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# MeteorNews

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*Composite of Geminid meteors, captured on December 13–14 2021, between midnight and 5h am (local time). Canon 6D and Rokinon 14mm f/2.8, ISO800 (prior to 2h30m am local time), ISO3200 (after 2h30m am local time). Hundreds of 30 seconds exposures were taken, and the images with meteors were then combined together digitally (Pierre Martin).*

- tau Herculids
- Camelopardalids
- CAMS reports
- Visual observing reports
- Fireballs
- Radio meteor work

# Contents

# In memoriam Paul Sutherland (1952 – 2022)

**Paul Roggemans**

On June 20, 2022, the amateur astronomer's community lost an experienced science writer, a knowledgeable astronomer and a cheerful friend. With a lifelong interest in astronomy, Paul Sutherland contributed in many ways to astronomy. His main commitments were with the Society for Popular Astronomy (SPA) where he was a very active member for more than half a century. In 1971 he became a SPA section director and later took care as editor of the SPA magazine for almost ten years and he served as a SPA Council Member for many years.

Paul Sutherland, Mistelbach, Austria 2015 (Photo Axel Haas).

In 2012 a minor planet was named after Paul Sutherland for his many years of active support to the SPA. "6726 Suthers" with the provisional designation 1991 PS, is a background asteroid from the inner regions of the asteroid belt, approximately 3.5 kilometers (2.2 miles) in diameter. It was discovered on 5 August 1991, by American astronomer Henry E. Holt at Palomar Observatory in San Diego County, California. The asteroid was named after author Paul Sutherland, known as "Suthers" to friends and colleagues.

Paul was a professional journalist writing for the newspaper The Sun from the late 1970s, known as "The Sun's Spaceman". He had a long career as a highly respected sub-editor also working for "Today", the "News of the World" and the "Daily Mirror", making science understandable to the large public.

Paul Sutherland inspecting a meteorite in Poland in 2013.

In the late 1980s Paul discovered the marvelous night sky of the Haute-Provence in the South-East of France where astronomy could be combined with living like God in France. He bought a holiday residence and later a second one, in Puimichel, a small almost abandoned village that had 80 habitants left. He was a regular guest at the local observatory and associated amateur astronomer residence where Paul and his parents enjoyed sharing dinners with amateurs from all over Europe. Over the years many amateurs and meteor observers were hosted at Paul's holiday houses which also served for the 1993 International Meteor Conference in Puimichel. Paul was an enthusiastic meteor observer and when he was invited to attend the 2012 IMC at La Palma, Spain, as a journalist, he didn't hesitate a moment to accept the invitation. Paul had been among the first people to explore the circumstances on the Roque de Los Muchachos peak in the early 1970s when transport on the mountain roads were still carried out using donkeys.

Participation at this meteor conference strengthened Paul's interest in meteor astronomy and made him return to the annual meteor conference until 2016, keeping cheerful contacts with numerous meteor scientists and amateurs.

Paul felt sick in April, losing weight and lacking energy and at the beginning of June he got diagnosed with cancer in his esophagus, unfortunately already spread when discovered.

He spent his last few weeks continuing to do his usual activities until a few days before his death as Paul didn't want to disturb anyone with his medical conditions. Monday June 20, 2022, Paul died, leaving behind his identical twin brother Nigel and three other brothers, Martin, Andrew and Simon.

Paul will be missed, and we'll all remember how he used to minimize his merits just waving away any compliments with his hand and quickly change topics. With his British humor he knew to entertain people inspired by Monty Python, Fawlty Towers and other creations of actor John Cleese. Paul was always ready for some jokes while enjoying some local wine of the Provence region with amateurs from all over Europe and beyond around the dinner table during his many stays at his holiday residences. That's how most meteor observers will remember Paul.

Paul Sutherland having fun at the conference in Poznan, Poland August 2013.

Paul Sutherland at la Palma walking down the Roque de Los Muchachos in September 2012.

Paul Sutherland in 2014 posing in front of the huge particle-identification detector at CERN, Geneva, Switzerland (photo Axel Haas).

# Anticipating a meteor outburst: global CAMS video network detects first 2022 tau Herculids

**Peter Jenniskens**

**SETI Institute, 189 Bernardo Avenue, Mountain View, CA 94043, USA**
`pjenniskens@seti.org`

The Cameras for Allsky Meteor Surveillance (CAMS) project, which triangulates video-detected meteors visible to the naked eye, have detected the first 2022 tau Herculids (TAH #0061) starting on May 27. This is still days prior to an anticipated outburst of tau Herculids on 2022 May 31 from Earth's crossing of debris generated during the 1995 breakup of comet 73P/Schwassmann-Wachmann. On May 31 (evening May 30 for US observers), that outburst is expected to peak either around $03^h52^m$ UT or around $0^5h01^m$ UT, and last about 2 hours. The shower will be rich in faint meteors, and observers are recommended to search for a dark observing site that fully benefits from the New Moon conditions.

## 1 Introduction

A meteor outburst of tau Herculid meteors (TAH #0061) is anticipated for May 31 around $4^h$ – $5^h$ UT this year. This outburst is unusual in that the debris was generated during the 1995 breakup of comet 73P/Schwassmann-Wachmann (Luethen et al., 2001). Independent calculations at I.M.C.C.E. and the University of Maryland, using slightly different inputs, put the 1995 dust trail in the Earth's path with an expected peak on May 31, $05^h01^m$ and $03^h52^m$ UT, respectively (Ye et al., 2022; Jenniskens et al., 2022). In both models, meteors will radiate from R.A. = 209°, Decl. = +28° with an apparent velocity of 16.4 km/s (geocentric velocity 12.1 km/s), North-West of the star Arcturus in the constellation Bootes. The outburst is expected to last about two hours. Observers in the continental USA and Mexico are most favorably located to see this event in New-Moon conditions, with a radiant high in the northwest, in the evening of May 30 local time.

Calculations at the University of Maryland show that when the Earth crosses the meteoroid stream, a very faint glow from scattered sunlight may be visible in the sky centered around R.A. = 170°, Decl. = +20° in Leo, and around R.A. = 355°, Decl. = –15° in the opposite direction in Equuleus.

Finally, two dust trails from the normal 1892 and 1897 returns of 73P will also be in the Earth's path around $16^h$ UT on May 30 and $10^h$ UT on May 31, respectively (Wiegert et al., 2005). Because the comet has been known only since 1930, these trail crossings could shed new light onto the past activity of the comet, if detected.

*Figure 1* – Near-real time display of CAMS data for May 29, 2022. Tau Herculids are marked. The map is online[1] available (choose a date to bring up that night's observations).

## 2 First observations

Here, we report that the Cameras for Allsky Meteor Surveillance (CAMS) project now has detected the first 2022 tau Herculids (TAH #0061) starting on May 27 (UT). That day, five tau Herculids were detected by CAMS Texas,

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

LO-CAMS (Arizona), CAMS Namibia and CAMS BeNeLux. The meteors radiated from a geocentric radiant at R.A. = 205.6 ± 2.0°, Decl. = 24.1 ± 5.0° with $v_g$ = 10.2 ± 0.8 km/s.

The next day, May 28, 7 tau Herculids were triangulated by CAMS Namibia, CAMS Arkansas and LO-CAMS. The meteors radiated from a geocentric radiant at R.A. = 203.3 ± 2.1°, Decl. = 17.3 ± 2.5° with $v_g$ = 10.8 ± 1.4 km/s.

And on May 29, 12 tau Herculids were triangulated by CAMS Namibia, CAMS Chile, CAMS Arkansas, LO-CAMS and CAMS California. The meteors radiated from a geocentric radiant at R.A. = 203.5 ± 1.7°, Decl. = 20.2 ± 2.0° with $v_g$ = 11.1 ± 0.9 km/s.

All detected tau Herculids so far had a magnitude distribution from –3 up: 1, 1, 0, 2, 4, 13, 8, 3. Some of these were bright enough to be photographed, but overall, the distribution implies a shower rich in faint meteors.

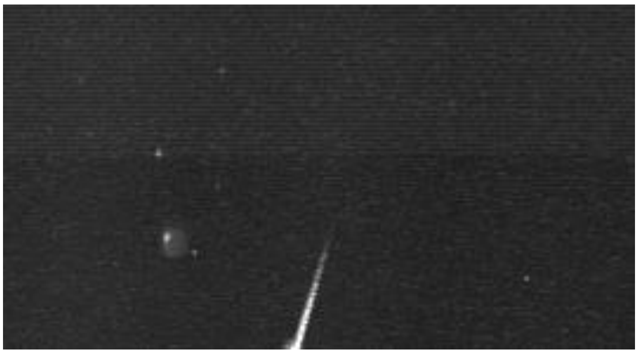

*Figure 2* – A tau-Herculid detected by camera 909 of LO-CAMS (Nick Moskovitz) at $06^h02^m28^s$ UT on May 29, 2022.

In prior years, only 18 tau Herculids were detected during the dust-trail crossings in 2011, 2017 and 2019. Those dust trails came from normal comet activity. These 18 meteors imply a steep magnitude-distribution index of 5.4 ± 1.1, meaning that there were five times more meteors of magnitude +4 than +3, five times more meteors of mag +3 than +2, etc., but with the camera sensitivity such that more meteors of magnitude +3 were detected. In practice, a few meteors were magnitude +1, but most were near the +4 magnitude detection limit of the video cameras.

## 3 What to expect for 1995 debris encounter?

There is already an unusual meteor shower in the sky now. The early sighting of tau Herculids bodes well for some further enhancement of rates, but it is unclear at present whether the current activity relates to the 1995 breakup or, perhaps more likely, dates from prior returns.

Model calculations (e.g., Ye et al., 2022) suggest that whether or not the rates will significantly increase on May 31 UT depends on the meteoroid ejection velocities during the breakup and decay of fragments. They need to be a factor of 2.5 higher than under normal cometary ejection conditions. Because the comet itself is not near the Earth, normal ejection does not have the meteoroids disperse far enough ahead of the comet to intersect the Earth's path. The higher gas-production rate of comet 73P in 1995 suggests that ejection velocities may have been higher by up to a factor of 2.7. However, the ejection velocities of cm- and mm-sized meteoroids were not measured in 1995.

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# 2022 tau-Herculids outburst observed by CAMS

**Peter Jenniskens**

**SETI Institute, 189 Bernardo Avenue, Mountain View, CA 94043, USA**
`pjenniskens@seti.org`

Preliminary results from the global networks of the Cameras for Allsky Meteor Surveillance (CAMS) low-light video survey are presented from observations of the 2022 tau-Herculids outburst on May 27–31, 2022. The observations confirm the fundamental predictions of encounter time and duration with the 1995 debris from the breakup of comet 73P/Schwassmann-Wachmann and sets constraints on how much material evolved into positions along its orbit far enough ahead of the comet to be encountered by Earth.

## 1 Introduction

A possible outburst of the episodic meteor shower tau Herculids (TAH #0061) had been predicted to happen on 2022 May 31 (Lüthen et al., 2001), peaking either at $3^h52^m$ or at $5^h01^m$ UT (Ye et al., 2022; Jenniskens et al., 2022). The outburst was expected to last about two hours and to consist of mainly faint meteors. The source of this expected outburst was the passage through the dust produced during the breakup of the parent comet 73P/Schwassmann-Wachmann in 1995. The fundamental uncertainty was how much debris was ejected in 1995 into orbits that placed it far enough in front of the comet in 2022 to be encountered by Earth, hence little was known about the expected zenithal hourly rate. In addition to the encounter with the 1995 dust trail, two other dust trails produced at earlier returns of 73P would be encountered by the Earth, namely the 1892 dust trail on 2022 May 30 at $16^h$ UT and the 1897 dust trail on May 31 at $10^h$ UT (Wiegert et al., 2005).

## 2 The observational results

Earlier reports were issued by Jenniskens (2022) and Jenniskens and Vida (2022), the latter also reporting on results from the Global Meteor Network. The global networks of the Cameras for Allsky Meteor Surveillance (CAMS) low-light video survey collected 2244 tau-Herculid orbits. The radiant distribution is depicted on the website[2] after choosing the date of 2022 May 31.

The predicted outburst took place on May 31 at $04^h42^m \pm 25^m$ UT, which corresponds to solar longitude 69.436 ± 0.017° (equinox J2000.0). At that time, the peak rate was about ZHR = 40/h from visual observations in California and as reported by the IMO[3]. The median geocentric radiant was at R.A. = 209.17 ± 0.09°, Decl. = +28.21 ± 0.07°, with a 1-sigma dispersion of 3.4 and 2.8 degrees, respectively, and geocentric velocity 12.01 ± 0.09 km/s. The predicted values were R.A. = 209°, Decl. = +28°, with geocentric velocity 12.1 km/s, in good agreement. As expected, the shower was rich in faint meteors. The number of video-detected meteors from all CAMS networks with peak brightness from magnitude –2 to +5 in one-magnitude increments was 20, 48, 172, 380, 461, 277, 120, and 3 tau-Herculids, corresponding to a magnitude-distribution index of $N(m+1)/N(m) = 3.79 \pm 0.12$ (where $m$ is the magnitude). The main peak lasted from about $01^h30^m$ to $09^h00^m$ UTC (solar longitude 69.30 to 69.61 degrees) and the peak had a Full-Width-at-Half-Maximum duration of 3.5 hours.

The first tau-Herculid orbits were recorded by CAMS days prior to the expected outburst (Jenniskens, 2022). Starting with a few scattered tau-Herculids on May 27, a compact radiant formed on May 28 and rates subsequently gradually increased leading up to the peak on May 31. During this time, the radiant of the shower shifted north and the geocentric speed increased (*Table 1*).

*Table 1* – The radiant drift and the change in geocentric velocity during the passage of the Earth through the 2022 tau Herculid meteoroid stream.

| Date | R.A. | Decl. | $v_g$ | $N$ | Cause |
|---|---|---|---|---|---|
| May 28 | 203.3 ± 2.1° | +17.3 ± 2.5° | 10.8 ± 1.4 km/s | 7 | |
| May 29 | 203.5 ± 1.7° | +20.2 ± 2.0° | 11.1 ± 0.9 km/s | 12 | |
| May 30, $4^h$–$6^h$ UT | 205.3° | +22.9° | 11.2 km/s | 59 | |
| May 30, $16^h$-$19^h$ UT | 206.8° | +25.2° | 11.4 km/s | 126 | 1892 debris? |
| May 30, >$23^h$ UT | 209.6° | +28.2° | 11.5 km/s | 53 | 1995 debris? |
| May 31, $1^h30^m$–$9^h$ UT | 209.17 ± 0.09° | +28.21 ± 0.07° | 12.01 ± 0.09 km/s | 1492 | 1995 debris |

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[2] URL http://cams.seti.org/FDL/

[3] http://www.imo.net

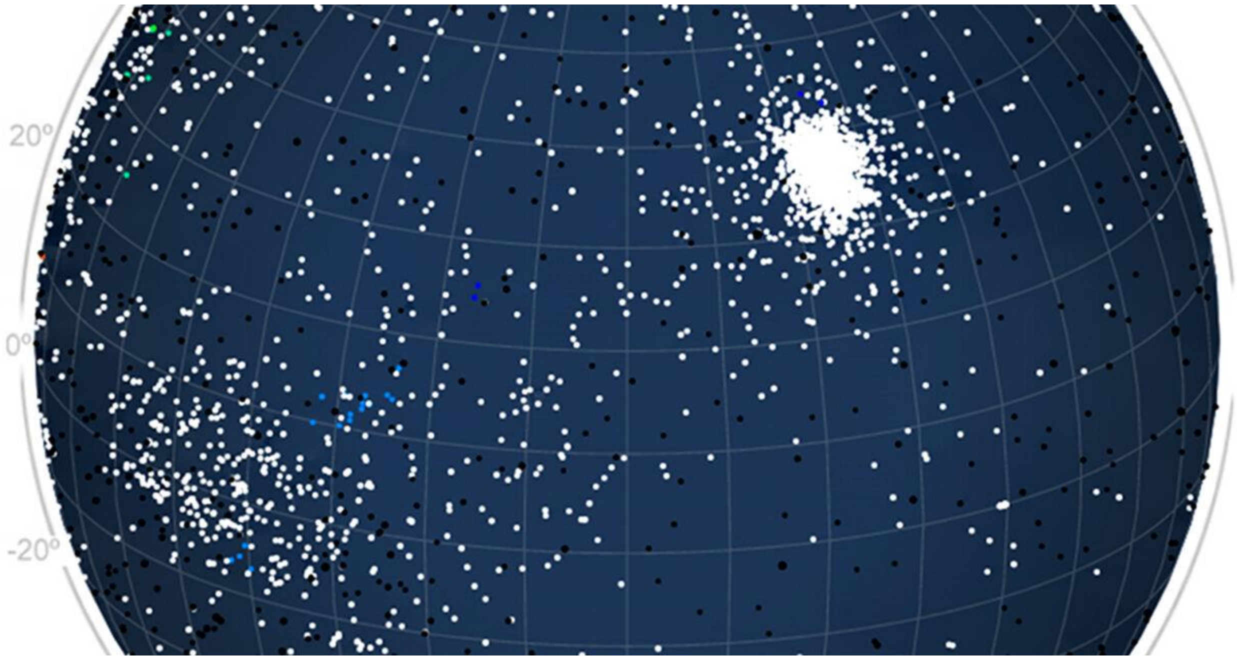

*Figure 1* – The large tau Herculid radiant based on the orbits collected by CAMS on 2022 May 31 (± 12 hours).

There is a hint that the radiant jumped in position, suggesting that dust from several different returns was observed. However, it is not certain at present that the 1892 and 1897 dust trails were detected. The 2022 outburst is the first instrumentally recorded outburst of tau-Herculids that is well documented. The shower is absent in other years and prior encounters with dust trails in 2011, 2017 and 2019 only resulted in a combined 18 CAMS-detected tau-Herculids (Jenniskens, 2022).

## Acknowledgment

Observations to this report were contributed by CAMS California (*P. Jenniskens*, *J. Albers*, *E. Egland*, *B. Grigsby*, *T. Beck*, and *D. Samuels*, SETI Institute), LO-CAMS (*N. Moskovitz*, Lowell Observatory), CAMS Texas (*W. Cooney*), CAMS Arkansas (*L. Juneau*), CAMS Florida (*A. Howell*), CAMS Mid-Atlantic (*P. Gural*), CAMS BeNeLux (*C. Johannink*, *M. Breukers*, and *S. Rau*), CAMS Turkey (*O. Unsalan*, Ege University; and *M. Boyukata*, Yozgat Bozok University), UAE Astronomical Camera Network (*M. Odeh*, International Astronomical Center), CAMS Namibia (*T. Hanke*, *E. Fahl*, and *R. van Wyk*, H.E.S.S. Collaboration), CAMS South Africa (*T. Cooper*, Astronomical Society of Southern Africa), CAMS Australia (*M. Towner*, Curtin University), CAMS New Zealand (*J. Baggaley*, University of Canterbury), CAMS Chile (*S. Heathcote* and *T. Abbott*, AURA/Cerro Tololo; and *E. Jehin*, University of Liege), and CAMS EXOSS (*M. de Cicco*).

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# A meteor outburst of the τ-Herculids 2022 by worldwide radio meteor observations

**Hiroshi Ogawa**[1] **and Hirofumi Sugimoto**[2]

[1] **The International Project for Radio Meteor Observations**
`h-ogawa@amro-net.jp`

[2] **The Nippon Meteor Society**
`hiro-sugimoto@kbf.biglobe.ne.jp`

The International Project for Radio Meteor Observations (IPRMO) has detected a meteor outburst of the τ-Herculids 2022 on May 31. Several meteor outbursts occurred at different times. The strongest peak was detected at $\lambda_\odot = 69.428°$ (May 31, $04^h30^m$ UT). The activity level was estimated to be 1.8 (corresponding to a $ZHR_r = 34$). A sub peak was observed at $\lambda_\odot = 68.909°$ (May 30, $15^h30^m$ UT) with an activity level = 0.5 and $ZHR_r = 19$.

## 1 Introduction

The τ-Herculid meteor shower is caused by the dust produced by comet 73P/Schwassmann-Wachmann 3. In 1995, 73P/Schwassmann-Wachmann 3 broke up. The possible encounter in 2022 of the Earth with the 1995 trail formed by meteoroids released during this event has been predicted (Rao, 2021).

For 2022, the encounter with the dust trail was predicted around $\lambda_\odot = 69.44°$ and $\lambda_\odot = 69.459°$ (May 31, $04^h55^m$ UT and $05^h17^m$) by Peter Jenniskens (Jenniskens, 2006). Mikiya Sato also calculated $\lambda_\odot = 69.451°$ (May 31, $05^h04^m$ UT) as most likely time for the passage.

Radio meteor observations make it possible to observe meteor activity continuously even if bad weather interferes or during daytime. Besides, the problem with the radiant elevation is solved by organizing radio observing as a worldwide project. One of the worldwide projects is the International Project for Radio Meteor Observations (IPRMO)[4]. IPRMO uses the Activity Level index for analyzing the meteor shower activity (Ogawa et al., 2001).

For Europe and Japan, the 1995-dust trail encounter would appear in twilight time and daytime. The best observing method was radio meteor observations. IPRMO monitored the τ-Herculids activity during this year.

## 2 Method

### 2.1 Activity Level Index and estimated *ZHRr*

This research adopted two methods for estimating τ-Herculid meteor shower activity. One is the Activity Level Index which used by IPRMO (Ogawa et al., 2001). Another is the estimated $ZHR_r$ (Sugimoto, 2017). This index is estimated by using the Activity Level index and a factor named $S_{bas}$ which translates to $ZHR_r$. This method is very useful in the case of comparing to visual observations.

### 2.2 Considering the zenith attraction

Since the geocentric velocity of τ-Herculids is very low with 16 km/s (Rendtel, 2021), it is necessary to consider the zenith attraction (Richardson, 1999). This research has considered to take this factor into account.

## 3 Results

### 3.1 Main peak

*Figure 1* shows the result of the τ-Herculids 2022 based on the calculation of the Activity Level Index using 37 observing data from 11 countries.

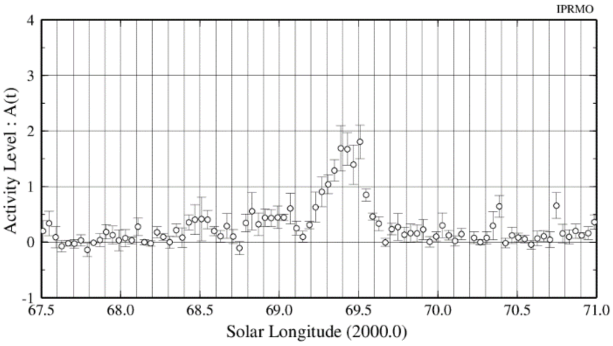

*Figure 1* – Activity Level Index of the τ-Herculids 2022.

The main peak started at $\lambda_\odot = 69.228°$ (May 30, $23^h30^m$ UT). The number of meteor echoes increased more and more. The maximum Activity Level reached a value around 1.8. Although a peak was recorded at $\lambda_\odot = 69.508°$ (May 31, $6^h30^m$ UT), a strong activity remained during a period of a few hours ($\lambda_\odot = 69.388–69.508°$ (May 31, $3^h30^m$ –$6^h$ $30^m$ UT)). After the main peak, the activity level became weaker and weaker. At $\lambda_\odot = 69.668°$ (May 31, $10^h30^m$ UT), the Activity Level felt back at the usual level.

*Figure 2* shows the result of τ-Herculids in 2022 based on the calculation of the $ZHR_r$ using 42 worldwide data. The estimated $ZHR_r$ of main peak reached 34 ± 7 at

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[4] https://www.iprmo.org

$\lambda_{\Theta}$ = 69.388° (May 31, $3^h30^m$ UT). The distinct activity started at $\lambda_{\Theta}$ = 69.2628° (May 31, $0^h30^m$ UT). The end of the activity was situated at $\lambda_{\Theta}$ = 69.668° (May 31, $10^h30^m$ UT).

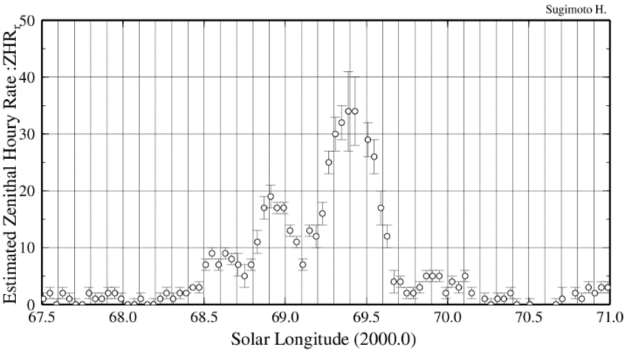

*Figure 2* – Estimated $ZHR_r$ of the τ-Herculids 2022.

*Table 1* – Activity Level Index (AL) and estimated $ZHR_r$ of the τ-Herculids 2022.

| Time (UT) | $\lambda_{\Theta}$ | Activity Level | | $ZHR_r$ | |
|---|---|---|---|---|---|
| | | *N* | *AL* | *N* | $ZHR_r$ |
| May 30 10h30$^m$ | 68.709° | 11 | 0.1±0.1 | 13 | 7±2 |
| May 30 11h30$^m$ | 68.749° | 11 | 0.0±0.1 | 10 | 5±2 |
| May 30 12h30$^m$ | 68.789° | 20 | 0.3±0.2 | 10 | 7±1 |
| May 30 13h30$^m$ | 68.829° | 21 | 0.6±0.3 | 10 | 11±2 |
| May 30 14h30$^m$ | 68.869° | 22 | 0.3±0.2 | 17 | 17±2 |
| May 30 15h30$^m$ | 68.909° | 24 | 0.4±0.2 | 26 | 19±2 |
| May 30 16h30$^m$ | 68.949° | 21 | 0.4±0.2 | 19 | 17±1 |
| May 30 17h30$^m$ | 68.989° | 24 | 0.4±0.2 | 28 | 17±1 |
| May 30 18h30$^m$ | 69.029° | 24 | 0.4±0.1 | 20 | 13±1 |
| May 30 19h30$^m$ | 69.069° | 20 | 0.6±0.3 | 15 | 11±1 |
| May 30 20h30$^m$ | 69.109° | 13 | 0.3±0.1 | 18 | 7±1 |
| May 30 21h30$^m$ | 69.149° | 14 | 0.1±0.1 | 15 | 13±1 |
| May 30 22h30$^m$ | 69.189° | 13 | 0.3±0.1 | 23 | 12±2 |
| May 30 23h30$^m$ | 69.228° | 14 | 0.6±0.3 | 23 | 16±2 |
| May 31 0h30$^m$ | 69.268° | 15 | 0.9±0.3 | 23 | 25±2 |
| May 31 1h30$^m$ | 69.308° | 15 | 1.0±0.2 | 25 | 30±3 |
| May 31 2h30$^m$ | 69.348° | 15 | 1.3±0.2 | 22 | 32±3 |
| May 31 3h30$^m$ | 69.388° | 15 | 1.7±0.4 | 10 | 34±7 |
| May 31 4h30$^m$ | 69.428° | 25 | 1.7±0.3 | 8 | 34±6 |
| May 31 5h30$^m$ | 69.468° | 20 | 1.4±0.4 | 7 | - |
| May 31 6h30$^m$ | 69.508° | 14 | 1.8±0.3 | 16 | 29±3 |
| May 31 7h30$^m$ | 69.548° | 13 | 0.9±0.1 | 16 | 26±3 |
| May 31 8h30$^m$ | 69.588° | 13 | 0.5±0.1 | 17 | 17±3 |
| May 31 9h30$^m$ | 69.628° | 13 | 0.3±0.1 | 17 | 12±2 |
| May 31 10h30$^m$ | 69.668° | 13 | 0.0±0.1 | 12 | 4±2 |
| May 31 11h30$^m$ | 69.708° | 11 | 0.2±0.1 | 10 | 4±1 |
| May 31 12h30$^m$ | 69.748° | 21 | 0.3±0.2 | 12 | 2±1 |

### 3.2 Sub peak

Half a day before the main peak, a small sub peak has been observed. The sub peak was recorded around $\lambda_{\Theta}$ = 68.829°–69.069° (May 30, $13^h30^m$–$19^h30^m$ UT). The Activity Level was around 0.5. The estimated $ZHR_r$ was 19 ± 2 at $\lambda_{\Theta}$ = 68.909° (May 30, $15^h30^m$ UT).

## 4 Discussion

### 4.1 Meteor shower components

*Figure 3* and *4* shows the activity components of the τ-Herculids 2021 estimated by using the Lorentz profile (Jenniskens et al., 2000).

One component (TAH22C01) had a maximum Activity Level = 1.8 at $\lambda_{\Theta}$ = 69.428° (May 31, $4^h30^m$ UT) with Full width half maximum (FWHM)= –3.0/+3.0 hours. The $ZHR_r$ was estimated to be 35. The other (TAH22C02) had an Activity Level = 0.5 at $\lambda_{\Theta}$ = 68.909° (May 30, $15^h30^m$ UT) with FWHM = –3.5/ +3.0 hours. The $ZHR_r$ was 15 (see *Table 2*).

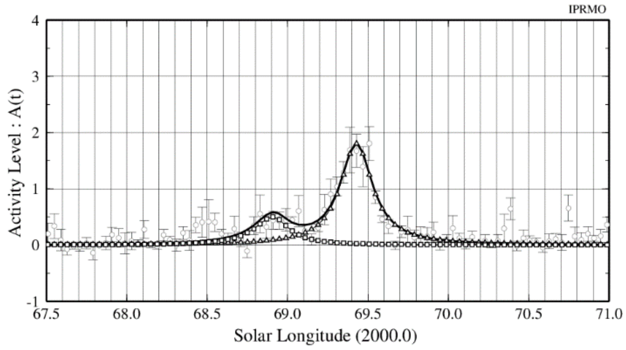

*Figure 3* – The Activity Level: estimated components using the Lorentz profile (the curve with triangles represents TAH22C01, the curve with the squares is TAH22C02. The line is TAH22C01 and TAH22C02 combined. Circles with error bars show the τ-Herculid activity observed in 2022).

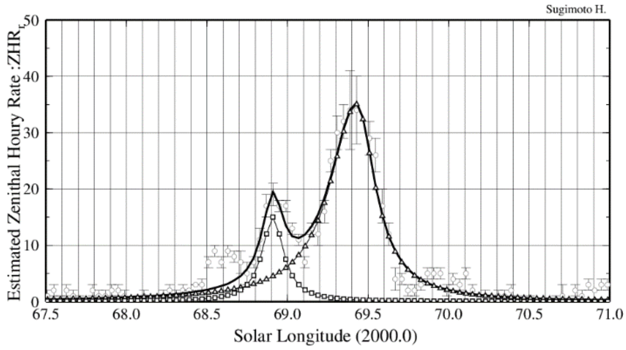

*Figure 4* – $ZHR_r$: estimated components using the Lorentz profile (the curve with triangles represents TAH22C1, the curve with the squares is TAH22C02. The line is TAH22C1 and TAH22C2 combined. Circles with error bars show the τ-Herculid activity observed in 2022).

It is possible that TAH22C1 relates to the meteoroids of the 1995 dust-trail. This research indicates that the peak caused by the 1995 dust trail occurred earlier than predicted, but no more than one hour. The TAH22C2 component on the other hand, might be caused by the 1892 or 1897 dust trail. These were predicted to occur between May 30, $16^h$ and May 31, $10^h$ (Wiegert et al., 2005).

*Table 2* – Estimated components of the τ-Herculids 2022 activity.

| | Activity Level | | | | Estimated Zenithal Hourly Rate (*ZHRr*) | | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum (UT) | $\lambda_\odot$ (2000.0) | Activity Level | FWHM (hours) | Maximum (UT) | $\lambda_\odot$ (2000.0) | $ZHR_r$ | FWHM (hours) |
| TAH22C1 | May 31, $4^h30^m$ | 69.428° | 1.8 | –3.0 / +3.0 | May 31, $4^h30^m$ | 69.428° | 35 | –5.0 / +3.5 |
| TAH22C2 | May 30, $15^h30^m$ | 68.909° | 0.5 | –3.5 / +3.0 | May 30, $15^h30^m$ | 68.909° | 15 | –2.0 / +2.0 |

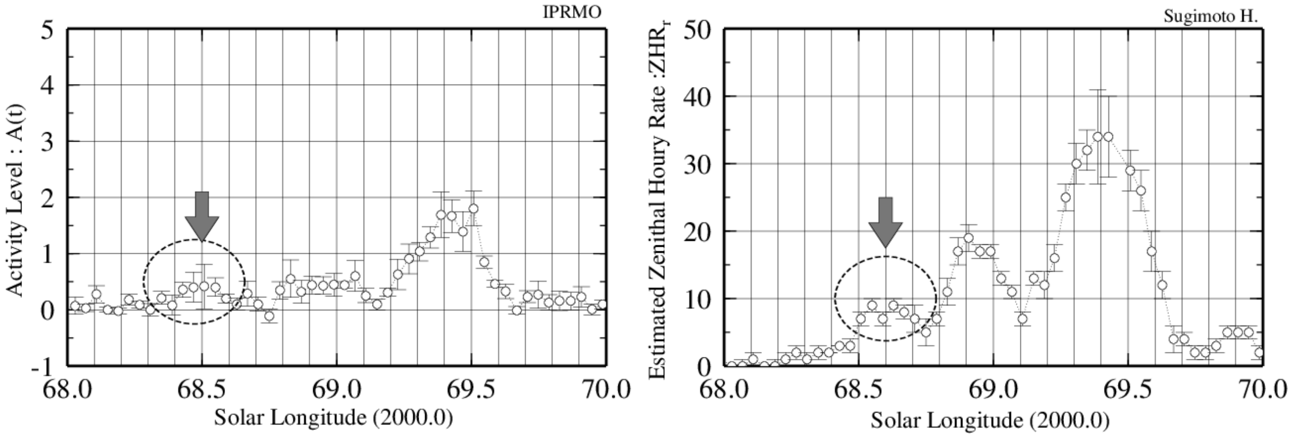

*Figure 5* – The possible presence of a narrow, small filament activity (left: Activity Level index, right: Estimated Zenithal Hourly Rate: $ZHR_r$).

