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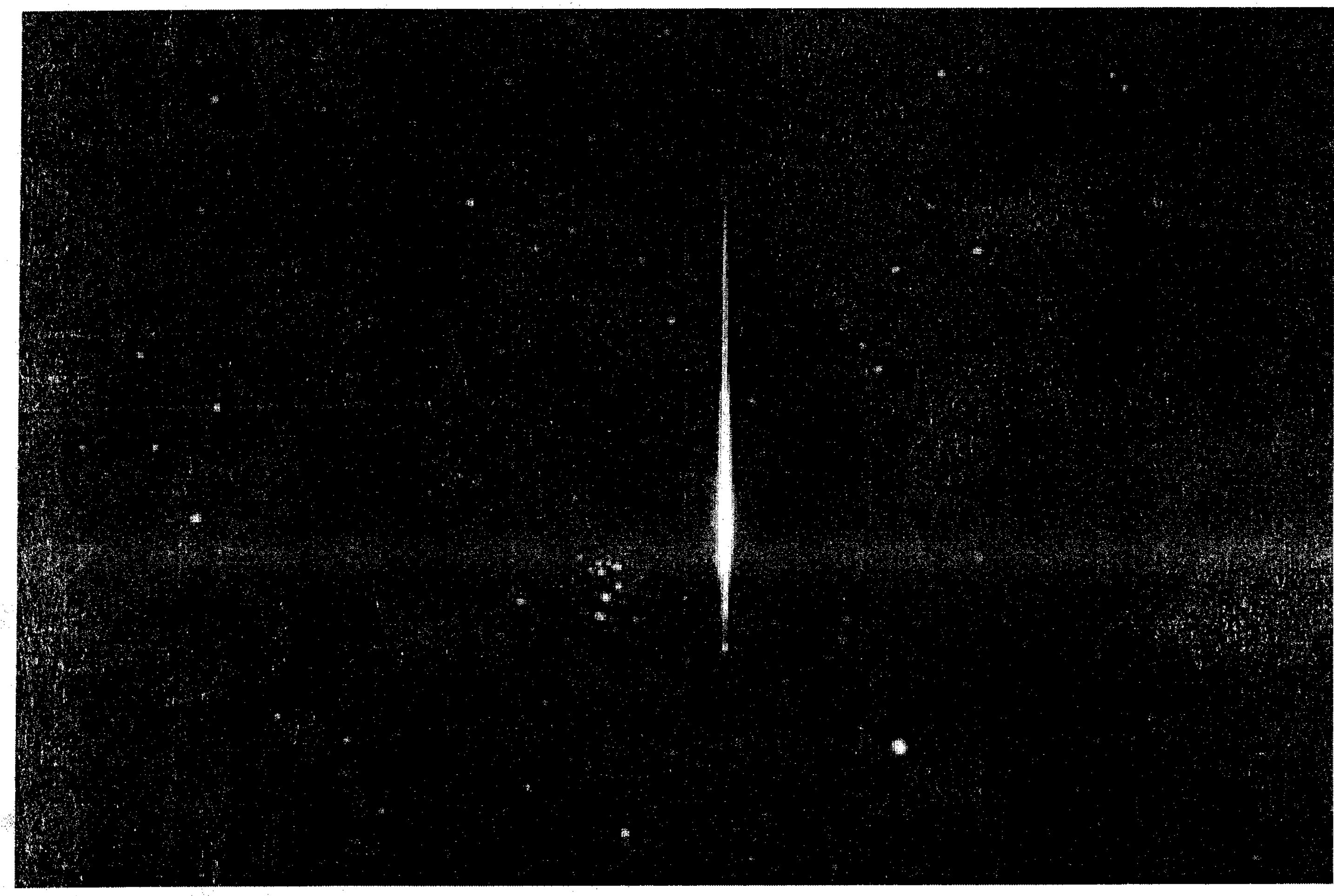

A Perseid fireball of magnitude −7 passed near the Pleiades on July 30, 2000, at 02^h53^m UT and was photographed by Marta Dueñas Minguez at the Tinieblas (Burgos) station of the *Spanish Photographic Meteor Network*. The bright object near the lower border is Saturn.

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

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Contents

Useful Information

The June issue *(WGN 29:3)*

The *June issue* will be mailed near the end of June Contributions are, therefore, due on *June 10* at the latest. They should be sent to *Marc Gyssens*.

Subscriptions and ordering of publications

Volume 29 (2001) of *WGN* is expected to contain at least 240 pages each and costs 35 DEM or 17.90 EUR per volume, including non-airmail delivery. Ordering other *IMO* publications is done in the same way as paying subscription/membership fees. Changes of address and complaints about not receiving *WGN* should be addressed to the Treasurer, Ina Rendtel.

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

From the President

Jürgen Rendtel

The leap year 2000 was unusual in several respects. It was one of the "irregular" leap years as 2000 can be divided by 400 with no remainder. Furthermore, all major meteor shower peaks, except the Quadrantids, were badly affected by moonlight. As for the Leonids, it was the return between *two intense showers with the 2001 return to come. We also lived to see unusual Ursid rates in December, not connected with the perihelion passage of their parent comet 8P/Tuttle.*

Again, the Leonids attracted great attention. The IMO*'s effort to collect and present results almost on-line on our web page was successful. The data was cited in many papers, indicating that this kind of data handling is well acknowledged and regarded as a reliable source despite the preliminary character of the derived rates.*

Not surprisingly, more video meteor systems became operable, using the available hardware and software for both major shower returns and regular meteor video patrol. The advantage of these cameras to be less affected by poor circumstances such as light pollution e.g. due to the full Moon allowed them to work during all major shower maxima in 2000. This characteristic will become important during the 2002 Leonids again. Fortunately, regular video meteor observations will be further temporally and regionally extended. Several debates about radiants may be solved with the increasing data, and we may expect a much clearer picture of the southern hemisphere minor showers.

The IMC 2000 *in Pucioasa, Romania, was attended by many meteor observers and it showed that such meetings with presentations and discussions are needed. It was a well prepared conference so that the next* IMC*s certainly will be attractive. Since the* IMO *is a world-wide organization, there are also discussions about future venues and how to allow as many as possible meteor workers to attend such conferences. So far, the Europeans were in the advantageous position that the* IMC*s were not too far from their homes. But how about the Far East or North American observers?*

As the moon is much better placed for major shower observations in 2001, there are certainly many plans observational campaigns. The predicted great Leonid return in 2001 requires long distance travel for many observers like in 1998. But do not forget that we also need the data from all other longitudes to obtain a complete image of the Leonid's particle density. So every result is important, even if you feel that you are not at the most exciting place. Besides the Leonid campaigns, do not restrict your activities on a few major shower returns. Often enough observers were granted with unexpected events well off the most attractive times.

I wish all members and friends of the IMO *a healthy, peaceful year and, of course, good luck with all your plans.*

The 2001 International Meteor Conference

Cerkno, Slovenia, September 20–23, 2001

Mihaela Triglav

The first *International Meteor Conference* in the third millennium will be held in a small town called Cerkno in Slovenia. It starts in the afternoon of September 20 and closes after lunch on September 23. It will be organized by the *Astronomical Association Javornik* with the support of the *Association for Technical Culture of Slovenia*.

Hotel Cerkno has 180 beds in different types of rooms. Therefore, we can offer you two different rates for hotel accommodation. For the standard participation fee of 200 DEM, you will be accommodated in second-category rooms with 2 to 4 beds. We can also offer a first-class room with a TV, hair dryer, and mini-bar for an additional fee of 45 DEM (so, for 245 DEM altogether).

There is a big lecture room for the main lectures, with a capacity of around 100 people. Speakers will have at their disposal a computer, a digital projector, a video projector, an overhead projector, and a slide projector. Workshops will be organized in smaller rooms which can accommodate 30 to 40 people each and in which a computer will be installed.

Please respect our **registration deadline on July 1, 2001** and send your registration form as soon as possible to *IMO* Treasurer Ina Rendtel and simultaneously inform the organizers via e-mail. The full participation fee is 200 DEM (245 DEM for first-class bedrooms). Late registrants will pay an additional fee of 40 DEM; thus, after July 1, the standard registration fee amounts to 240 DEM! For more information on this conference see the web page of the 2000 *IMC* at `http://www2.arnes.si/~sopezakr/IMC2001/` or contact the organizers via e-mail at `mtriglav@yahoo.com` or `jure.zakrajsek@kiss.uni-lj.si`.

International Meteor Conference

Cerkno, Slovenia, September 20–23, 2001

Registration Form

Each individual participant should fill out a form and return it to *Ina Rendtel, Mehlbeerenweg 5, 14469 Potsdam, Germany*, as soon as possible. Your registration will be guaranteed only after Ina Rendtel has received the minimum pre-payment of 100 DEM (51.13 EUR). If you wish to participate, but cannot yet decide, simply return this form with the proper option checked to stay on the mailing list for further circulars.

Name: ____ Birth date: ______________

Address: ____

____

____

Phone: ________________ Fax: ________________ E-Mail: ________________

- ○ wishes to register for the 2001 *IMC* from September 20 to 23;
- ○ intends to participate, cannot yet register, but wishes to stay on the mailing list.

I intend to travel by __________, together with ________________________________

Additional requests:

- ○ I need travel information from ____________________ to Cerkno;
- ○ I wish a 1st-category room (add 45 DEM or 23.01 EUR; also, contact the organizers).
- ○ I wish to stay in Slovenia before or after the *IMC* and require additional information.

For participants wishing to contribute to the program:

Lecture: ____

Duration: __________min. Required equipment: ______________________________

Workshop or discussion: ____

Poster presentation: ____________________________________ Space: __________ m^2

Either the entire fee of 200 DEM (102.26 EUR) or a pre-payment of 100 DEM (51.13 EUR) should be sent to the Treasurer, *Ina Rendtel*. Follow the payment instructions below. Participants making a pre-payment only have to pay the remaining 100 DEM (51.13 EUR) in cash upon arrival in Cerkno. Participants desiring a 1st-category room must pay the entire fee of 245 DEM (125.27 EUR) to the Treasurer.

Date and signature: ____

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

- in Europe: pay in DEM or EUR to Ina Rendtel, account number 547234107 at Postbank Berlin, bank code 10010010. No bank checks, please! (Bank checks can only be sent to Robert Lunsford, see below).
- in the UK: proceed as above or pay to Alastair McBeath, 12A Prior's Walk, Morpeth, Northumberland NE61 2RF, England.
- in Japan: pay to Masahiro Koseki, 4-3-5 Annaka, Annaka-shi, 379-01 Gunma-ken, Japan.
- all others pay in USD to Robert Lunsford, 161 Vance Street, Chula Vista, California 91910, USA. In case you pay by bank check, make it payable to Robert Lunsford, *not* the *IMO*!

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

Financial Support to Participants of the 2001 IMC

communicated by the IMO Council

As last year the *IMO* makes available funding to support attendance to the *2001 International Meteor Conference* (*IMC*). If you wish to apply for support, proceed as follows:

1. E-mail your application to the *IMO* President, Jürgen Rendtel, at `president@imo.net`. The application must be submitted by an *IMO* member, but may also request support for other meteor workers of the same local, national meteor group as the *IMO* member. The proposal must state that all the candidates are committed to attend the *IMC* (except unforeseen circumstances) if the requested support is accorded in full.
2. An *IMC* Registration Form for each of the persons for which support is requested should be returned for the application to be valid, except if such a form was already sent earlier.
3. The application must also contain a brief curriculum vitae of each of these persons, focusing on aspects relevant to meteor work. Supported participants are expected to present either a talk or a poster at the *IMC* (to be indicated on the Registration Form).
4. The application must contain a motivation for attending the *IMC* and the importance of it to the person or group of persons requesting support.
5. The application must contain a budget for travel costs and registration, and the amount of support requested from the *IMO*. Other sources of external support, or their absence, must be mentioned. Finally, the proposal must also indicate to which extent *IMO* support is essential for being able to attend the *IMC*.
6. The applications should reach the President no later than July 1, 2001. The decision of the *IMO* Council will be made within the week after receipt of the application. If the requested support is accorded in full, the registration forms become final. If the requested support is not accorded, or only partially accorded, the candidates should inform the President within three weeks after notification of the *IMO* Council's decision if they want to sustain or withdraw their registration. The accorded support will be paid in cash at the *IMC*. Any unpaid registration fees will be deducted from the amount paid to the candidates.

Since the deadlines for applications and *IMC* registration coincide, we would like to emphasize that the standard registration fee of 200 DEM holds beyond the deadline for support applicants.

We strongly encourage all meteor workers who are motivated to attend the *2001 IMC*, but who are prevented to do so by financial considerations, to make use of this opportunity and to apply for support. Information about this *IMC* can be found above.

Solar Longitudes for 2001

compiled by Rainer Arlt

A conversion table of dates to solar longitudes using [1] is given as every year. The longitudes given are only valid for 2001. The conversion formulae for interpolating any time of the day is repeated here for your convenience. The error of this interpolation is smaller than the given accuracy of two decimals.

If you want to calculate the solar longitude $\lambda_\odot$ of a specific time of the day, you may use a linear interpolation between two dates. Suppose you have a certain *Date* and the *Time* in hours (UT), you get the solar longitude by

$$\lambda_\odot = \lambda_{\odot,\mathrm{Date}} + (\lambda_{\odot,\mathrm{NextDay}} - \lambda_{\odot,\mathrm{Date}}) \times \frac{\mathrm{Time}}{24\ \mathrm{h}}.$$

Alternatively, if you want to convert a certain solar longitude $\lambda_\odot$ in a time of the day, look up the *Date* with the next-smaller solar longitude in the table and calculate

$$\mathrm{Time} = \frac{(\lambda_\odot - \lambda_{\odot,\mathrm{Date}})}{(\lambda_{\odot,\mathrm{NextDay}} - \lambda_{\odot,\mathrm{Date}})} \times 24\ \mathrm{h}.$$

The solar longitudes of 1988–2005 are given in 2-hour increments at `http://www.imo.net/solarlong`.

Reference

[1] Steyaert, C., "Calculating the Solar Longitude 2000.0", *WGN* 19:2, April 1991, pp. 31–34.

Table 1 – Solar longitudes 2001. Dates refer to 0^h UT.

Date	$\lambda_\odot$	Date	$\lambda_\odot$	Date	$\lambda_\odot$	Date	$\lambda_\odot$	Date	$\lambda_\odot$	Date	$\lambda_\odot$
Jan 1	280.63	Mar 1	340.46	May 1	40.68	Jul 1	99.22	Sep 1	158.61	Nov 1	218.61
Jan 2	281.65	Mar 2	341.47	May 2	41.65	Jul 2	100.18	Sep 2	159.58	Nov 2	219.61
Jan 3	282.67	Mar 3	342.47	May 3	42.62	Jul 3	101.13	Sep 3	160.55	Nov 3	220.61
Jan 4	283.69	Mar 4	343.47	May 4	43.59	Jul 4	102.08	Sep 4	161.52	Nov 4	221.61
Jan 5	284.71	Mar 5	344.47	May 5	44.56	Jul 5	103.04	Sep 5	162.49	Nov 5	222.62
Jan 6	285.73	Mar 6	345.47	May 6	45.53	Jul 6	103.99	Sep 6	163.46	Nov 6	223.62
Jan 7	286.75	Mar 7	346.47	May 7	46.49	Jul 7	104.94	Sep 7	164.43	Nov 7	224.62
Jan 8	287.77	Mar 8	347.47	May 8	47.46	Jul 8	105.90	Sep 8	165.40	Nov 8	225.62
Jan 9	288.78	Mar 9	348.47	May 9	48.43	Jul 9	106.85	Sep 9	166.37	Nov 9	226.63
Jan 10	289.80	Mar 10	349.47	May 10	49.40	Jul 10	107.80	Sep 10	167.34	Nov 10	227.63
Jan 11	290.82	Mar 11	350.47	May 11	50.36	Jul 11	108.75	Sep 11	168.31	Nov 11	228.64
Jan 12	291.84	Mar 12	351.47	May 12	51.33	Jul 12	109.71	Sep 12	169.28	Nov 12	229.64
Jan 13	292.86	Mar 13	352.47	May 13	52.29	Jul 13	110.66	Sep 13	170.26	Nov 13	230.65
Jan 14	293.88	Mar 14	353.46	May 14	53.26	Jul 14	111.62	Sep 14	171.23	Nov 14	231.66
Jan 15	294.90	Mar 15	354.46	May 15	54.22	Jul 15	112.57	Sep 15	172.20	Nov 15	232.66
Jan 16	295.91	Mar 16	355.46	May 16	55.19	Jul 16	113.52	Sep 16	173.18	Nov 16	233.67
Jan 17	296.93	Mar 17	356.45	May 17	56.15	Jul 17	114.48	Sep 17	174.16	Nov 17	234.68
Jan 18	297.95	Mar 18	357.45	May 18	57.11	Jul 18	115.43	Sep 18	175.13	Nov 18	235.69
Jan 19	298.97	Mar 19	358.44	May 19	58.08	Jul 19	116.39	Sep 19	176.11	Nov 19	236.70
Jan 20	299.99	Mar 20	359.44	May 20	59.04	Jul 20	117.34	Sep 20	177.09	Nov 20	237.71
Jan 21	301.00	Mar 21	0.43	May 21	60.00	Jul 21	118.30	Sep 21	178.06	Nov 21	238.72
Jan 22	302.02	Mar 22	1.42	May 22	60.96	Jul 22	119.25	Sep 22	179.04	Nov 22	239.73
Jan 23	303.04	Mar 23	2.42	May 23	61.93	Jul 23	120.21	Sep 23	180.02	Nov 23	240.74
Jan 24	304.06	Mar 24	3.41	May 24	62.89	Jul 24	121.16	Sep 24	181.00	Nov 24	241.75
Jan 25	305.07	Mar 25	4.40	May 25	63.85	Jul 25	122.12	Sep 25	181.98	Nov 25	242.76
Jan 26	306.09	Mar 26	5.39	May 26	64.81	Jul 26	123.07	Sep 26	182.96	Nov 26	243.77
Jan 27	307.11	Mar 27	6.38	May 27	65.77	Jul 27	124.03	Sep 27	183.94	Nov 27	244.78
Jan 28	308.12	Mar 28	7.37	May 28	66.73	Jul 28	124.98	Sep 28	184.92	Nov 28	245.80
Jan 29	309.14	Mar 29	8.36	May 29	67.69	Jul 29	125.94	Sep 29	185.90	Nov 29	246.81
Jan 30	310.16	Mar 30	9.35	May 30	68.65	Jul 30	126.90	Sep 30	186.88	Nov 30	247.82
Jan 31	311.17	Mar 31	10.34	May 31	69.61	Jul 31	127.85				
Feb 1	312.19	Apr 1	11.32	Jun 1	70.57	Aug 1	128.81	Oct 1	187.87	Dec 1	248.83
Feb 2	313.20	Apr 2	12.31	Jun 2	71.52	Aug 2	129.76	Oct 2	188.85	Dec 2	249.85
Feb 3	314.22	Apr 3	13.30	Jun 3	72.48	Aug 3	130.72	Oct 3	189.83	Dec 3	250.86
Feb 4	315.23	Apr 4	14.28	Jun 4	73.44	Aug 4	131.68	Oct 4	190.82	Dec 4	251.87
Feb 5	316.24	Apr 5	15.26	Jun 5	74.40	Aug 5	132.63	Oct 5	191.80	Dec 5	252.89
Feb 6	317.26	Apr 6	16.25	Jun 6	75.35	Aug 6	133.59	Oct 6	192.79	Dec 6	253.90
Feb 7	318.27	Apr 7	17.23	Jun 7	76.31	Aug 7	134.55	Oct 7	193.77	Dec 7	254.92
Feb 8	319.28	Apr 8	18.22	Jun 8	77.27	Aug 8	135.51	Oct 8	194.76	Dec 8	255.93
Feb 9	320.29	Apr 9	19.20	Jun 9	78.22	Aug 9	136.47	Oct 9	195.75	Dec 9	256.95
Feb 10	321.31	Apr 10	20.18	Jun 10	79.18	Aug 10	137.42	Oct 10	196.73	Dec 10	257.97
Feb 11	322.32	Apr 11	21.16	Jun 11	80.13	Aug 11	138.38	Oct 11	197.72	Dec 11	258.98
Feb 12	323.33	Apr 12	22.14	Jun 12	81.09	Aug 12	139.34	Oct 12	198.71	Dec 12	260.00
Feb 13	324.34	Apr 13	23.12	Jun 13	82.04	Aug 13	140.30	Oct 13	199.70	Dec 13	261.02
Feb 14	325.35	Apr 14	24.10	Jun 14	83.00	Aug 14	141.26	Oct 14	200.69	Dec 14	262.03
Feb 15	326.36	Apr 15	25.08	Jun 15	83.95	Aug 15	142.22	Oct 15	201.68	Dec 15	263.05
Feb 16	327.37	Apr 16	26.06	Jun 16	84.91	Aug 16	143.19	Oct 16	202.67	Dec 16	264.07
Feb 17	328.38	Apr 17	27.04	Jun 17	85.87	Aug 17	144.15	Oct 17	203.67	Dec 17	265.09
Feb 18	329.39	Apr 18	28.02	Jun 18	86.82	Aug 18	145.11	Oct 18	204.66	Dec 18	266.10
Feb 19	330.40	Apr 19	28.99	Jun 19	87.77	Aug 19	146.07	Oct 19	205.65	Dec 19	267.12
Feb 20	331.41	Apr 20	29.97	Jun 20	88.73	Aug 20	147.03	Oct 20	206.65	Dec 20	268.14
Feb 21	332.41	Apr 21	30.95	Jun 21	89.68	Aug 21	148.00	Oct 21	207.64	Dec 21	269.16
Feb 22	333.42	Apr 22	31.92	Jun 22	90.64	Aug 22	148.96	Oct 22	208.64	Dec 22	270.18
Feb 23	334.43	Apr 23	32.90	Jun 23	91.59	Aug 23	149.92	Oct 23	209.63	Dec 23	271.20
Feb 24	335.44	Apr 24	33.87	Jun 24	92.55	Aug 24	150.89	Oct 24	210.63	Dec 24	272.21
Feb 25	336.44	Apr 25	34.85	Jun 25	93.50	Aug 25	151.85	Oct 25	211.62	Dec 25	273.23
Feb 26	337.45	Apr 26	35.82	Jun 26	94.46	Aug 26	152.82	Oct 26	212.62	Dec 26	274.25
Feb 27	338.45	Apr 27	36.79	Jun 27	95.41	Aug 27	153.78	Oct 27	213.62	Dec 27	275.27
Feb 28	339.46	Apr 28	37.77	Jun 28	96.36	Aug 28	154.75	Oct 28	214.62	Dec 28	276.29
		Apr 29	38.74	Jun 29	97.32	Aug 29	155.71	Oct 29	215.61	Dec 29	277.31
		Apr 30	39.71	Jun 30	98.27	Aug 30	156.68	Oct 30	216.61	Dec 30	278.33
						Aug 31	157.65	Oct 31	217.61	Dec 31	279.35

Meteor Shower Calendar: April–September 2001

compiled by Alastair McBeath and Rainer Arlt

1. April–June

Meteor activity picks up towards the April-May boundary, with shower peaks from the Moon-free Lyrids and π-Puppids, and the brightly moonlit η-Aquarids (maximum expected around May 5, 23^h UT, but good rates may persist from about May 3–10, possibly with several sub-maxima). During May and June, most of the activity is in the daytime sky, with six shower peaks expected during this time. Although a few meteors from the o-Cetids and Arietids have been reported from tropical and southern hemisphere sites visually in past years, ZHRs cannot be sensibly calculated from such observations. For radio observers, the expected UT maxima for these showers are as follows.

Table 1 – Maxima of the daytime meteor showers in April–June

Shower	Maximum
April Piscids	April 20, 8^h UT
δ-Piscids	April 24, 8^h UT
ϵ-Arietids	May 9, 6^h UT
May Arietids	May 16, 6^h UT
o-Cetids	May 20, 6^h UT
Arietids	June 7, 9^h UT
ζ-Perseids	June 9, 9^h UT
β-Taurids	June 28, 8^h UT

Some signs of most of these peaks were found in data from 1994–1999, except the April Piscids and May Arietids. The visual ecliptical complexes continue with some late Virginids and the best from the minor Sagittarids in May–June. New Moon on June 21 should allow some monitoring of any possible June Lyrids or June Bootids this year.

Lyrids

Active: April 16–25; Maximum: April 22, 4^h UT ($\lambda_\odot = 32\overset{\circ}{.}1$); ZHR = 15 (can be variable, up to 90);
Radiant: $\alpha = 271°$, $\delta = +34°$; Radiant drift: see Table 3; $V_\infty = 49$ km/s; $r = 2.9$;
TFC: $\alpha = 262°$, $\delta = +16°$ and $\alpha = 282°$, $\delta = +19°$ ($\beta > 10°$ S).

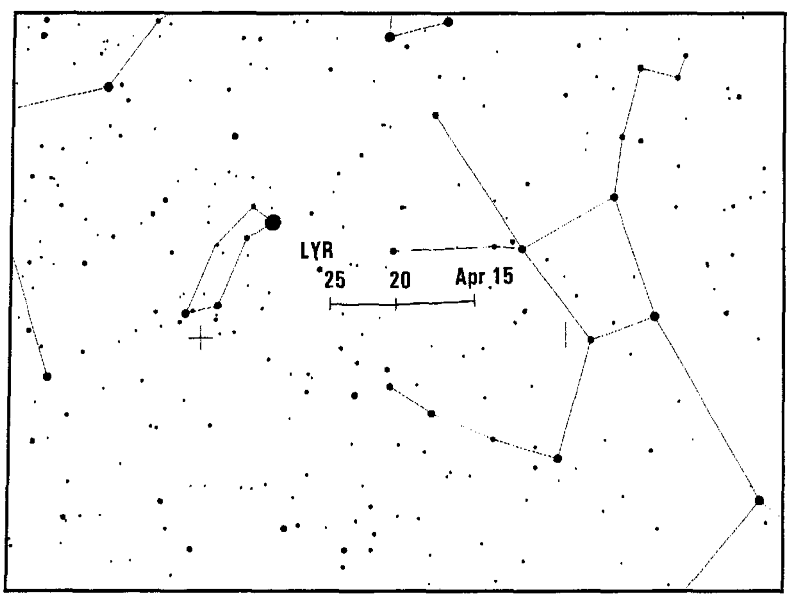

Figure 1 – Radiant position of the Lyrids.

The Lyrids are best viewed from the northern hemisphere, but they are visible from many sites north and south of the equator, and are suitable for all forms of observation. Maximum rates are generally attained for only an hour or two at best, although in 1996, mean peak ZHRs of 15–20 persisted for around 8–12 hours. The ZHR can be rather erratic at times, a variability also seen in 1996, when rates ranged between 10–30 from hour to hour during the peak. The last high maximum occurred in 1982 over the USA, when a very short-lived ZHR of 90 was recorded. This unpredictability always makes the Lyrids a shower to watch, since we cannot say when the next unusual return may occur.

As the shower's radiant rises during the night, watches can be usefully carried out from about 22^h30^m local time onwards. Perfect moonless conditions favor this year's mid-weekend display, with new Moon on April 23. The expected maximum should favor sites from extreme western Africa and the North Atlantic westwards to the eastern quarter of North America and the northern part of South America (where the radiant reaches a usable elevation) if correct, but variations in the stream could mean this is not the case in actuality.

π-Puppids

Active: April 15–28; Maximum: April 23, 15h UT ($\lambda_\odot = 33.5°$); ZHR periodic, up to around 40;
Radiant: $\alpha = 110°$, $\delta = -45°$; Radiant drift: see Table 3; $V_\infty = 18$ km/s; $r = 2.0$;
TFC: $\alpha = 135°$, $\delta = -55°$ and $\alpha = 105°$, $\delta = -25°$ ($\beta < 20°$ N).

This is a young stream produced by Comet 26P/Grigg-Skjellerup, and shower activity has only been detected from it since 1972. Notable short-lived shower maxima of around 40 meteors per hour took place in 1977 and 1982, both years when the parent comet was at perihelion, but before 1982, little activity had been seen at other times. In 1983, a ZHR of about 13 was reported, perhaps suggesting that material has begun to spread further along the comet's orbit, as theory predicts. Comet Grigg-Skjellerup is next due at perihelion in October 2002, so good activity is unlikely this year. However, as the peak falls exactly on new Moon, it is a superb year to check whatever happens.

The shower is best seen from the southern hemisphere, with useful observations mainly possible before local midnight, as the radiant is very low to setting after 1^h local time. This means sites from central Australia west to India should be best placed, if the maximum time proves correct. So far, visual and radio data have been collected on the shower, but the slow, bright nature of the meteors makes them ideal photographic subjects too. No telescopic or video data have been reported in any detail as yet either.

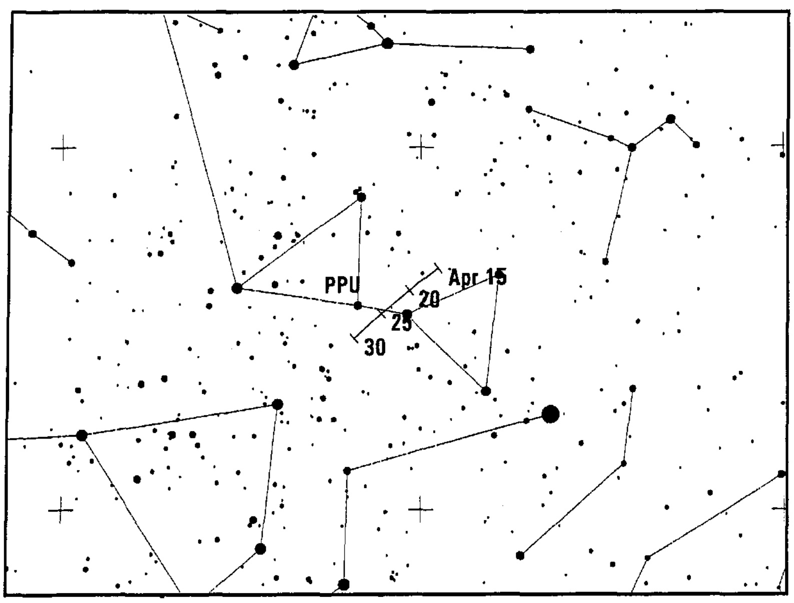

Figure 2 – Radiant position of the π-Puppids.

