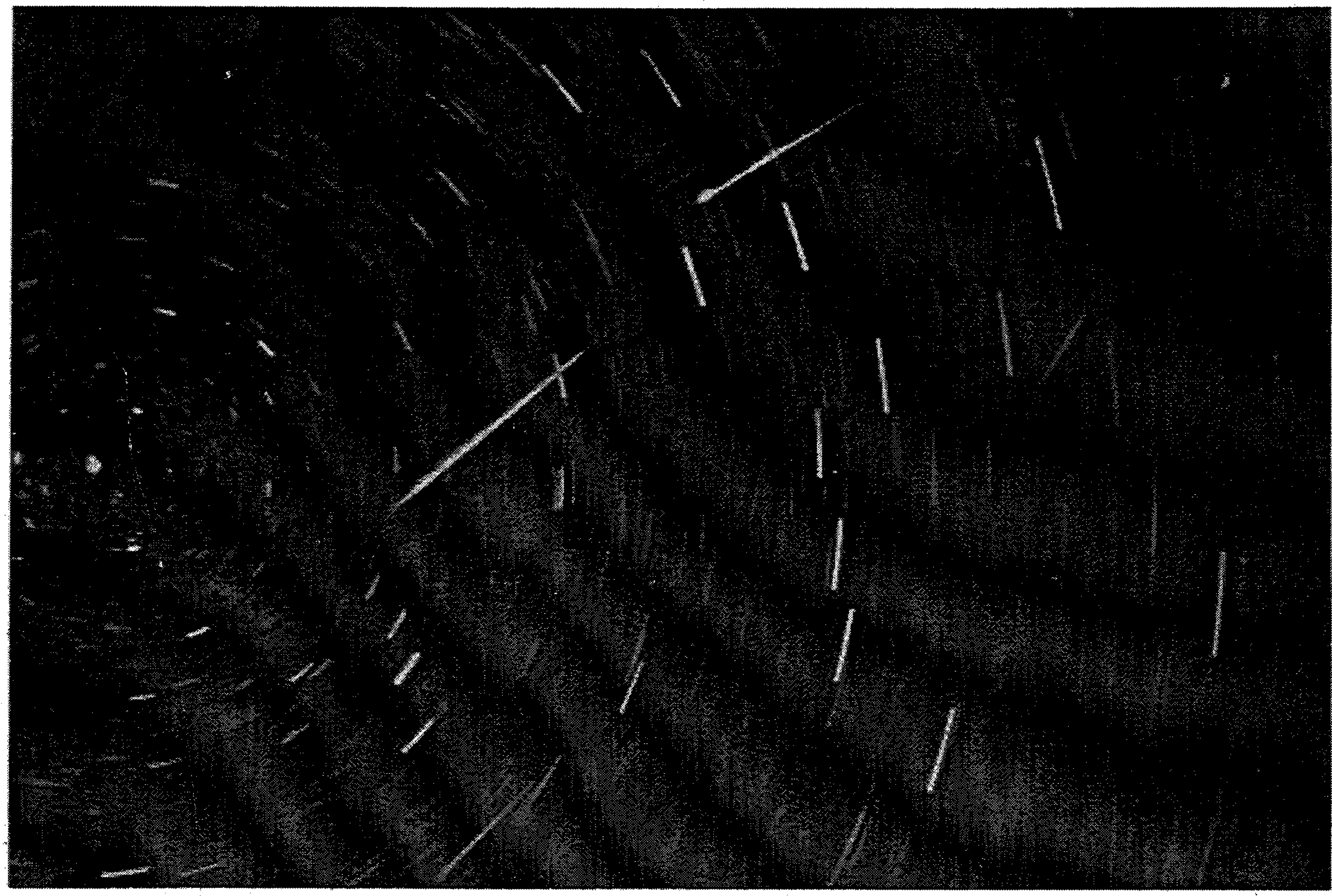
ISSN 1016-3115

wgn

27 - 1

february 1999

bimonthly journal of the international meteor organization



This photograph was taken by Valentin Grigore of the *SARM* from Târgovişte, Romania, in the morning of November 17, 1998, with a 28 mm $f/2.8$ Pentor lens, on Kodak 800 ASA film The exposure lasted from $2^h59^m15^s$ UT till $3^h11^m09^s$ UT, and shows 7 Leonids, including two fireballs of magnitude −7 (the faintest Leonids may not show on the print). Their persistent trains were visible with the naked eye for almost 15 minutes. (*See alsoelsewhere in this issue.*)

In this issue:

In case of non-delivery, return postage guaranteed. Please return to:

v.u.: Marc Gyssens, Heerbaan 74, B-2530 Boechout, Belgium

WGN, Vol. 27, No. 1, February 1999, pp. 1–82

Contents

Useful Information

The April issue *(WGN 27:2)*

The *April issue* will be mailed toward the end of April. Contributions are due on *April 2* at the latest. They should be sent to *Marc Gyssens.*

Subscriptions and ordering of publications

Volume 27 (1999) of *WGN* will contain at least 240 pages and costs 35 DEM or 17.90 EUR, including non-airmail delivery. Ordering other *IMO* publications is done in the same way as paying subscription/membership fees. Information can be obtained from the Treasurer, *Ina Rendtel*. Changes of address and complaints about not receiving *WGN* should also be addressed to the Treasurer.

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

From the President

Jürgen Rendtel

The year 1998 certainly was a most exciting one for the entire meteor astronomy community, as we lived to see enhanced activity of several meteor showers and of very different types. First, there were the regular returns of showers, such as the Quadrantids, the Perseids, and the Geminids. Of course, the Leonids gained the main attention in 1998, and the expectations were very high. Several expeditions took place, and we all saw something unexpected: a long-lasting activity made almost exclusively of bright meteors, something like a "fireball storm." The fresh meteoroids, which were suspected to cause high rates, arrived in time, but with relatively low rates only.

Before this highlight happened, two other showers produced high rates. The first one, the June Bootids, were omitted from meteor shower lists because their last observed significant occurrence dated back to 1927. This indicates that we are still far from a complete model of meteoroid stream evolution, and that further surprises may happen at various occasions, which is a good reason for a regular survey of meteor activity throughout the year.

The activity outburst of the Draconids, or Giacobinids, was to a certain extent expected. However, it was the first observation of an enhanced activity caused by particles leading the parent comet and being inside the Earth's orbit.

The 1998 IMC *was the second of our conferences held in conjunction with the professional* Meteoroids *conference in Slovakia, this time in Stará Lesná. As in 1992, the contacts between the amateurs of the* IMO *and the professional meteor workers were numerous and stimulating for both sides. The presentation of several contributed talks and posters by* IMO *members shows the acknowledgment of the* IMO*'s work.*

In 1999, there are many events which led already to plans for meetings and observational campaigns. Certainly, the Leonids will again attract most of the attention. The big question is, can we see a meteor storm this year? The experience of the 1998 expeditions will help a lot with all technical preparations, and the data collection will be more like a routine, even when more data arrive. The rates, however, will remain a surprise to us all.

I wish all members and friends of the IMO *a healthy, peaceful 1999 and good luck—not only with your meteor plans.*

Instructions to Authors

Marc Gyssens

Since the last time I published instructions to authors, a lot of new authors have joined *WGN*. We welcome them, and encourage them to continue submitting contributions to this journal, as we also encourage those who have not yet contributed to *WGN* to do so, and in this way let other people know about observational results or experiences, or about your opinion on matters being proposed or presented in the journal, for example via a Letter to the Editor. During the same period of time, electronic means of communication have become more generally available, which of course also had its effect on the way articles are submitted to *WGN*. For both these reasons, I think it is useful to print a new set of simple guidelines for authors.

As a general rule, always send me one hard copy of your article, which should also contain good-quality versions of the figures, suitable for reproduction.

If at all possible, you should also send me an electronic version of your article. This electronic version should be in plain ASCII format. *WGN* is not produced on a PC, but on a Unix Workstation, so MS-Word files, which I often receive, are not directly usable. I have to seek out a PC first, and then save it in ASCII format (as a "`.txt`" file), before I can start working on it. You can as easily save your document in ASCII format yourself and spare me this unnecessary work! Of course, saving an MS-Word document in ASCII format will mean that more or less complex formulae, special characters, accents, etc. will get lost. This should not worry you, as I can re-insert these using the hard copy you sent me. The electronic version may either be sent by e-mail (`wgn@imo.net`) or on a floppy disk that accompanies the hard copy. Notice that floppy disks are *not* returned to the sender.

You may also submit figures in electronic form, preferably as a Postscript file, and preferably via e-mail. However, avoid sending files of 1 MB or larger as they may jam my mail system. Other formats, such as GIF, TIFF, or JPEG, are also acceptable. However, since I have to convert these other formats to a Postscript file before printing, you should take into account a possible loss in quality, especially in graphs or diagrams, which then sometimes look as if being produced by a matrix printer. Therefore, I strongly encourage you to send graphs and diagrams either electronically as a Postscript file or as a good quality black-and-white hard copy together with the hard copy of your article.

As an exception to the general rule, I do *not* require a hard copy only if your article is in TeX or LaTeX format, or if in ASCII format but does not contain special characters, accents, or involved formulae whose exact composition cannot be made clear in the file, *and* if you can follow the instructions in the previous paragraph for electronic submission of the figures. If you must send the figures as hard copy, always enclose a copy of the text as well!

Finally, if you are not in the possibility to send me an electronic version of your article at all, I require *two* hard copies of your article (one copy of the figures suffices). People at the Public Observatory *Urania* assist me with typesetting articles, especially those for which I did not receive an electronic version. The extra copy is needed so that, during this process, I can keep one copy with the illustrations to minimize the risk of loss in transferring a copy to another person.

Producing *WGN* is a pleasant duty for me, but one that takes quite some time. Therefore, I thank you for having read these simple instructions above; by adhering to them, you save me unnecessary work and contribute to the timely appearance of your journal!

VISDAT: A Database System for Visual Meteor Observations

Janko Richter

We provide a database system together with a software which helps observers handle and utilize their observations, allows preliminary analysis of the data for direct feed-back to the observers' skills, and exports to other databases such as the VMDB and PosDAT. In contrast to those systems, the VISDAT package presented here preserves the complete information of an observing session.

1. Introduction

The increasing amount of visual meteor observations requires efficient tools to handle a huge amount of data. One approach is to decentralize a major part of the data reduction procedure. This concept comes up with a number of advantages, but with potential problems, too. A lot of routine work can be taken away from a small number of people but additional effort is needed to ensure, e.g., a unified computer-readable format for data exchange and unified criteria for shower association. In addition, there should not be any extraordinary hardware requirement for decentralized data reduction.

The VISDAT database system was developed several years ago by Thomas Rattei and the author to be used only during the annual observation campaigns of the *Astronomy Club of Radebeul* in Germany. During this period, a lot of improvements were included. Later, more people joined the VISDAT users group and contributed to the further development of the program.

It became obvious that VISDAT would meet the above requirements for a more decentralized data reduction within the *IMO*. Because the program was originally written with German-language menus and help files, it was necessary to create an English version, which was completed in late 1998. In the next paragraphs, it is explained in detail how VISDAT works. The text refers to the scheme in Figure 1 and the numbered positions therein.

2. The system

In general, there are two kinds of visual meteor observation, plotting and counting. In the case of plotting the observed meteors are entered in a chart with gnomonic projection. Session data and meteor data other than the position of the trajectory in the sky are stored on tape or paper (position 1 in Figure 1). The plotting method is preferred when the meteor activity is rather low, while the counting method is used when the meteor activity is high and the quality of meteor plots would become poor. Of course, it is possible to combine both methods in one observational session: only meteors of the major shower are counted while others are plotted.

Data storage and data processing can be done with the VISDAT software. First of all, the session data are entered (position 2 in Figure 1). In the case of plotted meteors, the information from the trajectories in the charts has to be transformed into a computer readable form. The following methods are supported by VISDAT (position 3):

- *input by a graphical tablet* (digitizer, actually GENIUS 1812HR only). Begin and end of every trajectory are determined by the pointer and stored directly;
- *input by a scanner* that can generate PCX graphics files. The maps are scanned. The trajectories on the image are measured by mouse clicks. So, a graphical tablet can be imitated when not available;
- *measurement by a ruler*. The meteor positions are determined by ruler and are entered via the keyboard. This method is rather slow by comparison, but it also works when neither a graphical tablet nor a scanner are present; and
- *measurement by another device*. Meteor positions acquired otherwise are stored in an ASCII file which is imported by VISDAT. With this option, you are free to design whatever input device providing appropriate ASCII code.

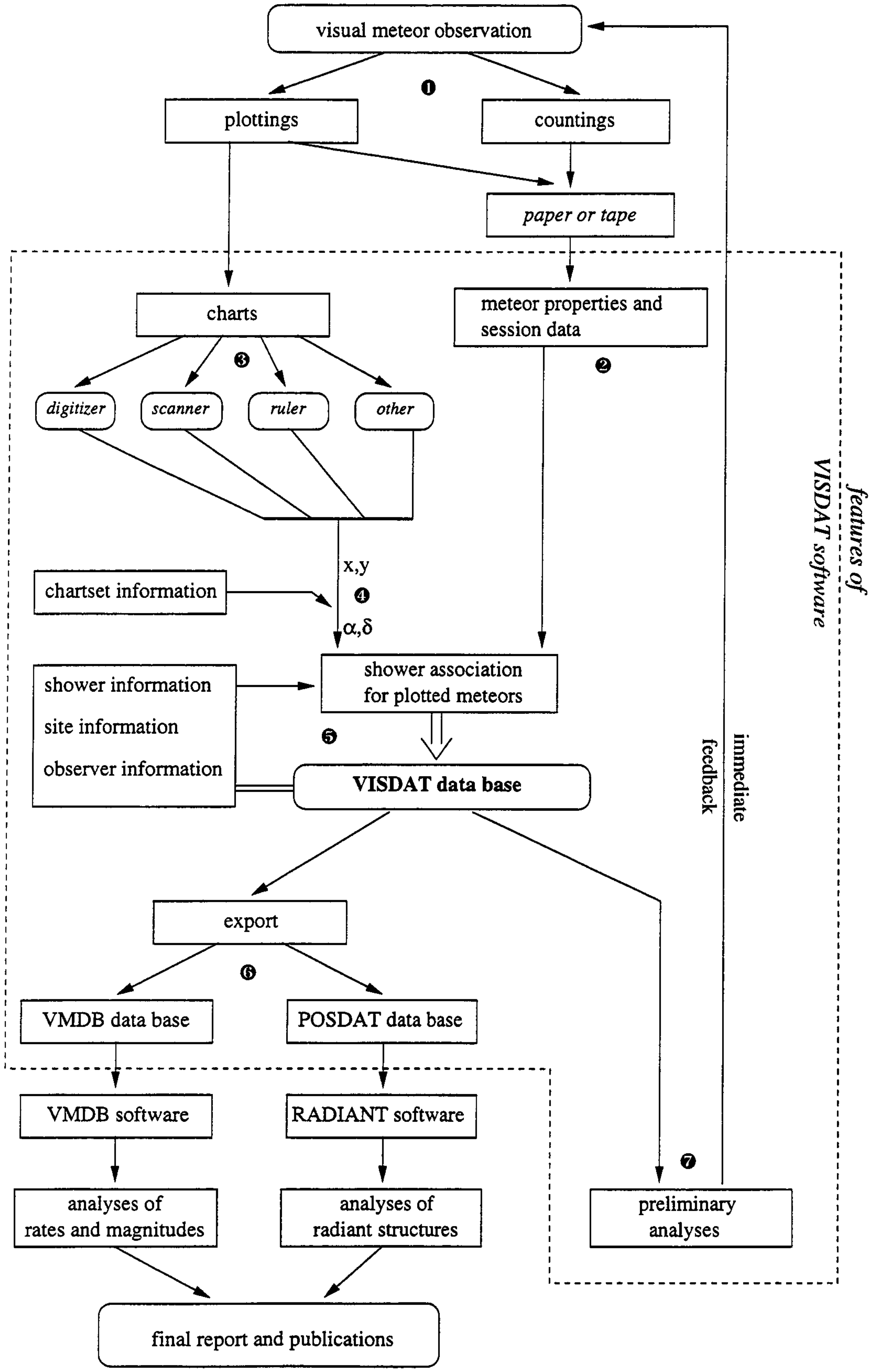


Figure 1 – Scheme of the VISDAT database system.

Now, the meteor positions are available in x, y-coordinates. By means of the chart-set information (i.e., origin, scale, and orientation of the chart) the x, y-coordinates are transformed into right ascension and declination (position 4). The results are kept in the VISDAT database.

Finally, for both methods, plotting and counting, the input of meteor properties follows (position 2). Meteor properties are, e.g., time, magnitude, color, train, and trail. If the counting method was used for a particular meteor, also the shower information is entered here.

When all data are stored, the shower association is carried out by VISDAT for plotted meteors (position 5). For that purpose, VISDAT makes use of a radiant position database and a radiant drift database.

The data can be analyzed either within the VISDAT software or with other computer programs. In the first case, only a small set of analysis procedures is available. These features were included to allow a *preliminary* analysis which is especially important during an observation campaign. The immediate feedback (position 7) can help the observers to avoid systematic errors already in the next night.

When other programs are used for further investigations, the VISDAT database has to be exported to the appropriate format. Currently, two standards are supported: VMDB and POSDAT. In the case of the VMDB, two files are generated (one for the rates and one for the magnitudes), that allow analyzing the data using well-established tools. The POSDAT format enables the RADIANT software to perform detailed investigations of radiant structures as well as to look for new radiants. In contrary to the simple analysis by VISDAT, these investigations are usually done when the observation campaign is completed and the results are merged with those from other observers.

3. Data reporting

Finally, the data are reported to the *IMO*. There are two possibilities to do this. The first one is to send the VMDB report form by mail or e-mail to the administrator who adds it to the VMDB database. Later, the material is analyzed for rates and magnitudes. The second possibility is to send the VISDAT data files to the administrator, who extracts the information needed for the VMDB. The VISDAT files are stored in an archive.

The second method should be the preferred one because, in this case, the *raw data* are archived. When the archive is made available via the Internet, everybody can perform his or her own data analysis. This analysis can be done with *any* possible set of criteria. For example, the shower association for old data can be re-calculated with improved radiant positions or even with new radiants, provided the observers plotted the meteors during their observations.

4. Support and feedback

To get more information about the project, or to obtain the meteor data currently included in the VISDAT database, please refer to the recently created WWW page `http://www.imo.net/visual/visdat`. On this page, more information is given about the project itself, as well as the required software and the current status of the received meteor data. Periodically, this information will also be published in journals like *WGN* or presented at conferences like the *IMC*. Of course, observer feedback is essential for success. Other projects failed for lack of this. So, any experiences and hints should be communicated to the author (e-mail: `richte-j@t-online.de`).

Many thanks are due to the people who contributed to the VISDAT project: Rainer Arlt, Detlef Koschny, Mirko Nitschke, Jürgen Rendtel, Thomas Schreyer, Harald Seifert, and Manuela Trenn.

Solar Longitudes for 1999

compiled by Rainer Arlt

A conversion table of dates to solar longitudes using [1] is given as every year. The longitudes given are only valid for 1999. The conversion formulae for any time of the day is 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 $\lambda_\odot$ in a time of the day, look up the *Date* with the next-smaller solar longitude in the table and calculate

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

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

Reference

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

Table 1 – Solar longitudes 1999. Dates refer to 0^h UT.

Date	$\lambda_\odot$	Date	$\lambda_\odot$	Date	$\lambda_\odot$	Date	$\lambda_\odot$	Date	$\lambda_\odot$	Date	$\lambda_\odot$
Jan 1	280°13	Mar 1	339°97	May 1	40°21	Jul 1	98°76	Sep 1	158°14	Nov 1	218°12
Jan 2	281°15	Mar 2	340°97	May 2	41°18	Jul 2	99°71	Sep 2	159°11	Nov 2	219°12
Jan 3	282°17	Mar 3	341°97	May 3	42°15	Jul 3	100°66	Sep 3	160°07	Nov 3	220°12
Jan 4	283°18	Mar 4	342°97	May 4	43°12	Jul 4	101°62	Sep 4	161°04	Nov 4	221°12
Jan 5	284°20	Mar 5	343°98	May 5	44°09	Jul 5	102°57	Sep 5	162°01	Nov 5	222°13
Jan 6	285°22	Mar 6	344°98	May 6	45°05	Jul 6	103°52	Sep 6	162°98	Nov 6	223°13
Jan 7	286°24	Mar 7	345°98	May 7	46°02	Jul 7	104°48	Sep 7	163°95	Nov 7	224°13
Jan 8	287°26	Mar 8	346°98	May 8	46°99	Jul 8	105°43	Sep 8	164°92	Nov 8	225°14
Jan 9	288°28	Mar 9	347°98	May 9	47°96	Jul 9	106°38	Sep 9	165°89	Nov 9	226°14
Jan 10	289°30	Mar 10	348°98	May 10	48°93	Jul 10	107°34	Sep 10	166°86	Nov 10	227°15
Jan 11	290°32	Mar 11	349°98	May 11	49°89	Jul 11	108°29	Sep 11	167°84	Nov 11	228°15
Jan 12	291°34	Mar 12	350°98	May 12	50°86	Jul 12	109°25	Sep 12	168°81	Nov 12	229°16
Jan 13	292°35	Mar 13	351°98	May 13	51°82	Jul 13	110°20	Sep 13	169°78	Nov 13	230°16
Jan 14	293°37	Mar 14	352°97	May 14	52°79	Jul 14	111°15	Sep 14	170°76	Nov 14	231°17
Jan 15	294°39	Mar 15	353°97	May 15	53°76	Jul 15	112°11	Sep 15	171°73	Nov 15	232°18
Jan 16	295°41	Mar 16	354°97	May 16	54°72	Jul 16	113°06	Sep 16	172°71	Nov 16	233°18
Jan 17	296°43	Mar 17	355°96	May 17	55°68	Jul 17	114°02	Sep 17	173°68	Nov 17	234°19
Jan 18	297°45	Mar 18	356°96	May 18	56°65	Jul 18	114°97	Sep 18	174°66	Nov 18	235°20
Jan 19	298°47	Mar 19	357°96	May 19	57°61	Jul 19	115°92	Sep 19	175°63	Nov 19	236°21
Jan 20	299°49	Mar 20	358°95	May 20	58°58	Jul 20	116°88	Sep 20	176°61	Nov 20	237°22
Jan 21	300°50	Mar 21	359°94	May 21	59°54	Jul 21	117°83	Sep 21	177°58	Nov 21	238°23
Jan 22	301°52	Mar 22	0°94	May 22	60°50	Jul 22	118°79	Sep 22	178°56	Nov 22	239°23
Jan 23	302°54	Mar 23	1°93	May 23	61°46	Jul 23	119°74	Sep 23	179°54	Nov 23	240°24
Jan 24	303°56	Mar 24	2°92	May 24	62°42	Jul 24	120°70	Sep 24	180°52	Nov 24	241°25
Jan 25	304°57	Mar 25	3°91	May 25	63°38	Jul 25	121°65	Sep 25	181°50	Nov 25	242°27
Jan 26	305°59	Mar 26	4°91	May 26	64°34	Jul 26	122°61	Sep 26	182°48	Nov 26	243°28
Jan 27	306°61	Mar 27	5°90	May 27	65°30	Jul 27	123°56	Sep 27	183°46	Nov 27	244°29
Jan 28	307°62	Mar 28	6°89	May 28	66°26	Jul 28	124°52	Sep 28	184°44	Nov 28	245°30
Jan 29	308°64	Mar 29	7°87	May 29	67°22	Jul 29	125°47	Sep 29	185°42	Nov 29	246°31
Jan 30	309°65	Mar 30	8°86	May 30	68°18	Jul 30	126°43	Sep 30	186°40	Nov 30	247°33
Jan 31	310°67	Mar 31	9°85	May 31	69°14	Jul 31	127°38				
Feb 1	311°68	Apr 1	10°84	Jun 1	70°10	Aug 1	128°34	Oct 1	187°38	Dec 1	248°34
Feb 2	312°70	Apr 2	11°82	Jun 2	71°06	Aug 2	129°30	Oct 2	188°37	Dec 2	249°35
Feb 3	313°71	Apr 3	12°81	Jun 3	72°01	Aug 3	130°25	Oct 3	189°35	Dec 3	250°37
Feb 4	314°73	Apr 4	13°80	Jun 4	72°97	Aug 4	131°21	Oct 4	190°33	Dec 4	251°38
Feb 5	315°74	Apr 5	14°78	Jun 5	73°93	Aug 5	132°17	Oct 5	191°32	Dec 5	252°40
Feb 6	316°75	Apr 6	15°77	Jun 6	74°89	Aug 6	133°12	Oct 6	192°30	Dec 6	253°41
Feb 7	317°77	Apr 7	16°75	Jun 7	75°84	Aug 7	134°08	Oct 7	193°29	Dec 7	254°43
Feb 8	318°78	Apr 8	17°73	Jun 8	76°80	Aug 8	135°04	Oct 8	194°28	Dec 8	255°44
Feb 9	319°79	Apr 9	18°72	Jun 9	77°76	Aug 9	136°00	Oct 9	195°26	Dec 9	256°46
Feb 10	320°81	Apr 10	19°70	Jun 10	78°71	Aug 10	136°96	Oct 10	196°25	Dec 10	257°47
Feb 11	321°82	Apr 11	20°68	Jun 11	79°67	Aug 11	137°92	Oct 11	197°24	Dec 11	258°49
Feb 12	322°83	Apr 12	21°66	Jun 12	80°63	Aug 12	138°88	Oct 12	198°23	Dec 12	259°51
Feb 13	323°84	Apr 13	22°64	Jun 13	81°58	Aug 13	139°84	Oct 13	199°22	Dec 13	260°52
Feb 14	324°85	Apr 14	23°62	Jun 14	82°54	Aug 14	140°80	Oct 14	200°21	Dec 14	261°54
Feb 15	325°86	Apr 15	24°60	Jun 15	83°49	Aug 15	141°76	Oct 15	201°20	Dec 15	262°56
Feb 16	326°87	Apr 16	25°58	Jun 16	84°45	Aug 16	142°72	Oct 16	202°19	Dec 16	263°58
Feb 17	327°88	Apr 17	26°56	Jun 17	85°41	Aug 17	143°68	Oct 17	203°18	Dec 17	264°59
Feb 18	328°89	Apr 18	27°54	Jun 18	86°36	Aug 18	144°64	Oct 18	204°18	Dec 18	265°61
Feb 19	329°90	Apr 19	28°52	Jun 19	87°31	Aug 19	145°60	Oct 19	205°17	Dec 19	266°63
Feb 20	330°91	Apr 20	29°50	Jun 20	88°27	Aug 20	146°57	Oct 20	206°16	Dec 20	267°65
Feb 21	331°92	Apr 21	30°47	Jun 21	89°22	Aug 21	147°53	Oct 21	207°16	Dec 21	268°66
Feb 22	332°93	Apr 22	31°45	Jun 22	90°18	Aug 22	148°49	Oct 22	208°15	Dec 22	269°68
Feb 23	333°93	Apr 23	32°42	Jun 23	91°13	Aug 23	149°45	Oct 23	209°14	Dec 23	270°70
Feb 24	334°94	Apr 24	33°40	Jun 24	92°09	Aug 24	150°42	Oct 24	210°14	Dec 24	271°72
Feb 25	335°95	Apr 25	34°37	Jun 25	93°04	Aug 25	151°38	Oct 25	211°14	Dec 25	272°74
Feb 26	336°95	Apr 26	35°35	Jun 26	93°99	Aug 26	152°34	Oct 26	212°13	Dec 26	273°75
Feb 27	337°96	Apr 27	36°32	Jun 27	94°95	Aug 27	153°31	Oct 27	213°13	Dec 27	274°77
Feb 28	338°96	Apr 28	37°29	Jun 28	95°90	Aug 28	154°27	Oct 28	214°13	Dec 28	275°79
		Apr 29	38°26	Jun 29	96°85	Aug 29	155°24	Oct 29	215°12	Dec 29	276°81
		Apr 30	39°24	Jun 30	97°81	Aug 30	156°21	Oct 30	216°12	Dec 30	277°83
						Aug 31	157°17	Oct 31	217°12	Dec 31	278°85

New Limiting Magnitude Tables

Rainer Arlt

Updated tables for the conversion of star counts in the standard areas for limiting-magnitude determination are given, based on the accurate astrometric and visual photometric data of the Tycho Skymapper.

1. The star count method

The star count areas for the determination of the stellar limiting magnitude have turned out to be a useful tool for many of the visual meteor observers. The observer counts the number of stars in pre-defined areas in the sky and converts the resulting number into a faintest-star magnitude with a table. There are 30 limiting-magnitude areas for the entire celestial sphere. A number of short-comings of these tables were detected in [1] and by several more observers. The main problem is that the magnitudes were mainly derived from the SAO Catalog, which is not a brightness catalog. Also, the treatment of stars near the boundaries of the star count areas and close pairs of stars has been questioned in [1]. The tables below should be a useful update of the limiting-magnitude lists.

If you are not interested in the technical details of how the new tables are made, you may skip over to the last section about general aspects of limiting-magnitude determination.

2. The star count software

The magnitudes given in the *SAO Catalog* are little more than guesses, since it was designed as a positional catalog. For our purpose of getting an ordered list of stars in a certain area, we need a catalog which is relatively reliable in visual magnitudes and, not less important, complete up to a magnitude of at least +7.5. Such a catalog is provided by the NASA in several versions since 1978 being complete to about magnitude +9. A look into the visual magnitudes of stars in the various versions of the *Skymap Catalog* reveals the difficulties in assigning a magnitude value to each star. I made tests with the *Skymap Catalog* of 1992, and *Skymap 4.1*, which was renamed into *Sky2000*. This is the last version of ground-based photometric measurements [2]. A new era of accuracy was achieved with the ESA satellite Hipparcos designed for precise positional and photometric measurements. The results of the mission between 1989 and 1993 are comprehensively compiled in the *Tycho Catalog*. Still, significant differences in visual magnitudes to both versions of *Skymap* were found. The accuracy of magnitude measurements of the Tycho experiment is 0.012 on the magnitude scale for stars brighter than magnitude +9, and all values are given as Johnson V magnitudes (effective wave length 555 nm); roughly 130 individual measurements were recorded for each object [3]. The catalog is 99.9% complete down to magnitude +10. I consider this information the most accurate to date and used it for this update of limiting-magnitude tables.

The algorithm checking for stars within a certain area in the sky is a so-called point-in-polygon test. Looking from the position of the star to be checked, the direction to each of the corner stars of the area is determined. The differences between all these directions are added. If the sum is 360°, the star is within the field; the sum is 0°, if the star is outside the field. Care is needed for differences straddling the 0°/360°-line.

Two additional problems need consideration: (*i*) stars very close to each other and (*ii*) stars near the borders of an area. With regard to the first problem, I assumed that an average human eye is capable of resolving $5'$. Very good eyes can resolve ε_1 and ε_2 Lyrae which are $3\overset{'}{.}5$ apart. If I encountered any pair of stars less than $5'$ apart, the pair was treated as a single star, and the overall magnitude was computed by adding the stars' intensities:

$$m_{\rm tot} = m_1 - 2.5 \log \left[1 + 10^{0.4(m_1 - m_2)}\right],$$

with m_1 and m_2 the magnitudes of the two stars and $m_{\rm tot}$ the total magnitude. The catalog used should in fact be complete beyond magnitude +7.5, since a faint star may add its light to a neighboring one and put them as a single object with greater brightness in the table.

With regard to the second problem, we first note that the mathematical boundary of an area is defined by the great circles in the sky or, which is equivalent, by the straight lines on a gnomonically projected map, between the corner stars. Obviously, these mathematical boundaries are not strictly followed by the observers, who face the problem of imagining great circles in the sky and will tend to decide questionable cases positively in order to achieve reasonable limiting-magnitude estimates. The observer will find it easy to decide correctly if the star is close to one of the corner stars; he will have severe difficulties, however, with stars in the middle of very long edges.

Therefore, I did not allow for all stars within a fixed number of arc minutes to an edge to be included in the conversion list. Instead, I used a projection which contracts the central part of the map dragging a few more stars into the field. Great circles through the corner stars are bended slightly inside the counting area. The angular distance d of an object from the map center is converted into a planar distance $D = R\tan(Bd)$, where B is a bending factor determining the strength of the contraction. The map can be scaled linearly by R, which does not affect the selection of stars. The formula is equivalent to a gnomonic projection if $B = 1$. I chose $B = 2.5$ for this update of the limiting-magnitude tables, a value which reproduces roughly the amount of stars included in the old tables. However, the value is small enough to exclude a number of obvious outliers which were included in the old tables. Now, the tables are generally a little shorter at the faint end above magnitude +7.0 than the original tables. The same slight geometric distortion is used for the set of figures at the end of this article.

The strength of the bending depends on how well the counting area is placed in the center of the projection. I searched for the optimum projection center (α_0, δ_0) by searching for the minimum of the total squared distances of the corner stars from the center:

$$\min_{\alpha_0,\delta_0} \sum_{i=1}^{N} D_i^2,$$

where N is the number of corner stars.

Table 2 repeats the corner stars of the 30 areas and gives comments regarding the new tables. The actual conversion table is found in Table 1. The tables for most of the deep southern counting areas 22 and 25–30 were found to be in error for all magnitudes above 6.2–6.3. I suppose a catalog was used which is not complete down to a sufficiently faint magnitude. I checked the new tables with the *Atlas Coeli Novus 2000.0* [4] and found perfect agreement with the Tycho search. I am very grateful to Marc Gyssens who gave me this atlas as a present.

3. Final remarks

The new tables certainly do not solve all the problems the observers had with the determination of the limiting magnitude. Still, the observer has to decide under the sky whether or not a certain star belongs to the area; the resolution capabilities will be different for each observer and only on average equal $5'$. It has always been recommended to count more than one area for the determination of the limiting magnitude. Two areas are already a whole lot better, and if you count three of them, you can be fairly sure you get a reasonable estimate of your sky quality.

Averaging. It is suggested that the average limiting magnitude of these three counts is used as a representative value for the time when they were obtained. If you notice that one of your counts falls on a lower value of a large gap (indicated by italic numbers in Table 1), you should omit this count and only average the other two.

Exceptional limiting magnitudes. I gave the (almost) complete tables from one star to the number corresponding to magnitude +7.5. Observations with limiting magnitudes lower than +5.0 introduce high uncertainties for two main reasons: (*i*) the limiting magnitude itself is uncertain because of the large gaps in the conversion tables; and (*ii*) the difference to the standard limiting magnitude of magnitude +6.5 is so large, that the correction will introduce additional uncertainties even if the limiting magnitude is exactly known.

The limiting magnitude is not a matter of competition. There is absolutely no need to push your limiting magnitude as high as possible. Your estimate should be representative for the entire observation. A few minutes of high concentration do not give you a typical estimate for your attention in any other minute.

Area 14. A lot of problems have been reported with area 14 in Cygnus, which lies in a part of the Milky Way and turned out to be very difficult to count up for several observers. A few of the closest stars were combined in the new tables, but it may still not be easy to derive a reasonable limiting magnitude from that area. I recommend to omit this field if possible until a replacement area is found, which is planned between Vulpecula, Cygnus, and Pegasus.

Averted vision. The limiting-magnitude study in [5] shows that estimates derived with direct staring at the stars are significantly too low. Averted vision is recommended to count the stars in the area; in fact most of the meteors appear in a more or less averted direction from your field of view. Some people have difficulties with the star counts, but yet see a good deal of meteors. These observers should try to avert their vision towards several directions, left and right, below and above the counting area. People having a strong astigmatism (like me) with the stars being stretched in one direction, should turn their head to resolve stars which are in line with the direction of the astigmatism.

Whatever method you prefer for the determination of the limiting magnitude, it is most important to use a method in a constant way and in a fashion typical for your entire observation.

References

[1] J. Gerboš, P. Rapavý, M. Znášik, "Problems of Limiting Magnitude Determination in Meteor Observations", *WGN* 24:1-2, February–April 1996, pp. 42–46.

[2] M.A. Slater Jr., A.C. Miller, W.H. Warren Jr., D.A. Tracewell, "The New Skymap Master Catalog (Version 4.0)", in *Astrodynamics 1995, Advances in the Astronautical Sciences* 90, August 1995, American Astronautical Society, AAS 95-304, pp. 67–81.

[3] E. Høg, G. Bässgen, U. Bastian, D. Egret, C. Fabricius, V. Grossmann, J.L. Halbwachs, V.V. Makarov, M.A.C. Perryman, P. Schwekendiek, K. Wagner, A. Wicenec, "The Tycho Catalogue", *Astron. Astrophys.* 323, 1997, pp. L57–L60.

[4] O. Hlad, F. Hovorka, P. Sojka, J. Weiselová, "Atlas Coeli Novus 2000.0 (1900.0–2050.0)", ETC Publishing, Praha, 1998.

[5] S. Lanfranco, G. Baldacchino, "An Investigation of Limiting Magnitude Determination: A Pilot Study", *WGN* 23:3, June 1995, pp. 87–90.

Table 1 – Conversion table for all 30 limiting-magnitude areas. Magnitude gaps of about 0.3 or more occurring for magnitudes fainter than +5.5 are marked by italic numbers.

1		2		3		4		5		6		7		8		9		10	
N	Lm	N	Lm	N	Lm	N	Lm	N	Lm	N	Lm	N	Lm	N	Lm	N	Lm	N	Lm
1	3.08	1	2.11	1	2.35	1	1.22	1	2.71	1	2.06	1	2.47	1	0.99	1	1.41	1	1.06
2	3.18	2	2.88	2	3.18	2	2.02	2	2.99	2	2.49	2	3.23	2	1.68	2	2.13	2	2.74
3	3.57	3	3.02	3	3.65	3	3.01	3	3.37	3	2.84	3	4.07	3	3.00	3	2.23	3	3.38
4	3.74	4	3.78	4	3.78	4	3.79	4	4.45	4	4.66	4	4.23	4	4.62	4	2.56	4	4.39
5	4.23	5	4.95	5	4.48	5	5.01	5	5.16	5	5.08	5	4.79	5	4.88	5	3.33	5	5.77
6	4.78	6	5.15	6	4.56	6	5.07	6	5.30	6	5.49	6	5.12	6	4.95	6	4.41	6	5.80
7	4.83	7	5.55	7	4.83	7	5.34	7	*5.53*	7	5.56	7	5.17	7	5.09	7	4.78	7	5.86
8	5.00	8	5.60	8	5.13	8	5.75	8	5.98	8	*5.80*	8	5.26	8	5.29	8	5.42	8	5.92
9	5.08	9	5.79	9	5.16	9	5.76	9	*6.02*	9	6.13	9	5.29	9	5.43	9	5.44	9	5.97
10	*5.25*	10	5.80	10	5.49	10	*5.78*	10	6.31	10	6.14	10	5.36	10	5.51	10	5.48	10	5.99
11	5.96	11	5.98	11	5.66	11	6.20	11	*6.36*	11	6.17	11	*5.42*	11	5.73	11	5.50	11	*6.12*
12	6.06	12	6.01	12	5.72	12	6.37	12	6.71	12	6.25	12	5.73	12	5.84	12	5.58	12	6.41
13	6.28	13	*6.07*	13	5.79	13	6.47	13	6.72	13	6.25	13	5.95	13	6.10	13	5.73	13	6.44
14	6.42	14	6.40	14	5.97	14	6.54	14	6.77	14	6.26	14	5.96	14	6.19	14	5.92	14	6.63
15	6.50	15	6.41	15	6.19	15	6.67	15	6.80	15	6.29	15	6.00	15	6.27	15	6.14	15	6.64
16	6.60	16	6.45	16	6.30	16	6.76	16	6.90	16	6.44	16	6.14	16	6.29	16	6.17	16	6.65
17	6.63	17	6.50	17	6.35	17	6.80	17	6.91	17	6.47	17	6.19	17	6.36	17	6.27	17	6.69
18	6.65	18	6.51	18	6.41	18	6.99	18	6.96	18	6.50	18	6.23	18	6.50	18	6.27	18	6.83
19	6.66	19	6.54	19	6.49	19	7.00	19	7.00	19	6.50	19	6.44	19	6.55	19	6.31	19	6.90
20	6.68	20	6.60	20	6.49	20	7.02	20	7.05	20	6.57	20	6.47	20	6.71	20	6.40	20	7.04
21	6.68	21	6.61	21	6.54	21	7.10	21	7.06	21	6.59	21	6.48	21	6.76	21	6.43	21	7.06
22	6.70	22	6.66	22	6.59	22	7.12	22	7.07	22	6.59	22	6.63	22	6.77	22	6.52	22	7.08
23	6.79	23	6.72	23	6.72	23	7.17	23	7.09	23	6.60	23	6.69	23	6.87	23	6.61	23	7.16
24	6.86	24	6.73	24	6.77	24	7.22	24	7.10	24	6.60	24	6.70	24	6.88	24	6.64	24	7.19
25	6.86	25	6.75	25	6.83	25	7.43	25	7.11	25	6.67	25	6.71	25	6.95	25	6.78	25	7.20
26	6.86	26	6.78	26	6.85	26	7.45	26	7.27	26	6.68	26	6.72	26	7.15	26	6.81	26	7.24
27	6.86	27	6.85	27	6.99	27	7.46	27	7.28	27	6.68	27	6.84	27	7.17	27	6.84	27	7.25
28	6.87	28	6.89	28	7.01	28	7.46	28	7.38	28	6.69	28	6.88	28	7.19	28	6.85	28	7.25
29	6.89	29	6.90	29	7.06	29	7.47	29	7.39	29	6.72	29	6.92	29	7.21	29	6.95	29	7.32
30	6.92	30	7.02	30	7.12			30	7.40	30	6.73	30	6.93	30	7.30	30	7.00	30	7.33
31	6.92	31	7.03	31	7.12			31	7.41	31	6.74	31	6.94	31	7.34	31	7.02	31	7.34
32	6.93	32	7.03	32	7.19			32	7.44	32	6.82	32	6.97			32	7.06	32	7.38
33	6.94	33	7.05	33	7.20			33	7.45	33	6.87	33	7.01			33	7.07	33	7.42
34	7.02	34	7.15	34	7.23			34	7.47	34	6.89	34	7.04			34	7.10		
35	7.03	35	7.15	35	7.24					35	6.89	35	7.06			35	7.12		
36	7.04	36	7.16	36	7.30					36	7.07	36	7.08			36	7.12		
37	7.09	37	7.18	37	7.33					37	7.07	37	7.16			37	7.12		
38	7.10	38	7.22	38	7.40					38	7.10	38	7.18			38	7.13		
39	7.10	39	7.23	39	7.41					39	7.11	39	7.23			39	7.13		
40	7.15	40	7.24	40	7.44					40	7.12	40	7.24			40	7.22		
41	7.24	41	7.24	41	7.45					41	7.12	41	7.25			41	7.26		
42	7.30	42	7.25	42	7.47					42	7.14	42	7.25			42	7.30		
43	7.31	43	7.26	43	7.48					43	7.15	43	7.27			43	7.30		
44	7.32	44	7.27	44	7.50					44	7.19	44	7.29			44	7.31		
45	7.33	45	7.28							45	7.24	45	7.30			45	7.33		
46	7.35	46	7.30							46	7.27	46	7.32			46	7.34		
47	7.35	47	7.31							47	7.33	47	7.35			47	7.36		
48	7.36	48	7.31							48	7.37	48	7.39			48	7.43		
49	7.39	49	7.33							49	7.43	49	7.43			49	7.43		
50	7.43	50	7.33							50	7.44	50	7.44			50	7.44		
51	7.50	51	7.35							51	7.45	51	7.46			51	7.45		
		52	7.35							52	7.45	52	7.49			52	7.48		
		53	7.36							53	7.45					53	7.49		
		54	7.42							54	7.49								
		55	7.45							55	7.49								
		56	7.48							56	7.50								
		57	7.49																
		58	7.50																
		59	7.50																

Table 1 – Conversion table for all 30 limiting-magnitude areas (continued).

