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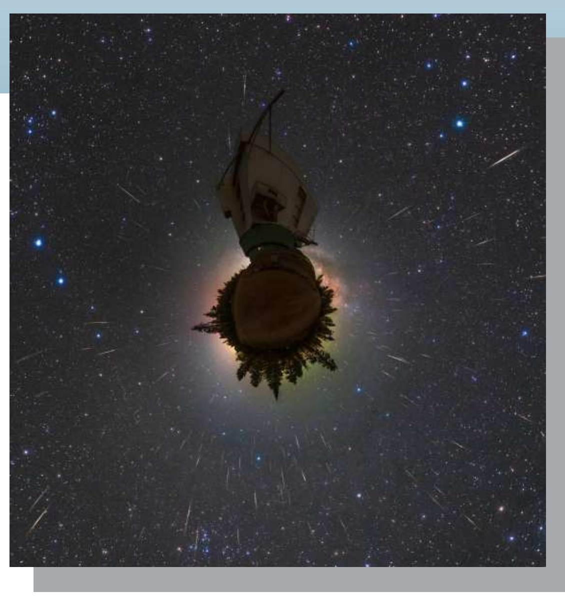

Janus
IMC 2023 announcement
Fourth Quarter 2019 IMO video meteors & 2019 summary
Relation between meteor brightness and radiant altitude
Recollection of 50 years of visual meteor observations

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Administrative

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Front cover photo

The 2022 Tau Herculids recorded on 2022 May 31 from Mt. Graham, Arizona, USA, in a "little planet" projection. The radiant was near the zenith, therefore the trails of meteors in this projection are perpendicular to the horizon. Radiant in this case is directly "behind the observer's head", and is not present in the picture. The cameras used were Canon 6Da, Sony A7III, and two Sony A7IIIa, equipped with Samyang 24 mm, Rokinon 12 mm, Sony GM 16-35 mm, Sigma ART 28 mm, and Sigma ART 50 mm lenses. Exposures ranged between 20 and 30 seconds, using ISO 3200-6400, at f/2.2 to f/2.8.
Image courtesy: Robert Barsa

Back over photo

The same photographs of the 2022 Tau Herculids from Mt. Graham, Arizona, USA were used as for the front cover image. There are totally 225 Tau Herculids meteors included in the final 360-degrees panorama.
Image courtesy: Robert Barsa

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` .

Legal address

International Meteor Organization, Jozef Mattheessensstraat 60, 2540 Hove, Belgium.

Janus

Cis Verbeeck[1]

2022 has not been an easy year for the world. In these difficult times, it's good to have hopes and wishes. First of all, I wish all our readers and their families a safe, healthy, prosperous, and rewarding year. I also hope we can meet again in person in 2023.

In 2022, we lost our dear friend and long-time IMO officer Jean-Louis Rault. Jean-Louis was very much involved in the IMO and in the International Meteor Conferences. We will dearly miss him.

The IMO Council has appointed Bob Lunsford as Director of the Fireball Commission, starting in January 2023. I am convinced that Bob will take up this role with passion, as he has been handling fireball reports for many years. It's my pleasure to congratulate Bob and to wish him a lot of success and satisfaction in his new function. The same goes for all volunteers who are helping the IMO, be it in an official function such as Council member or Commission Director or by fulfilling IMO tasks which are less visible. I am very grateful to all those people, and would like to thank them for all the great work they have done and are doing for the IMO!

2022 treated us to some exciting meteor displays, such as an outburst of the tau Herculids on May 31, close to the predicted time, and the flurry of 23 meteors that was observed within a few seconds by an AllSky7 Global Network station in Gaustatoppen, Norway on October 30. It was also the first year with two predicted Earth impacts (2022 EB_5 on March 11 and 2022 WJ_1 on November 19). The former asteroid was discovered by Krisztián Sárneczky (member of the Local Organizing Committee of the IMC 2022) less than 2 hours before it impacted the Earth's atmosphere!

When covid became endemic in most countries in 2022, this opened the door for the first on-site International Meteor Conference since 2019. The IMC 2022 was held in Hortobágy, Hungary on September 29 – October 2 and was a huge success, thanks to the quality of the talks and the organizational skills of the organizers (the Research Centre for Astronomy and Earth Sciences and Konkoly Thege Astronomical Institute in Hungary). Though unforeseen circumstances prevented me to take part in the conference myself, I have heard from many participants that they were delighted to meet meteor friends and colleagues again in real live after three years. In fact, I did participate in part of the conference, thanks to the fact that it was a hybrid conference, combining the on-site event with online participation. Though there were some hiccups in the online part of the conference (and lessons learned), all in all this was a great addition which allowed people from different time zones (34 countries) to participate that would not have attended the conference if it were only on-site. There were 104 online participants and 52 on-site participants.

I am particularly looking forward to the IMC 2023, which will be organized by the BRAMS meteor team from August 31 to September 3 in the Euro Space Center in Redu, in my home country Belgium. You can read all about the IMC 2023 in this issue of WGN, and soon on the IMO website.

I hope to meet you face-to-face again in September, to share a drink, and to hear about your meteor activities. Meanwhile, have clear skies and a great year!

Janus *was a Roman god with two faces, one looking to the past and one to the future, called upon at the beginning of any enterprise. Today he is often a symbol of re-appraisal at the start of the year.*

[1] Bogaertsheide 5, 2560 Kessel, Belgium.
Email: `cis.verbeeck@gmail.com`

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Erratum: Meteor halo phenomena – attempt at a morphological classification

The WGN Editorial Team

A wrong image has been supplied for Figure 4 (page 168) of the paper about meteor halo phenomena (Slansky, 2022). The wrong image showed fireball 3414-2018 (also depicted in Figures 1, 2 and 3 of the paper), and not the Aurigid described. The correct image is reprinted here, along with the caption.

We sincerely apologize to our readers.

References

Slansky P. C. (2022). "Meteor halo phenomena – attempt at a morphological classification". *WGN, the Journal of the IMO*, **50:6**, 165–178.

IMO bibcode WGN-511-erratum
NASA-ADS bibcode 2023JIMO...51....2E

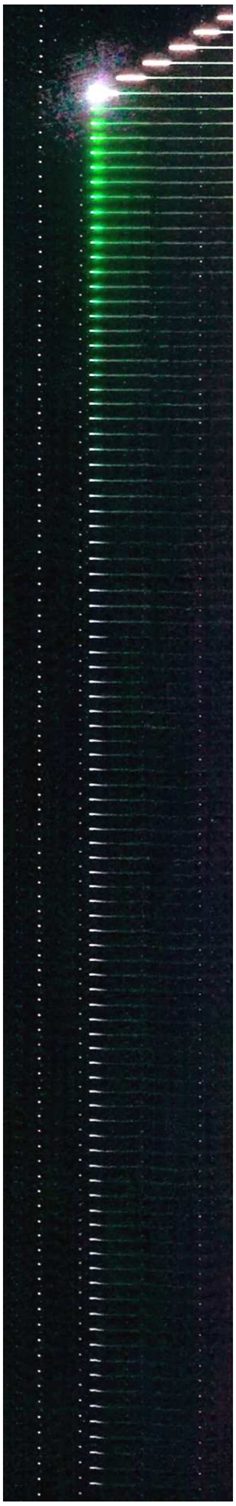

Figure 1 – Sequence analysis of an Aurigid on 2014 September 1 at $05^{\mathrm{h}}44^{\mathrm{m}}44^{\mathrm{s}}$ UT from La Palma (**?**). The meteor flies from right to left. Each vertical step represents 1/25 s. Due to the exposure time of 1/25 s for each video frame there is significant motion blur. The terminal flash inside frame 6 is very abrupt. It is followed by a green halo with a duration of nearly one second. The green halo has direct connection with a faint green train. A widespread pale blue halo can be seen very briefly around the terminal flash. Camera: Sony a7S at 25 fps and ISO 204 000 with Zeiss ZE 2.8/35 mm lens at $F = 4.0$.

Conferences

Forty-Second International Meteor Conference, Redu, Belgium, August 31–September 3

Hervé Lamy[1]

The next IMC will be organized at the Euro Space Center, near Redu in Belgium, from August 31 until September 3. This short article gives you some practical information and a little bit of teasing.

1 Introduction

The IMC returns to Belgium for the first time since 2005 when it was organized in Oostmalle. This year it will be organized from August 31 to September 3 at the recently refurbished Euro Space Center (ESC), located near Redu in the beautiful region of the Ardennes. ESC is a thematic center whose goal is to raise awareness about space science via a number of activities such as Space Hub, Mars Village, Space Flight Unit, Space Rotor, Planetarium, Moonwalk, Free Fall Slide, ... It is mostly intended for young visitors fascinated by space but is also adapted to families or VIP / team building events from various companies. It also provides all the facilities required to organize a perfect IMC. The people working at ESC are extremely enthusiastic to welcome the IMC 2023.

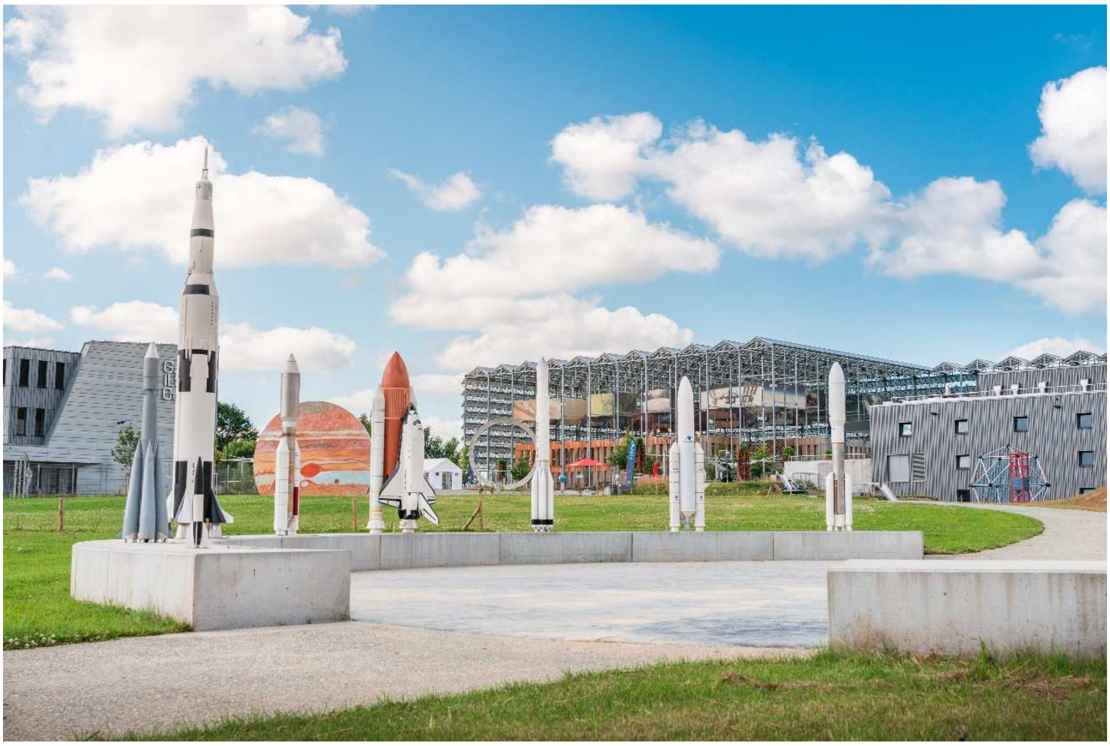

Figure 1 – The Cosmic Valley with the Euro Space Center in the background (left).