June Lyrids

Active: June 11–21; Maximum: June 16 ($\lambda_\odot = 85°$); ZHR variable, 0–5; Radiant: $\alpha = 278°$, $\delta = +35°$;
Radiant drift: June 10 at $\alpha = 273°$, $\delta = +35°$, June 15 at $\alpha = 277°$, $\delta = +35°$, June 20 at $\alpha = 281°$, $\delta = +35°$;
$V_\infty = 31$ km/s; $r = 3.0$;

This shower does not feature in the current *IMO* Working List of Visual Meteor Showers, as apart from some activity seen from northern hemisphere sites in a few years during the 1960s (first seen 1966) and 1970s, evidence for its existence has been virtually zero since. In 1996, several observers independently reported some June Lyrids, though no definite activity was subsequently found from 1997–1999 observations. The probable 2001 weekend maximum benefits from a waning crescent Moon, and we urge all observers who can to cover this possible stream. The radiant is a few degrees south of the bright star Vega (α Lyrae), so will be well on-view throughout the short northern summer nights, but there are discrepancies in its position in the literature. All potential June Lyrids should be carefully plotted, paying especial attention to the meteors' apparent velocity. Confirmation or denial of activity from this source by photography or video would be very useful too.

June Bootids

Active: June 26–July 2; Maximum: June 27, 07h UT ($\lambda_\odot = 95.7°$); ZHR variable, 0–100+;
Radiant: $\alpha = 224°$, $\delta = +48°$; Radiant drift: see Table 3; $V_\infty = 14$ km/s; $r = 2.2$;
TFC: $\alpha = 156°$, $\delta = +64°$ and $\alpha = 289°$, $\delta = +67°$ (β = 25–60° N).

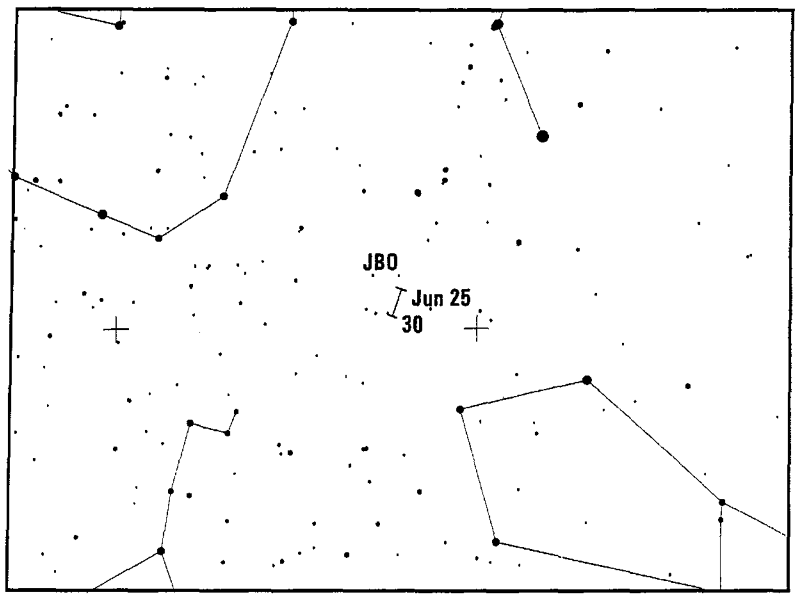

Figure 3 – Radiant position and drift of the June Bootids.

Following the wholly unexpected strong return of this shower in 1998, when ZHRs of 50–100+ were visible for more than half a day, we reintroduced this source to the Working List of Visual Meteor Showers, and encourage all observers to routinely monitor the expected activity period in case of future outbursts. Prior to 1998, only three definite returns of the shower had been detected, in 1916, 1921 and 1927, and with no significant reports between 1928–1997, it seemed probable the stream no longer encountered Earth. The dynamics of the stream are poorly understood. The shower's parent comet 7P/Pons-Winnecke was last at perihelion in January 1996 and is next due in May 2002.

The stream's orbit currently lies around 0.24 AU outside the Earth's at its closest approach, so the 1998 return resulted from a stream on a different orbit to the comet's, thus we have no way at present to predict any future June Bootid activity. The radiant is at a useful elevation for most of the short summer night in the northern hemisphere (only), and the setting crescent Moon will give dark skies after 23^h30^m to midnight local time on June 26-27.

2. July to September

The minor Pegasid (maximum July 9) and July Phoenicid (peak July 13) showers are both lunar casualties this year, but other minor shower activity continues apace from various near-ecliptic sources throughout the quarter, first from the Sagittarids, then the Aquarids and Capricornids, and finally the Piscids into September. The two strongest sources both suffer from the waxing gibbous Moon, the Southern δ-Aquarids (maximum on July 28, along with the minor Piscis Austrinids) and the α-Capricornids (peak on July 30). Moonset marginally favors more northerly sites for these, but their radiant declinations do not. The Southern ι-Aquarid and Northern δ-Aquarid maxima (August 4 and 8 respectively) are even worse-placed with full Moon on August 4.

Even the Perseids are badly hit by an early-rising last quarter Moon, with maxima expected near 14^h and 17^h UT on August 12. The former was next to non-existing in 2000 data, indicating the vanishing influence of fresh cometary material ejected in 1862 on the activity profiles of the next years. At least the κ-Cygnid and very weak Northern ι-Aquarid maxima fall in dark skies. The next full Moon on September 2 then helps ruin the best from both the α- (September 1, 0^h UT) and δ-Aurigids (around September 8)!

For daylight radio observers, the interest of May–June has waned, but there remain the visually-inaccessible gamma-Leonids (peak circa August 25, 9^h UT, though not found in recent radio results), and a tricky visual shower, the Sextantids (maximum expected at September 27, 9^h UT, but possibly occurring a day earlier. In 1999 a strong return was detected at $\lambda_\odot = 186°$, equivalent to 2001 September 29). The waxing Moon will present no problems for visual observers trying to catch some Sextantids in late September, though the radiant rises less than an hour before dawn in either hemisphere.

κ-Cygnids

Active: August 3–25; Maximum: August 17, ($\lambda_\odot = 145°$); ZHR = 3;
Radiant: $\alpha = 286°$, $\delta = +59°$; Radiant drift: see Table 3; $V_\infty = 25$ km/s; $r = 3.0$;
TFC: $\alpha = 330°$, $\delta = +60°$ and $\alpha = 300°$, $\delta = +30°$ ($\beta > 20°$ N).

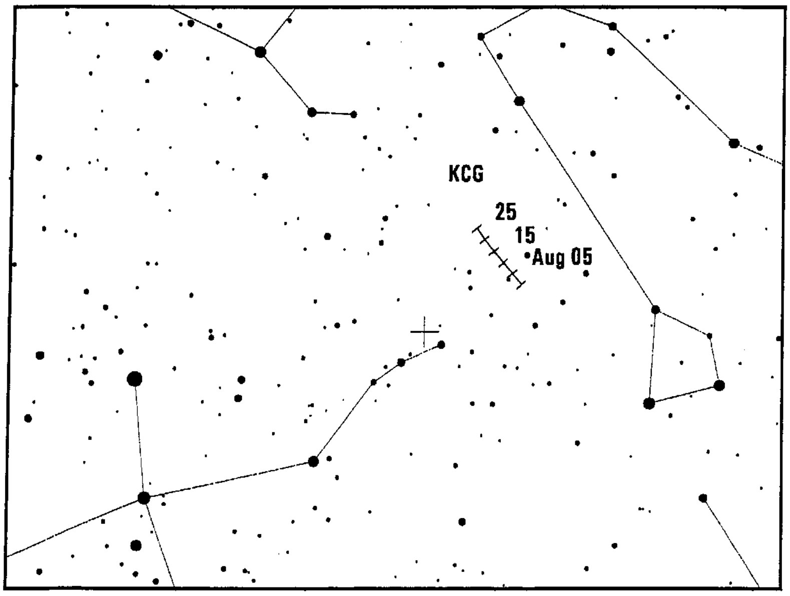

Figure 4 – Radiant position of the κ-Cygnids.

New Moon on August 19 presents no difficulties during the expected κ-Cygnid peak this year, but the shower is chiefly accessible from the northern hemisphere only. Its r-value suggests telescopic and video observers may benefit from its presence, but visual and photographic workers should note that occasional slow fireballs from this source have been reported too. Its almost stationary radiant results from its close proximity to the ecliptic north pole in Draco. There has been some suggestion of a variation in its activity at times, perhaps coupled with a periodicity in fireball sightings, but more data are urgently needed on a shower that often is ignored in favor of the Perseids during August.

Northern ι-Aquarids

Active: August 11–31; Maximum: August 19 ($\lambda_\odot = 147°$); ZHR = 3;
Radiant: $\alpha = 327°$, $\delta = -6°$; Radiant drift: see Table 3; $V_\infty = 31$ km/s; $r = 3.2$;
TFC: $\alpha = 255°$ to 0°, $\delta = 0°$ to +15°, choose pairs separated by about 30° in α ($\beta < 40°$ N).

The complex of July–August Aquarid showers are all rich in faint meteors generally, making them well suited to telescopic work. As moonlight favors only this very ill-known peak from the complex this year, 2001 is a good chance for some useful data collection on it.

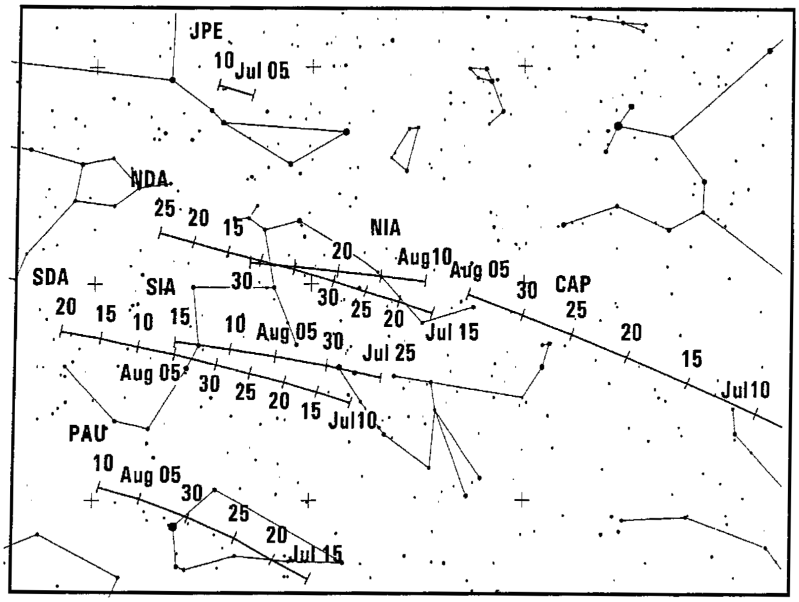

Figure 5 – Radiant position of the entire Aquarid complex.

An ill-defined maximum between $\lambda_{\odot} = 148°$–$151°$ was found in 1988–1995 visual results, which could mean the highest rates (even so, very weak) happen several days after the suspected peak time given here. Careful visual plotting is essential to define potential shower members for non-instrumental watchers.

Piscids

Active: September 1–30; Maximum: September 19, ($\lambda_{\odot} = 177°$); ZHR = 3;
Radiant: $\alpha = 5°$, $\delta = -1°$; Radiant drift: see Table 3; $V_\infty = 26$ km/s; $r = 3.0$;
TFC: $\alpha = 340°$ to $20°$, $\delta = -15°$ to $+15°$, choose pairs separated by about 30° in α (β any).

The Piscids are another poorly studied minor shower, with a peak radiant very close to the March equinox point in the sky. Consequently, they can be observed equally well from either hemisphere throughout the night near the September equinox, close to their probable maximum. This year, new Moon falls just two days before this time, but there is some doubt as to exactly when the Piscid peak may occur—or indeed, if there is only the one. Telescopic and video methods can be usefully employed to study it, along with methodical visual plotting.

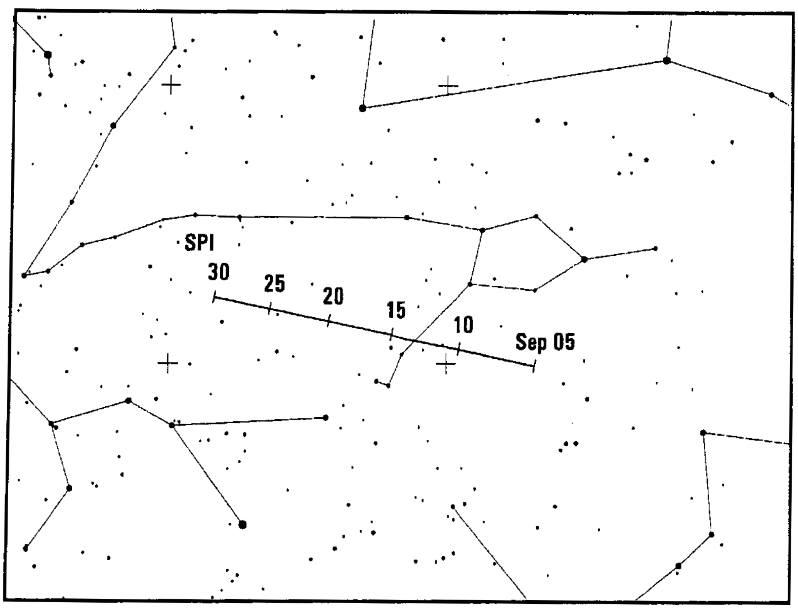

Figure 6 – Radiant position of the Piscids.

3. Working list of meteor showers

Table 2 – Working list of meteor showers for the period April–September 2001. Notice that the Perseids may have other or additional peak times; see text. Streams marked with an asterisk are periodically or occasionally active, and therefore no ZHR is cited. The "maximum" dates cited for the Virginids and the Puppid/Velids should be seen as reference dates rather than true maxima.

Shower	Activity	Maximum		Radiant		V_∞	r	ZHR
		Date	$\lambda_\odot$	α	δ	(km/s)		
Virginids (VIR)	Jan 25–Apr 15	Mar 24	4°	195°	−04°	30	3.0	5
Lyrids (LYR)	Apr 16–Apr 25	Apr 22	32°.1	271°	+34°	49	2.9	15
π-Puppids* (PPU)	Apr 15–Apr 28	Apr 23	33°.5	110°	−45°	18	2.0	
η-Aquarids	Apr 19–May 28	May 05	45°.5	338°	−01°	66	2.7	60
Sagittarids (SAG)	Apr 15–Jul 15	May 19	59°	247°	−22°	30	2.5	5
June Bootids* (JBO)	Jun 26–Jul 02	Jun 27	95°.7	224°	+48°	18	2.2	
Pegasids (JPE)	Jul 07–Jul 13	Jul 09	107°.5	340°	+15°	70	3.0	3
July Phoenicids* (PHE)	Jul 10–Jul 16	Jul 13	111°	32°	−48°	47	3.0	
Piscis Austrinids	Jul 15–Aug 10	Jul 28	125°	341°	−16°	35	3.2	5
Southern δ-Aquarids (SDA)	Jul 12–Aug 19	Jul 28	125°	339°	−30°	41	3.2	20
α-Capricornids (CAP)	Jul 03–Aug 15	Jul 30	127°	307°	−10°	25	2.5	4
Southern ι-Aquarids (SIA)	Jul 25–Aug 15	Aug 04	132°	334°	−15°	34	2.9	2
Northern δ-Aquarids (NDA)	Jul 15–Aug 25	Aug 08	136°	335°	−05°	42	3.4	4
Perseids (PER)	Jul 17–Aug 24	Aug 12	139°.8	46°	+58°	59	2.6	110
κ-Cygnids (KCG)	Aug 03–Aug 25	Aug 17	145°	286°	+59°	25	3.0	3
Northern ι-Aquarids (NIA)	Aug 11–Aug 31	Aug 19	147°	327°	−06°	31	3.2	3
α-Aurigids (AUR)	Aug 25–Sep 05	Sep 01	158°.6	84°	+42°	66	2.5	10
δ-Aurigids (DAU)	Sep 05–Oct 10	Sep 08	166°	60°	+47°	64	3.0	6
Piscids (SPI)	Sep 01–Sep 30	Sep 19	177°	5°	−01°	26	3.0	3

Table 3 – Radiant positions during April–September 2001 in α and δ.

					VIR			
Apr 10	SAG	LYR	PPU		203° −7°			
Apr 15	224° −17°	263° +34°	106° −44°	ETA	205° −8°			
Apr 20	227° −18°	269° +34°	109° −45°	323° −7°				
Apr 25	230° −19°	274° +34°	111° −45°	328° −5°				
Apr 30	233° −19°			332° −4°				
May 5	236° −20°			337° −2°				
May10	240° −21°			341° 0°				
May20	247° −22°			350° +5°				
May30	256° −23°							
Jun 10	265° −23°							
Jun 15	270° −23°							
Jun 20	275° −23°	JBO						
Jun 25	280° −23°	223° +48°						
Jun 30	284° −23°	225° +47°	CAP			JPE		
Jul 5	289° −22°		285° −16°	SDA		338° +14°		
Jul 10	293° −22°	PHE	289° −15°	325° −19°	NDA	341° +15°	PER	PAU
Jul 15	298° −21°	32° −8°	294° −14°	329° −19°	316° −10°		12° +51°	330° −34°
Jul 20			299° −12°	333° −18°	319° −9°	SIA	18° +52°	334° −33°
Jul 25			303° −11°	337° −17°	323° −9°	322° −17°	23° +54°	338° −31°
Jul 30	KCG		308° −10°	340° −16°	327° −8°	328° −16°	29° +55°	343° −29°
Aug 5	283° +58°	NIA	313° −8°	345° −14°	332° −6°	334° −15°	37° +57°	348° −27°
Aug10	284° +58°	317° −7°	318° −6°	349° −13°	335° −5°	339° −14°	43° +58°	352° −26°
Aug15	285° +59°	322° −7°		352° −12°	339° −4°	345° −13°	50° +59°	
Aug20	286° +59°	327° −6°	AUR	356° −11°	343° −3°		57° +59°	
Aug25	288° +60°	332° −5°	76° +42°		347° −2°		65° +60°	
Aug30	289° +60°	337° −5°	82° +42°	DAU				
Sep 5			88° +42°	55° +46°	SPI			
Sep 10				60° +47°	357° −5°			
Sep 15				66° +48°	1° −3°			
Sep 20				71° +48°	5° −1°			
Sep 25				77° +49°	9° 0°			
Sep 30				83° +49°	13° +2°			

The Meteor Train Observing Project

Jan Verbert and Goedele Deconinck

The meteor train observing project is restarted and extended. The goals of observing meteor trains are repeated and the specific research subjects are discussed. Finally the use of the new visual train observing form will be explained.

1. Introduction

At the start of the 1990s Mark Vints had set up an observing project for meteor trains [1]. Train observations became standardized and were recorded in a meteor database. In the first years many observations were sent in but in the last four years they decreased rapidly. Moreover, Mark himself could not give much time to work on the project. That is why we have decided to give the project a second chance, and we hope to get some useful results.

2. Why observe trains?

Meteor train data are very often neglected by a lot of observers. Since the project started, an improvement has been visible, but most observers still just mention when trains appear, sometimes with the train duration. Train observations are still sent for the database far too rarely. It is clear that many observations are needed because of the rather low frequency of meteor trains.

There are lots of reasons to study train phenomena, already pointed out in [1]. We will rephrase some of them here and add our specific research subjects:

a) From a physical-chemical point of view, there are two processes that govern train visibility, an activation process which creates ionization and a decay process that destroys ionization. The quantity of ionized atoms depends primarily on the energy or speed of the meteors. The decay of the train is influenced among other things by turbulent diffusion in the atmosphere. The relative influence of these two processes can be elucidated by a study of train percentages and durations for different showers as a function of meteor brightness.

b) There are indications that there might be some differentiation in train percentages in a meteor stream as the earth passes through filaments of different age. For example, the Perseids have already shown more trains on the maximum night than on the other nights [2]. Maybe this can also be seen in previous Leonid passages, despite the problem that probably no observers had time to mention train durations because of the high meteor frequency. Perhaps video observations can help here.

c) Apart from meteor spectra, trains are the only probe of ionospheric conditions. It is very likely that the number or duration of meteor trains is dependent on solar activity or other changing ionization events. The study of the upper atmospheric winds by observing long drifting trains can also be valuable.

d) It is known that different showers show different train percentages [3,4]. It is also clear that the speed is a primary factor, but not the only one. Maybe the population index or other properties (such as composition) are important too.

e) Then maybe there is a variation in train activities during the night. This would be the extension of the project. The observing form (see the next section) has also been adapted in this way. This would be the most challenging point of the project, and many observations are needed for this part. In [5], a type of long-enduring trains has been discussed, which occur only in the first half of the night and have a specific height. Maybe there are more (or longer) persistent trains in the first half of the night.

f) Of course, other train material is also of interest, such as drawings or photographs from drifting trains or telescopic observations of trains.

3. How to observe meteor trains?

The meteor train observing form composed by Mark Vints [6] has been adapted slightly. The main properties have been maintained but an additional table has been inserted.

First of all, visual observers are asked to estimate the train duration for every meteor seen. Merely mentioning that a persistent train appeared is definitely not enough. Drifting trains should be carefully plotted on the standard gnomonic maps.

Then, after the observation, the train form should be filled in. The first four lines are the standard lines as on the visual observing form. The first table gives the variation of trains during the night. The periods used for the standard visual observation can also be used here, thus periods from 1 to 2 hours (or 10 to 15 meteors when a shower maximum occurs). Per period and for each shower the number of meteors, the average magnitude, the number of trains and the average duration of the trains should be mentioned. If more periods are necessary or more showers are observed, a second form can be used.

International Meteor Organization

VISUAL METEOR TRAIN OBSERVING FORM

Date: _______ (day), _______ (month), ______ (year). Begin: _____^{h}_____^{m}. End: _____^{h}_____^{m}. (UT)

Location: λ = ____°____′____″ E/W, φ = ____°____′____″ N/S, h = _____ m. IMO Code: __________

Place: ______________________________ Country: ______________

Observer: ______________________________ IMO Code: __________

Observed numbers of meteors (*N*) and trains (*n*) per period and per shower (*m*: av. magn.; *d*: av. dur.):

Period (UT) (^{hm} - ^{hm})	T_{eff} (^{h})	*F*	Lm	____				____				____				____				Spor.			
				N	*m*	*n*	*d*	*N*	*m*	*n*	*d*	*N*	*m*	*n*	*d*	*N*	*m*	*n*	*d*	*N*	*m*	*n*	*d*
-																							
-																							
-																							
-																							
-																							
-																							

Magnitude & train distribution table. Shower IMO Code: __________

magnitude	<-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	Tot
meteors														
train 0.5 s														
1 s														
2 s														
3 s														
4 s														
5 s														
>5 s														
Total														
%														

Specify events brighter than magnitude -6 and/or exceeding 5 seconds duration:

magnitude: ___ duration ___ ___ ___ ___ ___ ___ ___ ___ ___ circle those events

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ that were drifting

___ ___ ___ ___ ___ ___ ___ ___ ___ ___

___ ___ ___ ___ ___ ___ ___ ___ ___ ___

Other showers: first line: magnitude distribution: (mag) nr, (mag) nr, (mag) nr, … + total
second line: trains in format nr x n^m of n^s (number, mag, duration)

Shower: _____ ______________________________
____

_____ ______________________________
____

_____ ______________________________
____

_____ ______________________________
____

The second table is needed to specify the different trains for the greatest shower observed during the whole observation. In the first line the magnitude distribution has to be filled in. The rest of the table is used for the train distribution of the shower. The last line gives the percentage of trains per magnitude class. Meteors brighter than −6 or train durations exceeding 5 seconds duration do not fit in the table and must be specified underneath.

The last lines have to be used for other showers and sporadics, each first line for the magnitude distribution and each second line for the trains. Write down the data of all observed showers; also if you did not see a meteor or train of that shower then just write 'no meteors' or 'no trains', this is valuable information too!

When the form is filled in, it can be sent to us. Alternatively it is certainly possible to send an e-mail with the observational data to the given address. You can put your data in your e-mail text or as an attachment in plain ASCII or text format if possible.

4. Conclusion

We hope that a lot of observations will come to us in order to set up a database that will be used for the above mentioned investigations. The possible daily variation will only be recognized if many observations are gathered together. That is why we encourage meteor observers to take this little effort extra to send in the necessary information. Observations from previous years can also be sent to us and would be very helpful.

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Dark Meteor Database: News from 1998–2001

Alastair McBeath

An update of information collected by the Dark Meteor Database since the previous article in 1998 [1] is presented and discussed. The proportion of observers who have reported dark meteors remains at about 70%. A possible new form of dark meteor which may be due to test flights of military vehicles is noted, along with some comments on a recent observation of far-ultraviolet meteors from space.

1. Introduction

Judging by the rate of dark meteor reporting, or its absence, where no fresh reports were submitted during 2000, though new information arrived in both 1998 and 1999, it seems clear that observers need more regular reminders that this project continues to exist, and that we need people to continue providing positive and negative reports of dark meteor sightings on a more regular basis. In order to assist potential observers, the standard dark meteor report form is again published with this article, and all who have not yet reported details are invited to do so.

For newcomers to the *IMO*, or those who have forgotten, dark meteors are meteor-like streaks of darkness seen against the night sky because they are apparently blacker than the very deep blue of the clear, starlit sky. Descriptions from observers of these events were given or referred to in earlier articles in this series (for references, see [1]), and as these are still available as back issues of the appropriate publications, there seems little need to repeat them again here.

Reasons were also outlined earlier for ensuring the anonymity of all observers reporting dark meteors, an anonymity which was extended to those people providing other thoughts and material on dark meteors in [1], and this policy is continued here.

2. New reports

Between April 1998 and March 2001, five more people provided dark meteor information for the first time, four with observations of such occurrences, and one who despite years of visual meteor watching had not seen any dark meteors. This brings the total number of observers to 44, with 12 confirming they had never knowingly seen a dark meteor, and 32 reporting at least one event. The proportion of positive sightings thus increased slightly to 73% this time, an imperceptible shift from the 72% of the previous report.

Two established observers also provided fresh data on the numbers of dark meteors seen over a given time interval (specifically during their meteor watching in 1998), and how many "ordinary" meteors were observed in the same time. The totals of these values now reported stand at 21 dark meteors in $454^{h}.4$, with 4751 normal meteors seen. From these, average "dark meteor rates" of roughly one per 22 h observing, or one dark meteor for every ≈ 226 ordinary events, can be derived, but these should be viewed more as confirming the relative rarity of dark meteors, rather than giving specific values for direct comparison. As was noted before, there is a tendency for dark meteors to avoid less clear nights, but the evidence for this is still tenuous.

The appearances described by most observers were generally unchanged from earlier discussions, though there seems a growing, if still too often circumstantial, body of reports favoring dark meteors as having moderate to fast apparent angular motions in the sky, compared to typical meteoric apparent speeds. There is a similar set of reports which suggest most dark meteor tracks are relatively short—no more than 10°–15° in the estimates so far. As with all the above details however, much more hard information is needed.

One observer reported seeing an unusual number of possible dark meteors over an extended period of time, which seemed rather different to the more commonly reported objects of this class. The descriptions of these included some seen using 10×50 binoculars as well as the naked-eye, and were often of a "V"-shaped effect, rather like the shock wave around the head of a bullet, though some were also described as looking a little like a dark half-Moon. These do not appear to have been reported by others before, even those past observers using optical instruments, and certainly not in comparable numbers (several a night at times). Attempts to clarify whether the effects were specific to that observer met with little success, as either clouds intervened when a suitable co-observer was available, or no one was on-hand to compare data with on clearer nights and one or more of these dark objects was observed. There was some concern that a military base was relatively nearby, and that some, perhaps all, of these curious objects resulted from nocturnal exercises using unknown types of flying vehicles. The nature of such military activity could not be established, unsurprisingly, and attempts by the observer to watch from different sites to see if anything similar was reported well away from the usual location, were also unsuccessful, with too little observing time amassed elsewhere to give a viable comparison. We can only hope that future efforts will be more fortunate in better-defining what was being seen in this case.

3. Ultraviolet meteors

A forwarded press release posted on *IMO-News* on February 17, 2000 ("NRL Instrument Makes First UV Observation of Meteor in Space"), discussed the first far-ultraviolet meteor image being recorded by an ionospheric monitoring instrument on board the US Department of Defense's ARGOS satellite, on November 18, 1999. Far-ultraviolet light is heavily absorbed by the Earth's lower atmosphere, so such observations from the ground are generally considered impossible, and although an actual height determination was not possible for this meteor, known atmospheric absorption parameters mean the meteor must have been significantly higher than 100 km above the surface.

One of a number of possible explanations I suggested in the first article in this series [2] for dark meteors was the rare detection of meteoric ultraviolet light, and this new observation brings us back to reconsider this aspect again. Obviously, a great deal more data is needed on ultraviolet meteoric emissions, but it is interesting that the presently available data suggests such emissions can occur well above where most visible meteor ablation happens in the atmosphere. This would tie in very well with I.S. Astapovich's visual observations of "blue pre-meteor trains" in very transparent skies (see [3] on these), if not the more typical dark meteors. The next step would be to establish whether and how well a range of human eyes can detect ultraviolet light, and compare that with the rarity of dark meteor sightings and overall levels of meteor activity.

Acknowledgments

My thanks are extended to all past contributors to the Dark Meteor Database. Anyone with new data to report is encouraged to do so.

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Ongoing Meteor Work

The Disintegrating Comet 73P/Schwassmann-Wachmann 3 and Its Meteors

Hartwig Lüthen, Rainer Arlt, and Michael Jäger

We report on the disintegration of Comet 73P/Schwassmann-Wachmann 3 (SW3) and its production of meteoroid trails. The evolution of dust trails of the Comet is studied for ejection years back to the 1890 perihelion passage. Close approaches were found for the 1908 dust trail in 1936 and the 1995 dust trail in 2022 with farther approaches in 1984, 2001, 2011, and 2017. Scrutinization of visual observing records reveals that no outburst of SW3 meteor activity has been reported until now, but distinct annual background activity is found with ZHRs between 1 and 3. The alleged SW3 meteor outburst in 1930 is severely questioned. Prospects for the 2001 encounter of the 1941 dust trail are given. The maximum would be on May 30.41, with a radiant position at $\alpha = 212°$, $\delta = +28°$.

