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IMC 2020 in Hungary from September 17 to 20
Height of meteors from video data and comparison with radio data
July–August IMO video meteors
Meteor reports in The Astronomer magazine - part V

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Front cover photo

This fantastic green fireball was captured on 2019 July 1 at $08^{\mathrm{h}}15^{\mathrm{m}}$ UT from Summer Lake, Oregon USA. Refer to IMO Fireball Report #2847-2019. Photo courtesy: Jason Ptaszek.

Writing for WGN This Journal welcomes papers submitted for publication. All papers are reviewed for scientific content, and edited for English and style. Instructions for authors can be found in WGN **45:1**, 1–5, and at `http://www.imo.net/docs/writingforwgn.pdf` .

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Conferences

IMC 2020 September 17–20 in Hortobágy, Hungary

Ákos Kereszturi[1]

The annual International Meteor Conference will be held in 2020 between 17–20th September in Hungary. The location is at the Great Hungarian Plain, Hortobágy area, nearby a village called Poroszlo. The International Meteor Organization held its founding General Assembly Meeting in Hungary in 1989 at Lake Balaton at the 1989 IMC in Balatonföldvár, which was the 8th of its kind. In 2020 the IMC will visit Hungary for the second time.

The proposed location is at the lake called Tisza-tó, at the area of the Natural Reserve Hortobágy (part of the UNESCO World Heritage sites). The meeting will be hosted by a farm-like hotel, where accommodation, catering, lecture hall are situated together, next to each other (Figure 1). All of the buildings are in 100–200 m walking distance from each other, except some of the low-cost rooms, which are in small motels around 20 minutes walking distance.

The organizer is the Research Centre for Astronomy and Earth Sciences (CSFK) working on several meteor-related topics, including fireball camera observations, lunar impact flash monitoring, infrasound system searching for atmospheric blasts, and laboratory based analysis of meteorites. There is a long tradition on asteroid observations, which are connected to sporadic meteors and comet observations related to meteor showers. Direct and close link exists between CSFK and the Hungarian Astronomical Association, the main amateur astronomy oriented organization in Hungary covering meteor observations.

The conference site is located at 1.5 hour driving from Budapest. For persons arriving to the airport, a shuttle service will be provided. Further details will be available online at the IMO website in this autumn, and in future issues of WGN. For more preliminary information on the meeting please contact Ákos Kereszturi (`kereszturiakos@gmail.com`).

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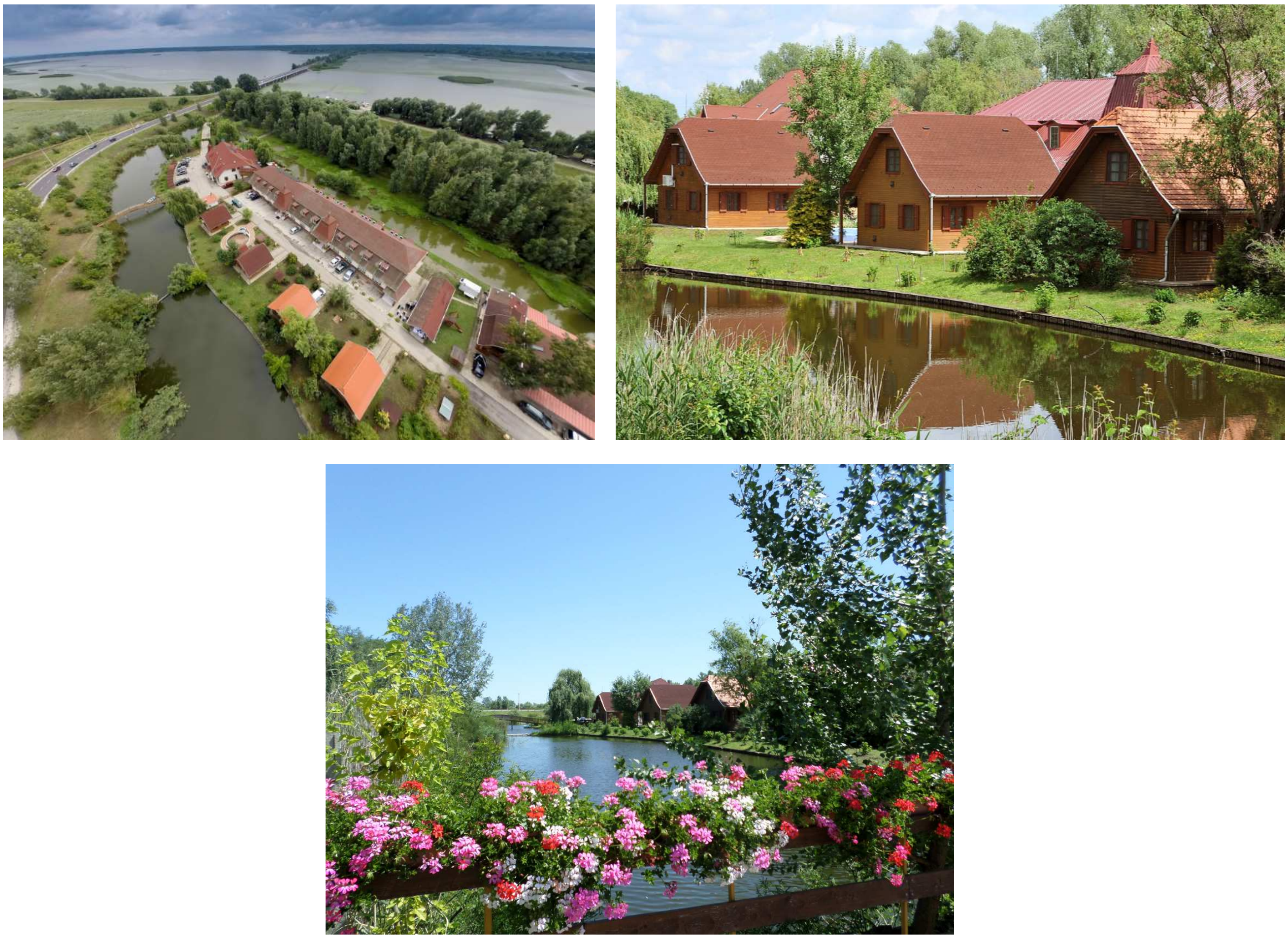

Figure 1 – The IMC 2020 venue.

Ongoing meteor work

Concerning the height of meteors

Lorenzo Barbieri[1,2], *Gaetano Brando*[1]

The height at which the meteors appear in the sky is not constant. The analysis of observational data shows a wide random variability. Within this we can see a systematic variation, both during the year and during each day. It has a sinusoidal shape, with an amplitude of 8 km around a mean value of 99 km. This systematic variation seems to depend on the 'i' parameter, 'i' being the inclination of the meteors orbital plane with respect to the ecliptic plane.

Received 2019 May 21

1 Introduction

The present study starts with the observational data collected in a year of RAMBo activity (Radar Astrofilo Meteorico Bolognese).

2 What is RAMBo

RAMBo is a meteor bistatic radar set-up placed at the AAB (Associazione Astrofili Bolognesi) headquarters. It works according to the "meteor scatter" principle.

Its purpose is to capture the meteor radio echoes and to record their characteristics. The set-up has been active since 2013, and is recording almost one million meteors per year.

As soon as a small meteoric particle entering the Earth's ionosphere impacts the air molecules, it disintegrates, generating a cascade of ionized molecules.

A long and narrow cylinder consisting of ions and free electrons is then created, which persists for a short period of time before the ambipolar diffusion and the recombination process dissolves it. The free electrons, when hit by a radio signal, oscillate at the frequency of this signal, behaving in turn as an emitter of an electromagnetic field. From the radioelectric point of view, the cylinder of free electrons therefore behaves like a reflective object, analogous to an airplane, a satellite or any other flying object. The re-emission of the incident radio signal is called "meteor scatter" (Figure 1).

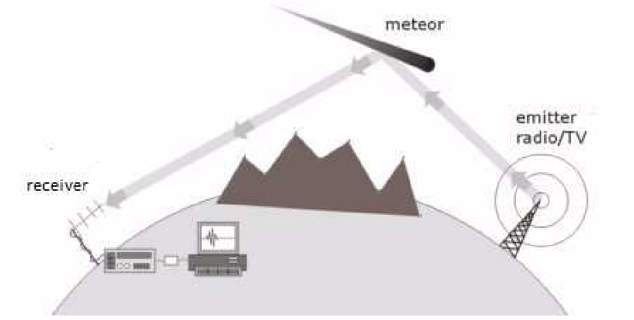

Figure 1 – Meteor scatter.

If we have a radio transmitter that illuminates a portion of sky and a distant receiver tuned to the same frequency, we can record the received radio echoes and evaluate the signals characteristics.

RAMBo uses the signal emitted by the military radar transmitter GRAVES located near Dijon (France), that continuously transmits in VHF at very high power (the frequency is approximately 143 MHz) – Figure 2.

Figure 2 – The GRAVES transmitter.

Its transmission is turned upwards and therefore, both for this reason and for the shielding opposite from the Alps, it cannot be received directly from Bologna. Our receiver has a 10 elements Yagi antenna pointing in azimuth in the direction of the transmitter, and in radiation angle at about 25 degrees over the horizon, where we have calculated to be the reflection point with the upper layers of the atmosphere (Figure 3).

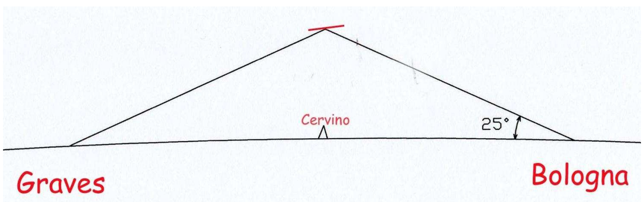

Figure 3 – The radio signal path in a forward meteor scatter.

The audio signal produced by the receiving device is analyzed in frequency and digitized using a microprocessor. Using this technique, each meteor echo is catalogued in a text file in which, together with other data (progressive event number, event number in the hour, date and time (UT), echo duration in milliseconds) the signal amplitude is recorded.

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For further explanation see RAMBO web page[a], and to see our data, visit the dedicated page of the Associazione Astrofili Bolognesi website[b].

3 The radio signal amplitude

When analyzed over the year, the average value of the signal amplitude is not constant, but instead presents a systematic variation having a sinusoidal course.

This variation over the time is even more pronounced if we analyze the daily data: in this we note that in the morning the radio amplitude is greater, and it then gradually diminishes during the day, and then increases again overnight (Figure 4).

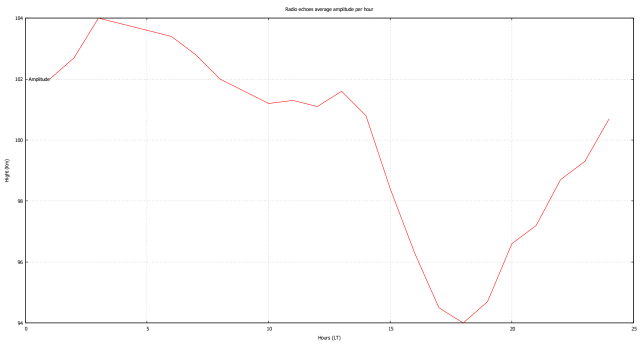

Figure 4 – Radio signal amplitude during a day.

A first evaluation, based on the length of the path covered by the radio signal from the transmitter to the receiver, led us to think about the height of the meteors, and on the possibility that a change in height might influence the length of the path and consequently the attenuation of the received signal power.

Hence, we decided to verify this hypothesis by looking at the trend in the meteor heights via a different observational method, i.e. video observations.

4 Video observation of meteors

The observation of meteors through the use of video cameras is a technique that has been performed for some years now by both amateur and professional astronomers.

It is based on the use of video cameras of good sensitivity, both analogue and digital, equipped lenses that are of very short focal length and as bright as possible. The images provided by these cameras are then digitized and processed by software.

In the professional field a variety of software packages have been developed via a number of different projects.

In the field of amateur astronomy, the first software developed was Metrec, and this was designed to run on MS-DOS platforms. Then, after the advent of Windows, UFO was developed, a Japanese software package composed of three parts: one for live image control and video clips recording of luminous transients, the second one to analyze these clips and to calculate the data related to meteor traces, and the third one to triangulate the observations obtained from a same meteor by two or more observers.

The practice of the automatic observation of meteors with video cameras, coupled with the relatively low costs involved, led to a rapid increase in observers. The data produced by these observations came together in a number of large databases among which we can mention Edmond, dedicated to the European area, SonotaCo, concerning Japan, and Bramon, a recent addition that stores observations made in Brazil. The data examined in this article come essentially from Edmond, both because it is a database in which we also participate, and because it is larger than SonotaCo. The Japanese database is far more "clean" than the European one, the latter including several gaps and stray values, thus making it necessary for us to perform an additional job of "cleaning up" the data. Bramon is still quite small and some gaps, especially in the temporal sphere, led us to disregard it. Hence, the analyses we carried out were essentially from the European samples, but after a verification we can assert that the trends and the measured quantities are completely in line with those obtainable from the Japanese data.

The sample of data we used was mainly "Edmond2016" referring to the last year available at the time when we started to write this article. As for the SonotaCo data, with Edmond we also performed checks on previous years, so as to always obtain homogeneous values and trends. Edmond2016 is a database that contains data relating to approximately 70 000 meteors, observed by observers spread all over the Europe. The software tools we used for data analysis were mainly Python and Gnuplot.

5 Meteor heights

For the analysis of the height of the meteors, we initially used the datum "H1" representing the height from the ground of the point where the visual trace of the meteor begins.

Looking at the annual trend, we see that a random variation overlaps a systematic variation with a sinusoidal trend. The maximum average height is reached at the autumn equinox and the minimum at the spring equinox (Figure 5).

The subtraction of the contribution of the main swarms (Quadrantids, Lyrids, Eta Aquariids, Perseids, κ Cygnids, Aurigids, Southern Taurids, Orionids, Northern Taurids, Leonids, Geminids and Ursids) shows how the sinusoidal trend is typically primarily of the so-called sporadic meteors (Figure 6).

For this subtraction we have eliminated all the meteors that UFO determined as coming from the corresponding radiants.

