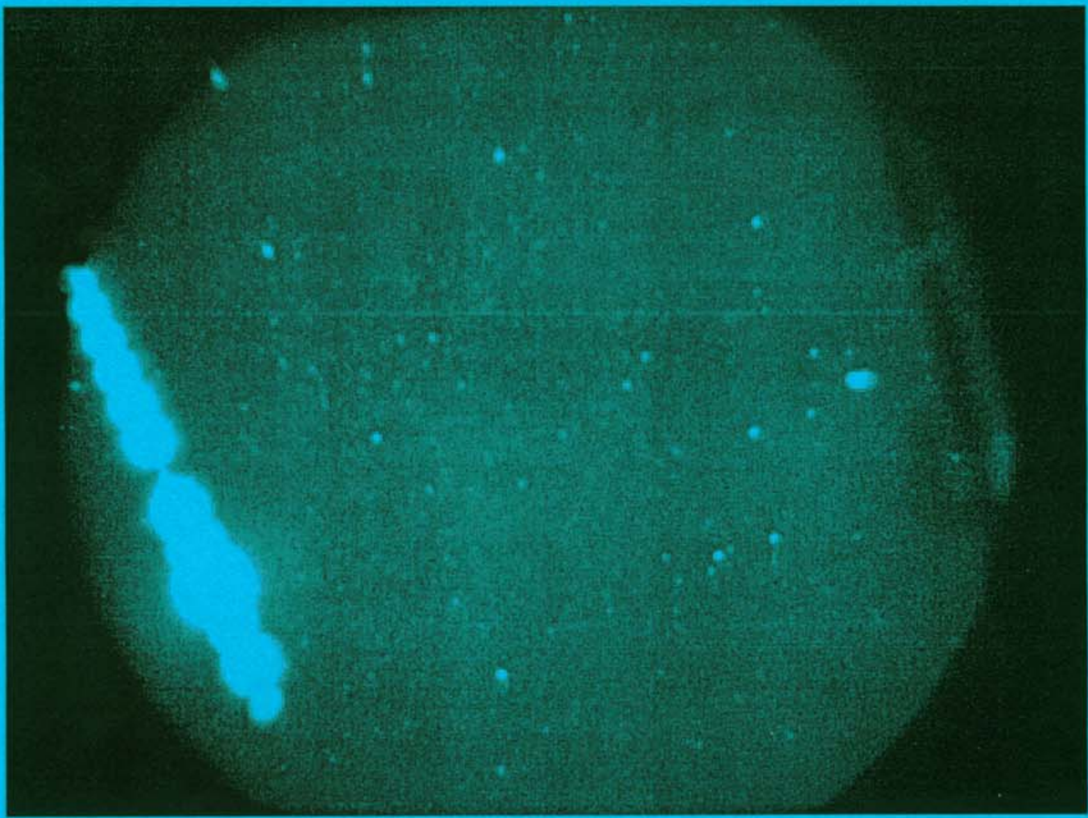
ISSN 1016-3115

wgn

30-5
october 2002

bimonthly journal of the international meteor organization



This bright Perseid was captured by Ulrich Sperberg with the image-intensified video camera AKM1 operated by the network of the Arbeitskreis Meteore, Germany. The meteor appeared at $22^{h}35^{m}57^{s}$ UT on August 2, 2002, and was recorded from Salzwedel, Germany. The camera was equiped with a 25-mm lens and an aperture of $f/0.85$. The "grub-like" appearance of the meteor is caused by adding several frames from the video signal.

In this issue:

In case of non-delivery, return postage guaranteed. Please return to:
v.u.: Marc Gyssens, Heerbaan 74, B-2530 Boechout, Belgium

WGN, Vol. 30, No. 5, October 2002, pp. 129–198

Contents

Useful Information

The December issue *(WGN 30:6)*

The *December issue* will be edited in the middle of December 2002 in order to include first impressions from the 2002 Leonids. Contributions should be sent to *Marc Gyssens* before December 5.

Subscriptions and ordering of publications

Volume 30 (2002) of *WGN* is expected to contain about 240 pages and costs 20 EUR, including non-airmail delivery. Ordering other *IMO* publications is done in the same way as paying subscription/membership fees. Changes of address and complaints about not receiving *WGN* should be addressed to the Treasurer, Ina Rendtel.

All addresses can be found on the inside of the back cover.

Renew Your IMO Membership/WGN Subscription Now

comm. by Ina Rendtel, Treasurer

We would like to remind you of the renewal of your subscription of this Journal. You can check for how long you have paid the subscription on the address label of *WGN*'s envelope: The year given is the the last for which you paid.

Please, send your payments to the Treasurer or one of her assistants as indicated below:

- **in Europe:** pay in *Euro* to *Ina Rendtel* by transferring to the postal giro account number 547234107 at Postbank Berlin, bank code 10010010. (Please send **no bank checks**!—If you must pay by check, pay to Robert Lunsford as indicated below.)
- **in the United Kingdom:** proceed as above, or pay to *Alastair McBeath*, 12A Prior's Walk, Morpeth, Northumberland NE61 2RF, England.
- **in Japan:** pay to *Masahiro Koseki*, 4-3-5 Annaka, Annaka-shi, 379-01 Gunma-ken, Japan.
- **All others** pay in *US Dollars* to *Robert Lunsford*, 161 Vance Street, Chula Vista, California 91910, USA.

All people insisting on paying by check should pay to Robert Lunsford in US Dollars, as indicated above. Make checks payable to Robert Lunsford, not to the IMO.

Type of subscription	2003	2003 + 2004
Regular subscription (*WGN*)	20 EUR/USD	40 EUR/USD
Combined subscription (*WGN*, Report)	30 EUR/USD	60 EUR/USD
Also possible outside Europe:		
Regular subscription with airmail delivery	40 EUR/USD	80 EUR/USD
Combined subscription with airmail delivery for *WGN* only	50 EUR/USD	100 EUR/USD

If you have *not received* a booklet with the *IMO* Membership Directory, you are *not a member* of the *IMO*, although you are a subscriber. If you missed to become a member, please fill in the below form and return it to the Treasurer; the subscription of *WGN* covers your membership fee.

Membership Application

Yes, I want to join the International Meteor Organization. I agree with the objectives and the constitution of the organization and wish to become an associate member starting January 1, 20____. I understand that my candidacy for voting membership will be submitted to the next meeting of the General Assembly.

First name: ____________ Middle Initial(s): ____________ Last Name ____________
Address: ____________

Phone number, fax or e-mail: ____________

Occupation: ____________
Place and date of birth (YYYY/MM/DD): ____________

Activities: ____________

I have special interest in:
- ○ visual observations: ____________
- ○ photographic observations: ____________
- ○ radio observations: ____________
- ○ telescopic observations: ____________
- ○ video observations: ____________

I request the following type of membership and/or order the following publications:

○ *WGN* surface mail	EUR 20/$20
○ *WGN* airmail	EUR 40/$40
○ Combined subscription, surface mail	EUR 30/$30
○ Combined subscription, air mail	EUR 50/$50

Method of payment: ____________

Read and approved, (date and signature): ____________

Cover Photo Erratum for August Issue

communicated by Guang-jie Wu

The cover of the August issue of *WGN* Volume 30 contained a photograph of the 2001 Leonids, which was sent by e-mail through a Chinese amateur. The editors assumed he was the author of the photo and obtained a few details from him. We have found that this is, unfortunately, not correct.

The true author of the cover photo is the amateur astronomer Jian-guo Jiang from Qingdao, province of Shandong. The exposure time was from $18^{h}00^{m}$ to $18^{h}23^{m}$ UT. The original photograph contains 16 meteors. It was not clouds interrupting the star trails, but intentional covering of the lens causing the breaks. The picture was awarded third prize in the "National Photograph Competition of the 2001 Leonids". The Yunnan Observatory holds the copyright of the photograph.

[The Editors would like to remind observers, who send meteor photos, that sending other photographers' images needs permission from the original authors and should be indicated clearly.]

Letters to the Editor

Existence of Iota-Aurigid meteor shower doubtful

Marc de Lignie

In a recent *WGN* paper [1] Huan Meng analyzed a sample of 196 visual plottings obtained during the mid-November periods in 1998, 1999 and 2000. He concludes that this sample provides evidence for a new meteor shower with a radiant near $\alpha = 76°$ and $\delta = 36°$, with a most probable geocentric velocity of 46 km/s. The shower was tentatively called the ι-Aurigids. The observation program from Huan Meng originated from an earlier observation from Detlef Koschny and Joe Zender who first suggested the possible existence of this shower, based on a sample of 36 video meteor trails obtained on November 17, 1998 [2].

As the administrator of a large database of double-station video recordings from the *Dutch Meteor Society*, I checked of course whether the proposed ι-Aurigid shower was present in this database. This turns out not to be the case, which is illustrated in Figures 1 and 2.

Figure 1 shows all Taurids from the *DMS* video database during from 16–22 November from the years 1995, 1998 and 1999 [3,4,5]. According to the *IMO* Visual Handbook the combined ZHR of Northern and Southern Taurids during this period is about 3. Thus, Figure 1 shows that the *DMS* video database around mid November is so well populated that even a meteor shower with a mere ZHR of 3 shows up with a larger number of members.

Now, let us take a look at Figure 2 where the radiant area is shown around $\alpha = 76°$ and $\delta = 36°$, indicating all meteors in the database from this same mid November period that have a radiant within this area (from a total of 345 non-Leonid double-station meteors). It is evident that no clear shower radiant shows up. Even if the ι-Aurigid shower existed, its ZHR would have to be much smaller than 3, rather than the value of 10 as suggested in [1]. The existence of the ι-Aurigids becomes even more doubtful when we realize that the meteors in Figure 2 have a velocity of 35 ± 6 km/s, while the set of Taurids has a velocity of 26 ± 2 km/s. The large standard deviation of the set of velocities of the meteors of Figure 2 indicates that these meteors do not belong to one shower.

The question remains why the analyses of [1] and [2] seemed to indicate the existence of a radiant near ι-Aurigae. Even though the authors of [1] and [2] refer to experiments with simulated data sets to provide credibility to the significance of their results, we have to conclude that radiant plots of small datasets of single-station meteor trails can result in unreliable outcomes.

To be complete, we have to note that also double-station observations can give biased results, because only meteors within an atmospheric height range of about 70–120 km are recorded. However, it is very improbable that the ι-Aurigids have stayed out of the *DMS* video database because they appeared outside this height range.

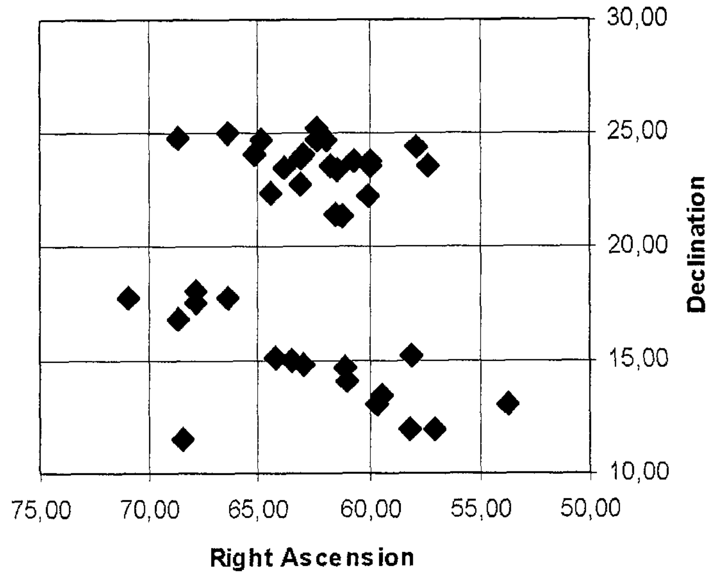


Figure 1 – Mid November Taurids from the *DMS* video database.

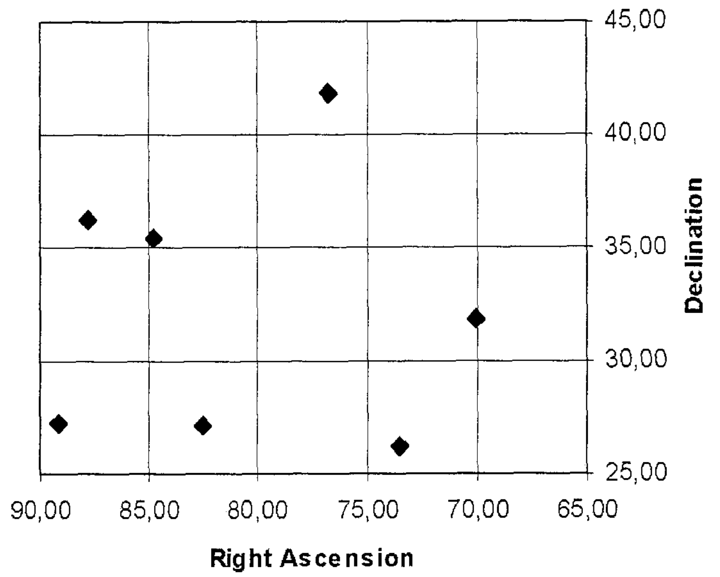


Figure 2 – Mid November radiant area near $\alpha = 76°$, $\delta = 36°$ from the *DMS* video database.

References

[1] H. Meng, "Determination and analysis of the new Iota-Aurigid meteor shower from 1998, 1999 and 2000 plotting data", *WGN* 30, 2002, p. 32.

[2] D. Koschny, J. Zender, "Possible new radiant in Auriga on November 17, 1998", *WGN* 27, 1998, p. 51.

[3] M. de Lignie, H. Betlem, "Simultane videometeoren van de Leonidenaktie 1995", *Radiant* 19, 1997, pp 68–75.

[4] M. de Lignie, C. Johannink, K. Miskotte, "Videoresultaten: niet-Leoniden uit de novemberexpedities van 1998 en 1999", *Radiant* 23, 2001, pp. 101–111.

[5] *DMS* double-station video database at the FTP section of `http://www.dmsweb.org`.

The Leonids

Leonid Dust Trail Structure and Predictions for 2002

Robert H. McNaught and David J. Asher

We discuss the influence of non-linearities in dust trail dynamics caused by the passage of the Earth close to or through dust trails. The effect is to make the derived parameters of these non-linear dust trail sections unreliable for prediction or for use in fitting observed data. These non-linearities become more common in dust trails as they age, but linear sections remain. The timing of encounters with linear sections of dust trails is confirmed as being within 10 minutes and typically ±5 minutes. A qualitative examination of incipient dust trails show that they have a profile that is skewed away from the Sun, that the dust trail profile is a function of Δa_0 and that trails have a dense core at formation which will diffuse out over a few revolutions. Despite this, the density model now gives a reasonable fit over the region of parameter space responsible for storms. There is evidence that the peak region in our model for young trails may be underpredicted due to the existence of this enhanced core. A new model to predict the FWHM of linear dust trail sections is given. The predictions for the two major peaks in 2002 are: (i) 7-rev trail, 2002 November 19, 03:56 ± 5 min UT, ZHR 1000 (810–2000), FWHM ≈ 130 min; (ii) 4-rev trail November 19, 10:34 ± 5 min UT, ZHR 6000 (2900–6000), FWHM 71 min. The 7-rev encounter will have a lower population index than the 4-rev.

1. Introduction

The technique for calculating dust trails from comets has been around for some fifty years, during which time it has been rediscovered on several occasions. Mostly it has been overlooked. It is only in the last four years that clear proof of its predictive value has existed, starting with Reznikov's successful prediction of the 1998 Draconid outburst. The next advance in storm prediction was in 1999 when models for predicting dust trail density, and hence ZHRs, made by McNaught and Asher [1] and Lyytinen [2] were the first to have any success in this regard.

Observations of Leonid outbursts and storms from 1998 to 2001, involving the Earth's passage through numerous dust trails from comet 55P/Temple-Tuttle, has provided a wealth of data on dust trail structure. With this, predictions for 2002 should be considered more reliable than ever before. The only caveat to this is that with this wealth of data, there are now clear indications of the limits of existing models and/or the existence of variations between various dust trails. Inherent variability in the activity of the parent comet is an ever present complicating factor that has had to be ignored in the past due to lack of any specific information to indicate otherwise.

2. The structure of dust trails

In [1] we mentioned the effect of solar radiation pressure (srp) in skewing the distribution of smaller particles to greater $r_E - r_D$. Here we investigate this more using a simple ejection model including ejection away from perihelion. Whereas the ejection model may be limited, the general conclusions are robust and these qualitative findings have significant consequences in understanding the structure of a dust trail.

Figure 1 displays six sample cross-sections from ejection in 1899. They refer to the incipient dust trail as it existed in that year and more specifically to the region around $\Delta a_0 = +0.15$ (range $+0.145$ to $+0.155$). We have previously shown that this general structure is basically invariant over several revolutions if gravitation and srp are the only factors considered [1]. We discuss later the effects of other factors which act to diffuse the dust trail structure.

The cross-section in each plot shows a slice through the dust trail in the ecliptic plane with the Sun (or rather the barycenter of the solar system) at $x = 0$, $y = 0$. Due to the inclination of the comet's orbit ($i \approx 162\overset{\circ}{.}5$), the cross-section is elongated in ecliptic longitude, but a cross-section perpendicular to the dust trail length is elongated away from the Sun (along the radius vector). Observations show that the elongation in the direction of the radius vector is rather more extended than given in these plots [3].

The top three plots are for $\beta = 0.000$ (no srp) and the bottom three for $\beta = 0.001$ (ratio of srp to solar gravity of 1:1000). The left plots are for an ejection velocity at heliocentric distance $r = 1$ of 10 m/s, middle 25 m/s and right 50 m/s. Ejection at other heliocentric distances is proportional to $1/r$ and ejection occurs $\pm 120°$ in true anomaly ($r \lesssim 3.4$). The plotted points are from a Monte Carlo simulation with the ejection in random directions (uniformly isotropic) and randomly in true anomaly, but only those particles with the specific required Δa_0 are selected.

It is clear from the top left box being blank, (other than the cross representing the comet's node in that year) that for ejection velocities of $10/r$ m/s, particles are unable to reach the required Δa_0. The increased ejection speed of the top middle plot ($v = 25/r$ m/s) results in a compact distribution and the top right plot for even higher velocities is more dispersed. There is a critical low velocity in which ejected particles can just reach the required Δa_0 and such particles are ejected at perihelion (which is close to the node). Just above this limiting velocity, the cross-section is very compact and ejection at true anomalies other than perihelion start to occur. With larger velocities (top right plot), less of the velocity is required to reach the required Δa_0 and more is available to change orbital elements other than the semi-major axis, hence the greater spread in nodes. The distribution is skewed away from the Sun for negative values of Δa_0 and towards the Sun for positive values of Δa_0 although the peak remains around the nominal "center".

The effect of srp is to increase the semi-major axis with respect to a purely gravitational orbit. Thus, in the lower plots with $\beta = 0.001$, the required Δa_0 (with ejection at perihelion) is -0.07, or 0.22 less than the purely gravitational solution. For reasons that need not be discussed here, for non-zero beta, the required value of Δa_0 is variable with true anomaly to have all particles comoving. This is accounted for in the simulations, but the perihelion value of Δa_0 equivalent to $\beta = 0.000$ is always the one quoted.

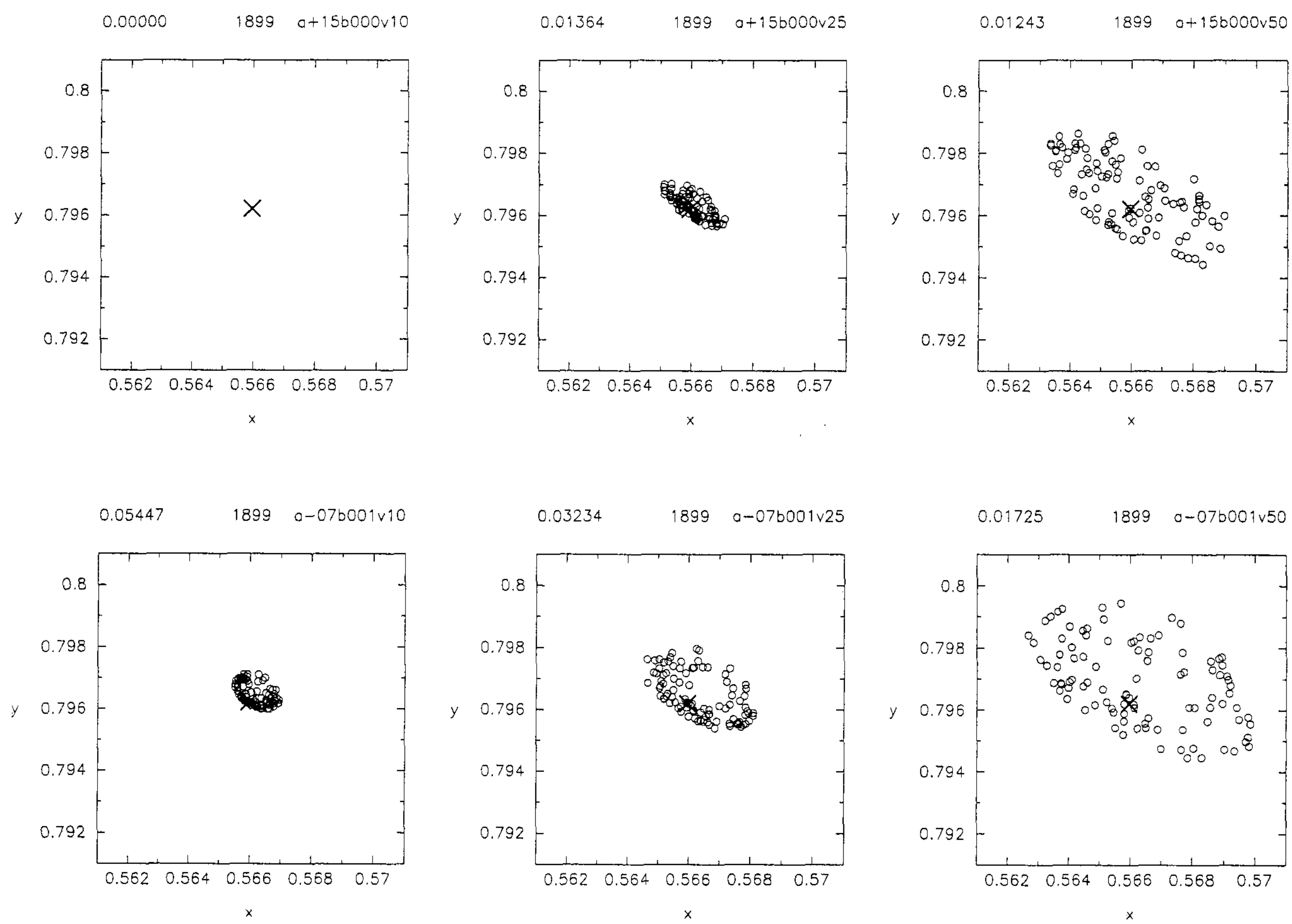


Figure 1 – Monte-Carlo simulations for cross-sections from ejection in 1899.

Whereas the above discussion with $\beta = 0.000$ would apply more to very large particles, for more typical visual meteors, with $\beta = 0.001$, the bottom plots are more representative. Due to the vagaries of the dynamics, it is now possible with non-zero β to have particles which are ejected away from perihelion at some specific v/r to reach the required Δa_0 when ejection at perihelion does not. Overall the whole distribution is pushed to greater heliocentric distance (greater r_D).

Combining the full range of velocities and beta will give a smooth dust trail profile without the sharp edges for precise ejection velocities given in the plots. Such a combination would display a prominent core in young trails. Diffusion effects would disperse this central core and change the overall shower profile making it more Gaussian with age. Thus in addition to the profile being a function of Δa_0, it is also a function of age. This may be the reason for our ZHR model underpredicting the near central encounters with the young 1833 (1-rev) and 1966 (2-rev) where diffusion is minimal. This is discussed more in Section 7.

It is of interest that ejection in the solar facing hemisphere alone retains the overall distributions given in these plots. Also, the true anomaly of ejection is correlated with the nodal longitude of the ejected dust. This latter effect can explain activity profile asymmetries due to variations of cometary activity pre and post-perihelion and quasi-periodic variability in the activity curve due to jet activity on a rotating nucleus [4].

3. The density model and its implications

Our 1999 model derived ZHRs from the parameters Δa_0 and $r_\mathrm{E}-r_\mathrm{D}$ and used a rigorously derived stretching factor f_M as the only diffusion of density with age. An additional aging (diffusion) factor was not included until 2001 due to a prior lack of clear evidence for its necessity.

The nature of these parameters are discussed here.

a) The Δa_0 distribution

Δa_0 represents the necessary change in semi-major axis (which is directly related to orbital period) of meteoroids at the instant of ejection. For an encounter in any particular year, the necessary Δa_0 is that which results in the particles arriving at their node at exactly the same instant as the Earth passes that point. Ejection models of meteoroids from comets imply that more massive (or denser) particles will be ejected at lower velocity and also be less affected by srp. Thus more massive particles tend towards the same orbital period of the comet. Without the action of srp, dust trails would expand symmetrically in front of and behind the comet. The effect of srp is to slightly counteract solar gravity, resulting in particles orbiting in Keplerian orbits more slowly than would otherwise be the case. Smaller particles are thus shifted systematically to higher Δa_0 and for typical visual sized Leonids, this shift is by $\sim +0.2$ (more specifically $+0.22$ for $\beta = 0.001$).

Encounters with a dust trail of a specific age (e.g. the 4-rev) will be at different Δa_0 from one year to the next. In 1998, the relevant section of the 4-rev trail had $\Delta a_0 = +0.04$ and large particles (bright meteors) would have been encountered had the Earth approached close enough to the trail. In subsequent years, the section of the 4-rev trail encountered would have had $\Delta a_0 = +0.08$, $+0.11$, and $+0.14$, the last value being for 2001. From one year to the next, the particles encountered from a specific trail will tend towards smaller sizes. It must be noted that ejection models, including srp, imply a wide range of sizes of particles for any encounter. The population index r will be a function of mass and below a certain mass the numbers of particles can decrease. In calculating r, one should expect it to be magnitude dependent.

It is interesting to note that the 7-rev trail encountered in 2002 will be at $\Delta a_0 = +0.11$, the same as the 4-rev in moonlit conditions in 2000. A similar distribution of magnitudes could be expected were the encounter at the same $r_\mathrm{E} - r_\mathrm{D}$. With the 7-rev being closer to the core and on the inside of the trail, one would expect brighter meteors as noted in Section 2. It is also probable that the 7-rev trail will involve a lower magnitude distribution than the 4-rev trail this year (with $\Delta a_0 = +0.17$)

b) The $r_E - r_D$ distribution

The parameter $r_E - r_D$ is simply the distance in AU that the Earth passes inside the nominal node of the dust trail (between the Sun and the trail, neg. $r_E - r_D$), or outside (pos. $r_E - r_D$).

As discussed in Section 2, the profile in $r_E - r_D$ is a function of Δa_0, age and ejection processes. Overall, it displays a skewed distribution towards increasing $r_E - r_D$. We have continued using a Gaussian fit to the profile in $r_E - r_D$, due to the lack of any quantified theoretical expression for how it varies with these dependent quantities. As trails age and diffuse, they are expected to become more Gaussian in profile, losing their sharp central core.

In making the fit to the data, $r_T - r_D$ is used in which r_E has been modified for the topocentric coordinates of the observer. In every case, this must make the value of $r_E - r_D$ become more positive, as visual observations are necessarily made from the night side of the Earth. The form of the correction is

$$r_T - r_D = (r_E - r_D) + 0.000043 \sin(\text{solar depression angle})$$

where the solar depression is the angle the Sun is below the horizon and the constant is the radius of the Earth in AU. In 1866, the peak observed from the UK had a solar depression angle of 52° giving an additional +0.000034 AU to $r_E - r_D$. In all other years, the correction is smaller and for all predictions a value of +0.00002 AU is used.

c) ageing

Any process that results in diffusion of the dust trail, beyond the stretching of the trail, will lower the peak trail and widen the profile. On the assumption that this effect is uniform with time, the loss of the peak intensity should be $y^{\text{age}-1}$, where age is given in revolutions, and y is the derived constant.

4. Dust Trail data

Calculation of dust trail parameters requires an accurate knowledge of the parent comet's orbit at the perihelia during which the dust trails were created. We used two orbits calculated by Nakano, one (55P-orb1) derived from modern observations and the other (55P-orb2) incorporating positions from the 1366 passage. Integrations were performed with the Mercury package. Table 1 gives the derived dust trail parameters using orbit 55P-orb1. The data for the 20-rev trail in 1998 is from 55P-orb2 which would be more reliable for the 1333 ejection.

5. Linear and non-linear dust trail encounters

A dust trail that evolves solely under the influence of solar gravity and srp will be uniform and pass from slightly inside and in front of the comet's orbit (shorter orbital periods), through the comet's position, to well behind and outside the comet's orbit (longer orbital periods). The bulk of the particles will be behind and outside the comet's orbit due to the effects of srp as mentioned above. Such a dust trail is linear in that the density, nodal position and cross-section are uniformly changing functions from one revolution to another and from year to year. Any disruption to the dust trail can result in erratic and unpredictable variations in sections of the trail and encounters at or near these sections are non-linear.

Due to the positioning of the dust trail nodes close to the Earth's orbit, the Earth can disrupt a small section of a dust trail once every year during the period the dust trail is passing through the node. While other planets can cause a more general bulk shift in the trail, the greatest cause of non-linearities is when the Earth passes through the center of the dust trail. This physically removes those particles that become meteors and scatters those that have very close approaches, but above the atmosphere. However at greater distances, the disruption is more orderly and can be calculated. The result is a complex region of stretching, compression, folding, tilting and scattering within a small section of the dust trail. Whilst a nominal dust trail center and density can be calculated for non-linear encounters, the effects described make it highly unreliable to assume these parameters apply to the region of the disrupted section actually encountered, at some specific $r_E - r_D$.

Table 1 – Dust trail parameters using orbit 55P-orb1 (from observations 1866–1998 by Nakano MPC 31070) r_E calculated using geocenter from DE403.

Year	Month	Day	Solar Long.	Revs	Δa_0	$r_E - r_D$	f_M
1833	11	13.435	233.184	1	0.174	−0.00021	1.028
1866	11	14.047	233.334	4	0.059	−0.00030	0.389
1867	11	14.394	233.421	1	0.373	−0.00015	1.043
1869	11	14.019	233.539	3	0.320	−0.00048	0.470
1966	11	17.497	235.159	2	0.168	−0.00013	0.535
1969	11	17.375	235.263	1	0.934	−0.00004	1.097
1998	11	17.013	234.460	20	−0.023	−0.00015	–
1999	11	18.091	235.292	3	0.138	−0.00067	0.398
2000	11	17.329	235.267	2	0.302	−0.00119	0.574
2000	11	18.149	236.096	8	0.066	0.00069	−0.138
2000	11	18.155	236.102	8	0.064	0.00077	0.292
2000	11	18.168	236.115	8	0.060	0.00086	−0.049
2000	11	18.328	236.276	4	0.114	0.00078	0.138
2001	11	18.387	236.083	7	0.092	−0.00082	−0.003
2001	11	18.418	236.114	7	0.081	−0.00044	0.157
2001	11	18.463	236.160	7	0.068	−0.00005	−0.005
2001	11	18.729	236.428	9	0.041	0.00015	0.395
2001	11	18.765	236.464	4	0.142	0.00023	0.139
2001	11	18.816	236.516	9	0.047	−0.00059	−0.017
2001	11	18.870	236.570	9	0.050	−0.00090	−0.005
2002	11	19.167	236.610	7	0.113	−0.00015	0.132
2002	11	19.180	236.623	7	0.093	0.00012	−0.004
2002	11	19.444	236.890	4	0.172	−0.00005	0.151

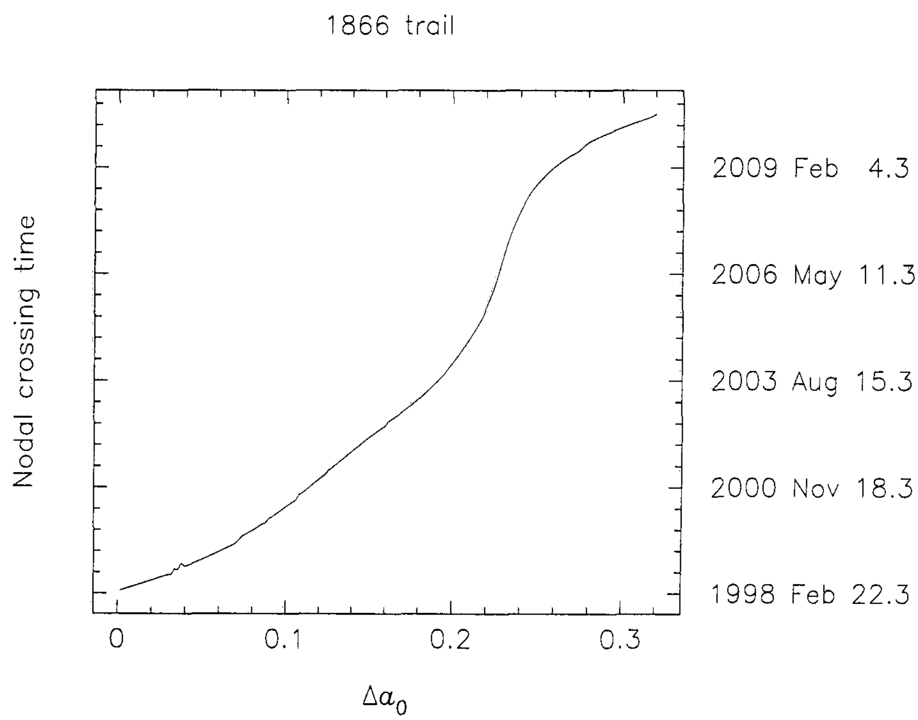


Figure 2 – Undisturbed 4-rev dust trail ejected in 1866.

