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Radio Meteors
δ-Aquariids
Video meteors

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Administrative

Ongoing meteor work

Delta Aquariids

Preliminary results

Front cover photo

This picture was taken on 2007 August 12/13 at $22^h38^m37^s$ UT in El Borge, (Andalucia, Spain). A sporadic magnitude −3 fireball had a duration of about 10 s and fragmented three times during the flight. Camera: Canon 10D with a Peleng $f/3.5$, 8-mm fish-eye lens. Photo: Jean-Marie Biets.

Writing for WGN

This Journal welcomes papers submitted for publication. All papers are reviewed for scientific content, and edited for English and style. Instructions for authors can be found in WGN **31:4**, 124–128, and at `http://www.imo.net/articles/writingforwgn.pdf` .

Cover design

Rainer Arlt

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Guest Editorial: WGN's new Editor-in-Chief

Jürgen Rendtel

In the first issue of volume 31, early in 2003, I happily announced that Chris Trayner had volunteered for the work as the Editor of WGN. When we discussed details with Chris before he took over, he said that he could imagine being in this position for about five years or so. As is the case for many IMO officers, the usual workload requires a lot of time, and additional tasks such as the editorship of a bimonthly journal add to this. This also explains the repeated delays in the production of WGN, but of course, Chris' work was very much appreciated — as is visible also from the replies to the recent questionnaire. When Chris told us that he wished to hand over the position as WGN Editor to a successor, the IMO Council discussed numerous possibilities for the future of our Journal.

WGN is a major communication platform among the IMO members, despite the importance of electronic communication, and it also allows obtained data, results of analyses and new projects to be presented to the meteor community.

Looking at the organisation of jobs in the IMO, we found that a lot of big tasks are in the hands of single persons. This may lead to the incorrect impression that the organizational aspect of the IMO is well taken care of, and that there is no need for other IMO members to volunteer to take over part of the work. These large work positions may also prevent candidates from volunteering. Concentrating jobs to very few persons also implies that a transfer of expertise must be organized. In addition, implicit procedures followed by a single person in his job must be made explicit so that they become practicable by a larger group of people.

In the case of our Journal, the submission and handling of papers can be organized using a web tool, with several handling editors involved. Then, the tasks of an Editor-in-chief include the overview of the contents and status of submitted publications as well as the planning of future issues. Here, the Editor-in-chief is the face of the journal. Of course, there is a need for the technical part of the assembly of all papers prepared for a given issue, ready for print the journal.

Members of the IMO Council have been in contact with candidates for the Editor-in-chief, the technical editor and handling editors. We are happy that Javor Kac has volunteered to become our Editor-in-chief. Among other items, Javor is known for his work concerning the Leonid storms and meteor observations in Slovenia. In fact, he already prepared the last issue of WGN, together with Chris, who will be available for questions also in the future. This guarantees a smooth transition and the preservation of the expertise. André Knöfel — supervising the IMO's fireball data base — works as our technical editor, finishing the journal for printing, which then is done in Germany as is the mailing. Once the web tool is fully operational, authors as well as handling editors will be able to follow the steps from the submission of a paper to its publication. Seeing the variety of topics in WGN, there is a need of handling editors, although we already received an encouraging number of messages from volunteers.

Over the years, the Journal WGN has seen several changes regarding the contents, the appearance, and the organization of the production. We hope that the now established procedures make the Journal more lively, including the possibility of getting more interested people involved at any position of the entire chain of (manageable) tasks. So we thank Chris for all his successful work over the last years, and we wish the new team, particularly Javor as our Editor-in-chief, lots of good ideas and interesting papers for the coming issues of WGN. Last but not least, everyone is invited to contribute to our Journal by submitting papers — short or long — or by taking part in the practical work to get WGN produced.

IMO bibcode WGN-366-rendtel-newed NASA-ADS bibcode 2008JIMO...36..115R

Letter — The new Editor

Chris Trayner [1]

The October WGN was edited by our new Editor-in-Chief, Javor Kac. He has shown that someone new to editing can produce a top class, professional issue and get it right first time.

It has taken IMO about a year to recruit a new Editor. This time has been spent talking to many people, both prospective Editors and others involved with WGN. It has been a far harder task than in the commercial world, where you pay a salary and the new recruit spends their working week on the job. WGN is very lucky in finding Javor, who is willing to give of his spare time for this.

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I leave the Editorship with a great feeling of relief that WGN is in safe hands. These are not only Javor's — he has a team of Handling Editors and Proofreaders who will provide much of the help. But Javor is the central plaza (Javorov trg?)* where people and papers meet and become a Journal. Under the new arrangements, I think WGN is far stronger than in my day.

[* trg (*in Slovenian*) = plaza, town square — *Ed.*]

IMO bibcode WGN-366-trayner-letter NASA-ADS bibcode 2008JIMO...36L.115T

Call for photographs

Javor Kac

We are currently short of photographs for the WGN covers that we publish in colour (front cover) or black&white (back cover). If you think you have a suitable meteor-related photograph, please offer it to us. For the moment we can only accept machine-readable forms. More or less any image format will do, though ideally not JPEG. You can send your photographs to `wgn@imo.net`, but remember to put 'Meteor' in the subject line to get round the anti-spam filters.

IMO bibcode WGN-366-kac-photocall NASA-ADS bibcode 2008JIMO...36..116K

International Meteor Conference 2009 September 24–27, Poreč, Croatia

Marc Gyssens and Korado Korlević

On behalf of the International Meteor Organization (IMO) and the local organizers, we are glad to announce that the 2009 International Meteor Conference (IMC) will take place from September 24 to 27 in Poreč, Croatia. Poreč is a very touristic city on the Istrian peninsula, bordering the Adriatic Sea. It is easily reachable and situated only 50 km (30 mi) south-southwest of the Italian city of Trieste.

The local organization is in the hands of the Višnjan Observatory which is situated near Poreč. The local organization is coordinated by Korado Korlević.

The conference fee is set at 150 EUR, which, as usual, includes attendance of all lectures, full board from Thursday evening till Sunday noon, and the conference proceedings which will be produced after the event.

Even though great efforts are made to keep IMC conference fees low, both the International Meteor Organization (IMO) and the local organizers realize that attending the IMC represents a significant financial burden to some interested participants. As ususal, the IMO will provide a limited amount of support. In addition, the local organizers can offer accommodation to about 30 participants outside the conference hotel to further reduce the costs.

Concrete details regarding accommodation, transportation, registration, and support will be provided in the February 2009 issue of WGN (*WGN*, **37:1**), which is due in the first weeks of February. By that time, this information will also be available at the IMO website, `http://www.imo.net`. All 2008 and 2009 IMO members and all participants of the 2007 and 2008 IMCs will receive an email (to the extent available) when this information is on-line.

IMO bibcode WGN-366-korlevic-imcpreann NASA-ADS bibcode 2008JIMO...36..116G

From the Treasurer — IMO Membership/WGN Subscription Renewal for 2009

Marc Gyssens

This is the last issue of the 2008 volume of WGN and also the last issue you will receive unless you renew your membership/subscription for 2009! Therefore, we invite all our members/subscribers to do so, if they have not already done it. The fees are as tabulated below. They are unchanged compared to 2008. The corporate subscription rate applies to institutions, libraries, etc. Individuals pay the IMO membership fee and get WGN as part of their IMO membership.

IMO Membership/WGN Subscription 2009				
surface mail delivery:		€26		US$ 36
airmail (outside Europe only):		€49		US$ 69
Supporting membership:	add	€26	add	US$ 36
Corporate subscription rate 2009				
surface mail delivery:		€50		US$ 70
airmail (outside Europe only):		€73		US$ 103

As indicated in the table, you can help the IMO by becoming Supporting Member for twice the standard membership fee. More information about supporting membership and what your support is used for can be found in a separate article, below.

It is also possible to renew for two years by paying double the amount.

General payment instructions can be found on the IMO's website, `http://www.imo.net`. Members and subscribers who have not yet renewed will find enclosed a leaflet with payment instructions that apply to their geographical region. Please follow these instructions! Choosing the most appropriate payment method results in low or even no additional costs for you as well as the IMO. The IMO strives to keeping these costs low in order to control the price of the journal!

We already thank all our members that have already renewed or will renew soon for their continued trust in our Organization.

One final request: every year, a lot of members renew late. As a consequence, back issues that already appeared have to be sent out to these members. Please support our volunteers in their bimonthly effort to have WGN shipped to you by renewing promptly! Thank you for your understanding and cooperation!

IMO bibcode WGN-366-gyssens-renewals NASA-ADS bibcode 2008JIMO...36Q.117G

From the Treasurer — Please support your organization!

Marc Gyssens [1]

1 Supporting members 2008

The following people have paid at least double the normal membership fee in 2008:

Lars Bakmann	Geert Barentsen	Luc Bastiaens	Luis Bellot Rubio
George John Drobnock	Marc Gyssens	Robert Lunsford	Bruno Mancusi
Michael Luciuk	Abbas Mokhtarzadeh	Sirko Molau	Tom Roelandts
Hans-Georg Schmidt	Fintan Sheerin	Cis Verbeeck	Jan Verbert

Casper ter Kuile provided a substantial gift to the IMO Suport Fund, which in turn helped the IMO to support IMC participants (see below) and Paul Roggemans contributed with a gift membership (see Section 2). Several members also regularly give smaller gifts that are equally appreciated!

Thanks to these gifts, we were able to support some meteor workers to attend the 2008 International Meteor Conference in Šachtička, Slovakia, who would otherwise not have been able to attend. Concretely, we supported two Bulgarian, two Romanian, and one Russian participant. By doing so, we try to prevent valuable meteor workers having to work in isolation and to ensure that they get integrated in the international network that is

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at the very basis of our Organization. Subsidies have been granted on the basis of a formal application. These applications were judged by the Council.

To all these people, our sincerest thanks!

2 How to become a supporting member in 2009?

This is quite simple: by paying at least double the normal membership fee in 2009, i.e., €52 or $72 (€75 or $105 for airmail delivery outside Europe). Please mention 'supporting membership' as comment with your payment!

Currently, most of the support is contributed to the IMO Support Fund, to which prospective IMC participants can turn for help to be able to actually attend. Up to some years ago, the IMO has spent part of the reserves it has built up over the years for this purpose, over and above the gifts it received. However, we obviously cannot continue doing so, and, therefore, we appeal to our members to become supporting member if they can, so that we can balance the support we wish to provide against your gifts!

The 2009 Supporting Members will be listed in WGN late in 2009.

Also note, as already indicated above, that smaller gifts are of course also welcome as they also contribute to this goal!

3 Gift memberships

Another way to support the meteor community is by providing gift memberships to one or more meteor worker for whom this would otherwise constitute a considerable financial effort. If you want to do this, take the following, easy steps:

1. Inform the meteor workers concerned of your intention, to make sure he or she accepts your kind gift. After all, nobody can be forced to join or rejoin an organization!

2. In case of *new* members, i.e., for those meteor workers concerned that have not been IMO member before, ask them to fill out a membership form on the website. (It is possible to clarify that this concerns a gift membership by adding a comment.) In case of a *renewal*, the person is already in our membership database, and must therefore not take any special action.

3. In the comment accompanying your payment, please mention clearly for whom the membership fees are intended!

Providing gift memberships is another way to ensure that valuable meteor workers do not get isolated by providing them access to the information disseminated by the IMO!

Again, the International Meteor Organization needs your support! Any support, whether general or earmarked for a special purpose, is most welcome and the international meteor community will be grateful for it!

IMO bibcode WGN-366-gyssens-supportmemb NASA-ADS bibcode 2008JIMO...36R.117G

Solar Longitudes for 2009

Compiled by Rainer Arlt

A conversion table of dates to solar longitudes using (Steyaert, 1991) is given as every year. The longitudes are given on the next page; they are only valid for 2009. The conversion formulae for any time of the day are repeated here for your convenience.

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 $\lambda_\odot$ into 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 1988–2020 are given in two-hour increments and with three decimals at `http://www.imo.net/data/solar`.

IMO bibcode WGN-366-arlt-solarlong
NASA-ADS bibcode 2008JIMO...36..118A

References

Steyaert C. (1991). "Calculating the solar longitude 2000.0". *WGN*, **19:2**, 31–34.

Solar longitudes 2009. Dates refer to 00^{h} UT.

Jan	1	280.58	Mar	1	340.41	May	1	40.63	Jul	1	99.18	Sep	1	158.57	Nov	1	218.57
Jan	2	281.60	Mar	2	341.42	May	2	41.61	Jul	2	100.13	Sep	2	159.54	Nov	2	219.57
Jan	3	282.62	Mar	3	342.42	May	3	42.58	Jul	3	101.09	Sep	3	160.51	Nov	3	220.57
Jan	4	283.64	Mar	4	343.42	May	4	43.54	Jul	4	102.04	Sep	4	161.47	Nov	4	221.57
Jan	5	284.65	Mar	5	344.42	May	5	44.51	Jul	5	102.99	Sep	5	162.44	Nov	5	222.57
Jan	6	285.67	Mar	6	345.42	May	6	45.48	Jul	6	103.95	Sep	6	163.41	Nov	6	223.57
Jan	7	286.69	Mar	7	346.43	May	7	46.45	Jul	7	104.90	Sep	7	164.38	Nov	7	224.57
Jan	8	287.71	Mar	8	347.43	May	8	47.42	Jul	8	105.85	Sep	8	165.35	Nov	8	225.58
Jan	9	288.73	Mar	9	348.43	May	9	48.38	Jul	9	106.80	Sep	9	166.32	Nov	9	226.58
Jan	10	289.75	Mar	10	349.42	May	10	49.35	Jul	10	107.76	Sep	10	167.30	Nov	10	227.59
Jan	11	290.77	Mar	11	350.42	May	11	50.32	Jul	11	108.71	Sep	11	168.27	Nov	11	228.59
Jan	12	291.79	Mar	12	351.42	May	12	51.28	Jul	12	109.66	Sep	12	169.24	Nov	12	229.60
Jan	13	292.80	Mar	13	352.42	May	13	52.25	Jul	13	110.62	Sep	13	170.21	Nov	13	230.60
Jan	14	293.82	Mar	14	353.42	May	14	53.21	Jul	14	111.57	Sep	14	171.19	Nov	14	231.61
Jan	15	294.84	Mar	15	354.41	May	15	54.18	Jul	15	112.53	Sep	15	172.16	Nov	15	232.62
Jan	16	295.86	Mar	16	355.41	May	16	55.14	Jul	16	113.48	Sep	16	173.14	Nov	16	233.62
Jan	17	296.88	Mar	17	356.40	May	17	56.10	Jul	17	114.43	Sep	17	174.11	Nov	17	234.63
Jan	18	297.90	Mar	18	357.40	May	18	57.07	Jul	18	115.39	Sep	18	175.09	Nov	18	235.64
Jan	19	298.91	Mar	19	358.39	May	19	58.03	Jul	19	116.34	Sep	19	176.06	Nov	19	236.65
Jan	20	299.93	Mar	20	359.39	May	20	58.99	Jul	20	117.30	Sep	20	177.04	Nov	20	237.66
Jan	21	300.95	Mar	21	0.38	May	21	59.96	Jul	21	118.25	Sep	21	178.02	Nov	21	238.67
Jan	22	301.97	Mar	22	1.37	May	22	60.92	Jul	22	119.21	Sep	22	179.00	Nov	22	239.68
Jan	23	302.99	Mar	23	2.37	May	23	61.88	Jul	23	120.16	Sep	23	179.98	Nov	23	240.69
Jan	24	304.00	Mar	24	3.36	May	24	62.84	Jul	24	121.12	Sep	24	180.95	Nov	24	241.70
Jan	25	305.02	Mar	25	4.35	May	25	63.80	Jul	25	122.07	Sep	25	181.93	Nov	25	242.71
Jan	26	306.04	Mar	26	5.34	May	26	64.76	Jul	26	123.03	Sep	26	182.91	Nov	26	243.72
Jan	27	307.05	Mar	27	6.33	May	27	65.72	Jul	27	123.98	Sep	27	183.89	Nov	27	244.73
Jan	28	308.07	Mar	28	7.32	May	28	66.68	Jul	28	124.94	Sep	28	184.88	Nov	28	245.75
Jan	29	309.09	Mar	29	8.31	May	29	67.64	Jul	29	125.90	Sep	29	185.86	Nov	29	246.76
Jan	30	310.10	Mar	30	9.30	May	30	68.60	Jul	30	126.85	Sep	30	186.84	Nov	30	247.77
Jan	31	311.12	Mar	31	10.29	May	31	69.56	Jul	31	127.81						
Feb	1	312.13	Apr	1	11.27	Jun	1	70.52	Aug	1	128.76	Oct	1	187.82	Dec	1	248.78
Feb	2	313.15	Apr	2	12.26	Jun	2	71.48	Aug	2	129.72	Oct	2	188.81	Dec	2	249.80
Feb	3	314.16	Apr	3	13.25	Jun	3	72.44	Aug	3	130.68	Oct	3	189.79	Dec	3	250.81
Feb	4	315.18	Apr	4	14.23	Jun	4	73.39	Aug	4	131.63	Oct	4	190.77	Dec	4	251.82
Feb	5	316.19	Apr	5	15.22	Jun	5	74.35	Aug	5	132.59	Oct	5	191.76	Dec	5	252.84
Feb	6	317.21	Apr	6	16.20	Jun	6	75.31	Aug	6	133.55	Oct	6	192.74	Dec	6	253.85
Feb	7	318.22	Apr	7	17.19	Jun	7	76.26	Aug	7	134.51	Oct	7	193.73	Dec	7	254.87
Feb	8	319.23	Apr	8	18.17	Jun	8	77.22	Aug	8	135.46	Oct	8	194.71	Dec	8	255.88
Feb	9	320.24	Apr	9	19.15	Jun	9	78.18	Aug	9	136.42	Oct	9	195.70	Dec	9	256.90
Feb	10	321.25	Apr	10	20.13	Jun	10	79.13	Aug	10	137.38	Oct	10	196.69	Dec	10	257.91
Feb	11	322.27	Apr	11	21.11	Jun	11	80.09	Aug	11	138.34	Oct	11	197.68	Dec	11	258.93
Feb	12	323.28	Apr	12	22.09	Jun	12	81.04	Aug	12	139.30	Oct	12	198.67	Dec	12	259.95
Feb	13	324.29	Apr	13	23.07	Jun	13	82.00	Aug	13	140.26	Oct	13	199.66	Dec	13	260.96
Feb	14	325.30	Apr	14	24.05	Jun	14	82.96	Aug	14	141.22	Oct	14	200.65	Dec	14	261.98
Feb	15	326.31	Apr	15	25.03	Jun	15	83.91	Aug	15	142.18	Oct	15	201.64	Dec	15	263.00
Feb	16	327.32	Apr	16	26.01	Jun	16	84.87	Aug	16	143.14	Oct	16	202.63	Dec	16	264.02
Feb	17	328.33	Apr	17	26.99	Jun	17	85.82	Aug	17	144.10	Oct	17	203.62	Dec	17	265.03
Feb	18	329.34	Apr	18	27.97	Jun	18	86.78	Aug	18	145.07	Oct	18	204.61	Dec	18	266.05
Feb	19	330.35	Apr	19	28.95	Jun	19	87.73	Aug	19	146.03	Oct	19	205.61	Dec	19	267.07
Feb	20	331.35	Apr	20	29.92	Jun	20	88.68	Aug	20	146.99	Oct	20	206.60	Dec	20	268.09
Feb	21	332.36	Apr	21	30.90	Jun	21	89.64	Aug	21	147.95	Oct	21	207.60	Dec	21	269.11
Feb	22	333.37	Apr	22	31.87	Jun	22	90.59	Aug	22	148.92	Oct	22	208.59	Dec	22	270.13
Feb	23	334.38	Apr	23	32.85	Jun	23	91.55	Aug	23	149.88	Oct	23	209.59	Dec	23	271.14
Feb	24	335.38	Apr	24	33.83	Jun	24	92.50	Aug	24	150.84	Oct	24	210.58	Dec	24	272.16
Feb	25	336.39	Apr	25	34.80	Jun	25	93.46	Aug	25	151.81	Oct	25	211.58	Dec	25	273.18
Feb	26	337.40	Apr	26	35.77	Jun	26	94.41	Aug	26	152.77	Oct	26	212.58	Dec	26	274.20
Feb	27	338.40	Apr	27	36.75	Jun	27	95.37	Aug	27	153.74	Oct	27	213.57	Dec	27	275.22
Feb	28	339.41	Apr	28	37.72	Jun	28	96.32	Aug	28	154.71	Oct	28	214.57	Dec	28	276.24
			Apr	29	38.69	Jun	29	97.27	Aug	29	155.67	Oct	29	215.57	Dec	29	277.26
			Apr	30	39.66	Jun	30	98.23	Aug	30	156.64	Oct	30	216.57	Dec	30	278.27
									Aug	31	157.60	Oct	31	217.57	Dec	31	279.29

Ongoing meteor work

Calculation of the incident flux density of meteors by numerical integration. I

Galina O. Ryabova [1]

A method for calculation of the flux density of meteors from backscatter radar observations is proposed. The method is a modification of the Kaiser-Belkovich method, aimed at performing direct numerical calculations instead of approximations. It allows one to work with physical models of a user's choise.

