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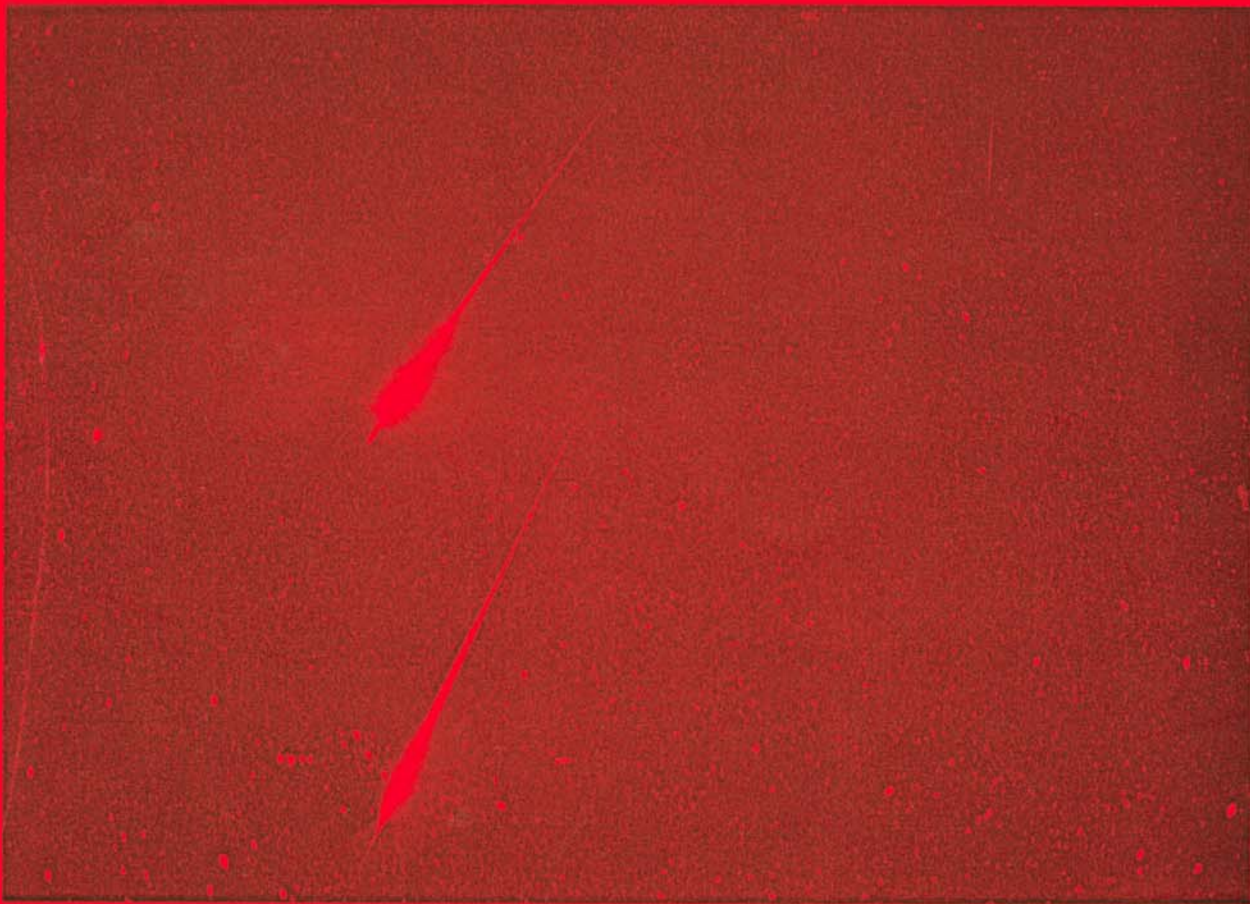

This photograph was taken by Carlos Vera Hernández of the *Agrupación Astronómica de Fuerteventura* from Fuerteventura (Canary Islands, Spain) in the morning of November 17, 1998, with a 24 mm $f/2.8$ camera, on Kodak Tmax 3200 ASA film. The exposure lasted from $3^h30^m00^s$ UT till $3^h33^m00^s$ UT, and shows two Leonid fireballs, as well as a fainter Leonid towards the top right corner.

In this issue:

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Useful Information

The February Issue *(WGN 27:1)*

The *February issue* will be mailed around the second week of February. Contributions are due on *January 22* at the latest. They should be sent to *Marc Gyssens*.

Administrative Correspondence

Ordering *IMO* publications is done in the same way as paying subscription/membership fees. Changes of address and complaints about not receiving *WGN* should be addressed to *Ina Rendtel*.

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

From the Editor-in-Chief

Marc Gyssens

These are certainly exciting times for meteor observers. Since the last issue of WGN appeared, we had the Draconids, which showed some good activity over Eastern Asia, and then there were, of course, the Leonids. Although the Leonids did not produce a storm this year, they surprised us with an outburst of very bright meteors in the night of November 16-17, best seen in Western Europe and the East Coast of North America. To both these exciting events, we pay attention in this issue with preliminary analyses and observational reports.

As it looks now, the 1998 Leonids will represent the biggest meteor observing effort ever up to now. I wish to use this opportunity to thank all who have contributed to this success. First of all, there are those having set up the International Leonid Watch to give additional structure for the Leonid observing efforts, there are the people who spread information to both observers and the general public, there are all the observers, several of whom have spared neither efforts nor money to set up observing campaigns in Central or Eastern Asia, or even airborne missions, and, finally, there are those trying to make sense out of the observations as quickly as possible to provide us with feedback. In this last respect, my special thanks go to Rainer Arlt, our Visual Commission Director, who has stretched his capabilities to the limit to present us the first results on both the Leonids and *the Draconids in the present issue of* WGN, *as well as via the* IMO *Website. That these efforts are appreciated is illustrated by George Spalding's letter further on in this issue.*

There is one aspect of the 1998 Leonid campaign I feel less comfortable about, however, notably the press coverage. True, the media covered the Leonids extensively, and this is, of course, encouraging. For instance, CNN interviewed our own Peter Brown. Unfortunately, the information given was not always that accurate. Several news sources ignored astronomers' cautioning remarks and failed to mention the possibility that no storm would materialize, thus causing disappointment among the general public, who blamed the astronomers for this rather than the media. Even more disturbing is the nonsense that was spread after the event. The outburst of bright meteors in the night of November 16-17 was mistaken for the storm that did not occur, so the conclusion was predictable: the astronomers had "miscalculated" the storm... Just like in 1899, the astronomical world lost its face in the eyes of the public opinion, prompting poor jokes such as "Hopefully, the total solar eclipse of August 11 next year will not be a day early."

For sure, this blemish on an otherwise magnificent observing campaign should not be allowed to overshadow our accomplishments, but, nevertheless, I think we should take lessons from what has happened for the 1999 Leonids. A still greater effort will have to be made to inform the press as well as to encourage it to instruct the general public accurately of what they may expect. Also, we must try to provide the press with a—necessarily rough, but accurate—interpretation of the actual activity within hours after the event, for later, the media will have lost interest. Of course, such an effort can only be successful if it is supported by all our members and subscribers and all meteor workers in general to spread this information to the national, regional, and local press, to public observatories, and other channels via which it can finally reach the general public.

Looking back, 1998, which is almost over as I am writing this, has been an exciting year meteor-wise. However, 1999 promises to be even more exciting, especially if a Leonid storm were to materialize next November. So, in case you have not yet renewed your membership or subscription, please take a few minutes to review the easy renewal instructions which we have reprinted below for your convenience and pay your dues; surely you want to be kept informed about meteors next year. Meanwhile, enjoy reading this issue!

Renew Your IMO Membership/WGN Subscription Now!

Ina Rendtel

General information

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You can combine your renewal with an order for other *IMO* publications (outside back cover), *New* IMO *publications* are Report 10 containing the 1997 visual observations, and the Proceedings of the 1997 and 1998 *IMC*s, the latter of which will appear shortly and can already be ordered. You can also pay your subscription for *two* years. You can **become a supporting member** by adding at least 15 DEM or 10 USD per year to your membership.

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All people insisting on paying by check should pay to Robert Lunsford in US Dollars, as indicated above. Make checks payable to Robert Lunsford, not to the IMO!

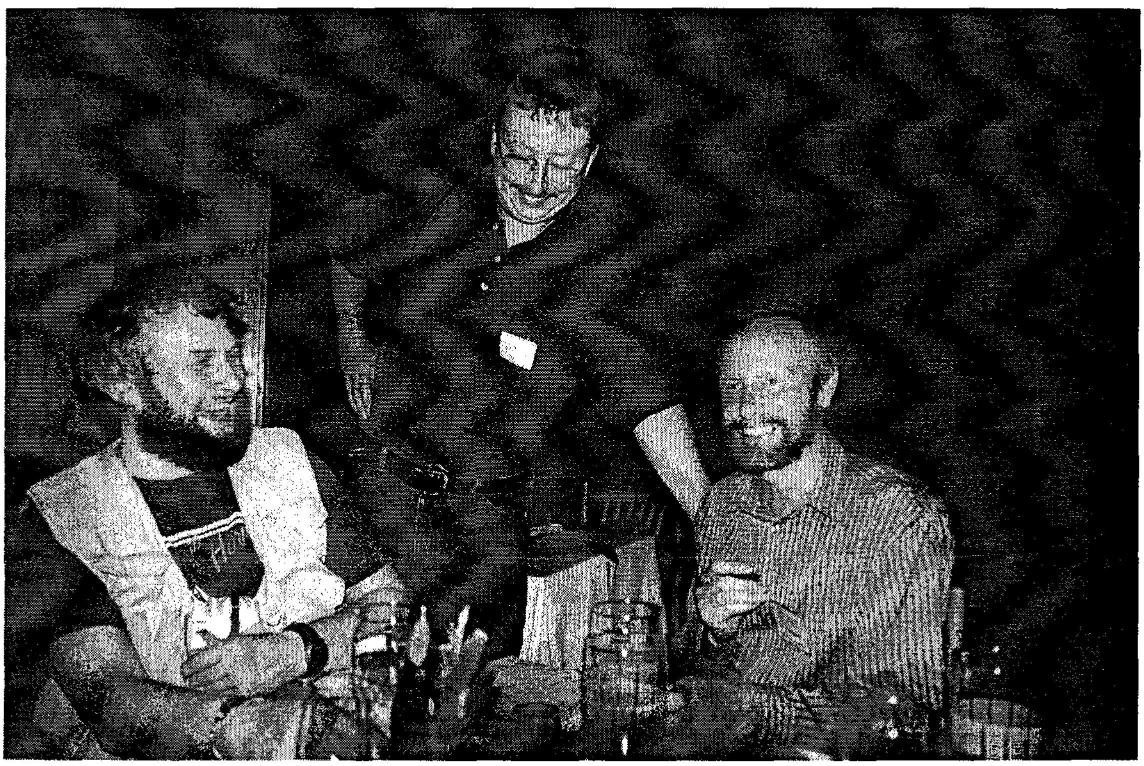

Figure 1 – At the 1998 *International Meteor Conference*, which took place in Stará Lesná, in Slovakia's High Tatra Mountains, from August 20 to 23, there was a lot of exchange between amateur and professional meteor workers, not only in terms of formal presentations, but, first and foremost, at the informal level. On the photograph, we see, from left to right: Christopher Trayner (United Kingdom), Harald Seifert (Germany), and Jack Baggaley (New Zealand, President of the IAU Commission 22).

Letters to WGN

compiled by Marc Gyssens

Meteor observers—a world-wide team

Congratulations to Rainer Arlt and *IMO* colleagues for their preliminary report on the recent fine Leonid display.

I was immediately struck in reading the names of the observers at the world-wide nature of the team, truly a "United Nations" of meteor enthusiasts. I hope this fact will be noted in a future detailed report.

It was good to know I was a member of a cosmopolitan team; in finishing observing near dawn on November 17, I knew I had done my bit, and could hand on to America, just as I had taken over from colleagues in Asia and then the Middle East.

Let us also not forget those many other observers who stood ready to go on watch like the rest of us, but whose names are missing because they were clouded out. I trust they will be consoled to some degree by the tales they have heard from luckier colleagues, and that they will be among the well-placed observers in 1999.

George Spalding, November 27, 1998

The 1999 International Meteor Conference

Frasso Sabino, Italy, September 23–26, 1999

communicated by Massimo Calabresi and Roberto Gorelli

The 1999 *International Meteor Conference* will be held in the village of Frasso Sabino in Italy and the local organization is in the hands of the *Associazione Romana Astrofili*.

Frasso Sabino is located at 50 km from Rome along the Via Salaria. The name goes back to Roman times. In Latin, *fraxare* means "to stand guard," so, probably, Frasso Sabino was a Roman sentry-post.

At the center of the village is the Sforza Cesarini Castle, constructed between the 15th and 16th centuries; nearby is the church of San Pietro in Vincoli, built before the 14th century.

The Conference will be held near the village (at 1 km), in a locality called Osteria Nuova, on the Via Salaria, in an old 17th-century country palace built on top of a Roman tomb of the 2nd century BC, called "Grotta dei Massacci." This national monument has two lecture rooms and all facilities required for a conference.

The participants will be lodged in a new hotel in Osteria Nuova at only 300 m from the lecture rooms; near the hotel, there are some shops, a bar, and bus stops for buses to Rome and other cities.

Frasso Sabino is also the place where the *Associazione Romana Astrofili* has its astronomical observatory. It is situated in an old mill near the church of San Pietro in Vincoli. The telescope is a self-made 0.37-m $f/12$ Cassegrain, and inside the old structure, which has been completely renewed, a planetarium has recently been installed.

About 100 professional and amateur astronomers in Italy are interested in meteor observations. Among this group, 20 are active observers. Presently, the *Associazione Romana Astrofili* and other amateur clubs are trying to enlarge this group by training new observers.

The *Associazione Romana Astrofili* is very glad to provide the local organization of the 1999 *International Meteor Conference*. This conference represents a unique opportunity for the Italian meteor observers to meet colleagues from other countries in Europe and the world, so we hope that a large number of people will attend the meeting.

The conference will start on Thursday evening (September 23) and end on Sunday (September 26); the full registration fee amounts to 240 DEM. The payment includes accommodation in double rooms, meals, and a copy of the proceedings. Details about the registration procedure can be found on the Registration Form.

There are many ways to reach the conference location, including good connections by bus from Rome and the Leonardo Da Vinci International Airport. By car, Frasso Sabino is located 25 km from the A1 motorway (take the exit *Roma Nord* in the direction of the city of Rieti) on a major road.

For further questions, the *Associazione Romana Astrofili* can be contacted via Mr. Fausto Porcellana (tel. +39(6)40 79 39 94, fax +39(6)40 79 36 30, email `fausto_porcellana@telespazio.it`), Mr. Roberto Gorelli (email `md6648@mclink.it`), and Dr. Massimo Calabresi (email: `mc7851@mclink.it`).

International Meteor Conference

Frasso Sabino, Italy, September 23–26, 1999

Registration Form

Each individual participant should fill out a form and return it to *Ina Rendtel, Mehlbeerenweg 5, D-14469 Potsdam, Germany*, as soon as possible.

Your registration will be guaranteed only after Ina Rendtel has received the minimum pre-payment of 100 DEM. If you wish to participate, but cannot yet decide, simply return this form with the proper option checked to stay on the mailing list for further circulars.

Name: __________________________________ Birth date: ____________

Address: ____

____

____

Phone: ______________ Fax: ______________ E-Mail: ______________

- o wishes to register for the 1999 *IMC* from September 23 to 26;
- o intends to participate, cannot yet register, but wishes to stay on the mailing list.

I intend to travel by ________, together with ____________________________

Additional requests:

- o I need travel information from __________________ to Frasso Sabino;
- o I wish to stay in Italy before or after the *IMC* and require additional information re. this matter.

For participants wishing to contribute to the program:

Lecture: ____

Duration: _________min. Required equipment: ____________________________

Workshop or discussion: ____

Poster presentation: _______________________________ Space: _________ m^2

Either the entire fee of 240 DEM or a pre-payment of at least 100 DEM should be sent to the Treasurer, *Ina Rendtel*. Follow the payment instructions below. Participants paying only 100 DEM have to pay the remaining 140 DEM upon arrival in Frasso Sabino.

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- in the UK: proceed as above or pay to Alastair McBeath, 12A Prior's Walk, Morpeth, Northumberland NE61 2RF, England.
- in Japan: pay to Masahiro Koseki, 4-3-5 Annaka, Annaka-shi, 379-01 Gunma-ken, Japan.
- all others pay in USD to Robert Lunsford, 161 Vance Street, Chula Vista, California 91910, USA. In case you pay by bank check, make it payable to Robert Lunsford, *not* the *IMO*!

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

Leonids

Bulletin 13 of the International Leonid Watch: The 1998 Leonid Meteor Shower

Rainer Arlt

An overview of the 1998 Leonid activity is given based on visual records from 217 observers who saw more than 47 000 Leonids in 858 observing hours. A broad component rich in bright meteors (background component) was found to have its maximum at $\lambda_\odot = 234.^\circ52$ (eq. J2000; 1998 November 17, $1^{\rm h}40^{\rm m}$ UT) with ZHR $= 340 \pm 20$. The actual "storm" component of the Leonid meteoroid stream turned out to be weak in 1998 with a peak at $\lambda_\odot = 235.^\circ308$ (1998 November 17, $20^{\rm h}30^{\rm m}$ UT) reaching ZHR $= 180 \pm 20$. The first component is characterized by an extremely low population index of $r = 1.19 \pm 0.02$ at $\lambda_\odot = 234.^\circ43$ (1998 November 16, $23^{\rm h}30^{\rm m}$ UT), whereas relatively high values of $r = 2.00 \pm 0.05$ are found between $\lambda_\odot = 235.^\circ15$ and $\lambda_\odot = 235.^\circ32$ (1998 November 17, $16^{\rm h}40^{\rm m}$–$20^{\rm h}50^{\rm m}$ UT). The full width at half maximum of the background component is 17 hours, that of the "storm" component is 0.75 hours. The data indicate a strong dependence of observable rates from the zenith distance through other than geometrical effects.

1. Introduction

A strong return of the Leonid meteor shower was expected for 1998; predictions concentrated on the time between $19^{\rm h}$ and $21^{\rm h}$ UT on November 17, equivalent to solar longitudes of $\lambda_\odot = 235.^\circ25$–$235.^\circ30$ (equinox J2000). This time favored eastern Asian geographical longitudes. Observers in Asia were highly alerted to watch a possible strong outburst of Leonid activity and several expeditions from other parts of the world headed to China, Mongolia, and Korea to monitor the Leonid meteor shower. We are very grateful to the following observers who submitted regular meteor reports; a total of over 1500 observing periods were available to this analysis as recorded by:

Ghazalaha Al-Abed (`ABEGH`, $5.^{\rm h}95$), Iyad Ahmad (`AHMIY`, $1.^{\rm h}83$), Ahmad Al-Niamat (`ALNAH`, $5.^{\rm h}00$), Rainer Arlt (`ARLRA`, $0.^{\rm h}63$), Joseph D. Assmus (`ASSJO`, $3.^{\rm h}11$), Zaid Ata (`ATAZA`, $5.^{\rm h}00$), Juan Alberto Aveledo (`AVEJU`, $1.^{\rm h}20$), Jlia Babina (`BABJL`, $3.^{\rm h}28$), Halim Baituk (`BAIHA`, $2.^{\rm h}30$), Ana Bankovic (`BANAN`, $4.^{\rm h}12$), Rony Barry (`BARRO`, $0.^{\rm h}54$), Luc Bastiaens (`BASLU`, $1.^{\rm h}66$), Rizlane Bechar (`BECRI`, $1.^{\rm h}67$), Sanae Bechar (`BECSA`, $1.^{\rm h}67$), Luis R. Bellot Rubio (`BELLU`, $4.^{\rm h}97$), Mahjoub Belfahim (`BELMA`, $6.^{\rm h}83$), Pavel Belov (`BELPA`, $2.^{\rm h}15$), Vladimir Belchenko (`BELVL`, $2.^{\rm h}55$), Abdelaziz Bennouna (`BENAB`, $1.^{\rm h}08$), Felix Bettonvil (`BETFE`, $4.^{\rm h}39$), Neil Bone (`BONNE`, $1.^{\rm h}97$), Mark Borg (`BORMR`, $6.^{\rm h}25$), Michael Boschat (`BOSMI`, $4.^{\rm h}00$), Joana M. Brunet (`BRUJO`, $5.^{\rm h}30$), Marija Cajetinac (`CAJMA`, $5.^{\rm h}75$), Arturo Carvajal R. (`CARAR`, $0.^{\rm h}50$), Tal Carmon (`CARTA`, $0.^{\rm h}04$), Andrew Casely (`CASAN`, $1.^{\rm h}00$), Matthew Collier (`COLMA`, $0.^{\rm h}24$), Tim Cooper (`COOTI`, $1.^{\rm h}00$), Uroš Čotar (`COTUR`, $1.^{\rm h}03$), Stefano Crivello (`CRIST`, $5.^{\rm h}78$), Hani Dalee (`DALHA`, $4.^{\rm h}00$), Luigi d'Argliano (`DARLU`, $1.^{\rm h}41$), Mark Davis (`DAVMA`, $7.^{\rm h}50$), Goedele Deconinck (`DECGO`, $1.^{\rm h}71$), Benoit Dejust (`DEJBE`, $2.^{\rm h}00$), Marc de Lignie (`DE MA`, $15.^{\rm h}23$), Vincent Desmarais (`DESVI`, $2.^{\rm h}20$), Peter Detterline (`DETPE`, $5.^{\rm h}06$), Asdai Diaz Rodriguez (`DIAAS`, $2.^{\rm h}00$), Anton Dimitrov (`DIMAN`, $2.^{\rm h}14$), Elena Dimovski (`DIMEL`, $6.^{\rm h}08$), John Drummond (`DRUJO`, $2.^{\rm h}50$), Tonis Eenmae (`EENTO`, $3.^{\rm h}07$), Maurizio Eltri (`ELTMA`, $2.^{\rm h}75$), Frank Enzlein (`ENZFR`, $2.^{\rm h}69$), Tamás Fodor (`FODTA`, $1.^{\rm h}93$), Keiiti Fukui (`FUKKE`, $11.^{\rm h}73$), Nobuyuki Fukuda (`FUKNO`, $4.^{\rm h}15$), Ofer Gabzo (`GABOF`, $0.^{\rm h}25$), Christoph Gerber (`GERCH`, $15.^{\rm h}18$), Jaroslav Gerboš (`GERJA`, $8.^{\rm h}50$), Ivanka Getsova (`GETIV`, $3.^{\rm h}52$), George W. Gliba (`GLIGE`, $3.^{\rm h}25$), Orly Gnat (`GNAOR`, $0.^{\rm h}17$), Shelagh Godwin (`GODSH`, $0.^{\rm h}66$), Amit Gokhale (`GOKAM`, $2.^{\rm h}05$), Sagar Gokhale (`GOKSA`, $1.^{\rm h}03$), Yeshodhan Gokhle (`GOKYE`, $3.^{\rm h}68$), Alexandra Golova (`GOLAL`, $3.^{\rm h}28$), Prerana Gore (`GORPA`, $2.^{\rm h}67$), Roberto Gorelli (`GORRO`, $8.^{\rm h}20$), Valentin Grigore (`GRIVA`, $4.^{\rm h}45$), Monica de la Guardia (`GUAMO`, $4.^{\rm h}36$), Michal Haltuf (`HALMI`, $1.^{\rm h}41$), Torsten Hansen (`HANTO`, $1.^{\rm h}98$), Takema Hashimoto (`HASTA`, $10.^{\rm h}50$), Roberto Haver (`HAVRO`, $5.^{\rm h}12$), Kim Hay (`HAYKI`, $2.^{\rm h}37$), Amera Hemsy (`HEMAM`, $5.^{\rm h}33$), Kamil Hornoch (`HORKM`, $3.^{\rm h}39$), Daiyu Ito (`ITODA`, $4.^{\rm h}97$), Kiyoshi Izumi (`IZUKI`, $7.^{\rm h}23$), Helle Jaaniste (`JAAHE`, $3.^{\rm h}35$), Jan Janssens (`JANJA`, $12.^{\rm h}50$), Vibor Jelic (`JELVI`, $4.^{\rm h}52$), Ilhame Jemmah (`JEMIL`, $0.^{\rm h}50$), Carl Johannink (`JOHCA`, $16.^{\rm h}35$), Ivan Jokic (`JOKIV`, $2.^{\rm h}20$), Kevin Jones (`JONKE`, $6.^{\rm h}24$), Javor Kac (`KACJA`, $5.^{\rm h}87$), Primož Kajdič (`KAJPR`, $2.^{\rm h}09$), D. Kalayda (`KALDU`, $3.^{\rm h}33$), Dmitrij Karkach (`KARDM`, $3.^{\rm h}28$), Niladri Kar (`KARNI`, $3.^{\rm h}72$), Kenya Kawabata (`KAWKE`, $3.^{\rm h}71$), Srdjan Keca (`KECSR`, $3.^{\rm h}70$), Akos Kereszturi (`KERAK`, $3.^{\rm h}53$), Katarina Kerekesova (`KERKT`, $8.^{\rm h}78$), Noor Al-Khateeb (`KHANO`, $4.^{\rm h}44$), Mark Kidger (`KIDMA`, $1.^{\rm h}50$), Kevin Kilkenny (`KILKE`, $3.^{\rm h}09$), André Knöfel (`KNOAN`, $7.^{\rm h}68$), Daniel Köhn (`KOHDA`, $1.^{\rm h}46$), Khalil Konsul (`KONKH`, $5.^{\rm h}50$), Marija Kotur (`KOTMA`, $0.^{\rm h}91$), Jakub Koukal (`KOUJA`,