Calculating the full nature of these effects over the whole dust trail section requires considerable effort and is equivalent to the sort of work done by software like JPL's SENTRY and University of Pisa's Clomon, in calculating impact probabilities of asteroids for non-linear encounters with the Earth.

The 4-rev dust trail (ejection in 1866) has had no close encounters with the Earth since it was formed. As can be seen in Figure 2, encounters at the present epoch will be linear. The situation is very different for the 7-rev trail (ejection in 1767) shown in Figure 3. Numerous disruptions are caused by the Earth's passage close to the trail. Those to the left of the plot resulted from the encounters listed in Table 2.

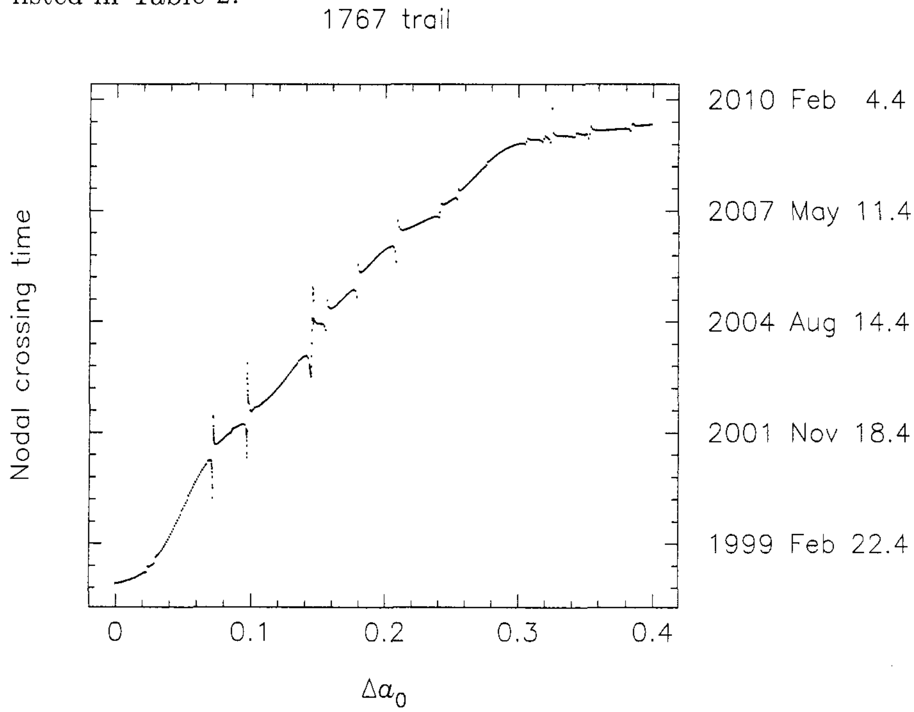


Figure 3 – Disruptions of the 7-rev dust trail ejected in 1767 due to close encounters with the Earth.

Table 2 – Parameters for some sections of the 7-rev (1767) trail that are disrupted by the Earth's passage in the years stated. Δa_0 is the difference in semi-major axis between the ejected particle and the comet at the time of ejection. $r_E - r_D$ is the miss distance by the Earth from the nominal trail center in the year given.

Year	Revolutions	Δa_0	$r_E - r_D$
1932	5	0.024	+0.0055
1899	4	0.029	+0.0120
1866	3	0.072	+0.0013
1833	2	0.097	−0.0015
1800	1	0.145	+0.0029
1867	3	0.155	−0.0056
1901	4	0.178	+0.0048
1834	2	0.208	−0.0042
1868	3	0.241	−0.0094
1835	2	0.319	−0.0064
1869	3	0.325	−0.0005
1801	1	0.353	+0.0030

The slope of the plotted line is inversely proportion to the trail density (f_M). Disrupted sections with near vertical lines have very low density with f_M approaching zero. A section that is horizontal would indicate a resonance with all orbital periods (represented by the range of Δa_0 in the horizontal section) coming back at the same time, although not necessarily at the same nodal distance. In the 1699 trail (Figure 4), there is a critical value of Δa_0 above which particles find themselves in the 3:1 resonance with Jupiter, hence that branch of the trail gets well seperated from the main part.

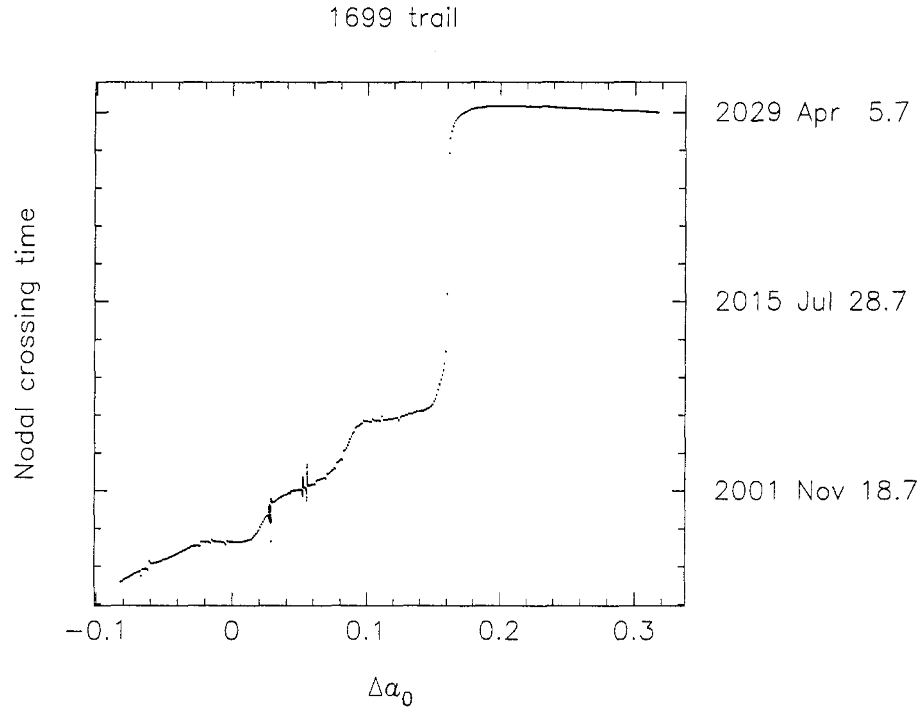


Figure 4 – Disruptions of the 9-rev dust trail ejected in 1699.

6. Prediction timing accuracy

Accurate methods of observation can derive the time of maximum of a meteor outburst to better than 3 minutes. This is better than the level of the prediction accuracy given that there is a difference of several minutes in calculating dust trail nodal longitudes using the two different orbits for 55P/Tempel-Tuttle. Use of these different orbits gives small differences in other dust trail parameters (Δa_0, $r_E - r_D$ and f_M) but these make little difference in the ZHR and outburst width calculations. It is useful to include the nodal longitudes derived using orbit 55P-orb2 to give two sets of residuals in the timing of maxima. In Table 3, the UT time and nodal longitude (C_2) are given from 55P-orb2 and residuals for both this and 55P-orb1 are $O - C_2$ and $O - C_1$ respectively. C_1 is given as the longitude in Table 1.

Two linear encounters, the 4-rev in 2000 and 2001, are possibly affected by the maxima of other trails nearby (the broad 8-rev in 2000 and the broad 9-rev in 2001). For the 2001 encounter, the same derived time of maximum is given by Arlt et al. [14] and by Uchiyama [15], the latter separating it from the 9-rev trail on the basis of differences in the population index. The 2001 4-rev peak time gives residuals less than 10 minutes. The analysis of the 2000 4-rev peak does not try to seperate the influence of the broad 8-rev trail and this may have pulled the 4-rev to an earlier peak (the $O - C$ is around 33 mins). Conversely, the 4-rev peak may have had less effect on the 8-rev timing; the 4-rev having a rather shorter duration. The small $O - C$ of the 8-rev is possibly fortuitous however, given that the encounter is non-linear and the peak poorly defined.

Table 3 – N = non-linear dust trail section, L = linear dust trail section. The observed (O, topocentric) longitude of the peak is taken from the reference in the last column. In cases where no topocentric correction to the time of maximum is made, or no mention is made of any such correction, the reported value has been corrected using the formula in [3] before inclusion in this table.
A "?" appears against values that are uncertain. This uncertainty takes two forms. Firstly, predictions may be uncertain due to the non-linearity of the dust trail and secondly, the maxima of several dust trails may be close together in time and influence the calculation of the time of the observed maxima.
The mean absolute error for eight encounters with no influencing factors (only one, weighted, $O-C$ derived for each encounter) is $|O-C_1| = 0\overset{\circ}{.}002$ and $|O-C_2| = 0\overset{\circ}{.}005$, being 3 minutes and 7 minutes respectively. The maximum error is 12 minutes for the 1999 storm using orbit 55P-orb1.

Node (Orbit C_2) in UT	Rev	O (topocentric)	C_2	$O-C_1$	$O-C_2$	Ref.
1833 11 13.429	1 L	233.15 ?	233.178	−0.022?	−0.028?	[5]
1866 11 14.041	4 L	233.334	233.328	0.000	+0.006	[5]
1867 11 14.389	1 L	233.423	233.416	+0.002	+0.007	[5]
1869 11 14.013	3 L	233.540	233.532	+0.001	+0.008	[1,6]
1966 11 17.493	2 L	235.159	235.155	0.000	+0.004	[5]
1969 11 17.370	1 L	235.276	235.268	+0.003	+0.008	[5]
		235.271		−0.002	+0.003	[7]
1999 11 18.086	3 L	235.285 ± 0.001	235.287	−0.007	−0.002	[8]
		235.284 ± 0.001		−0.008	−0.003	[9]
		235.283 ± 0.002		−0.009	−0.004	[10]
		235.285 ± 0.001		−0.007	−0.002	[11]
2000 11 17.324	2 L	235.28 ± 0.01	235.264	+0.011	+0.016	[12]
		235.266 ± 0.003		−0.003	+0.002	[13]
18.143	8 N		↗ 236.090			
		236.09 ± 0.01		−0.003?	+0.003?	[12]
18.149	8 N		↘ 236.096			
18.322	4 L	236.25 ± 0.01	236.270	−0.026?	−0.020?	[12]
2001 11 18.412	7 N	236.137 ± 0.003	236.108	+0.023?	+0.029?	[14]
		236.154 ± 0.003		+0.040?	+0.046?	[14]
18.724	9 N	236.431	236.423	+0.003?	+0.008?	[15]
18.758	4 L	236.458	236.457	−0.006?	+0.001?	[15]
		236.458 ± 0.003		−0.006?	+0.001?	[14]

The final two non-linear encounters are the 7 and 9-rev in 2001. The analysis by Uchiyama [15] has some uncertainty in the time of the 9-rev peak due to uncertainties in determining the appropriate population indices for the two trails, but his derived time of maximum is perhaps reliable to around ±7 minutes. The $O-C$s of 4 and 12 minutes against the two orbits is again pleasing but again possibly fortuitous. Other encounters with the 9, 10 and 11-rev trails in the hours after the main 9-rev encounter would act to skew the time of the 9-rev maximum and extend the declining branch. From the ZHR analysis below, these other trails would only contribute a total ZHR of up to 50 so would tend to extend the trailing branch of the derived 9-rev activity curve rather than shift the peak.

The observed activity from the 7-rev trail in 2001 was unusual. This non-linear encounter had a pronounced double peak and occured late by many tens of minutes. The suggestion [14] that the double peak represents passage through a hollow tube of material is untenable; a coherent tube being dynamically impossible. Even in our initial 1999 paper, it was clear that this encounter would be less reliable than others and it seems certain that detailed dynamical calculations are required before any useful conclusions about this encounter can be made. The main 7-rev encounter in 2001 appears in Figure 3 as a kink in the middle of on otherwise linear section of the dust trail (refer also to Table 2.).

The large residual for the 1833 storm is discussed in the ZHR Section below.

The times of the storm peaks in 2002 given in the abstract are a mean of predictions from both orbits.

7. ZHR fit

Most of the necessary discussion regarding the model fit of observed ZHR to calculated dust trail density is discussed in Section 3. Despite the caveats contained in that section, it is reasonable to fit a double Gaussian to the Δa_0 vs. $r_E - r_D$ parameter space. Data from twelve dust trail encounters are used in the fit. The input data and calculated ZHRs are given in Table 4.

Table 4 – ZHR and Width data and predictions using the dust trail parameters in Table 1. References for the data in specific years are the same as in Table 2. Weight has been arbitrarily assigned according to the quality of the observations, presence of moonlight, non-linearity of the observed trail or interference from other trails. (Nine reliable shower widths are used in the width fit, all with equal weight, the 2001 7-rev being excluded.) The 2001 4 and 9-rev observed ZHRs are derived from Uchiyama [15] and scaled (by a factor of 1.1) to give the *IMO* ZHR at maximum [14]. Calculations repeated using 55P-orb2 resulted in changes in derived ZHRs and widths of only a few percent.

Year	Rev	Obs. ZHR	Weight	Calc. ZHR	Width Obs. FWHM	Width Calc. FWHM
1801	2 L			4200		52
1833	1 L	(60000)	0	68000		42
1866	4 L	8000	2	7900	59	55
1867	1 L	4500	2	4700	75	55
1869	3 L	(1000)	1	1200		74
1966	2 L	90000	4	25000	38	50
1969	1 L				68	70
1998	20 N				720	(780)
1999	3 L	3700	8	4000	50	56
2000	2 L	100	4	87	71	61
2000	8a N	135	2	120	(210)	(110)
2000	8b N	135	2	170	(210)	(110)
2000	8c N			18		(110)
2000	4 L	450	4	460	(160)	63
2001	7a N			3		(98)
2001	7b N	1620	4	600	85	(95)
2001	7c N			33		(92)
2001	9a N	960	2	920	225	(120)
2001	11			18		170
2001	4 L	2450	8	2600	68	66
2001	10			18		140
2001	9b N			16		(120)
2001	9c N			1		(120)
2002	7a L			810–2000		105
2002	7b N			25–60		(100)
2002	4 L			2900–6000		71

It is understandable that the 1833 observed ZHR derived by Brown [5] is unreliable, all observations being fortuitous and, at the time, of a largely unknown phenomenon. The peak ZHR is probably a gross underestimation due to the calculated peak occuring some 45 mins after the derived "observed" maximum which occured at morning twilight for the observers in eastern N. America. A significantly increased ZHR for 1833 (possibly of the order of 150 000+) and the fact that the fit here calculates too low a ZHR for 1966 (by a factor of three) suggests that the 4-rev trail in 2002 is probably underpredicted. An enhanced peak in the model parameter space would occur at a certain Δa_0 (modified by β) for young dust trails when production of typical visual sized particles peak at ejection velocities which favour this Δa_0. The near-central 1867 1-rev encounter, however, appears to fit the model well. This observed peak ZHR in 1867 may not be reliable and this encounter is at a much larger Δa_0 which may be a significant difference. Alternatively 1867 represents a problem for the above speculation.

The use of a Gaussian in $r_\mathrm{E} - r_\mathrm{D}$ gives an adequate fit to the input data other than 1966 (mentioned above) and 2001 7-rev. As the 2001 non-linear 7-rev trail encounter had the maximum time significantly different from prediction, this implies that the use of its nominal dust trail parameters is unwarranted. As a result, the poor ZHR fit for this trail need not be a problem. This is discussed more below.

8. ZHR predictions for 2002

2002 4-rev

This trail possibly occurs closer to the peak in $r_\mathrm{E} - r_\mathrm{D}$ than any previous dust trail encounter in the last 200 years. Being very close to the 1833 and 1966 encounters (in parameter space) it is reasonable to expect this encounter to be underpredicted in the same way as these young trails, although of lesser magnitude due to the greater age. Whereas a factor of three seems applicable for the excess ZHR of 1833 and 1966, a factor of two might be more reasonable for this 4-rev trail. Other encounters with this dust trail in 2000 and 2001 suggest this dust trail has behaved as a "normal" trail in those encounters and thus gives no reason to scale the ZHR for unusual cometary activity at formation.

2002 7-rev

Due to the non-linearity of the encounter in 2001, it is difficult to infer the 2002 7-rev activity based on last year's encounter. With an observed ZHR of 1620 and the best fit giving 600, this is too low by a factor of ~ 2.5. Assuming the fit does not significantly depart from the double Gaussian in this region of parameter space (as evidenced by the good fits for 1866 and 1999), there could be two reasons for this poor result:

a)—the non-linearity acts to increase the ZHR in the 2001 encounter. Detailed calculations are necessary to interpret what the overall dust-trail shape and density would be for a non-linear encounter. We know that the density (from f_M) had a sharply increasing value at the node, and diffusion of the particles would act to increase the density at the node (as diffusion in any "gas" would cause an increased density in regions adjacent to higher density, until an equilibrium is reached). Also, the dust trail parameters, calculated for the nominal center, would be unreliable for this trail. More so, the parameters of the trail at the encountered $r_\mathrm{E} - r_\mathrm{D}$ must be significantly less reliable.

b)—the trail ejected in 1767 may be denser than the average trail. If so, the ZHR for other 7-rev encounters should perhaps be increased by a factor of ~ 2.5. This same trail produced the 1869 storm, but there is no evidence from the existing, albeit poor quality, observations that the shower was overstrength in that year. However, without any theoretical resolution to this situation it must be considered possible that the 2002 encounter will be stronger in proportion to that of last year.

Like the 4-rev trail, this is also a near central encounter but being of greater age and with a different Δa_0, there seems no need to apply any significant adjustment for an enhanced core density.

Despite the probably higher ZHR of the 4-rev trail in 2002, the lower Δa_0 of the 7 rev trail (+0.11 as opposed to +0.17) will result in a higher proportion of bright meteors. This will have a marked bearing on observed meteors for lower limiting magnitudes as would be expected in full moonlight.

9. Outburst widths

Observed widths appear in Table 4. A fit using the same parameters as the ZHR model was reasonably successful. It took the form

$$\mathrm{FWHM} = x_1^{\mathrm{age}-1}(x_2 + x_3|\Delta a_0| + x_4 \Delta a_0^2)$$

but this was a more or less arbitrary choise of function. The basis for the form chosen was as follows:

Higher values of Δa_0 (both positive and negative values) show a correlation with higher ejection velocities although there would be some magnitude dependence due to the influence of srp. This effect was modelled by linear and quadratic terms in Δa_0 although in the fit, the quadratic term is insignificant.

Width appeared to show no dependence on $r_E - r_D$ after trialing various relationships. All showed a flat profile in this term without improving the residuals.

Diffusion of the dust trail with age clearly occurs as evidenced by the improved ZHR fit when such a parameter is included. The fit gave $x_1 = 1.19$ implying a 19% increase in width from return to return. Inclusion of the resonant section of the 20-rev trail in 1998 was included to show that in principal such trails can be considered without dramatically affecting the fit. Fits that excluded the 1998 data showed no overall improvement and some small anomalies existed. With the 1998 data included there appears to be some divergence from the fit for the 8-rev trail in 2000 and the 9-rev in 2002, the FWHM being under-predicted. Both these trail sections are non-linear, the observed FWHM is affected by the higher peak of the 4-rev trail in both years and the 9-rev prossibly has the declining branch overestimated due to the influence of several older trail that peaked after the main 9-rev trail. Despite these possible influences, it can be reasonably argued that the 7-rev trail will be broader than the the 105 mins given by the fit and may be closer to a FWHM of 150 min. A value of 130 min would seem a reasonable working figure.

For 2002, the 4-rev trail seems well predicted with a FWHM of 71 min.

10. Conclusion

The standard dust trail theory using rigorous dynamical calculations, including srp, give a good fit to the time of maximum and a reasonable fit to the ZHR and width of Leonid outbursts and storms. The ZHR peak in the parameter space of our density model appears to be too shallow when dealing with central encounters of young dust trails; a conclusion that has some theoretical basis. Non-linear encounters require considerably more detailed dynamical computations which were beyond the scope of this work. Conclusions based on the nominal dust trail parameters for non-linear encounters must be considered unreliable.

The two major encounters in 2002 are both linear and should be well predicted to within about 10 minutes and of the order of ± 5 minutes using the derived dust trail parameters. Some uncertainty in the peak ZHR exists for both these trails that could increase the predictions by up to a factor of three. For the 7-rev trail over European longitudes the uncertainty results from the high ZHR from the same trail in 2001. Overall, it does not appear warranted to assume the observed activity of the non-linear encounter in 2001 should automatically imply higher than nominal rates in 2002, but without very extensive calculations we cannot deny this possibility. The 4-rev trail over N. American longitudes falls in roughly the same ZHR parameter space as the 1833 and 1966 Leonid storms. Given that both these storms seem rather underpredicted by our ZHR model, and bearing in mind that these are the only two linear encounters that are so badly predicted, it seems reasonable that the 4-rev encounter in 2002 could be double the nominal ZHR prediction.

References

[1] R.H. McNaught, D.J. Asher, "Leonid Dust Trails and Meteor Storms", *WGN* 27, 1999, pp. 85–102.

[2] E. Lyytinen, "Leonid Predictions for the years 1999–2007 with the satellite model of comets", *Meta Res. Bull.* 8, 1999, pp. 33–40.

[3] R.H. McNaught, D.J. Asher, "Variation of Leonid maximum times with location of observer", *Meteorit. Planet. Sci.* 34, 1999, pp. 975–978.

[4] W. Singer, S. Molau, J. Rendtel, D.J. Asher, N.J. Mitchell, U. von Zahn, "The Leonid 1999 Meteor Storm: Verification of Rapid Variations by observations at Three Sites", *MNRAS* 318, 2000, pp. L25–L29.

[5] P. Brown, "The Leonid meteor shower: Historical visual observations", *Icarus* 138, 1999, pp. 287–308.

[6] C. Meldrum, *Nature* 1, 1869, pp. 220–221.

[7] P.M. Millman, "Meteor News", *J. R. Astron. Soc. Can.* 64, 1970, pp. 55–59.

[8] R. Arlt, L. Bellot Rubio, P. Brown, M. Gyssens, "Bulletin 15 of the International Leonid Watch: First Global Analysis of the 1999 Leonid Storm", *WGN* 27, 1999, pp. 286–295.

[9] P. Jenniskens, C. Crawford, S. Butow, "Successful Hybrid Approach to Visual and Video Observations of the 1999 Leonid Storm", *WGN* 28, 2000, pp. 58–63.

[10] M. Simek, P. Pecina, "Radar observations of the Leonids in 1998 and 1999", *Astron. Astrophys.* 357, 2000, pp. 777–781.

[11] J. Rendtel, S. Molau, D. Koschny, S. Evans, O. Okamura, M. Nitschke, "Video Observations of the 1999 Leonid Meteor Storm Recorded at Different Locations", *WGN* 28, 2000, pp. 146–161.

[12] R. Arlt, M. Gyssens, "Bulletin 16 of the International Leonid Watch: Results of the 2000 Leonid Meteor Shower", *WGN* 28, 2000, pp. 195–208.

[13] P. Jenniskens, B.Å.S. Gustafson, "The Rare 1932 Dust Trail Encounter of November 17, 2000, As Observed from Aircraft", *WGN* 28, 2000, pp. 209–211.

[14] R. Arlt, J. Kac, V. Krumov, A. Bruchmann, J. Verbert, "Bulletin 17 of the International Leonid Watch First Global Analysis of the 2001 Leonid Storms", *WGN* 29, 2001, pp. 187–194.

[15] S. Uchiyama, "Estimated ZHR Profiles of the 4-Revolution and 9-Revolution Dust Trails during the 2001 Leonid Meteor Storm", *WGN* 30, 2002, pp. 47–55.

Authors' addresses

R.H. McNaught, P.O. Box 650, Coonabarabran, NSW 2357, Australia, e-mail `rmn@aaocbn.aao.gov.au`

D.J. Asher, Armagh Obs., College Hill, Armagh BT 9 DG, Northern Ireland, UK, e-mail `dja@arm.ac.uk`

Activity Level Prediction for the 2002 Leonids

Jérémie Vaubaillon, Inst. de Mecanique Celeste et de Calcul des Ephemerides

We present here a new method to evaluate the level of a meteor storm, and applied it to the 2002 Leonids. By simulating the ejection from the parent comet and the orbit of the particles, and taking the advantage of the measure of $[Af\rho]$, we have computed a "weight" for each of them (that is an indicator of the number each particle is supposed to represent). Looking at impacting particles close enough to the Earth, and calibrating the density computed, we predict that the ZHR of the 2002 Leonids will be 3200 for the 1866 stream, and 3600 for the 1767 stream, with an uncertainty of about 200.

1. Introduction

Today's theories to predict the Leonids storms (McNaught & Asher 1999; Lyytinen et al. 2000) use the fact that 55P/Tempel-Tuttle is the parent body of the streams as a starting point (initial conditions), for numerical simulations, that is, as an astrometric tool. But none of them take into account the photometric information that can be provided. We propose here to see how it can be useful to consider how the comet emits dust to predict the level of the coming 2002 Leonids. The idea here is to simulate the ejection of dust by the comet, and to characterize each of them with a cometary model.

2. Numerical simulations

2.1. Using the cometary informations

The cometary path at each perihelion gives us the initial conditions, whithout which nothing is possible. A point (position and velocity) near each perihelion is given by Rocher (2002, plus personal communication for other perihelions), and allows us to determine the path of the comet, where it is suposed to eject dust: that is as soon as the comet is below 3 AU from the sun (where water ice begins to sublimate. Note that we do not consider here CO emission).

The particles are taken in bins of size (0.1–0.5, 1–5, 5–10, and 10–100 mm) distributed all along the position of cometary orbit, with a time step of one day.

The ejection velocity is that given by Crifo & Rodionov (1997). It takes into account the gravitation of the comet and a hydrodynamical model. To simplify (for further details, see Crifo & Rodionov (1997), Appendix D), we can say that:

$$V = W(T)\Phi\left(\frac{a}{a_\star}\right)$$

with V—ejection velocity; W—factor that depends on T, the temperature of the nucleus of the comet; a—radius of ejected particle; $a_\star$—caracteristic radius, that depends (among other factors) on the angle of ejection (with subsolar point), heliocentric distance and the fraction of nucleus surface that indeed emits gas and dust.

2.2. Stream evolution

The stream simulated with all the particles is then integrated in time. We took into account gravitational and non-gravitational forces (solar radiation pressure and Poynting-Robertson drag (Burns et al. 1979). Note that the seasonal Yarkovsky effect is not considered here, unlike Lyytinen et al.'s (2000) works).

To do fast computations, we used parallelized computers (IBM SP) provided by CINES. Each run was done on 50 processors, 1000 particles per processor, thus in total 50000 particles per size bin. As only the smallest particles (0.1 to 1 mm, for a density of 2000 kg/m^3) are spread in a sufficient way, we will focus on them here.

Some results of the 1866 stream have already been published (Vaubaillon & Colas 2002). We point out here a special feature of the 1767 stream: we can see from Figure 1 that there are some "holes" in the stream. With 50000 particles simulated, this cannot be a statistical artifact. This is rather the effect of close encounters with the Earth at previous perihelions. Such holes can be very important for meteor storms predictions, as we will see further.

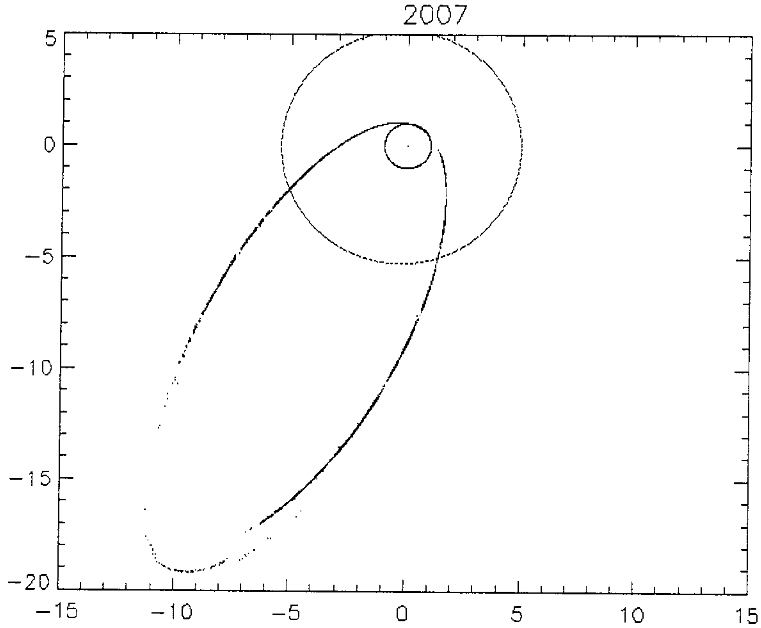


Figure 1 – Stream ejected in 1767. The two circles are the orbits of the Earth and Jupiter. The begining of the stream is situated in $(-5; -15)$ (approx. x and y ecliptic coordinates, in AU). It almost joins the end of the stream $(-19; -10)$ Note the "holes" along the stream (approx. coordinates : $(1;0)$, $(1;-8)$, $(0;-10)$). They result from close encounters with the Earth.

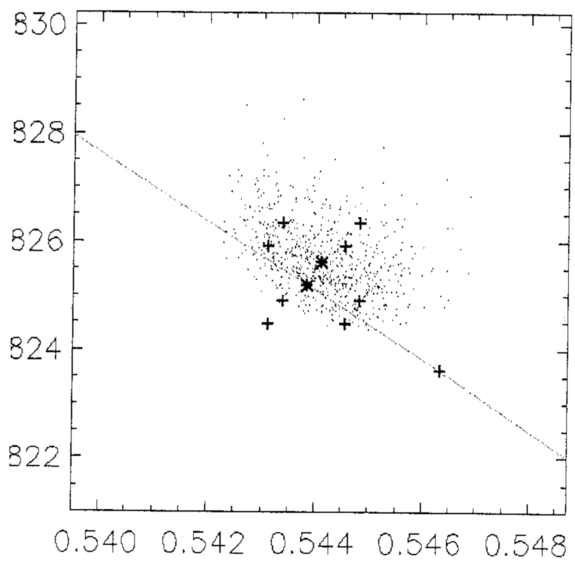


Figure 2 – Particles from the 1767 stream impacting the Earth. The line is the orbit of the Earth. The first cross at $x = 0.546$ is the position of the Earth on November 19, 2002, 0:00 UT. The second one (on the same line) is positioned at the expected time of the maximum. The one just upper right is the center of the stream. Around these 2 points, the 2×4 crosses represent the space criterion ΔX.

