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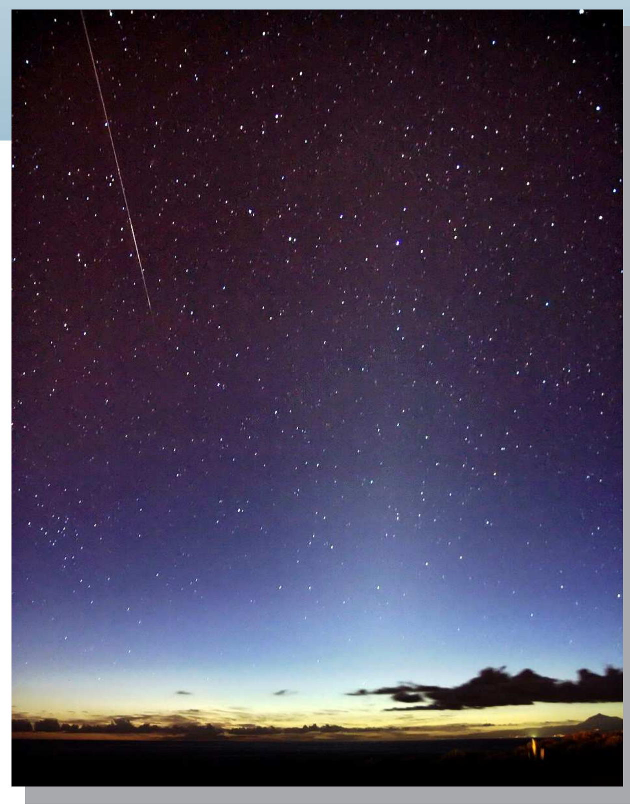

Conference
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Front cover photo

The cover photograph was taken from La Palma Island in the morning of 2010 October 22 at $07^{\mathrm{h}}08^{\mathrm{m}}$ UT with a Canon EOS 350D camera equipped with 17–50 mm lens set to 17 mm at $f/2.8$. The exposure time was 30 s at ISO 1600. A fireball can be seen probing into the zodiacal light. Photo courtesy: Valentin Grigore.

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 **31:4**, 124–128, and at `http://www.imo.net/articles/writingforwgn.pdf` .

Cover design

Rainer Arlt

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

Editorial — New project series

Javor Kac

This issue marks the start of a new project series – "The History of Meteor Observing Project". Mihaela Triglav-Čekada started promoting the idea of publishing a series of articles reviewing the history of meteor observing at the International Meteor Conference 2009 in Poreč. Unfortunately the project initiator is busy at the moment so she could not present her ideas in detail here. Nonetheless, the first article in the series is ready to be published – it is the overview of British meteor observing before 1860, written by Alastair McBeath (see page 24).

While a similar series was published in *WGN* by Martin Beech — an 18-part series "The makings of meteor astronomy", published from 1992 to 1999 — this new series aims to focus on meteor observing history at a national level.

If you would like to follow up with meteor observing history overview in your own country or nation, you are encouraged to either contact Mihaela as the project coordinator, or write directly to WGN editorial team by sending e-mail to `wgn@imo.net`.

IMO bibcode WGN-391-editorial NASA-ADS bibcode 2011JIMO...39Q...1K

Call for photographs

Javor Kac

We are frequently short of photographs for the *WGN* covers that we publish in colour (front cover) or black&white (back cover). If you think you have a suitable meteor-related photograph, please offer it to us. More or less any computer image format will do. You can send your photographs to `wgn@imo.net`, but remember to put 'Meteor' in the subject line to get round the anti-spam filters.

IMO bibcode WGN-391-kac-call NASA-ADS bibcode 2011JIMO...39R...1K

Janus

David Asher [1]

It is one of life's truths: 'You don't really know how it is unless you actually attempt it.' In 2010 we organised the IMC in Armagh. In collaboration with our IMO friends of course (I cannot imagine the IMC would have taken place without Marc's help, for example). I had attended several IMCs before, and enjoyed them all. Now I've seen how it is from the organisers' side rather than the visitors' side. My previous IMCs have been a wonderful chance to visit so many different countries. As an organiser, it is a rather different experience – and now just a happy memory. Regarding memories, Paul compiled a really nice photographic record of the meeting, available on the IMO website; thanks to all of you who contributed pictures.

In writing this piece, I had originally thought to say more about how it is to be involved in organising an IMC. Instead, if you are interested to know how it is, I'll simply encourage you to organise one. It's something you'll remember.

Looking to the future, this year's IMC will repeat the country of 11 years ago. Valentin and SARM will bring us the second IMC in Romania. If it's anything like the 2000 meeting, it will be something special. A trip to

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IMO bibcode WGN-391-asher-janus NASA-ADS bibcode 2011JIMO...39....1A

Romania, moreover, is a chance to visit the spiritual home of the Astropoetry Show. Maybe we have enough active and energetic meteor and astronomy groups in various nations that a decade is the timescale for us to return to the same country. But I predict the future will have new groups appearing who are willing to organise an IMC, as well as old friends who want to host the IMC *again.*

Over the years, the IMO has brought me into contact with many people whom I am very happy to know. And I have no doubt that by remaining part of the IMO, I'll get to know many more in the future. Each of us may have our own reasons for joining the IMO, but this is one of the main ones: it is a really successful way of keeping us in contact with each other, with those who share our interest in meteors. This interest can take many forms, as meteor astronomy has become a large and wide-ranging subject. Most active IMO members are observers, whether visual or photographic, or operating video cameras or radio meteor detectors, or running video, photographic or fireball networks. Some have an interest in meteors in history or literature, in meteor physics or dynamics. The IMO encourages you to look at the 'Who Is Who' page on the website, and to communicate with the names you find there. If you have (virtually!) any question on meteors, someone in the IMO will have the expertise to answer it. Or you might be one of the people who can share your knowledge with others. Together, we can contribute to science and new knowledge, or help others to do so. Or we can simply share with like-minded people the enjoyment of seeing meteors in the night sky.

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.*

From the Treasurer—How can you support your organization?

Marc Gyssens [1]

1 Supporting members 2010

The following people have paid at least double the normal membership fee for 2010:

Karl Antier	Lars Bakmann	Luc Bastiaens	Luis Bellot Rubio
Raka Dabhade	David Entwistle	Marc Gyssens	Detlef Koschny
Robert Malmström	Sirko Molau	Hiroshi Ogawa	Casper ter Kuile
Jan Verbert			

We are very grateful to the people above for their support. At the same time, however, it must be emphasized that many other people contributed to the IMO. For instance, many members gave gifts smaller than the regular membership fee; of course, these gifts are equally appreciated. Also, several members contribute by providing a gift membership to a friend, or by paying a friend's or colleague's registration fee for the very successful 2010 International Meteor Conference in Armagh, Northern Ireland. In particular, we wish to mention Jean-Luc Dighaye, whose support to participants from the Indian Subcontinent greatly contributed to the success of this IMC.

The annual International Meteor Conference plays a very important role in the international meteor work as it is the primary forum where meteor workers can physically meet. In particular, it helps hard-working meteor workers that were not yet in touch with the international meteor community to break out of their relative isolation, improve on their observing methods, and learn which problems have been solved already and which questions still beg for an answer.

Thanks to the support of our members, the IMO was able to provide support to 2 participants from India, 1 participant from Nepal, 2 participants from Romania, 1 participant from the United States, and 1 participant from Venezuela. This support was given based on formal applications, which were subsequently judged by the Council. The much wider geographical distribution of the people the IMO supported is also very encouraging for the future.

We encourage our members to continue providing support to our Organization in one of the may ways possible: supporting membership, smaller donations, gift memberships, or private support to IMC participants. The international meteor community will be very grateful for it!

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IMO bibcode WGN-391-gyssens-support NASA-ADS bibcode 2011JIMO...39....2G

Conferences

International Meteor Conference 2011 — 30th edition September 15–18, Sibiu, Romania

Valentin Grigore

Location and period

The 2011 International Meteor Conference (IMC) will take place in Sibiu, Romania, from September 15th (Thursday evening) to 18th (Sunday lunchtime). This 30th edition of IMC will be organized by the Romanian Society for Meteors and Astronomy (SARM), the national astronomical society of Romania. During its 18 years of existence, the SARM organized many national and international events. This is the already the second IMC organized by the SARM; the first one was the 2000 IMC hosted in Pucioasa.

The presentations of the 2011 IMC will be given in the conference room of the ASTRA Public Library, one of the oldest and most important public libraries of Romania. It was founded in 1861, and is thus celebrating its 150th anniversary this year! The lecture room with a capacity of 140 persons is located on the top floor of a new building (Figure 2). It has a terrace which offers a very nice view of the city (Figure 1) and the Făgăraş Mountains.

We reserved 86 places in a nice hotel not too far away from the conference building. More information will be available on the conference website `http://www.imo.net/imc2011` from March 30 onward.

Scientific content, trip and social events

Before the 2011 IMC (on September 14–15) there will be a Radio Meteor Workshop, organized by Jean-Louis Rault and Cis Verbeeck (contact `radio@imo.net`). We reserved 20 places in a hotel for the participants at this workshop. The costs for accommodation and meals (starting Wednesday with dinner and finishing Thursday with lunch) will be sponsored by the SARM. So, participation to this workshop is free.

The IMC proper will start with a Welcome Reception on Thursday evening, September 15, at 18:00, at the Sibiu City Hall. Scientific presentations will be given between Friday morning and Sunday noon. Participants are encouraged to contribute to the program of the 2011 IMC with a talk, a poster, a photo exhibition or video presentations on visual, photographic, video or radio observations, fireballs, orbit determination, stream modeling, meteor physics, extraterrestrial meteors, parent bodies, observing expeditions, or anything else related to meteors and their observation. Space for posters and photo exhibitions will be provided in the conference room.

The conference excursion will be organized Saturday afternoon in the Făgăraş Mountains,[1] on the famous Transfăgăraşan Highway (Figure 4).[2] No road in Romania climbs higher: up to 2042 meters, in the Glacial Hollow Bâlea. The lunch will be served in a restaurant at Lake Bâlea (Figure 5). The menu includes trout from the glacier lake!

Back in Sibiu, we will have dinner, followed by the Annual Meeting of the General Assembly of the International Meteor Organization, from 20:00 to 21:15. The remainder of Saturday evening is reserved for social activities. The traditional astro-poetry show will be held in a special theater room of the ASTRA Public Library (Figure 3), helping us to create that unique atmosphere, typical for an IMO conference.

Sibiu City

Known in German as Hermannstadt, Sibiu (`http://www.romaniatourism.com/sibiu.html`) is one of the most important cultural centers of Romania. It is located some 280 km north-west of Bucharest, and has a population of over 150 000. The first official record referring to the region of Sibiu dates back to 1191. Sibiu is home to the first hospital in Romania (1292), the first pharmacy (1494) and the oldest museum in Romania, the Brukenthal Museum (1817). The first book in the Romanian language was printed in Sibiu in 1544. It is therefore to no surprise that Sibiu was designated European Capital of Culture for the year 2007.

Sibiu is situated in the historical region of Transylvania, near the geographical center of Romania, in the Cibin Depression between the Făgăraş, Cindrel and Lotrului Mountains, at an altitude of 240 m. Sibiu's climate is temperate-continental with average temperatures of 8 to 9°C and September temperatures in the range of 10–20°C.

As you can image, there are many cultural and touristic attractions in Sibiu and the surrounding region. To give yourself the opportunity to explore some of these, it is good idea to come to Sibiu a few days earlier or to

[1] `http://en.wikipedia.org/wiki/Fagaras_Mountains`
[2] `http://www.romanianmonasteries.org/romania/fagaras-mountains`

Figure 1 – Sibiu as seen from the terrace of the conference room. Photo by Valentin Grigore.

stay a few days longer. The SARM is more than willing to assist participants interested in an extended visit to the area.

Travel information

Due to its geographical location, Sibiu is one of the most important transportation hubs in Romania. It has an international airport (located at 5 km from the city center) with connections to many domestic and European cities. Flight time from Bucharest is approximately 45 minutes. Sibiu is also served by several main railway lines. Numerous InterCity trains (nicknamed 'Blue Arrows') connect Sibiu to other major cities in Romania: Cluj-Napoca, Braşov, Craiova, Timişoara and Bucharest. The journey from Bucharest takes about 5½ hours. If you make the same journey via car taking advantage of the scenic routes over the Carpathians, you should count on approximately 4½ hours. Finally, Sibiu is also an important hub for domestic and international coach links.

Registration

The standard registration fee is 155 EUR (170 EUR after June 30). This covers presentations, proceedings, the conference excursion, a T-shirt and conference materials, all meals from the Thursday evening reception to Sunday noon lunch, and hotel accommodation for 3 nights (in principle, Thursday night till Saturday night). For this fee, we pre-booked double/twin rooms for 86 persons in a nice hotel in the vicinity of the conference location. For a single room, you must pay 30 EUR more.

We offer a reduced registration fee of 130 EUR (145 EUR after June 30) for accommodation in another hotel situated at 700 m (a 10-minute walk) from the conference location, where we pre-booked for 20 persons. For the remainder, this option gives you the same benefits as the standard fee.

Finally, if you wish to arrange your own accommodation, the registration fee amounts to 95 EUR (110 EUR after June 30). It covers all the benefits of the previous options (in particular, also the lunches and dinners), except for accommodation and breakfasts.

Regardles of the option choosen, lunches and dinners are at the same place for all participants.

To register, please visit `http://www.imo.net/imc2011` and fill out the registration form. The web page and the registration form will be available from March 30 onward. If you register in this way, you will be automatically directed to the page with payment information. Only if you do not have internet access, you can fill out the paper registration form.

For your registration to remain valid, the IMO expects to receive either the full sum for the option choosen, or a prepayment of at least 80 EUR, within two weeks after registration. If you make a prepayment, you can pay the balance at a later date or at the conference itself.

You will receive automatic confirmation e-mails for both receipt of your registration and receipt of (each) payment. For further questions regarding registration and payment, please contact the IMO Treasurer, Marc Gyssens (`treasurer@imo.net`).

Figure 2 – Conference building, a new building of ASTRA Public Library. Photo by Valentin Grigore.

Figure 3 – Astroshow room, ASTRA Public Library. Photo by Valentin Grigore.

Figure 4 – The top part of the Transfăgăraşan Highway, Făgăraş Mountains. Photo by Casper ter Kuile.

Figure 5 – The Bâlea restaurant, on Bâlea Glacial Lake, Făgăraş Mountains. Photo by Casper ter Kuile.

Further information and contact details

For all further information, latest updates, etc., please check the IMC 2011 web pages:
`http://www.imo.net/imc2011`
available from March 30 onward.

You can also contact the organizers via e-mail:
`imc2011@sarm.ro`
or post:
Valentin Grigore, CP 14, OP 1, Târgovişte 130170, Dâmboviţa, Romania
or phone:
+40 722 829 034 (Valentin Grigore).

