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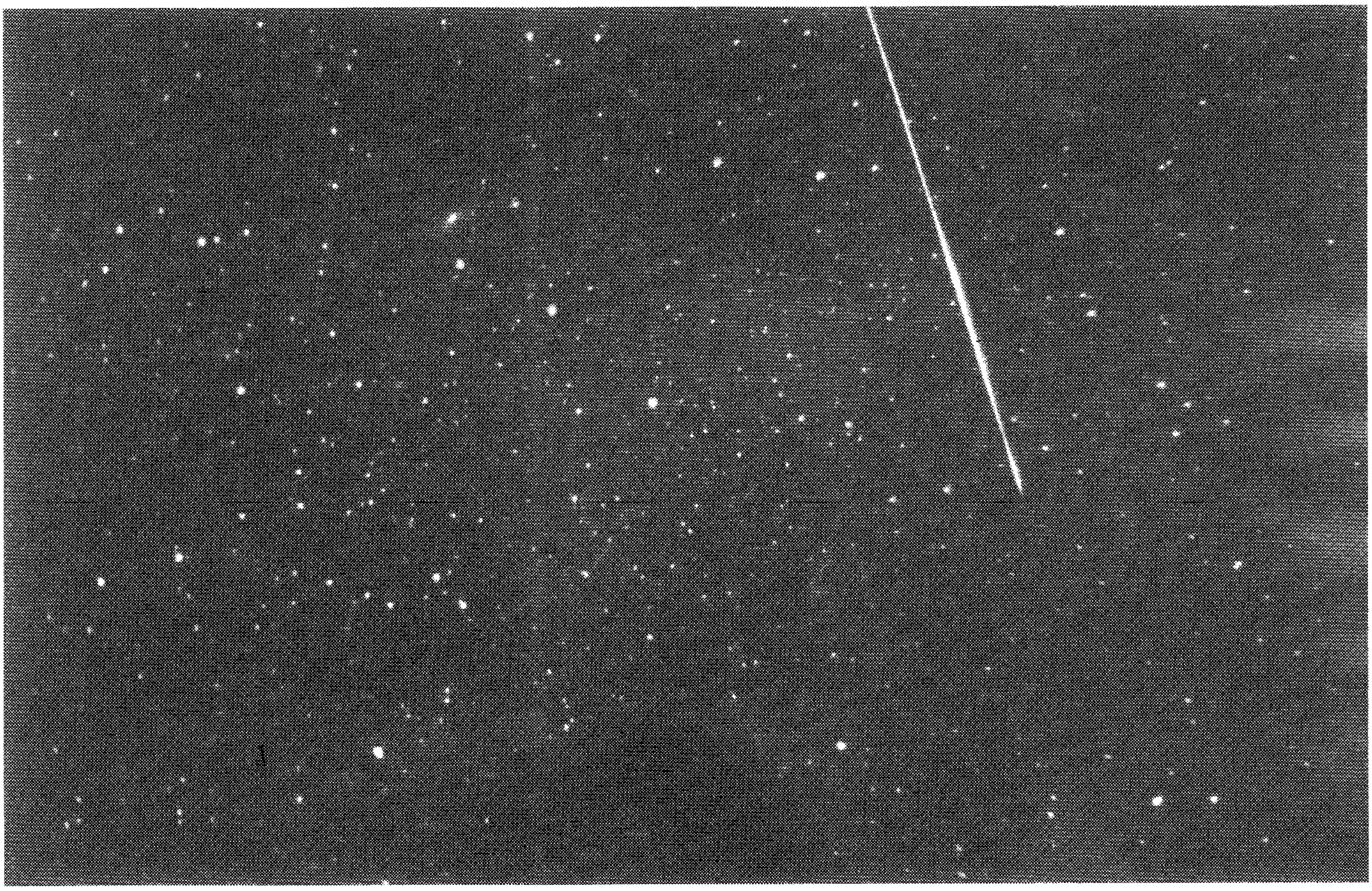

A magnitude −2.5 meteor in Andromeda, photographed by Rumen Shopov, Astroclub *Canopus*, at the village of Avren, about 30 km SW of Varna. The picture was taken on September 10, 1991, and was exposed from 21^h40^m to 22^h40^m UT. The Andromeda Nebula (M 31) is clearly visible.

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WGN, volume 19, nr 6, December 1991, pp. 219–244

Contents

Useful Information

The February Issue *(WGN 20:1)*

The *February issue* is expected to be mailed during the first week of February 1992. Therefore, contributions are due *January 7*. They should be sent to *Marc Gyssens* or to any member of the editorial board (addresses: inside of back cover).

WGN Subscription/IMO Membership 1992

The subscription rate for volume 20 (1992) is 25 DEM for six issues. Additional gifts are of course welcome. It is anticipated that volume 20 will contain over 240 pages. More concrete subscription information can be found on pp. 219 of this issue.

Administrative Correspondence

Ordering *IMO* publications is done in the same way as paying subscription/membership fees. Complaints about not receiving *WGN* or changes of address should be sent to Paul Roggemans. All addresses can be found on the inside of the back cover.

From the Editor-in-Chief

Marc Gyssens

Technically it would have been possible to produce a third thick issue in a row. However, we must keep an eye on the budget as well! With your help, the February issue will be a thick issue again, this is, if you renew in time! Last year, so many people paid late that with the final number of subscribers still being too uncertain it would have been too big a financial risk to print a thick issue. Please, do not let this happen again! For your convenience, we repeated the information about payment below.

At the end of the year, people often look back to what has been accomplished. The wide recognition the IMO *has already received from professionals and the discovery of a new Perseid peak three years before it produced the August outburst are successes all members involved should be duly proud of. But proud should never, never, lead to self-content. A lot of work still needs to be done. It is my wish for 1992 that more and more people will get aware of that fact and will contribute to achieve the* IMO*'s goals. Have a smooth transition from Old to New!*

1992 Membership and Subscription Renewal (Reminder)

Ina Rendtel and Marc Gyssens

If you have not yet renewed, you should do so promptly. For 1992, *membership/subscription dues* are set to **25 DEM**. People outside Europe wishing **airmail delivery** pay **40 DEM**. Preferably, payments should be made in in German marks (DEM) to the **postal (giro) account** of Ina Rendtel. Details figure on the inside of the back cover. If you do not have access to a postal account yourself, we advise you to inquire at your local post office as to how to make the transfer. However, you could also consider sending the required amount to Ina **cash**, in bank notes. Although involving some risk and not always being allowed by postal regulations, this is by far the easiest way to pay! To reduce the risk you take by paying cash, make sure that the bank notes are not visible through the envelope! In any case, **do not send international postal money orders!**

People who can only pay **from a bank account** should make an **international bank draft** payable in USD to Peter Brown (address on inside of back cover). In this case you pay 18 USD (without airmail delivery) or 28 USD (including overseas airmail delivery for destinations outside Europe). Both amounts contain 2 USD for banking costs. Please, **do not send checks to Ina Rendtel!** For some nationalities, there exist special arrangements. Belgian members/subscribers can pay 500 BEF through Paul Roggemans, British readers can pay 9 GBP through Alastair McBeath, and Japanese subscribers can pay 2100 JPY (without airmail delivery) or 3400 JPY (including airmail delivery) through Masahiro Koseki. All addresses appear on the inside of the back cover.

As mentioned earlier, we ask you to pay a little extra to support your journal, if you can. In this way, you help us to keep running *WGN* on a tight budget, which is especially important for observers in those countries where payments in freely convertible currencies still constitutes a problem! At the occasion of your renewal, you can also order some of the other *IMO* publications mentioned on the back cover.

Letters to WGN

compiled by Marc Gyssens

Controversial observations of the 1991 Perseids

In the previous issue, on p. 183, we discussed the 1991 Perseid observations of the Belgian Vereniging voor Sterrenkunde, *mentioned in IAU Circular 5330. While almost all European observers saw normal, at best slightly increased, activity, Aneca et al. reported unusually high rates, which we attributed to the limited overall experience of the group. We received the following reply from Peter Aneca in which he tries to clear the confusion caused by his and his colleagues' observations.*

IAU Circular 5330, published by Marsden on August 28, informed the world for the first time about a higher than usual Perseid activity. We now know that the Japanese saw a remarkably high activity indeed and that European observers did not see any outburst at all [1,2]. A slightly higher activity however, remains possible, but only a detailed analysis of all activity reports can prove this. So we will have to wait until the *VMDB* operators have finished their time-demanding job. Here we only want to publish the exact observations we have made in order to correct the errors appearing in [3], as a result of sending out first impressions rather than real observations, as we asked. I do not think it is necessary to give the data for other nights, or other observers being active in the same region at the same time: some preliminary results can be found in [4].

Observing in the Haute Provence was only possible from 0^h38^m UT onwards due to the bad weather in the evening and the first half of the night. This resulted in a very short observing period and few individual data to make comparisons. Some of us (ANEPE and DE BA) had the idea they were seeing much meteors, perhaps too much, of which a lot were faint (magnitude +4, +4.5). DEWJE and VANJE were seeing fewer meteors, perhaps missing those faint ones. This was not only the impression for the maximum night, but also for the three other nights we were observing (August 10-11, 11-12 and 13-14). Table 1 shows the results of the meteor countings for the maximum night.

Table 1 – Rate data of the VVS Perseid observations on August 12-13, 1991.

Obs	Time (UT)	T_{eff}	F	Lm	Per	ZHR	Spor	HR
ANEPE	$1^h.142$	1.00	1.00	6.3	114	180 ± 17	34	42.4 ± 7.3
DEWJE	$1^h.150$	0.82	1.11	6.2	33	78 ± 14	4	7.5 ± 3.8
DE BA	$1^h.200$	1.10	1.00	6.5	125	148 ± 13	19	17.3 ± 4.0
VANJE	$1^h.592$	1.91	1.00	6.2	126	110 ± 10	28	20.4 ± 3.9
DEWJE	$1^h.992$	0.72	1.11	6.2	38	94 ± 15	2	4.3 ± 3.0
ANEPE	$2^h.092$	0.87	1.00	6.3	77	128 ± 15	18	25.8 ± 6.1
DE BA	$2^h.350$	1.13	1.00	6.5	129	132 ± 12	14	12.4 ± 3.3
DEWJE	$2^h.700$	0.58	1.11	5.7	31	144 ± 26	6	27.7 ± 11.3

The values of 280 and 320 in [3] are not wrong: they are an estimated total number of meteors, including other showers too. Of course it is not very useful to calculate the ZHR of the total number of meteors. For the (Z)HR calculations, I used a population index equal to 2.6 for the Perseids [5] and 3.0 for the sporadics. The correction factor for the height of the radiant was calculated in the middle of the observation interval and not as was suggested in [6], merely to keep it simple. The $F = 1.11$ for DEWJE was caused by a tree: the observing directions were more or less restrained by the fact that we were photographing too. No dead time is reported because we could handle the aparatus while looking at the sky and only for the meteors brighter than magnitude +2 the time was registered, so almost no time was lost while observing.

Two things are important I believe : the rather high values, especially those for ANEPE and DE BA, the third observing interval of DEWJE being less reliable due to a rather low limiting magnitude and the wide spread on the ZHRs as well as on the HRs. To me, this can be caused by fatigue, lowering the attention, and also the perception of the observer, certainly in ANEPE's case. Looking for reasons for the high values, I found two possibilities: a rather high perception in general, as can be estimated with the perception coefficient k [7], or a rather high perception of faint meteors. This last one could be even more important if there was an excess of faint meteors, as is suggested in [1]. Therefore it is useful to have a look at the magnitude distributions for the four observers in that night. The results are given in Table 2.

Table 2 – Magnitude distributions for the VVS Perseid observations on August 12-13, 1991.

Obs	−3	−2	−1	0	+1	+2	+3	+4	+5	+6	Lm	$\overline{m}$	Tot
ANEPE		3	2	7	19.5	21	47.5	61	29	1	6.3	3.09	191
DE BA	1	2	2	9	27	45.5	68.5	66.5	26	6.5	6.5	2.96	254
DEWJE				7.5	33.5	22.5	22.5	16				2.06	102
VANJE	1	1	2.5	6.5	26	31	30	24	4		6.2	2.27	126

The population index has been calculated with the method described in [8] and [7], using the perception coefficients published in [9]. As has been done in earlier analyses, e.g., [10], the meteors fainter dan +4 were omitted, as has been done with magnitude classes with less than three meteors. The results are given in Table 3. The correlation coefficient is good for all the observers.

Table 3 – Population index for each observer.

Obs	Met.	Class.	r	Corr. Coeff.	Obs	Met.	Class.	r	Corr. Coeff.
ANEPE	156	5	3.08 ± 0.32	0.99	DEWJE	102	5	2.44 ± 0.15	0.99
DE BA	217	5	2.95 ± 0.26	0.99	VANJE	118	5	2.72 ± 0.22	0.99

Only VANJE's observations are such that 2.6, the standard population index, falls within the 68% confidence limits. While this may be surprising, many reasons can be found, e.g., a real change in the population index, wrong magnitude estimations, and a difference between the perception of the observer and the values published in [9]. It is not possible to evaluate this here further. The main remaining question is: "Are the high ZHR values due to a higher than normal perception or are they even too low because the population index used for the ZHR calculation was underestimated?". I shall not try to find an answer at this stage.

