wgn

19 - 2

april 1991

bimonthly journal of the international meteor organization

Sporadic meteor of magnitude −1 photographed on August 24, 1990, at $20^h59^m07^s$ UT, by Ragnar Bödefeld at Lindenberg, Germany, with a 35 mm $f/2.4$ lens. The photograph was exposed from $20^h37^m05^s$ till $21^h04^m40^s$ UT.

In this issue:



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

Afgiftekantoor: 2540 Hove

*WGN, volume 19, nr 2, April 1991, pp. 27–78*

# Contents



# Useful Information

## The June Issue *(WGN 19:3)*

The *June issue* is expected to be mailed during the first week of June. Contributions are due *May 3*. They should be sent to *Marc Gyssens* or to any member of the editorial board (addresses: inside of back cover).

## WGN Subscription/IMO Membership 1991

The subscription rate for volume 19 (1991) is 20 DEM for six issues. It is anticipated that volume 19 will contain over 240 pages. Subscriptions should be paid to Ina Rendtel, in DEM. However, read the note on p. 74 of this issue. People who can only pay from a bank account must send an international bankdraft in USD payable to Peter Brown. British subscribers may also contact Alastair McBeath and Japanese subscribers may contact Masahiro Koseki. All addresses can be found on the inside of the back cover. Please make sure we retain the full amount due after deduction of bank and/or exchange charges. Please refer to p. 3 of the February issue for further details. Additional gifts are of course welcome.

# From the Editor-in-Chief

*Marc Gyssens*

*Well, finally, we have a thick issue! The last few months again saw a steady flow of articles, making this possible. This however should not be a reason to sit back and relax; only a continuing effort of everyone involved is a guarantee for WGN being able to fulfill its tasks now as well as in the future. So keep sending in your articles, reports, photographs, etc.!*

*As a supplement to this issue, you will find indexes to the volumes 16 (1988), 17 (1989) and 18 (1990). They resulted from a very much appreciated effort of our Vice-President, Alastair McBeath. His work will certainly contribute to make WGN more accessible as a rich source of information. It is our intent to publish such an index annually.*

*As far as the page numbering is concerned, we decided to put each index at the end of the volume to which it refers. Subscribers wishing to bind their volumes should take this into account for the future.*

*Enjoy this issue!*

# Hints for authors of WGN

*Marc Gyssens*

When processing your articles, we often encounter minor problems that nevertheless cost us a lot of valuable time to solve them. Many of these problems can be avoided if authors would abide by the simple guidelines outlined below. We thank you in advance for your understanding and cooperation.

- Some contributors to *WGN* still seem to have difficulties as to whom they have to send their articles and reports. **Manuscripts should be send to:** *Marc Gyssens, Heerbaan 74, B-2530 Boechout, Belgium.* This address figures on the outside back cover of each issue of *WGN*.

- Please understand that **illustrations must be submitted camera-ready.** This means they must be drawn in *dark* black (preferably black ink) and of sharp contrast. So, do *not* use a blue pen, a pencil, colors etc. Laser printer figures are of course fine; if you use a dot printer, make sure that you use a new ribbon. Also, you should pay attention to the lettering on your illustrations: please avoid plainly handwritten text. If you really do not see any alternative, you can also include with your illustrations copies on which you have written the text and symbols to be inserted; in that case, we will take care of the lettering.

  The size of the illustrations is of minor importance, since we have the possibility to reduce or enlarge them, depending on space and lay-out considerations. However, when selecting a size, you should use some common sense. From the standpoint of quality, enlargements are to be avoided. So you better make your illustrations a little too large than a little too small, but do not exaggerate: very large reduction factors also result in quality loss, and, to some extent, in contortions of the picture.

Finally, make sure that the size of your figure and the size of your lettering are in a reasonable proportion. A large picture with very small symbols may cause problems: if we have to reduce the figure, the symbols may become hard to read.

- Still too often, we receive hard copies only of manuscripts that were typeset on computer. As a consequence, we have to re-type entire articles on computer that were already typeset by the author. This is really a waste of valuable time! **If you have a computer at your disposal, please use it to type your article** and send us a $3\frac{1}{2}''$ or a $5\frac{1}{4}''$ diskette (MS-DOS or Macintosh), containing a pure ASCII (text) file of your article. (Most word processors have an option to convert a file to ASCII format.) Together with the diskette, send a hard copy of your manuscript (formulae, special symbols, etc. can get lost in converting to ASCII), as well as possible illustrations.

  A possible reason why so many authors are still reluctant to send a diskette are the costs involved. **From now on, we will return all diskettes to the authors as soon as the articles they contain have appeared in print.** Another very convenient way of transferring computer text files is electronic mail. If you have electronic mail at your disposal (e.g. at the place where you work) you can send the file to: **gyssens@ccu.uia.ac.be.** From now on, this e-mail address will also figure on the outside back cover of each issue of *WGN*. If you use e-mail however, you should still send a hard copy of the text for the formulae and symbols, and, of course, your illustrations by paper mail.

- If you do not have a computer at your disposal, you can of course submit a type-written text. If you do not have a typewriter, a handwritten manuscript is fine, **provided it is written legibly!** Having to decipher someone's handwriting is also a waste of time!

# Exchange Publications Available from IMO

*Paul Roggemans*

Mr. Daniel Ocenas offers the following publications to *IMO* members, in exchange for Slovak membership in *IMO*. We stress to our members that these publications are of extremely high value for meteor workers: this is a very exceptional opportunity to obtain copies of these volumes of the *Contributions of the Astronomical Observatory Skalnaté Pleso*. The prices below cover surface mail postage.

| | | |
|---|---|---|
| Volume 1 (1955), 130 pages | Meteors, Stars | 20 DEM |
| Volume 2 (1957), 83 pages | Meteors, Comets | 15 DEM |
| Volume 3 (1966), 167 pages | Meteors, Stars, Sun | 25 DEM |
| Volume 4 (1969), 103 pages | Meteors, Stars, Sun | 15 DEM |
| Volume 5 (1973), 180 pages | Meteors, Comets, Sun, Stars | 25 DEM |
| Volume 6 (1976), 400 pages | Stars | 45 DEM |
| Volume 7 (1976), 200 pages | Meteors, Stars | 25 DEM |
| Volume 8 (1979), 200 pages | Meteors, Comets, Sun, Stars | 25 DEM |
| Volume 9 (1980), 190 pages | Meteors, Sun, Stars | 25 DEM |
| Volume 10 (1981), 133 pages | Meteors, Sun, Stars | 20 DEM |
| Volume 11 (1983), 329 pages | Meteors, Comets, Sun, Stars | 40 DEM |
| Volume 12 (1984), 285 pages | Meteors, Comets, Sun, Stars | 35 DEM |
| Volume 13 (1985), 253 pages | Meteors, Comets, Sun, Stars | 30 DEM |
| Volume 14 (1986), 189 pages | Meteors, Sun, Stars | 25 DEM |
| Volume 15 (1986), 728 pages | Stars | 80 DEM |
| Volume 16 (1987), 210 pages | Sun, Stars | 25 DEM |
| Volume 17 (1988), 345 pages | Meteors, Comets, Sun, Stars | 40 DEM |
| Volume 18 (1989), 275 pages | Comets, Sun, Stars | 35 DEM |
| Volume 19 (1990), 346 pages | Meteors, Comets, Sun, Stars | 40 DEM |

Now it is important to note that **only two copies are available per volume!** Therefore we urge you to use the following procedure:

1. First contact Mr. Daniel Ocenas. His address is: *M. Razusa Street 5, CS-97400 Banska Bystrica, Czechoslovakia* and his phone number is (+42)88 54 264. Tell him which publications you want, ask him which are still available and have them reserved for you.
2. Order the publications that Mr. Ocenas reserved for you in the customary way from our treasurer Ina Rendtel, **but please read the short note on p. 74!** As soon as she received your payment she will instruct Mr. Ocenas to send you the ordered volumes.

# Letters to WGN

*compiled by Marc Gyssens*

## The first international Tunguska expedition

*The article "Report on the 1st International Tunguska Expedition" in WGN 18:6, December 1990, pp. 215–216 mentions:*

> About 120 persons took part in this expedition. There were 26 foreign members (France 8, Yugoslavia 7, Bulgaria 6, Sweden 2) and about 100 members were from the USSR. Let us note that this was the 32th expedition organized by the Complex Independent Expedition of the Tomsk Branch of the All-Union Astronomical-Geodetical Society and it was one of the biggest expeditions since 1958.

*Regarding this excerpt, we received the following comment from the "Centre d'Organisation de Recherches et d'Expertises en Technologies Avancées (CORETA)" in Valence, France:*

We must do away with any possible confusion: my company organized an independent French expedition in cooperation with the Ukrainian Academy of Sciences in Kiev. Of the eight members of the French team, there were four scientists:

- Daniel Haccard, Ecole des Mines, Paris, geologist;
- Claude Perron, Muséum National d' Histoire Naturelle, Paris, cosmochemist;
- Raymond Baudouin, Muséum National d' Histoire Naturelle, Paris, botanist;
- myself, scientific manager of CORETA, former director of research – Ecole des Mines, Paris, Centre de Télédétection et d'Analyse des Milieux Naturels.

We were accompanied by 4 members of a television team organized by my company for co-producing, with the Ukrainian television, a film which has been sold to the French station FR3.

Briefly, our main scientific results are that no tracks of cosmic matter were found in the samples taken back from Tunguska, and that no geological evidence of impact was found in the visited area. We think, with specialist Mrs. Vera Semenenko from Kiev, that a porous meteorite of low density is presently the best explanation to the 1908 catastrophe and its characteristics.

We were very happy to meet Professors Vassiliev and Plekhanov and their co-workers in the field, and my company will help them in certain directions of research and international processing, but the French expedition of 1990 was independent of Tomsk, and dependent of the Kiev Laboratory for Scientific Innovation.

*Alain Chabaud, March 8, 1991*

## Fireballs

*With the 1988 December issue of WGN, we started to publish the fireball reports of the Ondřejov Observatory on a regular basis. We received a letter from Gotfred Møbjerg Kristensen telling us that with his radio equipment, he recorded the fireball mentioned in "Earth-Grazing Fireball, Czechoslovakia, Poland, October 13, 1990, $03^h27^m16^s$ UT", WGN 19:1, February 1991, p. 13.*

Every time I hear or read about fireball/bright meteors, I check my pen-recorder journal over bright radio meteors. My pen recorder is connected to my radio receiver at 100.50 MHz for around-the-clock observations of radio meteors. The antenna is an 8-elements Yagi. Its direction is always due south and its elevation 25°. Daily, I look over the pen-recorder paper, and note every radio meteor reflection with a duration over 8 seconds in a journal specifying time, duration, power and remarks.

My journal shows a note about a very bright radio meteor on October 13, 1990, at $03^h27^m24^s \pm 06^s$ UT, with a duration of 78 seconds and power 2.5 at 20 Volt (maximum: 5). It had been described as a massive signal. From various simultaneous radio/visual observations, it follows that the average visual magnitude for a meteor with a duration of 78 seconds on my equipment must be around −6.

I have no doubt: this is a radio signal from the Earth-grazing fireball over Czechoslovakia and Poland. The angle between the ground direction to the start point for the fireball in Czechoslovakia and my antenna direction was around 30° and the distance some 800 km. When the meteorite left the atmosphere over Poland, the angle was about 45° and the distance about 400 km.

During the entire year 1990, my pen-recorder registered 49 radio reflections from meteors with durations of 60 seconds or more (even up to 477 seconds!). The total number of radio meteors observed in 1990 with the pen-recorder was 390 137.

*Gotfred Møbjerg Kristensen, February 24, 1991*

### Interpreting radio meteor counts

*In response to some questions I raised to Dr. Manley about a submission on radio observations of the Perseids, he wrote to me the following letter and asked me to publish it in WGN.*

In the following paragraphs, I will try to clarify my method of interpreting radio meteor data.

For almost 3 years, I have been recording meteor data for 24 hours a day from Jacksonville and Miami, FL. I have divided the meteors into large, medium and small sizes since I began. The large division represents visual meteors of about sand size. Everything is computerized. Airplane reflections have been eliminated by accepting only reflections of relatively rapid attack time.

When I started recording meteors several years ago, I noticed that very few meteors could be observed around sundown, while meteors were relatively abundant near sunrise. I developed a correction for this which is called a diurnal correction. Meteor counts near sundown are multiplied by 3.33 while those near sunrise are multiplied by 1. The other hours have relatively linear multiplication values between these two extremes. Without this correction, many meteor showers are not discernable. This correction affects the background as well as the meteors belonging to a shower. This diurnal correction accentuates and clarifies the patterns of major meteor showers. According to Van Wassenhove, the program FORWARD does not utilize this correction. Additionally, most radio meteor data does not break out the sand or visual meteor size from their data. These two factors make the use of most radio meteor data difficult.

The observability function is empirically done in my graphic interpretation of a meteor shower. The actual observability percent can be read by subtracting the actual meteor counts from the missing values given in my graphs. The missing values are obtained by drawing a smooth sinusoidal curve which extends upward the values at lower elevations of the radiant. Many times this results in a peak value every 12 or every 24 hours. Only the peak values are valid. With the exception of the peak day, this means that there are usually only one or two valid peak counts per day in radio meteor data employing the method I have presented. Peaks can also occur every few hours. However, in most instances, a correction similar to the ZHR correction in visual data is needed to obtain more than one or two valid radio meteor counts per day. I have not yet attempted to calculate this correction because I have obtained good radio meteor data for about three years on 108 meteor showers per year without using this correction.

Missing counts must be determined with the appropriate vertical and horizontal scales. I have determined the correct scales empirically from my meteor count data by comparing my data to known meteor counts from reliable visual observations published in *WGN*. In any geophysical or astrophysical survey, one should always start with the known and then cautiously proceed to the unknown. Visual observations are the hard core known facts that we must use as a base to further the development of radio meteor data.

I have written to Jeroen Van Wassenhove requesting the formulae and flow sheets for the program FORWARD. I am very interested to see how my empirical graphical method compares with the more mathematically based one in the program FORWARD.

*Thomas R. Manley, February 11, 1991*

# Important Notes from FIDAC

*André Knöfel*

When a year has passed, the authors of the *WGN Report Series* have the task to compile their parts of the new report. Therefore it is necessary that all reports of observations arrive in time. The reports of 1988 and 1989 were published only after two years of data collecting. Of course, this situation is unsatisfactory. Therefore, Paul Roggemans made a call in the previous issue of *WGN* for the visual observations.

Now, the same situation occurs with fireball reports! Therefore my urgent request: rummage your observation in 1990 if perhaps a fireball has been forgotten. Remember: a fireball is a meteor of magnitude at least −3. Time and again, it is surprising to find such bright meteors in some magnitude distributions while no report was received by the *FIDAC*. Once more: please, check your observations of 1990 again, search in your local astronomical journals, and interview other non-meteor-amateurs having seen fireballs.

To avoid such campaigns under deadline pressure in the future, I suggest the following procedure: if you see a fireball, fill out the fireball report form and send it together with your regular visual observations to the person responsible for collecting data for the *VMDB* in your area. In this way, you save on postage and, by comparing with your magnitude distribution, you can make sure that no fireball has been forgotten. Your fireball report arrives at the *FIreball DAta Center* sooner or later with the regular correspondence between directors and/or council members.

# Calculating the Solar Longitude 2000.0

*Christian Steyaert*

A method is described to calculate solar longitude with respect to the equinox of 2000.0.

## 1. Introduction

An often asked question is the exact calculation of the solar longitude. The switch to equinox 2000.0 offers a good opportunity to revise the calculations completely, rather than adding a correction to the 1950.0 value.

In meteor work, the solar longitude is measured with reference to a standard equinox, such as 1950.0, or, for many years to come, the standard equinox 2000.0, i.e., the start of the Julian year 2000. Furthermore, the geometrical position of the Sun is used, excluding the aberration of the sun light. An accuracy of 0°001 will be obtained in applying all periodical terms in the interval 1000–3000 AD. Often, an accuracy of 0°01 is sufficient in meteor work.

The method described below is based upon VSOP87, the planetary theory of P. Bretagnon of the *Bureau des Longitudes* in Paris.

## 2. Formulae

*Universal Time (UT) versus Dynamical Time (DT):*

Our clocks give *Universal Time (UT)*. There is a small difference between UT and the uniform *Dynamical Time (DT)*. The difference, called $\Delta T$, equals $58^s$ in 1991. It is supposed to increase by about $0^s\!.9$ per year in the next decade.

We assume that the calculation of the *Julian date (JD)* from the given DT is known.

Calculate the quantity $T$, the *number of millennia since* 2000.0:

$$T = \frac{\text{JD} - 2451545}{365250} \tag{1}$$

Please note that $T$ is negative before the start of the year 2000.

*Mean solar longitude:*

The *mean solar longitude* $L_0$ (in radians) is calculated by:

$$L_0 = 4.8950627 + 6283.0758500T - 0.0000099T^2 \tag{2}$$

*Periodical terms*

Calculate the sums:

$$\begin{aligned} S_0 &= \sum_{i=1}^{28} A_{0i} \cos(B_{0i} + C_{0i}T) \\ S_1 &= \sum_{i=1}^{3} A_{1i} \cos(B_{1i} + C_{1i}T) \\ S_2 &= \sum_{i=1}^{2} A_{2i} \cos(B_{2i} + C_{2i}T) \\ S_3 &= \quad A_{3i} \cos(B_{3i} + C_{3i}T) \end{aligned} \tag{3}$$

with the constants from Tables 1–4.

*Solar longitude:*

Finally, the solar longitude for the standard equinox of 2000.0 is given by:

$$L = L_0 + (S_0 + S_1T + S_2T^2 + S_3T^3)10^{-7} \tag{4}$$

## 3. Practical aspects

In writing a computer program, several elements that influence the accuracy should be considered:

- the number of meaningful digits should be at least 11. "Single precision" (7 or 8 digits) is insufficient.
- large angles, such as $A_{ji} + B_{ji}T$, might have to be reduced to the interval $[0, 2\pi]$ before taking the cosine function. $L_0$ (2) and $L$ (4) are converted to degrees and reduced to the interval $[0, 360]$.

Table 1 – The constants $A_{0i}$, $B_{0i}$ and $C_{0i}$.

| $i$ | $A_{0i}$ | $B_{0i}$ | $C_{0i}$ |
|---|---|---|---|
| 1 | 334166 | 4.669257 | 6283.075850 |
| 2 | 3489 | 4.6261 | 12566.1517 |
| 3 | 350 | 2.744 | 5753.385 |
| 4 | 342 | 2.829 | 3.523 |
| 5 | 314 | 3.628 | 77713.771 |
| 6 | 268 | 4.418 | 7860.419 |
| 7 | 234 | 6.135 | 3930.210 |
| 8 | 132 | 0.742 | 11506.77 |
| 9 | 127 | 2.037 | 529.691 |
| 10 | 120 | 1.110 | 1577.344 |
| 11 | 99 | 5.233 | 5884.927 |
| 12 | 90 | 2.045 | 26.298 |
| 13 | 86 | 3.508 | 398.149 |
| 14 | 78 | 1.179 | 5223.694 |
| 15 | 75 | 2.533 | 5507.553 |
| 16 | 51 | 4.58 | 18849.23 |
| 17 | 49 | 4.21 | 775.52 |
| 18 | 36 | 2.92 | 0.07 |
| 19 | 32 | 5.85 | 11790.63 |
| 20 | 28 | 1.90 | 796.30 |
| 21 | 27 | 0.31 | 10977.08 |
| 22 | 24 | 0.34 | 5486.78 |
| 23 | 21 | 4.81 | 2544.31 |
| 24 | 21 | 1.87 | 5573.14 |
| 25 | 20 | 2.46 | 6069.78 |
| 26 | 16 | 0.83 | 213.30 |
| 27 | 13 | 3.41 | 2942.46 |
| 28 | 13 | 1.08 | 20.78 |

Table 2 – The constants $A_{1i}$, $B_{1i}$ and $C_{1i}$.

| $i$ | $A_{1i}$ | $B_{1i}$ | $C_{1i}$ |
|---|---|---|---|
| 1 | 20606 | 2.67823 | 6283.07585 |
| 2 | 430 | 2.635 | 12566.152 |
| 3 | 43 | 1.59 | 3.52 |

Table 3 – The constants $A_{2i}$, $B_{2i}$ and $C_{2i}$.

| $i$ | $A_{2i}$ | $B_{2i}$ | $C_{2i}$ |
|---|---|---|---|
| 1 | 872 | 1.073 | 6283.07585 |
| 2 | 29 | 0.44 | 12566.15 |

Table 4 – The constants $A_{3i}$, $B_{3i}$ and $C_{3i}$.

| $i$ | $A_{3i}$ | $B_{3i}$ | $C_{3i}$ |
|---|---|---|---|
| 1 | 29 | 5.84 | 6283.07585 |

Note also that $C_{01} = C_{11} = C_{21} = C_{31}$. Yet, less decimals are given for the sums with higher rank. This is merely done to avoid keypunching extraneous digits which do not influence the result.

### 4. Example: longitude conversion from 1950.0

Calculate the solar longitude, standard equinox 2000.0 for January 4, 1992, at $5^h00^m$ UT.

Results:

$$L_0 = -45.3229550 \text{ rad}$$
$$S_0 = 1245,\ S_1 = -19243,\ S_2 = 404,\ S_3 = 27$$
$$L = 283^\circ\!.195$$

According to Poole et al. [1], the solar longitude of the (radar) maximum of the Quadrantid stream is 282°5. However, this is the value for the equinox 1950.0. *Solar longitudes for equinox* 1950.0 *can be corrected to* 2000.0 *by adding* 0°70 *(with* 0°01 *accuracy).* Hence, the 2000.0 longitude of the Quadrantid maximum is approximately 283°2. To avoid confusion, please always mention the equinox. It will be assumed that older references have equinox 1950.0.

### Acknowledgment

Many thanks go to Jean Meeus for the permission to use his reference [2] as the base for this article.

### References

[1] Poole et al., *Mon. Not. R. Astr. Soc.* 156, 1972, p. 223.
[2] Meeus, J., "Berekening van de zonnelengte 2000.0", *Heelal* 36:1, 1991, pp. 8–9.

# 1991 BA and the Canids, and Other New Earth-Grazers

*Christian Steyaert*

Information is provided on possible meteor showers associated with the recently discovered Earth-grazing asteroids 1991 BA, 1991 AQ and 1991 BB.

There was excitement when the discovery of a new record-close Earth-grazing asteroid by the Spacewatch team at Kitt Peak was announced in IAU Circular 5172. B.G. Marsden obtained the following approximate orbital elements, based on seven position measurements of 1991 BA:

| | |
|---|---|
| $T = 1991.17$ | $\omega = 70^\circ\!.58$ |
| $e = 0.682$ | $\Omega = 118^\circ\!.34$ |
| $q = 0.713$ AU | $i = 1^\circ\!.96$ |
| $a = 2.242138$ AU | |

1991 BA is intrinsically very faint, and becomes the celestial object of smallest known size, only 5 to 10 meter across. The asteroid passed the Earth at a record geocentric distance of 0.0011 AU.

Our shortest distance-between-orbits calculation shows an even closer approach of only 0.000 35 AU, i.e., 53 000 km. (It should be noted that the gravitational pull of the Earth was not included). The corresponding longitude is $\lambda_\odot = 297^\circ\!.66$, January 18.15. The associated radiant has $\alpha = 109^\circ\!.5$, $\delta = 18^\circ\!.6$, $V_\infty = 21.2$ km/s. In a message on Compuserve Astroforum (via Astromail), Gary W. Kronk indicates that the orbit of 1991 BA matches very well that of the Canes Venaticids (Canids), discovered during radio surveys by Z. Sekanina in the 1960's. The orbit, based on 18 radio meteors was:

| | |
|---|---|
| $a = 2.113$ AU | $\omega = 70°6$ |
| $e = 0.656$ | $\Omega = 122°5$ |
| $q = 0.727$ AU | $i = 4°5$ |

with an average radiant at $\alpha = 113°4$ and $\delta = +12°6$.

1991 BA makes a second close approach to the Earth's orbit on June 15.11 ($\lambda_\odot = 83°65$) of 0.0197 AU. The theoretical radiant has $\alpha = 92°7$, $\delta = +25°2$ and $V_\infty = 21.2$ km/s.

There are two more other new Earth-grazers. 1991 AQ was discovered by E. Helin (IAU Circular 5171). The orbital elements by B.G. Marsden are based on only five observations and hence are uncertain:

| | |
|---|---|
| $T = 1991.2$ | $\omega = 239°74$ |
| $e = 0.754700$ | $\Omega = 341°91$ |
| $q = 0.5048$ AU | $i = 3°14$ |
| $a = 2.057888$ AU | |

The closest approaches occur at $\lambda_\odot = 304°16$ (January 24.54, 0.0331 AU) with an associated radiant at $\alpha = 132°2$ and $\delta = +22°9$, $V_\infty = 26.5$ km/s and at $\lambda_\odot = 141°27$ (August 14.42, 0.0196 AU) with a radiant at $\alpha = 138°8$ en $\delta = 13°5$, $V_\infty = 26.5$ km/s.