2.3. Collision with the Earth

In any simulation of this sort, the amount of simulated particles is some orders of magnitudes less than the real amount ejected by the comet. So there is quite no possibility for a given simulated particle to encounter the Earth. To predict meteor showers we have to define an impact criterion much larger than the Earth's diameter. Brown (2000) considered also a time criterion (centered on the time of the maximum). We have prefered to keep only a space criterion, as, in a long-time simulation, we do not always know when the shower occured. It is also a simple way to do predictions over a large range of time with a single run. The space criterion is defined as :

$$\Delta X = \Delta T\, V_{\mathrm{e}}$$

with ΔX—space criterion; ΔT—time criterion (here 6.5 days); V_{e}—velocity of the encounter. We consider that there is an impact if the particle reaches its (descending) node at the next integration time step, and is in the space criterion.

2.4. Time of the maximum

The estimated time of the maximum of the storm encountered is established by computing the median value of the positions of the nodes, and by deducing the closest point on the orbit of the Earth. Of course, this method can be improved by considering only the node close to the orbit of the Earth, instead of the entire set, but first results are in good agreement with previous works (Asher 2000) (see Table 1).

3. Photometric considerations

The parameter which is important to consider here is $[Af\rho]$, because it takes into account the light scattered by the dust. It has been introduced by A'Hearn et al. (1995), and its advantage is that it is independent of the instrument with which it has been measured. Indeed, ρ is the aperture of the telescope. A is the albedo and f the filling factor, that is, the proportion of dust in the image, in terms of effective area. A and f are known with a large uncertainty, but the parameter $[Af\rho]$ can be measured.

As annouced by Vaubaillon & Colas (2002), this parameter has been measured. Imre Toth (Konkoly Observatory, Budapest) has provided it, from measurements done by Lamy (1998) with HST. We thank here these two astronomers for having provided these measurements. We have deduced $[Af\rho] = 78.91$ cm at perihelion, considering $[Af\rho]_r = [Af\rho]_q(q/r)^\gamma$, with r being the heliocentric distance, q the perihelion distance, and $\gamma = 2$.

In order to derive some information from $[Af\rho]$, a certain number of assumptions are of necessity. We consider here that:

- The dust production rate is proportional to gas emission rate: $Q_{\mathrm{d}} = K\,Q_{\mathrm{g}}$, and K is constant with heliocentric distance.
- the grain size distribution index s is taken between 2 and 6 (range deduced from cometary results (Fulle et al. 2000) and meteor observations (Gural & Jenniskens 2000)).

Q_{g} is deduced from the comet's magnitude (Beech et al. 2001), with Jorda's equation (cited by Crifo & Rodionov 1997).

4. Estimation of ZHR

This model allows us to give a "weight" to each ejected particle, that is the number of particles that it is supposed to represent, if the model is totally right. Indeed, thanks to Jorda's equation and Crifo & Rodionov model, we can compute the amount of gas emitted in the sunlit hemisphere (with a dependence on the angle from the subsolar point), and then deduce the "real" number of particles ejected, by unit of time.

As, of course, we cannot be "totally right" because of the assumptions we had to do, these "weights" computed is more an indicator rather than a real value.

By considering the impacted particles and the weight of each of them, we have an indicator (again) of the amount of dust encountered by the Earth. Now care must be taken from these results, because the center of the trail does not inevitably coincide with the orbit of the Earth. So we have defined a criterion to take into account only the impacting particles, close enough to the Earth. This space criterion is set to corespond to a time criterion of one hour, at the orbital speed of the Earth. To have relevant results, we have to simulate a large number of particles. By this way, we also take into account the holes in the stream (see Section 2.2).

Then, a density of weighted particles is computed. To predict leonids storms, we have calibrated the data with past observed showers. The results are shown in Figure 3.

A very (too?) simple linear fit allows us to give some predictions of the 2002 Leonids (see Table 1).

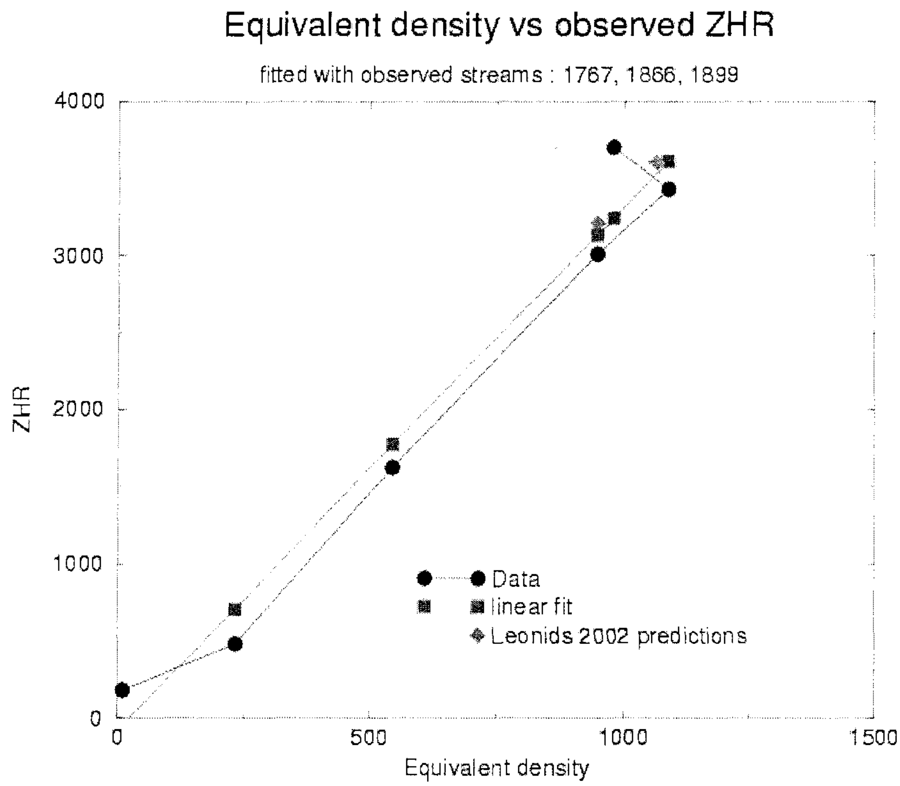


Figure 3 – Computed density of weighted particles versus observed ZHR. The observations are those done from 1999 to 2001, and reported by the *IMO* (Arlt et al. 1999, 2000, 2001). They concern the streams of: 1866, 1767, 1733, and 1699

Table 1 – Predictions for the maxima of the 2002 Leonids.

Stream	Time of maximum	Expected ZHR
1767	November 19, 2002, 04:04 UT	3600
1866	November 19, 2002, 10:47 UT	3200

As a result of this fit, the uncertainties are about 200 for the ZHR. Although our method is different in many ways from others (McNaught & Asher 1999; Lyytinen et al. 2000), we have found very similar results here, which is encouraging.

5. Conclusion

We have performed some numerical simulations to reproduce the emission of dust from comet 55P/Tempel-Tuttle. By considering impacting particles with the Earth and taking into account some measurements done for the comet, we have estimated the activity level of the 2002 Leonids. This gives a new method to make some predictions of meteor storms.

Acknowledgments

This work is supported by CNES (French space agency). We thank particularly David Asher (Armagh Observatory), Imre Toth, Phillipe Lamy and Laurent Jorda (LAS, Marseille, France), J.-F. Crifo (Service d'aeronomie, CNRS, France) and the whole CINES team.

References

A'Hearn et al. (1995), *Icarus* 118, pp. 223–270.

Asher D.J. (2000), *Proc. IMC, Frasso Sabino 1999*, IMO, pp. 5–21.

Beech et al. (2001), *Earth, Moon and Planets* 84, pp. 143–145.

Arlt et al., "Bul. 15, 16 and 17 of the International Leonid Watch", *WGN* 27:6, pp. 286–295, *WGN* 28:6, pp. 191–204 and *WGN* 29:6, pp. 187–194.

Brown P. (2000), ESA/ESOC study report (cited by Göckel & Jehn 2000).

Brown P. & Jones J. (1998), *Icarus* 133, pp. 36–68.

Burns J.A., Lamy P.L., Soter S. (1979), *Icarus* 40, pp. 1–48.

Centre Informatique National de l'Enseignement Superieur, `www.cines.fr`.

Crifo J.F., Rodionov A.V. (1997), *Icarus* 127, pp. 319–353.

Fulle et al. (2000), *Astron. Journ.* 119, pp. 1968–1977.

Gural P., Jenniskens P. (2000), *Earth, Moon and Planets* 82/83, pp. 221–247.

Hainault et al. (1998), *Astron. Astrophys* 333, pp. 746–752.

Jorda et al. (1998), IAUC No. 6595.

Lamy P., Znojil V., Biver N. (1998), IAUC No. 6851.

Lyytinen E., Van Flandern, T. (2000), *Earth, Moon and Planets* 82/83, pp. 449–466.

McNaught R.H., Asher D. (1999), *WGN* 27:2, pp. 85–102.

Rocher P. (2002), `www.bdl.fr/ephem/comets/HTML/english/Comete_e.html`.

Vaubaillon J., Colas F. (2002), *Proc. of ACM 2002 Berlin*, in press.

Author's address

Jérémie Vaubaillon, Institut de Mecanique Celeste et de Calcul des Ephemerides, 77 Avenue Denfert Rochereau, F-75014 PARIS, France, e-mail `vaubaill@imcce.fr`

On The Frequency of Pointer Meteors and Grazers

Peter S. Gural

Meteor simulations indicate that the appearance of point-like meteors of less than 5 arc-minute extent should occur on the average of once every 10 000 meteors. To observe long high arching grazing meteors, observations are best made when radiant altitudes are between 2° below the horizon to 3° above. Conditions for grazer observations during the 2002 Leonids are discussed.

The frequency of occurrence of meteors that nominally head straight towards the observer (pointer meteors) and those that tangentially slice through the atmosphere to produce long illuminated trails (grazer meteors) have been informally discussed in recent years by several observers. To try to place a firmer analytic footing on the relative appearance of these phenomena, one can use a meteor simulation tool to estimate the flux level strengths of pointers and grazers as well as determine the best visible times for observing grazer meteors. The meteor simulation tool used for this discussion was described in Gural (2002). The nominal parameters used for the simulation were based on Leonid shower properties to specifically address the upcoming Leonid storm of 2002 (begin height of 108 km, end height of 95 km, 71.3 km/s, $r = 2.0$, plus losses for extinction, distance, and angular velocity). Estimation on the frequency of occurrence however applies to other showers as well.

For pointer meteors the first step is to define what does one mean by "pointer". This can have different definitions depending on the observer whose discussing the topic. The common thread is that they are described as meteors that appear to travel directly towards the observer from out of the radiant, thus showing little angular motion in their track, or may even be stationary and appear star-like. Just how little angular motion is acceptable to ascribe the term "pointer" varies with the observer, so it was decided to bin the results with one arc-minute resolution and plot the counts from the simulation. To process the data, meteors are generated randomly and a track established between a begin height and an end height and the subtended arc length computed. This was computed for an observer on the ground and radiant elevation of 45°.

Two billion meteor tracks were simulated to improve statistics due to the infrequent geometry alignment of a pointer-type meteor. The result in Figure 1 was normalized so that the total flux of all meteors that was possible to be seen above the horizon and brighter than the limiting magnitude (+6.5) equaled 10 000. For reference the total flux of all visible meteors above 30° elevation was 2400.

What should one use for the maximum angular arc length of a pointer meteor? The average human eye can typically resolve 4 arc-minutes whereas the separation between Mizar and Alcor, the middle star of the dipper handle in Ursa Major, is 11.75 arc-minutes, an easy double split for most individuals. If one were to use 5 arc-minutes as a reasonable definition of a pointer meteor that will show little visible cross-track motion, then summing the values for 5 arc-minutes or less in Figure 1 would produce a flux of about one pointer meteor for every ten thousand visible meteors in the rest of the sky. Restricting this to all meteors visible above 30° elevation increases the relative pointer flux by a factor of four. Thus during a meteor storm with counts in the thousands, one would expect a handful of true star-like pointer meteors as geometry makes this a highly unlikely event but not an entirely impossible one.

Of greater potential flux is the type of meteor that has been named "grazer". This is a meteor that enters the atmosphere over an observer's site at such a shallow angle that it reaches the begin height and starts to ablate, but skims through the lower density atmosphere never penetrating to the end height. This will occur when the radiant is low on the horizon or below it. Since the meteors travel for a longer period of time through lower density air, their tracks remain illuminated longer, plus the geometric effect of low radiant elevation, makes for some very long and visually pleasing meteor trails.

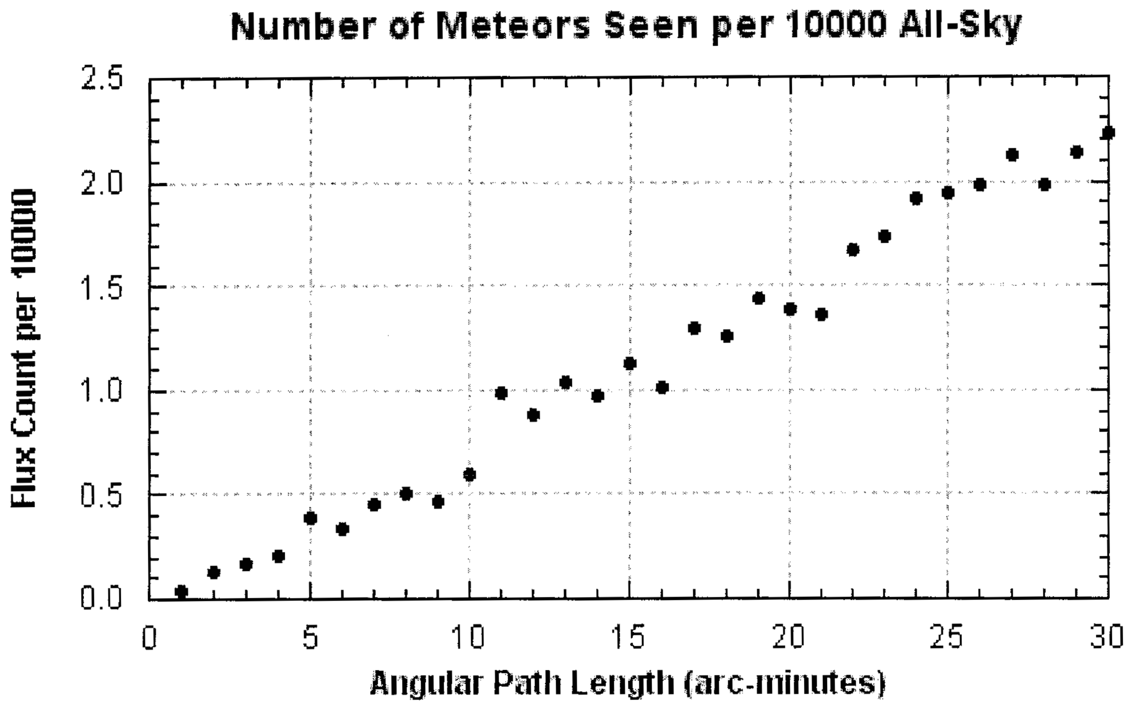


Figure 1 – Number of meteors visible of specified arc length normalized to all meteors visible above the horizon.

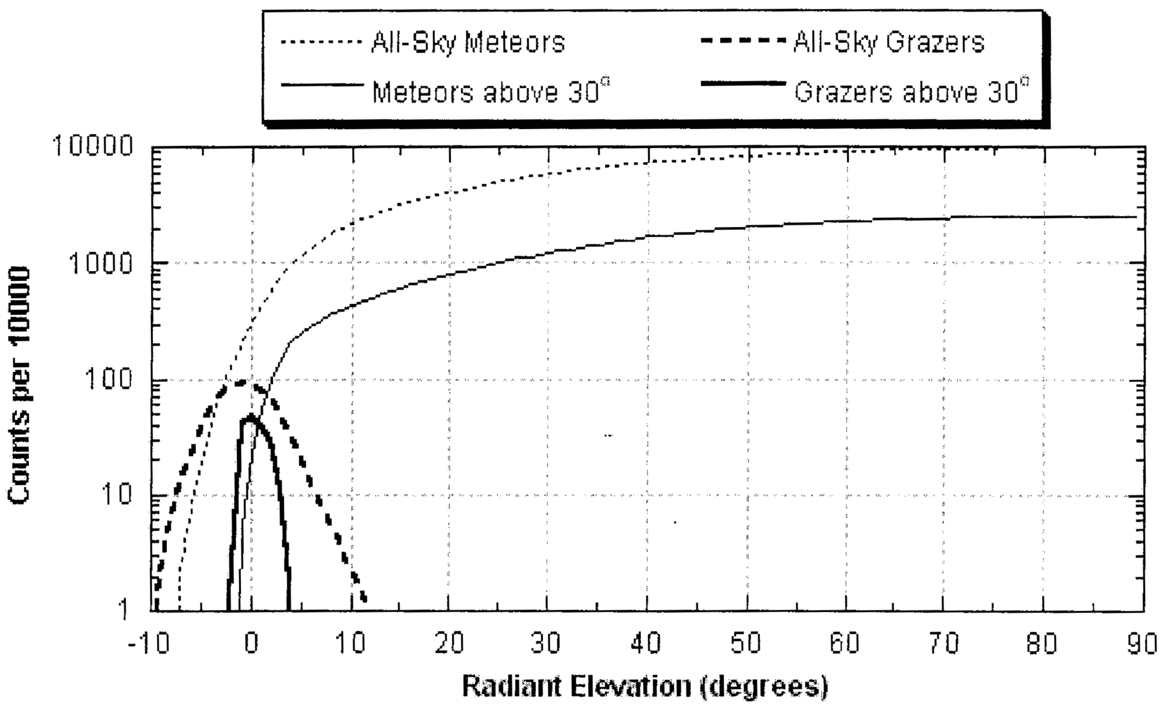


Figure 2 – Number of grazers and non-grazers as a function of radiant elevation normalized to all visible meteors above the horizon. Note that the surplus of meteors between each respective solid curve and its corresponding dotted curve are the counts for meteors that are visible below 30° elevation.

For the purposes of the meteor simulation, a grazer will be defined as a meteor whose closest point of approach to the Earth falls between the begin and end heights and is above the horizon (all-sky) or reaches at least 30° above the horizon (aesthetically nice) along some portion of its track. In Figure 2 is plotted the contributions of grazers and non-grazers as a function of radiant elevation wherein one can see there is a critical period of time over which one can observe these unique skimming meteors. Non-grazers are those that reach both the beginning and the ending heights.

For the long over-arching meteors exceeding 30° elevation we should examine the solid lines. These show that at least 10 grazers (and as high as 50) are visible for someone with a low elevation radiant during a storm of 2500 being witnessed by an region with a high radiant elevation. This corresponds to a time period when the radiant is between 2° below the horizon and 3° above. Thus, though the grazer flux rates correspond to only a moderate shower during the expected storm rates of the Leonids in 2002, these are significantly observable events. Note that for observations down to the horizon, grazers can be seen over plus/minus ten degrees of radiant elevation.

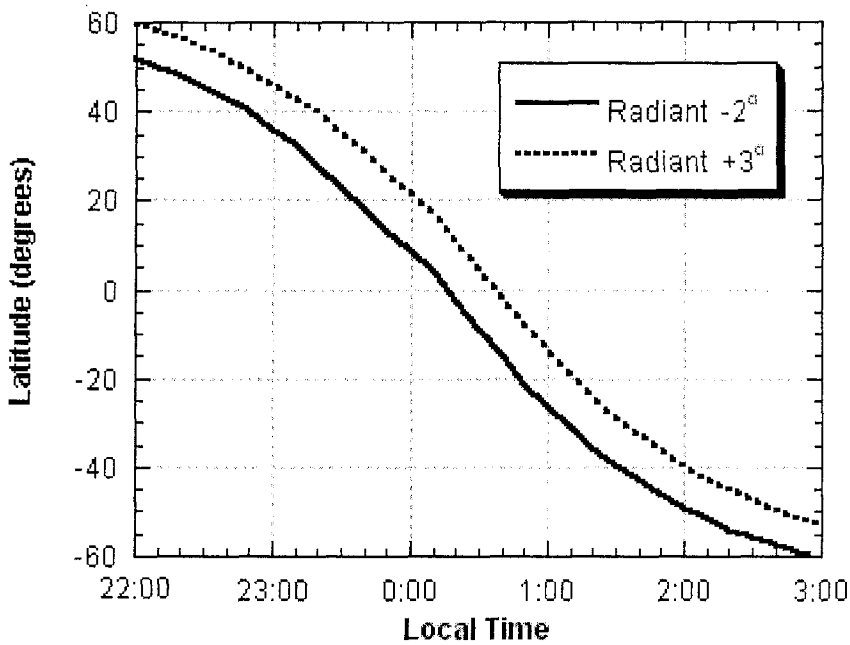


Figure 3 – Best local times for observing Leonid grazers as a function of latitude. Based on standard time zone longitudes. Best times fall to the right of the solid curve and to the left of the dotted curve.

Since radiant elevation is a strong function of the observer's latitude a plot of the local time for the best grazer counts is shown in figure 3 for the Leonid meteor shower. For extreme northern and southern latitudes the duration for observing grazers is longest (40 minutes) while at the equator the duration is shortest (25 minutes). Most observers fall between and should have nearly 30 minutes of grazing meteor observations nearly centered on the radiant rise time in their respective location.

References

[1] Gural, P.S., 2002, "Meteor Observation Simulation Tool", Proceedings of the 2001 International Meteor Conference, in press.

Author's address

Peter S. Gural, 351 Samantha Drive, Sterling, VA 20164, USA, e-mail `peter.s.gural@saic.com`

VLF Signatures from non-Fireball Meteors—Observations from the 2001 Leonid Shower

George John Drobnock

Observations suggest a correlation between non-fireball meteors and VLF electromagnetic radiation.

1. Introduction

The following is from field observation notes from the evening and morning of November 17 and 18, 2001, during the Leonid Meteor shower. The observation site was located in central Pennsylvania, Juniata College Field Station, Penn Township, Huntingdon County. The terrain is hilly, located within 1 kilometer of Raystown Lake. The observation of the shower began at 8:15 UT, 18 November, and concluded 11:30 UT the same day.

The equipment was placed at the site the evening before, 17 November. A check was performed to assure proper electrical connections, proper battery power, and operation stability.

A check of the background noise was performed. The background noise seven hours before the shower was low (see below for additional information). There was no indication of strong sferics. At the time of observation the air temperature was, at ground level, 0°C.

2. Background Literature

The question of meteors producing electromagnetic signatures has been discussed for the past half century [1,2]. The early research suggested that electromagnetic noise may be produced by means of a plasma resonance within the tail of a meteor [1].

Hawkins did a test in the ELF or the range of 1 Hz, he was attempting to replicate work of A.G. Kalashnikov who "seemed to show that meteors produced radio noise at the lower end of the (electromagnetic) spectrum at a frequency of about 1 Hz [2]." Hawkins concluded that Kalashnikov misinterpreted his data. Hawkins exception to to the VLF research was his research was in the VHF range (30 to 475 MHz). He concluded that there were no detectable signatures at these frequencies.

In 1988 [3] a project to detect the VLF signature of a meteor was conducted. The research was based on Hawkins [2] and Keay [12]. A VLF receiver was constructed following a design for a fixed tuning by Charles Welch [4] to detect the VLF signature of a rocket's exhaust when launched from earth. The initial research showed that a meteor with a visual magnitude of +1 does produce a very low frequency (VLF) signature. Additional observations indicate that meteors within the range of −2 to +1 were detected.

In 1992 the initial findings, published in Sky and Telescope, stated that VLF signals were detected from a non-fireball event. All research to date has been the detecting of signatures from a fireball. The 1988/1992 research was questioned by Zeljko Andreic [5] and Martin Beech [6].

Takash Watanaba, Tashimi Okada, and Kazuhiro Suzuki, in 1988 described the detection of a −6 magnitude Perseid fireball in the frequency range between 300 Hz to 6 kHz [7].

V.A. Bronshten in 1991 [8] using the theory that ELF/VLF radiation would be produced by trapping and tangling Earth's magnetic field in the turbulent plasma tail of an ablating meteoroid, stated that a meteor with a minimal brightness of −12 was necessary for the production of VLF related sounds.

Zeljko Andreic et al. in 1993 [5] were unsuccessful in the detection of a meteor signature. They concluded that if a radio emission exist during and after the flight of a meteor in the ionosphere, the intensity of such an event is below the sensitivity of their equipment, or the signal was masked by ionospheric noise, or the maximum of the emitted energy is at a different frequency than monitored.

Martin Beech et al. in 1995 [6,9] suggest it is possible to detect a meteor with a visual magnitude of -10 ± 1 with a very low frequency radio receiver. Beech concludes that the detection of a meteor in the visual magnitude range of magnitude between +1 to −10 can not produce a VLF radio emission. Beech suggested detection of a non-fireball signature may have been natural VLF radio emissions.

S. Garaj et al. published at year's end of 1999 [10] state that the Leonids of 1998 had a high rate of correlation between visual and VLF meteors. The research suggests that brightness for VLF emissions is much lower than previously thought. The team suggest a limit of −5 magnitude and stated that they did not detect electrophonic sounds due to "insufficient intensity of the signal or the absence of proper objects for electrophonic conversion."

Colin Price & Moshe Blum [11] disagree with Keay [12] about only fireballs creating very low frequency electromagnetic radiation. Price and Blum suggest that small meteors entering the atmosphere produce ELF/VLF spectral pulse signatures. These pulses could be separate from the production of an audible sound. Price stated that a definite radio signal was detected in the 1 to 15 kHz range. The signals occurred only within the initial entry of the meteor into the atmosphere lasting no longer than ten milliseconds, and then nothing, even though the meteor is visible for up to a few seconds [13].

Goran Zgrablic et al. [14] have done research indicating that fireballs of −6.5 to −12 magnitude produce electrophonic signatures. Zgrablic and co-author Zeljko Andreic [9] indicate a strong possibility of fireballs creating a coupling of atmospheric charge dynamics.

On reviewing Andreic's work, he and his team indicate that there was a slow change in intensity, an increase in ionospheric emissions, with no visible increase in meteor activity. The team observed that there were no local thunderstorms. A table showing magnitude distrubution of observed meteors indicate the greatest visual activity was between meteors having a magnitude of 0 to +4 [9].

The literature indicates that there is a possible correlation between meteors below non- fireball status and VLF electromagnetic disturbances. Accounting for tweaks and cracks that are usually credited to natural sferics may now be examined closer as meteor activity. These observations [5,11,14] may be close to observations presented by Ya Qi Li et al. [15] who suggest that there are more high-altitude electrical discharges occurring than currently being detected.

3. Equipment

The antenna of the receiver was a loop measuring 1×1 meter on a wooden maple frame using 200 turns of number 25 plastic coated copper wire mounted on a metal tripod, with the centre of the antenna at two meters above the ground. The antenna was by formula, calculated to be tuned to a resonating frequency of 4.5 kHz with a fixed capacitor. The system was not fitted with filters.

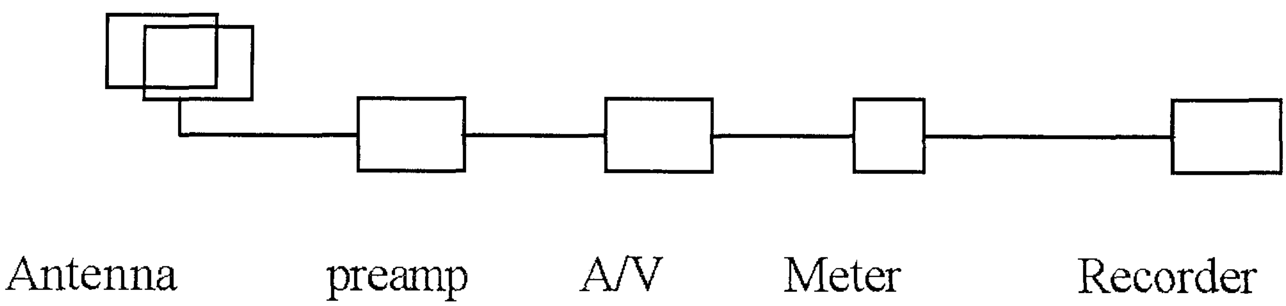


Figure 1 – Scheme of receiver.

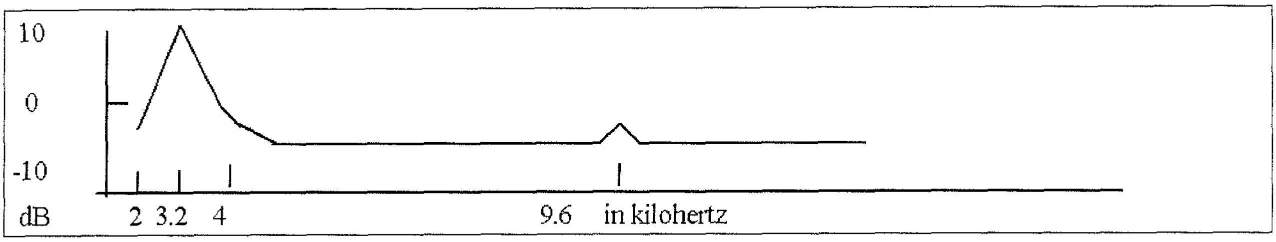


Figure 2 – Resonating frequency of loop antenna.

The frequency at which the inductor and capacitor resonated was found to be 3200 kHz. A third harmonic appears at 9600 kHz.

The antenna was oriented in a north-west to south-east configuration. At all times during the observation session the Leonid constellation would be orientated to the portion of the sky to the Leonids.

The receiver consisted of a two transistor low-noise preamplifier, fed into a secondary stage consisting of a LM308 operational amplifier. The LM308 functions as a current to voltage amplifier. The output is fed to a 50 microampere meter, with additional output for headphones or to audio recording equipment.

The receiver output was bench tested, showing that at a reading of 50 microaamperes on the meter scale, was equivalent to 0.80 microvolts.

The final output was recorded on an audio tape recorder for final analysis.

4. Visual Observations

The location was isolated from street and village lighting. All local lighting was turned off and the visibility was limited to magnitude (estimated) +5. The intent was not to count the shower per magnitude/number but to estimate an hourly rate. The other part of the observation was to coordinate VLF signatures with the appearance and disappearance of a meteor.

The estimated number per hour was averaged to 4000.

5. VLF Observations

We had five observers, four were visual observers and one monitored the equipment. The observations began at 8:15 UT, the sky was clear with limited meteoric activity observed from meteors. The audio and meter output indicated usual atmospheric tweaks and crackles rough the headphones. The meter gain was adjusted for background activity to give a meter reading of 25 microamperes. This was calibrated to be a voltage reading of (estimated) 0.65 microvolts.

About 20 minutes into the observation (8:35 UT) as meteor activity began to increase, the output reading of the meter was rising with an occasional peaking of the meter. The meter would go going off scale as a meteor passed through the atmosphere. The peak meter reading was 50 microamperes, adjusted to be (estimated) 0.80 microvolts. During observation, 18 November, the meters indicated a background of 30 microamps to a peak or +50 microamps. Bench testing indicated an electrical potential between 0.6 and 0.8 microvolts in the surrounding air during the shower.

It was suggested that the observer closest to the receiver and observing the meter call out any peaks or rise above background noise to see if there was a correspondence between an observed meteor and meter indication. A correlation appeared to be evident. As the equipment operator would call out a peak or spiking of the meter the visual observer saw a meteor at the same time.

To eliminate a possible bias of the equipment operator a switch in observers was made. The results were the same; the equipment operator noted a rise in background and visual observers noted meteor activity.

During the observation period meteors were observed from magnitude +5 to −10. A −10 meteor did appear causing to ground to "light-up". As this event occurred the meter peaked. Upon replaying the audio tape later, a buzz was heard, as well as an indicated spiking of recording voltage.

To summarize the VLF and visual observations, the atmospheric emissions at the beginning of the observation period were stable, indicated by moderate to quarter scale meter readings. As the visual shower activity increased, the meter readings increased to three-quarter to full scale. The equipment operator was calling out increased meter activity while the visual observers confirmed visual observations of Leonid Meteor activity.