In order to examine the possible effect of "general" perception factors k (defined by $ZHR_{st} = k \times ZHR_{obs}$) on the values given in Table 1, the results in earlier Perseid analyses of 1988 [11] and 1989 [10] can be used as the perception factors for 1991 are not known yet. The perception factors k were computed using $k = r^(- \Delta Lm)$ with $r = 2.33 \pm 0.07$, the value calculated for August 13 and are given in Table 4.

Table 4 – Perception coefficients calculated for earlier Perseid observations and the corrected ZHRs.

Obs	$k(88)$	$k(89)$	ZHR_{obs}	$ZHR_{k(88)}$	$ZHR_{k(89)}$	Obs	$k(88)$	$k(89)$	ZHR_{obs}	$ZHR_{k(88)}$	$ZHR_{k(89)}$
ANEPE	0.74	0.82	181	134	148	DEWJE	0.68	–	78	53	–
			128	95	105				94	64	–
DE BA	1.00	1.17	148	148	173				144	98	–
			132	132	154	VANJE	–	–	110	–	–

This suggests that the ZHR results of ANEPE were overestimated and should be reduced to a lower and more "usual" value. DE BA's observations get even worse due to overcorrecting and DEWJE shows the opposite effect, making his observations worse too. For VANJE there were no perception coefficients available. As to me the only conclusion here can be that k can vary from shower to shower and from year to year, due to the changing observers, shower characteristics and observer and that it is not useful to use earlier ks. The detailed analysis of the 1991 Perseid display will perhaps reveal the real reason for these values. Meanwhile, it is interesting to note that it is impossible to jump to conclusions based on only a few observations and that the reduction of visual meteor data should be more standardized and elaborated. Finally, we hope that everybody now knows the real observed rates and that peace might return.

[1] Roggemans P., Gyssens M., Rendtel J., "One-Hour Outburst of the 1991 Perseids Surprises Japanese Observers", *WGN* 19:5, October 1991, pp. 181–184.

[2] Betlem H., "Perseïden 1991", *Radiant* 13:5, October 1991, p. 121.

[3] Marsden B.G., *IAU Circular 5330.*

[4] Aneca P., "Een losse meteorenbabbel", *Werkgroepeninfo* 4, September 1991, pp. 123–128.

[5] Koschack R., "Hints for Visual Observations", IMO_INFO 5, 1991.

[6] Arlt R., "The Zenith Correction Factor", *WGN* 18:3, June 1990, pp. 73–74.

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

[8] Steyaert C., "Populatie-index bepaling", Technische Nota 5, VVS, Belgium, 1981.

[9] Kresakova M., "The Magnitude Distribution of Meteors in Meteor Streams", *Contr. Skalnate Pleso Obs.* 3, 1966, pp. 75–109.

[10] Roggemans P., Koschack R., "The Perseids 1989", *WGN* 19:3, June 1991, pp. 87–98.

[11] Roggemans P., "The Perseid Meteor Stream and Observers' Perception Coefficients", *WGN* 17:5, October 1989, pp. 189–193.

Peter Aneca, November 5, 1991

Comment by the editor: *First, the values of 280 and 320 in [3] were indeed* wrong, *as they were meaningless. Turning to the observations, even a short look at the tables confirms what has been said in the last issue. The widely varying values, both in the rate data and the magnitude data, clearly point towards a lack of experience among the observers. Groups of experienced observers, such as the one that observed in Bulgaria do* not *find such a spread on their data. Finally, the last lines of Peter Aneca's expose seem to suggest that there might be something wrong with the method. We think on the contrary that the incoherencies found above rather tell something about the observations! Anyway, as Peter Aneca rightly states, all has been said now that can be said now on this issue. I think it is therefore appropriate to close the discussion at this point and await the global analysis of the 1991 Perseids.*

Proposal for long-basis Geminid observations

José Trigo asked us to communicate to our observers a proposal for long-basis Geminid observations, which we publish in abridged form due to space limitations. Interested persons should contact Trigo. However, we do want to point attention to the fact that although such observations can be potentially interesting, IMO *has a crying need for "ordinary" observations as it is still hardly possible to analyze* basic *stream characteristics, even for major showers!*

During 1990, several members of the *Spanish Meteor Society* studied the appearance of meteor groups in the Geminid maximum. Although such phenomenon does not occur frequently in the case of Geminids according to [1], it should be studied again in 1991, using long-basis observations as explained in [2]. An unusual fragmentation of particles due to solar radiation could explain grouping. Solar activity was indeed very high in 1990. However, we need confirmation in 1991!

In Spain, several stations are preparing in Barcelona, Castelló, València and Granada. The distance between some of the stations is 500 to 1000 km, but we still need the participation of other groups, e.g., in Southern France. The campaign runs from December 13 to 15, which is a weekend. We only use meteor counts in five-minute intervals starting from an exact hour: e.g., 22^h00^m, 22^h05^m, 22^h10^m, etc. The distance between stations must be about 1000 km for the detection of large groups. We also need the time of appearance of dense minor groups and the numbers of meteors seen.

[1] Grishchenyuk A.I., "On Groups of Bodies in the Perseid and Geminid Meteor Streams", *WGN* 17:6, December 1989, pp. 257–259.

[2] Grishchenyuk A.I., "Large-Scale Structure of the Perseid Meteor Shower from Long-Basis Observations", *WGN* 19:4, August 1991, pp. 142–147.

José Trigo, November 1991

Observers' Notes: January–February 1992

Jeff Wood, Ralf Koschack and Dirk Artoos

1. Introduction

Despite often low rates and the winter in the northern hemisphere, there are plenty of things to be seen by the diligent observer in this time of the year. See also the *IMO 1992 Meteor Shower Calendar.*

Table 1 – Some of the meteor showers to be seen in January and February 1992.

Shower	Activity	Max	Radiant			Drift		V_∞	r	ZHR
			α	δ	Diam.	$\Delta\alpha$	$\Delta\delta$			
Puppid/Velids	Sep 28–Jan 26	several	120°	−45°	20°/5°			40	2.9	12
Coma Berenicids	Dec 12–Jan 23	Dec 19	175°	+25°	5°	+0°.8	−0°.2	65	3.0	5
Quadrantids	Jan 01–Jan 05	Jan 04	230°	+49°	5°	+0°.8	−0°.2	41	2.1	110
δ-Cancrids	Jan 05–Jan 24	Jan 17	130°	+20°	10°/5°	+0°.9	−0°.1	28	3.0	5
α-Crucids	Jan 06–Jan 28	Jan 20	192°	−63°	10°/5°	+1°.1	−0°.2	50	2.9	5
α-Carinids	Jan 24–Feb 09	Feb 01	95°	−54°	5°			25	2.5	
Virginids	Feb 01–May 30	several	195°	−04°	15°/10°			30	3.0	5
θ-Centaurids	Jan 23–Mar 12	Feb 02	210°	−40°	6°	+1°.1	−0°.2	60	2.6	
α-Centaurids	Jan 28–Feb 21	Feb 08	210°	−59°	4°	+1°.2	−0°.3	56	2.0	25+
o-Centaurids	Jan 31–Feb 19	Feb 12	177°	−56°	6°	+1°.0	−0°.3	51	2.8	
δ-Leonids	Feb 05–Mar 19	Feb 16	159°	+19°	8°	+0°.9	−0°.3	23	3.0	3
γ-Normids	Feb 25–Mar 22	Mar 14	249°	−51°	5°	+1°.1	+0°.1	56	2.4	8

Table 2 – Moonlight and observing conditions in January–February 1992.

Date	k	Date	k
Friday December 27	0.62−	Friday January 31	0.12−
Friday January 03	0.03−	Friday February 07	0.09+
Friday January 10	0.21+	Friday February 14	0.75+
Friday January 17	0.88+	Friday February 21	0.90−
Friday January 24	0.77−	Friday February 28	0.25−

New Moon:	January 4, February 3, March 4
First Quarter:	December 14, January 13, February 11
Full Moon:	December 21, January 19, February 18
Last Quarter:	December 28, January 26, February 25

2. Quadrantids

Named after the now defunct constellation Quadrans Muralis, the Quadrantids are the first major shower to occur each year. They are active from January 1 to 5 with a maximum ZHR of around 100 occurring on the morning of January 4 at 6^h UT. The Quadrantids are fastish meteors ($V_\infty = 41$ km/s) which radiate from $\alpha = 230°$ and $\delta = +49°$. Their radiant diameter is 5°. They are best observed from the northern hemisphere in the last few hours before sunrise. With a New Moon on January 4, they are very good viewing in 1992.

3. δ-Cancrids

Very little is known about this stream which can be seen from either hemisphere during mid January. The δ-Cancrids therefore need urgent attention from meteor observers and 1992 is a good time to start. The δ-Cancrids are best seen during the early to middle part of the night. Meteor workers should monitor the period January 4 to 14 since after this time there will be increasing interference from the Moon. As rates are low, observers should ensure they center their field of view no further away than 30° from the radiant and also plot all possible δ-Cancrids seen. As this ecliptical shower has a complex radiant structure. Therefore, the radiant diameters to be taken into account for shower association of meteors of different radiant distances differ a bit from those of sharply defined radiants (see the article on pp. 225–241 of this issue). Please use the values in Table 7 on p. 239.

Table 3 – Radiant drift of the δ-Cancrids. x, y coordinates refer to chart 8 of the *Atlas Brno 2000.0*.

Date	α	δ	x	y	Date	α	δ	x	y
Jan 05	116	+22	288	236	Jan 20	130	+19	237	216
Jan 10	121	+21	269	228	Jan 25	134	+18	223	210
Jan 15	125	+20	252	222					

4. α-Crucids

The α-Crucids are active from January 6 through to 28. With a radiant occurring near the Southern Cross this southern hemisphere stream has a complex activity period with several submaxima occurring on or around January 12, 15, 19 and 24. The January 19 peak seems to be the greatest when the ZHR can reach upward of 5. α-Crucid meteors are fastish and often colored. Since they have relatively low rates, all possible α-Crucids should be plotted. Observers should center their fields around $\alpha = 160°$ and $\delta = -55°$ so that both the tail of the Puppid/Velids and the α-Crucids may be monitored simultaneously. As there is a Full Moon on January 19, meteor workers should concentrate on the period January 5–15 in 1992.

5. α-Carinids

The α-Carinids are a virtually unknown southern hemisphere stream. They are active from January 24 to February 9 reaching a sharp maximum on February 1 of between 5 and 10 meteors per hour. Observations to date seem to indicate that this stream is quite variable and more research is urgently needed. 1992 promises to be a good time to view the α-Carinids they being best seen in the evening.

6. Virginids

As there are a large number of low activity radiants close together, it is very difficult to delineate what branches of the Virginids are active at which time and also to classify each individual meteor seen into its appropriate stream. Consequently, observations over the years have shown a whole myriad of Virginid showers, some real, some fictitious. Also reported rates have varied from nil to over 10 meteors per hour! With this in mind then, the *IMO* has for the time being to incorporate all of the Virginids seen into the one "shower". The "Virginids" are active from February 1 to May 30. They have a V_∞ of 30 km/s and are reknown as fireball producers, though their population index r of 3.0 indicates there are many fainter members as well.

The *IMO* would appreciate your efforts to monitor this shower in 1992. Intending observers should locate their center of field of view no more than 40° away from the radiant and should plot all meteors seen. Since the Virginids have a velocity typical of the sporadic background and also come from a large radiant area, careful attention to path length and angular velocity should be given before classifying a meteor as Virginid. As for the δ-Cancrids, please use Table 7 on p. 239 for determining the radiant diameter.

Table 4 – Radiant drift of the Virginids. x, y coordinates refer to charts 8 and 5 respectively of the the *Atlas Brno 2000.0*.

Date	α	δ	x_8	y_8	x_5	y_5	Date	α	δ	x_8	y_8	x_5	y_5
Feb 03	159	+15	149	199			Apr 04	200	−06			169	144
Feb 13	167	+09	125	181			Apr 14	204	−08			157	138
Feb 23	174	+05	103	169	256	179	Apr 24	208	−09			146	135
Mar 05	182	+01	74	157	226	164	May 04	211	−11			137	129
Mar 15	189	−02	45	146	202	155	May 14	214	−12			128	126
Mar 25	195	−04	15	138	183	150	May 24	217	−13			120	123

7. θ-Centaurids

This shower has a complex radiant structure and is active from January 23 to March 12. With the complex radiant structure also comes a complex activity period with several submaxima. The main ones seem to occur on or around February 3, 21 and 26 with a peak ZHR of between 5 and 10 meteors per hour. θ-Centaurid meteors are fast and often leave a train. They are also noted for producing fireballs of a lemon yellow or greenish hue. They are best seen in the morning hours from the southern hemisphere. Observers should center their field of view around $\alpha = 200°$ and $\delta = -50°$ to aid in separating the θ-Centaurids from the other two Centaurid showers that occur at a similar time in mid February. In late February and mid March, the observer's field should be centered around $\alpha = 200°$ and $\delta = -20°$ so that the θ-Centaurids and the Virginids can both be monitored. All possible θ-Centaurids should be plotted.