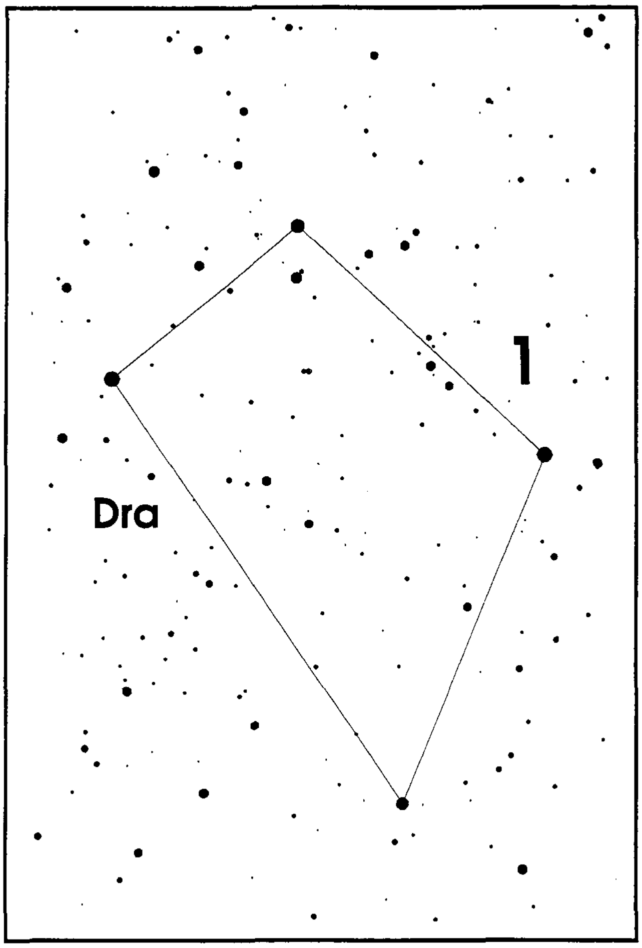
11		12		13		14		15		16		17		18		19		20	
N	Lm	N	Lm	N	Lm	N	Lm	N	Lm	N	Lm	N	Lm	N	Lm	N	Lm	N	Lm
1	0.16	1	2.61	1	3.52	1	2.23	1	2.80	1	1.76	1	0.08	1	2.17	1	2.06	1	4.03
2	2.22	2	2.63	2	3.84	2	2.49	2	3.14	2	1.86	2	1.90	2	3.87	2	3.65	2	4.31
3	2.36	3	2.73	3	4.32	3	3.90	3	3.90	3	2.89	3	2.65	3	4.10	3	3.89	3	4.62
4	3.04	4	3.55	4	4.34	4	4.65	4	4.82	4	4.67	4	3.03	4	4.26	4	5.19	4	4.77
5	3.57	5	5.10	5	4.41	5	4.73	5	5.07	5	5.15	5	3.73	5	4.83	5	*5.50*	5	5.14
6	4.47	6	5.23	6	4.98	6	4.79	6	5.50	6	5.64	6	3.97	6	4.87	6	*5.81*	6	5.44
7	4.51	7	5.39	7	5.42	7	4.94	7	5.67	7	5.79	7	4.33	7	4.96	7	6.20	7	5.47
8	4.79	8	5.39	8	5.49	8	5.06	8	5.82	8	5.85	8	4.52	8	5.01	8	6.33	8	5.62
9	4.81	9	5.51	9	5.56	9	5.39	9	5.92	9	5.88	9	5.21	9	5.04	9	6.40	9	*5.63*
10	4.93	10	5.53	10	5.72	10	5.58	10	5.98	10	*6.11*	10	5.46	10	5.64	10	6.53	10	6.00
11	5.28	11	*5.57*	11	5.99	11	5.64	11	6.06	11	6.42	11	5.64	11	5.67	11	*6.70*	11	6.04
12	5.51	12	*5.87*	12	6.01	12	5.87	12	6.11	12	6.48	12	5.91	12	5.94	12	7.00	12	6.17
13	5.67	13	6.25	13	6.03	13	5.91	13	6.16	13	6.55	13	5.99	13	5.98	13	7.17	13	6.17
14	5.79	14	6.34	14	6.05	14	6.04	14	6.17	14	6.70	14	6.09	14	6.13	14	7.22	14	6.20
15	5.81	15	6.51	15	6.10	15	6.25	15	6.29	15	6.79	15	6.11	15	6.13	15	7.25	15	6.21
16	5.88	16	6.52	16	*6.17*	16	6.29	16	6.34	16	6.80	16	6.23	16	6.39	16	7.30	16	6.24
17	5.90	17	6.54	17	6.47	17	6.31	17	6.36	17	6.81	17	6.30	17	6.42	17	7.33	17	6.25
18	6.00	18	6.71	18	6.59	18	6.34	18	6.36	18	6.84	18	6.30	18	6.52	18	7.41	18	6.35
19	6.01	19	6.85	19	6.62	19	6.38	19	6.45	19	6.96	19	6.41	19	6.55	19	7.45	19	6.36
20	6.04	20	6.87	20	6.67	20	6.47	20	6.46	20	6.98	20	6.44	20	6.58	20	7.49	20	6.38
21	6.06	21	6.88	21	6.70	21	6.48	21	6.58	21	6.98	21	6.47	21	6.60			21	6.43
22	6.13	22	6.95	22	6.89	22	6.60	22	6.66	22	7.05	22	6.48	22	6.64			22	6.49
23	6.13	23	6.96	23	6.93	23	6.73	23	6.66	23	7.06	23	6.51	23	6.65			23	6.61
24	6.22	24	6.97	24	7.00	24	6.74	24	6.74	24	7.23	24	6.54	24	6.68			24	6.62
25	6.27	25	7.04	25	7.01	25	6.82	25	6.78	25	7.26	25	6.56	25	6.68			25	6.63
26	6.32	26	7.13	26	7.02	26	6.87	26	6.82	26	7.28	26	6.57	26	6.77			26	6.64
27	6.38	27	7.16	27	7.02	27	6.90	27	6.85	27	7.33	27	6.58	27	6.77			27	6.64
28	6.38	28	7.16	28	7.03	28	6.96	28	6.87	28	7.38	28	6.58	28	6.84			28	6.66
29	6.40	29	7.19	29	7.04	29	7.00	29	6.87	29	7.47	29	6.59	29	6.90			29	6.69
30	6.40	30	7.21	30	7.06	30	7.02	30	7.00	30	7.48	30	6.60	30	6.95			30	6.71
31	6.56	31	7.23	31	7.08	31	7.02	31	7.02			31	6.63	31	7.07			31	6.74
32	6.68	32	7.25	32	7.19	32	7.08	32	7.04			32	6.66	32	7.14			32	6.81
33	6.70	33	7.26	33	7.23	33	7.09	33	7.12			33	6.69	33	7.19			33	6.82
34	6.71	34	7.27	34	7.27	34	7.10	34	7.17			34	6.75	34	7.21			34	6.85
35	6.76	35	7.27	35	7.29	35	7.12	35	7.23			35	6.77	35	7.23			35	6.86
36	6.77	36	7.28	36	7.31	36	7.13	36	7.24			36	6.80	36	7.23			36	6.88
37	6.79	37	7.32	37	7.33	37	7.23	37	7.35			37	6.81	37	7.25			37	6.89
38	6.83	38	7.34	38	7.34	38	7.27	38	7.37			38	6.82	38	7.26			38	6.89
39	6.84	39	7.35	39	7.37	39	7.29	39	7.38			39	6.84	39	7.26			39	6.92
40	6.87	40	7.36	40	7.37	40	7.30	40	7.39			40	6.86	40	7.27			40	6.95
41	6.89	41	7.41	41	7.38	41	7.32	41	7.47			41	6.86	41	7.27			41	6.97
42	6.94	42	7.42	42	7.41	42	7.33	42	7.48			42	6.89	42	7.30			42	6.98
43	6.95	43	7.43	43	7.43	43	7.34	43	7.49			43	6.93	43	7.33			43	6.99
44	6.96	44	7.44	44	7.44	44	7.42	44	7.49			44	6.95	44	7.43			44	7.01
45	6.96	45	7.47	45	7.45	45	7.42	45	7.50			45	6.95	45	7.44			45	7.03
46	7.01	46	7.48	46	7.45	46	7.43	46	7.50			46	6.98	46	7.46			46	7.05
47	7.03	47	7.48	47	7.46	47	7.44					47	6.98	47	7.47			47	7.08
48	7.04	48	7.50	48	7.46	48	7.44					48	7.01	48	7.48			48	7.12
49	7.12	49	7.50	49	7.49	49	7.44					49	7.16	49	7.50			49	7.12
50	7.14					50	7.47					50	7.19					50	7.14
51	7.15					51	7.47					51	7.20					51	7.17
52	7.17											52	7.21					52	7.27
53	7.21											53	7.24					53	7.28
54	7.22											54	7.24					54	7.30
56	7.25											60	7.27					56	7.32
63	7.30											61	7.31					57	7.37
66	7.38											67	7.37					59	7.40
67	7.43											68	7.40					61	7.43
70	7.45											71	7.46					64	7.45
73	7.49											76	7.50					65	7.47

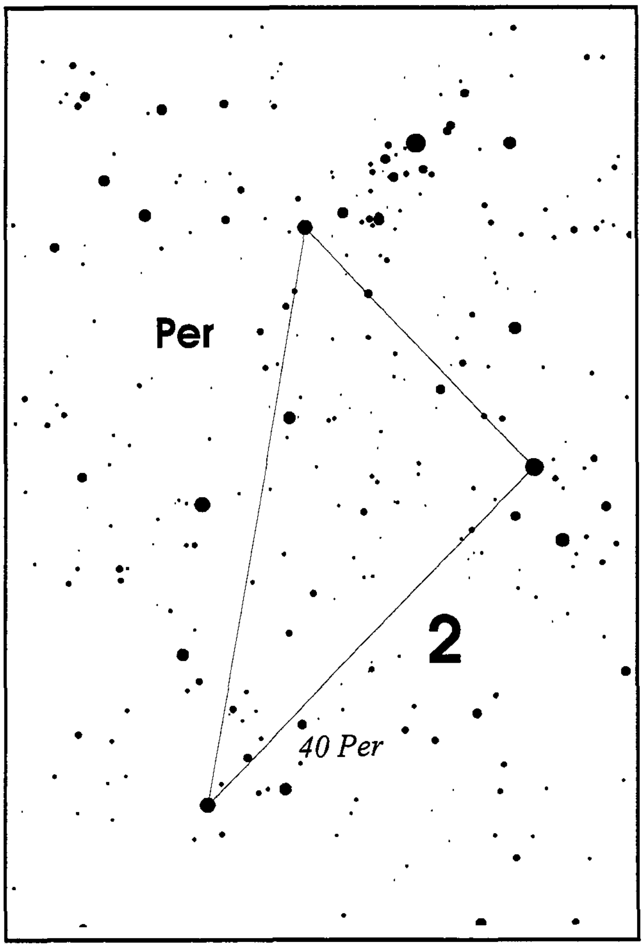
Table 1 – Conversion table for all 30 limiting-magnitude areas (continued).

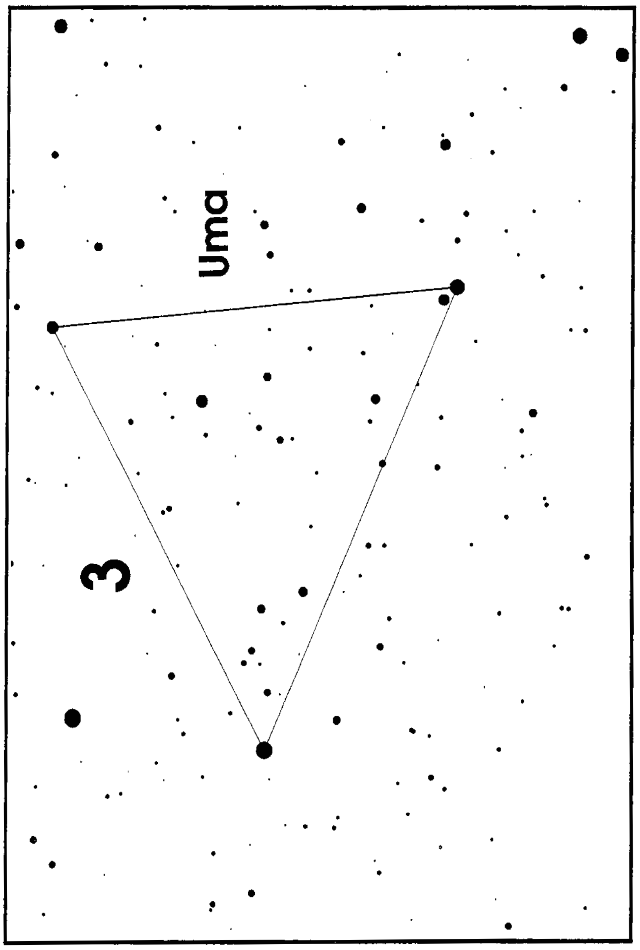
21		22		23		24		25		26		27		28		29		30	
N	Lm	N	Lm	N	Lm	N	Lm	N	Lm	N	Lm	N	Lm	N	Lm	N	Lm	N	Lm
1	1.23	1	0.28	1	2.59	1	2.61	1	1.07	1	-0.01	1	0.64	1	1.67	1	2.82	1	1.92
2	3.27	2	2.84	2	2.66	2	2.75	2	2.29	2	1.91	2	1.31	2	1.95	2	2.86	2	2.86
3	3.68	3	3.29	3	2.97	3	3.28	3	3.96	3	2.84	3	1.58	3	2.25	3	3.26	3	3.42
4	3.96	4	3.87	4	3.01	4	3.92	4	5.26	4	2.88	4	1.65	4	3.84	4	4.08	4	3.65
5	4.48	5	4.28	5	5.21	5	4.56	5	5.40	5	3.76	5	4.31	5	3.96	5	4.69	5	3.95
6	4.72	6	4.43	6	5.81	6	5.19	6	*5.50*	6	3.85	6	4.56	6	4.00	6	4.74	6	4.23
7	5.54	7	4.47	7	*5.95*	7	5.64	7	5.84	7	4.11	7	4.59	7	4.33	7	5.51	7	4.76
8	*5.66*	8	4.78	8	6.40	8	*5.72*	8	5.92	8	4.85	8	4.61	8	5.46	8	5.57	8	4.86
9	*5.98*	9	5.46	9	6.62	9	6.08	9	6.00	9	5.08	9	4.69	9	5.54	9	*5.67*	9	5.12
10	6.28	10	5.49	10	6.84	10	6.14	10	6.09	10	5.10	10	4.92	10	5.78	10	5.99	10	5.15
11	6.30	11	5.68	11	7.06	11	6.15	11	6.15	11	5.11	11	5.50	11	*5.79*	11	6.09	11	5.18
12	*6.35*	12	5.68	12	7.25	12	6.17	12	6.32	12	5.17	12	5.75	12	6.36	12	6.36	12	5.61
13	6.79	13	5.69	13	7.30	13	6.19	13	6.41	13	5.18	13	5.82	13	6.36	13	6.43	13	5.62
14	6.82	14	5.72	14	7.41	14	6.41	14	6.47	14	5.29	14	6.04	14	6.49	14	6.57	14	5.76
15	6.97	15	5.82	15	7.44	15	6.46	15	6.56	15	5.50	15	6.20	15	6.54	15	6.59	15	5.92
16	7.05	16	5.96	16	7.44	16	6.50	16	6.56	16	5.72	16	6.20	16	6.63	16	6.65	16	6.09
17	7.25	17	5.96	17	7.46	17	6.63	17	6.62	17	5.75	17	6.23	17	6.72	17	6.66	17	6.22
18	7.42	18	6.05			18	6.64	18	6.85	18	5.77	18	6.42	18	6.85	18	6.69	18	6.22
19	7.45	19	6.15			19	6.67	19	6.90	19	5.89	19	6.61	19	6.90	19	6.69	19	6.28
20	7.46	20	6.23			20	6.75	20	6.97	20	5.89	20	6.61	20	6.93	20	6.71	20	6.33
21	7.48	21	6.27			21	6.76	21	6.98	21	5.95	21	6.66	21	6.99	21	6.77	21	6.35
22	7.50	22	6.35			22	6.76	22	7.01	22	5.95	22	6.69	22	7.04	22	6.81	22	6.36
		23	6.40			23	6.80	23	7.07	23	6.02	23	6.73	23	7.08	23	6.84	23	6.40
		24	6.42			24	6.87	24	7.13	24	6.07	24	6.74	24	7.14	24	6.85	24	6.50
		25	6.46			25	6.94	25	7.14	25	6.12	25	6.75	25	7.15	25	6.86	25	6.59
		26	6.47			26	7.07	26	7.15	26	6.14	26	6.92	26	7.16	26	6.88	26	6.70
		27	6.54			27	7.14	27	7.26	27	6.16	27	6.93	27	7.18	27	6.89	27	6.70
		28	6.68			28	7.16	28	7.40	28	6.17	28	6.96	28	7.19	28	6.89	28	6.73
		29	6.71			29	7.19	29	7.46	29	6.20	29	6.98	29	7.25	29	6.91	29	6.77
		30	6.73			30	7.20			30	6.20	30	7.07	30	7.29	30	6.94	30	6.83
		31	6.75			31	7.22			31	6.21	31	7.11	31	7.31	31	7.01	31	6.84
		32	6.76			32	7.24			32	6.22	32	7.13	32	7.37	32	7.09	32	6.86
		33	6.96			33	7.25			33	6.25	33	7.19	33	7.38	33	7.09	33	6.87
		34	7.02			34	7.29			34	6.25	34	7.19	34	7.38	34	7.10	34	6.91
		35	7.04			35	7.29			35	6.30	35	7.21	35	7.38	35	7.13	35	6.92
		36	7.12			36	7.32			36	6.31	36	7.24	36	7.38	36	7.19	36	6.92
		37	7.14			37	7.35			37	6.33	37	7.26	37	7.44	37	7.22	37	6.97
		38	7.14			38	7.37			38	6.39	38	7.27	38	7.45	38	7.22	38	7.00
		39	7.21			39	7.38			40	6.42	39	7.29	39	7.46	39	7.23	39	7.03
		40	7.21			40	7.41			41	6.48	40	7.31			40	7.24	40	7.09
		41	7.22			41	7.46			43	6.50	41	7.37			41	7.26	41	7.10
		42	7.28			42	7.49			47	6.57	42	7.38			42	7.27	42	7.10
		43	7.32			43	7.50			49	6.61	43	7.40			43	7.29	43	7.12
		44	7.32							50	6.70	44	7.45			44	7.30	44	7.15
		45	7.33							53	6.75	45	7.50			45	7.30	45	7.18
		46	7.34							54	6.81					46	7.32	46	7.20
		47	7.34							58	6.85					47	7.32	47	7.21
		48	7.37							64	6.90					48	7.37	48	7.23
		49	7.38							66	6.95					49	7.37	49	7.24
		50	7.38							70	7.00					50	7.37	50	7.24
		51	7.41							75	7.05					51	7.38	51	7.27
		52	7.42							76	7.10					52	7.39	52	7.35
		53	7.43							81	7.14					53	7.41	53	7.36
		54	7.43							83	7.20					54	7.46	54	7.41
		55	7.45							86	7.24					55	7.47	55	7.44
		56	7.45							90	7.29					56	7.50	56	7.44
		57	7.47							92	7.34					57	7.50	57	7.47
		58	7.48							97	7.40							58	7.48
										102	7.45							59	7.50
										106	7.50							60	7.50

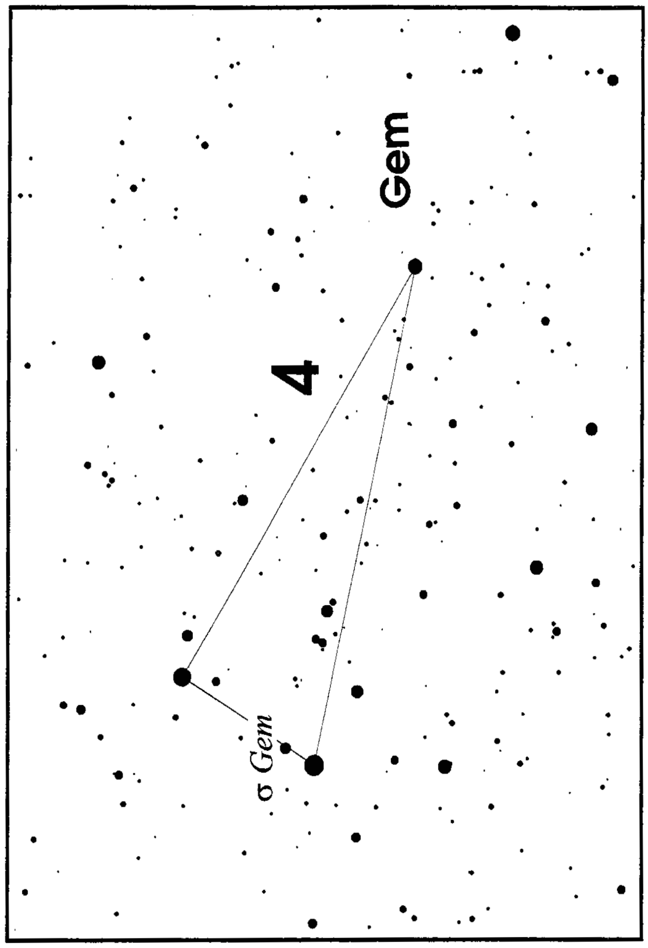
Table 2 –Limiting magnitude areas for the entire celestial sphere. Some additional remarks are given concerning the changes compared with the old tables.

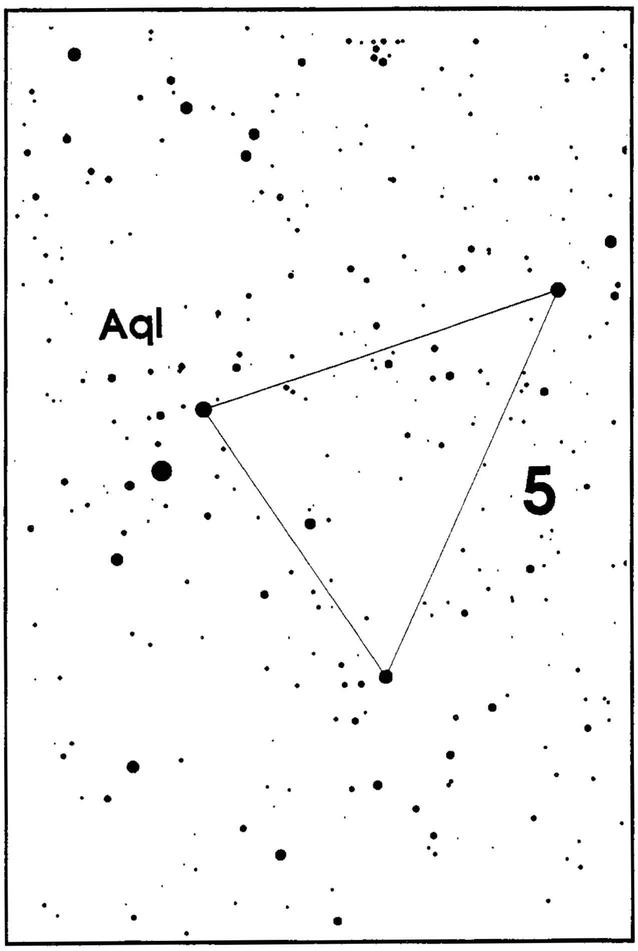
Field	Corner stars	Remarks
1	χ Dra – ζ Dra – δ Dra – ξ Dra	good agreement in full range
2	β Per – δ Per – ζ Per	40 Per now excluded, also a few fainter ones
3	23 UMa – ϑ UMa – β UMa	good agreement in full range
4	α Gem – ε Gem – β Gem	σ Gem now excluded
5	ζ Aql – γ Aql – δ Aql	larger gaps: 6.02–6.31 and 6.36–6.71
6	α And – γ Peg – α Peg	good agreement up to +6.8
7	α Cep – β Cep – δ Cep	3 stars with more than $0^{m}_{.}2$ difference; good agreement
8	α Tau – β Tau – ζ Tau	differences in range 5.5–6.0 and > 6.5
9	α Leo – β Leo – γ Leo – δ Leo	86 Leo excluded; good agreement
10	α Vir – ζ Vir – γ Vir	good agreement in full range
11	α CrB – γ Boo – α Boo	good agreement in full range
12	α Ser – β Lib – δ Oph	ε Ser now excluded, whence gap 5.87–6.25 shifted
13	β Lyr – ζ Lyr – ϑ Her – ν Her	good agreement in full range
14	ε Cyg – η Cyg – γ Cyg	Lm now generally higher with several close stars combined
15	β Dra – τ Her – π Her	good agreement in full range
16	α CVn – ε UMa – η UMa	larger gap 6.11–6.42; mediocre agreement
17	ε Aur – ϑ Aur – δ Aur	β Aur, π Aur, ϱ Aur included; very good agreement
18	μ And – γ And – φ And	good agreement for > 6.3
19	κ Dra – α Dra – β UMi	severe differences for > 6.0
20	42 Cam – β Cam – γ Cam	17 Cam included; 36 Cam excluded; mediocre agreement
21	α PsA – 98 Aqr – δ Aqr	77 Aqr included
22	β Lep – β Ori – 53 Eri	
23	δ Crv – γ Crv – ε Crv – β Crv	
24	β Lib – γ Lib – σ Lib – α Lib	34 Lib excluded
25	α Sco – ε Sco – χ Lup	τ Sco now excluded; d Sco excluded
26	γ TrA – α TrA – η Ara – α Cen	
27	β Cen – α Cru – γ Cru	
28	β Car – ε Car – ι Car	
29	γ Hyi – α Hyi – β Hyi	
30	α Tuc – α Pav – ε Pav	