The IMC 2023 is organized by the Royal Belgian Institute for Space Aeronomy (BIRA-IASB) located in Uccle, in the South of Brussels (`https://www.aeronomie.be`). BIRA-IASB is a Belgian Federal Scientific Institute. Since its foundation in 1964, it has been conducting research and providing public services in space aeronomy, i.e. the physics and chemistry of the atmosphere of the Earth and other planets, and of outer space. The Space Physics division has been active in meteor research for more than 12 years, mostly by developing the BRAMS (Belgian Radio Meteor Stations) network for radio forward scatter observations of meteors with a dedicated transmitter and over 40 receiving stations in Belgium and neighboring countries. The network is constantly growing and improving. Moreover, the team is participating in a growing number of optical camera networks (CAMS-BeNeLux, FRIPON, All-Sky7, GMN, EFN) to study meteors and fireballs.

The BRAMS team will be in charge of the practical organization together with local support from people at ESC and of course support from the IMO. We intend to provide a really great IMC and a fantastic experience for each participant, both on a scientific and on a social level.

[1] Royal Belgian Institute for Space Aeronomy, Avenue Circulaire 3, 1180 Brussels, Belgium.
Email: `herve.lamy@aeronomie.be`

The situation with Covid-19 has strongly improved in the last year and therefore we are aiming for an on-site participation with as many participants as possible. However, we will keep offering an online participation as well. We look forward to seeing many of you on-site or online at the end of August.

2 Venue and location

The Euro Space Center (`https://www.eurospacecenter.be/en/`) is located in the village of Redu, which is part of the municipality of Libin. It has all the facilities needed to organize a great IMC.

The conference room / auditorium has 150 seats, but note that only 50 seats in front of the room are equipped with a writing desk. Each seat has a 220 V socket and two USB sockets. There is a forum of 25 m^2 on top of the room which can welcome additional participants. It is accessible via a discrete door on top of the room. It is a very modern auditorium with all the current technical facilities, including the possibility to have a videoconference and hence a hybrid mode.

Figure 2 – Views from of the conference room.

The Galaxy Inn at ESC has 24 bedrooms, each with 10 beds, 2 showers, 2 sinks and one toilet. They are located on 3 floors (called Earth, Mars and Sky). For the IMC 2023, we will offer 18 rooms of 4 people and 6 rooms of 2 people in order to accommodate a maximum of participants on site. So 84 participants will be able to stay at the ESC. If you want to benefit from this option, we recommend that you book early. During the registration process, you can suggest partners for your room and we will try to accommodate these wishes as much as we can. Alternatively, nearby hotels are listed on our website. Note that none of them is reachable by foot and therefore you will need a car or you may want to rent a bicycle. Each participant staying at the ESC will receive linen and breakfast in the morning.

Figure 3 – Pictures of the rooms at the Galaxy Inn.

The ISS room will be used for the breakfasts (for those staying at ESC), for the lunches and dinners (for everyone), and for the coffee breaks. This will also be the location for the social evenings. If weather permits, there is a terrace next to the room that we can also access for discussions around a drink or for the meals.

A small bar will be available in the ISS room with water, a selection of soft drinks and typical Belgian beers including the local Trappist beer from Rochefort (located 20 km from the ESC).

Until 23$^{\mathrm{h}}$, we will also have access to the Voyager Café (the main official bar/restaurant from ESC) where participants will also be welcome to order their drinks. The small bar in the ISS room will allow us to run the social events that are an important component of every IMC.

Figure 4 – The ISS room (left) and the terrace nearby.

3 External accommodation

There are no hotels within walking distance of the ESC. If you stay in one of the hotels listed on our website, you will need either a car or a bicycle. If you choose to arrange your own accommodation, you must select the "no accommodation" option on the registration form. In that case, all costs related to your accommodation are of course at your personal expense.

We have negotiated prices and secured rooms until April 15 with Hotel du Val de Poix (`https://www.levaldepoix.com/`) in Poix-Saint-Hubert. We secured 18 twin rooms (119 EUR/night) and 12 rooms with a large bed that can then be booked either as double (119 EUR/night) or as single room (91 EUR/night). After April 15, the rooms will be freed and can be sold to the general public. If you plan to stay there, please book as soon as possible.

If you choose to arrange your own accommodation, keep in mind that it will be summertime and therefore demand can be high since ESC is located in a very touristic region. If you do not have a car or do not want to rent one to commute between your hotel and the ESC, there are possibilities to rent bikes with links also provided on the website.

4 Program and events

As usual, the scientific program will start in the evening of Thursday, August 31 and will terminate at lunch on Sunday, September 3.

On Thursday, August 31, at 20$^{\mathrm{h}}$, we will start with the opening ceremony. Before that a dinner will be served. For those interested to participate in the VIP event (see below), it will start on Thursday at 16$^{\mathrm{h}}$ and will last approximately 2 hours. On Saturday evening, we will also have a special gala buffet dinner with many local products. This dinner is included in the registration fee.

Before the IMC in Oostmalle in 2005, a workshop about radio meteor observations was organized during a few days. This year, we will be less ambitious but would nonetheless like to keep this tradition and will organize a small radio workshop on Wednesday, August 30, also at the ESC. Practical details about the workshop and the scientific content is available on a separate page on the IMC 2023 website. This activity will not be included in the registration fee. A separate registration by e-mail will be organized by the LOC.

On Saturday afternoon, an excursion will be organized to visit the radio-astronomical site of Humain and then the caves of Han. We will use coaches to go there and leave the ESC at 13$^{\mathrm{h}}$30$^{\mathrm{m}}$.

The radio-astronomical site located in Humain, near Rochefort, belongs to the Royal Observatory of Belgium (ROB). It is a small area of only a few square kilometers, which is protected against electromagnetic radiation. The site was used since the 1950s for radio astronomical observations, mainly solar observations. From 1957 to 1972, ROB built a solar radio interferometer with 48 parabolic antennas oriented along the North-South and East-West axes. It was operational until 2001. Most of the antennas are still there ... although in a poor state but still nice for pictures if you do not get too close.

Since 2008, using a new funding from the Solar-Terrestrial Center of Excellence, new radio experiments were installed. During this short excursion, you will have the possibility to see SPADE (a new solar radio interferometer), several refurbished antennas equipped with different types of instruments monitoring the solar radio spectrum (see Figure 6), the BRAMS radio interferometer for VHF observations of meteors (see Figure 7), and a VLF antenna made of two magnetic loops belonging to AWDA-Net, a worldwide network of antennas dedicated to the study of whistlers and the plasmasphere.

Figure 5 – Antennas from the old solar radio interferometer in Humain.

Figure 6 – Antenna refurbished by ROB to track the Sun and take solar radio spectra.

There are also a number of meteor optical observations carried out there, taking advantage of one of the darkest skies in Belgium.

The visit will last about one hour. The BRAMS and VLF antennas are located in the grass, so consider wearing walking shoes. You will need them anyway in the Caves of Han! The grass will be cut just before our visit. The other solar antennas are accessible via a road with concrete.

Figure 7 – The BRAMS radio interferometer with 5 Yagi antennas.

The Caves of Han are a natural complex of caves in Belgium. A major Belgian tourist attraction (around 250-300 000 visitors per year), the caves are located in Wallonia, on the outskirts of the village of Han-sur-Lesse. The caves are formed as the result of an underground erosion of a limestone hill by the river Lesse. For most of its length a meandering river, it abruptly plunges into a sinkhole not far from Han-sur-Lesse. This hole is known as the *gouffre de Belvaux* (the Belvaux abyss), where it forces its way under the hill over a distance of over 1 kilometer as the crow flies before streaming through the cave complex known as the "Grottes de Han".

Figure 8 – Caves of Han.

The temperature in the Cave is on average around 9–10°C with also a lot of humidity, so although we will be in summertime, do not forget to bring warm clothes for the excursion. There are 365 steps so no strollers or pushchairs or wheelchairs. There are no toilets in the Cave.

The tour will be the classical "discovery" tour and will be conducted in English. Its duration is $1^{h}15^{m}$. It is a walking tour with a distance of 1.6 km.

5 VIP event

This activity is kindly proposed by the ESC. It is not included in the registration fee. You can book for the event via the registration page. The activity costs 25 EUR per participant and will be organized **on Thursday afternoon from 16^{h} to 18^{h}**.

People who would like to participate are invited to arrive early enough on the site. The visit will be done by groups of 15 to 20 persons. There is the possibility for participants who would like to arrive the day before (Wednesday) to stay one additional night at ESC. This night and the meals at ESC will not be included in the registration fee and must be paid separately. Those interested to stay one additional night on Wednesday will need to contact the LOC by e-mail.

The VIP activity will include:

- **The Space Hub**: An area dedicated to testing Astronauts' skills. Play to find if you have the skills to join our team of Astronauts.
- **Space Tour**: Our multimedia exhibition invites you to follow the footsteps of those who helped mankind discover our fascinating universe.
- **Mars Village**: Be the first to tread the Martian soil. Habitat, exploration, daily life, rover driving, etc. How will you survive on Mars?
- **Mars Walk and Moonwalk XP**: Experience of sensation of Martian and Lunar gravity by trying out our seat equipped with a virtual reality mask.
- **Free Fall Slide**: Experience the sensation of weightlessness with a free fall from 8 meter high.
- **Space Flight Unit**: Fly over the red planet aboard your spacecraft. It is up to you to navigate the Martian canyons to complete your mission.
- **Space Rotor**: Test you ability to resist centrifugal force in our Space Rotor. You will be subjected to the g-forces like real astronauts.

There is no possibility to organize a similar event on Sunday afternoon since the ESC will be open to public. However, people interested in participating to some activities below can participate in the public event.

Figure 9 – Mars-Walk (left) and rotor (right) as example of activities of the VIP event.

6 Travel information

On the website you will find a list of possibilities on how to reach Belgium by plane (via the two main airports), by international train or by car. A possibility to fly to Luxembourg is also listed.

Once you are in Belgium, the ESC is most easily reached by car. If you come to Belgium by car or if you rent a car at the airport, the ESC is located near exit 24 of the E411 Motorway. There is a very big and free parking there.

If you come by train, we will organize shuttles (at no extra cost) from the Libramont train station which is about 18 km from the ESC. During the registration process (or later on when you have more details), you can provide your estimated arrival time in Libramont. For that, you can use the website of the national trains in Belgium: `https://www.belgiantrain.be/en`. Note that whether you come by plane to any of the airports or by international train, the travel by local trains to Libramont will last about 2^{h}–$2^{\mathrm{h}}30^{\mathrm{m}}$. Please also inform us of your flight number, international train number or if you come by car to facilitate the organization of the shuttles.