$11^h.36$), Zoran Kraljevic (KRAZO, $3^h.47$), Nikola Kresojevic (KRENI, $5^h.55$), Gary W. Kronk (KROGA, $6^h.50$), Tom Kucharski (KUCTO, $2^h.42$), Brigitte Kuneth (KUNBR, $2^h.00$), Werfried Kuneth (KUNWE, $1^h.00$), Zsolt Lantos (LANZS, $2^h.96$), Anne-Laure Lebacq (LEBAN, $1^h.71$), Adrian Lelyen (LELAD, $1^h.00$), Anna S. Levina (LEVAN, $3^h.33$), Mihir Limaye (LIMMH, $1^h.18$), Alister Ling (LINAL, $1^h.38$), Vladimir Lukić (LUKVL, $6^h.02$), Robert Lunsford (LUNRO, $5^h.00$), Hartwig Luthen (LUTHA, $9^h.20$), Mirjana Malarić (MALMR, $5^h.00$), Katuhiko Mameta (MAMKA, $1^h.50$), David Martinez Delgado (MARDA, $2^h.01$), José Alfonso dos Reis Martins (MARJO, $2^h.88$), Khalid Marwat (MARKH, $2^h.48$), Pierre Martin (MARPI, $4^h.65$), Takuya Maruyama (MARTA, $0^h.67$), Antonio Martinez (MARTI, $4^h.42$), Yukihisa Matumoto (MATYU, $1^h.50$), Alastair McBeath (MCBAL, $7^h.05$), Stephen McCann (MCCST, $0^h.23$), Bruce McCurdy (MCCBR, $1^h.38$), Kevin McKeown (MCKKE, $1^h.00$), Lukas Mecir (MECLU, $0^h.13$), Mark Mikutis (MIKMR, $12^h.20$), Ana Milovanovic (MILAA, $6^h.42$), Dragan Milisavljevic (MILDR, $1^h.02$), Iris Miljački (MILIR, $2^h.65$), Hidekatu Mizoguchi (MIZHI, $2^h.41$), Amruta Modani (MODAM, $2^h.66$), Sirko Molau (MOLSI, $14^h.17$), William Morgan (MORWI, $1^h.84$), Erick Mota Perez (MOTER, $2^h.90$), Darshan Mundada (MUNDA, $3^h.86$), Sin Nakayama (NAKSI, $3^h.76$), Koji Naniwada (NANKO, $4^h.33$), Sven Näther (NATSV, $12^h.35$), Dalibor Nikolic (NIKDA, $2^h.46$), Prakash Nitsure (NITPR, $4^h.05$), Mohammad Odeh (ODEMO, $4^h.15$), Ibrahim Odwan (ODWIB, $4^h.75$), Eran Ofek (OFEER, $3^h.47$), Hiroyuki Okayasu (OKAHI, $4^h.98$), Masayuki Oka (OKAMA, $5^h.59$), Dragana Okolić (OKODR, $3^h.91$), Kazuhiro Osada (OSAKA, $8^h.50$), Ketan Pendse (PENKE, $1^h.33$), Miroslav Penev (PENMI, $2^h.15$), Alfredo Pereira (PERAF, $5^h.71$), Dusan Perovic (PERDU, $5^h.01$), Radame Perez (PERRA, $1^h.00$), Suyin Perret-Gentil (PERSU, $1^h.52$), Furio Pieri (PIEFU, $4^h.73$), Mila Popović (POPMI, $1^h.20$), Dubravko Potkrajac (POTDU, $1^h.08$), Tushar Purohit (PURTU, $2^h.85$), Daniela Rapava (RAPDA, $7^h.09$), Simona Rapava (RAPSI, $2^h.96$), Pavol Rapavy (RAPPA, $8^h.34$), Ina Rendtel (RENIN, $1^h.08$), Jürgen Rendtel (RENJU, $21^h.68$), Mileny Roche Lamas (ROCMI, $1^h.00$), Francisco Rodriguez Ramirez (RODFR, $5^h.05$), Juan Rodríguez (RODJU, $3^h.72$), Victor Ruiz Ruiz (RUIVI, $3^h.91$), K.V. Sankaranarayanan (SANKV, $2^h.50$), René Scurbecq (SCURE, $4^h.22$), Abderazak Sersouri (SERAB, $1^h.67$), Shashank Shalgar (SHASH, $4^h.03$), Brian Shulist (SHUBR, $3^h.10$), Hendrik Sielaff (SIEHE, $5^h.67$), Hiroyuki Sioi (SIOHI, $5^h.24$), Vesna Slavković (SLAVE, $2^h.65$), James N. Smith (SMIJN, $6^h.65$), Andrey Solodovnik (SOLAD, $3^h.05$), Manuel Solano Ruiz (SOLMA, $1^h.25$), George Spalding (SPAGE, $4^h.92$), Ulrich Sperberg (SPEUL, $3^h.90$), Mark Stafford (STAMA, $1^h.82$), Enrico Stomeo (STOEN, $1^h.19$), Niko Štritof (STRNI, $3^h.04$), Paul Sutherland (SUTPA, $1^h.39$), David Swann (SWADA, $6^h.10$), Eva Szabados (SZAEV, $0^h.90$), Richard Taibi (TAIRI, $4^h.42$), Masaaki Takanasi (TAKMA, $0^h.75$), Mika Takanasi (TAKMI, $4^h.49$), Khaled Tell (TELKH, $10^h.47$), István Tepliczky (TEPIS, $1^h.51$), Kazumi Terakubo (TERKA, $1^h.00$), Neelima Thatte (THANE, $5^h.90$), Danilo Tomic (TOMDA, $2^h.40$), Yasuhiro Tonomura (TONYA, $1^h.83$), Michael Toomey (TOOMI, $2^h.60$), Tamas Tordai (TORTA, $4^h.10$), Hamid Touma (TOUHA, $3^h.25$), Gabrijela Triglav (TRIGA, $0^h.93$), Mihaela Triglav (TRIMI, $5^h.31$), Josep M. Trigo Rodriguez (TRIJO, $1^h.07$), Arnold Tukkers (TUKAR, $15^h.41$), Anne van Weerden (VANAE, $5^h.10$), Erwin van Ballegoy (VANER, $4^h.92$), Jan Verbert (VERJN, $1^h.60$), Ivaylo Videv (VIDIV, $2^h.30$), Miquel A. Villalonga Vidal (VILMQ, $1^h.36$), Catarina Vitorino (VITCA, $3^h.35$), Marija Vlajic (VLAMA, $2^h.40$), Björn Voß (VOSBJ, $8^h.60$), Maja Vuckovic (VUCMJ, $1^h.17$), Barbara Wilson (WILBA, $5^h.15$), Larry Wood (WOOLA, $1^h.38$), Kim S. Youmans (YOUKI, $3^h.88$), George Zay (ZAYGE, $12^h.08$), and Jin Zhu (ZHUJI, $1^h.75$).

We would also like to thank and encourage all those meteor observers whose reports did not go in the analysis because of insufficient data to continue their efforts in meteor astronomy:

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The list of residence countries of the observers is extensive; however, many of them were not observing from home:

Aruba, Austria, Belgium, Bulgaria, Canada, China, Croatia, Cuba, Czech Republic, Ecuador, Estonia, Finland, Germany, Hungary, India, Iran, Israel, Italy, Japan, Jordan, Korea, Malta, Marocco, the Netherlands, New Zealand, Pakistan, Philippines, Portugal, Russia, Slovakia, Slovenia, South Africa, Spain, UK, Ukraine, USA, Venezuela, and Yugoslavia, with additional observing sites in Cyprus and Mongolia. We would like to acknowledge the great efforts of several amateur groups here, who popularized meteor observations and sent in their results quickly for the analysis, in particular the *Jordanian Astronomical Society* with reporter Mohammad Odeh, the *Israeli Astronomical Association* and Ilan Manulis, the Spanish *Sociedad de Meteoros y Cometas de España* and Luis Bellot Rubio, the *North American Meteor Network* and Mark Davis, and the *Association of Meteor Observers in and around Tokyo Area* from whose internet homepage a number of records were taken; a list which is certainly far from complete and without a ranking by its order. The list of contributors is so impressive, that we can say for sure the 1998 Leonids were the most successful observing campaign ever carried out. Thank you for all the observing reports!

2. Population index profile

As we cannot repeat all the details of the analysis of visual meteor observations here, we refer the reader to [1] and [2] for a thorough description.

The large number of bright meteors, mostly during the night of November 16-17, indicated a small population index r. Indeed, the profile given in Figure 1 shows a broad period of low r-values between solar longitudes $\lambda_\odot = 233\overset{\circ}{.}8$ and $\lambda_\odot = 235\overset{\circ}{.}5$ (November 16, 9^h and November 18, 1^h UT), except for a period of high r-values between $\lambda_\odot = 235\overset{\circ}{.}0$ and $\lambda_\odot = 235\overset{\circ}{.}3$ (November 17, 13^h to 20^h30^m UT). A detailed graph of that period (Figure 2) shows that the population index was almost constant and, compared to the maximum, relatively high with $r = 2.00 \pm 0.05$ for several hours between $\lambda_\odot = 235\overset{\circ}{.}15$ and $\lambda_\odot = 235\overset{\circ}{.}32$ (November 17, 16^h40^m–20^h50^m UT). It will be argued that this part of the activity represents the actual fresh-material component of the Leonid meteoroid stream. The r-value is not extraordinarily high; it is actually comparable to annual major-shower maxima. A real peak in the population index profile may be masked by the bright-meteor component, and the thorough investigation of magnitude distributions can perhaps reveal a two-range structure.

The beginning of the whole activity period is covered by few data; the earliest r-value of 2.4 in the graph was derived from 4 magnitude distributions, and it indicates that the population index resembles values of other major showers off their maximum. The r-value starts to increase quickly after $\lambda_\odot = 235\overset{\circ}{.}3$ ending up at values of about 2.1 on November 19.

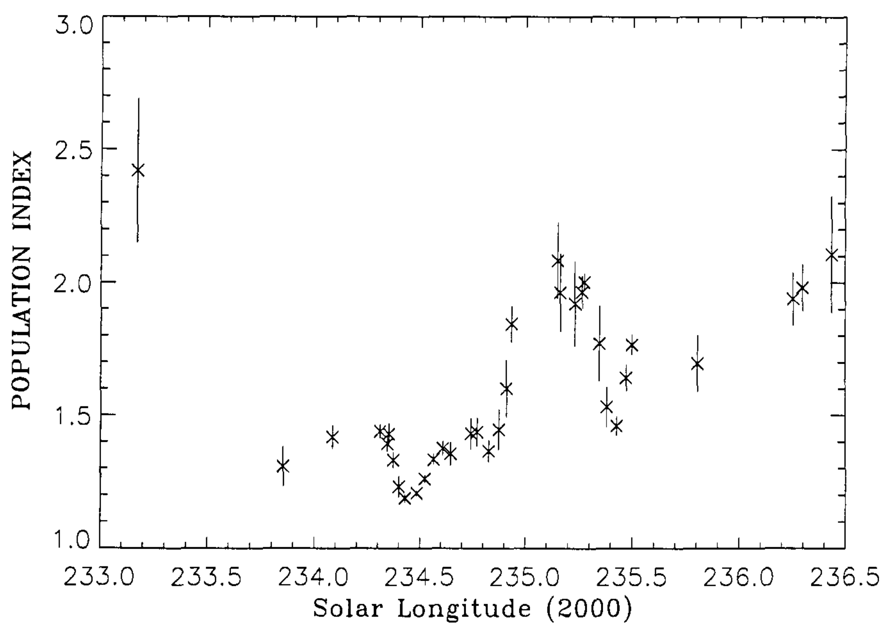

Figure 1 – Population index profile of the 1998 Leonids.

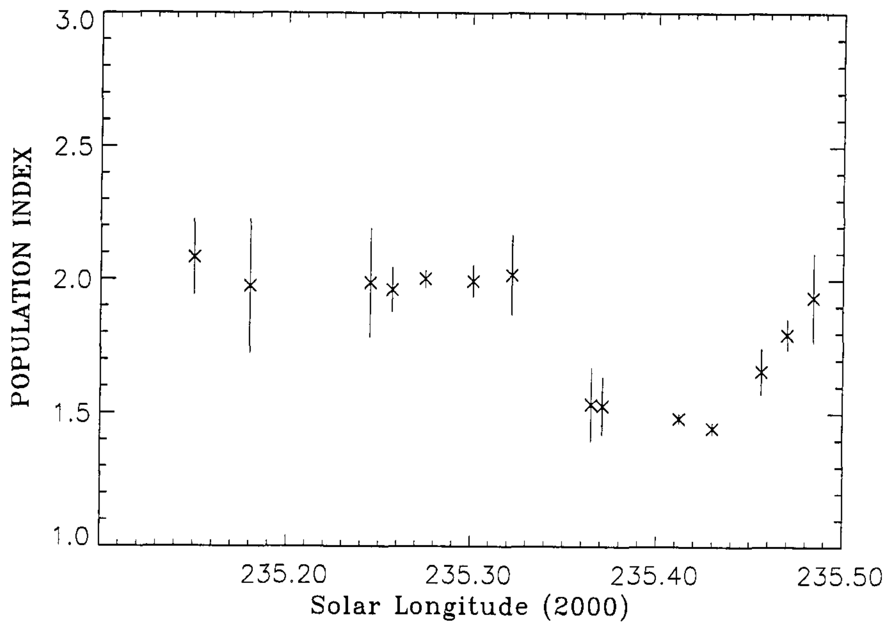

Figure 2 – Small-scale variation of the population index of the 1998 Leonids around the faint-meteor component. The magnitude distributions were binned in 0°05 classes shifted by 0°025.

The lowest r-value of 1.19 ± 0.02 at $\lambda_\odot = 234°43$ (November 16, 23^h30^m UT) coincides quite well with the highest ZHRs observed in 1998 (see below). Such a low population index is very rare, even among major meteor showers. A value of $r = 1.0$ means that no faint meteors are appearing at all. Because of the excitement of the observers and the abundance of meteors, we should bear in mind that the population index as well as the activity are lower limits for the true values. A considerable number of faint meteors may have been missed during the impressive show of fireballs. When operating with r-values, we should not forget that the population index as a power law may not be valid at all for a magnitude range as wide as in the bright-meteor component of the Leonids stream, and r may not be a suitable measure to define the mass distribution within the stream.

3. ZHR-profile

Thanks to the great number of observations reported within the first two weeks after the Leonid maximum, the ZHR profile in Figure 3 looks very smooth, and the error margins at the data points are very small (only observations with radiant elevations over 20° and total correction factor smaller than 5 were taken into account). A very broad component with a maximum centered at $\lambda_\odot = 234°5$ (November 17, 1^h30^m UT) reaches a ZHR of 250 ± 3. This average is lower than reliable values of individual observers; a higher maximum ZHR and reasons for the spread in results are given below. The duration of this activity component is comparable with annual major showers; the full width at half maximum is 0°73 corresponding to about 17 hours or $B \approx 0.8$ in terms of [3]. The profile has almost Gaussian shape between solar longitude 234°0 and 235°0.

First impressions of the Leonid fireball night of November 16-17 gave higher values for the hourly rate. The very low population index is probably the main reason for the ZHR being so much lower. First calculations with a major-shower r-value of 2.0 give rates which are 1.5 times higher at lm = 5.5 than with $r = 1.3$. Again, the activity might be underestimated by some of the observers, since less attention may have been paid to faint meteors under the fireball display. A selection of those observations which report no meteors fainter than magnitude +2 gives no preference to either high-rate or low-rate observers. Video records will tell us more objective numbers, though they will not cover the whole activity period.

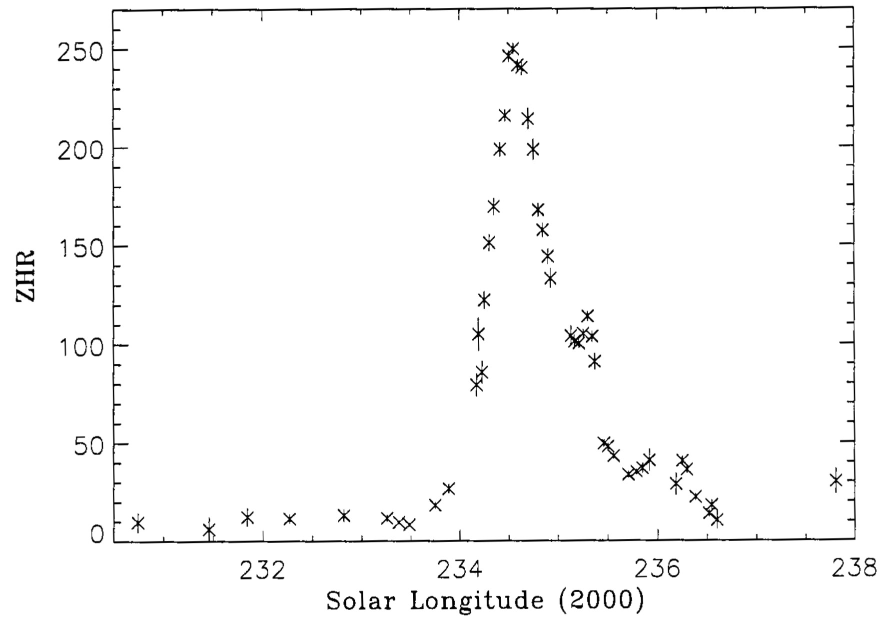

Figure 3 – ZHR profile of the 1998 Leonids. The radiant elevation is corrected for by the geometrical factor $\sin^{-1} h_{\mathrm{R}}$, which may underestimate low-elevation ZHRs. See the details in Figures 4 and 5 and the discussion in the text for final values of a maximum ZHR.

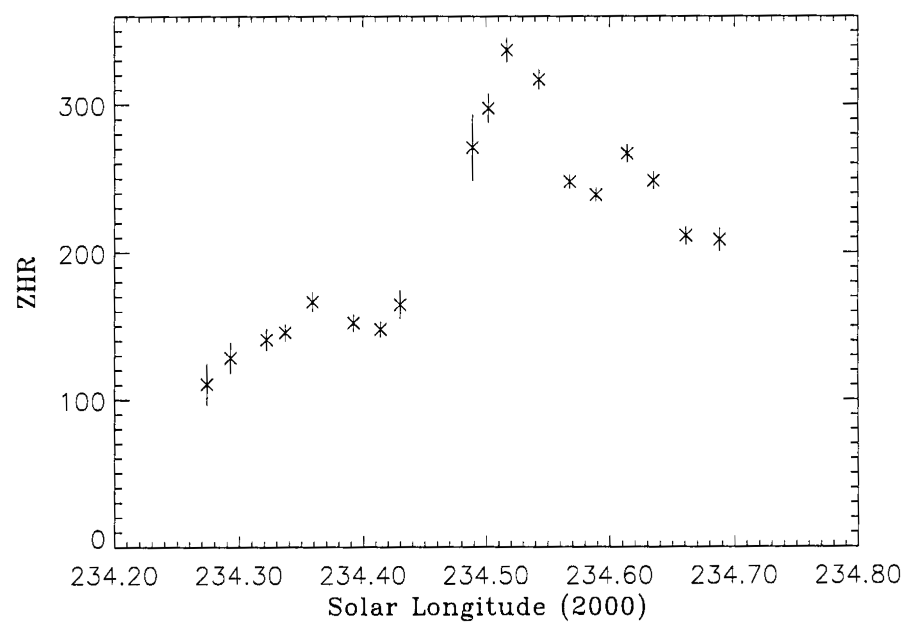

Figure 4 – Small-scale ZHR profile of the 1998 Leonids around the time of highest activity. Only observations with radiant elevation $h_{\mathrm{R}} > 50°$ were used to avoid any influence of non-geometrical zenith corrections. The observations were binned in 0°05 classes shifted by 0°025.

The ZHR may be subject to deviations of the zenithal correction from the geometric value $\sin^{-1} h_{\mathrm{R}}$, with h_{R} being the radiant elevation. A correction factor $\sin^{-\gamma} h_{\mathrm{R}}$, where the so-called zenith exponent γ may have values higher or lower than unity, has been proposed. A general value of $\gamma = 1.4$ was adopted in [3], and a re-calculation of the ZHR profile with a zenithal exponent of $\gamma = 1.4$ shifts the whole graph up with a maximum ZHR near 300, which is simply a consequence of γ increasing the corrections at all elevations.

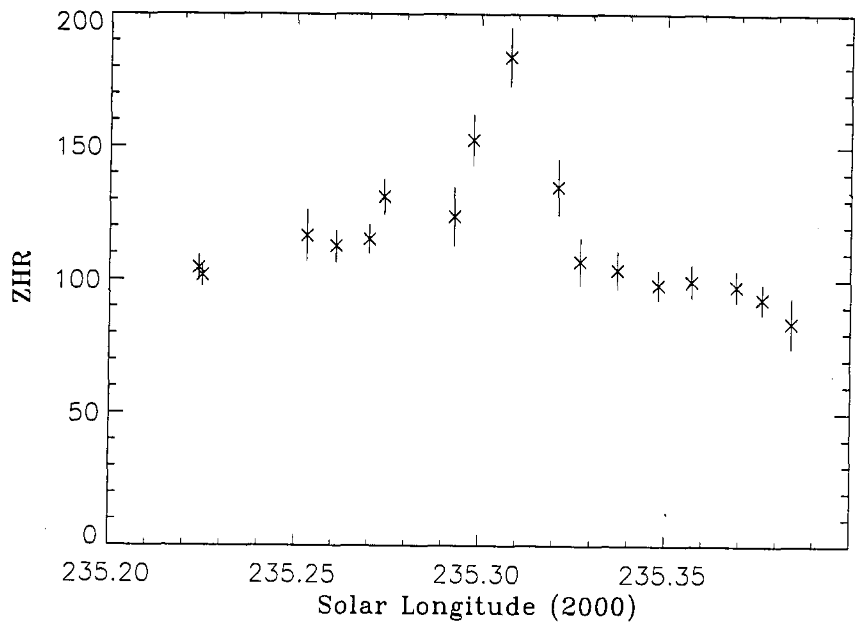

Figure 5 – Small-scale ZHR profile of the 1998 Leonids around the time of storm prediction. Again, only observations with $h_R > 50^\circ$ were used. The observations were binned in $0\overset{\circ}{.}02$ classes shifted by $0\overset{\circ}{.}01$.

An alternative to considering a zenith exponent $\gamma > 1.0$ is restricting the set of rates to those which were obtained with $h_R > 50^\circ$, which are not so much affected by the uncertainty in the zenith correction. The abundance of observations allowed such a restriction. The results of it for the broad component and the "storm" component are given in Figures 4 and 5, respectively.

The ZHRs appear to be significantly higher than the averages for all the rates used in Figure 3, which include those obtained with $20^\circ < h_R \leq 50^\circ$. These indications for $\gamma > 1.0$ contradict the finding in [4] that γ is not larger than unity for the Leonids.

Another difficulty at very low population indices is the change in effective field of view. Usually, about 98% of all observed meteors appear within a field of 105° diameter. This will hardly be true for an abundance of fireballs. Future analyses should scrutinize the influence of a low r on the actual activity measure and on the spatial number density (flux density) in particular.