Received 2008 October 28

1 Introduction

Mathematical modelling of meteoroid stream formation was stimulated by increasing computer power. Now, when large scale integration studies have become possible, we are able to construct extensive models explaining a meteoroid stream structure (Ryabova, 2006). Still there exists a problem which can hamper the progress, namely, lack of flux-based activity curves of meteor showers. It is important, because activity curves constructed on the base of hourly rates can be distorted by observational selection (Belkovich 1971, Fig. 18; Ryabova 2007, Fig., 4).

A method for calculation of the incident flux density of meteors was proposed by Kaiser (1955, 1960) and developed by Belkovich and co-authors (Belkovich, 1971; Bel'kovich & Tokhtas'ev, 1974a; Bel'kovich & Tokhtas'ev, 1974b; Belkovich & Suleymanova, 1999; Belkovich et al., 1999). The last version of the Kaiser-Belkovich method was arranged for a series of lectures given by Prof. O. Belkovich on the Radio Meteor School 2005 (Belkovich et al. 2006a-e)[a]. The method is excellent, but some potential for its improvement exists. The modifications in the version of the method presented in this paper are aimed at elimination of approximations. Direct numerical integration was not effective 20 years ago on the slow computers, now calculations take quite reasonable time. I tried also to make the method more universal, allowing one to work with physical models of the user's choice.

The main additions allowing one to pass on to the pure numerical approach are 1) a method to find a radar sensitivity, and 2) a method for numerical calculation of the mean meteor layer thickness, described in the Sections 5 and 6 of the second part of this paper, correspondingly. Both methods were invented almost 25 years ago (Andreev & Ryabova, 1984a,b). The main idea of the first method belongs to Gennadij Andreev, and the second method was developed by Ryabova. The implementation belongs to both of us. It so happened that the methods were published in Russian in a local journal, and therefore remains obscure to the the academic community.

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The following will keep to the designations introduced in the Lectures.

2 Flux density

Let us recollect the most essential definitions and equations. It is known that meteoroid's mass distribution obeys a power low. So the probability density $p(m)$ can be written as

$$p(m) = (s-1)m_0^{s-1}m^{-s}, \qquad m \in [m_0, +\infty), \quad (1)$$

where s is the mass index, m is the meteoroid mass, m_0 is the minimal detectable mass, and the distribution function can be written as

$$F(m) = \mathrm{Prob}\{m_0, m\} = \mathrm{Prob}\{\xi \le m\} = \\ = \int_{m_0}^{m} p(x)\,dx = 1 - \left(\frac{m}{m_0}\right)^{1-s}. \quad (2)$$

Here Prob is designation for probability, and ξ is the random variable. Hence it appears

$$\mathrm{Prob}\{m > m^*\} = 1 - F(m^*) = \left(\frac{m^*}{m_0}\right)^{1-s}. \quad (3)$$

Let total number of observed meteoroids be $N = N(m > m_0)$. Then number of meteoroids having $m > m^*$ is

$$N(m > m^*) = N \cdot \left(\frac{m^*}{m_0}\right)^{1-s}. \quad (4)$$

The *meteoroid flux density* $Q(m^*)$ is the number of meteoroids having masses greater or equal to m^* that intersects the unit area, perpendicular to the meteoroid's velocity vector, per unit time:

$$Q(m^*) = Q(m > m^*) = \frac{N(m > m^*)}{S \cdot t}, \quad (5)$$

where S is the total area intersected by meteors, and t is time. From (4) and (5) follows

$$\frac{Q(m > m^*)}{Q(m > m_0)} = \frac{N(m > m^*)}{N(m > m_0)} = \left(\frac{m^*}{m_0}\right)^{1-s}. \quad (6)$$

Or, in other words,

$$Q(m^*) = Q(m_0) \cdot \left(\frac{m^*}{m_0}\right)^{1-s}. \quad (7)$$

[a]The talk was given by O. Belkovich, but the published text evolved from brief lecturer's notes by joint efforts of the author and editors. In what follows I'll refer to these papers as *the Lectures* for short.

3 Height of maximal echo amplitude

The variation of the electron line density α along the meteor trail could be described by following equations (Belkovich & Verbeeck 2006a, (5-7)):

$$\alpha(t) = \alpha_{\max} \cdot z(t), \tag{8}$$

where

$$z(t) = \begin{cases} \frac{9}{4}e^{-t}(1-\frac{1}{3}e^{-t})^2, & \text{if} \quad -\ln 3 \le t \le 1.7, \\ 0, & \text{if} \quad t \le \ln 3 \quad \text{or} \quad t \ge 1.7. \end{cases} \tag{9}$$

The relative height is given by

$$t = \frac{h - h_{\max}}{H}, \tag{10}$$

where h is the height of the considered reflecting point on the trail, $h_{\max}$ is the height of the point with maximal electron line density $\alpha_{\max}$ on the same trail, and H is the atmospheric scale height.

It is reasonable to suggest that the minimal electron line density α_0 is produced by an underdense trail. The value of amplitude of a signal at the receiver input is (Belkovich 1971, (1.28)):

$$A = \sqrt{R_i} F d^{-3/2} g, \tag{11}$$

where R_i is the input impedance of the receiver, d is the distance to the reflection point, g is the reflection coefficient, and

$$F = \sqrt{\frac{P_{\mathrm{T}} G_{\mathrm{T}} G_{\mathrm{R}} \lambda^3}{32\pi^4}}. \tag{12}$$

Here P_{T} is the power of the transmitter, G_{T} and G_{R} are the gain of the receiver and transmitter antennas in the direction of the reflecting point, λ is the radio wavelength. Dimensionality for all values will be given below, after equation (17).

For underdense meteor trails the maximal reflection coefficient is equal to (Belkovich 1971, (1.29)):

$$g_1 = g_{01} \exp\{-(kr_0^2)\}\alpha, \tag{13}$$

where $g_{01} = \pi r_e$, and $r_e = 2.81 \times 10^{-15}$ cm is the classical electron radius, $k = 2\pi/\lambda$, r_0 is the initial radius, and α is the electron line density in the reflecting point.

But the maximal amplitude will be less than in formula (11). The first factor influencing the amplitude is the diffusion of the meteor trail while it passes through the first Fresnel zone. The second factor is the minimal time for a trail registration (Belkovich & Wislez 2006b, p.29). Detailed derivation of the attenuation coefficient φ_w is given in (Belkovich 1971, p.15). Here only final the formulae are presented:

$$\varphi_w = \frac{\tau_0}{\tau_f + \tau_r}\left(1 - \exp\left\{-\frac{\tau_f + \tau_r}{\tau_0}\right\}\right), \tag{14}$$

where

$$\tau_f = \frac{1}{V}\sqrt{\frac{d\lambda}{2}} \tag{15}$$

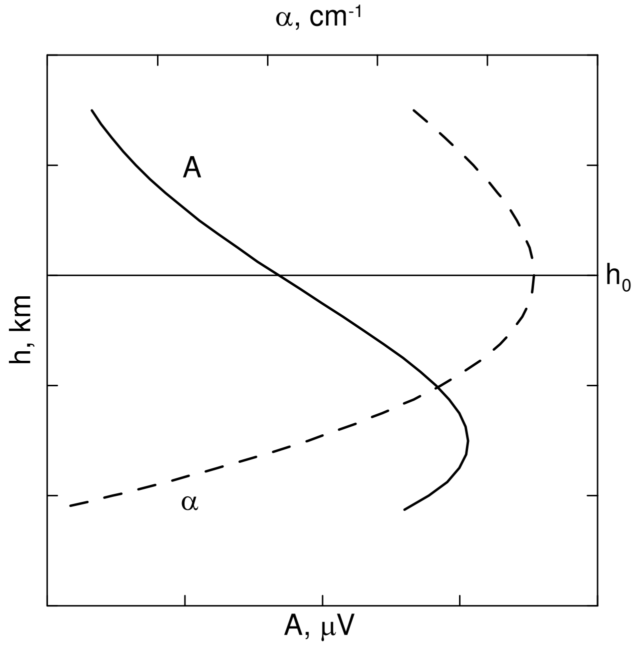

Figure 1 – The variation of the electron line density α and amplitude A along a meteor trail.

is the time the meteoroid needs to pass half of the first Fresnel zone, V is the meteoroid velocity; τ_r is the time between pulses, and

$$\tau_0 = \frac{\lambda^2}{16\pi^2 D_a} \tag{16}$$

is the decay constant for the echo amplitude at the height h_0, where D_a is the ambipolar diffusion coefficient.

So the final formula for the echo amplitude from an underdense meteor trail is:

$$A = \sqrt{R_i} F d^{-3/2} g_{01} \exp\{-(kr_0)^2\}\varphi_w \alpha_m z(t) \tag{17}$$

The dimensions of the values involved are: A (V), R_i (Ω), d (m), λ (m), P_{T} (W), g_{01} (m), r_0 (m), V (m s^{-1}), D_a (m^2 s^{-1}), τ_r (s), α_m (m^{-1}). Certainly, the units could be reduced to a unified system, but in practice just the listed units are used.

The value of amplitude of a signal at the receiver input for an overdense trail is (Belkovich 1971, (1.36)):[b]

$$A = \sqrt{R_i} F g_{02} d^{-3/2} [\alpha_m z(t)]^{1/4} \tag{18}$$

Here dimensions are as in equation (17), and the reflection coefficient for overdense trail is

$$g_{02} = 0.84 \exp(-\frac{1}{4}) \left(\frac{\pi^2}{4} r_e\right)^{1/4}. \tag{19}$$

In all examples the following parameters were used for the antenna: the threshold level of the radar detector unit $U = 17\ \mu$V, $R_i = 75\ \Omega$, $\lambda = 7.9$ m, $P_T = 80$ kW, $G_{\mathrm{T}} = G_{\mathrm{R}} = 32$ for the direction of maximal sensitivity, $\tau_r = 0.02$ s and the elevation angle for maximum sensitivity $\delta_m = 25.5°$. For meteoroids $V = 40$ km/s, and density $\rho = 3.4 \times 10^3$ kg m^{-3} were used.

[b]Also (Belkovich & Wislez 2006b, (8)-(9)).

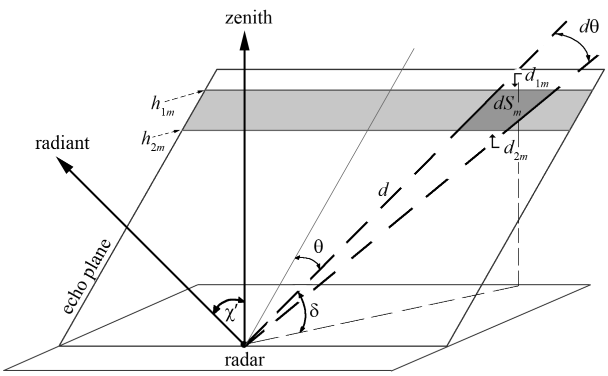

Figure 2 – The geometry of trail registrations by a backscatter radar. The echo plane is perpendicular to the radiant direction, χ' is the zenith angle with respect to the zenith of the radar, θ is the angle in the echo plane, dS_m is the collecting area, d is the distance from the radar, δ is the elevation angle.

Figure 1 shows α and A as functions of the height h for a meteor trail. The maximum of the echo amplitude is lower in altitude than the maximum of ionization, and the reason is the influence of the two abovementioned factors and of the distance (multiplier $d^{-3/2}$).

4 From rates to flux

In our considerations we imply that all trails of a shower are parallel, and all meteoroids have geocentric velocity $\mathbf{V}$. So for a backscatter radar the reflection points are all lie in the echo plane normal to $\mathbf{V}$ (or, what is the same, to the radiant direction). The geometry is shown in Figure 2. If we have number of shower meteors registered per unit of time, then to calculate flux we need to know the area in the echo plane intersected by these meteors (see (5)). The area is called also the 'collecting area'. Let us begin from calculation of the collecting area dS in an infinitesimal sector of the echo plane (the sector $d\theta$ in Figure 2).

For the elemental collecting area of the echo plane in the direction θ we can write:

$$dS_{\theta m} = \frac{1}{2}(d_{1m}^2 - d_{2m}^2)\, d\theta, \tag{20}$$

where distance to some point in the echo plane d can be calculated as

$$d = \frac{h}{\cos\theta \sin\chi'} = \frac{h}{\sin\delta}, \tag{21}$$

and h is the height of this point, χ' is the zenith angle with respect to the zenith in the radar location, δ is the elevation angle, and indices 'm' show that we consider only meteors with masses between m and $m+dm$. The equation (20) follows from the formula for area of a trapezium and the fact that $\tan(d\theta/2) \approx d\theta/2$ for very small angles. All shower meteors with the same mass have the same height of maximal ionization, so they have the same beginning heights and end heights. Hence all reflection points for meteors with mass m are located in the meteor layer between lines d_{1m} and d_{2m} or between heights h_{1m} and h_{2m}. Then for the mass m we have

$$dS_{\theta m} = \frac{h_{1m}^2 - h_{2m}^2}{2\cos^2\theta \sin^2\chi'}\, d\theta. \tag{22}$$

Our radar registers masses from the minimal detectable mass m_0 to infinity. In the direction θ the radar registers masses between m_θ and ∞. Therefore to calculate the mean dS for all masses in the direction θ we should calculate

$$dS_\theta = \int_{m_\theta}^{\infty} dS_{\theta m} \cdot p_\theta(m)\, dm = \frac{m_\theta^{s-1} d\theta}{\cos^2\theta \sin^2\chi'} I'(\theta). \tag{23}$$

Here

$$p_\theta(m) = (s-1) m_\theta^{s-1} m^{-s}, \qquad m \in [m_\theta, +\infty). \tag{24}$$

where m_θ is the minimal detectable mass in the direction θ, and

$$I'(\theta) = \frac{s-1}{2} \int_{m_\theta}^{\infty} (h_{1m}^2 - h_{2m}^2) \cdot m^{-s}\, dm. \tag{25}$$

Let us define $I'(\theta)$ as the mean meteor layer thickness in the direction θ of the echo plane. It is not quite the same $I(\theta)$ as in the Lectures or in (Belkovich 1971, (2.8)).

Now we may write the number of shower meteors dN_θ registered per unit time in the direction θ in the infinitesimal sector $d\theta$:

$$\begin{aligned} dN_\theta &= Q(m_\theta) \cdot dS_\theta = \\ &= Q(m_\theta) m_\theta^{s-1} \sin^{-2}\chi' \frac{d\theta}{\cos^2\theta} \cdot I'(\theta). \end{aligned} \tag{26}$$

To calculate total number of registered meteors N we should integrate (26) over the whole range of θ. Using equations (7) and (23), we obtain *the final formula*:

$$N = Q(m_0) \cdot m_0^{s-1} \cdot \sin^{-2}\chi' \cdot \int_\theta I'(\theta) \cdot \cos^{-2}\theta\, d\theta. \tag{27}$$

From this equation it is easy to calculate the flux density $Q(m_0)$. Knowing that $Q(m_0) \cdot m_0^{s-1} = Q(m_*) \cdot m_*^{s-1}$ we can calculate flux density for any given mass m_*.

What we should know to calculate $Q(m_0)$ from the formula (27)? We should know the minimal detectable mass m_0 and we should know how to calculate $I'(\theta)$ from the formula (25). We also should know the mass index s.

5 Conclusions

In the first part of the paper we have introduced the main definitions of the proposed method (Sections 2 and 3) and derived a formula for calculation the flux density for any given meteoroid mass from the total number of observed meteoroids (Section 4).

In the second part of the paper, which will be published in a forthcoming issue, we shall consider: calculation of the minimal detectable mass m_0, and also the minimal detectable mass m_θ in the arbitrary direction θ of the echo plane (Section 5); calculation of the mean meteor layer thickness $l'(\theta)$ in arbitrary direction of the echo plane, introduced in the Section 4 (Section 6); calculation of mass index s (Section 7).

The paper was divided into two parts for technical reasons. So for convenience of the Reader, numeration of the Sections and Equations will be kept through.

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On the average altitude of (video) meteors

Sirko Molau [1] *and SonotaCo* [2]

In this paper, we derive a new formula for the average altitude of (video) meteors. It was determined from double-station data of the Japanese SonotaCo Network, and confirmed by single-station data of the IMO Video Meteor Network. In the simple form, the relationship between the mean meteor altitude h_m [km] and the velocity at infinity v_inf [km/s] of a meteoroid is $h_\mathrm{m} = 0.48 \times v_\mathrm{inf} + 73$. The average altitude range in which the meteor is visible is 12 km, independent of v_inf. Hence, the mean begin height h_b [km] is $h_\mathrm{b} = 0.48 \times v_\mathrm{inf} + 79$ and the mean end height h_e [km] is $h_\mathrm{e} = 0.48 \times v_\mathrm{inf} + 67$. The average meteor altitude depends on the apparent meteor brightness m [mag], the meteor duration d [s] and the entry angle of the meteoroid ea [°], which is equivalent to the zenith attraction corrected height of the radiant. If these parameters are taken into account, the average meteor altitude becomes $h_\mathrm{m} = 0.48 \times v_\mathrm{inf} + m - ea/10 + 78$, and the altitude range $h_\mathrm{b} - h_\mathrm{e} = 38 \times d$.

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1 Introduction

In the last decade, two major video observation networks have been established in (mainly) Europe and in Japan, namely the IMO Video Meteor Network and the SonotaCo Network. Both networks sparked a lot of interest among amateur meteor observers and have therefore considerably grown in recent years. The strength of video networks is their ability to obtain a large set of accurate meteor records in the optical domain with only little manual and financial effort. After a first data collection phase, both networks yielded a database of meteor records, which allows serious statistical analyses of meteor shower characteristics. First results have already been published, but we expect a much deeper insight into the properties of meteoroids and meteor showers from future analyses.

In this paper, we concentrate on one particular parameter – the average altitude of meteors recorded by video. Because this is the first joined research project of the two networks, we will first give a short introduction to both networks and the underlying meteor databases, before we present the motivation of this paper and our findings.

2 IMO Video Meteor Network

The IMO Video Meteor Network is a joint effort of amateur meteor observers mainly located in Europe that started in March 1999 (Molau, 2001). Based on the MetRec software, most observers record meteors during any given clear night. The meteor data is centrally collected, quality checked, and archived by the IMO Video Commission. It is made available through the web (`http://www.imonet.org`) and other channels. In 2007, a total of 30 intensified and non-intensified cameras operated by 22 observers in 9 countries contributed to the network. Even though the camera density in central Europe (especially in Southern Germany, Slovenia, and Northern Italy) has grown such, that most of the sky is covered by more than one camera (Figure 1), the fields of the individual cameras are usually not specifically aligned and the observations can be regarded as single-station recordings. Only recently some observer have started to check for double-station records and to analyze them with the UFOOrbit software (SonotaCo, 2007c).

