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Leonids
Perseids
Glanerbrug meteorite
Fred Whipple

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Obituary

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Front cover photo

Fred Whipple, who died this August. See the Obituary on the following page. Photograph courtesy of the Harvard-Smithsonian Center for Astrophysics.

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Cover design Rainer Arlt

Fred Lawrence Whipple

1906 November 5 — 2004 August 30

It is with great regret that we announce the death of Fred Whipple, one of the great solar system astronomers of the last century. He is best known for explaining the nature of comets, the origin of many meteoroids.

He was born in Red Oak, Iowa, USA. His first degree was in mathematics from the University of California at Los Angeles. He studied for his PhD at Berkeley from 1927 to 1931, working on the orbit of Pluto. During this time he was also a teaching fellow at Berkeley for two years, and a fellow at the Lick Observatory from 1930 to 1931. He became instructor in astronomy at Harvard in 1932, and lecturer in 1938. During this time he also worked at the Harvard College Observatory.

During the Second World War he worked on equipment to produce Chaff, otherwise known as Window, which was large quantities of foil strips dropped from aircraft to defeat enemy radar.

He became an Associate Professor of Astronomy at Harvard in 1945 and a Full Professor in 1950. From 1955 to 1973 he was director of the Smithsonian Astrophysical Observatory. In 1963, President Kennedy awarded him the Distinguished Federal Award. He retired in 1977, becoming Phillips Emeritus Professor of Astronomy. In 1999 he joined the NASA team working on the Contour spacecraft, scheduled to visit two comets.

Most of his research concerned comets; he discovered six. The work for which he is best renowned was presented in three classic papers (Whipple, 1950; Whipple, 1951; Whipple, 1955), which provide our current understanding of comets. Though many of the details have been refined, the 'muddy snowball' model presented in these papers has remained essentially unchanged.

During his time at the Harvard College Observatory he conducted successful two-station meteor photography (Whipple, 1938). Though he did not invent this technique, he improved its precision sufficiently to show that no recorded meteors came from outside the solar system.

He was married twice, with a son from his first marriage and two daughters from his second.

References

Whipple F. L. (1938). "Photographic meteor studies, I". *Proc. Amer. Philosophical Soc.*, **79:4**, 499–548.

Whipple F. L. (1950). "A comet model. I. The acceleration of Comet Encke". *Ap.J*, **111**, 375–394.

Whipple F. L. (1951). "A comet model. II. Physical relations for comets and meteors". *Ap.J*, **113**, 464–475.

Whipple F. L. (1955). "A comet model. III. the Zodiacal Light". *Ap.J*, **121**, 750–770.

Sources:

Harvard-Smithsonian Center for Astrophysics Press Release 04–28, 2004 August 24:
`www.cfa.harvard.edu/press/pr0428.html` (downloaded 2004 September 8).

The Times, 2004 September 4.

The Daily Telegraph, 2004 September 8.

Photograph courtesy of the Harvard-Smithsonian Center for Astrophysics.

Editorial

Chris Trayner

WGN is produced by a few people giving what time they can afford. Readers will have noticed that it tends to be published late. Unfortunately my paid job is very demanding of time, especially at certain times of year, occupying evenings as well as days. I regret not being able to produce WGN on time, but often it is not possible.

WGN would benefit from more people joining in, even if they just did a small amount. One job is preparing articles in LaTeX. Another is proofreading — this does not require knowledge of LaTeX. If you think you could help, please email me at `wgn@imo.net`; remember to put 'meteor' in the subject line to get past the anti-spam filters. You would make a real contribution to WGN and the IMO in general.

Letter

from Alexandra Terentjeva [1]

In the Journal of the IMO (WGN) 32:2, April 2004 was published the paper 'Trajectory and orbit of the EN200204 Łaskarzew fireball' by P. Spurný, A. Olech and P. Kedzierski. It is interesting to note that the EN200204 Łaskarzew fireball belongs to the m-Orionid fireball stream of the Tagish Lake meteorite (see the paper 'The fireball stream of the Tagish Lake meteorite' by A. Terentjeva and S. Barabanov, WGN 32:2, April 2004). The detailed research about a minor body family connected with the Tagish Lake meteorite will appear in a Russian publication.

IMC 2005 — Announcement

Jan Verbert [2]

We are very pleased to inform you that next year's IMC will take place in Oostmalle, Belgium, and will be organized by the meteor section of Urania, the public observatory of Antwerp. The village pf Oostmalle is located at 25 km from Antwerp, the second largest city of Belgium, in the northern part of our country. Belgium is a small and populated country in Western Europe, very famous for its tennis players Kim Clijsters and Justine Henin, light pollution, but most of all for its beer and chocolates. The conference centre is located in a green area, offers accommodation for 100 people or more, and has a conference hall and some smaller rooms for posters. The IMC will be held from 15 – 18 September 2005. We hope to give you more detailed information soon at the website `www.imo.net/imc2005` and in the December issue of WGN.

If you have comments or questions, don't hesitate to ask!

Catalogue of video meteor orbits — Part 1

Pavel Koten [3]

The double station program of video meteor observation has been in operation at the Ondřejov observatory in Czech Republic since 1998. Observations are made mainly during the activity of major meteor showers. Orbits of more than 1500 meteors were computed and 817 of them are included in first part of the catalogue, which covers the period 1998–2001. Note that the Leonid meteor shower is not included in this version of the catalogue. The catalogue was issued as the Publication of the Astronomical Institute no. 91 (2003). Its electronic version is accessible on the web at `http://www.asu.cas.cz/~meteor/catalogues`, where ASCII, HTML and XLS versions are available. Members of the meteor community are encouraged to use these data.

[1] Institute of Astronomy, Russian Academy of Sciences, Pyatnitskaya ul. 48, Moscow, 119017 Russia. Email: `ater@inasan.rssi.ru`

[2] *Email:* `Jan.Verbert@fidea.be`

[3] Astronomical Institute, Ondřejov Observatory, Czech Republic

Leonids

The unexpected 2004 Leonid meteor shower

Jérémie Vaubaillon[1], *Esko Lyytinen*[2], *Markku Nissinen*[3] *and D.J. Asher*[4]

In 2004 the Earth will encounter meteoroids released around the 1333 and 1733 returns of comet 55P/Tempel-Tuttle (respectively 20 and 8 orbital revolutions ago). The resulting enhancements in the Leonid ZHR profile will only be of the order of 10 (for the 20-rev) and a few tens (for the 8-rev) above the Leonid background ZHR, and will be rather diffuse, but should be observable. The 20-rev trail will be encountered in the early hours of November 19 and the 8-rev in the late hours of the same date (UT). In this paper we compare details of the predictions from our three dynamical models.

Received 2004 September 30

1 Introduction

The task of making meteor shower predictions has been attempted since the XIXth century, but significant success was achieved only in the late XXth (Kondrat'eva & Reznikov, 1985; Lyytinen, 1999; McNaught & Asher, 1999). Several studies (e.g., Lyytinen & Van Flandern, 2000; Vaubaillon, 2002) indicate that the great Leonid meteor storm period is now over until at least 2033, although noticeable outbursts will occur in 2006 and 2007.

However, as in 2003 (Vaubaillon et al., 2003) we announce here an unexpected Leonid meteor shower in 2004 November. The 2003 shower was unusual in the way that an earlier than normal shower was predicted, i.e. on November 13. This enhancement of activity was observed (Arlt, 2003), as well as the other predicted shower, on November 19. Generally speaking, expected and observed ZHR values were low ($\lesssim 100$). Combined with the existence of gaps in the observational coverage, this makes it harder to define a maximum, and indeed no clear peak was found.

Though nothing was previously expected for 2004, as the time of the Leonid shower approaches, we once again examined our results. It was found that Leonid trails will approach the Earth. The most surprising thing is that no 2004 prediction has been published yet, though models are now correctly predicting the different showers. We present in the following the details of the results from our 3 different models (McNaught & Asher, 1999; Lyytinen & Van Flandern, 2000; Vaubaillon, 2002).

2 Predictions for 2004 Leonids

The model of Vaubaillon (2002, 2003) follows the orbital evolution of millions of particles (50 000 meteoroids ejected at each perihelion return of comet 55P/Tempel-Tuttle since 1300 A.D., plus several streams back to 604 A.D., in each of various size bins). In this way 1333 and 1733 are identified as the only returns of the comet from which there are significant concentrations of meteoroids (leading to meteors superimposed on the normal Leonid background) near the Earth's orbit in 2004 November.

Figure 1 provides the position of the 1333 and 1733 trails relative to the Earth. A different part of the same 1333 trail is thought by several authors to have been the main component of the great 1998 Leonid fireball storm (Asher et al., 1999; Vaubaillon, 2003), although other results suggest large contributions from other trails (Lyytinen, 1999; Brown & Arlt, 2000). This is a very perturbed trail, and substantially dispersed particles are found in the plot of Figure 1.

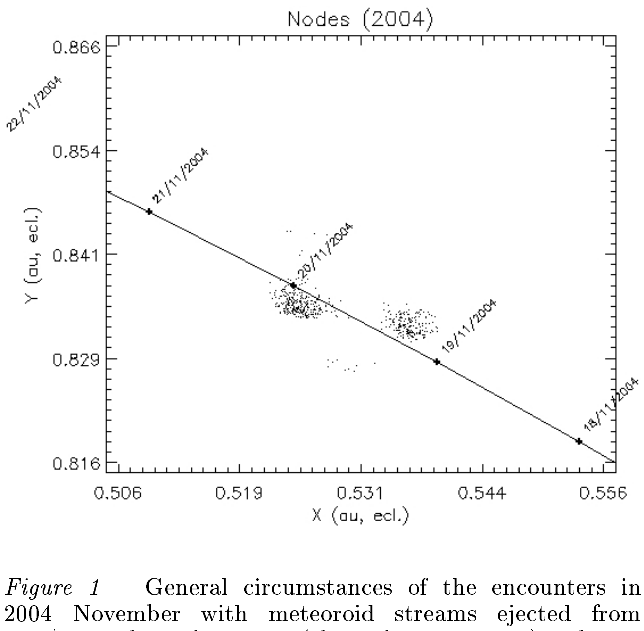

Figure 1 – General circumstances of the encounters in 2004 November with meteoroid streams ejected from 55P/Tempel-Tuttle in 1333 (the earlier encounter) and 1733 (the later encounter). The particles away from the two main concentrations are from 1333.

The 1733 trail was encountered in 2000 (McNaught & Asher, 1999; Arlt & Gyssens, 2000; Lyytinen & Van Flandern, 2000), i.e. only two years after the comet's perihelion return. In 2004 the situation is different, since six years separate the comet's return and the time of the shower. A more dispersed trail is expected, resulting in a lower ZHR value than in 2000.

[1]Institut de Mécanique Céleste et de Calcul des Éphémérides, 77 Avenue Denfert Rochereau, 75014 Paris, France. Email: vaubaill@imcce.fr

[2]Kehäkukantie 3 B, 00720 Helsinki, Finland. E-mail: esko.lyytinen@luukku.com

[3]Naavakuja 9 B 8, 78870 Varkaus, Finland. Email: markku.nissinen@pp.inet.fi

[4]Armagh Observatory, College Hill, Armagh BT61 9DG, Northern Ireland. Email: dja@arm.ac.uk

Table 1 – Trail encounter parameters, times and ZHR forecasts for 2004 Leonids (excluding normal Leonid background). Negative $r_E - r_D$ means Earth is closer than the trail to the Sun.

Model	Trail	Δa_0	$r_E - r_D$	f_M	Peak time (UT)	ZHR
M & A	1333	+0.15	−0.0019	0.02	Nov 19, 06^h40^m	
Lyytinen	1333	+0.15		0.02	Nov 19, 01^h30^m	5–10
Vaubaillon	1333				Nov 19, 06^h42^m	$\simeq 10$
M & A	1733	+0.22	+0.0024	0.10	Nov 19, 21^h20^m	
Lyytinen	1733	+0.22		0.11	Nov 19, 19^h00^m	$\simeq 30$
Vaubaillon	1733				Nov 19, 21^h49^m	65

Table 1 gives the details of the encounters with the two trails, on 2004 November 19. Vaubaillon's predictions are based on past observations, with a higher statistical weight given to the 2000 data for the 1733 trail. Thus these calibrations from past observations lead to moderate ZHR enhancements, as shown in the Table.

Alternatively, some idea of the meteor activity level can be obtained from the trail encounter parameters Δa_0, $r_E - r_D$ and f_M (McNaught & Asher, 1999). The first of these, defined as the difference in semi-major axis from the cometary value at the time when a meteoroid is released, is equivalent to the orbital period (which evolves under planetary perturbations). Therefore Δa_0 specifies the distance along the trail during the following orbital revolutions, and determines when the meteoroid reaches the ecliptic. Conversely the constraint that a meteoroid reaches its node in mid-November, so as to produce a Leonid meteor, determines Δa_0 (values in Table 1).

Most meteoroids experience significant solar radiation pressure, which increases the period. The above definition of Δa_0 is for the case of no radiation pressure, when Δa_0 for any given meteoroid is determined entirely by its ejection location on the comet's orbit and by the ejection velocity; we define meteoroids with the same period (experiencing different amounts of radiation pressure) as having the same Δa_0. Greater values of Δa_0 tend to be associated with smaller particles because these are more affected by radiation pressure. The Δa_0 values in Table 1 (McNaught & Asher model) are compatible with visual meteors (i.e., the number of meteoroids, of sizes corresponding to visual Leonids, is a maximum near such values of Δa_0). The particle size ranges simulated in other models agree with this conclusion.