There is a possibility to arrive at the ESC via a bus from Libramont train station but it does not run very often or even regularly so we do not recommend this option particularly.

7 Registration and payment

You can register for the meeting at `https://imc2023.imo.net/reg_choice`. If you stay at the ESC, the registration fees include full board (accommodation, breakfast, lunch, and dinner) from August 31 (dinner included) till September 3 afternoon (lunch included), IMC lectures, conference materials, coffee breaks, excursion and Saturday evening program (buffet dinner). The price is 285 EUR for double room occupancy (6 rooms available) and 245 EUR for quadruple room occupancy (18 rooms available). If you prefer to stay at a nearby hotel, the price for the registration fee is 150 EUR which includes everything above except the accommodation and the breakfasts. Keep in mind that 84 people will be able to stay at the ESC but that the maximum number of participants can reach 150 (maximum capacity of the auditorium without taking into account the extra space on top). After June 15, 20 EUR will be added to all registration fees for onsite participation. The fee for online participation to the IMC is 20 EUR.

There will be a supplement fee for t-shirt (10 EUR), printed posters (5 EUR) and printed proceedings (20 EUR), all of them can be selected during the registration process.

We are looking forward to welcome you in Redu!

IMO bibcode WGN-511-lamy-imc2023 NASA-ADS bibcode 2023JIMO...51....3L

Preliminary results

Result of the IMO Video Meteor Network – Fourth Quarter 2019

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

The IMO Video Meteor Network cameras recorded nearly 65 000 meteors in almost 13 000 observing hours during 2019 October, over 25 000 meteors in more than 6 500 observing hours during 2019 November, and more than 56 000 meteors in nearly 11 000 observing hours during 2019 December. Flux density profiles are presented for the Northern and Southern Taurids, October Camelopardalids, October Ursae Majorids, Orionids, Leonids, α-Monocerotids, and Geminids.

Received 2022 December 12

1 Introduction

As reported at the 2022 IMC (Molau, 2022), the observational database of the IMO video meteor observers was migrated to the AWS cloud recently. In addition, a new web service was programmed, that can generate monthly and yearly statistics as well as a number of further reports. All figures and data for observing statistics in this report were generated for the first time via the new web service at the push of a button.

The number of active video cameras remained at the level of 80 in the fourth quarter of 2019 and therefore unchanged from the previous months. The weather was unusually good in October, but from the end of October until December it remained poor. Only at the end of year was the number of clear nights rising again (Figure 1).

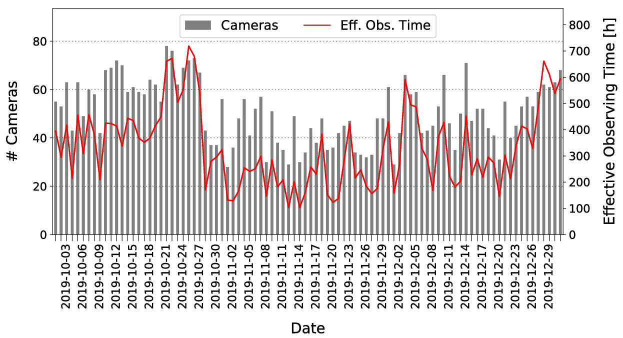

Figure 1 – Number of active cameras per night (grey bars) and effective observing time of these cameras (red line) in the fourth quarter of 2019.

With nearly 13 000 hours of effective observing time and 65 000 meteors, the output of October was slightly lower than in the previous two years, but better than in earlier years. In November we had the lowest yield since 2010. No more than 25 000 meteors were recorded in more than 6 500 hours of effective observing time. December, on the other hand, slightly outperformed the previous two years and matched the average since 2013 with 56 000 meteors from almost 11 000 observing hours.

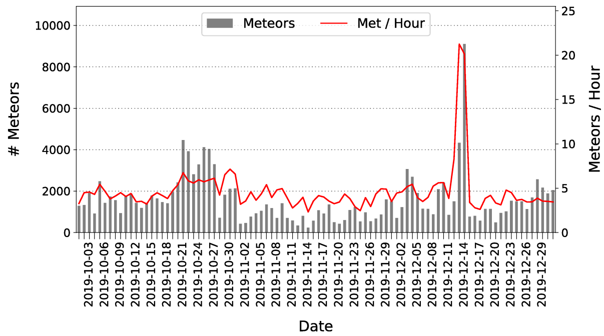

Figure 2 – Number of recorded meteors per night (grey bars) and average number of meteors per hour (red line) in the fourth quarter of 2019.

The average meteor rate (Figure 2) fluctuated in the last quarter of 2019 around the value of five meteors per hour. Clear outliers are visible in the last third of October during the Orionids, and during the Geminids in December. At these times, also the absolute number of recorded meteors increased significantly.

2 Taurids

We start the analysis of meteor showers with the Taurids, which are active over a long period of time. Figure 3 compares the activity of both Taurid branches in 2019. As usual, the southern Taurids dominate in the first half up until the end of October. Thereafter, the northern branch becomes stronger.

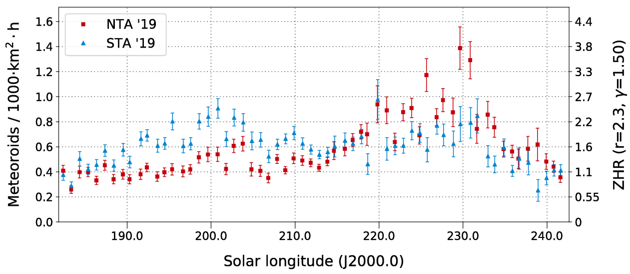

Figure 3 – Flux density of the Northern (red) and Southern (blue) Taurids in 2019, derived from observations of the IMO Network.

[1]Abenstalstr. 13b, 84072 Seysdorf, Germany.
Email: sirko@molau.de

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NASA-ADS bibcode 2023JIMO...51....9M

The population index is showing unusually high values at the start of the activity interval (Figure 4). In fact, we even had to extend the range of possible values in the software, which was only ranged to $r = 3.5$ so far. We consistently measured values beyond that, not just single outliers. Only by the Orionid peak had the population index fallen to a normal level of 2.5. Until the end of the activity interval, the population index remained in the range of 2.5 to 3.0. Only around November 12 was it reaching smaller values near $r = 2.0$. That matches exactly with full moon. At the same time, the flux density shows outliers in the opposite direction. Hence, we assume that we observe the "usual" artefact, that at full moon the rates are getting higher and the population indices smaller due to a hitherto misunderstood systematic effect in limiting magnitude calculation.

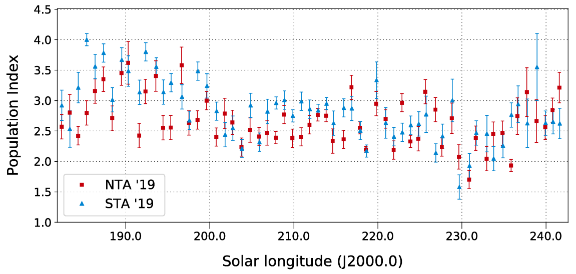

Figure 4 – Population index of the Northern (red) and Southern (blue) Taurids in 2019, derived from observations of the IMO Network.

To verify whether these variations in flux density and population index are a long-term trend, we also calculated the average long-term profiles from 2011 to 2019 (Figure 5). Indeed, we see two maxima for the Southern Taurids (mid-October and near November 5), whereas the Northern Taurids have just a single maximum in mid-November.

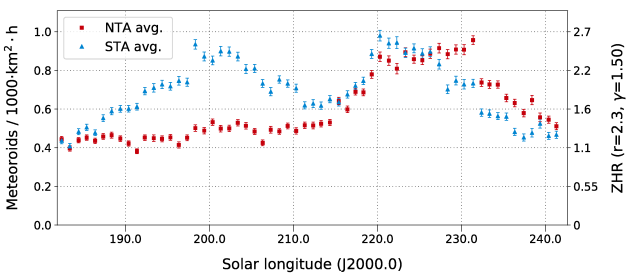

Figure 5 – Flux density of the Northern (red) and Southern (blue) Taurids in the years 2011–2019, derived from observations of the IMO Network.

We can also confirm the trend, that the population index of the Southern Taurids is large (above 3.0) at the beginning, then it remains for most of the time near 2.5, and only at the end of the activity interval is it reaching values below 2.5 (without influence of moon phase). The Northern Taurids show less variations, but their population index is also higher at the beginning than at the end (Figure 6).

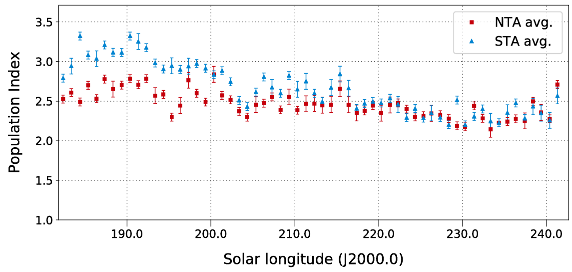

Figure 6 – Population index of the Northern (red) and Southern (blue) Taurids in the years 2011–2019.

3 October Camelopardalids

The October Camelopardalids were almost invisible in 2019. If we compare the profile of 2019 with their long-term profile (Figure 7), we also see why: The narrow peak fell just inside European daytime hours in 2019.

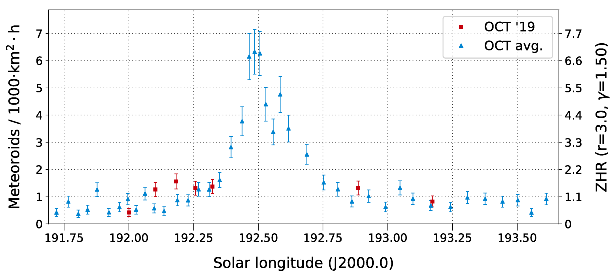

Figure 7 – Flux density of the October Camelopardalids in 2019 (red) as well as in the average of the years 2011–2018 (blue), derived from observations of the IMO Network.

4 October Ursae Majorids

The activity profile of the October Ursae Majorids (Figure 8) matches well with the long-term profile of 2011 to 2018, including the peak at 202°15 solar longitude. Hence this shower right before the Orionids did not present a surprise.

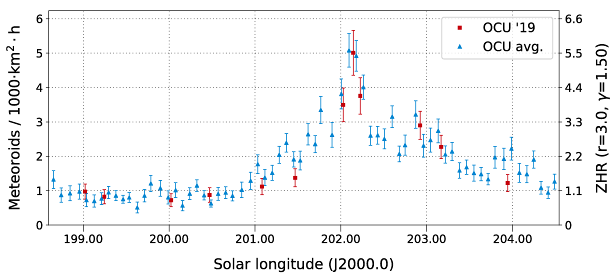

Figure 8 – Flux density of the October Ursae Majorids in 2019 (red) as well as in the average of the years 2011–2018 (blue), derived from observations of the IMO Network.