1. Introduction

The disintegration of Comet 2D/Biela last century has always been cited as a classical textbook example for the origin of meteoroids. A similar case of fragmentation has recently been observed in 73P/Schwassmann-Wachmann 3. Discovered at Hamburg-Bergedorf observatory in 1930 [1,2] this typical Jupiter group comet has an orbital period of about 5.3 years and a perihelion distance q close to 1 AU, making it a potential source for meteors. In fact there is a report of a meteor outburst observed on June 9-10, 1930 which may be related to this Comet.

During the 1995 return, the Comet underwent a massive outburst of about 5 magnitudes in amplitude, bringing that Comet to the edge of visibility for the naked eye. Within the distinctly elongated coma (Figure 1b) Boehnhardt and Käufl (see [3,4,5] for full history) discovered four fragments in the nucleus [6]. During the return of the Comet in late 2000, two of these fragments were recovered by Galad and Koleny (Fragment B) and Kadota (Fragment C). A fragment not observed in 1995, but obviously also released at the 1995 return, was discovered by Jäger (Fragment E). The fragments had separated by more than 30′ and appeared as individual small comets following the main object. ([7] and Figure 1c).

This study follows three objectives: (i) to reanalyze the historical material claiming a meteor outburst in 1930; (ii) to use a dust-trail model to pinpoint the times at which we passed through dust trails in the recent past, in order to allow a reanalysis of still existing observations, and (iii) to alert observers for possible future meteor showers due to debris ejected from 73P/Schwassmann-Wachmann 3.

2. Methods

Comet Photography

Comets were photographed by one of us (MJ) by means of a Schmidt camera ($f = 300$ mm, $f/1.5$; Celestron) or a "Deltagraph" ($f = 990$ mm, $f/3.3$, basically a parabolic mirror with a highly sophisticated coma corrector, Astrooptik Keller), on hyper-sensitized technical pan film (tp2415 or 6415).

Dust trail computations

The orbit of P/Schwassmann-Wachmann 3 was integrated back to 1890, using the orbit from the JPL database, allowing for the gravitational effects of all nine planets and for the non-gravitational terms $A1$ and $A2$. Extending the computation further backwards was not attempted. Slight variation of the initial orbit resulted in massive changes in the times of perihelion passage when integrated to back to the pre-1890 years, indicating that the accuracy of the initial orbit does not warrant such an attempt. Then orbits of test particles having the orbital elements of the comet at perihelion, but different semimajor axis were generated, and integrated to the present time (using the gravitational effects of the major planets except Pluto). This approach is similar to that of McNaught & Asher for the Leonids [8].

Another approach would be to leave the semimajor axis unchanged and to vary the radiation pressure parameter β as done by Lyytinen and van Flandern [9]. However the results of both techniques are very similar as checked for the Leonids and for the Ursids (Lyytinen, *pers. comm.*).

For the integrations the orbit integrator K11, Version 3.0 by Christian Glowinski was used at an accuracy factor of 50 (for the comet integration) or 25 (for the trail computation). This is basically a Runge-Kutta integrator working with a dynamical adjustment of the integration interval. The main advantage is its possibility to process batch jobs, since computation times were quite lengthy on a 366-MHz Celeron PC. Software for generating the input batch files and for analyzing the output files were written by one of us. The resulting $r_D - r_E$ values were plotted as a function of perihelion time; this type of plot giving a rapid overview of even the most chaotic trails. Radiant positions were predicted using software published elsewhere [10]. Star maps were plotted using the package GUIDE 7.0.

3. Assessment of observational records

Reported 1930 meteors

Significant or even strong meteor activity observed from Japan in 1930 is often cited in connection with the discovery of Comet 73P/Schwassmann-Wachmann 3 in the same year. However, the term of a rich meteor display connected with that Comet needs caution.

When we look into the original Kyoto Bulletins of 1930, we find an interesting note in Bulletin 172 about enhanced meteor activity. T. Miyasawa observed faint meteors on May 21, 1930, from a radiant at $\alpha = 219\overset{\circ}{.}75$, $\delta = +29\overset{\circ}{.}67$ [11]. The estimated orbit seemed close to SW3's.

In Bulletin 173, we find details: Miyasawa observed 14 meteors in 1.13 hours (particular period: 11 in 0.42 hours), and his colleague K. Nakamura, 100+ in 0.42 hours [12]. They claim it was "impossible to record all of them." They noted "rapidly declining activity on later days" drawing the conclusion that the meteors are of "other origin than the above mentioned cometary orbit" (SW3, whose orbit was passed on June 9).

The predicted radiant according to Kyoto Bulletin 171 is $\alpha = 234\overset{\circ}{.}5$, $\delta = +44°$ (typo corrected in Kyoto Bulletin 173, [13,14]); if we use their parabolic orbit (Bulletin 171) for a modern radiant prediction by the program of Neslusan et al. [10], we get $\alpha = 219°$, $\delta = +45°$. If we use the orbit given by Kronk [2], we get $\alpha = 220°$, $\delta = +44\overset{\circ}{.}5$, with a minimum distance between the orbits of Comet and Earth of 0.005 AU. As the peak time was predicted for about June 9, a report by K. Nakamura emerges:

On June 9, 1930, he reports 59 in 1.00 hours; on June 10 he reports 36 in 0.50 hours. These rates of 60–70 meteors per hour are generally cited. However, the observations by K. Nakamura should be carefully scrutinized. A similar report for the June Bootids (Pons-Winneckids) in 1921 came from him which turns out to be most questionable. He always claims all meteors were very faint. Consider the comments about the SW3-meteors: "all of those meteors were very faint, and only few of them were as bright as 4th magnitude." There was a full Moon on June 9-10. He further writes about "June 9 and June 10 when bright lunar haloes were high above the southern horizon" [15]. Even observers with very high perception will hardly be able to spot a considerable number of +5 and +6 meteors under such poor conditions (moon and cirrus).

Another item makes us extremely cautious. Checking the original plots of Nakamura for the June Bootids we found that what he calls high activity consists of very many meteors which start *within* the radiant and move out of it for about 10° [16]. Every present-day meteor observer knows that this is nonsense. His companion observer, I. Yamamoto, provides much more consistent plots, though an activity around 10 at best for the 1921 June Bootids.

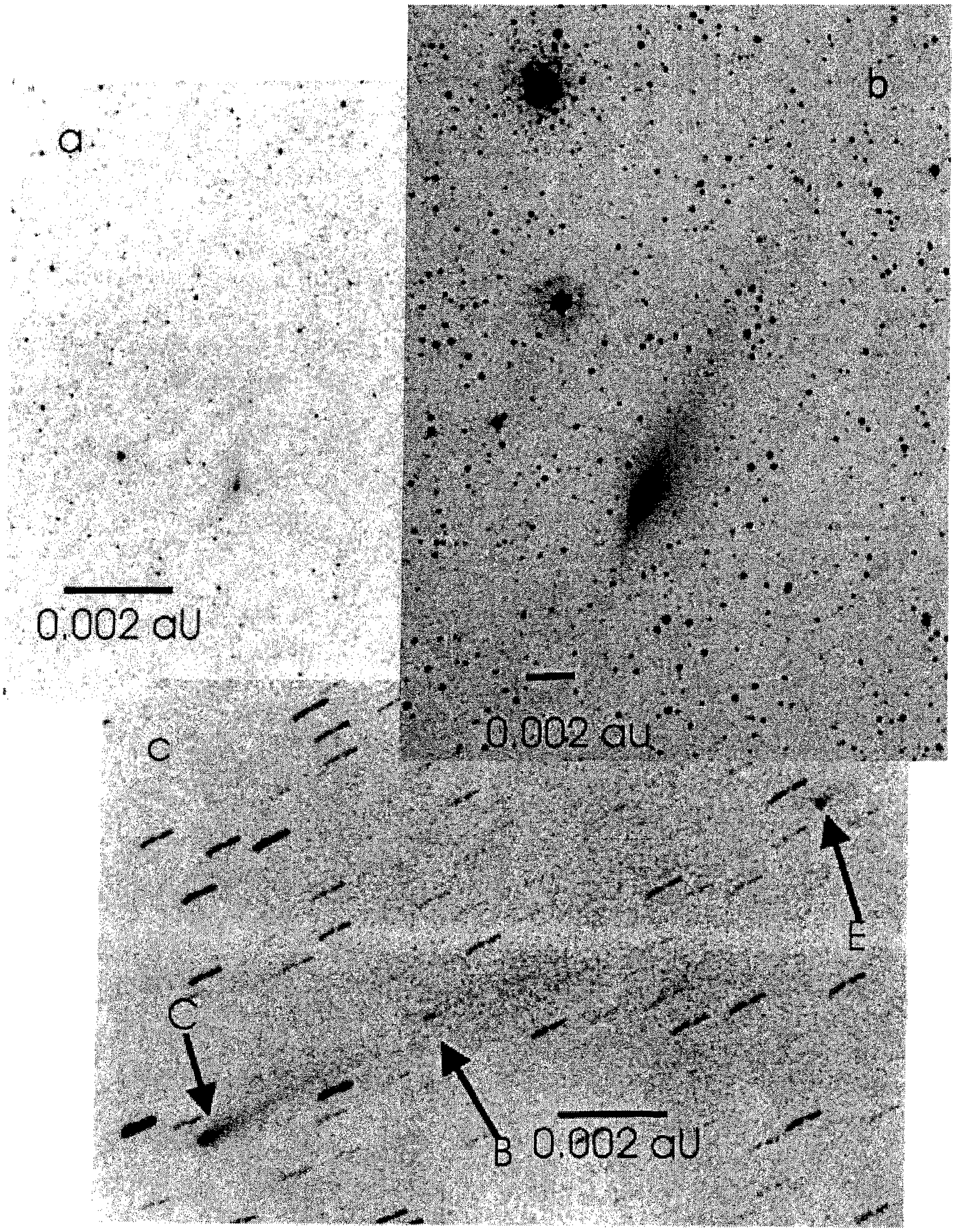

Figure 1 – Development of Comet 73P/Schwassmann-Wachmann 3 as shown by photographs of co-author MJ. a) April 3, 1990, 2^h36^m–2^h40^m UT, taken with the Schmidt camera. Although very close to the Earth ($\Delta = 0.41$ AU), the Comet is quite small and faint (magnitude +10.5). The scale of 0.002 AU is also shown. Note the small coma; the central condensation is surrounded by a faint (gaseous?) halo. b) Composite image of the Comet taken with the same camera on December 15, 1995, 17^h13^m–17^h18^m and 17^h22^m–17^h26^m UT. Although the Comet is very far away from the Earth ($\Delta = 1.79$ AU), it was about 2 magnitudes brighter than in 1990, and the coma was larger in size (compare the 0.002 AU scale). The bright globular cluster in the field is M30; c) the Comet during the somewhat unfavorable 2000 apparition, image taken with the Deltagraph on December 5, 2000. The image is a composite of two images guided indirectly on the Comet (4^h30^m–4^h44^m and 4^h50^m–5^h01^m UT). Three fragments are shown: The main object (Fragment C), the tiny Fragment B and the brighter Fragment E which was discovered by co-author MJ during the 2000 perihelion approach. All three fragments display tails.

Other old sources

We tried to reveal other observations or at least hints on activity from a possible shower of the Comet. Very old reports in Chinese chronicles were compiled by Tian-shan [17]. He found a few descriptions of showers in May; one prominent example is that of 245 B.C. on April 12. This date would fall on May 13 for the epoch 1900. The striking fact is that Tian-shan infers a radiation from ζ Herculis ($\alpha = 250°$, $\delta = +32$) from the chronicle report.

Other sources of meteors in May are not reliably locatable and must be neglected. Only the report of 1539 is interesting as it has an exact date of May 30, corresponding to June 4 for the epoch 1900.

Without exact date but annotated with some additional information is the report from May 1910 describing that the meteors "glided as though weaving." We may interpret the word "weaving" as a non-linear motion, an impression which is much stronger for very slow meteors. The possible link to the η-Aquarids would thus not be suitable, but as the expression is also used for definite Leonid records (very high velocity), we cannot use the description for the distinction between η-Aquarids and Schwassmann-Wachmann-3 meteors.

The first comprehensive radiant catalog by Denning of 1899 gives quite a few suitably located radiants of which we list the most probable ones formed by considerable meteor numbers [18]. It is worth noting that Denning did not give any interesting radiant in his more recent list of 1923 [19]. The probability that the shower was active is thus somewhat higher for the last century then for the time 1900–1923; the only significant meteor sources are found from Italian 1872 data when a comprehensive meteor project was carried out by the Associazione Meteorica Italiana. The convergence position of 18 meteors at $\alpha = 210°$, $\delta = +48°$, for May 3–15, 1872, is found to be closest to the expected radiant area, though the date is early. Other convergence areas are made of 17 meteors from $\alpha = 215°$, $\delta = +55°$, for May 26–June 11, 1872, and 12 meteors from $\alpha = 214°$, $\delta = +16°$, for May 26–June 13, 1872.

The radiant list of Malzev reporting on meteors from 1929 does not contain any reasonable position [20]; the same holds for lists in the same journal of other years in the 1920s which we are not going to cite here explicitly. It is at least interesting that there was probably no notable activity in the year before the dubious outburst of 1930.

The analysis of 19 689 radar meteors by Sekanina [21] which were observed from 1966 to 1969 reveals no radiant clearly linked to Comet 73P/Schwassmann-Wachmann 3. Sekanina mentions a shower called α-Draconids at $\alpha = 207°$, $\delta = 64°$ for June 22 as the closest candidate, but it is obviously too far from the source we search for.

T. Hashimoto from the *Nippon Meteor Society* kindly searched the Society's Journal, the *Astronomical Circular*, for radiant determinations of the so-called May α-Bootids [22]. The five occurrences given in Table 1 may indicate weak annual activity, but the meteor numbers are small, and no real assessment of the data is possible without the original details. As the observers apparently searched for listed positions instead of unknown radiants, we cannot evaluate the prominence of these convergence points above the background noise level.

Table 1 – A search through the *Astronomical Circular*, the journal of the *NMS* (in Japanese), by Takema Hashimoto [22].

Date	α	δ	N	Observer
1969 May 17-18	215°	+25°	5	Y. Takeuchi
21-22	215°	+20°5	6	A. Kawagoe
1970 May 30-31	212°	+23°	4	Ogasawara
30-31	214°	+19°	7	Ogasawara
1971 May 30-31	215°	+20°	5	K. Oikawa

Recent observations

The full set of meteors recorded by intensified video within the network of the Arbeitskreis Meteore and by other camera operators contains more than 24 000 meteors [23]. We checked the period May 20–June 10 of 1999 and 2000 for a possible convergence of meteors near the theoretical position in Bootes. The methods of radiant determination with the Radiant program are described in [24]. We used the most elaborate probability mode and considered zenithal attraction and diurnal aberration. None of the radiant distributions shows an indication for meteors from Schwassmann-Wachmann 3 in 1999–2000 as covered by the video data. An example of such a radiant distribution is shown in Figure 2

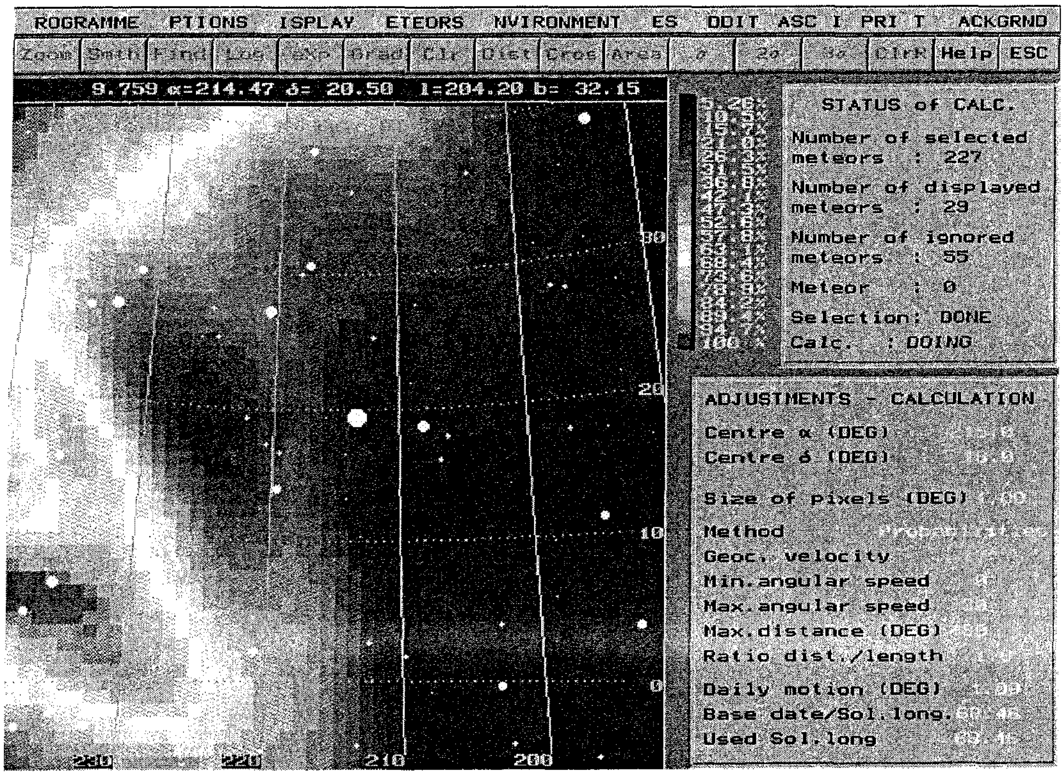

Figure 2 – Radiant analysis of the SW3-ids from video meteor monitoring in 1999 and 2000.

This is at odds with the weak but possibly distinct activity from the source of the so-called May α-Bootids as reported by the Nippon Meteor Society [25]. We use the data reported therein to obtain a rough ZHR profile. Quite a few observers among the contributors have very high corrected sporadic hourly rates. Since the numbers of sporadic meteors are larger than those of the shower, we obtain perception corrections from the sporadic rates assuming a standard value of HR=15 (which is certainly an upper limit). These corrections are: Seishi Akagi (AKASE), $c_\mathrm{p} = 0.9$, Takema Hashimoto (HASTA), $c_\mathrm{p} = 2.3$ Hiroyuki Kodama (KODHI), $c_\mathrm{p} = 0.8$, Kazuhiro Osada (OSAKA), $c_\mathrm{p} = 3.5$, Mitsue Sakaguchi (SAKMI), $c_\mathrm{p} = 1.3$, Koetsu Sato (SATKO), $c_\mathrm{p} = 1.3$, and Kazuhiro Sumie (SUMKA), $c_\mathrm{p} = 2.5$, Satomi Yokochi (YOSKA), $c_\mathrm{p} = 1.2$, for Mikiya Sato (SATMI) we assumed $c_\mathrm{p} = 1.0$ because of lack of data. The average ZHR is thus calculated by

$$\overline{\mathrm{ZHR}} = \left(1 + \sum_i n_i\right) \Bigg/ \sum_i \frac{T_{\mathrm{eff},i}}{C_i}$$

as was described in [26]. The values of C_i include the also the perception correction c_p here. We have to emphasize that the the c_p-values for some of the observers are extremely large, and the straight-forward calibration with c_p might not be applicable.

Figure 3 shows the resulting activity profile; significant ZHRs are found in the beginning of the period. Rates drop below the typical detection limit for a minor shower (ZHR ≈ 1) at $\lambda_\odot = 70°$ (June 1). The average limiting magnitude is given in the upper part of Figure 3 and shows that there is no trend because of the the waning Moon. Systematic effects of decreasing lunar interference during the investigated period (last quarter at $\lambda_\odot = 65.^\circ6$) are thus unlikely. It is regrettable that the ascending branch of the profile is not available. The entry-velocity of the Schwassmann-Wachmann-3 meteoroids is near 17 km/s, and all meteors will appear extremely slow. As the observers of the "May α-Bootids" in Japan report meteors up to medium velocity, we suppose that a few additional sporadics might contaminate the rates given in Figure 3. Weak activity was also reported in 1998 from the same source [27]. More observational facts will be given in the sections about the dust-trail encounters.

Since several radiant lists and reports note activity from a radiant close to the theoretical position at Schwassmann-Wachmann debris, we conclude that a weak annual source of this stream exists.

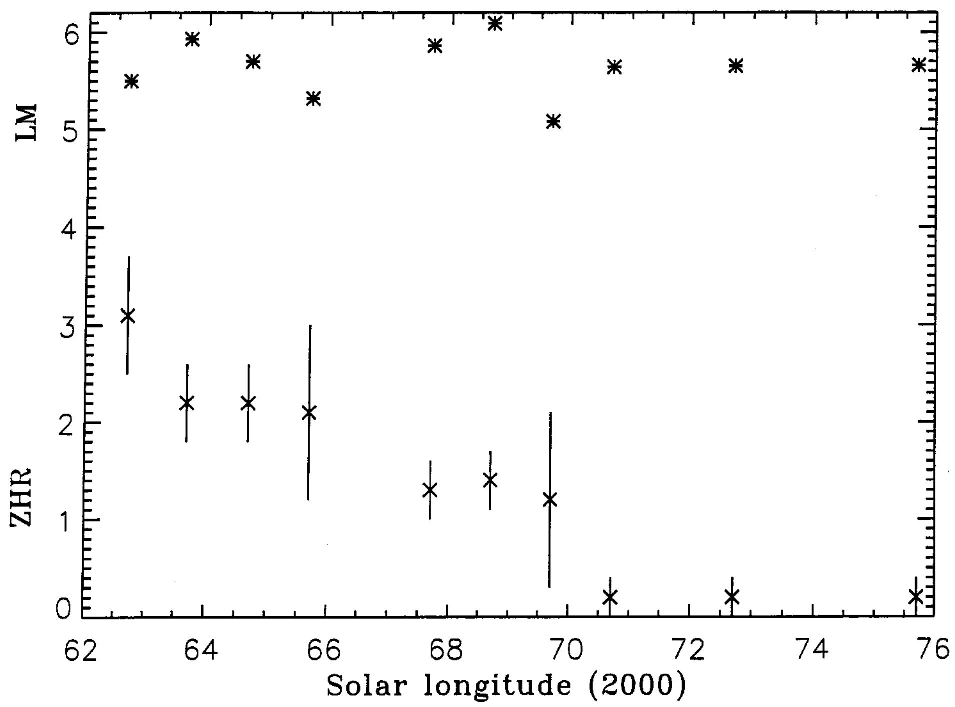

Figure 3 – ZHR-profile for the 2000 SW3-ids reported by Japanese observers. The upper dots give the average limiting magnitude of the same bins.

4. Dust trail encounters in the 20th century

The dust trail situation in 1930

Dust trail computations do not show any direct evidence for enhanced activity. In the $r_D - r_E$ versus T plot (Figure 4) particles within the 1892 dust trail do cross the Earth orbit in May, but the encounter geometry with this trail is quite unfavorable. When the Earth is close to the node, particles were more than 0.01 AU from the Earth. Uncertainty of the comet orbit may shift the trail's position somewhat. However, the nodal longitudes of these particles are at $77.^\circ75$, corresponding to June 8.30 UT, 1930. This is more than 1 day from the time when Nakamura reported his outburst. Other trails do not approach closer than 0.01 AU. The nodal longitudes of their closest particles ($\lambda_\odot = 77.^\circ71$ to $77.^\circ90$) do not match Nakamura's observing time either. A radiant computed with the 1892 trail orbit gives $\alpha = 219°$, $\delta = +45°$, far away from the listed radiant of Nakamura.

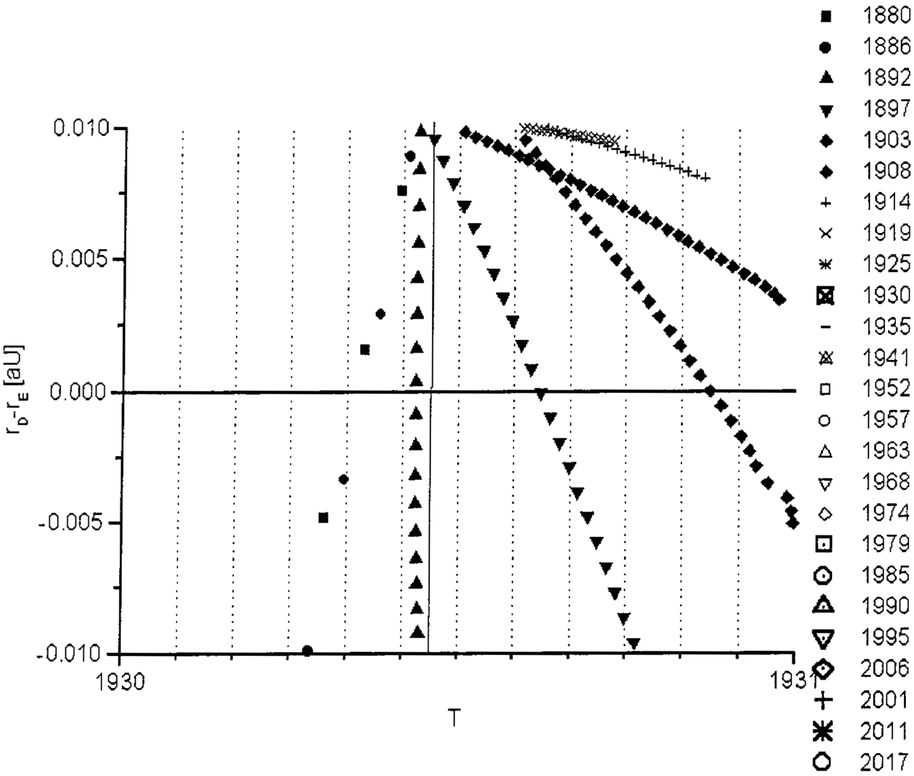

Figure 4 – Distance of the particle at the node from the orbit of the Earth ($r_D - r_E$) as a function of Perihelion time T. The particles reaching the node at the same time as the Earth are marked with the vertical line. Dust trails approaching Earth during 1930 are shown. Earth is not at the intersection with the 1892 trail at the proper time.

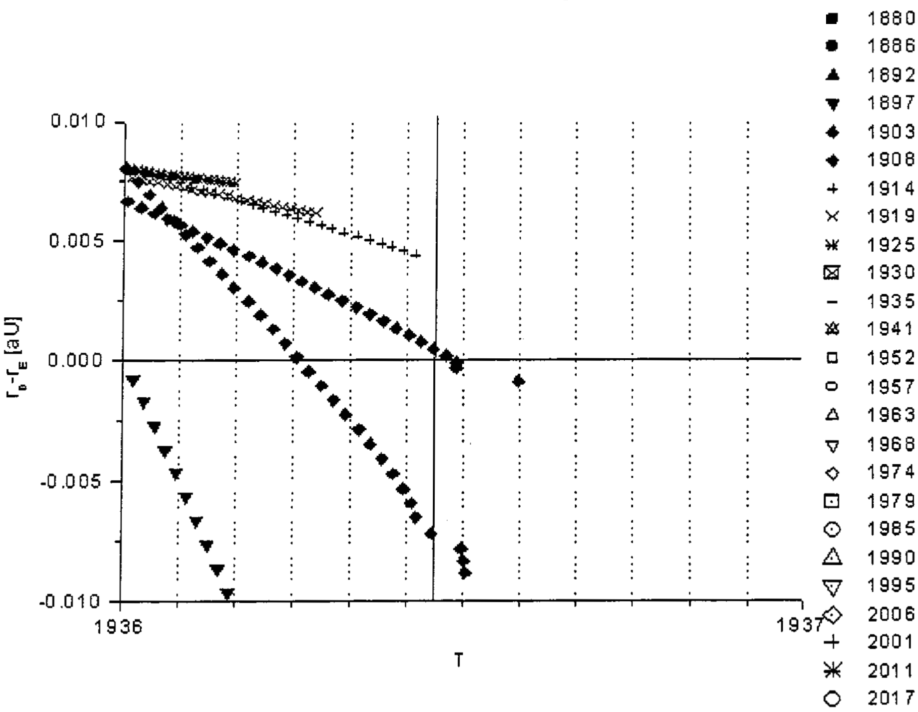

Figure 5 – Distance of the particle at the node from the orbit of the Earth ($r_D - r_E$) as a function of Perihelion time T. The particles reaching the node at the same time as the Earth are marked with the vertical line. Dust trails of particles that reach perihelion in the year 1936 are shown. Note the close encounter with the 1908 trail that should have generated a significant meteor activity on June 7, around 18^h43^m UT.

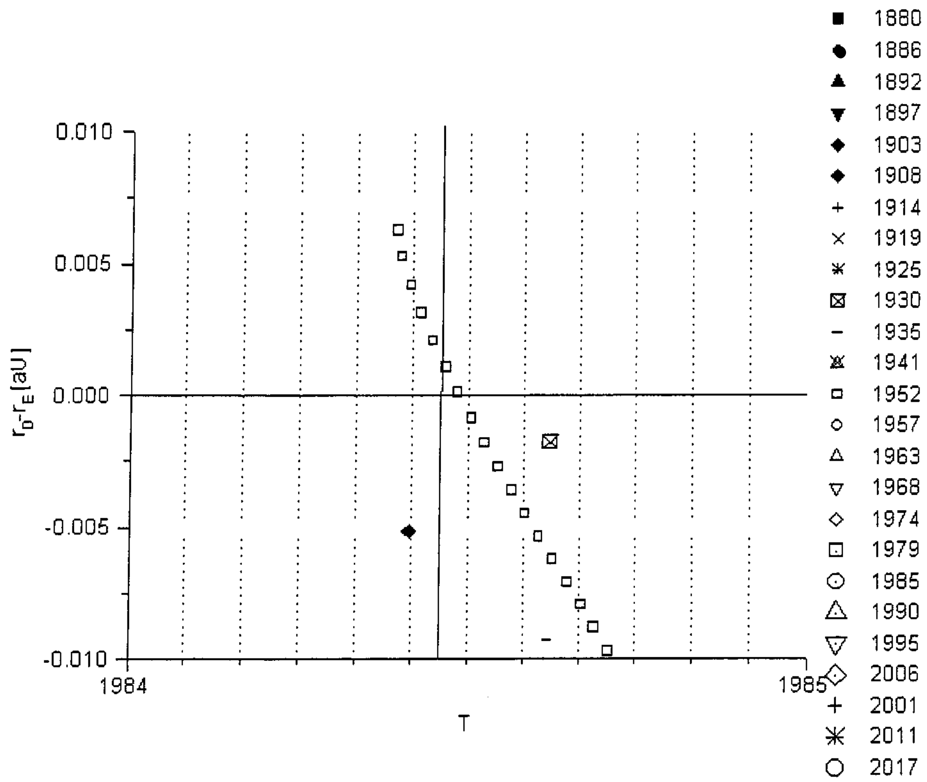

Figure 6 – Fig. 6: Dust trail situation in 1984. Although the miss distance was higher than in 1936, there might have been some activity at June 3, around 11^h17^m UT.

