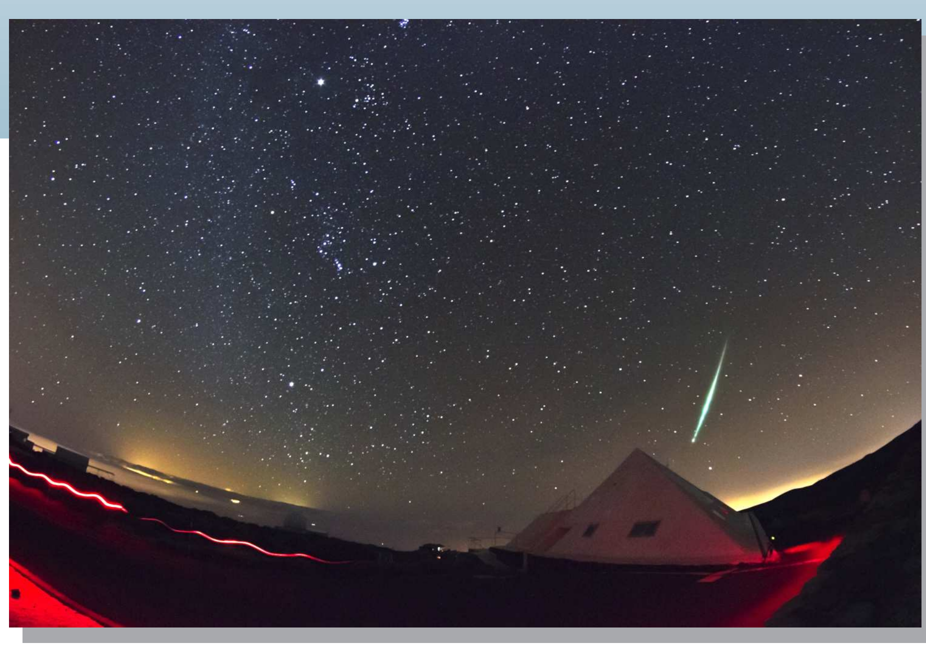
journal of the international meteor organization

WGN

41:1
february 2013



Chelyabinsk Fireball/Airburst
December σ-Virginids
Short-perihelion streams
CAMS double-station observations
October–November video meteors

ISSN 1016-3115

WGN Vol. 41, No. 1, February 2013, pp. 1 – 36

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Front cover photo

Bright fireball about magnitude −9, photographed on 2012 November 11 from the Teide Observatory at Tenerife. Canon 600D camera was used with 8 mm fisheye lens at $f/5.6$, and 45 s exposure at ISO 1600. Photo courtesy of Alex Tudorica.

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` .

Cover design Rainer Arlt

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Editorial – Large meteoroid impact dangers

Javor Kac

Just before this WGN issue went to press, an extraordinary event took place in the Chelyabinsk region, Russia. A superbolide, reportedly many times brighter than the midday Sun, traversed the morning sky. A couple of minutes later the shock wave arrived, smashing windows and causing other structural damage. About 1500 people were reported injured, mostly from flying glass after the shock wave hit.

The impact was a completely unexpected event, resulting from a $\sim$ 20 m sized meteoroid impact. Only about a thousand similarly-sized asteroids have been discovered to date from an estimated many millions of such objects in Near-Earth orbits. While dedicated programs have discovered the majority of $\geq$ 1 km size Near-Earth asteroids and comets, only a very small fraction of objects smaller than 300 m are known.

The amount of damage that a small, relatively slow and fragile meteoroid did in the Chelyabinsk region, is surely a heads-up to governments and responsible agencies. I am quite certain that programs capable of detecting many of the decameter-sized and larger asteroids before they impact the Earth are going to be deployed in the near future.

A more detailed article from Peter Brown on the Chelyabinsk event is published on page 22, and two photographs of the superbolide and its dust trail are presented on the back cover.

IMO bibcode WGN-411-editorial NASA-ADS bibcode 2013JIMO...41....1K

Correction — Results of the IMO Video Meteor Network — August 2012

Sirko Molau, Javor Kac, Erno Berko, Stefano Crivello, Enrico Stomeo, Antal Igaz and Geert Barentsen

We regret that Table 4 of (Molau et al., 2012) contained an error in the V_∞ data for the newly discovered shower θ-Piscids (508 TPI). The corrected Table is reproduced below.

Table 4 – Parameters of four possibly new showers from the analysis of the IMO Network in 2012. The first one received the MDC designation θ-Piscids (508 TPI).

Source	Solar Longitude		Right Ascension		Declination		V_∞	
	Mean [°]	Interval [°]	Mean [°]	Drift [°]	Mean [°]	Drift [°]	Mean [km/s]	Drift [km/s]
IMO 2012	147	135–158	352.0	+0.78	+4.1	+0.36	40.6	−0.16
	155	149–158	0.6	+0.3	+77.5	−0.0	42.4	—
	155	153–157	106.5	+1.8	+40.0	−0.3	55.6	—
	160	153–166	70.4	0.0	+41.5	+0.4	70.0	—

References

Molau S., Kac J., Berko E., Crivello S., Stomeo E., Igaz A., and Barentsen G. (2012). “Results of the IMO Video Meteor Network – August 2012”. *WGN, Journal of the IMO*, **40:6**, 201–206.

IMO bibcode WGN-411-molau-correction NASA-ADS bibcode 2013JIMO...41....1M

Janus—25 Years of the International Meteor Organization

Jürgen Rendtel [1]

The start of a new year is often used for a look-back and an occasion for planning future activities. Meteor observers today consider the IMO as a constant, persisting organization. Indeed, it meanwhile exists for a timespan usually called a generation. This becomes also quite obvious by just looking at the participants of the IMCs. There are people who seem to be the face of the conference as they are always there. At the same time, new faces appear continuously and I would not be surprised if we soon see children of the veterans becoming IMO members.

In March 1988—still in the days of the "iron curtain"—a meteor weekend took place in Hengelo in the Netherlands. It was attended by enthusiasts from "both sides". At this occasion, numerous details of the foundation of the IMO have been discussed and decided. Of course, most of the basic discussions had already taken place by then. There were countless letters (yes, old style paper letters which took days or longer to reach their destination) sent and phone calls (not using a flat rate like nowadays) made around the globe to establish the constitution and the structure of the planned IMO. This happened just or already—depending at which time you joined the field—25 years ago, followed by the first IMC in October 1989 in Balatonföldvár, Hungary, with the IMO in existence. Today, conferences like the IMC and "Meteoroids" are attended by both amateurs and professionals, and many results are based on data collected by very different means.

Over the years, we have seen a wide variety of events and an incredible evolution in the field of meteor science. Just as an example, I think of the initial establishment of visual observing standards used for global shower analyses which allowed to reveal a double maximum of the Perseids in 1988 and 1989 well before the high peaks occurred. Another big step forward was the prediction of Leonid peaks after the 1998 fireball night. Despite the huge increase of knowledge, surprises like the September ε-Perseids in 2009 or the Draconids 2012 happen—making regular observations interesting throughout the year.

A huge evolution of the observing techniques happened as well. About 20 years ago, video (also called low light level TV, LLLTV) observations while still out of reach of most amateurs, were becoming more accessible at a fast rate. These data—collected by widespread camera stations—give access to meteor activity surveys as well as minor shower detection. I must admit that the current shower list alone reminds me on Denning's comparatively "naive" list when the current compilation includes about 500 showers detected optically (not to mention radar detections).

In the coming years, we certainly will see results derived from the continuing programs devoted to the study of meteoroid stream evolution. Close approaches to minor planets and comets by spacecraft (such as Dawn or Rosetta, just to mention two of these) certainly will shed new light on our understanding of small bodies. Similar windows will be opened when such objects approach or hit the Earth. Recent events of this kind were the minor planets 2008 TC_3 and 2012 DA_{14}. While the latter 45 meter object just missed the Earth, meteorites dropped in Sudan on 2008 October 7 (Almahata Sitta meteorite fall). A very dramatic meteorite fall happened at Chebarkul near Chelyabinsk in Russia just while writing this text, being almost comparable with the Tunguska event on 1908 June 30 and the Sikhote-Alin meteorite fall on 1947 February 12. All this indicates that, despite the enormous increase of our knowledge, most of the small objects are still unknown.

Of course it is difficult to predict or even to estimate the meteor astronomy situation another 25 years from now. By this time, the next series of intense Leonid showers, around 2033, has already happened as well as other outbursts and unexpected events. I am sure the checks of the accuracy of stream evolution models with reality will allow more precise answers when dust trails will be crossed and how dense these are. Observational data covering more than half a century will yield obvious long-term evolutionary effects in several showers. This was already the case with the Perseids and Leonids mentioned above. Models also suggest that the Geminids may weaken and eventually disappear as a big shower, not in the far future.

Besides the public outreach, all enthusiasts should preserve their curiosity for these volatile phenomena. Events such as the above mentioned Chebarkul meteorite fall and the close approach of 2012 DA_{14} will generate additional interest in our field. While the starry skies look almost constant for decades, minor objects and therefore also meteors provide us with traceable changes in the Solar System.

Janus *was a Roman god with two faces, one looking to the past and one to the future, called upon at the beginning of any enterprise. Today he is often a symbol of re-appraisal at the start of the year.*

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IMO bibcode WGN-411-rendtel-janus NASA-ADS bibcode 2013JIMO...41....2R

Conferences

International Meteor Conference 2013 August 22–25, Poznań, Poland

Przemysław Żołądek, Mirosław Krasnowski, Mariusz Wiśniewski, Karol Fietkiewicz, Maciej Maciejewski, Andrzej Skoczewski

Venue

The 2013 International Meteor Conference will be organized in Poznań, Poland, just few days before the Meteoroids 2013 Conference. The conference will take place from August 22 (Thursday evening) to August 25 (Sunday lunchtime). This year the conference is organized in the western part of Poland which is easy reachable for European participants. Coincidence with the Meteoroids 2013 Conference will help both amateurs and professionals to meet and exchange their scientific results.

The IMC 2013 will be organized in the IOR Congress Center (Figures 1 and 2). This modern facility provides the hotel, dining room and large conference rooms in one place. The IOR is located close to the Poznań Airport and 5 km from the Poznań center (Figure 3).

The city of Poznań is a capital of Greater Poland Voivodship and it is a quite big city with its own airport and good railway and motorway connections.

The climate is continental humid. Typical temperatures for the middle of August is 24–26°C but temperatures higher than 30°C are also possible.

The IMC 2013 is organized by the Polish Comets and Meteors Workshop (PKiM). Members of this group organized the IMC 2002 in Frombork eleven years ago.

Scientific content

The IMC 2013 is a conference open for both amateur and professional meteor astronomers. This conference is focused particularly on meteor science. Each participant can give a talk or prepare a poster about observational results, technical aspects of meteor observing, about newly discovered meteor showers, fireballs, analysis of the meteor data and catalogs, about analysis methods, meteor software, simulations, predictions, meteor physics and any other meteor related topics.

For each presentation, lectures and posters, a written paper is required for publication in the 2013 IMC Proceedings. We strongly recommend to prepare this paper before the conference when the lecture or poster is being prepared.

Travel information

Poznań is located in the western part of Poland. This town is easy reachable by plane, train or by car.

The Lawica airport is located inside the city borders and is well connected with most of major European cities. One can also travel by the Frederic Chopin airport in Warsaw (direct connections with USA and Canada) or by Warsaw Modlin airport (low cost connections).

Travelling by train is especially fast and comfortable using connections from Warsaw and Berlin. Detailed

Figure 1 – IOR Congress Center.

Figure 2 – The IOR conference room B with 120 seats.

informations and timetables are available on the PKP website: http://rozklad-pkp.pl/bin/query.exe/en?

Participants travelling by car may reach Poznań using the A2 motorway connecting Warsaw and Poznań with the German A12 highway.

Registration

The IMC 2013 will take place in August so any registration deadlines will be moved backward in comparison with a typical IMC. The registration deadline is 31 July 2013. The standard lower fees are valid till 31 May 2013. After this date an additional fee of 15 Euro is charged.

The standard IMC 2013 registration fee is 150 Euro (before 31 May 2013, 165 Euro after 31 May). The registration fee includes 3 nights accommodation in double rooms (Thursday, 22 August to Sunday 25 August), full board (breakfast, lunch and dinner), IMC lectures, coffee breaks, excursion, T-shirt and IMC proceedings. Unless the "no accommodation" option is chosen, accompanying persons older than 12 years sharing a room with a participant must also register as a participant. Single rooms are available for a supplement of 50 Euro. IOR has 48 double and 12 single rooms. When the number of participants exceeds 108 persons extra hotel capacity is available within 5 minutes walk distance.

You also have the option of the 100 Euro "no accommodation" fee (before 31 May, 115 Euro after 31 May). This option includes all conference benefits except accommodation and breakfast. In this case, you are responsible for arranging your own accommodation in Poznań. We can recommend some alternative hotels if you wish.

Figure 3 – The old town of Poznań.

For people who need extra nights before or after the IMC it is possible to book some extra nights. An extra night in a single room is 38 Euro per night and 49 Euro in a double room for two persons, breakfast included in both cases. For participants of Meteoroids 2013 it is useful to know that the sessions of Meteoroids 2013 will take place at the University which is a few kilometers away from the IMC host. Therefore it is recommended to book another hotel closer to the University during Meteoroids 2013.

Cancellation policy

- before 2013 June 1: full reimbursement, reduced with a cancellation fee of 15 EUR;
- from 2013 June 1 onward, but before 2013 July 31: partial reimbursement of 75 EUR;
- from 2013 July 31 onward: no reimbursement.

Further information and contact details

For all new informations, updates and registration details check the IMC 2013 website: http://www.imo.net/imc2013/.

The Local Organizing Committee is Mirosław Krasnowski (chairman), Przemysław Żołądek (contact person), Mariusz Wiśniewski, Karol Fietkiewicz, Maciej Maciejewski and Andrzej Skoczewski.

You can contact us by email:
imc2013@imo.net.

IMO bibcode WGN-411-zoladek-imcann NASA-ADS bibcode 2013JIMO...41....3Z

International Meteor Conference
2013 August 22–25, Poznań, Poland
Registration form

Do not use if you have internet access! Please register electronically on `http://www.imo.net/imc2013` if you can. Only if you have **no** internet access, fill out one form for each individual participant and return it to Marc Gyssens, IMO Treasurer, Heerbaan 74, B-2530 Boechout, Belgium, as soon as possible. Registration will be guaranteed only after Marc Gyssens has received the full registration fee for the option chosen. We expect this payment to arrive within two weeks after the form.

Name: ____________________ Address: ____________________

____

____

Phone: __________ Fax: __________ E-mail: __________

- I wish to register for the IMC 2013 from August 22 to 25:
  - ○ I opt for the standard fee (150 EUR early/165 EUR late);
  - ○ I opt for arranging my own accommodation (100 EUR early/115 EUR late).
- I prefer a double room (no supplement) and share a room with __________ (if applicable).
- I prefer a single room (add 50 EUR).
- T-shirt: Size (S–M–L–XL): ______ Gender: ______ (included in fee)
- Food requirements (e.g., vegetarian, nut allergy): __________
- I intend to travel by ____, together with __________
- I will arrive at ______ (e.g. Aug.22 15h), and my departure is ______ (e.g. Aug.25 14h).
- I need extra nights for the dates ______ (e.g. Aug.20–22) in a single or double room (mark choice).

For participants wishing to contribute to the program:

Lecture: ____________________

Requirements: ____________________

Duration: ______ minutes (including a few minutes for questions and discussion)

Poster(s): ____________________ Space: ______ m^2

Comments:

○ I am paying the entire registration fee for the option selected.

○ I acknowledge having read and I agree with the cancellation policy.

The indicated amount should be sent to IMO Treasurer, Marc Gyssens. The following payment options are available:

- **International bank transfer** to the International Meteor Organization, Mattheessensstraat 60, B-2540, Hove, Belgium, IBAN account number: BE30 0014 7327 5911, BIC bank code: GEBABEBB (Fortis Bank, Belgium). This is recommended for people living in the European Union, as it is no more costly than a domestic bank transfer when done correctly.
- **PayPal payment** to `payment@imo.net`. In that case, we must ask you to add the costs involved in the transaction (3.4% of the total sum including costs, plus 0.35 EUR).
- **Other arrangements**. Please contact the IMO Treasurer for information.

Call for Future IMCs

Paul Roggemans

The IMO Council invites candidate IMC organizers to consider proposals to organize the IMC in 2014, 2015 or later.

Typically, an *IMC* is supposed to take place around the third week of September, from Thursday evening (arrival of the participants) to Sunday lunchtime (departure of the participants). When it is possible an IMC can be combined with some professional conference such as *Meteoroids* or *Asteroids, Comets and Meteors*.

Proposals are due 2013 May 31, and should be sent to the IMC liaison officer, `paul.roggemans@gmail.com`. The PDF "IMC Essentials", explains how to select a site, how to make a proposal, how to organize such conference and lists the details for all past IMCs. This PDF will be provided to candidate organizers. Before you decide to organize an *IMC*, consider the following characteristics of the past IMCs:

1. **Scientific conference.** The *IMC* hosts about 10±1 hour of lectures and a poster session as main activity. The content of the conference is rather technical and aims at both professional and amateur astronomers specialized in meteor astronomy. This main activity requires a suitable lecture room.

2. **Low cost event of volunteers.** To assure accessibility to amateurs, the *IMC* traditionally offers the lowest price possible as standard fee in a youth hostel while more luxury accommodation can be offered as an option in nearby hotels. Participants live an *IMC* very intensely spending just few hours in the overnight accommodation to sleep. Therefore fancy hotel rooms with nice panoramas are rather meaningless for IMCs. Suitable accommodation should be selected in function of the lowest price possible, a principle that rules out commercial service providers.

3. **Socializing to stimulate cooperation.** A bar for socializing determines the success of an *IMC*. Hotels without any suitable bar are not recommendable for IMCs. A short excursion on Saturday afternoon combines some socializing with some sightseeing as most participants otherwise have no time to see anything of the conference region.

4. **Keep travelling costs low.** Preferably, an *IMC* takes place at a site that is easy to reach. Although IMCs move around to reach more people, remote and expensive travelling destinations are to be avoided.

5. **The IMC spirit and tradition.** The IMC is a conference with a very warm hospitality and long tradition. Any candidate organizer should have attended at least a couple of IMCs in order to continue the typical IMC style.

Interested to organize a future IMC? Contact the author to obtain a copy of the IMC Essential PDF with all detailed documentation.

We hope to receive many candidacies!

IMO bibcode WGN-411-roggemans-futureimcs NASA-ADS bibcode 2013JIMO...41....6R

Meteor science

December σ-Virginids

Yasuo Shiba and Masayoshi Ueda[1]

We studied the December σ-Virginids from the TV meteor observation network database in Japan (the "SonotaCo Network"). The December σ-Virginids are a minor annual meteor shower that has a broad peak around December 20 and about 40 days active duration. The visual maximum zenithal hourly rate (ZHR) is estimated at 1.5.

Received 2012 May 13

1 Introduction

Greaves (2012) identified four meteor showers from the SonotaCo Network database. In our study presented here we have also found a new meteor shower individually. This shower is the same as one of Greaves' showers named the December σ-Virginids, 428 DSV at the IAU Meteor Data Center (MDC). Additionally, this shower may be the same as the unnamed meteor shower in (Molau 2007, Table 2, no. 82). In fact the radiant position at the shower maximum that we derive is closer to the stellar position τ Virginis than to σ Virginis, especially using the radiant and velocity selection method (Section 4 below). However, we use the name DSV for this meteor shower in order to be consistent with the existing IAU MDC name.

2 Observation data

We researched the database of the Japanese TV meteor observation network, the SonotaCo Network (SonotaCo, 2009), over five seasons from 2007 November to 2012 January. Many reliable orbit data can be used for statistical research. The duration we studied is from November 20 to January 20 each year. Observers use high sensitivity CCD cameras, typically such as Watec 100N or Watec 902h, equipped with lenses having focal length from 3.8 mm to 12 mm. The locations of observers are shown in Figure 1. All observers analysed detected meteors with UFOAnalyser V2 and after the analysis uploaded `csv` data files to the network site. We downloaded these data and calculated all available orbits using UFOOrbit V2. Details of observations and the network are described in (SonotaCo, 2009; Uehara et al., 2006).

3 December σ-Virginid meteors

We found unclear concentrated radiants in Virgo from meteor radiant mapping in 2011 December. Thus we reviewed the recent five years of meteor radiant and orbit data from each November 20 to January 20. The total numbers of meteor orbit data available each year are shown in the second column ("All meteors") of Table 1. We used two methods to identify the meteor shower among these data of all meteors.

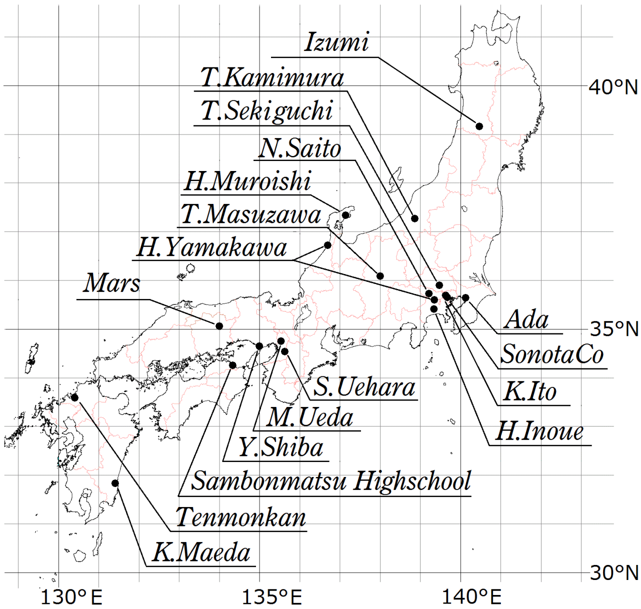

Figure 1 – Observers distribution

One is to use the D' criterion (Drummond, 1981). We selected meteor orbits with $D' < 0.105$ compared with estimated mean orbital elements. After this, we recalculated the mean radiant and geocentric velocity using the selected meteors only, thus obtaining corrected mean shower orbital elements. We continued by reselecting shower members related to the new corrected orbital elements, using the D' criterion. We repeated calculations until the results converged, leading to a selection of shower members with mean orbital elements. The second method is to use radiant position and meteor velocity. We selected meteors with radiants differing by less than 3° from the estimated mean radiant and velocity less than ±5% from the mean. From these

Table 1 – Meteor numbers in seasons investigated. December σ-Virginids selected by two methods (D' or radiant/velocity).