IMO bibcode WGN-391-grigore-imcann NASA-ADS bibcode 2011JIMO...39....3G

International Meteor Conference
Sibiu, 2011 September 15–18
Registration form

Do not use if you have internet access! Please register electronically on `http://www.imo.net/imc2011` if you can. Only if you have **no** internet access, fill out one form for each individual participant and return it to Marc Gyssens, IMO Treasurer, Heerbaan 74, B-2530 Boechout, Belgium, as soon as possible. Registration will be guaranteed only after Marc Gyssens has received either the full registration fee for the option choosen, or a pre-payment of at least 80 EUR. We expect this payment to arrive within two weeks after the form.

Name: ______________________ Address: ______________________

____

____

Phone: ____________ Fax: ____________ E-mail: ____________

- I wish to register for the IMC 2011 from September 15 to 18:
  - ○ I opt for the standard fee (155 EUR early/170 EUR late);
  - ○ I opt for a more distant hotel, if still available (130 EUR early/145 EUR late);
  - ○ I opt for arranging my own accommodation (95 EUR early/110 EUR late).
- I prefer a single room (add 30 EUR)/to share a room with ______________(if applicable).
- T-shirt: Size (S-M-L-XL): ________ Gender: ________ (included in fee)
- Food requirements (e.g., vegetarian, nut allergy): ______________________
- I intend to travel by ______, together with ______________________

For participants wishing to contribute to the program:

Lecture: ____

Requirements: ____

Duration: ________ minutes (including a few minutes for questions and discussion)

Workshop: ____

Poster(s): ______________________________ Space: ________ m^2

Comments:

○ I am paying the entire registration fee for the option selected.

○ I am paying the advance (80 EUR) now, the remainder later.

The indicated amount should be sent to IMO Treasurer, Marc Gyssens. The following payment options are available:

- **International bank transfer** to the International Meteor Organization, Mattheessensstraat 60, B-2540, Hove, Belgium, IBAN account number: BE30 0014 7327 5911, BIC bank code: GEBABEBB (Fortis Bank, Belgium). This is recommended for people living in the European Union, as it is no more costly than a domestic bank transfer when done correctly.
- **PayPal payment** to `payment@imo.net`. In that case, we must ask you to add the costs involved in the transaction (3.4% of the total sum including costs, plus 0.35 EUR).
- **Other arrangements**. Please contact the IMO Treasurer for information.

Financial support for IMC 2011 participants

Jürgen Rendtel and Marc Gyssens

As during previous years, IMO is making limited funds available to support participation in the *IMC* 2011. To apply for support, please do the following:

1. E-mail your application to IMO President Jürgen Rendtel, at `president@imo.net`. Include the word 'Meteor' in the subject line to get round the anti-spam filters. IMO cannot be held responsible for applications which are lost or arrive late. The application must be submitted by an IMO member, but may also request support for other meteor workers. The proposal must state that all the candidates are committed to attend the *IMC* (except for unforeseen circumstances) if the requested support is granted in full.
2. Complete an *IMC* Registration Form (preferably electronically) for everyone seeking support (unless already done before).
3. Include a brief curriculum vitae of everyone seeking support, focusing on aspects relevant to meteor work. Supported participants are expected to present either a talk or a poster at the *IMC*. (Indicate and detail this on the Registration Form.)
4. The application must explain the motivation for participating in the *IMC* and the importance of this participation to the person or group of persons requesting support.
5. Include a budget for travel costs and registration, and the amount of support requested. Other sources of external support, or their absence, must be mentioned. The proposal must indicate to what extent IMO support is essential to attend the *IMC*.
6. The applications should reach the President no later than Friday, 2011 June 10. The decision of the IMO Council will be made as soon as possible, probably within two weeks after this deadline. If the support is granted in full, the registration becomes definitive. If the requested support is not granted, or only partially granted, the candidates should inform the President within three weeks after notification of the IMO Council's decision if they want to sustain or withdraw their registration. Most likely, the support will consist of waiving registration fees, which will be settled directly between the IMO and the Local Organizers. Any additional support, if granted, will be paid in cash at the *IMC*.

Should the application be turned down, the 'early' registration fee (i.e., without the surcharge for a late application) will still apply. We strongly encourage all meteor workers who want to attend the *IMC* 2011, but who are prevented from doing so by financial considerations, to apply for support.

IMO bibcode WGN-391-rendtel-imcsupport NASA-ADS bibcode 2011JIMO...39Q...7R

Call for Future IMCs

Jürgen Rendtel and Marc Gyssens

Regularly, the IMO Council sends out calls for organizing future *IMC*s. In this way, the Council wants to avoid the situation that no spontaneous proposals is offered, with as a possible undesirable consequence that we might have a year without *IMC*.

Hence, this is a formal call for organizing the 2012 *IMC*, as well as later editions. Typically, an *IMC* is supposed to take place around the third week of September, from Thursday evening (arrival of the participants) to Sunday lunchtime (departure of the participants).

Proposals are due 2011 June 1, and should be sent to the President, `president@imo.net`, preferably in PDF-format.

The IMO Council will normally decide on the proposal to be accepted in 2011 September, at the *IMC* in Sibiu, Romania. The Council may take advantage of the intermediate time to ask for clarifications or additional information from the candidates.

From past experience, we know it is often difficult to choose between several proposals. If multiple proposals merit the opportunity to host an *IMC*, the Council will contact such candidates to ask them to retain their candidacy for the next year. If in the next round the Council must decide between equally worthy proposals, priority will be given to the older one.

There are no forms to solicit for the 2012 *IMC* or subsequent editions, but your proposal should at least contain the following elements:

1. **Who are you?** Who is going to be the local organizers? Which local, regional, or national astronomical organization(s) is/are backing you up? What is your experience with meteor work? Have you been involved in past *IMC*s, as passive/active participant or as co-organizer? Do you or the organization(s) to which you belong have experience in organizing events that can be compared to an *IMC*?

2. **Why do you want to do it?** What is your motivation for wanting to organize an *IMC*?

3. **Where do you want to do it?** At what location do you want to organize an *IMC*? Why is this a good location? Can it easily be reached by plane, public transportation, and/or car? How many hours is it by public transport from the nearest major international airport? Provide a few pictures of the location, or, a weblink to such pictures.

4. **At what venue are you going to hold the *IMC*?** Preferably, lectures and accommodation should be under the same roof, but there is no real objection to the lecture room being at a separate location within easy walking distance from the accommodation. Describe the accommodation at your disposal. Preferably, add an offer from the hotel and/or the institution providing additional accommodation to prove that the venue you propose is indeed available and that the price is within the limits of your budget (see below). Provide also a few pictures of the accommodation, or, a weblink to such pictures.

5. **What will it cost?** Draft a preliminary budget for the *IMC* proposed. Mention all sources of income, in particularly sponsors or subsidies. Take into account that the price per participant should not exceed 150 EUR by much. Of this amount, 10 EUR must be reserved for producing and mailing the (post-)proceedings to the participants. With respect to the expenditures, take into account that the participants must be offered full board from Thursday evening, dinner, up to Sunday, lunch, inclusive. Of course, lecture room facilities should be accounted for, as well as a coffee break in the morning and in the afternoon. Finally, it is also customary to have a half-day excursion, usually on Saturday afternoon.

   Note that, although the IMO provides the service of collecting the registration fees for you, the IMO will in principle *not* cover any negative balance that you might incur, so, please, draft your budget responsibly!

6. **Can it also be done in a later year?** We can only have one *IMC* every year. It is therefore important for us to know if you can also make this offer in a subsequent year. If there are reasons why the application cannot be postponed, please describe these reasons clearly! It is imperative that you answer the questions honestly. Of course, we understand that you are keen to organize next year's *IMC*, otherwise you would not have applied, but having a clear picture of the real time constraints of all the candidates is a serious help for the Council to make the best decision possible!

Of course, you may add to your application any information or considerations which you think may influence your candidacy favorably. In general, however, help the Council in seeing the wood for the trees! While it is important that your application is complete and addresses all the issues mentioned above, please do so *concisely*! Avoid beating about the bush with meaningless phrases and be as factual as possible!

If you are interested in applying for the local organization of the 2012 *IMC*, please email the President as soon as possible that you intend to apply by the due date of 2011 June 1. Even though such a declaration of intent is not a formal commitment, it is an indication for the Council as to how many applications may be expected: based on this information, the Council may actively solicit additional candidacies.

We hope to receive many candidacies!

IMO bibcode WGN-391-rendtel-futureimcs NASA-ADS bibcode 2011JIMO...39R...7R

Ongoing meteor work

Interstellar zenithal skimmers

Martin Beech [1]

A simplified, spherically symmetric Earth atmosphere model is developed, and the conditions under which a meteoroid might first penetrate and then escape from such an atmosphere are investigated. In particular, the special case of meteoroids passing through the atmosphere, while also passing through the observer's zenith, is considered, and example heating and ablation domain diagrams are presented.

Received 2010 September 9

1 Introduction

In recent years, the terms "Earth grazer" and "skimmer" have been increasingly used to describe meteors with very long trails. While the terms are mostly applied incorrectly with respect to what is actually happening, they are certainly descriptive of the phenomenon and are now (apparently) a fixed part of the meteoritical lexicon (by common usage rather than through reasoned endorsement). Be all this as it may. While there are a number of classic examples of larger mass meteoroids encountering the Earth's atmosphere along shallow angles of trajectory and acquiring temporary Earth orbiting status (Ceplecha, 1979; Hills and Goda, 1997), here we wish to investigate a specific, somewhat idealized sub-set of such encounters. As part of an ongoing project to develop a two-dimensional meteoroid ablation code that includes gravitational attraction as well as the curvature effects of Earth's surface and atmosphere, it has been useful to consider a few simplified test cases. We are accordingly here moving beyond the plain-parallel atmosphere model, which cannot be used to study grazing incidence encounters, to that of an spherically symmetric atmosphere in which (and this is the idealized part) Earth's gravitational attraction is ignored. This approximation simplifies the atmospheric flight characteristics (they are straight lines), but it enables the skimming effect to be broadly investigated. Also, it becomes more realistic the faster the meteoroid's initial atmosphere encounter velocity, and this suggests the study of interstellar meteoroids since they are expected to have initial velocities in excess of 72 km/s and indeed, more typically velocities between 100 km/s and 200 km/s (Rogers et al., 2004).

2 Zenithal skimmers

The special case of zenithal skimmers will be considered in this brief article; these are here defined as the subgroup of grazing meteoroids that pass through the observer's zenith and are tangential to the horizon at that point. Again, at this stage in the analysis, the gravitational attraction of the Earth and the deflection of the meteoroid's path during its flight through the atmosphere will not be considered (but they will be addressed in a future publication).

The essential geometry of the problem to be considered is shown in Figure 1. The coordinates are Earth-centered and the variation in the meteoroids altitude $h(\alpha) = H(\alpha) - R_\oplus$, with $R_\oplus$ the Earth's radius, is given by the relationship $H(\alpha) = H_0 \sin\beta / \sin(180° - \alpha - \beta)$, with $H_0 = h_0 + R_\oplus$ a reference starting distance having h_0 as the initial altitude; the angles α and β are defined as shown in Figure 1. The atmospheric altitude of the meteoroid at its closest approach to Earth's surface (its perigee height) is given by $h_{\min} = H_0 \sin\beta - R_\oplus$, while the total atmospheric path length $L_{\rm atm}$ is given by $L_{\rm atm} = 2H_0 \cos\beta$. We note here that, according to the initial mass, initial velocity, and ablation parameters adopted, the meteor's visual trail length will be less than $L_{\rm atm}$. If a finite mass remains after the meteoroid has traversed the distance $L_{\rm atm}$, then it can truly be called a zenithal skimmer – having literally passed through Earth's atmosphere and out into space again.

The standard time variable equations (in Appendix) of meteoroid heating and ablation (Bronshten, 1983) have been solved for numerically to yield the temperature, mass, and velocity as a function of the Earth-centered sky angle α (see Figure 1), with the time step

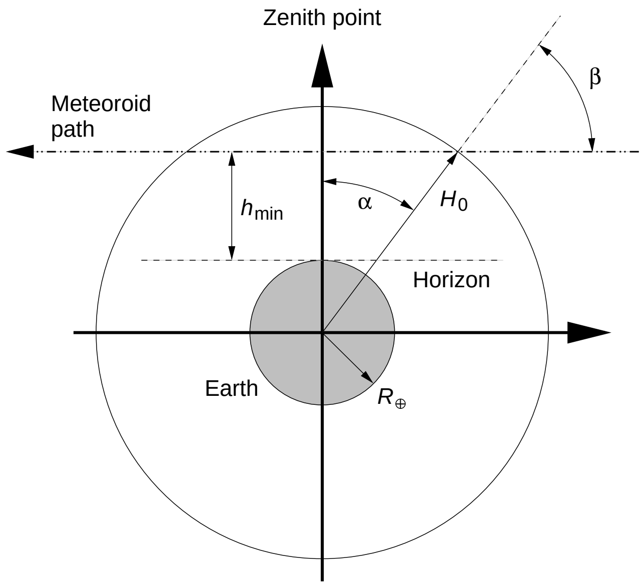

Figure 1 – Geometry of a zenithal skimmer encounter.

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IMO bibcode WGN-391-beech-skimmers
NASA-ADS bibcode 2011JIMO...39....9B

being determined through the relationship

$$\Delta t = [L(\alpha_{\text{now}}) - L(\alpha_{\text{last}})]/V(\alpha_{\text{now}}),$$

where α_{now} and α_{last} correspond to the present and previous values of the Earth-centered sky angle, the $L(\alpha)$ terms correspond to the flight path length $L(\alpha) = h(\alpha)\sin\alpha/\sin\beta$, and $V(\alpha)$ is the meteoroid velocity. For convenience in this analysis, we use the least-squares atmospheric density approximation derived by Beech and Murray (2003):

$$\rho_{\text{atm}} = \rho(\alpha) = 101.9882\, e^{-\frac{h(\alpha)}{5.2504}}.$$

This expression is technically valid in the altitude range for h_{min} between 90 km and 130 km, but for convenience we use it here at all altitude ranges, allowing for the fact that the density beyond 130 km is going to be an overestimate. This being said, we find that the altitude range where the important heating and all of the ablative mass loss takes place is confined to the region in which the atmospheric density is well approximated.

The solution procedure is to first choose angle β. With this angle set, we then have the path length angle subtended at the Earth's center as $\alpha_{\text{path}} = 2 \times (90° - \beta)$. The corresponding angle φ subtended by the meteoroid's atmospheric path, as seen by an observer on the Earth's surface, is then given by

$$\tan\frac{\varphi}{2} = \left(1 + \frac{R_\oplus}{h_{\text{min}}}\right)\tan\frac{\alpha_{\text{path}}}{2}.$$

Next, we choose the perigee height h_{min} in the range between 90 km and 130 km. With these parameters set, the atmospheric path is determined. Then, we must choose an initial mass and initial velocity. Since the heating and ablation equations depend upon the cross-section area presented by the meteoroid to the oncoming air flow, we must also assume some specific meteoroid profile – here, again for simplicity, we take the meteoroid to be a homogeneous sphere. The physical properties of the meteoroid are taken to be stone-like, with a density of $\rho_{\text{met}} = 3300$ kg/m^3, a specific heat of $c = 1000$ J/kg, and a latent heat of vaporization of $\zeta = 5 \times 10^6$ J.