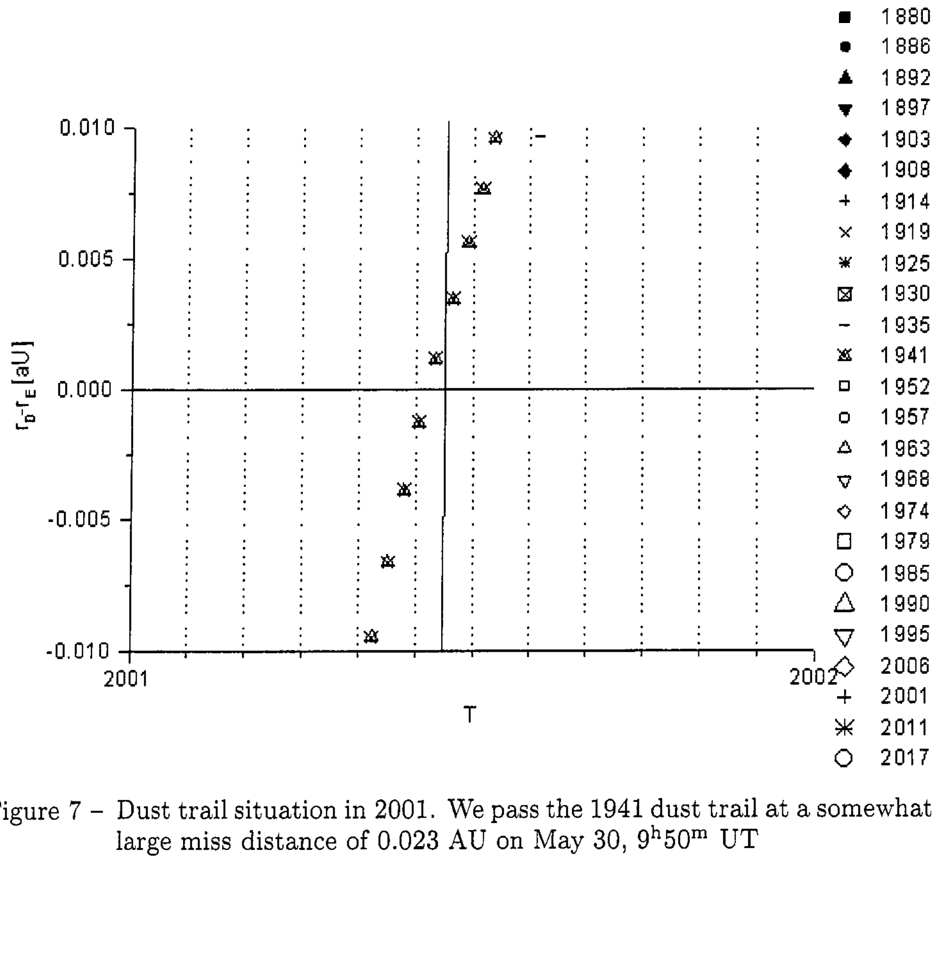

Figure 7 – Dust trail situation in 2001. We pass the 1941 dust trail at a somewhat large miss distance of 0.023 AU on May 30, 9^h50^m UT

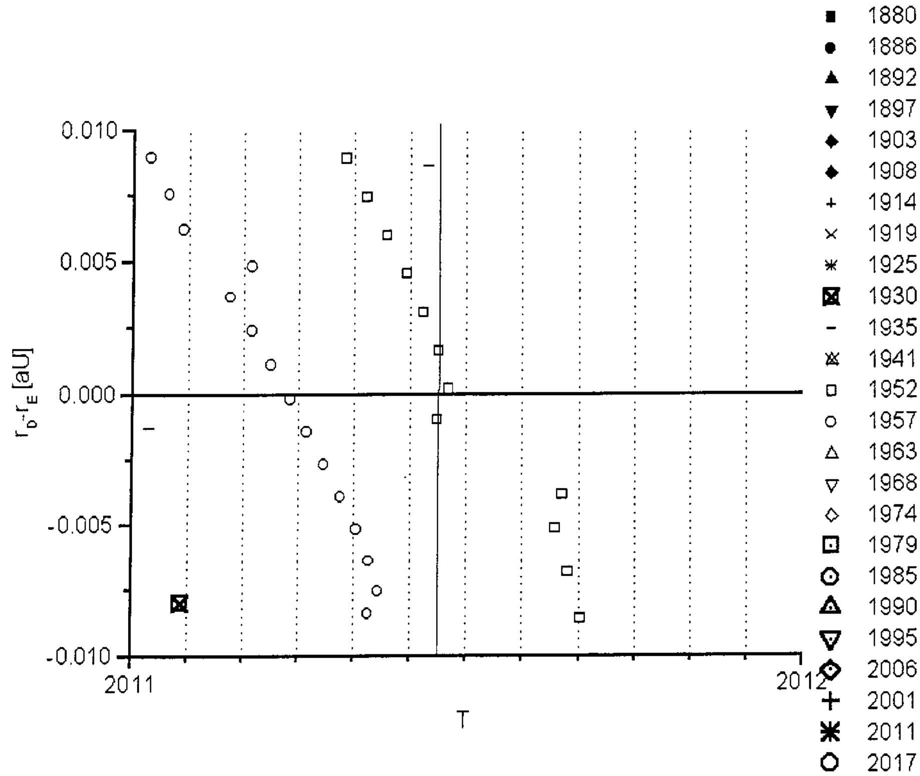

Figure 8 – Dust trail situation in 2011. We will pass the 1952 dust trail at a distance of about 0.0011 AU.

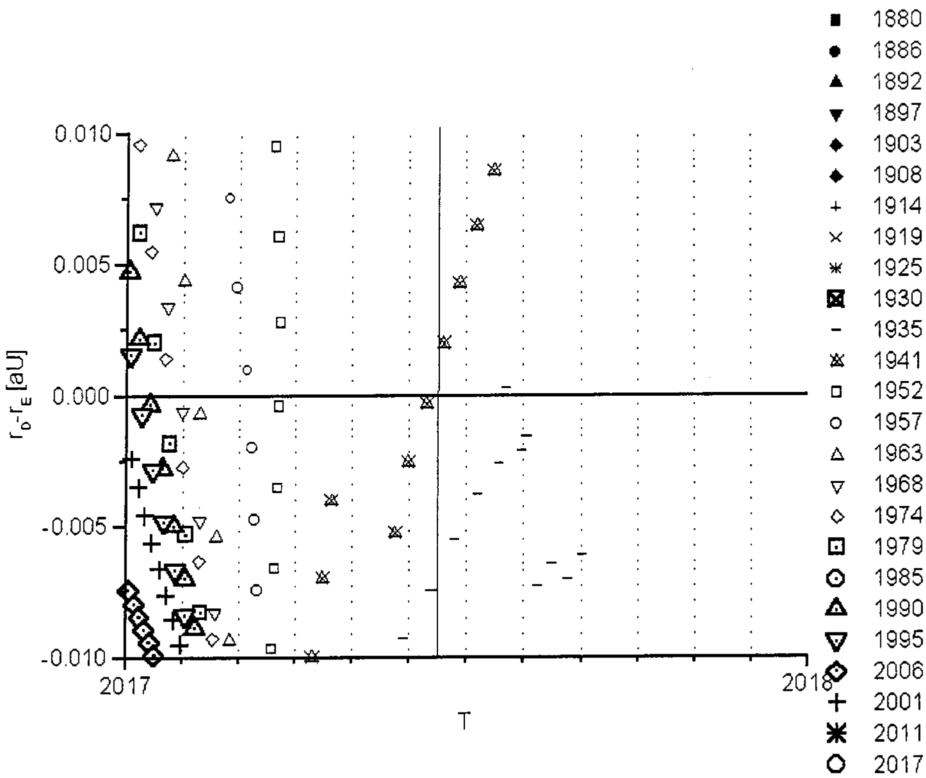

Figure 9 – The 2017 dust trail situation. We will pass the 1941 dust trail at a smaller distance than in 2001. ($r_D - r_E = 0.0013$ AU).

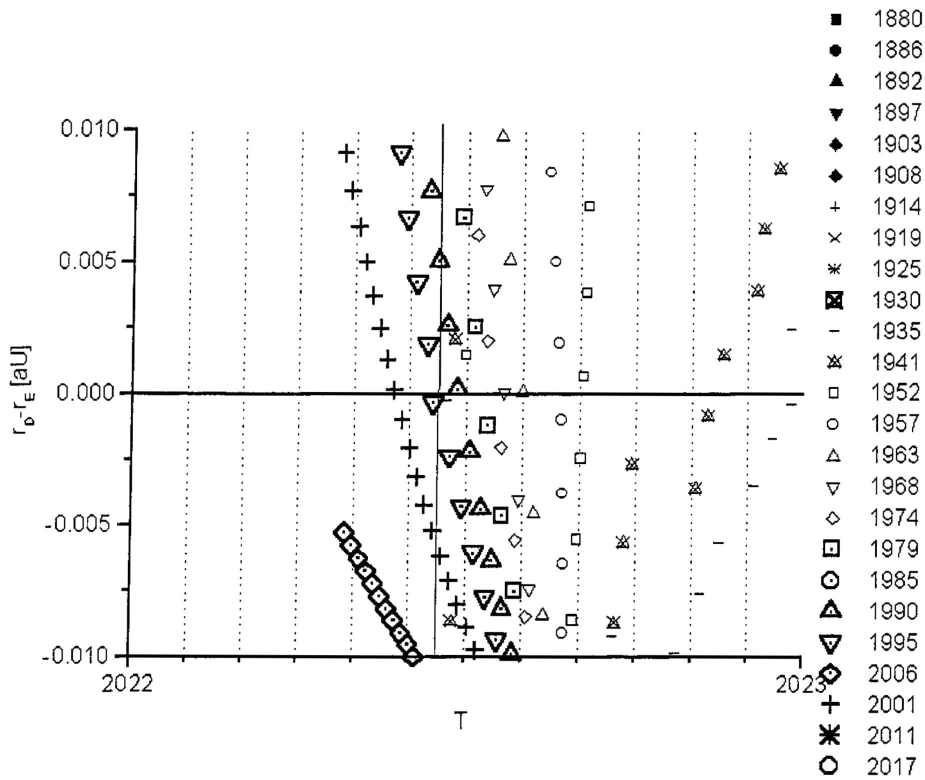

Figure 10 –Probably the best chance to see an SW3-id display will come in 2022, when we pass the 1995 trail at about only 0.0004 AU distance. The display is especially promising: the disintegration of P/SW3 in 1995 should have introduced a lot of dust particles into the trail.

This result does not exclude the possibility that Nakamura observed an outburst from a trail older than those studied here. Since they report activity not only during the reported outburst, but during the week before, their report may reflect a broad background activity rather than a true outburst. Since the orbit in the pre-1890 years appears to be ill defined, we did not check these possibilities by integrating very old trails. Taking all factors together it appears that, apart from the activity enhancement in May 1930, there was *no activity* from Schwassmann-Wachmann 3 on June 9-10. This is supported by Yamamoto's comment that Nakamura "was practically the sole observer of this rich display."

1936 meteors

Figure 5 shows the dust trails in 1936.There is a very close encounter with particles ejected in 1908 ($r_D - r_E = 0.0003$ AU). Of all past encounters found in this study this appears to be the most promising, especially as the particles have a positive value of Δa_0. Particles can reach this position in the trail not only by the ejection process itself, but because radiation pressure will tend to move particles towards positive Δa_0 values. A scan in old archives may be worthwhile, but perhaps the display remained unobserved. Viewing geometry would have favored the Middle East. The radiant will have been a bit low in China and even lower in Japan, and there was a 19-day-old moon in the sky. In Europe it turned dark hours later, but perhaps the descending slope of the peak may have been observed, especially in eastern Europe.

1984 meteors

The next promising-looking encounter is the passage of the Earth near the 1952 trail in the year 1984 (Figure 6). The miss distance (0.0023 AU) was much larger than in 1936. However, uncovering old observations may be easier for 1984. The encounter should have taken place on June 3 around $11^{h}17^{m}$ UT. The 4-day-old moon was surely not a problem. At the US west coast evening twilight was just ending at the time of the maximum, whereas in Japan it fell into the morning twilight. Hawaii would have been an ideal place to see that maximum. In any case, plotting data from the hours before and after the expected outburst would be interesting to check for activity from the radiant in the head of Bootes. Katz observed from Canada a maximum hourly rate of six SW3-ids. "This marked some of the highest rates in recent years" [28]. Before being taken as confirmation of the dust trail prediction, the original observations from 1984 should be carefully reanalyzed, since most observers in the past assumed a wrong radiant position (see below). Unfortunately, the observations are not included in the *IMO* database which is comprehensive starting with 1988 only.

5. Comet 73P/Schwassmann-Wachmann 3 1990–2000—the decade of breakup

In 1990, the Comet was no brighter than magnitude +9, despite a close approach to Earth. Figure 1a shows the feeble Comet at a distance of only 0.41 AU ($r = 1.15$ AU, pre-perihelion). A faint outer gaseous coma is visible. The post-perihelion photographs of 1995 (Figure 1b) do not show this outer coma. Photographs using the blue-sensitive emulsion Ectagraphic HC (not shown), which records gas tail and coma structures much better than the red-sensitive tp2415, did not reveal traces of any outer gas coma in 1995. Nevertheless the coma was much larger and brighter than in 1990, considering the larger image scale at the much larger geocentric distance. A (dust) anti-tail is visible in Figure 1b. These images give the impression that during the 1995 outburst/breakup event much more dust was released than during typical perihelion passages of the Comet.

The fragments that were originally discovered in 1995 separated drastically during the following revolution of the Comet. In 2000, the observational conditions were quite inferior to both 1990 and 1995. Comet 73P/Schwassmann-Wachmann 3 was visible before perihelion, with the Comet at a very large geocentric distance of about 2 AU. Nevertheless, the Comet still displayed an increased brightness compared to 1990 and no faint gaseous outer coma. Figure 1c shows, besides the main object (termed Fragment C), the faint fragment of B which was already observed in 1995 and separated from the Comet ($\Delta T = 0.3$ days). The brighter Fragment E, obviously also ejected in 1995 but not observed at that perihelion passage, was first discovered in 2000 by co-author MJ.

6. Future meteor events

After the 1995 disintegration of the Comet, massive amounts of dust appear to have been ejected, and it may be promising to look for SW3-id activity in the coming years. Especially in the years 2017 and 2022 we will be closer to the Comet orbit than in the years before. Therefore we extend this study to these upcoming encounters. It appears that in the years 2011, 2017 and 2022 we may expect meteor activity from the Bootes radiant. The 2022 encounter seems to be especially promising since we pass very close to the possibly richly populated 1995 trail.

Possible 2001 meteors

This encounter does not seem to be especially favorable, with a miss distance even larger than in 1984 (Figure 7). However, since the encounter occurs this year we feel obliged to warn the meteor community of the possible display, although rates may be low. The passage near the 1941 trail occurs at May 30 at $9^{h}50^{m}$ UT. Conditions will be fine in the western parts of the US, where the radiant will be 40° high with the Sun 25° below the horizon. The first quarter moon will just have set.

Possible 2011 and 2017 meteors

The next encounters with dust trails will be in 2011 (1952 dust trail, Figure 8) and in 2017 (1941 dust trail, Figure 9). The miss distance will be still fairly large (0.0013 and 0.0011 AU, respectively), but in any case half as far as in 1984 and 2001. On June 2nd, 2011, the maximum will happen at 5:46 UT, favoring observers throughout the USA. The moon is new. In 2017 the eastern and central parts of the USA will have the radiant directly overhead. Even in westernmost Europe the maximum will occur in bright twilight, only the Canary Islands will see it in a dark sky, but with the radiant at about 30 degrees altitude. Again, the waxing moon (5 days old) won't interfere too much.

Possible 2022 meteors

The probably best chance for some activity will be in 2022, when we very narrowly pass the possibly richly populated 1995 dust trail (Figure 10), at a miss distance no more than 0.0004 AU. This maximum will occur at 4^h55^m UT on May 31, again favoring the USA. On the Canary islands, twilight will just have begun, and the radiant will be about 11° high. However in the US, the radiant will again be directly overhead.

7. Conclusions

Overview of past and future trail encounters

Table 2 shows a compilation of the Earth's passages close to SW-3 dust trails found in this study. The rates of all these displays are hard to predict, since there is no reliable previous observation helping to establish any idea of the particle distribution as a function of Δa_0. Since all the displays occur at negative Δa_0, on orbits which radiation pressure cannot assist particles to achieve, we feel that the rates would not be too high. This is especially true for the 2001, 2011 and 2017 events. However it appears possible that careful observation may establish some activity at the times of the predicted maxima. We are a bit more hopeful for the 2022 event, since the miss distance $r_D - r_E$ is much smaller, and the chance is that the trail is more populated due to the massive expulsion of dust observed in 1995.

Table 2 – Overview of six close encounters with dust trails ejected from Comet 73P/Schwassmann-Wachmann 3. The geocentric velocity V_g (given in km/s) needs to be increased by the about 4 km/s for observing purposes due to the gravity of the Earth.

Date of encounter	Trail	Δa_0	$r_D - r_E$	Node (J2000.0)	α	δ	V_g
1936 June 7.78	1908	+0.051	0.0003	77°69	221°5	+44°7	13.9
1984 June 3.47	1952	−0.052	0.0023	77°28	219°3	+36°8	13.2
2001 May 30.41	1941	−0.027	0.0026	69°04	212°2	+28°4	12.5
2011 June 2.24	1952	−0.022	0.0011	71°22	214°2	+33°5	12.9
2017 May 31.136	1941	−0.012	0.0013	69°64	212°6	+29°7	12.4
2022 May 31.205	1995	−0.022	0.0004	69°44	205°4	+29°2	12.1

Predicted radiants

Table 2 also shows the radiant positions, which were computed from the particle orbits that were passing the Earth at the closest possible distance. We plotted these radiant position with Guide 7.0 (Figure 11). It should be noted that the radiant commonly listed for the SW3-ids ($\alpha = 236°$, $\delta = +41°$) is based on observations (or better: a radiant prediction of a preliminary orbit of the parent Comet) of 1930. The designation of these meteors as τ-Herculids is extremely confusing and should be avoided, since the meteors in fact should come from an area between Bootes and Coma. Correct radiant positions should be considered when the shower is observed in 2001, and when old plots from the interesting years are reanalyzed.

The enormous spread in the predicted radiant positions (Figure 11) is also important for the detection of a possible annual activity. It is due to two factors: the orbit of the particles is strongly affected by frequent passages close to Jupiter, and the radiant is very close to the antapex. Due to the vectorial addition with the movement of the Earth slight changes in the orbits of the particles translate to large variations in the radiants. A similar case is the June Bootids which also display quite an extended radiant [29]. Thus it has to be considered that SW3-id meteors do not come from a distinct radiant, but emerge from quite a large area in the sky.

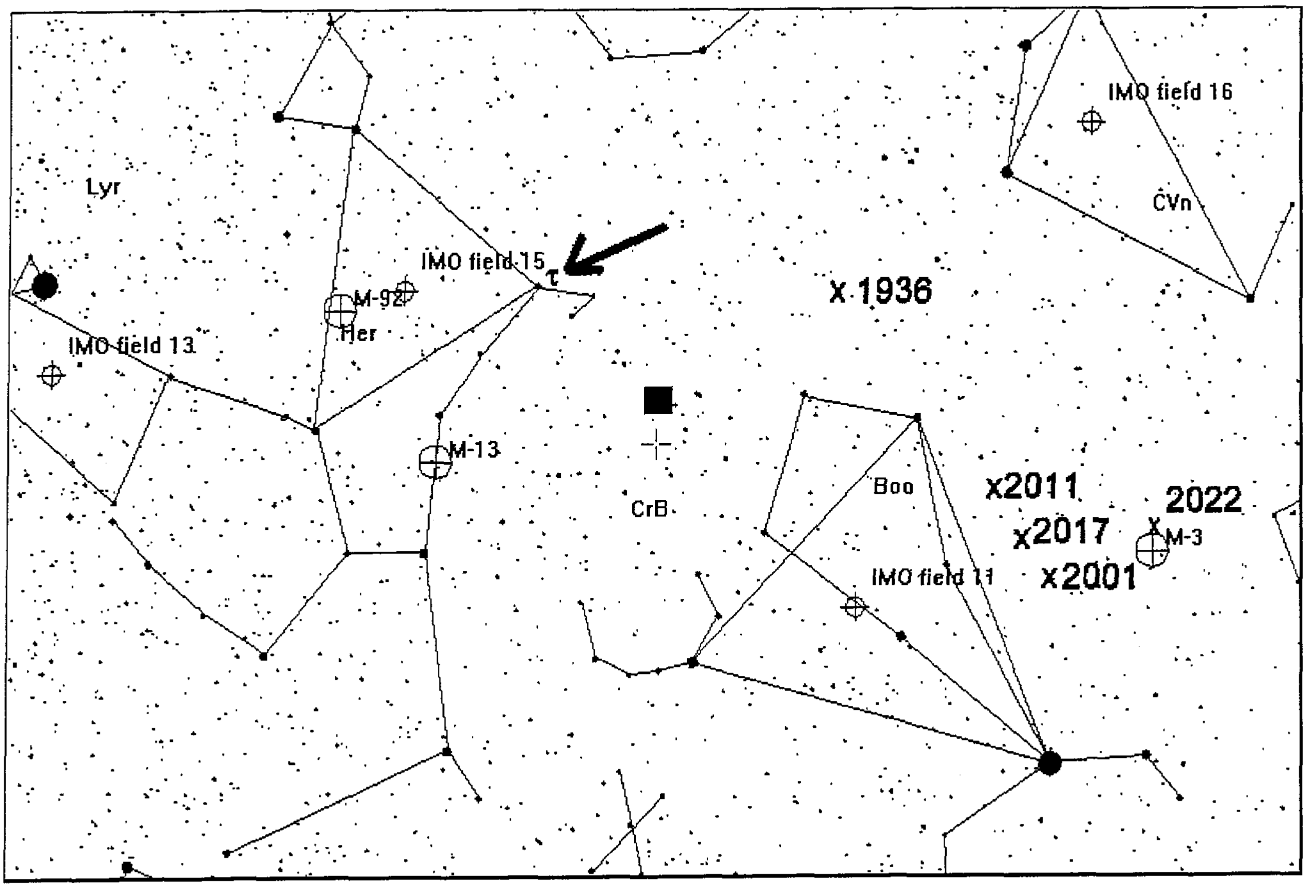

Figure 11 –Localization of the predicted radiants for the SW3-ids dust trail encounters plotted with GUIDE 7.0 (crosses). The gray square marks the frequently cited radiant position of $\alpha = 236°$, $\delta = +41°$. An arrow indicates the star τ Her.

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Activity of the Southern Piscid Meteor Shower in 1985–1999

Audrius Dubietis

The activity of the Southern Piscid meteor shower in 1985–1999 was studied using data accumulated in the Visual Meteor Data Base of the *IMO*. Assuming that the shower can be reliably detected with ZHR > 1, the effective activity period of the Southern Piscids is established to be from September 3 to October 2 ($\lambda_\odot = 160°$ and $\lambda_\odot = 188°$, respectively). The broad maximum with typical ZHR = 3.1 falls predominantly between September 18 and September 21 ($\lambda_\odot = 175\overset{\circ}{.}5$–$178\overset{\circ}{.}5$).

1. Introduction

Meteor activity in September is high, although there are only two minor showers reasonably observable by visual means during this period—δ-Aurigids and Southern Piscids (*IMO* code SPI), and excepting the short descending activity of α-Aurigids, which ends at the very beginning of September. The available *IMO* records on the Southern Piscids date back to 1984, nevertheless low hourly rates combined with a prolonged activity period (more than a month) still keep this shower in the "poorly studied" list.

The radiant of the Southern Piscid shower lies right on the celestial equator, and these rare yellowish meteors can be observed from both hemispheres. The mean radiant position is $\alpha = 5°$, $\delta = -1°$ (given for $\lambda_\odot = 177°$) and possesses a daily motion of $+0\overset{\circ}{.}8$ and $+0\overset{\circ}{.}3$ in right ascension and declination, respectively (data taken from the 2001 Meteor Shower Calendar [1]). At first sight, the Southern Piscid shower could be treated as a part of the ecliptical activity, which lasts over the whole year. The shower radiant position is close to the anthelion point [2]. Besides the sporadic meteor activity, the anthelion source includes a number of known minor streams and possesses two prominent maxima in June and October [3]. In September it displays moderate activity, and it is worth noting that during this period only the Southern Piscids are recognized as an annually reliably detectable meteor shower. Jones and Brown found that anthelion meteor orbits are identical to those of the short period comets and characterized by low inclination and eccentricity of 0.8–0.9 [4]. The orbit of the Southern Piscids determined by Sekanina [5] in the course of the Radio Meteor Project shows that the Southern Piscid shower is an undoubted member of this family.

A search through the literature failed to produce reliable data, either on the shower activity or on its origin. Denning was the first to notice meteor activity from the Pisces region and characterized the meteors as slow. He provided seven different radiants active in September with coordinates close to those of Southern Piscids [6,7]. A decade later, McIntosh made a global survey of 320 southern meteor showers, and three of them can be recognized as possible Southern Piscids [8]. Kronk [9] presented the further history of the shower by providing some details on its activity up to year 1980. The Southern Piscids were characterized as a weak and diffuse shower with peak activity from $\lambda_\odot = 168°$ to $\lambda_\odot = 177°$ and maximum ZHRs ranging from 1 to 2, as reported by various groups of observers [9]. It was established that two branches of the shower are active—Southern (active from August 12 to October 7) and Northern (possibly active from the second part of September until the beginning of November). The latter has been attributed to the Taurid complex of Comet 2P/Encke [10]. Despite the low shower activity according to data collected by Kronk, there is a large scatter in hourly rates and shower maxima as well. For instance, Hughes [11] with reference to the British Astronomical Association gives ZHR = 7 at $\lambda_\odot = 188°$ for the shower simply named "Piscids". And finally, the actual radiant positions the ZHRs refer to are not available, making the comparisons of numbers and activity periods problematic. In this regard, the activity of the Southern Piscid shower requires more precise study.

2. Meteor Data

The aim of this work was to study and characterize the activity of the Southern Piscid meteor shower using data accumulated in the Visual Meteor Data Base (*VMDB*) of the *IMO*. In general, the *VMDB* represents a global dataset of visual observations throughout the entire year. This gives an excellent opportunity to study weak minor showers such as Southern Piscids. A note should be added with regard to the structure of the *VMDB*. The observational data is collected according to the standardized shower list (see [1]), which is not altered every year by numerous minor showers that do in fact exist. The information in that sense is not entirely accurate, but it is consistent in terms of data on the showers presented.

The *VMDB* has accumulated over 2000 records on the Southern Piscid meteors starting in 1984. Early reports on the Southern Piscid meteors in the *VMDB* occasionally appear starting from August 16–18. For the sake of clarity, it should be noted that the evaluation of the radiant position finds it somewhere in Aquarius, producing the interference with Aquarid complex members, which in turn makes the Southern Piscid shower practically indistinguishable. Therefore these observations were not included in the analysis. Table 1 summarizes the data on the Southern Piscids obtained by *IMO* observers in 1985–1999. The effective observing time of more than 5600 hours provided a record of 2422 shower meteors, and 2058 of them were used in the analysis. The selection criteria applied to the data are given in the next Section.

Table 1 – Southern Piscid data from the *VMDB* of *IMO*. Note that the period given in the table does not necessarily refer to the activity period of the shower.

Year	Period ($\lambda_\odot$)	Activity period totals		Totals used in the analysis	
		T_{eff}	N	T_{eff}	N
1985	164°–180°	131ʰ13	104	85ʰ73	95
1986	157°–196°	281ʰ10	95	173ʰ75	68
1987	156°–188°	124ʰ33	37	79ʰ45	22
1988	161°–197°	331ʰ99	131	276ʰ47	95
1989	150°–195°	493ʰ95	142	352ʰ70	115
1990	153°–198°	309ʰ92	46	370ʰ18	46
1991	154°–197°	448ʰ88	183	358ʰ76	179
1992	152°–191°	284ʰ90	86	220ʰ34	67
1993	152°–185°	232ʰ32	61	169ʰ36	53
1994	154°–196°	336ʰ39	112	227ʰ03	88
1995	153°–190°	368ʰ10	185	296ʰ18	172
1996	153°–194°	373ʰ90	220	286ʰ44	197
1997	153°–188°	545ʰ27	237	419ʰ65	204
1998	153°–187°	542ʰ52	266	356ʰ39	198
1999	157°–188°	800ʰ32	517	617ʰ54	459

3. The activity profiles

Since the activity of the shower is low, the expected value of ZHR was calculated as proposed by Arlt [12]:

$$\mathrm{ZHR} = \frac{1 + \sum\limits_i N_i}{\sum\limits_i \frac{T_{\text{eff},i}}{C_i}},$$

where N_i is the sum of shower meteors at each observing period, $T_{\text{eff},i}$ is the effective duration of the period, and C_i is the correction factor:

$$C_i = \frac{r^{6.5-\mathrm{lm}} F}{\sin h_{\mathrm{R}}}.$$

which accounts for the limiting magnitude lm, field obstruction F and radiant elevation h_R. Error bars of the ZHR were estimated as

$$\sigma_{\mathrm{ZHR}} = \frac{\mathrm{ZHR}}{\sqrt{1 + \sum_i N_i}}.$$

It was assumed that no small features in the shower activity are expected, therefore 1° bins for the ZHR estimations were applied. This was not a firm limit, and 2° or even 3° bins were applied where there were insufficient data within the smaller bins. Such a division of the activity period imposed some smoothing of the ZHR profile, nevertheless increased its reliability. The number of the observing periods in the calculations of the ZHR varied widely from 1 to over 50. Estimates over less than 3 observing periods usually represent individual rates and require consideration of the particular observer perception, thus they were omitted or linked up with the neighboring ones within the larger bins. As each ZHR estimate is the resulting value from different observers observing under different conditions, some limitations were applied. Only observing periods with $C_i < 5$ were included. This was not a strict limitation, and the major part of the observations fitted this criterion (see Table 1). Under ideal observing conditions ($\mathrm{lm} = 6.5$, $F = 1$), $C_i = 5$ corresponds to the radiant elevation $h_R = 11.5°$, and hence it looks rather favorable. The reason for this was simple—most of observations were carried out during evening hours or at comparably low radiant elevation and thus were saved. The other specific observer-dependent corrections, e.g. observer perception and direction of the field of view, were not applied. Of course, some systematic errors due to this may persist. Another important point is the shower association. The method of data representation in the *VMDB* allows one to distinguish whether the shower produced "0" meteors in the given observing period or has not been recognized by an observer at all. In order to simplify the data analysis, overall observations in the ZHR estimates were included. Of course, such a straightforward approach may introduce some errors in the ZHR determination at the margins of the activity profile. On the other hand, observations labeled "no shower" at the vicinity of the maximum are too few and could not significantly affect the final result. And finally, the ZHR was calculated using $r = 3.0$ and the radiant drift as given in [1].

