$0\overset{\circ}{.}1$ from the nodal position of Comet 55P/Tempel-Tuttle in 1966 and might represent the first material from the main, narrow, outburst component of the stream. It is very important that observers closely monitor this position in 1996, which will recur near November 17, $0^h$ UT. If this does represent recent material close to the comet, then this time offers the greatest potential for high rates in 1996.

After this apparent quasi-"outburst" peak, the increase to maximum continues with nearly the same slope and reaches a clear peak near $\lambda_\odot = 235\overset{\circ}{.}5 \pm 0\overset{\circ}{.}1$. The ZHR data are particularly abundant in the interval $\lambda_\odot = 235\overset{\circ}{.}25$–$235\overset{\circ}{.}50$, making this determination reliable. In contrast to the relatively slow rise to maximum lasting roughly 1°, the falling portion of the profile is much steeper reaching background levels less than $0\overset{\circ}{.}5$ after the maximum. The apparent continuation of Leonid activity after $\lambda_\odot = 236°$ is due, at least in part, to the higher values of $r$ found after this time. The large errors in the $r$-profile in this region suggest that this continued plateau is most probably an artifact.

### 3. Outlook for the sixth ILW period

In 1996, the sixth *ILW* period will take place from November 5 to 25, 1996. Observers are asked to concentrate on the shower during these dates, with special emphasis on the nights from November 16 to 18. This year, the Moon will be out of the way for most of the *ILW* period, with a First Quarter Moon on November 17. This implies that observations made in the early morning hours near the peak should be very dark. The time of the apparent peak observed in 1995 at $\lambda_\odot = 235\overset{\circ}{.}5$ corresponds to $12^h$ UT on November 17. Enhanced activity is most likely in the interval from $0^h$ to $12^h$ UT on November 17.

### Acknowledgment

The author wishes to thank Rainer Arlt for help with the visual analysis.

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# The Perseids

# Perseids 1995 and 1996—An Analysis of Global Data

*Jürgen Rendtel and Rainer Arlt*

This analysis is based on a sample of more than 14 000 Perseids of 1995 and 7 500 Perseids of 1996. Peak activity re-occurred in 1995 at $\lambda_\odot = 139\overset{\circ}{.}63 \pm 0\overset{\circ}{.}02$ (2000.0) and in 1996 at $\lambda_\odot = 139\overset{\circ}{.}66 \pm 0\overset{\circ}{.}03$. Due to the coincidence of Full Moon and the Perseid maximum in 1995, the sample is small and of limited quality compared with the 1996 data. Therefore, we were not able to obtain a well-resolved profile of the population index $r$ in 1995, while the 1996 $r$-profile indicates a *higher* value of $r = 2.03 \pm 0.02$ during the peak period than in the surrounding time intervals where we found values of $r \approx 1.8$. Based on a number of 10-minute counts, the maximal EZHR of the 1996 peak reached a level of 120 with a kind of plateau of ZHRs above 100 lasting from $\lambda_\odot = 139\overset{\circ}{.}64$ to $139\overset{\circ}{.}67$ (i.e., August 12, $0^h40^m$–$1^h25^m$ UT). The position of the 'outburst peak' is found to have shifted backwards in solar longitude from $\lambda_\odot = 139\overset{\circ}{.}78$ in 1988 to $139\overset{\circ}{.}48$ in 1992, and then forward to $\lambda_\odot = 139\overset{\circ}{.}67$ in 1996. During this period, the peak was closest to the ascending node of 109P/Swift-Tuttle in 1992.

### 1. Introduction

After the 1995 Perseid maximum interfered with moonlight, many observers in Europe awaited the ideally located peak of the Perseids in the night of August 11-12, 1996. Unfortunately, most of them suffered from the bad weather in that and the following night.

