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# WGN

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Perseids
Leonids
IMC 2005
Lunar impacts
William Blake and meteoric imagery

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# WGN Vol. 32, No. 6, December 2004, pp. 147 –174

## Administrative



## Perseids



## Leonids



## Ongoing meteor work



## History



### Front cover photo

The Zodiacal Light from Gran Canaria (Spain) on 2004 March 21. A 10-minute exposure on an equatorial mount with Ektachrome 1600 slide film exposed at $f/4$. Venus is clearly visible in the center. Photograph by Orlando Benitez Sanchez.

### Future covers

Have you an interesting or spectacular meteor photograph that you think would look good on the cover of WGN? If so, please offer it to us. For the moment we can only accept machine-readable forms. More or less any image format will do, though ideally not JPEG as the JPEG compression algorithms lose information. A brief description will also be required: this should say what the photograph shows, when and where it was taken, plus (if possible) technical details such as the camera and exposure. We can be contacted at `wgn@imo.net`, but remember to put 'Meteor' in the subject line to get round the anti-spam filters.

**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

# Editorial — which magnitude?

*Chris Trayner*

Bolometric magnitude is little used in meteor science. The main reason is the impracticality of measuring it. It is based on the entire electromagnetic emission from the object (meteor or star) being described. This means everything from long-wave radio to high-energy gamma rays, not just visible light. An instrument (imaging system plus detector) to cover this range would be remarkable indeed.

Fortunately, things are not quite that bad, certainly for meteors. These emit in the visible and no doubt infra-red, plus maybe a little ultra-violet, but the energy outside that range will presumably be slight. One could imagine a CCD camera that would cover this range quite well, though a CCD chip sensitive to the far infra-red would be expensive, as would the optics. Let us ignore image intensifiers for the moment. A traditional problem is that normal lenses are only designed for the visible waveband, and focus infra-red at a different point. This is changing: lenses are now available to cover more of these wavelengths, at least the near infra-red, though they are expensive as yet. Ordinary CCDs have useful sensitivity at these wavelengths.

There is a second traditional problem with bolometric magnitudes: the atmosphere absorbs significant amounts of radiation outside the visible waveband of about 400 to 700 nm. For meteors, however, this may not be so much of a problem. Most of the infra-red down to 1300 nm reaches the top of high mountains like Kitt Peak, though the situation near sea level would be less rosy.

Why worry about bolometric magnitudes anyway? Why not stay with visual magnitudes? Certainly most meteor science does so, and it progresses well. When writing the article on magnitudes for the next issue, however, I was struck by the complicated definitions of many of the magnitude systems and the derivations of their constants. Some of them are Byzantine. It is hard to relate any real instrument, whether film camera or CCD equipment, to non-bolometric standards.

Wheather the effects are really that bad is debatable. Meteors produce a black-body spectrum plus plenty of spectral lines, the latter probably dominating. As regards the black-body part of the spectrum, a simple simulation suggests to me that using visual magnitude rather than bolometric does surprisingly little harm. How much the spectral lines would affect this result is unclear.

There may be other reasons for dis-satisfaction with visual magnitude. By its very nature, it ignores infra-red emissions.

But what is the advantage of seeing in the infra-red? Meteoroids start cold and heat up. As they do so, their radiation moves to shorter wavelengths. Only when they emit significantly in the visible band can we observe them at present (except by radio techniques). If we could observe them in the infra-red, even just the near infra-red, we would observe them earlier and higher in their trajectories.

You don't need to measure magnitude to make such observations, but you do for a light curve. Let us start by considering a hypothetical CCD system that operates only in the visible wavebands and has the correct response for visual magnitude. Suppose it can detect meteors as faint as magnitude 6, typical of current systems. The light curve of a randomly chosen simulated meteor, observed with this system, is shown in Figure 1: the Visual curve.

Now let us imagine extending the infra-red sensitivity of this system to 1400 nm, and make the spectral response bolometric within this range. The resulting simulated light curve is shown as the Bolometric curve in the same Figure; it has been shifted vertically so that it coincides with the Visual curve at the peak. It can be seen that it does indeed tell a more useful story at the start of the light curve, where the meteoroid is cooler and radiating less visible light. In this region the visual magnitude is underestimating (or, perhaps, mis-representing) by nearly three magnitudes.

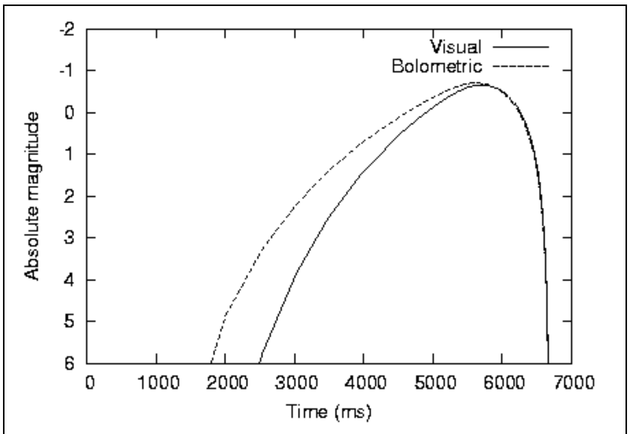


**Figure 1:** Simulated light curves in Visual and band-limited Bolmetric magnitudes.

At some point in the future, we may need to look carefully at the spectral responses of the CCD and film systems we are using. It might even be justified to invent yet another magnitude system and add it to the annoyingly large number already in use in astronomy. Perhaps we should consider bolometric magnitude, albeit a variant within limited wavelengths, to avoid yet another standard.

The above simulations were based on unpublished work by Jonathan McAuliffe, a PhD student at the Armagh Observatory, Armagh, Northern Ireland. I am grateful to Jonathan for the use of his results.

# Letter
# The daylight meteor of 1866 June 20, and train effects on meteor perception

*from Alastair McBeath*[1]

Chris Trayner mentioned the poor referencing offered by Edward Dunkin in his commentary on the daytime bolide of June 20, 1866, in Chris's short article in WGN (**32** : **4**, August 2004, p. 122). Unfortunately, such is true for virtually all English-language authors on whatever subject prior to the early 20th century. Occasionally there may be names dropped into the text, from which it may be possible to trace the original source (assuming it still survives), but it is a time-consuming task to do so.

I can provide one reference which gives a few more notes on this bolide. It is the *Report on Observations of Luminous Meteors,* 1866–67 by J. Glaisher, R. P. Greg, E. W. Brayley, A. S. Herschel and C. Brooke in the *British Association for the Advancement of Science Report* 1867, pp. 288–430 (published by the BAAS in 1868). Unfortunately, but not unexpectedly, the 1866 Leonid storm's description from various eye-witnesses occupies many of the published pages, and it seems no direct observations of the June bolide were received by the BAAS, since the event is relegated to a supplementary table (*Catalogue of Luminous Meteors and Aërolites. By R. P. Greg. Supplement No. II. (Continued from* 1860*, Brit. Assoc. Report)*) on pp. 414–430. The daylight bolide's details, as extracted from p. 430 of this table, are as follows (regrettably occupying rather less space than the BAAS Report's title and table references...):

Date: 1866 June 20. Time: '11 a.m.' Duration: 3.5s. 'Size or weight': half Moon. Direction: north to south. Observed from: 'Calais; Boulogne; France, and England'. Remarks: 'Aërolitic; white; red sparks; train of smoke 15 minutes; violent detonation; 15 miles over Calais to $4^1/_2$ miles over Montreuil and Boulogne; velocity 9 miles; seen in sunshine.'

Items in quotation marks are exactly as given in the table. The 'size or weight' column appears to cover the apparent angular size, an estimate of the object's brightness, or the physical weight of any recovered meteorites, judging by other entries. Meteor magnitudes seem to have been considered of very little importance at this period. The heights (equivalent to 22.5 km and 7.2 km respectively) seem rather too low, though the velocity (14.5 km(/s ?)) seems plausible enough, if it was intended in miles per second, but no indication of how they were obtained was given, nor did Greg cite the source(s) for his information. Other similar catalogues in earlier BAAS reports drew on all manner of previously published and unpublished sightings, originally in an effort to compile some kind of master listing of meteor reports, though this was, not unexpectedly, never fully accomplished. Given the list of places sightings were made from, perhaps our French colleagues might be able to recover some additional notes from their sources?

Peter Gural's paper in the same issue of WGN (pp. 97–108) on visual perception and the population index corrections for ZHR calculations, raised a number of issues which will no doubt be discussed, and models refined, for some time to come. One thing which occurred to me, and which does not seem to be discussed in Peter's paper, is the effect of persistent trains on the perception of meteors. In terms of a very short meteor trail seen near a radiant, a persistent train makes it far easier to spot from my experience, because the meteor's effective duration is prolonged. This will also work for longer trails further from the radiant, but given the dark adapted human eye-brain's excellent linear motion sensing power anyway, this may have relatively little impact. It may work to increase the observed counts of meteor showers which produce a good proportion of persistent trains however, as the train confirms the presence of the original meteor, even where that meteor may have been poorly seen. This may be compensated for by the lower apparent velocities of the less train-productive showers, however, or at least for those slower shower meteors seen away from the radiant.

Although Peter commented in his Conclusion that a comparison between visual and video observations would enable the better calibration of the visual data, as I have done several times previously in these pages, I would again urge caution in any such attempts. Video and visual observations do not record the same things in the same way, largely because of the video method's excess infra-red sensitivity compared to the human eye, or indeed to most ordinary photographic films, used for meteor work. While a carefully corrected examination might show up some interesting features, it would be most unwise to assume the raw video method alone will provide some sort of useful 'truth' to which visual observations can be directly compared, or to which visual observers should aspire.

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# International Meteor Conference 2005

## September 15–18, Oostmalle, Belgium

*The IMC 2005 Committee*

### The first time

For the first time since the foundation of IMO, the International Meteor Conference will be held in Belgium, on September 15–18, 2005. Oostmalle is a Belgian village located 30 km northeast of the beautiful city of Antwerp, second largest city of Belgium, fourth largest port in the world, and the world capital of diamonds. Urania, the Public Observatory of Antwerp, has maintained regular contacts with IMO since 1988. Actually, Urania is IMO's official seat, and its meteor section is very proud to organize this IMC.

### Go Belgian

The conference center 'Provinciaal Vormingscentrum' lies in a green area, and offers accommodation for 100 people or more (rooms for 1 to 6 persons). There is one big lecture hall and some smaller well-equipped rooms with Internet access. The evenings can be spent in the two cosy bars we have at our disposal. Beer lovers can taste a selection of the finest Belgian beers there.

### The weather

The temperature is typically around 15–20 degrees Celsius (60-70 degrees Fahrenheit) in September.

### Currency

The official currency in Belgium is the Euro. Foreign currency can be exchanged in banks and exchange offices.

### The excursion

A traditional part of the program is the excursion, which will lead us to the nice and small characteristic city of Lier, famous for its beguinage and the 'Zimmertoren'. Even Albert Einstein was impressed by this old tower in which Louis Zimmer built a whole range of high-quality astronomical clocks in the 1930s.

### Participation fee

If you wish to register, please fill out the registration form on the next page or register online at the IMC 2005 website (see below). The participation fee for the IMC 2005 is €120 for people who register before July 1st and €130 for those who register later. This fee includes lodging, meals, excursion and the Proceedings. Either a prepayment of €60 or the total amount should be sent to IMO treasurer Ina Rendtel (details inside back cover and IMC 2005 website).

### Visas and invitations

We will gladly send official invitations to people who need these to get a visa, provided that they inform us about this in due time. You can find out on the IMC website whether visa are required for citizens of your country.

### Radio meteor school 2005

We proudly present the 'Radio Meteor School 2005', a five-day tutorial (Oostmalle, September 10 till 14) in which Prof. Dr. Oleg Belkovich, Russian eminence grise in meteor astronomy, will lecture on the physical and mathematical theory of radio meteor observations. We stress the fact that this is not an easy course, and it will be helpful only to devoted radio observers highly skilled in mathematics and willing to get the utmost data out of their observations. For these people, it is very worthwhile to arrive in Belgium five days before the IMC to participate in the Radio Meteor School. The additional price will be around €150, and should only be paid upon arrival. However, you must register for this school before July 1st. Contact the organizers in order to register.

### Contact information

For more information, check the IMC 2005 website at http://www.imo.net/imc2005 or contact the organizers by e-mail at imc2005@imo.net. You can also write to us: IMC 2005 — Jan Verbert, Public Observatory Urania, Jozef Mattheessensstraat 60, B-2540 Hove, Belgium.

# International Meteor Conference Oostmalle, Belgium, September 15–18, 2005
## Registration form

Each individual participant should fill out a form and return it to IMC 2005 — Jan Verbert, Public Observatory Urania, Jozef Mattheessensstraat 60, B-2540 Hove, Belgium, as soon as possible. Your registration will be guaranteed only after Ina Rendtel has received the minimum pre-payment of €60. If you wish to participate, but cannot yet decide, simply return this form with the proper option checked to stay on the mailing list for further circulars.

Name: __________ Date of birth (YYYY-MM-DD): __________

Address: __________

Phone: __________ Fax: __________ E-mail: __________

- I wish to register for the IMC 2005 from September 15 to 18.
- I intend to participate, cannot yet register, but wish to stay on the mailing list.
- I intend to travel by ______, together with __________
- I need travel information from __________ to Oostmalle.
- I wish to stay in Belgium before and/or after the IMC and would like additional information.
- Vegetarian.

T-shirt: Size (S-M-L-XL): ______ Gender: ______

For participants wishing to contribute to the program:
Lecture: __________ Duration: ______ minutes

Workshop or discussion: __________

Poster presentation: __________ Space: ______ $m^2$

Required equipment: __________

Comments:

Either the entire fee of €120 or a pre-payment of €60 should be sent to IMO treasurer Ina Rendtel. Follow the payment instructions inside the back cover or on the IMC 2005 website `http://wwww.imo.net/imc2005` . Participants making a pre-payment only have to pay the remaining €60 in cash upon arrival in Oostmalle. The registration fee increases to €130 for participants registering after July 1st.

The following payment options are available.

- **International bank transfer** payments should be made to Ina Rendtel, Mehlbeerenweg 5, D-14469 Potsdam, Germany, BIC bank code: PBNKDEFF, IBAN code: DE86 1001 0010 0547 2341 07. When paying, always state BIC bank code and IBAN code together. Always contact your local bank to verify charges for international transfers.
- **German postal giro** Pay in euros to the German postal giro account 547234-107 of Ina Rendtel, Postbank Berlin. Bank code 100 100 10. The bank code and 'Postbank Berlin' should be mentioned together with account number.

# Perseids

## DMS results of the 2004 Perseids

*Koen Miskotte* [1] *and Carl Johannink* [2]

In this article we present the results of visual and image intensified video observations of the Perseids on 2004 August 11/12 by members of the Dutch Meteor Society (DMS). Using these techniques we can confirm higher activity of faint Perseids at 21:00 UT. The Perseids showed up with many bright meteors later that night, atypical for a normal return of this stream.

Received 2004 October 17

### 1 Introduction

Based upon predictions by Lyytinen et al. (2004), observers of the Dutch Meteor Society spread out over several parts of Europe to get the best chance to observe this year's Perseid return.

One team consisting of Rita Verhoef, Koen Miskotte, Romke Schievink and Carl Johannink profited from clear spells in the southwestern parts of Germany during August 11/12. After some last checks of the weather on the morning of August 11, they traveled to the small village of Britzingen about 30 km south of Freiburg. An image intensified video camera setup was operated by this team.

Another team consisting of Casper ter Kuile, Jos Nijland and Arnold Tukkers joined the Romanian Society for Meteors and Astronomy, SARM (Valentin Grigore et al.) observing from Darmanesti and Corbasca, Romania. Image-intensified video systems were operated from both stations.

In the Netherlands, at least part of the night was clear too, so a third set of video data was gathered from Biddinghuizen (the Netherlands) by Robert Haas and Marco Langbroek.

Successful double station photography was conducted from Spain by Hans Betlem and Jean-Marie Biets.

This article deals with video and visual results obtained by all these DMS-observers spread over Europe.

### 2 Visual observations

The observers whose visual data from the night August 11/12 were used for further reduction are mentioned in Table 2 (page 153).

ZHRs were calculated using periods of 15 minutes and the well known formula

$$\mathrm{ZHR} = \frac{n r^{6.5-\mathrm{LM}}}{((\sin h)^{\gamma}) C_{\mathrm{p}} T_{\mathrm{eff}}} \tag{1}$$

where $n$ is the number of stream meteors observed in time $T_{\mathrm{eff}}$, LM is the limiting magnitude, $h$ is the altitude of the radiant, $r$ and $\gamma$ are stream-dependant constants that describe the adjustments for LM and $h$ respectively, and $C_{\mathrm{p}}$ is the observer's personal correction factor. See (Jenniskens, 1994) for further details. $\gamma$ was taken as 1.4 (Jenniskens, 1994). When the $C_{\mathrm{p}}$ of an observer was undefined, we used $C_{\mathrm{p}} = 1$.

The results are plotted in Figure 1. It can be seen that around solar longitude $\lambda_{\odot} = 139\overset{\circ}{.}44$ (2000.0) the ZHR of the Perseids is two to three times above the normal level for this solar longitude (Jenniskens 1994).