### 4.2 Another sub-peak?

Before the higher described sub-peak, a very small sub-peak was detected around $\lambda_\odot$ = 68.549° (May 30, $6^h30^m$ UT) with $AL = 0.4 \pm 0.2$ and $ZHR_r = 9 \pm 1$ (*Figure.5*). It was uncertain activity because the meteor activity level was very weak. It has a possibility of something observed error.

### 4.3 Poor long echoes

Major meteor showers such as Quadrantids and Perseids show a lot of long echoes (strong overdense meteor echoes). During the period of the τ-Herculid outburst, however, there were few long echoes. It is possible that there were few bright meteors. Also, it could be due to the influence of the very slow geocentric velocity.

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# Enhanced Camelopardalids (CAM #0451) activity recorded in 2022 by Global Meteor Network

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

[1] **Astronomical Society Istra Pula, Park Monte Zaro 2, 52100 Pula, Croatia**
`damir@astro.hr`

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

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

Seven very similar Camelopardalid orbits were collected by cameras of the Global Meteor Network in a time span of less than 7 hours around solar longitude 63.56° (2022 May 25, $01^h48^m$ UT). More dispersed orbits related to this meteor shower have been recorded during the entire month of May 2022. It is not yet clear if the short interval with a slight increase in number of orbits is due to an unknown dust trail related to comet 209P/LINEAR.

## 1 Introduction

The Camelopardalids are a recent discovered meteor shower associated with comet 209P/LINEAR, formerly known as 2004 CB, which was discovered on February 3rd 2004 by Lincoln Near-Earth Asteroid Research. Comet 209P/LINEAR is a weakly active Jupiter Family comet with an orbital period of 5.02 years. The close approach of the comet's orbit to the orbit of the Earth inspired some researchers to check for possible meteor activity. The models suggested enhanced meteor activity on May 24th, 2014. The first modeler to predict meteor activity produced by dust from this comet was Esko Lyytinen, whose predictions were included in a book by Jenniskens (Table 6j, page 689, Jenniskens, 2006). Later this prediction was recalled in a CBET, Central Bureau Electronic Telegrams, by Jenniskens and Lyytinen (2014). The forecast was also studied by Ye and Wiegert (2014).

A Polish team of meteor observers organized an observing expedition to Canada following the outlook for a possible Camelopardalid outburst (Wiśniewski et al., 2015). The unpredictable nature of meteoroid streams once again confirmed its reputation. The Earth crossed the stream of meteoroids at the time it was expected but the activity level of the outburst was much lower than expected which greatly reduced the number of registered meteor trajectories and calculated orbits. Observations of the Camelopardalid meteor shower in May 2014 were obtained with six different sets of cameras near two different geographical locations; Alabama, USA, and Ontario, Canada (Campbell-Brown et al., 2016) The calculated flux and the corresponding Zenithal Hourly Rate of 20 was in good agreement with the results of Toth et al. (2015) and Jenniskens (2014). Madiedo et al. (2014) obtained coordinates for the geocentric radiant from the analysis of seven Camelopardalids as $\alpha_g = 121.9 \pm 1.1°$, $\delta_g = 78.3 \pm 0.4°$ recorded during the main activity period, The averaged geocentric velocity calculated for these meteors was $v_g = 16.4 \pm 0.6$ km/s agreed with the predicted values and results published by other researchers (Jenniskens, 2014). The tensile strength of the Camelopardalids compares well with other fragile meteoroids of cometary origin, such as the Orionids and the Leonids. This conclusion is similar to that of Campbell-Brown et al. (2016). The spectral data obtained for the Camelopardalids suggests non-chondritic meteoroids with a low abundance of Fe with respect to the chondritic value (Madiedo et al., 2014). Jenniskens (2014) found that approximately half of the Camelopardalids had higher beginning heights than typical for meteors of the same speed, and half began lower than typical. This could indicate that half were more fragile than average meteors and half stronger. Many of the light curves showed early or symmetric light curves, which are associated with fragmenting meteoroids. Light curves were U-shaped, with peak luminosity at 88 km altitude.

The Camelopardalid shower appeared in earlier stream searches. A search in 2013 for meteor orbits matching comets and NEO orbits revealed 23 orbits similar to the orbit of 209P/LINEAR, active between April 24 and June 4. This shower was added to the IAU MDC database as the May λ Draconids (MLD #0532) (Šegon et al., 2014). When the shower entry CAM #0451 in the IAU MDC database was updated, it was obvious that the new entry was a duplication of the until then poorly documented Camelopardalids (CAM #0451).

Camelopardalid orbits were identified among 2007–2009 SonotaCo and 2010–2011 CAMS orbit data (Rudawska and Jenniskens, 2014). Eight Camelopardalid orbits were identified between April 22 and May 6 that fulfilled the orbit similarity criterion of Southworth and Hawkins (1963) with $D_{SH} < 0.05$. Another search among 83369 EDMOND meteor orbits collected until 2012 revealed another four

Camelopardalid orbits (Kornoš et al., 2014). A new stream search on the 2010–2013 CAMS data resulted in 19 Camelopardalid orbits (Jenniskens and Nénon, 2016).

In more recent years the Global Meteor Network identified each year a number of Camelopardalid orbits, 4 in 2019, 1 in 2020 and 2 in 2021 (Roggemans et al., 2022). Three Camelopardalids were recorded in a ~4-hour window, from $04^h45^m$ to $09^h00^m$ UTC on 2019 May 24, around the time of a low activity outburst at $7^h44^m$ UT on 24 May 2019 predicted by Mikhail Maslov[6] (Vida and Eschman, 2020). More shower members would be identified if the shower activity period and the appropriate radiant and orbital drift would be better known for this shower. Beyond the predicted shower outbursts, there is also evidence for a dispersed annual component of this Jupiter Family comet type meteoroid stream exposed to strong orbital perturbations by Jupiter.

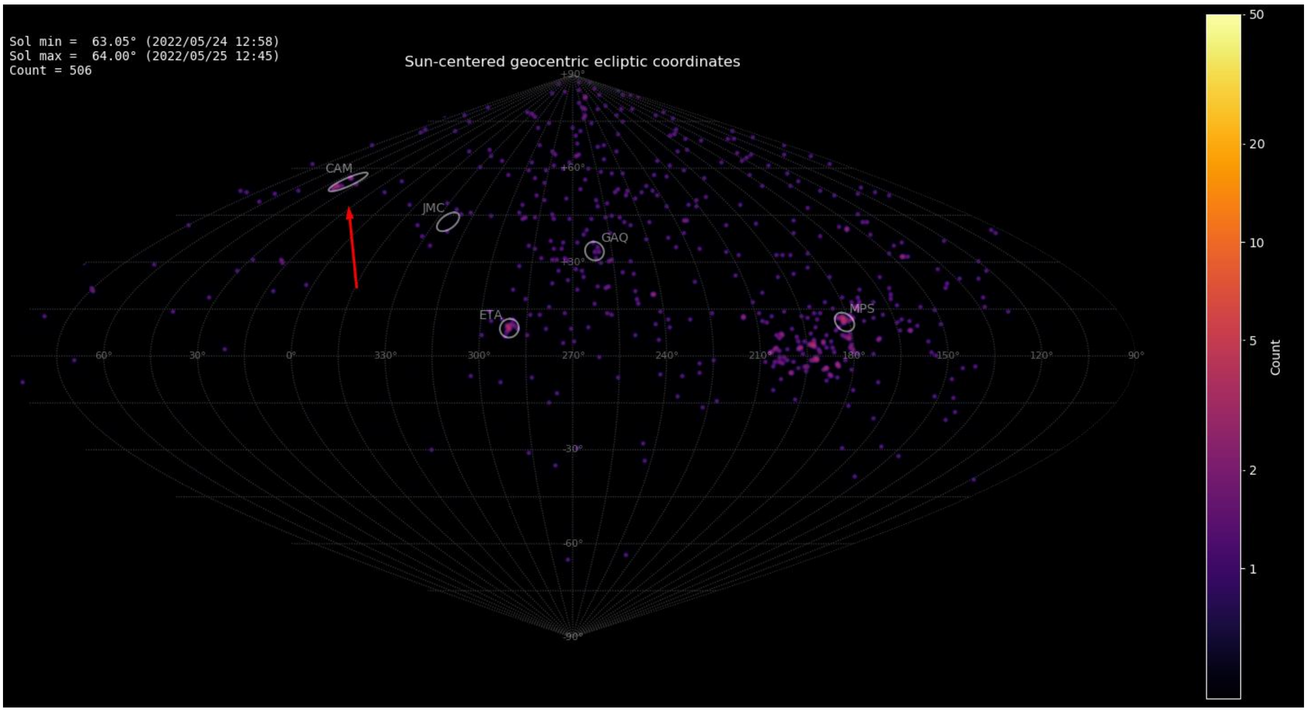

*Figure 1* – The appearance of the Camelopardalid radiant based on orbits collected by the Global Meteor Network during the observing window $63.05° < \lambda_{\odot} < 64.00°$.

*Table 1* – The orbital elements of the 2022 Camelopardalids recorded between solar longitudes 63.415° and 63.685° and the mean orbit compared to results published in the literature.

| $\lambda_{\odot}$ | R.A. | Dec. | $v_g$ | $a$ | $q$ | $e$ | $i$ | $\omega$ | $\Omega$ | $T_j$ | $N$ | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (°) | (°) | (°) | km/s | AU | AU | | (°) | (°) | (°) | | | |
| 52.0 | 155.0 | +73.0 | 14.4 | 2.82 | 0.987 | 0.651 | 18.7 | 165 | 52 | 2.90 | 23 | Šegon et al., 2014 |
| 39.0 | 170.9 | +76.8 | 14.0 | 2.73 | 0.999 | 0.633 | 19.1 | 167.6 | 39.1 | 2.96 | 19 | Jenniskens & Nénon, 2016 |
| 40.6 | 182.7 | +83.2 | 13.0 | 2.07 | 1.000 | 0.517 | 19.0 | 167.9 | 40.6 | 3.53 | 4 | Kornoš et al., 2014 |
| 62.8 | 120.0 | +78.7 | 15.3 | 2.59 | 0.966 | 0.627 | 20.2 | 151.5 | 62.8 | 3.04 | | 2014 Jenniskens et al., 2018 |
| 62.9 | 119.7 | +79.8 | 15.6 | 2.58 | 0.965 | 0.626 | 20.9 | 151.4 | 62.9 | 3.04 | | Jenniskens et al., 2018 |
| 63 | 122.7 | +79.0 | 15.5 | 2.65 | 0.966 | 0.635 | 20.6 | 152.2 | 62.8 | 3.00 | 9 | 2014 outburst |
| 62.59 | 121.2 | +79.5 | 15.3 | 2.53 | 0.967 | 0.618 | 20.5 | 151.9 | 62.6 | 3.08 | 3 | Mean orbit 2019 |
| 65.69 | 120.6 | +73.9 | 15.8 | 2.93 | 0.904 | 0.691 | 19.35 | 150.3 | 65.69 | 2.80 | | 209P/LINEAR |
| 63.42 | 119.4 | +75.5 | 15.1 | 2.75 | 0.963 | 0.650 | 19.1 | 151.1 | 63.4 | 2.93 | – | 20220524_221115 |
| 63.46 | 112.0 | +76.7 | 14.6 | 2.34 | 0.958 | 0.591 | 19.0 | 148.8 | 63.5 | 3.24 | – | 20220524_231829 |
| 63.49 | 119.0 | +75.8 | 15.1 | 2.71 | 0.963 | 0.644 | 19.2 | 150.9 | 63.5 | 2.97 | – | 20220524_235946 |
| 63.55 | 124.2 | +78.5 | 14.9 | 2.45 | 0.968 | 0.605 | 19.8 | 152.0 | 63.6 | 3.15 | – | 20220525_013235 |
| 63.67 | 118.6 | +76.3 | 15.4 | 2.75 | 0.962 | 0.650 | 19.6 | 150.8 | 63.7 | 2.93 | – | 20220525_042550 |
| 63.67 | 119.9 | +76.4 | 15.7 | 2.93 | 0.963 | 0.671 | 19.9 | 151.2 | 63.7 | 2.82 | – | 20220525_042552 |
| 63.69 | 98.9 | +78.0 | 16.2 | 2.57 | 0.945 | 0.632 | 21.3 | 145.9 | 63.7 | 3.04 | – | 20220525_045610 |
| 63.56 | 116.0 | +76.7 | 15.3 | 2.63 | 0.960 | 0.634 | 19.7 | 150.1 | 63.6 | 3.01 | 7 | Mean orbit 2022 |

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[6] http://feraj.ru/Radiants/Predictions/209p-ids2019eng.html

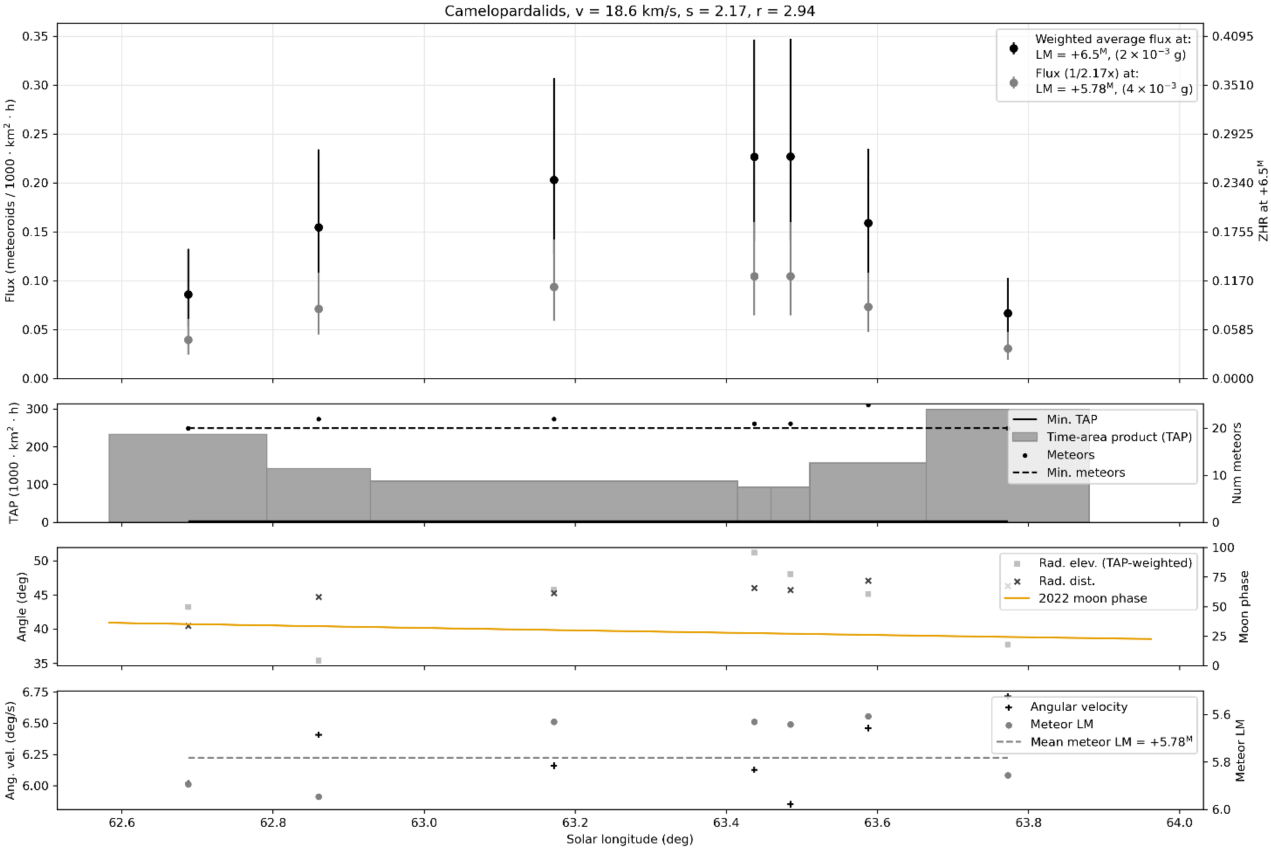

*Figure 2* – The flux data obtained for the Camelopardalids recorded by the Global Meteor Network.

## 2 Activity enhancement in 2022

Like previous years the Global Meteor Network detected Camelopardalid orbits in May 2022 (*Figure 1*). Between solar longitudes 63.415° and 63.685°, corresponding to 2022 May 24, $22^h$ and 2022 May 25, $05^h$ UT, a remarkable activity enhancement with 7 Camelopardalid orbits has been recorded in this relative short time interval. The magnitudes ranged between –1.4 and +3.3. The time slot in which these orbits were recorded coincides with the ascending branch of the radio activity profile presented by Ogawa and Sugimoto (2022); The time of maximum for the radio observations occurred at $\lambda_{\odot} = 63.71°$ (May 25, $5^h33^m$ UT), slightly before the theoretical predicted encounter at $\lambda_{\odot} = 63.8°$ (2022 May 25, $8^h$ UT). The activity level for radio observations was about half of the level recorded during the previous outburst in 2014, but much stronger than the activity level suggested by the 2022 GMN results. This discrepancy could indicate that the radio meteor activity consisted mainly of fainter meteors beyond the detectability of the optical system of the RMS cameras.

Computing the average and mean orbital elements using the method described by Jopek et al. (2006) all 7 orbits fit within a threshold of $D_{SH} < 0.075$. Using this mean orbit to look at a wider observing window for orbits with $D_{SH} < 0.075$, 14 similar orbits are found between May 18 and May 30. Using more tolerant D-criteria with $D_{SH} < 0.20$ and $D_D < 0.08$ (Drummond, 1981) we find as many as 150 similar orbits during the entire month of May 2022. It seems that the dust from comet 209P/LINEAR got dispersed to an extent that it takes Earth from end of April till begin of June to cross the dispersed meteoroid stream. The presence of relatively young dust trails such as observed in 2014, 2019 and 2022 should be distinguished from the dispersed annual component.

The individual orbits of the concentration of the Camelopardalid orbits and their mean orbit are listed in *Table 1*. The 2022 orbit data can be compared with some past data for this meteor shower.

*Figure 2* shows the flux measurements of the activity enhancement. Due to the small number of events, the mass index could not be independently measured, so a previously measured value of $s = 2.17$ (Campbell-Brown et al., 2016) was used. The peak occurred at 63.45 ± 0.03° of solar longitude. A peak flux of $0.23 \pm 0.1 \times 10^{-3}$ meteoroids km$^2$/h was measured at the limiting magnitude and mass of +6.5M and $2 \times 10^{-3}$ g. The equivalent ZHR is 0.3 ± 0.1. This is about 130 times less than the activity derived from radio observations (Ogawa and Sugimoto, 2022), indicating that the stream is rich in small particles. Due to the low activity of the shower, most cameras either did not observe a single Camelopardalid, or only 1-2. However, such a small activity could be measured with confidence because flux observations from hundreds of meteor cameras were combined to produce a virtual global instrument, following the method described in Vida et al. (2022). Each time bin had a minimum time-area product of 100000 km$^2$ h and 20 meteors.

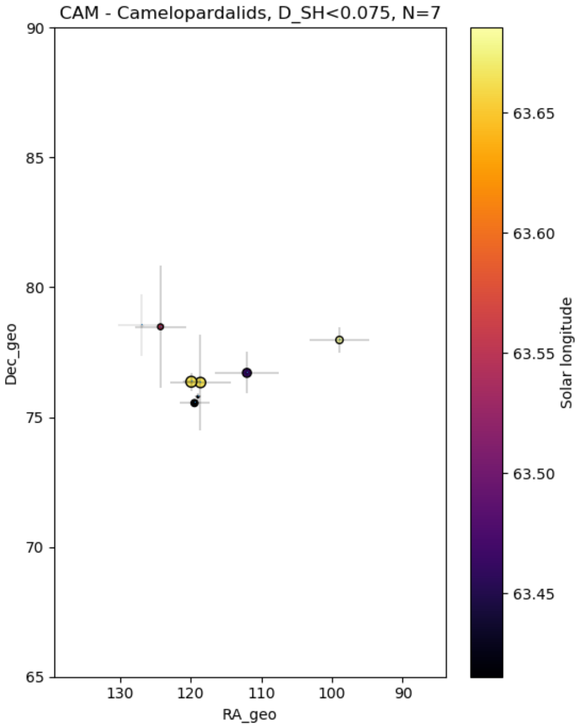

*Figure 3* – The geocentric radiants in equatorial coordinates for the 7 Camelopardalid orbits.

The average duration of the 7 Camelopardalids was 1.3s, the beginning height $H_b$ = 93.5 km and ending height $H_e$ = 78.7 km. The height with maximum brightness occurred at $H_{peak}$ = 84.3 km, slightly lower than the 88 km found in 2014 by Jenniskens (2014). The average observational median fit error was 66.3”. *Figure 3* shows the radiant points in geocentric equatorial coordinates and *Figure 4* shows the radiants in Sun-centered geocentric ecliptical coordinates. The very compact radiant size in 2022 was also observed in 2014.

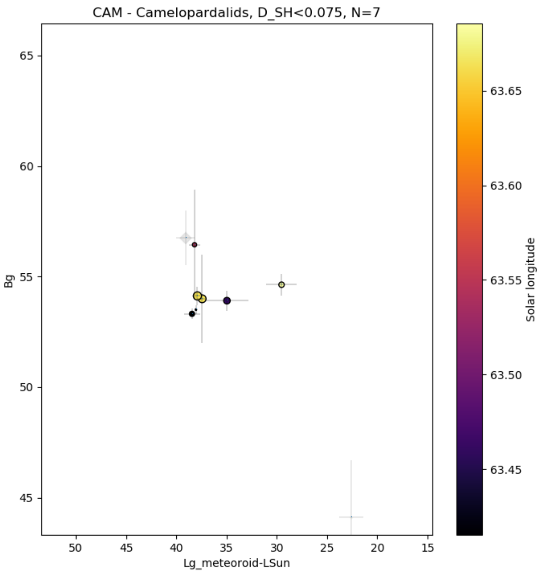

*Figure 4* – The geocentric radiant in Sun-centered ecliptic coordinates for the 7 Camelopardalid orbits.

## 3 Conclusion

Camelopardalid orbits have been recorded in the past years indicating a large dispersion in time from end of April until beginning of June. This annual component could be recorded in 2022 with a peculiar small concentration of 7 very similar orbits that appeared around solar longitude 63.56° and which might be related to an unknown dust trail.

The orbit data collected so far during the past 15 years by different video camera networks may justify an in-depth analysis of this meteor shower in order to establish its activity period, radiant and orbital drift.

## Acknowledgment

This report is based on the data of the Global Meteor Network which is released under the CC BY 4.0 license[7]. The peculiar concentration of 7 very similar orbits has been recorded by GMN cameras in Belgium, Canada, Croatia, Germany, the United Kingdom and the US. A more detailed study will be possible thanks to the joined efforts of all GMN collaborators:

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# Meteor activity related to 209P/LINEAR by worldwide radio meteor observations

**Hirofumi Sugimoto**[1] **and Hiroshi Ogawa**[2]

[1] **The Nippon Meteor Society**
`hiro-sugimoto@kbf.biglobe.ne.jp`

[2] **The International Project for Radio Meteor Observations**
`h-ogawa@amro-net.jp`

The encounter of meteoroids released by comet 209P/LINEAR had been predicted on 25th May ($\lambda_{\odot}$ = 63.8°). At $\lambda_{\odot}$ = 63.708° (May 25, 05$^{h}$30$^{m}$ UT), some possible of meteor activity has been detected by using radio meteor observations from around the world. A maximum $ZHR_r = 14 \pm 2$ was recorded. This activity level was about half of the level recorded during the previous outburst in 2014 (estimated $ZHR_r$ = 26).

## 1 Introduction

An outburst of meteor activity related to comet 209P/LINEAR was observed in 2014. The estimated activity level by worldwide radio meteor observations was $ZHR_r$ = 26 at 62.91° (Sugimoto, 2014)[8].

For 2022, an encounter with meteoroids released by comet 209P/LINEAR was expected on 25th May around 08$^{h}$ ($\lambda_{\odot}$ = 63.8°) (Rendtel, 2021).

Radio meteor observations allow meteor activity to be monitored continuously even with bad weather or during daytime. Besides, the radiant elevation problem is solved by organizing this as a worldwide project. One of the worldwide projects is the International Project for Radio Meteor Observations (IPRMO)[9]. IPRMO uses the Activity Level index to analyze the meteor shower activity (Ogawa et al., 2001).

## 2 Method

This research adopted the $ZHR_r$ index (Sugimoto, 2017). The $ZHR_r$ index is very useful and has been used in many past articles because it is helpful to compare radio observations to visual observations.

## 3 Results

*Figure 1* shows the result based on the calculation of the $ZHR_r$ using 35 datasets from around the world collected by the Radio Meteor Observation Bulletin (RMOB).

The peak occurred at $\lambda_{\odot}$ = 63.708° (May 25, 5$^{h}$30$^{m}$ UT). The zenithal hourly rate reached $ZHR_r = 14 \pm 2$. The distinct increase in activity started at $\lambda_{\odot}$ = 63.428° (May 24, 22$^{h}$30$^{m}$ UT), and ended at $\lambda_{\odot}$ = 63.828° (May 25, 8$^{h}$30$^{m}$ UT). Although the Activity Level Index which is adopted by IPRMO was only a reference value, a small peak has been detected at the same time (see *Table 1*).

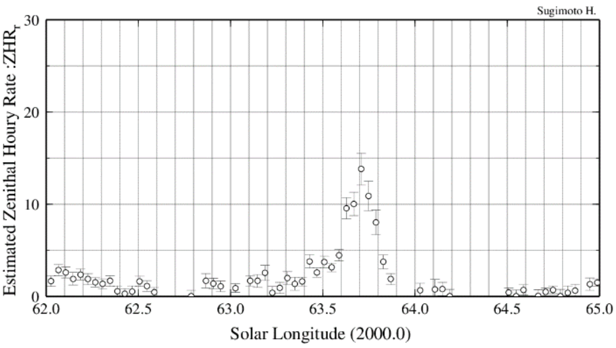

*Figure 1* – Estimated $ZHR_r$.

*Table 1* – The estimated $ZHR_r$ and Activity Level Index (AL), the Activity Level Index is a reference value.

| Time (UT) | $\lambda_{\odot}$ (°) | $ZHR_r$ | | Activity Level | |
|---|---|---|---|---|---|
| | | N | $ZHR_r$ | N | AL |
| May, 24 23$^{h}$30$^{m}$ | 63.468 | 29 | 3±1 | 13 | 0.1±0.1 |
| May, 25 0$^{h}$30$^{m}$ | 63.508 | 25 | 4±1 | 12 | 0.2±0.2 |
| May, 25 130$^{m\ h}$ | 63.548 | 28 | 3±1 | 15 | 0.1±0.2 |
| May, 25 2$^{h}$30$^{m}$ | 63.588 | 26 | 4±1 | 12 | 0.0±0.1 |
| May, 25 3$^{h}$30$^{m}$ | 63.628 | 27 | 10±1 | 21 | 0.3±0.3 |
| May, 25 4$^{h}$30$^{m}$ | 63.668 | 22 | 10±1 | 8 | 0.2±0.1 |
| May, 25 5$^{h}$30$^{m}$ | 63.708 | 23 | 14±2 | 10 | 0.4±0.3 |
| May, 25 6$^{h}$30$^{m}$ | 63.748 | 21 | 11±2 | 10 | 0.1±0.2 |
| May, 25 7$^{h}$30$^{m}$ | 63.788 | 23 | 8±1 | 10 | 0.1±0.2 |
| May, 25 8$^{h}$30$^{m}$ | 63.828 | 24 | 4±1 | 14 | 0.2±0.1 |
| May, 25 9$^{h}$30$^{m}$ | 63.868 | 25 | 2±1 | 17 | -0.0±0.2 |

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[8] Sugimoto H. (2014). "2014 May Camelopardalids (209P/LINEAR) Radio results" on the website, http://www5f.biglobe.ne.jp/~hro/Flash/2014/CAM/index.html

[9] https://www.iprmo.org

## 4 Discussion

*Figure 2* shows the estimated component by using the Lorentz profile (Jenniskens et al., 2000). It had a maximum $ZHR_r$ = 14 at $\lambda_{\odot}$ = 63.708° (May 25, $5^h30^m$ UT) with Full width half maximum (FWHM) = -2.5 / +2.0 hours. The ascending branch was longer than the descending branch.

In 2014 (previous outburst), the component of the meteor activity was estimated as $ZHR_r$ = 26 with -3.0/ +3.0 hours at $\lambda_{\odot}$ = 62.909° (May 24, $8^h30^m$ UT). The 2022 activity therefore was about half of the activity level of 2014 (see *Table 2*).

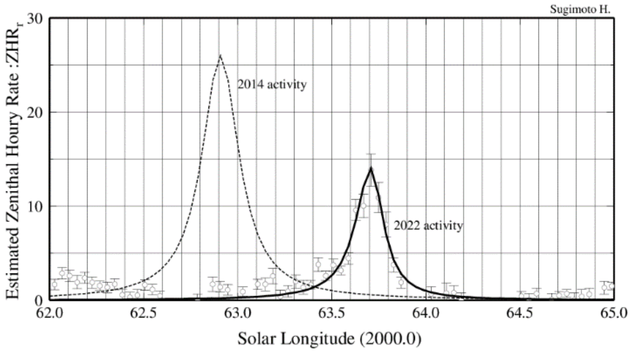

*Figure 2* – $ZHR_r$: the estimated components using the Lorentz Profile (dashed line indicate the estimated component in 2014).

*Table 2* – The estimated components of meteor activity in 2022 and 2014.

| | Peak Time | $\lambda_{\odot}$ (°) | Peak Level | FWHM (hours) |
|---|---|---|---|---|
| $ZHR_r$ 2022 | May 25 $5^h30^m$ UT | 63.708 | 14 | -2.5/+2.0 |
| $ZHR_r$ 2014 | May 24 $8^h30^m$ UT | 62.909 | 26 | -3.0/+3.0 |

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The worldwide data were provided by the Radio Meteor Observation Bulletin (RMOB)[10]. The following observers provided data: *Chris Steyaert* (Belgium), *Felix Verbelen* (Belgium), *Johan Coussens* (Belgium), *HFN-R1* (Czech Republic), *SVAKOV-R12* (Czech Republic), *NACHODSKO-R5* (Czech Republic), *DDMTREBIC-R3* (Czech Republic), *Jean Marie F5CMQ* (France), *Balogh Laszlo* (Hungary), *Istvan Tepliczky* (Hungary), *Mario Bombardini* (Italy), *Hirofumi Sugimoto* (Japan), *Hironobu Shida* (Japan), *Hiroshi Ogawa* (Japan), Kenji Fujito (Japan), *Masaki Kano* (Japan), *Masaki Tsuboi* (Japan), *Minoru Harada* (Japan), *Nobuo Katsura* (Japan), *Norihiro Nakamura* (Japan), *Juan Zapata* (Mexico), *Rainer Ehlert* (Mexico), *Salvador Aguirre* (Mexico), *Rafael Martinez* (Puerto Rico), *Karlovsky Hlohovec Observatory* (Slovakia), *Ian Evans* (UK), *Philip Norton* (UK), *Philip NortonVert* (UK), *Philip Rourke* (UK), *Eric Smestad_KC0RDD* (USA), *Richard Schreiber* (USA), *Stan Nelson* (USA).

We wish to thank *Pierre Terrier* for developing and hosting rmob.org.

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[10] https://www.rmob.org

# Meteor activity related to 2006GY2 by worldwide radio meteor observations

**Hiroshi Ogawa**[1] **and Hirofumi Sugimoto**[2]

[1] **The International Project for Radio Meteor Observations**
h-ogawa@amro-net.jp

[2] **The Nippon Meteor Society**
hiro-sugimoto@kbf.biglobe.ne.jp

Possible meteor activity connected to the minor planet 2006GY2 had been predicted for 15th May 2022. Worldwide radio meteor observers caught meteor activity possibly related to it. The peak was detected at $\lambda_{\odot}$ = 54.325°–54.365° (May 15, $11^h30^m$ –$12^h30^m$ UT). The Activity Level Index (AL) was estimated as AL = 0.4 and the estimated $ZHR_r$ was 15.

## 1 Introduction

An encounter with meteoroids released from minor planet 2006GY2 was expected on May 15 around $10^h20^m$ ($\lambda_{\odot}$ = 54.28°) (Rendtel, 2021).