Despite the clear maximum near $\lambda_\odot = 234\overset{\circ}{.}5$, we should pay attention to the additional activity enhancement, which is close to the prediction for the storm component. This secondary peak was hardly detectable by the observers in the field, but the significant increase of the population index makes the enhancement more prominent. The ZHRs are far below even pessimistic predictions—no meteor storm was observed. Very fine temporal binning of ZHRs in windows of $0\overset{\circ}{.}02$ length (about 30 minutes), shifted by $0\overset{\circ}{.}01$, reveals a short peak at $\lambda_\odot = 235\overset{\circ}{.}308 \pm 0.010$, (November 17, 20^h30^m UT) as shown in Figure 5. The set of observations was restricted to those with $h_R > 50^\circ$ in order to find the actual peak ZHR being less affected by uncertainties related to zenithal correction. Since systematic errors are involved in addition to the statistical uncertainty, we are well advised if we double the errors and fix the sharp peak at ZHR $= 180 \pm 20$. The same rule gives a Leonid maximum of ZHR $= 340 \pm 20$ for the bright-meteor component.

The extremely short period cut out in Figure 5 allows us to subtract a roughly linear decrease of the background component from the ZHR values, such as $\mathrm{ZHR_{back}} \approx 40288 - 170.9\lambda_\odot$. The full width at half maximum of the remaining component is $0\overset{\circ}{.}031$ corresponding to about 45 minutes or $B \approx 20$ in terms of [3] which is quite similar to $B \approx 30$ for the Leonid outbursts in 1866, 1867, 1966, and 1969. A first detection of the short-lived peak in this Leonid epoch (which has produced enhanced activity since 1994) was found in 1996 data in [5] with $B \approx 30$.

The lowest population index of $r = 1.19$ occurred about 0°09 earlier than the ZHR maximum in solar longitude (2.2 hours), which is not exceptionally much, given the broad shape of the background component. The faint-meteor component peaks also at the end of the high population-index period.

4. Spatial number densities

The computation of meteoroid fluxes or, which is the same number divided by the velocity v_∞, the spatial number density of particles in the Leonid stream, runs into difficulties with the method worked out in [1,2]; the principal formula for particles causing meteors brighter than magnitude +6.5 is repeated here:

$$\varrho_{6.5} = \frac{c(r)}{A_{\text{red}}\, v_\infty} \times \text{ZHR}.$$

The factor $c(r)$ is the correction of the observed ZHR to a true ZHR in the observing field, taking into account that the probability to detect meteors of various magnitudes is less than 100%. ZHR measurements have to be reduced to a standard collection area A_{red}, which depends on the population index r and the elevation of the field of view h_{field}. The so-called "reduced area" A_{red} depends only weakly on the field elevation between $r = 2.0$ and $r = 3.5$. The area A_{red} is thus a function of just r in that range. For very low population indices, however, the graphs for different elevations diverge strongly. The reduced area for 50° field height will be 2–3 times higher than for a field in the zenith when using $r = 1.3$ as observed in 1998.

New numerical integrations of the standard collection area

$$A_{\text{red}} = \int\limits_{\text{Field of view}} r^{5 \log \frac{100\text{km}}{d} - \varepsilon}\, \mathrm{d}A$$

were carried out, where d is the distance to the infinitesimal area $\mathrm{d}A$ and ε is the extinction. As in [1], meteors appearing lower then 4° above the horizon are excluded, and the curvature of the Earth is taken into account. An approximate function

$$\varepsilon = 0.002 e^{0.00785 z}$$

was used for the extinction at zenith distance z (here given for z expressed in degrees). A look-up table of $A_{\text{red}}(r, h_{\text{field}})$ was created to compute the flux densities. The function $c(r)$, which corrects the observed ZHR to the true ZHR using the perception probabilities of a human observer, was also re-calculated. The linear function given in [1] is perfectly valid within the usual range of $r = 2$–3. However, for a population index of 1.0—which is an asymptotic lower bound corresponding to the hypothetical situation in which there are only infinitely bright meteors—the factor $c(r)$ should become 1, as no meteors can be missed. A better approximative function is therefore

$$c(r) = 0.987 - 5.918r + 6.637r^2 - 0.7540r^3,$$

which is perfectly valid between $r = 1.1$ and $r = 4.4$.

The flux density profile is given in Figure 6 and exhibits a completely different shape than the ZHR profile. The maximum of the ZHR curve has no equivalent in the flux density graph—at best, a maximum 4 hours later near $\lambda_\odot = 234°7$. A high ZHR made of mostly bright meteors does not mean a high spatial density of particles within the stream, since the observer misses very few meteors due to perception limitations (represented by $c(r)$), and the magnitude loss of meteors at greater distances from the observer is more than compensated by the slow decrease of meteor numbers towards brighter magnitudes, seen in a larger volume (represented by A_{red}).

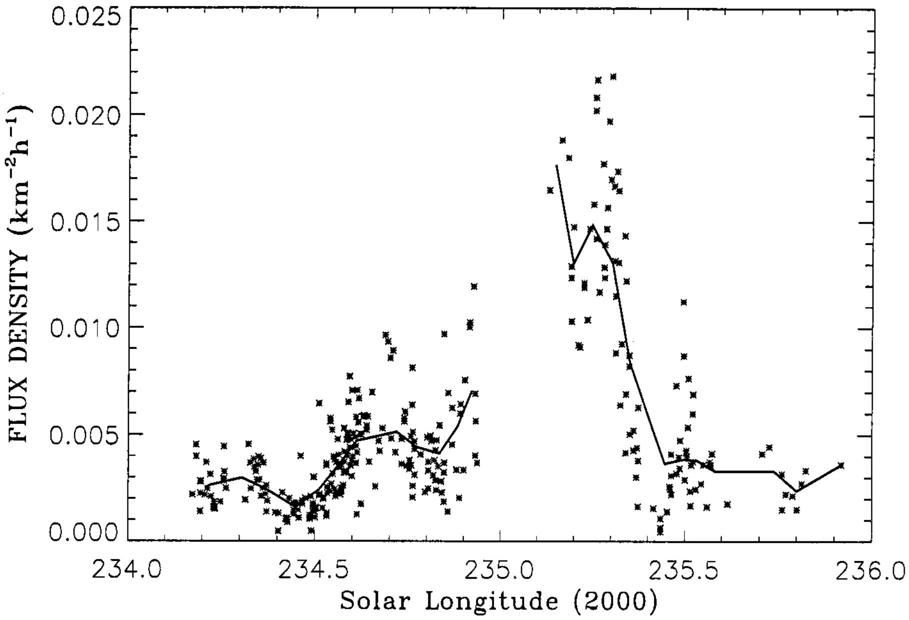

Figure 6 – Flux density profile of the 1998 Leonids. Individual data points of observers giving the center of their field of view are plotted along with an average flux density graph with maximum between $\lambda_\odot = 235.^\circ1$ and $\lambda_\odot = 235.^\circ3$.

The relatively high population index and the activity enhancement at roughly $\lambda_\odot = 235.^\circ3$ reveal the young component of the Leonid stream very distinctly. The flux of about 0.02 particles per km^2 and per hour is higher than that of 1996 with 0.012 km^{-2}h^{-1} as derived in [6,7] and comparable to that of 1997 from [8], the latter being, however, highly uncertain.

It must be emphasized here that only observations which report a center of the field view were used for the spatial number density profile. Otherwise, no accurate collection area determination is possible. The observers are encouraged to care for complete observational reports. The missing fields may just be a matter by the preliminary nature of the reports received, which will be updated soon, for use in more definitive analyses.

5. Discussion

The Leonid activity is characterized by two main components [9]: A storm component consisting of very freshly ejected material, which is no older than two or three cometary revolutions. The particles in this component will cover all sizes from considerable fireball-producers down to tiniest grains of dust. The appearance time of this component can be narrowed down by considering the closest approach of the Earth to the orbit of the comet and can be further improved in accuracy by particle simulations of freshly ejected material. The longitude of this peak has shifted from 1996 with $\lambda_\odot = 235.^\circ17$ [6] and 1997 with $\lambda_\odot = 235.^\circ22$ [8] to 1998 with $\lambda_\odot = 235.^\circ308$ (this study).

The second component is called "the background component" of the stream. The large fraction of bright meteors is a typical feature of such a stream component which has already made several revolutions around the Sun. Gravitational perturbations and solar radiation pressure have affected the motion of smaller particles more than that of large particles, resulting in lower mass and population indices. Since orbital dispersion has taken place for a considerable time, the background component is broad.

The 1998 Leonids are characterized by a strong background component with a maximum ZHR of about 340 centered at $\lambda_\odot = 234.^\circ5$. The "storm component" exhibited a relatively weak enhancement of activity to ZHR $\approx$ 180 at $\lambda_\odot = 235.^\circ308$.

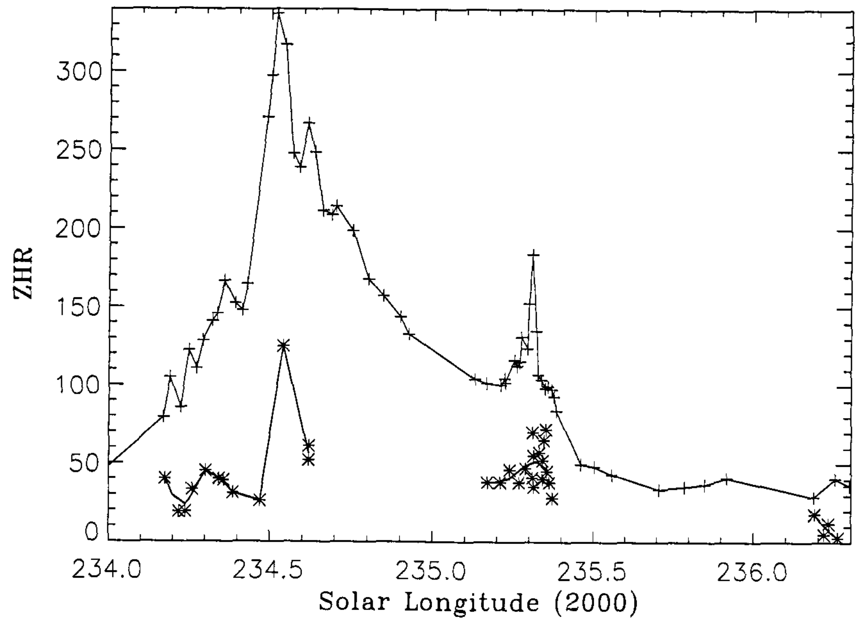

Figure 7 – Comparison between the 1965 and 1998 Leonids from visual observations. The high ZHR value of 125 and those two left and right of it, are estimates from satellite-tracking cameras.

In contrast to popular information spread quickly after the Leonid maximum, astronomers have not miscalculated the Leonid peak, since they all referred to the faint-meteor component observed in 1998, very close to the predicted time.

We should compare the 1998 results with those of 1965. The number of observational data is very small for 1965; a good summary is given in [10], but this mainly covers North-American observations.

The actual ZHRs derived from these records are lower than in 1998; the maximum was probably ZHR $\approx$ 100 near $\lambda_\odot = 234\overset{\circ}{.}5$. The abundance of bright meteors was noted, particularly from sites in Hawaii and Australia. An average magnitude from the (moderate) Leonid number of 38 in three hours was -3 [11].

Radar data from the Springhill device as described in [12] and re-analyzed and compared with radar data from Ondřejov in [13] indicate a very broad maximum at $\lambda_\odot \approx 234\overset{\circ}{.}5$ (November 16, 1965, 15^{h} UT), coinciding exactly with the visual and photographic records. A population index of $r = 1.7$ was derived from the echo-duration distribution (echo durations of more than 1 s). A most interesting feature in the 1965 radar data is a short-lived peak present in both the Springhill and Ondřejov data at $\lambda_\odot = 235\overset{\circ}{.}16$ (November 17, 1965, 6^{h} UT).

The few visual observations of 1965 are compared with the 1998 ZHR profile in Figure 7. The 1965 data are individual values, and there is no global coverage of the profile; the comparison should be treated with care, particularly as the high value of ZHR = 125 was derived from the records of a Baker-Nunn satellite-tracking camera. Nevertheless, the radar, visual, and photographic records of the 1965 Leonids indicate an activity profile which resembles that of the 1998 Leonids.

Even the low population index seems comparable. Judging from these phenomenological facts, we may expect 1999 to show a similar *shape* of activity as in 1966. The actual maximum meteor numbers are hardly predictable.

6. Outlook

The large amount of visual data of the 1998 Leonid meteor shower will allow plenty of further studies on various topics of meteor astronomy, dealing with both the structure of the Leonid meteoroid stream and the development of observing and analysis methods.

Once the complete set of data for the 1998 Leonids is available, it will be worthwhile to study the following:

- the small-scale structure of the faint-meteor peak, including possible two-component magnitude distributions;
- the structure, particularly the flux density, of the background component and its evolution over the last decade, and, in conjunction with this,
- the thorough extension of the flux density theory to population indices as low as the ones derived in this paper;
- the validity of a population index as a power law and the mass distribution in the bright-meteor component;
- the precise influence of the radiant elevation on both the population index and the zenithal hourly rate; and
- the quality of visual observations in comparison with results obtained from video observations.

I would like to encourage all friends of the *IMO* to tackle these items and many more, taking advantage of the data pool gathered.

For sure, the Leonid shower takes us a wide step forward in all aspects of meteor astronomy.

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Successful Leonid Airborne Mission

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We report on a successful effort to explore the 1998 Leonid shower by a team of 28 scientists with a range of instrumental techniques from two airborne platforms flown out of Okinawa, Japan. The Leonid meteors were observed by a two-beam iron lidar, high-definition intensified TV and other imaging techniques and by UV/Visible slit-less spectroscopy and mid- and near-infrared spectroscopic techniques. This paper gives a brief informal report of the 1998 Leonid multi-instrument aircraft campaign just days after the event.

1. Introduction

Meteor observing got a whole new meaning when our wildest dream came true last November. Just in time, all pieces fell in place of what became NASA's first astrobiology mission: a NASA-sponsored effort to fly two aircraft stacked with instruments and eager scientists to explore what promised to be a highly unusual meteoric event [1].

Scientists and crew shared with amateur observers worldwide the excitement of going out to explore one of nature's most impressive natural phenomena: a meteor storm. For that purpose, we brought some unusual instrumentation: the University of Illinois at Urbana-Champaign contributed a two-beam laser-radar called "lidar," and the Aerospace Corporation of California contributed a helium-cooled infrared detector for mid-infrared spectroscopy, to mention a few. The airborne platforms were supposed to bring the scientists to the best place for studying the event, above clouds, water vapor and aerosols, while the two platforms would make stereoscopic observations possible.

The goal of the mission was to learn about comets and how cometary matter interacts with our atmosphere. A meteor storm results from the most recent comet ejecta and the meteoroid orbits and size distribution can provide information about how comets eject large dust grains. Also, if a meteor storm would occur, we would have a window on our past, 4 billion years ago, when Earth just about started to be a cozy place for life, and meteors rained at hundred times the rate at the present time. Any molecule detected in the light of the meteors might provide clues to how meteoroids may have contributed molecules that could have played a role in the origin of life on our planet.

Furthermore, ground-based support would be provided at locations one and two time zones further East, where amateur observers of the *Dutch Meteor Society* teamed up with Chinese astronomers of Nanjing and Beijing Observatories to provide flux measurements and multi-station imaging in case the event happened late in the night. And in Albuquerque, New Mexico, a ground-based lidar would probe meteor trains, if any would occur.

At the time of writing, the mission is just behind us and below is a first informal report of events.

2. The mission

The Leonid Multi-Instrument Aircraft Campaign proceeded according to plan, with both the NSF (NCAR) Lockheed Electra and the US Air Force 452nd Flight Test Squadron KC-135 FISTA executing their mission from Kadena Air Force Base in Okinawa in the night of November 17 (with strong local support at Kadena Air Force Base). Both aircraft were able to fly above the cloud cover that prevented ground-based observations at that time. Twenty-eight scientists on board, 7 nationalities from universities, government, and private institutions, and a total of 46 including crew and media, witnessed an intense shower of Leonid meteors.

The meteors were probed by lidar, imaging, and spectroscopic techniques, covering the UV, visible, near-infrared, and mid-infrared wavelength ranges. All instruments performed as planned and there were no last-minute drop-outs.

The Leonid shower returned with a bang. Numerous bright fireballs were reported in the day and a half leading up to our mission. On mission-date itself, rates had decreased slightly, but an intense shower was observed with ZHRs up to about 200. The shower was rich in faint meteors, unlike the prior night, from which we suspect that we did witness the storm component. Especially in the hour before dawn (20^h–21^h UT) rates picked up somewhat, which is likely the most recent debris that we were hoping to detect.

At the time of writing, only scant information on the scientific results is available. However, the tally of detections is impressive.

Some 30 iron debris trails were detected by lidar, compared to a typical 1–2 trails per night under normal conditions, and excellent HD-TV imaging was obtained in parallel for studies of iron chemistry and physical processes in the train. One of the two lidar beams was tuned off the iron resonance line in order to detect Rayleigh scattering from potential dust. No strong dust signal was detected, as expected, and such a potential detection awaits further data analysis. The University of Illinois all-sky airglow imager recorded numerous trails for flux measurements at the bright meteor end. The intensified cameras mapped the shower flux distribution around the position of the expected storm, and they measured the particle size distribution, which was markedly different from that reported one night earlier. The Mount Allison University intensified cameras recorded many trails at high resolution for studies of meteor ablation and fragmentation properties.

A number of meteors were recorded from both aircraft simultaneously for the measurement of trajectories and orbits. At least one long-lasting persistent train was imaged from both aircraft in high resolution, and turbulent motion was for the first time detected. This train was also studied by the near-infrared spectrographs, and we have good hopes to have obtained the first 1–3 μm spectroscopy of a meteor train from these measurements (and of meteors in general for that matter). The Ames CCD camera recorded six spectra, two of which do show excited atmospheric molecular bands for the study of excitation temperatures in the meteor. Finally, the Czech Ondřejov spectrograph was estimated to have recorded some 50 ultraviolet/visual spectra for main element abundances.

It seems that we achieved some 70% of our science objectives. We were not able to aim the University of East Anglia telescope at a persistent train: none was suitably located, and we do not know yet if the mid-infrared spectrometers were successful. We are also in doubt if we have sufficient numbers of meteors to study the mass dependence of ejection velocities from the flux measurements, but that may still be possible if all video tapes are analyzed. Clearly, a meteor storm would have given much more data for all instruments. In hindsight, we could have obtained significantly more data on persistent trains if we would have had the funds and the opportunity (no curfew and no constraints due to crew rest) to do a mission in the night of November 16.

All in all, we are very happy. We did not see a storm, but we did see one of the best showers ever and we obtained a lot of exciting data. And there is hope for the future. This year's return was almost identical to the return of 1965 when the broad component of bright meteors peaked a little over half a day before nodal passage as it did this year, and a narrow peak of faint meteors was detected just after the time of nodal passage just as in 1965 [2]. This raises hopes that next year will see a return of the storm of 1966 (although perhaps not as intense). Peak activity is expected over Europe and Africa this time.

3. Ground-based efforts

The airborne campaign provided a strong motivation for ground-based observing efforts in China, the United States, and Europe. Several of those ground-based efforts were widely successful, notably a ground-based lidar of the University of Illinois in an effort directed by Dr. Mike Kelly of Cornell University at Kirtland Air Force Base in New Mexico, and the ground-based effort of multi-station photography in China, performed by the *Dutch Meteor Society* in collaboration with the Nanjing Observatory (and Beijing Observatory).

Figure 1 – The science team. From left to right: Sandra Nierman (AFRL), Joe Kristl (AFRL), Hajime Yano (NASA/JSC), Mike Koop (California Meteor Society), Jiři Borovicka (Ondřejov Observatory), Alan Stern (SWRI), Yasumasa Fujii (Kobe University), Chris Riley (BBC), Dave Lynch (Aerospace Corporation), Ryosuke Nakamura (Kobe University), Chet Gardner (University of Illinois at Urbana-Champaign), Weilin Pan (University of Illinois at Urbana-Champaign), Tom Hudson (AFRL), Xinxhao Chu (University of Illinois at Urbana-Champaign), Gary Swenson (University of Illinois at Urbana-Champaign), George Papen (University of Illinois at Urbana-Champaign), Mike Wilson (NASA/Ames Research Center), Beverley Allan (University of East Anglia), Ian Murray (Mount Allison University), and George Rossano (Aerospace Corporation). Not present: Ray Russell and Ted Tessensohn of Aerospace Corporation, the team of the Japanese Broadcasting Company NHK, and the authors. (Photo: Peter Jenniskens.)

Both ground-based teams in China (at Xinglong Station and near Delingha) had clear weather on all important nights and obtained numerous multi-station meteors by two-station photography and intensified video. These meteors are typically brighter than those recorded by the HD-TV cameras on the aircraft and the results are complimentary for an analysis of radiant dispersions as a function of meteoroid mass. In addition, flux information was obtained that complements the counts made by intensified video techniques from the airborne platforms one and two time zones earlier, respectively.

The ground-based effort to probe meteor persistent trains with a sodium lidar from the Starfire range at Kirtland Air Force Base in New Mexico was widely successful. The lidar was pointed at several trains, one of which was probed for 20 minutes, another for 30 minutes. These data on meteor trains nicely compliment the lidar detections of the meteors themselves that were obtained from the Electra aircraft.

We are only beginning to sift through the data. There is clearly plenty of material for our post-mission Leonid workshop, tentatively scheduled for April 12–15 at NASA/Ames Research Center, and we have no doubt that some exciting new insight will emerge in the coming months when the data reduction is performed. At this moment, we all need some rest, pay the bills, and gloat over the images!

Acknowledgments

Many people contributed to the success of this mission. SETI Institute researchers initiated the campaign and the Institute provided strong logistic support. The NASA Headquarters' Programs for Planetary Astronomy, Exobiology, and Astrobiology and NASA Ames Research Center provided most of the necessary funds, with contributions and material/manpower support from the US Air Force, the Air Force Office of Scientific Research - Asian Office, and the National Science Foundation. The participating scientists were from all realms: universities, government agencies and private institutions. Many were from the United States, but participating were also researchers from Canada, Japan, the United Kingdom, the Netherlands, and the Czech Republic. The two aircraft and much of the logistic support were provided by the National Science Foundation (NSF) and the US Air Force. The aircraft were operated by the National Center for Atmospheric Research (NCAR) Research Aviation Facility in Broomfield, Colorado, and the United States Air Force 452nd Flight Test Squadron at Edwards Air Force Base in California. The mission was flown out of Okinawa, Japan, with strong support from Kadena Air Force Base. The Japanese Broadcasting Company provided intensified high-definition TV imaging of the meteors from both platforms and, together with a team of NASA/Ames Research Center, informed the world about our activities. Thank you all.

For first results and next year's mission, see `http://www-space.arc.nasa.gov/~leonid`.

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Can We See the Radiant Glow of the Leonids?

Vladimir Lukić

Simple arguments are given implying that the radiant glow of the Leonids cannot be observed by standard meteor observing techniques.

Every time when we expect storm-like activity of a meteor shower, the question of the possibility of observing the glow of the meteor stream (comparable to the zodiacal light) is raised [1]. Here, I shall give an estimate of the magnitude of the radiant glow of the Leonid meteor shower close to its maximum. I will derive the result without referring to elaborate models of meteor streams, and in a way that can be easily modified and applied to other meteor streams.

