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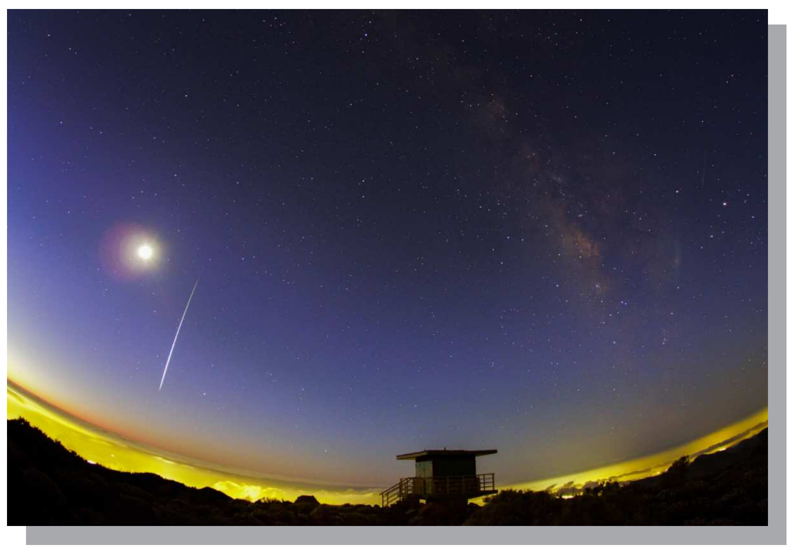

Kappa Cygnid rate variations over 41 years
December Alpha-Bootids observed by CAMS
Central European MetEor NeTwork introduced
Taurids Swarm exists only as Southern Taurids
January video meteors

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Front cover photo

Bright fireball photographed on 2016 May 2 at $05^{\mathrm{h}}21^{\mathrm{m}}59^{\mathrm{s}}$ UT from Pico de la Gorra (Gran Canaria, Spain) using Canon 60 Da camera with 10-mm fisheye lens at $f/2.8$, and a 20 s exposure at ISO 1600. Photo courtesy: Pedro Pérez Corujo.

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Conferences

The International Meteor Conference 2016 experience

Manuel Moreno-Ibáñez [1]

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I was there, and since I was there I can state that there was no better place to be. I may not deny that a couple of months ago I was not sure of attending the 35th International Meteor Conference (IMC) held in Egmond (the Netherlands) between the 2nd and 5th June, however I was finally convinced. My decision had to do with the kind invitation by an (at that point) unknown Felix Bettonvil, who seemed to be quite nice by e-mail. But it also had to do with Marc Gyssens who helped me with the financial details, encouraged me to attend Meteoroids 2016 (which took place immediately after the IMC at ESTEC, quite convenient though), and monitored my evolution in getting student support to Meteoroids 2016 as well. Frankly, during the registration deadline time I had different personal affairs to solve which kept me so busy that I could not focus on the importance of attending this meeting. Nevertheless, my thesis supervisors highly recommended attending and so I accepted the suggestion. I was there.

June the second, I was not nervous at all. I love travelling, not only visiting different countries but also the fact of travelling, the adrenalin of making your way through unexpected adversities and prove yourself that the human kind is the same all around the world. During my trip to Egmond I encountered difficulties (e.g.: my flight was delayed, my debit card was not accepted at Schiphol, etc.) but the excitement of travelling, meeting an old acquaintance and news about acceptance of a paper (I am a PhD student and these sort of things still make my day) obviously overcome any inconvenient.

Once at the youth hostel at Egmond where the meeting took place I realized that I might had arrived too soon. The hall was quite lively but it seemed it was the moment where old friends catch up on their lives and there is not much room to start any neutral conversation. Thus, I left my luggage in the shared room I was assigned. We were four people there, two senior Japanese and two junior Spaniards. No problem arose during the three days cohabitation, however I discovered that my Spaniard roommate was able to extend the siesta up to its controversial limits (a.k.a. when dinner is no longer served in any Spanish restaurant). Later, I decided to take a stroll to the nearby beach despite the strong wind, the cloudy sky and the high chances of getting soaked by any threatening rain.

I was back for the opening speeches which were quite cheerful and welcoming. I believe that the first impressions constrain the following movements as if a chess game was going on, however, in this occasion I immediately gave up the game to the promising three days that were about to fascinate me. That day I met one of my thesis supervisors and (among others) the Australian troop, one of whom had very kindly recently reviewed a chapter I wrote for a book. The revision was nice, but the person nicer. The dinner and the spare time afterwards were quite useful to meet new people and to glimpse the general ambient.

Figure 1 – The author talking to Jürgen Rendtel during the poster session. Communicated by: Roy Keeris.

Friday morning opened with a grey blanket of clouds which indicated that I would not find any warmer place than the seminar room where the presentations would be taking place. All in all, presentations were really amazing. I admit that there are several fields within meteor science that are out of the scope of my research and I have had no time yet to do a thorough read about them. Fortunately, IMC 2016 was an outstanding opportunity to learn as much as possible and to fill my notebook with ideas and explanations. I guess the topics were similar to previous versions but I feel it is worth

Figure 2 – Dušan Pavlović playing guitar and Detlef Koschny playing darbuka. Communicated by: Roy Keeris.

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Figure 3 – IMC participants following a presentation in the lecture hall. Communicated by: Roy Keeris.

mentioning them all again: radar, visual, radio and optical meteor observation techniques; entry flight atmospheric models; fireballs and meteor recovery; numerical modeling; meteor showers; atmospheric processes and phenomena; instrumentation; data pipelines and software; ongoing work, history and miscellaneous. I could not ask questions to the speakers since I felt quite inexperienced in most of the subjects. However, I did it the other way round – I questioned myself whether I could answer my own doubts in the near future with the expectation to be fully ready for next IMC.

I gave my talk during the second session of the first morning. I am currently working on mathematical modeling of the fireball atmospheric entry, thus my talk consisted mainly on mathematical equations and graphics, quite in contrast with the previous talks full of pictures. Mine was easy to follow as I tried to do it as simple and friendly as possible, but there was still the possibility of people losing attention. I reckon I was not comfortable during those 12 minutes, but not because of the attentive public. It was an easy talk and I knew it by heart, but I had kind of unease inside. Anyway, people seemed to like it and I had several friendly discussions with other participants during the lunch break which helped to improve my skills in answering questions.

Regarding the IMC participants, the diversity was huge. As far as I remember we were nearly 160 people. I would not say who was (or seemed) the most aged, but certainly I could point to the youngest one: Javor's daughter. With only 3 months of life this jovial baby was introduced to either the very beginner amateur astronomer or the most senior scientist. Every one showed her their respect, and she showed none for anyone.

As for the rest of participants, we were people from all around the globe, I remember meeting colleagues from: Japan, Canada, USA, Russia, Europe, a little group coming from Australia (they were Europeans though) and one African (from Egypt) hidden within the Japanese group. In spite of the cultural background being so diverse, their enthusiasm pointed in a unique direction, meteor science. I was quite excited to match faces with the well-known scientists whose papers are the guidelines of my research. Borovička, Brown, Campbell-Brown, Jenniskens, and many others were so unfamiliar to me physically that I was quite excited to reveal the secret. Normally, senior scientists shed some light on the goals you may want to achieve, the limits you want to push or the errors you should not repeat (if any). Nonetheless, it is from the other PhD students that I met at IMC where I found the motivation to give my best and the certainty that the way ahead is tough for all of us. I think I got along very well with the other students as they were nice people doing serious research, which means that future collaborations may be possible and prosperous. Finally, I shall remark the role of amateurs – why do they say amateur astronomers when they want to say passionate inspiring people? I have participated and contributed in several amateur astronomers' meetings, and I do always feel as if I should sit on the first line and pay attention carefully. Their observational experience is overwhelming. On top of that, they are responsible for such a fantastic meeting as the IMC. I do appreciate their effort in organizing this highly appealing meeting where they take care that everyone feels comfortable. All treated as equals.

Last but not least, I shall mention the social activities we enjoyed during the meeting. Every night, the youth hostel bar opened till very late (which usually meant till the last participant admitted that being

Figure 4 – The IMC 2016 group photo aboard the ship during the excursion to the Waddenzee. Credit: Casper ter Kuile.

alone in the bar was no longer useful). This precious time allowed the participants to socialize, strengthen bonds and complete previous research topic conversations in a more relaxed way. Furthermore, night time revealed the artistic skills of unsuspected participants. I have seen well known scientists and amateurs play the accordion, the darbuka (sort of African drum) or the guitar. On the hostel walls the joyful music bounced, we enjoyed nice Japanese lyrics (according to the sound, lyrics were completely indecipherable to me), strong Russian hymns, Serbian solos, French chores, old-fashioned Spanish songs and, scarcely, any English theme. I would like to take the opportunity here to thank the kind and friendly mood of all the youth hostel staff, not only for their capacity to stand such out-of-tone music but for their cooperation and understanding.

The IMC Local Committee organized an excursion to a world heritage site, the Waddenzee. Once the morning session ended on Saturday 4th of June, we travelled to some point in the north of the Netherlands where a fishing boat awaited. The trip mainly consisted of sailing on the protected area waters where fishing activities are common. The boat crew (fishermen) taught us some basic knowledge about the local fauna. However, the real amazement of this trip was fishing. The big fishing nets were released several times, and once back, different kind of sea life species were dropped in prepared buckets. Among them, small local shrimps were cooked for our enjoyment. We ate as many shrimps as we wanted and, on top of that, the IMC organizers, who had helped feed us the seafood, invited us to one beer or refreshment. Beautiful weather, delicious snack, international company, nice stroll, outstanding excursion.

The next IMC will be at Petnica Science Center, located in Serbia. Some representation attended this meeting and they showed really good manners to host it. I am definitely trying to attend it. My first IMC was great. I was told in advance it was going to be so, but you always try to reduce expectations. Now, it is time to work on the proceedings. I shall thank Paul Roggemans for his editing tasks (which I guess will consume most of his spare time), and all the rest of organizers for this awesome experience. I was lucky, I was there.

About the author: Manuel Moreno-Ibáñez, PhD student under the supervision of Josep Ma. Trigo-Rodriguez (Institute of Spaces Sciences, Barcelona) and Maria Gritsevich (Finnish Geospatial Research Institute, Helsinki). His studies are focused on the impact hazard due to large meteoroids disrupted from asteroids and comets.

Thirty-Sixth International Meteor Conference, Petnica, Serbia, September 21–24, 2017

Dušan Pavlović, Snežana Todorović, Miroslav Živanović, and Nikola Božić[1]

The very successful 35th International Meteor Conference (IMC), which took place from June 2 to 5, 2016, in Egmond, the Netherlands, is still fresh in our minds, and we are already looking forward to next year's edition. The 36th IMC will be held from September 21 to 24, 2017, in the Petnica Science Center (PSC), near Valjevo, Serbia. Mind that this is not the first IMC at this location. The Petnica Meteor Group, operating from the PSC, already hosted an IMC here in 1997, exactly 20 years ago. Hosting the IMC gave a tremendous boost to our activities. It attracted a large number of very active young meteor observers, and, after the IMC 1997, the Petnica Meteor Group continued to bring together meteor observers and those interested in other fields of meteor science (not only high school students, but people from all subjects and professions). Visual observations were complemented by video and all-sky observations, theoretical work, and data analysis. Those are all the reasons to bring the IMC back to Petnica next year. As you will read, a lot has changed over these twenty years, though...!