Using radio meteor observations, it is possible to observe meteor activity continuously even with bad weather or during daytime. Besides, the problem of the radiant elevation is solved by organizing a worldwide project. One of the worldwide projects is the International Project for Radio Meteor Observations (IPRMO)[11]. IPRMO uses the Activity Level index for analyzing meteor shower activity (Ogawa et al., 2001).

## 2 Method

This research adopted two methods for estimating the meteor shower activity. One is the Activity Level Index which is used by IPRMO (Ogawa et al., 2001). Another is the estimated $ZHR_r$ (Sugimoto, 2017). This index is estimated by using the Activity Level index and a factor named $S_{bas}$ which translates the Activity Level index to $ZHR_r$. This method is very useful to compare radio observations to visual observations.

## 3 Results

*Figure 1* shows the result based on the calculation of the Activity Level Index using 39 sets of observing data from 11 countries. The peak occurred at $\lambda_{\odot}$ = 54.365° (May 15, $12^h30^m$ UT). The Activity Level Index was 0.4 ± 0.3 with Full Width of Half Maximum (FWHM) –1.5hrs / +3.0hrs. The distinct activity remained for three hours according to the result of the Activity Level Index.

*Figure 2* shows the estimated $ZHR_r$ using 33 observations from the world. The estimated $ZHR_r$ was 15 ± 2 at $\lambda_{\odot}$ = 54.325° (May 15, $11^h30^m$ UT). The activity started at $\lambda_{\odot}$ = 54.245° (May 15, $9^h30^m$ UT) and ended at $\lambda_{\odot}$ = 54.566° (May 15, $17^h30^m$ UT).

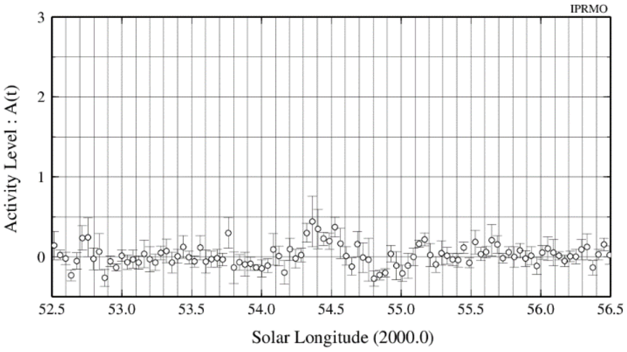

*Figure 1* – Activity Level Index.

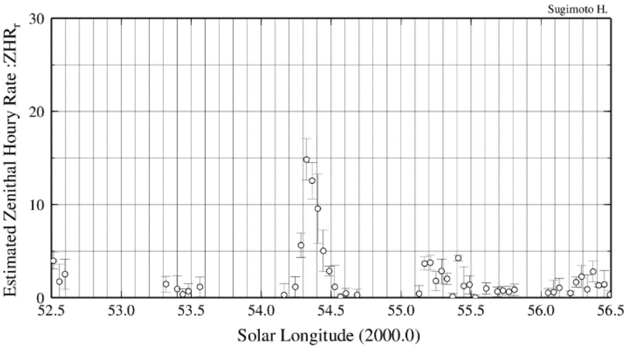

*Figure 2* – Estimated $ZHR_r$.

*Table 1* – Activity Level Index (AL) and estimated $ZHR_r$.

| Time (UT) | $\lambda_{\odot}$ | Activity Level | | $ZHR_r$ | |
|---|---|---|---|---|---|
| | (°) | N | AL | N | $ZHR_r$ |
| May 15, $9^h30^m$ | 54.245 | 18 | -0.0±0.1 | 7 | 1±1 |
| May 15, $10^h30^m$ | 54.285 | 16 | 0.0±0.1 | 10 | 6±1 |
| May 15, $11^h30^m$ | 54.325 | 15 | 0.3±0.1 | 15 | 15±2 |
| May 15, $12^h30^m$ | 54.365 | 17 | 0.4±0.3 | 12 | 13±2 |
| May 15, $13^h30^m$ | 54.405 | 15 | 0.3±0.2 | 8 | 10±4 |
| May 15, $14^h30^m$ | 54.445 | 12 | 0.2±0.1 | 9 | 5±2 |
| May 15, $15^h30^m$ | 54.486 | 11 | 0.2±0.1 | 9 | 3±1 |

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[11] https://www.iprmo.org

## 4 Discussion

*Figure 3* and *Figure 4* show the estimated components of the Activity Level and $ZHR_r$ which were calculated by using the Lorentz profile (Jenniskens et al., 2000). It had a maximum Activity Level = 0.4 and $ZHR_r = 15$ at $\lambda_{\odot} = 54.325°–54.365°$ (May 15, 11$^h$30$^m$ –12$^h$30$^m$ UT) with Full width half maximum (FWHM) = –1.0 / +2.0 hours. The descending branch was longer than the ascending branch. Although this result may indicate a possible meteor activity related to 2006GY2, we need to keep in mind that the Activity Level Index was very weak.

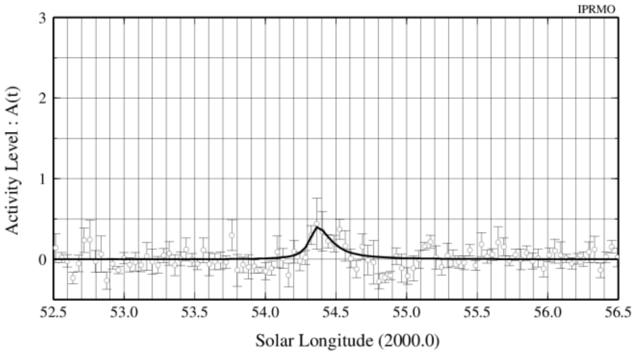

*Figure 3* – Activitiy Level: Estimated components using the Lorentz Profile.

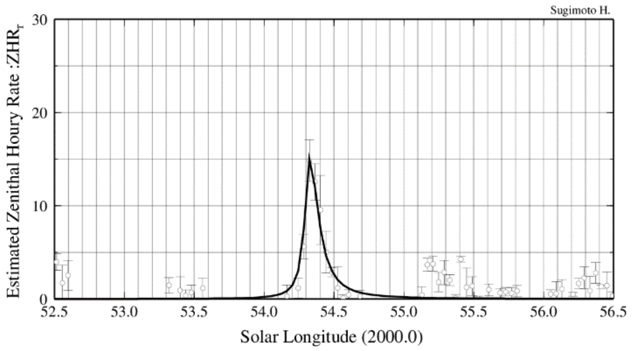

*Figure 4* – $ZHR_r$: Estimated components using the Lorentz Profile.

*Table 2* – Estimated components of meteor activity (Activity Level is reference values).

| | Peak Time | $\lambda_{\odot}$ | Peak Level | FWHM (hours) |
|---|---|---|---|---|
| $ZHR_r$ | May 15<br>11$^h$30$^m$ UT | 54.325° | 15 | –1.0/+2.0 |
| Activity Level | May 15<br>12$^h$30$^m$ UT | 54.365° | 0.4 | –1.5/+3.0 |

## Acknowledgment

The worldwide data were provided by the Radio Meteor Observation Bulletin (RMOB)[12]. The following observers provided data:

*Chris Steyaert* (Belgium), *Felix Verbelen* (Belgium), *Johan Coussens* (Belgium), *HFN-R1* (Czech Republic), *OBSUPICE-R6* (Czech Republic), *VALMEZ-R1* (Czech Republic), *DanielD SAT01 DD* (France), *Jean Marie F5CMQ* (France), *Balogh Laszlo* (Hungary), *Istvan Tepliczky* (Hungary), *Mario Bombardini* (Italy), *Hirofumi Sugimoto* (Japan), *Hironobu Shida* (Japan), *Hiroshi Ogawa* (Japan), *Kenji Fujito* (Japan), *Masaki Kano* (Japan), *Masaki Tsuboi* (Japan), *Nobuo Katsura* (Japan), *Norihiro Nakamura* (Japan), *Juan Zapata* (Mexico), *Rainer Ehlert* (Mexico), *Salvador Aguirre* (Mexico), *Karlovsky Hlohovec Observatory* (Slovakia), *Jochen Richert* (Switzerland), *Jochen Richert 1* (Switzerland), *Ian Evans* (UK), *Philip Norton* (UK), *Philip NortonVert* (UK), *Philip Rourke* (UK), *Eric Smestad KC0RDD* (USA), *Mike Otte* (USA), *Richard Schreiber* (USA), *Stan Nelson* (USA).

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Ogawa H., Toyomasu S., Ohnishi K., and Maegawa K. (2001). “The Global Monitor of Meteor Streams by Radio Meteor Observation all over the world”. In, Warmbein Barbara, editor, *Proceeding of the Meteoroids 2001 Conference*, 6-10 August 2001, Swedish Institute of Space Physics, Kiruna, Sweden. ESA Publications Division, European Space Agency, Noordwijk, The Netherlands, 189–191.

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Sugimoto H. (2017). “The New Method of Estimating ZHR using Radio Meteor Observations”. *eMetN*, **2**, 109–110.

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[12] https://www.rmob.org

# Three showers in Aries, two new and one known, or just one?

**John Greaves**

midmet@mail.com

Two radiant clusterings are noted in UKMON data near 41 Arietis, whilst *D* criterion analyses show two discrete showers, and to a far lesser extent the somewhat earlier and even more discrete λ Arietids, the overall similarities of these three suggest that they may have a common long past parent body from which meteoroid orbits have changed over time.

## 1 Introduction and methodology

The sheer continual increase in number of meteor orbits available over the past decade or so can lead to it being difficult to assess radiant clustering of minor sparse showers and avoiding false positives. At times it can be useful to use relatively homogeneous sets of data from one source (relative in the sense that equipment and processing algorithms for most groups have evolved over time) and then testing any potential clustering via orbital similarity analyses using the complete collection of publicly available meteor orbits, or at least optically derived ones.

Examination of areas of apparent radiant clustering amongst UKMON sporadic meteor orbits (Campbell-Burns and Kacerek, 2014) showed a mild overdensity near to one end of the constellation Aries. However *D* criterion analysis (Jopek, 1993), henceforth denoted $D_J$, demonstrated that despite the similarity in clustering there were two adjacent showers that although similar where quite distinct from each other, with the relation $D_J = 0.244$ for their mean orbits being much higher than the canonical 0.105 stated by Jopek (2013) as the initial threshold value for likely connectivity (where the lower the $D_J$ value between two compared orbits the better the likelihood of non-random association). Also, the relatively high retrograde inclination of the orbits precluded any circumstance derived orbital similarity such as that which can be found in showers derived from Jupiter Family Comet parent bodies.

Meanwhile, a not-too-distant published meteor radiant, the λ Arietids (Jenniskens et al., 2016), henceforth LAR, although quite markedly distinct being up to 20° in both solar longitude and right ascension distance (that is both temporally and spatially) nevertheless has some commonality amongst some of its orbital elements. Yet the $D_J$ values of the LAR orbit relative to the two new apparent streams are quite distinct at 0.309 and 0.212 respectively, albeit ironically with the shower most distant in time and space from the LAR having an orbit better matching than it does its spatial and temporal twin.

Accordingly, $D_J$ analyses were made upon the mean orbital particulars of all three showers using data from multi-station meteor survey publicly available data archives of SonotaCo Network (e.g., SonotaCo, 2009), CAMS (e.g., Jenniskens et al., 2018), EDMOND (e.g., Kornoš et al., 2014) and Global Meteor Network (Vida et al., 2019a; 2019b), with the published orbit for the LAR being used as the analysis seed in that case. For the other two showers a span of right ascension and declination and solar longitude was culled from the UKMON subset and the means of both clusterings used as an orbit seed. The mean orbit derived from that processing was then freshly used as a new seed giving more and better matches and this led to the following results.

## 2 Results

The results gave over 50 distinct meteors for each of the three showers to a better than $D_J$ 0.100 level, with the two new potential showers henceforth referred to as the 41 Arietids (41 Ari) and the 59 Arietids (59 Ari) respectively for convenience. To add a further level of rigor to the investigation only the objects for each shower matching the mean to better than 0.080 were kept for the final examination leading to 24, 21 and 30 meteor orbits for the 41 Ari, 59 Ari and LAR respectively. None of the resulting meteors in any particular one of the showers was common to any meteor in either of the other showers. Throughout it should be remembered that the surveys are predominantly biased towards the detection of bright optical meteors, and in the following the mean magnitudes and standard deviations for the 41 Ari, 59 Ari and LAR are –0.7 ± 1.3, –0.7 ± 1.3 and 0.3 ± 1.4 respectively.

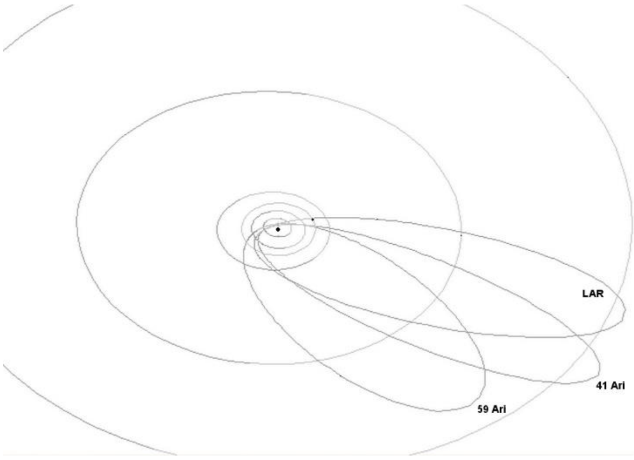

*Figure 1* – The mean orbits for all three showers, with the more circular orbits representing planets out to and including Saturn, all to scale for a representative date of 1st September 2022. Darker grey parts of the orbits and lighter grey parts of the orbits represent above ecliptic and below ecliptic parts of the orbits respectively, with the position of the Sun and the Earth being shown in black.

*Table 1* gives the particulars of each shower based upon a mean and standard deviation, whilst *Figure 1* illustrates these mean orbits with respect to each other. *Figure 2* demonstrates their relation in terms of ecliptic latitude and Sun centered ecliptic longitude whilst *Figure 3* does the same in terms of orbital inclination and longitude of perihelion. In each figure a background of UKMON sporadic meteors is included to highlight the nature of the showers with respect to the general background for the same spatial and temporal ranges as denoted by the axes of the plots.

*Table 1* – The mean and the standard deviation on the mean of the meteor orbits for all three showers are given for :- right ascension (in degrees); declination (in degrees); solar longitude, $\lambda_\Theta$, (in degrees); perihelion distance, $q$, (AU); eccentricity, $e$; inclination, $i$, (in degrees); argument of perihelion, $\omega$, (in degrees); ascending node, $\Omega$, (in degrees); ecliptic longitude, $\lambda$, (in degrees); ecliptic latitude, $\beta$, (in degrees); ecliptic latitude minus solar longitude, $\lambda - \lambda_\Theta$, (in degrees) and longitude of perihelion, $\Pi$, (in degrees).

| Shower | R.A. | Decl. | $\lambda$ | $q$ | $e$ | $i$ | $\omega$ | $\Omega$ | $\lambda$ | $\beta$ | $\lambda - \lambda_\Theta$ | $\Pi$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 41 ARI | 43.4<br>± 2.8 | 26.3<br>±0.9 | 172.0<br>±2.9 | 0.305<br>±0.016 | 0.962<br>±0.021 | 154.7<br>±1.8 | 295.0<br>±2.0 | 172.0<br>±2.9 | 48.7<br>±2.6 | 9.3<br>±0.7 | 236.7<br>±0.9 | 107.0<br>±4.6 |
| 59 ARI | 50.1<br>±2.7 | 27.7<br>±1.0 | 175.0<br>±2.7 | 0.382<br>±0.012 | 0.946<br>±0.023 | 157.8<br>±2.1 | 286.0<br>±2.6 | 175.0<br>±2.8 | 54.9<br>±2.5 | 9.0<br>± 0.8 | 239.9<br>± 0.8 | 101.0<br>±5.0 |
| LAR | 28.2<br>±2.3 | 23.6<br>±1.0 | 154.6<br>±2.5 | 0.407<br>±0.024 | 0.950<br>±0.023 | 152.6<br>±1.7 | 283.1<br>±1.7 | 154.6<br>±2.5 | 34.6<br>±2.3 | 11.2<br>±0.8 | 240.0<br>±1.0 | 77.7<br>±4.5 |

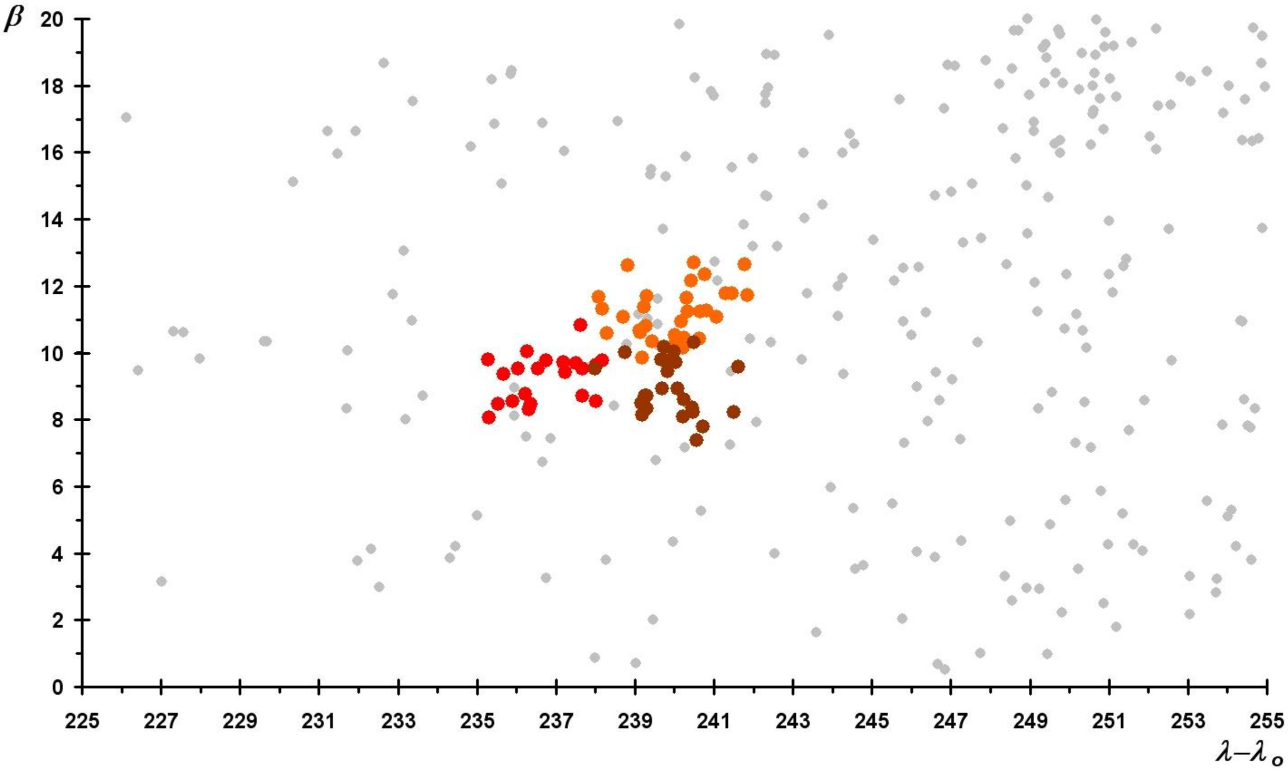

*Figure 2* – The ecliptic latitude, $\beta$, and Sun centred ecliptic longitude, $\lambda - \lambda_\Theta$, both in degrees, for the 41 Arietids, red, 59 Arietids, brown, and, the λ Arietids, orange, with the UKMON sporadic meteors covering the same full range of solar longitude also shown in grey.

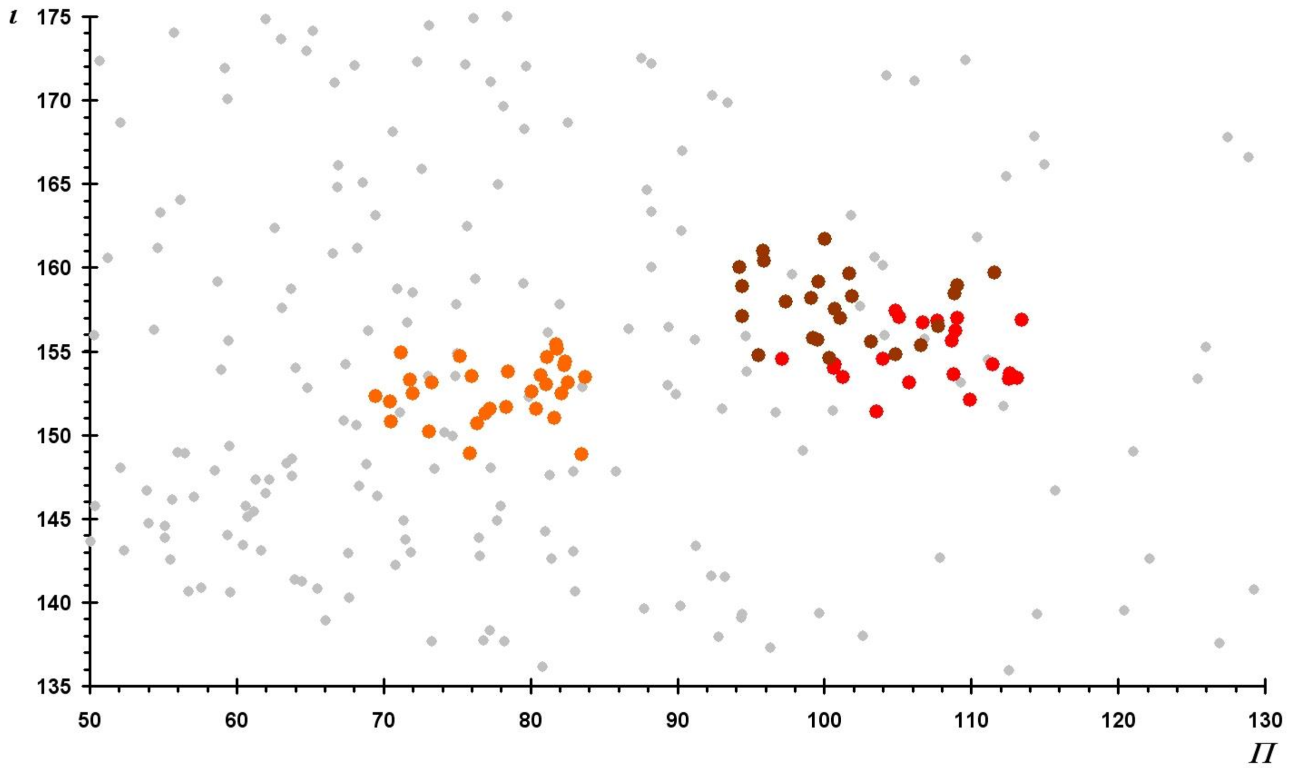

*Figure 3* – The orbital inclination, *i*, and longitude of perihelion, *Π*, both in degrees, for the 41 Arietids, red, 59 Arietids, brown, and, the λ Arietids, orange, with the UKMON sporadic meteors covering the same full range of solar longitude also shown in grey.

## 3 Discussion

The distinctness of the three showers is demonstrable, yet at the same time the similarities of the showers, especially with respect to the background, cry out against coincidence. Nevertheless, said distinctness within the orbital and/or spatial/temporal parameters suggests against this being one long duration stream with attendant radiant drift given the gap in meteors between the LAR and the mutually temporally and spatially adjacent 41 Ari and 59 Ari, whilst ironically the most distant apart showers in those parameters, the 59 Ari and the LAR, have greater similarity in orbital parameters than they do with the 41 Ari. The similar inclination for all three showers leads to the geocentric velocities overlapping at 61.0 ± 0.6, 62.4 ± 0.6 and 62.2 ± 0.4 km/s respectively.

Jenniskens et al. (2016), in their comments for their LAR shower (this was the discovery publication for that shower, derived from 11 orbits), state that that shower is an apex shower likely derived from a long period or possibly Halley type comet. If this is the case it is not difficult to imagine this relatively minor and sparse trio of streams, having drifted or precessed over time, although that does not explain the gap in time and space between the LAR and the other two showers, as well as the mutual distinctness of the latter, nor is it a quantitative assessment (the latter is beyond the remit of these analyses).

One evident trend is a decrease/increase in the mean perihelion distance between the three distinct mean orbits without any overlap in standard deviation (although the 59 Ari and LAR come very close to overlapping), which could be interpreted as a spread due to solar radiation pressure (which can both decrease and increase the size of an orbit but not necessarily affect its orientation) and/or orbital precession. This again is not reflected by the lack of continuity across the data, each being distinct and with a conspicuous gap in distribution of radiants between the LAR and the two new and overlapping showers, more suggestive of orbital shifts related to gravitational interactions during planetary close approaches. Further, any putative evolution due to precessional effects suffers from the fact that the mean orbit of the smallest perihelion stream lies between the other two orbits, and thus at some point the orbit would have had to precess in two opposing directions unless the apparent perihelion drift can be shown not to be connected with change in orbital shape and orientation.

There are reports of meteor complexes which suggest some streams belong to “families” of streams, however the group of showers here could not only be taken as siblings, but rather as snapshots of a single shower’s orbital evolution over time. Yet again this leaves the issue of lack of any smooth and gradual spread of meteoroids along a contiguous continuity of orbital parameters. No real proximity of any of the orbits’ aphelia suggest any close approaches to the massive outer planets either, for despite all mean orbits just crossing the orbit of Saturn their inclinations are large relative to the ecliptic plane.

The assumption of the three showers being derived from a common parent body is taken here, with one apparition of the comet leading to all three streams being due to orbital evolution of an initial meteoroid stream, as the likely long to very long period of any such parent body is likely to be far too long for meteoroids derived over three apparitions widely separated in time to not have dispersed by now and all still be extant.

Such assumptions would need to be tested for any validity by those more capable of deriving the orbital evolution of meteoroid streams over long time periods.

## 4 Conclusion

Examination of a relatively homogeneous collection of data from UKMON lead to the noting of radiant clustering in Aries around mid-September. Further exploration upon the orbital elements using $D_J$ criterion led to two discrete showers, one centered just South of 41 Arietis and the other centered very near to 59 Arietis, which although marginally overlapping in time and radiant were also distinct in orbit. Although some similarities could be seen with the late August λ Arietids there existed not only a marked temporal and spatial offset but further said offset represented a complete gap between this shower and the two putative new ones.

Given the past claim of the λ Arietids being an apex shower likely derived from a long period comet the assumption is taken that all three showers shared the same parent body, possibly even originally from just one apparition, that has evolved into the present triad over time. The discrete nature of the three showers, with no sharing of meteoroids when utilizing $D_J$ criterion testing upon their mean orbits, as well as the gaps in radiants and at times peak meteor periods, along with the the lack of smooth orbital continuity, suggest that if they are from a past common source subsequent orbital changes should be due to gravitational interaction with other bodies as opposed to solar radiation (whether electromagnetic or the solar wind) or precessional effects.

However, a quantitative numerical analysis of the three sets of orbits would be required to assess any validity in the assumption that one historic stream became three discrete streams.

All that can be said with some surety now is there are three discrete but nevertheless strongly similar streams in Aries from latest August to mid-September.

## Acknowledgments

The meteor survey groups and especially their volunteers and operatives are expressly thanked not only for their work but for making their data public and thus available for analytical examination by all instead of just wallowing in a private archive. The individual groups are mentioned in the body text of the article and fully referenced below.

Strangely, for the case of public domain scientific data, the Global Meteor Network (GMN) and UKMON data are released under the following licence[13].

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# The UAE Meteor Monitoring Network observations: 2018 – 2020

**Maryam E. Sharif**[1], **Ilias Fernini**[1,2], **Aisha Al-Owais**[1], **Masa Alnaser**[1],
**Yousef Eisa Yousef Doostkam**[1], **Anas Omar Adwan**[1], **Issam Abu-Jami**[1], **Hamid Al-Naimiy**[1,2]

[1] **Sharjah Academy for Astronomy, Space Sciences, and Technology,
University of Sharjah, Sharjah, POB 27272, UAE**
msharif@sharjah.ac.ae, ifernini@sharjah.ac.ae, aalowais@sharjah.ac.ae,
malnaser@sharjah.ac.ae, yeisa@sharjah.ac.ae, aadwan@sharjah.ac.ae,
ijami@sharjah.ac.ae, alnaimiy@sharjah.ac.ae

[2] **Department of Applied Physics and Astronomy, University of Sharjah, Sharjah, POB 27272, UAE**
ifernini@sharjah.ac.ae, alnaimiy@sharjah.ac.ae

The Sharjah Academy for Astronomy, Space Sciences, and Technology (SAASST) developed a unique system in the Middle East and North Africa (MENA) to observe space debris, natural ones (meteors), or artificial ones (falling rockets boosters and satellites). The UAE Meteor Monitoring Network (UAEMMN), sponsored by the UAE Space Agency and the University of Sharjah, consists of three towers spread over the UAE territory. Each tower has 17 sophisticated cameras that observe the sky from sunset to sunrise. Since the first station started to observe in September 2018 until the end of 2020, we have observed more than 30000 meteors. This report describes the UAEMMN observations in light of the single meteor observations, fireball detections, and meteor showers. We also highlight the observing conditions concerning the count of meteors for each month. This work provides substantial meteor data from the UAE, which neighboring countries can further utilize for comparative studies.

## 1 Introduction

Meteors appear in the sky of the MENA region just as they do in any other part of the world. However, unlike the United States (Bruzzone et al., 2020), Australia (Bland et al., 2012), and Europe (Asensio et al., 2021; Colas et al., 2020; Šegon et al., 2018), this region does not have enough meteor monitoring stations except for Morocco with a monitoring network (Ibhi, 2013). Thus, intending to cover part of the Gulf skies, the Sharjah Academy for Astronomy, Space Sciences, and Technology (SAASST) developed the UAE Meteor Monitoring Network (UAEMMN), a unique system in the Gulf area to observe space debris, natural ones (meteors), or artificial ones (falling rockets boosters and satellites). The UAEMMN, sponsored by the UAE Space Agency and the University of Sharjah, consists of three towers spread over the UAE territory (*Figure 1a*). Each tower has at the top 17 cameras that observe the sky from sunset to sunrise (*Figure 1b*) (Fernini et al., 2020b).

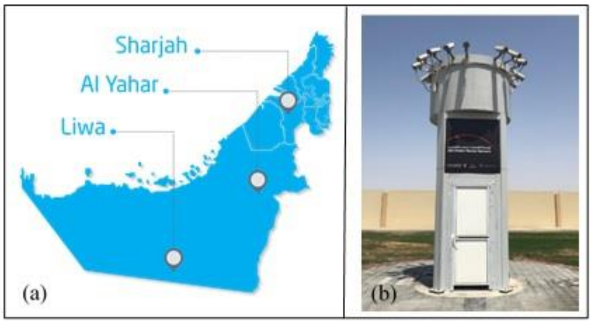

*Figure 1* – (a) The location of the UAEMMN towers. (b) The Sharjah UAEMMN tower with at its top 17 cameras to detect meteors.

The network started operating in September 2018, with its first station in Sharjah, followed by Liwa in the same month, and finally Al-Yahar in January 2019. The Sharjah tower is located within the city of Sharjah, while the Liwa and Al-Yahar towers are located in the deep desert. The UAEMMN observations reached a total of 30000 meteors as of December 2020. More than 10% of these detections were double and triple (Fernini et al., 2020a), where two or three towers observed the same meteor. These double and triple detections are important for orbit determination to pinpoint the possible falling areas of the meteorites to be then collected for analysis. In addition, the UAEMMN was able to detect a large number of fireballs. It is most likely that these fireballs were able to survive their atmospheric entrance and fall on Earth as meteorites. This report focuses on the annual statistics of the network to be used by other meteor monitoring network operators. It also includes the fireball occurrences and meteor shower observations, leaving out the double and triple detections for another study.

The UAEMMN daily observations play a role in constructing a meteor database for the UAE and the Gulf region. Moreover, they compensate for the lack of daily meteor detections and meteor science. Nevertheless, with the UAEMMN, an archive in the form of photos, videos, and statistics is stored and accessible for educational purposes.

Consequently, this article serves as a basis for future comparative studies vis-à-vis meteor activity in the Gulf sky. Therefore, establishing meteor stations in the neighboring regions is highly encouraged, as it would result in a larger meteor database for the Gulf countries.

## 2 Network annual observations

Annual statistics were carried out to observe the difference in meteor activity from one year to another, bearing in mind external factors that affect the observation. The UAEMMN recorded a total of 32839 meteors from September 2018 until December 2020. Individually, the Sharjah tower registered 5815, Al-Yahar 11647, and Liwa 15377 meteors. Among these detections, 4169 were double detections, and 389 were triple detections among these detections.

In 2018, from September to December, the Sharjah tower recorded 1237 meteors while the Liwa tower detected 3456 meteors, resulting in a total of 4693 meteors. December 2018 was the most prolific month for both towers due to the Geminid meteor shower, with 679 and 1928 meteors observed by Sharjah and Liwa. *Section 4* details the number of meteors observed during the peak days. It can be seen that the location of the tower plays a significant role in increasing the number of detections. The farther the tower is from the city, the better its detections are.

