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Stacked image of the "Ibros" fireball as recorded from Calar Alto on 2021 July 23 at 22h00m40.8 ± 0.1s UTC (Credit J.M. Madiedo)

Contents

Esko Lyytinen (1942–2020)

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When Esko Lyytinen heard about the start of MeteorNews at the beginning of 2016 he was among the first to respond, to support and to encourage the new initiative with a report about a fireball over Finland (Lyytinen, 2016a). Later that year Esko published an article about his October Camelopardalis outburst model (Lyytinen, 2016b). Whenever advice was asked for reviewing articles in MeteorNews or about outburst predictions, Esko always replied quickly, providing plenty of information, always eager to discuss topics in detail. In 2019 Esko sent a draft for an article about the likely alpha Monocerotids outburst on the morning of November 22, 2019 (Lyytinen and Jenniskens, 2019), when the article was already online, he was still working to improve his ephemerids and asked to include some last-minute updates of the article. The article on MeteorNews caught the interest from CNN, National Geographics, etc. and got an exceptional attention worldwide. The predicted alpha Monocerotids outburst did materialize, be it less spectacular than what the media had suggested (Roggemans et al., 2020). Esko planned to look up a number of other past outburst predictions to highlight these in MeteorNews but needed to find some time to check his notes and calculations.

Figure 1 – Esko on the photograph titled 'my first telescope' (source: Esko's own photograph album).

Figure 2 – Photograph of the comet Seki-Lines of 1962 (photo taken by Esko on 16 April 1962, source: Esko's own photograph album).

On Christmas Eve 2020 Esko Lyytinen, 78 years old, passed away at the Malmi Hospital in Helsinki following sudden heart surgery and the planetary science community lost one of the most dedicated and passionate meteor researchers.

Esko Lyytinen was born on 6 November 1942 in Helsinki, Finland. He lived most of his childhood in Kuru, today part of Ylöjärvi. His family moved to Helsinki in the 50s, where Esko lived for the rest of his life. His father taught and worked in forestry and public administration. His mother had a Master's degree in biology and natural sciences and was a teacher for a short time, before she devoted her life to the family and bringing up the children.

A deep love of nature was very much part of the family ethos.

From a very early age Esko was fascinated by the stars and the universe. Esko was 14 when the Earth's first artificial satellite, Sputnik 1, was launched in 1957 and already at that age he could figure out exactly where and when to look to see it in the sky. He would get the whole family to look at it the very first night it was visible. While for the rest of the family it was a one-night spectacle, Esko continued observing it as well as subsequent satellites. It may come as no surprise then that years later he named his first model of meteoroid stream formation "the satellite model of comets" (Lyytinen E., 1999).

He outgrew his very first telescope quickly and built his own reflecting telescope. He ground the main mirror himself and managed to source an eyepiece. He built the frame with whatever leftover planks he could find. It was not pretty but it worked. Its scruffy appearance did not stop it being placed in a prime spot on the small balcony in the family's home. This inventive approach would be repeated many times with the various other contraptions he created throughout his life. Antennae, cameras, directional microphones, metal detectors and so on would be taped or glued together with whatever spare objects he could find or source to get the job done. Wherever they needed to go, be it the front of the house, on the roof, installed on a laptop, or literally attached to his own forehead, the look did not matter as long as the concept worked.

Esko's interests in photography, astronomy and amateur radio converged in the 60s when he started receiving weather satellite imagery with his equipment. This was at a time when others would see such images only rarely printed in newspapers. Esko was always extraordinarily capable of applying and combining his fields of knowledge to new problems and filling in the gaps by persistently educating himself.

While the far distance of space fascinated Esko, he was not enthusiastic about traveling long distances back on Earth. In November 1998 Esko had chosen to holiday with his family at Madeira over a 'meteor storm chasing' trip to China at the time when the Leonid meteor shower was predicted to peak and be most visible. He believed that his holiday location was far from the ideal spot to observe the Leonids; the peak of the shower was calculated to be at a time when the opposite side of the Earth was facing the dust trail that produced it. Nevertheless, Esko got up that night and to his surprise, and against the predictions, he was treated to a spectacular meteor shower, not only visible from an area not predicted but also earlier than expected.

As it turned out, the shower had peaked earlier than predicted and Esko was close to an ideal location to observe it. He was perplexed at how inaccurate and far "off-schedule" the predictions had been and set his mind to developing better comet dust trail models on his home computer. Soon after that, Esko indeed came up with an independent model of the formation and evolution of dust trails from comets (Lyytinen, 1999).

Esko went on to successfully forecast and (post)-predict many meteor outbursts. His dust trail predictions yielded many important publications, including improved 2001 Leonid storm predictions from a refined model (Lyytinen et al., 2001). The work was continued and for the 2003 and 2004 predictions Esko teamed up with other researchers. Hence, different models were compared with older cometary trails (Vaubaillon et al., 2003). In the following years, much work was done to try to improve the predictions using possible changes from radiation pressure. Observed ZHR values were quite low, but different predicted dust trail encounters could indeed be recognized in the observations (Vaubaillon et al., 2004; Trigo-Rodríguez et al., 2006).

In 2000, Esko started a very fruitful collaboration with meteor astronomer Peter Jenniskens that led to 33 co-authored publications. "*I first interacted with Esko leading up to the 2000 Leonids,*" recalls Jenniskens. *"Esko analyzed the effects of radiation on the moving particles, which moved the dust trails near Earth's orbit enough to cause quite different predictions that year.*"

"*Later that year, the Ursid meteor shower was expected to show an unusual meteor outburst, which occurred when the parent comet 8P/Tuttle was at aphelion, and Esko worked out why that was. We published our predictions of the peak time in Jenniskens & Lyytinen (2000) and the outburst was confirmed (Jenniskens & Lyytinen, 2001; Jenniskens et al., 2002).*" Calculations on the Ursids by Esko and Markku Nissinen were published in a table in Jenniskens' book "Meteor Showers and Their Parent Comets" (Jenniskens, 2006; Jenniskens et al., 2006).

"*In the following years, I directed Esko's attention to long-period comet dust trails, like the one that caused the alpha Monocerotid outburst in 1995. Again, Esko was able to model key features of the observations. His results on long-period comets were published in the journal Icarus (Lyytinen & Jenniskens, 2003). Ever since I have turned to Esko for future predictions when a new long-period comet shower was seen. Esko predicted a shower from comet C/1976 D1 (Jenniskens & Lyytinen, 2003) and I traveled to South Africa to try to confirm that, but the weather and far southern declination of the radiant proved too big a challenge. Even this campaign led to greater collaborations. Examples being studies of the October Camelopardalids and the 2008 September Perseids (Jenniskens et al., 2005, 2006, 2008). Most recently, Esko found a clever way to use meteor shower observations to measure the orbital period of poorly observed long-period comet Grigg-Mellish (Jenniskens et al., 2020).*"

With the return of comet 8P/Tuttle in January 2008, close to the 2007 encounter, further modeling of the Ursid shower was carried out. In addition, there was even a prepared airborne observing campaign from NASA Ames Research Center to observe the Ursid shower over the Canadian arctic. This was fascinating and very inspiring for Esko to follow (Jenniskens et al., 2007). This work found there were two predicted encounters with old trails, from years 1466 and 1533 and they were coinciding in time. The trail of 1466 produced an outburst in 2008. This allowed Esko to update the prediction by running the model with the increased number of particles (Lyytinen and Nissinen, 2009; Vaubaillon et al., 2009a, 2009b).

When comet 17P/Holmes exploded in October 2007, Esko immediately realized the possibility to observe the dust trail produced by the explosion in the future. In the 'Tähdet ja Avaruus' article of the comet explosion Esko suggested that a phenomenon "shaped like an hour-grass" may appear at the explosion site at the next revolution of the trail. Esko expected that this phenomenon may be a vivid reminder of the past explosion event. Unfortunately, the phenomenon was too dim to be seen without a powerful telescope and this did not prove to be as amazing sight for the public as had been hoped, compared to if the trail would have been much brighter and easier to see (Lyytinen et al., 2014; 2015). When the material from the explosion had travelled half revolution to the other common node of the particle's orbits Esko and Markku Nissinen had succeeded in observing the phenomenon in the southern sky using remote controlled telescopes at the Siding Spring Observatory in Australia (Lyytinen et al., 2013a, 2013b).

The hobby-motivated research soon made Esko famous in the meteor, and later, in the planetary science community. In 2003 Esko was invited to review and serve as an opponent of the PhD thesis defended by Jérémie Vaubaillon

Figure 3 – Photograph of Esko made in July 2004 near Savonlinna, in Eastern Finland. The picture is taken during the comparison test with metal detectors — a commercial version (which Esko is holding) and the metal detector which Esko had made himself (on the ground). (Images credit: Markku Nissinen).

in the Paris Observatory in France (Esko declined the invitation for personal reasons). Later (in 2014) the International Astronomical Union (IAU) named the asteroid 15699 Lyytinen (1986 VM6) to highlight his long-term outstanding contribution to planetary science[1]. Often, he would be contacted concerning the annual shower calendar as well as his model calculations that he could graciously perform for meteor showers. Esko would readily share findings about meteor events he had analyzed as well as his ideas on meteoroid stream evolution.

It was while he was up at his summer house in the small town of Vesanto in central Finland that Esko would engage in his latest attempts of pushing both radio and video methods of meteor detection. His temporary modification of his video camera to push the infrared end led to fascinating videos of nocturnal birds and waterfowl migrations and aurora. Although these may not have always been the results, Esko was looking for the most; they were unique and charming nonetheless. Esko was a true tinkerer as seen in a photo of a bay of UHF antennas duct taped to a hockey stick. Despite its comical look, it allowed Esko to pursue his goals quicker and, as always, it worked.

Esko was always eager to testing, using or even improving the software with his brilliant ideas, be it the 'α-β model' (Gritsevich 2009; Lyytinen and Gritsevich, 2016), orbit determination with 'Meteor Toolkit' (Dmitriev et al., 2015a; 2015b) or anything else. In fact, the diversity of different ideas and tools that Esko had used, and developed will significantly impress many.

Figure 4 – The Annama fireball — leading to the first meteorite recovery based on the Finnish Fireball Network observations. Photo from Kuusamo, Finland on April 19th 2014. (Image credit: Asko Aikkila).

Esko would gladly engage in complex video calibration of any unknown camera if it happened to capture an interesting meteor case in any part of the world (Lyytinen and Gritsevich, 2016a; Trigo-Rodríguez et al., 2015; Hildebrand et al. 2018; Larionov et al. 2018; Meier et al., 2020). In fact, when we received a physical dash-cam that captured the daylight Osceola fireball in the US, its robust study with stars on Finnish skies practically did not improve on Esko's previously made remote calibration of the camera.

Figure 5 – The photograph of the first recovered fragment of the Annama meteorite taken by Esko the same day as it arrived to Finland, 1st of June 2014 (Esko biked to MG the same day to see the sample and this is when he used his phone to make this picture of the sample lying on the kitchen table). The sample was later given to the Ural Federal University meteorite collection in Russia.

[1] A new proposal has been put forward to exceptionally name the Swedish iron case observed on November 7, 2020 following the last Esko's birthday on this planet as Esko Lyytinen. The present article comprises a lot of justifications for that exceptional reasoning. Even if not achievable, that will be an association that we will always carry with those of us who knew and worked with him.

Figure 6 – Top: The photograph of the second recovered fragment of the Annama the day it was donated for the display at the Finnish Museum of Natural History. Bottom: Esko Lyytinen, Maria Gritsevich and the Annama meteorite fragment just placed on the museum display. (Images credit: Jarmo Moilanen).

Various smart techniques were proposed by Esko in processing meteor observations, including the height correction method to account for real atmospheric conditions (Lyytinen and Gritsevich, 2016b). Similarly, the atmospheric refraction correction method allows for retrieving a fireball position with high accuracy without the need to consider at which distance from the observer (or height above the Earth's surface) the fireball is situated (Visuri et al., 2020).

Finland is a relatively small and not well-populated country, with an area elongated from south to north of ~338000 km². It is Europe's most heavily-forested country and subsequently it has one of the most difficult terrains for meteorite recovery. In addition, Finland's water area is vast: 187888 lakes and ponds with an area of more than 500 m², as well as a total of 25000 km of rivers. The total area of water bodies takes ~10% of the area of the country and forests take ~74% of the land area. Despite the effort, no meteorites from the observed falls were recovered in Finland within the last 50 years. Out of the 5 historically witnessed meteorite falls (and a total of 13 meteorite falls), the last one, Haverö, was collected in 1971.

Despite this, Esko played an essential role in the recovery of several meteorites abroad, including in the two neighboring countries of Russia and Sweden. The most prominent successful cases were the recoveries of 3 meteorite falls made with the engagement of the FFN: Annama, Ozerki and that of the asteroid 2018 LA (Gritsevich et al., 2014, 2015; Trigo-Rodríguez et al., 2015; Lyytinen and Gritsevich, 2016b; Kohout et al., 2017; Maksimova et al., 2020; Moilanen et al., 2021; Jenniskens et al., 2021). In addition, right post-predictions of the strewn field were made for the Chelyabinsk, Osceola, Flensburg meteorites, and more, including the Swedish iron case observed on November 7, 2020. A number of important physical aspects were proposed and specified in treating the fireball trajectories including the dark flight stage (Moilanen et al., 2021).

In 2013 an analysis of a potential meteorite-dropping fireball spotted over the south of Spain in 2011 was presented at the LPSC (Rodriguez A. et al., 2013). A software tool developed by Esko (fb_entry) was unique and very helpful to obtain information about this single-station event. Esko has also contributed to the book published in 2017 (Blanch E. et al., 2017). This was a chapter in the book "Assessment and Mitigation of Asteroid Impact Hazards" (Trigo-Rodríguez et al. 2017) focused on the detection and analysis of nocturnal and diurnal bolides from Ebre Observatory in Spain.

Esko was certainly much more than his extensive meteor work. Even though he lived in Helsinki for most of his life and was always very capable with technology, he loved being in nature, a lifestyle he had gotten used to in his childhood. Most summers he would retreat to the family summer house in Vesanto, situated by the lake and surrounded by thick forests. He would fish and forage for food, collect the birch sap in spring and could concentrate on his research and hobbies in peace. In addition to astrophotography, Esko also loved photographing nature and birds in particular and was also active in bird ringing in his earlier years. One of the themes that kept Esko extremely excited was the search for planet X.

Figure 7 – Photograph of Esko hearing birds sing taken right outside the family summer house in Vesanto in 2011 (image credit: Leena Elliot).

Figure 8 – Esko Lyytinen shortly following the recovery of the Annama meteorite in 2014. (Image credit: Emma Herranen / Tähdet ja avaruus, Ursa).

In 2010 Esko participated in developing the iPhone application "Hear Birds Sing". It changed the frequency of high-pitched sounds, like grasshoppers and high-pitched birds, to lower frequencies, which would be better hearable in real time by people with reduced hearing abilities, a challenge that Esko himself faced in later life. The users could have heard the sounds of high-pitched animals that otherwise would be impossible to hear using headphones without applying a delay. This application was popular in the App Store and was heavily in use around the world for a long time. Unfortunately, it is not available anymore. Esko has also developed an Android version of this application.

Many readers may have scratched their head by this point wondering, "Wow! If this was what Esko achieved in retirement, then what did he engage with in his professional career?!" That, however, is another story entirely and would require a larger volume. The story that has been just explained here is truly unique. Because of its unusual nature it may not resemble a stretch of biography what could have been originally envisaged, but truly captures the contributions Esko made to our lives and also to science.

Beyond science, Esko was a loving father, husband, and grandfather; a slightly introverted, private man who was always helpful to others, a sincere giver/sharer and a real mentor to many of us, and presumably to the many others that he knew. Besides his great enthusiasm he always had empathy, modesty and (only) kind, optimistic and positive words in what he wrote or spoke. Even on his very last Christmas Eve day Esko's messages were "Sairaalassa kaikki hyvin. Everything well. Hyvää Jouluattopäivää 🙂🙏" (in the morning) and "Kiitos Maria !💥🌲" (in the afternoon). Esko certainly already is and will be greatly missed.

Over the past years Esko taught us much about both meteors and life in general. The last lesson Esko taught was the hardest lesson of all; how harsh it makes us feel to lose such a great friend, such a brilliant mind, and how much rethinking it demands.

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Perseid outburst 2021

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An unexpected outburst of Perseids was detected by low-light video observations on August 14, 2021. The outburst peaked at solar longitude 141.474 ± 0.005 degrees (equinox J2000.0) and the activity profile had a Full-Width-at-Half-Maximum of 0.08 degrees solar longitude and a peak rate of ZHR = 130 ± 20 per hour above the normal ~45 per hour annual Perseid activity. The Perseids had a steeper magnitude size distribution index than the normal annual shower component. The activity profile is similar to that derived from visual and forward meteor scatter observations. This activity may be related to the earlier smaller enhancements observed in 2018 and 2019.

1 Introduction

In 2018, visual observers reported a narrow peak of Perseid shower activity around solar longitude 140.95°, about ~30 hours after the traditional Perseid maximum, with a peak of about ZHR = 25 per hour above the normal Perseid activity of ZHR ~ 45 per hour at that time (Miskotte 2019). In 2019, a similar peak was recorded by forward meteor scatter observations collected by the International Project for Radio Meteor Observation. That year, the outburst peaked at solar longitude 141.02° with a peak ZHR ~30 per hour above normal activity (Miskotte 2020a; 2020b). Here, we report the detection of a more significant outburst on August 14, 2021 (Jenniskens, 2021). This outburst was not anticipated from known 109P/Swift-Tuttle dust trail encounters

2 CAMS low-light video observations

The Perseids are best observed from the northern hemisphere. The 2021 outburst happened between 6h and 12h UTC on August 14, 2021, at a time best suited to the CAMS video-based meteoroid orbit survey networks in the United States. The networks triangulated meteors using low-light video cameras and determined the meteor's radiant and speed in a continuous night time surveillance. The weather was mostly clear for networks in Texas (coordinated by W. Cooney and including D. Selle, F. Cyrway and J. Brewer) and California (P. Jenniskens, D. Samuels, J. Albers, E. Egland, B. Grigsby and J. Wray). CAMS Mid-Atlantic (coordinated by P. Gural), CAMS Florida (A. Howell), CAMS Arkansas (L. Juneau) and LO-CAMS in Arizona (N. Moskovitz) also observed some of the meteors under partial clear skies (c.f. CAMS-website[2] for date of August 14).

Early results from the new CAMS Texas network in mostly clear skies and the CAMS California network in clear skies show an activity profile with peak Zenith Hourly Rate ZHR = 130 ± 20 per hour on top of normal ZHR = 40–45 per hour annual Perseid activity (*Figure 1*). The Full-Width-at-Half-Maximum of the fitted Lorentzian profile is 0.08 ± 0.01 degrees solar longitude. The peak occurred at solar longitude 141.474 ± 0.005 degrees (equinox J2000.0), corresponding to 8.2^h UTC on August 14. The combined magnitude distribution index was 3.59 ± 0.36, compared to 2.94 ± 0.04 for the annual component in other years at this solar longitude.

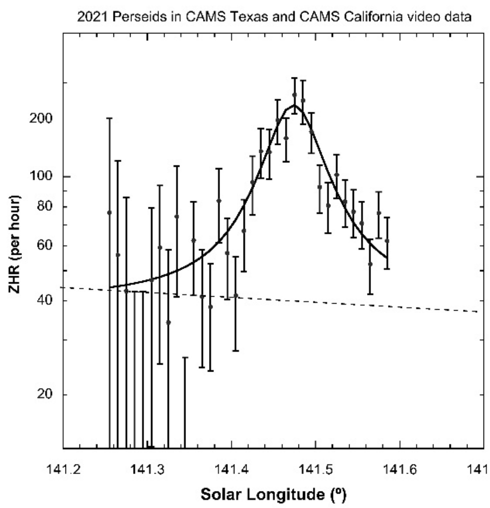

Figure 1 – 2021 Perseid rates according to CAMS Texas and CAMS California video data. The vertical scale is logarithmic. The dashed line is the level of normal annual Perseid activity.

3 Comparison to other observations

Pierre Martin, visually observing from Ottawa, Canada, reports "*I just witnessed very strong Perseids activity Aug 13/14 06-09 UT. Multiples Perseids per minute with many bursts. Sometimes 3-4 in a second. Much busier than previous night but I had a great sky mag 6.7. Was this an*

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

unexpected outburst? I've never seen so many Perseids a full day after the normal peak. I think the rate might have been as high as 300/hr but I'll know more when I listen to the tape. Average brightness, perhaps a bit below average. There was a very large number of mag 4 and 5 meteors but still good numbers of +1s and 0s. Brightest we're –3". Starting at 6^h UTC. He observed until 9^h UTC, under clear skies with star limiting magnitude 6.7. From his 5-minute interval counts, we calculated a peak ZHR = 210 ± 20 per hour at solar longitude 141.474 ± 0.005 deg. The visually observed meteors follow the video data profile well (*Figure 2*).

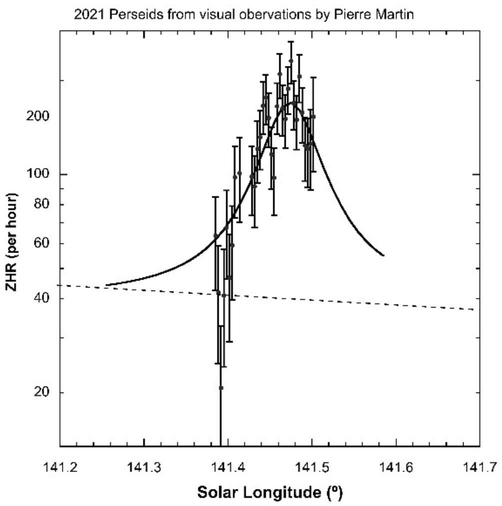

Figure 2 – 2021 Perseids from visual observations by Pierre Martin.

This also confirms radio forward meteor scatter observations posted by H. Ogawa of the International Project for Radio Meteor Observation[3] (*Figure 3*). A compilation of rates from 49 observers in 14 countries saw the detection count increase above normal levels after 6.4^h UTC (141.40 deg solar longitude), and peak at about 8.8^h UTC (141.49 deg) at a level of 3 times the Perseid peak level, before declining to normal levels at 12.5^h UTC (141.65 deg solar longitude). Combined Zenith hourly rates peaked around ZHR = 210 per hour[4], in good agreement.

The outburst cannot be identified yet with a known dust trail crossing from 109P/Swift-Tuttle. On the other hand, the width of the outburst is similar to that of past Perseid Filament returns (Jenniskens, 2006). The Filament is thought to be an accumulation of dust in mean-motion resonances from many past returns. That could perhaps mean that this dust was directed into Earth's path this year. These observations may help better understand the origin and evolution of that dust component.

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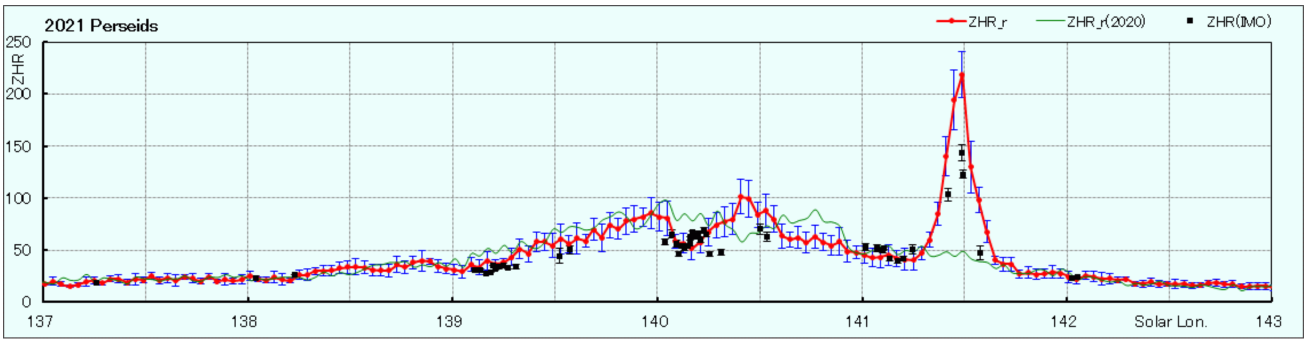

Figure 3 – ZHR_r presented by Hirofumi Sugimoto. $ZHR_r = CHR_r$ * 1/sin(h) (h:radiant elevation),(excluding h < 20°.), CHR_r is the number of meteors with the sporadics being substracted from the total. The sporadic meteor activity is calculated from the past data during a period of 10 days.

[3] https://www.iprmo.org/flash/perseids-2021.html

[4] http://www5f.biglobe.ne.jp/~hro/Flash/2021/PER/index-e.htm

Enhanced κ-Cygnid (KCG#0012) activity in 2021

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The kappa Cygnids are absent in most years, but the years 2020 and 2021 fit in a 7-year sequence of past returns when the shower was active. Modest activity was detected in 2020. Now, Northern-hemisphere networks of the CAMS video-based meteoroid orbit survey are detecting stronger activity of the kappa Cygnids than in 2020. In past returns, the shower peaked on August 13, a few days from now, close to the peak of the Perseids. The shower is known to produce occasional fireballs with multiple flares.

1 Introduction

The kappa Cygnids are an episodic shower, absent in most years, but clearly present in some. In those years when the shower is active, the radiant emerges from the antihelion source in late June, then moves gradually north towards Cygnus, where activity peaks in mid-August.

Following an outburst in 2007, Masahiro Koseki first noticed that the active years came in a 7-year sequence (Koseki, 2014) and concluded that the shower might return again in 2021 (Koseki, 2020). Indeed, I find that since the first sighting in 1879, the kappa Cygnids have returned in 1893, 1950, 1957, 1985, 1993, 1999, 2007, and 2013/2014, quite regularly every 7.063 ± 0.019 years on average.

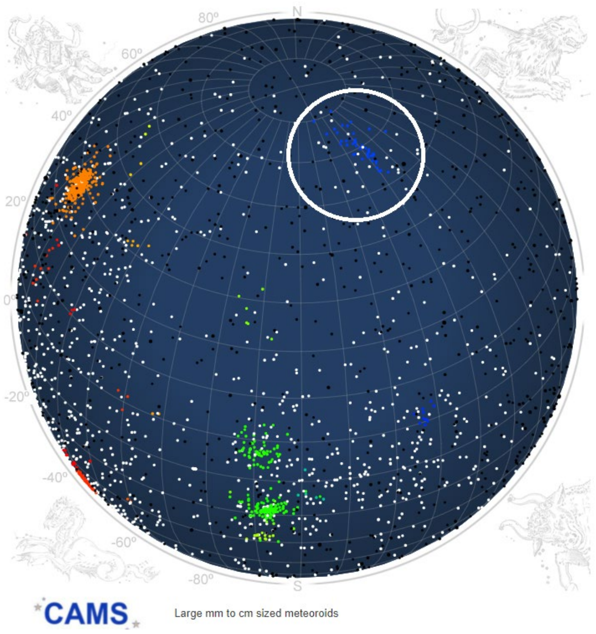

Figure 1 – Radiant plot displaying 41 κ-Cygnids (KCG#0012) recorded by CAMS networks between 2021 August 9.5 and 10.5 UT.

The peak of the shower coincides with that of the Perseids and, back in 1993, the kappa Cygnids photobombed the outbursting Perseids. The shower creates occasional fireballs that have multiple flares and are very photogenic. Observers in southern France noticed a –6 to –7 magnitude kappa Cygnid several nights in a row (Langbroek, 1993).

The years 2020 and 2021 fit in that sequence. The CAMS video network detected some kappa Cygnid activity in 2020. Now, CAMS BeNeLux (C. Johannink) reports that 2021 activity is stronger than that of 2020 (*Figure 1*).

2 Enhanced activity in 2021

All northern hemisphere networks of the video-based meteoroid orbit survey CAMS (Cameras for Allsky Meteor Surveillance) have detected the shower. There are CAMS networks in the USA (coordinated by P. Jenniskens, A. Howell, N. Moskovitz, J. Juneau, T. Beck, P. Gural, and W. Cooney), the BeNeLux (C. Johannink), and the United Arab Emirates (M. Odeh). Meteors filmed from two or more locations are tracked and triangulated to determine their path in the atmosphere. The radiant is the direction from which the meteors are seen to approach. The radiant plots for the combined network, displayed on the celestial sphere, can be consulted on the CAMS website[5] selecting the date in the calendar.

The shower was first detected in late June, the radiant gradually moving to higher declination. On the night of August 8 (solar longitude 135.6 deg), the shower radiant was elongated in a north-south direction and located just east of Vega at R.A. = 282.9°, Decl. = +44.1° (equinox J2000.0), with shower meteors having geocentric velocities of 21.6 km/s. These are relatively slow meteors.

In past returns, the shower has a shallow peak on August 13 (solar longitude 140.8), close to the peak of the Perseid meteor shower. The radiant then will be at R.A. = 285.6°, Decl. = +51.4° near kappa Cygni.

The shower makes a great target for photographic and spectroscopic observations and will delight the casual viewers of this year's Perseid meteor shower in the days to come.

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

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Fireballs recorded between May and July 2021 by the Southwestern Europe Meteor Network

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This work focuses on the analysis of the most remarkable bolides recorded over the Iberian Peninsula and neighboring areas in the framework of the Southwestern Europe Meteor Network (SWEMN) and the SMART project. These events were spotted from May to July 2021.

1 Introduction

The Southwestern Europe Meteor Network (SWEMN) is a research project coordinated from the Institute of Astrophysics of Andalusia (IAA-CSIC) with the aim to analyze the Earth's meteoric environment. For this purpose, we monitor the interaction of meteoroids with both the Earth and the Moon. This network is also integrated by researchers from the Complutense University of Madrid (UCM), the Public University of Navarre (UPNA), and the Calar Alto Observatory (CAHA). With the recent deployment of a new SWEMN meteor-observing station at the facilities of La Casa de las Ciencias de La Coruña (Galicia, Spain), this Institution has started to collaborate with this research network in June 2021.