We start from the basic astrometric formula

$$m_{\rm S} - m_{\rm glow} = 2.5 \log \frac{\sum_{\rm p} I_{\rm p}/r_{\rm Ep}^2}{I_{\rm S}/r_{\rm SE}^2}\,, \tag{1}$$

where $m_{\rm S}$ is the magnitude of the Sun, $m_{\rm glow}$ the magnitude of the glow of the meteoroids due to the reflection of solar radiation, $I_{\rm S}$ is the intensity of the Sun, $I_{\rm p}$ the intensity of the reflection of solar radiation by a *single* meteoroid particle, $r_{\rm SE}$ is the distance Sun-Earth, and $r_{\rm Ep}$ is the distance between the Earth and the meteoroid under consideration; the sum goes over all the meteoroids concerned. The fraction of solar radiation reflected by a single meteoroid particle can be computed from

$$I_{\rm p} = \frac{S_{\rm p}}{4\pi r_{\rm Sp}^2} k A I_{\rm S}\,, \tag{2}$$

where $S_{\rm p}$ is the cross-section area of the meteoroid, $r_{\rm Sp}$ is the distance between the Sun and the meteoroid under consideration, k is the illuminated fraction of the meteoroid "disk" as seen from Earth, and A is the albedo. Thus, substituting (2) in (1),

$$m_{\rm S} - m_{\rm glow} = 2.5 \log \left(\frac{kAr_{\rm SE}^2}{4\pi} \sum_{\rm p} \frac{S_{\rm p}}{r_{\rm Sp}^2 r_{\rm Ep}^2} \right) . \tag{3}$$

Let us now consider the total cross-section area S_V of all the meteoroids reflecting sunlight in some arbitrary volume V. These are the particles of diameter $d > 1\mu$m, which I take to correspond to the magnitude +10 meteors. Denoting by N_m the number of meteoroids in volume V that would produce meteors of magnitude m, and by S_m the surface area of such a meteoroid, we have

$$S_V = \sum_{m=-\infty}^{+10} N_m S_m \approx \sum_{m=-5}^{+10} N_0 r^m S_m . \tag{4}$$

I have cut off the sum at magnitude −5, as statistics begin to fail for brighter meteors, and the number of meteors drops rapidly [2]. I have also used the approximate relation between the numbers of meteors in two magnitude classes through the population index r: $N_{m_1}/N_{m_2} \approx r^{m_1 - m_2}$.

To find the relation between S_m and quantities known from meteor observations, we turn to the single-body theory [3], which states that the intensity of the radiation of a *meteor* is directly proportional to the cross-section area of the meteoroid. On the other hand, the magnitude of a meteor is directly proportional to the negative logarithm of the intensity of its radiation. Combining the two, we obtain

$$\frac{S_{m_1}}{S_{m_2}} = 10^{0.4(m_2 - m_1)} . \tag{5}$$

Using equation (5), we can rewrite equation (4) in terms of meteoroids producing magnitude 0 meteors:

$$S_V = \sum_{m=-5}^{10} N_0 S_0 \left(\frac{r}{10^{0.4}} \right)^m . \tag{6}$$

Since $r \approx 2.4$ for regular Leonids, and $10^{0.4} \approx 2.512$, we shall approximate $r/10^{0.4} \approx 1$. The resulting error in the magnitude of the radiant glow should not exceed one magnitude for any reasonable variations of r that are likely to occur during the storm. After applying the approximation to equation (6), we obtain

$$S_V = \sum_{m=-5}^{10} N_0 S_0 = 16 N_0 S_0 . \tag{7}$$

Thus, the total cross-section area of the meteoroids capable of producing meteors of magnitude m is *independent* of m! This is not essential, but leads to the nice, explicit formula above.

In order to be able to substitute the above result in the radiant glow magnitude equation (3), we first have to rewrite that formula. Thereto, we slice up to volume V in slices of thickness Δr which are orthogonal to the direction of the radiant glow. Since it is reasonable to assume that the cross sections of these slices are fairly small, we may assume that all the meteoroids in a single slice do not only have the same distance to the Earth, but also the Sun. We may therefore group together in equation (3) all meteoroids belonging to the same slice, yielding

$$m_{\rm S} - m_{\rm glow} = 2.5 \log \left(\frac{kAr_{\rm SE}^2}{4\pi} \sum_{i} \frac{S_i}{r_{{\rm S}i}^2 r_{{\rm E}i}^2} \right) , \tag{8}$$

where S_i is the total cross-section area of all the meteoroids reflecting sunlight in the ith slice, r_{Si} is the distance between the Sun and the ith slice, and r_{Ei} is the distance between the Earth and the ith slice.

If we assume that the meteoroids are more or less uniformly distributed over the volume V under consideration, and we denote by V_i the volume of the ith slice, $i = 1, 2, 3, \ldots$, we obtain, using equation (7), that

$$S_i = S_V \frac{V_i}{V} = 16 N_0 S_0 \frac{V_i}{V} = 16 n_0 S_0 V_i \,, \tag{9}$$

where n_0 is the number density of magnitude 0 particles. Substituting (9) in (8), we obtain

$$m_S - m_{\text{glow}} = 2.5 \log \left(\frac{4kAn_0 S_0 r_{SE}^2}{\pi} \sum_i \frac{V_i}{r_{Si}^2 r_{Ei}^2} \right) . \tag{10}$$

We are now going to examine the volume we are interested in.

Naturally, we are looking through a cylindrical tube containing the highest density of meteoroids. Knowing that the major axis of the orbit of the meteoroids is about 15 AU, the estimated duration of the maximum is at most a few hours, and the distance from the comet's node to the Earth is 0.008 AU, and taking into account the geometry of the intersection (almost head-on impact with the Earth) [4], it follows that the diameter of the high-density "tube" is at most of order $d = 2 \times 10^6$ km. Since this tube is wrapped around the (elliptical) orbit of the Leonids, the (straight) view-line through the high-density tube cannot be greater than 2 AU. Both values derived are safe upper bounds; the real values are probably much smaller.

Now, suppose we want to estimate the total magnitude of the glow coming from the $\theta = 1°$ diameter area around the densest region of the stream. Since equation (10) requires the meteoroids to be more or less uniformly distributed over the volume under consideration, this volume must be partly conical and partly cylindrical, as shown in Figure 1.

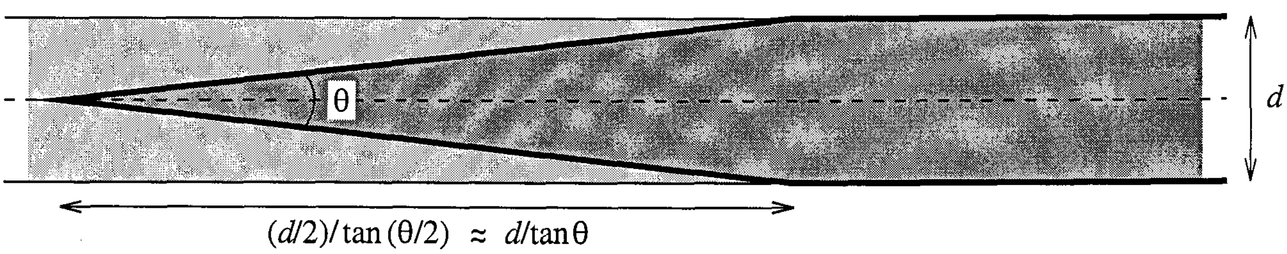

Figure 1 – Volume under consideration in equation (10).

Hence, the ith slice can be approximated by a cylinder with height Δr and a radius which depends on whether the slice is in the conical or the cylindrical part of the volume under consideration:

$$\text{radius}_i = \begin{cases} r_{Ei} \tan \frac{\theta}{2} & \text{if } r_{Ei} \le d/\tan\theta; \\ \frac{d}{2} & \text{if } r_{Ei} > d/\tan\theta. \end{cases}$$

Consequently, the volume of the ith slice is given by

$$V_i = \begin{cases} \pi (r_{Ei} \tan \frac{\theta}{2})^2 \Delta r \approx \frac{1}{4} \pi r_{Ei}^2 \Delta r \tan^2\theta & \text{if } r_{Ei} \le d/\tan\theta; \\ \pi (d/2)^2 \Delta r = \frac{1}{4} \pi d^2 \Delta r & \text{if } r_{Ei} > d/\tan\theta. \end{cases} \tag{11}$$

Taking into account the geometry of the impact, it is reasonable to approximate

$$r_{\mathrm{S}i}^2 = r_{\mathrm{SE}}^2 + r_{\mathrm{E}i}^2 \,. \tag{12}$$

Substituting (11) and (12) in (10), and going to the continuum limit (Δr infinitesimally small), and starting integration from $r = 0$ (say that we are watching from just above the atmosphere), we obtain

$$m_{\mathrm{S}} - m_{\mathrm{glow}} = 2.5 \log \left[kAn_0 S_0 r_{\mathrm{SE}}^2 \left(\tan^2\theta \int_0^{\frac{d}{\tan\theta}} \frac{dr}{r_{\mathrm{SE}}^2 + r^2} + d^2 \int_{\frac{d}{\tan\theta}}^{2\ \mathrm{AU}} \frac{dr}{r^2 (r_{\mathrm{SE}}^2 + r^2)} \right) \right] . \tag{13}$$

The second term in equation (13) is negligible compared to the first (and, therefore, the assumed length of our view-line through the high-density tube will have no effect on our final result), yielding

$$\begin{aligned} m_{\mathrm{S}} - m_{\mathrm{glow}} &= 2.5 \log \left(kAn_0 S_0 r_{\mathrm{SE}}^2 \tan^2\theta \int_0^{\frac{d}{\tan\theta}} \frac{dr}{r_{\mathrm{SE}}^2 + r^2} \right) \\ &= 2.5 \log \left[kAn_0 S_0 r_{\mathrm{SE}} \tan^2\theta \arctan \left(\frac{d}{r_{\mathrm{SE}} \tan\theta} \right) \right] . \end{aligned} \tag{14}$$

(Within a reasonable error margin of about 15%, the right-hand side of the above equation can be further simplified to $2.5 \log(kAn_0 S_0 d\theta)$, θ expressed in rad.) Assuming that very-high-density regions producing storms such as the one in 1966 are not present in the significant portion of the relevant volume, a ZHR of 10 000 yields a number density of meteoroids producing meteors of magnitude 6.5 or brighter of $\rho_{6.5} \approx 10^{-6}$ km^{-3}, from which we derive $n_0 \approx 0.005 \times 10^{-6}$ km^{-3} [5]. Standard estimates for the other quantities in the right-hand side of equation (14) are $k = 0.5$ (taken into account the impact geometry) $A = 0.3$, $S_0 = 0.5$ cm^2 $= 0.5 \times 10^{-10}$ km^2, and $r_{\mathrm{SE}} = 150 \times 10^6$ km. From $m_{\mathrm{S}} = -26.7$, we finally obtain

$$m_{\mathrm{glow}} \approx +10. \tag{15}$$

The answer to the question posed in the title is obvious: *no, we cannot see the radiant glow*! A diffuse object of total magnitude +10 spread out over approximately 1 square degree is inaccessible to regular meteor observing techniques (optimized to record meteors). However, such an object may be accessible to appropriate photographic/CCD equipment. In this respect, it should be noted that several quantities were estimated in a very optimistic way to maximize the radiant glow. Thus, equation (15) gives only a lower bound for the magnitude of the radiant glow (i.e., an upper bound for its brightness). The actual brightness of the magnitude glow may be several magnitudes weaker. Even if we stretch our optimism to the limit by increasing the particle density of the *entire* volume under consideration to a level corresponding to a storm ZHR of 150 000, a highly unrealistic assumption, we only gain a couple of magnitudes, without changing the overall conclusion.

Finally, do not forget, when trying to observe radiant glow, to search for it in the *heliocentric* (and not the geocentric) radiant of the stream.

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Draconids

Summary of 1998 Draconid Outburst Observations

Rainer Arlt

The observations of the 1998 Draconids are summarized based on the reports of visual and radio observers. Regular observations of 87 observers, who recorded 1920 Draconids in 190 observing hours, were collected. The peak time was found to be at $\lambda_\odot = 195\overset{\circ}{.}075 \pm 0\overset{\circ}{.}010$ (October 8, 1998, $13^{\rm h}10^{\rm m} \pm 15^{\rm m}$ UT) with ZHR $= 720 \pm 90$. The population index of $r \approx 3.0$ is higher than for many annual major meteor showers; no clear r-profile could be derived. The outburst occurred about 8 hours before the nodal longitude of the comet, 4 hours more than in 1985. The order of magnitude of the maximum activity as well as the high population index make the 1998 outburst comparable to that of 1985.

1. Introduction

Thanks to the calls for observations in [1] and [2], a great number of meteor observers were out for the maximum of the October Draconid shower and performed visual, radio, and video observations. The meteoroid stream originates from the periodic comet 21P/Giacobini-Zinner with a revolution period of 6.6 years. Every 13 years, the comet is close to its perihelion when the Earth passes the Draconid meteoroid stream. Expectations were high for 1998 after the Draconid outburst in 1985.

Strong meteor activity outbursts occurred in 1933 and 1946, and, compared with these, moderate activity was seen in 1952, 1985, and 1998. This year's observing conditions were far from ideal with a Full Moon on October 5. Only about the first hour after dusk was free from lunar disturbance.

A strong narrow outburst of Draconid activity was witnessed by Asian visual meteor observers and a number of forward-scatter radio observers in Japan and Europe. Many of the results were quickly distributed on the *IMO News* mailing list. We are very grateful to the following observers who sent in regular meteor observations:

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2. The 1998 Draconid outburst in detail

The peak time of the Draconid activity is not well covered by magnitude distributions; after the peak, European observations are numerous, but the actual numbers are small. A few population indices are shown in Figure 1, but no clear profile is visible; note that the activity peak is at the left edge of the graph. It is nevertheless evident that the population index is significantly higher than that of annual major-shower maxima like the Perseids or η-Aquarids with r going down to about 2.0 during their maximum. For further activity calculations, a typical population index of $r = 3.0$ was used.

The peak of the Draconids is so sharp that we apply a logarithmic scale for the graph in Figure 2. Because of the strong disturbance by the Moon, the selection criterion for the ZHR averages was set to a total correction of 10 instead of 5 as in many other analyses. The mean radiant elevation in an observing period had to exceed 20°. The radiant elevation h_R was corrected for by the geometrical factor $\sin^{-1} h_R$.

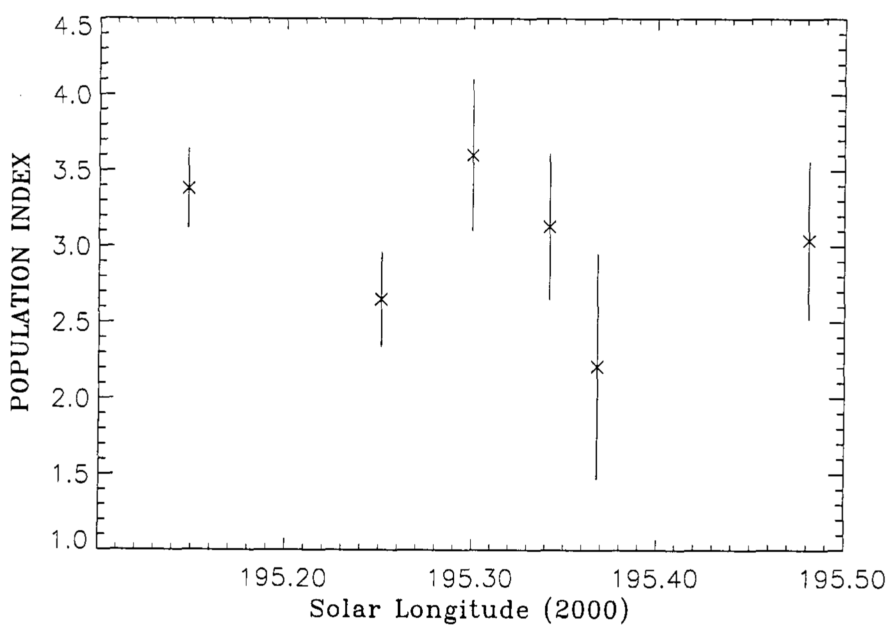

Figure 1 – The population index of the 1998 Draconids, derived from 38 magnitude distributions. Since the error bars are large and no clear profile is found, a population index of $r = 3.0$ was used for activity calculations.

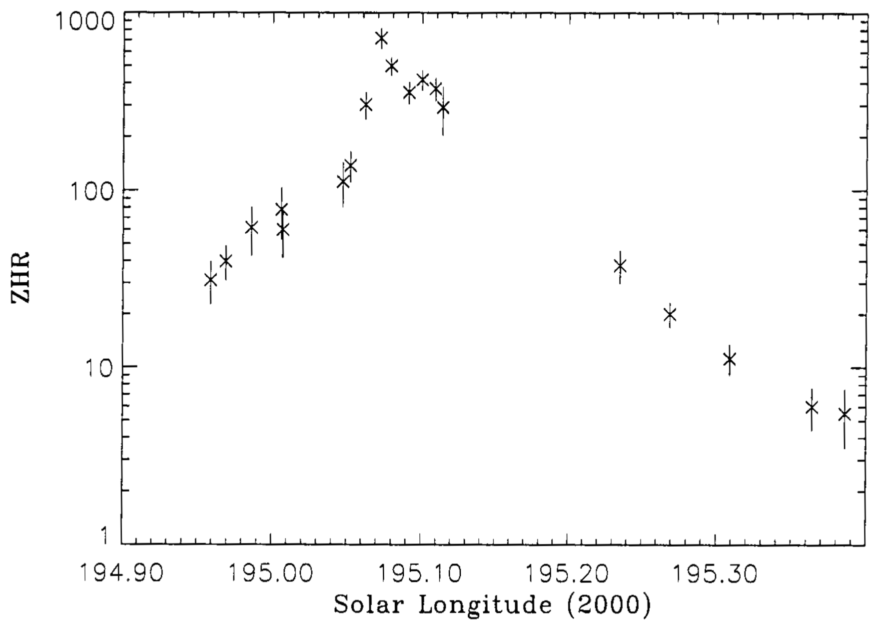

Figure 2 – The ZHR profile of the 1998 Draconid maximum in logarithmic scale. The data between $\lambda_\odot = 195\overset{\circ}{.}00$ and $\lambda_\odot = 195\overset{\circ}{.}15$ were binned in $0\overset{\circ}{.}02$ classes shifted by $0\overset{\circ}{.}01$.

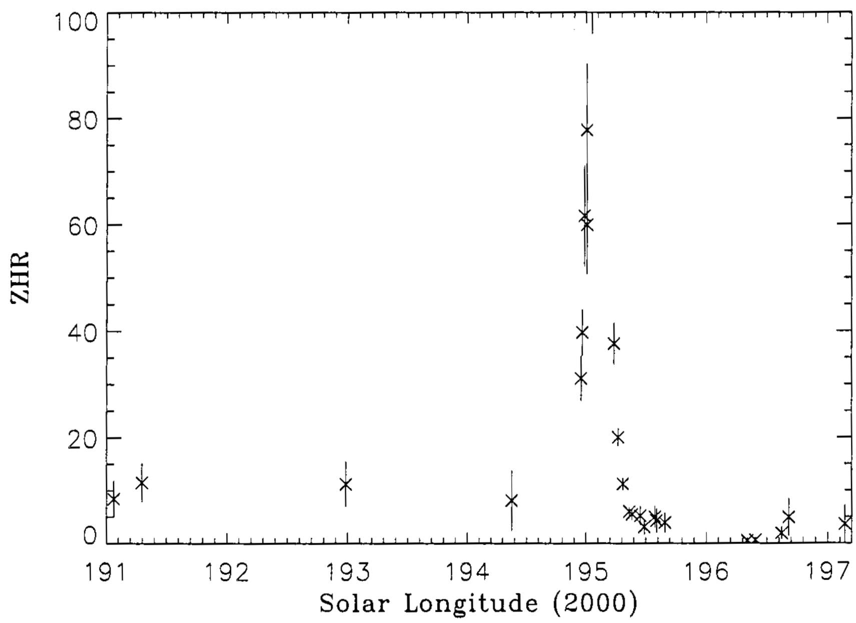

Figure 3 – The lower part of the 1998 Draconid activity in linear scale.

The averages near the peak are based on only 4–6 observing periods, and the peak time and activity may be subject to systematic effects not being averaged out statistically. However, I wanted to make the averaging bins as small as possible not to smear out the stream structure. We may narrow down the peak time to $\lambda_\odot = 195\overset{\circ}{.}075 \pm 0.010$ (October 8, 1998, $13^{\text{h}}10^{\text{m}} \pm 15^{\text{m}}$ UT); the highest activity is ZHR = 720 ± 90. The full width at half maximum is about $0\overset{\circ}{.}045$ or 65 minutes. If we derive values for B as in [3] from the slopes in Figure 2, we find $B = 8$ for the descending branch, but run into difficulties at the ascending branch, which is all but linear in the logarithmic graph. A rough estimate gives $B = 11$ for the pre-peak curve. At least, we can state that the Draconid outburst ZHR graph is not as steep as the narrow outburst component of the Leonids and comparable to what was found in [3] for the 1985 Draconids.

A cut-out of Draconid activity below ZHR = 100 is given in Figure 3. Considerable activity of ZHR = 5–10 is reported several days before and after the Draconid peak. Full-Moon interference, sporadic pollution, significant for high-elevation radiants, and failure to take into account the strong limitations to angular meteor speeds, imposed by the very slow entry velocity of the Draconids, upon doing shower association, may have contributed to these high values.

Counts of radio observations published on the *IMO News* mailing list are shown in Figure 4; they are uncorrected hourly rates, except for the data from Ton Schoenmaker, which were corrected for sporadic background using the echo rates of October 10. These forward-scatter data perfectly match the visual data with regard to the peak time of October 8, 13^h10^m UT. Miloš Šimek reported that a first look at Ondřejov radar data yielded highest rates near 13^h30^m UT.

A comparison with the 1985 Draconid outburst near $\lambda_\odot = 195\overset{\circ}{.}25$ [6] led to a predicted peak on October 8, around 17^h30^m UT [1], 3–4 hours before the nodal longitude. The outburst occurred another 4 hours earlier, but with similar strength as in 1985. The actual ZHRs of about 700 in 1998 are somewhat higher than the 1985 ZHRs one would obtain with the same parameters ($r = 3.0$ and a geometrical correction $\sin^{-1} h_R$ for the radiant elevation h_R). According to the detailed report about observations of the *Nippon Meteor Society* in [4] and the summary and analysis in [5], we get a maximum ZHR of 300–500. Also the population index turned out to be near $r = 3.0$ in 1985.

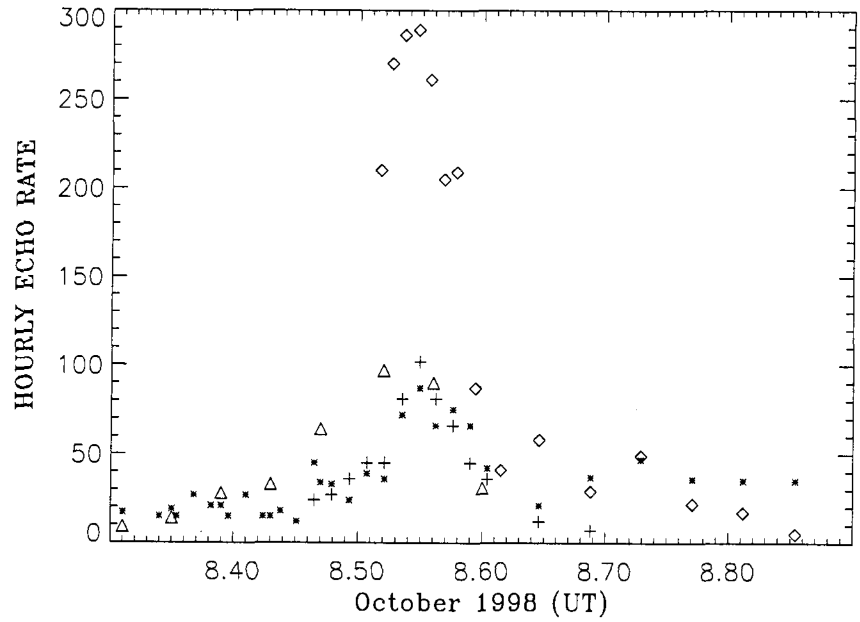

Figure 4 – Hourly radio counts during the Draconid outburst as reported by Eisse Pieter Bus (△), Ton Schoenmaker (⋄), and Kazuhiro Suzuki (∗, transmitter of K. Maegawa; +, Miyazaki Univ. transmitter). Counts of October 10 were subtracted from the data of Schoenmaker to account for the sporadic background.

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Giacobinids Returned in the Japanese Sky: Video and Photographic Observations

Masahiro Koseki, Kaoru Teranishi, Junpei Shiba, and Yusuke Sekiguchi

The Giacobinids had an outburst on October 8, 1998, at 13^h10^m UT and reached video rates of about five per minute. This is about the same rate as seen by visual observers. The Giacobinids are rich in faint meteors when compared with other major streams, and their meteoroids are fragile.

1. Introduction

The *Nippon Meteor Society* (*NMS*) has been preparing the Giacobinid campaign for a year. Finally, the Giacobinids returned in the Japanese sky after the memorable 1985 display and the sky conditions were very fortunate for Japanese observers, except for the Moon.

