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WGN

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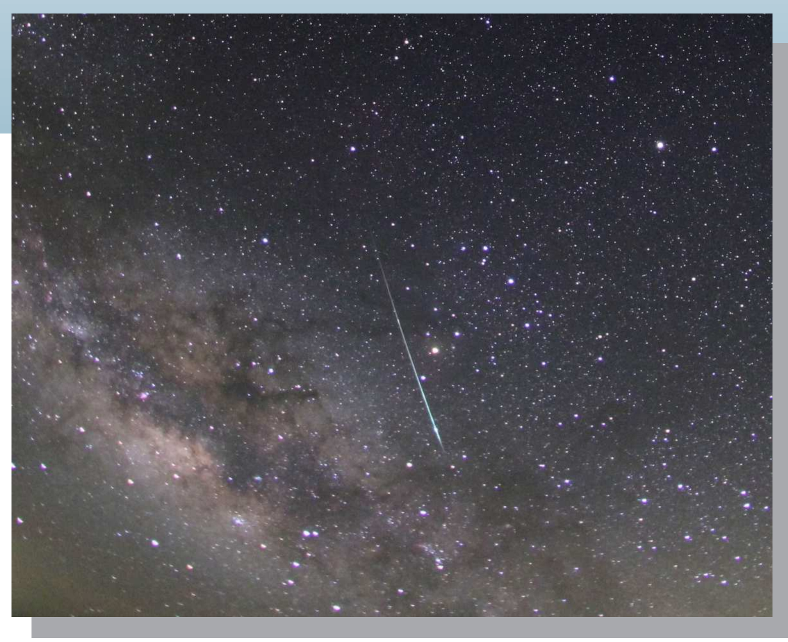

IMC announcement, report, and Proceedings abstracts
Perception and conception of a meteor shower
Cygnid-Draconid meteor shower complex
Meteorite from Apophis' orbit
June video meteors

ISSN 1016-3115

WGN Vol. 42, No. 5, October 2014, pp. 155 – 204

Administrative

Conferences

Meteor Science

Preliminary results

Front cover photo

This meteor was recorded from Observatorio del Teide, Izaña, Tenerife on 2014 May 29, at 23^h33^m UT (start of exposure). The photograph was taken with a Canon EOS 60Da, exposed for 4 minutes using a fisheye Peleng $f/d = 3.5$, $f = 8mm$. Photo courtesy: Jürgen Rendtel.

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

Legal address International Meteor Organization, Jozef Mattheessensstraat 60, 2540 Hove, Belgium.

Letter — Meteoroid streams, meteor showers

Jürgen Rendtel[1]

Among the many interesting and enlightening lectures during IMC 2014 in Giron both the observers' view and the modeller's views were well covered. The more we know about identifying meteoroid streams with parents on the one hand and to detect weak meteor shower radiants particularly from video data on the other hand, the more complex the image gets. I felt that at some point it really becomes difficult to describe or define what a meteor shower or a meteoroid stream is.

As long as the meteoroids released from a parent object form more or less an extended dust trail following or tailing the object, all seems easy or at least straightforward. As disturbances significantly broaden the distribution of orbits, it will become tricky. I do not refer to the orbits which form the outer regions of extended streams which make showers such as the Perseids or the Orionids traceable for more than six weeks or so. The images of Maria Hajdukova's talk about predictions of meteor showers from potential parent objects puzzled me in particular. Some objects such as 126P/IRAS or 102P/Shoemaker yield possible radiant positions scattered over essentially the entire sky. Another famous complex consists of the comet 96P/Machholz and the minor planet 2003 EH_1. Currently the complex is connected with six showers (Figures 1 and 2). Of course, the evolution towards a complex system of orbits (meteoroid streams) needs some time. From the observer's point of view it is impossible to distinguish, for example, during the Quadrantid peak, between meteoroids originating from either of the potential parent objects: one radiant, different origin and history. So do we speak about two meteoroid streams (referring to the parent objects) or about six (referring to the currently detectable shower radiants)? What do selection parameters such as the Southworth-Hawkins D criterion tell us? It is a description of the scatter of the stream's parameters at the moment of the observation, not more and not less.

Seen the distribution of possible radiants from comets 126P (Figure 3) and 102P (Figure 4) one can expect radiants at almost every point in the sky. Since such a situation will certainly occur also in the case of other parent objects, what do countless radiants tell us about the structures in the interplanetary matter? Jupiter family streams see frequent disturbances leading to dust trails which are (relatively) quickly filling a nearly spherical region.

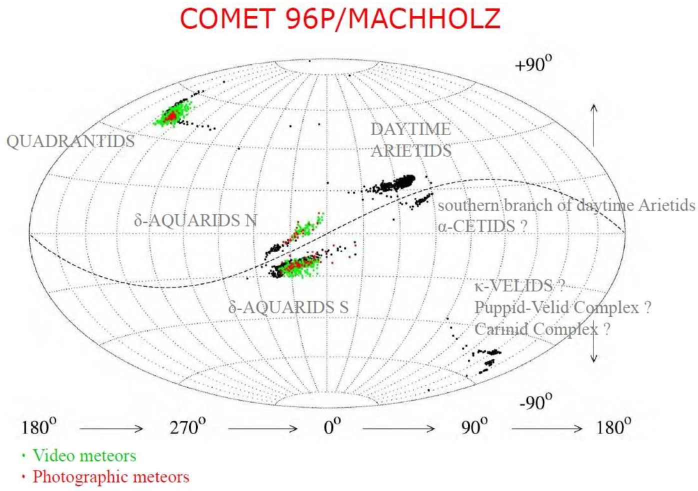

Figure 1 – Meteor showers currently associated with comet 96P/Machholz (Neslusan et al., 2014).

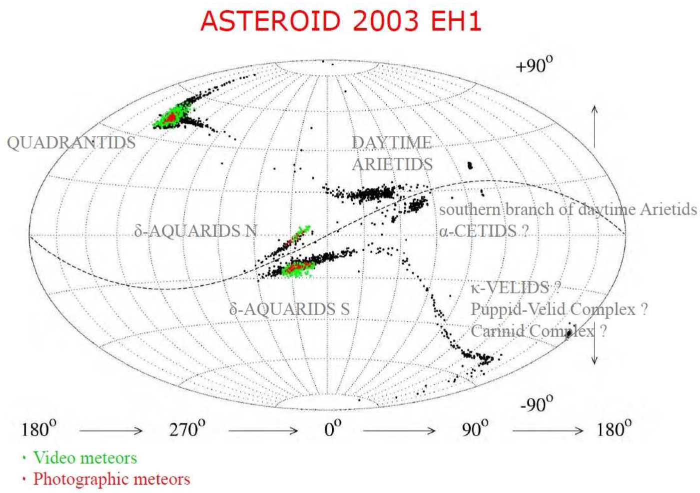

Figure 2 – Meteor showers currently associated with the minor planet 2003 EH_1 (Neslusan et al., 2014).

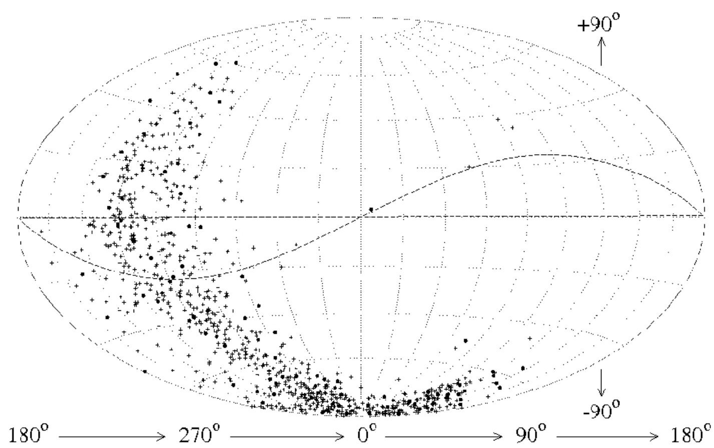

Figure 3 – Result of modelling radiants of the meteoroid stream originating from comet 126P/IRAS (Neslusan et al., 2014).

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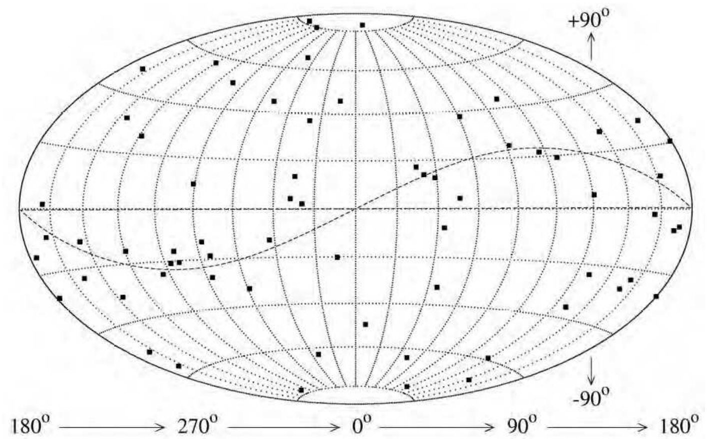

Figure 4 – Radiants caused by meteoroids originating from comet 102P/Shoemaker (Tomko, 2013) essentially distributed over the entire sky.

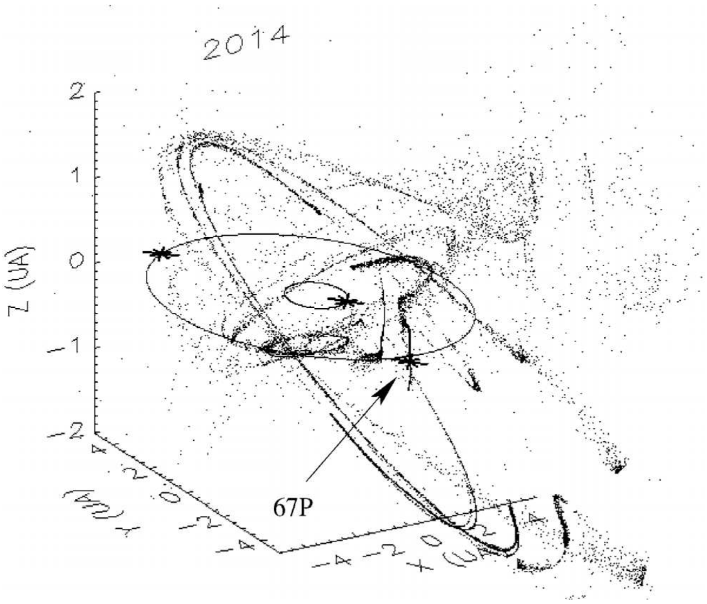

Figure 5 – Meteoroid stream of comet 67P/Churyumov-Gerasimenko (Vaubaillon et al., 2006) at the time of the rendezvous with the Rosetta spacecraft. The structure of the stream is a consequence of the close encounter of the comet with Jupiter in 1959.

Jeremie Vaubaillon showed examples of such Jupiter family meteoroid streams (Figure 5).

One complex mainly concentrated towards the ecliptic is the Antihelion source. Of course, each meteoroid has its specific parent, but after some time the relation becomes difficult to prove. Only for freshly released meteoroids and comparatively concentrated streams a one-by-one relation can be observed. So what do we learn from a list of numerous ecliptical radiants? Can we indeed resolve various subcomponents of the Antihelion sources if they do not represent material from distinct objects staying closely together? Further, we know about the limited lengths of dust trails and the (quasi-)periodic nature of meteor showers. In this sense, our current (working) lists of meteor showers represent the recently observed events. Known showers disappear (such as the famous Andromedids), others become visible (the Geminids in the 19th century), are limited to outburst events (the Aurigids, alpha Monocerotids, September epsilon Perseids to mention a few). Weak showers seem to have occurred for some time (June Lyrids, February Aurigids) and, as another example, the delta Aurigids may have been more prominent in the 20th century (since Drummond (1982) listed a number of bright photographic meteors which allowed him to describe the shower by orbital parameters).

This brief compilation is far from being complete as it completely ignores radar results. The paper of Masahiro Koseki (2014) in this issue also deals with the issue of defining meteor showers and meteoroid streams. Seen the currently available data the definition certainly is not easier than in Denning's or Hoffmeister's time — perhaps it is even more complicated.

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IMO bibcode WGN-425-rendtel-letter NASA-ADS bibcode 2014JIMO...42..155R

From the Treasurer — IMO Membership/WGN Subscription Renewal for 2015

Marc Gyssens

We invite all our members/subscribers to renew for 2015. The fees are as tabulated below. We are happy that we can offer WGN at the same cost as last year. We also continue to offer an electronic-only subscription at a reduced rate.

IMO Membership/WGN Subscription 2015				
Electronic + paper with surface mail delivery:		€26		US$ 39
Electronic + paper with airmail delivery (outside Europe only):		€49		US$ 69
Electronic only:		€21		US$ 29
Supporting membership:	add	€26	add	US$ 39

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

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

When you renew, give a few minutes of thought to becoming a **supporting member**. As you may know, there is an IMO Support Fund. With this Support Fund, we support to meteor-related projects. Our ability to provide this service to the meteor community depends primarily on the gifts we receive from supporting members!

Another way to help meteor workers with limited funds is to offer them a gift subscription.

We already thank all our members that will renew for their continued trust in our Organization!

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

IMO bibcode WGN-425-gyssens-renewals NASA-ADS bibcode 2014JIMO...42..157G

Letter — The CMN catalogue of orbits for 2012

Croatian Meteor Network [1]

The Croatian Meteor Network (CMN) has released its catalogue of orbits for 2012. The catalogue contains 9774 orbits. It can be accessed from the CMN download page:
`http://cmn.rgn.hr/downloads/downloads.html`

IMO bibcode WGN-425-cmn-letter NASA-ADS bibcode 2014JIMO...42..157C

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Conferences

International Meteor Conference 2014 report

Auriane Egal [1]

Received 2014 October 12

In September 2014, the 33rd session of the International Meteor Conference took place in Giron, France, in a charming cottage in the Jura mountains. This event was my first experience of international conferences, given the fact that I am just arriving in the meteors world. Forming unofficially part of the local committee organization, I had the opportunity of talking with the most part of the participants, to assist to all the talks given during these few days, and to help organizing the arriving and the departure of the people who needed it. After four intensive days of meetings and science, *WGN* asked me to write my impressions as a first time participant at the IMC.

My first thought then was that it would be quite hard to describe such an unusual event. I do not exactly know what I was expecting when we left Paris to come to Giron. I was a little stressed by the event, thinking it would be a kind of baptism that any researcher has to pass, and I was a bit scared of giving my first talk in English and not in a language more familiar to me. It is quite impressive, when you go to your first international conference, to know that you will meet the researchers who are authors of articles you are studying, given they have laid the foundations of your future work. So I imagined a really formal encounter, with serious people talking of nothing else but science.

I could not be more wrong.

We had just come down from the car when we were served a glass of white wine for an aperitif (if you are wondering where stereotypes about French people come from, take a walk in the region!). It was a day before the start of the IMC, but some participants were already there. Because some of them came with an unusual means of transport (like Alan, who rode from Britain on an old motorcycle that had raced the Paris-Dakar) or from far away, it was difficult for all the participants to arrive just at the beginning of the conference, and we therefore had the pleasure to meet ten or twenty amateurs and professionals in a reduced committee.

The next day, we focused our efforts on welcoming people from a huge diversity of countries. People came from Poland, Netherlands, France, Croatia, Britain, United States, Spain, Russia, Morocco, Belgium, and so many other places. The dinner, rich of cheese and wine (stereotypes again!), was the first occasion to mix all these different cultures and trainings. We spoke about music, literature, travels, science of course, and about the work exchanges we could do. It was a very friendly atmosphere, and I really enjoyed the people I met there. For those who were not too tired, this festive ambiance continued in the bar for a while. I then realized the important variety profiles of the IMC 2014 members; there were a lot of radio amateurs and professionals, talking about their new detection networks all around the planet, a lot of students, beginning a PhD like me or just coming by interest, and a respectable number of professionals working in various areas in the field of meteors.

Figure 1 – The author having her talk at the IMC. Credit: Dominique Richard.

The talks took place the third day, and the following days in the morning. A lot of pieces of meteor research were presented, like the new camera networks (like the FRIPON project in France) operational soon, the advances in radioastronomy, the identification of meteor showers and their possible parent bodies, and the new software of meteor detection available. I personally talked about a new method of computation of the meteor velocity, working on the data provided by the CAmera for BEtter Resolution NETwork project (France). I was happy to see the interest aroused by my presentation; during two days, I had the occasion to talk about it with a lot of persons who wanted to give me some advices about the continuation of this work, or were just interested by using this velocity computation method for their own work. I was surprised by the availability and the kindness of everybody to discuss about my results and my problems, and I hope some of the travels planned at the IMC to share our work with many researchers will happen soon.

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NASA-ADS bibcode 2014JIMO...42..158E

Figure 2 – The IMC 2014 group photo in front of the hostel. Credit: Lucie Maquet.

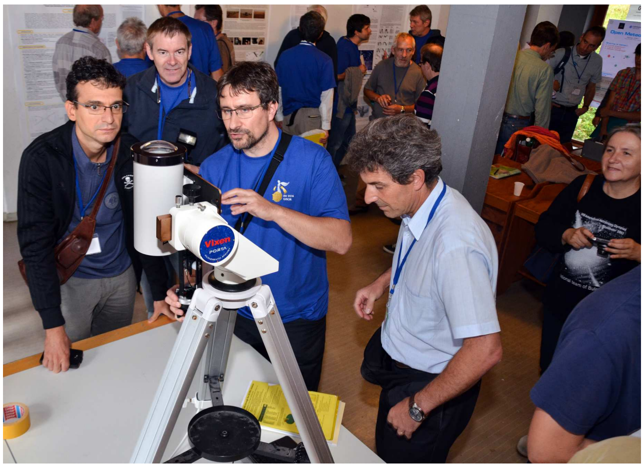

Figure 3 – One of the French BOAM allsky cameras being displayed in the poster room. Participants, from left, are Radu Gherase (Romania), Bernd Klemt (Germany), Jouin Stéphane (France), Jonas Schenker (Switzerland) and Eva Bozhurova (Bulgaria). Credit: Dominique Richard.

After those busy days, we spent the evening at the bar to discuss the works presented during the previous sessions and to build future projects together. It was also the occasion to have fun and relax; some participants brought their musical instruments, and the evenings have passed singing the Beatles, Proud Mary, or improvisations like "the IMC blues". So we were far from the idea of the cold, serious conference I was expecting!

It is sometimes difficult to live surrounded by people all day and all night, with no moment to stay alone and quiet. But when the IMC ended, I felt really sad to let leave the incredible persons I met there. Because we are living all around the world, we know that maybe it will be difficult to keep in contact with everybody, especially with the persons who work in an area slightly different from ours. That is why some of us expect impatiently the next edition of the IMC, to confirm the evolution of the meteor science and to renew the friendship links created in Giron. When I came back in Paris, I felt a little stupid to have feared this international encounter of meteor passionates, while this event will stay an excellent memory and a great start for my PhD.

See you next year in Austria!

Auriane EGAL, IMCCE (Observatoire de Paris), starting a PHD with Jérémie Vaubaillon as a director about the exploitation of the CABERNET project data and the identification of parent bodies of meteor showers.

First announcement of the International Meteor Conference 2015

Thomas Weiland

The 2015 International Meteor Conference will be held at Mistelbach, Austria. The conference will be organized by the *Wiener Arbeitsgemeinschaft für Astronomie (Vienna Astronomy Association) – WAA* and will take place from 2015 August 27-30.

Mistelbach represents a small town (11 000 inhabitants), some 45 km north-north-east of the capital of Austria, Vienna, and 25-30 km from the Czech-Slovakian border. It is thus easily accessible for most European residents. Participants arriving by plane can reach it via Vienna.

The conference will be held at the *Landwirtschaftliche Fachschule* (Agricultural School), not far from the town's centre. The school has no large conference room itself, but the sports hall can be used as such. With its capacity of 96 beds (32 triple rooms) the school has enough space for housing most of the participants. The remaining will be accommodated on private basis in Mistelbach and nearby villages. All rooms at the school offer basic facilities with shower / WC. Breakfast (buffet), lunch and dinner (two menus each) will be served at the school's dining room.

On Saturday afternoon an excursion to the *Naturhistorisches Museum Wien* (NHM) is planned. This Natural History Museum of Vienna hosts the largest and probably most important meteorite collection in the world (it contains about 7000 objects, most of them historical falls, of which about 2200 are shown to the public). Therefore a guided tour with a meteorite expert will be offered. Special attention is paid to a recently donated lunar rock sample and the purchased Martian meteorite Tissint, whose fall was observed by nomads in Morocco in 2011. It is the fifth documented fall of a Martian meteorite and the second largest one from Mars ever found. With a mass of nearly 1 kilogram the museum owns the biggest single piece of that find.

In the evening we will return to Mistelbach and visit a *Heuriger*, a typical wine restaurant, which is, with respect to its socializing effect, comparable to the English Pub to some extent. The Heuriger lies very close to the Agricultural School. There a special closing dinner (cold buffet) will be served.

Before 2015 May 31 the standard registration fee is €150 and €180 after then. The registration deadline is 2015 July 15. Non-accommodated participants are charged €100. Private accommodations are booked by the LOC, but have to be paid together with the fee in advance. The LOC can be contacted via E-Mail on `imc2015@imo.net`. Additional information about the 2015 IMC will be soon available at the IMO website (`http://www.imo.net/imc2015`). This is the first time that an IMC will take place in Austria. Hope to see you next year there!

IMO bibcode WGN-425-weiland-imc2015 NASA-ADS bibcode 2014JIMO...42..160W

Details of the Proceedings of the International Meteor Conference, Poznań, Poland, 22–25 August 2013

Marc Gyssens, Paul Roggemans, and Przemysław Żołądek, editors

Following are the abstracts of all the contributions published in the IMC 2013 Proceedings. Those who attended the Conference have either received the Proceedings at the IMC 2014 in Giron, France, or will receive them shortly in the mail. Others can order them from the International Meteor Organization: details are in the lower half of the inside back cover of this Journal and on the IMO website `http://www.imo.net/imo/publications`.

Twenty five years of IMO (1988–2013)

Paul Roggemans

The 25th anniversary of the creation of the International Meteor Organization in 1988 was remembered during the General Assembly at the International Meteor Conference. An overview was given of the evolution of amateur meteor astronomy and how this led to the creation of a formal international cooperation.

IMO bibcode WGN-425-gyssens-proceedings2013 NASA-ADS bibcode 2014JIMO...42..160G

Development of the CAMS Spectrograph (CAMSS)

Pete Gural and Peter Jenniskens

The Cameras for Allsky Meteor Surveillance (CAMS) has been recently expanded to include a CAMS Spectrograph in the meteor collection system. From the amateur meteor community's point of view, spectroscopy is a reasonable and affordable capability that can make a valuable contribution to meteor composition analysis. When coupled to a multi-station network of cameras, the orbital information identifies the parent body, thus providing compositional information of those comets or asteroids known to produce meteoroid streams. The low cost of an objective grating and simple equipment configuration makes it fairly easy to add a spectrographic camera to an amateur-run CAMS network.

A new software application for all-sky camera networks

Chris Peterson

We report on a new software system for managing all-sky cameras intended for meteor analysis. The software is split into a client component local to each camera, and a central server component which each camera supplies with data. The software is highly modular and major components are open source. Key analysis components consist of published, publicly available code.

Update on IMCCE meteor activities

Jérémie Vaubaillon, Regina Rudawska, Lucie Maquet, Rachel Soja, François Colas, Sylvain Bouley, Brigitte Zanda, Pavel Koten, Diane Berard, Alexandre Clovirola, and Maxime Mougeot

An overview is given of recent meteor-related activities of the IMCCE.

EDMOND Meteor Database

Leonard Kornoš, Jakub Koukal, Roman Piffl, and Juraj Tóth

A next version of the video meteor orbit database EDMOND (European viDeo MeteOr Network Database) is presented. The database is a result of the cooperation and data sharing among several European video networks. The IMO VMN (Video Meteor Network) data are also included. The latest version (v. 4) of the database contains 83 369 orbits selected by conservative criteria.

Meteor showers identified from one million video meteors

Sirko Molau

We present results from the latest meteor shower search in the IMO Video Meteor Database based on over one million single-station meteors. For the first time, a bi-directional match between individual radiants found in the IMO data and the MDC working list was carried out. An overall of 106 meteor showers from the MDC list could be confirmed, plus 23 streams belonging to the Antihelion Source. We found a number of inconsistencies in the MDC list, where two or three different showers are the same meteor shower according to our data. Based on these findings, we propose a number of improvements to the current MDC list.

CAMO—the Canadian Automated Meteor Observatory

Peter G. Brown

The Canadian Automated Meteor Observatory, located in Southwestern Ontario became operational in 2009. Its goal is fully automated meteor detection and partial analysis. In this summary, the system is described, and an overview is given of some initial results.

Romanian ALLSKY Network—a systematic approach for meteor detection

Tudor Georgescu, Ana Georgescu, Ileana Ghiță, Sabina Potlog, Cezar Leșanu, Mirel Birlan, Dan Savastru, Cosmin-Karl Banică, and Claudiu Drăgășanu

Romanian amateur astronomers have an important and long-term activity of visual observations of meteors and meteor showers. Records and reports to the International Meteor Organization are mainly due to visual observations on Romanian territory. Our main objective is to deploy a network of stations which will monitor meteor phenomena. The Romanian All-Sky Network (acronym ROAN) will be able to monitor meteors in both visual and radio domain, based on the infrastructure developed on the ongoing concept and technology inside a consortium lead by Elcos Project Ltd. Several scientific approaches will be studied, such as detection of simultaneous events on two/multiple optical detectors, establishing the radio Doppler speed of meteors, targeting the phase of dark-flight of the object, and matching the optical and radio tracks into one single event.

One year of United Kingdom Meteor Observation Network

Richard Kacerek and Peter Campbell-Burns

United Kingdom Meteor Observation Network (UKMON) began data gathering in April 2012 with its first station placed in Ash Vale, Surrey. This contribution shows our progress of building a network in the UK during one year.

Performance of Watec 910 HX camera for meteor observing

Francisco Ocaña, Jaime Zamorano, and Carlos E. Tapia Ayuga

The new Watec 910 HX model is a 0.5 MPix multipurpose video camera with up to ×256 frames integration capability. We present a sensitivity and spectral characterization done at Universidad Complutense de Madrid Instrument Laboratory (LICA). In addition, we have carried out a field test to show the performance of this camera for meteor observing. With respect to the similar model 902 H2 Ultimate, the new camera has additional set-up controls that are important for the scientific use of the recordings. However the overall performance does not justify the extra cost for most of the meteor observers.

Video meteor observations at Nikolaev Astronomical Observatory—developed software and results

Nikolay Kulichenko, Oleksandr Shulga, Yevgen Kozyryev, and Yevgeniya Sybiryakova

Based on experience of real time video stream processing for low Earth orbit satellites, observation software for automated meteor detection was designed at Nikolaev Observatory. Video meteor observations started at Nikolaev Observatory in 2011. Several cameras with a small field of view of 3–7°, are used in double-station mode. 11 double-station meteors were obtained during 5 months of observing from two station with two camera's at each station. There are plans to develop software for heliocentric meteor orbit calculation from double station observations.

Update on the Colorado All-Sky Camera Network

Chris Peterson

The Colorado All-Sky Camera Network was established in 2001, and continues to collect nightly meteor video data. This report provides an updated summary of the primary data available for analysis, and details of analyses performed recently.

