ISSN 1016-3115

wgn

26 - 2
april 1998

bimonthly journal of the international meteor organization

The photograph shows part of a 55° long light-purple Quadrantid fireball of magnitude -7 which appeared on January 3, 1998, at $23^h14^m50^s$ UT. The photograph was exposed from $23^h13^m14^s$ till $23^h16^m00^s$ UT by Valentin Grigore from Târgoviste, Romania, on 800 ASA Fuji film, using an $f/1.8$ 50 mm Pentacon lens. A persistent train was visible with the naked eye for 15 seconds.

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. 26, No. 2, April 1998, pp. 59–102

Contents

Useful Information

The June Issue *(WGN 26:3)*

The *June issue* will be a normal-sized issue which will be mailed during the last week of May. Contributions are due on *May 15* at the latest. They should be sent to *Marc Gyssens*.

Administrative Correspondence

Ordering *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 *Ina Rendtel*.

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

From the Editor-in-Chief

Marc Gyssens

The April issue was anticipated to be a normal-sized issue; because we received so many contributions, however, it grew into a thick issue. The articles in this issue are on a wide variety of topics, including observation sessions, the detection of meteor outbursts, the history of meteor astronomy, and the search for hitherto unknown meteorite craters.

The key article in this issue, however, is beyond doubt the global analysis of the 1997 Perseids. To this analysis, an impressive number of observers from an equally impressive number of countries contributed with their observations. Looking to this result and the evolution that led up to it, it is safe to say that the term "amateur meteor observers community" is no longer an abstract concept, but a really existing group of people.

Several initiatives contributed to this. More and more initiatives are taken to organize observers. The rapid proliferation of electronic communication makes it much easier to get in touch with each other. And, finally, there are the International Meteor Conferences *which allow observers to see each other face-to-face. Making publicity for an* IMC *to past participants is generally superfluous; those who did not yet attend an* IMC *and see the chance to do so in 1998, I strongly encourage to register. For their convenience, a registration form is included in this issue.*

Keeping the amateur meteor observers community alive, however, requires a lot of work, too, and it still remains the weak spot of our Organization that too much work is resting on too few shoulders... so if you feel like helping us, do not hesitate!

Erratum

Results of Forward-Scatter Radio Observations

Eisse Pieter Bus

Pieter Bus communicated to us the following erratum to his article which appeared in WGN *25:6, pp. 248–251.*

On p. 249, on the line above Figure 2, "more than 11 seconds" should read "more than 1 second."

The following note should be added to Figure 4 , *left*, on p. 251:

> In 1994, only long-duration reflections of more than 10 seconds were counted. Experience showed there are about 1.2 times more reflections of 7 seconds compared with 10-second reflections (the 1994 counts (open squares) are not corrected with this factor).
>
> In 1994 and 1995, the frequency was 72.11 MHz. In 1996, I was in Spain listening to the transmitter at Lousa in Portugal at a frequency of 87.9 MHz. Literature [4] gives an inverse quadratic relation between duration-time and frequency (a 7-second reflection at 72 MHz is about a 5-second reflection at 88 MHz).

(*The above note was omitted for reasons of lack of space.*)

We apologize to the reader for any inconvenience caused by the above-mentioned error and omission. (Ed.)

The 1998 International Meteor Conference

Stara Lesna, Slovakia, August 20–23, 1998

Daniel Očenáš and Peter Zimnikoval

The 1998 *IMC* will take place in Stara Lesna, in the High Tatra Mountains, Slovakia, from August 20 to 23, 1998. The *IMC* will be held in conjunction with two professional events: the International Conference *Meteoroids 1998* (August 16–21) and the Colloquium *Sources of Asteroids and Comets* (August 24–28). The *IMC* will be located in a hotel near the building of the *Astronomical Institute* of the *Slovak Academy of Science* (the professional events will be located in this place).

The full registration fee amounts to 170 DEM. This payment includes accommodation, meals, proceedings, and an excursion. The participants may send the full fee or a prepayment of at least 100 DEM to Ina Rendtel. Please use the form on the next page (or a copy of it if you do not want to damage your copy of this issue) for registering! For further questions, the authors, who organize the event, can be contacted at the e-mail address `hvezdar@isternet.sk`.

International Meteor Conference

Stara Lesna, Slovakia, August 20–23, 1998

Registration Form

Each individual participant should fill out a form and return it to *Ina Rendtel, Mehlbeerenweg 5, D-14469 Potsdam, Germany*, as soon as possible.

Your registration will be guaranteed only after Ina Rendtel has received the minimum pre-payment of 100 DEM. If you wish to participate, but cannot yet decide, simply return this form with the proper option checked to stay on the mailing list for further circulars.

Name: ______________________ Birth date: __________

Address: ______________________

____

____

Phone: __________ Fax: __________ E-Mail: __________

- ○ wishes to register for the 1998 *IMC* from August 20 to 23;
- ○ intends to participate, cannot yet register, but wishes to stay on the mailing list.

I intend to travel by ________, together with ______________________

Additional requests:

- ○ I need travel information from ______________ to Stara Lesna;
- ○ I wish to stay in Slovakia before or after the *IMC* and require additional information re. this matter.

For participants wishing to contribute to the program:

Lecture: ______________________

Duration: ________min. Required equipment: ______________________

Workshop or discussion: ______________________

Poster presentation: ______________________ Space: ________ m^2.

Either the entire fee of 170 DEM or a pre-payment of at least 100 DEM should be sent to the Treasurer, *Ina Rendtel*. Follow the payment instructions below. Participants paying only 100 DEM have to pay the remaining 70 DEM upon arrival in Stara Lesna.

Date and signature: ______________________

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

- in Europe: pay in DEM to Ina Rendtel, postal giro account number 547234107 at Postbank D-10916 Berlin, post office code 10010010. No bank checks, please! (Bank checks can only be sent to Robert Lunsford, see below).
- in the UK: 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 USD to Robert Lunsford, 161 Vance Street, Chula Vista, California 91910, USA. In case you pay by bank check, make it payable to Robert Lunsford, *not* the *IMO*!

People wishing to pay in other currencies should contact the appropriate IMO *contact person for exchange rates*

The 1997 Perseids

Global Analysis of the 1997 Perseids

Rainer Arlt

A total number of 79 730 Perseids seen by 520 observers in 5061^h observing time were available for a global activity analysis of the Perseids. The traditional maximum occurred over eastern Asian sites at $\lambda_\odot = 140\overset{\circ}{.}03 \pm 0\overset{\circ}{.}03$ (eq. 2000.0) with a maximum ZHR of 94 ± 2. The new filament, which has been observed since 1988, showed its maximum at $\lambda_\odot = 139\overset{\circ}{.}71 \pm 0\overset{\circ}{.}01$ with a ZHR of 137 ± 5. A third distinct activity peak was monitored by European observers at $\lambda_\odot = 140\overset{\circ}{.}35 \pm 0\overset{\circ}{.}03$ reaching a ZHR of 68 ± 5. When the ZHR profile is converted into a meteoroid flux profile using the population index profile, two distinct maxima before and after the traditional maximum occur, having about the same strength of about 0.02 $km^{-2}h^{-1}$. These maxima are rich in faint meteors.

1. Introduction

A fair First-Quarter Moon at low declinations spared observers lunar disturbances during the maximum of the 1997 Perseids. A whole week of brilliant weather covered the maximum nights at many European sites. Observers in the western US also enjoyed good conditions, whereas the eastern part saw some cloudy periods and rain. An impressive community of 520 observers from 28 countries monitored the Perseid activity between mid-July and the end of August. We are very grateful to the following observers for their efforts, as well as to those whose observations could not be used, because they were not lucky with the observing conditions:

S. Abdo, A. Al-Niamat, J. Ambroz, M. Andrejko, R. Arlt, J. Assmus, L. Babarikova, B. Baca, A. Bajc, L. Bakmann, L. Balint, A. Bankovic, M. Bares, L. Bastiaens, P. Becvar, G. Beeckman, P. Belov, P. Belak, P. Belcak, I. Benyo, L. Benner, R. Beres, R. Berg, V. Berlecky, F. Bettonvil, D. Bidlen, B. Biller, N. Biliškov, Z. Biliškov, L. Binder, M. Blaho, R. Blatak, R. Bödefeld, E. Bojurova, N. Bone, F. Bové, E. Brezina, M. Broncek, S. Broos, B. Brown, M. Broz, N. Bucek, A. Budovicova, M. Bujdos, I. Buljan, M. Cabala, P. Caillian, P. Campbell, A. Cervek, L. Cerveny, M. Cernak, A. Cesen, D. Chakarov, N. Chambers, P. Chladny, P. Ciljak, V. Cillik, O. Cioroianu, K. Cisar, K. Clement, M. Collier, B. Colyn, U. Cotar, H. Dalee, G. Deconink, W. Deconinck, J. de Hert, S. de Jonge, M. de Lignie, V. Desmarais, P. Detterline, M. Diallova, D. Dielen, L. Diko, M. Djordjevic, D. Dlhopolcekova, L. Dobrovoda, P. Dolinsky, I. Donik, D. Dotzinsky, T. Drăndeva, P. Drengubiak, R. Dreveny, J. Drga, M. Dujava, J. Dygos, O. Dzafic, T. Dziubiński, D. Edwards, F. Enzlein, F. Erben, B. Everaert, T. Fajfer, J. Fedor, L. Fekete, M. Fenovcik, D. Ferdinandy, R. Fernandez, K. Fialova, T. Fodor, R. Formanek, C. Foyt, A. Friebel, K. Fukui, N. Fukuda, Y. Fuyube, K. Gaarder, M. Gajos, V. Gajdos, R. Gehlhaar, M. Geltner, J. Gerboš, I. Getsova, B. Geys, T. Giguere, M. Gillis, G. Gliba, I. Goethals, R. Gorelli, L. Gramer, J. Griscik, M. Growe, E. Guetens, P. Gural, P. Habuda, M. Hadidi, C. Hall, J. Halkova, K. Halíř, W. Hally, H. Handjiiski, J. Hancar, K. Hanusova, T. Hansen, P. Harmady, T. Hashimoto, R. Haver, R. Hays, L. Heen, B. Heinrich, B. Held, A. Hemsy, B. Hendrickx, U. Henning, V. Herrygers, M. Hevesi, Z. Hevesi, T. Hillestad, W. Hinz, M. Hiriak, A. Hirv, D. Holman, R. Holodnak, N. Hontelé, D. Hostetter, S. Hribar, Z. Hrotekova, V. Hrušovský, D. Hubner, J. Hudecek, R. Hughes, M. Husnaj, R. Huziak, O. Iiyama, O. Imamura, C. Ishikawa, M. Isii, N. Ishiwata, D. Ito, M. Ivanović, P. Ivanov, K. Izumi, S. Izuhara, Y. Izuhara, V. Jankov, M. Jarski, M. Jedlicka, C. Johannink, W. Jonderko, H.-S. Jung, J. Kac, V. Kalas, K. Kamiński, M. Kania, P. Kanuk, J. Karabas, J. Kašparová, H. Kawaguchi, K. Kawabata, T. Kawasima, Á. Kereszturi, K. Kerekesova, M. Kereszteśsy, K. Kilkenny, L. Kirby, A. Knöfel, J. Kohout, H. Koide, Z. Komarek, K. Konsul, M. Konopka, M. Korec, R. Koromhaz, R. Koschack, D. Koschny, G. Koschny, N. Kosiyama, M. Kotur, A. Kovalova, J. Kovarik, J. Kozak, A. Krajčírová, A. Kratochvil, A. Krawietz, L. Krajci, L. Kral, D. Krcmarova, A. Kremzer, I. Krestianko, Ø. Kristiansen, V. Krumov, R. Kucman, T. Kucharski, G. Kudor, A. Kupco, Y. Kurosawa, P. Kušnirák, R. Kuschnik, M. Kwinta, J. Lacko, M. Lacko, M. Langbroek, A. Latkoczy, A. Latini, L. Lenza, M. Leuštek, M. Limpens, R. Liska, M. Litavsky, R. Löwenherz, R. Lunsford, H. Luthen, G. Maciejewski, K. Maeda, T. Maets, G. Mahres, S. Majnik, M. Mala, T. Malek, K. Mameta, R. Manak, T. Mancic, A. Marek, B. Martinak, J. dos Reis Martins, P. Martin, R. Marecek, J. Masiar, M. Maturkanic jr., Y. Matumoto, M. Mazak, A. McBeath, N. McLeod, S. McLeod, L. Mecir, R. Medlín, D. Metakhov, H.-J. Mettig, I. Miček, J. Micikova, V. Micu, P. Mikulka, R. Mikusinec, T. Miklos, I. Miljački, N. Milutinovic, V. Miovic, I. Miseje, J. Miskuf, K. Miskotte, H. Mizoguchi, J. Mocek, M. Mocak, H. Mokrisova, S. Molau, I. Momcheva, M. Morrow,

S. Mori, S. Moravcik, T. Morgan, M. Mraz, T. Morikawa, W. Murakami, J. Murin, M. Muraki, S. Nakayama, Y. Nakayama, T. Nasku, S. Näther, S. Nedeljković, K. Nicasi, D. Nikolic, M. Nitschke, T. Nonay, H. Nose, M. Novak, D. Ocenas, M. Odeh, I. Odwan, M. Oka, A. Olech, J. Olesen, J. Ondrus, P. Onufrak, A. Oreshonok, Z. Orsag, D. Ortmanns, E. Ortmanns, K. Osada, K. Osaki, K. Pagacova, P. Panda, A. Panos Moya, A. Papista, T. Pavlovic, L. Pekarik, S. Pelckmans, M. Penev, K. Perunska, L. Petersen, N. Petelin, K. Piekarzova, P. Pisara, R. Pitaluga, J. Plazar, H. Plott, I. Polakova, J. Polak, K. Popanastasov, M. Popović, L. Porozhanova, Ł. Pospieszny, Z. Pospechova, P. Potucek, L. Pozdisek, J. Prudič, M. Rankin, P. Rapavy, L. Rashkova, T. Rattei, A. Rendtel, I. Rendtel, J. Rendtel, P. Rendtel, J. Richter, J. Ridzyova, V. Rodiger, D. Rombauts, M. Rosseel, M. Rosina, M. Rudolph, V. Ruiz Ruiz, B. Ruzickova, S. Ruzicka, J. Sajdl, M. Sakaguchi, R. Sampson, J. Sandel, Ł. Sanocki, K. Sárneczky, K. Sato, T. Sato, T. Sato, M. Schmidhuber, T. Schreyer, R. Scurbecq, P. Sedlak, M. Sefara, H. Seifert, T. Sekiguchi, I. Sergey, M. Serra Martin, B. Shulist, G. Sill, H. Sioi, A. Skoczewski, I. Skokić, K. Skoczewska, M. Skreka, J. Škvarka, V. Slavković, J. Sližová, J. Sliz, L. Smahel, J. Smith, T. Sobczak, K. Socha, M. Sochan, J. Solomon, M. Solano Ruiz, A. Sosik, P. Spanik, J. Srba, J. Stancel, J. Stas, U. Stagno, J. Štefeček, J. Stehlik, K. Stefanikova, L. Steensgaard, S. Štefeček, C. Stijn, T. Satomi, E. Stomeo, S. Stomeo, W. Stone, E. Strivinska, N. Štritof, S. Sullivan, B. Susmak, E. Suskova, M. Sustr, M. Suzuki, P. Svozil, R. Svrcina, R. Sykora, A. Szaruga, G. Szasz, K. Szaruga, R. Szczerba, R. Taibi, H. Takiguchi, M. Takanasi, M. Takanasi, K. Tanaka, S. Tanaka, K. Tell, M. Tirpak, M. Tkacik, M. Toda, R. Togni, J. Tomcik, Y. Tonomura, T. Tornyos, D. Toth, T. Tóth, M. Trenn, G. Triglav, M. Triglav, J. Trigo Rodriguez, P. Trybus, S. Uehara, M. Uhlar, H. Ulbricht, J. Urban, D. Vajda, B. Vajdova, E. van Ballegoy, K. Van Beurden, M. Van den Broeck, H. Vandenbruaene, J. Vandenbruaene, G. Van de Weyer, K. van Gorp, S. Van Impe, M. Vanko, F. van Loo, P. van Loo, B. Van Opstal, C. Van Olmen, G. Van Olmen, J. Vansteelandt, A. van Weerden, P. Vargovic, J. Varju, V. Velkov, C. Verbeeck, J. Verbert, S. Veren, G. Vince, E. Vinceova, M. Vingerhoets, W. Vinken, A. Vlasaty, M. Vucelja, F. Wächter, S. Wächter, B. Wagner, G. Wagner, J. Wagner, T. Weiland, N. Werner, T. Westphal, B. Wilson, R. Winkler, G. Witzler, K. Wtorek, N. Wünsche, O. Wusk, Y. Yabu, S. Yanagi, H. Yamashita, N. Yamashita, Y. Yonekura, N. Yosimura, K. Yosino, K. Yosizaki, S. Žabić, J. Žaček, M. Zapletal, E. Zapletalova, H. Zaunick, G. Zay, M. Zibar, B. Zimnikovalova, M. Znášik, I. Zsolnai, and T. Żywczak.

The observers are from the following countries:

Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Germany, Gibraltar, Hungary, Italy, Japan, Jordan, Korea, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, United Kingdom, United States, and Yugoslavia.

Besides the traditional maximum around a solar longitude of $\lambda_\odot = 140°$, a new peak of variable activity has been observed since 1988, which is mainly associated with the perihelion passage of the parent comet, 109P/Swift-Tuttle. The position of this new peak was expected to occur several hours before the traditional maximum, at $\lambda_\odot = 139\overset{\circ}{.}71$ (eq. 2000.0), or August 12, 8^h30^m UT)[1]. We will refer to this maximum by the terms "first" peak or "new-filament" peak.

2. Method of analysis

The calculation of a population index profile should precede any serious ZHR calculation. The population index r describes the increase of meteor numbers from one magnitude class to the next fainter one, and is needed to correct observations with other than the standard limiting magnitude (lm) of 6.5. The r-value of the Perseids can be computed from the magnitude distribution when the perception probabilities for meteors of each magnitude are known. These probabilities were derived from a considerable meteor sample in [2].

Individual magnitude distributions should fulfill the following significance criteria:

- at least 5 magnitude consecutive classes should be filled with at least 2 meteors;
- the magnitude distribution should contain at least 15 meteors; and
- the faintest magnitude class should be at least 1.5 magnitudes from the limiting magnitude, since the correction for perception probabilities will be less reliable with numbers at the faint end of the magnitude distribution.

The meteor numbers observed per magnitude are converted into true meteor numbers using the perception probabilities. The population index results from the regression line through the logarithm of the true meteor numbers versus magnitude. The individual r-values are averaged for a population index profile.

The Zenithal Hourly Rate (ZHR) of a meteor shower at a certain time is calculated by

$$\mathrm{ZHR} = \frac{r^{(6.5-\mathrm{lm}-\Delta\mathrm{lm})} \times F \times n}{\sin h_\mathrm{R} \times T_\mathrm{eff}},$$

where r is the population index, lm the limiting magnitude, F the correction for obstructions of the field of view (clouds), n the number of shower meteors, h_R the radiant elevation, and T_eff the effective observing time. The value of Δlm corrects the observer's individual perception of meteors and must be derived in the course of the analysis. The correction for perception should not be confused with the perception probabilities which give the fraction of the true meteor number seen by a typical observer per magnitude class. In the case of correction of perception, we deal with the systematic, individual deviation in the total number of meteors seen.

In this analysis, the values of Δlm were derived from a ZHR profile computed without perception correction ($\Delta\mathrm{lm} = 0.0$). Periods of constant or slowly increasing activity were used to obtain several perception factors for each observer, considering the average ZHR as the true rate. These factors are then averaged and expressed as a difference in stellar limiting magnitude and meteor limiting magnitude, Δlm. The computation of perception from the ZHR profile is preferred to a calibration by sporadic rates, since the meteor numbers the ZHR profile is based on are much larger than the sporadic meteor numbers, which suffer considerably more from Poissonian errors.

Individual rates selected for the ZHR profile have to fulfil the following criteria:

- the radiant elevation must be higher than 20° above the horizon; and
- the total correction for limiting magnitude, sky obscuration, and zenith distance of the radiant must not exceed 5.0.

An empirical exponent in the zenith correction was suggested by Öpik [3]. The zenith correction factor he proposed is $\sin^\gamma h_\mathrm{R}$, with γ the so-called zenithal exponent. Bellot Rubio [4] and Koschack [5] showed that this exponent is close to 1.0 for visual Perseid data. Hence, we ignore the zenith exponent in our analysis; the lower limit for the radiant height prevents us from too large errors by doing so.

The averaging procedures for both the population index profile and the ZHR profile include an outlyer rejection algorithm. The position of the averaged value in the diagram is the mean solar longitude of the values involved in the average. All solar longitudes in this paper refer to equinox 2000.0.

3. Population index profile

The full profile of the population index between July 28 and August 16 is shown in Figure 1. Too few meteors were recorded before and after these dates to derive a reliable r-value. Most of the averages before the activity maximum lie between roughly 2.1 and 2.2, except for two fairly reliable values at $\lambda_\odot = 135\overset{\circ}{.}5$–$136°$ (August 8), when the population index drops to 2.03 ± 0.04. Whilst these points are based on 44 and 69 individual observations, respectively, the two higher values before are averages of only 21 and 23 observations, respectively. Such variations seem to be a feature of just one particular year, since, e.g., the 1989 profile [6] shows a significant increase in r up to 2.3 at the same time. The same holds for the 1992 profile, where r reached 2.5. In 1991, the population index was almost constant at 2.2 around $\lambda_\odot = 135\overset{\circ}{.}5$ [7].

Figure 2 shows a magnification of the population index profile between $\lambda_\odot = 138\overset{\circ}{.}2$ (August 10, 19^h UT) and $\lambda_\odot = 140\overset{\circ}{.}6$ (August 13, 7^h UT). A strong decrease of r down to $r = 1.80 \pm 0.04$ can be seen around $\lambda_\odot \approx 139\overset{\circ}{.}7$, where we expect the first, sharp activity peak to take place. No population index information is given at solar longitudes $\lambda_\odot = 139°$ and $\lambda_\odot = 140°$, since no magnitude distributions are available from Japanese observers. Hence, we have no r-value where the traditional maximum is expected. At $\lambda_\odot = 140\overset{\circ}{.}31$, a sharp peak in the population index reaches $r = 2.24 \pm 0.06$. This increase is linked with a feature in the activity profile described below.