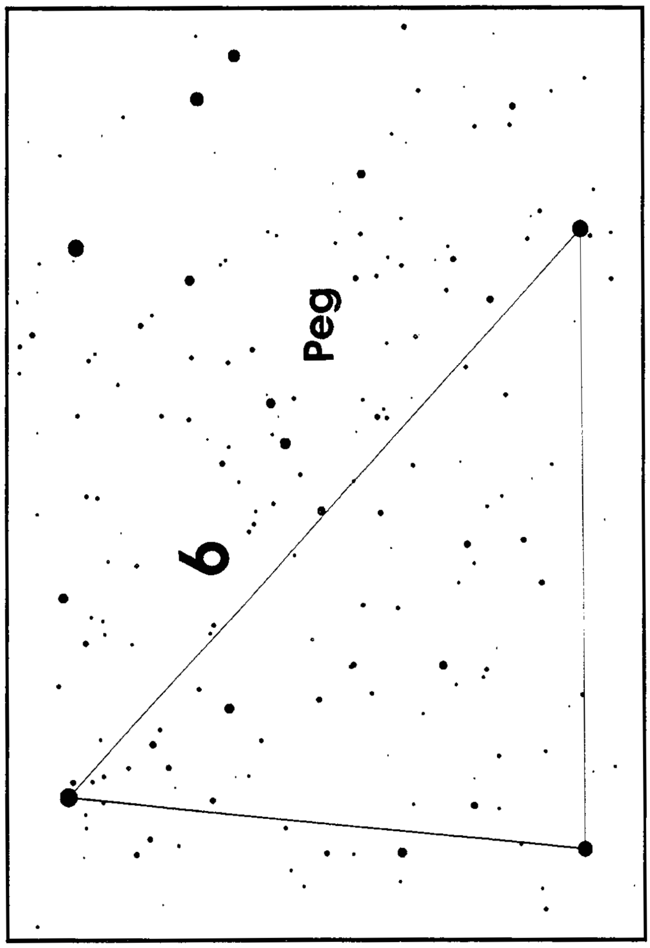


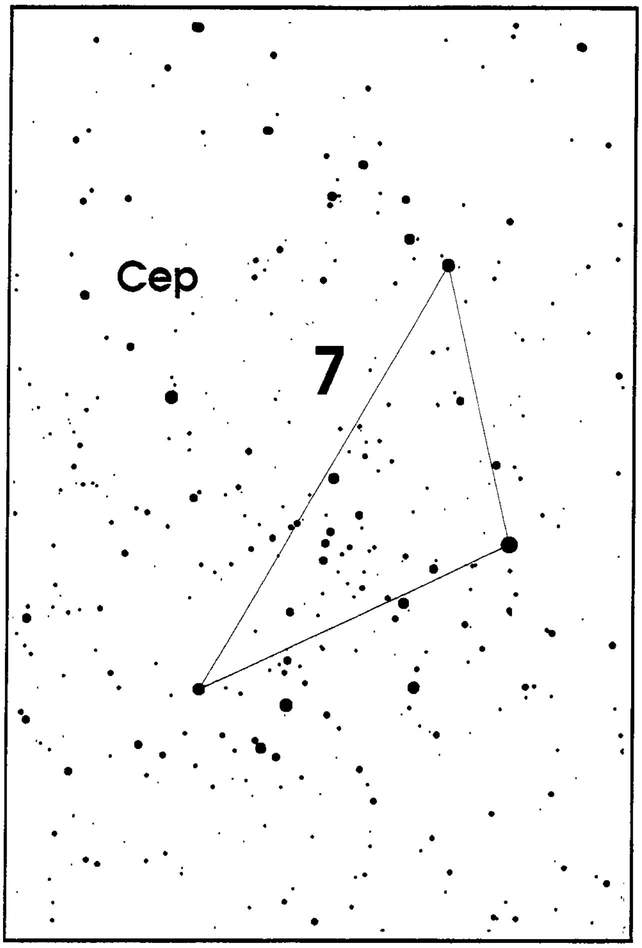


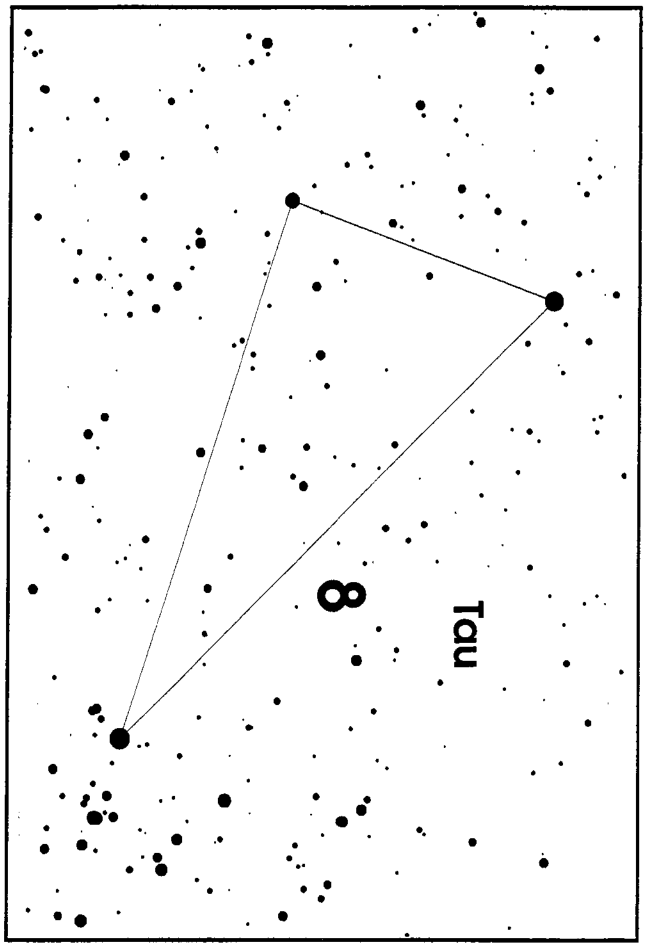

Uma
3

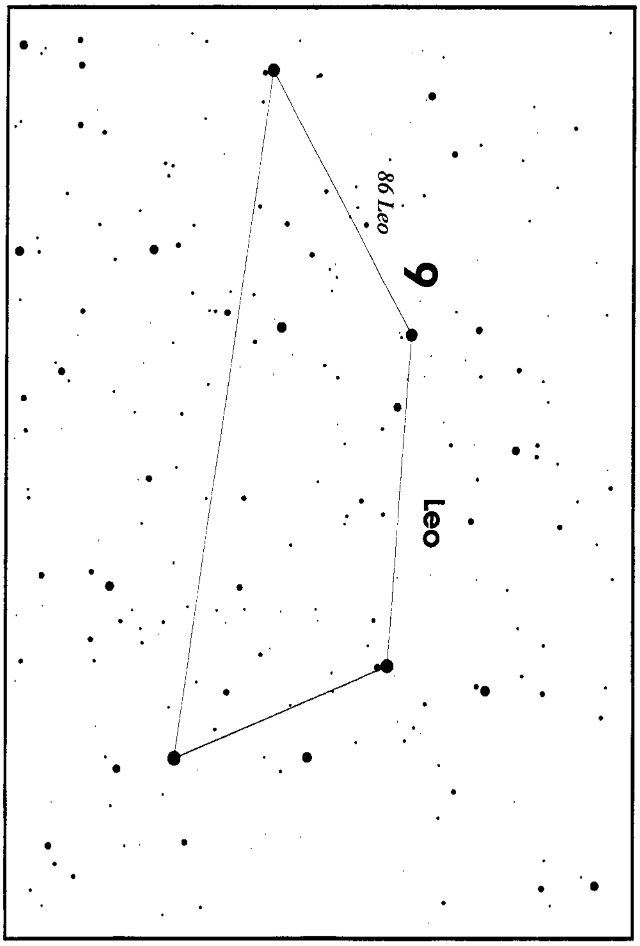

Gem
4
σ Gem

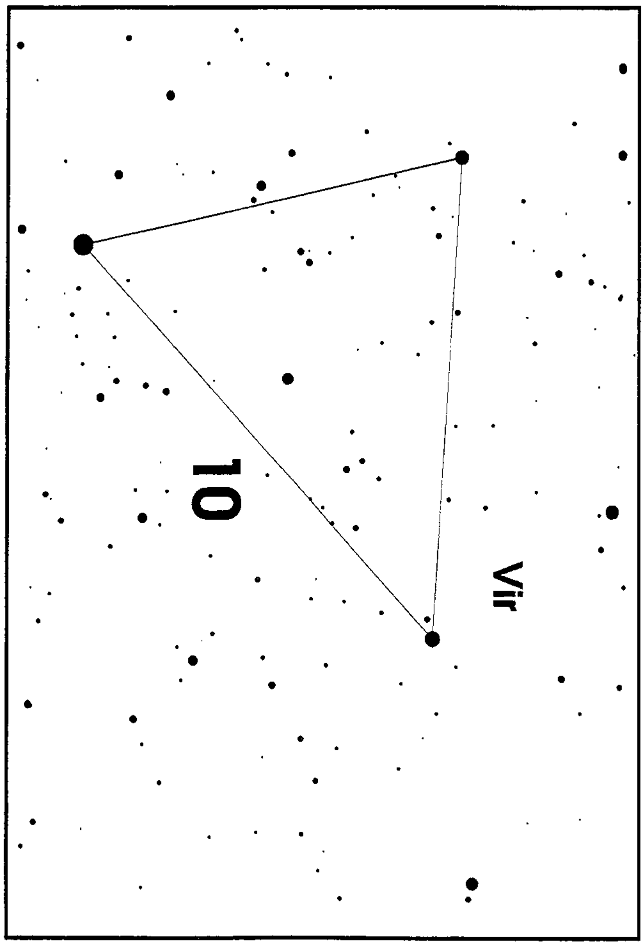

Aql
5

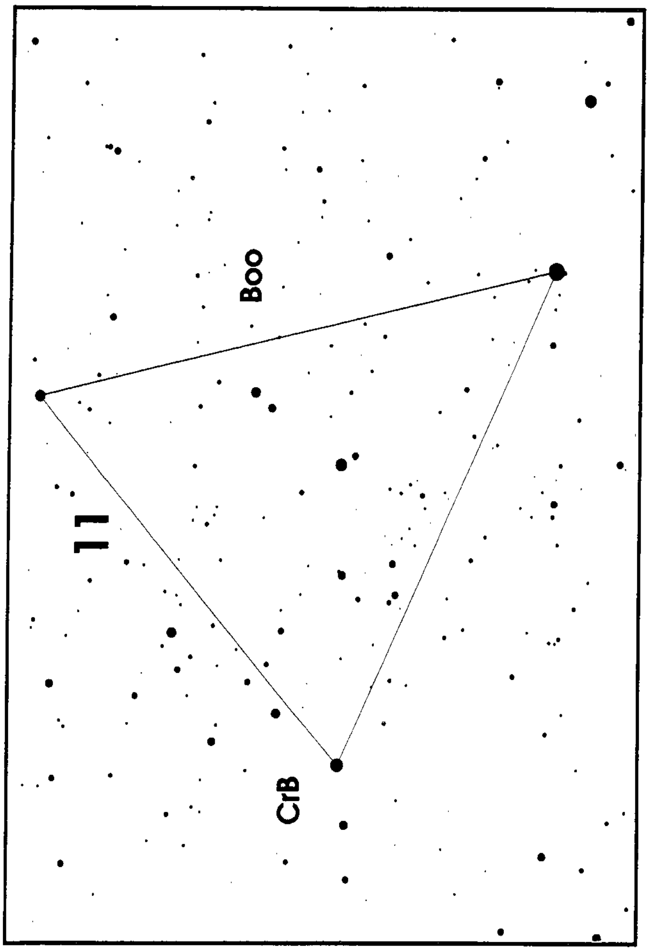

Peg
6

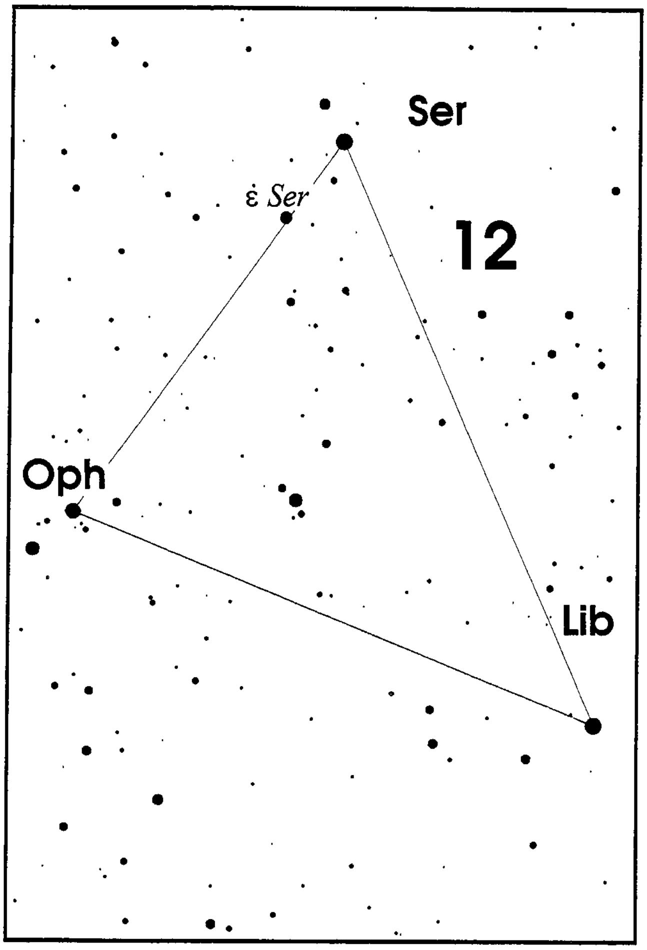

Cep
7

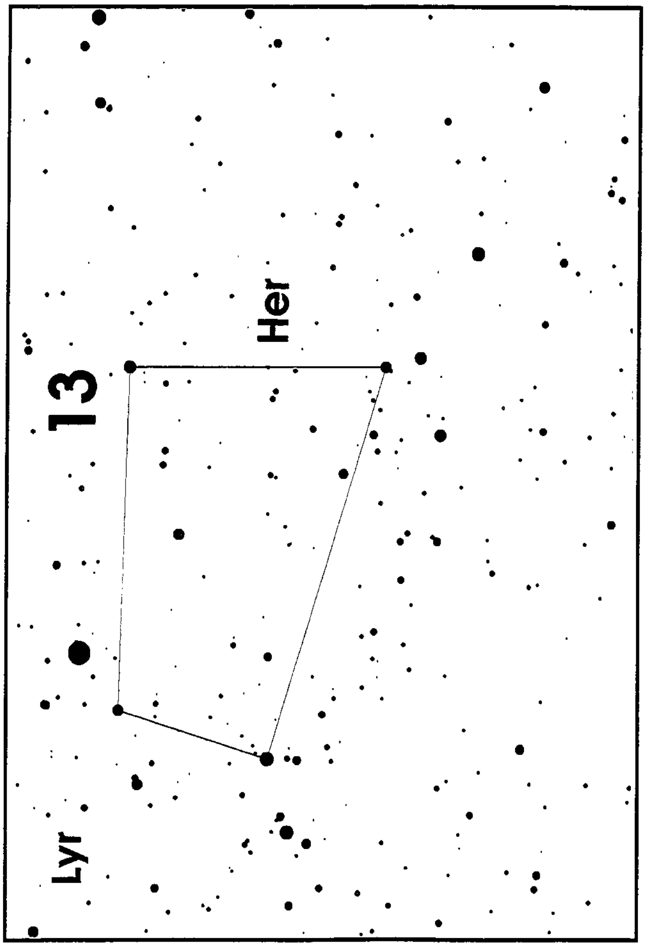

8
Tau

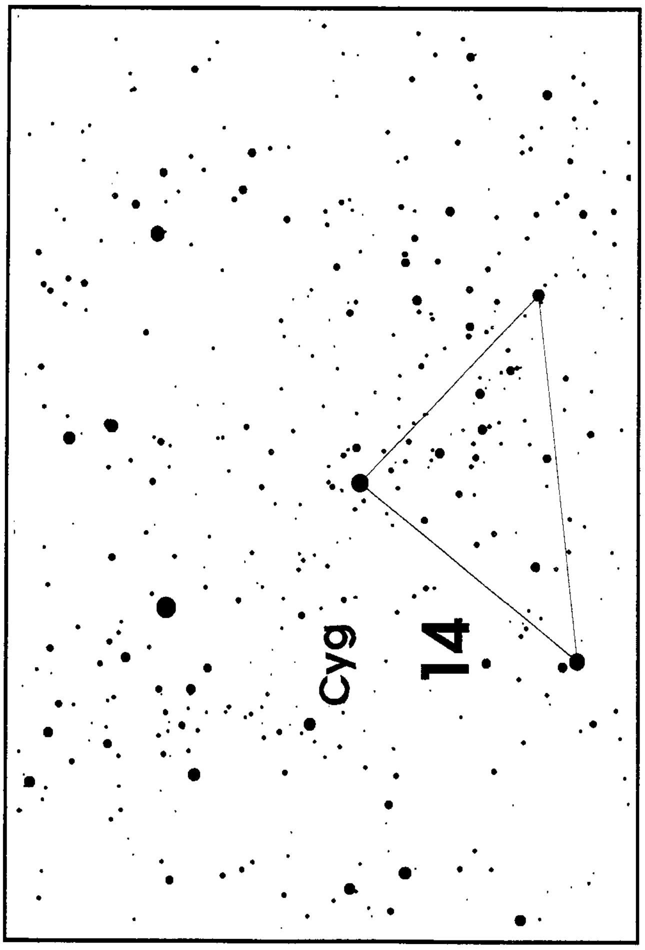

86 Leo
9
Leo

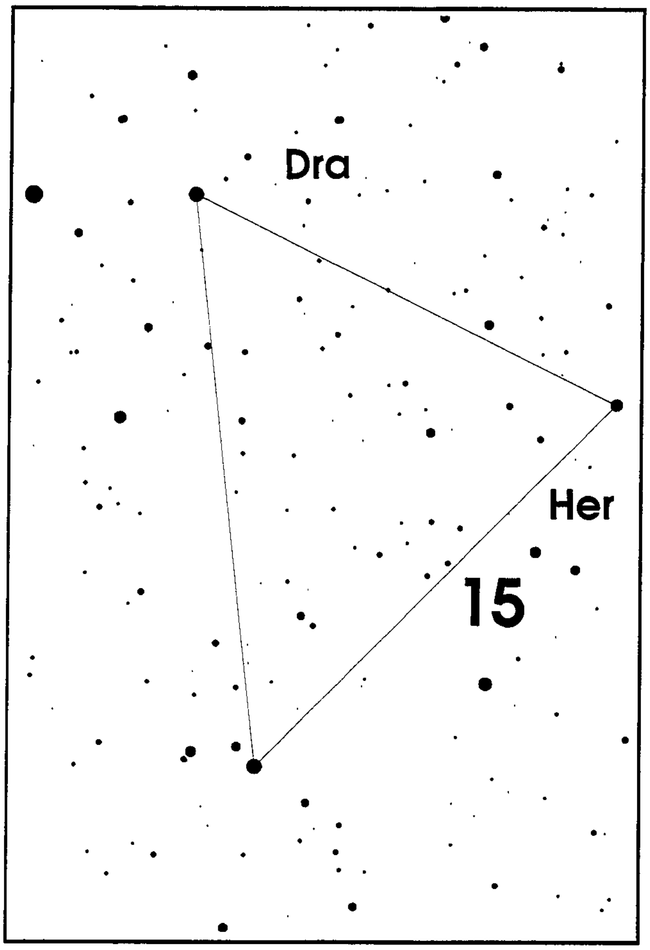

10
Vir

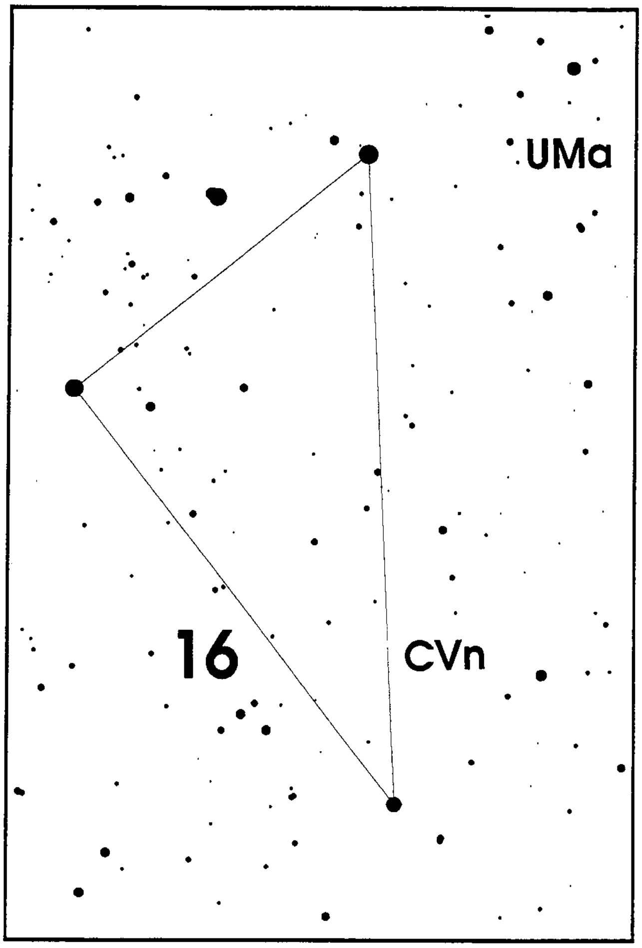

Boo
11
CrB

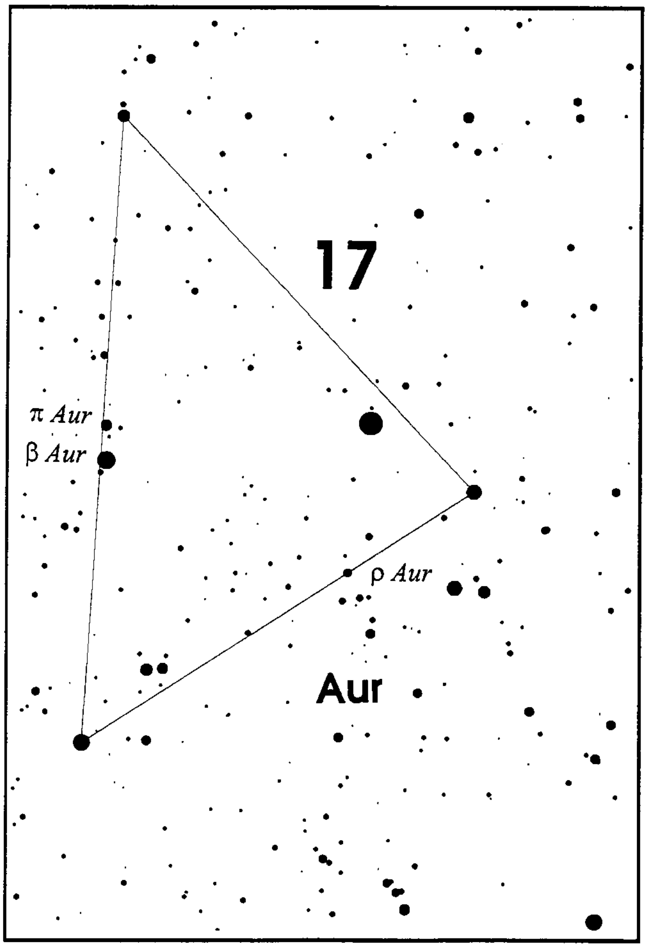

Ser
ε Ser
12
Oph
Lib

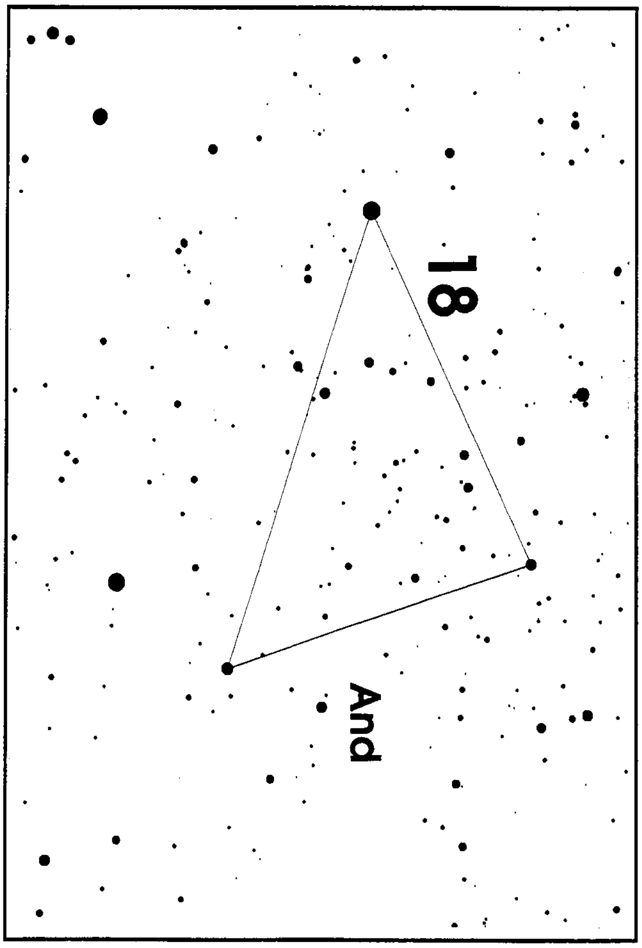

Her
13
Lyr

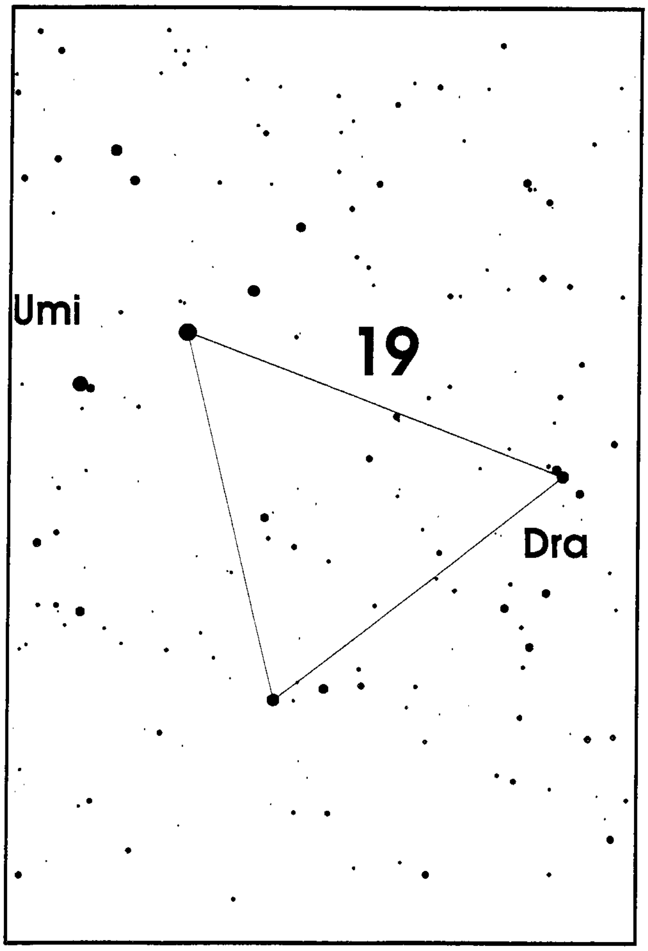

Cyg
14

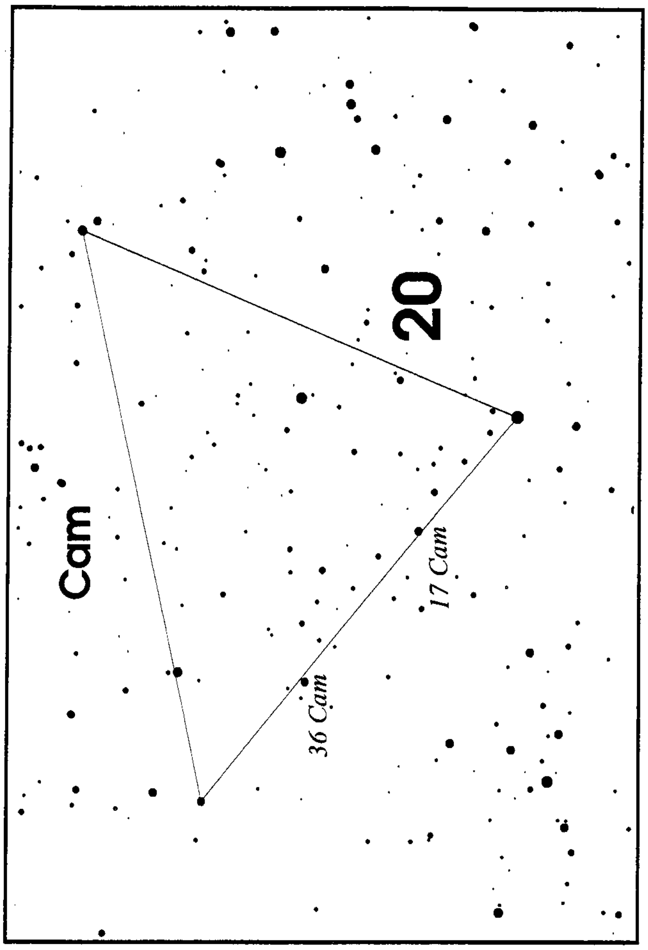

Dra
Her
15

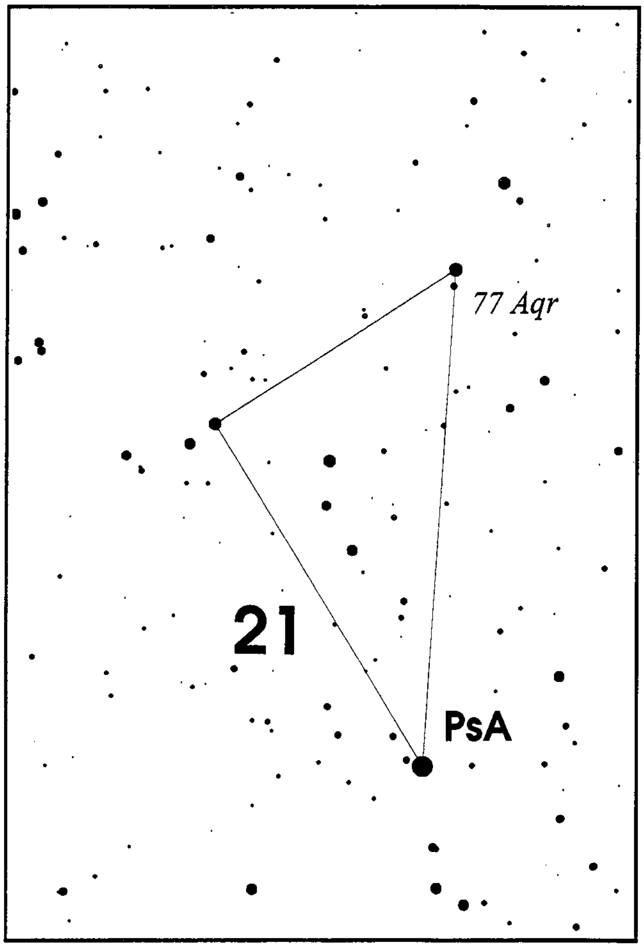

UMa
16
CVn

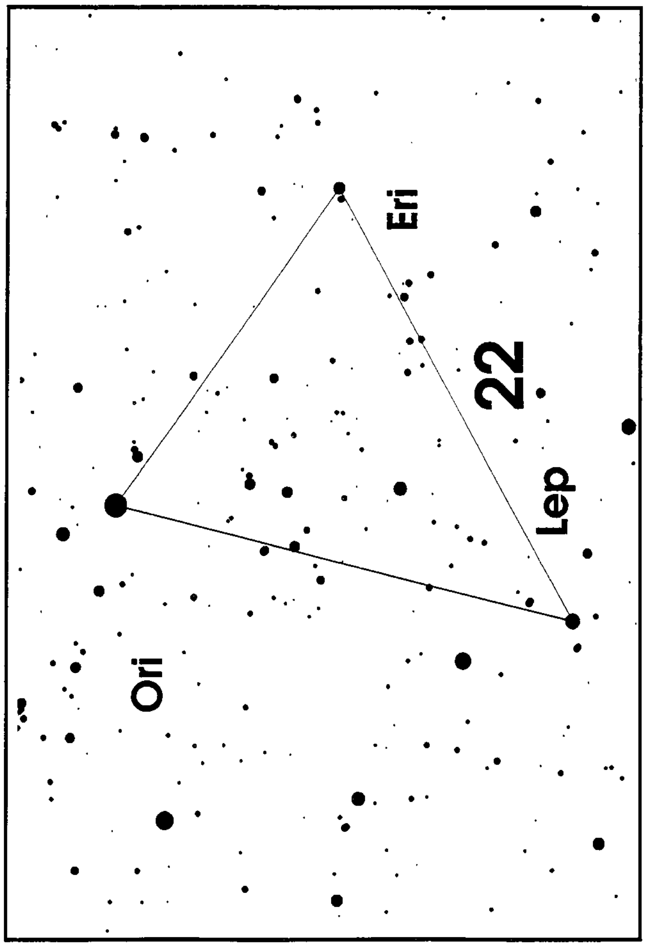

17
π Aur
β Aur
ρ Aur
Aur

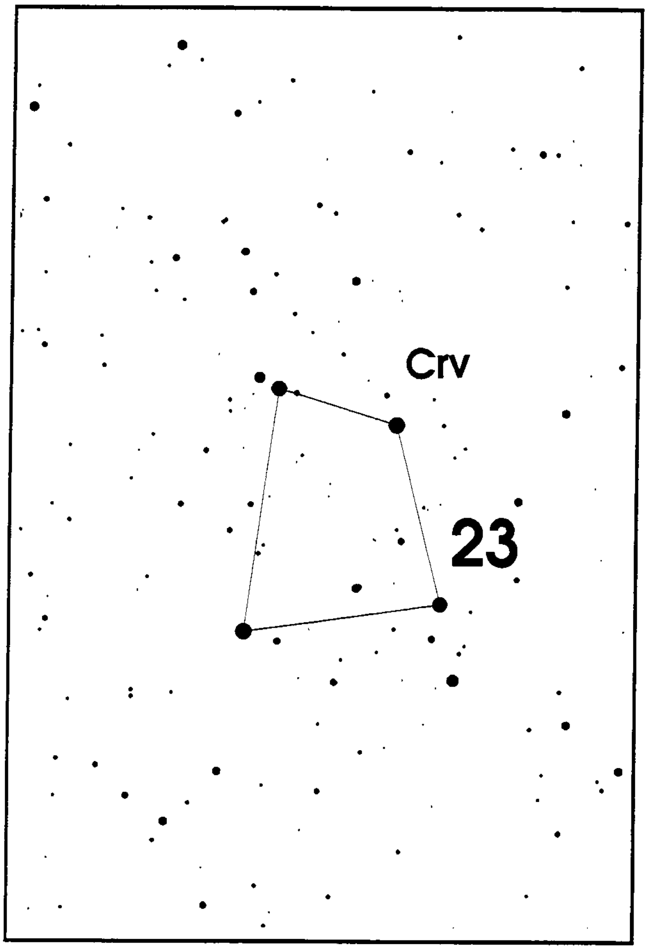

18
And

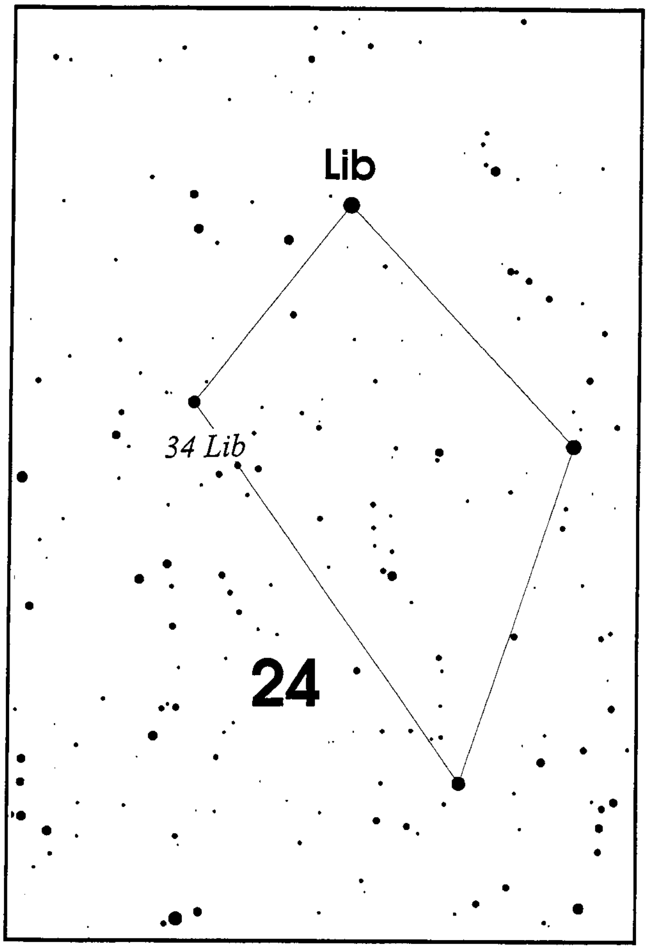

Umi
19
Dra

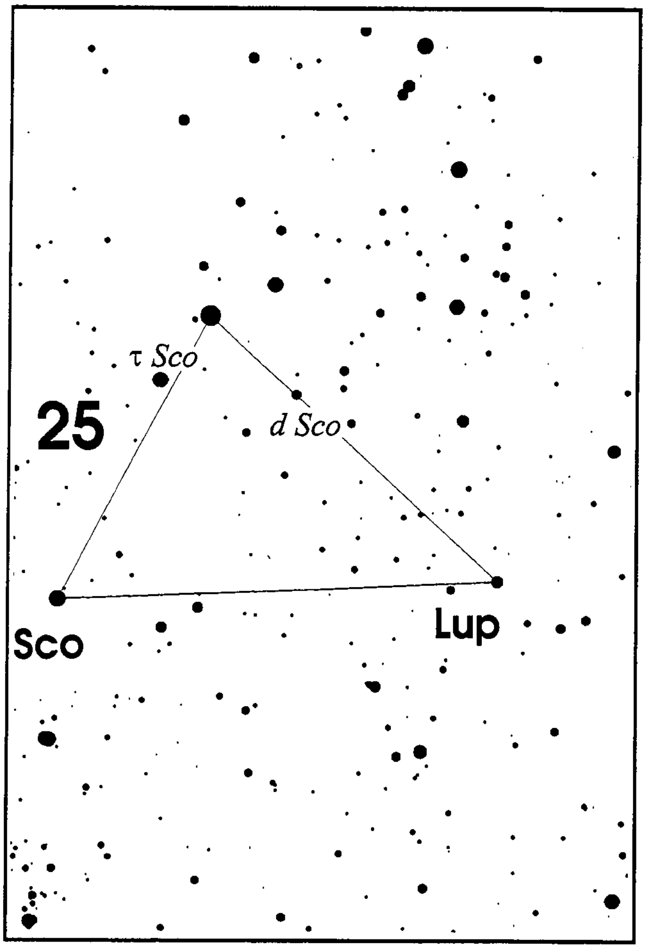

20
Cam
17 Cam
36 Cam

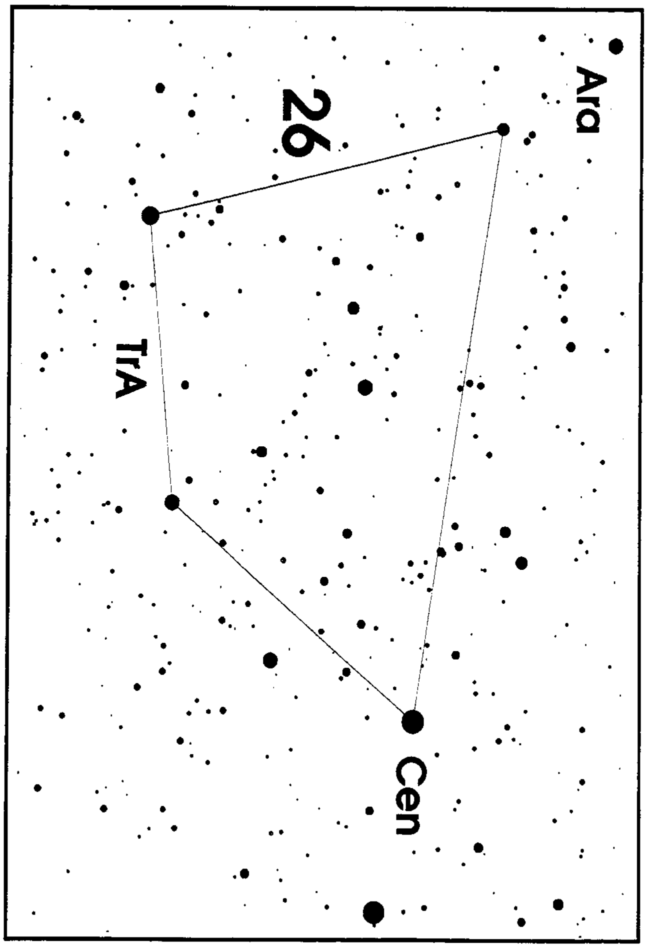

77 Aqr
21
PsA

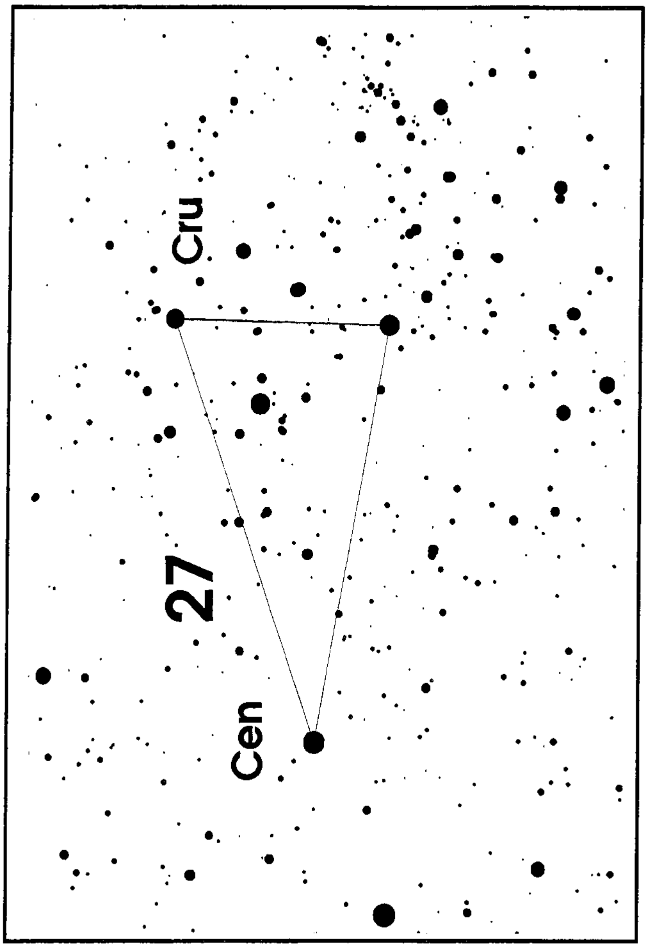

Eri
22
Lep
Ori

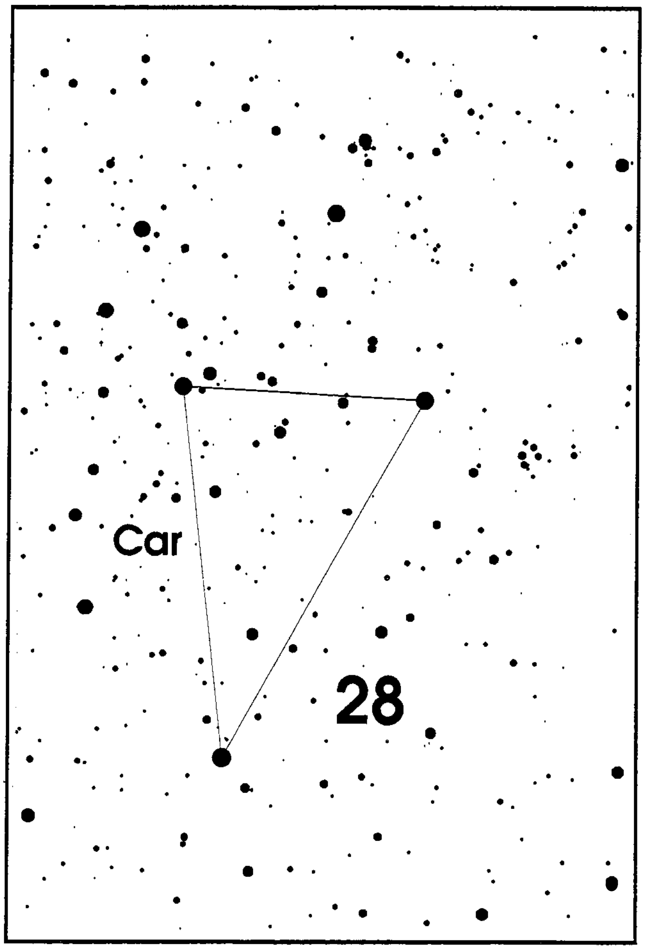

Crv
23

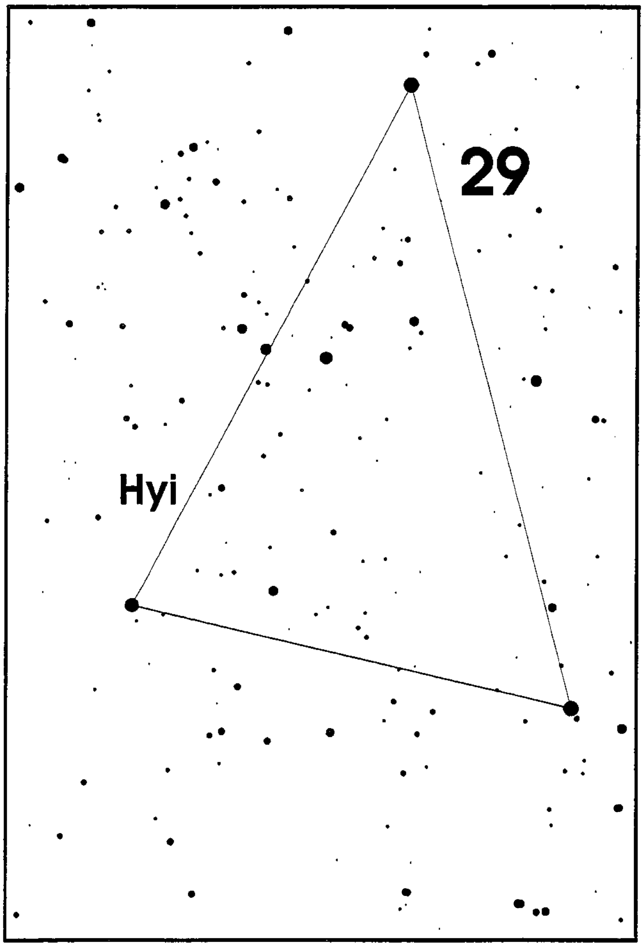

Lib
34 Lib
24

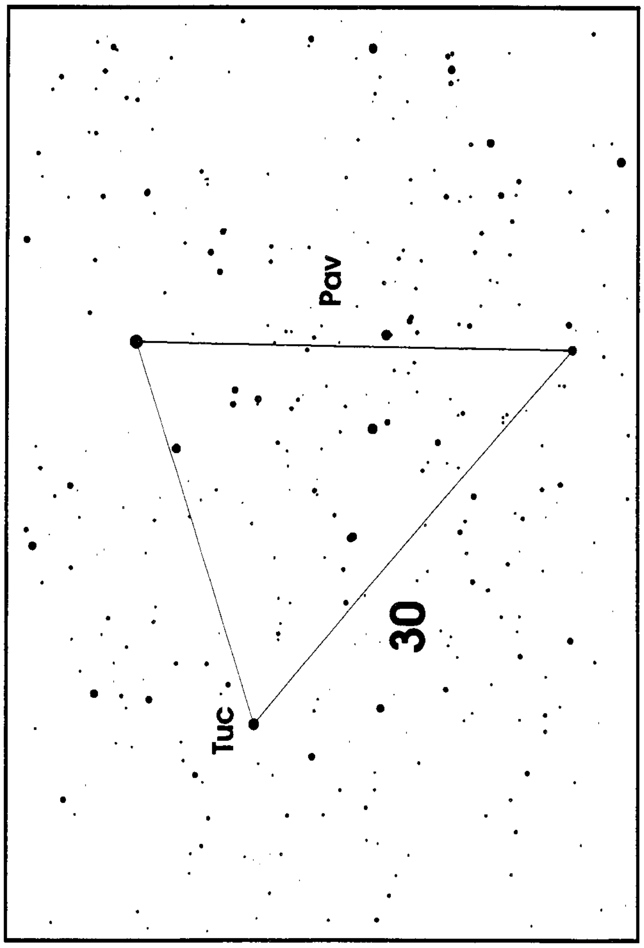

τ Sco
25
d Sco
Sco
Lup


26
Ara
TrA
Cen


Cru
27
Cen


Car
28


29
Hyi


Pav
30
Tuc

Meteor Shower Calendar: April–September 1999

compiled by Alastair McBeath

1. April to June

Meteor activity picks up towards the April-May boundary, with showers like the Lyrids, π-Puppids (maximum due around April 24, 2^h UT), and η-Aquarids (peak between May 5, 10^h UT and May 6, 11^h UT), with both these latter sources suffering from moonlight this year. During May and June, most of the activity is in the daytime sky, with six shower peaks expected during this time. Although a few shower members from the o-Cetids and Arietids have been reported from tropical and southern hemisphere sites visually in previous years, sensible activity calculations cannot be carried out from such observations. For radio observers, the expected UT maxima for these showers are as shown in Table 1.

Table 1 – Expected maxima in UT for radio observations of meteor showers in April–June, 1999.

Shower	Maximum	Shower	Maximum	Shower	Maximum
April Piscids	Apr 20, 10^h	May Arietids	May 16, 19^h	ζ-Perseids	Jun 09, 20^h
δ-Piscids	Apr 24, 19^h	o-Cetids	May 20, 17^h	β-Taurids	Jun 28, 20^h
ε-Arietids	May 09, 18^h	Arietids	Jun 07, 21^h		

The ecliptical complexes continue with some late Virginids and the best from the minor Sagittarids in May–June. Visual observers should also be alert for any possible June Lyrids this year.

Lyrids

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

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

As the shower's radiant rises during the night, watches can be carried out usefully from about 22^h30^m local time onwards. This year, the First-Quarter Moon sets around 1^h–2^h local time north of the equator, so will cause only slight problems in the early post-midnight period. The predicted maximum should favor sites in Eastern Russia and Asia if correct, but variations in the stream could mean this is not the case in actuality.

June Lyrids

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

This shower does not feature in the current *IMO Working List of Visual Meteor Showers*, as, apart from some activity seen from northern hemisphere sites in a few years during the 1960s (first seen 1966) and 1970s, evidence for its existence has been virtually zero since. In 1996, several observers independently reported some June Lyrids, however, and because the shower's probable maximum benefits from a waxing crescent Moon this year, we urge all observers who can to cover this possible stream. The radiant is a few degrees south of the bright star Vega (α Lyrae), so will be well on-view throughout the short northern summer nights, but there are discrepancies in its position in the literature. All potential June Lyrids should be carefully plotted, paying especial attention to the meteors' apparent velocity. Confirmation or denial of activity from this source in 1999 would be very useful.

2. July to September

Minor shower activity continues apace from near-ecliptic sources throughout this quarter, first from the Sagittarids, then the Aquarid and Capricornid showers, and finally the Piscids into September. The two strongest sources, the Southern δ-Aquarids (peak on July 28, 12^h UT) and the α-Capricornids (maximum July 30), are lost to July's Full Moon, along with the less-active Piscis Austrinids and the Southern ι-Aquarids. However, the Pegasids and Phoenicids in July, the Perseids in August, and the δ-Aurigids in September do much better. The Northern δ-Aquarid (around August 9) and κ-Cygnid (August 18) maxima should be good too, but the α-Aurigids (peak due around September 1, 12^h UT) are another lunar casualty, together with the most likely Piscid peak, on September 20.

For daylight radio observations, the interest of May–June has waned, but there remain the visually inaccessible γ-Leonids (peak due August 25, 21^h UT), and a tricky visual shower, the Sextantids (maximum expected September 27, 20^h UT). The latter has particular problems from the almost Full Moon, and rises less than an hour before dawn in either hemisphere anyway.

Pegasids

Active: July 7–13; Maximum: July 10 ($\lambda_\odot = 107.^\circ5$); ZHR = 3;
Radiant: $\alpha = 340^\circ$, $\delta = +15^\circ$; Radiant drift: see Table 3; $V_\infty = 70$ km/s; $r = 3.0$;
TFC: $\alpha = 320^\circ$, $\delta = +10^\circ$ and $\alpha = 332^\circ$, $\delta = +33^\circ$ ($\beta > 40^\circ$ N);
$\alpha = 357^\circ$, $\delta = +02^\circ$ ($\beta < 40^\circ$ N).

Monitoring this very short-lived minor shower is not easy, as a few cloudy nights mean its loss for visual observers, but with the Moon nearly New for its peak this year, everyone—particularly those in the northern hemisphere—should attempt to cover it. The shower is best-seen in the second half of the night, and the Moon will be only a slight distraction near dawn. The maximum ZHR is generally low, and swift, faint meteors can be expected. Telescopic observation would be especially useful.

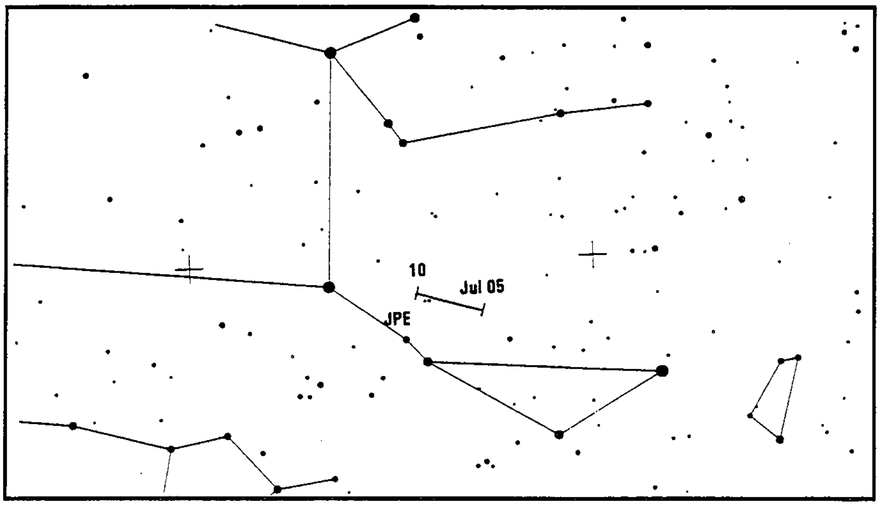


Figure 1 – Radiant position and drift of the Pegasids.

July Phoenicids

Active: July 10–16; Maximum: July 13 ($\lambda_\odot = 111^\circ$); ZHR: variable, 3–10, usually below 4;
Radiant: $\alpha = 32^\circ$, $\delta = -48^\circ$; Radiant drift: see Table 3; $V_\infty = 47$ km/s; $r = 3.0$;
TFC: $\alpha = 41^\circ$, $\delta = -39^\circ$ and $\alpha = 66^\circ$, $\delta = -62^\circ$ ($\beta < 10^\circ$ N).

This minor shower can be seen from the southern hemisphere, from where it only attains a reasonable elevation above the horizon after midnight. This is an ideal year to watch it, since New Moon falls perfectly for its expected peak. Activity can be quite variable visually, and indeed observations show it is a richer radio meteor source (possibly also telescopically too, but more results are needed). The peak has not been well-observed for some considerable time, though recent years have brought maximum ZHRs of under 4, when the winter weather has allowed any coverage at all. More data would be very welcome!

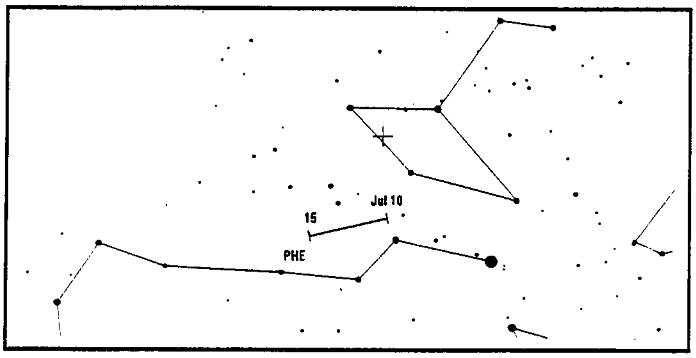


Figure 2 – Radiant position and drift of the the July Phoenicids.

Perseids

Active: July 17–August 24;
Maxima: August 12, 23^h UT ($\lambda_\odot = 139.^\circ81$) and 13, 5^h UT ($\lambda_\odot = 140.^\circ03$) and 13, 13^h UT ($\lambda_\odot = 140.^\circ35$);
ZHR: primary peak: variable, recently 120–160; secondary and tertiary peaks: 100;
Radiant: $\alpha = 46°$, $\delta = +58°$; Radiant drift: see Table 3; $V_\infty = 59$ km/s; $r = 2.6$;
TFC: $\alpha = 19°$, $\delta = +38°$ and $\alpha = 348°$, $\delta = +74°$ before 2^h local time;
$\alpha = 43°$, $\delta = +38°$ and $\alpha = 73°$, $\delta = +66°$ after 2^h local time ($\beta > 20°$ N)
PFC: $\alpha = 300°$, $\delta = +40°$, $\alpha = 0°$, $\delta = +20°$, or $\alpha = 240°$, $\delta = +70°$ ($\beta > 20°$ N).

Together with the Leonids, the Perseids have become the single most exciting and dynamic meteor shower in recent times, with outbursts producing ZHRs over 400 in 1991 and 1992, around 300 in 1993, 220 in 1994 and about 120–160 since, at the shower's primary maximum. Allowing for an average annual shift around $+0.^\circ05$ in solar longitude since 1991, this peak is expected to fall around 23^h UT on August 12. Other timing variations cannot be ruled out, however. A new feature in 1997 was a tertiary peak, of strength comparable to the traditional (currently secondary) maximum, but a few hours after it. The timing for this third peak is based on just this one return, whence there are no guarantees it will recur in 1999. Even now, as the Perseids' parent comet 109P/Swift-Tuttle returns to the outer Solar System after its 1992 perihelion passage, the shower can still spring surprises! The August New Moon provides the perfect opening for all watchers, certainly. As the radiant rises throughout the night for the northern hemisphere, near- and post-midnight watching is most valuable. If the maxima appear as predicted the places to be should be Europe; Eastern North America; Far Eastern Siberia, Alaska and the Northern Pacific Ocean, respectively.

Visual and photographic observers should need little encouragement to cover this stream, but telescopic watching near the main peak would be valuable in confirming or clarifying the possibly multiple nature of the Perseid radiant, something not detectable visually. Video observations would be very helpful in this respect, too. Radio data would naturally enable early confirmation, or detection, of a perhaps otherwise unobserved outburst if the timing proves unsuitable for land-based sites. The only negative aspect to the shower is the impossibility of covering it from the bulk of the southern hemisphere.

δ-Aurigids

Active: September 5–October 10; Maximum: September 9 ($\lambda_\odot = 166°$); ZHR = 6;
Radiant: $\alpha = 60°$, $\delta = +47°$; Radiant drift: see Table 3; $V_\infty = 64$ km/s; $r = 3.0$;
TFC: $\alpha = 52°$, $\delta = +60°$, $\alpha = 43°$, $\delta = +39°$, or $\alpha = 23°$, $\delta = +41°$ ($\beta > 10°$ S).

This is an essentially northern hemisphere shower, badly in need of more observations. The δ-Aurigids are actually part of a series of showers with radiants in Aries, Perseus, Cassiopeia, and Auriga, active from late August into October. They typically produce low rates of generally faint meteors, and have yet to be well-seen in more than an occasional year. Circumstances are perfect for their peak in 1999, with New Moon on September 9. Telescopic data to examine all the radiants in this region of sky—and possibly observe the telescopic β-Cassiopeids simultaneously—would be especially useful, but photographs, video records, and visual plotting would be welcomed too. The δ-Aurigid radiant is at a useful elevation from roughly 23^h–24^h local time onwards, so protracted watching is distinctly possible.

3. Working list of meteor showers

Table 2 – Working list of meteor showers for the period April–September 1999. Streams marked with an asterisk are periodically or occasionally active. The "maximum" dates cited for the Virginids and the Puppid/Velids should be seen as reference dates rather than true maxima.

Shower	Activity	Maximum		Radiant		V_∞	r	ZHR
		Date	$\lambda_\odot$	α	δ	(km/s)		
Virginids (VIR)	Jan 25–Apr 15	Mar 25	4°	195°	−04°	30	3.0	5
Lyrids (LYR)	Apr 16–Apr 25	Apr 22	32°1	271°	+34°	49	2.9	15
π-Puppids* (PPU)	Apr 15–Apr 28	Apr 24	33°5	110°	−45°	18	2.0	
η-Aquarids	Apr 19–May 28	May 06	45°5	338°	−01°	66	2.7	60
Sagittarids (SAG)	Apr 15–Jul 15	May 20	59°	247°	−22°	30	2.5	5
Pegasids (JPE)	Jul 07–Jul 13	Jul 10	107°5	340°	+15°	70	3.0	3
Jul Phoenicids* (PHE)	Jul 10–Jul 16	Jul 13	111°	32°	−48°	47	3.0	
Piscis Austrinids	Jul 15–Aug 10	Jul 28	125°	341°	−16°	35	3.2	5
Southern δ-Aquarids (SDA)	Jul 12–Aug 19	Jul 28	125°	339°	−30°	41	3.2	20
α-Capricornids (CAP)	Jul 03–Aug 15	Jul 30	127°	307°	−10°	23	2.5	4
Southern ι-Aquarids (SIA)	Jul 25–Aug 15	Aug 04	132°	334°	−15°	34	2.9	2
Northern δ-Aquarids (NDA)	Jul 15–Aug 25	Aug 09	136°	335°	−05°	42	3.4	4
Perseids (PER)	Jul 17–Aug 24	Aug 12	140°0	46°	+58°	59	2.6	90
κ-Cygnids (KCG)	Aug 03–Aug 25	Aug 18	145°	286°	+59°	25	3.0	3
Northern ι-Aquarids (NIA)	Aug 11–Aug 31	Aug 20	147°	327°	−06°	31	3.2	3
α-Aurigids (AUR)	Aug 25–Sep 05	Sep 01	158°6	84°	+42°	66	2.5	10
δ-Aurigids (DAU)	Sep 05–Oct 10	Sep 09	166°	60°	+47°	64	3.0	6
Piscids (SPI)	Sep 01–Sep 30	Sep 20	177°	5°	−01°	26	3.0	3

Table 3 – Radiant positions during 1999 in α and δ.

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

4. Lunar phases

In Table 4, the dates for the lunar phases are the UT calendar dates in which these phases occur. As a consequence, there may be slight variances with tables that are based on local time.

Table 4 – Lunar phases for April–September 1999.

Phase	Calendar dates (UT) on which the phase occurs						
New Moon	Apr 16	May 15	Jun 13	Jul 13	Aug 11	Sep 09	Oct 09
First Quarter	Mar 24	Apr 22	May 22	Jun 20	Jul 20	Aug 19	Sep 17
Full Moon	Mar 31	Apr 30	May 30	Jun 28	Jul 28	Aug 26	Sep 25
Last Quarter	Apr 09	May 08	Jun 07	Jul 06	Aug 04	Sep 02	Oct 02

5. Daytime radio meteor streams

In the working list of daytime radio meteor streams (Table 5, below), the "Best Observed" columns give the approximate local mean times between which a four-element antenna at an elevation of 45° receiving a signal from a 30-kW transmitter 1000 km away should record at least 85% of any suitably positioned radio-reflecting meteor trails for the appropriate latitudes.

Note that this is often heavily dependent on the compass direction in which the antenna is pointing, however, and applies only to dates near the shower's maximum.

Table 5 – Working list of daytime radio meteor streams.

Shower	Activity	Max	$\lambda_\odot$	Radiant		Best Observed		Rate
		Date	2000.0	α	δ	50° N	35° S	
Piscids (Apr)	Apr 08–Apr 29	Apr 20	30°3	7°	+07°	07^h–14^h	08^h–13^h	low
δ-Piscids	Apr 24–Apr 24	Apr 24	34°2	11°	+12°	07^h–14^h	08^h–13^h	low
ε-Arietids	Apr 24–May 27	May 09	48°7	44°	+21°	08^h–15^h	10^h–14^h	low
Arietids (May)	May 04–Jun 06	May 16	55°5	37°	+18°	08^h–15^h	09^h–13^h	low
o-Cetids	May 05–Jun 02	May 20	59°3	28°	−04°	07^h–13^h	07^h–13^h	medium
Arietids	May 22–Jul 02	Jun 07	76°7	44°	+24°	06^h–14^h	08^h–12^h	high
ζ-Perseids	May 20–Jul 05	Jun 09	78°6	62°	+23°	07^h–15^h	09^h–13^h	high
β-Taurids	Jun 05–Jul 17	Jun 28	96°7	86°	+19°	08^h–15^h	09^h–13^h	medium
γ-Leonids	Aug 14–Sep 12	Aug 25	152°2	155°	+20°	08^h–16^h	10^h–14^h	low
Sextantids*	Sep 09–Oct 09	Sep 27	184°3	152°	00°	06^h–12^h	06^h–13^h	medium

More information on observing these and other showers can always be obtained by addressing you to the relevant *IMO* Commission. Addresses (including e-mail addresses) are mentioned on the inside back-cover.

From the Vice-President

Alastair McBeath

I have been seriously ill since December 21, 1998, and would like to apologize to all those people who have written to me since then for any delay they have had in receiving a reply. It may be some months before I will be well enough to respond to all the correspondence awaiting attention, and would be grateful if those who are expecting replies could please exercise patience in the interim.

I would like to apologize particularly for any problems caused to those people who sent IMO/WGN *Sterling renewal payments to me after this data, as not all of these have been processed as quickly as normal.*

1998 Leonids
Joint Efforts to Watch the Storm: International 1998 Leonid Expedition to Mongolia

Jürgen Rendtel and Sirko Molau

The 1998 Leonids probably caused the most numerous meteor expeditions and observing plans in the history of meteor astronomy so far. The reason was the anticipation of very high rates in the night of November 17-18, when the Earth crossed the orbital plane of 55P/Tempel-Tuttle. It was the first nodal crossing since the Leonids' parent comet passed its perihelion again, and it was one of the rare chances to possibly experience and investigate a real meteor storm.