3 Results of selected calculations

Figure 2 shows a set of representative calculations for $\beta = 70°$, $V_\infty = 125$ km/s, and $m_\infty = 10^{-4}$ kg. With the chosen angle of β, the sky angle of the atmospheric trail for a perigee height of 115 km is $\varphi = 174\overset{\circ}{.}4$. For $h_{\text{min}} =$ 125 km, respectively, 100 km, $\varphi = 173\overset{\circ}{.}9$, respectively, $175\overset{\circ}{.}1$, and so the atmospheric trail, but not necessarily the observed meteor trail length, covers the entire sky of the observer. In Figure 2, we show the heating zone and the threshold beyond which ablation takes place and where the skimming status, that is where the meteoroid exits the atmosphere with a finite mass, is satisfied.

Meteoroid heating beyond its assumed initial 300 K planetary space value only begins once $\alpha > 10°$ – this is an atmospheric density condition, which reduces the first bracket term in equation (A1), and the meteoroid

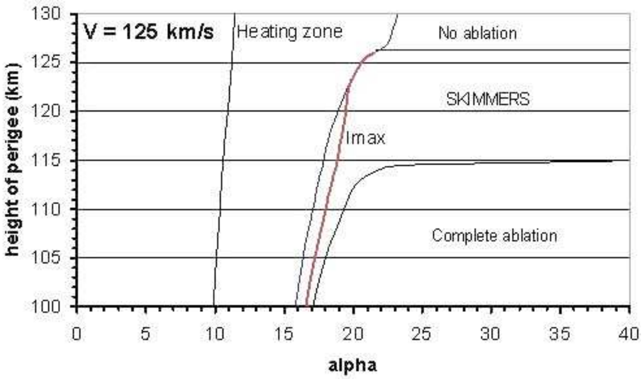

Figure 2 – Meteoroid heating and ablation characteristics as a function of the Earth-centered sky angle α and adopted height of perigee. The meteoroid mass is taken to be 10^{-4} kg, the initial velocity is 125 km/s, and $\beta = 70°$. The heating, no ablation, skimmer and full ablation zones are indicated, and the (thick) curve labeled "Imax" indicates the attainment location of maximum brightness.

can effectively cool by thermal re-radiation, as expressed by the second bracket term in (A1). Beyond $\alpha \approx 10°$, the meteoroid temperature increases towards some maximum. For $h_{\text{min}} < 125$ km, the maximum temperature is greater than 1500 K, and ablative mass loss will begin to take place. At $h_{\text{min}} = 130$ km, the maximum temperature realized is just under 1000 K, which indicates that no significant mass loss via ablation will take place, but it is possible that out-gassing of volatile elements and chemical alteration may occur. Likewise, at such heights, sputtering effects (ignored in our main calculation at this stage) may also take place, and produce observable high-altitude meteor trails (Koten et al., 2006; Hill et al., 2004).This being said, the meteoroid mass range and velocities being considered (less than 10^{-4} kg and faster than 100 km/s) are such that sputtering, and high-altitude luminosity effects are likely to be minimal. For perigee heights between 125 km and 115 km, vigorous ablation accompanies part of the meteoroids interaction with the atmosphere and a skimmer is produced. For perigee heights below 115 km, the meteoroid mass is rapidly reduced to zero once vigorous ablation begins and the meteoroid no longer exits the Earth's atmosphere. The time variations of meteoroid properties for $h_{\text{min}} = 115$ km are shown in Figure 3. In this case, the meteoroid mass is reduced by a factor of 431 during its atmospheric passage, while the velocity is reduced by just 0.2%. The rate of meteoroid mass loss dm/dt reaches amaximum about 1 second after the onset of vigorous ablation begins (at $\alpha = 19\overset{\circ}{.}5$), but rapidly thereafter drops towards zero. The decline in the mass loss rate is driven entirely by the fact that the atmospheric density is decreasing once $\alpha > 20°$ and the meteoroid is heading out of the Earth's atmosphere. We find that the meteor trail length corresponding to dm/dt being within a factor of 100 of its peak value is approximately 90° for an observer located on the Earth's surface.

The time evolution of the mass loss rate dm/dt is of interest since this term partially dictates the shape of the meteor light curve. Here, we adopt the approach

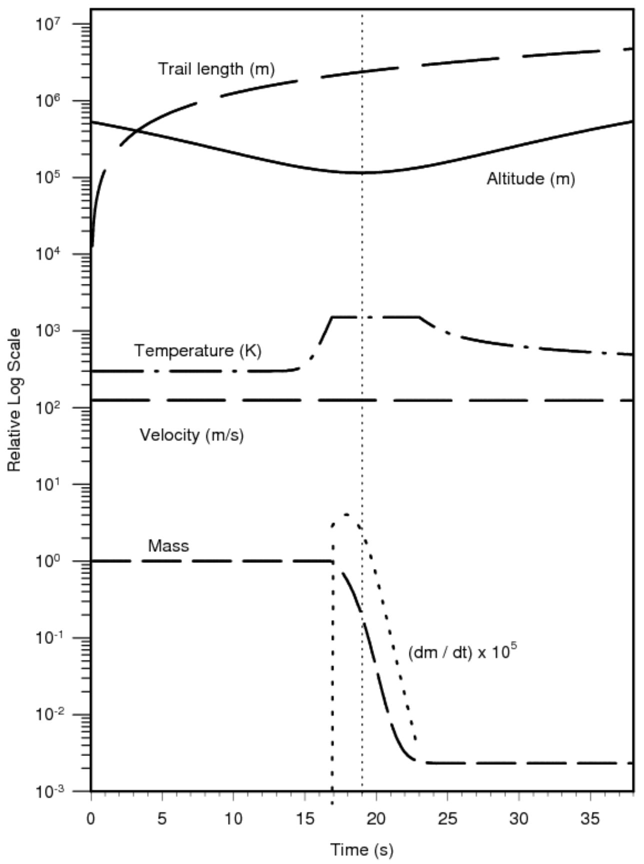

Figure 3 – Time variation of meteoroid altitude, trail length, temperature, velocity, mass and mass loss rate. In this particular case, the altitude at perigee is 115 km. The curve labeled "mass" shows the meteoroid mass relative to its starting value of 10^{-4} kg. The curve labeled "$(dm/dt) \times 10^5$" is the mass loss rate multiplied by an arbitrary scale factor of 100 000. The vertical dotted line indicates the midpoint of the atmospheric path where the meteoroid attains its perigee.

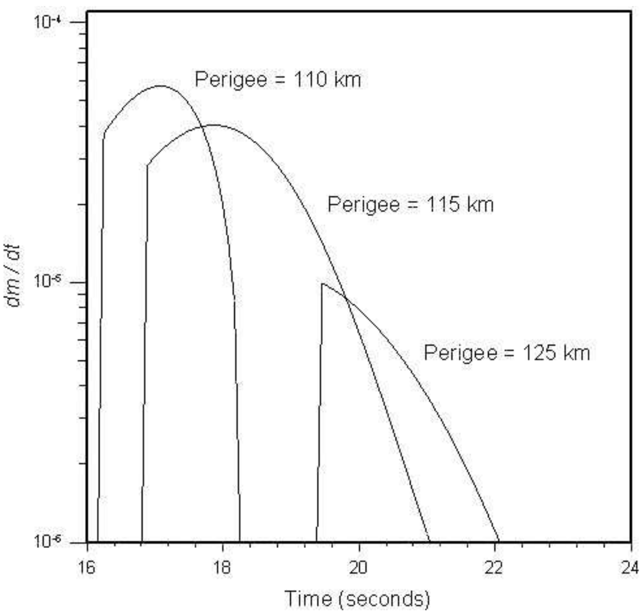

Figure 4 – The ablative mass loss rate, dm/dt, versus time for perigee heights of 125 km, 115 km and 110 km. We notice that the shape of the light curve moves from being early peaked to near symmetrical and then late peaked as the perihelion height decreases.

that meteor brightness will vary in step with changes in the meteoroid's kinetic energy. Accordingly, the intensity $I(\alpha)$ is given by $I(\alpha) = 1/2[dm/dt]V^2(\alpha)$. For the moment we do not choose to estimate the actual meteor magnitude, since the instantaneous luminosity coefficient is not well constrained at the heights and velocities being considered and our interest is mostly directed towards light curve shape (Beech, 2007). The numerical simulations indicate that when vigorous ablation is taking place the velocity remains essentially constant indeed the entire variation along the atmospheric path is typically less than 0.2%. The curve labeled "Imax" in Figure 2 indicates the location (angle α) at which the dm/dt term reaches its maximum value. This location further corresponds to the position of peak brightness in the meteor trail. For perigee heights between 122 km and 126 km, the light curve will peak very early on, indeed, reaching maximum brightness almost as soon as vigorous ablation begins. As the height of perigee drops below 122 km, the position of peak brightness shifts away from the location of ablation onset. For perigee heights less than 115 km, the light curves become increasingly late-peaked. Figure 4 shows a selection of proxy light curves for perigee heights of 125 km, 115 km, and 110 km.

4 Discussion

In this brief study we have looked at a very specific subgroup of atmosphere skimming meteoroids. The main aim is to provide a semi-analytic test case scenario for what will be a more complex two-dimensional atmosphere interaction code presently under development. The simulations, while being made under a series of approximations are, nonetheless, not without some interest with respect to the possible observation of skimming meteoroids.

Two factors militate against the detection of interstellar zenithal skimmers. Firstly, the flux of interstellar meteors is very low (Hajduková and Hajduk, 2006; Baggaley et al., 2007) and second the geometric conditions will rarely be fully satisfied (Pierazzo and Melosh, 2000). Estimates to the flux of interstellar meteoroids vary considerably, but it seems clear that no more than perhaps 0.1% of the photographic and electro-optically observed meteors, with masses greater than approximately 10^{-6} kg, have an origin from outside of our Solar System (Hajduková and Hajduk, 2006; Baggaley, 2007; Hawkes and Woodworth, 1997). The data summarized by Hajduková and Hajduk (2006) suggest that the flux of interstellar meteoroids with mass greater than 10^{-4} kg (our adopted mass in the numerical calculations) is about 4×10^{-7} meteoroids per square kilometer and per hour, which is about 2 orders of magnitude smaller than the flux of interplanetary meteoroids in the same mass range. At smaller meteoroid masses, the flux can be estimated through radar measurements of orbits as well as initial velocities. To a limiting mass of 10^{-8} kg, the observed flux of interstellar meteors with CMOR (Weryk and Brown, 2004) is reported to be 6×10^{-6} meteoroids per square kilometer and per hour. To a limiting mass of 10^{-9} kg, the flux of interstellar meteors found with AMOR (Baggaley, 2000; Murray et al., 2004) is about 10^{-2} metoroids per square km and per hour. The Arecibo survey data (Murray et al., 2004), finally, suggest that, to a limiting mass of 10^{-10} kg, the flux is of the order of 1 metoroid per square kilometer and per hour. Given such survey data, it seems clear that only a very few interstellar meteoroids are likely to be seen in many hours of accumulated observations. Not only is the flux of interstellar meteoroids low, but also the zenith skimming condition considered in this paper provides for a further strong selection effect against detection. Pierazzo and Melosh (2000), for example, estimate that about 77% of observed meteors are likely to have zenith angles Z in the range $20° < Z < 70°$, and fewer than 1% will have $Z > 85°$. In addition to the geometrical constraints just described, the high speed of interstellar meteoroids dictates that they will have a rapid pixel transverse time (Rogers et al., 2004), and this will further reduce their probability of detection with electro-optical equipment. An additional problem for electro-optical detection is the relatively small field of view that such systems can monitor, and accordingly only partial trails of zenithal skimmers might, at best, be recorded. To conclude, we may say that the circumstances surrounding the possible detecting of zenithal interstellar skimmers via electro-optically or radar means are not particularly good ones, but, encouragingly, neither are they absolutely hopeless.

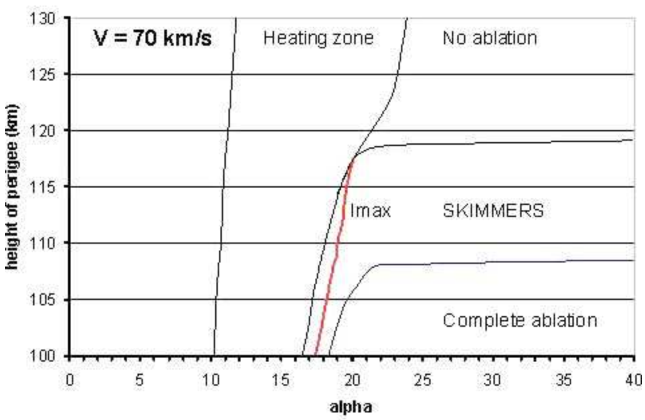

Figure 5 – Same as Figure 2, but for a Leonid meteoroid of mass 10^{-4} kg, velocity of 70 km/s, and $\beta = 70°$.

Of the annual meteor showers, the Leonids, because of their high encounter speed, come closest to satisfying the approximations considered in this paper, and Figure 5 shows the domain in which the zenithal skimming phenomenon might proceed. Our calculations suggest that, for $\beta = 70°$ and a velocity of 70 km/s, the perigee range between 116 km and 108 km could potentially produce Leonid zenithal skimmers when the radiant is located close to the observer's horizon.

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Appendix

The standard meteoroid heating, deceleration and mass loss equations are taken as

$$\frac{dT}{dt} = \frac{3}{8r\rho_{\rm met}c}\left[\rho_{\rm atm}\Lambda V^3 - 8\sigma(T^4 - T^4_{\rm space})\right]\ ; \quad \text{(A1)}$$

$$\frac{dV}{dt} = -\Gamma\frac{S}{m}\,\rho_{\rm atm}V^2\,; \quad \text{(A2)}$$

$$\frac{dm}{dt} = -\frac{\Lambda}{2\zeta}\,S\rho_{\rm atm}V^3\,, \quad \text{(A3)}$$

where T is the meteoroid temperature, $T_{\rm space}$ is the pre-atmosphere encounter temperature of the meteoroid (assumed to be 300 K), σ is the Stefan-Boltzmann constant, r is the meteoroid radius, S is the meteoroid's instantaneous area of cross-section, Γ is the meteoroid drag coefficient, and Λ is the heat-transfer efficiency – all of the other terms are defined in Section 2. We adopt the following values throughout: $\Gamma = 0.5$; $\Lambda = 1.0$.

A fourth order Runge-Kutta scheme has been employed to solve equations (A1) to (A3). Initially, just equations (A1) and (A2) are solved for. When the meteoroid temperature exceeds a value of 1500 K, vigorous ablation is assumed to set in, and the solution scheme then solves for equations (A1), (A2), and (A3).

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A Note on Poisson inference and extrapolations under low raw data and short interval observation conditions

Peter V. Bias [1]

To obtain ZHRs under very short observation periods and/or poor observing conditions, meteor counts must be significantly magnified. However, using a large correction factor can lead to substantially uncertain ZHRs. This paper examines the statistical uncertainty that results when large correction factors are applied to poor data. The Poisson distribution used in ZHR calculations is reviewed, concentrating on its significant skew under low raw data conditions. Real structural, asymmetric differences in probability densities between high certainty/high ZHRs and low certainty/high projected ZHRs are shown to exist for the same reported ZHR.