Until now 14 092 Perseids of 1995 and 7 557 Perseids of 1996 are available in the *Visual Meteor Database* (*VMDB*). The following observers contributed to the analysis of the Perseid maxima in 1995 and 1996:

Vida Angel, Rainer Arlt, Mária Bartolomejová, Jozef Bezak, Nikola Biliškov, Lucian Boboc, Grzegorz Bonikowski, Emil Brezina, Bob Brown, Marek Bujdos, Jacek Burda, Branko Burmaz, Jaroslava Cablkova, Anja Cervek, Jiang Chang-gui, Vratislav Cillik, Koen Clement, Peter Craven, Jozef Csipes, Mark Davis, David de Wolf, Monika Diallova, Marta Dikova, Iveta Dobrovolna, Joachim Draeger, Radek Dreveny, Jozef Drga, Tomasz Dziubiński, Bert Everaert, Andrea Friebel, Josipa Friščić, Marcin Gajos, Slaven Garaj, Paweł Gembara, Jaroslav Gerboš, Ivanka Getsova, Benny Geys, Vincent Giovannone, George W. Gliba, John Glover, Lew Gramer, Neven Grbac, Valentin Grigore, Andrey I. Grishchenyuk, Adam Grzeszuk, José Luis Guixeras Romero, Andrej Guliš, Peter S. Gural, Wayne T. Hally, Pavol Hanzlíček, Peter Harmady, Yukiti Hattori, Robert Hays, Monika Hazukowa, Veerle Herrygers, Sylwia Hołowacz, Kamil Hornoch, Filip Hroch, Vladimír Hrušovský, Su Hua, Richard Huziak, Oomi Iiyama, Daiyu Ito, Jan Janča, Miroslav Jedlicka, Jaroslava Jelchova, Liu Jing, Michał Jurek, Vaclav Kalas, Stanislav Kaniansky, Fumihiko Kanno, Niladri Kar, Jana Kasparova, Kevin Kilkenny, Timo Kinnunen, Hitomi Kisanuki, André Knöfel, Ľubica Kobová, Ralf Koschack, Detlef Koschny, Jaroslav Kovarik, Ales Kratochvil, Dita Krcmarova, Gotfred M. Kristensen, Øyvind Kristiansen, Silvija Križak, Jan Kucera, Martin Kundrat, Alexander Kupco, Lívia Kusá, Ralf Kuschnik, Jari Kuula, Maciej Kwinta, Jan Kyselý, Juraj Lacko, Jean-Christophe Lernould, Inge Leyssens, Vladimir Lukić, Robert Lunsford, Kouji Maeda, Peter Majchrak, Urszula Majewska, Veikko Mäkelä, Miroslava Mala, Štefan Malár, Radek Maly, Katuhiko Mameta, Petr Masek, Jan Masiar, Alastair McBeath, Tom McEwan, Norman McLeod, Jana Micikova, Vasile Micu, Carl B. Miller, Koen Miskotte, Radovan Misovic, Hidekatu Mizoguchi, Jan Mojzsis, Sirko Molau, Ivelina Momcheva, Tibor Mrmus, Adrian Mrska, Hisayuki Nagai, Tomas Nasku, Dragana Okolić, Arkadiusz Olech, Jens O. Olesen, Jan Ondrus, Artyom E. Oreshonok, John Penner, Christian Pinter, Jiri Polak, Mila Popović, Lilia Porozhanova, Tim Printy, Wen Qingliu, Leo Rajala, Pavol Rapavy, Ina Rendtel, Jürgen Rendtel, Maciej Reszelski, Alberto J. Roldán Piracés, Manca Rotner, Julián Ruiz-Garrido Zabala, Łukasz Sanocki, Koetu Sato, Branislav Savic, René Scurbecq, Peter Sedlak, Miguel Serra Martin, Francisco Sevilla, Gregory Shanos, Yasuo Shiba, Anna Sikchina, Eva Skvarkova, Zbynek Slama, Jana Slizova, Lukas Smahel, Alexander Smetanko, James N. Smith, Milos Sochan, Manuel Angel Solano Vinuesa, Manuel Solano Ruiz, Zdeno Sovcik, Ulrich Sperberg, Jiři Srba, Elisa Stefani, Katarina Stefanikova, Svetozár Štefeček, Enrico Stomeo, Wesley Stone, Niko Štritof, Marta Svancarova, Pavel Svozil, David Swann, Richard Taibi, Marko Toivonen, Jiri Tomcik, Daniel Toth, Manuela Trenn, Mihaela Triglav, Josep M. Trigo Rodriguez, Juraj Trojak, Peter Trojak, Elena Valero Rodriguez, Hendrik Vandenbruaene, Michel Vandeputte, Maarten Vanleenhove, Cis Verbeeck, Jan Verbert, Marco Virsek, Bruno Wagner, Thomas Westphal, Linda Wilson, Jean-Marc Wislez, Nikolai Wünsche, Zhou Xingming, Yasuo Yabu, Satiko Yamaguti, Vasilij Yaremchuk, Hiromiti Yosidome, Ilkka Yrjölä, Jerzy Zagrodnik, George Zay, Goran Zgrablic, Peter Zimnikoval, Beata Zimnikovalova, Krzysztof Żurek

A detailed investigation of the recent Perseid activity revealed that it consists of three major parts [1]:

1. a broad plateau displaying weak activity (background Perseids);
2. a more concentrated component centered around the traditional Perseid peak (core Perseids); and
3. a strongly time-varying component of short duration which appears in all profiles shortly after the nodal longitude of the parent comet (outburst Perseids).