Detection of meteors by the MAIA system

Pavel Koten, Petr Páta, Karel Fliegel, and Stanislav Vítek

Meteor Automatic Imager and Analyser (MAIA) is a new system which was developed for automatic video observation of meteors. An important part of the data processing pipeline is the detection of meteors in video sequences. Because the system can produce up to 61 frames per second, it was necessary to implement a very effective method for this task. The first data suggest that the new system is able to effectively record and detect meteors. Comparison with an older analogue system shows that the astrometric precision is similar whereas the photometric calibration is better.

An introduction to radio meteor astronomy

Cis Verbeeck

While radio observations are complementary to video and visual observations—allowing smaller particles to be observed with large statistics regardless of weather and time of day—they are a much less direct way of observing meteors. Hence, radio observations are more difficult to interpret. This paper aims to provide a basic overview and understanding of radio meteor observations and their benefits to meteor science, and is intended for meteor workers that are not involved in radio observations or are relatively new to the field.

New trends in meteor radio receivers

Jean-Louis Rault

Recent progresses in low cost—but performing—SDR (software defined radio) technology presents a major breakthrough in the domain of meteor radio observations. Their performances are now good enough for meteor work and should therefore encourage newcomers to join the meteor radio community.

The global radio η-Aquariids 2013

Christian Steyaert

Most of the years, the η-Aquariids are not very conspicuous for (radio) observers in the Northern Hemisphere. In 2013, a strong return was observed, confirming a last minute prediction of old dust trails that approached the Earth.

Progress on radio astronomy in Munich, Germany

Giancarlo T. Tomezzoli

The start of the EurAstro radio astronomy project in Munich coincided with the decision of the BRAMS of the Belgian Institute of Spatial Aeronomy to build a network of radio stations for radio observations of meteor showers, about three years ago. We present a review of the development and the results of the EurAstro radio astronomy project.

Radio meteor observations at Nikolaev Astronomical Observatory—developed software and results

Vasyl Vovk, Oleksandr Shulga, Yevgen Kozyryev, Felix Bushuev, and Nikolay Kalyuzhny

We started radio meteor observations at the Nikolaev Observatory in 2010, using the signal from an FM station in Kielce (Poland). The software for automated meteor detection by FM radio signals using spectral analysis was developed at the Nikioaev Observatory. We present ideas on how to improve observation techniques and to get more information about radio meteors. The methods to use the data of radio observations are being developed.

Relation between meteor head echo mass-velocity selection effects, shower mass distribution indices, and mass threshold of the MU radar

Johan Kero

Observations are described that led to a study of the relationship between the head echo mass-velocity selection effect, the mass distribution indices of the Geminid and Orionid meteor showers, and the mass threshold of the MU radar, published by Kero et al. (2013).

The Canadian Meteor Orbit Radar (CMOR): system overview and recent work

Robert J. Weryk

A brief description is given of the Canadian Meteor Orbit Radar (CMOR), and the results of some recent work with it are summarized.

Meteoroid stream modeling at the University of Western Ontario

Abedin Y. Abedin and Paul A. Wiegert

Observational and numerical studies on meteoroid stream modeling are described. One such study indicated that the Quadrantids may be no older than 200 years if associated with 2003 EH_1. Another study links the Andromedid activity witnessed in 2011 with meteoroids ejected from the now defunct comet 3D/Biela in 1649, i.e., prior to the Comet's discovery in 1772.

The interesting case of the ι-Cygnids (525 ICY)

Željko Andreić, Damir Šegon, Denis Vida, Filip Novoselnik, and Ivica Skokić

One of the showers recently reported by the Croatian Meteor Network, the ι-Cygnids (525 ICY), is described. From the 40 available orbits, the mean orbit of the shower and some other parameters were obtained. The ι-Cygnids were detected from October 16 ($\lambda_\odot = 203°$) to November, 19th ($\lambda_\odot = 237°$), with a slightly higher activity around October 31 ($\lambda_\odot = 218°$). The possible parent body is Asteroid 2001 SS_{287}, with $D_{SH} = 0.16$, indicating that 525 ICY is probably asteroidal in origin. However, a few more asteroids have $D_{SH} < 0.20$, so the question of the parent body requires a more detailed study to be solved. In depth analysis of IAU MDC has found two showers that are quite similar to the 525 ICY: 83 OCG and 282 DCY. By gathering additional data outside the IAU MDC, we found out that 282 DCY is a rediscovery of 83 OCG. Also, 525 ICY is identical to 83 OCG, but this fact was not recognized before, probably due to incorrect coordinates for the 83 OCG radiant in the IAU MDC database and the lack of information about the activity period of the showers in the IAU MDC database.

Observed and real orbital dispersion within meteoroid streams

Mária Hajduková Jr.

The present paper, based on a statistical analysis of orbits obtained from video meteors, shows the orbits' distribution within the meteoroid streams with heliocentric velocities close to the parabolic limit. The high proportion of hyperbolic orbits among the corresponding meteor showers was used to deduce the contribution of the real orbital dispersion within the stream, because an excess of a heliocentric velocity of a stream meteoroid over the parabolic value can be regarded entirely as the result of measuring errors. Four meteor showers, April Lyrids, Perseids, Orionids, and Leonids, were selected for this analysis. The orbital dispersion within the investigated meteoroid streams, based on the distribution of their reciprocal semimajor axes, obtained from different catalogues, were compared. It was shown that the major part of the observed differences in the semimajor axes within meteoroid streams from the European Video Meteor Network data is indeed due to measuring errors.

The Geminid stream modelling: lessons of history

Galina O. Ryabova

Earlier mathematical models of the Geminid meteoroid streams (1982–1986) are discussed.

Meteor shower search in the CMN and SonotaCo orbital databases

Damir Šegon, Peter Gural, Željko Andreić, Denis Vida, Ivica Skokić, Korado Korlević, and Filip Novoselnik

The following article is a summarized version of a paper published for the *Meteoroids 2013* Conference on the topics of meteoroid-stream parent-body search and new stream discovery in which further details and published findings can be obtained (Šegon et al., 2014).

The analysis of casual video records of fireballs

Jiří Borovička

An increasing number of fireballs is being recorded casually, e.g., by security cameras or dashboard cameras. In some cases, these records may have high scientific value. Positional calibration must be, however, done before any casual record can be used for fireball trajectory determination. Here, I describe a calibration method based on stellar imagery. Practical hints for taking the calibration images are given, and the required precision of finding the site, where the original record was taken, is discussed. Formulae for converting the image pixel coordinates to astronomical coordinates are provided.

The greatest fireballs over Poland

Przemysław Żołądek and Mariusz Wiśniewski

A brief description of some most interesting fireballs observed by the Polish Fireball Network is given. All these meteors appeared over Poland in the years 2010–2012. The presented fireballs include a great Perseid fireball over Poznań photographed during the 2010 Perseids maximum, the "Ciechanów" fireball, and the "Myszyniec" Orionid fireball which is exceptional due to its extreme beginning height.

High-altitude wind traced by persistent train from Geminid fireball

William Ward

Images of a persistent fireball train obtained during observation of the Geminid meteor shower maximum (December 13/14, 2012) are used to determine the wind speed at the assumed height of the fireball. The images were taken using ordinary consumer grade photographic equipment and analyzed to determine the relative positions of the persistent train over an interval of time. The positional data were then used to determine the wind speed using simple plane geometry and an assumption of the fireball altitude based on past determinations. The speed of the wind was determined to be 139 m/s.

American Meteor Society online fireball report

Mike Hankey, Vincent Perlerin, Robert Lunsford, and David Meisel

This short paper describes the American Meteor Society (AMS) online form that allows the general public as well as advanced astronomers to report fireballs and bolides.

AMS fireball program, community website, mobile app, and all-sky camera

Mike Hankey and Vincent Perlerin

This short paper describes the content of a video produced by Mike Hankey for the American Meteor Society (AMS) about the technology platform of the organization. This video can be watched on the web at `https://vimeo.com/72551924`.

From rates to fluxes of meteoroid streams

Jürgen Rendtel

We describe the steps and necessary data to calculate meteoroid stream parameters, such as the spatial number density, meteoroid flux, and mass index, from optically observable quantities. The main aim is to describe the established observing procedures and to emphasize the importance of the magnitude data per meteor shower. These are essential for the calculation of the requested meteoroid stream data. Effects of the magnitude data on the derived quantities are demonstrated on some examples. A summary lists parameters of several meteoroid streams.

Calibration of spectral video observations in the visual: theoretical overview of the ViDAS calibration pipeline

Joe Zender, Detlef Koschny, and Kevin Ravensberg

During several campaigns, the ESA Meteor Research Group has collected a multitude of meteor spectral events using video intensified cameras with a spectral grating atop. The calibration of the individual movie frames towards time-resolved spectral information is still ongoing, and we try to achieve a semi-automatic data pipeline. We will describe the individual steps of the calibration pipeline to compute the (x, y) position of a wavelength in an image from the celestial coordinates of the meteor for a given time instance.

Meteor shower search for amateurs

Denis Vida, Filip Novoselnik, Damir Šegon, Željko Andreić, and Ivica Skokić

In this paper, the method and the results of a meteor shower search using SonotaCo and Croatian Meteor Network data are presented. The graphs used are shown and, for the animations, the web links are given.

The Virtual Meteor Observatory (VMO)

Detlef Koschny, Hans Smit, and Geert Barentsen

The Virtual Meteor Observatory (VMO) was designed to store all types of meteor data: visual, camera, and radio observations. It currently hosts the IMO video network data from 1993 to 2007. After a hardware upgrade foreseen for the fall of 2013, it will contain all IMO video data. It aims at storing not only derived data (e.g., orbits) but also at allowing access to the raw observational data. This gives highest flexibility for data mining and makes the VMO complementary to other existing meteor databases.

Infrasound as a scientific tool to study meteors

Elizabeth A. Silber

Meteoroids are some of the most fascinating and elusive sources of infrasound. Information we may gain from meteoroids entering the Earth's atmosphere is of significant scientific value, and spans from learning about the origins of our Solar System and flux of smaller Near Earth Objects, to ascertaining constraints for numerical models. During their hypersonic flight through the atmosphere, meteoroids generate a cylindrical blast wave, which can be recorded at the ground as infrasound.

Effects of general relativity on meteoroid orbits

Aswin Sekhar

There are only a handful of previous works which have concentrated on the general relativistic effects on meteoroid stream evolution. In this work, we find that the small effects due to general relativistic precession could make the subsequent changes in nodal distances substantial due to the geometric nature of some combinations of the Keplerian orbital elements. In some cases of long-term orbital evolution, these effects could be decisive to determine the intersection or miss of a dense dust trail with the Earth and hence play an important role in meteor storm or outburst forecasts.

Correct brightness estimations of optical meteors

Alexander Bagrov and Vladislav Leonov

The meteor brightness is a very valuable parameter that has to be determined from observations. Traditionally, meteor brightness is determined to be equal to the brightness of a star that seems as bright as the meteor at its brightest point. As meteors are observed at different distances from the observer, the term "absolute brightness" was introduced as the visible brightness of the same meteor if it were at 100-km distance. The determined meteor brightness is an estimate based on the observer's sense in non-system units. The photometrical meaning of a star's brightness is the illumination made by this light source on the Earth's surface. When a moving light source is observed, such as a meteor, it is only necessary to measure the illumination produced by the meteor. The paper presents an analysis of the main features of meteor brightness estimates by a traditional method and points out that they are all disturbed by systematic errors up to 2 magnitudes. The required formulae to connect the reference signal from a meteor with that of a standard star are derived by calculating the meteor brightness in energetic units.

Analysis of MOID values for hyperbolic comets

A. S. Guliyev, Sh. A. Nabiyev, and R. Guliyev

We investigate the relationship between hyperbolic comets (HC) and trans-Neptunian objects (TNO) with diameters of more than 200 km. To this end, we analyze the distribution of the minimum orbit intersection distances (MOID) of these bodies and 37 HC. The results of these calculations are compared with similar cases where cometary data are used without their corresponding accuracy. There is parity in 8 cases (19 against 18) between positive and negative values of Tisserand's parameter C. In 5 cases, positive values prevail over the negative ones. MOID values of HCs relative to the large TNOs differ noticeably from the same data for other comets by their small values. Also, it was found that, for Tisserand's parameter of HCs relatively to some large TNOs, positive values prevail over the negative ones.

Paths of risk of the potentially dangerous asteroid (99942) Apophis

Ireneusz Wlodarczyk

We present several paths of risk of the potentially dangerous asteroid (99942) Apophis for the next 100 years. They are computed using all astrometric and radar observations of Apophis till July 12, 2013. Main orbital computations were made using the software package OrbFit. Different values of the non-gravitational parameter, da/dt were used.

Meteorites in Japan II

Nagatoshi Nogami

The paper gives further examples as to how Japanese people handled meteorites, collecting and recorded them.

Notes on Chelyabinsk meteorites hunting, spring-time expedition, April 22 to May 1, 2013

Marcin Stolarz, Paweł Zaręba, Maciej Burski, and Iwo Szklarski

On 15 February 2013, a huge amount of debris of the biggest recorded sky event since the Tunguska blast reached the Earth near Chelyabinsk. The first meteorites spread out in the strewnfield were identified by impact holes in the snow cover and collected by locals. After two months in mid-April, the strewnfield hosted meteorite hunters from all over the world. The members of the Meteoritical Section of the Polish Fireball Network (PFN) established by the Comets and Meteors Workshop (PKiM) participated in a 10-day expedition to the Chelyabinsk area as well. In this article, the preparation for the expedition and the most efficient methods to search are described. The features of the strewnfield area are summarized.

A field study of the Chelyabinsk airburst event

Anna Kartashova, Olga Popova, Peter Jenniskens, Vaycheslav Emel'yanenko, Sergey Khaibrakhmanov, Alexandr Dudorov, Evgeny Biryukov, Dmitry Glazachev, and Irina Trubetskaya

In the morning of February 15, 2013 ($3^{\rm h}20^{\rm m}$ UT), a 20-m sized meteoroid entered the Earth's atmosphere over Chelyabinsk Oblast, and the subsequent airburst created widespread glass damage and caused related injuries on the ground. This was the first time that an impact of this magnitude was well documented. The impact occurred in a densely populated area and was recorded on more than 400 photos and videos. In the weeks following the event, a fact-finding mission was conducted in the surrounding area. Over 150 eye-witnesses were interviewed, meteor videos were calibrated, the extent of the glass damage was documented, and the location of the fallen meteorites was traced by interviewing the finders. The results can be used to improve asteroid impact models and impact hazard prevention scenarios for future impacts.

CILBO—Two years operation of a double-station meteor camera set-up in the Canary Islands

Detlef Koschny, Jonathan McAuliffe, Felix Bettonvil, Javier Licandro, Cornelis van der Luijt, Hans Smit, Høakan Svedhem, Olivier Witasse, and Joe Zender

Since the Summer of 2011, the Meteor Research Group of the Research and Scientific Support Department of ESA has been operating a meteor camera on Tenerife. At the end of 2011, a second station on La Palma was added to the set-up, completing the double-station setup CILBO (Canary Island Long-Baseline Observatory). Here, we give an overview of the data obtained from 1 January to 31 August 2013. The system's availability is just below 70%.

Meteor detection in wide-field survey telescopes

Francisco Ocaña, José Daniel Ponz, and Jaime Zamorano

Meteor observing requires a huge field of view (FOV) as its appearance in the sky cannot be foreseen. In the new era of the time-domain astronomy, many telescopes will cover the whole sky with a cadence of a few days. These requirements lead to fast large telescopes with wide FOVs, like the Schmidt cameras that were widely used for meteor observing in the past. We present an estimation of the number of meteors detected as a by-product of these surveys, with the detailed example of the Test-Bed Telescopes, an ESA project for NEO and space debris surveillance.

Recent developments in the BRAMS project

Stijn Calders, Hervé Lamy, Emmanuel Gamby, and Sylvain Ranvier

In 2009, the Belgian Institute for Space Aeronomy (BIRA-IASB) initiated the development of BRAMS, a Belgian network of radio receiving stations using forward scattering techniques to detect meteors. The primary goals of the project are (1) to collect data and to provide them to the community; (2) to retrieve information about the meteoroid trajectory; and (3) to study the activity profiles of the main meteor showers. In this paper, the work performed since the 2012 International Meteor Conference in La Palma, Canary Islands, Spain, is presented: (1) a software to decode the GPS signal has been developed and added to all BRAMS stations; (2) a workshop about automatic detection of features in radio data was organized in order to discuss about suitable image processing techniques that can be used for radio meteor echoes detection in the BRAMS spectrograms; (3) to assess the quality of such an image processing technique, a big set of manually counted meteors is necessary. A web application has been developed to support this task and facilitate the comparison of counts by different users; (4) to compute the meteoroid flux and for other applications, the radiation pattern of the different antennas must be known. Someone has been hired recently to make simulations of these radiations patterns as well as to carry out measurement campaigns; and (5) detection of solar flares in BRAMS data has been investigated.

The Benelux CAMS Network—status July 2013

Paul Roggemans, Hans Betlem, Felix Bettonvil, Jean-Marie Biets, Martin Breukers, Robert Haas, Klaas Jobse, Carl Johannink, Marco Langbroek, Koen Miskotte, Piet Neels, Jos Nijland, and Casper ter Kuile

A network of CAMS, "Cameras for All-sky Meteor Surveillance", is being built up in the Benelux since early 2012. If weather permits, the network has curently 18 CAMS active at 10 observing posts. More than 2000 accurate meteor orbits were recorded so far.

The Romanian Video Meteor Network

Alexandru Tudorica

Romanian astronomers (both professional and amateur) have had little contribution to the field of meteor science in the last few decades. Only recently, with the advent of the new and affordable electronic systems that allow an unbiased, long-term coverage of meteoric activity, the interest of both communities started to gain momentum. The Romanian Video Meteor Network was started as an initiative of a few amateur astronomers, with the long-term goal of covering the entire territory of Romania with a network of double-station video cameras, able to accurately constrain the meteoroid orbits and other observables, also potentially acquiring high-quality spectra of some meteors if additional funding can be secured. The network plan and time line are described in rather general terms as the project is ongoing and potentially changing slightly in size and scope. Partial funding for the network costs was secured through a successful IMO grant proposal in mid 2013.

Draconids 2012—Unexpected outburst

Juraj Tóth, Jakub Koukal, Roman Piffl, Štefan Gajdoš, Przemysław Żołądek, Mariusz Wiśniewski, Antal Igaz, Pavol Zigo, Leonard Kornoš, Dušan Kalmančok, Jozef Világi, and Jérémie Vaubaillon

Observations and preliminary results of the unexpected 2012 Draconid outburst are presented.

Studying meteors at the Institute of Astronomy of the Russian Academy of Science

Alexander Bagrov, Galina Bolgova, Anna Kartashova, Sergey Kruchkov, Vladislav Leonov, and Vladimir Mazurov

The Institute of Astronomy of the Russian Academy of Science (INASAN) is a scientific organization of the Russian Federation that systematically observes meteors and supervises the activity of associated groups of meteor observers. The main tasks of our investigations are devoted to physical properties of meteors as well as the study of meteoroid streams and meteoric material within the Solar system.

Spectrosopic airborne observations of the 2011 Draconids meteor shower outburst

Regina Rudawska, Joe Zender, Jérémie Vaubaillon, Pavel Koten, Anastasios Margonis, Juraj Tóth, Peter Jenniskens, Jonathan McAuliffe, and Detlef Koschny

We summarize the results obtained from the spectral airborne observations, and confirms the expected main constituents of the Draconid meteors, with an early sodium release in the meteor event.

Lyrids—analyses of worldwide video data

Roman Piffl, Leonard Kornoš, Jakub Koukal, and Juraj Tóth

In this paper, an analysis of 1616—mostly video—orbits of Lyrids is presented. We confirm the existence of a short- and long-period part of the stream. However, the dispersion in semi-major axis and eccentricity is quite large. So, based on a distribution in semimajor axis, the short-period part of the Lyrids is divided into nine groups. The distribution suggests a finer structure of the short-period part which might be caused by resonance effects with the giant planets.

Eye-witness interviews on the Chelyabinsk airburst

Anna Kartashova, Olga Popova, Peter Jenniskens, Vaycheslav Emel'yanenko, Stanislav Korotkiy, Sergey Khaibrakhmanov, Alexandr Dudorov, Evgeny Biryukov, Dmitry Glazachev, Irina Trubetskaya, and Ilya Serdyuk

Eye-witness accounts of the Chelyabinsk airburst have provided unique information that is not recorded in the many security and dash-cam videos of the event. Accounts were collected from in-person interviews during a field study from March 9 to 25, 2013, and from phone and internet surveys. In total, about 2000 accounts were collected, which provide information about sensations of heat, smells, sounds, the occurrence of sunburn, and the nature of injuries.

Samples at gamma spectrometry laboratory—investigations of specific radio-activity

Zbigniew Tymiński, Anna Listkowska, Ewelina Miśta, Anna Patocka, Ewa Kołakowska, Katarzyna Tymińska, Mariusz Wiśniewski, Przemysław Żołądek, Arkadiusz Olech

Non-destructive high-resolution gamma spectrometry techniques were used to measure cosmogenic radionuclides in meteorites. Most radio-isotope signals were detected for ^{26}Al, ^{22}Na, ^{54}Mn, ^{57}Co, and ^{60}Co in the Oslo meteorite whose fall was unobserved. The most extreme concentration of ^{26}Al was found in the Dhofar 007 eucrite (about 150 decays per minute (dpm) per kg), and the lowest in the Chelyabinsk LL5 meteorite, which was close to minimal detectable activity.

Meteors and meteorite falls in Morocco

Abderrahmane Ibhi

During the last eighty years, thirteen meteorite falls were recorded in Morocco, ten of which are well documented and named Douar Mghila, Oued el Hadjar, Itqiy, Zag, Bensour, Oum Dreyga, Benguerir, Tamdakht, Tissint, and Aoussred, respectively. This represents only 0.011% of the declared Moroccan meteorites.The authenticated observed falls represent three different types of meteorites: there are eight ordinary chondrites, one carbonaceous chondrite, and one Shergottite basaltic achondrite.

The Isli-Agoudal meteorite strewnfield

Hassane Nachit, Abderrahmane Ibhi, and Carmela Vaccaro

New meteorite prospections at different places in the region of Imilchil showed that (1) besides the Ataxite of Tasraft, all the other collected specimens belong to the same and only IIAB iron mother meteorite; (2) the strewnfield of the meteorite has a length of about 38 km along the north-south direction; (3) the small crater of Agoudal as well as the impact crater of Isli are situated on a parallel north-south axis, if not taken together with the strewnfield of the Imilchil meteorite; (4) these two structures might be the result of the fall of the single common mother meteorite of the IIAB type.

The Chelyabinsk superbolide

Krzysztof Wlodarczyk and Ireneusz Wlodarczyk

A detailed analysis of the passage through the atmosphere of a very bright meteor that exploded in the air near Chelyabinsk, Russia, on February 15, 2013, is presented. A number of videos and photographs were examined thoroughly to determine the meteor trajectory beginning from the recorded atmospheric entry at a height of about 62.5 km until its disappearance at a height of about 9.8 km. The calculated velocity changes with time revealed an unusual behavior: during the first 10 seconds, the meteor velocity increased from 16.6 km/s up to about 20.6 km/s in the main air burst at an altitude of 26.5 km, and only afterwards decreased rapidly. The light curves derived from videos enabled the total radiant energy and mass loss variations to be calculated and discussed here. The heliocentric orbits of the meteoroid and some possible parent bodies were computed.

Monturaqui impact crater

Stanislav Kaniansky and Kristian Molnár

The presentation describes one of the most impressive meteorite craters in the world that was visited during the 2012 Zodiac Expedition.

Meteor terminology

Vincent Perlerin and Mike Hankey

The American Meteor Society (AMS) has decided to create a set of educational posters, the first one of which has become available and deals with meteor-related terminology

Light pollution versus meteor observation—an imminent extinction?

Jure Atanackov

There has been an enormous increase in light pollution over the past two decades. In few fields in astronomy do observers feel the impact of light pollution as much as in visual meteor observations. Based on experience with young people starting out in meteor astronomy, I feel there is a strong connection between the quality of the night sky and the probability that a person will retain interest in visual meteor observations and possibly later advance to other techniques. With increasing light pollution, fewer people become interested in meteor observations. Meteor observers are also in the unique position to provide hard data for long term light pollution trend research. I discuss some possibilities on how to obtain such data that may ultimately help preserve or improve night sky quality and with it meteor astronomy.

Meteor Science

Various meteor scenes I: the perception and the conception of a 'meteor shower'

Masahiro Koseki[1]

Not all 'established showers' are recognisable by every method. Some might be lost ('dead') or have recurrent (periodic) nature and are not observable annually. Some are dominated by faint meteors and not observable visually but by radar systems. Other showers are rich in fireballs and their low meteor rates make them a good target for video and photographic observations, while visual observers may not notice their activity because of the low rates. The perception limit in magnitude differs between the observing methods on the one hand, but depends on the magnitude ratios of shower meteors on the other hand. Differences in the definition of a 'meteor shower'/'meteoroid stream' work important roles composing the shower list and we need to know how much various researchers' definitions differ. Depending whether we use observational raw data of the visible meteor shower or orbital elements of the meteoroid stream this may lead to either an obvious meteor showers or an undetectable stream. This paper (paper I) describes the reasons why we can see a meteor shower and why not, Paper II proves the condition by the example of Cygnid-Draconid complex, especially for the κ-Cygnids, and Paper III looks at the different views of several minor showers from the different kind observations.

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1 Introduction

We could enjoy a meteor shower, such as the Perseids, at its maximum but would be disappointed towards late August. The 'major' shower activity does not always exceed the sporadic activity. Japanese observers witnessed wonderful Draconid displays in 1985 and 1998, but not in 1972. Several meteor showers have a periodic appearance and show only weak recurrent activity.

Video observers record Perseids and many September ε-Perseids as well, but visual observations note much less of the latter. The December Leonis Minorids had not been known well till photographic observations and the September ε-Perseids were noticed only more recently, although there were several visual observations related to them. Their meteors are so bright that photographs and CCD can record the paths but their scarcity keep naked eyes off a fireball display in long period.

The Toroidal and the Apex source are more dominant in radar observations than in optical observations. They are mostly comprised by fainter meteors below the naked eyes' perception limit.

The difference in magnitude ratios and the difference in their frequency cause the different views. We will start to study the cases why we can notice given meteor showers and why not by the model calculations.

2 Differences in the perception

2.1 Model distributions of the meteor frequency in magnitude

Meteor showers show very different profiles year by year and by observing devices. It is because of the difference in their magnitude distributions and of the fluctuations of the meteoroid flux. We may see the conditions by the model study with the assumptions:

1. The magnitude distribution might be expressed by $N = N_0 \times (m - m_0)^r$; N_0 is the initial number of meteors at magnitude m_0 and r is the so-called magnitude ratio or population index (Koschack & Rendtel, 1990).

2. The magnitude ratio r differs between sporadic meteors and meteor showers and, moreover, meteor showers have peculiar values (and profiles; see Rendtel, 2014); we assume here $r = 1.5$ for showers rich in fireballs, $r = 2.5$ for average showers, $r = 3.0 - 3.5$ for sporadic meteors and $r = 4.5$ for showers rich in faint meteors.

3. For our study, we apply Kresáková's perception coefficient (PC) for visual observations (Table 1).

4. Hourly meteor rates under the ideal sky condition are set as follows (corrected by PC): major shower HR = 60, sporadic rates HR = 20, and minor shower HR = 2.