Conference dates

The dates of the IMC 2016 were unusual, and already at the IMC 2015 in Mistelbach, Austria, many student participants feared that their exams would interfere. However, this was the only way to pair this event with *Meteoroids*, which proved very effective, especially for attracting more professional meteor astronomers.

In 2017, however, there are no such constraints, and the IMC returns to its traditional period, in the second half of September, more concretely from Thursday evening, September 21, till Sunday noon, September 24, 2017.

Organization, location, and venue

The IMC 2017 will be hosted by the PSC. The PSC is an extracurricular science education center for high school students from all countries of former Yugoslavia. It is located in Petnica, a small village near the city of Valjevo, about 100 km southwest of Belgrade. Those of you who attended the IMC 1997 will probably not recognize the site anymore, because the PSC campus has undergone a significant expansion since then. The PSC campus today (Figure 1) includes several separate buildings hosting lecture halls and classrooms, a library, laboratories, dormitories, a restaurant (350 seats), a café, and a small shop. Since all conference activities are hosted on-campus, there will be plenty of opportunity for the meteor community to interact, both formally and informally. The IMC 2017 participants will also be accommodated on-campus[2]. There will be 14 single, 20 double, and 28 triple bedrooms (138 beds in total) available in the dormitory building, which is connected by a covered walkway to the main conference building, where the talks and poster sessions will be held. The talks will be presented in an amphitheater (150 seats) and the posters will be displayed in the hallway and two small classrooms (50 seats per classroom) across the hall and at the lower floor of the building. The campus is covered by free WiFi Internet, and all bedrooms also have LAN connections. Also, there is an open amphitheater with 500 seats which can be used for the evening activities. The restaurant and café open up to a nice terrace overlooking the area. Special food requirements can be arranged in advance.

Program and social events

Of course, the program will mainly consist of talks and poster sessions. The exact schedule will be determined shortly after the end of the registration period, when we get a clear picture of the number of speakers and topics. We anticipate that there will be both short talks and extended sessions, as well as workshops organized by the prominent specialists in various fields of meteor science. All presentations, both talks and posters, will be included in the IMC 2017 Proceedings as full-length papers or abstracts. As this year, there will be a contest for the best poster and the best meteor photo. Social events include evening activities, an excursion to points of interest in and around Valjevo, and a visit to one of the local wineries in the evening after the excursion.

Cost

We are able to offer the IMC 2017 at a most reasonable price, which is also good news for students. The standard registration fee has been set at 130 EUR. This includes full board (accommodation in a triple bedroom, breakfast, lunch, and dinner) from Thursday evening September 21 (dinner included) till Sunday noon September 24 (lunch included), all lecture and poster sessions, coffee breaks, and the excursion. T-shirts and printed proceedings can be purchased separately upon registering, but electronic proceedings will be made available to all participants. Participants who wish to be accommodated in a double or single bedroom pay 170 EUR or 240 EUR, respectively.

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[2]We will report later on the availability of a non-accommodation option.

Figure 1 – Campus of the Petnica Science Center.

Registration is expected to open in January 2017, and this will be announced, together with more detailed information on the conference, in WGN and on the IMO and IMC 2017 web sites. The early-bird registration deadline is set at June 30, 2017. After this date, an additional late registration fee of 20 EUR is charged. The final registration deadline is set at August 15, 2017, but mind that registration may have to be closed earlier if full capacity is reached before that date, which was the case for both the 2015 and 2016 editions.

Traveling to Petnica

As Petnica is a small village, there is no bus connection, but a shuttle will be available from the Valjevo bus and train stations located 7 km from Petnica. So, participants (if not arriving by car directly to the PSC) should come to Valjevo, from where an organized free shuttle bus will bring them to Petnica Science Center. The PSC is located at $44°14'48''$ N and $19°55'52''$ E. As detailed travel information will be published in due time on the IMC 2017 web pages, we limit ourselves here to some rough information to give you a general orientation.

If you travel by plane, the best way is to fly to Belgrade (Airport "Nikola Tesla"), then go to the Belgrade central bus or train station, and from there to Valjevo by bus or train (there is a connection approximately every hour). You can also rent a car at the airport—you will find the car rental agencies at the arrivals terminal. Bus or train travelers should of course also go to Valjevo from the Belgrade central bus or train station.

If you travel by car, you can use the E70 and E75 Motorways connecting Zagreb, Novi Sad, Belgrade and Niš. Or simply drive to Belgrade and from Belgrade to Valjevo. We encourage participants to consider carpooling. The Local Organizing Committee (LOC) will provide assistance once registration is closed.

Contact information

As mentioned above, detailed information will be published in WGN in due time and posted at the IMC 2017 web pages. As usual, a link to these pages will be provided on the homepage of the IMO website as soon as they are active. Meanwhile, you may contact the LOC at `imc2017@imo.net`.

Acknowledgements

This first announcement is based on a text written for the IMC 2016 Proceedings. We thank Vladimir Lukić, Marc Gyssens, Dragana Okolić, and Branislav Savić for useful comments on this text.

Meteor science

Kappa Cygnid rate variations over 41 years

Jürgen Rendtel[1] *and Rainer Arlt*[1]

Enhanced rates of the kappa Cygnids in 2007 and 2014 had been considered as a hint at periodic rate/flux enhancement. Here we use an extended data set of visual observations covering the 41-year period 1975–2015. Applying a wavelet analysis to the data series yields no periodic ZHR variations in the given period and the optical meteor magnitude range.

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1 Introduction

The κ-Cygnids can be traced in visual meteor data back to the 1870s (e.g. Tupman, 1873). Further, but less certain detections may go back to the middle ages (Roggemans, 1987). Reports frequently refer to radiants in Draco and Cygnus. A recent study of Koseki (2014) has shown that the radiant is indeed complex and extends over a region of the order of 10 degrees in diameter (see Figure 16 in Koseki's paper). At the same time also the activity from the various sub-radiants is supposed to vary. If we consider the individual dust trails of the complex having a specific size and shape each, such an appearance in the sky is not unexpected. As a consequence, we may expect various periodicities for average shower rates and the occurrence of bright meteors. Years with apparently more frequent fireball occurrences are 1879 and 1893 (Denning, 1899) as well as 1922 and 1993 (Jenniskens, 2006). With no given source for this, the 1995 edition of the IMO visual handbook (Rendtel et al., 1995) as well as the earlier handbook of Roggemans (1987) mention a possible period in fireball occurrences of 6.6 years. Even after an intense search, we were not able to recover the original source of this comment.

Enhanced rates of the κ-Cygnids have been observed recently in 2007 (Jenniskens et al., 2007) and 2014 (Rendtel & Molau, 2015; Moorhead et al., 2015), using different techniques. This raised the question of a periodic rate variation again. Koseki (2014) mentions 7 years, while Moorhead et al. (2015) give 7.116 years based on an assumed orbit of a potential parent object.

In a first analysis we listed the years 2000, 1993, 1986, 1979, ... which would result from a simple 7-year backward count starting from 2014 and 2007. The list changes to 2001, 1994, 1988, 1981, 1975, ... when a shorter period of 6.6 years is assumed (Rendtel & Arlt, 2015). We now present a nearly complete set of annual κ-Cygnid rates since 1975, partly based on the reanalysis of visual meteor observations.

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2 Visual meteor data 1975–2015

Meteors of the κ-Cygnids are easily distinguishable from other sources because their radiant area is far away from all other significant sources in August and the low entry velocity of the shower meteors is a another good discriminating criterion. The activity period is usually well covered because it partially overlaps with many campaigns arranged for the Perseid observations. Therefore we included data prior to the start of the IMO's Visual Meteor DataBase (VMDB) in 1985. However, the amount of data neither allows the calculation of a population index per year nor of annual rate profiles. The findings from good annual data sets show that the ZHR does not significantly vary over an interval of 6° in solar longitude. Hence we calculated a ZHR value per year, representing the maximum in a roughly 2°-wide interval between 142° and 148° solar longitude. The applied constant value of $r = 2.5$ is lower than the usually tabulated value and was determined from the 2014 video data (Rendtel & Molau, 2015). During a meeting of the German Arbeitskreis Meteore (AKM) in 2015 we added data back to 1977 which were presented in an analysis by (Rendtel & Arlt, 2015), including data from the period 1977–2008 and for the year 2014.

3 Data analysis

For the present analysis we further added the previously missing rates for the years 2009–2013, and for 2015, i.e. after the described ZHR peak in 2014, and eventually for 1975. This provides us with a series of data for 38 individual years in the 41-year period 1975–2015 (Table 1 and Figure 1). Gaps occur in the years 1976, 1981 and 1984 with no visual data due to poor weather and a moonlit period. Further years with strong moonlight interference are marked in Table 1. Although the ZHR correction seems to be well established over years, there are often deviations which seem to be caused by an inappropriate correction for the conditions involving strong scattered light. In the case of high ZHRs the correction seems to be too low (see, for example, the Perseid profile of the 1990 Perseid return shown in Figure 3 in the paper by Brown & Rendtel, 1996), while in most cases an overcorrection is found. This is not the subject of the present paper, but needs to be mentioned.

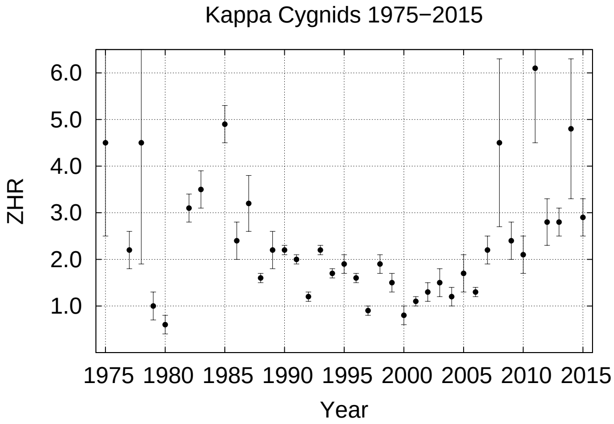

Figure 1 – Annual ZHR maximum of the κ-Cygnids for the period 1975–2015 as listed in Table 1.

4 Period search

Our data series now shows ZHRs higher than in the neighbouring years for 1985 and 2014 as well as insignificantly in 1978, 2008, and 2011. The latter three have already been attributed to poor observing conditions, with uncertain corrections and small samples and consequently large error margins. Note that there is no peak in the visual ZHR for the 2007 return in our data set contrary to the observations reported (Jenniskens et al., 2007). Obviously, there are no enhancements visible in the suspected years which might be associated with either of the previously listed periods.