Traces of the outburst Perseids situated roughly 12 hours before the regular Perseid maximum near $\lambda_\odot = 140°$ were found in the 1988 and 1989 Perseid analyses [2]. A peak of very high ZHRs was first observed in 1991 and in all subsequent years. Generally, the peak ZHR decreased since 1991 from about 400 to 120 in 1996. This is in agreement with model calculations of Wu and Williams [3] who predicted enhanced rates for the remainder of the century. However, the activity level may decrease to a level which makes its separation from the regular Perseid rates very difficult.

The position of this peak varied from one return to the next, and the pattern of the variations seemed to be unpredictable. The 1996 peak occurred quite close to the 1994 and 1995 positions.

The population index $r$ determined from the magnitude data showed no peculiarities during the activity of the outburst Perseids. However, there seems to occur a significant local maximum of $r$ in the 1996 data. It has to be checked with the complete data whether this feature is really a new phenomenon associated with the increasing distance from the high activity part of this component of the Perseids.

In our analysis, we restrict ourselves to the time period $\lambda_\odot = 139\overset{\circ}{.}5$ to $140\overset{\circ}{.}1$, i.e., the outburst Perseids and the ascending branch of the regular maximum, designated as core Perseids.

## 2. The population index $r$

As explained above, the 1995 data do not allow a detailed analysis of the changes in $r$ due to the strong disturbance by moonlight. The analysis showed that there is no obvious structure in the profile of $r$ in the vicinity of the peak. Surprisingly, the figures of $r \approx 2.2$ are higher than during the previous Perseid peak returns when $r$ was of the order of 2.0 (see Table 1).

We already mentioned a feature found in the 1996 data analyzed for this report (Figure 1). Here, the value of the population index $r$ seems to steadily decrease from $\lambda_\odot = 138°$ from 2.1 towards 1.9 close to $139\overset{\circ}{.}0$. Coinciding with the position of the peak, we find $r = 2.03 \pm 0.02$, while the later figures can be interpreted as a continuation of a general dip with an ascending branch reaching $r = 2.1$ just after the regular Perseid maximum. If this is a significant structure, this indicates a change in the particle population as compared to the previous passages of the Earth through this region with an increasing portion of fainter meteors. Profiles of the population index $r$ [1] did not show any local structure in the vicinity of the outburst peak.

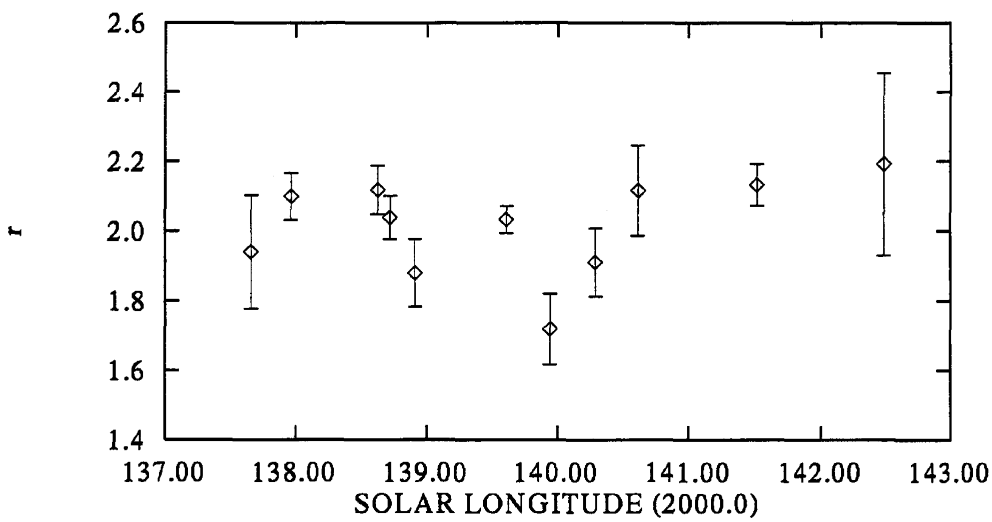


Figure 1 – Profile of the population index $r$ for the 1996 Perseids obtained from all available magnitude data (as of September 1996). The point at $\lambda_\odot = 138\overset{\circ}{.}911$ coincides with the peak period and indicates that the particle size distribution may be different from the surrounding region where $r$ shows a wider dip, just interrupted by the mentioned value. Considering the error bars, the higher figure of $r$ at this moment seems to be significant.