5. Even if the backward prolonged path of a meteor trail hits a minor shower radiant, we cannot be certain that it was the member of it strictly. If we knew orbital elements of a meteoroid from multiple station observations, we could judge whether we should reject it as a sporadic one that shot from the similar path by chance. Due to sporadic background activity we cannot exclude possible contaminations of 'shower members' by accidentally aligned sporadic meteors. This holds even if we know the orbits.

Therefore it is necessary to use a perception limit for the ratio of shower meteors (source) on the background contaminations (noise), that is, S/N ratio. When the ratio of shower meteors to the noise background, i.e. sporadic meteors, (S/N) exceeds 0.1, a visual observer can notice the shower activity. Radar, photographic, and video observations, worked out for orbital calcula-

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Table 1 – Visual perception coefficient (Kresáková, 1966).

Mag.	−6	−5	−4	−3	−2	−1	0	1	2	3	4	5	6
PC	1	0.98	0.95	0.87	0.73	0.57	0.48	0.42	0.343	0.232	0.064	0.008	0.00007

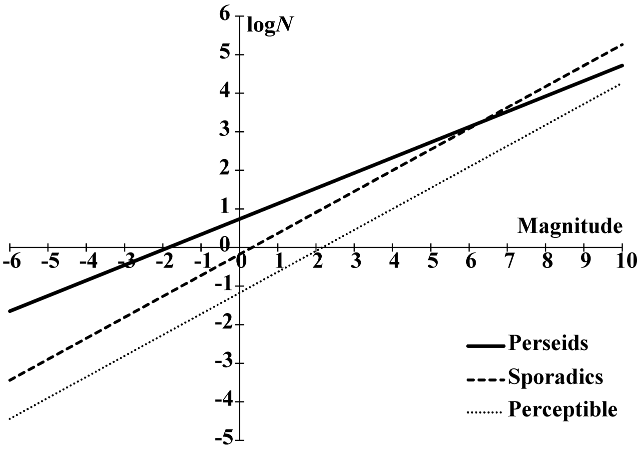

Figure 1 – The model magnitude distribution of a major shower (solid line) and the sporadic background (dashed line) with the visual perception limit (dotted line).

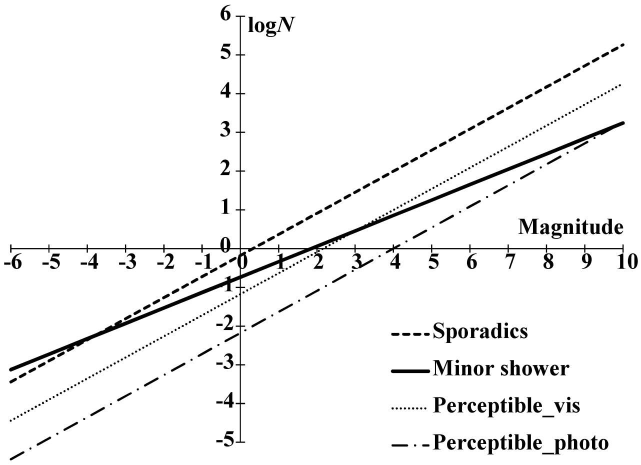

Figure 2 – The model magnitude distribution of an ordinary minor shower (solid line) and the sporadic background (dashed line) with the visual perception limit (dotted line) and with the photographic perception limit (dash-dotted line).

tions, may be applied to a S/N = 0.01. It is necessary to note that these are not far from empirical though tentative values. We can show the observational conditions by following figures.

2.2 Major meteor showers: Perseids

The Perseids is one of the major showers and Table 2 gives the result of the calculation for the common magnitude distribution of sporadic and Perseid meteors at its maximum on the basis of the above assumptions. These seem to express very familiar profiles of our visual observations during an hour. We now study the different views of meteor showers as follows.

The numbers are obtained by multiplying the perception coefficient of Kresáková to the real meteor numbers. We can determine the real numbers by calculating backwards. The results are shown in Table 3.

Figure 1 shows the distributions of both meteor numbers in logarithmic units; the dotted line under the dashed line represents the perceptible limit for visual observers based on S/N = 0.1. Clearly, the Perseids exceed the sporadic meteors and consequently the Perseids is called a major shower.

If we extrapolate the lines to the fainter range, we realize that sporadic meteors would exceed the Perseid rates at some point. The Perseids are not the strong meteor shower in the telescopic or radar observations because its rates are barely above the perception limit, i.e. the Perseids' ratios to sporadic meteors become smaller and smaller.

2.3 Minor meteor showers

We can estimate the magnitude distribution of a minor meteor shower on the assumption (HR = 2) as described above. Table 4 gives the model examples for the case of $r = 2.5$ (ordinary shower), $r = 1.5$ (shower rich in brighter meteors or fireballs), and $r = 4.5$ (meteor shower with mainly faint meteors). Each upper line gives the supposed magnitude distribution for a visual meteor observer and the lower line shows the real meteor number obtained by recalculating backwards in the same manner as described above for the Perseids.

We will refer to and discuss many observations and studies which are summarized in the Appendix. The references given in the Appendix will be not indicated repeatedly and only ones not cited in the Appendix are pointed out by parentheses hereafter.

Table 2 – Hypothetical magnitude distribution of Perseids and the sporadic meteors normalized to HR = 60 for Perseids and HR = 20 for the sporadic meteors.

Magnitude	−6	−5	−4	−3	−2	−1	0	1	2	3	4	5	6	Total
Perseids	0.0	0.1	0.1	0.3	0.6	1.2	2.6	5.7	11.7	19.7	13.6	4.2	0.1	60.0
Sporadics	0.0	0.0	0.0	0.0	0.0	0.1	0.3	1.0	2.8	6.6	6.3	2.8	0.1	20.0

Table 3 – Real magnitude distributions calculated backward by using Kresáková's coefficients.

Magnitude	−6	−5	−4	−3	−2	−1	0	1	2	3	4	5	6
Perseids	0.0	0.1	0.1	0.3	0.9	2.2	5.4	13.6	34.0	85.0	212	531	1328
Sporadics	0.0	0.0	0.0	0.0	0.1	0.2	0.7	2.3	8.1	28.3	99.1	347	1214

Table 4 – Magnitude distributions of hypothetical minor showers normalized to HR = 2. Each second line gives the real magnitude distributions calculated backwards by using Kresáková's coefficient.

Magnitude	−6	−5	−4	−3	−2	−1	0	1	2	3	4	5	6	Total
Ordinary	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.7	0.5	0.1	0.0	2.0
	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	1.1	2.8	7.1	17.8	44.4	
Bright	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.1	0.0	0.0	2.0
	0.0	0.1	0.1	0.1	0.2	0.3	0.5	0.7	1.0	1.5	2.3	3.4	5.2	
Faint	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.6	0.7	0.4	0.0	2.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	2.5	11.4	51.3	231	

2.3.1 An ordinary minor shower such as COM

The Comae Berenicids (020 COM) have been observed by both visual and photographic technique and seem to be an ordinary minor shower. Figure 2 shows the logarithmic meteor number of COM (solid), sporadic background (dashed), the perception limit for visual observers (dotted), and that of observations which can give orbits (dash-dotted line).

The line of COM is below sporadic background almost all magnitude range but slightly above the perception limit for visual observers brighter ($m < 2$) range. May we expect that COM become predominant over sporadic meteors brighter $m < -5$? Figure 2 is drawn in logarithmic scale and the real number of $m = -5$ COM meteors is supposed to be 0.002. If we observe 500 hours and more and we could witness such a fireball. Though Figure 2 is not corresponding to the accumulated meteor number and the meteor rates are not corrected by the perception coefficient, it is proper to reject the $N < 1$ range as no observable meteor limits. COM are, therefore, perceptible only in narrow range between $m > -1$ and $m < 2$. It is clear COM have been observable for visual observers by chance.

If we plot meteor paths in a star chart, the perception limit might be lower in the graph and the chance to notice COM activity would increase. If we record meteor paths more accurately by using photo or video, the chances increase. If we could get meteoroid orbits, the chance grows much higher, that is, the S/N decreases to 0.01 (dash-dotted line). COM might observable over a wider magnitude range and, moreover, video and photographic observations can pile up observations in the longer period than visual ones which are restricted one day (less than 4 hours usually, see the Appendix). The range for observable meteor limits might be lower and one meteor a day is enough for such sophisticated techniques. COM is one of the active minor showers for the observations giving orbital data but not the same in visual observations.

We have studied the statistical case until now. HR = 2 describes the probable number of shower members and we cannot expect exact two meteors an hour. Hence it may happen that one visual observer reports that COM were active but another denies. Meteor activities vary very widely over a long term and the HR is not pinned at 2. The solid line of Figure 2 might rise and fall time after time. COM is not always observable even by video and photo.

If we observe when sporadic rates are low, as in winter to spring, we see very few sporadic meteors an hour. Then the lines for sporadic background and the perception limits would be lower and the perceptible magnitude range becomes wider — detecting a new minor shower seems easier. During the Perseids we might see more abundant sporadic meteors than shown in Figure 1. In that case it becomes more difficult to notice a minor stream that has not been known.

2.3.2 A shower with many bright meteors and fireballs: the December Leonis Minorids

Although the December Leonis Minorids (formerly 032 DLM) was deleted from the IAU list, it is a good example for a shower with a large portion of bright meteors. How do meteor showers with different magnitude ratios r appear? Figures 3 and 4 compare what we can see. Figure 3 shows a fireball rich shower which emerges from sporadic background brighter meteors ranging −1 and smaller. Although $N < 1$ in this range, visual observers could notice the fireball rich showers only by accumulating observations of several days. Olivier stated the radiant (of a meteor shower) should be defined within a day, but Hoffmeister joined several observations and found the ecliptic showers (see the Appendix). Although a fireball is a rare event, a fireball rich shower produces more meteors in the magnitude range $m < -2$ than the sporadic background. The Antihelion source (ANT) including the Virginids has such sources.

Many meteor activities have been reported in the ANT area by visual and photographic observations (Figure 5a & 5b). Photographic meteor showers may be dominated by those being rich in brighter meteors than visual and radar showers. It is necessary to add up long term observations and to restrict the magnitude range brighter than −1 in order to detect these meteor showers. It is natural that photographic and video observers enjoy the DLM although visual observers could hardly notice it. We will study in detail the different views from the different observational methods in Paper III.

2.3.3 Shower rich in faint meteors: the November ι-Draconids

The November ι-Draconid (392 NID) shower was discovered with the CMOR radar and includes currently 2059 orbits. Figure 4 represents how strange the appearance such a shower rich in faint meteors is. Meteor rates, more exactly N in the figure, exceed the perception limit for visual observers, that is, the dotted line in the range of fainter than $m > 4$. If your eyes were very sensible or your sky was as good as in the remote desert regions, you might notice the activity of such a

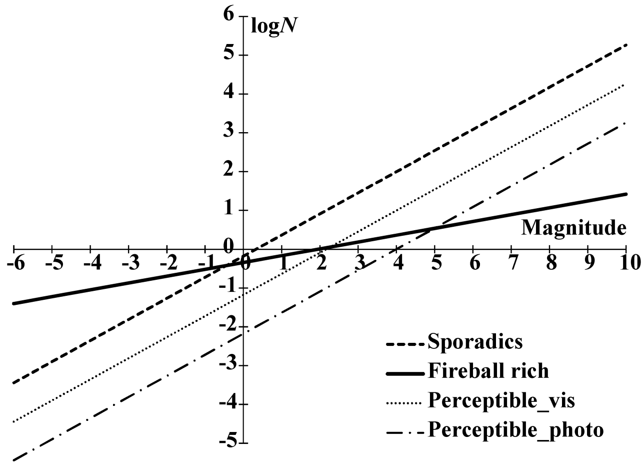

Figure 3 – The model magnitude distribution of a bright meteor rich minor shower (solid line) and the sporadic background (dashed line) with the visual perception limit (dotted line) and with the photographic perception limit (dash-dotted line).

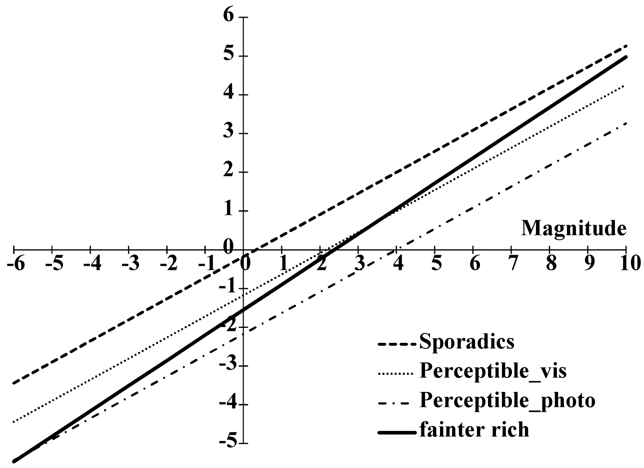

Figure 4 – The model magnitude distribution of a faint meteor rich minor shower (solid line) and the sporadic background (dashed line) with the visual perception limit (dotted line) and with the photographic perception limit (dash-dotted line).

minor shower. What is the most important point is this shower can be recognized easily by the sensible observations to fainter meteors such as radar. NID may be one of the most active showers in the IAU list but there is no identical observation in photo and in video. Figure 4 shows clearly why photo and video cannot detect showers rich in faint meteors. Meteor rates exceed also the dash-dotted line, i.e. the perception limit for orbit available observations and it might suggest sophisticated search could find out a weak activity in contaminated background activity. These meteor showers may give a brighter meteor $m < -1$ on more than 100 hours. If such a single meteor was recorded, one could not define whether the meteor belongs to the meteor shower. Even if its orbit was calculated, one could not have enough data to state the shower / meteoroid group is recognized.

2.4 Observational results

Hoffmeister listed 5406 candidates of meteor radiants, which he called the area of convergence, in his Appendix I. Figure 5a shows their distribution on $(\lambda - \lambda_\odot, \beta)$ coordinates and the main source of visual meteors is from the ecliptic showers. His candidates of radiants seem to have no tendency to concentrate to other areas, except for Perseids, although other visual observations of Denning's, AMS', and NMS' have clear concentrations at the major shower positions. The latter two groups, AMS and NMS, mainly had the intention to determine precise positions of meteor shower radiants while Hoffmeister's goal was different. The distribution of photographic meteor radiants (Figure 5b) shows the concentration of radiants of meteors from the ecliptic source as clear as visual observations. The major difference between photographic and visual distribution is the existence of the concentrations to the major meteor showers. The photographic distribution clearly shows Perseids, Orionids, Geminids (which are clear although located near the ecliptic), and several other radiants. The photographic and the visual distribution do not show the Apex source.

The video radiant distribution of SonotaCo 2012 (SonotaCo, 2013, Figure 5c) is similar to the photographic distribution. One of the most distinct features is the emphasis of meteor shower radiants. Major meteor showers are clearly shown and some possible new showers are suggested. It is noticeable also the appearance of the Apex source and the decrease of the Antapex radiants.

Both CCD and image intensified (II) cameras are video techniques to record meteors. II cameras can detect fainter ones than CCD. Figure 5d gives the results and shows the similar feature to photographic and CCD distribution (Figure 5b & 5c), but the contribution from the major shower decreases and the portion of the Apex source more clear than CCD. Though the CCD distribution shows the Apex source, the contribution from several meteor showers in them is pretty large.

Figure 5e gives the distribution of radar radiants and makes the differences from other observations obvious. At first, the Toroidal source is dominant in high northern latitudes, and secondly the Helion source becomes clear prominent. The radiants seem to concentrate to three areas, including the ecliptic (ANT) in addition to above two, and, thirdly, the radiants in the Antapex area become scarce. Fourthly, it is noteworthy to note that the major showers are not dominant comparing with other observations.

3 The differences in the conception

3.1 Two ways for the meteor shower research

There are many definitions (discrimination) for a 'meteor shower' and there might be, therefore, various kinds of 'meteor showers'. In other words, many researches of meteor showers are based on various definitions (conceptions) of a meteor shower. The conception has de-

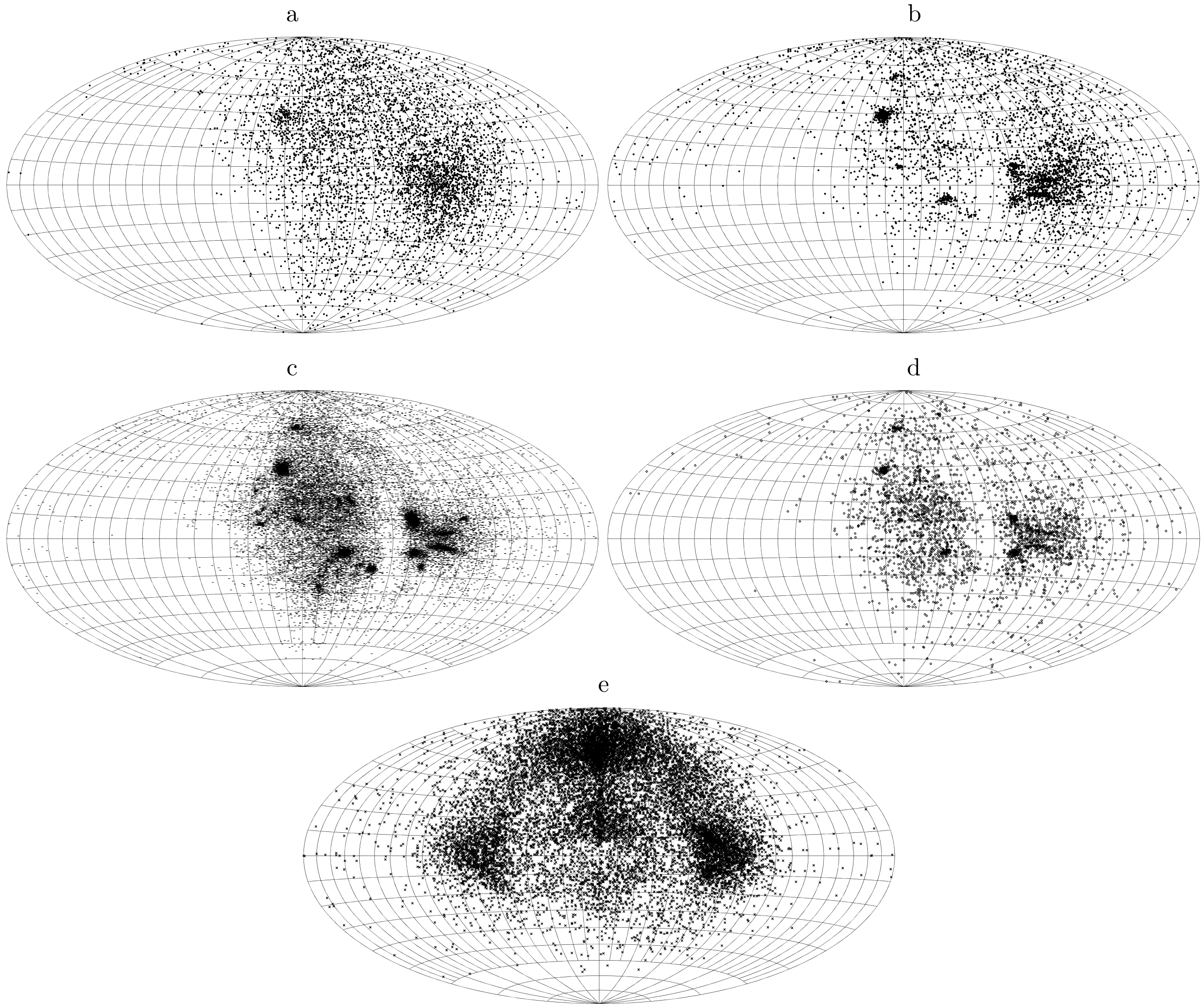

Figure 5 – Radiant distribution on $(\lambda - \lambda_{\odot}, \beta)$ coordinates centered at $(\lambda - \lambda_{\odot}, \beta) = (270, 0)$. a: Visual radiants (1925.0) Data are taken from Hoffmeister's Appendix I that shows the convergence areas. b: Photographic radiants. c: Video radiants. Symbols are; 2007 (plus), 2008 (asterisk), 2009 (cross), 2010 (triangle), 2011 (box), and 2012 (short bar). d: II radiants. e: Radar radiants of the Harvard 1961–65 radar survey.

veloped over times and varies with the observing techniques. We summarize several research methods and the conceptions on the meteor shower in the Appendix. We will discuss the differences in appearances of a 'meteor shower' referring the Appendix.

A meteor shower is defined by two manners.

(1) The observed elements themselves; the radiant position (α, δ), the geocentric velocity V_g and the time of the appearance T. Hereafter we call this "geobased".

(2) The calculated elements derived from the observed elements; the eccentricity e, the perihelion distance q, the inclination of the orbital plane i, the arguments of the perihelion ω and the ascending node Ω. We call this "orbbased".

Though the latter seems to have five elements, its degree of freedom is the same as the former. The latter could be described in other words; the direction of the perihelion, the angle between the orbital planes, the shape of the orbit and the size of the orbit. Southworth-Hawkins' D-criterion is based on these four dimensions. Thus we have two ways of meteor shower research: comparing the observed elements or calculating the similarity of the orbits. They have both advantages and disadvantages. The spread of the observed elements does not strictly reflect in the four dimensional space of the orbital elements. For example, the small difference of the observed data near the Apex becomes larger difference in the orbital elements and, by contrast, the large spread data of observations near the Antapex would be in the smaller space of the orbital elements.

Observations have inevitably errors and they distort the similarity of the orbits. Though the research in the space of the orbital elements seems to be superior to the comparison of the observed data, the observed data could be useful when we handle the data taking the errors into consideration. Observational errors are not only peculiar to the observational methods but also different in the methods themselves. For example, photographic observations are supposed to be the most accurate one, but the so-called small camera data and graphical reduction data of Super-Schmidt camera images are not better than the precise reduction data of selected meteors. Investigation of minor showers requires a very careful consideration of their errors. The orbital data are not always more useful than the observational raw data.

3.2 Reviews on the research methods

When we study the meteor showers we had better to pay attention to what the research methods were used as well as the observational methods. The research methods shown in the Appendix are also divided into two groups mentioned above. As the observing techniques have own favorites, so the research methods have also. We begin to study the differences of the researches by the observational techniques.

3.2.1 Visual observations

Meteor shower surveys depend on the radiant point and the period of the activity with some additional properties in their appearance. Denning and Hoffmeister suggested that meteor paths might be combined during five day intervals but Olivier stated it should be done within only one night. Denning and Hoffmeister thought there are meteor activities continuing over months, such as ecliptic showers. In this case, fictitious radiants (convergences) might increase and different activities might be put together. Denning's General Catalogue lists many aggregates as one shower and Hoffmeister combines several ecliptic activities as one series. The author has re-analyzed their results (Koseki, 2009).

Olivier's strict limitation aims at the precise determination of a radiant point and Olivier settled the controversy on the drift of meteor shower radiants. Olivier's instruction works well for radiant determination for the major showers and made their radiant shift clear. The NMS had accepted Olivier's guide. But we could not get enough meteor paths in one night within four hours and might miss sources of weak meteor activity. It is necessary to notice their characteristics when we use them. Terentjeva found out the long term transformations of minor meteor showers comparing visual observations in 19th century with photographic data. We must pay attention to the difference in ages of observations, because the change is more swift and larger than we suppose. Many visual radiants were reported over 50 years ago and some even over one hundred.

3.2.2 Photographic observations

Meteor shower surveys were carried out almost the same manner as visual ones in their early period; the velocity in addition to the radiant point and to the period of the appearance. Southworth and Hawkins presented the computerized search on mass data by calculating the similarity of the orbits in the four dimensional space.

Lindblad applied the conception of Southworth-Hawkins and the discrimination level should vary inversely as the fourth root of the sample size. This made subdivisions of some meteor showers, such as hyperbolic Perseids. Meteor observations inevitably have larger errors than in comets or minor planets observations. Lindblad's idea is suitable for classification of comets and minor planets and not for meteor shower detections. He had done several searches within precise data apart from graphical data. Koseki compiled photographic shower list by the cluster analysis (centroid method) using Southworth-Hawkins' criterion and the rejection level set the distance between the mean orbit and individuals as $D(M,N) < 0.15$ and $N > 3$. He did not take the difference of errors in each observation into considerations.

3.2.3 Radar observations

Meteor shower surveys on radar observations are very complex, because the mechanics themselves are complicated and the conditions for receiving meteor echoes are not simple. We will see the difference in the radiant distributions in the following Section 3.3. The systems used at Harvard-Smithsonian survey and CMOR are different and the research techniques are quite different as well as Nilson, Kashchejev, and Lebedinets (see the Appendix).

3.2.4 Hybrid search

Cook stressed the threshold for visual detection of a stream and Terentjeva combined photographic data with visual ones and investigated minor showers by using observational elements not by orbital ones. It might be suggested she did not restrict the border on the similarity of photographic data. If we calculated D-criterion between each meteors $D(A,B)$ for her shower members, the border values of Apex showers in $D(A,B)$ are larger than those of the Antapex showers, whose geocentric velocity is lower than those of the Apex ones. This management seems to be better than strict use of $D(A,B)$ in search for meteor showers, because the errors in velocity determination become larger with observed velocity and the standard deviations in velocity of the Perseids by the graphical reduction is larger than we thought (Koseki, 1986). Several showers indicated by her has only one photographic data linked with visual record(s) and recognized some sub centers of wide spread activity as independent showers on the basis of visual observations.

Koseki also did the survey on the meteor shower lists by the same method as photographic shower survey (the reference list; see the Appendix).

3.3 Results of various searches

Figure 6a-g show the differences in the radiant distributions by the different conception of a meteor shower clearly. Although Hoffmeister found wide spread ecliptic showers (Figure 6a) in $170 < \lambda - \lambda_\odot < 210$, $-10 < \beta < +10$, he could not detect more scattered showers in the region $\lambda - \lambda_\odot < 160$ which are detected by Lindblad's D-criterion search (Figure 6b). On the other hand, the D-criterion survey lacks meteor showers which are located in the large area $190 < \lambda - \lambda_\odot < 280$, $+10 < \beta < +50$, but Terentjeva's hybrid searches revealed many showers (Figure 6c). Terentjeva's searches had been carried out using both visual and photographic observations and represent both features. Figure 6c shows that both scattered showers missing in Hoffmeister's analysis and as well as the showers not found by Lindblad are detected by Terentjeva's hybrid searches.