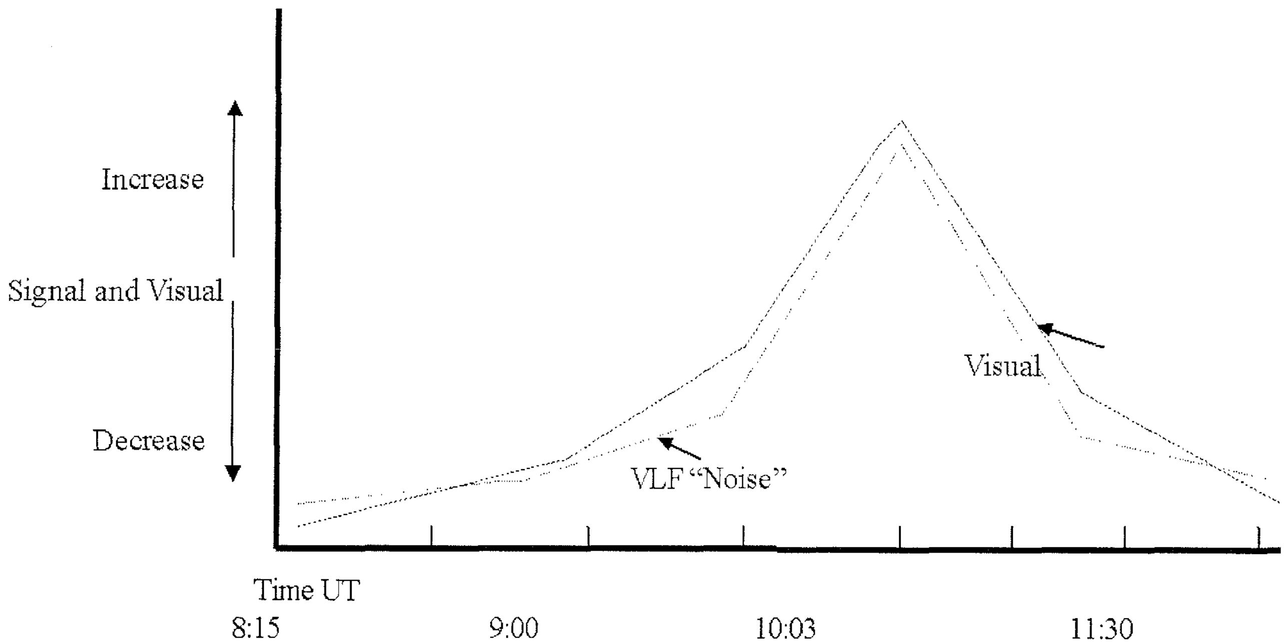


Figure 3 – Relationship between increase in microvolts and number of observed meteors.

The observer viewing only the meter was indicating to the visual observers that there was increased VLF activity followed by the appearance of a meteor.

The period from the beginning to the end of the shower was akin to observing an electrical storm. There was an increase of audio cracks and tweaks at the headphones and a high meter reading. As the meteor storm subsided the audio decreased and the meter activity returned to a normal pre-shower condition.

6. Conclusion

The intent of the observation was to identify a correlation between meteors and VLF signatures. The observation team was not aware of any electrophonic sounds during the observation period.

The observation made November 2001 demonstrated a relationship between visual meteors and an increase in background noise. As the shower peaked, so did atmoshperics and higher meter readings were observed. As the meteor shower proceeded westward, as the east coast observation site continued to rotate away from the main swarm, the indicated electrical discharges decreased. Along with the number of visual meteor sightings. The VLF observations were similar to an electrical storm within a storm cell, with each passing cell producing lighting strikes or discharges.

The electrical disturbances created by nature are broad spectrum. A meteor may produce a VLF signature or electromagnetic signal within a specific frequency. The experimental range may be between 1000 kHz and 4000 kHz [3,5,6,11].

Acknowledgment

Special thanks to Norm Siems, Physics Department Juniata College, Huntingdon, Pennsylvania and Charles Yohn, Juniata College Field Station. Thanks to observers: Stefanie B. Drobnock, G.J. Christopher Drobnock, and Ryan Ross.

7. References

[1] Hawkins, Gerald S., "Radio Noise from Meteors", *Nature* 7 June 1958, Vol. 181, No. 4623, p. 1610.

[2] Hawkins, Gerald S., "Search for Radio Emissions from Meteors", *Astrophysical Journal* November 1958, vol. 12., No 3, pp. 724–726.

[3] Drobnock, George John, "Radio Waves from a Meteor?", *Sky and Telescope* March 1992, pp. 329–330.

[4] Welch, Charles, "Build a Black Box That Hears Missiles", *Popular Electronics* April 1959, pp. 102–103.

[5] Andreic, Z., Lucano, B., Korlević, K., "No Evidence of Change in Ionospherical Radio Emission at 1.25–10.6 kHz during and after Meteor Flight", *WGN* 21:2, 1993, pp. 69–71.

[6] Beech, Martin et al., "VLF Detection of Fireballs", *Earth, Moon, Planets* 68, 1995, pp. 181–188.

[7] Takash Watanaba, Tashimi Okada, Kazuhiro Suzuki, "Meteors and Radio Waves", *HAM Journal* No 54, 1988.

[8] Bronshten, V.A., "Electrical and electromagnetic phenomena associated with meteor flight", *Solar System Research* 25, 1991, pp. 93–104.

[9] Beech, Martin, "VLF Detection of Fireballs", e-mail January 21, 1998, to George John Drobnock.

[10] Garaj, S et al., "Observational Detection of Meteor Produced VLF Electromagnetic Radiation", *FIZIKA A (Zagreb)* 8:3, 1999, pp. 91–98.

[11] Price, Colin, Blum, Moshe, "ELF/VLF measurements of the 1999 Leonids", Department of Geophysics and Planetary Science Tel Aviv University, Ramat Aviv, Israel.

[12] Keay, Colin S. L., "Anomalous Sounds from the Entry of Meteor Fireballs", *Science* 3 October 1980, Vol. 210, No. 4465, pp. 11–15.

[13] Price, Colin, *e-mail March 9, 2000*, and January 18, 2001.

[14] Zagrablić, Goran et al., "Instrumental Recording of Electrophonic Sounds from Leonid Fireballs", *Journal of Geophysical Research*, 2001.

[15] Li, Y.Q., Holzworth, R.H., Hu, H., McCarthy, M., Massey, R.D., "Anomalous Optical Events Detected by Rocket-Borne Sensor in the WIPP Campaign", *Journal of Geophysical Research* 96, 1991, pp. 1315–1326.

[16] Beech, M. and Foschini, L., "Leonid Electrophonic Bursters", *Astronomy and Astrophysics* 367, 2001, pp. 1056–1060.

Author's address:

George J. Drobnock, 213 S. Jefferson St., Mount Union, PA 17066, USA, `drobnock@penn.com`

The Leonid 2001 observations by the MBK Team from Arizona

Jure Atanackov and Javor Kac

In 2001, three *MBK Team* members observed the Leonid meteor storm from Arizona, employing both visual and photographic techniques. During the peak night more than 10 000 Leonids were recorded in just over 15 hours of observing time. The calculated peak ZHR of the Leonids was 4000 at $\lambda_\odot = 236\overset{\circ}{.}153$. Observing experiences as well as a few useful directions are given.

1. Leonid MAC 2001 and the American ground support location at Mt. Lemmon

The *Leonid Multi-Instrument Aircraft Campaign* (*MAC*) and first results from the 2001 mission were recently described in [1]. Three *MBK Team* members were taking part in the ground support team located at Mt. Lemmon, Arizona [2].

The prospect of observing from the American Southwest is no doubt attractive to every meteor observer. Characterized by very stable weather and clear skies, the large, sparsely inhabited desert areas provide very dark sky, much darker than the average European observer is used to. Also the Southwest is considered to be the world's astronomy capitol—and that for good reason—many of the world's most famous observatories are situated here. The northern half of Arizona State is an elevated plane, covered mostly by grassland and pine forests. Situated in the north is Flagstaff, known as the world's leader in light pollution prevention. The city is also known for the Lowell Observatory, founded in 1894 by Percival Lowell. Less than 20 miles outside the city are US Naval Observatory and Anderson Mesa—Lowell Observatory's dark sky site. And dark it is!

Adding to the special feeling was the fact that many meteor observers from all over the world flocked to Arizona to observe the Leonids: two groups from *Dutch Meteor Society* were stationed just outside Benson and Safford, east of Mt. Lemmon—all trusting Arizona's excellent climate and almost unparalleled dark skies to make the Leonids of 2001 a show to remember.

2. Getting ready for the grand show—the pre-peak night

Arriving to the observatory in early afternoon we found most observers asleep. After finally locating David Holman, we promptly joined them for some much needed sleep. After a good sleep in the afternoon it was time to get familiar with the equipment and the people in the team. The team consisted of David Holman—the team leader, organizer, and observer, Jim Richardson—the computer specialist, and observers Ana Mančić from Yugoslavia, Jure Atanackov, Javor Kac and Jure Zakrajšek from Slovenia and Tom Kucharski, joined the next night by Robert Lunsford, both from USA (Figure 1).

Mt. Lemmon Observing Facility (MLOF) is located on the summit of Mt. Lemmon at 2791 m elevation and some 32 km north-east of Tucson. The observing facility was first used as an early nuclear threat warning station during the 1960s and was operated by the US Air Force. Later converted to an astronomical observatory it utilizes a 1.5-m, a 1.0-m and a number of smaller telescopes. Not far away in plain view from MLOF is the dome of the famous 1.5-m Catalina Observatory, currently used in the LONEOS asteroid search. Further east of Mt. Lemmon is Mt. Graham, the location of the new Large Binocular Telescope. Also in the vicinity is Mt. Hopkins observatory. In the opposite direction, north-west from Mt. Lemmon, at about 100 km distance is the world-famous Kitt Peak Observatory.

In the evening it was time to proceed uphill to the dome of the 1-m telescope, which would serve as our observing station for the following three nights. In contrast to our expectations, the dome seemed disproportionately huge regarding the size of the instrument it sheltered. After receiving first instructions from David and Jim, we settled in front of the dome, each observer facing in different direction. Data collection would be done by "smart mice"—each observer received a computer mouse on a very long cable, connected to Jim's computer inside the dome. For each Leonid seen the observer would click the left mouse button, with the right button being used for everything else. Also, in regular intervals, Jim would collect each observer's limiting magnitude counts (in actual fact this was done by shouting). Jim would also collect Leonid magnitudes from an observer to make a rough estimate of the shower's population index. Finally, the sporadic rates from each individual observer during the first night would be used to make an estimate of his or her perception coefficient.

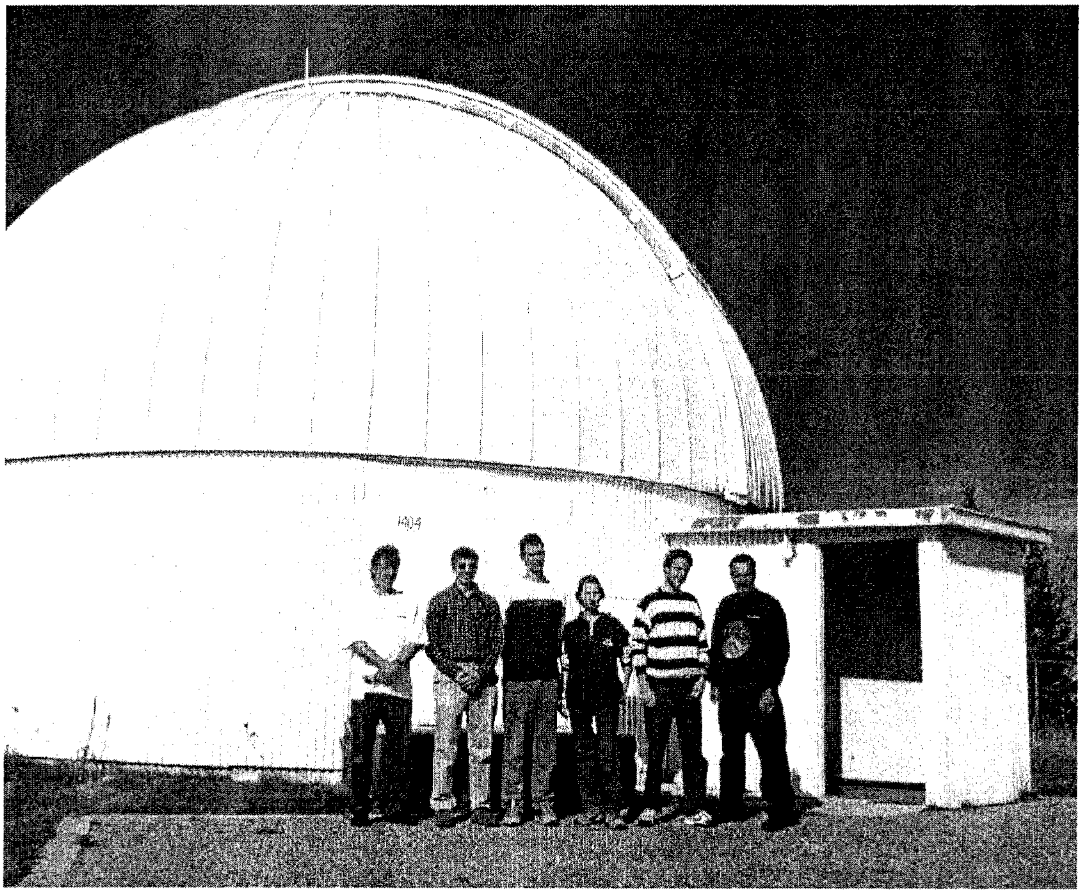


Figure 1 – Visual observers at MLOF, from left: David Holman, Jure Zakrajšek, Jure Atanackov, Ana Mančić, Javor Kac, and Robert Lunsford.

After receiving a short presentation from David and Jim it was time to begin. We plugged in our "smart mice" and began observing (at this time it was still about an hour to radiant rise). The Leonid rate during the first night was as expected—not spectacular but still entertaining. The ZHR ranged from 15 to 25. Observational results are shown in Table 1. More impressive was the sky at Mt. Lemmon, with the rather low activity we had enough time to really take a good look at the sky. In spite of Tucson's proximity, the sky was quite impressive. The winter Milky Way was an impressive light bridge across the sky, we could also see the gegenschein in Taurus and the zodiacal band running along the ecliptic. Top limiting magnitudes were above +7.0. In the morning we were treated to the brightest zodiacal light any of the present observers had ever seen—just before onset of dawn it reached over 100° across the sky, 35° wide at its base and bright enough to cast weak shadows!

For a great finish of the night, a brilliant magnitude −10 Leonid fireball exploded in Ursa Minor at $12^h57^m21^s$ UT, leaving a snaking train for over 5 minutes (see Figure 2). Using his image intensified video camera equipped with an objective spectral grating (slit-less spectroscopy), Dr. Jiři Borovička obtained a spectrum of the train.

Table 1 – Total effective observing time in hours ($T_{\rm eff}$), average limiting magnitude (LM) and number of meteors recorded during the night November 16/17, 2001.

Observer	Code	$T_{\rm eff}$	LM	$n_{\rm LEO}$	$n_{\rm TAU}$	$n_{\rm AMO}$	$n_{\rm Spor}$
Jure Atanackov	ATAJU	6.88	+6.95	113	41	2	145
Javor Kac	KACJA	4.97	+6.46	52	14	1	70
Jure Zakrajšek	ZAKJU	4.96	+6.61	68	27	1	101

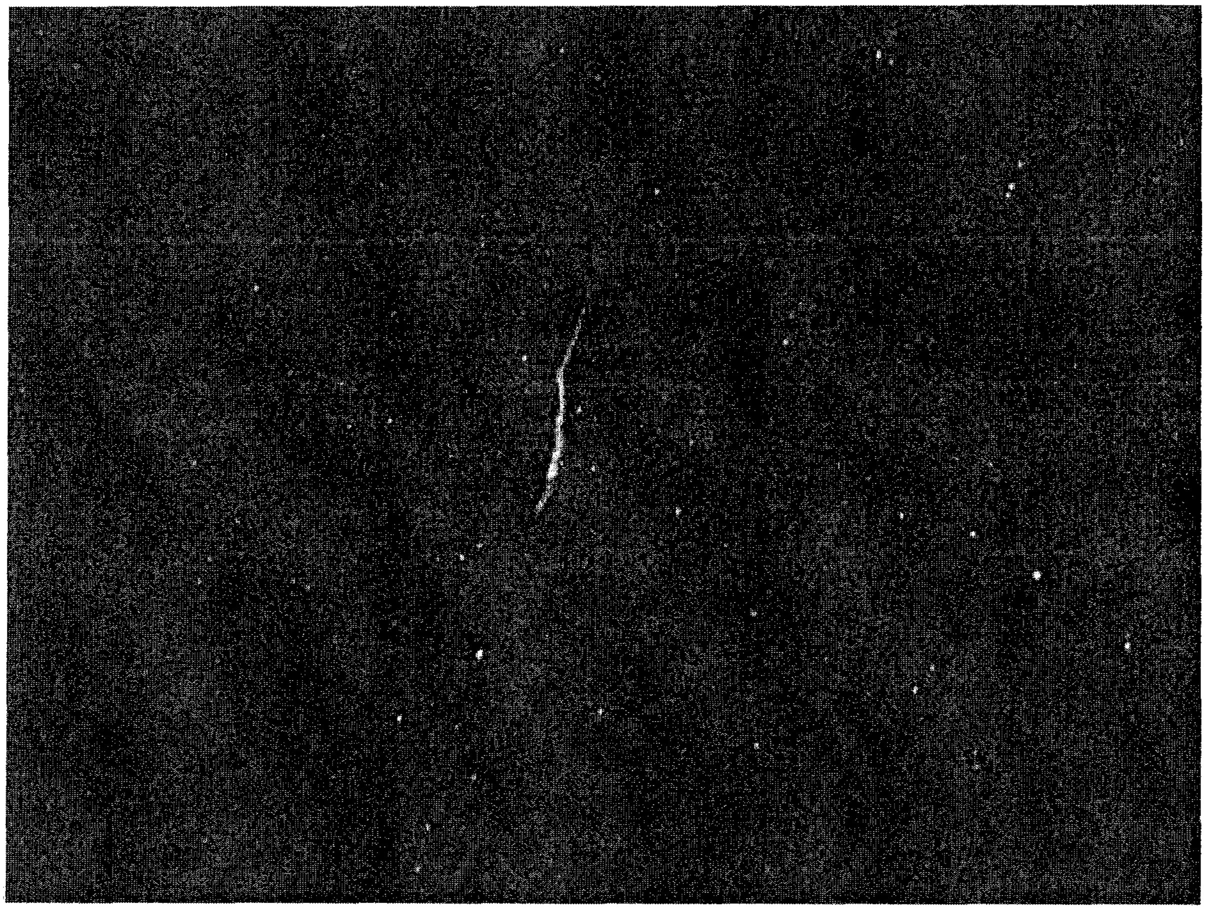


Figure 2 – The persistent train of a magnitude −10 fireball about 20 seconds after the fireball.

3. November 18—a flurry of Leonids

Waking up in the afternoon we were slightly shocked to find the sky partially covered with thin cirrus clouds. As the day drove on the weather didn't show any signs of improving and we were beginning to seriously consider relocating. At about 11 pm, we still had thin cirrus cover, reducing LM to about +4.0, while it seemed to be clear south-east of our location. Fortunately, Bob remained cool and estimated the weather would improve after midnight, but by how much he couldn't tell.

Twenty minutes after midnight, local time ($7^{\rm h}20^{\rm m}$ UT) we began observing. The sky was still partially overcast with thin cirrus clouds, but clear enough to produce *IMO*-worthy data. Immediately a show of amazing Earthgrazers began. We were seeing one per minute on average, most were close to zero magnitude or brighter, vividly coloured and leaving long persistent trains. Jim was already making real-time ZHR calculations, ZHR was about 180 at the time (Figure 3).

The rate slowly increased thereafter. Shortly after 1 am (8^h00^m UT) we began seeing first fireballs. Already the meteors were bright, already brighter than the average Perseid display. As the time approached two in the morning the sky cleared up almost completely—there were still occasional isolated patches of cirrus, but it wasn't making much effect on the show unfolding in the sky. By now we had some company—several casual observers drove up to Mt. Lemmon, among them Dr. Glenn Schneider of the University of Arizona with his daughter. At 2 am, we were already seeing 3 to 5 Leonids per minute, with many bright meteors and fireballs. The authors began continuous recording on tape at 9^h15^m UT—when also, unexpectedly, our "mouse system" crashed for the first time. Time for Jim to reboot the computer and us to temporarily disconnect the mice—Jim: *'Everybody unplug!!'*.

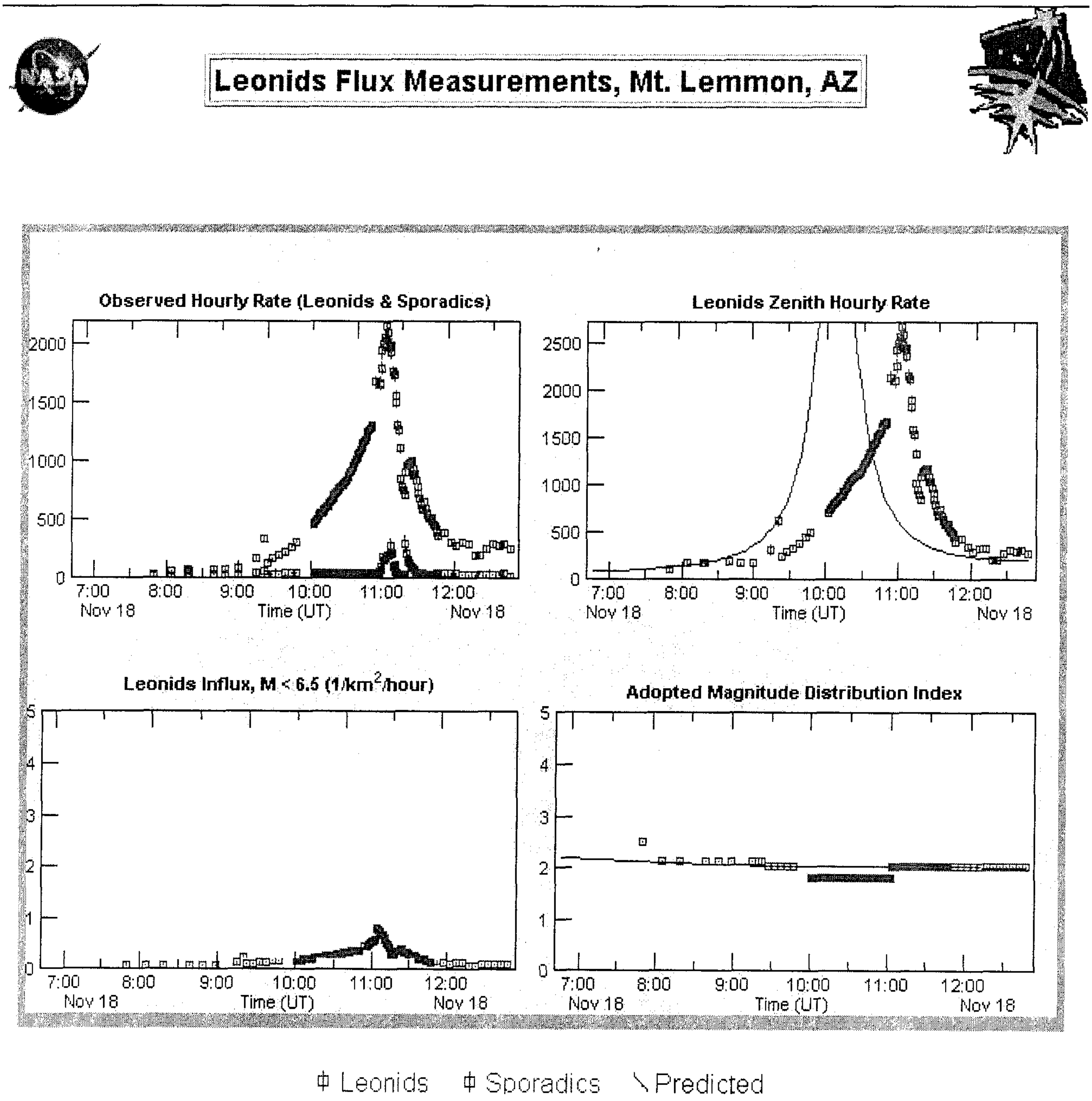


Figure 3 – Screen shot from NASA Leonid live meteor flux and ZHR page.

Jim had the system up in no time and we continued. By 10^h UT we were already seeing 15–20 Leonids per minute. Leonids would sometimes appear in rapid succession or even in groups so at times the recording became quite hectic. By 10^h30^m UT we had abandoned recording magnitudes, the rate was already about 30 to 45 per minute. Bob's early comment that *"your brain turns to mush at this rate"* (speaking from his own experience during Leonids of 1999 from Spain) was definitely true! Our "smart mice" were really suffering now. We reached the peak around 11^h UT with the authors seeing a top rate of 53 and 64 per minute, respectively. Jim announced from the dome that ZHR was now steady at 2600. We saw many fireballs up to magnitude −8. The Leonids were appearing all over the sky. The rate dropped off quite sharply after about 11^h15^m UT. Half an hour later we were seeing about 10 Leonids per minute on average. Quite surprisingly, the rate remained stable thereafter and the superb show continued until dawn. The summary of visual results is shown in Table 2. Some of the photographic impressions are depicted in Figures 4 and 5.

We finished the memorable night inside the 40-inch dome with a toast of champagne and headed down to the dorm for some sleep.

Figure 4 – A −3 Leonid fireball and at least three more Leonids close to the radiant.

Table 2 – Total effective observing time in hours (T_{eff}), average limiting magnitude (LM) and number of meteors recorded during the night November 17-18, 2001.

Observer	Code	T_{eff}	LM	n_{LEO}	n_{TAU}	n_{AMO}	n_{Spor}
Jure Atanackov	ATAJU	5.50	+6.34	4112	12	0	64
Javor Kac	KACJA	5.08	+5.53	2803	6	0	52
Jure Zakrajšek	ZAKJU	4.97	+6.16	3241	12	–	62

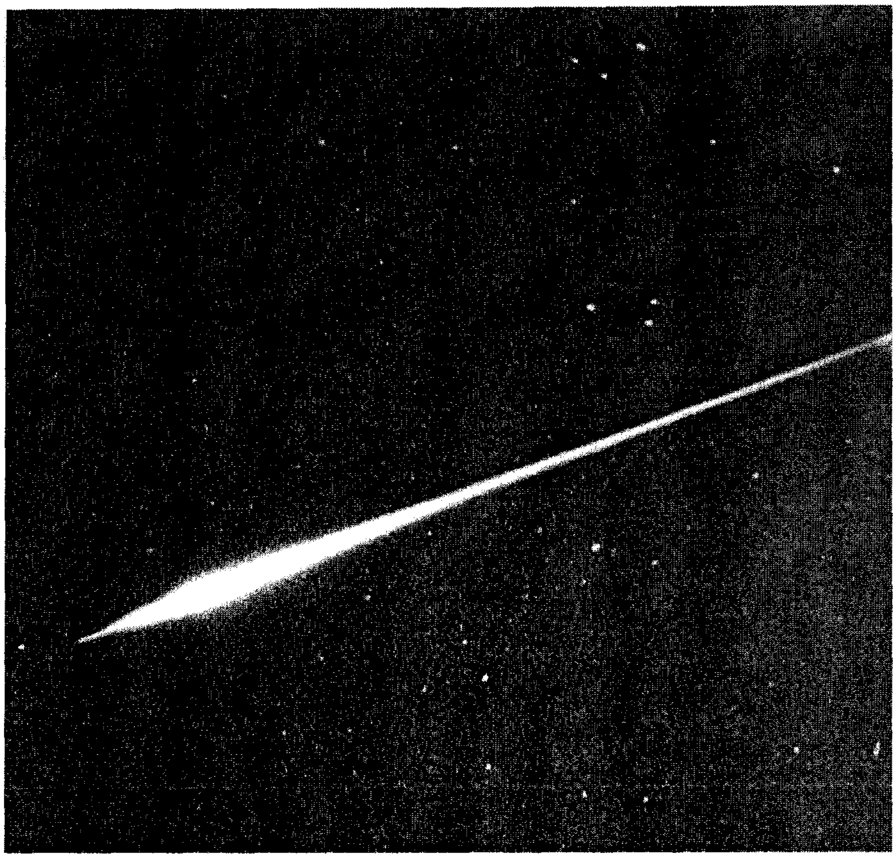


Figure 5 – A magnitude −8 Leonid fireball.

4. After day break...

Waking up in late morning most observers raced to check e-mail reports from other observers stationed across the world. By now also MAC near-real-time flux data from the Asian peak was coming in. The observers in Alice Springs were apparently enjoying a similar show to what we had witnessed not six hours ago! Seeing the ZHR was still very high around $19^{\rm h}$ UT we posted a warning to our observing colleagues back in Slovenia for "heads up" on any remaining elevated activity. The final night proved to be uneventful—only Bob persisted under cirrus-plagued skies for about an hour before retiring for the night.

As well as providing valuable data on the Leonid outburst our observations were an excellent preparation for this years final Leonid meteor storm. We suggest especially the readers who haven't observed a meteor storm to read this—you might make one mistake or two less. First on the recording method: while familiar with using a tape recorder we all experienced failures of some sorts during the storm. It might be a good thing to have a backup recorder and spare batteries nearby. Also, sometimes the tape recorder does not eject the "record" button when reaching the end of the tape. Try to remember when you replaced the tape and check the recorder with a flashlight just before you expect the tape to run out. And bring enough tapes—the first author ran out of his second tape about 30 minutes after the peak—he lost valuable time looking for a new tape!

5. Activity analysis

We computed the ZHR with a constant population index $r = 2.0$ and no corrections for the radiant elevation hR other than sin(hR). The error margins are computed as $\mathrm{ZHR}/\sqrt{n_{\rm LEO}}$. The calculated Leonid activity profile is shown in Figure 6. A double maximum is found at $\lambda_\odot = 236\overset{\circ}{.}139 \pm 0\overset{\circ}{.}004$ (November 18, $10^{\rm h}42^{\rm m} \pm 5$ min UT) with ZHR $= 3800 \pm 100$ and $\lambda_\odot = 236\overset{\circ}{.}153 \pm 0\overset{\circ}{.}004$ (November 18, $11^{\rm h}02^{\rm m} \pm 5$ min) with ZHR $= 4000 \pm 100$. The times are in good agreement with [3] while the ZHR are higher, probably due to higher perceptions of the observers.

Acknowledgments

We would like to thank David Holman for accepting us into the ground support team for the Leonid MAC 2001 mission. We would also like to thank Robert Lunsford for his help with organizing the expedition from the start, and Jim Richardson for his expert work behind the computer. We are grateful to the *Orion Astronomical Society* from Maribor, Banka Koper and Potna Banka Slovenije (PBS) for the financial support.

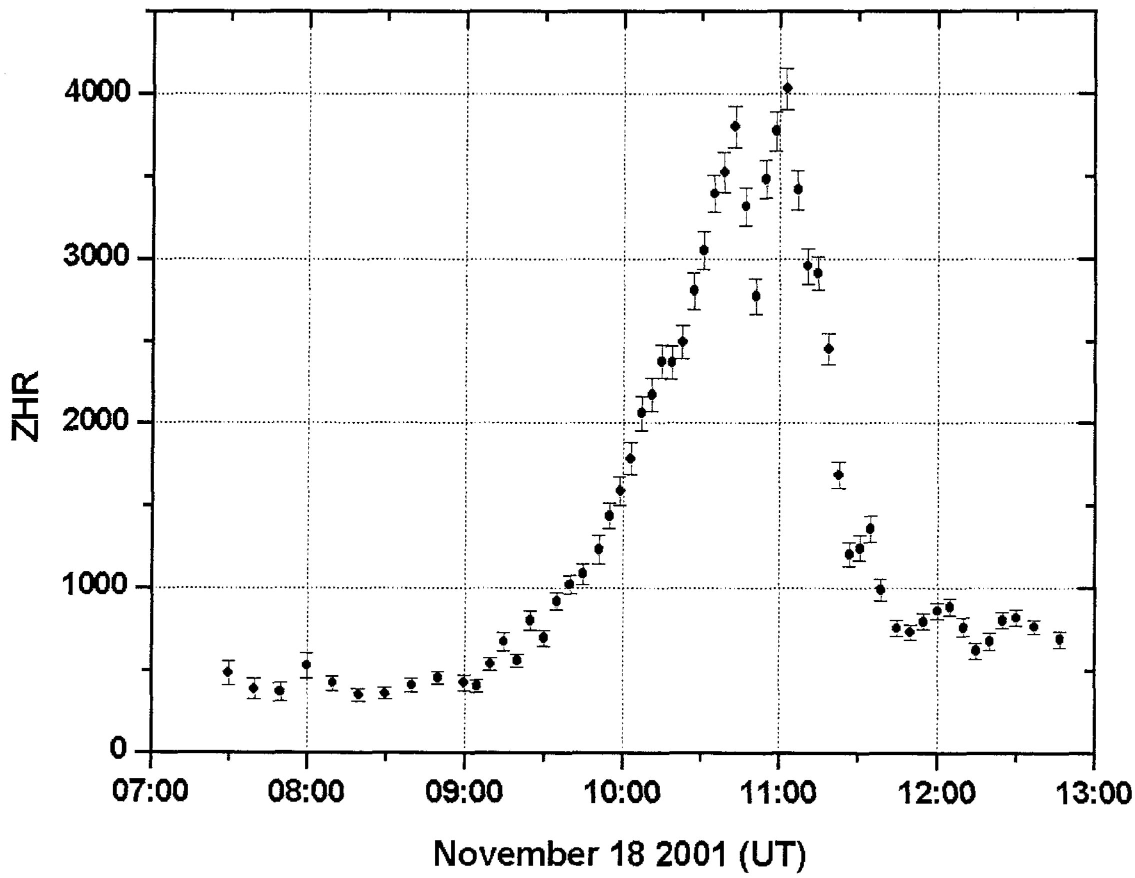


Figure 6 – Activity profile of the 2001 Leonids from MBK Team observations.