## 3. The activity profile

Again, we can derive only little information from the 1995 data concerning the details of the activity profile (Figure 2). The peak at $\lambda_\odot = 139\overset{\circ}{.}63 \pm 0\overset{\circ}{.}06$ is obvious. The maximal ZHR obtained from the data stored in the *VMDB* is 170. It is very difficult to determine to which extent the higher figure of $r$ or the uncertainties of the counts themselves lead to an overestimate of the ZHR. Hence we want to restrict the conclusion to the fact that the outburst Perseids in 1995 showed a ZHR which is lower than the figures found from the 1994 analysis [4].

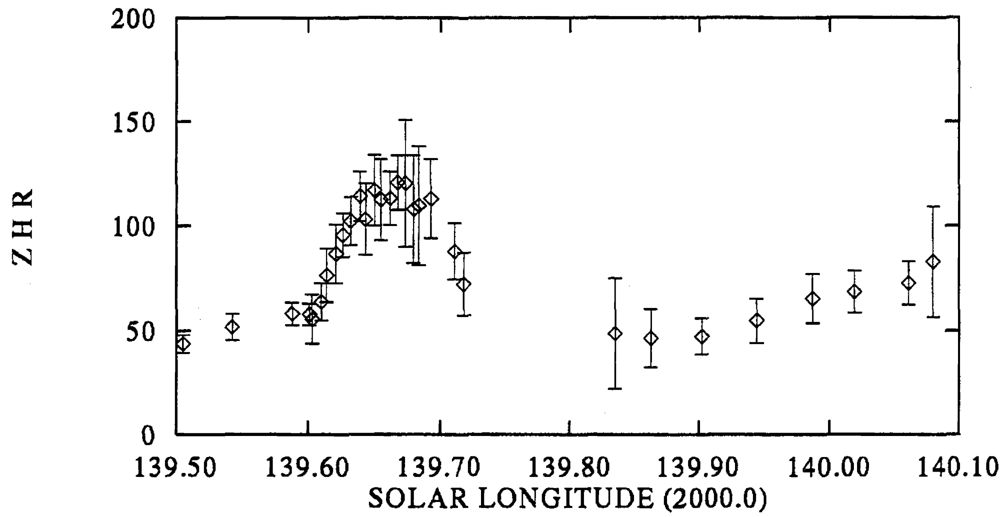


Figure 2 – Profile of the ZHR for the 1995 Perseid peak and the ascending branch to the "regular maximum." The small sample did not allow a better temporal resolution.

The typical profile of the peak as observed in the years 1991 to 1994, particularly well observed in 1993 and 1994, consisted of an ascending branch lasting for some hours, a short peak, and a quite rapid decrease of the ZHR [1]. Leaving out the value of 1992, average full width at half maximum (FWHM) was 0°11, or 2.8 hours.

Since the ascending and descending branches were different, we distinguish between the half widths at half maximum (HWHM) for the two periods. These are 0°06 (1.5 hours) and 0°04 (1.0 hours) for the ascending and descending branches, respectively.

The 1996 peak showed a slightly different shape (Figure 3).

