Aurigids

Visual observations of the Aurigid peak on 2007 September 1

Jürgen Rendtel [1]

We analyse data of 368 α-Aurigids observed visually in 53.16 hours effective observing time around the predicted peak of the shower on 2007 September 1. We find a peak time of $11^{\rm h}20^{\rm m}$ UT ±3 minutes ($\lambda_\odot = 158\overset{\circ}{.}556 \pm 0\overset{\circ}{.}003$), a peak ZHR of 132 ± 26 (based on counts in five-minute intervals) and a duration (FWHM) of 45 minutes with a slightly asymmetric profile (ascent 27, descent 18 minutes). The population index in the peak period was low ($r = 1.74 \pm 0.08$).

Received 2007 October 30

1 Introduction

Predictions of an outburst of the α-Aurigids have been published by Lyytinen and Jenniskens (2003) and updated by Jenniskens and Vaubaillon (2007). This activity caused by the long-period comet C/1911 N1 (Kiess) yielded a unique opportunity to study meteoroids from this comet ejected around 83 BC. The predicted peak time was $11^{\rm h}36^{\rm m}$ UT on 2007 September 1 (Jenniskens & Vaubaillon, 2007).

The annual activity of the α-Aurigids reaches a ZHR of about 10 (Rendtel et al., 1995; Dubietis & Arlt, 2002). Other short lived outbursts have been reported in 1935, 1986, and 1994 (Jenniskens, 2006).

2 Observing conditions

Short-lived outbursts require a careful selection of the observing location: the radiant must be high enough in the sky at the instance of the peak and other disturbances should be minimized. In the case of the 2007 α-Aurigid peak time at $11^{\rm h}33^{\rm m}$ UT (±20 minutes according to the Aurigid web page `http://aurigids.seti.org`), observers in the western regions of North America were best placed. However, a waning gibbous Moon (80% illuminated) was high in the southwestern sky. This is already problematic under clear conditions, but becomes disastrous when haze occurs. A significant deviation from the reference limiting magnitude of 6.5 was the consequence. The effect was less strong because a large portion of bright meteors was expected.

In fact, most observers reported limiting magnitudes between 4.0 and 5.3 mag, with only a few exceptions towards better conditions. Different attempts were made to block the bright moonlight: shadow of trees or buildings were useful, but a dark umbrella has helped as well.

3 Visual data

Despite the poor circumstances we received numerous reports. Many of these reports were sent through the IMO's live web page. Others have been collected from the Aurigid web page `http://aurigids.seti.org`. Several observers have been contacted for details of their reports. Their useful comments and revised data breakdowns helped to establish a good sample for the analysis. This is important because the short duration of the outburst and the circumstances limited the sample of each individual observer to about 30–50 meteors at best (Table 1). If we try to obtain a temporally resolved rate profile, we need to accumulate all available data.

The total sample for the peak period included in this paper was collected by 26 visual observers from eight countries worldwide. It contains data of 368 α-Aurigids

Table 1 – Observers contributing to the 2007 α-Aurigid analysis (5-letter code of the VMDB, effective observing time, and number of α-Aurigids). This list summarizes observations made between August 31, $21^{\rm h}30^{\rm m}$ UT and September 1, $22^{\rm h}10^{\rm m}$ UT.