8. α-Centaurids

The α-Centaurids produce a good display of meteors each year for southern hemisphere observers. They are active from January 28 through to February 21 with a sharp maximum on February 8. For most of their period of activity ZHRs range between 1 and 3, but at maximum ZHRs generally rise to between 5 and 10. Every 4 to 6 years, the maximum activity seems to be greatly enhanced and on two notable occasions in 1974 and 1980, rates exceeded 25 meteors per hour. Always, this enhancement has been short lived lasting no more than 2–3 hours. The α-Centaurids are fast meteors which are noted for their brightly colored fireballs. Many α-Centaurids also leave a train. In 1992 there is virtually no interference from the Moon except towards the very end of the shower's activity period.

This year, southern hemisphere observers must make this shower priority viewing. If ZHRs are less than 10, then all possible α-Centaurids must be plotted. If ZHRs exceed 10 then they may be recorded in the manner of the major showers. To avoid confusion with the other Centaurid showers, observers should watch for the α-Centaurids with a field center at $\alpha = 200°$ and $\delta = -50°$.

9. o-Centaurids

The o-Centaurids are a minor shower that occurs during a similar time to the other two February Centaurid showers. The o-Centaurids are visible only from the southern hemisphere and can be seen in dark skies after midnight for much of its period of activity. Only after February 15 is there much interference from the rapidly waning Moon. The o-Centaurids are fast meteors. Observers should plot all possible o-Centaurids seen. To aid in identification, their center of field of view should be located at $\alpha = 200°$ and $\delta = -50°$.

10. δ-Leonids

The δ-Leonids are thought to possibly be related to the minor planet 1987 SY and so a top priority of the *IMO* is to investigate the activity of this shower to see if this is indeed the case. Despite some interference from the Moon, much of their activity period can be observed in dark skies. δ-Leonid meteors are of average brightness, slow in speed ($V_\infty = 23$ km/s) with very few leaving a train. Since there are numerous sporadic meteors as well as the Virginid meteor shower occurring in the vicinity of the δ-Leonid radiant area, great care needs to be taken in identifying them. Observers should center their field of view around $\alpha = 180°$ and $\delta = +20°$ or $\alpha = 160°$ and $\delta = 0°$. As the δ-Leonids are few in number, all should be plotted. Meteors coming from the radiant area should only be classified as δ-Leonids if their path lengths and their angular velocities are appropriate.

Table 5 – Radiant drift of the δ-Cancrids. x, y coordinates refer to chart 8 of the the *Atlas Brno 2000.0*.

Date	α	δ	x	y	Date	α	δ	x	y
Feb 05	141	+25	202	234	Feb 28	161	+18	144	210
Feb 10	145	+24	189	228	Mar 05	165	+17	131	205
Feb 15	150	+22	176	223	Mar 10	169	+15	119	201
Feb 20	154	+21	164	218	Mar 15	173	+13	105	196
Feb 25	158	+19	151	213	Mar 20	177	+12	92	192

11. Call for radio observations

For the third time in a row, Dirk Artoos noticed enhanced radio activity on January 22-23. This can hardly be a coincidence any more. The highest peak occurred during early morning hours ($\lambda_\odot = 301.^\circ7$, eq. 2000.0). Therefore Dirk Artoos would like to suggest radio observers to listen around 10^h UT between January 19 and 25, 1992. When you observe several times a day, you could also listen around 4^h UT and 17^h UT. We are looking forward to your findings!

Analysis of Visual Plotting Accuracy and Sporadic Pollution and Consequences for Shower Association

Ralf Koschack

An analysis of the plotting accuracy and of the sporadic pollution for visual meteor observations is given. It is found that both factors limit the observability of minor showers to ZHR ≥ 3. Based on the results of the analysis, rules are developed for minor shower observations.

1. Introduction

Analyzing his observations each active observer will sometimes ask the question: "Shower meteor or sporadic?" In such cases the backward prolongation of the concerned meteor often passes the radiant at an already considerable distance while the other characteristics (angular velocity and path length) agree quite well with shower membership. The decision is then more or less subjective. This work aims at establishing objective rules for shower association.

Imagine first the situation that there are only meteors of one shower and no sporadics. Obviously, no shower association is necessary in this case. The situation changes as soon as there are sporadic meteors. The more sporadics appear, i.e., the smaller the ratio *shower meteors/sporadics* becomes, the more problematic the situation gets. Then it is necessary to distinguish shower members from sporadic meteors. This is done by applying criteria for shower membership the most important of which is the direction of the meteor, followed by its angular velocity and the length of the path.

As visual observations suffer from certain inaccuracies, the question arises how strict the criteria have to be applied, or, in other words, which errors with respect to the expected values are to be permitted.

It is obvious that the answer must depend on the ratio *shower meteors/sporadics*. Observations around the maximum of a major shower can be approximated by the first situation, i.e., the criteria can be used loosely: a resulting sporadic pollution in the order of 2 to 4 meteors per hour does not significantly affect a ZHR more than ten times higher. For this reason it is possible to carry out shower association (or better in this case: filtering out obvious sporadics) directly under the sky without plotting the path. For such observations the present work is only of academical importance.

For minor shower observations on the contrary, where the sporadic pollution can easily reach the order of magnitude of the shower rate itself, it is of vital importance to have a well-founded theory.

As mentioned, the direction of the path is the main criterion for shower membership. Thus we have to consider it first and then proceed to the other criteria in a suitable way.

Dealing with errors on the direction of the path comes down to defining a radiant diameter for shower association, i.e., a maximum distance by which the backwards prolongation is allowed to pass the radiant. If we choose the diameter too small, the sporadic pollution will be very low but a considerable fraction of shower meteors will be classified as sporadics due to plotting errors. If, on the other hand, we choose the diameter too large we will catch almost all shower meteors but also a considerable number of sporadics.

Hence, *we have to choose the radiant diameter and the error margins for the other criteria in such a way that the loss of shower members due to observational errors is compensated by the sporadic pollution.*

For this purpose, it is necessary to know both plotting accuracy and accuracy of the angular velocity estimate, with the resulting losses in shower members, as well as the sporadic pollution.

2. Sporadic pollution

Sporadic pollution obviously depends on the sporadic HR. Furthermore the percentage of sporadic meteors meeting a radiant area is directly proportional to the radiant diameter. Based on the assumption of a fully random distribution of sporadic meteors, this percentage was determined theoretically in [1]. Since the randomness assumption is not entirely valid and the other criteria (angular velocity, path length) were not taken into account in that work, it seemed necessary to determine the sporadic pollution by an experiment.

For this purpose, observations of three observers of the *Arbeitskreis Meteore (AKM)* were analyzed, obtained outside the activity periods of the Quadrantids and the Lyrids between January and June. In this period, there is no significant shower activity. Pairs of *fictive* radiants of 10° in diameter were selected, one at about 30° and one at about 60° elevation. They were chosen far away from the known ecliptical showers and less than 40° away from the center of the field of view. For each individual observation, a new pair was determined in order to avoid systematic errors. With respect to these radiants shower association was carried out:

a) considering the direction of the path only;
b) considering all criteria assuming $V_\infty = 30$ km/s; and
b) considering all criteria assuming $V_\infty = 60$ km/s.

The results of items *b* and *c* are expected to depend on the error margins allowed for the angular velocity and path length criteria. These error limits applied in this experiment had to be the same as for regular shower observations. The problem is similar to that for the radiant diameter described in the previous section: the sporadic pollution will be less if the criteria are applied strictly, but the loss of shower members due to observational errors will be higher. Since in this article we want to determine the error limits for the main criterion, it is necessary to define suitable error limits for the secondary criteria in advance. In other words, we have to decide which losses we are prepared to accept by applying the secondary criteria due to observational inaccuracies. For this purpose we have to judge the value of each of the secondary criteria separately.

The length of the path is not very well-defined and hence the corresponding criterion is very rough only. Using the criterion strictly as it is stated in [3]:

> *"For radiants of more than 30° elevation the distance radiant-start point of the path must be at least twice as long as the path itself unless the meteor is a fireball."*

we do not loose any significant fraction of shower meteors due to plotting errors on the path length.

The angular velocity criterion on the contrary, is very well-defined. To determine the errors on the velocity estimates for experienced observers, we used the simultaneous observations described in the next section. For the same meteor seen simultaneously by two, three, four or five observers, each observer estimated the angular velocity in degrees per second according to the procedure described in [4]. The average was considered to be the true value whence the individual deviations from the average were the errors. The error distributions for different ranges are shown in Figures 1–3.

The achieved accuracy should convince people believing the opposite that estimating the angular velocity in degrees per second is feasible. The distributions are Gaussian-like. It seems appropriate to take as error limit for the application of this criterion the 2-σ interval, thus allowing a loss of 5% of the shower meteors due to erroneously estimated angular velocities.

In Figure 4 the distributions of Figures 1–3 were plotted cumulatively considering the absolute value of the error only. It can be clearly seen that the relative cumulative numbers reach 0.95 very close to the 2-σ limit indicating that the distributions are indeed Gaussian. Based on Figure 4, the error limits for the angular velocity were defined as a function of the angular velocity itself (Table 1).

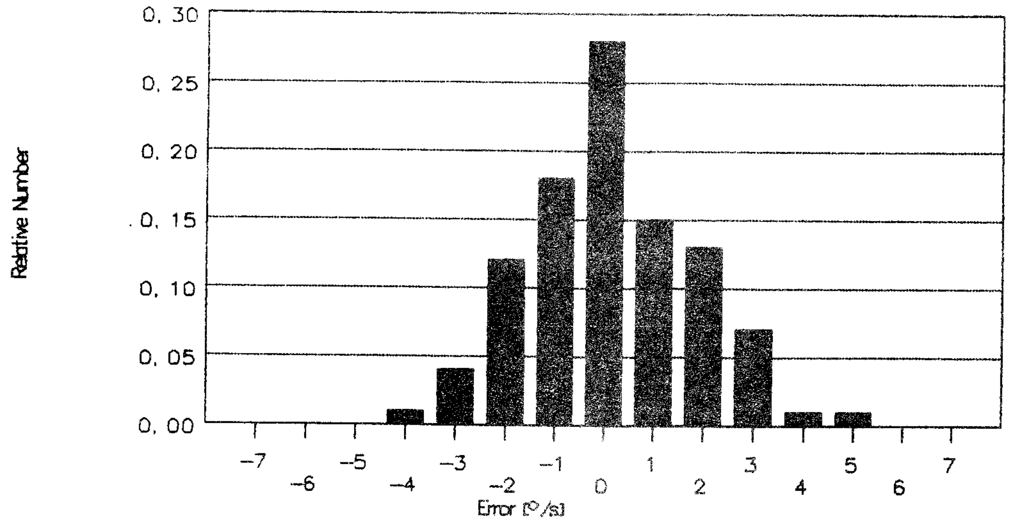

Figure 1 – Relative error numbers of angular velocity estimates in the range 3–8°/s (average 6°/s). The standard deviation is 1.67°/s.

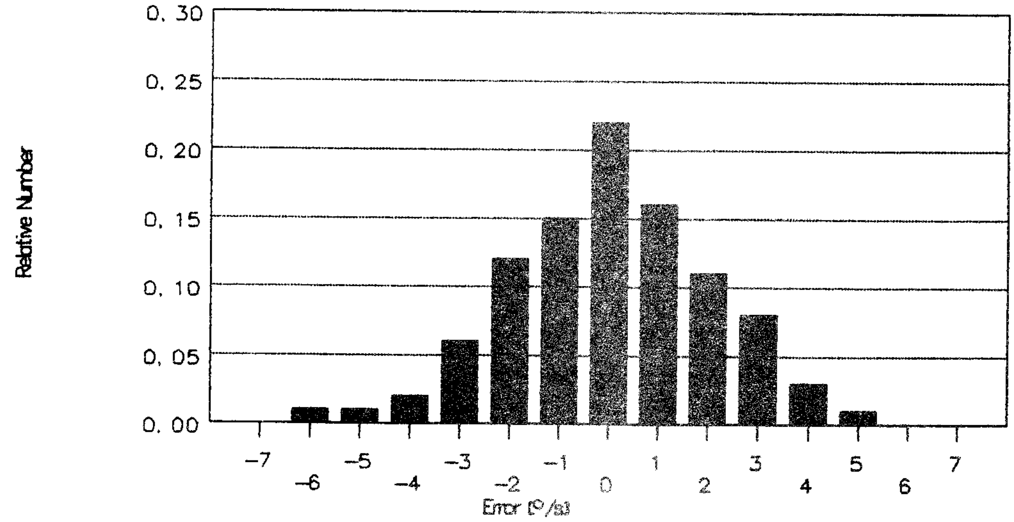

Figure 2 – Relative error numbers of angular velocity estimates in the range 7–13°/s (average 10°/s). The standard deviation is 2.3°/s.