According to several computer simulations and analyses of historical Leonid peak records, the most probable time for an activity outburst was November 17, between 18^h and 21^h UT. A suitable observing site had to fulfill some requirements: the radiant had to be at least 20° above the horizon during the given period, the Sun had to be well below the horizon, and the site had to be easily reachable. Furthermore, a plan had to be worked out to escape possible cloudy weather during the peak time. The astronomical conditions and the weather statistics put southeastern Siberia, Mongolia, and central China at the first places. During the preparation phase, which began in 1996, it turned out that the political conditions had changed quite rapidly in Mongolia, making travel into the country and within the country much easier than in the neighboring regions. As weather conditions were not significantly different in the three areas and all countries were practically unknown to us, we decided to concentrate our preparational efforts on Mongolia, in the vicinity of the capital Ulaanbaatar. We were in the lucky situation to visit Ulaanbaatar early September to prepare the November expedition on site. An agreement was established between the Mongolian *Research Center for Astronomy and Geophysics*, the Canadian *CresTech* and the German *Arbeitskreis Meteore (AKM)*. The Khurel Togoot Observatory was chosen as the main observing site. The preparations also included a detailed search for a second site some 50 km away and possibilities for an escape expedition with helicopters.

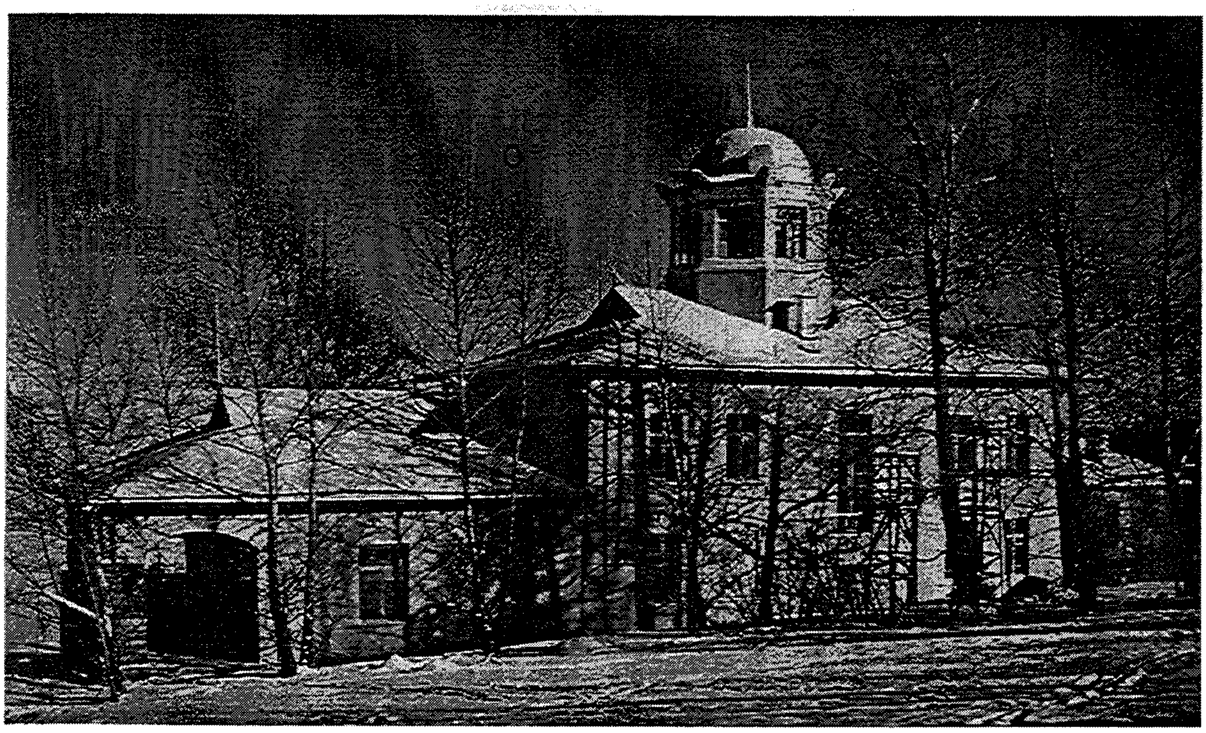


Figure 1 – Main building of the Khurel Togoot Observatory near Ulaanbaatar.

The major goals of the German *AKM* expedition included video, photographic, and visual observations. One intention was the comparison of video and visual data in order to calibrate the 1966 visual count estimates. For the same purpose, the METSIM software (Meteor storm simulation—available at the *IMO* Web site `http://www.imo.net`) was developed and used in advance. The main task of the video cameras was to gather flux and magnitude data over a large magnitude range. For this purpose, we used similar video cameras, equipped with different lenses. One intensified video camera was especially devoted to record persistent trains.

The Canadian/US group concentrated on accurate real-time flux measurements based on a battery of video systems. They operated a second site in parallel, useful to do triangulation from multi-station meteor records. Besides a number of persons doing visual observations and observing the control monitors, a computer-based meteor detection system was operated for test purposes.

The preparation tour to Mongolia in September reduced the tension for the participants very much, as we knew what to expect on arrival. On November 8, the 14 German *AKM* expedition members met at Berlin-Schönefeld airport with a huge amount of luggage, including special clothing for the expected low temperatures and observing equipment. Fortunately, our arrangements with MIAT Mongolian Airline proved to work fine, so that we were not charged for the extra luggage of the group. The first part of the journey led us to Frankfurt am Main, where we met most of the Canadian/US expedition members. After a non-stop flight of about 8 hours, we arrived at Ulaanbaatar in the early morning of November 9.

While the professionals started to unpack and prepare their camera systems at the observatory the next day, we made a five-day round trip to visit the capital and some famous Mongolian attractions, like the monastery Erdene Zuu close to the site of the old Mongolian capital, Kharhorin.

We lived in a remote ger camp (Figure 2) and met nomadic people (Figure 3) in their gers. It was surprisingly warm in the beginning of the tour. The Sun was shining and the snow disappeared soon. Being far from any light pollution, we also made a few meteor observations.

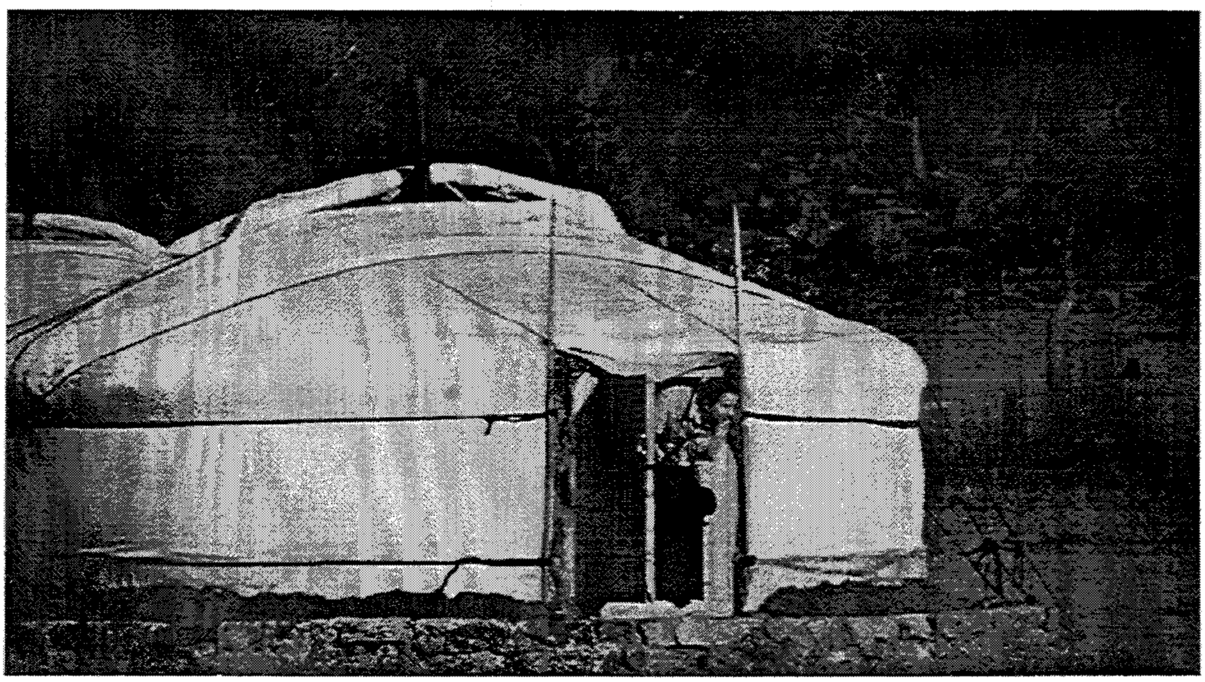


Figure 2 – For a few days, we stayed in traditional Mongolian gers. These tents are well-prepared for the cold climate and provide enough room for a Mongolian family.

Figure 3 – Mongolians love to ride their horses across the steppe, and, sometimes, they use their cars the same way...

The weather changed, however, when we returned to Ulaanbaatar: a snow front passed from the northwest, followed by a clear and cold Siberian air mass. The temperatures dropped rapidly and fell below $-30°$ C in the nighttime over the freshly fallen snow at the observing site.

At the observatory we met other observing teams from Slovakia, Yugoslavia, and Croatia, friends we knew from *IMC*s and correspondence. We started to install the video equipment (Figure 4) in one of the buildings of the observatory (Figure 5), kindly provided by the observatory staff.

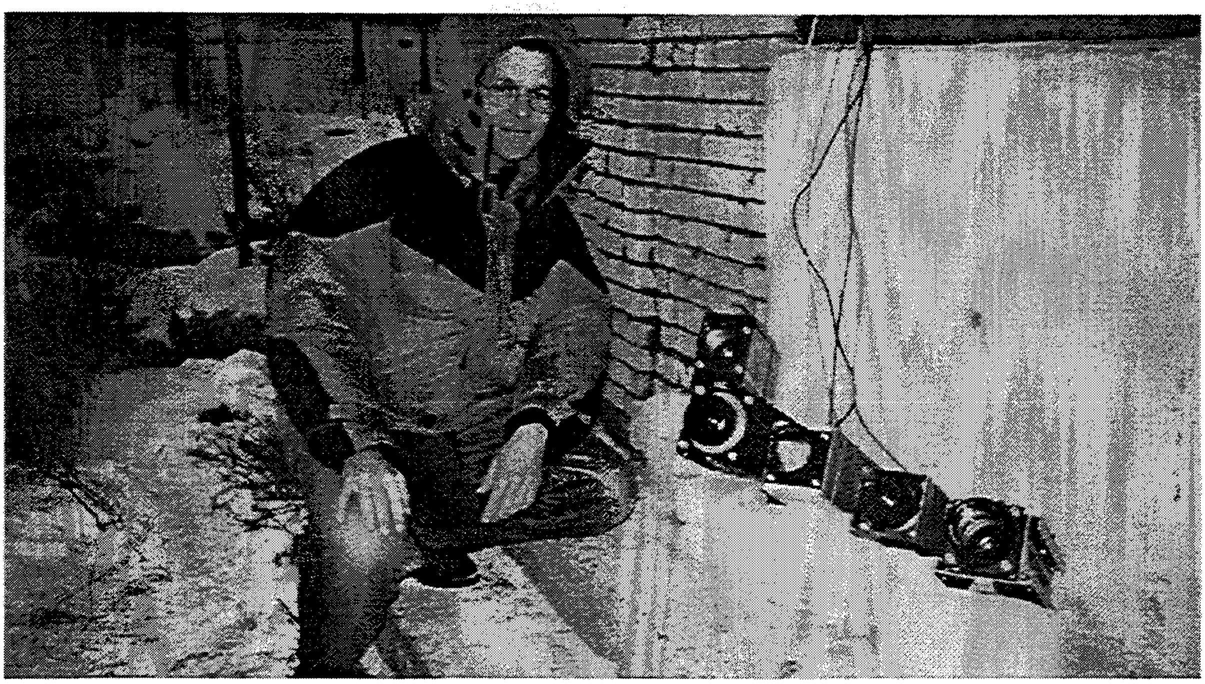


Figure 4 – Sirko Molau and the intensified video cameras of the *AKM* in front of the "operator building." To save on luggage, the cameras were put on bricks and oriented to the chosen direction early in the evenings.

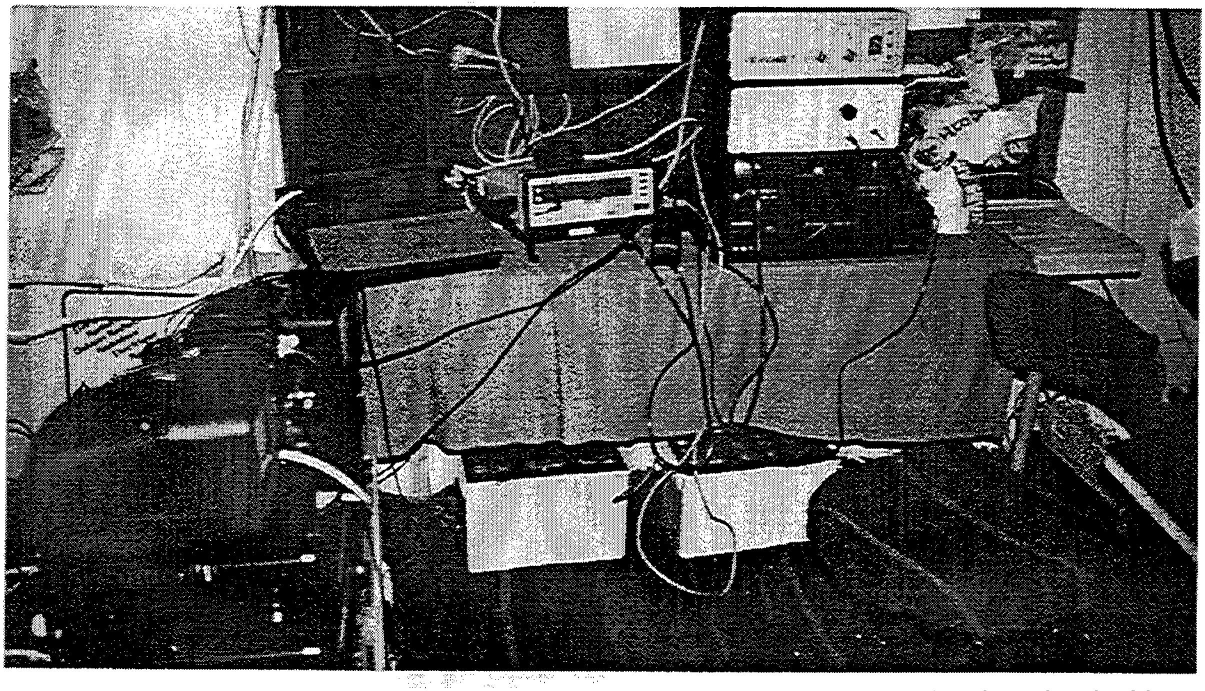


Figure 5 – The electronic devices for the cameras and the video recorders were placed inside a building. There was also a power generator which would have been used in case of a power failure.

Figure 6 – Magnitude −13 Leonid over a dome of the Khurel Togoot Observatory during the "fireball night" November 16-17, photographed with a fish eye lens.

Fortunately, it turned out transport caused no damage of the equipment, so that all six cameras and recorders were ready to work. In the cold air mass, the sky conditions were quite good as well, and so we were prepared for a full night test run at November 16-17. Thanks to our relaxed schedule we were able to record the entire "fireball night" (Figure 6), except for a short period of time, when fog moved in. Our records include numerous very impressive video recordings of persistent trains (Figure 7).

The highly unexpected appearance of the Leonid meteor shower in 1998, with high fireball activity way before the night of the nodal crossing, but no storm or real outburst of activity around the time of the nodal crossing, has been described repeatedly and was analyzed by Rainer Arlt in the previous issue of *WGN*. It was difficult to find out whether the observers were disappointed or not. Probably, everyone had in mind that the expected storm was the most optimistic prediction, and that there could be just "nothing."

Of course, the fireball night was the most thrilling event for all observers. Still, the reactions were interestingly different. The bandwidth of emotions was impressive—from the cool witness of the event, who only concentrated on recording what happened in the sky, to the emotional spectator who was completely overwhelmed by the fireworks.

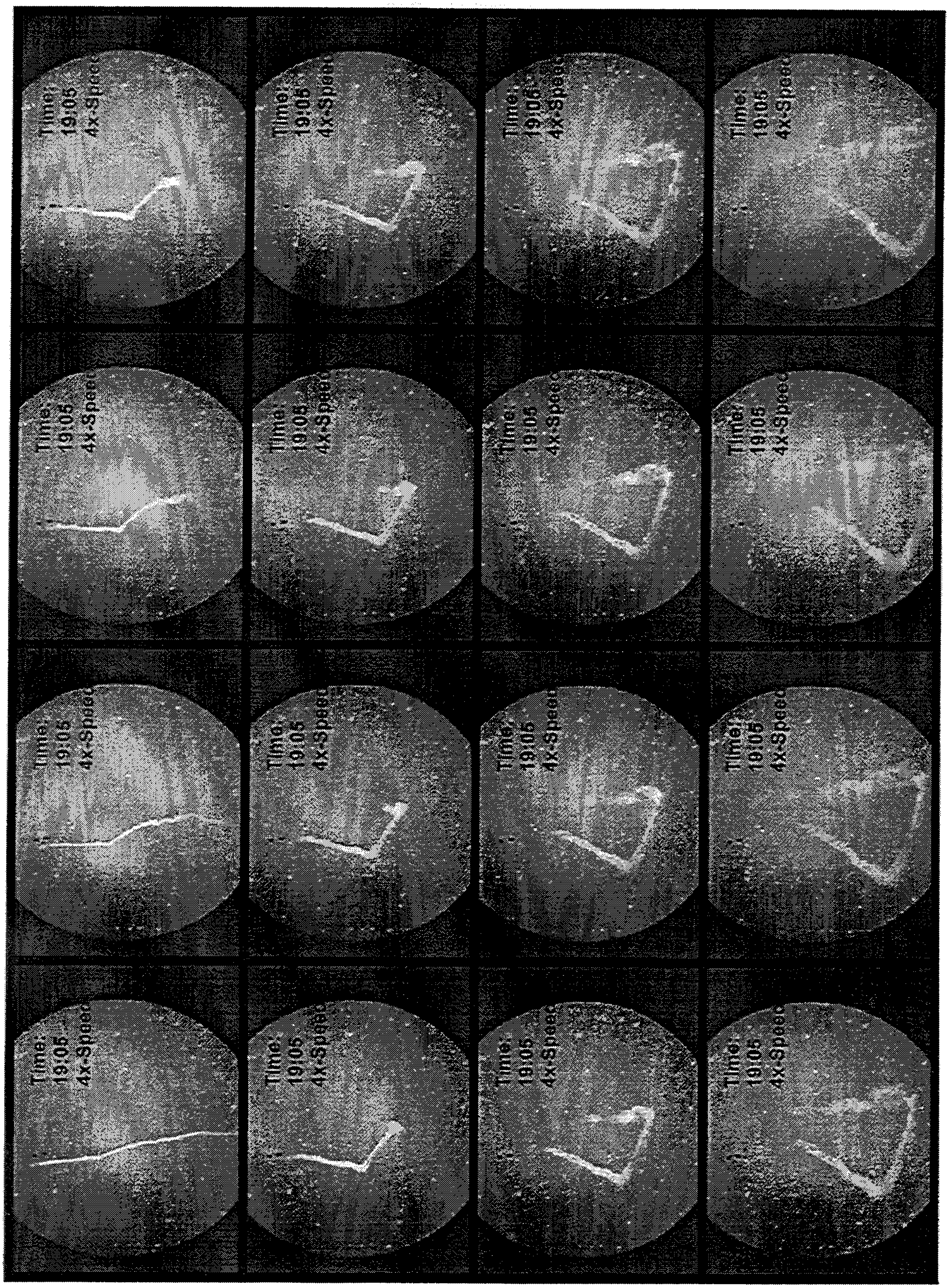


Figure 7 – Image sequence of a persistent train, left by a bright Leonid meteor and recorded on video. Some trains remained visible to the red-sensitive video cameras for more than half an hour.

The next morning, expectations were quite high: if there was such activity already 20 hours before the peak time, what had still to be in store? Everybody wondered whether another major increase in activity was thinkable at all at the nodal crossing time? It was not, as we learnt in the next night.

The highly organized Canadian effort during this expedition had a second objective that went well beyond basic research: the visual counts competed with the data gleaned in real-time from one of the video cameras. For this purpose, the computer program METEORSCAN of Peter Gural was used. This was another fortunate occasion, because, as it happens, Peter Gural and Sirko Molau have been working on similar problems for a long time already—meteor recognition from video systems. They could discuss the topic and exchange their ideas for many hours, including during the long flight across the Eurasian continent back to Germany.

During the observations, the visual and video raw data were telephoned every 15 minutes to Canada. There the data was transformed to ZHRs and passed on to the US Air Force's Space (Weather) Forecast Center in Colorado, which would have warned satellite operators in case of a real storm.

The storm did not materialize, of course, and obvious satellite anomalies were not reported either. However, the Mongolian experiment was a good demonstration and test of principles. Thanks to our collaboration, we were also able to transfer our visual data to Rainer Arlt in Germany, who included this information in the reports spread via mailing lists and the *IMO*'s Web site. So, the whole procedure was also a test for handling real-time information.

After another night at the observatory used for further reference observations, we had to pack all equipment to bring it back to the city of Ulaanbaatar. Certainly, all of us appreciated the achievements of civilization, mainly a warm shower. The facilities at the observatory were rather limited.

We used the time in the hotel rooms in Ulaanbaatar for listening to the tapes of the visual observations and to break down the counts for later input into the *Visual Meteor Database*. Others had a look at the video tapes and produced a first raw collection of meteor trails and trains. First impressions were presented at a reception at the German Embassy in Ulaanbaatar. As we stayed in the same hotel as the members of the Canadian/US group, we continued our contacts and discussions, not only about the Leonids.

The generally positive experience with the real-time gathering, distribution, and analysis of meteor videos could one day lead to a world-wide network of automated meteor monitoring stations. The 1998 Leonids did not live up to some people's expectations, no doubt, but the observed display will eventually bring forward meteor science, perhaps more than the appearance of the primarily expected peak at the predicted position. And on an "operational" level, the Leonid expeditions have already made history.

Acknowledgments

The German and Canadian participants of the 1998 Leonid expedition are grateful to the Mongolian partners of the *Research Center of Astronomy and Geophysics* of the *Mongolian Academy of Sciences*.

In particular, we wish to thank the director, Bazar Bekhtur, who supported our preparations already back in September and the logistics during the November expedition, Damdin Batmunkh and Munkhoo Olziibat, who helped us a lot during the search for the second observing site, Sharav Amarjargal and Delger Lkhagvasuren, who allowed us to install the video equipment in their laboratory, and, last but not least, Togookhuugiin Bayaraa, who was at the main observing site almost all the time to help us with many details.

Preliminary 1998 Sino-Dutch Leonid Expedition Results on Two Short-Lived Activity Peaks near Nodal Passage

Marco Langbroek and Marc de Lignie

Following a prominent activity peak of bright meteors peaking about 0.75 days earlier, the Leonid outburst recurrence of 1998 displayed a second pronounced activity peak in the hours around passage through the node of parent comet 55P/Tempel-Tuttle on November 17.82 UT. Here, we report preliminary video results from two observational networks established in China by the 1998 *Sino-Dutch Leonid Expedition*. The results suggest that two separate activity structures might have been responsible for the short-lived activity around nodal passage: a $B = 5$ background peaking near $19^{\rm h}20^{\rm m}$ UT ($\lambda_\odot = 235.^\circ260$, eq. 2000.0) and a $B = 30$ narrow structure peaking near $20^{\rm h}40^{\rm m}$ UT ($\lambda_\odot = 235.^\circ316$). These come in addition to the broader structure that produced the fireball activity on November 16-17. The two structures near nodal passage appear similar in shape and equivalent width (but not in activity level) to the two structures in the historic 1866 storm display.

1. Introduction

A number of dedicated observational efforts have been employed from Asia during the 1998 Leonid maximum. These include the *AKM*/Canadian expedition to Mongolia [1] (*see also this issue, Ed.*), the international airborne mission under the banner of *NASA* over the Chinese Sea (the Leonid Multi-Instrument Aircraft Campaign [2]), and an initiative of Dutch and Chinese investigators of the *Dutch Meteor Society* (*DMS*), *Purple Mountain Observatory* (*PMO*), and *Beijing Astronomical Observatory* (*BAO*), cooperating in the *Sino-Dutch Leonid Expedition.*

The *Sino-Dutch Leonid Expedition* involved the establishment of two temporary observational networks in China, providing an extension and backup facility of the Leonid Multi-Instrument Aircraft Campaign one and two time-zones further [2]. The first network, hosted by Dr. Lei Chengming and Zhao Haibin (*PMO*), was located in the deserts of the northwestern part of the central Chinese Qinghai Province, with a station at the Qinghai Radio Astronomical Observatory in the 3200-m-altitude desert near Delingha, and a second station 65 km to the southwest near the desert hamlet of Ulan. The second network, hosted by Dr. Zhu Jin (*BAO*), was established 2400 km to the east, located in the low mountains of Hebei province in northeast China with a station at the Xinglong Observatory about 150 km northeast of Beijing, and a second station near the hamlet of Lin Tin Kou, 85 km to the south.

The stations successfully employed multi-camera photographic platforms and image-intensified video systems for the purpose of multi-station orbital determinations of Leonid meteoroids from the activity structures discussed below. The video systems, together with visual observers at the observing sites, also served to gather activity data on the stream. In addition, spectroscopy and radio meteor scatter observations were employed in the Hebei network.

2. Preliminary activity data for November 17 from the video systems

The 1998 Leonid activity displayed a clear two-fold structure [3]. Here, we will add a possible third activity structure as suggested by our video data. During the night of November 16-17, a broad and very spectacular activity structure of extremely bright meteors was active. Although peak rates were over Europe, the fireball display was well observed from China [4] with ZHRs rising to 200 according to preliminary results. This structure had almost ceased activity during the last hours of November 17, when a second pronounced—but more short-lived—activity structure consisting of fainter meteors became active in the hours around passage through the node of Comet 55P/Tempel-Tuttle, the parent of the Leonid Meteoroid Stream [3].

Figure 1 shows very preliminary results on the activity behavior of the Leonids near nodal passage, gathered by two video systems: the Ulan station in the Qinghai network (operated by ter Kuile, black dots) and the Lin Tin Kou station in the Hebei network (operated by Jobse, open dots). The results suggest that this second peak in the 1998 Leonid display might actually have been due to a merger of two separate activity structures peaking close to each other.

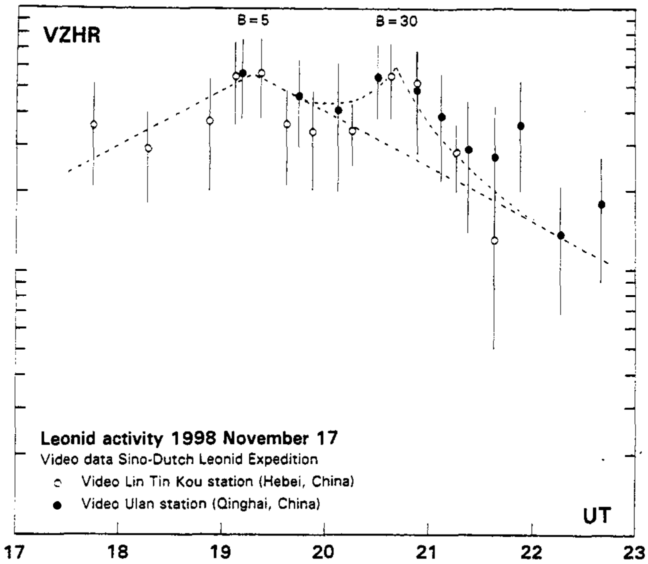


Figure 1 – Video data of the 1998 *Sino-Dutch Leonid Expedition* for November 17.

Video meteors were classified according to their direction of movement and angular speed. The classifications should be regarded as preliminary. Rates of the two video systems in intervals of 15–30 minutes were converted to hourly rates and then corrected for radiant altitude (employing a zenith exponent $\gamma = 1.4$). Data obtained when the radiant altitude was below 25° were rejected.

It was assumed that the limiting magnitude was constant over the operation period of the cameras (a reasonable assumption according to the visual observations from both stations). Likewise, it was assumed that the population index r remained constant over the period covered by the two systems, an assumption which is supported by the visual observations from both networks.

Data from Ulan station in the Qinghai network (black dots) have been scaled by a factor 1.38 in order to bring them on a similar activity level as the data from the Lin Tin Kou system (open dots): the purpose of this first preliminary analysis was to determine the shape(s) of the activity curve(s), not the influx level (the difference in level between the data from both stations mainly represents a difference in the technology between both systems).

3. Presence of two structures: a $B = 5$ background and a $B = 30$ narrow peak

The results (Figure 1) suggest the presence of two peaks in the profile, one near $19^{\mathrm{h}}20^{\mathrm{m}}$ UT ($\lambda_\odot = 235\overset{\circ}{.}260$, eq. 2000.0) and a second near $20^{\mathrm{h}}40^{\mathrm{m}}$ UT ($\lambda_\odot = 235\overset{\circ}{.}316$), both with similar activity levels. The data of both stations (which were located over 2000 km apart) have been depicted separately in order to show that the apparently two-peaked activity behavior is present in *both* independent data sets. When data of both systems are combined, the standard deviations on the data become smaller and the two-peaked structure more significant.

The data can be fitted by a combination of two activity structures superimposed on each other, both represented by the equation [5] $\mathrm{ZHR} = \mathrm{ZHR_{max}} \times 10^{-B|\lambda-\lambda_{\max}|}$. The first structure, peaking near $19^{\mathrm{h}}20^{\mathrm{m}}$ UT, has $B = 5$. Superimposed on its descending slope is a much narrower activity structure peaking near $20^{\mathrm{h}}40^{\mathrm{m}}$ UT with $B = 30$. Both structures have been depicted by dashed lines in Figure 1 to guide the eye for their presence. Very preliminary visual results from both networks also suggest the presence of a similar two-peaked activity behavior, and indicate maximum activity levels near ZHR = 200, with a rather constant r-value of 2.3 (on a scale with $r_{\mathrm{sporadic}} = 3.4$), clearly different from the fireball display 0.75 days earlier. The second peak is similar to that reported in preliminary results in [3]. The first peak is not obvious in the preliminary data reported in [3] but a private communication with Rainer Arlt reveals that data from the Mongolia expedition do show a peak near this moment.

4. Comparison with earlier Leonid displays

An interesting thing to note is that these two structures with $B = 5$ and $B = 30$ do not appear out of the blue, but ring a historic bell. The activity curve for the 1866 storm occurrence [5] exhibits two similarly shaped activity structures, albeit at a different level of activity. In 1866, a $B = 30$ narrow structure (the storm peak) was present upon a broader $B = 6$ background structure [5], closely resembling the 1998 situation. Notwithstanding the difference in activity levels, it appears that both the 1866 activity and the 1998 activity near the cometary node are, therefore, the result of dust structures of a similar character concerning their shapes and width (as measured by their effective durations ($2 \times 1/e$ peak rates), which are 0°15 and 0°17 in solar longitude, respectively for the backgrounds of 1866 and 1998, and 0°03 for the narrow components of both years). In other words, they seem to represent the same dust structures. A surprising observation, but perhaps just coincidence, is that the 1998 narrow $B = 30$ peak also occurred at a similar distance (0°055) from the cometary node as that of 1866 (see Table 1*b* in [5]). In addition, the $B = 30$ narrow structure has appeared earlier in the current outburst cycle: it could first have been well-defined for the 1996 appearance [6,7], and was also present with the 1997 appearance [8]. The occurrence of similar structures in 1866 and 1998, and during several years of the current outburst cycle, supports the model of presence of extended dust sheets causing these outburst phenomenon [5].

The activity structures described here occurred close to the moment of passage through the node of 55P/Tempel-Tuttle. Since it has been the $B = 30$ component which has been responsible for the historic meteor storms [5], we strongly support the conclusion in [3] that, contrary to currently popular tales in the regular as well as popular-scientific press, the predictions for the moment of recurrence of the Leonid activity component which has produced storms in the past (but unfortunately did not do so in 1998) were correct. We disagree with opinions voiced that present the 1998 Leonid activity as representing an extended plateau in activity without multiple peaks.

5. Summary and concluding remarks

The 1998 Leonid activity in the hours around passage through the 55P/Tempel-Tuttle node appears to represent two activity structures according to preliminary data of the 1998 *Sino-Dutch Leonid Expedition*, which add to the additional structure that caused the early fireball activity 0.75 days earlier. The two structures found closely resemble two structures present in the activity profile of the historic 1866 outburst in shape and equivalent width. Data reduction will continue, and a full report integrating video and visual results will be published in a later stage.

Acknowledgments

The 1998 *Sino-Dutch Leonid Expedition* was made possible thanks to support of the *Royal Dutch Academy of Sciences* (grant 98CDP026) and the *Chinese Academy of Sciences*. Additional financial, material, and other support was provided by *NASA*, *Leiden Observatory*, the *Kerckhoven-Bosscha Fund*, *Kodak*, and *Canon*. We thank *VNC* (Utrecht, Holland) for arranging the logistics of our travel, and Peter Jenniskens (*NASA/Ames Research Center*) for much support in the background. Last but not least, we want to thank the people, most notably Klaas Jobse, Casper ter Kuile, Carl Johannink, and Koen Miskotte, who operated the video cameras and viewed the tapes for video rates and our Chinese colleagues without whose efforts the preliminary results reported would not have been obtained: most notably we thank Dr. Li Guangyu (*PMO*), Dr. Xu Pinxin (*PMO*), Dr. Zhu Jin (*BAO*), Dr. Lei Chengming (*PMO*), and Zhao Haibin (*PMO*).

For more about the 1998 *Sino-Dutch Leonid Expedition*, see `http://home.wxs.nl/~dms-web/`.

References

[1] C. Trayner, *WGN* 25, 1997, pp. 236–247.
[2] P. Jenniskens, S. Butow, *WGN* 26, 1998, pp. 249–252.
[3] R. Arlt, *WGN* 26, 1998, pp. 239–248.
[4] M. Langbroek, H. Zhao, *IAU Circular* 7052, November 17, 1998.
[5] P. Jenniskens, *Astronomy and Astrophysics* 295, 1995, pp. 206–235.
[6] M. Langbroek, *WGN* 24, 1996, pp. 207–208.
[7] M. Langbroek, *Meteoritics and Planetary Science* 34, 1999, pp. 137–145.
[8] R. Arlt, P. Brown, *WGN* 26, 1998, pp. 161-165.

SPA Meteor Section Results: Personal Recollections of the 1998 Leonids

Alastair McBeath

A review of comments received by the *SPA Meteor Section* from witnesses of the 1998 Leonid activity on November 16-17 is presented, including a personal summary of the night by George Spalding.

1. Introduction

The wonderful Leonid display of November 16-17, 1998, will live long in the memories of the fortunate observers who witnessed it. Data has flooded in to the *IMO* from around the world from the 1998 Leonid epoch, and will allow the most detailed examination of the Leonids—perhaps of any meteor shower—ever. The fact that the highest rates were seen from more than half a day earlier than we originally anticipated, and persisted at a very active level for around twelve hours, had two main effects.

Firstly, it caught observers by surprise, and some who had clearer skies but held themselves in reserve for the expected peak the next night were to be gravely disappointed.

Secondly, unlike many previous Leonid outbursts, which have often been relatively short-lived, this event was seen well by observers from Eurasia to the Americas. Even those in the Pacific and Oriental areas enjoyed a level of Leonid activity not seen since the 1960s.

Perhaps the single most obvious feature was the very high percentage of bright to brilliant meteors the Leonids produced. Preliminary *SPAMS* figures suggest around 15-20% of Leonids on November 16-17 were fireballs, ranging up to magnitude -12 or -13, for example. This meant many people living in street-lit areas, or with poor sky conditions, were able to still see much of the display, and numerous casual witnesses were thrilled by the spectacle.

Even with the large number of observations submitted to the *SPAMS* on the shower in 1998, it would be ludicrous to pretend a serious analysis of these data could compete with that of the *IMO*, with access to far greater observer-resources. Instead, what this article attempts is to add something of the human element to the equation, which the technical analyses of necessity cannot demonstrate. Here, I have compiled a series of comments made by observers who saw the event, together with some summarized ideas of how the witnesses saw the spectacle, and what they saw. All the items used here were communicated to the Section within a month of the shower's peak.

The observers providing this material and other Leonid data not used here included

> Rainer Arlt (Germany), David Asher (Northern Ireland), John Coates (England), Heather Couper (England), Andrea Csiki (Romania), Maggie Daly (England), Ade Dimmick (England), Carol Downs (England), Steve Foggo (England), Doug Fox (England), Dave Gavine (Scotland), Andrei Dorian Gheorghe (Romania), Bob Gilmour (Scotland), Shelagh Godwin (England), Valentin Grigore (Romania), Alan Heath (England), Kath Hodges (England), Simon Jenner (England), John Lambert (England), Trevor Law (Western Australia), Alan Longstaff (England), Andrew Mark (Scotland), Tony Markham (England), Alastair McBeath (England), Peter McBeath (England), Tom McEwan (Scotland), R.B. Minton (New Mexico, USA), Neil Mortimer (England), Guy Ottewell (South Carolina, USA), Jürgen Rendtel (Mongolia), Tony Rickwood (England), Joan Robinson (England), Maurice Robinson (England), Vanya Rodiger (Croatia), Paul Roggemans (Belgium), Fred Schaaf (New York, USA), Amanda Scott (England), Jonathan Shanklin (in flight between England and Ascension Island), Dierdra Shepherd (Western Australia), Jamie Shepherd (Western Australia), Adrian Şonka (Romania), George Spalding (England), Paul Sutherland (Southern France), Melvyn Taylor (Cyprus), David Todd (England), Manuela Trenn (Germany), Mihaela Triglav (Slovenia), Valeriu-Mihai Tudose (Romania), Andrew Walker (Scotland), Peter Ward (England), and David Weldrake (England).

More details on the events of November overall as seen by *SPAMS* contributors will be published in the usual on-going series of results papers in *WGN* in due course.

2. The night itself described

Most of our contributors live in and observed from Europe on November 16-17. Only Trevor Law had sought clearer skies in the summer hemisphere of November by going to Western Australia with Jamie and Dierdra Shepherd, all from the UK, though Jonathan Shanklin, en route to the Antarctic that night, came very close to observing through his aircraft window from south of the equator. He was stopped by the dawn twilight coming up, while still around 4° north latitude at 5^h48^m UT, but he continued to see occasional bright Leonids after this until just a few minutes before dawn. Even under such difficult observing circumstances, Jonathan logged about 450 Leonids in 3^h20^m, many of them very bright, and commented that *"it was certainly a spectacular sight. Several colleagues on the plane were also able to enjoy it, and one estimated that he saw a meteor every 10 seconds when rates were highest."* This level of observed activity was comparable to what watchers across Europe and North America saw with an unobstructed view of the sky, an indication of the numbers and brightnesses of the Leonids about.

In Western Australia, Trevor, Jamie, and Dierdra were clouded-out completely after local midnight on November 16-17, but Trevor noted that a tremendous storm was seen the following night from the city of Perth. This was not of Leonids, however. Instead, an unseasonal thunderstorm hit, producing golf-ball sized hailstones, continuous thunder, and lightning flashes about once per second at its height. Luckily, Trevor's party were around 700 km further north at the time, near Shark Bay, but even there, clouds prevailed, so they drove over 400 km north-east to find better skies on November 17-18. Observed rates were still good for them, at 3–6 Leonids per minute at times, but with hardly a fireball all night, it was a somewhat disappointing contrast with what happened over their homes in Britain. Even so, the one Leonid fireball that did chance-by, magnitude -4, appeared just over half an hour before sunrise, in deep twilight!

Of course, not everyone was lucky in seeing something of the display. The weather was always liable to be a problem in the northern hemisphere's early winter, with reports indicating much of north-west England and Northern Ireland were completely clouded-out, or had fog, on the critical night, for instance. In inland South Carolina, USA, Guy Ottewell reports fog ruined any chance to see the Leonids at all from there too, while in Germany, the heavily overcast sky was a severe problem. Rainer Arlt and Manuela Trenn drove across the country for a total of 10 hours on November 16-17, hunting for better skies, but managed just one 9-minute observation in a cloud gap, even so seeing 7 Leonids in that time. Rainer comments that the next night had only marginally better conditions, permitting a 50-minute watch, for much poorer Leonid rates.

Several observers picked the "wrong" night to observe, after relying entirely on the predicted peak time, and a few decided against watching in clear skies on November 16-17, expecting another clear night and better rates on November 17-18. In many cases, such people saw only clouds the next night, and were disappointed not to have observed when they had the chance. Although disheartening, such a mistake is good experience, and is also an error most experienced watchers have made in the past. George Spalding, a veteran who also watched the 1966 Leonids from Britain, explains his feelings when he woke at 1^h local time, ahead of the alarm he had set, and saw there were some breaks in a rather cloudy sky:

> *"I was not too keen to venture out, but then recalled the past opportunities I have wasted only to be clouded out later."*

If the Leonid storm does occur in 1999, at least those who did so made their mistake before that happened! One poor soul, who I shall leave nameless, intended to observe on November 16-17, but then slept through the alarm clock ringing...

Those who could observe on November 16-17 all had a wonderful night. Even around radiant-rise from Europe, Leonids were already apparent. Several UK watchers noted Leonids from around 23^h local time—Maurice Robinson spotted three in a matter of five minutes while walking his dog, despite a fairly cloudy sky, for example. The following are some brief quotes from the reports received: *"Four of the meteors were so brilliant they illuminated my garden."* (John Coates); *"It was very exciting!"* (Maggie Daly); *"A wonderful celestial gala evening."* (Carol Downs);

"A wonderful display, with many bright and colorful meteors," (Doug Fox); *"Photographed 22* [Leonids] *in 1 hour on 16 mm lens, 7 of them on 1 frame. That is more than in my entire meteor watching career!"* (Dave Gavine); *"I spotted some amazing events: flashes near the radiant, one of which was almost blinding and cast shadows, exceedingly fast bright (and not so bright) meteors, and more flashing through the haze."* (Shelagh Godwin); *"That was not a meteor shower; it was a fireball shower!"* (Andrew Mark); *"Conditions were already deteriorating by the time that I reached my observing site... However, I started observing and five meteors in the first minute is not at all bad!"* (Tony Markham); *"Meteors averaging 3 or 4 per minute... A number of meteors (not seen) lit up the entire sky."* (Peter McBeath); *"After 3 months of almost non-stop rain, 16–19 November were the first transparent nights... in a long time. I was out, just for a look... before the assumed maximum... there were many bright Leonids."* (Paul Roggemans); *"Even now, I can scarcely believe my luck at having seen such a spectacle... It was a cold night, but I hardly felt it as I was entertained both by the number of meteors and their brightness."* (George Spalding); *"Some 'cracking' trains seen—and there are no railways in Cyprus!!"* (Melvyn Taylor); *"Awe-inspiring"* (Peter Ward).

Many observers—including the author—enjoyed their best night of meteor observing of all-time, in terms of meteor numbers in so short a time, overall meteor tallies, and the number of bright meteors around. Flashes lighting up the sky from otherwise unseen meteors were commonly reported from numerous places, confirming the ability of a spectacular Leonid outburst to awaken people from their beds behind closed curtains, as happened in 1833, in days before light pollution. Good as it was, one observer, R.B. Minton, commented:

> *"This display was the 2nd best meteor display I have witnessed. His reason? The best was the Leonid display of 1966 while I was living in Las Cruces (New Mexico, USA)!"*

R.B. and his wife had turned their home into a Leonid observing station for the 1998 event, recording what happened visually, by video, photography, and forward-scatter radio.

Several people commented with surprise at the silence of the 1998 Leonids, despite so many very bright meteors, which tends to give the lie to the supposed psychological explanation used by those who wish to ignore meteor sounds, both of the simultaneous electrophonic type, and the acoustic sort. Surely with so many bright events, somebody should have imagined they heard something if any kind of psychological effect of this sort really happens? R.B. Minton's comments on this point are very telling:

> *"In all 600 (or so) observations of meteors, my wife and I never heard any kind of meteor noise. No boom, hiss, crackle, or other kind of noise... I viewed the November 17, 1966 Leonids from* $1^{\mathrm{h}}00^{\mathrm{m}}$ *a.m. to* $5^{\mathrm{h}}30^{\mathrm{m}}$ *a.m. MST* [Mountain Standard Time = UT − 7^{h}] *and also never heard meteor noises. But in this case, the sample size must have been closer to 200 000!!!"*

Meteor noises of whichever kind seem to require deeply-penetrating meteors, whereas even bright Leonids occur higher in the Earth's atmosphere than most other meteor showers thanks to their greater relative entry velocities.

Superb, long-lasting trains were another hallmark of the night, with most observers under reasonably clear skies seeing one or more lasting for upwards of five minutes, twisting into an "S"-shape or a ring before fading away. Valentin Grigore reported trains up to 25 minutes in duration, enough time to photograph or video them. One that R.B. Minton videod *"expanded into a hollow tube and showed spiral structure in several places. Several others showed a hollow-tube appearance after 1 minute."* Most of the videod trains were brightest near their termini, and R.B. comments that in about half the cases he recorded that bright "blobs" occurred where late flares had happened in the meteor's flight:

> *"These blobs would frequently split into 2 or 3 pieces, with perhaps one remaining smaller and more spherical than the rest. These multiple blobs would then exhibit a common motion."*

However, the individual "blobs" also showed a differential motion between one another, and R.B. suggests, using the analogy of high-altitude barium releases he had previously witnessed, that perhaps the electrical charge of each "blob" helped determine its behavior.

The Meteor Group of the *Astronomical Association Javornik* in Slovenia also managed to record some long-lasting trains photographically, and Mihaela Triglav sent in some excellent photos of two, one of which lasted for around 11 minutes after a magnitude −12 Leonid. It distorted into a magnificently serpentine coil before fading away, which, as Mihaela said, really resembled a dragon, as I described, in *WGN* 25:1, February 1997, pp. 34–36.