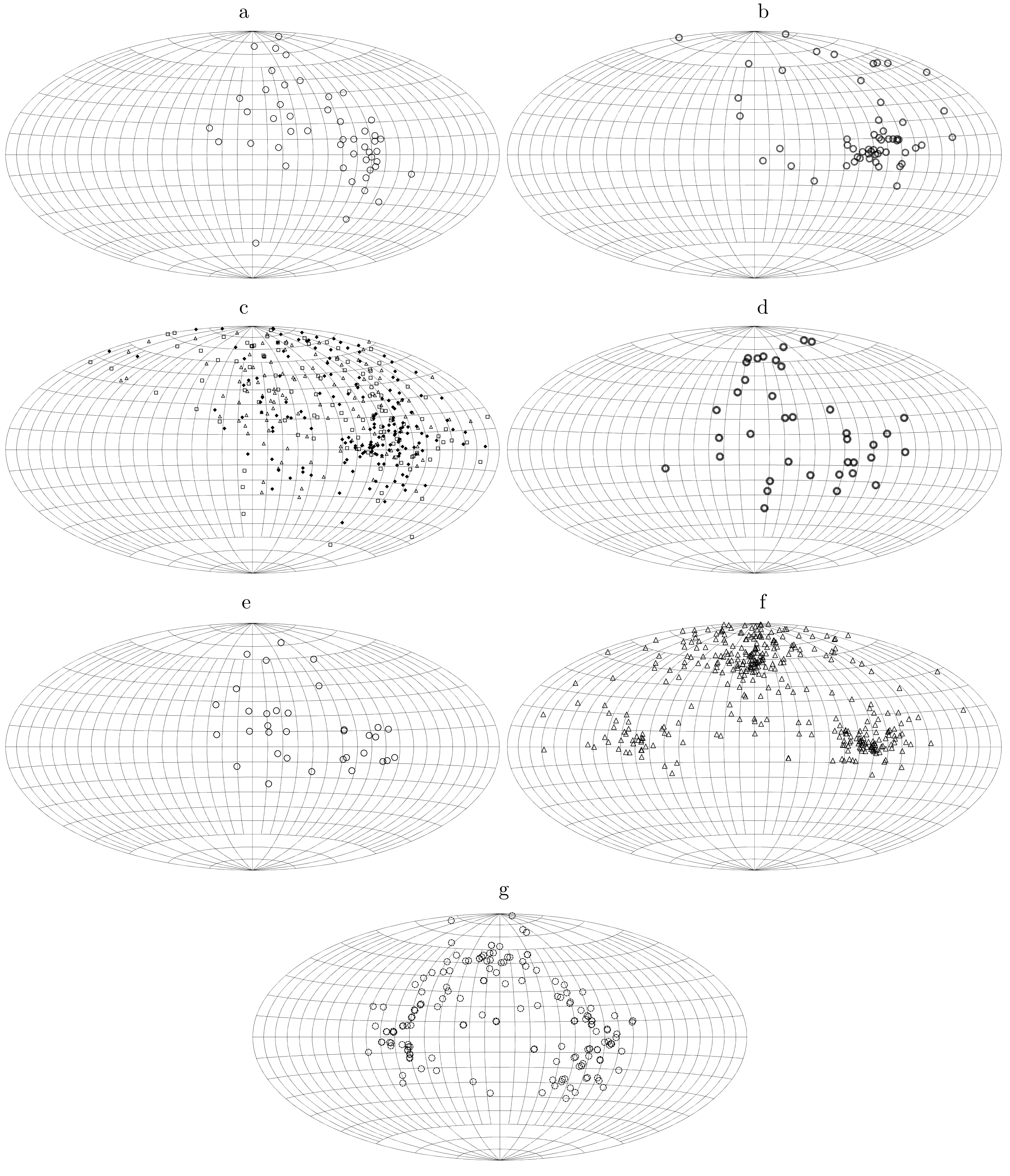

Figure 6 – Meteor shower radiant distribution on $(\lambda - \lambda_\odot, \beta)$ coordinates by the different conception. a: Hoffmeister's "preliminary catalogue of meteoric currents" that was established by himself from 5406 areas. b: Linblad's survey on 2401 photographic meteor orbits by using D-criterion. c: Trentjeva's hybrid search on photographic and visual data. Symbols; T1 (black diamond), T2 (box), T3 (triangle). d: SonotaCo's CCD video showers observed from 2007 January 1 to 2009 January 1. e: Shigeno's catalogue on II meteors. His newly found meteor showers, which had been searched excluding formerly detected ones, are shown in addition to his major shower list. f: Sekanina's radar showers. All shower of S1 – S3 is shown. g: CMOR radar showers. All showers including previously known ones is shown.

The distribution of radiants detected by SonotaCo (2009) from CCD video meteor data shows the lack of radiants with $\lambda - \lambda_\odot < 160$ (Figure 6d) because this search was based on geobased data, i.e. radiant point, date, and geocentric velocity. It is noticeable there are southern showers which Hoffmeister did not recognize, and possible new showers which have not been perceived by any others. The differences between Lindblad's and SonotaCo's distributions suggest that the results are affected much by the time lapse of more than 50 years between them and by the difference of the search methods.

Shigeno's II shower (Shigeno & Yamamoto, 2012) distribution (Figure 6e) looks like Hoffmeister's and SonotaCo's because they searched for meteor showers on the radiant maps. Figure 6e shows the lack of radiants $\lambda - \lambda_\odot < 170$ and the abundance of radiants in Lindbald's 'empty' area. Many showers found by II observations are located near the Apex and they suggest the characteristics of II systems is much like that of radar data.

Both Figures 6f and 6g are from radar observations but they are quite different. CMOR surveys are operated 30 years after the Harvard surveys and some changes in meteor activity might be expected of course. It is natural that there are many differences between the Harvard and CMOR radar systems and surveys which will cause selection effects. For example, the used frequencies are different and there were long interruptions in the Harvard surveys.

Only two showers are detected in the area $\lambda - \lambda_\odot <$ 180 by CMOR except the α-Capricornids and the radiants of both showers are located at high latitudes. Basically CMOR seems to detect the radiants located in a circle centered at the Apex with 60 degrees radius, though many major showers exist in this area of course. The concentration band of radiants found by CMOR is smaller as compared with Sekanina's surveys based on Harvard radar meteors clearly. The main reason of these differences comes from the difference in the applied search methods: geobased data are used for CMOR data and the D-criterion in Sekanina's analysis. A geobased search may overlook the showers which show a dispersed radiant position and the search by D-criterion may overestimate the accuracy of the observations and lead to subdivisions of single showers into several parts.

4 Discussion and antedates for Paper II and III

The author published a reference list of meteor showers and emphasized that there are not so many showers recognized by each method and for a long time (Koseki, 2009, Table 6). We studied the reasons for such differences in this paper: the differences in the perception and in the conception.

(1) Differences of the perception cause the different meteor scenes for different meteor observations.

Although the Perseids are one of the most abundant meteor showers for visual observations, it is not the best shower for radar. The number of major meteor showers is limited, because they must be prominent enough in the perception for all observing techniques.

The fact that major showers are not observable equally well by each method says nothing about the minor showers. It is noticeable that major visual showers are confirmed by photographic or by video observations but some remarkable photographic showers had not been listed in visual catalogues. The December Leonis Minorids are one of the well determined showers now but had been scarcely known. Photographic and video records can provide more patient observations than visual ones and thus can catch rare awesome fireballs though not faint meteors.

It is also natural that well observed radar showers show no clear evidence in optical observations:

S3-183 (September Ursids) is listed as $\Lambda = 90$ (see Appendix) and $D_{0.25} = 65$ (cumulative meteors less than $D = 0.25$) which means it is a rich and a noticeable shower, but no visual observation exists.

S3-205 (September Camelopardalids) has $\Lambda = 32$ and $D_{0.25} = 57$ but D-67 (Denning's radiant) might be the only candidate. S3-208 (A-Camelopardalids) $\Lambda =$ 660, $D_{0.25} = 52$ has none.

There are also many strong CMOR showers which have no representation in optical observations: Northern June Aquilids (164 NZC), ψ-Cassiopeids (187 PCA), November ι-Draconids (392 NID), January Leonids (319 JLE), ξ-Coronae Borealids (323 XCB), α-Antliids (110 AAN): no optical detection; November Orionids (250 NOO) radiant close to several showers, σ-Serpentids (330 SSE) is a daytime shower; λ-Bootids (322 LBO), ϑ-Coronae Borealids (321 TCB) may be associated with several weak showers

(2) Differences of the conception limit the chance for perceiving meteor activities. Orbbased researches can detect meteor shower radiants of widely scattered showers such as the ecliptic ones. The α-Capricornids are well known, though not determined clearly, by visual and photographic/video observations but former radar observations show very confused figures that researchers named some hillock over the sporadic ground as α-Capricornids freely without coincidence. CMOR shows recently the it has low W_c value (see the Appendix), that is a small level above the sporadic background. The κ-Cygnids are also well known as a shower rich in fireballs. Further, the α-Capricornids and κ-Cygnid radiants are broad like the ecliptic showers as well. It is necessary to apply both geobased and orbbased research for such cases (Paper II).

We see meteor showers with other restrictions: the time of the event, the observer's location. Though the splendid displays of the Leonids recur every 33 years, the shower might be almost buried in the sporadic background around the middle of these events. Although the η-Aquariids are a difficult target for optical observers in the northern hemisphere especially for high latitudes, it is one of the most active showers for southern locations and for radio observers.

We will investigate the Cygnid-Draconid complex (κ-Cygnids) in Paper II and discuss the reasons for the differences. The difference by the changes of the activity level and by the perception will be studied in Paper III including radar showers. We will see the different views from different observations including recurrent events such as the June Bootids (170 JBO) in detail.

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Appendix: The various conceptions (discrimination level) summarized from their expressions.

Denning

There are considerably more than 50 showers in play on any and every night of the year, and, moreover, certain (in fact the great majority) of these displays are not confined to limited periods, but extend their activity over several weeks, and in many cases over several months.

The radiant of the Orionids appears to be quite of a different character from the Perseids, for it retains a fixed place amongst the stars during the three weeks it is visible.

Radiants should be determined at the time of observation, or as quickly as possible, while the details respecting individual meteors are still fresh in the memory of the observer.

Reference: (Denning, 1899).

Hoffmeister

Hoffmeister stated in his book that the observation of five consecutive nights might be used to form a group, the motion of radiants points during the interval of no more than 4.5 days being not larger than 3 degrees or 4 degrees. Hoffmeister revealed the ecliptical showers that are weak but last more than a month this way, though it might cause spurious radiants as he noticed and may combine different showers into one. His procedures was as follows:

An area of 50 degrees in right ascension and 40 degrees in declination has been divided into 320 equal minor areas. Combining several maps of neighboring days there has been counted the number of intersecting path prolongations for every minor area.

1. The areas of convergence are taken from the working maps containing the observed paths in adequate groups. The catalogue embracing 5406 points is printed as Appendix I.
2. Configurations are sought for by comparing results from neighboring days.
3. The Second Grade List is examined for confirmations in different years at approximately the same longitude of the sun, dividing the whole material into five groups.
4. The preliminary Catalogue of Showers. Confirmations are established from comparisons of the different groups.

Reference: (Hoffmeister, 1948).

Olivier

(1a) A radiant shall be determined by not less than four meteors whose projected paths all intersect within a circle of 2 degrees diameter, and which are all observed within a period of at most four hours on one night, by one observer.
(1b) Or by three meteors on one night and at least two on the next night, seen during the same approximate hours of GMT, and all five intersecting as described above.

Make it possible to study the question of the motion or fixity of a given radiant point, with some degree of precision.

Reference: (Olivier, 1925).

Koseki

Shower members are chosen from radiant plots on the sphere of $(\lambda - \lambda_\odot, \Omega)$ coordinates each 15 degrees bin in solar longitude. The extent of the radiant area is not fixed one because radiant areas near the Apex are smaller than those of around the Antapex. The author studied visual radiants of Denning, Hoffmeister, AMS and NMS.

References: (Koseki, 1978; Koseki, 1979a; Koseki, 1979b; Koseki, 1980).

McCrosky & Posen

The radiants, corrected for zenith attraction and diurnal effect, were plotted on equal-area projection, one for each month of the year. The shower members were chosen by eye from the radiant plots.

Reference: (McCrosky & Posen, 1959).

Southworth and Hawkins

We measure a difference of shape by the difference in eccentricity e, and of size by the difference in perihelion distance q. We measure a difference in orbital plane by the angle I_{AB} between the orbital planes. A difference in orientation of the orbit within the plane is measured by the angle Π_{AB} between the major axes, weighted by the scale factor e. Angles, and thus the differences of angular elements, are measured by their cords, i.e., by twice the sine of half the angle:

$$[D(A,B)]^2 = (e_A - e_B)^2 + (q_A - q_B)^2 + (2\sin\frac{I_{\mathrm{AB}}}{2})^2 + \\ + [\frac{1}{2}(e_A + e_B) 2\sin\frac{\Pi_{\mathrm{AB}}}{2}]^2$$

(1) A stream may be defined, for example, as all meteors N such that $D(M,N)$ does not exceed a given value D_M.

(2) We may define a stream by serial association between members. We may state that two meteors A and B are associated if $D(A,B)$ does not exceed a standard value D_S. A stream may then be defined as a group of meteors in which every member is associated with one or more other members, and all members are associated together directly or indirectly.

We applied D first to the known streams that were sufficiently represented in the sample, using both forms of the stream criterion discussed above.

It will be seen that $D(M,N)$ exceeds 0.20 for only four meteors. Thus we may use the condition $D(M,N) < D_M$, where $D_M = 0.20$, as an empirical test for membership in these known streams. Similarly, no value of $D_{S\min}$ exceeds 0.20, and we may use $D_S = 0.20$ as an empirical test.

The numerical values $D_M = D_S = 0.20$, which were empirically determined from this sample of meteors, will require re-evaluation if applied to a different sample, particularly to a much larger sample. If, as above, we use a four-dimensional point distribution as a model of the distribution of meteor orbits, D_S should vary inversely as the fourth root of the sample size in random samples.

Reference: (Southworth & Hawkins, 1963).

Lindblad

Southworth and Hawkins proposed the rejection level D_S should vary inversely with the forth root of sample size. For sample of 360 precise photographic orbits, they used $D_S = 0.20$. If N is the sample size, we therefore have $D_S = 0.20(\frac{360}{N})^{\frac{1}{4}}$.

Reference: (Lindblad, 1971).

Nilsson

The use of the orbital elements has the advantage that the parameters are more fundamental, having regard to the initial formation of the streams, and that these parameters generally do not vary with time as markedly as does the radiant position. The disadvantage of using the orbital elements as a basis of classification lies in the fact that observational errors are not known to the same order of accuracy as for the radiant coordinates $|1/a_1 - 1/a_2| \le 0.15$, $|e_1 - e_2| \le 0.07$, $|i_1 - i_2| \le 7°$, $|\nu_1 - \nu_2| \le 7°$, (The true anomaly ν means the argument of the perihelion in this case.)

Southworth and Hawkins have based their values of c_j on an idealized dispersive mechanism acting on the meteor streams, i.e. they have concluded that the apparent differences $D(A,B)$ between orbits in a given stream are true differences and not just due to observational error. This difference in approach is reasonable because the expected observational errors in the orbits of the 360 photographic meteors they analyzed are about an order of magnitude less than these for the orbits determined in this survey.

Reference: (Nilsson, 1964).

Kashcheyev and Lebedinets

1. Selection of the candidates on the radiant distribution divided by velocity; 10–20, 15–25, 2. Preliminary calculation of the mean elements for the candidates. 3. Estimation of the standard deviations in orbital elements from the observational errors: $\Delta V, \Delta\alpha, \Delta\delta$. 4. Determination of the classification.
$|e-\bar{e}| < 2\sigma e$, $|q-\bar{q}| < 2\sigma q$, $|i-\bar{i}| < 2\sigma i)$, $|\omega-\bar{\omega}| < 2\sigma\omega$

Reference: (Kashcheyev et al., 1967).

Lebedinets

1. The observational errors $\sigma\nu, \sigma\alpha, \sigma\delta$ are described as a function of α, δ, ν.
2. Search of the candidates of meteor showers by the progressive steps: $|\frac{1}{a} - \bar{\frac{1}{a}}| < 2\sigma(\frac{1}{a})$, $|e-\bar{e}| < 2\sigma e$, $|q-\bar{q}| < 2\sigma q$, $|i-\bar{i}| < 2\sigma i$, $|\omega-\bar{\omega}| < 2\sigma\omega$, $|\Omega-\bar{\Omega}| < 30°$
3. Determination of the classification on the radiant distribution around the candidate.

Reference: (Lebedinets et al., 1972).

Sekanina

The population index, Λ, as the ratio between the number of stream and background meteors between $D = 0$ and $D = \sigma\sqrt{2}$, $\Lambda = \frac{\int_0^{\sigma\sqrt{2}} N_s(D)dD}{\int_0^{\sigma\sqrt{2}} N_b(D)dD}$ where subscripts s and b denote the stream and background, respectively.

The search for meteors dynamically associated with every single meteor in the sample required a computer memory capacity several times larger than at that time. Orbits of previously known streams and potentially related objects are used as the initial orbits for the stream search. To detect streams not associated with any previously known object, S1&S2 and S3 used somewhat different methods (abbreviations used here are the same as by Koseki, 2009, Table 5).

S1&S2: high concentrations of meteor orbits in the sample were looked for, using a three-dimensional searching scheme; interrelating the longitude of perihelion with the longitude and latitude of the orbital pole.

S3: in order to get the initial orbits, the samples were divided into 12 sections with the parameters; the longitude of perihelion and the inclination. The Southworth-Hawkins' search program was applied for each section at rejection level suggested by Lindblad and at peculiar level by Sekanina.

Reference: (Sekanina, 1970).

CMOR

The Mexican hat mother wavelet (which is well suited to point distributions having Gaussian shapes of enhancements) $W[(\lambda-\lambda_0)_{g_0}, \beta_{g_0}, V_{g_0}]$ (Eq. (1)). To search for showers in our orbital data, we apply Eq. (1) to all our data and locate local temporal maxima in W_c.

We define a local maxima as a point in a single solar longitude bin where the value of $W_c(x_0, y_0, V_{g0})$ is more than $3r$ above the annual median.

The largest maximum in any linked chain is required to be at least $3r$ above this median limit.

Reference: (Brown et al., 2010).

Cook

This list is restricted to streams that the author is convinced do exist. It is perhaps still too comprehensive in that there are six streams with activity near the threshold of detection by photography not related to any known comet and not shown to be active for as long as a decade. Unless activity can be confirmed in earlier or later years or unless an associated comet appears, these streams should probably be dropped from a later version of this list. The author will be much more receptive to suggestions for deletions from this list than he will be to suggestions for additions to it. Clear evidence that the threshold for visual detection of a stream has been passed (as in the case of the June Lyrids) should qualify it for permanent inclusion.

Reference: (Cook, 1973).

Terentjeva

Bakharev and Astapovich reviewed meteor radiants observed between 19th century and the beginning of the 20th century and found out following condition change within half a century; one third of former radiants have been replaced with new one, next one third have changed in the intensity of the activity, the period of observations or the radiant position, only last one third remain as they have been. The last groups are mainly of long period streams with highly inclined orbit.

Both visual and photographic observations are necessary to investigate minor showers, because photographic observations would not be carried out following years though visual ones might be done. It is important to note that comparisons should be including various factors; visibility period, position of radiant and velocity, of course, and more, extent of radiant area, its shape, drift of radiant and other characteristics, location on the heaven at last. Identification is evaluated in 10 grades; similarity within photographic data, affinity between photographic and visual data and weight of visual observations

Reference: (Terentjeva, 1966).

Koseki

The cluster analysis is applied for photographic meteors by the measure of D_M. The author detected 181 possible candidates of meteor showers having more than 4 members with discrimination level $D_M < 0.15$.

References: (Koseki, 1981a; Koseki, 1981b).

Various meteor scenes II: Cygnid-Draconid Complex (κ-Cygnids)

Masahiro Koseki[1]

Japanese video observers caught a rich 'κ-Cygnid' recurrent event in 2007 after an outburst observed by DMS in 1993. Classic 'κ-Cygnids' were observed photographically in 1950 and 1957. The shower might be recurrent with a 7 year period. This led to a call for 2014 observations in WGN (42:3, p. 89).
The author showed in Paper I (Koseki, 2014) that the perception and the conception of a meteor shower are so different that there are many confused results. 'κ-Cygnids' are a good such example and give different impressions from different observational techniques and from different years.
It is suggested modern so-called 'κ-Cygnids' now are not a single shower but a part of the Cygnids-Draconids Complex (CDC). CDC consists of several minor showers: the classic (photographic) one KCG1, the modern recurrent one KCG2, the one in average years KCG3, and three other activities. 'κ-Cygnids' in average years are different from classic 'κ-Cygnids' and CDC looks different based on the different conception and the different perception (observing methods) of a meteor shower.

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1 History

It is said that 'κ-Cygnids' is one of the most well-defined showers. However, the meteor activities around 'κ-Cygnids' are very complicated. The meteor activities around Cygnus (Cygnids-Draconids Complex, abbreviated CDC hereafter) have attracted attention of observers since the last quarter of the 19th century. Possible Cygnid meteor radiants catalogued by Denning (1899) are shown in Table 1, and Figure 1 with photographic ones. Because Denning's index list of radiant groups gives mean radiant position around the year, it is not necessary to compensate the precession of a little more than a hundred years. Denning's catalogue does not give exact observational days. If we adopt the days as between $120 \le \lambda_\odot < 160°$, the plausible radiant positon in the (λ–$\lambda_\odot$, β) system would move on the arc shown in Figure 1. The radiants draw arcs round the ecliptic pole and the left side of the arc represents the earlier position of the radiant. The corrected radiant taking the precession into account would locate approximately on the arc. It seems that Denning's radiants locate near the concentrations of photographic radiants. But, if we select radiants detected from less than 5 nights (Koseki, 2009), there remain no significant concentrations of radiants around these 9 showers. CDC does not seem to produce many observable meteors a night or to have a recurrent nature.

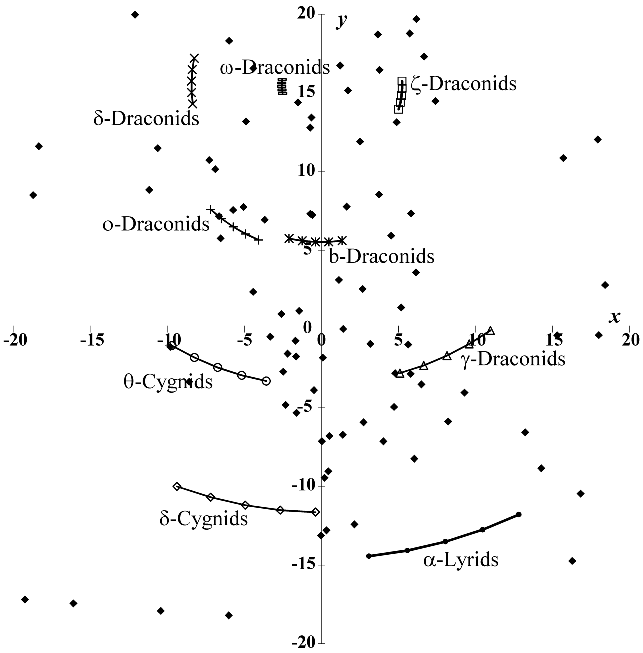

Figure 1 – Denning's radiants in the CDC area with photographic radiants (solid diamonds; see Koseki 2009): azimuthal equidistant projection in ecliptic coordinates centered at (λ–$\lambda_\odot$, β)=(160°, +75°). The line λ–$\lambda_\odot$=160° runs along the y-axis. Ecliptic pole at (x,y)=(0,15). Intervals on axes marked in degrees.

Kronk (1988) wrote in his learned book that the first observation of κ-Cygnids is due to Konkoly, but Denning, who noticed 'κ-Cygnids' according to Kronk, designated his observations θ-Cygnids, including Konkoly's radiant; $\alpha = 291°$, $\delta = +50°$, 1874 Aug. 11–12, $N = 7$. Jenniskens (2006, p. 443) citing Kronk's book wrote 'κ-Cygnids' had been noticed since the 19th century. More details may be found in Kronk's book.

'κ-Cygnids' had been little observed by Hoffmeister, so Hoffmeister's column is empty (No. 37 of Table 8 of Koseki, 2009). It is worth noting Japanese visual observer Kyozaburo Komatsuzaki's report (Komatuzaki, 1950). His observations had been done from 1941 to 1949, that is, prior to Whipple's photographic observations (Whipple, 1954). He distinguished three meteor activities in Cygnus during July to August. His report might be summarized as follows:

Activity A: reaches the maximum at August 4 and consists of faint meteors. Activity varies year to year.

Activity B: reaches the maximum at August 16 and rich in bright meteors. Strong in 1942, 1943 and 1948.

Activity C: annually observed between August 14–21.

Though these were bad times unfortunately for visual observers especially in Japan and his reports of radiant points have large errors because of the poor meteor

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Table 1 – Candidates of CDC members in Denning's catalogue. Denning listed N of RP (number of radiant points) in his 'Summary or Index List of the Radiant Groups given in the General Catalogue'. Remarks are Denning's.

No.	Name	α	δ	N of RP	Remarks
CXCVIII.	ζ Draconids	260.5	+63.3	34	Fine shower often repeated from same point, if not continuously in play during the entire year.
CCVIII.	γ Draconids	271.1	+47.6	29	A beautifully defined series of radiants. In spring the meteors are very swift, in summer slow, and in autumn very slow and trained.
CCXIII.	ω Draconids (II)	276.0	+67.6	10	A very definite shower situated near the pole of the ecliptic.
CCXIV.	α Lyrids	277.5	+36.8	10	Perhaps connected with CCVI.
CCXV.	b Draconids (39)	279.4	+57.6	26	Frequently observed, but exact place open to some doubt.
CCXXIV.	o Draconids	288.8	+60.0	17	One of the most prominent of the minor showers. It furnished quite a special display of bright, slow, trained meteors, August 21–25, 1879. The radiant is active during a long interval, and its RA is really 291°.
CCXXV.	δ Draconids	291.0	+69.6	17	Often recognised in July, August, September.
CCXXVIII.	δ Cygnids	292.9	+42.5	15	A very pronounced shower in July and August.
CCXXIX.	θ Cygnids	293.4	+51.4	24	A fine shower often perceptible in July and August, and especially rich in August 1893.

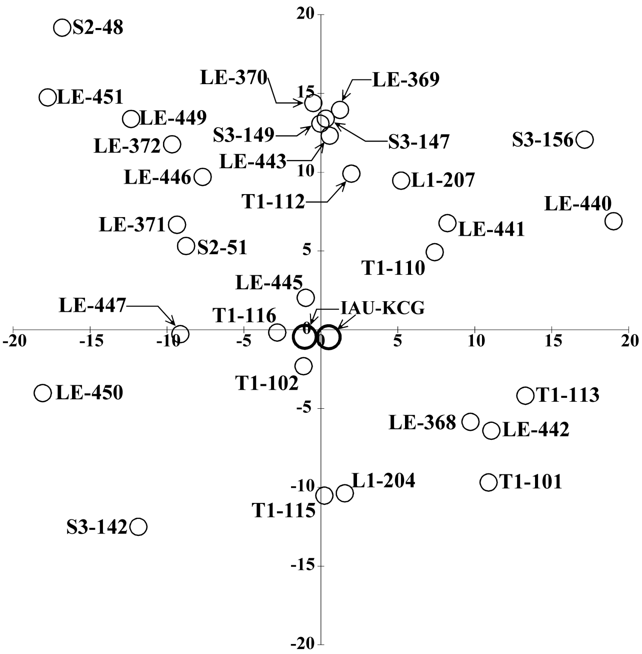

Figure 2 – Meteor showers observed by photograph and radar. Abbreviations used here follow Koseki (2009, Table 5).

charts, his careful observations lead us to a very interesting view suggesting CDC activities.

The designation 'κ-Cygnids' became famous since Whipple's photographic study, though he himself wrote this designation is taken from Norton (1943) and Jacchia (1952). Now so-called 'κ-Cygnids' signifies showers photographed mainly in 1950 (discussed in detail below) and all five of Whipple's 'κ-Cygnids' were observed in 1950. 'κ-Cygnids' and other meteor showers around it have been reported by many observers since then (Table 2 and Figure 2).

Lindblad's (1971a) L1 list does not have 'κ-Cygnids', because he analyzed only Super-Schmidt data in L1. His study which includes former Soviet and Whipple's small camera data detected 'κ-Cygnids' properly (Lindblad, 1971b). It is natural Terentjeva (T1; 1966) recognized 'κ-Cygnids', because she used Whipple's data. So many meteor shower radiants have been reported in the CDC area that the situation is quite confused (Figure 2).