The observations from 1985 to 1988 and 1993 supplied only scarce data on the shower activity, thus they were not included in Figure 1. Some characteristic features became clear after examining the activity profiles. In most cases the shower activity in the vicinity of the maximum is seen as a broad plateau which extends from $\lambda_\odot = 165°$ to $\lambda_\odot = 185°$ without a prominent peak. The shower activity does not change significantly from year to year, and the results of this analysis are consistent with previously known data. The period of the suspected maximum ($\lambda_\odot = 170°$ to $180°$) was rather poorly covered by the observations. The 10° gaps in the activity profiles were inevitably set by the full Moon. In 1989, 1992, 1994 and 1997 these gaps fell right on the suspected shower maximum. Table 2 lists some most probable dates of the maximum. Apparently it falls within $\lambda_\odot = 171°$ to $179°$, and more precise examination may reveal a shorter period of $\lambda_\odot = 175.^\circ5$ to $178.^\circ5$ with reasonable accuracy. Definite dates listed in Table 2 represent merely some statistical conclusions in the sense of numbers. In fact, the maximum is rather broad as is evident from the yearly activity profiles depicted in Figure 1, and this is exactly what can be expected from the ecliptical shower. Although the maximum dates exhibit some scatter in time, no correlation with respective dates of the full Moon has been found. In addition, there is no large scatter in ZHRs, and ZHR = 3.1 should be considered as a typical value being in good agreement with that given in [1].

The data presented in Figure 1 suggests that some additional peaks may exist at $\lambda_\odot \approx 165°$ and $\lambda_\odot \approx 185°$, as best seen in the 1997 activity profile, however they are not clearly present in the mean ZHR profile (see Figure 2).

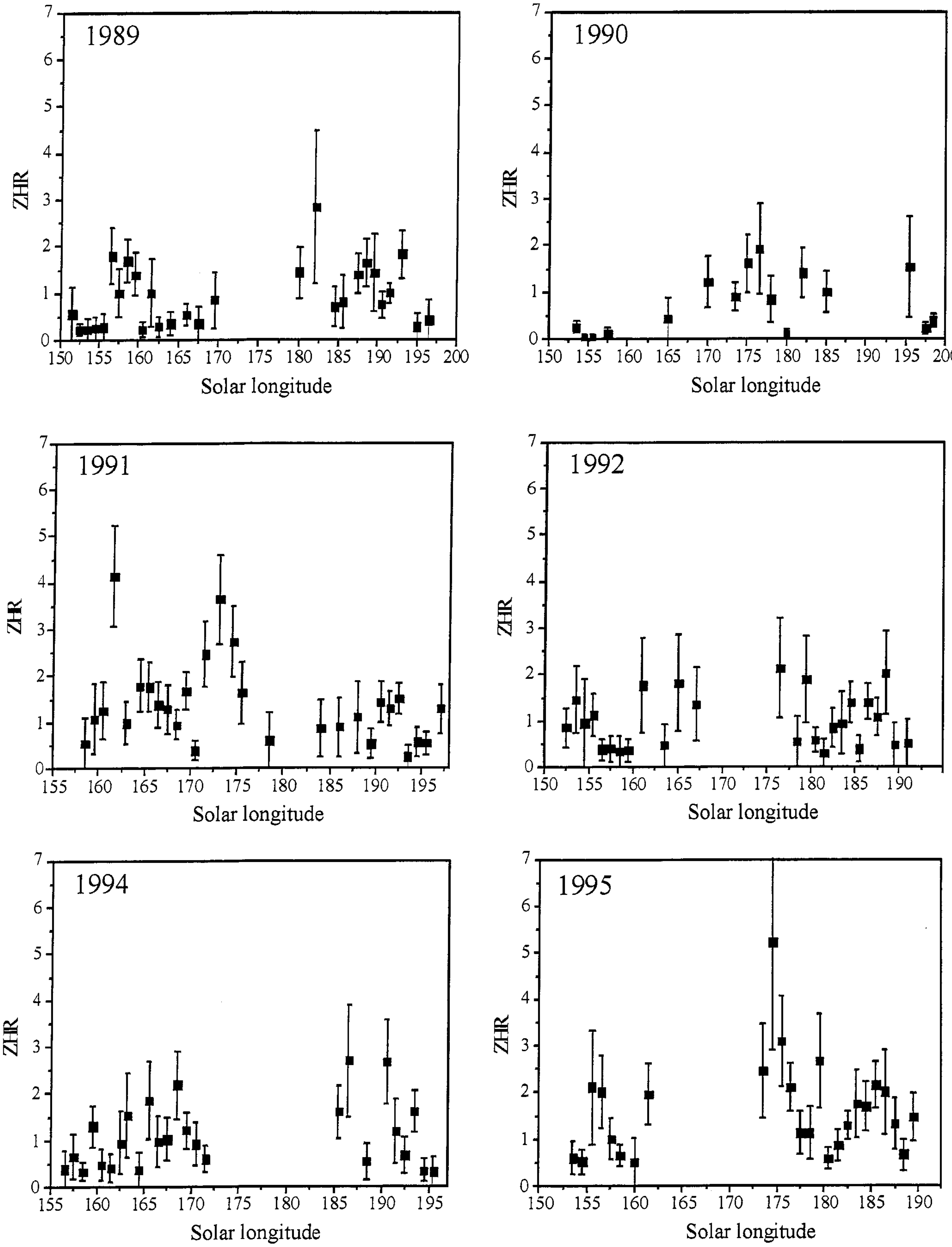

Figure 1 – Activity profiles of the Southern Piscid meteor shower in 1989–1999.

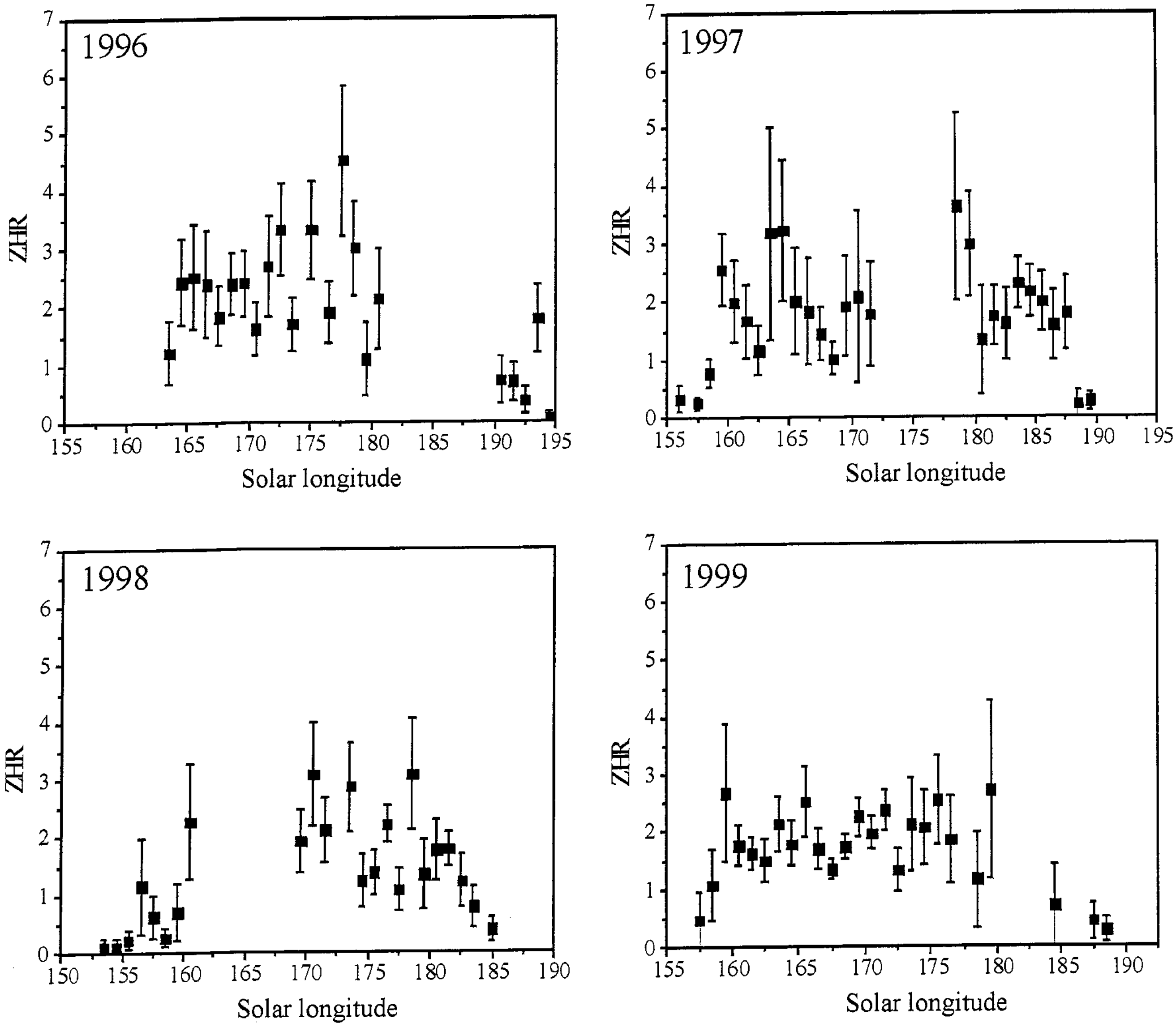

Figure 1 – continued.

Table 2 – Probable maximum dates of the Southern Piscid meteor shower.

Year	$\lambda_\odot$ of maximum	ZHR
1985	$178\overset{\circ}{.}5$	4.59 ± 0.97
1987	$178\overset{\circ}{.}0$	3.08 ± 0.93
1990	$176\overset{\circ}{.}5$	1.93 ± 0.97
1991	$173\overset{\circ}{.}0$	3.64 ± 0.94
1995	$175\overset{\circ}{.}5$	3.09 ± 0.98
1996	$177\overset{\circ}{.}5$	4.53 ± 1.31
1998	$170\overset{\circ}{.}5$	3.09 ± 0.89
	$178\overset{\circ}{.}5$	3.08 ± 0.97
1999	$175\overset{\circ}{.}5$	2.54 ± 0.77

In order to reveal the effective shower duration, all the data from years 1989–1999 have been processed keeping a firm 1°-bin limit. The same ZHR formula as given above was applied, i.e. the mean ZHR was calculated not by simple averaging over data presented in Figure 1, but again using the small-ZHR equation.

The mean ZHR should not be considered as an equivalent to the maximum ones presented in Figure 1, however it is helpful to establish the overall activity trend. If one assumes that the shower is reliably detectable by visual means with ZHR > 1, the effective shower duration is then approximately one month (from $\lambda_\odot = 160°$ to $\lambda_\odot = 188°$), again in good agreement with the already established period [1]. Figure 2 suggests the maximum at $\lambda_\odot = 172.^\circ5$–$176.^\circ5$—slightly shifted with respect to that following from the yearly activity profiles. Such a discrepancy could be in part described by various observer-dependent features along with a highly nonuniform distribution of the observing periods. In fact, the number of observed shower meteors peaked at $\lambda_\odot = 170°$. It simply reflected the increased number of contributions and longer observing times, whereas the period of shower maximum was still poorly observed.

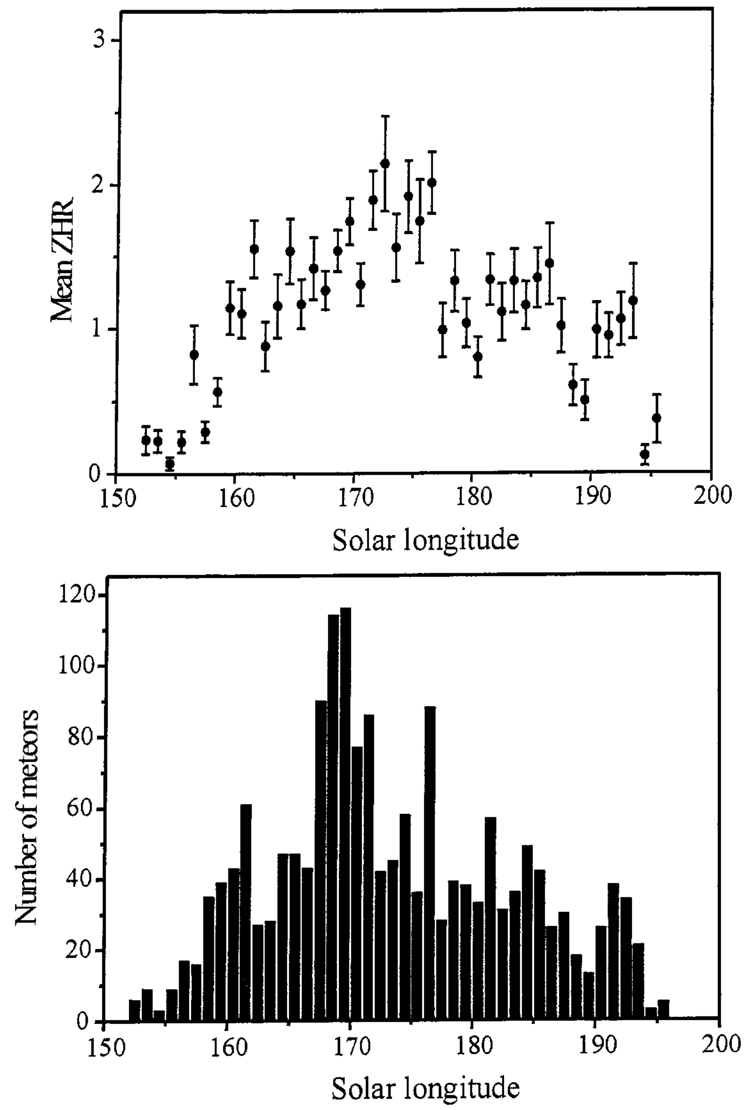

Figure 2 – Mean ZHR (above) and number of shower meteors (below) as combined from the one-decade (1989–1999) observations.

4. Conclusions

The activity analysis of the Southern Piscid meteor shower from 1985 to 1999 has clarified several points. The shower activity does not vary significantly from year to year within the studied time period. The effective shower activity with ZHR > 1 lasts from $\lambda_\odot = 160°$ to $\lambda_\odot = 188°$ with a probable peak between $\lambda_\odot = 175.^\circ5$ and $\lambda_\odot = 178.^\circ5$ and a typical ZHR = 3.1. The obtained numbers are in good agreement with present data provided in the *IMO* yearly Meteor Shower

Calendar. Unfortunately, the period of the maximum was not well covered by the observing data which do not therefore permit a more precise estimate of the maximum date. Finally, there is a hope that increased contributions and the inexhaustible enthusiasm of *IMO* observers will permit the gathering of more reliable data in the near future.

5. Acknowledgment

The author would like to thank Rainer Arlt for a critical reading of the manuscript and his constructive suggestions that helped to improve the paper.

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No Outbursts from Comet C/2000 WM1 (LINEAR)

P. Jenniskens and E. Lyytinen

The close encounter of long period comet C/2000 WM1 with the Earth's orbit is not expected to lead to a meteor outburst this year, or in the near future, because the comet's dust trail will not intersect with the Earth's orbit.

Several people have noticed the relatively close encounter of comet C/2000 WM1 (LINEAR) with the Earth's orbit in early March 2002. At the time of writing, the comet is expected to be a magnitude +4 naked-eye object around Christmas 2001 [1]. Meteoroids might collide with the Earth on the following May 19.1, from $\alpha = 37°$, $\delta = -30°$, $V_\infty = 47$ km/s, solar longitude $\lambda_\odot = 57.^\circ9$ (J2000), when the Earth passes the comet orbit at only 0.010 AU. Unfortunately, there is no chance that dust released during this return could be sufficiently delayed to hit the Earth at that time. And, sadly enough, this is a long period comet. Any dust trail will have stretched very long, resulting in a low spatial density. However, that alone does not dismiss the possibility that dust from the previous encounter could be detected in the near future.

There are an estimated 70 (mostly unknown) long period comets with orbital periods of around 1000 years that do cause meteor outbursts [2]. Two examples are the Lyrid comet P/Thatcher and the Aurigid comet P/Kiess, with orbital periods of 415 and 1900 years respectively. Photographic observations of the α-Monocerotid outburst in November of 1995 settled the debate whether outbursts of such showers were clumps of matter in an unusually short (10-year) period orbit, or wagging trails that occasionally intersect the Earth's orbit, in favor of the latter. These meteoroids had orbital periods in excess of 140 years [2].

When Earth encounters the dust trails of these comets, the resulting outbursts are brief (0.5–1.5 hours) and their timing bears no relation to the return of the comet to perihelion. Instead, their occurrences are controlled by planetary perturbations, which cause the dust trail to wag in and out of the Earth's orbit on a time scale that reflects the orbital period of the major planets. Planet Jupiter has the biggest effect, causing a wave of 12-year period, while Saturn is runner up, with a period of 30 years. Together, they typically cause recurrences once or twice every 60 years [3]. The amplitude of these motions do not tend to exceed ± 0.010 AU, but that is also the minimum separation of comet C/2000 WM1 and the Earth's orbit in this return. For that reason, an outburst of this comet can not be dismissed offhand.

We examined the two aspects that determine if a long period comet will cause a meteor outburst. First, we calculated the 1-revolution dust trail of this comet for an assumed orbital period. We adopted two different orbital periods of 1000 years and 2400 years, to demonstrate that the adopted orbital period has little effect on the calculated position of the trail. For practical reasons, we chose periods that are not too long. Figure 1 shows the trail lingering near the Earth's orbit in the coming years. The true separation is about 30% smaller than the separation along the Earth's orbital plane in this case. The dark markings were obtained for the shorter period and the lighter ones for the longer period. Both results follow closely the same pattern. Hence, it is not critical what orbital period is assumed and it is generally not necessary to know where Jupiter was during the past return.

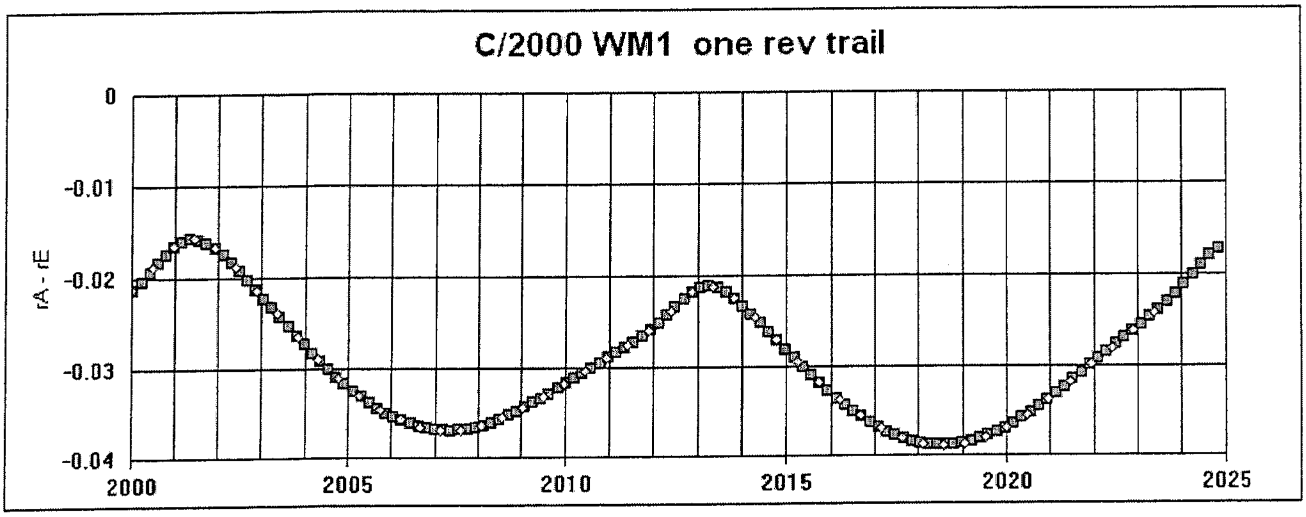

Figure 1 – The separation along Earth's orbital plane of the one-revolution dust trail of comet C/2000 WM1 (LINEAR) in the years following January 1, 2000.

We find that the comet itself is currently not far from the minimum separation and, unfortunately, the trail tends to wag completely inside of the Earth's orbit in the years to come. So there is very little hope to see anything in our lifetime. Later revolution trails are expected to have dispersed significantly and are less likely to cause recognizable showers. To study those, we would need to know earlier orbits of the comet.

Now, if the trail would have intersected the Earth's orbit, could we detect an outburst of this comet? That depends on how much dilution of the grains has occurred after one orbit, which follows from knowing when the comet was last near the Sun. The latest published osculating orbit [4] is actually slightly hyperbolic: $1/a = -0.000516 \pm 0.000041$ AU^{-1}, where a is the semi-major axis of the orbit and the period in years, $P = a^{1.5}$ (a in AU). On request, Brian Marsden (*priv. comm.*) calculated the "original" barycentric orbit. He found that the comet did pass by the Sun at that time, with $1/a = +0.000510$ AU^{-1}, or a period of 87 000 years (orbit as of March 28, 2001). Hence, a dust trail can have formed. In first approximation, the spatial density in one dimension is inversely proportional to the power 2.5 of the semi-major axis. From that, we find that the dust density would be only 1 part in 500 000 compared to that in a similar Leonid dust trail, or a peak ZHR much less than one per hour. That excludes any significant shower activity even if the trail would have been in the Earth's path.

To our knowledge, this is the first publication regarding the computation of a one-revolution trail of a long period comet. A more detailed paper on other showers is planned for the future.

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Video Meteor Observations from the Canary Islands: First Results and Prospects

Orlando Benítez Sánchez

We report our observations of meteors made with an image intensifier placed on Maspalomas (Gran Canaria, Spain). From 2000 September to 2001 March our system has detected 2321 meteors, of which 1485 were sporadics and 836 were from various active radiants.

1. The video meteor camera, calibration system and first observations

We use a second-generation model XX1451A image-intensifier from Delft Electronics Products [1]. The video signal is recorded with a Panasonic NV-RS7E commercial video camera, equipped with a Minolta $f/1.4$ 50 mm photographic lens. This equipment is mounted on a mechanical housing built by the Instituto de Astrofísica de Canarias, and made in black anodized aluminum. The camera and intensifier are used on a photographic tripod.

The lens provides a 20° diameter circular field of view. The meteor record is searched with the MetRec software by Sirko Molau [2] with a Pentium III (600 MHz, 64 MB RAM memory and 10 GB hard disk) and a Matrox II frame grabber. The system is able to record stars down to magnitude +8.0, but meteors only down to +5.5 to +6.0.

The camera is placed in Maspalomas, Gran Canaria at longitude $\lambda = 15°36'28.4''$ W and latitude $\phi = 27°45'3.24''$ N, $H = 50$ m (see Figures 5 and 6), but our first observations were in San Mateo and La Avejerilla in 2000 July, August and September. Initially, we used MetRec version 3.0 to avoid the flash that the system detected continuously[1]. In these early stages few meteors were detected, only 10–15 each night. Now, with better results and more experience, we use MetRec 3.3. Each night we observe between 40 and 70 meteors. Antón Fernández Villanueva operates this video meteor station every night.

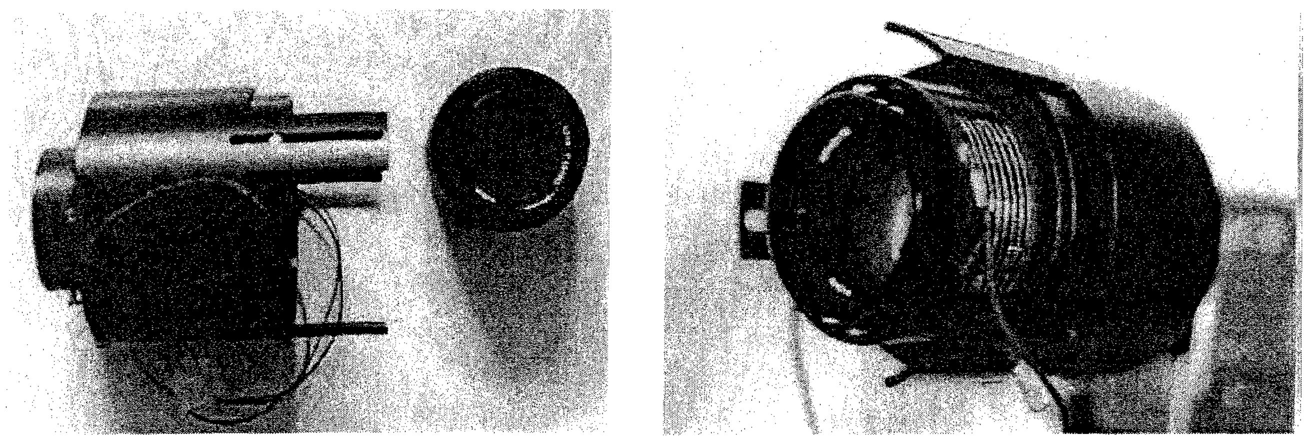

Figure 1 – The mechanical housing, built by the Instituto de Astrofísica de Canarias.

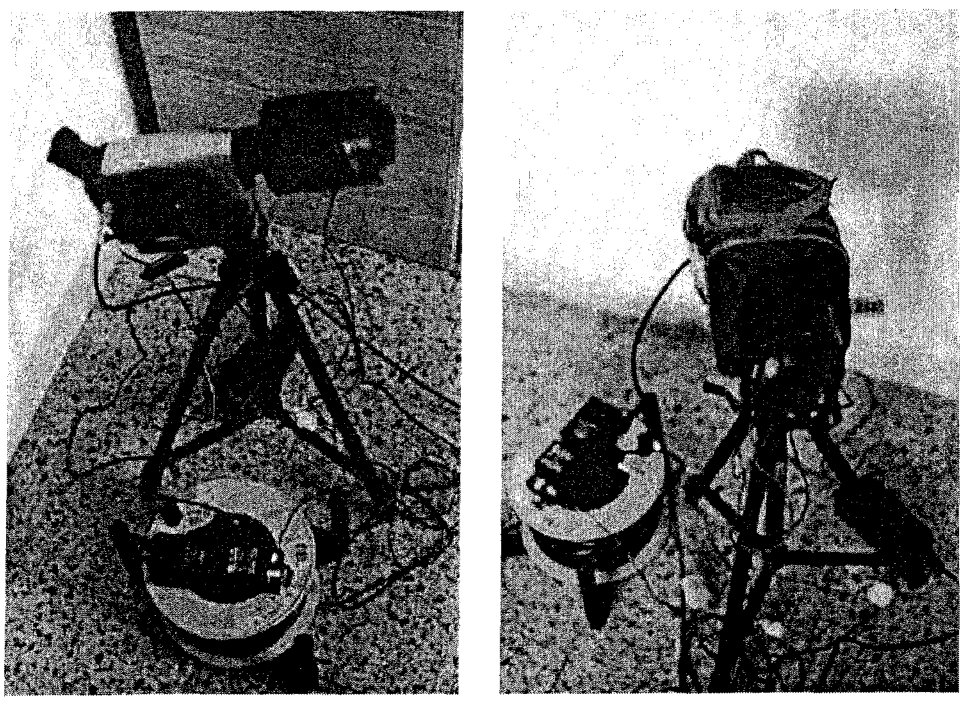

Figure 2 – Two snap-shots of the video camera and intensifier mounted on a tripod.

[1] The author of MetRec informed us that, instead of a software error, a configuration problem was the reason—Ed.

2. Observations

On 2000 July 24 we made our first observation from San Mateo, but we have only conducted permanent observations since 2000 September 23, weather permitting. The visual limiting magnitude is +5.5 to +6.0 at Maspalomas. Tables 1 to 5 give the effective time (in hours) and the total meteors detected by the end of March. In total 2321 meteors have been recorded, 1485 sporadic and 836 from various showers.

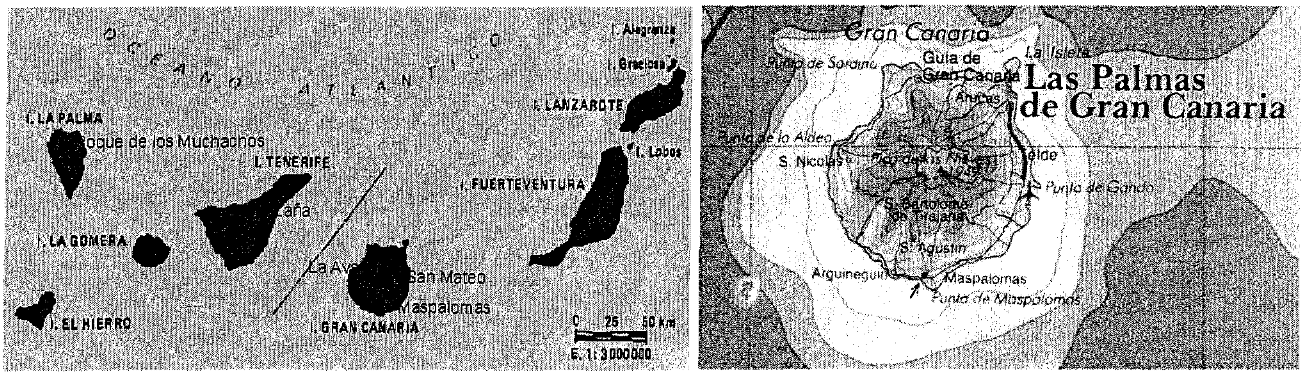

Figure 3 – Geographical coordinates of Canary Islands. Below, a map of Gran Canaria. In the center of the circle is Maspalomas (arrowed).