For young enough trails, orbital evolution due to planetary perturbations is essentially a function only of Δa_0. Moreover, ejection at perihelion tangential to the comet's orbit, varying only the ejection speed, can generate any value of Δa_0. This idealisation, with a 'trail centre' defined by tangential ejection at perihelion, vastly reduces the required computation and has been shown to successfully predict any meteor storm (e.g., Kondrat'eva et al., 1997). Ejection over an extended arc of the comet's orbit and in directions other than tangential can be related to trail cross sections (Kondrat'eva & Reznikov, 1985; McNaught & Asher, 1999). The Table 1 (M & A model) values of the peak time are for the Earth's closest approach to the trail centre; the values of $r_E - r_D$ are the 'miss distance' in AU of the Earth from the trail descending node. The miss distance of storm level Leonid displays has been within a few × 0.0001 AU and so the 2004 trail encounters are a long way below storm level, even with the favourable values of Δa_0.

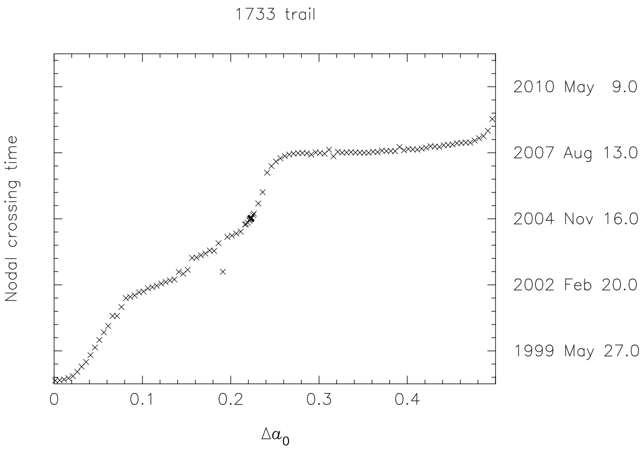

Figure 2 – Nodal crossing time around present day of particles ejected tangentially at perihelion in 1733, as a function of orbital period at ejection time (equivalently Δa_0).

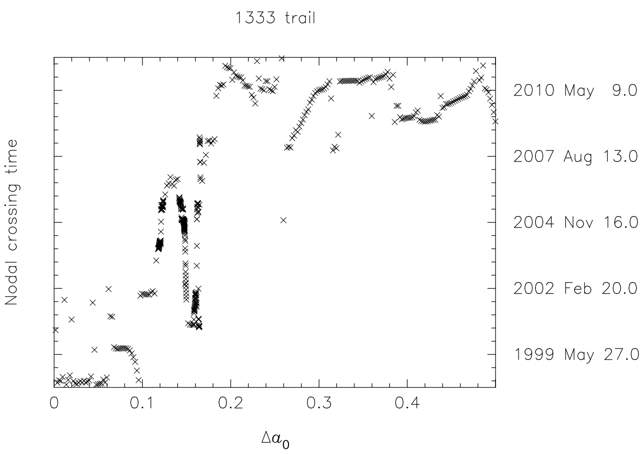

Figure 3 – Nodal crossing time around present day of particles ejected tangentially at perihelion in 1333, as a function of orbital period at ejection time (equivalently Δa_0).

The third parameter f_M measures how 'stretched' any given part of a trail is in the along-orbit direction. When nodal crossing times (Figures 2 and 3) are more spread out, f_M and the spatial density of particles are lower. In the 8-rev trail, the nodal crossing time is a (moderately) smooth function of Δa_0 (Figure 2), and f_M can easily be evaluated from the tangential ejection at perihelion model. For this trail, $f_M \approx 0.10$ (Table 1) and the particle density is 10× down on that for a 1-rev trail (additional to any dependence of the density on Δa_0 and $r_{\rm E} - r_{\rm D}$).

The 20-rev trail is old enough to be more scattered (Figure 3). Although the tangential ejection at perihelion model successfully identifies parts of the trail near the Earth (i.e., where $|r_{\rm E} - r_{\rm D}|$ is small), resulting values of f_M cannot be relied on (essentially, the curve in Figure 3 is not smooth enough). Indeed, at finer resolution (not shown here), Figure 3 shows multiple Earth encounters with the idealised trail centre (not listed separately in Table 1 since $r_{\rm E} - r_{\rm D}$ and especially Δa_0 are quite similar). The value of $f_M \approx 0.02$ in Table 1 was derived by following the orbital evolution of particles ejected along the comet's orbital arc and with different velocities (all particles having Δa_0 that placed them at or near the appropriate part of the trail). This simulation with multiple particles also allows cross sections to be plotted but these are not shown here as they show similar features to Figure 1; in any case Figure 1 relates to a fuller model (which has been calibrated by past observations). The low f_M and fairly high $r_{\rm E} - r_{\rm D}$ suggest quite a low ZHR.

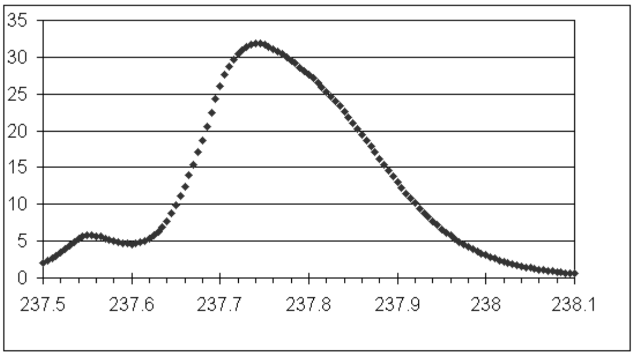

Figure 4 – ZHR due to 8-rev trail, as function of $\lambda_\odot$, taking into account the A2-effect.

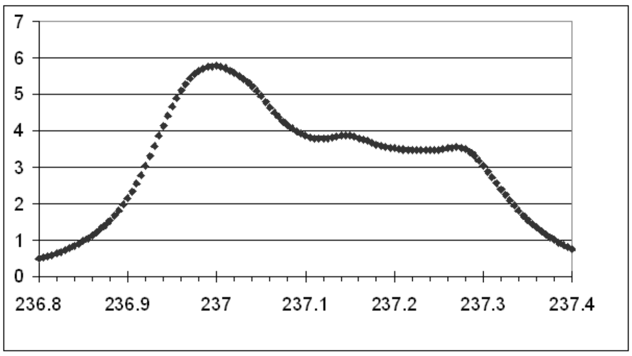

Figure 5 – ZHR due to 20-rev trail, as function of $\lambda_\odot$, taking into account the A2-effect.

Because perturbations are a function of orbital period, any systematic change to the period can affect particles' perturbation histories. We use the term 'A2-effect' to refer to systematic changes in the period due to radiative (i.e. nongravitational) forces. The size of the A2-effect is different for different meteoroids, as they experience radiative forces to differing extents. The overall A2-effect results from the range in the individual effect on different particles. It can firstly cause trail cross sections to spread over time, and also modifies the density profile encountered by the Earth along its orbit. A complete nongravitational model was calculated with the technique of Lyytinen & Van Flandern (2000) and Lyytinen et al. (2001). The model has been somewhat updated, taking into account the data from the years 2001 and 2002, but the main principles are the same. The derived ZHR plots are shown in Figures 4 and 5. The peak times that are evident as solar longitudes in these Figures are listed as UT in Table 1.

It appears that the nongravitational A2-effect (also called continuous acceleration) will bring particles closer to the Earth's orbit with positive values (that increase orbital period at each revolution) in the 8-rev encounter and with negative values in the 20-rev encounter. This effect may increase to some degree the total amount of meteors seen, but because these will be distributed over an extended time interval, the ZHR seems actually to be lower than would be expected without the effect. The times of maximum will be shifted earlier by some hours in each case, because of the effect. In the trail from 1733, this shift is expected to be about two or three hours and in the 1333 trail maybe as much as five hours (Table 1). The given times are not expected to be very accurate. The observations are expected to be valuable in studying this nongravitational effect, although the relatively small rates will probably not allow the observational results to give very accurate ZHR plots.

3 Comments and conclusion

The best estimates for this year's Leonids, excluding the normal Leonid background, are in Table 1. The background is traditionally associated with the Earth's passage through the comet's orbital plane; using the value of the comet's longitude when it last reached its node gives a time of 2004 November 17, $08^{\rm h}$ UT. The 20-rev and 8-rev trail encounters are two days later.

In general, the longer the time since the meteoroids were released from the comet, the harder it is to make precise quantitative predictions: we note that the majority of spectacular Leonid storms have been due to younger trails. Also, in the observations, lower level showers are harder than storms to separate quantitatively from the background. However, as in 2003 we can see that the Leonid meteor shower time is still not over now. Observers are therefore encouraged to gather data on November 19. We recall that IMO reports are the basis for constraining models of evolution of meteoroids and predictions of meteor showers.

References

Arlt R. (2003). "IMO news and forthcoming events, Leonids 2003". http://imo.net/news/news.html.

Arlt R. and Gyssens M. (2000). “Bulletin 16 of the International Leonid Watch: results of the 2000 Leonid meteor shower”. *WGN*, **28**, 195–208.

Asher D., Bailey M., and Emel’yanenko V. (1999). “Resonant meteoroids from Comet Tempel-Tuttle in 1333: the cause of the unexpected Leonid outburst in 1998”. *MNRAS*, **304**, L53–L56.

Brown P. and Arlt R. (2000). “Detailed visual observations and modelling of the 1998 Leonid shower”. *MNRAS*, **319**, 419–428.

Kondrat’eva E., Murav’eva I., and Reznikov E. (1997). “On the forthcoming return of the Leonid meteoric swarm”. *Solar System Res.*, **31**, 489–492.

Kondrat’eva E. and Reznikov E. (1985). “Comet Tempel-Tuttle and the Leonid meteor swarm”. *Solar System Res.*, **19**, 96–101.

Lyytinen E. (1999). “Leonid predictions for the years 1999–2007 with the satellite model of comets”. *Meta Research Bulletin*, **8**, 33–40.

Lyytinen E., Nissinen M., and Van Flandern T. (2001). “Improved 2001 Leonid storm predictions from a refined model”. *WGN*, **29**, 110–118.

Lyytinen E. and Van Flandern T. (2000). “Predicting the strength of Leonid outbursts”. *Earth Moon and Planets*, **82**, 149–166.

McNaught R. and Asher D. (1999). “Leonid dust trails and meteor storms”. *WGN*, **27**, 85–102.

Vaubaillon J. (2002). “Activity level prediction for the 2002 Leonids”. *WGN*, **30**, 144–148.

Vaubaillon J. (2003). *Dynamique des météoroïdes dans le système solaire. Application à la prévision des pluies météoritiques en général et des Léonides en particulier*. PhD thesis, Observatoire de Paris.

Vaubaillon J., Lyytinen E., Nissinen M., and Asher D. (2003). “The 2003 Leonid shower from different approaches”. *WGN*, **31**, 131–134.

Perseids

The 2004 Perseid outburst from Lithuania

Audrius Dubietis [1]

We present a short summary of the one-revolution dust trail Perseid outburst witnessed by a small group of three observers on the night of 2004 August 11/12 in Lithuania. A short outburst with full width of half maximum duration of 50 minutes with a peak ZHR of 244 ± 29 was observed at $20^{\rm h}59^{\rm m}$ UT ($\lambda_\odot = 139.^\circ 43$) in good agreement with model predictions.

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1 Introduction

The return of the comet 109P/Swift-Tuttle in 1992 has resulted in highly dynamic behavior of the Perseid meteoroid stream, which produced series of outbursts and multiple maxima during the past decade (Brown & Rendtel 1996, Jenniskens *et al* 1998). After some 'quiet' years of nearly normal activity, which was close to annual rates (Arlt & Buchmann 2002), enhanced activity of the Perseid meteor shower was expected again in 2004. Lyytinen and Van Flandern (2004) predicted a short outburst on the night of 2004 August 11/12, caused by freshly ejected meteoroids during the perihelion passage of the parent comet in 1862. According to their predictions this one-revolution dust trail was expected to cross the Earth's orbit at $20^{\rm h}54^{\rm m}$ UT, producing a short-lived (40 minutes) outburst with estimated rates of a few hundred to thousand meteors per hour. The expected outburst time was favorable for Asian locations, however observers in Eastern Europe also had a chance of viewing this event in the late evening. In this short Communication we share our impressions on the Perseid outburst observed from Lithuania.

2 Observations

A small team of three observers, Dovilė Kraulaidienė, Jurga Zieniūtė and the author carried out an observing session in the small country town of Salakas, Lithuania ($55.^\circ 6$ latitude North, longitude $26.^\circ 2$ East). Perfect sky conditions ($lm \geq 6.4$ for most of observations) with almost no interference from the late-rising waning crescent moon allowed collection of a reliable meteor dataset, see Table 1. During the nights of August 11/12 and 12/13 (20.89 hours of net observing time), a total of 1768 meteors were sighted, 1433 of them being the Perseids, 291 sporadics, while the remainder were attributed to minor showers – Northern δ-Aquarids (27), Northern ι-Aquarids (3) and κ-Cygnids (14).

A nice display of Perseid meteors was observed on the night of August 11/12. Exceptional Perseid activity was noticed at once, even though darkness has not completely arrived ($lm < 6$) – Perseid meteors appeared at a frequency of 1 meteor per minute. The rate gradually increased to 3 meteors per minute (on average) as the expected time of the maximum approached. Each observer counted more than 50 shower meteors just within a short 20-minute interval from $20^{\rm h}44^{\rm m}$ to $21^{\rm h}04^{\rm m}$ UT. Thereafter the rates steadily dropped, however the activity remained high. On the night of August 12/13 (the annual maximum was at the daytime, around $10^{\rm h}$ UT), Perseid activity was just around its annual level.

Table 1 – Summary of the observational data collected on the nights of 2004 August 11/12 and 12/13.