One of the discussed possibilities is the superposition of different periodicities (Rendtel & Arlt, 2015). Wavelets offer a chance to test whether there are any hints of periods which may not be immediately apparent from the data set. This method has been used widely as part of meteor shower analysis, such as determining periodic density variations in the Leonid meteor shower stream (Singer et al., 2000). We applied a wavelet analysis provided by Torrence & Compo (1998) which is available through an interactive web page. The main advantage of this method is the possibility to detect periodicities which are present only in a part of the series. Of course, the duration of the Cygnid series is still limiting the search for longer periods. Further, we filled the three gaps mentioned above with the average ZHR of the neighbouring years. This has little or no effect on the periods detected by the method. Even if we apply a factor of 2 or 0.5 to the three values, there is no different period visible in the series.

The result of the wavelet analysis of the data listed in Table 1 is shown in Figure 2. At a first glance there seems to be a 6–7 year period in the beginning of the series and a roughly 3-year period towards the end. When interpreting such data, care needs to be taken for the hatched areas (longer periods in the lower section of the graph, or data close to the ends of the series). This region of the diagram is called the cone of influence. In our case the mentioned 6–7 year period between 1975 and 1985 is uncertain and definitively not present throughout the data series.

Table 1 – Maximum κ-Cygnid ZHR in the solar longitude interval 142°–148° per year. The given solar longitude (J2000) gives the position of the highest value used as a representative ZHR for the analysis. The last column lists the full moon date in August for the year. Values in *italics* are considered as badly moonlit (see text).

Year	$\lambda_\odot$	ZHR	Moon
1975	141.50	4.5±2.0	21
1976			10
1977	143.01	2.2±0.4	28
1978	142.97	4.5±2.6	*18*
1979	142.12	1.0±0.3	08
1980	142.85	0.6±0.2	26
1981			*15*
1982	145.15	3.1±0.3	05
1983	142.49	3.5±0.4	23
1984			*11*
1985	145.12	4.9±0.4	30
1986	141.64	2.4±0.4	19
1987	148.60	3.2±0.6	09
1988	144.33	1.6±0.1	27
1989	144.40	2.2±0.4	*17*
1990	147.85	2.2±0.1	06
1991	142.25	2.0±0.1	25
1992	150.23	1.2±0.1	*13*
1993	141.77	2.2±0.1	02
1994	141.33	1.7±0.1	21
1995	145.64	1.9±0.2	10
1996	143.68	1.6±0.1	28
1997	143.80	0.9±0.1	*18*
1998	144.43	1.9±0.2	08
1999	142.40	1.5±0.2	27
2000	145.80	0.8±0.2	*15*
2001	143.78	1.1±0.1	04
2002	142.06	1.3±0.2	23
2003	147.55	1.5±0.3	*12*
2004	142.97	1.2±0.2	30
2005	141.68	1.7±0.4	19
2006	144.15	1.3±0.1	09
2007	142.45	2.2±0.3	28
2008	145.94	4.5±1.8	*16*
2009	145.33	2.4±0.4	06
2010	143.17	2.1±0.4	24
2011	144.73	6.1±1.6	*13*
2012	146.70	2.8±0.5	02
2013	141.53	2.8±0.3	21
2014	144.70	4.8±1.5	10
2015	142.38	2.9±0.4	29

We think that the apparently better defined 3-year period around 2010 is an artefact due to the above mentioned moonlight influence as the respective peak years are just those which coincide with bright moonlight in the Cygnid activity period. If we arbitrarily assume the ZHR being over-corrected by a factor of 2 for all moonlight-affected years in the series, we obtain the result shown in Figure 3. Here the suspicious 3-year period after 2007 disappears. Surprisingly, this modified data set not only reproduces a 6-year signal in

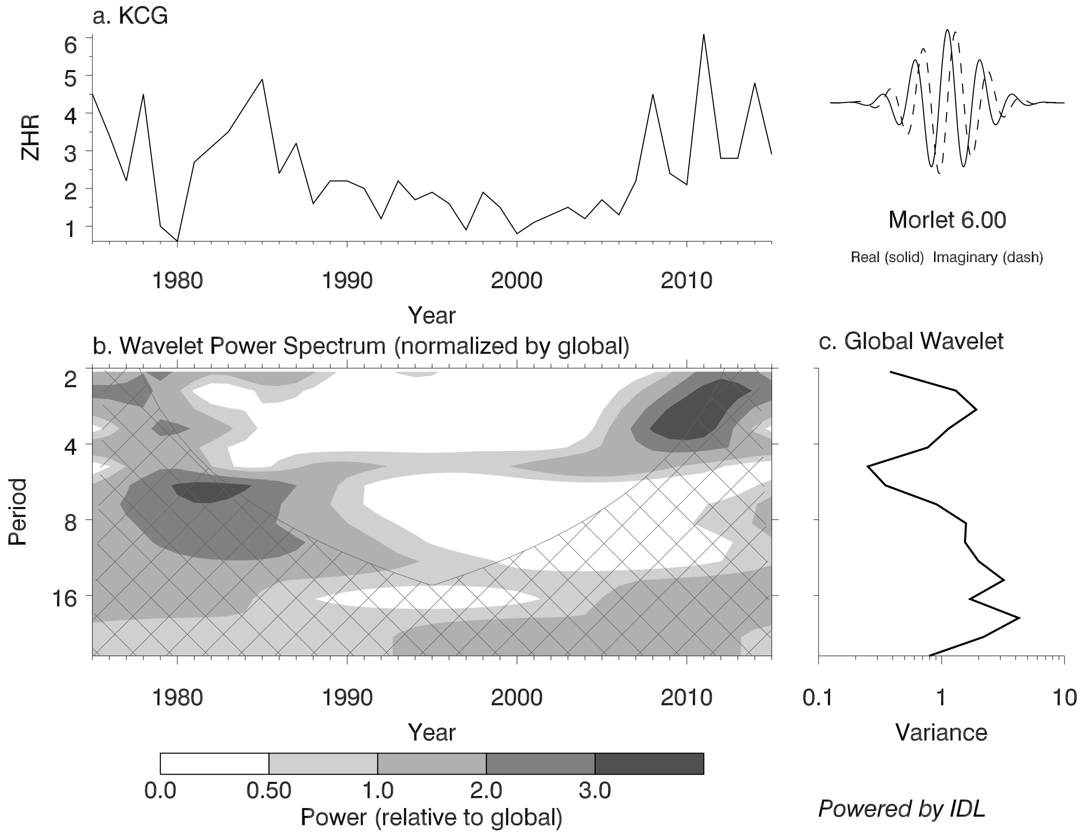

Figure 2 – Kappa Cygnid data wavelet analysis: (a) ZHR of the (012) κ-Cygnids. (b) The wavelet power spectrum. The power has been scaled by the global wavelet spectrum (at right). The cross-hatched region is the cone of influence, where zero padding has reduced the variance. (c) The global wavelet power spectrum.

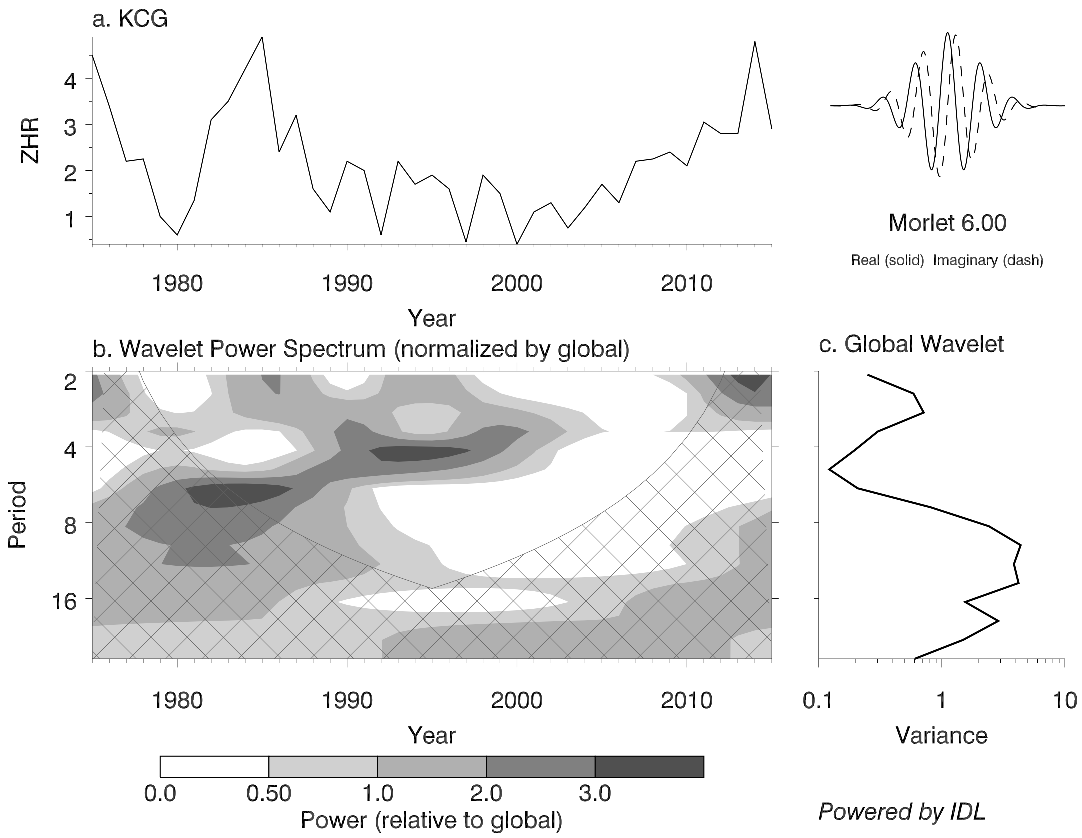

Figure 3 – Wavelet analysis of the same data set as presented in Figure 2 with the moonlight-affected ZHRs divided by 2. For the three panels see the description in Figure 2.