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1 Introduction

On 2007 September 1, a far-comet outburst of Alpha-Aurigids, which had been predicted earlier by Peter Jenniskens (Jenniskens, 2007) and Jérémie Vaubaillon (Vaubaillon, 2007), was seen by several favorably located observers on the US west coast. As has become custom, a request was made for observers to immediately send in data so that the IMO could put together an, admittedly informal, on-the-fly ZHR activity profile, which has been reproduced in Figure 1. Included in the caption is a short quote from the website listing some of the correction processes that were used to generate the graph. The raw data for the periods used to generate the graph are listed in Table 1.

The error amounts and the associated error bars in the graphic are immediately interesting when compared to the raw data. How is it that no Alpha-Aurigids are seen in the first several time intervals and yet there are positive, even high, ZHRs listed for each? In looking at previous issues of *WGN* going back several years or more recent on-the-fly ZHR profiles reported on the IMO website, we see the same thing: some observing intervals have no meteors and yet still report a positive ZHR with error bars reaching zero as the minimum of a symmetrical range around the ZHR. As an example, Arlt and Barentsen's (Arlt & Barentsen, 2006) presentation of the ZHR activity profile for the 2006 Leonids shows the same interesting result. Quoting from their paper, "The last row is a typical effect of small-number statistics as 0 Leonids produce a ZHR of 1.1 which looks odd at first glance. However, the fact that zero meteors were seen, can be the result of a true rate (measured over an infinitely long time) larger than 0." The authors state later in the paper that "In statistical terms, the ZHR is the expectation value of all possible true rates which may have caused the observer to see 0 Leonids. It results from an integration over a Poisson-like function." An interpretation of this methodology is presented below.

Table 1 – Numerical data of the activity profile for the 2007 Alpha-Aurigids. "For each estimation interval: [...] n_{INT} is the number of observing periods and n_{AUR} is the number of Alpha-Aurigids involved. ZHR $= (1 + n_{\mathrm{AUR}})/\sum_{i=1}^{n_{\mathrm{INT}}}(T_{\mathrm{eff},i}/C_i)$ where $T_{\mathrm{eff},i}$ is the effective observing time of observing period i and C_i is the total correction for limiting magnitude, clouds and zenith correction for observing period i." (International Meteor Organization, 2007).

n_{INT}	n_{AUR}	ZHR	error
2	0	2	± 2
1	0	4	± 4
3	0	14	±14
3	4	30	±13
4	7	12	± 4
3	7	15	± 5
2	1	3	± 2
3	1	4	± 3
4	4	6	± 3
2	0	2	± 2
16	44	52	± 8
7	51	140	±19
11	60	216	±28
14	40	69	±11
11	8	14	± 5
3	4	14	± 6
1	1	24	±17
2	1	5	± 4
1	3	17	± 8
1	0	5	± 5
4	3	8	± 4

Table 2 – A comparison of Poisson's theoretical expectations ("predicted") with actual occurrence ("actual") for the 2001 November 18 Leonid shower (well before peak) using a mean of 1.6 meteors per minute (Bias, 2005).

Number of Leonids seen in a one-minute interval	Number of minutes in an hour that number is seen	
	Predicted	Actual
0	12.75	12
1	19.74	19
2	15.27	19
3	7.89	5
4	3.06	3
5	0.99	1
6	0.24	1
7	0.06	0

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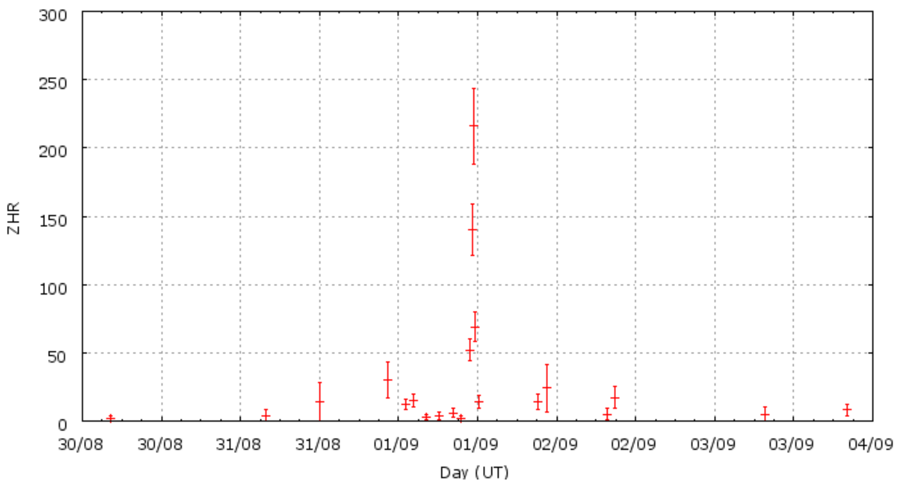

Figure 1 – The on-the-fly (not fully processed for final report) activity profile for the Alpha-Aurigid meteor shower of 2007 September 1. For this graphic, "ZHRmax = 216 based on 239 Alpha-Aurigids in 98 data intervals, assuming fixed population index $r = 2.0$ and zenith correction $1/\sin h_{\mathrm{R}}$."

2 Important Characteristics of a Poisson probability distribution

The Poisson discrete probability distribution is ideally used to determine the theoretical probabilities of random occurrences of small counting-number events that take place over defined intervals of space or time. That it is well suited for the task of accurately predicting the numbers of meteors seen is demonstrated in Table 2, which includes an observation during the 2001 Leonid shower.

Table 2 can be interpreted in the following manner. If the average number of meteors per minute is 1.6, then in any given hour an observer will witness that some one-minute intervals will go by where no meteors are seen at all (here, 12.75 minutes out of an hour, on average, are like that), some one-minute intervals will pass with only one meteor seen (here, 19.74 minutes in an hour are like that), some one-minute intervals will pass with exactly two meteors seen (here, 15.27 minutes out of an hour are theoretically like that), and so on. Importantly, even if the average number of meteors is 1.6 per minute, it is possible for an observer to randomly view the sky for only one minute and see, say, five meteors. Indeed, in the example here there is approximately one minute out of the 60 minutes, on average, that would seem like a very strong meteor shower. The key point is that the number one sees per interval is not necessarily the true average number. Instead, the number seen is dictated by the chance occurrence of meteors based on the entire probability distribution for a particular mean.

To get an understanding of what assumptions and expectations a Poisson distribution conveys, some pertinent characteristics of a Poisson process are listed below:

1. Individual discrete (countable) independent events take place in a defined interval of space or time.
2. No limit is established for the number of events that may take place in an interval.
3. The average number of events, λ, in a defined interval is proportional to the size of the interval such that if the interval is broken into half its original size, the average number expected is also decreased by one half; i.e., λ is multiplied by 1/2 to achieve the new λ.
4. The important parameters are: the mean, $\mu = \lambda$; the variance, $\sigma^2 = \lambda$; and the standard deviation, $\sigma = \sqrt{\lambda}$.
5. The Poisson distribution is heavily skewed to the right when λ is close to zero, but gradually changes toward a more bell-shaped (although never precisely Gaussian) distribution as λ gets farther away from zero (see Figure 2).
6. The precise probabilities are determined by the formula
$$f(x) = \frac{e^{-\lambda}\lambda^x}{x!},$$
where $x = 0, 1, 2, \ldots$

Even a cursory look at these tables and figures will make it clear that meteor rates will exhibit irregular behavior even when the true rates are known. Some observers will see more than others and there will always be a range of uncertainty from the data. The problem for determining ZHRs, then, is paramount. If an observer spies exactly x number of meteors in an interval under perfect IMO conditions, what is the ZHR?

From Figure 2 we see that there is approximately a 10% chance of seeing exactly one meteor if the true rate λ is 6 meteors/hour ($\lambda = 0.1$ per minute); about a 30% chance of seeing exactly one if the true rate is 30 meteors/hour ($\lambda = 0.5$ per minute); a 37% chance of seeing exactly one if the true rate is 60 meteors/hour ($\lambda = 1.0$ per minute); a 15% chance if the true rate is 180 meteors/hour ($\lambda = 3.0$ per minute); and about a 4% chance if the true rate is 300 meteors/hour ($\lambda = 5.0$ per minute). This is the essence of the ZHR problem: it being true that an observed rate reflects a random segment of a larger interval and may therefore be higher or lower than the true rate, what true rate can be inferred, given all of these possibilities?

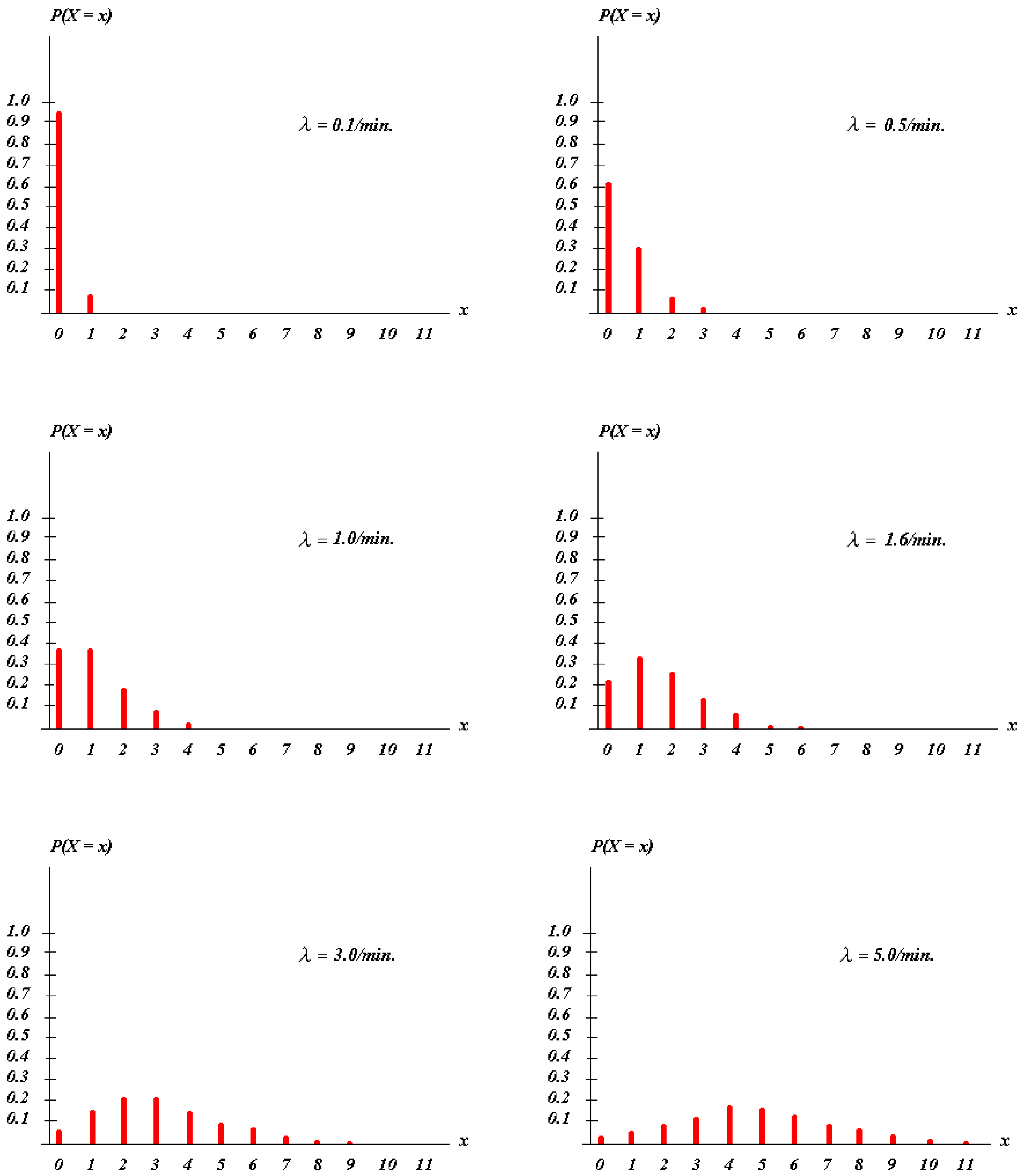

Figure 2 – Examples of differing theoretical Poisson probabilities as λ (the average number of meteors per minute) gradually changes from 0.1 meteors per minute (6 meteors per hour) to 5 meteors per minute (300 meteors per hour). The x-axis shows the number of meteors that may be seen in one minute, while the y-axis shows the theoretical probabilities of that number of meteors being seen.

3 Standard ZHR and Error Methodology under ideal conditions

3.1 Case 1: the mean is far from zero

Consider a case where, under the IMOs ideal conditions, one observer with a normal perception coefficient sees 10 meteors in exactly one hour. Because there will be no corrections needed, one might expect that the ZHR would be listed at 10. But it is not. Instead, the ZHR will be listed as 11 with a standard deviation of $\sqrt{11} \simeq$ 3.3. How is this determined? The standard IMO ZHR formula as used, for instance, by Arlt (2003) or Arlt, Rendtel, and Bader (Arlt et al., 2008) is

$$\overline{\text{ZHR}} = \frac{\left(1 + \sum_{i=1}^{N} n_i\right)}{\sum_{i=1}^{N} \frac{T_{\text{eff},i}}{C_i}},$$

where the average zenithal hourly rate is determined using N (the number of individual observing periods), n_i (the raw number of meteors seen by each observer in observing period i), $T_{\text{eff},i}$ (the effective time or amount of time an observer actually scans the sky for meteors during observing period i), and C_i (a normalization factor that accounts for all the imperfections in the observing period i such as haze, buildings, low radiant, moon, etc.).

It is necessary to include +1 in the numerator to correct for the asymmetric high and low end possibilities in a Poisson distribution. To find the *low end* possible true mean, λ, we need to find the smallest mean where the raw number of meteors seen (here $n = 10$) is unusually high; in other words, the average number where seeing 10 is just a lucky interval but that most of the time there would have been fewer seen. Arbitrarily, but often used in statistics, we assume 95% confidence of seeing 10 or fewer meteors in an hour (although any confidence level could be used). Formally, $P(n \leq 10|\lambda) \simeq 0.95$ is solved for λ. A perusal of a Poisson table reveals that $\lambda = 6.2$ is the closest value that makes the equation approximately correct. Similarly, the *high end* possible mean is the one such that the chance of seeing only $n = 10$ is unusually low and that most of the time we would see more than that. Solving for λ using $P(n \geq 10|\lambda) \simeq 0.95$ yields $\lambda = 15.7$. Thus, we are roughly 90% assured (i.e., $0.95 \times 0.95 = 0.9025$) that an observer may see 10 meteors from a shower that had a true ZHR of anywhere between, approximately, 6 and 16. Note that the actual number seen, 10, is not in the middle of this range but is instead closer to the low end of 6 meteors, so the error is asymmetrically placed around 10. Adding one to the raw number seen yields a more symmetric distribution of 11 and a distribution which is representative of the expected value of all possible means that could yield a 10.