In order to identify and analyze meteors in the Earth's atmosphere, SWEMN develops the Spectroscopy of Meteoroids by means of Robotic Technologies (SMART) survey (Madiedo, 2014; Madiedo, 2017). SMART was started as a professional project in 2006. But since some amateur astronomers expressed their interest in establishing some kind of collaboration with us, we decided in 2021 to convert SMART into a Pro-Am project.

Besides, from IAA-CSIC we conduct the MIDAS survey (Moon Impacts Detection and Analysis System). MIDAS uses the Moon as a laboratory that provides information about meteoroids hitting the lunar ground (Ortiz et al., 2015; Madiedo et al., 2018; Madiedo et al., 2019a). A strong synergy has been proved to exist between this survey and the SMART project (Madiedo et al., 2015a,2015b; Madiedo et al., 2019b).

This work presents the most remarkable fireball events recorded along May, June, and July 2021 by our systems.

2 Instrumentation and methods

The bolides analyzed in this work were recorded by means of analog CCD video cameras manufactured by Watec. (models 902H and 902H2 Ultimate). 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 90 × 40 degrees. A detailed description of this hardware and the way it operates was given in previous works (Madiedo, 2017).

The atmospheric path and radiant of meteors, and also the orbit of their parent meteoroids, were obtained with the Amalthea software, developed by J.M. Madiedo (Madiedo, 2014). This program employs the planes-intersection method (Ceplecha, 1987). However, for Earth-grazing events atmospheric trajectories are obtained by Amalthea by means of a modification of this classical method (Madiedo et al., 2016). Emission spectra were analyzed with the CHIMET software (Madiedo, 2015a).

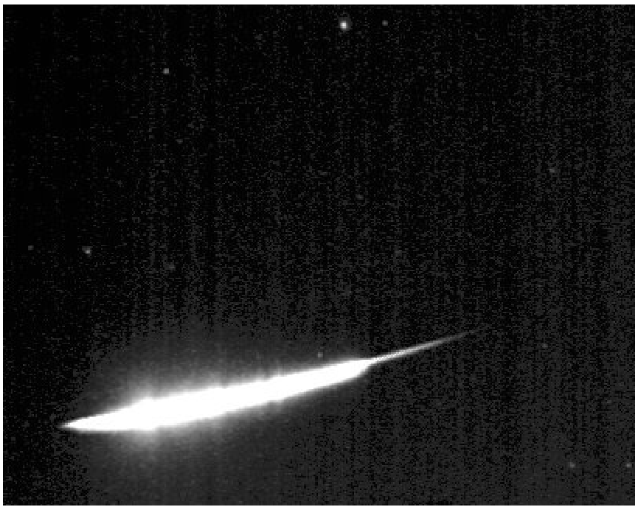

Figure 1 – Stacked image of the SWEMN20210516_223207 “Benicasim” fireball as recorded from the SWEMN meteor-observing station at La Hita Astronomical Observatory.

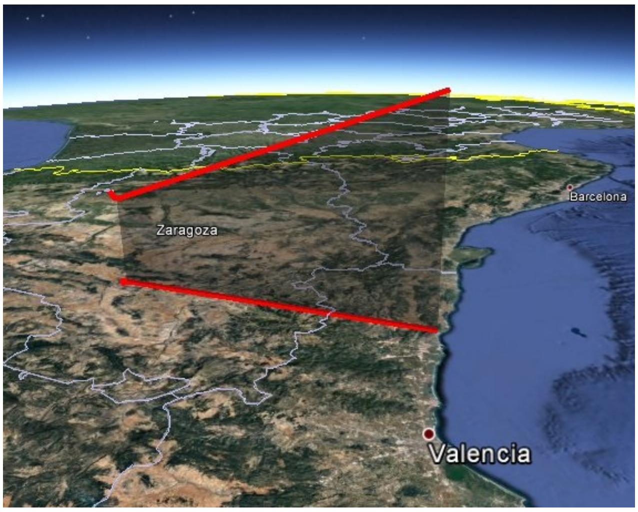

Figure 2 – Atmospheric path and projection on the ground of the trajectory of the SWEMN20210516_223207fireball.

3 The 2021 May 16 bolide

At $22^h32^m07.2 \pm 0.1^s$ UTC on May 16, we recorded a bolide from the SWEMN stations operating at La Hita, La Sagra, and Calar Alto. The event had a peak absolute magnitude of –9 ± 1 (*Figure 1*). This fireball was included in our new digital meteor database (Madiedo et al., 2021) with the code SWEMN20210516_223207.

Table 1 – Orbital data (J2000) of the progenitor meteoroid of the SWEMN20210516_223207 fireball.

a (AU)	2.29 ± 0.14	ω (°)	317.1 ± 0.7
e	0.926 ± 0.005	Ω (°)	55.96078 ± 10^{-5}
q (AU)	0.168 ± 0.004	i (°)	8.5 ± 0.2

Atmospheric trajectory, radiant and orbit

The analysis of the recordings revealed that this bolide overflew the provinces of Castellón (region of Valencia) and Teruel (region of Aragón). We obtained a pre-atmospheric velocity for the progenitor meteoroid of $v_\infty = 37.7 \pm 0.4$ km/s, with the apparent radiant at the equatorial coordinates $\alpha = 256.1°$, $\delta = -17.21°$. The meteor began at a height $H_b = 94.4 \pm 0.5$ km, and ended at an altitude $H_e = 38.9 \pm 0.5$ km. The zenith angle of this trajectory was of about 69°. Since the initial point of the bolide’s path was almost over the vertical of the town of Benicasim (Castellón), we named the fireball after this location. The atmospheric path of the meteor and its projection on the ground are shown in *Figure 2*.

The calculated geocentric velocity of the progenitor meteoroid yields $v_g = 35.8 \pm 0.4$ km/s. The orbital parameters of this particle before its encounter with our planet are shown in *Table 1*, and this orbit is drawn in *Figure 3*. The information found in the IAU meteor database[6] shows that the fireball belonged to the phi Ophiuchids (USG#0809). This poorly-known meteoroid stream produces every year a display of meteors peaking around May 11. NEO 2015 DU180, a potentially hazardous asteroid (PHA), has been proposed as its parent body (Amaral et al., 2020). However, according to the calculated value of the Tisserand parameter with respect to Jupiter ($T_J = 2.7$), the meteoroid followed a Jupiter Family Comet orbit before impacting the Earth’s atmosphere.

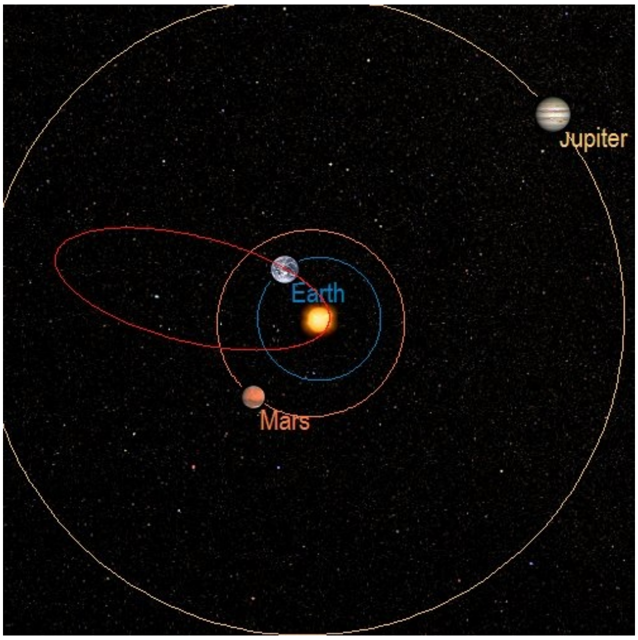

Figure 3 – Projection (dark red line) on the ecliptic plane of the orbit of the parent meteoroid of the SWEMN20210516 “Benicasim” fireball.

Emission spectrum

The emission spectrum of the SWEMN20210516_223207 fireball was recorded by our spectrographs from the astronomical observatories of Calar Alto and La Hita. As in previous works, this spectrum was analyzed with the ChiMet software, which calibrates the signal in wavelength and then corrects it by taking into account the spectral sensitivity of the device (Madiedo, 2015b; Passas et al., 2016). The calibrated spectrum is shown in *Figure 4*, where the most remarkable contributions have been highlighted. The majority of these correspond to neutral iron, as usual in

[6] http://www.astro.amu.edu.pl/~jopek/MDC2007/

meteor spectra (Borovička, 1993; Madiedo, 2014). Thus, we have identified the emissions from Fe I-4, Fe I-41, Fe I-318, Fe I-15, and Fe I-686. The most important emissions are those of Fe I-4, Ca I-2, and the Mg I-2 triplet (516.7 nm). The Na I-11 doublet is also remarkable, and the contribution from atmospheric N2 is present in the red part of the spectrum.

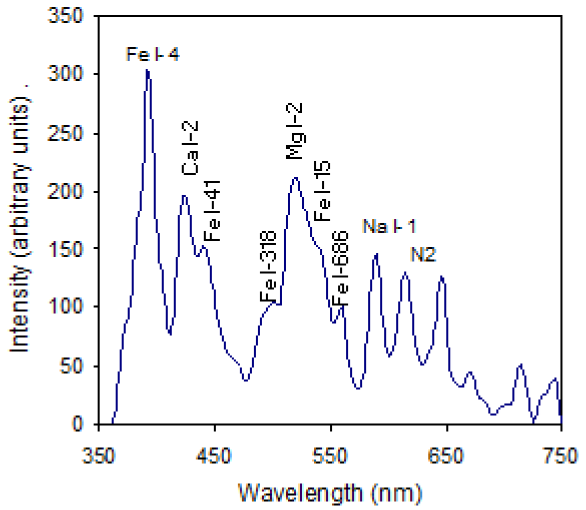

Figure 4 – Calibrated emission spectrum of the SWEMN20210516_223207 "Benicasim" fireball.

4 The 2021 June 12 fireball

This fireball reached a peak absolute magnitude of –8 ± 1. It was recorded on 2021 June 12 at $22^h05^m48.3 \pm 0.1^s$ UTC from the SWEMN meteor-observing stations operating at La Sagra, La Hita, Madrid, Sevilla, Sierra Nevada and Calar Alto. A video showing the event can be viewed on YouTube[7]. The bolide was included in our database under the code SWEMN20210612_220548.

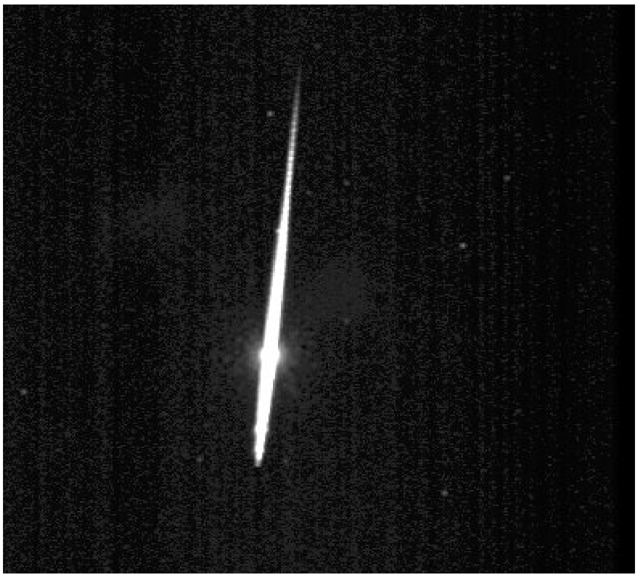

Figure 5 – Stacked image of the SWEMN20210612_220548 "Siruela" fireball as recorded from the SWEMN meteor-observing station located at La Hita Observatory.

Atmospheric path, radiant and orbit

The analysis of the trajectory reveals that this fireball overflew the northeast of the province of Badajoz (region of Extremadura). The meteoroid hit the atmosphere with an initial velocity $v_\infty = 19.2 \pm 0.3$ km/s, and the apparent radiant of the meteor was located at the equatorial coordinates $\alpha = 236.39°$, $\delta = +52.72°$. The calculated atmospheric path and its projection on the ground are shown in *Figure 6*. The bolide began at an altitude $H_b = 89.7 \pm 0.5$ km, near from the vertical of the town of Siruela (province of Badajoz). For this reason, we named the event in our database after this location. The terminal point of its luminous path was reached at a height $H_e = 40.8 \pm 0.5$ km over the northeast of the same province. This atmospheric trajectory had a zenith angle of around 15º.

Figure 6 – Atmospheric path and projection on the ground of the trajectory of the SWEMN20210612_220548 fireball.

Table 2 – Orbital data (J2000) of the progenitor meteoroid of the SWEMN20210612_220548 fireball.

a (AU)	2.59 ± 0.14	*ω* (º)	189.36 ± 0.03
e	0.61 ± 0.02	Ω (º)	81.84937 ± 10^{-5}
q (AU)	1.0104 ± 0.0001	*i* (º)	22.9 ± 0.4

From the calculation of the orbital elements of the meteoroid we obtained the results are listed in *Table 2*. The corresponding orbit is drawn in *Figure 7*. The value derived for the geocentric velocity is $v_g = 15.6 \pm 0.3$ km/s. The value of the Tisserand parameter with respect to Jupiter ($T_J = 3.0$) shows that the orbit followed by this meteoroid would lie in the limit between an asteroidal orbit and a Jupiter Family Comet (JFC) orbit. Radiant and orbital data are consistent with a fireball belonging to the τ-Herculids (TAH#0061). This meteor shower is associated with Comet 73P/Schwassmann-Wachmann 3 and peaks around June 2.

[7] https://youtu.be/3l8gk3S8jbs

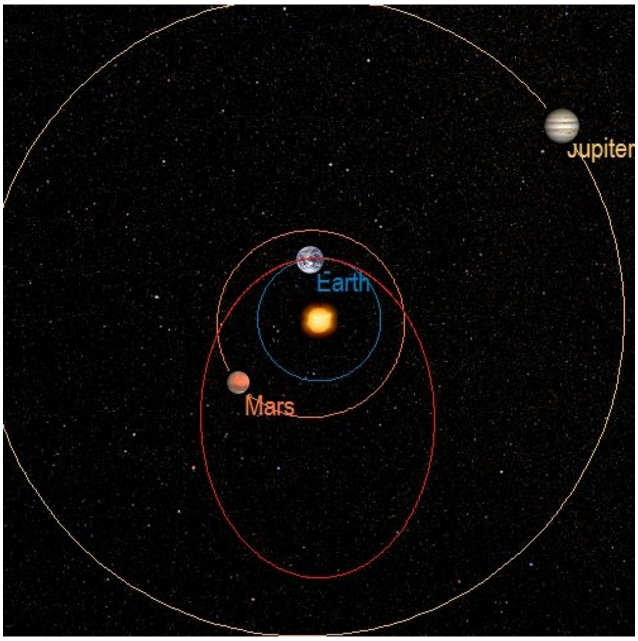

Figure 7 – Projection on the ecliptic plane (red line) of the orbit of the parent meteoroid of the SWEMN20210612_220548 fireball.

5 The 2021 June 14 fireball

This bolide was observed on 2021 June 14, at $21^h33^m14.0 \pm 0.1^s$ UTC. It was recorded from the SWEMN meteor-observing stations located at El Arenosillo, La Hita, La Sagra, Calar Alto, Sevilla, and Sierra Nevada. It reached a peak absolute magnitude of –9 ± 1 (*Figure 8*). A video about this fireball was uploaded to YouTube[8]. The meteor was included under the code SWEMN20210614_213314 in the SWEMN meteor database.

Atmospheric path, radiant and orbit

According to our analysis, the pre-atmospheric velocity of the meteoroid yields $v_\infty = 14.4 \pm 0.2$ km/s, and the apparent radiant of the meteor was located at the equatorial coordinates $\alpha = 197.0°$, $\delta = –28.28°$. The event overflew the provinces of Málaga and Sevilla (Andalusia). It began at an altitude $H_b = 83.4 \pm 0.5$ km over the southwest of the province of Málaga, and ended at a height $H_e = 38.4 \pm 0.5$ km over the east of the province of Sevilla. At this final stage the event was located almost over the vertical of the town of Casariche, and so we named the bolide after this location. This atmospheric trajectory of the event and its projection on the ground are shown in *Figure 9*.

Table 3 – Orbital data (J2000) of the progenitor meteoroid of the SWEMN20210614_213314 fireball.

a (AU)	2.18 ± 0.11	*ω* (°)	15.7 ± 0.1
e	0.54 ± 0.02	Ω (°)	263.76246 ± 10^{-5}
q (AU)	1.0023 ± 0.0006	*i* (°)	9.06 ± 0.07

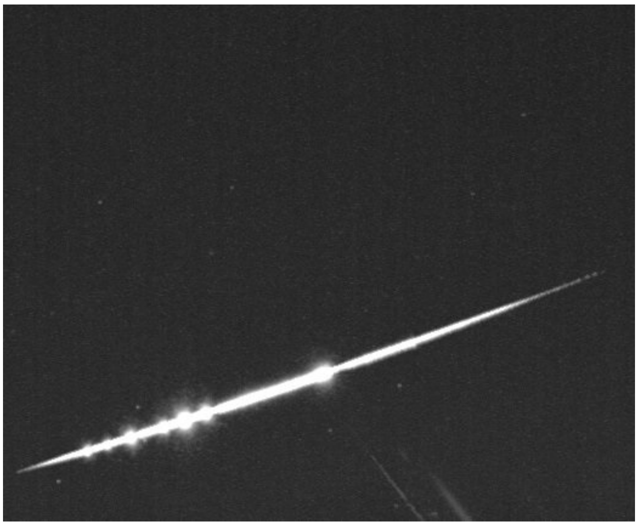

Figure 8 – Stacked image of the SWEMN20210614_213314 "Casariche" fireball as recorded from the SWEMN meteor-observing station located at El Arenosillo Observatory.

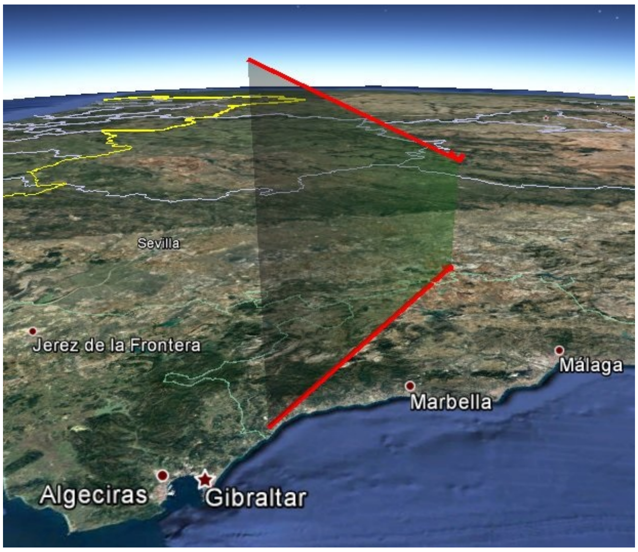

Figure 9 – Atmospheric path and projection on the ground of the trajectory of the SWEMN20210614_213314 fireball.

The orbital elements calculated for the parent meteoroid are listed in *Table 3*. This orbit is drawn in *Figure 10*. The value calculated for the geocentric velocity of this particle yields $v_g = 9.5 \pm 0.3$ km/s. The Tisserand parameter with respect to Jupiter yields $T_J = 3.4$, which suggests that this meteoroid followed an asteroidal orbit before entering the atmosphere. According to the information contained in the IAU meteor database, these results show that the fireball was associated with the Corvids (COR#0063). This meteor shower peaks around June 26, and the potentially hazardous asteroid 2004 HW has been suggested as parent body (Jenniskens et al., 2016).

[8] https://youtu.be/ASnLydyCVHI

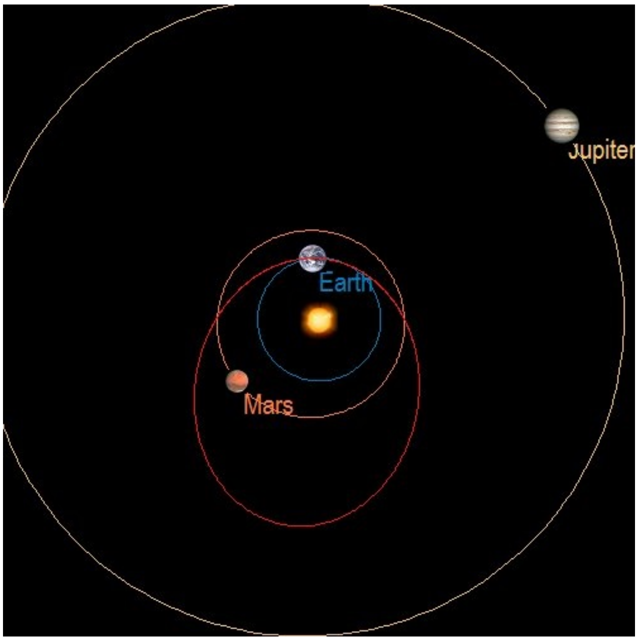

Figure 10 – Projection on the ecliptic plane (red line) of the orbit of the parent meteoroid of the SWEMN20210614_213314 fireball.

Figure 11 – Stacked image of the SWEMN20210723_220040 "Ibros" fireball as recorded from Calar Alto.

6 Fireball on 2021 July 23

This bright bolide was observed by a wide number of casual eyewitnesses along Spain at $22^h00^m40.8 \pm 0.1^s$ UTC on 2021 July 23. Some of these reported this event by means of our online fireball report form. The fireball was also recorded from the SWEMN meteor-observing stations located at La Hita, La Sagra, Calar Alto, Sevilla, El Arenosillo, Madrid, and Sierra Nevada. It reached a peak absolute magnitude of -11 ± 1 (*Figure 11*), and a video about this fireball was uploaded to YouTube[9]. The meteor was included in the SWEMN meteor database with the code SWEMN20210723_220040.

Atmospheric path, radiant and orbit

The analysis of the images recorded by our meteor cameras revealed that the bolide overflew the provinces of Ciudad Real (region of Castilla-La Mancha) and Jaén (Andalusia). The meteoroid entered the atmosphere with an initial velocity $v_\infty = 23.4 \pm 0.4$ km/s, and the apparent radiant of the fireball was located at the equatorial coordinates $\alpha = 274.9°$, $\delta = +34.0°$. Its atmospheric trajectory and the corresponding projection on the ground are shown in *Figure 12*. The event began at an altitude $H_b = 85.2 \pm 0.5$ km over the south of Ciudad Real, and ended at a height $H_e = 35.1 \pm 0.5$ km over Jaén. We named this bolide "Ibros", since at this final stage it was located almost over the vertical of this town in the province of Jaén.

Table 4 – Orbital data (J2000) of the progenitor meteoroid of the SWEMN20210723_220040 fireball.

a (AU)	1.95 ± 0.08	ω (°)	152.9 ± 0.5
e	0.50 ± 0.02	Ω (°)	120.96300 ± 10^{-5}
q (AU)	0.9788 ± 0.0005	i (°)	34.1 ± 0.5

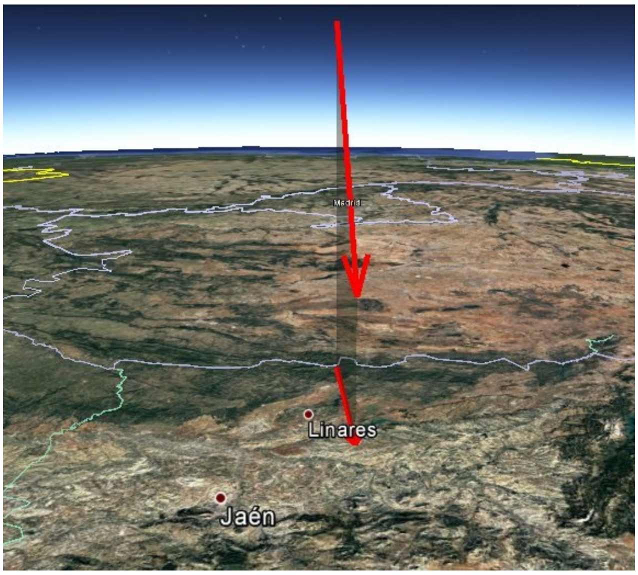

Figure 12 – Atmospheric path and projection on the ground of the trajectory of the SWEMN20210723_220040 fireball.

Table 4 contains the orbital elements calculated for the parent meteoroid. This orbit is plotted in *Figure 13*. The calculated value of the geocentric velocity of this meteoroid yields $v_g = 20.7 \pm 0.4$ km/s. The Tisserand parameter with respect to Jupiter yields $T_J = 3.5$, which shows that this particle followed an asteroidal orbit before entering our atmosphere. The orbital and radiant data obtained from our analysis do not match any of the meteor showers listed in the IAU meteor database. So, this fireball was associated with the sporadic background.

[9] https://youtu.be/5FmxYSaDkZk

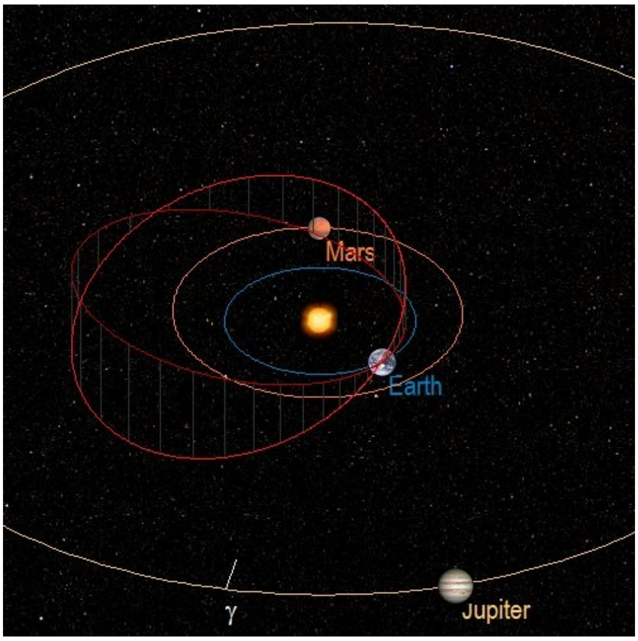

Figure 13 – Orbit (light red line) of the parent meteoroid of the SWEMN20210723_220040 fireball, and its projection (dark red line) on the ecliptic plane.

Figure 14 – Stacked image of the SWEMN20210731_211843 "Cebolla" fireball as recorded from La Hita Astronomical Observatory.

7 Fireball on 2021 July 31

On 2021 July 31, a wide number of casual eyewitnesses observed a very bright fireball crossing the night sky over Spain at $21^h18^m43.0 \pm 0.1^s$ UTC. The event was also recorded from the SWEMN meteor-observing stations located at La Hita, La Sagra, Calar Alto, Sevilla, Madrid, and Sierra Nevada. It reached a peak absolute magnitude of –9±1 (*Figure 14*). A video about this fireball was uploaded to YouTube[10]. The meteor was included in the SWEMN meteor database with the code SWEMN20210731_211843.

Atmospheric path, radiant and orbit

The meteoroid that gave rise to this bolide hit the atmosphere at $v_\infty = 59.1 \pm 0.5$ km/s. The apparent radiant of the resulting meteor was located at the equatorial coordinates $\alpha = 33.7°$, $\delta = +55.8°$. The event overflew the provinces of Segovia, Madrid and Toledo. It began at an altitude $H_b = 138.9 \pm 0.5$ km over the northeast of Segovia, crossed the west of Madrid, and ended at a height $H_e = 81.1 \pm 0.5$ km over the west of Toledo. This atmospheric trajectory and its projection on the ground are shown in *Figure 15*. At its ending point the event was located over the town of Cebolla, and so we named the meteor after this location.

Table 5 – Orbital data (J2000) of the progenitor meteoroid of the SWEMN20210731_211843 fireball.

a (AU)	8.7 ± 3.1	*ω* (°)	146.1 ± 0.8
e	0.89 ± 0.03	Ω (°)	128.58516 ± 10^{-5}
q (AU)	0.933 ± 0.002	*i* (°)	111.3 ± 0.3

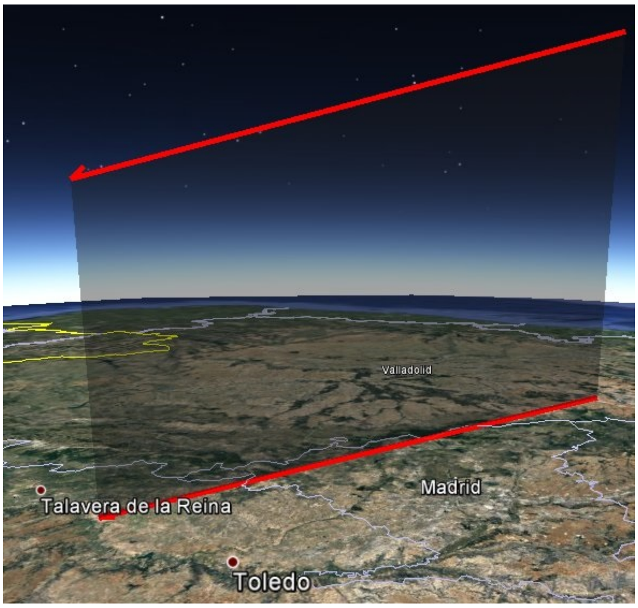

Figure 15 – Atmospheric path and projection on the ground of the trajectory of the SWEMN20210731_211843 fireball.

From this information we have calculated the orbital elements of the progenitor meteoroid. These are listed in *Table 5*, and the orbit is plotted in *Figure 16*. The calculated value of the geocentric velocity of this particle is $v_g = 57.8 \pm 0.5$ km/s, and the Tisserand parameter with respect to Jupiter yields $T_J = 0.1$. The value of this parameter suggests that this meteoroid followed a cometary orbit before entering our atmosphere. These results indicate that the fireball was a bright Perseid (IAU code PER#0007) that occurred about two weeks before the peak of this meteor shower.

Emission spectrum

The emission spectrum of this bright Perseid was recorded by the SWEMN spectrographs located at La Hita Observatory. The calibrated signal is shown in *Figure 17* shows the calibrated signal, together with the most important emissions. As can be noticed, the most important

[10] https://youtu.be/sjomWIRhdB0

contributions are those from Fe I-4 and the H and L lines of ionized calcium (Ca II-1). Additional contributions from neutral iron have been also found, and the most significant ones are those from Fe I-23, Fe I-43, Fe I-42, Fe I-41, Fe I-318, and Fe I-15. The lines produced by Mg I-2 and Na I-1 are also present. The emission from atmospheric N2 bands in the red region of the spectrum are also noticeable.