Name	VMDB code	Obs. time	No. of AUR
Salvador Aguirre	AGUSJ	$5\overset{\rm h}{.}00$	1
José Alvarellos	ALVJO	$2\overset{\rm h}{.}41$	17
Bernd Brinkmann	BRIBJ	$2\overset{\rm h}{.}57$	37
Dustin Brown	BRODU	$0\overset{\rm h}{.}23$	5
Clark Chapman	CHACJ	$0\overset{\rm h}{.}35$	9
Steve Chapman	CHASJ	$1\overset{\rm h}{.}00$	7
Daniel Fischer	FISDA	$1\overset{\rm h}{.}16$	21
Bill Godley	GODBJ	$1\overset{\rm h}{.}75$	9
Mitja Govedic	GOVMI	$2\overset{\rm h}{.}03$	14
Robin Gray	GRARO	$3\overset{\rm h}{.}10$	21
Wayne T. Hally	HALWA	$4\overset{\rm h}{.}00$	4
Kim Hay	HAYKI	$1\overset{\rm h}{.}35$	5
Robin Hegenbarth	HEGRJ	$0\overset{\rm h}{.}96$	22
Carl Hergenrother	HERCJ	$1\overset{\rm h}{.}81$	21
Jakub Koukal	KOUJA	$1\overset{\rm h}{.}42$	3
Peter Kozich	KOZPJ	$1\overset{\rm h}{.}16$	52
Robert Lunsford	LUNRO	$5\overset{\rm h}{.}00$	28
Paul Martsching	MARPA	$4\overset{\rm h}{.}25$	9
Bruce McCurdy	MCCBR	$1\overset{\rm h}{.}25$	9
Eran Ofek	OFEER	$0\overset{\rm h}{.}23$	6
Krzystof Polakowski	POLKJ	$2\overset{\rm h}{.}00$	3
David Stine	STIDA	$2\overset{\rm h}{.}33$	9
Wesley Stone	STOWE	$2\overset{\rm h}{.}77$	33
William Watson	WATWI	$2\overset{\rm h}{.}95$	1
Alan Whitman	WHIAL	$1\overset{\rm h}{.}08$	21
Ilkka Yrjölä	YRJIL	$1\overset{\rm h}{.}00$	1