3 SonotaCo Network

The SonotaCo Network (SonotaCo, 2004) is a night sky video observing network in Japan, that started operation in August 2004. It is operated by amateur meteor observers and professional researchers, who use the motion detect software UFOCapture (SonotaCo, 2005) in combination with the single-station object analyzer software UFOAnalyzer (SonotaCo, 2007b), and the meteoroid orbit determination software UFOOrbit (SonotaCo, 2007c). UFOCapture and UFOAnalyzer together cover a similar functionality as MetRec, whereas UFOOrbit is an additional tool for multi-station analysis.

By January 2008, the SonotaCo Network had grown to 31 stations with more than 130 cameras. These cameras are almost exclusively non-intensified monochrome video cameras with fields of view between 30° and 90° diameter. There are a number of stations that operate up to 8 cameras simultaneously to cover a wider area with improved limiting magnitude. Thus, most of the observational area of the SonotaCo Network is covered by two or more cameras. The focus of the network is not only meteors, but also transient luminous events (TLEs) caused by lightning discharge that appears at almost the same altitude as meteors and can therefore be observed with the same equipment.

Eighteen stations of the SonotaCo Network with a total of 80 cameras are located on the main island of Japan. More than 140 000 single-station meteor records were reported by these cameras in 2007. The data are published on a daily basis on the web (SonotaCo, 2007a), and have been analyzed already. Almost 71 000 meteors were simultaneous recordings, but 17 000 of these records did not pass the standard quality check of UFOOrbit because of insufficient accuracy or inappropriate geological pairing conditions. The remaining set of roughly 54 000 meteors was reduced to 18 650 re-

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NASA-ADS bibcode 2008JIMO...36..124M

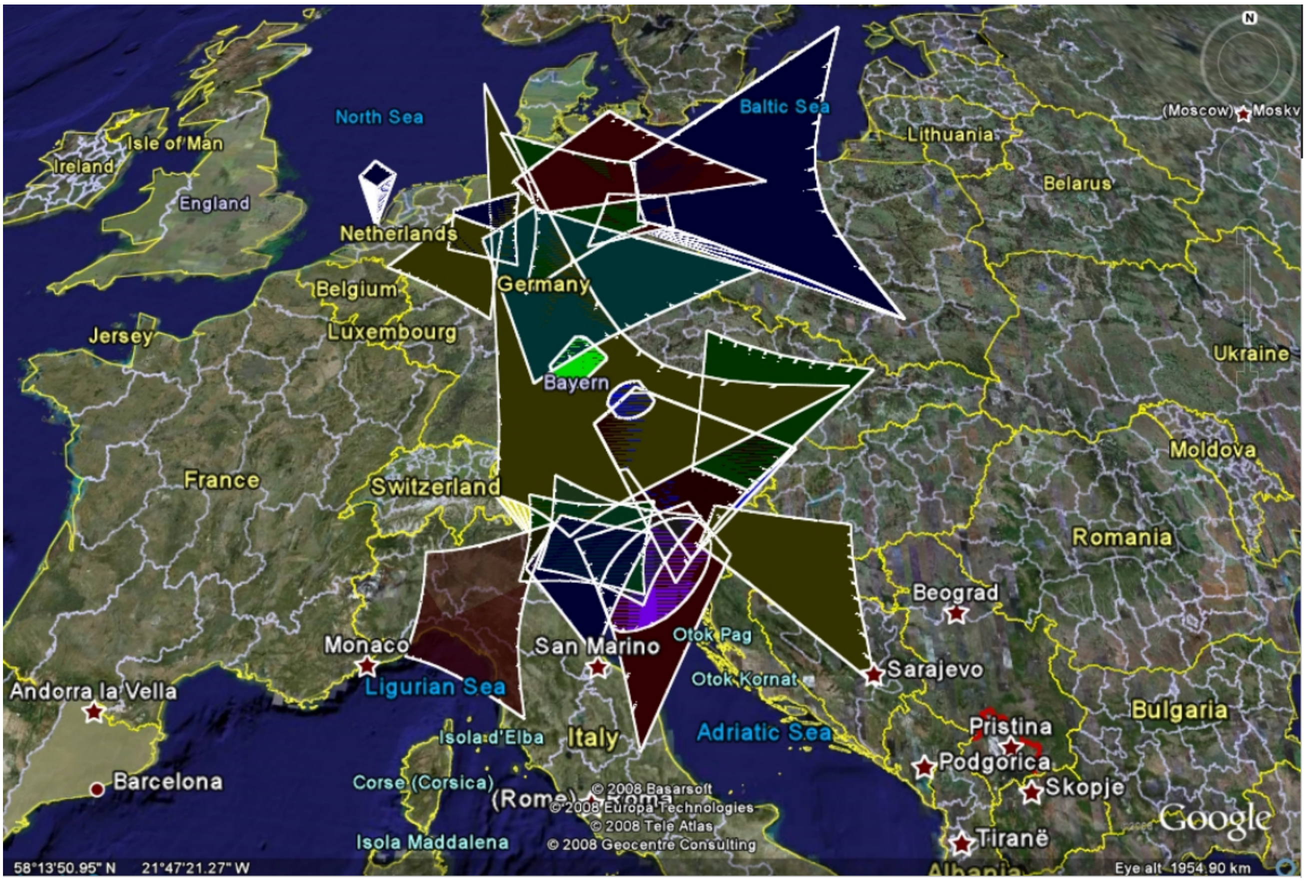

Figure 1 – The field of view of video cameras from the IMO Video Meteor Network in central Europe as of May 2008.

liable meteoroid orbits, which gives an average of 2.9 multi-station records per meteor. This set of orbits was used throughout this study.

Figure 2 shows the observing stations and the apparent paths of the 18 650 meteors projected onto a ground map of Japan. It shows that most double-station meteors were recorded in the area with the highest camera density.

Figure 3 shows the radiant distribution of the same data set. A number of well-known major shower meteors such as Perseids, Orionids, and Geminids are easily noticable. Based on the UFOOrbit shower catalog, which contains 146 entries, a total of 40% of all meteors were classified as shower members, and 60% as sporadic. This fits well to a recent analysis of the IMO Video Meteor Database, presented in May at the 'Meteoroid and Meteor Observations as a Basis for Models' conference in Huntsville, Alabama. There we came up with 25% shower meteors, 15% meteors from sporadic sources, and 60% sporadic meteors.

4 Motivation

By 2006 the number of records in the IMO Video Meteor Database had grown to nearly 200 000. That made it worthwhile to analyze the single-station data set in detail and search for known and unknown meteor showers based on probabilistic algorithms. The results were presented at the 2006 IMC (Molau, 2006). Nearly all meteor showers of the IMO Working List were detected, even though the parameters for some showers (activity period, radiant position and drift) differed significantly from the expected values.

One effect could not be explained readily – a systematic deviation of the velocity at infinity ($v_{\rm inf}$) of detected well-known meteor showers compared to the values given in the literature. Whereas there was little to no deviation for low and medium velocities showers, the velocity was underestimated by up to 10% for fast showers (Figure 4).

To determine the reason for the systematic shift it was necessary to inspect the algorithm used in the shower determination process more closely. The main loop is as follows: For each meteor, the search routine tests all possible radiants (i.e., all possible combinations $\alpha/\delta/v_{\rm inf}$) and computes the probability that the meteor belongs to this particular radiant. The probabilities are accumulated over all meteors in short solar longitude intervals, and those $\alpha/\delta/v_{\rm inf}$ pairs with highest probability are considered to be active radiants. Besides certain boundary conditions (e.g., a radiant has to be above the horizon at the appearance time of the meteor) that have to be met, the radiant probability is computed from two quantities – the distance at which the backward prolongation of the meteor misses the radiant [°], and the difference of the expected and the observed angular meteor velocity [°/s].

The first quantity can be derived from simple geometric considerations, whereas the second one is based on a formula that describes the expected angular velocity of the meteor at a certain position in the sky (Gural, 1999). This formula has two basic parameters, $v_{\rm inf}$ and

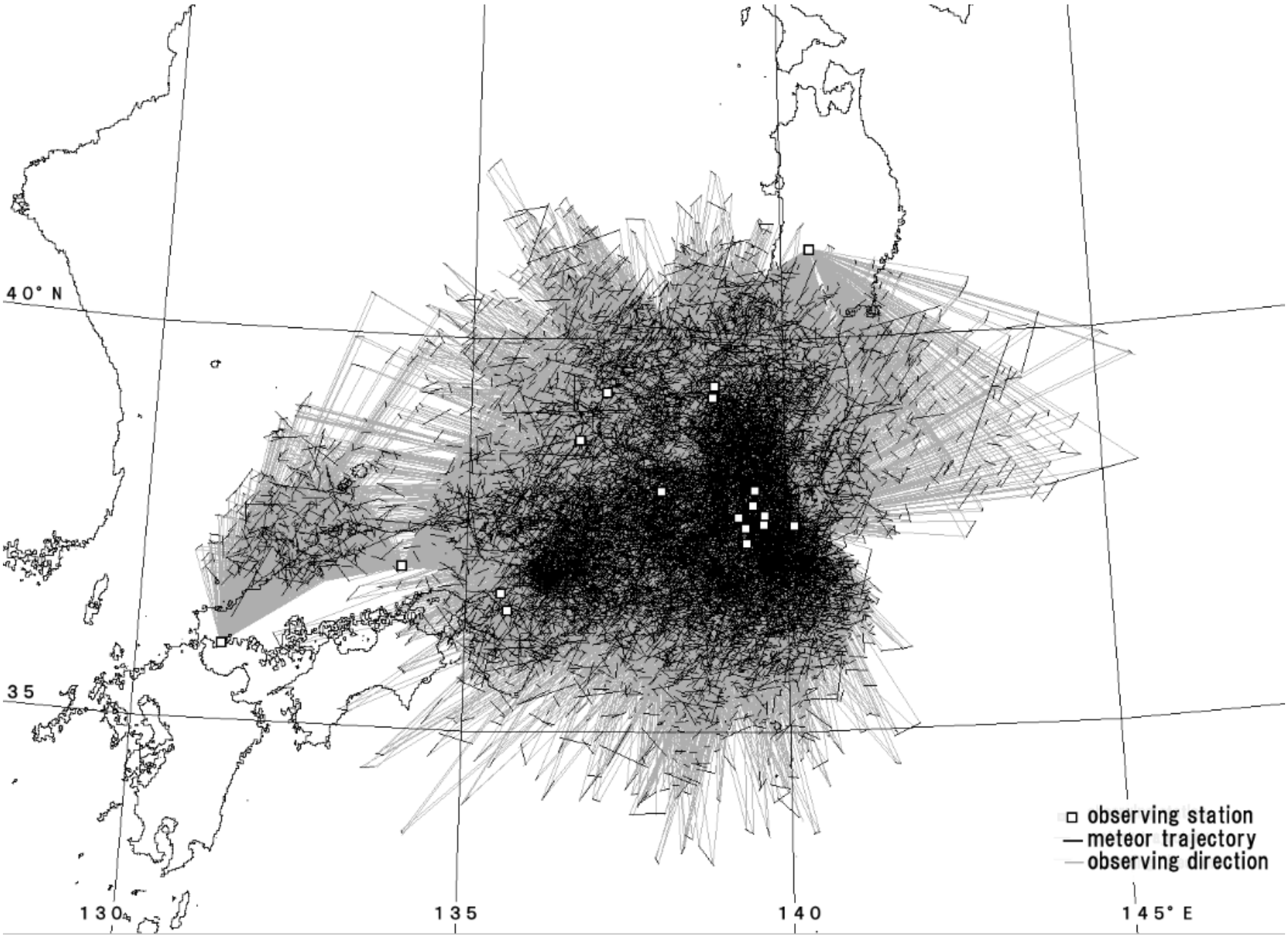

Figure 2 – Ground projection of 18 650 meteors recorded simultaneously by cameras of the SonotaCo Network in 2007. For each of these, a high-quality meteoroid orbit could be obtained.

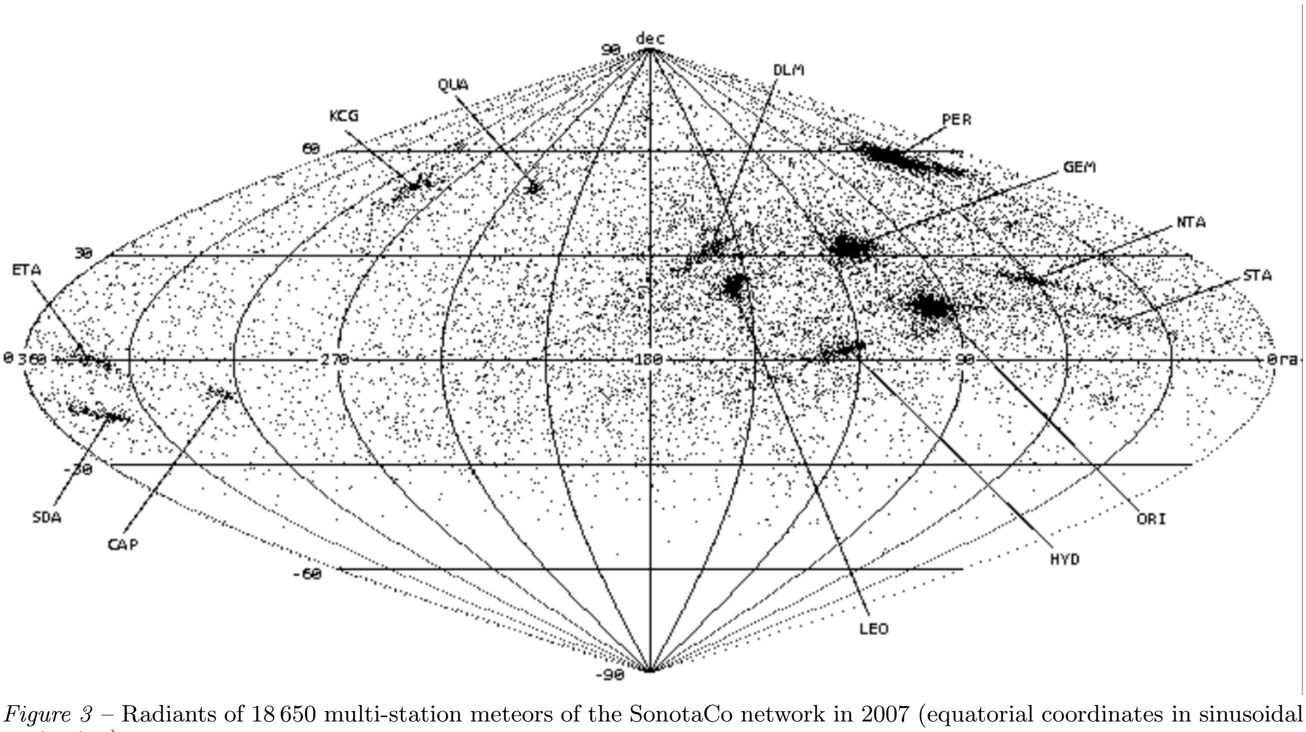

Figure 3 – Radiants of 18 650 multi-station meteors of the SonotaCo network in 2007 (equatorial coordinates in sinusoidal projection).

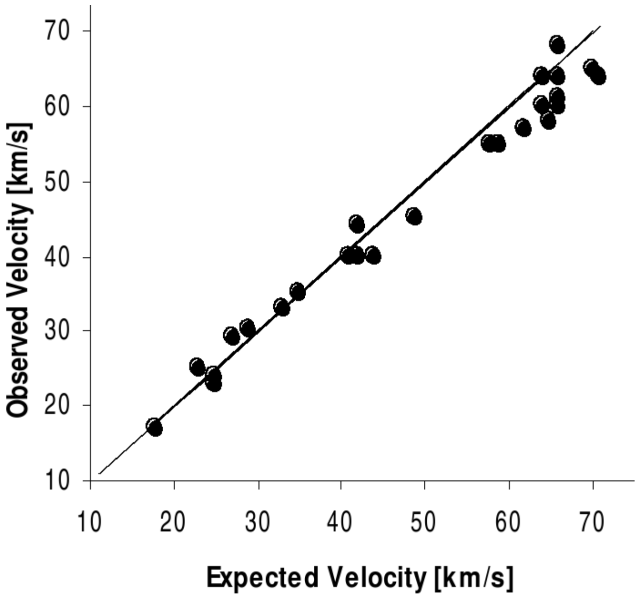

Figure 4 – A comparison of the observed velocity at infinity of known meteor showers from the 2006 IMO Video Meteor Database analysis with the value given in the IMO Visual Handbook (Rendtel et al., 1995). The velocity of fast showers is systematically underestimated.

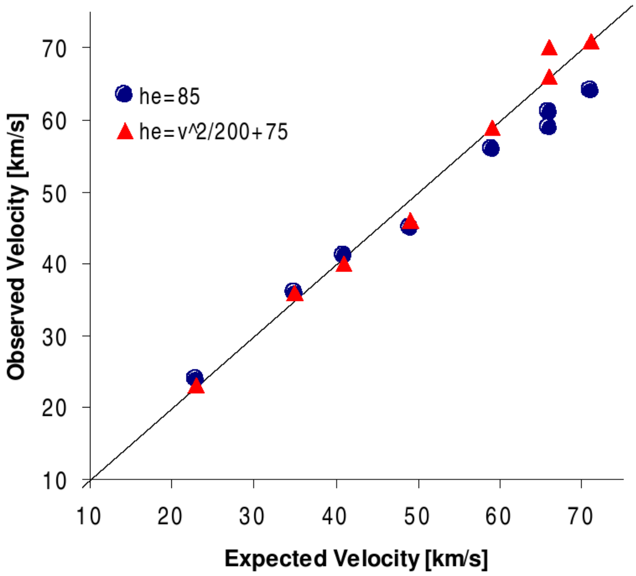

Figure 5 – A comparison of the estimated velocity of eight well-known showers using the original formula $h_\mathrm{e} = 85$ and the improved formula $v_e = v_\mathrm{inf}^2/200 + 75$.

the meteor begin and end height (h_b, h_e), or alternatively the mean height (h_m). For the probabilistic algorithm described above, v_inf is given, because the procedure computes the probability of each possible v_inf value and each radiant position. The begin and end height, however, have to be provided as prior knowledge. It turned out that the parameter choice of the 2006 analysis ($h_\mathrm{b} = v_\mathrm{inf}^2/200 + 100$, $h_\mathrm{e} = 85$) was not optimal. The observed velocity deviation of fast meteor showers could be removed, if other parameters were used.

For this reason, an analysis was started to find better estimates of the average begin and end height of video meteors.

5 First approach based on single-station data

The first approach was based on single-station data from the IMO Video Meteor Database, containing nearly 330 000 meteor records as of December 2007. A subset of roughly 20 000 meteors from the maximum times of eight well-observed meteor showers (CAP, GEM, QUA, LYR, PER, ETA, ORI, LEO) was chosen, which covered the full velocity range of meteor showers. For each of these, the most probable radiant position and velocity at infinity was repeatedly determined within a restricted search space (i.e., only radiant positions and velocities near the expected value were tested), and each time the parameter for the begin and end height was slightly modified. For the begin height, the exponent (2), the linear term (1/200), and the absolute term (100) were adjusted, and for the end height the absolute term (85). With this procedure, a set of parameters for h_b and h_e was determined such that the determined meteor shower velocities matched best the values known from literature.

It turned out that there was a dependency of the derived meteor shower velocities with each of these parameters: increasing one of these values lead to consistently increasing or decreasing shower velocities. In fact, even a minor modification of the begin or end height resulted in a clear change of the determined meteor shower velocity, which proved that the whole algorithm depends on a good choice of h_b and h_e. However, none of the four parameters alone was able to increase only the estimated velocity of fast meteor showers.