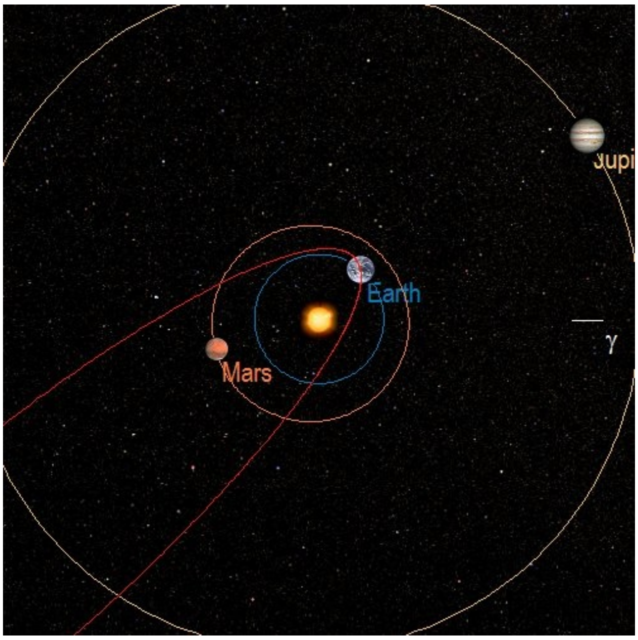

Figure 16 – Projection on the ecliptic plane of the orbit (red line) of the parent meteoroid of the SWEMN20210731_211843 fireball.

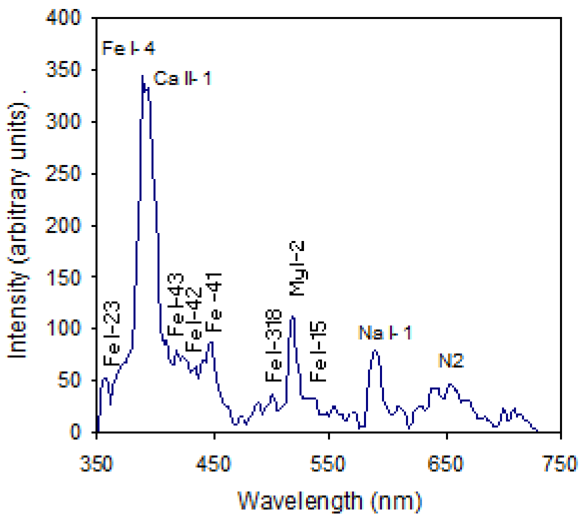

Figure 17 – Calibrated emission spectrum of the SWEMN20210731_211843 fireball.

8 Conclusion

In this work we have presented the most relevant bolides recorded in the framework of the SWEMN meteor network from May to July 2021. Their peak absolute magnitude ranged from –8 to –11.

The first event analyzed here was the magnitude –9 "Benicasim" bolide. This was recorded on 2021 May 16 and overflew the provinces of Castellón and Teruel. It was associated with the phi-Ophiucids, a minor meteor shower that has been associated with a PHA (2015 DU180). The value obtained for the Tisserand parameter with respect to Jupiter, however, suggests that the progenitor meteoroid followed a JFC orbit instead of an asteroidal orbit. The spectrum of this bolide is dominated by the contributions from Fe I-4, Ca I-2, and Mg I-2. It also contains the contribution from the Na I-1 doublet and several neutral iron multiplets.

A mag. –8 τ-Herculid bolide was recorded on June 12. It overflew the province of Badajoz. We named this event "Siruela". Two nights later, on June 14, the magnitude –9 Corvid fireball named "Casariche" overflew the provinces of Málaga and Sevilla. Our results are consistent with an asteroidal origin of the Corvid stream, which has been associated with the potentially hazardous asteroid 2004 HW.

The sporadic fireball "Ibros" reached a peak absolute magnitude of –11. This is the brightest event presented in this work, and a wide number of eyewitnesses observed it from all over the Iberian Peninsula. It overflew the provinces of Ciudad Real and Jaén (south of Spain) on 2021 July 23. Our results suggest an asteroidal origin of the progenitor meteoroid, which would belong to the sporadic background.

The last bright meteor included in this report is the Perseid named "Cebolla", which ended over this town in the west of the province of Toledo after crossing the provinces of Segovia and Madrid. Its peak luminosity was equivalent to a stellar magnitude of –9. It was spotted on 2021 July 31, and a wide number of casual eyewitnesses could observe it. We have also presented the emission spectrum of this bolide. The most remarkable contributions in this spectrum are those produced by Fe I-4 and Ca II-1 (H and L lines of single-ionized calcium). The contributions from several neutral iron multiplets are also present, together with those of Mg I-2 and Na I-1.

Acknowledgment

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A possible new meteor shower in August during the Perseids

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A possible new meteor source has been detected during the Perseids in 2020. The apparent radiant position is located near the star rho Ser with approximately coordinates: R.A. = 238º ± 1º; Dec. = +18º ± 1º on 13–14 August 2020, 19^h43^m UT, corresponding to Solar longitude: λ_{O} = 141.221º.
The author didn't find information about the existence of such a meteor shower during that time of the year. In this article the author is trying to find evidence for the existence of that possible new meteor shower, using additional non-standard sources of information, including pictures from social media such as Facebook, Instagram and Twitter.

1 Introduction

Watching at the pictures on Facebook of the Perseids in 2020, in the account of the Department of Astronomy at Sofia University, Bulgaria, among the Perseid meteors, I was Impressed of two meteors which obviously weren't Perseids. On the mosaic image, a composition of a few frames, their directions were perpendicular to the other meteors, appearing to come from another common source. I contacted the author of the pictures, Kalina Stoimenova, who is working in the Institute of Astronomy, a branch of the Bulgarian Academy of Science. She kindly provided me with the original pictures of the single frames of both meteors, with the complete required information. The pictures have taken with a camera Nikon D7100, lens Tokina 11-16mm f/2.8:11mm, ISO 1600. The meteors appeared in an interval of ten minutes. (*Figure 1, 2 and 3*).

The meteors seen in the single frames look like belonging to one shower but it could be a coincidence. Two meteors are insufficient for any criteria. If such a radiant really exists, it should be noticed from different places and adjacent dates. That is the reason why I searched for more sources of information.

Figure 1 – The mosaic picture, composition from all photographed meteors during the observing night and the meteors from the unknown source (right).

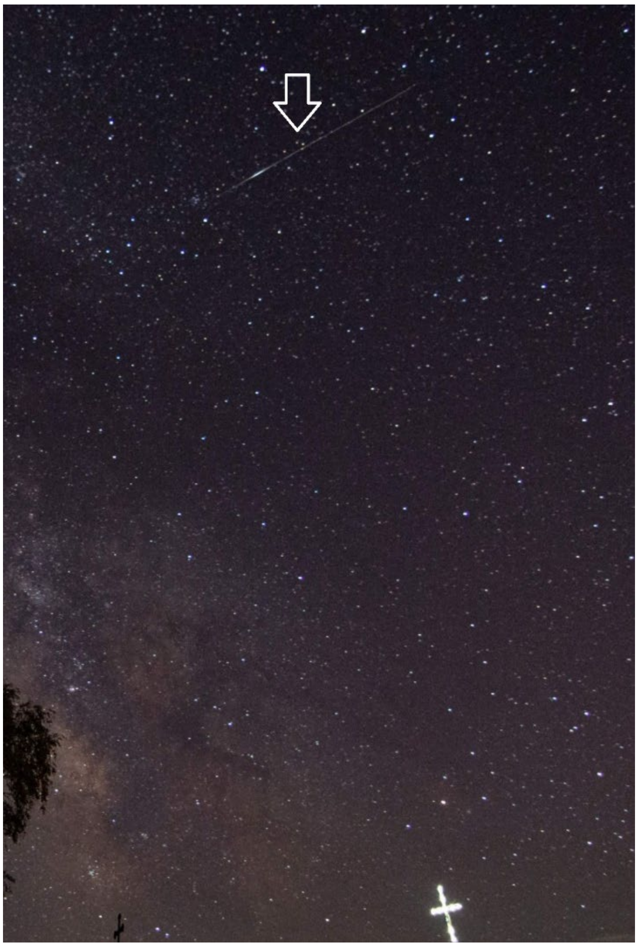


Figure 2 – Individual frame of one of the meteors from the unknown source.

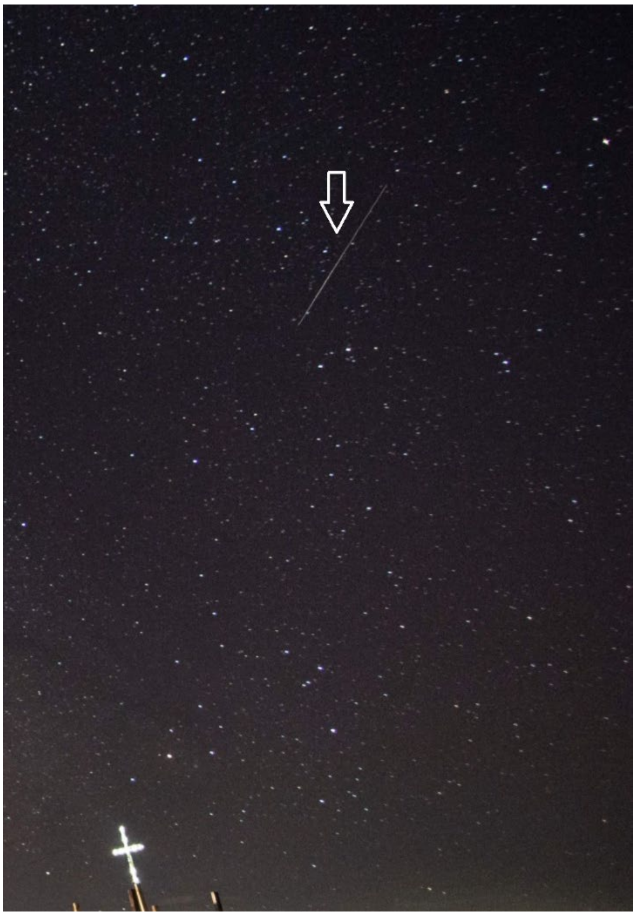


Figure 3 – Individual frame of one of the meteors from the unknown source.

2 The social media as a source of scientific information

The method is very common in astronomy, aka "data mining". There are lots of visual, photographic, video networks which are storing exact information about meteors. Some of them are professional, other amateurs, but they all have correct information about meteor events, for which the most important is the date, time (in UT) and the location. To work with their data is easy and a pleasure. But why do I choose such a difficult and complicated source of information for my investigation? The answer is, because for some very rare events, so rare, that even the available numbers within networks are insufficient for their detection. For very short intervals of time and rare events, one thing is very important, which we call "luck"! During my work I saw some incredible examples. What would be the probability to catch one Perseid meteor from the main radiant, one late Piscis Australid meteor and one epsilon Perseid, which is actually not related to the Perseids, in one 30 seconds interval on a single frame? Three independent different events to be realized in such a short interval of time! Furthermore, it happened to a photographer, who for over five years has less than ten nights sky pictures! Or, another case happened to a photographer from Japan, who was waiting an entire night under a sky, covered with clouds. Accidentally early in the morning, when twilight appeared, the clouds started to resolve and the sky got clear. In this short time interval, he managed to catch one of the best examples of all the meteors from the new source!

That is why I decided to search among the pictures and videos in more widespread platforms such as Twitter, Facebook and Instagram, spread all over the globe. This way, the chance to find something increases, but at the expense of reliability! A wide spectrum of photographers: professionals, amateurs and art-photographers can be found here. They are using different quality equipment, but most of them don't care about important details such as the time of the exposure. For them, the object or event they are photographing is the most important.

First, I want to share my own experience with working on those media. I already mentioned the time, or at least the date of the photography. Most of them are using descriptive categories such as: "during the Perseids this year", "last Wednesday", "a few days ago", etc. Then I have to look for other, indirect circumstances such as the date of the post, the position of the planets Jupiter and Saturn in the nights around the maximum of Perseids, or the red glow of the sky around sunset and sunrise for the approximate time. In shots of missing planets, I even used the sequels of the Perseid directions captured in the frame and their distance from the ephemeris position of the radiant for the night of the maximum! Of course, if the source it had been active enough, I would have never wasted so much time to investigate all this, and I would just ignore every complicated case. But for an activity level which is many times less than the sporadic background, I can't afford it. Sometimes the date of publication can serve as an approximate reference for the date, but this is not always mandatory. Photographs of Perseids can be found, weeks, months, and even years after they were taken. In such cases, the available references are the comments made by the authors of the photos, in which they explicitly mention when the photo was taken. Another problem is the reposting of the pictures after a long period of time since their previous publication. It is a very common practice among the photographers on Instagram. When I find a meteor, it probably belongs to the investigated radiant without any written date in the author's comment, I had to follow all the author's pictures from the very beginning of his account on the platform to be sure that it is the first appearance of that meteor picture!

For the art photographers it is very common to use one and the same sky background with meteors from many, different pictures, changing only the landscape below. The most strange and confusing case I have seen is a meteor, which matches very well with the possible new radiant, used by six different art photographers as a background for their art photos during four years! They have used it sometimes mirrored, sometimes upside down, sometimes as winter either summer time. It's impossible to find who is actually the author, and when that meteor has been captured for the first time! (Acknowledgements number 74).

When I have to use some meteors from mosaic pictures, I'm very careful, because when some photographers are gathering meteors from different frames to one, they are doing it incorrectly. Instead trying to orientate the meteors according to their positions among the stars, they are doing it according to the landscape orientation. As a result, some real stars on the picture disappear and other new stars are appearing! And the last thing, among the hundreds of pictures, I have checked, there were pictures which matched the radiant very well but from another time of the year, which I ignore for this reason. This is not surprising as the possible new radiant is located close to the ecliptic, which is rich in ecliptic sources as well as sporadic meteors during the entire year.

As a conclusion, after all this I can say that using information from such social media requires to use something like a scale of reliability of the data comparable to the accuracy of the visual observations. The most reliable should be single frames with known date and time of the recording. The most unreliable are meteors from mosaic pictures or with unknown date but known period derived from the descriptions by the author.

3 Some results

My researches went in two directions, following a simple logic, if something really exists, it should reveal itself in space and time. At first, meteors of the same source would be photographed from different locations of the planet, as well as in the same period in the current year and also in this period in different years. I found evidence, I found meteors from the USA, UK, Bulgaria, Serbia, France, The Netherlands, Italy, Spain, Germany, Macedonia, Albania, Poland, Japan, Turkey, Ireland, Canarias Islands, Iran, and Denmark.

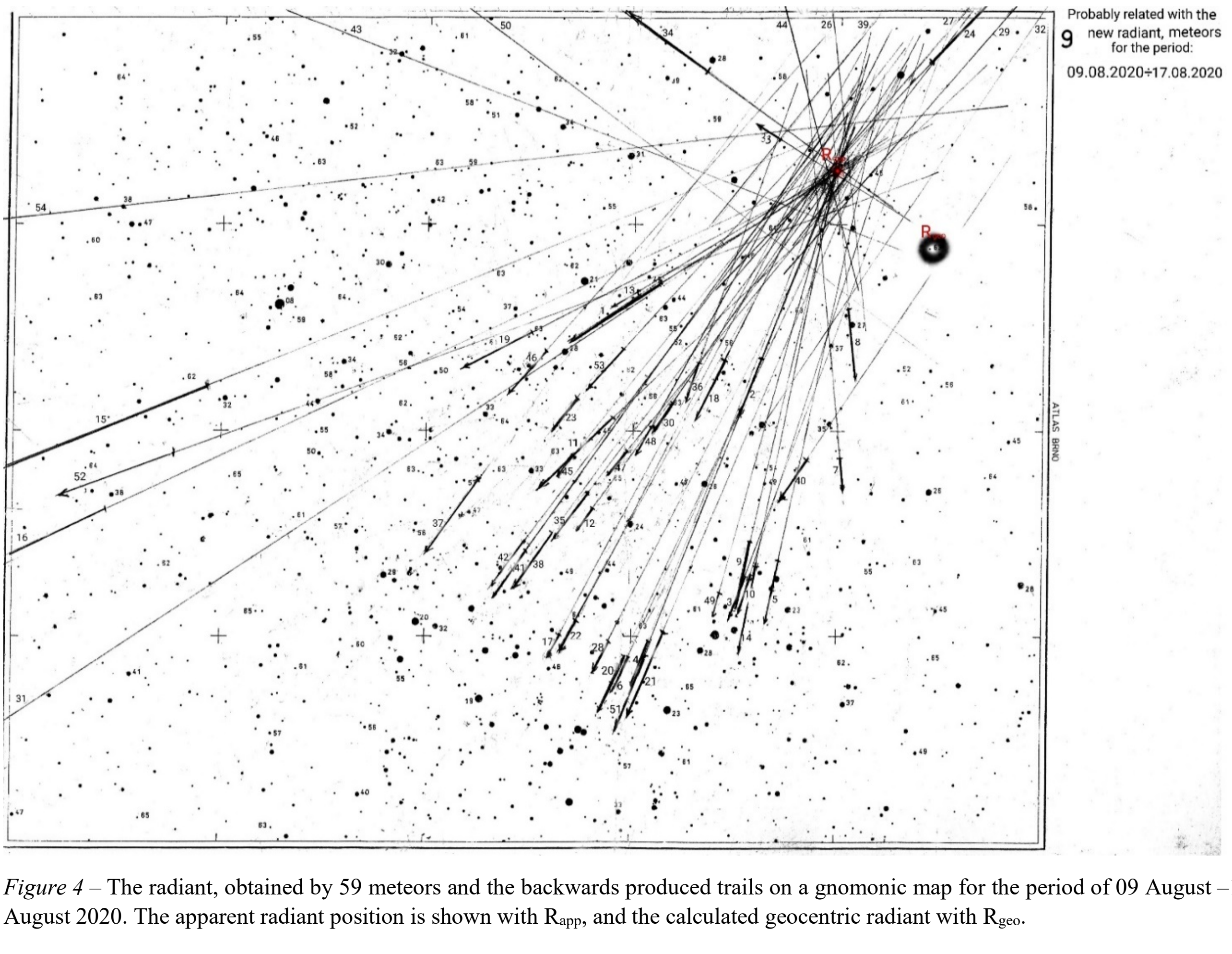


Figure 4 – The radiant, obtained by 59 meteors and the backwards produced trails on a gnomonic map for the period of 09 August –17 August 2020. The apparent radiant position is shown with R_{app}, and the calculated geocentric radiant with R_{geo}.

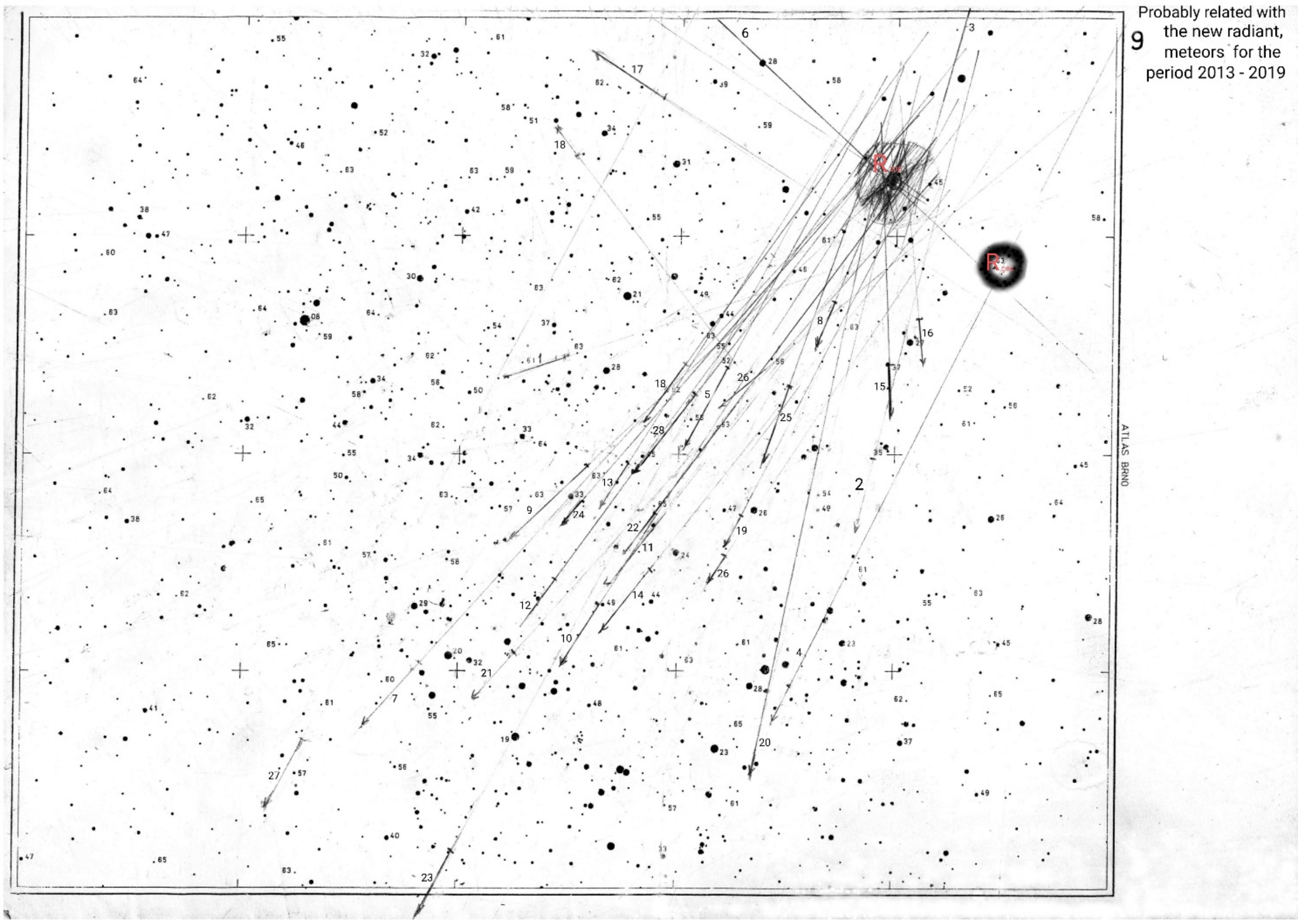


Figure 5 – 28 meteors and their backwards produced trails on a gnomonic map for the period of the Perseids in 2013, 2015, 2016, 2017, 2018, 2019 years, using the radiant positions from 2020. The apparent radiant position is shown with R_{app}, and the calculated geocentric radiant with R_{geo}.

After searching almost one year I found 59 meteors photographed in the year 2020 during the period between 9th and 16th of August, all coming from an area with a diameter of five degrees, which could belong to the new source. That area includes the daily motion of the radiant drift and the possible dispersion because of the different time and elevation of the radiant during the night. *Figure 4* shows the position of the possible apparent radiant. The radiant is obtained graphically, by a precise transfer of all single meteors to gnomonic maps of Atlas Brno 2000, used by IMO for visual observations of meteors (Rendtel, 2014).

I found also meteors recorded in 2013, 2015, 2016, 2017, 2018 and 2019, shown in *Figure 5*.

The radiant position is located very close to the Antapex of the Earth's orbit. That means, the meteoroids have to catch up with Earth and the meteors will be very slow. The position of the apparent radiant of such slow meteors is very sensitive to its zenithal distance because of the effect of the zenith attraction. The value of the difference with the position of the geocentric radiant depends on the apparent velocity. The higher the velocity, the less becomes this difference. The apparent velocity can be represented as a vector which depends on the directions of some of its components:

- the direction of the geocentric velocity v_g, which is a geometric vector between the direction of the Earth on its orbit and direction of the meteoroid on its orbit as a difference between their heliocentric velocities.
- the direction of the gravitational attraction of the Earth, which gives to the body an additional acceleration, or pre-atmospheric velocity v_∞.
- the vector of the direction of the diurnal aberration of the Earth because of its rotation, which depends on the latitude of the observer's location.
- the direction of the Earth's atmospheric resistance, which gives only a negative acceleration or deceleration. It is always oriented in the opposite direction to the direction of the apparent velocity.

Only when the apparent radiant is at the zenith its position coincides with that of the geocentric radiant, as the directions of the main components of the apparent velocity such as the geocentric and topocentric (pre-atmospheric) velocities also coincides. The influence of the diurnal aberration is negligible.

The effect is the strongest when the radiant is on the horizon, because then the two vectors make an angle of 90 degrees. Since the vector of the force of the Earth's acceleration is the same for all meteor bodies, but the vector of the tangential velocity in the direction of motion of the meteoroid is different for different meteors, the effect is most pronounced in the slowest meteors.

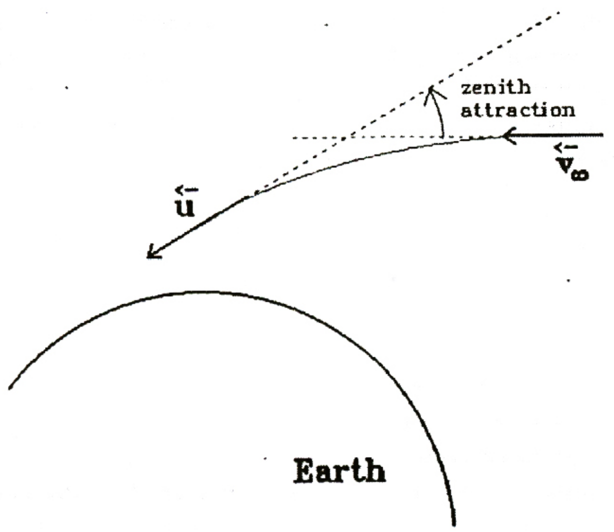


Figure 6 – A drawing of the effect of the zenith attraction on the radiant. v_∞ denotes the topocentric (pre-atmospheric) velocity, and u the apparent velocity of the meteor. The apparent velocity is changing during the movement of the meteor along its entire trajectory, so that its difference between its value at the beginning and ending of the trajectory includes the correction for the resistance of the atmosphere at its final stage. (Arlt et al., 2008).

The effect of the zenith attraction of the apparent radiant position could be calculated, using the following formula (Arlt et al., 2008):

$$\Delta z = 2\, arc\, tan\, (\frac{v_\infty - v_g}{v_\infty + v_g} tan \frac{z}{2}),$$

Where z is the zenith distance of the apparent radiant and Δz is the correction of the radiant position in degrees.

The relation between v_g and v_∞ is given by the formula (Babadzhanov, 1987):

$$v_\infty = \sqrt{v_g^2 + \frac{2\gamma M_t}{R}} \approx 10^3 \sqrt{v_g^2 + 125}\, [m/sec],$$

Where γ is the gravitational constant ($\gamma = 6.673 \times 10^{-11}$ [$m^3 \times kg \times sec^{-2}$]), M_t the mass of the Earth ($M_t = 5.976 \times 10^{24}$ [kg]), R the average radius of the Earth ($R = 6.37 \times 10^6$ [m]). This means that at a sufficiently long distance, a body with zero relative velocity relative to the Earth would accelerate to 11.2 km/sec and it is the minimum possible pre-atmospheric velocity for a meteoroid.

Knowing the equatorial coordinates of the apparent radiant in Right Ascension and declination, the pre-atmospheric velocity v_∞ and the geocentric velocity v_g of the meteors of a given shower, a correction for the effect of the zenith attraction can be made by a transformation to the horizontal coordinate system.

The radiant corrected in this way is called topocentric. For the slowest meteors with a radiant located on the horizon, Δz can exceed 15 degrees!

Although less pronounced than the effect of the zenith attraction, the following effect must also be taken into account. The eastward displacement is calculated by the formula (Arlt et al., 1999):

$$sin\, \Delta\beta = \frac{\sin\beta\, \cos\varphi\, v_e}{v_\infty},$$

where: β is the distance of the visible radiant from the point at East in azimuth at 0° elevation, φ the latitude of the location and $\Delta\beta$ is the correction of the position of the radiant.

After these two corrections, the position of the geocentric radiant is obtained, which, unlike the position of the apparent radiant, is the same for the whole Earth at a given moment in time.

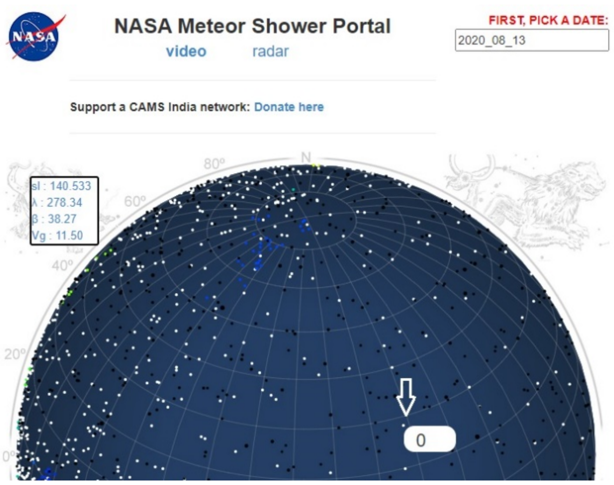
This means that the area formed by the individual apparent radiants belonging to the possible new source, could be very large with a diameter of over 10 degrees around the position of the geocentric radiant! It can be assumed that if such a radiant exists, related meteors will be most likely captured at the highest position of the radiant above the horizon, which falls around the beginning of the local night for the middle North latitudes, where the density of observers is optimal. Their back-extended trajectories would come from an area with a higher concentration, shaping the position of the visible radiant at that time. All later meteors would give a wide blurred area around this position.

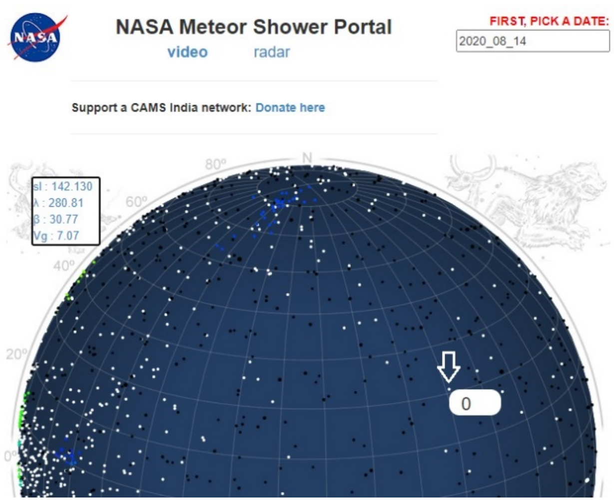
The most important is to have information about the velocity of the meteors which we don't know.