[1] Eschenweg 16, 14476 Marquardt, Germany.
Email: `jrendtel@aip.de`

IMO bibcode WGN-355-rendtel-aurigids
NASA-ADS bibcode 2007JIMO...35..108R

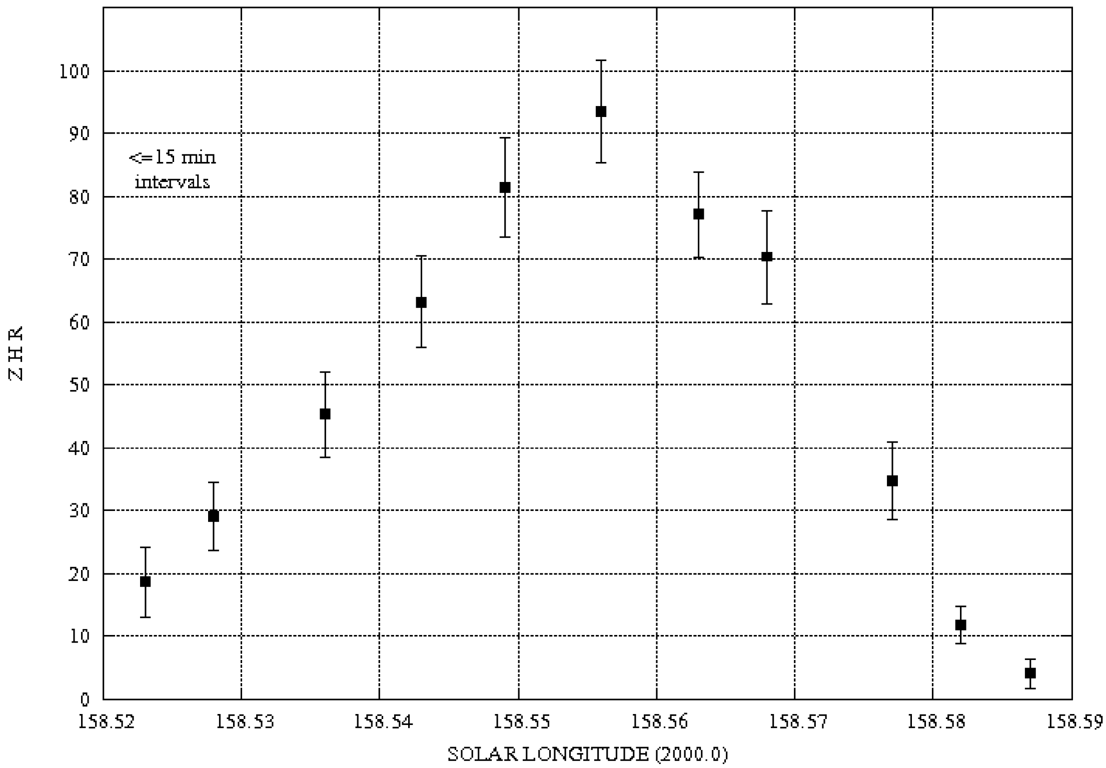

Figure 1 – ZHR-profile of the α-Aurigids based on 144 count intervals of 15 minute maximum duration using a constant population index of $r = 1.74$. The longer intervals yield a smooth profile.

observed in 53.16 hours effective observing time. Additional observations in the nights before and after the peak confirmed the typical annual rates and are not analysed here.

4 Population index profile 2007

The short duration of the outburst limits the possibilities of deriving a profile of the population index r. We can just calculate one (average) value for the entire outburst period, and still the size of the sample is lower than for usual studies of this type.

In order to find out what influence the moonlit sky may have had, we calculated the population index r first from the entire sample, and then from all α-Aurigids observed under LM ≥ 4.0 and finally for data obtained with LM ≥ 5.0. Of course, the samples become smaller when we limit the conditions (see Table 2). For comparison: the annual α-Aurigids yield a value of $r = 2.3 \pm 0.1$ (Rendtel et al., 1995).

The difference between the three values shown in Table 2 is surprisingly small and indicates that the calculation procedure is robust against observing conditions, and that the population index obviously was almost constant over the magnitude interval between $m = -4$ and about $m = +3$. The low r-value underlines the predicted and reported large portion of bright shower meteors. However, it was not that low to neglect the effect of the limiting magnitude on the ZHR calculation as expected by a few observers. Because of the size of the sample, we favour the population index obtained from the observations made under skies with LM ≥ 4.0 as the representative figure and use this for the next steps. The size of the sample and the short duration of the outburst did not allow us to look into details of the population index in the central and outer parts of the meteoroid stream. Hence, we use a constant value of the population index for the further analysis.

Table 2 – Population index r of the α-Aurigid peak period $\lambda_\odot = 158\overset{\circ}{.}50 - 158\overset{\circ}{.}60$ (2007 September 1, 10^h00^m UT – 12^h30^m UT). For three data sets defined by the observing conditions the limit of LM, the calculated population index r, the size of the sample and the average LM of the data set are listed.

Data set	r	Sample	LM(avg.)
All data	1.76 ± 0.07	206	4.85
≥ 4.0	1.74 ± 0.08	186	5.04
≥ 5.0	1.63 ± 0.08	107	5.48

5 ZHR profile

For the ZHR calculation we use $r = 1.74 \pm 0.08$ as shown and explained above. Before we calculate the ZHRs right away, we had to deal with some details of the reports. Because the activity varied strongly over a short period, we need to have information for short intervals. For example, we cannot derive the peak moment with