Many observers discussed the colored nature of the Leonids they had seen. Such colors are not unexpected with meteors of magnitude +1 and brighter, which covered a very high proportion of the Leonids on November 16-17. Green was certainly popular, and shows up on some of the color photos as well as in the visual sightings. R.B. Minton noted that all 13 Leonids he photographed like this showed green in their upper (earlier) stages, despite his using several different cameras, lenses and films. This could have resulted from 557.7 nm oxygen emission, which is known to occur with high-altitude meteor ablation, and is a facet of the shower worth further investigation. Tony Markham also noted another effect:

> *"Two of the trains showed strong coloration for the first second—red/yellow/green/blue bands—like a spectrum. Both were very low in the sky—was this an atmospheric effect (red was lowest) or related to the meteors themselves?"*

Tony experienced problems, because of a lot of cirrus cloud during his watch, so there is the possibility of some kind of corona effect due to diffraction, or halo-effect due to refraction, in the ice-crystal clouds. Both effects have been observed with the Sun, Moon, planets and even bright stars like Sirius at times, so either could be suitable explanations.

As we might have expected, it was a cold night across Europe and parts of North America. Temperatures across the clearer parts of the UK were around, or below, freezing—it was −6° C at Morpeth by dawn, for instance, with a white frost over everything, including the outer layers of my observing kit! This was nothing compared to conditions for the observing teams in Mongolia, from where Jürgen Rendtel reported temperatures dipping to −27° C, or −34° C above the snow! Jürgen went on to say the following:

> *"The only disadvantage of the beautiful winter landscape (about 20 cm snow) was the noise of the snow... We even heard wolves howling—in the distance!"*

Such colder temperatures were not to everyone's liking, even in the relatively milder Europe. John Lambert in northern England found his car frozen solid, so ended up stuck in his garden at home with a street lamp directly in front of the Leonid radiant! Even so, he saw numerous Leonids, some bright enough to light up the sky in spite of the obvious man-made lighting problems.

Three UK observers unable or unwilling to risk the cold watched from indoors, but even so, still saw around 30–50 Leonids per hour at times, and were greatly cheered by the view. One of these, Bob Gilmour, lives in the extreme northernmost part of Scotland, and deserves a special mention here as being the oldest observer to report his watch from November 16-17, as he was nearing his 83rd birthday at the time. There can be few more superb ways to celebrate such an event for any astronomer than with a display of meteors like the 1998 Leonids.

Leonid fireballs continued raining down into strong twilight across Europe, and some were seen shortly before, or after, sunrise, giving the observers a real feeling of being part of a greater, global, meteor community, knowing they were "passing the baton" of observing on to watchers further west in Europe (from eastern Europe), or across the Atlantic to North America (from western Europe), who in turn saw still excellent activity fading into their dawn as the Leonid "torch" was passed back round to the Far East and Asia. As George Spalding put it, it was like being part of one big family, a "United Nations" of observers.

This is an appropriate point to let George make some further comments, to continue his personal recollections of the Leonids begun in our joint article in *WGN* 26:1, February 1998, pp. 9–10.

3. George Spalding's personal impression of the 1998 Leonids

Even now, writing on November 19, it hardly seems believable that I have witnessed my best ever meteor shower in the UK in 34 years of observing. The peak of the Leonid shower was scheduled for an estimated time of 1998 November 17, 19^h–20^h UT, best visible in the Far East. However, especially since the forecast for November 17-18 at my site looked rather unfavorable, I certainly planned to cover the night of November 16-17, to monitor the expected rise in activity, and it is just as well I did.

There was rather a lot of cloud in the evening of November 16, so I went to bed at 22^h00^m UT [= local time], having set the alarm for about 2^h00^m UT. When I woke early at about 1^h00^m UT, there was still lots of cloud. But luckily, I decided to get outside and start observing right away. At the start, the stars in Leo, still at a low elevation, were only barely visible, and there was a fair bit of cloud in the east. But it was soon apparent that the shower was much more active than on the previous night.

After only 10 minutes of watching, at 1^h31^m UT, came one of the highlights of the night. A magnitude -3 Leonid raced through Auriga and left a train which persisted over 3 minutes; it gradually widened as it slowly faded, and slightly twisted. Long-duration trains lasting many seconds were to be a feature of the display. It was also evident from this first watch (1^h21^m–2^h21^m) that there were many bright Leonids, negative magnitudes being quite common.

For the second watch (2^h35^m–3^h35^m), I shifted round to look south-west from then on, rather than east as previously. This second watch probably had the best conditions (limiting magnitude of $+5.4$) as the clouds dispersed, though it was hardly ideal. Another great meteor, of magnitude -5, flashed at $2^h57^m30^s$, and its train was of 10 seconds duration, followed within a minute by a magnitude -2 Leonid with a train of 5 seconds. Then, at 3^h09^m, a Leonid of magnitude -5 was seen in the low south-east, with a train of 7 seconds. Some very minor clouds appeared in the west in the last 15 minutes of this watch.

My third watch (3^h51^m–4^h16^m) was shortened as diffuse cloud and fog grew steadily, though meteors continued to be visible behind the cloud. This watch saw my brightest Leonid of the night, magnitude -6, which appeared at $4^h05^m30^s$; the train was 3 seconds, and there was a vivid green as the event exploded. When I had to stop the watch at 4^h16^m, I thought that that was the end of my work. However, as I took a coffee break, the fog began to lift again, and I was able to start my fourth and final watch at 4^h33^m.

This watch (4^h33^m–5^h23^m) proved notable for good rates and many negative-magnitude meteors. For example, the period $4^h49^m00^s$ to $4^h50^m30^s$ saw 11 meteors. Also, 6 of the 8 meteors noted between $4^h50^m00^s$ and $4^h51^m30^s$ were brighter than magnitude 0. The train that accompanied a magnitude -4 Leonid at 4^h59^m lasted at least 13 seconds. Finally, the fog returned to prevent my completion of a full hour. The watch had to stop at 5^h23^m, but only about 45 minutes remained till nautical twilight would start. As thick fog came down, I had time to reflect on a truly memorable night.

The total of 271 meteors in 3^h15^m watching was the highest number of meteors I have noted in a single night in the UK, and also the highest observed rates. November 17-18 and 18-19 proved to be hopeless for observing, the former owing to fog, the latter owing to cloud. Roll on 1999!

4. Conclusion

I can only echo George's closing remark, and end by thanking all those who troubled to provide observations, thoughts, comments, and reports from the great night, commiserate with those who, for whatever reason, did not have the chance to see the events of November 16-17, 1998, and to wish everyone good luck for whatever the Leonids produce in 1999 November. Clear skies!

The Leonid Fireball Night from Romania

Valentin Grigore and Ştefan Berinde

An overview of the 1998 Leonid activity as seen in Romania by *SARM* members, with a description of the event on November 16-17 as seen by Valentin Grigore (GRIVA) at Târgovişte, $\lambda = 25°29'00''$ E, $\varphi = 44°57'18''$ N, $h \approx 350$ m.

1. Introduction

The meteor network of the *Romanian Society for Meteors and Astronomy* (*SARM*) was active for the 1998 Leonid activity with nine observational centers in Romania and two abroad (one in Pakistan, where the radiant was above the horizon at the time of the expected maximum, and the other in Ontario, Canada). In Pakistan, Dănuţ Ionescu had clear skies on November 16-17, between 22^h and 1^h UT (3^h–6^h local time) and saw good activity. The next night he reported disappointing activity between 22^h00^m and 23^h50^m UT. In Ontario, Canada, Dr. Ovidiu and Simona Văduvescu had covered sky on November 16-17 and a few clearings on November 17-18. Of course, we all know now that the surprise produced by the Leonids was an unexpected very bright outburst produced practically one night before the expected maximum on November 17-18. Because of the disappointing activity during the latter night, the event in the night on November 16-17 is the main subject of this article.

On November 16-17, skies were clear over only three of our nine active centers in Romania:

> *Târgovişte*: Valentin Grigore (GRIVA); *Popeşti-Prahova*: Valeriu Tudose, Andrea Csiki, Bruno Adrian Şonka, and Mirela Arsene; *Bucharest*: Anda Tiţa, Ionuţ Toader, Iulian Olaru, Ştefan Oprea, and Laura Unci.

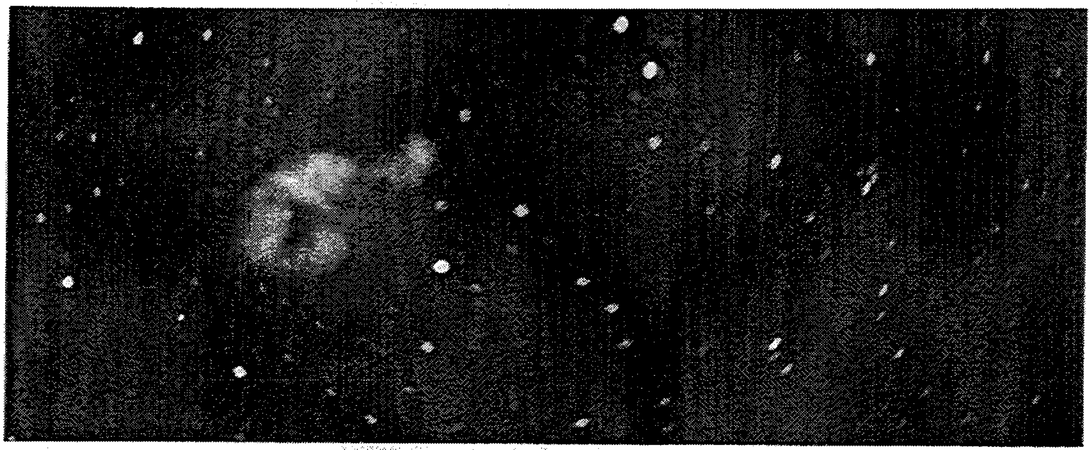
In Bucharest and Popeşti-Prahova, beginning meteor observers were active (both visual and photographical), so only Valentin Grigore's results were available for analysis. Here is a brief presentation of the events in that unforgettable night in Târgovişte, as seen by Valentin Grigore.

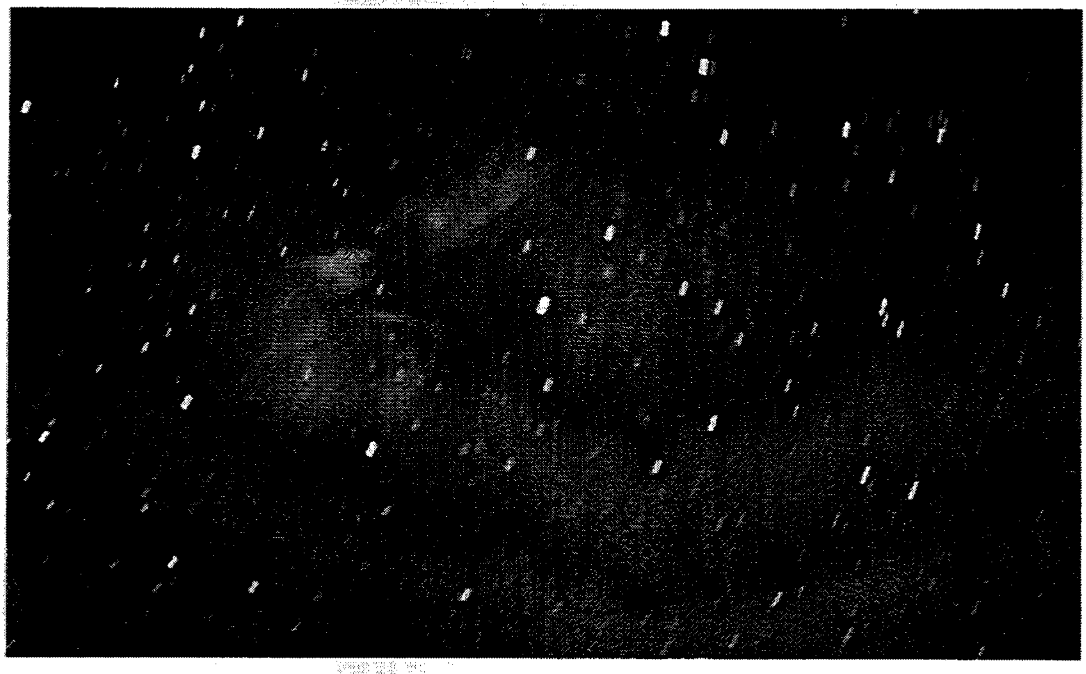
2. The event at Târgovişte

Unfortunately, I observed alone during the night of November 16-17, as the other members (most of them pupils) preferred to come the following night to observe the "maximum." At 22^h44^m UT, while I was installing my camp, I observed an unexpected Leonid fireball of magnitude −7 toward the northern horizon. It was very long (about 60°) with a persistent train broken in many parts, visible 140 seconds with the naked eye and 250 seconds with binoculars. During the same minute, I observed another Leonid of magnitude +2. I thought that I was a very lucky man to see a Leonid fireball so long before the announced maximum...

I left the camp to bring the other utilities from the house (it was quite cold outside). At 23^h10^m UT, I started the visual observations. The amazement grew, while observing the increasing activity. Although during the next half of hour I saw only one fireball of magnitude −4.5, the activity was good, with about 1–2 meteors per minute. At 23^h40^m UT, I saw an other fireball of magnitude −7, with a persistent train visible for 13 minutes with the naked eye. It was dispersed, and, after 5 minutes, it looked like a little cloud. Unfortunately, a short time after the beginning of my observations, my tape recorder crashed, and left me alone, forcing me to write down my observations in a notebook, despite the big amount of data and the cold weather. Due to the increasing activity, I decided to focus on visual observations. Nevertheless, I tried to make some photographs using one camera at first and two cameras after 2^h06^m UT. All photographs shown in this article were taken from Târgovişte by Valentin Grigore on November 16-17 with a 50 mm $f/1.8$ lens on Kodak 400 ASA film.

The frequency of the fireballs seemed to increase around midnight UT. Most of the persistent trains of the fireballs were shaped spirally, which was distinctly visible with the naked eye (see photographs). The persistent trains were deformed and dispersed over a pretty large area, and became little clouds floating freely for tens of minutes.





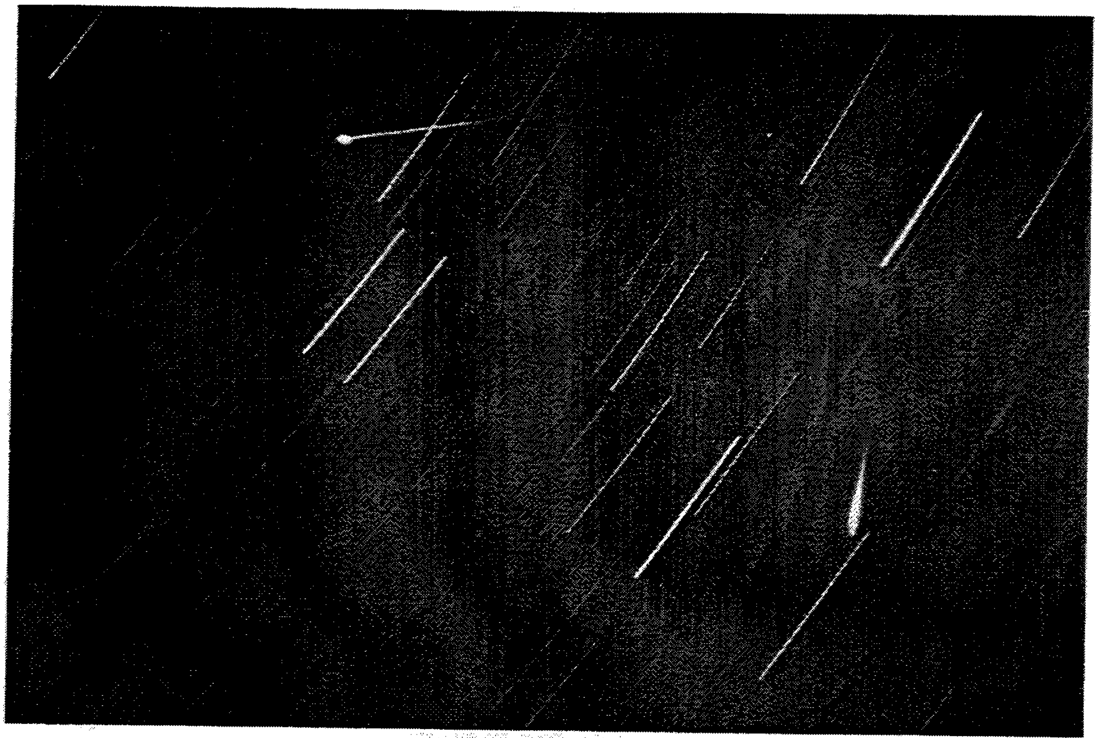


Figure 2 – *Top*: Two fireballs in Leo on an exposure from $2^h54^m00^s$ to $3^h11^m55^s$ UT. The brighter fireball was of magnitude -7 and appeared at $3^h11^m40^s$ UT. *Bottom*: The persistent train of the latter fireball, which was seen for almost 15 minutes with the naked eye, at 3^h12^m UT. The exposure lasted 60 seconds.

Figure 1 – *Page 39*: Three images showing the evolution of a persistent train produced by a magnitude -15 Leonid fireball which appeared at 1^h43^m UT in Ursa Major. The persistent train was visible for over 25 minutes with the naked eye. *Top*: A 60-s exposure at $1^h52^m20^s$ UT. *Center*: Exposure $1^h53^m45^s$–$1^h56^m00^s$ UT. *Bottom*: Exposure 1^h56^m–2^h02^m UT.

Nevertheless, they did not all move in the same direction, not even for meteors that appeared about the same time. This was the case, for example, for the following set of meteors. At 23^h54^m UT, a magnitude -7 fireball that flew toward the north-northwest near Cassiopeia, produced a spiral-structured persistent train. After three minutes, another fireball of magnitude -7 appeared near the zenith and produced a spiral-structured persistent train, too. At 0^h02^m UT, while the trains of the two fireballs were transformed into small clouds, another fireball of magnitude -8 produced a similar persistent train. All three trains were clearly visible with the naked eye at the same time, moving in different directions at the sky. The train of the first fireball moved toward the northwest, the second toward the east-northeast, and the third toward the south-southwest.

Sometimes, because of the high frequency of the meteors, I was not able to note down the magnitude for each meteor. As the activity continued to increase, meteors were counted only after 2^h34^m UT, and the magnitude was recorded only for the fireballs... The very high frequency of the fireballs left the impression that the sky really burned and that the ground was assaulted by an unseen heavenly "artillery"... Sometimes, the sky was illuminated by powerful flashes that must have been produced by fireballs that lit up below the horizon!

Most of the meteors were very bright, the "weakest" ones of magnitude $+2$ or fainter being seen rarely (see Table 2). The small frequency of the fainter meteors was a reality, and not a false impression of the observers seeing the very bright meteors.

Most of the time, I saw more fireballs in ten or even five minutes than in an entire Perseid or Geminid campaign. Here are only two examples: between 1^h40^m and 1^h50^m UT, from 29 Leonids, 10 were fireballs, which appeared in the following order with the following magnitudes: -15, -8, -10, -11, -3, -6, -11, -3, -4, and -3; between 3^h05^m and 3^h10^m UT, from 21 Leonids, 10 were fireballs: -3, -3, -3, -5, -7, -5, -4, -4, -3, and -3 (see Table 1). In total, from the 812 Leonids that I saw during the entire night, 195 were fireballs. (In the mean time, my wife and our 4-year-old son saw with me, for some minutes, this incredible show.)

Three fireballs illuminated both the sky and the ground around me as during daybreak. The first one was of magnitude -15 and appeared at 1^h43^m UT near Ursa Major. It produced a spiral-structured persistent train visible for more that 25 minutes with the naked eye (see Figure 1). The second one, again of magnitude -15, appeared at 4^h10^m in Coma Berenices, in the bright morning sky (limiting magnitude already under $+4$) with a spiral-structured persistent train (see Figure 3). The third very bright event happened at $4^h38^m40^s$ UT, when, because of daylight, only Capella and Sirius were visible through some very fine clouds... At that moment, while I was recording a fireball of magnitude about -8 in my notebook, the paper was illuminated by a strong violet lightning. Immediately I looked up into the sky and saw the end of a fireball, estimated at magnitude -17, near Capella. This fireball was also seen by other people going to work who happened to pass near my observing site. I heard their exclamations!

Although it was day, fireballs continued to appear. At 4^h57^m UT, upon ending my observations, I wrote down the following remark into my notebook: "no star in the sky, only meteors!" Ten minutes before sunrise, while packing, I saw another fireball toward the south, near some little red clouds. Five minutes after sunrise, another meteor (admittedly, it was barely visible) passed toward the south. Half an hour after sunrise (!), however, while walking the steps to my house, I was surprised by the apparition of a very bright white fireball, with a broken 40°–50° trail, from the zenith to the east-northeast. This was the end of the unforgettable Leonid show on November 16-17.

The Leonid fireballs had very bright, unusual metallic colors: orange with a ruby shade, blue with green reflections, etc. Many were green. Their persistent trains were very bright and had the same color as the fireballs for some seconds. The apparent diameters of the fireballs were not too big. Almost all of them showed flashes in their final part. My impression was that these fireballs had a radiant shifted a little to the north-northeast from the known position.

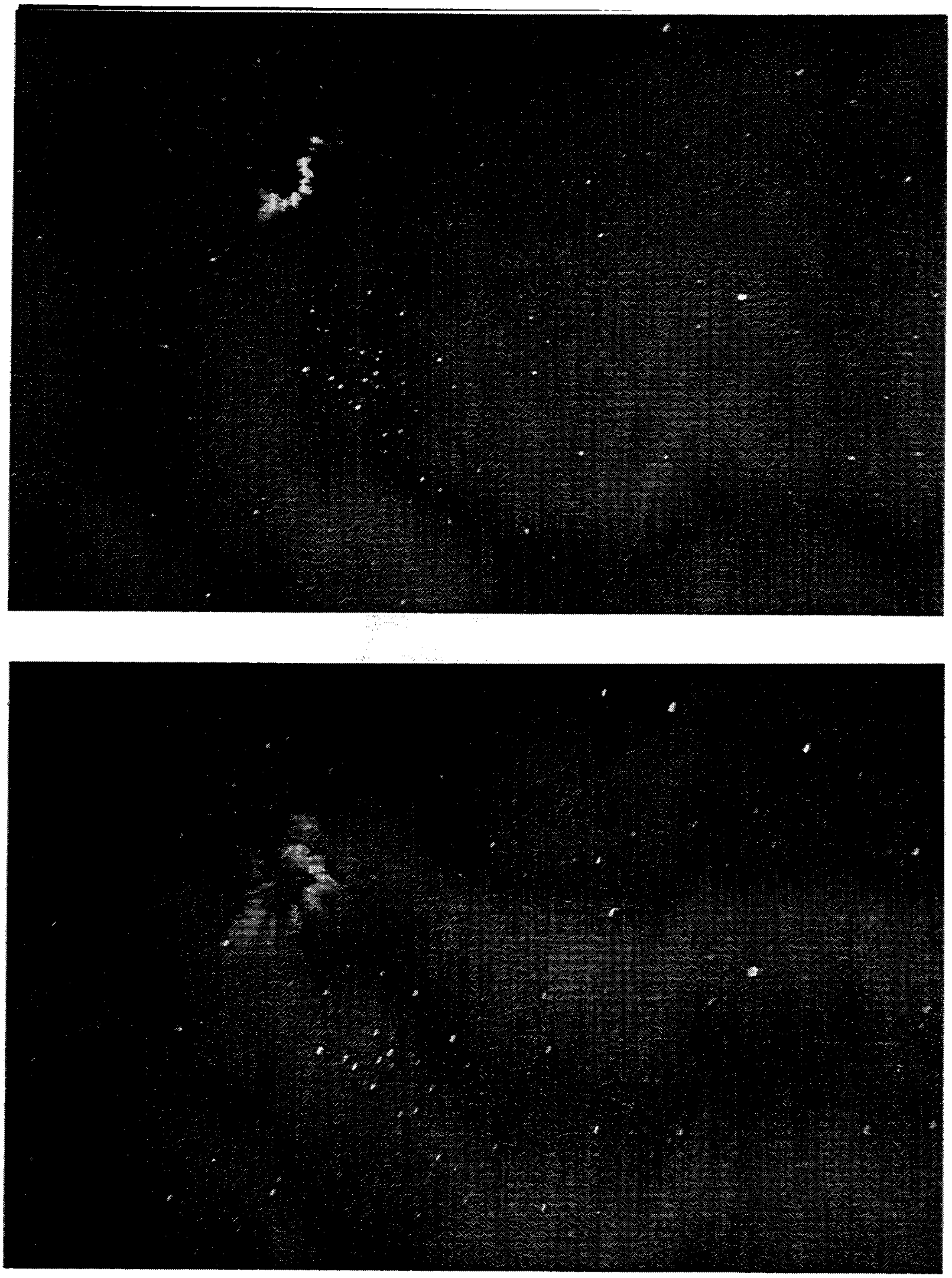


Figure 3 – *Top*: Two images of the persistent train of a magnitude −15 Leonid fireball which appeared at 4^h10^m UT in Coma Berenices. The persistent train was visible over 15 minutes with the naked eye. The limiting magnitude was already below +4 because of dawn. *Top*: A 30-s exposure at $4^h10^m20^s$ UT. *Bottom*: A 60-s exposure at $4^h11^m00^s$ UT.

About 4 km from my observing camp, Adrian Sima, a young *SARM* member, observed the Leonids from town (hindered by light pollution) through the windows of his apartment, because he was forced to stay inside by a minor health problem. He saw many fireballs reflecting in the windows of the neighboring buildings. Sometimes, he saw only a strong flash in the sky and ran to the other window to see the possible persistent train.

Overall, many people have witnessed this great show, even though most of them had no prior knowledge of the expected Leonid shower. Many people living in the countryside reported they were woken up by the fireball flashes. The public interest was very big. As a consequence, a lot of people planned to see the event the following night, and hundreds of inhabitants came from the city to the observing camp of *SARM*: unfortunately, the show was over...

During the next night, November 17-18, over 50 observers were active in the camp at Târgovişte, obviously disturbed by hundreds of people coming to observe the event. Shortly after midnight, the general public left the hill. It was too late for them to see the show. May be in 1999 they will be more lucky! *SARM* members, however, remained till the morning, trying to find more information on the Internet (a special connection was set up in the camp), but not with big success. No more information was available in time.

3. ZHR profile

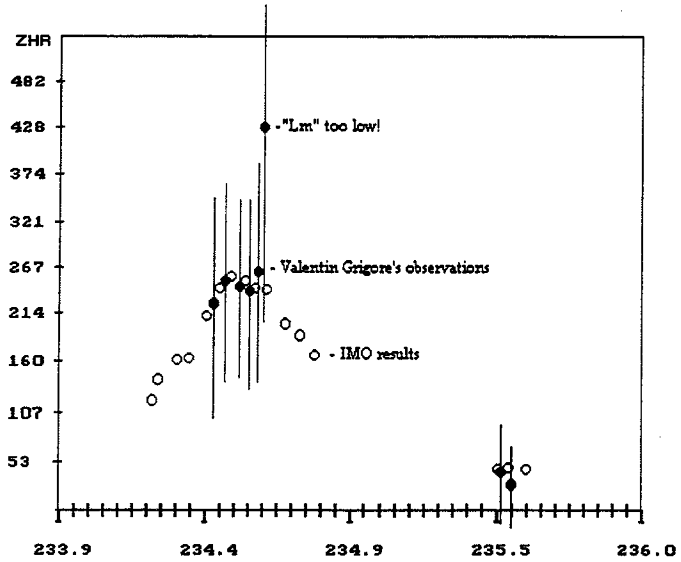


Figure 4 – ZHR profile for Valentin Grigore compared with *IMO* results.

Valentin Grigore's results are presented in Figure 1 and compared with the *IMO*'s results published at that time. The graph is made by Ştefan Berinde who was active with Vasile Micu in Bunila, where, unfortunately, the sky was covered all the time. The observing periods were given in short intervals, so we had to bin them in larger ones with sizes of around 60 minutes.

The very large ZHR value in the graph is probably overestimated due to a too low limiting magnitude during dawn (see also Table 1). For our calculations, we adopted the value of 1.3 for the population index, as was obtained by the *IMO* from much more reliable data.

Table 1 – Leonid rates and fireball distribution on November 16-17, 1998, as seen from Târgovişte by Valentin Grigore.

Period (UT)	T_{eff}	Lm	Leonids	Fireballs
22^h44^m–23^h10^m	0.16	+6.35	11	−7, −4.5
23^h10^m–23^h27^m	0.26	+6.35	19	?
23^h35^m–23^h45^m	0.15	+6.35	12	−3, −7
23^h45^m–23^h55^m	0.15	+6.35	12	−7
23^h55^m–00^h00^m	0.15	+6.35	10	−7, no other magnitudes recorded
00^h00^m–00^h10^m	0.15	+6.35	14	−8
00^h10^m–00^h20^m	0.15	+6.35	25	−5, −6, −4
00^h20^m–00^h30^m	0.15	+6.35	21	−4.5
00^h30^m–00^h40^m	0.15	+6.35	15	−10, strong flash of an unseen fireball
00^h40^m–00^h50^m	0.13	+6.35	12	−4, −5, −10, −8, −4, −3, another strong flash
00^h50^m–01^h00^m	0.15	+6.35	31	−3.5, −3
01^h00^m–01^h10^m	0.15	+6.35	32	−4, −6, −3, −4, another strong flash
01^h10^m–01^h20^m	0.16	+6.35	15	−3.5, −5
01^h20^m–01^h30^m	0.16	+6.35	32	−7, −6, −6, −5, −7
01^h30^m–01^h40^m	0.15	+6.35	22	−8, −9, −3

Table 1 – Continued.

Period (UT)	T_{eff}	Lm	Leonids	Fireballs
01^h40^m–01^h50^m	0.16	+6.35	29	−15, −8, −10, −11, −3, −6, −11, −3, −4, −3
01^h50^m–02^h00^m	0.14	+6.35	35	no magnitudes recorded
02^h00^m–02^h10^m	0.13	+6.35	16	−3, −4, −6, −6, −12, −5
02^h10^m–02^h19^m	0.15	+6.35	20	−5, −11, −4, −4, −5, −5, −3, −10
02^h19^m–02^h23^m	0.06	+6.35	17	−9, no other magnitudes recorded
02^h23^m–02^h26^m	0.05	+6.35	17	−3, −3, −6, −5
02^h26^m–02^h31^m	0.10	+6.35	11	−7, −4, −5, −3, −4
02^h34^m–02^h38^m	0.06	+6.35	16	−4, −3, −4, −3, −6, −3
02^h38^m–02^h43^m	0.08	+6.35	11	no magnitudes recorded
02^h43^m–02^h47^m	0.06	+6.35	13	−4, −12, −7, −6, −3, −5
02^h47^m–02^h51^m	0.06	+6.35	13	−3, −3
02^h51^m–02^h55^m	0.05	+6.35	11	−3, −4
02^h55^m–02^h59^m	0.06	+6.35	12	−4, −3, −5, −7
02^h59^m–03^h05^m	0.10	+6.35	16	−2, −4.5, −3, −10, −6, −6
03^h05^m–03^h10^m	0.08	+6.35	21	−3, −3, −3, −5, −7, −5, −4, −4, −3, −3
03^h10^m–03^h16^m	0.08	+6.30	25	−6, −7, −6, −3, −3, −4, −5, −7
03^h20^m–03^h25^m	0.08	+6.30	14	−4, −3, −3, −3, −6, −4
03^h25^m–03^h30^m	0.08	+6.20	18	−3, −3, −3, −3, −3
03^h30^m–03^h35^m	0.08	+6.10	22	−6, −6, −7, −3, −4
03^h35^m–03^h40^m	0.08	+5.90	18	−3, −3, −3, −4, −7, −3, −5, −3
03^h40^m–03^h45^m	0.06	+5.70	11	−3, −6
03^h45^m–03^h50^m	0.08	+5.60	14	−3, −4, −6, −10
03^h50^m–03^h55^m	0.08	+5.30	15	−4, −3, −5, −3, −4, −3
03^h55^m–04^h00^m	0.07	+5.20	16	−5, −7, −3, −9
04^h00^m–04^h05^m	0.08	+5.10	20	−3, −10, −3, −3, −12, −6, −4
04^h07^m–04^h10^m	0.05	+4.50	17	−10, −3
04^h10^m–04^h15^m	0.07	+3.90	16	−15, −8, −6, −3, −3, −3
04^h15^m–04^h20^m	0.08	+3.00	15	−4, −4, −4, −4, (−10, −4, −5 at 4^h17^m)
04^h20^m–04^h25^m	0.08	+2.50	9	−3, −3
04^h25^m–04^h30^m	0.08	+2.00	8	−4, −5, −3, −5
04^h30^m–04^h35^m	0.08	+1.00	10	−4, −3, −5, −5, −4, −3
04^h35^m–04^h42^m	0.13	−0.50	7	−5, −3, −8, −17, −4, −7

Table 2 – Magnitude distribution of the 1998 Leonids on November 16-17, as seen by Valentin Grigore from Târgovişte. Sometimes, it was impossible to record the magnitude. After 2^h34^m, only fireballs were estimated, and this proved hard at times; hence no data are given here for these observations.

Period (UT)	−15	−12	−11	−10	−9	−8	−7	−6	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5
22^h44^m–23^h27^m							1		0.5	0.5		1.5	7.5	7	5.5	4.5	0.5	0.5	1
23^h40^m–00^h00^m							3				1	1.5	4	4.5	4.5	1	0.5	1	
00^h00^m–00^h30^m						1		1	1.5	1.5	0.5	4.5	11	17.5	14.5	6.5	0,5	1	
00^h30^m–01^h00^m				2		1			1	2.5	3.5	7	7.5	14	9.5	2			
01^h00^m–01^h30^m							2	3	2	2.5	2	5.5	16	17.5	19.5	5.5	2.5		
01^h30^m–01^h50^m	1		2	1	1	2		1		1	4	1.5	12.5	15	6.5	2	0.5		
01^h57^m–02^h19^m		1	1	1	1			2	4	3	2	3.5	11.5	5.5	3.5	2			

4. More information

At the Internet address `http://www.geocities.com/CapeCanaveral/Cockpit/5865/sarm.htm` and at the *SARM* Web site `http://sarm.ccs.ro`, more Leonid results and photographs are available.

Ongoing Meteor Work

The Makings of Meteor Astronomy: Part XVIII

Martin Beech, Campion College, University of Regina

The free-flying balloon is an instrument of great importance in the study of the Earth's lower atmosphere, and in the past they were used as platforms from which to observe meteors. The hay-day of balloon-borne meteor astronomy appears to have coincided with the return of the Leonids in 1899.

> *"Journeying on high, the silken castle glides, Bright as a meteor through azure tides."*
>
> Erasmus Darwin, 1789—On the Montgolfier Balloon.

1. The silken castles

The era of balloon-borne adventure was ushered in with the daring flights of the Montgolfier brothers in 1783. Initially just a plaything and sensational vehicle for stunt displays, launched to please an awe-struck public, the potential of the free-flying balloon as a scientific platform was not truly realized until the mid-19th century.

One of the great practitioners of the early scientific flights was James Glaisher (1809–1903). Glaisher, in fact, conducted a whole series of balloon ascents between 1862 and 1866 for the *British Association for the Advancement of Science* [1], and the aim of these flights was to measure the changes in the temperature and pressure of the Earth's atmosphere as a function of height. Indeed, as Glaisher himself wrote in his classic book *Travels in the Air* (written with aeronautical pioneers Camille Flammarion, W. de Fonvielle, and Gaston Tissandier in 1871) [2],

> *"We have been enabled to ascend among the phenomena of the heavens, and to exchange conjecture for instrumental facts, recorded at elevations exceeding the highest mountains of the Earth."*

Indeed, from the earliest measurements obtained by Glaisher (and others), it became clear that the then standard rule of a one-degree[1] drop in temperature per 300 feet (90 m) of elevation would have to be abandoned.

The risks associated with the early balloon flights were not inconsiderable, and many scientists and aeronauts were killed when balloons burst in flight or landed badly. This being said, however, the balloon was the new object of high adventure and there was no shortage of people prepared to "journey on high" [3]. Indeed, Glaisher himself had one remarkable adventure, when on September 5, 1862, he undertook a flight with his friend and fellow aeronaut Henry Coxwell. Leaving from Wolverhampton in England, the balloon attained a record-breaking ascent of 6 miles (10 km). At one stage, Glaisher passed out, and Coxwell had to use his teeth to pull on the cord that operated the balloon's regulator, his hands being frozen and useless.

The earliest account that I have so far found of meteors being observed from a balloon is that by M. Garnerin in 1807. The account is contained in T. Forster's book *Annals of Some Remarkable Aerial and Alpine Voyages*, published in 1832 [4]. The flight began at night from the gardens of Tivoli in Paris on August 4, and Garnerin noted

> *"About two, I perceived the stars, and saw several meteors dancing about my balloon, but at such a distance as not to give me alarm."*

We can probably assume that the meteors observed were either Aquarids or early Perseids. More interestingly, however, we note that the account was written just eight years after E.F.F. Chladni had first suggested that meteors were not atmospheric in origin, but caused by extra-terrestrial matter crashing through the Earth's atmosphere [5]. Garnerin's concern was probably genuine fear, therefore, and his worry was that, should a meteor pass too close to his balloon, it might set it on fire.

[1] *Fahrenheit, approximately half a degree Celsius, Ed.*

Figure 1 – James Glaisher and Henry Coxwell shown in dramatic adventure during their heroic 6-mile-high flight of September 5, 1862. Glaisher lost consciousness for about 30 minutes during the peak of the flight, and later, upon landing, had to walk 7 miles to the nearest railway station to get help [1].

Henry Coxwell also wrote of observing what appears to have been a magnificent fireball during a balloon flight in 1887. While journeying in his balloon called the Sylph, Coxwell recorded, [6]

> *"I noticed a splendid meteor, which passed below the level of the car and apparently about six hundred feet distant—it was blue and yellow, moving rapidly in a north-easterly direction and became extinguished without noise or sparks. It is just possible that the apparent closeness of this meteor was illusory, and that the real distance was very many miles; its size was half that of the Moon, and I could not but feel that, if such another visitor were to cross my path, the end of the Sylph and its master would be at hand."*

Once again, we find some confusion as to the true heights of meteors and to the greatly overstated possibility of meteors destroying balloons in the Earth's lower atmosphere.

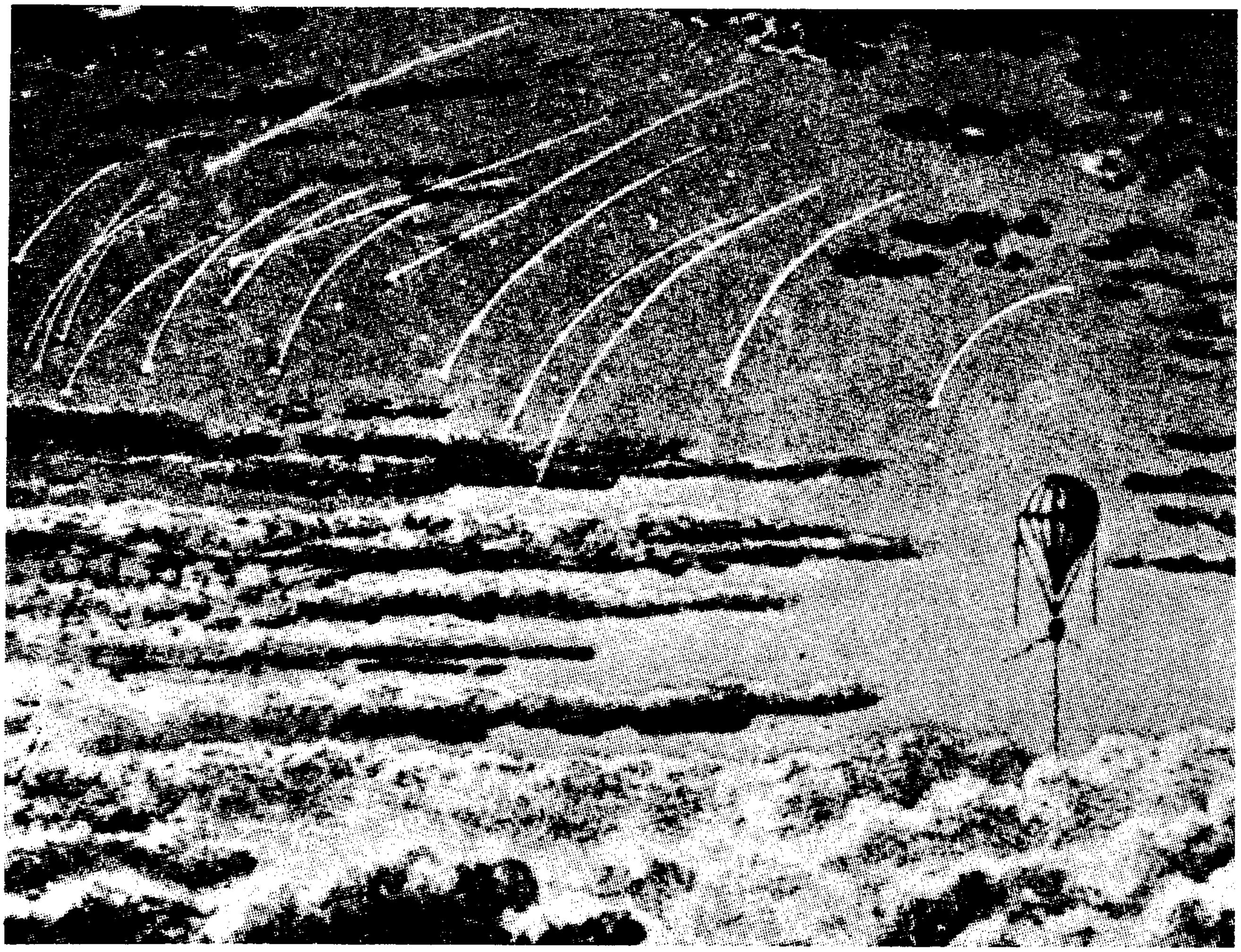


Figure 2 – Meteors seen from a balloon in 1870. Drawing by Albert Tissandier [2].

2. Looking for the Leonids

The earthly elements and the vagaries of the weather have long been the bane of astronomers. Indeed, we can all probably recount the annoying occasions when the anticipation of a good night's viewing was dashed by the arrival of obscuring clouds. Typically, the weather is simply an uncontrollable factor that the meteor observer has to put up with, but there are some circumstances when all efforts are required to compensate for the worst scenario. One such significant circumstance was that relating to the return of the Leonids at the close of the 19th century. Great fervor and public anticipation presaged the arrival of the 1899 Leonids [7], and many observers wary of the weather that might be expected in the autumnal months in Northern Europe prepared to make their observations from balloons.

One of the earliest accounts of Leonids being specifically observed from balloons was published in the report of the Luminous Meteors Section of the *British Astronomical Association* for 1867. The flights discussed in the *BAA* report took place in France, and the account begins,

> *"A partially successful attempt was made, on the occasion of the November meteors, by M. W. de Fonvielle to surmount the clouds, and to view the shower, at Paris, in Mr. Giffard's captive balloon... on the night of the 13th-14th of November, a still more adventurous voyage in a free balloon... and although the height attained did not exceed a few thousand feet, a clear atmosphere was reached, and observations were obtained of several shooting stars not visible to observers on the Earth's surface."*

During the 1899 Leonids, the air was literally a-buzz with balloons. Indeed, the astronomers had good cause to go aloft. The *Times* newspaper for November 16 reported, for example, *"London has been badly disappointed regarding the Leonid shower. Tuesday night was foggy, and last night cloudy and misty. It is believed that no observations were practicable anywhere in England."* The same short article goes on to say, however, *"M. de la Vaulx, who ascended in a balloon from Paris, saw about 100* [meteors] *on Tuesday night."* The *Times* for November 17 continued to report on the Leonids. The paper, in fact, carried a lengthy account of one balloon flight as described by "our correspondent." The article reads,

> *"Neath, November 16 ... starting soon after 4* [am], *we rapidly reached a cloud stratum at 1500 ft. Passing clear through this at 3000 ft, the Moon and stars burst upon us with great suddenness in a brilliant clear sky. There was no meteor shower in progress. Seven true Leonids were counted in the first hour, but, owing to the altitude of the radiant, any meteors coursing upwards would have been hidden by the balloon... perfect silence prevailed except for the sound of a large volume of air passing through the gun-cotton which we had provided to catch any debris of the Leonids. The Moon shone a dull copper color and Sirius scintillated greatly with a variable blue light. At* $5^{\rm h}58^{\rm m}$*, a low dawn broke rapidly, greenish gray with a copper-colored flush. Below the height of the balloon, 3000 ft, a few straggling meteors could still be detected, their frequency slightly increasing. Much ballast had been spent to preserve our equilibrium. The balloon came to Earth spontaneously at Neath after an unparalleled voyage of ten hours.*

The account of the balloon flight is truly wonderful, and one can only imagine the excitement and adventure. One interesting point contained in the above *Times* article is the idea of trailing a mass of gun-cotton in the hope of "catching" Leonid meteoroids. We now know, of course, that no Leonid ablation material would be expected in the atmospheric region sampled by the balloon—even if a great meteor storm had developed. No mention is made in the article whether anything was apparently found.

The *Times* for November 18 carried yet another story on balloon observations of the Leonids. This time the report was from France.