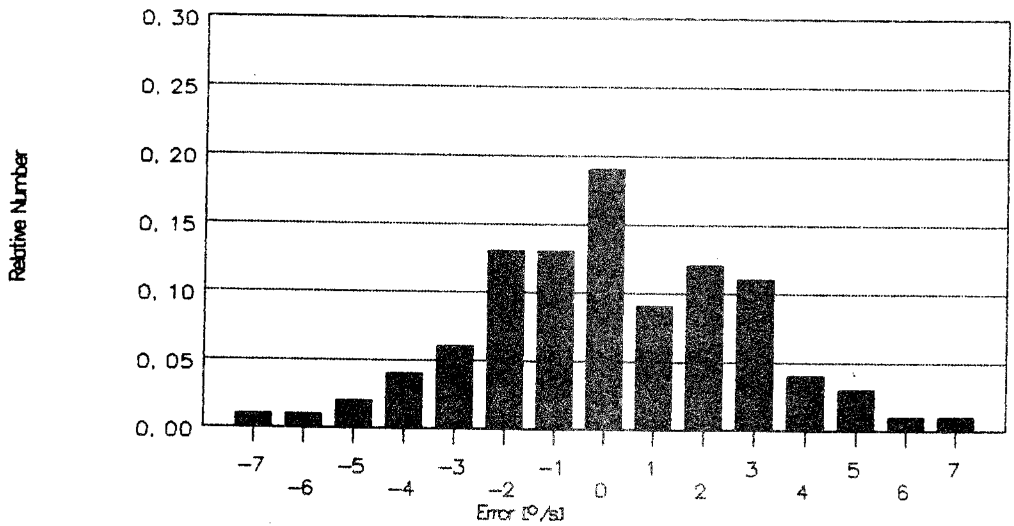

Figure 3 – Relative error numbers of angular velocity estimates in the range 12–18°/s (average 15°/s). The standard deviation is 2.8°/s.

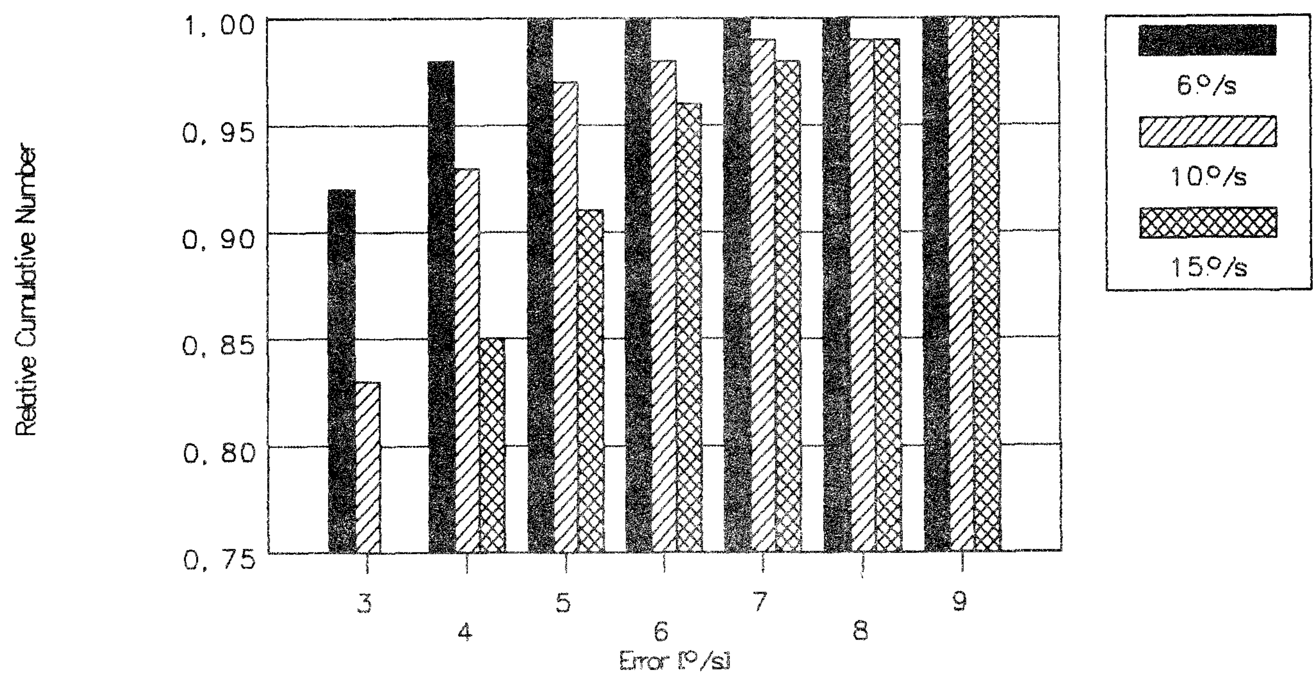

Figure 4 – Cumulative relative error numbers of angular velocity estimates in the range 3–8°/s (average 6°/s), 7–13°/s (10°/s), and 12–18°/s (15°/s).

Table 1 – Error limits for the angular velocity.

Angular velocity	5°/s	10°/s	15°/s	20°/s	30°/s
Permitted error	3°/s	5°/s	6°/s	7°/s	8°/s

Using the error limits defined in Table 1, items *b* and *c* above for the shower association to the fictive radiants were carried out. The results can be seen in Table 2 (sample: 1757 meteors).

Table 2 – Fractions of sporadic meteors associated to fictive radiants of 10° in diameter positioned at an elevation h.

Method	Direction only		Direction, length and velocity			
			$V_\infty = 30$ km/s		$V_\infty = 60$ km/s	
	$h = 30°$	$h = 60°$	$h = 30°$	$h = 60°$	$h = 30°$	$h = 60°$
Meteors Percentage	143 8.4%	147 8.1%	51 3.1%	50 2.6%	85 4.6%	80 4.7%

The results of item *a* should correspond to those of [1]. For $h = 60°$ the fraction determined in [1] is 5.2% and for $h = 30°$ it is 4.3%, i.e., the real pollution is a little higher than the theoretical one, while its dependence on the radiant elevation can be neglected. The somewhat higher pollution may be due to the fact that the participating observers watched the southern part of the sky and thus the fictive radiants lie also in this direction, i.e., in the vicinity of the ecliptic where a concentration of real sporadic meteor radiants is present. The theoretical model in [1] in contrast, is based on randomly distributed sporadic meteor radiants. However, most showers are located in this part of the sky and are thus affected by the higher sporadic pollution there.

Most interesting to see is that the application of the secondary criteria reduces the pollution by a factor of about 2. It seems that slow showers are somewhat less affected by sporadic pollution, but considering the scatter this difference is not that striking. Thus we simply average the results of items *b* and *c* and obtain a mean sporadic pollution *sp* of 3.75% of the sporadic HR for a 10° radiant diameter (radius $r = 5°$). For other diameters the sporadic pollution is:

$$sp = 0.0375 \times \frac{r}{5^\circ} \times \mathrm{HR_{spor}} \qquad (1)$$

3. Plotting accuracy

For shower association two kinds of plotting errors are important: the *tilt* ε and the *parallel shift* d (Figure 5).

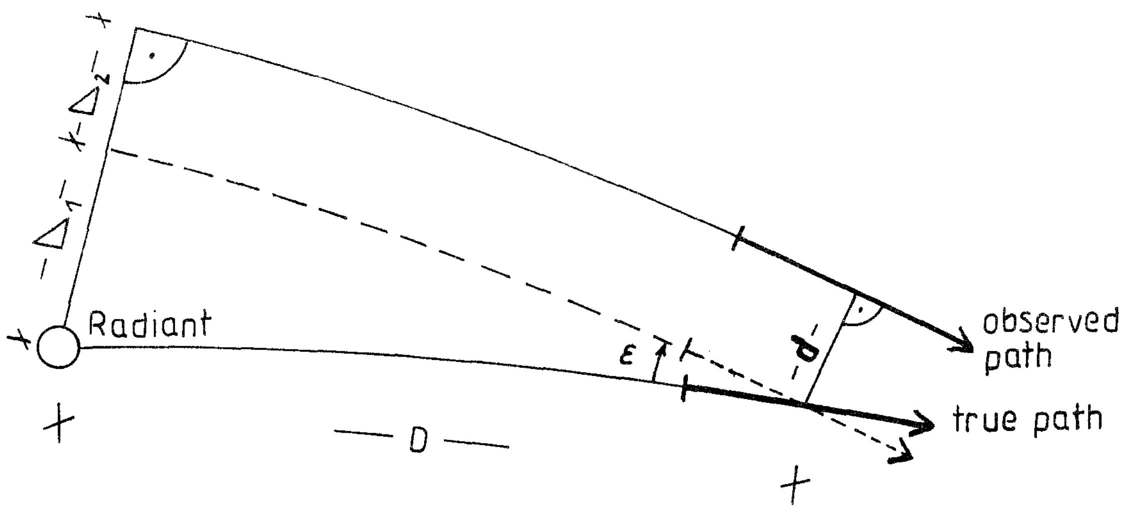

Figure 5 – Plotting errors and resulting error at the radiant

The resulting error Δ consists of the two components Δ_1, the error due to the tilt, and Δ_2, the error due to the shift, Δ_2. We have $\Delta = \Delta_1 + \Delta_2$ if observed and true path converge, and $\Delta = |\Delta_1 - \Delta_2|$ if case of divergence:

$$\begin{aligned} \sin\Delta_1 &= \sin\varepsilon \sin D \\ \cos\Delta_2 &= \sin^2 D + \cos^2 D \cos d \\ \Delta &= |\Delta_1 \pm \Delta_2| \end{aligned}$$

with D the radiant distance of the meteor.

For simplicity's sake, we approximate the above equations using $\sin x \approx x$ and $\cos x \approx 1 - x^2/2$ for small x and obtain:

$$\begin{aligned} \Delta_1 &\approx \varepsilon \sin D \\ \Delta_2 &\approx d \cos D \end{aligned}$$

The equations can now more easily be interpreted. The influence of the tilt increases with the sinus of the radiant distance. It is very small near the radiant and maximal at 90° distance. The influence of the shift is zero at 90° radiant distance and maximal at the radiant.

So far for the theory. The question now arises how to determine the plotting errors in practice. The most obvious solution, using visual-photographic simultaneous meteors yields a sample that is too small and restricted to bright meteors only. Simultaneous visual-video observations suffer from the small field of the video camera. For the most simple procedure, simultaneous plotting of different observers, the main problem is that the true path is unknown. But this problem can be reduced as will be seen later.

The main bulk (approximately 95%) of the data used here was obtained during the observing campaign for the 1990 Orionids in Lardiers, Southern France. Four observers being very experienced in plotting and one observer with medium experience plotted meteors seen simultaneously on maps of the *Atlas Brno 2000.0*, the best set of charts for meteor plotting ever published. No selection was applied to the meteors: each meteor seen by more than one person was plotted even if the observer was very uncertain about the path. The reason for this is the *IMO* standard taking into account *all meteors seen* for the ZHR computation, also those far away from the center of view and thus very uncertain. Therefore this standard is not optimal; it would have been better to limit the field to 40° or 50° radius. But that standard is very old, many observations have been carried out according to it and the problems it causes now are not that critical. Thus we can live with these problems knowing that any change of the current standard would cause much greater difficulties. Anyway the obtained result is representative for all meteors seen.

Table 3 – Number of meteors simultaneously plotted by n observers.

Nr. Obs. n	Meteors
2	215
3	112
4	85
5	54
Tot	466

The coordinates of the individual plottings were stored in *PosDat*, the positional database of the *IMO*. The true path was then assumed to be the average of the individual plots. In practice, the coordinates of the start/end points stored in right ascension and declination were transformed into x, y coordinates by gnomonic projection with the projection center in between both plots (Figure 6). coordinates in the projection plane. Then the individual orientation angles α_i were computed and averaged. The center of the true path $\overline{x}_c, \overline{y}_c$ resulted from averaging the coordinates of the centers of the individual plots. The average meteor was then obtained by plotting the average orientation angle $\overline{\alpha}$ and path length $\overline{l}$ from the average center $\overline{x}_c, \overline{y}_c$.

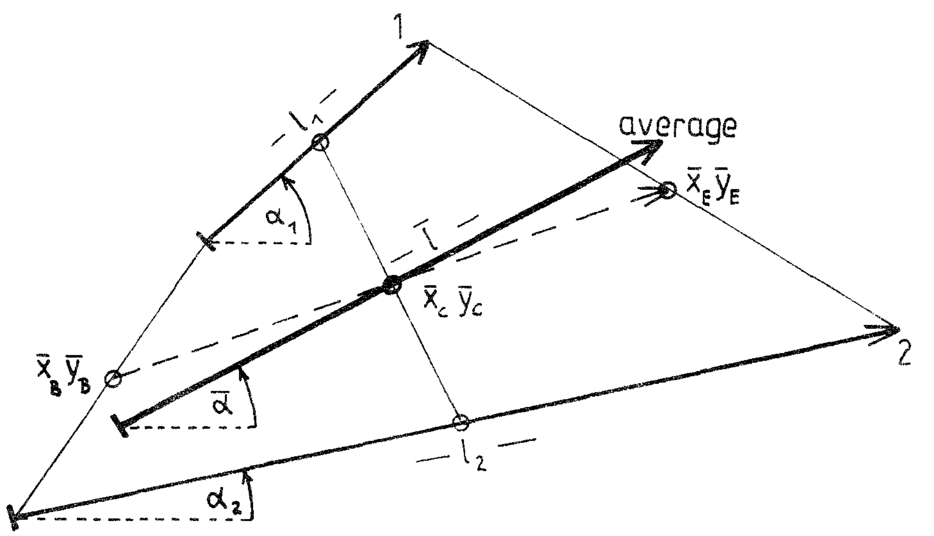

Figure 6 – Averaging procedure for meteors. For details, please refer to the text.