After solar longitude $139\overset{\circ}{.}45$ there is an abrupt decline back to normal activity. However, we want to emphasize that the radiant of the Perseids was below 30 degrees above the horizon for all observers (unfortunately no visual data are available from Tukkers / Nijland in Romania; see Video observations, below). Moreover, all observations from the Netherlands had to deal with astronomical twilight (see Table 3, page 153) until at least $21^{\mathrm{h}}45^{\mathrm{m}}$ UT ($\lambda_{\odot} = 139\overset{\circ}{.}47$). Some observers in the Netherlands were not quite convinced about higher activity while, conversely, for their foreign-based DMS-colleagues higher activity was immediately very obvious.

When we remember that the peak mainly contained faint meteors, it is clear that observers in the Netherlands simply missed most of them because of twilight. Some observers saw higher activity of the Perseids at solar longitude $139\overset{\circ}{.}6$ too, as mentioned by Arlt (2004).

#### 2.1 Population index

The observers were surprised by the occurrence of numerous bright Perseids after $22^{\mathrm{h}}00^{\mathrm{m}}$ UT, making this night a very worthwhile one to observe. We split up the visual results in two periods: before $22^{\mathrm{h}}00^{\mathrm{m}}$ UT, and after.

In Table 1 we present the calculated population index (using the magnitude interval $[-2{:}5]$ ) for these periods for two 'types' of observers: Dutch and German.

*Table 1* – $r$-values of the Perseids before and after $22^{\mathrm{h}}00^{\mathrm{m}}$ UT for observers in Germany ($r_{\mathrm{D}}$) and the Netherlands ($r_{\mathrm{NL}}$)

| Period $\leq 22^{\mathrm{h}}00^{\mathrm{m}}$ UT | $r$ | Period $> 22^{\mathrm{h}}00^{\mathrm{m}}$ UT | $r$ |
|---|---|---|---|
| $r_{\mathrm{D}}$ | 3.01 | $r_{\mathrm{D}}$ | 2.35 |
| $r_{\mathrm{NL}}$ | 2.4 | $r_{\mathrm{NL}}$ | 2.11 |
| Difference | 0.61 | Difference | 0.24 |

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[2] Schiefestrasse 36, 48599 Gronau, Germany. Email: c.johannink@t-online.de

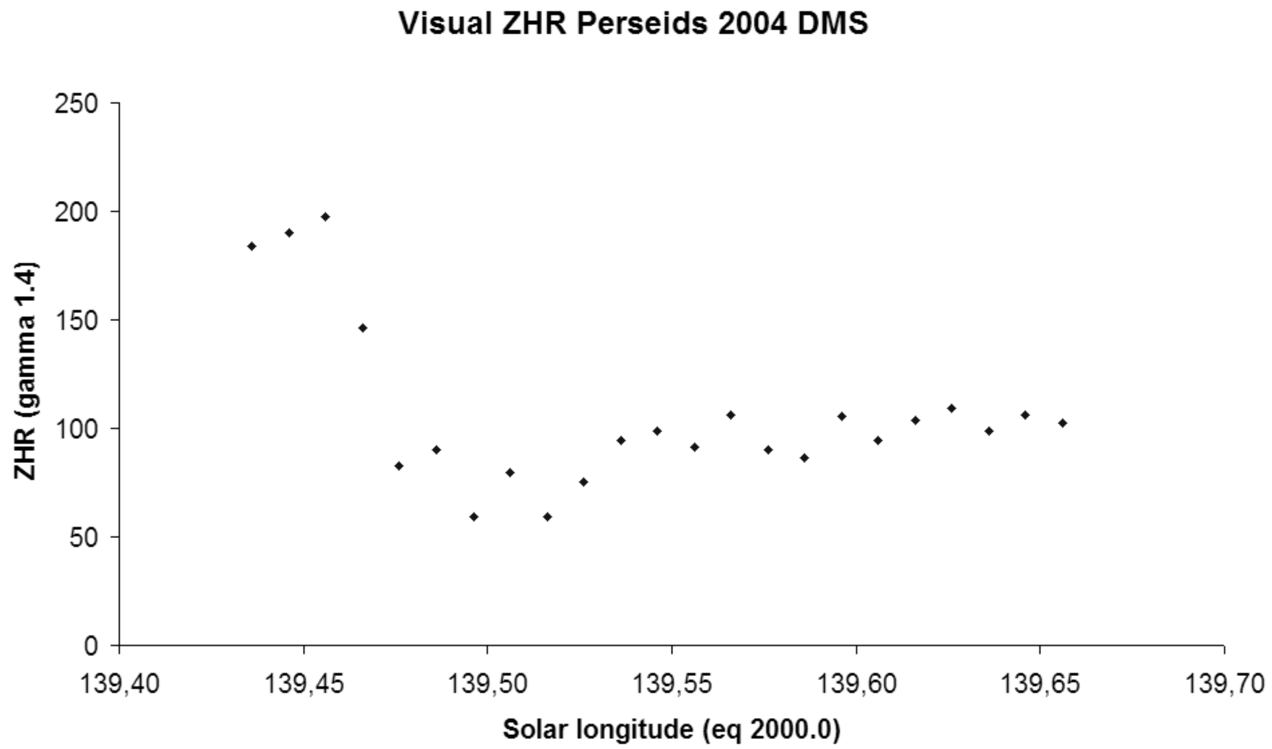


*Figure 1* – Visual ZHRs based on observations from Table 2.

From this Table we see a great difference in $r$ between Dutch (NL) and German (D) observers before $22^{h}00^{m}$ UT. The fact mentioned above, that twilight made it impossible for most Dutch observers to see the peak in full strength, could explain this difference.

After $22^{h}00^{m}$ UT the difference is much smaller, with $r$ around or even a bit below normal (i.e. brighter meteors) and clearly below the values observed prior to $22^{h}00^{m}$ UT.

## 3 Video observations

As mentioned earlier video observations were conducted from three different locations in Germany, Romania and the Netherlands listed in Table 3. All observers at these stations made use of image intensified video systems of which the technical characteristics are described in Table 4 (page 154).

Between $20^{h}07^{m}$ and $00^{h}27^{m}$ UT, Romke Schievink carried out video observations from Britzingen. The video was pointing continuously towards the radiant. The images were analyzed by Carl Johannink in the days following the maximum. The higher amount of Perseids around $21^{h}00^{m}$ UT was clearly visible. We decided to take a closer look at the period $20^{h}45^{m}$ – $21^{h}20^{m}$ UT. Therefore Romke Schievink made a copy of the period $20^{h}42^{m}$ – $21^{h}19^{m}$ UT on his PC. He then duplicated this fragment twice and overlaid the three fragments, but shifted each of them one frame with respect to the other. Following this he gave each of them a 'transparency' of 33%, in order to get an 'average' of these three fragments. (The same technique is used by WEBCAM astronomy, and is a variant of 'stacking'.) This resulted in a much more 'stabilized' view, and, as another advantage, every meteor lasted two frames longer. Both effects made it easier to pick up meteors from the screen.

Romke Schievink and Carl Johannink simultaneously scanned the whole period from $20^{h}42^{m}$ until $21^{h}19^{m}$ UT twice, more than doubling the number of meteors during this interval: 52 meteors.

In Romania, Jos Nijland and Casper ter Kuile set up image intensified video systems at Darmanesti and Corbasca respectively in order to obtain orbital elements from simultaneously filmed Perseid meteors. Unfortunately the Darmanesti station appeared to be clouded out on August 11/12 so no multistation Perseids could be obtained.

In Corbasca the sky appeared to be clear except from the passage of a small cloud in the interval from about $20^{h}52^{m}$ until $21^{h}02^{m}$ UT. The video system at Corbasca was operated from $19^{h}30^{m}$ until $21^{h}30^{m}$ UT when 176 meteors were filmed. 143 Perseids were filmed in the interval from $20^{h}30^{m}$ until $21^{h}30^{m}$. The aiming point at $18^{h}00^{m}$ UT for this video system was located in Corona Borealis.

Last but not least, Robert Haas made observations from Biddinghuizen in the Netherlands between $20^{h}27^{m}$ and $21^{h}32^{m}$ UT. He captured 47 meteors with his video aimed at Cassiopeia.

We used these data to produce Figure 2.

The length of the interval (bin) was calculated from the amount of minutes and the number of meteors observed using a number of statistical 'rules of thumb'. We computed the bin to be 5 minutes taking the total number of observed meteors and the observation interval into account. A sliding mean period of one minute

*Table 2* – Total observing time ($T_{\rm eff}$), number of Perseids ($N_{\rm per}$), other streams and sporadics ($N_{\rm oth}$), and total numbers ($N_{\rm tot}$) of all DMS observers who participated in the Perseid campaign during 2004 August 11/12. $L$ is Longitude (East) and $\phi$ is Latitude (North), both in degrees. Country abbreviations: D = Germany, E = Spain, NL = the Netherlands.

| Observer | Location | $L$ | $\phi$ | Period (UT) | IMO code | $T_{\rm eff}$ | $N_{\rm per}$ | $N_{\rm oth}$ | $N_{\rm tot}$ |
|---|---|---|---|---|---|---|---|---|---|
| Jean Marie Biets | Aznalcazar, E | -5.2 | 7.2 | $20^{\rm h}25^{\rm m}$–$04^{\rm h}15^{\rm m}$ | BIEJE | 7.61 | 183 | 29 | 212 |
| Sietse Dijkstra | Poio, Portugal | -8.2 | 37.2 | $20^{\rm h}45^{\rm m}$–$04^{\rm h}38^{\rm m}$ | DIJSI | 5.35 | 335 | 28 | 363 |
| Carl Johannink | Britzingen, D | 7.4 | 47.5 | $20^{\rm h}15^{\rm m}$–$02^{\rm h}00^{\rm m}$ | JOHCA | 5.25 | 251 | 70 | 321 |
| Marco Langbroek | Biddinghuizen, NL | 5.4 | 52.2 | $20^{\rm h}33^{\rm m}$–$00^{\rm h}30^{\rm m}$ | LANMA | 3.61 | 182 | 41 | 223 |
| Koen Miskotte | Britzingen, D | 7.4 | 47.5 | $20^{\rm h}20^{\rm m}$–$02^{\rm h}03^{\rm m}$ | MISKO | 5.00 | 359 | 83 | 442 |
| Remco Scheepmaker | Lattrop, NL | 7.0 | 52.4 | $20^{\rm h}30^{\rm m}$–$02^{\rm h}15^{\rm m}$ | SCHRE | 4.74 | 211 | 29 | 240 |
| Alex Scholten | Bussloo, NL | 6.1 | 52.2 | $20^{\rm h}20^{\rm m}$–$00^{\rm h}00^{\rm m}$ | SCHAL | 5.33 | 174 | 32 | 206 |
| Peter van Leuteren | Lattrop, NL | 7.0 | 52.4 | $20^{\rm h}15^{\rm m}$–$02^{\rm h}15^{\rm m}$ | LEUPE | 4.90 | 232 | 26 | 258 |
| Daniel van Os | Lattrop, NL | 7.0 | 52.4 | $20^{\rm h}15^{\rm m}$–$02^{\rm h}15^{\rm m}$ | OSVDA | 5.08 | 274 | 35 | 309 |
| Michel Vandeputte | Reillane, France | 5.7 | 44.0 | $20^{\rm h}30^{\rm m}$–$03^{\rm h}20^{\rm m}$ | PUTMI | 7.16 | 624 | 95 | 719 |
| Rita Verhoef | Britzingen, D | 7.4 | 47.5 | $20^{\rm h}05^{\rm m}$–$01^{\rm h}45^{\rm m}$ | VERRI | 5.33 | 263 | 47 | 310 |

*Table 3* – Stations at which image intensified video systems were operated and essential astronomical data in the Perseids campaign during 2004 August 11/12.

| Station<br>Country | Biddinghuizen<br>the Netherlands | Britzingen<br>Germany | Corbasca<br>Romania |
|---|---|---|---|
| Longitude | 52°27′ | 47°50′ | 46°16′ |
| Latitude | 05°42′ | 07°40′ | 27°10′ |
| Civil twilight ends | $19^{\rm h}49^{\rm m}$ | $19^{\rm h}23^{\rm m}$ | $18^{\rm h}03^{\rm m}$ |
| Nautical twilight ends | $20^{\rm h}40^{\rm m}$ | $20^{\rm h}06^{\rm m}$ | $18^{\rm h}44^{\rm m}$ |
| Astronomical twilight ends | $21^{\rm h}45^{\rm m}$ | $20^{\rm h}56^{\rm m}$ | $19^{\rm h}31^{\rm m}$ |
| Radiant elevation at $21^{\rm h}00^{\rm m}$ UT | 29° | 29° | 33° |

was used to smooth the statistical scatter. The observed number of meteors has been corrected for radiant height only, using the factor $\sin^{-1.0}(h)$ to get a 'video ZHR'. In these plots the higher activity around $21^{\rm h}00^{\rm m}$ UT is clearly visible for each station.

More information regarding the image intensified video measurements is presented in the proceedings of IMC 2004 (ter Kuile, 2004).

## 4 Conclusion

In both visual and video data the Perseid return of 2004 showed up with a peak of faint meteors on August 11 around $21^{\rm h}00^{\rm m}$ UT as predicted by Lyytinen et al. (2004).

## Acknowledgments

Thanks to all observers for their data and to Marco Langbroek and Casper ter Kuile for their comments on this article. Special thanks also to our Romanian friends from SARM (Valentin Grigore et al.) who made the stay in Romania so pleasant.

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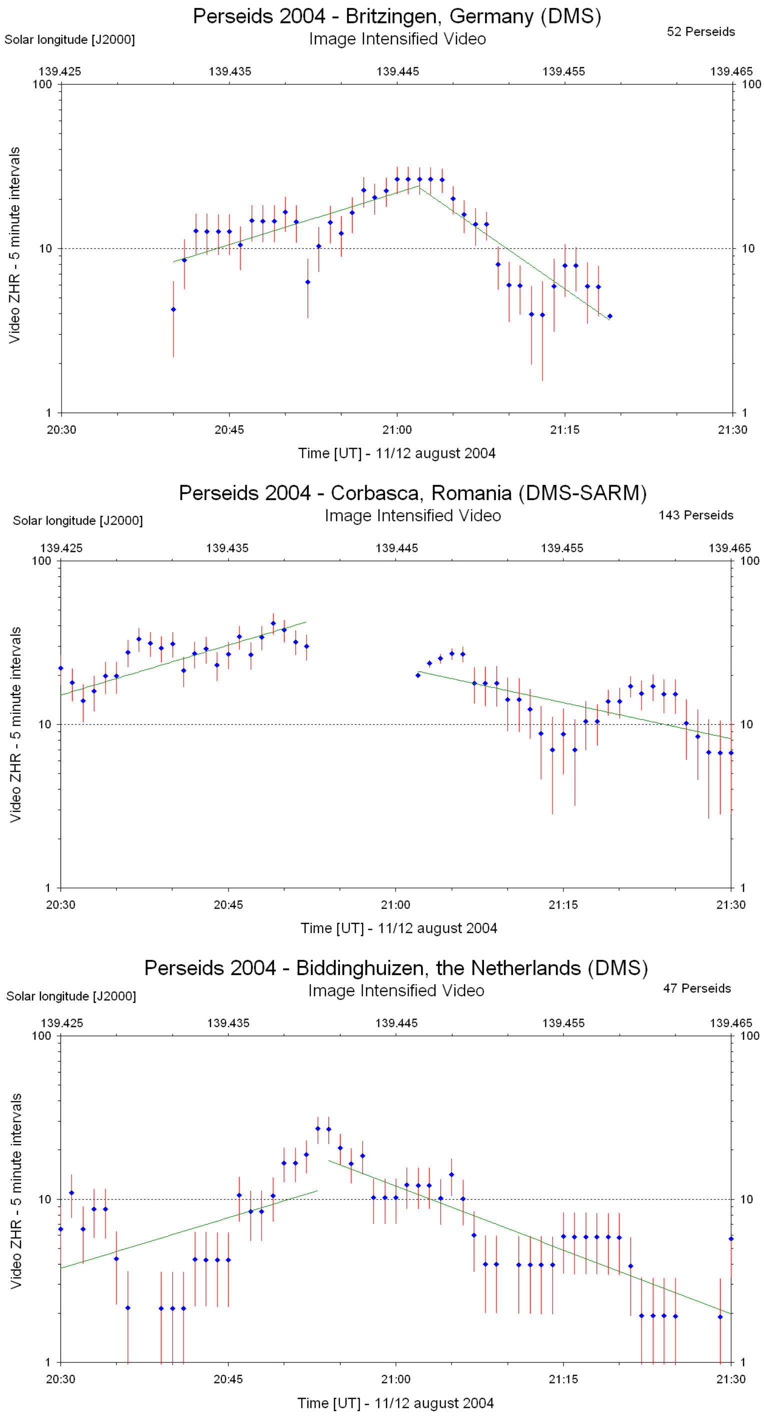


*Figure 2* – Video results. Stations — top: Britzingen, middle: Corbasca, bottom: Biddinghuizen.