Even in the analysis of the daily data, which is limited to the hours in which the meteors are observable, we can still see signs of a sinusoidal trend, in which the meteors start higher in the morning and lower in the evening (Figure 7).

[a] `http://www.ramboms.com/index_eng.html`
[b] `http://www.associazioneastrofilibolognesi.it/rambo/`

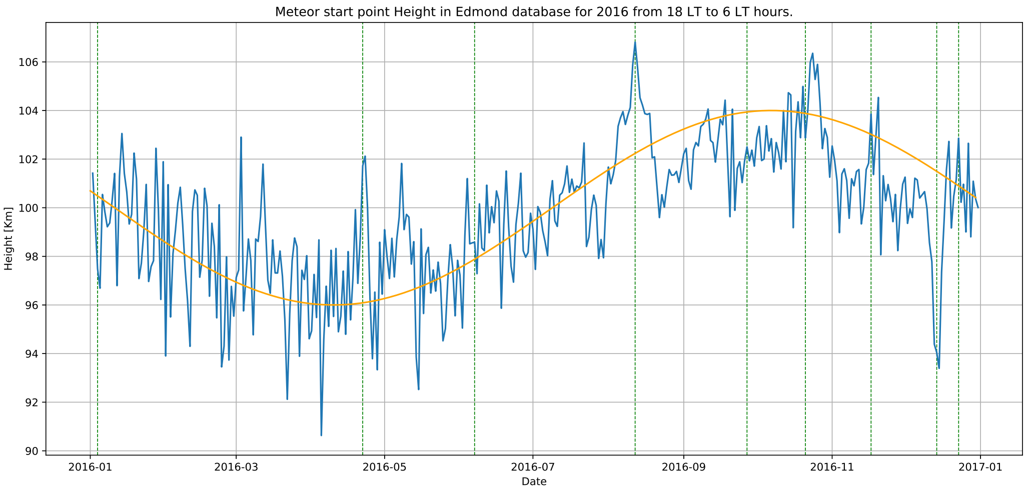

Figure 5 – Average meteor heights during the year. (The yellow line is a generic sinusoidal curve.)

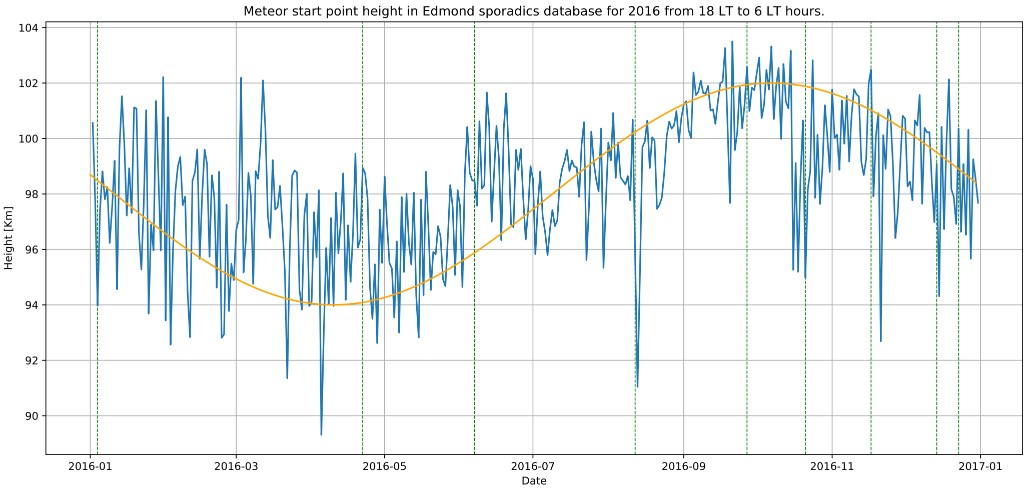

Figure 6 – Average meteor heights: sporadics and minor showers only. (The yellow line is a generic sinusoidal curve.)

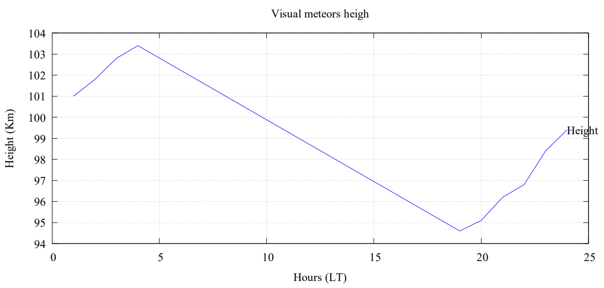

Figure 7 – Average meteors height during the night.

The average spread in the meteor start heights is about 8 km around an average start height of about 99 km.

It is, however, not only the starting height that changes: the up and down movement covers all of the meteoric trace. In fact the analysis of the H2 data that represents the height above the ground where the meteors "go out" undergoes the same identical variation.

This is illustrated by Figure 8, in which it can be seen that the average lengths of meteors is constant.

6 Why do meteor heights vary?

What is the reason why meteors either appear higher or lower, depending on the season of the year or the time of day?

The atmosphere temperature?

The speed of the meteoroids?

The radiant position?

The first two explanations can be cleared ruled out by comparing the average start heights for two of the major winter showers, Geminids and Ursids.

As can be seen in Figure 9, the average height of the Geminids is 93.5 km while Ursids height is 103 km. The two showers peak only 8 days apart, which cancels the hypothesis concerning significant variations of the ionosphere temperature or other atmospheric physical parameters. Moreover Geminids and Ursids are streams with roughly the same speed in the reference system of the solar system: 32 km/s for the former and 33 km/s for the latter. This consideration therefore leads us to also reject the second hypothesis, regarding the streams' own velocities.

There is, however, a relevant factor that helps us to reflect on the cause of the phenomenon. As we can see, the height of the meteors has a daily maximum at six

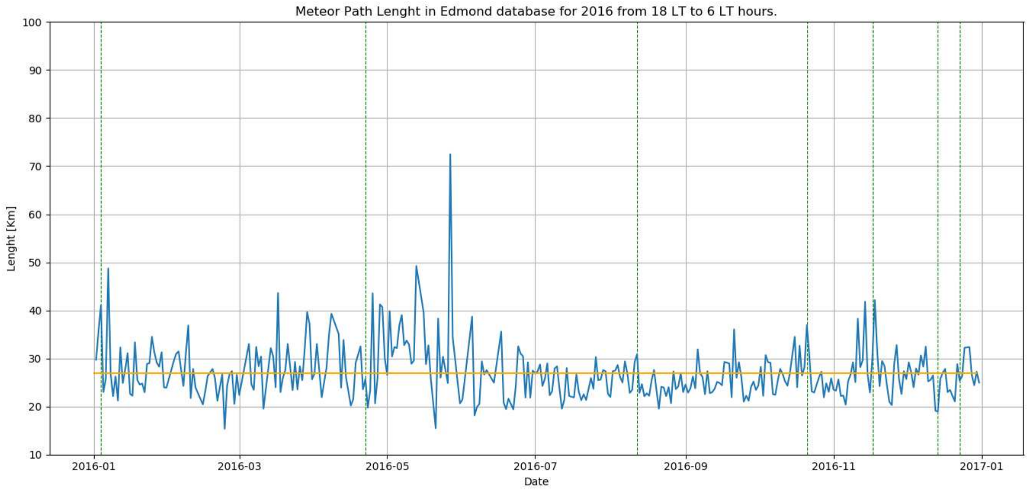

Figure 8 – Average meteors length.

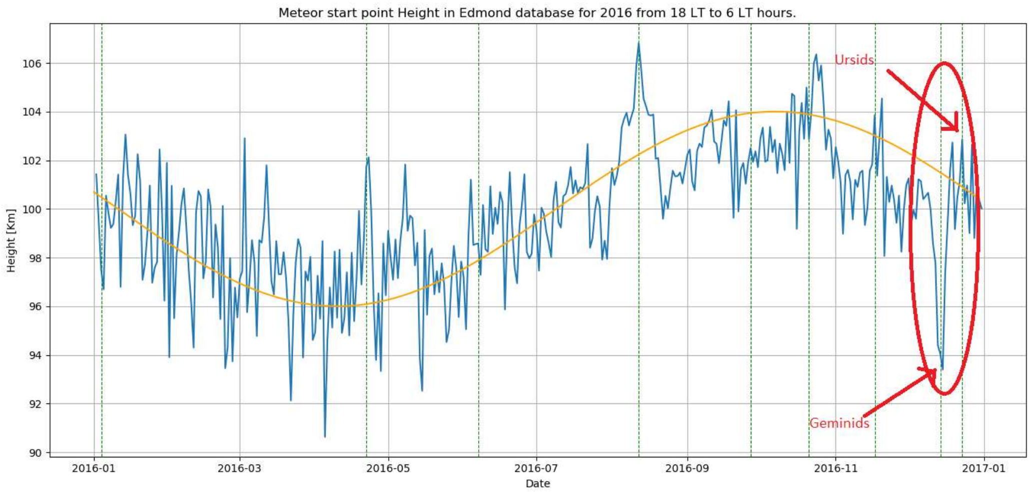

Figure 9 – Comparison between Geminids and Ursids.

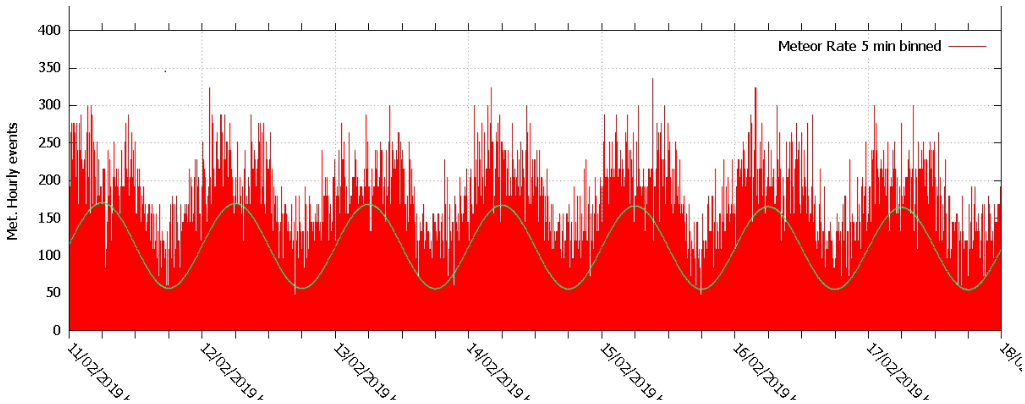

Figure 10 – Hourly rate measured by RAMBo (5 minutes bin).

in the morning (local time), and a minimum at 18^{h}. It is just as for the better known parameter: the hourly rate.

The hourly rate also sees meteor numbers far more abundant at six in the morning than at 18^{h}.

In Figure 10 we can see the hourly rate measured by RAMBo in a generic week. In it the trend is almost pure sinusoidal, less than a daily decrease of pings at 6 LT between two peaks, before and after. This phenomenon is due to the "observability function" of the bistatic set-up that depends on the radiation lobes of the GRAVES radar, the reception lobe of the RAMBo antenna and the geometry of the meteor trajectories (Verbeeck, 1997).

The reason for the sinusoidal behavior of the meteoric rhythm resides, as it is known, in the position of the observer with respect to the apex (or to the anti-apex). Thinking about meteoric impacts, if we consider the motion of the Earth around the Sun we can define the apex as the point towards which the Earth seems to be directed in its movement, while the anti-apex is the opposite direction.

7 Geometry of meteoric impacts

If we consider the motion "of the spaceship Earth" around the sun we define apex as the point towards which the Earth seems to be directed in its movement, while the anti-apex is the opposite point (Figure 11).

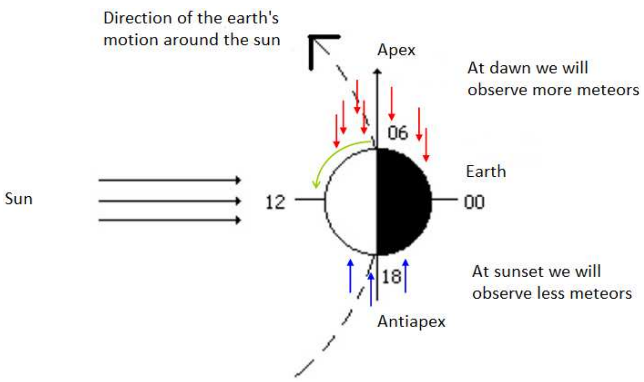

Figure 11 – Comparison of meteor rates around sunset and towards dawn.

The apex is therefore the point that we see in front of us looking ahead, while the anti-apex is what we see from the rear window. From this last observation point all the meteors that can hit the Earth are exclusively those which are faster then us. They are a fraction of the totality (in blue in the drawing). In contrast, in the forwards direction we can be hit by all the meteors, both slow or fast. And this is because the speed of the impact (in vectorial form) is:

$$V_i = V_m - V_t$$

where V_i is the speed of the impact, V_t the speed of the Earth, while V_m is the meteor speed, which depends both on the speed of the meteor in the solar system and on the angle of inclination of its own orbit with respect to the terrestrial one. This is therefore the reason why at dawn (on average at 6am locally) the Earth is hit by the greatest possible number of meteors, while at around 6pm, we record the minimum.

As we have seen, even the phenomenon we are investigating i.e. the height of the meteors, shows a maximum when the observer is near the apex, and a minimum when it is near the anti-apex. We can deduce that the cause of the variation lies in the angle between the point of origin of the meteors and the apex. This consideration calls into question the orbital parameters of meteors, first of all the parameter "i" defined as "the inclination of the orbital plane with respect to the ecliptic plane" (Jenniskens, 2006).

Figure 12 shows the "i" parameter as calculated by UFO for each meteor.

It should be noted that the trend of the "i" parameter is completely similar to that of the graph (Foschini, 1999).

Therefore, trying to put the two quantities "H1" and "i" directly in relation, we obtain a proportional relation.

In the Figure 13, each dot represents the height and inclination of a meteor for each of the meteors recorded for 2016.

Therefore, the closer "i" that approaches to 180°, the more that the angle from the apex becomes closer to 0 and vice versa for those tending to 0.

As proof of this we can put the inclination i directly in relation to the impact speed: in Figure 14, the relation is evident.

Hence, we can see that the direction of origin of the meteor affects the speed of impact.