I contacted Paul Roggemans and asked him to look up data from their video surveillance network in the BeNeLux[11,12]. Of course, such meteors would be classified as sporadic meteors. He kindly provided me with this information, and there was only one meteor from 2013 with similar solar longitude and a radiant corresponding sufficiently with the search area. Its speed was expectable slow with a geocentric velocity of $v_g = 11.38$ km/sec. Using that speed only as an approximate estimation I calculated the coordinates of the geocentric radiant to be at R.A. = 231° and Dec. = +12°. (*Figure 7*). I calculated this using a software, created in our Astronomical club Canopus many years ago[13,14].

Then, I looked for other sources of information from the NASA video archive of meteor observations[1] for 2020, where I found a few radiants probably belonging to the new source (*Figure 7*).

[11] http://cams.seti.org/FDL/
[12] https://www.facebook.com/groups/432897660237082
[13] Software "Radiant" created by Panayot Yanazov, https://www.facebook.com/loshia
[14] Astronomical club "Canopus" Varna city, Bulgaria. https://www.facebook.com/groups/250677344956298





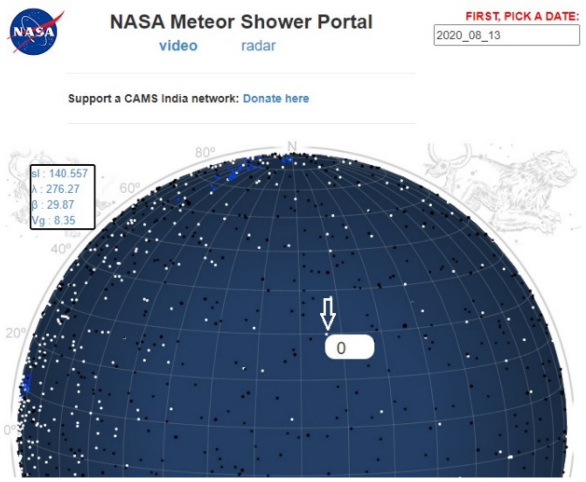
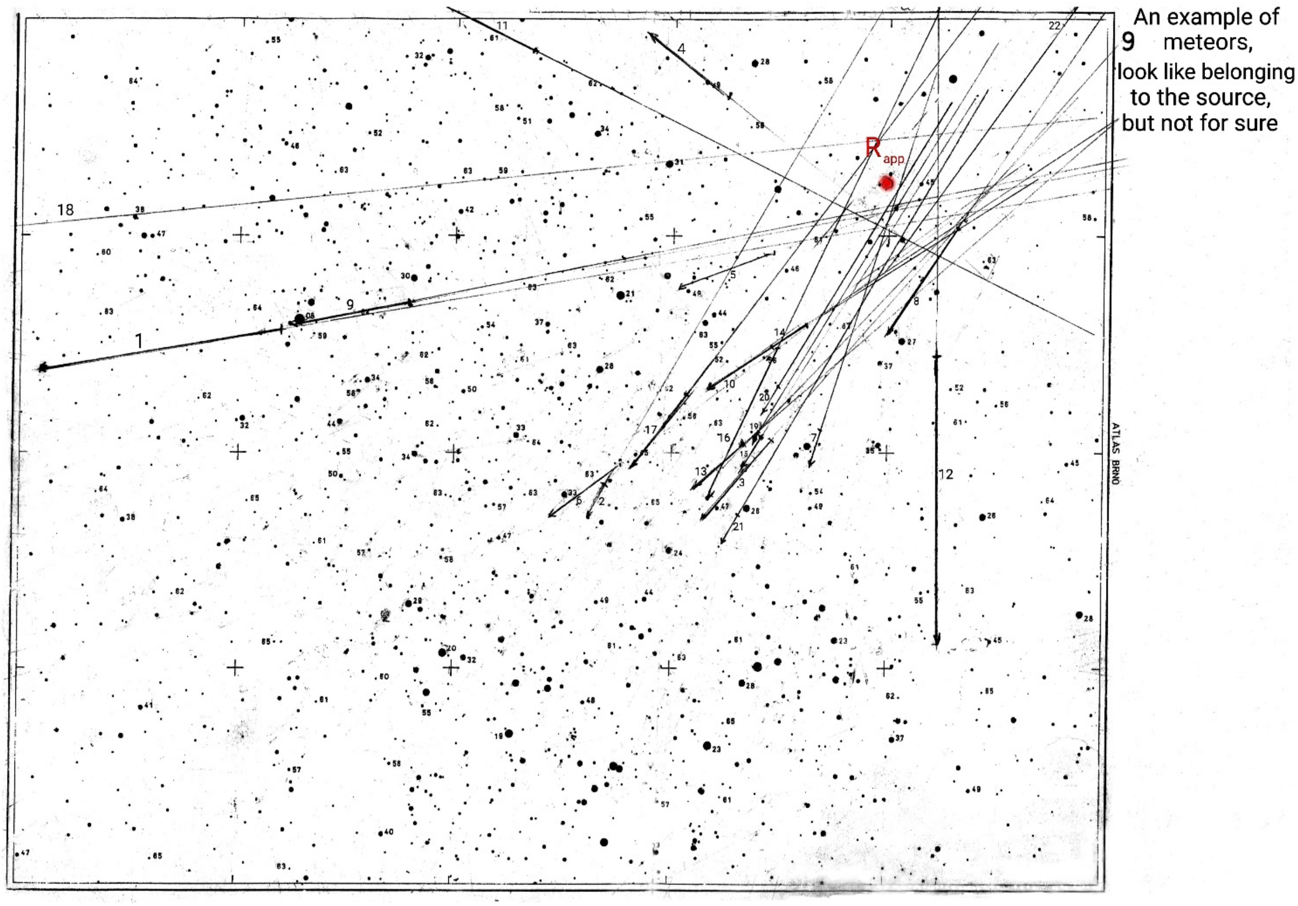


Figure 7 – Left and above, screenshots from the NASA archive for the nights 13th and 14th of August 2020. There are two close radiants from which, one is closer to the apparent radiant and the other closer to the geocentric radiant. The geocentric velocity of the first one is close to the velocity I have used for the calculation of the coordinates of the geocentric radiant. For the second radiant the geocentric velocity is even slower.

Figure 8 – Below: An example with meteors which trails are matching very well with the radiant position of the new possible source, but with pictures, taken during another time of the year. There are only two exceptions. Meteor number one has no known date of the photography and author. It is used by six different art photographers as part of a background sky, for their art photocompositions. Especially one of them is using it many times, and it appeared for the first time in 2017. So there is a probability that he is the author and that the meteor has been recorded during the Perseid time in the same year. Another one, is the meteor number 12, which is a typical Perseid meteor from 2020, which trajectory accidentally lies on the direction to the new radiant.



I also downloaded the archive for previous years from 2011 to 2016 and among the huge amount of data I found only 14 very close but never identical individual radiants. For the recent years I also found individual radiants which could be associated with the suspect possible new shower.

What is the probability that a random meteor can be associated with an existing meteor shower radiant, only because of the direction of its trail? There are two different explanations: statistical and physical. In the first one it is just a coincidence, and for the second the physical relation of a common origin. In *Figure 8* some examples of meteors are shown coming from the same area, but recorded at another time of the year as well as meteors from other radiants which are active during the same period, for instance Perseids, which are obviously not related to the suspected new meteor shower.

Is there among all those meteors any statistical relevant relationship? It could be! But their number will be hardly big enough to influence the results. A curious case is a Fireball captured this summer on June 9,2021, from Glashütte Sachsen, Germany[15], which is matching well with the position of the possible new radiant in August! It is logic that the background of the distant stars can be the same for many, different meteor radiants during the year.

As a joke, after more than 10 years of meteor observations in our Astronomical club Canopus, we reached to the conclusion, defined as a law: "*Every point of the celestial hemisphere is a meteor radiant!*" This fundamental meteor astronomy law, makes any searching for new radiants meaningless because every newly discovered source is simply a logical confirmation of this law!

4 Conclusions

This article cannot confirm unambiguously the existence of such a new shower radiant, as the requirement is, to have at least the orbital elements of three bodies, which needs video or radar observations with determined velocities of the meteors. The purpose of the article is just to pay attention to all so far sporadic meteors, coming from that area during the Perseids and if that new shower really exists, to be confirmed and included to the list of the meteor showers. I hope this year the question about the existence of the meteor shower rho Serpentids can be figured out.

Acknowledgments

I want to thank to Paul Roggemans for the information, given to me from the CAMS BeNeLux video network, for helping with advising me where to search more information from other sources and for editing my article. I want to thank also to Tim Cooper for ideas, which he gave me when we discussed that possible radiant.

And finally, I want to thank to all photographers, which meteors I used for my analyze. Some of them I will mention by their names, but others which names I don't know, by their Instagram names as follow:

1.Kalina Stoimenova, Bulgaria, @kallystoimenowa; 2. P I K S, USA, @chriskpickens; 3.p_i_r_o_s_h_k_i , Serbia, @p_i_r_o_s_h_k_i; 4. Melanie Guerrero, Spain, @melg.photography, @melanieguerrero.photography; 5. Antonio Lobelle Toro, Spain, @lobellant; 6.Pablo.j, Spain, @pablo.jae; 7. Jose y Adrian, Spain, @locos_noctambulos; 8.Marcos del Mazo, Spain, @marcos_del_mazo; 9.Alberto Cañete, Spain, @albertoknt; 10.Tomasz Dyziek Szostak, Poland, @dyziekcom; 11. Cees Kassenberg Photography, The Netherlands, @case_Kassenberg; 12.@rongille, Japan; 13. Ehsan Yousefi, Iran, @ehsun.yousefi; 14. Ronny Behnert, Germany, @haggardphotography; 15. Arbër Shkurti, Albania, @fantastic_albania; 16. Takuya Yoshida, Japan, @takupocho; 17. Johnnie, Japan, @johnnie_photography; 18. Yoshinobu Naito, Japan, @shooting.brake; 19. @tsubassa_photo, Japan; 20. @monacamera, Japan; 21. Frank William, Canada, @sirfrankwilliam; 22. Caroline, Canada, @carrhayes; 23. Fernando D. Cala Dominguez, Canarias Islas, @fernandocala87; 24.Charalambos Chrysostomou, Cyprus @charalambos.chrysostomou; 25. Dom Reardon, UK, @dom_reardon_photo; 26. Etienne Simouneau, France, @tnnsmn; 27. Robert Urbaniak, Poland, @uerbe; 28. Haocheng Fang, China, @frankfang1; 29. Mario Shumanov, Bulgaria, @marioshumanov; 30. Riste Spiroski, North Macedonia, @ristespiroskiphotography; 31.@bigwednesday66, Canada; 32. Wobblycat's Moto Adventures, Canada, @wobblycat; 33.Alfonso Cuchi, USA, @alfonsocuchi; 34. Dejan Kostic, Sweden, @dmkostic; 35. Nikolay Shopov, Bulgaria, @nikolayshopov.ph; 36.Wolfgang Falter, Austria, @falter.w; 37. Erin Malone,USA, @erinemalone; 38. Berk Uçak, Turkey, @omnesphoto; 39. Gareth Wray, Ireland, @garethwrayphotography; 40. Ole Spata, Germany, @olespata; 41.David Behan, Ireland, @davidbehan; 42.Holly Burton, UK, @_hollyburtonphotography; 43.Michal Mancewicz, Poland @kreyatif; 44. Paul O'Brien, Ireland,@mrpaulobrien; 45. Matt Melbert, USA, @mattmelbert; 46.Oz, Mexico, @elvaldo; 47. Kouji, Japan, mizumo1975; 48. Alberto Masó, Spain, @albertomaso; 49. Wesley White,USA, Alaska , @wesleywhitepro; 50. @aozoragaragemaa, Japan; 51. Ayumi, Japan, @ayumi.kosaka.121; 52. Pep Sanchez, Spain, @pepinair; 53. Ruslan Merzlyakov, Denmark,Norway, @astrorms; 54.Erik Colombo, Italy, @erikcolombophotography; 55. Joseph Zhao, USA, @josephsphotography; 56. Emma, UK, @emcon81; 57.Kenneth Denton,USA, @kennethhhd; 58. Max Pedi, Italy, @maxcrack90; 59. Cody Limber,USA, @codylimber; 60.Christopher M. Georgia, USA, @christophergeorgia.photography; 61.Carlos Fernandez, Spain; 62.Darla Young, USA; 63.Jeremy Perez, USA, @jperezmedia; 64. Arpan Das, Italy, @arpandas_photography; 65.ji-ji8800, Japan, @8800ktmt; 66. Alfonso Cuchi, USA, @alfonsocuchi; 67. Asif Islam, USA, @asif.photography; 68.Nick Page, USA,

[15] https://www.amsmeteors.org/2021/07/meteor-activity-outlook-for-july-3-9-2021

@nickpagephotography; 69.Amr Abdulwahab, Egypt, @amr_abdulwahab; 70.Amir H Dehqan, Iran, @amir.dqn99; 71. Mitch Stather, UK, @mitchellstather; 72. Kerry-Ann Lecky Hepburn, Spain, @weatherandsky; 73. Matteo Rovatti , Italy, @matteorovattiphotography; 74. ART: Brent Shavnore, USA,@shavrone; @daisuke_diving, Japan; @nights_dreamworld;@itsanoemithing, Spain; Sabrina, Switzerland,@sabrina.binkert; Plus Minus, @sven_plusminus; Volpe Imagens, @volpeimagens; 75. Sean Parker,USA, @seanparkerphotography; 76. Glashütte Sachsen, Germany.

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Arlt R., Asher D.J., Brown P.G., Campbell-Brown M., Dubietis A., Koschack R., Koschny D., Lyytinen E., McBeath A., McNaught R.H., Molau S., Rentdel J., Roggemans P., Triglav M., Vaubaillon J., Verbeeck C., Wislez J.-M., Znojil V. (2008). Handbook for meteor observers, International Meteor Organization, Potsdam, Germany.

Babadzhanov P. B. (1987). "Meteors and their observation". Science – Main edition of physical and mathematical literature, Moscow, U.S.S.R.

Rendtel J. (2014). Meteor Shower Workbook. IMO.

Spring 2021 observations from Ermelo (Netherlands) and Any Martin Rieux (France)

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An overview of visual meteor observations done by the author during spring 2021 is presented.

1 Introduction

The weather didn't cooperate one bit during the autumn campaigns: no Leonids and no Geminids were seen. Autumn 2020 was followed by a bad winter and spring season 2021. During the Bootids it was cloudy and so was the rest of January and February. During March there was some hope for clear weather but in the end it was disappointing. Only four sessions were the result, all for a maximum of 1.5 hours.

Figure 1 – Our rented house in Any Martin Rieux, northern France.

Then it was time to observe the Lyrids. First quarter moon on April 20 means moonlight all night long during the Lyrid maximum. Despite this, observations were scheduled for 21–22 and 22–23 and 23–24 April. But again, the weather let me down, only 16–17 and 17–18 April could be observed. The month of April was wet and much too cold compared to the long-term average temperatures. The same was true for May, this month was just as cold as April with a lot of rain. In addition, the corona pandemic raged through Europe at full speed. Lockdowns were reinforced and borders remained closed.

In February I decided to book a two-week holiday at the Bel Any gite in Any Martin Rieux in northern France. It was by no means certain whether or not we could actually go, but if the lockdowns were eased, we had at least booked something. Any Martin Rieux is located 11 km east of the town of Hirson in the Champagne-Ardennes region. At this location we rented a very spacious house for two persons where also our 5 dogs were welcome. This is in a dark area. We were here before in October 2017 (Miskotte, 2017) and June 2018 (Miskotte, 2018), the best SQM I ever achieved here was on October 22, 2017 (SQM 21.6) under not yet optimal conditions. Observing was of course not a must, but if it was clear I could at least observe under good conditions. The last time I could observe under perfect sky conditions was in May 2019 from Buzancy, also in northern France (Miskotte, 2019). Furthermore, the region is very beautiful, sloping with alternating meadows and forests.

Due to the disappointing weather in 2020 and early 2021, the pleasure of observing meteors visually had gradually taken a serious blow. I hoped to get the hang of it again in Any Martin Rieux. We took the actual decision whether to go or not to go mid-May. At that time, both Lizzie (fully) and I were (partly) vaccinated against corona. The owners of the cottage were also vaccinated. In addition, you actually already live there in quarantine as it is a very remote site.

2 Observing at Any Martin Rieux

We booked the gite for the period from May 29 to June 12. In the week before departure, a switch to more stable and sunnier weather finally seemed to take place, exactly when we had our first day off. I got some equipment with me: the all-sky camera EN-908 (Canon 6D, Sigma 8 mm F 3.5 fish eye lens with a LC Shutter, the visual observing material (of course!) and a Sony A7s II with a battery of lenses. The Sony A7II camera was already purchased in March 2020 but had barely been used. This holiday was used to get to know this camera better.

Figure 2 – Regular deep blue Provencal like skies at Any Martin Rieux. This is the view from the rented cottage. The visual observations were made from a location left of the tree group.

2021 May 29–30

As expected, the first night was already clear. After a short nap in the evening, I got a good two-hour session. Longer was not possible due to the rising moon. The all-sky camera did run all night of course. In the Netherlands you can visually start around 22^{h}15^m UT during this time and continue until 01^{h}00^m UT at the most (Lm minimum 5.9). That is different in Any Martin Rieux, which is about 3 degrees more south than Ermelo. The observations can already start around 21^{h}30^m UT, the lm then reaches already 5.9. As time went on, the lm was rising to 6.65 and the SQM to 21.4. That's as good as southern France. The starry sky was beautiful, especially the Milky Way was spectacular. This session started at 21^{h}29^m and ended two hours later at 23^{h}31^m UT. Meteors from the Antihelion radiant and tau Herculids were monitored. The two-hour effective yielded 23 meteors. No bright meteors but a lot of faint ones as can be expected in these conditions. A fast +2 SPO in Ophiuchus was the best. At 22^{h}59^m UT, a short very slow +3 meteor has been seen in Serpens Caput and this appeared to be a good candidate for the tau Herculids moving out of the 2017 position. Despite the lack of bright meteors, this was a nice session: a very clear starry sky really helps!

Incidentally, a lot of satellites were also seen, including a low ISS passage in the southwest. A flash of –6 at 23^{h}15^m UT in Ursa Major was caused by a satellite. The temperature dropped this night to +3 at ground height. No satellite trains occurred this night, but sometimes satellites passed with exact the same trajectory, most likely Starlinks.

2021 May 30–31

The sky turned into beautiful deep blue during the day, announcing a crystal-clear sky. I had chosen a place a little further away from the house so that the view was better with less obstruction. However, a few cows from the nearby meadow curiously came to see what I was doing. It went well, it was just a bit of booing and splashing…. Observations were done between 21^{h}29^m and 00^{h}11^m UT. The moon rose a little later than previous night. Thanks to the beautiful dark sky, 31 meteors were seen in 2.68 hours. Most of them were faint, but also a few bright meteors. 5 meteors were coming from the Antihelion source and again one possible tau Herculid! The most beautiful meteor was at the end of the session: a beautiful white slow magnitude 0 SPO meteor. This meteor appeared to be coming from the same area as the beautiful fireball captured with the all sky camera (May 31, 2021 at 01^{h}44^{m}25^s UT). The nice sky in Any Martin Rieux is often accompanied by beautiful bird sounds, of which the call of the Jay and a number of owls is the most unusual. In addition, on the property there is a large pond with dozens of frogs that continue to croak all night. Sometimes you hear rustling in the high grass from rabbits or hedgehogs.

2021 May 31 – June 1

This night it was possible to observe a little longer. However, a slightly later start was made, which meant that there was effectively almost the same observation time as the previous night. Between 21^{h}44^m and 00^{h}35^m UT, 2.65 hours were observed and that resulted in 37 meteors, 6 of which were ANT and again a possible tau Herculid. Nice +2 and +1 ANT were the highlights. The sky was very transparent and dark. The Milky Way was fantastic to see, with the deep sky objects low to the south. SQM values rose to 21.45 and the limiting magnitude eventually to 6.7. This night I also used the Canon A7s II in combination with the Sigma ART 20 mm f/1.4 DG HSM E lens for the first time to take a series of images. The camera is actually intended for making high-quality video recordings, especially at night with low light. But the camera also does well with photography, as can be seen from the beautiful images that emerge.

Figure 3 – Startrails composition of the night May 30–31, 2021. Three bright satellites are visible, as well as the bright fireball of that night. The rising moon can also be seen at the bottom left.

Figure 4 – Crop of the original all-sky image of the fireball of May 31, 2021. The fireball is simultaneous with the all-sky stations in Wilderen (Jean Marie Biets), Oostkapelle (Klaas Jobse), Benningbroek (Jos Nijland) and AstroLab Ieper (Franky Dubois). Calculations on this fireball have been already done by Hans Betlem (Dutch Meteor Society).

2021 June 1–2

This was another day with clear Provencal like skies. However, after the nap time, the sky quality appeared to have deteriorated and low in the south, black spots were visible: clouds. Fortunately, this remained limited low on the horizon during the session. Only at the end of the session the clouds moved into my field of view. This would be the start of a period of more unstable weather.

Observations were done between 21^h40^m and 00^h55^m UT. 33 meteors were counted during 3.05 hours. A nice +2 ANT appeared in Scorpius. An even nicer +1 ANT moved slowly through Sagittarius. And a +3 ANT left a short persistent train in Aquila, which was also special! The most beautiful meteor was a +1 fast sporadic meteor with a 2 second persistent train in Ophiuchus. When I ended the session, Saturn and Jupiter were visible in the southeast. It was such a beautiful sight with those two planets near each other. As mentioned, the weather changed after this night. That didn't mean it got bad, but meteor observations were not possible due to cirrus clouds. On Friday, June 4, we had some fierce thunderstorms in the evening. However, it took until June 6–7 before anything could be done again. This night would be clear but because of a heavy hay fever attack resulting in watery and itchy eyes I could not observe. Afterwards it appeared from the all-sky recordings that there were still too many clouds, so I hadn't missed anything at all. The next night was clear.

2021 June 7–8

During the day a beautiful deep blue sky led to another crystal-clear night. Despite the good transparency and darkness, it seemed that the sky background didn't get as dark as, say, May 31 – 1 June. Perhaps I saw the difference here that the sun set a little less deeply during the night? Limiting magnitude was 6.6 maximum, SQM maximum was 21.40. Later in the night, some low fog banks formed in the adjacent meadows. Observations were done between 21^h50^m and 01^h06^m UT. In total I counted 28 meteors, and to my surprise also this time I saw a candidate for the tau Herculids (+4). The most beautiful meteor appeared immediately at the start of the observations. A beautiful earth-grazing magnitude 0 ANT moved from Serpens Caput to Ursa Major! Another beautiful meteor was a +1 SPO which moved from Lyra to Bootes. The Sony A7s II made several videos of the starry sky this night. The ISO was set to 25000. The result was stunning and sharp images shot at 20mm F 1.6 and 25 fps. Limiting magnitudes for the camera with these settings were around 6. Several meteors were recorded, see also *Figure 5*. All in all, this was a successful night.

June 8–9 was clear but with a lot of cirrus. Fog banks in the morning. No visual observations were possible because of this.

2021 June 9–10

This night was again very clear. When I inspected the sky to see Mars and Venus together around 20^h50^m UT I saw a tuft of illuminated cirrus clouds low north. Hmm, those looked like noctilucent clouds. I quickly walked to a place with a better view and saw several of the characteristic elongated clouds hanging in the northeast: Yes, these were NLCs. Not an extensive display, but the NLC low north was very bright.

When I started the session, limiting magnitude reached 6.6 and SQM 21.40. And the air was now very dry. This was the maximum quality sky you can get in June at this location! Observations started at 21^h55^m and ended at 01^h10^m UT. In addition to the Antihelion and tau Herculids, fast meteors originating from Delphinus were also monitored. They are called gamma Delphinids, a meteor shower that had a strong outburst on the night of June 10–11, 1930.

Figure 5 – Video still of one of the meteors captured with the Sony A7 S II with the SIGMA 20MM F/1.4 DG HSM ART.

Figure 6 – The evening of the 9th of June, Noctilucent Clouds (NLCs) were visible, photo taken with a Samsung smartphone.

Figure 7 – This bright meteor of magnitude –3 was captured on June 9, 2021 at 21^h48^m UT. Camera: Sony A7s II with a Sigma 20MM F/1.4 DG HSM ART, F 1.6, 10 sec at 4000 ISO. Single shot.

Table 1 – Overview of the observations made at Any Martin Rieux, northern France.

Date	Period UT	$T_{eff.}$	Lm	SQM	ANT	TAH	GDE	SPO	TOT	Location
29–30/05	21^h29^m-23^h31^m	2.00	6.7	21.42	3	1	~	19	23	AMR
30–31/05	21^h29^m-00^h11^m	2.67	6.7	21.45	5	1	~	25	31	AMR
31–01/06	21^h44^m-00^h35^m	2.60	6.7	21.46	6	1	~	30	37	AMR
01–02/06	21^h40^m-00^h55^m	3.13	6.6	21.44	7	1	~	25	33	AMR
07–08/06	21^h50^m-01^h06^m	3.10	6.6	21.36	4	1	~	23	28	AMR
09–10/06	21^h55^m-01^h10^m	3.17	6.6	21.34	9	2	1	26	38	AMR
10–11/06	21^h50^m-23^h55^m	1.92	6.5	21.35	2	0	0	13	15	AMR
7 Sessions		18.58			36	7	1	161	205	
13–14/06	22^h30^m-00^h32^m	2.00	6.2	20.27	2	~	~	8	10	ERM

The first hour started nicely with 4 Antihelions of which three appeared within 7 minutes and resp. +2, –1 and +2. Especially the –1 ANT was beautiful, low in the west this meteor moved right through Leo. Two minutes later another nice +2 appeared in Bootes.

Furthermore, 2 possible tau Herculids (!) were seen this night, the first one (+3) with a short path from Bootes to Corona Borealis. The second one was a slow magnitude 0 meteor in Virgo. However, I did see this one with a DCV of 50 degrees…. During 3.18 hours effective I counted 38 meteors, including 9 ANT, 2 possible tau Herculids and 1 gamma Delphinid (+4). The Sony A7s II took photos of meteors all night. Two were captured, including a –3 sporadic fireball on June 9, 2021 around 22^h48^m UT. This fireball was also captured (very weakly) with the all-sky camera.

2021 June 10–11

This night was also completely clear, but it was a bust at the end. The strong winds blazing during the day persisted and so did the grass pollen that whirled around. As a result, I had to stop after 1.88 hours due to a heavy hay fever attack. Too bad, because I was curious about the gamma Delphinids. In the 90s I saw a few members of this obscure meteor shower. In total I counted 15 meteors of which 2 ANT and no gamma Delphinids.

The last night June 11–12 in Any Martin Rieux was also clear, but again with cirrus. So, no visual observations were possible. All in all, I had a nice holiday and observed a lot.

The night 13–14 June was clear in the Netherlands and so I did a two-hour session from Ermelo. Nice to be able to see the difference of a few degrees in latitude. Capella was clearly higher in the sky, while Antares was much lower. The sky background also remained much brighter with a maximum SQM of only 20.27 and Lm 6.2. In total, it was possible to watch for two hours between 22^h30^m and 00^h32^m UT, resulting in 10 meteors, 2 of which were ANT.

3 SQM measurements in Any Martin Rieux

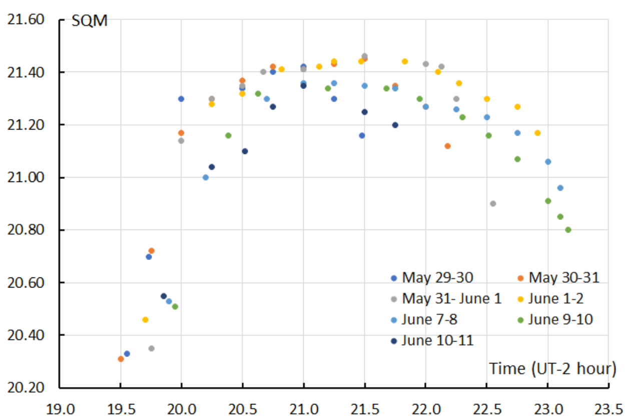

Figure 8 – All SQM observations from Any Martin Rieux, northern France, May–June 2021.

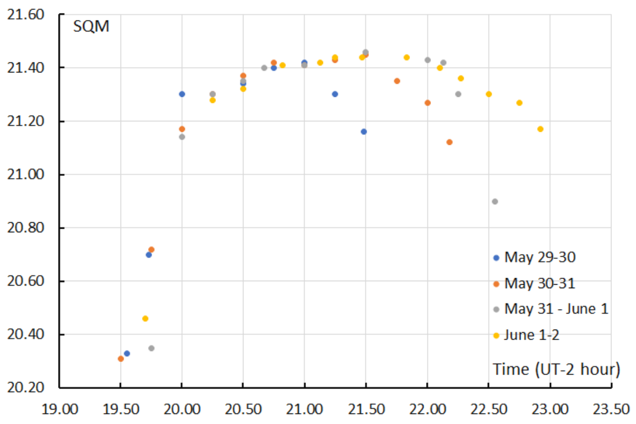

Figure 9 – SQM from the first four nights in which the moon was clearly a declining factor each night.