*Table 4* – Technical characteristics of image intensified video systems applied on the Perseids campaign on 2004 August 11/12.

| | Biddinghuizen<br>the Netherlands | Britzingen<br>Germany | Corbasca<br>Romania |
|---|---|---|---|
| Optics | Canon<br>$f = 135$ mm $f/2.0$<br>FOV $= 12°$ | Sony V-mount<br>$f = 25$ mm $f/2.8$<br>FOV $= 35°$ | Canon<br>$f = 55$ mm $f/1.2$<br>FOV $= 35°$ |
| Image Intensifier | XX1332<br>2nd generation<br>Mullard | Delnocta<br>1st generation<br>OlDelft Instruments | XX1332<br>2nd generation<br>Mullard |
| Camcorder | Panasonic<br>NV-DA1 | Sony<br>DCR-TRV900E PAL | Panasonic<br>NV-DA1 |

# Bulletin 20 of the International Leonid Watch
# Global analysis of the 2004 Leonids

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An analysis of visual observations of the 2004 Leonid meteor shower is presented. The shower was weakly active, and a total of 1650 Leonids were recorded during an observing time of $262^{\rm h}.17$. A background activity ZHRs of 20–30 with a maximum of ZHR $= 30 \pm 3$ is found for the period between $235^\circ.5$ and $238^\circ.0$ solar longitude (2004 Nov 17, $14^{\rm h}$–Nov 20, $02^{\rm h}$ UT). Two times of enhanced rates appear to be significant. The first reaches a ZHR of $37 \pm 4$ at $\lambda_\odot = 235^\circ.8 \pm 0.1$ (Nov 17, $21^{\rm h}$ UT). The second peak has a ZHR of $26 \pm 3$ at $\lambda_\odot = 237^\circ.95 \pm 0.03$ (Nov 20, $00^{\rm h}10^{\rm m}\pm 40$ m UT). Additionally, the temporal variation of the population index shows a significantly increased value (large fraction of faint meteors) of $2.5 \pm 0.2$ at that time. This peak falls about 2.5 h after the predicted encounter time of the 1733 dust trail of the Leonids.

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## 1 Overview

The Leonid meteor shower has played a key role in giving shower maximum predictions in 1999–2003. Numerical computer simulations of the evolution of individual dust trails ejected at various perihelion passages of the parent Comet 55P/Tempel-Tuttle led to fairly precise predicted peak times.

The year 2004 was special in that the youngest dust trail encountered had already completed eight revolutions around the Sun. The predicted encounter time for this trail ejected in 1733 was Nov 19, $21^{\rm h}49^{\rm m}$ UT according to Vaubaillon et al. (2004), or $21^{\rm h}26^{\rm m}$ UT according to M. Sato (2004). Predictions of the activity level are more difficult and resulted in a "mediocre peak" (Sato), ZHR $= 65$ (Vaubaillon et al.) and ZHR $=$ 26 (Meng).

Additional predictions were given for the 20-revolution trail ejected from the Comet in 1333. The encounter times were Nov 19, $6^{\rm h}39^{\rm m}$ UT (M. Sato) or $6^{\rm h}42^{\rm m}$ UT (Vaubaillon et al.) with low-level ZHRs of the order of 10.

The most peculiar prediction concerned the dust trail ejected in 1001 having orbited the Sun 30 times. Vaubaillon et al. give an encounter time of Nov 8, $23^{\rm h}30^{\rm m}$ UT, very early before the passage of the Comet's orbit. This was recomputed by D. Asher and led to Nov 8, $23^{\rm h}38^{\rm m}$ UT. The trail was not found to be close to the Earth by M. Sato and was expected to show faint meteors.

The observational results sent to the IMO include 1650 Leonid meteors seen during $262^{\rm h}.17$ observing time from 26 countries in Australia, Asia, Europe, and the Americas. Observing reports were submitted by the following observers, to whom we are very grateful:

Harshad Abhyankar (`ABHHA`, $2^{\rm h}.00$, 7), Puya Ahmadifard (`AHMPU`, $0^{\rm h}.83$, 0), Alexandre Amorim (`AMOAL`, $1^{\rm h}.33$, 0), Karl Antier (`ANTKA`, $0^{\rm h}.40$, 0), Lars Bakmann (`BAKLA`, $2^{\rm h}.00$, 1), Ricardas Balciunas (`BALRC`, $1^{\rm h}.00$, 3), Geert Barentsen (`BARGE`, $1^{\rm h}.32$, 1), Luc Bastiaens (`BASLU`, $1^{\rm h}.27$, 1), Peter V. Bias (`BIAPE`, $1^{\rm h}.07$, 11), Kristiaan Bonjean (`BONKR`, $2^{\rm h}.26$, 6), Andreas Buchmann (`BUCAN`, $2^{\rm h}.16$, 7), Vladimir Burgić (`BURVL`, $5^{\rm h}.10$, 35), Marianne Busschots (`BUSMA`, $2^{\rm h}.85$, 9), Tibor Csörgei (`CSOTI`, $0^{\rm h}.66$, 16), Sarthak Dasadia (`DASSA`, $4^{\rm h}.50$, 23), Charuta Deshpande (`DESCA`, $1^{\rm h}.41$, 10), Shrikant Dhumal (`DHUSH`, $1^{\rm h}.00$, 10), David Dickinson (`DICDA`, $0^{\rm h}.71$, 5), Sietse Dijkstra (`DIJSI`, $2^{\rm h}.73$, 17), Jelena Djuricin (`DJUJE`, $4^{\rm h}.77$, 28), Lucio Furlanetto (`FURLU`, $1^{\rm h}.82$, 16), Lalit Garg (`GARLA`, $4^{\rm h}.87$, 9), Benny Geys (`GEYBE`, $2^{\rm h}.95$, 8), Maarten Gillis (`GILMA`, $1^{\rm h}.95$, 5), George W. Gliba (`GLIGE`, $2^{\rm h}.00$, 7), Madhura Gokhale (`GOKMA`, $1^{\rm h}.00$, 7), Robin Gray (`GRARO`, $3^{\rm h}.00$, 1), Pavol Habuda (`HABPA`, $2^{\rm h}.84$, 22), Amir Hassanzadeh (`HASAM`, $1^{\rm h}.33$, 1), Takema Hashimoto (`HASTA`, $5^{\rm h}.17$, 16), Roberto Haver (`HAVRO`, $1^{\rm h}.78$, 2), Davood Hemati (`HEMDA`, $1^{\rm h}.83$, 3), Veli-Pekka Hentunen (`HENVE`, $2^{\rm h}.36$, 11), Kamil Hornoch (`HORKM`, $6^{\rm h}.15$, 27), Greg Hudson (`HUDGR`, $2^{\rm h}.00$, 7), Carl Johannink (`JOHCA`, $1^{\rm h}.45$, 2), Ashwini Kadam (`KADAS`, $4^{\rm h}.87$, 8), Ajinkya Shrish Kamat (`KAMAJ`, $5^{\rm h}.49$, 21), Jay Kansara (`KANJA`, $4^{\rm h}.18$, 24), Jakub Kapuš (`KAPJP`, $1^{\rm h}.98$, 6), Martin Kapuš (`KAPMP`, $2^{\rm h}.32$, 15), Jitendra Karekar (`KARJI`, $3^{\rm h}.90$, 25), Srdjan Keca (`KECSR`, $7^{\rm h}.73$, 63), Harshad Khaladkar (`KHAHA`, $4^{\rm h}.67$, 82), Soheil Khoshbin Far (`KHOSO`, $0^{\rm h}.92$, 4), Ralf Koschack (`KOSRA`, $1^{\rm h}.22$, 0), Richard Kramer (`KRARI`, $0^{\rm h}.53$, 0), Mayuri Kulkarni (`KULMR`, $1^{\rm h}.05$, 1), Rhishikesh Kulkarni (`KULRH`, $2^{\rm h}.83$, 18), Adrian Lelyen (`LELAD`, $1^{\rm h}.27$, 7), Peter van Leuteren (`LEUPE`, $1^{\rm h}.54$, 1), Michael Linnolt (`LINMI`, $0^{\rm h}.25$, 2), Ming-hui Liang (`LINMN`, $10^{\rm h}.77$, 126), Robert Lunsford (`LUNRO`, $9^{\rm h}.83$, 104), Qiang Ma (`MA QI`, $4^{\rm h}.00$, 49), Sheetal Mantri (`MANSH`, $4^{\rm h}.60$, 21), Adam Marsh (`MARAD`, $3^{\rm h}.67$, 13), Grigoris Maravelias (`MARGE`, $4^{\rm h}.47$, 40), Pierre Martin (`MARPI`, $3^{\rm h}.92$, 36), Mikhail Maslov (`MASMI`, $6^{\rm h}.23$, 29), Alastair McBeath (`MCBAL`, $6^{\rm h}.50$, 26), Norman McLeod (`MCLNO`, $0^{\rm h}.50$, 3), Huan Meng (`MENHU`, $0^{\rm h}.63$, 6), Ivica Mihaljevic (`MIHIV`, $3^{\rm h}.49$, 25), Koen Miskotte (`MISKO`, $1^{\rm h}.17$, 1), Amruta Modani (`MODAM`, $1^{\rm h}.00$, 1), Francisco Munoz (`MUNFR`, $0^{\rm h}.30$, 1), Markku Nissinen (`NISMA`, $1^{\rm h}.10$, 4), Jens O. Olesen (`OLEJE`, $0^{\rm h}.50$, 0), Carles Pineda Ferré (`PINCA`, $1^{\rm h}.08$, 3), Nilesh Puntambekar (`PUNNI`, $2^{\rm h}.50$, 21), Pulin Raje (`RAJPU`, $1^{\rm h}.25$, 11), Jürgen Rendtel (`RENJU`, $7^{\rm h}.56$, 25), Branislav Savic (`SAVBR`, $8^{\rm h}.65$, 76), Nikhil Sharma (`SHANI`, $1^{\rm h}.00$, 12), Nastassia Smeets (`SMENA`, $2^{\rm h}.93$, 13), George Spalding (`SPAGE`, $1^{\rm h}.00$, 7), Leo Stachowicz (`STALE`, $1^{\rm h}.83$, 16), Wesley Stone (`STOWE`, $5^{\rm h}.50$, 64), Ouyang Tianjing (`TIAOU`, $1^{\rm h}.50$, 19), Shigeo Uchiyama (`UCHSH`, $5^{\rm h}.76$, 26), Koen van Gorp (`VANKE`, $1^{\rm h}.03$, 1), Michel Vandeputte (`VANMC`, $8^{\rm h}.78$, 51), Erlien Vázquez Álvarez (`VAZER`, $0^{\rm h}.30$, 1), Valentin Velkov (`VELVA`, $3^{\rm h}.69$, 53), Cis Verbeeck (`VERCI`, $1^{\rm h}.03$, 1), Jan Verbert (`VERJN`, $2^{\rm h}.74$, 11), Nilesh Wani (`WANNI`, $1^{\rm h}.00$, 4), Yi Wang (`WANYY`, $2^{\rm h}.10$, 28), Hao Wu (`WU HA`, $1^{\rm h}.16$, 7), Yu Xun (`XUNYU`, $2^{\rm h}.22$, 30), Quanzhi Ye (`YE QU`, $3^{\rm h}.23$, 33), Ilkka Yrjölä (`YRJIL`, $1^{\rm h}.04$, 4), Menglin Zhang (`ZHAME`, $1^{\rm h}.58$, 11), and Jin Zhu (`ZHUJI`, $2^{\rm h}.40$, 26).

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The observer code, the effective observing time, and the number of Leonids are given in brackets. A few of the observers have actually seen no Leonids at all; nonetheless, their contribution is appreciated since negative detections of Leonids are also relevant in the study of the 2004 Leonids. The observations cover the countries

> Australia, Belgium, Brasil, Bulgaria, Canada, China, Cuba, Czech Republic, Denmark, Finland, France, Germany, Greece, India, Iran, Italy, Japan, Lithuania, the Netherlands, Russia, Serbia, Slovakia, Spain, Switzerland, the UK, and the USA.

This paper will first deal with the computation of the population index of the Leonid meteor shower, as a function of time. The population index is denoted by $r$ and basically measures the ratio of faint meteors to bright meteors. The value of $r$ is necessary to apply a correction of meteor observations to a standard limiting magnitude of +6.5. If $r$ is large, a considerable fraction of faint meteors may be lost when observing under conditions with a stellar limiting magnitude of lm < +6.5. The population index thus serves two purposes: it can be translated into the mass index of the particle distribution within the Leonid meteoroid stream, and it is needed for the activity estimates of the Leonid shower. The profile will be given in Section 2.

The activity of the shower is expressed in terms of the Zenithal Hourly Rate (ZHR) which is based on a stellar limiting magnitude of +6.5 and a radiant elevation of 90° above the horizon. The resulting ZHR profiles will be shown in Section 3.

## 2 The population index profile

The determination of the population index of the Leonid meteor shower follows the algorithm described in (Arlt, 2003). The average magnitude distance from the limiting magnitude is a unique function of $r$. The population index is found using a finely spaced version of Table 2 in (Arlt, 2003).

The averaging algorithm employs an adaptive bin size; large time bins are used for periods with few observing records, and small bins are used where observations are numerous.

The number of observed Leonid meteors remained low compared with the previous years 1998–2003. A very detailed profile of the population index with a resolution of less than an hour is thus not possible. The adaptive-bin-size algorithm tries to compile 100 Leonids in one average. Maximum and minimum time span allowed for this collection are 1° and $0\overset{\circ}{.}1$ in solar longitude respectively.

The population index profile obtained from this way of averaging is shown in Figure 1. The first two values have next to no meaning as only 23 Leonids with magnitude estimates were available for the time before $\lambda_\odot = 232°$. They are given for reasons of completeness. A tabular compilation of the result is given in Table 1.

Given the predictions of dust trail encounters in 2004, a closer look for peculiar features in the $r$-profile is certainly interesting. A very sharp peak in $r$ near $\lambda_\odot = 238°$ is found. Before the significance of such a feature is taken for granted, the actual data contributing to the averages should be scrutinized. The value of $r = 2.00$ of $\lambda_\odot = 237\overset{\circ}{.}84$ is obtained from 21 different observers from China, India, Iran, Finland, Slovakia, and the Czech Republic. The Europeans of them provided small meteor numbers as the radiant was still low in the sky. The high population index of $r = 2.49$ at $\lambda_\odot = 237\overset{\circ}{.}96$ (Nov 20, $0^{\rm h}20^{\rm m}$ UT) is based on data by 15 different observers from India, Finland, Greece, Serbia, Slovakia, the Czech Republic, and the UK. Out of the 140 Leonids, 35 were seen from India, at a high radiant elevation, while the rest were seen from Europe.

A resampled set of averages was obtained with averaging periods different from those of Table 1 and is shown in Table 2. The population index peak is now present with a maximum of $r = 2.36$. The $r$-peak is not an effect of unlucky sampling. We conclude that the Leonids exhibited a high population index of $r = 2.5 \pm 0.2$ on Nov 20, most likely between $0^{\rm h}00^{\rm m}$and $0^{\rm h}30^{\rm m}$ UT. At that time, the fraction of faint meteors was increased compared to the surrounding periods of time.

The other high value of $r = 2.39$ at $\lambda_\odot = 236\overset{\circ}{.}68$ in Table 1 is also an interesting feature, although less significant judging from the error margins. It is definitely not a signature of the a rapid radiant height change in the sequence of observations. It is based on a longer

*Table 1* – Numerical data of the population index variation of the 2004 Leonid meteor shower.

| $\lambda_\odot$ (J2000.0) | $n_{\rm Int}$ | $n_{\rm LEO}$ | $r$ |
|---|---|---|---|
| $226\overset{\circ}{.}863$ | 9 | 13 | $3.02 \pm 1.92$ |
| $230\overset{\circ}{.}452$ | 3 | 10 | $2.14 \pm 1.16$ |
| $234\overset{\circ}{.}572$ | 10 | 60 | $2.32 \pm 0.29$ |
| $235\overset{\circ}{.}606$ | 12 | 105 | $2.02 \pm 0.15$ |
| $235\overset{\circ}{.}938$ | 8 | 116 | $1.92 \pm 0.13$ |
| $236\overset{\circ}{.}681$ | 7 | 121 | $2.39 \pm 0.21$ |
| $236\overset{\circ}{.}967$ | 31 | 101 | $2.16 \pm 0.18$ |
| $237\overset{\circ}{.}078$ | 21 | 107 | $2.13 \pm 0.17$ |
| $237\overset{\circ}{.}391$ | 4 | 107 | $1.87 \pm 0.12$ |
| $237\overset{\circ}{.}637$ | 12 | 112 | $1.91 \pm 0.13$ |
| $237\overset{\circ}{.}835$ | 22 | 175 | $2.00 \pm 0.11$ |
| $237\overset{\circ}{.}959$ | 27 | 140 | $2.49 \pm 0.21$ |
| $238\overset{\circ}{.}032$ | 13 | 103 | $2.16 \pm 0.18$ |
| $238\overset{\circ}{.}988$ | 10 | 57 | $2.21 \pm 0.27$ |

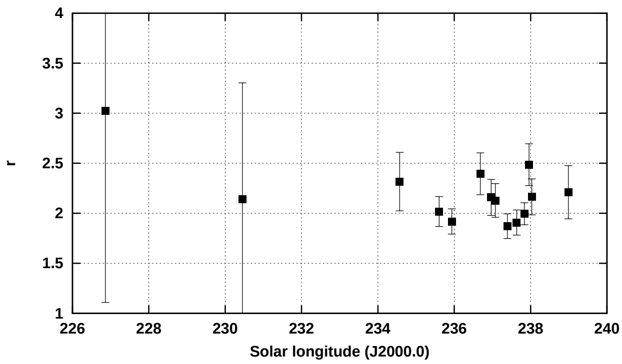


*Figure 1* – Population index profile of the 2004 Leonids.