In Figure 15, the measured speed and height of the meteors show a direct proportionality.

The small deviation from the line at the bottom left could be attributed to the debris, the return from space of anthropogenic space debris. Such bodies, as is known, have lower speeds than those of slower meteors.

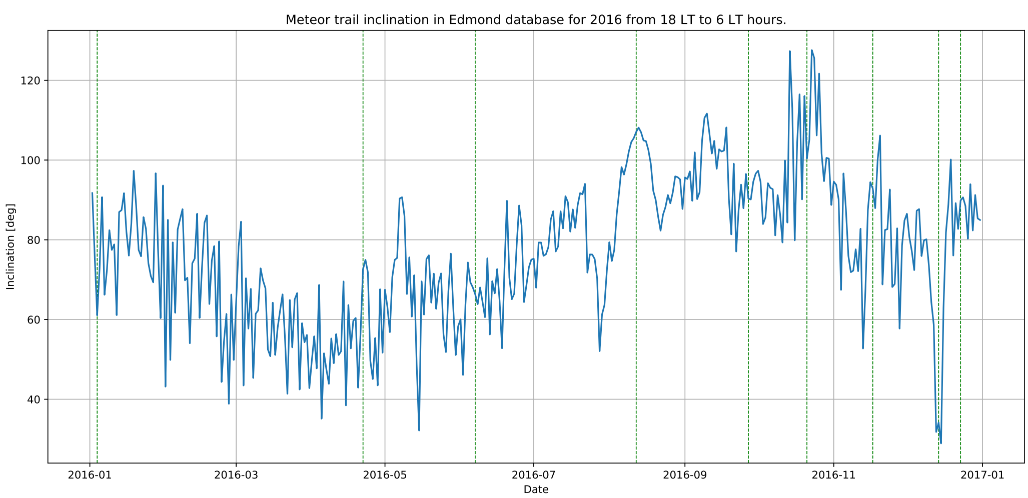

Figure 12 – Average of i parameter, in the year.

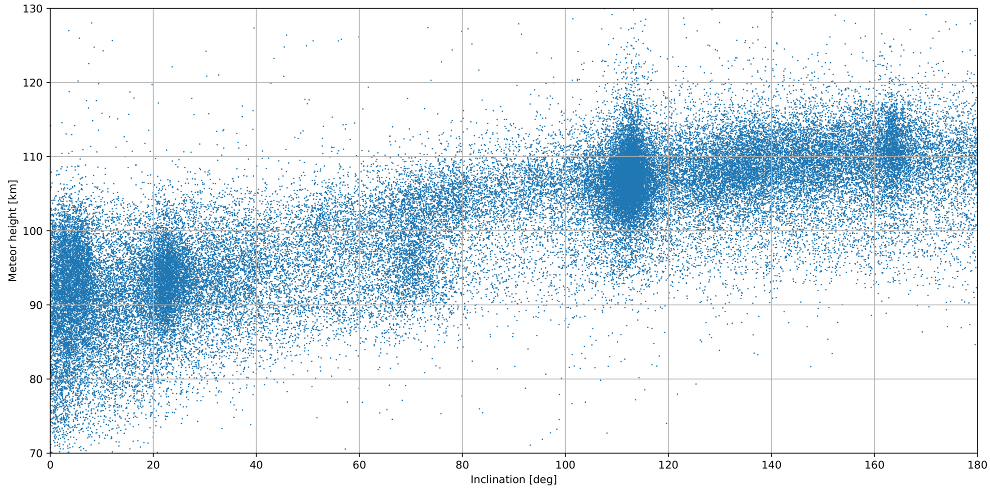

Figure 13 – Inclination vs height.

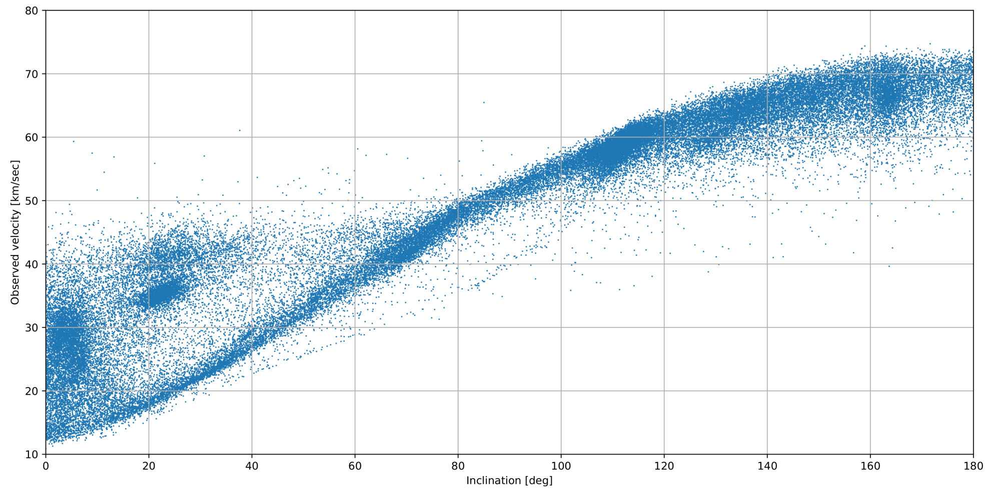

Figure 14 – Speed vs inclination.

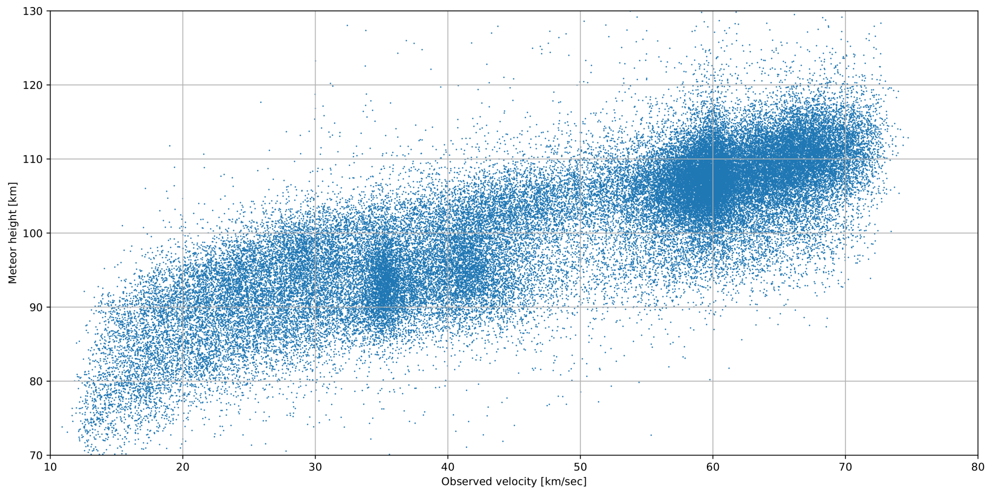

Figure 15 – Height vs speed.

8 Meteor inclination and heights as a function of time

Figures 12 and 14 show how for the great majority of meteors both the height at which they light up, and the speed of entry are linked to the parameter "i" defined as "the inclination of the orbital plane with respect to the plane of the ecliptic" (Jenniskens, 2006).

This parameter varies between 0° and 180° due to the rotation of the Earth. To this consideration, we subtract the Geminids and Taurids (both the STA and the NTA) that show a different behavior (Figure 16), probably due to the particular orbit of the parent body.

The direction of origin of the meteor with respect to the apex does not change only because of the orbital

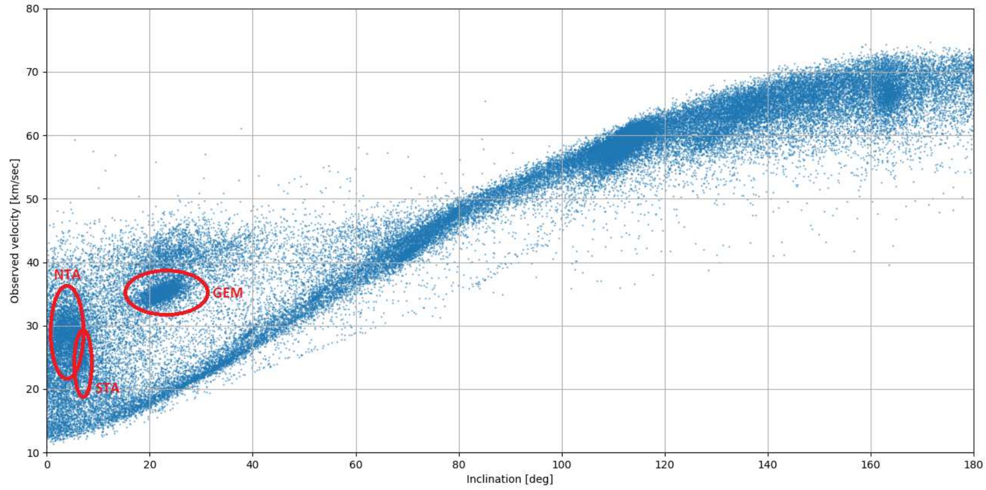

Figure 16 – Three streams with orbital parameters different from the majority.

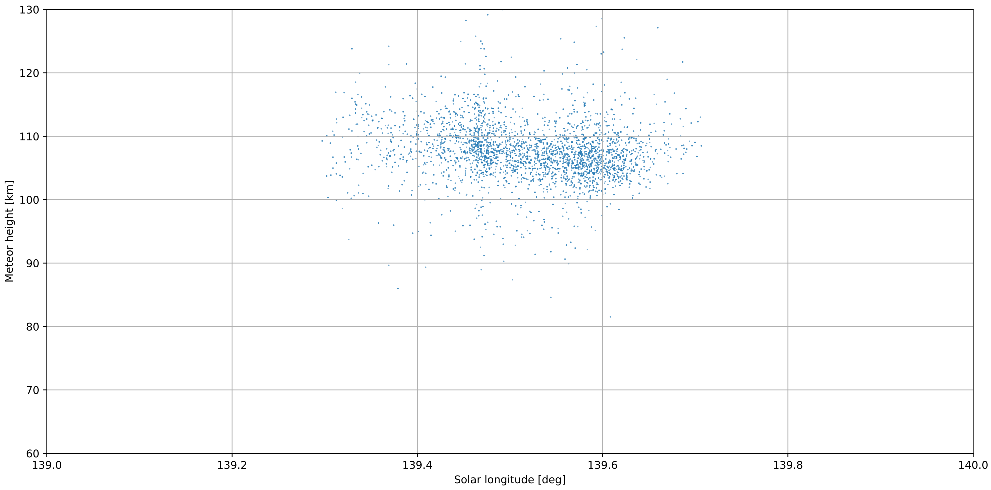

Figure 17 – Perseids start heights during the night of 2016 August 13.

parameters of the swarm but also due to the rotation of the Earth.

If it is true, then over the course of a night, a very rich stream should be affected by this effect, leading to a change in height of the meteors depending on the variation in the distance of the radiant from the apex.

With this in mind, we then choose the Perseids during the night of their peak and analyzed the height of the meteors attributed to this shower.

Figure 16 shows that, as the hours pass, the average height of meteors goes from 110 to 104 km.

9 Comparison with radio data

The kinetic energy of a body depends on its mass and speed.

Higher speeds lead to greater kinetic energy, which leads us to assume that the impact with the first molecules of the ionosphere generates larger cylinders of free ions and electrons.

The intensity of radio signal reflected by the meteors and received on the ground is proportional to the number of free electrons contained in the cylinder of ionized material and this explains why at dawn (at the 6 AM of local time) the intensity of the radio echoes is greater than at 18^{h} (Foschini, 1999).

$$A \propto \frac{1}{l^3} m v^4$$

Where A is the power of the received signal, m is the mass of the meteor and v is its speed, while l represents the distance transmitter/meteor/observer, according with the Proceedings of the IMO radio meteor school 2005 (Belkovich, 2006; Wislez, 2006).

Ignoring the mass role, we can evaluate the influence of the other two quantities.

The variation of the length l of the distance traveled is small: with a height variation of 8 km on a 500 km section, that is the Dijon-Bologna distance, by applying the Pythagorean theorem, a length variation of 4 km is obtained, around 1%.

In contrast, the speed change is much higher, from a minimum of 11 km/s to a maximum of 73 km/s: about 60%.

Hence, the radio signal power is mainly linked to the meteor velocity.

The comparison between the trend of meteoric heights measured via video observations and the inten-

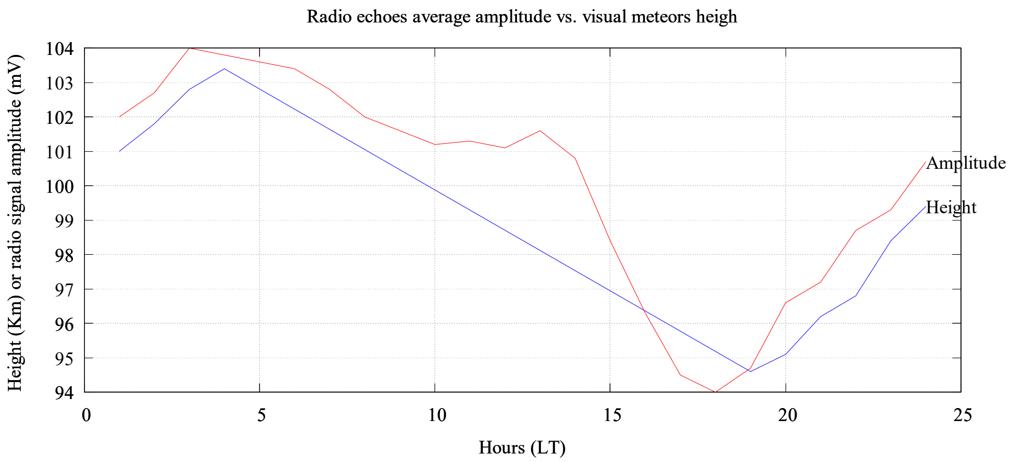

Figure 18 – Comparison of video data and radio data.

sity of the radio signal measured by our amateur radar shows a perfectly similar trend (Figure 18).

10 Conclusions

The meteors light up in the sky at a height on the horizon that varies around the average altitude of about 100 km.