Season	All meteors	December σ-Virginids	
		D' criterion	radiant/ velocity
2007 Nov–2008 Jan	4093	19	26
2008 Nov–2009 Jan	4022	25	27
2009 Nov–2010 Jan	2883	12	27
2010 Nov–2011 Jan	7016	29	44
2011 Nov–2012 Jan	7377	49	46

[1]SonotaCo Network; Aioi-cho 2-2-7-404, Akashi-city, Hyogo pref., Japan, 673-0882. Email: kqc43540@biglobe.ne.jp

IMO bibcode WGN-411-shiba-dsv
NASA-ADS bibcode 2013JIMO...41....7S

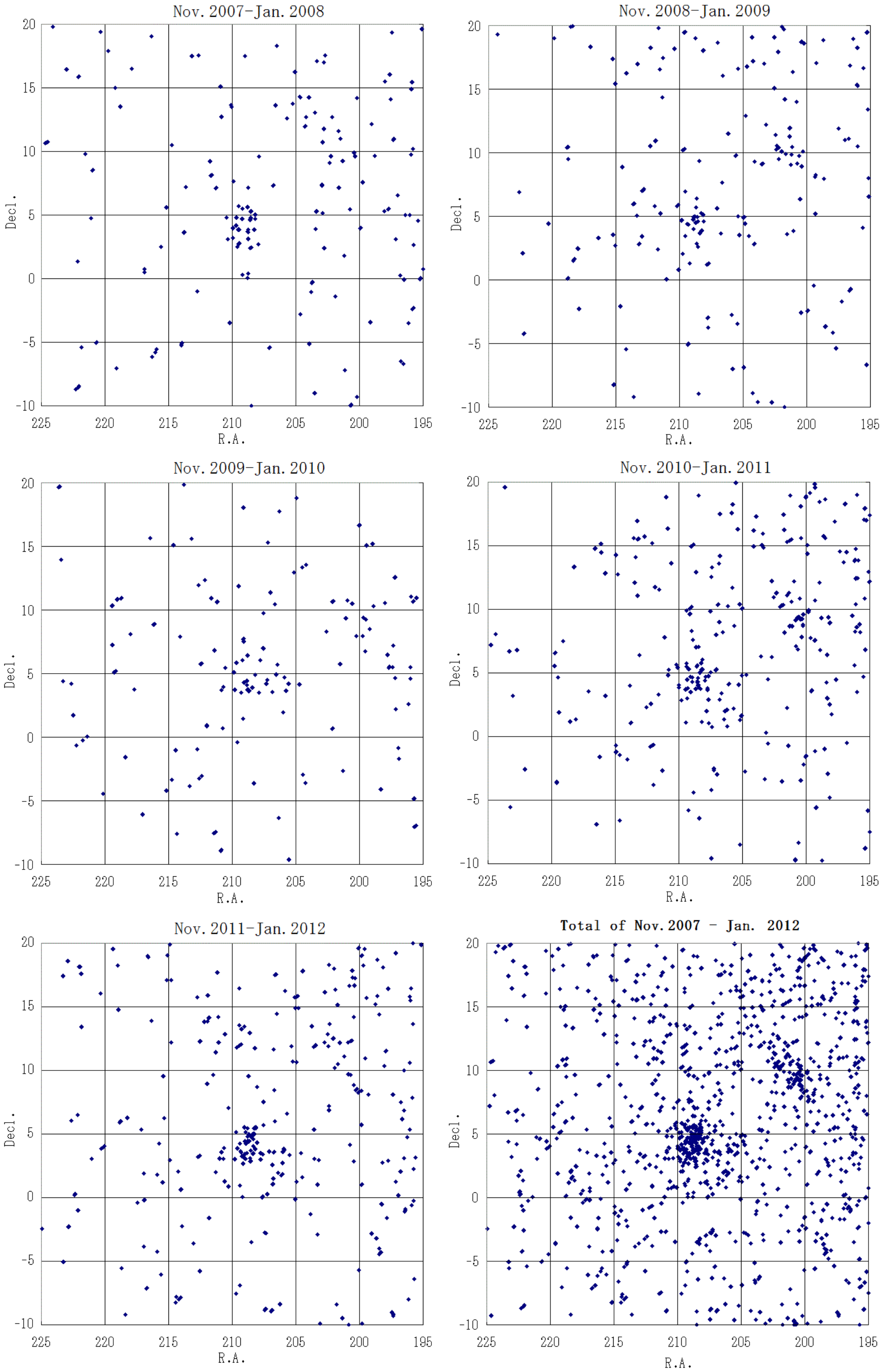

Figure 2 – Radiant distribution around December σ-Virginids in five seasons. Each radiant shifted to solar longitude $\lambda_\odot = 271\overset{\circ}{.}9$ by DSV radiant drift equation.

meteors a corrected mean radiant (with its drift) and velocity can be calculated. We repeated this until the results converged, yielding shower members and mean radiant, radiant drift and velocity. As a result, the numbers of DSV meteors are shown in the right two columns of Table 1.

4 December σ-Virginids properties

The mean radiant position obtained when meteors are selected by the D' criterion method is $\alpha = 206\overset{\circ}{.}30$, $\delta = +4\overset{\circ}{.}78$, $V_g = 66.63$ km s^{-1}, $\lambda_\odot = 269\overset{\circ}{.}307$ (J2000.0) where $\lambda_\odot$ is solar longitude. From this radiant, orbital elements are calculated and shown in Table 2.

Table 2 – December σ-Virginid orbital elements (J2000.0)

a [AU]	q [AU]	e	ω [°]	Ω [°]	i [°]	P [year]
23.54	0.619	0.974	104.42	269.31	149.89	114.2

Radiant position and radiant drift shown next are from the radiant and velocity selection method, while meteor velocity is constant with solar longitude.

$$\alpha = 208.^{\circ}73 + 0.819(\lambda_{\odot} - 271.^{\circ}90) \quad (1)$$

$$\delta = +4.^{\circ}36 - 0.198(\lambda_{\odot} - 271.^{\circ}90) \quad (2)$$

$$V_g = 66.40 \text{ km/s} \quad (3)$$

where $\lambda_{\odot} = 271.^{\circ}90$ is the mean solar longitude of selected meteors. Radiant plots are shown in Figure 2. The radiant positions are corrected for the radiant drift using equations (1) and (2) and are shown for the solar longitude $\lambda_{\odot} = 271.^{\circ}90$. Figure 2 clearly shows radiant concentrations at the common position every year.

The number of December σ-Virginids versus solar longitude is shown in Figure 3. Meteor numbers are binned in 1° intervals of $\lambda_{\odot}$. The left column of a pair is D' criterion results, right is radiant and velocity selection results. The active season begins on December 1 and ends on January 10. Maximum is several days around December 20. We compared with the number of σ-Hydrid (16 HYD) meteors recorded. The number ratios of recorded meteors (DSV to HYD) are about 1/7, for the peak value about 1/10.

The magnitude distribution is shown in Figure 4 in bins of 0.5 mag. In this Figure, left is also D' criterion results, right is radiant and velocity selection results. The population index γ was calculated from the magnitude distribution of meteors from −4.5 to −2 mag:

$$\gamma = 3.1 \quad (D' \text{ criterion}) \quad (4)$$

$$\gamma = 3.2 \quad \text{(radiant and velocity selection)} \quad (5)$$

The σ-Hydrid population index was $\gamma = 2.6$ (from −5 to −2.5 magnitude) for radiant and velocity selection.

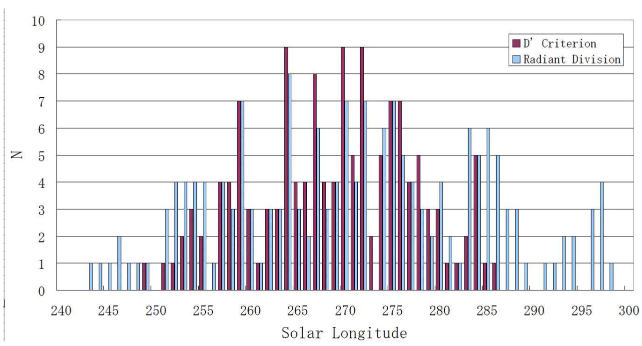

Figure 3 – Recorded numbers of December σ-Virginid meteors.

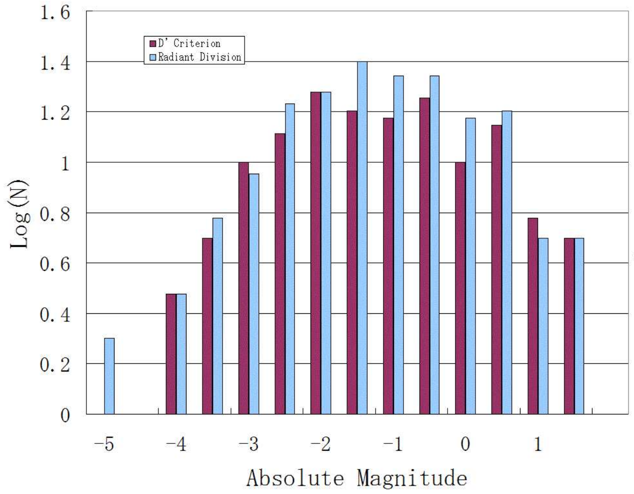

Figure 4 – Magnitude distribution.

5 Discussion

We estimate the visually observable number of December σ-Virginids as a ZHR (zenithal hourly rate), by comparison with σ-Hydrids. These two meteor showers are good for comparison because they have common features, namely a long and overlapped active duration, broad maximum and high velocity. Firstly, the observable time for DSV on one night is about half that for HYD and additionally the radiant elevation for DSV is low. As a result of this, DSV are 2.8 times as difficult to observe (in terms of number of meteors that can be seen) as HYD. Secondly, the effect of the difference in population index γ is considered: $\gamma = 3.1$ or 3.2 for DSV and $\gamma = 2.6$ for HYD. Visual observations generally allow meteors 3–4 mag fainter to be recorded than TV observations. This reason means that the number of December σ-Virginids relative to σ-Hydrids will be increased by a factor of 1.7 times when we extrapolate from TV observation to visual observation. Combining these two effects, and from the relative numbers (DSV to HYD) of *recorded* meteors (Section 4), the ratio of the ZHRs of the two showers is about $1/10 \times 2.8 \times 1.7 = 1/2$. IMO's "Handbook for Meteor Observers" (Rendtel & Arlt, 2011) gives a ZHR of 3 for σ-Hydrids. As a result, we estimate the December σ-Virginid ZHR for visual observation is about 1.5 at its maximum.

The DSV argument of perihelion is about 100 degrees. The shower's long observable duration suggests a dispersed meteor stream orbit. These two features suggest that the meteor stream orbit comes close to Earth's orbit not only at the descending node where it was identified as the December σ-Virginids but also at the ascending node. The "Q-adjustment method" of (Hasegawa, 1990) was applied and a twin-shower radiant was predicted: $\alpha = 319.^{\circ}0$, $\delta = -29.^{\circ}7$, $V_g = 65.4$ km/s, $\lambda_{\odot} = 66.^{\circ}6$. We analysed recorded meteor orbits in the same database from May 1 to July 15 to detect similar orbits as December σ-Virginids. We find three small D' criterion meteor orbits that have $D' < 0.105$. These were observed individually at 2009 June 25 ($D' = 0.064$), 2010 June 12 ($D' = 0.052$), 2010 June 21 ($D' = 0.0736$). Because these meteors were not concentrated together, we estimate that they are not shower members but instead are sporadic meteors. However, during the predicted season for this twin shower, the night-time is short and the rainy season occurs in Japan. Moreover, the radiant elevation is very low from the northern hemisphere. This negative result is therefore possible because of the unfavorable observing conditions. The research must be concluded by means of a large quantity of orbit data from southern hemisphere observations.

In Figure 2, you can find a concentrated radiant at $\alpha = 201°$, $\delta = +9°$ in some years. We find rather many radiants at December 6 and for a few days around then, at $\alpha = 185°$, $\delta = +13°$. Future accumulation of observational data will make sure whether a meteor shower exists or not. The SonotaCo Network database will be an outstanding data source for such new meteor shower detection. New features even in well known meteor showers will also be found with SonotaCo Network data.

Acknowledgments

All the basic data in this paper come from the valuable SonotaCo Network database planned and managed by Mr. SonotaCo whose contribution is especially useful. Network camera operators continue to observe and analyse to support the database. Mr. K. Maeda, Mr. SonotaCo and Mr. T. Sekiguchi helped us with precious advice. We would like to say a great thank you for all their support.

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Handling Editor: Javor Kac

On Short-Perihelion Meteor Streams

Alexandra Terentjeva[1,2], *Elena Bakanas*[1,3] *and Sergey Barabanov*[1,4]

Research was conducted concerning the relation of short-perihelion meteor streams with comets and asteroids. But the origin of meteor streams with small perihelion distance (of the Arietid and Geminid types) has always represented a special problem for obvious reasons. Over four hundred meteor and fireball streams (by optical and TV-observations) contained 20 streams of perihelion distance $q \leq 0.26$ AU. The research shows that 8 of 20 streams displayed a relation with small bodies. No relation was found either with comets or asteroids for the remaining 12 streams. Short-period streams may be formed on quasiparabolic comet orbits with small q in the perihelion area as well. In particular, SOHO comets may be a rich source both of small and large meteor bodies, forming short-perihelion meteor streams among others.

Received 2012 July 3

Our knowledge as to the origin of meteor streams of small perihelion distance remains problematic, in particular concerning meteor streams on orbits of small size (of the Arietid and Geminid types). Lebedinets (1985) proposed and mathematically substantiated a mechanism for the formation of short-period meteor streams of such type. He showed that comet orbits of large size might transform into meteor-type orbits of small size during evaporation of their ice nuclei under the action of reactive drag. An alternative mechanism for the formation of meteor orbits of small size was considered on the basis of close approaches with inner planets (Terentjeva & Bayuk, 1991; Andreev et al., 1990). A source of additional information on the solution of this problem may be the recent discovery of SOHO comets, a fraction of which may be short-period (Hönig, 2006).

Over four hundred meteor and fireball streams by optical and TV-observations (Terentjeva, 1963a; Terentjeva, 1966; Terentjeva, 1967a; Terentjeva, 1967b; Terentjeva, 1990; Ueda et al., 1997) contained 20 streams of perihelion distance $q \leq 0.26$ AU. Our research shows that 8 of 20 streams display a relation with small bodies: 4 streams with comets (including with SOHO comets), one of which might additionally have a relation with an asteroid of the Apollo group (see the Scorpionids, Table 1), and 4 streams with asteroids (one of the Aten group, and the other ones of the Apollo group). No relation was found either with comets or asteroids for the remaining 12 streams.

Thus, streams of small q may be originating equally both from comets and asteroids (no matter what the nature of these objects is). Short-period streams may be formed on quasiparabolic comet orbits with small q in the perihelion area as well (see, for example, the α-Virginids, Table 1 and Figure 1). Decrease of the orbit size even almost from parabolic to an orbit of such small size that its aphelion turns out to be approximately 2 AU (maybe even less) occurs during very moderate drag of particles when released from the comet nucleus.

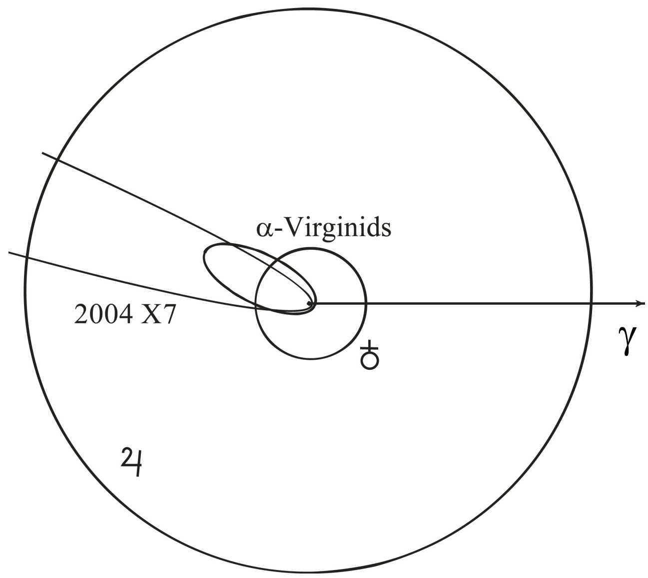

Figure 1 – The α-Virginid meteor stream and the comet C/2004 X7 (SOHO) (orbital planes are superposed on the ecliptic plane).

According to the well-known formula

$$V_h^2 = GM_\odot \left(\frac{2}{q} - \frac{1}{a} \right) \tag{1}$$

it can be found that the decrease of the velocity during release into the perihelion comparing to the velocity of the parent body will be: from 470 m/s to 740 m/s (for a parabolic orbit having q from 0.002 AU to 0.005 AU), about 1 km/s ($q = 0.01$ AU to 0.02 AU) and 3.4 km/s ($q = 0.1$ AU).

For the μ-Virginid meteor stream (Table 1, Figure 2) the theoretical radiant of the comet C/1737 C1, according to our calculation, refers to the southern (S) branch of the stream, if the μ-Virginids represent its northern (N) branch. We found that a similar situation applies for the 31-Pegasid meteor stream and its parent 1995 LG (Table1).

We discovered (Terentjeva & Barabanov, 2008) vast streams of meteor bodies related with large streams of SOHO comets or with separate SOHO comets. So, in the results from the existing comet catalogue (`http://ssd.jpl.nasa.gov/dat/ELEMENTS.COMET`) a family of the comet C/2002 V5 (SOHO), consisting of 20 SOHO comets in total (Figure 3), was discovered. Their orbits come to the Earth's orbit at the point of

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IMO bibcode WGN-411-terentjeva-streams
NASA-ADS bibcode 2013JIMO...41...11T

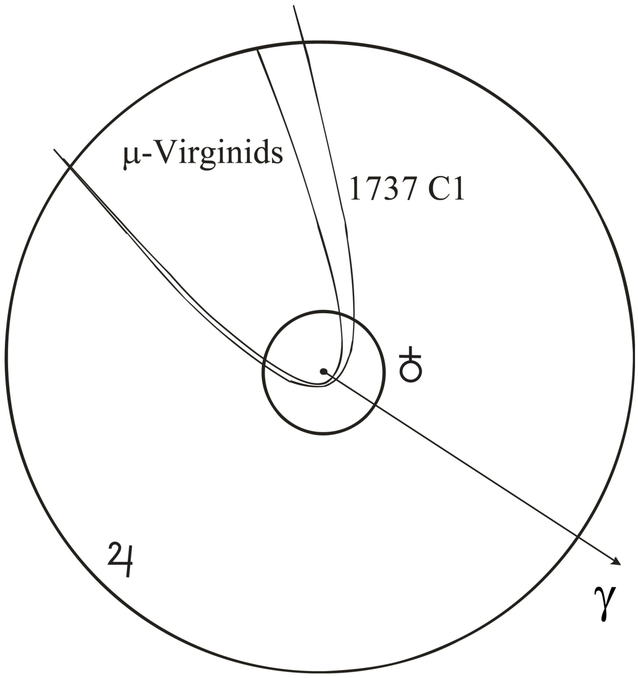

Figure 2 – The μ-Virginid meteor stream and the comet C/1737 C1 (orbital planes are superposed on the ecliptic plane).

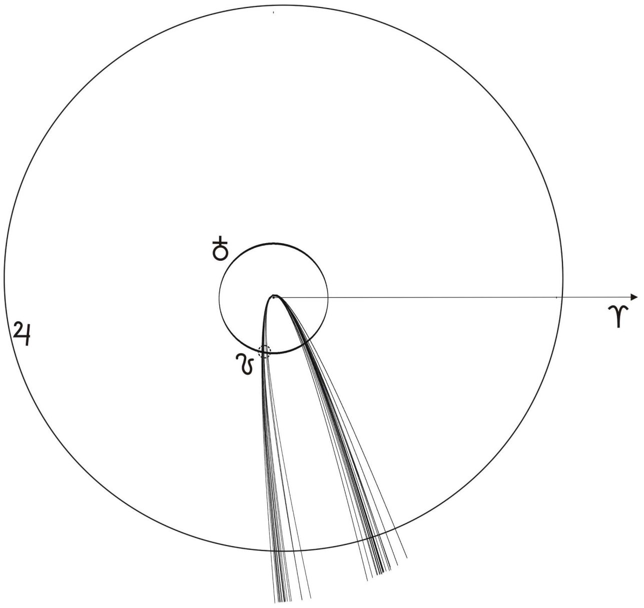

Figure 3 – Family of the comet C/2002 V5 (SOHO) (orbital planes are superposed on the ecliptic plane). The comets belonging to the family are: C/2002 V5, C/1996 V2, C/1999 N5, C/2004 W10, C/1998 A2, C/2000 C3, C/2000 C4, C/2004 V10, C/2005 G2, C/1999 J6, C/2004 V9, C/1999 U2, C/1998 A3, C/1999 P6, C/2000 C7, C/1999 P9, C/1999 P8, C/2005 E4, C/1998 A4, C/2002 R4.

closest approach, which we term the appulse (Kramer, 1953), at a distance ρ within the range from 0.00444 AU to 0.131 AU in the area of the descending nodes of the orbits, in the period from June 7 till 13. Similar values of Tisserand's constant C (where the perturbing planet is Jupiter) do not contradict the fact that this compact group of comets once (and probably recently) could be a unitary whole. Theoretical radiants of these comets are located at a small angular distance from the Sun (up to 30°), which is why their meteors are unavailable for optical observations. At the same time, by means of radio observations in Adelaide, Harvard and Obninsk (Terentjeva & Barabanov, 2008) we found 191 orbits of meteor bodies related with the above mentioned family of SOHO comets. This stream of small meteor bodies generating a twilight meteor shower meets the Earth within 20 days (from June 2 till 22) forming a continuous population of small bodies together with the comet family.