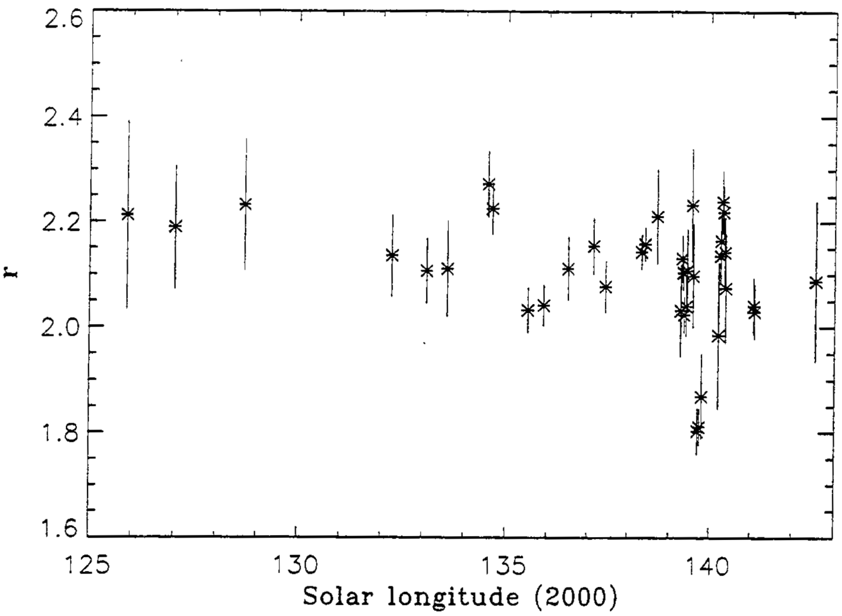

Figure 1 – Complete profile of the population index r of the 1997 Perseids.

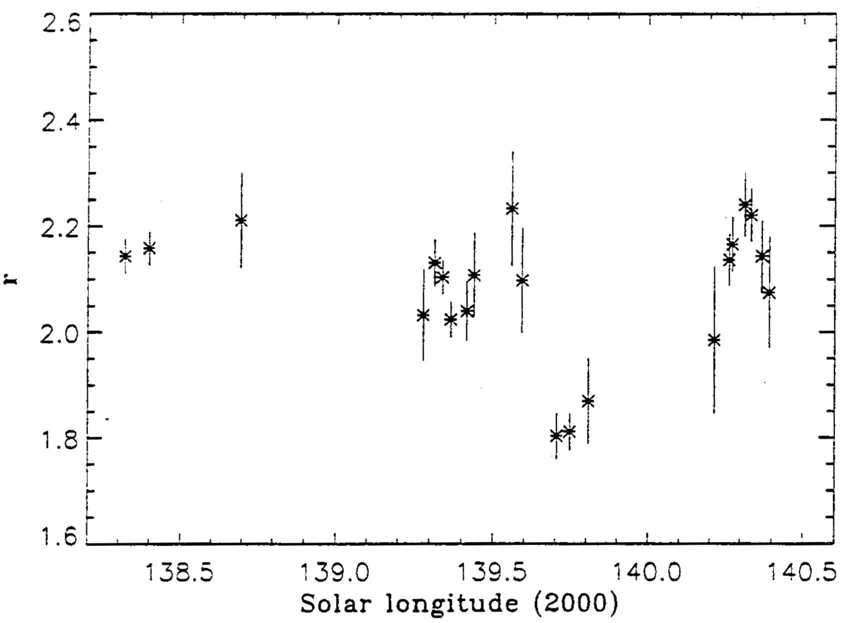

Figure 2 – Magnification of Figure 1 around the maximum of the 1997 Perseids.

4. ZHR profile

The activity profile of the Perseids includes the application of a personal perception correction which is derived from activity averages of periods with constant or only gradually changing activity. Since the perceptions of individual observers were computed within this analysis, they may be quite representative for the observers' capabilities *at that time*, but leave us with rather large uncertainties due to the limited sample. The correction values are given in Table 1: "Obs" is the number of perception estimates being averaged, c_p is the perception coefficient, which is the mean factor by which the observer deviated from the average ZHR, and Δlm is the resulting difference in meteor limiting magnitude and stellar limiting magnitude.

An alteration in the limiting magnitude is more appropriate than a correction factor, since observers usually differ in their abilities to detect faint meteors. Hence, their perception correction should depend on the r-value, which is properly reproduced by a Δlm. Positive values mean that the observer saw too many meteors, and that his or her actual meteor limiting magnitude is higher than what was given on the observing report. Negative values reduce the limiting magnitude estimate, since the observer saw too few meteors. Note that not all observers listed in the Introduction were active in the periods selected for perception estimates. Moreover, only observers with more than 3 perception estimates were selected.

Figure 3 shows the complete activity profile of the 1997 Perseids from $\lambda_\odot = 110°$ (July 12) to $\lambda_\odot = 152°$ (August 25). A minor increase of the ZHR up to values around 15 seems significant around $\lambda_\odot = 123°$ (July 24–26). Off-maximum features of major-shower profiles are difficult to interpret as they usually appear in only one year.

The main structures of the activity profile were already given in [8]. The most prominent feature in the detail of the activity profile shown in Figure 4 is the new Perseid peak at $\lambda_\odot = 139\overset{\circ}{.}72 \pm 0\overset{\circ}{.}01$ with a maximum ZHR of about 130. This activity level is not lower than the 1996 one, despite a gradual decrease between 1993 and 1996 [9,10].

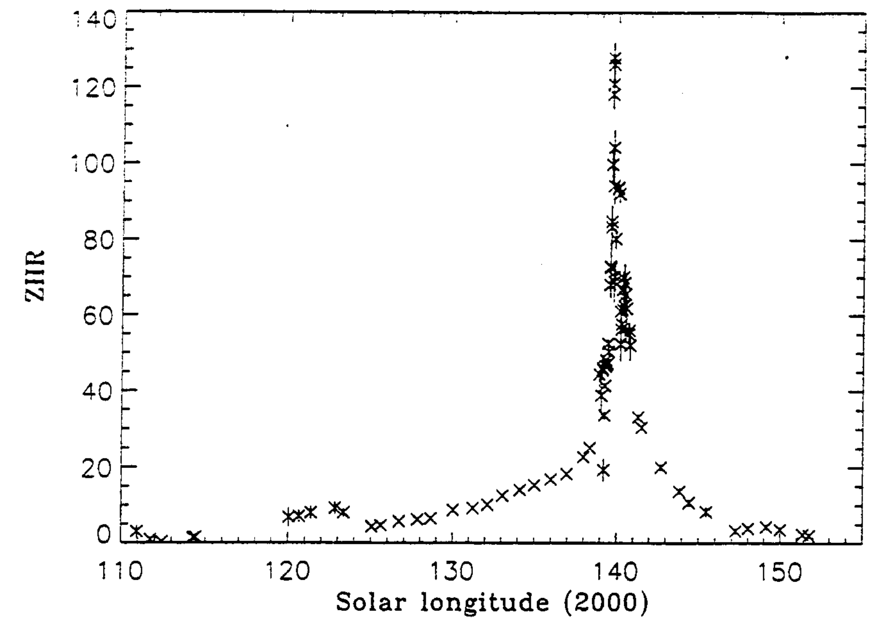

Figure 3 – ZHR-profile of the 1997 Perseids.

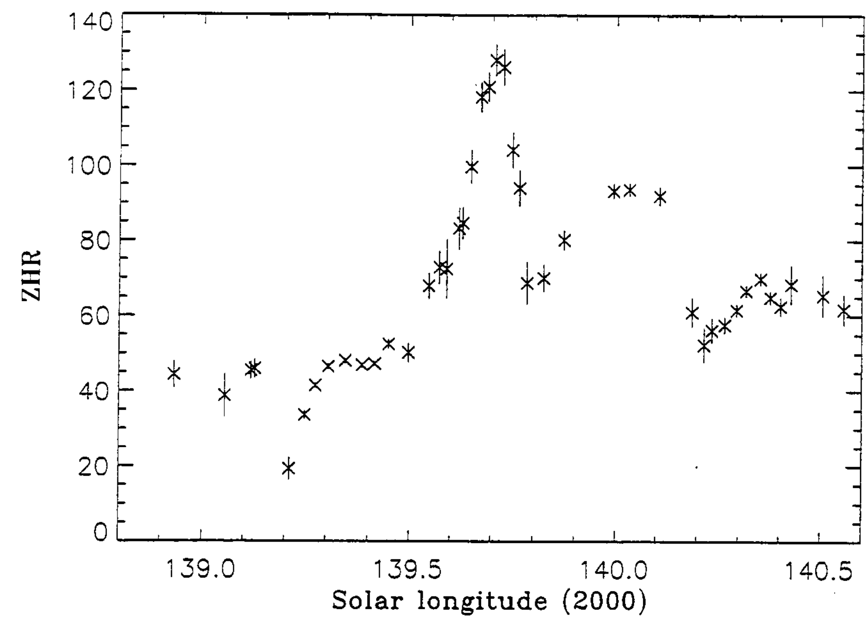

Figure 4 – Magnification of the ZHR profile of Figure 3 around the maximum of the 1997 Perseids.

Table 1 – Perceptions.

Observer	Obs	c_p	Δlm	Observer	Obs	c_p	Δlm
Abdo Sana'a	4	1.06	$+0.03 \pm 0.37$	Gerboš Jaroslav	20	1.34	$+0.38 \pm 0.22$
Al-Niamat Ahmad	4	1.46	$+0.51 \pm 0.18$	Giguere Tom	4	0.90	-0.16 ± 0.19
Ambroz Jaroslav	24	0.99	-0.05 ± 0.33	Gillis Maarten	10	0.87	-0.19 ± 0.21
Andrejko Marcel	6	0.91	-0.17 ± 0.34	Gliba George W.	4	1.33	$+0.35 \pm 0.33$
Arlt Rainer	27	1.12	$+0.08 \pm 0.42$	Goethals Ivan	12	1.02	$+0.02 \pm 0.13$
Assmus Joseph D.	8	0.92	-0.14 ± 0.10	Gorelli Roberto	4	0.99	-0.13 ± 0.63
Baca Branislav	18	1.00	-0.06 ± 0.40	Gramer Lew	6	1.46	$+0.46 \pm 0.44$
Bakmann Lars	6	1.45	$+0.50 \pm 0.16$	Griscik Jurai	8	1.36	$+0.35 \pm 0.41$
Balint Ladislav	6	1.40	$+0.46 \pm 0.13$	Growe Matthias	4	0.60	-0.71 ± 0.21
Bares Michal	28	0.55	-0.94 ± 0.66	Habuda Pavol	18	1.26	$+0.29 \pm 0.32$
Becvar Petr	12	0.61	-1.12 ± 1.25	Hadidi Muammar	8	1.29	$+0.35 \pm 0.10$
Belcak Pavol	4	0.49	-0.99 ± 0.30	Halkova Jaroslava	10	0.72	-0.85 ± 1.22
Benyo Igor	4	0.73	-0.53 ± 0.61	Hall Cathy	26	1.11	$+0.02 \pm 0.61$
Beres Rastislav	4	1.13	$+0.16 \pm 0.06$	Hally Wayne T.	4	1.21	$+0.26 \pm 0.16$
Berg Ray	15	1.23	$+0.18 \pm 0.54$	Hancar Jozef	10	0.90	-0.17 ± 0.32
Berlecky Viktor	16	0.58	-1.05 ± 1.00	Handjiiski Hristo T.	5	1.35	$+0.31 \pm 0.53$
Bidlen David	14	0.77	-0.59 ± 0.93	Hansen Torsten	6	0.82	-0.48 ± 0.87
Biliškov Nikola	4	0.61	-0.68 ± 0.05	Hanusova Katerina	24	0.86	-0.25 ± 0.35
Blaho Miroslav	11	1.10	$+0.11 \pm 0.25$	Harmady Peter	17	1.64	$+0.64 \pm 0.16$
Bödefeld Ragnar	16	0.95	-0.10 ± 0.31	Hashimoto Takema	18	1.16	$+0.18 \pm 0.40$
Bojurova Eva	20	0.61	-0.78 ± 0.64	Haver Roberto	12	0.88	-0.31 ± 0.63
Bone Neil	32	1.25	$+0.20 \pm 0.53$	Heinrich Bernd	6	1.36	$+0.39 \pm 0.36$
Bové Frederick	9	0.75	-0.44 ± 0.43	Held Branislav	4	1.49	$+0.54 \pm 0.13$
Brezina Emil	4	1.28	$+0.35 \pm 0.07$	Hemsy Ala'a	6	0.84	-0.28 ± 0.29
Broncek Michal	17	0.64	-0.64 ± 0.41	Henning Udo	19	0.88	-0.21 ± 0.32
Brown Bob	4	0.59	-0.89 ± 0.16	Hevesi Mónika	6	0.61	-0.71 ± 0.33
Broz Miroslav	4	1.43	$+0.47 \pm 0.27$	Hevesi Zoltán	6	0.62	-0.66 ± 0.11
Cabala Milos	4	0.82	-0.39 ± 0.66	Hiriak Mario	8	1.03	-0.01 ± 0.38
Cernak Milan	4	1.37	$+0.43 \pm 0.09$	Holodnak Rudolf	9	0.97	-0.12 ± 0.54
Cerveny Lukas	8	1.00	-0.11 ± 0.58	Hontelé Nathalie	4	0.78	-0.32 ± 0.10
Chakarov Decho	16	1.20	$+0.16 \pm 0.45$	Hribar Stanka	5	1.38	$+0.40 \pm 0.37$
Chladny Pavol	10	1.56	$+0.54 \pm 0.40$	Hrušovský Vladimír	10	1.08	$+0.04 \pm 0.47$
Cillik Vratislav	13	1.41	$+0.45 \pm 0.20$	Hubner Dusan	4	1.15	$+0.12 \pm 0.48$
Ciorolanu Ovidiu	15	1.35	$+0.35 \pm 0.37$	Hughes Robert	8	1.02	-0.12 ± 0.73
Collier Matthew	9	0.94	-0.12 ± 0.19	Husnaj Milan	4	1.00	-0.02 ± 0.19
Dalee Hani	4	1.30	$+0.35 \pm 0.03$	Huziak Richard	10	0.92	-0.17 ± 0.44
Deconink Goedele	17	0.68	-0.57 ± 0.42	Imamura Osamu	4	0.78	-0.39 ± 0.13
Diallova Monika	14	0.90	-0.23 ± 0.49	Ishikawa Chiaki	4	1.02	-0.12 ± 0.79
Dielen Didier	8	0.57	-0.95 ± 0.88	Ishiwata Noriko	4	1.09	$+0.12 \pm 0.20$
Diko Lukas	4	1.58	$+0.63 \pm 0.18$	Ito Daiyu	6	0.99	-0.03 ± 0.09
Dlhopolcekova Dagmar	11	0.68	-0.53 ± 0.30	Ivanov Peter	4	0.94	-0.09 ± 0.08
Dobrovoda Lubomir	8	1.01	-0.05 ± 0.43	Izuhara Sinitirou	7	0.89	-0.17 ± 0.06
Dolinsky Peter	4	1.19	$+0.16 \pm 0.53$	Izuhara Yumi	8	1.11	$+0.07 \pm 0.56$
Dotzinsky Doytchin	4	0.90	-0.25 ± 0.60	Izumi Kiyoshi	10	0.72	-0.50 ± 0.16
Drengubiak Peter	6	0.66	-0.62 ± 0.41	Jedlicka Miroslav	4	0.99	-0.03 ± 0.11
Dreveny Radek	6	0.66	-0.64 ± 0.46	Johannink Carl	39	1.59	$+0.60 \pm 0.23$
Drga Jozef	6	1.01	-0.13 ± 0.67	Jonderko Wojciech	21	0.55	-0.83 ± 0.25
Dujava Milan	10	1.28	$+0.32 \pm 0.26$	Kalas Vaclav	28	0.66	-0.64 ± 0.53
Dygos Jarosław	44	0.57	-0.82 ± 0.48	Kamiński Krzysztof	4	1.14	$+0.17 \pm 0.25$
Dzafic Oliver	14	1.63	$+0.62 \pm 0.23$	Kania Maciej	10	0.91	-0.50 ± 0.98
Enzlein Frank	10	1.58	$+0.61 \pm 0.21$	Kanuk Pavol	8	1.39	$+0.45 \pm 0.11$
Erben Frantisek	8	1.48	$+0.53 \pm 0.22$	Karabas Jan	22	1.51	$+0.52 \pm 0.30$
Everaert Bert	13	1.12	$+0.09 \pm 0.46$	Kašparová Jana	27	0.88	-0.23 ± 0.43
Fajfer Tomasz	40	1.42	$+0.43 \pm 0.33$	Kerekesova Katarina	6	1.24	$+0.29 \pm 0.15$
Fedor Juraj	20	1.05	-0.05 ± 0.54	Keresztessy Michal	12	0.96	-0.16 ± 0.58
Fialova Karolina	6	0.81	-0.50 ± 0.85	Kereszturi Ákos	6	0.90	-0.18 ± 0.25
Fodor Tamás	6	0.81	-0.44 ± 0.74	Knöfel André	4	0.84	-0.24 ± 0.02
Foyt Charles	6	0.58	-0.94 ± 0.37	Kohout Jan	4	0.74	-0.46 ± 0.31
Friebel Andrea	6	1.10	$+0.09 \pm 0.36$	Koide Hideki	4	0.82	-0.30 ± 0.15
Fukuda Nobuyuki	4	0.86	-0.26 ± 0.37	Komarek Zdenek	18	1.49	$+0.50 \pm 0.39$
Fukui Keiiti	5	0.65	-0.72 ± 0.68	Konopka Marcin	17	0.87	-0.27 ± 0.47
Gaarder Kai	4	1.09	$+0.11 \pm 0.17$	Konsul Khalil	4	0.59	-0.85 ± 0.68
Gajdos Vladimir	10	0.87	-0.31 ± 0.64	Korec Matej	12	1.66	$+0.62 \pm 0.41$
Gajos Marcin	4	1.37	$+0.43 \pm 0.07$	Koromhaz Ratislav	12	0.74	-0.52 ± 0.56
Gehlhaar Robert	12	0.47	-1.10 ± 0.57	Koschack Ralf	7	0.94	-0.09 ± 0.13

Table 1 – continued.

Observer	Obs	c_p	Δlm	Observer	Obs	c_p	Δlm
Koschny Detlef	8	1.71	$+0.70 \pm 0.24$	Odwan Ibrahim	4	1.08	$+0.08 \pm 0.31$
Kosiyama Nobuyuki	4	0.90	-0.17 ± 0.19	Oka Masayuki	12	1.21	$+0.29 \pm 0.17$
Kovalova Alzbeta	11	0.60	-0.97 ± 1.04	Olech Arkadiusz	33	0.95	-0.09 ± 0.19
Kovarik Jaroslav	23	0.80	-0.38 ± 0.56	Olesen Jens O.	8	0.85	-0.30 ± 0.51
Krajčírová Anna	7	0.92	-0.15 ± 0.35	Ondrus Jan	6	0.83	-0.29 ± 0.33
Kral Lukas	4	0.73	-0.44 ± 0.26	Onufrak Peter	13	0.67	-0.60 ± 0.37
Krawietz Andreas	20	0.56	-0.83 ± 0.38	Osada Kazuhiro	8	1.60	$+0.61 \pm 0.13$
Krcmarova Dita	12	0.92	-0.13 ± 0.26	Osaki Kazuhiko	6	1.05	$+0.01 \pm 0.38$
Krestianko Imrich	8	1.19	$+0.23 \pm 0.10$	Pagacova Katarina	4	1.06	$+0.04 \pm 0.48$
Krumov Vladimir	8	0.77	-0.38 ± 0.32	Panos Moya Andres Rafael	14	0.62	-0.86 ± 0.79
Kucharski Tom	6	0.68	-0.61 ± 0.62	Papista Adrian	6	1.45	$+0.50 \pm 0.24$
Kucman Roman	4	1.46	$+0.50 \pm 0.17$	Pekarik Ladislav	18	0.80	-0.43 ± 0.62
Kudor Gyöngyvér	6	0.80	-0.34 ± 0.25	Pelckmans Simon	7	0.59	-0.73 ± 0.37
Kupco Alexander	26	1.36	$+0.39 \pm 0.31$	Piekarzova Katerina	20	0.65	-0.65 ± 0.51
Kuschnik Ralf	21	1.28	$+0.30 \pm 0.30$	Pisara Peter	3	1.08	-0.11 ± 0.87
Kušnirák Peter	4	1.13	$+0.15 \pm 0.17$	Plazar Janja	4	1.66	$+0.67 \pm 0.25$
Kwinta Maciej	34	0.83	-0.28 ± 0.30	Polakova Ivana	4	1.03	$+0.01 \pm 0.33$
Langbroek Marco	27	1.38	$+0.39 \pm 0.35$	Popanastasov Kostadin	12	0.96	-0.21 ± 0.73
Lenza Libor	14	1.08	$+0.08 \pm 0.25$	Porozhanova Lilia	6	1.13	$+0.07 \pm 0.57$
Liska Robert	6	0.74	-0.42 ± 0.13	Pospechova Zuzana	12	0.72	-0.45 ± 0.17
Litavsky Milan	4	1.19	$+0.24 \pm 0.08$	Pospieszny Łukasz	10	0.45	-1.15 ± 0.37
Löwenherz Richard	11	1.48	$+0.49 \pm 0.34$	Potucek Peter	6	1.74	$+0.76 \pm 0.09$
Lunsford Robert	25	1.23	$+0.15 \pm 0.59$	Rankin Mel	4	0.82	-0.38 ± 0.52
Maciejewski Gracian	23	1.03	-0.02 ± 0.42	Rapavy Pavol	13	1.18	$+0.18 \pm 0.28$
Majnik Szabolcs	6	0.61	-0.68 ± 0.17	Rashkova Lina Hristova	8	1.32	$+0.32 \pm 0.29$
Mala Miroslava	23	0.72	-0.48 ± 0.38	Rendtel Andreas	8	0.66	-0.80 ± 0.63
Malek Tomas	4	0.96	-0.06 ± 0.12	Rendtel Ina	6	1.10	$+0.12 \pm 0.24$
Mameta Katuhiko	4	0.96	-0.10 ± 0.40	Rendtel Jürgen	18	1.32	$+0.39 \pm 0.30$
Manak Roman	6	0.53	-0.97 ± 0.56	Rendtel Petra	10	1.30	$+0.41 \pm 0.27$
Marecek Robert	8	0.93	-0.18 ± 0.49	Richter Janko	14	0.48	-1.03 ± 0.52
Marek Ales	14	1.44	$+0.40 \pm 0.48$	Ridzyova Jana	14	1.30	$+0.24 \pm 0.51$
Martin Pierre	34	1.35	$+0.35 \pm 0.36$	Rodiger Vanja	11	1.34	$+0.26 \pm 0.74$
Martinak Boris	8	1.46	$+0.50 \pm 0.07$	Rombauts Dirk	4	0.31	-1.62 ± 0.26
Maturkanic Michal jr.	4	0.38	-1.32 ± 0.18	Rosina Milan	4	1.23	$+0.27 \pm 0.12$
Mazak Miroslav	4	1.08	$+0.07 \pm 0.32$	Ruiz Ruiz Victor	6	0.60	-0.85 ± 0.66
McBeath Alastair	6	1.85	$+0.75 \pm 0.51$	Ruzicka Stefan	25	1.29	$+0.28 \pm 0.38$
McLeod Sherri	4	1.24	$+0.31 \pm 0.42$	Ruzickova Blanka	12	1.36	$+0.41 \pm 0.20$
Mecir Lukas	16	0.51	-1.08 ± 0.76	Sajdl Jaroslav	14	0.46	-1.83 ± 1.63
Medlín Rostislav	6	0.48	-1.59 ± 1.75	Sampson Russ	6	1.45	$+0.59 \pm 0.26$
Metakhov Dimiter	16	1.35	$+0.33 \pm 0.52$	Sandel Jeffery	4	0.95	-0.14 ± 0.46
Miček Ivo	6	1.14	$+0.14 \pm 0.35$	Sanocki Łukasz	6	0.74	-0.43 ± 0.31
Micikova Jana	4	1.30	$+0.35 \pm 0.12$	Sárneczky Krisztián	6	0.65	-0.60 ± 0.21
Micu Vasile	4	0.66	-0.62 ± 0.46	Sato Koetu	9	0.60	-0.71 ± 0.34
Mikulka Pavel	6	1.35	$+0.40 \pm 0.23$	Schreyer Thomas	4	0.73	-0.41 ± 0.16
Mikusinec Roman	10	1.10	$+0.09 \pm 0.35$	Scurbecq René	17	1.28	$+0.29 \pm 0.39$
Miljački Iris	4	0.98	-0.02 ± 0.07	Sedlak Peter	18	1.90	$+0.81 \pm 0.28$
Miseje Ivan	6	0.59	-0.95 ± 0.94	Sergey Ivan M.	11	1.40	$+0.38 \pm 0.39$
Miskotte Koen	44	1.24	$+0.27 \pm 0.22$	Shulist Brian	19	1.00	-0.05 ± 0.30
Mizoguchi Hidekatu	4	1.24	$+0.13 \pm 0.68$	Sill Godfrey	4	1.07	$+0.08 \pm 0.10$
Mocek Jan	4	0.62	-0.67 ± 0.04	Sioi Hiroyuki	6	0.76	-0.46 ± 0.44
Mokrisova Hava	12	0.59	-0.79 ± 0.41	Skoczewski Andrzej	10	0.99	-0.03 ± 0.23
Molau Sirko	27	1.18	$+0.21 \pm 0.13$	Skreka Marcel	6	0.72	-0.46 ± 0.11
Momcheva Ivelina	4	0.60	-0.71 ± 0.24	Slavković Vesna	15	0.99	-0.02 ± 0.15
Morgan Thom	10	0.95	-0.16 ± 0.48	Sliz Julius	8	0.94	-0.21 ± 0.70
Mori Sigehiro	4	0.92	-0.13 ± 0.16	Sližová Jana	8	1.15	-0.04 ± 0.98
Mraz Michal	6	1.04	$+0.04 \pm 0.20$	Smahel Lukas	9	1.56	$+0.60 \pm 0.13$
Muraki Minoru	12	0.79	-0.51 ± 0.74	Smith James N.	18	0.80	-0.40 ± 0.53
Nakayama Sin	4	0.33	-1.73 ± 0.09	Sobczak Tadeusz	28	1.04	$+0.02 \pm 0.32$
Nasku Tomas	6	0.49	-0.98 ± 0.09	Socha Krzysztof	10	0.97	-0.07 ± 0.33
Nedeljković Saša	4	1.14	$+0.17 \pm 0.25$	Sochan Milos	17	1.49	$+0.47 \pm 0.39$
Nitschke Mirko	4	1.27	$+0.32 \pm 0.06$	Solomon Jan	12	0.68	-0.77 ± 0.87
Nonay Terry	6	0.79	-0.42 ± 0.34	Srba Jiři	6	1.58	$+0.63 \pm 0.06$
Novak Matus	20	1.20	$+0.21 \pm 0.29$	Stancel Jan	6	1.14	$+0.06 \pm 0.61$
Ocenas Daniel	8	1.12	$+0.09 \pm 0.48$	Stefanikova Katarina	6	1.11	$+0.08 \pm 0.47$
Odeh Mohammad	7	1.33	$+0.39 \pm 0.12$	Štefeček Ján	6	0.98	-0.21 ± 0.80