Observer	IMO code	$T_{\rm eff}$	N	$N_{\rm PER}$
A. Dubietis	DUBAU	7.52	749	593
D. Kraulaidienė	KRADO	6.30	495	408
J. Zieniūtė	ZIEJU	7.07	524	432
	Total	20.89	1768	1433

We applied the standard IMO procedure for data processing, involving computation of individual perception coefficients and subsequent conversion into correction for limiting stellar magnitude. First of all, we derived a population index. The amount of data did not allow the production of a reliable high-resolution population index profile, therefore we divided the magnitude dataset into three subsets, containing roughly 500 magnitude estimates each, that cover the there relevant periods: outburst, post-outburst and post-annual-maximum. It has to be noted that no Perseids of exceptional brightness had been seen; in the time of the outburst we recorded only a few meteors brighter than $m = -3$. Nevertheless, high percentage of bright meteors resulted in very low population indexes, namely $r_{\rm out} = 1.87 \pm 0.05$, $r_{\rm po} = 1.81 \pm 0.05$ and $r_{\rm pa} = 1.70 \pm 0.04$, where subscripts denote outburst, post-outburst and post-annual-maximum periods, respectively.

The individual perception coefficients had been derived from the individual sporadic rates:

$$c_p = \frac{\rm HR_{ind}}{\overline{\rm HR}_{\rm spo}} = r^{\Delta \rm lm}, \qquad (1)$$

where $\rm HR_{ind}$ and $\overline{\rm HR}_{\rm spo}$ denote individual and average sporadic rates, respectively. We used $r_{\rm spo} = 3.0$ and $\overline{\rm HR}_{\rm spo} = 15$ as reference values. Thereafter perception coefficients $c_{\rm p}$ were converted into a correction for a limiting magnitude Δlm, see Table 2.

In fact, these corrections were small, pointing to correct estimation of limiting stellar magnitude by all the observers, and had just a minor impact on the derivation of the activity level.

[1]Baltupio 101-2, LT-2040 Vilnius, Lithuania.
Email: audrius.dubietis@ff.vu.lt

Table 2 – Derivation of individual perception coefficients and corrections for limiting magnitude.

Observer	$N_{\rm spo}$	$\rm HR_{ind}$	$c_{\rm p}$	Δlm
DUBAU	135	17.8 ± 1.5	1.187	+0.16
KRADO	75	14.2 ± 1.6	0.947	-0.05
ZIEJU	81	13.7 ± 1.5	0.913	-0.08

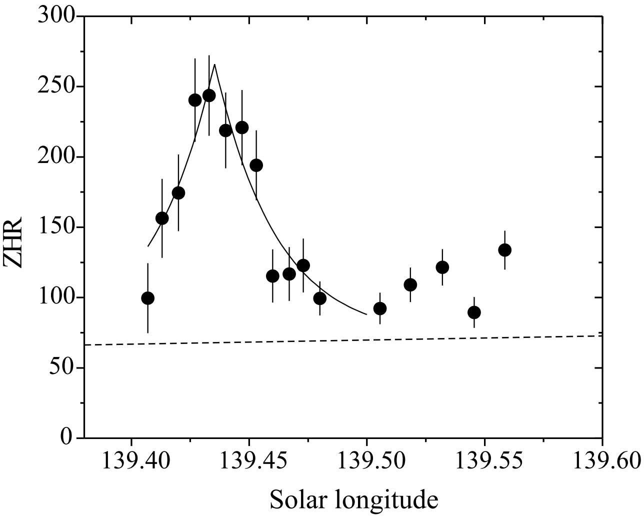

Figure 1 – Perseid activity on the night of 2004 August 11/12. The solid curve is an exponential fit of the outburst, while the dashed curve represents annual activity level.

The ZHR-plot of data collected on the night of August 11/12 with the clearly featured outburst is shown in Figure 1. We used 10-minute counting intervals for each data point at the time of the outburst and 20-minute intervals thereafter. For a comparison we present a best-fit annual activity curve with relevant parameters of $\rm ZHR_{max} = 86$, $\lambda_\odot^{\rm max} = 139{^\circ\!\!.}96$ and $B_{\rm max} = 0.20$, which was simulated from summaries of systematic observations provided by Brown & Rendtel (1996) and Jenniskens (1994).

Relevant parameters of the outburst were derived from the exponential fit, with three free parameters, related to outburst $\rm ZHR_{out}$, $B_{\rm out}$ and $\lambda_\odot^{\rm out}$, while others related to annual activity were fixed as given above:

$$\rm ZHR = ZHR_{max} 10^{-B|\lambda_\odot - \lambda_\odot^{max}|} + ZHR_{out} 10^{-B_{out}|\lambda_\odot - \lambda_\odot^{out}|}. \qquad (2)$$

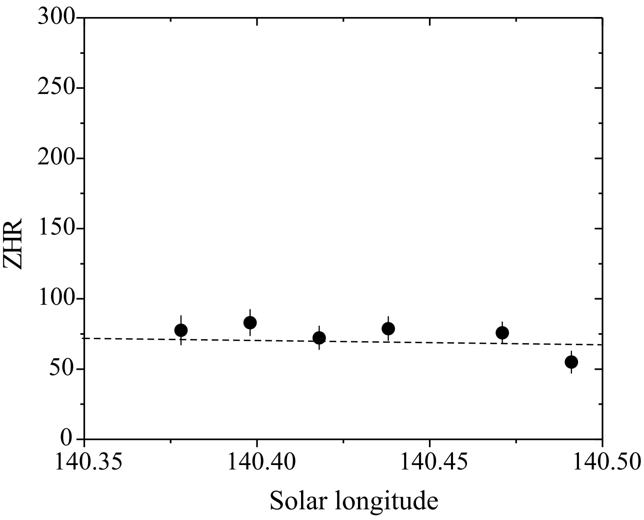

Figure 2 – ZHR-profile of Perseids on the night of 2004 August 12/13. The annual activity level is shown by the dashed curve.

A fit suggested $\rm ZHR_{out} = 200$ centered at $\lambda_\odot^{\rm out} = 139{^\circ\!\!.}43$ with a slope parameter $B_{\rm out} = 16.2 \pm 3.3$. This corresponds to FWHM (full width of half maximum) duration of $0{^\circ\!\!.}037$ in terms of Solar longitude, and 50 minutes in terms of time. These values are in fair agreement with the prediction by Lyytinen and Van Flandern (2004). It must be noted that actual rates of the outburst extracted from the fit were lower than those observed, because the overall activity is represented by a composition of outburst and annual rates. We also note high ZHRs of $\sim 100 - 120$ that remained after the outburst.

On the following night, when the annual maximum has passed, our data indicated just a normal Perseid activity level, see Figure 2. The data is represented using 30-minute counting intervals, and note how impressive is agreement with the annual activity curve.

3 Conclusions

In conclusion, we have observed a short-lived one-revolution Perseid outburst on the night of 2004 August 11/12, with maximum $\rm ZHR = 244 \pm 29$ at $20^{\rm h}59^{\rm m}$ UT. The time, the level and the duration of the outburst are in good agreement with model prediction provided by Lyytinen and Van Flandern (2004).

Acknowledgement

My best thanks go to Dovilė Kraulaidienė and Jurga Zieniūtė for their time, patience, and their rapid progress in observing skills.

References

Arlt R. and Buchmann A. (2002) "Global analysis of the 2002 Perseids", *WGN* **30:6**, 232–243.

Brown P. and Rendtel J. (1996) "The Perseid meteoroid stream: characterization of recent activity from visual observations", *Icarus* **124**, 414–428.

Jenniskens P. (1994) "Meteor stream activity I. The annual streams", *Astron. Astrophys.* **287**, 990–1013.

Jenniskens P., Betlem H., de Lignie M., ter Kuile C., van Vliet M. C. A., van't Leven J., Koop M., Morales E., and Rice T. (1998) "On the unusual activity of the Perseid meteor shower (1989-96) and the dust trail of comet 109P/Swift-Tuttle", *Mon. Not. R. Astron. Soc.* **301**, 941–954.

Lyytinen E. and Van Flandern T. (2004) "Perseid one revolution outburst in 2004", *WGN* **32:2**, 51–53.

Ongoing meteor work

SPA Meteor Section results: April–June 2002

Alastair McBeath[1]

Details from notes and observations reported to the SPA Meteor Section from April to June 2002 are given, with some discussion. Highlights included a cluster of four bright fireballs on April 6/7 and 7/8, the best-seen of which was at 00^h28^m UT on April 6/7. This was observed from the UK, Belgium and the Netherlands. Its probable trajectory passed from the English Midlands to the East Yorkshire coast, with any meteorites ending up in the North Sea, if so. A relatively weak Lyrid maximum was suggested around $08^h \pm 2^h$ UT on April 22 ($\lambda_\odot$ (eq. 2000.0) = $32\overset{\circ}{.}0 \pm 0\overset{\circ}{.}08$). Some radio π-Puppids may have been detected too, possibly with a peak on April 23 or 24. The η-Aquarid maximum probably fell as expected on May 5/6, perhaps with ZHRs $\sim 45 \pm 17$, as with the Lyrids, giving a lesser radio signature than might have been hoped for. Radio interference problems in June created numerous difficulties, but the Arietid and ζ-Perseid maxima probably happened on June 8 and 10/11 respectively. No June Lyrid or June Boötid activity was clearly apparent visually or by radio. Two bright fireballs were seen on June 21/22 and 22/23 from Britain, and the β-Taurid peak seems to have occurred roughly to time on June 27 or 28, but no evidence for the possible Taurid Complex 'swarm' return in 2002 June was noted.

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1 Introduction

A moonlit Lyrid return, a better η-Aquarid one (though always a difficult shower for northern hemisphere watchers), and the possibility of a Taurid Complex meteoroid 'swarm' recurrence during the June daytime streams, were the main anticipated events this quarter. In the end, these were largely upstaged by bright sporadic fireballs, as weather and Moon took their toll of visual observations especially. There was much radio interference from mid-May onwards too.

Table 1 presents the general quarterly totals.

The declining radio hours' tally through May and June reflected increasing problems with Sporadic-E (Es) over time, during the northern summer months. Around half the June datasets were entirely lost, either because no interference times were reported, or because of too much interference overall. The raw radio data were examined as usual in these reports, a procedure modified following the comments in (McBeath, 2004). By contrast, the increased June visual hours' total showed the efforts northern observers made to cover the possible June Lyrid and June Boötid epochs, despite twilight, unhelpful weather at times, as well as lunar difficulties.

Radio results were provided by Dirk Artoos in Belgium, and the following Radio Meteor Observation Bulletin reporters (RMOB; website: `www.rmob.org`), which data came from RMOBs 105–108 (April to July, 2002 respectively) edited by Chris Steyaert:

> Enric Fraile Algeciras (Spain), Mike Boschat (Nova Scotia, Canada), Maurice de Meyere (Belgium), Minoru Ehara (Japan), Valter Gennaro (Italy), Ghent University (Belgium), Patrice Guirin (France), Patrick Mergan (Belgium), Toshihide Miayake (Japan), Stan Nelson (New Mexico, USA), Robert Obraz (Croatia), Hiroshi Ogawa (Japan), Sadao Okamoto (Japan), Robert Savard (Quebec, Canada), Hironobu Shida (Japan), Dave Swan (England), Pierre Terrier (France), Garfield Tsao (Taiwan, China), Toshiaki Tsuruoka (Japan), Takashi Usui (Japan), Ilkka Yrjölä (Finland).

Video data came exclusively from people contributing results to the German Arbeitskreis Meteore (AKM; website: `www.meteoros.de`), extracted, with the other AKM material here, from their monthly journal Meteoros 5:5, 5:6 and 5:8 (2002), provided by Ina Rendtel. The observers were:

> Orlando Benitez-Sanchez (Canary Isles), Detlef Koschny (Netherlands), Rob McNaught (New South Wales, Australia), Sirko Molau (Germany), Mirko Nitschke (Germany), Steve Quirk (Australia), Jürgen Rendtel (Germany), Ulrich Sperberg (Germany), Rosta Stork (Czech Republic), Jörg Strunk (Germany).

Visual results came from:

> American Meteor Society observers (AMS; website: `www.amsmeteors.org`; data extracted from summaries in the AMS' journal 'Meteor Trails' 16, September 2002, kindly provided by observer Bob Lunsford in California, USA): George Gliba (West Virginia, USA), William Goodart (Arizona, USA), Paul Jones (Florida, USA), Pierre Martin (Ontario, Canada), Paul Martsching (Iowa, USA), Norman McLeod (Florida, USA); AKM watchers (in Germany where not stated): Rainer Arlt, Pierre Bader, Christoph Gerber, Darja Golikowa, Daniel Grün, Ralf Kuschnik, Sven Näther, Jürgen Rendtel (Germany and Canary Islands), Roland Winkler; Terry Churms (England), Alastair McBeath (England), Jonathan Shanklin (England).

2 April

April opened with a flurry of fireball reports. At least three bright events happened over western Europe on April 6/7, each reported from multiple sites. A fourth fireball over the UK was suspected around 02^h30^m UT, but the one notice received on it remained unconfirmed,

[1]12a Prior's Walk, Morpeth, Northumberland, NE61 2RF, England, UK. Email: `meteor@popastro.com`

Table 1 – Visual, video and radio hours' totals, visual and video meteor numbers recorded (with a partial breakdown of visual types), per month.

Month	Visual	LYR	Meteors	Video	Video meteors	Radio
April	$59\overset{\mathrm{h}}{.}1$	62	376	$511\overset{\mathrm{h}}{.}1$	2 879	4067^{h}
		ETA				
May	$44\overset{\mathrm{h}}{.}5$	31	277	$547\overset{\mathrm{h}}{.}7$	3 342	3661^{h}
June	$80\overset{\mathrm{h}}{.}7$	–	490	–	–	3349^{h}

and no additional sightings were recovered. Another very bright fireball, but on April 7/8 at $02^{\mathrm{h}}55^{\mathrm{m}}$ UT, was seen by only a lone witness in Scotland.