*Table 2* – Resampled population index variation of the 2004 Leonid meteor shower of Nov 19/20.

| $\lambda_\odot$ (J2000.0) | $n_{\rm Int}$ | $n_{\rm LEO}$ | $r$ |
|---|---|---|---|
| 237°.788 | 12 | 115 | $1.89 \pm 0.12$ |
| 237°.847 | 19 | 110 | $2.08 \pm 0.16$ |
| 237°.948 | 24 | 124 | $2.36 \pm 0.20$ |
| 238°.014 | 14 | 100 | $2.26 \pm 0.20$ |
| 238°.411 | 8 | 70 | $2.24 \pm 0.24$ |

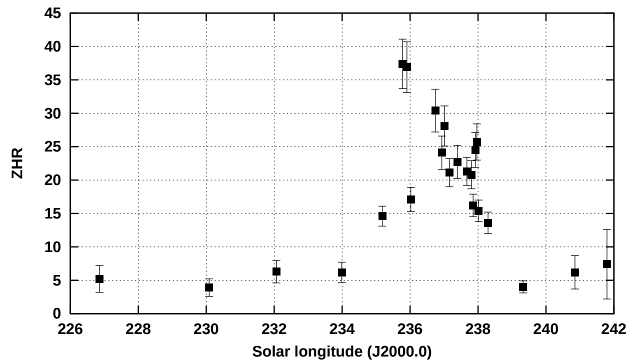


*Figure 2* – ZHR profile of the 2004 Leonid meteor shower.

*Table 3* – ZHR profile of the 2004 Leonids. The value of $n_{\rm Int}$ refers to the number of individual observing periods involved in the average ZHR, $n_{\rm LEO}$ refers to the number of Leonid meteor. lm is the mean limiting magnitude.

| $\lambda_\odot$ (J2000.0) | $n_{\rm Int}$ | $n_{\rm LEO}$ | ZHR | lm |
|---|---|---|---|---|
| 226°.856 | 12 | 6 | $5.2 \pm 2.0$ | 6.28 |
| 230°.086 | 5 | 8 | $3.9 \pm 1.3$ | 6.63 |
| 232°.063 | 3 | 13 | $6.3 \pm 1.7$ | 6.28 |
| 233°.988 | 8 | 16 | $6.2 \pm 1.5$ | 5.87 |
| 235°.178 | 19 | 90 | $14.6 \pm 1.5$ | 6.01 |
| 235°.778 | 9 | 99 | $37.4 \pm 3.7$ | 5.59 |
| 235°.906 | 27 | 91 | $36.9 \pm 3.8$ | 5.68 |
| 236°.021 | 28 | 88 | $17.1 \pm 1.8$ | 5.93 |
| 236°.739 | 10 | 91 | $30.4 \pm 3.2$ | 5.74 |
| 236°.935 | 37 | 93 | $24.1 \pm 2.5$ | 5.69 |
| 237°.013 | 19 | 89 | $28.1 \pm 3.0$ | 5.92 |
| 237°.154 | 15 | 99 | $21.1 \pm 2.1$ | 5.76 |
| 237°.390 | 5 | 79 | $22.7 \pm 2.5$ | 6.49 |
| 237°.670 | 9 | 99 | $21.3 \pm 2.1$ | 6.29 |
| 237°.802 | 17 | 97 | $20.8 \pm 2.1$ | 5.81 |
| 237°.853 | 24 | 87 | $16.2 \pm 1.7$ | 5.42 |
| 237°.917 | 21 | 88 | $24.5 \pm 2.6$ | 5.51 |
| 237°.965 | 32 | 91 | $25.7 \pm 2.7$ | 5.76 |
| 238°.017 | 24 | 98 | $15.4 \pm 1.6$ | 6.10 |
| 238°.294 | 18 | 70 | $13.6 \pm 1.6$ | 5.90 |
| 239°.327 | 7 | 19 | $4.0 \pm 0.9$ | 6.49 |
| 240°.854 | 3 | 5 | $6.2 \pm 2.5$ | 5.50 |
| 241°.794 | 1 | 1 | $7.4 \pm 5.2$ | 5.00 |

averaging period comprising data by Chinese, Russian, UK, and US observers watching the Leonids at various radiant elevations.

## 3 ZHR profile

Observations are weighted by the total correction and effective observing time, hence

$$\overline{\rm ZHR} = \frac{1 + \sum\limits_{i=1}^{N} n_i}{\sum\limits_{i=1}^{N} T_{{\rm eff},i}/C_i}, \qquad (1)$$

where $N$ is the number of individual observing periods whose middle solar longitude fall into the window of averaging. This middle is corrected for topocentric encounter of the Leonid stream as described by McNaught & Asher (1999). The $n_i$ are the individual Leonid numbers, $T_{{\rm eff},i}$ are the individual effective observing times, and $C_i$ are the total corrections for each period consisting of $C = r^{6.5-{\rm lm}} F/\sin h_{\rm R}$ depending on the population index $r$ from Section 2, the stellar limiting magnitude lm, the field obstruction factor $F$, and the radiant elevation $h_{\rm R}$.

The adaptive-bin-size procedure assumes an optimum meteor number of 100 Leonids per average. The bin-width is then varied between 1° and 0°.01 in solar longitude, corresponding to roughly 1 day and 15 minutes, respectively. Because of the small number of observations available, the selection criteria were not very tight: a maximum total correction by lm, clouds, and radiant height of $C_i = 8$ was allowed, and a minimum radiant height of 10° was required.

The most striking feature of the ZHR profile is the peak at $\lambda_\odot = 235°.8$ (about Nov 17, 21$^{\rm h}$ UT) exhibiting the maximum ZHR of the entire profile with ZHR = 37. Upon scrutinizing the data behind this peak, a new observer from India is found (Harshad Khaladkar) who contributes a lot to the two high averages. A ZHR profile without this observer, however, still shows a peak ZHR of 30 at that time.

The closest approach to the orbit of the parent comet, 55P/Tempel-Tuttle, occurs at $\lambda_\odot = 235°.27$. Now, as we are not facing spectacular dust trail encounters anymore, we should bear in mind that the Leonids have an annual background activity, also observed long before 1998. The particular moment of orbital approach is not well covered by observations in 2004, but all we see after $\lambda_\odot = 235°.5$ may be the decline of activity after the orbital approach. If that is what Figures 2 and 3 show, the question might be why there is such a *low* value of ZHR = 17 at $\lambda_\odot = 236°.0$. Radiant height effects are not very likely to play a role here, since all three values – 37.4, 36.9, and 17.1 – are based on observations with radiant height of 24°–64°, 22°–67°, and 30°–65°, respectively. So the ZHR of 37 seems to be a short-lived activity peak.

Regarding the 30-rev dust trail, the individual observations of the night Nov 8/9 are given in Table 4. Observations which are not used for the average in Table 3 and Figure 2 are marked with '×'. But actually, if all these 29 observations are used for the average, the result is ZHR = $6.7 \pm 1.7$ and is not significantly dif-

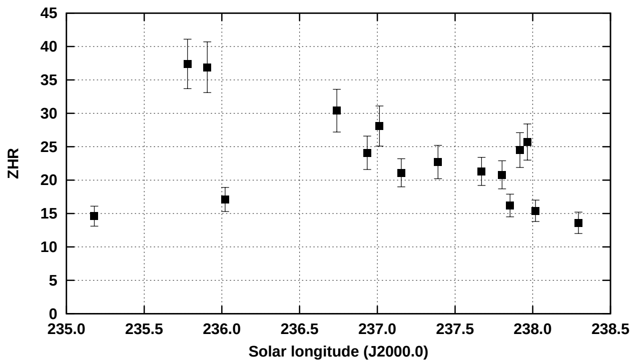


*Figure 3* – Detail of the 2004 Leonid ZHRs.

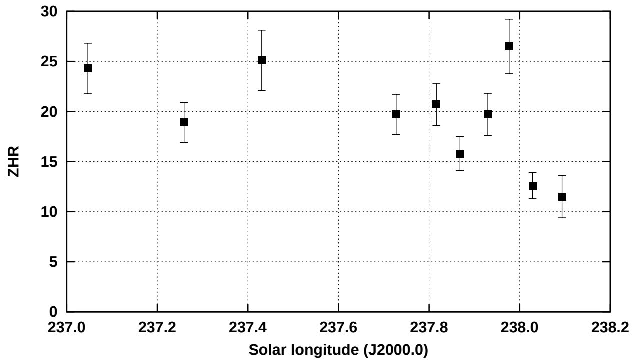


*Figure 4* – Crude ZHR profile of the 2004 Leonids neglecting $r$-value variations. The peak near $\lambda_\odot = 238°$ is not a pure result of the population index peak of Figure 1.

ferent from the value of Table 3. The weighting by the total correction factor through Eq. (1) is effective with a tendency of bad-condition observations to overestimate the ZHR. Splitting these 18 Leonids into a profile is obviously useless. Whether there was a peak caused by the 30-rev trail can only be answered with observations from Asia which are not available.

We conclude that there was a level of background activity of about 20–30 in terms of ZHRs during the entire period of $\lambda_\odot = 235\overset{\circ}{.}5$ to $\lambda_\odot = 238\overset{\circ}{.}0$. Two significant maxima are superimposed. Apart from these two maxima, the curve is broad with a maximum of ZHR $= 30 \pm 3$ at $\lambda_\odot = 236\overset{\circ}{.}7^{+0.1}_{-0.6}$. The first of the two individual maxima occurred at $\lambda_\odot = 235\overset{\circ}{.}8$ with ZHR $= 37 \pm 4$. That maximum does not coincide with a notable feature in the population index profile, $r$ is very near 2.0. The second maximum occurred at $\lambda_\odot = 237\overset{\circ}{.}95$ with ZHR $= 26 \pm 3$ and has a duration of 2 hours. This duration may be overestimated as the relatively few observations do not allow a higher resolution in the ZHR profile. The average ZHRs have a temporal spacing of 70 minutes in that part of the profile. A finer profile leads to stronger scatter and no definite peak moment. It is very interesting that this peak coincides with a peak in $r$ at the same time. The population index reaches $r = 2.5 \pm 0.2$ at $\lambda_\odot = 237\overset{\circ}{.}96$. The temporal resolution of the $r$-profile is 2–3 hours.

It must be noted that the feature can still be an effect of radiant height change plus a change of observing alertness between the groups in India and Europe. But the profile of Figure 2 has the advantage of overlap of the two groups. It is nevertheless possible that the 1733 dust trail of Comet 55P/Tempel-Tuttle was detected on Nov 20, $0^{\rm h}10^{\rm m} \pm 40$ m UT.

*Table 4* – Individual observing periods of 2004 Nov 8/9. The solar longitude is already corrected for topocentric stream encounter (changes by a few minutes), $n_{\rm LEO}$ is the number of Leonids see in the interval, lm is the limiting magnitude, and $h_{\rm R}$ is the average radiant elevation of the interval. The column "used?" marks those records which were not used in the average ZHR because the total correction exceeded 8.

| Observer | $\lambda_\odot$ | $n_{\rm LEO}$ | lm | $h_{\rm R}$ | used? |
|---|---|---|---|---|---|
| LEUPE | 226°7801 | 0 | 6.10 | 3° | × |
| LEUPE | 226°7908 | 0 | 6.10 | 5° | × |
| RENJU | 226°7910 | 2 | 6.23 | 8° | × |
| BAKLA | 226°7967 | 0 | 5.20 | 10° | × |
| LEUPE | 226°8014 | 0 | 6.10 | 7° | × |
| RENJU | 226°8035 | 0 | 6.23 | 10° | × |
| LEUPE | 226°8121 | 0 | 6.10 | 9° | × |
| JOHCA | 226°8164 | 2 | 5.90 | 10° | × |
| RENJU | 226°8176 | 0 | 6.23 | 13° | |
| LEUPE | 226°8228 | 1 | 6.10 | 11° | |
| KOSRA | 226°8275 | 0 | 6.77 | 16° | |
| MISKO | 226°8280 | 1 | 6.30 | 11° | × |
| OLEJE | 226°8282 | 0 | 5.00 | 17° | × |
| RENJU | 226°8318 | 1 | 6.20 | 16° | |
| LEUPE | 226°8334 | 0 | 6.10 | 13° | |
| HAVRO | 226°8401 | 1 | 6.00 | 11° | × |
| KOSRA | 226°8416 | 0 | 6.77 | 19° | |
| RENJU | 226°8460 | 1 | 6.18 | 19° | |
| PINCA | 226°8485 | 0 | 5.20 | 11° | × |
| RENJU | 226°8602 | 1 | 6.18 | 22° | |
| PINCA | 226°8717 | 3 | 5.00 | 15° | × |
| RENJU | 226°8778 | 0 | 6.20 | 26° | |
| KOSRA | 226°8788 | 0 | 5.00 | 26° | × |
| HAVRO | 226°8827 | 1 | 6.00 | 25° | |
| BARGE | 226°9058 | 1 | 5.13 | 27° | × |
| BASLU | 226°9068 | 1 | 5.19 | 27° | × |
| VANKE | 226°9110 | 1 | 5.29 | 28° | |
| VERCI | 226°9110 | 1 | 5.15 | 28° | × |
| KOSRA | 226°9191 | 0 | 6.75 | 35° | |

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# Ongoing meteor work

## Lunar meteoroid impact prediction plots for 2005

*Peter S. Gural* [1]

Maps for optimizing the telescopic pointing direction for lunar meteoroid impact observations are given for the most favorable meteoroid streams in 2005.

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For several years, the Association for Lunar and Planetary Observers (ALPO) has hosted a web site devoted to providing information related to lunar meteoroid observations. To reach a larger audience, this short article is being published in WGN for those meteorists that may have an interest in lunar impact phenomena and would like to make an observational contribution. Previous papers published on the visibility and science of lunar meteoroid impacts using modest sized amateur telescopes equipped with frame rate CCDs and video recorders can be found in the reference section at the end of this article. These have confirmed the fact that amateurs can make a vital contribution to this field of meteor science when multi-station cameras are used in a mode of coincidence observations (having two cameras recording with at least 20 kilometer separation can rule out pixel flares, cosmic rays, and satellite sun glints). For greater detail on the science that can be gleaned from this work and an observational guide to performing lunar impact monitoring, please see the referenced articles and the ALPO web site coordinated and maintained by Brian Cudnik. The latter may be found by web browsing for 'ALPO LUNAR IMPACT' or going to the site:

`http://www.lpl.arizona.edu/~rhill/alpo/lunarstuff/lunimpacts.html`

On the next page are shown plots of the five meteoroid streams in 2005 that have the required conditions and geometry for observing lunar impacts. That is: (1) when the lunation cycle is within several days of first or last quarter and a reasonable portion of the unlit moon is visible, (2) a meteoroid stream of ZHR at least ten or greater is active, and (3) the hemisphere centered on the meteoroid stream's lunar sub-radiant point covers a significant portion of the unlit lunar surface facing Earth. The plots in figures 1 through 5 show the Moon in its correct phase near the time of maximum meteoroid flux for the Quadrantids, Southern Delta Aquarids, Perseids, Puppids, and Ursids respectively. The pinpoints cover the potential impact region that one would monitor on the lunar disk. This region is facing into the oncoming meteoroid stream with the plus sign representing the sub-radiant point on the Moon. A white '+' signifies that this point is on the Earth-facing hemisphere of the moon; a black '+' means that the sub-radiant point is on the hemisphere facing away from the Earth (i.e. the far side of the Moon). The plots show a curved line, which marks the limit of the region of impacting meteoroids that would be visible from the Earth. The plots assume a meteoroid stream with a uniform particle density, and they are plotted with lunar north up. The approximate time of local moonrise/moonset with respect to local sunrise/sunset is given, along with the percentage of impacts visible from the Earth-facing part of the un-illuminated lunar hemisphere (relative to the total number possible). The light gray region is the sunlit part of the moon, where impacts are generally regarded as unobservable due to the brightness of the lunar surface, thus possessing poor contrast with respect to the impact flashes. The universal time and date of the meteoroid stream maximum (as seen from the Earth) as well as the advance or delay time of the stream's peak arrival at the Moon are listed for each figure.