Then we determined that the deviation could be well accounted for, if the end altitude was not fixed but expressed as a function of v_inf. In fact, the same formula could be used for h_b and h_e with just a different absolute term. Best results were obtained with $h_\mathrm{b} = v_\mathrm{inf}^2/200 + 100$ and $v_e = v_\mathrm{inf}^2/200 + 75$ (which is equivalent to an average height of $h_\mathrm{m} = v_\mathrm{inf}^2/200 + 86$).

This was the proof that the systematic deviation in meteor showers velocities observed in the 2006 analysis was in fact caused by a poor parameter choice for the meteor end height (Figure 5). For a new full analysis of the IMO Video Meteor Database, a better formula needed to be applied.

6 Second approach based on double-station data

To further improve the quality of the mean meteor altitude estimates we decided to join forces with the SonotaCo Network. In their 2007 orbit set, the begin and end height of each individual meteor is known from triangulation, which is why this data set is perfectly suited to analyze the dependency of the average meteor altitude from different meteor parameters in more detail.

At first, we determined the average meteor begin and end height depending on the velocity at infinity v_inf (Figure 6). Two main facts can be derived immediately from the resulting plot (Figure 6).

- When we omit the few meteors below 15 km/s, there is a linear dependency of the meteor altitude with v_inf.

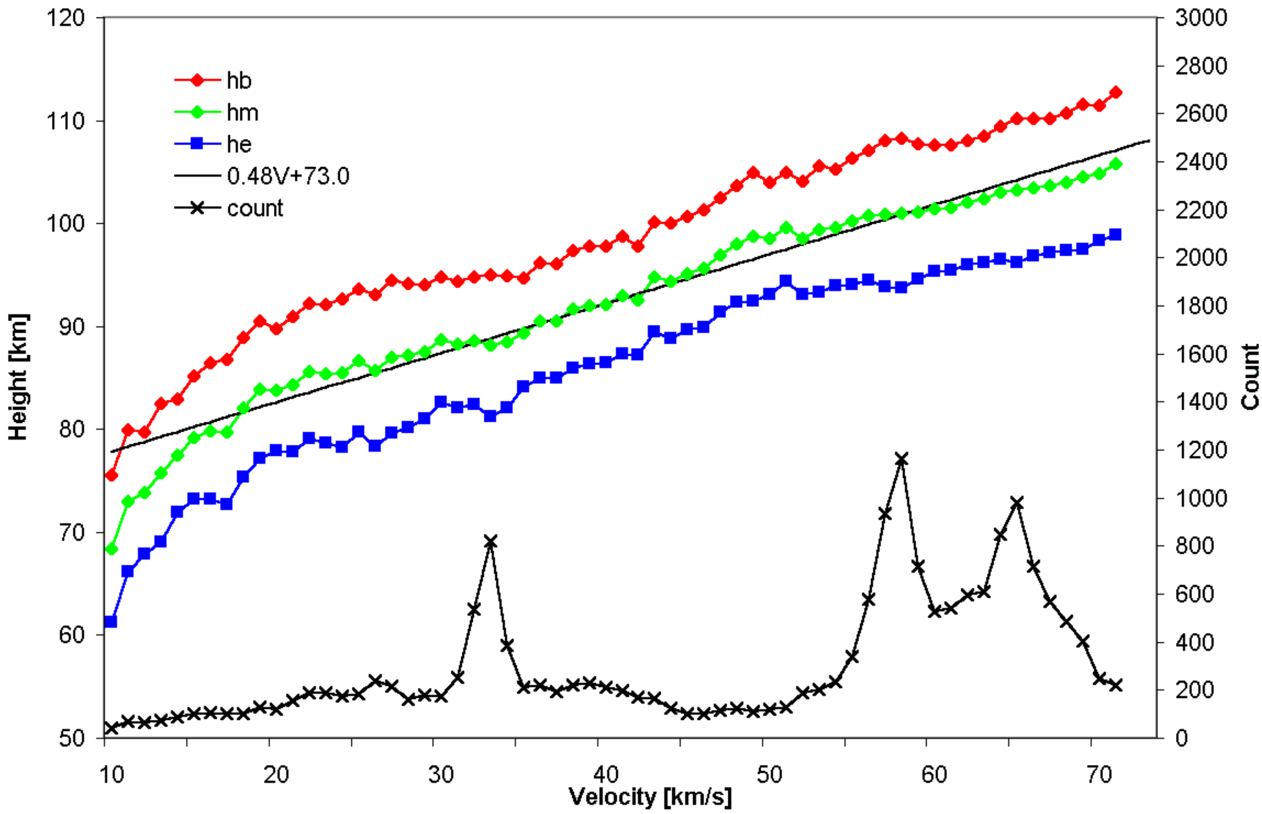

Figure 6 – The dependency of the average begin (h_b), mean (h_m), and end (h_e) heights with the velocity at infinity (v_inf), based of 18 650 meteors of the SonotaCo Network 2007 data set.

- The altitude range in which the meteors are observed, i.e., the difference between begin and end height, is 12 km, independently of v_inf.

A least squares fit yielded the following formula (Equation 1) for the mean meteor altitude h_m:

$$h_\mathrm{m} = 0.48 \times v_\mathrm{inf} + 73 \qquad (1)$$

That seems to differ significantly from the formulae derived from single-station IMO data. However, if both functions are plotted, it becomes clear that in the v_inf range typical for meteor showers, the deviation is below 3%.

To check the result, the single-station analysis of the IMO data was repeated with a linear function $h_\mathrm{m} = 0.48 \times v_\mathrm{inf} + x$, where only the absolute term x was adjusted. The computed meteor shower velocities matched best for x between 74 and 75. Thus, there was only a tiny deviation between the best fit of both databases, which is a nice independent confirmation of Equation 1. Still we were curios where the minor systematic shift of 1 to 2 km originated from. We came up with two possible reasons:

- the single-station analysis was only based on meteors of major showers, whereas the double-station data contained all meteors, i.e., mainly sporadics;
- the Japanese data set was derived almost exclusively with non-intensified cameras, whereas a significant fraction of the IMO data origins from intensified cameras with the net effect that meteors of the IMO database are on average fainter.

For this reason, we extended the analysis and studied the dependency of the mean meteor height from other parameters than v_inf.

7 Impact of the meteor brightness

We analyzed the impact of the meteor brightness by grouping meteors according to their apparent brightness, and determining the average meteor altitude for each subset independently. In this analysis, the scatter was larger because each data set in itself was smaller, but it turned out that fainter meteors were observed on average at slightly larger altitudes. In short, the average meteor altitude increased by about 1 km per magnitude in the analyzed range between magnitudes 0 and +3.

8 Impact of the meteor duration

The duration of a meteor has no effect on the average altitude, but for simple geometric reasons it can be assumed that the altitude range is directly proportional to the duration of the meteor. That was confirmed by the data set, from which we derived that the average altitude range $h_\mathrm{b} - h_\mathrm{e}$ [km] can be approximated by the meteor duration d [s] using the formula $h_\mathrm{b} - h_\mathrm{e} = 38 \times d$. Hence, the mean begin and end height of a particular meteor can be estimated from the average height by $h_\mathrm{b} = h_\mathrm{m} + 19 \times d$ and $h_\mathrm{e} = h_\mathrm{m} - 19 \times d$.

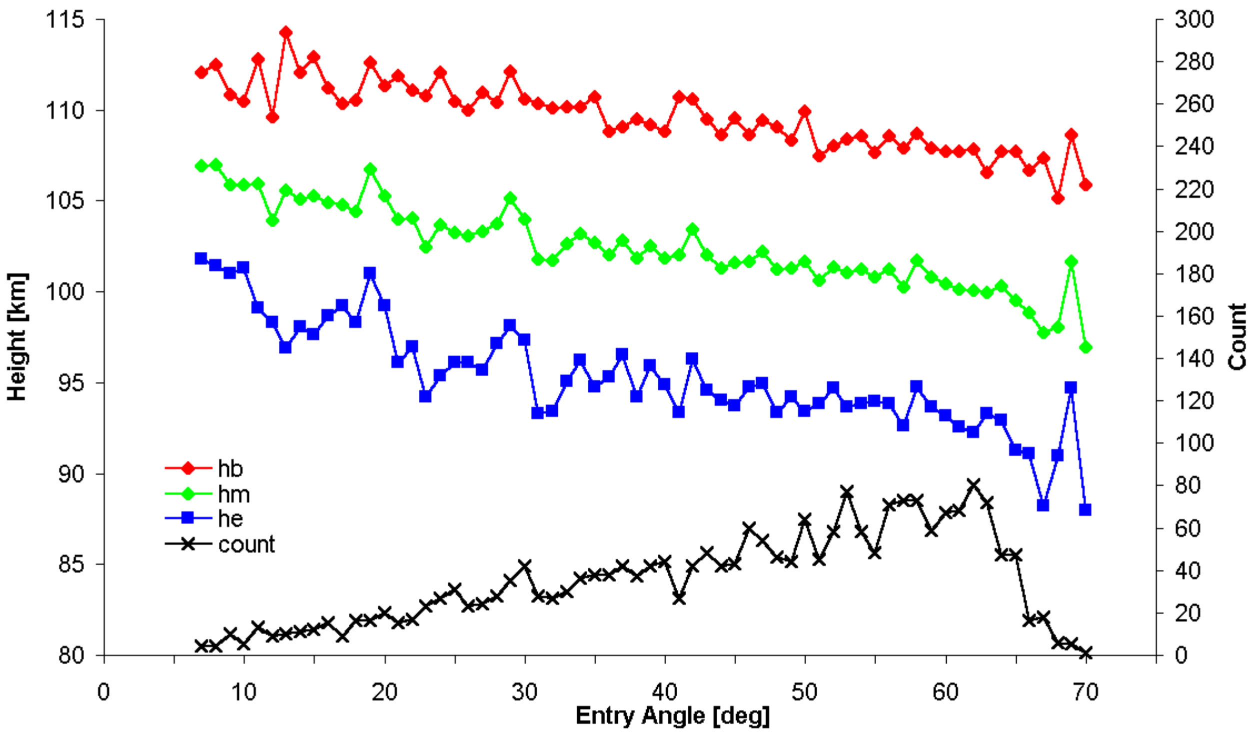

Figure 7 – Dependency of the average begin (h_{b}), mean (h_{m}), and end (h_{e}) height with the entry angle (ea) of a subset of 2 240 Perseids taken from the SonotaCo Network 2007 data set.

9 Impact of the entry angle

There are good reasons to believe that a meteoroid that hits the Earth at a shallow angle will burn up at a different altitude than one that hits the atmosphere head on. The entry angle ea [°] is equivalent to the altitude of the meteor shower radiant, corrected for the zenith attraction. Remember that, even though the radiant of a particular meteor is unknown in single-station analysis, each possible radiant is tested in the analysis procedure described above, which is why also the zenith distance can be computed for each of these.

Figure 7 shows the dependency of the meteor begin, mean, and end height from the entry angle. This time, we restricted the SonotaCo Network data set to one shower (Perseids) to avoid bias from individual showers which distinct v_{inf} culminating at different altitudes. Once more, there is a clear linear dependency with meteoroids that enter the atmosphere at shallow angles burning up higher than those colliding head-on. On average, the mean altitude h_{m} decreases by 1 km for every increase of 10° in entry angle.

Single-station tests with the IMO database have shown that the entry angle correction further removes systematic velocity deviations. In particular, the velocities of the η-Aquariids and Orionids, two showers with the same origin, could be improved. Before the correction, the determined velocities deviated from one another by 3 km/s (Figure 4), because the η-Aquariids were typically observed at lower radiant altitudes than the Orionids. After the entry angle correction, the same velocity at infinity was obtained for both showers.

10 Impact of the meteor shower

Meteor showers have different origins (e.g., cometary vs. asteroidal) and their meteoroids have therefore a different composition and density. It is to be expected that various meteor showers have different mean altitudes, even when the analyzed meteor parameters (v_{inf}, m, d, ea) are the same. We conducted some experiments with subsets for each meteor shower, which indeed showed some parameter variation from one shower to the next. However, the deviation was typically much smaller than the standard deviation of the average meteor altitude, i.e., the observed scatter in altitudes for meteors with identical parameters. Furthermore, the composition of a meteoroid cannot be derived directly from the optical appearance of the meteor, which is why we did not investigate meteor shower dependencies any further.

11 Resulting formulae

If all the derived dependencies are put into one formula, we get the following more elaborate estimate for the average altitude of (video) meteors:

$$\begin{aligned} h_{\mathrm{m}} &= 0.48 \times v_{\mathrm{inf}} + m - ea/10 + 78 \qquad (2)\\ h_{\mathrm{b/e}} &= h_{\mathrm{m}} \pm 19 \times d \end{aligned}$$

We derived the absolute term (78) independently of each other from both the single-station data of the IMO Network and the double-station data of the SonotaCo Network. Hence, the minor deviations that were observed with the simplified formula (Equation 1) fully disappeared.

This is a most encouraging result for both networks given that they use completely different cameras, data sets, meteor detection and measurement software and algorithms, and analysis methods.

12 Conclusions

Based on double-station data from the Japanese SonotaCo Network we have derived the dependency of the mean altitude of video meteors from the velocity at infinity (Equation 1). In the more elaborate form (Equation 2), the meteor brightness, duration, and the entry angle are additionally taken into consideration. The formula was confirmed by single-station data from the IMO Video Meteor Network, and it will be employed for the next full analysis of that data set.

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The meteor year of the Meteor Research Group of the European Space Agency's Research and Scientific Support Department

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A lot of activities took place in 2007 at the Meteor Research Group (MRG) of the European Space Agency's (ESA) Research and Scientific Support Department (RSSD). Both special observing campaigns as well as continuous observations were performed, mainly with intensified video cameras, but also with still CCD cameras. Over 1400 meteors were observed; about 150 meteors were observed from more than one station allowing orbit computations. In addition to collecting observational data, ESA/RSSD further pursued the idea of setting up standards for a 'Virtual Meteor Observatory'. The activities are summarized here to allow referencing for more detailed, scientific papers.

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1 Introduction

The Research and Scientific Support Department (RSSD) of the European Space Agency (ESA) has been involved in observing meteors since 1998. In the years 1999, 2001, and 2002, the activities focused on observing campaigns for the Leonid meteor storms. 2007 saw an increase in the activity of the Meteor Research Group (MRG) again, mainly due to an increase in dedicated manpower. This paper is a summary of the activities performed during the period 2006/2007 and is intended as a reference for the camera deployment and locations for the various observing campaigns performed in this period.

2 Camera overview

The MRG employs several different image-intensified video cameras, also called low-light level TV (LLTV) cameras. Two types are used. The first uses a CCD camera from Sony which is fibre-coupled to a 2nd generation image intensifier from Delft Electronics Products (DEP XX1700DB and DE). This camera type is called ICC (Intensified CCD Camera). The second type uses a comparatively cheap image-intensifier (DEP) which is re-imaged via single-board CCD cameras from Conrad electronics. These cameras are about one order of magnitude cheaper the ICCs, and are therefore called Low-Cost Cameras (LCC). Also, their quality is somewhat lower—they yield only a circular field of view rather than illuminating the complete sensor. The noise level is higher, and the distortion greater.

The cameras are typically used with 25 mm $f/0.85$ Fujinon lenses, or normal photographic 50 mm lenses. With a 25 mm lens, the ICC has a field of view of about $22^\circ \times 28^\circ$. When using the program refstars from S. Molau (Molau, 1999), typical mean square deviations of the reference stars are between $0\overset{\prime}{.}9$ and $1\overset{\prime}{.}5$ for the ICCs, and $1\overset{\prime}{.}5$ and $2'$ for the LCCs (approximately 0.3 to 0.5 pixel). Additionally, we have used a Watec-910N (EIA/CCIR) camera with a Computar 12 mm $f/0.8$ lens, which was prepared mainly for the airplane campaign conducted by one of the authors (JPH) for the Aurigid observations. This camera was tested during the Perseids and has the advantage of being extremely portable in one small suitcase.

Another camera which was used during the Perseids and during the Aurigid campaign on Hawaii was the so-called SPOSH (Smart Panoramic Optical Head) camera. This camera uses a scientific-grade E2V 42-10 back-illuminated sensor and a custom-designed lens yielding a 120 deg field of view. It was developed as a prototype for a camera which can be used from space-based platforms like the International Space Station (Koschny et al., 2006). A total of four of these cameras were used during the Perseid campaign organised by the DLR Berlin (German Institute for Space Exploration). MRG participated with one camera located at the Solar Observatory Kanzelhöhe (Austria). Two of these cameras (one shuttered) were used during the Aurigid campaign from the Big Island of Hawaii and Maui, under the management of RSSD/MRG in collaboration with the Kobe University, Japan.

Table 1 gives an overview of the deployment of all cameras used during 2007. Table 2 gives the geographic coordinates of the deployment locations.

3 Campaign overview

The main goal of 2007 was to start up long-term double-station observations. This was done in collaboration with Frans Lowiessen (FL) and Felix Bettonvil (FCB) from the Werkgroep Meteoren in the Netherlands. Two meteor cameras were used to observe intersecting volumes of atmosphere between Noordwijkerhout and Bergharen in the Netherlands (DSSN – Double Station Setup in the Netherlands). In addition, we carried out preliminary tests of a similar system in the Canary Islands, between La Palma and Tenerife, with the view to installing a permanent double station meteor observatory between the islands. This system will be called CILBO (Canary Islands Long Baseline Observatory).

Special campaigns were conducted for the Perseid meteor shower, together with the DLR Berlin who focused on using their SPOSH cameras for meteor observations, and the Aurigid meteor shower. The latter was observable from the western United States and Hawaiian Islands, and was observed from the Aurigid Multi-

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NASA-ADS bibcode 2008JIMO...36..131K

Table 1 – Cameras used in the Meteor Research Group in 2007 and their deployment.

Camera	Campaign	Location/Time	Operator	Comments
ICC2	DSSN	Bergharen 2007 Feb–May	FL	Double station with ICC4
	Perseids	Ramsau 2007 Aug 12/13+13/14	JJZ	Double station with LCC2
	Aurigids	Hawaii, Maui 2007 Aug 30/Sep 1	SA, Kobe University	Double station with ICC4 on Big Island
ICC4	DSSN	Noordwijkerhout 2007 Feb–Apr	DVK	Double station with ICC2 Camera has an insensitive area due to Moon damage
	Perseids	Kanzelhöhe 2007 Aug 12–13	DVK	With grating, recording on video tape
	Monitoring	2007 Oct–Dec	DVK	
	Aurigids	Hawaii, Big Island 2007 Aug 30/Sep 1	JMA	Double station with ICC2 on Maui
ICC5	CILBO	Tenerife, OGS 2007 May 6–10	JMA	Double station with LCC2 Intensifier has strange response, very high contrast
LCC2	Perseids	Kanzelhöhe	JMA/DVK	Double-station with ICC2
LCC3	CILBO	La Palma – Santa Cruz 2007 May 6–9	FCB	Double station with ICC5
		La Palma – DOT 2007 May 10	FCB	Double station with ICC5
		Hawaii, Big Island 2007 Aug 30/Sep 1	JMA	Intended spectral observations in parallel to ICC4. Gain too low!
TEC1	Aurigids	Aurigid MAC airplane, moving location 2007 Sep 1	JPH	Watec camera, used during airplane campaign. Also used a Canon 350D DSLR with 28 mm $f/2$ lens
ESA- SPOSH	Perseids	Kanzelhöhe 2007 Aug 10–13	DVK, JMA	Double-station with DLR-SPOSH operated by DLR
	Aurigids	Hawaii, Maui	SA, Kobe University	Double-station with DLR-SPOSH
DLR- SPOSH	Aurigids	Hawaii, Big Island	JMA	With rotating shutter

Table 2 – Locations used during the activities of the MRG in 2007. Negative longitudes refer to western longitudes.