> *Mdlle. Klumpke, of the Paris Observatory, who was sent up in a balloon by the Meudon Observatory and the Aerial Navigation Society to observe the Leonids in the region above the fog and cloud, alighted yesterday morning at Saint-Germain-sur-Ay, near the channel. She saw only 12 shooting stars, several of them of the first magnitude. This, M. de Fonvielle thinks, proves that the greatest display was on Tuesday night, when 80 were counted by another balloon observer... A balloon from Strassburg containing three German observers fell to-day at Fanxault, near Beaune, and one of the party was seriously injured."*

The last section of the article underscores the danger associated with the early balloon flights, and, indeed, the story associated with the balloon adventure of the Reverend Bacon and his daughter on the night of November 16 is equally remarkable. Again, the story was carried by the *Times* (the November 21 edition) under the special heading *"In Quest of the Leonids—A record balloon voyage."* The article was written by the Reverend Bacon, and describes a flight begun in Newberry, in central Southern England, and which ended in near tragedy in a remote corner of South Wales. The Reverend describes how most of their ballast had been used up to get the wet balloon to ascend, and that this caused them considerable problems when they eventually wanted the balloon to land. At one stage, the aeronauts threw out pieces of paper with the message *"Urgent! Large balloon from Newberry traveling overhead above the clouds. Cannot descend. Telegraph to sea coast to be ready to rescue."* After a ten-hour flight, the balloon eventually came down with a bump, the result of which was that *"Miss Bacon sustained a fracture of the right arm, while her father was severely shaken."* And, after all this adventure and anxiety, the report continues, *"the party only saw five shooting stars, but were near enough to catch some of the fiery vapor by means of an apparatus specially constructed for the purpose..."*.

The closing section of the balloon flight article is interesting in that it suggests *"fiery vapors"* were collected. Since the balloon only attained an altitude of several thousand feet, it is clear that no meteors would have passed "close" to the balloon, and, indeed, the idea that the meteors produced a "vapor" was entirely antiquated even by 1899.

The apparent misconceptions about the properties of meteors shown by the Reverend Bacon, while surprising at so late a date, were not uncommon, and act to underscore the fact that old ideas often take on a life of their own, irrespective of being out-moded since many years. Indeed, similar "old-style" arguments were reported during the meeting of the *British Astronomical Association* in November 1899. The *BAA Journal* report of the meeting [8] begins with a discussion of the poor showing of the Leonids, and then turns to the comments offered by "Captain Steele." Apparently, *"he had some doubts whether the stream really existed. If it were a stream of any dimensions, it should reflect light, and that reflected light should be shown on a photograph, if not by our eyes. Until he saw that a photograph had shown that this stream reflected light, he could not believe it really existed, but rather that these meteors were simply the creatures of our Earth."* Steele's comments are interesting for two reasons. Firstly, it is remarkable that they were actually published. This is a seemingly harsh statement but it is really directed towards the editor of the *Journal*, in the sense that the views expressed were entirely outdated and indefensible by 1899. Secondly, and perhaps more interestingly, the irony behind Steele's comment is that his point was entirely correct, but at the wrong level. Meteor night-glow is certainly possible [9], and was seen during the 1866 Leonid storm (*however, see also the article by Vladimir Lukić in the previous issue of* WGN, *Ed.*), but the effective brightness of the reflected light, even under the most intense storm conditions, was entirely beyond the capability of the then photographic techniques to record.

With the dismal show of the Leonids in 1899, there appears to have been no further interest in using balloons to observe subsequent returns. The hay-day of meteor balloon flights had passed.

3. An outburst in Triangulum?

I am aware of just one singular event associated with the observation of meteors from a balloon. The matter was discussed, in fact, in a letter of correspondence between W.F. Denning and Alexander S. Herschel [10]. The letter dates from November 26, 1898, and reads,

> *"...I return Mr. Hansay's letter... The aeronauts' account may be considerably exaggerated, and Mr. Hansay to some extent misled about the strength of the shower which they saw, but as the report seems to have been submitted scientifically to the staff of the Meudon Observatory for discrimination (perhaps altogether under Mr. Jansson's superintendence there, as he is both an atmosphere investigator and an aeronaut who escaped from Paris in a balloon to see the total eclipse of December 22, 1870 in Algeria!* [11]*), there can be scarcely any doubt that there really was an exceptional meteor shower at about 2 am September 26th and that it radiated from in or near Triangulum..."*

There is, as far as can be realized, no known end-September meteor shower with a radiant in the constellation of Triangulum. The Piscid shower, however, does reach a present day maximum around September 20, and indeed, Pisces is adjacent to Triangulum on the sky. Interestingly, it was Denning who first suggested that there might be an active radiant in Pisces during the month in question. He observed distinct meteor radiants in Pisces in 1879 and 1885, but did not conclude that the shower was annual. The Piscid radiant is near $\alpha = 5°$ and $\delta = -1°$, which does suggest that an association with the balloon observations is questionable, since Triangulum is situated at $\delta = +30°$. The Piscids are a weak annual shower at best and a ZHR of about 3 meteors per hour is derived at shower maximum. Gavajdova, however, has linked the stream to some fireball activity [12], but finds no obvious parent to the stream. I have not as yet been able to verify the details and content of the letter discussed by Herschel and Denning. But, should the account be true, then one might speculate that either a singular, Corvid-like display of meteors was seen by the aeronauts on September 26, 1898, or, a rare (and incorrectly identified) outburst of the Piscids was recorded.

4. Otherworldly views of meteors

Meteors have been seen from many lofty locations, but perhaps the most singular observation was that obtained by the camera aboard the Voyager 1 spacecraft when a fireball ablating in the atmosphere of Jupiter was recorded on March 5, 1979 [13]. In the modern era, the nearest equivalent to the balloon-borne adventurers are the Space-Shuttle astronauts. Indeed, ESA astronaut Claude Nicollier commented [14], *"there was one night, as we were flying over Brazil as I remember it, ... when suddenly I saw a shooting star cross my line of vision and disintegrate in the atmosphere below the Shuttle. It was absolutely incredible."* In the Space-Shuttle case, the threat of meteoroid impacts is much more of a direct concern than that believed by the pioneering aeronauts, and, indeed, the meteors do occur below the craft.

Notes and references

[1] J.L. Hunt, "James Glaisher FRS (1809–1903) Astronomer, Meteorologist and Pioneer Weather Forecaster: A Venturesome Victorian", *Quarterly J. R. Astr. Soc.* 37, 1996, p. 315.

[2] J. Glaisher, C. Flammarion, W. de Fonvielle, G. Tissandier, "Travels in the Air", Richard Bentley, London, 1871.

[3] An anonymous reviewer of Glaisher's book wrote in *Nature* 4, 1871, p. 3, *"Both the scientific and the lover of adventure will find abundance to interest them in this handsome volume. The terrestrial fields of enterprise are getting exhausted. Mont Blanc has long since been used up. We are getting tired of Central Africa and the Steppes of Tartary... ".*

[4] T. Forster, "Annals of Some Remarkable Aerial and Alpine Voyages, Including Those of the Author", Keating and Brown, London, 1832.

[5] M. Beech, *WGN* 22:6, December 1994, p. 214.

[6] H. Coxwell, "My Life and Balloon Experiences", 2 vol., W.H. Allen, London, 1887, 1889.

[7] M. Beech,, "Public Perception, Meteor Astronomy, and Leonid Storms", *WGN* 25:3, June 1997, p. 124.

[8] "Report of the Meeting of the Association Held on November 29th", *JBAA* 10, 1899, p. 61.

[9] W.F. Baggaley, "The Meteoric Night-Glow", *Mon. Not. R. Astr. Soc.* 181, 1977, p. 203. Meteoric night-glow was also reported during the Andromedid storm of 1872.

[10] M. Beech, "The Herschel-Denning Correspondence: 1871–1900", *Vistas in Astronomy* 34, 1991, p. 425.

[11] Pierre Jules César Janssen (1824–1907) was a pioneer of scientific ballooning and first director of the Meudon Observatory. The adventure mentioned by Herschel in his letter to Denning took place during the Franco-Prussian War. Being primarily interested in solar observations, he had hoped to observe the eclipse predicted for December 22, 1870. The eclipse would have been total from Algeria, but Paris was under siege. To circumvent the restrictions of the encircling forces, Janssen left Paris by balloon on December 2. Unfortunately, when the eclipse occurred, it was cloudy and he no longer had use of the balloon for observations. (*The Dictionary of Scientific Biography*, Charles Gillespie, ed., Charles Scribner's Sons, New York, 1973).

[12] M. Gavajdova, "Search for Associations Between Fireball Streams and Asteroids", *Earth, Moon and Planets* 68, 1995, 289.
[13] A.F. Cook, T.C. Duxbury, "A Fireball in Jupiter's Atmosphere", J. Geophys. Res. 86, 1981, pp. 8815–8817.
[14] ESA press information note 24-93.

Possible New Radiant in Auriga on November 17, 1998

Detlef Koschny and Joe Zender, ESA/Space Science Department, Noordwijk

During the Leonid observing campaign in 1998, we found indications for a possible radiant in Auriga. We provide an analysis of the sporadic meteor data to support this, and invite other observers to check their data and to confirm our conclusion.

1. Introduction

During the regular Leonid observing campaign of ESA/SSD, our video system DS1 (Digital System 1) was recording the sky for 5 hours. Analyzing the directions of the non-Leonid meteors on the tapes, we found that, in the evening of November 17, 1998, a high percentage of the sporadic meteors seem to come from the Auriga area.

2. Observing and measurement methods

We observed with a group of the Dutch *Werkgroep Meteoren* from Molenaarsgraaf, close to Dordrecht, the Netherlands ($\lambda = 4°53'09''$ E, $\varphi = 51°52'54''$ N). The visual limiting magnitude was 5.4, the faintest stars on the video recordings were between 7.5 and 8.0. Our video equipment consisted of the modified IMCA camera. In its basic form, it is one of the cameras described in [1], using a 50 mm $f/0.75$ Rayxar lens and a Hamamatsu-compatible second-generation image intensifier. We recorded the image with a digital camera (Sony DCR-VX1000E) on DVD tape. The field center was $\alpha = 85°$ and $\delta = +40°$ (Capella in Auriga) until 0^h30^m UT, $\alpha = 110°$ and $\delta = 26°$ (Gemini) after that time.

The tapes were copied to a PC via a Matrox Meteor II frame grabber card. To obtain a quick position measurement of the meteors, we displayed them using the VIDAS Quicklook software [2], and compared their position to a display generated with the star display *Guide 7.0* using the Hipparcos star catalog. Independent measurements of the same meteor showed the accuracy to be about $\pm 0\overset{\circ}{.}2$ in declination and $\pm 0\overset{\circ}{.}6$ in right ascension. The apparent velocity of the meteor was determined by dividing the length of the path by the elapsed time as determined by counting the video frames on which the meteor was visible. We estimate the accuracy of the velocity determination to be about 30%. We plotted the meteors using the RADIANT 1.41 software [3].

3. Results

In the time interval from 21^h40^m UT to 1^h18^m UT, a total of 38 meteors was recorded on video, 14 of which were Leonids. Of the remaining 24 sporadic meteors, 9 have positions and apparent velocities consistent with a common radiant at about $\alpha = 77° \pm 1°$ and $\delta = 35° \pm 2°$. Figure 1 shows the output of the RADIANT software. We plotted the "probability distribution" for all sporadic video meteors. Radiant traces the meteor paths backward, allowing for errors in the position determination. It also assigns a probability distribution for the radiant of the meteor on its backward track, as a function of apparent velocity. In the figure, the maximum at the mentioned position is clearly visible.

To estimate whether this could be a statistical effect, we compare our findings with [4].

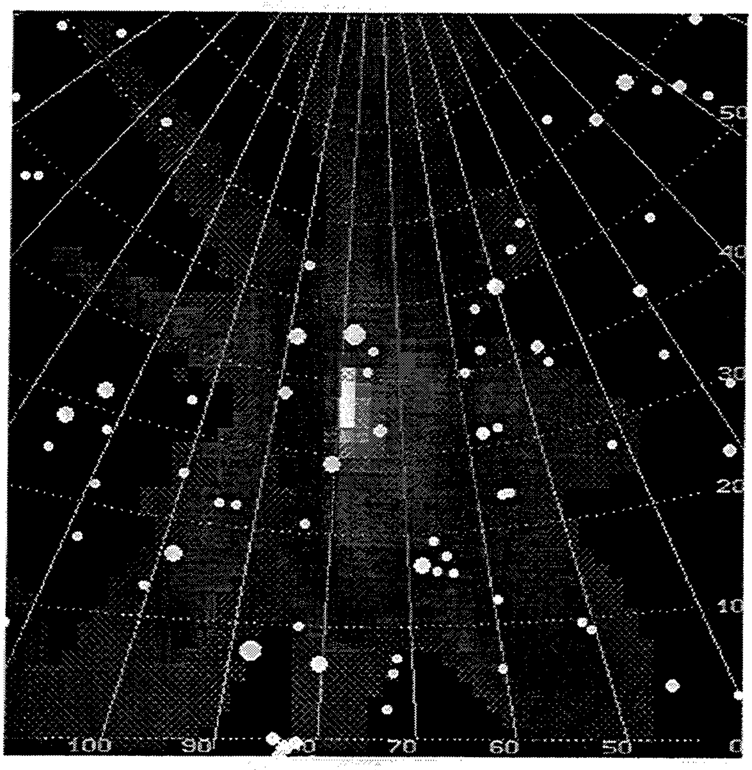


Figure 1 – The radiant "probability distribution" of 24 sporadic meteors between 21^h40^m and 1^h18^m UT in the night of November 17-18, 1998. About half of the meteors have paths consistent with a common radiant at $\alpha = 77°$ and $\delta = +35°$ in Auriga. Stars down to 4th magnitude are shown; the bright star above the center is Capella.

Arlt simulated a realistic random distribution of 1500 meteors and searched for radiants in this data set. He found a convergent point for 5 or more meteors on average only in every seventh run. The number of meteors Arlt used is almost 2 orders of magnitude larger than in our sample. Therefore, we are confident that our result is significant.

4. Conclusions

Even though the radiant of an individual meteor can only be determined with multi-station observations, the high percentage of sporadic meteors (about 40%) from the direction of Auriga looks significant. A confirmation of this result by other observers is mandatory. Many groups were active in that time period in the frame of the Leonid observing campaigns. This article is intended to stimulate these groups to analyze their data not only in view of the Leonids, but also to search for a possible radiant in Auriga. We kindly ask other observers having positional meteor data from non-Leonids in the time period November 16–18, 1998, to make them available to us for a more detailed analysis.

References

[1] M. Nitschke, "New TV Cameras for Meteor Observations", in *Proceedings IMC*, Apeldoorn, September 19–22, 1996, A. Knöfel, P. Roggemans, eds., IMO, pp. 80–81.

[2] D. Koschny, J. Zender, A. Knöfel, P. Chilson, G. Schmidt, "A Data Evaluation System to Compare Meteor Observations Obtained with Video and Radar", in *Proceeding Meteoroids 98*, Astronomical Institute of the Slovak Academy of Sciences, Special Publication, 1999, *submitted*.

[3] R. Arlt, "The Software 'Radiant'", *WGN* 20:2, April 1992, pp. 62–69.

[4] R. Arlt, "Radiants from Simulated Meteors", in *Proceedings IMC*, Apeldoorn, September 19–22, 1996, A. Knöfel, P. Roggemans, eds., IMO, pp. 24–31.

On the Occurrence of Bright Taurids

Alastair McBeath

Following David Asher and Kiyoshi Izumi's timely warning about possible unusual Taurid activity in 1998 [1], this present paper re-examines the overall occurrence of bright (magnitude 0 or less) Taurids from *IMO* records between 1988 and 1997. A generally higher percentage of such bright Taurids, and also fireballs, is found during the period from October 23 to November 15, coincident both with the typical Taurid maximum epoch (November 5-6 to 12-13 [2]) and the period suspected of occasional enhancements due to "swarms" of material within the Taurid stream, from late October to early November. Although individual years' statistics show fluctuations in the appearance of brighter Taurid events within or without this period, a remarkably consistent difference in the corrected mean magnitude $\overline{m}_{6.5}$ of 0.2 is found in comparing the October 23 to November 15 spell with the entire Taurids' active period. The Taurids in the former period are consistently brighter. Taurid fireball proportions are also compared with those in the Perseid and Geminid showers, and the sporadics.

1. Introduction

Back in 1992, the present author carried out an analysis of Taurid fireball proportions, comparing several different visual data sets [3], using the standard international definition that a fireball is a meteor attaining magnitude −3 or brighter. The general consensus of that work was that the Taurids produced a proportion of fireballs (1.4%) equivalent to that seen with the major showers of the Perseids (1.7%) and Geminids (1.4%), and significantly greater than the sporadic fireball fraction (0.4%). The conclusions of that paper also suggested variations in the Taurid fireball percentage from year to year might be apparent, but that the data sample was too limited to be more specific. Since then, *IMO* observers have continued to monitor the Taurids each year, and that data has been republished by the *IMO* in printed form for all interested parties to see in the annual *WGN Report Series* volumes. The reports in volumes 1–7 (1988–1994 data) were edited by Paul Roggemans, the reports in volumes 8–10 (1995–1997 data) by Rainer Arlt. It is this ten-year printed series of data which has been drawn upon exclusively in this present examination.

However, rather than simply re-analyze the data for fireball-class meteors only, following the suggestions in [1], meteors of magnitude 0 and brighter were also considered, and a simple time-base was employed, segregating Taurid events between October 23 to November 15 (a period hereafter referred to as "O23–N15") from those seen before and after this period, again following suggestions in [1] coupled with the known period of maximum Taurid activity from [2]. Preliminary reports to the *SPA Meteor Section* indicated this period in 1998 seems to have produced a higher than normal number of minor Taurid fireballs (magnitudes −3 to −5), as well as anomalously higher visual Taurid activity (ZHRs around 7–10) between roughly October 28 to November 1, and unexpectedly enhanced radio rates between approximately October 25 to November 1, most especially around October 30–31. Neither visual nor radio rates were greatly increased above normal levels, but a significant difference was seen. This is reported in more detail elsewhere [4].

2. Bright Taurid analysis and discussion

From the various *WGN Report Series* volumes, appropriate Taurid data were extracted from those observations where the limiting magnitude was at least +5.5, and where the observers were known to be at least reasonably experienced. This latter criterion was maintained less stringently than usual, especially in years where less than 300 Taurids were available for examination. With the primary concern to establish approximate proportions of meteors greater and less than magnitude 0, it was felt any minor personal errors in magnitude estimations could be effectively ignored without seriously influencing the result. Other details, including corrected mean magnitudes and mean limiting magnitudes, were computed as the analysis proceeded. It was not felt viable to compute r-values from the magnitude details, as, in most years, too few Taurid meteors were seen for such values to have especial statistical reliability. A global value from the entire ten-year data set would have been more practical, but this would not have shown up any variations between separate years, for which an r-value analysis would have been most useful. An attempt was made to separate the Taurids into their Northern and Southern components, too, but this was unsuccessful, as insufficient observers regularly made this distinction in their published reports, with a sizeable fraction (about 20%) of all these shower members just called "Taurids." The ongoing examination of plotted Taurids by Mihaela Triglav [5] should help in resolving this problem in the future, as long as plenty of observers continue providing details of plotted meteors during October and November. Table 1 gives the results of this examination. Table 2 gives the percentages of fireball-class Taurids per year, together with numerical and percentage figures for Perseid, Geminid, and sporadic meteors and fireballs during the same period for contrast.

Table 1 – The numbers of Taurids of the indicated magnitude classes and brighter (subscript number), together with the appropriate mean limiting magnitudes and corrected mean magnitudes ($\overline{m}_{6.5}$) for all Taurids, and those seen in the O23–N15 period, per year. The percentage (%) of the main magnitude bins occurring during O23–N15 is also indicated.

Year	All					O23–N15							
	TAU_{-3}	TAU_0	TAU_{All}	Lm	$\overline{m}_{6.5}$	TAU_{-3}	$\%_{-3}$	TAU_0	$\%_0$	TAU_{All}	$\%_{All}$	Lm	$\overline{m}_{6.5}$
1988	13.5	123.5	1132	6.22	3.43	13.5	100	120.5	98	906	80	6.12	3.17
1989	0.5	11	355	6.50	3.48	0		4	36	210	59	6.53	3.27
1990	7	38	864	6.51	3.67	0	0	14.5	38	218	25	6.41	3.17
1991	8	62.5	882	6.36	3.45	8	100	53	85	583	66	6.39	3.24
1992	3	32	255	6.16	3.22	2	67	19	59	198	78	6.18	3.02
1993	5	30.5	280	6.34	2.77	1	20	11	36	87	31	6.47	2.48
1994	1.5	9.5	242	6.29	3.20	1.5	100	7.5	78	185	76	6.31	3.01
1995	8	91	987	6.30	3.07	0	0	13.5	15	113	11	6.46	2.56
1996	6	36	579	6.24	3.14	3	50	19.5	54	251	43	6.33	3.04
1997	2	21	262	6.18	3.25	2	100	19.5	93	220	84	6.19	3.18
Tot	54.5	455	5838	6.30	3.23	31	57	282	62	2971	51	6.34	3.03

Table 2 – Overall and O23–N15 ("Main") Taurid fireball percentages per year, compared with the numbers of Perseid, Geminid, and sporadic meteors and fireballs, and the fireball percentages in each of these categories. For the non-Taurid material, all data where the limiting magnitude was at least +5.5 have been used for simplicity.

Year	Taurids		Perseids			Geminids			Sporadics		
	$\%_{All}$	$\%_{Main}$	N	N_{-3}	%	N	N_{-3}	%	N	N_{-3}	%
1988	1.2	1.5	27202	182.5	0.7	7575	66.5	0.9	44773	65	0.2
1989	0.1		25050	119.5	0.5	337	3	0.9	40093	27	0.1
1990	0.8	0.0	4240	34	0.8	10720	54.5	0.5	40927	53.5	0.1
1991	0.9	1.4	43966	318	0.7	26922	153	0.6	46045	87.5	0.2
1992	1.2	1.0	10505	142.5	1.4	1338	12.5	0.9	30578	96.5	0.3
1993	1.8	1.2	83817	1523.5	1.8	20968	188	0.9	55247	279.5	0.5
1994	0.6	0.8	49461	528.5	1.1	3936	21.5	0.5	40066	118.5	0.3
1995	0.8	0.0	14092	150.5	1.1	1604	23.5	1.5	50007	201.5	0.4
1996	1.0	1.2	46285	626	1.4	24107	207	0.9	59676	230.5	0.4
1997	0.8	0.9	83595	910.5	1.1	939	8	0.9	85177	305	0.4
Tot	0.9	1.0	388213	4535.5	1.2	98446	737.5	0.7	492589	1464.5	0.3

Prior to 1996, *IMO* information indicated that Taurid meteors might first be observed as early as mid-September, but from that year, during the analysis work leading to the publication of the new *Handbook for Visual Meteor Observers* [2], it became clear that the first genuine Taurid activity was not apparent before early October, and the activity dates for both Northern and Southern Taurid showers were amended accordingly. In this analysis, the majority of Taurids claimed significantly beyond the currently accepted activity dates (October 1 to November 25) were ignored. Very few meteors fell into this category in any case. If we thus assume a total active period of 56 days for the Taurids each year, 22 days of which fall before the O23–N15 spell, and 10 after, this means the 24 days of the O23–N15 period represent 43% of the total time the Taurids are active. From Table 1, it is clear that, on average, a disproportionately high percentage, around 60%, of both fireballs and Taurids of magnitude 0 and brighter, occur during this time, along with just over half the total number of Taurid meteors. This is not unexpected, since a different meteoroid population has been noted nearer the maxima of several other showers, too, and rates should of course be increased compared to other times. The differences are perhaps not as great as might have been suspected from observers' impressions, and there are variations from year to year, but much of the fluctuations are probably attributable to the small numbers of meteors involved. This is especially true for the fireballs.

There is no clear pattern in the occurrence of brighter Taurids year to year from these numbers alone, though periods of moonlight and difficulties due to poor weather must be taken into account. For instance, all the fireballs and almost all the magnitude 0 and brighter Taurids occurred during the 1988 and 1991 O23–N15 time, which were both years identified as possible Taurid "swarm" years in [6], yet this period in 1995, another year similarly listed, yielded no fireballs and the very lowest percentage of Taurids of magnitude 0 or brighter of any year, in spite of the Taurid numbers seen being exceptionally high. The November 1995 Full Moon period coincided perfectly with the Taurids' extended maximum, however, as shown by the very low number of Taurids seen in the O23–N15 period, whereas New Moon fell perfectly for this time in both 1988 and 1991. It should be noted that significant numbers of casual sightings of Taurid fireballs were made from the end of October until mid-November 1995, as reported in [7], for instance. Consequently, the *IMO* data, though invaluable, are not infallible, since such casual fireball sightings not observed during meteor watches will not feature in the *WGN Report Series* volumes.[1] It may be that the probable identification of casually seen fireballs reported to *FIDAC*, based on the observed meteor tracks, should also be routinely published in *FIDAC News* to assist in future investigations of this kind.

The pattern of Taurid fireball occurrence is probably not as variable from year to year as Table 2 might suggest, and is probably more a result of the small numbers of Taurids and Taurid fireballs reported in many years. The overall percentage is comparable with the proportions found in the Perseid and Geminid showers, and remains around three or more times the proportion seen from the sporadics. The Perseids and Geminids show more consistent fireball populations from year to year, but note the increase in the Perseid percentage after 1991, the first year the new primary maximum produced such notable outbursts. The low percentage in 1991 is almost certainly a result of too few Far-Eastern observers providing full magnitude distributions to the *Visual Meteor Database* in that year, as the main proportion of Perseid fireballs would have been seen from such sites in 1991. The differences in the percentage of Taurid fireballs as a whole and seen during the O23–N15 period are relatively slight, but hint at this period being a little richer in Taurid fireballs in at least half the years investigated. The statistics so far provide some support for a marginally different meteoroid population during the O23–N15 period, and provide some tentative support for the Taurid "swarm" concept as proposed in [6]. The difference between the O23–N15 time and the remainder of the Taurids' active period does not appear very consistent from these figures, however.

[1] *However, it must be noted that, in order to keep the size of the* Report Series *reasonable, only magnitude distributions with 5 meteors or more are printed. The total number of Taurids in the* Visual Meteor Database *is more than twice as large as given in Table 1 in all categories, Ed.*

If we look again at the difference in corrected mean magnitudes between these two intervals in Table 1, however, there is a significant finding to be made. This is illustrated by Table 3. The first thing to notice is the difference is always positive, which means that those meteors seen within the O23–N15 timespan are on average brighter than those seen during the remainder of the Taurid shower. The second thing is that the difference is relatively consistent from year to year. The main times of variation may well be worth further examination, where a statistically significant number of Taurids were observed—for example, 1990. Note too that 1995 now appears a more interesting year during the O23–N15 period than the other indicators initially showed.

Table 3 – The difference in corrected mean magnitudes between the Taurids seen in the O23–N15 interval, and all Taurids observed, per year. The former are consistently brighter.

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	*Mean*
$\Delta m_{6.5}$	0.26	0.21	0.50	0.21	0.20	0.29	0.19	0.51	0.10	0.07	0.2

3. Conclusion

The Taurids have proved a difficult shower to examine in the past, because of their relatively low rates. For this reason, it has been attempted to examine the shower by combining data from many different years. Although this may provide some useful material on the shower as a whole, it does not yield the more interesting information on variations between different years which Asher and others have suggested.

The present analysis shows it is possible to derive some useful Taurid results from the *WGN Report Series* on an annual time scale. It is to the credit of the *IMO*, and more importantly all those people who have contributed data to it in its internationally recognized standard formats, that this is now possible. It is of central importance that such observations should continue to be made, not simply at times when major shower maxima are expected.

Since details found here, and the preliminary *SPAMS* Taurid data from 1998, provide some support for Asher's Taurid "swarm" model, radio observers should note his 1994 paper [6] indicates that we may see a possible "swarm" appearance during the daytime β-Taurids in June 1999, and again in June 2002, though the next October-November "swarm" passage is not predicted before 2005.

References

[1] D. Asher, K. Izumi, "Taurid Swarm Appearing in 1998?", *WGN* 26:5, October 1998, p. 217.

[2] J. Rendtel, R. Arlt, R. Koschack, A. McBeath, P. Roggemans, J. Wood, "Meteor Shower Descriptions: Taurids", in *Handbook for Visual Meteor Observers*, J. Rendtel, R. Arlt, A. McBeath, eds., IMO, 1995, pp. 230–235.

[3] A. McBeath, "Taurid Fireball Proportions", *WGN* 20:1, February 1992, pp. 22–26.

[4] A. McBeath, "SPA Meteor Section Results: September–October 1998", *WGN* 27, 1999, *to appear*.

[5] M. Triglav, "The Taurid Radiants", in *Proceedings IMC*, Stará Lesná, Slovakia, 1998, A. Knöfel, A. McBeath, eds., IMO, *to appear*.

[6] D. Asher, "Meteoroid Swarms and the Taurid Complex", in *Proceedings IMC*, Puimichel, France, 1993, P. Roggemans, ed., IMO, pp. 88–91.

[7] A. McBeath, "SPA Meteor Section Results: November–December 1995", *WGN* 24:3, June 1996, pp. 96–100.

Observing Meteor Trails with Radio Dopplergrams

Bev Ewen-Smith

A method for detection of meteor trails by radio is described which provides rather more information about the scatterer than the conventional radio method. By also registering the Doppler shift caused by the movement of the scatterer, more quantitative measurements may be derived.

1. Introduction

It has always been problematic to reconcile meteor observations made visually and those made using detection by radio forward scatter. This is partly because the conventional radio technique simply detects an enhancement in the received signal level of an over-the-horizon radio transmitter, above a certain threshold. In essence, it constitutes a one-bit measurement with respect to a threshold whose definition is itself uncertain. Consequently, it is difficult to relate the absolute magnitude of radio detection rates to an equivalent visual rate.

This paper describes a method of detection of meteor trails by radio which provides rather more information about the scatterer than the conventional radio method and which may permit more quantitative measurements to be derived.

2. Radio scattering

In general, radio energy can travel from a radio transmitter to a radio receiver directly by line-of-sight, by diffraction over the intervening terrain, by ionospheric reflection, by tropospheric scattering, or by scattering by other objects illuminated by the transmitter and visible from the receiver. The conventional over-the-horizon, forward-scattering method of meteor detection uses a signal whose frequency and distance from the transmitter are selected such that the receiver does not normally receive a significant signal level by any but the last of those mechanisms. Then, if the geometry is favorable, the appearance of a meteor trail within the illuminated, visible volume scatters some radio energy towards the receiver. As a result, there is a brief increase in signal strength which may exceed the detection threshold in the receiver and the meteor event is counted. Figure 1 illustrates the concept of over-the-horizon scattering.

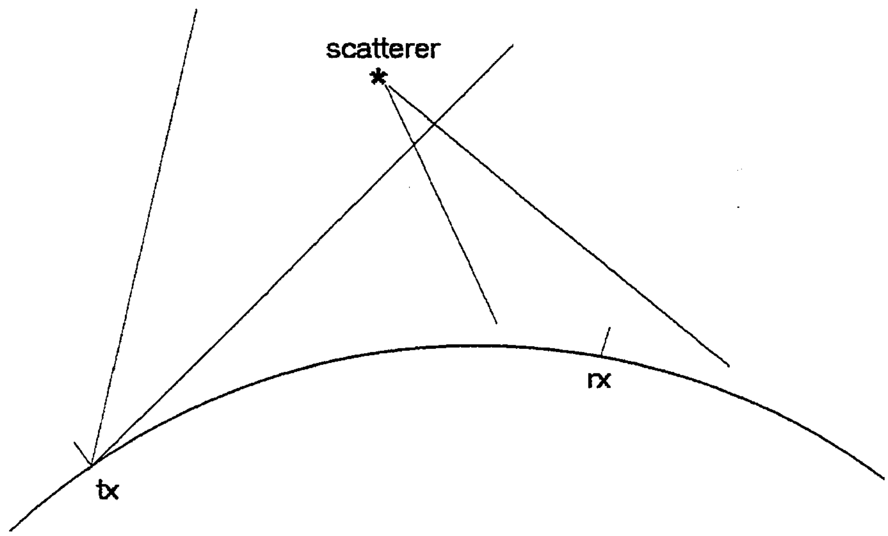


Figure 1 – Over-the-horizon forward-scattering method of meteor detection.

The Dopplergram method uses the same geometry but, instead of detecting only the amplitude of the received signal, it also measures the frequency with great precision. If the radio signal is scattered by an object which is moving, then there will be a Doppler shift imposed on the scattered signal. By examining the spectrum of the scattered signal, information is revealed about the movement of the scatterer.

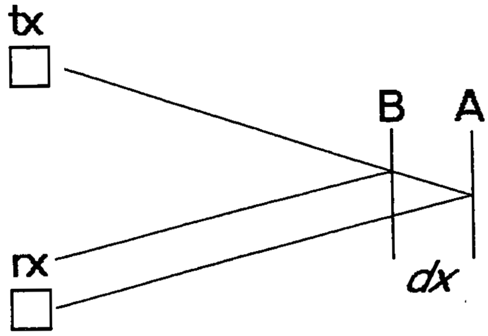


Figure 2 – Relationship between Doppler shift and velocity of the scatterer.

Because of the path geometry, the Doppler shift will be that corresponding to the rate of change of path length transmitter-scatterer-receiver, which is not quite the same as the velocity of the scatterer.

For example, if the transmitter and receiver are relatively close and the scatterer is approaching both, the rate of change of path length approximates to twice the velocity of the scatterer. In Figure 2, the reflector moves a distance of dx units from A to B, while the path length tx-A-rx differs from tx-B-rx by approximately 2 dx units.

There are two velocity regimes in the context of meteor events. The velocity of the meteoroid itself, generally tens of kilometers per second, and the velocity of the resulting ionization trail, which is equal to the upper winds at the 80–100-km level, typically of the order of a few hundred meters per second. The former typically lasts for a fraction of a second; the latter, which is detected by the Dopplergram method, often endures for seconds or minutes.

3. Choice of transmitter signal

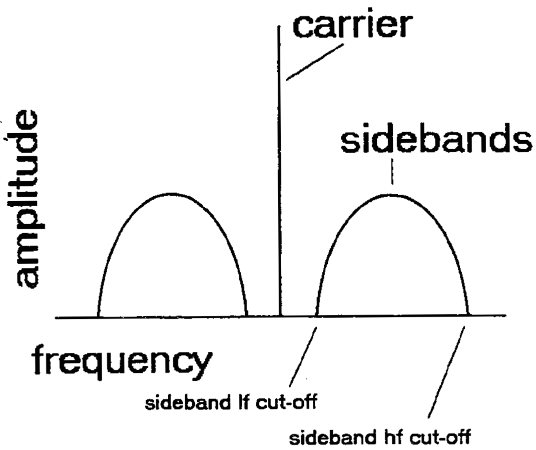


Figure 3 – AM signal spectrum.

As the method detects the small Doppler shift imposed on the transmitted signal, it is necessary to employ a signal which has a spectrally pure carrier signal. This requirement excludes all frequency-modulated (FM) signals such as VHF sound broadcasting often used for the threshold method, as well as the sound component of TV signals (also FM). The transmitted spectrum of an amplitude-modulated (AM) signal consists of the carrier itself, surrounded by sidebands at the carrier frequency plus or minus the frequency of the modulating signal.

Figure 3 illustrates the disposition of the carrier and the two symmetrical sidebands in an AM signal.

In order to detect the Doppler-shifted, scattered signal from the meteor trail, it is necessary that the transmitted signal does not include sidebands which would overlap the expected Doppler frequencies. For example, at a carrier frequency of 100 MHz, the Doppler shift corresponding to a path length rate-of-change of 400 m/s would be 133 Hz. Higher carrier frequencies would produce a proportionally higher Doppler shift.

Conventional TV broadcast video signals are amplitude-modulated, but the sidebands begin at ±50 Hz, corresponding to the lowest video component of the signal. Therefore, even low-band TV signals do not have sufficient clearance between the carrier and the sidebands for the detection of the Doppler-shifted, scattered signals.

Short-wave sound broadcast signals also use AM, but because the program material usually has a low frequency cut-off of around 300 Hz, there is a gap of up to 300 Hz between the carrier and the modulation sidebands. With carrier frequencies closer to 10 MHz than 100 MHz, this means that the Doppler-shifted signals have plenty of quiet spectrum within which to be detected.

The disadvantage of short-wave signals is that they are often strongly reflected by the ionosphere. As a result, care must be exercised in choosing a transmitter which is, in radio parlance, "inside the skip distance." This implies that, at the operating frequency, the transmitter is too close to allow "sky-wave" propagation (too acute an angle of reflection at the ionosphere), but too far to allow "ground-wave" propagation (by line-of-sight or terrain diffraction propagation).

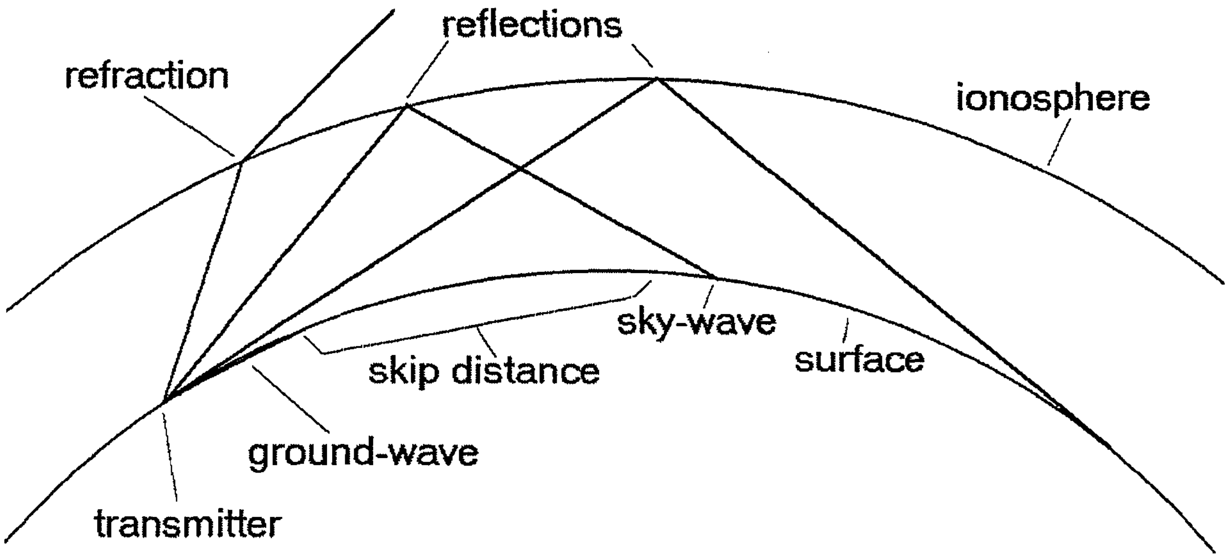


Figure 4 – The concept of "skip distance."

The former limit is strongly frequency-related, and depends on the time of day and the properties of the ionosphere (linked to sunspot levels), while the latter is weakly frequency-dependent, but typically demands a range greater than about 150 km at short-wave broadcasting frequencies. Figure 4 illustrates the concept of "skip distance."

The experiments described below have principally employed a short-wave AM broadcast signal transmitted from a site in Lisbon, 250 km north of the receiving site, operating on a frequency of 21.655 MHz. The broadcast is intended for reception in Brazil at a range of more than 6000 km. The incident angle at the ionosphere for the path to Brazil is small enough to permit effective reflection at the ionosphere (analogous to total internal reflection), but the incident angle for the path to our receiver is too acute for effective reflection.

4. Detection of the Doppler-shifted signal

As noted above, the signal consists of the carrier frequency (21 MHz in the example cited), program material in the form of sidebands which begin at around 300 Hz either side of the carrier, and Doppler-shifted, scattered signals within a few tens of Hz of the carrier. The carrier and program sidebands arrive at the receiver by scattering from ionospheric and tropospheric inhomogeneities or by back-scatter from the terrain in the target area after two ionospheric reflections. In all cases, it is generally at low signal levels. The strength of the Doppler-shifted signals depends on the scattering cross-section and range of the scatterers.

Because communication receivers themselves do not generally furnish frequencies below 100 Hz within the audio output signal, it is convenient to receive the signal in the single-sideband mode (SSB) offset by, say, 1 kHz from the nominal carrier frequency. The unmodulated carrier then corresponds to a 1 kHz audio tone and the Doppler-shifted signals (frequency df Hz) to audio frequencies of $1000 \pm df$ Hz.

In order to create a frequency-domain display (Dopplergram) from the composite audio signal, the signal is first digitized at 8 kHz, and then processed as follows.

The digital audio is multiplied by two signals (from a digital look-up table), one equivalent to the cosine of 1 kHz and the other the sine of 1 kHz. The two multiplicands are low-pass filtered in a Finite Impulse Filter (FIR) to ± 25 Hz and the two resulting time-domain signals are sampled at the Nyquist frequency of 50 Hz. A set of 256 samples from the two data streams at 50 Hz are cyclically buffered and presented to a Fast Fourier Transform (FFT) algorithm which converts the 256 complex time-domain samples to a set of 256 complex frequency domain samples with a range of 50 Hz centered on the 1 kHz, which corresponds to the original radio frequency carrier frequency. The amplitude of the signal in the frequency-domain is given by the magnitude, $\sqrt{r^2(f) + i^2(f)}$, of the complex components.

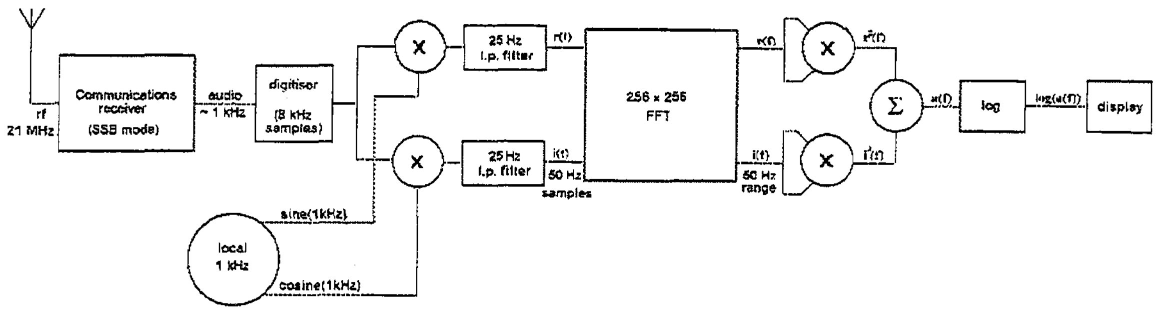


Figure 5 – Block diagram of the signal processing sequence.

For convenience, the dynamic range of the signal is then compressed by applying a logarithmic function to the square of the amplitude, avoiding the square root, and the result is displayed in real-time, with elapsed time along the horizontal axis and the spectrum in the vertical axis.

Figure 5 illustrates the signal processing sequence as a block diagram.

In our embodiment, the digitization, multiplication, and FIR filtering stages are performed in a dedicated Digital Signal Processor (DSP) operating at 20 Mips and the FFT, magnitude, logarithmic, and display functions are performed in a 166 MHz Pentium PC-compatible.

5. Results

Figure 6 shows a typical Dopplergram recording over a period of 16 minutes. Time proceeds from left to right with UT annotations along the top edge of the diagram. The vertical scale is radio frequency with a total range of 50 Hz, or ±25 Hz either side of the nominal frequency. High frequencies are at the top of the diagram.

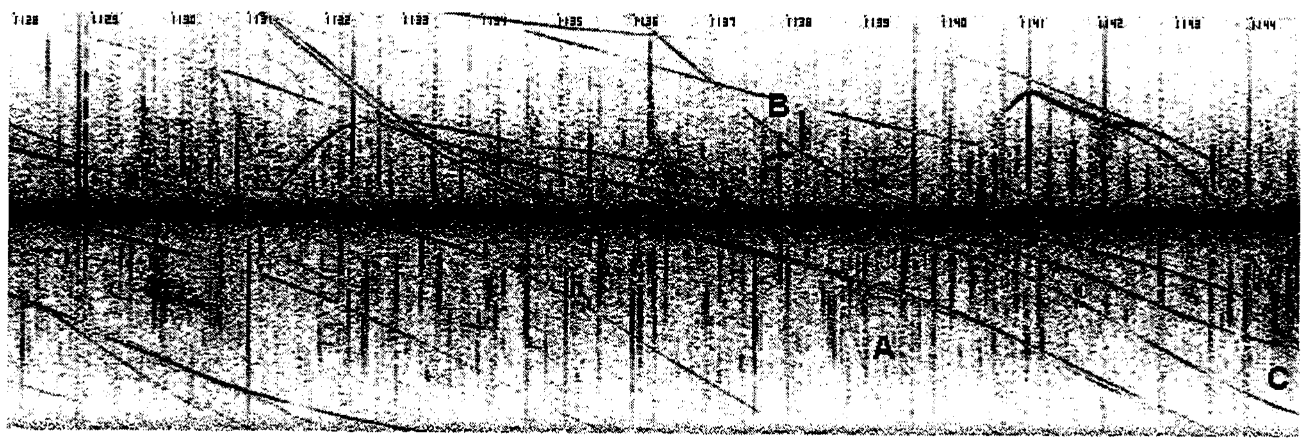


Figure 6 – Typical Dopplergram recording over a period of 16 minutes.

The conspicuous thick line in Figure 6 is the *rf* carrier signal, which, although not of significant signal strength audibly in the receiver, is clearly evident on the Dopplergram. The characteristics of the carrier trace result from the mechanism by which energy reaches the receiver. In this case, among other mechanisms, tropospheric scatter from air mass discontinuities with typical velocities of a few meters per second.

More than a dozen curvilinear features running generally from upper left to lower right are tracks of overflying aircraft at an altitude which means that they are both visible from the receiver and illuminated by the transmitter. The typical speed of a jet aircraft is around 225 m/s which, as noted above, yields an asymptotic rate-of-change of path length of twice that figure. At a carrier frequency of 21.655 MHz, the corresponding Doppler frequency is 32 Hz which is consistent with the aircraft traces shown, which generally appear to asymptote to a frequency just off the 25 Hz frequency range. Overflying aircraft first approach and then recede which explains why the traces all trend from high frequency (positive Doppler shift) to low frequency (negative Doppler shift).