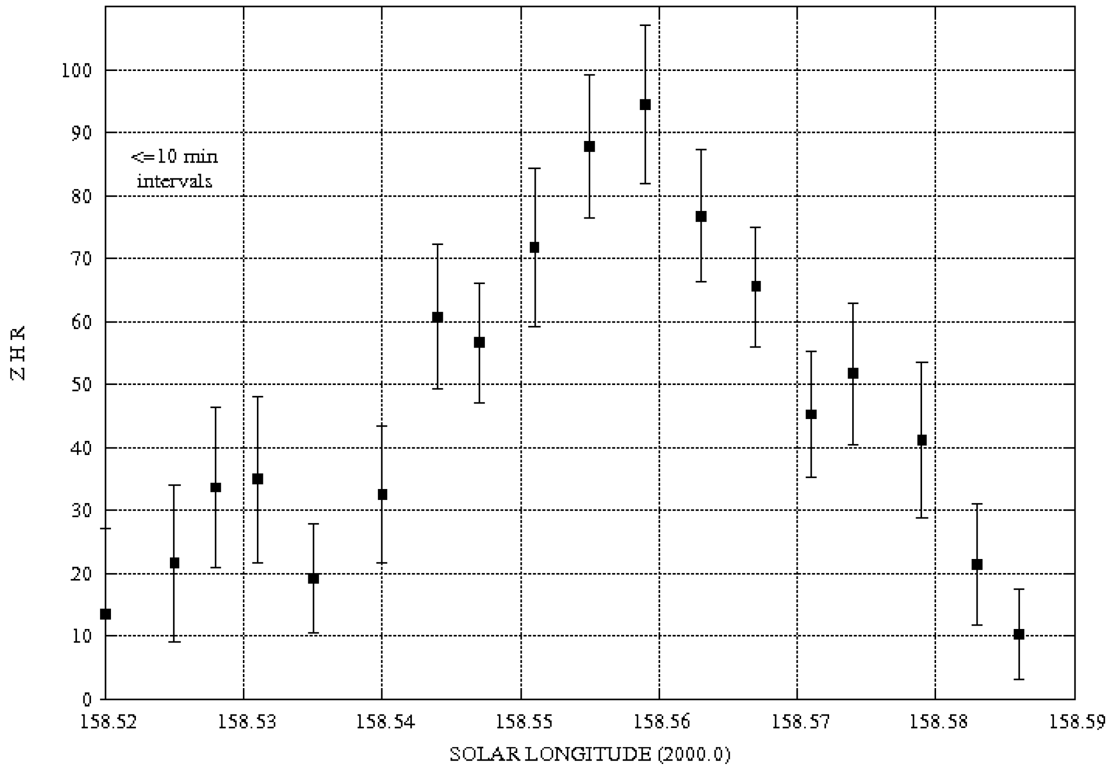

Figure 2 – ZHR-profile of the α-Aurigids based on 97 count intervals of 10 minute maximum duration. The lower ZHR values at $\lambda_\odot = 158\overset{\circ}{.}550$ and $\lambda_\odot = 158\overset{\circ}{.}560$ are poorly defined. Structures are difficult to confirm.