The *Niijima Gakuen High School Astronomical Club* (*NGHAC*) observed the Giacobinids at the NGH Astronomical Observatory by using two image intensifiers (IIs) and three cameras with a rotating shutter. The observations already started at 18^h40^m JST (i.e., 9^h40^m UT), since, in 1985, the outburst preceded the predicted time of maximum by about four hours.

2. Observations

Video

We used two II sets, summarized below, one of which was oriented towards the zenith and the other towards the celestial north pole.

Camera lens: Nikon, $f = 28$ mm, $f/2.8$
II: C-3100 (Hamamatsu); mean gain=6×10^4
CCD: C-3077 (Hamamatsu)
Processor: DVS-3000 (Hamamatsu)
Limiting magnitude: 6.5–5.5
Field: $21° \times 32°$

Each set of observations spanned about 6 hours, although interrupted by clouds occasionally.

It is very difficult to search all tapes just by the "naked eye;" actually, this would "degrade" the video observations to visual observations "on tape." Here, meteor trails were detected by the DVS-3000 (Hamamatsu Photonics), which is a small computer system for CCD observations. It has a useful function for meteor observations, that is, showing the maximum brightness of each pixel during free time.

When a point or a trail brighter than background noises appears and moves, it could draw a path like a meteor photograph (see Figure 1). It is possible to detect faint meteors more easily than with the "naked eye," and the system is very effective for searching a slow-moving object. We think that a perception coefficient is not necessary for video meteors about 1.5 to 2.0 magnitudes brighter than the limiting magnitude.

The results of the video observations of the Giacobinids are shown in Table 1 and Figure 2.

Photo

Three cameras had $f = 50$ mm, $f/1.4$ lenses with a rotating shutter (1:1) which made it possible to expose for longer times in spite of the interference of the Moon. We used a rather high rotating speed of 50 cycles per second because we did not intend to calculate the meteoroids' orbits. We obtained 3 Giacobinids during a total exposure of 213 minutes. This is a small number for an outburst, and is due to cloud obstruction. Trails could not be cut, indicating that Giacobinids have a short-lived train and that their meteoroids are fragile.

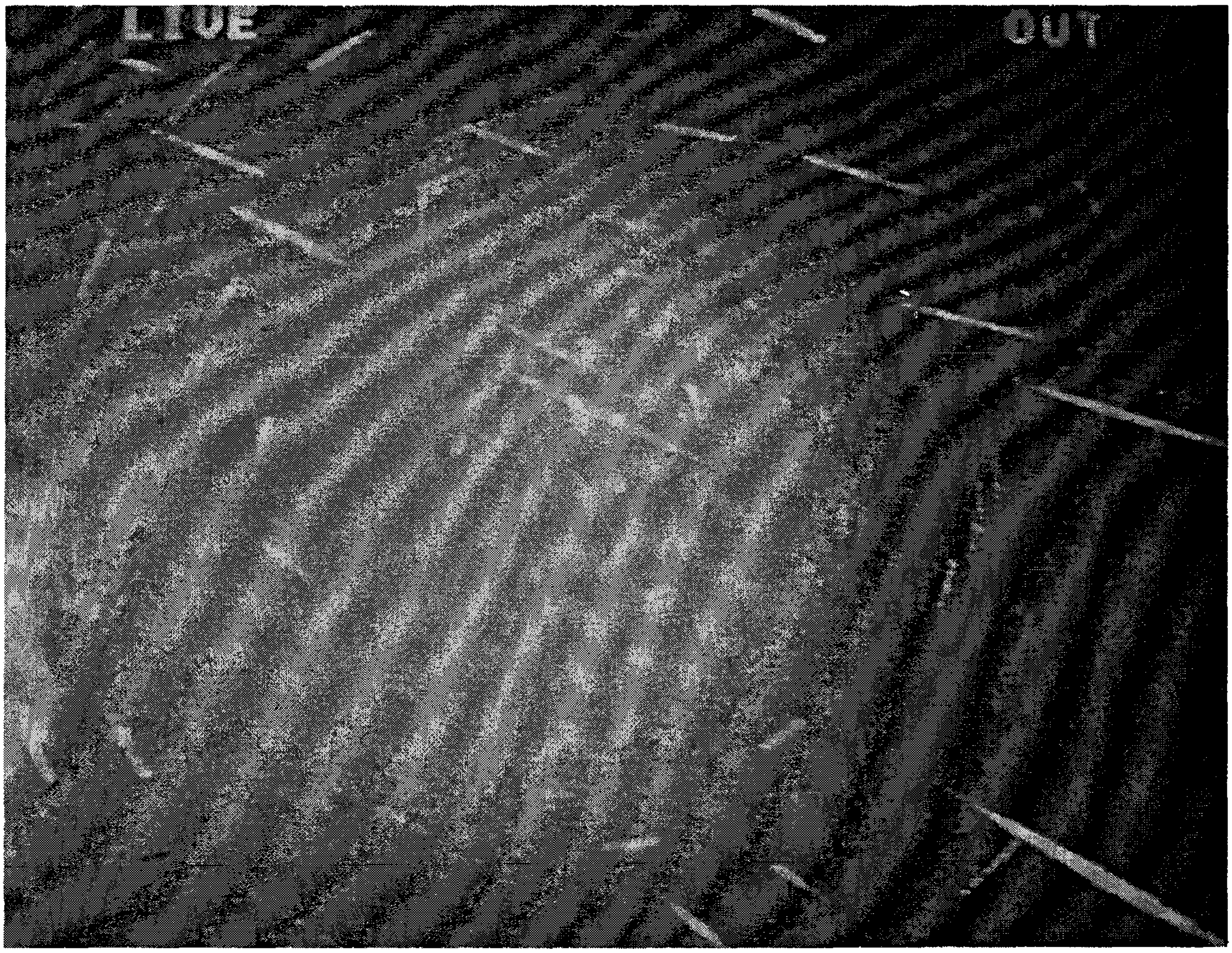

Figure 1 – Composite image of video Giacobinids of magnitude +4 and brighter, just before the maximum. The brightest Giacobinids in this 30-minute composite image is in the lower right corner and has magnitude −2. The bright star in the center is Polaris.

3. Magnitude distribution and activity

Although the sporadics are contaminated by shower meteors, for example, Piscids, we can say that the Giacobinids are definitely richer in faint meteors than the Perseids. Koseki observed the Perseids [1] and Orionids [2] in 1993 with the same video system, and obtained the magnitude distributions shown in Tables 2 and 3. It seems that the 1998 Giacobinids are slightly richer in brighter meteors (i.e, have a lower population index) than the 1985 Giacobinids ($r = 3.26$, [3]).

Table 1 – Magnitude distribution of the 1998 Giacobinids on October 8-9.

Magnitude	−2	−1	0	+1	+2	+3	+4	+5	+6	Tot	$\overline{m}$
Giacobinids	2	1	1	5	14	29	49	51	23	175	4.02
Sporadics					4	8	9	29	5	46	4.30

Table 2 – Magnitude distribution of the 1993 Perseids on August 12-13.

Magnitude	−6	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	+6	Tot	$\overline{m}$
Perseids	1		2	1	2	1	5	12	29	16	28	50	23	170	3.51
Sporadics			1						2	6	11	16	8	44	4.32

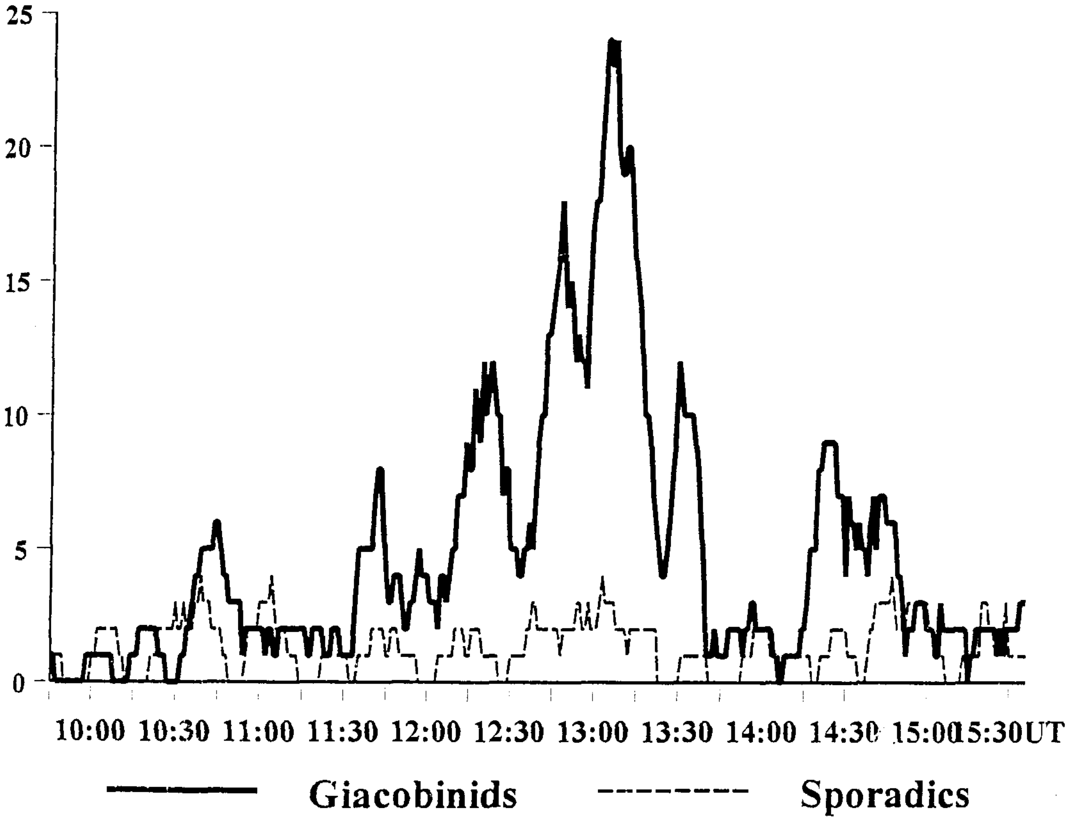

Figure 2 – Sliding mean of ten-minute video rates for the 1998 Giacobinids. The deep dip between 13^h10^m UT and 14^h10^m is caused by obstruction from clouds.

Table 3 – Magnitude distribution of the 1993 Orionids on October 24-25.

Magnitude	−2	−1	0	+1	+2	+3	+4	+5	+6	Tot	$\overline{m}$
Orionids	2	1		1	2	4	4	18	13	45	4.36
Sporadics	1			1	3	6	8	20	12	51	4.45

We must note, however, that magnitude estimates for meteors cannot be compared directly to visual ones because the angular velocity and the II's infrared sensitivity affect the estimates. Also, the Moon wiped out faint meteors in this case.

It is clearly shown in Figure 2 that the 1998 Giacobinids reach their maximum around 13^h10^m UT although we could not trace the decline of the activity, but it is clear that the outburst was short. It is most likely that the visually observed rates reached 300 at their maximum, because rates per minute for our video system are comparable with the visual counts [1]. This suggests the ZHR might have reached 1000. Mameta, the standard observer in the 1985 Giacobinid report [3], informed the *NMS* mailing list that the Giacobinids were richer in 1998 than in 1985.

4. Conclusion

A Giacobinid outburst re-occurred in 1998, with an activity comparable to that of the 1985 outburst, although the current display was slightly richer and brighter.

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June Bootids

June Bootid Outburst: Optical Observations from Japan

Takema Hashimoto and Kazuhiro Osada

Kazuhiro Osada and Ryuji Shimoji observed an outburst of the June Bootids ("Pons-Winneckids") on June 27, 1998. High activity continued for about 9 hours (10^h15^m–19^h00^m UT), and the maximum occurred around 12^h30^m UT ($\lambda_\odot = 95.^\circ693$). The ZHR reached 270 at the maximum and the shower was rich in faint meteors, with a population index $r = 3.1$. Most meteors were yellowish and slow with a short path, though brighter meteors left a short-living train. The members of the *Nippon Meteor Society* did follow-up observations and detected activity till July 2. The apparent radiant position was found at $\alpha = 221^\circ$ and $\delta = +51^\circ$ ($\lambda_\odot = 95.^\circ663$, J2000), and the outburst is most likely a repetition of the 1916 outburst.

1. Introduction

A meteor outburst occurred in June 1998, and two fortunate Japanese observers witnessed it, despite the mostly rainy season in Japan. R. Shimoji is a high-school student and lives in Okinawa, where the rainy season had passed. K. Osada is an experienced visual observer and has special interest in meteor observations. Members of the *Nippon Meteor Society* (*NMS*) carried out a continuing survey until July 3. Clouds obstructed the view of the maximum.

2. Observations and calculations

Most visual observers, including ourselves, could plot because the rate was not so high before and after the maximum. R. Shimoji, who is a beginner in meteor observations but an experienced amateur, recorded rates and magnitudes. K. Nose and T. Sekiguchi used TV independently. T. Seki sent photographic data. Here, we treat these optical data.

We selected visual data according to the following criteria: (*i*) limiting magnitude at least +4.5; (*ii*) cloud cover less than 30%; and (*iii*) observations longer than 30 minutes. From these data, ZHRs were calculated. For computing the limiting-magnitude correction $r^{6.5-\mathrm{lm}}$, lm being the limiting magnitude, a population index $r = 3.06$ was used (see below). For the radiant-elevation correction $\sin^\gamma h_\mathrm{R}$, h_R being the radiant elevation, a zenith exponent $\gamma = 1.5$ was used.

3. Results

Activity

Figure 1 and Table 1 show a summary of the visual observations. Osada caught the ascending branch in twilight but missed the maximum activity due to clouds. Shimoji started his first meteor observation noticing 3 or 4 meteors per minute at 12^h UT and was then experiencing the maximum (12^h–13^h UT). He continued his counts and recorded the full descending branch of the activity. These two independent observations indicate that the maximum occurred at $\lambda_\odot = 95.^\circ693$, when the ZHR reached 270. The high activity lasted for more than 9 hours (10^h15^m–19^h UT).

During the following nights, this shower was still active. On June 28 ($\lambda_\odot = 96.^\circ635$), Nose recorded 4 TV meteors. The following ZHRs were determined: ZHR = 16 by Hashimoto on June 29 ($\lambda_\odot = 97.^\circ749$); ZHR = 10 by Osada on July 1 ($\lambda_\odot = 99.^\circ508$); and ZHR = 3 by Osada on July 2 ($\lambda_\odot = 100.^\circ466$).

During the preceding nights no activity was noticed. K. Mameta observed on June 11, 15, 16, 17, and 20 and found no June Bootids; Osada did not recognize an activity on June 25 and 26, and Osada and M. Sakaguchi also saw no June Bootids on June 26.

The June Bootids seem to be active in the period June 27 to July 2. This indicates a wide spread of meteoroids, and suggests a possibly annual shower.

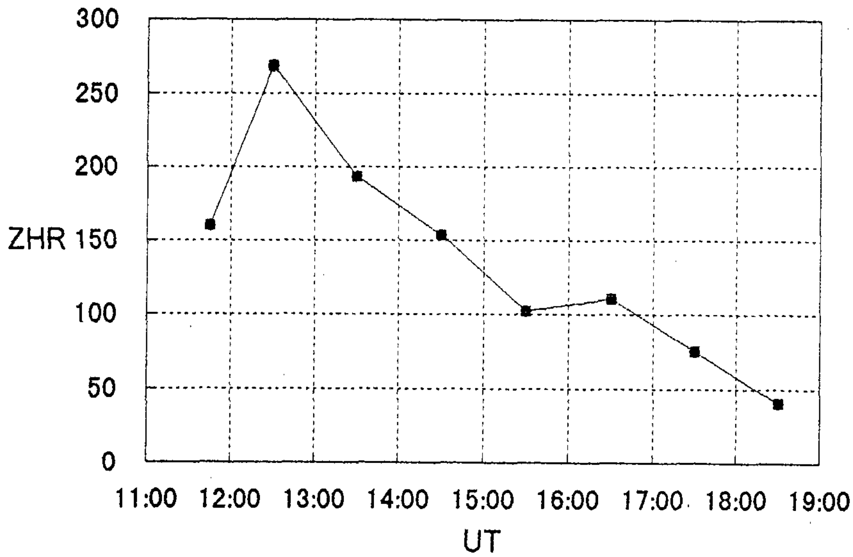

Figure 1 – ZHR profile of the June Bootids on June 27, 1998.

Table 1 – Rate data for June Bootids on June 27, 1998. In this table, $F = 1/(1-k)$, k being the percentage of the sky obstructed, is the cloud correction factor, and h_R is the radiant elevation. For the ZHR calculation, a population index $r = 3.06$ was used.

Period (UT)	$\lambda_\odot$	$T_{\rm eff}$	Lm	F	h_R	SPO	JBO	ZHR	Obs.
10^h15^m–11^h15^m	95°623	1.00	3.0	1.00	74°	3	12	–	OSAKA
11^h15^m–12^h15^m	95°663	1.00	5.1	1.25	73°	11	25	160	OSAKA
12^h00^m–13^h00^m	95°693	1.00	6.5	1.11	63°	3	203	269	SHIRY
13^h00^m–14^h00^m	95°732	1.00	6.8	1.11	59°	2	192	193	SHIRY
14^h00^m–15^h00^m	95°772	1.00	6.7	1.00	52°	2	133	154	SHIRY
15^h00^m–16^h00^m	95°812	1.00	6.8	1.00	43°	2	80	102	SHIRY
16^h00^m–17^h00^m	95°852	1.00	6.7	1.11	34°	2	51	111	SHIRY
17^h00^m–18^h00^m	95°891	1.00	6.8	1.25	24°	3	22	76	SHIRY

Radiant

The chart from Osada (Figure 2) clearly shows that the meteors came from $\alpha = 221°$ and $\delta = +51°$ ($\lambda_\odot = 95°663$), and that the apparent radiant area is rather large, with a diameter of about 10°. Y. Yabu informed us that he measured 4 photographic June Bootids taken by T. Seki and obtained $\alpha = 229°3 \pm 2°$ and $\delta = +48°5 \pm 2°$ ($\lambda_\odot = 95°878$) [1]. K. Suzuki suggested $\alpha \approx 225°$ ($\lambda_\odot = 95°626$) based on the culmination of the radiant, which could be detected by the change in the number of radio meteors [2]. Nose finds $\alpha = 225°$ and $\delta = +58°$ ($\lambda_\odot = 96°635$) from 3 TV Bootids [3]. The spread on these radiant positions is about 10°, due to the large zenith attraction because of the low meteoroid speed. In the following nights, Hashimoto ($\alpha = 229°$ and $\delta = +50°$, $\lambda_\odot = 97°749$) and Osada ($\alpha = 227°$ and $\delta = +48°$, $\lambda_\odot = 99°508$) confirmed the above-mentioned radiant positions. Table 2 lists the radiants derived from visual observations.

Table 2 – The 1998 June Bootid apparent radiant derived from visual observations. "Weight" is on a scale from 1 (very poor) to 5 (very good). Speeds: S(low), R(apid), v(ery), r(ather).

Date (UT)	α	δ	Diam.	Met.	Weight	Speed	$\overline{m}$	HR	Obs
June 27.49	221°	+51°	10°	22	4	rS–rR	3.1	25	OSAKA
June 29.68	229°	+50°	5°	5	1	vS–rS	2.6	3.3	HASTA
July 01.52	227°	+48°	5°	4	1	S–rS	2.3	2.0	OSAKA

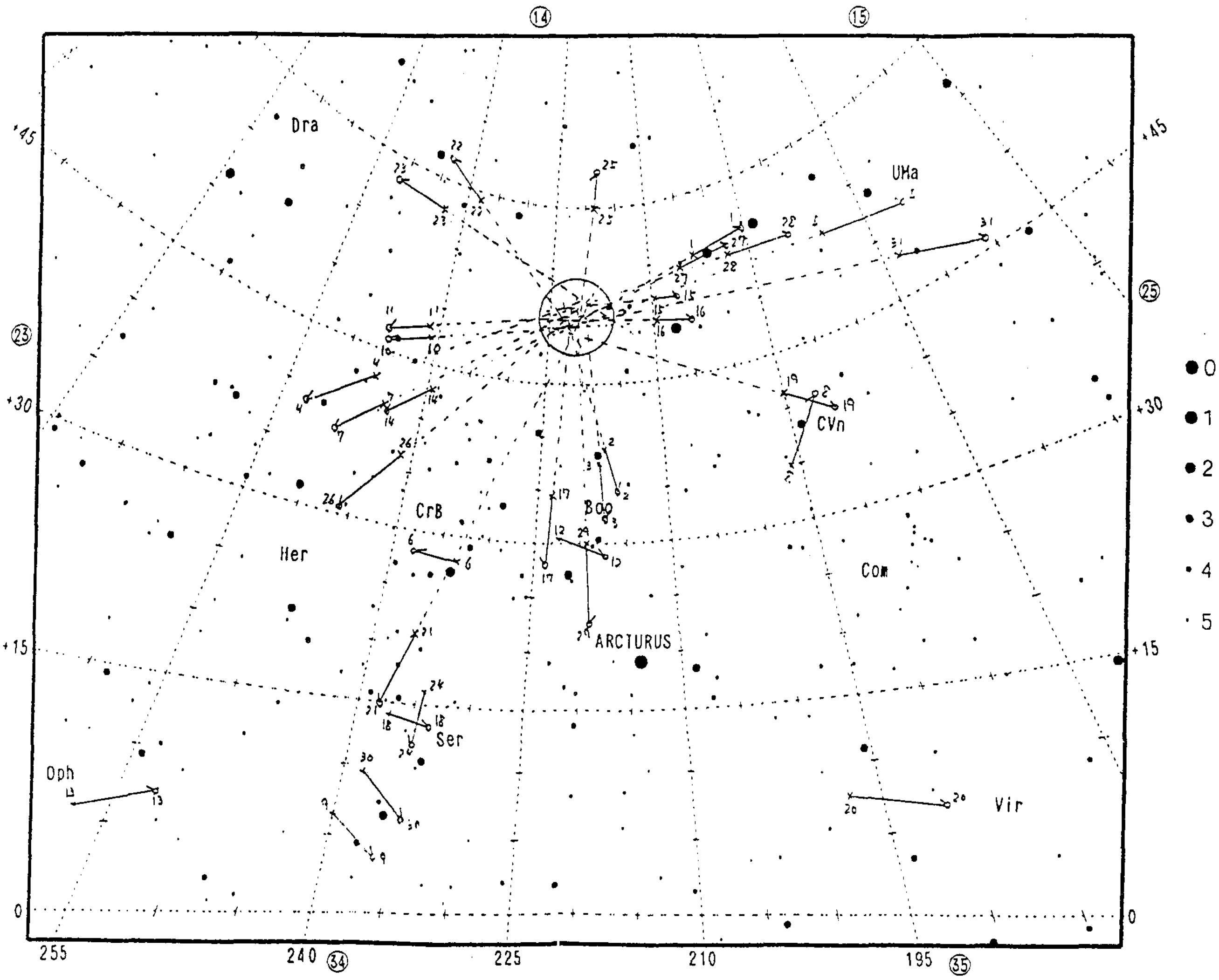

Figure 2 – Observational chart of Osada.

Population index

The population index r was calculated from the magnitude range $+1$–$+5$ in Osada's observations (Table 3), adopting the limiting magnitude shift given by Arlt [4, p. 67]. We did not use magnitude data from Shimoji, because, as a beginner, he tended to overestimate meteor brightnesses. The procedure for calculating r is described in *WGN* [5,6]. The result ($r = 3.06$) indicates that the June Bootids are rich in faint meteors, like the Lyrids ($r = 2.9,\ 2.7$) and the Orionids ($r = 2.9,\ 3.1$) [7,8]. Magnitude distributions of several major showers given by Osada (Table 4) show that the June Bootids are one of the showers with the highest r-value. This coincides very well with Shimoji's mean magnitude difference between sporadics and June Bootids, but contradicts earlier observations ($r = 1.7$) [9].

Table 3 – Magnitude distributions of the 1998 June Bootids.

Magnitude	−6	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	Tot	$\overline{m}$	Lm	Obs.
June Bootids						1	1	2	3	9	6	3	25	2.92	5.1	OSAKA
Sporadics										4	6	1	11	3.73	5.1	OSAKA
June Bootids	1				5	150	185	140	167	37			686	0.61	6.5–6.8	SHIRY
Sporadics							5	12	2				19	0.84	6.5–6.8	SHIRY
June Bootids									2	3			5	2.60	5.1	HASTA
Sporadics								1	1	2	3		7	3.00	5.1	HASTA

Table 4 – Magnitude distribution of major streams observed by Osada.