The variation of this height is a function of the kinetic energy of the individual meteoroids.

In this analysis, in which the statistical behavior was evaluated, we ignored the masses of the individual meteoroids, and we examined only the systematic variation of meteor heights and speeds.

The speed variation and the height variation appear to depend directly on parameter i (inclination of the orbit).

The variation (from 0 to 180°) of the inclination i involves an average height variation of about 8 km measurable both during the day and during the year.

This behavior, measured in the visual data of the video footage, appears to be in excellent agreement with the radio data.

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Preliminary results

Results of the IMO Video Meteor Network — July 2018

Sirko Molau[1]*, Stefano Crivello, Rui Goncalves, Carlos Saraiva, Enrico Stomeo, Jörg Strunk, Javor Kac*

During 2018 July, cameras of the IMO Video Meteor Network recorded over 34 000 meteors in more than 8 300 hours of observing time. The flux density profile of the γ-Draconids is presented and shows barely noticeable activity in 2018. The flux density profiles of the Pisces Austrinids, α-Capricornids, and Southern δ-Aquariids in 2018 match well the average profiles for each meteor shower obtained during 2011–2017. The population index profiles are presented for the α-Capricornids and Southern δ-Aquariids.

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1 Introduction

In July the number of cameras and observers in the IMO Network increased again – 41 meteor observers have operated video cameras. Among them is Javor Kac, who reactivated SRAKA from Mihaela Triglav and also operates five video cameras.

The weather in July was fine. We could record over 34 000 meteors during more than 8 300 hours of effective observing time (Table 1 and Figure 1). 64 video cameras spread across all regions managed to observe during twenty or more observing nights. Three of the four cameras of Stefano Crivello even operated without a single missing night. That all sounds very promising, but the results were in fact below average compared to the previous years. Between 2015 and 2017 we collected more observing hours and meteors in the month of July.

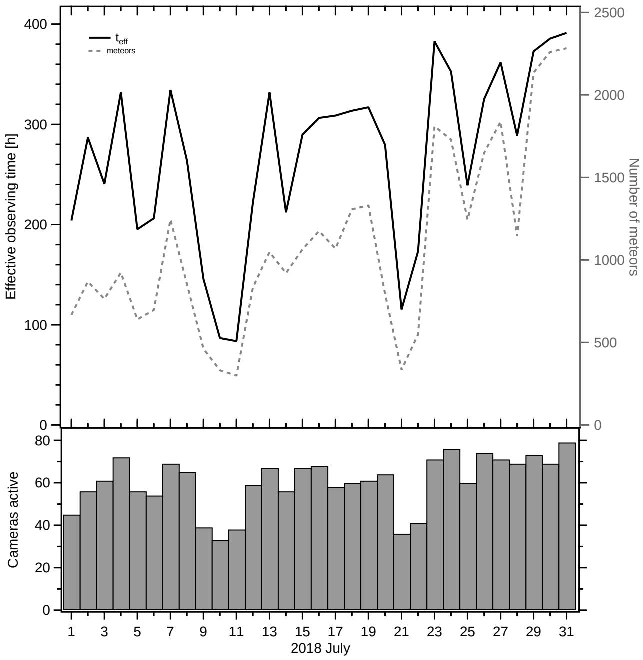

Figure 1 – Monthly summary for the effective observing time (solid black line), number of meteors (dashed gray line) and number of cameras active (bars) in 2018 July.

2 Meteor showers of July

There is no relevant meteor shower activity in the first half of July, but a number of meteor showers compete with each other towards the end of the month. Since we have most of the August data available already, we can perform a detailed analysis of these showers.

2.1 γ-Draconids

The smallest of them are the γ-Draconids which no one would have on their radar had they not experienced a short-duration outburst in 2016 at 125°132 solar longitude (Molau et al., 2016). Unfortunately, that time interval was outside the European observing window in 2018, so we could not check if there was another outburst that year. Figure 2 compares the activity profile of 2018 with the average of the years 2011–2017 (without 2016). The peak time (125° solar longitude) matches well, but the activity level was lower in 2018.

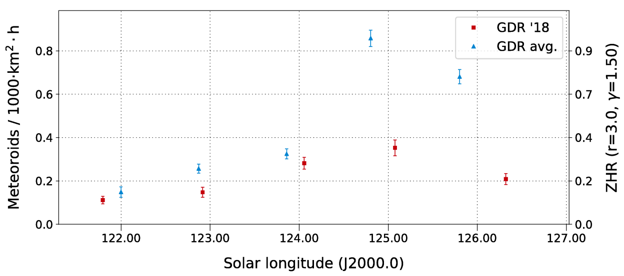

Figure 2 – Flux density profile of the γ-Draconids 2018 (darker/red) and the average of 2011–2017 (without 2016, lighter/blue), derived from video data of the IMO Network.

2.2 Pisces Austrinids

The Pisces Austrinids are somewhat stronger and their activity interval lasts longer, but they are more difficult to observe because of their southern radiant position. The activity profile shows no clear peak but rather some enhanced activity over an interval of about ten days. The 2018 data match well to the long-term profile of the years 2011–2017 (Figure 3).

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IMO bibcode WGN-474-molau-vidjul
NASA-ADS bibcode 2019JIMO...47..116M

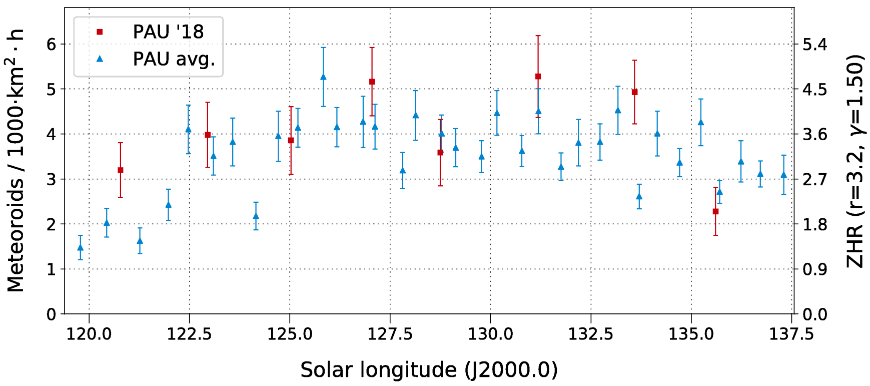

Figure 3 – Flux density profile of the Pisces Austrinids 2018 (darker/red) and the average of 2011–2017 (lighter/blue), derived from video data of the IMO Network.

2.3 α-Capricornids

Less active, but with better visibility are the α-Capricornids. With their peak flux density of about 2 meteoroids per 1 000 km^2 per hour they cannot compete with large meteor showers, but their rate is sufficient to create a well-defined activity profile (Figure 4). Also in this case, the observations of 2018 match to the long-term average of the previous years – only the peak activity occurred one day earlier. However, if the error bars are taken into consideration, the regular peak time of 126° solar longitude has about the same activity level (Figure 4).

The population index of 2018 shows no peculiarities (Figure 5, left). The sporadic r-value varies in the observing interval between $r = 2.5$ and 2.9. The population index of the α-Capricornids varies in a similar fashion, but the difference between both profiles is not constant. At the begin and end of the activity period both values are almost identical. However, with $r = 2.0$ the population index of the α-Capricornids at peak time is about by 0.4 lower than the sporadic r-value. We obtain the same picture when we take all data between 2011 and 2018 to calculate the population index profile (Figure 5, right).

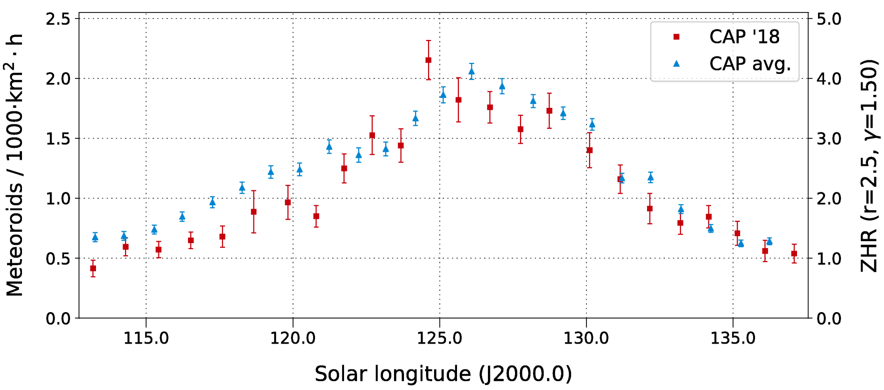

Figure 4 – Flux density profile of the α-Capricornids 2018 (darker/red) and the average of 2011–2017 (lighter/blue), derived from video data of the IMO Network.

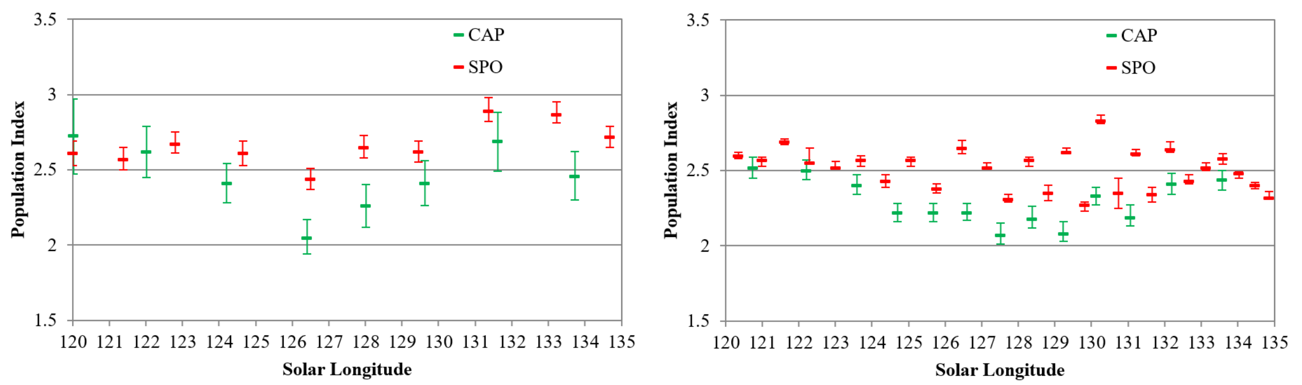

Figure 5 – Population index of the α-Capricornids (green) and sporadic meteors (red) in 2018 (left), and the average of 2011–2018 (right).

2.4 Southern δ-Aquariids

Finally, we have the strongest meteor shower of July, the Southern δ-Aquariids. Their flux density is comparable to the Perseids, but the ZHR is clearly lower and the southern radiant is not as well-positioned for the European observers. The activity profile of the Southern δ-Aquariids is almost symmetric – only towards the end of the activity interval the flux density is not going fully down to the start value. The profile shows hardly any scatter thanks to the high number of meteors, and the values of 2018 fit well to the average of the previous years (Figure 6).

The population index of the Southern δ-Aquariids over the full activity interval is about 0.4 lower than the sporadic r-value. Just after the peak, the population index rises shortly and does not deviate from the sporadic meteors anymore, i.e. the percentage of faint meteors is increasing. Due to scatter in the population index profile of sporadic meteors, however, we cannot say for sure if that is an one-time effect of 2018 or not, even if we combine all available data from 2011 to 2018 (Figure 7, right).

References

Molau S., Crivello S., Goncalves R., Saraiva C., Stomeo E., and Kac J. (2016). "Results of the IMO Video Meteor Network – July 2016". *WGN, Journal of the IMO*, **44:6**, 205–210.

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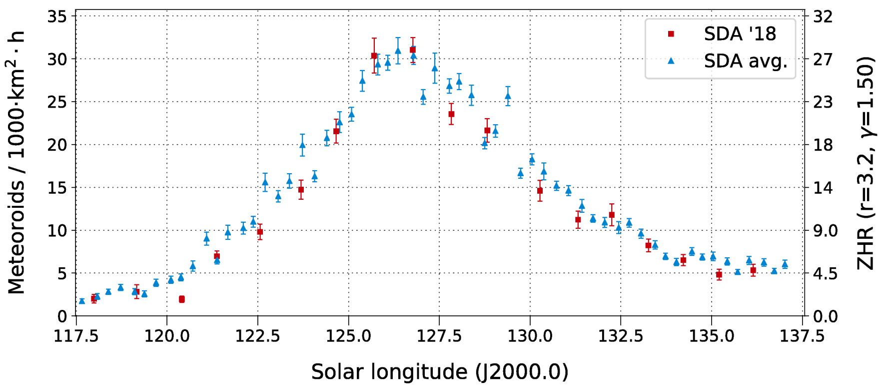

Figure 6 – Flux density profile of the Southern δ-Aquariids 2018 (darker/red) and the average of 2011–2017 (lighter/blue), derived from video data of the IMO Network.

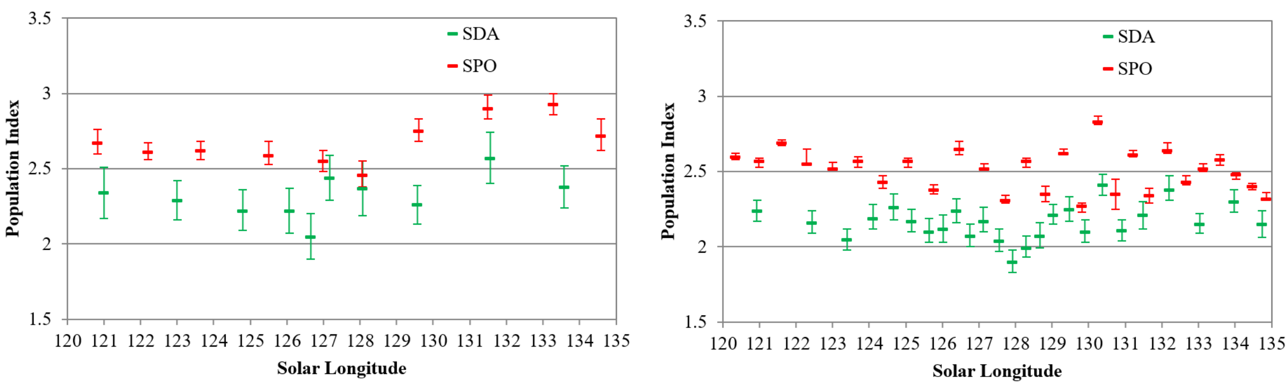

Figure 7 – Population index of the Southern δ-Aquariids (green) and sporadic meteors (red) in 2018 (left), and the average of 2011–2018 (right).