5 Orionids

Only a few days later, the Orionids presented their slight asymmetric activity profile with nearly constant

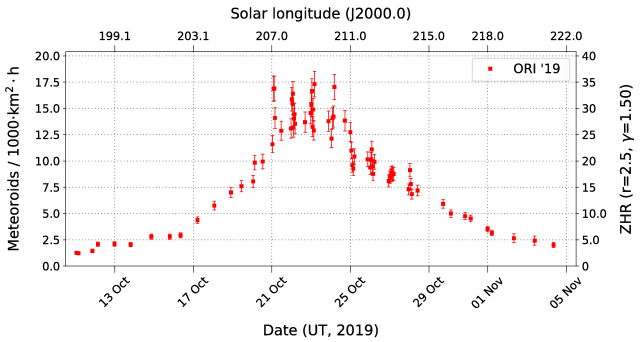

Figure 9 – Flux density of the Orionids in 2019, derived from observations of the IMO Network.

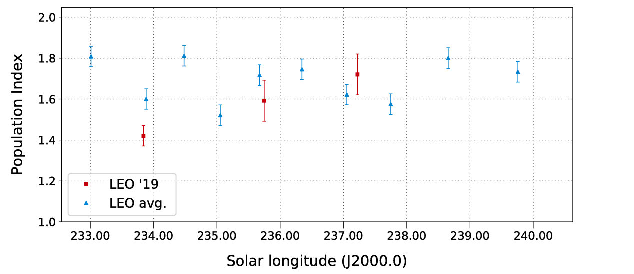

Figure 12 – Population index of the Leonids in 2019 (red) as well as in the average of the years 2011–2018 (blue).

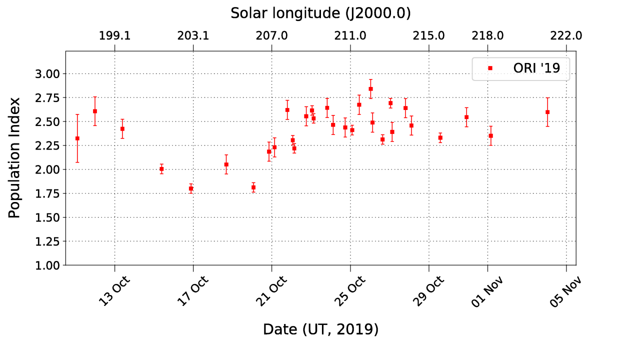

Figure 10 – Population index of the Orionids in 2019.

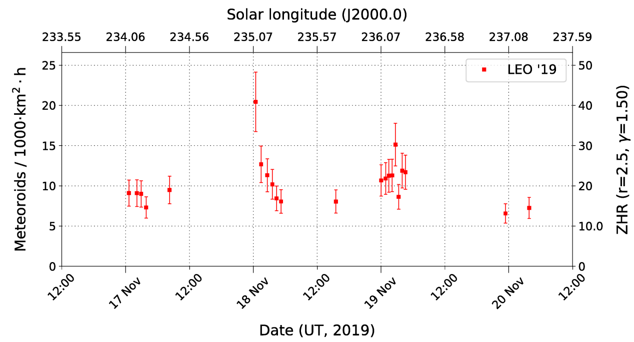

Figure 13 – High resolution flux density profile of the Leonids at the 2019 peak.

high rates between October 20 and 25 (Figure 9). Starting from October 16 they emerge from the sporadic background, and by the end of the month, they disappear there again.

With values near 2.0, the population index of the Orionids is at first relatively low (Figure 10). At the activity peak the r-value rises to 2.5 and remains there until the end of the activity period.

6 Leonids

The Leonids have been more active in mid-November 2019 than in the average of previous years (Figure 11). With a flux density of 10 meteoroids per 1 000 km^2 per hour they are still far away from the outbursts at the turn of the last millennium, but a ZHR of 20 is respectable, in particular since the population index was as usual well below 2.0, so that proportionally brighter Leonids could be seen (Figure 12).

It is worthwhile to zoom into the activity of the shower near November 17/18, 2019 (Figure 13). More than a decade ago, M. Maslov predicted in the IMO journal WGN, that the ZHR should raise to values of the order of 20 near 23$^{\rm h}$ UT (Maslov, 2007). The first flux density measures of that night directly after the radiant rose are indeed clearly enhanced.

7 α-Monocerotids

Also, for the α-Monocerotids right thereafter there were predictions of enhanced rates at 2019 November 22, 04$^{\rm h}$56$^{\rm m}$ UT. Even though that point in time was rather close to dawn for most European cameras, combined with the November-typical poor weather, the active cameras could indeed report a sudden rise in rates at about 04$^{\rm h}$40$^{\rm m}$ UT, which declined similarly abrupt at 05$^{\rm h}$20$^{\rm m}$ UT. In the activity profile of the shower, this short outburst becomes clearly visible (Figure 14). However, due to the short duration of the peak, the flux density is not particularly spectacular.

You have to select a very high resolution at the minute level to unveil the true nature of the outburst

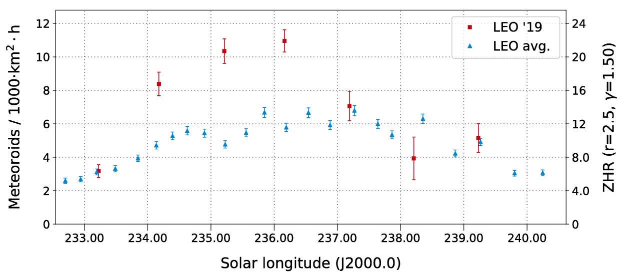

Figure 11 – Flux density of the Leonids in 2019 (red) as well as in the average of the years 2011–2018 (blue), derived from observations of the IMO Network.

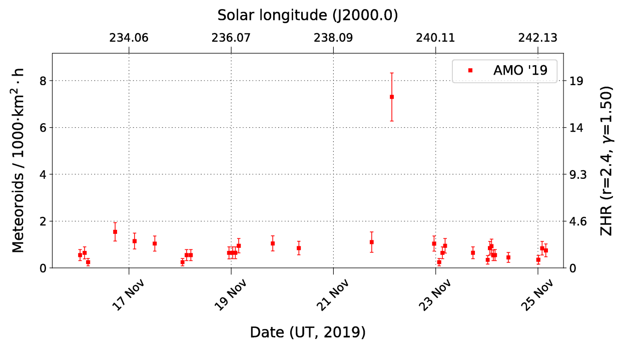

Figure 14 – Flux density of the α-Monocerotids in 2019, derived from observations of the IMO Network.

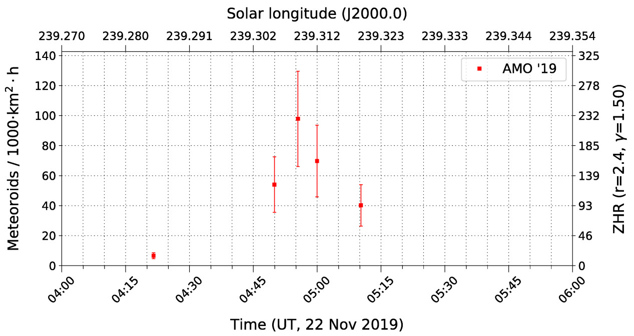

Figure 15 – High resolution flux density profile of the α-Monocerotids at the 2019 peak.

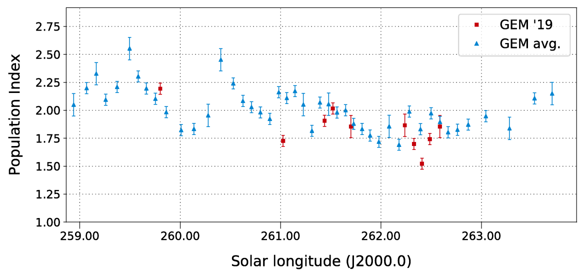

Figure 17 – Population index of the Geminids in 2019 (red) as well as in the average of the years 2011–2018 (blue).

(Figure 15). Highest rates were indeed reached at 04^h55^m UT and the whole outburst lasted not much longer than 20 minutes. In this short interval, the flux density reached values of up to 100 meteoroids per 1 000 km^2 per hour, which translated to an effective ZHR of more than 200. This is in agreement with visual observations, which also yielded a ZHR beyond 100 at 04^h55^m UT (International Meteor Organization, 2019). You can imagine that almost instantaneously you are in the middle of the Perseid maximum, but less than half an hour later the show stops suddenly.

8 Geminids

The maximum of the Geminids in December occurred just at full moon, which explains the higher-than-average flux density compared to the long-term profile (Figure 16). The peak itself fell just in-between the European nights of December 13/14 and 14/15. Note that it seems as if we observed an early peak in the first night at a solar longitude of 261.°4. However, that can be easily explained by the fact, that the full moon culminated near midnight and impacted the flux density strongest by that time, whereas it was less disturbing at the start and end of the night.

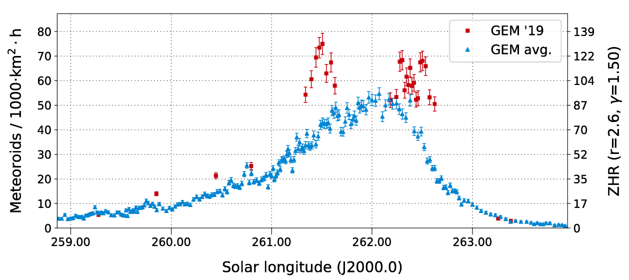

Figure 16 – Flux density of the Geminids in 2019 (red) as well as in the average of the years 2012–2018 (blue), derived from observations of the IMO Network.

As in previous years, the population index of the Geminids reached values between 1.7 and 2.0 (Figure 17). Once more, we can explain slightly smaller than average values with the moon phase.

9 Ursids

The activity of the final shower of the year varies from one year to the next. In 2019, the Ursid peak fell into the night of December 22/23. With 10 meteoroids per 1 000 km^2 per hour, the flux density in 2019 was slightly above the long-term average of 2011 to 2018 (Figure 18), but it fell short of those years with enhanced activity like 2011, 2014 and 2018 (Figure 19).

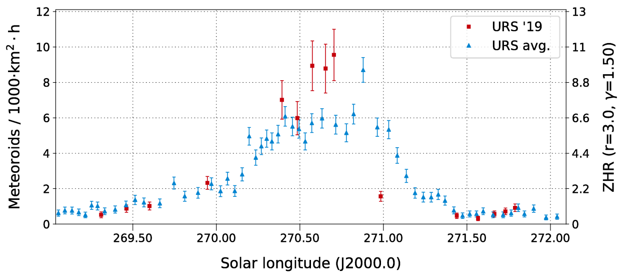

Figure 18 – Flux density of the Ursids in 2019 (red) as well as in the average of the years 2011–2018 (blue), derived from observations of the IMO Network.

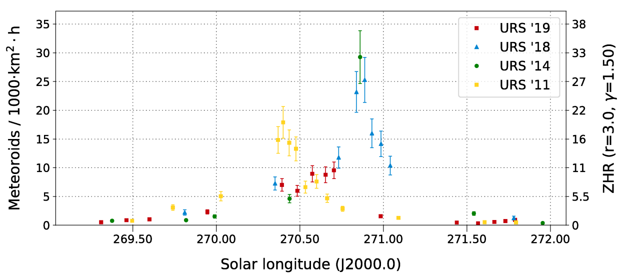

Figure 19 – Comparison of the flux density of the Ursids in the years 2011, 2014, 2018, and 2019.