This procedure is not identical to simply averaging start and end points. Simple averaging would give the highest weight to the orientation angle α_i of the longest plot. The average path resulting from simple averaging is indicated as a dashed line in Figure 6.

In order to compute the resulting errors at the radiant it is also necessary to know the radiant distance of the meteor. For meteors classified as shower members this of course does not constitute any difficulty, but for sporadics it is not clear how to handle this problem. One possibility is to assume a constant distance for these meteors. However, this solution is not very adequate. Indeed, for different radiant distances the paths have also different lengths. It is to be expected that longer meteors can be plotted more accurately than shorter ones appearing near the radiant, although the error resulting the tilt (which will turn out to be dominant) will be much larger. The assumption of a constant radiant distance for sporadic meteors would neglect the relationship between radiant distance and path length. Hence, we have to find a characteristic radiant distance for each sporadic meteor depending on its path length.

If the altitudes of begin and end point above the Earth's surface are known it is possible to compute the radiant position of a plotted meteor. The radiant position then depends on the direction of the path and its elevation above the horizon and on the elevation of the radiant itself. Thus an iterative procedure has to be applied. To obtain begin and end altitudes all values given in [2] were simply averaged. The average altitude was found to be 104 km for the begin point and 88 km for the end point, both with an empirical standard deviation of 7 km. Using these values, the most probable radiant distance of each average sporadic meteor was computed.

The resulting error at the radiant of each individual plot was calculated from the tilt and the shift against the average path and the radiant distance. The result can be seen in Figure 7.

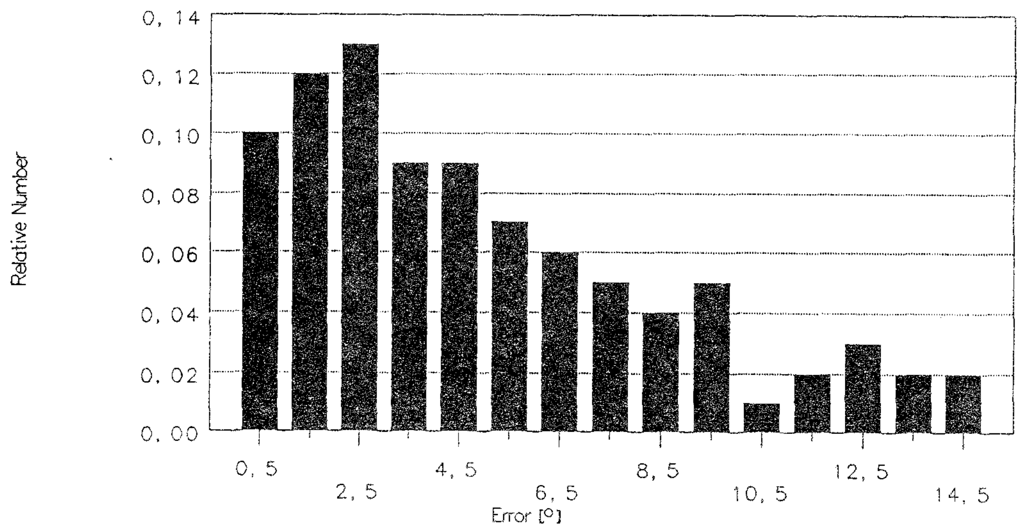

Figure 7 – Relative numbers of resulting errors at the radiant (all meteors). Computation without rejection of outliers.

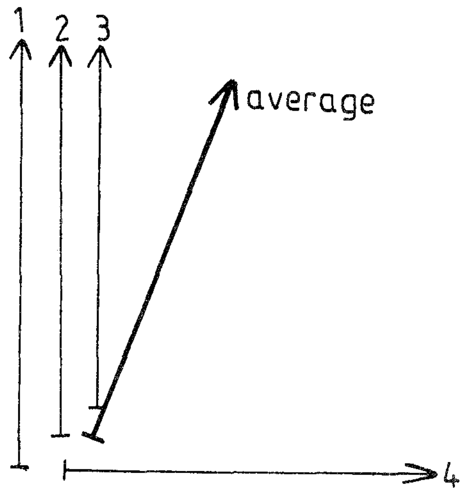

Figure 8 – Influence of outliers. For details, please refer to the text.

Instead of an expected one-sided Gaussian-like distribution the picture of Figure 7 came out. It is very strange that an observer avoids to meet the radiant exactly with his plots; he prefers an error of about 2°5. The reason for this crazy result is the disadvantage of the method that the true path is unknown. The more observers plot the same meteor the greater the probability that one of them makes a big error. To show the principle an extreme example is given in Figure 8. Observers 1–3 plotted the meteor in the same direction. It can be assumed that they are quite correct. Observer 4 plotted it tilted over 90°. Using the averaging procedure observers 1–3 get medium errors instead of zero errors while the major error of observer 4 is somewhat reduced a bit. This is exactly what we see in Figure 7: There is a lack of small errors and an excess of medium ones.

Therefore, a commonly used test for rejection of outliers was applied after the first averaging. If one plot turned out to be an outlier averaging was carried out again without the outlier. The resulting average path can now be assumed to be closer to the true path than before. The errors, also for the outlier, were then computed with respect to the average path.

Figure 9 shows the distribution of relative error numbers for the same data and the same error computing procedure as in Figure 7, the only difference being the application of the test for rejection of outliers. The result is much more convincing than the one in Figure 7. In this way the effect of the disadvantage of the true path being unknown has been reduced considerably.

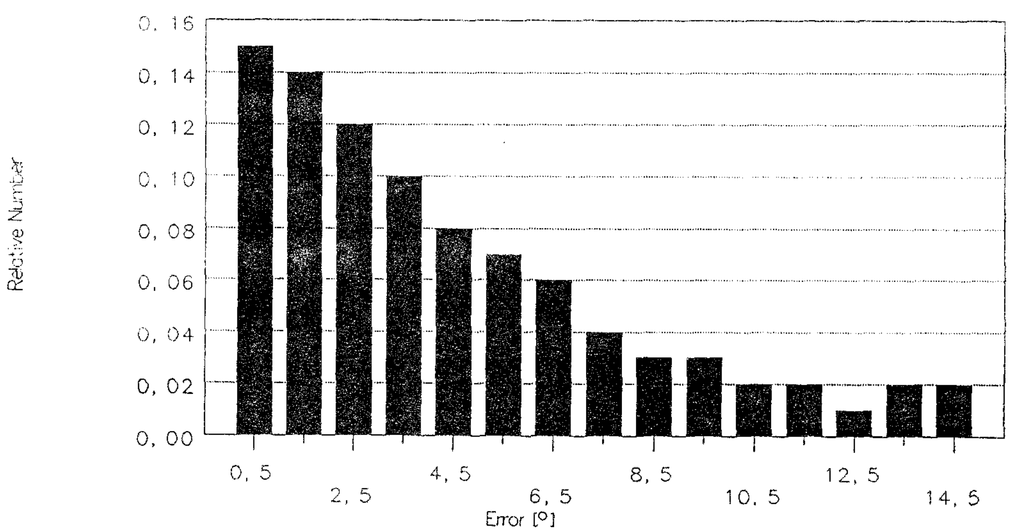

Figure 9 – Identical with Figure 7, but computation with rejection of outliers.

After solution of these more technical problems we can come to the analysis of the error distribution.

Figures 10 and 11 show the error distributions for different ranges of radiant distance.

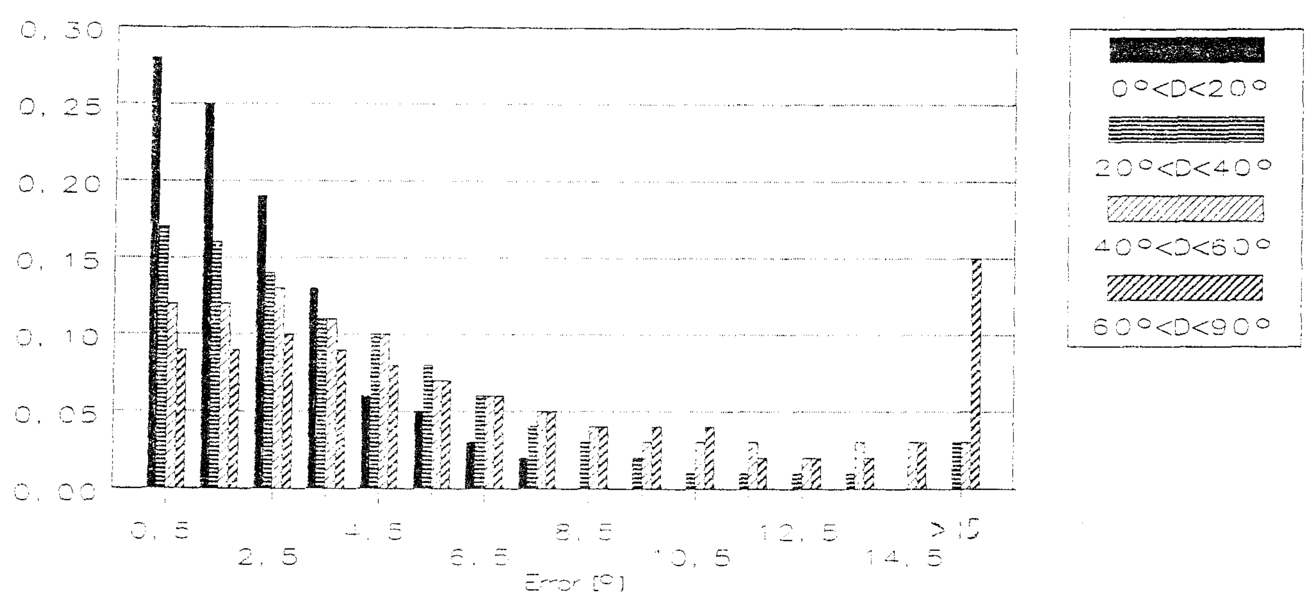

Figure 10 –Relative error numbers for different ranges of radiant distance D. The average distances are: 15° for $0° < D \leq 20°$, 30° for $20° < D \leq 40°$, 50° for $40° < D \leq 60°$, and 70° for $60° < D \leq 90°$.

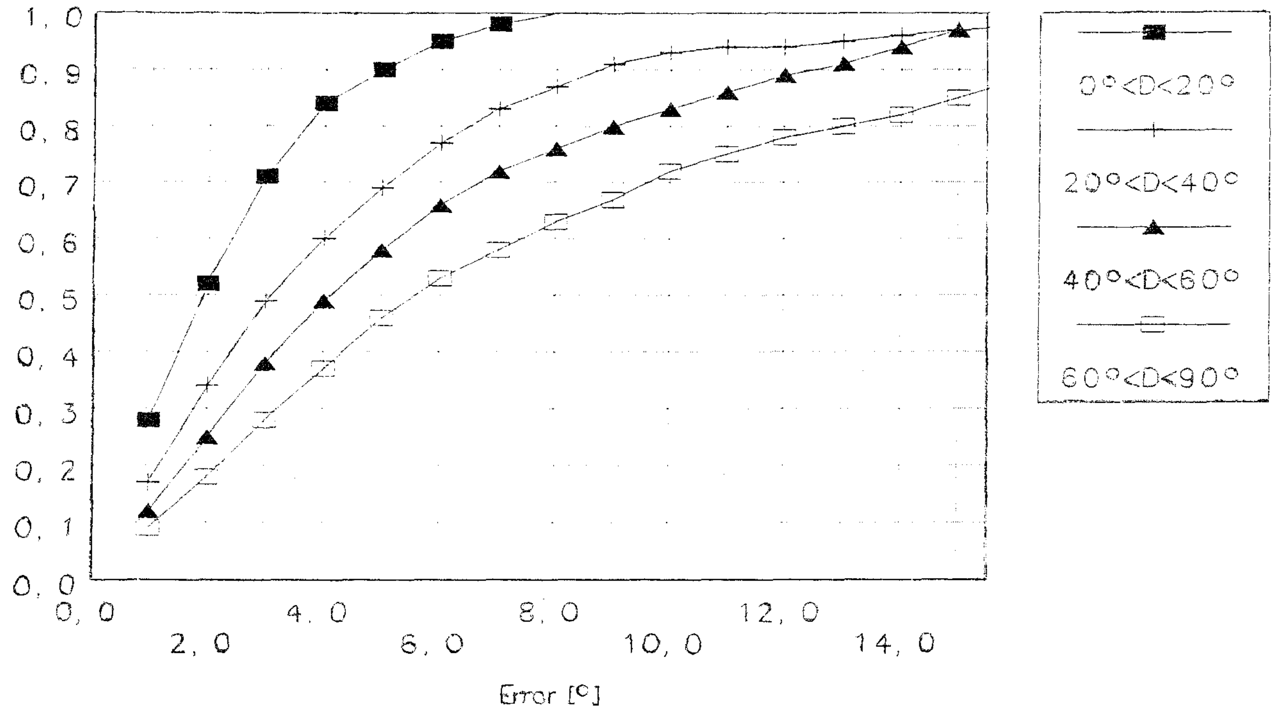

Figure 11 –Cumulative relative error numbers for different ranges of radiant distance D. The average distances are: 15° for $0° < D \leq 20°$, 30° for $20° < D \leq 40°$, 50° for $40° < D \leq 60°$, and 70° for $60° < D \leq 90°$.

