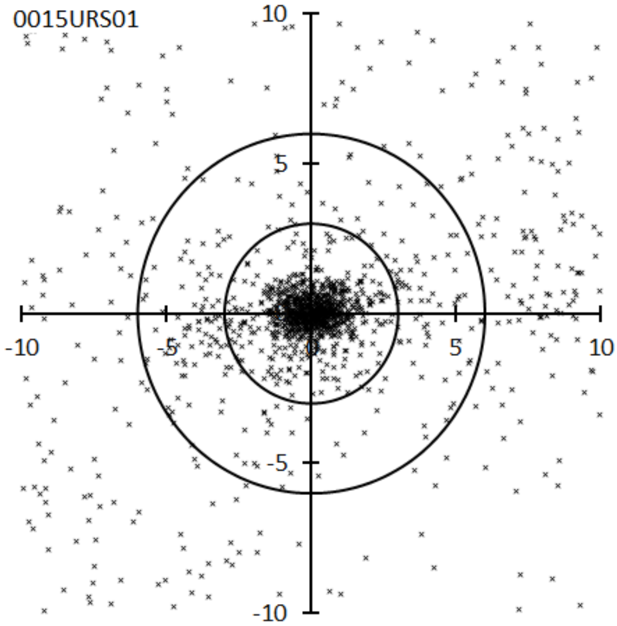

Figure 199 – Radiant point distribution map for the Ursids.

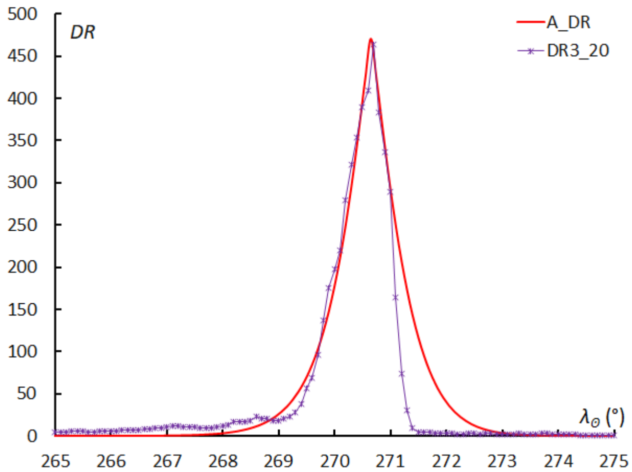

Figure 200 – Activity profile for the Ursids.

After a sudden burst of activity in 1945 (Ceplecha, 1951), high activity in 1986 and 2000 is well known (Kronk, 2013). Irregular activity has been observed since then. Currently, annual activities are captured by video observations, and subtle changes in the solar longitude of the maximum and radiant point are also observed from year to year.

0428DSV: December sigma-Virginids

$\lambda_\odot = 271.5°$, $\lambda{-}\lambda_\odot = 293.4°$, $\beta = 15.0°$,
$\alpha = 208.5°$, $\delta = 4.4°$, $v_g = 66.1$ km/s.

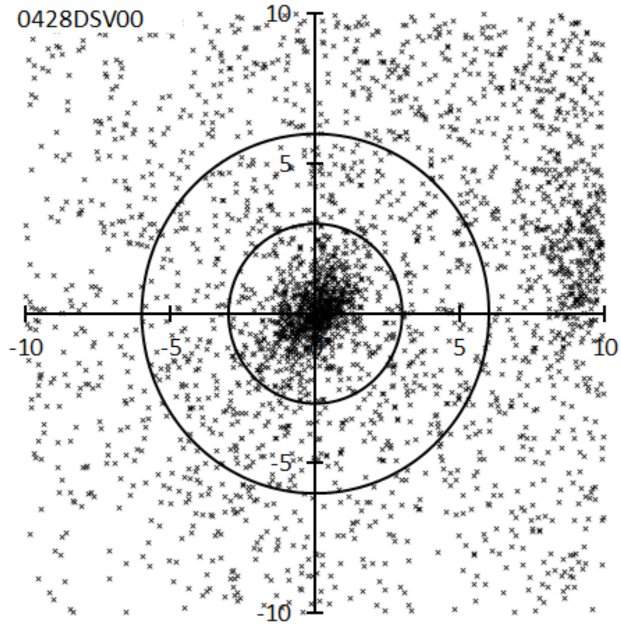

Figure 201 – Radiant point distribution map for the December sigma-Virginids.

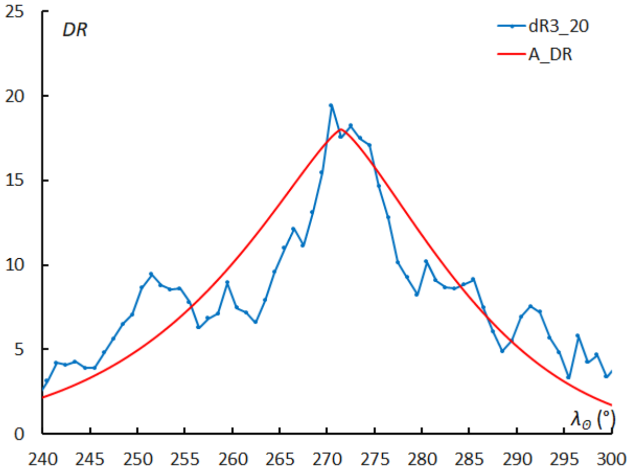

Figure 202 – Activity profile for the December sigma-Virginids.

0513EPV00, 0500JPV00~02, and 1124HTV00 are included in this activity. DSV was discovered by British researcher Greaves (2012) using data from the SonotaCo net, and EPV was reported the following year in a study using observations from Croatia and data from the SonotaCo net (Šegon et al., 2013). Although it is not clear because the number of meteors per night is not large, the solar ecliptic longitude at the maximum seems to differ depending on the year. In the SonotaCo net J14 list, DSV and JPV are included in EPV, and in GMN these are unified as DSV.

0784KVE: kappa-Velids

$\lambda_\odot = 274.9°$, $\lambda{-}\lambda_\odot = 259.4°$, $\beta = -59.6°$,
$\alpha = 142.3°$, $\delta = -50.5°$, $v_g = 43.3$ km/s.

It was detected by SAAMER (Pokorný et al., 2017), an Argentine meteor radar, and no subsequent observations have been reported. Including 0255PUV, there is an active area of radiant points in the region around $\lambda{-}\lambda_\odot = 250°$–$280°$ and $\beta = -60°$ during the period of $\lambda_\odot = 240°$–$280°$. Future observations in the Southern Hemisphere are expected to show how they can be classified and organized. It was not mentioned in the previous article (Koseki, 2021) and is not in the SonotaCo net J14 list.

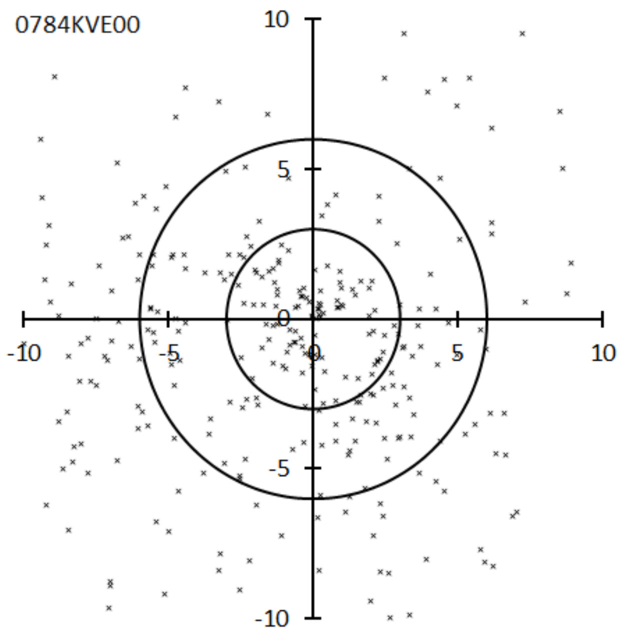

Figure 203 – Radiant point distribution map for the kappa-Velids.

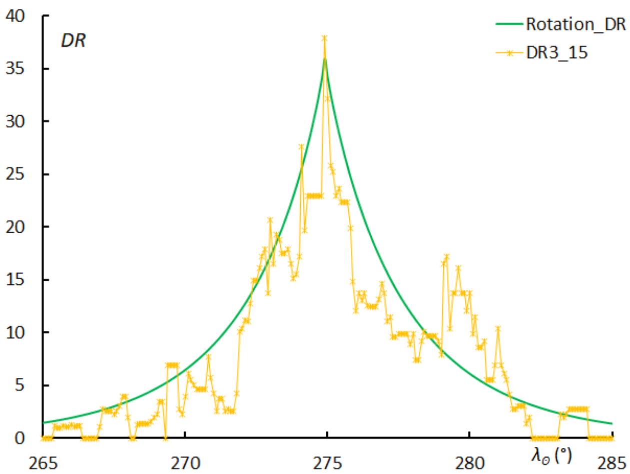

Figure 204 – Activity profile for the kappa-Velids.

0319JLE: January Leonids

$\lambda_\odot = 281.6°$, $\lambda{-}\lambda_\odot = 219.5°$, $\beta = 10.2°$,
$\alpha = 147.0°$, $\delta = 24.1°$, $v_g = 51.9$ km/s.

This meteor shower was detected by radar observation by CMOR1 (Brown et al., 2008). Even in CMOR images[15], the radiant points are clustered small, similarly in the radiant point distribution map in *Figure 205*, only the small cluster near the center is KVE, and the surrounding radiant points are probably sporadic meteors. The actual activity

[15] https://fireballs.ndc.nasa.gov/cmor-radiants/earth.html

profile may be much sharper than the estimated curve shown in *Figure 206*.

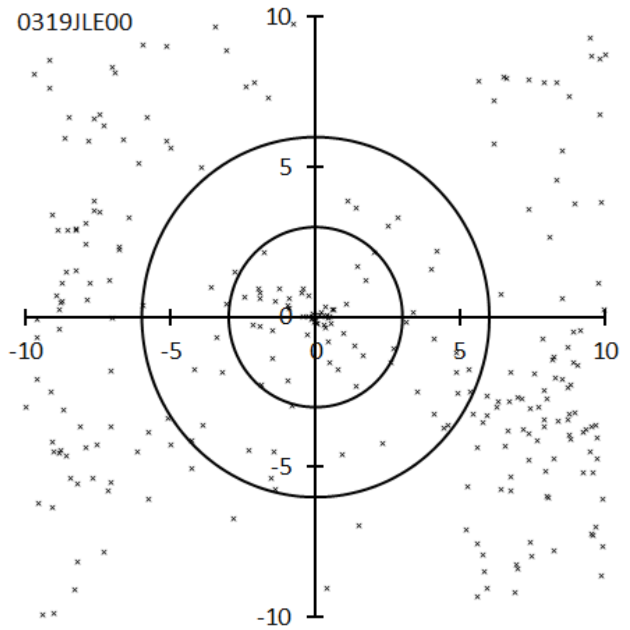

Figure 205 – Radiant point distribution map for the January Leonids.

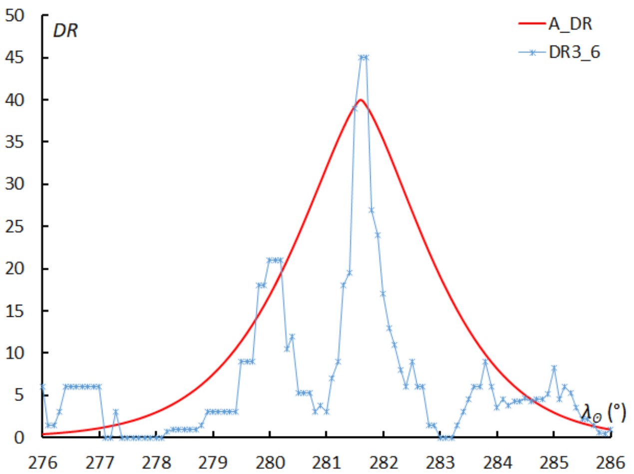

Figure 206 – Activity profile for the January Leonids.

0010QUA: Quadrantids

$\lambda_\odot = 283.25°$, $\lambda–\lambda_\odot = 276.7°$, $\beta = 63.8°$,
$\alpha = 230.0°$, $\delta = 49.7°$, $v_g = 40.4$ km/s.

The radiant point distribution is unique, extending in a heart shape to the upper right and lower upper left. The same result was obtained from SonotaCo net observations, so this seems to be a feature of QUA (Koseki, 2021). The activity curve is asymmetric, and weak activity with a gradual peak can be seen around $\lambda_\odot = 287°$, which is the same result as the SonotaCo net data. However, GMN defines the activity of QUA as $\lambda_\odot < 285°$.

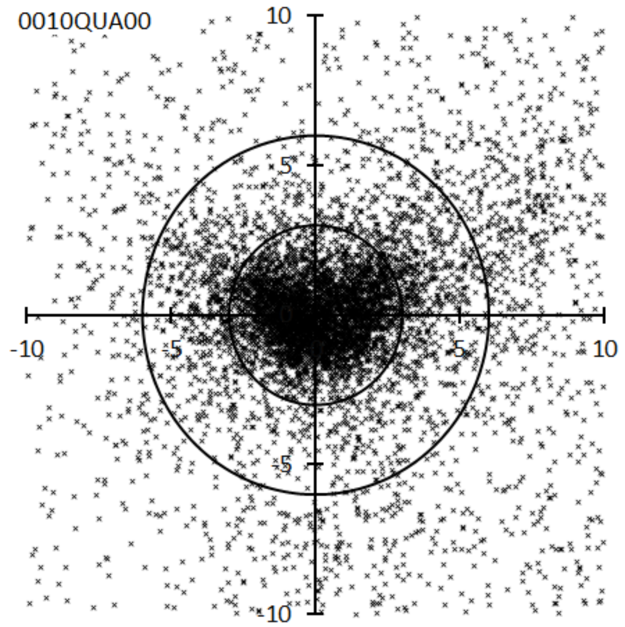

Figure 207 – Radiant point distribution map for the Quadrantids.

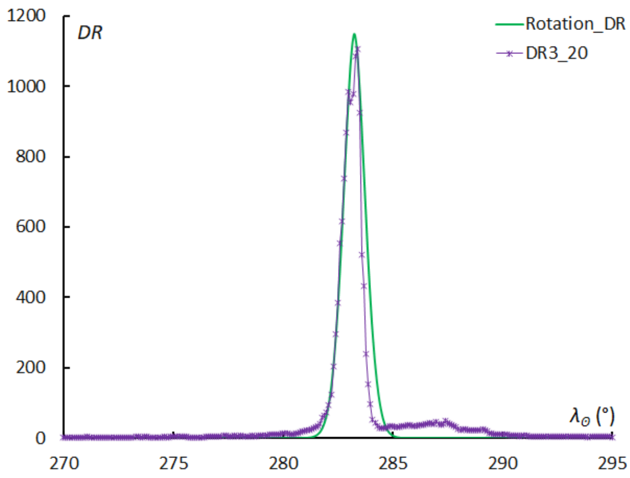

Figure 208 – Activity profile for the Quadrantids.

0331AHY: alpha-Hydrids

$\lambda_\odot = 283.8°$, $\lambda–\lambda_\odot = 207.9°$, $\beta = –26.2°$,
$\alpha = 127.1°$, $\delta = –8.0°$, $v_g = 43.6$ km/s.

This meteor shower was discovered by radar observation by CMOR1 (Brown et al., 2008), but it is also well captured by video observations. Compared to 0319JLE, which was also discovered in CMOR1, AHY seems to be a meteor shower suitable for video observation. There is no clear maximum seen in the CMOR image[16], and even in the activity profile in *Figure 210*, the activity during the period $\lambda_\odot = 280°$ to 286° is at almost the same level.

[16] https://fireballs.ndc.nasa.gov/cmor-radiants/earth.html

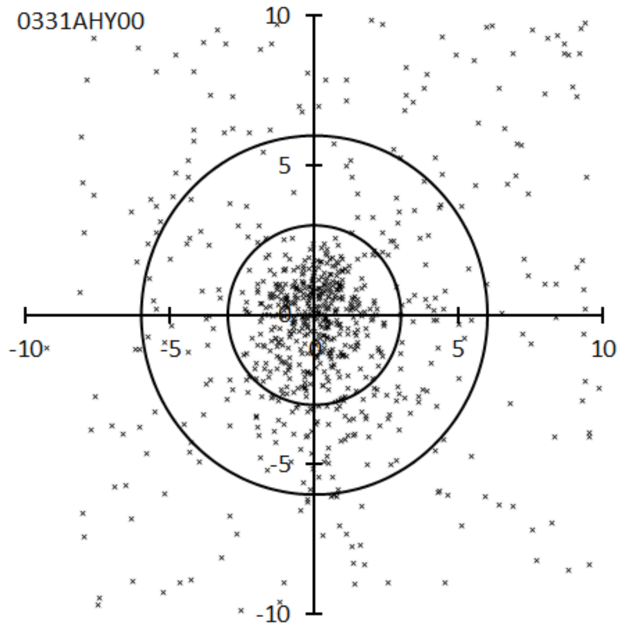

Figure 209 – Radiant point distribution map for the alpha-Hydrids.

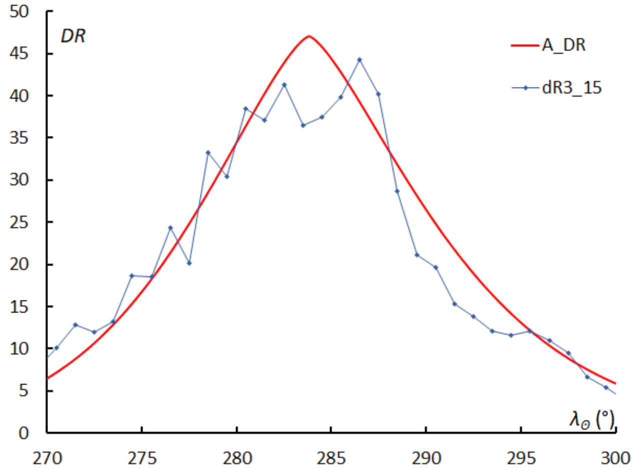

Figure 210 – Activity profile for the alpha-Hydrids.

0515OLE: omicron-Leonids

$\lambda_\odot$ = 288.3°, $\lambda - \lambda_\odot$ = 209.2°, β = –7.3°,
α = 137.7°, δ = 8.6°, = 46.5 km/s.

Table 2 – Three similar meteor showers.

Code	$\lambda_\odot$	$\lambda - \lambda_\odot$	β	v_g
0643OLS00	287	209.3	–7.4	44.9
0793KCA00	289	208.5	–7	47.3
0515OLE00	296	208	–6.9	41.5

In the previous article (Koseki, 2021), we covered this activity as 0515OLE, so this time we will continue to use that name. However, as shown in *Table 2*, there are three similar activities in the same area. The distribution of the geocentric velocity for meteors within 3 degrees from the OLE radiant with $\lambda_\odot$ = 285°~295° is shown in *Figure 213*. When we investigated the activity above and below v_g = 44.5 (km/s), we found that the results were more consistent for v_g > 44.5 (km/s). The radiant distribution and activity profile shown in *Figures 211 and 212* are the results of regression analysis for meteors v_g > 44.5 (km/s). In the radiant distribution, those within 3 degrees from the center and with v_g > 44.5 (km/s) are marked with a circle. Although the results for v_g < 44.5 (km/s) were similar, they were not as clear-cut. The three activities in *Table 2* seem to represent the same meteor shower, but OLS and KCA seem to represent the activity a little better. The SonotaCo net J14 list uses KCA, and GMN lists OLE and KCA.

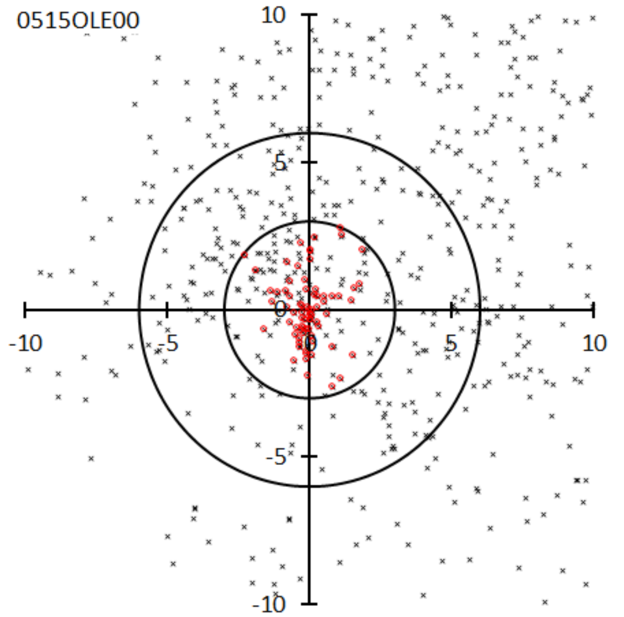

Figure 211 – Radiant point distribution map for the omicron-Leonids. Radiants with v_g > 44.5 km/s are marked in red.

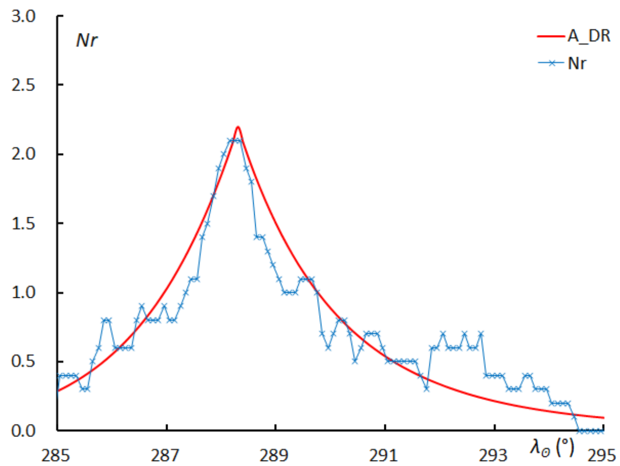

Figure 212 – Activity profile for the omicron-Leonids.

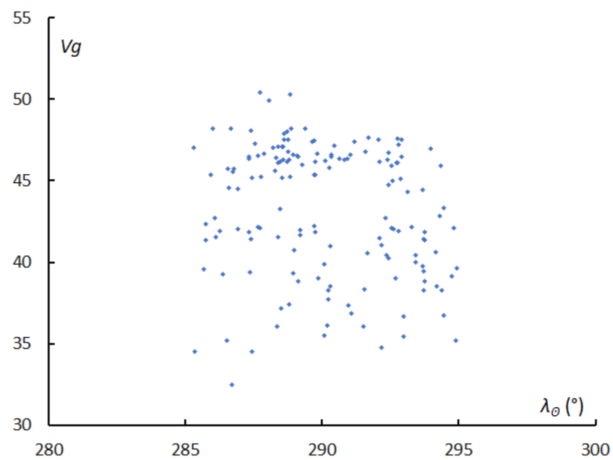

Figure 213 – Distribution of the geocentric velocity for meteors within 3 degrees from the OLE radiant with $\lambda_\odot$ = 285°~295°.

0323XCB: xi-Coronae Borealids

$\lambda_\odot = 294.8°$, $\lambda\text{–}\lambda_\odot = 307.3°$, $\beta = 50.8°$,
$\alpha = 250.2°$, $\delta = 29.3°$, $v_g = 45.4$ km/s.

0321TCB, 0322LBO, and 0323XCB are all meteor showers detected by CMOR1 radio observations (Brown et al., 2008). Although TCB and LBO are more active in radar observations, video observations show that TCB and LBO are buried in sporadic meteor activity. XCB is probably better suited for video observations. In the previous article (Koseki, 2021), only XCB was mentioned, but none of them are listed in the SonotaCo net J14 list. LBO and XCB are listed on GMN. Activity seems to change from year to year, and the unevenness of the activity profile is thought to be due to this.

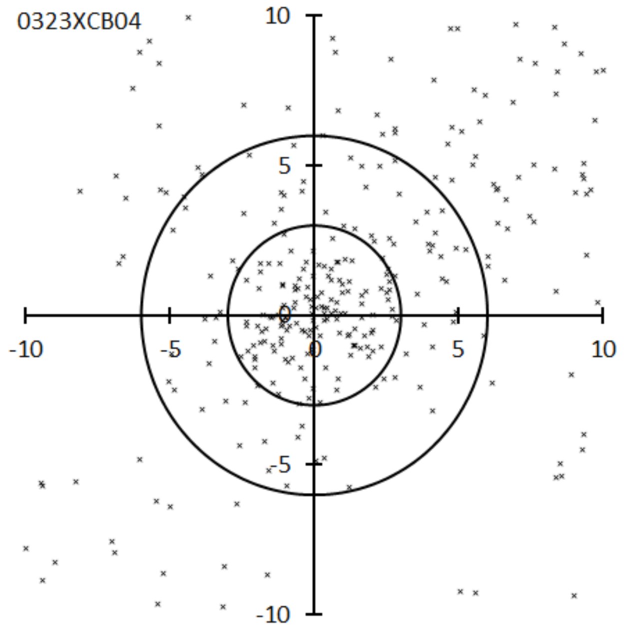

Figure 214 – Radiant point distribution map for the xi-Coronae Borealids.

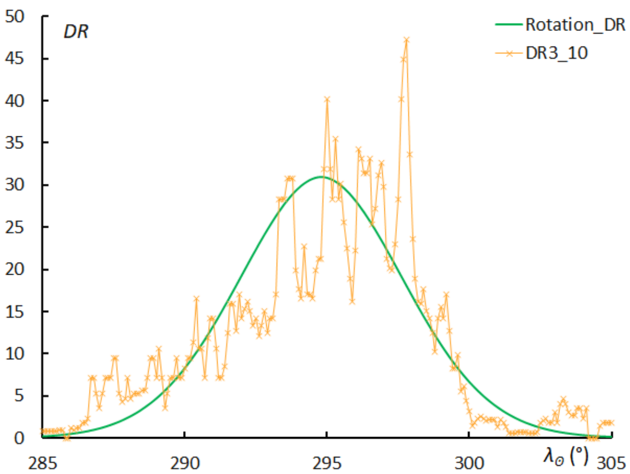

Figure 215 – Activity profile for the xi-Coronae Borealids.

0341XUM: January xi-Ursae Majorids

$\lambda_\odot = 298.6°$, $\lambda\text{–}\lambda_\odot = 218.1°$, $\beta = 25.8°$,
$\alpha = 169.5°$, $\delta = 32.8°$, $v_g = 41.0$ km/s.

This activity was first detected through observations by the SonotaCo net (SonotaCo, 2009). More than half of the data used was observed in 2023, so the activity profile can be said to represent the activity in 2023. The radiant point distribution by the SonotaCo net in the previous paper (Koseki, 2021), is also downward sloping. The direction of the radiant drift is also downward to the right, but the distribution in *Figure 216* takes the radiant shift into consideration, and this shape is probably a characteristic of XUM.

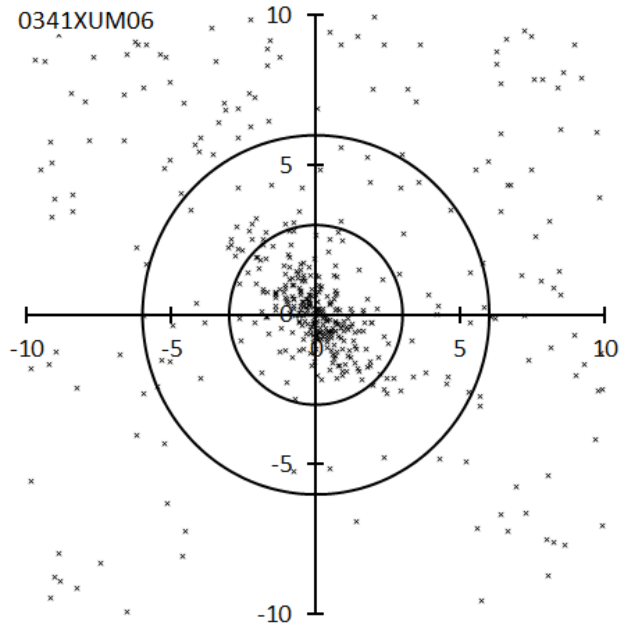

Figure 216 – Radiant point distribution map for the January xi-Ursae Majorids.

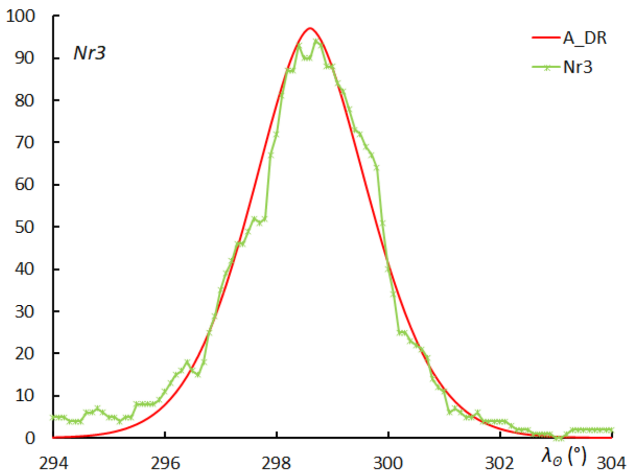

Figure 217 – Activity profile for the January xi-Ursae Majorids.

0404GUM: gamma-Ursae Minorids

$\lambda_\odot = 299.8°$, $\lambda\text{–}\lambda_\odot = 218.8°$, $\beta = 74.5°$,
$\alpha = 229.7°$, $\delta = 67.3°$, $v_g = 29.4$ km/s.

This activity was detected by CMOR2 radar observations (Brown et al., 2010) but is also well captured by video observations. Although it was active on the same scale and around the same time as XUM, it was unknown until the observations of CMOR2 were analyzed. Although GUM activity is not clear in SonotaCo net observations from 2007 to 2009, its existence is clearly recognized in observations since 2010. This is a meteor shower that was not covered in the previous article (Koseki, 2021), and changes in its activity will be of interest in the future.