3.2 Case 2: the mean is near zero

Consider another case where in an hour's interval an observer under ideal conditions sees no meteors at all. What, then, are the correct ZHR and error ranges? Following the same procedure developed above, that is, $P(\lambda_{\text{low}} \leq 0 \leq \lambda_{\text{high}}|n = 0) \simeq 0.95$, yields $P(0 \leq 0 \leq 3.0|n = 0) \simeq 0.95$; in other words, seeing 0 in an hour is most probable if the true mean ZHR is any number between and including 0 and 3. The middle of this range would generate a ZHR around 1.5 and a quick check of a Poisson table reveals that when λ is at 0.7 there is a 50% chance that no meteors will be seen, and a 50% chance that one or more will be seen. Thus, even when the mean is closer to one than it is to zero there is still a high chance of seeing nothing at all in an observing interval. It is this sort of reasoning that generates positive ZHRs when zero meteors are seen.

4 Asymmetries of ZHR and Error determination under less than ideal conditions

Where does all of this lead us? Unfortunately, any errors and asymmetries are magnified under the normalization procedures used to determine ZHR and error. If a high ZHR of 38 is listed, the actual raw number of meteors seen to derive that ZHR may be much lower because of low radiant, short observing period, poor sky conditions, clouds, etc. Thus, the small sample value properties discussed earlier are again important. For instance, suppose 10 meteors were seen in an hour but due to imperfect conditions are then extrapolated to a ZHR of 38, based on the formula,

$$\overline{\text{ZHR}} = \frac{\left(1 + \sum_{i=1}^{N} n_i\right)}{\sum_{i=1}^{N} \frac{T_{\text{eff},i}}{C_i}}.$$

The observing conditions apparently warranted a large correction value, C, of 3.4545, that is,

$$38 \simeq \frac{1 + 10}{\frac{1}{3.4545}}.$$

We know from the earlier discussion that the true raw mean could fall anywhere between 6.2 and 15.7 when we observe 10 meteors in an hour. Therefore, after correcting for the observing conditions, the new 90% confidence range will be between 23.6 and 59.7. Moreover, asymmetries are immediately apparent: the low end 23.6 is only 14.4 below the mean of 38 while the high end 59.7 is 21.7 above 38. That is, the new Poisson probability distribution with its mean normalized to 38 does not have the same probabilities as a Poisson probability distribution with a true mean of 38. The differences can be seen in Figure 3, where the cumulative probabilities of two different Poisson distributions, one with a mean of 11 and the other with a mean of 38, are shown. The distribution with a mean of 11 has been normalized to fit with the actual distribution with a true mean of 38, and the results show that there are striking differences. It is seen that extrapolated small sample, small interval, observations are not fully comparable to true distributions. Figure 4 has been added

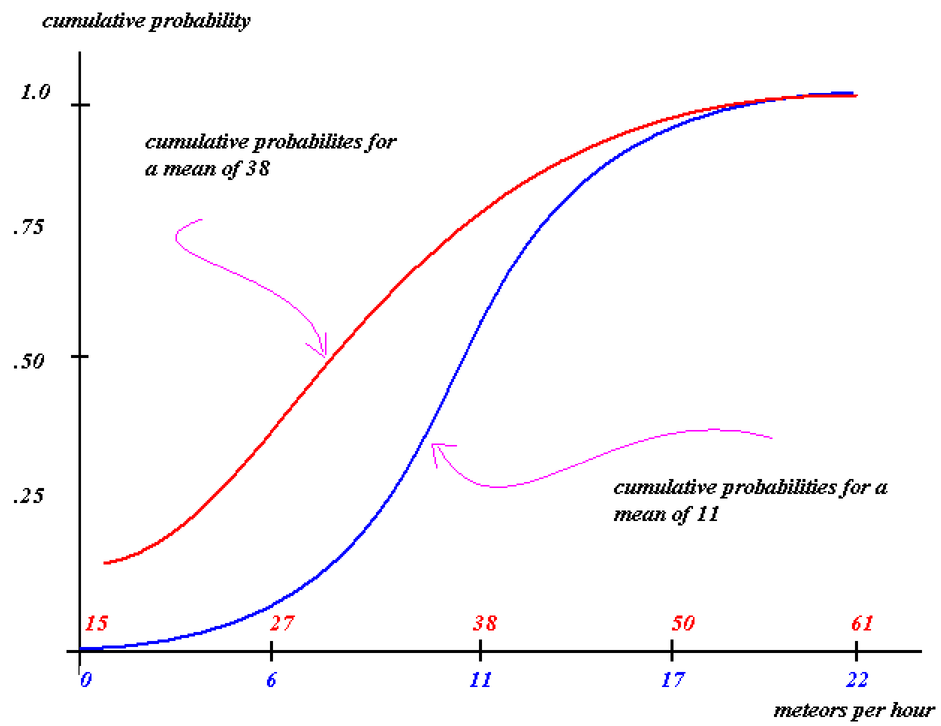

Figure 3 – The cumulative probabilities of two different Poisson distributions with means of 11 and 38 are compared. When the distribution with a mean of 11 is extrapolated to fit with the actual distribution with a true mean of 38, the result is that the cumulative probability distributions are markedly different. This shows that the process of correcting small sample, small interval, observations are not accurately comparable to true distributions.

to get another view of the problem. The graphs of the probability distributions when per minute and the per minute have been superimposed in such a way to get a different feel for the distinct asymmetries that occur when extrapolating per minute by a multiple of 6. The graphs, of course, do not actually fit together as shown. Because higher means also requires more numbers, the probabilities at particular numbers will necessarily be smaller than one that has a smaller mean value. However, here they have been contorted to the same horizontal distance for the probabilities in order to get another visual interpretation of the claims in this paper.

A real and common example of the situation just addressed can be seen in Table 1. The fifth observation from the bottom of the n_{AUR} column shows that one observer counted only one Alpha-Aurigid in the observing session. The ZHR, however, is listed as 24 with an error range of plus or minus 17. This high ZHR is obviously a result of a substantial magnification of the one meteor due to, presumably, poor or shortened observing conditions. Using the formula above we can see that the correction factor was 12, so the 90% range was 0.6–57.6 and the standard deviation is magnified by 12 as well: $12 \cdot (\sqrt{2}) = 17$. Note that asymmetric error range does not match up with the usual ±17 around the mean.

5 Where asymmetries occur

Asymmetric probability densities occur only under cases where the *raw data* (i.e., before any corrections to ideal conditions) numbers push the raw high end projected mean equal to 10 or more. When the mean of a Poisson distribution is at least as large as 10 the probability distribution becomes very nearly a symmetric mound-shaped distribution and is no longer noticeably skewed to the right. Therefore, it is only when the possible *raw data* counts fall below about 14 (because the possible true rate is then almost assuredly above 10) that there will be differences between the errors as they are currently reported and the asymmetric errors seen above.

6 Conclusion

It has been shown here that the process of extrapolating low raw data counts to obtain ZHRs is imperfect. The resulting magnified distributions are a distorted proxy for the true rates with the same ZHRs and do not actually reflect the same probabilities. Magnified counts have unequal error probabilities above and below the projected ZHR, with more probability below than above, and this skew is more pronounced as raw data counts get closer to zero. Solutions to this issue can run the gamut between a simple acknowledgment in a footnote that the asymmetries exist, to requiring some minimal level of correction before counts can be used as ZHRs, to requiring more than one simultaneous count before using the data to calculate ZHRs (which would significantly lower the error by a multiple of $\frac{1}{\sqrt{\text{number of observers}}}$), or perhaps a host of other possibilities.

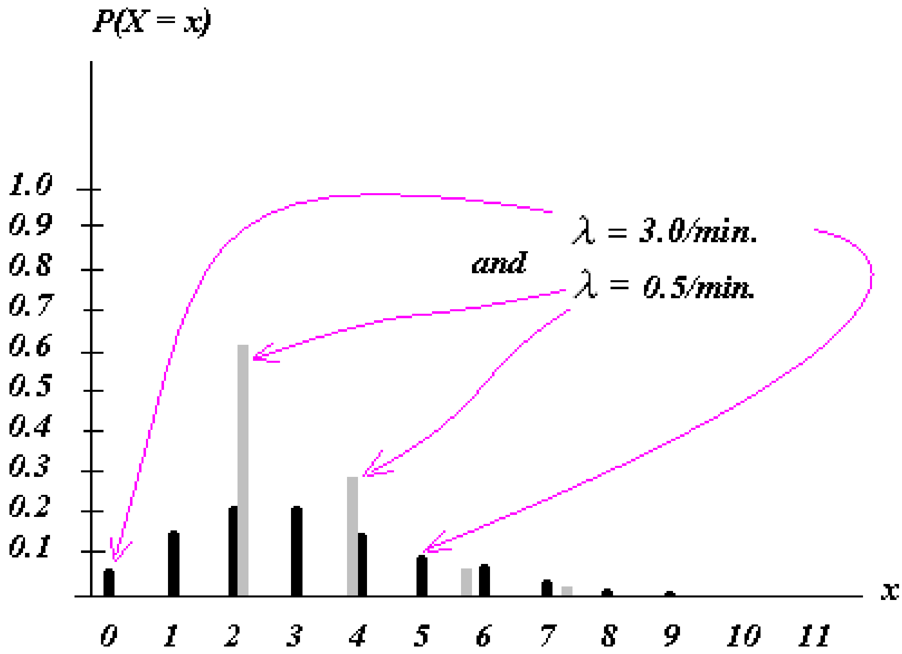

Figure 4 – Separate Poisson probability distributions with means of 0.5 (grey) and 3.0 (black) have been lined up and contorted in such a way to compare their differences in probabilities despite having the "same" means. Though not precisely showing the theoretical problem, the diagram at least gives the proper impression that extrapolating small numbers to large ones leads to distorted and asymmetric probabilities.

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Handling Editor: Cis Verbeeck

Results of the IMO Video Meteor Network — November 2010

Sirko Molau[1], Javor Kac[2], Erno Berko[3], Stefano Crivello[4], Enrico Stomeo[5] and Antal Igaz[6]

Preliminary results of the IMO Video Meteor Network data, collected by 50 cameras of the network, are presented. Almost 16 000 meteors were recorded in more than 3 300 hours of observing time. The activity profile of the Leonids is presented, with their maximum occurring on November 18. Activity profiles of two November minor showers, the Andromedids and the November Orionids, are also presented, fitting well to results from previous years.

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1 Introduction

After the proverbial "golden October" we run not fully unexpected into the "black mood": In the first week of November, the weather was still fine so that more than 30 out of 48 cameras were active on selected nights. But then the weather deteriorated. After the middle of November, clear skies became rare. Only a small data set could be collected during the Leonids, and by November 21 the rock-bottom was reached: Even though the IMO Video Meteor Network is spread over three continents by now, there were just two active cameras that night, which recorded no more than 17 meteors in less than 5 hours observing time. So we almost ended the interruption-free observation series that started in May 2007. Observers in Germany and Slovenia were in particular affected by the bad weather, but also the typically more spoiled Italian and Portuguese observers experienced only mediocre conditions.

Both of our American observers could not complain, though. On the contrary: Carl Hergenrother of Tucson smashed the record series of 45 observing nights in a row back from 2003 by operating his camera SALSA3 without interruption starting from August 27. It continued well into December, when he had reached more than 80 nights in a row. We are curious how long this streak will persist.

Our Hungarian network enjoyed quite nice weather conditions. It grew again by one camera station: A team around Szilárd Csizmadia has been operating HUVCSE01 since early November. The last two digits hint on further plans of these meteor observers.

In Slovenia, the number of cameras grew as well, after Mihaela Triglav Čekada resumed operation of her camera SRAKA after a longer break. In fact, the camera has been observing for over a year already. Now all the data is archived.

Looking at the monthly totals, the overall output of November was noteworthy thanks to the first half of the month. With more than 3 300 hours of effective observing time and 16 000 meteors (Table 1 and Figure 1), we surpassed the previously best November result by 50% (Molau & Kac, 2010). The monthly average of 4.8 meteors per hour remained unchanged with respect to the preceding year.

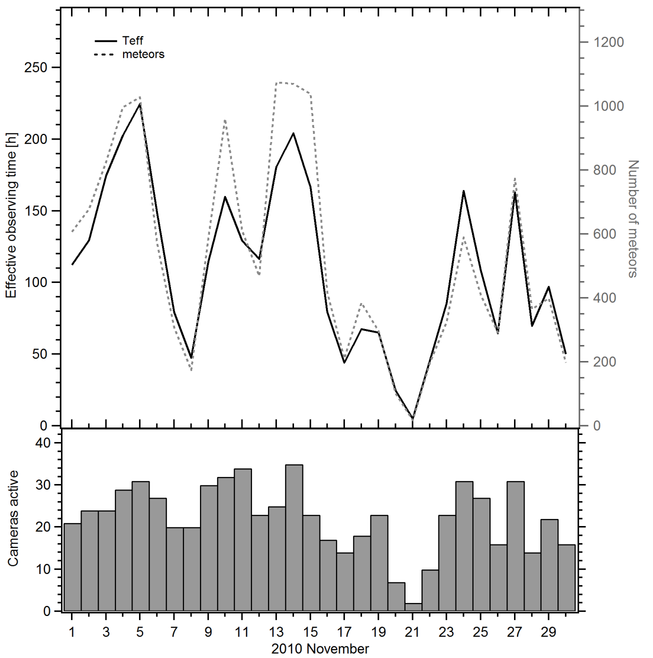

Figure 1 – Monthly summary for the effective observing time (solid black line), number of meteors (dashed gray line) and number of cameras active (bars) in 2010 November.

The organization of the IMO network changed significantly over the past few weeks. As mentioned in the previous report, one person was simply overcharged with collecting, checking and archiving the data of up to fifty cameras. With Erno Berko, Stefano Crivello, Enrico Stomeo and Antal Igaz we now have a team of analyzers that share the work load. More observers from the IMO network are ready to join the team. Beside the shared work load these observers gain more experience by analyzing the data of other cameras. In return they can use this knowledge for their own observations, and the number of competent contacts for questions on METREC and the IMO network is growing.

2 Leonids

With respect to meteor showers, the Leonids were the highlight of the month. There were no predictions for

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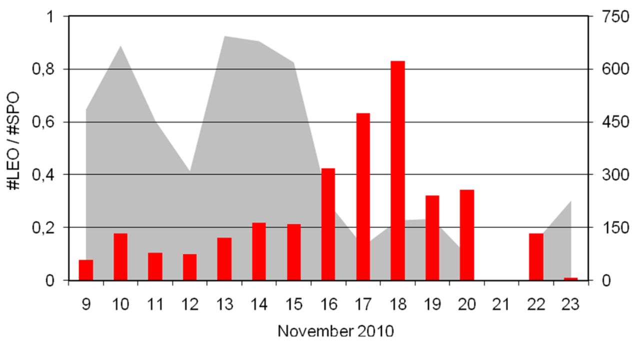

Figure 2 – Activity profile of the Leonids 2010. Presented is the number of Leonids per night, divided by the number of sporadics (bars). The shaded area in the background represents the number of sporadic meteors (keyed to the right-hand y-axis) and characterizes the size of the corresponding data set.