Name	Latitude	Longitude	Elevation	Comments
Noordwjikerhout	52.2634°	4.4892°	3 m	MPC code B12
The Netherlands	52°15′48″	4°29′21″		Home of DVK
Bergharen	51.8633°	5.6522°	10 m	Home of FL
The Netherlands	51°51′48″	5°39′08″		
Santa Cruz	28.6814°	−17.7661°	5 m	Home of FCB
Spain/La Palma	28°40′53″	−17°45′58″		
La Palma DOT	28.680 °	−17.8812°	2329 m	DOT (Dutch Open Telescope)
Spain/La Palma	28°40′48″	−17°52′52″		operator FCB
Tenerife OGS	28.301 °	−16.511°	2380 m	OGS (ESA Optical Ground Station)
Spain/Tenerife	28°18′04″	−16°30′04″		operator JMA
Ramsau	47.4064 °	13.6303°	1120 m	At Dachstein mountain
Austria	47°24′23″	13°37′49″		operator JJZ
Kanzelhöhe	46.6783 °	13.9067°	1530 m	Close to Gerlitzen mountain
Austria	46°40′42″	13°54′6″		operators DVK and JMA
Maui	20.7076 °	−156.2570°	3032 m	Operator SA
Hawaii	20°42′27″	−156°15′25″		Kobe University, Japan
Big Island	19.7593 °	−155.4559°	2805 m	Operator JMA
Hawaii	19°45′33″	−155°27′21″		
Grumman Gulfstream airplane	Variable, western United States		about 14 000 m	Operator JPH; moving location: Western U.S: (Nevada, California, Pacific Ocean off Californian coast) see `http://aurigids.seti.org/` for details

Table 3 – Pointing directions for the double-station setup in the Netherlands. The field centers are east and west of the pole star, respectively.

Observing location	Pointing elevation	Pointing azimuth
Noordwijkerhout	60.6°	217.6°
Bergharen	45.1 °	253.7°

Aircraft Campaign (MAC) organised by Peter Jenniskens, and from the Big Island of Hawaii and Maui by the MRG, in collaboration with Kobe University, Japan.

4 Double-station setup Netherlands (DSSN)

To start up a long-term double-station setup, we collaborate with amateur groups, in particular the Werkgroep Meteoren of the Netherlands. A very interesting station was located in Bergharen, which allowed the setting-up of a double-station system with Noordwijkerhout, observing the same volume of sky while keeping the Moon out of the field of view. Another requirement for the pointing direction was that it should be more than 45° above the horizon. The two resulting pointing directions are shown in Table 3.

Table 4 shows that performing double-station observations from a location such as the Netherlands is not easy. In the period 2007 February to April (89 nights), at least one of the cameras was active for a total of 34 nights, i.e., 38% of all nights. However, in only 13 of these nights (38%) were double-station meteors observed, i.e., 15% of all nights.

ICC4, located at Noordwijkerhout, always had the worse conditions as the sky is much brighter at that location than at Bergharen. Still, not all meteors registered by ICC4 were simultaneously observed by ICC2 and vice versa. Typically, 30 to 60% of the number of meteors recorded by ICC4 were registered simultaneously by ICC2. In this observing run of three months, a total of 72 meteors were observed by both cameras. While this is a small number compared to the setup on the Canary Islands (see next section), it still shows that it is possible and useful to operate a regular double-station setup under these conditions.

5 The CILBO campaign in the Canary Islands, May 2007

In 2007 May, a member of the MRG (JMA) travelled to the Canary Island of Tenerife in order to carry out a capability demonstration of a potentially permanent double station installation at ESA's OGS site at the El Teide Observatory. In collaboration with Felix Bettonvil at the Dutch Open Telescope (DOT) on La Palma, 2 cameras were deployed for a total of 5 nights from May 6 to 10. On La Palma, FCB set up the LCC3 camera for 4 nights from a site in Santa Cruz and for 1 night (May 10) from the DOT (see Table 2 for the locations). At the OGS, JMA set up the ICC5 camera for 5 nights following an initial night of testing on May 5.

At the OGS on the nights of May 5 and 6 strong winds were an issue and the location of the camera had to be changed for the rest of the campaign. On La Palma, relatively poor sky transparency at the site in

Table 4 – Effective observing time T_{eff} and number of meteors n observed during the double-station observations between Berharen and Noordwijkerhout in spring 2007. A time difference of 1 or 2 hours comes from the usage of different time zones. A difference of a few seconds comes from the lack of continuous synchronisation of either of the time inserters.

Date	ICC2 (Bergharen)		ICC4 (Noordwjikerhout)		Simult. meteors	Comment
2007	T_{eff}	n	T_{eff}	n		
Feb 03	3.4 h	7	–	–	–	
Feb 04	8.5 h	8	–	–	–	
Feb 11	–	–	4.3 h	10	–	
Feb 17	–	–	10.4 h	16	–	
Feb 21	–	–	2.4 h	3	–	
Mar 03	–	–	1.6 h	2	–	
Mar 05	–	–	2.6 h	2	–	
Mar 09	11.5 h	53	6.5 h	14	10	$T_{\text{icc2}} = T_{\text{icc4}} + 1^{\text{h}}00^{\text{m}}20^{\text{s}}$
Mar 10	11.1 h	31	9.1 h	13	7	$T_{\text{icc2}} = T_{\text{icc4}} + 1^{\text{h}}00^{\text{m}}22^{\text{s}}$
Mar 11	11.5 h	49	–	–	–	
Mar 12	11.9 h	26	–	–	–	
Mar 13	7.7 h	30	8.7 h	4	0	Clouds
Mar 14	8.2 h	28	9.2 h	9	6	$T_{\text{icc2}} = T_{\text{icc4}} + 1^{\text{h}}00^{\text{m}}03^{\text{s}}$
Mar 15	4.8 h	8	–	–	–	
Mar 25	10.1 h	39	3.4 h	4	0	Almost no overlap in time
Mar 26	12.0 h	29	8.7 h	17	tbd	
Mar 27	10.9 h	24	2.0 h	3	0	Almost no overlap in time
Mar 28	10.9 h	13	5.9 h	5	0	
Apr 01	–	–	8.3 h	13	–	
Apr 02	–	–	4.6 h	4	–	
Apr 05	–	–	7.8 h	10	–	
Apr 06	–	–	4.0 h	8	–	
Apr 07	–	–	6.9 h	22	–	
Apr 08	6.7 h	11	7.8 h	4	0	Clouds
Apr 09	7.2 h	9	5.5 h	8	2	Clouds; $T_{\text{icc2}} = T_{\text{icc4}} + 2^{\text{h}}00^{\text{m}}03^{\text{s}}$
Apr 11	7.5 h	27	7.3 h	19	9	$T_{\text{icc2}} = T_{\text{icc4}} + 2^{\text{h}}$
Apr 12	–	–	4.0 h	4	–	
Apr 13	7.6 h	30	7.1 h	11	0	Alignment ok?
Apr 14	7.7 h	34	6.0 h	14	9	$T_{\text{icc2}} = T_{\text{icc4}} + 2^{\text{h}}00^{\text{m}}03^{\text{s}}$
Apr 15	7.7 h	38	7.3 h	20	13	$T_{\text{icc2}} = T_{\text{icc4}} + 2^{\text{h}}$
Apr 20	6.3 h	21	4.5 h	13	6	$T_{\text{icc2}} = T_{\text{icc4}} + 2^{\text{h}}$
Apr 21	6.6 h	22	5.7 h	30	2	Clouds in Bergharen
Apr 22	–	–	6.7 h	28	–	2/8 clouds
Apr 30	6.7 h	23	5.8 h	21	8	$T_{\text{icc2}} = T_{\text{icc4}} + 2^{\text{h}}$
Total	186.5 h	560	195.4 h	331	72	

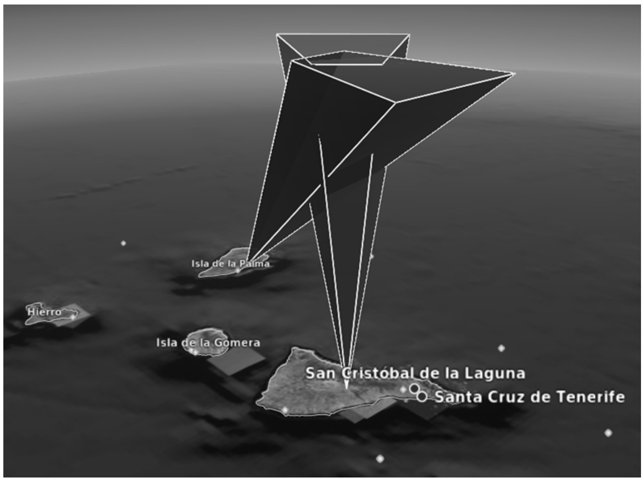

Figure 1 – Google Earth visualisation of the intersecting observation volumes for the CILBO system under correct pointing conditions. The volumes are capped at 120 km.

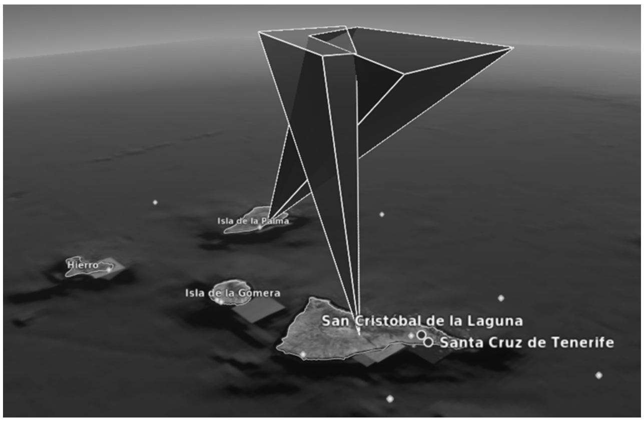

Figure 2 – Google Earth visualisation of the intersecting observation volumes for the CILBO system under the incorrect pointing conditions of 2007 May 7. The volumes are again capped at 120 km. This figure, when compared to Figure 1 and in view of the results from the rest of the 2007 May CILBO campaign, clearly demonstrates the importance of accurate pointing.

Santa Cruz reduced the sensitivity of the camera compared to the observations from the DOT on May 10. The results of the campaign are presented in Table 6.

As a first demonstration of the feasibility of conducting effective double station meteor observations from the Canary Islands the MRG campaign of 2007 May proved encouraging. From 10 nights (5 nights at 2 stations) of observations only one night returned no meteors—due to clouds. A total of 101 meteors were detected, 25 of which were orbit producing double station events.

Were it not for a pointing error on the night of May 7 at the OGS station (see Figure 1 and Figure 2), this number of double station events is likely to have been greater. For the night of May 10—when both cameras were at altitude—the marked difference in counts between the two islands was mainly due to a stuck gain control on the ICC5 being used at the OGS. The ICCs are more sensitive than the LCCs and, for the same length of time, should on average record more meteors.

Table 5 – Pointing directions for the double-station setup on the Canary Islands.

Observing location	Pointing elevation	Pointing azimuth
La Palma – DOT	51.8°	90.0°
Tenerife – OGS	53.1°	312.9°

Table 7 – Pointing directions for the double-station setup in Austria.

Observing location	Pointing elevation	Pointing azimuth
Kanzelhöhe	67.8°	345.5°
Ramsau	66.8°	166.0°

Table 8 – Effective observing time $T_{\rm eff}$ and number of meteors n observed during the double-station observations between Ramsau and Kanzelhöhe in 2007 August.

Date	ICC2 (Ramsau)		LCC2 (Kanzelhöhe)		Simult. met.
2007	$T_{\rm eff}$	n	$T_{\rm eff}$	n	
Aug 12	5.4 h	167	3.3 h	32	25
Aug 13	5.6 h	163	–	–	–

Steps are now well under way towards installing permanent automated meteor observatories at the DOT and OGS sites. The main scientific focus of this Long Baseline Observatory will be a year round study of the orbital distribution and chemical composition of meteoroids, providing continuous data for orbit determination as well as looking for faint water lines in high altitude meteors.

6 The Perseid campaign in Austria, August 2007

The German Institute for Space Exploration (DLR) Berlin organized an extended campaign to observe the Perseid meteor shower from a total of four locations in Austria/Southern Germany and around Berlin. ESA's Meteor Research Group participated in this DLR campaign by operating one of the SPOSH cameras. We also operated one double-station setup between the Kanzelhöhe Observatory and Ramsau, including one camera with an objective grating. Table 7 shows the pointing directions for the double-station setup.

Weather conditions at Kanzelhöhe were marginal. Out of four potential observing nights, only about 3 hours in the maximum night yielded useable data. JJZ in Ramsau was more successful and was able to record for two nights. Table 8 shows the effective observing time and the number of meteors from the double-station setup between Ramsau and Kanzelhöhe.

It can be seen that in the one night 78% of the meteors seen by the less sensitive camera (LCC2) were registered simultaneously. Again, this is consistent with the percentage observed in the other double-station campaigns.

We also used for the first time in an observing campaign the SPOSH camera, which uses a back-illuminated scientific grade CCD sensor read out with 14 bit dynamical range, and a wide-angle lens yielding 120° field of

Table 6 – Effective observing time T_{eff} and number of meteors n observed during the double-station observations between La Palma and Tenerife in 2007 May.

Date	LCC3 (La Palma)		ICC5 (Tenerife)		Simult. meteors	Comment
2007	T_{eff}	n	T_{eff}	n		
May 06	5.3 h	15	4.1 h	14	8	
May 07	5.3 h	9	4.8 h	14	0	Tenerife pointing error: elev. off by $\approx +15°$ azimuth off by $\approx -17°$; see Figures 1 and 2
May 08	–	–	0.7 h	1	–	Clouds
May 09	4.7 h	14	8.2 h	12	7	
May 10	7.0 h	38	7.8 h	18	10	ICC5 not working properly – contrast very high and not changeable
Total	22.3 h	76	22.3 h	59	25	

Table 9 – Pointing directions for the double-station Aurigid 2007 campaign in Hawaii.

Observing location	Pointing elevation	Pointing azimuth
Big Island	48.0°	284.3°
Maui	55.3°	181.8°

Table 10 – Effective observing time T_{eff} and number of meteors n observed during the double-station observations between the Big Island of Hawaii and Maui during the 2007 Aurigid Campaign (August 30–September 2). In total, only 4 Aurigids were observed using the ICCs.

Date	ICC2 (Maui)		ICC4 (Big Island)		Simult. met.
2007	T_{eff}	n	T_{eff}	n	
Sep 01	5.92 h	44	4.17 h	62	0

view. It is used in a mode where it takes exposures of 2 s, continuously. It generates a FITS file with multiple images in the file, thus after 30 min the image recording has to be stopped to avoid files larger than 2 GByte (which may pose problems with certain operating systems).

Since the data analysis software is not yet ready for the camera no detailed analyses have been done. However, the camera registered many meteors and seems to be a promising instrument for this kind of work. Figure 3 shows an image captured with the SPOSH camera.

7 The Aurigid campaign in Hawaii, September 2007

At the end of August 2007 a member (JMA) of the ESA/RSSD Meteor Research Group travelled to the Hawaiian Islands to observe a rare outburst of the Aurigid meteors in the early hours of September 1st. This campaign was carried out in collaboration with research groups from Kobe and Kochi Universities, Japan. The teams observed from two sites: one at the Onizuka Visitors' Center on Hawaii and the other from the Haleakala Observatory site on Maui.

The MRG provided five cameras for this campaign: two SPOSH cameras as discussed above, two ICCs and one LCC. The Japanese team on Maui operated one of the SPOSH cameras as well as ICC2 but had the misfortune of being clouded out for an hour around the predicted peak. On the Big Island the MRG team successfully deployed a second SPOSH as well as ICC4 in order to perform double-station observation with the team on Maui. The intended use of LCC2 for spectral observations was again affected by gain issues. The data are summarized in Tables 9 and 10.

8 The Aurigid campaign from the MAC airplane, September 2007

The SETI Institute & NASA Ames Research Center organised an airborne observing campaign for the predicted outburst of the Aurigid meteor shower on the 2007 September 1, under the direction of Dr Peter Jenniskens (SETI Institute). The observing campign is described in detail, along with preliminary results on the SETI webpage (`http://aurigids.seti.org/`). The predicted outburst peak occurred around 2007 September 1, $11^{\text{h}}30^{\text{m}}$ UT which co-incided with darkness and reasonable radiant elevation over the western United States and Pacific Ocean. Two Gulfstream V aircraft were used for the airborne campaign, each of which had 12 large high quality (40cm × 70cm) windows. The aircraft were flown in parallel approximately 300 km apart to permit double station observation of some meteors on one side of each aircraft. The aircraft cruised above an altitude of 14 km and provided an excellent platform for meteor observations well above the moonlit haze layer.

A wide range of imaging and spectroscopic instruments were deployed by various science teams on both aircraft and observations were also coordinated with five ground stations in California. JPH participated in the mission, with the MRG Watec 120N video camera with a 12 mm lens used for meteor flux measurements, along with a Mintron video camera and a 5 mm lens. Additionally a Canon 350D digital SLR camera was used with a 28 mm, $f/2$ lens and continuous 5 s exposures at 800ISO to provide flux and photometric measurements. A Meade DSI CCD camera was used for BVR filter band photometric observations of approximately +2 magnitude stars at different elevations to provide data on atmospheric extinction.

Figure 3 – A composite of 30 minutes of exposure with the ESA-SPOSH camera from the Kanzelhöhe Observatory, 2007 August 13. About 10 meteors can be seen in the original.

All cameras were pointed slightly above the horizon since the high altitude of the aircraft permits observation of meteors down to the horizon due to the low extinction and a slightly depressed physical horizon compared to ground based observations (approximately 3 deg). The result is a larger usable surface area ($\approx 5\times$) of atmosphere can be observed compared to comparable ground based observations, resulting in higher raw flux. The data from the WATEC camera and flux cameras of other teams indicated that the predicted peak time and flux rate of the outburst was comparable with the values predicted by the model (described in detail at `http://aurigids.seti.org/`). 21 Aurigids were recorded on the digital stills images, with one meteor recorded very close to the horizon. At least one meteor was recorded simultaneously by a ground based imager in California, but unfortunately periodic aircraft roll prevented accurate double station measurements to be performed. The raw DSLR data can be used to determine Red, Green, Blue light curves of the meteors. A composite image of the 21 Aurigids recorded by DSLR can be found at `http://airborne.seti.org/LegacyAur1.html`.

9 The Meteor Orbit Determination Working Group (MOD WG)

We have organised the first meeting of the 'Meteor Orbit Determination Working Group' (MOD WG), a workshop supported by the European Union in the framework of the EuroPlanet initiative, after the IMC2006. At the workshop it was decided to stay in touch with each other via a Yahoo group
(`http://tech.groups.yahoo.com/group/modwg/`)
which saw reasonable activity and allowed the exchange of information between people interested in the determination of meteor orbits. We have triggered a test to compare different orbit software, however, no conclusive results have been obtained yet. Another meeting of this working group will be at the International Space Science Institute in Bern, organised by Rainer Arlt, in November 2008.

10 The Virtual Meteor Observatory (VMO)

The Virtual Meteor Observatory (VMO) is an online database for meteor science, allowing datasets from different observing campaigns to be accessed and combined easily. MRG started to design and implement the VMO in the second part of 2007, focusing on datasets derived from single- and double-station video observations. The design of the VMO is based on the SQL (Structured Query Language) standard, which is a computer language used to manage and query data in relational databases. The actual database is being implemented using PostgreSQL, which is an open source database software package. The database will be made accessible through a user-friendly web-interface implemented in the Drupal framework, which is also an open source software package. For more details, see (Barentsen et al., 2007).

11 Summary and conclusions

This paper summarises the meteor observation campaigns of the Meteor Research Group (MRG) of the European Space Agency (ESA). At the beginning of the year, two cameras were operated as double-station system in the Netherlands. We have tested a similar setup in the Canary Islands and plans are well under way to install a permanent double station system on the islands. Campaigns were carried out for the Perseids in Austria, and the Aurigids in Hawaii. One of us participated in the Aurigid MAC airplane campaign.