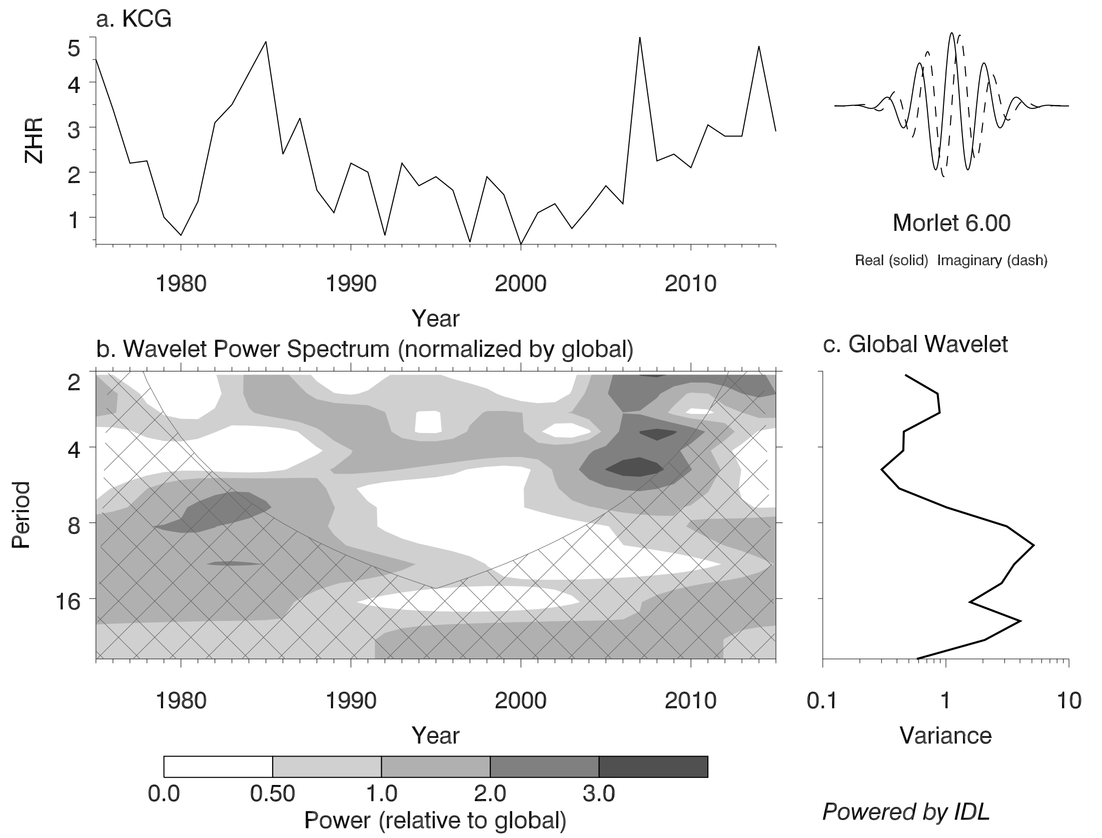

Figure 4 – Wavelet analysis of the same data set as presented in Figure 3, additionally replacing the 2007 value of 2.2 by 5.0 as discussed in the text. For the three panels see the description in Figure 2.

the period 1980–1987 similar to Figure 2 but also an additional sign of a roughly 4-year period 1991–1998 when the general ZHR level was very low. The fact that the eight values 1980–1987 produce a 6-year periodicity signal indicates that this period appears just once and cannot be attributed to a real feature in the stream. Covering 41 years in total allows us to exclude all periods less than 20 years length.

At this point we briefly come back to the 2007 return. Replacing ZHR = 2.2 from our data set (Table 1) with ZHR = 5 quoted by Jenniskens et al. (2007), provides no support for a 7-year period in the wavelet diagram (Figure 4) but just one peak centered at 2007 supposing a 3.5–5.5 year periodicity which is not significant as the above discussed case.

All diagrams provide us with a strong hint that there is no periodicity which can be derived with any certainty over the entire 41-year interval under study. Periods appearing within parts of the series may be attributed to the moonlight influence on the ZHR (3-year) or are very weak (6–7 years). The global wavelet power shown in the panels (c) of Figures 2–4 indicates, that all periods in the range 4–6 years are of minor importance and may be signals which appear just by chance from a noisy data series.

5 Conclusions

From the data set covering 41 years we find no conclusive evidence for periodic ZHR variations shorter than about 10 years. An apparent long-term trend appears to be present with an overall broad ZHR minimum of activity roughly between 1988 and 2006 with a subsequent rise after about 2002 (Figure 1). The higher ZHR values before 1988 indicate another period of stronger activity, but are less certain than the post-2000 values and vary strongly.

The question of a possible mass sorting raised in the first analysis paper (Rendtel & Arlt, 2015) remains open as all periodicity searches are based on visual data. The magnitude range is similar to the analysis of the 2014 outburst based on visual and video meteors (Rendtel & Molau, 2015). The fact that the radar meteor flux of the κ-Cygnids in 2014 was at least 5 times the 2007 flux (Moorhead et al., 2015) while the visual ZHR of 2014 is only about 3 times the 2007 ZHR – and 2007 is no peak year at all in the visual data – indicates that the flux variations may be more significant in the small-meteoroid population. Hence a study of radar flux data over a long period might provide us with information about the low-mass structure within the complex κ-Cygnid meteoroid stream.

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Strong return of the December α-Bootids (IAU#497, DAB)

Peter Jenniskens[1]

The CAMS network detected a stronger than usual return of bright meteors from the compact December α-Bootids meteor shower in 2015. The observed activity was spread over three nights. The shower is detected at a weaker level in other years by CAMS and by the SonotaCo network. Orbital elements show a gradual increase in longitude of perihelion with solar longitude from $\Pi = 12°$ to $25°$. This behavior is currently not understood.

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When examining the results of the CAMS network from the month of December, I noticed a compact shower in the apex source, on the early morning side. All but one of the 13 meteors in the gray square of highlighted ecliptic radiants in Figure 1 are from the nights of December 14–16. The one outlier was from December 31. Results for the smaller solar longitude interval $\lambda_\odot = 261.^\circ0$–$265.^\circ0$ are reproduced in the right graph of Figure 1.

The shower is identified as the December α-Bootids (#497, DAB) in the IAU Working List of Meteor Showers, first detected by Rudawska & Jenniskens (2014) and confirmed by Kornos et al. (2014) and Jenniskens & Nénon (2016). It nominally peaks at solar longitude $263.^\circ9$, with a geocentric radiant at RA = $213.^\circ5$, Dec = $+22.^\circ3$ (and geocentric entry speed 59.5 km/s), not far from Arcturus.

The trajectory and orbital elements data are given in Table 1. The meteors are spread fairly evenly over three days, with rates highest in the early morning hours when the radiant is well above the horizon. Meteors on December 16 have slightly higher longitude of perihelion ($\Pi = 17.^\circ8$–$25.^\circ6$) than those seen on December 14 and 15 ($13.^\circ3$–$19.^\circ9$).

All meteors are bright. From -4 magnitude and brighter, the number of observed meteors is $N = 1$, 1, 2, 3, 4, and 1. Compared to the magnitude distribution of all meteors observed in December, and assuming that the population is complete for bright meteors, the magnitude distribution index for the shower is a low $\chi = 1.61 \pm 0.18$. The lightcurves were mostly broad U-shaped, irregular at the top, with meteors on December 15 rising noticeably slower (Table 1).

In past years, the December α-Bootids were only a weak shower compared to the more prominent December σ-Virginids (DSV) and December χ-Virginids (XVI) showers (Figure 2).

The shower was also detected annually by the SonotaCo network (SonotaCo, 2009), again weaker in activity than those other streams (Figure 3). The number of DAB detected each year since 2007: 0, 3, 3, 2, 3, 3, 2. The SonotaCo data confirm the change in Π (Figure 4).

The reason for the unusual activity is not clear. The orbital elements are those of a long-period comet. The 1-revolution dust trail of a typical few-km size long-period comet wagging into Earth's path is expected to cause only a 1–2 hour increase of rates, unless the ejec-

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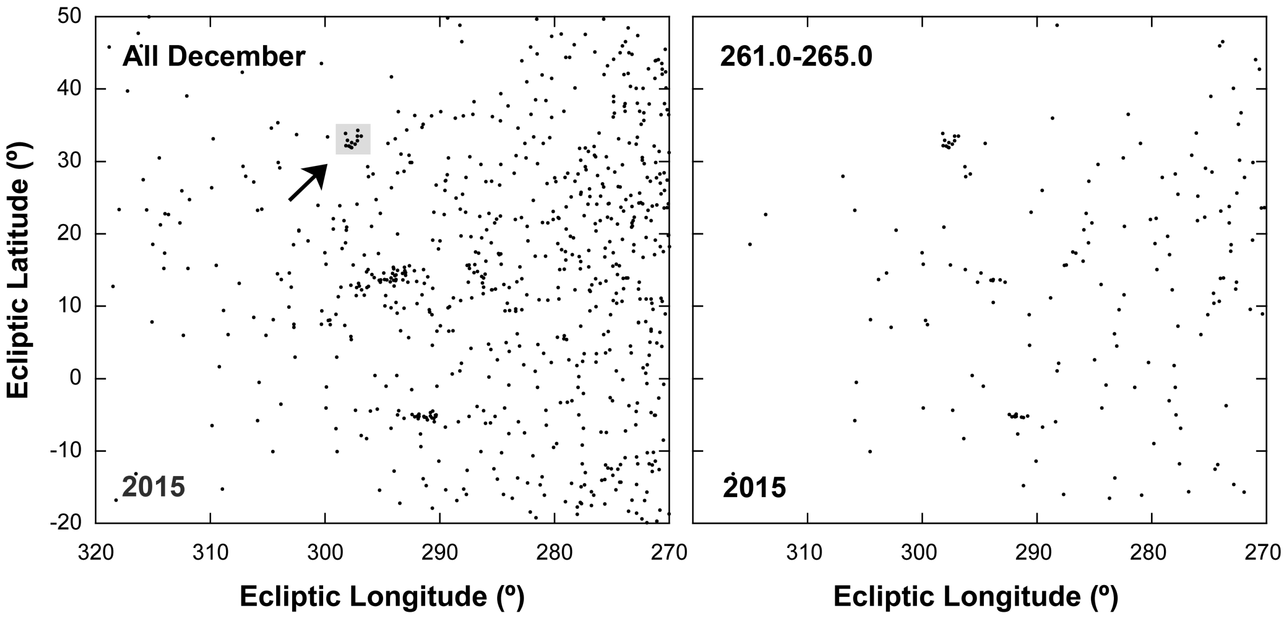

Figure 1 – Meteors detected by the CAMS network in the month of December. Right: Meteors in 2015.

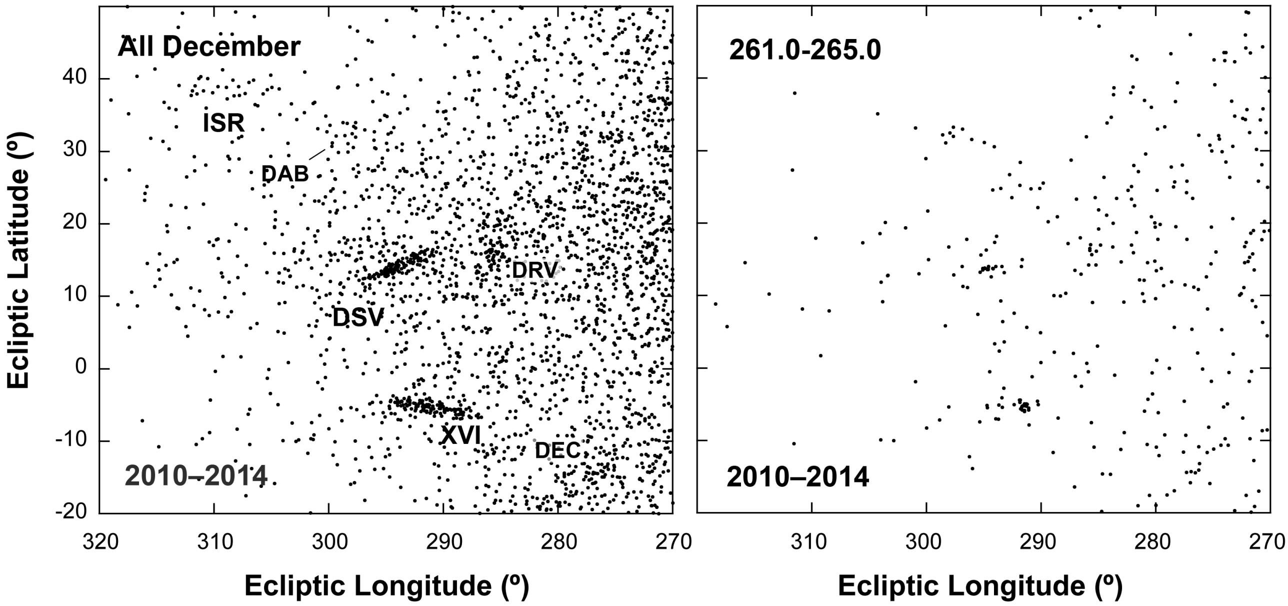

Figure 2 – December meteors detected by CAMS in 2010–2014, with known showers marked: the December α-Bootids (DAB), ι-Serpentids (ISR), December σ-Virginids (DSV), December ρ-Virginids (DRV), December χ-Virginds (XVI), and December ε-Craterids (DEC).