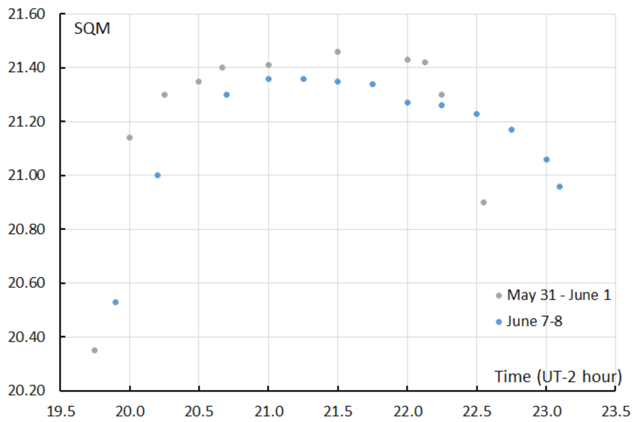

Figure 10 – Difference in SQM measurements between the nights 31 May – 1 June and 7–8 June 2021, the two nights with the highest transparency. Despite the fact that both nights had high transparency, the night of June 7–8 is slightly less in terms of sky background and SQM. Perhaps because the Sun is less far below the horizon in the night 7–8 June compared to the night 31 May – 1 June.

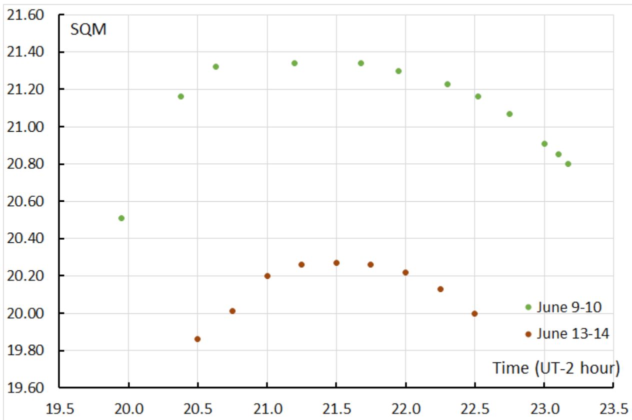

Figure 11 – Difference SQM measurements between the night 9–10 June 2021 (Any Martin Rieux, northern France) and 13–14 June 2021 (Ermelo, The Netherlands). It is remarkable how much difference a few degrees in latitude shows.

In 2018 I obtained the SQM meter from the late Peter Bus (Miskotte, 2016) through Jaap van 't Leven. Since most of the clear nights in Any Martin Rieux made little difference in terms of brightness, I have put all measurements in a graph. The SQM measurements were plotted on a timeline containing time = UT – 2 hours. This is because times after

0^h00^m UT are incorrectly displayed in the graph. Some interesting things can be learned from the graphs.

4 Conclusion

We had a nice quiet holiday together and enjoyed the clear starry sky there. Effectively, meteors were observed for 18.58 hours, yielding 205 meteors. The all-sky camera scored 2 fireballs including a very nice one.

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June 2021 report CAMS BeNeLux

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A summary of the activity of the CAMS BeNeLux network during the month of June 2021 is presented. 4347 multiple station meteors were captured which allowed to calculate 1389 orbits. June 2021 was the worst month of June since 2016.

1 Introduction

The last weeks of May and first weeks of June display very low meteor activity combined with short nights with between 7 hours and less than 6 hours of capture time. Therefore, no spectacular numbers of orbits are to be expected. Collecting orbits under these circumstances remains a challenge. What did June 2021 bring us?

2 June 2021 statistics

June is the most difficult month for CAMS BeNeLux because of the short observing window of barely 5 hours dark sky each night. The first half of June 2021 had a number of clear nights and several with partial clear sky. However, the second half of June came with exceptional poor weather, much too cold and totally overcast with a lot of rain. The worst possible weather pattern made astronomical observing almost impossible. As many as eight nights remained without any paired meteor (3 in June 2020). Three nights resulted in more than 100 orbits in spite of the short duration of these nights (against 8 in June 2020 and 13 nights in June 2019 when two nights scored more than 200 orbits). The best night for June 2021 was June 12–13 with 146 orbits. The statistics for June 2021 are compared in *Figure 1* and *Table 1* with the same month in previous years since the start of CAMS BeNeLux in 2012.

Table 1 – June 2021 compared to previous months of June.

Year	Nights	Orbits	Stations	Max. Cams	Min. Cams	Mean Cams
2012	0	0	4	0	–	0.0
2013	16	102	9	12	–	7.0
2014	23	379	13	31	–	19.0
2015	20	779	15	44	–	32.9
2016	18	345	17	50	15	35.7
2017	26	1536	19	66	30	52.1
2018	28	1425	21	78	52	64.9
2019	28	2457	20	84	63	75.6
2020	27	1833	24	93	60	83.1
2021	22	1389	26	81	54	73.3
Total	208	10246				

While all CAMS stations in Belgium operate 7/7 with AutoCams, some of the Dutch CAMS stations still operate occasionally when the weather is clear. This way the coverage of the northern part of the network area isn't as good as the southern part. For the coverage of the atmosphere by a camera network the chances for multiple station events especially during nights with variable weather depend on how many cameras are operational. When the weather happens to be poor but unpredictable like in June 2021, the only way not to miss unexpected clear sky is to have the camera systems running all nights, regardless the weather. To make the situation for June 2021 even worse some of the Dutch station were temporarily shut down for various reasons.

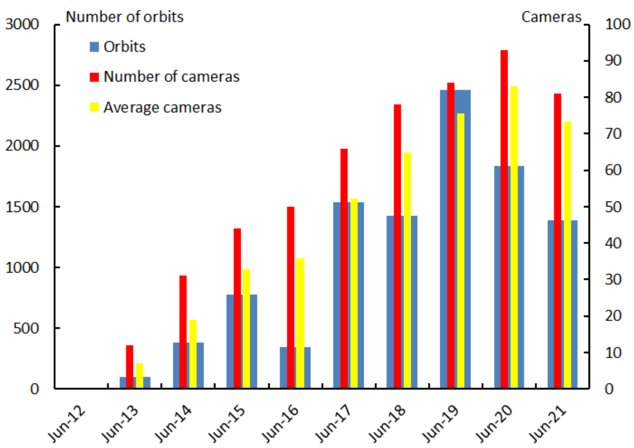

Figure 1 – Comparing June 2021 to previous months of June in the CAMS BeNeLux history. The blue bars represent the number of orbits, the red bars the maximum number of cameras running in a single night and the yellow bar the average number of cameras running per night.

During the best nights 81 cameras were operational (93 in June 2020 and 84 in 2019). Thanks to AutoCAMS at least 54 cameras were all nights operational (60 in 2020 and 63 in 2019). On average 73.3 of all available cameras were active, much less than the 83.1 of last year. The ratio of multiple station coincidences depends on the number of stations with clear sky during the same time span. The more stable the weather conditions are network wide and the less technical problems, the better the chances to catch a meteor from at least two stations.

The total number of orbits collected for the month of June reached 10246 in 208 nights of June that allowed to collect orbits. This way the month of June remains the poorest covered month of the year for CAMS BeNeLux, mainly because of the short duration nights.

Two RMS cameras produced the best scores in terms of orbits of all cameras in the CAMS BeNeLux network. There is no competition to nominate any most successful camera in the network, but in this case, it is interesting to see how the RMS performs compared to the Watecs. Certain cameras are pointed at regions where the chances for multiple station events is simply significant less, for instance towards the borders of the camera network coverage. However, to illustrate the order of difference for these RMS cameras, it is useful to compare these numbers with what the most successful Watecs obtained.

For the future of the CAMS BeNeLux network, the installation of extra RMS cameras will make the difference.

Table 2 – The ten cameras of the CAMS BeNeLux network with the best score in terms of orbits during the poor weather month of June 2021.

Camera	Total orbits	Total nights
Genk BE (RMS 003815)	159	30
Lesve BE (RMS 003816)	158	30
Dourbes BE (000394)	119	30
Mechelen BE (003891)	115	30
Mechelen BE (003836)	103	30
Mechelen BE (003837)	101	30
Uccle BE (000393)	100	30
Mechelen BE (003835)	99	30
Mechelen BE (RMS 003831)	98	30
Mechelen BE (RMS 003830)	97	30

3 Conclusion

June 2021 was a poor month due to the very bad weather and to make things worse several CAMS stations remained temporarily unavailable. No surprise that June 2021 ended as the worst month of June since 2016.

Acknowledgment

Many thanks to all participants in the CAMS BeNeLux network for their dedicated efforts. The data on which this report is based has been taken from the CAMS website[16]. The CAMS BeNeLux team was operated by the following volunteers during June 2021:

Felix Bettonvil (Utrecht, Netherlands, CAMS 376 and 377), *Jean-Marie Biets* (Wilderen, Belgium, CAMS 379, 380, 381 and 382), *Ludger Boergerding* (Holdorf, Germany, RMS 3801), *Martin Breukers* (Hengelo, Netherlands, CAMS 320, 321, 322, 323, 324, 325, 326 and 327), *Guiseppe Canonaco* (Genk, RMS 3815), *Pierre de Ponthiere* (Lesve, Belgium, RMS 3816), *Bart Dessoy* (Zoersel, Belgium, CAMS 397, 398, 804, 805, 806 and 3888), *Tammo Jan Dijkema* (Eelderwolde, Netherlands, RMS 3198, Dwingeloo, Netherlands, RMS 3199), *Jean-Paul Dumoulin, Dominique Guiot and Christian Walin* (Grapfontaine, Belgium, CAMS 814 and 815, RMS 3814), *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 and 813), *Kees Habraken* (Kattendijke, Netherlands, RMS 378), *Klaas Jobse* (Oostkapelle, Netherlands, CAMS 3031, 3032, 3033, 3034, 3035, 3036 and 3037), *Carl Johannink* (Gronau, Germany, CAMS 3001, 3002, 3003, 3004, 3005, 3006, 3007, 3008, 3009 and 3010), *Reinhard Kühn* (Flatzby, Germany, RMS 3802), *Hervé Lamy* (Dourbes, Belgium, CAMS 394 and 395), *Hervé Lamy* (Humain Belgium, CAMS 816), *Hervé Lamy* (Ukkel, Belgium, CAMS 393), *Tim Polfliet* (Gent, Belgium, CAMS 396), *Steve Rau* (Zillebeke, Belgium, CAMS 3850 and 3852), *Paul and Adriana Roggemans* (Mechelen, Belgium, RMS 3830 and 3831, CAMS 3832, 3833, 3834, 3835, 3836 and 3837), *Hans Schremmer* (Niederkruechten, Germany, CAMS 803) and *Erwin van Ballegoij* (Heesch, Netherlands, CAMS 348).

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

Delta-Aquariids 2021 by worldwide radio meteor observations

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The δ-Aquariids are one of the major meteor showers. In 2021, worldwide radio meteor observations caught a distinct activity. The peak occurred at $\lambda_{\odot}$ = 125.64° (July 28. 18^h UT) with an Activity Level = 4.0 ± 0.7. Another peak before the main peak has been observed at $\lambda_{\odot}$ = 122° (July 25). This activity was composed by two components. One was the traditional activity, and the other was a sub-component activity. The peak of the traditional activity appeared earlier than for visual observations. The sub-component activity has been also detected in the past.

1 Introduction

The δ-Aquariids are one of the most prominent annual meteor showers. The peak occurs around July 30th ($\lambda_{\odot}$ = 127°) with a ZHR = 25 (Rendtel, 2020).

With Radio Meteor Observations it is possible to observe meteor activity continuously even if the weather is bad or during daytime. Besides, the radiant elevation problem has been solved by organizing the worldwide radio project. One of these worldwide projects is the *International Project for Radio Meteor Observations* (IPRMO)[17]. IPRMO uses the Activity Level Index for the analyzing of meteor shower activity (Ogawa et al., 2001).

This project has covered the δ-Aquariids activity since 2005 (Ogawa and Steyaert, 2017). The annual activity for the period of 2005–2020 shows the maximum Activity Level = 3.0 at $\lambda_{\odot}$ = 125.00° with *FWHM* = –2.8° / +5.3°. The maximum of the δ-Aquariids in the case of radio meteor observations appears earlier than for the visual observations.

2 Method

Similar to previous investigations, the meteor activity was calculated by using the Activity Level Index. The profile of the meteor activity was estimated by using the Lorentz profile (Jenniskens et al., 2000). Although the total number of meteor echoes did not only include δ-Aquariids but also α-Capricornids, it has been assumed that most of the increase in activity was caused by the Southern δ-Aquariids.

3 Results

Figure 1 shows the result of the δ-Aquariid activity based on the calculation of the Activity Level Index using 40 observations from 12 countries. The distinct increase started around $\lambda_{\odot}$ = 118° (July 19). The highest activity occurred between $\lambda_{\odot}$ = 124.00° and 126.00°. The maximum peak displayed an Activity Level = 4.0 ± 0.7 at $\lambda_{\odot}$ = 125.64° (July 28, 18^h UT). Since the solid line shows the average for the period of 2005–2020, the whole activity profile was similar to the previous year's average. In detail, however, the ascending shoulder produced a higher activity than

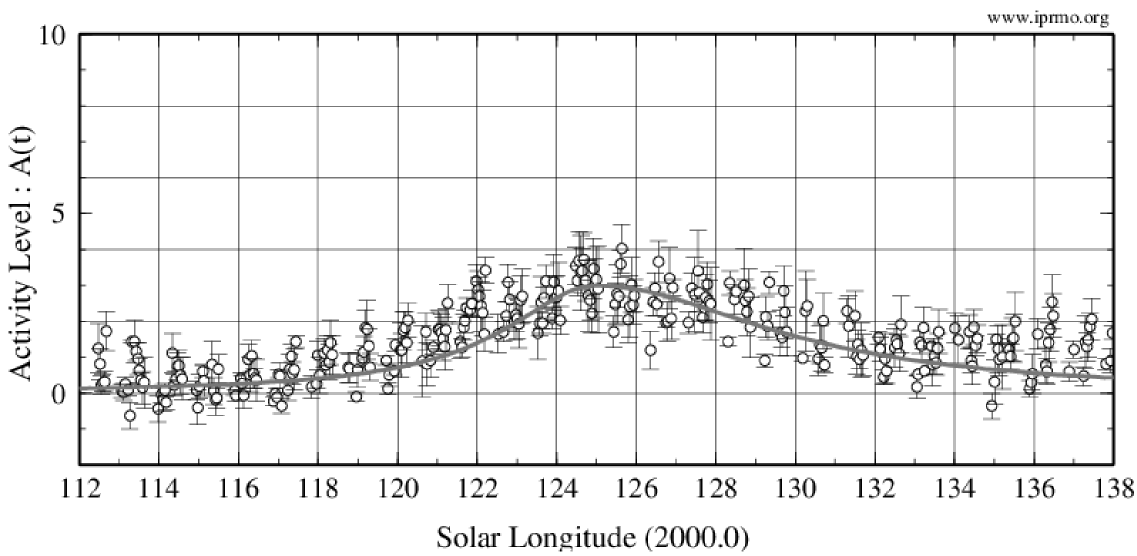

Figure 1 – The Activity Level Index of the δ-Aquariids 2021 by radio meteor observations from all over the world (solid line is the average for the period of 2005–2020).

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

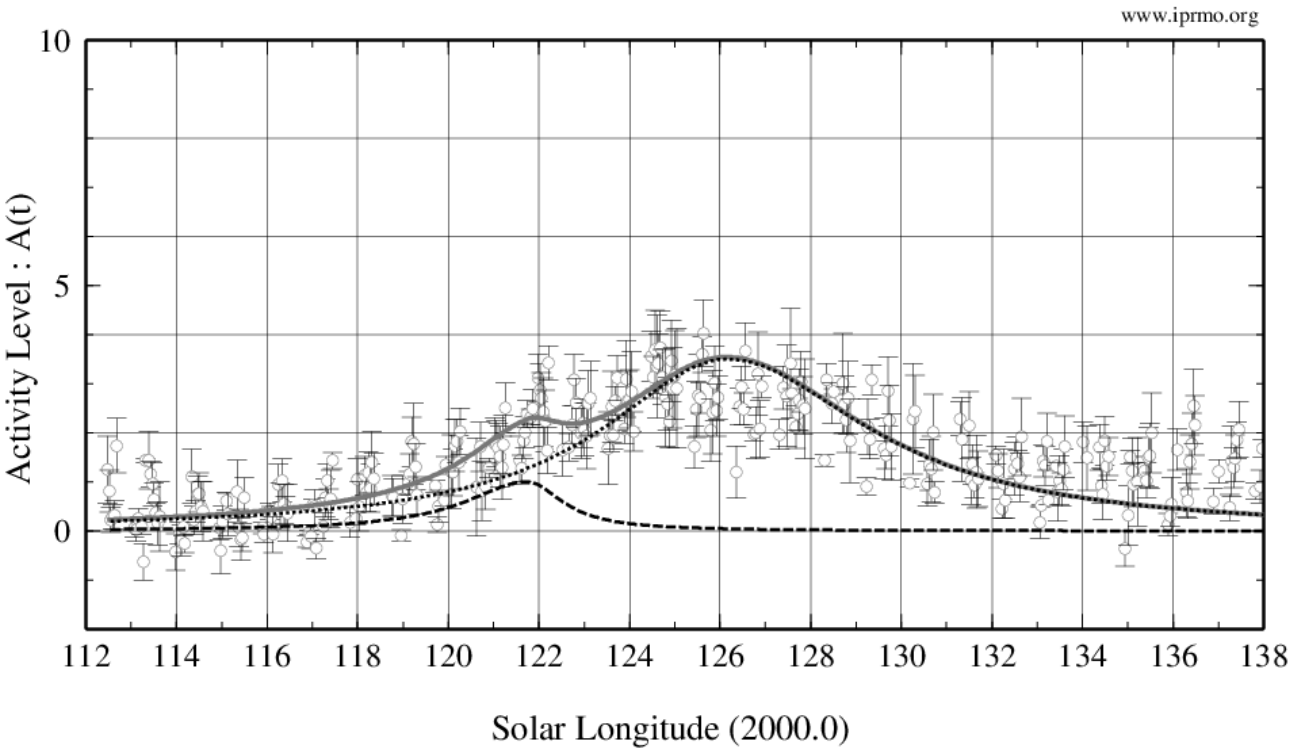

Figure 2 – The estimated components of the δ-Aquariids 2021 (dotted and dashed lines represent the main and the sub components, the gray line represents the total activity profile).

previous year's average. Another peak appeared at $\lambda_{\odot} = 122°$ (July 25). The peak had an Activity Level = 3.4 ± 0.3 at $\lambda_{\odot} = 122.22°$ (July 25, 5^h UT). Although the Activity Level Index seemed to increase again after $\lambda_{\odot} = 125.64°$ (August 6), this was probably due to the influence of the beginning Perseid activity. This is because it is impossible to distinguish the total number of meteor echoes for the different meteor showers.

4 Activity profile components

Figure 2 and *Table 1* show the activity components of the δ-Aquariids 2021 estimated by using the Lorentz profile. One component represents the main activity and had a maximum Activity Level = 3.5 at $\lambda_{\odot} = 126.16°$ (July 29, 8^h UT). It seems that this activity represents the traditional activity profile. The other component appeared with a maximum Activity Level = 1.0 at $\lambda_{\odot} = 121.74°$ (July 24, 17^h UT).

Table 1 – The estimated components of the δ-Aquariids 2021.

	DAQ21C01	DAQ21C02
Peak Time	July 29, 8^h UT	July 24, 17^h UT
Solar Longitude	126.16°	121.74°
Activity Level	3.5	1.0
FWHM (hours)	-84.0 / +96.0	-42.0 / +24.0

5 Discussion

The earlier peak time than in visual observations

Since 2005, the peak of the δ-Aquariids in radio meteor observations was observed to appear earlier in time than in the visual observations. *Table 2* shows the list of data for past observations. The average time for the main peak for the period of 2005–2020 was estimated at $\lambda_{\odot} = 125.00°$. Although the time of the peak activity has a certain width, these occurred almost every year earlier than the visual peak.

Table 2 – The list with the data for both components of the main and the sub activity. AL* is the Activity Level at the peak time.

	Main activity		Sub activity	
	$\lambda_{\odot}$	AL*	$\lambda_{\odot}$	AL*
2005	125.93°	3.5	121.39°	0.5
2006	125.22°	4.0	121.63°	1.0
2007	126.40°	3.5	122.58°	1.0
2008	124.96°	4.0	–	–
2009	124.72°	5.0	121.65°	2.0
2010	126.39°	4.0	123.36°	2.0
2011	125.42°	3.0	122.08°	1.5
2012	126.93°	4.0	122.79°	2.0
2013	126.60°	3.0	123.34°	2.0
2014	124.69°	3.0	–	–
2015	125.24°	3.0	122.06°	1.0
2016	125.94°	3.5	–	–
2017	126.50°	2.5	121.68°	0.6
2018	126.14°	2.5	122.91°	0.5
2019	125.77°	3.0	120.24°	0.5
2020	125.45°	3.0	121.79°	1.0

A possible explanation may be that the activities caused by different meteor showers have been combined because with radio meteor observations it is difficult to separate the activity from different meteor showers. Another possible explanation is that the mass distribution of the meteors is different for the visual and for the radio observations.

The sub activity component

The sub activity component seen in the 2021 δ-Aquariids has been also detected in almost every previous year (see *Table 2*). The average for the previous years 2005–2020 was at $\lambda_{\odot} = 122.1 \pm 0.8°$ with an Activity Level = 1.2 ± 0.6. It is important to note that the time of the peak and the activity level had a width.

There is no obvious explanation what is causing this activity. Although it is possible that these occur within the error margins, there may be some other explanation because this has been observed almost every year.

Acknowledgment

The worldwide data were provided by the Radio Meteor Observation Bulletin (RMOB)[18]. The data has been provided by the following observers:

Chris Steyaert (Belgium), *Felix Verbelen* (Belgium), *Johan Coussens* (Belgium), *Pierre Micaletti* (France), *DanielD SAT01_DD* (France), Jean Marie F5CMQ (France), *WHS Essen* (Germany), *Balogh Laszlo* (Hungary), Associazione Pontina di Astronomia APA (Italy), *Fabio Moschini_IN3GOO* (Italy), *GAML Osservatorio Astronomico Gorga* (Italy), *Mario Bombardini* (Italy), *Oss Monte San Lorenzo DLF* (Italy), *Hirofumi Sugimoto* (Japan), *Hironobu Shida* (Japan), *Hiroshi Ogawa* (Japan), *Hirotaka Otsuka* (Japan), *Kenji Fujito* (Japan), *Masaki Kano* (Japan), *Masaki Tsuboi* (Japan), *Tomohiro Nakamura* (Japan), *Juan Zapata* (Mexico), *Rainer Ehlert* (Mexico), *Salvador Aguirre* (Mexico), *Kees Meteor* (Netherlands), *Jose Carballada* (Spain), *Jochen Richert* (Switzerland), *Ian Evans* (United Kingdom), *John Collins* (United Kingdom), *Philip Norton* (United Kingdom), *Philip Rourke* (United Kingdom), *Simon Holbeche* (United Kingdom), *Eric Smestad KC0RDD* (United States of America).

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

Radio Observations in May 2021

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This article presents the results of radio observations made in May 2021. The results of the radio observations are compared with the CAMS video network summaries.

1 Introduction

The observations were carried out at a private astronomical observatory near the town of Molodechno (Belarus) at the place of Polyani. A 5 element-antenna directed to the west was used, a car FM-receiver was connected to a laptop with as processor an Intel Atom CPU N2600 (1.6 GHz). The software to detect signals is Metan (author – Carol from Poland). Observations are made on the operating frequency 88.6 MHz (the FM radio station near Paris broadcasts on this frequency). The "France Culture" radio broadcast transmitter (100 kW) I use is at about 1550 km from my observatory which has been renewed in 1997.

2 Automatic observations

High signal activity was recorded from 6^h to 8^h30^m UT on May 7, 2021. This activity can be classified as belonging to ETA (#031) (Rendtel, 2020). Three waves can be distinguished on the general graph of activity: May 1–12, May 12–19, and May 19–30. Weak daily showers DEA (#154) maximum May 9, DCE (#293) maximum May 20, DMA (#294) maximum May 16, do not stand out against the general background of signal activity.

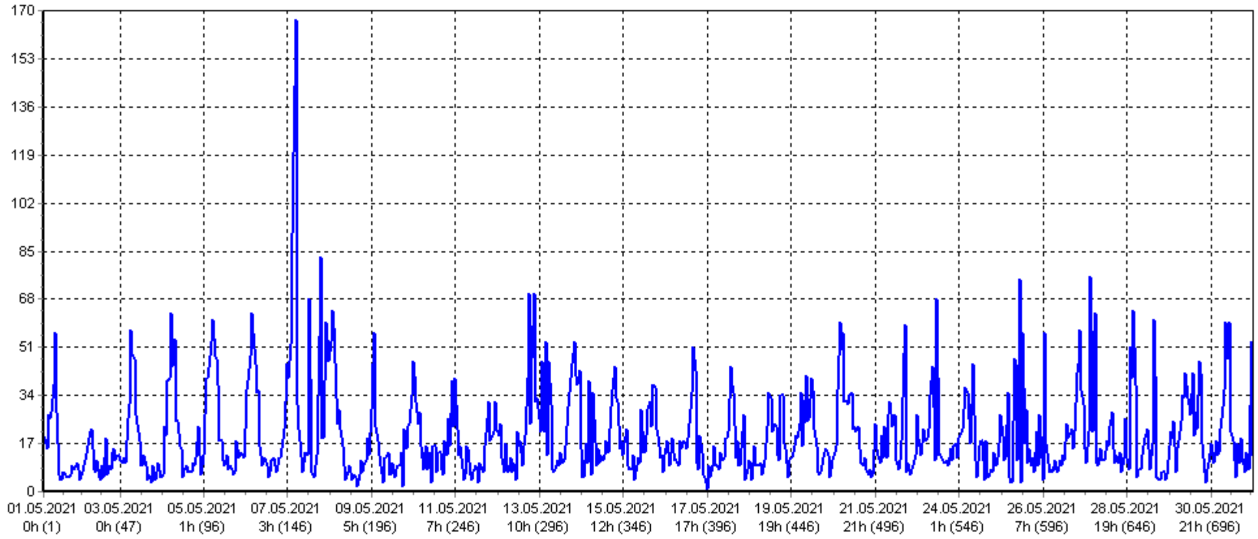

Figure 1 – Radio meteor echo counts at 88.6 MHz for May 2021.

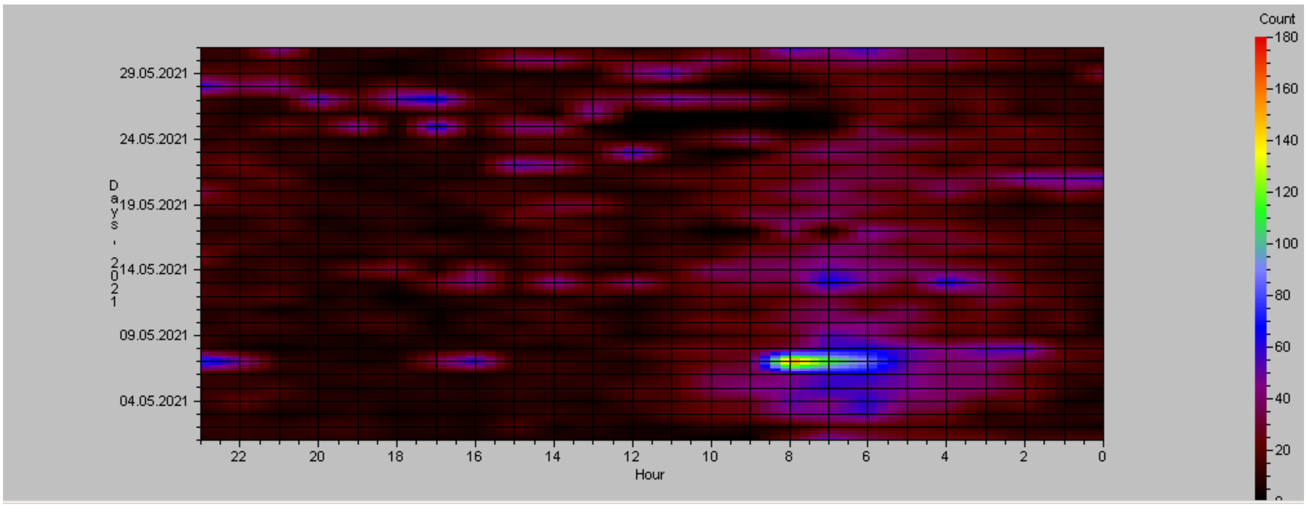

Figure 2 – Heatmap for radio meteor echo counts at 88.6 MHz for May 2021.

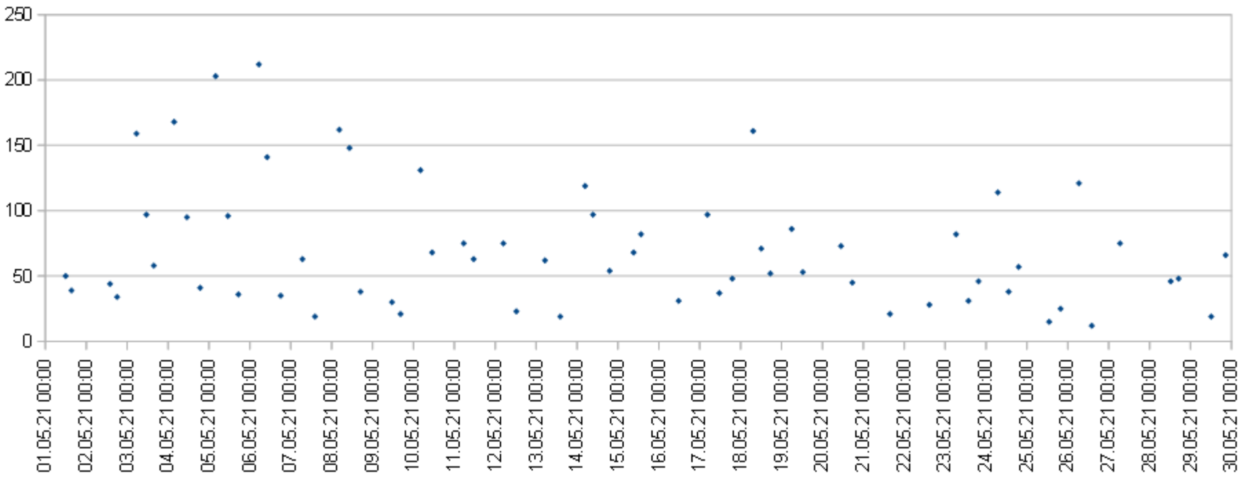

Figure 3 – The result with the calculated hourly numbers of echoes of meteors by listening to the radio signals for May 2021.