1991 BB was discovered by J. Mueller and has been announced in IAU Circular 5173:

| | |
|---|---|
| $T = 1991.44$ | $\omega = 318°447$ |
| $e = 0.2762$ | $\Omega = 294°784$ |
| $q = 0.88803$ AU | $i = a41°213$ |
| $a = 1.226900$ AU | |

A closest approach occurs at $\lambda_\odot = 116°32$ (July 7.37), shortest distance: 0.0751 AU, and radiant: $\alpha = 84°5$, $\delta = -50°7$, $V_\infty = 25.7$ km/s.

# Visual Observers' Notes: May and June 1991

*Jeff Wood and Ralf Koschack*

The months of May and June contrast greatly between the northern and the southern hemispheres. In the northern hemisphere there are few showers active and hence overall meteor rates tend to be low. In the southern hemisphere there are quite a few showers to be seen. This together with the ecliptic being high overhead ensures that good rates are seen.

Table 1 lists some of the meteor showers to be seen in May and June 1991. Table 2 shows moonlight and observing conditions. The illuminated part of the Moon is always given for $0^h$ UT on the date indicated. The dates of the phases of the Moon are also given in UT. Note that the activity period data for the June Bootids and the $o$-Cetids are uncertain.

The Visual Commission of the *IMO* although requiring data on all streams realizes practical considerations like work, study, family, Moon and weather prevent people from observing regularly on a day by day basis throughout most of the year. With this in mind, it has been decided to encourage everyone who has time to observe to concentrate on a couple of showers per month rather than the whole lot. This means we should be able to get a good set of data on these few rather than sparse data on many showers. The showers chosen for special investigation for the months of May and June are the Scorpio-Sagittarid showers, the $o$-Cetids and the June Lyrids.

Table 1 – A list of some of the meteor showers to be seen in May–June 1991.

| Shower | Activity | Max | Radiant | | | Drift | | $V_\infty$ | $r$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | $\alpha$ | $\delta$ | D. | $\Delta\alpha$ | $\Delta\delta$ | | |
| $\eta$-Aquarids | Apr 19–May 28 | May 05 | 336° | −02° | 4° | +0°.9 | +0°.4 | 66 | 2.7 |
| $\beta$-Corona Australids | Apr 23–May 30 | May 18 | 284° | −40° | 4° | +0°.9 | +0°.1 | 45 | 3.1 |
| Southern Ophiuchids | May 10–May 29 | May 20 | 258° | −24° | 5° | +0°.9 | −0°.1 | 30 | 2.9 |
| Northern Ophiuchids | Apr 25–May 31 | May 13 | 249° | −14° | 5° | +0°.9 | −0°.1 | 30 | 2.9 |
| $\kappa$-Scorpids | May 04–May 27 | May 19 | 267° | −39° | 4° | +0°.9 | 0°.0 | 45 | 2.8 |
| $\theta$-Ophiuchids | Jun 04–Jul 15 | Jun 13 | 267° | −20° | 5° | +0°.9 | 0°.0 | 27 | 2.8 |
| $\gamma$-Sagittarids | May 23–Jun 13 | Jun 06 | 272° | −28° | 5° | +0°.9 | 0°.0 | 29 | 2.9 |
| $\lambda$-Sagittarids | Jun 05–Jul 25 | Jul 01 | 276° | −25° | 5° | +0°.9 | 0°.0 | 23 | 2.6 |
| Lyrids (June) | Jun 11–Jun 21 | Jun 16 | 278° | +35° | 5° | +0°.8 | 0°.0 | 31 | 3.0 |
| Bootids (June) | Jun 26–Jun 30 | Jun 28 | 219° | +496° | 8° | | | 14 | 3.0 |
| $o$-Cetids | May 06–Jun 05 | May 15 | 25° | −04° | 5° | | | 36 | 3.0 |
| $\alpha$-Scorpids | Mar 26–Jun 04 | May 03 | 246° | −25° | 5° | +0°.9 | −0°.1 | 35 | 2.5 |

Table 2 – Moonlight and observing conditions in May–June 1991.

| Date | $k$ | Date | $k$ |
|---|---|---|---|
| Friday May 03 | 0.85− | Friday June 07 | 0.36− |
| Friday May 10 | 0.22− | Friday June 14 | 0.03+ |
| Friday May 17 | 0.11+ | Friday June 21 | 0.69+ |
| Friday May 24 | 0.81+ | Friday June 28 | 0.99− |
| Friday May 31 | 0.94− | Friday July 05 | 0.51− |

| | |
|---|---|
| New Moon: | May 14, June 12, July 11 |
| First Quarter: | April 21, May 20, June 19 |
| Full Moon: | April 28, May 28, June 27 |
| Last Quarter: | May 7, June 5, July 5 |

## 1. Scorpio-Sagittarids

The Scorpio-Sagittarids encompasses a number of streams that occur in the constellations of Scorpius and Sagittarius during the months of March, April, May, June and July. Named by Dr. C. Hoffmeister during the 1930s, these ecliptic streams are thought to have originated from comet Lexell (1770 II). The Scorpio-Sagittarid showers are noted for greatly varying rates. At times, they are virtually not active while on other occasions, ZHRs of around 10 have been recorded. The Scorpio-Sagittarid showers are noted for bright colored fireballs and the occasional meteor that produces a persistent train.

As mentioned previously, the Scorpio-Sagittarids consists of a number of sub-streams. The major components whose details are described in Table 1 are the $\beta$-Corona Australids, Southern and Northern Ophiuchids, $\kappa$-Scorpids, $\theta$-Ophiuchids, $\alpha$-Scorpids, $\gamma$-Sagittarids and the $\lambda$-Sagittarids. Since Scorpio-Sagittarid meteors have velocities similar to those of the majority of sporadic meteors, great care needs to be taken in identifying them. Observers should be facing the radiant area and plot all meteors seen.

## 2. $o$-Cetids

This shower was detected by radio astronomers during the 1950s and belongs to the family of daytime showers. For a long time, it was thought that with the radiant reaching culmination during late morning it would be impossible to record meteors visually. However, observations made during the late 1970s by *W.A.M.S.* members demonstrated that during the last hour before twilight prevented viewing, the radiant rose sufficiently in the Southern Hemisphere skies for rates of between 1 and 4 to be recorded. Indeed, not only were rates recorded, but also several visual determinations of the radiant positions were made. These together with the radio determinations form the basis for the crude ephemeris described in Table 3, below.

Table 3 – Radiant positions of the $o$-Cetids (diam.: 5°).

| Date | $\alpha$ | $\delta$ | Date | $\alpha$ | $\delta$ |
|---|---|---|---|---|---|
| May 08 | 21° | −06° | May 23 | 28° | −03° |
| May 13 | 24° | −05° | May 28 | 31° | −01° |
| May 18 | 26° | −04° | Jun 02 | 33° | 00° |

Southern Hemisphere observers are encouraged to give the $o$-Cetids particular attention in 1991. With favorable moon conditions during and after maximum (May 16 to 25) together with, hopefully, good weather, a great deal of new knowledge should be uncovered about this shower. Observers should take great care in viewing this stream. They should locate their center of field of view no more than 40° from the radiant and ensure all meteors are plotted.

## 3. June Lyrids

For the last years, only few observations of this minor shower are known. In most cases, weak or even no activity was reported. Maybe this shower only produces periodic activity or has been perturbed in such a way that is does not encounter the Earth any longer.

But nevertheless, with favorable conditions moonwise, there will be a chance to monitor this shower in 1991. Center your field at a distance of about 20° to 40° from the radiant. Plot all possible shower members and carry out shower association taking into account path direction, angular velocity (cfr. [1]) and path length.

Table 4 – Radiant positions of the June Lyrids.

| Date | $\alpha$ | $\delta$ |
|---|---|---|
| Jun 11 | 274° | +35° |
| Jun 16 | 278° | +35° |
| Jun 21 | 282° | +35° |

## 4. Theoretical radiant of comet 1983 VII

The orbit of the long period comet 1983 VII approaches the Earth at a minimum distance of 0.003 AU on May 12, yielding a theoretical radiant at $\alpha = 289°$ and $\delta = +44°$ with $V_\infty = 45.4$ km/s. This radiant is well situated for observers in the Northern Hemisphere. The geocentric velocity as well as the very close approach of the comet's orbit leave a chance that there will be a detectable shower.

The actual radiant position may differ somewhat from the predicted one. To determine it, plot all meteors possibly radiating from an area of about 15° radius around the predicted radiant, fill out a list as for the Aquarid project [2] and send it to the Visual Commission. Using *PosDat* and a radiant analyzing program it will be investigated whether there is a radiant and where.

For plotting, the *Gnomonic Atlas Brno 2000.0* is recommended. The field of view should be centered at a distance of about 10° to 30° from the predicted radiant. For observations the time from around May 5 until May 20 is recommended.

## References

[1] R. Koschack, "Estimating a Meteors Angular Velocity", *WGN* 18:4, 1990, pp. 103–104.

[2] R. Koschack, J. Rendtel, "Aquarid Project 1989", *WGN* 17:3, 1989, pp. 90–92.

# Telescopic Observers' Notes: May and June 1991

*Malcolm J. Currie*

Hitherto these *Telescopic Observers' Notes* have concentrated on forthcoming events. Such material will tend to become repetitive from year to year unless there are new findings and showers to investigate further. Therefore, I should like to expand the brief of these notes to include summarized reports of recent observations and a preliminary analysis of them. Generally speaking, small numbers of meteor plots do not yield much insight on their own, but when the data of several watchers are combined, and possibly the archives consulted, interesting results emerge. It is these, that do not warrant a separate article, that I intend to highlight in this series. Of course, my plan depends on receiving your data. Major data sets will be reported fully in separate papers in *WGN*.

To monitor activity the Commission needs a few observers who can make regular watches on each clear, dark night. As little as an hour's observation is needed per night, so you will not become bored. In the *BAA* we had one such person. His contribution enabled many radiants to be identified or confirmed. Please write to me if you would like to participate.

1990 was a year of mixed fortune. In all I have received 1840 meteor observations, but over 1000 of these were secured by Mark Vints and myself during a successful Geminid/Monocerotid campaign at Lardiers, France. (Any observers who have secured data on the Geminid shower, but have not yet communicated such to the Commission, should do so as soon as possible.) By way of contrast, no data were reported for August. As for the Orionid campaign, I have received reports from two observers, Norman Kiernan and Malcolm Currie, of 134 meteors plotted during three nights. Bad weather affected western Europe greatly reducing the total. These will be combined with data from earlier years, but analysis of the Geminid data will be tackled first.

## Forthcoming events

During May and June radiants from the southern ecliptic from Ophiuchus to Aquarius dominate other showers. The only major shower being the $\eta$-Aquarids. It is an excellent event for southern watchers, though in the north twilight interferes badly, indeed there are many experienced European campaigners who have yet to record their first $\eta$-Aquarid. This shower is one of two intersections of the Earth with the P/Halley stream, the other being the Orionids, and has sub-streams that cannot be separated by naked-eye methods. Careful plotting can bring the sub-centers into focus. Therefore the aim of telescopic observation is to probe the structure of the radiant, and to compare with that of the Orionids. See [1] for more details. In 1991 moonlight will interfere though data from the second week of May would be of great interest.

The *Scorpius-Sagittarius* complex is another of the associations of numerous radiants about the ecliptic. Such complexes lend themselves to telescopic investigation because of their low rates from individual radiants and the unreliability of naked-eye plotting. A most worthwhile study would be to monitor the complex over a number of years particularly for our southern members. Since the complex is of long duration, moonlight is not a problem. There is always something to watch each year. Despite the low altitude of the radiant from Britain, *BAA* members saw a high proportion (a quarter) of meteors from this complex in 1990 May–June. Field centers should be near the celestial equator, between $\alpha = 230°$ and $\alpha = 310°$, the pair separated by about 30°. Start at the west of this range in early May moving eastwards to follow the distribution of radiants [2].

During May there are two main *Ophiuchid* showers that persist throughout the month; the northern component also appears to be active during mid-April judging by 1990 data, where 5 of the 28 meteors observed during the April 18–21 intersect within 2° at $\alpha = 237°$, $\delta = -10°$. This is consistent with being the May Northern Ophiuchids assuming a radiant motion of 1° per day. During 1990 May, this shower gave good rates, typically a third of the sporadic rate, despite its low altitude. This is a better showing than visually. The visual maximum is not affected by moonlight in 1991. The centers for the Scorpius-Sagittarius complex will also be satisfactory for these showers.

The $\tau$-*Herculid* shower was predicted following the discovery of its parent comet, Schwassmann-Wachmann, in 1930. Japanese observers recorded weak activity from May 25 until June 9 and 10, when a rate of about one per minute was observed [3]. In the following four decades there were no positive visual observations of the $\tau$-Herculids, though subsequent analysis of photographic data revealed residual activity. Visual watches during the last two decades have only yielded rates around 1 per hour. Personally, I doubt that naked-eye observations can detect such low activity. Chance alignment of sporadic meteors can give comparable rates [4]. Telescopic monitoring ought to show whether this shower is still active, and if so, from where.

Another "lost" shower is the June Lyrids. Discovered in 1966 and well studied in 1969 by the *BAA*, where the peak ZHR was 9, it is debatable whether or not the shower has been observed during the last decade. Certainly rates have been less than 2. Its $r = 3.0$ would suggest that it is a candidate for telescopic watches.

What I have been leading up to in the last two paragraphs are some interesting watches made by Mark Vints on 1990, May 28–29 with a $10 \times 50$ binocular. Mark noticed that six of the fourteen meteors seen emanated from a $0\overset{\circ}{.}8$-diameter radiant at $\alpha = 266°$, $\delta = +36°$. They all had speed 2 on a scale of 1–5. It is not inconceivable that Mark witnessed $\tau$-Herculid or June Lyrid activity—unlikely, but not inconceivable. Kronk [3] lists the $\tau$-Herculids as active from May 19–June 19 with a maximum on June 9 from $\alpha = 236°$, $\delta = +41°$. Interestingly, the meteors seen in 1930 were mostly dim meteors, magnitude 4 and fainter, so the stream is a good candidate for telescopic activity. Fox's [5] analysis of orbital perturbations indicates that the radiant of this shower is moving rapidly, *e.g.*, about 7° south in declination per century. If we allow for this motion during the sixty years since the original observations, Mark's radiant is some 25° distant, though the orbital elements are not well known. Thus Mark's shower appears unlikely to be the $\tau$-Herculids. If we extrapolate the position of the June Lyrid radiant, on May 28 it would be at $\alpha = 264°$, $\delta = +35°$—very close to the observed radiant. Of course, I have been speculating wildly; the shower has yet to be confirmed, but it is fun. We need more data to determine the extent and maximum of this shower, to ascertain whether it is transient or a known radiant. Watches from more-southerly latitudes, where twilight is less interfering, would be particularly welcome.

## References


[1] M.J. Currie, *WGN* 19:5, October 1990, pp.181–182.

[2] J. Wood, *WGN* 18:2, April 1990, p. 39.

[3] G.W. Kronk, "Meteor Showers: a Descriptive Catalog", Enslow, 1988, pp. 94–99.

[4] M. Gyssens, *WGN* 17:6, December 1989, pp. 217–222.

[5] K. Fox, *Asteroids, Comets, Meteors II*, H. Rickman, C.-I. Lagerkvist, eds., University of Uppsala, 1989, pp. 521–525.


---

## Some 1991 fireballs:

These are some fireballs reported to *FIDAC* early this year:

| | | | | |
|---|---|---|---|---|
| Jan 10 $17^h20^m15^s$ | UT | −4 | Gent (Belgium) | R. Scurbecq |
| Jan 18 $22^h18^m$ | UT | −4 | Frankenmarkt (Austria) | A. Schobesberger |
| Jan 27 $19^h48^m$ | UT | −4 | Sankt Johann (Austria) | A. Sudy |
| Feb 02 $19^h43^m$ | UT | −4 | Weißkirchen (Austria) | E. Freuenberger |

Do not forget to send in *your* reports to *FIDAC*!

# On Several Problems of Meteor Astronomy

*A. Terentjeva, Astr. Council, USSR Acad. of Sciences*

The following topics are considered: (*i*) A possible great meteor shower in connection with the returning of the dense part of the Leonid stream to perihelion in 1998-2000. Attention is paid to the elaboration of the program of observations. The main tasks of the shower investigation are postulated. The solar longitudes for the moments of the maximum activity of the Leonid shower in 1997–2000 are given. (*ii*) Meteor bodies in the Earth's orbit (the system of the Cyclid meteor bodies). On the basis of investigation of long approaches of the Cyclid orbits to the Earth's orbit and ephemeris calculations of geocentric radiants it is shown that the Cyclids can be observed during a long time—from several months to the whole year. (*iii*) Meteor bodies inside the Earth's orbit (the system of the Eccentrid meteor bodies). It is shown that one of the reasons for the formation of such extremely small orbits of meteor bodies of a moderate or high eccentricity are close encounters of minor bodies with the Earth and Venus. Among the given population of meteor bodies the streams related to the Aten group asteroids are revealed. As an example, the meteor stream associated with the Aten-type asteroid 2340 Hathor is given.

In the present paper, I would like to address the the following three topics.

## 1. The forthcoming return of the Ortho-Leonids

In the last decade of this century, the astronomical world will obviously witness a most rare natural phenomenon—the great meteor shower which is caused by the return to perihelion of a most dense part of the Leonid meteor stream. The great Leonid meteor shower is observed once in 33.25 years. The last, 33rd apparition of the shower was during 1964–1968, with the maximum activity of 1966 on November 17, $12^h$ UT. The moment of the maximum activity of the shower was predicted by us with an accuracy of 2 hours [1]. At the Kitt Peak Observatory in the USA, the intensity of the great meteor shower at the moment of its maximum was 40 meteors per second, i.e., about 140 000 meteors per hour.

According to our investigations, during the 34th apparition of the Leonids, a rich meteor shower is to be expected in 1998, 1999 an maybe in 2000. In 1997 a shower will be of a low intensity and its intensity will probably be even less in 1996. Taking into account secular perturbations, the maximum activity of the Leonid shower will be observed at the following solar longitudes $\lambda_\odot$ (equal to those of the ascending nodes) [2]:

Table 1 – Maximum activity of the Leonids

| Year | $\lambda_\odot = \Omega$ |
|---|---|
| 1997 | 235°34.′0 |
| 1998 | 235°35.′7 |
| 1999 | 235°37.′4 |
| 2000 | 235°39.′2 |

G.H. Stoney and A.M.W. Downing gave the name *Ortho-Leonids* to a most compact and dense part of the stream that produced the great meteor shower of 6 hours duration in 1866. The Ortho-Leonid stream is extended along its orbit however, so it passes perihelion during nearly three years. The remainder of the stream, annually producing a shower, is called the *Clino-Leonids*. The Clino-Leonid orbits slightly differ from the main Leonid orbit, defined as that of the Ortho-Leonids.

Since the process of the development of the stream has proceeded far, it has extended along its orbit and the transition from the central condensation to the remainder the stream is smooth. Therefore, the observations should be started well in advance, in 1995 at the latest, and carried out probably during 8 years so as to obtain a picture as complete as possible of the stream on the Ortho-Leonid borders.

I would like to draw the *IMO*'s attention to the fact that it is necessary to begin discussing the project of the *IMO*'s program on the Leonid observations during their coming apparition as early as next year. This program should envisage a solution of the following problems:

1. Determination of radiants and velocities of the shower with an accuracy as high as possible in order to obtain precise elements of particle orbits of the Ortho-Leonids (photographic, television and radiolocation observations);
2. Determination with up to a several minutes' accuracy of the moment of maximum activity of the shower in order to obtain a most precise longitude of the orbit node subject to noticeable planetary perturbations (visual and radiolocation observations);
3. Investigation of the mass distribution of meteor particles, space density of the stream (visual and radiolocation observations);
4. By means of longitudinal global stations network of the visual observations it is necessary to investigate:
   a) The spatial structure of the stream (revealing heterogenities, clumpiness of the structure, the presence of meteor "bundles", lacunae, etc.),
   b) The structure of the shower radiant area and its time variations.

At the 1989 *IMW* I spoke about the possibility of studying the structure of the meteor stream by means of simultaneous meteor counting along an extended arc of several thousand kilometers. *IMO* could realize such a program (at least along the arc from France to Japan over a distance of 12 000 km) during the forthcoming apparition of the Leonids and it would be a great experiment which has never been carried out before.

Taking into account the possibility of a great meteor storm, a complex investigation method will be applied to the Leonids. All known methods will be used here: photographic, radiolocation, television, spectral, visual and maybe a direct method, for example by launching a probing space rocket from the Earth, proposed by us before the last Leonid apparition, but unfortunately not realized.

## 2. Meteor bodies in the Earth's orbit

As known, by photographic observations, R.B. Southworth and G.S. Hawkins [3] detected meteor bodies moving along orbits near the Earth's orbit. They named this complex of meteor bodies *Cyclids*. Later on, the knowledge of the Cyclids was broadened. The perturbed motion of the Cyclids, the motion of their radiants, etc. were investigated [4,5,6]. The Cyclids are not believed to be a system in which meteor bodies are interconnected by their common origin. One may think of them as a system in which bodies are brought in and taken out by gravitational and non-gravitational effects, thereby conserving dynamical equilibrium.

The Cyclids have unique properties, nowhere else found in meteor astronomy. During its orbital motion, the Earth is constantly within this sytem and encounters its meteor bodies. What effect does this have on the picture of radiants?

Let us consider the orbit of the Cyclid meteor body No. 4084 [5,7,8]: 1952 May 19.215, $\alpha_R = 57.^\circ5$, $\delta_R = +27.^\circ2$ (corrected geocentric radiant), $V_\infty = 11.5$ km/s, $a = 1.03$ AU, $e = 0.131$, $q = 0.896$ AU, $\omega = 90.^\circ6$, $\Omega = 58.^\circ1$, $i = 0.^\circ8$, $\pi = 148.^\circ7$ (equinox 1950.0).

Theoretical radiants for the point of the closest approach (appulse) of the Earth's orbit with the orbit of the Cyclids and then from it in both directions (at every degree of the Earth's longitude) were calculated [5]. The calculations were carried out up to a given limit which was determined by the value of the shortest distance $\rho$ between the orbits being equal to 0.100 AU. Thus, the ephemeris of the geocentric radiant of the Cyclids (not subject to the influence of zenith attraction and diurnal aberration) was obtained.

Figure 1 presents the path of this radiant in the celestial sphere in the equatorial coordinate system (equinox 1950.0) for the chosen Cyclid orbit.

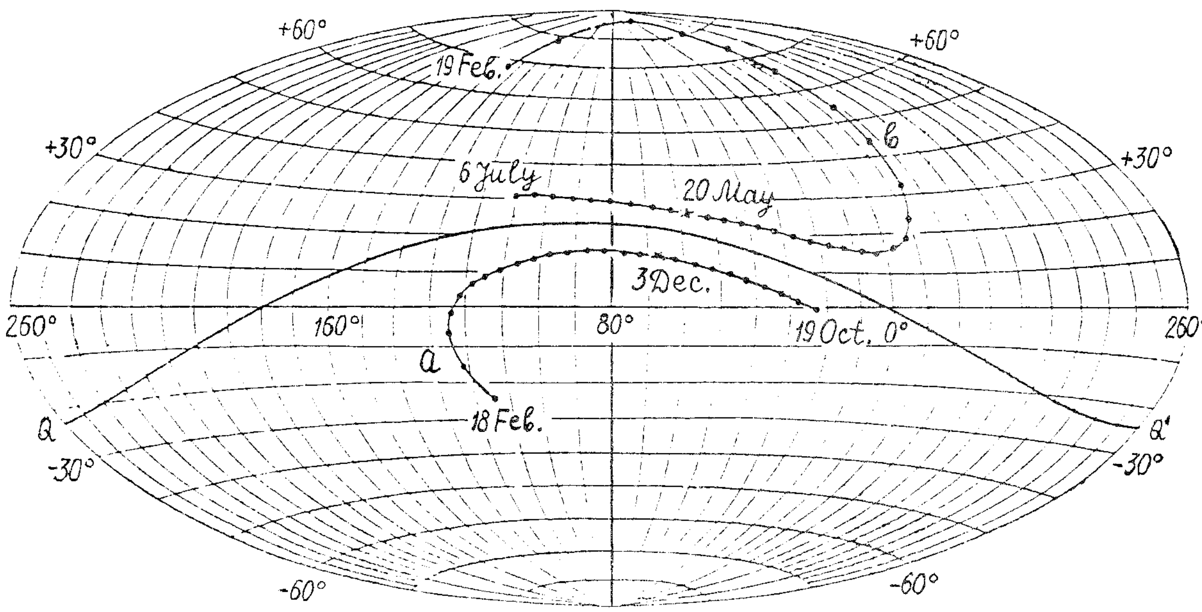



Figure 1 – Ephemeris curve of the geocentric radiant of the Cyclids.