The first April 6/7 fireball was very precisely timed at $20^{\mathrm{h}}20^{\mathrm{m}}18^{\mathrm{s}}$ UT, thanks to three Czech radiometric detectors. It was very widely seen, and was photographed from seven European Fireball Network stations, five in Germany, one in the Czech Republic, and the seventh in Austria. The photographic data thus secured enabled a very accurate atmospheric trajectory and orbital determination to be derived. Spurný (2002) provided substantial early details, while (Spurný et al., 2003) give a fuller, final account, of the event.

To précis, the fireball had a visible flight nearly 91 km long, and penetrated unusually deeply into the atmosphere at a steep angle of $49\overset{\circ}{.}5$ from the horizontal. It first became luminous at 84.9 km altitude some 10 km east-north-east of Innsbruck, Austria, and headed north-west towards the Austro-German border, ending about 20 km west of Garmisch-Partenkirchen, Germany, terminating at just 16 km altitude. Its brightness peaked in a late flare around 21 km altitude, where it reached absolute magnitude −17.2. Its entry velocity was 20.9 km/s, but its violent deceleration meant its end-luminous velocity was down to 2.4 km/s.

The original mass was estimated at around 300 ± 100 kg, of which perhaps 20 kg of fragments might have reached the surface. Using the trajectory information, a single 1.75 kg EL6 enstatite chondrite was recovered from near Neuschwanstein, previously most famous for its castle, in southern Germany. The orbit determined was almost identical to that of the Příbram meteorite's, which fell in Czechoslovakia on 1959 April 7, and (Spurný et al., 2003) suggested this might indicate a 'stream' of meteoritic objects in an Earth-intersecting orbit in early April each year. While the orbits are similar, the meteorite types are not, as Příbram is an H5 chondrite, and the cosmic-ray exposure ages of the two meteorites are substantially different too: 12 million years (Příbram) and 48 million years (Neuschwanstein). However, April does enjoy a reputation for producing more sporadic fireballs than normal, so it would do no harm for observers to be alert to this possibility in future years.

The second April 6/7 event was a magnitude −8 or −12, yellow-orange brightening to green fireball, at $00^{\mathrm{h}}28^{\mathrm{m}}$ UT. It received detailed reports from ten UK sites, plus others in Belgium and the Netherlands. The information given here was derived chiefly from the British sightings. The meteor first became visible around 120 km above the surface between the cities of Birmingham and Coventry (near 52°21′ N, 1°45′ W), and flew north-eastwards from there, ending probably a short way out over the North Sea offshore between Skipsea and Atwick in Humberside (around 53°57′ N, 0°12′ W) at about 25 km altitude. The luminous atmospheric trajectory was thus about 222 km long, at an angle of descent from the horizontal of some 25°, giving a projected surface track approximately 200 km long. This is illustrated in Figure 1.

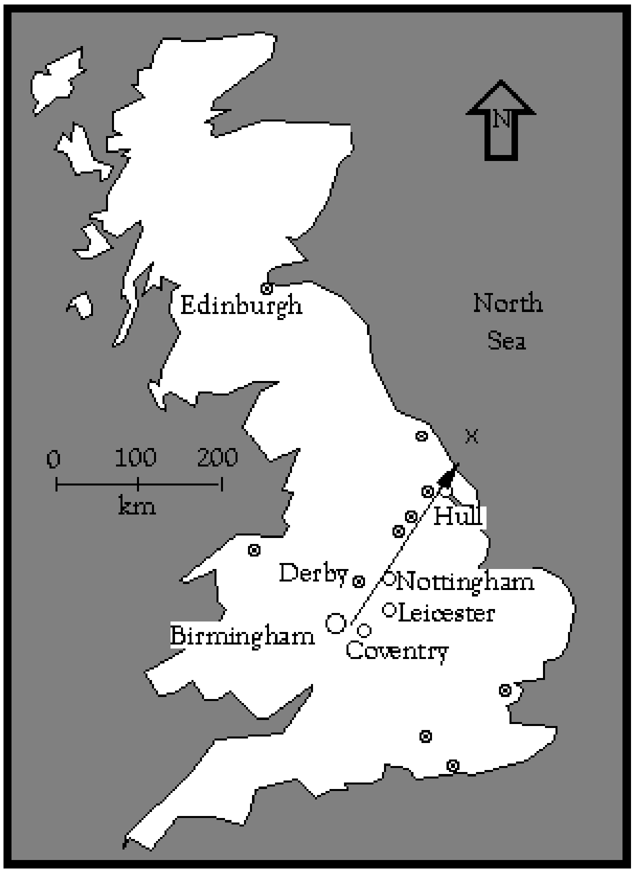

Figure 1 – A sketch map of mainland Britain, showing the projected surface track and direction of the April 6/7, $00^{\mathrm{h}}28^{\mathrm{m}}$ UT fireball as the arrowed line. Named cities close to the ground path are shown as open circles, while small target symbols show the locations of the ten observers. The 'X' in the North Sea, roughly 40 km offshore of the town of Scarborough, indicates the probable splashdown point for any surviving meteorites.

Sonic booms were reported from the site nearest Hull in Figure 1 around two minutes after the meteor had passed, which helps support the low visible end-point. Best estimates for the flight time were between six to eight seconds, implying a mean atmospheric velocity, not allowing for deceleration, of some 32±5 km/s.

The final April 6/7 fireball happened at 03^h56^m UT. Three sightings were received, from north-west England and south-west Scotland, indicating the event was of magnitude −8 or so. Unfortunately, only one observer could give a reasonably accurate position for the meteor's apparent path through the sky, so it was not possible to define a trajectory for this object. It probably flew on a roughly south to north track (possibly south-west to north-east) high over the Irish Sea somewhere between the Cumbrian coast and the Isle of Man.

Later in the month, visual watchers struggled against poor weather and the waxing Moon to cover the Lyrids. The predicted peak for the shower was around 10^h30^mUT on April 22 (McBeath & Arlt, 2001, p. 5). Regrettably, very little North American visual data was available from near that time. What there was, was affected by poor LMs (+4.5 to +5.0 only). There was a slight suggestion rates may have been a little higher earlier than expected (around $09^h45^m \pm 30^m$ UT), but this was highly inconclusive. Over Europe, where somewhat more results were collected on April 21/22, ZHRs were $\sim 13 \pm 3$ at roughly 02^h UT (assuming $r = 2.9$), but seemed rather lower both before and after that time. This rate probably does not indicate what the best ZHRs may have been anyway.

In the radio observations, surprisingly few datasets showed a clear Lyrid signature. Of those that did, that by Ghent University (Figure 2) gave the most obvious peak. Figure 3, from Pierre Terrier's data, is much more typical of the weak Lyrid response found more generally. A careful inspection of the minority of results with a Lyrid peak visible from Europe and North America (no Japanese results covering the expected Lyrid maximum were presented) indicated the maximum fell somewhere between 04^h–12^h UT on April 22 ($\lambda_\odot = 31.^\circ8$–$32.^\circ2$), with the most probable time around $08^h \pm 2^h$ UT ($\lambda_\odot = 32.^\circ0 \pm 0.^\circ08$). If roughly correct, this earlier maximum might account for the poor Lyrid showing in many of the results, following from Dubietis & Arlt (2001), who found Lyrid maxima between 1988–2000 had been weaker the further from the ideal peak time, equivalent to $\lambda_\odot = 32.^\circ32$, they fell.

Immediately after the Lyrids, there was the suggestion in some radio observations of a possible π-Puppid appearance on April 23 or 24. However, none of the reports was from far enough south to be certain on this point, nor were any southern hemisphere visual observations on-hand for comparison. The shower's maximum was due around 21^h UT on April 23.

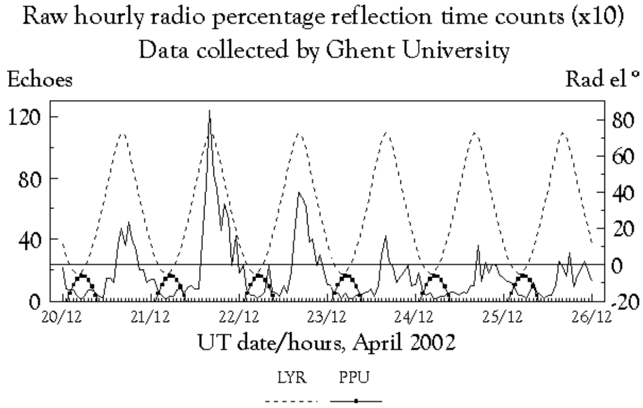

Figure 2 – Raw hourly radio percentage reflection time echo counts (×10) in data recorded over the Lyrid maximum by Ghent University. Echo counts are shown by the irregular line, keyed to the left-hand *y*-axis. The two daily-symmetrical curves are keyed to the right-hand *y*-axis, and give the Lyrid and π-Puppid radiant elevations (or lack thereof) for the Ghent site.

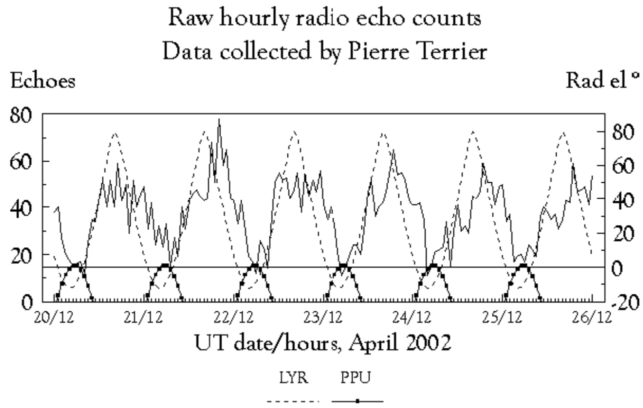

Figure 3 – Raw hourly radio echo counts collected over the Lyrid peak by Pierre Terrier. Other details are as in the caption to Figure 2.

3 May

Although radio data only began to be seriously affected by Es during the second half of May, in the northern summer 'season' for such interference, few continuous datasets were complete enough to be checked for the η-Aquarids even in early May. Those that were often showed unusually strong spikes on isolated days, with no consensus between observers regarding these, commonly indicative of unidentified reception problems. η-Aquarid activity seemed to show up relatively weakly, and there was only a limited indication that rates may have been marginally better on May 6, the expected peak (McBeath & Arlt, 2001, p. 6).

In the few visual results, ZHRs seemed highest on May 5/6, at about 45±17 (assuming $r = 2.7$). On dates nearby, rates were typically between $\sim$ 15–30. This near-maximum ZHR, plus the generally slack radio display, are in line with the findings of Dubietis (2003), who indicated η-Aquarid rates should be at about their lowest in 2001–2002, during their proposed circa 12-year cycle.

4 June

Despite the annual problems for northern observers with the midsummer twilight, and consequent brief overnight observing interval, plus Es interference for radio observers, there is plenty of potential meteoric interest to check for in June these days. The main daytime meteor shower peaks for the year should fall around June 7 (Arietids) and 9 (ζ-Perseids), too close together in time, and with their radiants too near one another in the sky, for radio observations to be able to easily separate them. Es spoilt many observers' attempts to capture a view of what transpired around this time in any case. Those whose data survived, showed no clear peak signature on either date. Slightly enhanced rates on June 8 were found in some results, though the enhancement was typically rather marginal. A somewhat more marked enhancement, but still not a very clear one, was present on June 10–11 in several sets of results. Assuming this second maximum was chiefly due to the ζ-Perseids, there is little to suggest rates were elevated by the possible Taurid 'swarm' return of 2002 June, as noted by Asher (1993).

The potential June Lyrid peak, around June 16, enjoyed a waxing crescent Moon, and six visual watchers provided coverage during parts of its assumed June 11–21 active spell. Just 7.5 possible June Lyrids were seen in $35^{h}06^{m}$, and as every night between June 11/12 and 18/19 inclusive saw at least one watcher active, it seems reasonably conclusive that no detectable June Lyrid activity occurred in 2002.

Two bright fireballs in strong twilight were recorded from southern British locations near the summer solstice. The first was picked up by a single witness at about $22^{h}00^{m}$ UT on June 21/22. From that observer's approximate positional details (estimating which was made more difficult than normal, as very few stars were visible in the twilight sky), a possible origin from the sub-horizon β-Taurid radiant could not be excluded. Four sightings were received on the second object, which was of at least magnitude $-4/-5$, but was probably brighter given the sky conditions. This occurred around $21^{h}30^{m}$ UT on June 22/23. The four observers were each able to give some idea of where the event had passed in the sky, but these did not give a clear consensus, regrettably. It seems likely the fireball started somewhere over south Wales and headed northwards from there, moving either south to north, or south-west to north-east. In either case, a β-Taurid origin is excluded by such a trajectory.

If the Arietid/ζ-Perseid maxima had been difficult to define in early June's radio data, the June Boötid/β-Taurid epoch in late month was worse. Only three continuously-operated systems had enough interference-free time to give useful coverage in the last week of June. As with the early-month daytime peaks, the β-Taurid maximum seemed present around June 27 or 28 (expected on June 28), but not with any clarity. No obvious June Boötid radio signature was found, although the sometimes patchy observations cannot rule out some minor activity from this source near its potential June 27 peak (shower maximum predictions from (McBeath & Arlt, 2003, p. 6)). Given that the visual data formed a subset of that analyzed by Rendtel (2002), it is not surprising no obvious visual June Boötid rates were found in the SPAMS results either. The radio results at least give some confidence that no strong Boötid activity, similar to that in 1998, took place during the substantial gaps in the visual results discussed by Rendtel.

Regarding the possible Taurid Complex 'swarm' recurrence, there was nothing in the radio or visual data to suggest a readily-detectable return in 2002 June. However, given the difficult radio observing conditions during the month, this is inconclusive. The noctilucent cloud data (with grateful thanks to Tom McEwan for providing it; see also www.kersland.u-net.com/nlc/), in which it was earlier indicated that anomalous sightings might provide information on unusual June Taurid Complex meteor activity (McBeath, 2000), showed no unexpected events in 2002. The next possible June 'swarm' return is in 2009 (Asher, 1993).