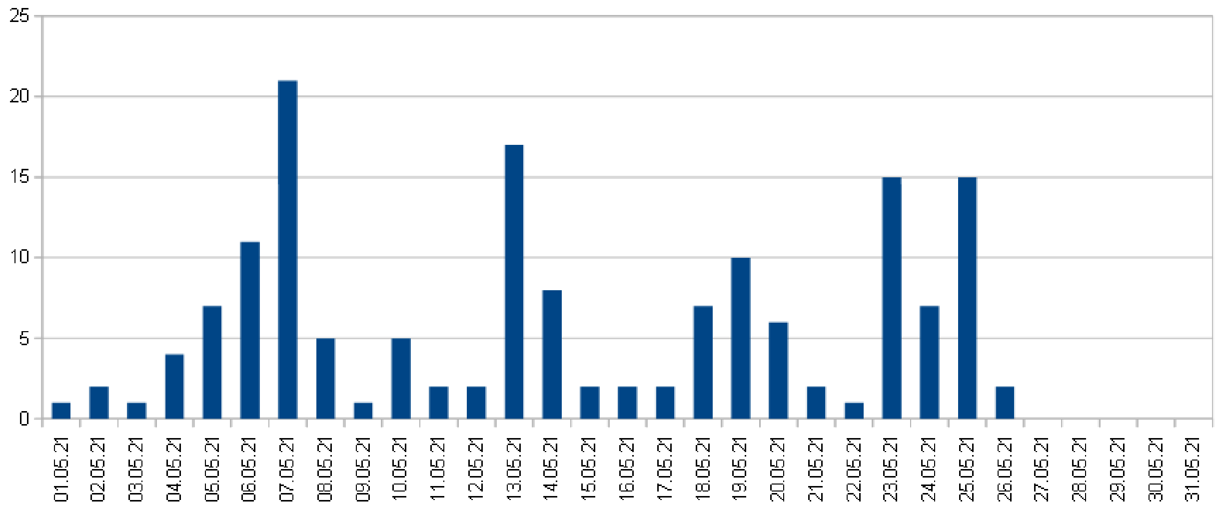

Figure 4 – Daily activity of radio fireballs in May 2021.

Figure 1 shows the hourly rates of radio meteors in May 2021 at 88.6 MHz. *Figure 2* shows the corresponding heat map.

3 Listening to radio echoes on 88.6 MHz

Listening to the radio signals 1 to 3 times a day for one hour was done in order to control the level of the hourly rates, as well as to distinguish between periods of tropospheric passage and other natural radio interference. The total effective listening time was 67 hours. Conditionally, the month can be divided into 3 waves of activity: May 1–12, the second May 13–22, and the third May 22–30. The first wave of activity is associated with ETA (#031).

4 Fireballs

In order to quickly search for signals of the radio fireballs, the program SpectrumLab was running in parallel to the Metan program. Screenshots were saved every 10 minutes. The search for fireball events was performed visually by viewing many thousands of screenshots obtained over a month. Then, we selected fireball events from the log files of the Metan program. For fireball activity statistics, I have selected signals from the log files with a peak power greater than 10000 as fireballs and with a signal duration greater than 10 seconds. *Figure 4* shows the daily activity of the fireball radio signals.

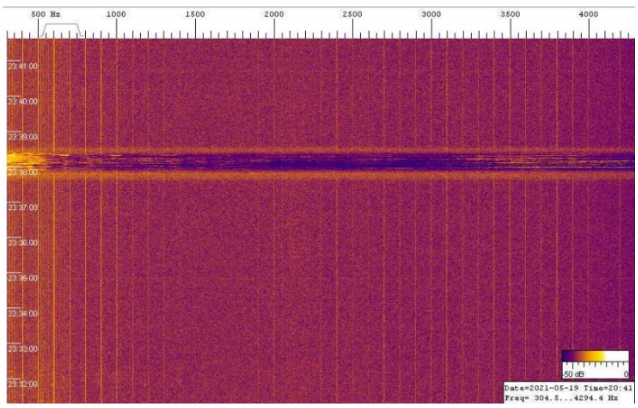

Figure 5 – Radio fireball recorded by SpectrumLab on May 19 at 20^h38^m UT.

Figure 5 displays one of the fireball radio echoes. For technical reasons, SpectrumLab screenshots were not saved from May 27 to 31.

5 CAMS Data

Figure 6 shows the total daily activity of meteors from the CAMS video network data (Jenniskens et al., 2011). There is a noticeable correlation between the activity level of sporadic meteors and the activity level of shower meteors.

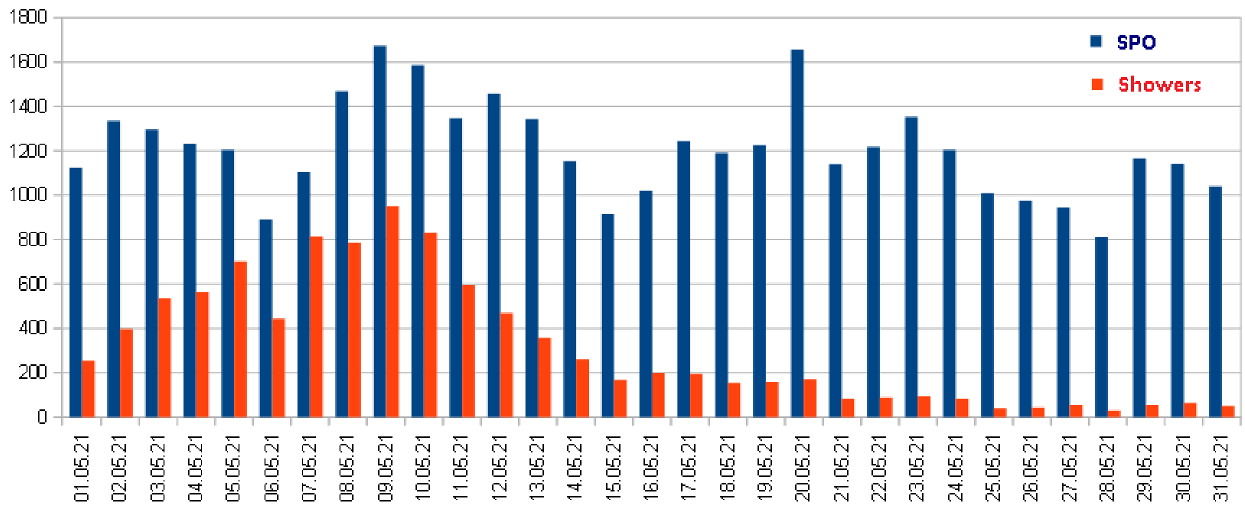

Figure 6 – Daily activity meteors of video networks CAMS in May 2021.

6 Conclusion

There is a satisfactory correlation for the data obtained by the automatic method of observation, the method of listening to the radio echoes and CAMS video observation data. Some discrepancy in the time of the ETA (#031) peak activity according to the two methods can be explained by the fact that the listening method is more sensitive than the automatic detection method. The Metan software is poor at detecting very weak signals at the detection threshold. Both methods show 3 waves of meteor signal activity within a month. CAMS data shows the peak eta Aquariids (ETA#031) on May 9, not in agreement with the IMO meteor calendar. Probably IMO data is outdated and needs to be updated.

Acknowledgment

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This article presents the results of radio observations made in June 2021. The results of the radio observations are compared with the CAMS video network summaries.

1 Introduction

The observations were carried out at a private astronomical observatory near the town of Molodechno (Belarus) at the place of Polyani. A 5 element-antenna directed to the west was used, a car FM-receiver was connected to a laptop with as processor an Intel Atom CPU N2600 (1.6 GHz). The software to detect signals is Metan (author – Carol from Poland). Observations are made on the operating frequency 88.6 MHz (the FM radio station near Paris broadcasts on this frequency). The "France Culture" radio broadcast transmitter (100 kW) I use is at about 1550 km from my observatory which has been renewed in 1997.

2 Automatic observations

The increased meteor signal activity from June 6–8 is associated with the peak of the Arietid (#0171) and zeta-Perseid (#0172) activity. The JBO peak activity (#0170) at the end of June was too weak or non-existent and it does not stand out in the overall activity profile. Similarly, the small daily showers of beta-Taurids (#0173) with a peak on June 28 (Rendtel, 2020) cannot be distinguished on the general activity profile.

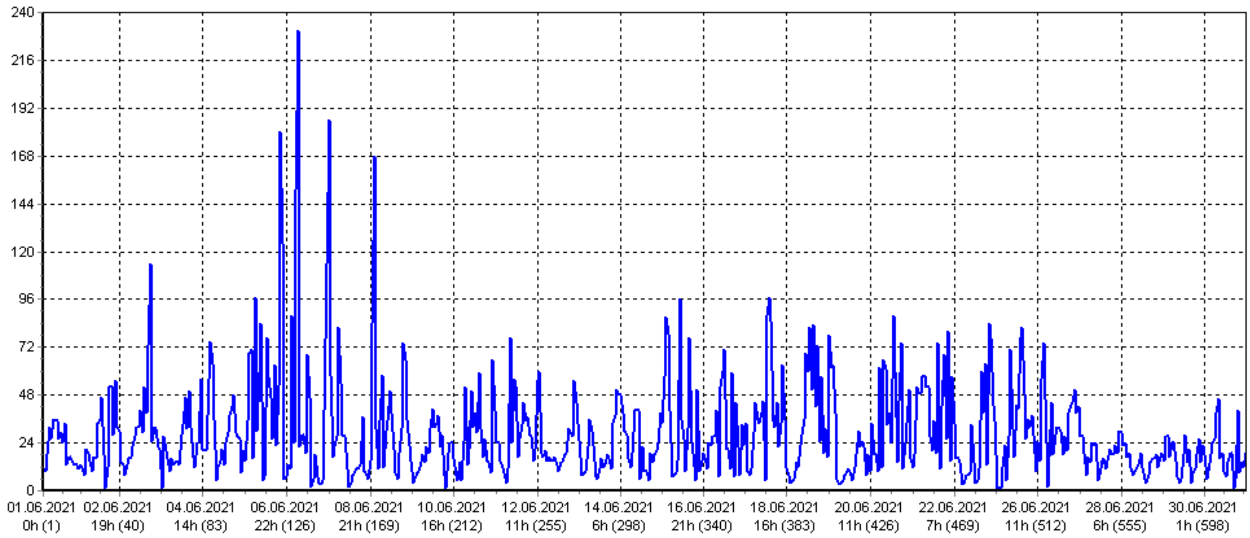

Figure 1 – Radio meteor echo counts at 88.6 MHz for June 2021.

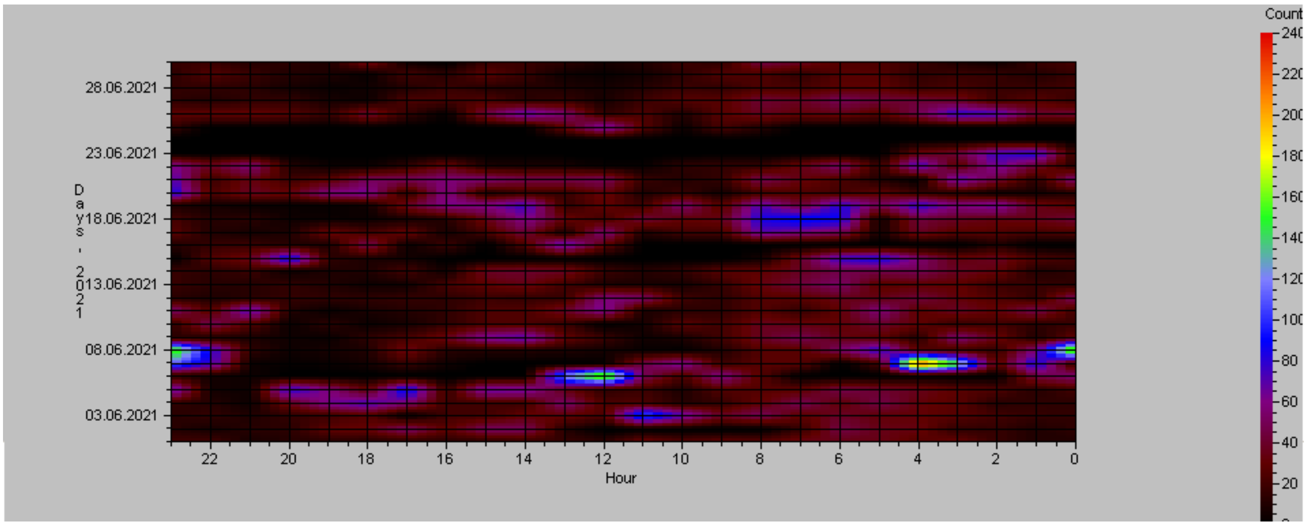

Figure 2 – Heatmap for radio meteor echo counts at 88.6 MHz for June 2021.

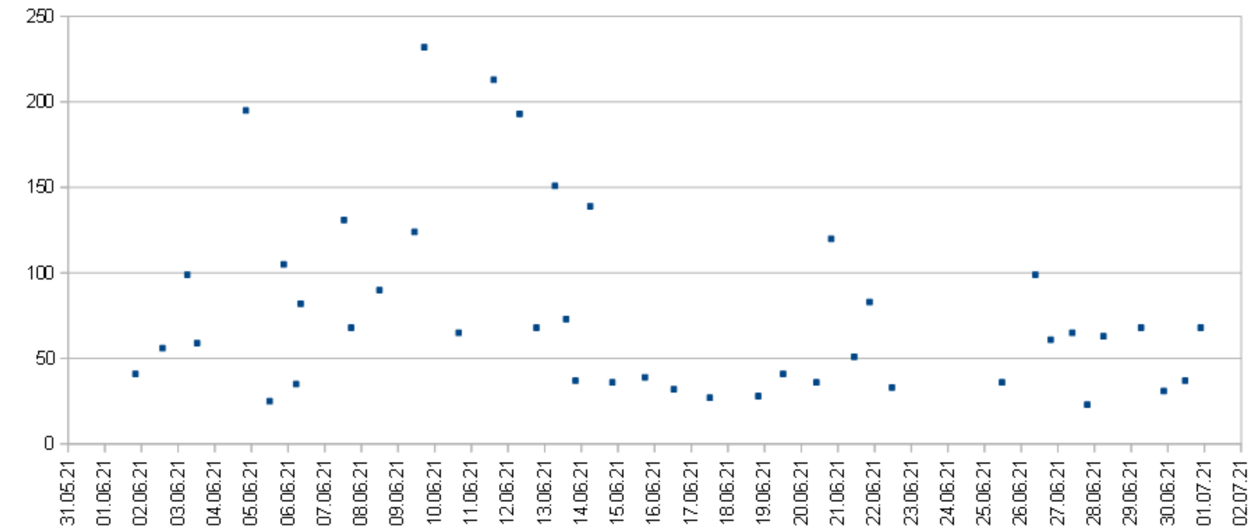

Figure 3 – The result with the calculated hourly numbers of echoes of meteors by listening to the radio signals for June 2021.

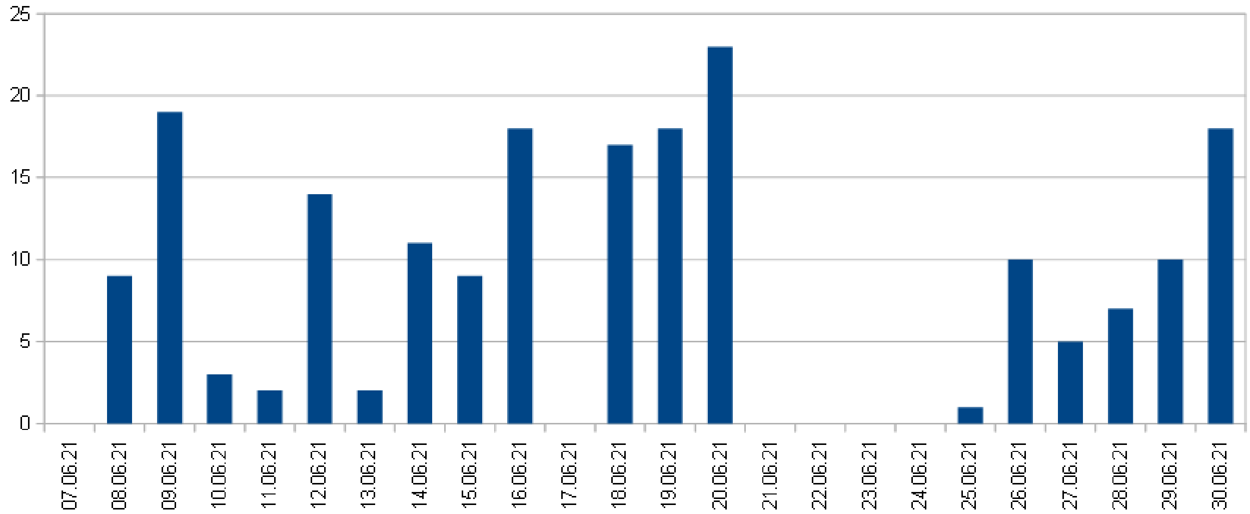

Figure 4 – Daily activity of radio fireballs in June 2021.

Figure 1 shows the hourly rates of radio meteors in June 2021 at 88.6 MHz. *Figure 2* shows the corresponding heat map.

3 Listening to radio echoes on 88.6 MHz

Listening to the radio signals 1 to 3 times a day for one hour was done in order to control the level of the hourly rates, as well as to distinguish between periods of tropospheric passage and other natural radio interference. The total effective listening time was 43 hours.

The broad high activity of June 9–12 is associated with ARI (#0171) and ZPE (#0172) daylight showers. The increased activity on June 21 may be associated, according to CAMS (Jenniskens et al., 2011), with increased activity of the June Aquilid NZC (#0164) and SZC (#0165) complex, and DPI (#0410).

4 Fireballs

In order to quickly search for signals of the radio fireballs, the program SpectrumLab was running in parallel to the Metan program. Screenshots were saved every 10 minutes. The search for fireball events was performed visually by viewing many thousands of screenshots obtained over a month. Then, we selected fireball events from the log files of the Metan program. For fireball activity statistics, I have selected signals from the log files with a peak power greater than 10000 as fireballs and with a signal duration greater than 10 seconds. *Figure 4* shows the daily activity of the fireball radio signals. *Figure 5* displays one of the fireball radio echoes.

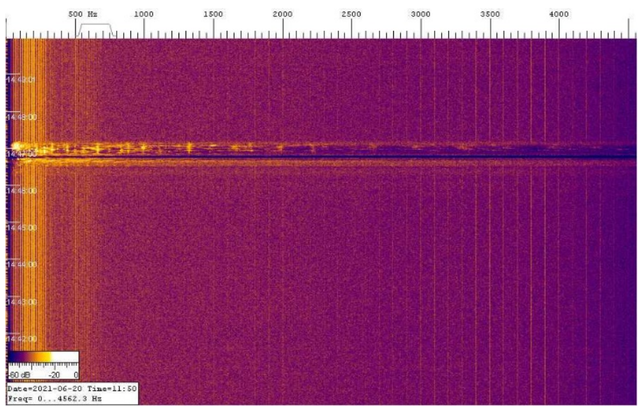

Figure 5 – Radio fireball recorded by SpectrumLab on June 20 at $11^{h}47^{m}$ UT.

For technical reasons, the SpectrumLab program screenshots were not saved from June 1 to 7 and June 21 to 24.

5 CAMS data

Figure 6 shows the total daily activity of meteors from the CAMS video network data (Jenniskens et al., 2011). There is a noticeable correlation between the activity level of sporadic meteors and the activity level of shower meteors.

CAMS data show peak activity around June 22. It is associated with an increase in the activity of the June Aquilid complex NZC (# 0164) and SZC (# 0165), as well as DPI (# 0410). The second increase in the activity of the Aquilid complex is detected on June 27–28.

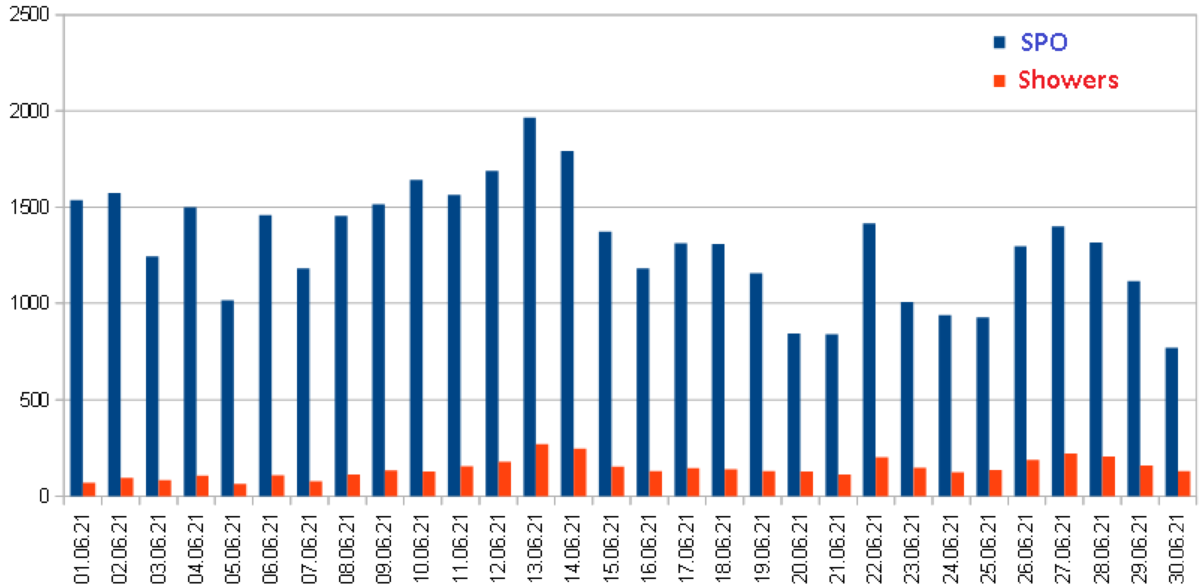

Figure 6 – Daily activity meteors of video networks CAMS in June 2021.

6 Conclusion

Leaving aside the fact that the daytime meteor shower ARI (#0171) is poorly detected by CAMS video observation networks, there is a satisfactory correlation for the data obtained by the automatic method of observation, the method of listening to the radio echoes and CAMS video observation data. The method of automatic detection and the method of listening to signals recorded very well the activity of the daytime meteor shower ARI (#0171). Some discrepancy between the activity profiles can be explained by the different sensitivity of both methods. The listening method is more sensitive than the automatic detection method. Comparing the data obtained by both methods, one can more objectively understand what is happening in the meteoric sky in the radio range.

Acknowledgment

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

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Radio meteors June 2021

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An overview of the radio observations during June 2021 is given.

1 Introduction

The graphs show both the daily totals (*Figure 1 and 2*) and the hourly numbers (*Figure 3 and 4*) of "all" reflections counted automatically, and of manually counted "overdense" reflections, overdense reflections longer than 10 seconds and longer than 1 minute, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during the month of June 2021.

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

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

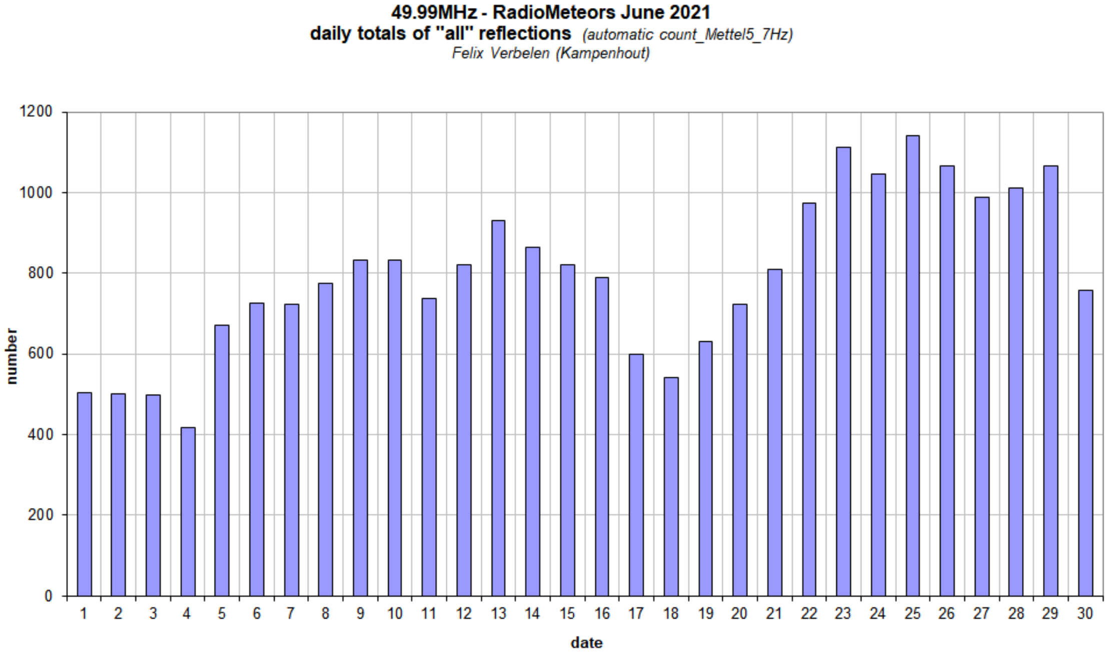
This month quite severe local interference or unidentified noise sometimes disturbed the registrations, while weak lightning activity was recorded on 3 days. Most of this unwanted interference was manually corrected before the automatic counting.

Local interference and unidentified noise were quite strong at times, and on 9 days lightning activity, at times making counts problematic, was detected.

This month was mainly dominated by the known daylight showers, in particular the Arietids (ARI), zeta Perseids (ZPE) and beta Taurids (BTA), but also other showers were quite active. (*Figures 5, 6 and 7*) Only 8 reflections of more than 1 minute were observed during this month, but the one that showed up on June 20^{th} lasted here for more than 5 minutes (*Figure 8*) and was thereby the strongest reflection in many years!

A selection of others striking or strong reflections is also included. (*Figures 9 to 16*).

If you are interested in the actual figures, or in plots showing the observations as related to the solar longitude (J2000) rather than to the calendar date. I can send you the underlying Excel files and/or plots, please send me an e-mail.



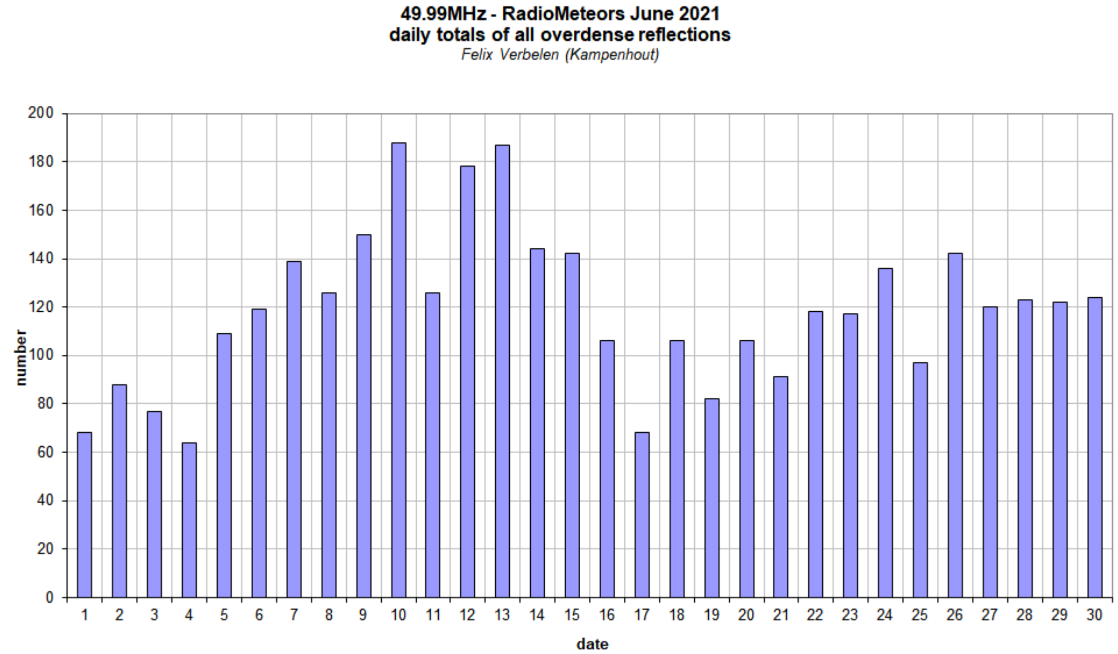
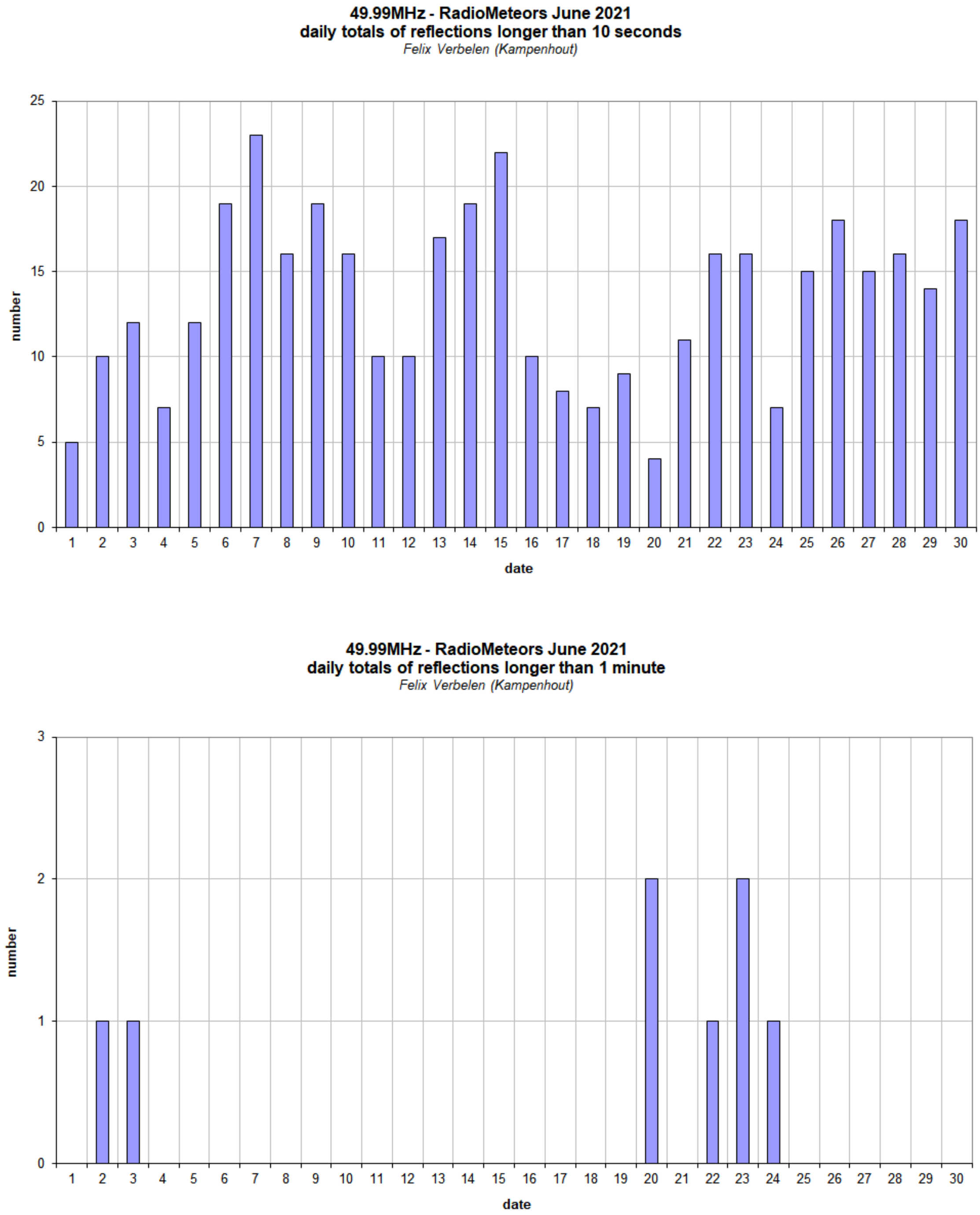


Figure 1 – The daily totals of "all" reflections counted automatically, and of manually counted "overdense" reflections, as observed here at Kampenhout (BE) on the frequency of our VVS-beacon (49.99 MHz) during June 2021.