References

[1] Jenniskens P., "The 2001 Storm from 11 Kilometers Altitude: First Results", *WGN* 29 (2001), pp. 195–199.

[2] Atanackov J., Kac J., "Leonids 2001—Mt. Lemmon, Arizona", *Spika* 10 (2002), pp. 60–63 (in Slovenian).

[3] Arlt R., Kac J., Krumov V., Buchmann A., Verbert J., "Bulletin 17 of the International Leonid Watch: First Global Analysis of the 2001 Leonid Storms", *WGN* 19 (2001), pp. 187–194.

Author's addresses

Jure Atanackov, Aškerčeva 22, SI-3420 Velenje, Slovenia, e-mail `excel@siol.net`

Javor Kac, Na Ajdov hrib 24, SI-2310 Slovenska Bistrica, Slovenia, e-mail `javor.kac@orion-drustvo.si`

The 2001 Leonids from "Down Under"

Thomas Weiland

After observing the 1999 Leonid outburst on Tenerife, Canary Islands, I had the opportunity to witness the 2001 storm from Central Australia, about 50 kilometers east of Alice Springs, where atmospheric conditions were superb and skies absolutely dark. During 3.12 hours of effective observing time I was able to record 1372 Leonids, of which 51 were brighter than magnitude 0. Spectacular earth-grazers added to the scene, together with the Southern Skies as a setting.

1. Introduction

Despite long-distance travel I decided in favour of Central Australia as a suitable observing site for the awaited 2001 Leonid storm. With a maximum radiant elevation of 24° at the predicted peak times of the 1866 trail, according to [3,5,6], geometric conditions were not ideal, but skies expected to be pretty dark and weather prospects quite good. Moreover, a good street network would allow to stay mobile during the event, therefore I had rented a car in advance. On Sunday, November 11, I left Vienna, Austria, via Frankfurt and Singapore for Melbourne. Regrettably my arrival in the heart of the red continent began with a disappointment: large parts of Central Australia suffered from overcast skies! Not enough of that I was told at the rental car office in Alice Springs that I am not allowed driving at night resp. I could do so but at my risk! The next days fared better and I made trips to famous sites as Uluru (Ayers Rock) and Kata Tjuta (The Olgas), both Australian landmarks, to get familiar with the countryside. Since I am a geologist/paleontologist, their estimated age of 600 million years (Late Precambrian) left a deep impression on me. At night I was touring the Southern Skies with binoculars to see all the glories of the Milky Way and the Magellanic Clouds as well.

Once in a while a single Leonid rushed across the sky, the brightest one of magnitude −2. During the night before the storm (November 17-18) clouds posed a great problem and I was driving east off Alice in search for clear breaks. But I could only observe for short periods to find Leonid activity rather low. More luckily I got my observing place: Corroboree Rock (Eastern McDonnells; 134°11′E, 23°41′S), an aboriginal site, which served as a deposit for sacred objects in former times. Built up of Precambrian algae-dolomite its origin dates back 800 million years. It offered an almost perfect horizon (field obstruction 5%), especially facing northeast. There, troubled with clouds, Leo had already risen. Some minutes later clouds got me too and it began to rain. I went back to Alice, in hope for better prospects.

2. The storm night, November 18-19

As I woke up two hours before noon or so the sky was totally blue! I headed to the airport to see the friendly guy of the weather forecast, who told me that the low pressure trough bothering me last night had already passed and the odds for clear skies during the storm were pretty good. He should be right! Gladly I went back to town and stocked up on supplies, most important drinking water and fuel. Surprisingly most of the Australians I talked to were aware of the event, informed by newspapers and on TV weeks in advance. I spent a peaceful afternoon at Trephina Gorge and went back to Corroboree Rock later. There were no clouds in the sky, but the southeasterly wind persisted. After meal I prepared for the storm. Though being a thin crescent the moon shone brightly, illuminating the rock, and the scene became rather mystic. I fancied the people here in former times and their "Perentie dreaming". With more than 2.5 meters length "Perenties" (Varanus giganteus) are huge lizards and, behind the Komodo dragon, the second largest in the world. They are said still to be living here today, but I neither saw nor heard them. Only cicadas and birds gave their concert and some kangaroos hopped around. To stay awake during the storm I decided to sleep in the car for some hours. As I got up, landscape was plunged in darkness. I determined the sky's limiting magnitude at +6.3 and looked for snakes, of which I had been warned many times.

At 15^h50^m UT (1^h20^m local time) I started to observe and it took me only 3 minutes and 15 seconds to catch my first Leonid. With the radiant still 2.5° below the horizon it was a spectacular earth-grazer of magnitude −1 and orange-blue tint. It appeared near Leo's head and traveled some 120°, leaving a thin train behind its bulbous head. Followed by a 70° long one at $15^h56^m55^s$ UT the first 50 minutes saw 36 Leonids, of which 11 were earth-grazers. By the time Leonid paths became shorter, but more numerous. From 16^h44^m UT on at least one Leonid per minute shot across the sky. Between 16^h44^m and 17^h00^m UT I saw 52 Leonids and during the next 15 minutes 59. Most meteors were centered on magnitude +1, leaving short trains behind. Around 17^h15^m UT, as the radiant had reached an elevation of 14°, meteors tended to become brighter. Many Leonids were now within the −1 to −3 magnitude range, highlighted by a magnitude −4 fireball, which flared low in the northeast at $17^h29^m40^s$ UT. The brighter ones exhibited mostly orange, though some other colors were seen too. This could be part of the 1699 trail, I supposed. But rates showed only a slight increase with 86 Leonids between 17^h15^m and 17^h30^m UT and 59 between 17^h30^m and 17^h40^m UT.

After that Leonid numbers jumped up quickly to at least 10 per minute and I decided to speak magnitudes and time markers on my tape recorder running continuously instead of writing down each meteor. Quite in time, I recognized later, as rates were still going up. Between 17^h42^m and 17^h55^m UT I recorded 167 Leonids, followed by 234 between 17^h57^m and 18^h10^m UT. My best single minute came between 18^h05^m and 18^h06^m UT, when the count yielded more than 30 Leonids (> 1800 per hour!), of which at least 3 appeared simultaneously. This coincided well with the predicted peak time of the 1866 trail for Central Australia (18^h03^m UT), according to [5,6]. Though it was hard to keep up I managed to record magnitudes all the time, except for those Leonids raining down simultaneously. It became obvious that the bulk was now centered on magnitude +3, garnished with some brighter ones. One of these highlights came at $18^h22^m10^s$ UT, a blue-green fireball of magnitude −3, which passed swiftly over my head and ended with a terminal burst. Its train was visible for about 1 minute. Most of the meteors had now a bluish to greenish cast with even faint ones leaving short trains, similar to contrails, behind. For most of the time I had the impression that the Leonids kept coming in waves, with occasional bursts of up to 7 meteors within a single second. It was stunning, the most dramatic meteor show I ever had! Contrary to the 1999 outburst, which lasted definitely less than 1 hour, the 2001 storm lingered for some while. So I counted 212 Leonids between 18^h13^m and 18^h26^m UT and 226 between 18^h29^m and 18^h43^m UT.

At 18^h45^m UT astronomical twilight began, but average rates stayed well beyond 10 per minute. A quick glance still showed shooting stars in different parts of the sky. Meanwhile the Southern Cross as well as α and β Centauri, the "flagstars" of Australia, had risen. At 19^h00^m UT the sky's limiting magnitude was already down to +5.5 and the Leonids were beginning to lose strength. I felt completely exhausted. At 19^h15^m UT nautical twilight started (lm +4.4), well in time with the end of my tapes 1 minute earlier. I waited for sunrise and slept in the car until it became too hot.

3. Aftermaths

The day after the spectacle I gave me some rest, then I continued my tour with a visit of Watarrka (Kings Canyon) and the Henbury Meteorite Craters. The latter lie some 140 kilometers south-southwest of Alice Springs. One can find there 12 impact craters of 6 up to 160 meters in diameter scattered over an elliptical field stretching less than 1 kilometer. Two of the main craters merge into a double structure and another one is watered by a creek, discernible at the lush vegetation covering the floor. The craters were already discovered at the beginning of the last century. The causing object was made up of nickel-iron. With an estimated age of 4700 years, they belong to the youngest known impact structures on earth. I tried to imagine what would have happened if the Leonids were behaving like that.

4. Discussion

Back home in Austria I made an attempt to break down the data. To my joy I found calibration of the tapes less stressing than in 1999, since the tapes of 30 minutes duration showed little deviation in effective playing time compared to those of 60 minutes used before. After thorough examination it came out that I had recorded a total of 1372 Leonids during 3.12 hours of effective observing time. The meteor magnitude distribution for each time interval and in total is given in Table 1 (except for those Leonids, which appeared simultaneously) including the corrected mean and mean limiting magnitudes and the population indices as well. The latter were derived using the average magnitude difference to the limiting magnitude.

Table 1 – Magnitude distribution of 1347 Leonids obtained by the author. There are no magnitudes available for meteors, which appeared simultaneously.

Time (UT)	−6	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	+6	Tot	$m_{6.5}$	lm	r
15:50-16:40	0	0	0	0	0	5	10	10	5	3	3	0	0	36	1.2	6.3	1.60
16:44-17:00	0	0	0	0	0	2	14	18	14	3	0	1	0	52	1.3	6.3	1.64
17:00-17:15	0	0	0	0	3	2	10	26	12	2	4	0	0	59	1.3	6.3	1.63
17:15-17:30	0	0	1	1	4	6	11	42	13	7	1	0	0	86	1.0	6.3	1.55
17:30-17:40	0	0	0	2	1	3	9	30	11	2	1	0	0	59	1.1	6.3	1.56
17:42-17:55	0	0	0	0	1	3	20	45	39	38	21	0	0	167	2.1	6.3	1.87
17:57-18:10	0	0	0	1	0	0	18	50	43	57	55	7	0	231	2.6	6.3	2.10
18:13-18:26	0	0	0	1	0	4	17	29	38	55	49	8	0	201	2.7	6.3	2.13
18:29-18:43	0	0	0	0	0	4	20	33	54	56	42	6	0	215	2.5	6.3	2.05
18:45-18:59	0	0	0	0	0	3	12	26	38	44	29	3	0	155	2.9	5.9	2.29
19:00-19:14	0	0	0	0	0	4	12	18	24	17	10	1	0	86	3.3	5.0	2.65
Totals	0	0	1	5	9	36	153	327	291	284	215	26	0	1347	2.3	6.2	1.94

Though it seems quite bold for a single observer to compete with *IMO*-data obtained on a global scale some remarks may be given here, especially since Leonid storm activity has been proven to show distinct features from different observing sites [1,4]:

1.—Compared to results obtained from observations across East Asia the Leonids seemed to produce much less fireballs over Central Australia than at similar longitudes further north. Out of the observed total of 1372 Leonids only 6 (!) can be considered as fireballs (magnitude brighter than or equal to −3), whereas a good number within the 0 to −2 magnitude range (198 meteors) has been observed.

2.—The covered period between $15^{\mathrm{h}}50^{\mathrm{m}}$ and $19^{\mathrm{h}}14^{\mathrm{m}}$ UT (11 observing intervals) shows two distinct magnitude distributions before and after $17^{\mathrm{h}}40^{\mathrm{m}}$ UT. The period between $15^{\mathrm{h}}50^{\mathrm{m}}$ and $17^{\mathrm{h}}40^{\mathrm{m}}$ UT (5 intervals) is first characterized by corrected mean magnitudes not higher than magnitude +1.3 and population indices varying slightly between $r = 1.60$ and 1.64, which is remarkably constant despite the relatively low meteor numbers sampled by a single observer. A small dip of r down to 1.55 together with corrected mean magnitudes around magnitude +1.0 between $17^{\mathrm{h}}15^{\mathrm{m}}$ and $17^{\mathrm{h}}40^{\mathrm{m}}$ UT may give a hint on the 1699 trail, which is not significant in meteor rates. For Central Australia the 1699 trail was expected to peak at $17^{\mathrm{h}}14^{\mathrm{m}}$ UT, according to [5,6]. During the second period between $17^{\mathrm{h}}40^{\mathrm{m}}$ and $19^{\mathrm{h}}14^{\mathrm{m}}$ UT (6 intervals) a substantial change in the magnitude distribution could be observed. Within that period the corrected mean magnitudes went down to +2.7, staying around this value for most of the time. In correspondence the population index shows an almost steady climb to $r \approx 2.20$, which looks significant due to the fact that observing conditions did not change until $18^{\mathrm{h}}45^{\mathrm{m}}$ UT. The rise of the corrected mean magnitudes and population indices beyond that point is probably not real because of morning twilight interference.

3.—Although generally regarded to be of little value, another interesting feature is the color. In 1999 the bulk of meteors making up the background component showed a deep orange together with some yellowish and greenish tints. At the moment rates jumped to storm levels colors turned almost exclusively to yellow-green. A similar behavior could be observed in 2001 as well. Most of the meteors appearing before 17^h40^m UT showed an orange, sometimes yellowish or greenish cast, whereas those beyond that point exhibited blues and greens. Around 17^h40^m UT both types persisted. Regrettably the 1699 trail was not distinguishable by color, as I had hoped for.

References

[1] R. Arlt, L. Bellot Rubio, P. Brown, M. Gyssens, "Bulletin 15 of the International Leonid Watch: First Global Analysis of the 1999 Leonid Storm", *WGN* 27, 1999, pp. 286–300.

[2] R. Arlt, J. Kac, V. Krumov, A. Buchmann, J. Verbert, "Bulletin 17 of the International Leonid Watch: First Global Analysis of the 2001 Leonid Storm", *WGN* 29, 2001, pp. 187–194.

[3] E. Lyytinen, M. Nissinen, T. Van Flandern, "Improved 2001 Leonid Storm Predictions from a Refined Model", *WGN* 29, 2001, pp. 110–118.

[4] A. McBeath, "SPA Meteor Section: 1999 Leonids—Visual and Imaging Results", *WGN* 28, 2000, pp. 69–76.

[5] R.H. McNaught, "Visibility of Leonid Showers in 1999–2006 and 2034", *WGN* 27, 1999, pp. 164–171.

[6] R.H. McNaught, D.J. Asher, "The 2001 Leonids and Dust Trail Radiants", *WGN* 29, 2001, pp. 156–164.

Author's address

Thomas Weiland, Ospelgasse 12-14/6/19, A-1200 Wien, Austria, e-mail `weiland@a1.net`

Ongoing Meteor Work

The Current Delta-Aurigid Meteor Shower

Audrius Dubietis and Rainer Arlt

The activity and magnitude distribution profiles of the δ-Aurigid meteor shower were derived from one decade (1991-2001) Visual Meteor Database records. Activity profiles suggest a persistent feature of two local maxima at $\lambda_\odot = 166.7°$ and $\lambda_\odot \approx 181°$ with typical ZHR values of 4.5±0.4 and 2.6±0.2, respectively. This finding shows that current δ-Aurigid meteor shower represents a combination of two separate (related?) meteor showers—September Perseids and δ-Aurigids, overlapping in time and celestial sphere, as well.

1. Introduction

The δ-Aurigids are a poorly studied minor meteor shower of early autumn. The shower activity period extends from September 5 to October 10 with a maximum on September 8-9 ($\lambda_\odot = 166°$) [1]. Different sources provide different activity periods of the shower which in some cases do not even overlap. This leads to some confusion of the shower treatment, especially for visual observers. Since recent times, there were not much reliable observations that may provide a full picture of the shower behavior and characteristics. Historically, the shower was discovered by W.F. Denning in the nineteenth century [2]. He called them "September Perseids" and found the maximum around September 10. This name appears also in some of the modern sources, and a rather short activity period is assumed [3,4].

Drummond first introduced the name of "δ-Aurigids" [5] with an activity period from September 29 to October 18 possessing a series of weak and diffuse maxima [6]. These dates differ considerably from the activity period of the September Perseids. Interestingly, four photographic radiants in the Per-Cam-Aur region with overlapping activity periods that fit the period of interest are revealed in [7].

Considering all the above facts, one might presume that the today's δ-Aurigid shower is a combination of at least two showers with radiants, which produce occasional geometrical overlap in the celestial sphere. The shower is listed as a single source in the *IMO* Working List of Visual Meteor Showers. In this Paper, we will also discuss whether or not this was a suitable choice. Note that there is no proof of a relation of the mentioned showers with the α-Aurigids, and neither September Perseid nor δ-Aurigid showers could be seen as the extension of the α-Aurigid activity.

2. Orbits

The strongest argument in favor of two separate showers could be the derivation of the mean orbit of the meteoroid stream. Indeed, some attempts already exist to date; see Table 1 where average orbits obtained by various authors are given. Kronk [6] made a compilation of meteor orbits obtained from different sources and found four distinct orbits that may represent the shower of Drummond [5] suggesting a weak possibility of an association with Comet Bradfield (C/1972 E1).

Rendtel [8] found two different orbits which may be related to the September Perseids and δ-Aurigids, respectively. Individual δ-Aurigid orbits could also be found in [9], but no mean orbit is derived. The September Perseid orbit was recently confirmed by double-station video observations [10]. Gavajdova [3] revealed mean orbital parameters for the September Perseids only, that point to a parabolic orbit of the stream. And finally, Welch [11] derived orbital parameters for a number of major and minor meteoroid streams, including the orbit of the δ-Aurigids.

A somewhat different orbit is obtained by TV observations, indicating the existence of an ε-Aurigid shower around September 13 [12]. The latter is probably caused by a different stream since the given radiant position also differs from that of δ-Aurigids. Excluding the orbit of the ε-Aurigids, one may notice two apparent groups with very close parameters—the September Perseids (provisionally called SPR here) and the δ-Aurigids (DAU). The longitudes of ascending nodes suggest a maximum of the September Perseids at $\lambda_\odot = 166°$ to $168°$, which coincides very well with that derived from the visual observations. The date of maximum of the δ-Aurigids is far less precise, it falls between $\lambda_\odot = 189°$ and $\lambda_\odot = 195°$ (first decade of October).

Table 1 – Mean orbital parameters of the September Perseids (SPR) and δ-Aurigids (DAU) derived by the authors of the sources given.

Stream	Ω	ω	i	e	q	a	Method	Reference
DAU	195.3	229.5	131.1	0.956	0.823	18.71	photo	[6]
DAU	188.6	226.4	123.9	0.878	0.617	2.292	radar	[6]
DAU	191	226.7	130.2	0.965	0.845	18.7	photo	[8]
SPR	166.2	242.6	140.5	1.031	0.733	−23.2	photo	[3]
SPR	168	241.3	142.8	0.95	0.75	15	photo	[8]
SPR	165.9	242.8	138.9	1.00	0.74	–	photo	[11]
ε-Aur	170.8	182.6	146.7	0.71	1.01	3.4	TV	[12]

3. Observations

The activity of the δ-Aurigids was analyzed within the solar longitude interval $\lambda_\odot = 157°$ to $202°$. Only a few reports were available before 1991, so the analysis was performed with observations collected during the past decade. The Visual Meteor Database (*VMDB*) provides 4040 observational records in the years 1991–2001 which contain 3474 δ-Aurigids. With routine data reduction, 3336 shower meteors were available for the activity analysis. Magnitude data contain 702 distributions with magnitudes of 2700 shower meteors ($\mathrm{lm} \geq +5.0$). Because of the long activity period and the incomplete datasets, the activity profiles for individual years have not been derived. The observational data were split into two time intervals: 1991–1995 and 1996–2001 (with 926 and 2320 meteors, respectively), whereas the population index was derived using the entire magnitude dataset. Some standard data reduction criteria were used: $C_i \leq 8$ for the ZHR estimates and $\mathrm{lm} \geq +5.0$ for the calculation of the population index. The condition of $h_R \geq 20°$ often used in activity analyses has been omitted in this case, as it was shown to be insignificant in the case of α-Aurigids, observed under very similar conditions [13].

4. Activity and population index profiles

The entire magnitude dataset ($\mathrm{lm} \geq +5.0$) gives a value for the population index of $r = 2.61 \pm 0.05$ which is very close to that obtained with $\mathrm{lm} \geq +5.8$: $r = 2.59 \pm 0.05$. For the calculation of the activity profiles, an average $r = 2.60$ was used. ZHR profiles were calculated using the standard procedure. In brief, each data point in the activity profile represents an average

$$\overline{\mathrm{ZHR}} = \left(1 + \sum_i n_i\right) \Big/ \sum_i \frac{T_{\mathrm{eff},i}}{C_i}, \qquad (1)$$

where n_i is the individual number of shower meteors observed during a time period $T_{\mathrm{eff},i}$, and C_i is the total correction for a limiting magnitude lm, field obstruction factor F, and the radiant elevation h_R:

$$C_i = r^{(6.5-\mathrm{lm})} F \Big/ \sin h_\mathrm{R}. \qquad (2)$$

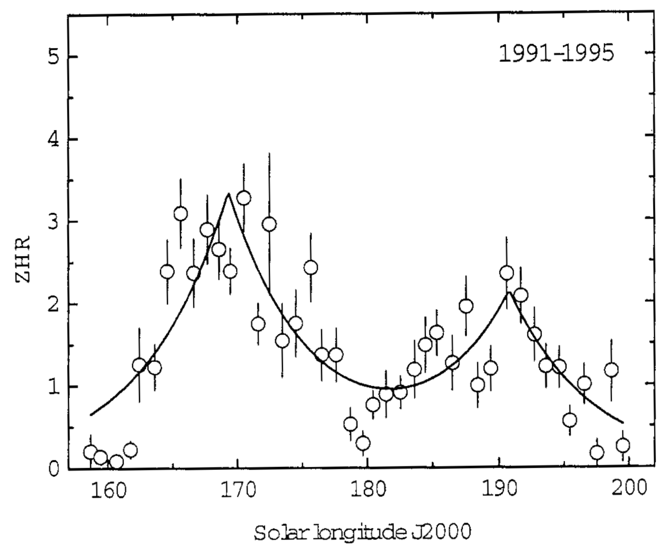


Figure 1 – Activity profile of the 1991–1995 δ-Aurigids. The resultant curve of a two-exponential fit is shown by a solid line.

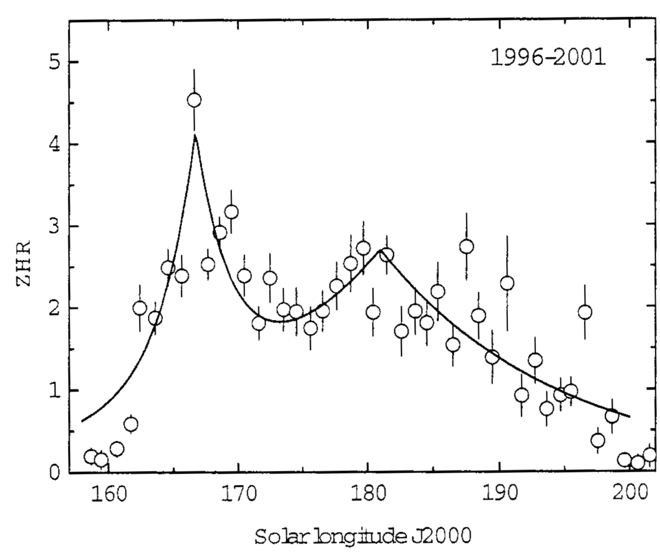


Figure 2 – Activity profile of the 1996–2001 δ-Aurigids. The resultant curve of a two-exponential fit is shown by a solid line.

With the amount of data available, 1° bins were used. Smaller bin sizes result in noisy profiles with low confidence of the averages. Figures 1 and 2 depict the activity profiles of the years 1991–1995 and 1996–2001, respectively. The double-peaked ZHR graphs clearly indicate two local maxima separated by $\sim 15°$ to $\sim 20°$ in solar longitude.

Two exponential function

$$\mathrm{ZHR} = \mathrm{ZHR}_1 \exp\left(-\mathrm{B}_1|\lambda_\odot - \lambda_\odot^{\max_1}|\right) + \mathrm{ZHR}_2 \exp\left(-\mathrm{B}_2|\lambda_\odot - \lambda_\odot^{\max_2}|\right) \qquad (3)$$

was used to fit the observational data and derive the shower parameters. $\mathrm{ZHR}_{1,2}$ and $\lambda_\odot^{\max_{1,2}}$ represent the maxima, where indexes 1 and 2 stand for September Perseids and δ-Aurigids, respectively. $B_{1,2}$ is the steepness of the exponentials corresponding to appropriate full widths at half-maximum

$$\mathrm{FWHM}_{1,2} = \ln 2 \times 2/B_{1,2}. \tag{4}$$

The fitting procedure involves the variation of six free parameters: ZHR_1, ZHR_2, $\lambda_\odot^{max_1}$, $\lambda_\odot^{max_2}$, B_1, and B_2. In the case of the combined 1991–2001 profile, $\lambda_\odot^{max_1} = 166\overset{\circ}{.}7$ was fixed. The combined profile (Figure 3) preserves the same features as the previous two. The presence of two showers with overlapping activity periods is strongly suggested by the graphs. The earlier local peak may be attributed to the September Perseids, whereas the later one is a signature of the δ-Aurigids. The main parameters of both showers are given in Table 2. The combined data gives maximum of September Perseids at $\lambda_\odot = 166\overset{\circ}{.}7 \pm 0\overset{\circ}{.}5$ with $ZHR = 3.1 \pm 0.4$. The numbers derived for the δ-Aurigids are less precise. The fit curve results in a maximum at $\lambda_\odot = 184\overset{\circ}{.}5 \pm 1\overset{\circ}{.}1$ with $ZHR = 2.2 \pm 0.2$. The maximum seems to be rather flat and not well pronounced with the activity level being just slightly above the visual detection limit ($ZHR \geq 1$).

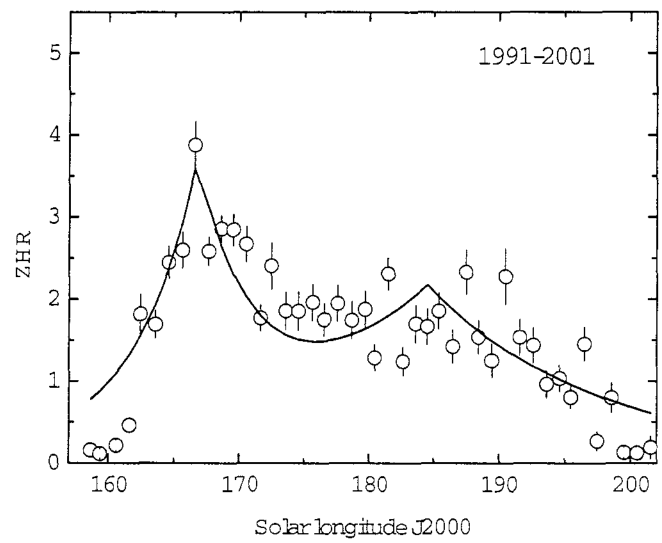


Figure 3 – Combined activity profile of the 1991–2000 δ-Aurigids. The resultant curve of a two-exponential fit is shown by a solid line.

Table 2 – Shower parameters derived from two-exponential fits according to Equation 3. Subscripts 1 and 2 stand for September Perseids and δ-Aurigids, respectively. Uncertain values are given in brackets.

Timespan	$\lambda_\odot^{max_1}$	ZHR_1	B_1	$\lambda_\odot^{max_2}$	ZHR_2	B_2
1991–1995	(169.3 ± 0.5)	3.4 ± 0.3	0.16 ± 0.03	190.8 ± 0.8	2.0 ± 0.3	0.16 ± 0.05
1996–2001	166.7 ± 0.5	3.2 ± 0.5	0.36 ± 0.06	181.0 ± 1.0	2.7 ± 0.3	0.07 ± 0.02
1991-2001	166.7 ± 0.0	3.1 ± 0.4	0.24 ± 0.04	184.5 ± 1.1	2.2 ± 0.2	0.07 ± 0.02

The population index profile is shown in Figure 4. Each data point is obtained from 75 magnitude distributions containing from 200 to 400 meteors each. Despite the large error bars, a change of the population index with solar longitude is noticeable. The September Perseids are likely to possess a lower population index with a lowest r-value of 2.46 ± 0.11 around their local maximum. Conversely, the maximum of the δ-Aurigids is characterized by a higher population index, $r = 2.91 \pm 0.22$. In order to provide evidence for the r-profile features, of cause, larger magnitude datasets or a refined analysis with individual observers' characteristics are required for better accuracy.

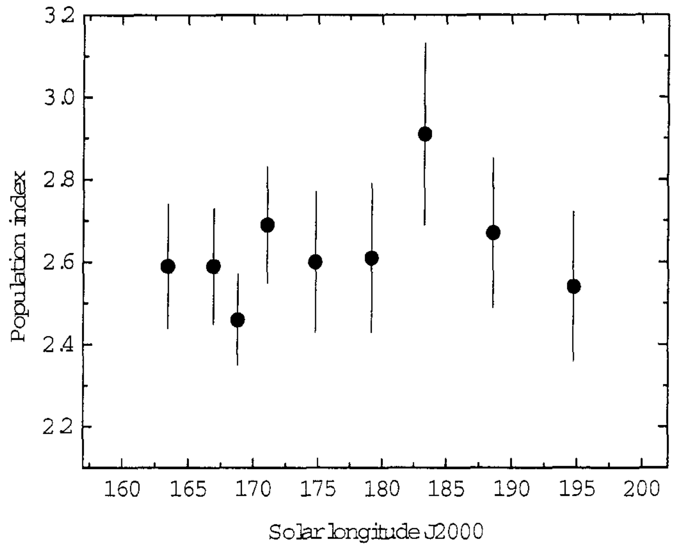


Figure 4 – Population index profile of the δ-Aurigids as derived from observations in 1991–2000.

Let us for a moment assume the r-minimum is real. Such feature is often observed in conjunction with or near major-shower maxima. One could argue that this is a selection effect due to the abundance of meteors. Faint meteors are overlooked since the number of bright meteors is "entertaining" enough. If we find such signature of an r-minimum in a minor shower, the explanation of a selection effect hardly holds, and the presence of r-minima during shower maxima may be a physical feature of meteor showers. Nevertheless, too weak evidence is found here to draw wide conclusions. We may keep this fact in mind for future minor-shower analyses.

The counterexample is of course the r-peak near maximum of the δ-Aurigids. While the population index of the September Perseids decreased below $r = 2.5$, the δ-Aurigids reach r exceeding 2.9. The difference in r is obviously significant and may be another hint on the heterogeneous origin of two actual streams or peculiar particle sorting in a single steam.

5. Discussion

According to Figure 5, the September Perseids are active from $\lambda_\odot = 163°$ to $\lambda_\odot = 170°$ with a maximum of ZHR $= 3.2 \pm 0.5$ at $\lambda_\odot = 166\overset{\circ}{.}7$. The shower FWHM is 3.8°. These parameters were calculated from the two exponential functions fitted to the sequence of ZHR averages. The maximum dates obtained from fitting as well as from the highest point in the ZHR curve ($\lambda_\odot = 166\overset{\circ}{.}6$) are in good agreement with that predicted by orbital parameters of the stream. Probably, the September Perseid meteor shower may produce higher rates up to ZHR $= 6$ in some years.