Table 1 – Observers contributing to 2018 July data of the IMO Video Meteor Network. Eff.CA designates the effective collection area; the overall number of nights is the number of nights with at least one camera operating, the overall observing time and number of meteors are sums over all cameras.

Code	Name	Location	Camera	FOV [°²]	Stellar LM [mag]	Eff.CA [km²]	Nights	Time [h]	Meteors
ARLRA	Arlt	Ludwigsfelde/DE	Ludwig2 (0.8/8)	1475	6.2	3779	27	100.5	678
BERER	Berkó	Ludányhalászi/HU	Hulud1 (0.8/3.8)	5542	4.8	3847	8	47.5	322
BIATO	Bianchi	Mt. San Lorenzo/IT	Omsl1 (1.2/4)	6435	4.0	1705	27	129.1	369
BOMMA	Bombardini	Faenza/IT	Mario (1.2/4.0)	5794	3.3	739	29	168.5	943
BREMA	Breukers	Hengelo/NL	Mbb3 (0.75/6)	2399	4.2	699	29	134.3	336
BRIBE	Klemt	Herne/DE	Hermine (0.8/6)	2374	4.2	678	29	128.9	577
		Bergisch Gladbach/DE	Klemoi (0.8/6)	2286	4.6	1080	29	130.8	479
CARMA	Carli	Monte Baldo/IT	Bmh2 (1.5/4.5)*	4243	3.0	371	22	116.1	766
CASFL	Castellani	Monte Baldo/IT	Bmh1 (0.8/6)	2350	5.0	1611	19	107.8	376
CINFR	Cineglosso	Faenza/IT	Jenni (1.2/4)	5886	3.9	1222	30	184.5	727
CRIST	Crivello	Valbrevenna/IT	Arci (0.8/3.8)	5566	4.6	2575	31	158.4	603
			Bilbo (0.8/3.8)	5458	4.2	1772	31	154.4	674
			C3P8 (0.8/3.8)	5455	4.2	1586	27	113.9	464
			Stg38 (0.8/3.8)	5614	4.4	2007	31	139.1	913
ELTMA	Eltri	Venezia/IT	Met38 (0.8/3.8)	5631	4.3	2151	24	95.9	357
FORKE	Förster	Carlsfeld/DE	Akm3 (0.75/6)	2375	5.1	2154	23	87.7	489
GONRU	Goncalves	Foz do Arelho/PT	Farelho1 (0.75/4.5)	2286	3.0	208	8	20.8	44
		Tomar/PT	Templar1 (0.8/6)	2179	5.3	1842	28	153.4	721
			Templar2 (0.8/6)	2080	5.0	1508	25	147.3	546
			Templar3 (0.8/8)	1438	4.3	571	25	127.6	224
			Templar4 (0.8/3.8)	4475	3.0	442	27	146.1	574
			Templar5 (0.75/6)	2312	5.0	2259	25	121.5	409
GOVMI	Govedič	Središče ob Dravi/SI	Orion2 (0.8/8)	1447	5.5	1841	20	96.1	308
			Orion3 (0.95/5)	2665	4.9	2069	22	112.5	201
			Orion4 (0.95/5)	2662	4.3	1043	23	95.7	180
HERCA	Hergenrother	Tucson/US	Salsa3 (0.8/3.8)	2336	4.1	544	15	90.3	229
HINWO	Hinz	Schwarzenberg/DE	Hinwo1 (0.75/6)	2291	5.1	1819	28	122.2	518
IGAAN	Igaz	Budapest/HU	Hupol (1.2/4)	3790	3.3	475	17	77.7	90
JONKA	Jonas	Budapest/HU	Husor (0.95/4)	2286	3.9	445	26	118.2	254
			Husor2 (0.95/3.5)	2465	3.9	715	25	111.9	244
KACJA	Kac	Kamnik/SI	Cvetka (0.8/3.8)*	4914	4.3	1842	14	53.0	330
			Rezika (0.8/6)	2270	4.4	840	14	58.4	420
			Stefka (0.8/3.8)	5471	2.8	379	13	52.8	240
		Kostanjevec/SI	Metka (0.8/12)*	715	6.4	640	24	94.5	256
		Ljubljana/SI	Sraka (0.8/6)	2222	4.0	546	20	80.6	438
KOSDE	Koschny	La Palma/ES	Icc9 (0.85/25)*	683	6.7	2951	7	37.6	454
			Lic2 (3.2/50)*	2199	6.5	7512	9	45.8	574
LOJTO	Łojek	Grabniak/PL	Pav57 (1.0/5)	1631	3.5	269	3	6.9	33
MACMA	Maciejewski	Chełm/PL	Pav35 (0.8/3.8)	5495	4.0	1584	23	61.4	237
			Pav36 (0.8/3.8)*	5668	4.0	1573	26	90.2	366
			Pav43 (0.75/4.5)*	3132	3.1	319	23	42.6	112
			Pav60 (0.75/4.5)	2250	3.1	281	26	176.2	862

Table 1 – Observers contributing to 2018 July data of the IMO Video Meteor Network – continued from previous page.

Code	Name	Location	Camera	FOV [°²]	Stellar LM [mag]	Eff.CA [km²]	Nights	Time [h]	Meteors
MARRU	Marques	Lisbon/PT	Cab1 (0.75/6)	2362	4.8	1517	28	176.2	862
			Ran1 (1.4/4.5)	4405	4.0	1241	21	97.7	276
MOLSI	Molau	Seysdorf/DE	Avis2 (1.4/50)*	1230	6.9	6152	28	117.8	1223
			Escimo2 (0.85/25)	155	8.1	3415	28	140.0	389
			Mincam1 (0.8/8)	1477	4.9	1084	28	134.4	800
		Ketzür/DE	Remo1 (0.8/8)	1467	6.5	5491	26	104.5	831
			Remo2 (0.8/8)	1478	6.4	4778	25	107.9	760
			Remo3 (0.8/8)	1420	5.6	1967	25	122.0	676
			Remo4 (0.8/8)	1478	6.5	5358	25	120.7	995
MORJO	Morvai	Fülöpszállás/HU	Huful (1.4/5)	2522	3.5	532	23	125.2	227
MOSFA	Moschini	Rovereto/IT	Rover (1.4/4.5)	3896	4.2	1292	24	96.1	208
NAGHE	Nagy	Budapest/HU	Hukon (0.8/3.8)	5500	4.0	1575	27	99.8	387
		Piszkéstető/HU	Hupis (0.8/3.8)	5615	4.0	1524	28	88.2	420
		Zamardi/HU	Huzam (0.8/6)	2358	4.7	1266	7	32.4	65
OCHPA	Ochner	Albiano/IT	Albiano (1.2/4.5)	2944	3.5	358	14	62.6	158
OTTMI	Otte	Pearl City/US	Orie1 (1.4/5.7)	3837	3.8	460	29	177.3	586
PERZS	Perkó	Becsehely/HU	Hubec (0.8/3.8)*	5498	2.9	460	19	89.1	265
ROTEC	Rothenberg	Berlin/DE	Armefa (0.8/6)	2366	4.5	911	21	85.5	222
SARAN	Saraiva	Carnaxide/PT	Ro1 (0.75/6)	2362	3.7	381	19	69.4	145
			Ro2 (0.75/6)	2381	3.8	459	22	115.0	247
			Ro3 (0.8/12)	710	5.2	619	23	125.5	338
			Ro4 (1.0/8)	1582	4.2	549	19	96.0	116
			Sofia (0.8/12)	738	5.3	907	21	59.3	162
SCALE	Scarpa	Alberoni/IT	Leo (1.2/4.5)*	4152	4.5	2052	23	95.7	142
SCHHA	Schremmer	Niederkrüchten/DE	Doraemon (0.8/3.8)	4900	3.0	409	30	127.1	475
SLAST	Slavec	Ljubljana/SI	Kayak1 (1.8/28)	563	6.2	1294	21	79.6	334
			Kayak2 (0.8/12)	741	5.5	920	17	92.7	165
STOEN	Stomeo	Scorze/IT	Min38 (0.8/3.8)	5566	4.8	3270	27	98.4	691
			Noa38 (0.8/3.8)	5609	4.2	1911	21	78.0	333
			Sco38 (0.8/3.8)	5598	4.8	3306	27	93.3	632
STRJO	Strunk	Herford/DE	Mincam2 (0.8/6)	2354	5.4	2751	28	120.6	783
			Mincam3 (0.8/6)	2338	5.5	3590	28	104.2	235
			Mincam4 (0.8/6)	2306	5.0	1412	30	120.3	310
			Mincam5 (0.8/6)	2349	5.0	1896	28	113.7	414
			Mincam6 (0.8/6)	2395	5.1	2178	30	112.3	476
TEPIS	Tepliczky	Agostyán/HU	Huago (0.75/4.5)	2427	4.4	1036	25	115.6	420
			Humob (0.8/6)	2388	4.8	1607	27	116.3	376
WEGWA	Wegrzyk	Nieznaszyn/PL	Pav78 (0.8/6)	2286	4.0	778	23	82.1	285
YRJIL	Yrjölä	Kuusankoski/FI	Finexcam (0.8/6)	2337	5.5	3574	2	4.2	31
ZAKJU	Zakrajšek	Petkovec/SI	Tacka (0.8/12)	714	5.3	783	21	103.0	259
* active field of view smaller than video frame						Overall	31	8 348.7	34 264

Results of the IMO Video Meteor Network — August 2018

Sirko Molau[1], *Stefano Crivello, Rui Goncalves, Carlos Saraiva, Enrico Stomeo, Jörg Strunk, Javor Kac*

During 2018 August, 85 cameras of the IMO Video Meteor Network recorded over 88 000 meteors during more than 13 100 hours of observing time. The flux density profile of the Perseids that is presented shows lower activity in 2018 when compared to the average profile of the previous years, with a maximum value of 30 meteoroids per 1000 km^2 per hour. The population index profile of the Perseids reaches a value of $r = 1.85$ around the time of maximum. The flux density and population index profiles are also presented for the κ-Cygnids.

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1 Introduction

In August, the number of IMO Network video cameras grew to 85 again. Jure Zakrajšek started to operate his second camera Petka, which is just like his first one a Mintron but with a 8 mm $f/0.8$ Computar lens. During the Perseids, Peter Slansky experimented with a Sony α7S to determine the population index of the shower – and in addition his HD video data were analyzed in a complex multi-pass process with MetRec and inserted into the video database.

The weather in August was nearly perfect. Looking at the statistics we see only a few individual cameras which for technical reasons were not constantly in operation, and a short phase of unsettled weather around August 25. Other than this, all cameras were in operation without any longer break. On all but five days, almost 70 IMO Network cameras scanned the night sky. The highlight was August 22/23, when 81 of 85 cameras managed to capture meteors, but even on the worst day of the month more than half of all cameras were in operation.

65 cameras managed to observed on twenty or more observing nights, 23 of these even on 30 or more nights. It is therefore no surprise that the overall effective observing time added up to more than 13 100 hours, which is our best ever August result (Table 2 and Figure 1). We recorded more than 78 000 meteors, which is slightly less than in 2015 and 2016. This implies that the average rate of 6.7 meteors per hour was below the average of previous years. This in turn is surprising since the Perseid peak coincided roughly with new moon. Our experience from previous years is, that the flux density tends to be higher in years with new moon and dark skies, and it is lower in years when skies are illuminated by the full moon (because of systematic effects in the limiting magnitude determination algorithm).

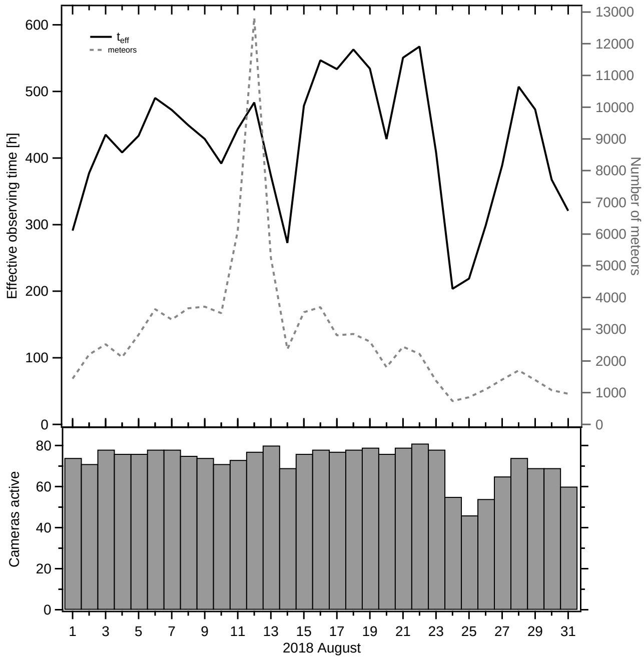

Figure 1 – Monthly summary for the effective observing time (solid black line), number of meteors (dashed gray line) and number of cameras active (bars) in 2018 August.

2 Perseids

The highlight of the month are the Perseids. Figure 2 shows the activity profile of the Perseids close to the maximum, compared to the average Perseid rate 2011–2017 (without 2016, due to enhanced activity occurring that year – see Molau et al. (2017)). The flux density of August 11/12 is indeed a little below the long-term average and that of August 12/13 is significantly below the long-term average.

Even if we consider only the years 2012 and 2015 with similar good lunar conditions, and if we restrict the analysis to cameras, which were active in all three years, the picture does not change: The activity level in 2018 remains clearly below average (Figure 3).

Let us finally compare our data set with visual Perseid observations of 2018. Figure 4 contrasts the video profile form the IMO Network with observation from the IMO Visual Meteor Database (International Meteor Organization, 2018), which were collected via the online report form. Both profiles look similar, and visual observations also revealed a mediocre maximum with zenithal hourly rates below 100.