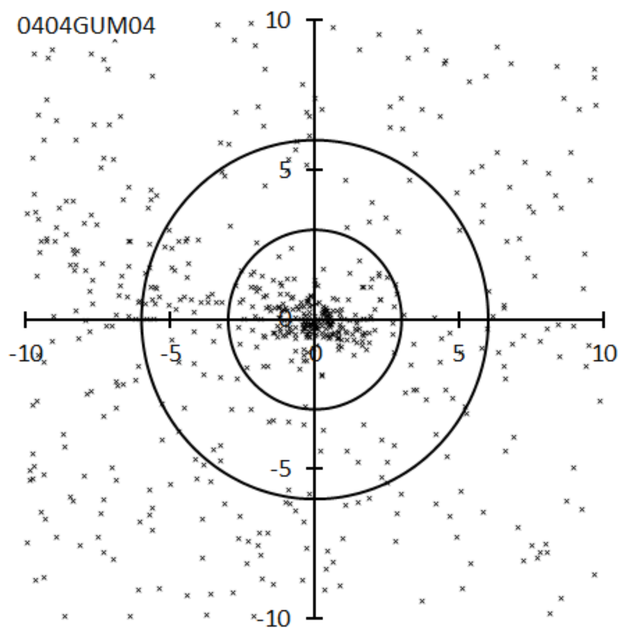

Figure 218 – Radiant point distribution map for the gamma-Ursae Minorids.

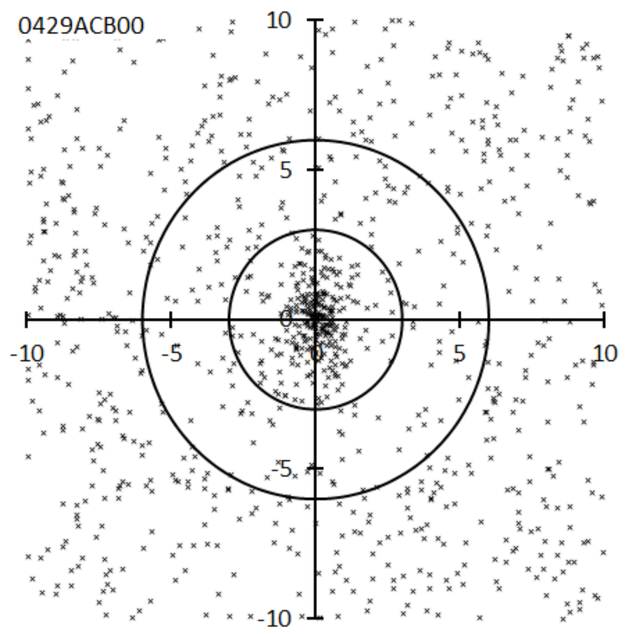

Figure 220 – Radiant point distribution map for the alpha-Coronae Borealids.

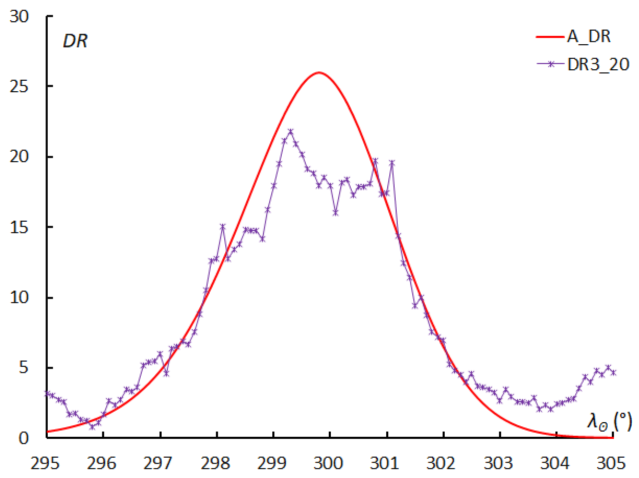

Figure 219 – Activity profile for the gamma-Ursae Minorids.

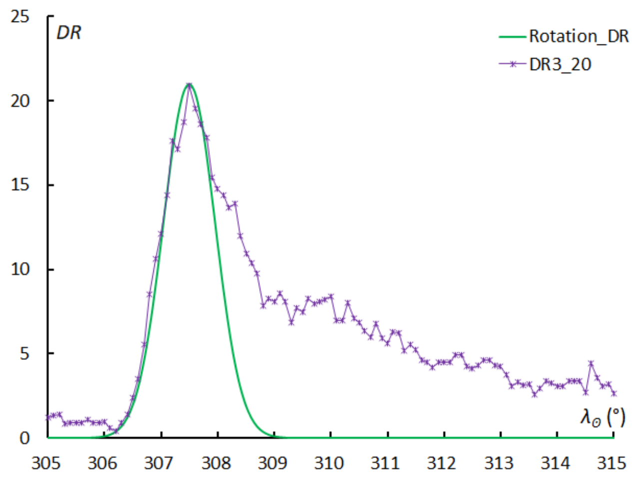

Figure 221 – Activity profile for the alpha-Coronae Borealids.

0429ACB: alpha-Coronae Borealids

$\lambda_\odot = 307.5°$, $\lambda–\lambda_\odot = 271.4°$, $\beta = 44.7°$,
$\alpha = 231.3°$, $\delta = 27.9°$, $v_g = 57.2$ km/s.

ACB was discovered by British researcher Greaves (2012) using data from the SonotaCo net. A characteristic of this meteor shower is the large asymmetry of the activity profile (*Figure 221*), which reaches its maximum soon after the start of activity, and then gradually declines in activity.

0110AAN: alpha-Antliids

$\lambda_\odot = 312.5°$, $\lambda–\lambda_\odot = 211.0°$, $\beta = –17.4°$,
$\alpha = 158.1°$, $\delta = –9.6°$, $v_g = 43.9$ km/s.

This meteor shower was detected by AMOR radar observations (Galligan and Baggaley, 2002). After that, it remained conspicuous in radar observations of CMOR1 and CMOR2 (Brown et al., 2008, 2010), but confirmation by video observation was delayed. This meteor shower is not listed in the SonotaCo net J14 list. Looking at the CMOR image[17], 0405MHY is visible on the southeast side. In the radiant distribution in *Figure 222*, MHY is located at the bottom left of AAN, but it is not as clear as in radar observations.

[17] https://fireballs.ndc.nasa.gov/cmor-radiants/earth.html

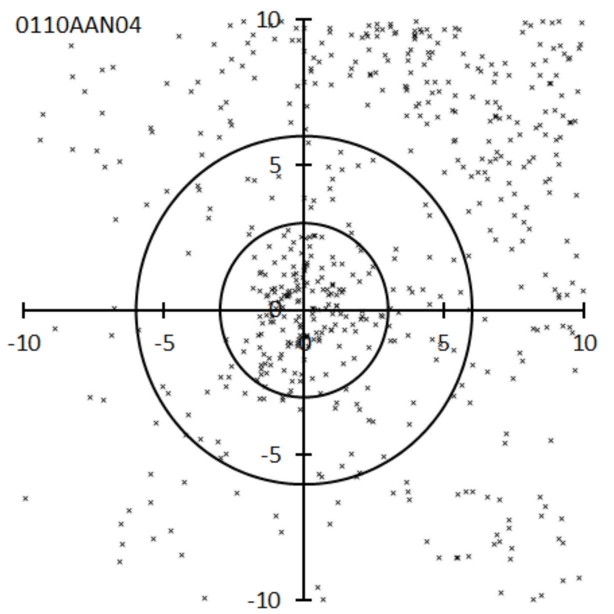

Figure 222 – Radiant point distribution map for the alpha-Antliids.

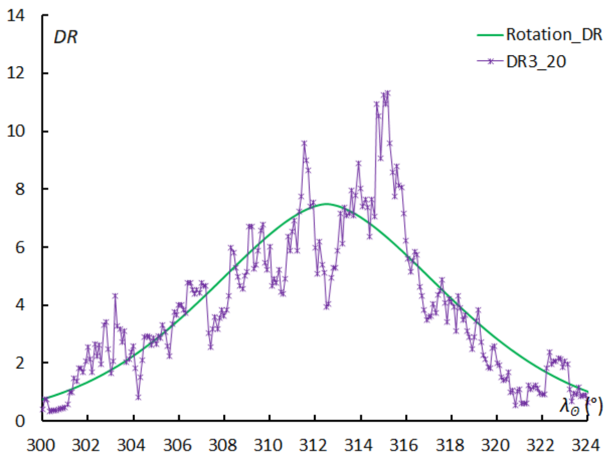

Figure 223 – Activity profile for the alpha-Antliids.

0427FED: February eta-Draconids

$\lambda_\odot = 314.84°$, $\lambda - \lambda_\odot = 230.6°$, $\beta = 76.0°$,
$\alpha = 239.3°$, $\delta = 61.8°$, $v_g = 35.2$ km/s.

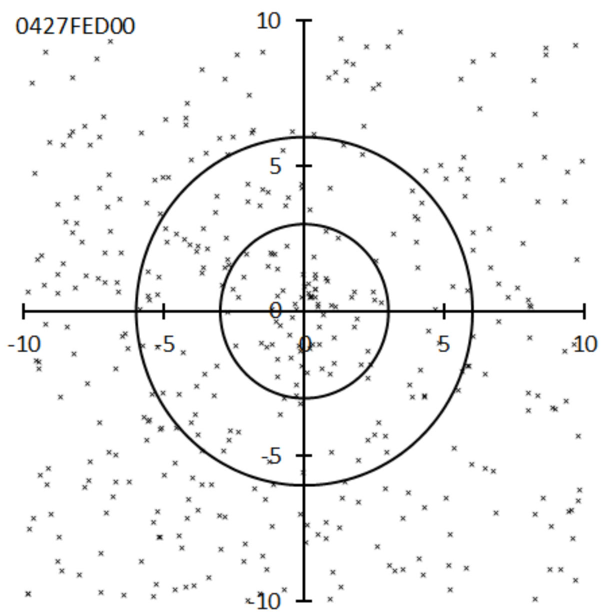

Figure 224 – Radiant point distribution map for the February eta-Draconids.

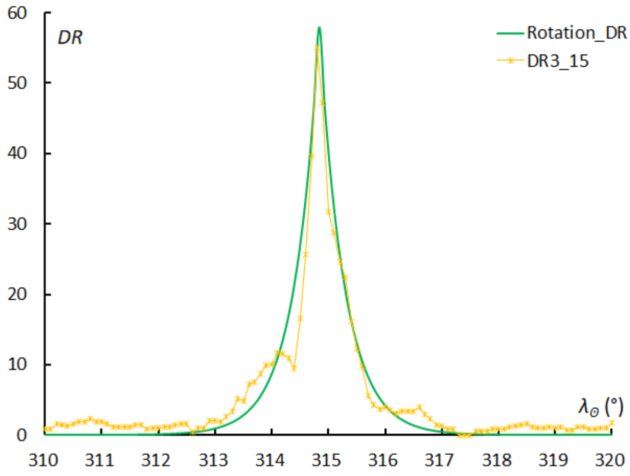

Figure 225 – Activity profile for the February eta-Draconids.

The first report was that six meteors were captured by CAMS on February 4, 2011 (Jenniskens and Gural, 2011). Even in the activity profile in *Figure 225*, the half-width is approximately half a day, and it is difficult to capture unless the observation time coincides with the maximum. This activity is not in the SonotaCo net J14 list and was not mentioned in the previous article (Koseki, 2021).

1032FHY: February Hydrids

$\lambda_\odot = 325.4°$, $\lambda - \lambda_\odot = 160.7°$, $\beta = -18.9°$,
$\alpha = 123.9°$, $\delta = 0.4°$, $v_g = 16.1$ km/s.

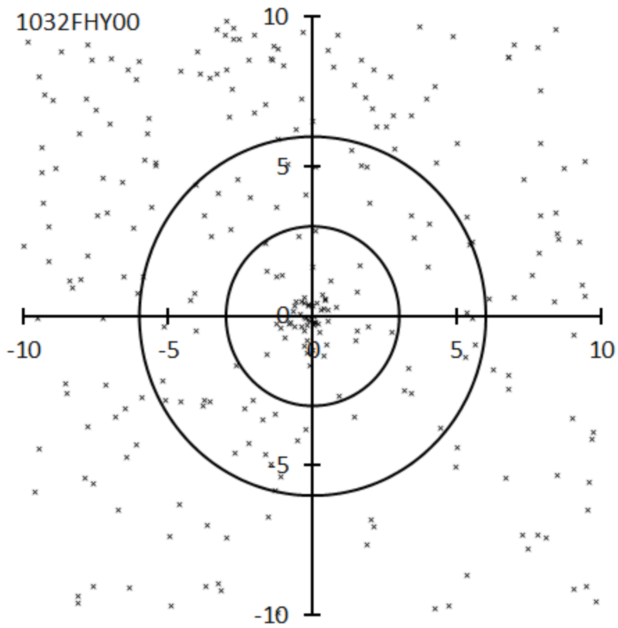

Figure 226 – Radiant point distribution map for the February Hydrids.

The first record was a preliminary report that 17 meteors were captured by CAMS between February 9 and 17, 2018 (Jenniskens et al., 2018a). It was not mentioned in the previous article (Koseki, 2021), and it is not in the SonotaCo net J14 list or GMN. The radiant points are well concentrated and the maximum is clear. Considering the location of the radiant and the geocentric velocity, the spatial density of meteoroids seems to be quite high.

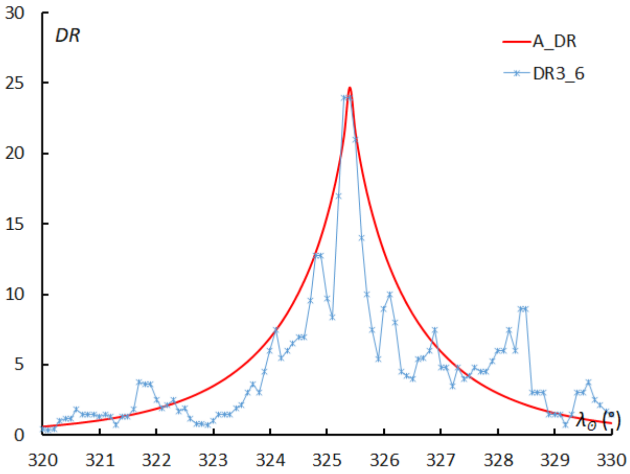

Figure 227 – Activity profile for the February Hydrids.

1166TTR: theta-Trianguli Australids

$\lambda_O = 332.1°$, $\lambda-\lambda_O = 285.4°$, $\beta = -43.9°$,
$\alpha = 247.0°$, $\delta = -66.4°$, $v_g = 56.3$ km/s.

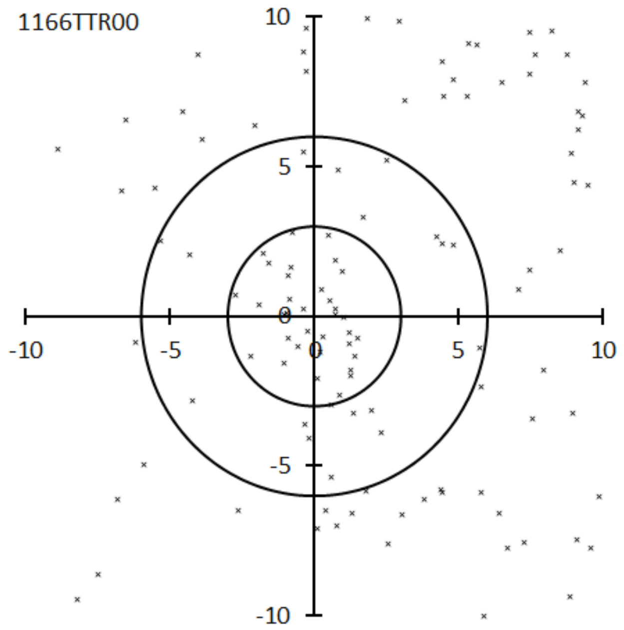

Figure 228 – Radiant point distribution map for the theta-Trianguli Australids.

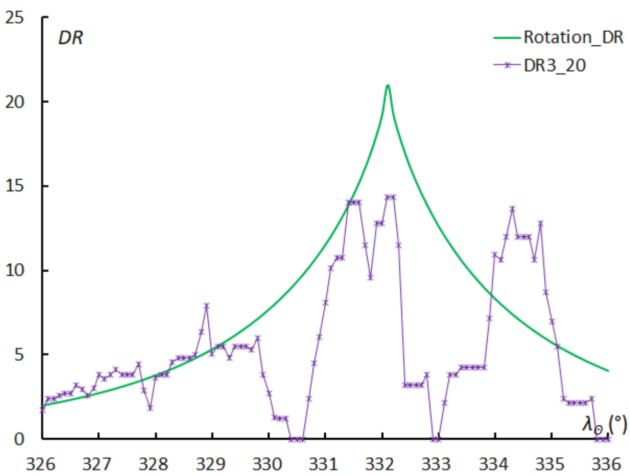

Figure 229 – Activity profile for the theta-Trianguli Australids.

This is a new meteor shower that appeared in the third CAMS report (mentioned '2022 submitted' in the IAUMDCSD). It was not mentioned in the previous article (Koseki, 2021), and it is not in the SonotaCo net J14 list or GMN. The total number of meteors observed by GMN is only 34, of which 28 were in 2023. Future progress in observation in the Southern Hemisphere is expected. From the trends in the raw number of meteors in 2023, it appears that the activity profile might be asymmetrical, with a rapid decline after the peak.

0915DNO: delta-Normids

$\lambda_O = 334.2°$, $\lambda-\lambda_O = 271.5°$, $\beta = -24.9°$,
$\alpha = 237.8°$, $\delta = -45.7°$, $v_g = 66.7$ km/s.

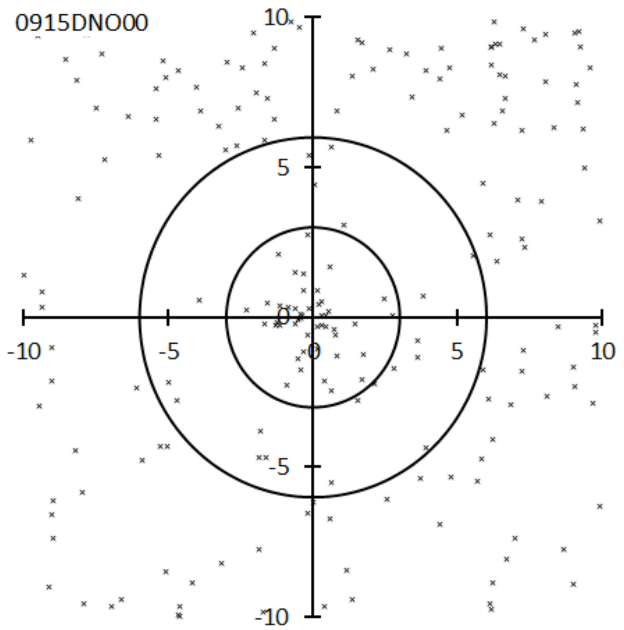

Figure 230 – Radiant point distribution map for the delta-Normids.

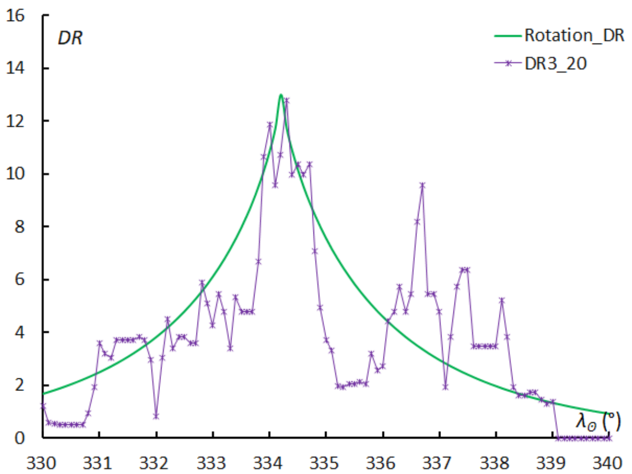

Figure 231 – Activity profile for the delta-Normids.

This meteor shower appeared in the second CAMS report (Jenniskens et al., 2018b). It was not mentioned in the previous article (Koseki, 2021) and is not in the SonotaCo net J14 list, but GMN has it listed. This is also a southern meteor shower, with 33 out of 46 observed in 2023, indicating progress in observation in the Southern Hemisphere.

0571TSB: 26-Bootids

$\lambda_\odot = 343.7°$, $\lambda–\lambda_\odot = 220.8°$, $\beta = 36.7°$,
$\alpha = 216.7°$, $\delta = 24.6°$, $v_g = 49.4$ km/s.

This activity was detected by combining observations from Croatia and the SonotaCo net (Andreić et al., 2014). This activity was not covered in the previous article (Koseki, 2021). Although the number of meteors obtained was small (55), the activity profile is clear. It is also listed in the SonotaCo net J14 list and GMN. Setting the active period as $\lambda_\odot = 342.73°$~ 343.46° in J14 is probably too short.

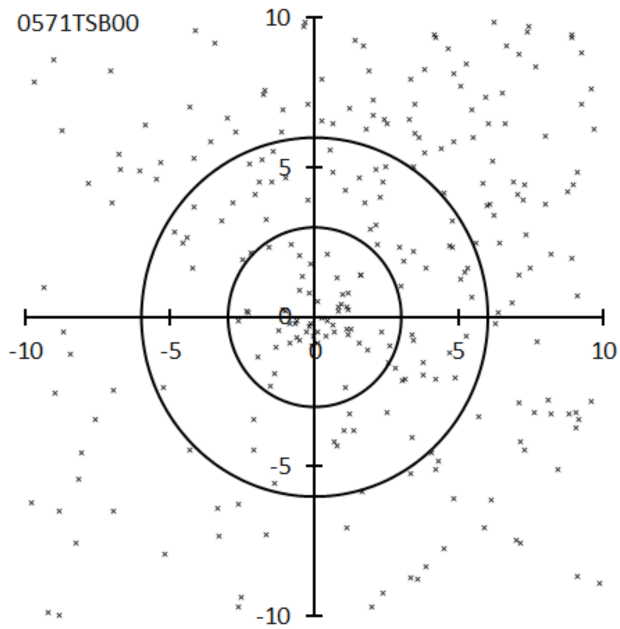

Figure 232 – Radiant point distribution map for the 26-Bootids.

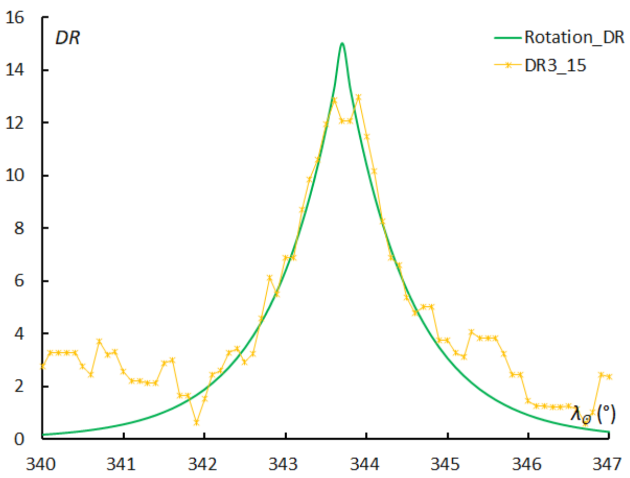

Figure 233 – Activity profile for the 26-Bootids.

0346XHE: x-Herculids

$\lambda_\odot = 351.9°$, $\lambda–\lambda_\odot = 249.0°$, $\beta = 70.8°$,
$\alpha = 255.9°$, $\delta = 48.8°$, $v_g = 34.5$ km/s.

IMO's Video network observations in March 2009 were the first detection report (Molau and Kac, 2009). Only traces can be seen in the CMOR image[18], and it appears to be a meteor shower suitable for video observation.

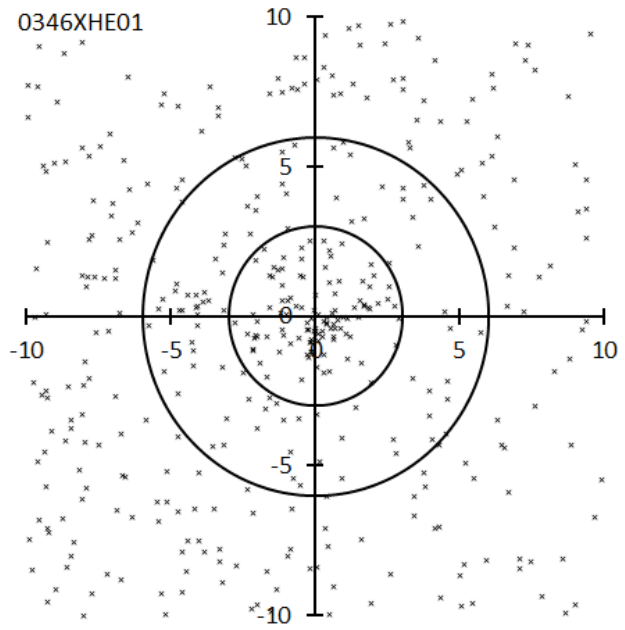

Figure 234 – Radiant point distribution map for the x-Herculids.

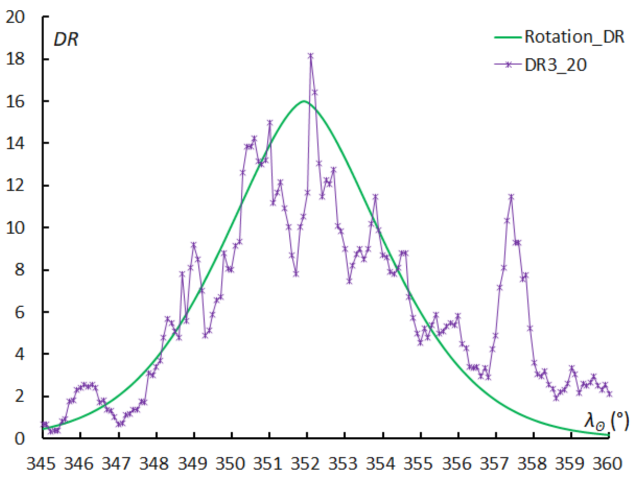

Figure 235 – Activity profile for the x-Herculids.

0011EVI: eta-Virginids

$\lambda_\odot = 358°$, $\lambda–\lambda_\odot = 187.0°$, $\beta = 5.3°$,
$\alpha = 186.7°$, $\delta = 2.8°$, $v_g = 27.2$ km/s.

Jenniskens pointed out that five EVIs were recorded on Super Schmidt on March 12–13, 1953 (Jenniskens, 2006). There are years when EVI appears intensively, and it has been pointed out that there is a four-year cycle (Shiba, 2018). Even though the total number of observed meteors in GMN is higher in 2022, the number of EVIs is higher in 2021. The radiant distribution has extremely elongated shape even when radiant drift is considered. This is because, as the author pointed out, EVI's orbit has a rotating spread along the ecliptic plane (Koseki, 2020).

[18] https://fireballs.ndc.nasa.gov/cmor-radiants/earth.html

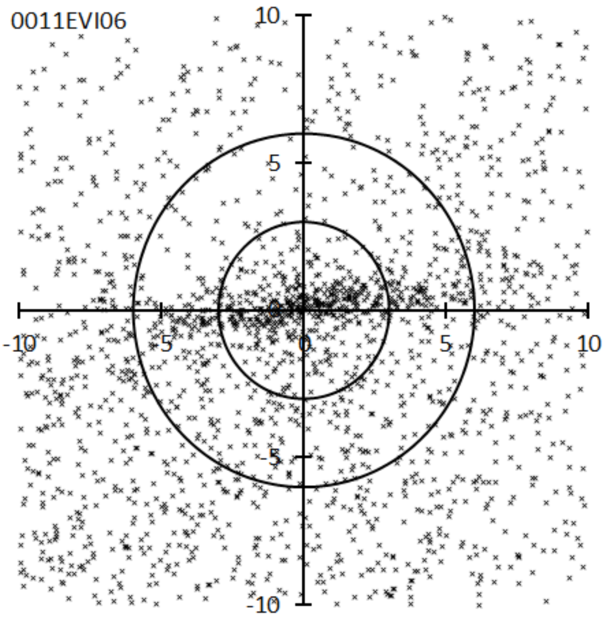

Figure 236 – Radiant point distribution map for the eta-Virginids.

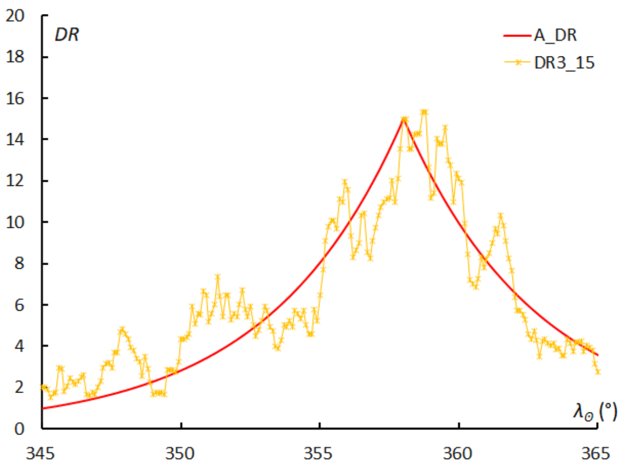

Figure 237 – Activity profile for the eta-Virginids.

0893EOP: eta-Ophiuchids

$\lambda_\odot = 358.2°$, $\lambda–\lambda_\odot = 262.8°$, $\beta = 6.7°$,
$\alpha = 260.7°$, $\delta = –16.5°$, $v_g = 70.8$ km/s.

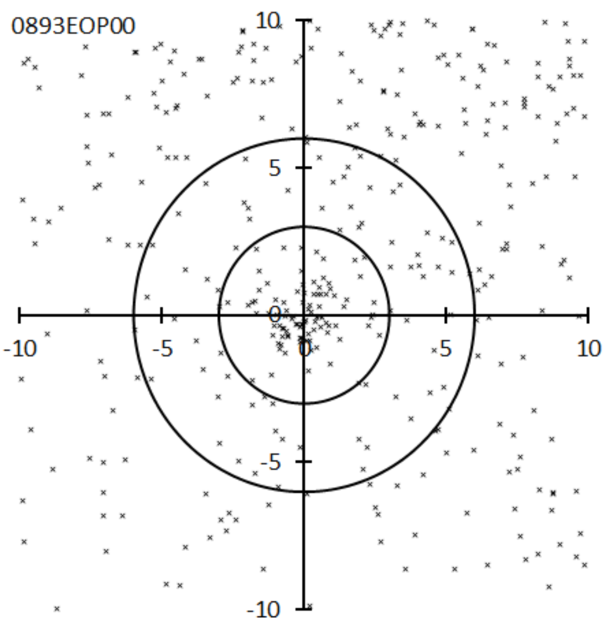

Figure 238 – Radiant point distribution map for the eta-Ophiuchids.