However, the observed maximum of the September Perseids with ZHR $= 4.5 \pm 0.4$ is likely to comprise the combined activity level of both showers. In fact, the maximum activity level of the isolated September Perseids must be lower, as was derived from the fit and being only 1.5 times higher than that of the δ-Aurigids. However, the early onset of the δ-Aurigid activity gives an impression that September Perseid shower is stronger. To be precise, there is still some uncertainty in the definition of the September Perseid shower duration in terms of ZHR > 1. Excluding the 2001 data, the fit curve indicates a more extended activity period from $\lambda_\odot = 162°$

to $\lambda_\odot = 175°$ (September 4/5 to September 17/18), thus further systematic monitoring of the shower is still necessary. The activity period of the δ-Aurigids extends from $\lambda_\odot = 168°$ to $\lambda_\odot = 194°$ (September 10/11 to October 6/7) with a rather flat maximum centered at $\lambda_\odot \approx 181°$ (about September 24).

It seems difficult to speculate on the existence of several late maxima of the δ-Aurigids as noted in [6], but these small features could be easily smeared in the activity profiles covering a 5-year period due to low rates. Nevertheless, the time of maximum shifted severely between the graphs even from 5-year sets, as can be seen in Figures 1 and 2. Maxima obviously do appear when choosing only a few years. The Moon can play a selective role in single-year's curves, but is unlikely to affect significantly the peak time in a 5-year average.

The δ-Aurigid meteoroid stream is likely to be produced by an assembly of scattered orbits with slightly different perihelion lengths, in particular. Definitely, the activity of the δ-Aurigid meteor shower could hardly be traced after $\lambda_\odot \geq 200°$.

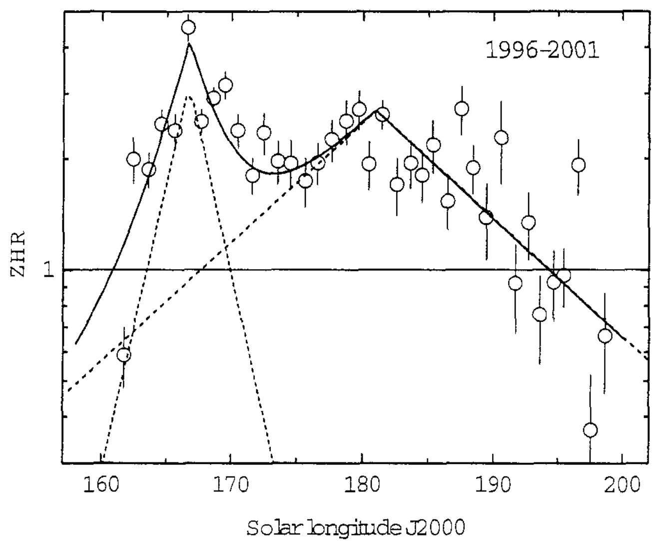


Figure 5 – Logarithmic plot of the 1996–2001 δ-Aurigid activity profile. The resultant curve of a two-exponential fit is shown by a solid line. The dashed curves represent single-exponential fits, generated using the values from Table 2.

The characteristics of the September Perseids and δ-Aurigids are—from the observer's point of view—very similar. Meteoroids of both showers encounter Earth with very close geocentric velocities, and the radiants overlap on the celestial sphere, so visual observers could hardly distinguish one shower from another. Also the general lack of bright meteors ($r \geq 2.5$) is common to the two. We find though, that $r \approx 2.5$ and $r \approx 2.9$ during the maxima of the September Perseids and δ-Aurigids respectively, and consider the variation significant. The second difference is more striking: The steep activity profile of the September Perseids, which is little wider than that of e.g. the Lyrids, versus the very long-lived δ-Aurigids, which may be comparable to showers like the Coma Berenicids. If we compare this finding with the node positions in Table 1, we see that the different widths of activity periods also show up in the orbits of multiple-station data.

Video observations offer better accuracy and could shed some more light on the fine-structure of the radiant, possibly containing two close radiants. According to personal communication with

Malcolm Currie at the *IMC* in Frombork [14], the radiants are well distinguishable by telescopic observations. Whether of not for visual observations the showers may be separable, will be a matter of future discussion. For now, we do not propose to alter the Working List of Visual Meteor Showers, unless accurate radiant or orbit searches reveal two clear stream classes.

The intuitive approach may suggest the common origin of the September Perseid and δ-Aurigid meteoroid streams, since their similarity in orbits points to that. Yet, the parent bodies (body?) of the streams are not determined for sure making the orbital analysis rather difficult.

References

[1] J. Rendtel, R. Arlt, A. McBeath, "Handbook for visual meteor observers", IMO 1995.

[2] W. F. Denning, "The September Perseids", *The Observatory* 5 (1882), pp. 262–265.

[3] M. Gavajdova, "On the population of very bright meteors in meteor streams", *Contrib. Astron. Obs. Skalnate Pleso* 24 (1994), pp. 101–110.

[4] C. Johannink, "Minor showers for visual observations", *Radiant* 22 (2000), pp. 47–48.

[5] J. Drummond, "A note on the δ-Aurigid meteor stream", *Icarus* 51 (1982), pp. 655–659.

[6] G. Kronk, "Meteor showers: a descriptive catalog", `http://comets.amsmeteors.org`.

[7] V. K. Abalkin, "Astronomical calendar. Constant part", Moscow, 1981.

[8] J. Rendtel, "Radiants and orbits of δ-Aurigids and September Perseids", *Proceedings of the IMC Smolenice 1992*, Banska Bystrica, 1993, pp. 67–73.

[9] T. Sarma, J. Jones, "Double station observations of 454 TV meteors. II. Orbits", *Bull. Astron. Inst. Czechosl.* 36 (1985), pp. 103–115.

[10] M. de Lignie, K. Jobse, "Meteor shower activity after the Perseid maximum", *WGN* 25 (1997), pp. 130–135.

[11] P. G. Welch, "A new search for streams in meteor data bases and its application", *Mon. Not. R. Astron. Soc.* 328 (2001), pp. 101–111.

[12] M. Ueda, T. Nakamura, M. Sugimoto, M. Tsutsumi, "Detection of three meteor streams by double-station TV observations in 1994", *WGN* 25 (1997), pp. 165–181.

[13] A. Dubietis, R. Arlt, "Annual activity of the Alpha Aurigid meteor shower as observed in 1988–2000", *WGN* 30 (2001), pp. 22–31.

[14] M. Currie, *personal communications*, September 2002.

Authors' address:

Audrius Dubietis, Baltupio 101-2, LT-2057 Vilnius, Lithuania,
e-mail `audrius.dubietis@ff.vu.lt`

Rainer Arlt, Friedenstr. 5, D-14109 Berlin, Germany, e-mail `rarlt@aip.de`

Activity of the Iota-Aurigids in 2001 and the Possible Orbit of the Meteoroid Stream

Huan Meng

The activity of the ι-Aurigids in 2001 was analyzed and combined with the previous work in 1998–2000. Based on 119 possible shower meteors, the average population index of the meteor shower in the four years was determined as $r = 1.88 \pm 0.12$. The maximum ZHR and the corresponding solar longitude were $\mathrm{ZHR_{max}} = 14.4 \pm 5.4$ and $\lambda_\odot = 233\overset{\circ}{.}637$. The second peak was confirmed to be true, and the maximum was $\mathrm{ZHR} = 8.2 \pm 2.8$. Potential shower meteors were also found in meteor the orbital database. Having these characteristics and parameters, the parent body, history and some other problems were discussed.

1. Introduction

The ι-Aurigids are a possible new meteor shower in mid-November. It was first discovered in 1998 [1], and then noticed in 1998–2000 [2]. Recently, de Lignie published a new paper [3] doubting the existence of it, because of the lack of possible shower meteors in the *DMS* meteor database, and the inconsistency of its flux with the Taurids.

In 2001, we had a cooperation with the North American Meteor Network (*NAMN*) for the ι-Aurigids [4]. More observations were obtained in the campaign. Furthermore, we also checked another meteor database to look for any possible shower meteors. The possible parent body was tried to search for in the orbital database of small bodies.

2. The activity in 2001

In Table 1, the entire visual observations from our cooperation with *NAMN* in 2001 were listed [4]. The T&A stands for the Taurids North and South, and the Alpha-Monocerotids; the Leonids and the ι-Aurigids were separated; and all other meteors were regarded as sporadics.

Table 1 – The data of entire observations in 2001.

Year	Date	Observer	T_{eff} (h)	Lm	nLEO	nIAU	nT&A	nSPO
2001	Nov 15/16	MULUM	1.25	+5.3	5	8	–	6
2001	Nov 16/17	MENHU	3.09	+5.1	7	8	10	56
2001	Nov 16/17	MULUM	5.33	+5.9	262	21	–	12
2001	Nov 16/17	SHUBR	4.50	+6.5	34	10	9	75
2001	Nov 16/17	HALCA	2.49	+6.0	16	0	2	26
2001	Nov 17/18	MENHU	2.33	+5.9	47	10	9	25
2001	Nov 17/18	HALCA	2.52	+6.1	1038	3	0	41

The population index and the ZHR profile with limited visual observations in 1998–2000 have already been determined in [2], but they were both preliminary. In this work, the accuracy of the parameters was improved by the observations in 2001.

All the observations listed in Table 1 were processed by the same means as in [2]. As the result, the population index from the regression-line method for the entire four years (1998–2001) was determined as $r = 1.88 \pm 0.12$. Such small error margin is due to the large number of meteors and the low r-value. As a comparison, the previous value was $r = 2.4 \pm 1.0$. But here, our aim is to determine an average population index for later calculation of the ZHRs instead of obtaining an r-profile or analyzing the detailed structure of the shower. The attempt to get an r-profile with such low flux and a lack of observations must lead to large errors and will be less significant. In addition, it is not true that the more years' data we use, the more accurate r and ZHR profile we obtain. So, in fact, the result from combining observations of four years will produce some error accounting for the different activity level of the shower in each of these years.

Plugging the new population index into the formulae for the ZHR, a new profile for 1998–2000 was obtained and is shown in Figure 1.

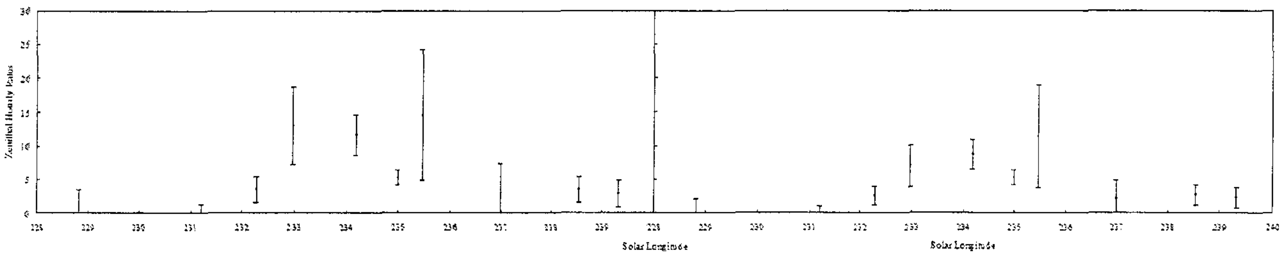


Figure 1 – ZHR profile of 1998–2000. As a comparison, the first graph is cited from [2] with the old population index, and the second with the new one.

While combining the data points at the same or similar solar longitudes, the following formula as derived in [5] was used.

$$\overline{\mathrm{ZHR}} = \left(1 + \sum_i n_{\mathrm{IAU},i}\right) \Bigg/ \sum_i \frac{T_{\mathrm{eff},i}}{C_i} \qquad (1)$$

Adding all the observations in 2001 and combining the data points as described above, a new graph (i.e. Table 2 and Figure 2) was obtained.

Table 2 – The numerical values of the ZHR profile from the observations.

Solar Long. (J2000.0)	Observing Periods	n_{IAU}	ZHR	Average lm
228.822	1	0	0(+2.1)	+4.5
231.205	1	0	0(+1.1)	+5.8
232.264	1	4	2.5 ± 1.4	+5.2
232.974	1	6	7.0 ± 3.1	+4.0
233.637	1	8	14.4 ± 5.4	+5.3
234.183	7	19	9.8 ± 2.7	+5.3
234.372	2	5	6.5 ± 3.7	+5.2
234.702	1	11	5.9 ± 1.9	+6.4
234.830	5	10	5.2 ± 2.0	+6.1
234.960	5	22	4.0 ± 1.0	+5.7
235.075	6	10	1.9 ± 0.7	+6.0
235.475	2	13	8.2 ± 2.8	+5.7
236.092	3	3	2.6 ± 1.9	+6.1
236.996	1	1	$2.0 + 2.9(-2.0)$	+4.9
238.539	1	4	2.6 ± 1.5	+5.4
239.305	1	3	2.3 ± 1.6	+5.6

Figure 2 indicates the structure of the ZHRs. A structure of two peaks is shown in the graph. The maximum is located at $\lambda_\odot = 233.^\circ 637$ with $\mathrm{ZHR}_{\max} = 14.4 \pm 5.4$. The peak was observed in Tunisia in 2001. This solar longitude was just out of our coverage in 1998–2000 [2], but the data points around it had suggested a possible peak, as the ones before were climbing up, and there was a depression afterwards. In addition, there was also a second peak at about $\lambda_\odot = 235.^\circ 475$. This peak has been observed twice. In [2], because of the large error range, it used to be regarded as the maximum. But in 2001, this peak was caught again, and confirmed to be true. The dip between the two peaks has been noticed before. Again, there were more data combined at that longitude in 2001.

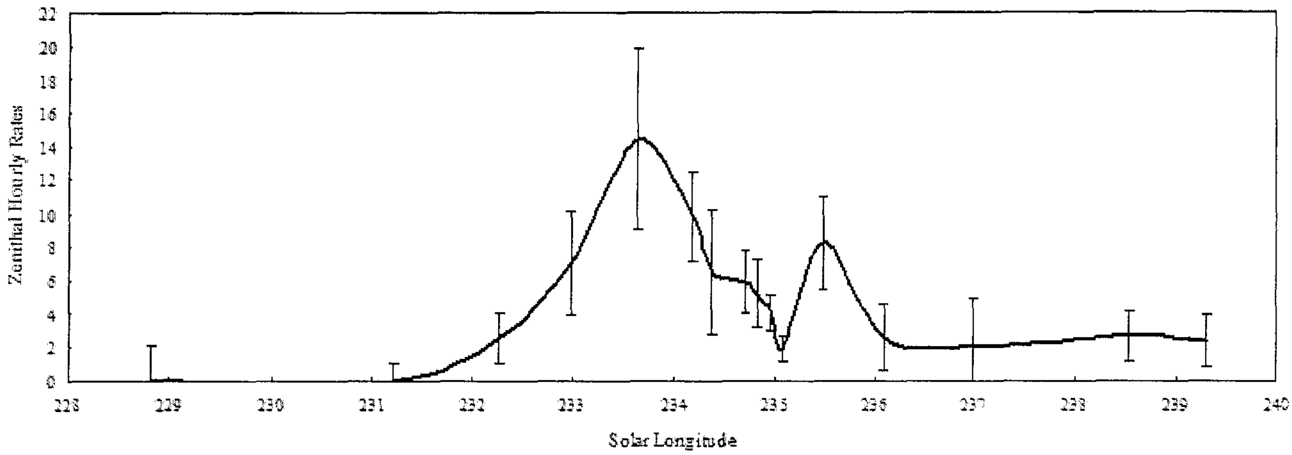


Figure 2 – Comprehensive ZHR profile of the ι-Aurigids in 1998–2001.

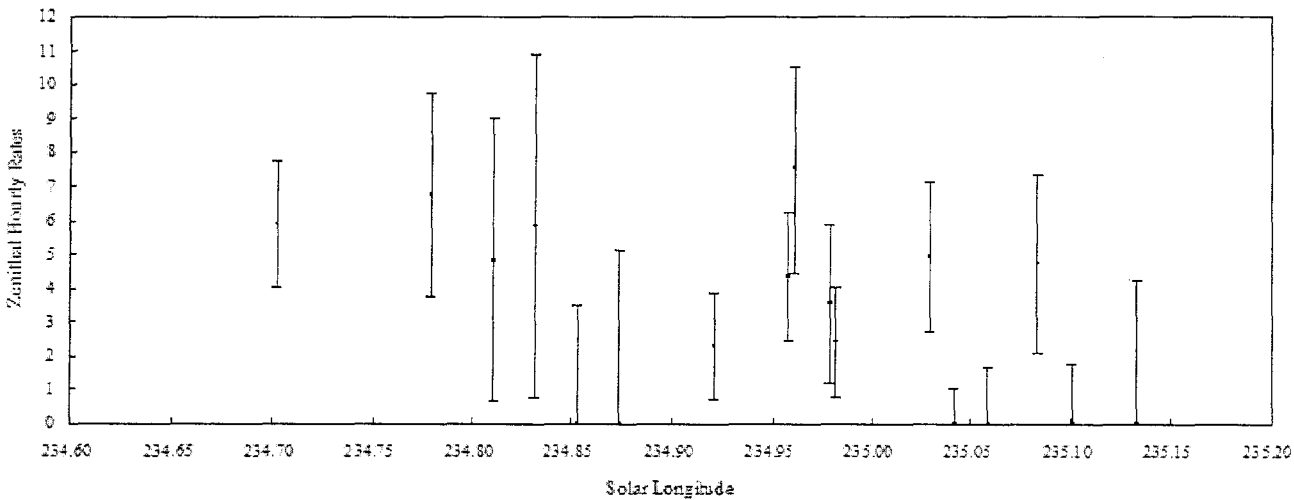


Figure 3 – Comprehensive ZHR profile of the dip near $\lambda_\odot = 235\overset{\circ}{.}0$ in 1998–2001, without combining any data points of similar solar longitudes.

3. The Orbits and the Possible Parent Body

If a meteor shower is physically true, the members of it must have similarity in their orbits. For the ι-Aurigids, we searched in the databases [6–14] to try to find out the heliocentric orbit of the meteoroid stream. Our evidence of judging possible shower meteors was twofold. The first one was the coordinates of the radiant, and the second one was the geocentric velocity. Both of these two values were cited from [2], i.e. $\alpha = 76° \pm 5°$, $\delta = +36° \pm 5°$; $V_g = 46$ km/s. But it should be clear that because of the lack of the angular speed of meteors in the records, the geocentric velocity could only be determined by adjusting with radiant set in the conditions like in [2]. The radiant set was obtained from the backward prolongations without considering the zenithal attraction and any speed. Such a new method was certainly able to get an approximate V_g-value of the entire shower, but at the same time, reduced the accuracy a lot. Furthermore, the software RADIANT 1.43 was used in the first paper [2], but this software could not distinguish the geocentric velocity (V_g) and the pre-atmosphere velocity (V_∞) [15]. Thus, the accuracy was reduced again. So in the new work, all the V_g-values in the range of [35 km/s, 55 km/s] were considered. Finally, quite a few possible shower meteors were found. But after extending the considered range of coordinates of the radiant, this number was increased. The meteors found suggested similarity among their orbits. As a result, 6 meteors were regarded to be likely to belong to the stream, listed in Table 3; and another 4 meteors also seemed to be, but had different parameters; they are listed in Table 4.

Table 3 – The orbital elements of 6 possible stream meteoroids of the ι-Aurigids.

No.	q (AU)	e	i (°)	ω (°)	Ω (°)	α (°)	δ (°)	V_g (km/s)
95532	0.159	0.980	8.4	314.1	235.3	73.5	26.2	39.44
95579	0.174	0.984	5.8	311.5	236.3	73.5	25.2	39.16
1995210	0.108	0.996	25.1	321.7	236.3	78.8	30.9	43.33
1998046	0.110	0.994	10.1	321.5	236.1	77.4	26.3	42.29
98328	0.064	0.980	15.3	332.9	235.2	82.6	27.2	42.11
MSSItW	0.121	0.954	9.3	322.9	235.9	78.9	26.6	38.32

Table 4 – The orbital elements of 4 meteoroids, which might also belong to the ι-Aurigids, but with one or several parameter(s) a bit far from others.

No.	q (AU)	e	i (°)	ω (°)	Ω (°)	α (°)	δ (°)	V_g (km/s)
MSSIim	0.118	0.912	35.7	327.8	235.2	86.1	36.7	36.31
MSSIj6	0.132	0.883	18.3	327.9	235.2	84.2	31.8	32.21
MSSItu	0.134	0.907	33.9	324.9	236.0	85.1	37.0	36.08
MSSI6A	0.050	0.967	24.6	338.6	233.4	85.9	29.1	39.67

Table 3 (and Table 4) indicate the characteristics of the meteoroid stream. The orbits of it belong to the type of Apollo asteroid orbits. Their average geocentric velocity was about 39 km/s. The difference between this value and the previous one (46 km/s) was still acceptable. But the differences in the inclination and the argument of perihelion were a bit large.

On the other hand, a possible connection with a comet or asteroid was found. In [2], C/2000 WM1 (LINEAR) was guessed to be the parent body. But, according to Table 3 and Table 4, its orbit is much too distant from the orbits of the stream. Also, Jenniskens & Lyytinen's paper [16] pointed out the improbability of C/2000 WM1 (LINEAR)'s producing a meteor shower on the Earth in a short period.

This time, we checked the Minor Planet Center Orbit Database (MPCORB) [17] carefully, and finally found that asteroid 2000 NL10 has the most similar orbit to the ι-Aurigid meteoroid stream.

In Table 6, even the D-Disc value of method $-B$ was still large, so is the difference between the geocentric velocities. These inconsistencies may be caused by the evolution of the orbit of the asteroid. If 2000 NL10 is really the parent of the ι-Aurigids, it might have been a comet in ancient times, and then became an asteroid because of lack of ice. On the other hand, the low population index suggests the old age of the stream, according to the same principle as for the Leonids [19]. It was also found that such low population index ($r = 1.88 \pm 0.12$) was rare. But this radical assumption is still too wide a conclusion. However, 2000 NL10 is the best candidate of the parent body, but not perfect enough. A comparison of their spectra would be difficult, but definitive.

Table 5 – The orbital elements of asteroid 2000 NL10.

a (AU)	q (AU)	e	i (°)	ω (°)	Ω (°)
0.9142963	0.1672669	0.8170541	32.50965	281.47781	237.54019

Table 6 – The theoretical shower parameters of asteroid 2000 NL10 calculated according to various methods by the program of [18]. Dates refer to 2000 and coordinates and solar longitudes refer to eq. J2000.0

Method	α	δ	V_g	V_h	$\lambda_\odot$	Date	D-Disc.
$-Q$	65.7	+50.8	30.58	37.94	237.5	Nov 19.6	0.288
$-B$	65.0	+48.0	33.16	39.89	237.5	Nov 19.6	0.273
$-W$	93.1	+41.0	29.54	28.73	237.5	Nov 19.6	0.645
$-A$	Method not applicable						
$-H$	41.8	+30.4	27.80	28.39	195.5	Oct 08.5	0.391
$-P$	54.1	+41.7	31.32	28.46	203.2	Oct 16.3	0.504
$Q+$	58.4	−19.0	27.73	38.77	57.5	May 18.2	0.480
$B+$	58.7	−16.1	29.79	40.46	57.5	May 18.2	0.468
$W+$	27.3	− 7.6	28.78	27.99	57.5	May 18.2	0.942
$A+$	27.3	− 7.6	28.78	27.99	335.2	Aug 28.2	1.367
$H+$	94.4	+16.2	26.79	27.87	124.8	Jul 27.5	0.522
$P+$	77.2	+1.5	30.91	27.85	114.0	Jul 16.2	0.703

4. Discussion

All the visual observations used in this paper were made before de Lignie's paper [3]. So, the existence of the shower hadn't been doubted. Because of the wide range of sources of these visual observations, we supposed them to be objective. However, the evidence of the doubt in [3] was from photographic and video observations, which were more reliable. Nevertheless, we found the comparison in [3] was biased towards the Taurids. The Taurids always last a long period of activity [20] and have one or several flat peaks, but according to [2] and Figure 2, the peak(s) of the ι-Aurigids was much sharper. So the integral of the height of their ZHR-graphs must bring in "unfairness", since the maximum flux of Taurids would remain but that of the ι-Aurigids would be reduced a lot due to the long activity depression. In that database, however, the few meteors with accurate coordinates of the radiant are in any way an inconsistency. On the other hand, as shown in Section 3, the orbits of possible stream members and that of 2000 NL10 were all found to be similar, but still not good enough to conclude the link confidently. More observations will be needed in the future.

5. Conclusion

All the new visual observations in 2001 were combined, and we added them to previous data. The average population index in the entire four years was obtained by the regression-line method. The result was $r = 1.88 \pm 0.12$. A double peak structure was found. The main peak was at $\lambda_\odot = 233\overset{\circ}{.}637$ with ZHR $= 14.4 \pm 5.4$. The minor peak was located at $\lambda_\odot = 235\overset{\circ}{.}475$ with ZHR $= 8.2 \pm 2.8$. The characteristics of the orbit of the meteoroid stream were found from meteoroid orbital databases. The distance of perihelion, eccentricity, inclination, the argument of perihelion and the longitude of the ascending node were 0.12 AU, 0.96, 10°, 320° and °236, respectively. The parent body status of Comet 2000 WM1 in [2] was rejected. Instead, asteroid 2000 NL10 might be the parent body.

Acknowledgments

I would like to thank Dr. Jin Zhu from the National Astronomical Observatories of the Chinese Academic Society (*NAOC*) for his reviewing on this paper. Am also very grateful to Marc de Lignie from the Dutch Meteor Society (*DMS*) and Mark Davis from the Northern American Meteor Network (*NAMN*) for their discussion with me and other help. And I express my thanks to the National Natural Science Foundation of China (Grant No. 10073012) for the support of my observations.

References

[1] D. Koschny, J. Zender, "Possible New Radiant in Auriga on November 17, 1998", *WGN* 27:1/2, 1999, pp. 51–52.

[2] H. Meng, "The Determination and Analysis of New Iota-Aurigids Meteor Shower Visual Plotting Data in 1998, 1999 and 2000", *WGN* 30:1/2, 2002, pp. 32–38.

[3] Marc de Lignie, "Existence of Iota-Aurigids Doubtful", *WGN* 30:5, 2002 (this issue), pp. 129–130.

[4] H. Meng, "Special Call for Observations: ι-Aurigids", *MeteorObs Mailing List*, presented by Mark Davis, October 2001.

[5] R. Arlt, "The Analysis of a Weak Meteor Shower: The June Bootids in 2000", *WGN* 28:4, 2000, pp. 98–108.

[6] M. de Lignie, H. Betlem, "Simultane Videometeoren van de Leonidenaktie 1995", *Radiant* 19, 1997, pp. 68–75.

[7] P. Jenniskens, H. Betlem, M. de Lignie, M. Langbroek, "The Detection of A Dust Trail in the Orbit of An Earth-threatening Long-period Comet", *Astrophys. J.* 479, 1997, pp. 441–447.

[8] H. Betlem, et. al, "DMS Photographic Meteor Database", Leiden, 1995.

[9] B. Lindblad, in: Z. Ceplecha, P. Pecina (eds.), Interplanetary Matter, Proc. 10th European Reg. Meeting of the IAU, vol. 2, 1987, Prague, pp. 201–204.

[10] B. Lindblad, in: A.C. Levasseur-Regourd (ed.), 1991.

[11] H. Hasegawa, "Origin and Evolution of Interplanetary Dust", Kluwer Adad. Publishers, pp. 311–314.

[12] Y. Shigeno, H. Shioi, "Double-Station TV Meteor Observations", *WGN* 24:1, 1996, pp. 37–42.

[13] Y. Shigeno, H. Shioi, S. Tanaka, "Double-Station TV Meteor Observations (Part II)", *WGN* 24:5, 1996, pp. 161–170.

[14] Y. Shigeno, H. Shioi, S. Tanaka, "Double-Station TV Meteor Observations in 1996", *WGN* 25:4, 1997, pp. 161–165.

[15] R. Arlt, "The Software RADIANT", *WGN* 20:1/2, 1992, pp. 62–69.

[16] P. Jenniskens, E. Lyytinen, "No Outburst from Comet C/2000 WM1 (LINEAR)", *WGN* 29:1/2, 2001, pp. 35–37.

[17] Minor Planet Center, the Minor Planet Center Orbit Database (MPCORB), `ftp://cfa-ftp.harvard.edu/pub/MPCORB/`.

[18] L. Neslusan, J. Svoren, V. Porubcan, "A Computer Program for Calculation of a Theoretical Meteor-Stream Radiant", *Astron. Astrophys.* 331, 1998, pp. 411–413.

[19] R. Arlt, P. Brown, "Bulletin 14 of the International Leonid Watch: Visual Results and Modelling of the 1998 Leonids", *WGN* 27:6, pp. 267–285.

[20] J. Rendtel, R. Arlt, A. McBeath, "IMO Handbook for Visual Meteor Observers", IMO, Potsdam, 1995.

Author's address:

Huan Meng, Wangjing Part, Beijing No. 80 Middle School, Chaoyang District, Beijing 100015, China, e-mail `meteorobs_menhu@hotmail.com`

SPA Meteor Section Results: July–August 2001

Alastair McBeath

Abstract: Details from information sent to the *SPA Meteor Section* from July and August, 2001, are presented. July 6^d5^h–6^h UT ($\lambda_\odot = 104.^\circ19$–$104.^\circ23$) brought an unusual, short-lived radio meteor burst for Japan. Oddly this was not recorded elsewhere, although the suggested daytime radiant ($\alpha = 92°$, $\delta = +25°$) was observable from most of our other radio observers' locations. Moonlight affected both the late July Aquarid-Capricornid showers and the August Perseid maximum, but some visual results were secured on these even so. Two possible Perseid maxima were detected by radio on August 12, at roughly $10^h \pm 2$ h UT ($\lambda_\odot = 139.^\circ74 \pm 0.^\circ08$) and $19^h \pm 1$ h UT ($\lambda_\odot = 140.^\circ1 \pm 0.^\circ04$), the latter detected by more systems. Sporadic-E created further problems in both months for radio observers, along with other interference.

1. Introduction

Radio problems because of Sporadic-E (Es) propagation seem to have been a permanent feature of these reports during the main May to August season in recent years, and despite hopes that things might improve in this regard in 2001, these were not fulfilled. Indeed, the difficulties were compounded by thunderstorms especially for our European contributors. Visual observers had to contend with strong moonlight for the major shower maxima in July and August, not assisted at times by some indifferent weather! Table 1 gives the observing totals.

Most of the radio results were provided by Chris Steyaert in *Radio Meteor Observation Bulletins* (*RMOBs*) 96–98, July to September, 2001 respectively, except those from Dirk Artoos and Bev Ewen-Smith. The full list of radio observers was:

> Enric Fraile Algeciras (Spain), Dirk Artoos (Belgium), Mike Boschat (Canada), Maurice de Meyere (Belgium), Bev Ewen-Smith (Portugal), Ghent University (Belgium), Stan Nelson (New Mexico, USA), Hiroshi Ogawa (Japan), Sadao Okamoto (Japan), Ton Schoenmaker (Netherlands), Dave Swan (England), Kiss Szabolcs (Hungary), Istvan Tepliczky (Hungary), Pierre Terrier (France), Ouyang TianJing (China), Garfield Tsao (Taiwan), Bruce Young (Queensland, Australia), Ilkka Yrjölä (Finland).

Standard analyses and correlations were carried out on these raw data as described in (McBeath 2001), amended by the removal of that data which did not contain any comments on Es or other interference problems. This omitted data is not recorded in the totals in Table 1, but amounted to some 1450 h in July, and around 2400 h in August. Figure 1 shows a representative graph of one of the more complete July-August observing records.