Acknowledgements

As normal, my fulsome thanks go to all observers and correspondents for their efforts during the quarter. I would particularly like to send additional thanks to Mike Dale of Royal Observatory Edinburgh and John Lambert of Newcastle Astronomical Society for their assistance in collecting many of the April 6/7, $00^{h}28^{m}$ UT fireball reports.

References

Asher D. (1993). "Meteoroid swarms and the Taurid Complex". In Roggemans P., editor, *Proceedings IMC 1993, Puimichel, France*, pages 88–91. IMO, Potsdam.

Dubietis A. (2003). "Long-term activity of meteor showers from Comet 1P/Halley". *WGN*, **31:2**, 43–48.

Dubietis A. and Arlt R. (2001). "Thirteen years of Lyrids from 1988 to 2000". *WGN*, **29:4**, 119–133.

McBeath A. (2000). "Daytime Taurid Complex stream activities, May-July 1999: A provisional report". *WGN*, **28:1**, 21–29.

McBeath A. (2004). "SPA Meteor Section results: January-March 2002". *WGN*, **32:4**, 111–113.

McBeath A. and Arlt R. (2001). *2002 Meteor Shower Calendar*. IMO, Potsdam.

Rendtel J. (2002). "June Boötid observations in 2002". *WGN*, **30:4**, 85–86.

Spurný P. (2002). "EN060402 bolide". IMO-News e-mailing list, 2002 April 17.

Spurný P., Oberst J., and Heinlein D. (2003). "Photographic observations of Neuschwanstein, a second meteorite from the orbit of the Příbram chondrite". *Nature*, **423**, 151–153.

SPA Meteor Section results: July–September 2002

Alastair McBeath[1]

Analyses based on data submitted to the SPA Meteor Section from July to September 2002 are presented and discussed, except all the data from August, which was detailed earlier. The Southern δ-Aquarid maximum in late July produced a somewhat unusually weak radio signature. In early September, α-Aurigid activity was also disappointing. The anticipated daytime Sextantid peak on September 27 was not noted in the radio data, but a peak around September 29–30 was found instead.

1 Introduction

A superbly Moon-free Perseid return was the quarter's highlight, as discussed earlier (McBeath, 2003). Since all the August observers, and virtually all the month's data, were given previously, they are not repeated again here. Instead, this article concentrates on events in July and September, including the α-Aurigid maximum on the August-September border.

Table 1 gives the quarter's reported tallies. An additional 10 α-Aurigids were seen in late August.

Radio observations in July and September came from Dirk Artoos (Belgium), and the following Radio Meteor Observation Bulletin observers (RMOB; website: `www.rmob.org`; via editor Chris Steyaert in RMOBs 108, 110 and 111, July, September and October 2002 respectively):

> Enric Fraile Algeciras (Spain), Mike Boschat (Nova Scotia, Canada), Walter Boschin & Luca Donato (Italy), Jeff Brower (Colorado, USA), Maurice de Meyere (Belgium), Minoru Ehara (Japan), Ghent University (Belgium), Patrice Guérin (France), Michael Krocil (Czech Republic), Toshihide Miayake (Japan), Stan Nelson (New Mexico, USA), Robert Obraz (Croatia), Sadao Okamoto (Japan), TianJing Ouyang (China), Robert Savard (Quebec, Canada), Hironobu Shida (Japan), Dave Swan (England), Istvan Tepliczky (Hungary), Pierre Terrier (France), Garfield Tsao (Taiwan, China), Takashi Usui (Japan), Bruce Young (Queensland, Australia), Ilkka Yrjölä (Finland).

The raw radio results were analyzed as normal, the procedure modified after (McBeath, 2004). Sporadic-E interference during the northern summer was less problematic than earlier in the 'season' as July waned, but some observers continued to encounter difficulties with it into September.

Video results during July and September came from contributors to the German Arbeitskreis Meteore (AKM; website: `www.meteoros.de`). All the AKM data used here were extracted from their monthly journal Meteoros 5:8 to 5:11 (2002) inclusive, submitted by Ina Rendtel. The video observers were:

> Orlando Benitez-Sanchez (Canary Isles), Steve Evans (England), Detlef Koschny (Netherlands), Sirko Molau (Germany), Mirko Nitschke (Germany), Steve Quirk (Australia), Jürgen Rendtel (Germany), Ulrich Sperberg (Germany), Rosta Stork (Czech Republic), Jörg Strunk (Germany), Ilkka Yrjölä (Finland).

The visual watchers included:

> American Meteor Society observers (AMS; website: `www.amsmeteors.org`; taken from summaries in their journal 'Meteor Trails' 17, December 2002, sent via editor and observer Bob Lunsford in California, USA): Jure Atanackov (Slovenia), Ardalan Alizadeh (Iran), Javad Azizi (Iran), Amir Hasanzadeh (Iran), Javor Kac (Slovenia), Soheil Khoshbinfar (Iran), Pierre Martin (Ontario, Canada), Paul Martsching (Iowa, USA), Bert Matous (Kansas, USA), Mazyar Seyyednizhad (Iran); AKM observers (all in Germany, except where stated): Frank Enzlein, Daniel Grün, Ralf Kuschnik, Sven Näther, Jürgen Rendtel (Germany and Canary Islands), Roland Winkler; Alastair McBeath (England), Jonathan Shanklin (England), George Spalding (England).

Photographic data from Valentin Velkov (Bulgaria) was forwarded by Eva Bojurova.

2 July

A few July Pegasids were detected in early month, too few to sensibly analyze, but most visual observations were concentrated in mid to late month, either side of full Moon on July 24. For all this, relatively few Southern δ-Aquarids were seen — the α-Capricornids were more in evidence, as Table 1 shows. However, Valentin Velkov did manage to catch a lone SDA meteor on photographic film at 22^h55^m UT on July 13/14. The meteor passed across part of Cygnus, not far from Vega (α Lyrae) and Deneb (α Cygni), among the star-clouds of the Milky Way. Both the SDA and CAP meteors were too sparse to define any shower maxima, difficult anyway with the waning Moon.

In the late July radio results, there were traces of peaks around July 28 or 29 and 30, but these were not found consistently in all the available datasets. The SDA and CAP maxima were due on July 28 and 30 respectively (McBeath & Arlt, 2001, p. 7). Figure 1 gives some sample graphs showing both the radio data, and the problems in its interpretation, given that for mid-northern hemisphere watchers, observed rates of the Perseids, α-Capricornids and Southern δ-Aquarids are often quite similar to one another during the last week of July.

In past years, a late July 'bulge' in the radio activity graphs was often apparent, tending to last for a week or more (McBeath, 2001), so the difficulties in defining specific maxima here are not especially surprising. The

[1] 12a Prior's Walk, Morpeth, Northumberland, NE61 2RF, England, UK. Email: `meteor@popastro.com`

Table 1 – Visual, video and radio hours' totals, visual and video meteor numbers recorded (with a partial breakdown of visual types), per month.

Month	Visual	SDA	NDA	CAP	PER	KCG	Meteors	Video	Video meteors	Radio
July	168^{h}	28	19	39	29	—	1 041	554^{h}	1 930	6028^{h}
August	388^{h}	72	208	77	5 641.5	150	8 744	$627^{h}.7$	2 650	5595^{h}
		AUR	DAU	SPI	—	—				
September	$95^{h}.9$	17	118	47	—	—	842	$845^{h}.5$	3 863	4620^{h}

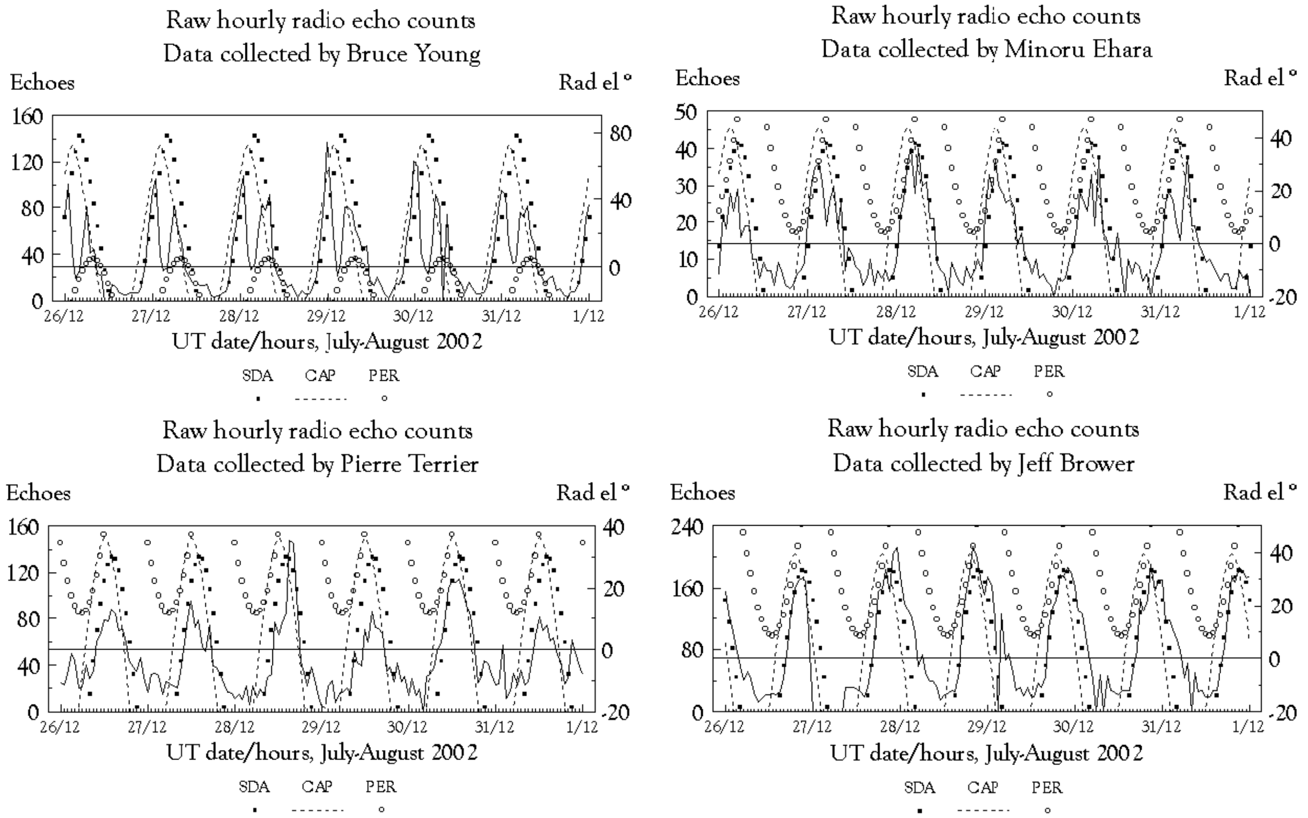

Figure 1 – Four graphs of raw hourly radio meteor echo counts, showing activity in late July and early August 2002. In each, the echo counts are given by the irregular lines keyed to the left-hand y-axes. The other, daily-symmetric, curves, indicate parts of the radiant elevations for the three showers noted, keyed to the right-hand y-axes. The four give an impression of how activity was perceived in different parts of the world. Top left: Australia (Bruce Young). Top right: Japan (Minoru Ehara). Bottom left: Europe (Pierre Terrier). Bottom right: North America (Jeff Brower).

general lack of definition in the SDA peak is a little less ordinary, but not unknown from recent times.

3 September

While the waning Moon was a nuisance for the anticipated α-Aurigid peak on September 1 (McBeath & Arlt, 2001, p. 7), the visual rates from the shower were more disappointing than expected. The radio peak is often minor, and nothing unusual was reported around August 31–September 1 in the radio results. Despite the quantities of δ-Aurigids seen, no clear peak was found for them, theoretically due around September 8 (McBeath & Arlt, 2001, p. 11).

The mid-September spell of occasionally enhanced radio activity, around September 15–17, was first identified as of potential interest by Artoos (1990). September 17 seemed the more popular date among the observers for a minor radio maximum in 2002 in the data to-hand, with weaker support for something more on September 15 and 16. This is much as has been seen before (McBeath, 2001), with no stronger signature present this time.

A useful series of radio reports was available from the Sextantid peak epoch in late September to early October. The maximum was due on September 27, but might have recurred on September 29 instead — or as well (see (McBeath & Arlt, 2001) for the general predictions; (McBeath, 2000) has notes on the Sextantids, as well as a strong probable Sextantid signature around this later time in 1999). September 29–30 provided more observers with at least a minor echo count peak in 2002, but almost no evidence for a peak on September 27. This is unusual, as the September 26 or 27 maximum has been generally clearer than that around September 29 or 30 in the past (McBeath, 2001). This is certainly a period which warrants continued radio monitoring.

Acknowledgements

It is as ever a pleasure to thank all the observers and correspondents for their efforts during the quarter, in making this report possible.

References

Artoos D. (1990). "Possible radio activity in September 1990". *WGN*, **18:4**, 101–102.

McBeath A. (2000). "SPA Meteor Section results: September–October 1999". *WGN*, **28:4**, 125–130.

McBeath A. (2001). "The forward scatter meteor year: 2001 update". *WGN*, **29:3**, 85–92.

McBeath A. (2003). "SPA Meteor Section results: 2002 Perseids". *WGN*, **31:2**, 69–72.

McBeath A. (2004). "SPA Meteor Section results: January–March 2002". *WGN*, **32:4**, 111–113.

McBeath A. and Arlt R. (2001). *2002 Meteor Shower Calendar.* IMO, Potsdam.