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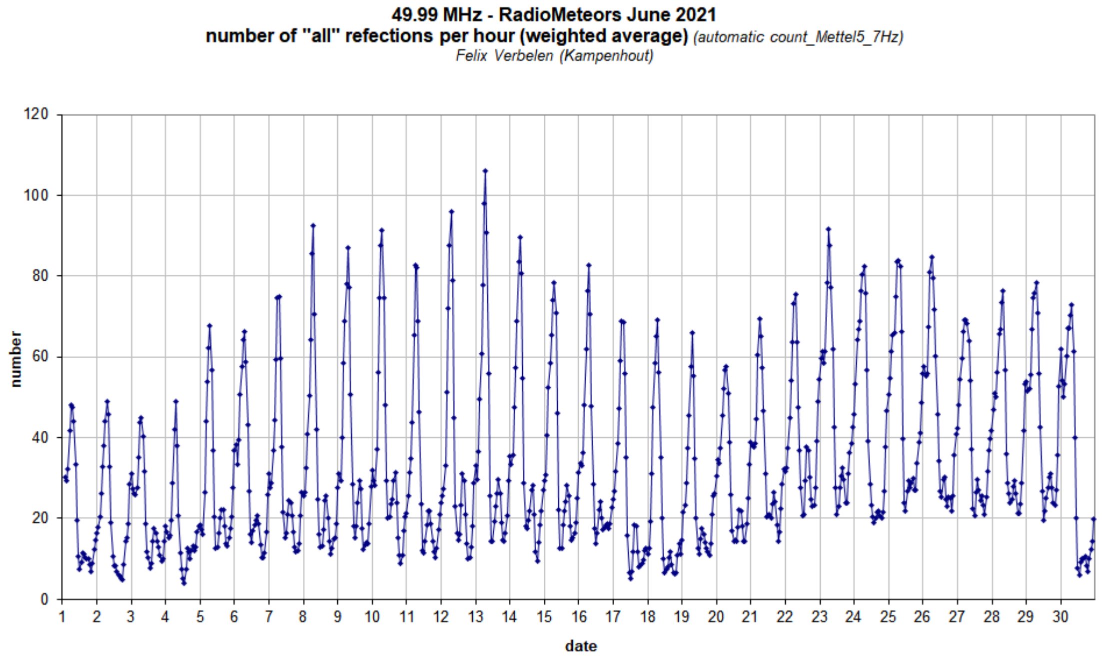

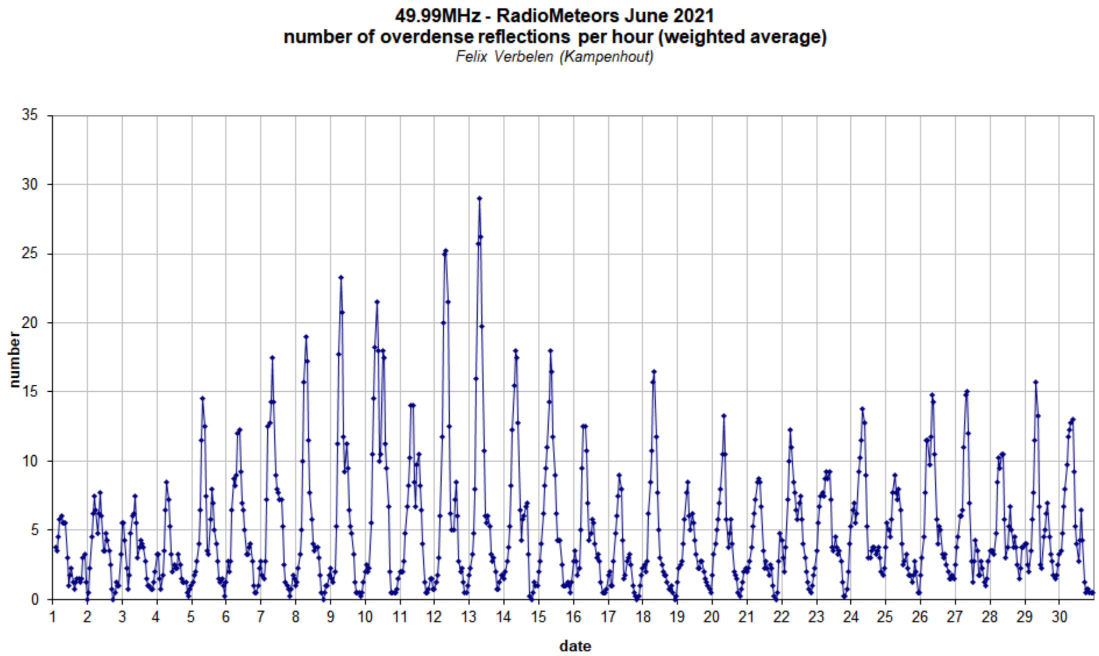

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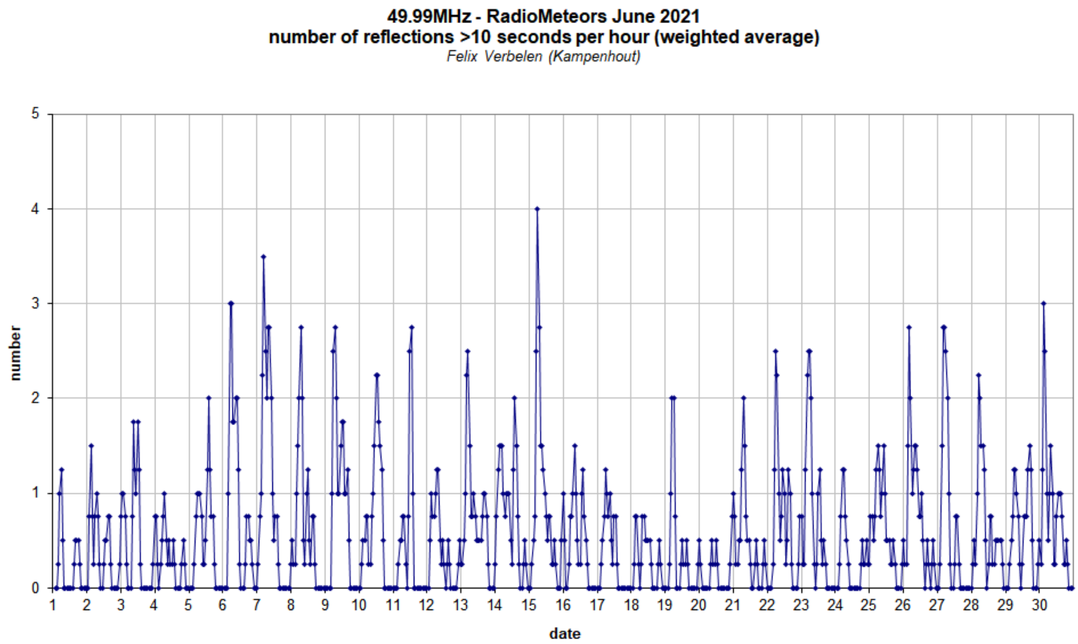

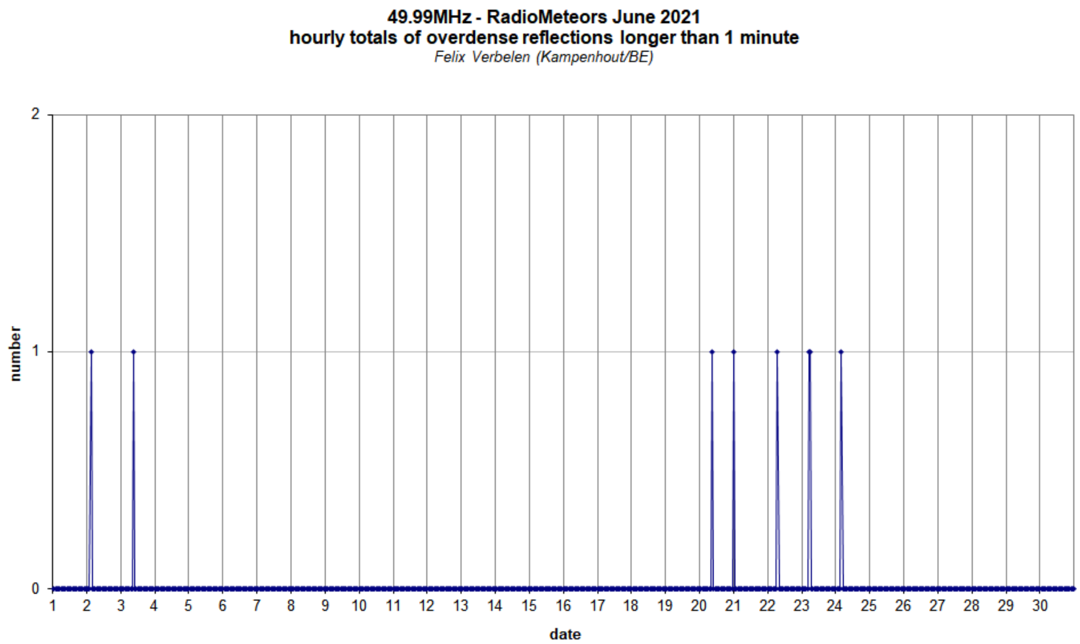

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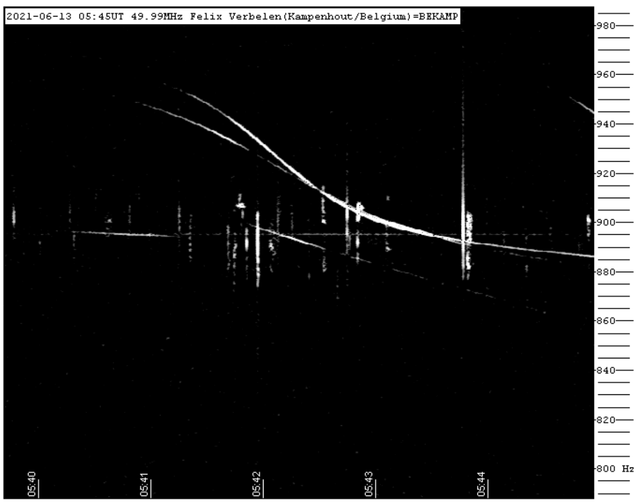

Figure 5 – Meteor reflection 13 June 2021, 05^h45^m UT.

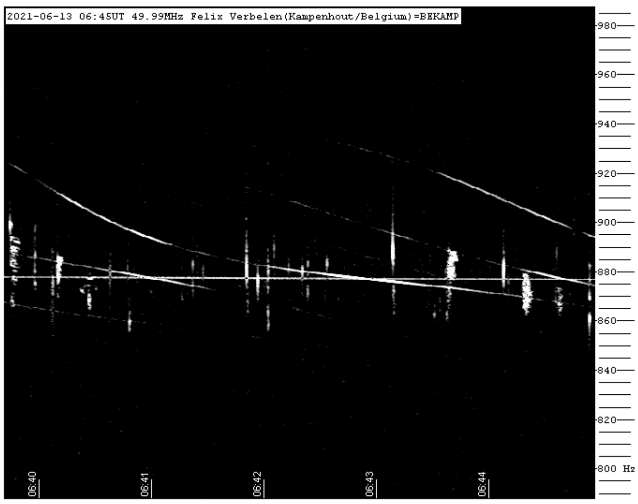

Figure 6 – Meteor reflection 13 June 2021, 06^h45^m UT.

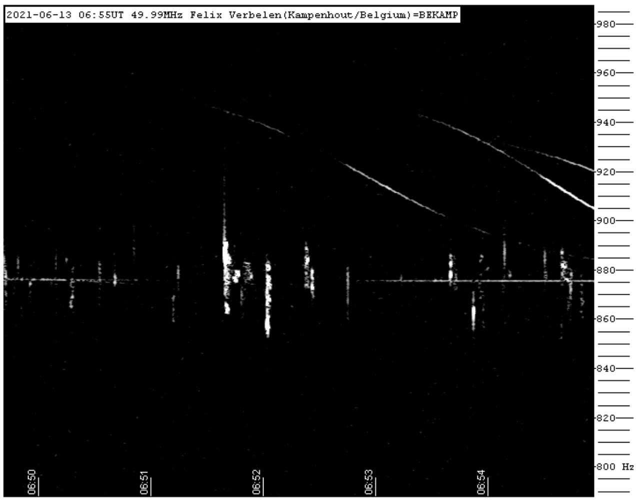

Figure 7 – Meteor reflection 13 June 2021, 06^h55^m UT.

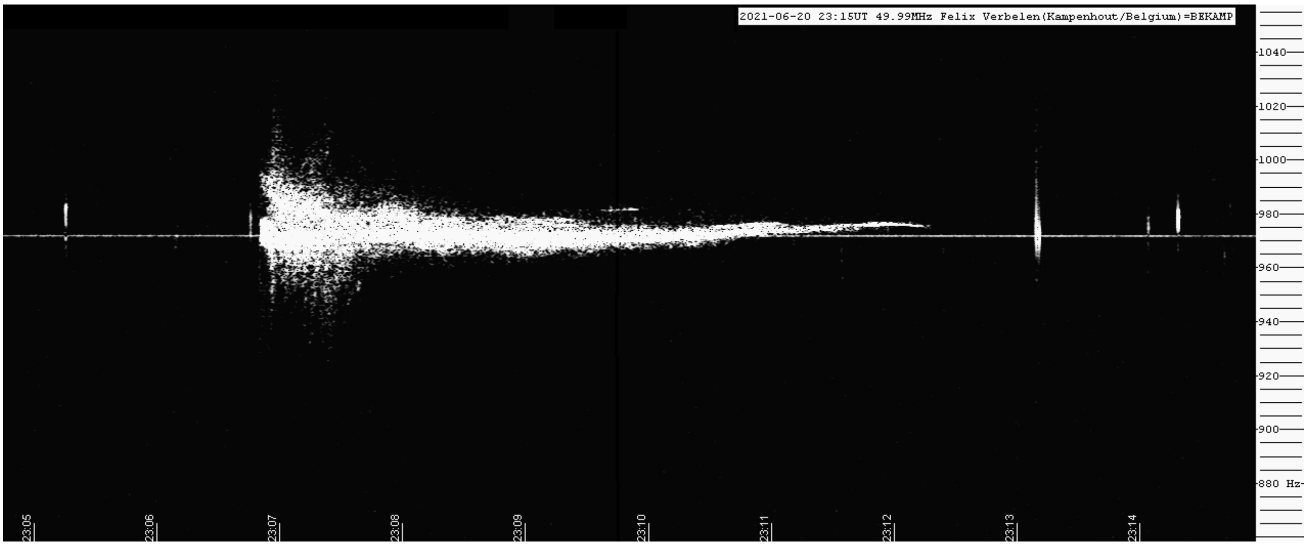

Figure 8 – Meteor reflection 20 June 2021, 23^h15^m UT.

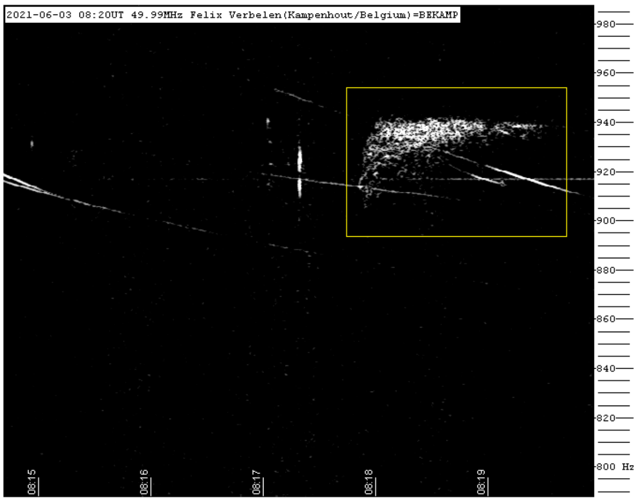

Figure 9 – Meteor reflection 3 June 2021, 08^h20^m UT.

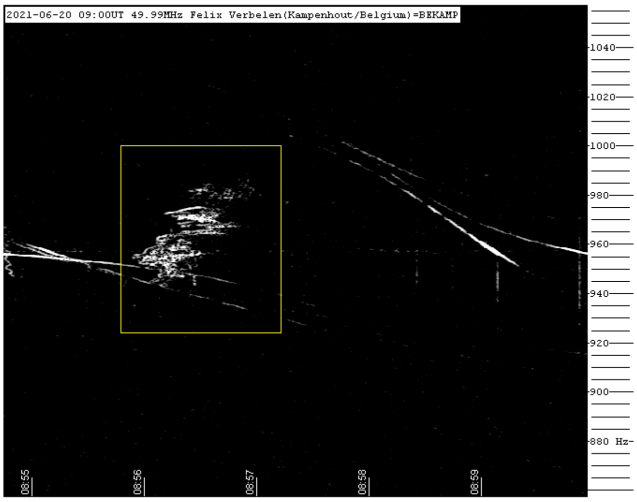

Figure 10 – Meteor reflection 20 June 2021, 09^h00^m UT.

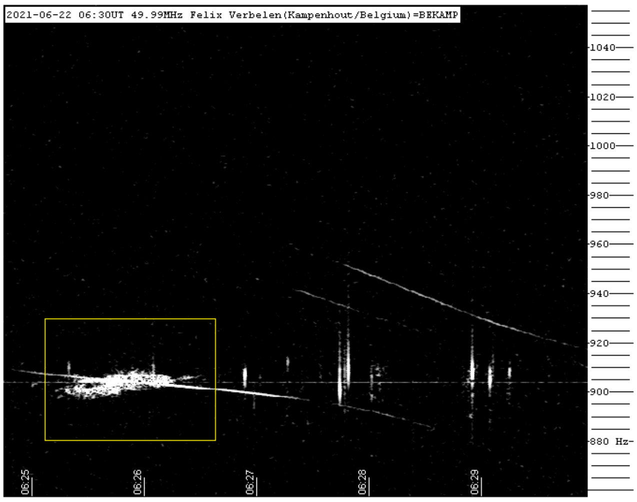

Figure 11 – Meteor reflection 22 June 2021, 06ʰ30ᵐ UT.

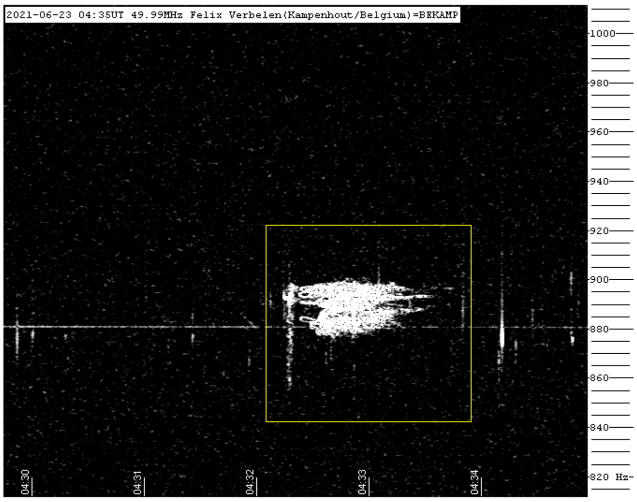

Figure 12 – Meteor reflection 23 June 2021, 04ʰ35ᵐ UT.

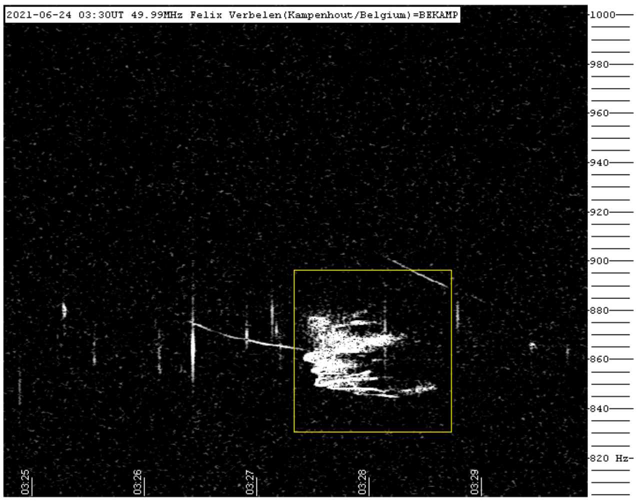

Figure 13 – Meteor reflection 24 June 2021, 03ʰ30ᵐ UT.

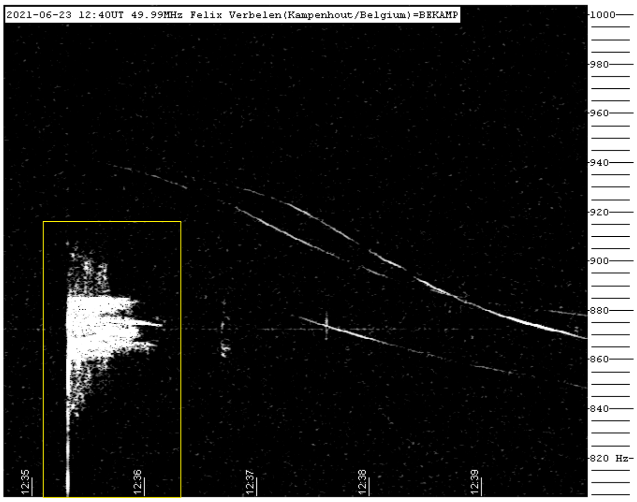

Figure 14 – Meteor reflection 23 June 2021, 12ʰ40ᵐ UT.

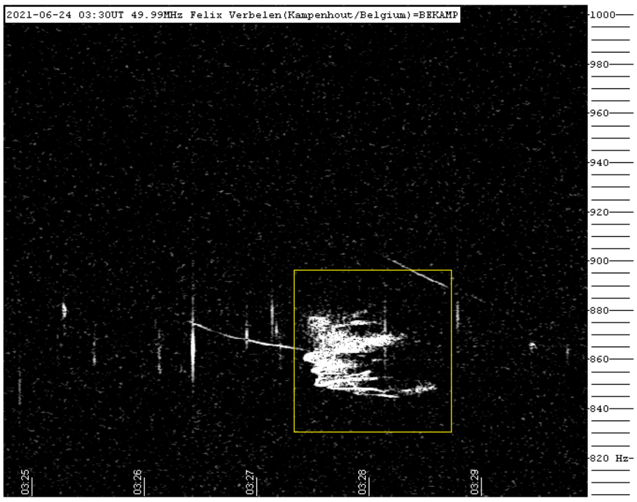

Figure 15 – Meteor reflection 24 June 2021, 03ʰ30ᵐ UT.

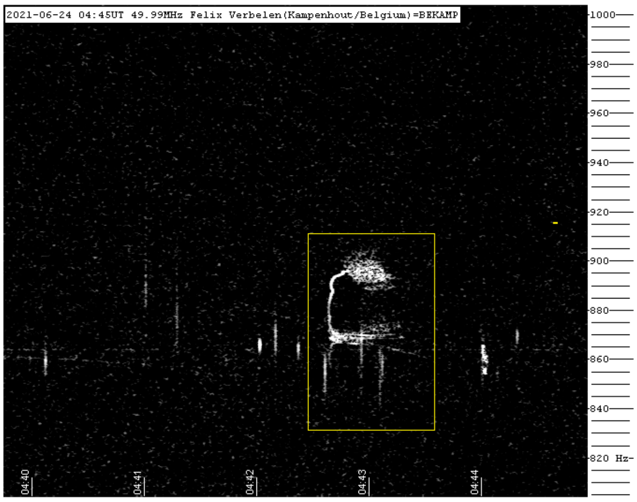

Figure 16 – Meteor reflection 24 June 2021, 04ʰ45ᵐ UT.

Radio meteors July 2021

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An overview of the radio observations during July 2021 is given.

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

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

As usual, observations were sometimes complicated by unwanted interference, unidentified noise, and on 9 days, moderate to strong lightning activity.

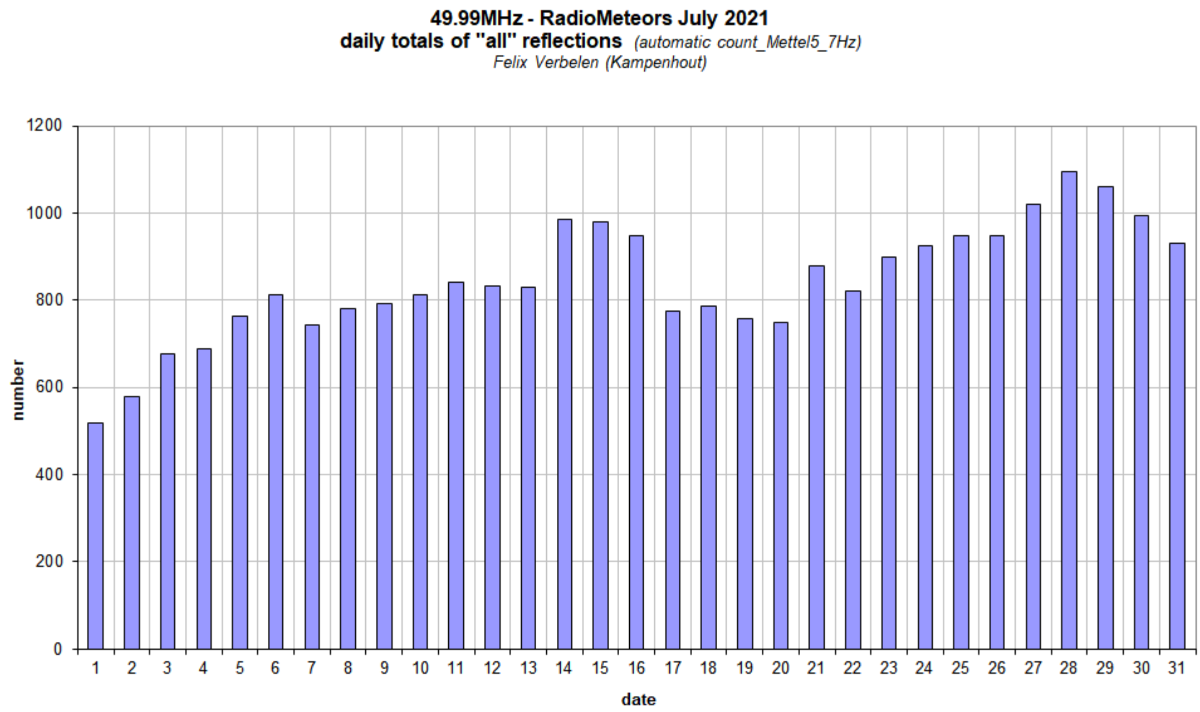
To minimize the effects of these disturbances as much as possible, the automatic counts were corrected manually.