Table 1 – continued.

Observer	Obs	c_p	Δlm	Observer	Obs	c_p	Δlm
Štefeček Svetozár	6	1.73	$+0.74 \pm 0.14$	Vandenbruaene Hendrik	7	1.20	$+0.24 \pm 0.23$
Stehlik Jaroslav	4	0.72	-0.47 ± 0.27	Vandenbruaene Jan	4	0.66	-0.59 ± 0.15
Stijn Calders	8	0.74	-0.41 ± 0.33	Vanko Martin	10	1.56	$+0.58 \pm 0.25$
Suskova Eva	19	1.38	$+0.40 \pm 0.37$	Vargovic Peter	6	1.24	$+0.23 \pm 0.49$
Sustr Matej	4	0.52	-0.91 ± 0.22	Varju Jozef	6	0.94	-0.10 ± 0.23
Suzuki Masafumi	13	1.31	$+0.41 \pm 0.09$	Velkov Valentin	9	1.13	$+0.12 \pm 0.27$
Svozil Pavel	4	0.87	-0.19 ± 0.10	Verbeeck Cis	10	1.31	$+0.34 \pm 0.32$
Svrcina Rudolf	4	1.67	$+0.69 \pm 0.08$	Verbert Jan	14	1.43	$+0.44 \pm 0.34$
Szaruga Konrad	20	1.31	$+0.31 \pm 0.36$	Veren Suzana	4	0.97	-0.12 ± 0.55
Szczerba Robert	41	0.93	-0.13 ± 0.30	Vince Gabriel	4	1.51	$+0.53 \pm 0.36$
Takanasi Masaaki	8	1.08	$+0.12 \pm 0.06$	Vingerhoets Myriam	6	0.66	-0.67 ± 0.65
Takanasi Mika	6	1.13	$+0.18 \pm 0.10$	Vucelja Marija	6	0.92	-0.16 ± 0.41
Tanaka Syoiti	8	1.08	$+0.11 \pm 0.18$	Wächter Sabine	6	0.62	-0.65 ± 0.20
Tell Khaled	7	1.26	$+0.30 \pm 0.14$	Wagner Bruno	4	1.44	$+0.49 \pm 0.13$
Toda Masayuki	4	0.73	-0.48 ± 0.01	Weiland Thomas	22	0.88	-0.22 ± 0.36
Tomcik Jiri	20	1.11	$+0.12 \pm 0.21$	Witzler Gudrun	4	1.39	$+0.45 \pm 0.17$
Tornyos Tomas	4	0.67	-0.58 ± 0.30	Wtorek Krzysztof	10	0.74	-0.55 ± 0.61
Toth Daniel	4	1.52	$+0.54 \pm 0.33$	Wünsche Nikolai	6	0.97	-0.11 ± 0.51
Tóth Tamás	6	0.67	-0.59 ± 0.31	Wusk Oliver	9	1.30	$+0.29 \pm 0.47$
Trenn Manuela	14	1.45	$+0.47 \pm 0.32$	Yabu Yasuo	11	0.75	-0.42 ± 0.14
Triglav Mihaela	8	0.99	-0.04 ± 0.33	Yanagi Sinitirou	4	0.82	-0.31 ± 0.22
Trybus Paweł	16	1.20	$+0.24 \pm 0.21$	Yonekura Yasuyuki	4	0.97	-0.04 ± 0.09
Ulbricht Heiko	4	0.35	-1.55 ± 0.70	Yosizaki Katuhiro	6	1.06	-0.14 ± 0.77
Urban Juraj	12	1.12	$+0.09 \pm 0.42$	Zapletalova Eva	6	0.67	-0.62 ± 0.48
Vajdova Bohdana	8	1.36	$+0.40 \pm 0.27$	Zaunick Hans-Georg	18	0.31	-1.66 ± 0.60
Van de Weyer Geert	10	0.73	-0.53 ± 0.60	Zay George	39	1.28	$+0.27 \pm 0.44$
van Loo Peter	8	1.24	$+0.24 \pm 0.36$	Zibar Martin	6	0.61	-0.71 ± 0.43
Van Olmen Christophe	4	0.46	-1.37 ± 1.15	Znášik Miroslav	17	1.03	-0.01 ± 0.35
Van Olmen Glenn	17	0.76	-0.39 ± 0.26	Zsolnai Imro	6	1.16	$+0.19 \pm 0.23$
van Weerden Anne	6	1.11	$+0.03 \pm 0.61$				

Figure 5 shows the details of the first Perseid peak, derived from observing periods no longer than 40 minutes. Although the averaging period is only about 30 minutes, the profile is still very smooth and has a maximum at $\lambda_\odot = 139\overset{\circ}{.}71 \pm 0\overset{\circ}{.}01$; the peak ZHR is 137 ± 5. It should be noted that this number represents the activity if peak rates would have lasted for 1 hour. In fact, the maximum lasted only about half an hour, whence the term "equivalent ZHR" (EZHR) would be more appropriate here [11].

The second strongest activity component is the broad traditional maximum at $\lambda_\odot = 140\overset{\circ}{.}03 \pm 0\overset{\circ}{.}03$, with a maximum ZHR of 94 ± 2. The actual level of activity may be altered by the true population index which is unknown as can be seen in Figure 3. The r-value is interpolated between the neighboring points at $\lambda_\odot = 139\overset{\circ}{.}8$ and $\lambda_\odot = 140\overset{\circ}{.}2$.

Finally, we observed a third slight increase of activity *after* the traditional maximum of the Perseids at $\lambda_\odot = 140\overset{\circ}{.}35 \pm 0\overset{\circ}{.}03$, reaching a ZHR of 68 ± 5. It should be noted that the peak was more prominent before the correction for individual observers' perception was applied.

Figure 6 shows the meteoroid flux per hour and square kilometer derived from the activity and population index profiles. This quantity refers to particles which produce meteors brighter than magnitude 6.5. The flux ϱ is very sensitive to the population index and varies roughly proportionately to r^2. High population indices cause higher fluxes than small r-values. The maximum flux of the first peak occurs about at $\lambda_\odot = 139\overset{\circ}{.}58 \pm 0\overset{\circ}{.}01$, which is $0\overset{\circ}{.}13$ (3 hours) before the ZHR peak. The ZHR gives the number of meteors an observer *sees* at lm = 6.5; for the flux, we need the *true* number of meteors up to magnitude 6.5. This is one of the reasons why the population index is again involved in the computation of fluxes, and the high r before the actual visible peak implies maximum meteoroid fluxes. The low r at the peak means that the observers did not "miss" too many faint meteors, because they were just less numerous.

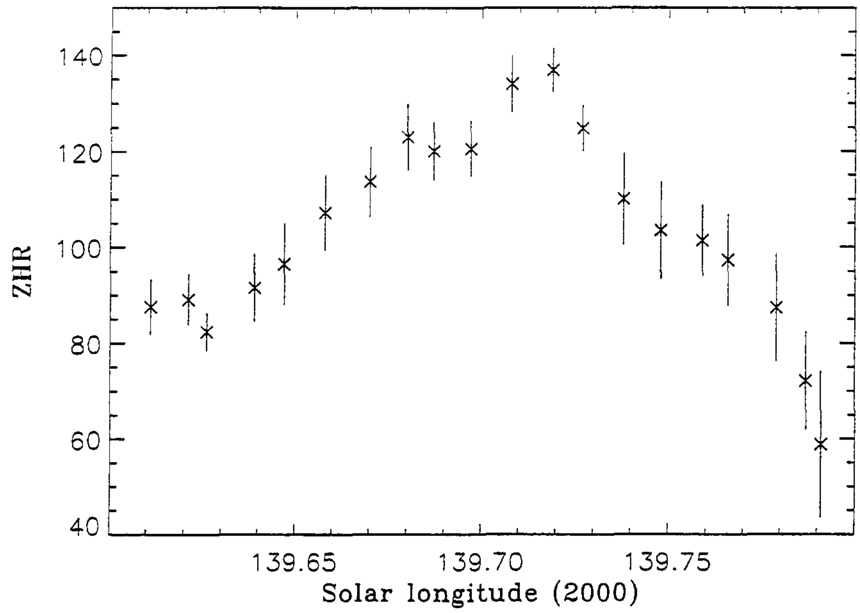

Figure 5 – Magnification of the ZHR profile at the first, sharp activity peak. Shorter averaging periods than in Figures 3 and 4 were used, whence the higher peak rates.

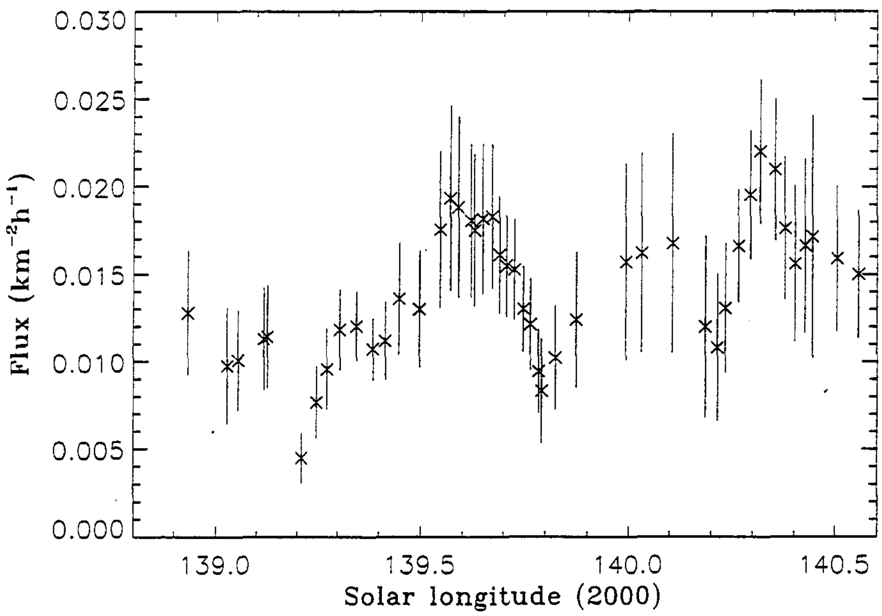

Figure 6 – Profile of the meteoroid flux of Perseid particles causing meteors brighter than magnitude 6.5.

The post-maximum increase, however, is well-pronounced in the flux profile, because of the relatively high population index of $r = 2.24 \pm 0.06$ at $\lambda_\odot = 140\overset{\circ}{.}31$. The peak is in fact of about the same level as the first peak. The flux strength at the traditional maximum is less significant, since we have no population index for that period.

5. Discussion

It is very astonishing how well the first peak of the Perseids was predicted, the difference being only $0\overset{\circ}{.}01$ (15 minutes) in solar longitude [1]. Fortunately, the peak ZHR was significantly underestimated, leaving us with the hope for future activity peaks from that stream component.

Another feature of the 1997 ZHR profile can be used to argue against this, however. The third, additional maximum at $\lambda_\odot = 140\overset{\circ}{.}35$ has not been observed in previous years. However, the

1989 profile shows a distinct shoulder of activity after the traditional maximum lasting until $\lambda_\odot = 140\overset{\circ}{.}5$. In the 1988 ZHR-profile, the traditional maximum was very broad and lasted until about $\lambda_\odot = 140\overset{\circ}{.}35$. These facts suggest that such a third activity increase accompanies both the first years of appearance of the new-filament peak as well as the last years when it is assumed to vanish. Consequently, we should be prepared to see nothing of the first peak anymore in one of the next years, probably in 1999.

A particle simulation of meteoroids ejected at the 1862 perihelion passage of Comet 109P/Swift-Tuttle by Wu and Williams [12] used three sets of orbital parameters of the comet to integrate the particle motion. The model with closest results to the observed rates between 1988 and 1997 indicates enhanced activity until the end of this century. The computation did not extend beyond 2000 AD.

The strong prominence of the post-maximum increase in 1997 may be due to a number of high-perception observers who were active in Europe on August 12-13. Although their influence was diminished by the perception correction, it might not have been compensated completely. Another explanation involves the population index which will also be affected by high-perception observers and which is not corrected by a similar limiting-magnitude shift Δlm. The easier detection of faint meteors moved the r-value up and affected the ZHR by too high lm-corrections (if lm < 6.5), despite the Δlm being correctly applied in the activity calculation. We computed another population index profile after a Δlm-correction in the magnitude distributions. In fact, some features change: the minimum in r becomes even more distinct with $r = 1.73 \pm 0.06$, but the r-dip at $\lambda_\odot \approx 135°–136°$ is much less prominent; the rest of the profile remains the same.

This way of population index correction is, however, based on ZHRs with the *uncorrected* r-profile. We should in turn recalculate the ZHR profile and derive new perception values. It becomes clear that we deal with an iterative process; such an analysis needs much more time and will not be given here. It may just be noted that the post-maximum increase remains distinct, but turns into a plateau between $\lambda_\odot = 140\overset{\circ}{.}3$ and $\lambda_\odot = 140\overset{\circ}{.}4$.

The lowest population index value, $r = 1.80 \pm 0.04$, occurs at $\lambda_\odot = 139\overset{\circ}{.}70 \pm 0.04$, coinciding with the first activity peak. This dip implies that the actual particle density in the Perseid stream (causing meteors brighter than magnitude 6.5) is much lower than the visual impression. Peak fluxes are found *before* the ZHR peak, very close to the passage time of the comet's orbital node. The high population index after the traditional maximum implies high fluxes at the third peak as well. Enhanced fluxes of about the same level before and after the traditional maximum are also present in the 1989 profile of spatial number densities (spatial number density is flux multiplied by geocentric velocity, a constant). We conclude the following:

- a twin structure can be observed in some years before and after the highest new-filament rates occurred, particularly in 1997;
- the first filament of the twin structure occurs at solar longitudes close to the node of the comet, the second filament occurs at solar longitudes of $140\overset{\circ}{.}3–140\overset{\circ}{.}5$;
- the twin structure seems to coexist besides the strong source of bright meteors observers enjoyed in 1991 to 1997; and
- the twin structure is rich in faint meteors.

The flux profiles for 1990 to 1996 should be revisited for traces of a similar twin structure besides the strong visual activity peak.

References

[1] R. Arlt, S. Molau, M. de Lignie, "Observers' Notes for the 1997 Perseids", *WGN* 25:3, June 1997, pp. 123–124.

[2] R. Koschack, J. Rendtel, "Determination of Spatial Number Density and Mass Index from Visual Meteor Observations (II)", *WGN* 18:4, August 1990, pp. 119–140.

[3] E. Öpik, "Analysis of 1436 Meteor Velocities", *Tartu Obs. Publ.* 30:5, 1940, pp. 3–86.

[4] L.R. Bellot Rubio, "Effects of a Dependence of Meteor Brightness on the Entry Angle", *Astron. Astrophys.* 301, 1995, pp. 602–608.
[5] R. Koschack, "Single Body Theory and Zenith Correction Factor", in *Proceedings IMC*, Belogradchik, 1994, pp. 31–43.
[6] R. Koschack, P. Roggemans, "The 1989 Perseid Meteor Stream", *WGN* 19:3, June 1991, pp. 87–98.
[7] R. Koschack, R. Arlt, J. Rendtel, "Global Analysis of the 1991 and 1992 Perseids", *WGN* 21:4, August 1993, pp. 152–167.
[8] R. Arlt, J. Rendtel, "First Analysis of the 1997 Perseids", *WGN* 25:5, 1995, pp. 207–209.
[9] J. Rendtel, R. Arlt, "Perseids 1995 and 1996—An Analysis of Global Data", *WGN* 24:5, 1996, pp. 141–147.
[10] P. Brown, J. Rendtel, "The Perseid Meteoroid Stream: Characterization of Recent Activity from Visual Observations", *Icarus* 124, 1996, pp. 414–428.
[11] J. Rendtel, "A First Global Analysis of the 1994 Perseids", *WGN* 22:6, 1994, pp. 205–209.
[12] Z. Wu, I.P. Williams, "The Perseid Meteor Shower at the Current Time", *Mon. Not. R. Astron. Soc.* 264, 1993, pp. 980–990.

An Analysis of the 1997 Perseids' Return in Poland

Arkadiusz Olech, Warsaw University Observatory

Visual observations of the 1997 Perseids are reported. Based on over 900 hours of observing time, an activity profile from July 15 to August 24 is given. The clear maximum of activity with a ZHR of 57.5 ± 3.1 was noted during the night of August 12-13, 1997. After averaging in shorter periods of time, we did not obtain any trace of the third maximum observed earlier by the *International Meteor Organization* observers. Also, the value of the population index r during this night is significantly larger than *IMO* estimates. Analysis of our 1995–1997 observations yielded confirmation of the presence of the wide plateau in the activity profile around $\lambda \approx 129°$ discovered by Olech [1].

1. Introduction

Since 1988, meteor observers worldwide are especially interested in the behavior of the Perseid stream. That summer, a new peak appeared in the Perseids' activity profile. Its activity was similar to that observed twelve hours later in the old and traditional maximum [2]. During the 1989 return, the situation did not undergo a change, but, in the years 1991–1993, the observed Zenithal Hourly Rates exceeded the level of 300 [3]. Rediscovery of the parent comet of the Perseid stream—109P/Swift-Tuttle—in 1992 clarified the situation.

Predictions made by Williams and Wu [4] showed that, in the years 1994–1997, we should expect activity decreasing from 250 to below 100. They were almost right. On August 12, 1994, at 11^h UT, observers in North-America estimated the Perseid activity around 250 ± 50 [5]. During the previously known maximum (hereafter called traditional or older maximum), European watchers noted a ZHR of 130 ± 44 [6]. In 1995, Ukrainian visual observers noted a ZHR of 160 ± 80 near 18^h UT on August 12 (solar longitude for eq. 2000.0 $\lambda_\odot = 139\overset{\circ}{.}64$) [7]. The year 1996 was very good for European observers. Predictions suggested that the higher maximum should have occurred on August 12 around 0^h UT with almost New Moon. These good conditions caused higher activity of Polish observers associated in the *Comets and Meteors Workshop* (*CMW*). From July 15 to August 25, 1996, a group of 50 *CMW* observers obtained 719^h14^m of observing time with 6706 meteors from the Perseid stream and 3505 sporadics. It was the most successful observing action in *CMW* history. We obtained a complete activity period profile with the new maximum at $\lambda_\odot = 139\overset{\circ}{.}64$ with a ZHR of 162 ± 26.

We also suggested the presence of a double maximum with the second peak occurring slightly after the first one at $\lambda_\odot = 139.^\circ66$, and detected a small dip near $\lambda_\odot \approx 129^\circ$ in the activity profile. For a more detailed discussion, see [1,8,9]. In addition, the older maximum with a ZHR of 85 ± 10 occurred at $\lambda_\odot = 140.08^\circ$ [9].