Table 3 shows the 3 sets of 'κ-Cygnid' data of IAUMDC (2013) with possibly related activities. The DMS (Dutch Meteor Society) observed a rich 'κ-Cygnid' display in 1993 by small cameras (Langbroek, 1993). Jenniskens described the details of the outburst (2006, pp. 444–448).

One can describe the 2007 event as an 'outburst'. The 'κ-Cygnids' occupied the attention of the visual and video observers in Japan 2007. It is very clear the 2007 Cygnids were special and stayed at a higher level than usual for 3 weeks (Figure 3; details discussed in Section 3.4.2). Figure 3 gives the running mean calculated from SonotaCo data selected by the discriminant $D(M, N) < 0.30$ for IAU-KCG (DMS) and demonstrates the excitement in those days. Moreover, it is noteworthy that there is no distinct peak or resemblance to the 2007 profile in any other year. Figure 3 also shows 'κ-Cygnids' have a flat activity profile in average years but some variations unique to individual years imply fluctuations in the activity or the existence of different activities.

LE-445 and S2-51 are not in the IAU list (Table 3) and there is no 'κ-Cygnids' record in radar observations. 'κ-Cygnids' do not seem to be a good object for radar (see next section).

2 Disguises of 'κ-Cygnids'

A meteor shower activity looks splendid when the time is proper, but poor when the observation is not adequate. CDC is weaker than the Taurid complex and may be as variable as Leonids. It is necessary to learn what is the most suitable type of observation to record

Table 2 – Three different 'κ-Cygnids'. Abbreviations used hereafter are the same ones (Table 5 of Koseki, 2009) and shower names in the table are given by the original authors.

Source	α	δ	λ–$\lambda_\odot$	β	V_g	e	q	i	ω	Ω	$\lambda_\odot$	Shower
LE-445	282.4	55.0	164.3	77.0	24.5	0.64	0.99	34.7	199.9	138.7	138.7	κ-Cygnids
S2-51	299.1	62.5	202.5	77.0	25.9	0.621	0.979	42.9	203.1	153.2	153.2	Kappa-Cygnids
T1-116	290.1	54.5	170.7	74.6	24.7	0.771	0.976	38.0	203.1	147.8	147.8	κ-Cygds

Table 3 – Meteor showers listed by IAUMDC in studied area.

IAU-No.	α	δ	λ–$\lambda_\odot$	β	V_g	e	q	i	ω	Ω	$\lambda_\odot$	Shower
12	284	52.7	158.1	74.5	24	0.808	0.984	35.9	201.4	139.4	145.2	KCG (DMS)
	286.2	59.1	177.0	79.6	24.8	0.68	0.99	38	194	145	145.2	KCG (Cook)
	286	59	176.4	79.5	24.8						145	KCG (IMO)
73	261.7	67.8	33.2	86.6	25						122	ZDR
184	280.1	51.1	167.8	73.7	27.4						125.3	GDR
197	272.5	65.1	164.2	88.2	17.3	0.335	1.007	30.4	185.6	141.9	142	AUD
463	265.1	36.4	137.6	59.7							124.6	JRH
464	277.5	33.3	154.6	56.4							126.8	KLY
470	253.7	58.8	73.2	79.3							145.4	AMD
699	300.5	38.8	172.2	57.4	21.3	0.692	0.879	30.1	227.0	145.8	145	GCY
701	325.4	75.8	258.9	70.9	39.8	0.948	1.006	65.8	188.3	153.2	153	BCE

CDC, when we can catch more CDC meteors, and where does the area of CDC locate. What, how, and where our former researchers reached are the necessary basis for future studies.

Optical observations, such as photo and video, caught meteor activities around Cygnus as listed in Denning's catalogue. The author analyzed them by cluster analysis, leading to three groups of meteor showers (Table 4). If we consider T1-116 (Ref-No. 144) which is derived from Whipple's meteors as a primary 'κ-Cygnid', LE-445 belongs to another group and S2-51 is missed. We had better investigate all meteor activities in this area first and think of 'genuine κ-Cygnids' later.

Sekanina insisted S2-51 is 'κ-Cygnids' but it locates far from photographic 'κ-Cygnids'. Sekanina's search was led by 'the initial orbit' which has been already known, and seems to move and settle near 'the Toroidal source'. LE-445 is the only radar observation near photographic 'κ-Cygnids'. LE-445 has 12 meteors of August 9–15 when Perseids, listed with $N = 13$, are at their maximum but preceding the maximum of 'κ-Cygnids'. This observation is connected by the authors to LE-562 which was detected during October 20–23, and the radiant drift is calculated based on the difference between the two observations. It is suggested that LE-445 and LE-562 are different events and the two are slight el-

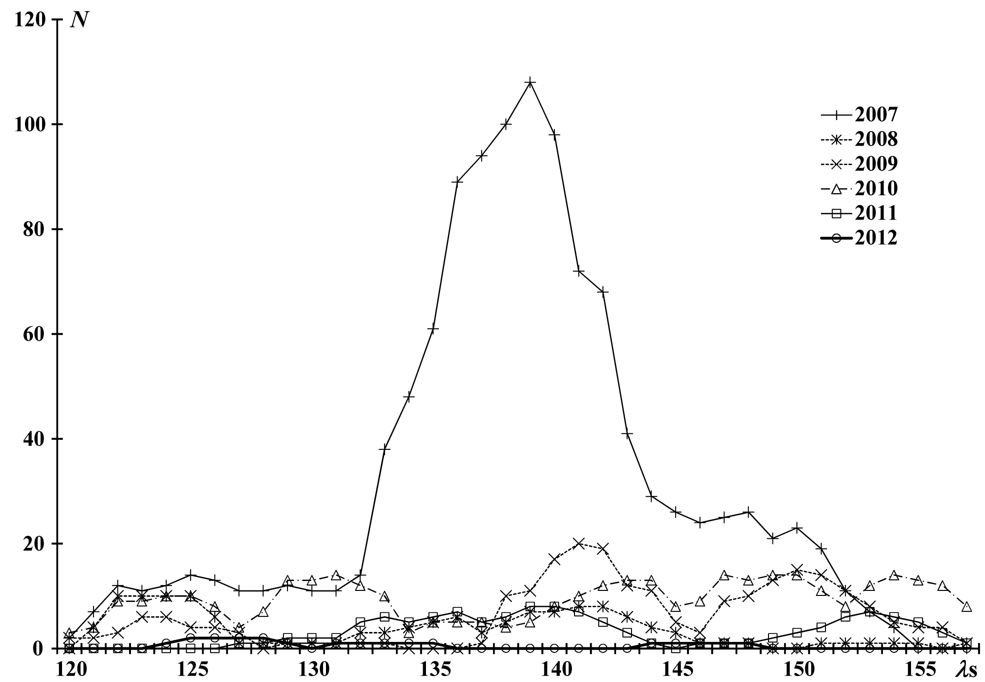

Figure 3 – Moving mean of 'κ-Cygnid' meteors in 5° solar longitude bins. Data are selected by $D(M, N) < 0.30$ (see Paper I) from IAU-KCG (DMS) orbit in SonotaCo's 2007–2012 video observations.

Table 4 – Three meteor shower groups recognized by cluster analysis with condition $D_M < 0.15$ (for meaning of D_M see Paper I). Abbreviations used here are the same in Table 5 of Koseki (2009) and the elements are converted from B1950 to J2000.

Ref-No.	α	δ	λ–$\lambda_\odot$	β	V_g	e	q	i	ω	Ω	$\lambda_\odot$	
125	279.0	42.2	149.3	65.0	21.4	0.707	0.967	28.1	205.8	136.6	136.6	LE-442, T1-115, L1-204
142	271.9	59.1	136.6	82.1	23.5	0.654	1.005	34.6	188.2	142.6	142.6	LE-441, LE-445, T1-112, S3-147, L1-207
144	293.8	54.6	181.0	73.4	27.2	0.771	0.968	40.7	206.1	143.9	143.9	LE-447, T1-116

Table 5 – Photographic meteor showers by Koseki from cluster analysis (converted from B1950 as shown in Koseki (1982, 2009) to J2000).

MK-No.	Month	Day	α	δ	λ–$\lambda_\odot$	β	V_g	e	q	i	ω	Ω	$\lambda_\odot$	N
74	8	9.54	281.0	44.6	153.2	67.2	20.7	0.728	0.968	30.1	206.4	137.2	137.2	12
83	8	21.40	290.8	55.8	175.2	75.2	25.0	0.758	0.978	38.8	202.5	148.5	148.5	6
84	8	25.29	267.1	60.6	109.3	82.8	21.6	0.659	1.009	34.3	183.5	152.4	152.4	11

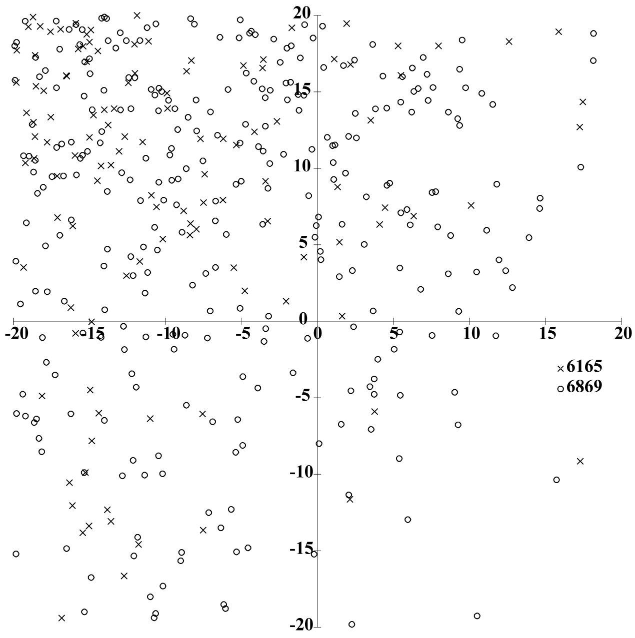

Figure 4 – Radar meteor radiants of Harvard surveys 1961–64 and 1968–69 in the CDC area.

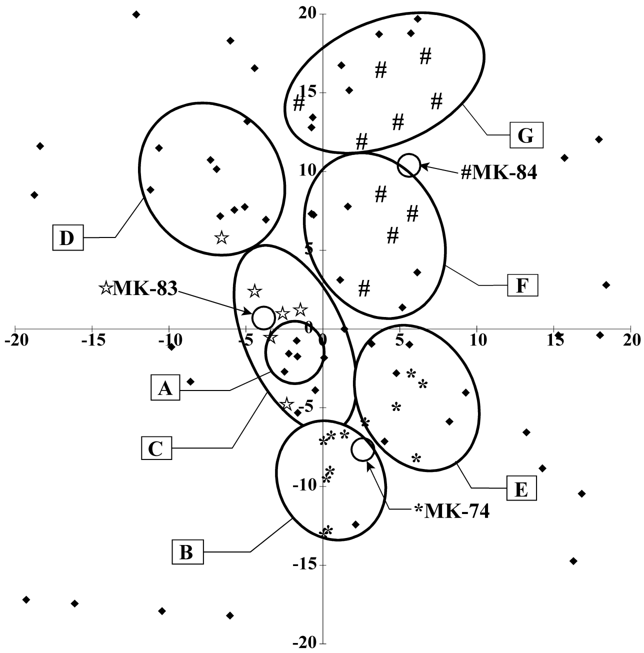

Figure 5 – Koseki's 3 photographic meteor showers in the CDC area: asterisks are members of MK-74, stars are members of MK-83, and sharps are members of MK-84. For ellipses A–G see Figure 6.

evations of radiant distributions on the sporadic background. There is no information concerning 'κ-Cygnids' in CMOR reports. Figure 4 shows that the radiant distribution of Harvard radar meteors indicates no definite meteor activity, though the Toroidal source comes within sight at the upper left. The geocentric velocity determined by radar observations may not be accurate enough to find out minor meteor activity when covered with plentiful sporadics. The use of the D-criterion means the distance between two orbits in the four dimensional space whereas the use of the radiant distribution divided by the short time bin and the velocity reduces the dimension to three. If we use the latter lacking the velocity information, it may be still useful as a first step of the meteor shower research especially with the considerations on the location of the radiant in (λ–$\lambda_\odot$, β) coordinates.

As noticed above, because 'κ-Cygnids' bears the name from photographic observations, it is proper to study them more carefully. Three photographic showers derived by the author (Koseki, 1982, 2009) are listed in Table 5 and drawn in Figure 5 with photographic radiants. It is clear that MK-83 corresponds to 'κ-Cygnids' and that the other two showers, MK-74 and MK-84, have more members than 'κ-Cygnids'. The 'κ-Cygnids' is not the most attractive meteor activity around the North-West border of Cygnus, though it has been the most famous shower of the three. It is also interesting that 'κ-Cygnids' consists mainly of 1950 Harvard meteors and all of them are records by so-called 'small-cameras'. If we exclude Whipple's four meteors from MK-83, we could not perceive 'κ-Cygnids'. Meteor activities can fluctuate widely year by year and 'κ-Cygnids' might be a good example of this.

Lindblad (1995) suggested there might be four meteor showers in this area by using the IAU photographic meteor database (Table 6). He indicated they have very

Table 6 – Photographic meteor showers by Lindblad (1995). Comments (by Lindblad) are as follows:
1) Same stream as the θ Cygnids, reported by Davidson (1914) and Cook (1922). No. CCXXIX in Denning (1899).
2) Same stream as Davidson's α Lyrids.
3) Same stream as reported by Besley (1903). Also No. CXCVIII in Denning (1899).

	N	α	δ	V_g	V_h	q	a	e	i	ω	Ω	π	λ	Comments
κ Cygnids	9	286.4	55.1	23.7	38.9	0.983	3.724	0.731	36.8	200.5	145.0	345.5	93.5	1)
α Lyrids	11	283.7	45.1	21.8	39.0	0.961	3.886	0.747	31.8	208.0	136.2	344.2	98.2	2)
ζ Draconids	12	267.9	61.7	22.0	38.2	1.007	3.024	0.665	34.9	181.7	147.8	329.5	94.3	3)
August Lyrids	6	277.6	46.2	19.0	38.2	0.984	3.099	0.680	28.0	201.5	139.5	341.0	102.2	

similar orbits and there might be a genetic relationship. κ Cygnids, α Lyrids, and ζ Draconids coincide with MK-No. 83, 74, 84 respectively, while August Lyrids are not found in MK list. There are differences in the constituent meteors, though the three showers in both lists are in good agreement.

Different research methods and different discrimination levels lead to different results. Minor meteor showers are usually only slightly above the sporadic activity and the research should be carried out by not only one method (D-criterion) but also the radiant distributions (see Paper I). The three meteor showers, common to both studies, will appear in different aspects (see Section 3).

3 What is CDC?

3.1 Overview: seven components of CDC

The video radiant distribution around (λ–$\lambda_\odot$, β)=(160°, +75°) seems to have several concentrations and in Figure 6 they are tentatively divided into 7 groups A–G.

Two methods of meteor shower research are by observed elements and by orbital elements. We apply these two methods to 'κ-Cygnids' and show the complex situation of the activity.

We can calculate the initial orbital elements of 7 groups on the basis of radiant classification (Table 7). Figure 7 gives the running mean calculated from SonotaCo data selected by the ellipses in Figure 6. The groups A, C, and G are distinguishable easily in their activity curves and the rest seem to be influenced by the three. It is necessary to investigate carefully the latter three, B, D, and F.

Table 8 gives the number of meteors encircled by the ellipses from each year. It is clear the 2007 event is very special and was caused by the group C activity. Group C was prominent in 2007 but then became lower than groups F and G. Something similar is true of group B and a relationship with group C is strongly suggested. The activity of group A does not seem to align with group C. The other four, D, E, F, and G are rather stable. It seems to be Group C is identified with late θ-Cygnids, Group D o-Draconids, Group E early γ-Draconids, Group F late b-Draconids, and Group G possibly ω-Draconids respectively.

We get the refined elements using the D-criterion (Paper I); classifying all meteors shown in Figure 6 according to $D(M,N)$ as the member of the group which shows the minimum $D(M,N)$ but not exceeding $D_M \geq 0.20$. The numbers of some groups increase because this

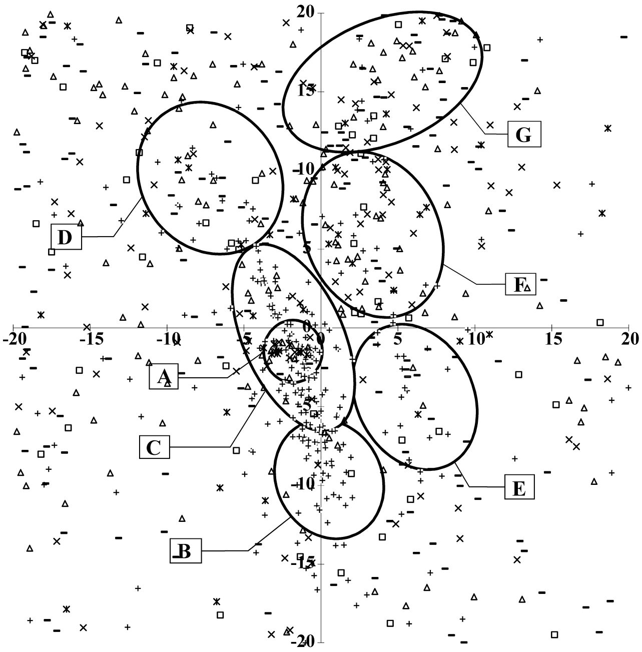

Figure 6 – SonotaCo's video radiants 2007–12 in CDC area $120 \leq \lambda_\odot < 160°$. Meteor radiants concentrate in 7 ellipses A–G. Symbols are 2007 (plus), 2008 (asterisk), 2009 (cross), 2010 (triangle), 2011 (square), and 2012 (short bar).

D_M condition works to widen the extents though groups C and D decrease because several meteors in the ellipse are sucked into a smaller D_M group. It is impossible to settle the members of each shower exactly, because the presence of sporadic activity can affect whether one meteor belongs to a shower. Though averages in Tables are only probable values, the data of Table 9 are in good agreement with Table 7 and suggest that the groups are stable enough for further studies.

Table 10 gives the $D(x,y)$ matrix for the refined orbits of the seven groups. It is clear that group A is special but the others are loosely connected with each other. Depending on 'the definition of a meteor shower', these 7 groups become one or resolve into different minute groups.

Another search, instead using photographic orbits, reveals a quite different aspect. The photographic radiant distribution for the CDC (Figure 5) looks somewhat like the video one but the author's cluster analysis indicates they comprise three main clusters as mentioned in Section 2 above. In Figure 5 we can see the overlaps of these three photographic showers on different groups of photographic meteor concentrations. If we try to refine photographic orbits by the same method as video, the

Table 7 – The average data of 7 groups encircled by the ellipses in Figure 6.

Group	Month	Day	α	δ	$\lambda - \lambda_\odot$	β	V_g	e	q	i	ω	Ω	$\lambda_\odot$	N
A	7	28.83	280.2	50.6	167.6	73.2	27.3	0.955	0.977	40.1	202.5	125.2	125.2	33
B	8	13.39	286.1	44.9	159.8	66.5	21.1	0.713	0.958	30.9	209.6	139.8	139.8	55
C	8	14.16	286.0	52.3	167.1	73.5	23.0	0.712	0.977	35.5	203.8	140.6	140.6	124
D	8	16.73	291.6	63.8	210.3	80.1	27.6	0.720	0.997	44.8	196.7	143.2	143.2	41
E	8	13.90	276.8	46.0	142.9	69.1	18.7	0.667	0.985	27.5	201.2	140.5	140.5	30
F	8	16.45	274.3	57.4	141.3	80.4	21.0	0.641	1.004	33.3	191.7	143.0	143.0	71
G	8	22.46	260.8	63.8	79.3	84.6	22.0	0.643	1.010	35.3	178.0	148.8	148.8	56

Table 8 – The number of meteors encircled by the ellipses (Figure 6) each year. Each second line represents the percentage of each group in the year.

	A	B	C	D	E	F	G	Total
2007	12	47	103	15	18	15	9	219
	5	21	47	7	8	7	4	
2008	9	0	4	4	1	8	4	30
	30	0	13	13	3	27	13	
2009	5	1	5	6	2	19	14	52
	10	2	10	12	4	37	27	
2010	7	6	10	10	2	22	19	76
	9	8	13	13	3	29	25	
2011	0	1	1	5	2	6	8	23
	0	4	4	22	9	26	35	
2012	0	0	1	1	5	1	2	10
	0	0	10	10	50	10	20	
Total	33	55	124	41	30	71	56	
Average (%)	9	6	16	13	13	23	21	

results cannot be acceptable. Conversely if we refine the video meteors by three photographic showers, MK-74, 83, and 84, the results are not good though may be suggestive. Video observations were carried out about half a century later and by rather more sensitive devices than the former small cameras. We should better study them excluding the premise that both observations recorded the same showers. We will study CDC activity using video and photographic data separately but refer the results to each other.

3.2 Group A

Group A is special, because it is distinguished from group C by both photographic and video analysis. This group is suggested by video observations clearly, but the distinction is recognized in photographic observations definitely. Group A locates in the center of the group C area and it is active at the outskirts of the group C profile, immediately before the main group C activity (Figure 7). If we exclude the radiants of 2007 data, we may not find group B and C but group A (see below). Video observations show group A is independent from group B and C activity.

Group A was noticed by Babadjanov in photographic observations for the first time in D2. The present author's cluster analysis on photographic meteors could not detect it and this shows the necessity of the hybrid research such as done by Terentjeva (T1-102) with vi-

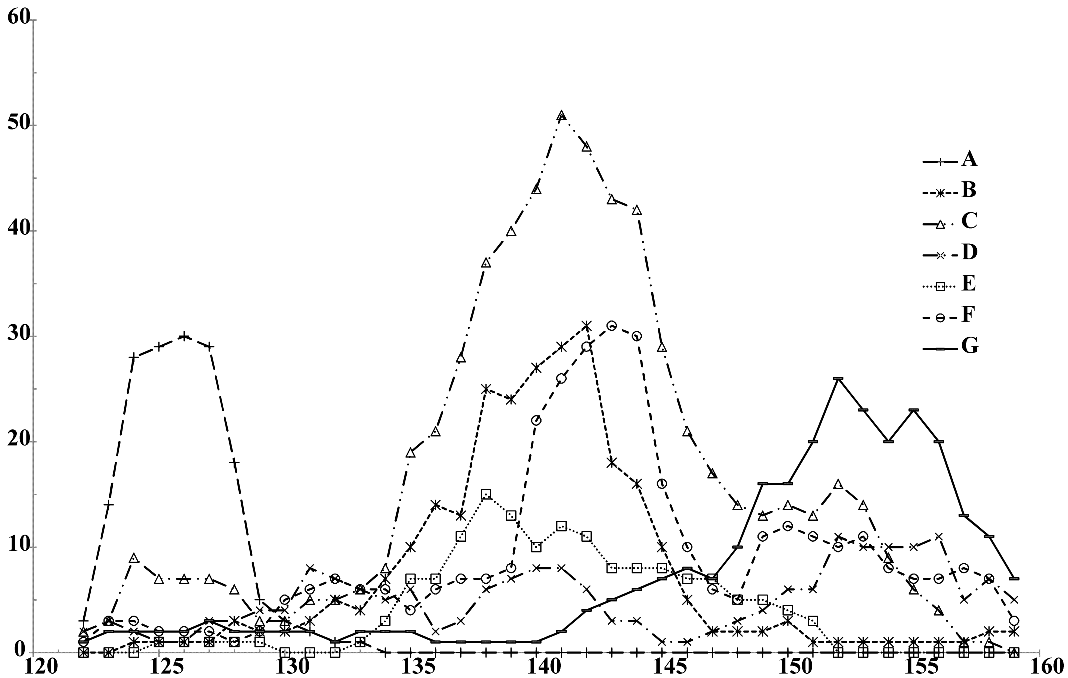

Figure 7 – Moving mean of 7 groups (corresponding to 7 ellipses in Figure 6) in 5° solar longitude bins. Data are SonotaCo's 2007–2012 video observations.

Table 9 – The 7 refined groups of meteor activities in CDC area by video. λ–$\lambda_\odot$ and β are recalculated from the average x and y in Figure 6.

Group	Month	Day	α	δ	λ–$\lambda_\odot$	β	V_g	e	q	i	ω	Ω	$\lambda_\odot$	N
A	7	29.76	280.2	51.2	167.6	73.9	27.3	0.948	0.980	40.2	201.7	125.9	125.9	45
B	8	15.40	286.8	45.5	160.2	67.2	21.3	0.712	0.958	31.2	209.1	141.8	141.8	92
C	8	15.47	286.8	53.1	168.1	74.1	23.z 2	0.706	0.977	36.0	203.6	141.9	141.9	95
D	8	22.83	290.1	63.6	204.1	80.9	27.2	0.720	0.993	44.0	195.4	149.2	149.2	29
E	8	11.61	275.5	44.7	142.0	68.3	18.1	0.645	0.983	26.5	201.5	139.9	139.9	80
F	8	17.26	274.1	57.3	141.7	80.8	21.0	0.634	1.003	33.3	191.6	143.9	143.9	89
G	8	23.21	260.6	63.0	64.1	84.8	21.8	0.643	1.010	34.8	178.2	149.7	149.7	77

Table 10 – The D-criterion for all combinations of the seven groups. $D(x, y)$ for the combination A with B is equal to 0.439 and so on.

$D(x, y)$	A	B	C	D	E	F
A						
B	0.439					
C	0.369	0.110				
D	0.393	0.258	0.166			
E	0.438	0.157	0.184	0.328		
F	0.389	0.210	0.152	0.233	0.145	
G	0.411	0.314	0.248	0.269	0.238	0.115

Table 11 – The matrix of $D(x, y)$ for preliminary photographic members of group A.

$D(x, y)$	D2-570706	D2-570774	K2-58	D2-592524	D2-570673	O3-294
D2-570706	0					
D2-570774	0.066	0				
K2-58	0.213	0.234	0			
D2-592524	0.216	0.241	0.021	0		
D2-570673	0.238	0.258	0.037	0.033	0	
O3-294	0.393	0.414	0.187	0.182	0.169	0

sual and photographic observations. Table 11 shows the matrix of $D(x, y)$ for preliminary photographic members of group A and why cluster analysis (centroid method) failed in its aim becomes clear. Some combinations are good enough for certification of their relation but other ones reject the membership. Computerized stream search fails to notice the real combination, when the premise is somewhat uncertain. There is a clear concentration of radiants but their deviation in geocentric velocity is slightly large. Strict use of D-criterion, then, leads us to misunderstanding of the membership in a meteor stream.

If we select K2-58 as a seed point (initial data set), we get 9 photographic meteors having $D(M, N) < 0.25$: K2-58, D1-3, D2-570673, D2-570706, D2-570774, D2-570827b, D2-592524, O3-294, H3-8089. Their mean elements are shown in Table 12; the declination of the radiant D1-3 might be misprinted and, therefore, the mean values of the radiant point are calculated excluding D1-3. Table 12 shows also the mean elements of SonotaCo video meteors having $D(M, N) < 0.25$ relative to photographic mean elements. Some group A video meteors are misidentified as group C and total group C video meteors amount to 41. The radiant position is calculated on the x-y coordinates centered at (λ–$\lambda_\odot$, β)=(160°, +75°) as shown in Figure 1.

The activity of the group A seems to be very changeable. Group A has no clear identification with any Denning shower. In photographic meteors 4 out of 9 were caught in 1957 and no video meteors were recorded in 2011 and 2012. This shower clearly coincides with IAU-184 (GDR) but has not been noticed by radar observations.