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Table 1 – Observational statistics for the fourth quarter of 2019.

Code	Name	Place	Camera	October			November			December		
				Nights	Time [h]	Meteors	Nights	Time [h]	Meteors	Nights	Time [h]	Meteors
ARLRA	Arlt	Ludwigsfelde/DE	LUDWIG2	29	183.2	1397	23	109.9	527	24	138.8	864
BERER	Berkó	Ludanyhalaszi/HU	HULUD1	15	146.3	599	7	59.7	280	12	107.9	574
BIATO	Bianchi	Mt. San Lorenzo/IT	OMSL1	27	186.9	816	21	53.5	225	21	140.4	930
BOMMA	Bombardini	Faenza/IT	MARIO	27	184.9	1117	16	52.9	302	21	162.1	1602
BRIBE	Klemt	Herne/DE	HERMINE	24	106.5	491	23	149.9	476	24	167.2	516
		Berg. Gladbach/DE	KLEMOI	23	122.6	598	24	128.1	464	22	159.1	562
CARMA	Carli	Monte Baldo/IT	BMH2	25	182.4	1558	6	46.1	335	—	—	—
CASFL	Castellani	Monte Baldo/IT	BMH1	20	167.6	581	—	—	—	—	—	—
CINFR	Cineglosso	Faenza/IT	JENNI	27	196.6	1249	21	92.1	476	24	164.3	1684
CRIST	Crivello	Valbrevenna/IT	ARCI	22	147.4	760	15	77.1	361	20	202.8	839
			BILBO	22	134.7	879	13	58.4	274	22	203.5	1317
			C3P8	18	116.9	556	14	83.5	319	19	172.0	836
			STG38	21	148.2	1161	13	64.3	325	22	212.7	1556
ELTMA	Eltri	Venezia/IT	MET38	21	94.7	685	11	63.3	270	22	193.4	1449
FORKE	Förster	Carlsfeld/DE	AKM3	25	149.3	810	16	82.8	293	13	113.3	578
GONRU	Goncalves	Tomar/PT	TEMPLAR1	28	230.2	1330	23	142.3	474	24	190.5	807
			TEMPLAR2	27	229.8	1063	23	140.2	381	23	190.5	723
			TEMPLAR3	25	213.6	452	21	102.9	125	24	174.2	225
			TEMPLAR4	28	224.9	895	25	132.8	335	23	178.6	683
			TEMPLAR5	26	201.6	943	21	90.0	256	25	176.0	610
GOVMI	Govedič	Središče ob Dr./SI	ORION2	27	194.6	868	16	65.8	173	21	132.6	504
			ORION3	24	176.7	370	16	43.0	89	23	81.2	171
			ORION4	24	179.5	357	14	26.6	78	23	73.3	182
HINWO	Hinz	Schwarzenberg/DE	HINWO1	28	191.6	991	24	155.6	593	20	147.8	687
IGAAN	Igaz	Budapest/HU	HUPOL	9	74.7	49	—	—	—	—	—	—
JONKA	Jonas	Budapest/HU	HUSOR	27	227.9	539	17	97.9	223	17	116.8	314
			HUSOR2	25	223.6	600	15	94.6	228	14	97.0	327
KACJA	Kac	Kamnik/SI	CVETKA	8	85.3	545	2	5.3	20	16	100.3	543
			REZIKA	8	84.8	1500	1	3.8	25	18	113.0	1315
			STEFKA	—	—	—	—	—	—	17	113.6	435
		Kostanjevec/SI	METKA	25	147.6	488	16	39.8	97	22	83.2	277
		Ljubljana/SI	SRAKA	22	134.1	426	6	21.9	53	—	—	—
KNOAN	Knöfel	Berlin/DE	ARMEFA	27	196.7	457	18	79.9	159	20	129.3	281
KOSDE	Koschny	La Palma/ES	ICC7	18	115.8	298	23	103.6	308	22	89.1	290
			ICC9	29	224.2	1330	28	223.7	1284	27	221.5	1642
			LIC1	20	98.0	372	21	83.1	279	23	109.5	308
			LIC2	28	256.7	3413	26	241.8	2564	25	233.4	2195
KWIMA	Kwinta	Krakow/PL	PAV06	23	206.2	423	12	83.1	98	12	82.6	173
			PAV07	23	202.9	476	12	76.1	101	12	92.8	199
			PAV79	23	202.5	729	13	79.6	163	12	98.6	356
LOJTO	Łojek	Grabniak/PL	PAV103	18	146.3	192	3	13.3	8	6	42.7	39
			PAV57	19	145.3	602	2	15.3	22	4	45.4	131
MACMA	Maciejewski	Chelm/PL	PAV35	26	160.5	608	13	63.4	132	21	82.5	281
			PAV36	27	203.7	1166	13	79.2	285	16	114.5	550
			PAV43	27	197.6	991	11	77.6	244	18	117.6	534
			PAV60	26	204.4	1345	14	95.7	368	21	131.1	599
MARRU	Marques	Lisbon/PT	CAB1	26	228.0	1058	3	4.3	14	6	33.1	54
			RAN1	22	150.3	553	20	53.7	201	25	163.1	686
MISST	Missiaggia	Nove/IT	TOALDO	17	119.0	956	7	37.4	91	20	191.0	851
MOLSI	Molau	Seysdorf/DE	AVIS2	21	134.1	870	18	107.3	464	25	181.8	966
			DIMCAM2	22	125.4	1421	19	99.8	824	25	162.8	1676
			ESCIMO3	15	96.4	588	14	83.4	346	25	193.2	990
		Ketzür/DE	REMO1	18	86.7	272	1	2.9	9	9	46.2	233
			REMO2	28	172.8	1204	20	100.7	472	25	163.0	1034
			REMO3	28	207.3	1171	22	116.3	463	26	198.4	956
			REMO4	28	208.7	1458	21	111.8	518	28	186.5	1020
MORJO	Morvai	Fülöpszallas/HU	HUFUL	29	230.4	494	22	143.4	230	18	113.9	376
MOSFA	Moschini	Rovereto/IT	ROVER	21	140.8	292	11	67.1	86	26	240.5	867
NAGHE	Nagy	Budapest/HU	HUKON	4	15.9	65	—	—	—	—	—	—
		Piszkestetö/HU	HUPIS	28	197.6	1455	14	86.8	285	8	64.0	379
OTTMI	Otte	Pearl City/US	ORIE1	19	12.3	73	13	9.3	52	22	20.3	117
PERZS	Perkó	Becsehely/HU	HUBEC	20	152.3	931	9	44.7	239	12	87.9	635
SARAN	Saraiva	Carnaxide/PT	RO1	26	224.6	697	25	173.8	322	25	226.8	573
			RO2	27	211.2	726	23	142.8	315	24	192.3	597
			RO3	21	173.4	934	25	160.2	492	21	196.4	762
			RO4	—	—	—	11	64.4	107	24	180.7	416
SCALE	Scarpa	Alberoni/IT	LEO	—	—	—	2	0.5	3	25	73.1	608
SCHHA	Schremmer	Niederkrüchten/DE	DORAEMON	19	93.1	355	24	114.9	313	24	109.8	376
SLAPE	Slansky	Munich/DE	SONYA7S	—	—	—	1	0.8	53	—	—	—
SLAST	Slavec	Ljubljana/SI	KAYAK1	23	146.1	628	4	15.8	25	19	151.6	478
			KAYAK2	23	176.1	205	3	10.6	11	15	154.7	146
STOEN	Stomeo	Scorze/IT	MIN38	28	147.0	1216	21	83.5	549	28	218.5	2076
			NOA38	25	127.7	762	21	96.8	466	28	230.5	2157
			SCO38	28	151.9	1198	21	88.1	592	30	221.5	2185
STRJO	Strunk	Herford/DE	BEMCE	23	148.5	1509	19	126.9	893	24	138.0	1264
			MINCAM2	25	145.8	1125	19	103.6	664	15	90.3	552
			MINCAM3	25	117.7	660	19	107.5	442	23	125.4	573
			MINCAM4	23	124.5	252	19	84.5	168	16	79.0	171
			MINCAM5	23	113.5	497	21	120.8	453	25	126.5	597
TEPIS	Tepliczky	Agostyan/HU	HUAGO	15	158.0	380	13	93.6	133	13	74.1	227
			HUMOB	26	237.0	1399	13	102.6	420	19	139.7	624
WEGWA	Wegrzyk	Nieznaszyn/PL	PAV78	23	150.3	531	20	86.3	235	22	102.0	358
YRJIL	Yrjölä	Kuusankoski/FI	FINEXCAM	19	76.3	315	8	61.2	187	9	67.5	171
ZAKJU	Zakrajšek	Petkovec/SI	PETKA	19	140.7	962	11	41.6	108	21	161.6	1168
			TACKA	25	172.6	451	9	39.8	61	22	187.4	440
Sum				31	12 963.5	64 739	30	6 589.0	25 418	31	10 989.8	56 047

IMO Video Meteor Network – Year-end Review 2019

Sirko Molau [1]

The annual summary of the 2019 IMO Video Meteor Network observations is presented. More than 433 000 meteors were recorded in almost 118 000 hours of observing time.

Received 2022 December 12

1 Introduction

The number of observers in the IMO Network has remained at at a constantly high level since 2015. In the 21st year of operation, 43 observers (2018: 43) from 9 countries (2018: 11) contributed to our network with a total of 93 meteor cameras (2018: 89). With regards to the number of video cameras, Germany was in the lead with 23 cameras, followed by Italy (16), Portugal (13), Hungary and Slovenia (12) as well as Poland (10). Fewer than 10 cameras were operated in the Nederlands, Finland and the USA.

So large was the difference between Germany and Italy with regards to the camera number, so small was it in the effective observing time (267 vs. 264 thousand hours) and in the number of recorded meteors (116 vs. 115 thousand meteors). These two countries each contributed more than a quarter of the observational database in 2019.

During 365 observing nights (2018: 365) and 117 970 observing hours (2018: 113 760) we recorded a total of 433 717 meteors (2018: 444 033). Figure 1 presents the output of recent years in a graphical way.

The average rate was 3.7 meteors per hour, which is slightly fewer than in previous years (Figure 2).

Table 1 shows the monthly distribution of video observations. On average, we collected 9 800 observing hours per month in 2019. In February and from August to October 2019 it was even more than 12 000 hours, which is sufficient for the 8th and 9th place in the monthly ranking of the IMO Network.

Six observers from Germany, Portugal and Italy could observe during more than 300 nights in 2019, one observer less than in the year before. The first three places have not changed with Sirko Molau (343 nights), Rui Goncalves (340 nights) and Rui Marques (333 nights) on top.