Since the Cyclid orbit has two appulses with the Earth's orbit, the ephemeris of the radiant is represented by two curves. During four months, from October 19 to February 18, the radiant is moving along the curve $a$, located to the south of the ecliptic ($QQ'$) and corresponding to the approach in the region of the ascending node of the orbit; but then—within twenty-four hours—the radiant "jumps" to the region north of the ecliptic (the ephemeris curve gets broken) and during the next 4.5 months, from February 19 to July 6, it moves along the curve $b$, corresponding to the approach in the region of the descending node of the orbit. The Earth was in the first appulse on December 3 ($\rho$ = 0.00296 AU) and in the second one on May 20 ($\rho$ = 0.000113 AU). In the points of the mentioned break of the ephemeris curves $a$ and $b$ are located the "radiants-antipodes", discovered earlier by the author from the analysis of photographic observations [9]. The angular distance of the radiants-antipodes from each other is here about 90°. But this is the topic for a separate paper.

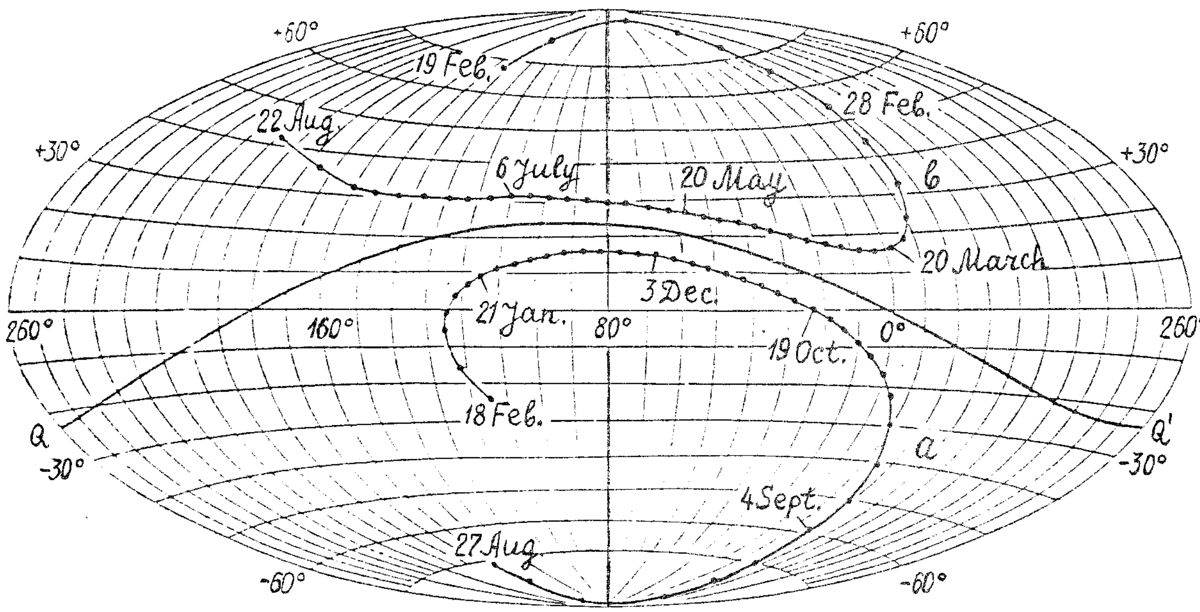



Figure 2 – The motion of the Cyclid geocentric radiant during a year.

This Cyclid orbit does not move away from the Earth's orbit farther than $\rho = 0.1548$ AU. To derive a clear idea of the motion of the Cyclid radiants during a whole year, theoretical radiants for all the values $\rho \leq 0.1548$ AU were calculated (though it is clear that the larger is $\rho$, the more approximate becomes the solution to this task). This ephemeris in the form of two curves is shown in Figure 2, also in the equatorial coordinate system.

The analysis of approaches of the Cyclid orbits with the Earth's orbit (up to the distance $\rho = 0.10$–$0.15$ AU) leads to the conclusion that the Cyclids can be observed during a long interval—from several months to the whole year. During this time, their geocentric radiants will describe various extended arcs in the celestial sphere depending on the character of the orbits and the approach conditions. So a large region of the celestial sphere actually becomes a radiant area for the Cyclids as a whole.

## 3. Meteor bodies inside the Earth's orbit

These are the most exotic representatives of minor bodies of the Solar System, having the smallest orbits ($a \leq 1$ AU) of a moderate or high eccentricity ($e > 0.14$) and completely located inside the Earth's orbit ($Q < 1.15$ AU).

As a system of meteor bodies, they were revealed by the author from photographic observations and named *Eccentrids* [10]. Later on, from all catalogues of photographic meteor and fireball observations available, we found 50 Eccentrids [11]. Besides, we attributed three asteroids of the Aten group to the Eccentrids: 2340 Hathor, 2100 Ra-Shalom and 1954 XA.

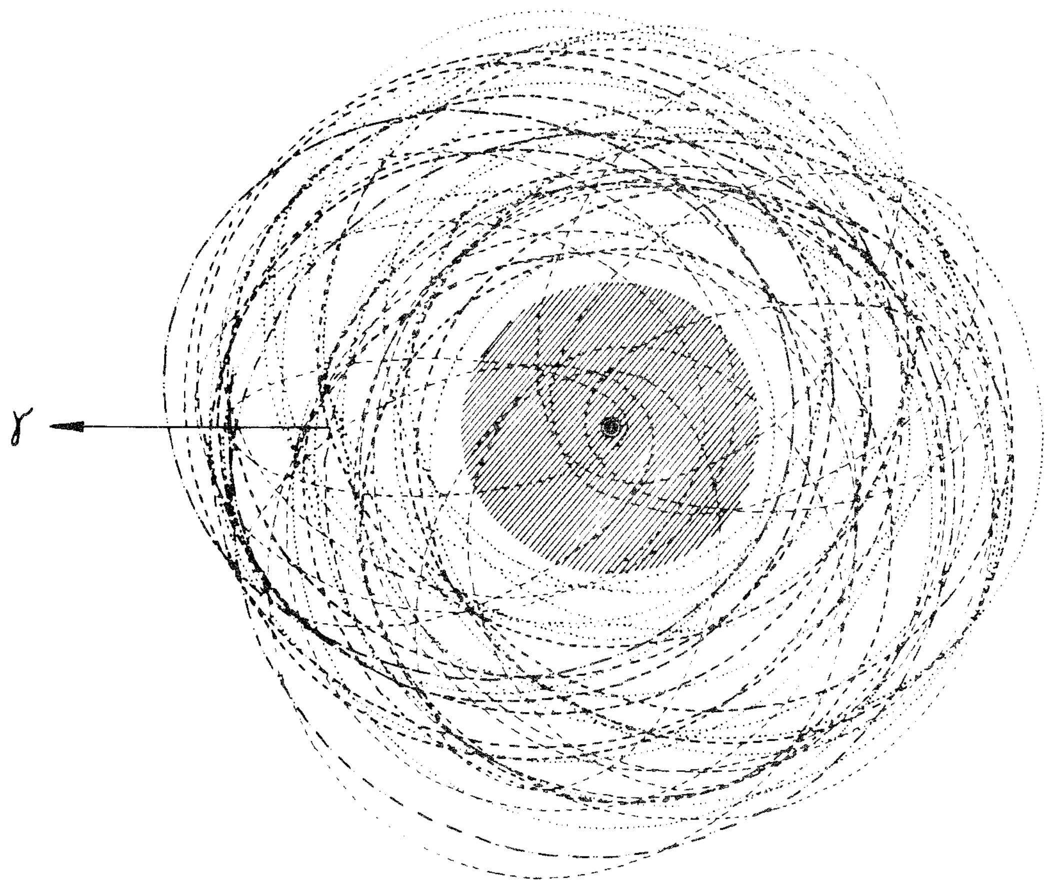



Figure 3 – Orbits of the Eccentrids (superposed with the ecliptic plane). The hatched region corresponds to the mean distance between the Sun and Mercury.

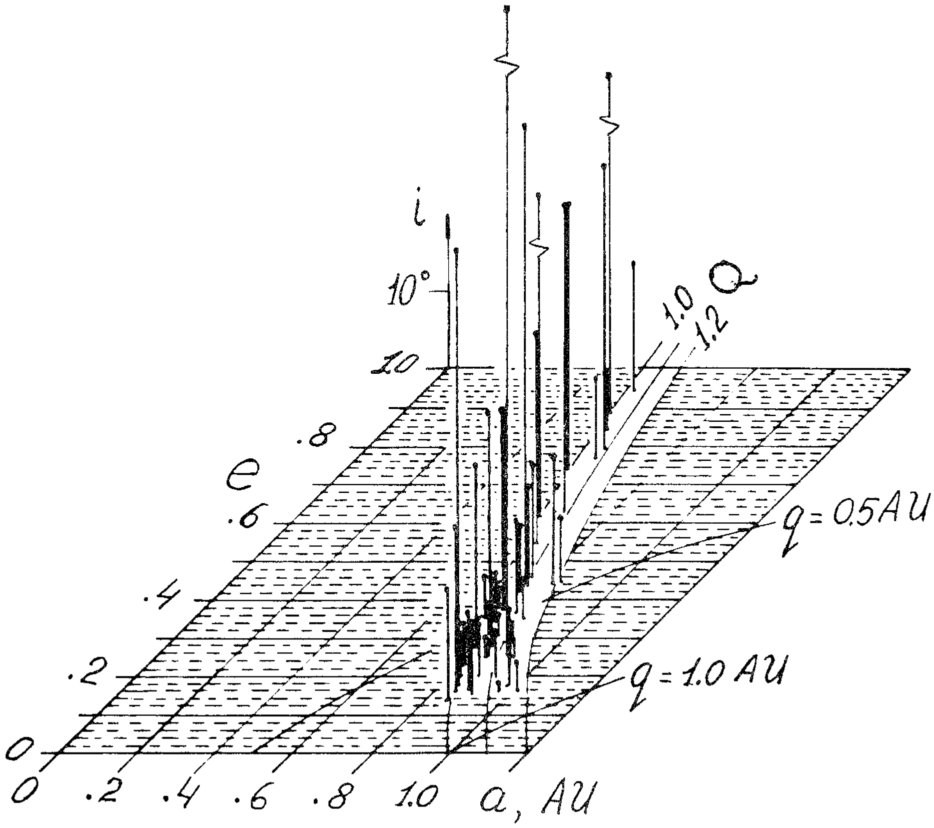



Figure 4 – Distribution of the Eccentrids in the three-dimensional $a$-$e$-$i$-space.

Figure 3 presents orbits of the Eccentrids. In Figure 4, the Eccentrids ae presented in the three-dimensional space $a$-$e$-$i$. Special attention should be paid to the group of extremely eccentric orbits in the upper part of the unhatched region (Figure 4).

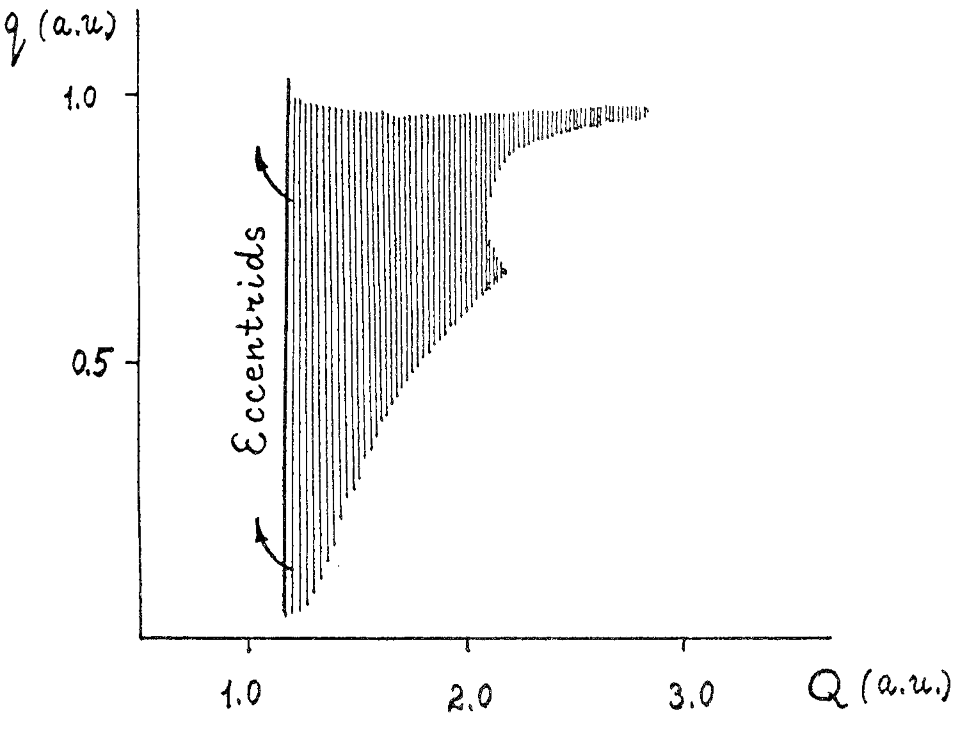



Figure 5 – The region of minor bodies' orbits that can be transformed into Eccentrids.

To study the formation of short-period orbits in the inner Solar System in general and the Eccentrids in particular, we investigated transformation of orbits as a result of close encounters of minor bodies with inner planets (Mercury–Mars) [12]. It was shown that close encounters with these planets are really a mechanism leading, in particular, to the formation of such unique orbits as these of the Eccentrids. Figure 5 in the two-dimensional $q$-$Q$ space shows a region from which orbits of meteor bodies (or asteroids) can be transformed—as a result of single encounters, mainly with the Earth and Venus—into orbits of Eccentrids.

The analysis of a small population of meteor bodies of the Eccentrids allowed revealing some of their peculiarities. Most unexpected was the existence of body streams in extremely small orbits. One explanation for their origin might be the fragmentation of bodies already in such orbits. It is unclear how long these streams can survive, but if they are formed and these objects are small in number, just because of this, it is easier to find them.

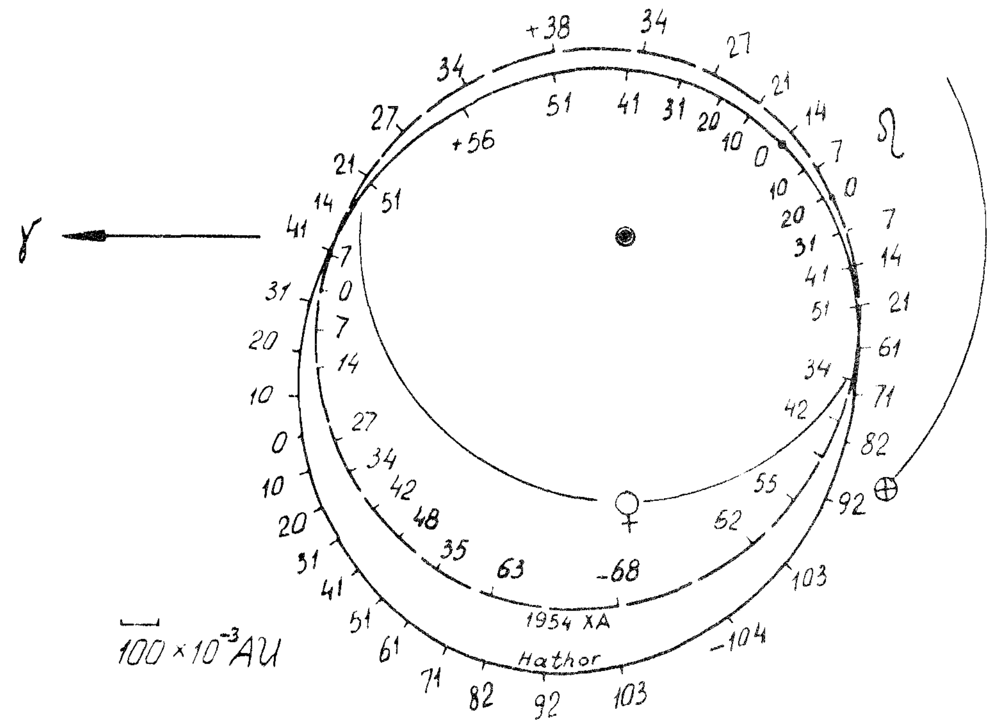



Figure 6 – The orbits of the asteroids Hathor and 1954 XA (superposed with the ecliptic plane). The numbers along the orbits denote the distance (in $10^{-3}$ AU) at which the orbit ascends above the ecliptic plane (+) or descends below it (−). The scale is shown at the bottom-left corner.

Let me give you an example of a most impressive stream in the orbit of the Aten-type asteroid 2340 Hathor. The similarity of the orbits of the asteroids Hathor and 1954 XA seems already surprising in itself (Figure 6). On most places, their orbits deviate from each other less than 0.1 AU. The maximum distance between both orbits is only 0.16 AU. In the region preceding the ascending nodes, the orbits are nearly blending together, and their distance does not exceed 0.03 AU for a long time. It is of interest to note that, it is through this region that Venus passes at the distance of 0.04 and 0.06 AU above the asteroid orbits. If this is not an accidental phenomenon, but a result of the fragmentation of a larger body, one may expect that there also exists other fragments in the same orbits. Indeed, among Eccentrids, there proved to be six more objects in orbits similar to the Hathor orbit (Figure 7, Table 1).

Among them, there is a larger meteor body (No. 1) that produced a fireball of magnitude −14 (registered by the Fireball Network in the USA), of type I according to Ceplecha's classification, with a pre-atmospheric mass of 4.3 tons. A meteorite fall was expected for it. Another fireball of −4 (No. 49) also belongs to type I and was registered by the same network. Two other objects (Nos. 35 and 36) are smaller meteor bodies that produced ordinary photographic meteors. All mentioned above support the assumption that in the Hathor orbit there exists a stream of solid bodies of asteroid origin that are genetically interconnected. Asteroid 1954 XA with a diameter of 600 m is the largest, and the second one in size is Hathor with a diameter of 200 m.

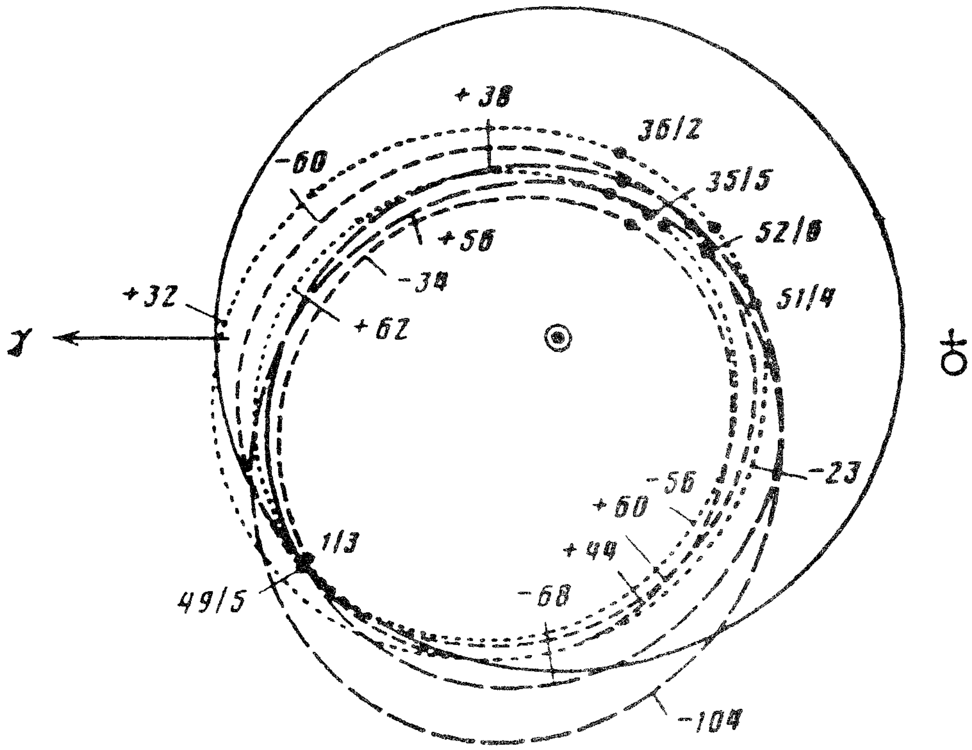



Figure 7 – The Hathor meteor stream (the orbits are superposed with the ecliptic plane). The dots indicate the positions of the perihelia and the ascending nodes. Near the latter, the number of the object and the orbit inclination are indicated (according to [11]). The distance (in $10^{-3}$ AU) from the ecliptic of the most distant point of every orbit is shown.

Table 2 – The Hathor meteor stream

| No. ([11]) Name | Date | Orbital elements (1950.0) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $a$ | $e$ | $q$ | $Q$ | $i$ | $\omega$ | $\Omega$ | $\pi$ |
| 1 | 1966 11 05.9 | 0.71 AU | 0.43 | 0.41 AU | 1.0 AU | 3° | 197° | 42° | 239° |
| 49 | 1974 11 06.8 | 0.76 AU | 0.31 | 0.52 AU | 1.0 AU | 5° | 180° | 43° | 223° |
| 35 | 1953 11 16.5 | 0.72 AU | 0.37 | 0.45 AU | 1.0 AU | 5° | 353° | 234° | 227° |
| 36 | 1953 12 04.5 | 0.82 AU | 0.31 | 0.57 AU | 1.1 AU | 2° | 325° | 252° | 217° |
| Hathor | | 0.84 AU | 0.45 | 0.46 AU | 1.2 AU | 6° | 40° | 211° | 251° |
| 1954 XA | | 0.78 AU | 0.35 | 0.51 AU | 1.1 AU | 4° | 57° | 190° | 247° |

If the width of this stream is about 0.2 AU, the visibility of the shower lasts from the end of October to the middle of January. In this case, the heliocentric radiant describes an arc of about 120°, while the geocentric radiant makes complicated oscillations near the point $\lambda = 165°$ and $\beta = 0°$. The shower is mainly observable during the dark hours before dawn. More detailed information about the conditions of visibility of the shower, etc. can be found in [11,13].

Thus, the analysis of the observational data shows that in the inner Solar System there can exist streams connected not only with Apollo asteroids (e.g., [14]), but also with Aten asteroids, whatever may be the nature of the asteroids themselves.

## References

[1] I.S. Astapovich, A.K. Terentjeva. "The Leonid meteor shower", *Komety i meteory, Dushanbe* 14, 1966, pp. 24–37.

[2] I.S. Astapovich, A.K. Terentjeva, "Conditions of an encounter of the Leonid meteor stream with the Earth in apparitions 1898–2000", *Problemy kosm. fiziki* 7, 1972, pp. 100-107.

[3] R.B. Southworth, G.S. Hawkins, "Statistics of meteor streams", *Smithson. Contr. Astrophys.* 7, 1963, pp. 261–285.

[4] A.K. Terentjeva, "Investigation of the perturbed motion of a meteor body of the Cyclids' system", *Astron. Tsirk.* 417, 1967, pp. 3–4.

[5] A.K. Terentjeva, "On the motion of the Cyclid geocentric radiants", *Problemy kosmicheskoj fiziki* 8, 1973, pp. 140–146.

[6] A.K. Terentjeva, "Investigation of minor meteor streams", in: *Physics and Dynamics of Meteors*, Ľ. Kresák and P.M. Millman (eds.), Dordrecht-Holland, 1968, pp. 408-427.

[7] G.S. Hawkins, R.B. Southworth, "The statistics of meteors in the Earth's atmosphere", *Smithson. Contr. Astrophys.* 2:11, 1958, pp. 349–364.

[8] G.S. Hawkins, R.B. Southworth, "Orbital elements of meteors", *Smithson. Contr. Astrophys.* 4:3, 1961, pp. 85–95.

[9] A.K. Terentjeva, "Minor meteor streams", *Rezultaty Issled. MGP-Issled. Meteorov, Moskva* 1, 1966, pp. 62–132.

[10] I.V. Galibina, A.K. Terentjeva, "The evolution of orbits of meteor bodies under the influence of secular perturbations", *Astron. Vestnik* 15:3, 1981, pp. 180–186.

[11] A.N. Simonenko, A.K. Terentjeva, I.V. Galibina, "Meteor bodies inside the Earth's orbit: the Eccentrid system", *Astron. Vestnik* 20:1, 1986, pp. 61–75.