3.3 Group B

Group B might be connected with the late activity of δ-Cygnids or early α-Lyrids (Figure 1). Previous studies (Section 2) suggest groups B and E might be united as MK-74 and Ref-No. 125. But recent video observations indicate group B is part of group C.

Group B consists of 55 meteors and 47 meteors are from 2007 (Table 8). This strongly suggests group B relates to group C and, moreover, the maxima almost coincide with each other. The elliptical radiant distribution of group B and C is not due to the radiant drift, though the combined radiant distribution of the two elongates still more and suggests the radiant drift (see below). This ellipse results from orbital characteristics, because the ecliptic latitude of the radiant, i.e. the y coordinate, correlates strongly with argument of perihelion (Figure 8) and the perihelia of its member meteors locate in an ellipse (Figure 9).

It is necessary to note that if we exclude the 2007 event, the radiant distribution of B looks like the photographic one (Figure 10). Table 9 and Figure 7 show two groups, B and F, reach maximum around $\lambda_\odot = 140°$ but these two have a different nature; group B consists of 2007 meteors mostly, 47 meteors out of 55, compared to 15 out of 71 in group F. It might be suggested two different activities exist in the area B. One is the south-

Table 12 – The mean elements of group A, i.e. GDR.

Month	Day	α	δ	λ–$\lambda_\odot$	β	V_g	e	q	i	ω	Ω	$\lambda_\odot$	Source
7	26.86	278.7	48.8	164.5	71.7	27.5	1.023	0.973	39.8	203.2	124.0	124.1	photo
7	28.90	280.3	50.9	168.1	73.5	27.2	0.947	0.978	40.2	202.3	125.3	125.3	SonotaCo

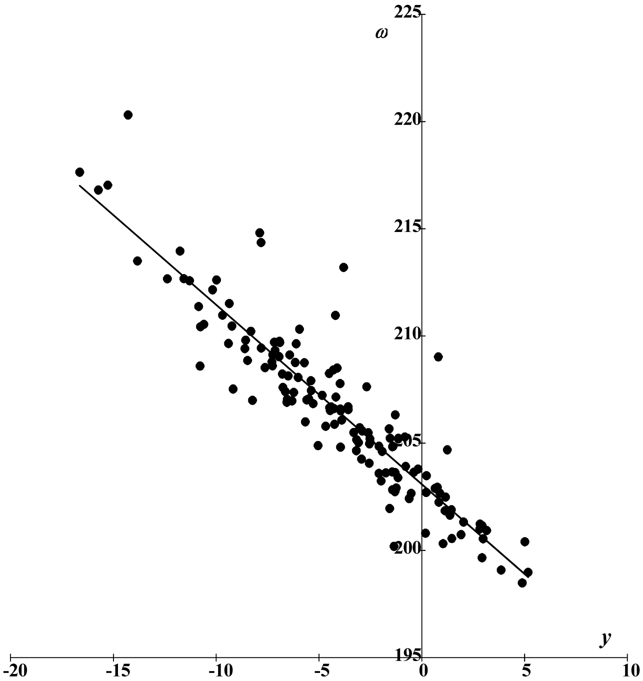

Figure 8 – The correlation of the argument of perihelion with the radiant y coordinate, for meteors classified as KCG2 (i.e. video groups B and C in 2007; see Section 3.4.2).

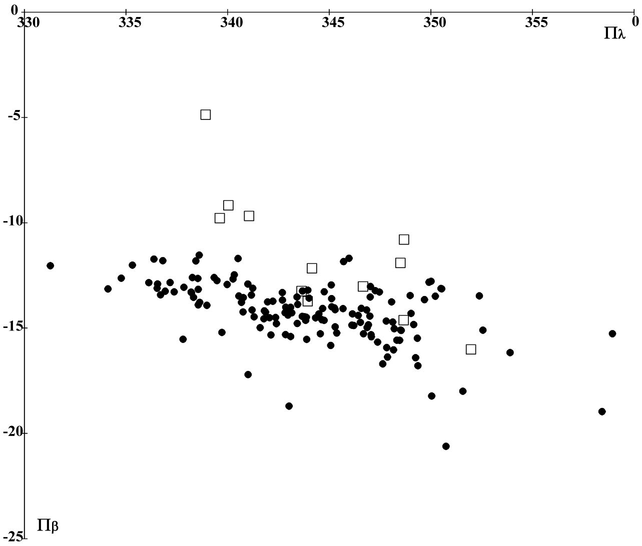

Figure 9 – The perihelia (ecliptic latitude and longitude of perihelion point) of KCG2; solid circle=video meteors, square=photographic meteors.

ern part of group C and another might be connected to group E as suggested by photographic data. We had better study photographic group B and video group B separately. Video group B will be investigated in Section 3.4 and photographic group B in Section 3.6.

3.4 Group C

The group C is the most interesting activity to need the most precise investigation. Traditional 'κ-Cygnids', that is the photographic shower, appeared in the group C area in 1950 and possible new 'κ-Cygnids', that is the video shower, became remarkable suddenly in 2007 near the former's radiant. It is proper that we study each event separately at first, because whether these two activities might be identical is not clear yet.

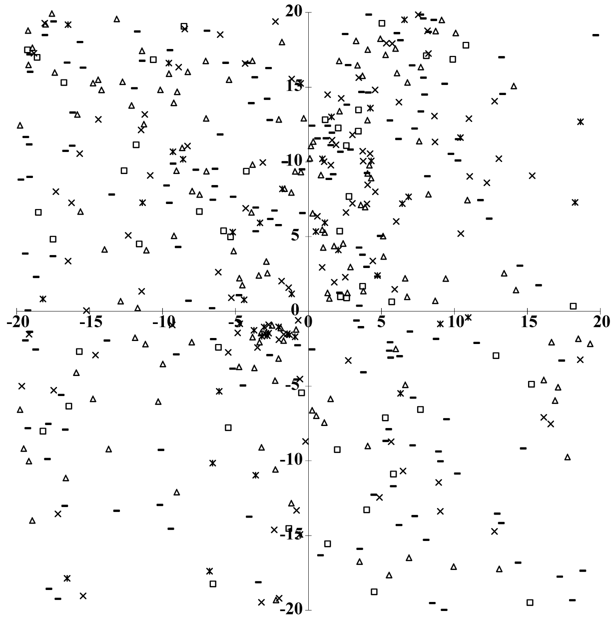

Figure 10 – SonotaCo's video meteor radiants 2008–12. Excluding 2007 radiants the distribution becomes quite different (cf. Figure 6).

3.4.1 Photographic 'κ-Cygnids'

We search possible members of MK-83 (photographic κ-Cygnids) among meteors shown in Figure 1 within $D(M,N) < 0.25$ excluding meteors nearer to the other three showers MK-74 and MK-84, and group A. These refined 'κ-Cygnids' have two remarkable characteristics: several meteors initially classified as group D are added in and 10 of the total 13 meteors appeared in 1950 or 1957.

Because one of these 13 meteors, O2-273, shows $D(M,N) = 0.244$ and seems to be too late, the following summary data are from 12 meteors: H5-2105, H5-2078, H5-2071, H5-2067, O1-16, H1-3652, K1-7, O1-18, O1-17, C4-9951, O2-269, C4-10021. The difference between these new elements and those of MK-83 is caused by the difference of the search methods for a meteor shower. The cluster analysis (centroid method) is suitable for the case the data are distributed spherically in the studied data space and might lead to false results in cases of irregularly shaped data distributions. The perihelion distribution in Figure 9 suggests the spherical presumption is not the case. We had better change the discrimination level and the method of classification.

The radiant drift is calculated on the x-y coordinates centered at $(\lambda–\lambda_\odot, \beta) = (160°, +75°)$ as shown in Figure 1 and daily motion in (α, δ) and in $(\lambda–\lambda_\odot, \beta)$ coordinates are not constant (Table 13).

If we apply the mean elements of video groups to photographic meteors, the results lead to confusion; six meteors of the former 'κ-Cygnids', i.e. MK-83, would be broken into three groups; three in C, two in D and one in B. If we select photographic meteors for MK-83 members by the mean elements of video group C, a curious set of meteors is figured in; three original MK-83 members remain and two sporadics, two MK-84 and one MK-74 join (see Section 3.6). If we combine photographic meteors of group C with group B like video groups, this does not work well also. Photo-

Table 13 – 'κ-Cygnids' in photographic meteor data with their radiant drift.

Month	Day	α	δ	λ–$\lambda_\odot$	β	V_g	e	q	i	ω	Ω	$\lambda_\odot$	N
8	22.92	289.1	58.7	176.8	78.3	25.5	0.757	0.987	40.0	198.6	150.1	150.1	12

$\lambda_\odot$	140	141	142	143	144	145	146	147	148	149	150
α	283.6	284.3	284.9	285.6	286.2	286.7	287.3	287.8	288.2	288.7	289.1
δ	46.8	47.9	49.1	50.3	51.5	52.6	53.8	55.0	56.2	57.4	58.6
λ–$\lambda_\odot$	156.7	157.8	159.1	160.5	162.1	163.8	165.8	168.0	170.5	173.4	176.6
β	69.0	70.0	70.9	71.9	72.9	73.8	74.8	75.7	76.6	77.4	78.3
$\lambda_\odot$	151	152	153	154	155	156	157	158	159	160	
α	289.4	289.7	289.9	290.0	290.1	290.1	289.9	289.7	289.3	288.8	
δ	59.8	61.0	62.2	63.5	64.7	65.9	67.1	68.3	69.5	70.7	
λ–$\lambda_\odot$	180.3	184.6	189.5	195.1	201.4	208.4	215.9	223.8	231.8	239.6	
β	79.0	79.8	80.4	81.0	81.5	81.9	82.2	82.3	82.2	82.1	

graphic showers might be distinct from video ones and could not be identified in the same manner. We refer to this photographic activity as KCG1 hereafter.

3.4.2 Video 'κ-Cygnids'

Group C is the most intense activity in video observations and relates to the 2007 event. The profile of group C in Figure 7 suggests it includes multiple activities. Koseki (2012) introduced an estimation method of the meteor activity profile on the basis of a simple model of modifications of an orbit. This method implies the complexity of the group C activity as shown in Figure 11. The y-axis in Figure 11 is standardized to the peak as $N = 10$ and the two hypothetical activities are set to $N = 8$ at $\lambda_\odot = 140°$ and $N = 6$ at $\lambda_\odot = 144°$. It is clear the composite curve expresses the observed one well and suggests contamination from group A around $\lambda_\odot = 125°$ and from group F or group G after $\lambda_\odot = 150°$. The author does not insist the two independent showers constitute video 'κ-Cygnid' activity but the video profile suggests it might keep a trace of historical 'κ-Cygnids', that is, KCG1.

As mentioned above, groups B and C might be one. The D-criterion between B and C is 0.11 (see Table 10). Some might distinguish them as different showers but others might combine them into one. The difference in the definition of a meteor shower causes confusion in meteor shower lists. Here we treat groups B and C as one and study them restricted to the 2007 event, because it is necessary to study meteor showers one by one as discussed above.

We reject 41 meteors observed after 2007 from the total 187 meteors (Table 9) of groups B and C at first. Two meteors are rejected additionally and there remain 144 meteors, because they locate far distant from the mean correlation between $\lambda_\odot$ and x in the 146 meteors. We use the averages shown in Table 14 for further studies.

This group, abbreviated as KCG2 hereafter, shows radiant drift and the results by least squares calcula-

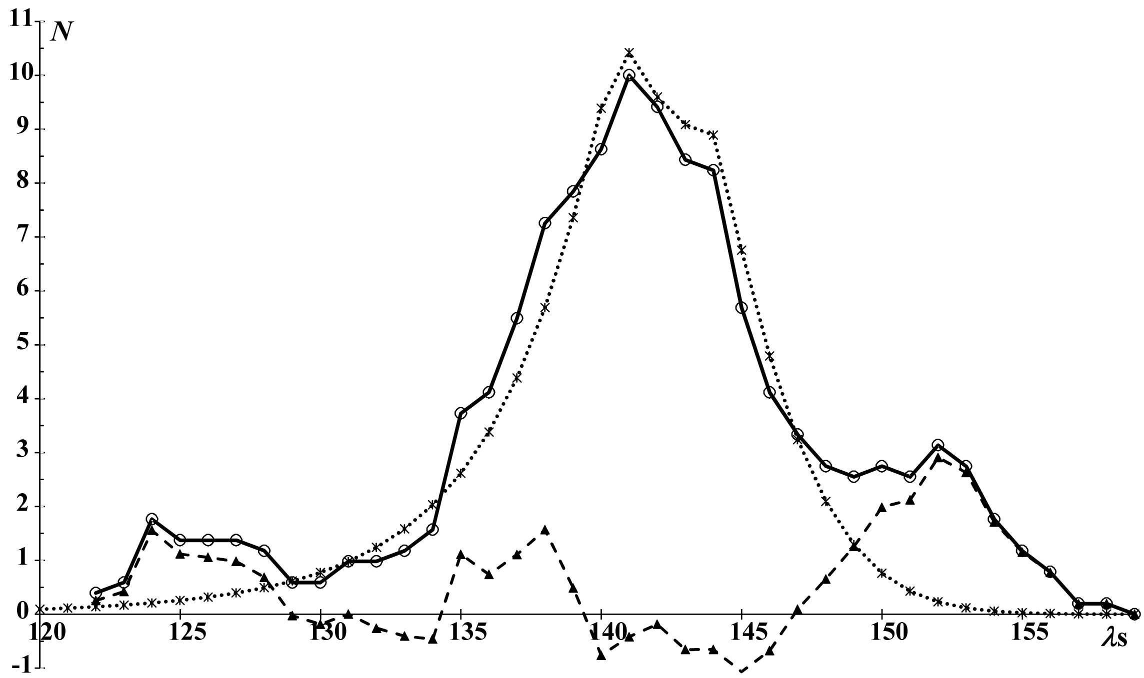

Figure 11 – Estimated KCG rate by the method of Koseki (2012). Open circle=observed rate, asterisk=estimated rate, and solid triangle=residual.

Table 14 – 'κ-Cygnids' in video meteor data with their radiant drift.

Month	Day	α	δ	λ–$\lambda_\odot$	β	V_g	e	q	i	ω	Ω	$\lambda_\odot$	N
8	15.02	287.0	49.6	164.4	70.9	22.3	0.703	0.968	33.8	206.5	141.4	141.4	144

$\lambda_\odot$	120	125	130	135	140	145	150	155	160
α	273.1	276.8	280.3	283.6	286.5	289.0	291.0	292.5	293.2
δ	36.6	39.4	42.4	45.5	48.7	51.9	55.3	58.7	62.2
λ–$\lambda_\odot$	154.9	156.5	158.4	160.7	163.5	167.1	171.9	178.3	187.1
β	60.0	62.6	65.2	67.7	70.2	72.6	74.9	77.2	79.1

Table 15 – The orbital elements of KCG1 and KCG2 at solar longitude 145.0 estimated by least squares results.

	e	q	i	ω	Ω
KCG1-145	0.788	0.978	36.4	203.2	145.0
KCG2-145	0.699	0.972	35.1	205.3	145.0

tions are in Table 14. The residuals of observed position subtracted from the estimated value might represent the real radiant expanse (Figure 12). It is clear KCG2 radiants spread in an ellipse over 10° in length and 5° in width. The radiant area is not a point and really elongates in (λ–$\lambda_\odot$, β) coordinates.

3.4.3 Are the 1950 and 2007 events identical?

Tables 13 and 14 show KCG2 locates systematically lower in ecliptic latitude than photographic event KCG1 (see also Figure 16). The mean node (= solar longitude at the maximum) of KCG2 is earlier than the photographic one. The D-criterion between KCG2 and the photographic shower amounts to 0.153 and suggests that the two events arose from different streams. But, if we estimate the orbital elements by the least squares expressions for $\lambda_\odot = 145°$ (Table 15), the D-criterion reduces to 0.096 meaning they can unite into one.

It is natural their radiant drifts between $\lambda_\odot = 140°$ and $\lambda_\odot = 150°$ are enough close to each other. It seems to be proper to choose $\lambda_\odot = 145°$ here as 'κ-Cygnids' maximum in accordance with the IAU list, but there are no 'κ-Cygnids' before $\lambda_\odot = 145°$ in the 12 photographic meteors mentioned in Section 3.4.1. How can we resolve these confusions?

3.4.4 Call for 'κ-Cygnids' observations in 2014

It is easy to classify two events as different sources or to unite them neglecting the slight differences. The difference in eccentricity between photographic and video orbits might be ignored, because the deceleration in the atmosphere is not taken into consideration in video observations. If we assume these events have a periodic nature, we can get the period as 7 years. Photographic meteors had been mainly recorded in 1950 and 1957 as mentioned above. DMS caught the outburst in 1993 and a video event occurred in 2007, that is, 14 years after DMS' observation. Japanese observers noticed higher 'κ-Cygnid' rates in 2013 and hoped for the return of the 2007 event.

If we accept the hypothesis of periodic nature and KCG1 evolved into KCG2, both the radiant and the maximum should be moving; $\Delta\delta = -9\overset{\circ}{.}0$ and $\Delta\lambda_\odot = -8\overset{\circ}{.}7$ during 50 years (Tables 13 and 14). Though it seems too fast, such a shift might be possible because the ascending node of 'κ-Cygnids' is near Jupiter's orbit. If we extrapolate the move backward more than one hundred years, we can find the past visual observations. The most plausible candidate in Denning's catalogue is o-Draconids, not θ-Cygnids or κ-Cygnids.

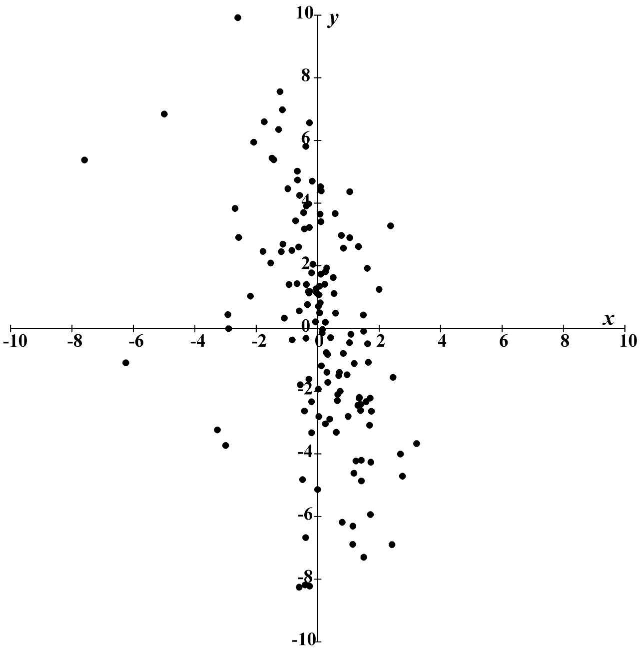

Figure 12 – Shape of KCG2 radiant: residuals from least squares estimation of radiant drift.

3.5 Group D

The study in Section 3.4.1 indicates the most part of photographic meteors in the group D area belong to KCG1. Figure 7 suggests the profile of video group D activity might relate to group B and C activity, that is, KCG2. If we extract 'κ-Cygnids' from group D meteors, the remaining meteors in the group D area (Figure 10) represent the normal background meteor activity. Group D might be an apparent concentration by KCG1, KCG2, and contamination from group G (see Section 3.8), though radar showers have been reported in the area of group D (Figure 4).

3.6 Group E

As mentioned in Section 3.3, group E is suggested to relate to group B by photographic data, i.e. MK-74, but, on the other hand, about half the video meteors of group E were recorded in 2007 the year of the group

C 'outburst' (Table 8). The 2007 video event had a dense core, i.e. KCG2, and might have a wide active region including the group E area clearly. If we accept group E and group B meteors constitute one shower, $D(M,N) < 0.20$ seems to be proper for the limit of a meteor shower but strict use of this condition for other cases leads us to confusion.

If we adopt $D(M,N) < 0.20$ as the ordinary limit for meteor shower identification, the cross searches between photographic and video meteors result in failure. Re-classification of video orbits based on the three photographic showers binds group B and E as members of MK-74 and, moreover, meteors classified as MK-74 are spread over groups C and F. Re-classification of photographic orbits based on KCG2 binds up MK-74, MK-83 and a part of MK-84. It is better to study group E video and photographic activity separately as well as in the case of KCG1 and KCG2.

We refine photographic meteors by the same manner of MK-83 (see Section 3.4.1) and get the orbit and radiant drift for MK-74 shown in Table 16. This activity MK-74 is the combination of Lindblad's α-Lyrids and August Lyrids (see Table 6). He discriminated the meteor activities between group B and group E, and designated them as α-Lyrids and August Lyrids respectively. We unite them into one and call it α-Lyrids instead of MK-74 hereafter. α-Lyrids are the weakest activity in CDC area, and if we change the discrimination level, there might be another view. If we divide α-Lyrids and take the elongated shape of the radiant into consideration, group B photographic activity might connect with group C and group E with group F as in video meteors (see below).

Video meteor radiants in group E should be studied carefully because of the influence of the 2007 event. Some 2007 radiants are related to KCG2 activity and the rest seem to originate from photographic α-Lyrid activity. But α-Lyrid activity in an average year is almost hidden in the sporadic background from video view.

Though group E meteors in 2007 might have the same origin with KCG2, there is a clear gap in the radiant distribution between B and E (Figure 6). Figure 13 shows the distribution of the seven groups we investigate and group E meteors are indicated by solid squares. We can see the area of group E meteors becomes wide in Figure 13b, because these group E meteors are refined by the D-criterion and are distributed spherically. We recognize the gap in Figure 13a between group B and group E as well as in the radiant distribution. As in the case of KCG1 and KCG2, we had better quit the spherical presumption and change the discrimination level or the method of the classification.

Table 10 shows the similarity of orbits, i.e. the D-criterion between groups E and B is as large as the value for group F. If we adopt $D(M,N) < 0.20$ as an ordinary limit for meteor shower identification, some group E meteors might be combined with group F as well as the case of groups B and C. Both the radiants and the perihelia have a somewhat flattened rather than spherical distribution, and both distributions suggest the relation of groups E and F (Figures 6 and 13a). It seems preferable to use a geobased search rather than an orbbased one, because Figure 13a,b suggests an orbbased search might confuse the results. We will study group E video meteors in the next section as the outer expanse of group F. Cygnus expands her wings in two directions; left as B, C and D, right as E, F and G.

3.7 Group F

The number of group F video meteors ranks second to group C. If we exclude 2007 video data, as in the case of group A, we may find group F as the most active shower in the region of CDC in late August because group A is finished then. But, there might be chaotic classification of observed meteors. When we look up at the sky during Perseid observations, we may see a group F meteor path as shown in Figure 14. Radiant areas of group C and F are very near in the field of view of observers regarding the direction of meteor paths. If veteran observers draw meteor paths very carefully, only they could recognize two different showers are active and may perceive the lower path comes from group C and the upper from group F. Many observers who do not record meteor paths on the chart might report the activity of group F as 'κ-Cygnids' in average years. There might be wing structures like a swan has underwings of primaries, secondaries, and so on.

Though group F is active, this group does not have a distinct center and overlaps with neighbor showers; group C, E, and especially G: the group F radiants move upward with time and seem to enter the group G area (Figure 15a–d). When we use the least squares solutions of x, y, and V_g as functions of $\lambda_\odot$ of refined group F, and the conditions Δx < 5, Δy < 5, $\Delta V_g < 5$ to reject possible contaminations and to search for possible group F members in groups F and G, we get 95 possible members of renewed group F, hereafter KCG3. The averages of this geobased revision are shown in the first line of Table 17 and the second line gives the result of the somewhat different (orbbased) method described in Section 3.8.1. The different classifying methods lead to different results and the number of member meteors increases apparently. When the sporadic rate is high, other meteor showers are active in the vicinity, and the activity of the meteor shower itself is not enough; the different method might lead to a quite different result. But both lines are in good agreement and we use the first line as KCG3. This is very close to MK-84 but if we search for KCG3 in photographic meteors, we could not get definite members. Photographic meteors in group F area should be studied in Section 3.8.2.

The radiant drift of KCG3 is calculated on the x-y coordinates on (λ–$\lambda_\odot$, β) and, therefore, daily motion in (α, δ) and (λ–$\lambda_\odot$, β) coordinates are not constant. It is necessary to note this renewed group F is not conclusive, because the distributions of meteor numbers along with solar longitude suggest there are two or more activities in it or remaining contaminations from neighbor groups.

The activity of group F is not found in Denning's list (Table 1 and Figure 1) and other visual observations could not discriminate it from other CDC activities.

Table 16 – MK-74 (α-Lyrids) in photographic meteor data with their radiant drift.

Month	Day	α	δ	$\lambda-\lambda_\odot$	β	V_g	e	q	i	ω	Ω	$\lambda_\odot$	N
8	9.20	278.7	44.8	149.5	67.8	20.2	0.723	0.971	29.3	204.7	136.9	136.9	21

$\lambda_\odot$	120	125	130	135	140	145	150	155	160
α	282.8	283.3	283.0	282.0	280.1	277.3	273.6	269.2	264.2
δ	32.0	36.0	39.8	43.3	46.4	49.1	51.1	52.5	53.1
$\lambda-\lambda_\odot$	169.0	165.8	161.8	156.6	149.8	140.7	128.5	112.9	95.3
β	54.6	58.5	62.2	65.8	69.1	72.1	74.5	75.9	76.2

Table 17 – Two sets of the elements of group F (KCG3) calculated by different methods; first line from geobased, second line from orbbased (see text). The radiant drift is based on the first line member meteors.

Month	Day	α	δ	$\lambda-\lambda_\odot$	β	V_g	e	q	i	ω	Ω	$\lambda_\odot$	N
8	18.71	272.9	58.2	139.0	81.7	21.3	0.642	1.004	33.7	190.1	145.0	145.0	95
8	16.92	275.2	55.8	144.0	79.1	20.9	0.640	1.000	32.8	193.3	143.5	143.5	145

$\lambda_\odot$	120	125	130	135	140	145	150	155	160
α	272.6	274.1	275.1	275.5	275.1	273.8	271.5	268.0	263.5
δ	44.8	47.7	50.5	53.3	56.0	58.5	60.8	62.7	64.1
$\lambda-\lambda_\odot$	155.0	153.6	151.7	149.2	145.3	139.0	127.1	101.8	58.5
β	68.2	71.0	73.7	76.5	79.1	81.8	84.2	86.0	86.4

KCG3 might be a recent shower or relate rather to ZDR than KCG (see Section 3.8).

3.8 Group G

The meteor activity in group G has been well known and it has been called ζ-Draconids by Denning (1899). This activity is observed clearly by both video and photographs (Figures 1, 6 and 7), and its yearly fluctuation is smaller than group C. The maximum of group G occurs far from those of 'κ-Cygnids' and KCG3 (Figure 7).

3.8.1 Video ζ-Draconids

Video radiant distributions (Figure 15a–d) suggest that group G radiants move to the upper right and go out of sight. It is necessary to research group G meteors from the entire meteor data, because, in addition to the radiant distribution, the profile shown in Figure 7 suggests group G activity exceeds the researched $\lambda_\odot$ limits.

As mentioned in Section 3.7, group F moves into the group G area, though their maxima differ clearly (Figure 7); it is necessary to take group F meteors into consideration in order to settle the candidates of group G membership. We apply the following steps.

Step 1: We exclude candidate meteors for group F from refined group G meteors (Table 9) within the limits of geobased group F, i.e. KCG3 (see Section 3.7).