Also, with regards to the effective observing time, the first two places have not changed: Rui Goncalves and Sirko Molau each contributed more than 10 000 observing hours. Third place went to Stefano Crivello this year.

With regards to the number of meteors, Sirko Molau dominated as in previous years with nearly 59 000 meteors. Second to fourth ranked Detlef Koschny, Rui Goncalves and Stefano Crivello with over 30 000 meteors each. An additional six observers each contributed more than 10 000 meteors to the database in 2019.

Table 3 shows the details for all active IMO Network observers in 2019.

Seven cameras were able to record during more than 300 observing nights in 2019 – in the year before it was just one. Thanks to good weather, most observing nights were collected at three sites in Portugal, Italy and Germany. The Top-10 of cameras is given in Table 2.

Two cameras that recorded more than 10 000 meteors are not in the Top-10: Lic2 (18 577 meteors) and Dimcam2 (13 225 meteors). With Dimcam2, we had for the first time a Night Owl based video camera active all year. It recorded an average of 9.1 meteors per hour, which is about 50% more than the most powerful Mintron cameras! In regular observation it was only beaten by the image-intensified Lic2 (11.0 meteor per hour) on the Canary Islands.

All meteor data can be downloaded in CSV format via the new web service `https://meteorflux.org/obs`, which was introduced at the 2022 IMC (Molau, 2022). The database holds observations from 1993 to 2019 and now contains 4 405 293 meteors from 1 099 932 hours of effective observing time in 7 199 nights.

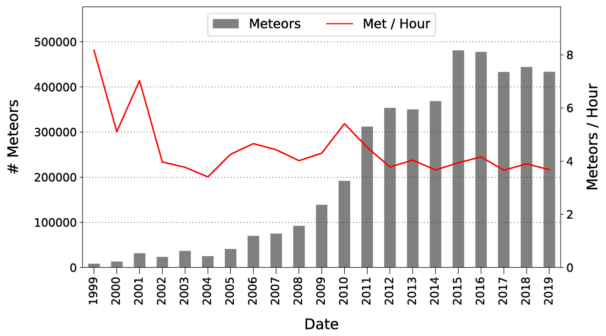

Figure 2 – Number of recorded meteors per night (grey bars) and average number of meteors per hours (red line) between 1999 and 2019.

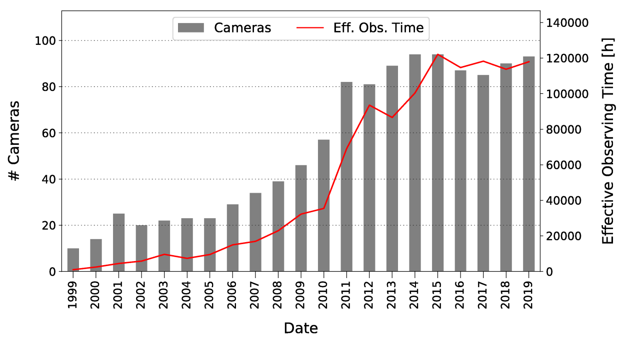

Figure 1 – Number of active cameras per night (grey bars) and effective observing time of these cameras (red line) between 1999 and 2019.

[1] Abenstalstr. 13b, 84072 Seysdorf, Germany. Email: `sirko@molau.de`

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NASA-ADS bibcode 2023JIMO...51...14M

Table 1 – Monthly distribution of video observations in the IMO Video Meteor Network 2019.

Month	# Observing Nights	Eff. Observing Time [h]	# Meteors	Meteors / Hour
January	31	9 335.3	33 228	3.6
February	28	12 712.0	26 248	2.1
March	31	11 579.7	22 034	1.9
April	30	8 353.2	18 119	2.2
May	31	5 725.0	12 420	2.2
June	30	7 952.6	19 664	2.5
July	31	7 722.0	32 217	4.2
August	31	12 047.6	73 336	6.1
September	30	12 000.4	50 247	4.2
October	31	12 963.5	64 739	5.0
November	30	6 589.0	25 418	3.9
December	31	10 989.8	56 047	5.1
Overall	365	117 970.1	433 717	3.7

As always, we like to thank our diligent observers who contributed to the camera network. Special thanks to Enrico Stomeo and Jörg Strunk, who, together with Sirko Molau, check the consistency of data each month and ensure the high quality of the database.

References

Molau S. (2022). "Meteor flux update". (presented at the IMC 2022 in Poroszló, Hungary).

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Table 2 – The ten most successful video systems in 2019.

Camera	Site	Observer	Observing Nights	Eff. Observing Time [h]	Meteors	Meteors / h
Templar1	Tomar (PT)	Rui Goncalves	323	2 401.8	8 895	3.7
Templar4	Tomar (PT)	Rui Goncalves	320	2 259.9	6 886	3.0
Templar2	Tomar (PT)	Rui Goncalves	320	2 392.9	7 307	3.1
Templar5	Tomar (PT)	Rui Goncalves	310	2 029.4	6 271	3.1
Sco38	Scorze (IT)	Enrico Stomeo	307	1 720.6	10 704	6.2
Min38	Scorze (IT)	Enrico Stomeo	307	1 698.7	10 269	6.0
Remo4	Ketzür (DE)	Sirko Molau	305	1 742.0	9 724	5.6
Noa38	Scorze (IT)	Enrico Stomeo	298	1 830.2	8 921	4.9
Remo3	Ketzür (DE)	Sirko Molau	298	1 794.8	7 715	4.3
Remo2	Ketzür (DE)	Sirko Molau	297	1 561.7	8 098	5.2

Table 3 – Distribution of video observations over observers in 2019.

Observer	Country	Observing Nights	Eff. Observing Time [h]	Meteors	Meteors / h	Cameras (Sites)
Sirko Molau	Germany	343	10 666.9	59 243	5.6	9 (2)
Rui Goncalves	Portugal	340	11 207.1	32 189	2.9	6 (2)
Rui Marques	Portugal	333	4 006.1	11 407	2.8	2 (2)
Enrico Stomeo	Italy	322	5 249.5	29 894	5.7	3 (1)
Stefano Crivello	Italy	312	7 092.8	31 101	4.4	4 (1)
Jörg Strunk	Germany	305	6 754.9	24 211	3.6	6 (1)
Carlos Saraiva	Portugal	299	6 981.3	18 971	2.7	5 (2)
Francesca Cineglosso	Italy	297	2 099.4	9 553	4.6	1 (1)
Mario Bombardini	Italy	294	1 971.8	9 338	4.7	1 (1)
Detlef Koschny	Netherlands	292	4 967.4	32 858	6.6	4 (2)
Mitja Govedič	Slovenia	292	3 817.9	7 677	2.0	3 (1)
Rainer Arlt	Germany	291	1 463.9	7 415	5.1	1 (1)
Bernd Klemt	Germany	288	2 507.2	8 576	3.4	2 (2)
Henrietta Nagy	Hungary	287	2 771.2	9 611	3.5	3 (4)
József Morvai	Hungary	275	1 844.1	2 798	1.5	1 (1)
István Tepliczky	Hungary	272	3 015.9	8 505	2.8	2 (2)
Wolfgang Hinz	Germany	267	1 627.1	5 685	3.5	1 (1)
Hans Schremmer	Germany	264	1 345.4	3 759	2.8	1 (1)
Javor Kac	Slovenia	261	4 729.7	19 044	4.0	5 (3)
Fabio Moschini	Italy	260	1 363.1	3 298	2.4	1 (1)
Thomas Bianchi	Italy	258	1 536.0	5 211	3.4	1 (1)
Maurizio Eltri	Italy	255	1 376.0	6 096	4.4	1 (1)
Jure Zakrajšek	Slovenia	252	2 972.9	9 730	3.3	2 (1)
Maurizio Carli	Italy	248	1 828.9	9 796	5.4	1 (1)
Károly Jónás	Hungary	247	2 314.9	4 902	2.1	2 (2)
Zsolt Perkó	Hungary	246	1 447.6	5 381	3.7	1 (1)
Maciej Maciejewski	Poland	240	4 479.3	17 412	3.9	4 (1)
Wala Węgrzyk	Poland	225	868.8	2 528	2.9	1 (1)
Stane Slavec	Slovenia	218	2 551.4	4 199	1.6	2 (1)
Flavio Castellani	Italy	215	1 617.1	3 624	2.2	1 (1)
Kevin Förster	Germany	215	1 137.5	4 969	4.4	1 (1)
Stefano Missiaggia	Italy	210	1 342.6	5 800	4.3	1 (1)
Leo Scarpa	Italy	201	958.5	1 860	1.9	1 (1)
Maciej Kwinta	Poland	187	3 207.3	6 069	1.9	3 (1)
Antal Igaz	Hungary	179	1 406.8	1 168	0.8	2 (2)
Andre Knöfel	Germany	167	920.9	2 030	2.2	1 (1)
Ilkka Yrjölä	Finland	154	822.2	2 337	2.8	1 (1)
Mike Otte	USA	129	163.4	594	3.6	1 (1)
Erno Berkó	Hungary	82	646.6	3 286	5.1	1 (1)
Eckehard Rothenberg	Germany	46	308.7	343	1.1	1 (1)
Tomasz Łojek	Poland	28	408.3	994	2.4	2 (1)
Martin Breukers	Netherlands	27	170.9	202	1.2	1 (1)
Peter Slansky	Germany	1	0.8	53	66.3	1 (1)

Relation between mean visual magnitude of shower meteors and altitude of the radiant

Peter Zimnikoval[1]

The dependence of the mean magnitude of shower meteors on the zenith distance of the radiant is disputed. To confirm this dependence, visual meteor observations were statistically processed. The data were taken from the IMO Visual Meteor Data Base. The meteor showers considered were the Perseids and Geminids. Results are discussed.

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1 Introduction

The radiant altitude is primarily considered as factor influencing the observed rates of meteors belonging to a shower. The correction factor to convert visually observed rates into ZHRs is a function of the zenith distance of the radiant. Varying the radiant's elevation above the horizon changes the entry angle of meteoroids entering the Earth's atmosphere. The gradient of the atmospheric mass densities along the meteoroid's trajectory is significantly changed in this way, too. Meteoroids that come from low-altitude radiants need longer trails to achieve the critical density for destruction than meteoroids coming from the zenith. Several authors (Ceplecha, 1952; Richardson, 1999) describe the influence of radiant altitude on the mean magnitude of shower meteors.

Figure 1 shows the relative length of meteoroid trajectories as a function of radiant elevation. As mentioned, the entry angle of a meteoroid has an influence on the visual magnitude of the corresponding meteor. Here, we present a very simplified model for the problem. The magnitude of meteor is defined as the magnitude of the brightest point on its trail. Now, on the one hand, the the total radiation energy produced by the meteor is proportional to the area under its light curve. On the other hand, it is also a function of the meteoroid's kinetic energy. In case of lower radiant elevation, the meteor's light curve is longer, and the luminosity maximum is lower correspondingly (Figure 2). Theoretically, the atmospheric trajectory of a meteoroid and the length of the corresponding meteor's light curve doubles if we move the radiant from the zenith to a zenith distance of 60°. Assuming that the kinetic energy of meteoroid is the same in both instances, the area below the light curve must also be the same in both instance, the amplitude of the light curve in the former case must be about twice as high as in the latter case. Hence, the decrease in brightness (which corresponds to an *in*crease of magnitude, is $2.5\log_{10} 2 \approx 0.75$. More generally, the increase in magnitude Δm as a function of the zenith distance z can be expressed by the formula

$$\Delta m = -2.5\log_{10}(\cos z) \qquad (1)$$

in this very simplified model.