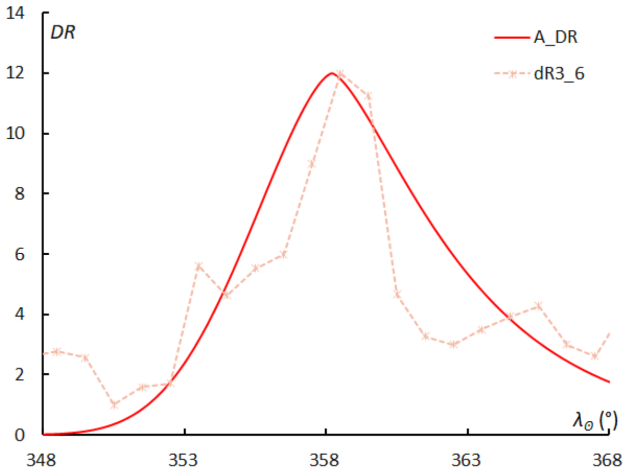

Figure 239 – Activity profile for the eta-Ophiuchids.

This meteor shower appeared in the second CAMS report (Jenniskens, et al., 2018b). The number of EOPs that have been obtained is still small at 58, the activity profile is asymmetric, and the activity in the latter half of maximum activity appears to be long. Although not mentioned in the previous article (Koseki, 2021), it is also listed in SonotaCo net J14 list and GMN. However, in the J14 list, the period of activity is limited to $\lambda_\odot = 354.60°$~$356.36°$, which is the first half of EOP's activity.

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Perseids 2024 by worldwide radio meteor observations

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Radio meteor observations in the world detected three unexpected peaks in the Perseid activity profile of 2024 before and after the annual peak around $\lambda_{\odot} = 140.00°$. They occurred at $\lambda_{\odot} = 139.75°–139.79°$ (August 12, 7^h30^m – 8^h30^m UT), $\lambda_{\odot} = 140.07°–140.15°$ (August 12, 15^h30^m -17^h30^m UT) and $\lambda_{\odot} = 140.75°$ (August 13, 8^h30^m UT). The third peak was the strongest activity with Activity Level $= 3.2 \pm 0.4$ and an estimated $ZHR_r = 160 \pm 5$ at $\lambda_{\odot} = 140.75°$.

1 Introduction

The Perseids are one of the strongest meteor showers in a year. The shower reaches a maximum with a $ZHR = 100$ at $\lambda_{\odot} = 140.0°$ for visual observers (Rendtel, 2023).

Radio Meteor Observation is also able to obtain a complete activity profile. In past research, activity profiles were derived from worldwide radio data from Radio Meteor Observation Bulletin (RMOB). As a result, The International Project for Radio Meteor Observations (IPRMO) which is organized to analyze a complete meteor shower activity without problems with radiant elevation and unstable weather, concluded that the peak of the Perseids occurred at $\lambda_{\odot} = 140.0°$ with FWHM (Full Width of Half Maximum) = –0.7°/+0.8° and a peak Activity Level of 1.2 (Ogawa, 2022).

For 2024, the Meteor Shower Calendar published by the International Meteor Organization (IMO) described a possible encounter with a weak filament on August 12 around $\lambda_{\odot} = 139.81$ and five very old trails between $\lambda_{\odot} = 139.6$ and $\lambda_{\odot} = 139.9$.

This paper reports the result for the Perseids 2024 using worldwide radio meteor observations.

2 Method

For analyzing the worldwide radio meteor observation data, the meteor activity is calculated by the "Activity Level Index: *AL*(t)" (Ogawa et al., 2001) and the estimated Zenithal Hourly Rate: ZHR_r(t) (Sugimoto, 2017). The activity profile was estimated using the Lorentz activity profile (Jenniskens et al., 2000).

This year, *AL* used 46 data from 14 countries and a ZHR_r was calculated from 35 observers. These data were provided by observes that reported to RMOB and Japanese observers.

3 Results

Figure 1 and 2 show the results of *AL* and an ZHR_r. The first peak with $AL = 2.6 \pm 0.3$ was observed at $\lambda_{\odot} = 139.79°$ (August 12, 8^h30^m). The estimated ZHR_r reached 123 ± 7. A secondary peak was observed at $\lambda_{\odot} = 140.07°$ (August 12, 15^h30^m UT) with $AL = 2.2 \pm 0.3$ ($ZHR_r = 105 \pm 3$). A third peak which was the strongest during this year was detected at $\lambda_{\odot} = 140.75°$ (August 13, 08^h30^m UT) with $AL = 3.2 \pm 0.4$, ($ZHR_r = 159 \pm 5$).

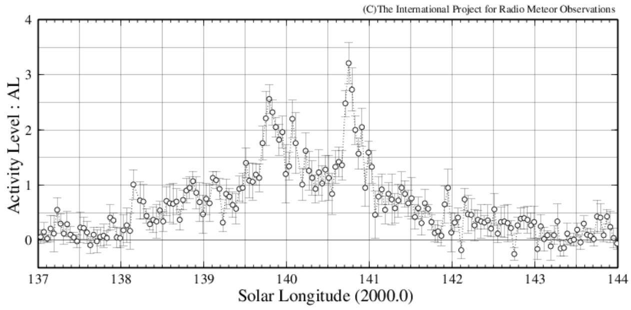

Figure 1 – Activity Level Index using 46 datasets worldwide.

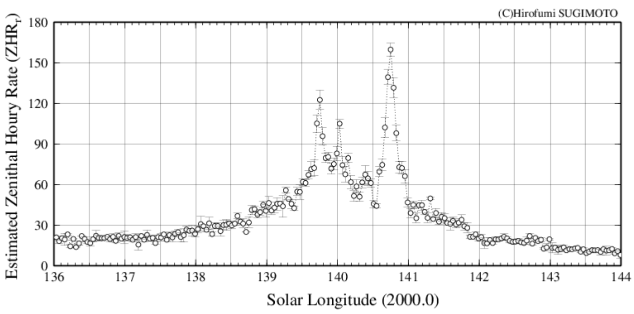

Figure 2 – Estimated *ZHRr* using 35 datasets worldwide.

Table 1 – The three detected peaks.

Peak Time(UT)	$\lambda_{\odot}$ (°)	Activity Level	ZHR_r
Aug 12, 08^h30^m	139.79	2.6 ± 0.3	123 ± 7
Aug 12, 15^h30^m	140.07	2.2 ± 0.3	105 ± 3
Aug 13, 08^h30^m	140.75	3.2 ± 0.4	159 ± 5

4 Discussion

4.1 Components of three peaks

Figure 3 and *4* show that the *AL* and ZHR_r of the Perseids 2024 displayed four components including a traditional component by using the Lorentz profile. *Table 2* shows the estimated components and some references.

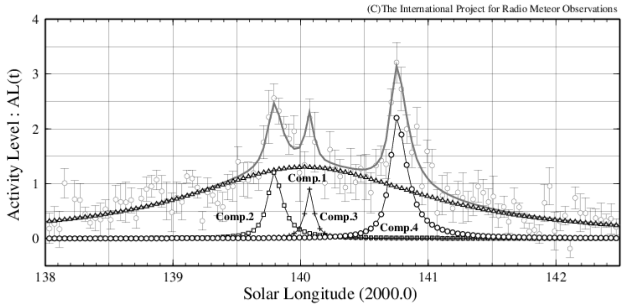

Figure 3 – The Activity Level Index: the estimated components using the Lorentz Profile (solid line: total activity of Comp1 – Comp4).

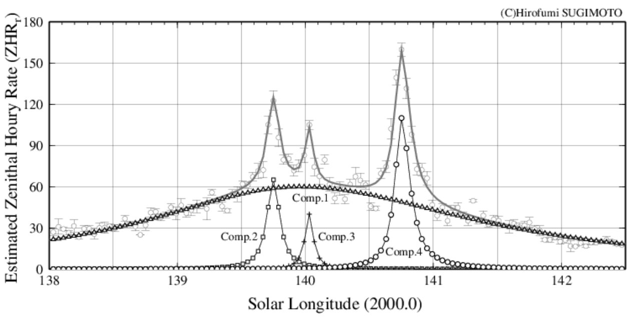

Figure 4 – The estimated ZHR_r: the estimated components using the Lorentz Profile (solid line: total activity of Comp1 – Comp4).

4.1.1 *Component 1*

This component corresponds to the traditional activity. The peak occurred at $\lambda_{\odot} = 139.95° – 140.03°$ (August 12, $12^h30^m – 14^h30^m$ UT). The maximum *AL* was 1.3 ($ZHR_r = 60$). It was the same activity level and peak time as the past average (Ogawa, 2022).

4.1.2 *Component 2*

The first peak occurred as the Component 2 (Comp.2). This component had $AL_{(max)} = 1.2$ at $\lambda_{\odot} = 139.75° – 139.79°$ (August 12, $08^h30^m – 09^h30^m$ UT). According to P. Jenniskens, there was a possibility to observe a weak filament around 139.81°. Although Comp.2 produced a similar result as this forecast, it might be different from the prediction because the activity level was higher than expected. P. Jenniskens indicated that the activity level was about one tenth of the 2018 filament. Radio Meteor Observation detected a filament with $AL = 0.5$ during the 2018 Perseids. Another possibility, five old dust trails predicted by J. Vaubaillon could be encountered between 139.61° and 139.91°. It is possible that Comp.2 mixed these resources.

4.1.3 *Component 3*

After a first peak, a sharp component was estimated as Comp.3. The maximum *AL* was 0.9 at 140.03° – 140.07°. This component was uncertain because the FWHM was too narrow (the possibility of a random error) and there was no prediction.

4.1.4 *Component 4*

A big surprise third peak was estimated as Comp.4. It had a maximum $AL = 2.2$ and correspond to $ZHR_r = 110$. Although this activity was unexpected, it was a very distinct activity in Europe and North-America. The strong activity began around $\lambda_{\odot} = 140.59°$ (August 13, 04^h30^m UT). The peak was estimated at $\lambda_{\odot} = 140.75°$ (August 13, 08^h30^m UT). After that, it ended around $\lambda_{\odot} = 141.03°$ (August 13, 15^h30^m UT). The descending branch was longer than the ascending branch.

4.2 Compare with recent results

In the past, an unpredicted peak after the annual peak was sometimes observed. *Figure 5* shows results for *AL* between 2021 and 2024. In 2021, many observers were surprised by a strong activity around $\lambda_{\odot} = 141.48°$ with $AL = 3.7$ ($ZHR_r = 220$) (Miskotte et al., 2021). Therefore, it was a stronger activity in 2021 than in 2024. In 2023, a sub-peak after the main peak was observed at $\lambda_{\odot} = 140.84°$ with $AL = 1.9$ ($ZHR_r = 126$). It is possible that this activity was released by some very old dust trails (Sugimoto and Ogawa, 2023). For 2022, two small sub-peaks around $\lambda_{\odot} = 141.09°$ and 141.53° with $AL = 1.4$ and $AL = 1.3$were also observed.

Miskotte and Vandeputte (2020), Miskotte (2020) and Roggemans (2023) also described the detection of sub-peaks between $\lambda_{\odot} = 140.5°$ and $\lambda_{\odot} = 141.6°$.

Table 2 – The estimated components using the Lorentz profile and some references.

	Radio Results by IPRMO				References		
	Peak Time (UT)	$\lambda_{\odot}$	FWHM (hours)	Peak Level (*AL*)	Peak Time (UT)	$\lambda_{\odot}$	Source
Comp.1	Aug 12 12^h30^m – 14^h30^m	139.95° - 140.03°	–28.0/+29.0	1.3 ($ZHR_r = 60$)	Aug 13, $13^h – 16^h$	140.0° – 140.1°	annual
Comp.2	Aug 12 08^h30^m – 09^h30^m	139.75° – 139.79°	–1.5/+2.0	1.2 ($ZHR_r = 65$)	Aug 12, 09^h Aug 12, $4^h – 11^h$	139.81° 139.61° –139.91°	P.Jenniskens J. Vaubaillon
Comp.3	Aug 12 14^h30^m – 15^h30^m	140.03° 140.07°	–1.0/+1.0	0.9 ($ZHR_r = 40$)			
Comp.4	Aug 13 08^h30^m	140.75°	–1.5/+2.5	2.2 ($ZHR_r = 110$)			

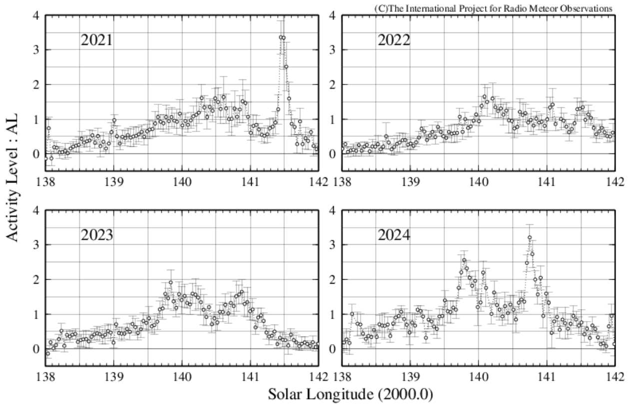

Figure 5 – Activity Level Index between 2021 and 2024.

5 Conclusion

For 2024, worldwide radio meteor observers caught three unusual peaks. The third peak at $\lambda_{\odot}$ =140.75°was very strong and a distinct activity. *AL* reached 3.2 and the estimated ZHR_r = 159.

In recent years, similar sub-peaks were observed such as in 2021 and 2023. The origin of these unusual sub peaks isn't clear yet, but this needs to be monitored in the future.

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Radio meteors June 2024

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An overview of the radio observations during June 2024 is given.

1 Introduction

The graphs show both the daily totals (*Figure 1 and 2*) and the hourly numbers (*Figure 3 and 4*) of "all" reflections counted automatically, and of manually counted "overdense" reflections, overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during the month of June 2024.

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

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

Local interference and unidentified noise remained quite low for most of the month. Weak to moderate lightning activity was detected on 5 different days, but on June 29 at 15^h59^m UT there was a lightning strike at very short distance from our observation station, causing significant electrical damage in the wider area. Fortunately, our meteor registration continued to work on 49.99 MHz.

The Sun also remained quite active, with powerful eruptions almost daily, mostly of type III (*Figure 5*).

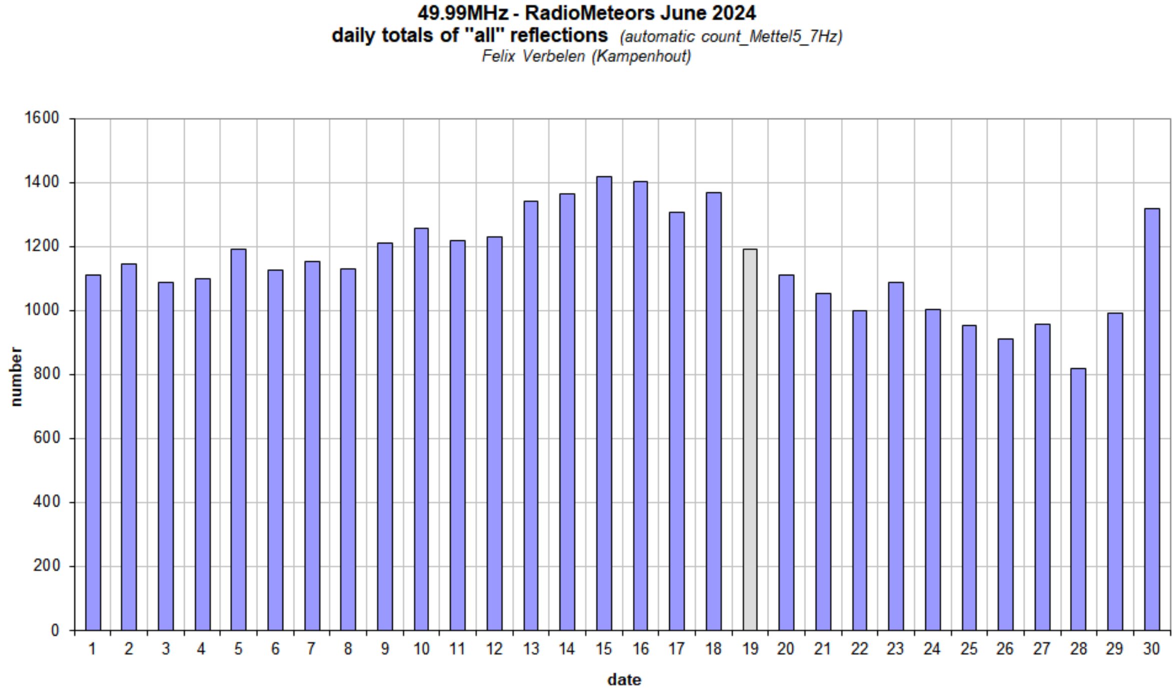
On June 19th between 09^h45^m and 11^h14^m UT the beacon was disabled due to maintenance work.

The meteor activity was mainly dominated by the daytime showers. If we compare the different graphs, we can see quite clearly the structure of the different showers: the maxima of the long-lasting reflections (and therefore more massive meteoroids) certainly do not coincide with those of the short-lived ones that make up the bulk of the total number of reflections.

During the entire month, 11 reflections longer than 1 minute were recorded. A selection of these, along with some other interesting reflections is included (*Figures 6 to 20*). More of these are available on request.

In addition to the usual graphs, you will also find the raw counts in cvs-format[19] from which the graphs are derived. The table contains the following columns: day of the month, hour of the day, day + decimals, solar longitude (epoch J2000), counts of "all" reflections, overdense reflections, reflections longer than 10 seconds and reflections longer than 1 minute, the numbers being the observed reflections of the past hour.

[19] https://www.emeteornews.net/wp-content/uploads/2024/07/202406_49990_FV_rawcounts.csv



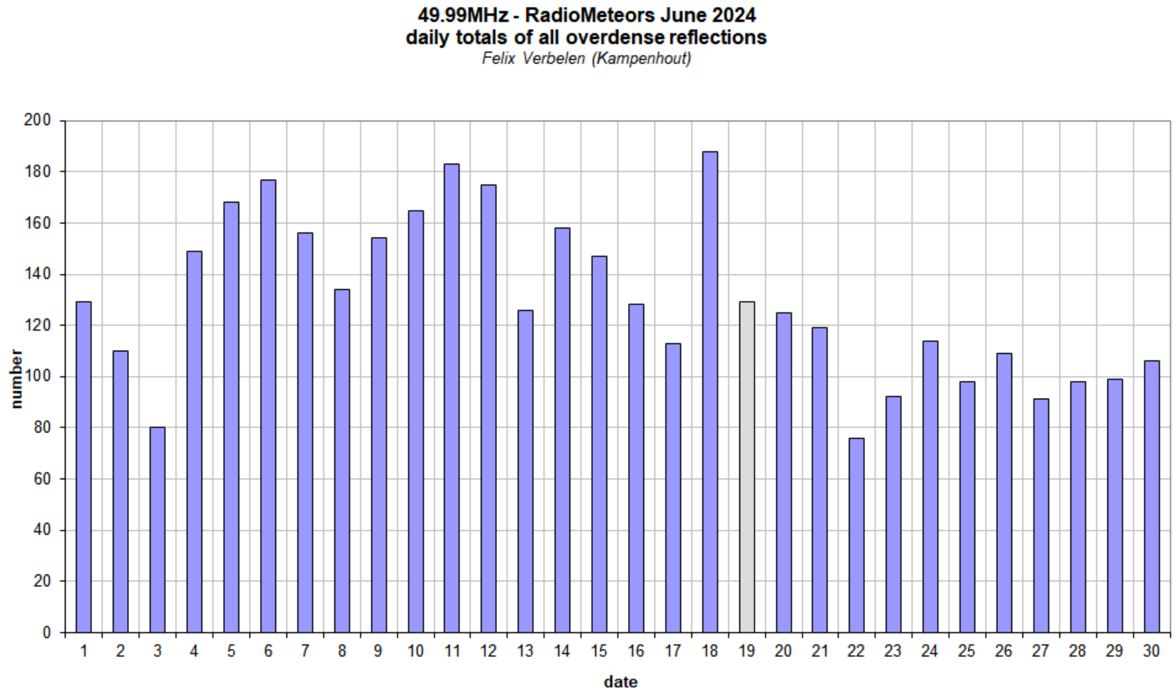
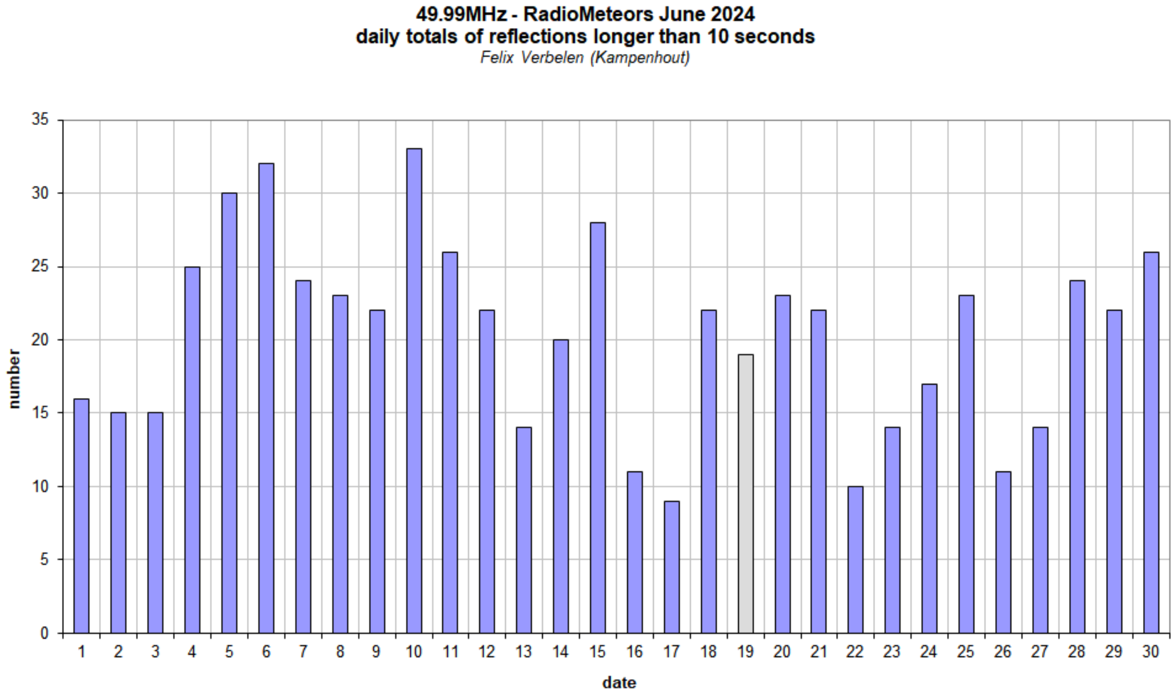


Figure 1 – The daily totals of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during June 2024.



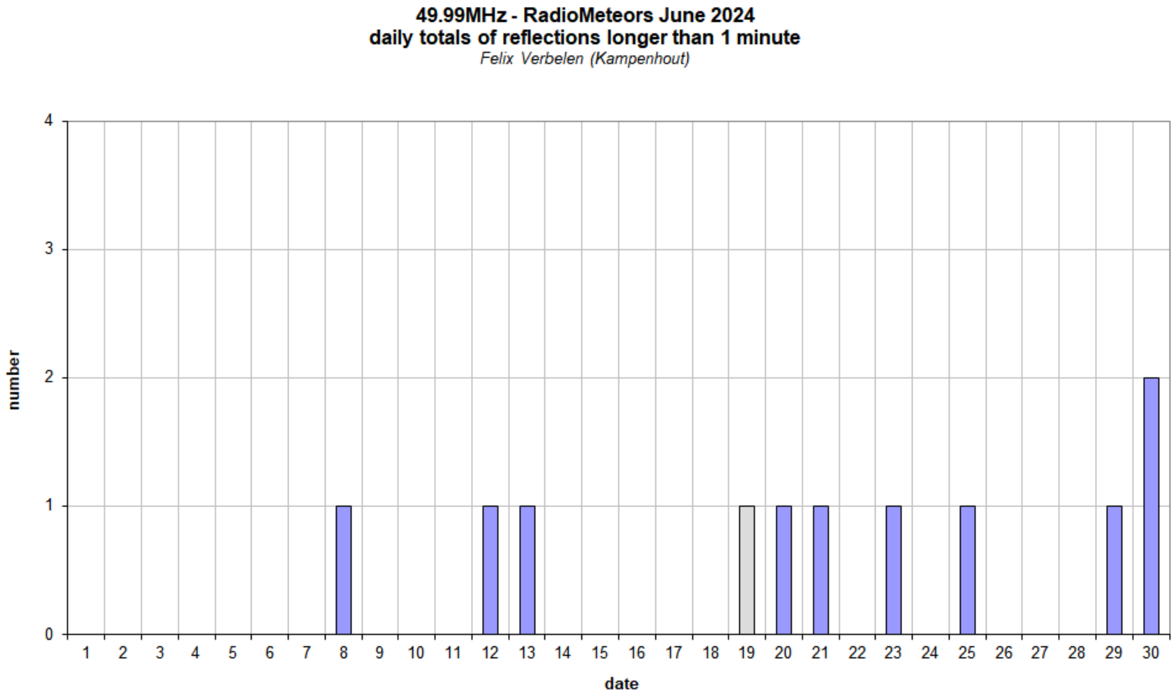
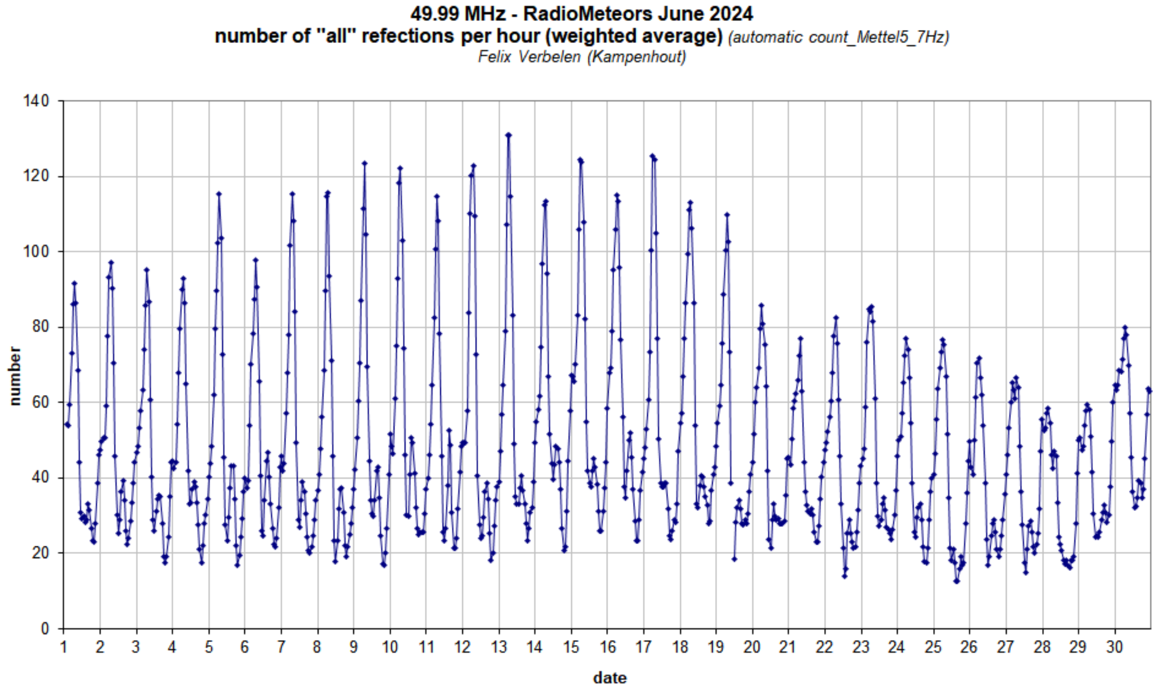


Figure 2 – The daily totals of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during June 2024.