[12] G.V. Andreev, A.K. Terentjeva, O.A. Bayuk, "Transformation of the orbits of minor bodies at close encounters with planets of the Earth's group", in: *Asteroids, Comets, Meteors III*, C.I. Lagerkvist et al. (eds.), Uppsala, 1990, pp. 493–496.

[13] A.N. Simonenko, A.K. Terentjeva, "On revealing genetically related bodies in the vicinity of the Earth's orbit", *Astron. Vestnik* 18:3, 1984, pp. 215–224.

[14] D. Olsson-Steel, "Meteoroid streams associated with Apollo asteroids: evidence from the Adelaide radar orbit surveys", in: *Interplanetary matter*, Z. Ceplecha, P. Pecina (eds.), *Publ. Astron. Inst. Czechosl.* 2:67, 1987, pp. 125–129.

# The Meteor Shower of November 19, 1630

*Roberto Gorelli*

The discovery is discussed of a mentioning in the literature of a meteor shower on November 19, 1630. An attempt is made towards identifying this shower with a currently known meteor stream.

The most ancient reports of meteor showers date from before 600 BC and meteorite falls have been recorded even earlier, since reports have been found dating back from 2000 BC. Sometimes, the direction from which meteors originated with respect to the horizon has been reported, and, less frequently, also the trajectories of fireballs. Hence, radiants have to be calculated based on testimonies which are most often difficult to interpret.

The author consulted in the Casanatese library in Rome of the the book *Diario delle cose piu' illustri seguite nel mondo* which means: "Diary of the most exceptional phenomena of this world", edited in Naples by Roberto Mollo in 1653. On pages 146–147, point 22 of November 19 the this book contains following passage:

> *Nel 1630, si ecclisso' horribilmente per 3. hore la luna & essendo il cielo sereno uscirino dalla testa di Orione alcune scintille bianche, che in forma di flagello si voltarono da mezzo giorno verso settentrione. Fu' poi stimato, che quel prodigo sig-*

*nificasse l'esterminio, che nella citta' di Magdeburgo fecero i cesarei a 10. di Maggio 1631. Io. Petr. Lot. Rer. Germ. L. 37. C. 6.*

("In 1630, the Moon has been eclipsed profoundly for 3 hours and the sky being clear, some white lightnings appeared at the head of Orion in the form of whips; coming from the south, they turned northwards. Later, it was thougth that this was an omen of the massacre carried out by the imperial troops in the city of Magdeburg on May 16, 1631.")

This text probably never caught the attention of historians, since one has to be familiar with the phenomenon of meteor showers in order to understand its importance. Moreover, no professional or amateur astronomer has a particular interest in reading this poorly known historical book.

In the vocabulary that is now commonly used to describe meteoric phenomena, the translation of the excerpt above could be recasted as: "In 1630, there was a lunar eclipse for 3 hours and, the sky being clear, some white colored meteors were seen originating from a radiant near the stars $\lambda$, $\varphi^1$ and $\varphi^2$ of Orion. These meteors had the form of whips and went from the south to the north." Here the reader might wonder how this translation and interpretation has been obtained. We are going to examine this.

The eclipse of November 19, 1630 took place in the constellation of Taurus, near the Pleiades, about 30° from the radiant. It was a partial eclipse with a maximum at $23^h20^m$ local time. The darkening of the moonlight by the eclipse enabled observations of the meteor shower. Really, the brightness of the Full Moon would have prohibited the observation. Moreover the impressive eclipse of the Moon made people pay more attention to the sky. We assigned following coordinates to the radiant to have a reference frame: $\alpha = 5^h36^m$, $\delta = +09°30'$ (equinox 1984). This point is near the center of the three stars $\lambda$, $\varphi^1$ and $\varphi^2$ Orionis which form the head of Orion. The inaccuracy on these coordinates $\alpha$ and $\delta$ is about 5°, taking into account the "location" of Orion's head on the celestial sphere. Moreover, since a radiant is not a point, but rather a circular or elliptic area of some degrees diameter, the 5°-zone mentioned probably contains the center of the radiant zone.

The text mentions some white lightenings, which is a simple and effective way of describing meteors. By "some," the author does not want to limit the number of meteors to, say, ten, but rather describes the number of brighter meteors seen by each observer. We also should be aware of the fact that the observers were certainly not concentrating on the meteoric event, which was called "flying fire", but rather on the eclipse itself. The city where this meteoric shower occurred is to be situated in Germany, since Gerardi has written this event in a book called *Rer(um) Ger(manorum)* i.e., "about German events". Moreover, the final part of the text under examination states the opinion, founded in astrology, that the eclipse and the meteoric shower were an omen of the massacre in Magdeburg that took place the following year. In general when a celestial indication predicts an event to come, the place were that event will take place is the place were the indications are observed. The Zenithal Hourly Rate surely cannot be calculated by deficiency of numerical data. Only the qualitative estimation of "high rate" is appropriate.

The testimony that the trajectories of the meteors went from the southern part of the celestial sphere to the northern part indicates that at the moment of observation the radiant was very near culmination. The radiant was at maximum eclipse in the south-east direction, and on the moment of third contact, i.e., at the end of the phase of direct shadow, the radiant was in the south-south-east direction . This fact shows that the shower was probably observed at the end of the final part of the eclipse, between $23^h20^m$ and $00^h50^m$ local time. Since the radiant was on the meridian at $1^h30^m$ local time, the observers could not observe the shower at maximum radiant elevation (which could not have been more than about 50°, since the southernmost part of Germany (Bavaria) is at about 48° N). Considering the position and the rising and setting of the radiant and the Moon, the shower could have been active without being noticed by Moon interference from November 17 or 18 on until about November 24.

From the information which can be derived from this report, one should try to identify this shower with one of the many radiants currently known. Before trying to make such an identification, one has to take into account thar 360 years have passed and, in the meanwhile, the time of maximum as well as the radiant position may have changed. Due to the precession of the equinoxes, the solar longitude of the maximum increases over time, the exact rate of the increase also depending of the evolution of the streams' orbit. A very strong perturbation, such as a close encounter between Jupiter and the stream's parent body may of course cause more drastic shifts in the shower's maximum as a well as in the radiant position and may even prevent the Earth from meeting the stream ever again in the future. So, we may expect that the maximum observed in 1630 happens a few days later now, say between November 20 and 30, provided that November 19 was indeed the maximum of the observed shower. Also, at maximum, the radiant should be no more than say 5° from its 1630 position mentioned earlier, assuming no drastic perturbations took place. At this point of the examination we do not have data to calculate the orbits of the meteors observed on November 19, 1630 and we have to examine all possible showers which can be observed in the temporal and spatial interval which we have deduced.

Between the principal streams, there are only three candidates: the November Monocerotids, the December Monocerotids and the $\chi$-Orionids South. The November Monocerotids have their radiant situated between $\alpha = 112°$ and $\alpha = 123°$ on a line 15° to 16° south of the radiant in consideration and are active from November 15 to 25. Their maximum is on November 20, with the radiant at $\alpha = 117°$ and $\delta = -6°$ [1]. The December Monocerotids have a radiant between $\alpha = 83°$ and $\alpha = 107°$ on a line 5° north of the considered radiant and are active from November 27 to December 17. Their maximum is on December 10 with a radiant at $\alpha = 100°$ and $\delta = +14°$ [2]. The activity period of the $\chi$-Orionids South is from December 7 to 14 and their radiant moves on a line from $\alpha = 80°$ to $\alpha = 89°$, 5° to 6° north of the considered radiant. At maximum, which is December 10, the radiant is at $\alpha = 85°$ and $\delta = +16°$ [2].

If we compare the data, we see that the area of displacement of the radiant of the December Monocerotids is compatible with the radiant of the shower, taking into account a five-degree error zone. Also, the $\chi$-Orionids Souths are compatible if one supposes a displacement in declination, but the November Monocerotids should be excluded. As to the activity period, the November Monocerotids have a large overlap with the proposed time interval, while the December Monocerotids have only a very small overlap but the radiant is very near the calculated radiant. The $\chi$-Orionids South have no overlap at all. Consequently, only the December Monocerotid radiant area overlaps with the calculated radiant area at the proposed interval, more in particular between November 27 and November 30. The parent body of the December Monocerotids is the comet P/Mellish (1917 I) [3]. Comet Mellish (1917 I) was discovered in 1917 and has a period of 145 years. The comet could have passed its perihelion in 1626 or 1627, some years before the shower activity. Moreover, since the period of a comet can change from one perihelion passage to another, it might be the comet passed through its perihelion in 1630.

We have to conclude that with the present data, the interpretation of the text and the analysis is not sufficient to associate the shower of 1630 to one of the actually known streams. Moreover, one should consider the possibility that the meteor stream of 1630 had its orbit radically changed by planetary perturbations. All the readers are invited to collaborate on the research of this scientific problem, by analyzing the original work from which the examined passage was taken, and which contains maybe other information on the shower. One can search for other reports on the same shower or for reports on showers in the years preceding or following 1630. Also the years of the other passages of the comet Mellish should be examined: the passage in 1771 or 1772, which was not observed, and the passage in 1917, when the comet was discovered.

## Acknowledgement

I am grateful to S. De Meis and M. Menichelli for having calculated the time and the conditions of the eclipse of November 19, 1630.

## References

[1] J. Wood, "Visual Observers' Notes: November–December 1990", *WGN* 19:5, October 1990, p. 174.

[2] A.F. Cook, "A working list of meteor streams", in: *Evolutionary and Physical Properties of Meteoroids*, NASA SP-319, Washington DC, 1973, pp. 183–191.

[3] G. W. Kronk, "Meteor Showers, A Descriptive Catalog", Enslow, Hillside, N.J., 1988, p. 254.


## Postscript from the Editor-in-Chief

*I feel it necessary to emphasize the author's words where he indicates the extreme difficulty of correctly interpreting information in historical texts. For instance, in my opinion, it is also possible that not the radiant itself was located within Orion's head, but that, rather, the meteors started very close to Orion's head and that the backward prolongations of the meteor trails more or less crossed this region of the sky. This interpretation to me also seems compatible with the excerpt. If this would the case, the radiant could easily be located 5–10° more to the south of the position assumed by the author.*

*Also, caution is needed when trying to identify historic showers. The author's reasoning is based on the assumption that no drastic changes occurred to the stream's orbit; the opposite is very often the case! For this reason, many meteor showers have been observed only once.*

*Despite of this difficulties and drawbacks, however, I think the study of historical meteor (stream) apparitions can be very rewarding and I am very grateful to the author that he has communicated his findings to us.*

*Finally, I want to thank R. Bonisenga, G. Canonaco, L. Moesen and J. Van Biesen for their help in translating the Italian manuscript.*

# The Observation of a Fireball Cluster Probably Belonging to the Taurid Family

*A. Grishchenyuk, V. Martynenko and A. Petrenko*

On November 22, 1990, a group of five fireballs with similar characteristics was observed in the Crimea. The possible association of this fireball cluster with the Taurid family is discussed.

On November 22, 1990, during twilight at $15^h$ UT, Anna Petrenko, an experienced meteor observer, saw the appearance of a fireball near the Moon. The fireball of magnitude $-3$ to $-4$ was observed on a twilighted sky background and was not too long. Further observations during half an hour allowed to see a very interesting, uncommon phenomenon: the appearance of five fireballs from the same radiant. The observed sky area was partly obstructed by houses, so there is a probability that some fireballs were missed. Four of the five fireballs seen were of magnitudes $-3$ to $-5$, while the remaining one, which passed near $\alpha$ UMi, was of $-6$ to $-7$.

All fireballs were bright yellow with a reddish hue, and had velocities of mark 3, corresponding to 35 till 45 km/s. There were seen flares on the ends and short-lived traces. The determination of the radiant was very difficult, since four out of the five fireballs had almost parallel trajectories (through the constellations of Aquila and Cygnus). The trajectory of the fifth one has a significant angle with respect to the other trajectories, but unfortunately it was noticed by side sight and thus has great errors. Hence the radiant must be situated in a narrow zone of declination (+15° to +30°), but in a wide interval of right ascension (10° to 90°).

The search for possible radiants in catalogues [1–4] allowed us to conclude that the observed fireballs possibly belonged to the Taurid family ($\alpha = 80°$, $\delta = +23°$). This radiant is observed since the end of the 19th century, and produced bright meteors with geocentric velocities of 44 km/s [1,2]. Apart from this one, there are two other candidates in the family of ecliptic radiants with coordinates $\alpha = 50°$, $\delta = +21°$ ($\xi$ Ari, no. 44 in [4]), respectively $\alpha = 60°$, $\delta = +20°$ ($\varepsilon$ Tau, no. 53 in [4]), but meteors of these streams are slow.

The stream of $\xi$ Tau ($\alpha = 80°$, $\delta = +23°$) produced fireballs time and again. For example in 1951, during October and November, 26 fireballs and bright meteors were noticed over the Netherlands [5], [6]. Also the famous Tunguska phenomenon probably belonged to the Taurid family. The geometrical conditions of meeting with the Earth admit situating the radiant in the Taurid family, explaining short trajectories of meteors that were observed near the anti-radiant, when the radiant was near the eastward horizon.

Observations after $15^h30^m$ UT on November 22, 1990 did not show anything unusual, possibly because of the low radiant elevation, or because the Earth previously just happened to meet 5–6 bodies that moved on almost identical trajectories.

### References


[1] *Issledovaniya meteorov* 1, (in Russian), M., Nauka, 1966.

[2] "Basic Catalogue of Meteor Radiants of the 19th Century", (in Russian), Ashkhabad, 1956.

[3] *Astronomical Circular* 264, (in Russian), 1963.

[4] *Izvestiya Turcmeniya Academyi Nauk* 4, (in Russian), 1950, p. 95.

[5] J. van Diggelen, C. de Jager, "Meteors", 1955, pp. 162–167.

[6] J. Rendtel and A. Knöfel, *Bull. Astron. Inst. Czechosl.* 40, 1989, pp. 53–63.


# Radiant Map 1928–1969 Derived from Visual Observations in Japan

*Norihito Kawamura*

A list has been compiled of radiants obtained from Japanese naked-eye observations in the period 1928–1969.

Mr. Kojiro Komaki, who contributed the early Japanese amateur meteor work, had begun to compile a list of radiants which had been detected by Japanese observers. Afterwards, Mr. Koseki continued his work and completed the radiant list. This list consists of 2924 radiants mainly observed with naked eyes during 1928 to 1969. This period includes the earliest days of Japanese meteor work. Concerning meteor showers in this list, Mr. Koseki has already covered [1–3]. The author has put the list on a floppy disk as a database of radiants.

Figures 1 and 2 show the location of all the radiants observed in Japan which are listed in the catalog. It should be noticed that some poorly determined radiants are involved. Some groups of crosses correspond to the radiants of major showers, e.g., the Perseids, the Taurids, the Orionids, the Leonids, the Quadrantids, the Lyrids, and the Aquarids. Some radiants of minor showers may also be noticed.

Furthermore, the author will complete the radiant map by adding the radiant list after 1969, in cooperation with Mr. Takema Hashimoto.

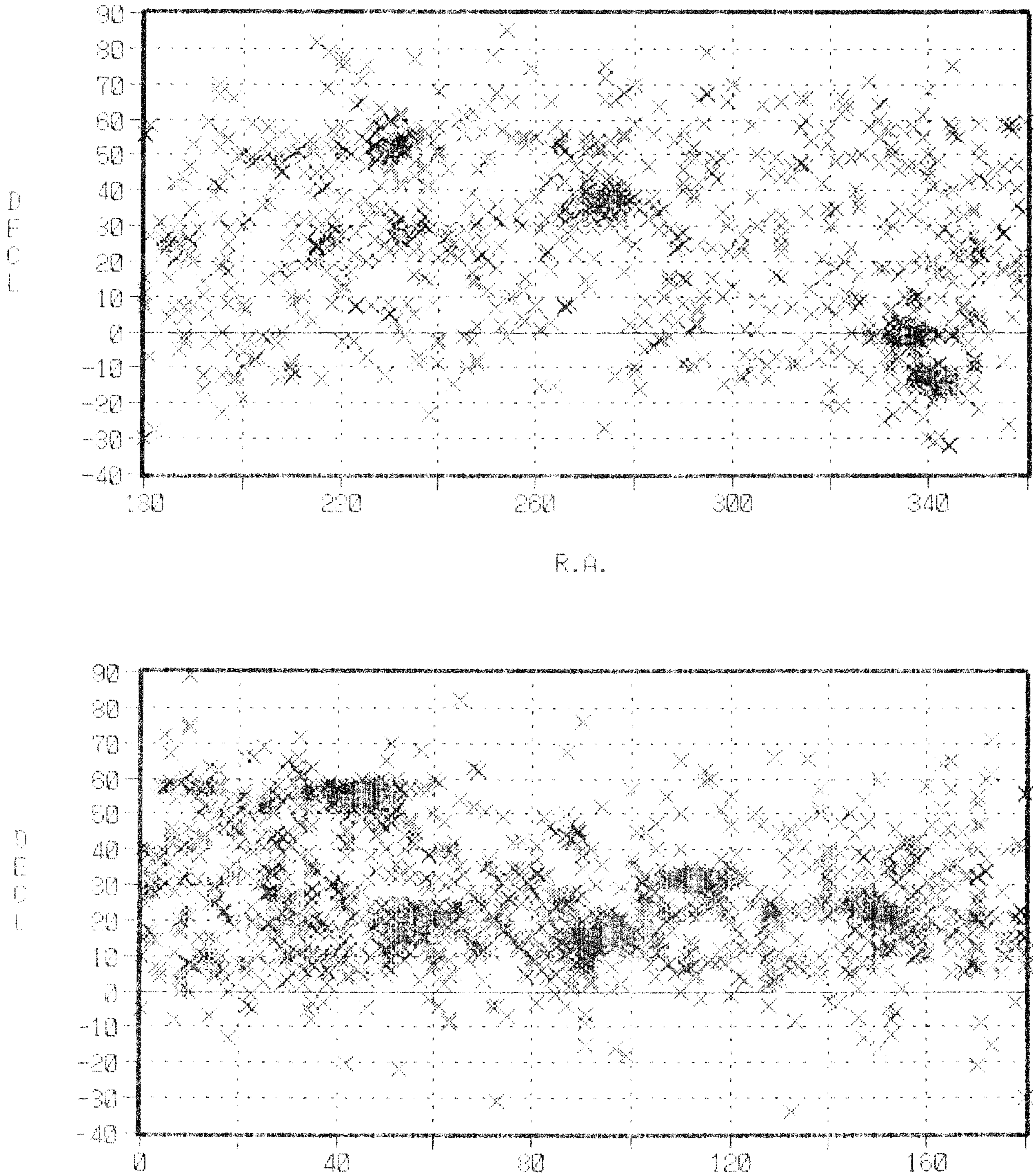



Figure 1 – Radiant Map 1928–1969

## Acknowledgment

The author could use the radiant list by courtesy of Mr. Masahiro Koseki, and thanks him very much for his kindness.

## References

[1] M. Koseki, *The Heavens* 652, pp. 237–241.

[2] M. Koseki, *The Heavens* 653, pp. 270–275.

[3] M. Koseki, *The Heavens* 654, pp. 295–298.

# The Activity and Structure of the Perseids

O.I. Bel'covich, A.I. Grishchenyuk, A.S. Levina, V.V. Martynenko

The activity and structure of the Perseid meteor stream are investigated, based upon visual observations made in the period from 1980 to 1990 in the USSR.

## 1. Introduction

For many years, the observations of the Perseids have been investigated sorted out with the purpose of getting information about the activity, radiant location and absolute characteristics of the shower. We think the total amount of data we possess should be investigated using the same method so that we can obtain the shower characteristics, for many years. The Perseid observations conducted in the USSR in the period from 1980 to 1990, and collected in the file of the Crimean Zateishchikov Meteor Station of the All-Union Astronomical-Geodetical Society, and the South Astronomical Observatory were investigated, using the method described in [1]. As the result of the investigation of more than 15 000 meteors of magnitude up to +3, which have been recorded during 4200 hours, about 620 hourly rates were obtained. These hourly rates were corrected for perception and the radiant elevation and position for the solar longitude range from $\lambda_\odot = 133.^\circ5$ to $142.^\circ5$ (eq. 1950.0).

Table 1 – Overview of the 1980–1990 USSR data on the Perseids

| Year | Number of groups | Number of observers | Number of sites | $T_{\rm eff}$ | Number of meteors | Number of Perseids |
|---|---|---|---|---|---|---|
| 1980 | 8 | 27 | 7 | $183.^h05$ | 6995 | 4324 |
| 1981 | 6 | 35 | 6 | $188.^h45$ | 7807 | 3520 |
| 1982 | 16 | 75 | 12 | $542.^h34$ | 13280 | 8553 |
| 1983 | 14 | 72 | 12 | $362.^h14$ | 9124 | 4711 |
| 1984 | 12 | 73 | 9 | $522.^h88$ | 7391 | 2753 |
| 1985 | 20 | 101 | 15 | $793.^h19$ | 22421 | 9842 |
| 1986 | 13 | 62 | 10 | $530.^h56$ | 21170 | 10879 |
| 1987 | 9 | 46 | 8 | $120.^h74$ | 2567 | 1373 |
| 1988 | 20 | 91 | 16 | $417.^h22$ | 12503 | 5626 |
| 1989 | 13 | 95 | 10 | $280.^h25$ | 8881 | 5668 |
| 1990 | 10 | 55 | 7 | $326.^h54$ | 5144 | 3095 |
| Tot | | | | $4167.^h36$ | 130786 | 60344 |

## 2. The global structure of the stream

A method of averaged hourly rates with a 30 minute step (12 hours interval) along the solar longitude (eq. 1950.0) has been used for getting information on the stream's global structure. The hourly rates that deviated more than ±30% from the average were excluded as erroneous. (This was the case for about 10% of the rates under consideration. The results of the averaging are shown in Figure 1. A first maximum (30 meteors per hour) is apparent at $\lambda_\odot = 134.^\circ5$. This level is reached after 2 degrees. After a slight fall of activity, the activity rises again from $\lambda_\odot = 137^\circ$. The maximum ZHR occurs at the $\lambda_\odot = 139.^\circ5$, amounting to $141 \pm 8$ meteors per hour. Moreover, we can distinguish the "plateau" at the descending branch of the activity ($\lambda_\odot = 140.^\circ5$, $N_z = 80$ meteors per hour), and a slight secondary maximum at $\lambda_\odot = 141.^\circ5$. The analysis of the activity profile of the meteors of −1 and brighter shows that the occurrences of the biggest quantities of bright particles are shifted relative to the weaker ones, and in both directions: the initial maximum is shifted a degree later whereas the main one is shifted $0.^\circ5$ earlier. It should be mentioned that the photographic meteor mass of −1 is about 0.05 gram, whereas +3 corresponds to about 0.001 gram [2].

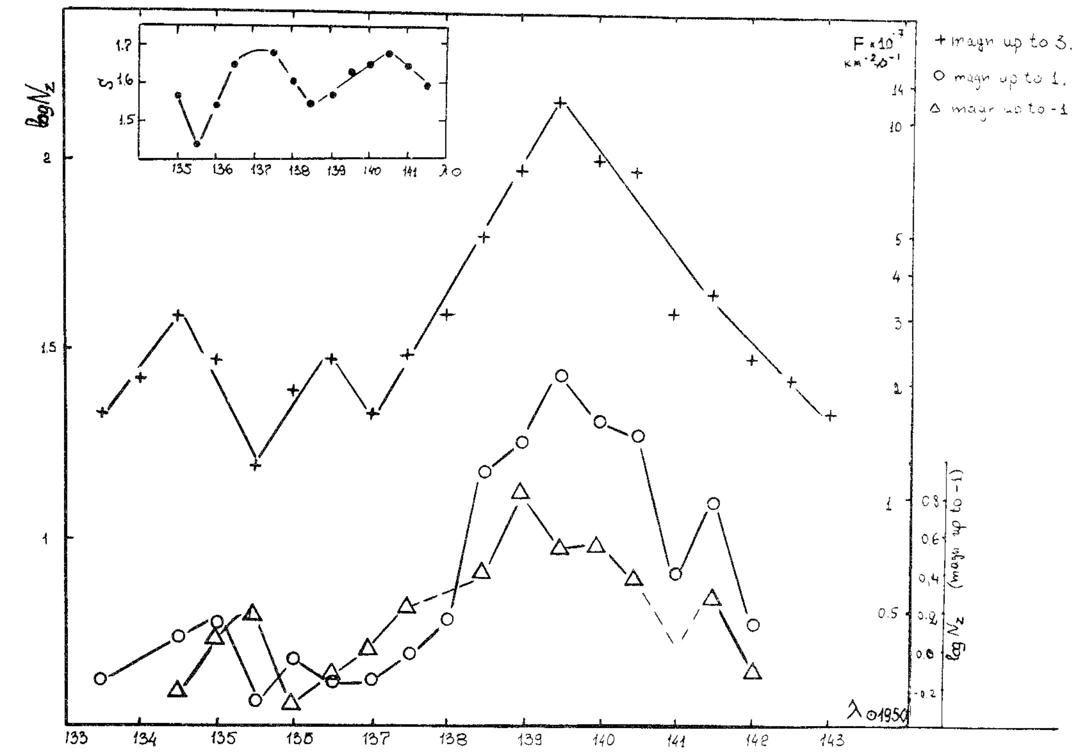



Figure 1 – The global activity profile of the Perseids.