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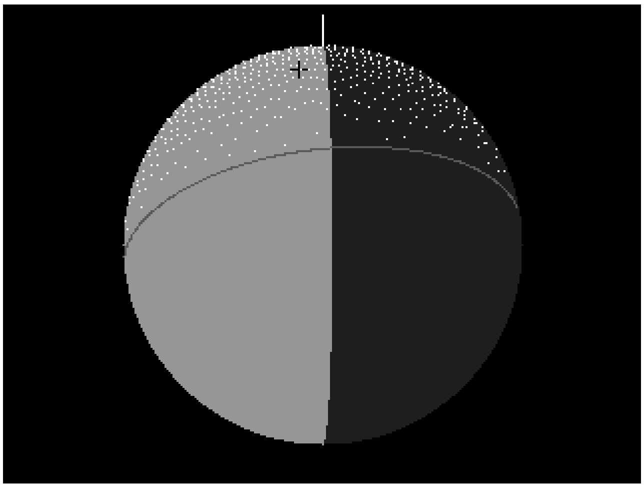

*Figure 1* – QUA 2005 Jan 3, at $12^h11^m$ UT
Lunar max −1.2 hrs
Moonrise 6.2 hrs before sunrise
10% impacts on unlit near side
Polar graze angle = 62°

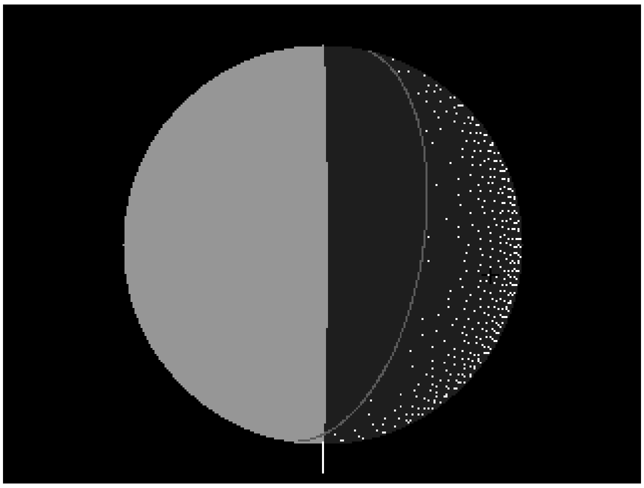

*Figure 2* – SDA 2005 Jul 28, at $00^h44^m$ UT
Lunar max −1.3 hrs
Moonrise 6.1 hrs before sunrise
24% impacts on unlit near side
Polar graze angle = −7°

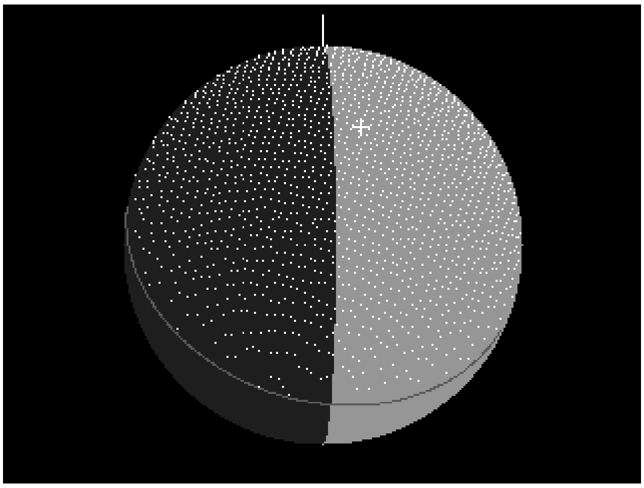

*Figure 3* – PER 2005 Aug 12, at $19^h09^m$ UT
Lunar max +1.4 hrs
Moonset 5.7 hrs after sunset
39% impacts on unlit near side
Polar graze angle = 39°

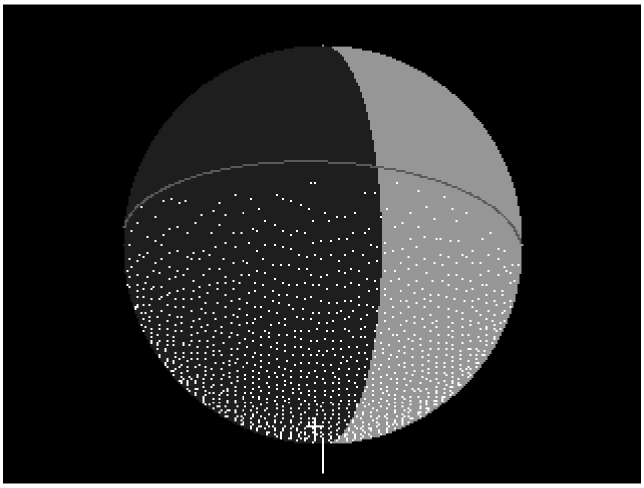

*Figure 4* – PUP 2005 Dec 7, at $02^h06^m$ UT
Lunar max +1.1 hrs
Moonset 4.9 hrs after sunset
44% impacts on unlit near side
Polar graze angle = −61°

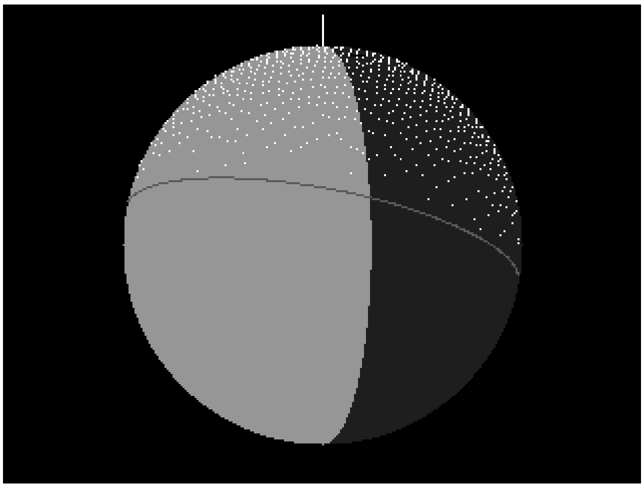

*Figure 5* – URS 2005 Dec 22, at $12^h33^m$ UT
Lunar max −0.9 hrs
Moonrise 6.9 hrs before sunrise
19% impacts on unlit near side
Polar graze angle = 72°

# History

## Meteor Beliefs Project: Meteoric imagery in the works of William Blake

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Meteoric images, which are sometimes not clearly distinguishable from cometary ones, in the poems and artworks of Englishman William Blake (1757–1827) are presented and discussed. Attention is drawn too to the turbulent events that occurred during Blake's lifetime, and which influenced his work. An annotated timeline, including major cometary, meteoric and meteoritic occurrences, covering 1757–1827, is also given.

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### 1 Introduction

According to old Chinese belief, William Blake (1757–1827) was cursed, since there is no question he lived in 'interesting times'. Blake was a visionary English poet and artist. He was fascinated by apocalyptic biblical beliefs and prophecies, and worked elements of these even into artworks commissioned of him to illustrate the texts of other poets. He studied widely in the literature and art of the past. His lifelong artistic heroes were Milton, Raphael and Michelangelo. As a result, his works are suffused with flowing forms and astronomical imagery, including meteors and comets.

Such a brief sketch could quite easily give the impression that Blake was an impractical dreamer, but not so. He was born and brought up in London, where he was trained as an engraver, a profession he continued for the rest of his life. He also painted watercolours, some of which he exhibited at the Royal Academy of Arts. In his engraving career, he invented relief etching, a process allowing a copper engraving plate to be used, and repeatedly re-used, as if it were a woodcut block. This centred around using an acid, and an acid-resistant protective solution, to etch out the areas of copper not intended to print, giving the text and design in raised relief. With this process, Blake was able to write, illustrate and print his own works, what he called his 'Illuminated Books'. This and other comments in his writings show he was well-versed in the science of his day.

Blake's life and works cannot be viewed in isolation, so Table 1 (page 172) provides an annotated list of important events from his time, and which moulded the world he inhabited. Such events included the American War of Independence, the Napoleonic Wars, and, of especial relevance to IMO members, the period of denial and eventual acceptance regarding the extraterrestrial nature of meteorites (on which, see Chapters 1 and 2 of (Burke, 1986)). It would be impossible here to give more than this mini-biography of William Blake. For further details on his life, see the biographical references in (Bindman, 2000) and (Olson & Pasachoff, 1998).

In this article, the more obvious meteoric images in Blake's poems and artworks are discussed. Sometimes, the imagery is more cometary than meteoric, but for Blake and his contemporaries, meteors and comets not only looked similar, but were often considered synonymous. This mistaken nomenclature continues occasionally modernly, although not usually among the more astronomically-experienced.

The material discussed is presented in chronological order of composition or creation, as far as this is known. As usual, anyone interested is encouraged to read more fully in the texts extracted from here, or in this case, to view the artworks and any variants as well, since there is much to catch the imagination of those with a feeling for astronomy in Blake's *oeuvre*.

### 2 Poetical Sketches (1769–1778)

These are the earliest surviving of Blake's poems, and as such are not well-dated. They may have been influenced in part by his seeing the Great Comet of 1769, but the group as a whole was not published until 1783. Two miscellaneous poems and one play from the 'Poetical Sketches' provide items of meteoric interest.

**Gwin, King of Norway** (Keynes, 1966, pp. 11–14):

> The King is seen raging afar,
> With all his men of might,
> Like blazing comets, scattering death
> Thro' the red fev'rous night.

(lines 81–84.)

This cometary section needs to be seen in the light of a subsequent verse, which gives a more meteoric slant to this concept:

> Like blazing comets in the sky,
> That shake the stars of light,
> Which drop like fruit unto the earth
> Thro' the fierce burning night

(lines 101–104.)

Blake is not intending a link between comets and meteors here. Instead, he is suggesting that unpredictable, chaotic, comets might shake the stars free from their fixed positions, drawing on imagery in the biblical 'Revelation to John' 6:13, where the stars fall to earth like figs dropped from a tree in a high wind.

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**In Imitation of Spenser** (op.cit., pp. 14–15): In a section describing how Mercury, messenger of the gods, brings Jupiter's decisions to Earth, lines 24–26 run:

Then, laden with eternal fate, dost go
Down, like a falling star, from autumn sky,
And o'er the surface of the silent deep dost
fly

The Spenser being imitated is the late medieval English poet Edmund Spenser (circa 1552–1599), most famous modernly for his epic poem 'The Faerie Queene' (first published 1590–1596).

**King Edward the Third** (op. cit., pp. 17–33): Two passages from this play feature potentially meteoric elements. The first may equally refer to planets, which brighten and fade significantly over time, or may simply be Blake using poetic licence to imagine stars that might move nearer the Earth, and thus brighten for a while. A cometary aspect is possible too, although there is little obviously comet-like about Blake's description.

Scene 1; King Edward, his army and nobles are at the French coast. The King is addressing this assembly, just before knighting his son the Black Prince, and other young nobles:

The world of men are like the num'rous stars,
That beam and twinkle in the depth of night,
Each clad in glory according to his sphere;—
But we, that wander from our native seats,
And beam forth lustre on a darkling world,
Grow larger as we advance! and some perhaps
The most obscure at home, that scarce were seen
To twinkle in their sphere, may so advance,
That the astonish'd world, with up-turn'd eyes,
Regardless of the moon, and those that once were bright,
Stand only for to gaze upon their splendour!

(lines 32–42, (op. cit., p. 18).)

The use of such a metaphor is understandable in its context, and is found elsewhere from ancient times in various forms, where stars are regarded as representing humans on Earth. This most commonly features in the idea that a falling star represents someone's death.

Scene 3, at Crecy in France, presents a more meteoric, or possibly cometary, trail. The Black Prince, Sir John Chandos and Lord Audley are holding a meeting. The Prince is speaking:

. . . but the pure soul
Shall mount on native wings, disdaining
Little sport, and cut a path into the heaven of glory,
Leaving a track of light for men to wonder at

(lines 272–275, (op. cit., p. 27).)

## 3 The Marriage of Heaven and Hell (circa 1790)

One of the earlier relief-etched of Blake's Illuminated Books, this illustrated poem is known from nine copies. Bindman (2000, pp. 106–133) reproduces Copy F from circa 1794, made using Blake's own technique of colour printing, which gave especially deep colours and rich surfaces, in places added to by the artist with pen and watercolour. This is the copy cited from here.

The poem itself describes a journey of religious or philosophical discovery, and is a satire on Emanuel Swedenborg's (1689–1772) 'Heaven and Hell'. Showing elements of influence due to the on-going French Revolution, the book is also a rejection of the Swedenborgians' sect, to which Blake had once been attracted.

The final section of the text, entitled 'A Song of Liberty', presages Blake's 'Prophecy' texts from 1793 and after. It is where the meteoric quotes are found. In it, the anonymous archetypal character called only 'The Eternal Female', gives birth to a fiery child, a new terror, which causes shadows of fear and prophecy to spread through the world. Then, a gigantic deity-like figure appears, the starry king (though it is unclear if this term is his name, or simply describes his appearance):

[Plate 25 (modern numbering)[1]]

8. On those infinite mountains of light
now barr'd out by the atlantic sea, the new
born fire stood before the starry king!
9. Flag'd with grey brow'd snows and thun-
-derous visages the jealous wings wav'd
over the deep.
10. The speary hand burned aloft, unbuck-
-led was the shield, forth went the hand
of jealousy among the flaming hair, and

[Plate 26]

hurl'd the new born wonder thro' the starry
night.
11. The fire, the fire, is falling!
12. Look up! look up!. . .
. . .
13.The fiery limbs, the flaming hair, shot
like the sinking sun into the western sea.
14. Wak'd from his eternal sleep, the hoary
element roaring fled away;

Note that the line numbering is embedded as part of this section of text, and that the text is here given exactly as Blake set it down, from (op. cit., pp. 131–132). Further description of the starry king suggests he is intended as an ill-defined variant on the biblical Old Testament's god Yahweh, who uses fire and thunder against his enemies, as 'he promulgates his ten commands' (line 18 of the 'Song of Liberty').

[1]Annotations thus: [Plate 25] indicate where the plates were placed in Blake's original. Note that the plate numbering is not always constant between different copies of Blake's Illuminated Books. Those used here and below may apply only to the specific copy cited.

The fiery child hurled by its hair through the heavens, like a meteor, echoes similar descriptions in Greco-Roman myths. Some of these we have examined in earlier Meteor Beliefs Project articles, such as (McBeath & Gheorghe, 2004), regarding Ate being flung by her hair from heaven by Zeus, for instance.

## 4 The French Revolution (1791)

Although this poem was printed in 1791, it was never published, and may have been deliberately suppressed by Blake when the actual French Revolution turned out to be very different to what he had anticipated. Just a single copy survives, perhaps the proofs. The brief meteoric notes describe Aumont bringing disastrous news to the Revolutionary Council; lines 159–160 in (Keynes, 1966, p. 141):

> ...When Aumont, whose chaos-born soul
> Eternally wand'ring a Comet and swift-falling fire, pale enter'd the chamber.

The 'swift-falling fire' seems probably meteoric in this context, curiously linked to a comet, but any such connection is at least as likely because comets and bright to brilliant meteors are superficially similar in appearance.

## 5 The Approach of Doom (1792)

This is a relief and white-line etching, showing to the lower right a huddled, fearful group of around seven standing adults in long robes, with bare feet, near a stylized, step-like shore. They are gazing out over a dark sea, at night. The sky seems either very hazy, misty, or cloudy. One woman at the back of the group may be holding a young child. In the sky to the top left corner is a pale, smoke-like, irregularly curving trail, which seems to broaden as it passes off the centre-left edge of the etching. The group are staring intently to where this line should meet the horizon, and the front members of the group are lit up as by a bright light, suggesting this may be a brilliant fireball's trail in the sky.

On its own, this image would not draw our interest here. However, the design is an almost identical mirror image of a larger composition in ink and wash, also called 'The Approach of Doom', but dated to circa 1785, by William's beloved younger brother Robert, who died tragically early in 1787, aged 19. Robert's design has the huddled figures to the left side, on a lighter area, gazing out over a dark expanse to a slightly curved, fiery trail, which ends off the right-hand edge of the sketch. This trail seems more cometary or meteoric than in William's etching. Robert's image shares much in common with several paintings and etchings of the great bolide of 1783 August 18, such as those by the Sandby brothers, Paul and Thomas, Samuel Scott, and Henry Robinson, a meteor which is described in some contemporary reproductions as a *draco volans* or 'flying dragon'. As the meteor was widely-seen in a partly clear sky from southern England, it is quite possible both Blake brothers might have seen the meteor, and later used their recollections of it in their art. It is clear from the artworks and reports by observers still preserved today that this bolide had a distinctly cometary appearance, as it streaked across the sky, shedding a trail of glowing fragments. This may explain where some of William Blake's meteor-comet links derive.

A detailed discussion, complete with an excellent set of images of the great fireball, is given by (Olson & Pasachoff, 1998, pp. 63–83 and Plates III and IV). This includes various of the Sandby illustrations, and both Robert and William's respective 'Approach of Doom' artworks (conveniently on facing pages 82 and 83, Figures 40 and 41).

## 6 Visions of the Daughters of Albion (1793)

Prepared by Blake in a relief-etched form, 17 copies of this Illuminated Book survive, of which (Bindman, 2000, pp. 141–152) presents Copy G, that Blake watercoloured by hand. This gives a bolder and clearer appearance to the images than the colour-printed 'Marriage of Heaven and Hell' ones, with which the effect of the illustrations, if not their content, has much in common in places.