The orbit of the comet C/2001 D1 (SOHO) has appulse with the Earth's orbit on March 26 in the area of the ascending node of the orbit with $\rho = 0.0577$ AU, and on May 8 – with $\rho = 0.210$ AU – the theoretical comet radiant is similar to the radiant of the excellent shower of the Scorpionids of bright meteors and fireballs (Table 1). Besides, for these two approach times of the comet orbit with the Earth's orbit, by means of radio observations in Mogadishu, Harvard, Kharkov, Obninsk and Adelaide, we discovered 155 orbits of meteor bodies related with the comet C/2001 D1 (SOHO), in total. Here we deal with a sufficiently wide (over 0.2 AU) stream of meteor bodies active continuously within two months.

Thus, as to SOHO comets, we can draw a conclusion that they represent a rich source of both small and large meteor bodies; they may generate meteor streams of small perihelion distance, and in particular of short period. SOHO comets may also form vast comet-meteor complexes.

Acknowledgement

This research is supported by Russian Foundation for Basic Research (grant 12-02-90444_Ukr_a).

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Handling Editor: Željko Andreić

Table 1 – Relation of meteor streams with comets and asteroids. Orbital elements of meteor streams are given for the 1950.0 equinox; for all the other objects they are given for the 2000.0 equinox.

Object name	Date (UT)	Corr. geocentric radiant		V_∞ (V_g) km/s	a AU	e	q AU	i [°]	ω [°]	Ω [°]	π [°]	Source
		α [°]	δ [°]									
μ-Virginids (N)	Apr 6–24	218	−10	44.0	56.8	1.01	0.16	12	314	20	333	No 52 [1]
C/1737 C1 (S)	Apr 17	218.3	−24.5	(39.9)		1	0.22282	18.3	99.5	230.1	329.6	[2]
α-Virginids	Mar 2–26	210	−10	35.2	1.16	0.91	0.10	10	334	0	334	No 27 [3]
C/2004 X7 (SOHO)	Mar 22	208.6	−14.4	(46.8)		1	0.0412	21.3	160.6	180.1	340.7	[2]
Scorpionids (N)	May 1–19	249	−17	38.4	2.13	0.93	0.14	12	323	46	9	No 71 [1]
Scorpionids (S)		250	−28	38.0	1.64	0.93	0.12	16	146	225	12	
2005 HC_4	Apr 29	241.6	−20.9	(35.6)	1.818	0.961	0.0708	8.4	309.0	63.8	12.8	[4]
C/2001 D1 (SOHO)	May 8	254.2	−25.0	(47.5)		1	0.0326	14.8	214.0	173.8	27.8	[2]
θ-Taurids	Mar 11–21	213	−31	55.3	61.40	1.00	0.16	105	133	181	314	No 28 [3]
C/1439 F1	Mar 31	219.0	−32.4	(50.2)		1	0.12	81	140	192	332	[2]
η-Librids	Apr 11–21	230	−19	29.5	0.87	0.84	0.14	2	152	201	353	No 45 [3]
1999 FK_{21}	Apr 7	236.4	−19.8	(24.6)	0.7388	0.703	0.219	12.6	172.3	180.5	352.9	[4]
β-Leonids	Feb 3–20	174	+11	36.0	1.50	0.90	0.16	16	322	324	286	No 23 [1]
1996 BT	Jan 27	155.2	+18.2	(29.8)	1.195	0.830	0.204	11.9	327.8	297.1	264.9	[4]
31-Pegasids (N)	Jul 15–19	334	+12	28.0	0.73	0.79	0.16	36	338	115	93	No 228 [5]
1995 LG (S)	Jul 10	336.7	−36.9	(29.8)	1.064	0.791	0.222	43.5	160.1	276.5	76.6	[4]
δ-Piscids (N)	Sep 10–13	10.2	+8.3	(34.6)	2.1	0.92	0.17	7.3	317.5	170.7	128.2	[6]
δ-Piscids (S)		13.7	+1.1	(35.7)	2.2	0.93	0.15	10.9	140.2	349.7	129.9	
1984 QY_1	Sep 15	5.7	+12.6	(33.6)	2.963	0.917	0.246	15.5	335.4	144.1	119.5	[4]
2000 SG_8	Sep 23	24.3	−5.0	(32.7)	2.461	0.902	0.242	24.1	151.8	338.3	130.2	[4]

Sources:
[1] – Terentjeva (1963a; 1963b; 1966)
[2] – `http://ssd.jpl.nasa.gov/dat/ELEMENTS.COMET`
[3] – Terentjeva (1967a)
[4] – `http://neo.jpl.nasa.gov/cgi-bin/neo_elem`
[5] – Terentjeva (1967b)
[6] – Ueda et al. (1997)

Preliminary results

Results for a CAMS double-station video observation Meterik — Gronau

Carl Johannink [1]

Due to perfect weather and astronomical conditions, plans for simultaneous video-observations during the maximum of the Orionids in 2011 were carried out successfully between the stations Meterik (Netherlands) and Gronau (Germany). Results of 96 simultaneous meteors are discussed in this article. Besides the well known showers Orionids and Taurids, some other minor showers could be identified.

Received 2012 May 21

1 Introduction

After the Draconid campaign Peter Jenniskens stayed till end of October in the Netherlands. With the Orionid shower under reasonable favorable circumstances and the required equipment available it would have been a pity not to take advantage of this opportunity to organize a double station session. For this occasion Peter left four camera's with the necessary hardware and software behind with the author. We already successfully used the set-up (Langbroek, 2012). A slightly downsized version of the two new CAMS systems of Peter was operated for the double station work and consisted of a few sensitive WATEC 902H ultimate video camera's with a 12 mm lens (20 × 30 degrees field of view per camera). The CAMS system is in principle completely automated. Once the camera's are pointed and focused, the PC takes it over. Registered meteors are automatically detected. After the observations the data from both stations are merged and the CAMS software derives the double station meteors from the data, with the images being measured and the astrometry, trajectory and orbit calculations all being performed automatically. For a more detailed description I refer to CAMS website (Jenniskens, 2011). In short time I assembled a temporary mounting that allowed to open the dormer window quickly without having to take down and to rebuild the camera mounting.

The weather gods proved to be favorably minded. Observations were possible under clear sky conditions during several nights around the Orionid maximum from both sites, Meterik and Gronau.

The camera's were aimed at the atmosphere above the city of Nijmegen, the Netherlands, because of the free view in northern direction from Meterik and the just acceptable elevation and direction from Gronau, Germany. A camera direction more towards the west is problematic from Gronau because of the proximity in that direction of the city of Enschede, the Netherlands. The video equipment functioned each night from the evening twilight till the morning twilight. The software is programmed as such that at the end of the observing session a data file is generated with all the data of the registered meteors. This routine takes a couple of hours of computation time and by 1 p.m. I could switch off the PC. The foregoing suggests that it was all very simple but it caused some headaches at the beginning. Each morning during a check at 7 a.m. the PC was already switched off while the PC was turned on during a check in the evening hours. A consultation by phone with Peter in Meterik learned that an internal instruction was active to switch off the PC at 2 p.m. local time in California. Once this command had been neutralized the system ran smooth, luckily just in time for the maximum of the Orionids. The nights of October 21/22, 22/23, 23/24, 26/27 and 27/28 produced almost 60 hours of video data for both stations.

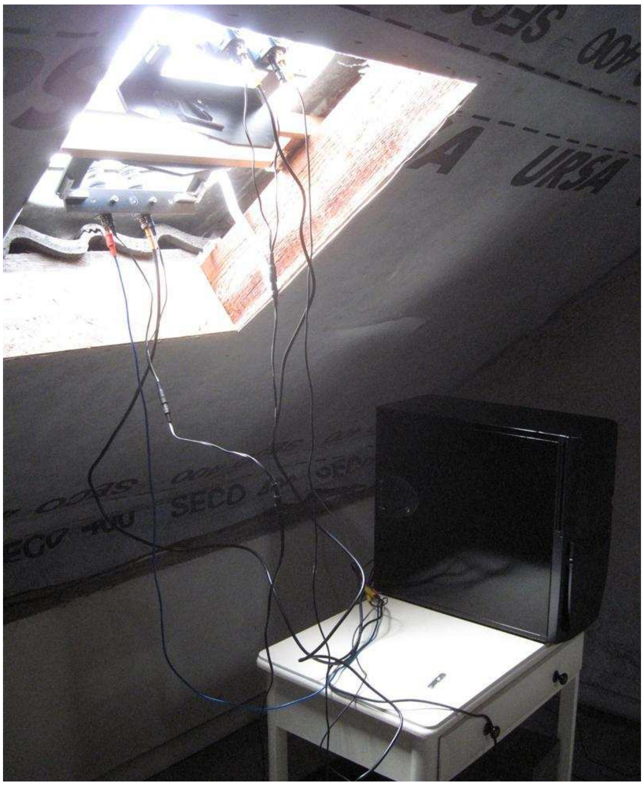

Figure 1 – PC and four operational cams.

2 Results

After applying 'coincidence', the program tool that filters the double station meteors from the entire dataset, 96 double station meteors were identified which will be considered in detail. The orbital elements are listed in this article. First of all a plot was made to map all the radiant positions of these double station meteors.

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NASA-ADS bibcode 2013JIMO...41...14J

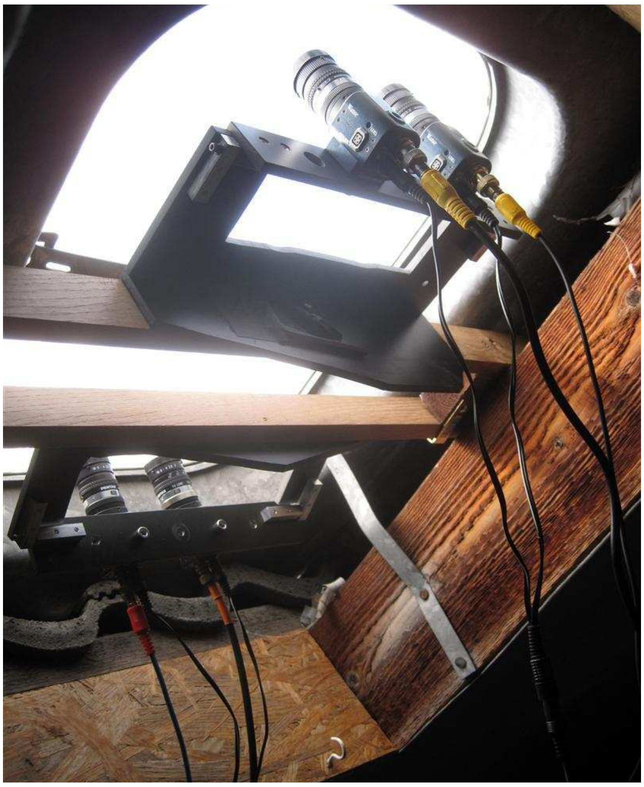

Figure 2 – close-up of the CAMS mounting.

Figure 3 – WATEC 902H-ultimate in detail.

The distribution of the radiant positions looks rather homogenous with an empty space around 200 degrees in right ascension. This is quite normal as the Sun is situated near this position in October and not observable under dark night sky conditions. Further two small clusters catch the attention, the same clusters which we notice also in the plot of 'inclination' against 'length of the perihelion'.

3 Orionids

We focus onto these two clusters and these indeed concern the well known Orionids and Taurids. We first consider the largest cluster: the Orionids. Figure 6 displays the radiant positions of the double station Orionids in detail. For comparison the radiant positions of the Orionids from the DMS photographic and video database are shown in Figure 7 (Jobse & de Lignie, 1995).

The radiant positions obtained in the current study fit perfectly with the older data (Jobse & de Lignie, 1995). Comparing both graphics we see an almost identical picture: the spread in declination is definitely smaller than the spread in right ascension. The DMS video database as far as the Orionids are concerned contains only meteors for the nights 1993 October 18/19 and 1995 October 21/22.

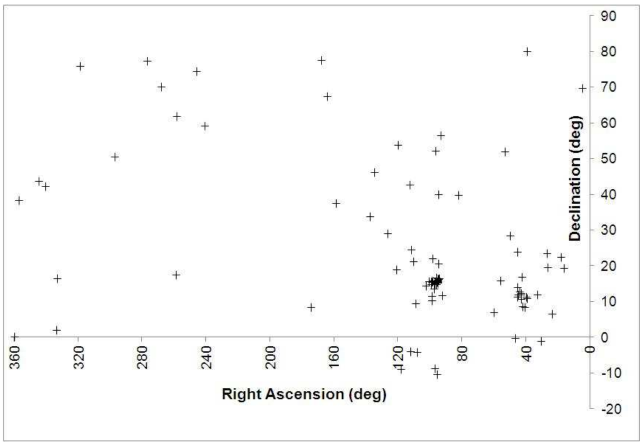

Figure 4 – Radiants for the 96 double station meteors recorded from Meterik and Gronau during the Orionid project.

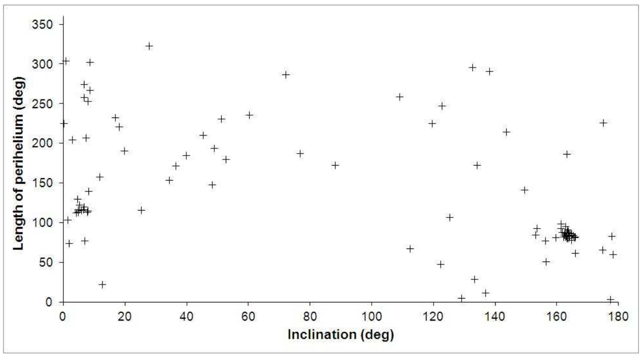

Figure 5 – Plot of the inclination against length of perihelion for all 96 double station meteors.

This is a time lapse for which the radiant drift should be taken into consideration. For the recent observing project, which runs from October 21 till 27, the radiant drift would affect the spread even more. We know that the radiant drift for the Orionids is about $\Delta\alpha/\Delta\lambda_\odot = +0\overset{\circ}{.}7$ and $\Delta\delta/\Delta\lambda_\odot = +0\overset{\circ}{.}11$ (Jenniskens, 2006), about a half degree per day in Right Ascension and about 0.1

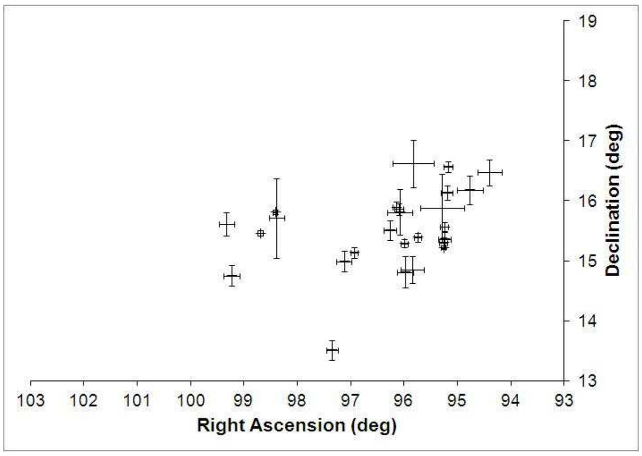

Figure 6 – The radiant position distribution for double station Orionids 2011.

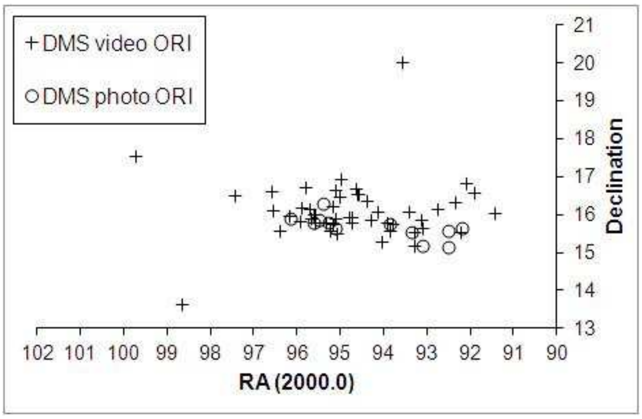

Figure 7 – The radiant position distribution for the Orionids from the DMS photographic and video database.

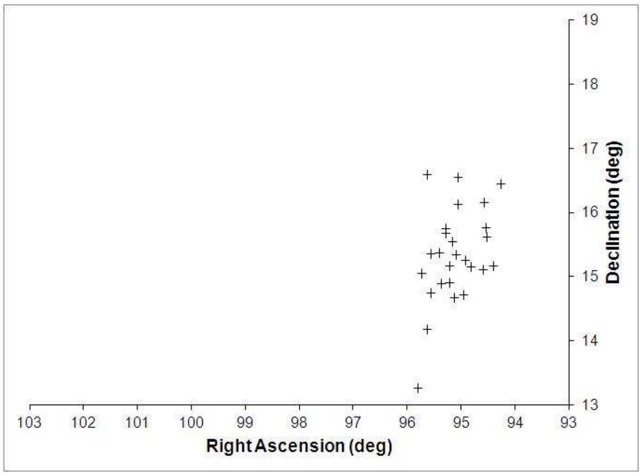

Figure 8 – The same data as Figure 6 but corrected for the radiant drift.

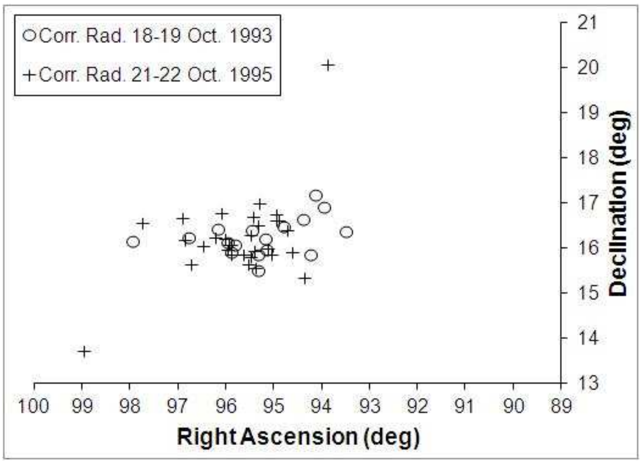

Figure 9 – The same data as Figure 7 but corrected for the radiant drift.

degrees in declination. We corrected Figures 6 and 7 for the radiant drift and referred all radiant positions to solar longitude $\lambda_\odot = 208\overset{\circ}{.}6$ (2000.0), the time of the Orionid maximum. The result is shown in Figures 8 and 9.

The radiant positions from both graphics fit very well. The compactness of the radiant area in both cases indicates that the measuring and positional accuracy of the CAMS software is as good as the accuracy of the older systems. However one catches more meteors with the CAMS.

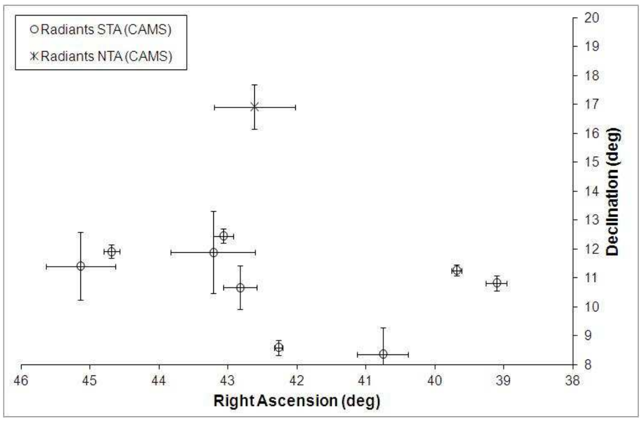

Figure 10 – Distribution of the radiant positions of the double station Taurids 2011.

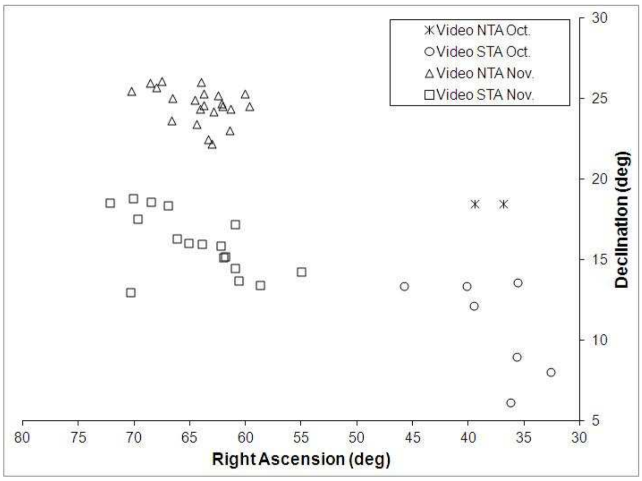

Figure 11 – Distribution of the radiant positions of the double station Taurids from the DMS photographic and video database.