Many of our initial eight image-intensified cameras have problems. ICC4 has parts of the image insensitive as the Moon went into the field of view a few years ago. ICC5 has a new intensifier, but the contrast of the camera is extremely high and faint objects cannot be seen. ICC1 and ICC3 are not functioning at all. LCC1 was lost. Only ICC2, LCC2, and LCC3 function properly. Replacement of the damaged equipment is underway.

We have regularly performed double-station observations; the tables in the paper give an indication of the yield. It can be seen that it is important to match the sensitivity of the cameras. Obviously, if one camera has a significantly better limiting magnitude than the other one, this will not increase the number of simultaneously observed meteors as the other camera will not see them.

Some meteors can be seen in one camera but not in the other one, even if they were bright enough. These meteors may be higher or lower than expected and will thus be outside the field of view of one of the cameras. Typically, 50 to 70% of the meteors will be observed simultaneously.

It could also be seen that it is important to synchronize the clocks of the cameras at least at the beginning of every observing night to avoid problems in identifying simultaneous meteors. Normally, the clock drift during the night is below 2 seconds, so the identification is still possible. Still, an uncertainty of 2seconds would correspond to an uncertainty of about 0.8 km in position due to the Earth's rotation (at 28° latitude, corresponding to the Canary Islands). Thus, it would be preferable to keep synchronizing the clocks several times during the night.

There are still doubts about the robustness of the software to determine orbits from the double-station observations (MOTS = Meteor Orbit and Trajectory Software). Heights and radiants however can be determined accurately. The software is under test and comparisons with other orbit determination software tools are ongoing as part of our activities within the Meteor Orbit Determination Working Group (MODWG).

For the first time, the SPOSH camera was used to observe meteors regularly. The performance of the SPOSH is excellent, it uses a scientific-grade 1024×1024 pixel^2 back-illuminated CCD sensor from the company E2V, which is read out with 14bit dynamical range. The lens is a custom-built lens from Jena Optronic, yielding 120° field of view system. The camera was used with and without a rotating shutter. It cannot be used without user attention for more than 30minutes and the detection software and analysis software is not yet really operational. This camera would need more work to be really deployed in a regular way.

As a result of a discussion during the Meteor Orbit Determination Workshop in Roden, The Netherlands, in Sep 2006, we have started the development of the Virtual Meteor Observatory (VMO) which is a database to store meteor data. In the beginning the focus will be on video observations, both single- and double-station data. This work is performed in close cooperation with the video commission of the IMO.

In the past year ESAs MRG have taken many steps in order to shift the focus to permanently installed observatories, while still maintaining the capabilities necessary to perform mobile shower or outburst observations, including state-of-the-art airborne campaigns. The group is looking back on a successful meteor year with many lessons learned, initiatives taken and a considerable volume of data collected.

12 Acknowledgements:

We thank the personnel of the Kanzelhöhe Solar Observatory for their kind hospitality. Thanks to our collaborators from Kobe University, in particular Shinsuke Abe and his team, who operated our SPOSH camera from Maui. The airplane campaign was organised by Peter Jenniskens, The SETI Institute, with the airplanes made available by Google.

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δ-Aquariids

Results of the Aquariid expedition to La Palma, July 2008

Carl Johannink [1], *Koen Miskotte* [2], *Klaas Jobse* [3], *Michel Vandeputte* [4] *and Peter van Leuteren* [5]

The authors observed the Southern δ-Aquariids from the Observatory of Roque de Los Muchachos on La Palma. The shower peaked around a solar longitude of 126.°2 (2000.0) with ZHR $= 32 \pm 1.5$. This peak coincided with a dip in r. Just like Arlt & Dubietis (2004) we checked the IMO database for SDA-observations in the years 1997–2002. We found this dip in r around the shower maximum in nearly every year with sufficient data. The difference in r-value found between northern- and southern-hemisphere data (Arlt & Dubietis, 2004) may be explained as the southern-hemisphere data was essentially collected around the time of the maximum. The video results show a peak in activity ~ 24 hours earlier than the visual results.

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1 Introduction

The favourable observing conditions at the end of July (New Moon on July 30) offered ideal circumstances to study the Southern δ-Aquariids. An invitation for this expedition to La Palma to observe this meteor shower was published in September 2007 (Miskotte & Johannink, 2007). On Friday, 2008 July 25, five observers took a flight to Santa Cruz, La Palma. For Klaas Jobse this was an excellent opportunity to get a better look at the nice southern summer hemisphere, for Peter van Leuteren it was his first real meteor expedition, for Michel Vandeputte and Koen Miskotte it meant an even better observing window to this shower than what they had already observed in 2001, 2003 and 2006 from Crete and Southern France. This makes a difference of 10° to 15° in radiant altitude compared to these regions, not to mention the difference with the Netherlands. Compared to Holland the difference in radiant altitude is as much as 24°!

Table 1 lists the radiant altitudes for the mentioned regions together with the percentage of the ZHR that may be observed from these latitudes. Also for Carl Johannink after the partially successful expedition to Brazil in 2006 the same arguments were valid as for Koen and Michel. The exceptionally good meteorological conditions at La Palma account for the record amount of data accumulated. Tables 2 and 3 illustrate this: seven nights in a row resulted in almost 134 hours of observing time by these 5 observers; in total almost 6000 meteors, including almost 1900 SDA's. This exceeded our expectations.

Table 1 – Percentage of the ZHR visible for a 'standard' observer ($C_p = 1.0$) with Lm = 6.50.

Location	Maximal radiant altitude	Maximal activity visibility ($\gamma = 1.4$)
the Netherlands (52° N)	22°	22%
Southern France (44° N)	30°	38%
La Palma (28° N)	45°	62%

Table 4 – Mean magnitude for the total number of observed SDA meteors and the sporadic background, both standardized to Lm = 6.50 per observer.

Observer	SDA		Spo	
	n	mean	n	mean
JOBKL	133	3.15	223	3.38
JOHCA	337	2.94	445	3.79
LEUPE	334	2.44	436	3.14
MISKO	504	3.10	709	3.68
VANMC	581	2.42	995	3.20
Total	1889	2.75	2808	3.42

2 Magnitude distributions

Magnitude distributions were obtained for each observer for all SDA and sporadic meteors. The mean magnitude per observer per night was standardized to a limiting magnitude of +6.50. The averaged magnitudes derived from these data sets show again that the SDAs have a rather modest mean brightness, but are distinctly brighter than the sporadic background meteors (Table 4). This is similar to the results from the analyses of the 2006 observations (Miskotte & Johannink, 2006).

3 Population index r

Using the probability function of Peter Jenniskens (which corrects for differences in Lm), the observed magnitude distribution was used to derive a correction for each magnitude class.

This probability function has been described in Jenniskens (1994). The r-values were calculated using the method described in (Miskotte & Johannink, 2005). The computed r-values are listed in Table 5.

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Table 2 – Summary of the total number of observed meteors per night.

Night	Obs	Period UT Start	End	$T_{\rm eff}$	Lm	SDA	CAP	PER	KCG	PAU	ANT	Spo	Total
Jul 25/26	4	23:02	00:55	$6^{\rm h}.31$	6.72	37	24	8	2	0	6	99	176
Jul 26/27	5	21:15	02:05	$18^{\rm h}.05$	6.67	151	72	61	4	0	21	290	599
Jul 27/28	5	21:15	03:15	$23^{\rm h}.13$	6.71	382	85	88	12	1	31	528	1127
Jul 28/29	4	21:10	05:00	$24^{\rm h}.87$	6.73	488	95	107	6	3	26	544	1269
Jul 29/30	5	21:15	04:15	$22^{\rm h}.57$	6.73	342	89	74	10	3	22	462	1002
Jul 30/31	5	21:10	05:15	$29^{\rm h}.48$	6.63	395	157	131	17	0	32	749	1481
Jul 31/01	4	23:15	02:15	$9^{\rm h}.52$	6.34	94	31	27	4	0	12	136	304
7 nights	5			$133^{\rm h}.9$		1889	553	496	55	7	150	2808	5948

Table 3 – Summary of the observations per observer per night. It is obvious that the excellent observing conditions favoured impressive totals.

Night	Obs	Period UT Start	End	$T_{\rm eff}$	Lm	SDA	CAP	PER	KCG	PAU	ANT	Spo	Total
Jul 25/26	JOHCA	23:24	0:45	$1^{\rm h}.35$	6.50	8	5	1	0	0	0	16	30
	LEUPE	23:15	0:50	$1^{\rm h}.58$	6.69	9	6	3			3	20	41
	MISKO	23:02	0:50	$1^{\rm h}.80$	6.72	11	6	2			1	34	54
	VANMC	23:20	0:55	$1^{\rm h}.58$	6.95	9	7	2	2	0	2	29	51
Jul 26/27	JOBKL	22:10	0:45	$1^{\rm h}.67$	6.55	12	8	3	0		0	25	48
	JOHCA	22:00	1:45	$3^{\rm h}.00$	6.50	21	11	7	0	0	3	41	83
	LEUPE	21:15	1:50	$4^{\rm h}.40$	6.72	30	15	17			6	45	113
	MISKO	21:34	2:00	$4^{\rm h}.15$	6.65	40	18	11	2		7	83	151
	VANMC	21:15	2:05	$4^{\rm h}.83$	6.83	51	20	23	2	0	5	93	194
Jul 27/28	JOBKL	21:40	2:55	$2^{\rm h}.95$	6.57	43	18	8	1		0	76	146
	JOHCA	22:53	3:00	$3^{\rm h}.93$	6.55	54	10	12	2		8	78	164
	LEUPE	21:15	3:00	$5^{\rm h}.45$	6.76	73	19	24	2		7	90	215
	MISKO	21:34	3:00	$4^{\rm h}.80$	6.81	92	16	18	4		9	144	283
	VANMC	21:15	3:15	$6^{\rm h}.00$	6.86	120	22	26	3	1	7	140	319
Jul 28/29	JOHCA	22:25	3:00	$5^{\rm h}.03$	6.48	84	14	19	1		5	83	206
	LEUPE	21:10	5:00	$7^{\rm h}.24$	6.71	117	32	24	2		8	111	294
	MISKO	22:22	4:04	$4^{\rm h}.85$	6.87	133	18	29	2		7	132	321
	VANMC	21:15	5:00	$7^{\rm h}.75$	6.86	154	31	35	1	3	6	218	448
Jul 29/30	JOBKL	23:00	4:00	$3^{\rm h}.42$	6.68	41	13	16	0			46	116
	JOHCA	22:30	4:07	$5^{\rm h}.00$	6.51	67	20	14	2		4	77	184
	LEUPE	00:50	2:00	$1^{\rm h}.17$	6.80	21	4	4	0		0	13	42
	MISKO	21:32	4:00	$5^{\rm h}.98$	6.78	99	30	17	4		8	138	296
	VANMC	21:15	4:15	$7^{\rm h}.00$	6.89	114	22	23	4	3	10	188	364
Jul 30/31	JOBKL	23:30	4:00	$3^{\rm h}.33$	6.60	40	17	5	0			73	135
	JOHCA	23:19	5:00	$5^{\rm h}.32$	6.38	85	34	27	4		9	117	276
	LEUPE	21:10	5:15	$7^{\rm h}.75$	6.63	79	33	32	4		8	152	308
	MISKO	22:19	4:48	$6^{\rm h}.08$	6.70	91	40	37	3		4	141	316
	VANMC	22:15	5:15	$7^{\rm h}.00$	6.83	100	33	30	6	0	11	266	446
Jul 31/01	JOHCA	23:26	2:11	$2^{\rm h}.75$	6.04	18	7	6	2		7	33	73
	LEUPE	23:30	0:30	$1^{\rm h}.00$	6.40	5	1	1	0		1	5	13
	MISKO	23:18	2:10	$2^{\rm h}.77$	6.40	38	13	11	1		1	37	101
	VANMC	23:15	2:15	$3^{\rm h}.00$	6.53	33	10	9	1	0	3	61	117
7 nights	5 obs.			$133^{\rm h}.9$		1889	553	496	55	7	150	2808	5948

Table 5 – r-value for the Southern δ-Aquariids (SDA) for the magnitude range $[-2; 5]$ during the nights of July 25-26 (26.0) until July 31–August 1 (32.0). Using the complete dataset of 1889 SDA-meteors, the r-value equals 2.67.

Date 2008 July	r $[-2; 5]$
26.0	2.28
27.0	2.94
28.0	2.93
29.0	2.39
30.0	2.82
31.0	2.86
32.0	2.69
Total	2.67

We consider also the remark made in eRadiant of November 2006 (Miskotte & Johannink, 2006). The analyses of the 2006 observations yielded a higher r-value than what the IMO obtained in earlier analyses (Arlt & Dubietis, 2004). The average r-value which we obtained in this work compares very well to the IMO result; 2.67 from this expedition (see Table 5) and 2.62 ± 0.04 based on all IMO observations from the Northern hemisphere. It is puzzling that IMO obtained an even lower r-value for the Southern hemisphere. We will discuss this in Section 4.

4 ZHR calculations

Based on these r-values by night and the C_p coefficients, we computed the ZHR according to the method described in (Miskotte & Johannink, 2005). In a first attempt the standard C_p coefficient was used for each individual observer. This approach resulted in unrealistically high ZHR values, up to 75. Given the large numbers of effectively observed meteors, both shower and sporadic, this could have been expected. The reason for this is probably the much more transparent and darker atmosphere at the Roque de Los Muchachos Observatory on La Palma. Especially at lower altitudes above the horizon, the difference with Crete or the Provence is very important. Obviously the advantage of being 2200 meters above sea level is significant.

According to the IAU references this makes a difference in limiting magnitude especially at lower altitudes. For instance at an altitude of 10°, a difference of 2000 meters in elevation accounts for a magnitude difference of 0.7 in extinction (Green, 1992). We avoided this effect by computing new C_p coefficients for all five observers based on their La Palma datasets. The calculation of a reliable C_p based on the sporadic activity per night was a problem due to the too small dataset of sporadic meteors per night. For this reason we decided to combine the sporadic data of two successive nights in order to calculate the C_p coefficients. The results for this calculation are listed in Table 6.

Much higher C_p coefficients were obtained for each observer compared with their usual standard perception coefficients, with much lower and more realistic ZHR values as a result. Note the variation in the C_p coefficient for some observers. It is quite possible that the sudden climb to 2200 meters above sea level for observing caused adaptation problems. After a few days we became acclimatized and this could have an effect on the observations.

Table 6 – C_p coefficients derived from the sporadic activity for each observer for the nights listed.

Observer	Period 25/26,26/27, 27/28	28/29, 29/30	30/31, 31/01	Entire period
LEUPE	0.9	0.6	1.0	0.8
MISKO	1.5	1.5	1.4	1.5
JOHCA	1.3	1.3	1.9	1.5
VANMC	1.3	1.2	1.5	1.3

In analyses so far we used only the observations with a radiant altitude of 30° or more. For La Palma this has the disadvantage that the radiant reaches the required altitude rather late in the night. Moreover, the first three nights had disturbing moonlight in the second part of the night. As a result, the radiant was not yet at 30° when we had to quit observing the first night because of the moonlight. This night would have been lost, and for the two following nights the number of ZHR data points would have been reduced. Therefore we made an attempt using ZHR calculations with 20° as the lower limit for the radiant altitude. The result is shown in Figure 1.

Luckily there is no significant difference visible so we can take the data for radiant altitudes between 20° and 30° into account for the analysis. This can be done only when the transparency of the atmosphere is very good. For observers watching in the southern direction, La Palma has the advantage that it is easier to identify SDAs and the Antihelion meteors which share the same part of the hemisphere. In short, this means a larger quantity of more reliable data for this shower.

Finally the ZHR could be computed for each single night using the r-value valid for that night (see Table 5) and the C_p coefficient valid for the observer for the night concerned. Working with a time dependent r-value and variable C_p coefficient per observer and per night reduced the scatter in the ZHR-values.

The ZHR values derived for each observer were averaged and the results are plotted in Figure 2 (top plot).

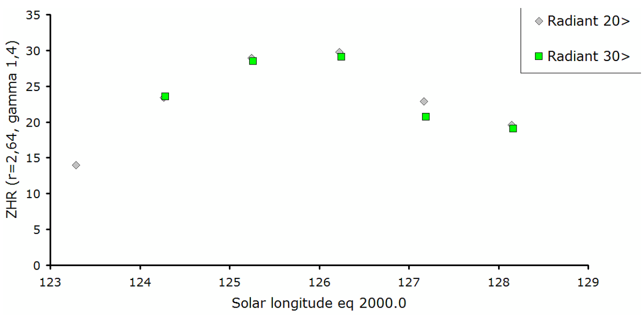

Figure 1 – The ZHRs with radiant elevations of 30° and higher (squares) and 20° and higher (diamonds). There is almost no difference. Note that the first night of July 25-26 disappears completely from the analysis for the 30° limit!

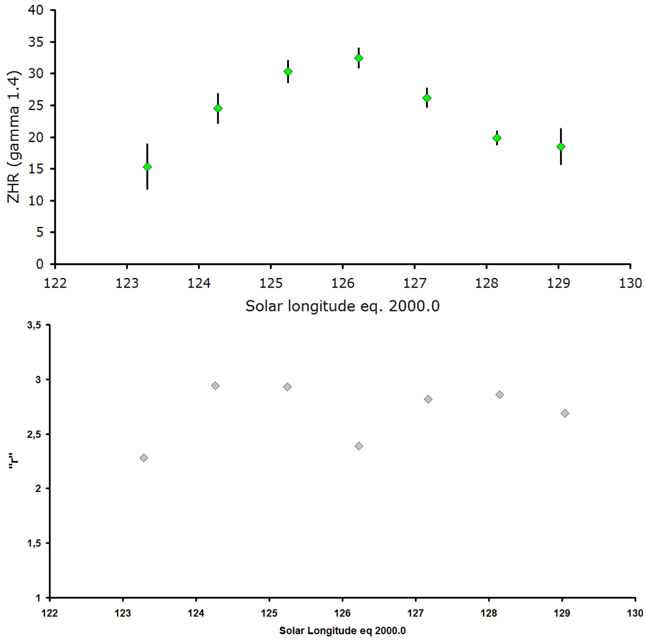

Figure 2 – ZHR-distribution and r-distribution of the Southern δ-Aquariids plotted against solar longitude.

In the lower panel, we plot the calculated r-values for the same solar longitude range (Figure 2).

Just like in 2006, this shows that the Southern δ-Aquariids (SDA) display relatively more bright meteors around the time of their maximum activity. The r-value displays a distinct dip exactly where the ZHR peaks. Year by year we can map the population index variation throughout this shower. The population index data from 1984, 2003, 2006 and 2008 were plotted against the solar longitude (2000.0) and is shown in Figure 3.

Between solar longitudes 122° and 124° the population index r seems to increase and to remain constant further on for about 48 hours and dips around the time of maximum activity before returning to the pre-maximum value. Indeed the outer data points suffer somewhat from the rather small amount of data available, but it might be worthwhile to study this shower structure further in the future.

Because of Figure 3 we reconsider the difference in r-values found for the northern and the southern hemispheres derived by (Arlt & Dubietis, 2004). Could it be that the observations of the SDAs on the southern hemisphere are essentially obtained around the maximum of this shower? At the southern hemisphere no one has to bother about the Perseids. Let us take a look into the Visual Meteor Database (VMDB) of IMO.