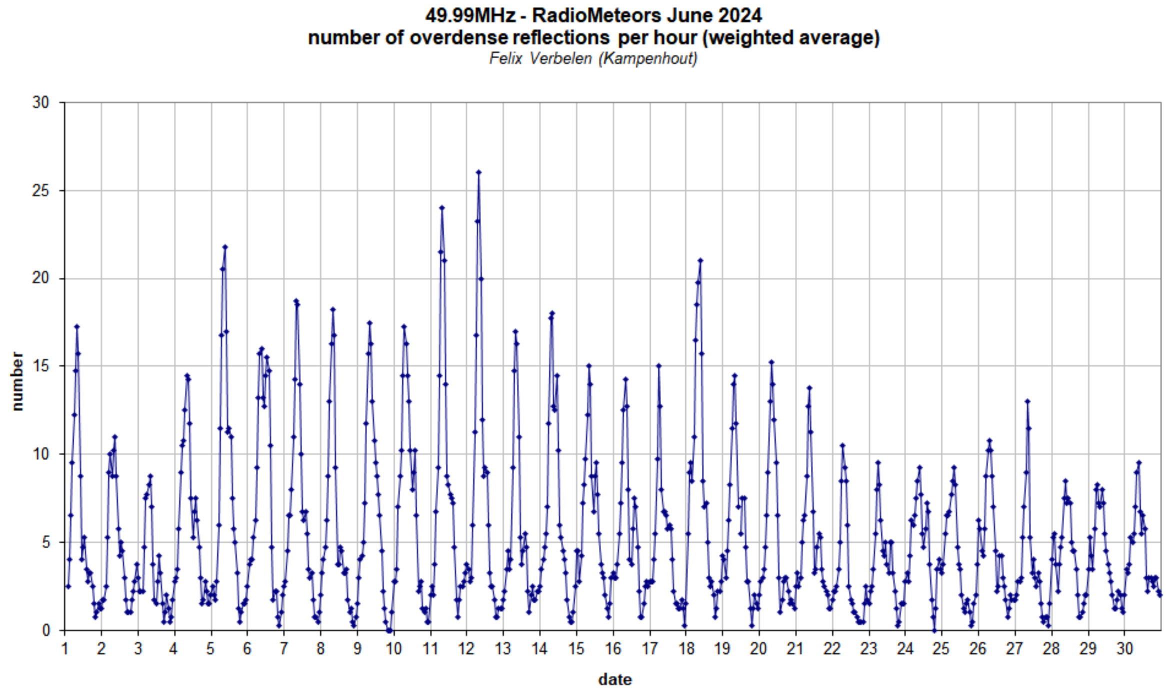
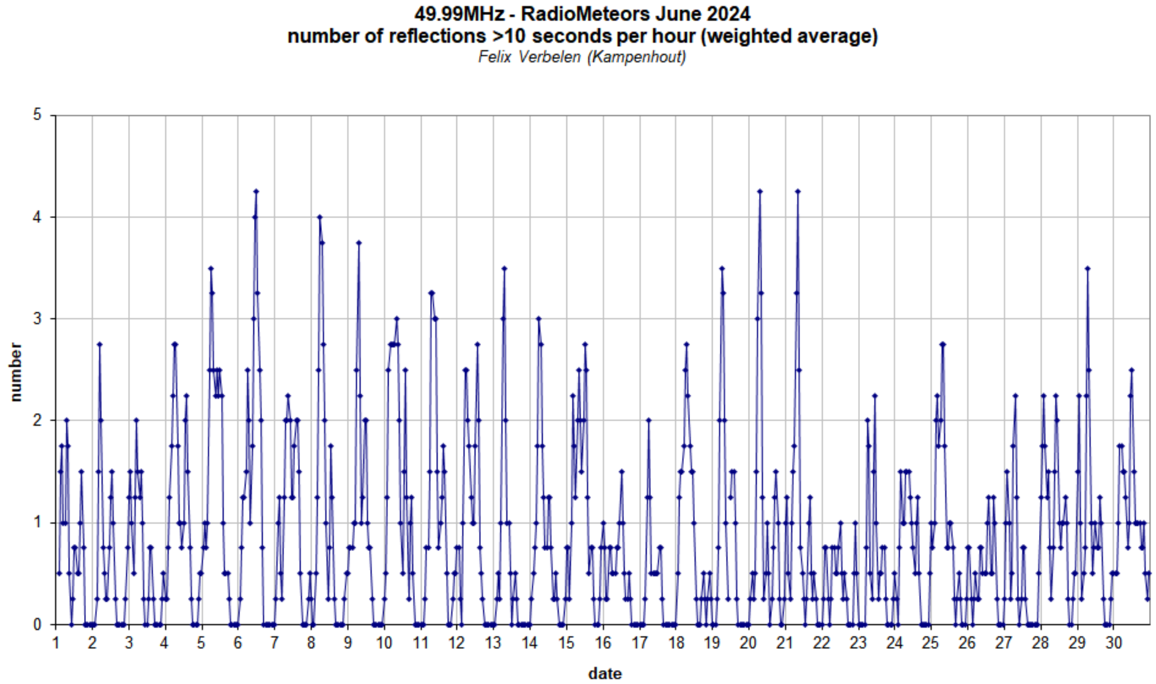


Figure 3 – The hourly numbers of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during June 2024.



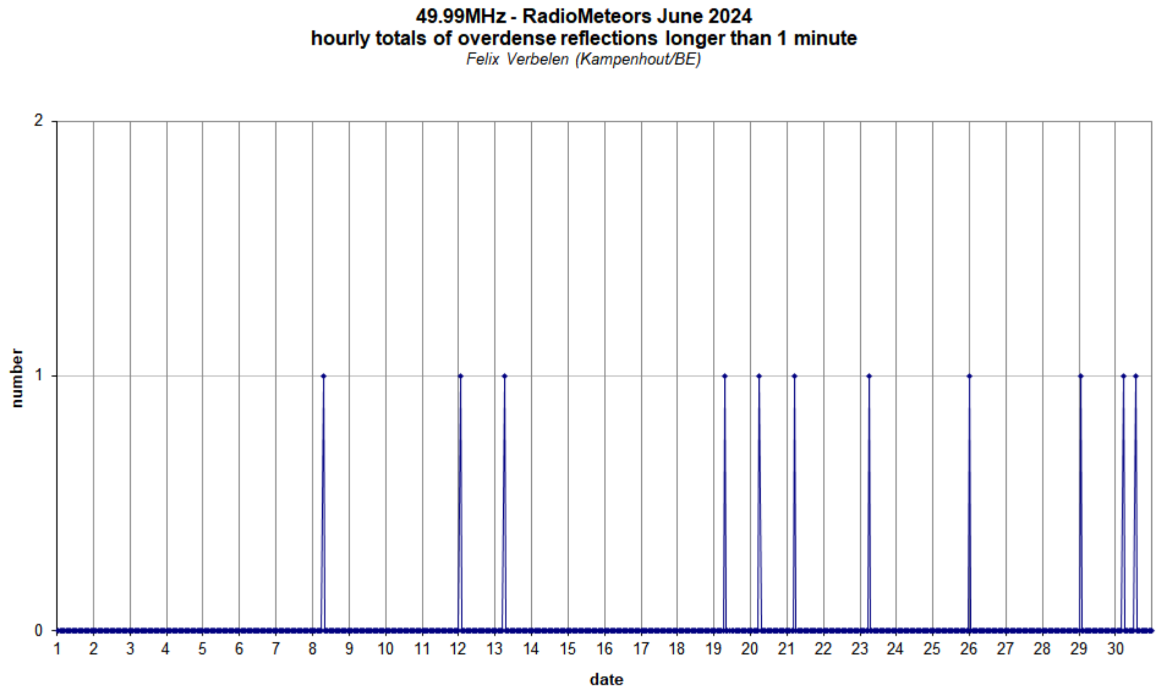


Figure 4 – The hourly numbers of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during June 2024.

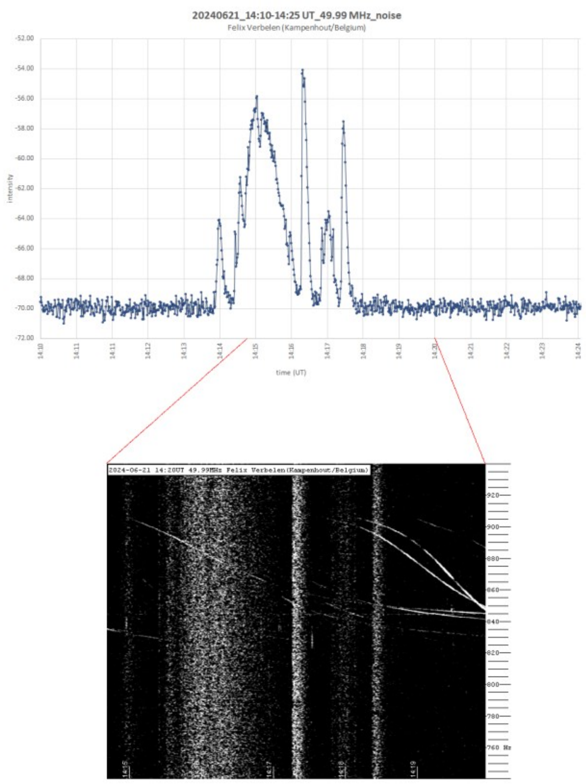


Figure 5 – Powerful eruption of the Sun on June 21st.

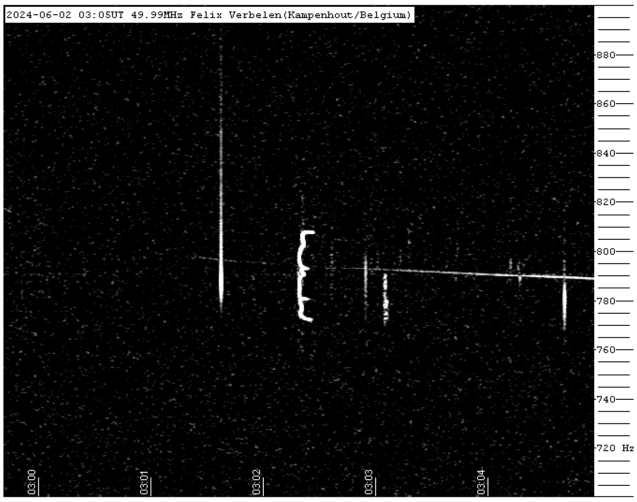


Figure 6 – Meteor echoes June 2, 03^{h}05^m UT.

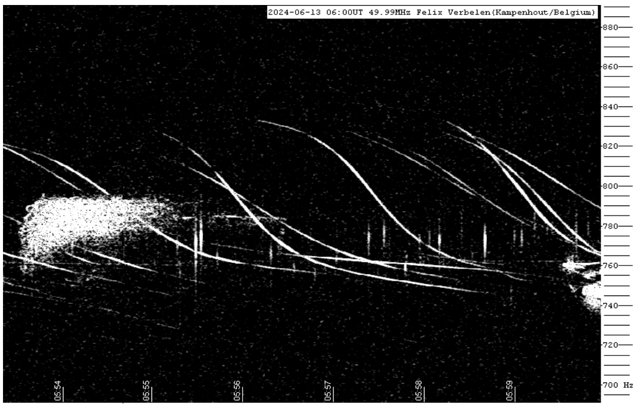


Figure 7 – Meteor echoes June 13, 06^{h}00^m UT.

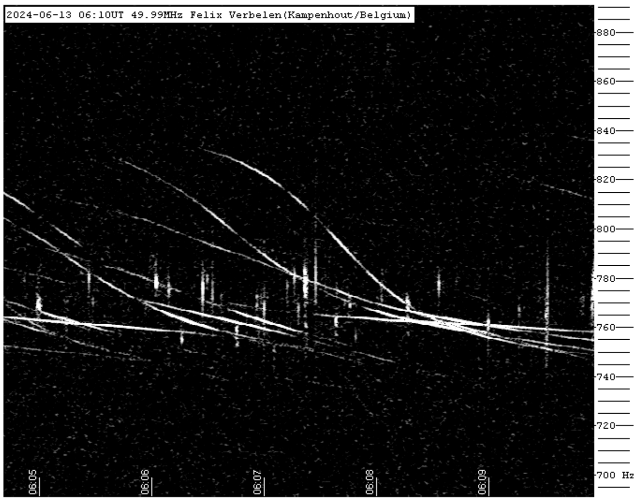


Figure 8 – Meteor echoes June 13, 06^{h}10^m UT.

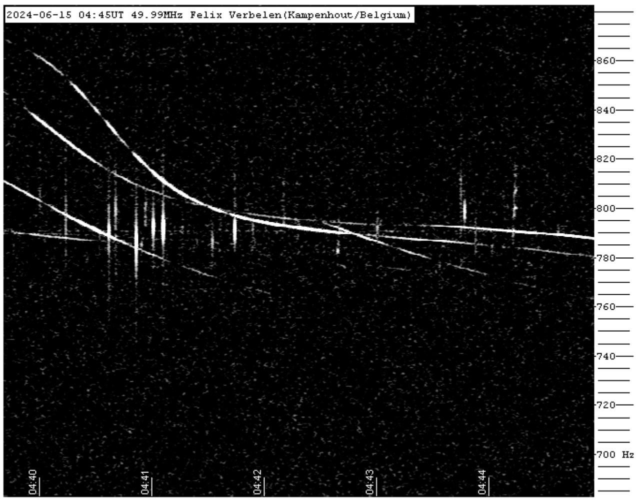


Figure 9 – Meteor echoes June 15, 04^{h}45^m UT.

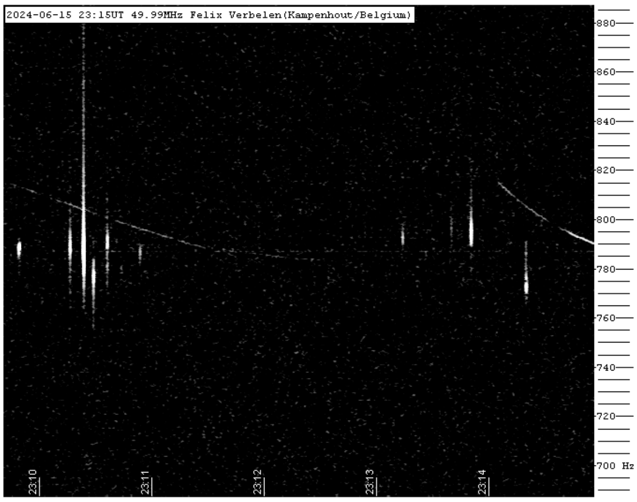


Figure 10 – Meteor echoes June 15, 23^{h}15^m UT.

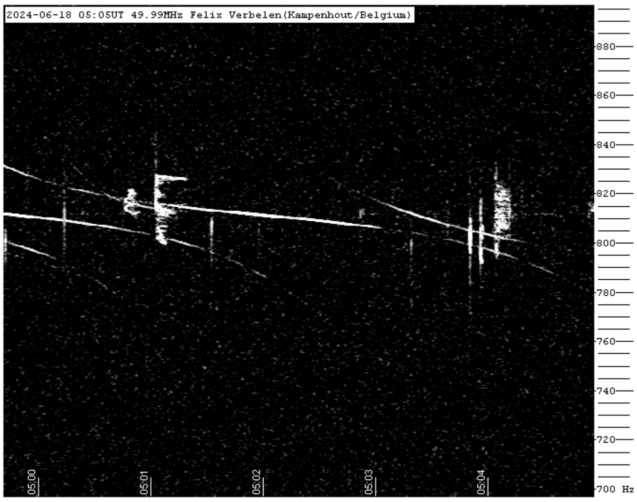


Figure 11 – Meteor echoes June 18, 05^h05^m UT.

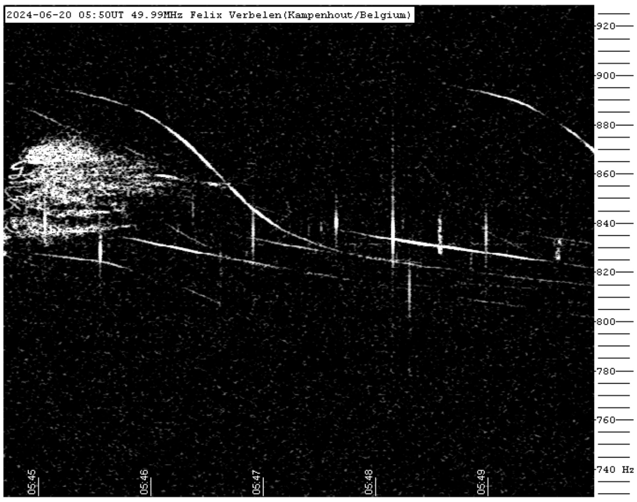


Figure 12 – Meteor echoes June 20, 05^h50^m UT.

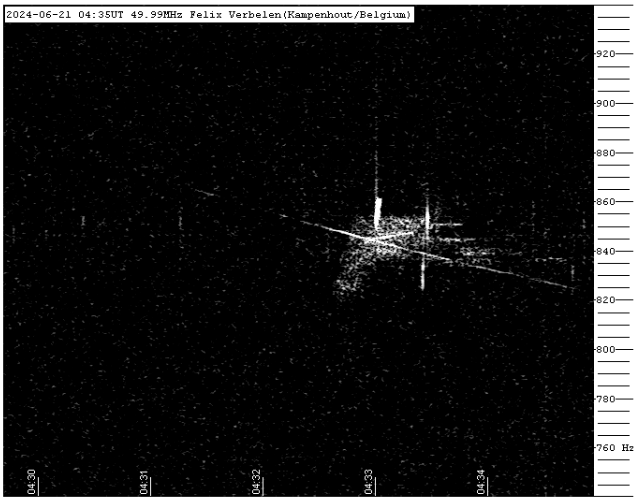


Figure 13 – Meteor echoes June 21, 04^h35^m UT.

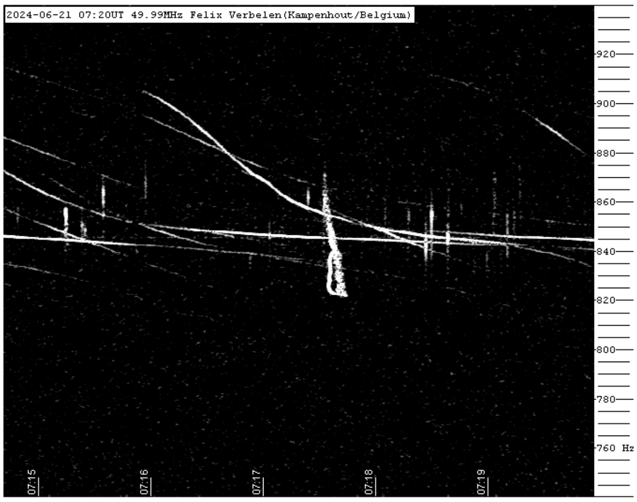


Figure 14 – Meteor echoes June 21, 07^h20^m UT.

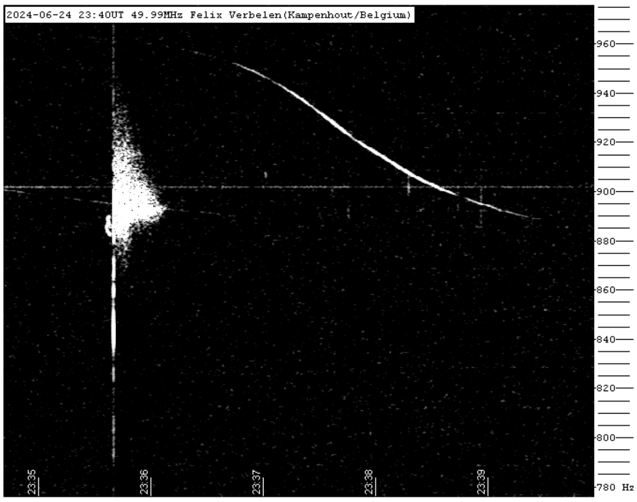


Figure 15 – Meteor echoes June 24, 23^h40^m UT.

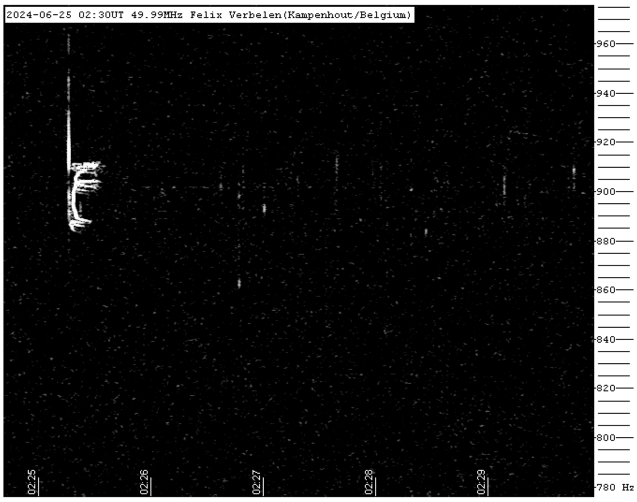


Figure 16 – Meteor echoes June 25, 02^h30^m UT.

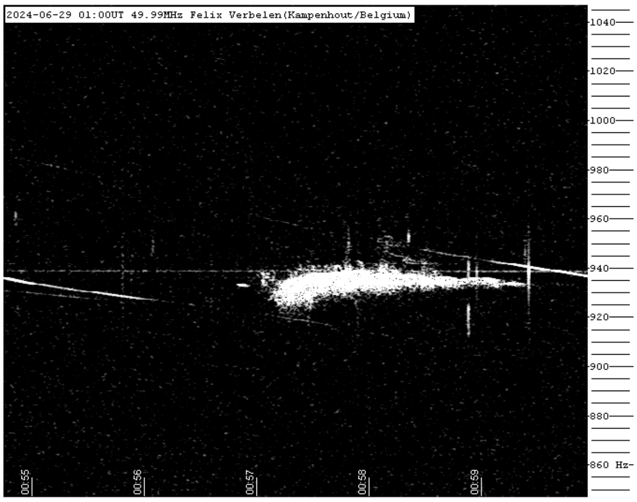


Figure 17 – Meteor echoes June 29, 01^{h}00^m UT.

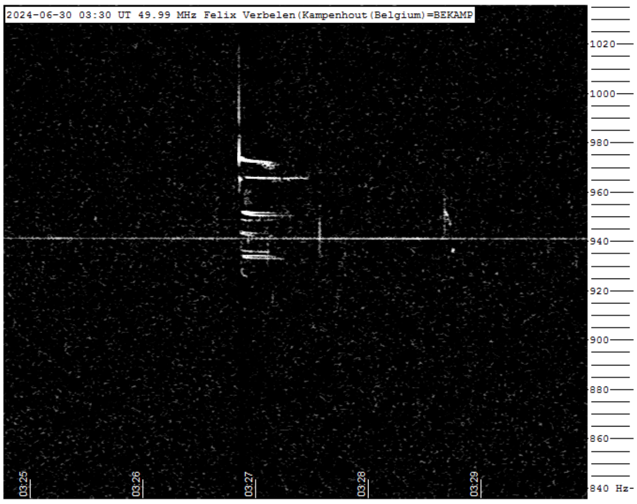


Figure 18 – Meteor echoes June 30, 03^{h}30^m UT.

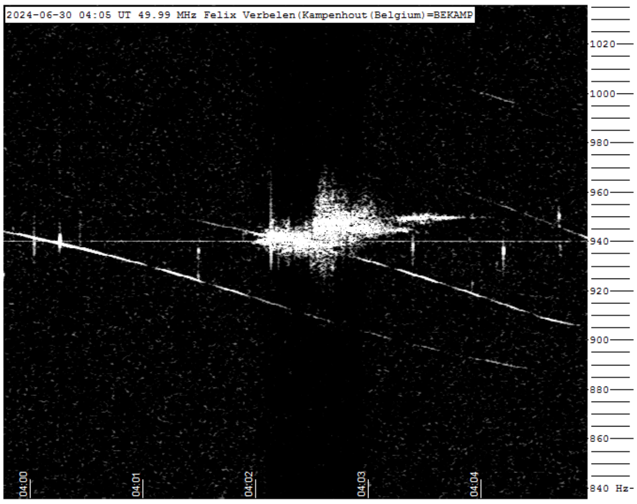


Figure 19 – Meteor echoes June 30, 04^{h}05^m UT.

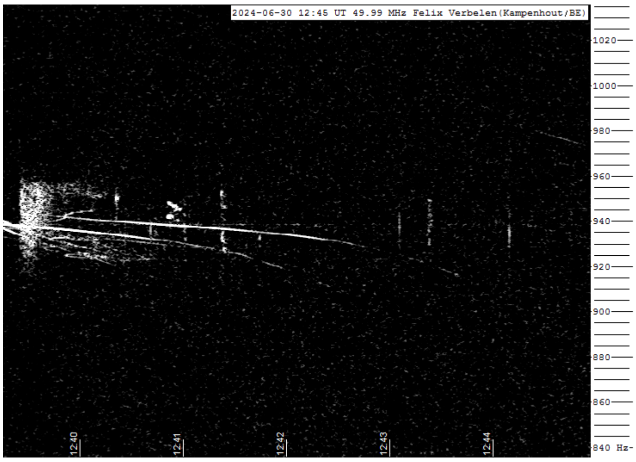


Figure 20 – Meteor echoes June 30, 12^{h}45^m UT.

Radio meteors July 2024

Felix Verbelen

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felix.verbelen@gmail.com

An overview of the radio observations during July 2024 is given.

1 Introduction

The graphs show both the daily totals (*Figure 1 and 2*) and the hourly numbers (*Figure 3 and 4*) of "all" reflections counted automatically, and of manually counted "overdense" reflections, overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during the month of July 2024.

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

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

Local interference and unidentified noise remained mostly low, while on only 4 days weak to moderate lightning activity was recorded. However, several times a day quite strong solar noise showed up, mostly type III bursts.

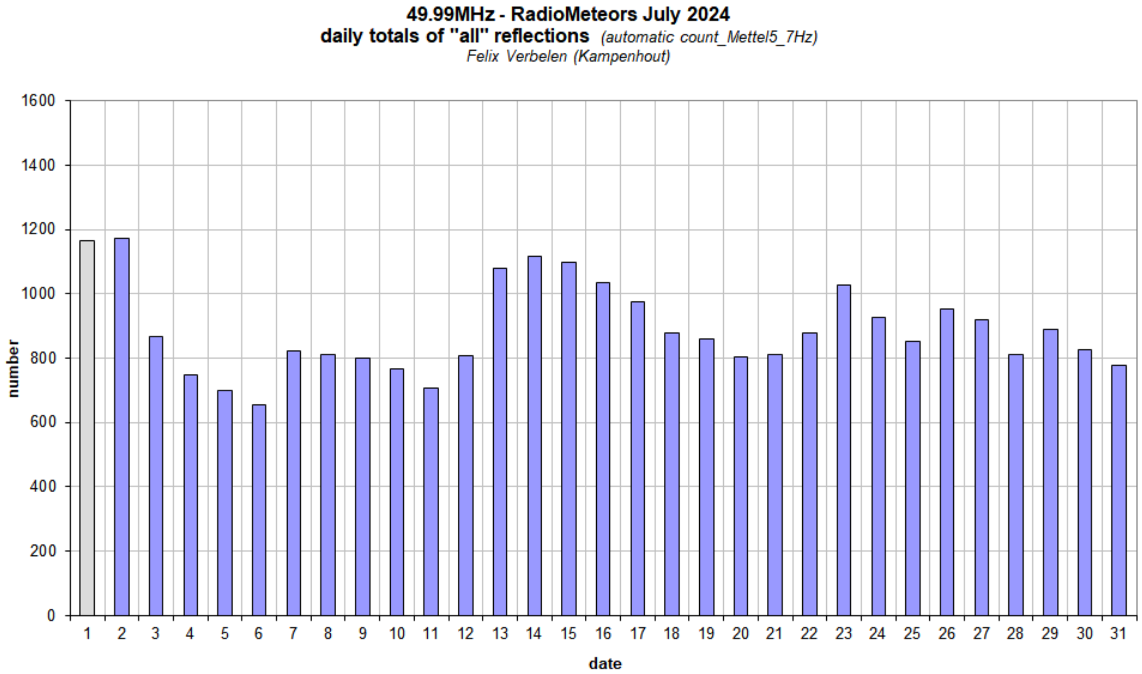
Due to works near the radio beacon, it had to be switched off on July 1st between 12^{h}00^m and 12^{h}58^m UT.

The general meteor activity is still increasing, with several nice showers. Also, compact groups of mostly underdense reflections were often prominent.

This month 20 reflections longer than 1 minute were observed here. A selection of these, together with a few compact groups of reflections and some other interesting registrations are also included (*Figures 5 to 19*). More of these are available on request.

In addition to the usual graphs, you will also find the raw counts in cvs-format[20] 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.

[20] https://www.emeteornews.net/wp-content/uploads/2024/08/202407_49990_FV_rawcounts.csv



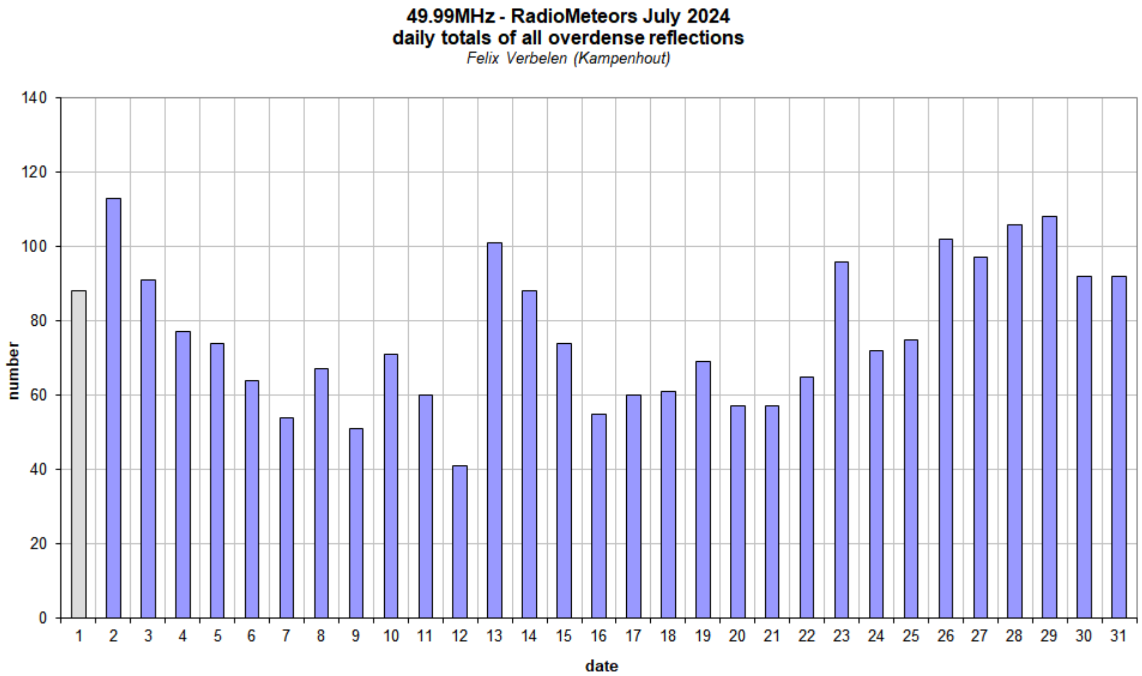
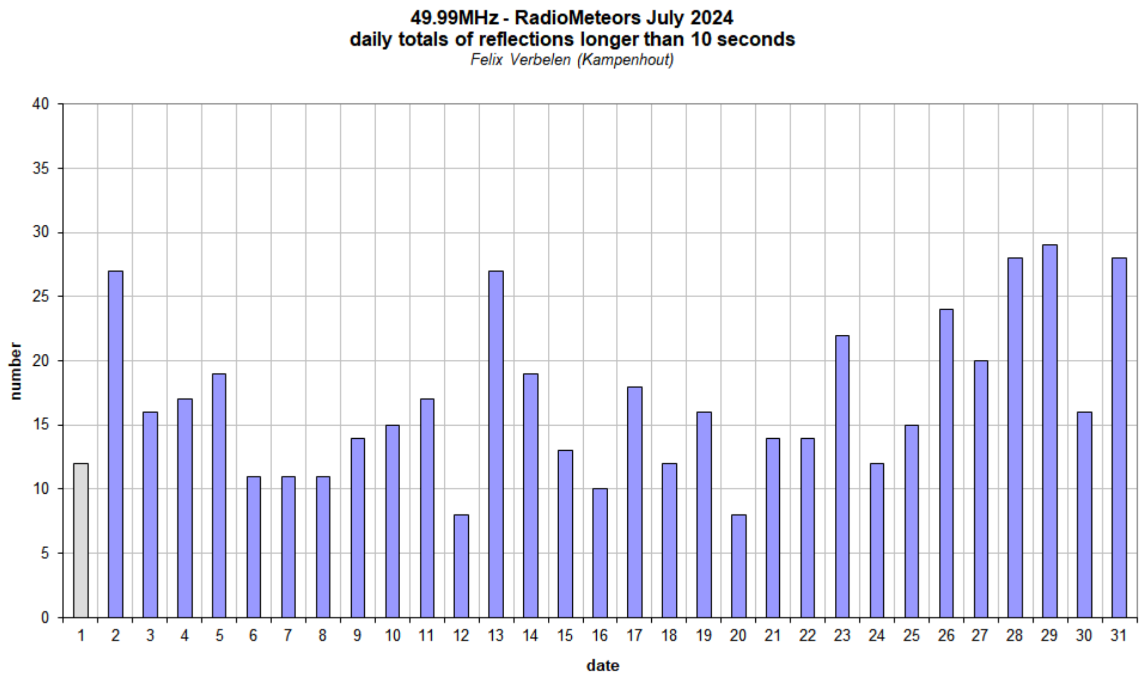


Figure 1 – The daily totals of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during July 2024.