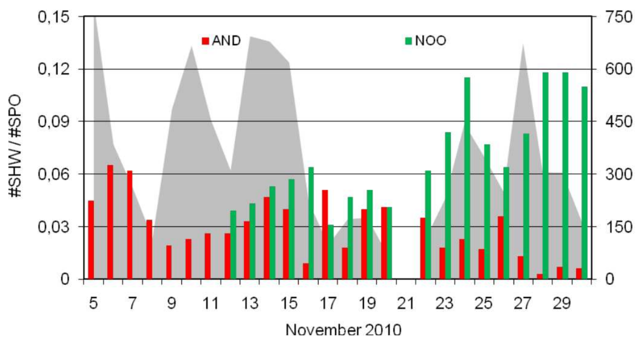

Figure 3 – Activity profile of the Andromedids and November Orionids in November 2010. The ratio between shower and sporadic meteors per night is presented (bars). The shaded area in the background represents the number of sporadics (keyed to the right-hand y-axis).

enhanced activity, but in recent years this shower surprised the observers more than once with variable rates. The quick-look analysis of visual observations by IMO yielded ZHR values of 15 and more between the morning UT hours of November 17 and 19. Near midnight on November 17/18 a short peak with rates twice as high was recorded, but the data set was rather sparse (71 Leonids) (International Meteor Organization, 2010).

In the video data, the maximum occurred one day later (Figure 2), but here the data set on November 17/18 and 18/19 was rather patchy (56 and 127 Leonids respectively). November 21 was not considered at all because of the lack of data.

The few active cameras observed more or less in cloud gaps only, which impacts the result significantly. If there are more data collected after midnight, for example, the percentage of Leonids will increase automatically. Due to lack of data, a more detailed analysis of the two nights in question was not feasible.

3 Andromedids and November Orionids

With the Andromedids (18 AND) and November Orionids (250 NOO), we had confirmed two more minor November meteor showers in our 2009 analysis. The Andromedids showed a relatively flat profile with only a minor peak of video rate 1 on November 13. The November Orionids, on the other hand, showed a continuous rise in activity from the middle of the month until the maximum on November 30 with a video rate of three. This was followed by a steep decrease in activity (Molau & Rendtel, 2009).

To verify both showers, the shower assignment of all recorded meteors was renewed. Thereafter, the ratio of shower to sporadic meteors was plotted as usual (Figure 3).

The 2010 observations fit well to the preceding results. The overall 270 Andromedids hardly stand out from the sporadic background with their approximately constant rate between November 5 and 26. The 416 November Orionids, on the other hand, show the expected clear uplift in activity towards the end of November.

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Table 1 – Observers contributing to 2010 November data of the IMO Video Meteor Network. Eff.CA designates the effective collection area and Tot.CA the total collection area.

Code	Name	Place	Camera	FOV [°2]	Stellar LM [mag]	Eff.CA [km^2]	Nights	Time [h]	Tot.CA [10^3km^{2}h]	Meteors
BENOR	Benitez-S.	Las Palmas	Times4 (1.4/50)	2359	3.2	492	12	35.8	—	93
			Times5 (0.95/50)	33	7.0	261	5	2.8	—	8
BERER	Berko	Ludányhalászi	HuLud1 (0.95/3)	6500	3.8	2209	18	110.9	—	373
			HuLud2 (0.95/2.8)	5977	4.2	2978	19	78.7	—	241
BRIBE	Brinkmann	Herne	Hermine (0.8/6)	2374	4.2	1074	13	28.6	—	114
CASFL	Castellani	Monte Baldo	Bmh1 (0.8/6)	2350	—	—	12	45.7	—	140
			Bmh2 (1.2/4.5)*	4243	—	—	21	83.8	—	321
CRIST	Crivello	Valbrevenna	C3P8 (0.8/3.8)	5575	4.2	2525	16	89.2	155.0	431
			Stg38 (0.8/3.8)	5593	—	—	22	117.8	—	680
CSISZ	Csizmadia	Zalaegerszeg	HUVCSE01 (0.95/5)	2439	—	—	19	91.2	—	303
CURMA	Currie	Grove	Mic4 (0.8/6)	1471	5.2	3008	7	27.1	—	111
ELTMA	Eltri	Venezia	Met38 (0.8/3.8)	5620	—	—	3	10.9	—	40
GONRU	Goncalves	Tomar	Templar1 (0.8/6)*	2188	5.3	2331	17	126.3	230.6	694
			Templar2 (0.8/6)*	2303	5.0	2397	18	123.6	274.5	539
GOVMI	Govedič	Središče ob Dravi	Orion2 (0.8/8)	1471	6.0	3916	25	149.3	—	544
HERCA	Hergenrother	Tucson	Salsa3 (1.2/4)*	4332	4.0	1471	30	203.5	151.5	725
HINWO	Hinz	Brannenburg	Akm2 (0.85/25)*	754	5.7	1306	12	88.3	105.0	421
IGAAN	Igaz	Baja	HuBaj (0.8/3.8)	5600	4.3	3338	22	128.6	79.4	535
		Hódmezővásárhely	HuHod (0.8/3.8)	5609	4.2	3031	19	110.0	96.5	445
		Budapest	HuPol (1.2/4)	3929	3.5	1144	22	102.0	116.8	320
JOBKL	Jobse	Oostkapelle	Betsy2 (1.2/85)*	1725	—	—	7	59.7	—	823
			Klara2 (1.2/85)*	1564	—	—	8	62.0	—	632
KACJA	Kac	Kostanjevec	Metka (0.8/8)*	1381	4.0	2246	7	55.6	35.2	234
		Ljubljana	Orion1 (0.8/8)	1420	5.3	2336	15	24.0	—	112
		Kamnik	Rezika (0.8/6)	2307	5.0	2293	5	24.5	—	131
			Stefka (0.8/3.8)	5540	4.2	2882	5	16.8	—	49
KERST	Kerr	Glenlee	Gocam1 (0.8/3.8)	5238	4.2	2637	9	58.4	152.8	371

Table 1 – Observers contributing to 2010 November data of the IMO Video Meteor Network – continued from previous page.

Code	Name	Place	Camera	FOV [°²]	Stellar LM [mag]	Eff.CA [km²]	Nights	Time [h]	Tot.CA [10³km²h]	Meteors
LUNRO	Lunsford	Chula Vista	Bocam (1.4/50)*	1860	—	—	21	153.5	—	1149
MOLSI	Molau	Seysdorf	Avis2 (1.4/50)*	1771	6.1	4182	10	60.2	139.2	674
			Mincam1 (0.8/8)	1477	4.9	1716	19	76.1	83.0	390
		Ketzür	Remo1 (0.8/3.8)	5592	3.0	974	9	22.3	26.7	66
			Remo2 (0.8/3.8)	5635	4.3	2846	6	6.4	17.9	25
MORJO	Morvai	Fülöpszállás	HuFul (1.4/5)	2522	3.5	532	21	114.5	51.5	371
OTTMI	Otte	Pearl City	Orie1 (1.4/5.7)	3837	—	—	23	141.6	—	600
PERZS	Perko	Becsehely	HuBec (0.8/3.8)*	5448	3.4	1500	23	134.3	133.7	675
ROTEC	Rothenberg	Berlin	Armefa (0.8/6)	2369	4.8	1801	9	24.6	55.0	85
SCHHA	Schremmer	Niederkrüchten	Doraemon (0.8/3.8)	5537	3.0	846	15	33.2	—	108
SLAST	Slavec	Ljubljana	Kayak1 (1.8/28)	596	—	—	8	18.9	—	48
STOEN	Stomeo	Scorze	Min38 (0.8/3.8)	5631	4.1	2407	14	57.0	—	234
			Noa38 (0.8/3.8)	5609	—	—	14	49.3	—	219
			Sco38 (0.8/3.8)	5598	—	—	13	46.0	—	225
STORO	Stork	Ondřejov	Ond1 (1.4/50)*	2195	5.8	4595	2	7.3	10.7	206
STRJO	Strunk	Herford	Mincam2 (0.8/6)	2357	—	—	5	4.4	—	20
			Mincam3 (0.8/12)	728	—	—	12	23.1	—	96
			Mincam5 (0.8/6)	2344	—	—	4	7.9	—	40
TEPIS	Tepliczky	Budapest	HuMob (0.8/6)	2375	4.9	2258	20	126.0	157.7	660
TRIMI	Triglav	Velenje	Sraka (0.8/6)*	2222	—	—	23	94.6	—	379
YRJIL	Yrjölä	Kuusankoski	Finexcam (0.8/6)	2337	—	—	10	67.6	—	273
						Overall	30	3 323.9	—	15 973

* active field of view smaller than video frame

History

History of Meteor Observing Project: An overview of British meteor observing, Part I, 1563 to 1860

Alastair McBeath[1]

An examination of the history of meteor observing in Britain is presented, in two parts. This first paper provides information from the period 1563–1860.

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1 Introduction

Deciding when something began often is not easy. When Mihaela Triglav-Čekada first asked me if I would consider preparing a history of British meteor observing, my initial thought was to start in 1847, since the encouragement and regular reporting of modern amateur meteor observing in the United Kingdom can be traced to that year. However, the question is not so straightforward, because, even in the present, meteor astronomy in Britain has always involved a mixture of amateur and professional observers, theorists and analysts, not all of whom have been closely linked to organized meteor work. The relative size and quality of each component has varied over time, while the labels "amateur" and "professional" have sometimes been assigned purely dependent on whether the individual's income derived mostly or solely from meteor studies, or from another source, rather than as a reflection of their relative expertise.

In Britain, into the mid 20th century, there were "gentleman amateurs", that is men whose private income was sufficient to mean they did not need to work, who could devote their time and money, perhaps very single-mindedly, to other pursuits, including scientific endeavours. When researching the history of science generally, it is notable too how many different clergymen featured in it. This is because such men frequently had both the education, from their religious studies, and enough spare time from their pastoral duties, to become involved with other subjects, including science and its forerunner natural philosophy. This began in medieval times, when major religious institutions, including the early universities, were the great centres of learning across Europe (Hannam, 2009).

Taking all this into consideration, and with clear "paper trails" of meteor observing leading back well before the 1840s, I eventually decided to start with clergyman William Fulke's *Goodly Gallerye* treatise of 1563 (Hornberger, 1979), as being the first detailed text describing the appearance of a whole variety of "meteors" in the English language, not simply what we would think of as 'meteoric' meteors now. This gave access to those people—most of the population—without a classical education, information on what meteors were considered to be, and thus how someone might observe them. Virtually everything subsequently in British meteor science, whether it accepted, rejected or challenged the views compiled in Fulke's book, and whether those views were directly sourced to William Fulke (1538–1589) or not, used them as a basis from which to argue for nearly three centuries afterwards.

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2 The 16th and 17th centuries

Events which can be more probably considered modernly as meteoric from Fulke's *Goodly Gallerye* were detailed and discussed earlier in WGN, as part of the Meteor Beliefs Project (McBeath & Gheorghe, 2007). As noted there, Fulke's work was repeatedly reprinted with little change over the century following its initial publication in 1563, a clear indication both of popular interest in its subject matter, and the fact there was no comparable text in English that covered it. William Leake, publisher of the last edition in 1670, stated as much in that version: "I may (without breach of Modesty) affirm, that there is not in our language any Booke of so small a Bulke, contains so much of the Doctrine of the *Meteors*" (Hornberger, 1979, p. 12).

The significance of Fulke's text should not be underestimated in Britain. As a proper noun, "Meteors" passed into the English language from the late 16th century as a word meaning any published study of meteors, solely because of this book (McBeath, 2004,p. 36). People wanted to better understand meteors of all kinds, and they would only have wished to do this if at least some of them had observed "our" sort of meteors directly.

A decade before the final edition of *Goodly Gallerye* was published, the oldest scientific society in Britain was founded, *The Royal Society of London for the Promotion of Natural Knowledge* (though its royal charter was not presented until 1662). It is better known still today as just "The Royal Society". Its main journal, the *Philosophical Transactions of the Royal Society* (hereafter "Phil. Trans."), was first printed in 1665. This contained articles written by a mixture of professional and amateur natural philosophers, mostly, but not exclusively, from Britain, on a wide range of topics. (The term "scientist" was not used in English until 1834, and it was not widely-accepted until 1840 (Simpson & Weiner, 1989, Vol. XIV, p. 652).)

A detailed discussion of reports collected by John Wallis (1616–1703) concerned a brilliant, fragmenting fireball on 1676 September 20. It was seen from numerous places across southern England, and was the first meteoric event presented in Phil. Trans. (**12**, 863–866, 1677). Even the sometimes crude information from inexperienced witnesses allowed Wallis to suggest either that the object must have been at a great height, or to have had an incredibly swift motion, to account for the sightings, and to ask if it may have been a small comet passing near the Earth (i.e. that the object was of extraterrestrial origin, not atmospheric, as the then-current Aristotelian view maintained that meteors were produced by ignited vapours having risen from the Earth).

Olson & Pasachoff (1998, pp. 32–33) carried out an analysis of the papers on meteors and comets in Phil. Trans., and found 57 were on meteors or meteorites, an average of about one article every three years, from 1665 to 1840. They also provided a bibliography for such publications from this journal as their Appendix I (op. cit., pp. 331–342), which indicated only one other meteoric item was presented before the end of the 17th century, an item from a letter of 1696 by Robert Vans in Ireland, "An Account of an Extraordinary Meteor, or kind of Dew resembling Butter, that fell last Winter and Spring" (*Phil. Trans.*, 19, 223). A second letter on the same topic by the Bishop of Cloyne followed on pp. 223–224. Naturally, this was not what we would consider meteoric now, and was likely referring to one of the yellow fungi, such as *Tremella mesenterica*, believed to have fallen from the sky at times in this period and later. Interestingly, Fulke had not discussed "fungal meteors" at all. Beech (1993a), however, gave additional notes on these "star jelly" fungi.

3 The 18th century

Virtually all "meteoric" meteor observations reported in Phil. Trans. throughout the 18th century concerned especially bright fireballs, with only one or two mentioning "ordinary", non-fireball, meteors. A few more items, sometimes included as part of reports on "meteoric" meteors were called "meteors" too, but were clearly observations of halo phenomena, sightings of the aurora, tornadoes or the *ignis fatuus* electrical lights instead.

Among the "genuine-meteor" papers were those by Edmund Halley (1656–1742) of 1714 and 1719, discussed previously in WGN (Beech, 1993b; 1994a). Halley's analyses of observations of widely-witnessed fireballs seen from Britain on 1708 July 31 and 1718 March 19 in these respective articles, combined with information from the 1677 Wallis Phil. Trans. paper, and analyzed details from fireballs over Italy (on 1676 March 21) plus near Leipzig (on 1686 July 9), enabled him to suggest bright meteors were occurring at heights equivalent to 65–100 km altitude, whereas his own experiments in the 1680s had found the Earth's atmosphere extended up to about 70 km. This could have overthrown the Aristotelian doctrine of meteors, but the idea did not take root then, despite casting further doubts on it. Halley's work also confirmed again what could be achieved with enough good-quality data from individual meteor sightings made from widely-separated places, even when witnesses unused to observing such things were involved.