The mass parameter $S$, which has also been averaged for all observations, has a step of 0°.5 in solar longitude, and two peaks ($\lambda_\odot = 135°.5$ and $\lambda_\odot = 138°.5$). Those peaks coincide with the peaks in the profile of the bright particles. The values of $S$ are in the range between 1.45 and 1.63 (1.6 to 2.0 for coefficient 2.5 in the formula $S = 1 + 2.5 \log \kappa$). It is in good agreement with earlier results [2,3].

## 3. The small-scale structure of the stream

The next process of "averaging" was conducted with a 12 minutes step in solar longitude (interval of 5 hours) to reveal the peculiarities of the profile. Only hour rates, obtained after $23^h$ local time were sorted out, when the radiant was rather high in the sky. The same data selection method was used. The data for high positions of the radiant were considered to be more reliable.

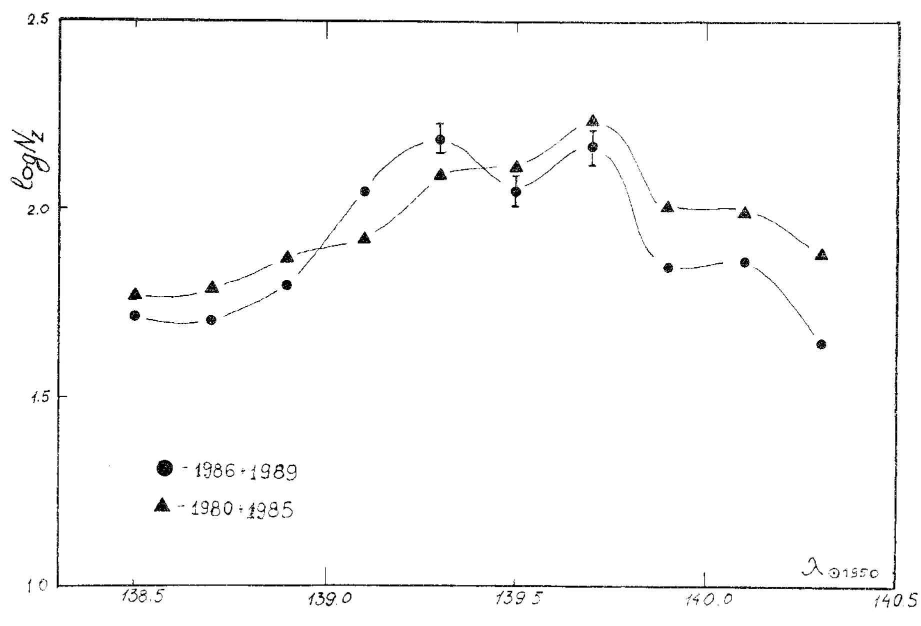



Figure 2 – Small-scale structure of the Perseids.

We were especially interested in the longitude range from 138° to 141°5. The maximum and the secondary maximum are clearly seen on the profile ($\lambda_\odot$ = 139°5 to 139°7) as well as an increase from 20 meteors per hour on solar longitude $\lambda_\odot$ = 141°1 to 45 meteors per hour for $\lambda_\odot$ = 141°3.

The general graph does not show the two maxima, which have been observed since 1986. That is why we analyzed the data for 1986–1989 separately. Those data show two real peaks at $\lambda$ = 139°2 (160 meteors per hour) and $\lambda$ = 139°6 (175 meteors per hour). The intermediate minimum falls at $\lambda_\odot$ = 139°4 (112 meteors per hour) (Figure 2).

## 4. The spatial density

The central (maximum) part of the global activity profile can be presented by a pair of straight lines between $\lambda_\odot$ = 137°0 and $\lambda_\odot$ = 141°0, so one can expect the same representation for graphs on an annual basis. Indeed, the average ZHRs per night are presented of the graphs as the straight descending and ascending branches. Using that, we can approximate both moment of maximum and maximum ZHR, even if the maximum itself could not have been observed (Figure 3).

Using the ZHR, determined by Figure 3 with a certain step along the solar longitude for the different years, one can calculate values of the shower's density ($F$), and reveal the $F$-distribution in the shower for different years. All we need for this is to know the area of the sky (cross section) through which the meteors pass an observer sees. The probability of a meteor being recorded, depending upon zenith distance, was investigated by us during the investigation of the 1980 Perseid outburst [4]. The area radius we sought for turned out to be between 40° and 50°. Comparing the shower's density value, obtained earlier [5] with the ones from this investigation, we determined the radius more correctly (47°). The results are presented in Table 2 and Figure 4.

Table 2 – Spatial number density in the Perseids for magnitudes up to +3, +1 and −1, and mass parameter $S$, calculated with $S = 1 + 1.67 \log \kappa$ and $\kappa = (\log N(M_1) - \log N(M_2))/(M_1 - M_2)$, $M_1$ and $M_2$ magnitudes of meteors.

| $\lambda_\odot$ | $\geq +3$ | | $\geq +1$ | | $\geq -1$ | | $S$ |
|---|---|---|---|---|---|---|---|
| (1950.0) | $\log N_z$ | $F \times 10^{-7}$ | $\log N_z$ | $F \times 10^{-8}$ | $\log N_z$ | $F \times 10^{-8}$ | |
| 133°5 | 1.33 | 1.64 | 0.56 | 2.79 | | | |
| 134°0 | 1.42 | 2.02 | | | | | |
| 134°5 | 1.58 | 2.92 | 0.73 | 4.13 | −0.22 | 0.46 | |
| 135°0 | 1.47 | 2.62 | 0.77 | 4.53 | 0.04 | 0.843 | 1.57 |
| 135°5 | 1.19 | 1.19 | 0.54 | 2.66 | 0.18 | 1.16 | 1.44 |
| 136°0 | 1.39 | 1.88 | 0.67 | 3.59 | −0.3 | 0.38 | 1.55 |
| 136°5 | 1.46 | 2.20 | 0.61 | 3.13 | −0.12 | 0.58 | 1.65 |
| 137°0 | 1.32 | 1.60 | 0.61 | 3.13 | 0.0 | 0.77 | |
| 137°5 | 1.48 | 2.32 | 0.69 | 3.76 | 0.22 | 1.27 | 1.69 |
| 138°0 | 1.58 | 2.92 | 0.77 | 4.53 | | | 1.61 |
| 138°5 | 1.79 | 4.74 | 1.16 | 11.11 | 0.4 | 1.93 | 1.55 |
| 139°0 | 1.97 | 7.17 | 1.24 | 13.36 | 0.84 | 6.32 | 1.58 |
| 139°5 | 2.15 | 10.8 | 1.42 | 20.2 | 0.56 | 1.3 | 1.64 |
| 140°0 | 1.99 | 7.51 | 1.30 | 15.3 | 0.56 | 1.3 | 1.65 |
| 140°5 | 1.96 | 7.01 | 1.26 | 13.99 | 0.38 | 1.84 | 1.68 |
| 141°0 | 1.58 | 2.92 | 0.89 | 5.97 | | | 1.65 |
| 141°5 | 1.63 | 3.28 | 1.09 | 9.46 | 0.26 | 1.39 | 1.60 |
| 142°0 | 1.46 | 2.22 | 0.76 | 4.42 | −0.14 | 0.56 | |

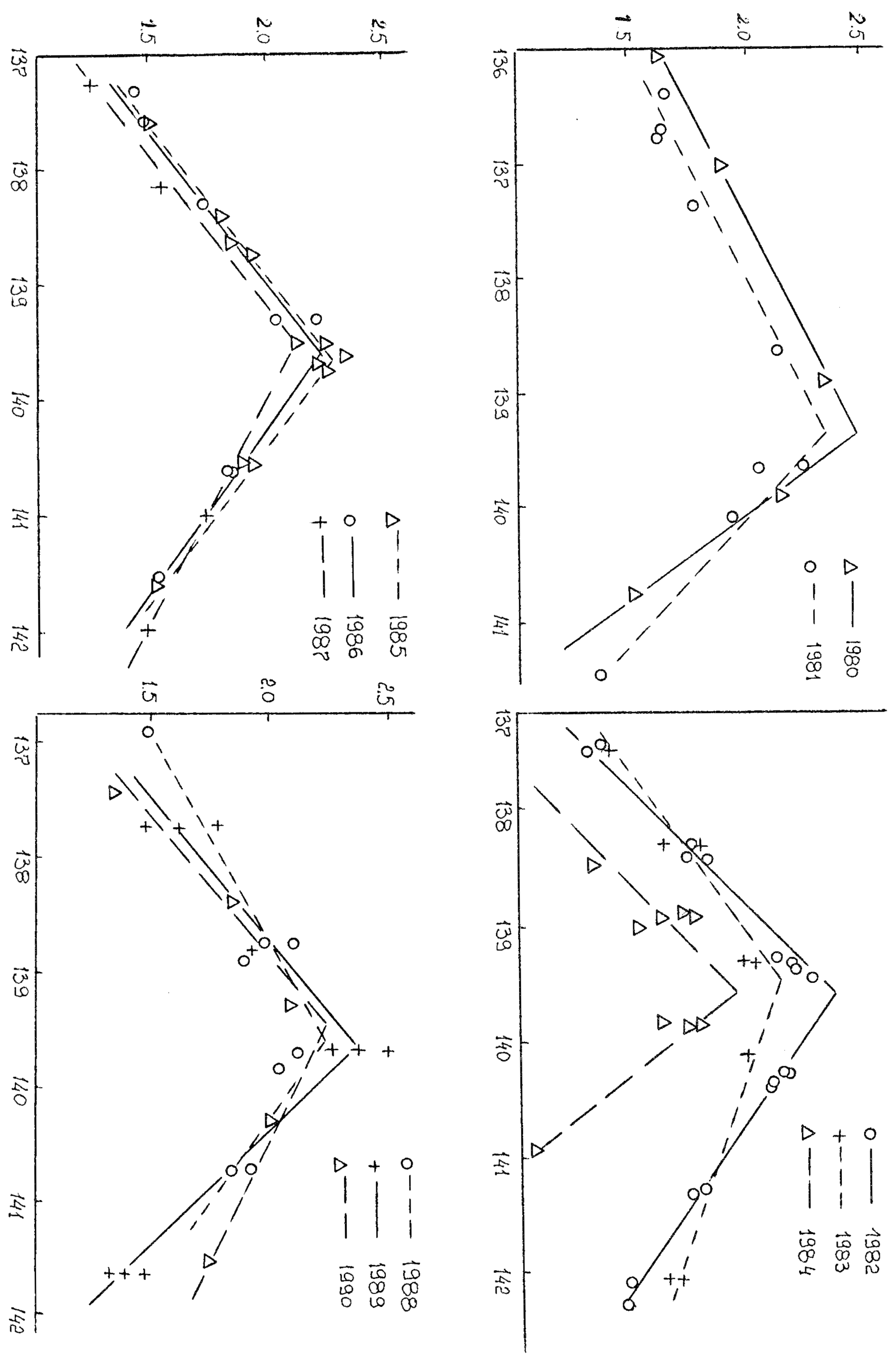



Figure 3 – Determination of the Perseid maximum.

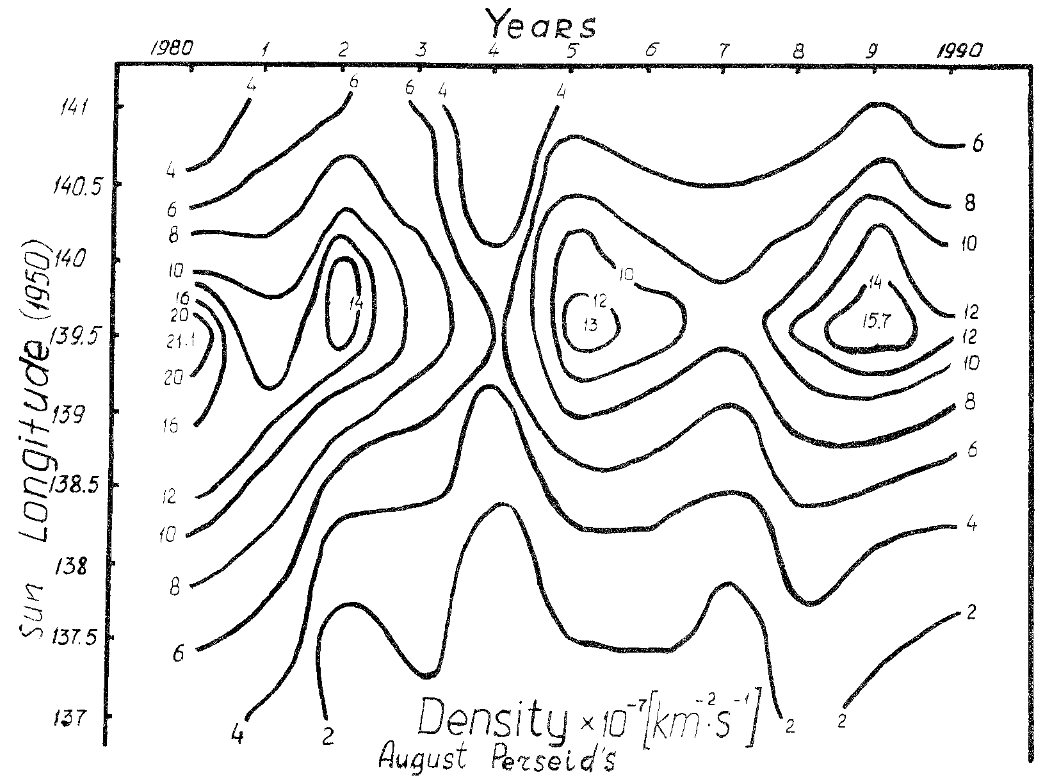



Figure 4 – Spatial density of the Perseid stream in different years.

## 5. Conclusions

1. During 1980–1990, the Perseid maximum was observed at $\lambda_\odot = 139^{\circ}.2$–$139^{\circ}.7$; in 1980 and 1981, the values were $\lambda_\odot = 139^{\circ}.2$–$139^{\circ}.3$, and in 1982–1989, the values were $\lambda_\odot = 139^{\circ}.5$–$139^{\circ}.7$. In recent years, two peaks in the range $\lambda_\odot = 139^{\circ}.3$ to $139^{\circ}.6$ have been observed, which have not been found for 1980–1985. Besides the main maximum, there have been two other ones ($\lambda_\odot = 134^{\circ}.5$ and $\lambda_\odot = 141^{\circ}.5$). The time of maximum activity of the bright meteors is shifted relative to the common maximum: for the initial maximum, one degree delay is seen, whereas for the main one, the bright meteors are $0^{\circ}.5$–$0^{\circ}.7$ ahead. The behavior of the mass parameter $S$ accurately correlates with the activity profile.
2. The activity at maximum is decreasing from year to year since the 1980 outburst.
3. B. Levin's conclusion (about the presence of a narrow condensation of high density in the stream) is confirmed.
4. It is possible that the initial maximum ($\lambda_\odot = 134^{\circ}.5$) is not due to the Perseids, but rather to radiant activity located near the early Perseids' radiant ($\alpha = 37^\circ \pm 5^\circ$, $\delta = +55^\circ \pm 2^\circ$). In order to reach a consensus over this problem, simultaneous photographic observations from August 1 to 10 are in need.

## References

[1] O. Belkovich, V. Martynenko, et al., "The Structure of the Geminid Meteor Shower", *WGN* 18:4, August 1990, pp. 109–110.

[2] P. Babadzhanov, "Meteori i ich nabljudenije", Moskva, 1987.

[3] G. Andreev, et al., "On the Spatial Structure of the Perseid Meteor Stream", *WGN* 17:6, December 1989, pp. 249–253.

[4] V. Martynenko, A. Grishchenyuk et al., "The Perseid Shower 1980", *Solar System Res.* 16:4, 1982.

[5] A. Grishchenyuk, V. Mozhzherin, "Determining a Meteor Stream's Density from Visual Observations in the USSR", *WGN* 18:3, June 1990, pp. 85–88.

# A Comparison of the $\eta$-Aquarid and Orionid Meteor Streams

*David Swann*

The author, using his own observations of the $\eta$-Aquarids and the Orionids, discusses the similarities and differences of the two streams originating from the same comet.

## 1. Introduction

The $\eta$-Aquarid and the Orionid meteor streams are debris from Halley's comet which the Earth encounters twice a year. They are made unique among related meteor showers in that both streams produce "major" activity and both can be observed visually. Table 1 below is a comparison of key characteristics.

Table 1 – Comparison of data elements for the $\eta$-Aquarids and Orionids.

| Shower | $V_\infty$ | Duration | % Trains | $\overline{m}$ | % colored |
|---|---|---|---|---|---|
| $\eta$-Aquarids | 65.5 km/s | Apr 21–May 12 | 30.3 | 2.99 | 22.6 |
| Orionids | 66.4 km/s | Oct 02–Nov 07 | 29.6 | 2.36 | 26.6 |

The $\eta$-Aquarids are visible between April 21 and May 12 with a visual maximum occurring between May 4 and 7. A secondary maximum occurs later between May 8 and 11. A decrease in rates occurs between the two maxima. The Orionids are visible between October 2 and November 7. Visual maximum occurs during October 20 to 24. The Orionids consist of several primary and secondary maxima and give the appearance of a stationary radiant. Both streams are complex and consist of filaments or belts of particles that have been shed away by Halley's comet.

This comparison includes all of the $\eta$-Aquarid and Orionid meteors observed, by the author, during routine observing sessions. These observing sessions were conducted during 1966–1990. The samples used in this analysis consisted of 234 $\eta$-Aquarids and 233 Orionids. The author wanted to know if his data showed any significant difference between the two streams. The remainder of this article will explore the similarities and differences as shown by the author's data.

## 2. Period of activity

Observations of the $\eta$-Aquarids conducted in 1988 indicated that the period of this stream lasted longer than May 12. Visual observations made on May 13 and 14 showed high rates of four per hour on both dates. Observations made in 1985 indicated that $\eta$-Aquarid were still present on May 18 with a high rate of two per hour. These observations were all conducted from the dark skies of Ft. Davis, Texas. *Cfr. also the longer activity period given for this shower in this issue's Visual Observers' Notes on p. 36 (ed.).*

## 3. Trains

Train durations varied from a fraction of a second up to 20 seconds for one very bright Orionid. The author made no attempt to distinguish between wakes and persistent trains. 71 $\eta$-Aquarids left trains, or 30.3%. The percentage for the Orionids was very similar at 29.6%. This represented 69 meteors. The author does not feel that 0.7 of 1% difference between the two streams is significant.

## 4. Average magnitude

This category showed a significant difference between the two streams. The average magnitude of the $\eta$-Aquarid sample (233) was +2.99 while the Orionid sample (231) showed an average magnitude of +2.36. The Orionids were 0.63 magnitudes brighter. See Table 2 below.

Table 2 – Magnitude distribution of the $\eta$-Aquarids and Orionids observed between 1966–1990.

| Shower | −2 | −1 | 0 | +1 | +2 | +3 | +4 | +5 | +6 | Tot | $\overline{m}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\eta$-Aquarid | 0 | 1 | 7 | 22.5 | 41.5 | 71 | 74 | 13 | 3 | 233 | 2.99 |
| Orionid | 3.5 | 8.5 | 12 | 29 | 64 | 63.5 | 39 | 11.5 | 0 | 231 | 2.36 |

The author decided that this difference was probably due to the $\eta$-Aquarids being observed under darker skies then the Orionids. In 1986, 108 $\eta$-Aquarids had been observed under dark skies near Ft. Davis, Texas. The author remembered other occasions where $\eta$-Aquarids had also been observed under darker skies. The decision was made to look at the data again and only use those meteors where the limiting magnitude had been +6.0 or fainter. This limiting magnitude should preclude any observations made near a large city or town. See Table 3 below.

Table 3 – Magnitude distribution of the $\eta$-Aquarids and Orionids observed with limiting magnitude at least +6.

| Shower | −2 | −1 | 0 | +1 | +2 | +3 | +4 | +5 | +6 | Tot | $\overline{m}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\eta$-Aquarids | 0 | 0 | 3 | 12.5 | 28 | 37 | 46.5 | 10 | 3 | 140 | 3.10 |
| Orionids | 2.5 | 4.5 | 7.5 | 16.5 | 34.5 | 39.5 | 25.5 | 7.5 | 0 | 138 | 2.42 |

When the analysis was finished the samples consisted of 140 $\eta$-Aquarids and 138 Orionids. Again, the samples were almost equal. The average magnitude showed very little change! The average magnitude of the $\eta$-Aquarids was +3.10 while the Orionid sample showed an average magnitude of 2.42. This time, the Orionids were 0.68 magnitudes brighter. There did seem to be a real difference between the two streams in average brightness.

Another indication of this difference was in the number of negative magnitude meteors in the two samples. The $\eta$-Aquarid sample of 233 meteors had just one negative magnitude meteor. This meteor was of magnitude −1. The Orionid sample of 231 meteors had 16 negative magnitude meteors with the brightest being magnitude −2.

## 5. Color

Color is subjective and can vary from one observer to another. The author was interested in seeing if there were any similarities in color groups between the two streams. He would not have to consider the biases that occur between the observations of different observers. If a meteor showed more than one color it was grouped by the dominant color. The majority of the meteors appeared white. The author did not consider white to be a color in this analysis. Many of the meteors were simply too faint to register any distinct color at all.

Color was observed in 22.6% of the $\eta$-Aquarid sample. This compared with 26.6% of the Orionid sample. The only color group that showed a good correlation was yellow. 19.2% of the $\eta$-Aquarids and 18.4% of the Orionids were in this category. Other color groups that were present were orange and blue. The $\eta$-Aquarids were fainter, on the average, than the Orionids. Considering the large number of $\eta$-Aquarids of magnitude +3.0 or fainter (144 versus 94) it would seem that the percentage of $\eta$-Aquarids showing color should be lower than the percentage of Orionids showing color.

## 6. Conclusions

This analysis was started by asking the following question: "Will two meteor streams from the same parent comet have the same characteristics?" It was thought that they would. Using this data the following conclusions have been drawn: *(i)* This analysis showed a real difference in the average magnitude of the two streams. This was attributed to a difference in average size of the particles. The $\eta$-Aquarids consist of smaller particles, on the average, than the Orionids. *(ii)* The percentage of trains was almost identical. Since the velocity of the two streams is almost identical, this indicates that the velocity is much more important than the mass in producing this phenomenon. *(iii)* The $\eta$-Aquarid data of 1985 and 1988 indicate that this stream lasts longer than May 12. *(iv)* There did seem to be some correlation between the two streams regarding color. The fainter stream ($\eta$-Aquarids) had a lower percentage of meteors showing color.

## References

[1] A.F. Cook, "A working list of meteor streams", in: *Evolutionary and Physical Properties of Meteoroids*, NASA SP-319, Washington DC, 1973, pp. 183–191.

[2] P. Roggemans (ed.), "Handbook Visual Meteor Observations", 1987, pp. 105–109.

[3] G.W. Kronk, "Meteor Showers, A Descriptive Catalog", Enslow, Hillside, N.J., 1988, p. 73.

## Comment by Paul Roggemans

*Not only the mass and velocity determine the luminosity of a meteor, also the entrance angle of the meteor (the radiant elevation) plays a roll. To put it in a very simplified way, a meteor entering the atmosphere at a very small angle will produce a much longer trail than when it hits the atmosphere straight on. The amount of energy that its mass and velocity allow to spend on its luminosity has to be smeared out over a much longer trail length when the meteoroid from a low elevation radiant enters the atmosphere. This may explain the difference in $\overline{m}$ between the $\eta$-Aquarids and the Orionids, described by Mr. Swann. Indeed, the $\eta$-Aquarid radiant never rises very high in the morning sky, while the Orionid radiant reaches a much higher elevation.*

*It must be remembered also that the Earth does intersect the Halley meteor stream which is build up through a complex process of cometary perihelion passages, at totally different cross sections in May and in October. In other words, the Earth does not encounter twice the same fraction of the stream.*

# The 1989 $\eta$-Aquarids in Spain, Uruguay, and Bolivia

*José M. Trigo*

An overview is given of extensive observations of the $\eta$-Aquarids in 1989 by Spanish and South-American observers.