Orbit of the Glanerbrug meteorite revisited

Marco Langbroek [1]

This paper revisits the orbit of the Glanerbrug LL5 meteorite. Based on a large number of eyewitness observations, a trajectory, speed and approximate orbit were published in 1992 (Jenniskens et al., 1992a,b). It appears that a human error was made in keying in radiant parameters at that time: the listed radiant and orbit are not in agreement. New revised orbital elements are given. An association of Glanerbrug with Přibram and Neuschwanstein has previously been suggested (Langbroek, 2001; Spurný et al., 2003). The new, revised orbit compares less well to the Přibram/Neuschwanstein orbits, with a Drummond D' criterion value of 0.13.

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1 Introduction

On 1990 April 7 at $18^{\rm h}32^{\rm m}38^{\rm s}$ UTC, around sunset in the Netherlands, hundreds of Dutch, German and even a few Danish citizens reported seeing a fireball dropping down from the sky. At Glanerbrug, near the Dutch-German border, the Wichmann family discovered that evening that something had fallen through their roof, spreading hundreds of stone fragments and roof tile fragments over the floor of their attic (Betlem 1990; Lindner et al. 1990). The 800 grams of recovered stone fragments turned out to be fragments of an LL5 brecciated chondrite (Lindner et al., 1990; Lindner and Welten, 2002): the fourth surviving meteorite of the Netherlands (Grady, 2000).

As the meteorite fall occurred around sunset, the Dutch All Sky camera network was not yet operational. In the days following the event, members of the Dutch Meteor Society and the NVWS meteor section, including this author, interviewed several eyewitnesses (Betlem, 1990). From measurements taken with 20 of these eyewitnesses on-site, as well as fall-angle estimates by over 70 eyewitnesses, a trajectory and approximate orbit for the fireball and meteorite could be derived (Jenniskens et al., 1992a, b).

That orbit recently got some attention, as it was thought to associate to the photographically obtained orbits of the Přibram and Neuschwanstein meteorites, which fell in 1959 and 2002 in the Czech Republic and Germany/Austria respectively (Langbroek, 2001; Spurný et al., 2003).

In this contribution it is pointed out that the published orbit for the Glanerbrug bolide (Jenniskens et al., 1991a) appears to have suffered from a human error in the data input, and hence is incorrect. This has bearing on the question of a possible relation to Přibram and Neuschwanstein.

2 Basic data, and a human error?

While testing a spreadsheet that calculates orbital elements from radiant and speed data (Langbroek 2004), the author discovered that published results for the Glanerbrug radiant (Jenniskens et al., 1992a) did not yield an orbit matching the published orbit. Extensive testing of the spreadsheet, using data on a large number of photographic multistation meteors, revealed this to be a solitary case: the spreadsheet functions correctly in all other test cases. Hence, the implication is that the Glanerbrug orbit published in the 1992 paper is in error.

The data in Table 1 (1950.0) have been published for the Glanerbrug (Jenniskens et al., 1992a).

Table 1 – Basic data for the Glanerbrug bolide, and orbit (1950.0) from Jenniskens et al. (1992a). Azimuth is measured eastwards from north.

Glanerbrug meteorite	
Apparent radiant	
Apparent azimuth	60°
Apparent altitude	41°
Apparent α	202°
Apparent δ	+49°
V_∞	23 km/s
Orbit	
q	0.85 AU
i	23°
e	0.69
ω	230°
Ω	17.117°

The orbital parameters given do not match the given apparent radiant. An apparent radiant at azimuth 60°, altitude 41°, corresponds to $\alpha = 203°$, $\delta = +49°$. After correction for zenith-attraction and diurnal aberration with V_∞ 23 km/s, this corresponds to a geocentric radiant at $\alpha = 207°$, $\delta = +47°$. The published orbit, however, is closer to the orbit resulting from a geocentric radiant at $\alpha = 205°$, $\delta = +39°$, which is 8° lower in declination. It appears that a human error was made when keying in the radiant data in the software.

Of course, we have to realize that the uncertainty in the radiant determination itself probably amounts to several degrees. Jenniskens et al. (1992a) report uncertainty values of ±7° on the mean RA and ±6° on the mean declination of the apparent radiant, which was the average of radiant positions determined by three different methods of data reduction. The published orbit however is for a radiant location outside even these quoted uncertainty boundaries.

3 Revised orbit

A new orbit was computed for Glanerbrug (Table 2). As is obvious from this, the eccentricity and the semi-major axis $a = q/(1-e)$, and hence the aphelion distance, is

[1]Diefsteeg 1, NL-2311 TS Leiden, the Netherlands.
Email: meteorites@dmsweb.org

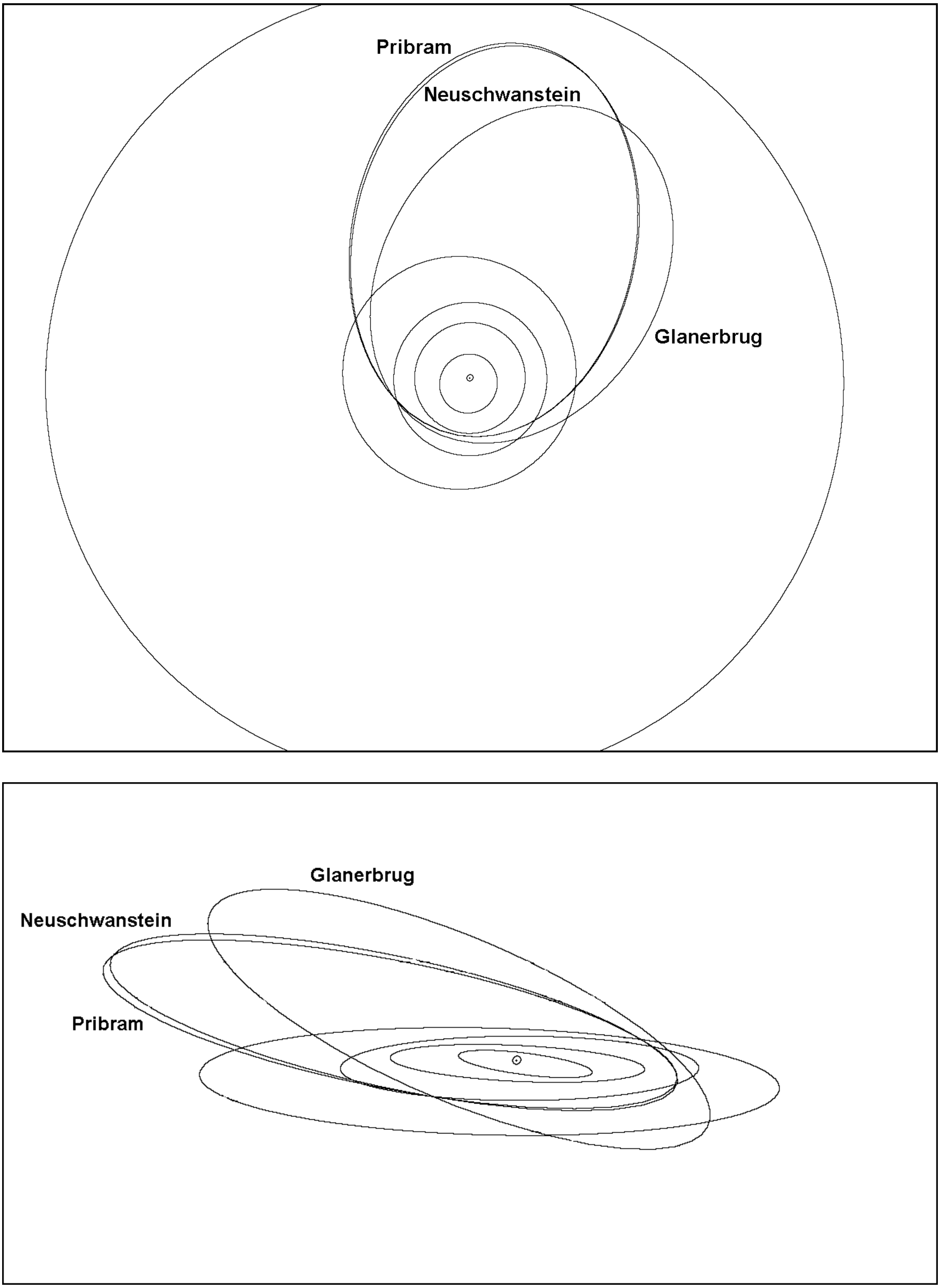

Figure 1 – The revised orbit for the meteoroid of the Glanerbrug meteorite, compared to those of the Přibram and Neuschwanstein meteorites.

Table 2 – Revised orbital elements for the Glanerbrug bolide (2000.0). The bold printed elements are the authors' best estimate.

V_∞	V_{geo}	α_{geo}	δ_{geo}	q (AU)	e	i (°)	ω (°)	Ω (°)	ϖ (°)	Q (AU)
23.0	20.0	207	+47	0.90	0.72	25	220	17.816	238	5.6
20.9	17.5	208	+46	0.91	0.59	23	222	17.816	240	3.5
20.0	16.4	208	+46	0.91	0.53	22	223	17.816	241	3.0

highly dependant on the speed, which is ill-defined in this case. Jenniskens et al. (1992a) favoured a V_∞ of 23 km/s. However, their decision is questionable as this speed hinges heavily on the timing accuracy of just one observer combined with non-quantitative descriptions of the fireball's apparent velocity. As can be seen in Table 2, the resulting orbit moreover crosses the orbit of Jupiter, which is unlikely for an Ordinary chondrite. The average trajectory length and the average of the duration estimates by all observers suggest a somewhat lower speed of ~20 km/s. Using that speed in calculations, the aphelion is located squarely in the asteroid belt. If we take into account some amount of deceleration, then the best estimate for the initial speed is in the range 20 km/s $< V_\infty <$ 22 km/s.

An initial speed of ~20.9 km/s, corresponding to a geocentric speed of ~17.5 km/s, has been chosen as the favoured solution, as it is near the center of the quoted range and comparable to the geocentric speeds of Přibram and Neuschwanstein (Spurný et al., 2003).

4 Discussion

Care should obviously be taken with this orbit, as the uncertainties are large. The revision of the orbit nevertheless has relevance for the proposed orbit association of Glanerbrug with Přibram and Neuschwanstein (Langbroek, 2001; Spurný et al., 2003). One result of the revision is that the perihelion distance q for the Glanerbrug orbit (q =~0.91 AU) becomes notably larger than that for Přibram and Neuschwanstein (q =~0.79 AU). Unlike a and e the perihelion distance is less influenced by the uncertainty in the fireball's velocity, as can be seen in Table 2. And only near the extreme lower end of the uncertainty in the radiant location does q become < 0.9. In terms of Drummonds' D' criterion (Drummond, 1981), the new ~20.9 km/s nominal orbit of Glanerbrug compares with $D' = 0.13$ to the Přibram and Neuschwanstein orbits, which is a less good match than the results previously published (Langbroek, 2001; Spurný et al., 2003), with $D' = 0.099$.

References

Betlem H. (1990). "Speciaal nummer: nieuwe Nederlandse meteoriet". *Radiant (J. DMS)*, **12:3**. Thematic number.

Drummond D. (1981). "A test of comet and meteor shower associations". *Icarus*, **45**, 545–553.

Grady M. (2000). *Catalogue of Meteorites.* Cambridge University Press, Cambridge, UK, 5th edition.

Jenniskens P., Borovička J., Betlem H., ter Kuile C., Bettonvil F., and Heinlein D. (1992b). "The Glanerbrug meteorite fall". *Pub. Astr. Inst. Czech. Acad. Sci.*, **79**, 1–18.

Jenniskens P., Borovička J., Betlem H., ter Kuile C., F. B., and D. H. (1992a). "Orbits of meteorite producing fireballs. the Glanerbrug — a case study". *Astron. Astroph.*, **255**, 373–376.

Langbroek M. (2001). "Pribram en Glanerbrug". *Radiant (J. DMS)*, **23:4**, 76–78.

Langbroek M. (2004). "A spreadsheet that calculates meteor orbits". *WGN*, **32:4**, 109–111.

Lindner L., Alderliesten C., Welten K., Maijer C., Poorter R., Schuiling R., Jenniskens P., Betlem H., and Arps C. (1990). "Glanerbrug: a new stony meteorite". *Meteoritics*, **25**, 379–380.

Lindner L. and Welten K. (2002). "The Glanerbrug revisited". *Radiant (J. DMS)*, **24:2**, 33–38.

Spurný P., Oberst J., and Heinlein D. (2003). "Photographic observations of Neuschwanstein, a second meteorite from the orbit of the Přibram chondrite". *Nature*, **423**, 151–153.

History

The Challis 'Meteoroscope'

Alastair McBeath [1]

Some additional details on, and description of, James Challis's 'meteoroscope', a device for measuring meteor positions under the sky, further to those in (McBeath, 2004), are given. It was invented in 1848, almost 20 years earlier than previously thought, but seems to have been little-known, even during the 19th century.

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1 Introduction

In (McBeath, 2004), I briefly discussed a device for measuring meteor positions in the sky, called a 'meteoroscope'. This was apparently invented by Professor James Challis, to help with his observations of the 1866 Leonid storm from Cambridge Observatory, England, according to (Challis, 1867). However, a recent chance discovery among the *Reports* of the British Association for the Advancement of Science, indicates it was actually invented by Challis nearly twenty years earlier, in 1848 (Challis, 1849). This also means the first citation for this use of the term 'meteoroscope' in the Oxford English Dictionary (Simpson & Weiner, 1989, Vol. IX, p. 686), dated to 1895 from Funk's Standard Dictionary, is almost fifty years after Challis originally so-named his device. Some further details on Challis's meteoroscope are given here.