Three other Phil. Trans. fireballs were particularly notable. The first was a brilliant daylight event that happened probably between 12 and 1 p.m. on 1741 December 11. This was seen and reported from places across southeast England west to the Isle of Wight. It produced a tremendous detonation that shook houses, and left a smoke train in the sky for around twenty minutes, according to some witnesses. However, the papers about it (*Phil. Trans.*, **41**, 871–873, 1741; **42**, 1, 25–27, 58–61, 138–139, 1742) were mostly presented by individual observers, sometimes compiling information from different witnesses, and occasionally with a little discussion, but nobody seemed to have tried to analyze all the sightings as a whole.

Nearly seventeen years later, the next significant Phil. Trans. fireball was more fortunate. John Pringle (1707–1782, actually "Sir John", better-known as a leading army physician) presented an amazingly detailed two-part report and discussion of a spectacularly bright, electrophonic fireball seen between 8 and 9 p.m. on 1758 November 26 (Pringle, 1759a; 1759b), based on observations he had collected from witnesses in twenty-six places, from Plymouth and London in the south of England to central Scotland in the north, and west as far as Dublin in Ireland. The meteor itself was suggested as having flown from somewhere around 145–160 km altitude above Cambridge in southeast England, to between 41–53 km above Fort William in northwest Scotland, a horizontal distance of about 650 km. He concluded the object must have been extraterrestrial and that such objects must therefore follow their own orbits. Sadly, again this idea failed to take root. Beech (1994a, p. 54) gave notes from Pringle's discussion regarding the nature of meteors, as did Olson & Pasachoff (1998, p. 57, including Fig. 24, and part of Footnote 46, p. 105).

Arguably the most important, as a widely-observed, hugely impressive, fireball reported by many people scattered over the British Isles in considerable detail, was an event on 1783 August 18 between 9 and 10 p.m. (Olson & Pasachoff, 1998, pp. 63–78, Footnotes 46–75 on pp. 104–106, and Plates III and IV) gave a full, illustrated discussion of this remarkable event, as they put it (p. 63), "One of the landmarks of meteor observation". Among the Phil. Trans. papers regarding it (**74**, 108–118 and 457–459, 1784), Charles Blagden (1748–1820) produced a report of this fireball, and another from 1783 October 4, in which he presented his theory on the electrical, not extraterrestrial, origin of meteors (Beech, 1994b). Unusual numbers of illustrations of the August fireball were prepared, some as line drawings in Phil. Trans., but others as full artworks in their own right, including those by artist brothers Thomas (1721/23–1798) and Paul (1730/31–1809) Sandby, and schoolmaster Henry Robinson.

In addition, this August 18 event was discussed, with extracts from the observations, in *The Gentleman's Magazine* (hereafter "Gent's. Mag." (**53**, 711–

713, 744, 795, 885, 888, 1783), a popular journal read by educated people with an interest in current affairs in Britain. Gent's. Mag. was first published in 1731 and featured astronomical topics occasionally from 1737 onwards (**7**, p. 126—a comet). Though the 1741 December 11 fireball seemed to have passed unremarked by it, notes on the 1758 November 26 fireball were published (*Gent's. Mag.*, 28, 608, 1758), if confusingly in an entry dated December 3. The general interest in the 1783 August meteor, and four other fireballs that followed during the next three months, led to Astronomer Royal Nevil Maskelyne (1732–1811), preparing an instruction pamphlet on how to observe and record fireballs, the first such information in English to help guide even novice amateur observers to produce better meteor data. He published a limited number of these pamphlets privately on 1783 November 6, with the text taken up and reprinted immediately in that November's issue of Gent's. Mag. (Maskelyne, 1783) This gave it a far wider circulation among the general populace, as *A plan for observing the meteors called fire-balls*. Maskelyne's opening comments set out his reasoning for doing this, citing a lack of proper observations of the 1783 August to October fireballs as hindering progress in understanding them, listing the key parameters to record, and giving advice on how to make various numerical estimates for the directions and timing of such events. The important items requested were in general identical to what we need from fireball sightings still today.

For all the significance of the events in 1783, the fireballs of August 18 and October 4 that year were the last British fireball reports to feature in Phil. Trans. Indeed, from the Olson & Pasachoff bibliography, there were no further meteoric papers there till three on meteorites appeared in 1802, and only four more were published in total before 1840 (three on the Cold Bokkeveld meteorite in the 1839 and 1840 volumes, and one on the strong meteor activity registered by medieval sources in 1095 and 1243, also in the 1840 volume).

Sightings of fireballs or lesser meteors continued to appear in Gent's. Mag. and elsewhere after 1783, but without the compilation of observations and detailed analyses seen in previous times. It is clear that Maskelyne's hopes of better reporting leading to an improved understanding of the fireball phenomenon remained unfulfilled. For example, in a lengthy letter touching on various matters, the pseudonymous "Theophrastus" included a note on the 1783 August 18 fireball which concluded, "This happened much about the time of the termination of the volcanic eruption in Iceland; and it is remarkable, that this meteor was first seen to the northwest of the Shetland and Orkney islands, in the quarter of Iceland" (*Gent's. Mag.*, **57**, 197–198, 1787). The quote is from p. 198, as in all cases here from this journal, with the long-s's replaced by the modern short form. This "volcanic meteor" concept was still current in places by the late 19th century, as discussed by Drobnock et al. (2009).

"Meteorological" meteors remained popular too. As Beech (1994c, p. 215) noted, when the initial issue of the independently-published *Philosophical Magazine* (hereafter "Phil. Mag.") featured an article, "An account of two singular meteors" (*Phil. Mag.*, **1**, 66–67, 1798), one was a halo display—probably of mock suns—the other a fireball seen on 1798 March 8. Worse still, the latter was explained only using the "ignited atmospheric gas" theory. This left Ernst Chladni and others in continental Europe to determine and define the true extraterrestrial nature of meteors and meteorites, beginning in the closing years of the 18th century. At least Phil. Mag. reported in English the works published in Europe by Baudin, Chladni and Fulda that discussed theories regarding the origins of meteorites and fireballs in its second and third volumes (*Phil. Mag.*, **2**, 1–8, 225–231, 337–345, 1798–99; **3**, 66–75, 1799).

Late 1799 brought fresh British fireball sightings to Phil. Mag. from September 22 (**4**, 434, 1799; **5**, 199–200, 1799), while the latter reference also had notes on bright meteors seen on November 2 and 12. Two fireballs were seen between 5 and 6 p.m. on the 12th, a very significant date, as 1799 November 11/12 produced the first, modern, great Leonid storm. Gent's. Mag. had the most interesting British observations immediately after the event (**69**, 987, 1799). These included comments on the tremendous meteor activity that happened after 5 a.m. for about two hours through to sunrise, as seen from Hull, Hereford, the Forest of Dean area on the southern Welsh-English border, northeast England near Hartlepool, and places north of London near Enfield and Barnet. The information showed many meteors had been visible, often leaving persistent trains for several minutes, with numerous, sometimes very brilliant, fireballs. However, there was no recognition that the meteors were radiating from any specific place in the sky. The Hull sighting stated the meteors "were crossing each other in different directions", while a witness at Greatham, just southwest of Hartlepool, noted the meteors "passed to the Northward" only.

Despite the astounding nature of this Leonid display, its impact on British meteor observing was startlingly negligible. No further reports appeared in Gent's. Mag., and there were none at all in Phil. Mag., or seemingly elsewhere. When Phil. Mag. (**53**, 312–314, 1819) featured details on the meteor storm as described in Von Humboldt & Bonpland's *Travels to the Equinoctial Regions of America 1799–1804*, though observations of the event were remarked from mainly northern hemisphere sites between North American longitudes east to mid-European ones (near Weimar, Germany), no British locations were mentioned. Even so, the storm was seen, but poorly-reported, from elsewhere in the UK. An example came to light following the 1866 Leonid storm, with a report by Professor John Cruickshank (1787–1875) in the *Aberdeen Journal* for 1866 November 21. Cruickshank had witnessed the 1799 event as a boy of twelve, living in Banffshire, inland of the Moray Firth coast in northeast Scotland, and recalled the meteors in great numbers, apparently coming from the southeast, mostly moving northwestwards. He also remembered the impression the storm had left in other witnesses in the countryside nearby. More notes on British observations of the 1799 Leonids were given in McBeath et al. (2010).

The editors of Gent's. Mag., after giving further fireball sightings from Lincolnshire around 6 a.m. on 1799 November 19 (loc. cit.), seemed to have wished to rationalize and dismiss the events altogether. The editorial comments concluded thus: "These meteorous appearances, so frequent of late, may be accounted for by the great moisture of the earth which, being exhaled by the heat of the sun, produces these inflammable vapours." Perhaps that attitude helped lead to less frequent meteor and fireball reports in Gent's. Mag. afterwards. That journal had, however, the distinction of reporting the 18th century's final British fireball, seen from Scotland around 7 p.m. on 1800 December 31, whose auspicious date was not lost on its fortunate witnesses (*Gent's. Mag.*, **71**, 76, 1801).

4 The 19th century to 1860

Reports of meteor activity seen from Britain were relatively few in the opening decades of the new century. Of the material that has survived, Phil. Mag. seemed to have been the main preferred journal for publishing on such matters. Those meteoric commentaries were dominated by the ongoing debate regarding whether stones really could fall from the clouds, through to 1805, and the possible connection of the claimed falls to fireballs. The few fireball reports separate from this were sometimes listed under "meteorology" (e.g., that seen from Belfort, France, on 1803 September 22 (*Phil. Mag.*, **18**, 94, 1809)), hardly surprising, given that some of the stones-from-the-clouds notes suggested the stones might themselves form within the clouds. By late 1806, these objects were typically referred to as "meteoric stones" in Phil. Mag.; by 1812, they might also be called "meteor stones", "meteorolites", or "aerolites", and later, where appropriate, "meteoric iron" (1816), but not "meteorites" till about 1823.[1]

The first brief discussion of 'ordinary' meteors in Phil. Mag., as separate from fireballs and sky-lights possibly associated with various fallen objects (such as gelatinous masses, blood, sand, and even the biblical "fire and brimstone" (*Phil. Mag.*, **44**, 217–224 and 253–360, 1815), was not until 1819. There, they were called "shooting stars" in a note by the pseudonymous "Scepticus" (*Phil. Mag.*, **53**, 201–202, 1819). Although this touched mainly on their velocities, it may have helped prompt "$A\sigma\tau\rho o\phi\iota\lambda o\sigma$" to forward the details from Von Humboldt's 1799 November 12 report remarked earlier, later that year (op. cit., 313–314).

The earliest serious discussion of these "normal" meteors was in 1821. John Farey (1766–1826), a noted natural historian of the period, presented a paper on "shooting stars" (Farey, 1821). In it, he referred to a series of meteor observations made on mostly one night per month from 1819 and 1820 by Dr. William Burney (1762–1832) at Gosport, by the Hampshire coast. These were made as part of Burney's routine meteorological reports. Farey drew especial attention to a total of 35 meteors seen in one hour on 1819 August 9/10, which he described as the "best display ever seen in so short a time" (presumably by Burney in this limited run, and ignoring the event of 1799 November). However, he ascribed this solely to the "gaseous or inflammable state of the air". Farey continued into a series of questions about meteors, including such things as whether they could be seen in moonlight, during which he mentioned that about twenty years previously (so, approximately 1799), he had made simultaneous observations of shooting stars from London, with a colleague, engineer and cartographer Benjamin Bevan (1773–1833), at Woburn and Leighton in Bedfordshire, sadly without elaborating on this statement. Presumably, these observations were made after learning of the experiments by Brandes and Benzenberg in Germany during late 1798, that were published in 1800 (Beech, 1995).

Dr. T(homas) Forster (1789–1860), who wrote widely on meteorological phenomena and atmospheric conditions, especially in relation to health—he believed that comets could create epidemics on Earth, for instance—replied to Farey's "meteor questions" paper later in 1821 (*Phil. Mag.*, **57**, 418–420, 1821). He commented he had observed meteors for many years, and referred to his 1814 book, *Researches about atmospheric Phenomena* in respect of them. His efforts had led him to believe that the classical authors were correct in suggesting meteors foretold windy weather (Gheorghe & McBeath, 2007). He mentioned other aspects too, that some meteors, especially the brighter ones, moved in a curve, and that they were commoner on fine, warm, summer evenings. He did not draw attention to any recurrent dates for meteor activity beyond this, but he appears to be the same person as the "Mr. T. Forster" that Edward Herrick later quoted Quetelet as citing as the solitary authority for the folkloric link between the Perseids and St. Lawrence in 1839 (Beech, 1997). Forster appeared to have made no such connection by 1821.

Burney also replied to Farey's queries (*Phil. Mag.*, **58**, 22–24, 1821), with notes on how meteors might form in the atmosphere, and confirmed Forster's opinion that from his own observations since 1817, there was a 4 : 1 preference for meteors to occur in the summer, compared to the winter. He suggested this could be due to greater solar heating affecting the meteoric vapours, though he broadened the definition by also including the St Elmo's Fire type of electrical "meteors". He subsequently presented details from his meteor observing between 1821 July 12 and August 11 (op. cit., 127–130), and between August 18 and September 18 (op. cit., 198–200). These data implied a rough peak in meteor counts on August 9, despite a waxing gibbous Moon then, and the fact the counts were non-systematic. His August 4 report gave plots of approximate paths for four of sixteen meteors seen between 9 p.m. and midnight, the

[1] The main Phil. Mag. stones-from-the-clouds discussions were **14**, 49–55 and 272, 1802; **16**, 217–224 (Villefranche fall), 224–228 (L'Aigle fall notes by Biot), 289–298 (discussion of earlier falls with a table back to Livy), 299–305 (L'Aigle again), 1803; **17**, 271–274, 1803; and **19**, 16–18, 1804 (under "History of Astronomy for 1803", the debate sparked by the L'Aigle fall, and various theories on the origin of the stones, including their possible intra-atmospheric formation).

first such information given in Phil. Mag. Burney's further comments indicated apparent confirmation of Forster's association of meteors and strong winds, but suggested they foretold rain too.

Farey returned with more discussion (op. cit., 183–186). Of greatest note was that, on pp. 185–186, he presented the first formal instructions for general meteor observing ever published in Britain. The information he suggested recording included the date and observing conditions, the time for each meteor, fixing its path in the sky mentally, then recording that information using a planisphere, and writing a description of each meteor's physical appearance. Farey recommended a gentleman observer should have up to three assistants to take down all the written data, while the observer simply watched the sky as relaxedly and comfortably as possible, with one of the assistants rotating tasks with the observer from time to time. He commented too on the usefulness of making simultaneous observations of the same meteors from two sites.

Sadly, but rather like Maskelyne's fireball reporting procedure of 1783, and despite all the meteor information given for 1821 that indicated a small, but active, meteor observing community existed in Britain then, Phil. Mag. reverted to featuring just occasional, casual fireball sightings after this until 1824. That year, Edward William Brayley (1801/02–1870), a voluminous literature researcher, popular-science author and lecturer on meteors, meteorology and physical geography, presented his first paper on what he called "igneous meteors" and meteorites in a review of the state of science in the subjects by 1823, in Phil. Mag. (**64**, 111–119 and 287–295, 1823). Many of the specific observations he cited were made from America, though his discussions included more general physical aspects of meteor phenomena, such as persistent trains. This fresh impetus led to another note on 'shooting stars' from Farey (op. cit., 180–181), his last such contribution, but once more, meteoric items lapsed back to infrequent fireball reports in this journal until 1837.