It can clearly be seen that the resulting errors increase with the radiant distance. This means that the tilt is the dominant error component and that observing fields close to the radiant(s) under study are most favorable with respect to accurate shower association.

In Figure 12 the error distribution for different subjectively evaluated plotting accuracies can be seen ($D < 60°$). No unexpected effects occur. It should be mentioned that the distributions are valid for the subjective evaluation of the participating observers. For other observers they will differ.

The quality of different observers' plottings can be evaluated by the cumulative error distributions in Figure 13. It can be seen that the observers with high experience have nearly identical distributions while the observer with medium plotting experience (Paul Roggemans) achieves somewhat less accuracy, but the difference is not so big.

Let us return now to the cumulative distribution in Figure 11 which is the most important for the initial aim of this analysis. The diagram is to be read as in the following example: "For radiant distances less than 20°, 90% of the meteors have resulting errors at the radiant of less than 5°" or, "If for a point-like radiant a radius of 5° was assumed for shower association, 10% of the shower meteors will be classified as sporadics due to plotting errors."

For this example, the cumulative relative error number $H(r)$ equals $H(r = 5°) = 0.90$. Using Figure 11 we can obtain the second parameter for the determination of the optimal radiant diameter, namely the loss l due to plotting errors:

$$l = (1 - 0.95 \times H(r)) \times \mathrm{HR_{sh}}$$

The factor 0.95 is for the loss of 5% due to errors in the estimation of the angular velocity: $H(r)$ is the fraction of shower meteors meeting a radiant of radius r (if the real radiant is point-like) of which we classify 95% as shower meteors while the remaining 5% are classified as sporadics due to erroneously estimated angular velocities.

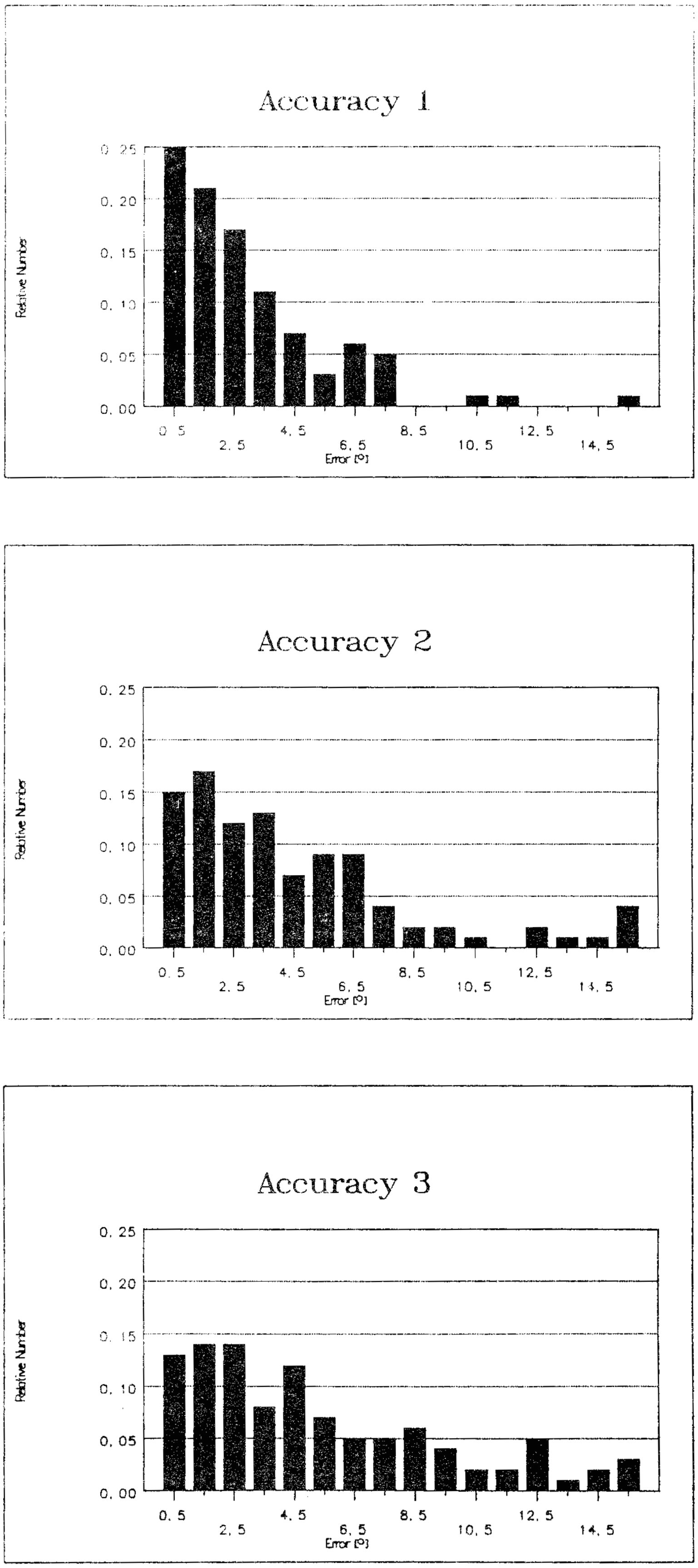

Figure 12 –Relative error numbers for different subjectively evaluated plotting accuracies (only meteors with radiant distances less than 60°). "1" means very accurate, "2", medium accuracy, and "3", bad accuracy.

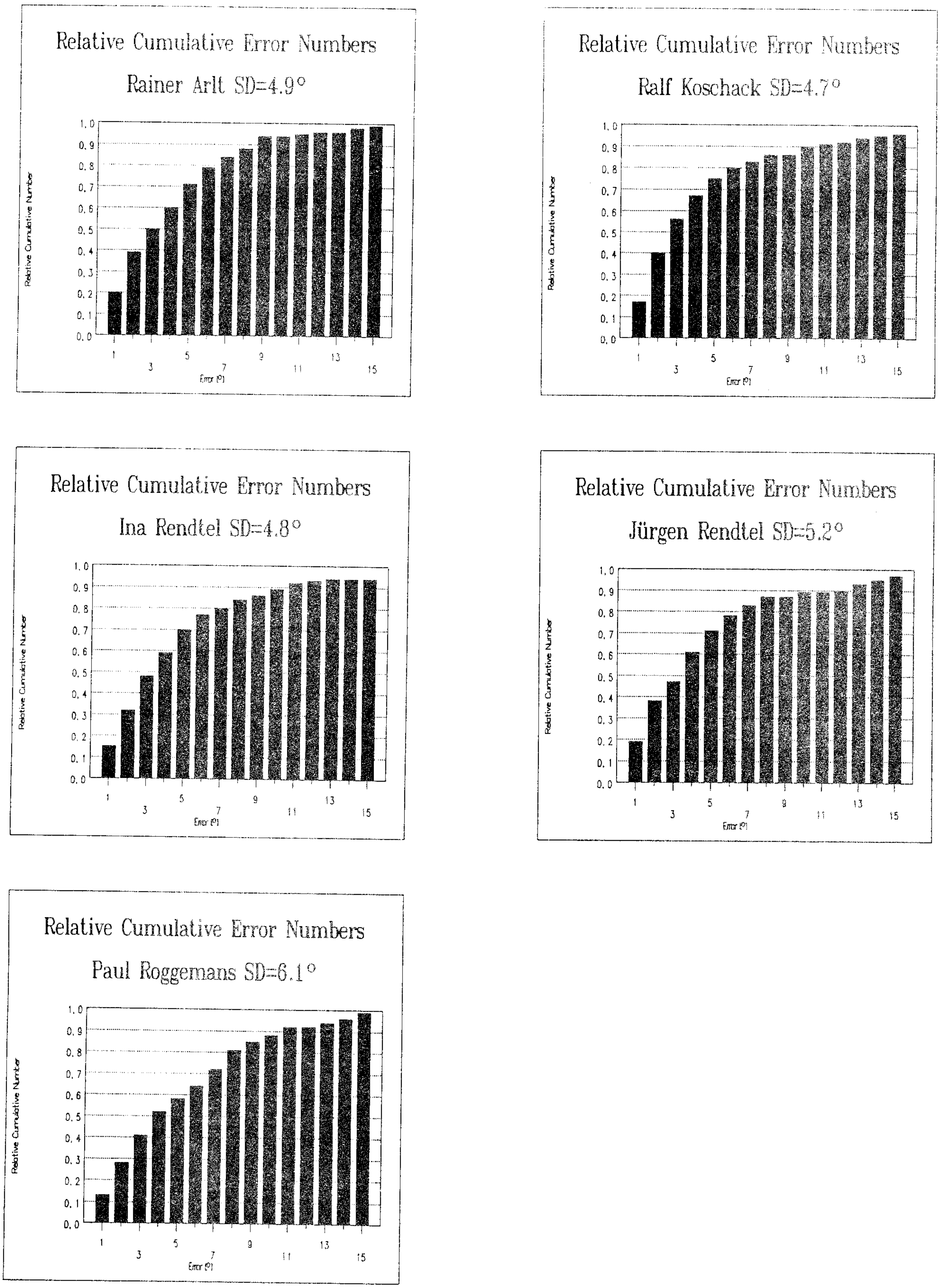

Figure 13 –Cumulative relative error numbers for different observers ($D < 60°$).

4. Determination of the optimal radiant diameter

It is our aim to determine the optimal size to be assumed for shower association such that the losses due to observational errors are compensated by the sporadic pollution. For this optimal radius r_{opt} the loss l is equal to the sporadic pollution sp. Using (1) and (2) we have:

$$0.0375 \times \frac{r_{\text{opt}}}{5^\circ} \times \text{HR}_{\text{spor}} = (1 - 0.95 \times H(r_{\text{opt}})) \times \text{HR}_{\text{sh}}$$

From this equation the optimal radiant radius r_{opt} follows by iterative computation. For a given radiant distance, i.e., for a given $H(r)$, we have HR_{spor} and HR_{sh} (*not* the ZHR!) as variables. HR_{spor} can be set to 10 for most of the year. Table 4 was computed with this value.

Table 4 – Optimal radiant radii and corresponding percentage of shower meteors being sporadics classified as shower members for $\text{HR}_{\text{spor}} = 10$, different ranges of radiant distances, and different shower HRs (HR_{sh}).

HR_{sh}	Rad. dist.	Opt. radius	% Spor. met. of HR_{sh}
1	$< 20^\circ$	3°7	25%
	20°– 40°	4°7	36%
	40°– 60°	5°3	41%
	60°–120°	6°2	47%
2	$< 20^\circ$	4°8	16%
	20°– 40°	6°4	25%
	40°– 60°	7°8	29%
	60°–120°	9°2	35%
3	$< 20^\circ$	5°3	13%
	20°– 40°	7°6	19%
	40°– 60°	9°2	23%
	60°–120°	11°1	28%
5	$< 20^\circ$	6°3	9%
	20°– 40°	9°0	13%
	40°– 60°	11°4	17%
	60°–120°	14°3	21%

Looking at Figure 12, it seems to be also possible to determine r_{opt} depending on the the subjectively evaluated accuracy of the plot. But as already mentioned, this scale may systematically differ from observer to observer, for instance if one observer gives accuracy "1" only in exceptional cases while another observer evaluates the accuracy more often as "1". For this reason it is better to rely on the objective criterion for radiant radius.

If the center of the field of view is in the vicinity of the radiant, we can assume that the majority of the meteors will have radiant distances in the range 20°–40°. For a minor shower of $\text{HR}_{\text{sh}} = 1$ (corresponding to ZHR = 1.5 for 40° radiant elevation), more than one third of the meteors classified as shower members are sporadics, i.e., any computation of the population index for example is meaningless. The situation improves with increasing shower HR. With about one quarter of sporadics, $\text{HR}_{\text{sh}} = 2$ (corresponding to ZHR = 3 for 40° radiant elevation) can be considered as a limit case, while for higher rates the sporadic fraction becomes acceptably small.

The high sporadic pollution is the reason for the fact that visual observations of very minor showers with maximum ZHRs of 1 or 2 do not make sense. As the shower HR rather than the ZHR is decisive for the observability, observers should take care to arrange their watches in such a way that the radiant(s) under study are high in the sky. While a ZHR = 3 shower produces a HR of 2 at 40° radiant elevation and thus is still analyzable, the same shower provides a HR of only 1 if the radiant is at 20° elevation. Therefore it should be also clear that observations of minor showers having a declination of -20° cannot be successful in Central Europe for instance.

Taking the fraction of 25% sporadics as the limit for shower observability, it can also be seen that we can analyze weaker showers if we observe closer to the radiant. If the observing field is located in the vicinity of the radiant the characteristic radiant distance for the shower meteors seen will be 20°–40°. In this range the limit of 25% is reached for a shower HR of almost 2. For an observing field at a distance of 90° from the radiant, most of the shower meteors seen will of course have this radiant distance. Hence in this case the limit is already reached at a shower HR of more than 3. In other words, observing at large radiant distances increases the limit for the HR of analyzable showers by a factor of 1.5 to 2, not to mention the increasing problems with distinguishing neighboring radiants.