Step 2: We select candidate meteors for group F by $D(M,N) < 0.20$ relative to the KCG3 orbit (Table 17) in all SonotaCo meteors without any restriction. We select candidates for group G by $D(M,N) < 0.20$ relative to the renewed group G average (*Step 1*) in all SonotaCo meteors, again without any restriction. This gives cumulative meteors of F and G.

Step 3: KCG2 meteors (Table 14) are very close to the cumulative meteors (*Step 2*) in orbital space and, therefore, it is necessary to exclude KCG2 from the candidates of group F and group G meteors (*Step 2*). We therefore classify each selected candidate (*Step 2*) as a member of the group that shows the minimum $D(M,N)$ for geobased F, renewed G and KCG2.

We get the average data of renewed group G and the estimated radiant drift from video, shown as ZDR2 in Table 18.

3.8.2 Photographic ζ-Draconids

Though ζ-Draconids are clearly shown in photographic observations, the group F activity is unclear unlike video meteors. We use the same methods described in Section 3.4.1 in order to refine MK-84 members and the results are shown in Table 18 as ZDR1. Photographic MK-84, i.e. ZDR1, is identified with video group G activity, i.e. ZDR2, but it is necessary to note video group F activity, i.e. KCG3, is nearer to ZDR1 than ZDR2. If we select photographic ζ-Draconids excluding supposed group F meteors, the results become close to ZDR2. It is unfortunate for us we do not have enough data confirming group F activity in photographic meteors. It is suggested there is some contamination from group F activity in ZDR1 and, therefore, we give the radiant drift on the basis of video observations.

3.8.3 The discrimination level: ζ-Draconids and neighbor activities

We use the orbbased method in this section and it leads to group F averages somewhat different from geobased ones (see Section 3.7). It is enough for us to indicate group G is probably connected with 'κ-Cygnids', that is, KCG3.

The estimated radiant of the renewed group G locates in the group D region during the early period of the activity. It is clear group D is the conglomeration of group C, group G, and the sporadic background, with possibly connected radar showers.

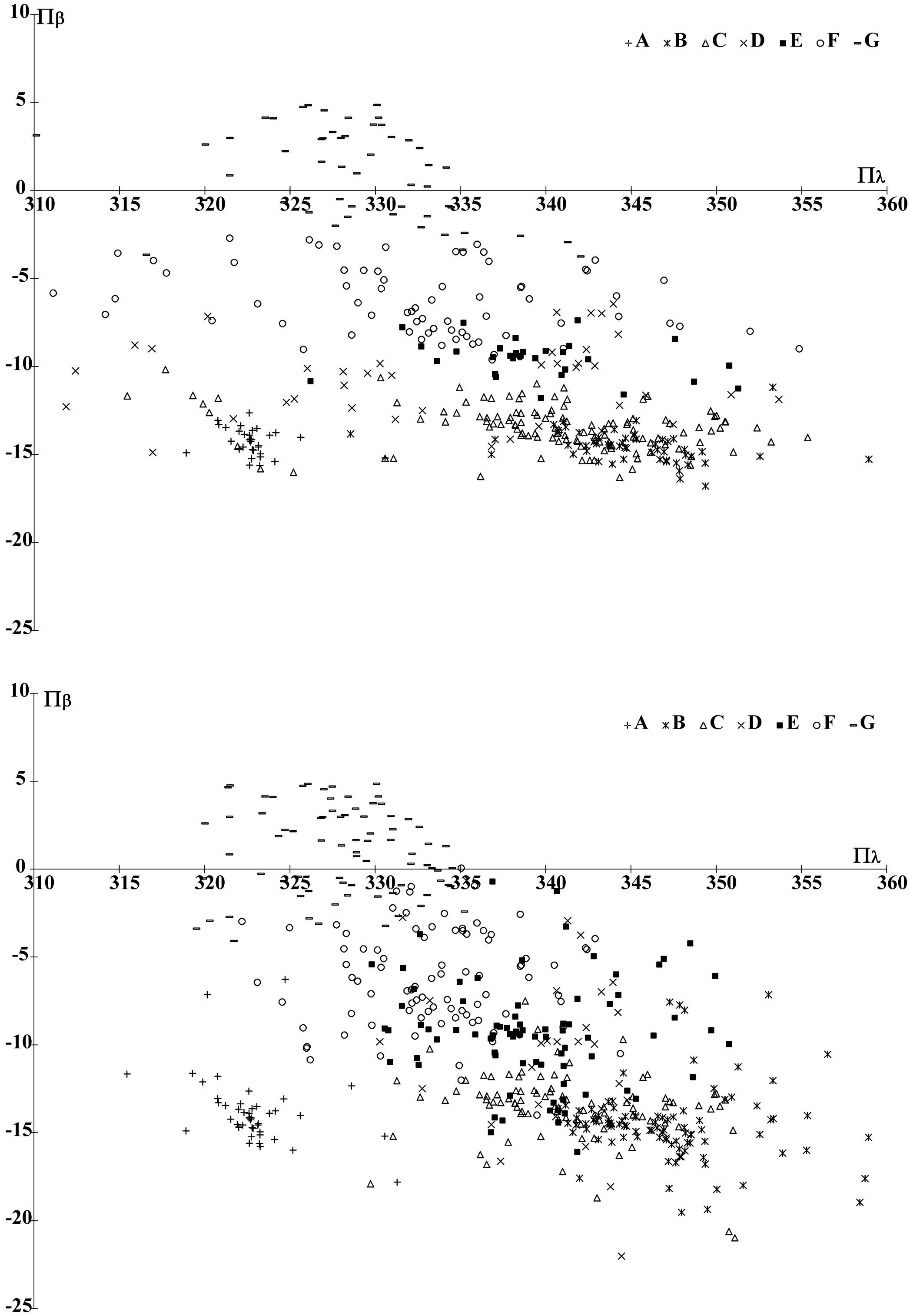

Figure 13 – The distribution of perihelia classified into 7 groups. top; 7 groups based on the radiant distribution (Table 7), bottom; 7 groups refined by D-criterion (Table 9).

If we choose a narrower condition such as $D(M, N) < 0.10$, CDC will be subdivided into several groups. The views of a meteor scene become different by virtue of what condition we choose. If we divide using the meteor shower narrower definition, we could 'discover' weaker and more numerous numbers of meteor showers. This study does not intend to find or define a new meteor shower but investigate how meteor showers look different case by case and method by method (Table 19).

3.8.4 Confusion in group G area

Meteor activity in the group G region is very complex and not so abundant to confirm the details. Group F activity becomes near to group G as time goes on and radar meteor radiants locate on the edge of the northern Toroidal region.

The IAU shower list is unclear concerning the group G region; ZDR has been changed completely from the

Table 18 – Two sets of the elements of group G by photo (ZDR1) and by video (ZDR2) with the radiant drift based on video meteors. (λ–$\lambda_\odot$, β) are calculated from the average (x, y) not arithmetic mean.

Observation	Month	Day	α	δ	λ–$\lambda_\odot$	β	V_g	e	q	i	ω	Ω	$\lambda_\odot$	N
Photo(ZDR1)	8	21.72	269.0	61.7	115.4	85.1	22.0	0.659	1.008	35.0	184.3	149.0	149.9	18
Video(ZDR2)	8	24.94	255.1	62.4	47.8	82.5	21.3	0.641	1.006	33.8	174.5	151.3	151.3	108

$\lambda_\odot$	120	125	130	135	140	145	150	155	160	165	170
α	280.9	279.0	276.0	272.0	267.1	261.4	255.6	250.1	245.4	241.6	238.8
δ	55.4	57.9	60.1	61.8	63.0	63.5	63.4	62.5	61.0	58.9	56.4
λ–$\lambda_\odot$	180.3	174.9	165.5	146.5	109.2	70.9	51.0	41.2	35.7	32.2	29.7
β	77.7	80.4	83.0	85.2	86.2	85.3	83.2	80.6	77.9	75.1	72.3

Table 19 – The group G related showers. Shower names as given by the original authors.

Source	α	δ	λ–$\lambda_\odot$	β	V_g	e	q	i	ω	Ω	$\lambda_\odot$	Shower
L1-167	260	30	120.6	52.9	18	0.667	1.005	16.7	194.3	135.0	135	θ Herculids
S3-142	303.2	42.7	184.1	60.1	17	0.378	0.880	27.1	238.8	139.7	139.7	Gamma-Cygnids
T1-110	270.7	54.1	123.4	77.5	21.9	0.785	1.008	32.6	188.9	148.4	148.4	ζ-Drads
L1-207	269	59	116.6	82.4	24	0.640	1.015	33.0	183.5	149.5	149.5	ζ Draconids
S3-147	271.3	65.0	148.7	88.4	23.6	0.636	1.010	38.5	183.1	140.8	140.8	August Draconids
S3-149	272.4	64.9	160.6	88.1	17.3	0.335	1.007	30.4	185.6	141.2	141.2	Phi-Draconids

first list[1] and several quoted observations in AUD are absent from the recent version.

ZDR was identified with θ-Herculids in the first IAU list which gave L1-167 and S3-142 as examples. The latest IAU list insists ZDR is further north and earlier (see Table 3) based on video observations and seems to use the classical name of ζ Draconids incorrectly. On the other hand, there are (Table 19) two ζ-Draconids published by Terentjeva (T1-110) and Lindblad (L1-207). Terentjeva pointed out that T1-110 has a very close orbit with T1-112 and T1-113 and that there was a ζ-Draconid meteor misidentified as Cygnids by another

[1] `http://www.astro.sk/~ne/IAUMDC/STREAMLIST/meteoroidstreamworkinglist.pdf`

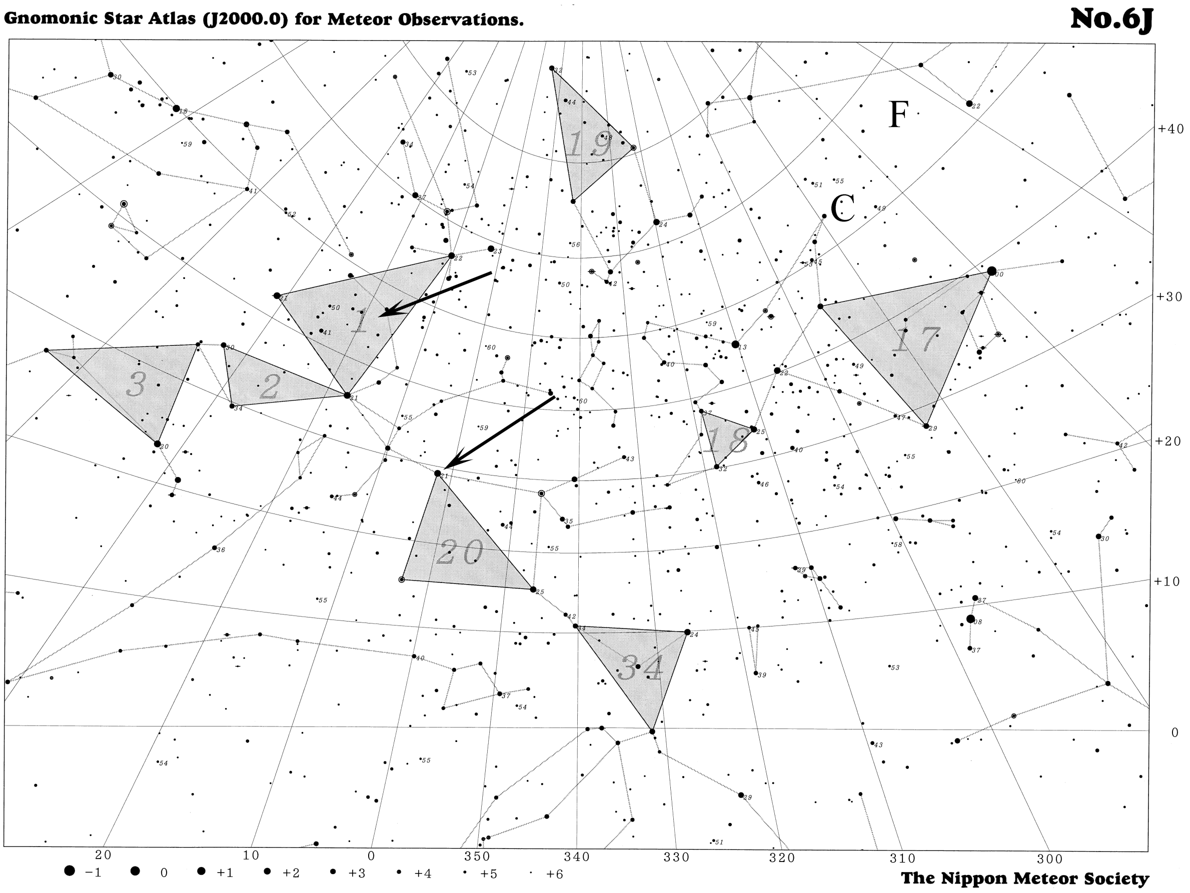

Figure 14 – Two CDC meteor paths on the gnomonic star atlas of the NMS. One comes from C and another F.

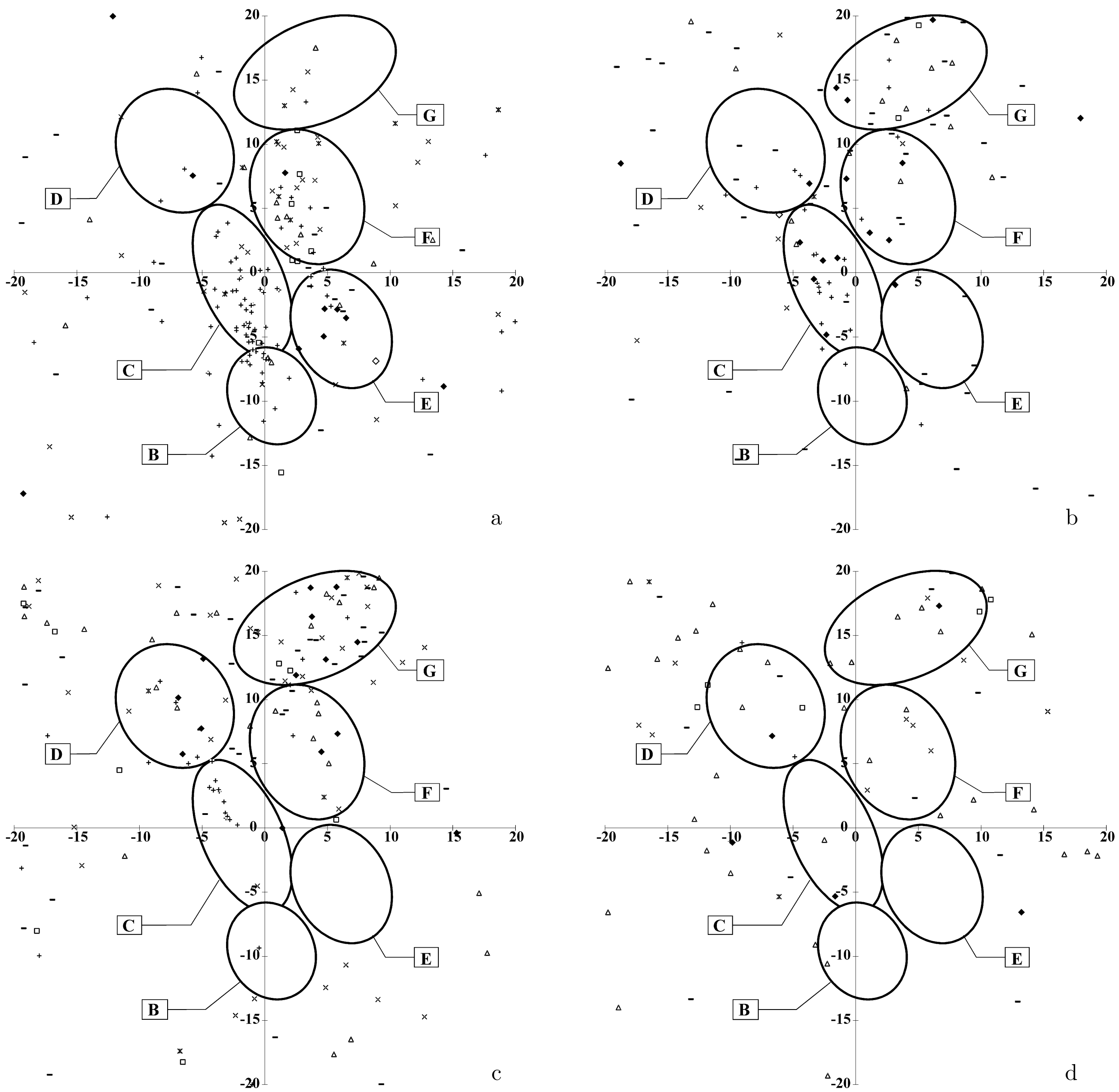

Figure 15 – SonotaCo's video meteor radiants with photographic ones. a; $140 \leq \lambda_\odot < 145$, b; $145 \leq \lambda_\odot < 150$, c; $150 \leq \lambda_\odot < 155$, d; $155 \leq \lambda_\odot < 160$.

researcher. T1-110 and L1-207 are a little different though both from photographic observations, because Lindblad did not use Russian observations but Harvard ones only. Though Denning's catalogue does not define the activity period of ZDR, recent observations indicate ZDR is active in late August. T1-110 and L1-207 more properly correspond than the observation shown in the IAU list.

The IAU list gives another meteor shower AUD, which is based on S3-149 only, in the group G region, but the author's survey showed S3-147 and L1-207 are in the same group (see Table 4). Figures 2 and 4 show AUD locates in the crowded area of radar radiants and Table 4 suggests additionally LE-441, LE-445, and T1-112 might be identified as AUD. Moreover, the predicted radiant of group F comes close to AUD (see Table 17). AUD seems very unclear whether it relates to ZDR activities or is another independent activity. If we accept S3-147 as the only observation of AUD, it is necessary to note the Harvard radar survey observations in 1968–69 stopped operating during $\lambda_\odot = 145.8$–152.7 when T1-110 and L1-207 (ζ-Draconids) are active. This is why we call the group G activity ZDR and not AUD in Table 18.

4 Various views of CDC

CDC activity is complex and consists of several minor showers. Photographic and video observations reveal the outline of CDC. So-called 'κ-Cygnids' have three activities;

(1) Historical activity recognized by photographic observations, i.e. KCG1, might cease to exist or evolve into (2).

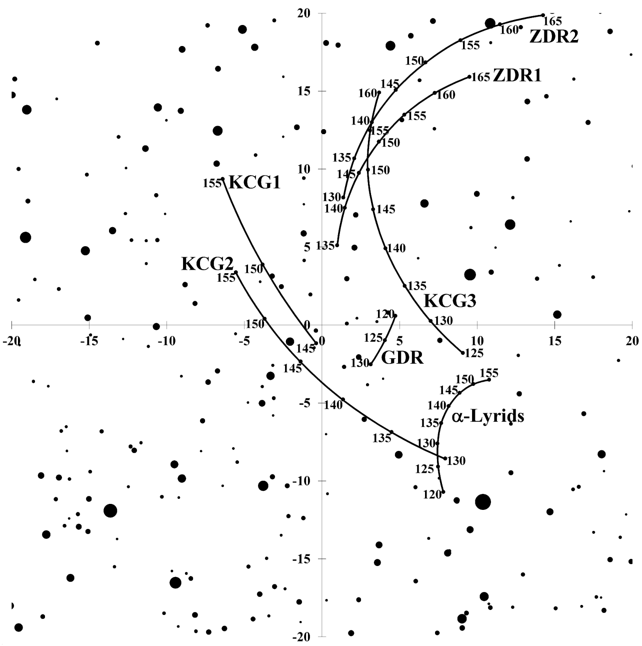

Figure 16 – Radiant drifts on a star chart.

(2) Periodic activity with 7 year period, i.e. KCG2, becomes excellent recurrently but buried in sporadic activity in average years.

(3) Steady activity, i.e. KCG3, is now called 'κ-Cygnids' and observed every year, but the relation between KCG3 and KCG1 or KCG2 is unclear.

Three other activities in CDC area are detected by this research;

(4) Terentjeva's ε-Lyrids or Lindblad's α-Lyrids are traceable in photographic observations but not recognizable in video ones. The radiant drift of this shower in Figure 16 is indicated as α-Lyrids.

(5) Denning's ζ-Draconids are recognized well by both photographic and video observations and surpass KCGs in the average year. Figure 16 shows both photographic (ZDR1) and video (ZDR2) radiant drifts. IAU-ZDR is referred to another observation incorrectly.

(6) Terentjeva's 13-Lyrids, i.e. GDR, are recognized by both photographic and video observations but might change their activity widely.

Optical observations, especially fireball capture systems, are good for detecting CDC activity. To perceive CDC activity is a matter of time, because CDC is rich in bright meteors but with a low hourly rate. Recent video observations are best for detecting CDC. Ordinary photographic observations were carried out in the period of major meteor showers and CDC activity was noticed because Perseids are active.

The nature of CDC rich in bright meteors is the one reason why radar observations missed CDC, because CDC is easily buried under the abundant sporadic background of faint meteors recorded by radar. Many radar observations, moreover, worked with long interruption and did not continue for many years.

Table 20 – Interrelation between CDC member showers.

	KCG1	KCG2	KCG3	α-Lyrids	ZDR1	ZDR2
KCG1						
KCG2	0.153					
KCG3	0.228	0.176				
α-Lyrids	0.238	0.115	0.166			
ZDR1	0.229	0.212	0.056	0.207		
ZDR2	0.322	0.301	0.130	0.276	0.096	
GDR	0.405	0.400	0.389	0.360	0.394	0.435

Lindblad (1995) indicated a genetic relationship between his showers (Table 6). CDC members excluding GDR connect loosely and comprise one meteor shower complex (Table 20).

'κ-Cygnids' i.e. KCG1 is mainly from photographic observations in 1950 (Harvard) and T1-102 (13-Lyrids) is from 1957 (Dushanbe). We are not certain whether video 2007 Cygnids, i.e. KCG2 have the same origin of photographic 'κ-Cygnids', i.e. KCG1. A meteor shower observed in the past is not always observable later.

NOTE ADDED: after this paper was first submitted, WGN (42:3, p. 89) published a call for observations of κ-Cygnids in 2014. Current indications are that the 2014 shower was active, equal to the 2007 apparition, in video observations, and poor for visual observers, however. Satoshi Uehara posted the information to the NMS mailing list citing
`http://sonotaco.jp/forum/viewtopic.php?t=3330`

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Meteorite producing fragment on the Apophis' orbit

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A meteorite producing object moving along an orbit similar to that of the near-Earth asteroid (99942) Apophis was found. The object may be a fragment of Apophis. It is shown that Apophis' orbit has approaches to the Earth's orbit (up to the indicated limit of $\rho \leq 0.20$ AU) over a long time interval. Asteroid 2012 BN1, whose orbit is very similar with the Apophis' orbit, was identified.

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1 Introduction

(99942) Apophis is a potentially hazardous asteroid for the Earth. Its next approach to the Earth is expected on 2029 April 13 at a geocentric distance[a] of 0.0002537 AU. Apophis has a diameter of approximately[b] 0.325 km. Apophis is an *Sq*-class asteroid and most closely resembles *LL* ordinary chondrite meteorites in terms of spectral and mineralogical characteristics (Binzel et al., 2009).

Defining Apophis' place in the population of meteor bodies, one should refer it to the Cyclids' system (Terentjeva & Barabanov, 2011). The Cyclids were discovered by Southworth and Hawkins (1963), and were later examined by Terentjeva (1968, 1973) in detail. Meteor bodies of the Cyclids move along orbits almost coinciding with the Earth's orbit ($e \leq 0.14$, $q' \leq 1.2$ AU, $i \leq 15°$).

Forming no physical system, like usual meteor streams, the Cyclids are an example of a set of evolving orbits, selected on the basis of their current similarity with the Earth's orbit. In the course of orbit evolution, instead of particles transferring close to the Sun ($a < 1$), new particles come from external areas ($a > 1$); so the Cyclids' system remains in a dynamic equilibrium (Terentjeva, 1968). According to the table of the Cyclids' orbits in the above work, Cyclids are found on orbits with the following orbital elements: $a = 0.86 - 1.09$ AU; $e = 0.02 - 0.14$; $q = 0.74 - 1.01$ AU; $q' = 1.0 - 1.2$ AU. All elements of Apophis' orbit lie within the range in elements of the Cyclids' orbits, differing only for an insignificant value of 0.05 in the eccentricity.

2 Results and conclusions

When studying the interrelation of various populations of minor bodies in the Solar System (asteroids, comets, meteor streams, large meteor bodies, including meteorites) and possible genetic relations in the families within the minor bodies complex, Terentjeva (1989) has found a population of 39 meteorite producing objects. Results of photographic observations of 379 bright fireballs of Prairie and European networks were analysed (McCrosky et al., 1976; Ceplecha, 1978). This population included objects for which the estimated terminal mass was 1/4 kg and more. All 39 objects of this population are essentially meteorites and could be recovered. The above work provides a Table (and Figure 1), containing a total of 39 orbits along which meteorite producing bodies with extra-atmospheric masses M_∞ from several kilograms to about thirty tons moved. Orbit (No. 14) of the meteorite producing object, which is almost identical to that of Apophis, was found within this population of bodies with coordinates of radiants that coincide perfectly (Table 1). Extra-atmospheric mass of the object $M_\infty = 1.2$ kg.

We calculated (Terentjeva & Barabanov, 2011) approaches of Apophis' orbit to the Earth's orbit and theoretical geocentric radiants in all points of approach (up to the distance of $\rho \leq 0.20$ AU). The study is based on the following system of the Apophis' elements (Shor, 2009):

$$\begin{array}{ll} a = 0.922 \text{ AU} & \omega = 126\overset{\circ}{.}41858 \\ e = 0.1911107 & \Omega = 204\overset{\circ}{.}43196 \\ q = 0.746 \text{ AU} & i = 3\overset{\circ}{.}33172 \end{array}$$

Orbital elements of the Apophis are given for the 2000.0 equinox (Epoch 2010 July 23).

The latest determination of the Apophis' orbit[a] (Epoch 2007 December 7) is different from the one above in the following way: $\Delta a = 0.00028$ AU, $\Delta e = 0.000031$, $\Delta\omega = 0\overset{\circ}{.}025$, $\Delta\Omega = 0\overset{\circ}{.}025$, $\Delta i = 0\overset{\circ}{.}00043$, which is not essential while comparing it to meteor orbits (considering their low accuracy).

Apophis' orbit turned out to have approaches to the Earth's orbit on the major part of its orbit (except for a perihelion area on the arc 117° in true anomaly) within a long 8-month period. There are two points of closest approach of the Apophis' orbit with the Earth's orbit (two appulses): in region of the orbit's ascending node of April 13 ($\lambda_\odot = 24\overset{\circ}{.}144$, equinox 2000.0) with $\rho = 0.000307$ AU and in region of descending node of December 20 ($\lambda_\odot = 268\overset{\circ}{.}736$, equinox 2000.0) with $\rho = 0.0520$ AU.

During three months, Apophis' geocentric radiant moves along the curve *a* (Figure 1), located north of the ecliptic and corresponding to the appulse area in region of the orbit's descending node, but further within a short period of time, the radiant is shifted southward from the ecliptic, and during five months moves along the folded line *b*, corresponding to the appulse area in region of the orbit's ascending node.