Sh.	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	+6	Tot	$\overline{m}$	r	Corr.	Lm	Date
QUA			2	1	5	9	18	43	75	104	25		282	3.04	2.50	0.959	5.5–6.0	Jan 3
SPO					1	1	7	17	45	102	44		217	3.70	3.70	0.985	5.5–6.0	1998
PER		1	2	3	12	19	43	71	128	170	91	5	545	3.13	2.63	0.993	5.5–6.3	Aug 12
SPO			1			2	4	8	32	113	51	5	216	3.94	.50	0.981	5.5–6.3	1997
LEO		4	12	3	13	15	20	45	80	78	10		280	2.29	2.22	0.887	5.3–5.5	Nov 17
SPO				1	3	1	1	9	27	94	20		156	3.66	5.56	0.958	5.3–5.5	1997
GEM	1	2	3	3	3	8	12	35	76	84	35		262	3.02	2.97	0.982	5.5–5.8	Dec 13
SPO				1		1	3	6	25	36	14		86	3.51	3.58	0.976	5.5–5.8	1996

Appearance

Osada noticed that all meteors brighter than +1 left a train, with two showing remarkable magnitude variations and explosions at the end. They were noticeably slow and yellowish, and looked like κ-Cygnids. Shimoji reported a color distribution: yellow, 73%; white, 22%; other, 5%. Other observers reported that the shower meteors were slow and had short paths.

Annual shower

We searched Japanese observations since 1990, and found the following: the *Japanese Fireball Network* caught a fireball associated with 7P/Pons-Winnecke on June 24, 1996 [10], and K. Izumi observed 3 slow meteors radiating from $\alpha = 228°$ and $\delta = +55°$ on June 29, 1997 (HR = 2.4) [11,12]. The 1916 June Bootid outburst was described by Denning [13]. It peaked with HR $\approx$ 30 on June 28, 1916. The radiant was at $\alpha = 231°$ and $\delta = +54°$. The current shower is a repetition of this event, and it is suspected that the June Bootids show a low annual activity, now.

Acknowledgments

We express sincere thanks to all observers of this rare event, especially to R. Shimoji who challenged himself to obtain useful data out of this first-time observation. We also thank M. Koseki, *NMS* General Secretary, for many useful suggestions.

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The June Bootids in 1995 and 1997

Harald Seifert

Re-examination of 1995 and 1997 observations revealed very weak June-Bootid activity in these years.

Until their outburst in 1998, the June Bootids were regarded as a past meteor shower which is not active any more. After the recent return of the shower, we used visual plotting observations to check for possible signs of this shower in previous years. The data at hand included about 14 hours of effective observing time from Jürgen Rendtel in 1995 and more than 15 hours between June 26 and June 30 in 1997 from Janko Richter, Thomas Schreyer, and Harald Seifert.

We present the result of a new analysis of these plots using the program VISDAT for measuring and storing the data. With the help of the RADIANT program, we found a distinct concentration of meteor path intersections in the region of Bootes-Draco. However, the radiant position does not coincide with that given by Rendtel and Arlt [1]. A reason for this can be the fact that the observers did not look into a direction which is favorable to analyze a radiant in the Bootes-Draco region. Using the radiant position derived from the plots, we found 7 June Bootids in the 1995 data and 10 in the 1997 data. The corresponding ZHR is always about 1 (Table 1).

Table 1 – ZHR range of the June Bootids in 1995 and 1997 derived from visual-plotting observations described in the text. Observations of several observers in one night were averaged.

Date 1995 (UT)	$\lambda_\odot$	JBO	ZHR	Date 1997 (UT)	$\lambda_\odot$	JBO	ZHR
June 25 – 26	93°9	0	–	June 26 – 27	95°4	1	0.6–3.8
June 26 – 27	94°9	2	1.0–3.9	June 27 – 28	96°3	2	0.7–2.5
June 27 – 28	95°9	1	0.5–2.7	June 28 – 29	97°3	3	0.7–2.0
June 28 – 29	96°8	1	0.5–2.8	June 29 – 30	98°2	4	0.7–1.8
June 29 – 30	97°8	1	0.5–2.8				
June 30 – 31	98°8	2	1.0–3.8				
July 01 – 02	99°8	0	–				

Taking our 1995 and 1997 data as a basis, the shower activity is hardly detectable from the ZHR. Janko Richter tried to detect the stream from the 1997 data [2], with the following result: provided the radiant was situated near the zenith and the limiting magnitude was 6.5, an unbiased observer would have decided after 9 hours effective observing time that the June Bootids are a random accumulation of sporadic meteors. (After the 1998 outburst he would have changed his mind, of course.) An analogous assertion is valid for 1995. From our observations of 1995 and 1997, we can conclude that some June Bootids were recorded, but with a ZHR too low to classify them as an active shower. Moreover, we examined our observations of July 1–13, 1997. Not a single June Bootid was recorded within 16 hours effective observing time (limiting magnitude 6.5).

We also re-analyzed *IMO* observations by Valentin Velkov (Bulgaria), Konrad Szaruga, Tomasz Fajfer, and Andrzej Skoczewski (Poland), and Marco Langbroek (the Netherlands), using their original plots and the program VISDAT. These observers recorded data of 171 meteors within 24 hours in 1997. No evident activity exceeding the rate mentioned above can be found between $\lambda_\odot = 92°$ and $\lambda_\odot = 100°$. However, this analysis is somewhat restricted, because the observers estimated angular velocities using a scale of 5 or even 3 steps only.

It will be most interesting to examine data of the period June 26–30 from the years prior to 1995. We would be very pleased if you can send us photocopies of your plottings (maps and tables with meteor data) obtained within this period in any year.

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Ongoing Meteor Work

The Makings of Meteor Astronomy: Part XVII W.F. Denning and Comets, Nebulae, and Novae

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In this article, we continue our celebration of the life and works of William Frederick Denning. As a tireless investigator of the heavens, Denning turned his attention towards many diverse astronomical subjects, and here we discuss aspects of his observation and discovery of comets, nebulae, and novae.

1. Comet-sweeping

Denning's personal journals and published works clearly indicate that he dedicated a considerable amount of telescope time towards searching for comets. And indeed, history tells us that in the gentle art of comet sweeping he was highly successful, with four cometary discoveries being accredited to his name. The faint, nebulous glimmerings of the comets, now designated 72P/1881 T1, C/1890 O2, C/1892 F1, and D/1894 F1, were first swept-up by Denning and his telescope, and he was pre-empted by just a matter of hours in the discovery of Comet C/1891 F1.

Denning's first official office within the *British Astronomical Association* was as the Director of the Comet Section. He held this post from 1891 to 1893, and only later, from 1899 to 1900, did he take on the role of Director of the Association's Meteor Section. Denning's views on comet-seeking afford a good example of his general belief that systematic and applied work inevitably provides successful results. As early as 1882, he was to write [1],

> *"success in this, as in other departments of research, depends, in a very large measure, upon the energy with which it is pursued. To an observer who devotes himself closely to it, and avails himself of every chance presented, there is an encouraging prospect of success."*

It is interesting to note, however, that, in his first book, published in 1872, Denning had commented *"comets are not interesting objects in telescopes"* [2].

Some measure of how much time Denning dedicated to cometary work can be gained from a calculation he presented [3] in 1894. At that time, he commented that in 596 hours of comet-sweeping he had discovered five comets. This averages to some 119 hours of searching per comet. Although he continually tried to promote cometary studies among English amateur astronomers, Denning found that they did not easily turn to the subject. As late as 1922, Denning can be found complaining in the journal *Nature* [4],

> *"it is remarkable that English astronomers appear hitherto to have taken little interest in cometary work, and that very few comets have been discovered from this country. ...there are a great number of telescopic observers in the United Kingdom who have the means and the time at their disposal to accomplish valuable work in this department if they would only engage in it in an earnest manner."*

Only two of the comets discovered by Denning are short-period comets, the others have parabolic orbital elements.

Denning's first comet was discovered on the morning of October 4, 1881, in the constellation of Leo, and it was subsequently found to have an orbital period of about 8.7 years. The comet he discovered on March 26, in the constellation of Leo Minor, has an orbital period of about 7.4 years. Denning's comet of 1881 was "lost" for 97 years after its discovery (11 perihelion passages) before being re-discovered by Fujikawa in 1978. The comet Denning has discovered in 1894 has only been seen then, and has now been "lost" for 104 years (which amounts to 14 perihelion passages).

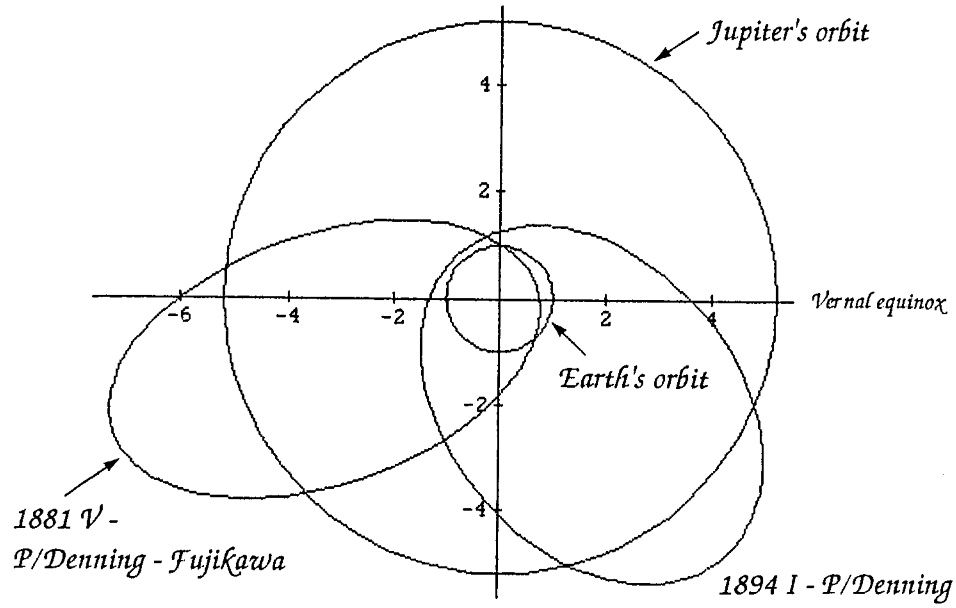

Figure 1 – Ecliptic projections of the orbits for comets 72P/Denning-Fujikawa (formerly 1881 V) and D/1894 F1 Denning (formerly 1894 I).

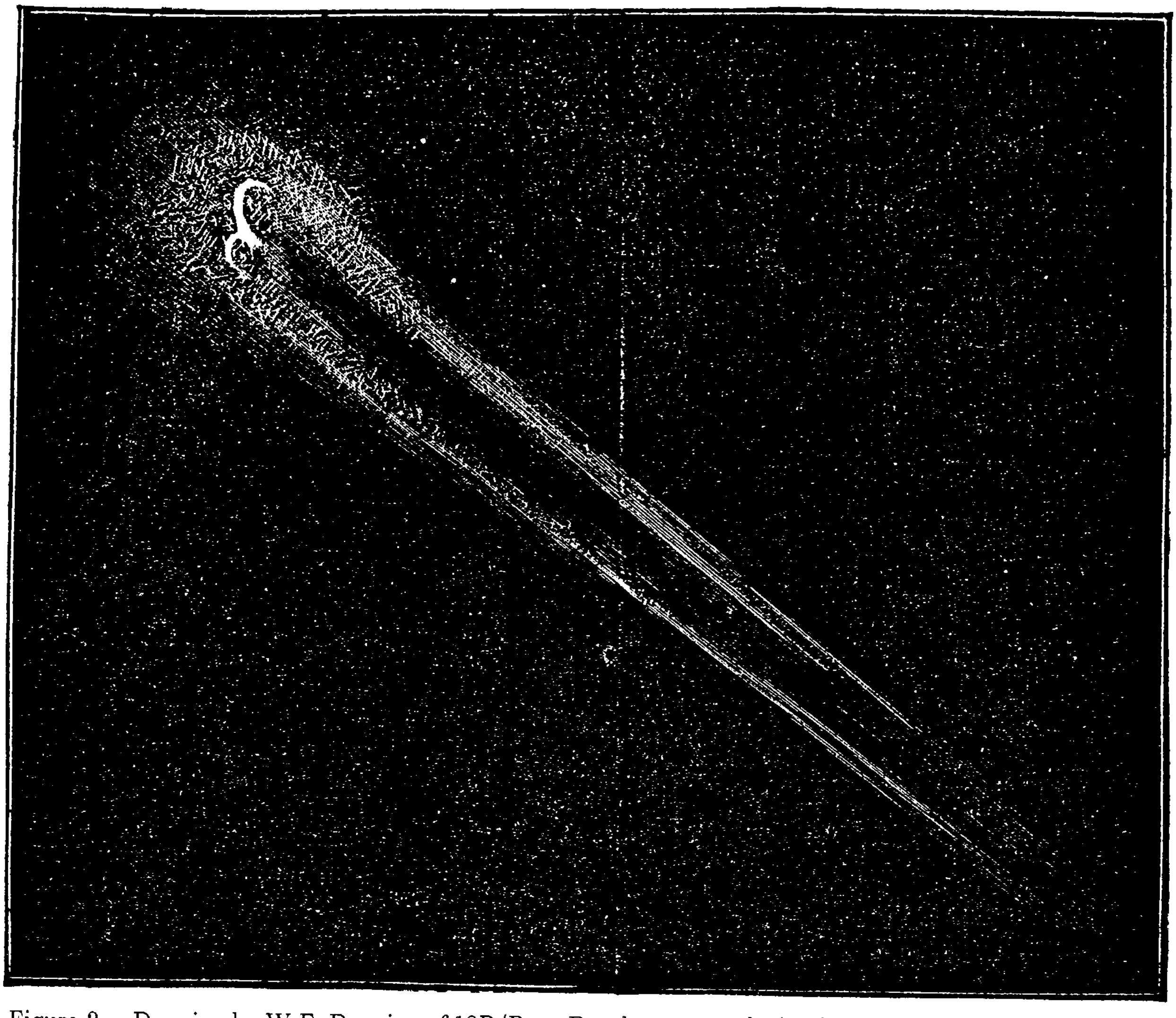

Figure 2 – Drawing by W.F. Denning of 12P/Pons-Brooks, as seen during its 1884 apparition. The 10-inch With-Browning telescope that Denning used to make the above drawing has been "lost" for many years, but one occasionally still hears rumors that it still exists. A number of Denning's astronomical instruments were donated to the *Royal Astronomical Society* in the mid 1960s, but the With-Browning was not one of them.

The nodal points of comet 72P/Denning-Fujikawa fall close to the orbits of both the Earth and Venus. While there is no conspicuous annual meteor shower that can be linked to 72P/Denning-Fujikawa, Olsson-Steel [5] has found a weak shower association with a radiant in the constellation of Sagittarius. Beech [6] has further speculated upon the possibility of a Venusian meteor shower from the comet. The nodal points of D/1894 F1 fall at 0.78 and 2.22 AU, and, consequently, no shower association would be expected at the Earth's orbit.

2. Nebulae—"the bane of the comet-seeker"

When Denning outlined the role of the *BAA*'s Cometary Section in the June 1891 issue of the *Journal of the British Astronomical Association*, he commented that, besides searching for comets, its main aims were to discover new nebulae and record telescopic meteors [7]. While a working knowledge of the positions of diffuse nebulae is of value to the would-be comet-searcher, since, as Charles Messier had long before pointed out, they can be confused with a new comet, Denning did refer to nebulae on one occasion [2] as *"the bane of the comet-seeker."*

Denning discovered several new and "unmarked" nebulae during his cometary searches and he described their position and visual characteristics in detail. The term "nebular" was not well defined in Denning's day, and objects such as galaxies, globular clusters, galactic clusters, and diffuse interstellar clouds were all included under the nebular umbrella. One contentious point concerning nebulae that Denning commented upon was the issue relating to their apparent variability. In particular, Denning made a number of comments on the supposed variability of the brightness of the nucleus of M 31, the Andromeda Galaxy [8]. While the variability that had been ascribed to M 31 had been based upon photographic observations, Denning showed typical disregard for such "hi-tech" results, and commented that, from his experiences, the supposed variability was probably due to "atmospheric disturbances." In this case, Denning was correct, but instrumental techniques would soon, thereafter, begin to outstrip the human observer in both sensitivity and versatility.

3. Novae

By their very nature, the appearance of novae and supernovae cannot be predicted, and, consequently, their discovery must rely upon serendipitous circumstances. When Denning wrote his *Telescopic Work for Starlight Evenings*, the mechanisms responsible for nova-like eruptions were completely unknown. Denning did know, however, that these *"new"* or *"temporary"* stars required an *"exceptional explanation,"* and he even questioned their classification as simple variable stars. He further commented in *Telescopic Work* that he had *"frequently, while watching for meteors, reviewed the different constellations in the hope of picking up a new object, but had never succeeded in doing so."* Some thirty years after writing his comments in *Telescopic Work*, Denning finally succeeded in his wishes. It is interesting to note that, in 1895 [9], Denning commented that one of the most wonderful sights that he had ever seen was the temporary star of August 1885 in M 31.

Between 1918 and 1920, Denning was party to the discovery of two novae [10]. While his priority on the discovery of the first of these novae, Nova Aquilae (V603 Aql) was not to be established [11], he is accredited with the August 20th, 1920 discovery of the nova in Cygnus (V476 Cyg). With respect to the discovery of the nova in Cygnus, Denning wrote that he had set out to begin a meteor watch, but had immediately noticed a new star of magnitude +3.5 in Cygnus [12]. To "immediately" recognize such an interloper in the crowded star fields of Cygnus is no mean-feat, and offers impressive testament to Denning's detailed knowledge of the sky (see also note [11]).

When he discovered Nova Cygni, Denning was 72 years old. While still an influential astronomer within England during the first two decades of the 20th century, Denning had long since established himself as a staunch recluse. Indeed, from the early 1900s onwards, he communicated with his astronomical colleagues through an extensive postal correspondence only.

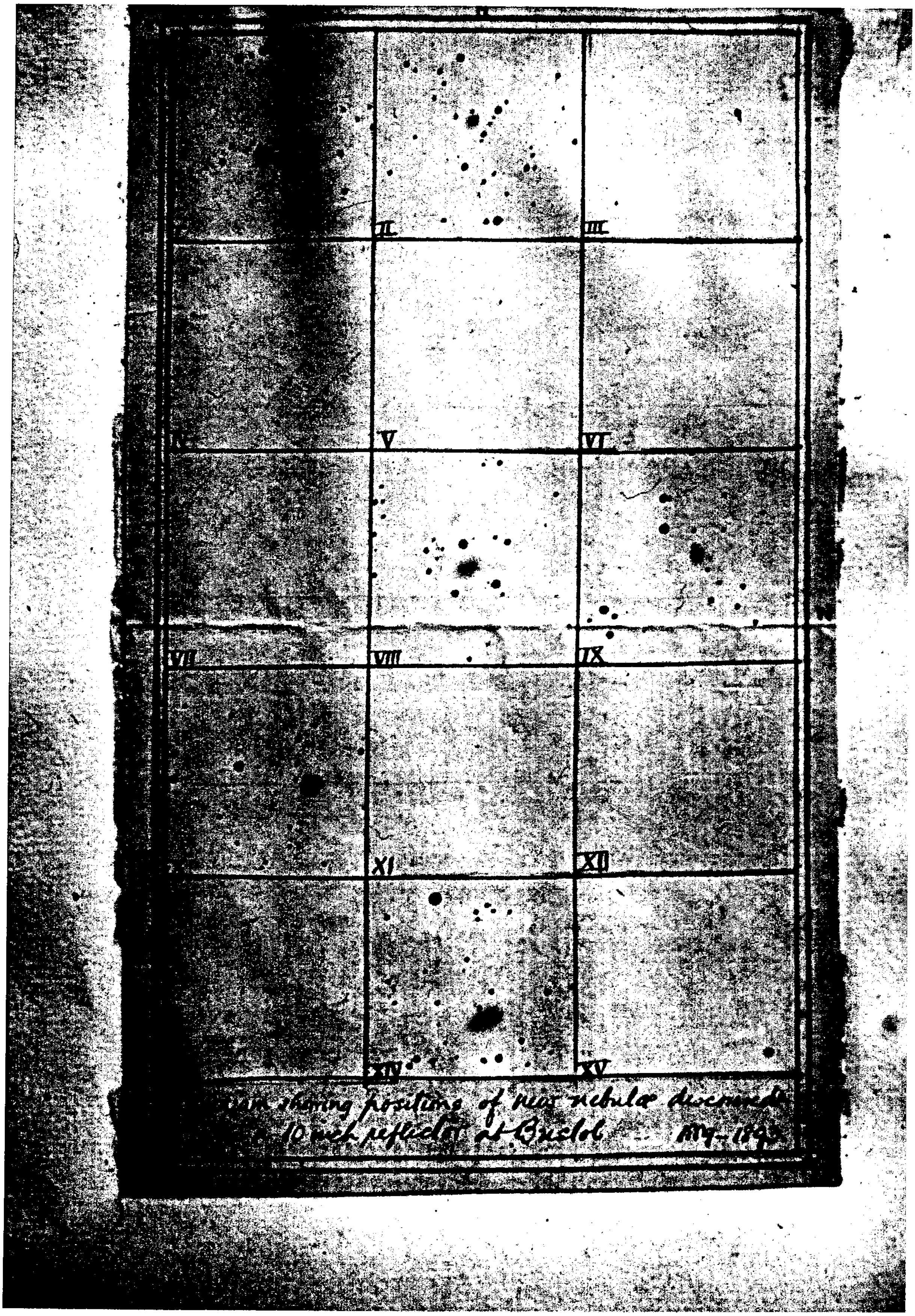

Figure 3 – Diagram prepared by W.F. Denning to illustrate the positions of new nebulae discovered between 1889 and 1893. All of the nebulae are within 15° of Polaris.

Some insight as to the personal impact that the discovery of Nova Cygni had made on Denning's life can be gained from a letter he wrote to his niece (Christine Gravely) on September 26, 1920 [13]. He noted in particular that *"the new star brought me about 100 letters extra and the event seems to be regarded as a very important one in the astronomical world."* In this latter respect, Denning was certainly correct, and an extensive visual and photographic study of the nova was initiated at the Greenwich Observatory, and the results were summarized by W.J. Luyten [14]. Denning also followed the brightness variations of the nova, and between August 20 and October 13, he observed the "star" on 47 nights, finding that the average rate of fading was 1/10 of a magnitude per day [15].

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[2] W.F. Denning, "Astronomical Phenomena in 1872", Wyman and Sons, London, 1872. This book was not well received by the reviewer in *Nature* 4, 1872, pp. 261–262. Denning was to completely change his opinions of comets, and comet-seeking, shortly after the publication of this book. He was later to remark, for instance, that *"comet-seeking is the most exciting work of any in which I have indulged."* (*Tit Bits*, August 31, 1895, p. 386).

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[7] Denning did comment in his *Telescopic Work for Starlight Evenings* that *"the discovery of new nebulae offers an inviting field to amateurs."* Denning would on occasion publish detailed observations of the nebulae that he came across while comet searching. In his first list (*Monthly Notices of the Royal Astronomical Society* 51, 1890, pp. 96–97), he gives detailed positions and descriptions of ten new nebulae. Interestingly, he has enlisted the help of several professional astronomers to determine accurate coordinates. M. Charlois of the Nice Observatory, France, even made observations at Denning's request. Further descriptions are given in *Transactions of the Astronomical and Physical Society of Toronto* 2, 1891, pp. 69–70, and *Observatory* 15, 1892, pp. 104–106.

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[11] W.F. Denning, "Observations of Nova Aquilae", *Monthly Notices of the Royal Astronomical Society* 78, 1918, p. 570. Denning commented in this paper, *"on commencing a watch for meteors on June 8, I immediately observed that a new star of considerable brilliancy had made its appearance in the western border of Aquila."*.

[12] Denning's discovery was announced in *Nature* 105, 1920, p. 838.

[13] I am very grateful to Maurice Brain of the *Bristol Astronomical Society* for access to his collection of letters written by Denning.