In January 2019, the Al-Yahar tower came into service. Because both Liwa and Al-Yahar towers have similar desertic locations, they seemed to be competing in terms of the number of meteors detected. For 2019, Al-Yahar observed 6493 meteors, Liwa 6273, and Sharjah detected 2245 meteors. This resulted in the detection of 15011 meteors, including double and triple detections. Like 2018, the most prolific month for Sharjah and Al-Yahar was December, with 440 and 1233 meteors detected, respectively. Liwa detected the highest number of meteors during January, about 1066 meteors. Due to a power failure in December 2019, the Liwa tower missed the Geminid peak dates and several days of the month.

The year 2020 witnessed a reduction in the total number of meteor detections as the Liwa and Al-Yahar towers went off mid-year and were not accessed efficiently because of the travel restrictions due to the COVID-19 pandemic. The Sharjah tower captured 2333 meteors, almost the same as in 2019, while Al-Yahar had 5154 meteors, about 1000 less than in 2019. Liwa detected 5648 meteors, about 600 less than what it detected in 2019. In total, the network observed 13135 meteors in 2020. The Sharjah and Al-Yahar towers shared the most active month in October due to the Orionid meteor shower. However, Liwa observed most meteors in November due to the Leonid shower.

Overall, it is noticed that the most active months differ from one year to another and from one tower to another, depending on the activity of the meteor showers and the weather conditions, and the out-of-service times due to technical problems. *Figure 2* shows the total counts per tower for each year, and *Figure 3* shows the annual number of meteors per month and tower.

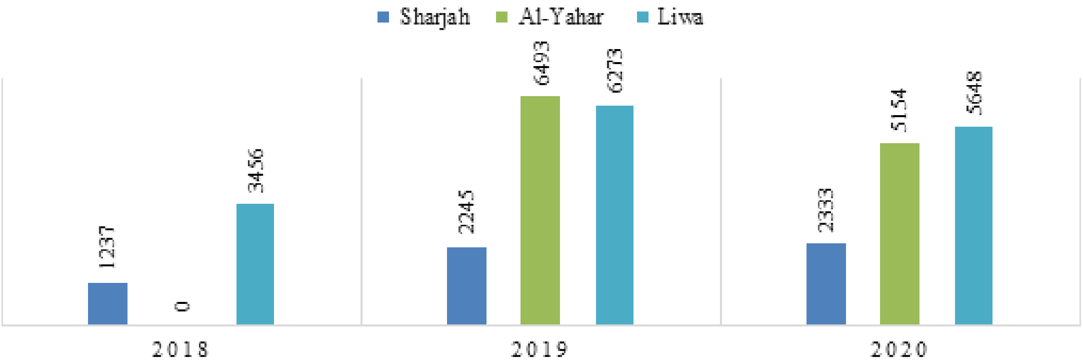

*Figure 2* – Total annual meteor counts per tower.

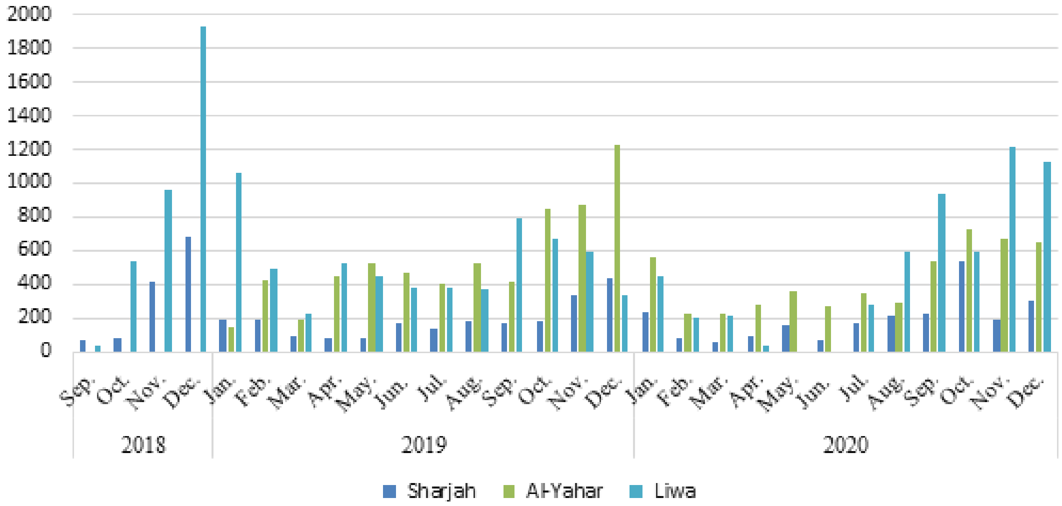

*Figure 3* – Network statistics September 2018 to December 2020, the number of observed meteors per month.

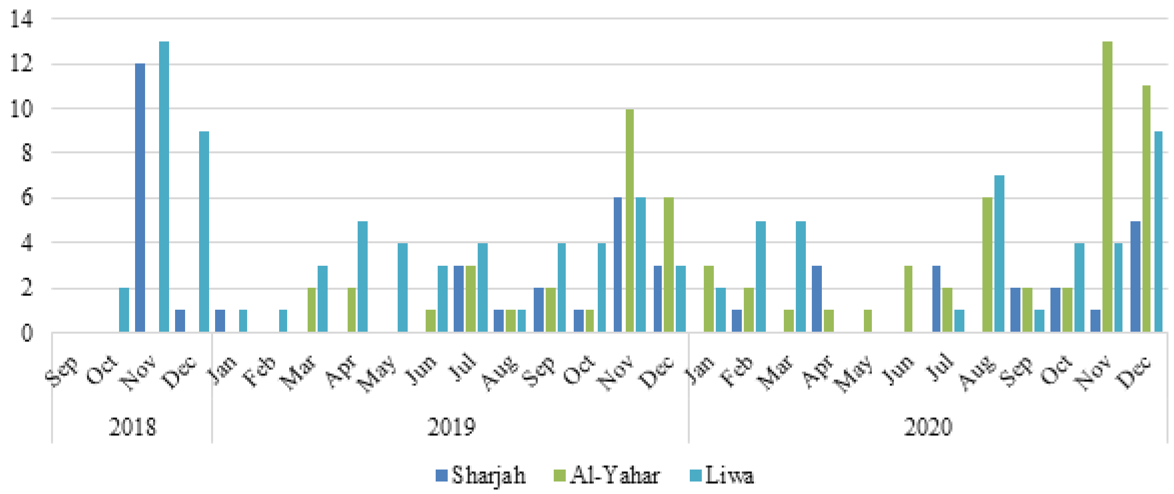

*Figure 4* – Fireball counts from September 2018 to December 2020.

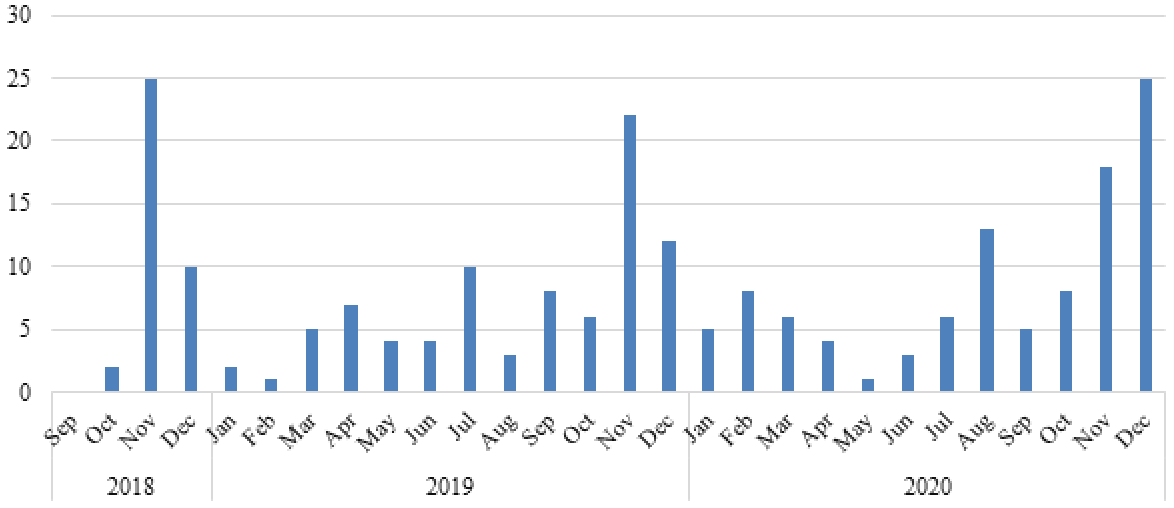

*Figure 5* – Fireball occurrences pattern.

Meteor observations are affected by several factors such as the station location (urban or non-urban), the weather conditions, and the Moon phase. The Liwa and Al-Yahar towers always show high detection due to their desert locations, far from any city lights. Of course, cloudy skies affect detections significantly and limit the number of observed meteors. Regarding the Moon effect, if the peak days of a meteor shower coincide with a full-Moon phase, then the number of meteors detected will dramatically fall because of the Moon's illumination. *Tables 2–4* show the effect of the mentioned factors on the number of meteor detections. The tables also list the meteor count per month and year.

## 3 Network fireballs

Although definitions of a fireball could be quite various, we have set –4 as a threshold in terms of magnitude. Therefore, a meteor with an apparent magnitude of –4 or less will be reported as a fireball. During the whole period of the study (Sep. 2018 – Dec. 2020), we registered 223 fireballs. *Figure 4* is a histogram showing the fireball detections per year and tower. For example, in 2018, the Sharjah and Liwa towers observed 13 and 24 fireballs. In 2019, the number of fireballs was 17, 28, and 39 for Sharjah, Al-Yahar, and Liwa, respectively.

Interestingly, in 2020, the total number of fireball observations remained almost the same in Sharjah and Liwa (17 and 38, respectively), while Al-Yahar scored the highest number of detections, reaching 47 fireballs. To observe the pattern of the detected fireballs, *Figure 5* demonstrates the fireball occurrence in the studied period, where each month represents the total number of fireballs observed by all towers. The number of fireballs tends to increase towards the year's end and gradually drops afterward (Sharif et al., 2021). This can be related to the meteor showers' peak, as explained in the following section.

## 4 Meteor shower observations

The best-known meteor showers and their respective rate for 2018, 2019, and 2020 are listed in *Table 1*. The table reports the total number of meteors and the average number of meteors. The average per day (5), (7), and (9) is calculated using equation (1), where a total number of

*Table 1* – UAEMMN observation of the best-known meteor showers. (1) represents the shower name; (2) represents the activity period of each shower; (3) represents the approximate number of night hours in each month; (4), (6), and (8) represent the total number of meteors of each shower in each year; (5), (7), and (9) represent the average number of meteors of each shower per day; (10) represents the average number of meteors per day of the three years; (11) represents the rate of meteors per hour in each shower.

| Shower Name (1) | Activity Period (2) | Approx. night hours (3) | 2018 | | 2019 | | 2020 | | Total Avg. (10) | Rate (11) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total (4) | Avg. (5) | Total (6) | Avg. (7) | Total (8) | Avg. (9) | | |
| Quadrantids | Jan. 01–05 | 10 | - | - | 22 | 5.5 | 12 | 2.4 | 3.95 | 0.40 |
| Lyrids | April 20–24 | 8 | - | - | 38 | 7.6 | 11 | 2.75 | 5.18 | 0.65 |
| η Aquariids | May 01–10 | 7 | - | - | 25 | 2.78 | 11 | 1.375 | 2.08 | 0.30 |
| δ Aquariids | July 26–31 | 7 | - | - | 9 | 1.5 | 29 | 4.83 | 3.17 | 0.45 |
| Perseids | Aug. 10–16 | 8 | - | - | 13 | 2.17 | 103 | 17.17 | 9.67 | 1.21 |
| Orionids | Oct. 17–27 | 10 | 20 | 5 | 42 | 7 | 105 | 9.55 | 7.18 | 0.72 |
| Southern Taurids | Nov. 01–07 | 10 | 26 | 3.25 | 5 | 0.71 | 16 | 2.29 | 2.08 | 0.21 |
| Northern Taurids | Nov. 09–15 | 10 | 42 | 8.4 | 26 | 5.2 | 26 | 3.71 | 5.77 | 0.58 |
| Leonids | Nov. 13–20 | 10 | 43 | 6.14 | 12 | 2 | 74 | 9.25 | 5.80 | 0.58 |
| Geminids | Dec. 12–17 | 11 | 297 | 49.5 | 53 | 10.6 | 118 | 29.5 | 29.87 | 2.72 |
| Ursids | Dec. 19–23 | 11 | 11 | 2.75 | 5 | 1.25 | 6 | 1.2 | 1.73 | 0.16 |

*Table 2* – UAEMMN meteor observations in 2018 per month and tower. (1) The major meteor showers for each month are listed with the peak (P) shower date. (2) The Full Moon date for each month; (3) The approximate number of cloudy nights per month; and (4) The meteor observations.

| Month | Meteor showers (1) | Full Moon (2) | Number of cloudy nights (3) | Meteors per tower (4) | | Total meteors |
|---|---|---|---|---|---|---|
| | | | | Sharjah | Liwa | |
| Sep. | Aurigids (P01Sep), ε Perseids (P09Sep) | 25 Sep | 8 | 66 | 38 | 104 |
| Oct. | Orionids (P20Oct), Southern Taurids (P10Oct), δ Aurigids (P11Oct), Draconids (P09Oct), ε Geminids (P19Oct), Leonids Minorids (P25Oct), Oct Camelopardalids (P06Oct) | 24 Oct | 7 | 77 | 534 | 611 |
| Nov. | Northern Taurids (P13Nov), Leonids (P18Nov), α Monocerotids (P22Nov), Andromedids (P09Nov), Nov Orionids (P28Nov) | 23 Nov | 5 | 415 | 956 | 1371 |
| Dec. | Geminids (P14Dec), Ursids (P23Dec), Comae Berenicids (P16Dec), Dec Leonis Minorids (P20Dec), Monocerotids (P09Dec), Phoenicids (P02Dec), σ Hydrids (P12Dec) | 22 Dec | 7 | 679 | 1928 | 2607 |
| Total | | | 27 | 1237 | 3456 | 4693 |

meteors has to be selected from one of the years (for example, either column (4), (6), or (8)) and divided by the number of days in a given period. It is important to note that because the number of peak days varies from one year to another, we considered the widest date range, which covered the peaks day throughout all years. For example, in January 2019, according to the observations by the UAEMMN, there were four peak days. However, in 2020, the number of peak days was five. Therefore, in 2019, the total number of meteors (22) was divided by four, while it was divided by five in the following year. The same idea applies to the rest of the data. Another example would be the Geminids. Its peak days were 6, 5, and 4 in 2018, 2019, and 2020. The average columns reflect the results (5), (7), and (9). Finally, the total average (10) and rate (11) are calculated using equations (2) and (3), respectively.

$$Average\ per\ day = \frac{\text{Total (4) or (6) or (8)}}{\text{Activity period (2)}} \qquad (1)$$

$$Total\ Average = \frac{Avg\,.(5) + Avg.(7) + Avg.(9)}{3} \qquad (2)$$

$$Rate = \frac{Total\ Average\ (10)}{Approximate\ night\ hours\ (3)} \qquad (3)$$

*Table 3* – UAEMMN meteor observations in 2019 per month and tower. (1) The major meteor showers for each month are listed with the peak (P) shower date. (2) The Full Moon date for each month; (3) The approximate number of cloudy nights per month; and (4) The meteor observations.

| Month | Meteor showers (1) | Full Moon (2) | Number of cloudy nights (3) | Meteors per tower (4) | | | Total meteors |
|---|---|---|---|---|---|---|---|
| | | | | Sharjah | Al-Yahar | Liwa | |
| Jan. | Quadrantids (P04Jan), γ Ursae Minorids (P18Jan), | 21 Jan | 1 | 195 | 142 | 1066 | 1403 |
| Feb. | α Centaurids (P08Feb) | 19 Feb | 2 | 193 | 421 | 495 | 1109 |
| Mar. | γ Normids (P15Mar) | 21 Mar | 6 | 93 | 194 | 225 | 512 |
| Apr. | Lyrids (P23Apr), π Puppids (P24Apr) | 19 Apr | 13 | 78 | 445 | 530 | 1053 |
| May | η Aquariids (P06May), η Lyrids (P09May) | 19 May | 1 | 80 | 524 | 444 | 1048 |
| Jun. | Daytime Arietids (P08Jun), Bootids (P27Jun), τ Herculids (P09Jun) | 17 Jun | 1 | 166 | 467 | 377 | 1010 |
| Jul. | δ Aquariids (P30Jul), α Capricornids (P30Jul), Piscis Austrinids (P28Jul) | 17 Jul | 2 | 134 | 404 | 381 | 919 |
| Aug. | Perseids (P13Aug), κ Cygnids (P18Aug) | 15 Aug | 8 | 179 | 524 | 372 | 1075 |
| Sep. | Aurigids (P01Sep), ε Perseids (P09Sep) | 14 Sep | 11 | 168 | 410 | 788 | 1366 |
| Oct. | Orionids (P20Oct), Southern Taurids (P10Oct), δ Aurigids (P11Oct), Draconids (P09Oct), ε Geminids (P19Oct), Leonids Minorids (P25Oct), Oct Camelopardalids (P06Oct) | 14 Oct | 5 | 177 | 854 | 667 | 1698 |
| Nov. | Northern Taurids (P13Nov), Leonids (P18Nov), α Monocerotids (P22Nov), Andromedids (P09Nov), Nov Orionids (P28Nov) | 12 Nov | 8 | 342 | 875 | 596 | 1813 |
| Dec. | Geminids (P14Dec), Ursids (P23Dec), Comae Berenicids (P16Dec), Dec Leonis Minorids (P20Dec), Monocerotids (P09Dec), Phoenicids (P02Dec), σ Hydrids (P12Dec) | 12 Dec | 12 | 440 | 1233 | 332 | 2005 |
| Total | | | 70 | 2245 | 6493 | 6273 | 15011 |

## 5 Discussion

Our UAEMMN observations of meteors and fireballs over slightly more than two years revealed important information regarding the observing conditions and the best meteor showers observed from the UAE. When comparing the yearly observations, 2019 was the most prolific year across all towers, with a total of 15011 meteors.

When investigating the weather conditions, it turned out that the year 2020 was the most affected one, which eventually resulted in a relatively lower number of observations compared to 2019. Coming to the location of the Sharjah tower, which is in a highly light-polluted area, the number of counts was lower than the other towers across all years. Moreover, the Al-Yahar tower was often disturbed by the light coming from neighboring constructions throughout the year, affecting the observation results. This leaves us with Liwa, which also had several outages due to electricity cuts during the years.

Although 2020 did not have the highest detection of meteors, it surprisingly scored the highest number of fireballs. The observations in 2019, especially in December due to the Geminid meteor shower, were disturbed by the cloudy skies and the Moon phase. The tower with the greatest number of fireball detection was Liwa. Moreover, since the months having major meteor showers usually score the highest number of meteor counts, they also had the highest number of fireballs. These two months are November and December, corresponding to the Leonid and Geminid meteor showers.

## 6 Conclusion

The UAEMMN, with its three towers, acts as an essential meteor station in the Gulf region as it keeps a record of space debris crossing the UAE sky. Moreover, it plays a significant role in the space situational awareness program since it can observe artificial debris, i.e., falling rockets boosters and break away satellites, increasing our awareness of these threats in addition to the meteors.

There is a plan to add more towers to the network to increase the number of double and triple detections. This addition of towers will be primordial to determine the meteorites' possible landing area using orbit determination methods.

*Table 4* – UAEMMN meteor observations in 2020 per month and tower. (1) The major meteor showers for each month are listed with the peak (P) shower date. (2) The Full Moon date for each month; (3) The approximate number of cloudy nights per month; and (4) The meteor observations.

| Month | Meteor showers (1) | Full Moon (2) | Number of cloudy nights (3) | Meteors per tower (4) | | | Total meteors |
|---|---|---|---|---|---|---|---|
| | | | | Sharjah | Al-Yahar | Liwa | |
| Jan. | Quadrantids (P04Jan), g Ursae Minorids (P19Jan), | 10 Jan | 13 | 238 | 555 | 445 | 1238 |
| Feb. | a Centaurids (P08Feb) | 9 Feb | 10 | 78 | 227 | 206 | 511 |
| Mar. | g Normids (P14Mar) | 9 Mar | 13 | 62 | 226 | 209 | 497 |
| Apr. | Lyrids (P22Apr), π Puppids (P23Apr) | 7 Apr | 9 | 89 | 279 | 41 | 409 |
| May | h Aquariids (P05May), h Lyrids (P08May) | 7 May | 7 | 154 | 361 | - | 515 |
| Jun. | Daytime Arietids (P07Jun), Bootids (P27Jun) | 5 June | 4 | 73 | 275 | - | 348 |
| Jul. | δ Aquariids (P29Jul), α Capricornids (P29Jul), Piscis Austrinids (P27Jul) | 5 Jul | 5 | 168 | 350 | 281 | 799 |
| Aug. | Perseids (P12Aug), κ Cygnids (P17Aug), Aurigids (P31Aug) | 3 Aug | 9 | 211 | 291 | 592 | 1094 |
| Sep. | ε Perseids (P09Sep), Daytime Sextantids (P27Sep) | 2 Sep | 3 | 229 | 535 | 941 | 1705 |
| Oct. | Orionids (P21Oct), Southern Taurids (P10Oct), d Aurigids (P11Oct), Draconids (P08Oct), ε Geminids (P18Oct), Leonids Minorids (P24Oct), Oct Camelopardalids (P05Oct) | 1 Oct<br>31 Oct | 1 | 539 | 732 | 595 | 1866 |
| Nov. | Northern Taurids (P12Nov), Leonids (P17Nov), a Monocerotids (P21Nov), Nov Orionids (P28Nov) | 30 Nov | 6 | 188 | 671 | 1213 | 2072 |
| Dec. | Geminids (P14Dec), Ursids (P22Dec), Comae Berenicids (P16Dec), Dec Leonis Minorids (P19Dec), Monocerotids (P09Dec), Phoenicids (P02Dec), s Hydrids (P09Dec), Puppid-Velids (P07Dec) | 29 Dec | 8 | 304 | 652 | 1125 | 2081 |
| Total | | | 88 | 2333 | 5154 | 5648 | 13135 |

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# The Southwestern Europe Meteor Network: remarkable bolides recorded from March to May 2022

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

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

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

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

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

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

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

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

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

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

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

Some of the remarkable bolides spotted in the framework of the Southwestern Europe Meteor Network from March to May 2022 are described here. These have been observed from the Iberian Peninsula. Their absolute magnitude ranges from –8 to –15. The emission spectrum of one of them is also analyzed. Bright meteors included in this report were linked to different sources: the sporadic background, major meteoroid streams, and poorly-known streams.

## 1 Introduction

Our team is performing since 2006 a systematic monitoring of meteor activity in the framework of the SMART project (Spectroscopy of Meteoroids by means of Robotic Technologies), which started operation in 2006 to obtain new clues about the properties of meteoroids that penetrate our planet's atmosphere (Madiedo, 2014; Madiedo, 2017). This includes chemical data derived from the emission spectra of meteors generated by these particles of interplanetary matter. This survey is being conducted in the framework of the Southwestern Europe Meteor Network (SWEMN) and employs an array of automated spectrographs deployed at a series of meteor-observing stations in Spain. In this way we can derive the atmospheric path of meteors and the orbit of the meteoroids that generate them, but also study the evolution of the conditions in meteor plasmas from the emission spectrum produced by these events (Madiedo, 2017). Besides SMART provides key data for our MIDAS project, which is being conducted at the Institute of Astrophysics of Andalusia (IAA-CSIC) to study lunar impact flashes produced when large meteoroids collide with the Moon's surface (Madiedo et al., 2015a,b; Ortiz et al., 2015).

In this report we focus on the preliminary analysis of seven fireballs recorded by the SWEMN network. The emission spectrum of one of them is also described. This work has been fully written by AIMIE (acronym for Artificial Intelligence with Meteoroid Environment Expertise) from the records included in the SWEMN fireball database (Madiedo et al., 2021; Madiedo et al., 2022).

## 2 Equipment and methods

The events analyzed here have been recorded by employing Watec 902H2 and Watec 902 Ultimate cameras. Their field of view ranges from 62 × 50 degrees to 14 × 11 degrees. To record meteor spectra we have attached holographic diffraction gratings (1000 lines/mm) to the lens of some of these cameras. we have also employed digital CMOS color cameras (models Sony A7S and A7SII) operating in HD video mode (1920 × 1080 pixels). These cover a field of view of around 70 × 40 degrees. A detailed description of this hardware and the way it operates was given in previous works (Madiedo, 2017). Besides digital CMOS cameras manufactured by ZWO, model ASI185MC were used. The atmospheric paths of the events were triangulated by employing the SAMIA software, developed by J. M. Madiedo. This program employs the planes-intersection method (Ceplecha, 1987). The emission spectrum was analyzed with the CHIMET software (Madiedo, 2014).

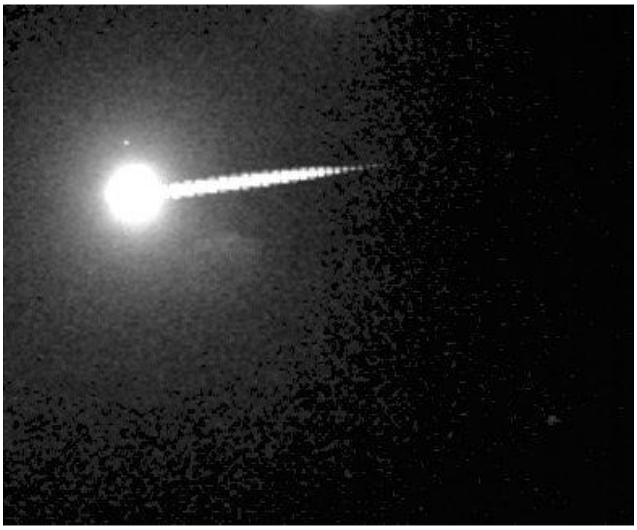

*Figure 1* – Stacked image of the SWEMN20220309_030144 fireball as recorded from La Hita.

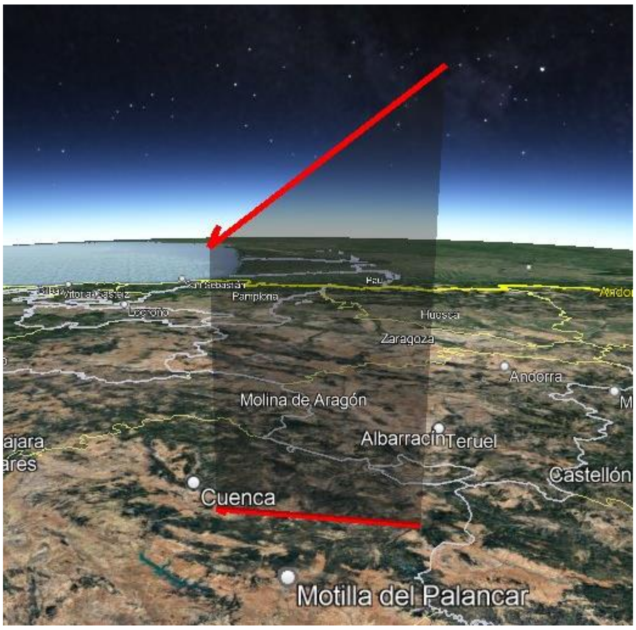

*Figure 2* – Atmospheric path and projection on the ground of the SWEMN20220309_030144 fireball.

## 3 The 2022 March 9 meteor

This striking event was recorded on 2022 March 9, at $3^h01^m44.0 \pm 0.1^s$ UT (*Figure 1*). The fireball, that displayed a bright flare at the terminal stage of its trajectory in the atmosphere, it had a peak absolute magnitude of –11.0 ± 0.5. This flare occurred as a consequence of the sudden disruption of the meteoroid. It was listed in the SWEMN meteor database with the code SWEMN20220309_030144. A video about this fireball can be viewed on YouTube[14].

### Atmospheric trajectory, radiant and orbit

It was obtained from the calculation of the path in the atmosphere of the event that the bright meteor overflew the province of Cuenca (Spain). Its initial altitude was $H_b = 121.9 \pm 0.5$ km. The bolide penetrated the atmosphere till a final height $H_e = 76.6 \pm 0.5$ km. The equatorial coordinates of the apparent radiant yield $\alpha = 259.89°$, $\delta = +11.25°$. Besides, we inferred that the meteoroid hit the atmosphere with a velocity $v_\infty = 64.0 \pm 0.3$ km/s. The trajectory in our atmosphere of the event is shown in *Figure 2*. *Figure 3* shows the orbit in the Solar System of the meteoroid.

*Table 1* – Orbital data (J2000) of the progenitor meteoroid of the SWEMN20220309_030144 fireball before its encounter with our planet.

| | | | |
|---|---|---|---|
| $a$ (AU) | 13.3 ± 4.6 | $\omega$ (º) | 179.75 ± 00.03 |
| $e$ | 0.92 ± 0.02 | Ω (º) | 348.216394 ± 10-5 |
| $q$ (AU) | 0.99277 ± 0.0 | $i$ (º) | 122.0 ± 0.1 |

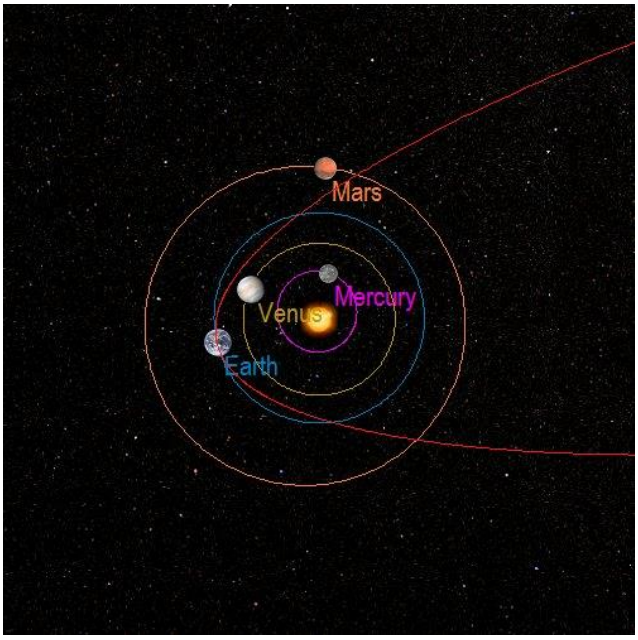

*Figure 3* – Projection on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20220309_030144 event.

The name given to the event was “Villar del Saz de Arcas”, since the fireball overflew this locality in the province of Cuenca during its final phase. The parameters of the

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[14] https://youtu.be/MPmthzpUWDw

heliocentric orbit of the parent meteoroid before its encounter with our planet have been listed in *Table 1*. The geocentric velocity of the meteoroid was $v_g = 62.8 \pm 0.3$ km/s. From the value estimated for the Tisserand parameter with respect to Jupiter ($T_J = –0.25$), we found that the meteoroid followed a cometary (Halley-type, HTC) orbit before hitting the Earth's atmosphere. These values and the calculated radiant confirm the sporadic nature of the bolide.

## 4 Description of the 2022 April 26 bolide

This bright fireball was spotted by SWEMN cameras at $1^h39^m03.0 \pm 0.1^s$ UT on 2022 April 26 (*Figure 4*). The peak luminosity of the bright meteor was equivalent to an absolute magnitude of –8.0 ± 0.5. The code given to the event in the SWEMN meteor database is SWEMN20220426_013903. A video containing images of the bolide and its trajectory in the atmosphere was uploaded to YouTube[15].

*Figure 4* – Stacked image of the SWEMN20220426_013903 bolide as recorded from Sevilla.

*Figure 5* – Atmospheric path and projection on the ground of the SWEMN20220426_013903 event.

### Atmospheric path, radiant and orbit

By analyzing the trajectory in the atmosphere of the event it was inferred that the bright meteor overflew the province of Huelva (southwest of Spain). The luminous event began at an altitude $H_b = 86.3 \pm 0.5$ km. The bolide penetrated the atmosphere till a final height $H_e = 50.5 \pm 0.5$ km. From the analysis of the atmospheric path, we also inferred that the apparent radiant was located at the position $\alpha = 201.36^o$, $\delta = –11.80^o$. The entry velocity in the atmosphere obtained for the parent meteoroid was $v_\infty = 20.8 \pm 0.5$ km/s. The trajectory in our atmosphere of the bright meteor is shown in *Figure 5*. The heliocentric orbit of the meteoroid is drawn in *Figure 6*.

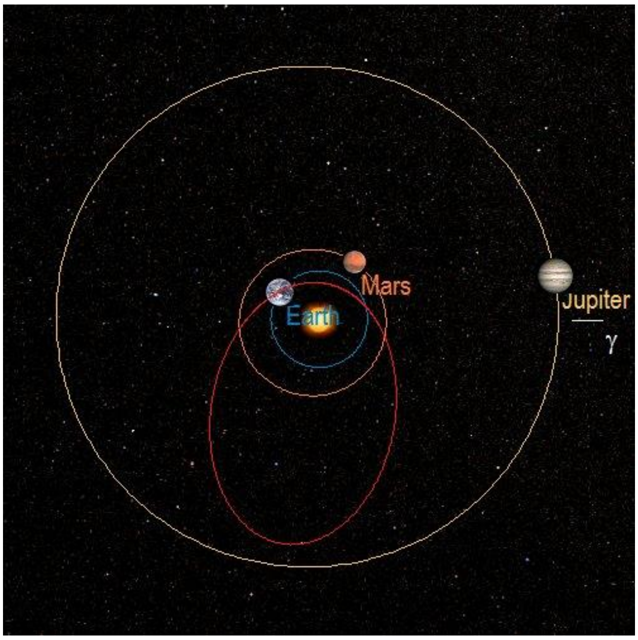

*Figure 6* – Projection on the ecliptic plane of the orbit of the of the progenitor meteoroid of the SWEMN20220426_013903 meteor.