The population index of the Perseids (Figure 5) remained unremarkable. Before the peak, it scattered around values of $r = 2.05$, during the maximum and thereafter it fell to values near $r = 1.85$. At the same time interval, the average sporadic population index

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IMO bibcode WGN-474-molau-vidaug
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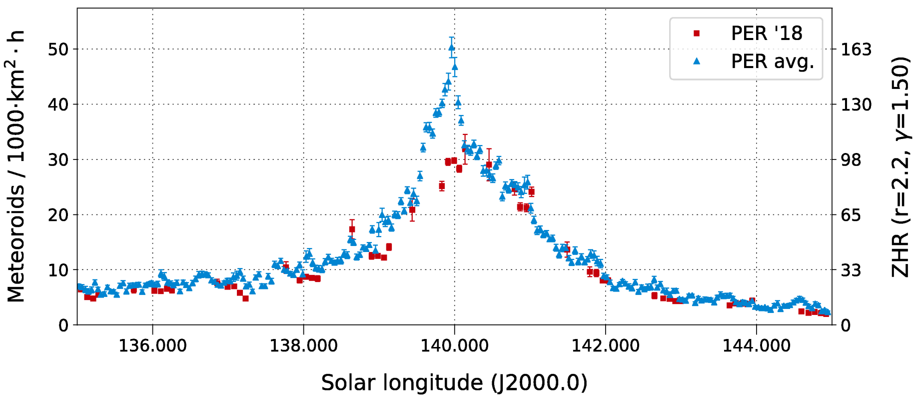

Figure 2 – Flux density profile of the Perseids 2018 (red) and in the average of 2011–2017 (without 2016, blue), derived from video data of the IMO Network.

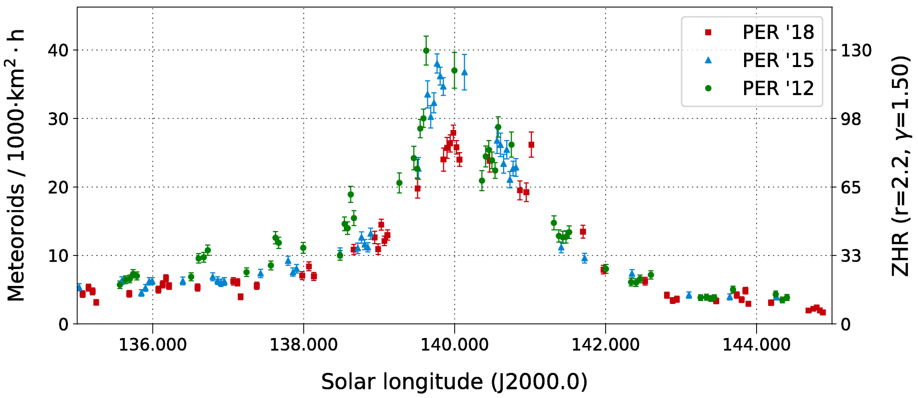

Figure 3 – Comparison of the Perseid flux density in moon-free years (2012, 2015, 2018) from a subset of cameras that were active in all three years.

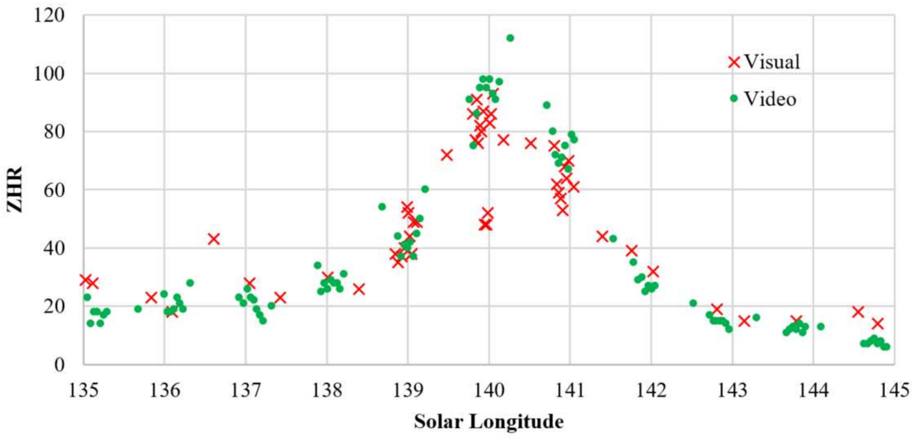

Figure 4 – Comparison of the zenithal hourly rate of the Perseids 2018 based on visual observations of IMO (red crosses) and video data of the IMO Network (green dots).

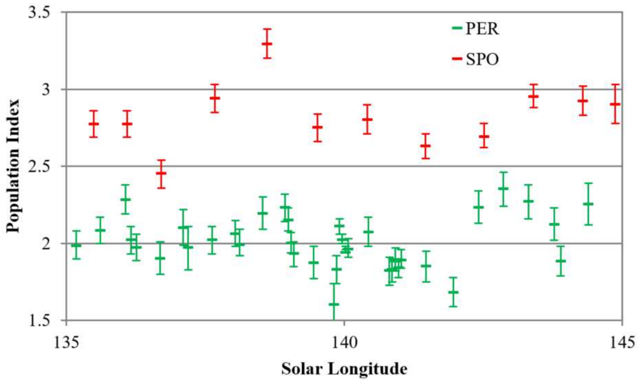

Figure 5 – Population index of the Perseids (green) and sporadic meteors (red) in 2018.

was $r = 2.85$. The values are comparable with 2015 and higher than in 2017, which matches with our previous experiences.

Note that most Perseid 2018 data were contributed by Stefano Crivello. With his four cameras he amassed less effective observing time than Sirko Molau and Rui Goncalves, but the effective collection area of his cameras for Perseids was larger, which is why he also recorded more Perseids (Table 1).

Table 1 – Contribution of individual observers with an effective collection area for Perseids of over 250 000 km^2 h.

Observer	# Cameras	Eff. Obs. Time [h]	Eff. Coll. Area [10^3 km^2 h]	# Perseids
Stefano Crivello	4	944.2	772.1	3524
Sirko Molau	7	1011.9	562.1	2916
Rui Goncalves	6	1252.9	520.3	1959
Enrico Stomeo	3	528.2	497.9	2173
Maciej Maciejewski	4	565.3	404.2	2438
Karoly Jonas	3	565.5	397.1	1739
Javor Kac	5	699.2	354.1	2847
Jörg Strunk	5	886.4	347.8	2120
Rui Marques	2	443.7	314.3	1134
Maurizio Eltri	1	218.4	282.9	679
Mario Bombardini	1	280.4	276.7	1063

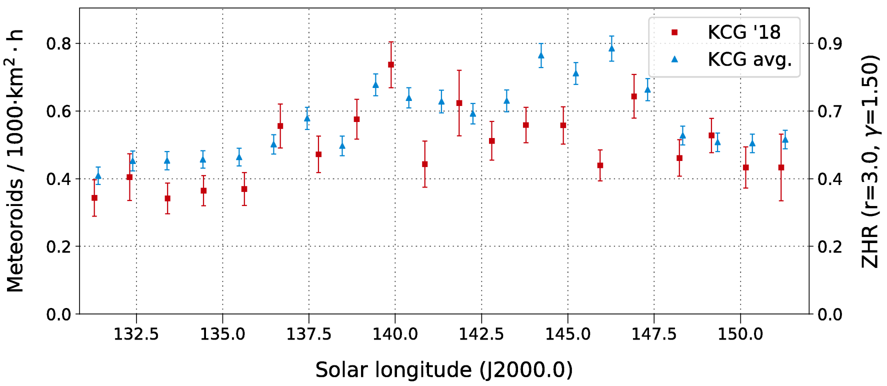

Figure 6 – Flux density profile of the κ-Cygnids 2018 (red) and in the average of 2011–2017 (without 2014, blue), derived from video data of the IMO Network.

3 κ-Cygnids

The second shower peaking in August are the κ-Cygnids. In Figure 6, we compare the 2018 activity profile of the κ-Cygnids with the average of 2011–2017 (without 2014). This was another case in which the rate tended to be lower than the long-term average. Otherwise the profile shows no surprises.

The population index of the κ-Cygnids had an average value of $r = 2.85$, which is slightly larger than the sporadic average population index of $r = 2.75$ in the same solar longitude interval. There are only few meteor showers with this property.

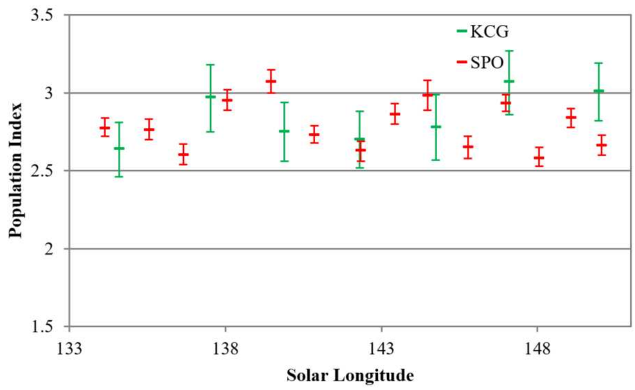

Figure 7 – Population index of the κ-Cygnids (green) and sporadic meteors (red) in 2018.

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			Stg38 (0.8/3.8)	5614	4.4	2007	31	179.2	2218
ELTMA	Eltri	Venezia/IT	Met38 (0.8/3.8)	5631	4.3	2151	28	167.3	1249
FORKE	Förster	Carlsfeld/DE	Akm3 (0.75/6)	2375	5.1	2154	26	136.6	1171
GONRU	Goncalves	Foz do Arelho/PT	Farelho1 (0.75/4.5)	2286	3.0	208	15	70.2	59
		Tomar/PT	Templar1 (0.8/6)	2179	5.3	1842	31	238.7	1248
			Templar2 (0.8/6)	2080	5.0	1508	31	239.4	1056
			Templar3 (0.8/8)	1438	4.3	571	30	209.7	436
			Templar4 (0.8/3.8)	4475	3.0	442	30	235.9	1280
			Templar5 (0.75/6)	2312	5.0	2259	31	197.0	947
GOVMI	Govedič	Središče ob Dravi/SI	Orion2 (0.8/8)	1447	5.5	1841	29	158.4	882
			Orion3 (0.95/5)	2665	4.9	2069	28	176.7	665
			Orion4 (0.95/5)	2662	4.3	1043	27	164.9	618
HERCA	Hergenrother	Tucson/US	Salsa3 (0.8/3.8)	2336	4.1	544	16	113.0	421
HINWO	Hinz	Schwarzenberg/DE	Hinwo1 (0.75/6)	2291	5.1	1819	30	156.9	1352
IGAAN	Igaz	Budapest/HU	Hupol (1.2/4)	3790	3.3	475	26	128.9	327
JONKA	Jonas	Budapest/HU	Husor (0.95/4)	2286	3.9	445	29	182.3	752
			Husor2 (0.95/3.5)	2465	3.9	715	29	177.7	895
KACJA	Kac	Kamnik/SI	Cvetka (0.8/3.8)*	4914	4.3	1842	24	148.0	1654
			Rezika (0.8/6)	2270	4.4	840	24	153.2	1572
			Stefka (0.8/3.8)	5471	2.8	379	24	151.2	1161
		Kostanjevec/SI	Metka (0.8/12)*	715	6.4	640	27	149.9	523
		Ljubljana/SI	Sraka (0.8/6)	2222	4.0	546	27	150.3	1144
KOSDE	Koschny	La Palma/ES	Icc9 (0.85/25)*	683	6.7	2951	30	187.7	2347
			Lic2 (3.2/50)*	2199	6.5	7512	30	171.1	2071
LOJTO	Łojek	Grabniak/PL	Pav57 (1.0/5)	1631	3.5	269	16	99.8	705
MACMA	Maciejewski	Chełm/PL	Pav35 (0.8/3.8)	5495	4.0	1584	30	137.1	1238
			Pav36 (0.8/3.8)*	5668	4.0	1573	28	171.3	1617
			Pav43 (0.75/4.5)*	3132	3.1	319	29	151.6	1110
			Pav60 (0.75/4.5)	2250	3.1	281	30	187.9	1594

Table 2 – Observers contributing to 2018 May data of the IMO Video Meteor Network – continued from previous page.