Table 5 – Cut-out of Table 4 computed with the sporadic pollution of 8.25% resulting from considering the direction of the path as the only criterion for shower membership (cfr. Table 2).

HR_{sh}	Rad. dist.	Opt. radius	% Spor. met. of HR_{sh}
1	20°–40°	3°	50%
2	20°–40°	4°	37%
3	20°–40°	5°	30%
5	20°–40°	6°	22%

At this point, people may doubt that the additional effort in shower association required by comparing the observed angular velocity with the expected value yields a proportional improvement of the results. To see the effect, Table 4 should be compared with Table 5. Considering the percentage of shower meteors being sporadics classified as shower members as limiting criterion it becomes obvious that the application of all criteria allows for a meaningful analysis of weaker showers. Taking the percentage of 25% for the range $20° < D < 40°$ as limit, we can analyze showers of HR = 2 if we apply all criteria. This limit increases by a factor of 2 (HR = 4) if only the direction of the path is used! Hence it is worth-while to estimate the angular velocity in degrees per second and to compare the observed value with the expected one according to [4]. The limit of ZHR = 3 (corresponding to HR = 2 for 40° radiant elevation) *IMO* has set in its shower list is the absolute minimum when considering all criteria and observing in the vicinity of the radiant. Weaker showers are simply not analyzable by means of visual observations.

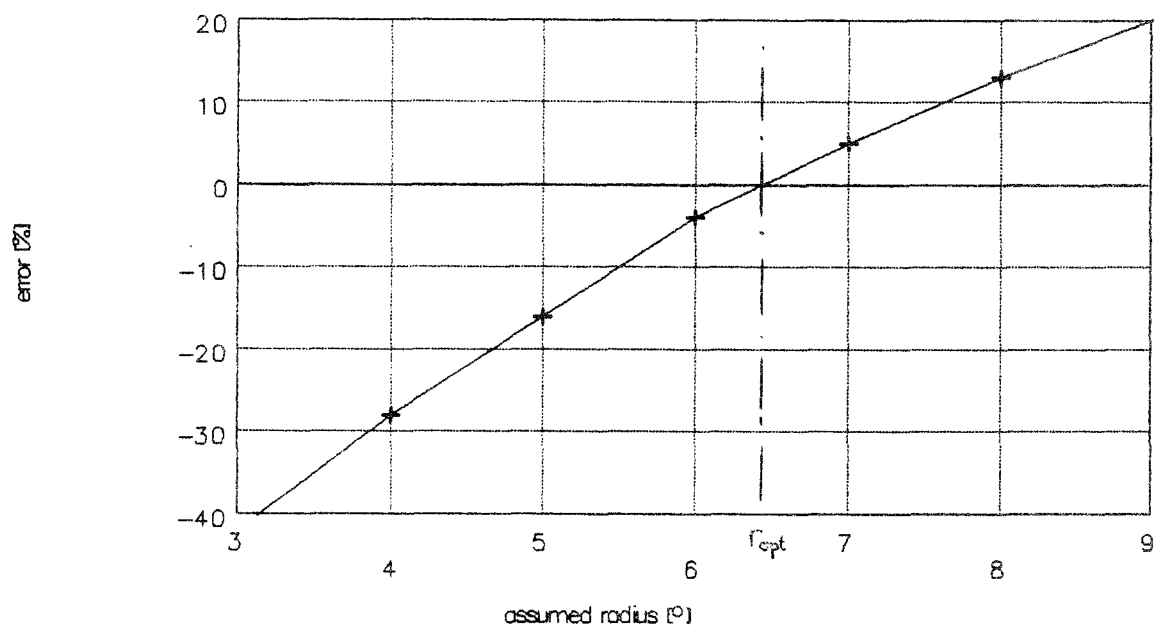

Figure 14 –ZHR errors depending on the assumed radiant radius for HR = 2 and radiant distances in the range 20°–40°.

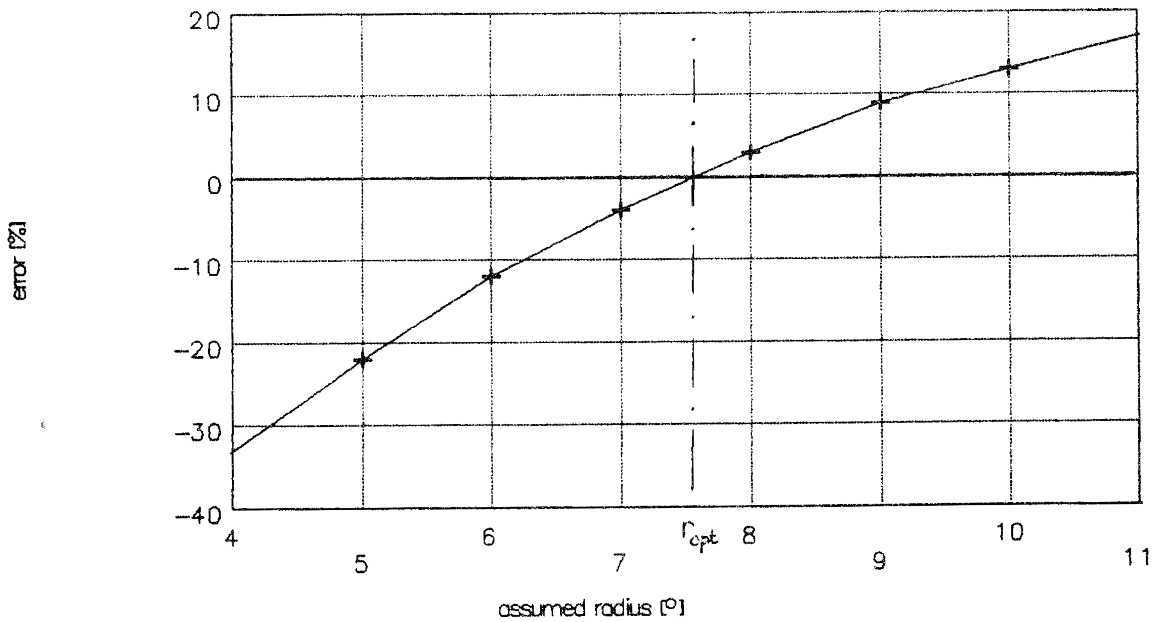

Figure 15 –ZHR errors depending on the assumed radiant radius for HR = 3 and radiant distances in the range 20°–40°.

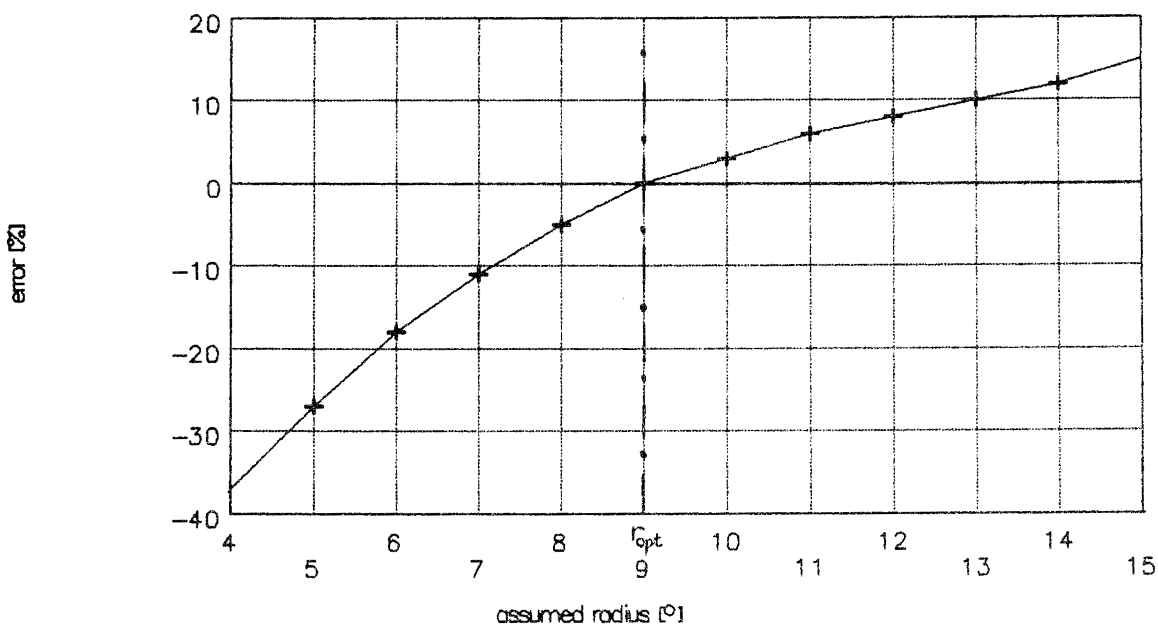

Figure 16 –ZHR errors depending on the assumed radiant radius for HR = 5 and radiant distances in the range 20°–40°.

Figures 14–16 show the errors of the HR and hence also of the ZHR if other radiant sizes than the optimal radii are assumed. Low rates are more sensitive against wrong diameters than higher ones. A difference between the assumed radius and the optimal one of 2° for instance causes a ZHR error of about 20% for a HR = 2 shower (Figure 14) and one of about 10% for a HR = 5 shower (Figure 16). Furthermore, the ZHR error for a radiant assumed too large is smaller than the ZHR error for a radiant assumed too small by the same amount.

In order to make the practical procedure of shower association not too complicated it is necessary to define an optimal radiant diameter for minor shower observations depending only on the radiant distance of the concerned meteor.

Indeed, also taking into account the HR would require an iterative procedure that cannot be handled practically. If we base ourselves on the values for HR = 3, then for HR = 2 and HR = 5, i.e., within the range of analyzable minor showers, we make an error of at most 15%.

As soon as the ZHR reaches about 10 (corresponding to HR $\approx$ 7 for a radiant elevation of 40°), the observing instructions recommend "counting", i.e., deciding shower membership directly under the sky without plotting. In this case, the radiant size choosen does not affect the ZHR as strongly as for lower activity.

From Figure 16 (valid for HR = 5 and $20° < D < 40°$) it can indeed be seen that the ZHR error due to wrong radiant sizes is less than 10% for assumed radiant diameters in between 14° and 26° (optimal for 18°) and that the error is less if the diameter was choosen too large rather than too small. For higher HRs this range becomes even wider. Thus there is no problem with the reliability of shower association for ZHR > 10 showers without plotting, while on the contrary it is essential to plot all shower candidates and to assume the optimal radiant diameters for ZHR = 3 showers.

Up to now we assumed point-like radiants. A real radiant however is a nearly circular area of a certain radius rather than a point. If one plots shower meteors and prolongs the paths backwards to the radiant, one gets an error distribution with respect to the center of the radiant area. This error distribution consists of two components: the plotting error and the real dispersion of the radiant area. Assuming both components to be Gaussian distributions the standard deviation of the resulting Gaussian distribution $\sigma_{\rm tot}$ can be computed from the dispersion of the radiant area $\sigma_{\rm rad}$ and that of the plotting errors $\sigma_{\rm plot}$ by:

$$\sigma_{\rm tot} = \sqrt{\sigma_{\rm rad}^2 + \sigma_{\rm plot}^2}$$

If c is the ratio between the optimal radiant radius for a point-like real radiant $r_{\rm pt}$ and $\sigma_{\rm plot}$, then c should also be about the ratio between the optimal radius for the error distribution resulting from both radiant dispersion and plotting errors $r_{\rm tot}$ and $\sigma_{\rm tot}$:

$$r_{\rm pt} = c\,\sigma_{\rm plot}$$
$$r_{\rm tot} \approx c\,\sigma_{\rm tot}$$

Hence we can write:

$$r_{\rm tot} \approx c \times \sqrt{\sigma_{\rm rad}^2 + \sigma_{\rm plot}^2}$$

In Figure 11, $\sigma_{\rm plot}$ follows from the point where the cumulative error distribution reaches 67% and for $r_{\rm pt}$, we use the value of $r_{\rm opt}$ for HR = 3 in Table 4. For $\sigma_{\rm rad}$ we assume a value of 2°5 which should meet the real situation for most minor showers. Computing $r_{\rm tot}$ using these values we find that due to the radiant dispersion we would have to add the following values to the optimal radiant radius obtained for point like radiants in Table 4: 1°7 for radiant distances $D < 20°$, 0°9 for $20° < D < 40°$, 0°6 for $40° < D < 60°$, and 0°4 for $60° < D < 120°$. These values are to be added to the optimal radii for $\mathrm{HR_{sh}} = 3$ in Table 4 the result of which is listed in Table 6.

So, we have obtained the optimal radiant diameter to be assumed for shower association to well- and medium-defined minor shower radiants. For complex radiants these computations (in this case rather estimations) were carried out individually. The optimal diameters or, rather, radiant areas, to be assumed for these complexes are summarized in Table 7.