## 1. Introduction

The study of this stream during the last decade in South America and Spain was important. This article analyzes the results of a total of 36 observers in 1989. Their names were as follows:

Rafael Barragán, Luís R. Bellot, Javier Caballero, José Cáceres, Raúl Cagigao, Diego Cancela, Alejandro Castillos, Oscar Cervera, Carmen Darias, José V. Díaz, Antonio Francisco, Blanca García, Pedro García, R. García, Carlos González, Fabiola González, Jorge González, Oswaldo González, Natalie Guillén, Mark Kidger, Paula Kolenc, Bernardo Landro, Rubén López, Gustavo Mastoros, Porfirio Miranda, José Moisés, Rosario Moyano, Francisco Narros, Marcello Núñez, Andrés R. Paños, Francisco Reyes, Iván Romero, Hans Salm, Miguel Sanz, José M. Trigo, Eduardo Valdenassi.

### 2. Observational results

During 16 nights, over 69 individual ZHR values were obtained. These ZHR values were grouped in 4-hour intervals. The results are visualized in Figure 1.

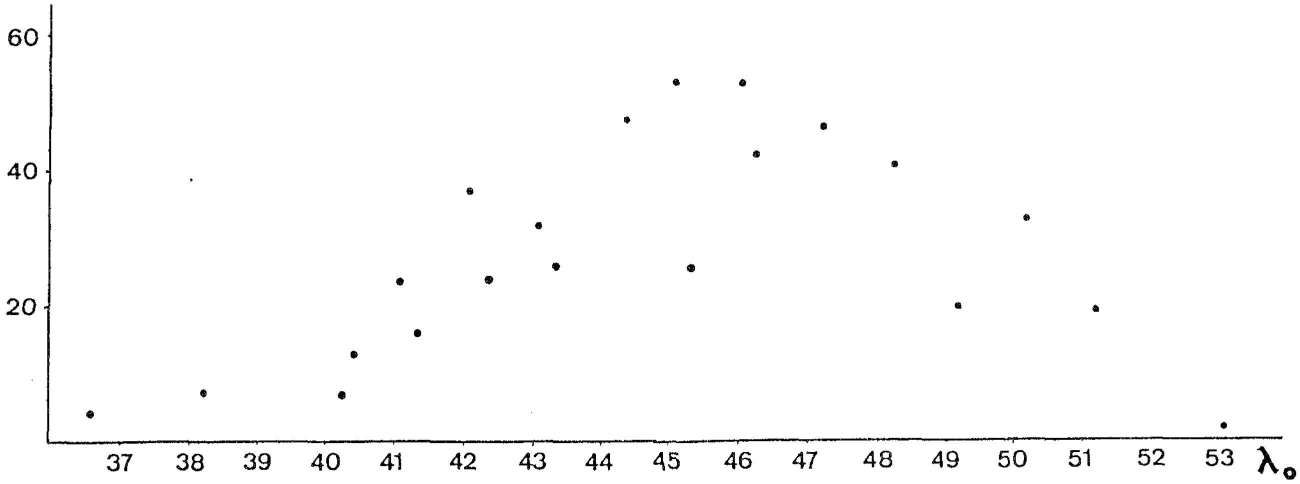



Figure 1 – ZHR values of the 1989 $\eta$-Aquarids.

The regularity of the stream between May 5 and May 9 is very evident and no great maximum can be found. The activity at the maximum in the night of May 05–06 is smaller than in previous years. Another submaximum was seen in the night of May 06–07, at $\lambda_\odot = 45^\circ\!.05$.

The population index value is $2.52 \pm 0.23$ for 425 meteors. At $\lambda_\odot = 45^\circ\!.05$, a value of $2.08 \pm 0.32$ was obtained for the population index. The magnitude distribution of the 1989 $\eta$-Aquarids is shown in Table 1. The average magnitude is 1.95 (or 3.00, corrected for the limiting magnitude).

Table 1 – Magnitude distribution of the 1989 $\eta$-Aquarids.

| Magnitude | −4 | −3 | −2 | −1 | 0 | +1 | +2 | +3 | +4 | +5 | +6 | Tot | $\overline{m}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | 1 | 5 | 15 | 24 | 46 | 59 | 93 | 92 | 75 | 14 | 1 | 425 | 1.95 |

# The $\alpha$-Capricornids and $\delta$-Aquarids South in 1989

*José M. Trigo*

The present study intends to be an analysis of the $\alpha$-Capricornid and the $\delta$-Aquarid South activity during July and August 1989. The study is a comparison between both streams and was carried out by the number density method. All the observations were carried out by some members of the Spanish Meteor Society, as well as by *IMO* members.

### 1. Observational results

The following data is based on 373 southern $\delta$-Aquarids and 160 $\alpha$-Capricornids registered by a total of 22 people participating in the study. Their names were as follows:

Javier Alonso, Luís R. Bellot, Miguel Camarasa, José A. Cáceres, Angel Carrera, Carmen Darias, Jośe V. Díaz, Antonio Fco. Marín, Blanca García, Fabiola González, Oswaldo González, Victor González, Natalie Guillén, Antonio Gutierrez, David Hernández, Mark Kidger, Roberto Molowny, Antonio J. Montesinos, Paul Roggemans, Javier Sánchez, José M. Trigo.

The evolution of the population index is shown in Figure 1.

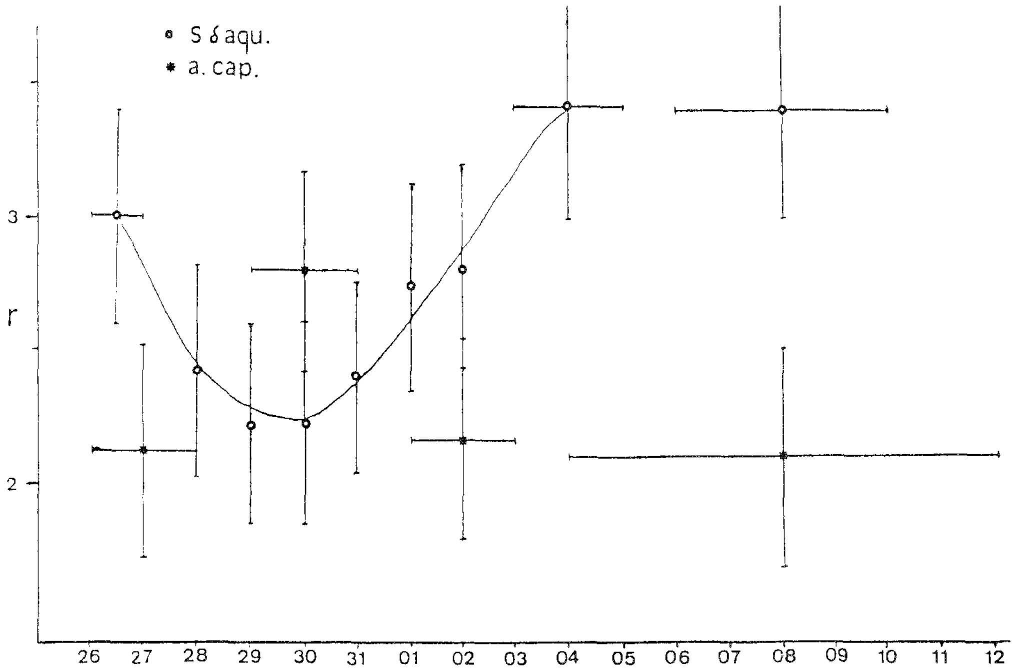



Figure 1 – Population index of the α-Capricornids and the δ-Aquarids South in July and August 1989.

As ZHR-values we took into account the average of the ZHR-values of the individual observers and calculated the standard deviation. During the observations different methods, such as plotting and counting, were used, depending on the number of observable meteors. Tables 1 and 2 show the results of our observations. Over 71 individual ZHR-values were obtained from the 22 observers.

Table 1 – Observational data and derived quantities for the δ-Aquarids in 1989. "Int" represents the magnitude range and $n$ the number of shower meteors used to calculate the population index $r$. The spatial number densities are expressed as the number of particles per $10^9$ km$^3$.

| Date | $\lambda_\odot$ | Int | $n$ | $r$ | ZHR | $\varrho_{6.5}$ | $\varrho_M$ |
|---|---|---|---|---|---|---|---|
| Jul 25–26 | 122°45 | } +1 – +5 | 13 | | $3.3 \pm 2.4$ | 20 | 15 |
| 26–27 | 123°40 | | | | $5.9 \pm 3.2$ | 36 | 27 |
| 27–28 | 124°36 | 0 – +5 | 39.5 | $2.43 \pm 0.38$ | $12.8 \pm 4.8$ | 49 | 39 |
| 28–29 | 125°27 | −1 – +5 | 57 | $2.22 \pm 0.36$ | $23.2 \pm 6.9$ | 72 | 58 |
| 28–29 | 125°31 | −1 – +5 | 57 | $2.22 \pm 0.36$ | $18.5 \pm 5.2$ | 57 | 47 |
| 29–30 | 126°27 | −1 – +5 | 45 | $2.22 \pm 0.37$ | $14.9 \pm 5.3$ | 46 | 37 |
| 30–31 | 127°23 | −2 – +5 | 66 | $2.41 \pm 0.36$ | $13.9 \pm 5.5$ | 53 | 42 |
| 31–32 | 128°18 | 0 – +5 | 43.5 | $2.73 \pm 0.38$ | $8.1 \pm 3.3$ | 40 | 31 |
| Aug 01–02 | 129°14 | 0 – +5 | 31.5 | $2.80 \pm 0.40$ | $8.0 \pm 3.0$ | 43 | 33 |
| 02–03 | 130°10 | } | | | | | |
| 03–04 | 131°06 | 0 – +5 | 46 | $3.41 \pm 0.37$ | $7.9 \pm 3.3$ | 60 | 44 |
| 04–05 | 132°01 | | | | $6.3 \pm 3.6$ | 48 | 35 |
| 05–06 | 132°97 | } | | | | | |
| 06–07 | 133°93 | | | | $4.3 \pm 2.1$ | 33 | 24 |
| 07–08 | 134°89 | +1 – +5 | 15 | | $3.8 \pm 2.0$ | 29 | 21 |
| 08–09 | 135°85 | | | | $1.3 \pm 0.9$ | 10 | 7 |
| 09–10 | 136°81 | | | | $1.1 \pm 0.8$ | 8 | 6 |
| 10–11 | 137°76 | | | | | | |
| 11–12 | 138°72 | | | | $0.7 \pm 0.5$ | 5 | 4 |

Table 2 – As in Table 1, for the $\alpha$-Capricornids in 1989.

| Date | $\lambda_\odot$ | Int | $n$ | $r$ | ZHR | $\varrho_{6.5}$ | $\varrho_M$ |
|---|---|---|---|---|---|---|---|
| Jul 25–26 | 122°45 | | | | $3.0 \pm 1.3$ | 14 | 63 |
| 26–27 | 123°40 | $-2-+5$ | 28 | $2.12 \pm 0.40$ | $4.2 \pm 1.9$ | 20 | 88 |
| 27–28 | 124°36 | | | | $2.8 \pm 1.7$ | 13 | 59 |
| 28–29 | 125°31 | | | | $2.8 \pm 1.5$ | 27 | 226 |
| 29–30 | 126°27 | $-1-+5$ | 37 | $2.89 \pm 0.38$ | $2.3 \pm 1.4$ | 22 | 186 |
| 30–31 | 127°23 | | | | $5.5 \pm 2.8$ | 54 | 445 |
| 31–32 | 128°18 | | | | $3.5 \pm 1.9$ | 18 | 85 |
| Aug 01–02 | 129°14 | $-2-+5$ | 44 | $2.16 \pm 0.38$ | $1.9 \pm 0.9$ | 10 | 46 |
| 02–03 | 130°10 | | | | $2.5 \pm 1.4$ | 13 | 61 |
| 03–04 | 131°06 | | | | $2.1 \pm 0.9$ | 10 | 43 |
| 04–05 | 132°01 | | | | $4.0 \pm 2.0$ | 19 | 82 |
| 05–06 | 132°97 | | | | | | |
| 06–07 | 133°93 | $-2-+5$ | 24.5 | $2.10 \pm 0.41$ | $1.5 \pm 1.1$ | 7 | 31 |
| 07–08 | 134°89 | | | | $1.5 \pm 1.1$ | 7 | 31 |
| 08–09 | 135°85 | | | | $1.8 \pm 1.3$ | 8 | 37 |
| 09–10 | 136°81 | | | | | | |
| 10–11 | 137°76 | | | | | | |
| 11–12 | 138°72 | | | | $1.0 \pm 0.7$ | 5 | 21 |

In the $\alpha$-Capricornid activity, a maximum is apparent on the night of July 30-31, at $\lambda_\odot = 127°7$. Another submaximum was registered at $\lambda_\odot = 123°88$ according to [1]. In the $\delta$-Aquarid South activity, the maximum is on the night of July 28–29 at $\lambda_\odot = 125°2$. During this maximum, the radiant elevation as viewed from Spain was low. Figure 2 shows the results for $\log \mathrm{ZHR}_o$ according to [2].

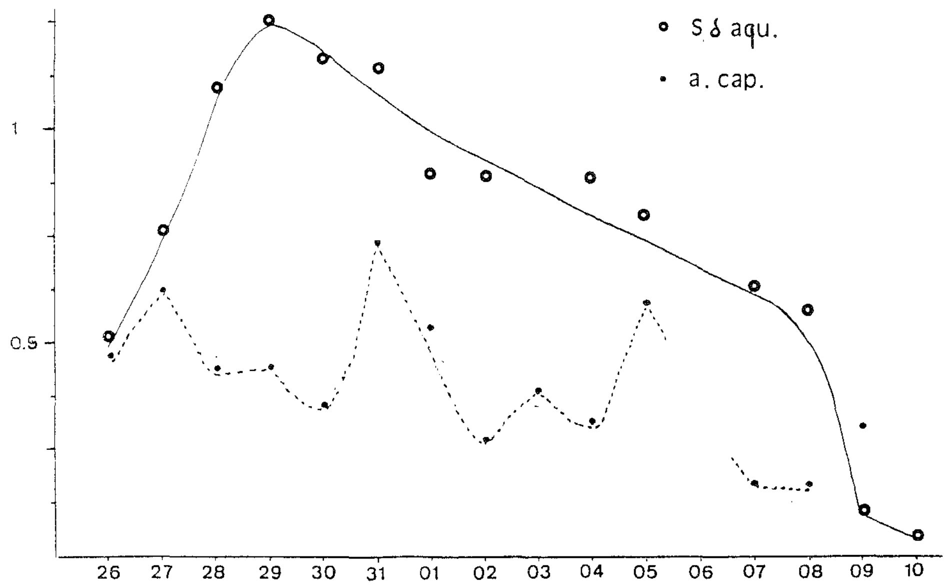



Figure 2 – Evolution of $\log \mathrm{ZHR}_o$ in July and August 1989, according to [2].

## 2. Comparison between $\alpha$-Capricornids and $\delta$-Aquarids South

The importance of a complete analysis of observational results concerning these showers is illustrated in [2]. To this end, we use observational data from experienced observers in Spain. Meteor data obtained under almost identical limiting magnitudes was taken together. Because of the uncertainties in the probabilities of perception for the faintest meteors, only meteors of magnitude 5.0 or brighter were considered.

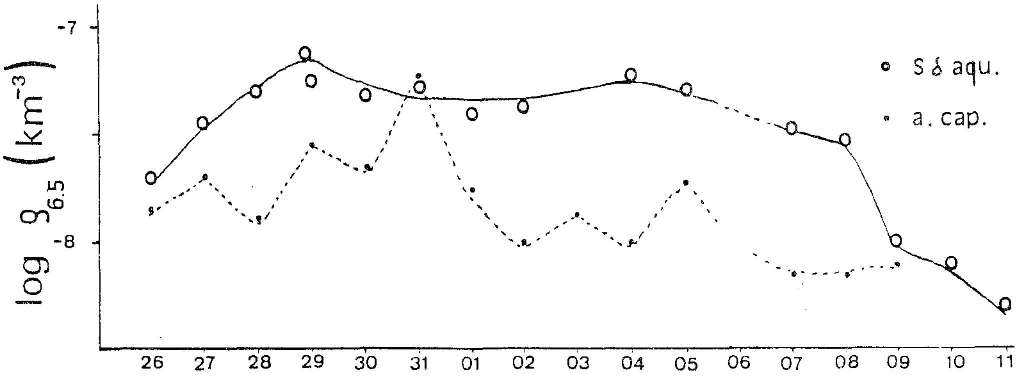



Figure 3 – Spatial number densities $\varrho_{6.5}$ in July and August 1989, according to [2].

The calculation of the spatial number density $\rho_{6.5}$ for the meteors of magnitude 6.5 and brighter was done according to [2]. The result, visualized in Figure 3, is remarkable. In the case of the $\delta$-Aquarids South, the activity is unpronounced by the fact that the maximum coincides with a decrease of the population index. Calculating $\rho_M$ according to [2] leads to Figure 4. This quantity allows to compare streams directly. In the case of the showers, the number density of the $\alpha$-Capricornids exceeds that of the Perseids by a factor between 5 and 10.

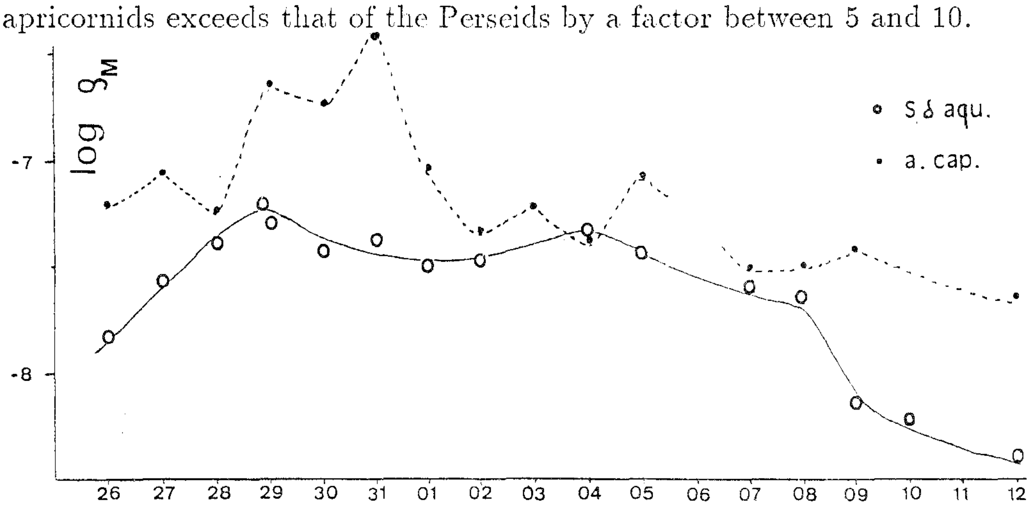



Figure 4 – Spatial number densities $\varrho_M$ in July and August 1989, according to [2].

## 3. Magnitude distribution and train percentage

Of 267 $\delta$-Aquarids South used for this purpose, 7% had a train; of 102 $\alpha$-Capricornids, 2% showed a train. The magnitude distribution of the $\alpha$-Capricornids and the $\delta$ Aquarids South is shown in Table 3.

Table 3 – Magnitude distribution of the 1989 $\delta$-Aquarids South and $\alpha$-Capricornids.

| Shower | −4 | −3 | −2 | −1 | 0 | +1 | +2 | +3 | +4 | +5 | +6 | Tot | $\overline{m}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\delta$-Aqr S | 1 | 1 | 1 | 4 | 20 | 29.5 | 49 | 107.5 | 114.5 | 43 | 2.5 | 373 | 3.02 |
| $\alpha$-Cap | 0 | 1 | 4 | 4 | 9 | 15.5 | 29.5 | 40 | 35.5 | 16 | 5.5 | 160 | 2.71 |

## References

[1] L.R. Bellot, "The $\alpha$-Capricornids in 1989", *WGN* 18:1, February 1990, pp. 26–28.

[2] R. Koschack, J. Rendtel, "Number Density in Meteor Streams", *WGN* 16:5, October 1988, pp. 149–157.

# Radio Observations of the 1989 and 1990 Geminids

# The 1989 Geminids

*Jeroen Van Wassenhove*

Radio observations of the 1989 Geminids yielded more than 6000 meteor reflections. The maximum was found to be at solar longitude $\lambda_\odot = 261.^\circ 9 \pm 0.^\circ 1$.

## 1. Introduction

This analysis of the Geminid meteor shower is based on more than 6000 meteor reflections. It was the first time that such a massive amount of Geminid data came in. The Radio Commission received radio data from three different countries, namely Germany, Denmark and Belgium. We are very grateful to the following observers who send in their observations:

> *Germany:* Ingo Reimann; *Denmark:* Gotfred Møbjerg Kristensen; *Belgium:* Maurice De Meyere, Dirk Artoos, Cis Verbeeck, Eric Crauwels, Albert De Clerck, An Caers, Werner Depoorter.

Ingo Reimann and Gotfred M. Kristensen listened on the normal FM band (87.50–108 MHz), while the other observers listened on the three-meter band (66–73 MHz).

## 2. Reduction of the radio data

Before we started to reduce the radio data, the data was checked on errors and some basic criteria. Observations lasting less then half an hour were omitted for statistical reasons. (By the way, one hour is recommended.) Only complete series of observations were used in this analysis. If during the observation the frequency or equipment set-up was changed, the observations were eliminated.

For each series of observation the sporadic background was determined, by examining the data at the extreme beginning and end of the observing period. This background rate was then subtracted. After this the Observability Function was calculated and applied for each series of observations. The Observability Function uses the following main parameters: radiant position, antenna radiation pattern and gain, the azimuth and location of the transmitter, antenna azimuth and elevation, power of the transmitter (kW) and population index. It is similar to the visual ZHR correction. Hereafter, the observations were plotted on a solar longitude scale, equinox 2000.0.

As some observers carried out several series of observations, they were plot on the same figure (same equipment, same conditions), which gave a beautiful result. This shower analysis could not have been performed without the *Radio Meteor DataBase*, which proved to be of great help in reducing radio data.

## 3. Results

The results are presented in the corresponding graphs. In the figures, the one standard deviation error bars were indicated. Remarkable is the fact that both Dirk Artoos and Maurice De Meyere had a significant decrease of meteor activity but on different days. The observations were *not* hampered by inversion or sporadic E.

The graphs of Gotfred M. Kristensen and Ingo Reimann give a nice view of the profile of the 1989 Geminid shower. Both observers listened minimum 6 hours a day.

All the graphs show a steep decrease after the maximum, which is characteristic for the Geminid shower.

We were able to calculate the maximum of the 1989 Geminids of each series of observations. The results of the calculations were combined and this gives us the final date of December 13, 1989 at $18.^h5 \pm 1.^h5$, which corresponds with a solar longitude (2000.0) of $\lambda_\odot = 261.^\circ 9 \pm 0.^\circ 1$.

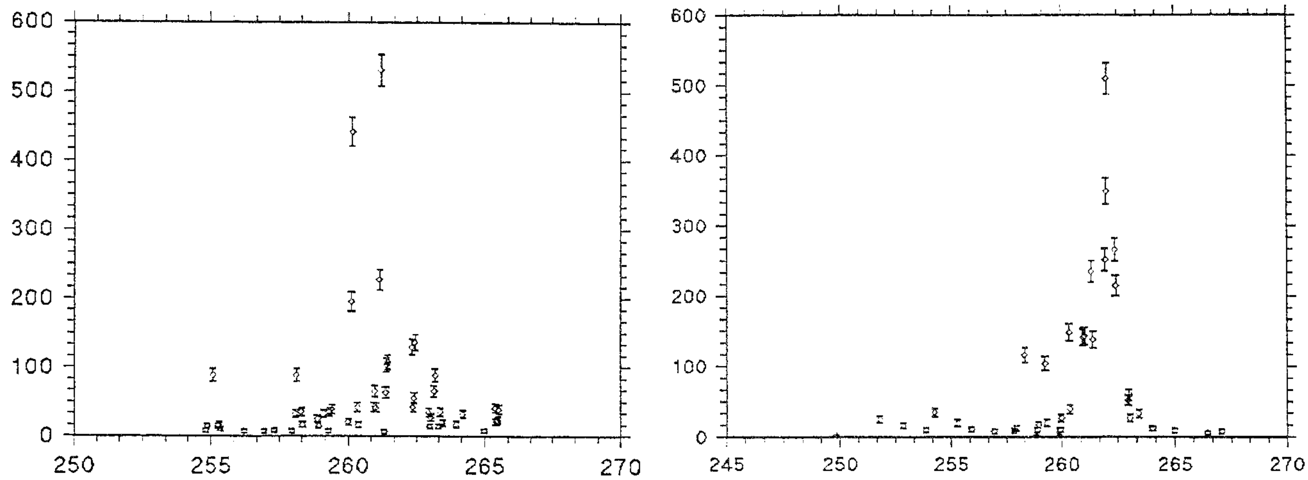



Figure 1 – Radio observations of the 1989 Geminids by I. Reimann at 105.60 MHz *(left)* and by G.M. Kristensen at 100.50 MHz *(right)*.