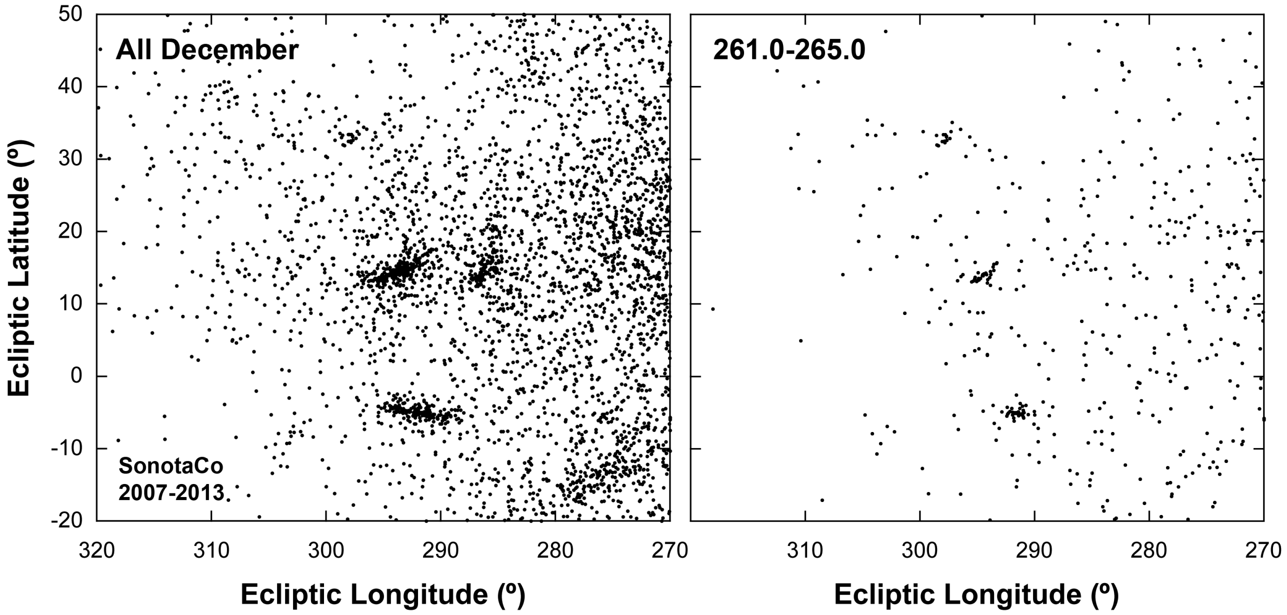

Figure 3 – December meteors detected by the SonotaCo network between 2007 and 2013.

tion velocities are particularly high (Jenniskens, 2006). Given that q is only about 0.7 AU, that could require a large comet nucleus. That said, I do notice that the 1-revolution dust trail of the long-period 1995 alpha-Monocerotids (Jenniskens et al., 1997) also had a trend of increasing longitude of perihelion (from $\Pi = 147°$ to $151°$) across the stream profile, possibly as a result of the ejection process.

Acknowledgements

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Table 1 – Trajectory and light curve of December α-Bootids in 2015.

Date (Dec.)	Time (UT)	$\lambda_\odot$ (°)	RA_∞ † (°)	Dec_∞ (°)	V_∞ (km/s)	a_1 (km/s)	a_2 (1/s)	H_b (km)	H_e (km)	Q (°)	M_v (magn.)	F	Shape ††	Stations
14	$12^h24^m13^s$	261.976	210.27 ± 0.31	$+21.96 \pm 0.10$	61.25 ± 0.09	0.01 ± 0.02	0.16 ± 0.09	109.9	95.6	28.3	+0.2	0.38	U,pe	FP,SV,LO
14	$13^h00^m58^s$	262.002	210.51 ± 0.79	$+21.94 \pm 0.18$	61.58 ± 0.69	0.02 ± 0.02	0.01 ± 0.08	107.5	100.0	38.9	+0.8	0.45	U,pe	SV,FP
15	$12^h20^m50^s$	262.991	211.66 ± 0.10	$+21.71 \pm 0.06$	61.35 ± 0.03	0.00 ± 0.00	0.32 ± 0.09	118.9	95.3	70.2	−1.8	0.88	U,sl	FP,FH,LO
15	$13^h15^m37^s$	263.030	211.62 ± 0.44	$+21.66 \pm 0.10$	61.03 ± 0.13	0.01 ± 0.07	0.25 ± 0.15	112.6	96.6	18.0	−0.9	0.75	U,sl	LO,FP
15	$13^h57^m47^s$	263.060	211.46 ± 0.11	$+22.07 \pm 0.09$	62.81 ± 0.32	0.51 ± 0.05	1.70 ± 0.15	117.8	86.7	51.7	−4.2	0.85	U,sl	LO,SV,FH
15	$14^h10^m54^s$	263.069	212.28 ± 0.27	$+22.30 \pm 0.10$	61.00 ± 0.84	0.00 ± 0.12	0.25 ± 2.19	111.9	94.6	20.2	−0.8	0.77	U,sl	LO,FP
16	$11^h27^m08^s$	263.970	211.76 ± 0.12	$+23.10 \pm 0.27$	61.10 ± 0.09	0.02 ± 0.02	0.62 ± 0.13	108.9	99.5	51.0	+0.4	0.42	U,pe	SV,FH
16	$12^h27^m35^s$	264.013	212.32 ± 0.46	$+22.85 \pm 0.11$	63.90 ± 1.63	0.54 ± 0.40	2.84 ± 0.36	110.1	99.0	31.7	−0.1	0.54	U,pe	SV,FP
16	$12^h31^m36^s$	264.016	212.04 ± 0.04	$+22.32 \pm 0.03$	61.04 ± 0.02	0.00 ± 0.01	0.16 ± 0.06	118.0	91.0	78.9	−2.8	0.68	U	all
16	$13^h19^m13^s$	264.050	209.86 ± 0.18	$+22.78 \pm 0.06$	62.17 ± 0.33	0.36 ± 0.03	3.09 ± 0.29	103.2	88.5	44.8	−0.6	0.72	U	FP,FH,SV
16	$14^h04^m19^s$	264.081	213.67 ± 0.09	$+22.79 \pm 0.03$	64.16 ± 0.42	0.01 ± 0.02	6.67 ± 0.92	119.3	78.9	46.7	−1.7	1.00	U,wd	FP,SV,LO
16	$14^h14^m37^s$	264.089	212.73 ± 0.33	$+21.81 \pm 0.34$	62.82 ± 1.83	0.10 ± 0.07	9.98 ± 0.08	109.5	101.9	43.8	+0.5	0.56	U	LO,SV
<median>		*263.52*	*211.71 ± 1.07*	*+22.19 ± 0.50*	*61.47 ± 1.15*	*0.01 ± 0.21*	*0.47 ± 3.15*					*0.70*		

† Errors in Right Ascension are given as ΔRA ∗ *cos*(Dec); a_1 and a_2 are defined in Jenniskens et al. (2011).

†† Notes: U = U-shaped; V = flare, V-shaped; wd = wide; pe = peak early; sl = slow rise.

Table 1 – (continued) – geocentric radiant and orbital elements.

$\lambda_\odot$ (°)	RA_g (°)	Dec_g (°)	V_g (km/s)	q (AU)	$1/a$ (1/AU)	a (AU)	e	i (°)	ω (°)	Ω (°)	Π (°)
261.976	210.59 ± 0.32	$+21.81 \pm 0.30$	59.91 ± 0.10	0.675 ± 0.007	0.034 ± 0.016	29	0.977 ± 0.011	114.98 ± 0.46	111.35 ± 0.90	261.9660 ± 0.0002	13.32 ± 0.91
262.002	210.69 ± 0.77	$+21.84 \pm 0.77$	60.29 ± 0.73	0.679 ± 0.018	-0.001 ± 0.070	∞	1.000 ± 0.048	115.13 ± 1.32	112.37 ± 2.73	261.9921 ± 0.0012	14.36 ± 1.73
262.991	211.98 ± 0.11	$+21.56 \pm 0.09$	60.01 ± 0.03	0.674 ± 0.002	0.002 ± 0.005	470	0.999 ± 0.003	114.36 ± 0.14	111.64 ± 0.26	262.9810 ± 0.0001	14.62 ± 0.26
263.030	211.76 ± 0.44	$+21.56 \pm 0.46$	59.73 ± 0.15	0.673 ± 0.010	0.036 ± 0.023	28	0.976 ± 0.015	114.40 ± 0.65	111.06 ± 1.36	263.0198 ± 0.0003	14.08 ± 1.36
263.060	211.47 ± 0.10	$+21.98 \pm 0.21$	61.59 ± 0.30	0.704 ± 0.005	-0.118 ± 0.026	∞	1.083 ± 0.019	115.71 ± 0.34	116.84 ± 0.81	263.0496 ± 0.0007	19.89 ± 0.81
263.069	212.26 ± 0.26	$+22.22 \pm 0.53$	59.76 ± 0.88	0.683 ± 0.014	0.003 ± 0.076	342	0.998 ± 0.052	113.30 ± 0.91	112.83 ± 2.63	263.0588 ± 0.0016	15.89 ± 2.63
263.970	212.27 ± 0.12	$+22.88 \pm 0.13$	59.75 ± 0.08	0.708 ± 0.003	0.015 ± 0.009	65	0.989 ± 0.006	113.22 ± 0.21	115.79 ± 0.39	263.9602 ± 0.0002	19.75 ± 0.39
264.013	212.58 ± 0.51	$+22.75 \pm 0.74$	62.62 ± 1.70	0.730 ± 0.019	-0.244 ± 0.153	∞	1.178 ± 0.115	115.04 ± 1.57	121.54 ± 3.63	264.0033 ± 0.0021	25.54 ± 3.63
264.016	212.31 ± 0.04	$+22.19 \pm 0.04$	59.71 ± 0.03	0.694 ± 0.001	0.031 ± 0.003	33	0.979 ± 0.002	113.81 ± 0.07	113.81 ± 0.14	264.0061 ± 0.0001	17.81 ± 0.14
264.050	209.94 ± 0.20	$+22.71 \pm 0.26$	60.91 ± 0.34	0.736 ± 0.006	0.014 ± 0.031	71	0.990 ± 0.023	116.70 ± 0.42	119.59 ± 1.14	264.0399 ± 0.0007	23.63 ± 1.14
264.081	213.63 ± 0.09	$+22.72 \pm 0.24$	62.98 ± 0.40	0.725 ± 0.005	-0.319 ± 0.037	∞	1.231 ± 0.028	114.22 ± 0.36	121.57 ± 0.91	264.0717 ± 0.0009	25.64 ± 0.91
264.089	212.68 ± 0.31	$+21.73 \pm 0.72$	61.63 ± 1.64	0.703 ± 0.020	-0.138 ± 0.147	∞	1.097 ± 1.06	115.26 ± 1.37	116.99 ± 3.89	264.0789 ± 0.0024	21.07 ± 3.89
<median>	*212.12 ± 1.03*	*+22.08 ± 0.49*	*60.15 ± 1.19*	*0.698 ± 0.023*	*0.003 ± 0.120*	—	*0.998 ± 0.008*	*114.69 ± 1.00*	*114.80 ± 3.88*	*263.51 ± 0.79*	*18.78 ± 4.49*