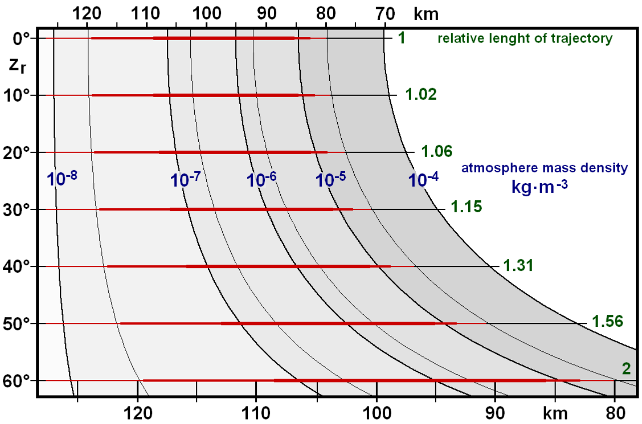

Figure 1 – Dependence of relative trajectory length on the zenith distance of the radiant.

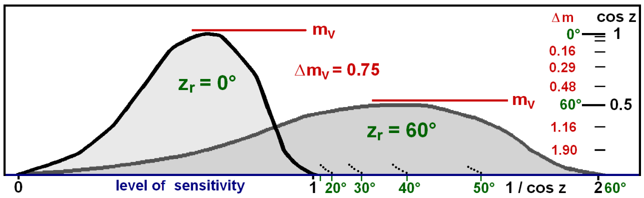

Figure 2 – Decrease of meteor brightness (i.e., increase in magnitude) for similar meteoroids at different entry angles into the atmosphere. For such meteoroids, the area under the light curve must be similar. A longer light curve will therefore be flatter, resulting in a lower brightness, or, equivalently, a higher magnitude.

Unfortunately, it is very hard to verify the effect described above from visual observations of individual meteors, because visual magnitude estimates suffer from inherent inaccuracies, and several other important factors influencing the magnitude—such as meteoroid mass, distance to the observer, and atmospheric conditions—-are at best only poorly known. Therefore, we made an attempt to find the dependence of the mean visual magnitude of shower meteors on the radiant's zenith distance (or, equivalently, zenith altitude) statistically from a large data set. For this purpose, we used the IMO Visual Meteor Data Base (VMDB). More in particular, some observations of Perseids and Geminids were selected.

2 Method of evaluation

The Perseids are the most observed meteor shower, and, therefore, they provide a very large data set. Perseid meteoroids are extremely quick, in particular when compared to Geminid meteoroids, wich are relatively

[1]Observatory in Banská Bystrica, Slovakia, retired.
Email: zimnikoval@gmail.com

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slow. Notice that the Geminids are also very well observed.

The Perseids observations in the VMDB that we used are from 1993, 1996, 1999, 2004, and 2007. For the Geminids, observations from 1993, 1996, 1998, 2001, 2004, and 2009 were selected. Notice that all these years are from the "golden era" of visual meteor observations, during which a lot of data were submitted to the VMDB. For the choice of individual years, we took into account the phase of the Moon at the time of maximum. We selected years with maxima near New Moon to eliminate moonlight as a factor of influence.

The method is based on statistics of individual mean magnitudes during time intervals reported by single observers. Per interval, the arithmetic mean magnitude of the shower meteors was computed, and the resulting value was then paired with the zenith distance of the radiant at mid-time of the interval concerned. Linear regression was then used to find a relationship between m_{v} and $\cos z$, where m_{v} is the mean visual magnitude and z the zenith distance, computed as explained above. Individual years of observation were processed separately.

3 Selection of data

In the VMDB, the observed brightness of meteors is reported in the form of a magnitude distribution. From the reported distributions, only the classes from +1 to +5 were considered. These classes cover meteors with magnitudes between +0.5 and +5.5. In this way, we tried to minimize the noise in the data. To compute the zenith distances of the radiant at mid-time of the intervals concerned, we used the geographic coordinates reported by the individual observers. Intervals for which the radiant's zenith distance was more than 70° were rejected. The calculated zenith distances were not corrected for zenith attraction. For the Perseids, this effect is minimal anyway, because of their high geocentric velocity. For the slower Geminids, we found that correcting the zenith distance for zenith attraction using the reduction factor γ (Zvolankova, 1983) does not change the results in any significant way.

4 Results

All data show only a weak dependence of mean magnitude of zenith distance: mean magnitudes increase only slightly with increasing zenith distance.

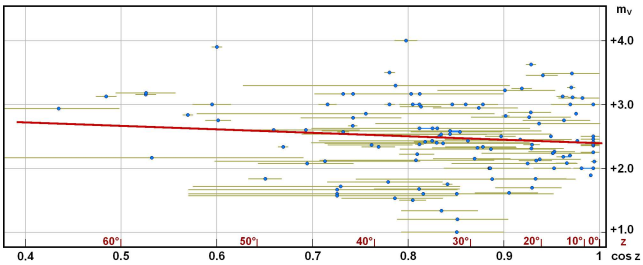

Figure 3 – Distribution of the mean magnitude of the Geminids from 2004 according to the zenith distance of the radiant.

As an example, Figure 3 shows our results for the Geminids in 2004. For each data point, the horizontal bar indicates the time interval on which the calculations were based. Notice that, during many intervals, the zenith distance of the radiant changed significantly.

To obtain more data for our statistics, we evaluated all Perseids observed at the selected years collectively. The same was done for the Geminids. Unfortunately, the available observations do not cover the full range of possible zenith distances. In particular, observations during periods of low radiant altitude (or high zenith distance) are underrepresented. Most observations only start when the radiant altitude is above 30°. Specifically for the Perseids, observations can only start in earnest after the end of nautical twilight. Moreover, the radiant of this shower culminated at an altitude of no more than about 60° at all observing sites.

For the Perseids, all selected data resulted in 3047 data points representing 95 007 meteors (Figure 4). The observations were carried out by 1205 observers from 48 different countries. The resulting linear relationship is

$$m_{\mathrm{v}} = 2.81 - 0.33 \cos z. \quad (2)$$

As can be seen from Figure 4, the correlation is low, however. (The linear regression resulted in a correlation coefficient of 0.07.) Equation 2 results in an increase of mean magnitude (decrease in brightness) between a radiant elevation of 60° and a radiant elevation of 30° of 0.12. (Equation 1 derived for the very simplified model in the Introduction would yield an increase of about 0.60.)

For the Geminids, all selected data resulted in 802 data points representing 37 014 meteors (Figure 5). The observations were carried out by 514 observers from 46 different countries. The resulting linear relationship is

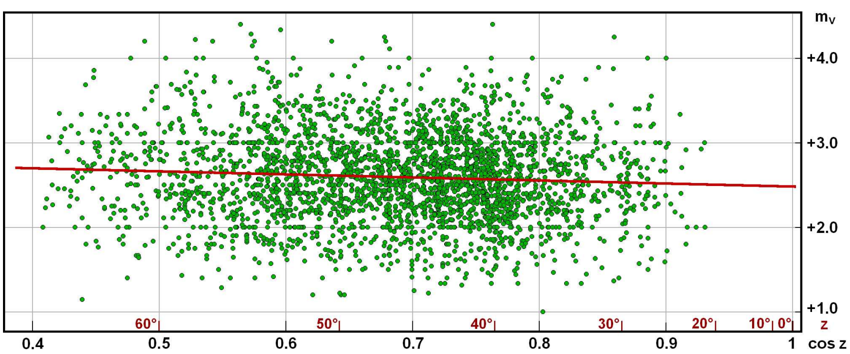

Figure 4 – Distribution of the mean magnitude of all processed Perseids according to the zenith distance of the radiant.

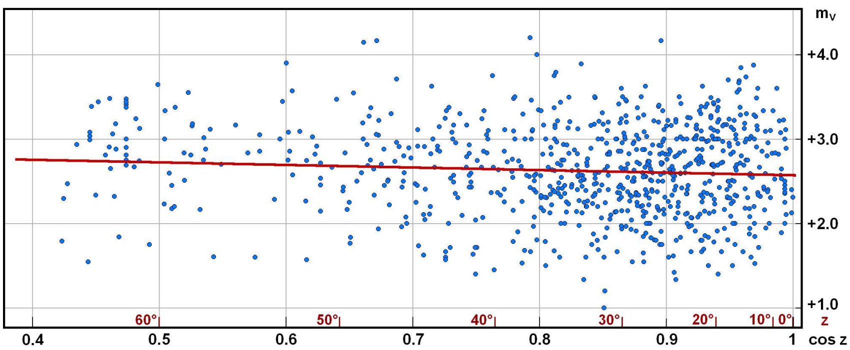

Figure 5 – Distribution of the mean magnitude of all processed Geminids according to the zenith distance of the radiant.

$$m_{\mathrm{v}} = 2.85 - 0.28 \cos z. \quad (3)$$

Again, the correlation is low. (The linear regression resulted in a correlation coefficient of 0.08.) Equation 3 results in an increase of mean magnitude (decrease in brightness) between a radiant elevation of 90° and a radiant elevation of 30° of only 0.14. (This should be compared with the value of 0.75 derived for the very simplified model in the Introduction.)

We also tried to derive a linear dependence of the mean magnitude on the value of the zenith distance in degrees. The following formulae were derived:

$$m_{\mathrm{v,PER}} = 2.40 + 0.0039 z^{(\circ)} \quad (4)$$

$$m_{\mathrm{v,GEM}} = 2.56 + 0.0020 z^{(\circ)} \quad (5)$$

Equations 4 and 5 show a similar increase in mean magnitude (decrease in brightness) with increasing zenith distance of the radiant.

5 Discussion

Since we see a systematic—albeit too small—increase of magnitude with increasing zenith distance, we conjecture that the discrepancy between the results of this study and the expected increase in mean magnitude according to the—albeit very simplified—theoretical model in the Introduction is probable caused by deficiencies in the data used. Indeed, there are several arguments implying that our statistics may not be very reliable:

1. As is illustrated by Figure 6, we do not have sufficient observations at low radiant altitudes. Moreover, under such conditions, relatively few shower meteors can be observed. Also, the radiant altitude range in the observations is further restricted by the combination of the geographical latitude and night-time interval of the observers.
2. The length of the intervals reported in the VMDB is often two hours and more. During such a time span, the radiant zenith distance can change significantly. Moreover, this effect is stronger at low radiant altitudes.
3. The influence of atmospheric conditions was not taken into account. Technically, meteor magnitude estimates are obtained by comparison with star magnitudes. Hence, estimates are to some extent a matter of perception, the accuracy of which is further restricted by the short duration of a meteor and the angular range of our central vision. This contributes to the large scatter of mean magnitudes in Figures 4 and 5.