Two other features are apparent on the Dopplergram: a large number of vertical lines and half a dozen or so cusped features with significant horizontal extent (in time). In both cases, the features are most commonly on only one side of the nominal frequency (either positive or negative Doppler shift but not both). Both of these families of feature are interpreted as resulting from scattering by meteor trails. The most common features (occurring several times per minute, in the quiescent case) have essentially no horizontal extent implying a maximum duration of one or two seconds of a detectable scatterer. The less common features (occurring every few minutes) have durations from about 10 seconds up to almost a minute in the example shown.

The short-duration events are interpreted as very small meteors which would not be detectable visually and whose ionization disperses almost immediately. The transient weak scattering from the near face of the very last stage of the decelerating plasma ball gives rise to the brief event and explains the observed vertical extent (in frequency) of the traces. Recall that the initial velocity of the meteoroid exceeds by more than two orders of magnitude the typical upper wind velocity and is therefore well off the frequency range of the Dopplergram.

The longer-duration events are produced by meteors which create ionization trails lasting tens of seconds or more. The trails move with the upper winds at the 80–100 km level (ca. 1 hPa), producing Doppler shifts of around 10 Hz. This corresponds to a rate-of-change of path length of 140 m/s or a limiting wind speed of 70 m/s. The cusped appearance of the trails arises from the way the path geometry and the manner in which the ionization trail is distorted by wind shear at the upper levels.

Recall that reflection by what is essentially a cylindrical ionization can be considered to be specular with respect to the long axis of the trail. The analogy is often made with reflections of oncoming vehicle headlights at night by roadside telephone wires made shiny by rain. A certain point along each wire produces an intense reflection corresponding to the specular case. Imagine the meteor trails to correspond to lengths of shiny wire and the distant transmitter to the vehicle lights. For a short trail, initially, there may be no point at which the specular condition is fulfilled. However, as the trail is bent and twisted by wind shear, at some point (frequently at many points) the specular condition is fulfilled, and there is a strong reflection of the radio signal in the direction of the receiver. The Doppler shift imposed on the scattered signal is that associated with the movement at that point (strictly the rate of change of path length as the reflection point moves). Different points along a single ionization trail usually produce different Doppler shifts either because of different wind velocities or because of different path geometries.

This explains the cusped appearance of the traces on the Dopplergram. For example, in Figure 6, on the low frequency side of the carrier is a C-shaped trace marked A. At the first instant at which a strong reflection occurred, there was a single point of reflection which quickly separated into two points with slightly different Doppler shifts. A more complicated situation with two points of inflection and three cusps is seen at the point labeled B on the high frequency side of the carrier. At the extreme lower right of Figure 6, labeled C, there is an even more complicated trace involving perhaps eight separate cusps with a whole range of Doppler shifts from zero to more than 10 Hz.

Although the Dopplergram shows essentially a velocity-domain view of the meteor trail, rather than a spatial view, these cusped traces are strongly reminiscent of photographs of the visible evolution of long-duration meteor trails, differential wind velocities along the path of the trail giving rise to both effects.

Figure 7 shows a montage of three Dopplergrams taken at the same time of day on successive days. Each trace shows 22 minutes of recording from 13^h13^m to 13^h35^m UT.

The upper and lower traces, recorded on October 7 and October 9, 1998 are broadly similar in appearance, with short-duration events occurring several times each minute and long-duration events every few minutes.

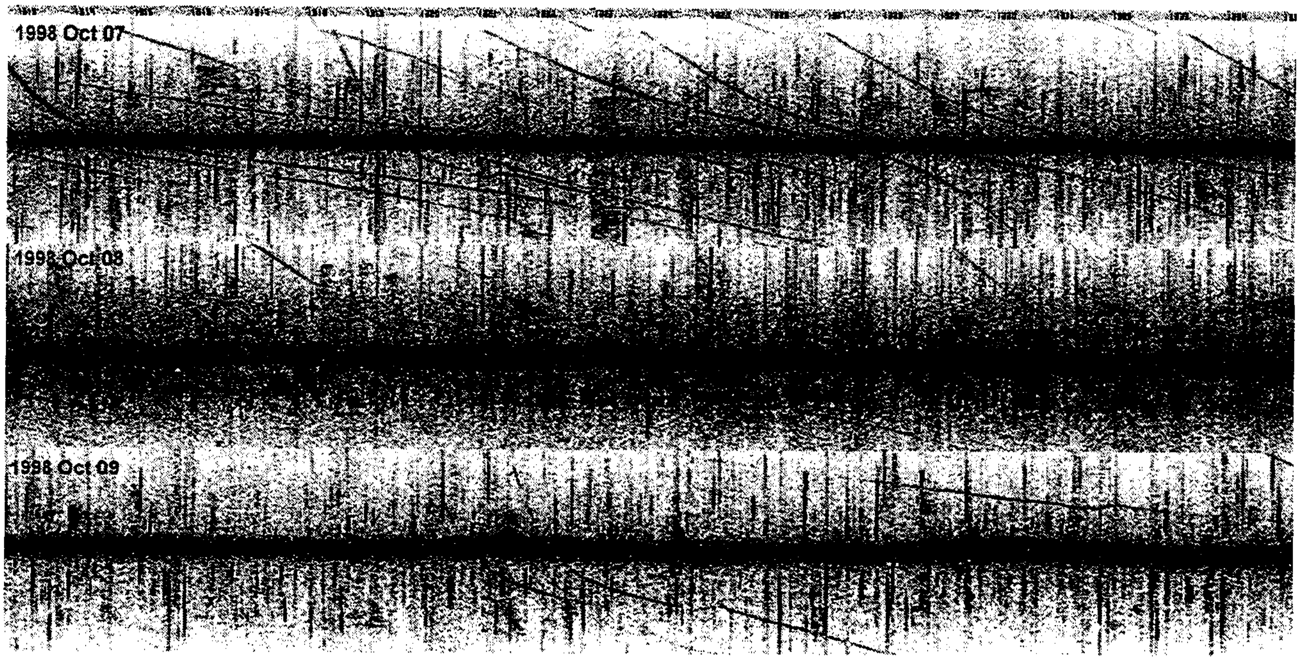


Figure 7 – A montage of three Dopplergrams taken at the same time of day on October 7, 8, and 9, 1998.

The central trace, recorded on October 8, 1998, the peak of the Draconid shower, is quite different in appearance. There is a continuous stream of multi-cusped, long-duration events, occurring several times each minute, with no gaps between them. Interestingly, to the extent that they can be distinguished, the duration of each of the longer events is not significantly greater than the duration of those events on the adjoining, quiescent days. They differ in number but not in duration.

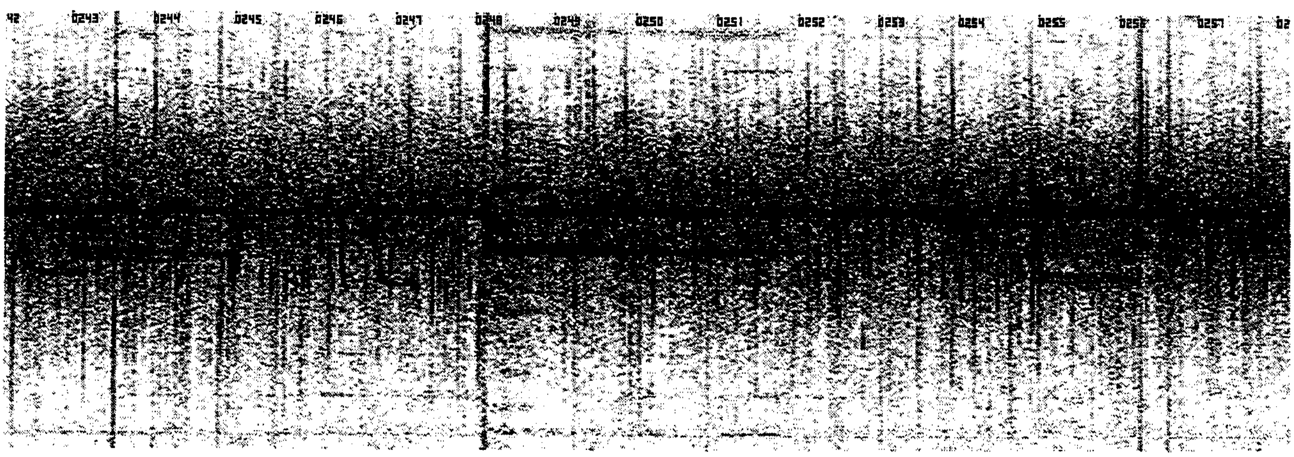


Figure 8 – Dopplergram recorded in the early morning.

Figure 8 shows another Dopplergram, this time recorded in the early morning. Within the space of just over ten minutes, three long duration events occurred, each exceeding a minute in length and one of them lasting for more than four minutes. The strongest event produced a scattered signal which was so strong that the receiver automatic gain control cuts in and attenuates the carrier signal for several seconds. It is interesting to note that all three events were on the low frequency side of the carrier. This suggests that the trails were all on the same side of the sky (downwind, at the upper level, to produce a negative Doppler shift), perhaps of common origin.

6. Other phenomena

From time to time, scattering events occur which produce a diffuse trace on the Dopplergram rather than the more familiar cusped, thin line which is essentially sharp-edged.

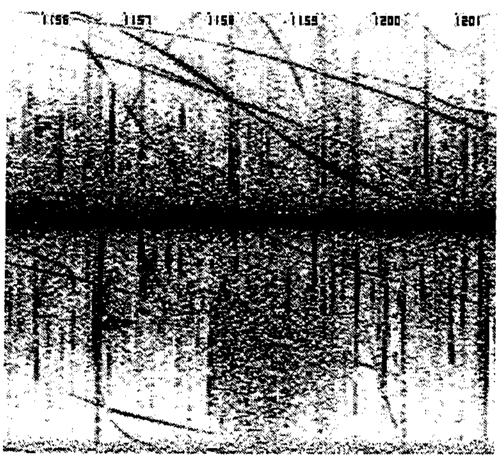


Figure 9 – Dopplergram with diffuse-scattering region.

Figure 9 shows such an event. For about a minute starting at 11^h58^m, on the low-frequency side of the carrier, a diffuse-scattering region appears which is quite unlike the characteristic signature of most of the traces. It is difficult to imagine the structure of the scatterer that would produce such a trace.

7. Detection range

The question arises over what range are the meteors being detected. Scattering of radio energy by meteor trails obeys the radar equation in which two, rather than one, inverse square laws apply. There is an inverse square law attenuation relating to the distance from the transmitter to the scatterer and another inverse square law relating to the distance from the scatterer to the receiver. Although geometrical considerations indicate that the region of the atmosphere at 80–100 km height, which is both illuminated by the transmitter and visible from the receiver extends to some 2000 km radius, signals scattered at that distance would be some 40 dB weaker than signals scattered at 200 km radius. Since the Dopplergrams do not show a range of intensities this broad, we have to assume that we only detect the strongest scattering signals corresponding to those at distances not large compared with the separation of the transmitter and receiver (250 km in our experiments). Expressed another way, to the extent that the meteor trails occupy a relatively thin layer in the upper atmosphere, detectable meteors are probably those at moderate to high elevations above the horizon.

8. Correlation with visible meteors

Work in this area is continuing, but initial results suggest that almost all meteors observed visually produce a detectable trace on the Dopplergram which is of moderate to long duration (more than 10 seconds, say). In some cases, the Dopplergram trace does not appear instantaneously with the visual meteor but up to ten seconds or so later; presumably related to the evolution of cusps with the specular geometry. Similarly, a high proportion of those that produce long-duration events are also observed visually under favorable conditions. Of those that are not detected visually, it may be simply a question of the area of sky accessible to the observer. This would seem to confirm the deduction made in the previous paragraph regarding the elevation of detectable meteors.

If further work confirms the early indications that Dopplergram traces lasting around 10 seconds or more have an essentially one-to-one correspondence with visual meteors, then the perennial problem of quantifying radio meteor counts may be close to being solved.

9. Further work

In addition to better statistics correlating visual and radio meteor rates, a number of other lines of investigation suggest themselves.

Upper wind data at the 1 hPa level is exceedingly sparse. Visual monitoring of the azimuth and elevation of visual meteors, correlated with the observed Doppler shift of the associated trail, would yield considerable information about the range of upper wind velocities across the range of heights where detection occurs.

Comparing simultaneous Dopplergrams recorded at a number of receivers over an area of a few tens of kilometers might, with certain assumptions about the locus of the scattering points on the trails, enable the location in the sky of the various cusps to be inferred. For multi-cusped events, it may even be possible to guess the path of the meteor in the sky. Unless some resolution in the vertical axis could be obtained using sufficient number of separate observations, the direction sign (e.g., north-to-south or south-to-north), and hence the radiant, could not be determined. Observers fortunate enough to have several candidate transmitters at appropriate ranges might achieve a similar result monitoring several transmitter frequencies at a single receiver site.

The ratio of short-duration events to long-duration events seems, subjectively, to vary from day to day and from hour to hour. In the case of showers, this may have a relation to the population index of the shower.

The enigmatic diffuse scattering events warrant further investigation. It may be that higher-resolution Dopplergrams would reveal them to be simply a large number of very small linear cusps. Alternatively, they may represent a different class of objects.

Erratum: System Design Considerations for Automated Meteor Recording and Detection Systems

Chris Trayner

In this paper (*WGN* 26:6, December 1998, pp. 273–283), the numbering of two sections (requirement specification and analysis) got upset, so that they no longer match each other. The pairs of matching items in both sections are 1-1, 2-2, 3-3, 5-4, 6-5, 7-6, 8-7, 9-8, 10-9, 12-10, 14-11, 15-12, 16-13, and 17-14. Specification items 4, 11, and 13 have no corresponding analysis.

HRO: A New Forward-Scatter Observation Method Using a Ham-Band Beacon

Kimio Maegawa

A new forward-scatter meteor observation method has been used since 1996 in Japan. It uses its own 50 W continuous wave beacon with a broad directivity antenna on 53.750 MHz. To compensate for the weak echo power from the beacon, observers use SSB mode receivers and narrow band echo detection methods with Fast Fourier Transform software on personal computers. More than 250 000 echoes have been counted per year so far. From these results, diurnal and seasonal variations have been derived and are presented and discussed here. This method (HRO) will continue to play a leading radio observation role in Japan for the future.

1. Introduction

The Ham-band Radio Observation (HRO) method uses an amateur radio broadcast station on the 6-m band (50–54 MHz). Suzuki et al. [1] started the first Japanese radio meteor observation (FRO: FM Radio Observation) in 1971, by receiving meteor scatter signals of an FM broadcast station with a conventional FM receiver and a pen-recorder. Using this method, a lot of valuable observational data for meteor research have been collected for many years [1,2].

However, the increase in FM broadcasting stations in recent years has caused serious problems of radio interference from the stations other than the desired FM one. A further problem is that the FM radio waves are not continuously transmitted 24 hours a day, and the schedule can be changed without warning, which makes it difficult to continue observing with constant conditions.

In 1991, Isobe and Fujiwara tried to use the transmission of the MU-radar (46.5 MHz, 1 MW peak) at Shigaraki, operated by the Radio Atmospheric Science Center of Kyoto University, as a source for radio meteor observations (MURO: MU-radar Radio Observation). Suzuki observed meteor showers by MURO several times, for example, the 1995 Perseids [3]. The MU radar is quite powerful, but the operational mode (duty cycle, pulse width, ANT beam pattern) is frequently changed, and therefore it is difficult to use this radar signal as a continuous radio source for meteor work.

2. Evolution of HRO

In the meantime, many Ham-radio operators had been enjoying meteor scatter communication on the 6-m and 2-m bands, using a narrow bandwidth (voice or Morse code) and modest power requirements. The author applied his experience of meteor scatter communication to initiate the continuous transmission of a beacon signal for meteor observations at 53.750 MHz (50 W) at Fukui National College of Technology in Sabae, Fukui, Japan, in April 1996. Since the sub-band between 52.9 MHz and 54 MHz is allocated for experimental use in Japan, it was appropriate to use this frequency for meteor observations because of the lower probability of radio interference from other amateur radio sources.

3. The HRO method

The characteristics of the HRO method are listed below.

Transmitter: To compensate for the low power of the Ham-band beacon, we decided to use a continuous wave transmission, so that any amplitude or frequency changes of the received signals depend only on the properties of the meteor trail. The transmitting antenna was designed to form an omni-directional azimuth pattern, as well as giving a wide elevation pattern of more than 70° zenith angle. This antenna is shown in Figure 1.

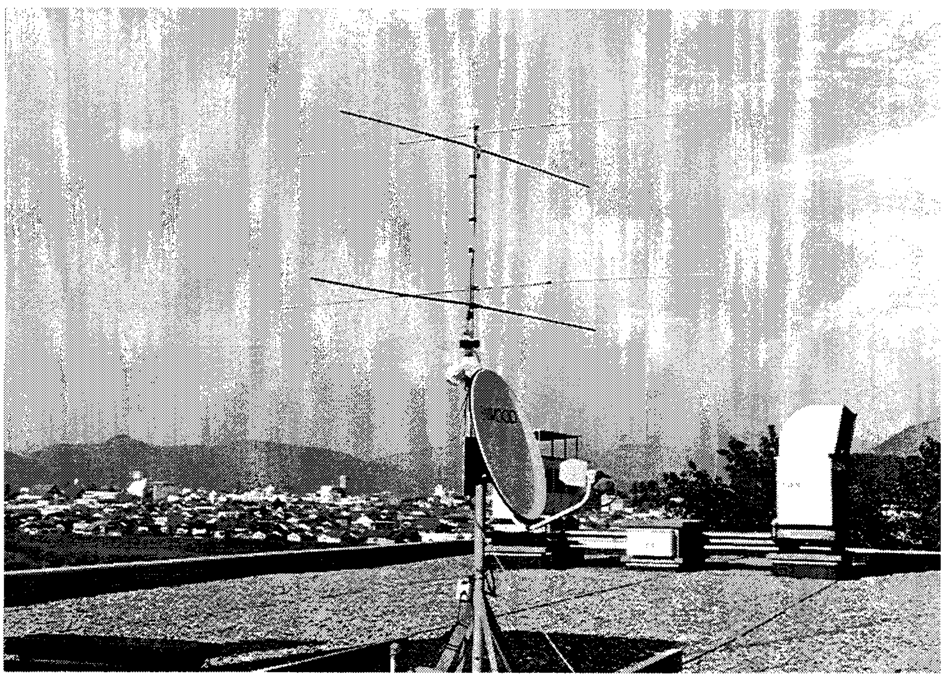


Figure 1 – The HRO transmitting antenna at Sabae City, Japan.

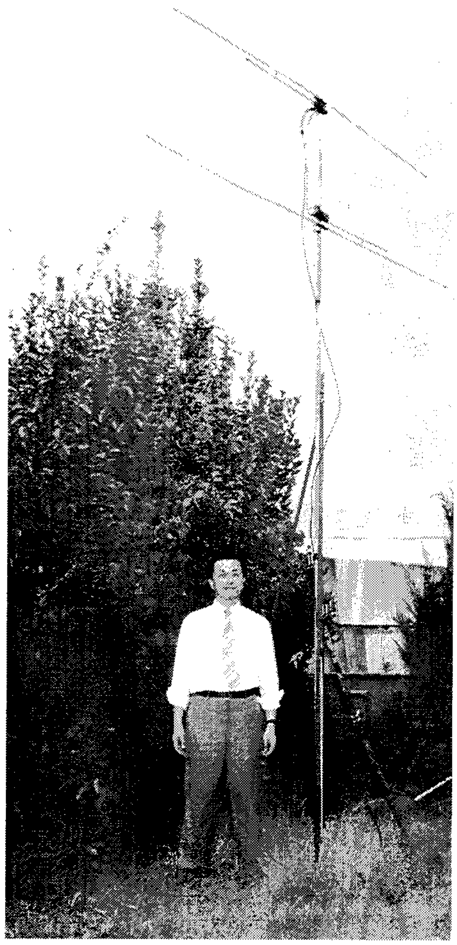


Figure 2 – An HRO receiving antenna, with one of the leading observers, Masayoshi Ueda.

Receiver: With an SSB receiver, we can convert radio frequency echoes into the audio spectrum. SSB receiving has a better Signal-to-Noise Ratio (SNR) due to its narrower bandwidth than AM or FM mode, and it is consequently less sensitive to signal interference. Through experimentation, we found that the HRO method using Fast Fourier Transform software (FFTDSP) is sensitive enough to even detect weak meteor scatter with reception power as low as 10–18 W. Most of the radio observers located within 200 km of the transmitter site use a two-element Yagi as a receiving antenna (see Figure 2), because it is difficult to make a dipole antenna with an ideal ground plane.

Beam patterns of Yagi antennas with 4 to 6 elements would be suitable for more remote sites, to enhance the signal strength at over 300 km from the beacon site. We were able to detect several times as many echoes as could be received by the FRO method using a 10 kW FM broadcasting station.

Echo detection and counting: Some radio amateurs use a spectral display software FFTDSP by Mike Cook for detecting weak radio signals reflected by the Moon. FFTDSP can be run on a standard PC system with a sound board. It displays in real time the spectrum of the audio input signals on the screen. We also have an improved automated image-saving tool for DOS, originated by Werfried Kuneth in order to operate the FFTDSP analysis continuously. The images of the spectrogram are stored on the hard disk with time markers and the SNR of the peak frequency component, between 300 Hz and 1.5 kHz.

Strong or long-duration meteor echoes can be counted, even in the presence of a direct propagation signal or of aircraft reflection. Aircraft echoes often disturb the detection of short or weak meteor echoes where the receiving site is within 200 km of the transmitter, but are rejected by manual counting. It is noteworthy that Sporadic-E (Es) does not cause too many problems when the distance between the transmitter and receiver sites is less than 200 km.

Some observers over 300 km from the transmitter have started to monitor meteor activity using an automatic signal detection program, but have suffered from the spurious reception of Chinese and Russian TV signals broadcast between 49.750 MHz and 55.750 MHz, rather than our beacon signal, during the strongest Es periods. Although European radio observers utilize TV carrier signals as a radio source, this is not useful in the Far East, because of their intermittent transmission schedule and poor frequency stability.

4. Observational results and discussion

Since August 1996, we have been collecting radio echo data using the method outlined above, and analyzing them. Observational data have also been made available to other workers in this field. For example, data collected by Maegawa and Suzuki during the 1996 Leonids were used by McBeath [4] in determining the peak of this shower.

Figure 3 shows the location of the Sabae transmitter and the distribution of the regular HRO receiving sites on Honshu and Shikoku as of September 1998. The total number of receiving sites typically increases to more than twenty during a major observing campaign.

Figures 4–7 show various observational results, described in the appropriate figure captions.

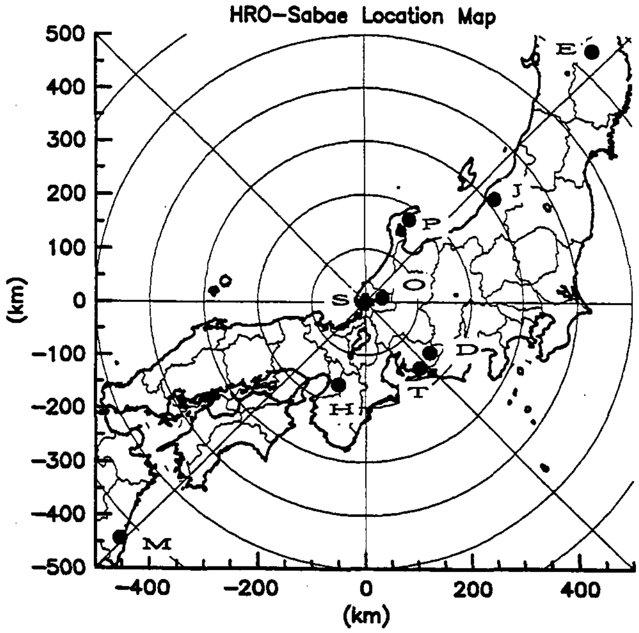


Figure 3 – The Sabae transmitting station ("S," marked with a cross), and the seven regular HRO receiving sites (September 1998).

5. Conclusion and Acknowledgments

After two years of operation, HRO has become the main method in Japanese amateur radio meteor observation. Although it is hard work to count echoes manually, it is the only possible way to get accurate observational data with such a short baseline, where aircraft echoes often intrude. The short range gives a stronger echo power and less disturbance from Es propagation.

Of the current regular observers, Masayoshi Ueda summarizes his data every month in *Tenkai* (the Journal of the *Oriental Astronomical Association*). Ueda also reported his HRO results on the 1998 June Bootid outburst at the 1998 *Meteoroids Conference* and the 1998 *IMC* in Slovakia [5]. A detailed paper on this event with the current author is in press [5].

Kazuhiro Suzuki presents his raw observational data at `http://www.tcp-ip.or.jp/kaze`. Sadao Okamoto sends his data to the *RMOB*, compiled and distributed by Christian Steyaert every month, and also to the *Global-MS-Net*.

I am grateful to all the contributing HRO group members. I must express my special thanks here to Werfried Kuneth who provided me with the idea of an automatic saving method for FFTDSP images. I also extend thanks to Dr. Takuji Nakamura of the Radio Atmospheric Science Center of Kyoto University for all his suggestions and helpful comments. However, I take this opportunity too to thank Alastair McBeath for his careful reading of the manuscript.

References

[1] K. Suzuki, Nagafuji, Kinoshita, *Sky and Telescope*, May 1976, pp. 359-362.

[2] C. Shimoda, K. Suzuki, K. Maeda, *WGN* 21:3, June 1993, pp. 130–132.

[3] K. Suzuki, T. Nakamura, *WGN* 23:1, February 1995, pp. 17–18.

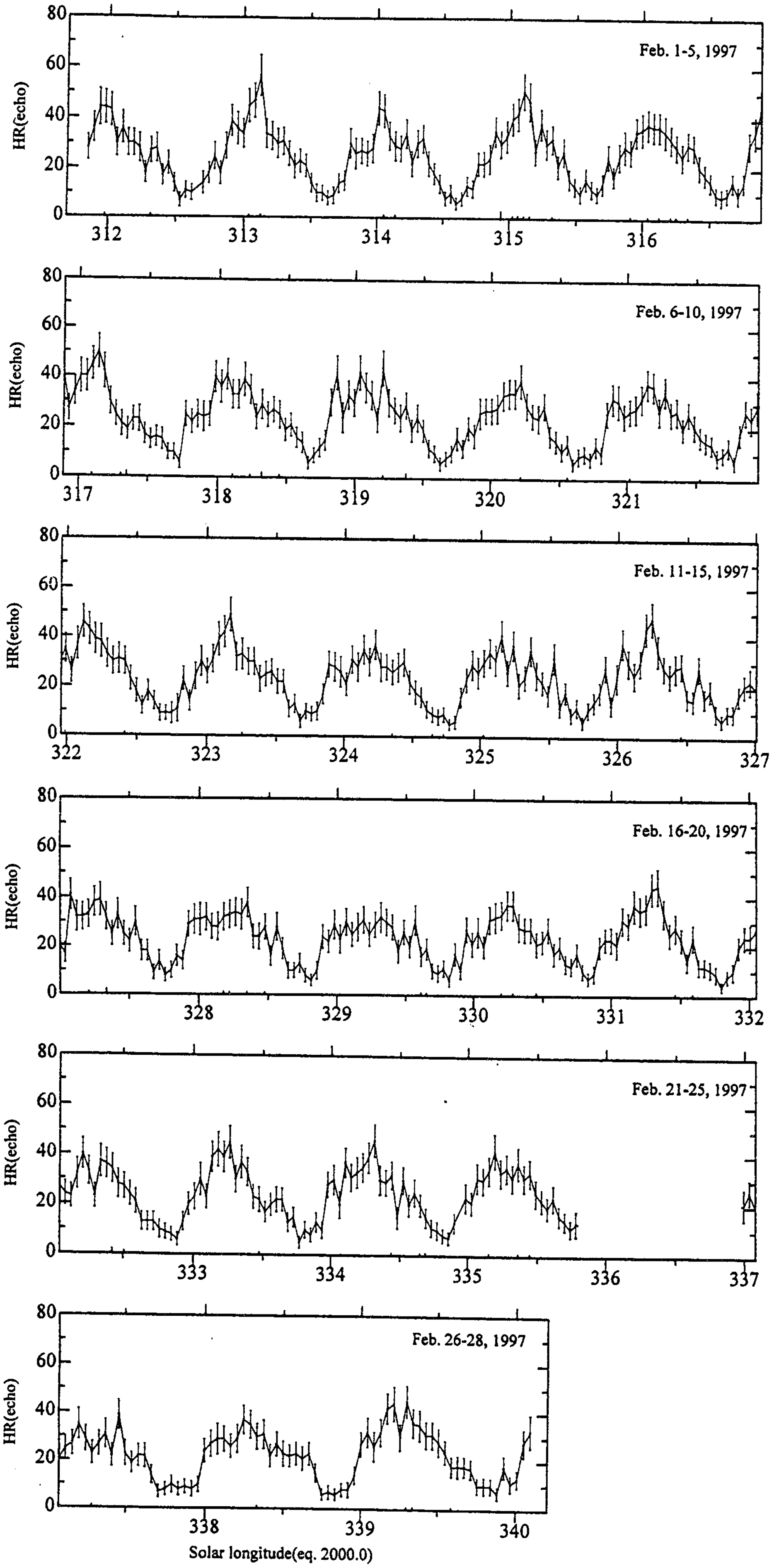
[4] A. McBeath, *WGN* 25:1, February 1997, pp. 45–53.

[5] M. Ueda, K. Maegawa, "Outburst of the June Bootids in 1998", in *Proceedings IMC*, Stará Lesná, Slovakia, 1998, A. Knöfel, A. McBeath, eds., IMO, *in preparation.*

[6] K. Maegawa, M. Ueda, Y. Minagawa, *WGN* 27:1, February 1999, pp. 76–80.

[7] D.W.R. McKinley, "Meteor Science and Engineering", McGraw-Hill, 1961, p. 113.

[8] P.M. Millman, B.A. McIntosh, "Meteor Radar Statistics II", *Canadian Journal of Physics* 44, 1966, p. 1593.


Feb. 1-5, 1997
Feb. 6-10, 1997
Feb. 11-15, 1997
Feb. 16-20, 1997
Feb. 21-25, 1997
Feb. 26-28, 1997
HR(echo)
Solar longitude(eq. 2000.0)

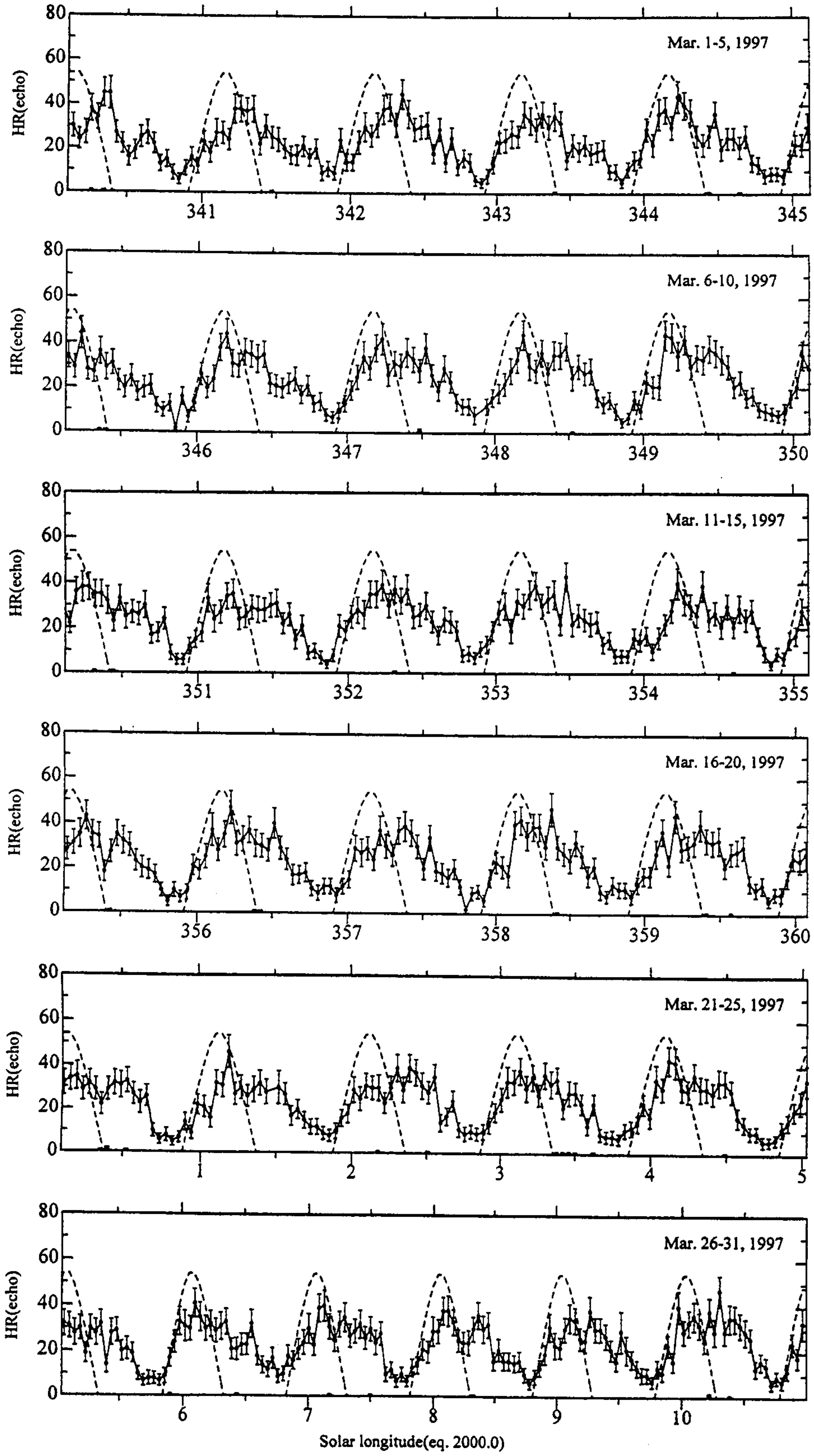
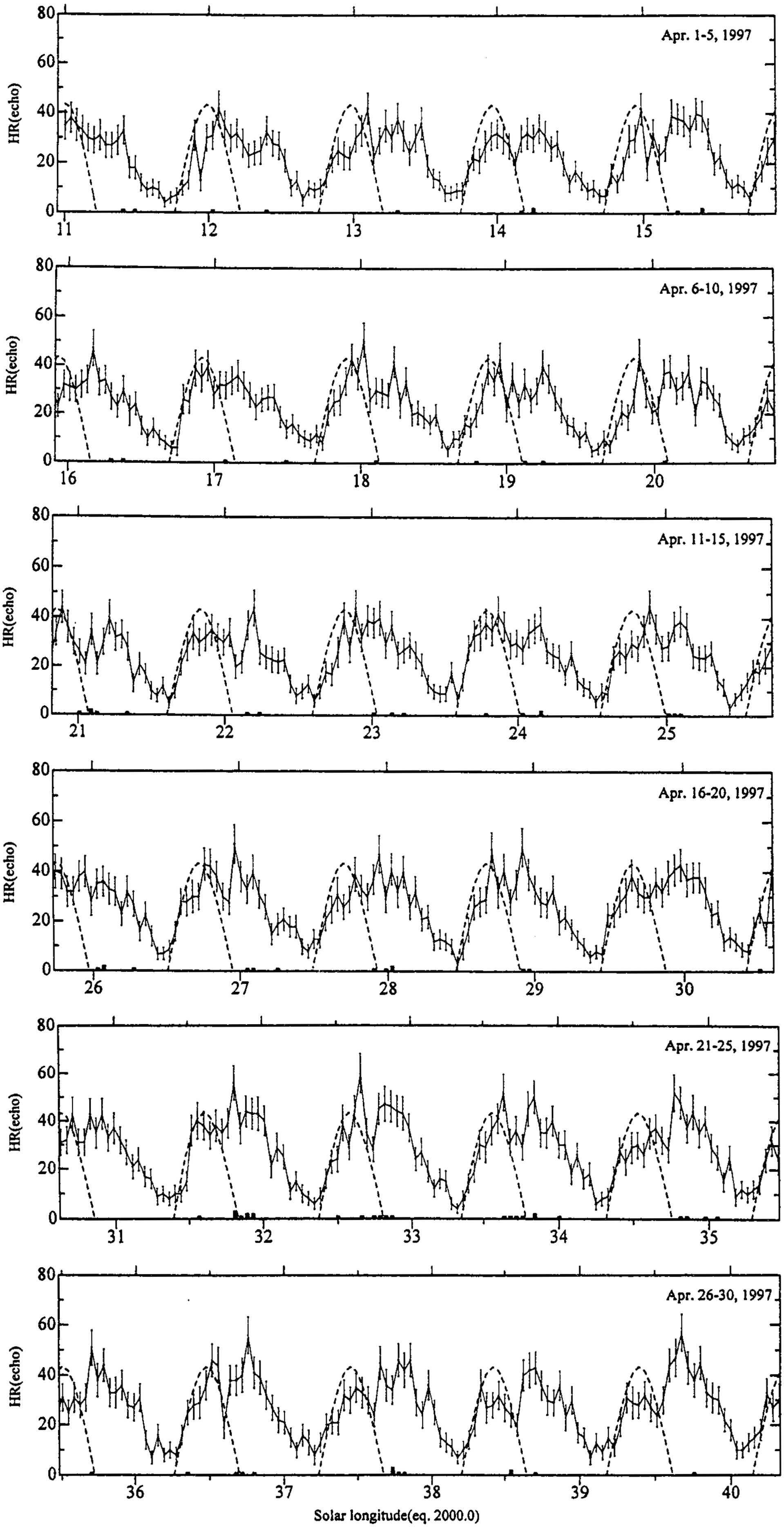


Figure 4 – Raw daily radio meteor echo counts during the period February 1 to March 31, 1997, from data collected by Masayoshi Ueda at Habikino City ("H" on the map in Figure 3). The line with error bars shows all detected echoes, while the small black bars, which occur infrequently, indicate increased numbers of longer-duration echoes. The graphs have been plotted using solar longitude (eq. 2000.0) on the horizontal (time) axis. The regular diurnal variation in echo counts is very obvious, while the broken curve (showing the relative radiant elevation for the Virginids) helps highlighting the times in March when an enhancement from this shower may occur.


Apr. 1-5, 1997
Apr. 6-10, 1997
Apr. 11-15, 1997
Apr. 16-20, 1997
Apr. 21-25, 1997
Apr. 26-30, 1997
HR(echo)
Solar longitude(eq. 2000.0)

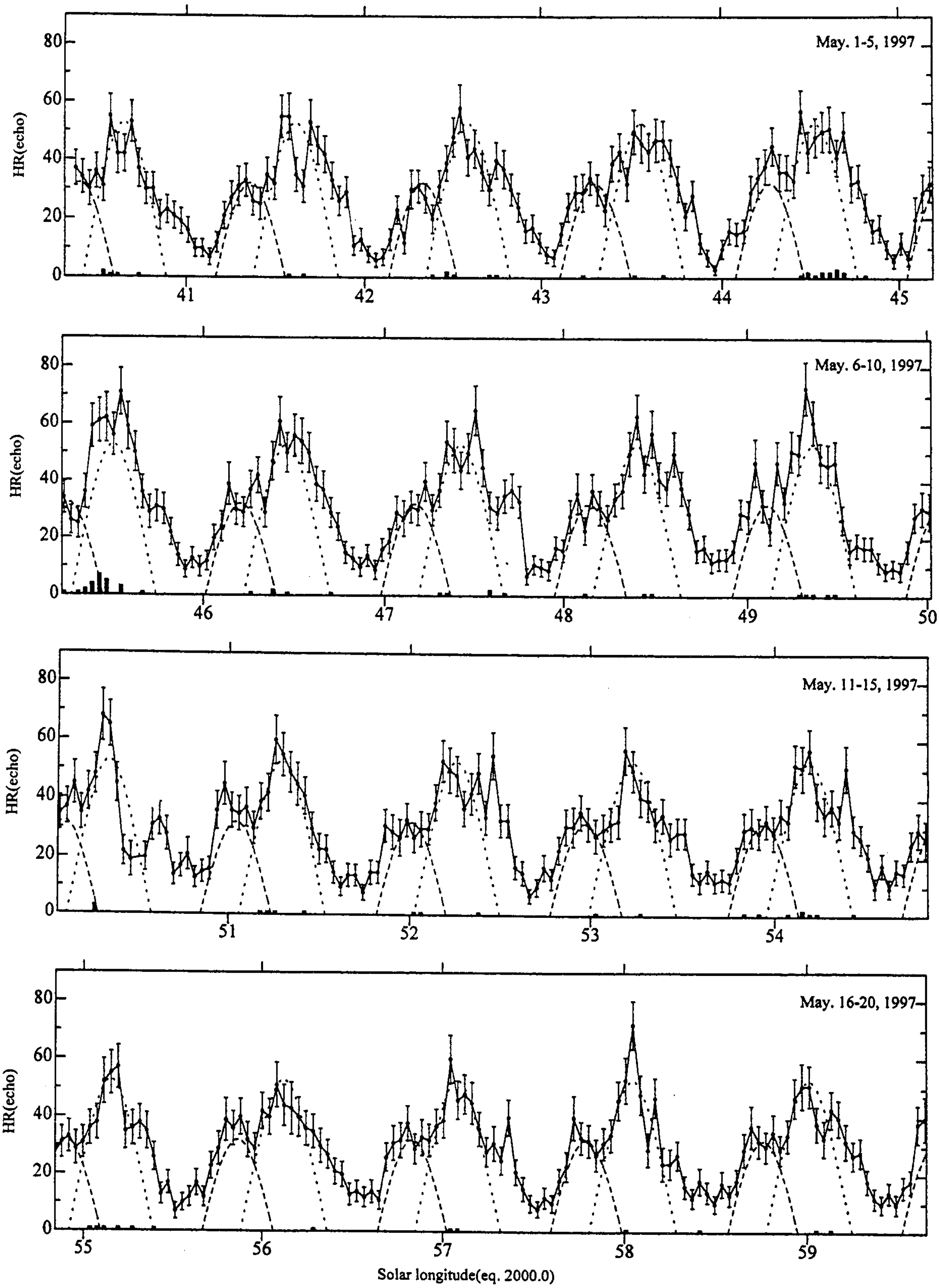


Figure 5 – As Figure 4, but showing raw diurnal radio meteor activity from April 1 to May 20, 1997. The Virginid radiant elevation curve is plotted for all of April as well. An enhancement in rates during the Lyrid shower can be seen around $\lambda_\odot = 32°–36°$. This is most noticeable in the long-duration echo counts from $\lambda_\odot = 32°–34°$. During May, the two radiant elevation curves are for the η-Aquarids (higher) and Sagittarids (lower), again to highlight times when their activity is more prominent in the results. The η-Aquarid peak is clear between $\lambda_\odot = 44°–46°$, both in the overall echo profiles and in the higher numbers of long-duration echoes.

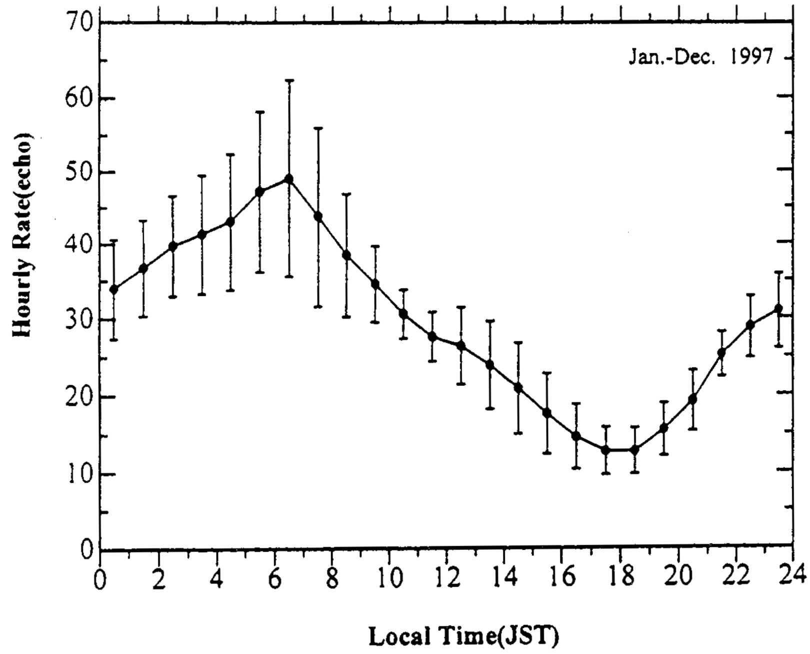


Figure 6 – A combined diurnal radio activity profile from 249 016 echoes collected by Masayoshi Ueda in 1997. The graph was prepared excluding data from the following periods: January 2–4, August 13–14, and December 12–14. The maximum-to-minimum ratio is around 4, which is very similar to the results obtained from backscatter radar data by McKinley [7].