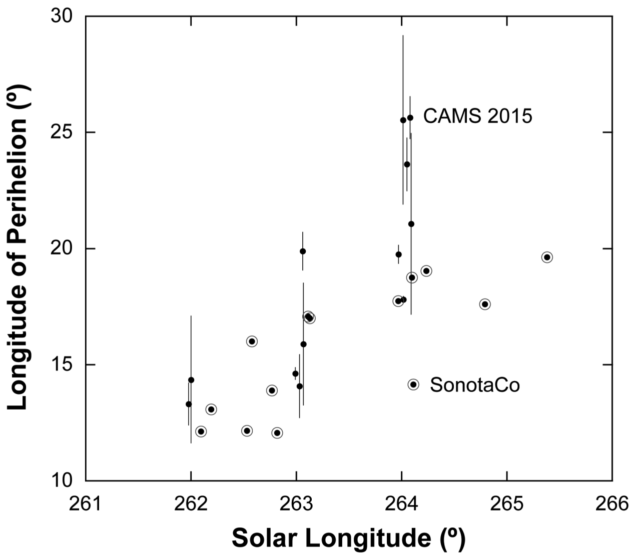

Figure 4 – Change of longitude of perihelion with position along Earth's path.

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Central European MetEor NeTwork: Current status and future activities

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The Central European video Meteor Network (CEMeNt) established in 2010 is a platform for cross-border cooperation in the field of video meteor observations between Czech Republic and Slovakia. During five years of operation the CEMeNt network went through an extensive development. In total, 37 video systems were working on 20 permanent stations located in Czech Republic and Slovakia during 2015. In this paper we summarize CEMeNt current status and introduce some future activities.

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1 Introduction

The Central European video Meteor Network (CEMeNt) was established in 2010 by Roman Piffl (Slovakia) and Jakub Koukal (Czech Republic, Society for Interplanetary Matter, SMPH, z. s.[a]) as a non-institutional platform for cross-border cooperation in the field of video meteor observations in central Europe. From the beginning the CEMeNt has been organized as a network of mostly amateur astronomers with low-cost, wide field video-systems for meteor activity monitoring. The CEMeNt observational activities have been coordinated with professional Slovak Video Meteor Network (SVMN, (Tóth et al., 2008)), as well as with other similar networks in the area of central Europe (especially Hungarian Meteor Network, HMN (Igaz, 2012) and Polish Fireball Network, PFN (Olech et al., 2006)). Acquired meteor data enables scientists to obtain high precision positions and velocity observations for multistation meteor orbits calculations.

Video-systems used in CEMeNt are based on various types of sensitive CCTV video cameras with 1/3" or 1/2" chip and fast ($\sim f/1.0$) varifocal lenses. For detection and analysis, the UFOTools software pack by SonotaCo (SonotaCo, 2009) is used. Most of the stations are 'wide field' with a diagonal field of view about 60–90 degrees. Camera systems are sheltered in weatherproof and heated housings (generally used for security camera systems). In the area of central Europe these stations are able to work for the whole year, without climatic limitations. Some of the stations can also be operated on-line with necessary technical service only. A new type of specialized high sensitive camera system with narrow field of view was introduced in 2015. The system is called the NFC (Narrow Field Camera, (Koukal et al., 2015b)) and now six NFC stations are operating in the CEMeNt network. For more information, see chapter 'NFC project'.

All meteor data produced in the CEMeNt network are available in an open database EDMONd (Kornoš et al., 2014).

Since 2014, the research in CEMeNt is also oriented on spectral observations of bright meteors (Koukal et al., 2015a). Spectroscopic systems are using a classical wide field station design with diffraction grating added in front of the lens. Detailed information on the CEMeNt meteor spectroscopy project is in the chapter entitled 'Spectroscopic observations'.

Except for the video meteor observations, a radio experiment SMRST (Small Meteor Radio Scatter equipmenT) is operated in cooperation with SMPH at Vsetín Observatory. The main goal of these devices is to monitor meteor activity during daylight. In cases of bright bolides, it is possible to link radio detections with their video counterparts.

2 Stations introduction

In total, 37 video systems had been installed on 20 permanent stations located in Czech Republic and Slovakia in February 2016. In the following chapter, we would

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like to introduce some stations with exceptional personal or institutional backgrounds. Stations are sorted alphabetically. In some cases, one observer/institution is operating more than one station. These are only mentioned briefly in the main text. The full station summary is in Table 1.

Banská Bystrica Observatory

The *Banská Bystrica Observatory*[b] is a subsidiary of *Maximilian Hell Observatory and Planetarium in Žiar nad Hronom* (Banská Bystrica Region, Slovakia). The observatory is located on the Vartovka Hill, near the town of Banská Bystrica, where the video meteor station **Vartovka** is also installed. In its scientific work, the observatory is focused on interplanetary matter research. Video-meteor observations, cooperated with CEMeNt, started in August 2012. Station operation and data processing is supported by observatory staff.

František Krejčí Observatory in Carlsbad

Stations **Karlovy Vary**, **Ostrov**, **Toužim** and **Sokolov** (all in Karlovy Vary Region, Czech Republic) are operated from *František Krejčí Observatory in Carlsbad* by observatory staff. These stations were installed in 2015 as a part of educational project realized in cooperation with SMPH.

Kroměříž

Kroměříž is privately funded station located at a loggia of an apartment house on the outskirts of the town Kroměříž (Zlín Region, Czech Republic). The station is equipped with two wide field cameras. The southeastern camera has been in operation since October 2011, the northeastern one from January 2012. The other CEMeNt station − Maruška − is also operated from Kroměříž. In April 2015 the first camera of the NFC system was also installed in Kroměříž (see chapter 'NFC project'). All of these camera systems' operation and data processing is supported by owner Jakub Koukal.

Maruška

Video meteor station **Maruška**[c] is located at a climatological station of the *Czech Hydro Meteorological Institute*[d] (CHMU) on the Maruška Hill in Hostýn Mountiens (Zlín Region, Hošťálková, Czech Republic). This station is equipped with two wide field cameras. The first camera has been in operation since June 2012. The second camera was installed in October 2012. These stations were realized in cooperation with SMPH.

Kysuce Observatory

The station in Kysucké Nové Mesto (Žilina Region, Slovakia) has a special importance among the CEMeNt stations. It is operated by *Kysuce Observatory* (headquarters of the *Regional Observatory in Žilina*, organization funded by Žilina Region local government). On the roof of the Kysuce observatory main building, an all sky camera system AMOS (Zigo et al., 2013) is installed. It was developed by *Astronomical and Geophysical Observatory* of the *Komenius University in Bratislava* for professional network SVMN. This station was installed in 2011 during parallel cross-border experiments with *Valašské Meziříčí Observatory*, within the framework of the educational/scientific project KOSOAP[e]. Data from this camera are also part of the SVMN archive and so the Kysucké Nové Mesto station plays a key role in CEMeNt /SVMN cooperation.

In 2015 the third station of the NFC system was installed in Kysucké Nové Mesto (see chapter 'NFC project'). The NFC system operation and data processing is supported by observatory staff.

Nýdek

The Nýdek (Nýdek Gora, Moravian-Silesian Region, Czech Republic) is a private founded station, one of the longest operational stations of the CEMeNt network with first meteor observation from April 2010. Since May 2011 the station is primary intended for TLE (Transient Luminous Events, (Mlynarczyk et al., 2015)) observations, but meteor cameras are still operational and useful for covering the northern part of the CEMeNt network. Station operation and data processing is supported by owner, Martin Popek.

Otrokovice

Station **Otrokovice** is in operation since 2015 and is equipped with one meteor camera. The system is located in the backyard of a family house in the town of Otrokovice (Zlín Region, Czech Republic). The system covers the same field of view as spectroscopic cameras in Valašské Meziříčí. Operation and data processing is supported by the owner, Michael Čechmánek.

Plzeň

The video-meteor station in Plzeň (Southern Bohemia Region, Czech Republic) is operated by **Observatory and Planetarium Plzeň** (contributory organization funded by town Plzeň). The station was installed in October 2012, with a field of view enabling meteor pairing with stations operated by **František Krejčí Observatory in Carlsbad** and with a private station in Stochov. Operation and data processing is supported by Jiří Polák and observatory staff.

SOLAR Senec Observatory

The video-meteor station in **Senec** is operated by the public astronomical association *SOLAR Senec Observatory* (*SOLAR Hvezdáreň Senec*[f]). Since 2006 the association operates an astronomical observatory on the roof of the *A. Molnar Szencziho Hungarian language elementary school in Senec*[g]). The observatory is located in the center of town Senec (Bratislava Region, Slovakia). In January 2015 SOLAR association joined the CEMeNt network when two CCTV camera sys-

[b] `http://www.astrobb.sk`
[c] `http://maruska.ordoz.com`
[d] `http://portal.chmi.cz`
[e] `www.astrovm.cz/cz/program/projekty/realizovane-projekty/kosoap.html`, in Czech
[f] `http://www.solarastronomy.sk`
[g] `http://zsamszencziho.edupage.sk`

Table 1 – CEMeNt 2015 detail station list. Used abbreviations: Loc. – location (state), Alt. – altitude, Dia. – field of view diameter, Az. and Ele. – azimuth and elevation of the field of view center; camera type abbr.: SC – standard wide field camera, SP – spectrograph, NFC – Narrow Field Camera.