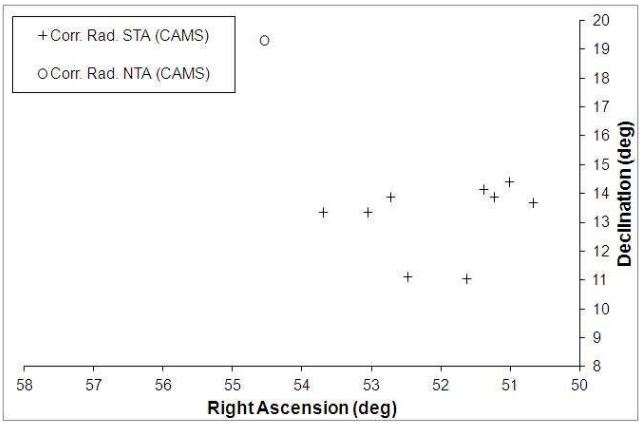

Figure 12 – The same plot like Figure 10 but corrected for the radiant drift.

4 Taurids

The other cluster concerns the Taurids and also here we display the radiant distribution derived from the latest observing project (Figure 10) but also the radiant positions for the Taurids from the DMS photographic and video database (Figure 11).

Also in this case we apply the correction for the radiant drift of the Taurids: $\Delta\alpha/\Delta\lambda_\odot = +0\overset{\circ}{.}73$ and $\Delta\delta/\Delta\lambda_\odot = +0\overset{\circ}{.}18$ for the STAs and $\Delta\alpha/\Delta\lambda_\odot = +0\overset{\circ}{.}80$ and $\Delta\delta/\Delta\lambda_\odot = +0\overset{\circ}{.}16$ for the NTAs (Jenniskens, 2006). The result is shown in Figure 12.

The overall majority of the double station Taurids is produced by its Southern component, only a single NTA could be detected. The time of the observations, around October 23, may explain this. Also the DMS photographic and video database shows that the overall majority of double station Taurids recorded in October belongs to the Southern branch which is confirmed by the 2011 data.

5 Minor meteor showers

We wondered if we had registered any meteors from minor meteor showers. Just one or two meteors of a minor shower will not catch the attention in Figure 4 like the clusters of the Orionids and Taurids. The remaining double station meteors were checked using the IAU meteor shower catalogue (IAU Meteor Data Center, 2011) and (Jenniskens, 2006). Possible meteor showers active during the observing project are listed in Table 1.

The list with simultaneous meteors was verified using characteristics such as radiant position, velocity and if available the orbital elements. This produced the Tables 2 till 5 with all the data for the 96 simultaneously recorded meteors with in the last column the meteor shower classification. From this data it seems that meteors were recorded from a few meteor showers listed in Table 1. However for some other meteor showers the association is questionable which is indicated with one or respectively two question marks. For a number of the meteor showers in Table 1 we must conclude that not a single member was recorded.

6 Conclusion

A few nights of observing with the CAMS-software and hardware delivers many results both quantity and quality. The reduction takes very little time especially when compared to working with Astrorecord. Here we got a technique that allows us to contribute to the study of meteor showers and give more sense to the statement that our hobby isn't just fun, but is valuable as well.

Acknowledgement

I want to thank Peter Jenniskens for his help guiding me through the CAMS software during this campaign. Further a word of thanks to Paul Roggemans, also for translating this article for WGN.

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Handling Editor: Paul Roggemans

Table 1 – Possibly active meteor showers during the observing campaign. $\lambda_\odot$, α and δ are all for Epoch 2000.0.

IAU	Shower	Code	Cat.†	$\lambda_\odot$ [°]	α [°]	δ [°]	V_g (km/s)	Parent
0002	South. Taurids	STA	E	224.0	54.2	14.2	28.3	2P/Encke
0008	Orionids	ORI	E	208.6	95.4	15.9	66.2	1P/Halley
0017	North. Taurids	NTA	E	224.0	56.8	21.2	28.3	2004 TG10
0018	Andromedids	AND	E	231.0	24.2	32.5	17.2	3D/Biel
0022	Leonis Minorids	LMI	E	209.7	161.4	36.2	61.9	C/1739 K1 (Zanotti)
0023	ϵ-Geminids	EGE	W	206.0	101.6	26.7	68.8	?
0024	μ-Pegasids	PEG	W	230.4	335.5	21.8	11.2	?
0025	North. October-δ Arietids	NOA	W	201.7	34.7	20.2	36.3	?
0028	South. October-δ Arietids	SOA	W	198.5	33.1	10.6	25.6	2P/Encke?
0083	October Cygnids	OCG	W	206.0	317.8	52.6	17.2	?
0086	October γ-Cetids	OGC	W	206.4	50.4	−6.9	3.3	?
0225	σ-Orionids	SOR	W	191.7	86.0	−3.0	65.0	?
0226	ζ-Taurids	ZTA	W	196.0	86.1	14.7	67.2	?
0227	October Monocerotids	OMO	W	206.0	101.9	−1.4	63.5	C/1723 T1 (Keggler-Crossat-Sau)
0228	October Lyncids	OLY	W	206.0	111.3	48.8	64.8	?
0229	ν-Aurigids	NAU	W	207.3	87.9	39.6	53.1	?
0230	October ι-Cassiopeiids	ICS	W	209.0	36.7	66.0	66.3	?
0233	October Capricornids	OCC	E	189.7	303.0	−10.0	10.4	D/1978 R1 (Haneda-Campos)
0235	λ-Cygnids	LCY	W	199.0	338.6	31.3	18.0	2005 CA?
0236	γ-Piscids	GPS	W	200.0	377.7	9.3	13.4	6344 P-L?
0237	σ-Arietids	SSA	W	202.0	44.7	14.2	40.5	?
0241	October Ursae Minorids	OUI	W	208.0	246.6	74.3	30.9	?
0242	ξ-Draconids	XDR	W	210.8	170.3	73.3	35.8	?
0244	ψ-Aurigids	PAR	W	227.	94.	50.	56.7	?

†Shower category: E – established; W – working

Table 2 – Orbital elements of double station Orionids.

No.	Date	Time (UT)	α_g [°]	δ_g [°]	V_g [km/s]	V_h [km/s]	q [AU]
7	22–10–2011	00:45:56	95.25 ± 0.08	15.56 ± 0.08	66.8 ± 0.08	41.7 ± 0.09	0.5917 ± 0.0023
14	22–10–2011	02:05:20	95.18 ± 0.08	16.57 ± 0.09	66.8 ± 0.09	41.6 ± 0.09	0.5832 ± 0.0025
15	22–10–2011	02:29:45	95.20 ± 0.11	16.14 ± 0.12	65.9 ± 0.16	40.8 ± 0.15	0.5681 ± 0.0041
17	22–10–2011	02:37:24	94.40 ± 0.23	16.47 ± 0.22	66.5 ± 0.13	41.6 ± 0.15	0.5617 ± 0.0053
18	22–10–2011	03:05:31	95.24 ± 0.12	15.36 ± 0.13	66.7 ± 0.13	41.6 ± 0.13	0.5883 ± 0.0038
21	22–10–2011	04:22:48	94.77 ± 0.24	16.18 ± 0.24	65.7 ± 0.21	40.8 ± 0.22	0.5534 ± 0.0064
22	22–10–2011	04:29:35	95.75 ± 0.07	15.39 ± 0.07	66.4 ± 0.06	41.2 ± 0.06	0.5926 ± 0.0019
23	22–10–2011	04:47:34	95.83 ± 0.39	16.62 ± 0.39	66.3 ± 0.63	41.0 ± 0.62	0.5856 ± 0.014
4	22–10–2011	21:00:26	95.27 ± 0.04	15.22 ± 0.03	66.6 ± 0.05	41.8 ± 0.05	0.572 ± 0.0011
8	22–10–2011	23:27:08	95.29 ± 0.41	15.88 ± 0.57	65.5 ± 1.09	40.7 ± 1.01	0.5443 ± 0.0245
15	23–10–2011	00:45:47	96.00 ± 0.07	15.29 ± 0.07	66.1 ± 0.07	41.1 ± 0.06	0.5731 ± 0.0021
17	23–10–2011	01:33:06	96.08 ± 0.23	15.81 ± 0.38	66.2 ± 0.67	41.1 ± 0.64	0.5731 ± 0.0141
20	23–10–2011	03:01:18	95.99 ± 0.15	14.81 ± 0.26	63.5 ± 0.49	38.7 ± 0.47	0.5214 ± 0.012
21	23–10–2011	03:33:37	96.15 ± 0.07	15.89 ± 0.09	67.6 ± 0.20	42.5 ± 0.19	0.5976 ± 0.0037
22	23–10–2011	03:34:57	96.27 ± 0.12	15.51 ± 0.16	63.1 ± 0.32	38.2 ± 0.30	0.5127 ± 0.0079
23	23–10–2011	03:40:53	95.27 ± 0.08	15.30 ± 0.09	65.5 ± 0.12	40.9 ± 0.11	0.545 ± 0.0029
25	23–10–2011	04:39:15	95.85 ± 0.22	14.85 ± 0.22	66.4 ± 0.45	41.5 ± 0.44	0.575 ± 0.0092
11	24–10–2011	03:06:18	97.35 ± 0.11	13.51 ± 0.16	65.9 ± 0.29	41.0 ± 0.28	0.587 ± 0.0059
13	24–10–2011	03:33:43	97.13 ± 0.15	14.99 ± 0.17	65.7 ± 0.22	40.8 ± 0.21	0.5679 ± 0.0053
14	24–10–2011	03:46:08	96.10 ± 0.08	15.86 ± 0.10	65.0 ± 0.15	40.3 ± 0.14	0.526 ± 0.0037
15	24–10–2011	03:46:50	96.94 ± 0.07	15.14 ± 0.09	65.2 ± 0.17	40.3 ± 0.16	0.5512 ± 0.004
5	26–10–2011	21:41:39	98.70 ± 0.05	15.46 ± 0.04	65.7 ± 0.06	41.1 ± 0.06	0.5357 ± 0.0012
6	26–10–2011	21:50:39	98.42 ± 0.04	15.81 ± 0.04	66.0 ± 0.04	41.4 ± 0.04	0.5327 ± 0.0009
14	27–10–2011	00:52:14	98.39 ± 0.14	15.71 ± 0.67	65.0 ± 2.86	40.5 ± 2.7	0.5107 ± 0.0591
16	27–10–2011	01:17:55	99.33 ± 0.14	15.61 ± 0.19	65.3 ± 0.13	40.6 ± 0.14	0.5373 ± 0.0044
20	27–10–2011	02:13:48	99.24 ± 0.15	14.75 ± 0.17	65.2 ± 0.17	40.5 ± 0.17	0.5375 ± 0.0049

Table 3 – Orbital elements of double station Taurids.

No.	Date	Time (UT)	α_g [°]	δ_g [°]	V_g [km/s]	V_h [km/s]	q [AU]
10	23–10–2011	00:07:15	42.62 ± 0.59	16.92 ± 0.76	30.1 ± 0.29	36.5 ± 0.29	0.279 ± 0.0069
1	21–10–2011	21:21:14	39.69 ± 0.07	11.27 ± 0.18	28.1 ± 0.08	36.6 ± 0.07	0.3448 ± 0.0018
11	22–10–2011	01:34:04	39.11 ± 0.15	10.83 ± 0.26	27.1 ± 0.08	36.3 ± 0.06	0.3673 ± 0.0017
12	23–10–2011	00:28:59	42.83 ± 0.24	10.67 ± 0.76	27.8 ± 0.36	35.8 ± 0.2	0.3301 ± 0.0048
14	23–10–2011	00:44:14	40.76 ± 0.37	8.36 ± 0.93	26.7 ± 0.39	36.1 ± 0.24	0.38 ± 0.006
7	23–10–2011	22:26:04	42.27 ± 0.06	8.59 ± 0.27	26.5 ± 0.12	35.9 ± 0.08	0.3742 ± 0.0022
7	26–10–2011	22:16:21	44.69 ± 0.11	11.91 ± 0.23	28.7 ± 0.09	37.0 ± 0.08	0.3431 ± 0.0021
9	26–10–2011	22:34:16	43.22 ± 0.61	11.89 ± 1.41	26.9 ± 0.58	36.5 ± 0.45	0.3792 ± 0.0113
15	27–10–2011	01:15:54	43.07 ± 0.15	12.45 ± 0.25	26.3 ± 0.09	36.1 ± 0.07	0.3862 ± 0.0016
18	27–10–2011	01:52:58	45.14 ± 0.5	11.41 ± 1.17	28.5 ± 0.77	36.9 ± 0.45	0.344 ± 0.0094

Table 4 – Orbital elements of meteors that may be associated with minor showers in Table 1.

No.	Date	Time (UT)	α_g [°]	δ_g [°]	V_g [km/s]	V_h [km/s]	q [AU]
12	24–10–2011	03:06:58	111.8 ± 0.61	24.64 ± 0.54	67.8 ± 0.21	38.9 ± 0.2	0.8686 ± 0.0117
21	27–10–2011	04:22:56	110.21 ± 0.25	21.21 ± 0.27	67.5 ± 0.25	39.4 ± 0.26	0.7774 ± 0.0062
9	22–10–2011	00:59:31	158.61 ± 0.1	37.63 ± 0.07	62.1 ± 0.08	42.1 ± 0.08	0.6414 ± 0.0017
16	24–10–2011	04:33:54	82.07 ± 0.23	39.76 ± 0.17	58.9 ± 0.21	41 ± 0.21	0.2933 ± 0.0039
10	22–10–2011	01:32:18	112.73 ± 0.15	42.71 ± 0.18	67.5 ± 0.18	41.8 ± 0.19	0.9125 ± 0.0018
1	26–10–2011	17:40:33	120.18 ± 0.32	53.91 ± 0.32	57.8 ± 0.12	37.4 ± 0.19	0.8844 ± 0.0038
16	22–10–2011	02:35:34	112.27 ± 0.05	-3.88 ± 0.08	67.2 ± 0.12	42.3 ± 0.12	0.986 ± 0.0003
2	23–10–2011	18:19:22	245.88 ± 10	74.43 ± 1.89	31.9 ± 1.2	39.3 ± 1.3	0.9949 ± 0.0047
11	27–10–2011	00:10:13	93.22 ± 0.12	56.52 ± 0.15	56.4 ± 0.15	40.9 ± 0.14	0.6136 ± 0.0034

Table 2 – (Continued from previous page)

No.	1/a	a	e	i	ω	Ω	ϖ	
7	0.051 ± 0.008	19.605	0.96982 ± 0.005	163.73 ± 0.2	79.85 ± 0.34	28.109 ± 0.001	107.96 ± 0.34	ORI
14	0.056 ± 0.008	18.006	0.96761 ± 0.005	165.77 ± 0.2	80.91 ± 0.37	28.164 ± 0.001	109.08 ± 0.37	ORI
15	0.136 ± 0.013	7.364	0.92285 ± 0.007	164.69 ± 0.3	83.95 ± 0.65	28.181 ± 0.001	112.13 ± 0.65	ORI
17	0.055 ± 0.014	18.232	0.96919 ± 0.008	165.28 ± 0.5	83.41 ± 0.64	28.186 ± 0.001	111.6 ± 0.64	ORI
18	0.057 ± 0.012	17.567	0.96651 ± 0.007	163.27 ± 0.3	80.33 ± 0.55	28.205 ± 0.001	108.54 ± 0.55	ORI
21	0.137 ± 0.02	7.313	0.92433 ± 0.011	164.59 ± 0.5	85.67 ± 0.89	28.259 ± 0.002	113.93 ± 0.89	ORI
22	0.095 ± 0.006	10.485	0.94348 ± 0.003	163.41 ± 0.1	80.42 ± 0.26	28.264 ± 0	108.68 ± 0.26	ORI
23	0.114 ± 0.057	8.757	0.93313 ± 0.032	165.93 ± 0.8	81.54 ± 2.35	28.276 ± 0.004	109.82 ± 2.35	ORI
4	0.04 ± 0.005	24.78	0.97692 ± 0.003	162.79 ± 0.1	81.98 ± 0.18	28.948 ± 0	110.93 ± 0.18	ORI
8	0.146 ± 0.092	6.845	0.92048 ± 0.047	163.86 ± 1.3	86.86 ± 4.28	29.049 ± 0.006	115.91 ± 4.28	ORI
15	0.11 ± 0.006	9.12	0.93716 ± 0.003	163.00 ± 0.2	82.92 ± 0.3	29.103 ± 0	112.02 ± 0.3	ORI
17	0.104 ± 0.059	9.6	0.9403 ± 0.032	164.10 ± 0.8	82.83 ± 2.54	29.136 ± 0.005	111.97 ± 2.54	ORI
20	0.32 ± 0.041	3.12	0.83288 ± 0.018	161.27 ± 0.5	92.73 ± 2.15	29.197 ± 0.003	121.93 ± 2.15	ORI
21	−0.024 ± 0.018	999.	1.01434 ± 0.011	164.59 ± 0.2	78.07 ± 0.66	29.22 ± 0.001	107.29 ± 0.66	ORI
22	0.366 ± 0.026	2.734	0.81247 ± 0.011	162.76 ± 0.4	94.68 ± 1.41	29.221 ± 0.002	123.9 ± 1.41	ORI
23	0.129 ± 0.011	7.755	0.92972 ± 0.006	162.62 ± 0.2	86.50 ± 0.45	29.225 ± 0.001	115.72 ± 0.45	ORI
25	0.068 ± 0.041	14.802	0.96115 ± 0.023	162.09 ± 0.4	82.04 ± 1.58	29.265 ± 0.002	111.31 ± 1.58	ORI
11	0.113 ± 0.026	8.813	0.93339 ± 0.015	159.53 ± 0.3	81.33 ± 1.07	30.196 ± 0.001	111.52 ± 1.07	ORI
13	0.136 ± 0.019	7.366	0.9229 ± 0.011	162.41 ± 0.4	83.93 ± 0.86	30.216 ± 0.001	114.14 ± 0.86	ORI
14	0.176 ± 0.013	5.691	0.90757 ± 0.006	163.67 ± 0.2	89.46 ± 0.62	30.224 ± 0.001	119.68 ± 0.62	ORI
15	0.182 ± 0.014	5.486	0.89953 ± 0.007	162.49 ± 0.2	86.66 ± 0.68	30.225 ± 0.001	116.88 ± 0.68	ORI
5	0.109 ± 0.006	9.145	0.94142 ± 0.003	163.21 ± 0.1	87.19 ± 0.2	32.962 ± 0	120.15 ± 0.2	ORI
6	0.079 ± 0.004	12.687	0.95801 ± 0.002	163.91 ± 0.1	87.06 ± 0.14	32.969 ± 0	120.03 ± 0.14	ORI
14	0.16 ± 0.246	6.264	0.91847 ± 0.116	163.41 ± 1.5	90.9 ± 10.94	33.094 ± 0.009	123.99 ± 10.94	ORI
16	0.157 ± 0.013	6.36	0.91552 ± 0.007	163.63 ± 0.4	87.79 ± 0.63	33.112 ± 0.001	120.9 ± 0.63	ORI
20	0.162 ± 0.016	6.19	0.91317 ± 0.008	161.75 ± 0.4	87.83 ± 0.74	33.151 ± 0.001	120.98 ± 0.74	ORI

Table 3 – (Continued from previous page)

No.	1/a	a	e	i	ω	Ω	ϖ	
10	0.511 ± 0.024	1.955	0.85729 ± 0.006	0.75 ± 0.8	303.94 ± 1.15	209.127 ± 0.493	153.07 ± 1.08	NTA
1	0.5 ± 0.006	1.999	0.82751 ± 0.002	4.74 ± 0.2	116.34 ± 0.26	27.95 ± 0.001	144.29 ± 0.27	STA
11	0.524 ± 0.005	1.91	0.8077 ± 0.002	4.72 ± 0.3	114.35 ± 0.22	28.133 ± 0.002	142.49 ± 0.22	STA
12	0.568 ± 0.016	1.761	0.81255 ± 0.008	6.61 ± 0.9	119.4 ± 0.31	29.084 ± 0.005	148.48 ± 0.32	STA
14	0.538 ± 0.019	1.858	0.79548 ± 0.01	7.65 ± 1	113.29 ± 0.53	29.096 ± 0.005	142.39 ± 0.53	STA
7	0.562 ± 0.007	1.78	0.78978 ± 0.003	7.93 ± 0.3	114.45 ± 0.29	29.993 ± 0.001	144.45 ± 0.29	STA
7	0.47 ± 0.007	2.128	0.83877 ± 0.002	5.82 ± 0.3	115.83 ± 0.32	32.976 ± 0.001	148.81 ± 0.32	STA
9	0.513 ± 0.037	1.95	0.80554 ± 0.015	4.82 ± 1.5	112.74 ± 1.57	32.988 ± 0.023	145.73 ± 1.58	STA
15	0.539 ± 0.006	1.854	0.79169 ± 0.002	4.07 ± 0.3	112.58 ± 0.22	33.104 ± 0.002	145.68 ± 0.22	STA
18	0.481 ± 0.038	2.08	0.83462 ± 0.017	6.52 ± 1.5	115.94 ± 0.48	33.132 ± 0.016	149.08 ± 0.49	STA

Table 4 – (Continued from previous page)

No.	1/a	a	e	i	ω	Ω	ϖ	
12	0.303 ± 0.018	3.3	0.73679 ± 0.016	175.05 ± 1	225.51 ± 2.16	210.191 ± 0.006	75.7 ± 2.16	EGE?
21	0.258 ± 0.023	3.868	0.79902 ± 0.017	178.24 ± 0.5	59.4 ± 1.08	33.25 ± 0.025	92.65 ± 1.08	EGE?
9	0.011 ± 0.008	93.207	0.99312 ± 0.005	125.16 ± 0.2	106.63 ± 0.28	208.116 ± 0	314.74 ± 0.28	LMI
16	0.113 ± 0.02	8.886	0.96699 ± 0.005	132.63 ± 0.5	295.75 ± 0.7	210.256 ± 0.001	146 ± 0.7	NAU?
10	0.038 ± 0.018	26.452	0.9655 ± 0.016	143.51 ± 0.3	213.85 ± 0.45	208.138 ± 0.001	61.99 ± 0.45	OLY?
1	0.439 ± 0.016	2.28	0.61211 ± 0.014	119.49 ± 0.5	224.83 ± 0.95	212.791 ± 0	77.62 ± 0.95	OLY?
16	−0.004 ± 0.011	999.	1.00394 ± 0.011	136.72 ± 0.1	11.13 ± 0.2	28.183 ± 0	39.31 ± 0.2	OMO?
2	0.269 ± 0.112	3.716	0.73227 ± 0.112	52.68 ± 1.8	179.82 ± 3.77	209.829 ± 0.002	29.65 ± 3.77	OUI
11	0.129 ± 0.013	7.754	0.92087 ± 0.007	108.87 ± 0.2	258.37 ± 0.57	213.063 ± 0	111.43 ± 0.57	PAR?