Code	Name	Location	Camera	FOV [°²]	Stellar LM [mag]	Eff.CA [km²]	Nights	Time [h]	Meteors
MARRU	Marques	Lisbon/PT	Cab1 (0.75/6)	2362	4.8	1517	24	171.1	1217
			Ran1 (1.4/4.5)	4405	4.0	1241	25	150.8	800
MASMI	Maslov	Novosibirsk/RU	Nowatec (0.8/3.8)	5574	3.6	773	11	44.6	496
MOLSI	Molau	Seysdorf/DE	Avis2 (1.4/50)*	1230	6.9	6152	29	155.8	2246
			Escimo2 (0.85/25)	155	8.1	3415	28	172.4	574
			Mincam1 (0.8/8)	1477	4.9	1084	29	133.0	1005
		Ketzür/DE	Remo1 (0.8/8)	1467	6.5	5491	30	147.6	1696
			Remo2 (0.8/8)	1478	6.4	4778	29	152.1	1425
			Remo3 (0.8/8)	1420	5.6	1967	30	173.9	1435
			Remo4 (0.8/8)	1478	6.5	5358	30	172.6	2080
MORJO	Morvai	Fülöpszállás/HU	Huful (1.4/5)	2522	3.5	532	23	166.0	406
MOSFA	Moschini	Rovereto/IT	Rover (1.4/4.5)	3896	4.2	1292	27	138.7	527
NAGHE	Nagy	Budapest/HU	Hukon (0.8/3.8)	5500	4.0	1575	30	137.9	1528
		Piszkéstető/HU	Hupis (0.8/3.8)	5615	4.0	1524	30	154.3	1413
		Zamardi/HU	Huzam (0.8/6)	2358	4.7	1266	23	145.2	525
OCHPA	Ochner	Albiano/IT	Albiano (1.2/4.5)	2944	3.5	358	11	59.7	253
OTTMI	Otte	Pearl City/US	Orie1 (1.4/5.7)	3837	3.8	460	22	113.7	324
PERZS	Perkó	Becsehely/HU	Hubec (0.8/3.8)*	5498	2.9	460	26	158.6	721
ROTEC	Rothenberg	Berlin/DE	Armefa (0.8/6)	2366	4.5	911	15	84.3	266
SARAN	Saraiva	Carnaxide/PT	Ro1 (0.75/6)	2362	3.7	381	30	189.1	483
			Ro2 (0.75/6)	2381	3.8	459	28	208.3	709
			Ro3 (0.8/12)	710	5.2	619	28	214.8	660
			Ro4 (1.0/8)	1582	4.2	549	28	202.9	318
			Sofia (0.8/12)	738	5.3	907	30	154.8	468
SCALE	Scarpa	Alberoni/IT	Leo (1.2/4.5)*	4152	4.5	2052	27	165.7	476
SCHHA	Schremmer	Niederkrüchten/DE	Doraemon (0.8/3.8)	4900	3.0	409	27	147.2	1010
SLAPE	Slansky	Munich/DE	SonyA7S (1.4/50)	1919	8.7	6674	2	6.7	727
SLAST	Slavec	Ljubljana/SI	Kayak1 (1.8/28)	563	6.2	1294	27	139.9	855
			Kayak2 (0.8/12)	741	5.5	920	26	146.8	335
STOEN	Stomeo	Scorze/IT	Min38 (0.8/3.8)	5566	4.8	3270	29	173.8	1921
			Noa38 (0.8/3.8)	5609	4.2	1911	29	176.5	1590
			Sco38 (0.8/3.8)	5598	4.8	3306	27	155.7	1813
STRJO	Strunk	Herford/DE	Mincam2 (0.8/6)	2354	5.4	2751	29	144.0	1282
			Mincam3 (0.8/6)	2338	5.5	3590	28	133.9	584
			Mincam4 (0.8/6)	2306	5.0	1412	28	136.8	479
			Mincam5 (0.8/6)	2349	5.0	1896	28	141.6	804
			Mincam6 (0.8/6)	2395	5.1	2178	28	135.7	963
TEPIS	Tepliczky	Agostyán/HU	Huago (0.75/4.5)	2427	4.4	1036	28	183.0	1214
			Humob (0.8/6)	2388	4.8	1607	28	152.2	978
WEGWA	Wegrzyk	Nieznaszyn/PL	Pav78 (0.8/6)	2286	4.0	778	28	129.4	777
YRJIL	Yrjölä	Kuusankoski/FI	Finexcam (0.8/6)	2337	5.5	3574	25	69.6	362
ZAKJU	Zakrajšek	Petkovec/SI	Petka (0.8/8)	1431	5.6	1955	10	66.9	438
			Tacka (0.8/12)	714	5.3	783	28	175.7	690
						Overall	31	13 140.5	88 080

* active field of view smaller than video frame

History

A History of Meteor Reports in The Astronomer magazine: part 5: 2013–2018

Tracie Heywood[1]

The magazine "*The Astronomer*" (TA) is a monthly magazine published in the UK whose aim is the rapid publication of observations made by amateur astronomers. It was first published in 1964. This is the final article in a series that provide an overview of the magazine's meteor content and covers the years 2013–2018.

Received 2019 June 4

1 Introduction

Leaving aside the meteor storms of 2001 and 2002 and a number of smaller meteor outbursts, meteor observing in the UK had seemed to be very much "in the doldrums" during most of the first decade of the 21st century.

Much was about to change, however. TA itself had already made a significant change in late 2010, with the introduction of an electronic (PDF) subscription option at a lower subscription rate. Although the driver for this had been to reduce printing and postage costs, it soon became clear that the inclusion of color images in the PDF version was also a big gain. This applied not only to the cover images but also to the meteor column itself. Furthermore, with fireball reports now becoming more common than routine meteor watch reports, the column had switched its title from "Meteor Notes" to "Meteor and Fireball Notes" during 2012.

2 Fireball Networks

Although video camera fireball detection networks had existed for some time in other parts of the world, the UK had lagged behind. Two such networks are established in the later part of 2012. NEMETODE (NEtwork for MEteor Triangulation and Orbit DEtermination)[a] is set up by William Stewart and Alex Pratt, while UKMON (UK Meteor Network)[b] is created by Richard Kacerek and Peter Campbell-Burns. The number of video cameras in each network grows. Both have UK-wide coverage, although NEMETODE tends to be more concentrated in the north and in Ireland, while UKMON has more cameras in the south and in Wales.

3 Fireball images

Whereas meteor images on the covers of TA had been quite rare during the first decade of the century, they now become much more frequent. Particularly impressive cover images are Denis Buczynski's image of a fireball and aurora on the cover of the February 2017 issue (Buczynski, 2017) (Figure 1) and David Strange's image of a Geminid fireball on the cover of the January 2018 issue (Strange, 2018).


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2017 February Vol. 53 No 634
1) Aurora and Fireball, Tarbatness (Scotland), 2017 January 22:
Denis Buczynski

The Astronomer Volume 53 No 643 2017 February page C1

Figure 1 – Denis Buczynski's image of a Fireball and an Aurora on the cover of the 2017 February issue.

Many fireball images appear within the Meteor & Fireball Notes column. A particular notable issue is that of December 2017 (The Astronomer, 2017) (Figure 2) in which the 4-page column is devoted almost exclusively to fireball reports.

4 Analyses

The new fireball detection networks did not merely provide images. They made use of UFO Analyser software to determine fireball ground tracks and used UFO Orbit to estimate former solar system orbits.

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[a]`http://nemetode.org/overview%20and%20history.htm`
[b]`https://ukmeteornetwork.co.uk/about-history/`

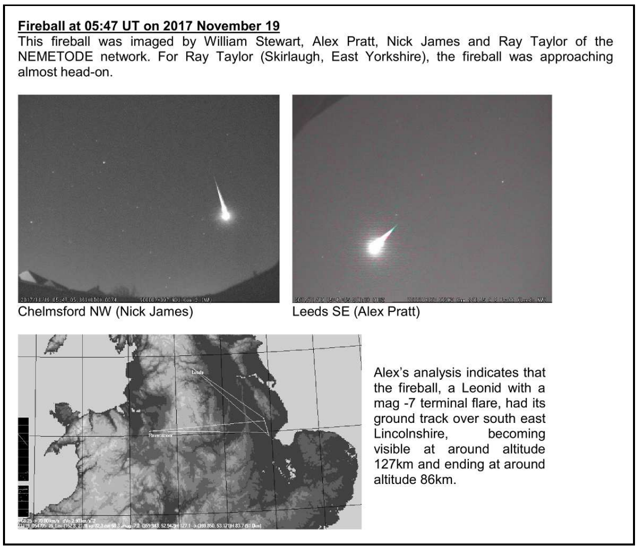


Figure 2 – Fireball Images and Triangulated ground track from a NEMETODE report in the 2017 December issue.

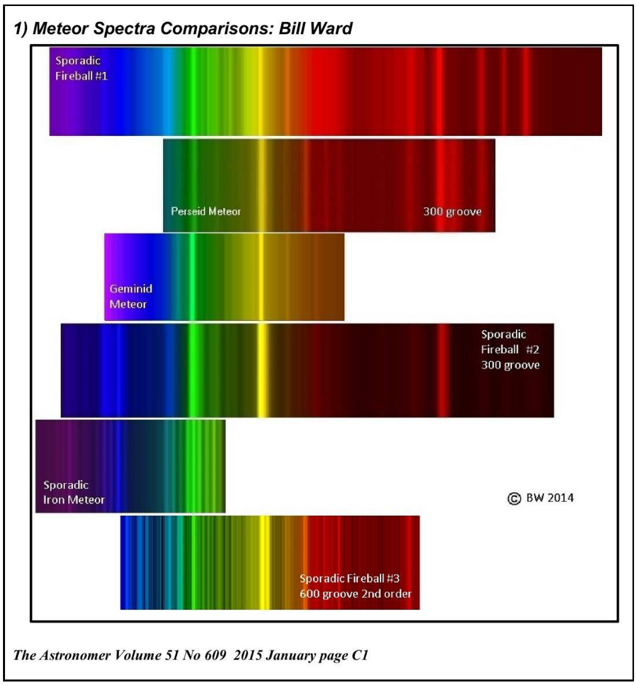


Figure 3 – Bill Ward's graphic on the cover of the 2015 January issue comparing six different colorized meteor spectra.

The December 2015 issue (The Astronomer, 2015a), for example, includes a ground track for a long duration twilight meteor, based on four images captured by NEMETODE cameras. Although few stars had been visible in the images, the analysis was able to exploit the known fixed directions of the field of view of each camera.

The large number of multi-station meteor images captured also allows some interesting plots to be generated. In the March 2018 issue (Pratt, 2018b), Alex Pratt provides four maps showing the UK ground tracks of all multi-station Perseids, Orionids, Leonids and November meteors imaged by NEMETODE cameras during 2017. The November 2018 issue (Pratt, 2018a) includes a similar map for the 2018 Draconids, while the 2018 December issue (Pratt & Heywood, 2018) includes a plot which shows the radiant motion of the 2018 Orionids.

5 Meteor Spectra

The fireball triangulation networks are not the only area of technological exploitation. Bill Ward is investigating and developing the collection and interpretation of meteor spectra, making use of improved gratings and cameras as these become available. There are many questions to investigate. How uniform are the spectra for a particular meteor shower? Is the spectrum primarily dependent on the composition of the meteor or is it influenced more by other factors, such as the speed of the meteor, its height in the atmosphere and its former solar system orbit?

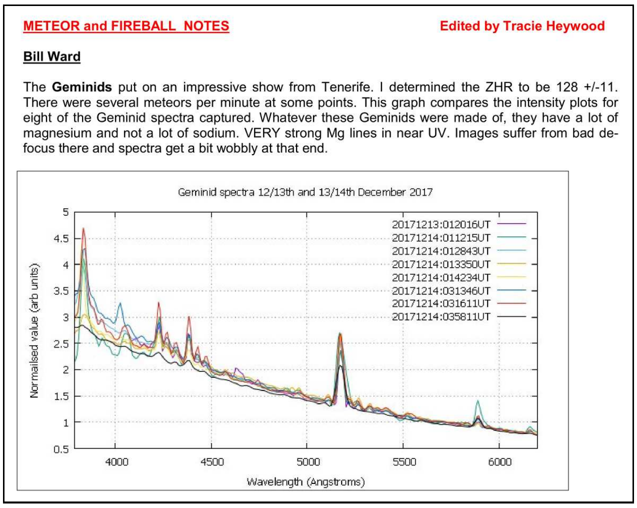
Historically, most investigators had focused on the maxima of the most active showers, in particular, those of the Perseids and the Geminids as the high rates at such times maximized the probability of capturing a spectrum. Bill, in contrast, is also observing lesser showers and sporadic meteors at other times of the year. In the 2014 November issue (Ward, 2014), for example, he reports his capture of a spectrum of a (probable) Taurid meteor.

Two months later, Bill is able to provide an eye-catching graphic for the front cover of the 2015 January issue (Ward, 2015g) (Figure 3) comparing the colorized spectra of six distinctive meteors. In the 2015 February issue (Ward, 2015c), he compares the spectra of four bright Quadrantids. One is discordant. It has sodium and magnesium lines that are less prominent than in the other three, the magnesium line particularly so. However, is the discrepancy due to the properties (e.g. mass) of the parent meteoroid, an artefact of the video-frame binning software, or might it not really have been a Quadrantid at all?

A few months later, in the 2015 May (Ward, 2015a) and June issues (Ward, 2015b), Bill records his success in capturing the spectrum of a meteor that has also been imaged on video elsewhere. The spectrum indicates a stony-iron composition and triangulation of the images reveals that it originated in the asteroid belt.

In the 2015 November issue (Ward, 2015d), Bill reports on his detection of two distinct spectra from the same meteor in the same video frame. One spectrum is linked to the meteor and flare; the other to a surviving fragment. There are significant differences between the two spectra. Additional notes regarding these spectra appear in the 2015 December issue (Ward, 2015e).

The 2015 December issue (Ward, 2015f) also includes Bill's first report about the unusual properties of some meteors. Whereas most meteors that he detects *"just stop"*, he is detecting some that "seem to ooze out of existence and fade away". More reports of unusual properties follow. In the 2016 March issue (Ward, 2016b), Bill reports on a meteor whose spectrum is very sodium deficient while having normal levels of silicon and magnesium. In the 2016 October issue (Ward, 2016a), he reports his first capture of the spectrum for a "melting" meteor that gradually faded away.



METEOR and FIREBALL NOTES Edited by Tracie Heywood

Bill Ward

The **Geminids** put on an impressive show from Tenerife. I determined the ZHR to be 128 +/-11. There were several meteors per minute at some points. This graph compares the intensity plots for eight of the Geminid spectra captured. Whatever these Geminids were made of, they have a lot of magnesium and not a lot of sodium. VERY strong Mg lines in near UV. Images suffer from bad de-focus there and spectra get a bit wobbly at that end.

Figure 4 – Bill Ward's report in the 2018 February issue comparing the spectra of 8 Geminid meteors.

In the 2017 December issue (Ward, 2016c), Bill reports on three quite different spectra captured during a single night. One shows a strong sodium line and is presumably from a young meteoroid while another, presumably from an older meteoroid, is relatively deficient in sodium compared with the first. This second meteor is also faster and has become luminous at a higher altitude at which the "forbidden" 557.7 nm emission line can be produced. The third is a stony-iron object and shows many iron emission lines. In the same issue, Bill also reports on another meteor that flared twice near the end. He notes that while all spectral lines became stronger at the time of the flares, three of the fainter lines brighten much more than others. These three lines are identified as being due to ionized states of magnesium, calcium and silicon.

In the 2018 February issue (Ward, 2018a), Bill reports on his Geminid observations from Tenerife and presents a graph (Figure 4) comparing the spectra of eight Geminids. He notes that they are all rich in magnesium but contain very little sodium. He goes on to compare intensity plots for spectra of meteors from for different meteor showers: the Lyrids, Perseids, Leonids and Geminids. For the three showers with cometary parent bodies he notes that

> "it can be seen that as the geocentric velocity increases the area under the spectrum at the red/near IR end of the spectrum graph increases. This is a reflection of the fact that at higher velocities there is more energy and the emission from atmospheric oxygen and nitrogen increases proportionally. The strong, unresolved O triplet at 777.4nm is saturated in the Leonid spectrum"

and

> "Close inspection of the Perseid and the Leonid spectra shows a feature at 557.7nm. This is due to the emission from a forbidden transition of Oxygen. This only occurs for fast meteors that start interacting with the atmosphere above 110km"

whereas, for the (non-cometary) Geminid spectrum, he notes

> "What is immediately apparent is that there is much less emission from the atmosphere. . . . Also, it is clear the metals at the blue end are significantly stronger than for the cometary particles".