Station, state	Approx. coordinates. (N, E, Alt.)	Field of view Code (Dia., Az., Ele.)	Type	Operator/ Observer	Institution/ Association
Vartovka, SR	48°.718, 19°.155, 568 m	N (62°.0, 30°.7, 53°.7)	SC	S. Kanianský	Banská Bystrica Obs.
Karlovy Vary, CR	50°.216, 12°.906, 615 m	N (73°.3, 359°.5, 51°.2) S (64°.1, 197°.8, 45°.1)	SC	S. Gorková	Karlovy Vary Obs.
Ostrov, CR	50°.303, 12°.953, 400 m	S (36°.0, 152°.4, 20°.0)	SC	J. Koukal	Karlovy Vary Obs.
Otrokovice, CR	49°.211, 17°.531, 205 m	N (78°.4, 2°.2, 45°.2)	SC	M. Čechmánek J. Koukal	
Blahová, SR	48°.085, 17°.547, 124 m	01 (57°.0, 83°.5, 29°.1) 02 (85°.0, 151°.2, 49°.3) 03 (74°.2, 305°.0, 38°.4) 04 (87°.2, 240°.5, 44°.2) NFC (6°.8, 6°.3, 38°.4)	SC SC SC SC NFC	T. Csorgei	UMa Astronomy
Kostolné Kračany, SR	47°.985, 17°.567, 120 m	05 (83°.5, 12°.1, 45°.6)	SC	T. Csorgei K. Molnar	UMa Astronomy
Kroměříž, CR	49°.290, 17°.383, 222 m	ENE (76°.3, 52°.8, 41°.6) SE (74°.9, 115°.0, 43°.6) NFC (6°.8, 28°.3, 43°.4)	SC SC NFC	J. Koukal	
Kysucké Nové Mesto, SR	49°.307, 18°.765, 417 m	NFC (6°.8, 0°.0, 45°.3)	NFC	S. Gorková	Kysucké N. Mesto Obs.
Lovčica, SR	48°.683, 19°.858, 696 m	SW (91°.1, 216°.4, 59°.8)	SC	M. Korec	
Maruška, CR	49°.366, 17°.828, 656 m	SE (79°.6, 148°.2, 43°.1) SW (79°.0, 231°.9, 46°.0)	SC SC	J. Koukal	SMPH
Nýdek, CR	49°.668, 18°.769, 475 m	W (42°.1, 262°.2, 18°.0) SW (34°.3, 223°.5, 16°.3) NW (40°.7, 304°.2, 21°.3)	SC SC SC	M. Popek	
Plzeň, CR	49°.744, 13°.349, 335 m	NW (75°.8, 331°.0, 44°.7)	SC	J. Polák	Plzeň Observatory
Senec, SR	48°.220, 17°.395, 128 m	W (57°.2, 296°.9, 42°.9) E (57°.3, 62°.4, 46°.8) N (57°.1, 359°.1, 44°.3) NFC (6°.8, 11°.8, 42°.0)	SC SC SC NFC	J. Simon	Solar Observatory Senec
Sokolov, CR	50°.176, 12°.640, 425 m	NE (35°.9, 53°.9, 18°.7)	SC	J. Koukal	Karlovy Vary Obs.
Toužim, CR	50°.057, 12°.991, 625 m	S (44°.9, 161°.4, 14°.9)	SC	J. Koukal	Karlovy Vary Obs.
Valašské Meziříčí, CR	49°.463, 17°.974, 337 m	E (79°.4, 94°.1, 45°.6) S (84°.4, 176°.1, 48°.6) NFC (6°.9, 4°.0, 53°.8) SW (81°.0, 227°.3, 48°.3) NW (90°.1, 286°.5, 51°.1) N (66°.6, 348°.2, 41°.7)	SC SC NFC SP SP SP	J. Srba J. Koukal S. Gorková	Valašské Meziříčí Obs. SMPH
Vsetín, CR	49°.661, 17°.996, 389 m	E (78°.2, 93°.8, 47°.6)	SC	M. Jedlička	Vsetín Observatory
Zlín, CR	49°.218, 17°.692, 349 m	N (70°.3, 359°.6, 49°.1)	SC	J. Koukal	Zlín Observatory
Zákopčie, SR	18°.703, 49°.404, 682 m	NFC (6°.9, 2°.7, 50°.4)	NFC	P. Delinčák	
Zvolenská Slatina, SR	48°.565, 19°.256, 320 m	S (72°.9, 182°.5, 39°.8)	SC	V. Bahýl	Observatory Júlia

tems were installed. The third wide field system (facing north) has been in operation since December 2015. Operation and data processing is supported by association member Jaroslav Simon. Since October 2015 the association is also involved in realization of the NFC project with one installed camera (see 'NFC project').

Stochov

A privately funded station in Stochov was installed in 2010 as one of the first CEMeNt stations. It is located in the western part of the Czech Republic in town Stochov (Central Bohemia Region, Czech Republic), in a region without CEMeNt Slovakia segment border. Station operation and data processing is supported by owner Martin Zima. This station is coordinating observations with *František Krejčí Observatory in Carlsbad* and *Observatory and Planetarium Plzeň*.

Valašské Meziříčí Observatory

The *Valašské Meziříčí*[h] is a contributory organization founded by Zlín Region local government. Experimental video-meteor observations in Valašské Meziříčí (Zlín Region, Czech Republic) started in 2011 within the frame of the cross-border educational/research project KOSOAP realized in cooperation with Slovak partner, *Kysuce Observatory*.

During the KOSOAP project, one station for video meteor observations was tested and operated in cooperation with CEMeNt. Based on the project results, two fixed wide field camera systems were installed in November 2012. Cameras are covering the eastern and southern sky for effective cooperation with the parallel build Slovak segment.

[h] `http://www.astrovm.cz`

Since 2014, the *Valašské Meziříčí* is also involved in other CEMeNt activities (NFC project and meteor spectroscopy; see appropriate chapters). Station operation and data processing is supported by observatory staff.

Vsetín Observatory

Vsetín Observatory[i] is a subsidiary of the *Museum of the Moravian Wallachia Region* funded by Zlín Region local government. The observatory joined CEMeNt network in February 2013, station is located in the northern part of the town Vsetín (Zlín Region, Czech Republic). Operation and data processing is supported by Miroslav Jedlička and observatory staff.

Since 2009 the Vsetín Observatory is also operating the SMRST[j] experiment (Small Meteor Radio Scatter equipmenT) for radio meteor detection.

UMa Astronomy Association

Civil astronomical association *UMa Astronomy* operates two stations for video meteor observations. In Blahová (Dunajská Streda, Slovakia) there are actually four wide field systems installed. The first camera is in operation since November 2014, others were installed during 2015. The fifth camera operated by the association members was installed in August 2015 at new location in village **Kostolné Kračany** (Dunajská Streda, Slovakia). *Uma Astronomy association* is also involved in the NFC project realization (see chapter 'NFC project'). All systems are operated and data reduced by Tibor Csörgei and K. Molnár. UMa Astronomy video meteor database and web presentation[k] is maintained by Libor Pálinkás.

Zákopčie

Station **Zakopčie** is situated on a hill above the village Zakopčie in the northwest Slovakia, near town Čadca (Žilina Region, Slovak Republic). Meteor observations are actually devoted to the NFC project. The NFC station is located next to a small private observatory primarily focused on asteroid occultation observations and astronomical photography. Station operation and data processing for further analyses is supported by observatory owner Peter Delinčák. The observatory has its own web site[l].

Zlín Observatory

This station is located on the building of *Zlín Observatory*[m] (Zlín, Zlín Region, Czech Republic). The whole observatory is operated and funded by Zlín astronomical society (ZAS) in a building owned by town Zlín. The video meteor station was installed in June 2014 with a field of view oriented to the north (azimuth 0 deg). This orientation is important for meteor pairing and orbit calculations in cooperation with station Otrokovice and spectroscopic stations in Valašské Meziříčí. Operation and data processing is supported by members of the astronomical society.

[i]http://www.hvezdarna-vsetin.cz
[j]http://www.hvezdarna-vsetin.cz/showpage.php?name=smrst_data
[k]http://observatory.sk/videometeor.php
[l]http://www.astronomy.sk
[m]http://www.zas.cz

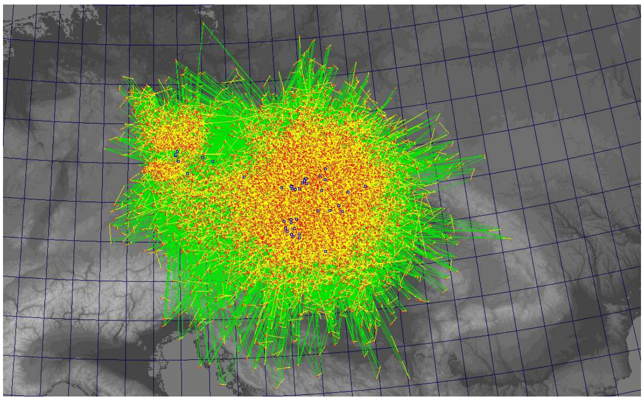

Figure 1 – Ground map (central Europe) of all multi-station meteors registered by CEMeNt stations from 2010 to 2015. Overall stations positions are marked (blue circles).

Zvolenská Slatina

Video-meteor observation at private Observatory Júlia started on August 2012 within the frame of the Bright Bolide Watch program running from May 2011. The station is located in the **Zvolenská Slatina** village, near town Zvolen (Banská Bystrica, Slovakia). The Observatory Júlia and its video-meteor station is fully privately funded and operated by owner Vladimir Bahyl. Data processing is supported in cooperation with CEMeNt co-founder Roman Piffl.

3 CEMeNt 2010–2015 short results overview

Since the CEMeNt network has now been operating for five years in a row, we would like to present here some short network observational statistics. During the period 2010 to 2015, in total, 147 368 individual meteors were registered, 26 207 of them were observed from more than one station, so it was possible to calculate their atmospheric trajectory and orbit. Figure 1 shows a ground map of central Europe with more than 26 thousand CEMeNt registered multi-station meteors.

The Figure 2 shows the radiant data for these meteors, along with color-coded velocity information. Some of the most prominent meteor showers are visible as radiant concentrations of meteors with same geocentric velocity.

The complete year/station statistics for CEMeNt network is shown in Table 2.

4 NFC project

In 2014 a new type of narrow field, highly sensitive camera system was introduced in CEMeNt. The system is called NFC (Narrow Field Camera) (Koukal et al., 2015b) and its main component is a fast 50 mm prime lens Meostigmat 1/50 (produced in CR by *Meopta*[n] since 1960, dedicated for 16 mm film projection). The

[n]http://www.meoptahistory.com/index.php?id=131

Table 2 – CEMeNt 2009–2015 wide field stations and observation statistics.