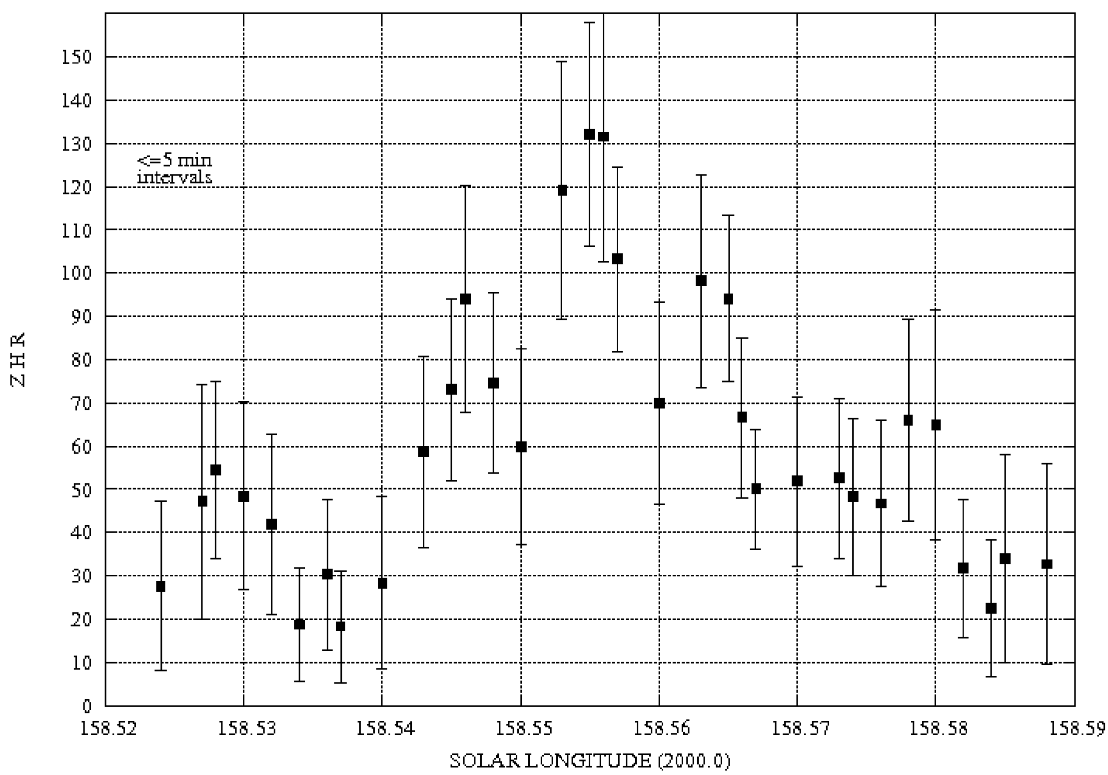

Figure 3 – ZHR-profile of the α-Aurigids based on 61 count intervals of 5 minute maximum duration. Like in Figure 2, lower ZHRs at $\lambda_\odot = 158\overset{\circ}{.}550$ and $\lambda_\odot = 158\overset{\circ}{.}560$ are based on very small samples as compared to their neighbours. Scatter becomes large because of the few meteors per bin.

an accuracy of 5 minutes if we use count intervals of 15 or 20-minutes length. Consequently, we cannot include reports which summarized large portions of the outburst or even the entire peak period in just one interval. Of course, the small samples for each individual observer may involve the case that *no shower meteor* was observed in a bin even close to the peak. Only a combination of data obtained by many independent observers (many measurements of the flux or rate in one and the same bin) may yield a reliable ZHR for each interval. The entire sample collected in the period between $\lambda_\odot = 158\overset{\circ}{.}02$ and $158\overset{\circ}{.}97$ (i.e. from August 31, $21^{\mathrm{m}}30^{\mathrm{m}}$ UT until September 1, $22^{\mathrm{h}}10^{\mathrm{m}}$ UT) contains data of 368 α-Aurigids (Table 1).

Here we present three graphs of the calculated ZHR. As in the case of other shower activity analyses, we set the maximum correction factor to 5 and include only data from periods with a radiant elevation of at least 20°. Since most observers of the immediate peak were located in western North America, this was not a critical parameter.

5.1 Maximum interval length 15 minutes

In the first case, we use all intervals (144 intervals, maximum bin length 15 minutes). From this sample we determine a peak time of $\lambda_\odot = 158\overset{\circ}{.}556 \pm 0\overset{\circ}{.}003$, corresponding to $11^{\mathrm{h}}20^{\mathrm{m}}$ UT (±3 minutes). This smooth profile consists of one ZHR average in about 10 minute steps (Figure 1), and the peak ZHR reaches 93 ± 8. Further details of the immediate peak period are listed in Table 3, top section.

5.2 Maximum interval length 10 minutes

We also run the ZHR calculation including only bins up to 10 minutes duration (97 intervals; Figure 2). Here we get one ZHR average every 6 minutes, with the peak ZHR of 95 ± 13 at $\lambda_\odot = 158\overset{\circ}{.}559 \pm 0\overset{\circ}{.}003$, i.e. $11^{\mathrm{h}}24^{\mathrm{m}}$ UT. This result is not deviating from the result obtained from the first data set. As a consequence of the smaller sample per bin the scatter increases, and there seem to occur small structures in the profile, of which a shoulder at $\lambda_\odot = 158\overset{\circ}{.}530$ seems significant. However, if we look into Table 3, middle section, we see that the two higher ZHRs are based on just 6 meteors and the peak therefore is highly questionable if not confirmed by other techniques.