We extracted all data from the VMDB for the period of July 16 until August 10 for the years 1997–2002 for the northern hemisphere and the years 1993–2002 for the southern hemisphere. Observations with a limiting magnitude of less than 5.0 were skipped. This way we use the same criteria as used by IMO in their analysis (Arlt & Dubietis, 2004), except that IMO considers a slightly larger time lapse; from July 3 until August 23. However in this extra period of time there are almost no SDA observations in the IMO database. The dataset

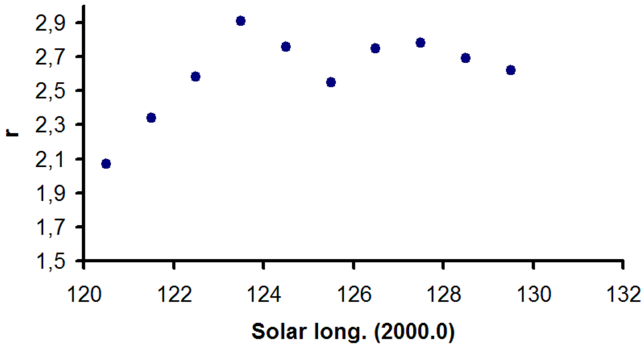

Figure 3 – Population index profile for the Southern δ-Aquariids (SDA) based on DMS observatios of 1984, 2003, 2006, and 2008.

extracted from the VMDB was split into northern hemisphere observations and southern hemisphere observations. Then the observations of each year were grouped in solar longitude intervals. The results are shown in Tables 7 and 8.

We see that as much as 42% of all southern hemisphere SDA observations are obtained within a time lapse when – according to our analysis – the r-value is somewhat lower. For the northern hemisphere this is only 22%, or in other words, there is more data before and after this period.

This may explain the difference in r-value as found by IMO for both hemispheres (Arlt & Dubietis, 2004). The dataset sizes were large enough for some years to investigate whether or not the population index also shows a dip around the shower maximum. The results are listed in Table 9.

These datasets confirm our impressions, 2001 being the only exception. We have no explanation for the situation in 2001. Future observations should investigate whether or not the lower population index r around the maximum of this shower is a constant characteristic for its structure. Our result for the discrepancy in the population index agrees with Arlt & Dubietis (2004).

5 Comparison with previous years

Of course we can not neglect a comparison of our data with previous observations from southern sites in the years 2001, 2003, and 2006. Figure 4 shows the result. The first striking feature is that the ZHRs of 2008 are higher than these in previous years. A possible question is whether or not the Southern δ-Aquariids show a variable activity from year to year like the Bootids

Table 9 – The population index r for the magnitude interval $[-2; 5]$ on the northern and southern hemisphere (NH respectively SH) for the time lapse around the maximum (125°–127° solar longitude) and for the entire dataset for each year 1997, 1998, 2000, and 2001. For 1997 there is no data for the southern hemisphere available.

Int.	NH tot	NH 125°–127°	SH tot	SH 125°–127°	Year
$[-2; 5]$	3.30	2.88	***	***	1997
$[-2; 5]$	2.96	2.88	2.92	2.21	1998
$[-2; 5]$	2.98	2.62	2.86	2.24	2000
$[-2; 5]$	2.92	3.26	2.35	2.48	2001

Table 7 – Number of observed SDAs from the southern hemisphere. 42.1% of the data is situated between solar longitudes 125° and 127°.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Percentage
< 120°	11	0	2	7	0	4	0	5	21	0	30	4.4
120°–122°	0	0	0	0	0	9	0	0	0	0	9	1.3
122°–124°	12	0	0	0	0	0	0	12	0	0	12	1.8
124°–125°	4	0	0	0	0	3	0	0	22	17	42	6.2
125°–126°	7	0	0	0	0	11	0	177	82	0	270	39.6
126°–127°	8	0	22	0	0	0	0	17	0	0	17	2.5
127°–128°	7	0	4	0	0	18	0	17	0	14	49	7.2
128°–129°	6	0	0	0	0	0	0	0	0	0	0	0
129°–130°	0	0	0	0	0	0	0	51	0	0	51	7.5
130°–131°	0	0	0	0	0	0	0	90	0	0	90	13.2
131°–132°	0	0	0	0	0	0	4	65	0	0	69	10.1
132°–134°	0	0	0	0	0	0	4	28	0	0	32	4.7
134°–136°	0	0	0	0	0	0	0	0	0	0	0	0
> 136°	0	0	0	0	0	0	11	0	0	0	11	1.6
						45	19	462	125	31	682	100

Table 8 – Number of observed SDAs from the northern hemisphere. 22.4% of the data is situated between solar longitude 125° and 127°.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Percentage
< 120°	0	0	0	0	6	152	120	12	43	10	343	6.3
120°-122°	0	0	0	0	4	59	29	39	25	0	156	2.9
122°-124°	0	0	0	0	18	54	13	45	27	0	157	2.9
124°-125°	0	0	0	0	36	28	2	49	130	1	246	4.5
125°-126°	0	0	0	0	128	119	7	295	157	4	710	13.1
126°-127°	0	0	0	0	79	207	8	124	77	7	502	9.3
127°-128°	0	0	0	0	145	156	10	227	47	2	587	10.8
128°-129°	0	0	0	0	99	77	9	220	6	5	416	7.7
129°-130°	0	0	0	0	58	57	13	230	9	13	380	7.0
130°-131°	0	0	0	0	86	20	7	258	5	22	398	7.3
131°-132°	0	0	0	0	95	8	10	105	0	13	231	4.3
132°-134°	0	0	0	0	170	17	27	132	0	46	392	7.2
134°-136°	0	0	0	0	181	5	87	103	4	26	406	7.5
> 136°	0	0	0	0	165	23	82	187	12	32	501	9.2
					1270	982	424	2026	542	181	5425	100

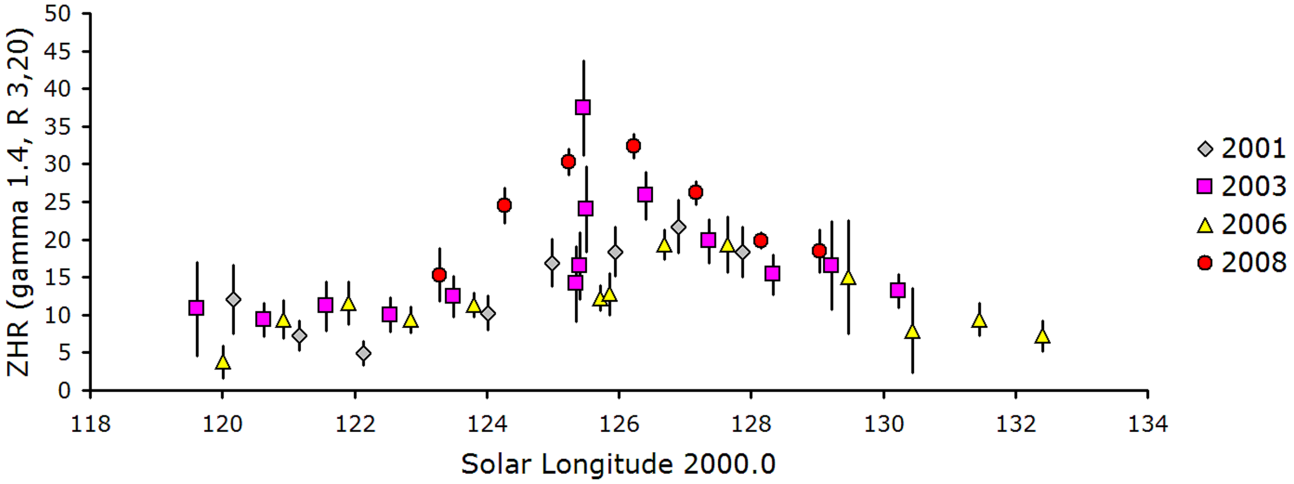

Figure 4 – ZHR values for the Southern δ-Aquariids (SDA) in 2001, 2003, 2006, and 2008. The graph covers the time lapse from July 20 until August 5 included.

Table 12 – Video ZHR for the Southern δ-Aquariids (SDA).

2008 July	T_{mid} UT	Solar longitude Eq 2000.0	N	Shower	ZHR
28	1:50	125°238	48	SDA	53.1 ± 7.7
29	2:00	126°214	83	SDA	49.4 ± 5.4
30	2:00	127°151	96	SDA	42.1 ± 4.3
31	2:50	128°147	87	SDA	30.1 ± 3.2
			314		

(QUA)? To find an adequate answer to this question we will have to collect more data in the coming years.

The shape of the 2008 ZHR curve is also smoother than those of other years. This may be due to the quantity of the 2008 data. One ZHR dot from 2003 exceeds all other levels. This was the night 2003 July 28-29 when Koen Miskotte witnessed the ZHR running up to 40 in a short period of time. Before and after this time, the ZHR was 20 or less. There are more examples of years with higher ZHRs; on www.meteorshowersonline.com we can read that Australian data indicated a ZHR of 40 for the night of 1977 July 28-29 and that ZHRs of 30 were observed in 1986 and 1987. Unfortunately we did not (yet) get access to this data; whenever possible we will study this in a separate article.

6 Video ZHR La Palma

Klaas Jobse took a video system to La Palma with the aim to compare the video recordings with the visual observers. The system consisted of a 1.8/50 mm Canon lens, an XX1332 Mullard intensifier ($\sim 30,000\times$) with an entrance window of 48 mm, and a mini DV Sony Camcorder. The image field was rounded off at 40°; it is somehow larger but due to some obstruction for a too luminous date/time display during the analysis of the images, a correction has been made. As Klaas Jobse watched the monitor at maximal contrast, the display outshined part of the field of view. The visual analysis of the tapes was done manually, a giant time-consuming job for which we are very grateful to Klaas.

The system was aimed at 132° azimuth and 45° altitude. The lens had a problem of strong vignetting towards the edges. However, this system was very successful; during the nights of July 27-28, 28-29, 29-30 and 30-31 the system filmed over 900 meteors, see Table 10.

The magnitude values provided by Klaas are estimates. The limiting magnitude was derived from averages taken from the entire field of view. The average luminosity of the SDAs remained rather constant, in contrast with the visual observations, see Table 11. The difference may be explained by the fact that this system has a fixed field of view which is smaller than that of visual observers. Bright meteors catch the attention of visual observers over a much larger field of view than the limited field of view of the video system.

The ZHR determination was done in a similar way to the visual observervations. Time periods of about one hour were used. Corrections for the limiting magnitude and radiant elevation were applied. Too short time intervals and data with a radiant elevation below 20° were rejected. The population index r was set to 2.6 for all intervals because the variation in average brightness was negligible. The results of these calculations are displayed in Table 12 and in Figure 6.

It is remarkable that the video system recorded maximum activity on July 27-28, one night before the visual observers. However the difference is very small and probably also here the explanation is that in this night mainly fainter meteors were visible while the next night produced more bright meteors whose visibility favours the visual observers with a much larger field of view. The video system is limited to its fixed field of view. In order to check whether or not the peak was real, we look at the proportion of sporadic meteors to SDAs. Also here the proportion of SDAs was largest in the night of 2008 July 27-28, but the differences are too small to be significant. Anyway the video finds the maximum one day earlier than the visual observers, see also Table 13 and Figure 5.

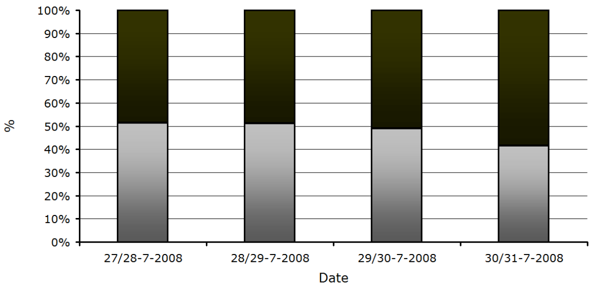

Figure 5 – Proportion between the number of SDA meteors (grey) and the sporadic activity (black).

Table 13 – Proportion of SDA to sporadic meteors in the nights mentioned.

Night	SDA %	Spo %
2008 Jul 27/28	51.4	48.6
2008 Jul 28/29	51.1	48.9
2008 Jul 29/30	49.1	50.9
2008 Jul 30/31	41.6	58.4

7 Conclusions

We think that the activity level of the SDAs is slightly higher than what research has so far indicated. The shower maximum coincides with a dip in the population

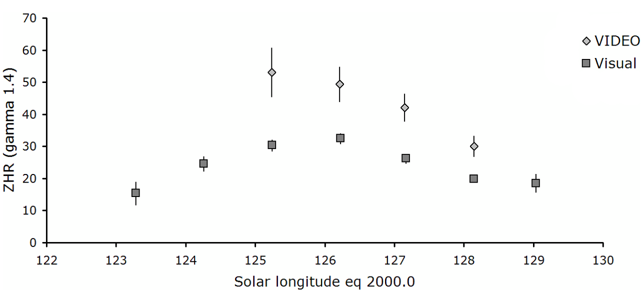

Figure 6 – ZHR curve comparing video and visual obsevations.

Table 10 – Video results for four nights.

Night	T_{eff}	Lm	SDA	PER	CAP	KCG	Spo	Total
Jul 27/28	$4^{\text{h}}37$	6.16	55	10	13	2	66	146
Jul 28/29	$4^{\text{h}}73$	6.32	95	9	18	3	89	214
Jul 29/30	$5^{\text{h}}18$	6.60	112	24	19	0	119	274
Jul 30/31	$5^{\text{h}}85$	6.60	100	29	16	3	136	284
Total	$20^{\text{h}}13$		362	72	66	8	410	918

Table 11 – Video magnitude distributions.

Year	Month	Day	Shower	Lm	−1	0	1	2	3	4	5	6	Total	$\overline{m}$	$\overline{m}/\text{Lm}_{6.5}$
2008	7	27/28	SDA	6.16	0	0	0	5	15	17	18	0	55	3.87	4.21
2008	7	27/28	Spo	6.16	0	0	1	1	12	22	16	0	52	3.98	4.32
2008	7	28/29	SDA	6.3	0	0	0	7	26	41	19	0	93	3.77	3.97
2008	7	28/29	Spo	6.3	0	0	0	0	18	36	35	0	89	4.19	4.39
2008	7	29/30	SDA	6.6	0	0	0	10	31	33	35	0	109	3.85	3.75
2008	7	29/30	Spo	6.6	0	0	0	7	24	38	44	0	113	4.05	3.95
2008	7	30/31	SDA	6.6	1	0	5	7	18	30	31	0	92	3.77	3.67
2008	7	30/31	Spo	6.6	0	1	4	2	21	42	59	0	129	4.14	4.04

index near a solar longitude of $126\overset{\circ}{.}2$. Supplemental observations will have to determine whether or not the maximal activity of the SDAs varies and if the shower maximum produces a larger fraction of bright meteors. Accurate shower classification remains essential to make valid conclusions about this shower possible.

Acknowledgements

The authors are grateful to Peter Bus and to Marco Langbroek for their critical screening of this article and for their useful suggestions. Thanks also to Paul Roggemans for translating this article. The entire observing team wishes to thank Felix Bettonvil for all the support and assistance at the observatory. It was an unforgettable experience!

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Figure 7 – Group photo of the team on one of the four helicopter platforms of the observatory Roque de los Muchachos where also the observations took place. In the background the dome of the large 10.4-meter Gran Telescopio Canarias. From left to right: Peter van Leuteren, Klaas Jobse, Koen Miskotte, Carl Johannink, and Michel Vandeputte.
Photo taken by PvL.

Figure 8 – Just besides the dome of the 10.4-meter Gran Telescopio Canarias this magnitude −5 Southern δ-Aquariid in the constellation of Grus (Common Crane). Camera: Canon 10D with a 2.8/15-mm fish-eye lens. The picture is cropped.
Photo taken by CJ.

Preliminary results

Results of the IMO Video Meteor Network — October 2008

Sirko Molau [1] *and Javor Kac* [2]

Received 2008 November 24

Once more, the previous month set new standards. The astronomical conditions were not perfect, since the waning Moon hindered Orionid observations significantly, but the weather was cooperative at many sites. Carl Hergenrother was again on top of the list. He missed only a single night and managed for the first time to obtain more than 300 hours of effective observing time. Carl wrote that because of the drought in Arizona he would even welcome a few more clouds with rain. Also our second American observer Bob Lunsford, Rui Goncalves from Portugal, and two cameras of Sirko Molau near Berlin managed to get 25 and more observing nights. All in all there were 10 cameras with 20 and more nights (Figure 1 and Table 1).

The analysis of visual observation revealed, that the Orionid activity did not reach the same level as in 2007, but was still significantly above the long-term value of the years before 2006. On October 19/20 and 20/21 alone, more than 4 000 meteors could be recorded. In total we got over 2 750 observing hours, which is a plus of 300 hours compared to the best month February 2008. With more than 17 000 meteors, also the previously best count of October 2006 was outbid by 2 000 meteors.

By the end of October, the number of meteors in the IMO Video Meteor Database had grown to 400 000, just one year after we reached 300 000 in October 2007.

It shows that the video network and the database linked to it continues to grow. However, sometimes there is also sad news, as a few days ago when he learnt that our oldest video observer submitted his last observation in October. We mourn for Milos Weber, who died on November 12 at the age of 88.

Not only because of the long nights and the enhanced meteor activity October is an intersting month – there is hardly another month with so many known meteor showers and further ones waiting for their detection. The Leo-Minorids were included in the IMO Working List during the last revision. With the October-Camelopardalids and the eta Ursa Majorids, two new showers could be identified in the last fews year, and in 2007 another meteor shower candidate was found (iota Cancrids). The more data we have, the better even minor showers with ZHRs of one stand out from the sporadic background and can subsequently be detected by statistical means. In the following, however, we will concentrate on the major showers of October.

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IMO bibcode WGN-366-molau-vidoct
NASA-ADS bibcode 2008JIMO...36..147M

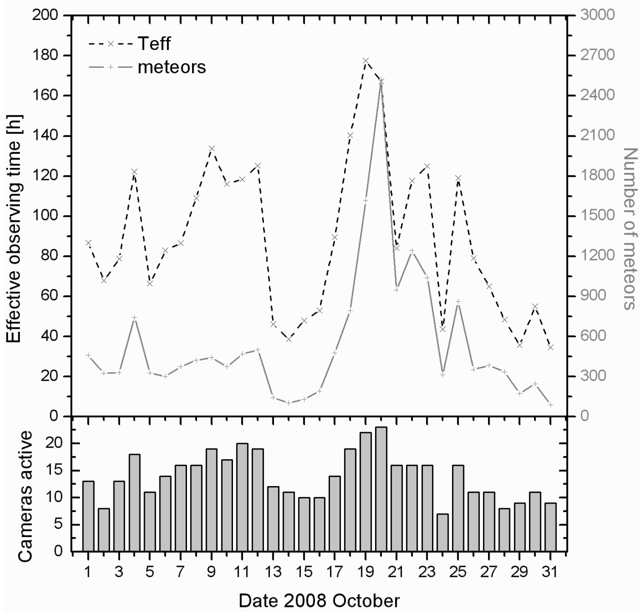

Figure 1 – Monthly summary for the effective observing time (dashed black line), number of meteors (solid gray line) and number of cameras active (bars) in October 2008.

According to the latest edition of the IMO handbook (Rendtel & Arlt, 2008), the Orionids are active between October 2 and November 7. In that time, the radiant moves from northern Orion towards Gemini. In the 2008 meteor shower analyses, (Molau, 2009) the Orionids could be tracked with 14 000 shower members over a much longer time interval, namely September 3 till November 21. However, the radiant position in the first and last few days is quite uncertain and it can not be said at exactly when the shower raises for the first time above the sporadic background. The radiant is well-defined between September 28 and November 10 (Figure 2). In that interval, its position and drift agrees well with the values from the IMO handbook. The velocity of the Orionids computed from the video data fits also to the value found in the literature (66 km/s).

According to the IMO handbook, the maximum of the Orionids is on October 21. The peak ZHR has been roughly 20 until 2005. In the last two years, however, the Orionid activity was much stronger over a period of several days with peak ZHRs of 50 (2006) and 70 (2007). The reason was found to be meteoroids trapped in a 1:6 resonance with Jupiter. The 2008 live ZHR profile of IMO revealed, that also this year the rates where higher, even though the peak ZHR was only of the order of 40 (IMO, 2008).