2. 1997 Observations

The second part of July 1997 was not good enough for meteor observers in Poland. The long-lasting period of rain fall between July 17 and 22 made it impossible to make any valuable observations. The situation in August, however, was completely different. Perfect weather conditions started around August 5 and lasted uninterruptedly till August 25. It allowed us to obtain many observational reports covering ideally the period near the maximum of activity. From July 15 to August 25, a group of 28 *CMW* observers obtained 937^h23^m of observing time (967 ZHR estimates) with 8273 Perseids and 5742 sporadics. The complete list of our observers with the corresponding effective observing times is as follows:

> Konrad Szaruga (141^h16^m), Jarosław Dygos (125^h51^m), Tomasz Fajfer (116^h00^m), Maciej Kwinta (67^h40^m), Robert Szczerba (66^h24^m), Arkadiusz Olech (55^h30^m), Wojciech Jonderko (42^h18^m), Marcin Konopka (42^h14^m), Gracjan Maciejewski (39^h45^m), Andrzej Skoczewski (34^h40^m), Tadeusz Sobczak (31^h20^m), Krzysztof Socha (25^h30^m), Marcin Gajos (24^h00^m), Paweł Trybus (22^h26^m), Krzysztof Kamiński (20^h58^m), Krzysztof Wtorek (18^h10^m), Artur Szaruga (14^h17^m), Łukasz Sanocki (11^h36^m), Maciej Kania (8^h43^m), Łukasz Pospieszny (5^h29^m), Katarzyna Skoczewska (5^h26^m), Michał Jurek (5^h00^m), Adam Pisarek (5^h00^m), Marcin Jarski (2^h42^m), Tomasz Żywczak (1^h54^m), Marek Piotrowski (1^h09^m), Marek Wojdat (1^h05^m), and Maria Woźniak (1^h00^m).

These over 900 hours of observations contain only good observations selected using our standard methods [10]. We required that the stellar limiting magnitude in the field of view had to be at least 4.80, the correction factor F resulting from clouds cover had to be smaller than 2.0, and the effective observing time of observations had to be at least 30 minutes.

3. Results

Magnitude distribution and evolution of the population index r

The good weather conditions in the wide vicinity of the maximum allowed us to collect as many as 8269 magnitude estimates for Perseids and 5714 for sporadic meteors. The final magnitude distributions (without a correction for the altitude of the meteor event) for the 1997 Perseids and sporadics are given in Table 1.

Table 1 – Magnitude distributions for the 1997 Perseids and sporadics.

Mag	-7^-	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	Tot
PER	12	12.5	24.5	39	65.5	150	338	620.5	1082.5	1514.5	1850.5	1621.5	789	144.5	4.5	8269
SPO	1	1	12.5	17	12.5	36.5	99.5	254	534	920	1398	1517	792	116.5	0.5	5714

Such a large amount of magnitude estimates for Perseids encouraged us to trace the behavior of the population index r defined as $r = \Phi(m+1)/\Phi(m)$, where $\Phi(m) = \sum_{-\infty}^{m} N(m)$ and $N(m)$ is the number of meteors of magnitude m corrected for probabilities of perception given by Koschack and Rendtel [11]. Results are presented in Figure 1. It is known that, far away from the night of maximum activity, values of r are about 2.6, and drop to 2.0 near that date. The behavior of r in 1997 was no exception to that rule. The clear minimum of r, with values of 2.10 ± 0.09, 2.09 ± 0.08, and 2.18 ± 0.08, was detected during the nights of August 10-11, 11-12 and 12-13, respectively.

The decrease of r values during the night of maximum is caused by a large amount of bright meteors observed around this time. It may appear obvious that, during the night of the maximum, we observed the brightest meteors, but, really, it is not. For example, the Quadrantid stream has two maxima, the first one only for faint meteors, and the second one for brighter events.

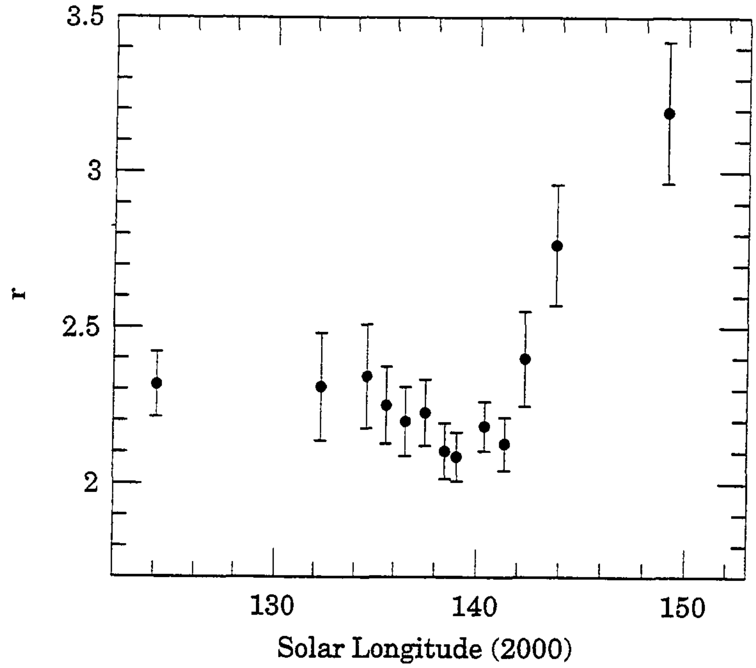

Figure 1 – Profile of the population index r for the 1997 Perseids.

In the more detailed profile of the population index r presented by Arlt and Rendtel [12], one can see two dips, the first one at $\lambda_\odot = 139.^\circ71$ with $r = 1.78$, and the second one at $\lambda_\odot = 140.^\circ4$ with $r = 1.87$. The first dip was not observed in Poland, because of the daytime, but the second one occurred exactly during nighttime, and its averaged value for the whole night is $r = 2.18 \pm 0.08$. This value is significantly higher than the one published in the abovementioned paper.

Activity profile around the maxima

Knowing the population index profile, we can compute ZHRs using the formula

$$\mathrm{ZHR} = \frac{r^{6.5-\mathrm{lm}}}{\sin^\gamma h_\mathrm{R}} \times N_h,$$

where lm is the limiting magnitude in the field of view, h_R is the altitude of the radiant of the stream, γ is the zenith exponent, and N_h is the observed number of meteors per hour (corrected for cloud coverage).

Although Jenniskens [13] obtained for Perseids $\gamma = 1.41$, Koschack [14] and Bellot [15] showed that, for visual observations with radiant altitudes higher than 20°, $\gamma \approx 1.0$. In our calculations, we adopted $\gamma = 1.0$.

The resulting activity profile of 1997 Perseids is shown in Figure 2. The maximum ZHR value of 57.5 ± 3.1 was noted during the night of August 12-13. This is not a high value. For comparison, the ZHR averaged for the whole night of activity on August 11-12, 1996, was 90.5 ± 5.2 [1], but, in 1996, the higher maximum was observed in Poland. In 1997, the highest ZHRs were noted by observers in North America at $\lambda_\odot = 139.^\circ72$ (August 12, $8^\mathrm{h}50^\mathrm{m}$ UT) with a ZHR of 137 ± 7. The traditional maximum with a ZHR of 105 ± 6 was observed by Japanese observers at about $\lambda_\odot = 140.^\circ0$ (August 12, 16^h UT) [12]. The sky at 16^h UT is still too bright to start useful observations in Poland, so in 1997 we could not observe any maximum.

A very interesting feature discovered by Arlt and Rendtel [12] was the presence of a third maximum in the activity profile of the 1997 Perseids. They noted ZHRs around 102 ± 8 at $\lambda_\odot = 140.^\circ32$, which corresponds $23^\mathrm{h}50^\mathrm{m}$ UT, a time very favorable for Central-European observers, including Polish watchers. So, we expected that this maximum should be detectable in our data. The point from August 12-13 in our activity profile in Figure 2 is the average value of almost 80 ZHR estimates. We decided to divide this point into shorter bins and check the results obtained by Arlt and Rendtel [12]. The same was done for the night of August 11-12. The result is shown in Figure 3.

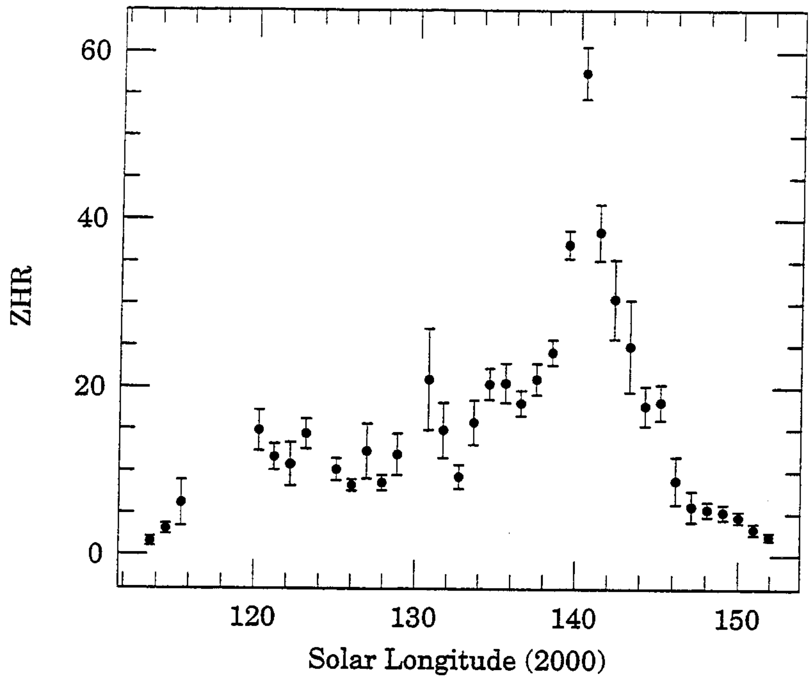

Figure 2 – Activity profile of the 1997 Perseids from July 15 to August 25.

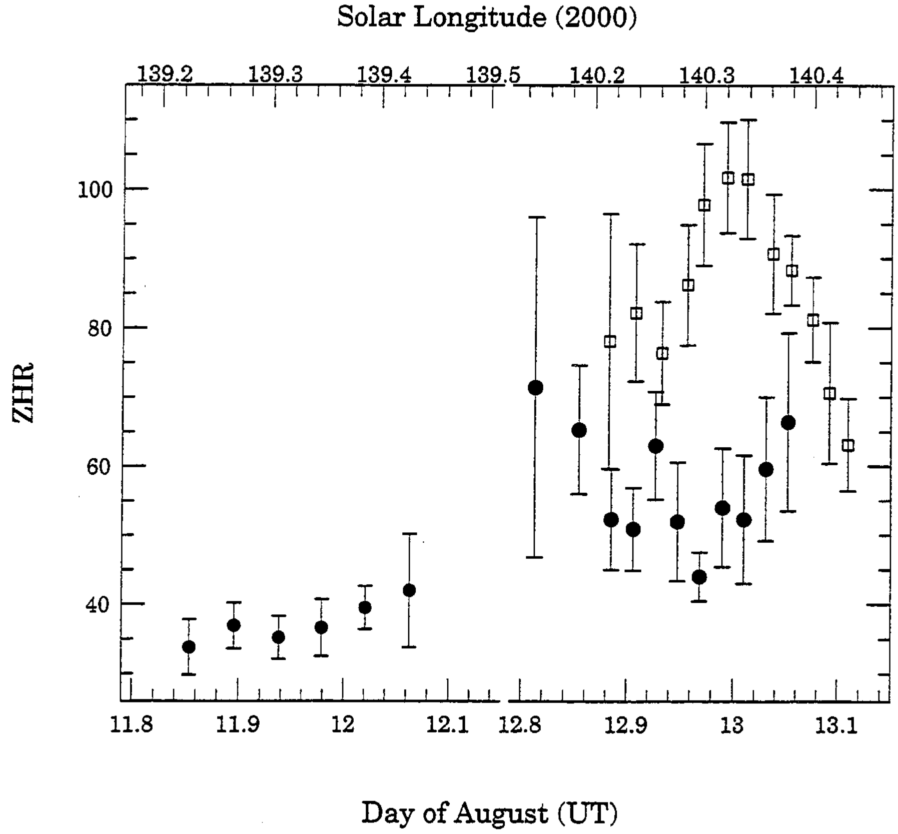

Figure 3 – The activity profile around the maximum of the 1997 Perseids. Filled circles denote *CMW* points and open squares represent *IMO* points.

During the first night, the ZHR rises from 34 ± 4 in the evening to 42 ± 8 in the morning. During the second night, the ZHR seems to oscillate chaotically around 60. In addition, the highest ZHRs around 70 were noted at the beginning and at the end of the night. At the moment when Arlt and Rendtel [12] noted the third maximum with a ZHR of 102 ± 8, we noted one of our lowest points for this night with a ZHR of 54 ± 9. The third maximum is not clearly visible in our data, and it is certainly not close to $\lambda_\odot = 140.^\circ 32$, but rather to $\lambda_\odot = 140.^\circ 4$, or even later.

Comprehensive investigation of the Perseid stream activity in the period 1988–1994 by Brown and Rendtel [16] showed that possible ZHR sub-maxima could appear around $\lambda_\odot = 140.^\circ2$–$140.^\circ3$ and $\lambda_\odot = 140.^\circ5$. The first moment strongly supports Arlt and Rendtel's [12] result, and the second one agrees with our estimate.

Arlt and Rendtel [12] also noted a clear dip of the population index r around the moment of the third maximum. For $\lambda_\odot = 140.^\circ4$, their r-value is 1.87. Our r-value averaged for the whole night of August 12-13 is 2.18 ± 0.08, which is significantly larger than Arlt and Rendtel's estimate.

This whole situation is very strange. Arlt and Rendtel [12] observe the third maximum in connection with a clear minimum of r, and *CMW* does not observe any maximum at that moment, and, additionally, obtains a larger value of r. It seems like both teams observed different streams...

Based on the methods described by Koschack and Rendtel [11] and Brown and Rendtel [16], we computed the spatial number densities of the meteor events. The spatial number density of meteors of magnitude at least 6.5 for our maximal value of ZHR of 57.5 ± 3.1 on August 12-13 is $\rho(m \leq 6.5) = 80 \pm 13$ particles/10^9 km^3. For the traditional maximum, Brown and Rendtel [16] obtained $\rho(m \leq 6.5) = 96 \pm 16$ particles/10^9 km^3, averaging data from the period 1988–1994. Taking into account that we did not observe exactly during the traditional maximum, but slightly later, our estimate is consistent with the result obtained by Brown and Rendtel.

Activity profile around $\lambda_\odot = 128°$

Analyzing the activity profiles of the 1995 and 1996 Perseids, Olech [1] found a clear minimum of activity around $\lambda_\odot = 129°$. The large amount of 1997 Perseid data in our database encouraged us to perform a more detailed analysis of the Perseids' activity near that moment. We used observational material of *CMW* from the last three years. The results are presented in Figure 4. It is clear that the activity of the stream increases linearly with similar slope in the periods $\lambda_\odot = 118°$–$123°$ and $\lambda_\odot = 131°$–$136°$. Between these two periods, i.e., from $\lambda_\odot = 124°$ to $\lambda_\odot = 131°$, we detected clear change of the ascending branch of the activity profile. There is no clear minimum anymore around $\lambda_\odot = 129°$, as was previously suggested by Olech [1], but rather a *plateau* between $\lambda_\odot = 124°$ and $\lambda_\odot = 131°$.

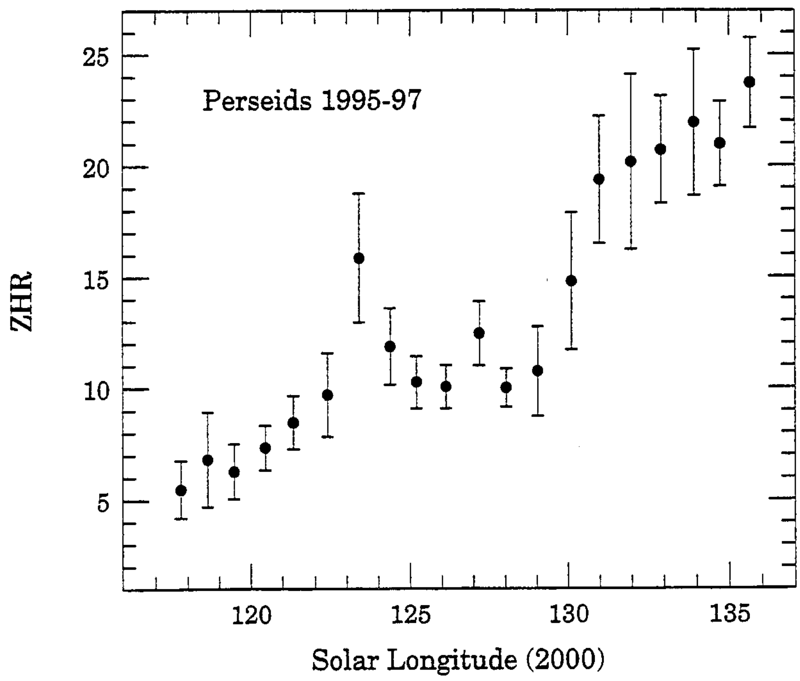

Figure 4 – Mean activity profile of the 1995–1997 Perseids with clear *plateau* between $\lambda_\odot = 124°$ and $\lambda_\odot = 131°$.

Looking at the complete activity profile presented in Figure 2, one can detect two different components. The first one is the background component characterized by weak activity and extending from $\lambda_\odot = 115°$ to $\lambda_\odot = 150°$. In the range $\lambda_\odot = 115°–137°$, the activity increases slowly. Around $\lambda_\odot = 138°$, the background component encounters the core component connected with the traditional maximum. The core component is slightly asymmetrical, with slower increase and steeper decrease of activity. Modeling the overall activity of Perseids based on returns of the parent comet 109P/Swift–Tuttle during the last 160 000 years, Harris et al. [17] obtained a theoretical activity profile which contained all the abovementioned features. Their model predicted also several strong secondary maxima occurring before the traditional maximum. The highest of such secondary maxima should occur around $\lambda_\odot = 125°$ and last several days. In Figure 4 the minimum around $\lambda_\odot = 129°$ reported by Olech [1] or the *plateau* discussed above may be a result of such a sub-maximum close to $\lambda_\odot = 125°$. From Figure 4, the center of such a sub-maximum is rather near $\lambda_\odot = 123\overset{\circ}{.}5$ than around $\lambda_\odot = 125°$. In spite of this small difference, it is obvious that both the theoretical results obtained by Harris et al. [17] and the observational results presented in this paper are consistent.

4. Discussion

The observational campaign for the 1997 Perseids was the most successful observational action in *CMW* history. We collected over 900 hours of observing time. Taking into account the fact that, each year, the *IMO* obtains around 5000–7000 hours from observers from many countries, and that the 1997 Perseid campaign is only a part of *CMW* activity in 1997, *CMW* may become the most active meteor group in the world.

Such a large amount of data allowed us to obtain a few valuable results. The graph showing the evolution of the population index r exhibited the clear and wide minimum around the nights of August 10-11, 11-12, and 12-13, with values between 2.0 and 2.2. In the remaining part of the activity period, the population index was closer to the typical value of 2.6. Such low values of r during the time of maximum activity suggest the presence of a large number of larger bodies in the central parts of the ribbon of meteoroids belonging to the Perseid stream.

Using the obtained values of the population index r, we plotted a precise activity profile for the whole period of activity of the Perseid stream. Due to bad weather conditions, a lack of the observations between July 18 and 22 ($\lambda_\odot = 116° - 120°$) caused the presence of a small gap in our activity profile. The maximum ZHR of 57.5 ± 3.1 was noted during the night of August 12-13. Such low values are caused by observing the activity of the descending branch after both maxima. According to Arlt and Rendtel [12], the new peak was detected at $8^{\rm h}50^{\rm m}$ UT on August 12 ($\lambda_\odot = 139\overset{\circ}{.}72$) and the traditional maximum around $16^{\rm h}$ UT ($\lambda_\odot = 140\overset{\circ}{.}0$).

Investigating the activity of the 1997 Perseids around both maxima with higher time resolution, we did not detect any trace of the third maximum reported by Arlt and Rendtel [12] around $\lambda_\odot = 140\overset{\circ}{.}32$. Our estimates of the population index r around this moment are also significantly higher than Arlt and Rendtel's results.

In order to check our hypothesis in [1] concerning a possible minimum of activity around $\lambda_\odot = 129°$, we analyzed *CMW* data from the last three years. We detected a wide *plateau* between $\lambda_\odot = 124°$ and $\lambda_\odot = 131°$, or a sub-maximum around $\lambda_\odot = 123\overset{\circ}{.}5$, instead of the minimum around $\lambda_\odot = 129°$. Our results confirm the theoretical models of Harris et al. [17]. They suggested the presence of the strong secondary maximum of activity around $\lambda_\odot = 125°$.

The spatial densities of the meteor bodies computed from our observations gave values similar to estimates obtained in previous years [9,16].

Acknowledgments

I would like to thank all observers who sent me their observations. I am especially grateful to Prof. Jerzy Madej for helpful discussions, reading, and commenting on the manuscript. This work was partially supported by KBN grant no. 2 P03D 020 11 to A. Olech.

References
[1] A. Olech, *Astron. Astrophys.* 325, 1997, p. 1249.
[2] P. Roggemans, *WGN* 17, 1989, p. 125.
[3] J. Rendtel, *WGN* 21, 1993, p. 235.
[4] I.P. Williams, Z. Wu, *MNRAS* 269, 1994, p. 524.
[5] J. Rendtel, *WGN* 22, 1994, p. 205.
[6] A. Olech, P. Woźniak, *Earth Moon and Planets* 73, 1996, p. 1.
[7] J. Rendtel, *WGN* 23, 1995, p. 115.
[8] A. Olech, *WGN* 24, 1996, p. 149.
[9] J. Rendtel, R. Arlt, *WGN* 24, 1996, p. 141.
[10] A. Olech, P. Woźniak, *Earth Moon and Planets* 73, 1996, p. 157.
[11] R. Koschack, J. Rendtel, *WGN* 18, 1990, p. 54.
[12] R. Arlt, J. Rendtel, *WGN* 25, 1997, p. 207.
[13] P. Jenniskens, *Astron. Astrophys.* 287, 1994, p. 990.
[14] R. Koschack, in *Proceedings of the IMC*, Belogradchik, A. Knöfel, P. Roggemans, eds., 1994, p. 31.
[15] L.R. Bellot Rubio, *Astron. Astrophys.* 301, 1995, p. 602.
[16] P. Brown, J. Rendtel, *Icarus* 124, 1996, p. 414.
[17] N.W. Harris, K.C.C. Yau, D.W. Hughes, *MNRAS* 273, 1995, p. 999.

Ongoing Meteor Work

Outburst of Activity of the α-Aurigid Meteor Shower

Alexandra Terentjeva, Institute of Astronomy, Russian Academy of Sciences

On December 12-13, 1996, Russian observers in Krasnotur'insk in the Ural Region witnessed an outburst of meteors from a radiant at $\alpha = 78\overset{\circ}{.}8$ and $\delta = +43\overset{\circ}{.}0$, which may be associated to the α-Aurigds (no. 77 in the author's Fireball Stream Catalogue [2,3]). Maximum activity was reached on December 12, 21^h–22^h UT, with a ZHR of 110, corresponding to a spatial number density of 71×10^{-9} km^{-3}.

Krasnotur'insk (Ural Region, Russia) is the location of the astronomical club "Pole Star." Most members of this club are secondary school students (see Figure 1). Altogether, there are about 40 members, who observe comets, meteors, variable stars, and eclipses. L. Makushina leads the club for 22 years, now. The club has a number of sufficiently experienced meteor observers amongst its members. They reported their observational results concerning the Perseids, Leonids, Geminids, and other meteor showers at Russian conferences, in the transactions of which their papers were published.