The duration of the outburst, defined by the FWHM (full width at half maximum) is about 45 minutes. In both cases, the ascending branch is slightly longer (25–27 minutes from half maximum to peak) than the descending branch (15–18 minutes from the peak to half maximum) of the profile.

Table 3 – right – ZHR of the 2007 α-Aurigids for the immediate peak period. Obs. gives the number of observers contributing to the average; AUR is the number of α-Aurigids recorded in the interval. A difference of $0\overset{\circ}{.}0067$ in solar longitude corresponds to 10 minutes.

$\lambda_\odot$(2000.0)	Obs	AUR	ZHR	Error
158.523	8	10	18.6	5.6
158.528	14	27	29.1	5.5
158.536	17	43	45.3	6.8
158.543	27	73	63.2	7.3
158.549	31	104	81.4	7.9
158.556	32	130	93.6	8.2
158.563	35	128	77.2	6.8
158.568	29	90	70.4	7.4
158.577	20	30	34.7	6.2
158.582	17	14	11.8	3.0
158.525	4	2	21.6	12.5
158.528	6	6	33.6	12.7
158.531	6	6	34.9	13.2
158.535	7	4	19.2	8.6
158.540	8	8	32.5	10.8
158.544	14	27	60.7	11.5
158.547	19	35	56.6	9.4
158.551	13	31	71.8	12.7
158.555	19	58	87.8	11.4
158.559	17	56	94.5	12.5
158.563	20	53	76.8	10.5
158.567	21	47	65.5	9.5
158.571	13	19	45.2	10.1
158.574	12	20	51.7	11.3
158.579	8	10	41.1	12.4
158.583	7	4	21.4	9.6
158.524	2	1	27.6	19.5
158.527	2	2	47.2	27.2
158.528	4	6	54.5	20.6
158.530	3	4	48.4	21.7
158.532	3	3	41.9	20.9
158.534	3	1	18.7	13.2
158.536	3	2	30.3	17.5
158.537	3	1	18.3	12.9
158.540	2	1	28.3	20.0
158.543	4	6	58.6	22.1
158.545	6	11	73.0	21.1
158.546	5	12	94.0	26.1
158.548	6	12	74.6	20.7
158.550	4	6	59.9	22.6
158.553	4	15	119.2	29.8
158.555	6	25	132.2	25.9
158.556	5	20	131.5	28.7
158.557	7	22	103.2	21.5
158.560	4	8	69.8	23.3
158.563	5	15	98.2	24.6
158.565	8	23	94.1	19.2
158.566	6	12	66.6	18.5
158.567	8	12	50.0	13.9
158.570	4	6	51.9	19.6
158.573	5	7	52.5	18.6
158.574	5	6	48.2	18.2
158.576	4	5	46.7	19.1
158.578	4	7	65.9	23.3
158.580	3	5	64.9	26.5
158.582	4	3	31.7	15.9
158.584	3	1	22.5	15.9
158.585	2	1	33.9	24.0
158.588	2	1	32.7	23.1

Table 4 – Peak time of the α-Aurigids 2007 – predictions and results. Sato published his prediction on August 26.

Peak (UT)	Source
11:33 ±20 min	Jenniskens at Aurigid web page `http://aurigids.seti.org`
11:22	Sato at `http://fas.kaicho.net/tenshow/meteor/aur2007/Aur2007.html`
11:20 ±3 min	This analysis

5.3 Maximum interval length 5 minutes

In a third attempt to get more precise peak and structure information, we allowed only 5-minute bins, thus reducing both the sample size per bin and the number of bins (61). Hence we obtain a larger scatter of the ZHR values shown in Figure 3. The peak ZHR increases to 132 ± 26, but as listed in Table 3, bottom section, the individual ZHRs are only based on some 20 meteors, instead of more than 100 and more than 50, respectively, in the first two profiles. Although we see higher ZHR values here, we cannot define the peak time with better accuracy than in the first two data sets. Here we get $\lambda_\odot = 158\overset{\circ}{.}555 \pm 0\overset{\circ}{.}002$ as the peak time ($11^\mathrm{h}19^\mathrm{m}$ UT). Further, we see dips and apparent sub-peaks, which cannot be regarded as significant until we have confirmation by other observing techniques. Both the rates at $\lambda_\odot = 158\overset{\circ}{.}550$ and $\lambda_\odot = 158\overset{\circ}{.}560$ are defined by fewer meteors than their neighbours (see Table 3, bottom section).