This fireball was named "Nerva", because the event was located near the zenith of this locality during its final phase. The orbital parameters of the progenitor meteoroid before its encounter with our planet have been listed in *Table 2*. The geocentric velocity of the meteoroid was $v_g = 17.9 \pm 0.6$ km/s. The value estimated for the Tisserand parameter with respect to Jupiter ($T_J = 2.90$) suggests that the particle was moving on a cometary (JFC) orbit before entering our planet's atmosphere. By taking into account this orbit and the radiant position, the event was produced by the h Virginids (IAU shower code HVI#0343) (Jenniskens et al., 2016).

*Table 2* – Orbital data (J2000) of the progenitor meteoroid of the SWEMN20220426_013903 event before its encounter with our planet.

| | | | |
|---|---|---|---|
| $a$ (AU) | 2.7 ± 0.2 | $\omega$ (°) | 63.7 ± 00.2 |
| $e$ | 0.71 ± 0.02 | $\Omega$ (°) | 215.539582 ± 10-5 |
| $q$ (AU) | 0.771 ± 0.006 | $i$ (°) | 4.39 ± 0.03 |

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[15] https://youtu.be/mgtwL6LHwfs

## 5 Analysis of the 2022 May 7 fireball

On 2022 May 7, at $4^h09^m01.0 \pm 0.1^s$ UT, our meteor stations recorded this bright event (*Figure 7*). Its maximum luminosity was equivalent to an absolute magnitude of –10.0 ± 1.0. It displayed a bright flare at the final phase of its atmospheric trajectory as a consequence of the sudden disruption of the meteoroid. It was listed in the SWEMN meteor database with the code SWEMN20220507_040901. The bright meteor can be viewed on this YouTube video[16].

*Figure 7* – Stacked image of the SWEMN20220507_040901 fireball as recorded from La Hita.

### Atmospheric path, radiant and orbit

We concluded as a result of the analysis of the luminous path of the event that the fireball overflew the province of Cuenca (Spain). The ablation process of the meteoroid began at a height $H_b = 108.0 \pm 0.5$ km, with the terminal point of the luminous phase located at a height $H_e = 74.2 \pm 0.5$ km. The position inferred for the apparent radiant correspond to the equatorial coordinates $\alpha = 247.02°$, $\delta = –3.27°$. The entry velocity in the atmosphere found for the parent meteoroid was $v_\infty = 38.5 \pm 0.4$ km/s. The path in the atmosphere of the bright meteor is shown in *Figure 8*. The heliocentric orbit of the parent meteoroid is drawn in *Figure 9*.

The event was named "Algarra", because the bolide overflew this locality during its final phase. The parameters of the heliocentric orbit of the parent meteoroid before its encounter with our planet have been listed in *Table 3*. The geocentric velocity obtained for the particle yields $v_g = 37.1 \pm 0.4$ km/s. The Tisserand parameter referred to Jupiter ($T_J = 1.64$) suggests that before impacting the atmosphere the particle was moving on a cometary (HTC) orbit. According to these parameters and the calculated radiant, this bright meteor was generated by the sporadic component.

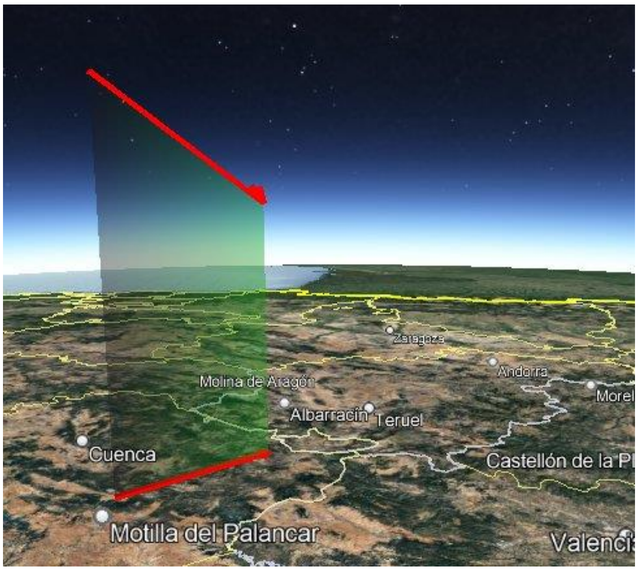

*Figure 8* – Atmospheric path and projection on the ground of the SWEMN20220507_040901 event.

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

| | | | |
|---|---|---|---|
| $a$ (AU) | 4.7 ± 0.5 | $\omega$ (°) | 300.2 ± 00.1 |
| $e$ | 0.943 ± 0.007 | Ω (°) | 46.292749 ± 10-5 |
| $q$ (AU) | 0.272 ± 0.002 | $i$ (°) | 30.3 ± 0.4 |

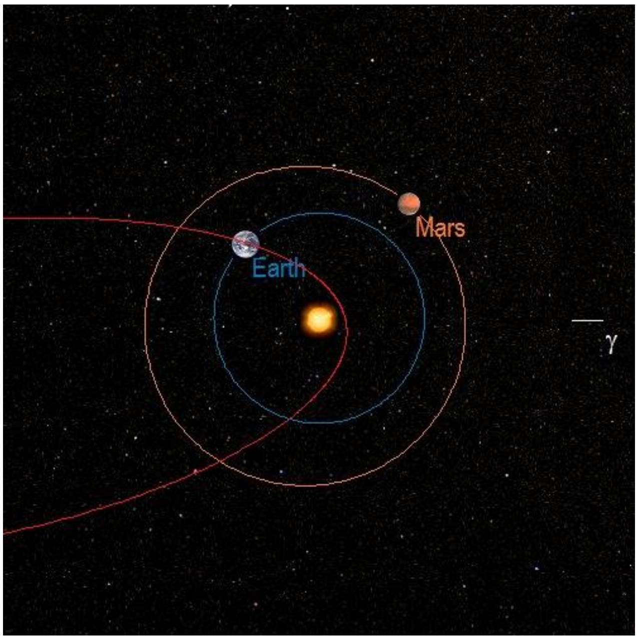

*Figure 9* – Projection on the ecliptic plane of the orbit of the SWEMN20220507_040901 event.

## 6 Description of the 2022 May 8 event

We captured this bright event from the meteor-observing stations located at La Hita, El Guijo, and Coruña. The bolide was spotted on 2022 May 8, at $4^h18^m40.0 \pm 0.1^s$ UT. The peak luminosity the fireball was equivalent to an

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[16] https://youtu.be/8OH15MBYKwA

absolute magnitude of –9.0 ± 0.5. It was listed in the SWEMN meteor database with the code SWEMN20220508_041840. A video about this fireball can be viewed on YouTube[17]. The bolide is shown in *Figure 10*.

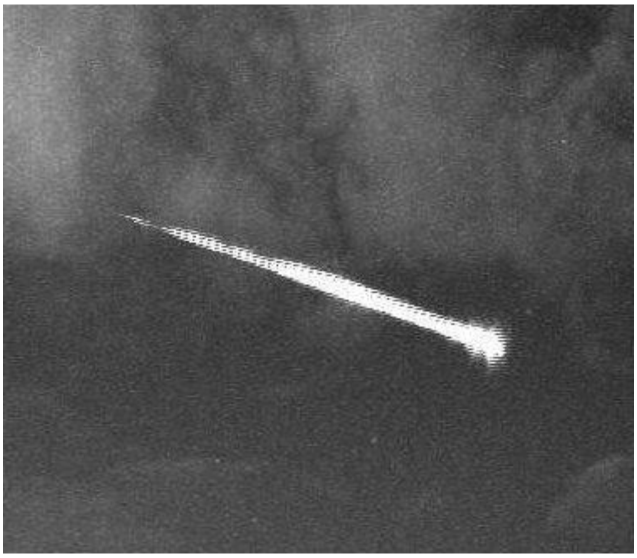

*Figure 10* – Stacked image of the SWEMN20220508_041840 meteor as recorded from Coruña.

### Atmospheric path, radiant and orbit

The fireball overflew the Atlantic Ocean. The ablation process of the meteoroid began at a height $H_b = 114.9 \pm 0.5$ km, with the terminal point of the luminous phase located at a height $H_e = 85.3 \pm 0.5$ km. The apparent radiant was located at the equatorial coordinates $\alpha = 338.90°$, $\delta = +0.39°$. The meteoroid collided with the atmosphere with an initial velocity $v_\infty = 66.7 \pm 0.4$ km/s. The atmospheric trajectory of the event is shown in *Figure 11*.

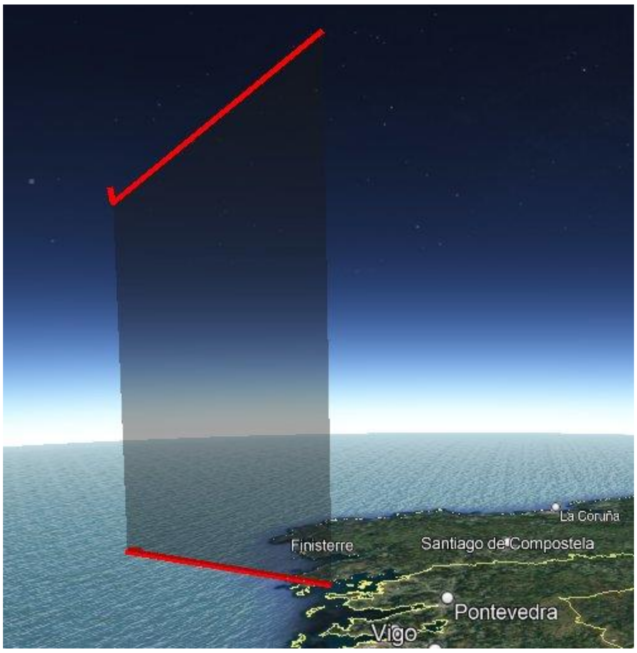

*Figure 11* – Atmospheric path and projection on the ground of the SWEMN20220508_041840 meteor.

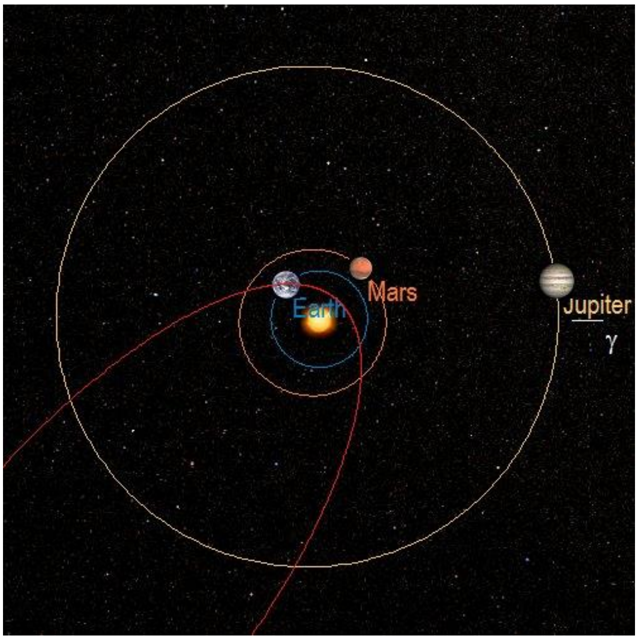

*Figure 12* – Projection on the ecliptic plane of the orbit of the SWEMN20220508_041840 event.

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

| | | | |
|---|---|---|---|
| $a$ (AU) | 8.9 ± 2.8 | $\omega$ (°) | 97.8 ± 01.4 |
| $e$ | 0.93 ± 0.01 | Ω (°) | 47.277521 ± 10-5 |
| $q$ (AU) | 0.587 ± 0.007 | $i$ (°) | 162.81 ± 0.08 |

The heliocentric orbit of the meteoroid is drawn in *Figure 12*. The parameters of this orbit are contained in *Table 4*. The geocentric velocity of the meteoroid was $v_g = 65.5 \pm 0.4$ km/s. The value found for the Tisserand parameter referred to Jupiter ($T_J = -0.31$) indicates that the particle followed a cometary (HTC) orbit before impacting our atmosphere. By considering this orbit and the radiant position, the bolide was associated with the η-Aquariids (IAU code ETA#0031). The proposed parent body of this shower is Comet 1P/Halley (Jenniskens et al., 2016.).

## 7 The 2022 May 15 bolide

On 2022 May 15, at $4^h08^m06.0 \pm 0.1^s$ UT, SWEMN cameras spotted this striking fireball. It had a peak absolute magnitude of –11.0 ± 0.0 (*Figure 13*). The code given to the bolide in the SWEMN meteor database is SWEMN20220515_040806. The bright meteor can be viewed on YouTube[18].

### Atmospheric path, radiant and orbit

The event overflew the provinces of Córdoba and Granada (south of Spain). It began at an altitude $H_b = 127.8 \pm 0.5$ km, and the terminal point of the luminous path was located at a height $H_e = 82.0 \pm 0.5$ km. The equatorial coordinates of the apparent radiant yield $\alpha = 334.69°$, $\delta = -8.36°$. The meteoroid stroke the atmosphere with an initial velocity $v_\infty = 71.2 \pm 0.3$ km/s. The luminous path of this bright meteor is shown in

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[17] https://youtu.be/SN8EGfxS_HE

[18] https://youtu.be/BaDZ7_un0fk

*Figure 14*. *Figure 15* shows the orbit in the Solar System of the meteoroid.

*Figure 13* – Stacked image of the SWEMN20220515_040806 event as recorded from Sierra Nevada.

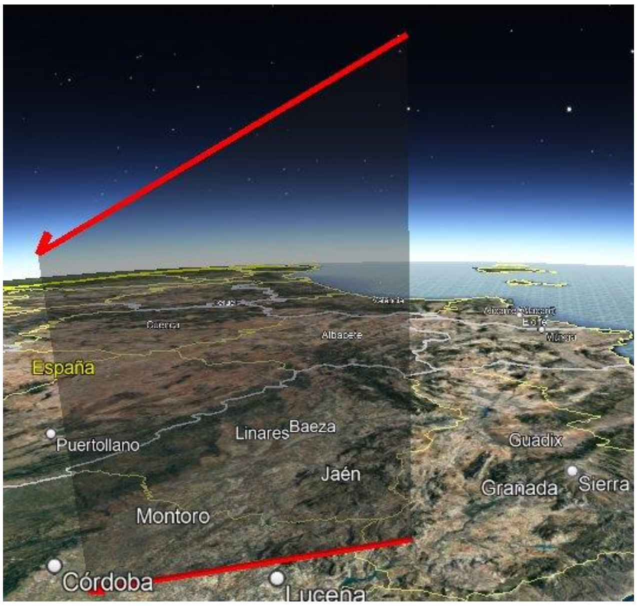

*Figure 14* – Atmospheric path and projection on the ground of the SWEMN20220515_040806 fireball.

The parameters of the orbit of the progenitor meteoroid before its encounter with our planet can be found in *Table 5*. The geocentric velocity of the meteoroid was $v_g = 70.1 \pm 0.3$ km/s. The value found for the Tisserand parameter with respect to Jupiter ($T_J = -0.90$) shows that the meteoroid followed a cometary (HTC) orbit before hitting the atmosphere. These values and the derived radiant confirm the sporadic nature of the fireball.

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

| | | | |
|---|---|---|---|
| $a$ (AU) | 18.6 ± 9.7 | $\omega$ (°) | 147.0 ± 00.8 |
| $e$ | 0.95 ± 0.02 | $\Omega$ (°) | 54.072283 ± 10-5 |
| $q$ (AU) | 0.931 ± 0.003 | $i$ (°) | 177.0 ± 0.1 |

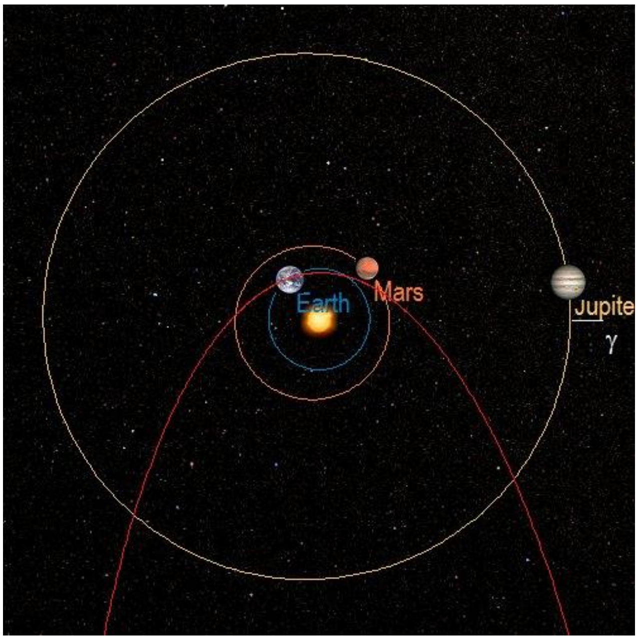

*Figure 15* – Projection on the ecliptic plane of the orbit of the SWEMN20220515_040806 fireball.

## 8 The 2022 May 19 fireball

This bolide was captured by SWEMN meteor stations at $2^h00^m02.0 \pm 0.1^s$ UT on 2022 May 19 (*Figure 16*). The maximum brightness of this bright meteor, that displayed a bright flare at the ending phase of its trajectory in our atmosphere, was equivalent to an absolute magnitude of –10.0 ± 0.0. This flare took place as a consequence of the sudden disruption of the meteoroid. The code assigned to the bolide in the SWEMN meteor database is SWEMN20220519_020002.

*Figure 16* – Stacked image of the SWEMN20220519_020002 event as recorded from Olocau.

## Atmospheric path, radiant and orbit

The fireball overflew the region of Murcia (southeast of Spain). The luminous event began at an altitude $H_b$ = 123.1 ± 0.5 km. It penetrated the atmosphere till a final height $H_e$ = 85.8 ± 0.5 km. The equatorial coordinates obtained for the apparent radiant are $\alpha$ = 310.57º, $\delta$ = +16.95º. Besides, we inferred that the meteoroid collided with the atmosphere with a velocity $v_\infty$ =63.1 ± 0.0 km/s. The trajectory in the Earth's atmosphere of the bolide is shown in *Figure 17*.

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

| | | | |
|---|---|---|---|
| $a$ (AU) | 16.15325 ± 0.0 | $\omega$ (º) | 203.96585 ± 00.0 |
| $e$ | 0.93999 ± 0.0 | Ω (º) | 57.796443 ± 10-5 |
| $q$ (AU) | 0.96937 ± 0.0 | $i$ (º) | 121.81741 ± 0.0 |

The orbit in the Solar System of the progenitor meteoroid is shown in *Figure 18*. We named this fireball "Los Zancarrones", because the bright meteor was located over this locality during its initial phase. The parameters of the orbit of the meteoroid before its encounter with our planet have been included in *Table 6*. The geocentric velocity obtained for the particle yields $v_g$ = 61.9 ± 0.0 km/s. From the value derived for the Tisserand parameter referred to Jupiter ($T_J$ = –0.31), we found that the particle was moving on a cometary (HTC) orbit before colliding with our atmosphere. These parameters and the calculated radiant confirm that the bright meteor was linked to the γ-Aquilids (IAU code GAQ#0531). The proposed progenitor body of this shower, which peaks on May 5, is Comet C/1853G1 (Schweizer) (Jenniskens et al., 2016.).

*Figure 17* – Atmospheric path and projection on the ground of the SWEMN20220519_020002 "Los Zancarrones" event.

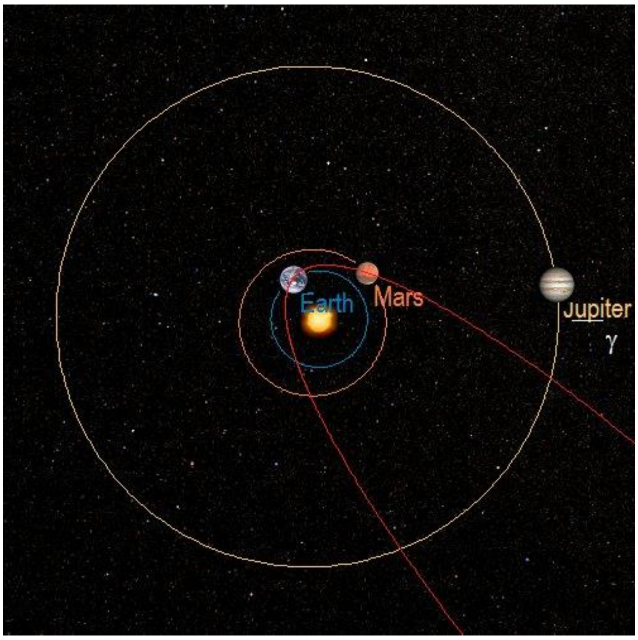

*Figure 18* – Projection on the ecliptic plane of the orbit of the SWEMN20220519_020002 fireball.

## Emission spectrum

The emission spectrum of the bolide was also recorded with the video spectrographs operated by the SWEMN network. This emission spectrum was calibrated in wavelength by taking into consideration typical lines appearing in meteor spectra, and then corrected by taking into account the sensitivity of the recording device. The resulting calibrated signal is shown in *Figure 19*. This plot also shows the most relevant contributions identified in the emission spectrum. These contributions correspond to Na I-1 (588.9 nm), Mg I-2 (516.7 nm), Fe I-15, and Fe I-4 (385.6 nm). In addition, the emissions from N2, O I and N I have been identified.

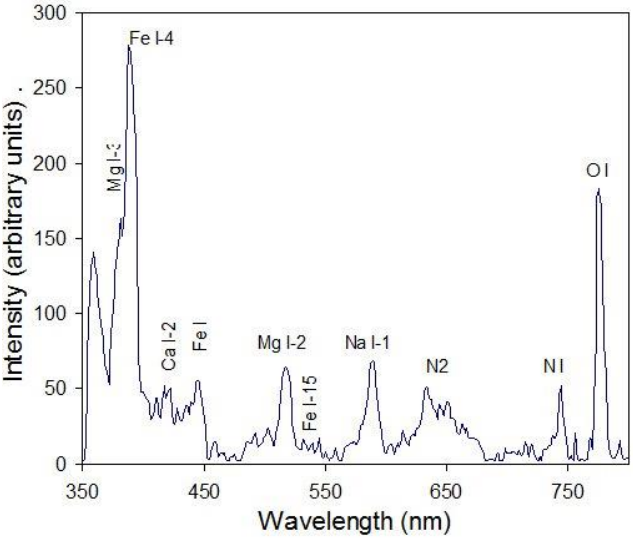

*Figure 19* – Emission spectrum of the SWEMN20220519_020002 "Los Zancarrones" fireball.

## 9 The 2022 May 23 fireball

This extraordinary bolide was captured on 2022 May 23 at $0^h42^m49.0 \pm 0.1^s$ UT from the meteor-observing stations located at Ayora, La Hita, CAHA, Olocau, and OSN (*Figure 20*). The bright meteor had a peak absolute magnitude of –15.0 ± 1.0. It was listed in the SWEMN meteor database with the code SWEMN20220523_004249.

*Figure 20* – Stacked image of the SWEMN20220523_004249 event as recorded from Olocau.

### Atmospheric path, radiant and orbit

It was found as a result of the analysis of the trajectory in the atmosphere of the event that this bright meteor overflew the province of Barcelona (northeast of Spain). It began at an altitude $H_b = 35.6 \pm 0.5$ km, and the event penetrated the atmosphere till a final height $H_e = 27.9 \pm 0.5$ km. The apparent radiant was located at the equatorial coordinates $\alpha = 223.47°$, $\delta = –8.03°$. The entry velocity in the atmosphere inferred for the parent meteoroid was $v_\infty = 17.3 \pm 0.2$ km/s. *Figure 21* shows the atmospheric path of the bolide.

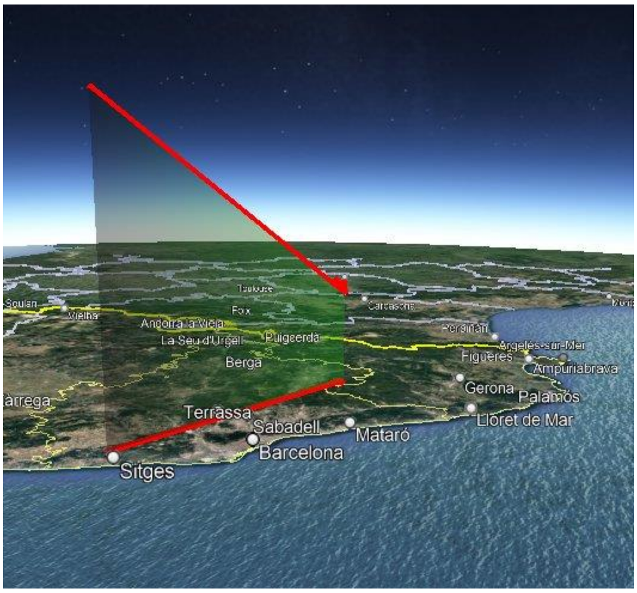

*Figure 21* – Atmospheric path and projection on the ground of the SWEMN20220523_004249 event.

This bright meteor was named "Vilanova de Sau", since the event was located over this locality during its final phase. The parameters of the heliocentric orbit of the parent meteoroid before its encounter with our planet can be found in *Table 7*. The geocentric velocity of the meteoroid was $v_g = 13.4 \pm 0.3$ km/s. From the value estimated for the Tisserand parameter with respect to Jupiter ($T_J = 3.58$), we found that the particle followed an asteroidal orbit before impacting the Earth's atmosphere. Radiant and orbital data do not match any of the meteoroid streams listed in the IAU meteor database. So, we concluded that this bolide was produced by the sporadic background.

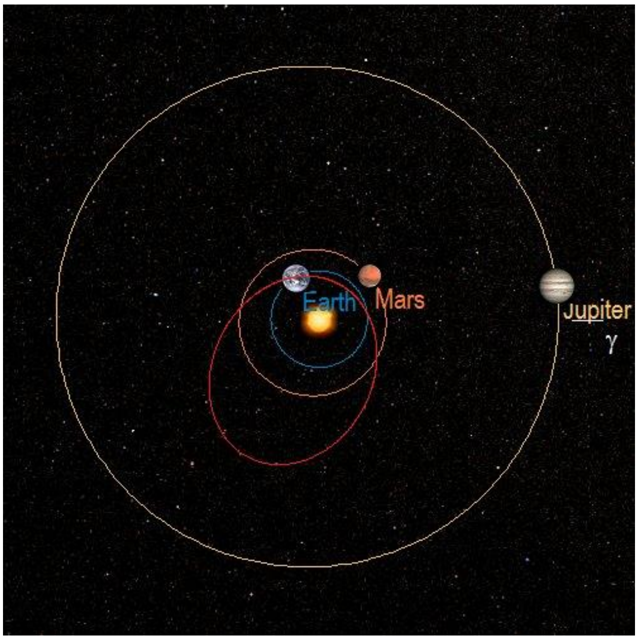

*Figure 22* – Projection on the ecliptic plane of the orbit of the SWEMN20220523_004249 fireball.

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

| | | | |
|---|---|---|---|
| $a$ (AU) | 2.02 ± 0.05 | $\omega$ (°) | 236.57 ± 00.07 |
| $e$ | 0.57 ± 0.01 | $\Omega$ (°) | 60.240703 ± 10-5 |
| $q$ (AU) | 0.852 ± 0.002 | $i$ (°) | 0.10 ± 0.09 |

## 10 Conclusions

Some of the brightest meteors recorded by SWEMN from March to May 2022 have been described here. They had a peak luminosity ranging from mag. –8 to mag. –15.

The "Villar del Saz de Arcas" bolide was recorded on March 9. Its peak magnitude was –11.0. The fireball was produced by a sporadic meteoroid and overflew the province of Cuenca (Spain). Before hitting the Earth's atmosphere, the meteoroid was moving on a cometary (HTC) orbit.

The second bolide analyzed here was an event recorded on April 26 and named "Nerva". It reached a peak absolute magnitude of –8.0, and belonged to the poorly known meteoroid stream of the h Virginids (HVI#0343). This meteor event overflew the province of Nerva (southwest of

Spain). Before striking the atmosphere, the progenitor meteoroid was moving on a cometary (JFC) orbit.

The next bolide analyzed here was the “Algarra” event. This was recorded on May 7. The peak magnitude of this sporadic meteor, which also overflew the province of Cuenca (Spain), was –10.0. Before colliding with the Earth’s atmosphere, the progenitor meteoroid was moving on a cometary (HTC) orbit.

The fourth bright meteor analyzed here was an event recorded on May 7. It belonged to the η-Aquariids (ETA#0031). Its peak magnitude was –9.0 and overflew the Atlantic Ocean. The progenitor particle was a meteoroid from Comet 1P/Halley.

Next we have presented a bright meteor recorded on May 15. Its peak magnitude was –11.0. The fireball was produced by a sporadic meteoroid and overflew the provinces of Córdoba and Granada (south of Spain). The meteoroid followed a cometary (HTC) orbit before colliding with the Earth’s atmosphere.

The next bolide in this report was the “Los Zancarrones” fireball. This was recorded on May 19. The peak magnitude of this γ-Aquilid (GAQ#0531), which overflew the region of Murcia (southeast of Spain), was –10.0. The parent meteoroid was moving on a cometary (HTC) orbit before striking the atmosphere. The analysis of the emission spectrum of this fireball was also performed, and revealed the contributions corresponding to Na I-1, Mg I-2, Mg I-3, Ca I-2, Fe I-4, Fe I-15, and N2. In addition, the emissions from O I and N I have been also found.

The last analyzed here was the “Vilanova de Sau” fireball, that was recorded on May 23. It reached a peak absolute magnitude of –15.0 and belonged to the sporadic background. This bolide overflew the province of Barcelona (northeast of Spain). Before entering our planet’s atmosphere, the parent meteoroid was moving on an asteroidal orbit. This deep-penetrating meteor event reached a terminal altitude of about 27 km.

## Acknowledgment

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# October – December 2021 observations

**Pierre Martin**

**Ottowa, Canada**

meteorshowersca@yahoo.ca

A report is presented on the October and December 2021 visual observations by the author.

## 1 2021 October 7–8

Here's a two-hour session I did last October at the Moosecreek site in an attempt to hunt for the 2021 Draconids. Although no special activity was predicted to happen, I always enjoy trying to spot these elusive meteors.

It was already quite late when I arrived at the site, and the Draconids radiant was quite low around midnight local time, so I didn't expect to see much. Indeed, only one possible Draconid candite was seen — a slow +3 meteor that was seen in the north-east. The South Taurids were however quite active with seven meteors, in addition to a couple of early Orionids, one October Camelopardalid and six sporadics. Altogether, seventeen meteors.

October 7–8, 2021, $03^h27^m$–$05^h30^m$ UT ($23^h27^m$–$01^h30^m$ EDT). Location: Moosecreek, Ontario, Canada (Long: –75°02'57" West; Lat: 45°15'13" North).

Observed showers:

- Draconids (DRA) – $17^h32^m$ (263°) +56°
- Southern Taurids (STA) – $01^h54^m$ (02°) +07°
- Orionids (ORI) – $05^h29^m$ (082°) +14°
- epsilon Geminids (EGE) – $05^h51^m$ (088°) +30°
- October Camelopardalids (OCT) – $11^h09^m$ (167°) +79°

$03^h27^m$–$04^h27^m$ UT ($23^h27^m$–$00^h27^m$ EDT); 2.5/5 trans; F 1.00; LM 6.20; facing NW60°; $t_{eff}$ 1.00 hr.

- STA: three: +3; +4(2)
- Sporadics: three: 0; +4; +5
- Total meteors: Six

$04^h27^m$–$05^h30^m$ UT ($00^h27^m$–$01^h30^m$ EDT); 2.5/5 trans; F 1.05; LM 6.20; facing NW60°; $t_{eff}$ 1.05 hr

- STA: four: +1; +4; +5(2)
- ORI: two: +1; +2
- DRA: one: +3
- OCT: one: +3
- Sporadics: three: +2(2); +3
- Total meteors: Eleven

Total meteors for this session: 17

## 2 2021 October 8–9

I returned to Moosecreek on the following night to observe meteors for another three hours, this time much earlier in the evening, for a much higher Draconids radiant. The sky transparency was not quite as good as on the previous night. During this session, I saw 19 meteors, including four South Taurids, three October Camelopardalids, one Draconid and eleven sporadics. The best meteor was a –1 golden October Camelopardalid that moved across 30 degrees! The only Draconid that I saw a very faint +5 meteor between Cepheus and Cassiopeia.

October 8–9, 2021, $00^h23^m$–$03^h30^m$ UT ($20^h23^m$–$23^h30^m$ EDT). Location: Moosecreek, Ontario, Canada (Long: –75°02'57" West; Lat: 45°15'13" North)[19].