Table 1 – *Monthly effective time and total meteors from July 2000 to March 2001.*

Month	Effective time	Sporadics	Shower members	Total
July (2000)	$15^{\rm h}.07$	84	84	168
August	$7^{\rm h}.02$	16	19	35
September	$5^{\rm h}.93$	8	10	18
October	$101^{\rm h}.05$	211	230	441
November	$74^{\rm h}.93$	140	133	273
December	$45^{\rm h}.40$	262	156	418
January (2001)	$132^{\rm h}.66$	292	110	402
February	$122^{\rm h}.82$	281	56	337
March	$103^{\rm h}.25$	191	36	227
Total	$608^{\rm h}.13$	1485	834	2319

Table 2 – Total number of meteors recorded in July and August 2000 broken down into meteor showers.

Showers	CAP	SDA	NDA	PER	PAU	SIA	KCG	Spo
July 2000	25	35	2	16	2	4	–	84
August	1	3	–	13	–	–	2	16
Totals	26	38	2	29	2	4	2	100

Table 3 – Total number of meteors recorded in September and October 2000 broken down into meteor showers.

Showers	SPI	NTA	STA	DAU	ORI	EGE	Spo
September	2	2	2	4	–	–	8
October	14	75	102	8	30	1	211
Totals	16	77	104	12	30	1	219

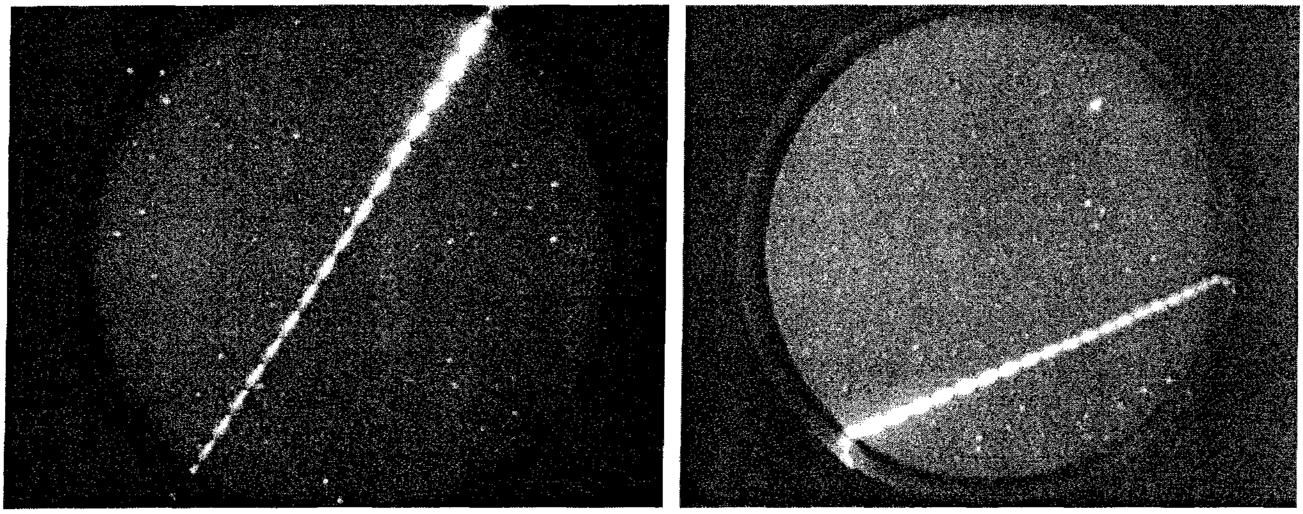

Figure 4 – A double-station Leonid. Left: the Leonid fireball of magnitude −4 from Maspalomas (Gran Canaria). Right: from the Izaña Observatory (Tenerife). The AVI file of this meteor can be viewed at `http://www.astrored.net/somyce`.

Table 4 – Total number of meteors recorded in November and December 2000 broken down into meteor showers.

Showers	NTA	STA	AMO	LEO	COM	PUP	HYD	XOR	GEM	MON	Spo
November	29	40	12	52	–	–	–	–	–	–	140
December	–	–	–	–	26	3	13	18	81	15	262
Totals	29	40	12	52	26	3	13	18	81	15	402

Table 5 – Total number of meteors recorded in January to March 2001 broken down into meteor showers.

Showers	DCA	COM	CUA	VIR	ACE	DLE	GNO	Spo
January 2001	53	27	15	11	4	–	–	292
February	–	–	–	38	10	6	2	281
March	–	–	–	30	–	2	6	191
Totals	53	27	15	79	14	8	8	764

Then, in 2000 November, we conducted our first double-station work with Izaña (Tenerife). On November 18 we recorded 33 double-station meteors (23 Leonids, 1 Northern Taurid, 1 Southern Taurid, and 8 sporadics).

3. Prospects and collaboration

Our present aim is to observe continuously all night. We are trying to observe all active meteor showers and, when possible, to conduct double-station work to compute the orbital elements. Were it economically feasible, we would like to mount a diffraction grating to obtain meteor spectra. Collaboration with other video meteors observers and especially with the *IMO* Video Commission is our priority.

Acknowledgments

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2000 Ursid Outburst Confirmed

Peter Jenniskens, SETI Inst./NASA Ames Res. Ctr, and Esko Lyytinen

The meteor outburst predicted from the Earth's encounter with the 1392 and 1405 dust ejecta of comet 8P/Tuttle was observed from California using video and photographic techniques. At the same time, five Global-MS-Net stations in Finland, Japan, and Belgium counted meteors using forward meteor scatter. Here, we present an account of the effort and some preliminary results that confirm the return of the Ursid outburst with a maximum at $8^h06^m \pm 07$ UT, December 22, when activity peaked at ZHR $\approx$ 90. The Ursid rates were above half peak intensity during 4.2 hours. The relative contribution from both dust trails to the outburst is discussed.

1. Introduction

The Ursid shower is dynamically related to the Leonid shower. Both are caused by comets in Halley-type orbits that are temporarily trapped in mean motion resonances with Jupiter. Application of the Leonid shower prediction models to the Ursids in early December revealed that the Earth was about to cross the dust trails of 1405 on December 22, 2000, at 7^h29^m UT [1]. The model predicted that the particles of the 1405 trail would be smaller than during past outbursts in 1945 and 1986, perhaps rather near the visual detection limit under good observing conditions. It was also predicted that the trailet of 1392 (with larger meteoroids) might show up at 8^h38^m UT and, if so, these events would probably make a continuous profile 4–5 hours wide, but might be recognized separately. The model left some questions as to the expected level of activity, but we anticipated a rate of about 1 meteor per minute. Allowing for some limitations to the depth of analysis, we suspected that another trail ejected in 1378 might also contribute around 8^h59^m UT. If confirmed, this would be only the second time that meteors are traced to a specific epoch of comet ejection and the lower Ursid speed would make comparison with the Leonids interesting.

The results were summarized in a *WGN* article, a preprint of which was widely circulated on the internet and in the meteor astronomy community prior to the shower. `Space.com` ran a story on the topic. Astronomers were alerted through a brief announcement in the *IAU Circulars*, which was possibly the first announcement of a meteor outburst published in this medium [2]. The public interest was peaked by the prospect of dust dating to before the time of Columbus hitting the Earth at a time just before Christmas. The NASA Ames Research Center, in collaboration with the SETI Institute, issued a press release that was widely circulated in the news media worldwide.

2. The observations

In order to confirm the predictions, observing teams were assembled in California that deployed intensified video cameras and photographic cameras at two separate sites for multi-station imaging. Low-resolution spectrographs were deployed as well, in the hope of comparing the physical properties of the Ursid meteoroids with those of the Leonids.

In search of clear weather, the two sites were set up a one-hour drive further south than usual. At Lake San Antonio, just south of King City, Mike Koop operated four intensified video cameras (two aimed at 70° elevation and two at 30°, due east), Mike Wilson ran a CCD spectrometer, and Chris Angelos and Peter Gural operated a photographic setup of thirteen 35-mm cameras and an all-sky intensified video camera for meteor timing. Peter Gural traveled for the occasion from the east coast (where it was clouded) to California to witness the event. At 74 km to the east, at a site south of Coalinga at the intersection of Routes 33 and 41, Peter Jenniskens operated six intensified cameras (four at 70°, two at 25° east) and the low-resolution slit-less spectrograph "BETSY", while Ming Li and Duncan McNeill ran a second thirteen-camera battery.

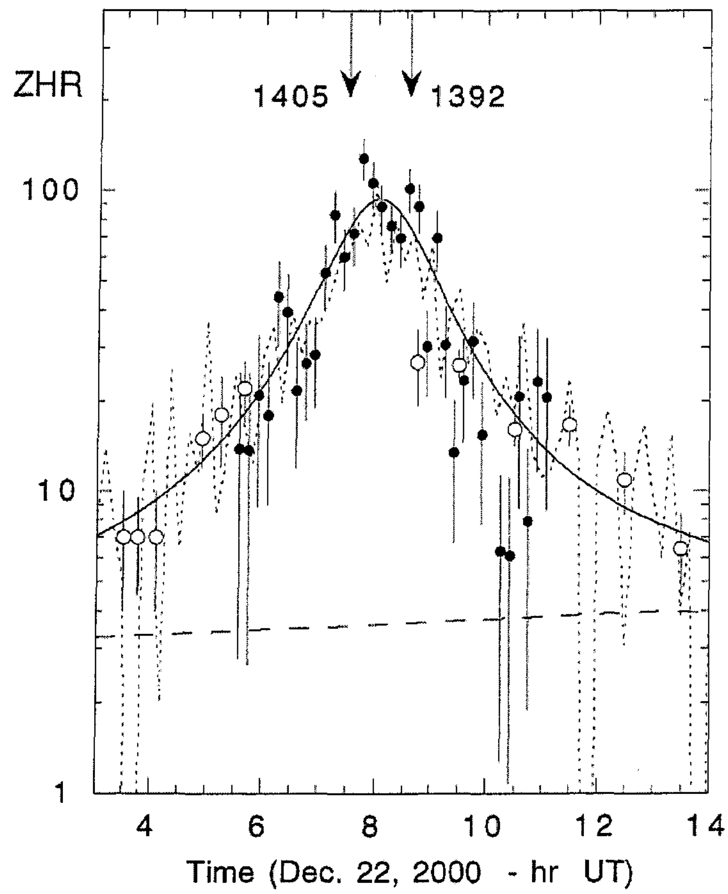

Figure 1 – ZHR curve of Ursids from video (•), visual (∘), and radio forward meteor scatter data (···). The dashed line shows the level of annual Ursid activity.

3. Results

Observations commenced at $5^{\mathrm{h}}25^{\mathrm{m}}$ UT and initially only the occasional Ursid was observed. After 7^{h} UT, Ursids were more and more frequent and at 8^{h} UT it was clear that an outburst was in progress when Ursids appeared at a rate of 1 every two minutes [3]. Most Ursids were relatively faint, of magnitudes +3 to +5. An hour later, the activity had declined. At $11^{\mathrm{h}}30^{\mathrm{m}}$, clouds came in and the observations were ended.

A total of 431 Ursids were detected in a single visual scan of the video tapes amidst 394 other meteors in a total of 28.4 hours of effective observing time. At least 42 fine video Ursids were recorded multi-station between $6^{\mathrm{h}}45^{\mathrm{m}}$ and $9^{\mathrm{h}}08^{\mathrm{m}}$ UT, the brightest only magnitude +1. Despite a significant effort, only two Ursids were photographed and both were not multi-station and only just bright enough to be detected. Four Ursid spectra were recorded with the slit-less spectrograph, all faint. No Ursid was bright enough and well enough placed to give a good signal on the CCD spectrometer.

Figure 1 shows the average number of Ursids counted in ten-minute intervals from eight independent cameras, six at the Coalinga site and two at the King City cite (dark dots). These counts are scaled to the Zenith Hourly Rates calculated from visual observations in the Netherlands, calculated by Marco Langbroek of the Dutch Meteor Society (left), and similar observations in Japan, calculated by Masaaki Takanash of the Nippon Meteor Society (right). The peak activity appears to have been rather high, with ZHR ≈ 90, but the high magnitude distribution index and the low radiant altitude (26°) made this a much less impressive shower than the Perseids. From the ratio of sporadics and Ursids, we find $r = 3.5 \pm 0.5$ before 8^{h} UT and $r = 2.8 \pm 0.3$ after 8^{h} UT, assuming all others have $r_{\mathrm{s}} = 3.4$. For the high cameras only, we have $r \approx 3.2$ and $r \approx 2.9$ respectively. From the Ursid count as a function of magnitude, we have $r \approx 2.6$ and $r \approx 2.4$, with $r_{\mathrm{s}} \approx 3.0$, but sensitive to the assumed magnitude range over which all meteors are detected.

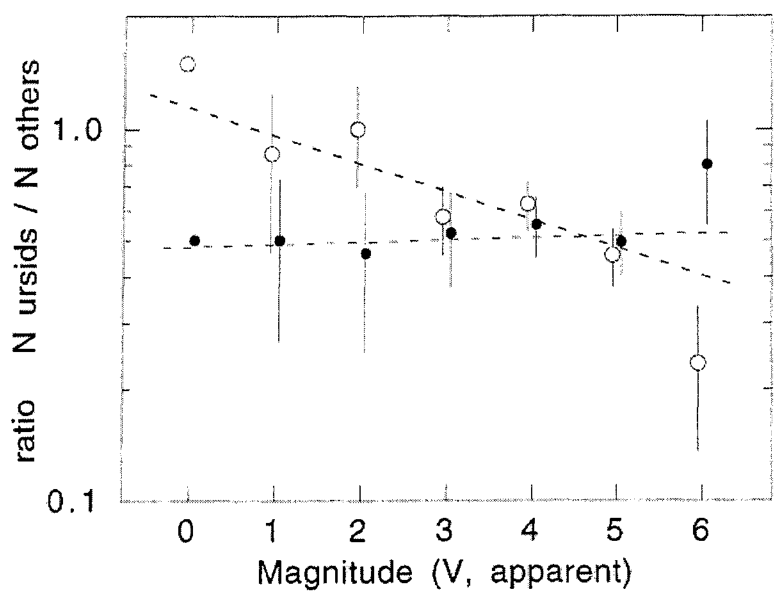

Figure 2 – Apparent magnitude distribution as manifested in the ratio of Ursids and Sporadics for periods prior to (•) and after (∘) 8^{h} UT (all cameras).

Radio meteor scatter observations were provided by five stations of the Global Meteor Scatter Network [4]. Ten-minute counts were obtained by Esko Lyytinen and Ilkka Yrjölä in Finland, Hiroshi Ogawa and Kazuhiro Suzuki in Japan, and Pierre de Groote in Belgium. The mean of those counts is shown as a dashed line in Figure 1 and corresponds well with the video record. A Lorentzian curve fitted to the data gives a full width at half maximum of $0\overset{\circ}{.}18 \pm 0\overset{\circ}{.}02$ (4.2 hours) and a peak time at $\lambda_\odot = 270.^\circ780 \pm 0.005$ (J2000), or $8^h06^m \pm 7$ min UT. The $8^h24^m54^s$ UT Ursid spectrum revealed a surprise. The element sodium was lost relatively early in the trajectory in a similar manner as observed before for the Leonids [5]. This has been interpreted as to imply that the meteoroids are very fragile and break apart in many pieces during flight, thus exposing the sodium-containing minerals to ablation. This is consistent with the Ursids being fresh cometary matter. It is clear that this feature of the meteoroids is not affected even after 44 revolutions or a total age of about 600 yr in the interplanetary medium.

Another interesting result is the relative strength of the first positive bands of nitrogen. The presence of the bands implies that the excitation temperature in the meteor wake is not much different from than observed in Leonid meteors that are double the speed of Ursids.

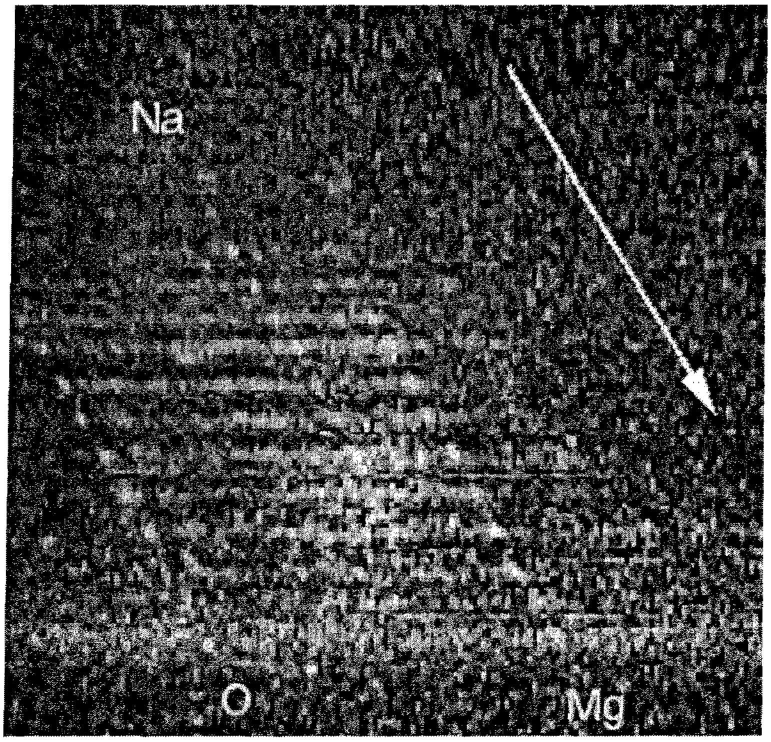

Figure 3 – Compilation of the video spectrum of the $8^h24^m54^s$ UT Ursid meteor. The wavelength scale runs right to left, while the meteor moved from top left to bottom right. Individual frames show the emission lines of atmospheric oxygen (O), meteoric sodium (Na) and meteoric magnesium (Mg). Diffuse horizontal bands are the atmospheric first positive bands of the nitrogen molecule.

4. Discussion

The return of the Ursids demonstrates that the basic approach of current models is valid even for as many as 44 orbital revolutions. The observed profile peaks exactly in between the predicted times for the 1405 and 1392 dust trails, as expected if both trails contribute to the profile. The 1378 trail was not detected. There is no clear sign of the activity curve being double-peaked and the shape and position of the profile can be interpreted in two extreme ways: either the 1405 peak time was later than calculated, or the 1392 dust trailet contributed more than expected. In particular, the 1405 trailet time could be off because the $A2$ effect may not have been taken into account correctly. Alternatively, the 1392 dust trail could be more spread out perpendicular to the Earth's orbit than the factor of four for the Leonids. If both trails were present and the peak times were correct, then they contributed about equal amounts. The truth, however, is probably somewhere in the middle. At least some contribution from the 1392 dust trailet late in the profile is implied by the hint that later Ursids were brighter on average.

The reduction of the multi-station video meteors may shed more light on the relative contribution of both trails. These results will be published elsewhere.

Acknowledgments

We thank all observers that participated in the California expedition and in Global-MS-Net, in particular Mike Koop and Ilkka Yrjölä who have continued to play a leading role in these efforts. All are congratulated with the nice observational results reported here. Part of this work is supported by the NASA Planetary Atmospheres program and by NASA Ames Research Center.

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Review of Current Literature

Meteors Producing VLF Signatures Independent of Producing Electrophonic Sounds

George John Drobnock

1. Introduction

It is the opinion of some researchers that meteors traveling through the upper atmosphere only produce a Very Low Frequency (VLF) electromagnetic signature in the form of an electrophonic sound, if the meteor is of sufficient mass to produce a fireball or bolide with a visual magnitude of greater than −6. Keay and others have stated a meteor will create a disturbance that produce VLF electromagnetic radiation that will be rectified into "sound."

Other research to date has not accepted that a meteor may be, by it's disintegration in the atmosphere generating small amounts of VLF electromagnetic radiation that has gone un-noticed.

The recent work of Colin Price and Moshe Blum [1] disagrees with Keay. Price and Blum suggest that small meteors entering the atmosphere produce ELF/VLF spectral pulse signatures. These pulses could be separate from the production of an audible sound. Price stated that a definite radio signal was detected in the 1 to 15-kHz range. The signals occurred only within the initial entry of the meteor into the atmosphere, lasting a no longer than ten milliseconds, and then nothing, even though the meteorite is visible for up to a few seconds (e-mail March 9, 2000 and January 18, 2001, C. Price [2]).

2. Background literature

The question of meteors producing electromagnetic signatures has been discussed for the past half century [3,4,5,6].

The exception to concentrating on VLF research was Hawkins. His research was in the VHF range (30 to 475 MHz). He did a test in the ELF or the range of 1 Hz. Hawkins was attempting to replicate work of A.G. Kalashnikov who "seemed to show that meteors produced radio noise at the lower end of the (electromagnetic) spectrum at a frequency of about 1 Hz [7]." Hawkins concluded that Kalashnikov misinterpreted his data.

In 1988 [8], I undertook a project to detect the VLF signature of a meteor entering the atmosphere. The research was based on Hawkins and Keay. And a VLF receiver I constructed was designed by Charles Welch [9] to detect the VLF signature of rockets exhaust launched from Earth. My initial research showed that a meteor with a visual magnitude of +1 does produce a very low frequency (VLF) signature. Additional observations indicate that meteors within the range of −2 to +1 were detected.

In 1992 the initial findings, published in *Sky & Telescope*, stated that VLF signals were detected from a non-fireball event. All research to date has been the detecting of signatures from a fireball. The 1988 and 1992 research was questioned by Zeljko Andreić [10] and Martin Beech [11].

Independent researchers have tried to repeat the detection of non-fireball events—any meteor with a magnitude less than −6. Takash Watanaba, Tashimi Okada, and Kazuhiro Suzuki, in 1988 described the detection of a magnitude −6 Perseid fireball in the frequency range between 300 Hz to 6 kHz [12].

V.A. Bronshten in 1991 [13] using the theory that ELF/VLF radiation would be produced by trapping and tangling Earth's magnetic field in the turbulent plasma tail of an ablating meteoroid, stated that a meteor with a minimal brightness of −12 was necessary for the production of VLF related sounds.

Zeljko Andreić et al. in 1993 [10] were unsuccessful in detection of a meteor signature. They concluded that if a radio emission exist during and after the flight of a meteor in the ionosphere, the intensity of such an event is below the sensitivity of their equipment, or the signal was masked by ionospheric noise, or the maximum of the emitted energy is at a different frequency than monitored.

Martin Beech et al. in 1995 [11,14] suggest it is possible to detect a meteor with a visual magnitude of -10 ± 1 with a very-low-frequency radio receiver. Beech concludes that the detection of a meteor in the visual magnitude range of magnitude $> +1$ to > -10 can not produce a VLF radio emission. Beech suggested my detection of a non-fire ball signature may have been natural VLF radio emissions.

S. Garaj et al. published at years end of 1999 [15] state that the Leonids of 1998 had a high rate of correlation between visual and VLF meteors. The research suggests that brightness for VLF emissions is much lower than thought. The team suggest a limit of magnitude −5. The team stated that they did not detect electrophonic sounds, due to "insufficient of the signal or the absence of proper objects for electrophonic conversion." An overview of VLF research is given in Table 1.

Table 1 – Research known published to date with detection criteria. (see Reference Section for sources.)

Researcher, Year	VLF Signal Detected	Meteor Magn. Limit	VLF Signal Range
G. Hawkens, 1958 [3,7]	no	−1	at 1 Hz
T. Watanabe et al., 1988 [12]	yes	−6	4–8 kHz(?)
Drobnock, 1992 [8]	yes	+1	4.85 kHz
Andreić et al., 1993 [10]	no	−1 (?)	1.25–10.6 kHz
M. Beech et al., 1995 [11]	yes	−10/ − 11	1–10 kHz
S. Garaj et al., 1999/00 [15]	yes	−5	1–10.5 kHz
C. Price & M. Blum, 2000 [1]	yes	> +6	1–15 kHz

3. Propagation of VLF signatures from a meteor

The problematic question that has arisen after the publication in *Sky & Telescope* is—"Can a meteor with a visual magnitude of less than (−6) produce a VLF signature of signal?"

The event I recorded was a serendipitous meteor signature, below magnitude −10 and with an energy level below that suggested by Beech and others. The serendipitous reception may be based on the nature of very low frequency radio waves and their propagation in the upper atmosphere.

Electromagnetic waves at any frequency normally propagate in straight lines or are bent around curves by the process of reflection, refraction, and diffraction. These three processes are the bases of radio propagation. Diffraction is the more significant of the propagation process for VLF [16]. The theory of diffraction is that every point on the edge of a VLF electromagnetic wave acts as a new source of wave.

A VLF signature from a meteor that produces a visual magnitude of less than −6 is in the process of loosing mass and signal strength, its signal may have already been reflected back to into space and not to the Earth. Or its signal may be ducted along the upper atmosphere to a point where reception of the VLF signal is not received by the observer.

The larger meteors, producing a visual magnitude greater than −6, in the range of −10 or −20, have sufficient mass (see Table 2) to continue to produce a VLF signature that may well follow Keay's concept of electrophonics. At the same moment produce a strong VLF signature capable of being received by a receiver. The mass may allow the meteor to penetrate the atmosphere to a point where the produced VLF signature is both received by a VLF receiver or perceived as sound.

It is an accepted idea that fireballs produce electrophonic sound somewhere on the spectrum of very low frequency radio or very high frequency audio [4]. Keay suggests low frequency radiation (VLF electromagnetic waves) intermingles with the atmosphere causing an audio rectification of the electromagnetic signal. The observer hears a "hissing" noise or a whistle. This is dependent on the propagation of a wave—some point where between a sound and an electromagnetic wave of the same frequency.

As any meteor enters the atmosphere, its destruction does produce ionization of the atmosphere; an ionized gas trail that can be detected by radar. If the meteor is of sufficient mass, it also produces a visible trail. The entry and destruction of most small meteors are visible. By passing through the atmosphere at a high rate of speed, vaporization of the meteor and the ionization of the upper atmosphere's gases are caused, releasing additional energy in the Earth's natural electromagnetic spectrum. This released energy may be perceived to be a "whistler". Under certain conditions the VLF signature produced by a meteor may travel away from the Earth and return along a magnetic field line.

Table 2 – Relationship of mass and size to visual magnitude of a meteor.

Visual Magnitude	+15	+7	0	−7	−15
Average Diameter Average Mass	100 μm 10^{-7} g	1 mm 10^{-4} g	2 cm 1 g	20 cm 100 g	2 m 10^{6} g

The smaller meteor releases a smaller amount of energy in the form of very low frequency radio waves, and under certain atmospheric conditions the propagation of these radio signals allows them to travel great distances or be absorbed or combined with other nature atmospheric enhancements. Under the right conditions, a VLF signature can be detected with a sensitive receiver.

Given that there is evidence that meteors and, most particularly, fireballs do produce audio noise [17]. A number of earlier written sources do relate to the sound emitting from meteors [18,19].

Price and Blum are showing that not all natural VLF radio emissions are natural earth bound discharges commonly associated with lightning or aurora. Without coordinating observed visual meteors and VLF signatures of a meteor, all VLF signals, static discharges, electromagnetic storms, or other sources, create a signal-to-noise ratio so large that the natural noise would cancel out the signal produced by the meteor.

It is accepted that VLF radiation follows a duct. The duct can be two layers of the ionosphere (referred to as the E, D, or F Layers with the layers being important to radio communications) or the surface of the Earth and the upper atmosphere forming the duct [20,21].

This may be the reason detection of a small meteor signal is difficult. As with the experimental observations that I have made to detect a VLF radio signal from a meteor entering the atmosphere, one needs to observe the object entering the atmosphere and listen for the related noise or discharge. Price has done demonstrated using correlated optical observations and VLF signals.

Ya Qi Li [22] suggest that there are more high-altitude electrical discharges occurring than currently being detected. Price has demonstrated the other discharges may be meteor activity.

We can not assume that as the meteor enters the atmosphere, it's signature will reach an earth bound receiving station.

Assume each meteor entering the atmosphere is an individual transmitter or producer of a electromagnetic VLF signature. Then the VLF long wave produced will be ducted between the layers in the electrical charged upper atmosphere. The size of the wave guide or duct affects the signal produced. The electrically charged wave guide can vary in size and position by the movement of the upper atmosphere. This in effect would weaken the signal or limit the frequency produced (cut-off). The term used by radio engineers is MUF—maximum usable frequency—under given atmospheric conditions [23].

In the upper atmosphere, the ionized gases shape the trail and possibly the direction of the radio signal. The effect of ducting is important to a signal generated by an incoming meteor reaching an Earth bound receiver.

The local reception of a weak VLF signal may need to have a "duct" open in the direction of the observer and receiver. Weak VLF signals may benefit from "ducting". A balloon at an altitude of 32 km may be within a duct allowing signatures from a VLF signal from a meteor 112 to 160 km above the Earth to be detected.

4. Conclusion

If a meteor with a mass from 1 to 100 grams can produce a visible trail between magnitudes 0 and −7, the same mass can ionize the upper atmosphere for radio communications. If a meteor of 100 grams or greater can produce a sound that is caused by rectification of a VLF signal and atmospheric mingling, then it's radio signature is a product of the event and attributed to creating an electrophonic event.

The research on the production of VLF signatures by smaller meteors has just begun. The upper atmosphere may be masking the VLF signatures of smaller meteors. The use of upper-atmosphere probes and the observations of observers at quiet ground sites will further capture and identify the electromagnetic radiation from non-fireball events.

The electrophonic sounds suggested by Keay and others may be the rectification of VLF electromagnetic spectrum to an audio VLF sound. It is suggested that the reason why not all electrophonic sounds are not heard is the result of proper objects being available for the conversion. Another explanation may be due to the upper atmosphere, the surface of the Earth, and the location of the observer acting as a solid-state semiconductor forming (at first glance) a simple series-resonant circuit. And only when an object of sufficient mass creates and releases the VLF signal it is heard.

At all other times a meteor entering the atmosphere is producing a VLF signature that has gone unnoticed and attributed to standard natural VLF emissions and not related to meteor activity.

If Dr. Price can research with an upper-atmosphere probe and detected a weak signal, then his research is a better case that all meteors do produce an electromagnetic spectrum signal. A meteor signal may have been observed many times before and but only attributed to atmospheric conditions related to electrical discharges in the form of lightning. Dr. Price has shown a meteor produces VLF radio signatures. Signatures that are masked with by other natural emissions. I hope some of the above comments are useful.