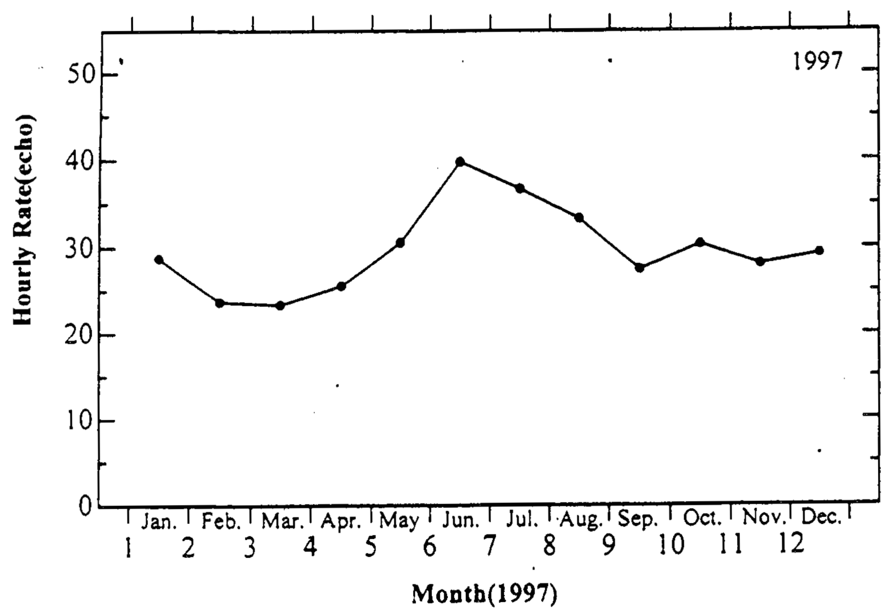


Figure 7 – As Figure 6, but here showing the annual variation in overall radio meteor activity, based on the 1997 data collected by Masayoshi Ueda. We cannot say very much from just one year's data collection, but this graph too is in good agreement with previous results, e.g., the results of Millman [8].

Observational Results

SPA Meteor Section Results: May–June 1998

Alastair McBeath

Results and news from 1998 May and June in the *SPA Meteor Section* files are presented. Weather and Sporadic-E conditions hindered all observers, but some useful η-Aquarid watching was possible, indicating a peak on May 5-6. Radio observers recorded the normal maxima in June coincident with the two most active daytime showers (Arietids and ζ-Perseids), but event of the month was unquestionably the June Bootid outburst on June 27-28, well-seen by radio and visual observers. A widely-reported brilliant fireball flew over south-western Britain on June 11-12, around 23^h05^m UT.

1. Introduction

Weather and extended twilight problems caused their regular difficulties for northern hemisphere visual observers at this time of year, which was also notable for frequent Sporadic-E (Es) events to hinder the radio observers. Even so, observing tallies were quite healthy as Table 1 shows.

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

Month	Visual	SAG	ETA	JBO	Meteors	Photo	Trails	Radio
May	$73^h.5$	51	188	–	684	$153^h.4$	0	3004^h
June	$50^h.5$	36	–	372	730	$66^h.4$	8	2722^h

Photographic data came from the following *Arbeitskreis Meteore* (*AKM*) observers: Ina Rendtel, Jürgen Rendtel, and Jörg Strunk, operating all-sky cameras of the *European Fireball Network* in Germany; and Veselka Radeva and Valentin Velkov from *Astroclub Canopus* in Varna, Bulgaria. All the *AKM* details used here are from *Meteoros*, issues 6 and 7-8 (1998), provided by Ina Rendtel.

Radio results came from the following *Radio Meteor Observation Bulletin* (*RMOB*) observers (data via Christian Steyaert, extracted from *RMOB*s 58–60, June–August, 1998):

> Enric Fraile Algeciras (Spain), Mike Boschat (Canada), Maurice de Meyere (Belgium), Ghent University (Belgium), Will Kelsey (California, USA), Werfried Kuneth (Austria), Sadao Okamoto (Japan), Chikara Shimoda (Japan), and Ilkka Yrjölä (Finland).

In addition, Kimio Maegawa has kindly provided a preprint copy of results for publication in *WGN* from around the June Bootid outburst [1], all observations using the Japanese Ham-band Radio Observation system. The participating observers included: Yoshifumi Minagawa, Kazuhiro Suzuki, and Masayoshi Ueda. Our normal practices for examining the raw radio meteor data were followed again here, and a graph representative of the May activity is given as Figure 1. Two graphs showing activity during June have already been published [2].

Visual results came from

> *AKM* members Sylvio Lachmann, Sven Näther, Jürgen Rendtel, Janko Richter (Czech Republic), Thomas Schreyer (Germany and Czech Republic), Harald Seifert (Czech Republic), Uwe Selbmann (Czech Republic), Hans-Georg Zaunick (Czech Republic), all observers in Germany except where noted; Eva Bojurova (Bulgaria), Tim Cooper (South Africa), Shelagh Godwin (England), Terry Holmes (England), Katya Koleva (Bulgaria), Bob Lunsford (California, USA), Alastair McBeath (England), Lyna Rashkova (Bulgaria), Ian Ridpath (England), Valentin Velkov (Bulgaria), Graham Wolf (New Zealand).

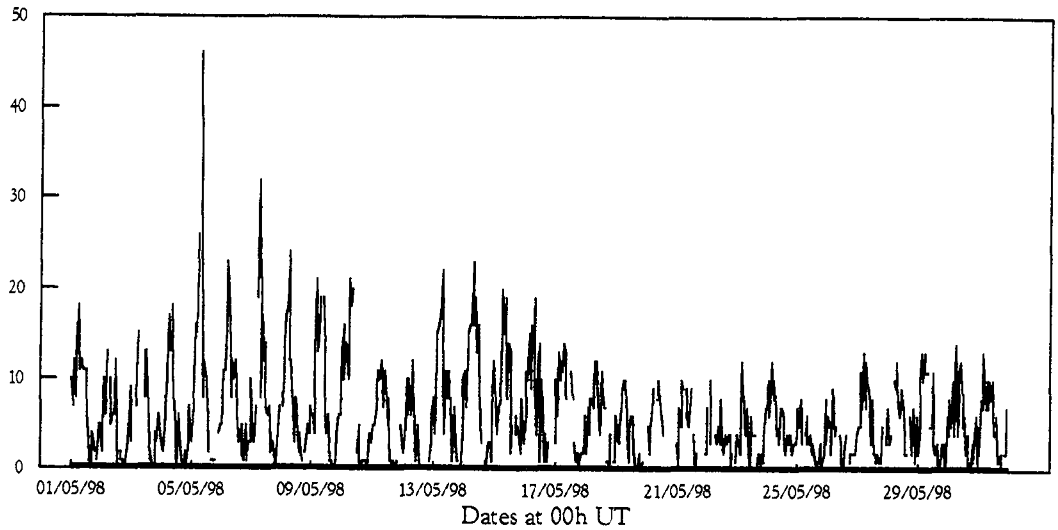


Figure 1 – Raw hourly radio meteor echo counts (echo durations more than 3 seconds) from 1998 May, as recorded by Werfried Kuneth. The main η-Aquarid peak on May 5 is very obvious. The enhanced activity in mid-May is probably due to the daytime May Arietids, coupled with late and declining η-Aquarid rates.

2. May

Most visual data were concentrated in the opening week, with only the *AKM* observers and Bob Lunsford recording results after mid-month. Low Sagittarid rates were noted throughout May, with a possible weak maximum at the very end of May or into early June. There is some confirmation of this from the radio results (see Figure 1), with slightly increased echo counts between $\lambda_\odot = 62°–66°$ (eq. 2000.0), blending in most cases into a somewhat more enhanced period lasting until $\lambda_\odot \approx 69°$. Both periods were already recognized in [3]. However, an additional event around $\lambda_\odot = 60°–61°$ not seen before was also detected by the majority of radio operators not affected then by Es.

Although the η-Aquarid results available to the Section this year were not as impressive as in 1997, a peak around May 5-6 is supported by visual and radio data. Es and other difficulties meant defining a more precise time for the peak was not possible, but the active visual observers found ZHRs were 50–60 on the night of May 5-6, as compared to 30–40 on May 4-5, for instance. Looking only at longer-duration radio echoes from the three people providing such data indicated highest counts on May 5 over Europe, but perhaps May 6 over Japan (though the difference from May 5 in the one Japanese data set is rather small). This may give further weight to a peak on May 5-6. Tim Cooper and Valentin Velkov both commented on the observed shower rates being lower than last year's, something of a disappointment for the watchers, but still valuable information on a poorly-studied major stream. Despite the relatively lower number of meteors seen, it has been possible to construct a global magnitude distribution for the η-Aquarids and May sporadics this year, given in Table 2. Too few train reports were received for a full analysis of them, but around 40–45% of η-Aquarids and 8% of sporadics left persistent trains.

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

Shower	-3^-	-2	-1	0	+1	+2	+3	+4	$+5^+$	Tot	Lm	$\overline{m}_{6.5}$
ETA		0.5	3	8.5	22.5	42	51	33	14.5	175	5.86	3.27
SPO		1	1	6	13.5	21.5	35	27	1	106	5.86	3.20
JBO	6	5	14.5	28.5	58	106.5	83.5	41	7	350	5.95	2.48
SPO	7.5	3.5	10	27.5	29.5	44	34.5	6.5	3	166	6.04	1.78

The other minor radio peaks from [3] not already mentioned were all found again, within the constraints of the Es problems. The most notable periods were around $\lambda_\odot = 52°–56°$, and especially around $\lambda_\odot = 58°$ (though this does not show up well in the long-duration echoes in Figure 1, unfortunately). This is only about 1° different in solar longitude from the predicted, if ill-known, daytime *o*-Cetid peak, and might perhaps indicate a stronger return of this shower in 1998 than in any recent year we have reliable data for (1994–1998).

3. June

By contrast to May, most of the June visual observing was concentrated towards the end of the month. The few reports from earlier showed traces of Sagittarid activity declining from its probable late May-early June "maximum," but persisting into July. No obvious June Lyrids were noted, however, which does perhaps further suggest it may be a periodic, not a regular, shower.

A very bright meteor was detected from the UK on June 11-12 around 23^h05^m UT, and many casual witnesses called the emergency services after its flight. A sizeable proportion reported "flames" or red fragments were seen to fall from the meteor, which was described in most reports as green-blue or blue. Although vague details are available from sightings stretching from the south-west English coast to Liverpool, and places north and west of London, there are almost no usable reports indicating a possible flight path. A roughly south-west to north-east direction is suggested by some sightings, with a possible track running up the south-west peninsula of England heading towards Oxfordshire, but this is really more an educated guess than a true estimate. Press reports were confused, as often happens, with some suggesting several events had happened within a 30-minute period, and the usual random selection of meteor showers active near the appropriate date, including the Arietids and ζ-Perseids, were stated by "experts" as the source, although both these daytime radiants were far below the horizon when the bolide occurred! There are too few useful reports to say what may really have taken place.

These two daytime-active showers were more assuredly responsible for the enhanced radio rates seen during the first half of the month, and most of the previously-detected minor peaks in echo counts throughout June were again noted when Es did not interfere. Most reports suggested activity was at its best around $\lambda_\odot = 75°–76°$, and again at $\lambda_\odot = 78°–79°$, much as was found before [3], and roughly coincident with the expected Arietid and ζ-Perseid peaks. The Arietid peak may have occurred slightly earlier than predicted, but it is difficult to be certain, as activity levels seem to fluctuate only slightly for several days around $\lambda_\odot = 73°–80°$. Several datasets showed enhanced activity from $\lambda_\odot = 82°–86°$ (part of the extended $\lambda_\odot = 84°$ period in [3]), though with patchy observing conditions, it is difficult to say how significant this may have been. Any possible June Lyrid rates should have manifested around $\lambda_\odot = 85°$ from past observations, which might suggest activity that passed visually unseen. Another source is at least equally plausible in the absence of confirming visual data.

The June Bootid outburst on June 27-28 was of course the event of the month. We have already discussed the preliminary radio results [2], but the additional radio reports now available from Japan (from Sadao Okamoto in *RMOB* 60, and extra data from Kimio Maegawa) confirm that the observers there enjoyed by far the clearest radio-view of the shower. From Europe, the overlap in visibility with the daytime β-Taurids created numerous problems in interpretation, but these are greatly reduced in considering the Japanese data, where the overlap is much less.

Visually, the Bootid outburst was a very pleasant treat for observers not used to seeing many meteors in the June sky. Several casual reports were submitted from people in the UK who had simply noticed there were more meteors about than normal that night, most not even amateur astronomers, but even the astronomers were often alerted after the unusual spectacle of seeing two or three meteors in a matter of minutes during a casual sky-check. The most unusual thing was that the event could be seen from more than one site in Britain, after several years of very poor skies, and poorer luck with the timing of any clearer nights. Perhaps the most fortunate observers were in Bulgaria, however, where a special observing expedition had by chance been planned for that weekend. As June Bootid meteors started raining out of the clear sky on the first night of their camp, they could hardly believe their luck, though as Eva Bojurova commented, there were problems keeping awake the next night, when rates had reduced to the normal June meteor "drizzle!" The Bulgarians also enjoyed an excellent night photographically, with all eight trails reported from the two months we are discussing here occurring on this one night, seven of them Bootids. Even in New Zealand, Graham Wolf was able to monitor what went on, demonstrating that the outburst was visible from the southern hemisphere as well the north. ZHRs from the available data were 80–100 for most of the night.

As Table 2 indicates, enough Bootids were identified to enable us to derive a global magnitude distribution for them. In addition to these figures, around 8% of Bootids left trains, but no trained sporadics were reported during June.

Acknowledgments

As ever, my grateful thanks are extended to all contributors to this report. Good luck for your next observing, and clear skies!

References

[1] K. Maegawa, M. Ueda, Y. Minagawa, "HRO Caught Outburst on June 27, 1998", *WGN* 27:1, February 1999, pp. 76–80.

[2] A. McBeath, "SPA Meteor Section Preliminary Radio Results: 1998 June Bootid Outburst", *WGN* 26:4, August 1998, pp. 173–176.

[3] A. McBeath, "The Forward Scatter Meteor Year", in *Proceedings IMC*, Petnica, Yugoslavia, 1997, A. Knöfel, A. McBeath, eds., IMO, pp. 39–54.

HRO Caught Outburst on June 27, 1998

Kimio Maegawa, Masayoshi Ueda, and Yoshifumi Minagawa

On the evening of June 27, 1998, many Japanese radio observers detected a sudden increase in meteor echoes. The number of meteor echoes were estimated to be three to five times the normal sporadic meteor count during this period of the year. The outburst was observed while the June Bootid radiant was above the horizon. We present a summary of the observational data from the period around June 27, and discuss the peak timing and duration of the outburst. This is further detailed in the reports that Ueda presented at the 1998 *Meteoroids Conference* and the 1998 *IMC* [2].

1. Introduction

Ham band Radio Observation (*HRO*) is the Japanese forward scatter meteor observation system using a beacon signal on the 6-m Ham band (50–54 MHz). Maegawa has been transmitting a 50 W continuous beacon from Fukui-NCT at Sabae City ($\lambda = 136\overset{\circ}{.}18$ E, $\varphi = 35\overset{\circ}{.}93$ N) with a wide directive antenna on 53.750 MHz since 1996 [1]. Ueda observes meteor echoes from Habikino City ($\lambda = 135\overset{\circ}{.}64$ E, $\varphi = 34\overset{\circ}{.}53$ N), so the base-line between the two stations is about 142 km at 20° south-west of Sabae. Ueda counts echoes from the saved images of FFTDSP software. He uses a two-element Yagi antenna aimed at the zenith, and an IC706 receiver on SSB mode. Minagawa monitors meteor activity at Sanjyo City ($\lambda = 138\overset{\circ}{.}98$ E, $\varphi = 37\overset{\circ}{.}63$ N). He is located 313 km from Sabae at 52° to the north-east. His receiver is an IC726 and his antenna is a 5-element Yagi aimed towards Sabae at zero elevation. He does not count individual meteor occurrences, but instead records the duty cycles of the beacon signals every minute, using Antony Mallama's AUDIMATE software.

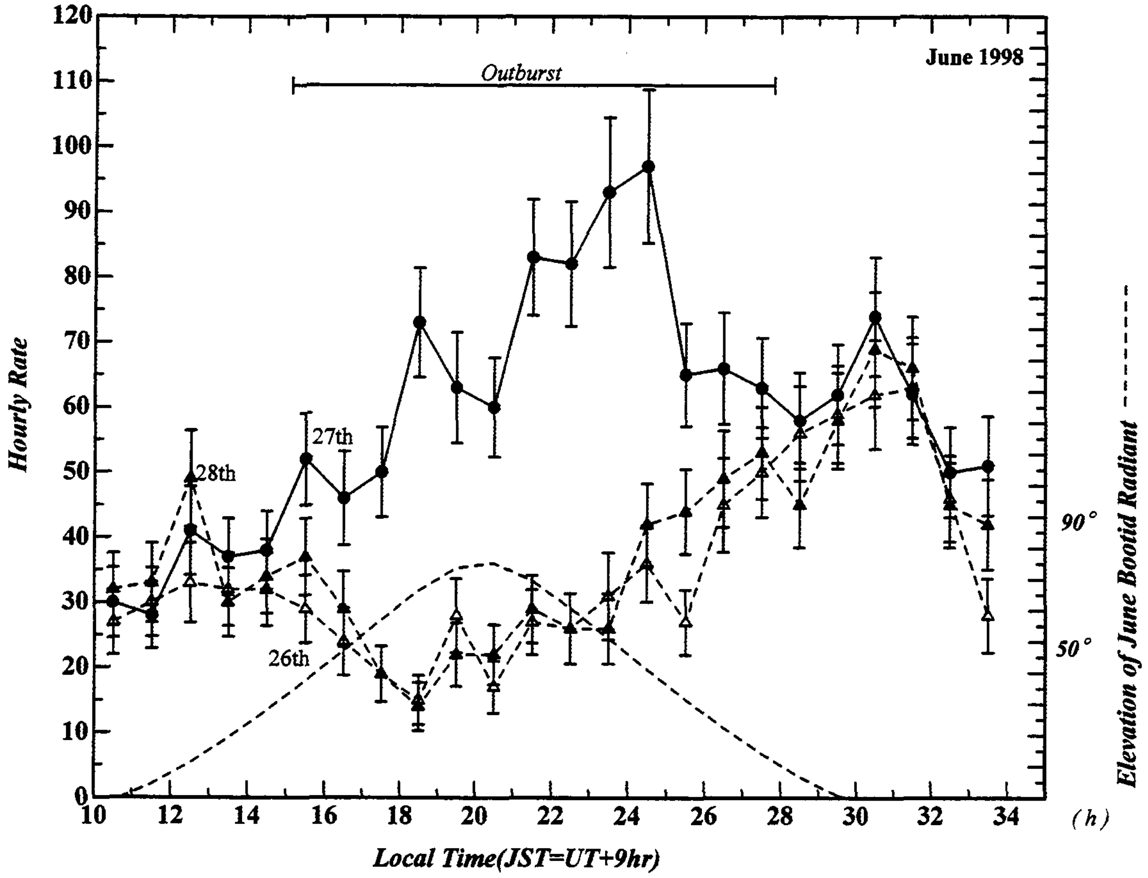


Figure 1 – Raw hourly radio meteor echo counts from data collected by Masayoshi Ueda between June 26–28, 1998, are shown in a single graph. The time-base is Japan Standard Time on the x-axis, and the dashed line shows the elevation of the June Bootid radiant as known from other results.

2. Observations and discussion

Figures 1–5 show the results of the radio monitoring carried out by various Japanese observers around the time of the 1998 June Bootid outburst.

From Figure 1, it is obvious that overall meteor counts were low both on June 26 and 28, but significantly higher on June 27, during the indicated outburst times. As this graph shows, Ueda suggests that the outburst occurred between 6^h UT and 21^h UT on June 27, 1998. It is difficult to derive the outburst peak from this curve, however.

Minagawa's activity curve (Figure 2) agrees with Ueda's in Figure 1 very well. We can also determine the activity peak of the outburst as between 23^h JST (14^h UT) and 27^h JST (18^h UT) on June 27, 1998, from this graph. A sharp dip in reception rates at $20\overset{h}{.}7$ JST suggests the possibility of a high elevation position for the radiant around this time. The mid-point between Sabae and Sanjyo is at $\lambda = 137\overset{\circ}{.}6$ E and $\varphi = 36\overset{\circ}{.}7$ N. We can thus estimate the radiant hour angle of this outburst source as at around 230°.

From data shown in Figure 3, Ueda concluded that the peak activity occurred between $13\overset{h}{.}5$ UT and $16\overset{h}{.}5$ UT on June 27, 1998. This timing interval converts to the solar longitude period $\lambda_\odot = 95\overset{\circ}{.}73$–$95\overset{\circ}{.}85$. Although no Observability Function is used, the peak timing of this outburst seems correct from both sets of observations in Figures 2 and 3, since both are in close agreement.

Having achieved this, we then looked for other radio results from different radio meteor observers. The comparison possible is shown in Figure 4. Kazuhiro Suzuki receives echoes from a 53.750 MHz beacon, and counts using the same method as Ueda at Toyokawa City ($\lambda = 137\overset{\circ}{.}32$ E, $\varphi = 34\overset{\circ}{.}81$ N) with a dipole antenna and an IC575 receiver. His numerical counts are somewhat smaller than Ueda's, but exhibit the same variation. Suzuki's counts have a deeper dip at 20^h JST (the hourly total from 20^h00^m JST to 20^h59^m JST).

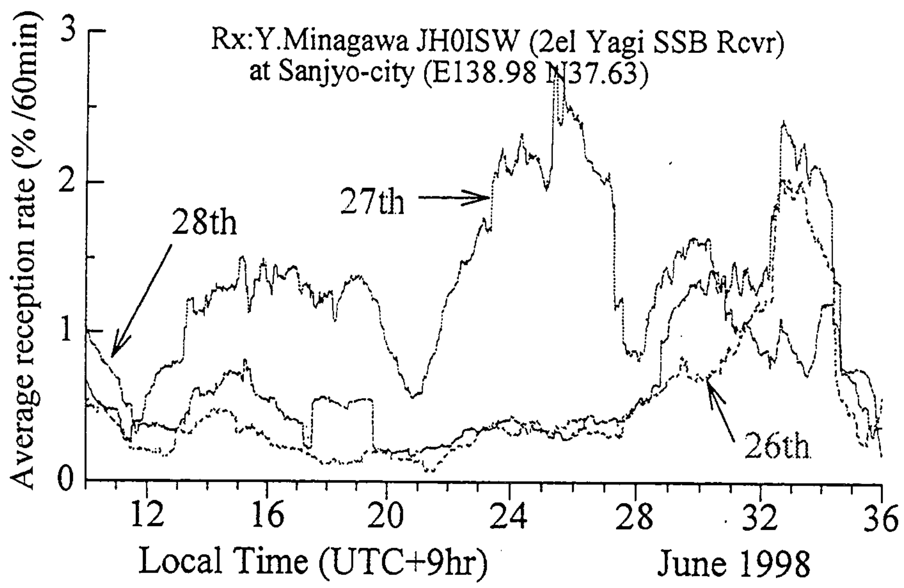


Figure 2 – Raw hourly radio reception rate counts from data collected by Yoshifumi Minagawa during June 26–28, 1998. As in Figure 1, the three days of data are plotted together for easy comparison. This data was processed using a 60-minute running average.

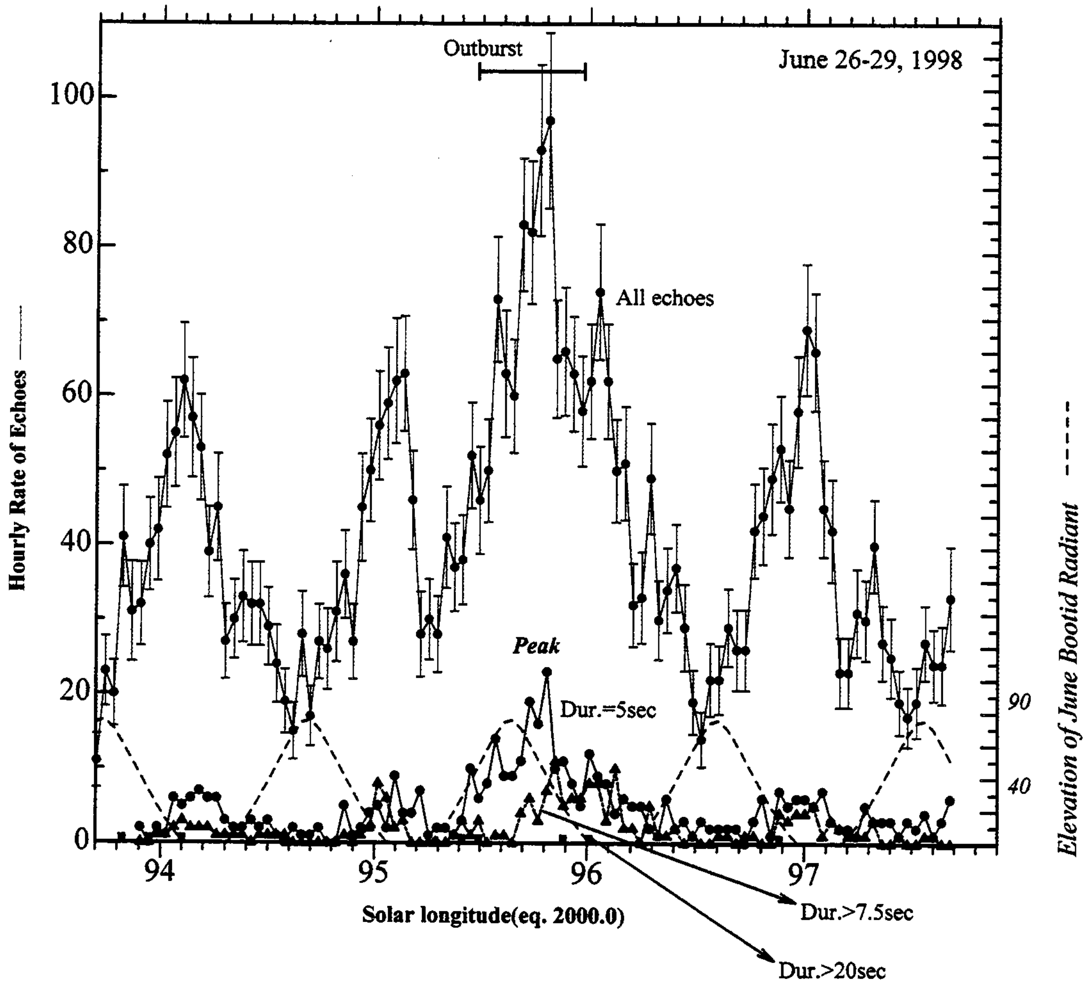


Figure 3 – Raw hourly radio meteor echo counts during June 26–28, 1998, in data collected by Masayoshi Ueda. Here we plot time in terms of the solar longitude (eq. 2000.0). The upper line shows all echo counts, while the three lower curves indicate longer-duration echo counts ($D = 5$ s, 7.5 s, and 20 s).

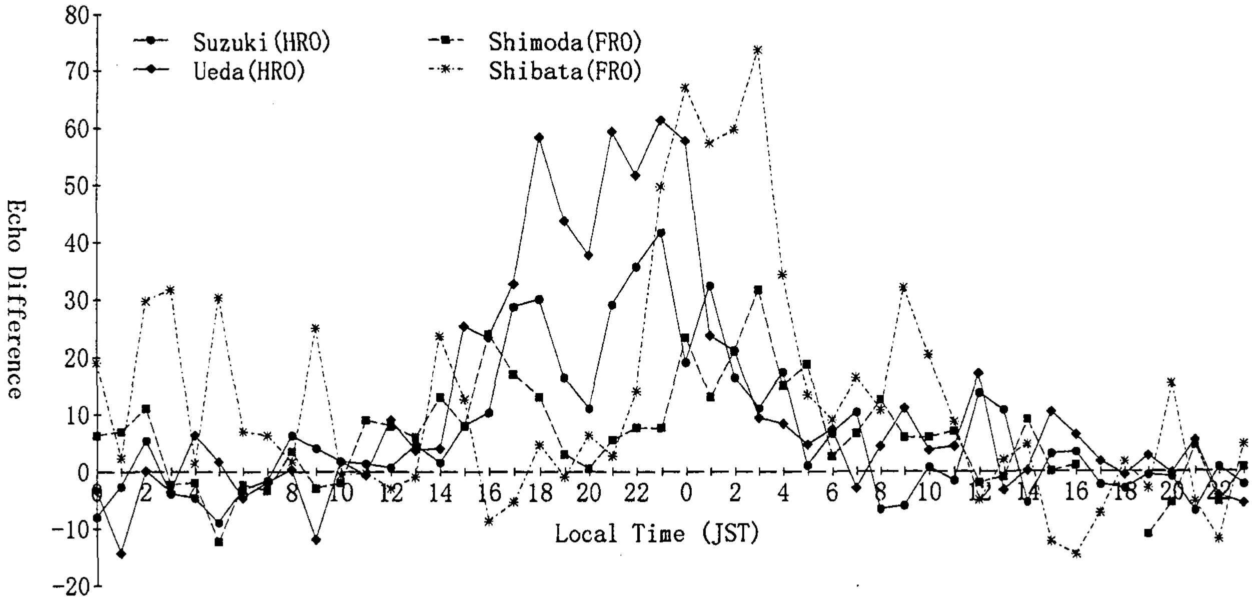


Figure 4 – Masayoshi Ueda's hourly radio echo counts, minus the assumed sporadic and other shower echo counts, on June 27 and 28, 1998. This was achieved by subtracting count data obtained on days beyond the outburst from the June 27–28 results. Three other observers' data are included for comparison (for details see main text). The horizontal time-base is in Japan Standard Time.

Both Shimoda and Shibata used received FM broadcast signals for meteor counting. The former used FM-Japan (10 kW, 81.3 MHz) as a radio source, with a short base-line of around 180 km. He obtained echo counts from a pen-recorder chart. It is difficult to determine the whole outburst period from Shimoda's raw counts alone. His raw data and equipment details are available in *RMOB* 9806 (Bulletin No. 59, July 1998; note only data from the period 11^h–22^h UT each day is presented in *RMOB* 9806, however). Shibata observed from Sapporo on 80.7 MHz, where FM-Aichi (10 kW), FM-Chiba (5 kW) and FM-Fukuoka (3 kW) are on the air. His base-lines are longer than 1200 km in a NE-SW direction. He used his own automated counting system to record echoes. He did not detect any distinct outburst before 22^h JST (13^h UT) on June 27, but counted several peaks between 2^h JST and 9^h JST. There are some problems with this receiver, unfortunately.

As a final step in our examination of the June Bootid data, we estimated the sporadic meteor activity from the average hourly rates on June 25, 26, and 29 and called it N_{Spor}. The hourly counts from June 27 and 28 we called N_{Sh}. We then computed the hourly ratio $N_{\mathrm{Sh}}/N_{\mathrm{Spor}}$ for data from the three observers Ueda, Suzuki, and Shimoda, and plotted these findings as Figure 5.

Both Ueda's and Suzuki's curves are very near to 1 before the possible Bootid radiant-rise, and after radiant-set. They also show a good agreement in the variation during the outburst, although the direction angle between Ueda and Suzuki is about 60°. From this graph, we estimate the outburst peak activity might have occurred around 17^h JST (8^h UT) to 28^h JST (19^h UT) on June 27, 1998.

3. Conclusion

We caught the June Bootid outburst on June 27, 1998, with various radio methods from Japan. Raw echo counts or reception rates from HRO methods clearly suggest the peak periods of this outburst at around 14^h UT to 18^h UT on June 27, and indicate the possible radiant's hour angle to be around 230° from the steep dip in the counts at the appropriate time. The outburst echoes to sporadic counts ratio gives us a different variation and an earlier peak activity time at around 8^h UT to 19^h UT on June 27. Observations using FM broadcast waves were unable to draw a clear determination for the activity period of this outburst.

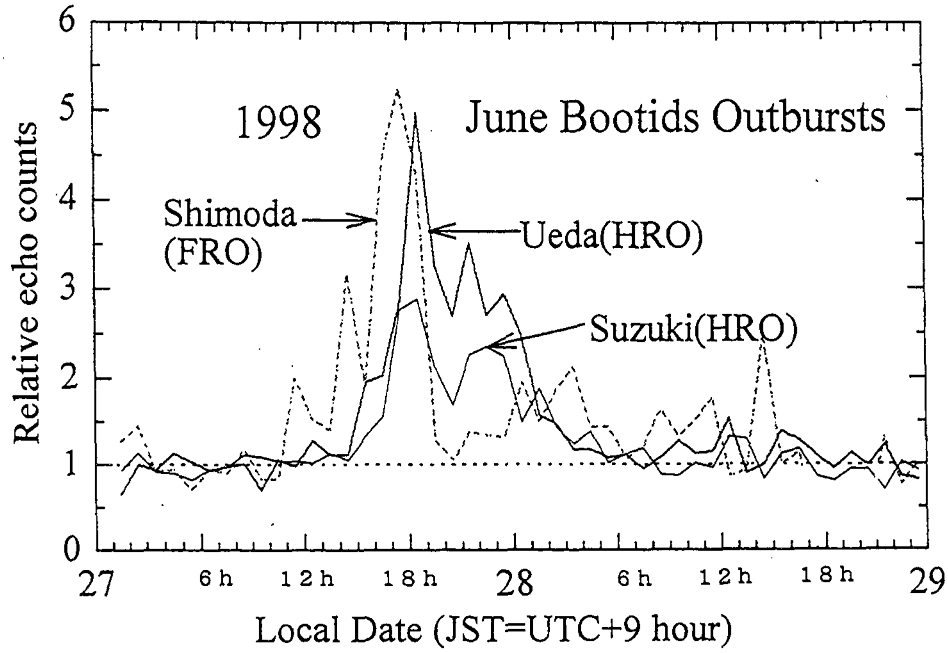


Figure 5 – The radio meteor echo ratio $N_{\mathrm{Sh}}/N_{\mathrm{Spor}}$ on June 27 and 28, 1998.

Acknowledgments

We are grateful to all the contributing HRO group members. We must express our special thanks to Dr. Takuji Nakamura of the Radio Atmospheric Science Center of Kyoto University for all his suggestions and helpful comments. I also express thanks to Alastair McBeath for his careful reading of the manuscript.

References

[1] K. Maegawa, "HRO: A New Forward-Scatter Observation Method Using a Ham-Band Beacon", *WGN* 27:1, February 1999, pp. 64–72.

[2] M. Ueda, K. Maegawa, "Outburst of the June Bootids (Pons-Winneckids) in 1998", in *Proceedings IMC*, Stará Lesná, Slovakia, 1998, A. Knöfel, A. McBeath, eds., IMO, *in preparation.*

EuRo Eclipse-Perseids '99

Romania, August 5–17, 1999

communicated by Valentin Grigore

1. Organizer

The event is organized by *SARM*, the Romanian Society for Meteors and Astronomy, with the support of *Romantic Travel* (Romanian tour operator) and *TSE '99* (Total Solar Eclipse '99, Canada).

2. Project Description

On August 11, 1999, Romania, from northwest to southeast, will be cast in shadow for $2^{\mathrm{m}}23^{\mathrm{s}}$ by the last total solar eclipse of this millennium. The maximum point of this eclipse ("greatest eclipse") will be recorded in Romania near Râmnicu Vâlcea. Even more, the capital Bucharest will be situated exactly on the central line of visibility! Much more, this exciting event will be followed by the main maximum of the Perseid meteor shower on August 12-13, around midnight local time, when the New Moon will facilitate the observations...

Having the support of Total Solar Eclipse '99 (Canada) and the Romanian tour operator Romantic Travel, the *SARM* (see `http://sarm.ccs.ro`) will organize *EuRo Eclipse '99*.

This is an international project, which will gather hundreds of amateurs, professional astronomers, and tourists from all over the world who want to observe these two great shows of the sky, but also to visit wonderful places, culture, and the friendly people of Romania.

Given the *SARM*'s experience as the organizer of the yearly astronomical camps and activities for the Perseids since 1993, August 1999 will be a great time to admire the splendors of the sky from Romania...

3. Seven tourist packages

Romantic Travel is one of the main tour operators promoting packages to various Romanian sites. We have set up seven tours to the gorgeous country side areas of Romania, richly endowed by nature and history. These tours have been published on the *EuRo Eclipse '99* site on the Internet: The Culture Tour, Journey Bucharest-Poiana Braşov, Historical Castle Dracula, Right Under the Sky, Mountain Camp in National Park Retezat, Camp in the Danube Delta, and Camp at the Black Sea Coast. These packages last between 6 and 11 days with prices in the range of 372–795 USD, all included. The packages are provided also with *SARM*'s minimum astronomical assistance. If you are interested, take a virtual tour of *EuRo Eclipse '99* and preview some of the gorgeous places to be seen: `http://www.ipgnet.com/~ovidiu/cgi-bin/ann3.pl`.

4. EuRo Eclipse-Perseids '99

Due to the many contacts we have had with astronomical groups, amateurs and professional astronomers worldwide, we were requested to set up another option, more astronomical. This project has been announced over the Internet and includes mainly some astronomical activities: camps for eclipse and Perseid observations (near Târgovişte, Piteşti, and the Parâng Mountains (1600–2400 m altitude, limiting magnitudes of 6.5–7.5), International Astronomical Meeting, astronomical exhibition of photographs, group poster, International Festival of Cosmopoetry, and more. Together with the main camp of the *SARM*, there will be other international groups and individuals there: the *Royal Astronomical Society of Canada* (Toronto Center), the *Dutch Youth Astronomical Association*, the *Warren-Wilson College* (from North Carolina, USA), and others. For a detailed description of this project, please check: `http://www.ipgnet.com/~ovidiu/perseids99.htm`.

5. Places

All our packages are easily accessible through the capital Bucharest. The accommodation, tours and meals are provided at accessible fees and include gorgeous places to be seen, great culture, and history. Here are some of the places to be visited with *EuRo Eclipse '99*: the cities of Bucharest, Târgovişte, Braşov, Sighişoara, Bistriţa, and Constanţa; the monasteries of Curtea de Argeş, Cozia, and Hurezi; the valleys of Prahova, Olt, and Bistriţa; the castles of Peles, Huniazi and Bran (Dracula's); the mountains Bucegi, Făgăraşi and Parâng; the Black Sea side; the national reservations of Retezat and the Danube Delta...

6. Advantages

Attending *EuRo Eclipse '99* in Romania has the following advantages:

- a very easy and large possibility to move in the country in case of covered sky;
- all the packages proposed are easily accessible through the capital Bucharest;
- the accommodation, tours, and meals are provided at accessible fees, and include gorgeous places to be seen, great culture, and history.

From the astronomical point of view, the *SARM* will provide *EuRo Eclipse '99* with the observing facilities and assistance. This will include observing the eclipse from the line of centrality, near or right in the sub-solar point of maximum visibility (2^m23^s) in central Romania. Dr. Jay Anderson in Canada mentions Romania as one of the choicest locations for viewing the eclipse, as Romania is warm and dry in August, with about a 63% chance of clear skies on the eclipse day.

EuRo Eclipse '99 has been one of the first eclipse projects referenced since its first announcement on the Internet, by Dr. Fred Espenak of NASA, Sky and Telescope, Yale University, Warren-Wilson College, the Astrophysical Institute of the Canary Islands, ...

7. Detailed information and reservations

Additional information on *EuRo Eclipse '99* and other related projects can be found on the Internet:

`http://www.ipgnet.com/~ovidiu/eclipsa.htm` (Canada);
`http://www.geocities.com/CapeCanaveral/Hall/9794/eclipsa.htm` (USA).

You can also send e-mail: `sarm@minisat.ro` (*SARM*); `ovidiuv@yahoo.com` (*TSE '99*).

Come together with us in Romania and you will never forget August 11, 1999!

Leonid Multi-Instrument Aircraft Campaign Workshop

NASA/Ames Research Center, Moffett Field, California, USA, April 12–15, 1999

communicated by Peter Jenniskens, NASA/Ames Research Center

1. Invitation

You are cordially invited to participate in an international workshop at *NASA/Ames Research Center* to discuss the recent Leonid observing campaigns.

The Leonid meteor shower has offered unprecedented opportunity to address outstanding issues in planetary astronomy, astro-biology, and the dynamics of the upper atmosphere.

This workshop aims to bring that science in focus, make a tally of observational data from the recent November 1998 observing campaign, and make recommendations for the next campaign in November 1999.

In particular, the workshop will discuss the first results from the *Leonid Multi-Instrument Aircraft Campaign* and related ground-based efforts.

2. Abstract and registration deadline

Technically, the deadline for registration has passed on March 1. However, interested persons should contact Peter Jenniskens (`peter@max.arc.nasa.gov`) to check about the possibility of late registration.

3. Preliminary program

The meeting will be held in the ballroom of the NASA/ARC Training Center at Moffett Field, California.

Monday, April 12

09^h00^m–12^h00^m: Session on the role of meteors in creating the conditions for life's origin on Earth. Related issues: astro-biology, atmospheric and surface conditions on the early Earth, formation of planetesimals.

14^h00^m–17^h00^m: Session on comet grain ejection and meteoroid stream dynamics. Related issues: the activity of the shower in 1998, Leonid meteoroid influx, size distributions, and the satellite impact hazard.

17^h00^m–18^h00^m: News conference.

17^h00^m–20^h00^m: Poster session and wine/cheese and buffet.

Tuesday, April 13

09^h00^m–12^h00^m: Session on meteoroid composition and ablation. Related issues: morphology and wake of meteoroids, organic matter in IDPs, organic matter on planetary surfaces, composition of comets, evaporation of silicates in proto-planetary environments.

14^h00^m–17^h00^m: Session on meteor-induced atmospheric chemistry. Related issues: meteor physics, shock and impact chemistry, flash pyrolysis of organic matter, upper atmosphere composition and chemistry.

18^h00^m–21^h00^m: Group dinner. Invited presentation: "meteors and sprites."

Wednesday, April 14

09^h00^m–12^h00^m: Session on physics and chemistry of neutral atom debris and particles. Related issues: implications for the dynamics of the upper atmosphere, sprites, meteoric signature of stratosphere aerosols, the ozone problem, and iron catalysis of precursor molecules for life.

14^h00^m–17^h00^m: Plans and coordination for November 1999 *Leonid Multi-Instrument Aircraft Campaign* and ground-based campaigns in the form of presentation reflecting past campaign and future plans (including presentations of capacity available airborne platforms) followed by working sessions along themes above.

Thursday, April 15

05^h00^m–13^h00^m: Site seeing tour: balloon tour over Napa valley to commemorate historic balloon flight in 1870 that viewed meteor shower above clouds.

4. Leonid Threat Conference

If you have not done so, do not forget to register for the *Leonid Meteor Storm and Satellite Threat Conference* in Manhattan Beach, California, USA, which is held between May 11 and 13, 1999. The conference focuses on aspects of meteoroids and their effects on spacecraft.

Further information: `http://www.aero.org/conferences/leonid/`.

The International Meteor Organization

Council

President: Jürgen Rendtel, Seestraße 6, D-14476 Marquardt, *Germany,*
tel. +49 (332) 08 50753, e-mail: `president@imo.net`

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

Secretary-General: Robert Lunsford, Vance Street 161, Chula Vista, *CA 91910, USA*
tel. +1 (619) 585 9642, e-mail `treasurer@imo.net`

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

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

Commission Directors

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

Telescopic Commission: M. Currie, 660, N'Aohoku Place, Hilo, *HI 96720, USA,*
e-mail: `tele@imo.net`

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

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

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

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

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

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

Typesetting: Urania, the Public Observatory of Antwerp

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

Addresses of contact authors not mentioned above

J. Richter, Martin-Luther-Platz 6, D-01099 Dresden, *Germany*
V. Grigore, CP 14, OP 1, R-0200 Târgovişte, Dâmboviţa, *Romania*
M. Beech, Campion College, Univ. of Regina, Regina, *Saskatchewan S4S 0A2, Canada*
D. Koschny, Zeestraat 46, NL-2211 XH Noordwijkerhout, *the Netherlands*
B. Ewen-Smith, Centro de Obs. Astr. no Algarve, Poio, P-8500 Portimão, *Portugal*
M. Ueda, 43-2 Asuka Habikino-shi, 583 Osaka, *Japan*
P. Jenniskens, NASA/Ames Res. Ctr., Mail Stop 239-4, Moffett Field, *CA 94035-1000, USA*

Do not miss it!

International Meteor Conference 1999

Frasso Sabino, Italy, September 23–26, 1999

Do not miss this unique opportunity to meet like-minded people! We anticipate that due to the location a lot of meteor enthusiasts from all over Europe, in particular Southern Europe, will participate. Results on the 1998 Leonids and discussions on the 1999 Leonids may be expected. Registration information can be found in the December 1998 issue and will be repeated in the April 1999 issue.

The stock of the IMO

	DEM	EUR	USD
Publications in English:			
Photographic Meteor Data Base (1986)	8	4.09	6
Proceedings International Meteor Conference 1990	10	5.11	8
Proceedings International Meteor Conference 1991	10	5.11	8
Proceedings International Meteor Conference 1992	10	5.11	8
Proceedings International Meteor Conference 1993	12	6.14	9
Proceedings International Meteor Conference 1994	10	5.11	8
Proceedings International Meteor Conference 1995	12	6.14	9
Proceedings International Meteor Conference 1996	12	6.14	9
Proceedings International Meteor Conference 1997	12	6.14	9
Proceedings International Meteor Conference 1998	12	6.14	9
Gnomonic Atlas Brno 2000.0	5	2.56	4
Photographic Astrometry + diskette	13	6.65	10
Visual Handbook	25	12.78	20
WGN Observational Report Series:			
Vols. 1–4 (1988–91): Visual and Fireball Obs., per vol.	15	7.67	12
Vol. 5 (1992): Visual Observations	15	7.67	12
Vol. 6 (1993): Vis. Obs. and Electrophonic Fireball Cat.	20	10.23	16
Vols. 7–10 (1994–97): Visual Observations, per vol.	20	10.23	16
Backissues of the WGN Journal:			
Volumes 19–20 (1991–92): complete, per volume:	20	10.23	16
Volumes 21–22 (1993–94): complete, per volume:	25	12.78	20
Volumes 23–26 (1995–98): complete, per volume:	35	17.90	25
Backissues of Fidac News:			
Volumes 1–6 (1993–98) : complete, per volume:	15	7.67	12