Observed showers:

- Draconids (DRA) – $17^h32^m$ (263°) +56°
- Southern Taurids (STA) – $01^h54^m$ (02°) +07°
- Orionids (ORI) – $05^h29^m$ (082°) +14°
- epsilon Geminids (EGE) – $05^h51^m$ (088°) +30°
- October Camelopardalids (OCT) – $11^h09^m$ (167°) +79°

$00^h23^m$–$01^h24^m$ UT ($20^h23^m$–$21^h24^m$ EDT); 1.5/5 trans; F 1.00; LM 6.08; facing N60°; $t_{eff}$ 1.00 hr.

- OCT: two: +3; +4
- Sporadics: three: +2(2); +3
- Total meteors: Five

$01^h24^m$–$02^h24^m$ UT ($21^h24^m$–$22^h24^m$ EDT); 2/5 trans; F 1.00; LM 6.25; facing N60°; $t_{eff}$ 1.00 hr.

- OCT: one: –1
- STA: one: +2
- Sporadics: two: +1; +5
- Total meteors: Four

$02^h24^m$–$03^h30^m$ UT ($22^h24^m$–$23^h30^m$ EDT); 1.5/5 trans; F 1.00; LM 6.13; facing N60°; $t_{eff}$ 1.10 hr.

- STA: three: +1; +2; +4
- DRA: one: +5
- Sporadics: six: +2(2); +3(2) +4; +5
- Total meteors: Ten

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[19] IMO session: https://www.imo.net/members/imo_vmdb/view?session_id=84002

Total meteors for this session: 19

## 3 2021 December 13–14

For the Geminids 2021 peak night, Raymond Dubois joined me for an excellent night of observing at the North Frontenac Dark Sky Preserve (NFDSP), located about 160 km west of Ottawa near the town of Plevna. The weather looked especially promising, although the waxing gibbous phase (10 days old) was up until $3^h00^m$ am (local time) that night. From past experience, the Geminids have often put on a good show even during moonlit or moderately light polluted skies. I was also hopeful that the timing for the predicted peak would favor seeing high rates on this night.

In terms of temperature, this was one of the most comfortable night that I've ever had for the Geminids! It was unusually mild for this time of the year, here, with a low of only –4C (25F). This made setting up equipment a breeze. Usually for the Ottawa region we would expect to have temperatures of –20C (–4F) or colder on clear nights in mid-December. The sky was nice and transparent, and the fence near us kept the Moon's glow out of sight after $1^h30^m$ am. A large number of cars arrived during the night, with a group of about 20 people coming to view and photograph meteors. They remained in the parking area, and again the fence shielded our eyes and cameras reasonably well.

I took my time setting up my cameras. My plan was to start observing later at night when the Moon would be lower. Yet, the moonlight did not seem to hinder the Geminids too much. Several meteors would catch my eyes, many bright ones too! I signed on at midnight (local time) and I'm glad I did because the Geminids were already producing visual rates of better than one per minute! My first hour had 65 Geminids, followed by another 60 in the second hour of my watch. A good number of negative magnitude GEMs were seen, including a –4 blue-green beauty that shot 30 degrees into Ursa Major, seen just after 1am (local time). The rates further increased to 80 GEMs seen in the third hour, with the Moon about to set. Then, the fourth hour was glorious, with dark mag 6.5 skies, and a visible winter Milky Way. Activity was high and superb… with 130 meteors seen (of which 110 were GEMs)! My fifth "hour" was cut short and lasted only a little over half an hour, due to clouds and haze that gradually covered the sky, but still yielded 50 GEMs. All in all, in over four and a half hours of observing, I saw 411 meteors (365 Geminids, 8 sigma Hydrids, 5 Comae Berenicids, 4 Monocerotids, 4 December Alpha Draconids, 3 December Sigma Virginids, 2 eta Hydrids, 2 December Leonis Minorids, 2 Ursids, one November Orionid and 15 sporadics). Ouf! It can be a bit of a challenge keeping track of so many active radiants active in mid-December, though I'm not complaining! A total of 7 fireballs were seen. The finest was a mag –5 GEM near the end of the night, that shot down into Orion and created haloes with the haze rising in that direction. Another GEM fireball, this time a –3 seen just a few minutes earlier, fragmented and had a vivid blue-green color.

My photography consisted of two cameras setup to track the sky for a period of about 5 hours, until the end of the night.

It was a fabulous night, and it was great to have Raymond's company.

Observation December 13–14, 2021, $05^h00^m$–$10^h05^m$ UT ($00^h00^m$–$05^h05^m$ EST). Location: North Frontenac Dark Sky Preserve Site, Ontario, Canada. (Long: –76°56'23" West; Lat: 44°55'04" North)[20].

Observed showers:

- Southern chi Orionids (ORS) – $05^h48^m$ (87°) +18°
- November Orionids (NOO) – $06^h40^m$ (100°) +14°
- Monocerotids (MON) – $06^h47^m$ (102°) +08°
- Geminids (GEM) – $07^h34^m$ (114°) +32°
- sigma Hydrids (HYD) – $08^h34^m$ (128°) +02°
- eta Hydrids (EHY) – $09^h02^m$ (135°) +02°
- theta Pyxidids (TPY) – $09^h52^m$ (148°) –23°
- December Leonis Minorids (DLM) – $10^h16^m$ (154°) +34°
- Comae Berenicids (COM) – $11^h19^m$ (170°) +21°
- December chi Virginids (XVI) – $2^h38^m$ (189°) –09°
- Ursids (URS) – $12^h43^m$ (191°) +77°
- December kappa Draconids (DKD) – $13^h18^m$ (199°) +66°
- December Sigma Virginids (DSV) – $13^h16^m$ (199°) +07°
- December Alpha Draconids (DAD) – $13^h43^m$ (206°) +57°

$05^h00^m$–$06^h04^m$ UT ($00^h00^m$–$01^h04^m$ EST); 3/5 trans; F 1.00; LM 5.90; facing SSE60°; $t_{eff}$ 1.00 hr.

- GEM: sixty-five: –4; –3; –2(2); –1; 0(3); +1(12); +2(12); +3(15); +4(15); +5(3)
- MON: one: +3
- Total meteors: Sixty-six

$06^h04^m$–$07^h04^m$ UT ($01^h04^m$–$02^h04^m$ EST); 3/5 trans; F 1.00; LM 6.00; facing S55°; $t_{eff}$ 1.00 hr.

- GEM: sixty: –3; –1(2); 0(8); +1(6); +2(10); +3(16); +4(8); +5(9)
- MON: one: +3
- HYD: one: +4
- Sporadics: four: +3(2); +4; +5
- Total meteors: Sixty-six

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[20] IMO session: https://www.imo.net/members/imo_vmdb/view?session_id=83502

*Figure 1* – This one is of 98 Geminid meteors, captured on December 13–14 2021, between midnight and 5$^h$ am (local time). Canon 5D and Rokinon 24mm f/1.4 (set at f/2.0), ISO800 (prior to 2$^h$30$^m$ am local time), ISO1600 (after 2$^h$30$^m$ am local time). Hundreds of 30 seconds exposures were taken, and the images with meteors were then combined together digitally[21].

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[21] https://pmartin.smugmug.com/Astronomy/20191213-14-Geminids-NFDSP-Ontario/i-FWnvM3v/A

*Figure 2* – The second composite is of 200 Geminid meteors, captured on December 13–14 2021, between midnight and 5$^h$ am (local time). Canon 6D and Rokinon 14mm f/2.8, ISO800 (prior to 2$^h$30$^m$ am local time), ISO3200 (after 2$^h$30$^m$ am local time). Hundreds of 30 seconds exposures were taken, and the images with meteors were then combined together digitally[22].

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[22] https://pmartin.smugmug.com/Astronomy/20191213-14-Geminids-NFDSP-Ontario/i-7KRZSGp/A

$07^h04^m$–$08^h16^m$ UT ($02^h04^m$–$03^h16^m$ EST); 3/5 trans; F 1.00; LM 6.24; facing S55°; $t_{eff}$ 1.00 hr.

- GEM: eighty: –3; –2(3); –1(2); 0(7); +1(11); +2(11); +3(17); +4(17); +5(11)
- HYD: four: +3(2); +4; +5
- NOO: one: +4
- COM: one: +3
- DAD: one: +4
- Sporadics: three: +4(3)
- Total meteors: Ninety

$08^h16^m$–$09^h24^m$ UT ($03^h16^m$–$04^h24^m$ EST); 3/5 trans; F 1.00; LM 6.50; facing SW50 deg; $t_{eff}$ 1.01 hr.

- GEM: one-hundred-and-ten: –4; –1(2); 0(9); +1(11); +2(20); +3(19); +4(25); +5(23)
- COM: three: +4; +5(2)
- DAD: three: +4(2); +5
- MON: two: +4(2)
- HYD: two: +3; +5
- URS: two: +2; +3
- DSV: two: +2; +5
- EHY: one: +5
- DLM: one: +2
- Sporadics: four: 0; +3; +4; +5
- Total meteors: One-hundred-and-thirty

$09^h29^m$–$10^h05^m$ UT ($04^h29^m$–$05^h05^m$ EST); 3/5 trans; F 1.11; LM 5.50; facing SW50 deg; teff 0.60 hr.

- GEM: fifty: -5; -3; -2; -1(5); 0(6); +1(5); +2(6); +3(9); +4(11); +5(5)
- HYD: one: +4
- EHY: one: +2
- DLM: one: +1
- COM: one: +4
- DSV: one: 0
- Sporadics: four: +2; +4(3)
- Total meteors: Fifty-nine

Total meteors for this session: 411.

# January – April – May 2022 observations

**Pierre Martin**

**Ottowa, Canada**
meteorshowersca@yahoo.ca

A report is presented on the January, April and May 2022 visual observations by the author.

## 1 2022 January 2–3

I decided to head out despite the cold (–26C, –15F) for a late-night session to catch the Quadrantids several hours before their predicted peak. The sky was very clear but windy, so I drove to Johnston Road, near the town of Bourget, about 50 km east of Ottawa. The trees on one side of the road create a good wind protection – reducing the windchill factor. Without that, the wind would have made the session unbearably cold. I was well prepared with my winter sleeping bag, insulated mat, heaters, down parka, and multiple layers of clothes. The site was quiet, with not a single car going by.

I observed exactly two hours, from $3^h15^m$ am to $5^h15^m$ am (local time). I saw 35 meteors (19 Quadrantids, 3 January Leonids, 2 December sigma Virginids, one anthelion, one December Leonis Minorid, one sigma Hydrid and 8 sporadics).

The QUAs hourly visual rates were 9 and 10. These low rates were well expected so far ahead of the maximum; one that is usually a sharp, narrow peak. Many of the QUAs were on the faint side. The brightest were two QUAs reaching +1.

January 2–3, 2022, $08^h15^m$–$10^h15^m$ UT ($03^h15^m$–$05^h15^m$ EST). Location: Bourget, Ontario, Canada (Long: –75.104° W; Lat: 45.434° N).

Observed showers:

- Anthelions (ANT) – $07^h32^m$ (113°) +22°
- alpha Hydrids (AHY) – $08^h24^m$ (126°) –08°
- Omicron Leonids (OLE) – $08^h44^m$ (131°) +11°
- sigma Hydrids (HYD) – $09^h45^m$ (146°) –04°
- January Leonids (JLE) – $09^h50^m$ (148°) +24°
- theta Pyxidids (TPY) – $11^h19^m$ (170°) –28°
- December Leonis Minorids (DLM) – $11^h10^m$ (168°) +28°
- December sigma Virginids (DSV) – $14^h28^m$ (217°) +02°
- Quadrantids (QUA) – $15^h16^m$ (229°) +50°

$08^h15^m$–$09^h15^m$ UT ($03^h15^m$–$04^h15^m$ EST); 3/5 trans; F 1.00; LM 6.10; facing NE55°; $t_{eff}$ 1.00 hr.

- QUA: nine: +1; +2; +3(3); +4; +5(3)
- JLE: two: +3; +5
- ANT: one: +1
- DLM: one: +5
- HYD: one: +3
- DSV: one: +5
- Sporadics: seven: +2; +3(3); +4(2); +5
- Total meteors: Twenty-two

$09^h15^m$–$10^h15^m$ UT ($04^h15^m$–$05^h15^m$ EST); 3/5 trans; F 1.00; LM 6.10; facing NE55°; $t_{eff}$ 1.00 hr.

- QUA: ten: +1; +2; +4(4); +5(4)
- JLE: one: +5
- DSV: one: +5
- Sporadics: one: +5
- Total meteors: Thirteen

Total meteors for this session: 35.

## 2 2022 January 3–4

On the following night, I went out again for the Quadrantids. The timing for the maximum activity was not well positioned for North America this year (predicted during the late afternoon hours with a low radiant). Nonetheless, I saw this as an opportunity to hunt for earthgrazers. The weather was marginal, but the Lennox & Addington Dark Sky Viewing Area (about 170 km south-west of Ottawa) seemed more or less favorable. I decided to take a chance and head out in the midafternoon, for an early observing start.

Once at the site, I quickly setup and started observing just after $6^h00^m$ pm (local time) in deep twilight. The temperature was milder than the previous night at –12C (10F) but with a –22C windchill. The sky transparency was good at the beginning, but the traffic on nearby highway 41 caused a lot of flashes of lights in my eyes. I moved my chair in a different position and that helped.

My first QUA was seen 12 minutes into the session; a 45 degrees long earthgrazer that travelled from Draco to Cepheus, and flared in and out three times! Four more earthgrazers were seen during the first hour. The radiant was less than 10 degrees high in the NNW. The brightest meteor of that hour was actually a –1 yellow-orange anthelion that travelled 40 degrees!

During the second hour, I saw 10 QUAs, and nearly all of them were earthgrazers! The most impressive was a 70 degrees long QUA at $8^h09^m$ pm (local time) seen going from Ursa Major all the way to Orion! It wasn't the brightest meteor at +3 but the path length made it very impressive. Just 30 seconds later, another QUA earthgrazer appeared, this time a +5 that shot 30 degrees! Seeing all these earthgrazers was impressive considering that the radiant was at its lowest point in the sky, near the northern horizon (less than 5 degrees high). Surely, the QUAs must have still been somewhere near full tilt at that time.

Unfortunately, my session was cut short just after 9$^{h}$ pm (local time) when a wall of clouds/haze quickly rose up from the west and obscured the entire sky. I checked the weather satellite map, and it didn't look good. There were more clouds than expected coming. I decided to pack it in and go to sleep in the car. I was a long way from home, and not too keen on driving back home fatigued at night.

I woke up just after 4$^{h}$ am (local time), and immediately noticed the sky overhead was quite clear! I decided to head back out and attempt another sign-on. The sky was now very different with the QUA radiant situated almost overhead. I was curious to see what the QUAs would be up to, now several hours past the expected maximum. Not surprisingly, the QUAs rates were very low with only 6 meteors seen in a little over one hour. The brightest meteor was actually a sporadic that reached –3 seen shortly after I signed-on. At 5$^{h}$31$^{m}$ am (local time), the sky clouded over again, and I sign-off.

In all, I saw 39 meteors (including 20 Quadrantids, 2 December Leonis Minorids, 2 December chi Virginids, one anthelion, one January Leonid, one December sigma Virginid and 12 sporadics).

January 3–4, 2022, 23$^{h}$05$^{m}$–10$^{h}$31$^{m}$ UT (18$^{h}$05$^{m}$–05$^{h}$31$^{m}$ EST). Location: L&A County Public Dark Site, Ontario, Canada (Long: -77.116° West; Lat: 44.559° North)[23].

Observed showers:

- Anthelions (ANT) – 07$^{h}$32$^{m}$ (113°) +22°
- alpha Hydrids (AHY) – 08$^{h}$24$^{m}$ (126°) –08°
- Omicron Leonids (OLE) – 08$^{h}$44$^{m}$ (131°) +11°
- sigma Hydrids (HYD) – 09$^{h}$45$^{m}$ (146°) –04°
- January Leonids (JLE) – 09$^{h}$50$^{m}$ (148°) +24°
- theta Pyxidids (TPY) – 11$^{h}$19$^{m}$ (170°) –28°
- December Leonis Minorids (DLM) – 11$^{h}$35$^{m}$ (174°) +25°
- December chi Virginids (XVI) – 13$^{h}$18$^{m}$ (199°) –15°
- December sigma Virginids (DSV) – 14$^{h}$28$^{m}$ (217°) +02°
- Quadrantids (QUA) – 15$^{h}$16$^{m}$ (229°) +50°

23h05m–00h15m UT (18h05m–19h15m EST); 3/5 trans; F 1.00; LM 6.38; facing N55°; $t_{eff}$ 1.17 hr.

- QUA: four: +3(2); +4(2)
- ANT: one: –1
- Sporadics: four: +2; +5(3)
- Total meteors: Nine

00$^{h}$39$^{m}$–02$^{h}$03$^{m}$ UT (19$^{h}$39$^{m}$–21$^{h}$03$^{m}$ EST); 3/5 trans; F 1.03; LM 6.47; facing N55°; $t_{eff}$ 1.20 hr.

- QUA: ten: 0(2); +2; +3; +4(2); +5(4)
- Sporadics: two: +2; +3
- Total meteors: Twelve

09$^{h}$15$^{m}$–10$^{h}$31$^{m}$ UT (04$^{h}$15$^{m}$–05$^{h}$31$^{m}$ EST); 3/5 trans; F 1.04; LM 6.55; facing N55°; $t_{eff}$ 1.26 hr.

- QUA: six: 0; +1; +2(3); +5
- DLM: two: +3; +4
- XVI: two: +5(2)
- JLE: one: +2
- DSV: one: +3
- Sporadics: six: –3; +4; +5(3); +6
- Total meteors: Eighteen

Total meteors for this session: 39.

## 3 2022 April 22–23

I enjoyed a pleasant night of observing at Shane Finnigan's property, near Renfrew (about 80 km west of Ottawa), with the company of Raymond Dubois and Shane to view the post-maximum Lyrids. (Unfortunately, the previous night was overcast for the peak rates). Hearing the sounds of the frogs, owls, birds and the country fresh air is always good. While chatting with Shane and Raymond, while the radiant was still very low, I casually saw a 30 degrees long Lyrids earthgrazer! Not too long after, a very slow +3 meteor came about and appeared to have radiated from the h-Virginid radiant.

I watched meteors for two and a half hours, from 11$^{h}$25$^{m}$ pm to 1$^{h}$55$^{m}$ am (local time). The sky had some passing cloudiness that delayed the start of my session, but after that, the clouds were thin and scattered, and were only a minor nuisance. I counted 12 meteors (6 Lyrids, one anthelion and 5 sporadics). The brightest Lyrid was a blue –2 meteor with a one second train. It appeared that the Lyrids activity tapered off even as the radiant climbed. Unfortunately, my session was cut short when the sky became overcast just before 2$^{h}$ am EDT.

April 22–23, 2022, 03$^{h}$25$^{m}$–05$^{h}$55$^{m}$ UT (23$^{h}$25$^{m}$–01$^{h}$55$^{m}$ EDT). Location: Renfrew, Ontario, Canada (45°25'48"N 76°38'24"W)[24].

Observed showers:

- h Virginids (HVI) – 13$^{h}$28$^{m}$ (202°) –10°
- Alpha Virginids (AVB) – 13$^{h}$39$^{m}$ (205°) +04°
- Anthelions (ANT) – 15$^{h}$04$^{m}$ (226°) –17°
- Lyrids (LYR) – 18$^{h}$17$^{m}$ (274°) +33°

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[23] IMO session: https://www.imo.net/members/imo_vmdb/view?session_id=84004

[24] IMO session: https://www.imo.net/members/imo_vmdb/view?session_id=84006

- eta Aquariids (ETA) – 22$^h$00$^m$ (330°) –05°

03$^h$25$^m$–04$^h$25$^m$ UT (23$^h$25$^m$–00$^h$25$^m$ EDT); 2/5 trans; F 1.09; LM 6.10; facing E60°; $t_{eff}$ 1.00 hr.

- LYR: four: –2; –1; +3; +5
- ANT: one: +2
- Sporadics: one: +2
- Total meteors: Six

04$^h$25$^m$–05$^h$25$^m$ UT (00$^h$25$^m$–01$^h$25$^m$ EDT); 2.5/5 trans; F 1.00; LM 6.20; facing E60°; $t_{eff}$ 1.00 hr.

- LYR: one: +2
- Sporadics: two: +3; +4
- Total meteors: Three

05$^h$25$^m$–05$^h$55$^m$ UT (01$^h$25$^m$–01$^h$55$^m$ EDT); 2.5/5 trans; F 1.07; LM 6.20; facing E60°; $t_{eff}$ 0.50 hr.

- LYR: one: +3
- Sporadics: two: +3; +5
- Total meteors: Three

Total meteors for this session: 12.

## 4 2022 May 24–25

Here's a report on my recent outing to Bootland Farm (near Stewartville, ON, about 75 km west of Ottawa). I observed meteors for a few hours until the morning twilight. The sky was clear with below-average transparency, and the low +7C (44F) was cool enough to keep the bugs away. It was very humid and damp; I was glad that I had my boots. In the three hours that I observed, I saw 21 meteors (including 2 anthelions, one eta Aquariid, one possible tau Herculid and 17 sporadics). The brightest meteor was a +1 yellow-orange sporadic. The possible tau Herculid seen was a +4 slow meteor that seemed to become nebulous or fragment.

The crescent Moon rising in the east in the morning dawn, along with the Jupiter, Mars and Venus grouping was quite pretty.

The weather is looking fairly promising for tomorrow night's potential tau Herculids outburst but scattered thin clouds and cirrus might mean a road trip to hunt for the clearest dark skies.

May 24–25, 2022, 05$^h$05$^m$–08$^h$15$^m$ UT (01$^h$05$^m$–04$^h$15$^m$ EDT). Location: Bootland Farm, Ontario, Canada (Long: 76°29' West; Lat: 45°23′ North)[25].

Observed showers:

- Anthelion (ANT) – 16$^h$56$^m$ (254°) –23°
- eta Aquariids (ETA) – 23$^h$13$^m$ (348°) +04°
- May Camelopardalids (CAM) – 08$^h$08$^m$ (122°) +79°
- Tau Herculids (TAH) – 13$^h$56$^m$ (209°) +28°

05$^h$05$^m$–06$^h$05$^m$ UT (01$^h$05$^m$–02$^h$05$^m$ EDT); 2/5 trans; F 1.00; LM 6.15; facing N55°; $t_{eff}$ 1.00 hr.

- ANT: one: +4
- Sporadics: five: +2; +4(2); +5(2)
- Total meteors: Six

06$^h$05$^m$–07$^h$05$^m$ UT (02$^h$05$^m$–03$^h$05$^m$ EDT); 2/5 trans; F 1.00; LM 6.20; facing N55 deg; $t_{eff}$ 1.00 hr.

- ANT: one: +2
- ETA: one: +2
- Sporadics: eight: +1; +2; +3; +4(3); +5(2)
- Total meteors: Ten

07$^h$05$^m$–08$^h$15$^m$ UT (03$^h$05$^m$–04$^h$15$^m$ EDT); 2/5 trans; F 1.00; LM 5.64; facing N55 deg; $t_{eff}$ 1.16 hr.

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

Total meteors for this session: 21.

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[25] IMO session: https://www.imo.net/members/imo_vmdb/view?session_id=84007

# April 2022 report CAMS BeNeLux

**Carl Johannink**

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

A summary of the activity of the CAMS BeNeLux network during the month of April 2022 is presented. This month was good for a total of 8363 multi-station meteors resulting in 2543 orbits.

## 1 Introduction

In April we welcome the first well-known meteor shower since the Quadrantids in early January, but in general meteor activity is still low for northern latitudes this month.

The month started with very poor weather, resulting in three successive nights with no simultaneous meteors at all on April 4, 5 and 6.

Weather improved after the first half of the month, so the Lyrid activity could be monitored very well from the BeNeLux.

## 2 April 2022 statistics

April 2022 showed two faces. During the first 10 nights observations at many stations were hampered by cloudy weather. During 7 nights in this period, we collected 493 orbits, a large part of this score during one clear night, April 2–3 with 144 orbits. After the first half of the month the weather improved and in this period we collected more than 2000 orbits.

CAMS-BeNeLux collected 8363 multi-station meteors this month, resulting in a total of 2543 orbits. Most meteors were of sporadic origin or from minor showers. Activity of the minor showers zeta Cygnids (ZCY, #0040), alpha Virginids (AVB, #0021) and mu Virginids (DLI, #0047) is clearly visible in the data.

In the second half of April, we see activity popping up from a few major showers too.

The first Lyrid meteor was captured by *Martin Breukers* (CAMS 321, Hengelo, NL) and *Adriana and Paul Roggemans* (CAMS 3832, Mechelen, BE) on April 14 at 23$^{h}$36$^{m}$26$^{s}$ UT.

The first eta Aquariïd meteor was captured by *Klaas Jobse* (CAMS 3033 and 3034, Oostkapelle, NL) and *Robert Haas* (CAMS 3165, Alphen aan de Rijn, NL).

The number of orbits derived from more than two stations was at a fairly high level of approximately 72.3%.

On average 77.2 cameras were active during the nights this month. This number is lower than last year (81.1), because for different reasons some stations were still not active at all this month.

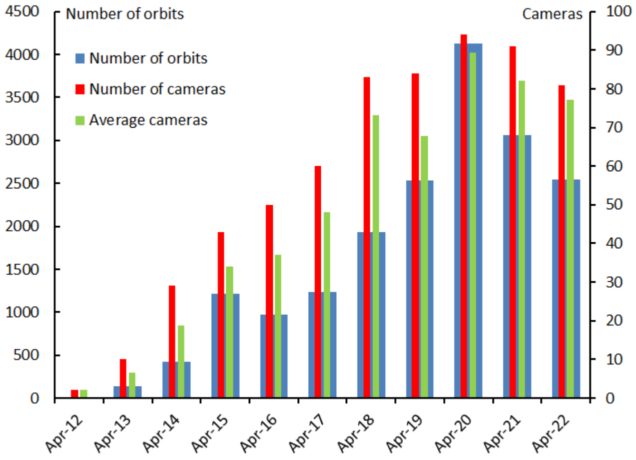

*Figure 1* – Comparing April 2022 to previous months of April in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the green bars the average number of cameras running per night.

*Table 1* – April 2022 compared to previous months of April.

| Year | Nights | Orbits | Stations | Max. Cams | Min. Cams | Mean Cams |
|---|---|---|---|---|---|---|
| 2012 | 6 | 11 | 4 | 2 | – | 2.0 |
| 2013 | 19 | 140 | 9 | 10 | – | 6.5 |
| 2014 | 19 | 421 | 12 | 29 | – | 18.8 |
| 2015 | 27 | 1212 | 15 | 43 | – | 33.9 |
| 2016 | 26 | 971 | 17 | 50 | 15 | 37 |
| 2017 | 28 | 1235 | 20 | 60 | 32 | 48.2 |
| 2018 | 27 | 1929 | 21 | 83 | 59 | 73.3 |
| 2019 | 29 | 2538 | 20 | 84 | 44 | 67.7 |
| 2020 | 29 | 4128 | 25 | 94 | 76 | 89.4 |
| 2021 | 28 | 3061 | 27 | 91 | 59 | 81.1 |
| 2022 | 27 | 2543 | 24 | 81 | 62 | 77.2 |
| Total | 265 | 18189 | | | | |

In May the stations at Ermelo and Zoersel are expected to deliver results again.

In Assenede (Belgium) a new camera was added to the network on April 14th by *Günther Boerjan, Steve Rau* and *Paul Roggemans*. This new RMS camera has been installed at the observatory "De Polderster" at Boekhoute (part of Assenede).

More new cameras will become active in the near future.

## 3 Conclusion

The results for April 2022 are the third best during 10 years of CAMS BeNeLux.

## Acknowledgement

Many thanks to all participants in the CAMS-BeNeLux network for their dedicated efforts.

The CAMS BeNeLux team was operated by the following volunteers during the month of April 2022:

*Hans Betlem* (Woold, CAMS 3071, 3072 and 3073), *Jean-Marie Biets* (Wilderen, Belgium, CAMS 379, 380, 381 and 382), *Ludger Boergerding* (Holdorf, Germany, RMS 3801), *Günther Boerjan* (Assenede, Belgium, RMS 3823), *Martin Breukers* (Hengelo, Netherlands, CAMS 320, 321, 322, 323, 324, 325, 326 and 327, RMS 319, 328 and 329), *Giuseppe Canonaco* (Genk, RMS 3818, RMS 3819), *Pierre de Ponthiere* (Lesve, Belgium, RMS 3816 and 3826), *Tammo Jan Dijkema* (Dwingeloo, Netherlands, RMS 3199), *Isabelle Ansseau, Jean-Paul Dumoulin, Dominique Guiot and Christian Walin* (Grapfontaine, Belgium, CAMS 814 and 815, RMS 3814, RMS 3817), *Uwe Glässner* (Langenfeld, Germany, RMS 3800), *Luc Gobin* (Mechelen, Belgium, CAMS 3890, 3891, 3892 and 3893), *Tioga Gulon* (Nancy, France, CAMS 3900 and 3901), *Robert Haas* (Alphen aan de Rijn, Netherlands, CAMS 3160, 3161, 3162, 3163, 3164, 3165, 3166 and 3167), *Robert Haas* (Texel, Netherlands, CAMS 811, 812), *Kees Habraken* (Kattendijke, Netherlands, RMS 378), *Klaas Jobse* (Oostkapelle, Netherlands, CAMS 3030, 3031, 3032, 3033, 3034, 3035, 3036 and 3037), *Carl Johannink* (Gronau, Germany, CAMS 3100, 3101, 3102, 3103 and 3104), *Reinhard Kühn* (Flatzby, Germany, RMS 3802), *Hervé Lamy* (Dourbes, Belgium, CAMS 394 and 395, RMS 3825), *Hervé Lamy* (Humain Belgium, CAMS 816, RMS 3821), *Hervé Lamy* (Ukkel, Belgium, CAMS 393), *Tim Polfliet* (Gent, Belgium, CAMS 396, RMS 3820), *Steve Rau* (Zillebeke, Belgium, CAMS 3850, 3852, RMS 3851, RMS 3853), *Paul and Adriana Roggemans* (Mechelen, Belgium, RMS 3830 and 3831, CAMS 3832, 3833, 3834, 3835, 3836 and 3837), *Hans Schremmer* (Niederkruechten, Germany, CAMS 803).

# May 2022 report CAMS BeNeLux

**Carl Johannink**

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

A summary of the activity of the CAMS BeNeLux network during the month of May 2022 is presented. We collected a total of 7133 multi-station meteors resulting in 2160 orbits during this month. At the end of the month the predicted tau Herculids (TAH#0061) activity has been confirmed by the network.

## 1 Introduction

During this month the sporadic activity is still low and because nighttime is short, the number of orbits obtained this month is one of the lowest in the year. In the first two weeks we can observe some activity of a major southern hemisphere shower shortly before dawn: the eta Aquariids.

This year there was one other possible highlight at the end of May with good prospects, although attended with great uncertainty, for activity of the tau Herculids, dust released by comet 73P/Schwassmann-Wachmann 3.

## 2 May 2022 statistics

Meteorological circumstances in the BeNeLux were in general good this month. During nearly all nights this month our network could collect simultaneous meteors. May 26–27 was the only night without any orbit.

A total of 7133 meteors were collected multi-station by the cameras in our network, resulting in 2160 orbits. Most of these were sporadic. Not for the first time we could monitor the activity of the eta Aquariids in early May very well. A total of 76 eta Aquariid shower members could be collected between April 24 and May 14.

As mentioned in the April 2022 rapport, the first eta Aquariid was captured on April 24 at $02^h47^m24^s$ UT by Klaas Jobse (CAMS 3033 and 3034, Oostkapelle, NL) and Robert Haas (CAMS 3165, Alphen aan de Rijn, NL). The last eta Aquariid was captured on May 14 at $02^h32^m02^s$ UT by Christian Wanlin (CAMS 814, Grapfontaine, Belgium) and Jean-Marie Biets (CAMS 380, Wilderen, Belgium). Most of the eta Aquariids were captured during the very transparent night May 8–9 with 14 shower members.

At the end of May, the tau Herculids could show enhanced activity, according to several forecasts. (Jenniskens 2006; 2022; Lüthen et al., 2001). Although observations at some stations were hampered by clouds, many tau Herculids could be captured simultaneously by our network. A compliment to our operators who delivered their results so quickly, that we could present first results, a clear drift of the radiant on May 29–30 and May 30–31, within 24 hours after 'the show'.

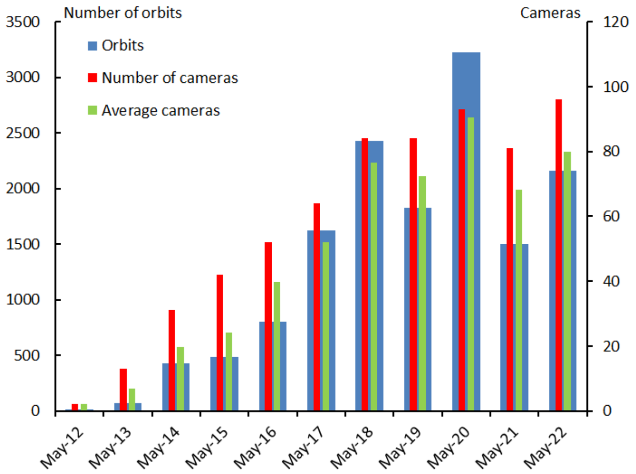

*Figure 1* – Comparing May 2022 to previous months of May in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the green bars the average number of cameras running per night.