2 The meteoroscope and its use

The meteoroscope Challis used for his 1866 Leonid observations on November 13–14 (Challis, 1867), was very vaguely delimited. He mentioned it having a sighting-bar 21 inches (53 cm) long, fixed to a tripod, but movable easily in altitude and azimuth, and from which angular alt-az (altitude/azimuth) measurements could be made using a vertical arc and a horizontal circle, graduated in degrees. In use, the estimated place of the meteor was pointed to with the bar, the alt-az positions read off and recorded, together with the time, rough magnitude (bright, medium, or faint), direction of flight, 'and incidental physical circumstances'. In total, 63 meteor and 7 star positions were so obtained, in $2^{\rm h}45^{\rm m}$, the star positions to correct the errors in setting up the instrument. Challis (1868) provided a full list of all the meteor and star data thus recorded, as well as additional information on the Leonid storm observations and their reduction. He also presented a second set of Leonid meteoroscope reports collected by another team at Cambridge, led by his colleague Professor Adams (the list attributed to Adams contains 272 meteor and 4 star positions).

Challis's 1868 paper indicated that meteor positions were taken near the middle or end of each meteor's flight. He went on to describe how he drew out on paper a sketch map of Regulus (α Leonis) and five other stars in Leo's 'head' asterism (η, γ, ζ, μ and ϵ Leonis, although his diagram (Challis, 1868, p. 366) has γ and ζ mislabelled as 'ν' and a second 'ϵ'), plus the estimated Leonid radiant's position (remembering this was during the height of the 1866 meteor storm, so this is not as impractical as it sounds). He also used the approximate mid-point between two well-seen, near-stationary Leonids to make a meteoroscope radiant measurement for comparison. The two positions derived were — paper: $\alpha = 148°59'$, $\delta = +22°47'$ (based on a star map in Johnston's Atlas of Astronomy for epoch 1850, but corrected by Challis to epoch 1867.0); meteoroscope: $\alpha = 150°58'$, $\delta = +23°36'$. Although Challis (1867) expressed disappointment the two did not coincide exactly, given the relatively crude methods, this is quite an achievement, and his weighted mean radiant (at $\alpha = 149°39'$, $\delta = +23°12'$) compares favourably with the modern Leonid radiant (epoch 2000.0) of $\alpha = 153°$, $\delta = +22°$, for the maximum night.

His earlier article (Challis, 1849), from a letter dated 1848 August 9, gave a more thorough description of the meteoroscope, but without any observational results, the instrument then being freshly-invented. Thus it is surprising to find Challis made no reference to this earlier paper in 1867–68.

The meteoroscope was like a theodolite, with a 0°–360° horizontal circle, and a 0°–120° vertical arc, each scale being about 4 inches (10 cm) in diameter. Instead of the theodolite's telescope, the sighting device was a movable bar 18 inches (46 cm) long, with a rectangular plate at each end. One plate had a 1/6-inch (4 mm) diameter hole drilled through it, the other a vertical and horizontal edge, meeting at a right-angled corner. Sighting required bisecting the viewed object with the right-angle as seen through the circular hole. For near-zenithal measurements, a small, silvered, flat mirror, set at 45° to the end-plate was fitted to the eye-end of the sighting bar, along with a second eye-hole drilled plate. Clamps to hold both the vertical and horizontal motions were fitted, together with a spring and counterpoise to prevent slipping when not clamped. The working head was fitted to a wooden tripod, secured into a wood base in use, with a small spirit-level for horizontal adjustment (only). Problems in using the sighting-bar at night were remedied by painting the faces of the end-plates white, which even a distant light source could illuminate sufficiently.

Challis intended the meteoroscope to be used for measuring distinct features of the aurora and the zodi-

[1] 12a Prior's Walk, Morpeth, Northumberland, NE61 2RF, England, UK. Email: meteor@popastro.com

acal light. Aurora observers still use simple hand-held alidades to give approximate alt-az measurements certainly, so in this sense the meteoroscope lives on. However, he also suggested his invention be used for defining 'the points of first appearance and disappearance of meteors and shooting stars'. Aside from the curious distinction between meteors and shooting stars, anyone who has tried plotting meteors will immediately appreciate the difficulties in using Challis's meteoroscope thus, which is perhaps why there are so few references to it, and why Challis was using a slightly different instrument and method by 1866.

He went on to note the advisability of simultaneous triangulated meteor observations using meteoroscopes, and commented how surprising it was no such instrument had been used before, as many prior observations of meteors had 'been comparatively useless on account of want of accuracy'. Measurement errors for stars Challis estimated at about two arcminutes, but said the alt-az of a known star near any meteors needed to be taken around the same time, to remove systematic errors if the device was not perfectly adjusted. He gave no idea of the probable errors for meteor positions, but one would assume these might be large, especially for the second point so measured. This may be why he later advocated taking just one reading per meteor, though this meant the loss of path-length data, which he drew attention to in his 1867 article.

3 Conclusion

The development of meteor photography, and now video, has rendered devices like Challis's meteoroscope obsolete. Even in his day, it seems it was little-used, so much so that he was able to reintroduce it in 1867 as if it would be new to his audience. Challis was apparently unfamiliar with the earlier, more astrological, meteoroscope, as mentioned in the 17th-century play Albumazar (McBeath, 2004). Had he been acquainted with it, he would probably have wished to choose an alternative name for a device he considered scientifically-accurate and important for detailed meteor observations.

References

Challis J. (1849). "Description of a new instrument for observing the apparent position of meteors". In *British Association for the Advancement of Science — Report — 1848*, pages 13–14. British Association for the Advancement of Science.

Challis J. (1867). "On the luminous meteors of November 13–14, 1866". *Monthly Notices of the Royal Astronomical Society*, **27**, 75–77.

Challis J. (1868). "Observations of meteors made at the Cambridge Observatory between November 13th, 11^h30^m and November 13th, 14^h15^m, in the year 1866". In *British Association for the Advancement of Science — Report — 1867*, pages 360–372. British Association for the Advancement of Science.

McBeath A. (2004). "Meteor Beliefs Project: 'Meteor' and related terms in English usage". *WGN*, **32**, 35–38.

Simpson J. and Weiner E. (1989). *Oxford English Dictionary*. Oxford University Press, 2nd edition. 20 volumes.

Meteor Beliefs Project: Manuscript reports of meteoric activity over Romania

Andrei Dorian Gheorghe [1] *Alastair McBeath* [2]

A collection of 15th to 19th century reports of meteoric, or possibly meteoric, events, is presented, drawn from manuscripts originating in the area of modern Romania. Aside from the popular beliefs represented in some of these, it seems there may also be important records of either strong Leonid or Andromedid activity from 1605 and 1765, neither year previously noted for producing such. If the first of these was the Andromedids, this may be the earliest-known European record of this shower, although the identification is uncertain. The second event, whatever its source, seems to show a very early appreciation of the radiant effect, from long before it was first supposed recorded, during the 1833 Leonid storm.

1 Introduction

In 1912, the noted astronomer Victor Anestin presented a paper to the Romanian Academy in Bucharest, entitled 'Comets, Eclipses and Fireballs observed in Romania between 1386 and 1853 from Manuscripts and Documents'. Much of this work was re-presented, with additional information, by V and D Mioc in 1977, in their book 'The Chronicle of Romanian Astronomical Observations', published in Cluj. We have drawn on both sources here, Anestin's via the *Romanian Academy Annals*, and have translated the texts into English for the first time, as far as we are aware. This has allowed us to compile a catalogue of what were, or may have been, meteoric or meteoritic events, witnessed from the general area of modern Romania between 1495 and 1884.

For each entry, we have given the relevant translated text extracted from the manuscript, plus, where appropriate, the Gregorian calendar date as given by Anestin or Mioc & Mioc (as parts of Romania other than Transylvania did not adopt the Gregorian calendar until the early 20th century, this can create problems), and the name of the manuscript's author. At the end of each item, we have added notes to highlight the probable nature of the event, or further discussion, where this was felt necessary. All our comments are given in square parentheses, thus '[ ]'.

Unfortunately, Anestin and Mioc & Mioc gave only limited information on their manuscript sources, so we have normally given just the chroniclers' names here. Those we do have a little more on, typically the titles of their texts, are as follows:

For Transylvania: Czack — 'Ephemeris'; Georgius Krauss — 'Tractatus', 'The Transylvania Chronicle'; Thoma Tartler — 'Diarium'; Teutsch — 'Nebenarbeit', 'Zugabe'. For Wallachia: Ilie Corfus — 'Notes'. For Moldavia: Iordachi Vârnav — 'Ceaslov'.

The three regions mentioned roughly equate with the following areas of modern Romania: Transylvania — the lands west and north of the Carpathian Mountain ranges; Wallachia — the plains between the River Danube and the Carpathians, as far north as the Danube delta, including modern Dobruja (between the Danube and the Black Sea); Moldavia — the area between the River Prut and the Carpathians, north of Wallachia. The modern Moldavian Republic, formerly known at times as Bessarabia, is not included in the survey discussed here. All the areas noted have had variable boundaries through the ages, and the delineations above are approximate only.

Regarding the dating of events, we note that some overnight events may be plus or minus a day, dependent on when the manuscript's author considered one date ended and the next began (sunset, midnight or sunrise). As there is often no way to be sure, almost all the overnight dates have this level of uncertainty about them.

[1] Bd. Tineretului 53, bl. 65, ap. 40, sect. 4, Bucureşti, Romania. Email: sarm@romwest.ro

[2] 12a Prior's Walk, Morpeth, Northumberland, NE61 2RF, England, UK. Email: meteor@popastro.com

2 Catalogue of events

15th century

One item, from Transylvania.

1495: *...In these days, an extraordinary sign appeared in the sky. We heard about it from those who saw it, and thought that it should not be forgotten. Nicolae, the friend of Sigismund, going to Buda to visit his king and master, saw and heard in the village of Solta a strong light among the clouds, accompanied by an immense thunder. Suddenly, frightened by the novelty of this thing, Nicolae threw himself on the ground, and after that, looking at the sky, he saw the Virgin Mary and her Son, surrounded by a very bright nimbus, which passed down through the clouds towards Buda...* (Antonius Bonfinius) [Probable daylight acoustic fireball.]

16th century

All items from Transylvania.

1558: *...On July 26, three stones fell from the sky to the Cross Field, weighing 13, 14 and 15 kg...* (Forgats) [Probable meteorite fall. The meteorites have not survived.]

1558: *...On the Field of Cristur, three stones fell from the sky, weighing 15 kg...* (Sepsi) [Probable meteorite fall. Most likely another record of the previous event.]

1589: *...The town of Iaz was hit by a stone from the sky; all that town was burnt, excepting the house of the preacher, on June 16...* (Sepsi) [Probable meteorite fall. The meteorites have not survived.]

1593: *...Small flying lights and burning vapours,* *which suddenly showed themselves in the sky's expanse, and strongly spread a lot of fire, struck horror into mortal souls...* (W Bethlen) [Possibly a strong meteor shower, or perhaps an auroral display?]

1596: *... On a time was seen in the sky from the Turkish country, something like an outburst of fire, explained as a strange sign in the sky and a sign of victory...* (Nagy) [Perhaps a fireball, or possibly a brief auroral outburst?]

1599: *... On the fourth day of April, at 10 o'clock in the evening, some fire fell with a rumble from the sky...* (Czack) [Probable acoustic fireball.]

1599: *... In the same summer, various kinds of burnings and fiery globes terrified the people's souls in different places...* (W Bethlen) [Possibly bright meteors, possibly lightning-induced fires and ball-lightning?]

17th century

All items from Transylvania.

1603: *... On March 25, a noise was heard in the air during the day, just like a gun salvo, such that the people threw themselves on the ground in fear...* (Teutsch) [Possibly a daylight acoustic fireball, but perhaps genuine cannon fire.]

1604: *... In this year, in May ... there appeared in the sky many falling stars and flying strips...* (W Bethlen) [Probable strong meteor activity.]

1605: *... On Good Friday, at 3 o'clock in the afternoon, while the sky was clear, it thundered strangely, just like gun salvos, and the echo was heard in all directions...* (Sepsi) [Possibly an acoustic daytime fireball, but perhaps genuine gunfire. Good Friday was on April 8.]

1605: *... Around May 17, there were the following unusual things in Arpăşel. Smoke like a big cask dropped from the sky, the forest of Arpăşel was set on fire, the green trees and the earth burnt for two weeks with much smoke. Also, masses of gun salvos and trumpet sounds were heard. King Stefan Bathori sent Kis Farcas, his manservant, to see what had happened in the Arpăşel forest...* (Sepsi) [Possibly a daylight fireball, with or without a meteorite strike, combined with a forest fire; possibly a deliberate attack to burn the forest with incendiary explosives, or perhaps an unusual lightning strike? There is no follow-up report of what the king's man found in the forest, unfortunately.]

1605: *... On November 15, a clear and luminous night, it was as if it rained stars, at first many stars, bigger and more luminous, after that small and big stars in a great number, which extinguished themselves before arriving at the earth...* (Krauss) [Meteor storm. There is a problem with the date, as this does not coincide with the expected Leonid maximum in the early 17th century, which should have been around November 6 or 7. Some Far Eastern reports from 1602 suggest strong activity on October 27, November 6, 7 and 11 (Roggemans, 1989, p. 161), but nothing in 1605. If the date has been wrongly corrected, there could be a shift of ±10 days from that above, which could mean it might have been November 5 (in which case this could be a previously unrecorded strong Leonid event), or November 25 (if so, it may be the earliest-known European record of the Andromedids. The previous earliest was 1741 (Roggemans, 1989, p. 169)). Unfortunately, there is no way to be sure, other than to hope additional records from this year might shed more light.]

1605: *... December 24 ... A few days before was a giant noise in the air, just like two armies fighting each other...* (W Bethlen) [Possibly an acoustic fireball, possibly the sound of a genuine gun-battle. Note the record is under December 24, but the event occurred an unstated 'few days' earlier.]