Meanwhile, in 1820 January, the *Astronomical Society* had been formed in London, a group made up of amateur and professional astronomers, with a view to putting the subject on a more scientific basis than had hitherto been the case. An announcement of its creation featured in Phil. Mag. (**55**, 147, 1820), with other notes regarding it after that. The Society's proceedings subsequently were reported briefly in each monthly issue of Phil. Mag., gaining the title *Monthly Notices of the Astronomical Society*. These began to be published separately in 1827 February, though they continued to be reprinted regularly in Phil. Mag. too, until 1828. (In 1827, Phil. Mag. was retitled *The Magazine and Annals of Philosophy*, but I have retained the "Phil. Mag." abbreviation here throughout.) These reprints grew increasingly erratic in Phil. Mag. after this though, as *Monthly Notices* established itself as a journal in its own right (Dreyer & Turner, 1923, pp. 38–41). In 1831, the Astronomical Society received its royal charter (op. cit., pp. 50–51), and it remains known as the *Royal Astronomical Society*—RAS—today.

The first meteor to feature in any RAS publication was a fireball, observed by a Mr. Haggard of Blackheath, London, on 1833 October 20. It was reported in the *Monthly Notices of the RAS*, hereafter MNRAS (**13**, 65, 1833). Scattered papers with fresh observations of meteors or fireballs, interspersed with discussions on periodic meteor activities and more theoretical aspects, were published in MNRAS after then, but significant numbers of such articles only started to appear there from 1864 onwards. Roggemans listed a total of just 14 MNRAS meteor papers from 1833 to 1857, for instance (Roggemans, 1987, p. 27). This paucity of reported meteor observations and analyses is reflected in the absence of any mention of meteors in the RAS' official history prior to the 1866 Leonids, something I have reflected on before with other colleagues.

Surprisingly, the 1833 Leonid storm passed unremarked by all the British journals mentioned up to this point, and indeed, if only the British sources were examined overall, the entire period from about 1825 to 1836 would have seemed meteorically routine, with predominantly the usual smattering of fireball sightings being published occasionally. However, the changes to meteor science begun thanks to the American 1833 Leonid analyses finally reached Britain in 1837, when Phil. Mag. published two papers by Quetelet, and a third by Wartmann, which discussed the periodic nature of some meteors, and the heights, motions and nature of "shooting stars" as a whole (*Phil. Mag.*, **11** 261–273, 1837). On Quetelet and his importance to meteor astronomy, see Sauval (1997). Wartmann especially concentrated on the meteors of 1833 November 13, detailing too the mid November meteor activity seen in 1799 and 1831–36, inclusive. The editors' concluding sentence (loc. cit., p. 273) gave the sole British contribution to the topic they were aware of: "The frequent appearance of shooting stars in August had been noticed in England by Dr. T. Forster (Phil Mag lxiv., p. 294) and at Pavia [Italy], we believe, by M. Bellani", their reference back to a note late in Brayley's review of meteor science for 1823.

The "November meteors" continued to spark interest, with single-observer reports from November 12/13 in 1837 by Professor James D. Forbes (1809–1868) at Edinburgh, and 1838 by Mr. W. R. Birt (William Radcliffe; 1804–1881) in London, featuring in Phil. Mag. (**12**, 85–86, 1838; **14**, 39–42, 1839). Birt's data included rough positional information on each meteor. Phil. Mag. then presented results from Edward Cooper in Birmingham (possibly Edward Joshua Cooper, 1798–1863, though he lived and observed from primarily Ireland and Cambridge in England) and "R. M. Z." in Clapham, Surrey, on the 1839 "August meteors" around August 10 and 11 (last op. cit., pp. 371–373 and 441). No further meteor reports followed during 1840, probably because a fresh body had become involved in recording meteor observations by then, the *British Association for the Advancement of Science* (BAAS).

Founded in 1831 on the model of the *Deutscher Naturforscher Versammlung* in Germany, the BAAS was part of a general social movement in Britain in the years after the Napoleonic Wars ended. Its intention was to give science greater prominence in British culture, and improve the lot of its practitioners, still called "philosophers" or also "natural philosophers" (Howarth, 1922, Chapter 1, especially pp. 1–7). Writing in 1830, one of the BAAS' founders, Sir David Brewer (1781–1868), illustrated the situation thus: "There is not a single philosopher who enjoys a pension, or an allowance, or a sinecure, capable of supporting him and his family in the humblest circumstances!" (op. cit., p. 5). Consequently, British science in 1830 can be seen as the near-exclusive province of the amateur!

Once formed, the BAAS held an annual meeting at a different place in Britain each year, running over several days. It continues to do so now. In time, these provided annual commentaries, observational notes and summaries of the state of science in numerous disciplines, information which was then published as a bound book under the convoluted title *Report of the* [number] *Meeting of the British Association for the Advancement of Science; Held at* [place-name] *in* [month] [year]. For obvious reasons here, these are referred to simply as "BAAS Report [year] ([publication year])". Each was published in London by John Murray during the period the BAAS Reports feature in these papers.

Forbes provided the earliest discussion of meteors in the BAAS Reports (Forbes, 1841) The title of the contribution, "Supplementary Report on Meteorology", indicates the continued uncertain status as to which branch of science meteors properly belonged. He began (p. 117), "This subject has occupied by far too much attention during the last few years to be passed over in silence", citing 1832 November 12/13 as the key moment in attracting notice to this date, and the fact the same night previously had also brought occasional unusual meteor displays, back to 1799 November 11/12. The year 1832 was not in error, as Forbes discussed briefly observations from Europe east to Russia and Arabia of the "very remarkable occurrence" of meteors that night, but which he had not seen himself. He then noted other November displays in 1822 (Potsdam, Germany) and 1831 (Spain and America), before detailing briefly every recurrence subsequently through to 1839, drawing on data published in various journals, and collected from different parts of the world, not just Britain. He concluded by remarking another good period for meteors, identified by Quetelet, was August 10–15, and that a radiant near γ Persei had been identified independently from British-European and North American observations in 1840 August.

No further formal meteor discussions were given in the BAAS Reports until 1847, though there were occasional individual observations published separately within them. The BAAS Report 1847 (1848, pp. 15–16) gave a simple table of meteor observations, including meteor showers and individual fireballs, reported from many places, some extracted from publications, from each year between 1841 and 1846, intended to complement a similar listing prepared by Quetelet, which had stopped in 1840. This was prepared by the Reverend Professor Baden Powell (1796–1860).

Powell is arguably the most important figure in establishing and promoting organized meteor observing in Britain, since the regular, annual meteor reports he published for the BAAS from 1847 onwards are those that link to all the organized meteor observing still performed in this country today. Despite this, meteor studies formed merely one tiny element of his life's activities. Among numerous glowing obituaries following his death (many are available online), the succinct details from that in the *Journal of the Society of Arts* for 1860 November 23 provided a perfect summary:

> "His general knowledge was extensive, his understanding was vigorous; his mind had been disciplined by laborious study; his habits were characterised by unwearied industry, and his eminence in physical and mathematical science is indicated by the distinguished position which he attained early, and enjoyed long, in the University of Oxford. His contributions to science were numerous and important, and he contributed largely to the reforms which have taken place at both our Universities."

The position referred to at Oxford was Savilian Professor of Geometry, to which chair he was elected in 1827, while the two British universities were at Oxford and Cambridge in this period.

The interest and correspondence Powell received following his 1847 presentation to the BAAS led to his publication of a formal table and list of additional notes as "A Catalogue of Observations of Luminous Meteors", including extracts from the original documents, in the BAAS Report 1848 (1849, pp. 1–11). This was given added prominence by beginning the Report volume. Fireballs, meteor showers and individual ordinary meteors were noted, as seen between 1833 to 1848 by numerous observers, including one of the most prolific of the period, Edward Joseph Lowe, a still more notable botanist (1825–1900), and others of significance, such as James Glaisher (1809–1903), Dr. Forster, Powell himself, and Sirs John Herschel (1792–1871) and Lubbock (1803–1865).

By the following year, BAAS Report 1849 (1850, pp. 1–53), the pattern for most of the Luminous Meteor Reports in later years was established, with one or more lengthy tables listing observations—often to descriptions, with sketches or plotted paths, for every separate meteor seen during a meteor watch—and accompanying text notes to provide further information, some taken from letters or papers published elsewhere, helping to indicate progress in the science since the previous Report. Frequently, Powell added material he had collected from earlier years as well. There was still no established, single visual observing procedure, but it is interesting that Powell's opening remarks for 1849 mentioned that while many observers used just "common clock time", "in all Mr. Lowe's observations it is Greenwich Mean Time", modernly UT, showing an early appreciation of the necessity of a standardized, accurate, time-base.

Meteorites, typically called "aerolit(h)es", featured as well, now generally associated as part of the possible family of meteoric bodies, and various correspondents drew attention to objects which might have favoured one or other theory then-current regarding the nature of meteors overall. Most attention remained concentrated on meteors and the development of better routine methods of recording details on them.

In the BAAS Report 1850 (1851, pp. 89–132), Powell had enlarged the table slightly, increasing the information for each meteor to include the date, time, magnitude, colour, train or fragmentation (if any), the event's apparent velocity or visible duration, the direction of the meteor's path in the sky, any additional comments, the observer's name and location. Though the details an observer provided might be rather variable, the amount of raw data thus preserved from the period is phenomenal, and can allow the reconstruction of entire observing sessions.

Pages 98–99 of the main table in this 1850 Report, with Appendix 18 (pp. 115–116), summarized the analyzed findings for a brilliant fireball on 1850 February 11, widely-seen across most of England (discussed further, with a mezzotint, by Olson & Pasachoff (1998, pp. 213–214, plus Footnotes 104–105 on p. 225)). The results were published in *Phil. Mag.*, **36**, 221, 249, 1850, but Powell's BAAS Report added extra sightings not collected by the author of the Phil. Mag. piece, Glaisher, then assistant to the Astronomer Royal, and also of the British Meteorological Society. It seems there was a degree of friction between this Society and the BAAS regarding meteors, as suggested by Powell's remarks in the BAAS Report 1851 (1852, pp. 1–52; quote from p. 1):

> "Some of the results collected by the British Meteorological Society have also been sent to me; and it is much to be wished that that Society would co-operate with the British Association by regularly furnishing copies of their Meteor Observations for this Report."

On the same page though, he could also state that, "for this first time, the tabular form of arrangement agreed upon by a Committee of the British Association last year, has been adopted by most of the observers", so that a standardized method of communicating meteor results had been achieved by the BAAS by 1851, quite an accomplishment.

The significance of Powell's efforts in just these few years cannot be underestimated. For example, when the anonymous reviewer summarized the state of meteoric and meteoritic science at length in Vol. 92 of *The Quarterly Review* (also published by John Murray, 1853, pp. 77–106), Powell's Luminous Meteor Reports from 1847 to 1851 formed one of only three key sources used, and the only texts originally published in English. Organized meteor observing, reporting and analysis in Britain had arrived!

Aside from the usual tabulated details in the 1852 and 1853 BAAS Reports (1853, pp. 178–239; 1854, pp. 1–36, respectively), Prof. Powell included several diagrams showing plotted meteor trails for specific dates and times, most of which were from reports submitted by William W. Boreham of Haverhill, Cambridgeshire (1804–1886). W. Boreham's diagrams seemed to have been drawn as stereographic projection circles, labelled clockwise from the top as "North", "East", "South" and "West", with a note of the zenith's RA during the 0.5–1 hour observations. The meteor trails were drawn as unlabelled, arrowed lines, and no stars were shown. As the data were from 1852 August 9 and 10, and 1853 August 10, between 22^{h}–$23^{\mathrm{h}}30^{\mathrm{m}}$, it is unsurprising to find quite a number, if not a majority, of the trails suggestive of a radiant towards the low northeast. Oddly, the diagram on p. 235 of the 1852 Report gave a much clearer impression of a radiant low to the northwest instead, with nothing to the northeast, perhaps indicative of an error in the drafting or labelling, but, if so, one which passed uncorrected in any subsequent Report. There seemed to have been no attempt to analyze this material, or to suggest alternative plotting charts be used for such work in future, probably because Powell was struggling to find time to do so, judging by his repeated apologies for exactly this from the 1853 Report onwards.

While the British weather may have played its role, and despite the continued activity of a few regular watchers, especially the hugely prolific Lowe, the Reports from 1854 to 1859 showed a general drop in contributions. The BAAS Report 1854 (1855, pp. 386–415), for instance, included text discussions drawn almost exclusively from overseas publications, chiefly on the "August meteors". Some interesting details still featured at times, including notes on the overall increase in meteor rates between 6 p.m. to their diurnal 6 a.m. peak in the BAAS Report 1857 (1858, pp. 131–153), which Report also contained an analysis of meteor colours (pp. 144–149). However, Powell's health was failing, and he arranged with the BAAS for others to continue the work beyond his last Luminous Meteor Report in 1859.

The BAAS, clearly aware of the difficulties Powell had faced in these later years, set up a Committee to oversee the future of meteor observing and reporting, which took over in the BAAS Report 1860 (1861, pp. 1–27). In that year, the Committee consisted of Glaisher (who was listed first in every successive Report too, suggesting whatever rift there may have been between the BAAS and the British Meteorological Society, it had been at least partly healed), J. H. Gladstone (1827–1902), Robert Philips Greg (1826–1906; already a noted contributor to discussions on meteors in UK publications, such as Phil. Mag.) and, quite naturally, Lowe. Their first duty was to record with great sadness, the loss of Professor Powell, who had died on 1860 June 11 (op. cit., p. 1). They continued with the template for the Reports Powell had established—some brief introductory comments, followed by a table of variable length detailing individual meteors from the, usually recent, past, and then an Appendix of text, tables and illustrations expanding some of the tabulated items, as well as summarizing information from important publications elsewhere, including those on meteorites.

Greg's analyses began to feature frequently, and he often added useful notes to the summaries of others' work. For the 1860 Report (pp. 20–21), for example, Greg constructed an analysis of fireball and meteorite (aerolite) falls by month, taken from his own compiled historical catalogue from 584 to 1860 AD, the catalogue itself published later in the same Report volume, beginning on p. 48. Without regard to the origin of any of the fireballs, this analysis concluded a little vaguely that such bright events were mainly commoner later in the year, while meteorite falls gave a fairly uniform distribution, but it did demonstrate an increasing desire to try to better understand the behaviour of meteors as a whole.

5 Conclusion

The second part of this investigation into British meteor observing since 1563 will continue the narrative from 1861 to the present day.

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Fireballs recorded in Slovakia

Presented below are two fireballs detected by the digital all-sky video system from Astronomical and Geophysical Observatory, Comenius University, Modra, Slovakia. Images courtesy of Juraj Toth.

Sporadic fireball of about −9 magnitude, recorded on 2010 October 10 at $21^{h}39^{m}43^{s}$ UT terminated over the town of Martin, Slovakia.

Sporadic fireball of about −7 magnitude, recorded on 2010 October 12 at $21^{h}46^{m}43^{s}$ UT appeared overhead the town of Modra, Slovakia.