*Table 1* – May 2022 compared to previous months of May.

| Year | Nights | Orbits | Stations | Max. Cams | Min. Cams | Mean Cams |
|---|---|---|---|---|---|---|
| 2012 | 5 | 13 | 4 | 2 | – | 2 |
| 2013 | 13 | 69 | 9 | 13 | – | 6.8 |
| 2014 | 22 | 430 | 13 | 31 | – | 19.7 |
| 2015 | 25 | 484 | 15 | 42 | – | 24.2 |
| 2016 | 26 | 803 | 17 | 52 | 16 | 39.9 |
| 2017 | 24 | 1627 | 19 | 64 | 22 | 52.0 |
| 2018 | 31 | 2426 | 21 | 84 | 64 | 76.6 |
| 2019 | 29 | 1825 | 20 | 84 | 53 | 72.4 |
| 2020 | 29 | 3226 | 24 | 93 | 70 | 90.5 |
| 2021 | 28 | 1500 | 25 | 81 | 50 | 68.2 |
| 2022 | 30 | 2160 | 28 | 96 | 65 | 79.8 |
| Total | 262 | 14563 | | | | |

The number of orbits that was collected from more than two stations was nearly 74%, and nearly 80 cameras were active every night in May. These numbers are higher than in recent months. The main reason for this was that technical problems at several stations could be solved in May.

Stations in Burlage and Terschelling started delivering data again. In Burlage the 4 Watecs were replaced by two RMS-cameras. At Terschelling Robert Haas and Jos Nijland succeeded in reactivating three of the four Watecs. In Zoersel Watecs 397, 398, 804, 805 and 806, got new dongles, so the station operator Bart Dessoy could deliver data since early May again. He also installed and activated RMS 3827 from Zoersel.

So, May was a successful month for CAMS BeNeLux.

## 3 Conclusion

Results in May 2022 were the third best since the existence of CAMS BeNeLux.

## Acknowledgement

Many thanks to all operators in our network for their efforts and their quick delivering of data. The CAMS BeNeLux team was operated by the following volunteers this month:

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

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# Radio meteors April 2022

**Felix Verbelen**

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

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

## 1 Introduction

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

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

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

Local interference and unidentified noise remained moderate to low for most of the month, but some strong noise was caused by solar eruptions (see an example from April 30th – *Figure 5*), but that noise was of course interesting in itself.

No lightning activity was recorded this month.

General meteor activity steadily increased, with clear increases in overdense reflections around April 8th, 15th, 23rd (Lyrids) and 29th. Six reflections lasting at least 1 minute were observed this month.

Attached are SpecLab images of some notable reflections (*Figures 6 to 12*). In addition to the usual graphs, you will also find the raw counts in cvs-format[26] 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.

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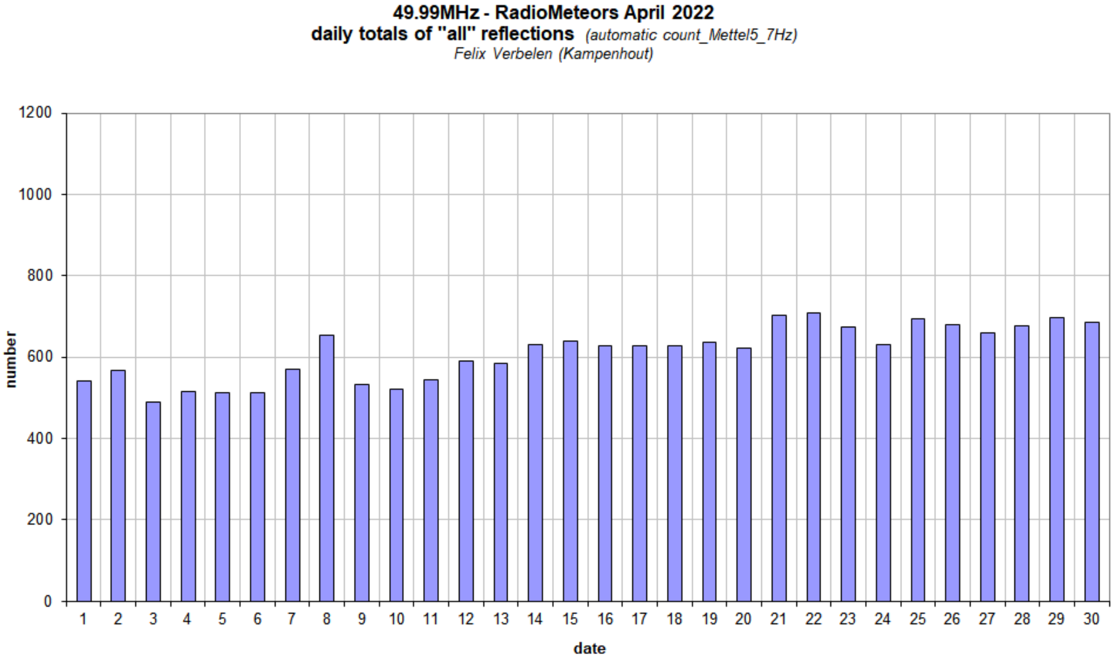
[26] https://www.meteornews.net/wp-content/uploads/2022/05/202204_49990_FV_rawcounts.csv



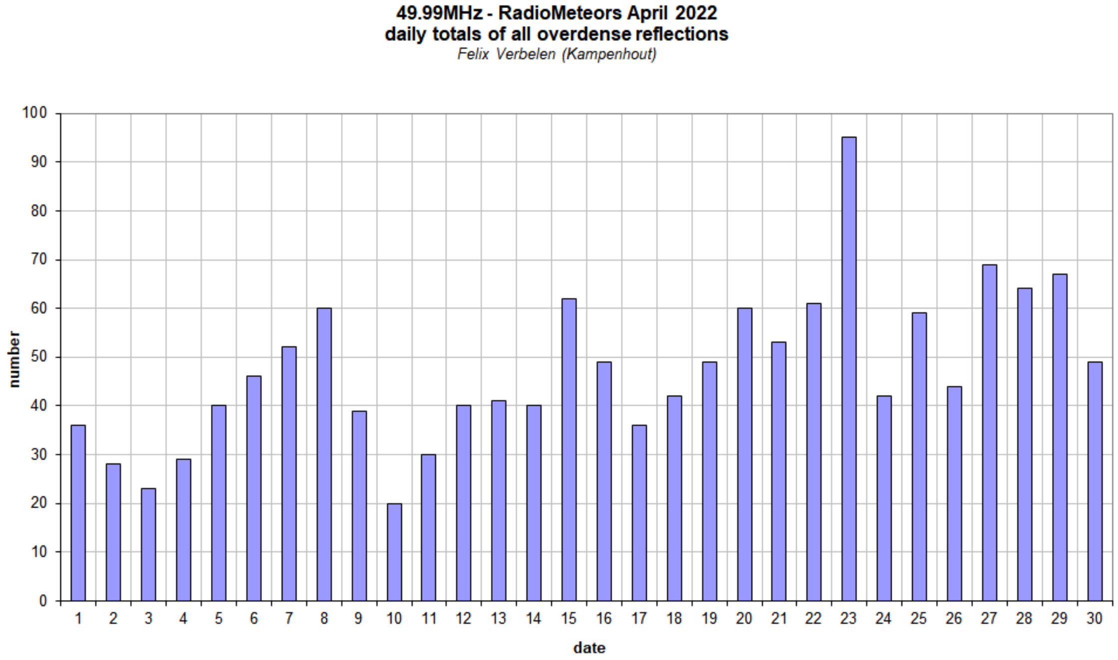
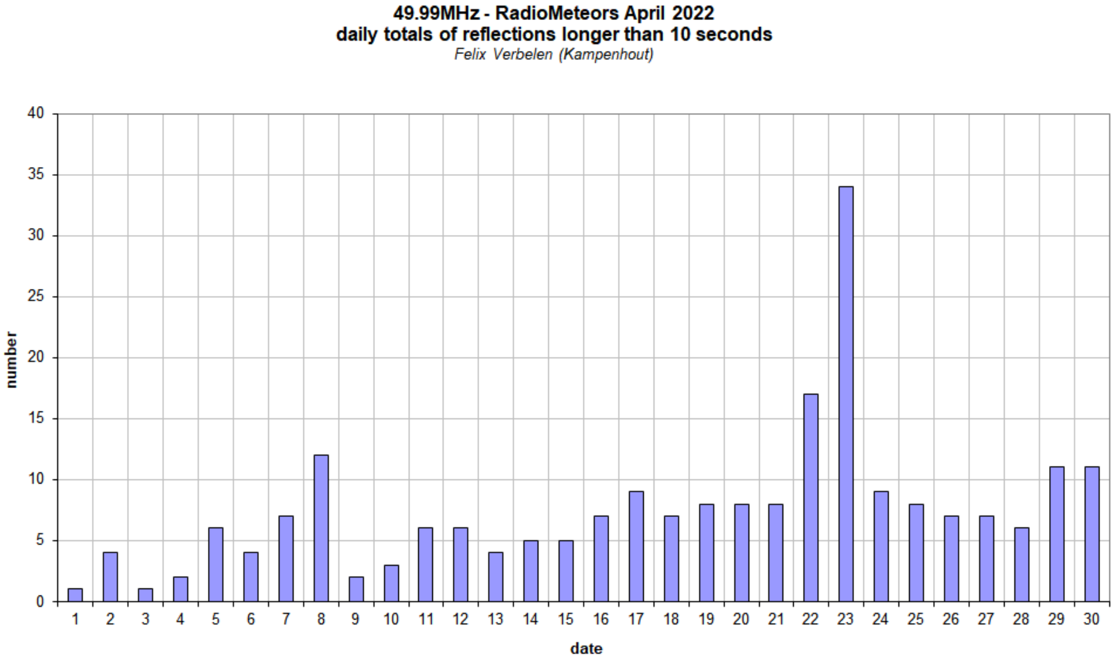


*Figure 1* – The daily totals of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during April 2022.



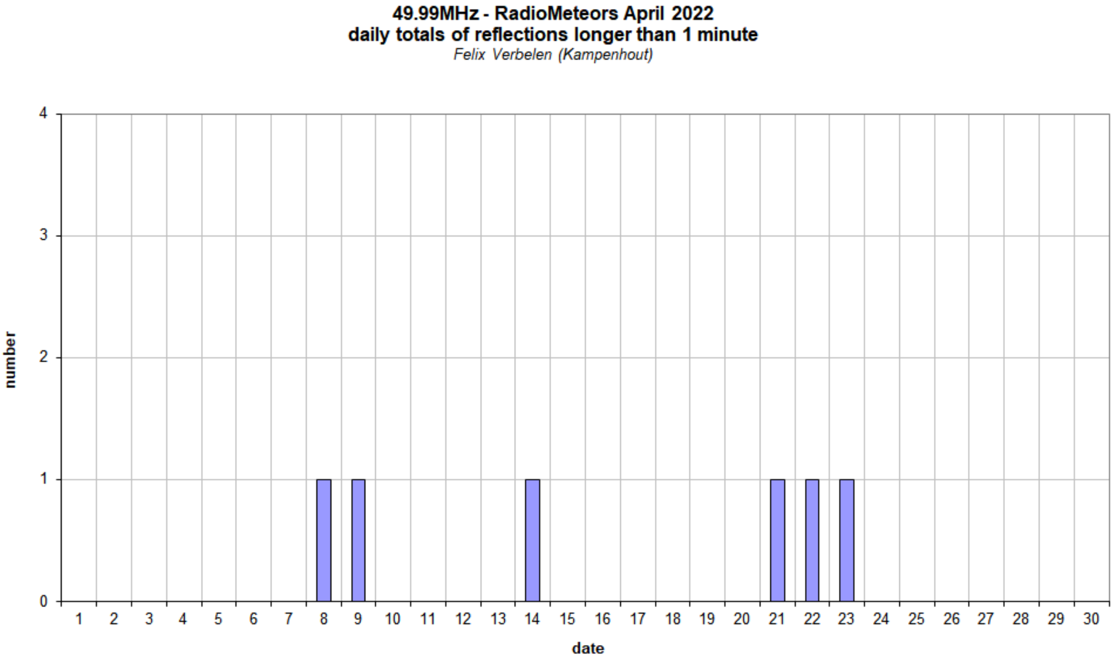


*Figure 2* – The daily totals of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during April 2022.

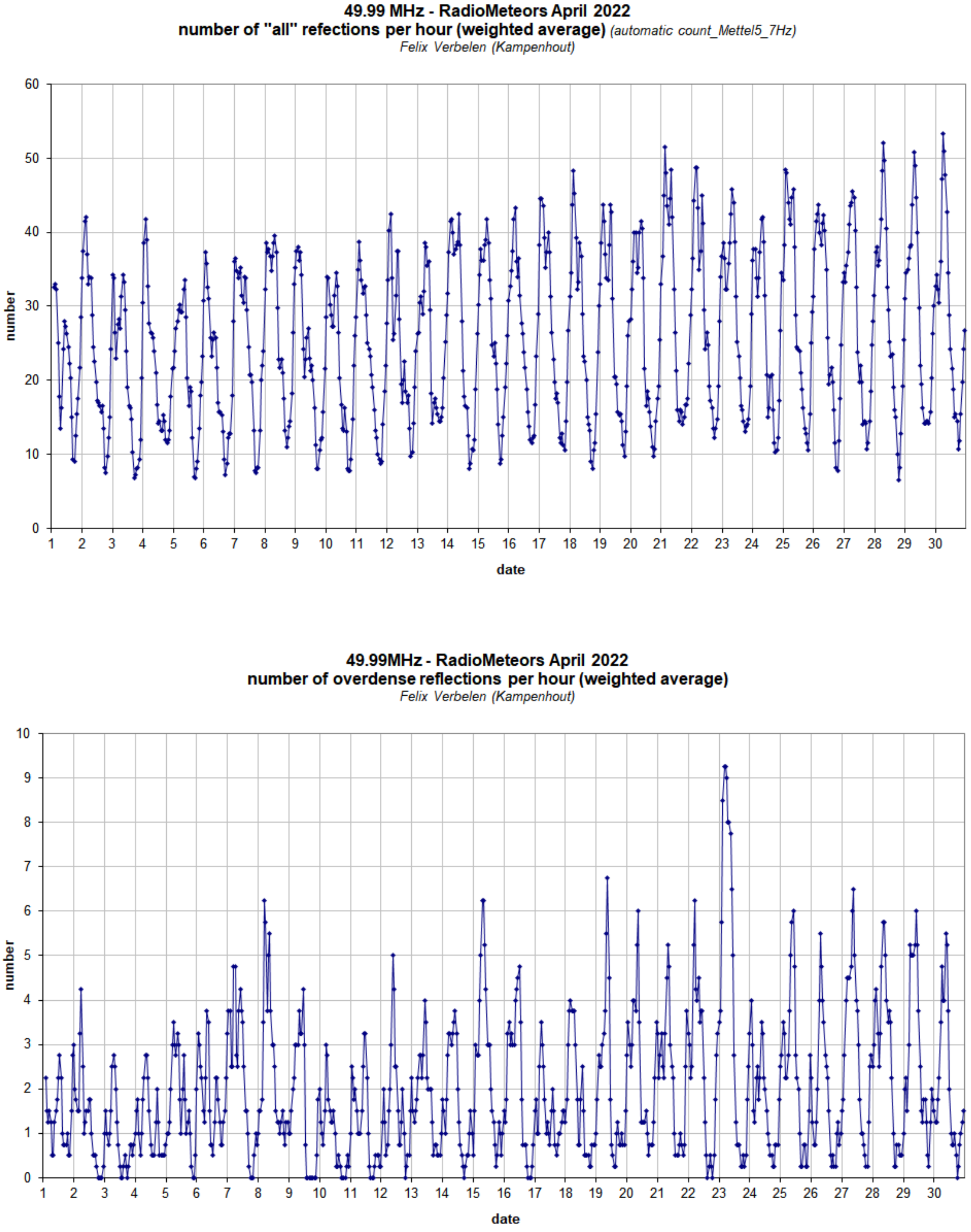


*Figure 3* – The hourly numbers of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during April 2022.

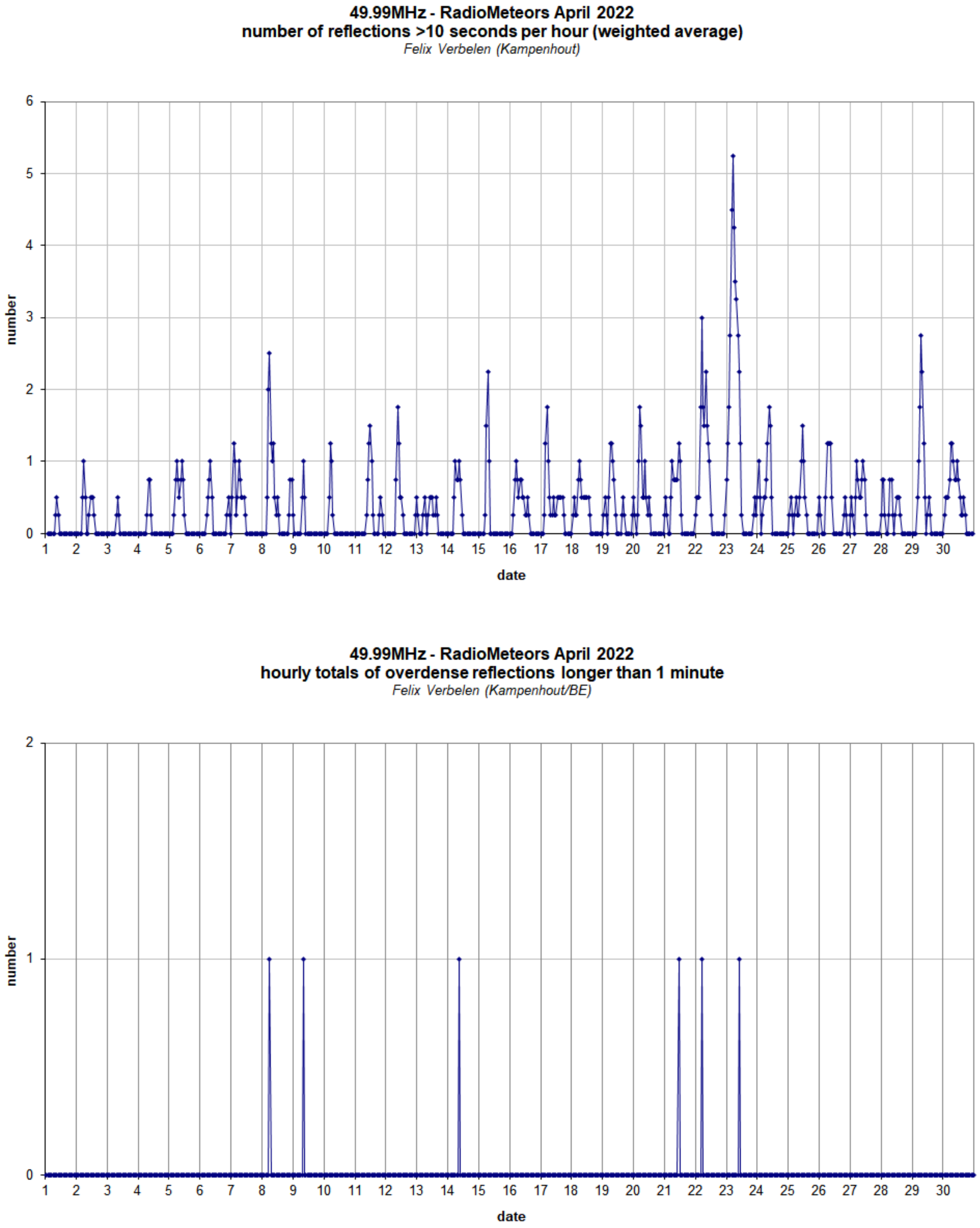


*Figure 4* – The hourly numbers of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during April 2022.

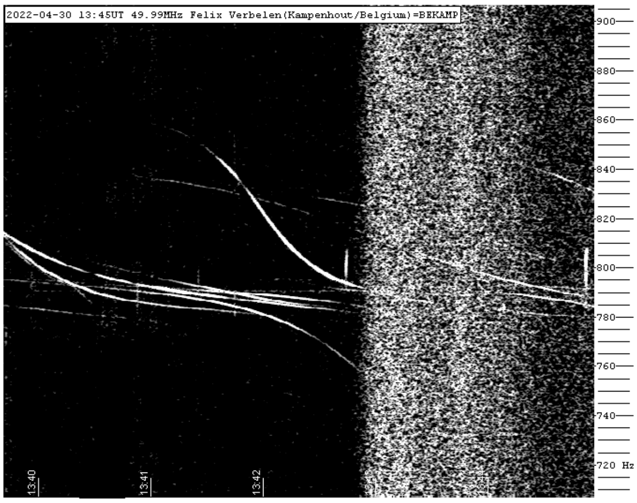


*Figure 5* – Meteor reflection 30 April 2022, 13$^h$45$^m$ UT.

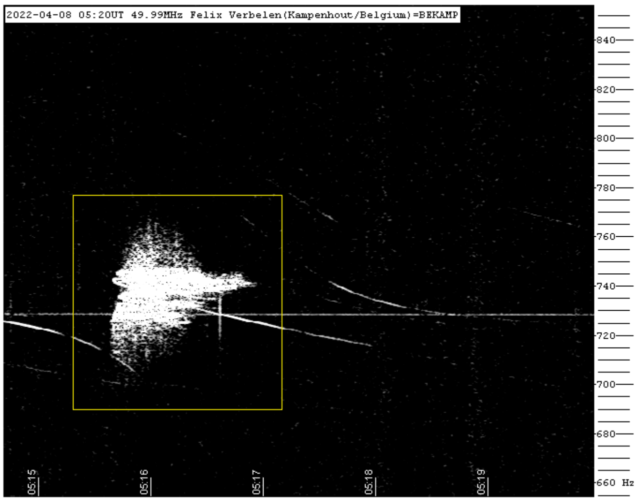


*Figure 6* – Meteor reflection 8 April 2022, 05$^h$20$^m$ UT.

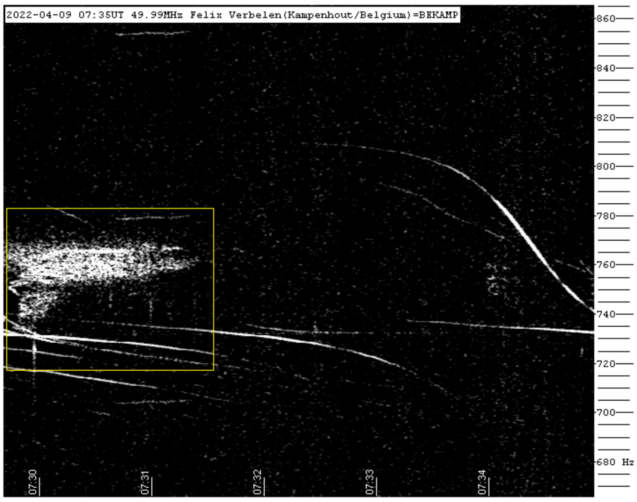


*Figure 7* – Meteor reflection 9 April 2022, 7$^h$35$^m$ UT.

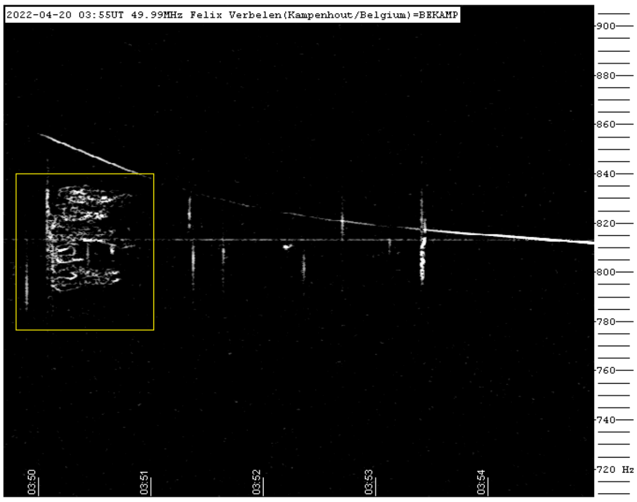


*Figure 8* – Meteor reflection 20 April 2022, 3$^h$55$^m$ UT.

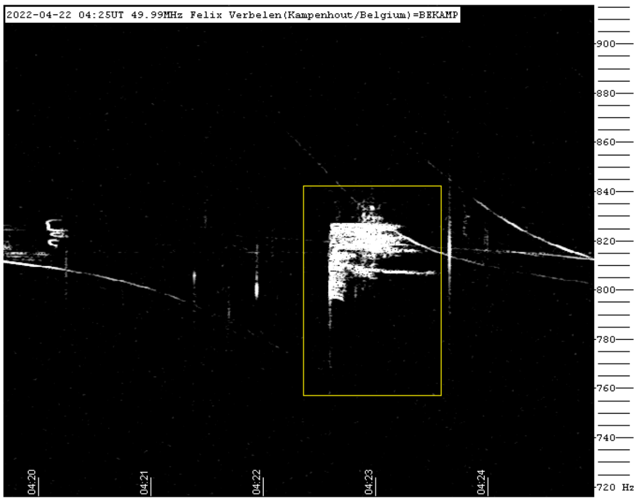


*Figure 9* – Meteor reflection 22 April 2022, 4$^h$25$^m$ UT.

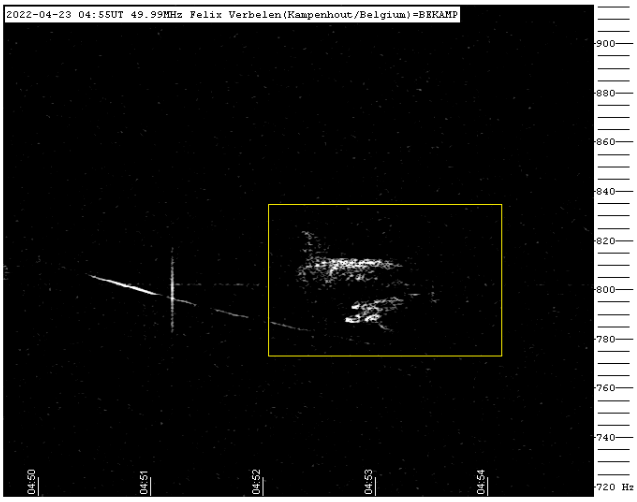


*Figure 10* – Meteor reflection 23 April 2022, 4$^h$55$^m$ UT.

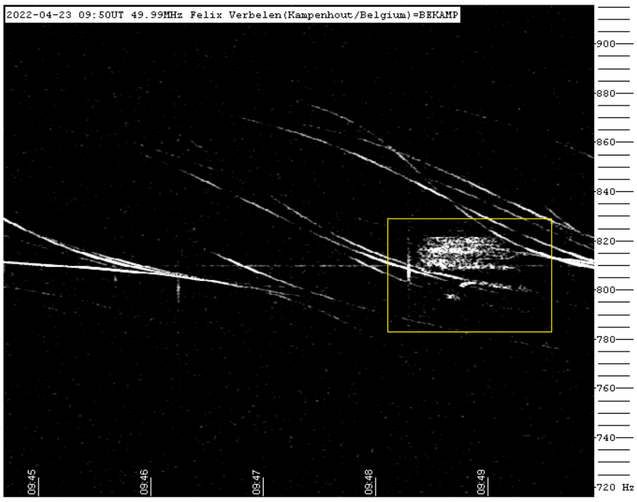


*Figure 11* – Meteor reflection 23 April 2022, 9$^h$50$^m$ UT.

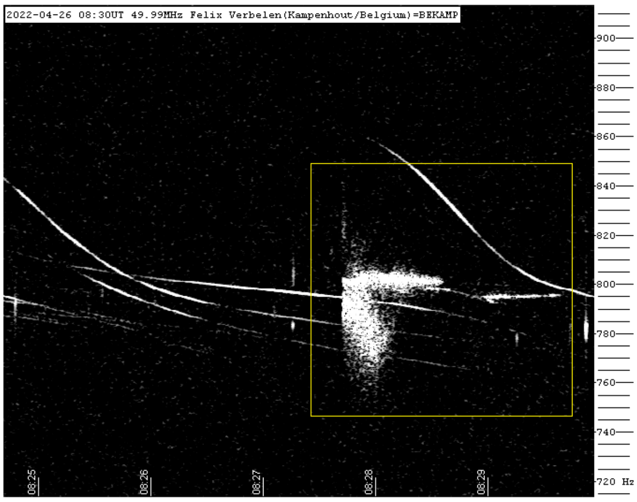


*Figure 12* – Meteor reflection 26 April 2022, 8$^h$30$^m$ UT.

# Radio meteors May 2022

**Felix Verbelen**

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

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

## 1 Introduction

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

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

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

Local interference and unidentified noise remained moderate to low for most of the month, but observations were sometimes difficult due to strong lightning activity (on 9 different days) and near daily powerful solar eruptions (see *Figures 5, 6 and 7*). This solar activity was of course interesting in itself.

The general meteor activity was quite high, with the eta Aquariids in the first days of the month, and throughout the month mainly daytime showers. In addition, on the 31th there was the predicted outburst of tau Herculids.

This month, 22 reflections lasting more than 1 minute were observed. A selection of SpecLab images is shown in *Figures 8 to 21*. In addition to the usual graphs, you will also find the raw counts in csv-format[27] from which the graphs are derived.

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

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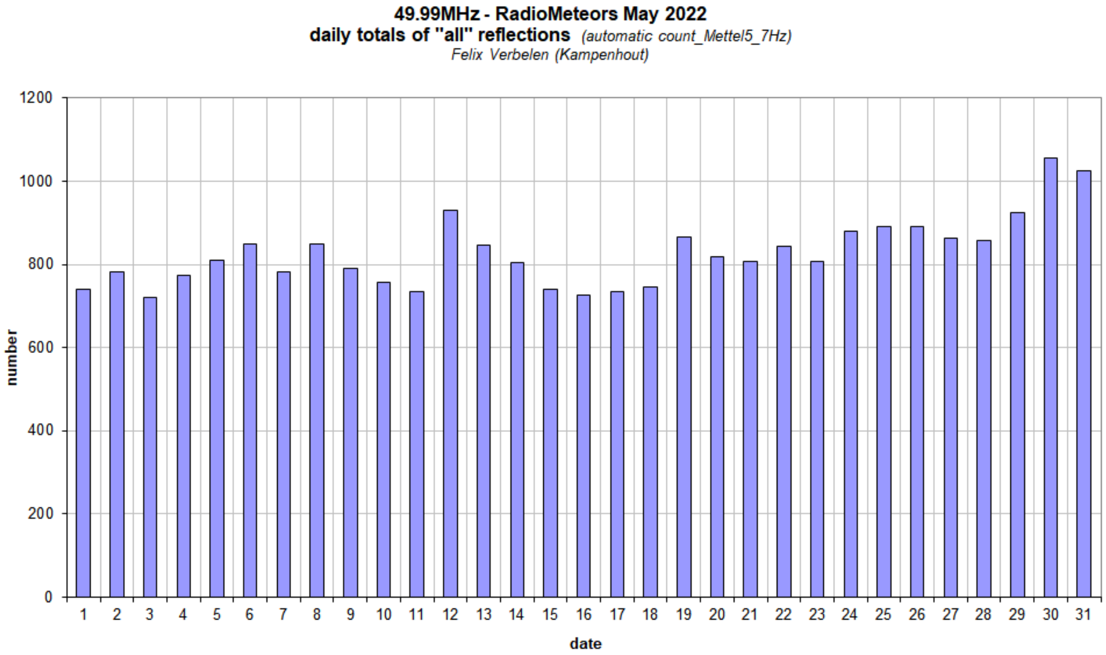
[27] https://www.meteornews.net/wp-content/uploads/2022/06/202205_49990_FV_rawcounts.csv



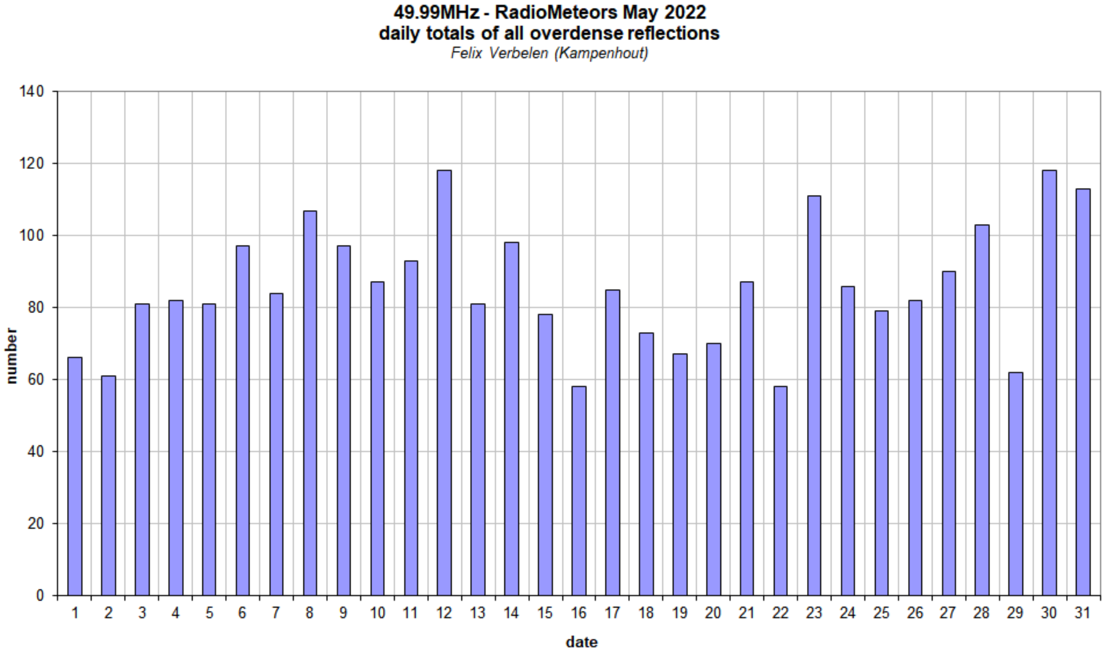
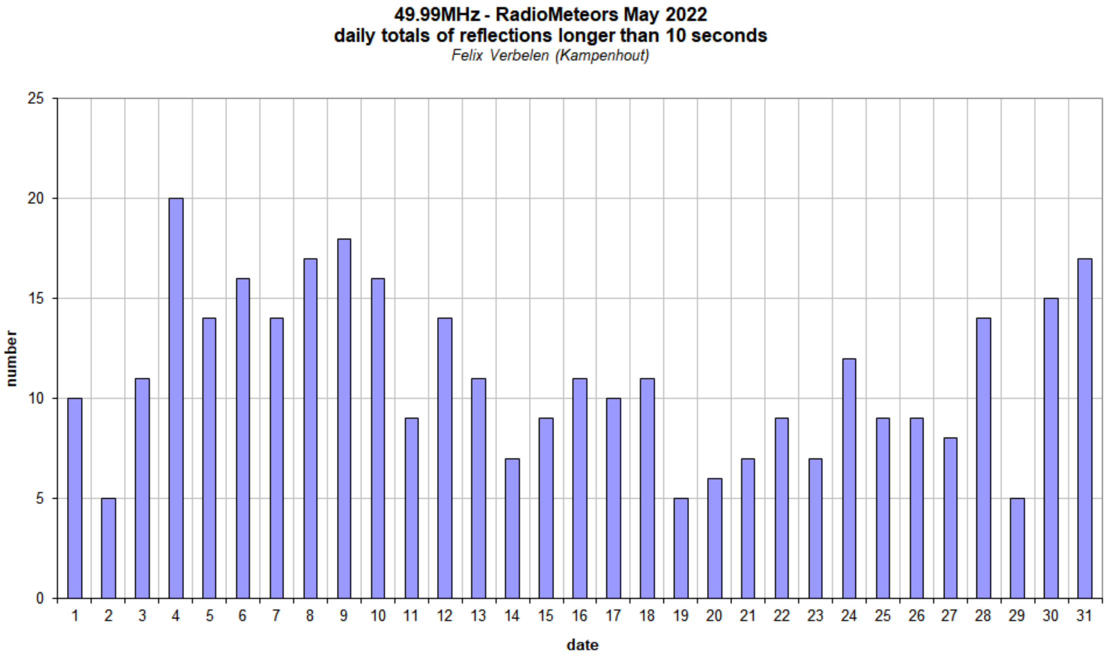


*Figure 1* – The daily totals of “all” reflections counted automatically, and of manually counted “overdense” reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during May 2022.