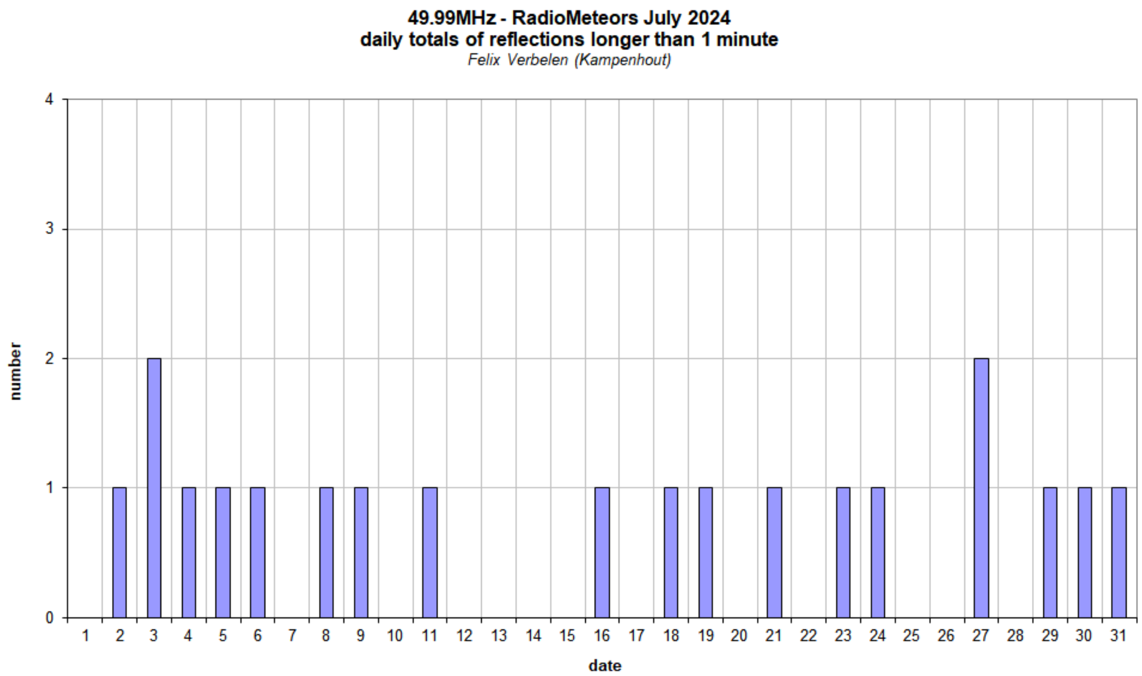
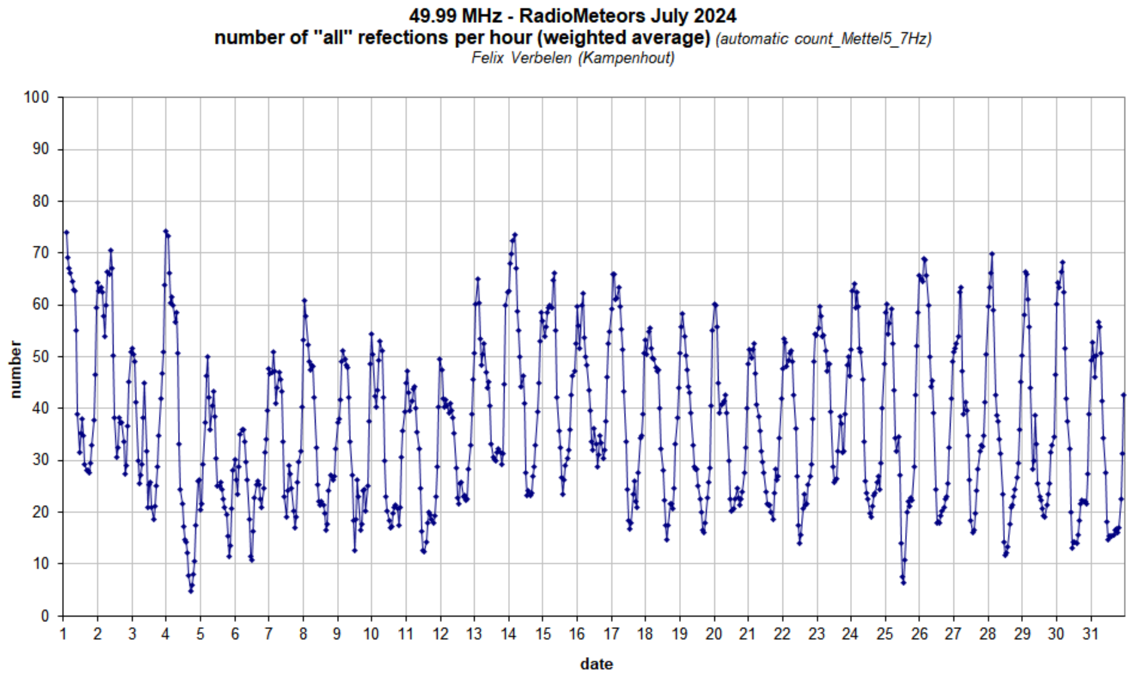


Figure 2 – The daily totals of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during July 2024.



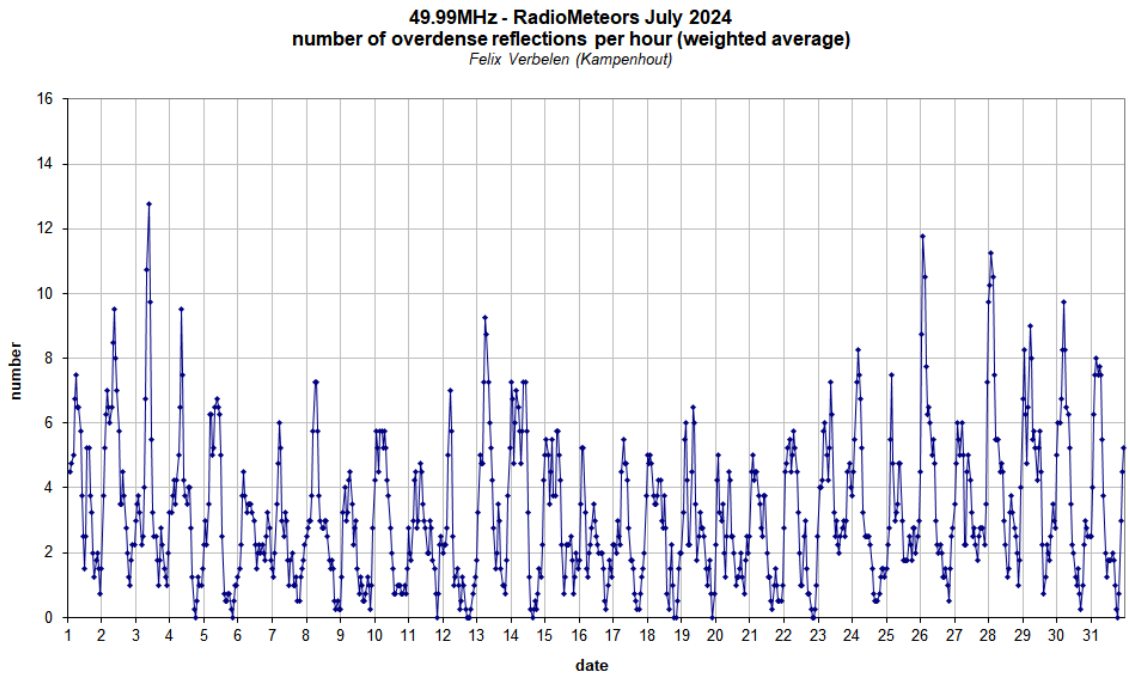
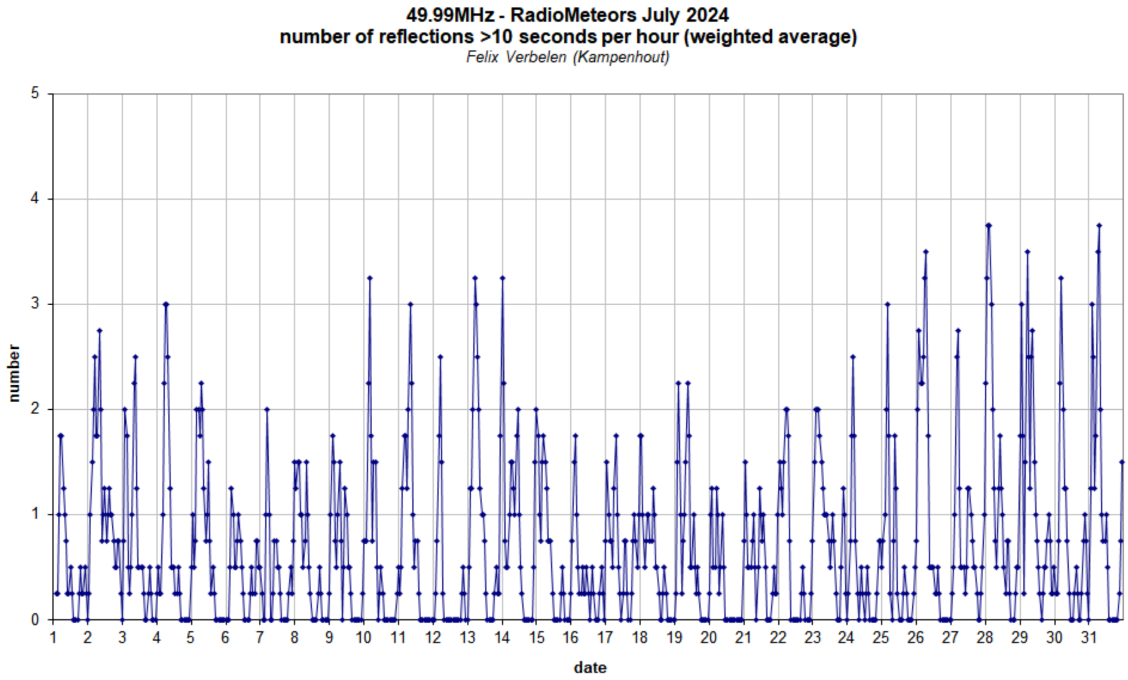


Figure 3 – The hourly numbers of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during July 2024.



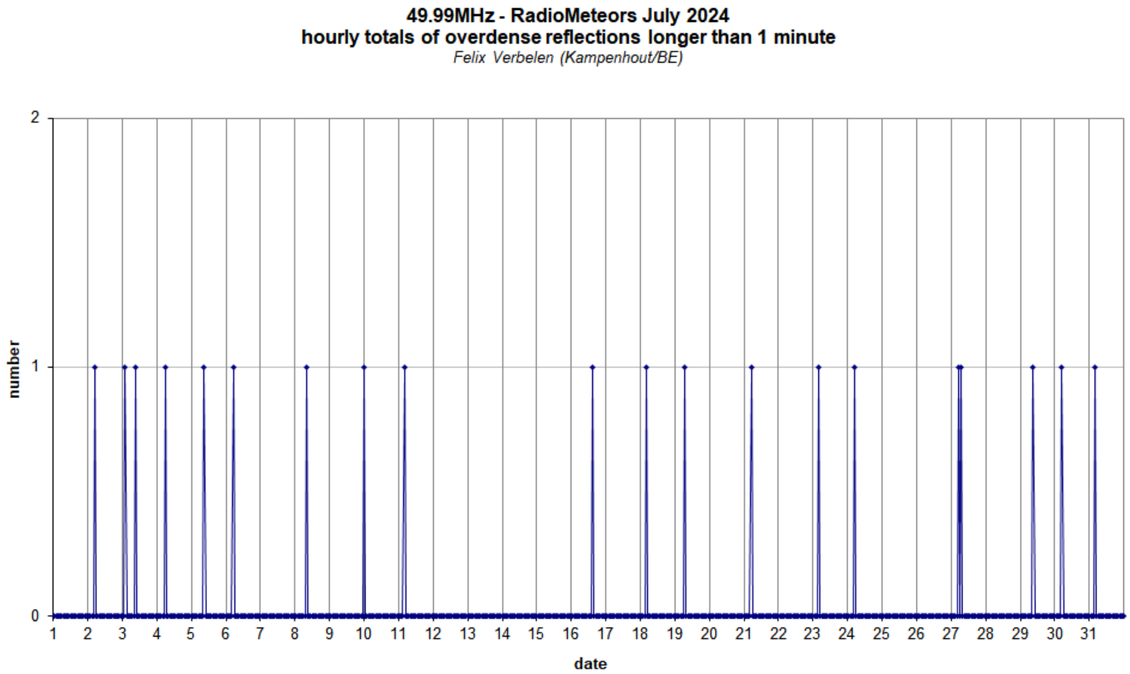


Figure 4 – The hourly numbers of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during July 2024.

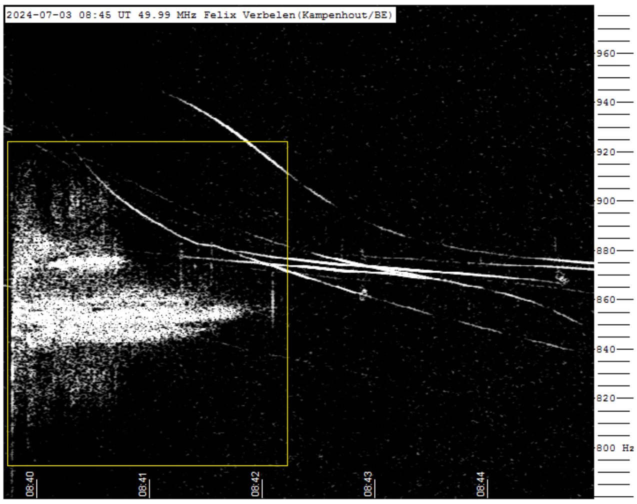


Figure 5 – Meteor echoes July 3, $08^{h}45^{m}$ UT.

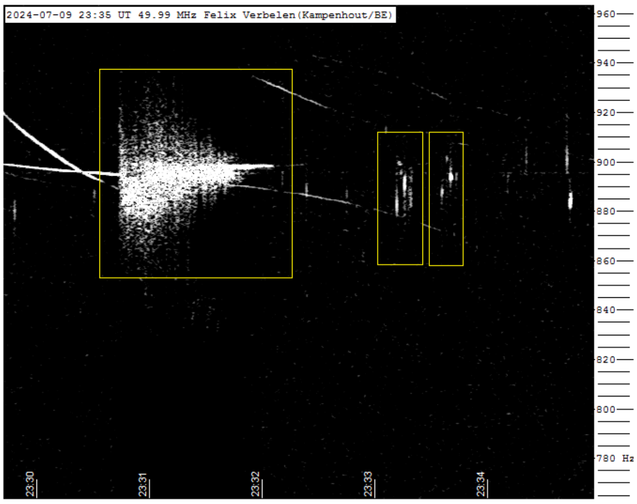


Figure 6 – Meteor echoes July 9, $23^{h}35^{m}$ UT.

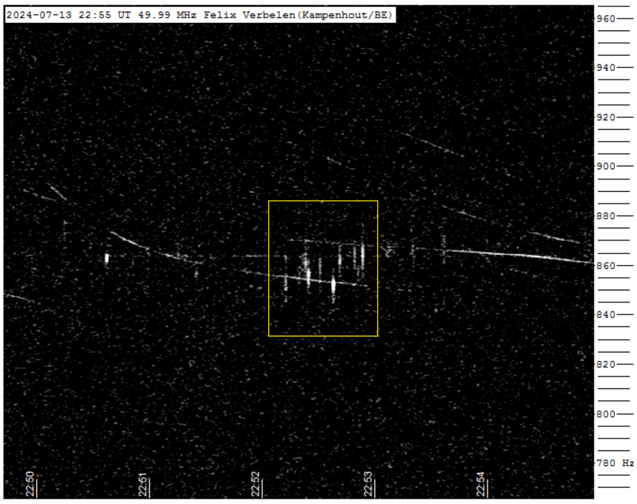


Figure 7 – Meteor echoes July 13, $22^{h}55^{m}$ UT.

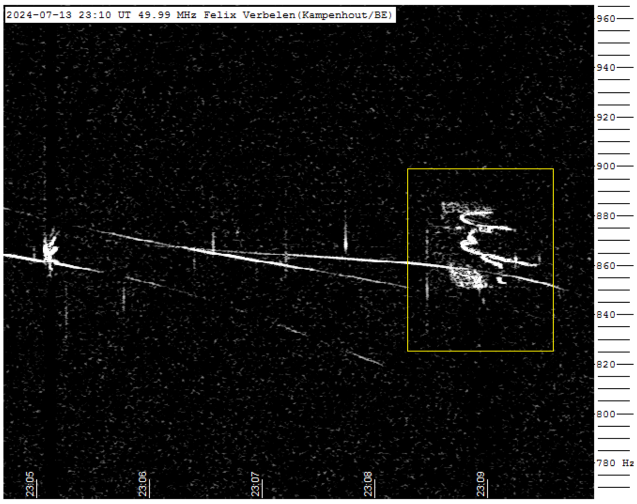


Figure 8 – Meteor echoes July 13, $23^{h}10^{m}$ UT.

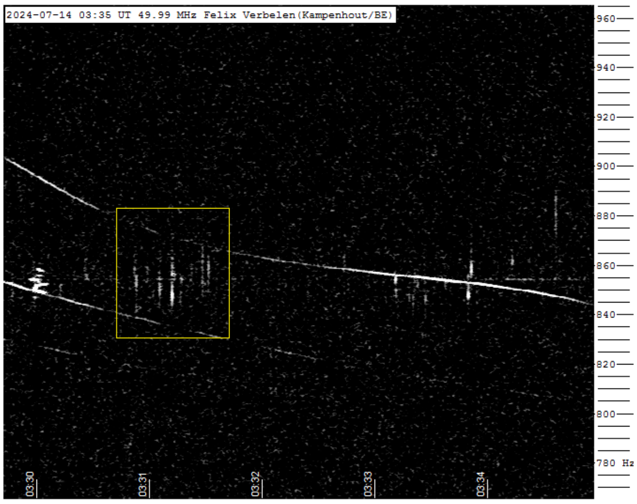


Figure 9 – Meteor echoes July 14, $03^{h}35^{m}$ UT.

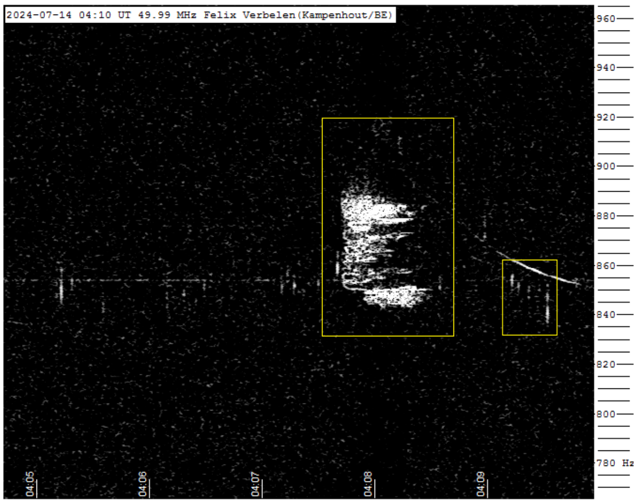


Figure 10 – Meteor echoes July 14, $04^{h}10^{m}$ UT.

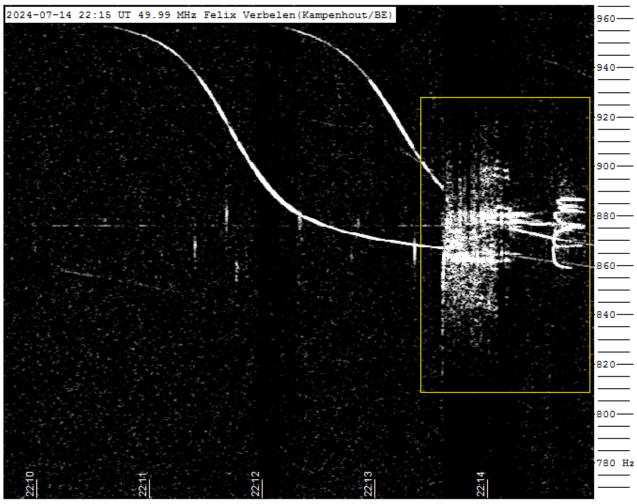


Figure 11 – Meteor echoes July 14, 22^{h}15^m UT.

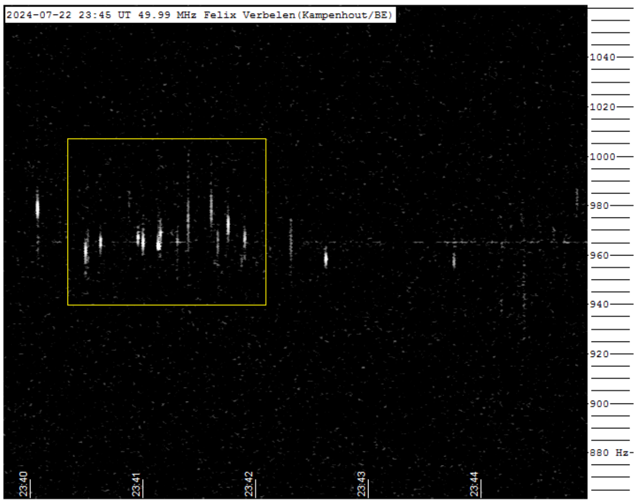


Figure 14 – Meteor echoes July 22, 23^{h}45^m UT.

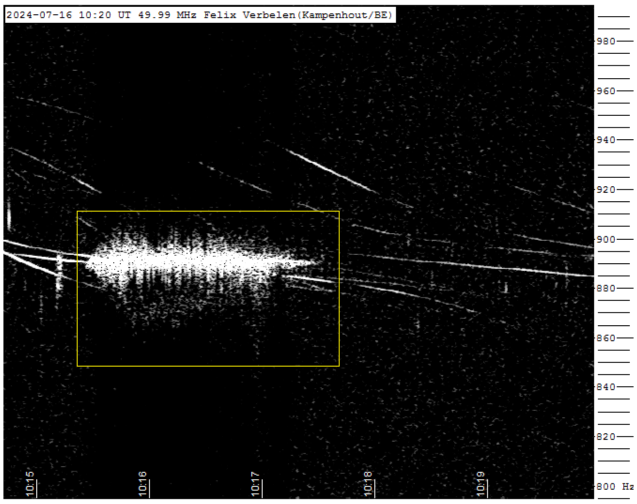


Figure 12 – Meteor echoes July 16, 10^{h}20^m UT.

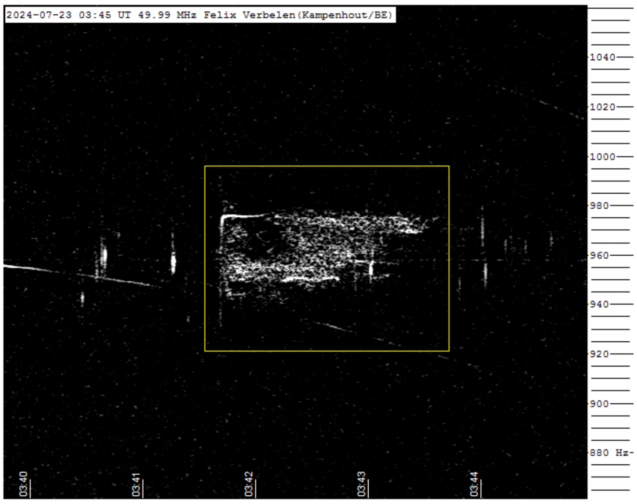


Figure 15 – Meteor echoes July 23, 03^{h}45^m UT.

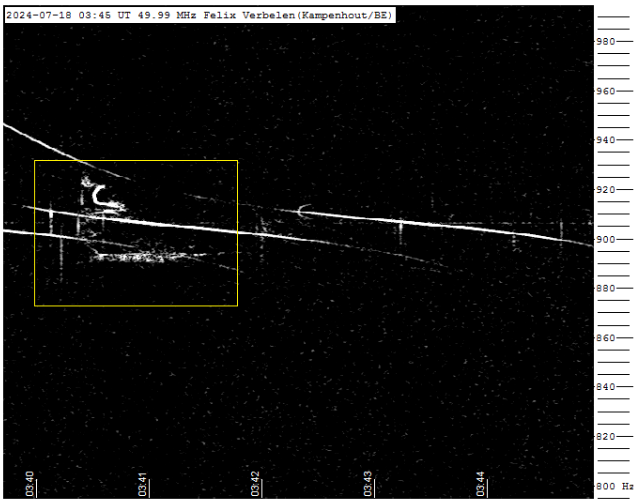


Figure 13 – Meteor echoes July 18, 03^{h}45^m UT.

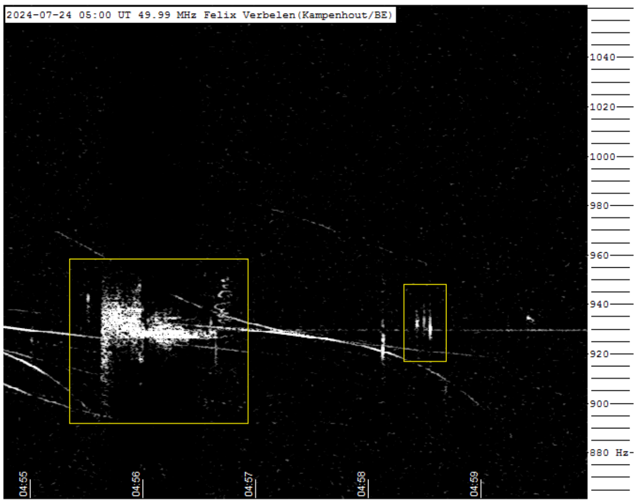


Figure 16 – Meteor echoes July 24, 05^{h}00^m UT.

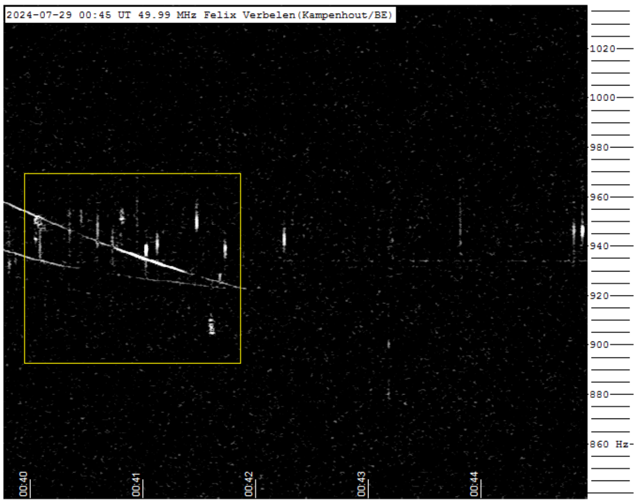


Figure 17 – Meteor echoes July 29, 00^h45^m UT.

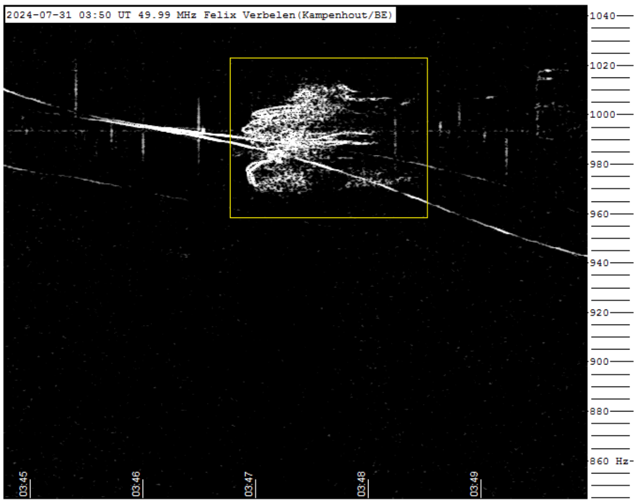


Figure 19 – Meteor echoes July 31, 03^h50^m UT.