Table 5 – Orbital elements of sporadic meteors.

No.	Date	Time (UT)	α_g [°]	δ_g [°]	V_g [km/s]	V_h [km/s]	q [AU]
12	22–10–2011	01:50:22	100.68 ± 0.04	15.72 ± 0.11	68.9 ± 0.2	42.1 ± 0.2	0.7379 ± 0.0032
12	27–10–2011	00:20:37	102.45 ± 0.05	14.44 ± 0.05	61.4 ± 0.04	35.9 ± 0.04	0.5205 ± 0.0015
2	21–10–2011	22:47:12	276.62 ± 0.66	77.27 ± 0.28	29.6 ± 0.06	38.8 ± 0.12	0.9841 ± 0.0006
3	21–10–2011	22:56:20	16.33 ± 0.18	19.32 ± 0.44	18.9 ± 0.09	37.1 ± 0.07	0.6725 ± 0.0015
4	21–10–2011	23:17:20	32.75 ± 0.24	11.88 ± 2.67	27.9 ± 1.64	38.9 ± 1.1	0.4279 ± 0.0197
5	21–10–2011	23:45:36	60.27 ± 0.17	7.08 ± 0.4	41.9 ± 0.28	37.5 ± 0.22	0.0949 ± 0.0039
6	22–10–2011	00:01:58	46.75 ± 0.17	-0.23 ± 0.27	33.8 ± 0.16	39.1 ± 0.14	0.3139 ± 0.0029
8	22–10–2011	00:55:33	318.75 ± 11	75.83 ± 0.62	28.1 ± 0.89	38.5 ± 0.9	0.9402 ± 0.0313
13	22–10–2011	02:01:39	107.98 ± 0.12	-4.13 ± 0.11	63.8 ± 0.05	39.8 ± 0.07	0.9439 ± 0.0016
19	22–10–2011	03:36:09	45.36 ± 0.25	14 ± 0.27	30.6 ± 0.13	35.7 ± 0.12	0.2447 ± 0.0022
20	22–10–2011	04:11:59	174.49 ± 0.76	8.45 ± 0.95	29 ± 0.44	26.1 ± 0.2	0.101 ± 0.0078
1	22–10–2011	17:45:30	49.75 ± 0.87	28.52 ± 0.71	39.5 ± 0.43	38.3 ± 0.53	0.1208 ± 0.0077
2	22–10–2011	19:24:51	26.62 ± 0.36	19.61 ± 0.39	23.7 ± 0.04	37.5 ± 0.13	0.5264 ± 0.0043
3	22–10–2011	20:11:36	258.23 ± 8.96	61.84 ± 2.39	22.6 ± 1.41	37.8 ± 1.62	0.9906 ± 0.0044
5	22–10–2011	21:11:39	240.96 ± 2.26	59.18 ± 0.64	20.2 ± 0.28	35.1 ± 0.27	0.9646 ± 0.006
6	22–10–2011	21:15:26	359.69 ± 0.85	0.15 ± 5.49	12.4 ± 1.01	37.7 ± 0.73	0.88 ± 0.0117
7	22–10–2011	21:57:54	333.72 ± 2.33	1.97 ± 6.2	8.63 ± 0.73	37.1 ± 0.56	0.9635 ± 0.0034
11	23–10–2011	00:23:46	96.57 ± 0.7	52.11 ± 0.71	61.2 ± 0.54	41.7 ± 0.51	0.6954 ± 0.0137
13	23–10–2011	00:42:23	259.05 ± 0.22	17.57 ± 0.21	11.6 ± 0.02	37.6 ± 0.02	0.9662 ± 0.0005
16	23–10–2011	01:31:21	340.25 ± 2.3	42.32 ± 0.66	15.9 ± 0.36	38.1 ± 0.24	0.9008 ± 0.0083
18	23–10–2011	02:14:52	92.29 ± 0.09	11.68 ± 0.1	64.3 ± 0.1	41.2 ± 0.1	0.4909 ± 0.0029
19	23–10–2011	02:31:25	98.92 ± 0.19	10.3 ± 0.21	62.9 ± 0.14	37.8 ± 0.15	0.6101 ± 0.0055
24	23–10–2011	04:22:34	96.93 ± 1.74	-8.67 ± 1.83	65.3 ± 3.82	45.7 ± 3.51	0.8159 ± 0.0428
26	23–10–2011	04:40:17	120.85 ± 0.16	18.91 ± 0.2	69.3 ± 0.2	39.4 ± 0.2	0.9947 ± 0.0002
27	23–10–2011	04:47:10	137.42 ± 0.18	33.85 ± 0.23	65.8 ± 0.4	38.8 ± 0.4	0.9006 ± 0.0044
1	23–10–2011	18:04:55	267.98 ± 2.79	70.11 ± 1.22	23.9 ± 0.42	37.2 ± 0.48	0.994 ± 0.0006
3	23–10–2011	19:03:11	332.97 ± 0.18	16.54 ± 0.8	10.9 ± 0.1	38.2 ± 0.1	0.9529 ± 0.0005
4	23–10–2011	19:03:40	39.45 ± 9.44	79.96 ± 1.37	35.1 ± 0.87	37.2 ± 0.96	0.8297 ± 0.0191
5	23–10–2011	19:37:48	53.35 ± 0.35	52.07 ± 0.21	45.8 ± 0.27	41.3 ± 0.25	0.3666 ± 0.0031
6	23–10–2011	21:02:43	4.78 ± 0.67	69.79 ± 0.73	34.8 ± 0.24	42 ± 0.25	0.8141 ± 0.0053
8	23–10–2011	22:33:34	134.98 ± 1.18	46.12 ± 0.82	69.4 ± 1.7	45.2 ± 1.62	0.9899 ± 0.0027
9	23–10–2011	22:38:19	44.02 ± 0.06	12.83 ± 1.14	30.5 ± 0.53	37.1 ± 0.36	0.2886 ± 0.0078
10	23–10–2011	22:43:14	94.79 ± 0.28	20.71 ± 0.64	75.8 ± 5.05	50.8 ± 4.88	0.6431 ± 0.0555
17	24–10–2011	04:47:12	167.82 ± 2.82	77.53 ± 2.07	43.7 ± 0.43	39.5 ± 0.86	0.9919 ± 0.0036
18	24–10–2011	04:53:47	98.45 ± 0.18	22.16 ± 0.18	66.5 ± 0.17	40.8 ± 0.17	0.5766 ± 0.005
19	24–10–2011	05:02:27	98.87 ± 0.61	11.51 ± 0.93	65.8 ± 6.11	40.7 ± 5.8	0.6313 ± 0.1201
2	26–10–2011	18:38:50	164.45 ± 0.29	67.54 ± 0.28	48.9 ± 0.09	39.5 ± 0.12	0.9898 ± 0.0007
3	26–10–2011	19:10:20	356.98 ± 0.28	38.37 ± 0.53	17.7 ± 0.14	38.6 ± 0.15	0.8345 ± 0.0016
4	26–10–2011	20:11:56	23.68 ± 0.65	6.51 ± 0.97	18.8 ± 0.15	37.9 ± 0.22	0.6929 ± 0.0068
8	26–10–2011	22:24:34	296.94 ± 4.71	50.48 ± 1.2	13.3 ± 0.44	36.7 ± 0.34	0.9891 ± 0.0026
10	26–10–2011	23:45:54	108.89 ± 0.07	9.45 ± 0.08	67.7 ± 0.06	40.7 ± 0.06	0.8224 ± 0.0015
13	27–10–2011	00:29:26	126.64 ± 0.26	29.12 ± 0.67	69.3 ± 2.12	40.1 ± 2.12	0.9917 ± 0.0008
17	27–10–2011	01:48:12	95.53 ± 0.13	-10.4 ± 0.14	58.3 ± 0.08	41.4 ± 0.1	0.7014 ± 0.0031
19	27–10–2011	02:09:32	118.11 ± 0.06	-8.96 ± 0.07	63 ± 0.04	39.7 ± 0.04	0.9928 ± 0.0001
22	27–10–2011	05:04:58	94.67 ± 0.5	40.09 ± 0.44	58.3 ± 0.43	37.6 ± 0.47	0.3802 ± 0.0113
1	27–10–2011	19:07:16	18.29 ± 0.72	22.54 ± 1.04	19.3 ± 0.15	38.1 ± 0.26	0.6985 ± 0.0065
2	27–10–2011	19:41:13	26.82 ± 0.06	23.45 ± 0.11	22.5 ± 0.03	37.9 ± 0.04	0.5863 ± 0.0007
3	27–10–2011	19:45:52	45.28 ± 0.15	24.01 ± 0.19	29 ± 0.1	36 ± 0.1	0.3044 ± 0.0019
4	27–10–2011	22:21:32	30.46 ± 0.11	-1.06 ± 1.49	17.5 ± 0.28	36.4 ± 0.18	0.6941 ± 0.0074
5	27–10–2011	23:15:02	55.77 ± 0.09	15.89 ± 0.13	35.3 ± 0.05	36.7 ± 0.05	0.1539 ± 0.0011
6	28–10–2011	00:24:51	344.44 ± 2.68	43.71 ± 1.42	16.1 ± 0.51	38.3 ± 0.33	0.8987 ± 0.0089

Table 5 – (Continued from previous page)

No.	$1/a$	a	e	i	ω	Ω	ϖ	
12	0.013 ± 0.019	78.89	0.99065 ± 0.014	165.95 ± 0.2	61.31 ± 0.65	28.153 ± 0.002	89.46 ± 0.65	ORI?
12	0.561 ± 0.004	1.784	0.70824 ± 0.002	161.33 ± 0.1	98.57 ± 0.23	33.072 ± 0	131.64 ± 0.23	ORI?
2	0.316 ± 0.01	3.166	0.68917 ± 0.01	48.84 ± 0.1	193.57 ± 0.42	208.025 ± 0	41.59 ± 0.42	
3	0.455 ± 0.006	2.196	0.69376 ± 0.004	6.74 ± 0.3	257.99 ± 0.22	208.037 ± 0.002	106.03 ± 0.22	
4	0.308 ± 0.096	3.247	0.86822 ± 0.045	1.3 ± 1.4	103.14 ± 1.87	28.009 ± 0.059	131.15 ± 1.86	
5	0.426 ± 0.018	2.345	0.95953 ± 0.002	48.16 ± 1	147.93 ± 0.74	28.064 ± 0	176 ± 0.74	
6	0.285 ± 0.012	3.507	0.91049 ± 0.004	25.33 ± 0.4	115.89 ± 0.43	28.074 ± 0	143.96 ± 0.43	
8	0.337 ± 0.074	2.971	0.68354 ± 0.053	45.29 ± 1.1	210.3 ± 7.74	208.114 ± 0.002	58.42 ± 7.74	
13	0.225 ± 0.006	4.435	0.78717 ± 0.006	133.32 ± 0.2	28.07 ± 0.44	28.16 ± 0	56.23 ± 0.44	
19	0.575 ± 0.009	1.739	0.85929 ± 0.002	4.59 ± 0.5	129.19 ± 0.33	28.219 ± 0.003	157.41 ± 0.33	
20	1.24 ± 0.012	0.807	0.87485 ± 0.01	12.48 ± 2.2	22.22 ± 0.88	208.252 ± 0.004	230.48 ± 0.87	
1	0.357 ± 0.046	2.803	0.9569 ± 0.004	27.69 ± 2	322.83 ± 1.61	208.812 ± 0.001	171.64 ± 1.61	
2	0.421 ± 0.011	2.373	0.77817 ± 0.004	6.58 ± 0.3	274.37 ± 0.73	208.89 ± 0.001	123.26 ± 0.72	
3	0.402 ± 0.132	2.49	0.60217 ± 0.129	36.45 ± 2.2	170.99 ± 4.88	208.912 ± 0.003	19.9 ± 4.88	
5	0.625 ± 0.021	1.601	0.3975 ± 0.018	34.24 ± 0.4	153.1 ± 2.96	208.954 ± 0.001	2.05 ± 2.96	
6	0.406 ± 0.062	2.462	0.64257 ± 0.057	0.09 ± 1.7	224.53 ± 2.32	209.661 ± 0.771	74.2 ± 2.13	
7	0.457 ± 0.047	2.188	0.55964 ± 0.046	2.8 ± 1.6	204.28 ± 0.89	209.005 ± 0.519	53.29 ± 0.74	
11	0.047 ± 0.048	21.502	0.96766 ± 0.033	122.67 ± 1.2	247.2 ± 2.13	209.086 ± 0	96.28 ± 2.13	
13	0.418 ± 0.002	2.39	0.59573 ± 0.001	11.68 ± 0.1	157.24 ± 0.21	209.102 ± 0	6.34 ± 0.21	
16	0.378 ± 0.021	2.648	0.65982 ± 0.018	18.13 ± 0.5	220.41 ± 1.96	209.135 ± 0.002	69.55 ± 1.96	
18	0.1 ± 0.009	10.013	0.95097 ± 0.004	153.47 ± 0.2	92.27 ± 0.42	29.165 ± 0	121.44 ± 0.42	
19	0.403 ± 0.013	2.483	0.75429 ± 0.008	153.12 ± 0.4	84.26 ± 0.79	29.176 ± 0.001	113.44 ± 0.79	
24	−0.341 ± 0.362	999.	1.27822 ± 0.303	122.22 ± 3.5	47.23 ± 8.29	29.253 ± 0.003	76.48 ± 8.28	
26	0.264 ± 0.018	3.784	0.73713 ± 0.018	177.4 ± 0.3	2.59 ± 0.63	29.275 ± 0.008	31.87 ± 0.63	
27	0.312 ± 0.035	3.204	0.71891 ± 0.031	149.45 ± 0.4	140.62 ± 1.34	209.269 ± 0.002	349.89 ± 1.34	
1	0.454 ± 0.04	2.203	0.5488 ± 0.04	39.85 ± 0.8	184.17 ± 1.27	209.82 ± 0.001	33.99 ± 1.27	
3	0.363 ± 0.009	2.751	0.65362 ± 0.008	7.23 ± 0.2	206.74 ± 0.22	209.87 ± 0.001	56.61 ± 0.22	
4	0.452 ± 0.081	2.21	0.62457 ± 0.066	60.18 ± 1.4	235.38 ± 4.24	209.86 ± 0.002	85.24 ± 4.24	
5	0.087 ± 0.024	11.453	0.96799 ± 0.009	71.97 ± 0.5	286.5 ± 0.56	209.883 ± 0.001	136.38 ± 0.56	
6	0.024 ± 0.023	41.061	0.98017 ± 0.019	51.11 ± 0.5	230.74 ± 0.73	209.943 ± 0.001	80.68 ± 0.73	
8	−0.288 ± 0.167	999.	1.28509 ± 0.165	134.06 ± 1.6	172.29 ± 1.81	210.004 ± 0.001	22.29 ± 1.81	
9	0.462 ± 0.03	2.166	0.86676 ± 0.01	5.24 ± 1.5	121.95 ± 0.91	29.999 ± 0.02	151.94 ± 0.93	
10	−0.902 ± 0.56	999.	1.58008 ± 0.403	174.79 ± 1.3	65.01 ± 9.91	30.021 ± 0.037	95.03 ± 9.9	
17	0.254 ± 0.077	3.938	0.74812 ± 0.077	76.72 ± 1.3	186.71 ± 3.49	210.265 ± 0	36.98 ± 3.49	
18	0.139 ± 0.016	7.21	0.92003 ± 0.009	177.79 ± 0.4	82.96 ± 0.72	30.282 ± 0.009	113.24 ± 0.72	
19	0.145 ± 0.543	6.914	0.90869 ± 0.34	156.14 ± 2.5	76.56 ± 22.57	30.277 ± 0.007	106.84 ± 22.57	
2	0.249 ± 0.01	4.008	0.75304 ± 0.01	88.16 ± 0.2	171.84 ± 0.68	212.832 ± 0	24.67 ± 0.68	
3	0.334 ± 0.013	2.99	0.7209 ± 0.01	16.78 ± 0.2	231.92 ± 0.4	212.858 ± 0.001	84.77 ± 0.4	
4	0.393 ± 0.019	2.547	0.72795 ± 0.011	1.8 ± 0.5	73.73 ± 1.26	32.862 ± 0.01	106.59 ± 1.26	
8	0.496 ± 0.028	2.015	0.50913 ± 0.028	19.81 ± 0.8	189.91 ± 2.57	212.991 ± 0.002	42.9 ± 2.57	
10	0.143 ± 0.006	6.97	0.88201 ± 0.005	156.37 ± 0.1	50.85 ± 0.25	33.047 ± 0	83.9 ± 0.25	
13	0.2 ± 0.195	5.012	0.80213 ± 0.193	163.13 ± 1.2	185.91 ± 1.27	213.075 ± 0.005	38.99 ± 1.27	
17	0.079 ± 0.009	12.735	0.94492 ± 0.006	112.41 ± 0.2	66.8 ± 0.45	33.132 ± 0	99.93 ± 0.45	
19	0.239 ± 0.004	4.187	0.76289 ± 0.004	128.98 ± 0.1	4.41 ± 0.22	33.147 ± 0	37.56 ± 0.22	
22	0.419 ± 0.04	2.385	0.84059 ± 0.012	138 ± 1	290.62 ± 1.92	213.268 ± 0.001	143.89 ± 1.92	
1	0.376 ± 0.022	2.663	0.7377 ± 0.014	7.95 ± 0.6	252.53 ± 1.29	213.858 ± 0.002	106.39 ± 1.29	
2	0.393 ± 0.003	2.547	0.76981 ± 0.002	8.49 ± 0.1	266.71 ± 0.14	213.881 ± 0	120.59 ± 0.14	
3	0.551 ± 0.008	1.815	0.83229 ± 0.002	8.59 ± 0.2	301.81 ± 0.32	213.884 ± 0.001	155.7 ± 0.32	
4	0.516 ± 0.015	1.939	0.64203 ± 0.011	6.86 ± 0.7	76.78 ± 1.1	33.98 ± 0.003	110.76 ± 1.1	
5	0.498 ± 0.004	2.009	0.92339 ± 0.001	8.08 ± 0.3	139.5 ± 0.19	34.019 ± 0.001	173.52 ± 0.19	
6	0.361 ± 0.028	2.768	0.67533 ± 0.025	18.1 ± 0.9	220.3 ± 2	214.073 ± 0.002	74.37 ± 2.01	

A Preliminary Report on the Chelyabinsk Fireball/Airburst

Peter Brown[1]

Received 2013 February 24

At 03^h20^m UT (09^h20^m local time) on 2013 February 15, a bright, long-lasting fireball was widely observed over the region of Chelyabinsk, Russia. Eyewitness reports extend out to more than 700 km.[a] This event was of such large energy that the shock wave reaching the surface had sufficient overpressure to blow out windows, doors and cause light structural damage particularly in the region to the South of Chelyabinsk, as well as in the city of Chelyabinsk. According to Russian media reports, over 1000 people were injured by flying debris (mainly broken windows) as a result of the shock wave. Many small meteorites, apparently ordinary chondrites, and by some reports L-type chondrites, have been recovered.

As this report is written one week after the event, some general features of this airburst are reasonably well established. From video recordings (Borovicka et al., 2013) and US government sensor data, the initial entry velocity of the fireball was about 18 km/s at a shallow angle of 16 degrees from the horizontal. The orbit of the object prior to impact was a typical Apollo-type with low inclination. The energy of the event has been estimated from the dominant airwave period at Infrasound frequencies to be approximately 500 kT of TNT equivalent. The airwave from the airburst was recorded by infrasound sensors over the entire globe; some records show at least one full revolution of the planet (including antipodal returns) some 24 hours after the event. This is the furthest any fireball airwave has been detected infrasonically since Tunguska.

Among these values, the greatest uncertainty is in the energy estimate – it could easily be a factor of two different from above. However, based on the airburst altitude (established by Borovicka et al. (2013) as 25–30 km) and the overpressures observed at the ground, yields below 100 kT can almost certainly be ruled out; the event was most likely in the several hundred kT energy range.