1607: *... On November 27, at the seventh hour of the night, on a clear moon, an appearance of light, fire, fell from the sky, with a noise and an earthquake, in the town of Bícsad and other places...* (Zavodskii) [Probably a bright acoustic fireball, possibly a meteorite fall.]

1609: *... In the same year, one day, after 7 o'clock in the evening a celestial lightning was seen, which transformed itself into a burning lance...* (W Bethlen) [Possibly a fireball, or perhaps an auroral display?]

1615: *... The day of January 5. Even at daybreak, a luminous appearance was seen, just like fire falling from the sky, or a rainbow, followed by thunders and earthquakes...* (Zavodskii) [Possibly an acoustic fireball near dawn, but the 'rainbow' reference especially might suggest an auroral display, or perhaps even a genuine rainbow near dawn, which would be reddened by the sunrise, and very high in the sky. Rainbows indicate showery weather, which could also account for the fire falling - if it was actually rain seen falling from a cloud catching the sunrise - and the later thunder.]

1640: *... After that, some fire fell from the sky...* (Krauss) [Perhaps a fireball, but unhelpfully very vague.]

1647: *... On September 27, in the evening, strong roaring was heard in the sky, from the west, as if there were cannon salvos. Later, it was found that these were heard over the whole world, and it was something like a forecast of future grief and the terrible destruction of our poor country...* (Krauss) [Perhaps an acoustic fireball, but it is more likely to have been genuine gunfire. We should mention that on 1648 October 24 at Münster, Germany, three 70-cannon salvos were fired to signal the end of the Thirty Years' War. There is no suggestion this is what was reported here, but war had been raging across much of central Europe for the previous three decades.]

1650: *... On October 9, in the afternoon, all of Transylvania heard loud roars in the air, just like cannon salvos. The people of Cluj thought that they came from Oradea ... the people of Braşov thought that they came from Făgăraş...* (Krauss) [Perhaps an acoustic fireball, but more likely to have been gunfire?]

1658: *... On April 19, in the morning, a globe of fire fell on the new castle near Braşov...* (Teutsch) [Possibly a fireball, but more probably ball-lightning.]

1661: *... At that time, at the end of summer, throughout Transylvania was heard in the air strong roaring ... In the fortress of Făgăraş, half of a very strong bulwark wall collapsed, filling the moat...* (Krauss) [Possibly an acoustic fireball, but more likely to have been gunfire?]

1663: *... On September 8, at 3 o'clock in the afternoon, some noises and roaring were heard from the sky in Transylvania, ... Moldavia, Wallachia and Hungary...* (Krauss) [Possibly an acoustic fireball, or maybe gunfire?]

1664: *... January 5. A large celestial sign appeared in Transylvania and other places. It was a big luminous fire, like a table burning with flames. Finally, this sky-sign threw out fiery lightnings, and disappeared with strong roaring and thundering...* (Krauss) [Probable bright acoustic fireball.]

1687: *... On the eighth day after the Sacred Trinity, at 8 o'clock in the evening, three small fire-clouds flew over Braşov and Mount Tâmpa, seen from the whole of Bârsa County...* (Teutsch) [A fragmenting fireball? The date would have been July 13.]

18th century

Locations are given with each item.

1707: *... January ... On the 25th, in the afternoon, from the mountains, over the forest near Făgăraş, a frightful thunder and crack was heard, and many men wanted the imperial garrison of Făgăraş to use its big and small cannons. But after that, it was certain that in Făgăraş County a strong storm had appeared, and three stones fell from it, on which Hebrew letters were seen...* (Christopher, Transylvania) [Possible meteorite fall? The stones have not survived for modern examination.]

1709: *... On January 28, a nice, clear day, on the other side of the Buzău river, was a thunder so loud that men and animals fell to the ground. A few stones from the sky fell too, and they were carried to the court of the prince, where all the people were astonished to see them ... But big, black stones fell only in two places...* (Greceanu, Wallachia) [Probable meteorite fall. The stones have not survived. The date is given in the Julian calendar. It would be February 8, Gregorian.]

1728: *... In December, before Christmas, a light fell on the roof of the cathedral of Braşov...* (Tartler, Transylvania) [Possibly a fireball, but more likely lightning or ball-lightning?]

1765: *... November 12 ... In this month, on three consecutive mornings, to the north was seen a strange light (which did not look like the dawn), tightening itself into a circle, from which many falling stars detached like candles, lighting the earth...* (Teutsch, Transylvania) [Very strong meteor shower. The fact the meteors were apparently seen on three consecutive mornings suggests the Andromedids as the most plausible candidate, a rare early report of the shower if so. The date itself was extracted from earlier in the chronicle entry, and the stock phrase 'In this month' probably indicates some time in November, beginning on or after after this date. November 12 would fit to the Leonids for this period (theoretical maximum around November 11 or 12), but there are no other known strong Leonid reports from the 1760s. Leonid maxima persisting for two consecutive nights were recorded in 1698 (November 8 and 9) and 1787 (November 9 and 10) however (Roggemans, 1989, p. 161). The probable Andromedid radiant (a number of observed and theoretical Andromedid radiants are known — c.f. (Kronk, 1988, pp. 211–220)) would have been to the north-west in the hours before dawn in late November, and the description implies an appreciation of the radiant effect long before it was officially reported, during the 1833 Leonids. It is possible some other phenomenon was present, perhaps an aurora, though the coincidence of an identical aurora on three consecutive mornings when very active meteor rates were present as well, seems unlikely, assuming the chronicle entry to be reliable. The note that the light was unlike the dawn could be taken as meaning unlike the aurora too, given that the term 'aurora borealis' means literally 'northern dawn'. The light could not have been dawn twilight in November, as then the Sun rises to the south-east in Europe.]

1774: *... In April, in Wallachia, Dâmboviţa County, near Târgovişte, there were the following incidents. One morning before sunrise, in a clear sky, a small luminous cloud appeared, which began to thunder, and from which many dark stones fell like rain. They seemed like solidified lumps of thick mud, or as if they had been broken off a tombstone; some of them bigger, some of them smaller; big like a punch, or small like a nut. And they fell so fast that the big stones entered deeply into the ground ... and the small stones remained on the ground like hailstones ... Their smell was like mud, and a little like sulphur...* (Corfus, Wallachia) [Shower of meteorites. The stones have not survived. The dating uses the Julian calendar. Depending on when the event took place, correcting by +11 days to convert it to the Gregorian calendar might carry it into early May.]

1786: *... On September 8, a Tuesday, in the night, a very bright light appeared in the sky that made light like the daytime, and from which fiery blazes fell, extinguishing themselves in the air. After its end, thunder like the roar of an earthquake came from the north; the day after, Wednesday, it began to rain for four days ... This light was seen in other remote places too...* (Cernica Monastery Manuscripts, Wallachia) [A brilliant, fragmenting, acoustic fireball. The date is Julian. It would be September 19, Gregorian.]

1786: *... On September 8, at 7 o'clock in the evening, to the north in the sky, there appeared behind the clouds something like the sun, and all places were lit up as if by fire...* (Corfus, Wallachia) [A brilliant fireball; another report of the previous event. The Gregorian date would be September 19 again.]

19th century

Locations are given with each item.

1818: *... On October 19, Saturday to Sunday, at half past three in the night, there was a big light like that you can see on the moon. And this light lasted half of a quarter of an hour. The sky was as if it had been opened, and in its middle, was something like a fire-dragon. After this compressed, a stripe like lightning remained in the sky. It lasted a little, and died...* (Dobrescu, Wallachia) [Probably an auroral display. 'Fire-dragon' might refer to a meteor, but the overall length and description of the event makes a meteoric explanation unlikely. The date is Julian. The Gregorian date would be October 31.]

1821: *. . . On June 27, the sky was split by a huge light. . .* (Dobrescu, Wallachia) [Probably a fireball, but perhaps an auroral display? The Gregorian date would be July 9.]

1821: *. . . On August 20, Saturday, at 2 o'clock in the night, there was a sign in the sky, to the north, a big bubble like a luminous house, which brightened all the earth, and went into the west. . .* (Dobrescu, Wallachia) [Possibly a bright fireball, or perhaps an auroral display? The Gregorian date would be August 31.]

1824: *. . . On July 30, at 1 o'clock in the night, there was a sign in the sky, at first a tailed star, which became just like a snake. It stayed half an hour, and hid itself. . .* (Iordachi Vârnav, Moldavia) [Perhaps a bright fireball leaving a very persistent train, or perhaps an auroral display? The Gregorian date would be August 10, so if a fireball, possibly a Perseid.]

1832: *. . . On February 25/26, between 10 and 11 o'clock, on the horizon at Bucharest, a meteor was seen from the east to the south, which, because of its unusual brightness and colour, red like fire, it seemed just as if the Vâcâreşti district was burning. . .* (Hiller, Wallachia) [Perhaps a near-horizon fireball? The direction makes an auroral display unlikely, but another explanation cannot be excluded. The date would be March 7/8 Gregorian.]

1847: *. . . On July 2, after I was awake at two hours after midnight, I saw lights with many ornaments, shining like beautiful Paradise, with wonderful burning brilliance. I wiped my eyes, but also many faces of luminous appearance were showed to me, like the burning of fire, from all directions. They lasted more than a quarter of an hour. I thought I was worthy to pass into eternal life. . .* (Father Boloş Filip, Transylvania) [Probably an auroral display. The Gregorian date would be July 14. Although most Transylvanian chroniclers used the Gregorian calendar, Fr. Filip was from Serbia, where the Julian calendar still held sway at the time.]

1866: *. . . On November 1, Tuesday, in the night there was a great sign in the sky, like a roll turning like a crown, coming undone, and dropping down millions of stars until the day, from the east to the west. . .* (Niţâ Andronescu, Wallachia) [Meteor storm - the Leonids. The phrasing suggests an attempt to describe the radiant effect seen with a great meteor storm. The corrected date would of course be November 13, Gregorian.]

1884: *. . . On February 20, Monday, at 12 o'clock, there was to the north a foreign thunder, different to that we know. . .* (Corfus, Wallachia) [Perhaps an acoustic fireball, or gunfire? The Gregorian date would be March 3.]

3 Conclusion

It is often difficult when working with medieval manuscripts, or even those later ones prepared by people without scientific training, to be certain what was being described when hunting for astronomical sightings. It may seem that we have included a number of vague gun-like sounds and probable auroral events, alongside the more obvious meteoric ones, but we have preferred to err on the side of including too much, than excluding something which might be important in future. The number of wars raging across eastern Europe throughout the timespan we have examined means that the people would have been generally familiar with the sounds of distant gunfire of all sorts, so at least some of the accounts preserved can be taken as implying something different to that was being experienced. This may be because of unusual atmospheric effects, or may be because something meteoric had occurred.

The recovery of what may be the earliest European observation of the Andromedids, from 1605, if not a hitherto unknown strong Leonid return, together with another probable early Andromedid display, lasting for several days in 1765, is both justification of, and some reward for, the necessary efforts in working with such problematic material. The beliefs and perceptions of the different witnesses are interesting too, and we should be grateful they considered these things worthy of recording, in however unusual or imaginative ways.

References

Kronk G. W. (1988). *Meteor Showers: A Descriptive Catalog.* Enslow Publishers Inc.

Roggemans P. (1989). *Handbook for Visual Meteor Observations.* Sky Publishing Corporation.

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Council

President: Jürgen Rendtel,
Eschenweg 16, D-14476 Marquardt, Germany.
tel. +49 33208 50753
e-mail: jrendtel@aip.de

Vice-President Alastair McBeath
12A Prior's Walk, Morpeth,
Northumberland NE61 2RF, UK.
tel. +44 1670 518487
e-mail: meteor@popastro.com

Secretary-General: Robert Lunsford
161 Vance Street, Chula Vista,
CA 91910-4828, USA. tel. +1 619 585 9642
e-mail: lunro.imo.usa@cox.net

Treasurer: Ina Rendtel
Mehlbeerenweg 5, D-14469 Potsdam, Germany
tel. +49 331 520 707
e-mail: IRendtel@t-online.de
Postal (giro) account number: 5472 34-107
Bank code: 100 100 10 Postbank Berlin
(When paying, state bank code and postbank as well as account number!)

Other council members:
Rainer Arlt, Friedenstraße 5, D-14109 Berlin, Germany. e-mail: rarlt@aip.de
David Asher, Armagh Observatory, College Hill, Armagh BT61 9DG, Northern Ireland, UK. e-mail: dja@star.arm.ac.uk
Malcolm Currie, 25, Collett Way, Grove, Wantage, Oxfordshire OX12 0NT, UK. e-mail: mjc@star.rl.ac.uk
Marc Gyssens, Heerbaan 74, B-2530 Boechout, Belgium. e-mail: marc.gyssens@luc.ac.be
André Knöfel, Habichstraße 1, D-15526 Reichenwalde, Germany. e-mail: aknoefel@minorplanets.de
Sirko Molau, Abendstalstraße 13b, D-84072 Seysdorf, Germany. e-mail: sirko@molau.de
Mihaela Triglav-Čekada, Streliška 9, SI–1000 Ljubljana, Slovenia. e-mail: mtriglav@yahoo.com

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Sporadic fireball over Slovenia

Photographed at A.S. Orion's 'Youth Astronomical Research Camp' on Trije Kralji, Slovenia (46°26′17″ N, 15°27′30″ E, 1200 m a.s.l.). The all-sky camera is made from a 50 cm diameter mirror and a camera with $f = 50$ mm lens about 1.4 m from the mirror. This photo was shot on 2004 August 16, from $22^h11^m48^s$ UT to $22^h21^m36^s$ UT with Fuji 800 film. The fireball appeared at $22^h12^m30^s$ and was estimated at magnitude -6 to -7. Photo: Javor Kac. Photographer's reference: spor20040816_221230col.