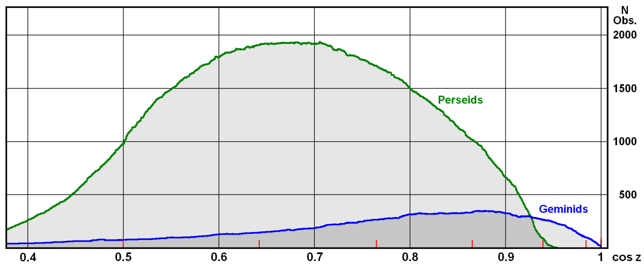

Figure 6 – Number of observers for whom data were included in this study as a function of radiant zenith distance, for both Perseids and Geminids.

The factors discussed above do not allow to find a more accurate relationship between the mean shower meteor magnitude and the zenith distance of radiant, unfortunately. For that purpose, we need short intervals, ideally even individual meteors. In addition, the range in geographical latitude of observations should be such that the range of zenith distances is as wide as possible. Unfortunately, this woud require a very large database, which is not available.

Acknowledgment

The author thanks all observers whose observations were included in this study. More generally, the author thanks all observers who hace contributed and still contribute to the great data set that the IMO VMDB is.

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Visual meteor observations over 50 years

Jürgen Rendtel[1]

Personal recollection of 50 years of visual meteor observations is given.

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1 Introduction

Observing meteors has changed a lot over time. When I was a young amateur astronomer, meteors were accessible only by visual and to some extent photographic techniques. There was a great "gap" between amateurs and professionals, and the amount of general information concerning meteors and their observation was rather scarce. Suddenly, I would almost say, I can look back on 50 years of own visual meteor observations. Since this period covers not only changes of technical nature, I try to summarise a few aspects from a very personal perspective. When typing this summary, I thought whether I should mention names. A first version was written "anonymous", but it seemed incomplete and diminishes at least a portion of the feelings and relations which developed. However, it is impossible to be complete and the selected events are just examples.

2 Start with a misconception

More than 50 years ago, the idea of dedicated meteor observations was rised in a group of amateur astronomers in Potsdam, Germany. At the end of the 1960-ies there was a small public observatory with a 150 mm telescope and an astrograph on a small mount to observe and to take photographs (on plates and films). For practical reasons, there were only two or three observers in the dome at one time. The others waited outside in the garden, watching the sky by naked eye or binoculars. From time to time a satellite (rare at this time) or a meteor was seen. We also noted that there are periods with larger numbers of meteors. The conclusion was to organise such observations as systematical campaign. For the preparation we read the few available books which had information on meteors. Compared to other fields, meteor observations were not well covered. Also among amateurs it sounded more interesting to use "large" telescopes and to obtain images of various objects, while naked eye sky watching seemed too simple, just for the absolute beginners. But we decided to try out and waited for a suitable occasion. This was in spring 1972.

Looking back, this first dedicated meteor observation was based on completely wrong information and missing understanding of the background. In a publication – which I unfortunately cannot find or trace back any more – a possible high activity of the π-Puppids on 1972 April 23 was described. It was mentioned that the radiant is below the horizon in Germany, but the essential sentence for us was, that in case of really high rates, a few meteors should also appear in our skies. So we decided with three observers to go to a place outside the town. The conditions were poor as well, with a bright waxing Moon south of Leo causing a lot of background illumination. At the end we saw meagre three meteors within 1.5 hours, and of course no Puppid at all.

Such a desaster could have been the end of the project. But we felt like curious discoverers and decided to continue at a better occasion (which was the Perseids 1972 which yielded more than 100 meteors in the pre-maximum night, counted together with a classmate within about 1.5 hours). This was fun and gave a much better feeling.

3 Observation campaigns

While the 1973 Perseids were badly affected by bright moonlight, we prepared a little excursion for the 1974 Perseid maximum with five observers and photographic equipment including a rotating shutter – based on batteries. Meteor paths were plotted on charts (not gnomonic – but sufficient to distinguish between Perseids and sporadic meteors). More important than the numbers was the situation that there were a few other observers also out for the Perseids at other locations. We easily found out, who else recorded data at this time. So we compared what we had collected and published these in an amateur astronomer's journal. For the Perseids 1975 we in our Potsdam group already had a one-week campaign some 20 km west of the town. This location, called Schmergow, became our summer meteor observing base for the following 15 years. Participants also came from other regions of East Germany, and another similar camp was organised in the mountains near Dresden.

Enthusiasts stayed at these camps for some nights, sharing the excitement of bright or many meteors as well as the disappointment when clouds ruined the prepared observations. This created a commonality and numerous friendships (you may just check the author combinations of meteor papers with German participation). Several of these freindships still exist nowadays, almost half a century later! Something I feel has a peculiar value on its own.

The common interest was the observation of meteors. But every participant could decide whether just observing fun was enough or whether the analysis of the collected data was of interest as well.

Over the years, we often thought to observe from a location which has better stable weather conditions than central Europe usually has. This lead to our first international expedition to the Rozhen observatory in

[1]International Meteor Organization, Eschenweg 16, 14476 Potsdam, Germany. Email: jrendtel@web.de

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the Rhodope mountains in Bulgaria. Ralf Koschack had the idea to collect specific visual data which are the basis for the perception studies and the development of the ZHR and number density calculations still in use today. I also remember well that once Detlef Koschny brought his "Schnusi" (Schnuppen-Simulator, meteor simulator) built from Lego components to test the accuracy of visual meteor paths which we extensively used when the sky was cloudy. Dedicated observations both outside under stars or under laboratory conditions helped a lot to find out what results we may obtain from visual observations.

In the following not systematic compilation I try to highlight a few aspects of meteor astronomy, again from my personal point of view.

One of the conclusions of the initial failure in 1972 was, that a good preparation of observations is important. The Perseids 1972 were my first successful meteor watch, and I followed the Perseids in each year since. A few maximum nights were missed, but I was able to see the first high peak in 1993 as well as the following series of peaks connected to the approach of the parent comet Swift-Tuttle from various locations.

During the 1980-ies, there were comparable evolutions in the observer groups in several countries. There was a lot of communication going on to exchange data or to discuss observing methods, even across the "Iron Curtain" in both directions. Probably the security services at both sides (?) had some extra work? One main idea was to create a structure which is able to maintain the information which in the past often got lost once a group or a single person stopped working in the field. These connections more or less directly lead to the foundation of the International Meteor Organization in 1989. If I would start mentioning names here, the list would be very long.

So I return to some astronomical events. One unique event was the short peak of the α-Monocerotids in 1995. Fortunately, I had the possibility to follow this from the backyard. Even looking back and having seen more dust trail passages, I remember how out of a sudden there were meteors from this shower and as fast as it started, it also ended. This gave really a physical feeling of the Earth passing a stream. Perhaps a bit similar to the impression if a very local rain shower passes and rain starts and stops quite abruptly.

This effect was even much stronger during the 1999 Leonid storm. At this occasion we (with Ralf Koschack, Sirko Molau, Manuela Rendtel) had company of observers from North America. Bob Lunsford, Cathy Hall and Pierre Martin joined us in Germany to see the storm. About two days before the event it became clear that all Germany would be cloudy during the storm night. So we organised a "crash expedition" to Malaga in southern Spain and were able to see the maximum – with the effect described above in a much stronger way – and to observe also during the following night for calibration. This was also a unique experience to witness the storm with fellows who travelled round the Earth.

I found such joint observations always encouraging – and there is a long list which would be too long to put here and certainly I might miss someone. So I again select a very few of such events. I remember well the invitation from the Jordanian Astronomical Society to give introductory talks and observe the η-Aquariids in the desert in May 1997, combined with unique impressions of the people and the country. The Perseid maximum 1999 with the total solar eclipse from the Bulgarian Black Sea coast is in my memory because of the two events and the many enthusiasts we met there. In November 1998, the Leonid expedition to Mongolia provided unforgettable impressions; and we repeated the Leonid travel to Mongolia also in 2001 with countless positive memories again.

Apart from the "major" expeditions, the wish to see a specific event, often requires travelling to cloud-free places. Sometimes this is necessary to decide on the last possible moment as the weather may be variable. Almost all such tours yielded results – if they were performed to the end, until the expected clear place is reached. For example, our Quadrantid peak tour in 1996 ended at the Col de Vars (at 2100 m in the Alps) in a cold winter world because our location in Lardiers was clouded out this night. On site we met other observers from the Netherlands and Paul Roggemans had a lot to explain when the mountain rescue service wanted to "save" us while laying around in the snow watching meteors.

Sometimes such last minute preparations can cause stress. My wife can tell stories about this. But once the decision is made, it works like a machinery. Of course, later the data and impressions are enjoyed a lot and they are often connected with peculiar memories.

4 Visible meteor shower evolution

During the 50 years it is possible to see a good portion of the evolution of meteor showers. Certainly, one may read about this, see diagrams and compare modelling results. But after several years of observing, I just see the effects. And like with the peaks, the long-term changes are a special experience, too. For example, the increasing Geminid activity is very special as this shower was impressive already in the past, but is stronger now. In the case of the Leonids, the more and more distant position of the parent comet combined with fewer and thinner dust trails becomes feelable.

In October 2007 I was at the observatory at Tenerife, Canary Islands and was surprised by the large amount of bright Orionid meteors, appearing during three nights. It turned out that also the next two returns had a large portion of large meteoroids – as shown by model calculations trapped in mean motion resonances. A look back into old notes revealed that there should be a periodicity in the resonant Orionid occurrence.

It is known that the October Draconids produce high rates only when the parent comet is close by. For some returns there are solid predictions published. So there is some expectation when starting an observation. The Draconids in 2011 behaved "normal", while the 2018 return surprised by the activity level and the duration. Honestly, I was not prepared to see an all-night maximum when I met with Ina Rendtel at the location Töplitz west of Potsdam in the evening with cirrus clouds which we assumed to leave a rather short window open.

Sometimes there are just a few meteors which somehow attract attention. In January 2016 I noted three meteors fitting one radiant in UMi. I asked Sirko Molau whether he can confirm this in video data. And, yes, these meteors were γ-Ursae Minorids. Something similar I experienced just recently (November σ-Ursae Majorids). It is not the way of detecting a shower, but the observational experience may tell you something. Finally, I enjoy the interaction between modelling results and subsequent observations. We experienced this e.g. with the Aurigids in 2021 when a minor enhancement seen in 2019 gave rise to the prediction of Esko Lyytinen for higher rates in 2021 (confirmed). Last but not least, the τ-Herculids of 2022 are an example where modelling, adjustment, travelling and observing went together with exciting results.

5 Conclusion

An observation or measurement is a kind of interaction with the nature. In the case of visual meteor observations, one also learns to wait patiently while being concentrated. One aspect which remained active all the time, is the curiosity and excitement – even if nothing spectacular happens. Even if apparently nothing happens, it is an undisturbed free time. Time for own thoughts and sometimes new ideas cross the mind.

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2022 Tau Herculids from Mt. Graham, Arizona