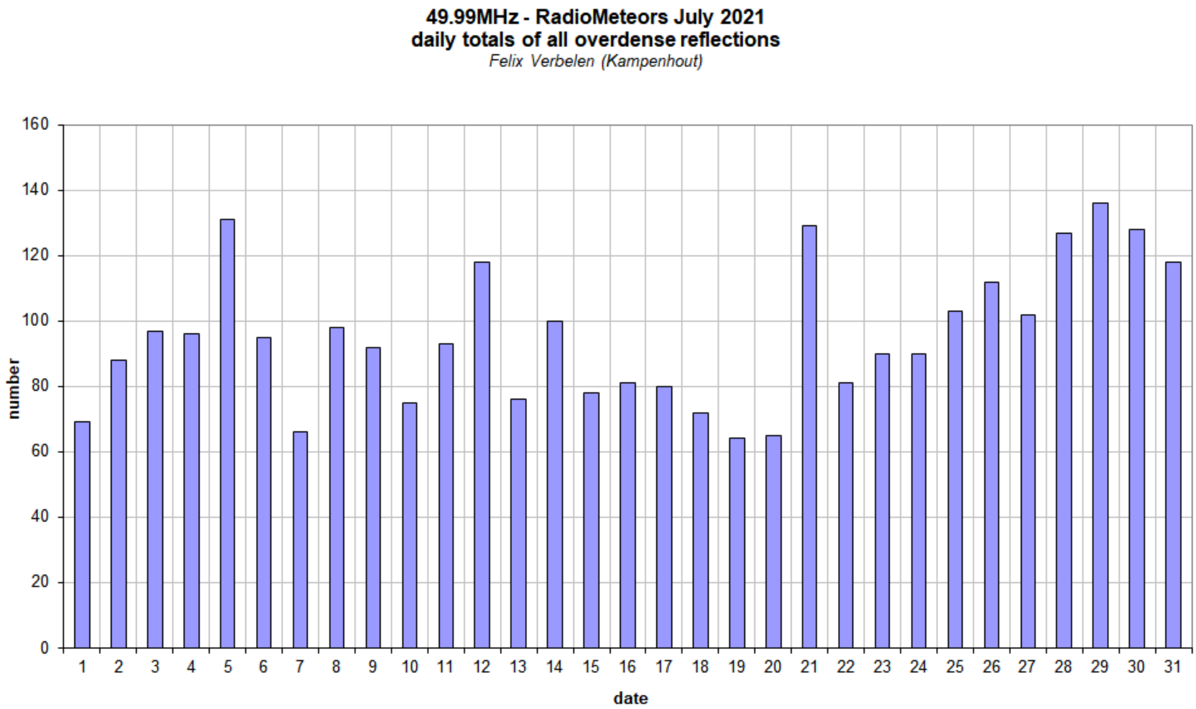
General meteor activity was quite high, with some nice showers and a marked increase towards the end of the month.

The rather remarkable increase of mainly shorter overdense reflections on 21 July is possibly due to the phi Piscids and/or the kappa Perseids, but this should be confirmed.

14 reflections of more than 1 minute were observed during this month. A selection of others striking or strong reflections is also included. (*Figures 5 to 15*).

If you are interested in the actual figures, or in plots showing the observations as related to the solar longitude (J2000) rather than to the calendar date. I can send you the underlying Excel files and/or plots, please send me an e-mail.





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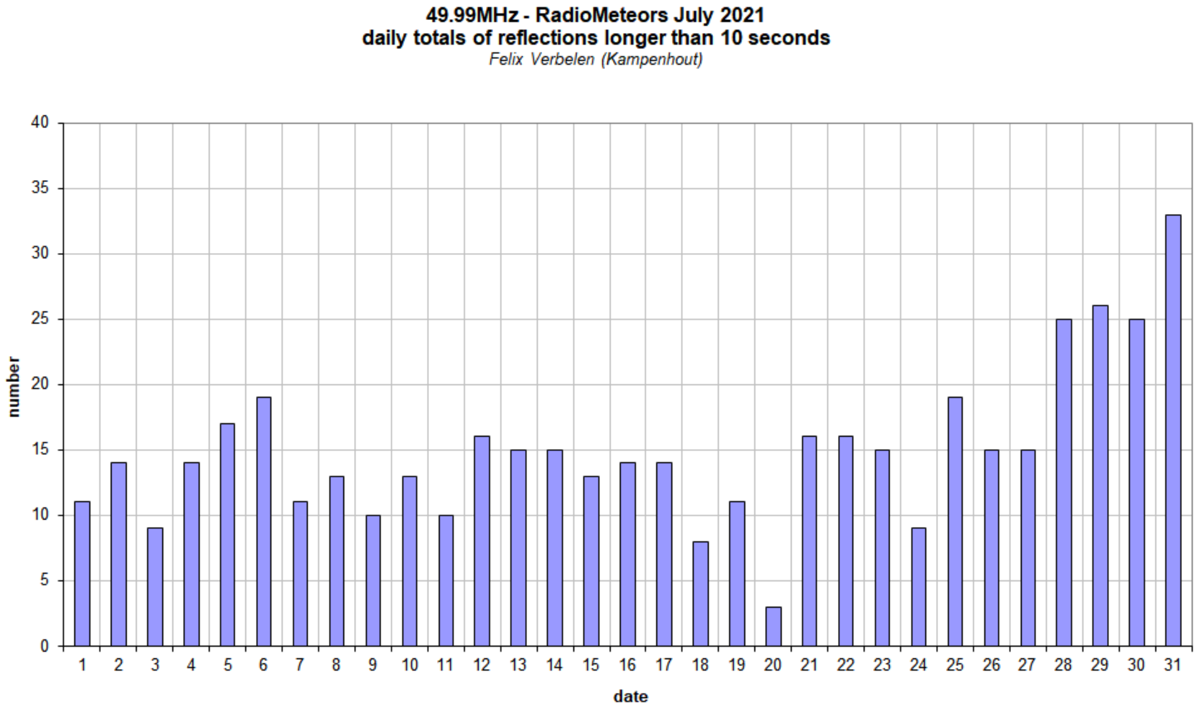

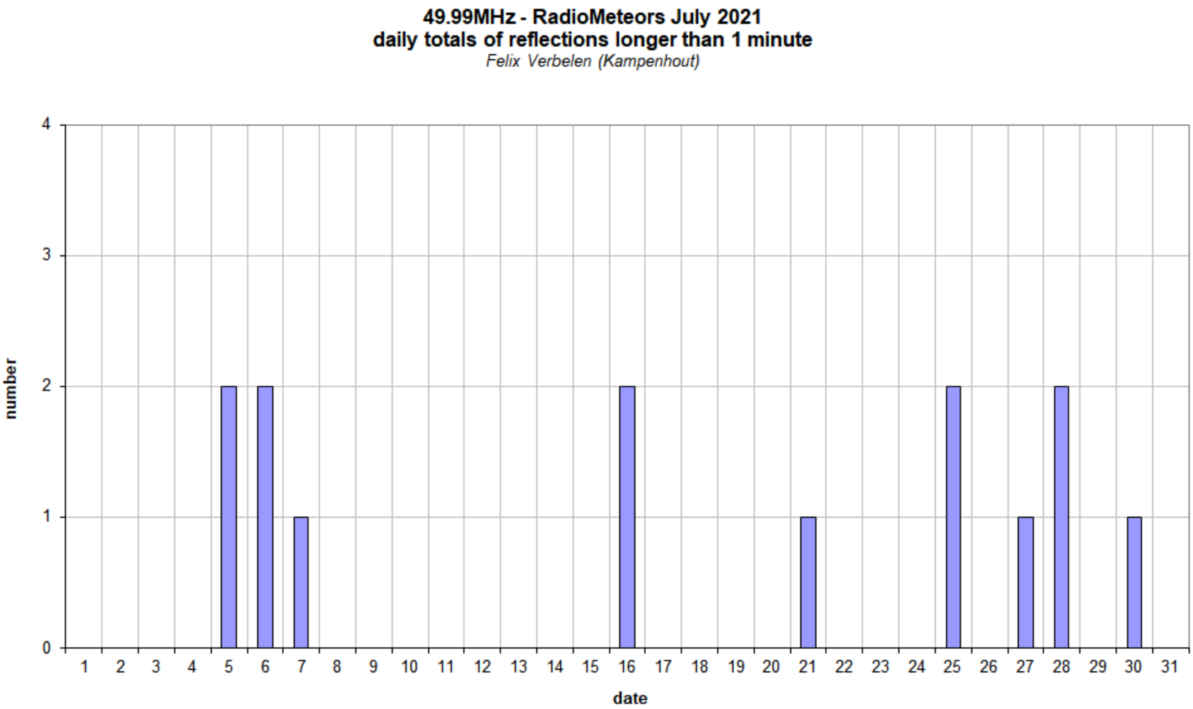

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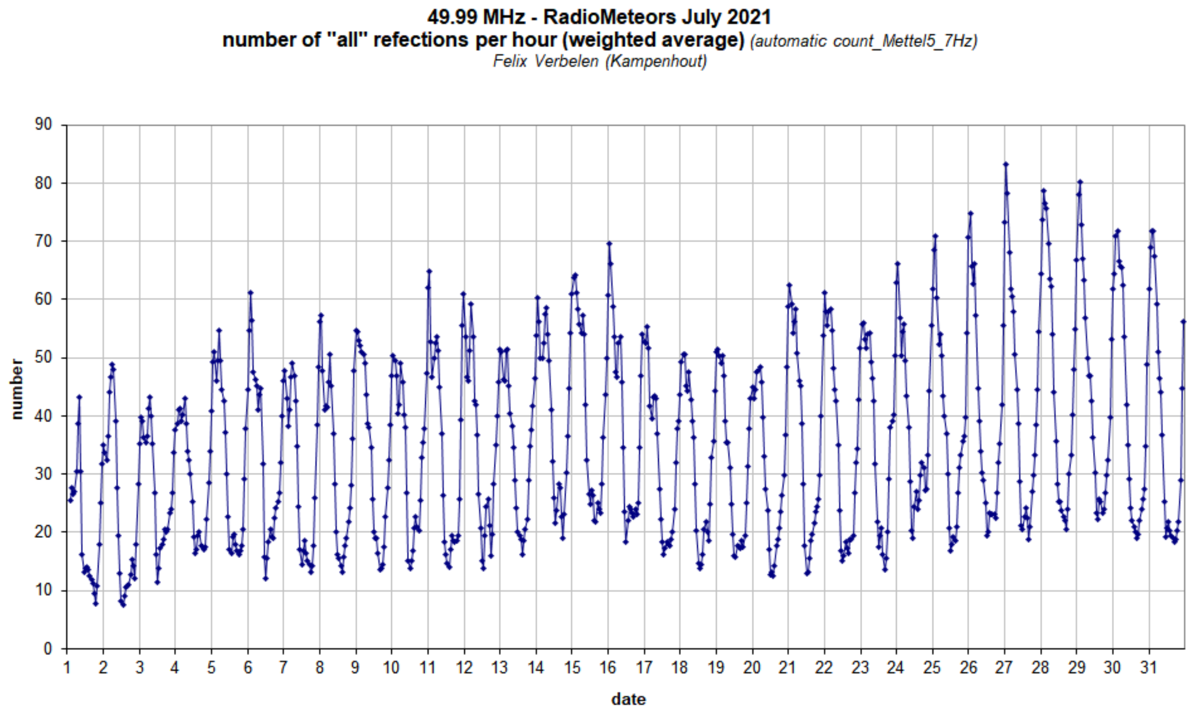

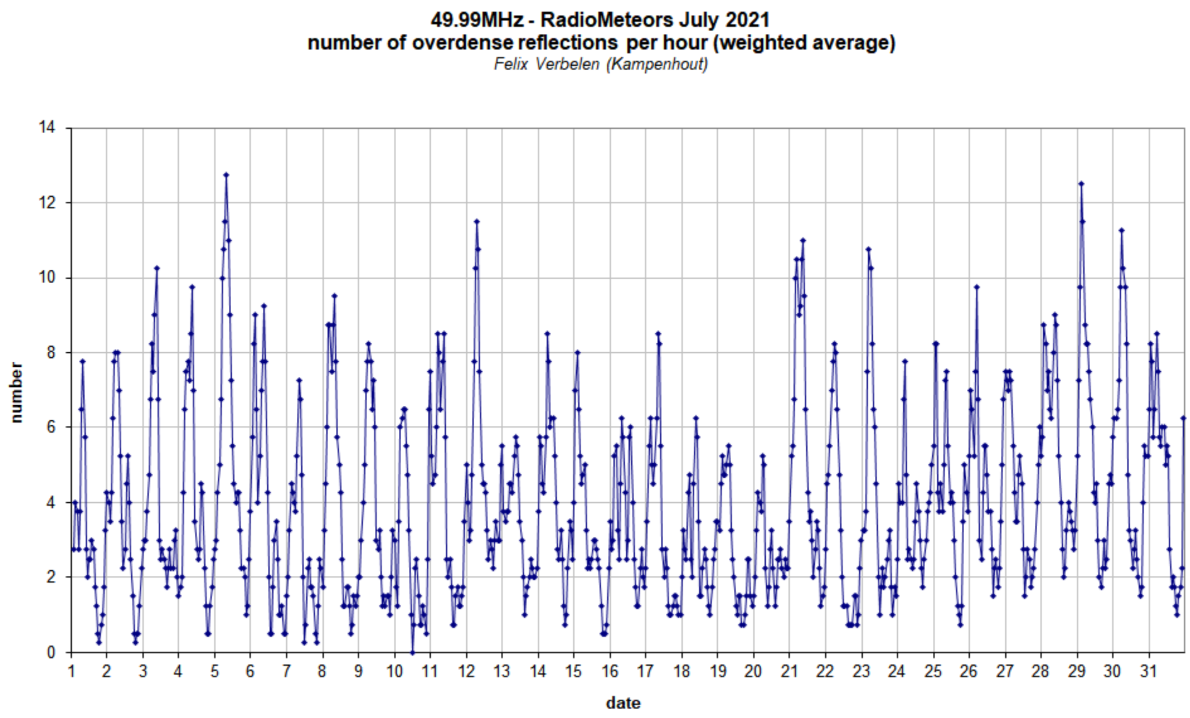

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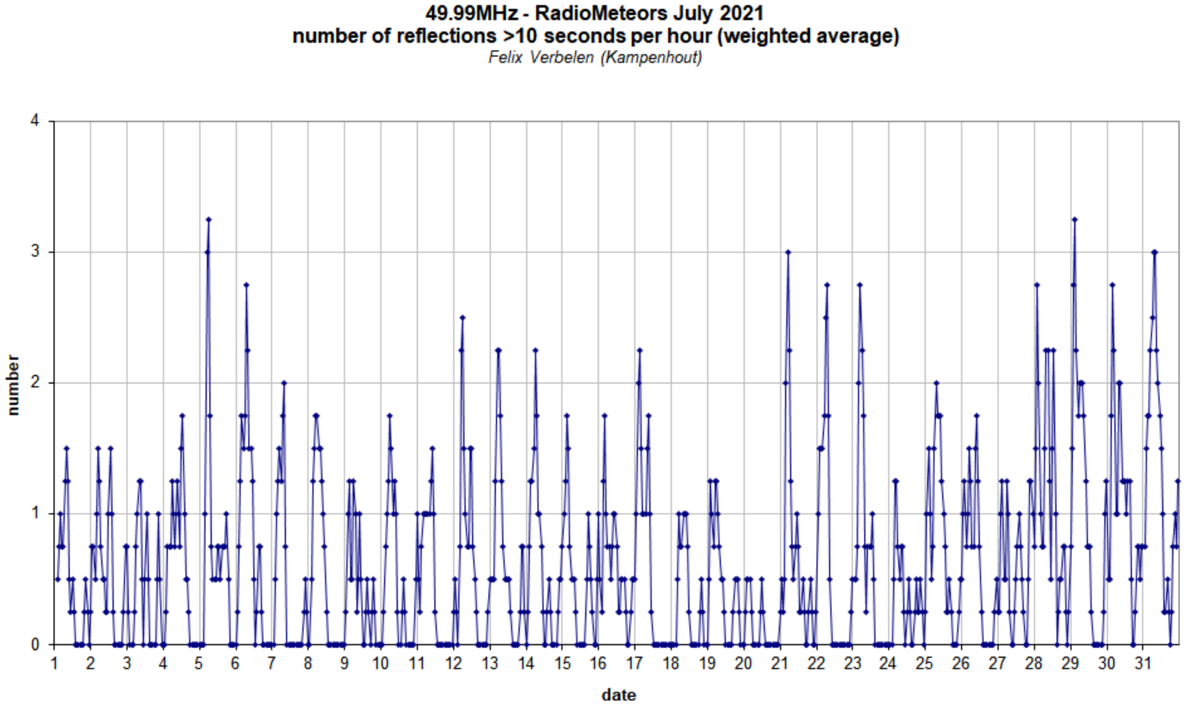

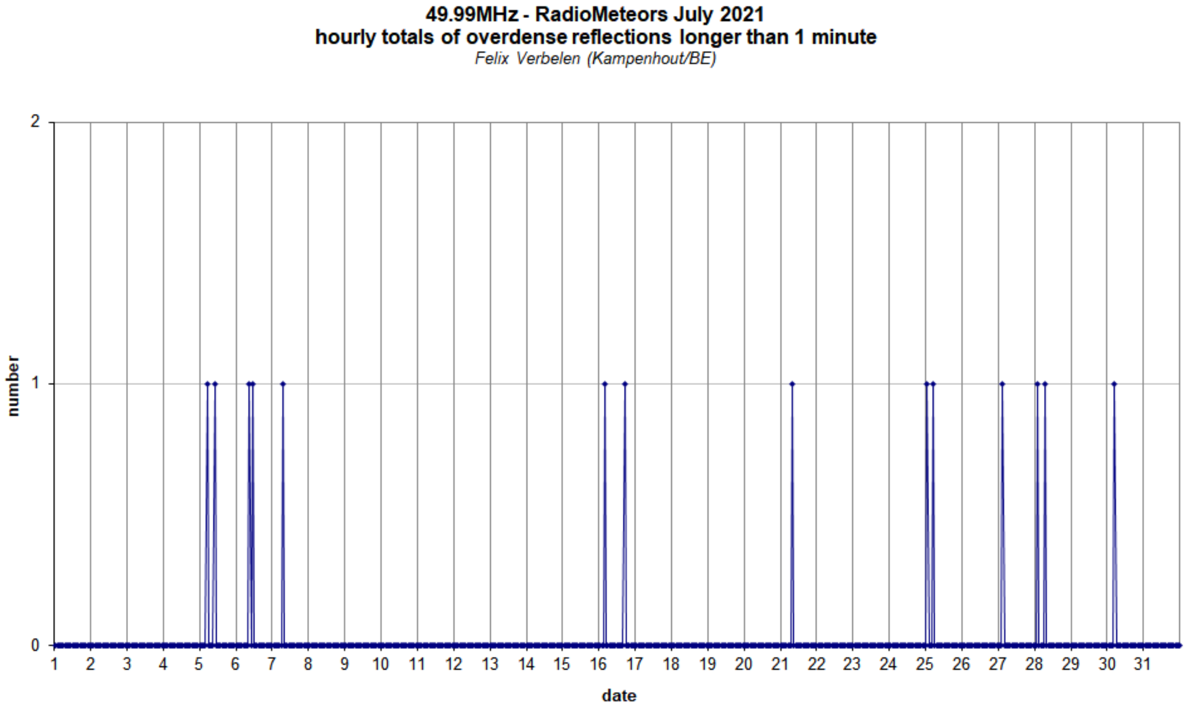

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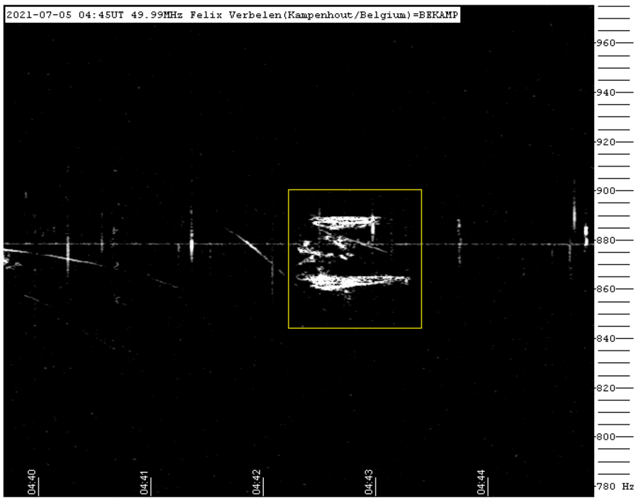

Figure 5 – Meteor reflection 05 July 2021, 04ʰ45ᵐ UT.

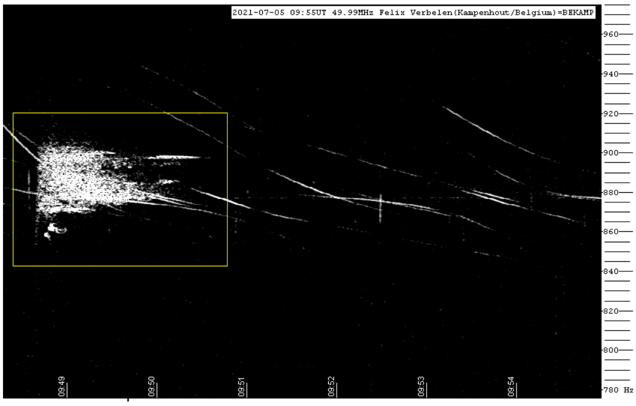

Figure 6 – Meteor reflection 05 July 2021, 09ʰ55ᵐ UT.

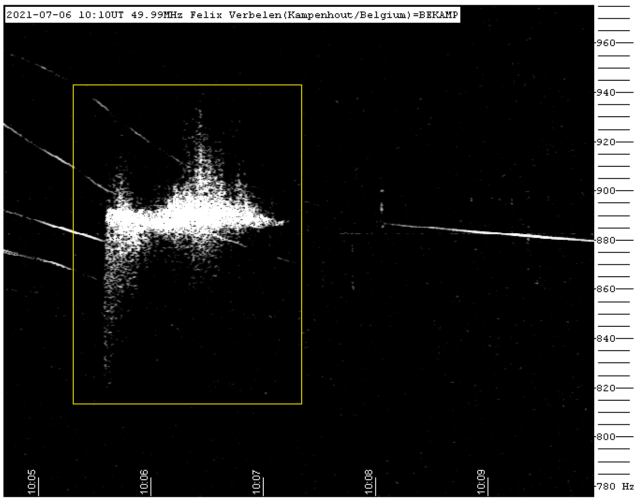

Figure 7 – Meteor reflection 06 July 2021, 10ʰ10ᵐ UT.

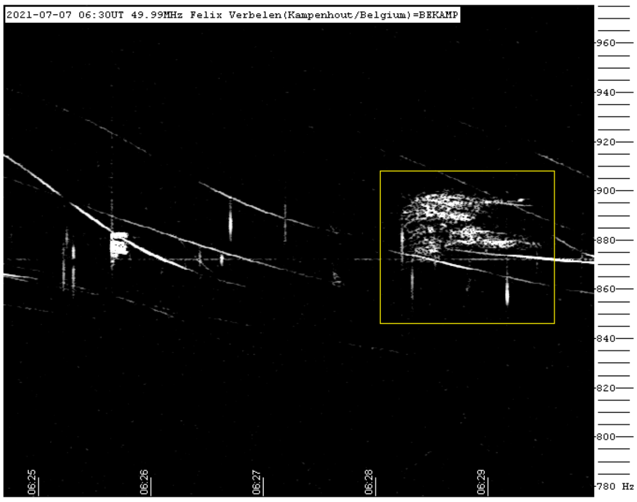

Figure 8 – Meteor reflection 07 July 2021, 06ʰ30ᵐ UT.

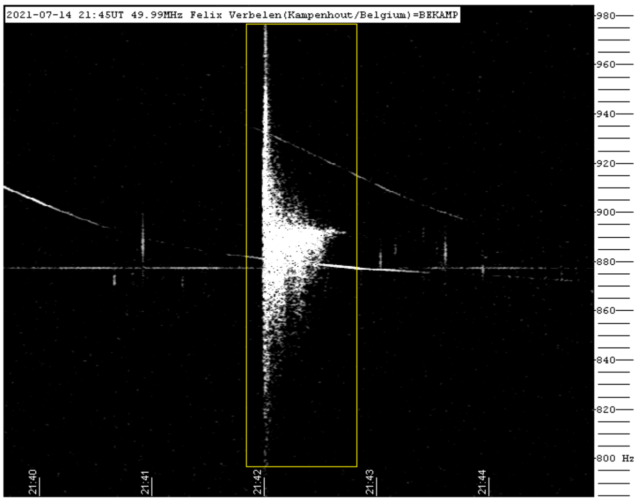

Figure 9 – Meteor reflection 14 July 2021, 21ʰ45ᵐ UT.

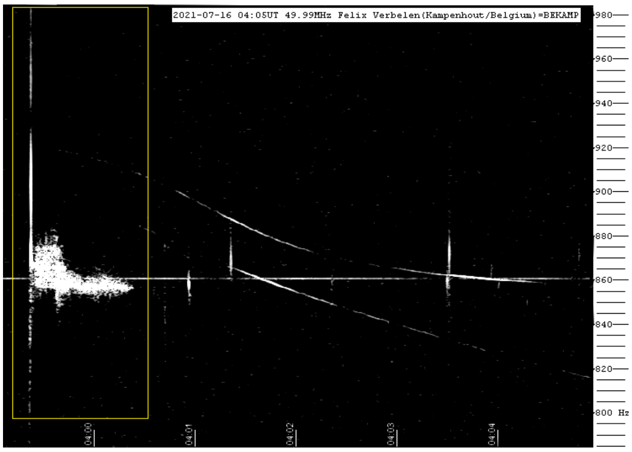

Figure 10 – Meteor reflection 16 July 2021, 04ʰ05ᵐ UT.

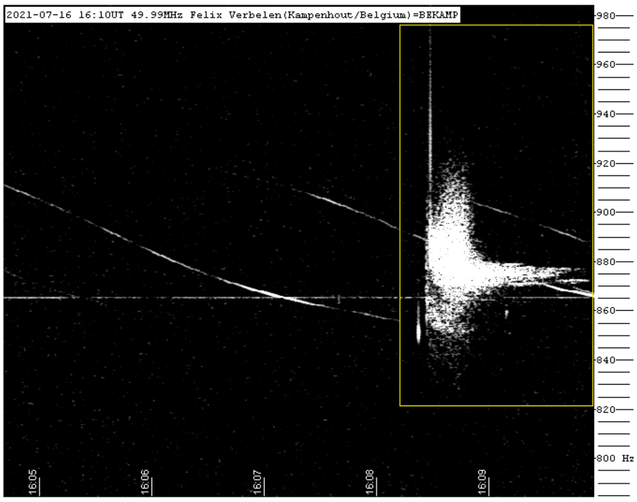

Figure 11 – Meteor reflection 16 July 2021, 16^h10^m UT.

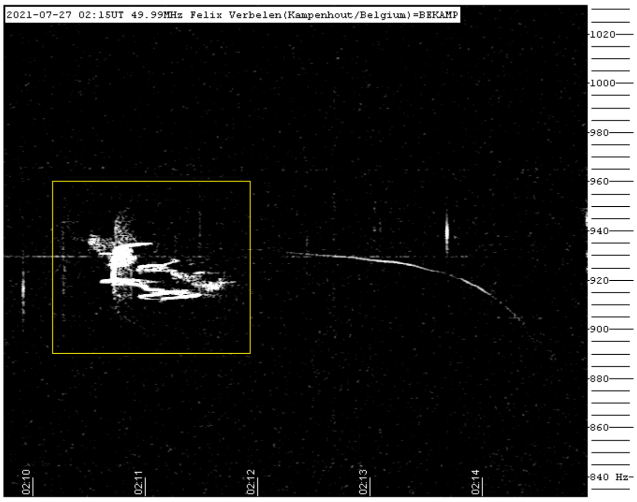

Figure 12 – Meteor reflection 27 July 2021, 02^h15^m UT.

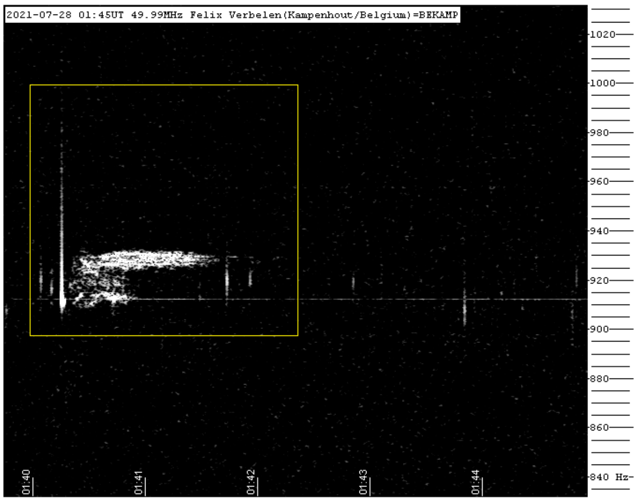

Figure 13 – Meteor reflection 28 July 2021, 01^h45^m UT.

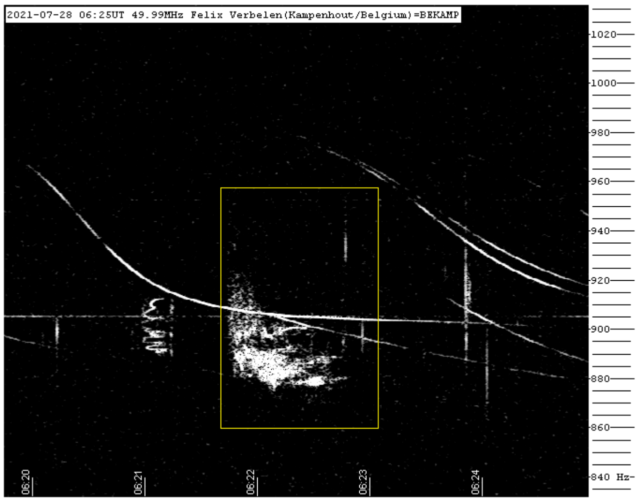

Figure 14 – Meteor reflection 28 July 2021, 06^h25^m UT.

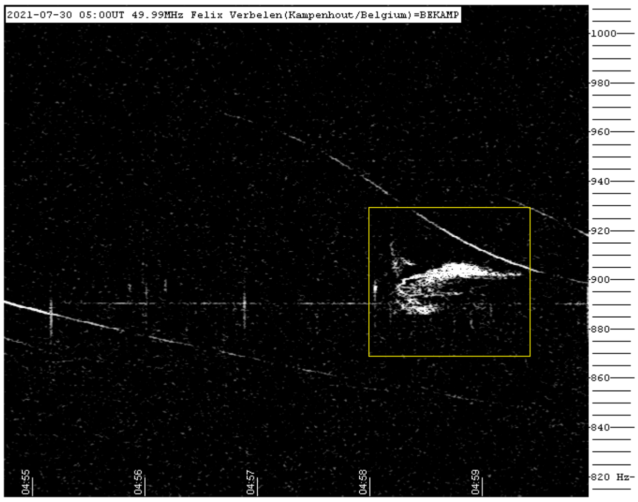

Figure 15 – Meteor reflection 30 July 2021, 05^h00^m UT.

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