More reports from Bill, featuring spectra that are notable for the presence/lack of certain lines, appear in the 2018 April (Ward, 2018b), May (Ward, 2018c), October (Ward, 2018d) and December (Ward, 2018e) issues.

6 Radio Methods

While some technological advances are aiding the imaging and triangulation of fireballs, other technological changes are making life harder for radio observers – the analogue/digital switchover is leading to the decommissioning of many of the analogue radio transmitters formerly used in forward scatter observations. For observers in the UK, the only suitable transmitter is now the GRAVES radar system in southern France.

Some radio results are received nevertheless. These include Alexei Pace's report in the 2013 November issue (Pace, 2013) on that October's Draconid activity and Bill Ward's report in the November 2018 issue (Ward, 2018f) on the 2018 Draconids. With the parent comet well past perihelion in 2013, Alexei detects no surprises, whereas Bill is able to record the outburst during the night of 2018 October 8–9.

7 Meteor Showers

Most visual observers focus on the major meteor showers and, in particular, their maxima, since these are the times when higher rates make observing more enjoyable. Video imaging has no such limitation since the imaging and the initial analysis are usually automated (and cameras are not "bored" by low meteor rates!). Nevertheless, imagers still make special efforts for the major showers. Visual meteor watches do continue but it is now video imaging that generates the most reports.

Well observed shower maxima include the 2014 Geminids (reported in the January 2015 issue, (The Astronomer, 2015b)), the 2015 Lyrids (May 2015 issue, (The Astronomer, 2015c)), and the 2017 Perseids (September 2017 issue, (The Astronomer, 2014b)). In addition, Alex Pratt provides regular monthly reports from his three video cameras during 2017 and 2018, often including magnitude distributions for the major showers.

8 Meteor Outbursts (or not)

The successful predictions of the Leonid storms around the turn of the century inevitably encouraged more people to carry out analyses and predict possible upcoming meteor outbursts. Many of these postulated outbursts prove disappointing or non-existent, while other outbursts still do take observers by surprise.

Mention has to be made, of course, of the much-hyped predictions for a Camelopardalid outburst on 2014 May 24. This came to nothing, as is reported in the June 2014 issue (The Astronomer, 2014a).

Reports of enhanced rates from 2013's Eta Aquarids are mentioned in the May 2013 (The Astronomer, 2013a), with a fuller report appearing in the June 2013 issue (The Astronomer, 2013b). The October 2013 issue (The Astronomer, 2013c) includes reports of the previous month's September Perseid outburst. Cloudy skies across the UK prevent the 2014 Ursid outburst from being observed unfortunately. The Gamma Draconids produce an unexpected outburst in late July 2016 and William Stewart's report appears in the September 2016 issue (Stewart, 2016). It is notable that the above outbursts are picked up by automated imaging systems rather than from visual reports.

Whereas, the observed outbursts listed above had taken most observers by surprise, the enhanced Perseid rates of 2016 Aug 11–12 and the Draconid outburst of 2018 Oct 8–9 are well signposted in advance and thus many observers are prepared for them. The 2016 Perseid outburst was largely clouded out from the UK, although the September 2016 issue (The Astronomer, 2016) reveals that Mark Kidger saw it visually from Tenerife, while Bill Ward detected it using radio methods from Scotland. The UK weather was again uncooperative for the 2018 Draconids, but the November 2018 issue does include a visual report from Paul Jones in Florida (Jones, 2018) and, once again, radio counts from Bill Ward (Ward, 2018f) from Scotland.

9 Unusual Meteors

Historically, reports of unusual meteors had been difficult to verify as there had been no permanent record of the event. The monitoring of the night sky using video cameras changes this. Although, these cameras are primarily looking for fireball events, they also detect many "non-meteors" and provide records of unusual meteors.

In the 2013 July issue (Arbour, 2013), Ron Arbour describes a mag −2 flash seen near Polaris that was clearly different from head-on meteors that he had seen over the years. The time and position of this event didn't tie in with any satellite predictions on Heavens Above, however. He also adds that he subsequently discovered that a brighter flash had been recorded at the same time by a video system operated by the nearby Clanfield Meteor Group, with the recorded image being slightly elongated. Nick James and Peter Meadows reply in the 2013 August issue (Meadows & James, 2013), noting that their imaging systems sometimes pick up similar events and link these "brightness flares" to specular reflections from satellites.

Whereas it is difficult for visual observers to be absolutely certain that two meteors were simultaneous, video records can give a definitive answer. We see this in the March 2014 issue (Pratt, 2014), in which Alex Pratt reports two occasions during the night of 2013 Dec 13–14, when he recorded pairs of simultaneous Geminid meteors within the field of view of a single video camera. Tony Markham reports having seen one of these pairs visually.

Bill Ward detects many examples of meteors with distinctive light curves. Some examples appear in the November 2017 issue (Ward, 2017). In the March 2018 issue (Ward, 2018g), Bill reports having recorded a number of meteors from Tenerife during the 2017 Geminids that appeared to have had wavy trajectories. He goes on to summarize the resulting Twitter discussions. These indicate that the most likely explanation relates to airline luggage weight limits and the consequent use of less sturdy camera tripods, these inevitably being more susceptible to wind gusts ...

Some longer duration phenomena prove more challenging.

In the 2013 January issue (The Astronomer, 2013d), Anne-Marie Eardley describes two bright flashes, seen from Aberdeenshire several hours apart on 2012 Dec 4–5, that lit up the western sky and were both followed by a developing orange glow. Neither event coincided with reports of fireballs seen elsewhere. Alastair McBeath suggests as over-the-horizon lightning as a possible source of the flashes.

A particularly unusual event is seen by a number of observers during the night of 2014 Dec 12–13. In the 2015 February issue (Toone, 2015), John Toone describes how he first noticed a very slow-moving fuzzy object in Serpens while variable star observing. The object brightened as it crossed into Corona Borealis, becoming comparable in brightness with Arcturus, before fading again and becoming more diffuse. Remaining visible for around an hour, it was clearly not a meteor. The possibility that it might be a previously unreported comet was initially considered, but soon afterwards, Nick James provided the correct explanation. It was a fuel dump from the Centaur upper stage of the NROL-35 launch.

10 Miscellaneous: Taurids, Shower Assignment, IMC 2016

In the October 2014 issue (Markham, 2014), Tony Markham, noting the widely differing dates of Taurid maxima quoted by the IMO and by other organizations, questions whether the assignment of a peak date for the Taurids helps potential observers or misleads them, given that the "popular" image of a meteor shower peak features high activity for a day or two and much lower activity at other times.

In the March 2016 issue (Pratt et al., 2016), Alex Pratt, Tony Markham and William Stewart discuss the problems associated with software-based shower identification with particular reference to the December Alpha Draconids and the Quadrantids of early January. Alex notes that although the meteor catalogue used by the UFO software considers the December Alpha Draconids to finish by late December, the software extends this into early January because, by default, it extends listed shower limits by 10 days. Consequently, some (single-station) Quadrantids are being mis-labelled as December Alpha Draconids.

A summary of the 2016 International Meteor Conference appears in the July 2016 issue (Heywood, 2016).

11 In Conclusion

During the first decade of this century it had seemed that, due to light pollution and other factors, UK based meteor observing was in a serious decline. The second decade produced a welcome "reprieve", with the cost of suitable video cameras and diffraction gratings dropping into the affordable price ranges of a significant number of amateur astronomers. Cooperation between observers proved very important, but it is notable that the imaging groups were set up independently rather than being initiated by the existing main national astronomy group. It is just a shame that this resulted in the creation of two groups rather than one.

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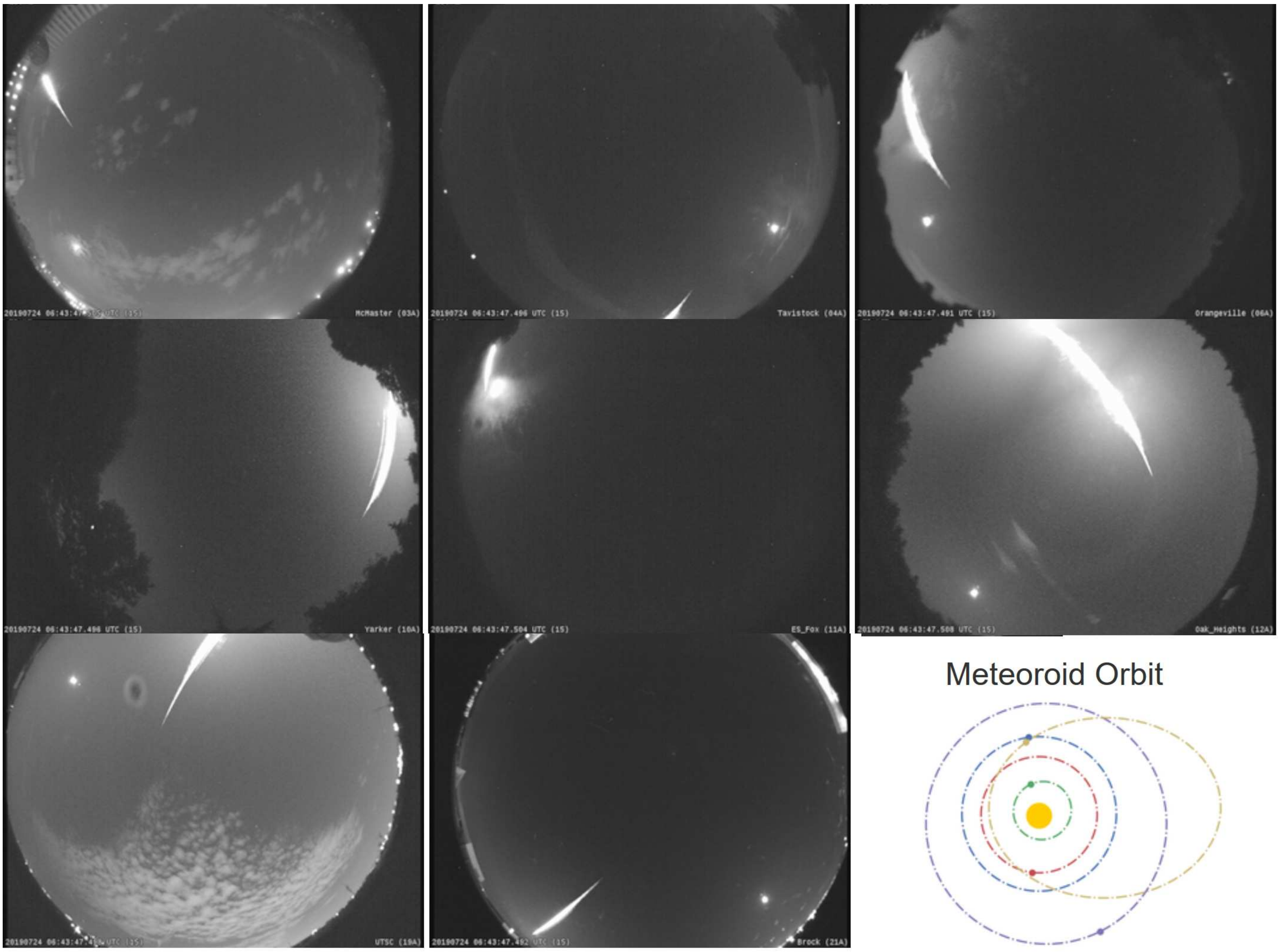
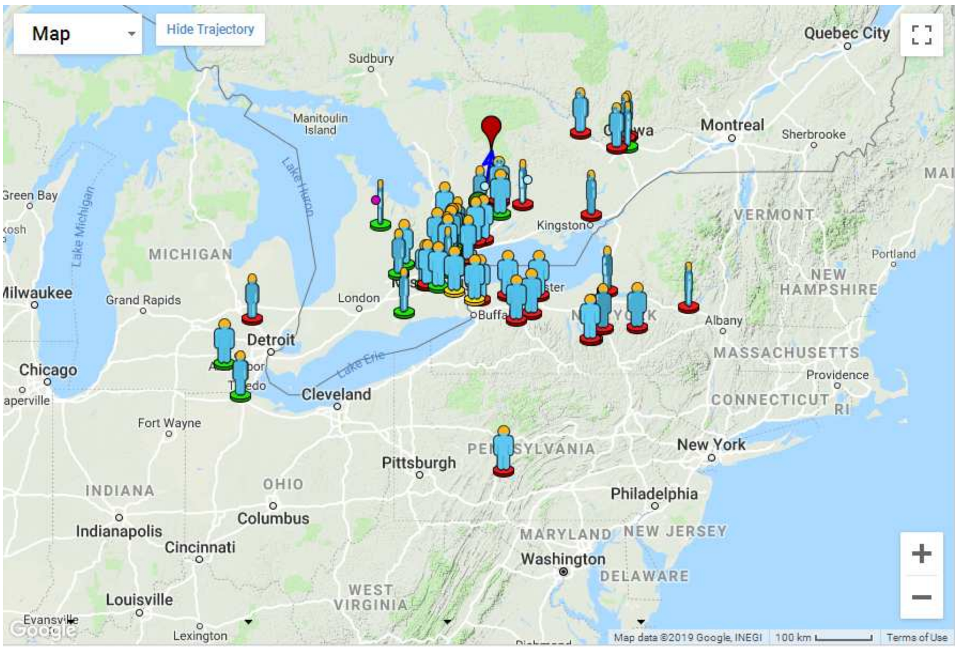
Bright fireball on 2019 July 24 over Canada



Stacked images from video of the 2019 July 24 meteorite-producing fireball over Southern Ontario. Shown are eight cameras which detected this bright fireball. The endpoint below 30 km height was near the town of Bancroft. Image courtesy of Peter G. Brown / University of Western Ontario.



The International Meteor Organization has received 48 witness reports for this fireball event #2019-3146. Source: `https://fireball.imo.net/members/imo_view/event/2019/3146`