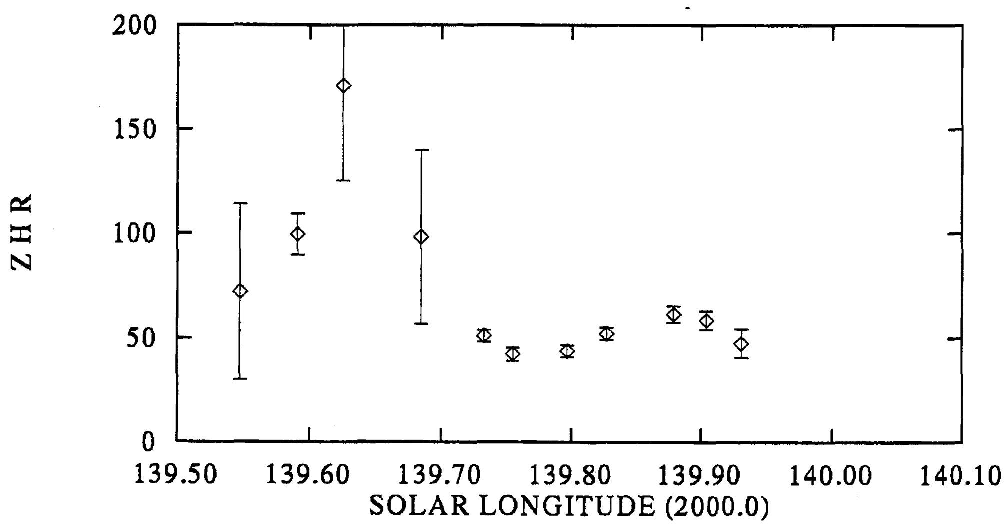


Figure 3 – ZHR profile of the 1996 Perseid peak and the ascending branch to the "regular maximum." The larger error bars during the peak period result from the scatter of the individual ZHRs of the short count intervals used here.

Until $\lambda_\odot = 139\overset{\circ}{.}55$, there was almost no increase in the ZHR, while, at $\lambda_\odot = 139\overset{\circ}{.}60$, an almost immediate rise has been reported. This ZHR rise coincided with the occurrence of a number of fireballs as well, but according to the magnitude data and the population index $r$ this part of the activity also included a large portion of fainter meteors. Here the ZHR reached a level of 120. Most interestingly, this enhanced ZHR lasted for more than one hour. The FWHM is almost 3 hours, the respective HWHMs are 1.3 and 1.7 hours for the ascending and descending branches again. This also shows the rapid increase of the ZHR mentioned above.

Although disturbed by moonlight and hence of less weight, we can detect a similar trend already in the 1995 data, when the duration of the ascending and descending branches was of about the same lengths, considering the HWHM values (see Figure 2).

If we use the FWHM as a measure for the width of the peak, we refer to a rate profile consisting of three components (see above). Since the ZHR of the background and core Perseids can be regarded as constant for each return, we suggest to use the width of the graph at a ZHR level above that of the other components as a measure for the width of the outburst component. This method also avoids errors caused by the uncertainty of the peak ZHR values, which may have been influenced by a possibly incorrect value of the population index $r$ *and* fluctuations in the observers' perception due to varying moonlight influences. We chose a ZHR of 80 as a reference level. This is sufficiently above the ZHR which occurred near the outburst peak position before the peak itself appeared, say before 1988. Except for 1990, where the ZHR of the peak remained below 80, the average duration of the period with a ZHR exceeding 80 is $0\overset{\circ}{.}20 \pm 0\overset{\circ}{.}12$ (about $5 \pm 3$ hours). The scatter of the individual values is remarkable, and there is no trend within the series between 1988 and 1996.

So, the main feature of the 1996 Perseid ZHR profile is the different relative duration of the ascending and descending branches as compared to the previous returns. The duration of the peak does not significantly differ from the 1991–1995 averages, neither in exceeding a given ZHR level nor considering the FWHM.

Table 1 – Summary of Perseid peak data for the period 1988 to 1994 [1] and this work. The 1990, 1992, and 1995 results should be considered as rough estimates only since these severely suffered from the full moon disturbance.