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Observational Results

SPA Meteor Section Results: May–June 2000

Alastair McBeath

Information drawn from observations and correspondence presented to the *SPA Meteor Section* from May and June, 2000, is given and discussed. The η-Aquarid maximum in early May was somewhat less extensive than in 1999, although ZHRs of 50+ seemed present on most mornings between May 2–8, perhaps at their best on May 5-6 at 65 ± 10 ($\lambda_{\odot} \approx 46°$, eq. J2000.0). The radio data indicate generally enhanced meteor activity from May 5–10, with all available results showing a peak around May 7–8 ($\lambda_{\odot} = 47°$–$48°$), and another, recorded by some as the strongest May peak, on May 10 ($\lambda_{\odot} \approx 50°$). The paucity of visual results from June, coupled with the strongest Sporadic-E season for years, combined to make analyzing data from then exceptionally difficult. However, a radiant determination was made for the Arietids on June 6–8 centered at $\alpha = 49° \pm 2°$ and $\delta = +24° \pm 1°$, as observed by the SKiYMET meteor radar system in southern Australia. The SKiYMET data also confirmed the Arietid maximum time as falling between June 6 and 8. No clear signatures due to either the proposed June Lyrid maximum around June 15, or the June Bootid peak on June 27, were found in the radio results, but this is inconclusive. A bright fireball in strong twilight was spotted soon after sunset from several sites in the UK between 21^h10^m and 21^h15^m UT on June 17-18.

1. Introduction

May and June are often difficult months for our mainly northern hemisphere observers because of the extended overnight twilight, and the increasing likelihood of Sporadic-E (Es) for our radio workers. After mid-May and continuing throughout the northern summer, Es produced some of the worst radio observing conditions for years, making the very fragmented observations impossible to sensibly analyze at times. Visual and imaging totals were also well down on previous years, as indicated by Table 1.

Table 1 – Visual, photographic, radio, and video hours' totals, plus visual meteor numbers and video trails recorded in each month. In January, 661 visual Quadrantids were reported from the meteor tally.

Month	Visual	Meteors	Photo	Radio	Video	Trails
May	$24^{\rm h}\!.0$	413		$4426^{\rm h}$	$101^{\rm h}\!.4$	338
June	$2^{\rm h}\!.6$	4	$57^{\rm h}$	$5544^{\rm h}$	$93^{\rm h}\!.5$	286

Photographic reports came exclusively from two *Arbeitskreis Meteore* (*AKM*) members, Jürgen Rendtel and Jörg Strunk in Germany, and were extracted from the *AKM* journal *Meteoros* 3:8/9 (2000), provided by Ina Rendtel.

Results from the SKiYMET meteor radar in southern Australia made in early June were reported to us by Brian Fuller.

Much of the radio results were kindly submitted by Christian Steyaert as *Radio Meteor Observation Bulletins* (*RMOB*s) 82–84, inclusive, June to August, 2000. The radio observers included the following:

> Enric Fraile Algeciras (Spain; *RMOB*), Dirk Artoos (Belgium), Mike Boschat (Canada; *RMOB*), Maurice de Meyere (Belgium; *RMOB*), Didier Favre (France; *RMOB*), Ghent University (Belgium; *RMOB*), Will Kelsey (Arkansas, USA; *RMOB*), Werfried Kuneth (Austria; *RMOB*), R.B. Minton (New Mexico, USA; data also in *RMOB*s 83 and 84), Ton Schoenmaker (the Netherlands; *RMOB*), Dave Swan (England; *RMOB*), Pierre Terrier (France; *RMOB*), Garfield Tsao (Taiwan; *RMOB*), Ilkka Yrjölä (Finland; *RMOB*).

These raw observations were processed as normal, and two graphs showing reasonably representative May and June results are given here as Figures 1 and 2. In both instances, the graphs were chosen as being among the data least affected by Es. Figure 2 in particular demonstrates clearly how exceptionally bad radio reception conditions were in June.

Video data made by *AKM* members Sirko Molau, Mirko Nitschke, and Jürgen Rendtel in Germany were extracted from *Meteoros* 3:6 and 3:8/9 (2000).

Visual observations came from the following observers:

> Mary Cook (England), Tim Cooper (South Africa), Marco Langbroek (Netherlands), and Koen Miskotte (the Netherlands),

along with a preliminary summary report on the *Astroclub Canopus* June Bootid watches sent in by observer Eva Bojurova.

2. May

Early May brought a moonless η-Aquarid return, whose maximum produced a clear "bulge" in the radio rates, as Figure 1 shows. The stronger rates were less long-lasting than was apparent last year, although visual ZHRs of 60 ± 20 seemed present on the mornings of May 2, and 5–8, inclusive, in our data, reaching 65 ± 10 on May 5-6 ($\lambda_\odot \approx 46°$). This possible visual peak is not clearly confirmed by the preliminary *IMO* reports [1,2], covering April 29–May 11, which show ZHRs between 35 and 50 with error margins between 5 and 10 between May 3 and 8.

The radio reports indicate generally enhanced meteor activity from May 5 to 10, with all available results showing a peak around May 7–8 ($\lambda_\odot = 47°$–$48°$), and another, recorded by some as the strongest May peak, on May 10 ($\lambda_\odot \approx 50°$). The few *SPAMS* and *IMO* visual results covering this later period suggest ZHRs were 60 ± 10 on May 8, but only 25 ± 5 by May 10.

The relative weakness of the radio signature on May 10 in longer-duration echoes (only one data set was available, however) might suggest more fainter meteors then, which would be more difficult for the visual observers to spot in near-dawn skies, even from the southern hemisphere, but this is not conclusive.

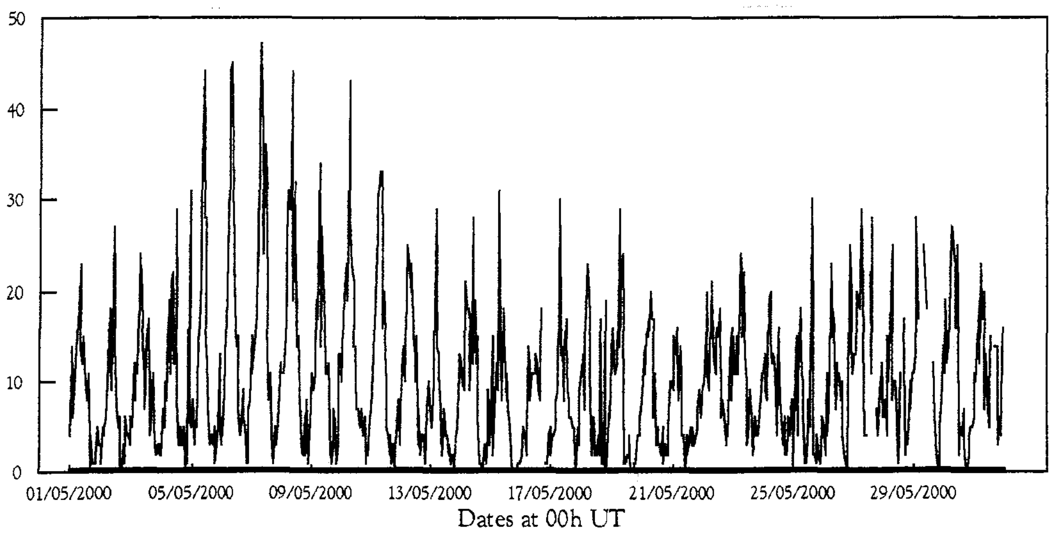

Figure 1 – Raw hourly radio meteor echo counts from May 2000 as reported by Pierre Terrier in *RMOB* 82 (June 2000). Pierre operated his system continuously all month, but did not record times when Es or other interference affected his set-up. To allow for this, breaks have been introduced on May 16, 27–29, inclusive, and ≈ 1 here to remove anomalously high echo counts not reported by other European observers, or when interference was problematic with other European radio systems.

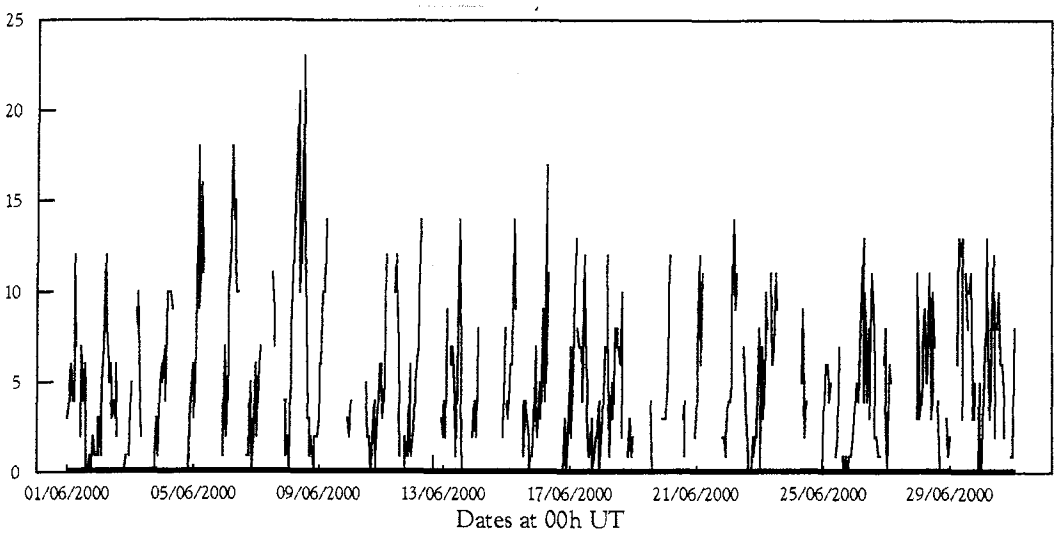

Figure 2 – Raw hourly radio meteor echo counts of duration 6.5 s or more during June 2000 in data from Werfried Kuneth in *RMOB* 84 (August 2000). Werfried's system was normally working 24 hours a day. He also provided a listing of all times when (primarily Es) interference affected his recording. To give a clearer indication of the problems Es created in June, all times noted by him as affected by Es have been deliberately removed here, along with the few other periods when the system was not operating. Despite the fragmentary nature of the graph thus created, Werfried's was one of the more complete data sets from 2000 June!

There is a slight difference between the corrected mean magnitude for η-Aquarids seen on May 10 (+3.26) and the overall shower mean (+3.15—see Table 2), though the small meteor sample (17 η-Aquarids on May 10) makes this of questionable use. Too few trains were recorded from the η-Aquarids to allow an examination of this aspect of the shower. Table 2 also has a magnitude distribution for the May sporadics.

Table 2 – Global magnitude distributions for the η-Aquarids and May sporadics seen in good sky conditions (limiting magnitude of +5.5 or better, average cloud cover of less than 20%), including mean limiting magnitudes and corrected mean magnitudes.

Shower	-3^-	-2	-1	0	+1	+2	+3	+4	$+5^+$	Tot	Lm	$\overline{m}_{6.5}$
η-Aquarids	1	2	5	4	18.5	33	39	27	13.5	143	5.9	3.15
Sporadics	–	–	2	2	10	20	52	61	40	187	6.9	4.04

No visual reports were received from after mid-May, though all the previously-detected radio echo count peaks detailed in [3] were recovered again, much as normal, including that around $\lambda_\odot = 60°$–$61°$ (May 21–22) first found in 1998 [4]. During the second half of May, Es became increasingly prevalent, which made both the $\lambda_\odot = 62°$–$66°$ and $\lambda_\odot = 69°$ peaks (May 23–27 and 30, respectively) significantly less easy to note than in past years. Something of these problems can be gleaned from Figure 1.

3. June

Figure 2 demonstrates how unhelpful Es became throughout June this year. There are too many times when only uncertain or even no radio data are available, and although most of the expected echo count peaks from [3] were noted by some observers, these results cannot be regarded as anything more than tentative. The $\lambda_\odot = 73°$ peak (June 3) was the only one definitely not found because of Es.

The expected Arietid and ζ-Perseid peaks, which normally cluster in a moderate to strong radio meteor echo count enhancement between $\lambda_\odot = 75°$ and $\lambda_\odot = 82°$ (June 5–13, sometimes beginning as early as $\lambda_\odot = 72°$), produced enhanced activity at some stage between these times in 2000, but there is no consensus between the various Es-affected datasets as to when the better peaks occurred. Indeed matters were worsened by auroral interference on June 8!

One positive result from this period was the radar determination of the Arietid radiant by the southern Australian SKiYMET meteor radar, the first such position to be reported for some years. Between June 6, 0^h30^m to June 8, 23^h29^m ($\lambda_\odot = 75\overset{\circ}{.}60$–$78\overset{\circ}{.}45$), the radiant was centered around $\alpha = 49°$ and $\delta = +28°$ derived using a spatial bin size of $\Delta\alpha = 4°$ and $\Delta\delta = 2°$. The expected radiant position for June 7 from previous radar observations, mostly made no more recently than the early 1970s, was at $\alpha = 44°$ and $\delta = +24°$, which is a close match for this latest report.

Brian Fuller, who provided the SKiYMET data, noted the June 6–8 spell was also the period of highest Arietid rates as seen by similar radars in Australia, Brazil, Sweden, and Germany, again a useful confirmation that we still have the peak time for this shower accurately fixed. The proximity of the Arietid (June 7) and ζ-Perseid (June 9) peaks to one another, and the fact that their radiants are relatively near one another, spatially, too, means radio systems are usually unable to separate the two sources at all.

The minor $\lambda_\odot = 84°$ (June 15) radio peak, which commonly shows a spread of small maxima between $\lambda_\odot = 81°$ and $\lambda_\odot = 87°$, was found at some stage by most observers between $\lambda_\odot = 84°$ and $\lambda_\odot = 87°$ when Es permitted, more especially around $\lambda_\odot = 85°$–$86°$ (June 16–17). Although this approximately coincided in time with when any June Lyrid peak might have occurred, around June 15 [5], it is unclear if it may be this source or the Sagittarids which has produced this radio signature in past years, while this year's poor observing circumstances mean it would be unwise to read too much into this detection anyway.

On June 17-18, between 21^h10^m and 21^h15^m UT, and still in strong evening twilight, a bright fireball of perhaps magnitude -6 to -9 or so at best, was observed from six sites in central-southern England and south Wales. Details were regrettably sketchy from most of the witnesses, but a track possibly passing on a general easterly to westerly trajectory, around 80–100 km above the Derby area of the northern English Midlands (near $\varphi = 53°$ N and $\lambda = 1\overset{\circ}{.}5$ W) is suggested by the more detailed sightings. It is most unlikely this event was related to the magnitude -12 daylight fireball that passed south to north over northwest Italy around 13^h35^m UT on June 18, reported on the *IMO-News* electronic mailing list on June 20 (message sent by Albino Carbognani).

In late June, the $\lambda_\odot = 89°$–$97°$ (June 20–28) radio peak, probably associated with the β-Taurids, was seen only patchily because of some very severe Es. No clear peak around $\lambda_\odot = 96°$ (June 27 [5]), which could have been due to the June Bootids, was found, though the often fragmentary nature of the radio record is unhelpful. A few suspected visual June Bootids were reported to us, the low rates not convincing, scarcely surprising, as the preliminary *IMO* findings showed only borderline weak to nonexistent activity from the shower this year [6].

One interesting aspect of late June was that, despite the Es problems, all the radio observers who could be active found a consistently strong peak at $\lambda_\odot \approx 98°$ (June 30). This has been seen before as the start of the extended $\lambda_\odot \approx 99°$ period (running from $\lambda_\odot = 97°$ to $\lambda_\odot = 99°$ in some years), though, typically, not quite as strongly. Whether this was genuinely unusual activity, perhaps from the β-Taurids, or simply resulted from the artificially suppressed Es-struck comparison data, is most unclear.

Acknowledgments

As always, I have great pleasure in ending by thanking all the *Section* observers and correspondents for their efforts in making this report possible. To those already credited, I would like to add thanks to Bob Lunsford for making the connection between Brian Fuller and myself, and John Lambert for his help in tracking down some of the June 17-18 fireball observers. Clear skies to all!

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SPA Meteor Section Results: July–August, 2000

Alastair McBeath

Information in reports provided to the *SPA Meteor Section* from July and August 2000 are given and discussed. The Perseid epoch from late July through to the moonlit maxima in mid-August received significant coverage, though the period closest to the main maximum on August 12 was not observed. Eleven fireballs were seen from the UK between August 19-20 and 30-31, several very bright, and three witnessed from multiple sites, apparently part of a loosely-defined "cluster" of internationally-reported fireballs during the second half of August. Radio observers in both months found continuing problems with Sporadic-E, and, near the Perseids' best, auroral interference too.

1. Introduction

Difficulties due to Sporadic-E (Es) propagation continued to plague our radio operators throughout July (especially) and August, but for visual observers, conditions were not as bad. In Britain for instance, although the 2000 summer was significantly cooler and wetter in many parts than for some years, some better skies right on cue for the Perseids meant just 6 of the 25 nights from July 19-20 to August 12-13 inclusive produced no visual meteor reports, a situation virtually unique from the past 17 years! Table 1 gives the observing totals.

All of the photographic results, and much of the video ones, came from the German *Arbeitskreis Meteore* (*AKM*) group, which, along with their visual data, were chiefly extracted from their Journal *Meteoros* 3:8/9 and 3:10 (2000) submitted by Ina Rendtel. The photographers were Jürgen Rendtel and Jörg Strunk (both of whom also made video observations), while other video observers included André Knöfel, Detlef Koschny (Netherlands), Jeff Lashley (Scotland), Sirko Molau and Mirko Nitschke. Jeff Lashley was able to provide probable identifications for 59 of his 62 video meteors, comprising 26 sporadics, 18 Perseids, 10 κ-Cygnids, four Southern δ-Aquarids and one α-Capricornid.

Of the radio reports, all the data except those from the team led by Albert Heyes, and R.B. Minton, were provided by Chris Steyaert in *Radio Meteor Observation Bulletins* (*RMOB*s) 84 and 85, August and September 2000 respectively. The radio observers were:

> Enric Fraile Algeciras (Spain), Mike Boschat (Canada), Maurice de Meyere (Belgium), Ghent University (Belgium), Albert Heyes (England; with John Blakeley and Jim Leviston), Will Kelsey (Arkansas, USA), Werfried Kuneth (Austria), R B Minton (New Mexico, USA; results also in *RMOBs* 85 and 86, September and October 2000), Sadao Okamoto (Japan), Ton Schoenmaker (Netherlands), Dave Swan (England), Pierre Terrier (France), Garfield Tsao (Taiwan), Ilkka Yrjölä (Finland).

The raw results were analyzed as usual, and Figure 1 gives a representative graph of what was detected in one of the more complete datasets from July–August. The trends in this are generally confirmed by most other radio reports.

Our visual watchers included:

> *AKM* members: Rainer Arlt, Pierre Bader, Lukas Bolz, Frank Enzlein, Mathias Growe, Daniel Köhn, Hartwig Lüthen, Sirko Molau, Sven Näther, Ina Rendtel (Austria and Germany), Jürgen Rendtel, Roland Winkler, Nikolai Wünsche, Oliver Wusk (Germany and Sweden) (all in Germany only, except where noted); Eva Bojurova (Bulgaria; including preliminary reports from two *Astroclub Canopus* observing camps) Julie Brandon (England), Jay Brausch (North Dakota, USA), Michael Brooke (England), Mary Cook (England), Maggie Daly (England), Clive Down (Wales), Steve Evans (Spain), Guy Fennimore (Wales), Elham Ghanbarian (Iran), Shelagh Godwin (England), Valentin Grigore (Romania), Philip Heppenstall (England and France), Zoltan Hevesi (Hungary), Bob Lunsford (California, USA), Tony Markham (England), Alastair McBeath (England), Tom McEwan (Scotland), Shefteh Mihanyar (Iran), Trevor Pendleton (England), Mohammad Ali Rahmani (Iran), Layla Rostami (Iran), George Spalding (England).

The Iranian results were forwarded to us by Mohammad Ali Khodayari.

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

Month	Visual	CAP	SDA	NDA	KCG	PER	Met.	Photo	Radio	Video	Trails
July	$37^{h}.3$	6	9.5	15.5	–	45	325	$25^{h}.5$	$4087^{h}.0$	$60^{h}.5$	344
August	$175^{h}.8$	35	29	44	71	1854	3437	$134^{h}.6$	$4326^{h}.1$	$341^{h}.9$	2833

2. July

With Es so bad all month, the radio results were fragmentary on numerous days, as Figure 1 indicates. Of the previously-detected radio peaks in [1], only the period around $\lambda_\odot \approx 126°$ to 128° (July 29–31) was clearly confirmed by the majority of active systems, this being part of the extended $\lambda_\odot = 122°$ to 126° period, running sometimes between $\lambda_\odot = 120°$ to 131°. Of the remaining radio peaks, most were found by some operators, but could not be properly examined thanks to interference. The $\lambda_\odot = 99°$ (July 1) and $\lambda_\odot = 115°$ (July 17) events, this latter so far detected clearly only in 1998 [2], could not be found in 2000, presumably because of severe Es on both dates.

In his report in *RMOB* 84, Werfried Kuneth commented that an ionospheric experiment, perhaps based in Italy, appeared to be in progress around 18^{h} UT on July 22, and requested further information on it, though nothing about this was featured in subsequent *RMOB*s. With only Werfried's and the Ghent University equipment operational at that time of the European observers, both of which systems were blanketed by Es then, nothing further could be discovered about this event.

Most of the visual results were collected during the last ten days of the month, and given the reasonably substantial observing effort put in, it is surprising that so few southern-sky shower meteors were observed, too few to allow any useful analysis of these showers from 2000 July–August. Why this should have been so is unknown, since new Moon on July 31 made the Southern δ-Aquarid and α-Capricornid maxima in particular extremely favourable, and weather conditions, while not perfect, were not notably problematic. There is a hint in the surviving radio data that the late July part of the July–August "bulge" of increased echo counts was less pronounced than in previous years, which might suggest lower meteor numbers from the Southern δ-Aquarids, but with the prevalence of Es during this period, it would be most unwise to use this to suggest the shower's activity was unusual in 2000.

Another curiosity in late July was a report of a fireball around 23^{h} UT on July 29-30, supposedly from two sites in southern England, although the details reported to the Section were very vague. However, two of our most active observers, Mary Cook and George Spalding, were both observing right across this time from southern England, yet neither saw any fireballs all night!

3. August

Radio results continued to be hampered by Es all month, which meant most of the echo count maxima found earlier [1] were recovered only weakly, or not by all observers. Of those occurring before August 12, the small peak around $\lambda_\odot \approx 131°$–133°, first noted especially in 1999 [3], was detected again, chiefly around $\lambda_\odot \approx 131°$ (August 3) in longer-duration echo numbers ($D > 1$ s), as was also the case in 1999.

Just to be different, Es was less prevalent on August 12, when radio interference due to a huge auroral storm disrupted several radio observers' efforts then! Visual observers in North America were able to enjoy the unusual spectacle of this superb, if moonlit, aurora as a backdrop to the best from the Perseids, though regrettably the combined effects of the Moon, waxing towards full on August 15, and auroral light often meant only the brightest Perseids remained visible.

Despite the typically strong showing by the radio Perseids in mid-August, as illustrated by Figure 1, only a weak confirmation of the visual Perseid peak timing ($\approx 9^{h}30^{m}$ UT) from the preliminary *IMO* results [4] was possible from the radio reports, as too many operators were unable to detect little except noise for much of the day.

Visually observed Perseid numbers were high enough to compute reliable ZHRs by July 26-27, although the first swift-flying Perseid meteors were noted in even casual sky-checks from about a week before this, much as normal. Figure 2 gives a graph showing mean Perseid ZHRs for most nights between July 26-27 to August 13-14 from our results. The highest mean ZHR on August 11-12 over Europe was 82±9, with ZHR values rising overnight in advance of the predicted and actual main peak. ZHR calculations from August 9-10 to 13-14, suffered problems because of increasingly strong moonlight, which persisted until almost the start of morning twilight from Britain by August 11-12, for instance. By the time August's full Moon was waning, Perseid rates had dropped well back, with the mean ZHR on August 19-20 being $\approx 7 \pm 5$.

Table 2 – Global magnitude distributions for the Perseids and sporadics seen during July and August 2000 in good sky conditions, including mean LM and corrected mean magnitudes. "Good sky conditions" were defined as having an average cloud cover less than 20%, and where the LM was +5.5 or better, except for nights close to the Perseid maximum when moonlight interference led to a relaxation of the LM parameter to +5.0 or better, in order not to lose all the important near-maximum data.

Shower	-3^{-}	-2	-1	0	$+1$	$+2$	$+3$	$+4$	$+5^{+}$	Total	LM	$\overline{m}_{6.5}$
PER	21	26	31	61.5	79.5	113	107	45	3	487	5.78	+2.31
Spor.	4	5	3	9	34	54	92.5	77.5	45	324	5.80	+3.47

Table 3 – Global train percentages and mean durations in seconds per magnitude class for the Perseids in July and August 2000. Train details were available for only 215 Perseids from the magnitude distribution. Too few trained sporadics were seen (3/209 meteors = 1.4%) for a sensible analysis of them to be made.

Magnitude	-3^{-}	-2	-1	0	$+1$	$+2$	$+3^{+}$	Total	%
PER train	86%	78%	87%	66%	37%	24%	13%	76	34.4%
PER train duration	6.6 s	2.4 s	2.2 s	1.1 s	1.1 s	0.6 s	0.5 s	–	–

Table 2 gives global magnitude details for the Perseids and July–August sporadics, while Table 3 presents a global train analysis for the Perseids.

Correspondence from UK watchers shows much of England enjoyed a good night on August 11-12 in spite of the Moon, with only thin, typically hazy, cirrus clouds reported, though these were quite widespread. Limiting magnitudes with the Moon still up were around +4.9 to +5.3 at best, but a few people were lucky in getting a +5.5 sky briefly between moonset and morning twilight. As often happens near Perseid maximum, several watchers were tempted into continuing their observing into too-strong twilight, still spotting occasional bright Perseids until just an hour before sunrise in one case. As Rainer Arlt in Germany noted, a little clearer sky would have been even better, however! Perseid rates were good without being spectacular, as veteran George Spalding commented, echoing the thoughts of other experienced meteor watchers, which suggested the best was indeed still to come after dawn over Europe. Plenty of bright Perseids (magnitude +2 or brighter) were seen, but fireballs were relatively rare, the brightest of magnitude −6, a blue-green-violet event at $0^{h}37^{m}$ UT on August 12 over England, which produced two flares and a 13-second-long persistent train.

In North America, where some of the highest Perseid rates were seen, Bob Lunsford remarked that the impressive meteor display was scarcely dimmed by a layer of smoke over his usually excellent Californian sky, the smoke due to the horrendous, extensive, forest fires all across the western USA then. Thankfully, there were no casualties among our North American meteor observing colleagues because of these fires, though most unfortunately, R.B. Minton's radio set-up was wrecked in a lightning strike during a storm on August 27. Bob Lunsford mentioned the smoke layer concealed any sign of the auroral activity coincident with the Perseids' best, though people at less smoke-influenced locations in California did apparently see this storm.

Eva Bojurova reported the Bulgarian *Astroclub Canopus* watchers had a very successful observing camp at Avren from July 24 to August 5, with plenty of clearer skies. They then returned to Kamen Bryag on the Black Sea coast to celebrate the first anniversary of the total solar eclipse beautifully witnessed from there on 1999 August 11. Their 2000 Perseid peak observing was less fortunate, as overcast skies appeared nicely in time for moonset on August 11-12!

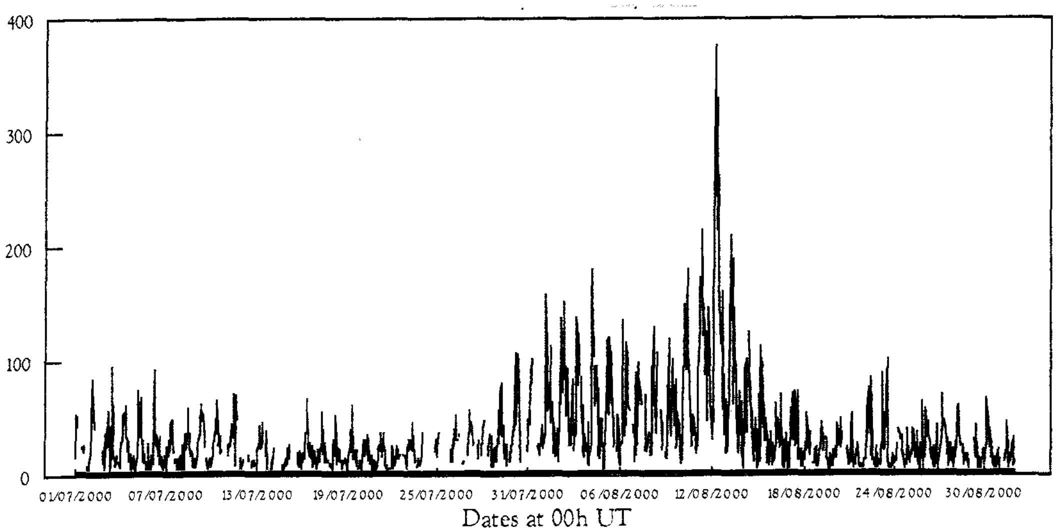

Figure 1 – Raw hourly radio meteor percentage reflection time echo counts (times 10) from 2000 July and August in data collected by Ghent University. The system was in continuous operation, when conditions allowed. Despite severe problems with Es at times, especially in July (a month noted more for its gaps in useful data collection than much of what still could be detected), the late July to early August "bulge" due to the various Aquarid and Capricornid showers is still visible, and the Perseid maximum on August 12 is particularly clear. Unlike a number of other radio set-ups, the Ghent observations seemed quite unaffected by the major auroral storm on August 12.

Relatively few visual watches were carried out after the Perseid maximum was passed. Low rates of κ-Cygnids were spotted throughout the month, but the expected peak was lost to moonlight. In the last week of August, the α-Aurigids produced a weak showing, with little sign of unusual rates around August 31. A preliminary *IMO* visual report [5] showed α-Aurigid ZHRs of ≈ 6–10 ± 2–4 then. The radio operators detected one of their best-confirmed minor maxima around $\lambda_{\odot} \approx 158°$ (August 31), but as the Ghent University data shows (Figure 1), Es was still creating problems! The other post-Perseid minor echo-count peaks were again confirmed only with difficulty.