The poem deals with themes of female sexuality and liberation, matters Blake was familiar with thanks to his connection to radical groups led by Mary Wollstonecraft (later Mary Shelley) and Joseph Johnson. In essence, the work is a tragedy of a free-spirited, mystic, archetypal heroine, and her relationship with two male archetypes who represent the heart and the head, emotion and reason.

'Albion' in Blake's works was an ancient man, who represented England, but also all of mankind. His daughters in this poem are the women of England, held in effective slavery by the dictates of society, and who yearn for America and freedom. Such a connection between freedom and America is derived from Blake's view of the American War of Independence, ended a decade before this work, as freeing the American people from British rule.

On Plate 8 (Blake's numbering) of the book is the meteoric quote, part of a depressing lament:

> ...& all the night
> To Turn the wheel of false desire: and longings that wake her womb
> To the abhorred birth of cherubs in the human form
> That live a pestilence & die a meteor & are no more.

(op.cit., p 149.)

## 7 America A Prophecy (1793)

This Illuminated Book was carefully printed from the relief etchings in blue-grey ink originally. The style of design in the illustrations suggests the watercolouring of some later copies indicated a change of mind by Blake. Copy H in (Bindman, 2000, pp. 153–172) is one of the first four printed, so shows the designs in monochrome to good effect. Thirteen later copies also survive.

The poem itself is the first of Blake's major 'prophecy' texts. It was his reaction to 'The Terror' in the French Revolution, and the especially violent events which led up to that phase. Three sections are particularly meteorically relevant, along with the illustrations on three pages.

Firstly, from Plates 5–6 (modern numbering), early in the section making up the bulk of the poem entitled 'A Prophecy', after George Washington has been speaking comes:

> [Plate 5]
>
> The strong voice ceas'd; for a terrible blast
> swept over the heaving sea;
> The eastern cloud rent; on his cliffs stood
> Albions wrathful Prince
> A dragon form clashing his scales at midnight he arose,
> And flam'd red meteors round the land of
> Albion beneath
> His Voice, his locks, his awful shoulders, and
> his glowing eyes,
>
> [Plate 6]
>
> Appear to the Americans upon the cloudy
> night.

(op.cit., pp. 158–159.)

On Plate 5, midway down the page, is an illustration of a naked man with his back towards us, lying horizontally, holding an enormous blazing torch (which some commentators call a trumpet) also horizontally in both hands. A gout of flames from the torch longer than the outstretched man and the torch combined, gush out towards the left-hand side of the page, there mingling with other flames, and those scattered in a line above the first quoted text line here. Three naked figures, a man, a woman and a child, are fleeing the fires in the bottom left-hand corner of the plate, looking back in terror (?) towards the flames. The form of the torchbearer, his long hair streaming from right to left, like the torch flames, implies he is flying in a strong wind blowing from right to left too. The torch looks very similar to a serpentine, maned, fire-breathing dragon at the bottom of Plate 16, which creature is also drawn moving from right to left, and seems deliberately created to mirror part of the illustration on Plate 5. Other illustrations in the work feature serpentine/draconic creatures, though not associated with fires, so this is all in keeping with the nature of the Book as a whole.

On Plate 6, two naked humans, one tightly clutching a naked, standing child, cower in fear at the bottom right of a low, sketchy landscape, with clouds above. In the sky, higher than the clouds, is a scaly, serpent-tailed, feather-winged dragon. It is flying from right to left, with its two, curiously human, paws and arms held before it, fingers extended in a fashion suggesting it is casting a spell. A zigzag line, like a lightning bolt, seems to emanate from near its left 'hand' and ends near the stomach of a naked flying man, positioned as if diving towards the ground. His long hair and beard flow back, impressing that the air is rushing past him in his descent. In his left hand he holds a slender staff, tipped with a tiny *fleur-de-lys*-style spear point. The man may be wearing a cloak, which curls out in a serpentine 'tail' behind him, ending near the dragon's paws. This may not be a cloak at all, but a draconic tail, as if he is changing into a dragon — or a dragon changing into a man. The idea the man and dragon may be the same is heightened as a zigzag lightning bolt descends from just below the man's left wrist. This is clearer on the coloured versions, where the line is often coloured differently to the nearby clouds. The lines of text below and beside these two beings include the following:

> Albion is sick. America faints! enrag'd the
> Zenith grew.
> As human blood shooting its veins all round
> the orbed heaven
> Red rose the clouds from the Atlantic in vast
> wheels of blood
> And in the red clouds rose a Wonder o'er
> the Atlantic sea;
> Intense! naked! a Human fire fierce glowing,
> as the wedge
> Of iron heated in the furnace; his terrible
> limbs were fire
> With myriads of cloudy terrors banners dark
> & towers
> Surrounded; heat but not light went thro'
> the murky atmosphere
> The King of England looking westward
> trembles at the vision
>
> [Plate 7]
>
> Albions Angel stood beside the Stone of
> night, and saw
> The terror like a comet, or more like the
> planet red
> That once inclos'd the terrible wandering
> comets in its sphere.
> Then Mars thou wast our center, & the
> planets three flew round
> Thy crimson disk; so e'er the Sun was rent
> from thy red sphere;
> The Spectre glowd his horrid length staining
> the temple long
> With beams of blood; & thus a voice came
> forth. and shook the temple

(op.cit., pp. 159–160.)

Coupled with the accompanying illustrations, there is a strong meteoric theme to all this, disastrously portentous, with a superbly evocative description of a personified fireball. As noted in Section 5 above, brilliant fireballs were still commonly known as 'flying dragons' in Blake's time. The lines about the enraged zenith, as if with blood-red veins pulsing across the sky, is suggestive of a great all-sky auroral storm as well.

Additional blazing humanoid meteor-like beings recur in Plate 14:

In sight of Albions Guardian, and all the thirteen Angels
Rent off their robes to the hungry wind, & threw their golden scepters
Down on the land of America. indignant they descended
Headlong from out their heavenly heights, descending swift as fires
Over land; naked & flaming are their lineaments seen
In the deep gloom, by Washington & Paine & Warren they stood
And the flame folded roaring fierce within the pitchy night
Before the Demon red, who burnt towards America

(op. cit., p. 167.)

The 13 fiery angels descending so meteorically are the personifications of the 13 States of America, the original 13 colonies which had risen in revolt against Britain in the American War of Independence.

## 8 Europe A Prophecy (1794)

Commonly bound with 'America A Prophecy' by Blake, among the 12 known copies, this is another of his relief-etched Illuminated Books, but this time, full colour printed, in some editions with additional watercolour and pen retouchings. The poem is a solemn, allegorical, and general, brief resumé of Europe's history — mostly wars, famines and plagues — between the birth of Christ and the revolutionary events of Blake's own time. Two short passages, and one illustration, are of especial interest to this investigation. All quotes are from Copy B in (Bindman, 2000, pp. 173–191).

From Plates 3–4 (Blake's numbering):

And Urizen unloos'd from chains
Glows like a meteor in the distant north
Stretch forth your hands and strike the elemental strings!
Awake the thunders of the deep,
The shrill winds wake!

(op.cit., pp. 178–179.)

Urizen is one of a catalogue of invented beings Blake repeatedly used in his works. Here, he represents the reactionary powers of the world, and is sometimes called 'Albion's Angel'. In other poems, Urizen features as a personification of reason, a figure who imposes order on the world following the biblical Fall of Man.

Further down Plate 4 is another hint of meteoric substance:

The horrent Demon rose. surrounded with red stars of fire,
Whirling about in furious circles round the immortal fiend.

Lastly, on Plate 9 (op. cit., p. 184), is a great crested serpent in a spiral coil, running down the left-hand side of the page. Its scaled skin is mottled with many colours, an impressive display of Blake's colour-printing ability. The serpent's head is surrounded by a blazing, fiery nimbus, possibly indicative of a meteoric dragon again.

## 9 The Tyger (1794)

This is perhaps the best-known of Blake's short poems modernly. It was published as part of a collection in a relief-etched Illuminated Book called 'Songs of Experience', first published in 1794. It was generally sold combined with an earlier Illuminated Book, 'Songs of Innocence' (1789), and as such was the one Illuminated Book to achieve some commercial success in Blake's lifetime. Bindman (2000, pp. 42–96) shows the combined work, Copy W, Blake's own, which was added to by Blake using pen, watercolour, and in places gold. 'The Tyger' is on Plate 42 (Blake's numbering).

Leaving aside the 'burning bright' nature of Blake's 'Tyger', and the burning fire in ite eyes, the verse of potentially meteoric interest runs:

When the stars threw down their spears
And water'd heaven with their tears:
Did he smile his work to see?
Did he who made the Lamb make thee?

(op. cit., p. 84.)

Olson & Olson (1990) drew attention to a possible connection between heavenly tears, spears and meteors, including citing the supposed name for the Perseids as the fiery tears of St Lawrence. From Martin Beech's detailed examination (Beech, 1997), it is clear there is little evidence beyond a very scant note or two to support the Perseids being known by this pseudonym. The Perseid maximum would have fallen on August 10 (St Lawrence's Day) during Blake's lifetime at least, and his interest in, and use of, astronomical imagery is undoubted. Plus, the Perseids seem to have produced unusually notable activity in 1779, 1784 and 1789, some of which events Blake may have seen. If there was an association between the Perseids as the tears of St Lawrence, Blake would almost certainly have known of it. It may be the link came about because of the strong returns in the 1770s and 1780s. This is entirely conjectural, however. Fiery spears as meteors have a better-established pedigree, with our modern term 'bolide' deriving from the Greek 'bolis' or 'bolidos', meaning 'a dart' (a short military throwing spear) or 'a missile'.

Spear-armed stars disarming and weeping as an image is superficially reminiscent of events in the biblical 'Revelation to John', with its war in heaven between God's champion Michael and his angels, against the draconic Satan and his angel followers. However, 'Revelation' 12 contains no such imagery, although 'Revelation' as a whole does feature a lamb frequently. It is typical of Blake's thinking that he might take a biblical concept and rework it to better fit to his beliefs and experiences. It would be entertaining to believe that Blake knew of the St Lawrence's tears — meteor shower link, and then slipped that knowledge into a pair of rather cryptic lines in one of his shorter poems. We may never know the truth, either way.

## 10 Vala or The Four Zoas (circa 1794–1803?)

This is an extremely long poem, written and revised repeatedly between about 1794, based on watermarks in part of the paper manuscript, until, or probably after, 1803. It remained unpublished on Blake's death, and no version was printed until 1893. The first complete manuscript, including all Blake's deletions, was published only in 1925.

Four sections are quoted here, which refer somewhat obliquely to meteoric effects. There are though several other passages scattered through the text which still more vaguely hint at meteoric imagery, or elements of mythology that are given in more distinctly meteoric terms elsewhere, but which are not here described specifically as meteors, falling stars, or the like.

'Vala' is Blake's term for Nature personified, or the worship of Nature, which worship in Blake's conception was delusional, leading only to despair. 'Zoas' in Greek is the name for the four beasts which feature in the biblical books of 'Revelation' and 'Ezekiel'. Blake uses the four Zoas to personify the four aspects of man — Reason (as Urizen, noted in Section 8 above), Imagination (Los; or sometimes Urthona, who represents Los's spiritual existence), Emotion (Luvah), and the Body or its senses (Tharmas). The four unified become Blake's Albion (see Section 6 on Albion). The biblical Fall of Man is expressed in Blakean terms by the splitting of Albion into these four beings, who then battle one another. Their reunification in Blake's works represents the Christian Redemption of Man.

From the section 'Night the Second', lines 41–44 (Keynes, 1966, p. 281)[2]:

> Albion gave his loud death groan. The Atlantic Mountains trembled.
> Aloft the Moon fled with a cry: the Sun with streams of blood.
> From Albion's loins fled all peoples and Nations of this Earth,
> Fled with the noise of Slaughter, & the stars of heaven fled.

Night the Third, lines 130–152 (op. cit., pp. 295–296):

> "And art though also become like Vala? thus I cast thee out!"
> So loud in thunders spoke the King, folded in dark despair,
> And threw Ahania from his bosom obdurate. She fell like lightning.
> Then fled the sons of Urizen from his thunderous throne petrific;
> They fled to East & West & left the North & South of Heaven.
> A crash ran thro' the immense. The bounds of Destiny were broken.
> The bounds of Destiny crash'd direful, & the swelling sea
> Burst from its bonds in whirlpools fierce, roaring with Human voice,
> Triumphing even to the stars at bright Ahania's fall.
> Down from the dismal North the prince in thunders & thick clouds —
> As when the thunderbolt down falleth on the appointed place —
> Fell down, down rushing, ruining, thundering, shuddering,
> Into the Caverns of the Grave & places of Human seed
> Where the impressions of Despair & Hope enroot for ever:
> A world of Darkness. Ahania fell far into Non Entity.
> She Continued falling. Loud the Crash continu'd, loud & Hoarse.
> From the Crash roared a flame of blue sulphureous fire, from the flame
> A dolorous groan that struck with dumbness all confusion,
> Swallowing up the horrible din in agony on agony.
> Thro' the Confusion, like a crack across from immense to immense,
> Loud, strong, a universal groan of death, louder
> Than all the wracking elements, deafen'd & rended worse
> Than Urizen & all his hosts in curst despair down rushing.

'Ahania' is the personified female aspect of Urizen in Blake's mythos. She represents pleasure, but also sin, because of her nature.

There is much in the above description to support a meteoritic view, coupled with the various earlier mythological events outside Blake's personal conception. Indeed, there are so many possible sources involved, it is difficult to single out specific threads. It is probably best not to try, but to simply enjoy the pattern of the weave as a whole.

The third quote comes from the probably earlier version of 'Night the Seventh'. Blake prepared two versions of this 'Night', but did not decide definitely on including either. Lines 25–26 run (op. cit., p. 320):

> Then bursting from his troubled head, with terrible visages & flaming hair,
> His swift wing'd daughters sweep across the vast black ocean.

The 'his' here probably refers to Orc, Blake's personification of the energy and spirit of revolution, most especially the American Revolution. Orc is a fiery being,

[2]In presenting the quotes from this poem here, a few potential alternative words crossed out in Blake's manuscript, but included marked as 'deleted' in Keynes's book, have been omitted here without comment.

whose fires burn up and cleanse away the hypocrisies of conventional morality.

Finally, from 'Night the Ninth Being the Last Judgement', lines 40–41 (op. cit., p. 358) comes:

> Or where the Comets of the night or stars
> of asterial day
> Have shot their arrows or long beamed spears
> in wrath & fury.

Comments like this recall the discussion regarding 'The Tyger' earlier, and to wonder what this work might have been like had Blake completed and illustrated it as one of his Illuminated Books, as he seems to have intended at one time.

## 11 The Book of Ahania (1795)

Having introduced Ahania, this short Illuminated Book particularly concerns her. The text covers elements of the biblical tale of Moses leading the Children of Israel, but Moses is here called 'Fuzon'. Blake draws on aspects and characters from his Urizen mythos in this work, in which Ahania starts out as representing pleasure, but becomes sin under Urizen's moral code. Only a single complete copy exists, as an intaglio etching, with three plates containing colour printed images, as given in (Bindman, 2000, pp. 233–237).

There are two main meteoric/meteoritic themes. The first begins with the very start of the poem, Chapter I.1, Plate 3 — modern numbering; (op. cit., p. 234):

> 1. Fuzon, on a chariot iron-wing'd
> On spiked flames rose; his hot visage
> Flam'd furious! sparkles his hair & beard
> Shot down his wide bosom and shoulders
> On clouds of smoke rages his chariot
> And his right hand burns red in its cloud
> Moulding into a vast globe, his wrath
> As the thunder-stone is moulded.

Chapter I.3, Plate 3:

> The Globe of wrath shaking on high
> Roaring with fury, he threw
> The howling Globe: burning it flew
> Lengthning into a hungry beam

Chapter I.9, Plate 3:

> But the fiery beam of Fuzon
> Was a pillar of fire to Egypt.

Urizen is the target of this wrathful meteoric Globe, and he prepares revenge. He slays a great serpent, then uses its venom to poison some rocks, forming its ribs and sinews into a great black bow. Chapter II.5–6, Plate 4 (op. cit., p. 235):

> . . . on this Bow.
> A poisoned rock plac'd in silence:
> He utter'd these words to the Bow.
> 6: O Bow of the clouds of secresy!
> O nerve of that lust form'd monster!
> Send this rock swift, invisible thro'
> The black clouds, on the bosom of Fuzon.

Chapter II.9–10, Plate 4:

> 9. Sudden sings the rock, swift and invisible
> On Fuzon flew, enter'd his bosom;
> His beautiful visage, his tresses,
> That gave light to the mornings of heaven
> Were smitten with darkness deform'd
> And outstretch'd on the edge of the forest
> 10: But the rock fell upon the Earth,
> Mount Sinai, in Arabia.

(Note two long 's's have been converted to the modern short form in this quote.)

The Earth shakes under the impact of the rock. The Wold Cottage meteorite fall in late 1795 is unlikely to have influenced Blake's thinking here, unless the work was finished later than generally thought. It seems intriguingly prescient regarding the fall, however.