| Year | $\lambda_\odot$ (outburst) | $r$ | ZHR | $S_{6.5}$ | $\lambda_\odot$ (max) | $r$ | ZHR | $S_{6.5}$ |
|---|---|---|---|---|---|---|---|---|
| 1988 | $139\overset{\circ}{.}78 \pm 0\overset{\circ}{.}03$ | 2.0 | $86 \pm 4$ | $97 \pm 16$ | $140\overset{\circ}{.}08 \pm 0\overset{\circ}{.}04$ | 2.1 | $106 \pm 22$ | $94 \pm 14$ |
| 1989 | $139\overset{\circ}{.}56 \pm 0\overset{\circ}{.}03$ | 2.1 | $102 \pm 10$ | $127 \pm 23$ | $139\overset{\circ}{.}80 \pm 0\overset{\circ}{.}09$ | 2.1 | $94 \pm 6$ | $120 \pm 20$ |
| 1990 | $139\overset{\circ}{.}55 \pm 0\overset{\circ}{.}05$ | 1.8 | $75 \pm 10$ | $45 \pm 35$ | $140\overset{\circ}{.}54 \pm 0\overset{\circ}{.}2$ | 2.1 | $81 \pm 61$ | $66 \pm 5$ |
| 1991 | $139\overset{\circ}{.}55 \pm 0\overset{\circ}{.}03$ | 2.2 | $284 \pm 63$ | $494 \pm 150$ | $139\overset{\circ}{.}94 \pm 0\overset{\circ}{.}04$ | 2.1 | $97 \pm 2$ | $124 \pm 20$ |
| 1992 | $139\overset{\circ}{.}48 \pm 0\overset{\circ}{.}02$ | (2.1) | $220 \pm 22$ | $257 \pm 60$ | $140\overset{\circ}{.}13 \pm 0\overset{\circ}{.}2$ | 2.0 | $84 \pm 34$ | $96 \pm 15$ |
| 1993 | $139\overset{\circ}{.}53 \pm 0\overset{\circ}{.}01$ | 2.0 | $264 \pm 17$ | $242 \pm 62$ | $139\overset{\circ}{.}91 \pm 0\overset{\circ}{.}04$ | 1.9 | $98 \pm 5$ | $79 \pm 34$ |
| 1994 | $139\overset{\circ}{.}59 \pm 0\overset{\circ}{.}01$ | 1.8 | $238 \pm 17$ | $151 \pm 28$ | $139\overset{\circ}{.}84 \pm 0\overset{\circ}{.}04$ | 1.9 | $86 \pm 2$ | $69 \pm 12$ |
| 1995 | $139\overset{\circ}{.}62 \pm 0\overset{\circ}{.}05$ | (2.2) | $171 \pm 30$ | $290 \pm 90$ | $139\overset{\circ}{.}90 \pm 0\overset{\circ}{.}15$ | 2.1 | $65 \pm 20$ | $95 \pm 20$ |
| 1996 | $139\overset{\circ}{.}66 \pm 0\overset{\circ}{.}03$ | 2.0 | $121 \pm 17$ | $114 \pm 24$ | $140\overset{\circ}{.}08 \pm 0\overset{\circ}{.}04$ | 1.7 | $85 \pm 10$ | $76 \pm 20$ |

The high figure of the number density of meteoroids causing meteors of magnitude at least 6.5 ($S_{6.5}$ in Table 1) for the 1995 Perseid peak is probably an artifact caused by the value of $r = 2.2$ which has been discussed above. Since this is very uncertain, the number density itself is an upper limit at best. While there are known problems with the determination of limiting magnitudes under moonlit conditions, there are obviously further effects which reduce the value of such observations for detailed analyses. These effects are expected to act in a systematic way. One might think about perception differences particularly of meteors close to the given limiting magnitudes and about selection effects in the procedures to determine the population index $r$. It is known that counts of high, observable rates under good conditions suffer from a kind of saturation [5], whereas in the case of disturbance by moonlight the number of visible meteors remains low even during the peak period. We suspect that the derived ZHRs during the moonlight-disturbed periods are closer to an upper limit than under "regular" conditions.

## 4. Conclusions

Although the analysis of the 1996 Perseid return is based only on a part of the entire data becoming available later, the results should be expected to be quite close to the final values. This is particularly valid for the peak period, although there may be some fine structures in this time interval which can be derived from a larger sample.

The uncertainties of quantities obtained from moonlight-disturbed observations, such as 1992 and 1995, underline that such data can only be used for deriving upper/lower limits of some parameters. Obviously, there are systematic effects from the moonlight disturbance which are difficult to separate. It seems that both the meteor magnitude data (hence the population index $r$) and the limiting magnitude estimates (hence counts and ZHRs) are affected. Of course, the effects on the values of $r$ and the ZHR do also yield erroneous figures of the spatial number density $S$.

The average of the 1991–1994 outburst peaks yields HWHMs of the ascending and descending branches of 0°06 (1.5 hours) and 0°04 (1.0 hours), respectively. For the 1996 Perseid ZHR profile, we find a different relation between these branches with 1.3 hours and 1.7 hours, respectively. With caution, this can be suspected also from the 1995 data. However, the duration of the 1995 and 1996 peaks is not significantly differing from the 1991–1994 averages, neither in exceeding a given ZHR level nor considering the FWHM.