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System Design Considerations for Automated Meteor Recording and Detection Systems

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Automated systems for the observation and photography of meteors are discussed. These are based on video cameras and image processing to detect meteors. The requirements of such a system are discussed and some possible implementation techniques are presented.

1. Introduction

Meteoritics benefits from photographic records of meteors. The trajectory across the frame can be analyzed to yield information about the nature of the meteoroid, its heliocentric trajectory and other factors. Accumulated records contribute to knowledge of the statistics of meteoroid populations. For practical reasons, the photography of fireballs and ordinary meteors is often conducted separately; this paper considers both.

Since at least as early as 1893 [1], such records have been made with film cameras. (By film is here meant photographic film, not motion pictures.) This research has been pursued by many individuals and small groups, as well as the three main fireball networks: the *European Fireball Network* [2,3], the *Prairie Network* [4] in the USA, and the *Meteor Observation and Recovery Program* [5] in Canada. Such work produces large quantities of exposed film, all of which must be developed and examined. These material and labor costs are significant, and only a small fraction of the negatives yield meteors. This is why the two North-American networks have closed down and the European one has problems of funding the film [6].

Nowadays, the obvious way to conduct regular meteor photography is with a (probably CCD) video camera and image processing on a computer. Such a system would observe the sky all night; most frames would be meteor-free and would be discarded. Those with meteors would be detected and recorded as computer data for later analysis. A variant is to record all frames on a video recorder; essentially the same analysis is performed on the tape later.

Such systems were suggested over ten years ago [7], but until recently the hardware to implement them was either not available or too expensive. This is now changing. The main reason is that computing power is becoming cheaper whilst its speed and data capacity are increasing. At some point, they will make the technique useful, and that point appears to be in the late 1990s. Another reason is the appearance of CCD video cameras, which have advantages of sensitivity, ruggedness and cost over the older, valve-based technology such as Vidicons [8,9].

Several people have realized that the time is ripe for such computerized systems. Studies include [9–18]. These have tended to concentrate on the major components, such as the image processing software. The system design has sometimes been discussed [11,12], but has often been taken as read. The present paper addresses the overall design. It is based on a study conducted two years ago [19], but not hitherto published. To a certain extent, it is one possible design; others can be conceived. It is intended as a fairly complete design, however, of which early systems might implement a large subset.

2. System requirements

A possible requirements specification follows, with analysis and comments on some specific items below.

Requirements specification

1. The system shall observe fireballs and other (fainter) meteors. All are here referred to as meteors.
2. The system shall observe meteors optically at night.

3. The system shall detect meteors and record details of them. These details shall include monochrome video images.
4. Additional information (such as dark frames and timing information), which is needed for data analysis shall be recorded as needed.
5. The system shall record meteors down to a limiting magnitude of about +5 or +6.
6. The Dynamic Range (from faintest to brightest meteors) shall be about 10 magnitudes.
7. The Intensity Resolution shall preferably be 12 bit, although useful work of restricted resolution can be performed with 8-bit systems.
8. The Spatial Resolution of the system shall be as good as available cameras allow.
9. The Temporal Resolution shall be 0.04 second or finer (equivalent to at least 25 frames per second).
10. By Timing Accuracy is meant the accuracy with which the time of day of each frame is recorded. For single-station work, this shall be at least to the nearest minute. For multiple station work, it shall be at least to the nearest second and preferably to 0.1 second.
11. The system shall be designed for year-round detection of all meteors and not be made specific to any shower.
12. The system shall avoid reacting to non-meteoric objects as far as possible, but shall err on the side of recording rather than ignoring events.
13. The system shall signal when it has detected and recorded a meteor.
14. The system shall run in real time.
15. The system shall be suitable for unattended operation over long periods. This shall mean a minimum of 24 hours and preferably several months.
16. The units shall be suitable for operation both singly and as components of a network where records of the same meteor from several units are valuable.
17. The output files shall be in FITS format [20,21]. This is the standard format for professional astronomical data.

Requirements analysis

1. Systems for fireball watch and for photographing fainter meteors have traditionally been separate. The systems described here might well serve both ends. It may be that these two categories of equipment will begin to merge, increasing the equipment available and the data collected for both types of study.
2. "Optically" implies radiation in the general region of visible light, and not, for instance, radio waves. In practice, the systems will probably have useful sensitivity in the near infra-red.
3. "Video" is not meant to imply a restriction to normal standards, such as 525 or 625 lines. In practice, though, these will probably be the most common systems in the near future.
4. Limiting magnitude: "as faint as possible" is the real requirement. There is a limit set by photon noise; for reasonable equipment, this has been estimated as +12 [13]. A magnitude of around +5 or +6 seems a reasonable target, being achieved by some existing video systems.
5. A bright limit of −5 would be desirable. Brighter meteors might saturate the detector: they would probably be detected, but the brighter parts of the light curve would be lost. With the faint limit of magnitude +5 or +6 (above), this implies a dynamic range of about 10 magnitudes, or a factor of 10 000 in photon flux per frame.

   This assumes the frame rate to be fixed: more advanced systems might shorten the frame time during bright bolides, avoiding over-exposure and gaining better temporal resolution. Moreover, some CCD chips have an Electronic Shutter electrode which can be operated to reduce the integration time. Some image intensifiers can be similarly gated. Such gates could be opened for a fraction of the frame time to avoid over-exposure [7].

Note that the dynamic range observed comes both from the variation between meteors and from the variation in brightness of each meteor, i.e., its light curve.

6. By Intensity Resolution is meant the smallest difference in brightness which can be measured. This will normally be the Quantization Level of the digitizer (or Analogue-to-Digital Convertor, ADC), related to its word length in bits. There are two constraints on it.

   First, it must be adequate for the detection algorithms to distinguish the meteor from the background. Further study is needed to quantify this, but initial work [12,16,18] indicates that detection can be achieved with 8-bit systems (i.e., capable of resolving 256 levels).

   Second, the resolution should allow the measurement of a light curve. If the resolution requirement is 0.1 magnitudes (a reasonable figure), this corresponds to about a 6-bit word length. No realistic ADC will have less than 8 bits, so this is not a limiting factor. There is another constraint, however. There is no point in setting the quantization level below the signal equivalent to the limiting magnitude: one would merely see the noise in more detail. As the meteor climbs above this minimum brightness, so the theoretically available intensity resolution rises. If the quantization level has indeed been set at the limiting magnitude, then that resolution will be obtained. As the meteor gets brighter still, one obtains more accuracy than is required, until the detector saturates.

   Thus, the required resolution is determined by the required dynamic range rather than the required accuracy. Resolutions of 8 bit give a range of about 6 magnitudes, 12 bit of 9 magnitudes, and 16 bit of 12 magnitudes. This suggests that 12-bit should be the preferred resolution, possibly replaced by 16-bit when prices fall. Eight-bit systems will presumably succeed in detecting meteors, but their light curves will rarely be accurate. This has been borne out by experience [22].

7. The spatial resolution of CCD cameras is currently far below that of photographic film. It is therefore accepted that the spatial resolution will not match that of existing photographic systems. This may improve in the medium-term, but affordable resolution will not match film for many years. See also the comments in the following subsection.

8. The Temporal Resolution is the resolution with which the motion of the meteor can be timed. It will determine the accuracy with which its speed can be calculated.

   Unless rotating shutters are used, which is unlikely, this resolution will be the frame rate. (With video cameras having a 2:1 interlace [23,24], the resolution could be the field rate if the two fields could be separated reliably.) The value will be somewhat constrained by technology and light limitations. If broadcasting-standard cameras are to be used, the only frame rates available are 25 and 30 frames per second. Prototype meteor detection systems have been made to work at these rates [11,12,16], and there is no motive to employ slower ones. Faster rates would yield better timing information, but at the cost of fewer photons per frame and thus reduced sensitivity. Were the frame rate selectable in the design but fixed at run-time, its choice would depend on whether the system were to be optimized for the largest number of faint meteors or for the best timing of fireballs. Were the frame rate adjustable at run-time, a reasonable strategy would be to use a relatively slow frame rate until a meteor was detected, then adjust the speed so that the required intensity resolution was just maintained. The frame rate would rise as the meteor brightened and fall as it faded.

   The technology may place two further constraints on the fastest rate attainable. One is the time to read the frame out of the CCD, through the ADC, and into the computer. The other is the computer processing time for each frame. Both these can be ameliorated, once a meteor has been identified and is being tracked, by only processing the part of each frame containing the meteor. If the camera allows, CCD chips can be read out in Fast Window Mode [25], where only a rectangular portion of the frame is read.

If better temporal resolution is required, an electronic equivalent of rotating shutters could be used. Some CCD chips and image intensifiers have electronic shutters (see Dynamic Range, above). Although intended to allow single fast exposures, there seems no reason why these may not be tuned on and off repeatedly during each frame.

See also the comments in the following subsection.

9. Absolute accuracy of times is not needed for speed measurements, which only need relative times. For most astronomical analysis, accuracy to the nearest minute will suffice.

   Greater accuracy may be needed for multiple-station work. The three-dimensional trajectory of a meteor can sometimes be calculated from simultaneous photographs from different locations. This requires that the meteor image from one camera can be identified with that from another. Most such 3-D analysis has been performed on fireballs, which are so rare that there is no problem in establishing identity. As systems become more sensitive, the probability of two similar meteors occurring within a given time slot will rise, and better timing may be needed to assist the correlation. An accuracy of 1 second would seem appropriate, though 0.1 second might be needed in spectacular showers.

10. A quality measure needs to be developed. It will presumably be expressed in terms of false positives (meteors reported where none existed) and false negatives (real meteors missed). This is not addressed here.

11. An alternative is to record all frames (e.g., on videotape), allowing later analysis to run slower than real-time. This is not a good option. Averaged over a year, astronomically useful night-time amounts to nearly half the twenty-four hour period, so only a factor of about two would be gained in processing speed requirement. This is trivial compared with the improvements in available processor speed over a few years. Moreover, the storage will, in practice, have to be on videotape; this limits quality, as discussed below.

12. The equipment will operate continually throughout all nights of the year. During the daytime and when cloud or moonlight render work impossible, it will simply fail to produce any results; there will no reason to turn it off. Some automatic protection against sunlight may be needed (see below).

    An additional desirable characteristic would be suitability for operation remote from mains supplies. This might involve low power consumption at 12 V, allowing operation from car batteries.

13. The main design constraint from this requirement is reasonably accurate timing information. This is needed for the identification of two-station meteors (see above).

14. The actual camera stations might record in a different format, provided that later processing could convert this to FITS. Outputs in other formats might also be desirable.

Commentary on the specification

As regards Spatial and Temporal Resolution, the conventional analysis procedure at this point would include establishing the users' (here astronomers') accuracy requirements. These would imply the required resolution of the images. In practice, a literature search and conversation with several professional astronomers have yielded no statement of their accuracy requirements. Nor is it apparent whether this is because all current techniques are of inadequate resolution or because the question has not been addressed. In these circumstances, the requirement is that the system should be at least as good as existing film-based ones.

3. Outline of the proposed system

Figure 1 illustrates the overall system. Components of this will be discussed.

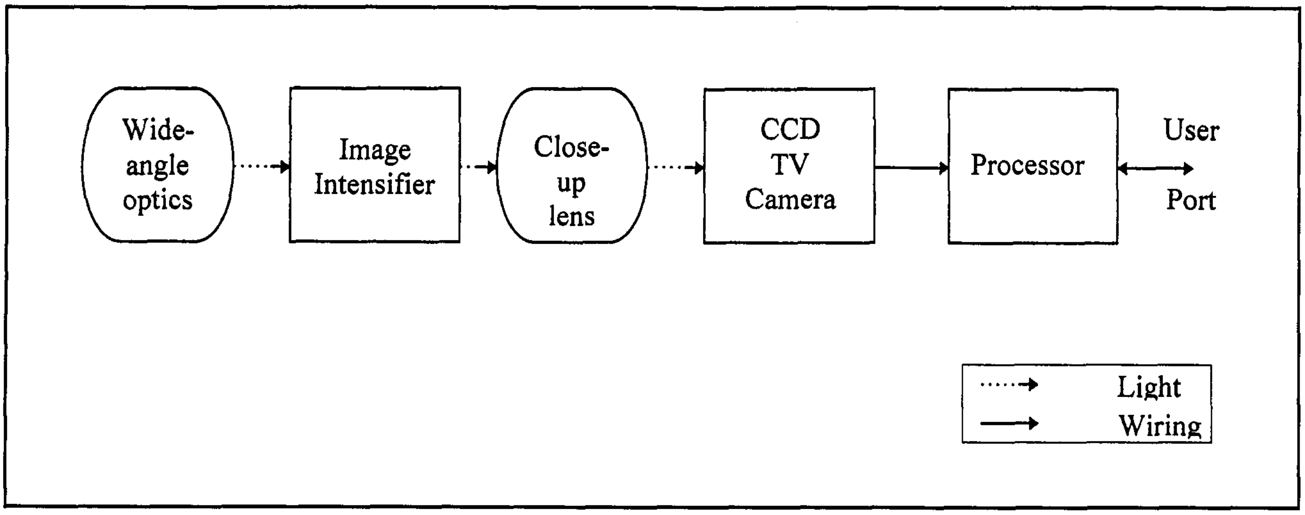

Figure 1 – System diagram of the proposed equipment. The image intensifier and close-up lens might not be used, in which case the wide-angle optics form an image directly on the CCD camera.

Wide-angle optics

These view some portion of the sky, probably a wide angle. They might comprise a lens with any field of view up to 180°; the choice of optimal lens is a matter for more detailed study. The number of meteors recorded will increase monotonically with lens aperture and with field of view. Better lenses will generally be more expensive, however, and it is not immediately obvious whether money is better spent on aperture or field of view. This decision also interacts with other quality measures such as the spatial resolution and thus the quality of the final data. Some work has already been done on this question [26].

An alternative to the wide-angle lens is a convex mirror viewing the whole sky with a normal lens to examine the reflection [3]. This optical subsystem forms an image either on the CCD chip or on the light-sensitive photo-cathode (the input) of the image intensifier.

Image intensifier and close-up lens

The image intensifier in this application has been the subject of design study for many years [27–29].

Image intensifiers amplify the number of photons received, but their limits are not always appreciated. A given front lens will provide a certain number of photons to its target, whether intensifier or CCD, and no device can improve on that: it cannot see a fraction of a photon. All it can do is multiply the number of photons to enable detection with less sensitive detectors. Typical CCD chips have quantum efficiencies QE of around 50%, averaged across their wavelengths [19,30]. That is to say, they record about 50% of the incident photons. An intensifier with a gain of 1000 cannot improve sensitivity by 1000, since a CCD, if used properly, is only about a factor of 2 below detecting every photon.

If the number of photons per pixel per frame is large, one can multiply the recorded number by 1/QE to provide an estimate of the number which actually hit the pixel. This can be done in software: it does not require an intensifier. If the number of incident photons is small, so that photon (i.e., quantum) noise is significant, the result is less satisfactory. If the intensifier has gain N, then there is a chance of $(1 - \mathrm{QE})^N$ that none of its output photons is registered by the CCD. This assumes that the intensifier itself reacts to every photon, i.e., that it has a QE of 100%; actual figures tend not to be published. In practice, N is large (many thousands), so virtually all photons registered by the intensifier are registered by the CCD: the QE of the system becomes approximately that of the intensifier.

In practice, what an intensifier does is to raise the number of photons above the noise level in the rest of the system (CCD chip, amplifier, analogue-to-digital converter, and videotape, if used).

It enables good photon detection with cheap, uncooled electronics. (Conventional astronomical CCD chips are cooled to reduce the significant thermal noise.) An intensifier should therefore be seen as (*i*) obviating cooling and low-noise electronics, and (*ii*) changing the QE from that of the CCD to that of the intensifier which, one hopes, is larger.

The former advantage not only removes the cost of cooling plant (typically, Peltier devices [30]). It also enables the use of economical, standard video cameras (which are not available with coolers) and frame grabbers.

The image intensifying subsystem is not essential, though most workers regard it as desirable. There may, in fact, be reasons to avoid its use:

- It adds to the cost, though the price is falling.
- It may limit the resolution. Affordable second-generation intensifiers are available with a circular output area of 19 mm diameter and a spatial resolution of 10 μm [29]. This would accommodate a square image of about 1300 pixels across, far better than domestic video standards, but of only moderate quality by current digital CCD camera standards.
- The theoretical maximum benefit from an intensifier would be a factor of about 2 (assuming QE $\approx$ 50%), or about three-quarters of an astronomical magnitude. This is a worthwhile improvement, but may not be worth sacrificing other benefits. A further optimization study might address the relative benefits of intensifiers *versus* a larger number of camera stations.

A close-up lens is used to couple the intensifier to the camera. This stage needs care to avoid significant light loss, but with good engineering an efficient design can be achieved [28].

CCD Camera

There are three *prima facie* possible approaches here.

Standard TV cameras

By these are meant cameras conforming to a broadcasting system, which in practice means 525-line NTSC or 625-line PAL or SECAM. These last two differ only with regard to color, which should be irrelevant since only monochrome recordings are required. (Theoretically, SECAM might be inferior to PAL if a modulated UHF signal from the camera is used. The SECAM color sub-carrier is frequency-modulated, which means that it spreads at a low level across the luminance (i.e., monochrome) signal, unlike NTSC and PAL. In practice, this will probably be unnoticed in the mediocre quality of domestic video systems. The problem should not occur if a direct video (i.e., base-band) signal from the camera is used.) For further details of these systems, see [23,24].

The advantage of these cameras is cost. They are manufactured for the mass market, often in the form of camcorders which provide videotaping facilities, if required. Frame-grabbers (which digitize the TV signal and present it to a computer) are also available and economic [31].

One problem of these systems is their limited spatial resolution. Both lose 50 lines for vertical blanking; with a 4:3 aspect ratio, their resolutions are approximately 475×633 pixels for 525-line and 575×767 pixels for 625-line. These are poor compared with film and good digital cameras.

Another problem is the limited intensity resolution. These systems are only designed to produce images for consumption by the human eye. The eye and brain are very tolerant of poor quality, so there is no motive to improve TV systems beyond a certain point. Systems sold for the domestic market rarely have thorough published specifications, but other factors constrain the achievable quality. Domestic (and even professional) frame-grabbers are normally 24-bit color. Although this sounds impressive, it actually means three 8-bit digitizers, one for each primary color. When all three colors are copies of the same monochrome channel, there may be some improvement in quality due to the averaging of noise, but it will be around 1 bit at most.

All current broadcasting standards have a 2:1 interlace. This means that the odd-numbered lines are scanned during the first half of a frame period (i.e., the first field), followed by the even-numbered lines during the second field [24]. With equipment built to domestic standards there can be differences between the two fields of a frame.

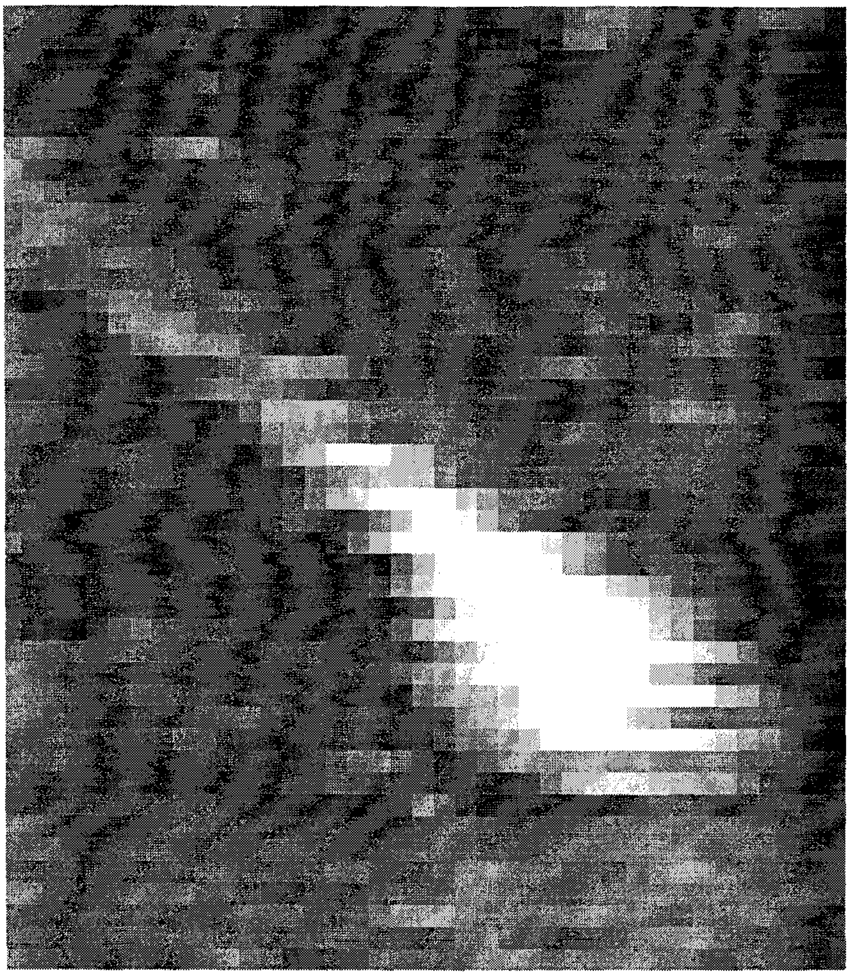

Figure 2 – Enlargement of a meteor captured on a 2:1 interlace camera. The images of odd- and even-numbered lines are offset horizontally from each other.

Figure 2 illustrates this with a horizontal offset between adjacent lines from the first and second fields. With the superficial published specifications of such domestic systems, it can be unclear whether this is due to meteor movement between fields or to shortcomings in camera, video recorder or frame grabber.

High-Definition TV (HDTV) systems are under development for broadcasting; these will have resolutions in the range 1000 to 1500 lines. It will be many years before domestic HDTV camcorders are available at economic prices. By this time, industrial digital cameras of 2000 lines and above are likely to be affordable.

Digital cameras

Cameras intended for industrial applications are not all designed round broadcasting standards. Typically characteristics are the following:

- The output format is unlike that of broadcast standards.
- Resolutions are generally high. Baseline systems are of 576×768 pixels (essentially the 625-line system). More common resolutions are from 1000 to 8000 pixels across.
- Aspect ratios are other than 4:3, often 1:1.
- There is a variety of frame rates, usually variable, typically from 25 to 1000 frames per second. Frame integration can often be asynchronously triggered.
- There is often no interlace.
- A full or partial frame output is often available (see Fast Window Mode, above).
- The output is often digitized; they include ADCs. These are termed Digital Cameras.

- Some are available with (typically, Peltier) cooling. This reduces thermal noise and would probably obviate image intensifiers.

These are far more suitable for the present task. They suffer from two disadvantages:

- The more advanced cameras are currently expensive (though baseline types are competitive with domestic camcorders). Suitable cooled models are in the 5000 to 10 000 USD price range.
- The increased resolution requires more processing speed.

Conventional astronomical CCD cameras

These are cooled digital cameras and might be thought suitable. Unfortunately, probably all have very slow readout times: several seconds to a minute are typical. They are designed for applications where exposures take many minutes, and where such slow readout is not a problem. In the present application, where a rate of several frames per second is needed, they are quite inadequate.

The computer

Once the unavailable component of such a system, the processor has now become one of the most easily obtained parts. In the last few years, affordable processors have reached the speeds required for these tasks. As with cameras, there are domestic and industrial options.

Host-based processing

A fast modern processor (Pentium or probably better) would be needed. The last limitation on speed was the frame-grabber, and these now appear to be fast enough [31]. The hard disk would be needed for the storage of results; thought should be given to the implications of running this all year round.

IBM PCs are relatively economical, being mass-production items. Their main advantage is that they are ready built.

Image processor boards

These are OEM equipment, that is circuit boards intended to be built into purpose-designed industrial equipment. They are now available with very high processing speeds. Since the system is built for the purpose, the designer has much fuller control over the hardware: this is their main advantage. Powering the hard disk up and down would be easy, an implementation with parallel processors relatively so. They might be easier than a PC to interface with a digital camera. Prices vary widely, but are broadly comparable with PCs.

Software

This has been the subject of much study elsewhere [12,14–18], and will not be addressed in depth here. One the one hand, the time to produce this software currently seems to be the determining factor on how fast these systems are being developed. On the other hand, the cost of production is essentially nil as, once written, is the cost of duplicating it for every station.