6 Discussion

The peak of the α-Aurigid outburst occurred close to the expected position. Like in the case of the Leonid peaks in the years 1999 to 2006, the prediction of the peak time deviated only little from the observations, while the activity level obviously remains difficult to predict.

We find a population index of $r = 1.74 \pm 0.08$ from the meteors observed under a sky with a limiting magnitude of at least $m = +4$. The effect of the bright skies due to the moonlight interference is relatively small, indicating that the meteoroid size distribution does not vary over the magnitude interval between $m = -4$ and about $m = +3$ within the error margins.

The observations during the immediate peak period were performed by observers in a very limited geographical region (California, Oregon, British Columbia, Arizona). When we combined Leonid observations from locations between Central Asia and Australia, we had to consider a correction to geocentric positions (McNaught & Asher, 1999; Molau et al., 2002). Such a correction is not necessary in the case of the α-Aurigids 2007.

The calculated peak ZHR depends on the maximum length of the included bins. Probably the best estimate for the peak time is obtained when the maximum bin length was set to 10 minutes. The peak occurred at $\lambda_\odot = 158\overset{\circ}{.}556 \pm 0\overset{\circ}{.}003$, that is $11^\mathrm{h}20^\mathrm{m}$ UT. In the ZHR profile we have to consider possible (true) density fluctuations which superpose with statistical effects. The best estimate of the peak rate seems to be the value ZHR $= 132 \pm 26$ derived from 6 minute intervals. Indications of substructures are very weak because of the error limits.

7 Conclusions

The short duration of the entire α-Aurigid outburst limits the accuracy in the determination of the peak ZHR and peak time. The best values derived from the available visual data are ZHR $= 132 \pm 26$ at $\lambda_\odot = 158\overset{\circ}{.}556 \pm 0\overset{\circ}{.}003$, corresponding to 2007 September 1, $11^\mathrm{h}20^\mathrm{m}$ UT. The width of the slightly asymmetric profile is 45 minutes (FWHM). The ascent from half peak to the peak lasted 27 minutes, the descent to half peak only 18 minutes. Substructures in the ascending branch are based on very small samples and need to be confirmed by data obtained with other techniques. During the peak period we find a low population index of $r = 1.74 \pm 0.08$ for the meteor magnitude interval between $m - 3$ and $m + 4$.

Acknowledgements

We thank all observers sending their data to the IMO's on-line Aurigid website. Further data was collected via `http://aurigids.seti.org`, NASA's Aurigid web page. Some observers sent details of their data sets on request which greatly improved the available sample.

References

Dubietis A. and Arlt R. (2002). "Annual activity of the α Aurigid meteor shower as observed in 1988–2000". *WGN*, **30**, 22–31.

Jenniskens P. (2006). *Meteor showers and their parent comets.* Cambridge University Press, Cambridge, 790 pages.

Jenniskens P. and Vaubaillon J. (2007). "Aurigid predictions for 2007 September 1". *WGN*, **35**, 30–35.

Lyytinen E. and Jenniskens P. (2003). "Meteor outbursts from long-period comet dust trails". *Icarus*, **162**, 443–452.

McNaught R. H. and Asher D. J. (1999). "Variation of Leonid maximum times with location of observer". *Meteoritics & Planetary Science*, **34**, 975–978.

Molau S., Gural P. S., and Okamura O. (2002). "Comparison of the "American" and the "Asian" 2001 Leonid meteor storm". *WGN*, **30**, 3–21.

Rendtel J., Arlt R., and McBeath A. (1995). *Handbook for Visual Meteor Observers.* IMO Monograph No. 2. IMO, Potsdam, 240 pages.