During their observations of the Geminid meteor shower on December 12-13, 1996, the members of "Pole Star" detected a very active shower of bright meteors from a radiant at $\alpha = 78\overset{\circ}{.}8$ and $\delta = +43\overset{\circ}{.}0$ [1]. This radiant can be associated with the α-Aurigid fireball shower no. 77 from the catalogue by the present author [2,3]. The orbital elements (eq. 1950.0) and other parameters of α-Aurigids from this catalogue are shown in Table 1. The study of the α-Aurigid fireballs shows that the radiant area of the shower has a diameter of 6°.

Table 1 – Data on the α-Aurigids (eq. 1950.0) from Terentjeva's Fireball Stream Catalogue [2,3] (V_∞ in km/s; q and a in AU).

No	Stream	Period	α	δ	V_∞	q	a	e	i	ω	Ω
77	α-Aurigids	December 19–31	85°	+42°	22.5	0.694	2.365	0.700	$11\overset{\circ}{.}2$	$253\overset{\circ}{.}6$	$274\overset{\circ}{.}0$

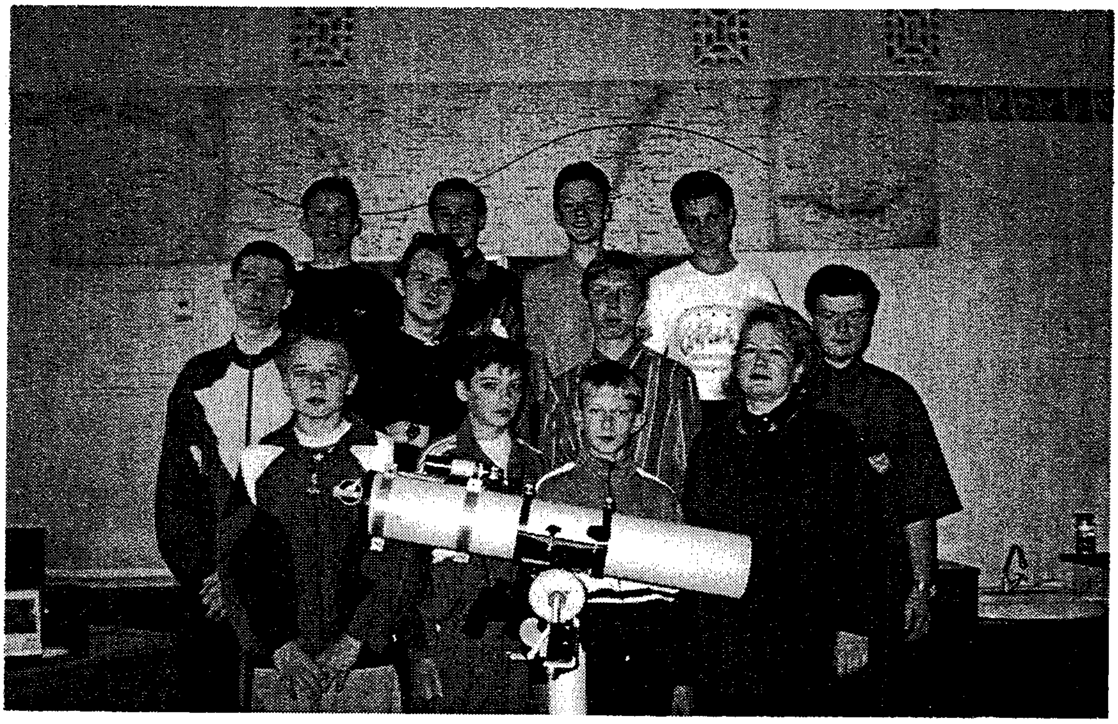

Figure 1 – Members of the astronomical club "Pole Star" in Krasnotur'insk in the Ural Region. The leader is L. Makushina (on the right).

A group of 5 persons (D. Golov, A. Derbichev, P. Kazantsev, A. Majer and L. Makushina) carried out the observations of the α-Aurigids using the "multiple skilled counting" method in a limited region of the sky near the zenith. The diameter of this area of the sky was 60°.

L. Makushina informed me that on December 12, from 18^h UT onwards, "clusters" of meteors, in other words several meteors simultaneously, emanated from the radiant of the α-Aurigids. The number of meteor clusters was growing from hour to hour. In the interval 21^h00^m–22^h36^m UT, 29 meteor clusters were observed. About 80% of the shower meteors had apparent magnitudes 0 or 1. On December 13, the activity of meteor clusters had steeply decreased. Maximum activity of the α-Aurigids occurred on December 12, from 21^h to 22^h UT. During this hour, the relative activity of shower amounted to 77%, and the zenithal hourly rate of the α-Aurigids reached values up to 110, corresponding to a spatial number density of 71×10^{-9} km^{-3} and an average distance between the particles in the stream of 241 km. The data cited above were obtained by L. Makushina. She will publish more complete information in Russian.

So, the α-Aurigid meteor shower contains both ordinary bright meteors and fireballs, and can be observed during December 12–31. A characteristic feature of this shower are meteor "clusters." In 1996, the shower had a sharp outburst of activity. On the average, the activity of α-Aurigids superseded the activity of the Geminids by a factor 1.2.

The observers claim they have never seen a meteor shower more brilliant and more exciting than this one.

References

[1] L.A. Makushina, *personal communications*, December 1996.

[2] A.K. Terentjeva, "Fireball Streams", *WGN* 17:6, December 1989, pp. 242–245.

[3] A.K. Terentjeva, "Fireball Streams", in *Proc. Asteroids, Comets, Meteors III*, C.-I. Lagerkvist, H. Rickman, B.A. Lindblad, M. Lindgren, eds., Uppsala, 1990, pp. 579–584.

First Results of Global-MS-Net: Annual Report for 1997

Peter Jenniskens, NASA/Ames Research Center

Global-MS-Net is a new network of forward meteor-scatter stations built and operated by amateur radio observers. The network was founded during 1997 after years of preparation. Here, we present the first year's meteor counts from seven participating stations and discuss their relative performance. Three outbursts of known meteor streams were recorded. Six other possible outbursts were investigated, but no outburst of a new stream could be confirmed with certainty this year. Further improvements of the network are needed.

1. Introduction

Seven amateur radio observers participated in this first year of Global-MS-Net, a global network of automatic meteor counting stations that use the technique of forward meteor scatter to monitor the level of meteor activity [1]. Our goal is to cover the whole sky at all hours of the day and be able to detect meteor outbursts such as those of the α-Monocerotid shower in November of 1995. These are caused by the dust trail of long period comets that only once or twice every 60 years move into the path of the Earth [2,3]. Hence, the network is planned to be a long-term project at minimal cost. The participating stations are built, operated, and maintained by the observers, who all have put in considerable time and effort. The result is a steady stream of data, which are presently collected once a month at *NASA/Ames Research Center*. The network is a prime example of how collaboration between professional and amateur meteor astronomers can advance the field and also provide a pleasant challenge in the meteor hobby.

After one year of operation, it is time to look back. This report is to summarize the condition of the network and to compare the results of individual stations in order to show where improvements can be made.

2. Results from individual stations

The participating stations are listed in Table 1. The location of the receiving station is given, as well as the distance and azimuthal direction to the transmitter. Seven graphs in Figure 1 show the daily count in the hour starting at 4^{h} local time for all dates of 1997, when the well known annual night-time streams are at their best. I will now consider the results of the individual stations.

Table 1 – Stations participating in the Global-MS-Net.

Observer	Country	λ	φ	Freq (MHz)	Dist (km)	Azimuth r → t	E-mail
I. Yrjölä	Finland	26°4 E	60°9 N	87.36	1200	SW	oh5iy@sci.fi
Ghent Univ.	Belgium	3°7 E	51°0 N	66°29	800	E	Pierre.DeGroote@rug.ac.be
W. Kuneth	Austria	13°9 E	46°6 N	48.25	400	S	kuneth@net4you.co.at
P. Sears	Hawaii	155°5 W	19°3 N	96.90	515	NNW	psears@aloha.com
K. Suzuki	Japan	137°3 E	34°8 N	53.75	150	NNW	kaze@tcp-ip.or.jp
K. Maegawa	Japan	137°5 E	35°1 N	53.75	174	zenith	kmaegawa@fukui-nct.ac.jp
C. Shimoda	Japan	137°9 E	36°1 N	81.4	180	zenith	DZB91458@biglobe.ne.jp

NASA/ARC: Peter Jenniskens (peter@max.arc.nasa.gov)

I. Yrjölä in Kuusankoski, Finland, had a successful year with an unusual small amount of down time. The northern latitude site keeps the disturbance by sporadic-E low and only aurora is occasionally a disturbance. Yrjölä and Jenniskens [4] describe the technique and give an analysis of the counts in 1994 and 1995 with the same technique. Some 45 annual meteor streams were identified in the variation of rates. The long baseline between transmitter and receiver and the strong output of the main transmitters make the system relatively sensitive to fast meteors and long-duration echoes. The automatic counting procedure leads to counts about 8 times higher than counts obtained by other participants, partially from multiple counts of overdense echoes.

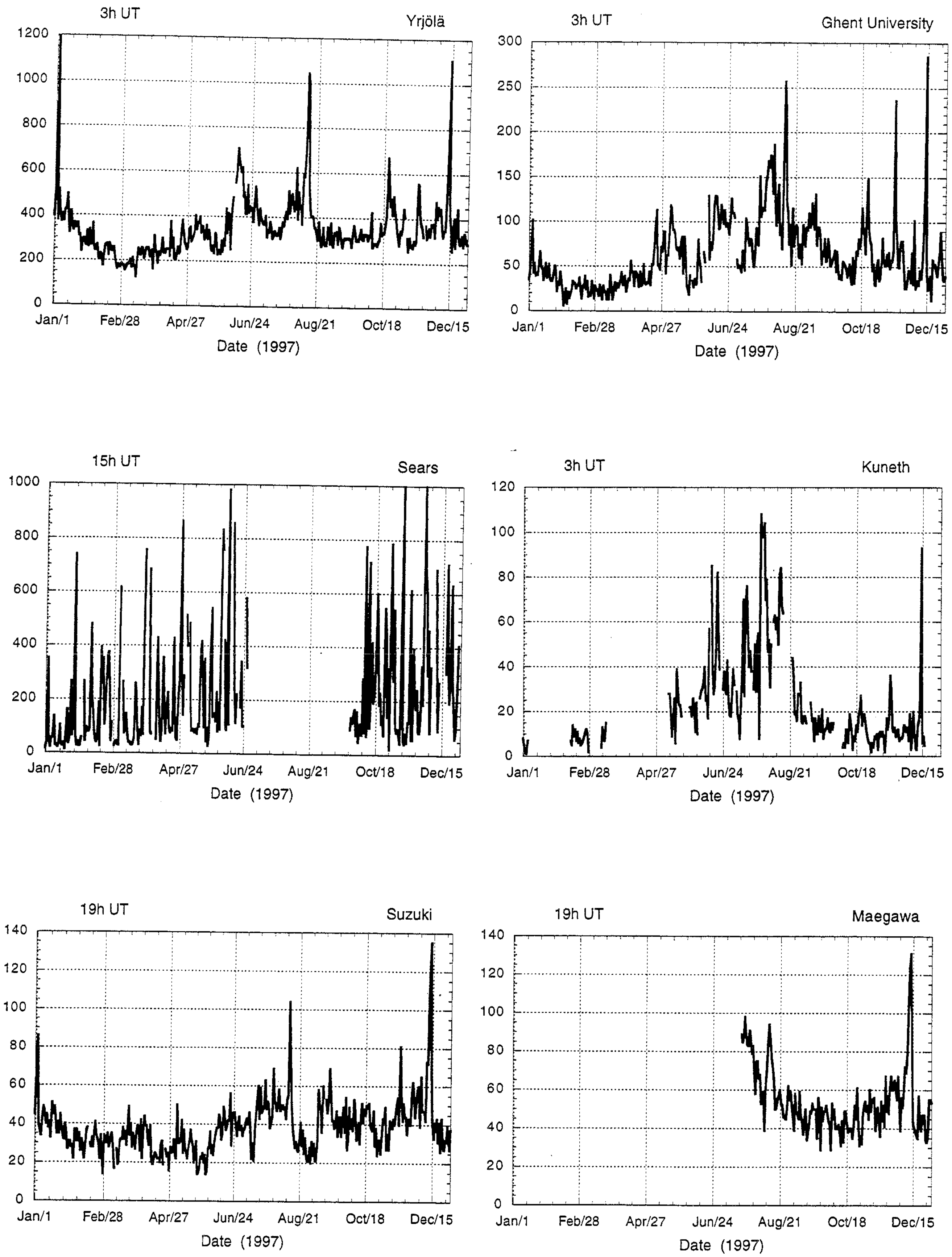

Figure 1 – Daily counts in the hour starting at 4^h local time for all participants of Global-MS-Net.

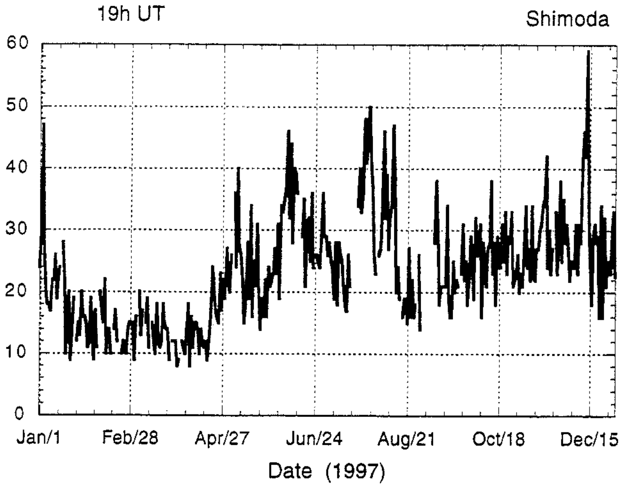

Figure 1 – continued.

Unfortunately, the main transmitter monitored until now will no longer be available in 1998, which may affect the performance of Yrjölä's system in the next years.

P. de Groote, P. Vauterin, Dr. H. de Jonghe, and colleagues at the University of Ghent, Belgium, have built a system that gives very similar results as that of Yrjölä. Two receivers are used to eliminate local interference, one being tuned just off the frequency of the transmitter. Again, a long baseline and strong transmitter make sure that long-duration echoes are efficiently recorded. In comparison with Yrjölä's system, the η-Aquarids and δ-Aquarids were detected somewhat better, but the Quadrantids not as well. This merely reflects the different azimuthal direction of the line from receiver to transmitter, which favors streams with a southern declination when the antenna is aimed due east or west. In combination with Yrjölä's system, all northern hemisphere radiants above the horizon at any given time (except close to the zenith) are probably efficiently observed.

W. Kuneth from Villach, Austria, uses a novel technique to make sure that the signal is not disturbed. The automatic setup uses FFTDSP42t software by ham operator AF9Y to record the audio signal. The radio signal is Fourier-transformed to represent the image of a small frequency band on a computer screen. Twenty channels of 2 Hz wide are used for meteor identification. The counting of reflections is automated. This system gives a nice view of local disturbances and can be used when local conditions are less favorable. Kuneth changed the observing geometry in February to monitor Italian instead of Spanish transmitters. During July, a transmitter from Bari, Italy, switched to the exact same frequency on 53.7592 MHz as a station in Sicily, Italy. Another change occurred in October, which brought the number of overdense echoes down, perhaps because the baseline from receiver to transmitter was again shortened. The variation of rates in the October–December period compares well to those of the Kuusankoski and Ghent stations, but the low count makes the statistical uncertainty relatively large. The graph in Figure 1 shows the results for echoes longer than 3 seconds. The meteor streams are not recognized in the more abundant shorter echo durations.

Three Japanese radio amateurs with a long history of radio meteor observations participate in Global-MS-Net. They have been the force behind other radio meteor-scatter activities in Japan, mostly concentrated in the region between Tokyo and Osaka. Two of the three participating stations monitor a 50 W CW ham radio beacon at 53.7592 MHz by Kimio Maegawa at Sabae City.

C. Shimoda of Asahi Village, Japan, records reflections on paper recorder and makes visual counts. Showers with lower entry velocity such as the Geminids, Quadrantids, Arietids, and δ-Aquarids are well observed. On the other hand, the system monitors a relatively nearby transmitter and is aimed at the zenith, covering a relatively small surface area in the atmosphere.

That has consequences especially for the fast meteor showers. The echo height ceiling is lower and streams such as the Orionids, Perseids, and Leonids are not well detected. Moreover, automatic recording could increase the total count by a factor of 2–4 by lowering the detection threshold.

K. Suzuki of Toyokawa Meteor Observatory, Toyokawa City, Japan, has been a leader of the Japanese meteor scatter work for many years. His system uses an electronic detection and a Fourier-transform routine similar to that of Kuneth and monitors the ham radio beacon of Kimio Maegawa. The counting still occurs by hand and is not automated. The fast Perseids and Leonids are better detected, but not so abundant as in Yrjölä's and the Ghent University systems, because of the short baseline and relatively low power transmitter. A north-south geometry makes the system less sensitive to low-latitude streams, but more sensitive to outbursts with a radiant in the east and west.

S. Okamoto of Daimine Meteor Observatory, Japan, uses the same technique as Suzuki. A continuous monitoring station came into operation early this year and from July 19 onward, it has been monitoring the same transmitter. The Geminids were well observed, but a relatively short baseline kept the total Perseid and Orionid counts low and also the Leonids were not detected, in spite of being strong and abundant in long duration echoes, for the same reasons as mentioned before.

Finally, Yrjölä's technique was transferred to Hawaii in a first attempt to found new radio forward meteor scatter stations. P. Sears at Naalehu, Big Island, has operated this system since 1996, producing a first successful detection of the 1996 Leonids. Unfortunately, strong local interference affected the rates on many dates and the problem got worse in 1997. The problem was identified in the summer months, when it was found that the interference was most severe on wet days. On request, the electric company checked the local electric power lines and temporarily made the problem much worse (gap of data). After a second inspection in September, the system suddenly worked well, proving beyond doubt that this is the problem. Unfortunately, the problem has returned in much the same way.

3. Investigation of possible outbursts

Outbursts of three known streams were detected: those of the Perseids, Leonids, and Ursids. All outbursts were anticipated and have also been observed by other techniques. The forward meteor scatter systems provided independent information about the meteor stream activity curves and particle size distribution (Figure 2).

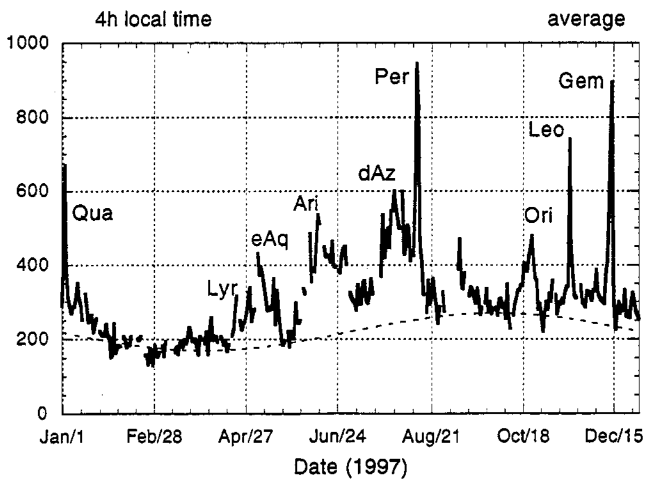

Figure 2 – Average activity profile of the Global-MS-Net participants.

The main purpose of the network is the detection of outbursts of unknown streams. In 1997, many possible outbursts were investigated, but none could be confirmed. The following events were examined in particular.

March 3, 1997, $4^{\rm h}00^{\rm m}$ *UT*

Jack and Bernice Long of Mortlach, Saskatchewan, Canada, were driving east of Highway 1 (Trans-Canada Highway), just 5 miles east of Swift Current, Saskatchewan. It was a beautifully clear night. Bernice noticed an unusual number of meteors, 4–6 in a few minutes time. Suddenly, she saw a *"burst of hundreds—a very brief, heavy meteor almost exactly at* $4^{\rm h}00^{\rm m}$ *UT."* A brilliant fireball as bright as the Moon appeared, colored red, blue, yellow, and white, and sporting a reddish tail. It lasted 3–4 seconds, then exploded in a quick flash, like a Roman candle, and disappeared. The tail remained visible for a second or so after the main body extinguished. The fireball moved east to west and was low in the sky.

No increase in the radio meteor scatter counts was observed. That may be because of unfavorable antenna geometry or a radiant below the horizon from European and Japanese sites. However, the report does not suggest that meteors and fireball were related, and it is unlikely that a meteor outburst was observed.

June 19, 1997, $18^{\rm h}30^{\rm m}$ *UT*

Ilkka Yrjölä detected a peak of more than 1500 reflections, with a total duration only just above what would be expected for a meteoric event. There is no confirmation. Given the summer season, this may have been Sporadic-E.

Meteors from P/Hartley 2, November 1–2, 1997

No activity was recorded that might be associated with the recent return of Comet P/Hartley 2, in agreement with no apparent activity in visual observations.

Canis Minorids, November 7, 1997, $3^{\rm h}$–$5^{\rm h}$ *UT*

This event was observed visually by meteor observer Josep Trigo, Spain, who noticed 12 meteors radiate from $\alpha = 111^\circ$ and $\delta = +9^\circ$, between $4^{\rm h}17^{\rm m}$ and $5^{\rm h}25^{\rm m}$ UT in a period of 1.08 hours under limiting magnitude 6.3. Three sporadic meteors were recorded in the same time.

No confirmation was obtained from the European radio-MS stations. The enhanced activity level may have been too low for detection in the current network.

November 24, 1997, $5^{\rm h}$–$7^{\rm h}$ *UT*

Another possible outburst was detected in the radio-MS data. A two-fold increase of meteor rates was recorded by Ilkka Yrjölä, Finland. Enhanced rates over a period of about 80 minutes. Relatively long lasting reflections. Aurora can not be excluded completely. Needs confirmation.

December 6, 1997, $0^{\rm h}$ *UT*

Holly Robinson of Broken Arrow, Oklahoma, USA, reported seeing 11 meteors in a period of 6 minutes. No apparent increase or decrease in rates was noticed. The meteors had an apparent medium velocity and were mostly in the range from magnitude 0 (like Betelgeuse) to +2. There were no persistent trains. The meteors smoothly brightened and faded. The sky was clear. The location was near her house, with a clear field of view: *"There was a fair amount of light pollution for our area, with the Pleiades just visible."* A second witness was Holly's son, who just turned 12 on December 7. In mid-November, Holly went out between $2^{\rm h}$ and $4^{\rm h}$ am on both nights of the Leonid peak and saw one meteor each night. Typically, she observes no more than 2 or 3 meteors per hour on sporadic nights.

No confirmation was obtained from the radio-MS record. However, this report does suggest that a meteor outburst may have occurred. The eye witness was interviewed and the period of the observation reconstructed by re-enacting the event. No radiant position could be determined, and it is not known if the meteors were related. The radio-MS record does not show an increase (see Figure 3), but that can again be due to incomplete coverage of the sky. This was the most likely account of a far-comet type outburst this year.