## 12 Blake's illustrations to Edward Young's 'Night Thoughts' (1795–1797)

In 1795, Blake was commissioned to prepare illustrations for Young's long poetic work 'The Complaint, or, Night Thoughts on Life, Death and Immortality'. This was a very popular poem in its day, concerning death and the consolation of Christianity, and the intention was for Blake's artwork to form the basis of an engraved edition. Blake completed 537 watercolours in two years (all of which survive), but only engraved 43 plates of a planned 200 as, after the first four of Young's nine 'Nights' were published in a single volume during the summer of 1797, the project was abandoned.

In the poem, Young mentions comets five times, indicating his grasp of the nature of periodic comets, as understood by the late 18th century (see (Olson & Pasachoff, 1998, pp. 86–95, including Figures 44–50) for further notes on comets in Young's poem). However, Blake used comets and meteors more liberally in his illustrations, and also added millennial features not found in Young's sometimes apocalyptic poetry. It is not always clear whether Blake's illustrations were meant to show comets or meteors. Sometimes the text from Young's poem, which occupies a block filling one-quarter of most of Blake's watercolours, assists in identification, but not always. Eight illustrations are discussed here, although many more have a strong astronomical content, especially in 'Night IX'. All the images can be found in (Grant et al., 1980), but only a fraction are given in colour, unfortunately. Some are also shown, in monochrome only, by Olson & Pasachoff (loc. cit.).

**Night IV, page 40, watercolour 149** (Grant et al., 1980, Vol. I): Illustrating a section of text which poetically describes the thousand-year path of a comet in the Solar System, this is probably intended to show a personified comet. Blake's painting has a naked man in side view descending from top right to mid-lower left, his legs at right angles to one another, as if he were running or leaping. All-but his lower legs, upper torso, head and left arm are hidden by the text block. His head is surrounded by a glowing eight-pointed star, and his hair blows in curls into a broad, fiery tail in which his left leg lies, streaming back to the top right corner. His left arm is extended, and holds a downward-pointing stake or wand, the tip of which has two faint, rounded, back-curving barbs (?) or decorations, rather like a *fleur de lys*. This figure is reminscent of the descending 'dragon-man' of Plate 6 in 'America A Prophecy' (Section 7 above), even to the extent that part of the fiery comet-tail is drawn as if it was a short cloak or cape reaching from the back of the figure's head.

**Night V, title page, watercolour 158** (op. cit., Vols. I & II; in colour in Vol. II): The opening page of 'Night the Fifth' shows a simple landscape. It has a walled city on fire in the background, to the right of the text block. Reddened clouds drip tongues of yellow fire towards a spired dome in the city, while reddened fiery circles with flaming tails also fall from the sky over the city, and in front of its crenellated wall. In the foreground stands a pale woman, tears flowing down her face, looking back to the city being destroyed. Her very long hair passes into the contours of the filmy, ankle-length robe she is wearing. Her hands are raised by her chest, palms outward, in horror. Whether the tadpole-like fiery objects are really meteoric, or Blake's meteoric interpretation of biblical fire from heaven descending on the unfortunate city, is not explained.

**Night VI, page 15, watercolour 236** (op. cit., Vol. I): The text block again hides most of a naked man, this time descending vertically, seen from behind. Only his lower legs, lower arms, upper torso and head can be seen. In each hand he grasps a large, glowing sphere with a fiery tail, while in the background, three smaller fiery-tailed spheres descend, each with a slightly curving tail. The text makes no comment that could help in identifying these objects, but it would seem very probable Blake intended them as meteors.

**Night VII, page 41, watercolour 313** (op. cit., Vol. II): Blake's watercolour shows two bright, five-pointed stars with fiery tails, looking very meteoric, or possibly cometary, partly in dark clouds across the whole illustration. Their tails point back towards the upper right, and are roughly parallel to each other. To the right of the text block, a fiery human figure with a fearful face drops in a slight curve from top to bottom of the painting, trailing a roiling cloud of smoke. The figure's hair partly streams back into the flames surrounding and trailing back from its body. Although the accompanying part of Young's text does not refer specifically to meteors or comets, it is clear what Blake has drafted. Young is referring to the human soul's annihilation and death (lines 818–823); note the long 's's in all the quotes from Young's 'Night Thoughts' here have been replaced by the short modern ones:

> ... And this spirit,
> This all-pervading, this all-conscious Soul,
> This Particle of Energy divine,
> Which travels Nature, flies from Star to Star,
> And visits Gods, and emulates their Pow'rs,
> For ever is extinguisht. Horror! Death!

Blake may well be using the familiar folklore regarding shooting stars and death in this painting, while Young's lines seem also to hint at this perceived connection between human life and meteors.

**Night VII, page 48, watercolour 320** (loc. cit.): A zigzag of light descends from the centre-top of the image, ending in a multi-pointed, large flare of light to the upper mid-left, beside the text block. Within the flare is a very young, smiling, naked child. Much of the background away from the right edge is a very dark, cloudy wash. Although seeming more lightning-like than meteoric, Young's text suggests otherwise (lines 964–968):

> ... Poor Man, a Spark,
> From Non-existence struck by Wrath divine,
> Glitt'ring a Moment, nor that Moment sure,
> 'Midst Upper, Nether, and Surrounding *Night*,
> His Sad, Sure, Sudden, and Eternal Tomb.

**Night IX, page 25, watercolour 443** (loc. cit.): This depicts a distinctly cometary star in a starry sky, over water, the comet's tail broad, luxuriant, and spreading out towards the top centre to top right edge. A group of elderly, bearded men in long robes stand quiescently on the shore to the bottom right corner, gazing towards the comet's head. Thus the composition is almost identical to the Blake brothers' versions of 'The Approach of Doom' (Section 5 above), except that the group are not afraid, and the object of their interest is completely in view. Young's text explains why (line 195):

> *Comets* good Omens are, when duly scann'd.

**Night IX, page 45, watercolour 463** (op. cit., Vols. I & II; in colour in Vol. II): A busy, swirling, complex design, with spirals and curves surrounding numerous naked human figures and several animals (an ox, two sheep, and a lion), fills the bulk of this composition. Scattered across it are eight stars, most with more or less fiery tails, as if falling in various, though chiefly downwards, directions, and a fiery circle with multiple rays extending from it — perhaps a star, a bright meteor, or a tailless comet. While the text does not suggest meteors, it does mention a manuscript of heaven, described as a parchment scroll. Blake seems to have interpreted this as the heavens rolling up like a scroll from 'Revelation' 6:14 (which has the stars falling in the immediately preceding line). The colour version shows red flames lick from parts of the scroll too, while the more obviously meteoric tailed stars are done in reds, yellows or oranges.

**Night IX, page 86, watercolour 504** (op. cit., Vol. II): The text describes flying with a bold comet, and this is what Blake has shown. A huge, seven-pointed star to the top left, has a long, broad, fiery tail descending from it, curving off to the bottom right. Within the tail is a naked man, shown from the front in a pose as if swimming up towards the comet's starry head, while his hands cling to the tail, as if it were solid fabric, like a curtain or hanging.

## 13 Blake's illustrations to the Poems of Thomas Gray (1797–1798)

Immediately after the Edward Young project was stopped, Blake was commissioned to illustrate the poems of Thomas Gray. He prepared 116 watercolours for this in 1797–98, all of which remain intact, but regrettably, once more, the project was terminated before completion, and the illustrations were never published in Blake's lifetime.

One of these watercolours was to illustrate Gray's 'The Bard, A Pindaric Ode' of 1754–57, whose meteoric quote was mentioned earlier in these articles (McBeath & Gheorghe, 2003) — 'Loose his beard, and hoary hair / Stream'd like a meteor, to the troubled air' (lines 19–20). Blake's watercolour does not include these lines in its text block, but he has shown a mighty, naked, crowned king floating above a sketchy landscape, holding a fiery, three-pronged whip in his right hand, each prong of which ends in a multi-pointed star. Directly below him, and clearly the objects of his next blow with his starry flail, are two fleeing figures, a man and a woman, with a second woman standing behind them, stooping and hiding her face in her hands as if in tears. Both women wear long robes, while the man has only a loincloth. The fleeing woman looks back at the celestial figure in fear, her face round and her hair streaming back in three main locks, making her look very meteoric. This seems to be Blake's reinterpretation of Gray's lines regarding hair streaming to the wind like a meteor. (The watercolour is shown in black and white in (Olson & Pasachoff, 1998, p. 84, Fig. 42).)

One other of Blake's watercolours for this project shows a cometary or meteoric object, rising from the bottom left above a city roofscape into a starry sky: a four-pointed star, with a long, straight, faint tail. A large, star-crowned, female angel, with very long, flowing hair and huge feathered wings, holding a trumpet in each of her widespread hands, hovers in the air filling the right half of the picture. This illustrates the title page to Gray's 'Ode for Music'. Olson & Pasachoff (op. cit., p. 93 and p. 85, Fig. 43 for the image) suggest this meteor/comet may have been intended as a metaphor of fame, '— swift, brilliant, and perhaps fleeting.'

## 14 From a Letter to Thomas Butts, 1800 October 2

Thomas Butts was a purchaser of Blake's works over many years, beginning in 1799. He lived near Blake in London, so this letter is one of only a relatively few between the two, written while Blake and his wife were living at Felpham on the Sussex coast of south-east England, in a cottage provided by William Hayley, a significant patron of Blake at this time. The Blakes moved to the cottage in September 1800.

Most of this letter was actually a poem dedicated to Butts, lines 25–32 of which run (Keynes, 1966, pp. 804–805, Letter 16):

> ...Each grain of Sand,
> Every Stone on the Land,
> Each rock & each hill,
> Each fountain & rill,
> Each herb & each tree,
> Mountain, hill, earth & sea,
> Cloud, Meteor & Star,
> Are Men Seen Afar.

Blake commented it was his first vision inspired by his new seaside location. It also confirmed his earlier and subsequent poetic beliefs concerning how things can be seen as people, or personified as such, as we have found already.

## 15 Milton, A Poem in 12 Books (circa 1804–1810)

Part of the reason Blake went to Felpham was to be near his patron William Hayley, to assist with Hayley's biography of the great English poet John Milton (1608–1674). Blake was already fascinated by Milton, whom he viewed as the poetic redeemer of England as a nation, and with whose life Blake closely identified. This fascination manifested itself in this work, the preliminaries for which were probably begun around the time the Blakes left Felpham and returned permanently to London, in September 1803. Blake continued to work on the poem and its etchings for his Illuminated Book during the following years, and the first of the four surviving copies was likely not printed until 1810 or 1811. It was prepared using Blake's relief etching process, with the full page illustrated plates using a new technique of black- and white-line engraving, giving an especially bold style. The prints were then watercolour-washed by hand.

As for the poem itself, given Blake's intimate interest in Milton, it is unsurprising it is a complex and difficult work. The narrative often jumps from biblical events, to those in British history, Blake's own life, or to places and people from Blake's personal mythos, and back. Characters merge and separate, sometimes allegorically as concepts, but there is little here that is straightforward and stable. As some commentators have noted, this is similar to some kinds of insanity, and not all readers are able to deal with this. While the work is definitely worth reading, this latter is an important caveat.

From the perspective of modern physics, there are intriguing ideas in 'Milton' regarding time, more specifically non-linear time. Time-travel in this work is natural and inevitable, not merely possible, and Blake views events as simply variations on an underlying, continually-repeated, pattern. Time and space are commonly circumvented with an almost dream-like simplicity.

A complete version of Copy C is given by Bindman (2000, pp. 245–296), but those who may find further detailed discussion useful should also see Essick & Viscomi (1993), who reproduce Copy C too.

The illustration at the top of Plate 1 (Bindman, 2000, p. 247), sets up the central theme of the whole work - certainly of 'Book the First'. This has a lively, huge, fiery, five-pointed star as the head of a comet to the top right, with a broad, fan-like tail descending from it across the width of the entire Plate, in which is the word 'MILTON'. Two naked humans, that to the right female, recline below this, their hands raised as if to reach up into the comet's tail, while tiny naked figures and birds mingle with the letters of Milton's name, or between and below them. The toes of the two main figures just touch, where a plant grows from the earth. Although distinctively cometary here, this close association of Milton with a cometary/meteoric body is quite deliberate, as are the two near-antithetical human figures.

Plate 10's poetic text provides a description of a flaming, celestial harrow, pulled by blazing horses, in a very cometary, or meteoric, form [(op. cit., p. 257); Plate 10, lines 16–30 of the transcript in (Essick & Viscomi, 1993, pp. 133–134)]:

> Satan astonishd, and with power above his own controll
> Compell'd the Gnomes to curb their horses, & to throw banks of sand
> Around the fiery flaming Harrow in labyrinthine forms.
> And brooks between to intersect the meadows in their course.
> The Harrow cast thick flames: Jehovah thunderd above:
> Chaos & ancient night fled from beneath the fiery Harrow:
> The Harrow cast thick flames & orb'd us round in concave fires
> A Hell of our own making, see, its flames still gird me round
> Jehovah thunder'd above: Satan in pride of heart
> Drove the fierce Harrow among the constellations of Jehovah
> Drawing a third part in the fires as stubble north & south
> To devour Albion and Jerusalem the Emanation of Albion
> Driving the Harrow in Pitys paths. 'twas then, with our dark fires
> Which now gird round us (O eternal torment) I form'd the Serpent
> Of precious stones & gold turn'd poisons on the sultry wastes.

Blake's mythos encompassed the idea that a character could physically divide into a female 'emanation' and a male 'spectre'. In the above segment, Albion's emanation, or female aspect, is Jerusalem, both a place — effectively in Blake's conception, part of England (= Albion) — and a person. The reference to 'Drawing a third part' calls to mind 'Revelation' 12:3–4, where Satan as the huge, red, multi-headed dragon, sweeps one-third of the stars from the sky with his tail, as well as 'Revelation' 8, which repeatedly refers to the destruction or damage of one-third of various items, including one-third of the stars.

Plate 14 reveals the crux of the meteoric matter in 'Milton', beginning with a first appearance of Milton's dead shadow, returning to Earth [(Bindman, 2000, p. 261); Plate 14, lines 17–20 of the transcript in (Essick & Viscomi, 1993, pp. 140–141)]:

> Onwards his Shadow kept its course among the Spectres; call'd
> Satan, but swift as lightning passing them. startled the shades
> Of Hell beheld him in a trail of light as of a comet
> That travels into Chaos: so Milton went guarded within.

[(ibid.); (loc. cit.), lines 45–50]:

> With thunders loud and terrible: so Miltons shadow fell,
> Precipitant loud thundring into the Sea of Time & Space.
> Then first I saw him in the Zenith as a falling star.
> Descending perpendicular, swift as the swallow or the swift;
> And on my left foot falling on the tarsus, enterd there;
> But from my left foot a black cloud redounding spread over Europe.

In the gap between the '...Sea of Time & Space' and the 'Then first I saw him...' lines is a small illustration of a naked man, left foot advanced, upper torso bent right back, and arms spread wide, as if falling from a shock. A six-pointed star with a fan-like, fiery tail is descending onto his left foot. Thus is Milton's soul and poetic spirit imparted into Blake.

Plates 29 and 33, though separated slightly in the Book, must be treated as a connected pair. Plate 29 is at the end of 'Book the First', or just at the start of 'Book the Second', depending on how one views it (Plate 30 is titled 'Book the Second'), while Plate 33 is the fifth page of the second Book (there are two Plates 32 in the finished work). Each Plate is a full page illustration of a man in a pose like that of the small figure described from Plate 14. Plate 29's figure is virtually identical in all respects - upper torso bent back, arms wide, left foot extended, with a glowing, five-pointed star and broad fiery tail set below his knee, above his left foot. In some copies, the figure is naked, but in others, Blake added a pair of trunks in pen and wash (as in Copy C, (Bindman, 2000, p. 276)). The figure stands on a flat, green area, with three stone steps rising off the left edge behind his right foot. A heavy, dark cloud hovers over the steps, while another cloud surrounds the falling star's tail, up to the top, left and right edges of the Plate. Above the figure, in a gap in the cloud mass, but spread over the burning tail of the star, is the name 'WILLIAM'. The background between the clouds is painted a daytime blue.

Plate 33 (op. cit., p. 281) is captioned 'ROBERT', and is a darker, less sharply-defined illustration. The figure stands in a near mirror image of that in Plate 29, so his right foot is advanced, with a five-pointed star above it. The star's fiery tail is less well-developed than Plate 29's, as is the dark cloud near the top of the tail, which seems to have been partly erased to allow the caption to be added. The figure stands on a green ground surface, with four steps rising behind him (the number of steps is somewhat variable between copies; as few as 3, while Copy C has a hint of a fifth step in its painting). The sky background is a dark blue, perhaps as if a twilight, or very smoky, sky. Again, in some versions, including Copy C, trunks have been added to the man.

The two figures are in poses suggesting a mingling of shock and ecstasy, as they are overwhelmed by Milton's spirit entering into them, in the form of the burning falling stars, as described on Plate 14. The captions indicate the two represent William and his beloved younger brother Robert, whose death in 1787 so devastated William. The fact their toes would touch were the two Plates brought together shows a definite link, as discussed for the two main figures on Plate 1 above, while their slight separation in the text may refer to their bodily separation because of Robert's death. This may also be why the 'William' plate is more clearly drawn. It has been suggested that Plate 29 is a daytime scene, while Plate 33 is set at night.