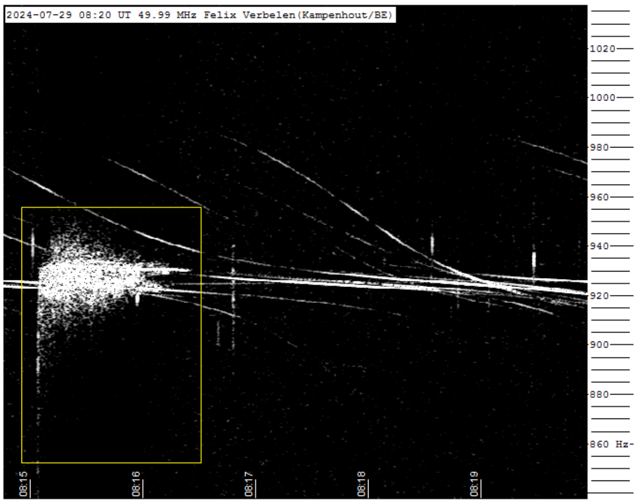


Figure 18 – Meteor echoes July 29, 08^h20^m UT.

June 2024 report CAMS-BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month of June 2024 is presented. This month was good for 10136 multi-station meteors resulting in 2845 orbits.

1 Introduction

In June the sporadic meteor activity is slowly rising. On the other hand, no major shower is present in this month and the astronomical twilight is lasting all night from BeNeLux latitudes. So, in all, meteor rates are low, and it is no surprise that the total number of orbits in June, after 11 years of CAMS activity is one of the lowest of all months. Only in March, when sporadic meteor activity reaches its lowest level, the number of orbits is at the same low level.

2 June 2024 statistics

The weather was very variable in June. In fact, the pattern of the previous months continued. Thanks to the increased number of stations and cameras, the total score of orbits was still comparable to the month of June 2023, when we could collect a record number of 2889 orbits.

In total, we captured 10136 meteors from multiple stations. This resulted in a total of 2845 orbits. In 15 nights, despite the short duration of these nights, more than 100 orbits per night were recorded. Compared to the special month of June 2023, that is still a very nice score. In that extremely sunny month, we had 17 nights with that criterion. The highest score was achieved in the night 25–26 June: 253 orbits. Never before so many orbits have been collected in one night in June. 56.1% of all orbits were recorded by more than 2 stations. If you look at the average percentage of cameras deployed in a night compared to the number of cameras in that night with meteors, that percentage is only 61%. As in several previous months this year, these percentages are somewhat lower due to the unstable weather.

On average, 116 cameras were active on each night during this month. At least 104 cameras were active every night to capture meteors. This is a significant increase compared to June last year. Unfortunately, the stations on Texel and Oostkapelle are not active for various reasons for the time being. However, the cameras in Burlage have been back in operation since 19 June.

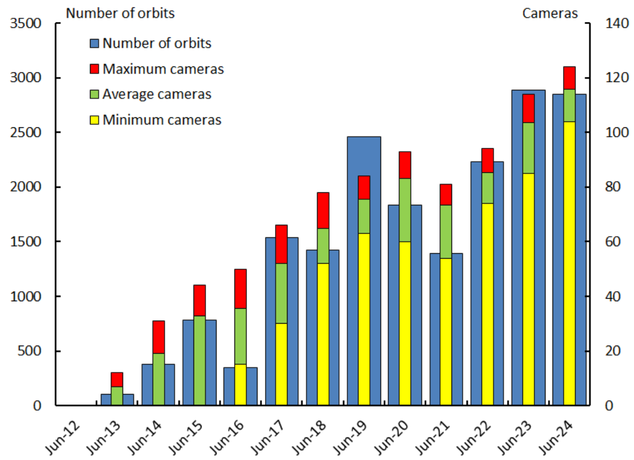

Figure 1 – Comparing June 2024 to previous months of June in the CAMS-BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras capturing in a single night, the green bars the average number of cameras capturing per night and the yellow bars the minimum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

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

Year	Nights	Orbits	Stations	Max. Cams	Min. Cams	Mean Cams
2012	0	0	4	0	–	0.0
2013	16	102	9	12	–	7.0
2014	23	379	13	31	–	19.0
2015	20	779	15	44	–	32.9
2016	18	345	17	50	15	35.7
2017	26	1536	19	66	30	52.1
2018	28	1425	21	78	52	64.9
2019	28	2457	20	84	63	75.6
2020	27	1834	24	93	60	83.1
2021	22	1389	26	81	54	73.3
2022	30	2228	30	94	74	85.2
2023	30	2889	35	114	85	103.7
2024	27	2845	44	124	104	115.9
Total	295	18208				

3 Conclusion

Compared to other months of June this year we have collected nearly a record number of orbits, despite moderate weather conditions. The good result is due to the greater number of cameras involved in our network.

Acknowledgment

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

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July 2024 report CAMS-BeNeLux

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A summary of the activity of the CAMS-BeNeLux network during the month of July 2024 is presented. This month was good for 27357 multi-station meteors resulting in 7671 orbits.

1 Introduction

In July sporadic meteor activity is picking up. Some major meteoroid streams are also active towards the end of the month, e.g. Capricornids and Southern delta Aquariids. Astronomical twilight comes to an end near July 20th. All-in all we can observe greater meteor activity this month during more hours per night.

2 July 2024 statistics

However, the weather let us down a bit this month as well. It was not until the end of the month that the weather improved, so the results increased noticeably in the last week of July. In 19 nights, the number of collected orbits exceeded 100. CAMS-BeNeLux collected data from 27357 simultaneous meteors from all locations during the month, resulting in a total of 7671 orbits. This is the best result for a July month since the observations began in 2012 (*Figure 1*). About 40% of all orbits were obtained in the last week, with the real highlights being the nights 28–29 and 29–30 July when 941 and 800 orbits were collected respectively. Never before have so many orbits been captured during one night in July.

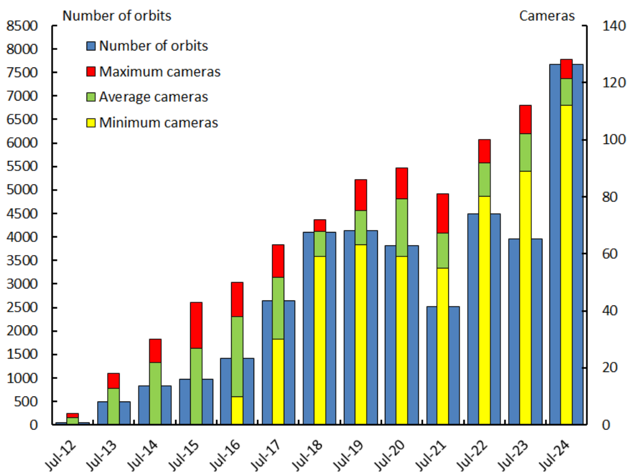

Figure 1 – Comparing July 2024 to previous months of July in the CAMS-BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras capturing in a single night, the green bars the average number of cameras capturing per night and the yellow bars the minimum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

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

Year	Nights	Orbits	Stations	Max. Cams	Min. Cams	Mean Cams
2012	7	49	4	4	–	2.6
2013	22	484	10	18	–	12.9
2014	19	830	14	30	–	22.0
2015	28	976	15	43	–	26.7
2016	28	1420	18	50	10	37.9
2017	27	2644	20	63	30	51.6
2018	30	4098	19	72	59	67.7
2019	30	4139	21	86	63	75.2
2020	28	3823	24	90	59	79.1
2021	28	2525	27	81	55	67.3
2022	31	4499	30	100	80	91.7
2023	30	3966	36	112	89	102.1
2024	30	7671	45	128	112	121.5
Total	338	37124				

The reason for this better-than-expected result is the significantly increased number of cameras in our network. Although it was common for some stations to have cloudy conditions, many meteors were still captured by the stations with clear conditions. Only in the night of 25–26 July not a single simultaneous event could be recorded. 58.5% of all orbits were obtained from more than two stations. That is a percentage that is comparable to other months. This percentage was mainly determined by the changeable first three weeks.

We welcome a new station this month. The data from the RMS camera NL000C in Elst (the Netherlands; CAMS - number 3191) have been made available to our network by *Erwin Harkink* since 13 July. This is a welcome addition to the coverage in the northern part of the BeNeLux. On average, more than 121 cameras were active every night this month. That is considerably more than a year ago in July. The reason for this is the substantial expansion with RMS cameras in recent months. We see in the July results that the RMS cameras capture just over twice as many orbits as the WATECS. No wonder, of course, given the larger field of view of these cameras, and the generally somewhat lower aiming height. Because a number of WATECS are currently not active (e.g. Texel and Oostkapelle), the coverage of these cameras is no longer optimal, that is reducing the chance of a simultaneous meteor.

In fact, the coverage of the WATEC camera fields should be upgraded with another optimization drive. Another minor reason for better results with RMS cameras, is that most RMS cameras are active above the southern part of the BeNeLux, and those regions often have better climate-wise conditions. Finally, we have to notice that not all WATECS are in operation every night. All in all, the WATECS continue to make a somewhat lesser, but valuable contribution to the results. There were at least 112 cameras active in each night this month.

3 Conclusion

July this year gave a record number of orbits, due to many new stations since the autumn of 2023.

Acknowledgement

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The earth-grazing meteor of July 2024

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At $00^h27^m46^s$ UT on the 7th of July 2024, an earth-grazer meteor was observed travelling from near Innsbruck in Austria to a point 30km north of Gravelines on the French coast. The meteor, travelling at 64km/s, traversed a distance of 841 km in 13.3 seconds at an altitude of between 114 and 102 km, crossing over Germany, Luxembourg, Belgium and France before returning to space. The event was detected by 35 cameras from the Global Meteor Network. A number of possible visual sightings were also reported to the IMO[21].
Analysis indicates that the meteoroid originated in the Kuiper Belt and likely last visited the inner solar system in 1536, the year in which Buenos Aires was founded and Anne Boleyn rose to and fell from power. In this article I present a summary of the results of manual data reduction and analysis. Full details of the event can be found on the UK Meteor Network's website[22].

1 Introduction

Earth-grazer meteors are meteors whose angle of entry into the atmosphere is so shallow that instead of penetrating downward, they skim across the surface and return to space. Earth-grazers are relatively rare as the likelihood of a meteor having a suitable entry angle of less than around ±2 degrees is low – see Gural (2002).

As they usually present long tracks and are frequently observed over a very wide area visually and on camera they can look quite spectacular. However, due to considerable timing differences between observations, automated systems often misinterpret earth-grazers as multiple events on parallel tracks. To resolve such issues, manual analysis is required.

The event of 7th July 2024 was no exception. Picked up by cameras stretching from Croatia to England it was initially identified as two or possibly three parallel meteors.

Figure 1 – Meteor as seen from NL0001.

2 Data collection and analysis

2.1 Collection

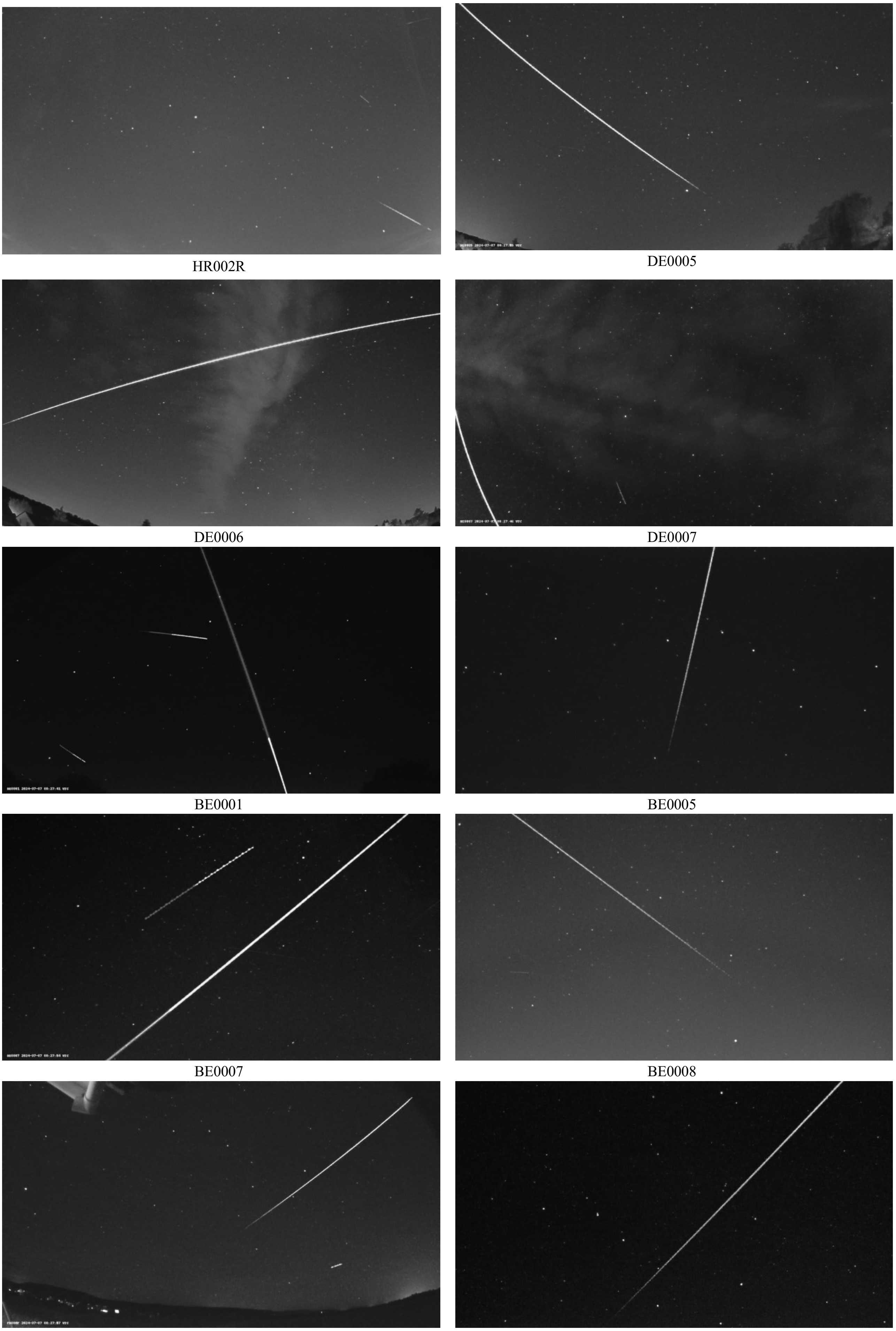
This event was detected by 35 separate cameras of the Global Meteor Network, GMN. GMN is a decentralized community of over 1000 cameras in 39 countries whose objective is to track and analyze meteors all around the world and which uses inexpensive security cameras optimized for low light detection, connected to a Raspberry Pi or Linux mini-PC running the opensource Raspberry Pi Meteor Station software, RMS. The methodology of data capture is further explained in Vida, et al., 2021

Each camera generates a small payload containing an initial analysis of the detection, plus a video which can be further analyzed. RMS has an Event Monitor facility which allows network coordinators to collect these data in near-real-time, and this was used to gather data from many cameras although multiple iterations were required as the meteor's start and end points were initially unclear. Further data were also identified and collected by camera operators the following two days.

2.2 Selection and analysis

Although captured on numerous cameras, many contained only a partial view or were difficult to analyze due to obstructions in the field of view. Experience has shown that careful selection of good views can yield much better results, so fifteen cameras were chosen as providing the clearest or most useful views of the event. A full list of cameras is shown in *Table 1*, with cameras selected for analysis marked in bold. Stills from each of these cameras are shown in *Figure 2*.

[21] https://ukmon.imo.net/members/imo_view/event/2024/3306
[22] https://archive.ukmeteors.co.uk/reports/2024/orbits/202407/20240707/20240707_002746.047_UK/index.html



HR002R DE0005

DE0006 DE0007

BE0001 BE0005

BE0007 BE0008

FR000F FR000X

Figure 2 – Stills for the fifteen cameras with the clearest or most useful views of the event.

UK00CJ

UK004E

UK009X

UK008C

UK0045

Figure 2 – Stills for the fifteen cameras with the clearest or most useful views of the event.

Table 1 – Full list of cameras with cameras selected for analysis marked in bold.

BE000G	BE000J	BE000K	BE000V	**BE0001**
BE0005	**BE0007**	**BE0008**	DE0002	**DE0005**
DE0006	**DE0007**	**FR000F**	FR000G	FR000R
FR000X	FR000Y	FR0011	HR000K	**HR002R**
NL000M	NL0001	UK000F	UK00AF	UK00BC
UK00CJ	UK003W	UK0004	UK004C	**UK004E**
UK006U	**UK008C**	UK009R	**UK009X**	**UK0045**

The video from each selected camera was then reanalyzed. First, the field of view was recalibrated using the visible stars, geographic location of the camera and timestamp of the video. Next, the position of the meteor centroid was marked in each frame of video, allowing the brightness, bearing and angle of elevation of the detection to be determined on a frame-by-frame basis. There are further details in Vida et al. (op cit).

2.3 Correlation

The data from the cameras were then correlated using the Western Meteor Python Library[23]. WMPL is a data analysis suite developed by the Western Meteor Physics Group at the University of Western Ontario. The tool performs an initial intersecting-planes solution on pairs of detections to determine if the pair admit of a physically realistic solution based on timestamp, fields of view overlaps, and so forth. Successful pairs are then merged into larger groups based on similar criteria. A Monte-Carlo model is then applied to each group to estimate a best fit trajectory to the data. The process is explained in more detail in Vida et al. (2019).

2.4 Initial failure

Initial attempts at correlation failed. Closer examination revealed that the correlator normally uses a ten second sliding window to decide whether cameras might be a matchable pair. However, in this case the duration of the event exceeded ten seconds and indeed some cameras had split the event into two videos. The ten-second sliding window was therefore insufficient to correlate between

[23] See https://github.com/wmpg/WesternMeteorPyLib/tree/master

cameras with views of the start and end of the event, leading to overall failure.

To resolve this issue, the approximate duration was determined and the data were reanalyzed with a wider sliding window of 15 seconds. This window is larger than the estimated duration and resulted in a successful solution.

3 Results

The object entered the atmosphere at an angle of attack of zero degrees, travelling at around 65.390 km/s ± 0.004 km/s. It did not significantly decelerate during passage through the upper atmosphere. The duration of the event was calculated at 13.24 seconds from first detection over Austria to final detection over the English Channel.

It was not a bright event. Despite being widely detected, its best visual magnitude was only –1.4 and its best absolute magnitude –4.0. However, due to its longevity it looks quite spectacular on images and would have been very noticeable visually. *Figures 1 and 2* are representative of the data collected by cameras. The GMN cameras have a field of view approximately 90 degrees by 45 degrees, so the visual size of this detection can be appreciated – to the human eye it would have appeared to traverse the entire sky in a few seconds.

Table 2 – Ground track and altitude with 95% CI.

Trajectory	Latitude (deg +N)	95% CI (deg)	Longitude (deg +E)	95% CI (deg)	Height MSL (m)	95% CI (m)
Start Point	47.1327	0.0001	11.9395	0.0002	117115	11
Lowest	49.398	0.000	6.9977	0.0000	102155	5
End Point	51.2928	0.0001	2.1426	0.0002	114929	10

The *Tables 2 and 3* show details of the calculated trajectory and orbit. *Figure 3* shows the location of the stations and the ground track of the meteor, while *Figure 4* shows its computed orbit as seen from above the Sun's north pole, and from a point in the plane of the ecliptic.

Table 3 – Pre-atmospheric Orbital Characteristics.

Orbital Characteristics	Value
Orbital Period T	488 years
Semimajor axis a	62.01 AU
Eccentricity e	0.98817
Inclination i	139.956°
Solar Longitude λ_{O}	105.066319°
Last Perihelion	1536 CE

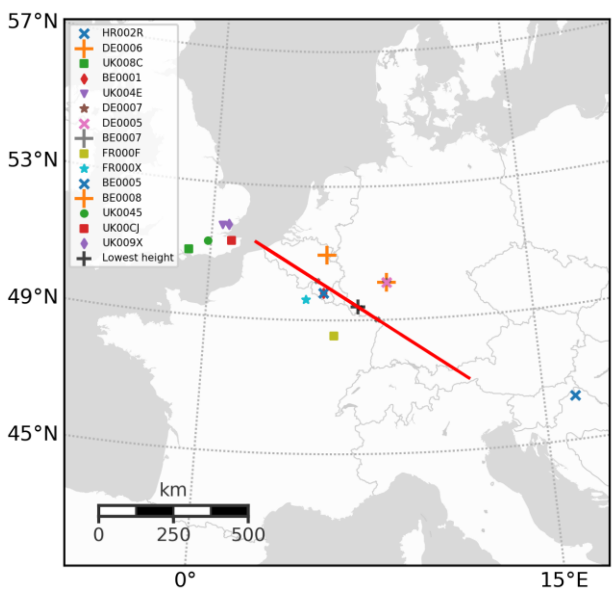


Figure 3 – Ground Track and Stations.

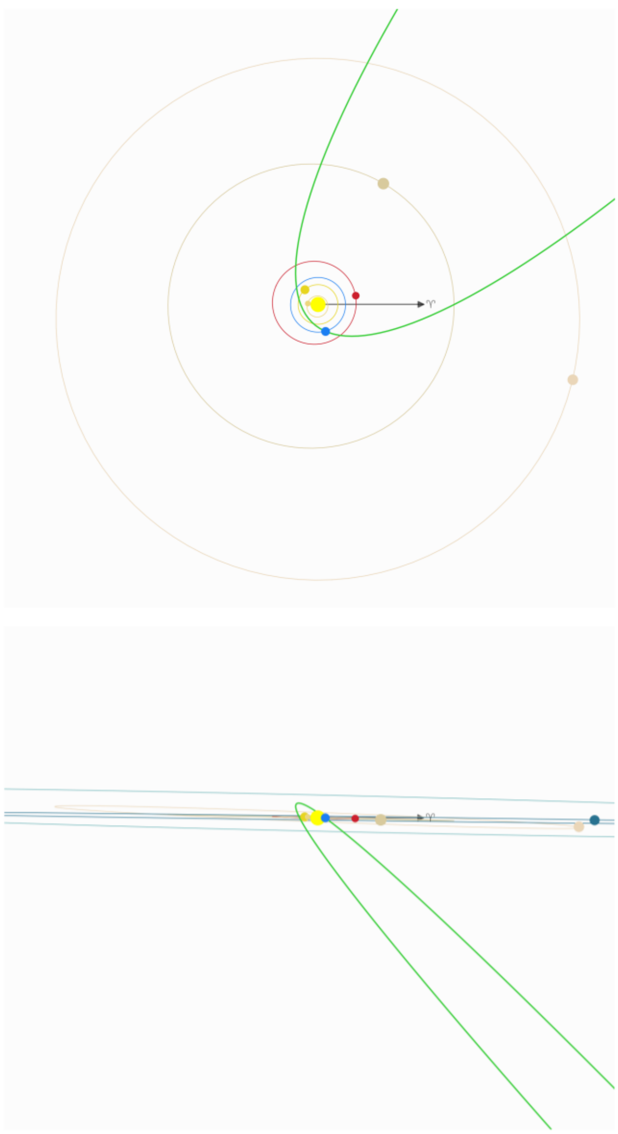


Figure 4 – Top view (top) and side view of the orbit (bottom).

4 Discussion

4.1 Difficult Analysis

Despite being detected by many cameras, this event was surprisingly hard to analyze, requiring several days of effort. There were a number of reasons for this.

Firstly, to collect in near-realtime it is necessary to have an estimate of the start and end points so that RMS can determine which cameras should have a view. However, in this case, initial estimates of the start were inaccurate by several degrees, as the detection by the camera in Croatia was not initially spotted. This led to some other cameras being initially overlooked.

Secondly, RMS collects data in ten second blocks, and as this event spanned more than ten seconds, several cameras split the event over two blocks. This complicated analysis as due to the time taken to reset the camera, there is always a small gap between videos. Consequently, care had to be taken during the recalibration and analysis of individual videos.

Furthermore, as mentioned earlier, the normal ten second sliding window proved inadequate and a larger window of fifteen seconds had to be used. A lesson to be learned from this is that when analyzing long-duration events, the sliding window must always be large enough to encompass both start and end points.

4.2 Trajectory

As shown in *Table 2*, the trajectory of this event curved downwards and then back up. However, this is not quite correct! As *Figure 5* shows, the trajectory was in fact very near to a straight line. The apparent track curvature is due to the curvature of the Earth itself. Studies of previous earth-grazers have often shown a similar effect.

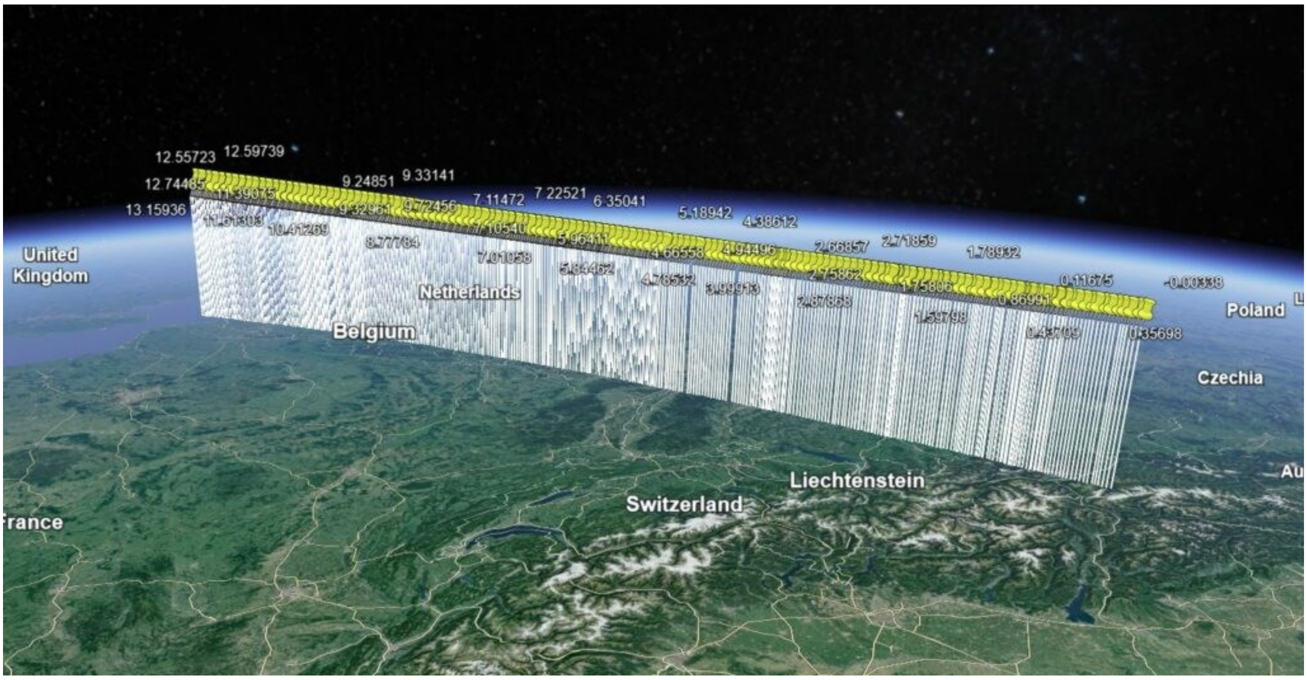


Figure 5 – Google Earth 3d representation of trajectory.

4.3 Orbit and Origin

The calculated orbit indicates that the object originated in the Kuiper belt. Normally, some degree of caution is required with orbits that seem highly eccentric as quite often, this is an artefact of high levels of uncertainty in the results due for example to poor viewing angles from one of the cameras. However, in this case the uncertainties in the data are low and so perhaps we can infer the origin with more confidence.

5 Conclusion

This was an interesting if difficult object to analyze, and some important lessons were learned which will aid with future analysis. In particular, quicker and more accurate estimation of the start and end points and of the duration is important.

It's unfortunate that this object wasn't larger and didn't arrive at a different angle of attack. If that had been the case, there's a possibility it might have dropped meteorites of Kuiper Belt origin which would have been very interesting to study.

Acknowledgments

I'd like to thank *Jamie Shepherd, Milan Kalina, David Rollinson, Jorgen Dorr, Paul Roggemans, Jamie Olver, Nick James* and *Denis Vida* who helped with obtaining and analyzing data. I'd also like to thank the camera operators whose cameras detected the event, and all other operators whose cameras have helped in the past and will help again in the future.

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Analysis of some of the most notable fireballs observed from November 2023 to February 2024 in the framework of the Southwestern Europe Meteor Network

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Some of the most important bolides registered by the Southwestern Europe Meteor Network between November 2023 and February 2024 are analyzed in this report. They have been observed from Spain. They had a peak absolute luminosity ranging from mag. –6 to mag. –14. One of these fireballs produced a meteorite. Fireballs included in this work were associated with 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).

This report describes the preliminary analysis of 13 fireballs spotted by our meteor stations. This work has been fully written by AIMEE (acronym for Artificial Intelligence with Meteoroid Environment Expertise) by using as a source of information the recordings found in the fireball database of the SWEMN project (Madiedo et al., 2021; Madiedo et al., 2022).

2 Equipment and methods

The events presented here have been recorded by using Watec 902H2 and Watec 902 Ultimate cameras. Their field of view ranges from 62 × 50 degrees to 14 × 11 degrees. To record meteor spectra we have attached holographic diffraction gratings (1000 lines/mm) to the lens of some of these cameras. We have also employed digital CMOS color cameras (models Sony A7S and A7SII) operating in HD video mode (1920 × 1080 pixels). These cover a field of view of around 70 × 40 degrees. A detailed description of this hardware and the way it operates was given in previous works (Madiedo, 2017). Besides digital CMOS cameras manufactured by ZWO (model ASI185MC) were used. The atmospheric path of the events were triangulated by means of the SAMIA software, developed by J.M. Madiedo. This program employs the planes-intersection method (Ceplecha, 1987).

3 Analysis of the 2023 November 13 fireball

This imposing bolide was recorded by our devices at $1^h40^m30.0 \pm 0.1^s$ UT on 2023 November 13. Its peak luminosity was equivalent to an absolute magnitude of –13.0 ± 1.0 (*Figure 1*). The identifier given to the bolide in the SWEMN meteor database is SWEMN20231113_014030. A video about this bright meteor was uploaded to YouTube[24].

Figure 1 – Stacked image of the SWEMN20231113_014030 meteor.