The bulk of the video data came from the German *Arbeitskreis Meteore* (*AKM*) group, which, along with their visual data, were chiefly extracted from their journal *Meteoros* 4 : 8 and 4 : 9 (2001), plus a small amount of belated August visual data in 5 : 3 (2002), all of which were sent in by Ina Rendtel. Steve Evans in England (whose data are summarised in the *AKM* reports) provided additional details, including identifications for the meteors he detected. These included 101 July-August sporadic, 10 α-Capricornid and 64 Perseid trails. The other video observers (all in Germany, except where noted) were:

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

The visual observers included:

> *American Meteor Society* (*AMS*) members, in the USA if not noted (extracted from summaries in the *AMS* journal *Meteor Trails* 13 (December 2001), submitted by Bob Lunsford): George Gliba, Robin Gray, Robert Hays, Carl Johannink (Netherlands), Thomas Lazuka, Pierre Martin (Ontario, Canada), Paul Martsching, Norman McLeod, Michael Morrow, Bill Sharp, Chris Stephan, David Swann, John Varn, Kim Youmans; *AKM* members (in Germany unless stated): Rainer Arlt, Lukas Bolz, Frank Enzlein, Darja Golikowa, Mathias Growe, Ralf Kuschnik, Hartwig Lüthen, Sirko Molau, Sven Näther, Jürgen

Rendtel, Ulrich Sperberg, Heinrich Wiechell (Greece), Roland Winkler, Oliver Wusk; Jay Brausch (North Dakota, USA), Dave Campbell (England), Chris Chambers (Wales), Bev Ewen-Smith (Portugal), Shelagh Godwin (England), Phil Heppenstall (England), Zoltan Hevesi (Hungary), Bob Lunsford (California, USA), Tony Markham (England), Alastair McBeath (England), George Spalding (England).

Table 1 – Visual, radio and video hours' totals, plus visual meteor numbers and video trail counts recorded in each month, including a partial breakdown of visual meteor types.

Month	Visual	CAP	SDA	NDA	KCG	PER	Meteors	Radio	Video	Trails
July	$126^{h}.7$	112	176	71	-	184	1021	5648^{h}	$497^{h}.5$	4709
August	$262^{h}.75$	34	28	59	87	2104	4144	$6419^{h}.5$	$924^{h}.8$	6772

2. July

When examining the evidence for a possible meteor "swarm" return during the daytime Taurid Complex streams in 1999 (McBeath 2000), I commented on the importance of recording future observations of unusual noctilucent cloud (NLC) displays, after several events in 1999 were found to penetrate further south than northern hemisphere NLC observations had been reported previously (including two seen between $\phi = 39^{\circ}\!.58$–$41^{\circ}\!.75$ N). This is essential to establish whether the displays in 1999 were unique, and thus possibly allied to the Taurid Complex "swarm" return year, if so, perhaps being useful diagnostic evidence for other such returns, or if they were a sign that NLC occurrence generally is changing. Using the international NLC website listing maintained by Tom McEwan for 2001 (personal communication dated 15 October, 2001), there is one weak NLC display of especial interest in this regard, on 2001 July 2-3, seen from Utah, USA, at $\phi = 41^{\circ}\!.6$ N. The display was also seen further north in the USA, in North Dakota, and weak NLC was observed on the same night from several European sites. No Taurid Complex "swarm" return was expected in 2001 June–July, so this may be an indication of an altered NLC occurrence instead. More observations are needed in the coming years to enlighten us further.

Continuing with this possible Taurid Complex theme, in *RMOB* 96 (July, 2001), both Hiroshi Ogawa and Sadao Okamoto reported a short-lived radio meteor outburst between 5^{h}–6^{h} UT on July 6 ($\lambda_{\odot} = 104^{\circ}\!.19$–$104^{\circ}\!.23$). This was visible in both their all-echo counts and their longer-duration echo numbers (D > 20 s and > 5 s respectively). Sadao further refined the activity he detected to the interval $5^{h}00^{m}$–$5^{h}30^{m}$ UT ($\lambda_{\odot} = 104^{\circ}\!.19$–$104^{\circ}\!.21$), and noted that Brian Fuller in Australia had indicated strong activity from a radiant at $\alpha = 92^{\circ}$, $\delta = +25^{\circ}$. He went on to suggest this might have been due to late β-Taurid activity. Such a radiant should have been visible to our radio observers in Europe and Australia, yet none of the available data from those active at the appropriate time showed anything unusual at all. In fact, the radio observers' locations make it extremely unlikely that any radiant visible from Japan around 5^{h}–6^{h} UT could have passed unobserved by several other systems operating simultaneously. This is very curious, though it is not the first time such a short-lived outburst has been reported by only one or a few radio operators. Bev Ewen-Smith detected an outburst on 1999 July 11, $13^{h}00^{m}$–$13^{h}45^{m}$ UT that nobody else did, for instance (McBeath 2000). In addition, a minor radio meteor peak has been found around $\lambda_{\odot} \sim 104^{\circ}$ before. In 1999, July 6-7 produced a clear small maximum in all the available datasets (*ibid.*), and several slight radio maxima have been recorded between $\lambda_{\odot} \sim 103^{\circ}$–$109^{\circ}$ in recent years (McBeath 2001). Although this extended $\lambda_{\odot} = 107^{\circ}$ period was reasonably well-confirmed again in 2001, there was no consensus on a specific main peak. The Japanese 2001 July 6 radio event must therefore remain something of a mystery.

Of the other minor early July radio maxima found previously, all were recovered at least moderately well, as far as Es allowed at times. The $\lambda_{\odot} = 115^{\circ}$ (July 17) one was found weakly in almost 60% of the available datasets, providing the first real confirmation of this since 1998, while the $\lambda_{\odot} = 116°$ (July 18) peak was found in nearly 70% of the usable reports, adding a third year of definite observations (the earlier ones were 1996 and 1999). As in 1999, there was a suggestion that this latter peak was somewhat more noticeable in the longer-duration echoes.

Most visual observations concentrated on the period from roughly mid-July onwards, and picked up increasing numbers of Aquarid-Capricornid shower meteors, along with the usual smattering of early Perseids. Too few Moon-free reports were available from late month to confirm the two expected stronger maxima of the Southern δ-Aquarids and the α-Capricornids, but the radio results suggested peaks at $\lambda_{\odot} = 123°$ (July 26; found in 60% of the datasets), 125° (July 28; 75%) and 128° (July 31; 55%), within the $\lambda_{\odot} = 122°–128°$ interval. That around July 28 was notably the strongest, coincident with the predicted Southern δ-Aquarid peak, as Figure 1 demonstrates.

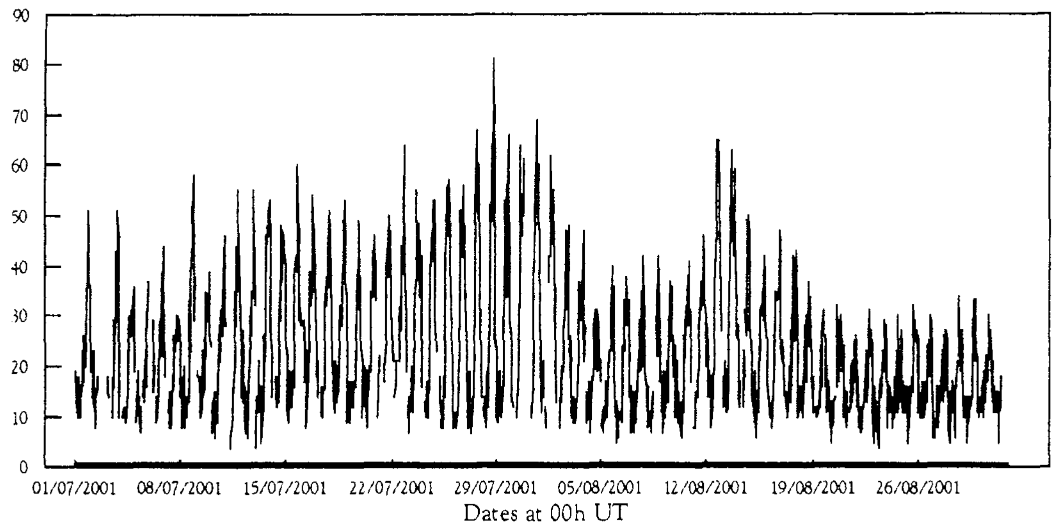


Figure 1 – Raw hourly radio meteor echo counts from 2001 July and August in data collected by Hiroshi Ogawa. Hiroshi's system was in continuous operation when conditions allowed, except between 13^{h}–4^{h} UT on July 2-3. The remaining gaps were due to almost daily Es interference during July, which thankfully lessened considerably in August (one of the few people to be so lucky!). The strength of the late July to early August Aquarid-Capricornid "bulge" is interesting, although this has been noted with some radio systems before. The Perseids here appear rather less strongly than the Southern δ-Aquarids, for instance.

3. August

Moonlight conditions continued to be unfavorable from late July through until after the Perseid maximum, and indeed there was scarcely any visual watching achieved before August 10 in our data. The normal early August minor radio peaks were all recovered though, including the $\lambda_{\odot} = 135°$ peak (August 7) which has not been found as clearly since 1996.

The Perseid maxima were due around August $12^{d}14^{h}$ and 17^{h} UT, most likely only at the latter time, but observers struggled with the last quarter Moon, and there was a large amount of scatter in the computed ZHRs as a result, giving unclear information as to when any peaks might have fallen in our data, and even in the *IMO*'s—see (Gyssens & Krumov 2001). On both August 11-12 and $12 - 13$ mean ZHRs in SPAMS data were around 75 ± 10, but neither predicted maximum time was covered by our watchers. The IMO preliminary report suggested two possible maxima may have happened on August 12 at 14^{h} (ZHR = 130; $\lambda_{\odot} = 139\overset{\circ}{.}9$) and 20^{h} UT (ZHR = 105), though a broad near-plateau of ZHRs $\sim$ 85 probably surrounded this from about August 12, 20^{h} UT to the early UT hours of August 13. Interestingly, the radio results also failed to show a clear, single peak, with no real consensus between the observers as to whether August 12 or 13 produced the strongest echo signature.

Careful examination of the radio data, using only those results where Es or other interference comments were given (where this happened), for several days across the expected Perseid peak, indicated two possible Perseid maxima on August 12, at roughly $10^h \pm 2$ h UT ($\lambda_\odot = 139\overset{\circ}{.}74 \pm 0\overset{\circ}{.}08$) and $19^h \pm 1$ h UT ($\lambda_\odot = 140\overset{\circ}{.}1 \pm 0\overset{\circ}{.}04$). The first of these was found in 60% of the data, the second in 80%. The better-detected, second, radio peak thus coincided closer to the weaker visual one in *IMO* data! It also fits with the expected "traditional" peak's timing too, around $\lambda_\odot = 140\overset{\circ}{.}0$–$140\overset{\circ}{.}1$. Although not especially numerous this year given the poor observing circumstances, Table 2 shows the magnitude distributions for the Perseids and July–August sporadics. Too few trained meteors were recorded to give details on those, but 33% of Perseids left trains, compared with 4% of sporadics in August.

Table 2 – Global magnitude distributions for the Perseids and sporadics seen during July and August, 2001 in good sky conditions (cloud cover < 20%, lm = +5.5 or better), including mean LM and corrected mean magnitudes.

Shower	-3^-	-2	-1	0	+1	+2	+3	+4	+5+	Tot	LM	$\overline{m}_{6.5}$
PER	3	4	5	19	26	37	32	16	5	147	+6.07	+2.22
SPO	1	5	7	14	27	49	88	76	45	311	+6.17	+3.22

More visual watching was reported during the second half of August, with the typical declining numbers of mostly minor shower meteors, and falling Perseid rates. None of the expected minor shower maxima were detected at all clearly, although the radio observers recorded those minor radio peaks previously found. These included the $\lambda_\odot = 148°$–$149°$ one (August 21-22), which while very weak, was found rather more convincingly than in any year since 1998. In the $\lambda_\odot = 155°$ extended period ($\lambda_\odot \sim 150°$–$156°$, August 23–29), two possible small maxima were found in 80% of the datasets, at $\lambda_\odot = 150°$ and $152°$. α-Aurigid ZHRs were around 8–10 on August 31 and September 1, coincident with the $\lambda_\odot = 158°$–$159°$ radio peak, but few meteors from this source were seen overall, because of the Moon.

Acknowledgments

My thanks as ever are sent to the observers and correspondents who have made this report practical. It was a frustrating spell at times for all involved, but not without its interesting facets. Good luck and clear skies for your future watching!

References

Gyssens M., Krumov V., "International Meteor Organization Meteor Shower Circular, 2001 Perseids", *IMO-news e-mailing list*, 15 August 2001.

McBeath A., "Daytime Taurid Complex Stream Activities, May–July 1999: A Provisional Report", *WGN* 28:1 (2000), pp. 21–29.

McBeath A., "The Forward Scatter Meteor Year: 2001 Update", *WGN* 29:3 (2001), pp. 85–92.

Author's address:

Alastair McBeath, 12a Prior's Walk, Morpeth, Northumberland NE61 2RF, England, UK, e-mail mcbal.gwyvre@virgin.net

The Accuracy of Meteor Plotting—an Example and Some Conclusions

Andreas Buchmann

1. Introduction

The goal of this paper is to have a closer look at the mechanisms that influence the accuracy of meteor plotting. A broader discussion on this topic could help to develop better methods. It's clear that I'm writing first of all out of my own experience.

2. Sample

Data from one Perseid observing session were used to test the consistency of the meteor plottings between three observers (Rainer Arlt = `ARLRA`, Darja Golikowa = `GOLDA` and the author = `BUCAN`). `ARLRA` is a long-term, but not frequent observer; `BUCAN` has been observing for just 2 years, but very frequently; `GOLDA` is a rather inexperienced observer.

The observations were made in Ketzür (Germany, *IMO* code 11181) in the night of August 15/16, 2002, between $20^{\rm h}45^{\rm m}$ and $22^{\rm h}00^{\rm m}$ UT under good conditions (no clouds, limiting magnitude approximately +6.0). `ARLRA` and `GOLDA` chose a center of field of view (CFV) in the west of Cygnus (about right ascension 292°, declination +40°), `BUCAN` near the star δ Cephei (337°, +58°). Both CFV would allow an easy separation of Perseids (PER), κ-Cygnids (KCG) and southern streams (CAP, NDA, SDA, NIA, SIA), but not between the different southern radiants, which were not high above the southern horizon and would therefore not produce high rates anyway. `ARLRA` and `GOLDA` plotted all meteors, `BUCAN` counted only obvious Perseid and plotted the rest. Total rates were just around 20 meteors per hour, so that experienced observers would manage plotting all the meteors without too much distress.

3. Results and discussion

Table 1 shows some measured values about the plottings that `BUCAN` had in common with `ARLRA` and `GOLDA`. Out of 27 meteors plotted by `BUCAN`, just 10 were also plotted by `ARLRA`, 2 also by `GOLDA` (no meteors were seen by `GOLDA` and `BUCAN` only). While `GOLDA` had significantly smaller rates, `ARLRA` and `BUCAN` had similar rates. Sometimes it was a bit difficult to identify meteors seen by more than one observer, if there were more than one meteor one shortly after another in similar regions of the sky. In one unsure case, a meteor was excluded.

The estimated magnitudes don't differ widely. The median of the magnitudes of the meteors commonly seen by `ARLRA` and `BUCAN` (+3.17) does not differ significantly from the median of all meteors seen by `BUCAN` (+3.25). This is a bit of a surprise, because bright meteors are seen in a larger radius, so we thought that brighter meteors should rather have been seen by more than one observer than weak ones. This could be the case because bright meteors at the periphery are very rare, so they didn't influence the median.

The angular speeds are less similar: `BUCAN`'s estimates are consistently lower than `ARLRA`'s estimates. Not visible in Table 1, `BUCAN` had also mostly shorter trails than `ARLRA`, which also partly declares the differences in angular velocities. The differences in velocity and length are not a big problem, because they are not so large that shower association will be wrong very often.

Disappointingly high were the differences in direction, though! The angle ε between the directions of the plottings often reached as much as 30°, most severely at the periphery of the field of view. Such deviations will affect shower association. Less bad are parallel shifts d, which were astonishingly big as well. Figure 1 shows as an example the different plottings of three meteors by three respectively two observers.

4. Discussion of the plottings in Figure 1

Meteor 1: This meteor was near the CFV of all three observers. The directions are quite consistent, there is practically no parallel shift. This example reminds us, that observers orient mainly by the bright stars: The trails parallel almost the heading of the Cygnus: It is not quite sure if the trails were really so near to the center of the Cygnus; consistency alone does not proof the objectivity of the plottings.

BUCAN's trail is shorter, the estimation of the angular speed smaller than the ones of his companions, a personal deviation observed in many examples. This is worse because of the velocities than because of the lengths.

Meteor 2: Should this be two plottings of the same meteor? Yes, unfortunately. There is a huge parallel shift and a very big deviation between the directions observed by ARLRA and BUCAN. We suppose that the direction of BUCAN's plotting has been biased by two different effects: At the periphery of the field of view (and the meteor was very far from Cepheus!) directions are optically distorted. Moving his head in the direction of the meteor, the constellations had changed their forms, while the trail of the meteor in memory stayed the same.

Unsure in the direction of the meteor, BUCAN unconsciously oriented by the left wing of Aquila, while ARLRA placed the meteor between fainter stars of Cygnus and Delphinus. Let us guess that ARLRA's plotting is more accurate (the meteor was also nearer to his CFV).

Meteor 3: There is also a huge deviation between positions and directions of that meteor. At first glance it could seem that GOLDA and BUCAN agree at least on the direction of the meteor, while ARLRA has seen a wrong direction. The big parallel shift between GOLDA's and BUCAN's plot does not really strengthen this thesis.

Let us figure out a more plausible explanation: The plottings mostly can not be remembered in a pictorial code, because pictures mostly do not last in our memories for longer than half a second or a second. In that short interval, we have to transform the information into a more stable form to keep it long enough to open our map, put on our red torch and track the meteor on the map. Such a code could look (for the example of BUCAN and meteor 3) like "parallel to the upper two stars of the Pegasus rectangle from left to right just above the triangle at the upper right a bit more left". In such a manner the meteors have to be caught between some stars that are in a model in our heads. For GOLDA, the stable stored code of the fading picture seen could have been "from top left in the direction of the Cygnus' neck to ε Cygni, ending in the triangle of faint stars behind the elbow of the left wing".

ARLRA oriented by very faint stars, with starting point at the lower end of Lacerta, end point at the highest star of the quadrangle around μ Cygni. This is the second hint on the supposition that ARLRA has a very fine-grained model of the sky in his head. This fine model enables him to remember positions in the sky very accurately before the after-image of the meteor has faded (note that meteors with persistent trains are plotted much more accurate than those without, because observers have more time to read out the information about the position). Rainer told me, that he often works with fractions of the distance between brighter stars, for example "start point is about on the line μ Pegasi–α Pegasi in 3/10 of the distance between the two stars from μ Pegasi"

5. General discussion

The human eye is biased in several ways: The big parallel shifts of up to 25° (7° in the median) can be explained by the observer's head being turned reacting on the meteor. In consequence, observers do not know exactly where to fix the image of the meteor in the background of the stars seen only afterwards. This bias can go in both directions, because we can over-compensate the turning angle of the head. Unfortunately, we are conditioned to turn our heads very fast after rapid events at the periphery of our fields of view.

Table 1 – The 10 meteors plotted by BUCAN and ARLRA or GOLDA; index 1 refers to ARLRA, 2 to BUCAN, 3 to GOLDA; times in UT; m are magnitudes; ω are angular velocities; "length ratio" is (length of the longer trail: length of the shorter trail); ε is the angle between plottings by ARLRA or GOLDA with respect to the plotting of BUCAN; d is the distance in degrees between the middle of the trails plotted by ARLRA or GOLDA to the plotting of BUCAN; (n) are the numbers of the examples in Figure 1.

Time	m_1	m_2	m_3	ω_1	ω_2	ω_3	Length ratio		ε		d		(n)
21:01	4	2.5	2	25	9	17	1.8	2.2	5	10	2.2	4.0	(1)
21:21	3.5	3		10	5		1.9		0		3.2		
21:22	4.5	4	3	22	12	22	1	1	30	12	17.6	27.7	(3)
21:33	3	3		8	7		1.1		29		24.1		(2)
21:49	4.5	5		9	7		1.6		27		4.3		
21:55	−2	−2		6	3		2.3		0		25.9		
21:58	2	2		18	10		1.0		10		6.8		
22:14	3	4		7	7		1.2		31		8.6		
22:55	4	3		7	5		1.1		28		4.0		
22:57	3.5	4		8	4		1.2		25		8.6		
median of differences		0.55			6.5		1.2		18		7.9		

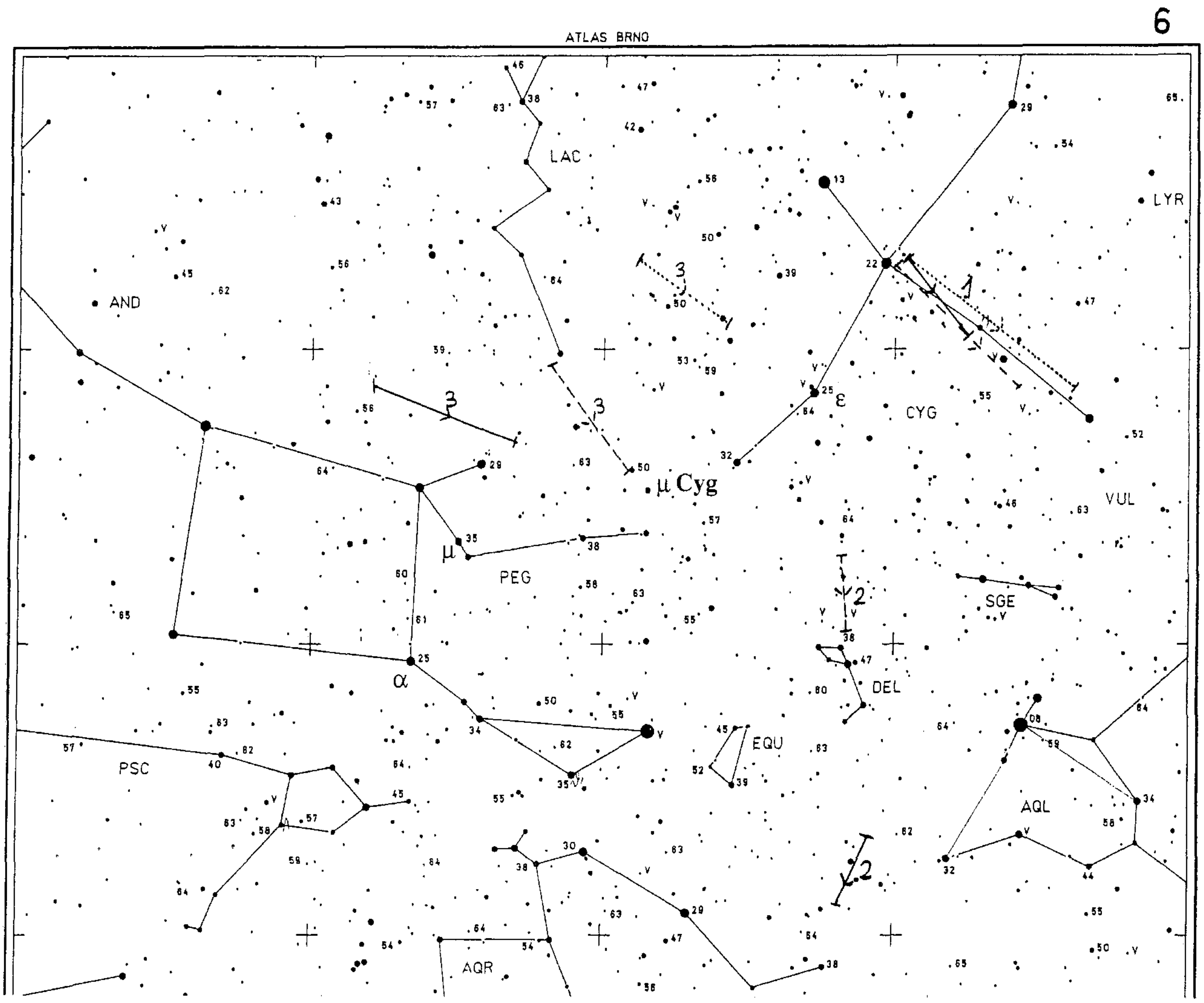


Figure 1 – Plottings of three commonly seen meteors by ARLRA (dashed), GOLDA (dotted) and BUCAN (solid line) later transferred to this Atlas Brno Chart 6. This three meteors are also included in Table 1 (numbers in the last column).

The accuracy of an observer's plottings depends critically on his detail knowledge of the starry sky. It is like a fine or less fine grid over the sky, and the starting and end points of the meteors are located in the fields of this grid. The problem is not accurate plotting, but accurate *seeing* or "reading out" of the meteors with respect to the constellations. This especially is the problem with occasional sightings of fireballs by lay-people: If they give positions with respect to the constellations at all, it is very rough, like "it moved from Polaris to Jupiter".

Observations are greatly influenced by expectations and other psychological biases: In unsure cases, your mind takes the first cue available to produce a place or direction of a meteor seen: Meteors are very often seen radially from the center of the field of view to the periphery. They seem to radiate from evident or well-known points in the sky (for example the Pleiades). This effect could cause practically any radiant you wish, and other observers read about your fantastic new radiant and consequently see also "quite a lot of meteors coming from". This is not a matter of inventing data, but of "top-down effects" in psychology:

"Top-down effects" are all processes that rely on information that is not contained in the objects we see, namely on expectations, personal goals, and earlier seeing experiences. The mean thing about such information is that we mostly do not have access to it: it is unconscious. And of course not objective. If you see out of the corner of your eye something like a snake in a tropical country, you will not have the time to check if it's a poisonous snake or a more harmless one, and will consequently base your actions upon a presupposition and run away.

There are a lot of different top-down effects, one example is saliency: if you see a fireball in the sky and hear a grumbling sound at the same time, you will think that the sounds stems from the bright object, although it would rather be a thunder, because a sound of a fireball would come only afterwards. Saliency is also one cause for racism: if you hear a cry in a crowd, turn around and see a dark-skinned man who is one or two heads bigger than the Europeans around, you could think that he is the cause for the cry, although this is not so exceedingly probable. Top-down effects are especially prominent, if you have little time for a decision, or you have to base a decision on very little information (we are obliged to make decisions in situations where we have not enough data to do it rationally—that is functional, but not always right).

An observer will often see movements in the sky, without having clearly seen a bright point moving, so he has to decide, whether he marks a meteor or not. This is an example for a conscious decision, that depends also on expectations (nearly over the horizon, you would less think of a meteor than high up in the sky) and personal experience.

At the periphery of your field of view, time resolution is very fine, the spatial resolution very bad. Especially bright meteors are detected in a huge field almost over the whole sky, but directions and exact positions are extremely difficult to fix, and sometimes it is even tricky to see the difference between a meteor and a blinking airplane, because the blinking can be taken for a fast movement. The advantage of planes is that they will normally keep on blinking, but the attention of the observer has by then been absorbed for a while, and probably missed meteors.

The image is also optically distorted in the periphery of your field of view. You will not notice this most of the time, because your mind constructs a stable model of the world that is updated every time your center of field of view passes an object.

The simplest issue is the estimation of a meteor's brightness, as long as it is in the range of the brightness of the stars. Magnitudes are a measure adapted to the psychophysical properties of human perception.

6. Some hints and simple rules of thumb for observers

- Observe preferably if at least one radiant is higher than 20° above the horizon.
- Choose a center of field of view (CFV) at 50° to 70° above the horizon.
- Choose your CFV in 20°–40° distance of the radiants. Make sure that not more than one radiant lies on a line through your CFV. Otherwise it will be difficult or impossible to separate the streams.
- Each observation needs a limiting magnitude (lm) measured by each observer for himself! Limiting magnitudes are measured by counting at least three star fields (see the Handbook by Rendtel et al. 1995) and take the average of the values given by the respective columns of the table (p. 59 of the cited Handbook or more accurate in WGN 27:1, pp. 8–10).
- Keep the direction of your head fixed to your CFV, *not* the direction of your eyes (they should wander freely around your CFV).
- When a meteor appears, first concentrate on starting and end point, then estimate the speed, then the brightness. If you have this information in your memory, start plotting.
- Angular velocities are measured as follows: imagine how far that meteor would have moved in one second, then measure this distance with your hand (you may calibrate this measure by the distance of two bright stars, which you can look up in a star atlas).
- Give effective observing times (T_{eff}) shortened by the time you needed for the plottings (and for breaks). You can measure your plotting time per meteor once or twice a year and then use that constant to calculate the T_{eff} of your actual observation.
- Take your time for plotting. If there is another meteor by the time you are plotting, do not worry: just count it. For the shower association of a meteor, parallel shifts are less bad than deviations in direction.
- If you are plotting, you do not have to know the exact positions of the radiants. Forget them. This sounds paradoxical, but otherwise your plottings could be influenced too much by the expectation that meteors could come from this point in the sky. Of course you have to consider the radiant positions when you choose a center of field of view, but you do not have to learn them by heart unless you are counting.
- The sense of plotting is making a more precise shower association, *not* showing some nice examples of a meteor shower. If you choose under the sky, which meteors you want to plot and which not, it is not plotting, but illustrated counting (crucial is the decision, which meteor belongs to which shower; this decision should be made *using* the plottings). It is another case if you have not enough time to plot a second meteor (see above), because then the criterion is not arbitrary.

7. Concluding remarks

Our example shows, that the difficult part of plotting is not accurate plotting, but accurate seeing and remembering positions and especially directions of the meteors. It seems wise to do plottings just for accurate shower association, but not for the search for new radiants or measuring of radiant position, unless you have a really enormous amount of data to average out the big deviances.

The bigger problem about observing biases is that they can be systematic, so that they do not average out. Group norms and expectations are dangerous and can produce a lot of "fancy" effects, that are psychologically more interesting than astronomically. So should we stop plotting? By no means!

Practically all flaws we mentioned for plotting are as bad or worse for counting: effects of expectation are even bigger, and so is the distress for thinking and memory, because shower association has to be made under the sky, sometimes in a fraction of a second. Plotting forces the observer only to note events that really have a defined direction and speed, which reduces tendencies to mark each bat or high speed neutrino as a meteor. An after-the-observation shower association allows also an reevaluation of the data, if you want to check new showers in old data or use refined criteria for shower association.

Plotting is recommended for every interval if hourly rates are up to about 20 at most. This is the case for the whole year except some days around the 3–4 biggest maxima. This makes it possible to obtain useful observations practically the whole year (warning: can be addictive!).

Acknowledgment

To Rainer Arlt for his data and comments on an earlier draft of this paper, and to Darja Golikowa for her data.

References

Rendtel J., Arlt R., McBeath A. (1995), "Handbook for visual meteor observers", IMO, Potsdam.

Author's address:

Andreas Buchmann, Chaletstrasse 7, CH-8600 Dübendorf, Switzerland, e-mail: abuchmann@mydiax.ch

SPA Meteor Section Results: September–October 2001

Alastair McBeath

Abstract: Summaries of reports and correspondence received by the *SPA Meteor Section* from September and October, 2001 are given. September was disappointing visually, while in the radio data Sporadic-E continued to be problematical from the main May–August spell, along with difficulties because of declining transmitter numbers, especially for European observers. A discussion of the supposedly new minor shower, the so-called "September Taurids" (O'Meara 2002), in connection with radio results back to 1989, is also provided. In October, the Orionids enjoyed moon-less conditions, and were seen to peak on October 21 (mean ZHR = 19 ± 5). The radio observations showed little consensus as to whether October 20 or 21 produced the higher echo counts however, and no specific timing could be defined beyond this. With strong aurorae present in some radio and visual data (unusually seen down to southern England on October 21-22), such difficulties were perhaps unavoidable. Radio data picked up a weak maximum around $\lambda_\odot = 214°–215°$ (October 27–28) which has been seen only occasionally before. The same night provided observers around and on the North Sea with a spectacularly brilliant green bolide at $19^h20^m20^s$ UT.

1. Introduction

Some healthy observing tallies were achieved in both September and October, as Table 1 demonstrates, though October did better on the whole. Radio interference decreased from its May-August worst, with Sporadic-E (Es) replaced at times by Auroral-E, or other atmospheric problems. Moonlight allowed watchers a clear run at the Orionids, while the early September Aurigid showers were far less favorable in this regard.

Table 1 – Visual, radio and video hours' totals, plus visual meteor numbers and video trail counts recorded in each month, including a partial breakdown of visual meteor types.