The imagery of the foot, and the steps in the background of both Plates, indicates a journey, in a spiritual as much as a physical sense, the stairs especially inferring an ascending one, improving the powers of the conjoined Blake-Milton entity. It is interesting that Milton's spirit as the meteor must descend all the way to Earth to make this possible.

Robert's appearance is quite remarkable, as he occurs nowhere else in 'Milton'. The fact he features in this connection may be a remembrance of his 'Approach of Doom' sketch (Section 5 above), and its potential inspiration by the great bolide of 1783 August 18. William believed his brother was always with him in spirit too, and he maintained he was in constant communication with Robert, following Robert's death. Indeed, it was Robert's spirit that William said had told him the basics of his relief etching technique. It would be easy to scoff at this, but many artists believe they are inspired by something intangible, beyond themselves, what the ancient Greeks personified as the Muses. Many other people have encountered such a meteor-like flash of inspiration, some sudden new realization or understanding, which turns that person's world-view into something completely different. Blake understood this. His choice of a meteor bringing him the new inspiration, while implying his brother, though dead, enjoyed — or had enjoyed while alive — a similar electric moment, was no idle whim.

Further discussion regarding all this can be found in (Essick & Viscomi, 1993, pp. 27–28) and (Olson & Pasachoff, 1998, pp. 112–113, including Figs. 54 and 55).

## 16 Jerusalem the Emanation of the Giant Albion (circa 1804–1820?)

This is the last, and arguably greatest, of Blake's Illuminated Books, created using his relief etching and white-line engraving processes, added to by pen, watercolour, and in places, gold. His comments show he was thinking about 'Jerusalem' in July 1803, before he left Felpham, and while the title page is dated 1804, it is obvious that no complete copy (the work runs to 100 plates) was ready before 1820; some still later. Only one of the five surviving copies, Copy E, was watercoloured throughout, and this is reproduced in (Bindman, 2000, pp. 297–397).

As the culmination of his prophetic poetry in the form he invented to display it, it is superb and unparalleled, if overwhelming for anyone coming to it for the first time. For all this, there are surprisingly few clearly meteoric items within it.

Plate 20 (op. cit., p. 317) shows a number of five- and six-pointed stars in a dark, night-time sky, with three crescent Moons. Three of the five-pointed stars have fiery, sometimes swirling, tails. All the illustrations on this Plate are as small marginal interpolations, or interlinear to the text. The text on this page makes no reference to these celestial objects, however. In addition, there are two fiery, swirling, star-like shapes, leaving fiery trails, being drawn or pushed by groups of white-haired male figures in blue-grey robes. These call to mind the imagery of the fiery Harrow drawn across the constellations described in Plate 10 of 'Milton' (Section 15 above). The tailed stars certainly seem meteoric, while the rotating fiery 'harrows' could also be cometary.

Plate 83, lines 80–81 (op. cit., p. 380) include:

> ...while Los all night watches
> The stars rising & setting, & the meteors
> and terrors of night.

Lastly, and shortly before the poem's end, the Night of Death is ending, as Eternal Day dawns. The four Zoas (on these, including Los, see Section 10 above), giant forms here, take up mighty bows, each facing a cardinal direction: Urizen — south — a breathing gold bow; Luvah — east — a shining silver bow; Tharmas — west — a flaming brass bow; Urthona — north — a thundering iron bow. Plate 98, lines 1–3 (op. cit., p. 395):

> Then each an Arrow flaming from his Quiver
> fitted carefully
> They drew fourfold the unreprovable String.
> bending thro the wide Heavens
> The horned Bow Fourfold, loud sounding
> flew the flaming Arrow fourfold.

## 17 Conclusion

Despite the length of this examination of the meteoric imagery in William Blake's poetry and art, it has done little more than scratch the surface of the totality of his surviving works. There remains much of wonder and delight to be found elsewhere, as astronomical imagery abounds throughout his entire canon, and many of the Illuminated Books in particular contain so many tiny, intricate, marginal illustrations, it is possible to find something new at virtually each return to even well-known texts.

Having begun in the depths of a 'red fev'rous night', it seems appropriate we should end with four superb, blazing meteoric Arrows drawing the night to a close. If only real meteors and fireballs were so obliging at the end of a night's observing. Like Blake, we can always dream.

## 18 Note

Aside from the printed works referred to, at least one copy of most of Blake's Illuminated Books is available at `www.blakearchive.org`. However, the plate numbering used does not always conform to that used here. [*Editor's note* — The author had wanted to include several such illustrations as part of this paper. Although they are long out of copyright, the owners of copies tend to charge reproduction fees, and the cheapest we could find were around €75 per illustration. Readers are encouraged to look at this website — Blake's work is worth the effort.]

*Table 1* – An annotated timeline of events influential on the life, times and works of William Blake. Details were extracted from: (Baldick, 1993, pp. xi–xxiii), (Beech, 1994a, b, c, 1995a, b), (Bindman, 2000), (Burne, 1989), (Knöfel & Rendtel, 1994), (Lovecraft, 1967, pp. 433–454), (McSween, 1987), (Olson, 1985), (Olson & Pasachoff, 1998), (Pearce, 1999), and (Ridpath, 1989).

| Year | Events |
|---|---|
| 1757 | William Blake born, November 28. |
| 1758 | First predicted return of Comet 1P/Halley, 1758–59. John Wesley, the English founder of the Methodist Christian sect, claimed this return of Halley's Comet as a warning of the impending Apocalypse. |
| 1760 | Charles Messier began compiling his catalogue of deep-sky, comet-like objects. This was published in several parts from 1771–1784. |
| 1763 | Treaty of Paris ended the Seven Years' War in North America and Europe. |
| 1764 | Unrest against British rule in the North American colonies, leading to the American War of Independence, began. The beginning of Gothic literature with Horace Walpole's 'The Castle of Otranto'. (The peak of Gothic literature is generally considered to be the 1780s–1790s.) |
| 1766 | Hydrogen discovered by Henry Cavendish. |
| 1767 | Blake's brother Robert born. |
| 1768 | James Cook's first voyage to the southern Pacific Ocean began (ended 1771). Royal Academy of Arts founded. |

| Year | Events |
|---|---|
| 1769 | Great Comet, or 'Napoleon's Comet' (C/1769 P1), seen for much of the year, taken retrospectively by Napoleon Bonaparte's supporters as a portent of his glorious reign; by his enemies as foretelling the devastating wars his reign brought. |
| 1772 | Slavery declared illegal on English soil, June 22. James Cook's second voyage to the South Pacific began (ended 1775). Emanuel Swedenborg died. |
| 1775 | American War of Independence began. |
| 1776 | Edward Gibbon published the first volume of his monumental 'Decline and Fall of the Roman Empire'; subsequent volumes appeared at intervals until 1788. |
| 1779 | World's first iron bridge built at Coalbrookdale on the River Severn in England, the latest element in the on-going late 18th century Industrial Revolution. Strong Perseid return, August 10. |
| 1780 | Luigi Galvani's first experiments with the effects of electricity on dead frogs. Blake's first painting exhibited at the Royal Academy. Hugely destructive anti-Catholic riots in London; later tales have it that Blake took part. |
| 1781 | William Herschel discovered Uranus. |
| 1782 | Blake married Catherine Butcher or Boucher. John Goodricke first determnined the regular periodicity of Algol ($\beta$ Persei). |
| 1783 | End of American War of Independence. First balloon ascent by the Montgolfier brothers. A brilliant, fragmenting bolide was widely-seen from southern England on August 18. |
| 1784 | Blake's father died. Strong Perseid return, August 10. |
| 1785 | William and Catherine Herschel's deep-sky catalogue published. |
| 1787 | Blake's brother Robert died. Blake was devastated by his untimely passing. |
| 1788 | George Gordon (later Lord) Byron born. Blake invented the relief etching process. |
| 1789 | The Bastille stormed in Paris on July 14, the start of the French Revolution. Strong Perseid return, August 10. |
| 1791 | Wolfgang Amadeus Mozart died. |
| 1792 | Blake's mother died. Percy Bysshe Shelley born. |
| 1793 | French king's execution led to France declaring war on England. This war continued on and off until 1815. 'The Terror' began in France in September. |

| Year | Events |
|---|---|
| 1794 | French 'Terror' ended with the execution of Maximilien Robespierre on July 28. Ernst Chladni published his treatise on meteorites, the beginning of scientific meteorite analysis. Erasmus Darwin published 'Zoonomia', positing the evolution of animals based on adaptability and competition. |
| 1795 | Large meteorite (about 25 kg) fell from a clear, daytime sky at Wold Cottage, north-east England on December 13. James Hutton, one of the founding fathers of geology, published his 'Theory of the Earth'. John Keats born. |
| 1796 | Rise to power of Napoleon Bonaparte, as army commander in Italy. France planned to invade Ireland, and incited rebellion against England there. |
| 1798 | Naval Battle of the Nile and ending of rebellion in Ireland forestalled French invasion plans. 'Philosophical Magazine' first published in Britain. The initial issue discussed meteors. Samuel Taylor Coleridge's 'Rime of the Ancient Mariner' published. Brandes and Benzenberg carried out their first simultaneous triangulated meteor observations. |
| 1799 | French Revolution ended. Napoleon's *coup d'état* in France. Leonid storm, November 11–12, seen from Europe westwards to the Americas, including in the British Isles. |
| 1800 | Alessandro Volta invented the electric battery. |
| 1801 | Giuseppe Piazzi discovered asteroid 1 Ceres, January 1. The first four asteroids were found between 1801 and 1807. Richard Trevithick invented the high-pressure steam engine, and his first steam locomotive ran in this year. |
| 1803 | Fall of around 2000–3000 stony meteorites at L'Aigle in France on April 26. An investigation by Jean-Baptiste Biot confirmed the extraterrestrial nature of these meteorites. Fresh French threats of invasion led to Blake being arrested on August 12 on the Sussex coast as a suspected spy. |
| 1804 | Napoleon became emperor. Blake acquitted of spying on January 11. |
| 1805 | Naval Battle of Trafalgar; British fleet defeated a combined French and Spanish one. On land, Napoleon's army defeated the Austrians and Russians at Austerlitz. |
| 1807 | Bright comet, C/1807 R1. |
| 1808 | John Dalton published his first work on the chemical atomic theory, leading to the modern chemical Periodic Table. |
| 1810 | High point of Napoleon's power, as Holland and North Germany were annexed. |
| 1811 | Great Comet (C/1811 F1), also called 'Napoleon's Comet', was visible to the naked eye from 1811 April 11 to 1812 January 20, sometimes in daylight, a record visibility not broken until Hale-Bopp (C/1995 O1) in 1995. Its tail reached about 70° in length in 1811 December, and its coma was estimated as larger than the Sun's diameter in 1811 October. Napoleon claimed the comet was his guiding star, and foretold his victorious forthcoming campaign against Russia. (Leo Tolstoy used a fiery comet in his novel 'War and Peace', as a symbol of war and the renewing power of love, probably drawing on this Great Comet.) |
| 1812 | USA declared war on Britain. French armies were defeated in Spain and Russia. The French 'Grande Armée' was devastated during its retreat from Moscow in the Russian winter. Comet 12P/Pons-Brooks visible to the naked eye at its first recorded apparition. British caricaturists repeatedly used humorous renditions of a comet to satirise Napoleon, following his defeat in Russia. |
| 1813 | Karl Friedrich Gauss calculated the first accurate orbit for asteroid 1 Ceres. Napoleon's army defeated in the 'Battle of the Nations' at Leipzig. |
| 1814 | Napoleon defeated at Paris, and exiled to the island of Elba. |
| 1815 | Anglo-American War ended by the Treaty of Ghent. Napoleon returned to power in France for 100 days, until his army was defeated at the Battle of Waterloo by the Anglo-German army, on June 18. Napoleon was exiled to the island of St Helena. The Tambora volcano on Sumbawa in Indonesia erupted catastrophically on April 10, said to be the greatest volcanic eruption in recorded human history. In Europe, the event passed unnoticed, except for brief press reports in November. |
| 1816 | The 'Year Without a Summer' in Europe and North America; dismal, cold weather all year, plus crop failures in Europe, North America and the Far East, attributed modernly to the 1815 Tambora eruption. Beginning of a long period of often violent social unrest in Britain. |
| 1818 | Mary Shelley's Gothic novel 'Frankenstein' published. |
| 1819 | Ernst Chladni claimed most of his scientific contemporaries accepted his idea that meteorites could and did fall from the skies, by this year, an ending to the controversy about meteorites which had persisted from approximately the 1780s. |
| 1820 | Royal Astronomical Society founded. Charles Robert Maturin published 'Melmoth the Wanderer', considered by some the last true Gothic novel. |

| Year | Events |
|---|---|
| 1821 | Napoleon died in exile. Michael Faraday built the first electric motor. English poet John Keats died. |
| 1822 | William Herschel died. English poet Percy Bysshe Shelley died. |
| 1824 | English poet Lord (George Gordon) Byron died. |
| 1825 | First steam locomotive railway opened between Stockton and Darlington in north-east England. |
| 1827 | Ludwig van Beethoven died. William Blake died, August 12. |

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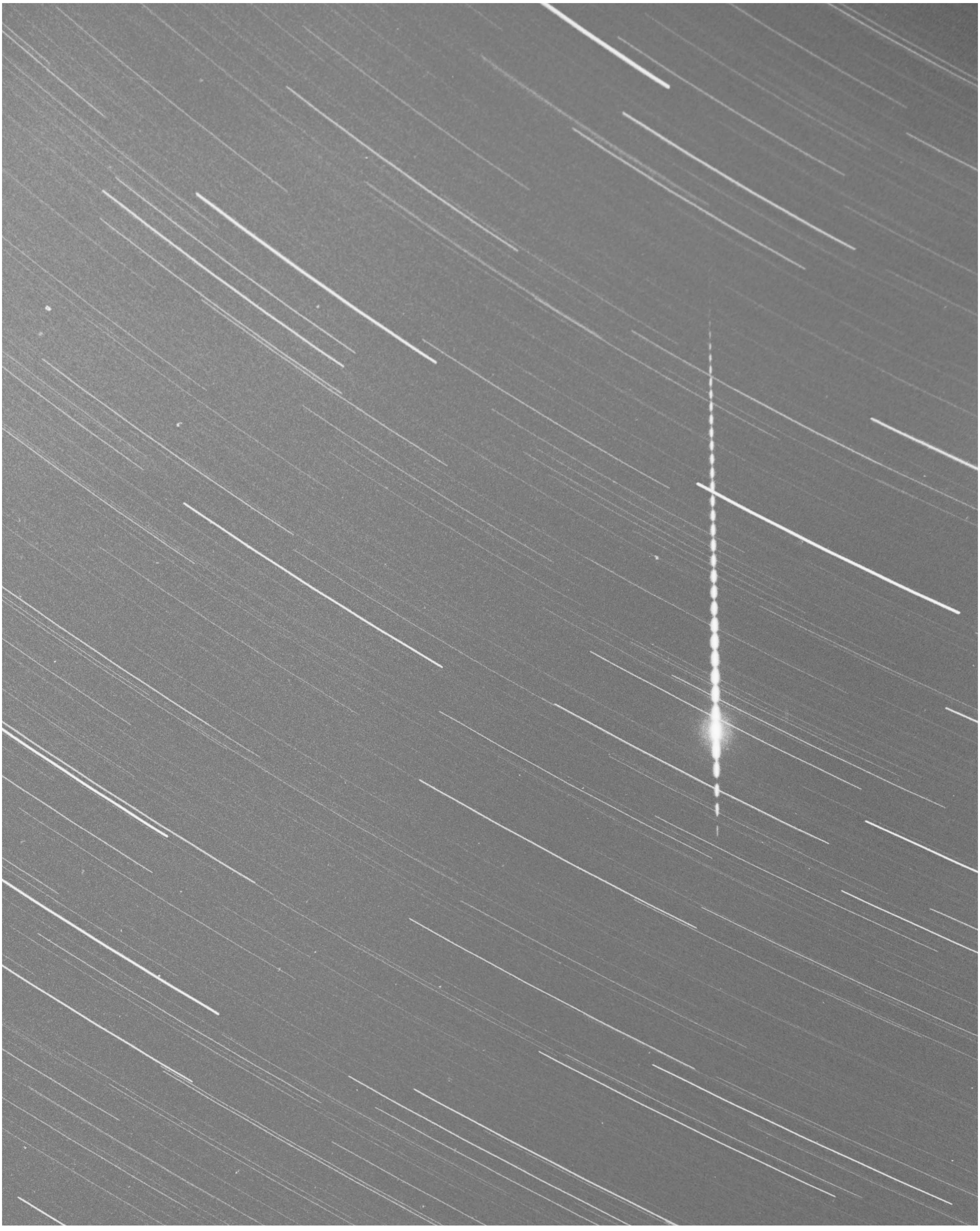
# Spanish Perseid



A Perseid photographed by H. Betlem and J.M. Biets in Spain on 2004 August 11.