Study of the long-term approaches of Apophis' orbit with the Earth's orbit (like Cyclids' orbits) leads

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IMO bibcode WGN-425-terentjeva-apophis
NASA-ADS bibcode 2014JIMO...42..198T

[a]`http://ssd.jpl.nasa.gov/`
[b]`http://www.esa.int/Our_Activities/Space_Science/Herschel_intercepts_asteroid_Apophis`

Table 1 – Asteroid (99942) Apophis and meteorite producing fragment. Orbital elements of the asteroid Apophis are given for the 2000.0 equinox; for the meteorite producing fragment they are given for the 1950.0 equinox (the difference from eq.1950.0 to eq.2000.0 is less than accuracy of the measured meteor orbit).

Object	Date	Corr. geocentric radiant α [°]	δ [°]	V_∞ km/s	a, AU	e	q AU	i [°]	ω [°]	Ω [°]	π [°]	Sources
Apophis (99942)	Apr 13	214.2	−30.8	12.5	0.922	0.191	0.746	3.3	126.4	204.4	330.9	[1]
Fragment	1969 Apr 7	212.2	−27.2	11.6	0.926	0.13	0.808	1.7	134.5	197	331.5	No 14 [2]

Sources: [1] – Shor (2009), `http://ssd.jpl.nasa.gov/`
[2] – Terentjeva (1989)

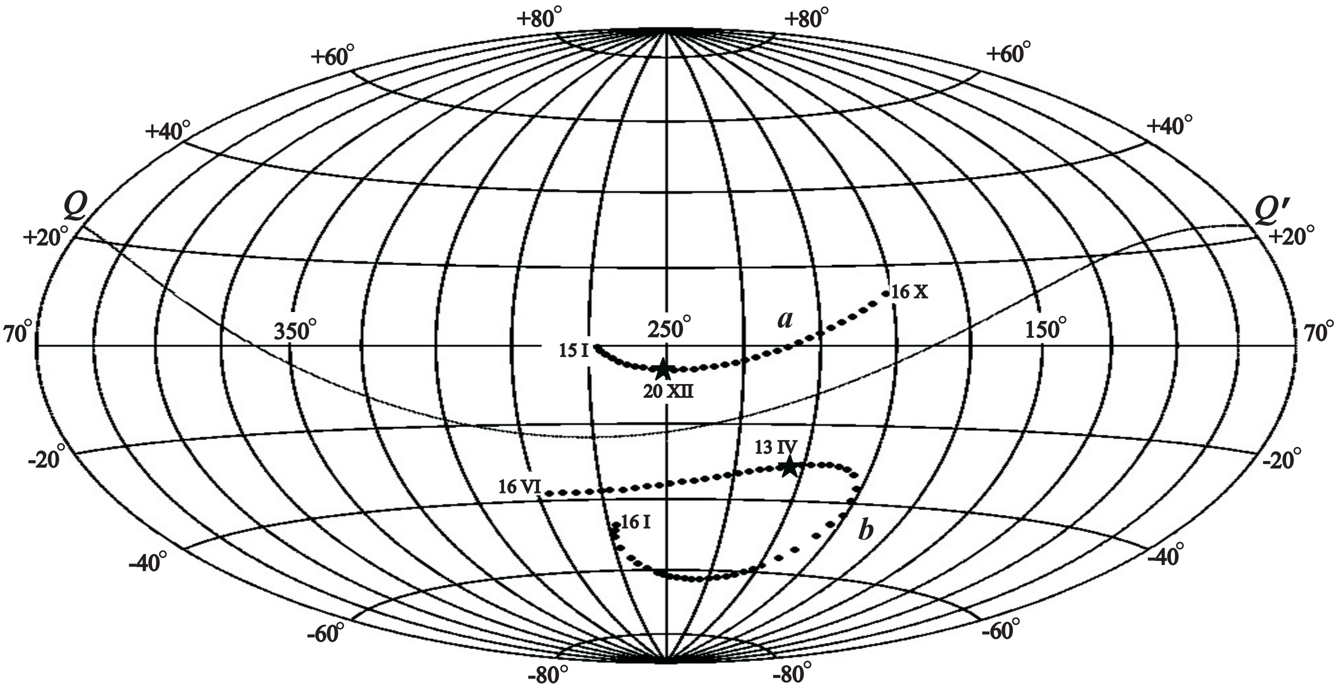

Figure 1 – Ephemerides of theoretical geocentric radiant of asteroid Apophis (a – in the area of the descending node, b – in the area of the orbit ascending node). Asterisk marks radiants for the moment of appulse. $\mathbf{QQ'}$ – ecliptic.

to the conclusion, that meteor bodies existing on such orbits may be observed over a long time interval up to 8 months (and longer, depending on the orbit character and approach conditions). During that time, their geocentric radiants move along various extended curves over the celestial sphere (Terentjeva, 1973), covering a wide area of the celestial sphere from 70° × 100° and more.

Table 1, provided herein, shows that the meteorite producing object was observed 6 days before the Apophis' passing the appulse of April 13 in region of its orbit's ascending node.

On the basis of the above, it can be concluded:
1) the discovered meteorite producing body could be a fragment of the asteroid Apophis or they both could have a common origin;
2) it is reasonable to observe large meteor bodies (in the appulse area – April 13), which can be found on the Apophis' orbit or nearby.

Having studied orbital elements of 10443 Near-Earth asteroids[c] we discovered asteroid 2012 BN1, whose orbit is very similar with the Apophis' orbit. Orbital elements of the asteroid 2012 BN1 for the 2000.0 equinox are as follows:

$$a = 0.9029114 \text{ AU} \qquad \omega = 24\overset{\circ}{.}15513$$
$$e = 0.1854054 \qquad \Omega = 296\overset{\circ}{.}76264$$
$$q = 0.7355067 \text{ AU} \qquad i = 4\overset{\circ}{.}15464$$

A possible relation between these two asteroids may exist.

Acknowledgments

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[c] `http://ssd.jpl.nasa.gov/sbdb.cgi`

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Preliminary results

Results of the IMO Video Meteor Network — June 2014

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About 18 500 meteors were recorded in almost 6 500 hours of effective observing time by 78 cameras of the IMO Video Meteor Network in 2014 June. Activity of the Daytime Arietids was studied and the first attempt to calculate the flux density profile is presented.

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1 Introduction

June is presenting shortest nights to the observers of the northern hemisphere. On the other hand, the average hourly meteor rate is slowly increasing again (from 2.6 in May to 2.9 in June). For this reason our video meteor database contains virtually the same number of meteors in May and June. That picture was confirmed also in this year. The weather was still quite sympathetic to the observers, so that 56 out of the 78 cameras in operation managed to obtain twenty and more observing nights. With 18 500 meteors from 6 500 hours of effective observing time (Table 1 and Figure 1), we recorded a few hundred meteors more than in May, and almost 15% more than in June 2013. Remarkable is the low fluctuation: In the best nights "only" 68 cameras were active, but even with the very short nights there were never fewer than 34 cameras in operation. TEMPLAR5 of Rui Goncalves was successful in every night of June.

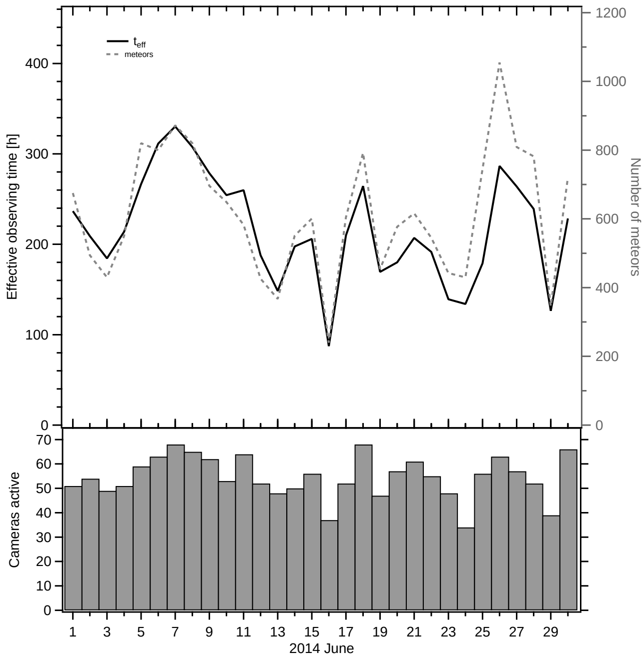

Figure 1 – Monthly summary for the effective observing time (solid black line), number of meteors (dashed gray line) and number of cameras active (bars) in 2014 June.

2 June Bootids

Unfortunately, the rise of the average meteor count is no hint for increasing meteor shower activity. The June Bootids, the only June representative in the IMO working list of meteor showers (McBeath, 2013), have not been active in the last four years. Even though we could assign almost 400 meteors to this radiant, it yields a flux density below 0.1 meteoroids per 1 000 km^2 per hour (Figure 2). Chances are high that these are just sporadic meteors which accidentally aligned to the JBO radiant.

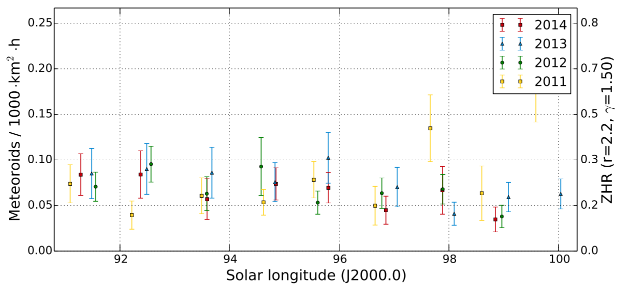

Figure 2 – Flux density profile of the June Bootids from observations of the IMO Network 2011 till 2014. The shower does not stand out from the sporadic background in any of these years.

3 The Antihelion source

The Antihelion source shows clear variations from one year to the next. If we average the data over the last four years, there is a slightly falling tendency starting at more than 4 down to about 3 meteoroids per 1 000 km^2 per hour (Figure 3).

4 Daytime Arietids

A particular challenge for visual and video observers was initiated by Jürgen Rendtel. At the 2014 IMC, he presented a lecture about "Daytime Meteor Showers" (Rendtel, 2014) and called for optical observations

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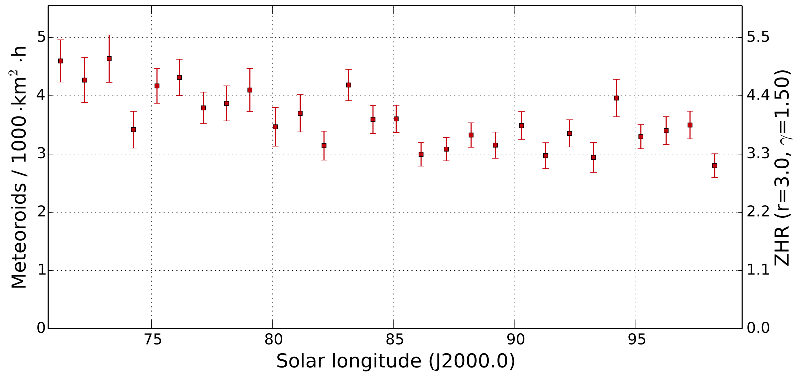

Figure 3 – Mean flux density profile of the Antihelion source in June from observations of the IMO Network 2011 till 2014.

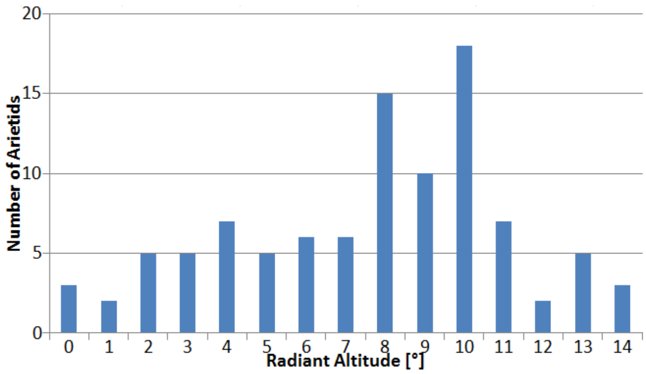

Figure 4 – Distribution of the Daytime-Arietids recorded in 2011–2014 over the radiant altitude.

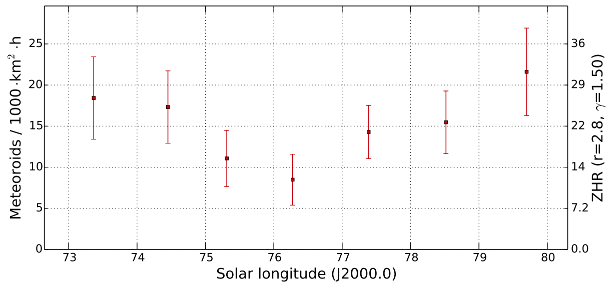

Figure 5 – Mean flux density profile of the Daytime Arietids from observations of the IMO Network 2011 till 2014.

of the Daytime Arietids in June and the Daytime Sextantids in September/October. Thanks to their radiant position, these are the daytime showers with best chances for observation, but still they are almost exclusively covered by radar observations so far. At least we detected the Arietids in our 2013 meteor shower search based on 70 meteors between 74° and 79° solar longitude (peak at 77°). According to a radar study by Campbell-Brown (2004), the Arietids, assuming a population index of 2.75, should reach a visual peak ZHR of almost 200, i.e. be more active than the biggest nighttime showers. That is a good reason to have a closer look at them.

Starting from 2011, we measured the stellar limiting magnitude with MetRec, so from this time on we can (re-)calculate the flux density of meteor showers. As expected, the data set is very small with just a hundred Daytime Arietids recorded since 2011 (40 of which in 2014). When plotting the flux density profile with flux viewer, you will first get an empty plot – no wonder since the minimum radiant altitude is set by default to 20°. Under such "perfect" conditions you will never record a Daytime Arietid, since the radiant is located only 35° west of the Sun. Most Arietids were recorded at about 10° radiant altitude, but none at 15° or higher (Figure 4).

If the minimum radiant altitude is set to zero, the sobering activity profile presented in Figure 5 is obtained. Instead of an activity peak we find a minimum at the expected time of maximum. Apparently the data set is still too small to obtain a reliable activity profile.

Furthermore, small systematic errors in the model will have a large impact under such extreme observing conditions (radiant at the horizon, observation at dawn).

The absolute value of the flux density depends significantly on the selected population index when the radiant is so low in the sky. At a moderate value of $\gamma = 1.5$ we yield flux densities beyond 10 meteoroids per 1 000 km^2 per hour, and the ZHR is one order of magnitude smaller than the values extrapolated from radar data. At $\gamma = 2.0$ all values increase by a factor of three.

In the end a last comparison: The total normalized collection area of the Daytime Arietids is only about $^1/_{1\,000}$ $^{\text{th}}$ of the June Bootid collection area, which is why 400 JBO disappear in the sporadic background, whereas 100 ARI represent significant meteor shower activity.

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Table 1 – Observers contributing to 2014 June data of the IMO Video Meteor Network. Eff.CA designates the effective collection area.

Code	Name	Place	Camera	FOV [°²]	Stellar LM [mag]	Eff.CA [km²]	Nights	Time [h]	Meteors
ARLRA	Arlt	Ludwigsfelde/DE	Ludwig2 (0.8/8)	1475	6.2	3779	25	79.9	455
BANPE	Bánfalvi	Zalaegerszeg/HU	Huvcse01 (0.95/5)	2423	3.4	361	16	15.0	96
BERER	Berkó	Ludányhalászi/HU	Hulud1 (0.8/3.8)	5542	4.8	3847	13	59.2	213
			Hulud3 (0.95/4)	4357	3.8	876	14	62.9	78
BOMMA	Bombardini	Faenza/IT	Mario (1.2/4.0)	5794	3.3	739	26	131.0	363
BREMA	Breukers	Hengelo/NL	Mbb3 (0.75/6)	2399	4.2	699	21	70.2	116
			Mbb4 (0.8/8)	1470	5.1	1208	20	62.8	88
BRIBE	Klemt	Herne/DE	Hermine (0.8/6)	2374	4.2	678	24	82.9	170
		Bergisch Gladbach/DE	Klemoi (0.8/6)	2286	4.6	1080	27	88.2	197
CASFL	Castellani	Monte Baldo/IT	Bmh1 (0.8/6)	2350	5.0	1611	23	73.7	164
			Bmh2 (1.5/4.5)*	4243	3.0	371	20	72.2	140
CRIST	Crivello	Valbrevenna/IT	Bilbo (0.8/3.8)	5458	4.2	1772	27	129.8	322
			C3P8 (0.8/3.8)	5455	4.2	1586	28	115.8	239
			Stg38 (0.8/3.8)	5614	4.4	2007	29	142.5	455
DONJE	Donani	Faenza/IT	Jenni (1.2/4)	5886	3.9	1222	26	141.7	524
ELTMA	Eltri	Venezia/IT	Met38 (0.8/3.8)	5631	4.3	2151	20	104.6	224
FORKE	Förster	Carlsfeld/DE	Akm3 (0.75/6)	2375	5.1	2154	17	59.3	135
GONRU	Goncalves	Tomar/PT	Templar1 (0.8/6)	2179	5.3	1842	28	163.2	524
			Templar2 (0.8/6)	2080	5.0	1508	28	164.9	409
			Templar3 (0.8/8)	1438	4.3	571	27	148.8	193
			Templar4 (0.8/3.8)	4475	3.0	442	29	155.9	378
			Templar5 (0.75/6)	2312	5.0	2259	30	161.5	367
GOVMI	Govedič	Središče ob Dravi/SI	Orion2 (0.8/8)	1447	5.5	1841	24	81.5	286
			Orion3 (0.95/5)	2665	4.9	2069	19	66.0	104
			Orion4 (0.95/5)	2662	4.3	1043	23	83.9	123
HERCA	Hergenrother	Tucson/US	Salsa3 (1.2/4)*	2198	4.6	894	21	172.5	292
HINWO	Hinz	Schwarzenberg/DE	Hinwo1 (0.75/6)	2291	5.1	1819	19	58.9	150
IGAAN	Igaz	Baja/HU	Hubaj (0.8/3.8)	5552	2.8	403	25	117.3	167
		Debrecen/HU	Hudeb (0.8/3.8)	5522	3.2	620	22	107.6	159
		Hódmezővásárhely/HU	Huhod (0.8/3.8)	5502	3.4	764	27	120.7	140
		Budapest/HU	Hupol (1.2/4)	3790	3.3	475	23	102.5	65
JONKA	Jonas	Budapest/HU	Husor (0.95/4)	2286	3.9	445	25	118.9	166
KACJA	Kac	Ljubljana/SI	Orion1 (0.8/8)	1402	3.8	331	21	88.1	86
		Kamnik/SI	Cvetka (0.8/3.8)*	4914	4.3	1842	20	81.3	292
			Rezika (0.8/6)	2270	4.4	840	21	92.8	430
			Stefka (0.8/3.8)	5471	2.8	379	21	81.3	230
		Kostanjevec/SI	Metka (0.8/12)*	715	6.4	640	2	11.9	34
KISSZ	Kiss	Sülysáp/HU	Husul (0.95/5)*	4295	3.0	355	24	66.3	67
KOSDE	Koschny	Izana Obs./ES	Icc7 (0.85/25)*	714	5.9	1464	27	155.1	1283
		La Palma/ES	Icc9 (0.85/25)*	683	6.7	2951	28	175.6	1550
		Noordwijkerhout/NL	Lic4 (1.4/50)*	2027	6.0	4509	16	45.4	112

Table 1 – Observers contributing to 2014 June data of the IMO Video Meteor Network – continued from previous page.

Code	Name	Place	Camera	FOV [°²]	Stellar LM [mag]	Eff.CA [km²]	Nights	Time [h]	Meteors
LOJTO	Łojek	Grabniak/PL	Pav57 (1.0/5)	1631	3.5	269	3	7.2	9
MACMA	Maciejewski	Chełm/PL	Pav35 (0.8/3.8)	5495	4.0	1584	10	23.2	165
			Pav36 (0.8/3.8)*	5668	4.0	1573	12	24.8	155
			Pav43 (0.75/4.5)*	3132	3.1	319	8	34.2	32
			Pav60 (0.75/4.5)	2250	3.1	281	10	16.2	96
MASMI	Maslov	Novosibirsk/RU	Nowatec (0.8/3.8)	5574	3.6	773	23	29.0	130
MOLSI	Molau	Seysdorf/DE	Avis2 (1.4/50)*	1230	6.9	6152	22	75.2	456
			Mincam1 (0.8/8)	1477	4.9	1084	27	114.7	257
		Ketzür/DE	Remo1 (0.8/8)	1467	6.5	5491	25	85.4	434
			Remo2 (0.8/8)	1478	6.4	4778	24	85.0	341
			Remo3 (0.8/8)	1420	5.6	1967	12	38.8	38
			Remo4 (0.8/8)	1478	6.5	5358	24	83.3	396
MOSFA	Moschner	Rovereto/IT	Rover (1.4/4.5)	3896	4.2	1292	23	31.0	128
OCHPA	Ochner	Albiano/IT	Albiano (1.2/4.5)	2944	3.5	358	15	63.0	74
OTTMI	Otte	Pearl City/US	Orie1 (1.4/5.7)	3837	3.8	460	15	52.8	183
PERZS	Perkó	Becsehely/HU	Hubec (0.8/3.8)*	5498	2.9	460	20	89.3	312
PUCRC	Pucer	Nova vas nad Dragonjo/SI	Mobcam1 (0.75/6)	2398	5.3	2976	20	80.2	184
ROTEC	Rothenberg	Berlin/DE	Armefa (0.8/6)	2366	4.5	911	18	61.3	97
SARAN	Saraiva	Carnaxide/PT	Ro1 (0.75/6)	2362	3.7	381	22	114.3	160
			Ro2 (0.75/6)	2381	3.8	459	24	118.6	206
			Ro3 (0.8/12)	710	5.2	619	23	125.8	334
			Sofia (0.8/12)	738	5.3	907	21	102.9	103
SCALE	Scarpa	Alberoni/IT	Leo (1.2/4.5)*	4152	4.5	2052	16	67.5	127
SCHHA	Schremmer	Niederkrüchten/DE	Doraemon (0.8/3.8)	4900	3.0	409	25	88.4	172
STOEN	Stomeo	Scorze/IT	Min38 (0.8/3.8)	5566	4.8	3270	26	93.0	375
			Noa38 (0.8/3.8)	5609	4.2	1911	25	91.8	305
			Sco38 (0.8/3.8)	5598	4.8	3306	25	90.8	399
STRJO	Strunk	Herford/DE	Mincam2 (0.8/6)	2354	5.4	2751	25	62.7	144
			Mincam3 (0.8/6)	2338	5.5	3590	23	53.2	136
			Mincam4 (1.0/2.6)	9791	2.7	552	21	48.4	93
			Mincam5 (0.8/6)	2349	5.0	1896	24	57.8	130
			Mincam6 (0.8/6)	2395	5.1	2178	20	33.3	87
TEPIS	Tepliczky	Agostyán/HU	Huago (0.75/4.5)	2427	4.4	1036	24	104.8	146
		Budapest/HU	Humob (0.8/6)	2388	4.8	1607	24	57.5	280
TRIMI	Triglav	Velenje/SI	Sraka (0.8/6)*	2222	4.0	546	18	50.1	150
ZELZO	Zelko	Budapest/HU	Huvcse03 (1.0/4.5)	2224	4.4	933	7	14.4	36
			Huvcse04 (1.0/4.5)	1484	4.4	573	7	15.2	37
* active field of view smaller than video frame						Overall	30	6 498.7	18 493

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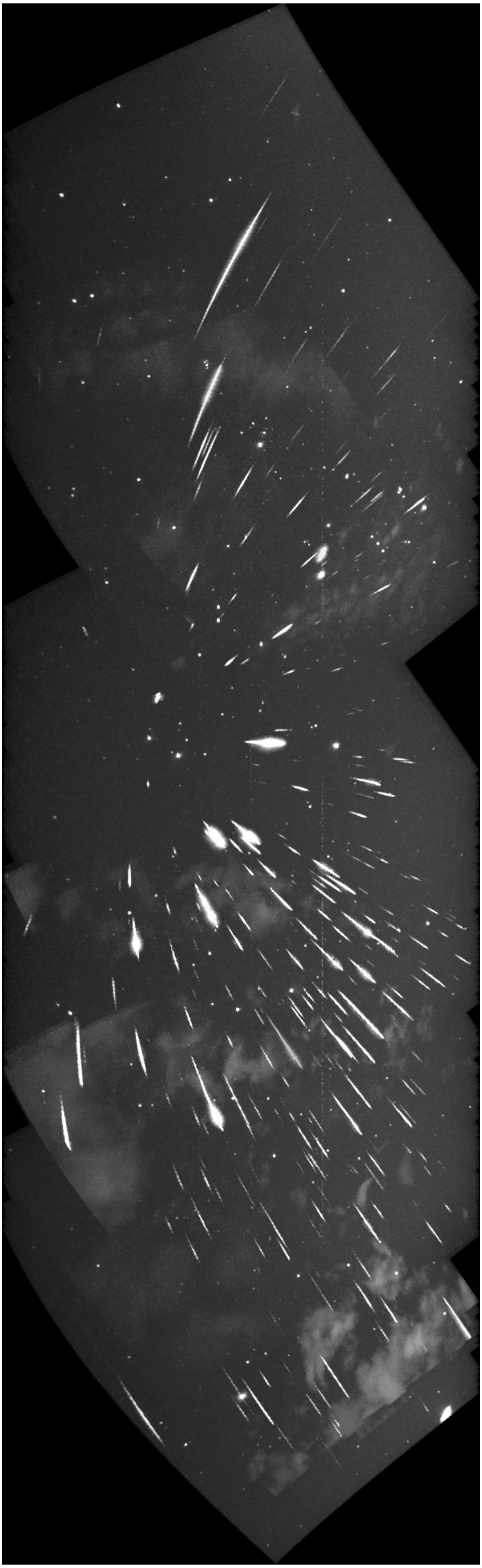
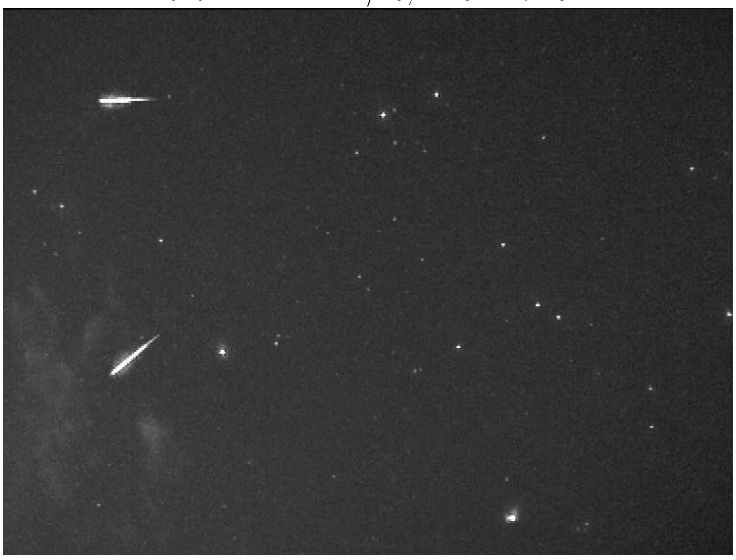
Composite of the 2010 Geminids



The image on the left is a composite of 302 individual Geminid meteor captures obtained with video camera Rezika on 2010 December 12/13. Individual images were stacked together with the Panorama tool of the MetRec software package using a Mercator projection. Some of the nicer captures are depicted below. Photo courtesy: Javor Kac.

2010 December 12/13, $18^h36^m53^s$ UT

2010 December 12/13, $22^h52^m17^s$ UT



2010 December 12/13, $23^h47^m53^s$ UT