Atmospheric trajectory, radiant and orbit

This bright meteor overflew the Mediterranean Sea, between the coasts of Spain and Morocco. The initial phase of the luminous path of the event yields $H_b = 90.2 \pm 0.5$ km, and the terminal point was located at a height $H_e = 30.3 \pm 0.5$ km. The equatorial coordinates of the apparent radiant yield $\alpha = 42.65°$, $\delta = +21.29°$. Besides, we deduced that the meteoroid stroke the atmosphere with a velocity $v_\infty = 22.0 \pm 0.3$ km/s. *Figure 2* shows the obtained trajectory in the Earth's atmosphere of the bolide. *Figure 3* shows the orbit in the Solar System of the progenitor meteoroid.

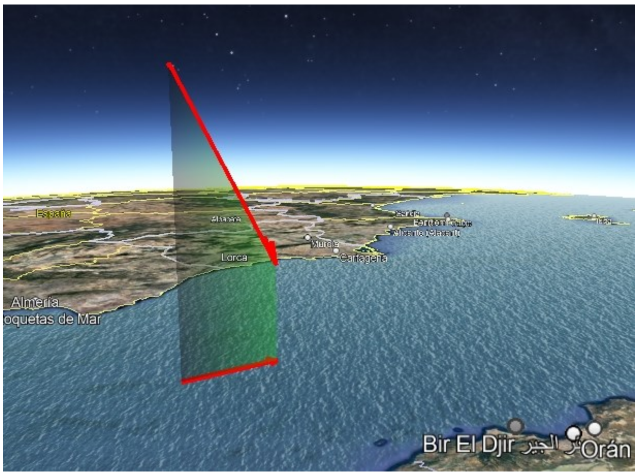

Figure 2 – Atmospheric path of the SWEMN20231113_014030 event, and its projection on the ground.

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

a (AU)	2.5 ± 0.1	ω (°)	255.3 ± 00.2
e	0.72 ± 0.01	Ω (°)	230.139343 ± 10^{-5}
q (AU)	0.677 ± 0.004	i (°)	2.37 ± 0.06

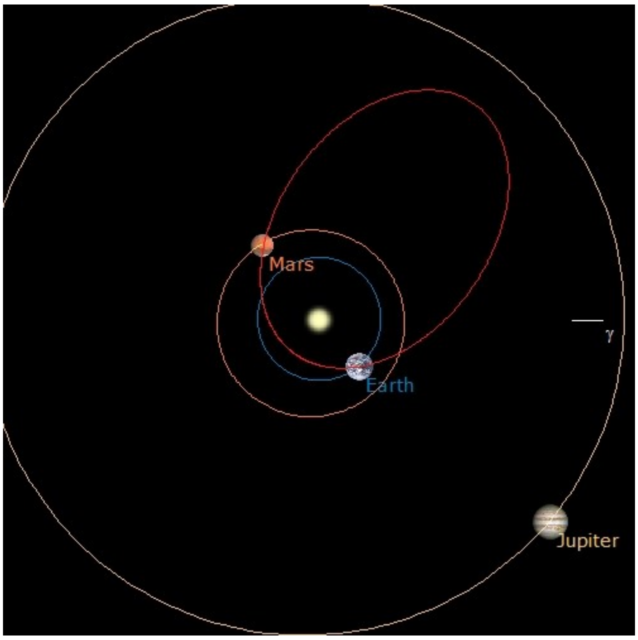

Figure 3 – Projection on the ecliptic plane of the orbit of the progenitor meteoroid of the SWEMN20231113_014030 event.

Table 1 shows the parameters of the orbit in the Solar System of the parent meteoroid before its encounter with our planet. The value calculated for the geocentric velocity was $v_g = 19.2 \pm 0.3$ km/s. The Tisserand parameter with respect to Jupiter ($T_J = 3.03$) shows that the particle followed an asteroidal orbit before impacting the Earth's

[24] https://youtu.be/fOubmGVeYs8

atmosphere. These parameters and the calculated radiant coordinates confirm that the event was produced by the sporadic background.

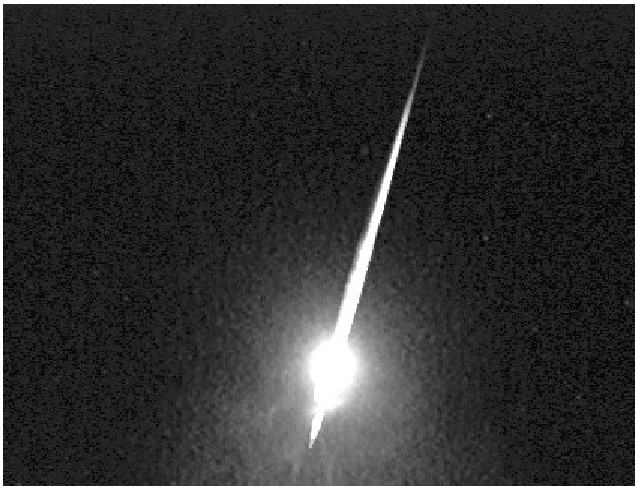

Figure 4 – Stacked image of the SWEMN20231122_233719 event.

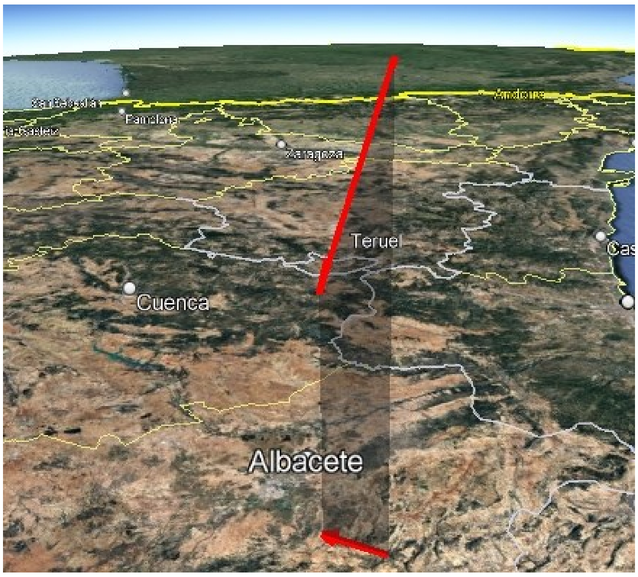

Figure 5 – Atmospheric path of the SWEMN20231122_233719 event, and its projection on the ground.

4 Analysis of the 2023 November 22 event

This bright meteor was captured on 2023 November 22, at $23^h37^m19.0 \pm 0.1^s$ UT. The maximum luminosity of the bolide, that presented a bright flare at the terminal stage of its atmospheric path, was equivalent to an absolute magnitude of -8.0 ± 1.0 (*Figure 4*). This flare appeared as a consequence of the sudden disruption of the meteoroid. The code assigned to the bright meteor in the SWEMN meteor database is SWEMN20231122_233719. A video containing images of the bolide and its trajectory in the atmosphere was uploaded to YouTube[25].

Atmospheric path, radiant and orbit

It was deduced following the analysis of the trajectory in the atmosphere of the event that this bolide overflew the province of Albacete (east of Spain). It began at an altitude $H_b = 106.3 \pm 0.5$ km, and ended at a height $H_e = 57.9 \pm 0.5$ km. The equatorial coordinates of the apparent radiant yield $\alpha = 67.89°$, $\delta = +24.56°$. The pre-atmospheric velocity found for the meteoroid yields $v_\infty = 28.9 \pm 0.2$ km/s. The obtained luminous path of the fireball is shown in *Figure 5*. The heliocentric orbit of the meteoroid is drawn in *Figure 6*.

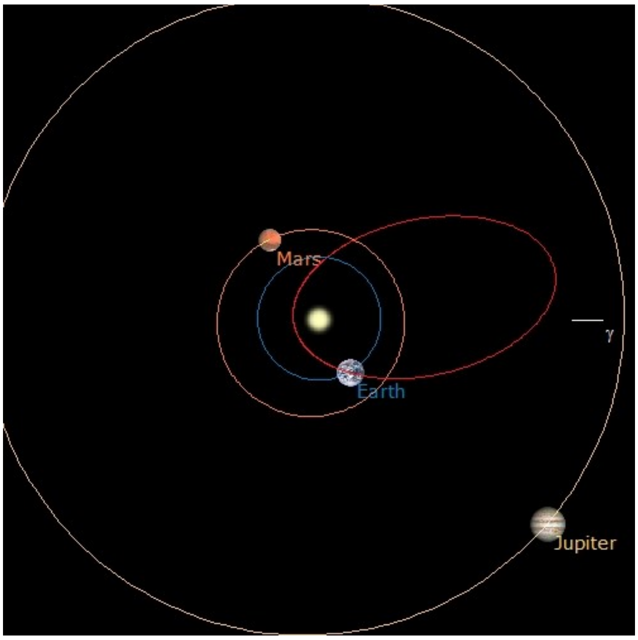

Figure 6 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20231122_233719 meteor.

The name given to the bright meteor was "Campillo del Hambre", since the bolide overflew this locality during its final phase. The parameters of the heliocentric orbit of the progenitor meteoroid before its encounter with our planet are included in *Table 2*, and the geocentric velocity yields $v_g = 26.6 \pm 0.2$ km/s. The Tisserand parameter with respect to Jupiter ($T_J = 3.16$) suggests that the meteoroid was moving on an asteroidal orbit before striking the Earth's atmosphere. By taking into account this orbit and the radiant location, the event was generated by the Northern Taurids (IAU meteor shower code NTA#0017). This meteor shower has its maximum activity around November 6 (Jenniskens et al., 2016).

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

a (AU)	2.16 ± 0.05	ω (°)	287.51 ± 00.03
e	0.809 ± 0.006	Ω (°)	240.145822 ± 10^{-5}
q (AU)	0.412 ± 0.002	i (°)	2.25 ± 0.03

5 The 2023 December 11 fireball

We recorded this bright bolide from the meteor-observing stations located at Huelva, La Hita (Toledo), Calar Alto, Sierra Nevada, La Sagra (Granada), and Sevilla (*Figure 7*). The event was spotted on 2023 December 11, at

[25] https://youtu.be/Zm3xtQb-hrw

$3^h22^m36.0 \pm 0.1^s$ UT. The bright meteor, that showed a bright flare at the final stage of its path in the atmosphere, had a peak absolute magnitude of –7.0 ± 1.0. This flare arose as a consequence of the sudden disruption of the meteoroid. The identifier given to the fireball in the SWEMN meteor database is SWEMN20231211_032236. A video about this bolide was uploaded to YouTube[26].

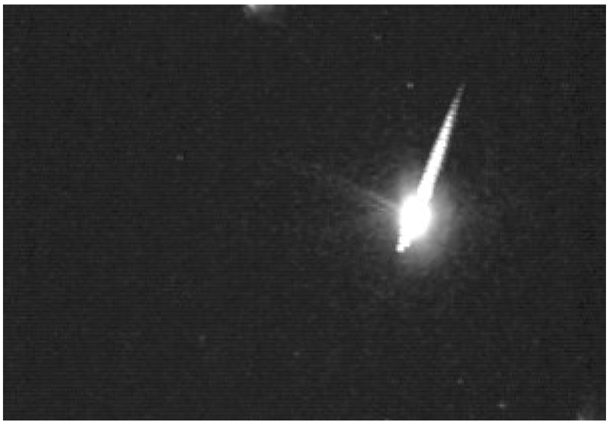

Figure 7 – Stacked image of the SWEMN20231211_032236 bolide.

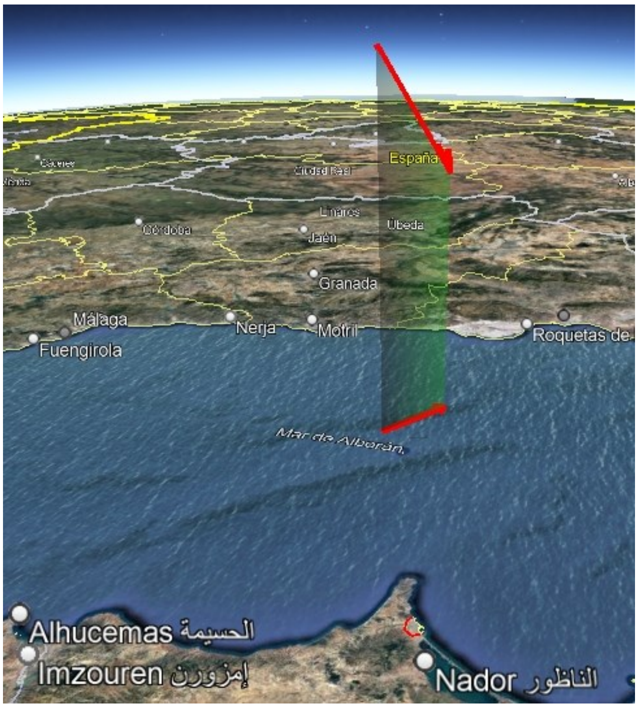

Figure 8 – Atmospheric path of the SWEMN20231211_032236 fireball, and its projection on the ground.

Atmospheric path, radiant and orbit

This fireball also overflew the Mediterranean Sea, between the coasts of Spain and Morocco. It began at an altitude H_b = 109.0 ± 0.5 km, and ended at a height H_e = 73.4 ± 0.5 km. From the analysis of the atmospheric path we also obtained that the apparent radiant was located at the position α = 101.96º, δ = +9.48º. The entry velocity in the atmosphere inferred for the progenitor meteoroid was v_∞ = 42.6 ± 0.3 km/s. *Figure 8* shows the calculated trajectory in our atmosphere of the bright meteor. The orbit in the Solar System of the progenitor meteoroid is shown in *Figure 9*.

Table 3 shows the orbital parameters of the progenitor meteoroid before its encounter with our planet, and the geocentric velocity yields v_g = 41.3 ± 0.3 km/s. The value found for the Tisserand parameter referred to Jupiter (T_J = 0.94) shows that the meteoroid followed a cometary (HTC) orbit before colliding with the Earth's atmosphere. By taking into account this orbit and the radiant position, the event was associated with the December Monocerotids (IAU shower code MON#0019). Since the December Monocerotids reach their maximum activity on December 12, the fireball was recorded during this activity peak. The proposed meteor body of this parent shower is C/1917 F1 (Mellish) (Jenniskens et al., 2016).

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

a (AU)	10.3 ± 2.3	ω (º)	130.4 ± 00.2
e	0.982 ± 0.003	Ω (º)	78.473796 ± 10^{-5}
q (AU)	0.180 ± 0.001	i (º)	33.8 ± 0.4

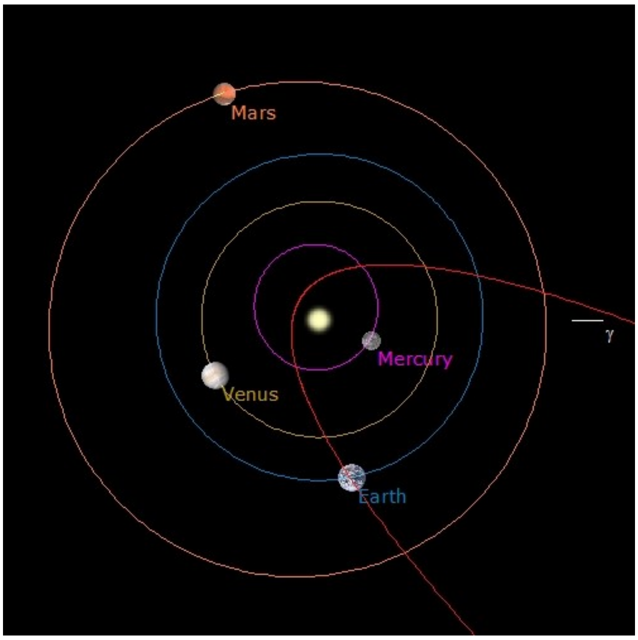

Figure 9 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20231211_032236 event.

6 Description of the 2023 December 13 bolide

On 2023 December 13, at $22^h58^m47.0 \pm 0.1^s$ UT, the systems operated by the SWEMN network spotted this bright bolide (*Figure 10*). The event had a peak absolute magnitude of –9.0 ± 1.0. The bolide was added to our meteor database with the unique identifier SWEMN20231213_225847. The meteor was witnessed by a wide number of casual observers.

[26] https://youtu.be/H8RrGkFpznU

Atmospheric path, radiant and orbit

This bolide overflew the province of Pontevedra (northwest of Spain). The luminous event began at an altitude H_b = 70.9 ± 0.5 km. The fireball penetrated the atmosphere till a final height H_e = 24.5 ± 0.5 km. From the analysis of the atmospheric path we also found that the apparent radiant was located at the position α = 61.01º, δ = +34.90º. Besides, we obtained that the meteoroid stroke the atmosphere with a velocity v_∞ = 17.7 ± 0.2 km/s. *Figure 11* shows the obtained path in the atmosphere of the bright meteor. The heliocentric orbit of the meteoroid is drawn in *Figure 12*.

Figure 10 – Stacked image of the SWEMN20231213_225847 bolide.

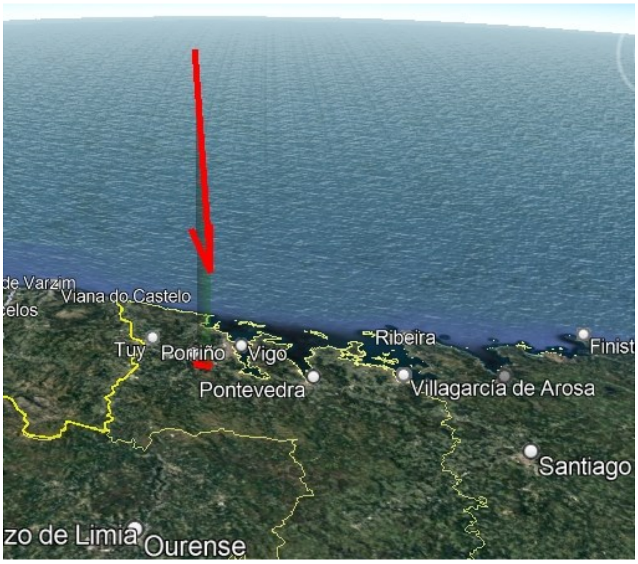

Figure 11 – Atmospheric path of the SWEMN20231213_225847 event, and its projection on the ground.

This bright meteor was named "Sanguineda", because the event overflew this locality during its initial phase. The parameters of the heliocentric orbit of the progenitor meteoroid before its encounter with our planet are listed in *Table 4*, and the geocentric velocity yields v_g = 13.9 ± 0.3 km/s. The value derived for the Tisserand parameter referred to Jupiter (T_J = 3.47) suggests that the particle was moving on an asteroidal orbit before colliding with the atmosphere. These parameters and the calculated radiant coordinates do not correspond with any of the streams listed in the IAU meteor database. Consequently, it was concluded that the bolide was linked to the sporadic background.

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

a (AU)	2.10 ± 0.05	ω (º)	235.1 ± 00.1
e	0.60 ± 0.01	Ω (º)	261.375614 ± 10^{-5}
q (AU)	0.824 ± 0.002	i (º)	5.21 ± 0.09

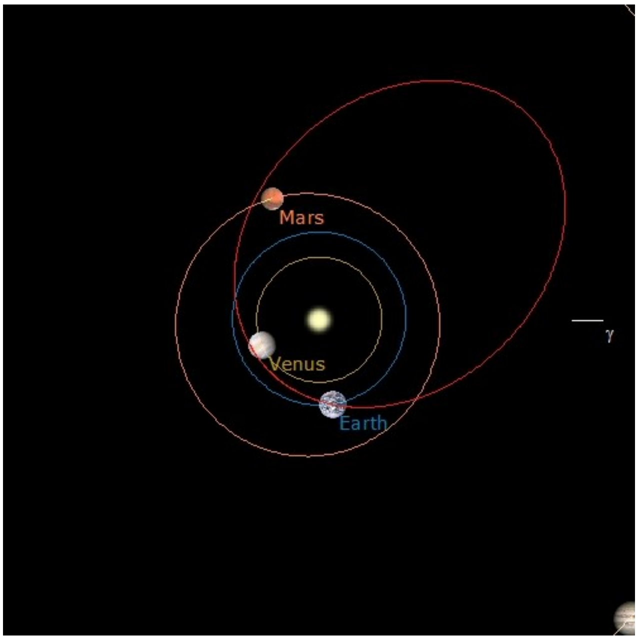

Figure 12 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20231213_225847 meteor.

Figure 13 – Stacked image of the SWEMN20231215_044119 bolide.

7 The 2023 December 15 bolide

This bright bolide was captured on 2023 December 15, at $4^h41^m19.0 \pm 0.1^s$ UT. The bright meteor had a peak absolute magnitude of –8.0 ± 1.0 (*Figure 13*). The identifier given to the bolide in the SWEMN meteor database is

SWEMN20231215_044119. A video about this fireball can be viewed on this YouTube[27] video.

Atmospheric path, radiant and orbit

It was concluded from the analysis of the path in the atmosphere of the bolide that this fireball overflew the province of Lugo (northwest of Spain. Its initial altitude was $H_b = 99.8 \pm 0.5$ km. The bright meteor penetrated the atmosphere till a final height $H_e = 44.2 \pm 0.5$ km. The apparent radiant was located at the equatorial coordinates $\alpha = 110.94°$, $\delta = +32.88°$. The meteoroid hit the atmosphere with an initial velocity $v_\infty = 33.1 \pm 0.2$ km/s. *Figure 14* shows the calculated atmospheric trajectory of the bolide. The orbit in the Solar System of the meteoroid is shown in *Figure 15*.

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

a (AU)	1.39 ± 0.01	ω (°)	315.8 ± 00.1
e	0.852 ± 0.003	Ω (°)	262.611231 ± 10^{-5}
q (AU)	0.206 ± 0.002	i (°)	16.3 ± 0.2

Figure 14 – Atmospheric path of the SWEMN20231215_044119 meteor, and its projection on the ground.

The name given to the bolide was "Souto de Torres", since the fireball overflew this locality during its final phase. The orbital parameters of the progenitor meteoroid before its encounter with our planet have been included in *Table 5*. The value calculated for the geocentric velocity was $v_g = 31.4 \pm 0.2$ km/s. From the value calculated for the Tisserand parameter with respect to Jupiter ($T_J = 4.25$), we found that before striking our planet's atmosphere the meteoroid was moving on an asteroidal orbit. These data and the calculated radiant position confirm that the event was produced by the Geminids (IAU shower code GEM#0004). 3200 Phaethon (=1983 TB) is the proposed progenitor body of this meteor shower (Jenniskens et al., 2016).

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

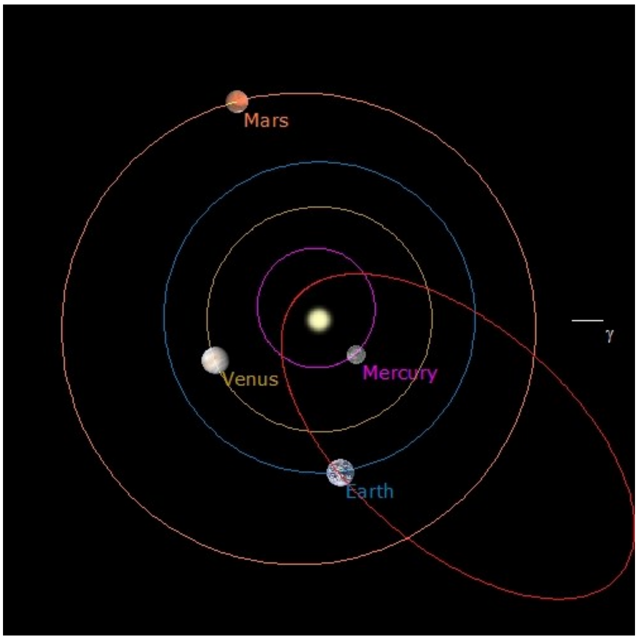

Figure 15 – Projection on the ecliptic plane of the orbit of the SWEMN20231215_044119 event.

8 The second event on 2023 December 15

On 2023 December 15, at $5^h25^m30.0 \pm 0.1^s$ UT, our cameras spotted this notable event. It had a peak absolute magnitude of –11.0 ± 1.0 (*Figure 16*). The code given to the bright meteor in the SWEMN meteor database is SWEMN20231215_052530. The bolide can be viewed on this YouTube video[28].

Figure 16 – Stacked image of the SWEMN20231215_052530 event.

Atmospheric path, radiant and orbit

This bright meteor overflew the provinces of León, Valladolid, and Palencia (north of Spain). The luminous event began at an altitude $H_b = 103.2 \pm 0.5$ km. The event penetrated the atmosphere till a final height $H_e = 46.1 \pm 0.5$ km. The equatorial coordinates inferred for the apparent radiant are $\alpha = 115.28°$, $\delta = +32.04°$. The pre-atmospheric velocity found for the meteoroid yields $v_\infty = 34.8 \pm 0.2$ km/s. The obtained trajectory in the Earth's atmosphere of

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

the bolide is shown in *Figure 17*. The orbit in the Solar System of the meteoroid is shown in *Figure 18*.

Figure 17 – Atmospheric path of the SWEMN20231215_052530 bolide, and its projection on the ground.

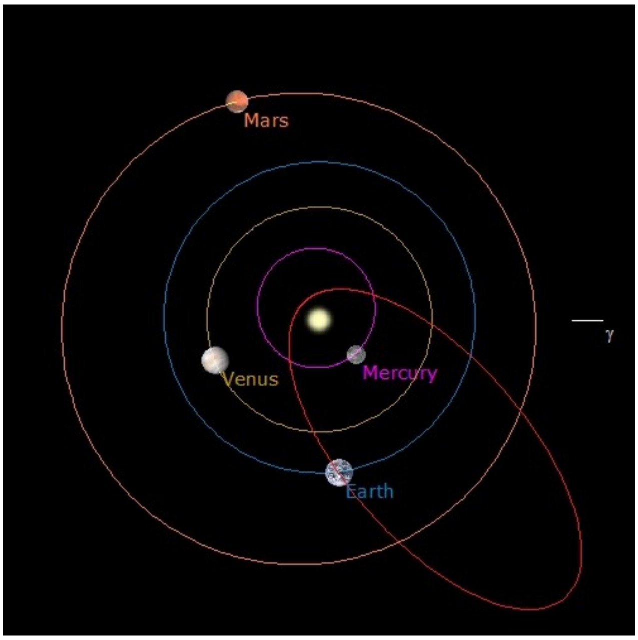

Figure 18 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20231215_052530.

This bright meteor was named "Valdemora", since the event overflew this locality during its initial phase. The parameters of the heliocentric orbit of the parent meteoroid before its encounter with our planet have been included in *Table 6*. The geocentric velocity of the meteoroid was $v_g = 33.2 \pm 0.2$ km/s. The value obtained for the Tisserand parameter referred to Jupiter ($T_J = 4.46$) reveals that the meteoroid followed an asteroidal orbit before entering the Earth's atmosphere. By taking into account these data and the calculated radiant position, the fireball was produced by the Geminids (IAU shower code GEM#0004). So, the bolide was captured near the activity peak of this meteor shower. Accordingly, 3200 Phaethon (=1983 TB) is the parent body of the progenitor meteoroid (Jenniskens et al., 2016).

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

a (AU)	1.29 ± 0.01	ω (º)	323.4 ± 00.1
e	0.882 ± 0.002	Ω (º)	262.640458 ± 10^{-5}
q (AU)	0.151 ± 0.001	i (º)	19.8 ± 0.2

9 Analysis of the third fireball on 2023 December 15

We captured this bright meteor from the meteor-observing stations located at Huelva, La Hita (Toledo), Calar Alto, Sierra Nevada, La Sagra (Granada), and Sevilla. The event was recorded on 2023 December 15, at $6^h32^m59.0 \pm 0.1^s$ UT. The peak brightness the bolide was equivalent to an absolute magnitude of –6.0 ± 1.0 (*Figure 19*). The code assigned to the bright meteor in the SWEMN meteor database is SWEMN20231215_063259. A video about this bolide can be viewed on YouTube[29].

Figure 19 – Stacked image of the SWEMN20231215_063259 meteor.

Atmospheric path, radiant and orbit

This event overflew the province of Almería (southeast of Spain) and the Mediterranean Sea. The luminous event began at an altitude $H_b = 97.1 \pm 0.5$ km. The bright meteor penetrated the atmosphere till a final height $H_e = 63.5 \pm 0.5$ km. The position deduced for the apparent radiant corresponds to the equatorial coordinates $\alpha = 114.21$º, $\delta = +32.75$º. The pre-atmospheric velocity inferred for the meteoroid yields $v_\infty = 34.2 \pm 0.2$ km/s. *Figure 20* shows the obtained path in the atmosphere of the event. The orbit in the Solar System of the progenitor meteoroid is shown in *Figure 21*.

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

Figure 20 – Atmospheric path of the SWEMN20231215_063259 meteor, and its projection on the ground.

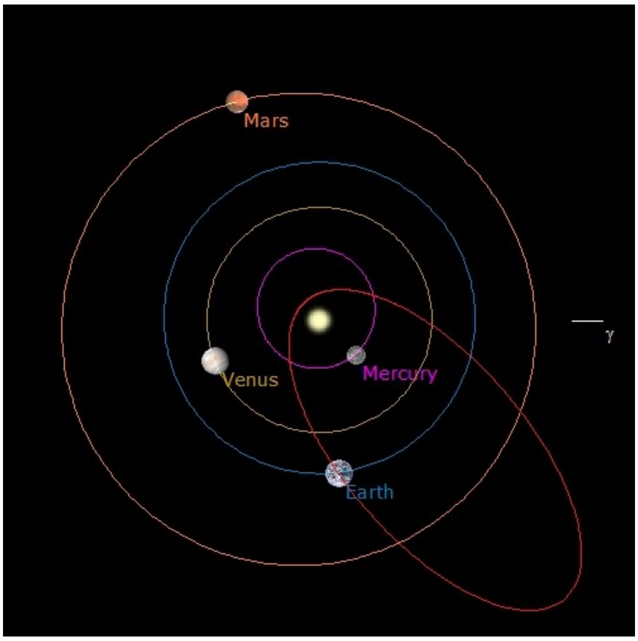

Figure 21 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20231215_063259 meteor.