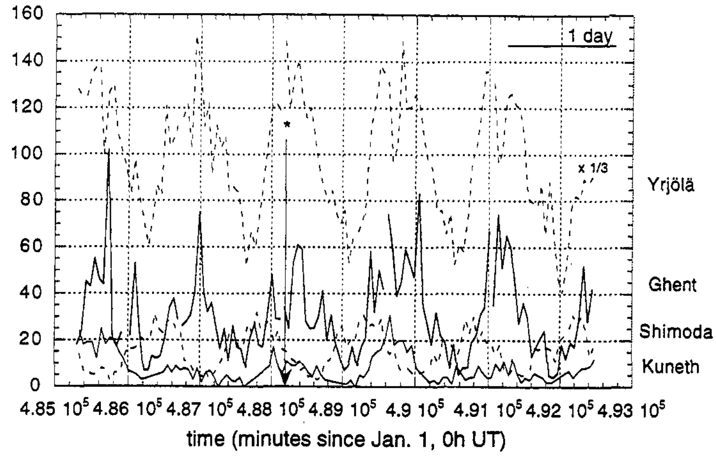

Figure 3 – Investigation of a possible outburst on December 6, 1997. The arrow with the asterisk indicates the time of the presumed outburst.

4. Publications and reports

The results of the network were used in several publications in the scientific literature. The 1995 detection of the α-Monocerotid outburst was described in a paper in *Astrophysical Journal* [3] and the 1996 Aurigid outburst was described in a paper in *Astronomy and Astrophysics* [2]. The analysis of two years of counts by I. Yrjölä was also published as a paper in *Astronomy and Astrophysics* [4].

The 1997 data were made available on CD-ROM for the participating stations. This included the raw data as well as publications and bulletins. Results from the stations of Ghent University, Toyokawa Meteor Observatory, and Daimine Meteor Observatory are available on the internet on a monthly basis. For links to these sites and further information, visit the Global-MS-Net website at `http://www-space.arc.nasa.gov/~leonid/GlobalMSNet.html`.

Finally, Christian Steyaert has issued 12 monthly *Radio Meteor Observing Bulletins* at his own initiative. These publications were of tremendous value to the participating stations. They are a very encouraging means of data exchange and comparison soon after periods of shower activity and serve to bridge the long delay caused by data analysis and publication in the literature. These *RMOB*s also contain observations by other radio observers that do not work on a continuous 24 hours a day basis. From these *RMOB*s, Alastair McBeath has published some raw data in recent reports for *WGN* [5,6].

5. Future work

The fundament has been put down for a continuous monitoring of meteor stream activity, and the potential for detecting and confirming meteor outbursts has been proven. Contacts among participants have been strengthened and mutual support is strong. Gladly so, because there is a large task ahead.

The network in its present form needs to be improved. We need to find a solution for the problem with interference of local power lines for the Hawaiian station. Also, a longer baseline and stronger commercial transmitter for some of the Japanese stations would improve the network's sensitivity in that part of the world. Further expansion of northern hemisphere stations would improve the coverage and sensitivity of the network.

The network is in need of stations on the southern hemisphere. Contacts have been made with observers in South Africa, Brasil, and New Zealand, but no concrete effort has been made yet to establish forward meteor-scatter stations.

It is my hope that the network will develop to its full potential in the next two years, after which the network should be able to function fully supported by the participating amateur radio observers for many years to come.

Acknowledgments

This work was made possible by the continuous enthusiastic support of I. Yrjölä and the participation of the radio observers in Global-MS-Net, and by financial support of the Planetary Astronomy program. Special thanks go to participants that recently joined: P. de Groote and staff members of the University of Ghent and the Japanese observers C. Shimoda, K. Suzuki, S. Okamoto, and K. Maegawa.

References

[1] P. Jenniskens, I. Yrjölä, P. Sears, W. Kuneth, T. Rice, "The Global Meteor-Scatter Network", *WGN* 25, 1997, pp. 141–144.

[2] P. Jenniskens, "Meteor Stream Activity. IV. Outbursts and the Sun's Reflex Motion", *Astronomy and Astrophysics* 317, 1997, pp. 953–961.

[3] P. Jenniskens, H. Betlem, M. de Lignie, M. Langbroek, "The Detection of a Trail in the Orbit of an Earth-Threatening Long-Period Comet", *Astrophysical Journal* 479, 1997, pp. 441–447.

[4] I. Yrjölä, P. Jenniskens, "Meteor Stream Activity. VI. A Survey of Annual Meteor Activity by Means of Forward Meteor Scattering", *Astronomy and Astrophysics* 330, 1997, pp. 739–752.

[5] A. McBeath, "SPA Meteor Section Preliminary Radio Results", *WGN* 25, 1997, pp. 45–53.

[6] A. McBeath, "SPA Meteor Section Results: January–February 1997", *WGN* 25, 1997, pp. 199–202.

The Makings of Meteor Astronomy: Part XVI W.F. Denning—In Quest of Meteors

Martin Beech, Campion College, University of Regina

In this article, we continue our look at the life and works of William Denning. We now focus our attention towards his contributions to meteor astronomy, and consider his observational methods.

1. Introduction

In the course of its orbit around the Sun, the Earth encounters a multitude of meteoroid streams. About a dozen of these streams produce strong and reliable meteor showers, each year, at the present epoch. When a meteor shower is active, the meteor rate from a localized section of the sky is enhanced over that of the so-called sporadic background. The sporadic background is the average number of meteors that a visual observer might see on any given night of the year, irrespective of shower activity. The sporadic rate does vary with the time of day and the season, but, for visual observers, the rate is typically about 8 to 10 meteors per hour on a clear moonless night. A meteor shower is deemed to be active if it can be unambiguously distinguished above the sporadic background level [1].

In 1864, the Reverend Charles Pritchard reviewed the state of meteor astronomy for the *Royal Astronomical Society* and noted [2], *"it is to amateurs in astronomy especially that we must look for assistance in this interesting branch of celestial mechanics: these mineral fragments, these* *celestial rockets, this fiery dust from the lathe of the Omnipotent Worker, will furnish to him the correlative to that which the naturalist so fondly traces in the organic regions of creation—all space teeming with life—beauty, order, scattered on all sides with a lavish hand—yet everywhere, and in all things, amenable to the control of law."* Pritchard's comments seem, in retrospect, to be almost tailor-made for Denning. Indeed, circa 1860, meteor astronomy was primed and waiting for an enthusiastic and dedicated observer to appear on the scene—Denning was destined to be the observer required.

2. The quest begins

According to an interview [3] Denning gave to *Tit Bits* magazine in 1895, it would appear that he first turned his "full-time" attention to astronomy in the mid-1860s. In the same article, Denning also commented, *"I have witnessed some wonderful phenomena, and amongst these I should regard as the best the transit of Venus in December, 1882; the great meteoric showers of November, 1866, 1872, and 1885."* From the earliest times, therefore, it appears that Denning was interested in observing meteors. Since Denning's initial interests were many and varied, however, he only slowly turned to the full-time study of meteors and meteor showers. Denning's first few notes on meteors reflect this situation in the sense that they are merely matter-of-fact accounts of observing sessions. During the 1870s, however, Denning developed a more intensive and directed meteor-observing program.

Denning's first radiant catalogue was published [4] in the *Monthly Notices of the Royal Astronomical Society*. This catalogue was based on *"nearly 900 shooting stars"* observed from Bristol between 1872 and 1876. A total of 27 meteor radiants were derived from the data set by *"pencilling the courses* [of the meteors] *on a Cary's 18-inch globe, and prolonging them backwards, the average places of convergence being selected as the approximate areas of radiation."* (We shall have more to say on Denning's reduction methods shortly). A second article, also published [5] in 1876, gives some indication of Denning's dedication to observing at that time. He wrote, *"Between October 13 and November 28, watching for forty-nine hours, I observed shooting stars, 306 of which were well seen and their paths registered."* Given the typically poor weather in Britain during the autumnal months, Denning must have been observing at virtually every opportunity to collect so many hours of observations.

Denning's observational intentions were made clear in an article published in 1879. He explained [6], *"In March, 1876, I commenced a series of watches for shooting stars, and have continued them to the present time; the result of the two years' work being that I have observed 3 749 of these bodies in 368 hours of work. My chief object all through has been to discover as many new systems as possible and to get the radiant points with accuracy."* This approach was typical of Denning's observing philosophy, and we find echoes of this ideology appearing in his *Telescopic Work For Starlight Evenings* (published in 1891). There he comments [7], *"Nearly all the most successful observers have been men of method. The work they took in hand had been followed persistently and with certain definite ends in view. They recognized that there should be a purpose in every observation."* He further noted, *"It need hardly be said, however, that every difficulty may be surmounted by perseverance, and that a man's enthusiasm is often the measure of his success, and success is rarely denied to him whose heart is in his work."* The benefits of adopting such an approach to observing soon paid dividends for Denning, and his first genuinely new contribution to meteor astronomy was announced in 1877, in a short article [8] published in the journal *Nature*. Denning's important announcement was concerned with observations of the radiant of the Perseids.

The Perseid meteoroid stream causes an annual meteor shower that returns each August. The stream also produces a steady display of meteors over several nights [1]. For such "long-lived" meteor showers, it had been predicted that the radiant point should show a night-by-night shift in its position with respect to the background stars. This shift is due to the Earth's movement through the stream. Through his accurate and near-continuous observation of meteors in the summer of 1877, Denning was able to show not only that the Perseid meteor shower first commenced activity in early August, but that its radiant point shifted across the sky as predicted. Denning continued to monitor the Perseid shower for many more years, and in 1884 published [9] a complete review of his observations.

In addition to making his own observations, Denning also worked with data obtained by other observers. In 1877, for example, Denning published [10] a radiant catalogue from data collected by Captain George Lyon Tupman between 1869 and 1871. Tupman's observations amounted to about 300 meteor trails, from which Denning derived 20 radiants. A year later (1878) Denning published [11] another radiant catalogue. This time, the catalogue was based upon observations collected by several Italian observers in 1872. Denning projected 4 143 meteor trails from the Italian observations, and found 315 radiant points. Denning was clearly spending a large amount of time on meteor reductions in the late 1870s. A measure of Denning's commitment can be found in an 1897 article published [12] in the *Bristol Naturalists Society Proceedings.* He comments, *"The number of meteors actually projected by me on star charts, including those observed and those selected from published catalogues, reaches over* 10 000*; but, in addition to this, the paths of fully* 20 000 *others were examined."* Denning believed that his observations and reductions indicated the existence of at least several hundred annual meteor showers. This number is an overestimate, in modern terms, of the actual number of annual meteor showers by a factor of about 4 or 5. We shall see later, however, that Denning's estimate of the number of active meteor showers was to become even more extreme. At the present time, it is believed that there is good evidence to support the existence of some 50 to 60 annual meteor showers. It is important, therefore, to explore the reasons why Denning believed that so many meteor showers existed.

Denning's belief in the existence of many hundreds (and later, circa 1900, many thousands) of meteor radiants is an example of what might be called the "Philosophical Parallel" [13]. That is, Denning was led to his erroneous conclusions by the unquestioned acceptance of a theoretic paradigm that in reality was untrue. The modern-day meteor astronomer now knows that probably only 10% to 30% of the observed meteors actually belong to well-defined meteoroid streams [14]. What this means is that the vast majority of observed meteors cannot in fact be traced to common radiant points. This principle, while clear to modern astronomers, was not, however, known to Denning or his contemporaries. They believed, in contrast, that all meteors could be traced to a radiant point, and that each radiant point could probably be associated with the orbit of a comet. This was the paradigm under which Denning operated.

In modern terms, a meteor shower is deemed to be active if at least four meteors can be associated unambiguously with a radiant during the course of one night's observing session (i.e., within a time span of some six to eight hours) by a single observer. Denning would on occasion deem a shower to be active on the basis of observing just one meteor per night.

Working in the late 1840s to early 1860s, Edmund Heiss and co-workers distinguished between the periodic meteors, which they believed returned in yearly showers, and those which fell outside of the times of yearly activity [15]. These latter non-periodic meteors were called sporadic or wandering meteors. More extensive analysis by A.S. Herschel and Denning began to indicate, however, that more and more periodic meteor showers existed. Consequently, it was believed that fewer and fewer meteors were actually sporadic. Denning and Herschel found few sporadic meteors, of course, because they believed that all meteors could be traced to radiants. In 1885, Denning was to write [16] of sporadic meteors *"the term hardly seems to me a commendable one, though undoubtedly useful to cancel our ignorance of the contemporary streams supplying meteors unconformable to any special display that may be under observation."* Norman Lockyer also commented [17] on sporadic meteors in his book, *The Meteoric Hypothesis* (published 1890), and exclaimed that *the term sporadic* [is] *simply a measure of our ignorance."* To this, he added, *"with every new radiant thus established the number of sporadic meteors naturally become less and less."* The reason that Denning found so many radiants, therefore, is explained on the basis that he believed every meteor issued from an active radiant. The vast majority of his radiants, however, where chance groupings in what we now call the sporadic background.

The crowning achievement to Denning's study of meteor radiants was the publication, in 1899, of his *General Catalogue*. This catalogue was not only a summary of Denning's observations, but was a summary of the collected observations of many other observers. The catalogue contained information on 43 647 radiants, and Denning commented [18] that *"the total number of projected meteor-paths from which they were determined is approximately* 120 000*."* Denning's catalogue was a monumental work, but, even so, he did not claim that it was complete, he merely believed that it *"includes the bulk of such radiants as have hitherto been published."* Denning further suggested that *"there are considerably more than 50 showers in play on any and every night of the year, and, moreover, certain (in fact the great majority) of these are not confined to limited periods, but extend their activity over several weeks, and in some cases over several months."* As we explained earlier, Denning's belief in the existence of many shower radiants is unfounded in reality, and virtually all of the radiants listed in his catalogue are spurious. This is not to say, however, that Denning's catalogue is of no contemporary value. Certainly, all the major, and lesser, meteor showers are included within its pages, and it is likely that there are some weaker showers in the catalogue that do exist, but have not been confirmed as such to date [19].

3. Observing conditions and methods

Having discussed the main achievements and problems associated with Denning's work on meteor radiants, it is worth saying a few words about where Denning was observing from. We should also discuss his observing methods and philosophy, since how an astronomer observes is just as important as what an astronomer observes. It is clear from his many works that Denning was a man of method. Indeed, he held this principle highly. Writing in his *Telescopic Work For Starlight Evenings*, Denning noted that *"if the 100 hours of exceptionally good seeing* [in England]*, ..., are to be profitably employed, we must be continually prepared with a scheme of systematic work."* [20]

Some insight into how Denning collected his observations can be gleaned from his meteor catalogue of 1890. There he explained, *"my plan of working may be briefly described as follows: All the observations were made in the open air and from the garden adjoining the house. Attention was almost invariably given to the eastern sky. In mild weather, I sat in a chair with the back inclined at a suitable angle; but on cold, frosty nights, I found it expedient to maintain a standing posture, and sometimes to pace to and fro, always, however, keeping the eyes directed towards the firmament in quest of meteors."* [21]

Working from an urban, Bristol back-street garden was probably not as problematic in Denning's days as it would be now [22]. This being said, however, Denning's garden was far from an ideal observing site, and one can find occasional references to this fact in his observing journals. He noted [23] on one night, for example, *"Depiction bad through smoke from adjoining chimneys."* In spite of such drawbacks, Denning recounted in one interview [6] that *"I have sometimes watched from my garden for meteors for ten or eleven hours continuously... The hours spent in this way have been intensely enjoyable. Amidst the trees and shrubs in the garden, solitary and with no sheltering canopy but the sky above, I have rarely experienced a feeling of loneliness or nervousness, or have had to make an effort to continue work."*

The manner in which Denning recorded his meteor data was innovative, yet simple. His main observing aid was a straight stick, or wand [24]. Held at arms length, he used the wand to "fix" the meteor's path across the sky. Then, by making a mental note of the star fields through which the meteor had passed, he marked its corresponding trail on an 18-inch celestial globe [25]. The time, magnitude, appearances, and position of the meteor where then recorded. Again, from Denning's 1890 radiant catalogue [21], we learn, *"at the end of each period of observation, I finally discussed the materials collected and deduced the radiants. In some instances a very definite little shower would be manifest from a single night's work, but I generally found it advisable to combine the paths recorded on several dates in order to obtain satisfactory positions."* The pooling of data over several nights, to "bring out" meteor radiants, was common practice prior to the early years of this century. Indeed, in the very earliest of meteor radiant catalogues, data would be pooled over several weeks, and, on occasion, months. As our earlier discussion on modern methods of radiant reduction explained, however, a reliable radiant can only be deduced from meteors observed on the same night. The pooling process was a major factor in Denning's erroneous detection of stationary radiants. This was so because such a process considerably enhances the chances of finding a radiant within the sporadic background [26].

With regard to his reduction procedures, Denning fell into a situation against which he had warned in his *Telescopic Work For Starlight Evenings*. In Chapter 4 of his text, Denning considered "Notes on Telescopic Work", and remarked [27], *"a person who relies upon guidance from prior experimentalists will probably make rapid headway... The want of this foreknowledge has often been the main cause of failure, and it has sometimes led to misconceptions and imaginary discoveries."* To this, he later added, *"let every observer judge for himself to a certain extent and let him follow original plans whenever he regards them as feasible. Let him test preceding results whenever he doubts their accuracy... An observer should take the direction of his labors from previous workers, but be prepared to diverge from acknowledged rules should he feel justified in doing so from his new experiences."* Denning did not strongly question the radiant reduction procedure, because, as far as he was concerned, it was correctly placing all the observed meteors in one group radiant or another, his working hypothesis being, as we saw earlier, that all meteors are derived from well-defined meteoroid streams with group radiants. It was only during the first few decades of this century that meteor astronomers began to question the concept of pooling meteor observations seriously [28].

4. A.S. Herschel and meteor theory

The early years of Denning's meteor observing career were nurtured by Alexander Stewart Herschel (1836–1907). Herschel was then one of Britain's foremost authorities on meteor astronomy, and he was a prominent member of the *Luminous Meteors Committee*, which reported to the *British Association for the Advancement of Science*. Denning's first contact with Herschel was prompted by the appearance of a bright fireball seen on the night of November 6, 1869. At that time Denning was 21 years old, and Herschel 43. A steady correspondence developed between the two observers, and the surviving letters clearly indicate that an extensive dialogue on meteor astronomy took place [29]. In the early letters, Herschel was the more experienced meteor observer, and, through his office with the *Luminous Meteors Committee*, he encouraged Denning to submit his observations for the yearly reports. Denning acknowledged his great gratitude to Herschel in 1907 when writing his obituary account for the journal *Nature*. Denning noted [30], *"the writer of this notice will always have reason to be grateful to him* [Herschel] *for kind encouragement, advice, and instruction in the early years of his observing career."*

Denning and Herschel pursued a campaign of systematic meteor observations. Indeed, the greater bulk of extant correspondence between Herschel and Denning is concerned with observations of meteor paths and the exchange of meteor observing notes. Denning and his collaborators were interested in the determination of meteor heights for several reasons. Firstly, knowledge of a meteor's beginning and end height offers important information about the meteor ablation process, and, secondly, the true path of a meteor can be used to estimate the initial velocity with which the meteoroid entered the Earth's atmosphere.

Systematic timing errors led early meteor astronomers to the belief that the majority of meteoroids entered the Earth's atmosphere with so-called hyperbolic velocities. The apparent observation of very high velocities was significant, since it implied that the meteoroids had an origin from outside of the Solar System. This implication followed, since basic orbital-motion theory imposes an upper limit to the velocity that an object can have and still remain in a bound orbit about the Sun [31]. We now know (from radar and photographic studies) that virtually all meteors are produced from meteoroids moving along bound, elliptical orbits—although there are indeed interstellar meteoroids. It took meteor astronomers some time to resolve the hyperbolic velocity problem [1], but, since Denning was not a major player in the debate, we do not follow its course here.

Towards the end of the 19th century, astronomers and physicists began to question the physical processes that accompanied the appearance of meteors [32]. The first real attempt at a detailed theory of meteoroid ablation was that presented by F.A. Lindemann and G.M.B. Dobson [33] in 1922. Since the structure of the Earth's atmosphere was completely unknown in the regions where meteoroids ablated (about 80 km), Lindemann and Dobson used data compiled by Denning to show that the density of the Earth's atmosphere was much higher than had previously been thought. Denning's height and velocity data were used, since they were deemed to be both the most accurate and the most extensive data set available.

Denning was never truly bothered with the physical details of meteor ablation theory, although he did discuss the topic with A.S. Herschel on several occasions. Writing on December 28, 1872, for example, Herschel explained to Denning that there was *"no possibility of any bolide-looking meteor being of atmospheric origin.* As we have discussed in previous installments, the idea that meteors might result from the ignition of gases collected in the Earth's upper atmosphere was essentially due to Aristotle. The correctness of Aristotle's ideas on meteor origins were first seriously questioned by Edmund Halley in 1714, but it was not until 1794 that Ernst Chladni was able to show that the ideas were most probably wrong. What Halley suggested, and Chladni was able to confirm, was that meteors, fireballs, and meteorites were essentially one and the same phenomenon [1]. Chladni correctly reasoned that meteors were caused by solid objects (what we now call meteoroids) hitting the Earth's atmosphere.

Denning did not write extensively on either meteorites or meteorite falls, although he did own at least one meteorite sample. The fragment in Denning's possession had been presented to him by Mr. J.T. Ward, Director of the Wanganui Observatory, in 1909, and was a piece of the Mokoia meteorite which fell in New Zealand on November 26, 1908. Clearly fascinated by the meteorite Denning wrote, *"it is interesting, after a person has habitually watched the luminous careers of these bodies during many years, to hold a similar object in one's hand and contemplate it from a much nearer point of view!"* [35]

Towards the close of his life, meteor astronomy had in many ways out-stripped Denning in both its development and requirements. Denning literally became the "old guard" of meteor astronomy, and his influence waned. Perhaps ultimately, however, it was Denning's continued belief in stationary radiants that compromised his later astronomical career [26].

Notes and references

[1] Several good texts on meteor physics are available, and that by A.C.B. Lovell, "Meteor Astronomy", The Clarendon Press, Oxford, 1954, can be recommended as a detailed guide. D.W. Hughes's "The History of Meteors and Meteor Showers", *Vistas in Astronomy* 26, 1982, pp. 325–345 is also highly recommended. A general discussion of meteor showers may be found in G.W. Kronk's *Meteor Showers: A Descriptive Catalogue*, Enslow Publishers, Aldershot, 1988.

[2] C. Pritchard, *Monthly Notices of the Royal Astronomical Society* 24, 1864, p. 139.

[3] "Experiences During thirty years Star Gazing," in *Tit Bits* magazine, August 31, 1895.

[4] W.F. Denning, "Radiant-Points of Shooting Stars", *Monthly Notices of the Royal Astronomical Society* 36, 1876, pp. 283–285.

[5] W.F. Denning, "Radiant Points of Shooting Stars", *Nature* 15, 1876, p. 158.