The range of energy yields translates into a meteoroid with a mass of order 10^4 tonnes and diameter of approximately 20 m. Many hundreds of video recordings of the event, including at least 30 direct videos showing the fireball, were obtained and posted to social media sites. Some videos show the distinct formation of strong local vertical plumes associated with intensive heating in the terminal detonation. The main airburst section of the trail shows a distinct double trail formation (as was also seen with the Tagish Lake fireball), likely indicating fast rising air flowing into the center of the trail – essentially a moving 3D version of a mushroom cloud. Based on video recordings, extrapolations of empirical mass-yield-brightness estimates from other bright fireballs and appealing to entry models of airbursts in this energy range, I estimate the peak absolute magnitude reached by the fireball to be in the -27 or -28 range; directly under the terminal detonation the apparent magnitude may well have exceed -30.

This fireball event is the most energetic confirmed airburst since the Tunguska fireball of 1908. Assuming the 500 kT yield is correct, the Earth is hit, on average, by a similarly energetic object only once every ~ 75 years.

By coincidence, the asteroid 2012 DA_{14} made a close pass to Earth (less than 30 000 km from the surface) just 16 hours later. The two objects have very different orbits and an association is very unlikely.

This extraordinary event marks a turning point in the study of objects colliding with the Earth, particularly the public perception of such events. I expect it will be recorded as a watershed moment for meteor science, marking the point when growth and interest in the field dramatically increased.

References

Borovicka J., Spurny P., and Shrbeny L. (2013). “Trajectory and orbit of the Chelyabinsk superbolide”. *CBET*, **3423**.

IMO bibcode WGN-411-brown-chelyabinsk NASA-ADS bibcode 2013JIMO...41...22B

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[a]See the back cover for two spectacular photographs of the fireball and its dust trail — *Ed.*

Results of the IMO Video Meteor Network — October 2012

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The IMO Video Meteor Network cameras recorded almost 43 000 meteors in 2012 October. The Orionid flux density profile is presented and the maximum flux in 2012 is found to be about half that in 2011. The Orionids were found to be active from mid-August until end of November. We present shower parameters for the whole activity range. The Draconids experienced another outburst in 2012 and the Network cameras could cover the descending part of the activity which is presented as a flux density profile. A number of minor showers is investigated and their parameters presented.

Received 2012 December 20

1 Introduction

October 2012 was an unexceptional month. There were phases like around October 7 and 19, when more than 50 video cameras were in operation, but also times such as end of October, when just 20 cameras could observe. The record-breaking result of 2011, which was obtained under perfect weather conditions, could not be realized again under these circumstances. With well above 8 700 hours, the effective observing time reduced by 15%. The number of recorded meteors dropped by 17 000 to 43 000 (Table 11 and Figure 1). Thus, we obtained about the same total as in 2010.

End of October Sirko Molau started to operate Remo3, a third automated and remotely operated meteor camera west of Berlin. It consists of a used Mintron camera and like the other two Remo systems of an 8 mm $f/0.8$ Computar lens. After years, when the creaky cameras with their 3.8 mm lens got almost blind, they are now back to the top with the 8 mm lenses. The number of meteors recorded by Remo1 has increased fourfold in 2012 compared to the same time interval in 2011. In fact, even though this camera has clearly less effective observing time, it recorded more meteors so far than the powerful video systems of Enrico Stomeo.

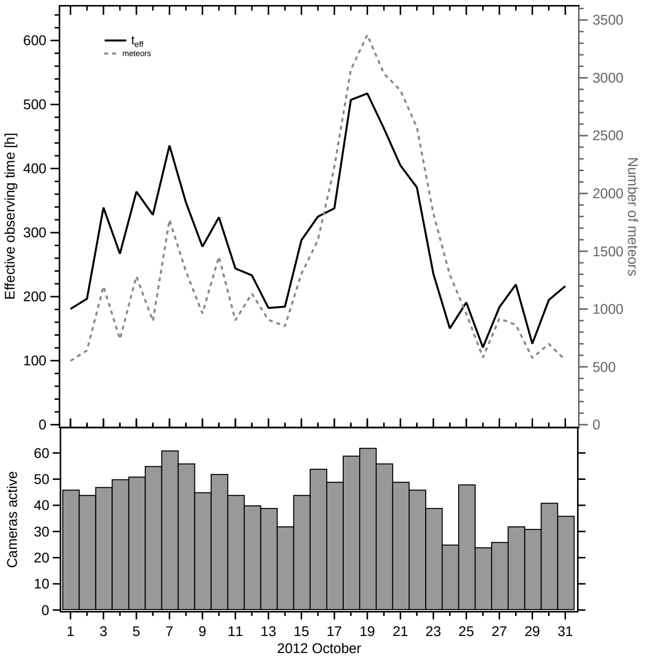

Figure 1 – Monthly summary for the effective observing time (solid black line), number of meteors (dashed gray line) and number of cameras active (bars) in 2012 October.

2 Orionids

With respect to meteor activity, October is dominated by the Orionids. Figure 2 shows an overview of the full activity interval in 2011 and 2012. It shows the typical plateau between October 19 and 24 with a peak flux density of 13 meteoroids per 1 000 km^2 per hour (using a zenith exponent of 1.0 to be comparable with visual observations). That is only half of the peak flux density in 2011.

A systematic observation error seems improbable, as both profiles match well until 205° and after 212° solar longitude. To be on the safe side, we compared the activity profiles of the Southern Taurids and sporadic meteors in the same time interval, anyway (Figure 3). Also here the rates between 2011 October 20 and 25 were 30 to 40% higher than in 2012. But that is not all:

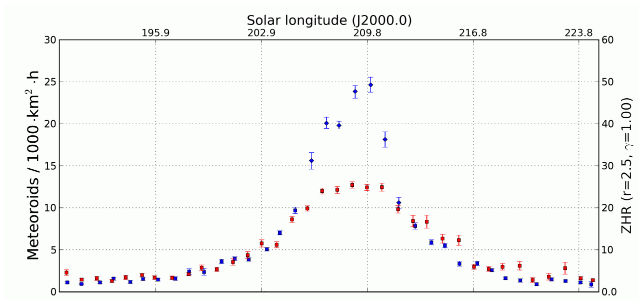

Figure 2 – Flux density profile of the Orionids from data of the IMO Network in 2011 (blue diamonds) and 2012 (red squares).

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IMO bibcode WGN-411-molau-vidoct
NASA-ADS bibcode 2013JIMO...41...23M

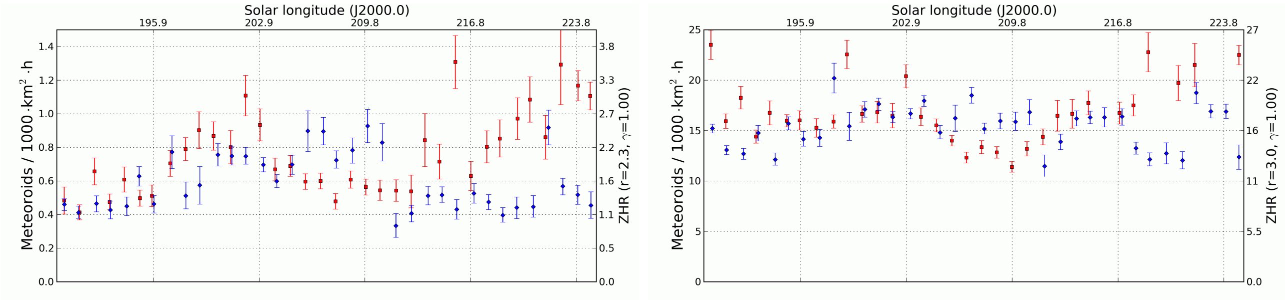

Figure 3 – Flux density profile of the Southern Taurids (left) and sporadic meteors (right) in the same solar longitude interval as the Orionids in Figure 2. Given are the values for 2011 (blue diamonds) and 2012 (red squares).

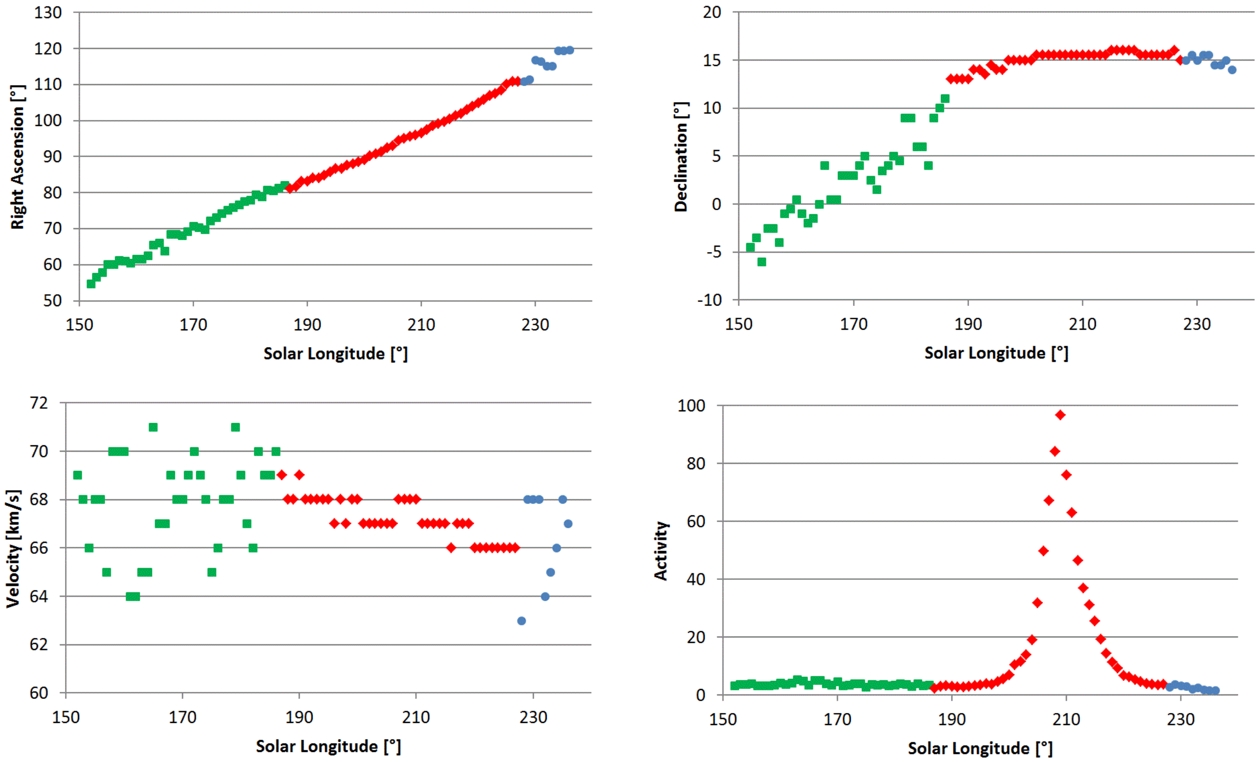

Figure 4 – Shower parameters of the Orionids in the activity interval from 152° to 236° solar longitude: Right ascension (up left), declination (up right), velocity (down left) and activity (down right). The three segments of activity are marked with different colors.

Two weeks before and after the Orionid maximum, the activity in 2011 was lower than in 2012.

Could there be a dependency from the lunar phase? Early October and early November 2011 there was only little disturbance from the Moon in the second half of the night, whereas the sky was brightly illuminated by the waning Moon during the Orionid maximum. In 2012, the observing conditions were poor in early October and early November (waning Moon), but the Orionid peak was only little affected by the waxing Moon. So it could be that the limiting magnitude is systematically underestimated under moonlit skies (when the Moon is possibly even inside the field of view), leading to increased flux densities.

That relativizes the observed difference in flux density between 2011 and 2012, but it does not fully explain the 100% excess in 2011. This year the peak flux density was simply lower than last year as confirmed by visual ZHR profiles of 2011 and 2012 (International Meteor Organization, 2011b; International Meteor Organization, 2012).

Let us now have a look at the Orionids (8 ORI) from the viewpoint of our last meteor shower analysis in spring 2012. Almost 55 000 Orionids could be used for the analysis, which is only 10% less than the number of Perseids. The biggest surprise was the activity interval that was obtained. We had shown before that the Orionid activity surpassed October to a great extent. In our last analysis, however, the shower could be tracked from mid-August till end-November. In other words: The Orionids start right after the Perseid maximum and vanish only after the Leonids!

The fuzziness of activity intervals at the edges, when the shower activity is slowly getting lost in the sporadic background, is well-known. But even when these questionable intervals are removed, the activity interval still lasts from August 25 to November 19. During that time, the rank never falls below 7, i.e. the radiant can be detected unequivocally. Figure 4 shows the development of the individual shower parameters (right ascension, declination, velocity, activity) over the full activity interval.

Table 1 – Parameters of the Orionids from the MDC Working List and the analysis of the IMO Network in 2012. Given are the mean parameters over the full activity interval, and the values for the three individual segments.

Source	Solar Longitude		Right Ascension		Declination		V_∞	
	Mean [°]	Interval [°]	Mean [°]	Drift [°]	Mean [°]	Drift [°]	Mean [km/s]	Drift [km/s]
MDC	209	—	95.6	+0.7	+15.9	+0.1	67.1	—
IMO 2012	209	152–236	97.7	+0.73	+13.5	+0.25	67.1	−0.02
	169	152–186	69.2	+0.78	+2.3	+0.39	67.9	—
	209	187–227	96.6	+0.75	+15.2	+0.06	67.1	−0.02
	232	228–236	117.2	+1.0	+14.9	−0.1	66.3	—

The drift in right ascension is almost constant in the full activity interval with 0°.73 per day (or more precisely: per degree solar longitude). With respect to declination and velocity, the shower can be split into three segments.

In the first segment until about 186° solar longitude, the declination grows constantly about 0°.4 per day with significant scatter from one day to the next. In the second segment until 227° solar longitude, the scatter is negligible. The declination grows only by a small amount and remains constant in the end. In the last segment, the declination is slowly decreasing.

The meteor shower velocity is almost constant in the first segment, but there is significant scatter. With the begin of the second interval, the scatter is almost gone and the velocity reduces by 0.06 km/s per day on average. In the last interval, there is once more significant day-to-day variation in the velocity.

Table 1 gives the average shower parameters for the full activity interval, and for each segment individually.

There may be different interpretations for the observed variations.

The most simplistic explanation is, that there is stronger scatter at the edges of the activity interval due to lower activity. That is unlikely, though, as the activity remains at a low level until 197° and after 225° solar longitude, i.e., the scatter is reducing dramatically at times when the number of Orionids is still very low.

In principle we could observe here the effects of more than one shower. However, there is no real discontinuity at 186° and 227° solar longitude – only the standard deviation of two parameters changes.

Another option could be, that the Orionid stream consists of an older and a younger component. Over time, the meteoroids of the older background component have dispersed more widely in space and time from the mean orbit of parent comet 1/P Halley, whereas the young component is still compact. It is well-known that the Orionid activity was significantly enhanced between 2006 and 2009, which hints on an additional component crossing the Earth orbit.

Last but not least it is thinkable that Earth crosses first remote areas of the meteoroid stream, where particles had to undergo strong perturbations to move that far from the comets orbit. Thus, the scatter in parameters is stronger here, whereas the near peak the Earth crosses the core of the particle stream with only little perturbations.

The last two explanations may sound plausible, but they are pure speculation at this time until they are confirmed by some computer simulations.

In the end we would like to hint on a little curiosity: In our meteor shower analysis we find two artifacts which are common for large meteor showers. They have certain similarity to the Orionids and are probably caused by observational errors. A third shower, however, is particularly interesting. It can be tracked between 208° and 213° solar longitude and fits well to the "classical" Orionids based on the radiant position and activity. With 38 km/s, the velocity is just half of the typical Orionid velocity, though! The origin of the artifact in unclear at this time.

3 Draconids

Back to other meteor shower of October 2012. The biggest surprise was not presented by the Orionids, but a few days earlier by the Draconids. An outburst was predicted for 2011, and it was well observed both visually and by the video systems of the IMO Network (International Meteor Organization, 2011a; Molau et al., 2012). There was no prediction for enhanced activity in 2012. The bigger was the surprise, when Peter Brown reported an outburst in the evening hours of October 8, based on data of the Canadian CMOR radar (Brown & Ye, 2012). That outburst was stronger than any other shower ever observed by CMOR. Soon it was suspected that the outburst mainly consisted of very faint radar meteors beyond the limits of our video cameras. A first analysis revealed a peak shortly after 17^{h} UT with a FWHM (full width at half maximum) of about 90 minutes – as short as the 2011 outburst. Unfortunately, skies were not yet dark at this time in Europe – even the most eastern stations started observation just at the peak. Furthermore the weather was not favorable at many observing sites. Still, we were able to record 170 shower members from the descending activity branch (Figure 5). The peak flux density was measured right

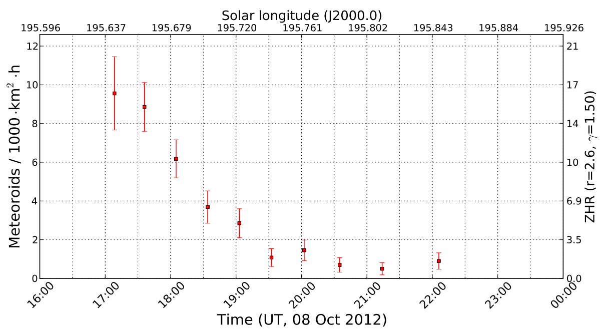

Figure 5 – Flux density profile of the Draconids in the evening hours of 2012 October 8.

after 17^{h} UT with 10 meteoroids per 1 000 km^2 per hour. Already three hours later, the rate had decreased so much that it did not stand out from the sporadic background anymore. Hence, the activity was clearly higher than usual, but in the visual range it could not compete with the 2011 outburst, when the flux density was more than ten times as high. In addition, the 2012 outburst was 0.°6 solar longitude or nearly 15 hours later than in the previous year.

In our latest meteor shower analysis, the October Draconids (9 DRA) are only detected between 194° and 196° solar longitude. The by far biggest amount of those 2 500 shower meteors were probably recorded in 2011. The parameters of the shower are summarized in Table 2.

4 ε-Geminids

The ε-Geminids (23 EGE) resemble the Orionids both with respect to radiant position and velocity, but they cannot compete with their "big brother" with respect to flux density. Their 2012 activity profile is not spectacular – the flux density amounted in the full activity interval to about 4 meteoroids per 1 000 km^2 per hour without any significant peak. In our recent analysis, the shower could be traced with more than 7 000 meteors between end of September and early November. The rank remains above 9 in the full activity interval. So it is no surprise that the shower parameters determined by us match perfectly the values from the MDC list (Table 3).

5 October Ursae Majorids

A little more surprising was the analysis of the October Ursae Majorid (333 OCU) activity. Typically this shower reaches peak flux densities of up to 5 meteoroids per 1 000 km^2 per hour. This year, the value grew beyond ten in the morning hours of October 15 (Figure 6). To exclude binning effects, we tested different parameter combinations. Still the higher the temporal resolution we chose, the more prominent was the peak. A detailed analysis revealed that the four Portuguese Templar cameras of Rui Goncalves had recorded an unusual number of shower meteors on October 15 after 05^{h} UT. Unfortunately there were hardly any other cameras active by that time. At least, also the Portuguese cameras of Carlos Saraiva detected a few October Ursae Majorids by that time, whereas Icc7 at the Canary Islands recorded nothing unusual.

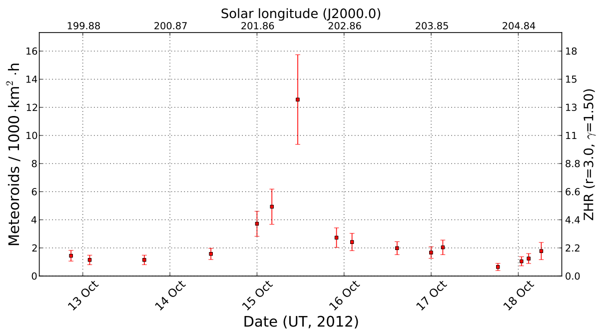

Figure 6 – Flux density profile of the October Ursae Majorids from data of the IMO Network in 2012, calculated with a zenith exponent of $\gamma = 1.5$.

Table 4 presents the parameters of this shower, derived from well over 1 200 shower members. The October Ursae Majorids are only active in five nights. Thanks to their large declination, the drift in right ascension is more than 2° per day. In total, the parameters derived recently by us fit well to the values given by MDC.

6 October Camelopardalids

The October Camelopardalids (281 OCT) remained inconspicuous this year. No surprise, as we had shown in 2009 that this shower is only active at 192°6 solar longitude for overall less than six hours (Molau & Rendtel, 2009). That observing window fell into the European afternoon hours this year, which explains why there are no observations of this shower.

Table 2 – Parameters of the October Draconids from the MDC Working List and the analysis of the IMO Network in 2012.

Source	Solar Longitude		Right Ascension		Declination		V_∞	
	Mean [°]	Interval [°]	Mean [°]	Drift [°]	Mean [°]	Drift [°]	Mean [km/s]	Drift [km/s]
MDC	196	—	264.1	+1.9	+57.6	+0.3	23.3	—
IMO 2012	195	194–196	262.0	—	+56.0	—	21.0	—

Table 3 – Parameters of the ε-Geminids from the MDC Working List and the analysis of the IMO Network in 2012.

Source	Solar Longitude		Right Ascension		Declination		V_∞	
	Mean [°]	Interval [°]	Mean [°]	Drift [°]	Mean [°]	Drift [°]	Mean [km/s]	Drift [km/s]
MDC	206	—	101.6	—	+26.7	—	69.7	—
IMO 2012	209	186–220	104.7	+0.84	+27.6	−0.11	70.5	0

Table 4 – Parameters of the October Ursae Majorids from the MDC Working List and the analysis of the IMO Network in 2012.