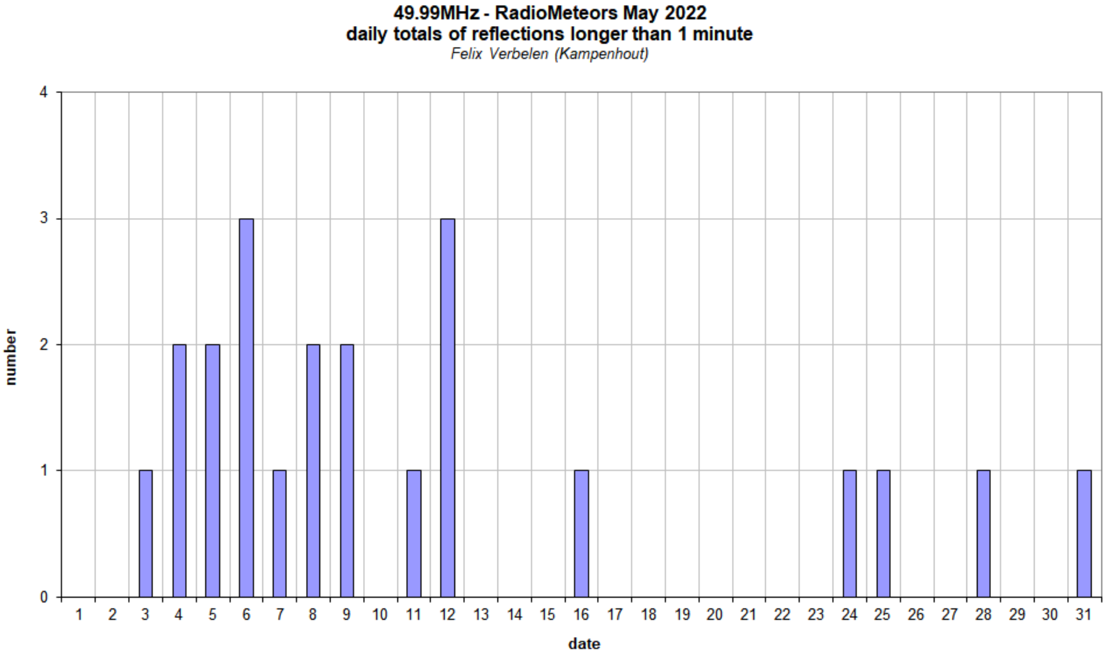
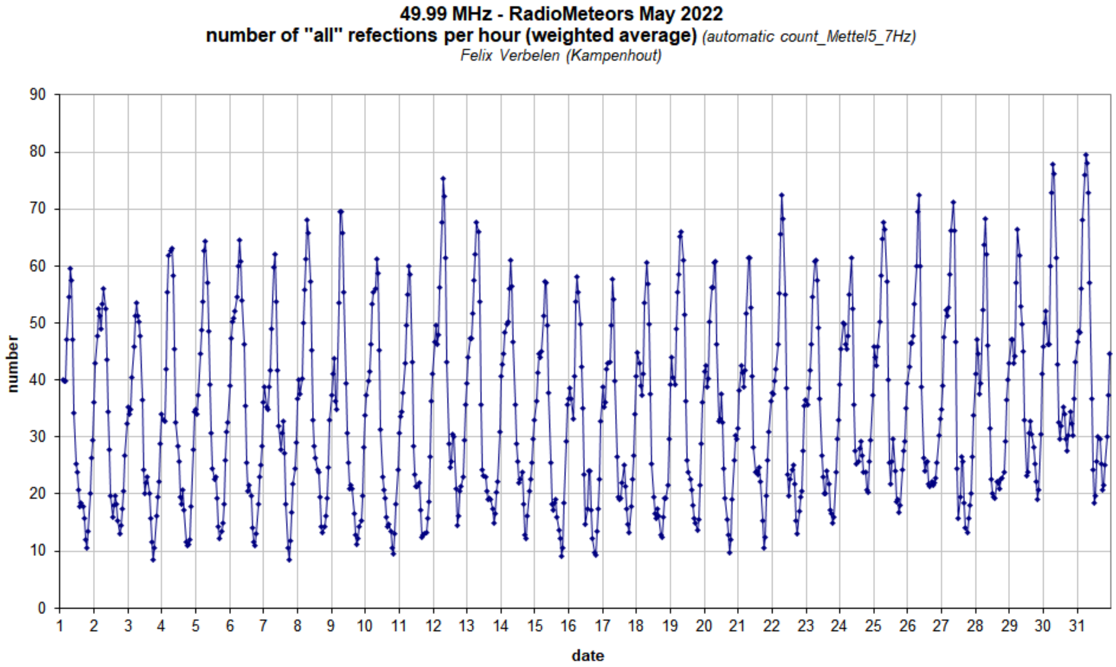


*Figure 2* – The daily totals of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during May 2022.



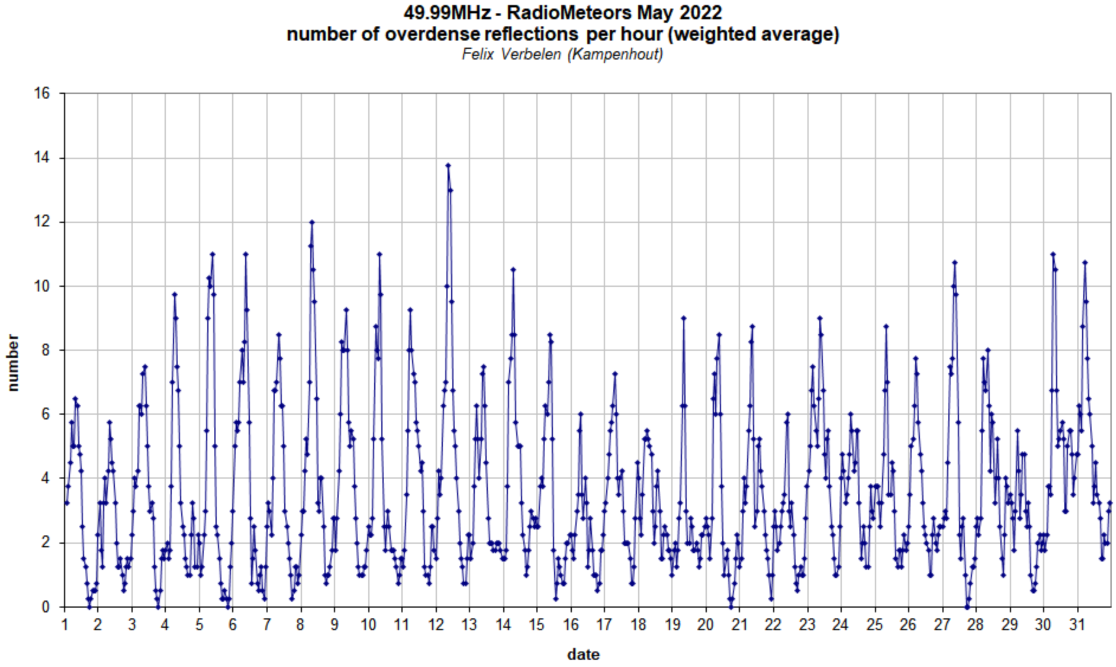
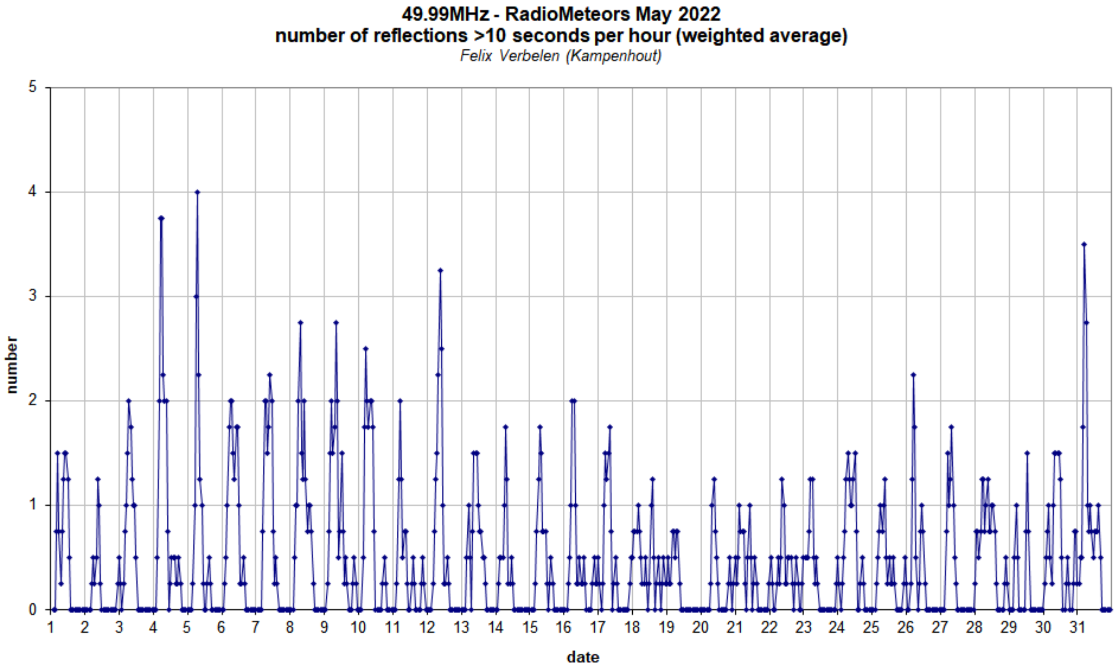


*Figure 3* – The hourly numbers of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during May 2022.



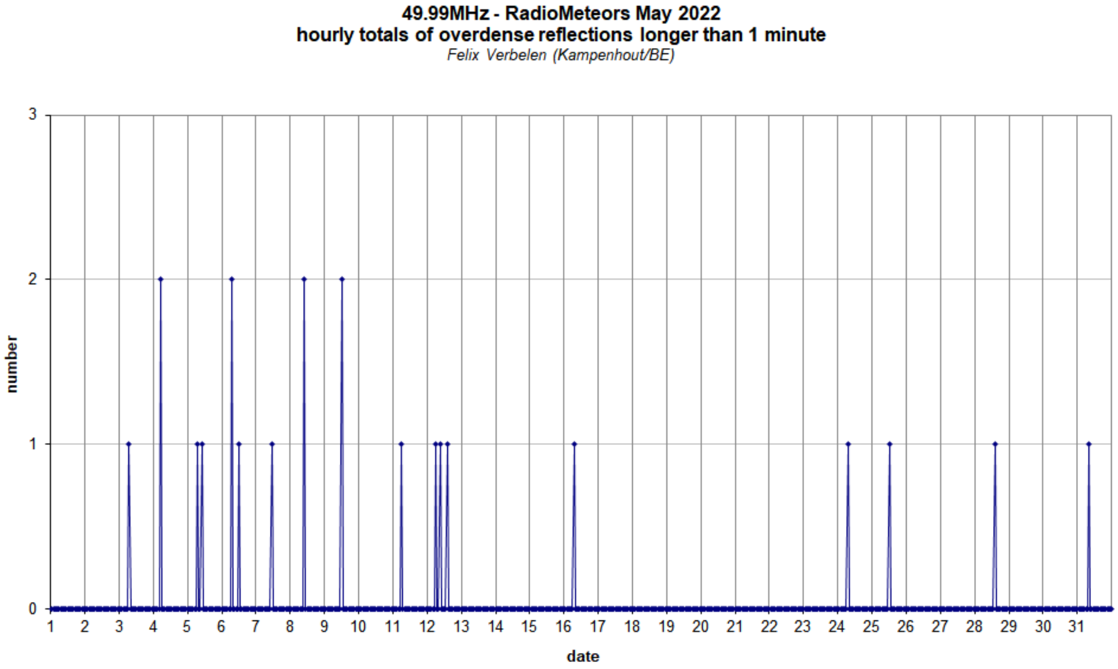


*Figure 4* – The hourly numbers of overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during May 2022.

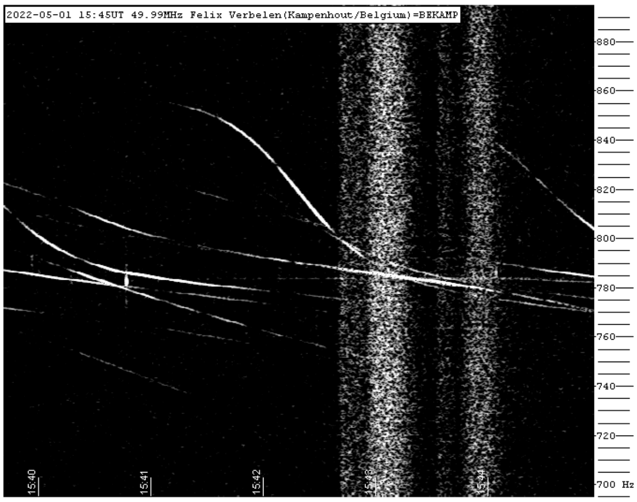


*Figure 5* – Solar eruptions 01 May 2022, $15^{h}45^{m}$ UT.

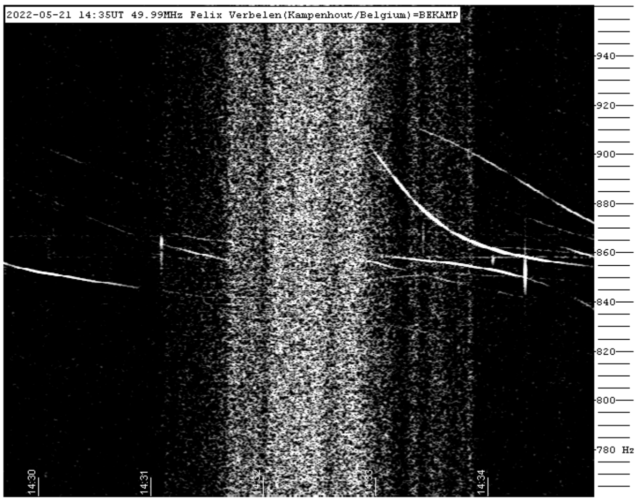


*Figure 6* – Solar eruptions 21 May 2022, $14^{h}35^{m}$ UT.

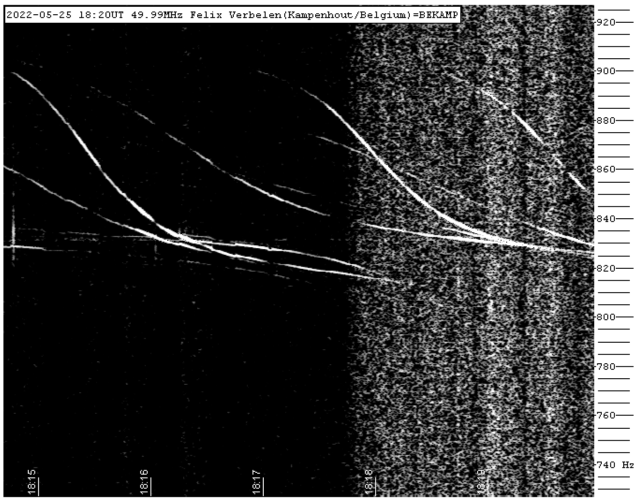


*Figure 7* – Solar eruptions 25 May 2022, $18^{h}20^{m}$ UT.

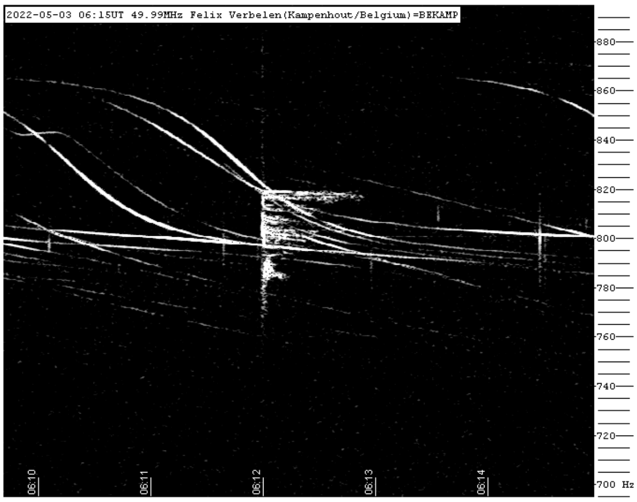


*Figure 8* – Meteor reflection 03 May 2022, $06^{h}15^{m}$ UT.

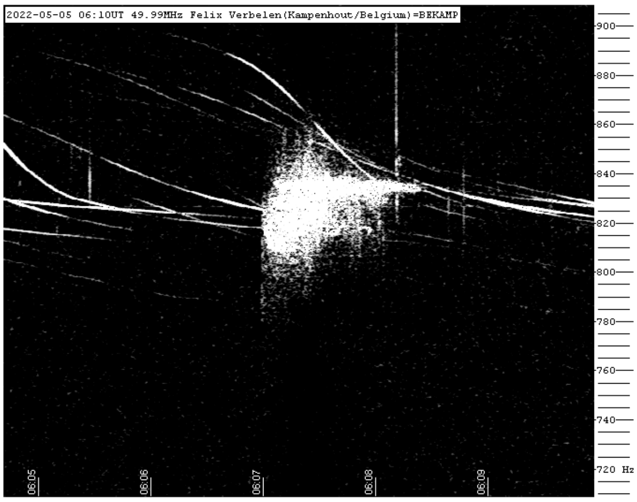


*Figure 9* – Meteor reflection 05 May 2022, $06^{h}10^{m}$ UT.

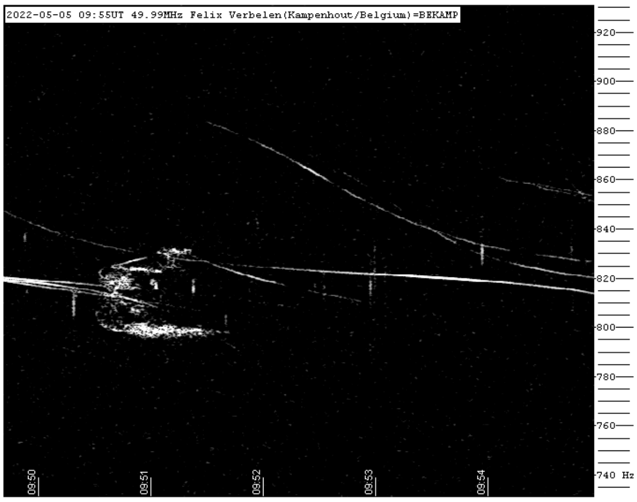


*Figure 10* – Meteor reflection 05 May 2022, $09^{h}55^{m}$ UT.

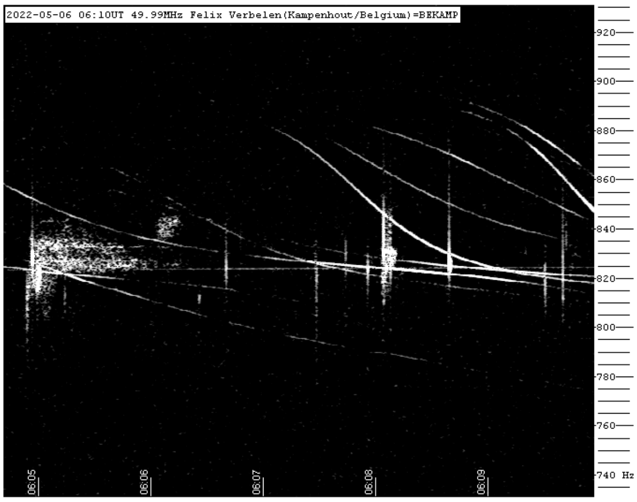


*Figure 11* – Meteor reflection 06 May 2022, 06$^{h}$10$^{m}$ UT.

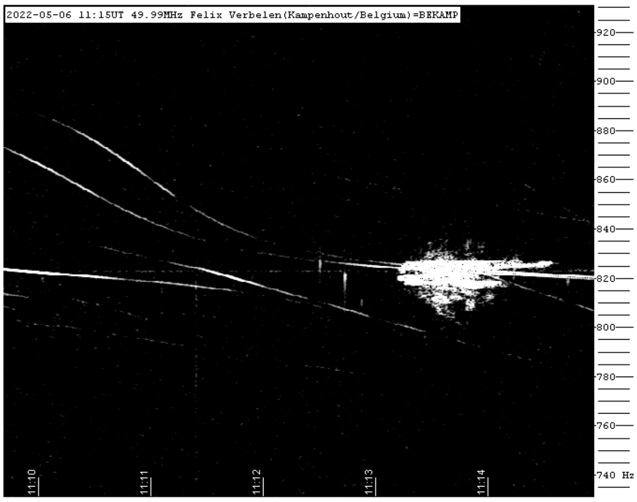


*Figure 12* – Meteor reflection 06 May 2022, 11$^{h}$15$^{m}$ UT.

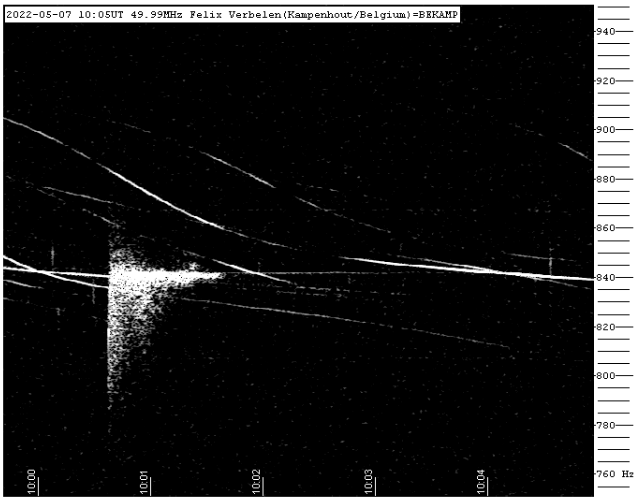


*Figure 13* – Meteor reflection 07 May 2022, 10$^{h}$05$^{m}$ UT.

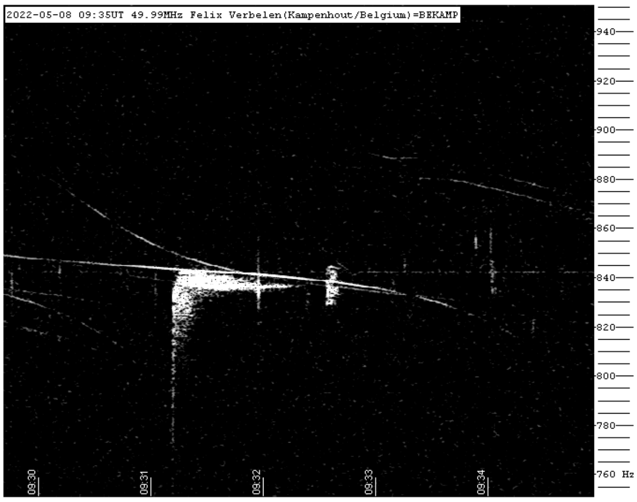


*Figure 14* – Meteor reflection 08 May 2022, 09$^{h}$35$^{m}$ UT.

*Figure 15* – Meteor reflection 08 May 2022, 09$^{h}$50$^{m}$ UT.

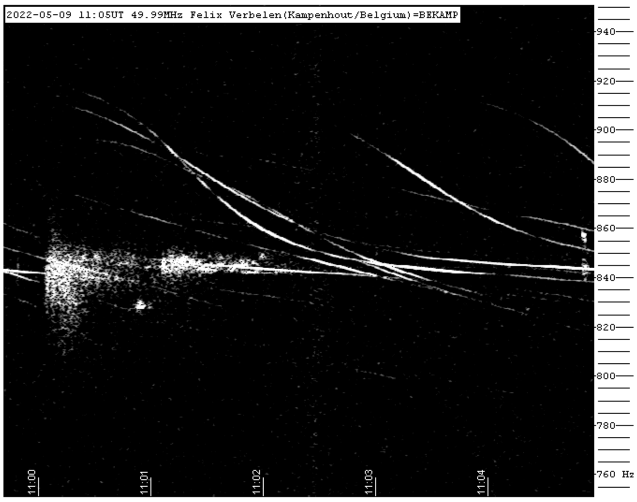


*Figure 16* – Meteor reflection 09 May 2022, 11$^{h}$05$^{m}$ UT.

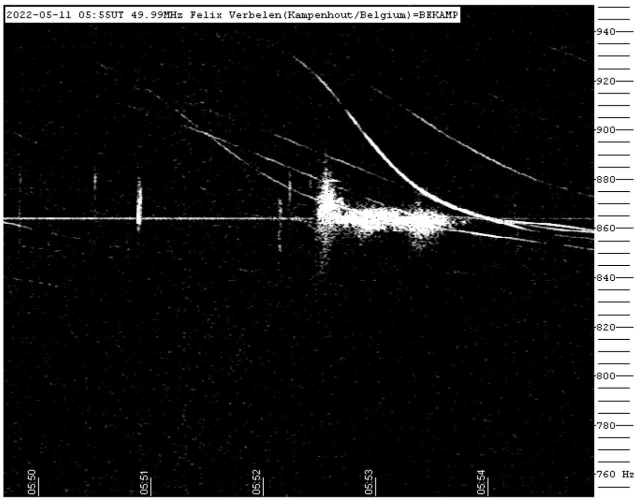


*Figure 17* – Meteor reflection 11 May 2022, 05$^h$55$^m$ UT.

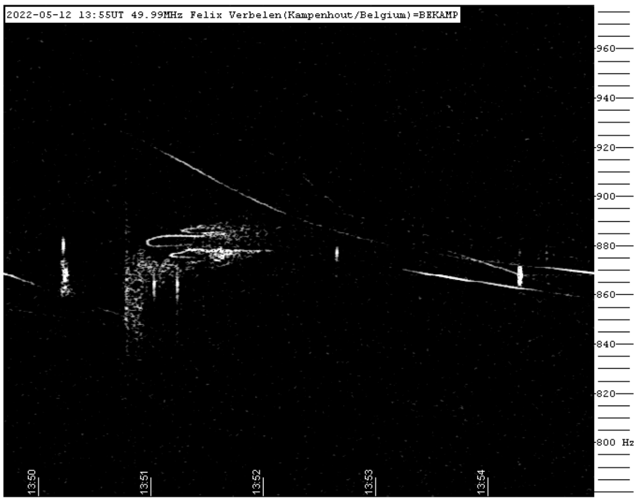


*Figure 18* – Meteor reflection 12 May 2022, 13$^h$55$^m$ UT.

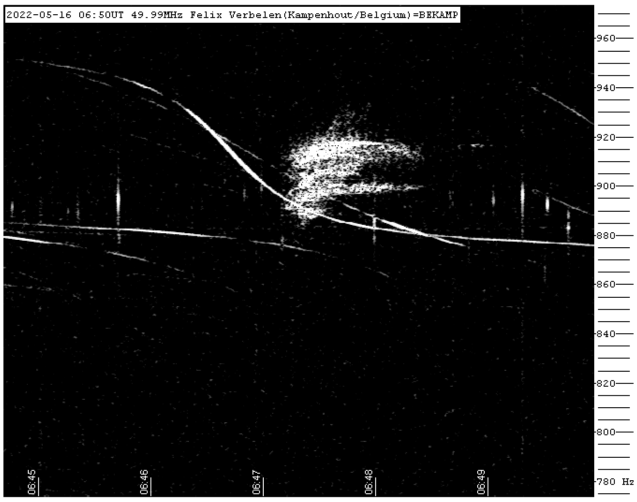


*Figure 19* – Meteor reflection 16 May 2022, 06$^h$50$^m$ UT.

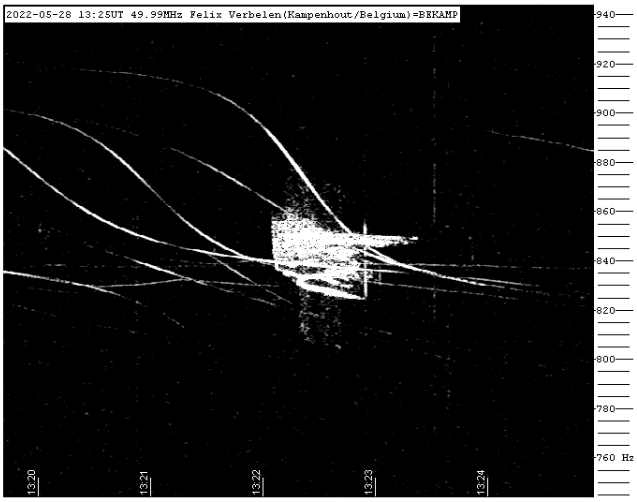


*Figure 20* – Meteor reflection 28 May 2022, 13$^h$25$^m$ UT.

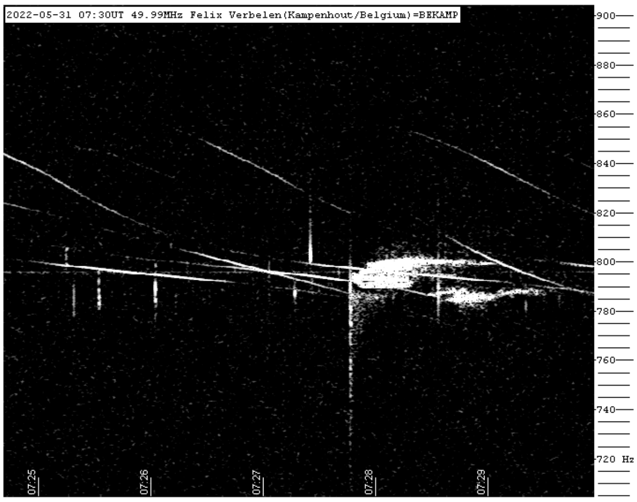


*Figure 21* – Meteor reflection 31 May 2022, 07$^h$30$^m$ UT.

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## *Contributing to this issue:*

- *Abu-Jami I.*
- *Aceituno J.*
- *Adwan A.O.*
- *Aimee A.I.*
- *Al-Naimiy H.*
- *Alnaser M.*
- *Al-Owais A.*
- *Ávila D.*
- *de Guindos E.*
- *Eisa Yousef Doostkam Y.*
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Valašské Meziříčí Observatory, Vsetínská 78, 75701 Valašské Meziříčí, Czech Republic

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