[6] W.F. Denning, "Shooting Stars", in *Proceedings of the Bristol Naturalists Society* 2, 1879, pp. 264–278.

[7] W.F. Denning, "Telescopic Work for Starlight Evenings", Taylor and Francis, London, 1891, p. 78.

[8] W.F. Denning, "The Radiant Centre of the Perseids", *Nature* 16, 1877, p. 362.

[9] W.F. Denning, "The Long Duration of Meteoric Radiant Points", *Monthly Notices of the Royal Astronomical Society* 45, 1884, pp. 93–116.

[10] W.F. Denning, "Radiant Points of Shooting Stars. From Captain Tupman's Unreduced Observations 1869–71", *Monthly Notices of the Roy. Astron. Soc.* 37, 1877, pp. 349–351.

[11] W.F. Denning, "Radiant Points Deduced from the Paths of 4 143 Shooting Stars Observed by the Members of the Italian Meteoric Association in the Year 1872", *Monthly Notices of the Royal Astronomical Society* 38, 1878, pp. 315–317.

[12] W.F. Denning, "Shooting Stars", in *Proceedings of the Bristol Naturalists Society* 2, 1879, p. 271. It is one of those sad ironies that virtually all of Denning's hard work on meteor trail projection is of little contemporary value.

[13] That meteors were once thought to be observable in the Moon's supposed atmosphere is another example of the philosophical parallel.

[14] D.W. Hughes, *Monthly Notices of the Royal Astronomical Society* 245, 1990, pp. 198–203.

[15] T.L. Phipson, "Meteors, Aerolites, and Falling Stars", Lovell Reeve, and Co., 1867, London, p. 160–161.

[16] W.F. Denning, "The Great Shower of Andromeda, November 26, 27, 28, and 30, 1885", *Monthly Notices of the Royal Astronomical Society* 46, 1886, p. 67.

[17] J.N. Lockyer, "The Meteoritic Hypothesis", Macmillan and Co., London, 1890, p. 135.

[18] W.F. Denning, "General Catalogue of the Radiant Points of Meteoric Showers and of Fireballs and Shooting Stars Observed at More than One Station", *Memoirs of the Royal Astronomical Society* 53, 1899, pp. 203–292.

[19] G.S. Hawkins, "Catalogues of Meteor Radiants", *Smithsonian Contr. Astrophys.* 3:2, 1958, pp. 7–8.

[20] W.F. Denning, "Telescopic Work for Starlight Evenings", Taylor and Francis, London, 1891, p. 68. Denning's estimate that only 100 hours of good seeing is available to British observers follows the earlier remarks on the same subject by Sir William Herschel.

[21] W.F. Denning, "Catalogue of 918 Radiant Points of Shooting Stars Observed at Bristol", *Monthly Notices of the Royal Astronomical Society* 50, 1890, pp. 410–467.

[22] Denning did claim that the skies were sufficiently clear over Bristol that the aurora could be plainly seen on many nights (*Nature* 33, 1885, p. 152). Suffice it to say here that this claim is quite impossible.

[23] Only one of Denning's meteor observing note books appears to have survived to the present day. This journal, which contains his observations for the year 1922, is held in the Denning archive of the *British Astronomical Association*'s Meteor Section. Several other note books have survived, but these contain various planetary and meteor observations, along with newspaper and journal cuttings.

[24] Many aids for visual meteor observing have been developed over the years. James Challis of Cambridge University Observatory, for example, designed a Meteoroscope to observe the 1866 Leonid meteors (*Monthly Notices of the Royal Astronomical Society* 27, 1867, pp. 75–77). This was the forerunner of Denning's "meteor-wand," and consisted of a pointer mounted on a tripod. The idea was to use the pointer to "mark" the altitude and azimuth positions of the beginning and end points of a meteor's train. Later, Ernst Öpik was to advocate the use of wire grids, or reticules (*National Academy of Sciences* 18, 1932, pp. 16–23) to record meteor beginning and end points. Other observers have suggested the use of a flexible string, or wire, to aid in identifying meteor paths (see, for example, J.P.M. Prentice, *Memoirs of the British Astronomical Association* 36:2, 1948, p. 107). Such aids are not in common use today, and observers tend to simply mark observed paths on specially drawn star charts.

[25] Denning's celestial globe was donated to the *Royal Astronomical Society*'s archive in 1942

(*Quarterly Journal of the Royal Astronomical Society* 27, 1986, pp. 212–236), and can be found in the society's library. The fate that befell Denning's several telescopes is not so clear. It is likely that they may no longer exist as functioning instruments.

[26] M. Beech, "The Stationary Radiant Debate Revisited", *Quarterly Journal of the Royal Astronomical Society* 32, 1991, pp. 245–264.

[27] W.F. Denning, "Telescopic Work for Starlight Evenings", Taylor and Francis, London, 1891, p. 66. Denning's views on the education and instruction of novice astronomers are further explored in Chapter 3.

[28] C.P. Olivier, "Meteors", Williams and Wilkins, Baltimore, 1925.

[29] M. Beech, "The Herschel-Denning Correspondence", *Vistas in Astronomy* 34, 1992, pp. 425–447.

[30] W.F. Denning, "Professor A.S. Herschel, F.R.S", *Nature* 76, 1907, pp. 202–203.

[31] The constraints on orbital dynamics are explained, for example, in J.C. Brandt and R.D. Chapman's "Introduction to Comets", Cambridge Univ. Press, Cambridge, 1981, pp. 61–65.

[32] A summary of the early work on meteor physics is given by E. Öpik's "Physics of Meteor Flight in the Atmosphere", Interscience Publishers, Inc., New York, 1958.

[33] F.A. Lindemann, G.M.B. Dobson, "A Theory of Meteors, and the Density and Temperature of the Outer Atmosphere to Which it Leads", *Proc. Royal Society* 102, 1922, pp. 411–437.

[34] Halley's early discussion on meteor origins are further explored in M. Beech's "Halley's Meteoric Hypothesis," *The Astronomy Quarterly* 7, 1990, pp. 3–18.

[35] W.F. Denning, "Fall of an Aerolite in Mokoia, New Zealand, on November 26, 1908", *Nature* 80, 1909, p. 128. It is not clear what happened to the sample that Denning received. Inquiries to the City Museum at Bristol have revealed that it was not donated to their collection (R.D. Clark, Assistant Curator, Geology, *personal communication*, 1991).

Fireballs and Meteorites

Meteorite Craters Discovered by Means of Examining X-SAR Images—Part I

Roberto Gorelli

We present geologic or geographic structures, assumed to be craters of meteoritic origin, discovered on radar images taken by the X-SAR on board of the Space Shuttle, during missions carried out in April and October 1994.

During the STS 59 and STS 68 Space Shuttle missions in April and October 1994, a new scientific instrument, the X-SAR radar, was taken on the Shuttle for scientific research and practical applications. Its electronic images, not photographs, made possible a great number of scientific discoveries. For some time now, part of these images, with degraded resolution, have been made accessible for public use in an Internet site thanks to *DLR*, a scientific institute specialized in remote sensing. The author, assuming that the available resolution could be sufficient, tried to verify if it were possible to confirm the meteoritic origin of some structures, previously discovered on optical photos taken from satellites, and of other curious structures found on geologic or geographic maps. For some structures, the verification has been positive: X-SAR images have confirmed the hypothesis of their meteoritic origin for some structures, while excluding it for the other ones. During this job, limited and well-finalized, some images erroneously requested to the *DLR* were studied, and some of these images also revealed meteorite craters, never discovered before. These accidental discoveries led the author to examine part of the approximately 25 000 available images in search of other meteorite craters. The results are beyond expectation: more than 20 geologic or geographic structures with certain, probable or possible meteoritic origin were found.

Naturally, the final word can only be given after a field survey. The recent discoveries by American investigators of a crater of approximately half a mile in diameter in Yemen, a crater of 13 km diameter in South Korea, the Aorounga crater chain in Chad, all of meteoritic origin, and the discovery by *DLR* investigators of a spectacular crater, perhaps more beautiful than the Meteor Crater in Arizona, whose discovery has not been yet made public[1], lead me to think that, even if not all the structures discovered in this study are meteoritic craters, surely a number of them will see meteoritic origin confirmed after being examined in the field.

Here, we present the structures discovered. For each one, we provide all the data obtained from the degraded X-SAR images; more accurate data and particulars are certainly to be found in the full-resolution images, which have not yet been examined. The data include the coordinates of the crater center, the crater diameter, its estimated age, the reliability of the proposed meteoritic origin, and notes of the author.

The crater coordinates, obviously not shown on the legend of the images, have been obtained from the author by means of a particular method, too long to be described in this paper, but the validity of which has been validated on well known meteorite crater images. Although professional geographers would probably propose other methods, the errors on the crater coordinates are less than one arc minute (notice that the coordinates are given in hundredths of degrees). The diameters of the craters have been derived with the same method, which has also been tested on diameters of known craters, from which we have deduced that the error of measurement is less than 10%. The crater ages are only estimates, based on geological and geographic considerations, so for some craters it could be off by even hundreds of millions of years, but, generally speaking, the error margin is between half and double of the proposed age. The reliability of the meteoritic origin has been qualified as "certain," "probable" and "possible." Since no crater has been investigated in the field, none of them can be designated as meteoritic with real certainty, strictly speaking; the qualification "certain" means that the craters show details and characteristics that cannot be attributed to a terrestrial origin. The other two qualifications, "probable" and "possible," indicate only a greater or smaller possibility that the meteoritic origin of the crater concerned will be confirmed. The notes provide all other relevant information.

1. *Crater coordinates*: $\lambda = 15\overset{\circ}{.}65$ E, $\varphi = 31\overset{\circ}{.}30$ N (Libya).

   Diameter: 16.74 km.

   Presumed age: less than 100 million years.

   Reliability: possible.

   Notes: Probably, the structure is not particularly noticeable from the ground, as it was formed at the sea side, where its ejecta formed a cape, today almost invisible due to the presence of coastal lakes.

2. *Crater coordinates*: $\lambda = 33\overset{\circ}{.}97$ E, $\varphi = 17\overset{\circ}{.}11$ N (Sudan).

   Diameter: 60.3 km.

   Presumed age: less than 100 million years.

   Reliability: probable.

   Notes: Discovered some years ago on the photo 01-107-03 taken from Spacelab I, on December 2, 1983, $6^{\mathrm{h}}27^{\mathrm{m}}$ UT, handled by DFVLR for the ESA agency, where it is clearly visible. It is not so evident on the X-SAR image, because only half of the crater is visible. However, the X-SAR image reveals clearer details than the optical image, and therefore confirms it. It is possible that the area where the crater is situated rose in north-eastern

[1] The author deems it appropriate not to disclose the location of this crater before the discoverers have made a formal announcement.

direction or sank in south-western direction. This geological phenomenon could explain the distinct asymmetry in the appearance of the crater. Since such phenomenon takes place on a long time scale, the crater is probably very old. Towards the SSW, a smaller, less distinct structure is visible, with a diameter of 15–19 km, which may also be a meteorite crater.

3. *Crater coordinates*: $\lambda = 32\overset{\circ}{.}75$ E, $\varphi = 18\overset{\circ}{.}93$ N (Sudan).

   Diameter: 0.9 km.

   Presumed age: less than 1 million years.

   Reliability: possible.

   Notes: The radar bundle lighting system shows perfectly the ring, higher than the surrounding territory.

4. *Crater coordinates*: $\lambda = 46\overset{\circ}{.}64$ E, $\varphi = 21\overset{\circ}{.}36$ S (Madagascar).

   Diameter: 0.86 km.

   Presumed age: less than 10 million years.

   Reliability: possible.

   Notes: The smallest of the proposed structures. It does not seem to have caused an appreciable relief outside the ring. It appears broken off towards the NNE.

5. *Crater coordinates*: $\lambda = 46\overset{\circ}{.}78$ E, $\varphi = 21\overset{\circ}{.}09$ S (Madagascar).

   Diameter: 2.47 km.

   Presumed age: less than 10 million years.

   Reliability: probable.

   Notes: The structure is formed on a very uneven area, and must therefore be very hard to identify from the ground. A view from medium-high altitudes is necessary to bring the crater into evidence.

6. *Crater coordinates*: (Crater A) $\lambda = 104\overset{\circ}{.}30$ E, $\varphi = 48\overset{\circ}{.}63$ N;
   (Crater B) $\lambda = 104\overset{\circ}{.}25$ E, $\varphi = 48\overset{\circ}{.}64$ N (Bulgan, Mongolia).

   Diameter: (Crater A) 2.57 km; (Crater B) 2.48 km.

   Presumed age: less than 10 million years.

   Reliability: (Crater A) certain; (Crater B) probable.

   Notes: Crater A is located on a gentle slope of a big massif, and is the perfect example of a meteorite crater, even more so than the famous Arizona Meteor Crater. Crater B is located on the summit of the same massif, and exhibits clearer signs of erosion. The difference of reliability is due to the possibility that the latter crater is a glacial circus. Near the craters, there are one or more less distinct structures that may also be meteorite craters. One of them has a diameter of 1.24 km.

7. *Crater coordinates*: (Crater A) $\lambda = 13\overset{\circ}{.}78$ W, $\varphi = 19\overset{\circ}{.}38$ N;
   (Crater B) $\lambda = 13\overset{\circ}{.}76$ W, $\varphi = 19\overset{\circ}{.}34$ N (Mauritania).

   Diameter: (Crater A) 1.32 km; (Crater B) 1.88 km.

   Presumed age: less than 10 million years.

   Reliability: (Crater A) certain; (Crater B) possible.

   Notes: Crater A is almost completely filled up, making it practically invisible from the ground. Its most remarkable characteristic is the deformation of the southern part of the crater rim, which may indicate that it was caused by a meteorite coming from the north, Around the crater, a halo with a diameter of about 2.5 km showing alterations caused by the impact is visible. Crater B is completely filled up; only the rim is visible. It is located between two sand dunes that may have been one dune before the impact. At the limit of visibility, some craters with diameters in the order of hundreds of meters can be distinguished: the presence in Mauritania of craters due to volcanic explosions makes it imperative to check their origin first before jumping to conclusions.

8. *Crater coordinates*: $\lambda = 38\overset{\circ}{.}98$ E, $\varphi = 32\overset{\circ}{.}78$ N (Syrian Desert, Iraq).

   Diameter: 2.82 km.

   Presumed age: less than 50 million years.

   Reliability: possible.

   Notes: The crater is embedded in an annular geological structure of about 7.2 km diameter. If the entire structure is a crater, then the central area with 2.82 km diameter is a drained lake in the center of the crater. This structure is about 40 km WNW of the Al Umchaimin structure also suspected to be a meteorite crater. The Al Umchaimin structure was examined, too. It is probably nearly invisible in the optical photographs from satellites, as it shows no relief. It is clearly found on the radar images, however, because of the ejecta that cover the crater: rays of ejecta can be seen on the image, to the perception limit, in opposite directions with respect to the crater, indicating a SW to NE or inverse trajectory.

9. *Crater coordinates*: $\lambda = 99\overset{\circ}{.}30$ W, $\varphi = 58\overset{\circ}{.}94$ N (Manitoba, Canada).

   Diameter: (external ring) 5.13 km; (internal ring) 3.80 km.

   Presumed age: more than 250 million years.

   Reliability: certain.

   Notes: The crater is invisible from the ground, because it is totally filled up with rocks. Seen from high altitudes, the place shows two nearly complete concentric rings that form two streams almost filled up with water and with a lake with irregular shape in the center. The crater, filled up and covered by rocks of later age, has then reappeared later due to the ablation of the last glaciation ice, which acted in a selective way on rocks of various hardness, making more evident the crater contour and one of the rock layers that had filled it up. This crater is probably nearly invisible in satellite photographs, but shows up clearly in the radar images of the X-SAR, which with its radar directional lighting system can register minimal height differences on the ground. Nearly adjacent and at the limit of visibility, there may be a slightly smaller crater filled up with rocks too, with a diameter of 2.47 km and the center at $\lambda = 99\overset{\circ}{.}55$ W and $\varphi = 58\overset{\circ}{.}94$ N. It shows a ring partially filled by two lakes and a depression filled by a lake at its center; the reliability of this last structure must be qualified as "possible."

10. *Crater coordinates*: $\lambda = 100\overset{\circ}{.}36$ W, $\varphi = 54\overset{\circ}{.}82$ N (Manitoba, Canada).

    Diameter: 4.40 km.

    Presumed age: less than 250 million years.

    Reliability: probable.

    Notes: The crater itself is buried by rock; what is observed from the surface is the incomplete annular contour of its inner rim, filled up with water. The contour must have been dug out by selective ablation of the last glaciation ice.

11. *Crater coordinates*: $\lambda = 112\overset{\circ}{.}91$ W, $\varphi = 32\overset{\circ}{.}38$ N (Arizona, USA).

    Diameter: 1.904×1.71 km.

    Presumed age: less than 1 million years.

    Reliability: possible.

    Notes: It is a very clear crater, without raised edge. The shadow reveals an elliptical shape, elongated in NNW-SSE direction. There is a little lake near the center of the structure. It does not appear to contain even minimal trace of ejecta, which have to fill up partially all meteorite craters on a planetary body with an atmosphere, which may suggest a terrestrial origin for the structure (karst). At the limit of the resolution, holes with a diameter of less than 200 m can be distinguished around the structure.

12. *Crater coordinates*: $\lambda = 27\overset{\circ}{.}10$ E, $\varphi = 22\overset{\circ}{.}87$ N (Lybian Desert, Egypt).

    Diameter: (main crater) 3.59 km; (SSW crater) 0.75 km; (NW crater) 1.04 km.

Presumed age: less than 50 million years.

Reliability: (main crater) probable; (SSW and NW craters) possible.

Notes: This is a very complex and curious geological structure. Its shape resembles an eye looking at the sky: it is composed of a big and perfectly round crater, which, slightly excentric, contains another perfectly round but much smaller crater. Internally this second crater contains a saucer-shaped black surface near its center, which is probable made up of sand or very small stones, with an average diameter of a few centimeters. As a consequence, the surface absorbs the radio waves used by the X-SAR radar, sending a very weak reflected beam, making the surface appear dark, almost black. The presence of ancient volcanoes within a radius of a few hundred kilometers must caution us in assigning a meteoritic origin to this structure. Verification on the ground is therefore very important. It is important to remember that a positive identification of this crater as meteoritic could solve the mystery of the "Kharga Oasis Glass" or "Libyan Desert Glass", natural glass of unknown origin that someone thought to be of impact origin (tektites), although the corresponding crater was never found.

13. *Crater coordinates*: $\lambda = 96^\circ\!.44$ W, $\varphi = 49^\circ\!.79$ N (Manitoba, Canada).

    Diameter: 5.74 km.

    Presumed age: less than 5 million years.

    Reliability: certain.

    Notes: The crater is very evident, it shows a raised rim in the south-eastern part, and apparently showed a fairly good depth.

14. *Crater coordinates*: (Crater A) $\lambda = 16^\circ\!.18$ E, $\varphi = 27^\circ\!.61$ N;
    (Crater B) $\lambda = 16^\circ\!.20$ E, $\varphi = 27^\circ\!.66$ N (Namibia).

    Diameter: (Crater A) 3.77 km; (Crater B) 0.57 km.

    Presumed age: 3.7 ± 0.3 million years.

    Reliability: (Crater A) certain; (Crater B) possible.

    Notes: Crater A is perhaps the most evident of the craters exhibited in this paper, to the extent that the author proposes to name this crater the "Dune Crater". It is at only 15 km from the well known Rotter Kamm Crater, which is of certain meteoritic origin. The proximity of the two craters suggest that both may have originated from the same impact, in which case they have the same age. Dune Crater, the bigger one of the two, is probably the main geological structure caused by this event. The reason that it has been missed previously is probably that it is completely covered by sand, and has a large sand dune within which prevented recognition of the crater shape from the air as well as from the ground. Crater B was discovered by Andrea Pelloni while reading and verifying an earlier draft of this paper. It is located between Dune Crater and Rotter Kamm. We qualified its meteoritic origin as "possible," because its size is near the limit of the resolution.

This overview concludes the first part. The bibliography is included in the second part.

Call for meteor photographs

We are always short of spectacular meteor photographs for the cover of WGN. *If you happen to make such a photograph, do not hesitate to send it in!*

Occasionally, other photographs, such as good photographs of observing groups, may also qualify for the front page. (Ed.)

Observational Results

SPA Meteor Section Results: July–August 1997

Alastair McBeath

News extracted from correspondence and observations submitted to the *SPA Meteor Section* from July and August, 1997, are discussed. The late-July to mid-August period in particular received moderate to good coverage by visual and forward-scatter techniques. The Perseid primary maximum appeared around 8^h–9^h UT on August 12 ($\lambda_\odot$ = 139°69–139°73, eq. 2000.0) in both radio and visual data, but detecting the "traditional" maximum proved more problematical. A spectacular probable meteor was detected from the UK on August 1-2, and the Section's Aurigid plotting project suggested a possible new minor shower radiant in Aries in the closing days of August.

1. Introduction

Weather across Europe, and moonlight conditions, restricted observations in both months, but more especially in July.

Even so, every night between July 27-28 and August 15-16 received some coverage, and a major bonus was our receiving data from the German *Arbeitskreis Meteore* (*AKM*) expedition to North America (sites used were spread between Arizona, California, Colorado, Texas, and Utah) for the Perseids in August. This and all the other *AKM* data used here were taken from *Mitteilungen des Arbeitskreises Meteore*, issues 9, 10, and 11 (1997), thoughtfully provided by Ina and Jürgen Rendtel.

The overall observing totals are shown in Table 1.

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

Month	Visual	SAG	JPE	PER	SDA	CAP	Meteors	Photo	Trails	Radio
July	$96^h.8$	33	28	82	19	11	1145	$128^h.1$	1	1972^h
August	$562^h.15$	–	–	8345	138.5	162	14533	$147^h.3$	11	2572^h

The list of photographic observers to report data so far included

> *AKM* members Axel Haubeiß, André Knöfel, Jürgen Rendtel and H. Ringk (all in Germany), Vasile Micu (Romania), Valentin Velkov (Bulgaria), and Deak Zoltan (Romania),

all of whom, except the German all-sky fireball patrol photographers, were successful in capturing at least one trail.

Much of the forward-scatter data were taken from *Radio Meteor Observation Bulletins* (*RMOB*) 48, 49, and 50 (August, September, and October, 1997, respectively), which were kindly provided by Christian Steyaert, but some were submitted by individual observers or Norman Fitch of the *Radio Society of Great Britain* (*RSGB*).

The list of radio observers included

> Enric Fraile Algeciras (Spain, *RMOB*), Eisse Pieter Bus (the Netherlands, *RMOB*), Maurice de Meyere (Belgium, *RMOB*), Ghent University (Belgium, *RMOB*), Alan Heath (England), Werfried Kuneth (Austria), Sadao Okamoto (Japan, *RMOB*), Chikara Shimoda (Japan, *RMOB*), Ilkka Yrjölä (Finland, *RMOB* and *RSGB*), and Wim Zanstra (the Netherlands, *RMOB*).

The usual techniques for examining raw forward-scatter data were followed, and representative graphs selected for display here from among those available.