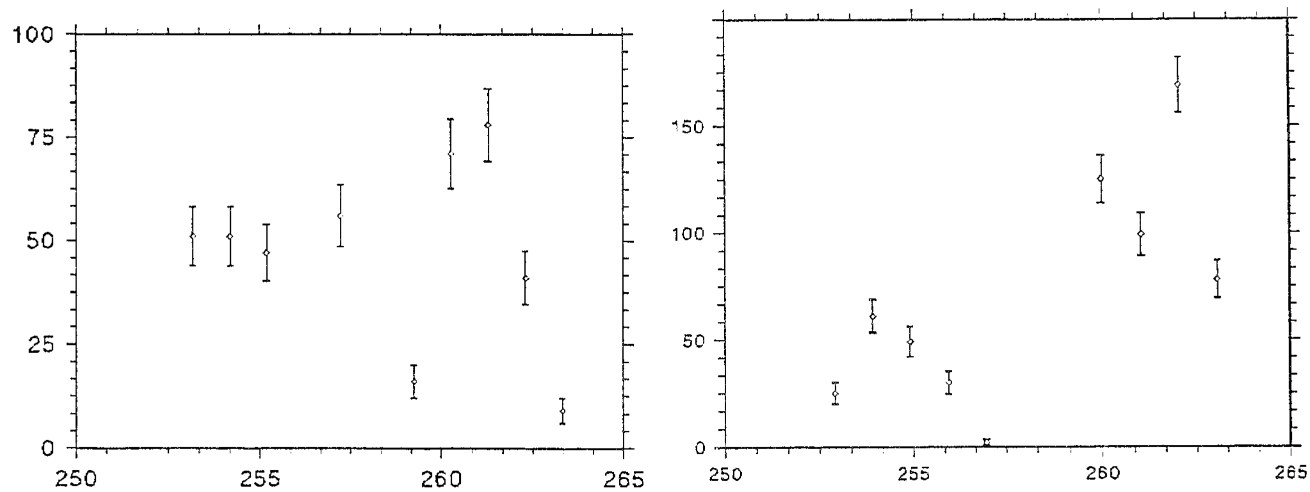



Figure 2 – Radio observations of the 1989 Geminids by D. Artoos at 66.45 MHz between $3^h45^m$–$4^h20^m$ UT *(left)* and by M. De Meyere at 66.17 MHz between $21^h30^m$–$22^h00^m$ UT *(right)*.

# First Impression of the 1990 Geminids

*Jeroen Van Wassenhove*

Radio observations by G.M. Kristensen (Denmark) suggest that the 1990 Geminid display was very strong compared to preceding years. The observer suspects a gap of about 24 hours between the maxima of the weaker and the brighter Geminid radio meteors.

Some radio observers reported a higher activity around December 10, some days before the maximum of the Geminids. Gotfred Møbjerg Kristensen (Denmark) wrote:

> *On December 9, meteor activity increased to 234 meteor reflections per hour at $22^h$ UT. The unusual high activity continued all night and reached 342 meteors per hour, in the morning at $5^h$ UT. In 1990, the Geminids showed a similar picture as in 1989, but the activity was very considerably higher. On the morning of December 13 at $5^h$ UT, 521 meteors per hour were counted. Again, the greatest number of bright radio meteors came the next morning ($6^h$–$7^h$ UT). It seems to me that the Geminids are assorted in weaker and brighter meteors separated by a gap of around 24 hours. The*

> *first Geminids appeared on December 2; the last were heard on December 16. The Geminids greatest rates were 88 in 9185, 163 in 1986, 72 in 1987, 246 in 1989. It is without doubt that the 1990 Geminid shower was the most active one of the last years.*

People who have observed during that period are invited to send their results to the Radio Commission.

*A graph very nicely showing the significant increase in radio activity of the Geminids in 1990 compared to 1989 accompanied the manuscript of this article. For technical reasons, unfortunately, the graph could not be reproduced. May we please ask all authors to respect the simple guidelines given on p. 27 of this issue? (ed.)*

# Experience Effects in Telescopic Meteor Observations

*Mark Vints*

The quantitative gain in telescopic meteor results with increasing experience is demonstrated from sets of observations obtained in Southern France between 1988 and 1990.

## 1. Introduction

I started telescopic meteor observations during the 1985 Perseids. Holding a pair of heavy 10 × 50 binoculars in my hands, with my elbows on the window, I managed to see 3 meteors in slightly more than 1 hour observing time dispersed over 5 watches, each of them limited by how soon the cramps set in. Similar results were obtained during the three following nights.

As difficult as the actual observing was, getting the right charts was no easy thing either. Some were traced from photographs in magazines, a few were enlarged from the Sky Atlas 2000, and others were hand-drawn prior to the observing run.

Work continued under inferior circumstances until the spring of 1988, by which time I had a total of 59 meteors from 13 hours of observing in 17 different nights. Observing comfort was still an abstract idea; decent rates were something to be dreamt about, and the milestone of my 1000th telescopic meteor seemed decades into the future.

## 2. The 1988 Perseid campaign in Lardiers

In the spring of 1988, I obtained a copy of the Uranometria 2000.0 atlas, which provides perfect charts for 50 mm binoculars, and more importantly, I bought a tripod for mounting the instrument. I was now ready to tackle the Perseid campaign which was organized in Lardiers (Southern France) for a period of 2 weeks around the maximum. In that period, I almost quadrupled my total number of meteors! The huge bulk of results, as seemed to me then, certainly got me hooked on telescopic meteor observing for good. The satisfying rate of 6 meteors per hour was comparable to what I read in some Czech papers. I remember writing to Malcolm Currie later that year: "You must have an exceptional perception to see 11 met/hours."

Table 1 – Characteristics of telescopic observations by the author

| Date | Shower | Nights | $T_{\rm eff}$ | Avg. run | $N$ | $\overline{m}$ | HR |
|---|---|---|---|---|---|---|---|
| 1988 Aug | Per | 12 | $25\overset{\rm h}{.}66$ | $22^{\rm m} \pm 8^{\rm m}$ | 162 | 7.2 | $6.3 \pm 1.3$ |
| 1989 Jul | Aqr/Cap | 7 | $20\overset{\rm h}{.}53$ | $43^{\rm m} \pm 6^{\rm m}$ | 303 | 7.6 | $14.8 \pm 1.6$ |
| 1990 Jul | Aqr/Cap | 12 | $17\overset{\rm h}{.}91$ | $40^{\rm m} \pm 9^{\rm m}$ | 295 | 7.8 | $16.5 \pm 2.9$ |
| 1990 Dec | Gem | 7 | $22\overset{\rm h}{.}40$ | $51^{\rm m} \pm 13^{\rm m}$ | 440 | 7.8 | $19.6 \pm 2.0$ |

## 3. The following years

1989 saw me back in Lardiers, this time for a one-week Aquarid and Capricornid campaign. I was well prepared after a series of routine observations in spring, and conditions were very good. This resulted in twice the number of meteors compared to 1988, in just one week, as you can see in the table above. Hourly rates doubled, as well as the average duration of an observation run (the time in between breaks which is only interrupted for writing down meteors). The average magnitude of the meteors was fainter too.

The 1990 summer campaign was characterized by less than perfect conditions (low limiting magnitude and frequent clouds) and more importantly the fact that I was the only observer in the group. This mainly affected the total number of hours observed per night, which was a lot less than could be hoped for from the 1989 results. Hourly rates and averaged magnitude were at least as good as the previous year.

Last December's Geminid campaign began very unfavorably with lots of snow and cloud cover. This resulted in 5 lost nights and one in which 0.22 hours observing was logged. Six other nights displayed harsh conditions (sub-zero temperatures combined with strong mistral) and perfect sky. Hourly rates shot up (aided by good Geminid rates) as well as the duration of an average observing run. My life-total of telescopic meteors raced past the 1000 mark. The total now stands at 1403, of which 1200 were observed in Lardiers. These 1200 are represented in the magnitude histogram below. It is clear at first sight that the majority of meteors are fainter than the naked-eye limit, even in this small instrument.

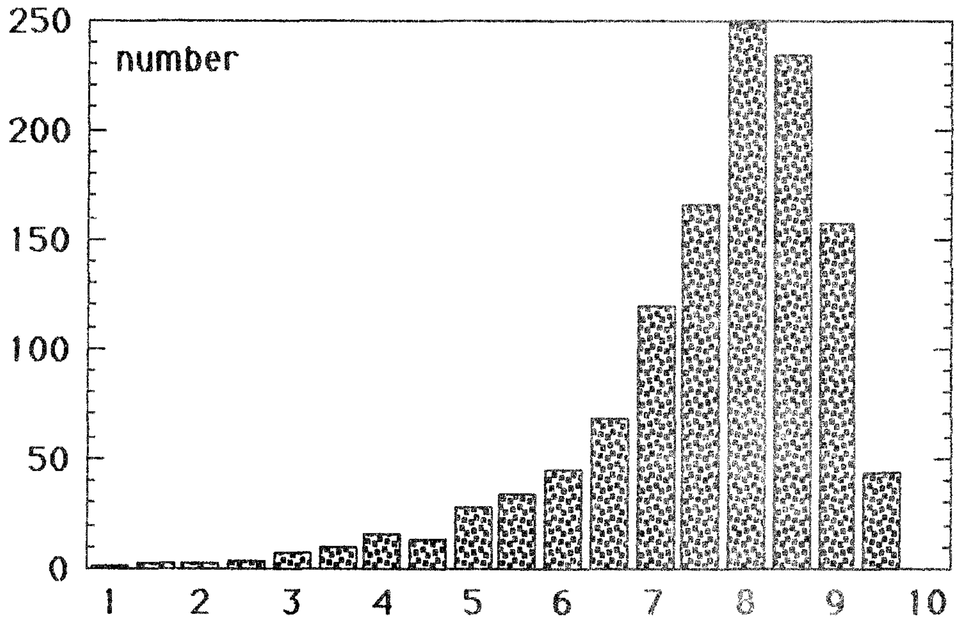



Figure 1 – Magnitude distribution of the telescopic meteors observed by the author.

## 4. Conclusion

Comparing results from different years and different showers can seem ambiguous, but it is not as bad as it looks. First, I am not looking at actual figures, just trends. Also, conditions were to a good degree similar from one year to another (limiting magnitude between 6.0 and 6.5). And as to shower rates, they are always a minority in telescopic observations. So it appears that with growing experience, the telescopic observer enjoys higher rates, fainter average magnitude, longer observing runs and more time per night.

For me the significant thing to learn yet is keeping up a high effective time over a significant number of nights. Observe that I have not addressed the question of how experience influences the plotting accuracy. This is because it is almost impossible to assess this question without experiments. If plotting confidence is a measure, I am certainly on the right track.

# The Baker Perkin-Elmer Super-Schmidt Meteor Camera

*Peter Brown*

The Super-Schmidt meteor camera has been one of the most efficient instruments ever used for the detection of meteors. The reason for the success of the camera system resides in its revolutionary optical design. The basic optical principles governing the camera's performance are outlined along with the specific optical characteristics of each Super-Schmidt.

## 1. Introduction

The modern science of astronomy relies very heavily on the telescope. Virtually all astronomical measurements are made with the telescope, usually in the form of photographs. Most conventional telescopes utilize aspheric mirrors to collect and focus light from small faint sources. In this application the aspheric mirror as found in a Newtonian or Cassegrainian telescope system is well suited to the task.

The study of meteors, on the other hand, relies heavily on the collection of large numbers of photographic meteor trails. Since meteors occur at random the only hope of building an efficient "meteor collector" is to design a wide field optical system which collects large amounts of light (to see the fainter meteors).

Hence for meteor astronomy, the aspheric mirror suffers one major drawback: an extremely narrow field of view. Additionally aspheric mirrors suffer from several optical aberrations which reduce image clarity and make the measurement of meteor trails almost impossible on photographs.

Thus a strong motivation exists in meteor astronomy to build a wide-field, fast, aberration free camera. This can be accomplished through the use of a spherical objective mirror in an optical system with lens correctors in a suitable arrangement. The optical system thus described for meteor astronomy was first designed in the 1940s and resulted in a camera called the Baker Perkin-Elmer Super-Schmidt of which 6 were ultimately built for use in meteor astronomy.

## 2. Basic principles of the Schmidt optical system

Before describing the Super-Schmidt in detail some background in the general theory of the Schmidt optical system is appropriate.

The Schmidt optical system used in both telescopes and cameras exploits the axial symmetry which is found in a spherical mirror section. Without this symmetry numerous image degrading aberrations result.

As an example, when incoming rays not parallel to the optical axis of an aspheric mirror are reflected, the peripheral rays, defined to be those rays distant from the auxilary optical axis which itself is defined to be the line through the extra-axial object, center of curvature down to the mirror, become focused over a region rather than a point. This serious optical flaw is called coma and manifests itself in distorted images at the edges of the optical field. By using a spherical primary mirror every incoming ray direction is equivalent due to symmetry and aberrations, such as coma, can be avoided.

Along with the loss of all aspherical aberrations, however, comes one additional aberration the spherical mirror produces: spherical aberration.

Spherical aberration results in rays reflected far from the optical axis coming to a focus closer to the objective than paraxial rays as shown in Figure 1. This is a higher order aberration, meaning that the paraxial approximation $\sin\theta \approx \theta$ is no longer valid for peripheral regions and higher order terms in the Taylor expansion of $\sin\theta$ must be included. This results when the aperture becomes large relative to the focal length [1]. Quantitatively the severity of spherical aberration can be characterized by the equation giving the distance between which paraxial rays and the outermost rays focus. This is given by [2]:

$$d = \frac{kD^2}{2R} \tag{1}$$

where $d$ is the distance between the paraxial and peripheral foci, $D$ is the diameter of the mirror, $R$ is the radius of curvature of the mirror and $k$ is a constant equal to 1/8 for spherical mirrors. The larger $d$ the greater the longitudinal extent along the optical axis the light is spread and the fainter the image along any given plane through the surface defined by the envelope of the reflected rays in Figure 1, called a caustic surface.

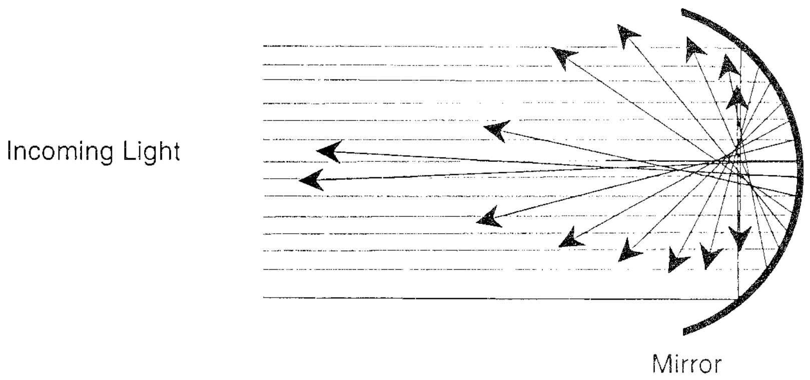



Figure 1 – Spherical aberration of a mirror.

Schmidt in 1930 first developed the technique to eliminate spherical aberration [3]. His solution is simplicity incarnate: introduce an equal yet opposite aberration to the incoming light through a properly formed corrector plate. This corrector plate is placed at the point rays coming at all angles to the optical axis must pass through; the center of curvature. The nature of this placement becomes clear when it is considered that every image point lies along an auxillary optical axis. The mirror's symmetry in this case results in a focal point along any optical axis lying at a fixed distance from the objective (namely $R/2$ for a spherical mirror). Thus as the image point rotates about the center of curvature a spherical focal surface is produced [4].

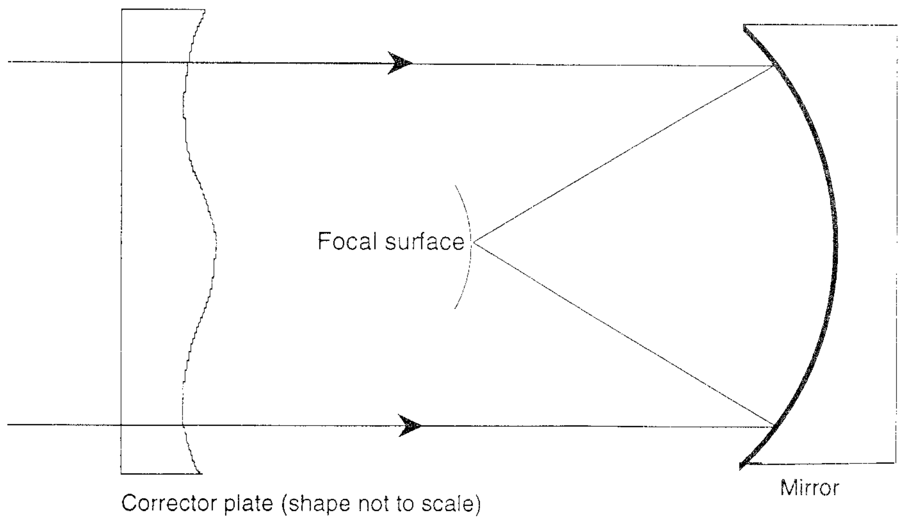



Figure 2 – Schematic of the Schmidt camera.

The figuring of the corrector is such as to make the spherical mirror appear to incoming rays as a centered parabolic mirror allowing all rays to come to a focus but avoiding coma associated with any physical paraboloid. The original Schmidt design is shown in Figure 2. While Schmidt used plates of negligible thickness to achieve correction, spherical meniscus lenses of considerable thickness have become the other popular means used to eliminate spherical aberration. Both versions of correction are employed in tandem on the Super-Schmidt and so a fuller description of each is warranted.

## 3. The correcting plate

The heart of the Schmidt principle is the correcting surface. Correcting plates are generally employed since they introduce very little chromatic aberration into the system. Chromatic aberration results in separate wavelengths being focused differentially since the index of refraction for any lens is somewhat wavelength dependent [5].

In this regard a thin correcting plate is superior to a thick meniscus shell.

The form of the correcting plate is generally one plane surface and a front surface whose shape can be expressed as a deviation from a planar surface by the formula [3]:

$$Y = \frac{X^4 - Kr^2X^2}{4(n-1)R^3} \tag{2}$$

where $X$ is the distance from the optical axis, $K$ a constant of curvature, $r$ is the full radius of the correcting plate, $n$ is the index of refraction of the plate glass and $Y$ the thickness of the correcting plate at $X$. This relation is a first term approximation to the general power series for a two mirror aplantic derived by Schwarzschild [1]. The design freedom arises from the choice of k, all other parameters being fixed for the system.

Thus while the corrector plate does not affect magnification it does affect path difference given by $(n-1)Y$. Since this path difference applied in the form (2) can bring all the zonal foci together at any region within the longitudinal extent of the spherical aberration (see (1)) the value of $k$ effectively determines where the focal surface will be found.

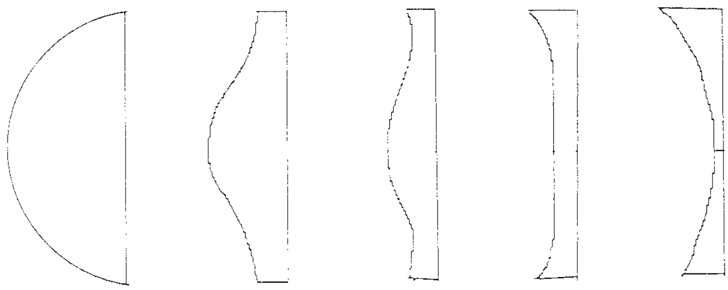



Figure 3 – Corrector plate forms from positive to negative $K$ values.

Figure 3 shows the shape of the corrector plate for various values of $k$. The physically meaningful quantity in Figure 3 is actually $Y'(X)$ as the curvature of the plate at each point determines how rays there will be affected. Thus for negative $K$ values the corrector acts as a negative lens and peripheral rays are bent out, coming to a focus as though rays from a zone of larger diameter; hence the focal surface is nearer the objective where peripheral rays normally focus. Hence as $K$ increases the focal surface moves slightly further from the objective as peripheral rays experience more of a positive correction from the plate [2]. Figure 3 shows the form of the plate going from positive to negative $K$ values. Note that in applications the maximum value of $|Y - Y_0|$ (deviation from a plane) is of the order of 10 $\mu$m [1].

## 4. The meniscus lens

In place of corrector plates, spherical shells of considerable thickness may be employed to respond in much the same way as corrector plates with relatively large positive or negative $K$ values. The shell is normally placed such that its center of curvature is coincident with that of the primary mirror's center of curvature.

The shells have the advantage over plates of capturing rays over a wider field as their added thickness permits significant bending of rays in peripheral regions. In addition since the lenses are spherical the optical system maintains complete symmetry, while the corrector plate suffers from minor higher order off-axis aberrations as it is designed to perfectly correct for spherical aberration along the primary optical axis only [6].

The form of the lens has its principle design freedom in its thickness rather than in its shape as is the case with the plate.

## 5. General optical design of the Super-Schmidt

The Super-Schmidt meteor camera borrows the essential philosophy of design found in the Schmidt principle but refines the practical optical system to a greater sophistication level.

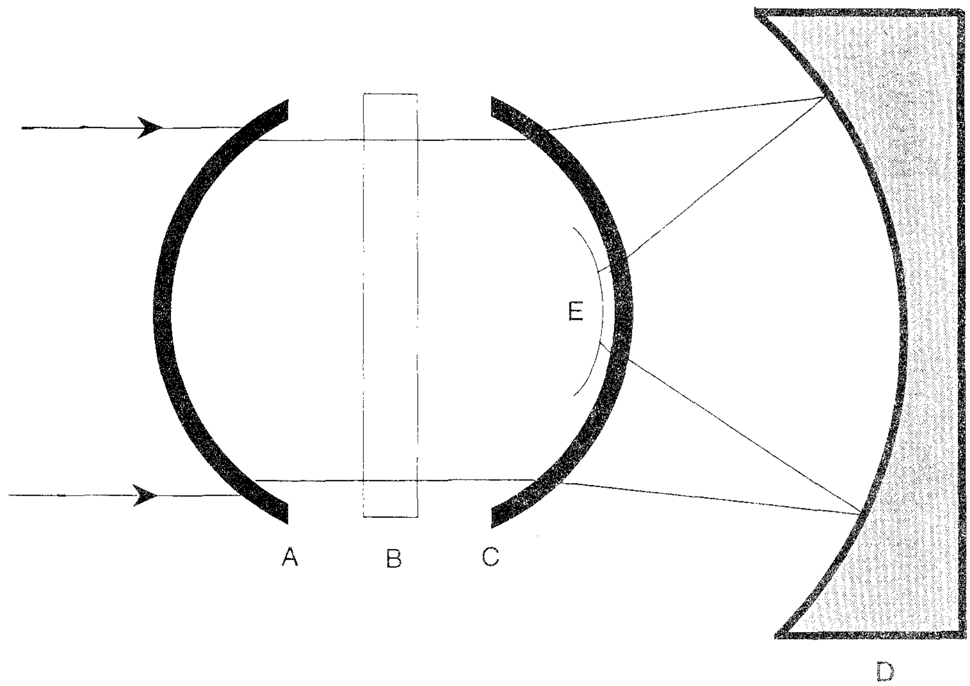



Figure 4 – The Super-Schmidt optical system.

The essentials of the optical system are given in Figure 4. Basically rays incident on the system first encounter the meniscus lens at $A$. are bent and pass through the correcting plate at $B$, then enter another meniscus lens at $C$ with the opposite radius of curvature as $A$ and are bent again. From here the light rays reflect off the spherical mirror at $D$, pass through $C$ again and come to a focus at $E$, where a photographic plate records the spectacle [7].

Thus in this Schmidt variation the spherical aberration is eliminated by two concentric meniscus shells and a correcting plate. The correcting plate serves to elimanate residual spherical aberration and correct for chromatic aberration introduced into the system. Chromatic aberration results in different wavelengths being focused differentially since the index of refraction for a lens is a somewhat dependent on wavelength. In this capacity the corrector becomes an aspheric hyperchromatizing element made from two correcting plates cemented together, one made of Crown glass the other of Flint glass [7]. This means that the combination of the curvature values of the cemented correcting plates and the ratio of the two glass' relative dispersion can be combined to permit differing wavelengths to be refracted equally through the system.