Month	Visual	DAU	ORI	TAU	Meteors	Radio	Video	Trails
September	$60^h_.1$	9	–	–	520	5857^h	$16^h_.4$	34
October	$148^h_.74$	18	490	174	1681	6879^h	$737^h_.4$	4595

Most of the radio data came from *Radio Meteor Observation Bulletins* (*RMOBs*) 98 and 99 (September and October, 2001 respectively), kindly provided by Chris Steyaert, except the results from Dirk Artoos, which were submitted directly. The radio observers comprised:

> Enric Fraile Algeciras (Spain), Dirk Artoos (Belgium), Mike Boschat (Canada), Maurice de Meyere (Belgium), Ghent University (Belgium), Stan Nelson (New Mexico, USA), Hiroshi Ogawa (Japan), Sadao Okamoto (Japan), Dave Swan (England), Istvan Tepliczky (Hungary), Pierre Terrier (France), Ouyang TianJing (China), Bruce Young (Queensland, Australia), Ilkka Yrjölä (Finland).

Normal procedures for examining the raw forward-scatter data were followed as usual in these articles, as outlined in (McBeath 2001), with the added proviso of removing 720 h from September's tally, for which no interference details were given. Figures 1 and 2 are given here as representative of the overall results.

The bulk of the video observations came from cameras operated by *Arbeitskreis Meteore* (*AKM*) reporters. Details on these and the other *AKM* data used here were published in their journal *Meteoros* 4 : 11 and 4 : 12 (2001), sent to us by Ina Rendtel. Steve Evans provided details of his observations directly (summaries of his data are also in the *AKM* journals), noting that he recorded 3 Piscid, 2 δ-Aurigid and 29 sporadic trails in $16^h_.4$ during September, plus 7 Taurids, 3 Orionids and another 17 sporadics in $7^h_.6$ during October. The full list of video observers (in Germany where not stated otherwise) was:

Orlando Benitez-Sanchez (Canary Isles), Steve Evans (England), Rob McNaught (New South Wales, Australia), Sirko Molau, Mirko Nitschke, Steve Quirk (Australia), Jürgen Rendtel, Ulrich Sperberg, Jörg Strunk.

Visual data came from:

American Meteor Society (*AMS*) members, in the USA if not noted (extracted from summaries in the *AMS* journal *Meteor Trails* 13 and 14 (December, 2001 and March, 2002 respectively), thoughtfully submitted by Bob Lunsford): Jure Atanackov (Slovenia), George Gliba, Robin Gray, Robert Hays, Edwin Jones, Javor Kac (Slovenia), Gene Kispert, Pierre Martin (Ontario, Canada), Felix Martinez, Paul Martsching, Jim McGraw, David Swann, Robert Togni, Kim Youmans; *AKM* members (all in Germany): Rainer Arlt, Pierre Bader, Frank Enzlein, Darja Golikowa, Sven Näther, Jürgen Rendtel, Roland Winkler; Chris Chambers (Wales), Phil Heppenstall (England), Bob Lunsford (California, USA), Tom McEwan (Scotland), Jonathan Shanklin (England), Mary Siek (England), George Spalding (England), Rich Taibi (Maryland, USA).

I am relieved to say that none of our correspondents, observers or members of their families was injured or killed in the USA during the dreadful events of September 11 in New York, Washington and Pennsylvania. The advantage of e-mail under such awful circumstances was proven in the aftermath, as a means of contacting many people near the affected areas quickly, even when most normal telephone communication was out of action. Our thoughts and condolences are with those families across the world who were not so fortunate.

2. September

September produced no real surprises meteorically this year, although the radio results all month were rather "spiky", especially the European observations. This has been an increasing problem in the last few years, as the number of suitable transmitters has declined notably. Interference of one sort or another has long been a problem, whether from terrestrial or atmospheric sources, and certainly Es was a nuisance again for some of our observers following on from another strong northern summer "season". However, added to fewer transmitters available, this made it difficult to be sure just what was being detected in some cases. Part of the purpose in examining larger numbers of radio reports was to try to counteract such difficulties, but as time has gone on, more anomalous peaks have occurred, especially in generally quiet meteoric months such as September. Whether radio meteor work can continue meaningfully under such trying circumstances is far from clear. For now our observers endeavor to do so at least.

All of the minor radio echo-count maxima during the month from (McBeath 2001) were recovered. There was no consensus as to a maximum within the $\lambda_\odot = 160°$–$163°$ period (September 2–5) though, while the $\lambda_\odot = 165°$ peak (September 7) was very ill-defined for once, apparently occurring at some stage between $\lambda_\odot \sim 164°$–$166°$. The $\lambda_\odot = 174°$ (September 16-17) peak was very weakly-seen generally, but did feature in Sadao Okamoto's longer duration echo counts ($D > 5$ s) from Japan. Our sole southern hemisphere observer, Bruce Young, picked up a stronger (but still minor) peak at $\lambda_\odot \sim 175°$ too. The late-month maxima probably due largely to the Sextantids, recurred as usual, without being especially noticeable.

Visually, few reports arrived from the first half of the month, and nothing was seen of the two Aurigid maxima due in the opening ten days. The radio reports implied perhaps quite a weak showing for the δ-Aurigids around September 8, but as mentioned previously (McBeath 2002), a peak probably due to the α-Aurigids was recovered well on August 31 and September 1. Small numbers of Aurigids were seen in observations from the second half of September, with some Piscids. Even when several watchers were active between September 18–21, little trace of the expected Piscid maximum (Dubietis 2001) was noted.

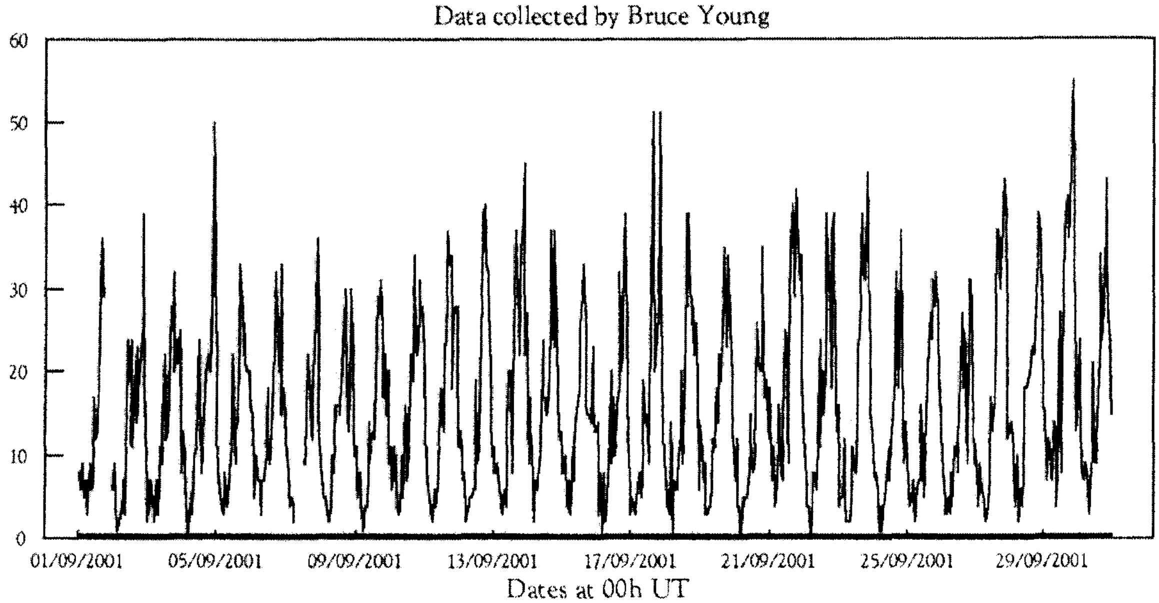


Figure 1 – Raw hourly radio meteor echo counts from September, 2001, as reported by Bruce Young. Bruce's system was operated continuously, except for a few short breaks on September 1, 7 and 8.

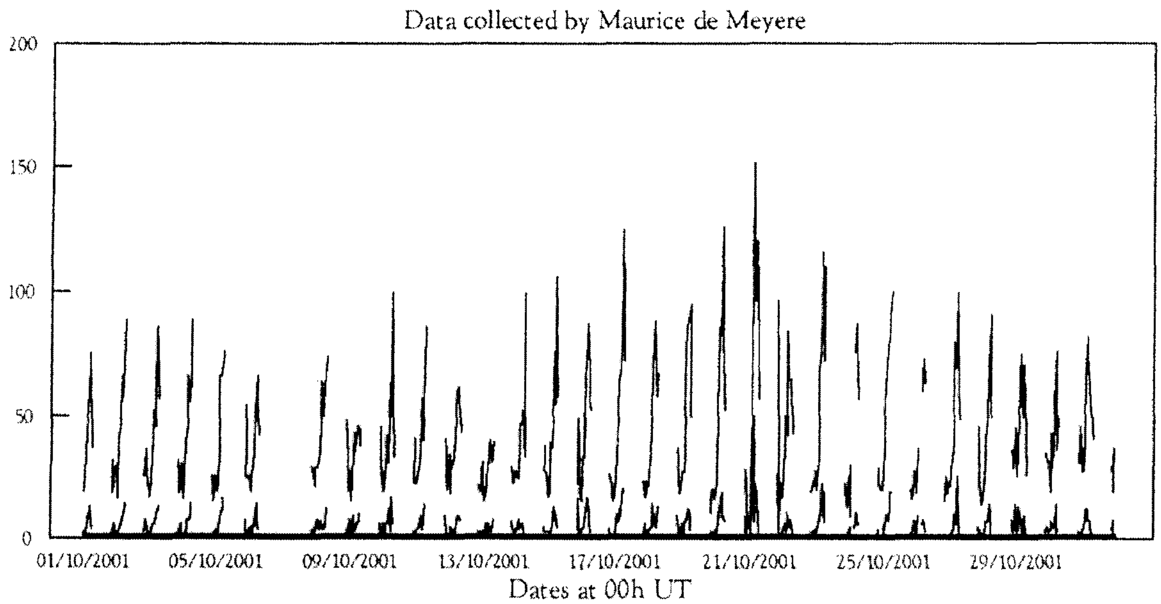


Figure 2 – Raw hourly radio meteor echo counts during October, 2001, in data collected by Maurice de Meyere. Maurice's equipment was run between 20^h–6^h UT daily until October 27, then from 21^h–7^h UT a day, after European Summer Time ended. Most of the few breaks in monitoring between these times were due to interference. The upper trace shows all-echo counts recorded, the lower one longer-duration echoes only, of $D >$ 1 s. Maurice's radio data are especially useful, as they show up the bulge in activity associated with the Orionids later in the month more clearly than any of the other whole-month datasets.

A recent article (O'Meara 2002) has suggested a new minor shower of swift meteors may have been especially active in mid-September, 2001, perhaps peaking around September 15, with a radiant in central-northwestern Taurus, between the Hyades and Pleiades star clusters (although this is based on just a single observer's data of apparently casually-made meteor plots). Three different single-observer reports made several days before or after this time in 1991 and 1996 were presented in support, spanning the period September 11–20. These only suggested a possible weak radiant however, vaguely located somewhere between eastern Aries/northwestern Taurus, Taurus-Perseus, or Taurus-Orion-Gemini. Several of our visual watchers were active during this spell in 2001, although not on September 14-15 or 15-16, but plots made on other nights around these do not confirm a radiant between the Hyades and Pleiades. There is the possibility of a swift-meteor radiant further east in Taurus though, possibly somewhere around the region where the borders of Taurus-Auriga-Gemini-Orion are nearest one another. No evidence favoring a strong minor shower was found in the radio data over this period.

Such a radiant in this area of sky is not new however, as something meteorically unexpected was first detected, emanating from somewhere perhaps near the Orion-Gemini border, by radio in 1989 by Dirk Artoos (Artoos 1990), probably peaking around September 16 or 17. Dirk recovered this radio source in 1990 (*ibid.*), and in 1993–96 results (McBeath 1998), I found a weak radio maximum around September 15–16 as well, which has been confirmed normally active in most years since, including 2001. It is not clear if this September 15–16 peak is due to the same source. In 1999, an unusual, but still minor, radio maximum was found in European data on September 17, which had not been seen as clearly since the 1989–90 events (McBeath 2000). This may indicate that the potential shower is not especially active every year, or is at its most active for only a short time. Oddly, visual observers did not report anything unexpected in either 1989–90 or 1999 September coincident with these radio events, and very few observers have provided accurate plotting observations supporting or denying such potential mid-September radiants since, despite repeated requests. Clearly there is something going on at this time of year which needs more investigation. We can but hope that in future years, visual plotting and video observers will be persuaded to cover this period more closely, bearing in mind that any Tau-Per or Ori-Gem radiant will be available throughout the second half of the night only.

3. October

Bright moonlight hindered checking for any possible Draconids in early October, but no significant activity was reported to us either visually or by radio, by which latter method only the normal $\lambda_\odot \sim 195°$–$196°$ (October 8–9) minor peak was registered, as in most years. The other minor radio peaks before the Orionids were recorded as usual.

The Orionids themselves were detected surprisingly poorly by many of our radio operators. Part of this may be down to transmitter problems, as outlined above, and part was undoubtedly due to some unfortunately-timed auroral activity near the expected maximum, notably on October 19 and 21. Even so, this seems insufficient to account for the weak to sometimes nonexistent Orionid activity bulge. Figure 2 is one of the very few radio datasets from October, 2001 to illustrate the typical Orionid profile within the month. There was no consensus as to which date produced the higher radio rates near the predicted October 21 maximum either, with roughly equal numbers favoring October 20 or 21. One dataset even gave its highest rates on October 19! This is certainly all very puzzling.

A similarly gentle profile to Figure 2's Orionid epoch can be seen in the visual ZHR graph of Figure 3. Here, the maximum was much clearer, and occurred as expected on October 21, with a mean peak ZHR $= 19 \pm 5$. Table 2 gives magnitude distributions for the Orionids and October sporadics. Too few train results were reported for a proper analysis, but 23% of Orionids and 10% of sporadics were noted as leaving persistent trains during the month. The visual results suggest a normal Orionid return, despite auroral distractions for European watchers, especially on October 21-22, when a bright display was seen well down into southern England, for instance. There is little in the visual or radio results to suggest the October 17–18 pre-peak maximum, last seen in 1998, recurred in 2001, though the rather variable radio rates before the Orionid maximum are not conclusive regarding this.

Table 2 – Global magnitude distributions for the Orionids and sporadics seen during October, 2001 in good sky conditions (cloud cover < 20%, LM = +5.5 or better), including mean LM and corrected mean magnitudes.

Shower	-3^-	-2	-1	0	+1	+2	+3	+4	+5+	Tot	LM	$\overline{m}_{6.5}$
ORI	1	1	3	4	19	36	26	18	10	118	+5.87	+3.02
SPO	0	0	5	10	10	25	32	28	5	115	+5.87	+3.15

The late October minor radio maxima were recovered as normal, including that around $\lambda_\odot$ = 216°–217° (October 29–30), although this was not nearly so obvious as during the stronger Taurid rates in 1998 (McBeath 1999). One somewhat unusual feature was a minor peak around $\lambda_\odot$ = 214°–215° (October 27–28), present in 70% of the available reports, including two of the three longer duration echo count ones ($D > 1$ s and $D > 5$ s respectively). Sometimes, this period has seemed to show a prolongation of the Orionid activity "bulge" into late October, and something at about this time was found in 1999 and 2000, albeit not quite so clearly or consistently. The few visual datasets for either date suggest no clues as to any unexpectedly enhanced meteor activity—Taurid rates were as low as anticipated for instance, and the northern hemisphere sporadic rates were at their typically good levels for late October. Another period to watch out for in future.

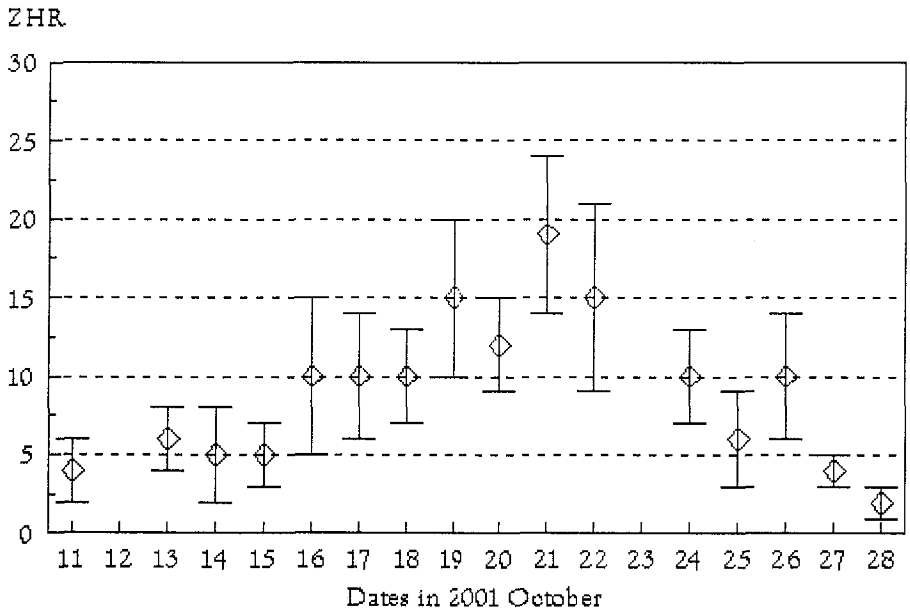


Figure 3 – Mean daily Orionid ZHRs during October, 2001, computed using r = 2.9, LM = +5.5 or better, cloud cover less than 20%, and a radiant elevation at least 20°, with standard error bars appended. Each datapoint combines observations from Europe and North America. These daily "mid-Atlantic" ZHRs have a mean timing of 5^h36^m UT, with a maximum spread in observation midpoints between 0^h–11^h UT. This gives an overview of how visual Orionid activity behaved.

One unexpected event which did occur on October 27-28 was a spectacular fireball seen from sites on and around the North Sea. This superb, very brilliant, green meteor occurred at $19^h20^m20^s$ UT, as timed by two *Dutch Meteor Society* (*DMS*) observers. Early UK media reports indicated it had been seen over a wide area of southern England, and that coastguards had been alerted to a possible incident offshore of East Anglia or Kent after the sound of "an explosion" was heard from Essex. Unfortunately, this item could not be traced to source, and no details of acoustic effects associated with the meteor were ultimately secured. The widely-seen nature of the fireball was confirmed however, and thirty useful observations of it were collected from England, Scotland, northern Germany, the Netherlands, and the Norwegian-sector Ekofisk and Valhalla oilfields in the North Sea. There were quite a number of additional witnesses who contacted the Section simply to mention having seen the event, but who were unable to give any further information. More sightings from Belgium, Denmark, northern France, and various vessels in the North Sea were also reported in various places, some of which, along with other valuable information regarding the object's trajectory, were gleaned from the preliminary analysis on the *DMS*'s website (the November 2, 2001 update. This is in English, though not all the sighting reports are; at: `http://www.dmsweb.org`). The *DMS* analysis proved especially important for details regarding the early parts of the fireball's flight, which were not well-observed by those reporting to the SPAMS.

Figure 4 shows a sketch-map of the approximate surface track of the fireball across the southern North Sea, as established from the available reports. These reports included that from Dave Taylor in Dollar, Scotland, who was very fortunate in catching part of the meteor's flight on a security video. The video recording shows how the event lit up the sky almost like daylight, despite being nearly on the local horizon at its best, and $\sim$ 410 km from the probable end-point! Figure 5 gives part of a single frame from this video, showing the brightest late-stage flare illuminating the entire visible sky. A video clip of the whole captured event is available on the SPAMS webpage report of this fireball (homepage: `http://www.popastro.com/sections/meteor.htm`).

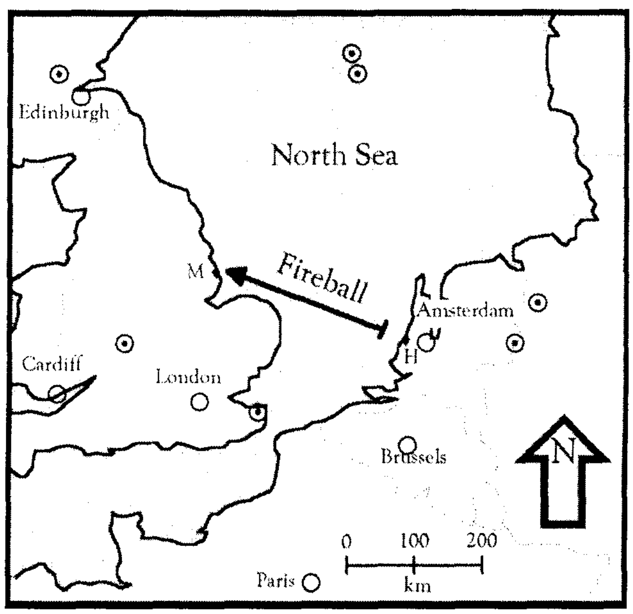


Figure 4 – A sketch-map showing the projected surface path of the October 27-28 fireball. National capitals are labeled, along with the towns of Haarlem (H) in the Netherlands and Mablethorpe (M) in England, probably the nearest places to the start and end of the track respectively. The target symbols show the approximate outer limits of the area of reports received by the Section. Clockwise from the pair in the North Sea, these are rigs and ships in the Ekofisk and Valhalla oilfields, Meppen in Germany, Enschede in the Netherlands, Canterbury and Warwick in England, and Dollar in Scotland.

Figure 6 gives a crude graphical estimate of the fireball's relative brilliance during the part of the trail on Dave Taylor's video. While not intended to give details on the video magnitudes of the bolide, the graph does help clarify the various flare events towards the end of the fireball's flight, although it covers the main fireball only. It is unclear if two distinct pieces visible after the main flare had faded away on the video were fragments following along the same path as the original meteor (some visual reports mention late fragmentation was seen) or were parts of a persistent train visible after the meteor itself had faded away completely (although such a persistent train featured in only a few visual sightings, given that the brilliance of the main flare dazzled the observers, this is not very surprising). Estimates by visual observers suggest the main flare was probably in the magnitude range -14 to -20. Several reports were made from lit rooms indoors through closed windows, and in three cases even through closed curtains!

Figure 5 – Part of a single still image from Dave Taylor's lucky video capture of the October 27-28 fireball, taken using a Sony LL202X bullet camera. The brightest late flare is shown, with the meteor almost on the local horizon. This gives some idea of Dave's good fortune, as the top edge is the upper edge of the video image! Extracted from the tape and prepared for re-use here by Robin Scagell and Peter McBeath.

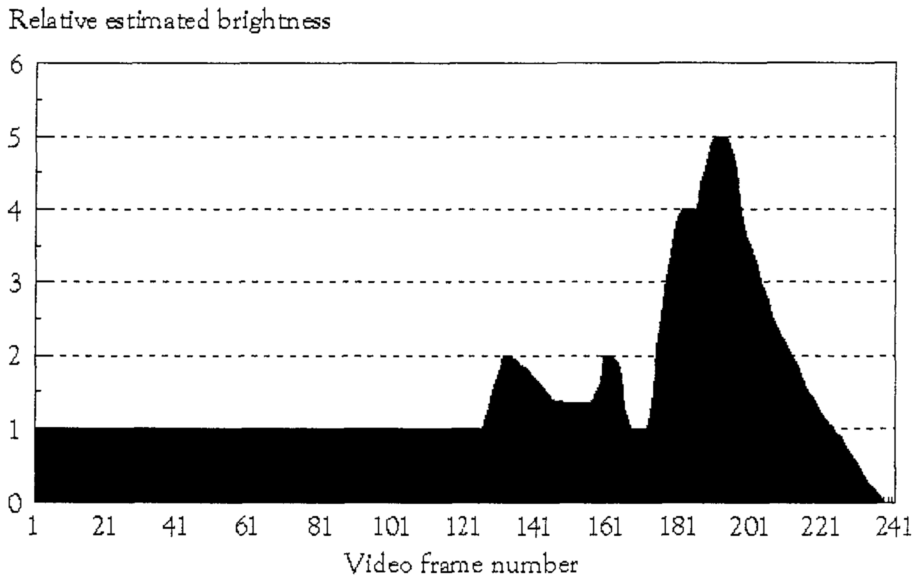


Figure 6 – A graph representing the approximate relative brightnesses of various stages of the October 27-28 fireball, extracted from Dave Taylor's video. The first clear appearance of the fireball on the top edge of the video image is assigned frame number 1, and the end assumed is at frame 238. These relative brightness estimates have been made by-eye only, and do not represent a serious attempt to give accurate bolometric magnitudes.

Positional data from our results supported the general track's position and roughly south-east to north-west direction already established by the *DMS* for this fireball. Using this, a best-estimate suggests the first 60 km of the atmospheric trajectory was missed by the video observation, while the true end may have been on or just below the local horizon from Dollar. The atmospheric track probably began at about 120 km altitude above the North Sea $\sim$ 35 km off the Dutch coast near Haarlem, at approximately $\phi = 52°45'$ N, $\lambda = 4°$ E (this specific positional data from Chris Steyaert of the Belgian *VVS* meteor observing group). The end was most likely around 25 km altitude, still over the North Sea, $\sim$ 15 km off Mablethorpe in Lincolnshire, England, near $\phi = 53°23'$ N, $\lambda = 0°30'$ E. The atmospheric path length implied by this is ~ 250 km, with an angle of descent from the horizontal of some 22° or 23°. The surface track was thus not dissimilar to the atmospheric trajectory, at ~ 230 km. The projected impact area for any surviving meteorites from this proposed trajectory would have been ~ 60 km north-west of the visible end-point, perhaps near Brigg in Humberside, England ($\phi \sim 53°34'$ N, $\lambda \sim 0°28'$ W). Enquiries to astronomically-interested individuals and groups in and around this area uncovered no reports of any suspected meteorite falls however.

Drawing chiefly on the video data, as very few flight-time estimates were made by other observers, a mean atmospheric velocity (not allowing for deceleration) for the section of the trail caught on video of $\sim 34 \pm 3$ km/s seems possible. Although it is unclear exactly how much of the trail was caught on the video, this figure is a useful guide to the object's likely speed. The lower limit of ~ 31 km/s is slightly higher than the *DMS*'s initial estimate of ~ 30 km/s based on visual reports, while the upper limit would make it definitely too swift to have been a Taurid, as suggested by some observers and also by the *DMS* preliminary analysis. The lower limit is not dissimilar to the Taurid range ($V_\infty \sim 27$–29 km/s), which with the low entry-angle would fit with a possible Taurid origin, as the double Taurid radiant area was still low in the east-south-east at the time. However, one British visual observer reported seeing almost the entire trail, and noted the start as being too close to the Taurid radiant, and the path far too long, for the meteor to have been a Taurid. Although a Taurid origin is not absolutely ruled out, it seems unlikely to have been the source of this fireball based on the available evidence. Overall, a stunning and highly memorable event for the many witnesses!

Acknowledgments

I am as ever indebted to all the observers and correspondents whose efforts continue to make such report articles possible. In addition, concerning the October 27-28 fireball, my grateful thanks go not only to all the observers for their sighting details, but also to: Mike Dale of Royal Observatory Edinburgh, John Lambert, Marco Langbroek of the *DMS*, Robin Scagell, and Jürgen Rendtel of the *AKM*, for rounding-up and forwarding reports from other observers; to Chris Steyaert for useful information and for alerting me to the *DMS* web-results; and most especially to Dave Taylor for his ready cooperation, rapid provision of his video data, and for his willingness to allow the re-use of his results in various formats.

References

Artoos D., "Possible Radio Activity in September 1990", *WGN* 18:4 (1990), pp. 101–102.

Dubietis A., "Activity of the Southern Piscid Meteor Shower in 1985–1999", *WGN* 29:1/2 (2001), pp. 29–35.

McBeath A., "The Forward Scatter Meteor Year", *In: A. Knöfel, A. McBeath (eds.), Proceedings IMC 1997, Petnica, Yugoslavia*, IMO, 1998, pp. 39–54.

McBeath A., "SPA Meteor Section Results: September-October 1998", *WGN* 27:3/4 (1999), pp. 209–214.

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

McBeath A., "The Forward Scatter Meteor Year: 2001 Update", *WGN* 29:3 (2001), pp. 85–92.

McBeath A., "SPA Meteor Section Results: July–August 2001", *WGN* 30:5 (2002), pp. 176–179.

O'Meara S. J., "New Meteor Shower from Taurus?", *Sky & Telescope* 104:3 (2002), pp. 85–87.

Author's address:

Alastair McBeath, 12a Prior's Walk, Morpeth, Northumberland NE61 2RF, England, UK, e-mail mcbal.gwyvre@virgin.net

The International Meteor Organization

Council

President: Jürgen Rendtel, Seestraße 6, D-14476 Marquardt, *Germany*,
tel. +49 (33208) 50753, e-mail: `jrendtel@aip.de`

Vice-Pres.: Alastair McBeath, 12A Prior's Walk, Morpeth, Northumberld. NE61 2RF, *UK*,
tel. +44 (1670) 518 487, email: `mcbal.gwyvre@virgin.net`

Secretary-General: Robert Lunsford, Vance Street 161, Chula Vista, *CA 91910, 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
(bank code and postbank to be mentioned together with account number!)

Other council members:
Rainer Arlt, Friedenstraße 5, D-14109 Berlin, *Germany*
David Asher, Armagh Obs., College Hill, Armagh BT 9 DG, Northern Ireland, *UK*
Marc Gyssens, Heerbaan 74, B-2530 Boechout, *Belgium*
André Knöfel, Saarbrücker Straße 8, D-40476 Düsseldorf, *Germany*
Sirko Molau, Verbindungsweg 7, D-15366 Hönow, *Germany*
Mihaela Triglav, Podkraj 10 c, SI-3320 Velenje, *Slovenia*

Commission Directors

Visual Commission: Rainer Arlt, e-mail: `rarlt@aip.de`

Telescopic Commission: M. Currie, 660, N'Aohoku Place, Hilo, *HI 96720, USA*,
e-mail: `mjc@jach.hawaii.edu`

FIreball DAta Center: André Knöfel, e-mail: `aknoefel@minorplanets.de`

Photographic Commission: Marc de Lignie, Prins Hendrikplein 42, NL-2264 SN Leidschendam,
the Netherlands, e-mail: `m.c.delignie@xs4all.nl`

Video Commission: Sirko Molau, e-mail: `molau@informatik.rwth-aachen.de`

Radio Commission: vacant

WGN — The Journal of the International Meteor Organization and Observational Report Series

Editorial board: Marc Gyssens, tel. 32 (477) 64 05 48, e-mail: `marc.gyssens@luc.ac.be`
fax: 32 (11) 26 82 99 (mention "for Marc Gyssens"),
Rainer Arlt, Alastair McBeath, Jürgen Rendtel, Mihaela Triglav

Advisory board: D.J. Asher, M. Beech, P. Brown, M. Currie, M. de Lignie, W.G. Elford, R.L. Hawkes, D.W. Hughes, J. Jones, C. Keay, G.W. Kronk, R.H. McNaught, P. Pravec, M. Šimek, G. Spalding, I. Williams.

Web Site: `http://www.imo.net`

Please renew promptly your

Subscription/Membership for 2003

and avoid problems in mailing the new issues

Each year, many *WGN* subscribers renew late. As a consequence, we have serious trouble in planning the new volume. Please save us this trouble by renewing early and have a look at p. 129 of this issue. The 2003 volume will contain results of the 2002 Leonid storms. Even more: the full review of the recent Leonid epoch is anticipated!

The stock of the IMO

	EUR	USD
Publications in English:		
Photographic Meteor Data Base (1986)	4	4
Proceedings International Meteor Conference 1990	5	5
Proceedings International Meteor Conference 1991	5	5
Proceedings International Meteor Conference 1992	5	5
Proceedings International Meteor Conference 1993	5	5
Proceedings International Meteor Conference 1994	5	5
Proceedings International Meteor Conference 1995	5	5
Proceedings International Meteor Conference 1996	5	5
Proceedings International Meteor Conference 1998	6	6
Proceedings International Meteor Conference 1999	6	6
Proceedings International Meteor Conference 2000	6	6
Gnomonic Atlas Brno 2000.0	3	3
Photographic Astrometry + diskette	7	7
WGN Observational Report Series:		
Vols. 1–5 (1988–1992): Visual Observations, per vol.	8	8
Vol. 6 (1993): Vis. Obs. and Electrophonic Fireball Cat.	8	8
Vols. 7–8 (1994–1995): Visual Observations, per vol.	8	8
Vols. 9–14 (1996–2001): Visual Observations, per vol.	10	10
Backissues of the WGN Journal:		
Volumes 19–20 (1991–1994): complete, per volume:	10	10
Volumes 23–29 (1995–2001): complete, per volume:	18	18