The list of visual observers included

> *AKM* members Rainer Arlt, Ragnar Bödefeld, Frank Enzlein, Andrea Friebel, Robert Gehlhaar, Mathias Growe, Bernd Heinrich, Udo Hennig, Wolfgang Hinz, Daniel Horn, André Knöfel, Ralf Koschack (Czech Republic only), Detlef Koschny, Gabi Koschny, Andreas Krawietz, Ralf Kuschnik, Richard Löwenherz, Hartwig Lüthen, Hans-Jörg Mettig, Sirko Molau, Sabine Wächter, Anita Müller, Sven Näther, Mirko Nitschke, Steffan Pelz, Hans-Peter Plott, Thomas Rattei, Andreas Rendtel (USA only), Ina Rendtel, Jürgen Rendtel (USA), Petra Rendtel (USA), Janko Richter, Marion Rudolph, Michael Schmidhuber, Thomas Schreyer (Rhodes), Harald Seifert, Manuela Trenn, Heiko Ulbricht, Frank Wächter, Bruno Wagner, Georg Wagner, Thomas Westphal, Roland Winkler, Oliver Wusk, Hans-Georg Zaunick (all in Germany only, except where noted), Jay Brausch (North Dakota, USA), Ovidiu Cioroianu (Romania), Shelagh Godwin (England), Richard Livingstone (Wales), Bob Lunsford (California, USA), Tony Markham (England), Alastair McBeath (England), Tom McEwan (Scotland), Vasile Micu (Romania), Graham Pointer (England), Ian Rigney (England), Vanja Rodiger (Croatia), Paul Roggemans (Belgium), Andy Salmon (England), George Spalding (England), and David Woodward (England).

2. July

Visually, most observations were concentrated in the last week of the month, but, for once, some Pegasids were reported from earlier in July, too.

Although shower numbers were not great, sufficient coverage was provided, most notably by the German observers, to suggest that best activity from the shower may have fallen on July 8, two days earlier than expected. One Pegasid photograph was secured by Valentin Velkov on July 9; the meteor was of magnitude -3 and left a visible train for several seconds. On the photograph, the train can be seen as a misty region around the terminal flare, and a distinct drift away from the original meteor's track is apparent as well.

By late month, the Aquarid and Capricornid complexes were much in evidence, along with some early Perseids. This is not so apparent from Table 1, as many observers did not provide details on which individual shower these Aquarid/Capricornid meteors had come from. Weather conditions across Europe made observing difficult, and only a suggestion of the Southern δ-Aquarid maximum on July 28 could be detected.

Radio observers battled against Sporadic-E, thunderstorms, and other atmospheric phenomena throughout July and August, and this has created particular problems in interpreting the raw data, since comparison information from neighboring days and times is often either unavailable, or uncertain. Some of these problems can be seen in the gaps in Figures 1–4. Any datapoints the observers themselves queried or identified specific problems with have been omitted here.

Despite these difficulties, some confirmation for most of the minor forward-scatter peaks found from August 1993–June 1997 data [1] was possible during July, although it would be unwise to treat this as definitive from a period so fraught with interference.

The rising activity after $\lambda_{\odot} \approx 120°$ (July 23, 1997) was the best-confirmed of these, with most set-ups registering a peak between $\lambda_{\odot} \approx 124°$ and $\lambda_{\odot} \approx 126°$ (July 27–29, 1997), exactly coincident with the expected highest Southern δ-Aquarid activity. This was also found in [1].

3. August

In a year when most of the other major showers were lost to bright moonlight, the Perseids promised to be one of the few surviving highlights for northern hemisphere watchers, and many people made considerable efforts to secure data on the shower.

We have already learned that a group of the German *AKM* observers traveled to the USA, for instance, but even back in Central and South-Eastern Europe, skies were clearer around the Perseid maximum.

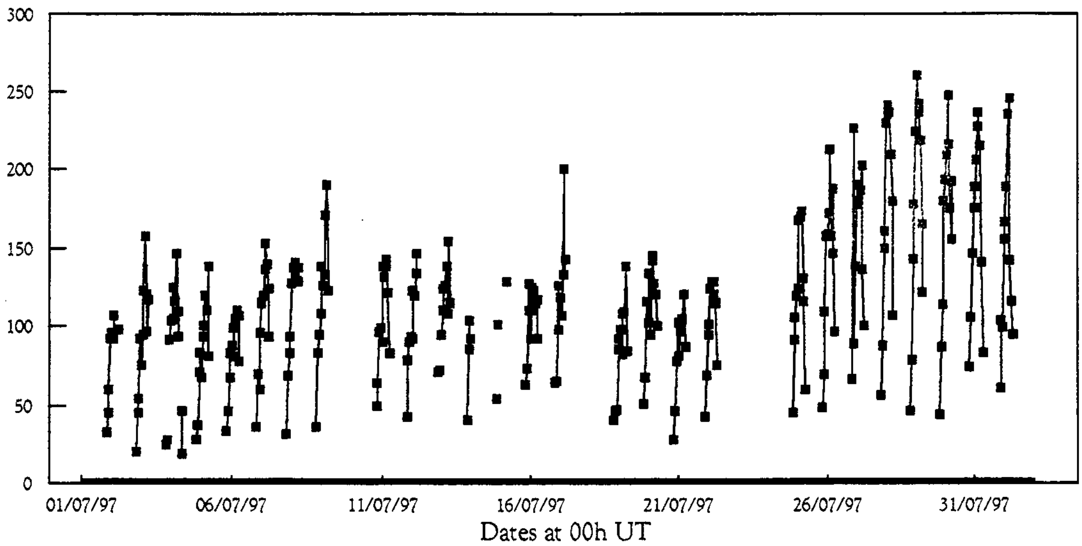

Figure 1 – Raw hourly radio meteor echo counts from July, 1997, in data collected by Maurice de Meyere. Maurice's set-up was usually operated for around 11 hours a day, between 20^h and 6^h UT. Note the gaps due to atmospheric interference. The rising trend in meteor activity towards late July was found in all data sets, and is almost certainly mainly due to the Capricornid and Aquarid streams. X- and y-axis scales vary between the graphs shown here.

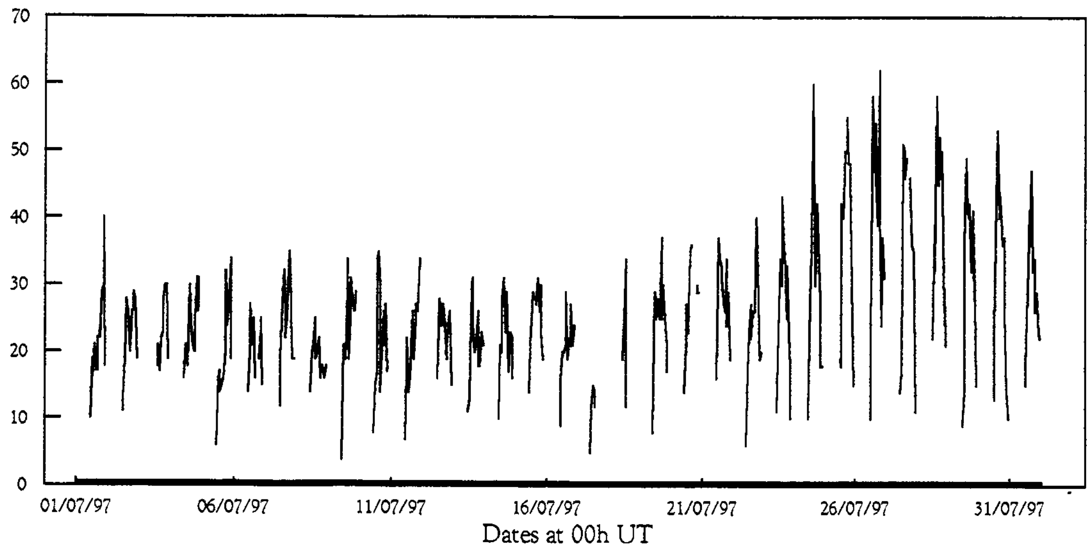

Figure 2 – Raw hourly radio meteor echo counts from July, 1997, recorded by Chikara Shimoda, whose equipment was typically operational for 12 hours daily, between 11^h and 22^h UT. Again, gaps due to interference are apparent (especially on July 17 and 18), but the Aquarid/Capricornid increase in late month is still obvious.

This did not happen everywhere, however. Vasile Micu in western Romania was able to observe on every night from August 10-11 to 15-16, in often superb skies, yet just about 250 km further east, Ovidiu Ciorojanu had no usable skies after August 4-5 until August 13-14. In Bulgaria, Eva Bojurova commented that no better nights appeared near the Perseid peak at all this year, while further north and west, Vanja Rodiger in Croatia enjoyed a good night on August 11-12, until fog appeared around 2^h UT, but most other mid August nights were much less helpful.

In Britain too, skies were clear in places on August 11-12, but the following night was generally overcast, frustrating, as this was closest to the expected secondary peak.

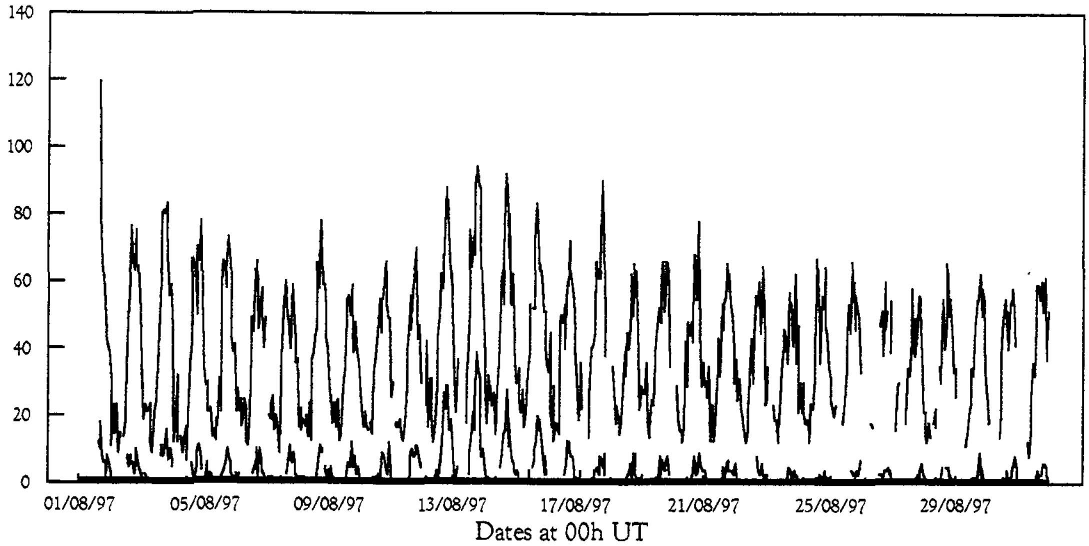

Figure 3 – Raw hourly radio meteor echo counts from August 1997, as reported by Sadao Okamoto. Sadao's set-up was continuously active, and so all breaks result from either atmospheric phenomena or equipment failure (almost all in the former category). The upper line illustrates all echoes detected, while the lower one shows just echoes whose duration was at least 5 s. These long-duration echoes make Perseid activity very obvious from August 12–15, though the overall echo totals show only a slight enhancement then. Late Aquarid/Capricornid activity accounts for the peak on August 1, and the enhancements during early August generally, as also found in other data not shown here.

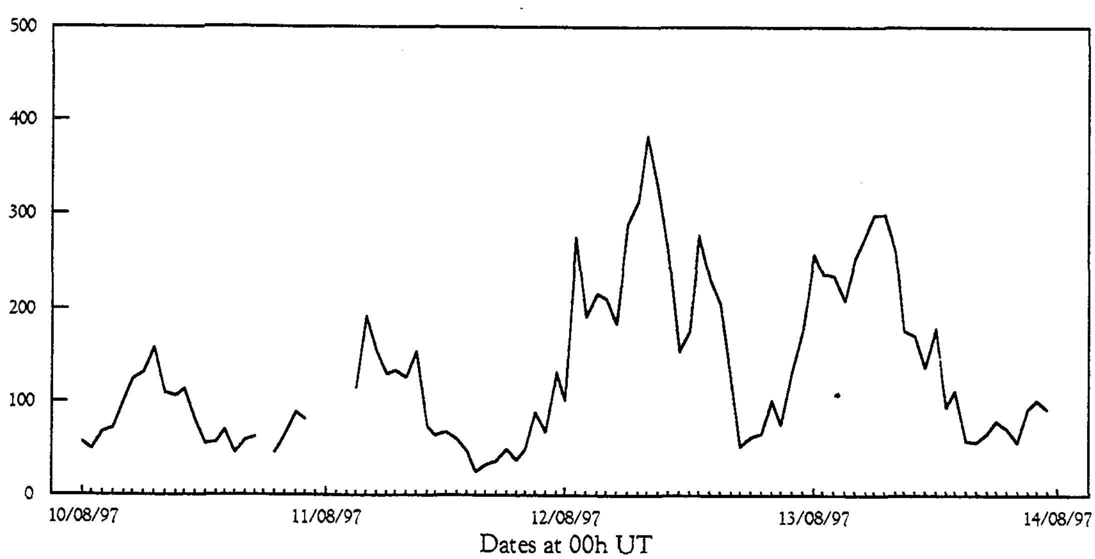

Figure 4 – Raw hourly forward-scatter echo counts between August 10–13, collected by Enric Fraile Algeciras. Thunderstorms and Sporadic-E caused problems, preventing complete 24h coverage on August 10 and 11, but the Perseid primary maximum shows up well on August 12 around 8^h–9^h UT. Rates were clearly still good the following day.

As the preliminary global data shows [2], August 12-13 was an interesting night because of an unexpected late enhancement in Perseid ZHRs.

The Perseid primary peak was confirmed in both visual and radio data as occurring around 8^h–9^h UT on August 12 ($\lambda_\odot = 139\overset{\circ}{.}69$–$139\overset{\circ}{.}73$, eq. 2000.0), slightly later than suggested in [3], producing visual ZHRs of 120–140.

The effect of the Perseids in enhancing long-duration echoes is well illustrated in Figure 3, while Figure 4 shows the primary peak, as detected by European radio observers, which was clearly defined. Visual observations from August 12-13 indicate ZHRs were 80–100 for much of the night over Europe, and radio counts imply activity at a level not far below that found the previous day too. As already commented, such activity levels were unusually late.

Thanks are due to Rainer Arlt for providing first news of this aspect, and also for drawing attention to the Japanese visual data, which showed the traditional Perseid maximum had occurred around its expected time in addition to this later "peak."

Several observers commented that bright Perseids seemed fewer in number this year, which is borne out to some extent in the magnitude distributions (see Table 2), but these are chiefly based on European data only, whereas the brightest Perseids have been seen in recent years near the primary maximum. Certainly, details on numerous fireballs were reported to the Section, mostly from August 11-12 and 12-13, but few were brighter than magnitude −4.

Perseid train proportions, detailed in Table 3, were also a little down in 1997 (31.1%; August sporadics 6.6%), but once more, this may reflect more on where the observers providing train data were located, than a real facet of the shower. No especially long-lasting trains were reported to us this August.

Table 2 – Global magnitude distributions, including mean limiting magnitudes and corrected mean magnitudes for the Perseids and August sporadics seen in good sky conditions (Lm +5.5 or better; cloud cover < 20%).

Shower	-3^-	−2	−1	0	+1	+2	+3	+4	$+5^+$	Tot	Lm	$\overline{m}_{6.5}$
PER	46	42	60.5	106	166	166	132.5	97	49	865	5.86	2.06
SPO	6	5	13	29	55.5	94.5	119	107.5	229.5	659	5.84	4.07

Table 3 – Global train percentages and mean duration in seconds per magnitude class for the Perseids and August sporadics. Train details were only available for 235 Perseids and 256 sporadics of the reported totals.

Magnitude	-3^-	−2	−1	0	+1	+2	+3	$+4^+$
Train % PER	80	60	56	67	49	33	15	5
Duration PER	6.8	3.7	2.1	1.3	1.2	1.0	0.7	0.4
Train % SPO	0	0	60	18	8	10	4	1
Duration SPO			2.3	1.8	2.0	1.8	0.7	3.0

One probable brilliant fireball was observed by the author as a sudden brightening of the south-eastern sky at 1^h05^m UT on August 2. At maximum light, the entire southern sky up to an elevation of about 50° turned daytime blue, perhaps suggesting a magnitude in the range of −15 to −20 or more. Unfortunately, the object itself was below the level of horizon obstructions (20°–30° elevation) in that direction, so it cannot be confirmed that this definitely was a meteor, and no other sightings, either from observers, DoD satellites or casual witnesses have come forward.

Aside from the Perseids, and the early August continuation of the declining Aquarid/Capricornid rates, forward-scatter observers were again bedeviled by atmospheric effects, which were especially severe over Europe.

There is some confirmation of the $\lambda_\odot \approx 144°$ peak found in [1] (notably around $\lambda_\odot \approx$ 144°–146°, August 17–19, 1997), and also the $\lambda_\odot \approx 155°$ one (range $\lambda_\odot \approx$ 150°–156°, August 23–29, 1996). Such a peak is a little early for the α-Aurigid maximum, due around August 31–September 1, but may have resulted from a possible new minor shower with a radiant in Aries detected visually during the opening phase of the Section's Aurigid and Taurid plotting project. On August 29-30 and 30-31, several swift meteors were noted by the author as coming from an approximate radiant area some degrees across centered on $\alpha \approx 40°$ and $\delta \approx +20°$. Rainer Arlt commented that observers in Italy had also reported a potential "Arietid" radiant in late August, although their suspected radiant positions were not in very close agreement with the above one. That some "Arietid" meteors did seem apparent in two independent data sets indicates the need for much more work on the Aurigid-Perseid-Arietid radiants active in late August and September in future years.

Acknowledgments

As ever, all observers and correspondents are gratefully thanked for their contributions to the Section during this interesting period, especially those who struggled, whether successfully or not, against adverse weather and atmospheric conditions affecting their observing. Clearer skies, and fewer atmospheric distractions, for your coming work!

References

[1] A. McBeath, "The Forward Scatter Meteor Year", in *Proceedings of the IMC*, Petnica, Yugoslavia, 1997, A. Knöfel, A. McBeath (eds.), IMO, 1998, pp. 39–54.

[2] R. Arlt, J. Rendtel, "First Analysis of the 1997 Perseids", *WGN* 25:5, October 1997, pp. 207–209.

[3] A. McBeath (comp.), "Meteor Shower Calendar: April–September 1997", *WGN* 25:1, February 1997, p. 10.

Figure 5 – A meteor trail very close to comet Hale-Bopp's position was photographed by George Zay on March 6, 1997. He took the photo through a 200 mm telelens using T-MAX 400 film. The 25-minute exposure was started at 4^h18^m UT.

The International Meteor Organization

Council

President: Jürgen Rendtel, Gontardstraße 11, D-14471 Potsdam, *Germany*,
tel. 49 (331) 960 727, e-mail: president@imo.net

Vice-Pres.: Alastair McBeath, 12A Prior's Walk, Morpeth, Northumberld. NE61 2RF, *Engl.*,
tel. 44 (1670) 518 487

Secretary-General: Robert Lunsford, Vance Street 161, Chula Vista *CA 91910, USA*

Treasurer: Ina Rendtel, Mehlbeerenweg 5, D-14469 Potsdam, *Germany*,
tel. 49 (331) 520 707, e-mail: treasurer@imo.net
postal (giro) account number: 547234-107
bank code: 100 100 10 Postbank D-10916 Berlin
(bank code and postbank to be mentioned together with account number!)

Other council members:
Rainer Arlt, Friedenstraße 5, D-14109 Berlin, *Germany*
Godfrey Baldacchino, "Sirius," Triq-Il-Migbha, ZBR 10 Marsascala, *Malta*
Marc Gyssens, Heerbaan 74, B-2530 Boechout, *Belgium*
André Knöfel, Saarbrücker Straße 8, D-40476 Düsseldorf, *Germany*
Sirko Molau, Weidenweg 1, D-52074 Aachen, *Germany*

Commission Directors

Visual Commission: Rainer Arlt, e-mail: visual@imo.net

Telescopic Commission: M. Currie, 25 Collett Way, Grove, Wantage, Oxon. OX12 0NT, *Engl.*,
e-mail: tele@imo.net

FIreball DAta Center: André Knöfel, e-mail: fidac@imo.net

Photographic Commission: Marc de Lignie, Prins Hendrikplein 42, NL-2264 SN Leidschendam,
the Netherlands, e-mail: photo@imo.net

Video Commission: Sirko Molau, e-mail: video@imo.net

Radio Commission: vacant, e-mail: radio@imo.net

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

Editor-in-chief: Marc Gyssens, tel. 32 (3) 455 68 18, e-mail: wgn@imo.net
fax: 32 (11) 26 82 99 (mention "for Marc Gyssens")

Typesetting: Urania, the Public Observatory of Antwerp

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

Addresses of authors not mentioned above

E.P. Bus, Eerste Spoorstraat 16, NL-9718 PB Groningenm, *the Netherlands*
D. Očenas, M. Razusa St. 5, SK-974 00 Banska Bystrica, *Slovakia*
P. Ziminkoval, Tatranska 6, SK-974 00 Banska Bystrica, *Slovakia*
A. Olech, Warsaw Univ. Astr. Obs., Al. Ujazdowskie 4, PL-00-478 Warszawa, *Poland*
A. Terentjeva, Institute of Astronomy, Russian Academy of Sciences, Pjatniskaja St. 48, 109 017 Moscow, *Russia*
M. Beech, Campion College, Univ. of Regina, Regina, *Saskatchewan S4S 0A2, Canada*
R. Gorelli, Via di Val Favara n. 72, Pal. B, I-00168 Roma, *Italy*

The stock of the IMO

	DEM	USD
Publications in English:		
Photographic Meteor Data Base (1986)	8	6
Proceedings International Meteor Conference 1990	10	8
Proceedings International Meteor Conference 1991	10	8
Proceedings International Meteor Conference 1992	10	8
Proceedings International Meteor Conference 1993	12	9
Proceedings International Meteor Conference 1994	10	8
Proceedings International Meteor Conference 1995	12	9
Proceedings International Meteor Conference 1996	12	9
Proceedings International Meteor Conference 1997	12	9
Gnomonic Atlas Brno 2000.0	5	4
Photographic Astrometry + diskette	13	10
Photographic Handbook	15	12
Visual Handbook	25	20
WGN Observational Report Series:		
Vols. 1–4 (1988–91): Visual and Fireball Obs., per vol.	15	12
Vol. 5 (1992): Visual Observations	15	12
Vol. 6 (1993): Vis. Obs. and Electrophonic Fireball Cat.	20	16
Vols. 7–9 (1994–96): Visual Observations, per vol.	20	16
Backissues of the WGN Journal:		
Volumes 19–20 (1991–92): complete, per volume:	20	16
Volumes 21–22 (1993–94): complete, per volume:	25	20
Volumes 23–25 (1995–97): complete, per volume:	35	25
Backissues of Fidac News:		
Volumes 1–5 (1993–97) : complete, per volume:	15	12