Video data from 2006 till 2008 were used for the activity analysis presented here. The ratio of the number of Orionids and sporadic meteors per night was taken as a measure of activity. Only those cameras from the

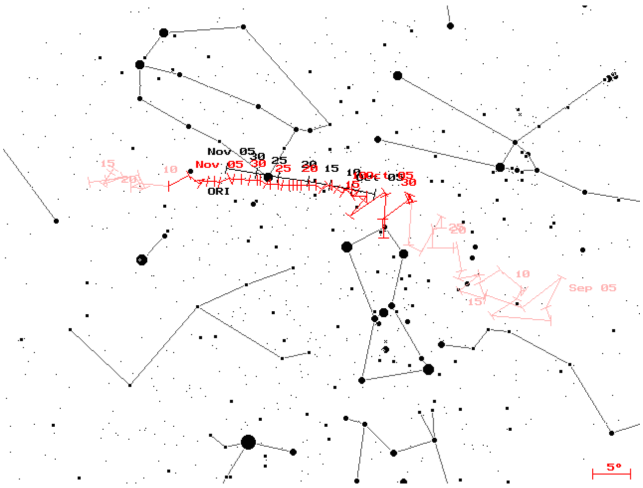

Figure 2 – Radiant position of the Orionids from data of the IMO Video Meteor Database.

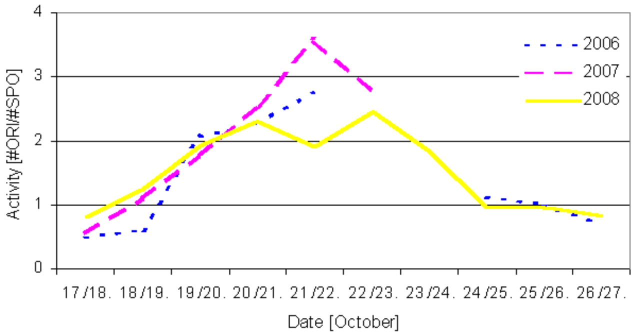

Figure 3 – Comparison of the activity profiles (only maximum times) of the Orionids in the years 2006 till 2008.

time interval October 17/18 to 26/27 were used, which were active all night long with only minor interruptions. Since the observing conditions (Moon) and the cameras (with and without image intensifier) were highly variable from one night to the next, there is significant scatter in the data. On the other hand, the data set (<u>2006</u>: 3258 ORI / 2433 SPO; <u>2007</u>: 2390 ORI / 1076 SPO; <u>2008</u>: 4113 ORI / 2486 SPO) was large enough to smooth out the activity profile statistically.

Figure 3 presents the resulting activity profile from the three years 2006 till 2008. It is confirmed, that the Orionid peak was highest in 2007, even though the descending branch could not be observed last year due to poor weather. The maximum rates vary only little between 2006 and 2008. However, it should be noted that according to visual observations the Orionids peaked already on 2008 October 21, whereas the video data show a second, slightly higher peak 36 hours later.

When comparing the long-term activity profiles from visual and video data (Figure 4) one should note, that the visual profile is based only on data from the 'normal' years until 2005, whereas most of the video data were obtained in 2006 and 2007. Until October 18, both profiles agree well. Thereafter the activity from the peak years 2006 and 2007 is dominating. It is interesting to see, that the surplus in activity holds not only for the Orionid maximum, but for the whole descending activity branch until the end of the visual observing period.

Whereas in the old IMO handbook (Rendtel et al., 1995) a number of ecliptical sources where listed as indi-

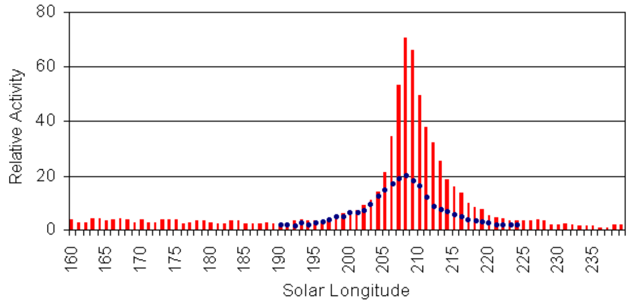

Figure 4 – Long-term activity profile of the Orionids. The dots correspond to the ZHR profile from the current edition of the IMO handbook (without the years 2006 and 2007).

vidual meteor showers, they were combined to the Antihelion source in the last revision of the meteor shower list (Arlt & Rendtel, 2006). The only exception are the northern and southern Taurids between September 25 and November 25, which are still listed as independent showers. In our video data, the Northern Taurids are clearly identified between October 20 and November 29, i.e. the radiant position shows only little scatter in that time interval and fits well to the position given in the IMO handbook. In total, the radiant could be traced with 4 500 shower members between October 1 and December 11, but there is significant scatter in the individual positions of the first and last few days (Figure 5).

The activity interval of the southern Taurids starts a little earlier. In our video data, they are identified with a total of 6 800 shower members between September 8 and November 30. The radiant is well-defined between September 18 and November 26, where it lies constantly about one or two degrees south of the position given in the IMO handbook.

According to the IMO handbook, the activity of the northern and the southern branch varies, whereby activity of the Southern Taurids ends a week earlier. The activity profile obtained in the 2008 analysis of the video meteor database (Figure 6) draws a more accurate picture. Both showers have a clear activity profile of their own. At first, the Southern Taurids (blue) dominate. They reach their maximum around October 12 and loose strength thereafter, whereas the activity

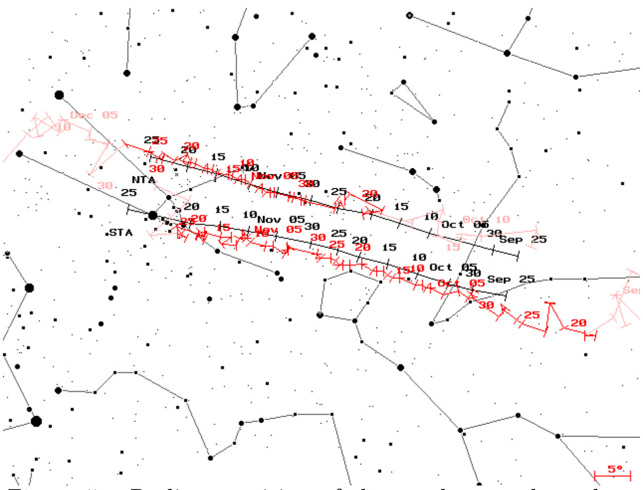

Figure 5 – Radiant position of the northern and southern Taurids from data of the IMO Video Meteor Database.

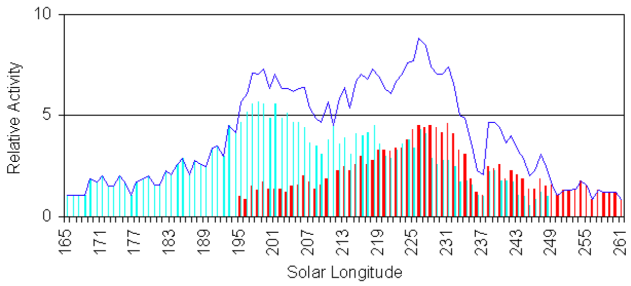

Figure 6 – Activity profile of the Northern (red) and Southern (blue) Taurids. The green line is the resulting total activity from both branches.

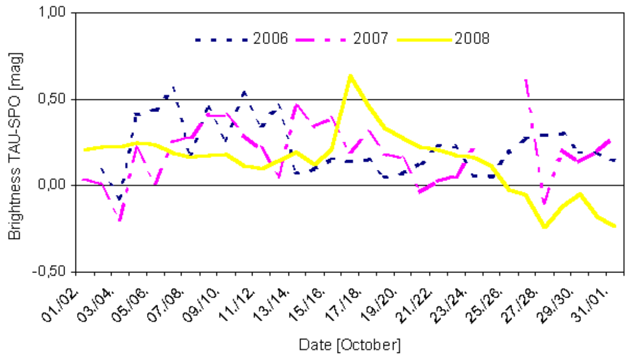

Figure 7 – Mean brightness difference between the Taurids and sporadic meteors in the years 2006 till 2008.

of the Northern Taurids (red) is increasing in parallel. In early November, both branches are of about the same strength, and then the Northern Taurids with their maximum around November 11 dominate. The breakdown in activity near solar longitude 236 is not real but an artefact from the Leonids.

In the last few days there have been hints, that the fraction of bright Taurids and fireballs early November 2008 was higher than usual. A preliminary analysis of visual data, however, revealed the same population index as in the years before (Barentsen, 2008). Here I tried for the first time to analyse the brightness data of video meteors. The average brightness of all Taurids and sporadic meteors from one night was computed and subtracted from each other. Figure 7 shows the development of the brightness difference for the years 2006 till 2008, averaged in a sliding 3-day interval. On average, the Taurids were 0.2 mag fainter than the sporadic meteors. That value shows some scatter from one night to the next, but there is no indication that the 2008 Taurids were brighter than in previous years. Only towards the end of the month such a deviation may be suggested. In remains to see whether this trend continues in November.

Lets have a brief look at the Leo-Minorids in the end. As mentioned before, this shower has been included in the IMO working list in the last revision, after among others also our video data confirmed their existence. The handbook lists an activity interval from October 19 till 27 with a maximum at October 24. This shower has been detected in the 2008 analysis of the video meteor database, too. Over 700 meteors recorded between October 17 to 27 confirm both the position and the drift of the radiant (Figure 8). The velocity of the Leo-

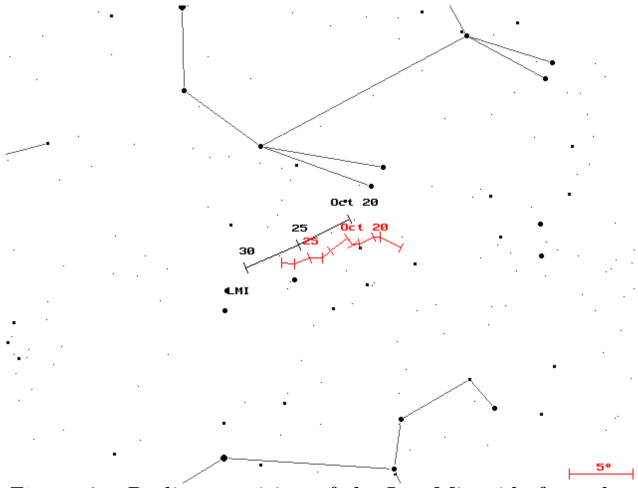

Figure 8 – Radiant position of the Leo-Minorids from data of the IMO Video Meteor Database.

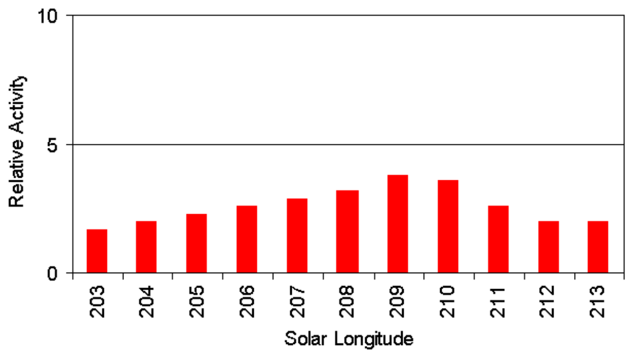

Figure 9 – Activity profile of the Leo-Minorids.

Minorids was determined to 61 km/s in the video data, which is a little less than the value from the meteor shower list (62 km/s).

The activity profile of the shower (Figure 9) is well-shaped. The maximum occurs on October 23/24. The peak activity is comparable to the Northern Taurids and should therefore be of the order of ZHR = 4 and not ZHR = 2 as presented in the IMO handbook.

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Table 1 – Observers contributing to October 2008 data of the IMO Video Meteor Network.

Code	Name	Place	Camera	FOV	LM	Nights	Time (h)	Meteors
BENOR	Benitez-S.	Las Palmas	TIMES5 (0.95/50)	⊘ 10°	3 mag	3	13.5	34
BRIBE	Brinkmann	Herne	HERMINE (0.8/6)	⊘ 55°	3 mag	20	115.1	748
CASFL	Castellani	Monte Baldo	BMH2 (0.8/6)	⊘ 55°	3 mag	16	69.9	220
CRIST	Crivello	Valbrevenna	STG38 (0.8/3.8)	⊘ 80°	3 mag	2	19.1	76
		Genova	C3P8 (0.8/3.8)	⊘ 80°	3 mag	14	96.5	484
ELTMA	Eltri	Venezia	MET38 (0.8/3.8)	⊘ 80°	3 mag	6	43.8	281
GONRU	Goncalves	Tomar	TEMPLAR1 (0.8/6)	⊘ 55°	3 mag	25	192.6	1516
HERCA	Hergenrother	Tucson	SALSA (1.2/4)	⊘ 80°	3 mag	30	304.0	1071
HINWO	Hinz	Brannenburg	AKM2 (0.85/25)	⊘ 32°	6 mag	16	103.9	697
KACJA	Kac	Kostanjevec	METKA (0.8/8)	⊘ 42°	4 mag	21	166.6	642
		Kamnik	REZIKA (0.8/6)	⊘ 55°	3 mag	13	108.1	1144
		Ljubljana	ORION1 (0.8/8)	⊘ 42°	4 mag	23	83.6	215
KOSDE	Koschny	Noord-wijkerhout	TEC1 (1.4/12)	⊘ 30°	4 mag	12	57.3	89
LUNRO	Lunsford	Chula Vista	BOCAM (1.4/50)	⊘ 60°	6 mag	26	222.7	2070
MOLSI	Molau	Seysdorf	AVIS2 (1.4/50)	⊘ 60°	6 mag	13	87.2	1584
			MINCAM1 (0.8/6)	⊘ 60°	3 mag	24	97.0	456
		Ketzür	REMO1 (0.8/3.8)	⊘ 80°	3 mag	25	173.4	827
			REMO2 (0.8/3.8)	⊘ 80°	3 mag	26	150.6	625
PRZDA	Przewozny	Berlin	ARMEFA (0.8/6)	⊘ 55°	3 mag	13	94.2	418
SLAST	Slavec	Ljubljana	KAYAK1 (1.8/28)	⊘ 50°	4 mag	18	71.0	157
STOEN	Stomeo	Scorze	MIN38 (0.8/3.8)	⊘ 80°	3 mag	14	107.2	496
STORO	Stork	Kunzak	KUN1 (1.4/50)	⊘ 55°	6 mag	2	11.6	565
		Ondrejov	OND1 (1.4/50)	⊘ 55°	6 mag	3	12.8	577
STRJO	Strunk	Herford	MINCAM2 (0.8/6)	⊘ 55°	3 mag	24	85.1	414
			MINCAM3 (0.8/8)	⊘ 42°	4 mag	15	82.6	400
			MINCAM5 (0.8/6)	⊘ 55°	3 mag	15	90.7	772
WEBMI	Weber	Chouzava	TOMIL (1.4/50)	⊘ 50°	6 mag	1	2.4	93
YRJIL	Yrjölä	Kuusankoski	FINEXCAM (0.8/6)	⊘ 55°	3 mag	16	98.6	367
					Overall	31	2761.1	17038

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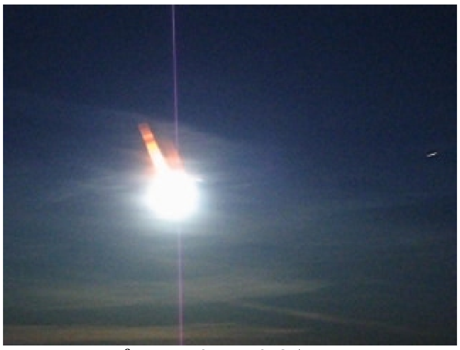
Meteorite-dropping fireball

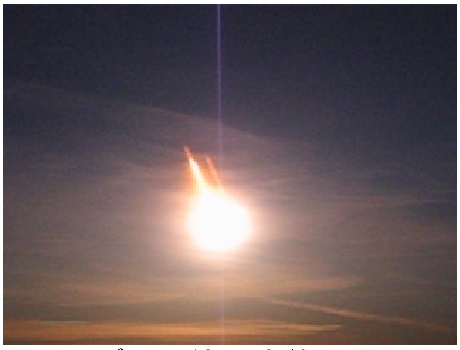

frame 2, t=0.08 s


frame 4, t=0.16 s


frame 6, t=0.24 s


frame 8, t=0.32 s

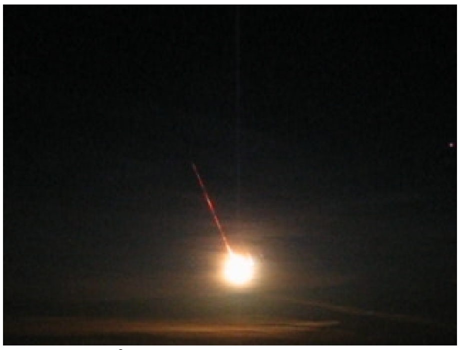

frame 10, t=0.40 s

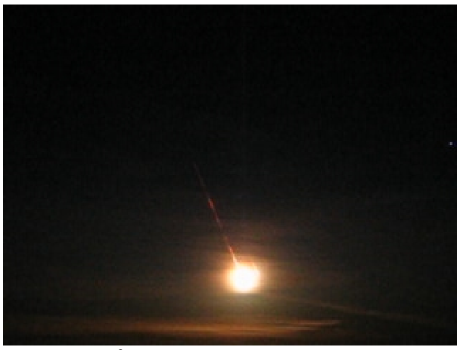

frame 12, t=0.48 s

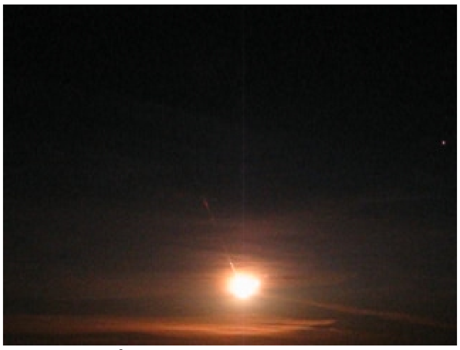

frame 14, t=0.56 s

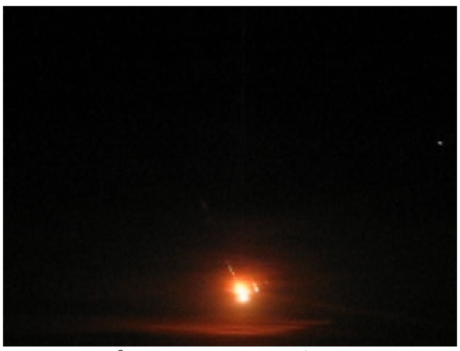

frame 16, t=0.64 s

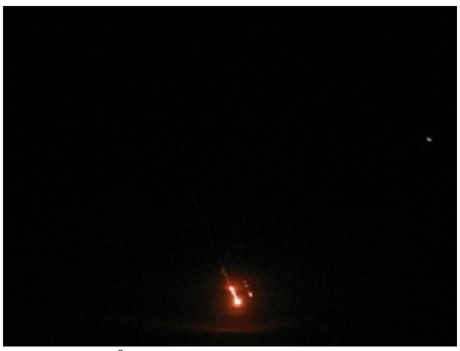

frame 18, t=0.72 s


frame 20, t=0.80 s


frame 22, t=0.88 s


frame 24, t=0.96 s


frame 26, t=1.04 s


frame 28, t=1.12 s


frame 30, t=1.20 s

This spectacular fireball shot over Canada on 2008 November 21, $00^{h}26^{m}04^{s}$ UT, shedding meteorites close to Lloydminster, SK. This series of images was extracted from a movie shot by Andy Bartlett using a Canon Powershot A510 camera. This view is looking generally east with the fireball moving north to south from a location in Edmonton ($53^\circ32'54''.3$ N and $113^\circ28'37''.1$ W, elev. 665 m).