Source	Solar Longitude		Right Ascension		Declination		V_∞	
	Mean [°]	Interval [°]	Mean [°]	Drift [°]	Mean [°]	Drift [°]	Mean [km/s]	Drift [km/s]
MDC	202	—	144.8	—	+64.5	—	55.2	—
IMO 2012	202	201–205	144.1	+2.4	+64.3	−0.4	53.6	—

Table 5 – Parameters of the Leonis Minorids from the MDC Working List and the analysis of the IMO Network in 2012.

Source	Solar Longitude		Right Ascension		Declination		V_∞	
	Mean [°]	Interval [°]	Mean [°]	Drift [°]	Mean [°]	Drift [°]	Mean [km/s]	Drift [km/s]
MDC	210	—	161.4	+1.4	+36.2	−0.4	62.9	—
IMO 2012	209	204–214	159.9	+1.0	+36.7	−0.2	60.9	—

Table 6 – Parameters of the γ-Piscids from the MDC Working List and the analysis of the IMO Network in 2012.

Source	Solar Longitude		Right Ascension		Declination		V_∞	
	Mean [°]	Interval [°]	Mean [°]	Drift [°]	Mean [°]	Drift [°]	Mean [km/s]	Drift [km/s]
MDC	200	—	17.7	—	+9.3	—	17.5	—
IMO 2012	204	201–208	17.4	+1.1	+16.8	+0.7	23.6	—

Table 7 – Parameters of the τ-Cancrids from the MDC Working List and the analysis of the IMO Network in 2012.

Source	Solar Longitude		Right Ascension		Declination		V_∞	
	Mean [°]	Interval [°]	Mean [°]	Drift [°]	Mean [°]	Drift [°]	Mean [km/s]	Drift [km/s]
MDC	207	—	137.5	—	+30.5	—	—	—
IMO 2012	204	196–212	134.2	+1.0	+29.4	+0.1	68.7	+0.22

Our meteor shower analysis of spring 2012 yields two shower candidates in the first third of October, which fit reasonably to the October Camelopardalids. Unfortunately, both show too much scatter to be regarded as a safe detection of a days-long background component for this shower.

7 Leonis Minorids

In 2012, the Leonis Minorids (22 LMI) showed a flat activity profile without a clear peak. They were traced between October 18 and 28 in our last meteor shower analysis. The shower parameters show only little scatter and the agreement with the MDC values is once more remarkable (Table 5).

8 Other meteor showers

Of course, our 2012 meteor shower analysis revealed further meteor showers in October which are less prominent. In the following, they shall be presented in more detail.

8.1 σ-Arietids

The σ-Arietids (237 SSA) were detected with over 4 600 meteors between October 1 and 29. A more detailed analysis revealed that there are in fact at least two very similar meteor showers. The first segment until 207° solar longitude does not fulfill our quality criteria, as it shows to strong scatter in declination and an unusually high reduction of meteor shower velocity. Still it yielded an average rank of 7, which hints on a real source.

The other segment has a clear activity profile. At maximum on October 28, a rank of 4 is reached.

If both segments are compared with the MDC parameters given for the σ-Arietids it becomes clear that the list values fit to neither of these segments. Thus, the first segment is omitted because of strong scatter in parameters, whereas the second segment is found to be the onset of the Northern Taurid activity.

8.2 γ-Piscids

The γ-Piscids (236 GPS) can be tracked between October 15 and 22 in our data set. The shower shows a constant activity without any noticeable peak. The scatter in parameters is acceptable, which is why we regard this shower as real even though it never reaches a rank higher than 10. The agreement with the MDC list values is mediocre (Table 6).

8.3 τ-Cancrids

Between October 9 and 26, we could identify a previously unknown shower with more than 3 000 shower members. The activity interval may last even a bit longer, but at the edges the shower parameters deviate significantly. The fast meteor shower presents only little scatter in right ascension and velocity, and some more scatter in declination. The rank is above 10 all the time, which is why it can be regarded as a safe detection. The activity profile shows a slight increase without a clear peak. The meteor shower velocity increases significantly in October.

To be on the safe side, we compared our shower parameters with the latest version of the MDC list, and there was indeed a match! The τ-Cancrid meteor shower (480 TCA) was only recently reported by Jenniskens (Meteor Data Center, 2012). There is no velocity information given for this shower, but only a radiant position. However, when the difference in solar longitude is taken into account, the two radiant positions from Jenniskens and us deviate less than one degree from one another (Table 7).

8.4 λ-Ursae Majorids

At the end of October, another previously unknown meteor shower could be discovered with about 600 members between 211° and 219° solar longitude. It shows a distinct activity profile with maximum on October 28. The shower closely resembles to the Leonis Minorids, but the radiant is located 15° further north. At peak, a rank of 6 is reached, which is a strong indicator for the reality of the shower. Once more we consulted the latest version of the MDC list, and once more there was a hit. This time our new shower fits perfectly to the λ-Ursae Majorids (524 LUM) reported only recently by Andreić et al. (2013) (Table 8).

8.5 Andromedids and December ϕ-Cassiopeiids

Also at the end of October, we could successfully detect the Andromedids (18 AND). Between October 27 and December 5, more than 2 400 shower meteors were registered. The analysis of this shower revealed some peculiarities: Typically the right ascension is growing monotonously, whereas for some showers the sign of growth in declination may change in the activity interval (like in case of the Orionids). Here we found the opposite: The increase in right ascension turns into a decrease towards the end of the activity interval, whereas declination rises continuously from 20° to 60°.

It turns out that the shower can easily be divided in two segments. The first segment fits perfectly to the MDC values for the Andromedids (Table 9). We see a moderate increase in right ascension and declination. The activity profile shows a prominent peak at November 9 with a rank of 5.

The second segment presents a decrease in right ascension combined with a steep increase in declination. This shower has an almost constant velocity and a flat activity profile with a maximum rank of 7. It fits well to the December ϕ-Cassiopeiids (446 DPC) recently reported to the MDC by Jenniskens (Table 10). Indirectly, also the reduction in right ascension and the strong increase in declination is confirmed. If the position obtained in this work is extrapolated to the solar longitude given by Jenniskens, the deviation in radiant position is less than a degree.

8.6 Further minor showers

Beyond these showers, we found traces of the ψ-Aurigids (133 PSA), ζ-Taurids (226 ZTA), η-Taurids (417 ETT), λ-Draconids (135 LDA) and October Lyncids (228 OLY) in our data. In all cases the scatter in meteor parameters was too high for a reliable confirmation of these showers, though.

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Handling Editor: Javor Kac

Table 8 – Parameters of the λ-Ursae Majorids from the MDC Working List and the analysis of the IMO Network in 2012.

Source	Solar Longitude		Right Ascension		Declination		V_∞	
	Mean [°]	Interval [°]	Mean [°]	Drift [°]	Mean [°]	Drift [°]	Mean [km/s]	Drift [km/s]
MDC	215	—	158	+0.99	+49	−0.52	60.3	—
IMO 2012	214	211–219	156.1	+1.1	+48.9	−1.1	61.5	0

Table 9 – Parameters of the Andromedids from the MDC Working List and the analysis of the IMO Network in 2012.

Source	Solar Longitude		Right Ascension		Declination		V_∞	
	Mean [°]	Interval [°]	Mean [°]	Drift [°]	Mean [°]	Drift [°]	Mean [km/s]	Drift [km/s]
MDC	232	—	24.2	+0.63	+32.5	+0.33	20.5	—
IMO 2012	226	213–238	22.7	+0.3	+29.4	+0.6	19.4	−0.19

Table 10 – Parameters of the December ϕ-Cassiopeiids from the MDC Working List and the analysis of the IMO Network in 2012.

Source	Solar Longitude		Right Ascension		Declination		V_∞	
	Mean [°]	Interval [°]	Mean [°]	Drift [°]	Mean [°]	Drift [°]	Mean [km/s]	Drift [km/s]
MDC	252.5	—	19.8	—	+58.0	—	19.8	—
IMO 2012	249	244–253	23.3	−0.5	+52.6	+1.7	17.8	0

Table 11 – Observers contributing to 2012 October 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	Ludwig1 (0.8/8)	1488	4.8	726	11	53.7	90
BERER	Berko	Ludányhalászi/HU	Hulud1 (0.95/3)	2256	4.8	1540	18	125.8	1049
			Hulud2 (0.75/6)	4860	3.9	1103	17	116.3	327
			Hulud3 (0.75/6)	4661	3.9	1052	16	109.5	217
BIRSZ	Biro	Agostyán/HU	Huago (0.75/4.5)	2427	4.4	1036	19	151.8	548
BOMMA	Bombardini	Faenza/IT	Mario (1.2/4.0)	5794	3.3	739	14	76.7	298
BREMA	Breukers	Hengelo/NL	Mbb3 (0.75/6)	2399	4.2	699	22	135.3	488
			Mbb4 (0.8/8)	1470	5.1	1208	19	141.5	437
BRIBE	Brinkmann	Herne/DE	Hermine (0.8/6)	2374	4.2	678	26	147.4	593
		Bergisch Gladbach/DE	Klemoi (0.8/6)	2286	4.6	1080	28	173.8	880
CASFL	Castellani	Monte Baldo/IT	Bmh2 (1.5/4.5)*	4243	3.0	371	21	131.0	667
CRIST	Crivello	Valbrevenna/IT	Bilbo (0.8/3.8)	5458	4.2	1772	24	147.0	989
			C3P8 (0.8/3.8)	5455	4.2	1586	24	146.7	714
			Stg38 (0.8/3.8)	5614	4.4	2007	22	73.4	547
CSISZ	Csizmadia	Zalaegerszeg/HU	Huvcse01 (0.95/5)	2423	3.4	361	17	87.4	310
ELTMA	Eltri	Venezia/IT	Met38 (0.8/3.8)	5631	4.3	2151	19	157.4	1026
GONRU	Goncalves	Tomar/PT	Templar1 (0.8/6)	2179	5.3	1842	21	171.3	793
			Templar2 (0.8/6)	2080	5.0	1508	22	183.8	755
			Templar3 (0.8/8)	1438	4.3	571	26	180.6	743
			Templar4 (0.8/3.8)	4475	3.0	442	22	160.3	629
GOVMI	Govedič	Središče ob Dravi/SI	Orion2 (0.8/8)	1447	5.5	1841	22	119.4	702
			Orion3 (0.95/5)	2665	4.9	2069	18	96.4	349
			Orion4 (0.95/5)	2662	4.3	1043	18	105.5	392
HINWO	Hinz	Brannenburg/DE	Acr (2.0/35)*	557	7.4	4954	11	55.1	584
IGAAN	Igaz	Baja/HU	Hubaj (0.8/3.8)	5552	2.8	403	23	144.4	531
		Debrecen/HU	Hudeb (0.8/3.8)	5522	3.2	620	26	170.3	875
		Hódmezővásárhely/HU	Huhod (0.8/3.8)	5502	3.4	764	20	158.9	766
		Budapest/HU	Hupol (1.2/4)	3790	3.3	475	17	58.3	102
JONKA	Jonas	Budapest/HU	Husor (0.95/4)	2286	3.9	445	22	159.9	550
KACJA	Kac	Kostanjevec/SI	Metka (0.8/12)*	715	6.4	640	4	28.7	199
		Ljubljana/SI	Orion1 (0.8/8)	1402	3.8	331	12	37.3	52
		Kamnik/SI	Rezika (0.8/6)	2270	4.4	840	16	110.9	1336
			Stefka (0.8/3.8)	5471	2.8	379	12	55.1	176
KERST	Kerr	Glenlee/AU	Gocam1 (0.8/3.8)	5189	4.6	2550	30	210.6	933
KISSZ	Kiss	Sülyśap/HU	Husul (0.95/5)*	4295	3.0	355	24	168.6	251
KOSDE	Koschny	Izana Obs./ES	Icc7 (0.85/25)*	714	5.9	1464	14	132.5	1136
		Noordwijkerhout/NL	Lic4 (1.4/50)*	2027	6.0	4509	16	57.2	216

Table 11 – Observers contributing to 2012 October 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
MACMA	Maciejewski	Chelm/PL	Pav35 (1.2/4)	4383	2.5	253	20	118.6	279
			Pav36 (1.2/4)*	5732	2.2	227	24	140.9	649
			Pav43 (0.95/3.75)*	2544	2.7	176	22	139.4	313
MARGR	Maravelias	Lofoupoli-Crete/GR	Loomecon (0.8/12)	738	6.3	2698	24	170.1	832
MOLSI	Molau	Seysdorf/DE	Avis2 (1.4/50)*	1230	6.9	6152	16	108.2	1518
			Mincam1 (0.8/8)	1477	4.9	1084	20	140.6	480
		Ketzür/DE	Remo1 (0.8/8)	1467	5.9	2837	25	206.6	2206
			Remo2 (0.8/8)	1478	6.3	4467	2	18.8	48
MORJO	Morvai	Fülöpszállás/HU	Huful (1.4/5)	2522	3.5	532	22	173.5	599
OCAFR	Ocaña Gonzáles	Madrid/ES	Fogcam (1.4/7)	1890	3.9	109	8	5.2	16
OCHPA	Ochner	Albiano/IT	Albiano (1.2/4.5)	2944	3.5	358	13	39.5	330
OTTMI	Otte	Pearl City/US	Orie1 (1.4/5.7)	3837	3.8	460	27	177.8	906
PERZS	Perko	Becsehely/HU	Hubec (0.8/3.8)*	5498	2.9	460	20	143.8	1281
PUCRC	Pucer	Nova vas nad Dragonjo/SI	Mobcam1 (0.75/6)	2398	5.3	2976	24	160.0	1049
ROTEC	Rothenberg	Berlin/DE	Armefa (0.8/6)	2366	4.5	911	22	139.3	322
SARAN	Saraiva	Carnaxide/PT	Ro1 (0.75/6)	2362	3.7	381	25	158.5	486
			Ro2 (0.75/6)	2381	3.8	459	24	172.3	625
			Sofia (0.8/12)	738	5.3	907	24	167.5	410
SCALE	Scarpa	Alberoni/IT	Leo (1.2/4.5)*	4152	4.5	2052	22	111.3	537
SCHHA	Schremmer	Niederkrüchten/DE	Doraemon (0.8/3.8)	4900	3.0	409	27	194.0	889
SLAST	Slavec	Ljubljana/SI	Kayak1 (1.8/28)	563	6.2	1294	13	58.3	271
STOEN	Stomeo	Scorze/IT	Min38 (0.8/3.8)	5566	4.8	3270	27	150.8	1547
			Noa38 (0.8/3.8)	5609	4.2	1911	27	150.4	1095
			Sco38 (0.8/3.8)	5598	4.8	3306	28	163.8	1454
STRJO	Strunk	Herford/DE	Mincam2 (0.8/6)	2362	4.6	1152	24	165.0	396
			Mincam3 (0.8/12)	728	5.7	975	25	161.8	448
			Mincam4 (1.0/2.6)	9791	2.7	552	21	118.2	188
			Mincam5 (0.8/6)	2349	5.0	1896	25	154.9	649
TEPIS	Tepliczky	Budapest/HU	Humob (0.8/6)	2388	4.8	1607	22	158.9	918
TRIMI	Triglav	Velenje/SI	Sraka (0.8/6)*	2222	4.0	546	18	98.7	389
YRJIL	Yrjölä	Kuusankoski/FI	Finexcam (0.8/6)	2337	5.5	3574	20	92.5	457
ZELZO	Zelko	Budapest/HU	Huvcse03 (1.0/4.5)	2224	4.4	933	7	40.0	109
						Overall	31	8 755.2	42 975

* active field of view smaller than video frame

Results of the IMO Video Meteor Network — November 2012

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More than 27 000 meteors were registered by the IMO Video Meteor Network cameras in 2012 November. Flux density profiles are presented for the Leonids, Northern and Southern Taurids and compared to profiles from 2011. It is confirmed that the Southern October δ-Arietids are an early segment of the Southern Taurids. Shower parameters for November ι-Draconids, November Orionids, December Monocerotids and σ-Hydrids are presented.

Received 2013 January 16

1 Introduction

The first half November was quite acceptable regarding the observing conditions. On November 5, for example, 57 out of the 71 cameras were in operation. In the second half of November, though, the weather became catastrophic, and it left big holes in our observing statistics. The absolute lowlights were November 23 and 24: 21 hours of effective observing time with 65 meteors in a single night – fewer data have last been collected in March 2011. It is therefore no surprise that there were no more than 18 cameras that collected twenty and more observing nights. In fact, without the Australian Gocam1 there would be no camera at all with 25 or more observing nights.

Overall, the effective observing time reduced from 8 800 hours in the previous to 6 600 hours in this year. Also the number of meteors dropped from almost 36 000 in 2011 to 27 000 in 2012 (Table 8 and Figure 1). So we better put this month immediately on file.

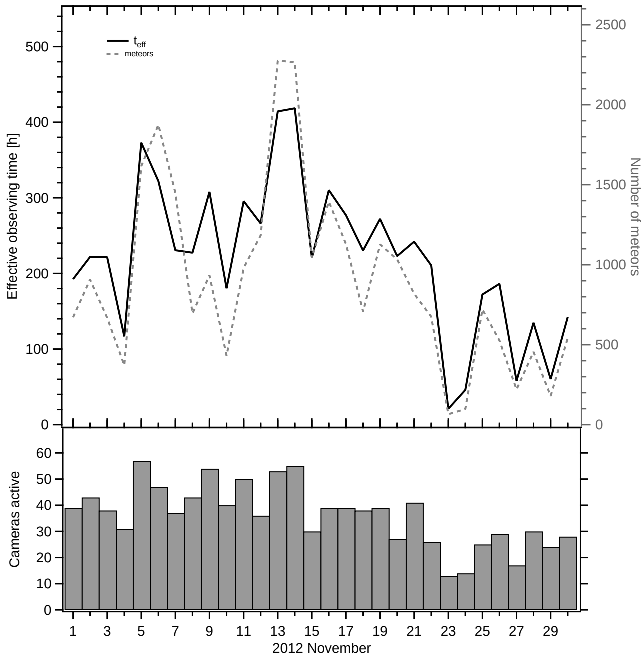

Figure 1 – Monthly summary for the effective observing time (solid black line), number of meteors (dashed gray line) and number of cameras active (bars) in 2012 November.

2 Leonids

After the big times for the Leonids are history and "normality" has returned, there is not really an attractive meteor shower in November. Figure 2 shows the flux density profile of the Leonids between November 10 and 22 (red squares). For comparison, the 2011 data are given as well (blue diamonds). Both profiles fit well to one another, only the peak at 236°.5 solar longitude was not visible this year. Instead, there was a plateau of enhanced activity between 236° and 238°.5 solar longitude.

In the 2012 meteor shower analysis, the Leonids (13 LEO) were detected between November 6 and 30. The radiants may be traceable a few days earlier and later, but at this time the parameters deviate more strongly from the average. In the given interval between 223° and 248° solar longitude, however, the scatter is low. As the Leonids are one of the most studied meteor showers of the last decade it is no surprise that there is excellent agreement between the MDC data and our meteor shower parameters derived from over 15 000 Leonids.

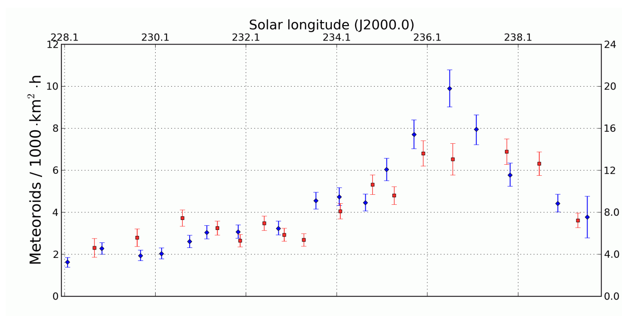

Figure 2 – Flux density profile of the Leonids from data of the IMO Network in 2011 (blue diamonds) and 2012 (red squares).

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IMO bibcode WGN-411-molau-vidnov
NASA-ADS bibcode 2013JIMO...41...31M

Table 1 – Parameters of the Leonids from the MDC Working List and the analysis of the IMO Network in 2012.

Source	Solar Longitude		Right Ascension		Declination		V_∞	
	Mean [°]	Interval [°]	Mean [°]	Drift [°]	Mean [°]	Drift [°]	Mean [km/s]	Drift [km/s]
MDC	235	—	153.5	+0.7	+22.1	−0.3	71.5	—
IMO 2012	236	223–248	154.3	+0.63	+21.5	−0.40	70.6	0

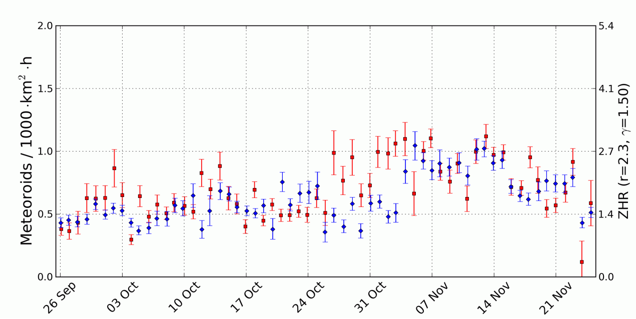

Figure 3 – Flux density profile of the Northern Taurids from data of the IMO Network in 2011 (blue diamonds) and 2012 (red squares).

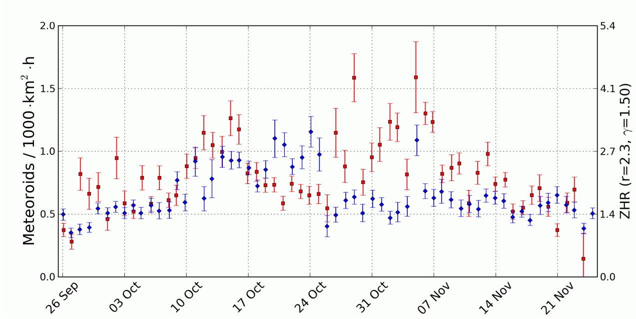

Figure 4 – Flux density profile of the Southern Taurids from data of the IMO Network in 2011 (blue diamonds) and 2012 (red squares).