4. Sundry considerations

Infra-red sensitivity

The sensitivity of both image intensifiers [29] and CCD chips [30] extends appreciably into the near infra-red. This may improve the sensitivity of systems, as meteors may well emit useful amounts of infra-red. The front lens must be considered carefully, however, as few are designed to operate outside the visible spectrum. The focal length may be different at infra-red wavelengths, making focusing difficult [29].

If accurate magnitude measurements or light curves are required, the inclusion of infra-red is problematical. Magnitudes are normally expressed as V (visual) magnitude, which is defined to exclude infra-red [8,32]. Measurements of V magnitude require infra-red to be filtered out [32]. The V magnitude could not be derived from a magnitude including infra-red, as this would require knowledge of (among others) the temperature of the meteoroid.

Videotape

Several proposals involve the recording of meteors on videotape for subsequent playback and analysis. This brings problems of intensity resolution, as discussed above. Most such equipment has used, at best, good domestic-grade tape systems such as Video-8 or good quality VHS. S-VHS, for instance, has a claimed signal-to-noise ratio of 45 dB [33], limiting the resolution to about 7–8 bits and the dynamic range to about 5.6 magnitudes. As with video systems (see above), even professional systems will not be much better. The use of videotape will restrict the quality of the final results severely and should be avoided if possible.

Accurate timing

There may be a requirement for time-stamping of frames to an accuracy of one second or better (see above). This could be achieved easily by including a radio time code receiver in the equipment. Suitable services in Europe are MSF in England, DCF77 in Germany, and HBG in Switzerland; equivalents exist on other continents [34,35]. These services are on LF (low frequencies), which have continent-wide coverage areas. Receivers are cheaply available. GPS satellites also distribute a time service, but receivers are far more expensive.

Meteor detectors

Some conventional fireball patrol systems have implemented fireball detectors to provide a warning when a fireball occurred; these have tended to be ineffective [36]. The systems described here could act as such a detector, providing a secondary output to indicate when a fireball was traversing the sky. This could be used to trigger subsidiary equipment, for instance, film cameras providing better spatial resolution.

A reasonable arrangement might involve three such cameras, all with wide-angle lenses to view most or all of the sky. Two cameras would have diffraction gratings over the lenses to obtain spectra of the bolide. These gratings would be at right-angles to each other, so that one would produce a spectrum at 45° to the trajectory or better, facilitating accurate analysis. The third camera would have no grating. Since fireballs are rare, the cameras would not need motor drives. The system would warn the operators (for instance by land-line) to unload the cameras.

Equipment environment

The equipment needs to operate, unattended as far as possible, outside in all weathers. Existing *European Network* camera housings [3] will probably be adequate. Should more complicated arrangements be necessary, for instance, involving shutters to protect upwards-looking wide-angle lenses, there are well-established "robotic telescope" techniques [37] to provide such protection.

5. Existing photographic records

This paper has addressed stations intended for continuous real-time operation with cameras viewing the night sky. There are other related applications:

- There are many videotapes, often of meteor showers, awaiting analysis. Some analysis has been done manually, but the systems described here could easily be used to automate it.
- There is a large and growing backlog of still negatives produced by the *European Network*; sufficient labor to examine them all manually is not available. This needs systems differing from those discussed here in that (*i*) all processing is off-line, (*ii*) there is no real-time requirement, and (*iii*) the images are still frames with the entire meteor, not moving images. These are the subject of separate development work [38].

6. Discussion

Most of the foregoing is a coherent set of recommendations for requirements and implementation, but one dichotomy stands out. There are two possible forms of camera technology: domestic broadcasting standard and industrial digital cameras.

The advantages of quality are clearly with the latter. Their spatial resolution is already approaching that of good 35-mm film, whereas the resolution of TV systems is roughly that of good astronomical film about 5-10 mm across, equivalent to 8 mm cine or 110-size film.

Digital cameras are normally 12- or 16-bit, meeting the requirements. Domestic TV equipment is limited to about 8 bits, probably allowing detection but limiting the quality of light curves. Variable frame rate, lack of interlace, and optional cooling are also advantages of digital cameras.

However, such equipment is currently very expensive if of high specification. The real aim of this development is not to build a single station aided by a research grant, but to enable several dozen stations to be spread across Europe (and elsewhere). Since this research is, effectively, amateur-funded, the cost must be restricted. Fortunately, it seems good work is possible with equipment based on domestic video, even if the quality of the results is not as high as wished for. As the cost of digital cameras falls, they will presumably take over. Much of the development (in particular the software) will be generic and easily adapted from one system to the other.

It seems unlikely that HDTV systems will ever be contenders.

7. Conclusion

Automated systems for the regular observation of fireballs and normal meteors have been under active development for the last few years; the system design presented here is another stage in the process. The requirements discussed probably represent a reasonable target attainable on the five-year timescale, with a large subset possible almost immediately. The implementation outlined above is one possible approach, with many optional facets discussed.

Systems based on broadcast television standards must likely be implemented first, with higher definition systems based on industrial digital cameras being added when prices fall significantly.

Finally, photographic meteor records have hitherto been produced manually and have been relatively rare: astronomers have tended to be data-starved. When the systems currently under development become common, astronomers may be overwhelmed by data. Some form of automated analysis may be needed to analyze the trajectories in the computer images, maybe even building a database for statistical analysis.

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1997 α-Aurigids from Poland

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We present the results of 119 hours of visual observations made by Polish observers during the activity of the α-Aurigid shower. Based on 150 magnitude estimates of meteors from this stream, we obtained a population index $r = 2.81 \pm 0.05$. The population index of 860 sporadic meteors was $r = 3.33 \pm 0.04$. Maximum activity with ZHR $= 13 \pm 3$ was noted at $\lambda_\odot = 158^\circ\!.7$. The radiant picture computed with the RADIANT software clearly shows a double structure with one component connected with the α-Aurigids and the second one with the Perseids.

The α-Aurigid stream was discovered by C. Hoffmeister and A. Teichgräber during the night of August 31-September 1, 1935. Activity of the stream exceeded 30 meteors per hour, and the radiant was at $\alpha = 84^\circ\!.2$ and $\delta = +42^\circ\!.0$. At the present time, we already knew that the meteors from this stream are observable from August 25 to September 5, with a clear maximum occurring on August 31 or September 1 ($\lambda_\odot = 158^\circ\!.6$). The coordinates of the radiant are almost identical to these obtained by the discoverers. The diameter of the radiant is about 5°, and its daily drift is $\Delta\alpha = +1^\circ\!.1$ and $\Delta\delta = 0^\circ\!.0$. The α-Aurigids are very fast ($v_\infty = 66$ km/s, [1]). At maximum, ZHRs are around 10, but they occasionally rise to 30–40 (e.g., in 1935, 1986, and 1994).

Till this year, observers of the *Polish Comets and Meteors Workshop* (*CMW*) have never obtained a sufficient amount of data to analyze the activity of the α-Aurigid shower, the main reason certainly being the short activity period of the shower. A few cloudy nights suffice to make any observational actions impossible. Additionally, many observers stop their activity around this time, and take some rest after the Perseid campaign.

The year 1997 was fortunate for our members. The Last Quarter Moon on August 25 and the New Moon on September 3 were very favorable. Also the weather conditions were very good. Only two nights lack observations: August 29-30 and September 5-6. During other nights, the conditions were very good with the limiting magnitude never below +5.0 and often over +6.0.

During the period August 25–September 5, 1997, a group of 14 Polish observers associated in the *CMW* totaled over 119 hours of effective observing time and recorded 150 α-Aurigids and 860 sporadic meteors. The list of our observers with their effective time and the number of α-Aurigids, respectively sporadics, seen is presented below:

> Tomasz Fajfer (32^h00^m; 51; 222), Marcin Gajos (17^h00^m; 15; 123), Maciej Kwinta (13^h00^m; 11; 55), Jarosław Dygos (10^h30^m; 1; 44), Maciej Reszelski (7^h00^m; 19; 107), Krzysztof Socha (7^h00^m; 2; 83), Robert Szczerba (5^h35^m; 5; 56), Marcin Konopka (5^h00^m; 9; 41), Konrad Szaruga (4^h51^m; 10; 13), Cezary Gałan (4^h43^m; 14; 51), Krzysztof Wtorek (4^h30^m; 6; 13), Michał Jurek (4^h00^m; 1; 19), Arkadiusz Olech (3^h00^m; 5; 26), and Andrzej Skoczewski (1^h00^m; 1; 7).

Magnitudes were estimated for all observed α-Aurigids and sporadics. The magnitude distributions are presented in Table 1. From these distributions we obtained the values of the population index r. For the α-Aurigids, $r = 2.81 \pm 0.05$ was found, and, for the sporadics, $r = 3.33 \pm 0.04$.

Table 1 – Magnitude distributions of the 1997 α-Aurigids and corresponding sporadics.

Magnitude	−4	−3	−2	−1	0	1	2	3	4	5	6	Tot
α-Aurigids			1	2.5	6	12.5	25	42	41	16.5	3.5	150
Sporadics	0.5	1	3	9	28.5	68	127.5	226	241.5	134.5	20.5	860

Knowing the population index r, and assuming a zenith exponent $\gamma = 1.0$, we can compute mean ZHR values for each night. The results are shown in Figure 1. One can see that the maximal activity with ZHR $= 13 \pm 3$ occurred on the night of August 31-September 1, which corresponds to $\lambda_\odot = 158^\circ\!.7$. This is in very good agreement with activity observed in recent years [1].

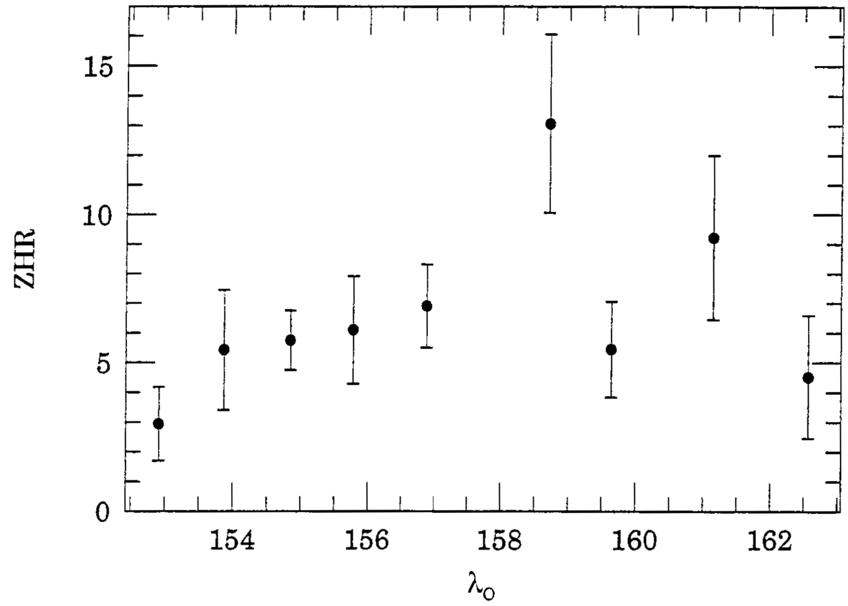

Figure 1 – ZHR profile of the 1997 α-Aurigids.

During the activity period of the α-Aurigids in 1996 and 1997, *CMW* observers have been plotting the meteors onto gnomonic charts of the *Atlas Brno 2000*. The total number of plotted meteors is 608.

The equatorial coordinates of the start and end points and the velocities of these meteors were put into the RADIANT program [2]. We computed the radiant probability map using the following parameters: geocentric velocity $v_\infty = 66$ km/s, maximum distance of the meteors 55°, angular velocity in the range 16°/s–30°/s, and daily drift $\Delta\lambda = 1{.}^\circ0$.

The resulting radiant picture is presented in Figure 2.

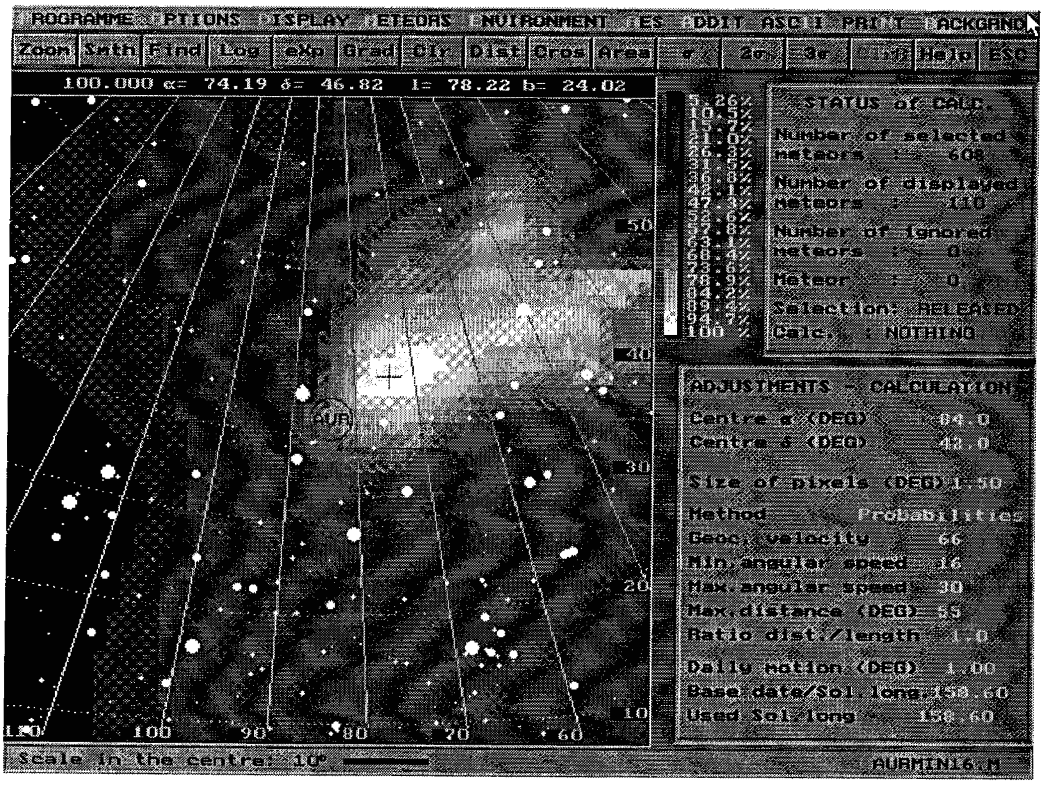

Figure 2 – Radiant picture of the α-Aurigids obtained with the RADIANT software.

One can see that the radiant position obtained from our sample is shifted in comparison with previously known coordinates. One possible reason for this is the fact that, during the August and September nights, the radiant of the α-Aurigids rises around local midnight, and the meteors are observed only at one side of the radiant. Another possible reason may be that some late Perseid activity may still be detectable during the α-Aurigid activity period.

To check this latter possibility, we recomputed our sample, changing the geocentric velocity from $v_\infty = 66$ km/s to $v_\infty = 59$ km/s (the geocentric velocity of the Perseids), and the angular speed from 16°/s–30°/s to 14°/s–30°/s. The result is presented in Figure 3. One can clearly see the double structure of the radiant with one component certainly connected with the α-Aurigid meteors and the second one probably with the late Perseids.

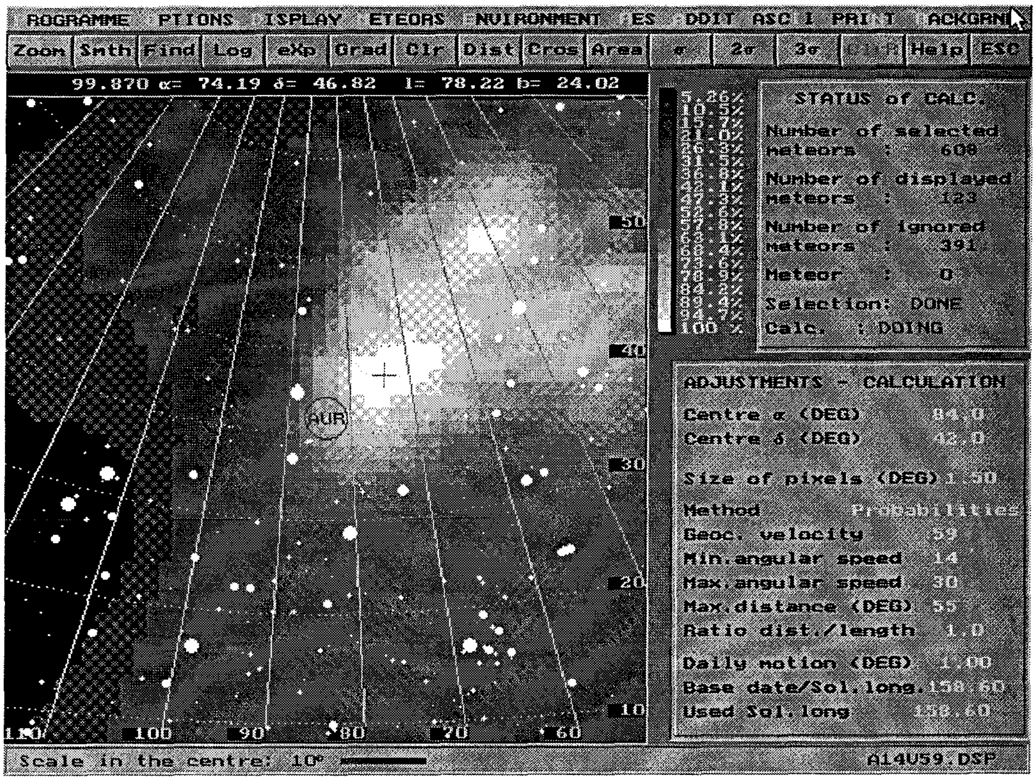

Figure 3 – The recomputed radiant picture. A double radiant becomes visible; the northern one may be due to late Perseid activity.

Acknowledgments

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We are grateful to Marcin Gajos for his help with data input, and for producing the figures.

References

[1] J. Rendtel, R. Arlt, R. Koschack, A. McBeath, P. Roggemans, J. Wood, in *Handbook for Visual Meteor Observers*, J. Rendtel, R. Arlt, A. McBeath, eds., IMO, 1995, p. 126.

[2] R. Arlt, *WGN* 20, 1992, p. 62.

Several other articles, among them observational results on the June Bootids, Draconids, and Leonids, which are still pouring in, had to be postponed to the February 1999 issue. We apologize for the delay, but, at the same time, we are convinced you will understand, as this is a record-breaking volume of WGN with regard to number of pages! (Ed.)

International Perseid and Solar Eclipse Observing Expedition

Kamen Bryag, Bulgaria, August 5–15, 1999

Eva Bojurova and Valentin Velkov

The total solar eclipse on August 11, 1999, is looked forward to by all European amateur and professional astronomers. The visibility zone of the total eclipse goes across the north-eastern part of Bulgaria—a region with an ancient history and natural beauty, where the climate is very pleasant and the probability for clear skies in August is very high.

By a lucky chance, the time of the total solar eclipse almost coincides with the period of the maximal activity of the Perseids—perhaps the most popular meteor shower. Making use of this unique opportunity, the *Astronomical Observatory and Planetarium "Nicholas Copernicus"* in Varna, Bulgaria, together with the *Astroclub "Canopus,"* and with the cooperation of the *International Meteor Organization*, organize an expedition to observe the Perseid meteor shower maximum and the total solar eclipse of August 11 in the village of Kamen Bryag, from August 5 to 15, 1999.

Location of the expedition camp. The village of Kamen Bryag is situated on the Black Sea coast, about 70 km to the north of Varna—the largest Bulgarian seaport. Very close to the village is the exceptionally beautiful, preserved area, called "Yaylata." It is a wild place with huge rocks up to 30–40 m high, a lot of caves, some of them under water, rare flowers and animals, and ancient ruins. There is natural gas coming from holes in the ground and burning all the time. The sea water is very clear in Kamen Bryag and, sometimes, when swimming during the night, one can see myriads of luminescent microscopic living beings.

History. The most ancient civilization having left its traces in this region dates from 5000 BC. The most ancient golden treasure known in the world, which was discovered near the Varna Lake and can be seen in the Varna Historical Museum, dates from almost the same time. Near Kamen Bryag, there are ruins of a Byzantine castle of the 5th or 6th century AD and tombs hewn into the rocks from the epoch of the early Christianity. Some remains of Antiquity are on the sea bottom now since the Black Sea changed its boundaries over the years. A lot of ships have sunk there, because of the dangerous sea streams and reefs. Legends are still alive about treasures hidden in the under-water caves.

Observing conditions. Kamen Bryag is a small village with simple houses and nice gardens, and friendly inhabitants, mostly old people. There is no sand beach, only rocks. That is why it is not visited by many tourists, even in summer. It is far from the noisy towns and sea-side resorts with their night lights. So, the astronomical observing conditions are excellent: dark skies and clear air. The horizon is completely unobstructed, especially to the east where the sea is. Kamen Bryag is about 10 km to the south of the central visibility line of the total solar eclipse on August 11, 1999. The central line goes almost exactly through the town of Shabla, also on the Black Sea. Weather forecast information can be obtained from the meteorological station in Varna and from a few other stations in the region. We are trying to ensure a way for quick crossing of the state border and going to Romania in case bad weather is expected for the day of the eclipse. According to the meteorological data for Varna, the average day-time high in August is 27° C and the average night-time low is 18° C. In August, the average number of days with rain is 1.5, the average number of days with fog is 0.8, and the average number of days with scattered clouds is 17. The probability for clear skies is 71%. We would only add that the temperature of the sea water is usually 23° C–27° C. Kamen Bryag is a lovely place for diving. Shabla and Kamen Bryag will be the main observing places for the amateur and professional astronomers who will come to Bulgaria for the total solar eclipse from a lot of foreign countries, so the participants in the meteor expedition will have the chance to meet many colleagues and interesting people.

Transport. Twice a day, there are buses traveling between the towns of Kavarna and Shabla, which have a stop in Kamen Bryag. Regular buses go between Kavarna and Varna. A special bus will be rented for the participants in the expedition if needed.

Accommodation. The participants in the expedition will be accommodated in private houses and in bungalows in the village for 5 DEM per person per night. All simplest living facilities—electricity, bathroom, hot water—will be available. By their choice, participants can stay also in tents. There will be two options for catering. The first one is an organized meal serving in a restaurant for 10 DEM per person per day (breakfast, lunch, dinner). The second one is individual purchasing of food in the shops of the village and preparing of meals. This will cost no more than about 5 DEM per person per day.

Registration form and payment. Every participant will have to pay his expenses himself during the expedition. A pre-payment of 50 DEM should be transferred to the Treasurer of the *International Meteor Organization*, Ina Rendtel (address and payment information on inside back cover). The pre-payment will cover the organizational expenses and part of the expenses for accommodation which has to be paid preliminary for reservation of the rooms. The deadline is March 15, 1999. Upon pre-payment, a registration form should be sent to the organizers: Eva Bojurova and Valentin Velkov, Astronomical Observatory and Planetarium "Nicholas Copernicus," P.O. Box 120, BG-9000 Varna, Bulgaria, tel. +359-52-222890, e-mail: `astro@ms3.tu-varna.acad.bg`.

Int'l Perseid and Solar Eclipse Observing Expedition

Kamen Bryag, Bulgaria, August 5–15, 1999

Registration Form

Each individual participant should fill out a form and return it to *Eva Bojurova and Valentin Velkov*, Astronomical Observatory and Planetarium "Nicholas Copernicus," P.O. Box 120, BG-9000 Varna, Bulgaria, e-mail: `astro@ms3.tu-varna.acad.bg`, as soon as possible, but no later than March 15, 1999.

Your registration will be guaranteed only after *IMO* Treasurer *Ina Rendtel* has received the pre-payment of 50 DEM.

Name: ______________________________

Address: ______________________________

____

____

Phone: ____________ Fax: ____________ E-Mail: ____________

I would like to stay in

- o a house or bungalow;
- o a tent.

I would like to have meals

- o organized in a restaurant;
- o prepared by myself.

I will travel to Varna

- o by train;
- o by plane;
- o by car.

For my observations, I would like to have the following technical equipment provided by the organizers:

____

I need the following information about the transport connections in Bulgaria:

____

Date and signature: ______________________________

This form should be sent to the organizers no later than March 15, 1999. A prepayment of 50 DEM should be transferred to the Treasurer of the *International Meteor Organization*, Ina Rendtel, Mehlbeerenweg 5, D-14469 Potsdam, Germany, e-mail: `treasurer@imo.net`, postal (giro) account number: 547234107 at Postbank Berlin, bank code: 10010010. No bank checks, please!

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