3.1. August fireballs

While late August visual watches may have been at a premium, the period between August 19-20 to 30-31 produced reports on eleven separate fireballs from Britain, three seen from multiple sites, with most reported only by casual witnesses (the list of observers above does not include these). Oddly, this period was bracketed by two near-superbolides seen over Europe as reported on *IMO-News*, one of magnitude $-12/-17$ at $\approx 18^{h}44^{m}$ UT on August 15 from Italy (message from Roberto Labanti posted to *IMO-News* on August 24, 2000), the other of at least magnitude −13 at 22^h52^m UT on August 31 over the Czech-German border (message from Jiří Borovička posted to *IMO-News* on September 1, 2000), while reports of three other fireballs by *SPAMS* correspondents outside the UK were equally curiously timed during this loose fireball "cluster". There is no indication that these events were from any specific, single source, and none could be definitely identified as belonging to known meteor showers. Details on each event are given below, with estimated surface tracks in the single-witness cases based on typical meteor ablation heights (start about 100–90 km, end about 80–70 km).

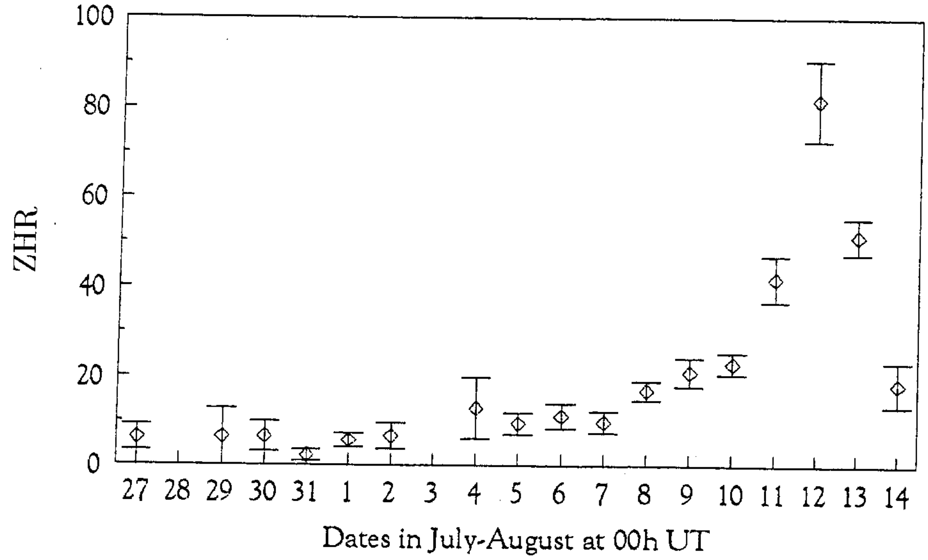

Figure 2 – Perseid visual ZHRs in July–August 2000. As most data was reported by European observers, each ZHR point is a mean value per night derived from observations made between roughly 22^h–3^h UT. ZHRs derived significantly outside this range were ignored in compiling this graph. Computations were carried out using the standard *IMO* ZHR formulae, using $r = 2.6$, and appending routine error bars.

August 19-20, 2000, $\approx 21^h30^m$ UT: Three observers at two sites around 20 km apart in Cheshire and Greater Manchester reported a very bright meteor, probably brighter than magnitude −8, as significant ground shadows were cast by its passage. One witness suggested it might have been a Perseid, but the estimated path lengths indicate this was unlikely. The more northerly observer on the southern outskirts of the Greater Manchester area (who was also closest to the object's ground track, as the meteor was reported as passing within $\approx 30°$–$40°$ of the zenith), also heard a distinct "boom" around 2–3 minutes after the fireball, although this cannot be definitely confirmed, and could have been either industrial or aircraft noise, with busy motorways and Manchester International Airport inside a $\approx$ 10 km radius of this location. An estimated NE to SW trajectory was implied, with the object perhaps passing above northern or central Lancashire, ending out over Liverpool Bay in the Irish Sea.

August 19-20, 2000, $\approx 22^h31^m$ UT: A single witness on the island of Anglesey off the north-west coast of Wales reported a magnitude -4 (?) meteor, which may have passed high above the north Wales-England border, terminating over the northern part of Cardigan Bay off western Wales. The similarity of this general ENE to WSW surface track to that of the event an hour earlier might indicate the same source, though follow-up enquiries indicated the time difference was genuine.

August 19-20, 2000, $\approx 5^h00^m$ UT ±30 minutes: A brilliant, probably west to east moving, fireball occurred during this hour, as witnessed by a large part of the audience at an outdoor evening concert in Las Vegas, Nevada, USA. Unfortunately, the brightly-lit urban setting prevented a usable sky position being secured for it, but the audience were greatly appreciative of the event!

August 20-21, 2000, $\approx 8^h33^m$ UT: A magnitude -4 fireball reported from North Dakota, USA, probably passing on a WNW to ESE track above west-central North Dakota, was seen less than an hour before the start of morning twilight.

August 20-21, 2000, $\approx 21^h30^m$ UT: One observer in Leicestershire reported a bright fireball, which perhaps passed roughly SW to NE over the English northern Midlands towards the Yorkshire-Humberside coast between roughly Hull and the North York Moors, though this is far from certain.

August 20-21, 2000, $\approx 22^h25^m$ UT: A lone sighting from south Wales of a magnitude $-4/-5$ (?) event which probably passed on a NE to SW trending trajectory above the English southwest Midlands to Somerset/Dorset, the end possibly as far south as over the English Channel, however.

August 24-25, 2000, $\approx 21^h20^m$–21^h30^m UT: This very bright fireball was reported by observers at three separate locations, one in Birmingham, one in Suffolk and one in West Yorkshire. The implied ground track was perhaps trending SSW to NNE, and if so, the meteor probably passed over or near the Cotswold Hills of south-western England to Nottinghamshire/Lincolnshire some way east of Nottingham. However, there are some discrepancies in the eye-witnesses' statements which make this track more uncertain than usual.

August 24-25, 2000, $\approx 22^h50^m$ UT: One sighting of this magnitude $-3/-4$ (?) yellow fireball was received from the English West Midlands. The object's track was probably in a SW to NE direction from over Derbyshire/Nottinghamshire to South Yorkshire.

August 24-25, 2000, $\approx 0^h20^m$ (?) UT: A single report of a brilliant meteor seen low to the north-eastern sky from just south of the Mersey estuary in north-west Cheshire was forwarded to us, but details were extremely sketchy, and even the timing may have been up to an hour later.

August 29-30, 2000, 23^h15^m UT: A spectacularly brilliant fireball, estimated by the observer closest to the track (which passed at around 70° elevation) to have reached a magnitude of about $-13/-16$, was reported from three locations in south Cumbria, Merseyside and Nottinghamshire. The reports, not all of which covered the whole fireball's flight, do not give a single, simple solution for where the object passed over unfortunately, not helped as all three observers were west of the object's flight path. The most likely track direction was roughly SW to NE, carrying the meteor from above an area west of the Cotswold Hills to Humberside/North Yorkshire, possibly ending out over the North Sea. The object's terminal flare produced the greatest brilliancy (even the two more westerly observers recorded it as being of magnitude $-6/-8$, despite its end being low in the sky for them), and there was some slight fragmentation late in the flight. All three observers made a point of noting that no sounds were heard associated with this fireball, either during or after its appearance.

August 30-31, 2000, $\approx 18^h35^m$ UT: An isolated observation of a magnitude $-3/-4$ fireball passing west to east across the sky was received from an observer on Malta.

August 30-31, 2000, $\approx 21^h05^m$ UT: A very short, but brilliant (magnitude about -10?), fireball was seen by a single witness in south Wiltshire. The apparent trail in the sky suggests the meteor was moving almost directly towards the observer, probably on a SSE to NNW trajectory, and was likely to be out over the English Channel, perhaps passing over the western part of the Isle of Wight.

August 30-31, 2000, $\approx 23^h24^m$ UT: A long, green fireball, estimated as brighter than magnitude -5, was spotted by one witness slightly west of central London. The report was very sketchy, but the object may have passed on a NNE to SSW trajectory some way east of London, perhaps over the Thames estuary, to end over the Channel off the East Sussex coast.

August 30-31, 2000, 23^h34^m UT: One sighting from Surrey of a point-source magnitude -4 (?) fireball, which was most likely pursuing an almost N to S flight above the Chiltern Hills north-west of London.

Acknowledgments

As normal, my grateful thanks go to all the observers and correspondents who have provided the details to make this report possible. Some of the information here, notably concerning the Perseids and the late August fireballs, was earlier presented at a somewhat different form on the *SPA* Website at: `http://www.popastro.com`.

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BAA Observations of the 2000 Perseids: A Provisional Report

Neil Bone

Normally the meteor observer's annual highlight, the Perseids have in recent years been rather overshadowed by the Leonids and Geminids. Unfavorable moonlight conditions in 1998 severely limited useful observations, while the 1999 Perseids fell victim, for those in the UK, to the same clouds which had robbed them of a once-in-a-lifetime total solar eclipse on home soil. Limited observations suggested Perseid ZHR just over 100 late on August 12-13, 1999.

The 2000 return again saw the Moon interfering close to maximum, expected around August 12, 9^h UT [1]. With Full on August 15, the waxing gibbous Moon was in the evening sky on August 11-12 and 12-13, setting late in the night. Its low declination on the ecliptic helped to lessen the Moon's glare to some extent, and on August 11-12, moonset around 1^h30^m local time presented a brief 1.5-hour window of dark skies before dawn. Weather conditions in the UK were relatively kind, with many good clear nights at many locations over the first ten days of August. Several useful watches, providing data for the initial part of the Perseids' rise, were made. Undeterred by the moonlight, many observers in the southern UK, particularly, made good use of fine skies on August 11-12, and were pleasantly surprised to find good activity.

In all, 42 individuals and four local society groups, as listed below, contributed 111^h00^m of watch time, amounting to 1732 meteors (291 sporadics, 1292 Perseids, and 149 others) between July 29-30 and August 12-13: by the latter date, the weather had deteriorated and moonlight was seriously restrictive on dark sky watch time in any case.

M. Adamson, S. Beaumont, D. Bingham, J. Bingham, N. Bone, G. Boots, C. Bradley, A. Bridson, F. Bridson, M. Bridson, J. Cook, A. Deveraux, P. Dyson, J. Fawkes, K. Gale, D. Gavine, M. Green, C. Hall, C. Henshaw, R. Johnson, T. Kaneen, P. Keig, M. Kelly, J. Lang, H. McGee, J. Maresh, A. Mark, T. Markham, S. Moore, S. Morley, T. Pendleton, C. Reulbach (Germany), J. Shanklin, H. Short, J. Smith (Germany and Canada), G. Spalding, M. Stephens (France), M. Taylor, C. Thomson, A. Vincent, P. Yates, Isle of Man AS, Manchester AS, Worthing AS, York AS

The results were analyzed as previously [2,3] to derive sporadic CHRs and Perseid ZHRs, listed in Table 1. Perseid activity was generally low until about August 6-7. By August 10-11, rates were, as usual, well on the rise, with ZHR of the order of 50. Dawn on August 11-12 intervened well before the expected regular peak, but the derived ZHRs, around 70, are much in line with what might be expected in a "normal" year, some 6–7 hours ahead of the established, permanent maximum. Nothing in the UK observations on August 11-12 suggests occurrence of an "early" peak in the interval from solar longitude (2000.0) 139°58 to 139°70.

As ever, the Perseids showed a good abundance of bright events, with mean magnitude +1.69 compared with a mean +3.29 for sporadics over the same interval. Respective values on August 11-12 (which accounted for three-quarters of the observed meteors) were +1.84 and +2.47. Probably the single most noteworthy bright event occurred on August 12, 1^h59^m UT, a Perseid estimated variously at magnitude −3 to −6, ending in a terminal flare and leaving a persistent train lasting up to 10 seconds. This meteor was visible from Sussex to Derbyshire. Overall magnitude distributions are summarized in Figure 1.

Table 1 – Perseid and Sporadic Activity 2000

Date, 2000	$\lambda_\odot$	T_{eff}	$\overline{LM}$	F	N_{Sp}	CHR	N_{PER}	h_R	ZHR
Aug 1, 22^h50^m	129°96	1.78	6.00	–	8	8.3 ± 2.9	2	32°9	3.2 ± 2.2
Aug 1, 23^h38^m	129°99	2.00	5.65	1.06	6	9.0 ± 3.7	3	37°5	5.7 ± 3.3
Aug 2, 00^h45^m	130°04	2.00	6.05	–	5	4.5 ± 1.9	10	45°4	10.3 ± 3.3
Aug 2, 02^h00^m	130°09	1.00	6.10	–	3	4.9 ± 2.8	2	54°2	3.5 ± 2.5
Aug 5, 22^h28^m	133°78	1.75	5.53	–	5	9.4 ± 4.2	3	32°3	7.3 ± 4.2
Aug 5, 23^h30^m	133°82	2.00	5.68	1.06	9	13.1 ± 4.3	10	38°3	17.2 ± 5.4
Aug 6, 00^h30^m	133°86	1.00	5.75	–	2	5.0 ± 3.5	4	44°1	10.9 ± 5.5
Aug 6, 01^h30^m	133°90	1.00	5.75	–	7	17.6 ± 6.7	6	51°3	14.6 ± 6.0
Aug 7, 00^h30^m	134°82	1.00	5.00	–	1	6.3 ± 6.3	8	47°8	38.9 ± 13.8
Aug 8, 00^h30^m	135°78	1.00	5.50	1.13	1	3.9 ± 3.9	8	46°4	29.3 ± 10.4
Aug 9, 00^h55^m	136°76	1.50	6.20	–	7	6.7 ± 2.5	11	49°1	12.5 ± 3.8
Aug 9, 02^h10^m	136°81	1.00	6.20	–	4	5.8 ± 2.9	10	58°5	15.2 ± 4.8
Aug 11, 01^h10^m	138°69	2.00	5.25	1.07	8	19.9 ± 7.0	25	50°7	50.3 ± 10.1
Aug 11, 02^h10^m	138°73	2.00	5.25	1.07	5	12.4 ± 5.5	21	58°4	38.4 ± 8.4
Aug 11, 23^h37^m	139°58	6.50	5.01	–	21	20.2 ± 4.4	83	42°2	67.9 ± 7.5
Aug 12, 00^h30^m	139°62	9.23	5.01	1.02	19	13.1 ± 3.0	141	48°2	74.7 ± 6.3
Aug 12, 01^h32^m	139°66	8.52	5.25	–	26	14.2 ± 2.8	159	55°1	66.2 ± 5.3
Aug 12, 02^h32^m	139°70	6.82	5.41	–	33	18.5 ± 3.2	173	62°9	72.3 ± 5.5

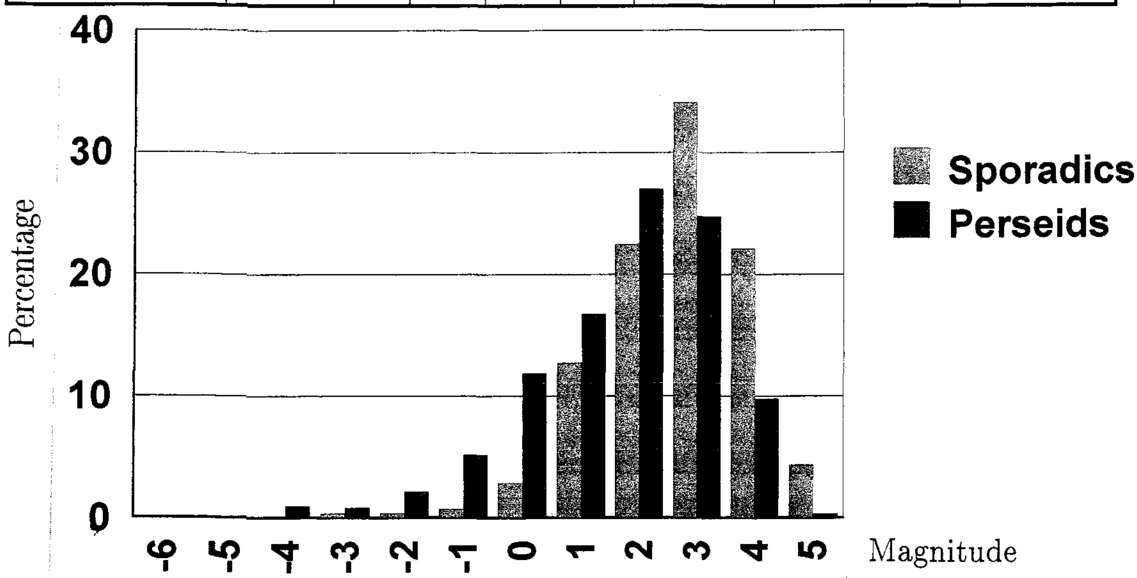

Figure 1 – Sporadic and Perseid magnitudes 2000.

In a year otherwise largely notable for poor weather and moonlight interference at the maxima of nearly all the major showers, the 2000 Perseids proved a welcome opportunity for the BAA's regular observers to witness some reasonably high activity. Thanks are, as always, expressed to all who contributed reports.

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SPA Meteor Section Results: September–October, 2000

Alastair McBeath

Observations and news sent to the *SPA Meteor Section* from 2000 September and October are summarized. Both months were fairly quiet, with bright moonlight spoiling the visual observers' view of the Orionids in October particularly, and poor weather proving unhelpful at other times. Nothing unusual was noted in the radio results from either month, though the signature of the Orionids was less clear-cut than had been seen in recent times. Fireballs were less prevalent in casual reports than earlier in 2000, but two bright, non-Orionid events occurred over Britain on the evening of October 19-20.

1. Introduction

Observer activity during September and October was good, though concentrated especially in the final ten days of both months (except for the radio work, which was more evenly spread). Unfortunately, moonlight and/or poor weather proved unhelpful in following the more potentially interesting periods. The observing totals are given in Table 1.

All the photographic and video results came from cameras operated by *Arbeitskreis Meteore* (*AKM*) observers, mostly in Germany. Details on these and the other *AKM* data used here were published in their Journal *Meteoros* 3:10, 3:11, 3:12 (all 2000), and 4:1 (2001), sent to us by Ina Rendtel. All-sky fireball cameras were run by: Jürgen Rendtel and Jörg Strunk (both of whom also ran video cameras), while the remaining video results were secured by Sirko Molau, Mirko Nitschke and Ilkka Yrjölä (Finland).

Dirk Artoos and the group led by Albert Heyes reported radio observations directly to us, while the bulk of the radio data came from *Radio Meteor Observation Bulletins* (*RMOBs*) 86 and 87 (October and November 2000), provided by Chris Steyaert. The radio observers were:

> Jean-Louis Aillaud (Réunion Island, Indian Ocean), Enric Fraile Algeciras (Spain), Dirk Artoos (Belgium), Mike Boschat (Canada), Maurice de Meyere (Belgium), Ghent University (Belgium), Rafael Haag (Brazil), Albert Heyes (England; with John Blakeley and Jim Leviston), Will Kelsey (Arkansas, USA), Sadao Okamoto (Japan), Ton Schoenmaker (Netherlands), Dave Swan (England), Pierre Terrier (France), Garfield Tsao (Taiwan), Ilkka Yrjölä (Finland).

Normal procedures for examining the raw forward-scatter data were followed as usual in these reports. Figures 1 and 2 are given here as generally representative of these examinations.

Visual data came from: *AKM* members (all in Germany) Pierre Bader, Frank Enzlein, Ralf Kuschnik, Sven Näther, Jürgen Rendtel, Christian Schmitt, Ulrich Sperberg, Roland Winkler; Jay Brausch (North Dakota, USA), Chris Chambers (Wales), Dee Choudhury (England), Mary Cook (England), Shelagh Godwin (England), Philip Heppenstall (England), Marco Langbroek (Netherlands), Alastair McBeath (England), Trevor Pendleton (England).

2. September

Few visual watches were carried out during the first half of the month, and although low rates of α- and δ-Aurigids were seen, along with similarly weak activity from the Piscids, no maxima for any of these sources could be clearly defined. The radio results revealed a distinct minor maximum at $\lambda_\odot \approx 158°$ to $159°$ (August 31–September 1) however, a time which was first noted as producing a significant radio peak only in 1998 [1] ([2] also briefly commented on the $\lambda_\odot \approx 158°$ part of this peak). This is likely to have been due to the α-Aurigids. A similar radio maximum was found as normal around $\lambda_\odot = 165°$ (September 7), which is probably the signature from the δ-Aurigid peak, expected about September 8 in 2000.

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

Month	Visual	DAU	SPI	ORI	TAU	Meteors	Photo	Radio	Video	Trails
September	$53^{h}0$	48	30	–	–	351	$72^{h}5$	$5285^{h}0$	$339^{h}2$	1601
October	$42^{h}8$	8	–	69	54	401	$126^{h}0$	$6400^{h}6$	$217^{h}3$	1321

Of the other minor radio maxima noted in September before [3], all were recovered much as expected, except those around $\lambda_\odot \approx 170°$ and $\approx 172°$–$173°$ (September 12 and 15-16, respectively), which were found only very weakly. Sporadic-E (Es) interference was prevalent on both these occasions, though not nearly as badly as earlier during the northern summer months, which could account for this.

The September 17 ($\lambda_\odot = 174°$) peak, which drew so much interest in 1999 [4], was weakly recovered in only half the available datasets this year. Half the results again showed a stronger peak on the following day (as Figure 1 indicates), but in some cases this seemed to blend into the established $\lambda_\odot \approx 176°$ to $177°$ (September 19-20) peak, which in 2000 seemed very ill-defined, perhaps extending to $\lambda_\odot \approx 178°$ to $179°$ (September 21-22), with a suggestion of somewhat stronger echo counts around $\lambda_\odot = 178°$. This may have been due to the expected main Piscid maximum around September 19, and this kind of vague extension has been recorded previously near this time.

Visual observations were concentrated between September 20-21 to 29-30, but these failed to reveal any especially enhanced Piscid—or indeed other—activity coincident with this September 19-22 period, but the difference in activity levels was most likely quite small judging by the radio graphs. Low Piscid and δ-Aurigid rates persisted during this late September interval at least.

The $\lambda_\odot \approx 183°$ (September 26) radio maximum was recovered poorly, with most observers reporting a generally enhanced late September spell between roughly $\lambda_\odot \approx 181°$ to $187°$ (September 24–30). Although the end-September Sextantid peak was nowhere near as clearly defined in most results as in 1999 [4], the expected $\lambda_\odot = 187°$ maximum stood out against this enhanced spell for most radio set-ups, with several people also finding another minor peak at $\lambda_\odot = 185°$ (September 28) as well. Peaks at both these times have been detected before.

3. October

The first half of October was again visually a quiet period, with few watches carried out. As any possible Draconid activity was liable to be concentrated within a few hours of the predicted maximum times on October 8 (either around 1^h30^m UT or 9^h UT [5]), it is unfortunate no watches were possible near then. The radio data showed the normal minor maximum around $\lambda_\odot = 195°$ to $196°$ (October 8-9), in most cases extending this year to $\lambda_\odot \approx 197°$, but this may well not be due to the Draconids. The repetition, and relative longevity, of this peak from year to year argues against it being from an irregularly active source like the Draconids, plus when a strong Draconid outburst has happened previously (as last in 1998 [1]), it stands out against the increased level on these dates. A further point can be made this year, as we see in Figure 2 that Rafael Haag detected a distinct echo-count peak on October 8-9. His latitude of $\approx 30°$ south means the Draconid radiant at $\delta = +54°$ only barely rises for a short time each day, around 16^h–17^h local (solar) time. His antenna is aligned to pick up broadcast stations to his north, which would increase the potential Draconid observing interval, perhaps by a couple of hours, but in examining his results, the enhanced rates on October 9 are due to a source visible between 3^h–8^h local time, the period when the Draconid radiant is about as far below his horizon as it can be for the day!

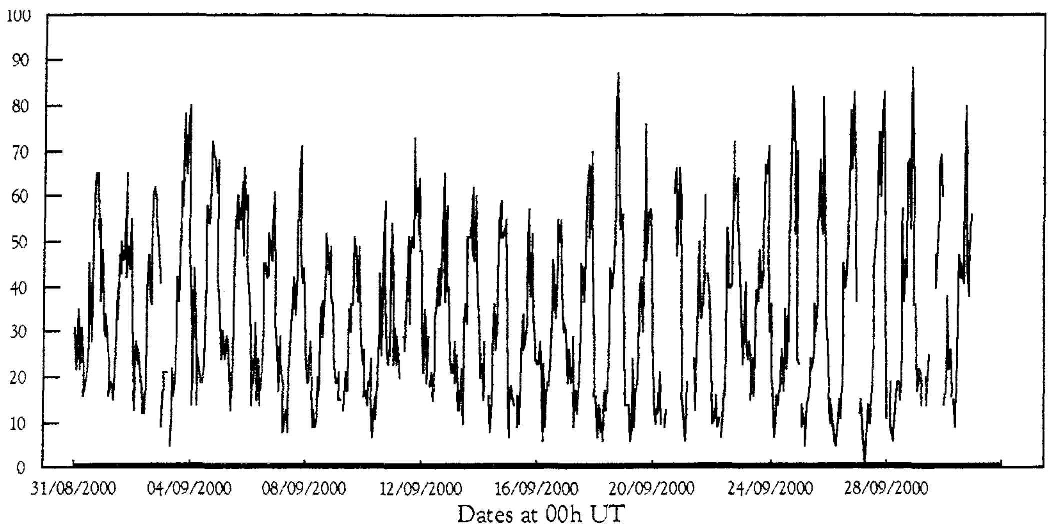

Figure 1 – Raw hourly radio meteor echo counts from 2000 September, as reported by Sadao Okamoto in *Radio Meteor Observing Bulletin* 87. Sadao's system was in continuous operation except when occasional interference intervened, as indicated by the breaks.

The $\lambda_\odot \approx 190°$ to $192°$ (October 3–5) radio peak was picked up as previously found [3], but as has been seen in recent years, it probably began around $\lambda_\odot \approx 188°$ to $189°$ (October 1-2). The $\lambda_\odot \approx 199°$ (October 12) minor maximum was recovered only weakly in 60% of the datasets, though some showed signs of a marginal enhancement from $\lambda_\odot \approx 197°$ to $200°$, ahead of the normal Orionid activity.

Much as anticipated, the Orionid peak on October 20-21 [5] was lost to last quarter moonlight for visual observers, and too few meteors were seen from the source to allow a serious examination of them at this return. What few ZHRs could be calculated in dark, pre-moonrise skies from October 21-22 onwards, implied fairly normal, declining Orionid activity. In radio results, the "bulge" in echo counts commonly seen for several days across the Orionid peak was rather erratic this year, as if rates might be altering markedly from one night to the next. Something of this can be seen in Figure 2, but in fact this dataset shows less of this aspect than some others.

There were a few, generally minor, problems from interference as well. Interestingly, David Butler, reviewing October's radio propagation for radio hams [6], described a mysterious form of propagation especially active on the 50 MHz band between Europe and Africa, which may be linked to Es, and which was also detected during the last solar maximum. This may account for the somewhat unusual meteor counts seen at times during October.

Little consensus is apparent between many of the seeming Orionid "sub-peaks" during the usual $\lambda_\odot = 201°$ to $212°$ (October 14–25) echo-count maximum epoch in different radio reports, though at best, 60% favored $\lambda_\odot = 208°$ (October 21) as producing the strongest rates, and a peak at this time was clearly present in 80% of the results. This tends to support the timing of the predicted main maximum at least. No evidence was found supporting the pre-maximum October 17-18 peak, seen visually most recently in 1998 [1], so it seems probable it failed to recur in 2000.

Two non-Orionid fireballs were seen from the UK on October 19-20 at 19^h34^m UT (two observers, in Lancashire and on the Isle of Man; very bright) and 21^h31^m UT (one observer in Wiltshire; of roughly full Moon brightness). Too few usable details were available on either event to reconstruct possible trajectories regrettably.

The final minor radio peak of the month, around $\lambda_\odot \approx 216°$ to $217°$ (October 29-30), was only detected weakly, and there was nothing to suggest the Taurids produced anything as interesting as the stronger rates and brighter meteors seen in late October, 1998 [1].

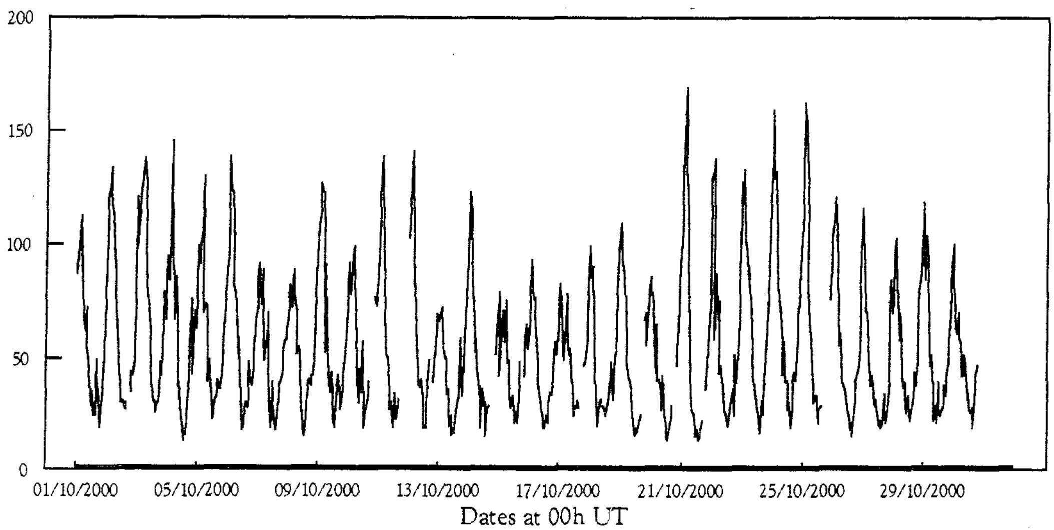

Figure 2 – Raw hourly radio meteor echo counts during 2000 October, in data collected by Rafael Haag from *RMOB* 87. Rafael's equipment was run continuously. Most of the few breaks in monitoring were due to interference, except that on October 12, when a power failure prevented recording between 17^h–24^h UT. With a latitude of 30°10′ S, Rafael's efforts make an interesting contrast with the majority of radio results reported in these papers, which have chiefly been made from sites north of 30° N latitude in the past. Even so, showers like the Orionids, which can be well-seen from most inhabited countries on Earth, still appear clearly in his results from October 21–25.

Acknowledgments

My closing, happy, duty is as always to pass on my grateful thanks to all our contributors, new and established. Please keep your reports and information flowing in!

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