3 α-Monocerotids

It has been quiet about the α-Monocerotids (246 AMO) after their outburst in 1995 – and there are good reasons, because the shower is practically unnoticeable away from the outburst years. Also the 2012 flux density profile shows just a constant level little below one meteoroid per 1 000 km^2 and hour. Our 2012 meteor shower analysis shows between 240° and 245° solar longitude a handful of radiants with some similarity to the α-Monocerotids, but there is big scatter in the radiant positions and an almost 10° displacement from the MDC position. Hence, this shower cannot be detected safely in our data.

4 Taurids

There have been already some comments on the Taurid activity in our last report (Molau et al., 2013). Here we want to compare the flux density profile of both shower branches between September 25 and November 25.

Both in 2011 and 2012, the Northern Taurids show low activity until the end of October, followed by enhanced rates until mid-November. There is good agreement between 2011 and 2012, only the activity rose about one week earlier in 2012. As will be described below, the Northern Taurids cannot be safely detected before the last week of October in our long-term analysis as well.

There are much stronger deviations between the Southern Taurid activity profiles of 2011 and 2012. In both years, the flux density raises first around October 10. Whereas activity in 2011 remained high until the Orionids and declined thereafter, we observed the decrease in this year already at October 17, only to raise once more at the end of October. The highest rates were measured on November 5 – at this time there was only a single outlier in the 2011 flux density profile.

The Taurids become in particular interesting when looking at the 2012 meteor shower analysis.

The Northern Taurids (17 NTA) are detected between October 30 and December 5. Inspecting the preceding solar longitude intervals in more detail we find, that the radiant can also be detected a little earlier, but is then assigned to the σ-Arietids discussed last month. There seems to be a more or less smooth transition between the two showers, but at least the last few radiant positions of the shower declared as σ-Arietids clearly belong to the Northern Taurids. So we can trace this shower between October 26 and December 5. The shower parameters, which were derived from almost 11 000 shower meteors, are summarized in Table 2.

Even more confusing is the case of the Southern Taurids (2 STA), because they are not found at all in our 2012 meteor shower analysis! A more detailed inspection reveals, that the Southern Taurids are indeed present with more than 20 000 shower members between September 22 and November 28, but they were declared by the software as Southern October δ-Arietids (28 SOA). We described this shower already in our September report, which is why we abstain from another detailed discussion this time (Molau et al., 2013). Table 3 lists once more the average shower parameters for the full activity interval. In addition, the shower is split into three segments to better describe the variable rate of change of certain parameters. The first segment ends at the primary peak at 201°, the second segment ends at a minor secondary peak at 227°, and the third segment lasts until the end of the activity interval at 246° solar longitude. For comparison, Table 3 lists additionally the MDC values for the Southern October δ-Arietids and the Southern Taurids.

Now it becomes clear why the meteors were assigned to the wrong shower: Extrapolating the radiant position of the Taurids backwards by 25° solar longitude yields almost exactly the radiant position of the Southern October δ-Arietids. The deviation in velocity between both showers is in the range of the error bars resp. the scatter from a diffuse ecliptical shower.

Table 2 – Parameters of the Northern Taurids from the MDC Working List and the analysis of the IMO Network in 2012.

Source	Solar Longitude		Right Ascension		Declination		V_∞	
	Mean [°]	Interval [°]	Mean [°]	Drift [°]	Mean [°]	Drift [°]	Mean [km/s]	Drift [km/s]
MDC	224	—	56.8	+0.8	+21.2	+0.2	30.4	—
IMO 2012	229	212–252	58.4	+0.82	+22.4	+0.15	29.3	−0.10

Table 3 – Parameters of the Southern October δ-Arietids and the Southern Taurids from the MDC Working List. They are compared with radiant parameters from the analysis of the IMO Network data in 2012. Given are the mean parameters over the full activity interval, and the values for three individual segments.

Source	Solar Longitude		Right Ascension		Declination		V_∞	
	Mean [°]	Interval [°]	Mean [°]	Drift [°]	Mean [°]	Drift [°]	Mean [km/s]	Drift [km/s]
MDC/SOA	199	—	33.1	—	+10.6	—	27.9	—
MDC/STA	224	—	54.2	+0.7	+14.2	+0.2	30.1	—
IMO 2012	**201**	**179–246**	**35.7**	**+0.74**	**+8.8**	**+0.18**	**29.1**	**−0.09**
	190	179–201	28.8	+0.84	+6.3	+0.33	29.7	−0.05
	215	202–227	47.0	+0.77	+12.3	+0.17	28.6	−0.08
	237	228–246	61.8	+0.55	+14.5	+0.01	25.4	−0.23

Hence, the Southern October δ-Arietids are in fact only an early segment of the Southern Taurids (Figure 5). When checking carefully the MDC entry for the Southern October δ-Arietids we find indeed a comment: "part of STA".

5 Further showers

Beyond these, our 2012 meteor shower analysis confirmed three further showers in November. Unknown meteor showers were not detected, though.

5.1 November ι-Draconids

Close to the limit is the detection of the November ι-Draconids (392 NID). This shower is recognized with more than 1 800 shower members from November 12 till the end of the month. It shows significant scatter in all parameters. Towards the end of November, however, it reaches a rank of four to five, which hints on a relatively strong source. The agreement with the MDC list data is only mediocre (Table 4).

5.2 November Orionids and December Monocerotids

Much better is the situation with the November Orionids (250 NOO). In our analysis, this shower exhibits only little scatter – and a massive change in declination at 254° solar longitude. A detailed analysis reveals that there are once more two consecutive, very similar showers whose activity intervals overlap by only two degrees in solar longitude. Looking at the right ascension or velocity, you get a flat progression without any discontinuity. In declination, however, there is this sudden change by seven degrees at the given solar longitude, and also the activity profile shows two well-separated peaks.

The first shower lasts from November 14 till December 7. Highest activity is reached at November 28. In the last few days of November, this shower is the strongest source in the sky. The shower parameters, which were derived from about 3 500 shower members, are given in Table 5. They are in excellent agreement with the MDC values for the November Orionids.

The second, slightly weaker shower, lasts from December 6 till December 21 with peak activity at December 9 and a maximum rank of four to five. The parameters for this shower (Table 6) were obtained from well above 2 000 shower meteors. They fit perfectly to the December Monocerotids (19 MON) as can be seen from a comparison with the MDC data.

5.3 σ-Hydrids

Last but not least, also the activity interval of the σ-Hydrids (16 HYD) starts in November. We can detect them between November 25 and December 21 with more than 5 000 members in our database. In early December, the σ-Hydrids are the strongest source in the sky. The shower has a prominent activity profile with a main peak at December 6 and a secondary peak of roughly half the activity on December 16. Interestingly, the values given in the MDC list refer to the solar longitude of the secondary peak.

The radiant position shows almost no scatter, but there is some deviation in the meteor shower velocity. Still there is good agreement with the MDC list values if the difference in solar longitude is taken into account (Table 7).

Beside these showers, we find also some traces of other showers like the χ-Taurids (388 CTA), o-Eridanids (338 OER) and November ν-Arietids (249 NAR). In all cases, the quality of the shower parameters is too low to declare a safe detection based on our current database.

References

Molau S., Kac J., Berko E., Crivello S., Stomeo E., Igaz A., Barentsen G., and Goncalves R. (2013). "Results of the IMO Video Meteor Network – October 2012". *WGN, Journal of the IMO*, **41:1**, 22–29.

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Table 4 – Parameters of the November ι-Draconids from the MDC Working List and the analysis of the IMO Network in 2012.

Source	Solar Longitude		Right Ascension		Declination		V_∞	
	Mean [°]	Interval [°]	Mean [°]	Drift [°]	Mean [°]	Drift [°]	Mean [km/s]	Drift [km/s]
MDC	241	—	200.0	—	+64.5	—	44.4	—
IMO 2012	239	229–249	189.6	+0.8	+69.3	−0.5	42.9	—

Table 5 – Parameters of the November Orionids from the MDC Working List and the analysis of the IMO Network in 2012.

Source	Solar Longitude		Right Ascension		Declination		V_∞	
	Mean [°]	Interval [°]	Mean [°]	Drift [°]	Mean [°]	Drift [°]	Mean [km/s]	Drift [km/s]
MDC	245	—	90.6	+1.0	+15.7	0.0	45.1	—
IMO 2012	246	231–255	90.6	+0.75	+15.5	−0.04	45.1	−0.19

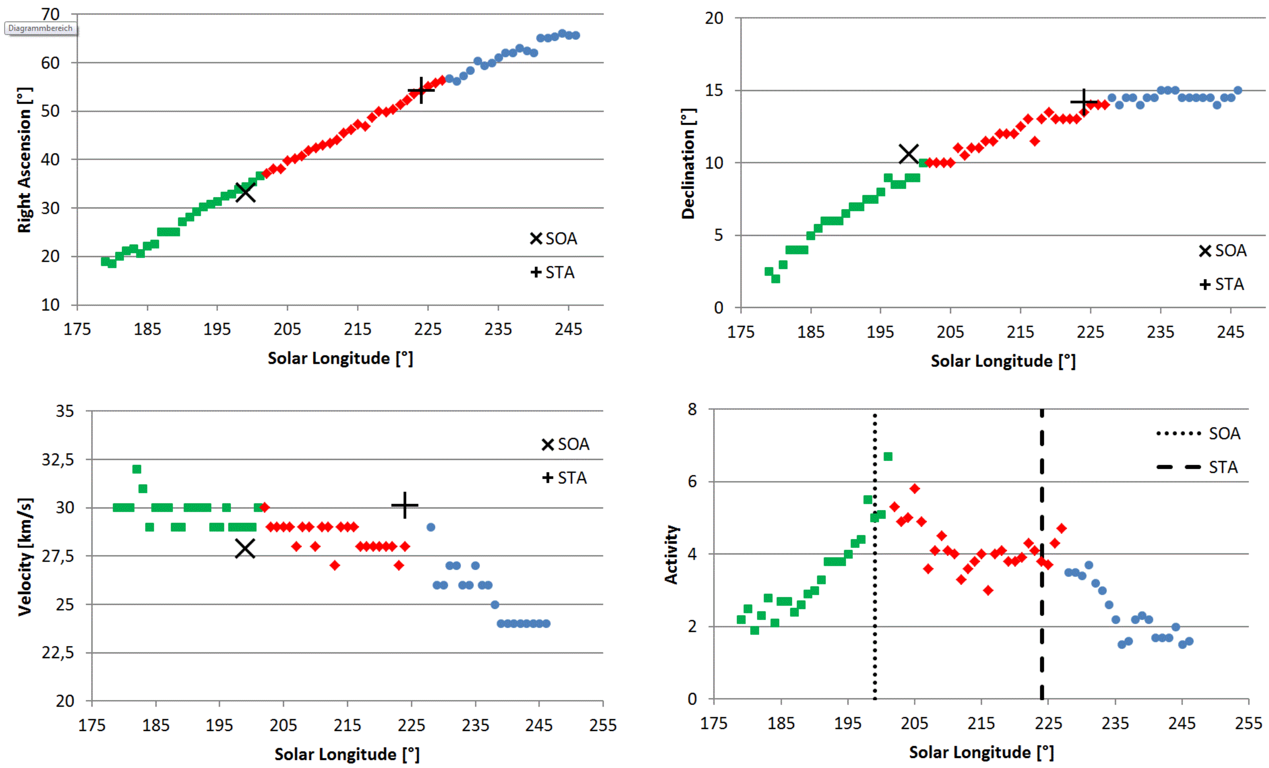

Figure 5 – Shower parameters of the Southern Taurids in the activity interval from 179° to 246° solar longitude: Right ascension (up left), declination (up right), velocity (down left) and activity (down right). The three segments of activity are marked with different colors. The MDC list values for the Southern October δ-Arietids and the Southern Taurids are shown as well.

Table 6 – Parameters of the December Monocerotids from the MDC Working List and the analysis of the IMO Network in 2012.

Source	Solar Longitude		Right Ascension		Declination		V_∞	
	Mean [°]	Interval [°]	Mean [°]	Drift [°]	Mean [°]	Drift [°]	Mean [km/s]	Drift [km/s]
MDC	261	—	102.4	+0.8	+8.1	−0.1	43.5	—
IMO 2012	257	254–269	100.1	+0.64	+8.3	−0.13	42.0	−0.15

Table 7 – Parameters of the σ-Hydrids from the MDC Working List and the analysis of the IMO Network in 2012.

Source	Solar Longitude		Right Ascension		Declination		V_∞	
	Mean [°]	Interval [°]	Mean [°]	Drift [°]	Mean [°]	Drift [°]	Mean [km/s]	Drift [km/s]
MDC	265	—	131.9	+0.72	+0.2	−0.21	59.1	—
IMO 2012	254	242–269	124.0	+0.81	+2.7	−0.19	61.7	−0.06

Table 8 – Observers contributing to 2012 November 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	Ludwig1 (0.8/8)	1488	4.8	726	4	26.3	39
BERER	Berko	Ludányhalászi/HU	Hulud1 (0.95/3)	2256	4.8	1540	16	91.8	890
			Hulud2 (0.75/6)	4860	3.9	1103	14	93.9	274
			Hulud3 (0.75/6)	4661	3.9	1052	13	90.1	238
BIRSZ	Biro	Agostyán/HU	Huago (0.75/4.5)	2427	4.4	1036	20	134.1	405
BREMA	Breukers	Hengelo/NL	Mbb3 (0.75/6)	2399	4.2	699	21	118.0	356
			Mbb4 (0.8/8)	1470	5.1	1208	20	124.8	349
BRIBE	Brinkmann	Herne/DE	Hermine (0.8/6)	2374	4.2	678	21	131.4	396
		Bergisch Gladbach/DE	Klemoi (0.8/6)	2286	4.6	1080	20	99.9	350
CASFL	Castellani	Monte Baldo/IT	Bmh2 (1.5/4.5)*	4243	3.0	371	19	124.4	504
CRIST	Crivello	Valbrevenna/IT	Bilbo (0.8/3.8)	5458	4.2	1772	16	132.8	582
			C3P8 (0.8/3.8)	5455	4.2	1586	19	147.4	567
			Stg38 (0.8/3.8)	5614	4.4	2007	7	28.5	106
CSISZ	Csizmadia	Zalaegerszeg/HU	Huvcse01 (0.95/5)	2423	3.4	361	14	72.5	186
ELTMA	Eltri	Venezia/IT	Met38 (0.8/3.8)	5631	4.3	2151	16	145.8	726
GONRU	Goncalves	Tomar/PT	Templar1 (0.8/6)	2179	5.3	1842	19	160.9	658
			Templar2 (0.8/6)	2080	5.0	1508	19	176.7	710
			Templar3 (0.8/8)	1438	4.3	571	20	170.0	625
			Templar4 (0.8/3.8)	4475	3.0	442	20	162.7	577
GOVMI	Govedič	Središče ob Dravi/SI	Orion2 (0.8/8)	1447	5.5	1841	19	95.0	330
			Orion3 (0.95/5)	2665	4.9	2069	15	55.0	179
			Orion4 (0.95/5)	2662	4.3	1043	15	73.8	152
HINWO	Hinz	Brannenburg/DE	Acr (2.0/35)*	557	7.4	4954	12	53.8	527
IGAAN	Igaz	Baja/HU	Hubaj (0.8/3.8)	5552	2.8	403	23	93.4	180
		Debrecen/HU	Hudeb (0.8/3.8)	5522	3.2	620	23	132.1	529
		Hódmezővásárhely/HU	Huhod (0.8/3.8)	5502	3.4	764	23	126.6	337
		Budapest/HU	Hupol (1.2/4)	3790	3.3	475	9	38.5	43
JONKA	Jonas	Budapest/HU	Husor (0.95/4)	2286	3.9	445	20	96.4	252
KACJA	Kac	Kostanjevec/SI	Metka (0.8/12)*	715	6.4	640	1	4.2	9
		Ljubljana/SI	Orion1 (0.8/8)	1402	3.8	331	9	30.5	22
		Kamnik/SI	Cvetka (0.8/3.8)	4914	4.3	1842	1	9.7	21
		Rezika (0.8/6)	2270	4.4	840	7	47.5	395	
			Stefka (0.8/3.8)	5471	2.8	379	2	8.1	27
KERST	Kerr	Glenlee/AU	Gocam1 (0.8/3.8)	5189	4.6	2550	28	147.6	850
KISSZ	Kiss	Sülyśap/HU	Husul (0.95/5)*	4295	3.0	355	22	73.1	117
KOSDE	Koschny	Izana Obs./ES	Icc7 (0.85/25)*	714	5.9	1464	9	78.9	768
		Noordwijkerhout/NL	Lic4 (1.4/50)*	2027	6.0	4509	10	62.0	167

Table 8 – Observers contributing to 2012 November data of the IMO Video Meteor Network – continued from previous page.

Code	Name	Place	Camera	FOV [$^{\circ 2}$]	Stellar LM [mag]	Eff.CA [km^2]	Nights	Time [h]	Meteors
LERAR	Leroy	Gretz/FR	Saphira (1.2/6)	3260	3.4	301	9	41.3	40
MACMA	Maciejewski	Chelm/PL	Pav35 (1.2/4)	4383	2.5	253	16	64.2	124
			Pav36 (1.2/4)*	5732	2.2	227	19	72.2	217
			Pav43 (0.95/3.75)*	2544	2.7	176	16	72.2	114
MARGR	Maravelias	Lofoupoli-Crete/GR	Loomecon (0.8/12)	738	6.3	2698	18	93.3	305
MOLSI	Molau	Seysdorf/DE	Avis2 (1.4/50)*	1230	6.9	6152	3	12.3	204
			Mincam1 (0.8/8)	1477	4.9	1084	14	60.9	139
		Ketzür/DE	Remo1 (0.8/8)	1467	5.9	2837	17	118.5	1098
			Remo2 (0.8/8)	1478	6.3	4467	17	128.6	977
			Remo3 (0.8/8)	1420	5.6	1967	18	122.5	294
MORJO	Morvai	Fülöpszállás/HU	Huful (1.4/5)	2522	3.5	532	19	107.1	220
OCHPA	Ochner	Albiano/IT	Albiano (1.2/4.5)	2944	3.5	358	12	27.5	168
OTTMI	Otte	Pearl City/US	Orie1 (1.4/5.7)	3837	3.8	460	24	97.2	482
PERZS	Perko	Becsehely/HU	Hubec (0.8/3.8)*	5498	2.9	460	13	54.7	340
PUCRC	Pucer	Nova vas nad Dragonjo/SI	Mobcam1 (0.75/6)	2398	5.3	2976	19	146.3	687
ROTEC	Rothenberg	Berlin/DE	Armefa (0.8/6)	2366	4.5	911	10	75.5	209
SARAN	Saraiva	Carnaxide/PT	Ro1 (0.75/6)	2362	3.7	381	23	171.9	483
			Ro2 (0.75/6)	2381	3.8	459	21	182.2	595
			Sofia (0.8/12)	738	5.3	907	22	167.2	407
SCALE	Scarpa	Alberoni/IT	Leo (1.2/4.5)*	4152	4.5	2052	17	114.3	365
SCHHA	Schremmer	Niederkrüchten/DE	Doraemon (0.8/3.8)	4900	3.0	409	19	113.0	417
STOEN	Stomeo	Scorze/IT	Min38 (0.8/3.8)	5566	4.8	3270	18	146.2	1110
			Noa38 (0.8/3.8)	5609	4.2	1911	19	157.7	863
			Sco38 (0.8/3.8)	5598	4.8	3306	20	152.5	1117
STORO	Stork	Kunžak/CZ	Kun1 (1.4/50)*	1913	5.4	2778	2	15.4	189
		Ondřejov/CZ	Ond1 (1.4/50)*	2195	5.8	4595	2	24.5	637
STRJO	Strunk	Herford/DE	Mincam2 (0.8/6)	2362	4.6	1152	17	102.7	229
			Mincam3 (0.8/12)	728	5.7	975	17	113.9	287
			Mincam4 (1.0/2.6)	9791	2.7	552	13	58.2	79
			Mincam5 (0.8/6)	2349	5.0	1896	19	108.8	345
TEPIS	Tepliczky	Budapest/HU	Humob (0.8/6)	2388	4.8	1607	18	133.3	521
TRIMI	Triglav	Velenje/SI	Sraka (0.8/6)*	2222	4.0	546	13	22.6	163
YRJIL	Yrjölä	Kuusankoski/FI	Finexcam (0.8/6)	2337	5.5	3574	7	30.6	117
ZELZO	Zelko	Budapest/HU	Huvcse03 (1.0/4.5)	2224	4.4	933	5	26.8	67
						Overall	30	6594.3	27052

* active field of view smaller than video frame

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Chelyabinsk meteor of 2013 February 15

These spectacular photographs of the Chelyabinsk meteor were shot from the city of Chelyabinsk, Russia, using Canon 5D at ISO 50 equipped with 24-70 mm lens and Cokin graduated filter.
Top: Direct image of the superbolide in flight, shot at $03^{h}20^{m}33^{s}$ UT with 0.6 s exposure at 35 mm $f/14$.
Bottom: Trail immediately after fireball extinction, at $03^{h}20^{m}43^{s}$ UT using 0.6 s exposure at 27 mm $f/14$.

Photographs by Marat Ahmetvaleev. Blog: `marateaman.livejournal.com`, e-mail: `tea-man@yandex.ru`

See page 22 for news about this event.