The meniscus lenses provide the system with its wide field of view. This is made apparent by considering that rays incident at an oblique angle to the front meniscus are bent toward the spherical mensicus' normal upon entering the shell and then away from the normal upon leaving. This process is repeated again at the inner meniscus before the mirror is encountered allowing rays from the peripheral regions to be captured. This wide-field capacity is critical for the Super-Schmidt's ability to record meteors.

Of course the ability to capture large areas of the sky is only half the story. If too little light reaches the plate at $E$ only the brightest meteors will be captured.

In general the light gathering power of an optical system (or its speed) in photographic applications is related to the light flux per unit area or irradiance ($I$) [4]. Clearly the large the aperature the more total light gathered since the mirror area increases, hence $I \propto D^2$. But the area over which light is spread on a plate is proportional to the focal length of the system [2] so $I \propto 1/F^2$. Hence $I \propto (D/F)^2$ or $I \propto f^2$ where $f$ is the relative aperture or speed of the system. Thus low $f$ values correspond to high irradiance systems or "light buckets". This is accomplished in the Super-Schmidt by using a large objective mirror and making the the radii of curvature of the shells large enough to ensure that the focal surface at $E$ in Figure 4 is close to the mirror.

## 6. Specific optical parameters of the Super-Schmidt

Each of the six Super-Schmidts ultimately built were given the same optical characteristics.

Each camera had a 58 cm diameter spherical objective, while each meniscus lens was ground from a 45 cm diameter spherical lens. The focal length of the system was 20 cm giving a theoretical unobstructed $f$-ratio of 0.35. In practice only 31 cm of the aperture was effective due to aperture stops, with this further reduced to 25 cm of clear aperture with the introduction of the photographic plate. Hence the operating system had an $f$-ratio of 0.80 corresponding to a field of view of 55° [7].

From (1) the longitudinal spherical aberration the 58 cm unobstructed primary would suffer without the correcting system amounts to more than 5 cm. In contrast, a mirror with the same final clear aperture of the Super-Schmidt of 25 cm would suffer a longitudinal spherical aberration value ($d$ in (1)) of 1 cm. The large value of $d$ suffered by the unobstructed primary underscores the need to stop down the aperture to 31 cm to make the correcting surfaces practical to build. Even with this compromise in aperture, however, the meniscus shells for the Super-Schmidts were the largest ever built up to 1950 and no optical company would undertake the job, the US bureau of standards having to ultimately manufacture the lenses.

The radical improvement in optical design attained by the Super-Schmidts is born out when their performance is compared to old cameras of the day designed for similar applications.

For example, the Meniscus Schmidt employing one meniscus shell and a plate corrector was typically built as fast as $f/1.3$ with fields 18° in diameter [2], while the largest classical Super-Schmidt cameras could reach $f/1.0$ and 20° field diameters [7]. The Super-Schmidt was more than 30% faster than either camera and was able to cover 6 times as much sky area.

In fact the speed of the Super-Schmidt was so great that normal plates can only be exposed to the sky for ten minutes. After this time, even at the darkest locations, the background light gathered is so intense as to fog the plate. This is in spite of the fact that the correcting hemispheres made of borosilicate glass and the ten air-glass surface interfaces in the Super-Schmidt absorb roughly 40% of the incoming light.

## 7. The cameras' impact on meteor astronomy

Of the six Super-Schmidts manufactured four were placed in the USA and one each placed in Meanook and Newbrook, Alberta. Each camera weighed over 2 tons, was mounted equatorially and could capture roughly three meteors per hour, an improvement of almost two orders of magnitude over previous systems [8].

The focal surface of the Super-Schmidt being a spherical surface creates several unusual requirements for other components of the optical system. For example, all plates must be similarly shaped and held firmly to the inner meniscus surface to clearly record incoming light. This task is accomplished through a vacuum holding system on the surface of the meniscus. Also, each plate being located inside the optical system requires that the entire camera be taken apart to change a plate, a problem solved by allowing the entire front of the optical system to be opened.

To determine the duration of each meteor a rotating shutter cuts each trail into temporally equal segments. Since the Super-Schmidt has a large aperture, external mounting of such a chopper would be dangerous so a small internal shutter directly in front of the spherical plate holder allows short bursts of the meteors' light to be recorded on the plate as the shutter's blades rotate [7].

The Super-Schmidt camera formed the core of the Harvard Photographic Meteor Program in the 1950s and directly led to several advances in the field of meteor astronomy [9]. The reduction of the photographed trails provided some of the first deceleration measures of meteors and led to the first accurate estimations of meteor densities. Stations in New Mexico provided two station coverage permitting orbital determination and accurate velocity measures. The information gathered in the early 1950s signaled the end of the interplanetary meteor debate as virtually all photographed meteors had velocities below the hyperbolic limit.

As a result of the high precision measures possible with the Super-Schmidt, the orbital catalogue compiled from the Super-Schmidts has been used in many searches for meteor streams. The Super-Schmidts provide data on particles too faint to photograph with wider angle conventional cameras, in addition to capturing brighter meteors due to their wide fields as compared to television techniques.

No astronomical photographic system with a wider field of view and faster optics has ever been constructed. The Super-Schmidt led to the development of the Baker-Nunn satellite tracking cameras widely used by the US air force in the 1960s. Only modern electro-optical devices exceed (in raw numbers) the Super-Schmidt's meteor capturing capacity.

## References

[1] A.G. Ingalls (ed.), "Advanced Amateur Telescope Making II", First edition, Scientific American Inc., 1972, pp. 393–410.

[2] J.B. Sidgwick, "Amateur Astronomer's Handbook", Fourth edition, Enslow Publishers, 1955, pp. 49–157.

[3] D.O. Hendrix, W.H. Christie, "Some Applications of the Schmidt Principle in Optical Design", *Scientific American* 161, 1939, pp. 118–123.

[4] E.B. Brown, "Modern Optics", Reinhold Publishing Corporation, 1965, pp. 269–283.

[5] M. Born, "Principles of Optics", Pergamon Press, 1959, pp. 243–249.

[6] E. Wolf, "Progress in Optics X", North-Holland, 1972, pp. 139–145.

[7] A.C.B. Lovell, "Meteor Astronomy", Oxford University Press, 1954, pp. 16–20.

[8] A.C. King, "The History of the Telescope", Charles Griffin and Co. Ltd., 1955, pp. 365–369.

[9] L.G. Jacchia, F.L. Whipple, "The Harvard Photographic Meteor Program", *Vistas in Astronomy* 2, 1956, pp. 982–994.

---

**An important note from Ina Rendtel:** Ina was informed that the German Mail in the former GDR **cannot yet handle international postal money orders.** Therefore, if you are used to pay this way, **send the international postal money order to Paul Roggemans** (address on inside back cover). We will let you know when this present inconvenience is over.

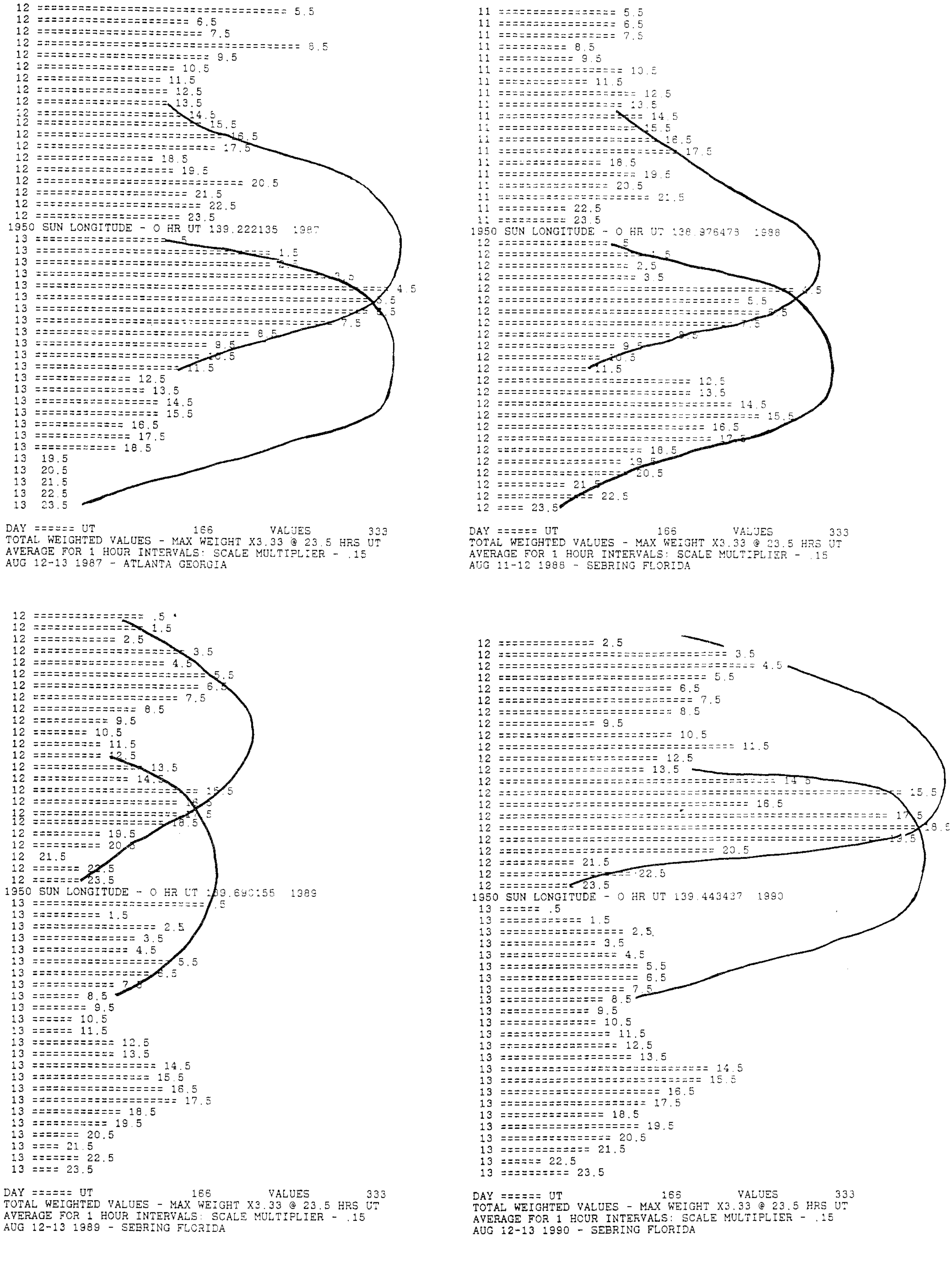



Figure 1 – Radio observations of the 1987 Perseids from Atlanta, Georgia (top left) and of the 1988 (top right), 1989 (bottom left) and 1990 (bottom right) Perseids from Sebring, Florida.

# Observational Results

## Total Radio Counts for the Perseids of 1987–1990

*T.R. Manley*

An overview is given of radio observations of the Perseids from Georgia and Florida between 1987 and 1990.

Total radio counts can be quite valuable for determining the solar longitude of the maximum of a meteor shower. A diurnal correction is necessary in order to get reliable results. I use a multiplication factor of 1 for $11^h30^m$ UT ($06^h30^m$ EST) and 3.33 for $23^h30^m$ UT ($18^h30^m$ EST).

The following four graphs show the total radio counts for the Perseids for 1987–1990. The 1987 data came from the reliable published data of William H. Black in issue 8 of the *Radio Observer*. The other observations are by the author. The diurnal correction, as described above, has been applied to these four computer printouts. The two highest peaks of the Perseids correspond to radio lows. The first approximation of a Fourier type interpolation is shown as a sinusoidal curve on all the graphs. In the 1988 and 1990 graphs there is evidence of a dip between the two peaks. This dip is not present in the 1987 and 1989 radio data. Hence, the graphs showing the total radio counts of the 1987–1990 Perseids indicate that the dip between the two peaks may come and go.

**Postscript from the Editor-in-Chief**

*Regarding this article, please also read Dr. Manley's letter in this issue's letter section, on* *pp. 30–31.*

## Fall 1990 Observations from the ALPO Meteor Team

*Robert Lunsford*

An overview is given of 1990 Fall observations carried out in the USA by the ALPO meteor team.

Observations during the fall months were made by 27 different members of the *ALPO* meteor team. We observed 2168 meteors during 140.07 hours on 29 nights. A majority of the activity was seen on the night of December 14 when seven observers combined for 1149 meteors, 1022 belonging to the Geminid shower. Both the Orionids and the Leonids were also well seen with 280 Orionids and 83 Leonids being logged.

Other interesting data includes the long stretch of activity for the Southern Taurids. Members of this stream were seen from September 28 to November 10. The northern branch was seen from October 2 to October 31. None was seen near the date of maximum which is November 13. One lucky observer caught an elusive member of the October Andromedids on the 6th of the month. He was lucky to be out and facing the right direction on a night with such an intense moonlight.

The $\delta$-Aurigids are not recognized by the *IMO* but this shower has shown activity for several observers during mid-October. Most observers are facing south toward Orion at this time of the year. It is then hard to pinpoint activity occurring in the northern sky opposite to the observer. Another source of activity occurs near the Geminid maximum. There is an active radiant producing bright blue meteors from Ursa Major. These meteors are very swift and greatly resemble the December Leonids which radiate some twenty degrees to the south. Once again this radiant occurs away from where most people face this time of the year. Therefore no precise radiant is known for these meteors. Perhaps the *IMO* can make these and other reported radiants a special project in the coming years.

Favorable conditions for the Ursids apparently were wiped out by overcast skies or observers apathy nationwide.

# The Fall 1990 Showers from Canada

*Bill Katz*

An overview is given of the author's observations in Canada of the 1990 Orionids, Leonids and Geminids.

As Rich Taibi has recently pointed out, clear skies and Fall nights seldom mix in Northeast North-America. Even rarer are clear, moonless Fall nights. In the past I have driven as much as 500 miles (round trip) in an attempt to escape the clouds, only to catch a handful of gems between the clouds. This year, I am happy to report that the meteors per liter of gas ratio was much better—we were able to catch the Orionids, Leonids, and Geminids in our visual observing spot just north of Toronto. Having caught the $\delta$-Aquarids, Perseids and Lyrids as well, 1990 was clearly a good year for showers in those parts.

October 1990 was my first night out since Augustus 13 after recovering from pneumonia. In 6.0 skies, I caught 71 meteors, including 45 Orionids in 3 hours, with Orionid rates of 17 meteors per hour in two of those hours. There were no very bright meteors. I noticed a number of meteors coming from Ursa Major.

November 17–18 brought another crystal clear night. My wife, Eva, and I did another 3 hours, catching over a hundred meteors between us. My best hour was the last ($06^h$–$07^h$ UT), when I caught 19 Leonids and 8 sporadics. I caught 14 Leonids the previous hour.

December 12–13 began with snow. It stopped by 8 p.m. local time, but it was still hazy, so I started the night in a friend's backyard at the north end of Toronto. As the haze lifted, the rates improved, from 19 to 49 per hour in total. After three hours, it was beautifully dark, so I jumped in the car and drove to the observatory, warming up and watching meteors along the way. (I caught 12 from the car on the highway). Under 6.0 skies, I continued 4 more hours, with rates between 61 and 101 per hour (maximum between $06^h$–$07^h$ UT). The best meteor was a −5 Geminid with an unusual blue color. Two other meteors left trains lasting 3 and 5 seconds. It was the first time in a year I managed to catch more than an hour of clear sky for the Geminids. The show buoyed my spirits going into a cold winter.

Table 1 – Magnitude distributions of 1990 Fall showers as observed from Canada.

| Shower | −5 | −2 | −1 | 0 | +1 | +2 | +3 | +4 | +5 | Tot |
|---|---|---|---|---|---|---|---|---|---|---|
| Orionids | | | | 2 | 2 | 5 | 8 | 7 | 19 | 43 |
| id. with trains | | | | 2 | 1 | 2 | 5 | 1 | | |
| Leonids | | | | | 1 | 4 | 6 | 8 | 10 | 29 |
| id. with trains | | | | | 1 | 4 | 1 | 1 | 1 | |
| Geminids | 1 | 4 | 2 | 23 | 28 | 44 | 29 | 38 | 52 | 221 |
| id. with trains | | | | 1 | 2 | 6 | 3 | | | |

# Radio observations of the 1991 Quadrantids in Japan

*Norihito Kawamura*

Japanese radio observations of the 1991 Quadrantids are presented.

I observe meteors with a forward scatter system on FM (76–90 MHz). My observing equipment consists of a 4 elements Yagi antenna directed to the zenith, a VHF-FM receiver and a pen-recorder. Every day I observe meteors for 24 hours, except when I check my equipment. Below you find one of my latest results (Quadrantids 1991).

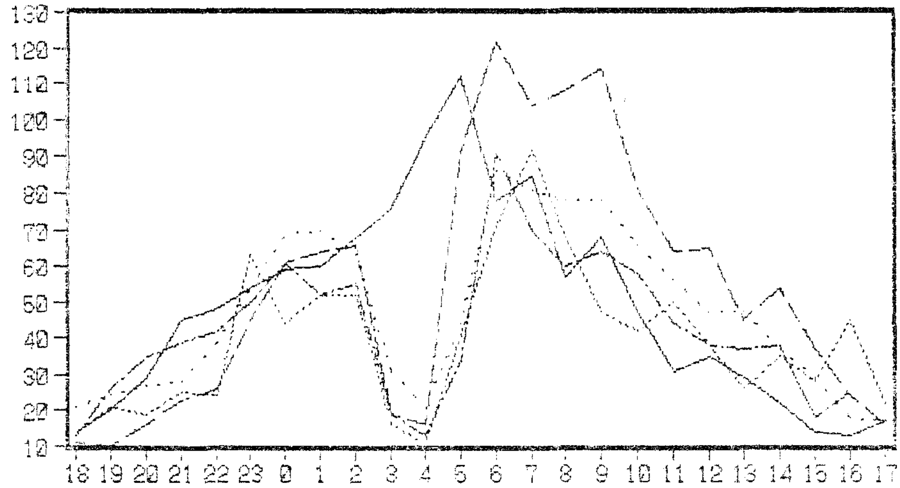



Figure 1 – 1991 Quadrantid counts from Japan at 80.8 MHz. Times are in JST. The minimum between $3^h$ and $4^h$ JST is due to a transmission stop.

# From the Meteor Library

*compiled by Paul Roggemans*

- *Jan Stohl and Vladimir Porubcan, "Structure of the Taurid Meteor Complex", Proc. Asteroids, Comets, Meteors III, C.-I. Lagerkvist, H. Rickman, B.A. Lindblad and M. Lindgren (eds.), Uppsala, 1990, p. 571.*

Orbital characteristics of the Taurid meteor complex are derived in its preperihelion activity based on all precise meteor orbits which are at the disposal from the IAU Meteor Data Center in Lund. Variations of the orbital elements and radiants of the complex are derived and used for verifying potential associations of minor showers with the complex.

- *John A. Russell, "Dissimilarities in Perseid meteoroids", Meteoritics 24, 1990, pp. 177–180.*

A shutter-chopped, direct photograph of a 1980 Perseid meteor is discussed in which no shutter breaks are apparent. Evidence is considered that it is indeed a Perseid and that the phenomenon is the result of an extraordinary fragmentation of the meteoroid. Tentative evidence is presented for the existence in 1980 of a second radiant from which the apparently unchopped meteor and a second meteor, also showing marked fragmentation, emanated. The fragmentation of these two meteors and the concentration of their radiant are consonant with the concept of their origin from recently released material from the nearby parent comet.

# The International Meteor Organization

## Council



## Commission Directors

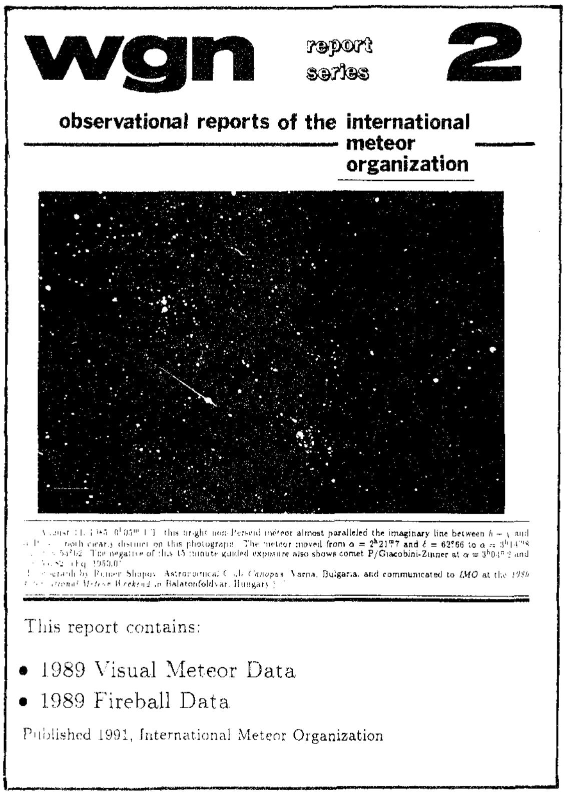


## WGN — The Journal of the International Meteor Organization and Observational Report Series


*Editor-in-chief:* Marc Gyssens, tel. 32 (3) 455 68 18, gyssens@ccu.uia.ac.be
*Editorial board:* Peter Brown, Masahiro Koseki, Jürgen Rendtel, Jeff Wood, and
Trond Erik Hillestad, Stengelsrud, N-3600 Kongsberg, *Norway*
*Typesetting:* Urania, the Public Observatory of Antwerp
*Printing:* André Gabriël


# Other author's addresses


Alain Chabaud, CORETA, Tour de l'Europe, 1, rue Georges Bizet, F-26000 Valence, *France*
Gotfred Møbjerg Kristensen, Vænget 13st.th, DK-4622 Havdrup, *Denmark*
Thomas R. Manley, 614 Killarney Drive, Sebring, *Florida 33872, USA*
Roberto Gorelli, Via di Val Favara Pal. B N 72, I-00168 Roma, *Italy*
Kawamura Norihito: please contact Jeroen Van Wassenhove
Swann David, 2023 Stein Way, Carrollton, *Texas 75007, USA*
José Trigo, Avda Antic Regne de Valencia 35, 9 aptda, E-46005 Valencia, *Spain*
Vints Mark, Acacialaan 35, B-3940 Beringen, *Belgium*
Lunsford Robert, Vance Street 161, Chula Vista, *California 92010, USA*
Katz Bill: please contact Marc Gyssens



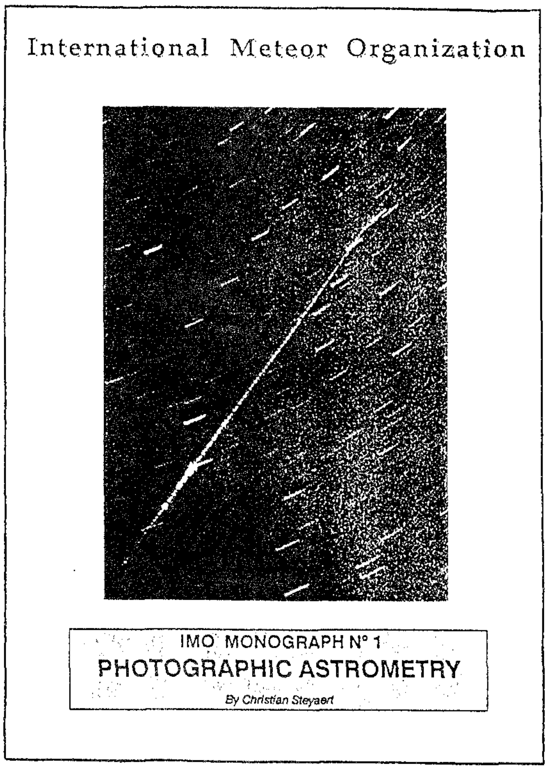

# Observational Report Series vol. 2

*edited by Marc Gyssens*

Volume 2 contains 187 pages with all *IMO* visual and fireball observations of 1989! In total, you will find 88 378 visual meteors seen during 5258 hours in 256 calendar dates by 410 observers from 21 different countries, as well as 341 entries on fireballs!

An invaluable work for meteor workers wishing to carry out further analyses or for meteor observers wanting to know how their contributions fit in on a global scale.

Despite the increased number of pages compared to volume 1, the price for the second issue of *WGN*'s Report Series has *not* been raised: 15 DEM post paid (surface mail delivery).




# Photographic Astrometry

*by Christian Steyaert*

This first volume in a new *IMO Monograph Series* deals with theory and practice of photographic astrometry.

Together with the companion diskette, it allows the photographer to measure himself his prints and do the necessary calculations. The diskette also contains the necessary software to supply the information to the *IMO* in the *PMDB* format!

The monograph costs 10 DEM post paid, plus 3 DEM for the companion diskette in (please specify) $5\frac{1}{4}''$ or $3\frac{1}{2}''$ (surface mail delivery).