5. Summary for observers

Here, the most important conclusions for *minor* shower observations (present ZHR less than about 10) are summarized:

- The center of the field of view should be at a distance of less than about 40° from the radiant(s) under study.
- The observation should be organized in such a way that the radiant is as high as possible in the sky.
- All possible shower meteors have to be plotted on maps of the *Atlas Brno 2000.0*.
- The angular velocity should be estimated in degrees per second according to [4].
- Shower association has to be carried out after the watch using the plots and the recorded data.
- To compensate for the losses due to plotting errors by sporadic pollution, the radiant diameters of Tables 6 and 7, depending on the radiant distance of the meteor, have to be assumed.

Table 6 – Optimal radiant diameters to be assumed for shower association of minor shower meteors with well- and medium-defined radiants.

Radiant distance	Radiant diameter
15°	14°
30°	17°
50°	20°
70°	23°

Table 7 – Optimal radiant diameters to be assumed for shower association of radiant complexes. For elliptic radiant areas the major axes are given (α/δ).

Radiant distance	15°	30°	50°	70°
δ-Cancrids	20°/15°	25°/20°	27°/22°	30°/25°
α-Crucids	20°/15°	25°/20°	27°/22°	30°/25°
Virginids	30°/20°	32°/25°	35°/26°	40°/30°
β-Pavonids	20°/15°	25°/20°	27°/22°	30°/25°
Scorpio-Sagittarids	30°/20°	32°/25°	35°/26°	40°/30°
Taurids South	20°/15°	25°/20°	27°/22°	30°/25°
Taurids North	20°/15°	25°/20°	27°/22°	30°/25°

Table 8 – Radiant dimensions in degrees and corresponding dimensions in millimeter on the maps of the *Atlas Brno* as a function of the distance radiant-chart center. Other diameters can be obtained by linear extrapolation, for instance 30° = 3 × 10° in the center of the map corresponds to 3 × 28 mm = 84 mm.

Distance to to chart center	Radiant diameter/major axis				
	10°	14°	17°	20°	23°
0 mm	28 mm	39 mm	48 mm	56 mm	64 mm
100 mm	39 mm	55 mm	66 mm	78 mm	90 mm
150 mm	52 mm	73 mm	88 mm	104 mm	120 mm
200 mm	71 mm	100 mm	121 mm	142 mm	163 mm

Practically, each radiant is indicated by a concentric circle or ellipse of the given dimensions at the chart. For the maps of the *Atlas Brno* the corresponding dimensions in millimeter, depending on the distance radiant-chart center due to the gnomonic projection, can be found in Table 8.

- For the comparison observed-expected value of the angular velocity the differences from the expected value shown in Table 9 should be allowed for.

Table 9 – Error limits for the angular velocity.

Angular velocity	5°/s	10°/s	15°/s	20°/s	30°/s
Permitted error	3°/s	5°/s	6°/s	7°/s	8°/s

- All data requested on the Visual Observing Form have to be reported.

6. Conclusions

We have seen that the sporadic activity limits the visual observability of minor showers to a ZHR of at least about 3. The closer we come to that limit the more careful we have to be in observing and analyzing and the larger are the errors to be expected.

Care alone however is not sufficient: to obtain the necessary accuracy much experience is required. Thus it cannot be expected that occasional observers are able to provide reliable results in a field at the edge of what can be obtained by visual techniques. Since only training can improve the quality of your observations, try to observe as often as possible!

Acknowledgments

The author is greatful to the observers having taken part in the simultaneous plotting sessions: Rainer Arlt, Pierre Bader, Ragnar Bödefeld, Ina and Jürgen Rendtel, and Paul Roggemans. Without their observational data this analysis would not have been possible.

Thanks are also due to the participants of the *AKM* Meeting in Radebeul in April 1991 and of the visual workshop at the 1991 *International Meteor Conference* in Potsdam for many useful discussions and valuable hints.

The author would welcome all comments and hints concerning the problems described here.

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Several articles had to be postponed and will be published in the February issue, that is if you allow us to produce a thick issue then by renewing your membership/subscription *now*. If not, we will not yet have a good estimate of the final numbers of subscribers in January, and then the financial risk to produce a thick February issue will be to great. In case we cannot make a thick February issue there is no alternative but to postpone some articles to the April issue. So please help us in avoiding this!

The 1991 Perseids

The 1991 Perseids from the United Kingdom

Alastair McBeath

A brief review of UK Perseid results is presented and discussed.

1. Introduction

Visual observations of the 1991 Perseids were obtained by 18 individuals and members of five groups from UK locations, and reported to the *JAS Meteor Section*. These observers are listed below:

> Shaun Ankers, K. Bearpark, Neil Bone, Debbie Borrell et al., Walter Bradford, Angela Bridson, Michael Dale et al., Shelagh Godwin, Guernsey A.S., Harperdean A.S., Terry Holmes, David Jenkins, Simon Jenner, T.E. Kaneen, Richard Livingstone, Tony Markham, J.W. Martin, Alastair McBeath, Steve Phipps, Graham Pointer, Ian Rigney, T. Sharpe et al., Simon Wragg.

Data from August 1991 totaling $173^h.42$ of observing and 3062 meteors of which 1447 were Perseids, was available for analysis. The results given below were derived from reliable observers under good skies. The mean limiting magnitude was +5.81.

Table 1 gives the magnitude distributions for the 476 Perseids and 385 sporadics deemed suitable for further analysis after applying the above selection criteria. The Perseid fireball proportion was 2.9%, while 0.8% of sporadics were this bright.

Table 1 – 1991 Perseid and August sporadic magnitude distributions from UK *JASMS* results.

Magnitude	-3^-	-2	-1	0	+1	+2	+3	+4	$+5^+$	Tot	$\overline{m}_{6.5}$
Perseids	14	14	33	62	77	111	103	45	17	476	+2.27
Sporadics	3	3	6	19	52	72	127	75	28	385	+3.26

Sufficient spread of observations was secured to allow the plotting of a useful Perseid mean ZHR graph, as shown if Figure 1.

Some 34% of Perseids left persistent trains, compared to 9% of sporadics. Table 2 shows a further breakdown of these results. Two Perseid trains were of especial note, both occurring on August 12-13. At 22^h53^m UT, a magnitude −9 Perseid left a 90-second train, and at 2^h55^m UT, a magnitude −6 Perseid produced a 26-second train.

Table 2 – Perseid and sporadic persistent train details. N_x is the number and $\%_x$ the percentage of trained meteors, while $\overline{D}_x$ gives the mean duration of those trains in seconds, for each source by magnitude class. No meteor fainter than magnitude +4 left a train.

Magnitude	-3^-	-2	-1	0	+1	+2	+3	+4	Tot
N_{Per}	13	11	21	45	38	25	7	3	163
N_{spor}	2	3	4	6	14	4	2	0	35
$\%_{Per}$	93	79	64	73	49	23	7	7	34
$\%_{spor}$	67	67	67	32	27	6	2		9
$\overline{D}_{Per}$	14.5	3.7	2.3	2.0	1.4	1.1	0.8	0.3	
$\overline{D}_{spor}$	2.0	2.0	2.8	1.0	1.4	1.1	1.8		

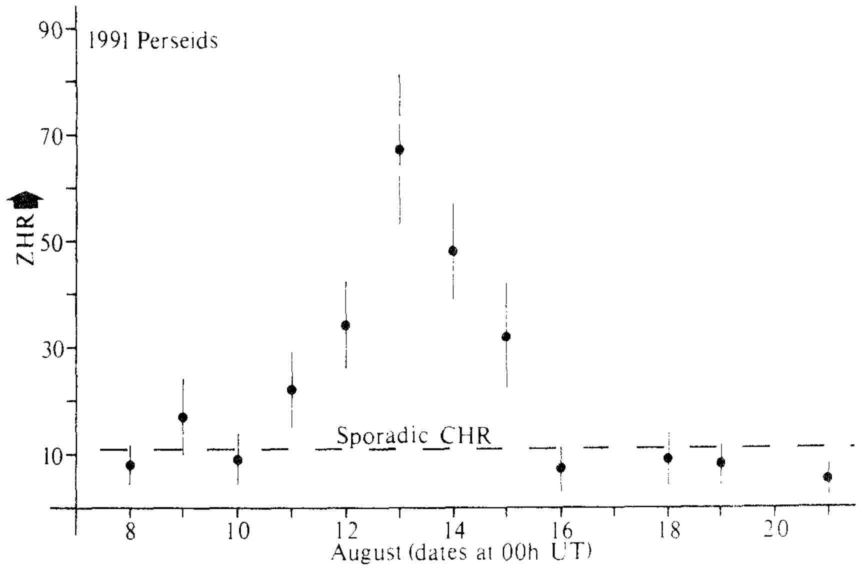

Figure 1 – Perseid mean ZHR from *JASMS* UK results. The mean sporadic computed hourly rate (CHR) for the period is also shown.

Although our results suggest a normal Perseid return, visual and radio data from elsewhere confirming an unexpectedly high maximum at around 16^h UT on August 12-13 make this statement superfluous. It seems most likely that British observers caught the trough between the two main maxima found in *IMO* results from the late 1980s. The data obtained were entirely compatible with those found from *JASMS* observations in the recent past certainly.

The highest mean ZHR for the Perseids was about 67 ± 14, recorded on August 12-13. One set of non-UK results did show a slight tendency for Perseid activity to increase to over 80 towards 3^h–4^h UT, but almost no British reports were available from this period for confirmation. For contrast, a mean sporadic computed hourly rate has also been added to Figure 1. This CHR was 11.3 ± 0.6 for August.

Essentially, the expected Perseid results were found in examining this year's summer analysis. News from other areas of a dramatic Perseid outburst thus came as quite a surprise, and it is very fortunate the *IMO* was able to cover it. There can be little talk now of the Perseids being a thoroughly understood stream no longer in need of regular observation, as some commentators had suggested only a few years ago!

The 1991 Perseids from Crimea and Siberia

communicated by A.I. Grishchenyuk

Observations from Crimea and Siberia confirm a Perseid outburst on August 12, 16^h UT and normal activity during the European observing window.

Well after the deadline for the December issue, but shortly before the editing was completed, we received an article on the 1991 Perseids by A.I. Grishchenyuk and V.V. Martynenko. While time and space considerations do not allow publication of the article in this issue, we do publish their data for the night of August 12-13, as they complement the picture of the shower given in the previous issue. By now, we also received confirmation of the outburst from one Chinese observer. Table 1 shows the data for a Crimean group lead by A.S. Levina that observed from Krasnoyarsk, Siberia. The outburst around 16^h *UT is striking. The data of the group in Malorechenskoe, Crimea in Table 2 on the other hand, show a normal return. (Ed.)*

Table 1 – Uncorrected Perseid rates obtained by A.S. Levina (LA), A. Smetanko (SA) and D. Karkach (KD) from Krasnoyarsk, Siberia, on August 12-13, 1991.

Period (UT)	T_{eff}			Lm			Per		
	LA	SA	KD	LA	SA	KD	LA	SA	KD
15^h10^m–15^h30^m	0.33	0.33		5.7	6.1		17	18	
15^h30^m–16^h30^m	1.00	1.00	1.00	6.2	6.3	5.8	166	171	157
16^h30^m–17^h14^m	0.74	0.74	0.74	6.2	6.3	6.0	72	81	74
17^h20^m–18^h30^m	1.16	1.16	1.16	6.2	6.3	6.0	92	104	90

Table 2 – Uncorrected Perseid rates obtained by A.I. Grishchenyuk (GA), D. Suchov (SD) and O. Semenov (SO) from Malorechenskoe, Crimea, on August 12-13, 1991.

Time (UT)	T_{eff}			Lm			Per		
	SD	GA	SO	SD	GA	SO	SD	GA	SO
19^h00^m	0.75	0.75	0.75	5.9	6.1	6.0	29	36	34
20^h00^m	1.00	1.00	1.00	6.1	6.3	6.1	43	57	44
21^h10^m	0.82	0.82	0.82	6.2	6.2	6.2	66	64	71
22^h20^m	1.12	1.12	1.12	6.2	6.3	6.2	97	118	99
23^h40^m	1.57	1.45	1.58	6.3	6.3	6.3	160	160	171
01^h05^m	0.66	0.66	0.66	6.0	6.0	6.0	88	62	51

Observational Results

Late 1991 η-Aquarid Activity from Texas

David Swann

Observations of the 1991 η-Aquarids from Ft. Davis, Texas, are summarized.

This year's Texas Star party, held near Ft. Davis, started on Sunday, May 12, and ended on Sunday, May 19. I arrived at Ft. Davis late on Monday May 13 and due to cloudiness I was not able to start observing η-Aquarids until May 15. I was able to observe for four mornings, May 15–18. My observing site, near the town of Ft. Davis, has an elevation of approximately 1550 m. The nearest major city is El Paso, Texas, and is located 288 km to the west. Ft. Davis is located in the Davis Mountains and the combination of elevation and low humidity produces some very good nights of observing. The limiting magnitude ranged from 6.5 to 6.8 on the four mornings that I observed this year.

A total of nine hours of observing were conducted over the mornings of May 15–18. During this interval, 14 η-Aquarids and 68 sporadics were counted. The average magnitude of the η-Aquarids was 3.93. Only one η-Aquarid left a train. The η-Aquarid radiant was well into Pisces by my last morning of observing and it was rising later each morning with morning twilight becoming a problem.

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