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

a (AU)	1.33 ± 0.01	ω (º)	320.74 ± 00.08
e	0.872 ± 0.002	Ω (º)	262.688672 ± 10^{-5}
q (AU)	0.170 ± 0.001	i (º)	18.7 ± 0.2

The parameters of the heliocentric orbit of the parent meteoroid before its encounter with our planet can be found in *Table 7*, and the geocentric velocity derived in this case was v_g = 32.7 ± 0.2 km/s. From the value found for the Tisserand parameter with respect to Jupiter (T_J = 4.36), we found that the particle followed an asteroidal orbit before colliding with the atmosphere. By taking into account these values and the calculated radiant coordinates, the fireball was also linked to the Geminids (IAU shower code GEM#0004).

10 The 2023 December 20 meteor

This superb bright meteor was spotted by SWEMN cameras at $0^h45^m21.0 \pm 0.1^s$ UT on 2023 December 20. It had a peak absolute magnitude of –13.0 ± 1.0 (*Figure 22*). The bolide was added to our meteor database with the unique identifier SWEMN20231220_004521. A video about this bright meteor was uploaded to YouTube[30].

Figure 22 – Stacked image of the SWEMN20231220_004521 meteor.

Atmospheric path, radiant and orbit

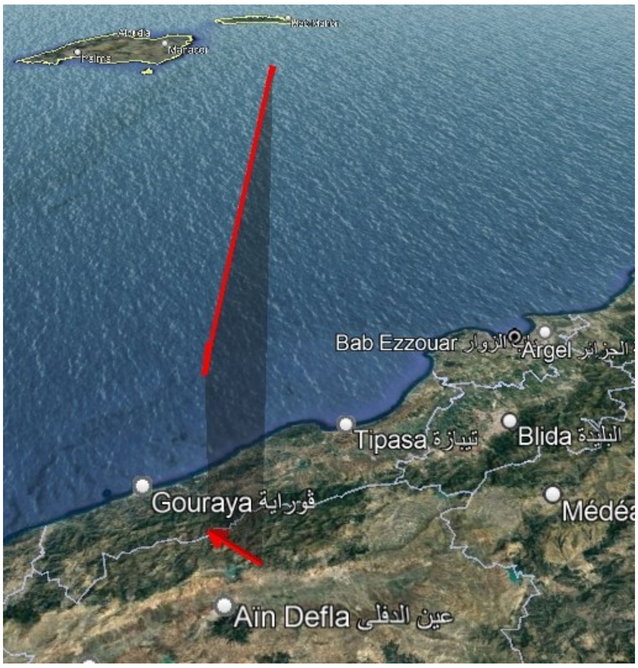

Figure 23 – Atmospheric path of the SWEMN20231220_004521 meteor, and its projection on the ground.

This bolide overflew Algeria. The luminous event began at an altitude H_b = 93.1 ± 0.5 km. The event penetrated the atmosphere till a final height H_e = 38.9 ± 0.5 km. The equatorial coordinates found for the apparent radiant are α = 108.30º, δ = +25.11º. The pre-atmospheric velocity

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

inferred for the meteoroid yields $v_\infty = 38.3 \pm 0.3$ km/s. The calculated trajectory in the Earth's atmosphere of the bright meteor is shown in *Figure 23*. The orbit in the Solar System of the progenitor meteoroid is shown in *Figure 24*.

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

a (AU)	3.8 ± 0.2	ω (º)	309.3 ± 00.1
e	0.947 ± 0.004	Ω (º)	267.559512 ± 10^{-5}
q (AU)	0.200 ± 0.002	i (º)	4.74 ± 0.07

This bright meteor was named "Mohammed Ben Kroula", since the event overflew this locality in Algeria during its initial phase. *Table 8* contains the calculated orbital parameters of the progenitor meteoroid before its encounter with our planet. The geocentric velocity of the meteoroid was $v_g = 36.6 \pm 0.3$ km/s. The Tisserand parameter referred to Jupiter ($T_J = 1.89$) reveals that before impacting our atmosphere the meteoroid was moving on a cometary (HTC) orbit. By taking into account these parameters and the derived radiant position, the fireball was generated by the φ-Geminids (IAU shower code PGE#0728) (Jenniskens et al., 2018).

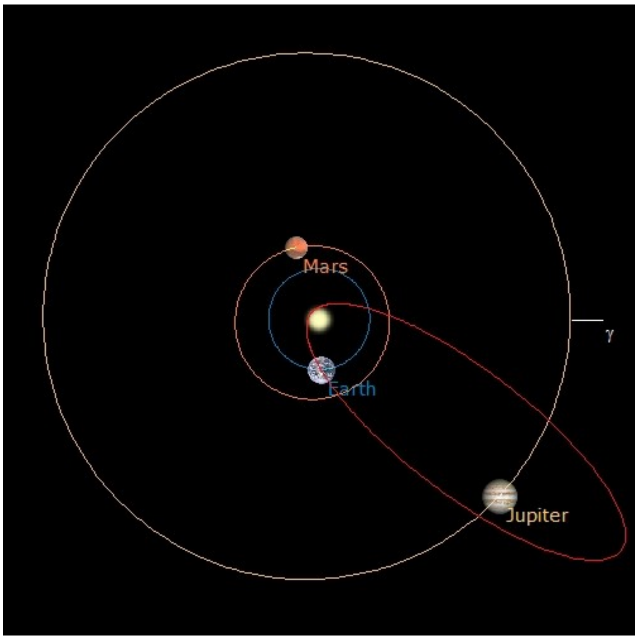

Figure 24 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20231220_004521 meteor.

11 Description of the 2023 December 23 bolide

This breathtaking bolide was spotted by SWEMN cameras at $19^h34^m12.0 \pm 0.1^s$ UT on 2023 December 23 (*Figure 25*). The bright meteor had a peak absolute magnitude of –14.0 ± 1.0. The identifier given to the bolide in the SWEMN meteor database is SWEMN20231223_193412. The fireball can be viewed on this YouTube video[31]. The event was witnessed by a wide number of casual observers.

Figure 25 – Stacked image of the SWEMN20231223_193412 meteor.

Atmospheric path, radiant and orbit

According to the analysis of the atmospheric path of the fireball it was inferred that this bolide overflew the Mediterranean Sea and the provinces of Almería and Granada (southeast of Spain). It began at an altitude $H_b = 96.6 \pm 0.5$ km, with the terminal point of the luminous phase located at a height $H_e = 32.4 \pm 0.5$ km. From the analysis of the atmospheric path we also inferred that the apparent radiant was located at the position $\alpha = 104.50º$, $\delta = +21.61º$. The meteoroid entered the atmosphere with an initial velocity $v_\infty = 32.6 \pm 0.3$ km/s. The calculated trajectory in the Earth's atmosphere of the bolide is shown in *Figure 26*. The orbit in the Solar System of the progenitor meteoroid is shown in *Figure 27*.

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

a (AU)	2.23 ± 0.09	ω (º)	118.16 ± 00.09
e	0.859 ± 0.006	Ω (º)	91.305369 ± 10^{-5}
q (AU)	0.314 ± 0.002	i (º)	2.574 ± 0.008

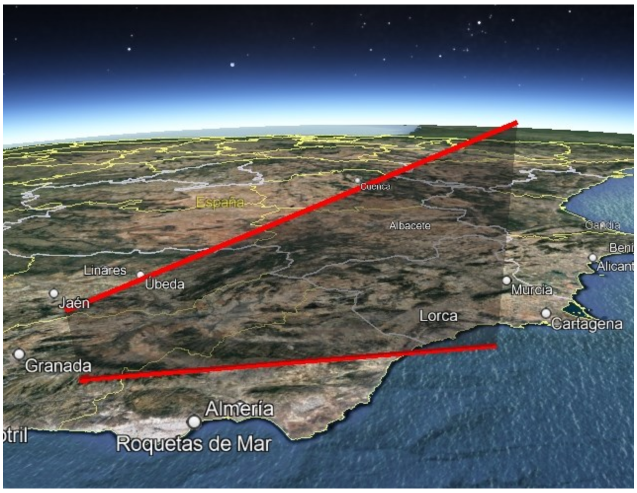

Figure 26 – Atmospheric path of the SWEMN20231223_193412 meteor, and its projection on the ground.

[31] https://youtu.be/c2qRLaQvAmQ

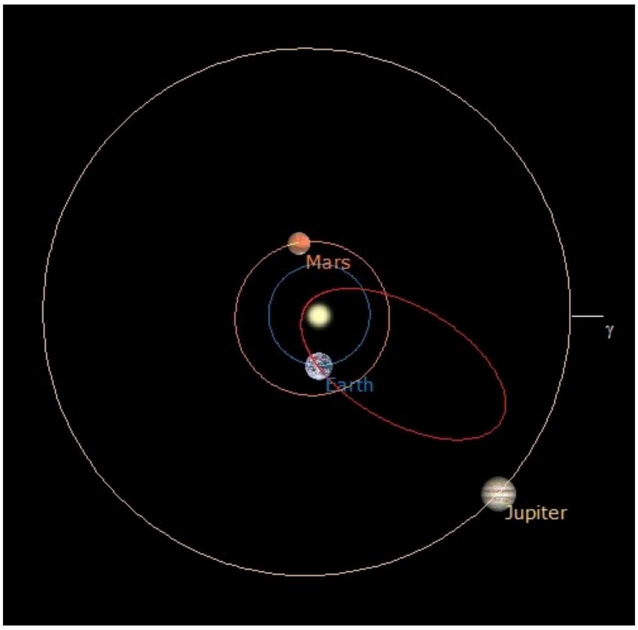

Figure 27 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20231223_193412 meteor.

We named this bolide “Berchules”, because the fireball passed near the zenith of this locality during its final phase. The orbital parameters of the parent meteoroid before its encounter with our planet are included in *Table 9*. The geocentric velocity of the meteoroid was $v_g = 30.3 \pm 0.3$ km/s. The Tisserand parameter referred to Jupiter ($T_J = 2.99$) reveals that the meteoroid was moving on a cometary (JFC) orbit before striking the atmosphere. These parameters and the calculated radiant location suggest the sporadic nature of the fireball.

12 Description of the 2023 December 25 event

On 2023 December 25, at $2^h53^m47.0 \pm 0.1^s$ UT, SWEMN cameras recorded this bright event. Its peak luminosity was equivalent to an absolute magnitude of -10.0 ± 1.0 (*Figure 28*). It presented some flares along its trajectory in the Earth’s atmosphere as a consequence of the sudden disruption of the meteoroid. It was listed in the SWEMN meteor database with the unique identifier SWEMN20231225_025347. The fireball can be viewed on YouTube[32].

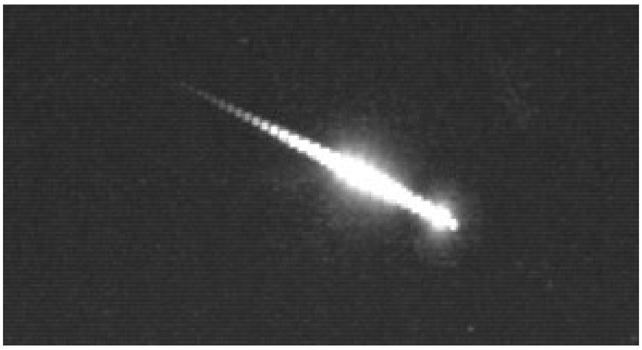

Figure 28 – Stacked image of the SWEMN20231225_025347 meteor.

Atmospheric path, radiant and orbit

This event overflew the Mediterranean Sea, between the coasts of Spain and Morocco. The luminous event began at an altitude $H_b = 131.3 \pm 0.5$ km. The bright meteor penetrated the atmosphere till a final height $H_e = 76.4 \pm 0.5$ km. The apparent radiant was located at the equatorial coordinates $\alpha = 155.93°$, $\delta = -5.74°$. The entry velocity in the atmosphere found for the progenitor meteoroid was $v_\infty = 67.5 \pm 0.4$ km/s. *Figure 29* shows the calculated trajectory in the Earth’s atmosphere of the fireball. The orbit in the Solar System of the progenitor meteoroid is shown in *Figure 30*.

Figure 29 – Atmospheric path of the SWEMN20231225_025347 meteor, and its projection on the ground.

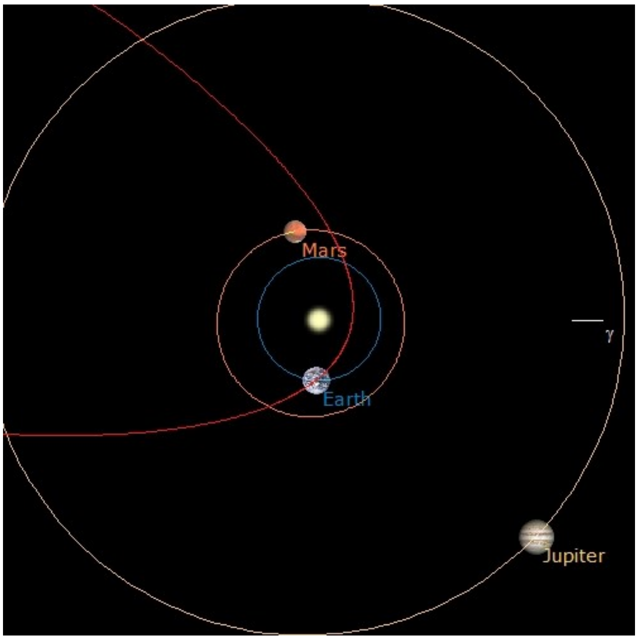

Figure 30 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20231225_025347 meteor.

The orbital data of the parent meteoroid before its encounter with our planet have been listed in *Table 10*, and the

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

geocentric velocity yields $v_g = 66.5 \pm 0.4$ km/s. According to the value obtained for the Tisserand parameter with respect to Jupiter ($T_J = –0.61$), before colliding with the atmosphere the particle was moving on a cometary (HTC) orbit. By taking into account this orbit and the radiant coordinates, the bolide was produced by the 6-Sextantids (IAU code SSX#0561) (Andreic et al., 2014).

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

a (AU)	23.2 ± 19.	*ω* (º)	75.6 ± 01.2
e	0.97 ± 0.02	Ω (º)	92.709714 ± 10^{-5}
q (AU)	0.618 ± 0.006	*i* (º)	148.9 ± 0.1

13 The 2024 January 21 fireball

On 2024 January 21, at 20^{h}03^{m}07.0 ± 0.1^s UT, SWEMN cameras spotted this stunning bright meteor (*Figure 31*). Its peak luminosity was equivalent to an absolute magnitude of –14.0 ± 1.0. It showed some flares along its atmospheric path as a consequence of the sudden disruption of the meteoroid. In the recordings it can be clearly seen how the meteoroid broke up into several fragments along the luminous trajectory of the meteor. Its unique identifier in the SWEMN meteor database is SWEMN20240121_200307. The bright meteor can be viewed on YouTube[33]. The bolide was witnessed by a wide number of casual observers.

Figure 31 – Stacked image of the SWEMN20240121_200307 meteor.

Atmospheric path, radiant and orbit

It was inferred by calculating the trajectory in our atmosphere of the event that this bolide overflew the south of Portugal and Spain. Its initial altitude was $H_b = 100.9 \pm 0.5$ km. The event penetrated the atmosphere till a final height $H_e = 40.2 \pm 0.5$ km. The apparent radiant was located at the equatorial coordinates $\alpha = 205.36°$, $\delta = +82.98°$. The meteoroid impacted the atmosphere with an initial velocity $v_\infty = 24.6 \pm 0.3$ km/s. *Figure 32* shows the calculated atmospheric trajectory of the bright meteor. The orbit in the Solar System of the progenitor meteoroid is shown in *Figure 33*.

Figure 32 – Atmospheric path of the SWEMN20240121_200307 meteor, and its projection on the ground.

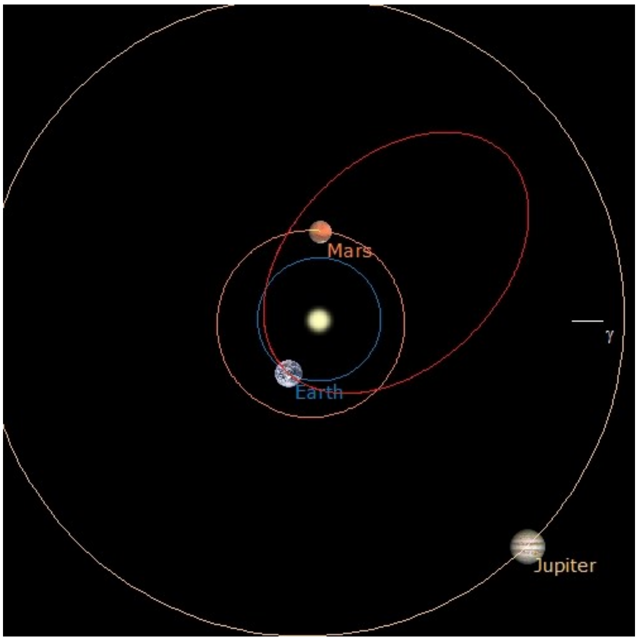

Figure 33 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20240121_200307 meteor.

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

a (AU)	2.5 ± 0.1	*ω* (º)	205.8 ± 00.1
e	0.63 ± 0.01	Ω (º)	300.944845 ± 10^{-5}
q (AU)	0.9459 ± 0.0004	*i* (º)	33.6 ± 0.3

The name given to the fireball was "Pasada del Palo", because the event was located over this locality during its final phase. The parameters of the heliocentric orbit of the progenitor meteoroid before its encounter with our planet

[33] https://youtu.be/afyqmnmUTas

are listed in *Table 11*. The value calculated for the geocentric velocity was $v_g = 21.9 \pm 0.3$ km/s. According to the value estimated for the Tisserand parameter referred to Jupiter ($T_J = 2.94$), before colliding with the atmosphere the meteoroid was moving on a cometary (JFC) orbit. By taking into account this orbit and the radiant position, the bolide was linked to the sporadic background.

14 The 2024 January 30 bolide

This event was recorded on 2024 January 30 at $22^h17^m13.0 \pm 0.1^s$ UT from the meteor-observing stations located at Huelva, La Hita (Toledo), Calar Alto, Sierra Nevada, La Sagra (Granada), and Sevilla (*Figure 34*). It had a peak absolute magnitude of -6.0 ± 1.0. The event was added to our meteor database with the code SWEMN20240130_221713. A video with images of the bolide and its atmospheric trajectory was uploaded to YouTube[34]. A wide number of casual observers saw how the fireball crossed the sky.

Figure 34 – Stacked image of the SWEMN20240130_221713 meteor.

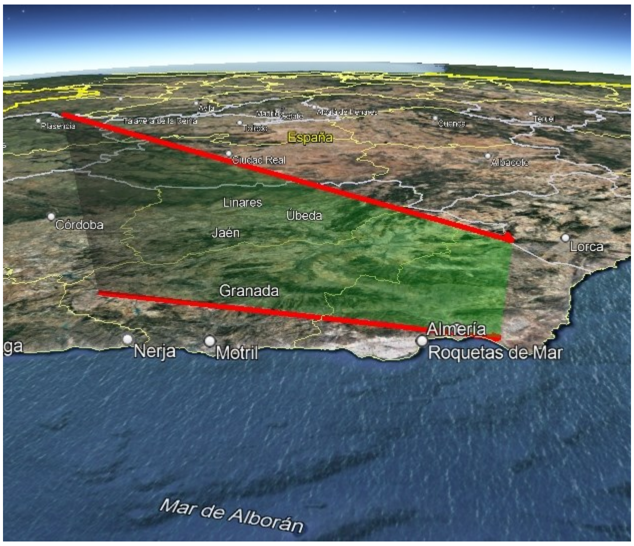

Figure 35 – Atmospheric path of the SWEMN20240130_221713 meteor, and its projection on the ground.

Atmospheric path, radiant and orbit

It was obtained from the analysis of the atmospheric trajectory of the bright meteor that this bolide overflew the provinces of Granada and Almería (southeast of Spain). The meteoroid ablation process began at a height $H_b = 76.2 \pm 0.5$ km, and the event penetrated the atmosphere till a final height $H_e = 41.9 \pm 0.5$ km. From the analysis of the atmospheric path we also inferred that the apparent radiant was located at the position $\alpha = 13.41°$, $\delta = +15.68°$. The entry velocity in the atmosphere obtained for the parent meteoroid was $v_\infty = 14.0 \pm 0.2$ km/s. *Figure 35* shows the obtained trajectory in the atmosphere of the bright meteor. The orbit in the Solar System of the progenitor meteoroid is shown in *Figure 36*.

The name given to the bolide was "Cañada de Junco", since the fireball was located over this locality during its initial phase. The parameters of the heliocentric orbit of the parent meteoroid before its encounter with our planet can be found in *Table 12*. The geocentric velocity of the meteoroid was $v_g = 9.1 \pm 0.3$ km/s. According to the value derived for the Tisserand parameter with respect to Jupiter ($T_J = 3.39$), the particle was moving on an asteroidal orbit before striking the Earth's atmosphere. These data and the derived radiant location do not fit any of the streams contained in the IAU meteor database. Consequently, it was concluded that the event was linked to the sporadic background.

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

a (AU)	2.2 ± 0.1	ω (°)	152.9 ± 00.5
e	0.57 ± 0.02	Ω (°)	310.327881 ± 10^{-5}
q (AU)	0.9460 ± 0.0005	i (°)	0.96 ± 0.08

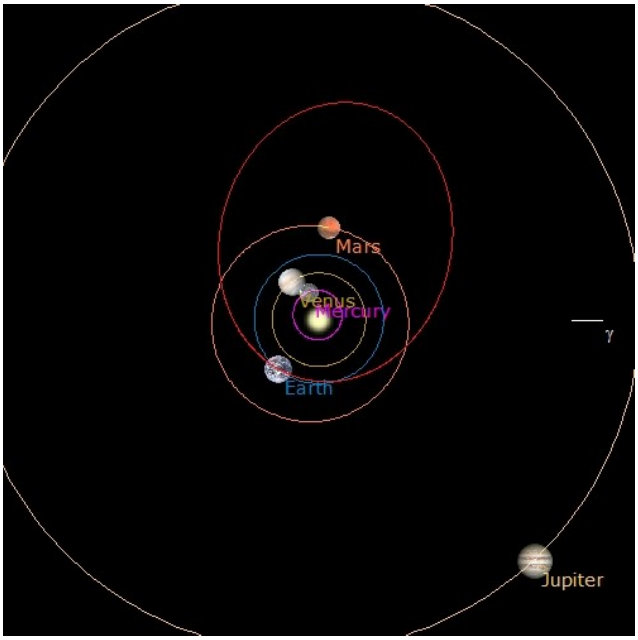

Figure 36 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20240130_221713 meteor.

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

15 Analysis of the 2024 February 18 meteor

Figure 37 – Stacked image of the SWEMN20240218_220832 meteor.

This notable fireball was recorded by our meteor stations at $22^h08^m32.0 \pm 0.1^s$ UT on 2024 February 18. Its maximum luminosity was equivalent to an absolute magnitude of –12.0 ± 1.0 (*Figure 37*). It showed several flares along its luminous path as a consequence of the sudden break-up of the meteoroid. The bright meteor was added to our meteor database with the unique identifier SWEMN20240218_220832. The fireball can be viewed on this YouTube video[35].

Figure 38 – Atmospheric path of the SWEMN20240218_220832 meteor, and its projection on the ground.

Table 13 – Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

a (AU)	1.87 ± 0.06	*ω* (º)	36.9 ± 00.1
e	0.50 ± 0.01	Ω (º)	149.375723 ± 10^{-5}
q (AU)	0.921 ± 0.001	*i* (º)	2.307 ± 0.007

Atmospheric path, radiant and orbit

This fireball overflew the province of La Coruña (northwest of Spain). The ablation process of the meteoroid began at a height $H_b = 88.5 \pm 0.5$ km, and the bolide penetrated the atmosphere till a final height $H_e = 25.6 \pm 0.5$ km. From the analysis of the atmospheric path we also concluded that the apparent radiant was located at the position $\alpha = 117.68º$, $\delta = +17.82º$. Besides, we found that the meteoroid stroke the atmosphere with a velocity $v_\infty = 14.9 \pm 0.2$ km/s. The calculated trajectory in the atmosphere of the event is shown in *Figure 38*. The orbit in the Solar System of the progenitor meteoroid is shown in *Figure 39*.

The name given to the fireball was "Queijeiro", since the bolide was located over this locality during its final phase. The orbital parameters of the progenitor meteoroid before its encounter with our planet are included in *Table 13*. The value calculated for the geocentric velocity was $v_g = 9.8 \pm 0.3$ km/s. The value derived for the Tisserand parameter with respect to Jupiter ($T_J = 3.81$) shows that before colliding with the Earth's atmosphere the meteoroid was moving on an asteroidal orbit. These parameters and the derived radiant location points to the sporadic nature of the event.

Following the analysis the terminal point of the path in the atmosphere we inferred that the bolide was a potential meteorite-dropper. As a consequence of this a portion of the meteoroid survived the ablation process and reached the ground. The calculations show that this mass would be very small (below 20 g).

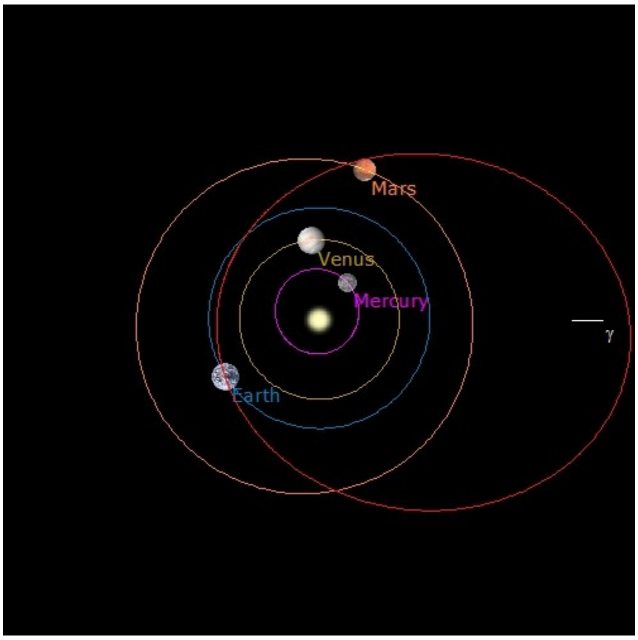

Figure 39 – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20240218_220832 meteor.

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

16 Conclusions

In this work we have discussed some of the most important fireballs captured by our meteor-observing stations between November 2023 and February 2024. Their absolute maximum luminosity ranges from mag. –6 to mag. –14.

The first event presented in this paper was captured on November 13. This sporadic bolide had a peak absolute magnitude of –13.0 and overflew the Mediterranean Sea. Before entering our planet's atmosphere, the progenitor particle was moving on an asteroidal orbit. This deep-penetrating meteor reached a terminal height of about 30 km.

The second fireball analyzed here was the "Campillo del Hambre" event, which was captured on November 22. It reached a peak absolute magnitude of –8.0, and was associated with the Northern Taurids (NTA#0017). This meteor overflew the province of Albacete. Before colliding with our atmosphere, the meteoroid was moving on an asteroidal orbit.

The third bright meteor presented here was an event captured on December 11. The peak magnitude of this December Monocerotid (MON#0019), which overflew the Mediterranean Sea, was –7.0. Before colliding with the Earth's atmosphere, the particle was moving on a cometary (HTC) orbit.

The next bolide described here was the "Sanguineda" fireball, which was captured on December 13. Its peak magnitude was –9.0. The fireball was produced by a sporadic meteoroid and overflew the province of Pontevedra. The particle was moving on an asteroidal orbit before striking the Earth's atmosphere. This deep-penetrating bolide reached an ending height of about 24 km.

The fifth bright meteor presented here was the "Souto de Torres" bolide, which was captured on December 15. It belonged to the Geminids (GEM#0004). Its peak magnitude was –8.0 and overflew the province of Lugo. At the ending stage of its luminous phase this deep-penetrating bolide was located at a height of about 44 km.

The "Valdemora" fireball was also captured on December 15. It reached a peak absolute magnitude of –11.0, and was also associated with the Geminids (GEM#0004). This event overflew the provinces of León, Valladolid, and Palencia. This meteor reached a terminal height of about 46 km.

The third Geminid meteor presented here was also spotted on December 15. It reached a peak absolute magnitude of –6.0, and overflew the province of Almería and the Mediterranean Sea.

The "Mohammed Ben Kroula" meteor was captured on December 20. This φ-Geminid (PGE#0728) bolide had a peak absolute magnitude of –13.0 and overflew Algeria. Before striking the atmosphere, the particle was moving on a cometary (HTC) orbit. The final altitude of this deep-penetrating fireball was of about 38 km.

The "Berchules" sporadic bolide, which was captured on December 23, overflew the Mediterranean Sea and the provinces of Almería and Granada, with a peak absolute magnitude of –14.0. The progenitor particle followed a cometary (JFC) orbit before colliding with the Earth's atmosphere. At the final stage of its luminous phase this deep-penetrating meteor event was located at an altitude of about 32 km.

The next event discussed here was a fireball captured on December 25. It reached a peak absolute magnitude of –10.0, and belonged to the 6-Sextantids (SSX#0561). This fireball overflew the Mediterranean Sea. Before entering our planet's atmosphere, the meteoroid was moving on a cometary (HTC) orbit.

Next, we have presented an event captured on January 21 named "Pasada del Palo". It was associated with the sporadic background. Its peak magnitude was –14.0 and overflew the south of Portugal and Spain. The meteoroid was moving on a cometary (JFC) orbit before colliding with our atmosphere. The terminal altitude of this deep-penetrating bolide was of about 40 km.

On January 30 we spotted another sporadic bolide named "Cañada de Junco". The peak absolute magnitude of this event, which overflew the provinces of Granada and Almería, was –6.0. The parent meteoroid followed an asteroidal orbit before hitting the Earth's atmosphere. The terminal height of this deep-penetrating fireball was of about 41 km.

And the last event described here was the "Queijeiro" event, which was captured on February 18. It reached a peak absolute magnitude of –12.0, and belonged to the sporadic component. This bolide overflew the province of La Coruña. The meteoroid was moving on an asteroidal orbit before colliding with the atmosphere. At the final stage of its luminous phase this deep-penetrating meteor was located at an altitude of about 25 km. Since our analysis of the final stage revealed a non-zero mass, this fireball was considered as a potential meteorite-dropper, but with a very small terminal mass.

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