As shown in Table 1, the position of the peak varied from one return to the next. Some years ago, the changes in the position looked rather accidental, but seen the entire series as given in Table 1 (plotted as Figure 4), there seems to be a systematic decrease in the solar longitude from 139°78 in 1988 back to 139°48 in 1992, and a subsequent increase in the solar longitude of the peak arriving at 139°66 in 1996. The ascending node of the comet 109P/Swift-Tuttle is at 139°44 [6], hence the 1992 passage was the closest to the orbit of the Perseid parent comet. We also find the longest duration of the outburst peak in 1992: The ZHR exceeded 80 for 0°40, i.e. roughly 10 hours, and the FWHM was of the order of 7 hours. However, these figures have been derived from moonlight-disturbed data, and one should regard the values as additional information.

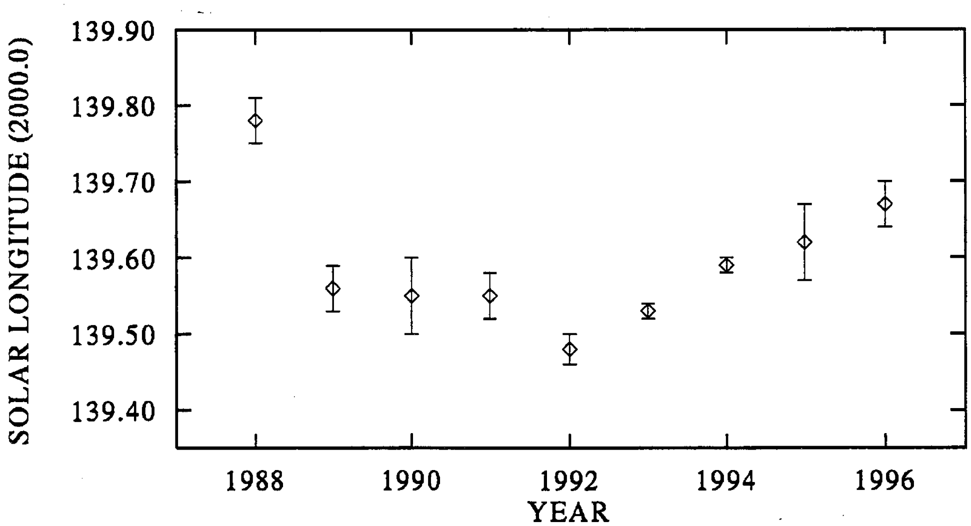


Figure 4 – Position of the outburst peak of the Perseids observed in the period 1988 to 1996. There is a systematic drift of the peak position towards the node of the Perseids' parent comet, 109P/Swift-Tuttle, at 139°44 until 1992, and a subsequent drift to a later position again until 1996.

Both the change in the solar longitude of the peak and the peak activity level indicate that the new peak might fall below the detection limit again within the next few years. Perhaps the solar longitude of the peak further increases, thus shifting the peak to a position with a higher ZHR of the core Perseids, making its detection even more difficult.

**Acknowledgments**

We wish to thank all observers who sent in their data very soon after the Perseids. This enabled us to present a reliable analysis based on a substantial sample already a few weeks after the event.

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# Review of the NAMN 1996 Perseid Program

*Mark Davis*

A review of the activities of the *North American Meteor Network* (*NAMN*) is presented for the 1996 Perseids. A summary of observing totals for August is included. In addition to providing 99.25 hours of observations in July, *NAMN* members submitted a total of 117.78 hours of Perseid observations during the month of August.

With the prospects of a favorable Moon and possible short-lived bursts of activity, the *North American Meteor Network* (*NAMN*) planned its largest effort yet for the 1996 Perseid meteor shower.

In the United States, media coverage prior to the shower made it possible to educate the public as well as collect scientific information. Dozens of e-mails were answered informing non-observers of the dates, times and fields that would best insure them a successful watch. The *Christian Science Monitor* contacted us wanting to collaborate on a summer science project for children between the ages of 10 and 14, the goal being to collect data about the Perseids. Many people wrote back with a report of their success with comments such as *...it was memorable...* and *...something none of us will ever forget.* The success of our educational program can best be expressed by those comments.

Of course, the main focus of our campaign was the coordination of observations. The *IMO* lists the Perseids as being active during the period July 17 through August 24, and *NAMN* observers were able to carry out observing programs over most of this period. During the month of July, for example, at least one observer was out on the mornings of July 14–21, 24, 27, and 28.