	Station location	2009	2010	2011	2012	2013	2014	2015	Total
Stations in operation	Vartovka				1 264	2 192	1 342	1 810	6 608
	Karlovy Vary				691	3 793	2 839	4 066	11 389
	Ostrov							152	152
	Otrokovice					842	893	2 134	3 869
	Blahová						364	7 561	7 925
	Kostolné Kračany							981	981
	Kroměříž		2 067	3 182	5 964	4 467	3 363	4 370	23 413
	Lovčica			73	151	596	336	609	1 765
	Maruška				4 292	5 730	4 742	4 552	19 316
	Nýdek		1 909	1 126	180	2 369	3 539	7 424	16 547
	Plzeň				837	1 854	1 499	1 186	5 376
	Senec							2 791	2 791
	Sokolov							32	32
	Toužim							356	356
	Valašské Meziříčí			520	1 799	6 051	5 713	8 007	22 090
	Vsetín					1 257	1 033	1 110	3 400
	Zlín						743	1 526	2 269
	Zákopčie				431				431
	Zvolenská Slatina				515	478	605	1 765	3 363
	Mobile st. (total)		805	432	739	70	119	355	2 520
Inactive stations	Bratislava	660							660
	Dunajská Lužná		153	318	1 017	432			1 920
	Mariánka		777	258					1 035
	Stochov		442	433	1 424	133			2 432
	Bílý Kříž				1 439	2 177	142		3 758
	Havlíčkův Brod				451	925	609		1 985
	Barrandov					1 474	1 016		2 490

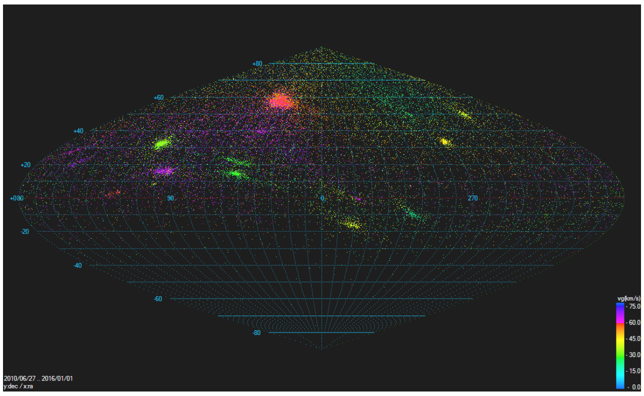

Figure 2 – Radiants of all multi-station meteors registered by CEMeNt stations from 2010 to 2015.

Watec 902H2 Ultimate CCD camera (with 1/2" chip) is used and the combination with the 50 mm prime lens results in the system narrow field of view about 10° on diagonal. The NFC camera system is able to capture meteors down to magnitude 7. At present, 6 stations equipped by the NFC are working in CEMeNt network.

Because of the narrow field of view, standard pairing of meteor observations with wide field stations is highly improbable. Since orbit calculations for meteors captured by NFC cameras has been required, the NFC network stations are organized in stable pairs. Alt./Az. orientation of cameras in each pair is set to be covering the same space in the atmosphere (at altitude 100 km). Cameras in one pair are registering the same meteors, so orbits can be calculated. Because of the lens limitations (full open construction without iris) NFC cameras are only covering an area around the northern celestial pole to avoid direct frontal solar illumination during the day.

The first two pairs of the NFC system were installed in April and May 2015 respectively. This part of the NFC network was build within the frame of the cross-border educational/research project RPKS[o] (*Evolvement of the Cross Border Network for Scientific Work and Education*) realized by Valašské Meziříčí Observatory and Regional Observatory in Žilina as KOSOAP follow-up project. The first NFC pair is operated at stations Kroměříž and Valašské Meziříčí. The second pair was installed in Slovakia at Kysucké Nové Mesto and Zákopčie.

The third NFC pair in CEMeNt was installed in October 2015, also in Slovakia. One camera is located at the observatory operated by astronomical association *SOLAR Senec Observatory* in Senec. The second is operated by *Uma Astronomy association* in Blahová.

During 2015, all six working stations of the NFC system registered together 4 324 individual meteors. The complete observation statistics of the NFC project (since the first experiments in 2014 to the end of 2015) is shown in Table 3.

[o] `http://www.astrovm.cz/cz/program/projekty/realizovane-projekty/rozvoj-preshranicni-kooperujici-site-pro-odbornou-praci-a-vzdelavani.html`, in Czech

Table 3 – NFC 2014–2015 stations and observation statistics.

NFC Station	2014	2015	Total
Kroměříž	29	1 306	1 335
Valašské Meziříčí	25	987	1 012
Senec	—	321	321
Blahová	—	403	403
Zákopčie	—	726	726
Kysucké Nové Mesto	—	581	581
Total	54	4 324	4 378
Orbits	14	919	933

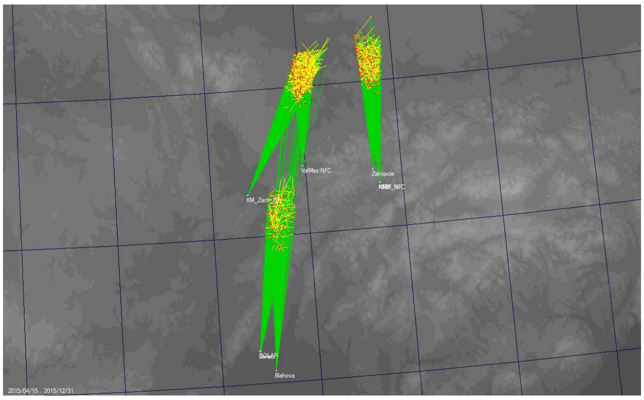

Figure 3 – Ground map of the NFC stations meteor pairings in 2015. Few three-station meteors from an experimental run of the NFC at Senec are visible (observation from Senec was for few weeks covering same atmospheric space as stable NFC pair Kroměříž-Valašské Meziříčí).

For 933 paired meteors it was possible to calculate very accurate trajectories in the atmosphere and the meteoroids' orbits in the solar system. A ground map (projection of the meteor atmospheric trajectory on the ground) for these paired meteors is shown on Figure 3.

5 Meteor spectroscopy

The first spectroscopic observations in the CEMeNt network were regularly performed by Jakub Koukal on an experimental setup from Kroměříž. Based on these experiments, two types of spectroscopic wide field systems are actually used in CEMeNt network.

The old system uses classic wide field CCTV station design only with diffraction grating (500 lines/mm) added in front of the lens. A still experimental new generation spectroscopic system uses higher resolution USB CMOS camera QHY 5L-II-M (Korec, 2015) (no TV-PAL output/input conversion, 1/3" chip with resolution 1920 × 1200). In front of the megapixel Tamron CCTV lens (M13VG308, (Korec, 2015) an Edmund Optics[p] 1000 lines/mm diffraction grating is placed. SonotaCo's UFO detection software in HD version is used experimentally in these spectroscopic systems. Theoretical spectral resolution is around 1 nm/pixel. Video data from both types of spectroscopic systems are also used for orbit calculations (together with other classic CEMeNt stations), so that we can obtain an accurate orbit of the meteoroid and basic spectral characteristic of its material.

[p]http://www.edmundoptics.com

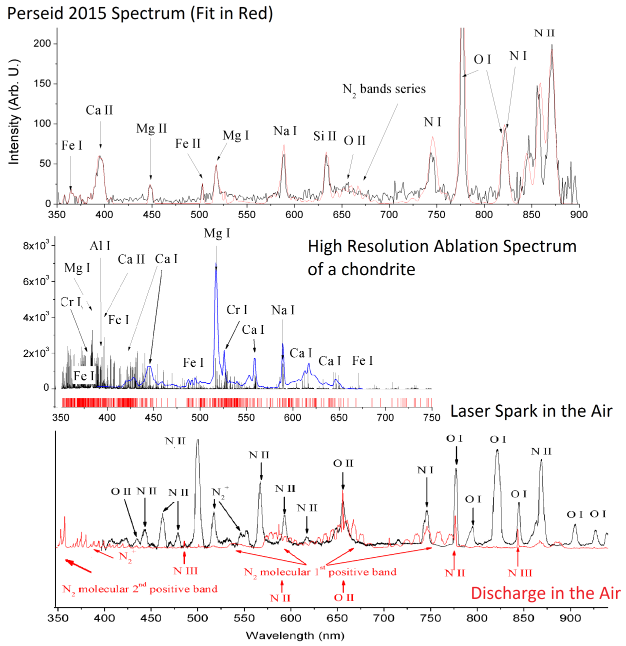

Figure 4 – Comparative spectra of a real meteor (one of the Perseid Meteor Shower 2015 – marked in black), spectra simulation (marked in red) together with high resolution laser plasma spectrum of chondrite Dhofar 1709 simultaneously measured using meteor spectrograph (in blue), and laser spark and discharge plasma in atmospheric gases.

Our goal is to collect large sample of CCTV/CCD meteor spectra for physical/chemical characteristics of incoming material, together with high quality orbits suitable for EDMOND database.

Since 2015, CEMeNt is cooperating on spectroscopic experiments with *J. Heyrovsky Institute of Physical Chemistry* (institute of the Czech Academy of Sciences) and Valašské Meziříčí Observatory. Our research project *Meteor Observation and Spectroscopy Infrastructure Evolvement*[q] has been funded by the programme of Regional cooperation of the Czech Academy of Sciences, grant no. R200401521. In order to better understand the chemistry and spectroscopy of meteor plasma, we implemented calibration free data processing in emission data evaluation and comparative algorithms for an analysis of reference spectra acquired in laboratory experiments involving Laser Induced Breakdown Spectroscopy of Meteorite samples, Laser Induced Sparks in atmospheric gases and electric discharges, together with in-situ simultaneous measurement by meteor spectrograph and high resolution echelle instrument. The results have been compared with real meteors spectra obtained from CEMeNt. All of the measurements are realized with professional laboratory equipment at J. Heyrovsky institute (Ferus et al., 2015). The example of spectral comparison is shown in Figure 4.

6 Future activities

For 2016 and the following years, we plan to expand the Slovak segment of the CEMeNt network to the mid and

[q]in Czech: Rozvoj pozorování a spektroskopie meteorů a meteoritů

eastern part of Slovakia to improve cooperation with the HMN (Hungarian Meteor Network, Magyar Hullócsillagok Egyesulet) and the MeteorsUA (Ukraine network). There are three new stations already scheduled for installation in 2016 – Rimavská Sobota Observatory (Hvezdáreň Rimavská Sobota), Roztoky Observatory (Hvezdáreň Roztoky) and Astronomical Observatory Kolonica at Kolonica saddle.

Expansion of the CEMeNt Czech segment is also planned. Some new stations are to be installed in 2016 in the central, western and northern parts of the Czech Republic – stations: Malá Skála, Aš, Žebrák Observatory and Soběslav-Svákov.

At Valašské Meziříčí Observatory two new spectroscopic cameras NE (north-east) and SE (south-east) are planned for installation to fully cover the whole sky for meteor spectra research. Other spectroscopic cameras with high resolution are to be installed by Uma Astronomy association.

In cooperation with SVMN, we plan to install wide field and spectral cameras along with the professional all sky cameras operated by SWMN at Canary Islands.

Acknowledgement

We would like to thank to all station owners, operators and observers for long term and precise work enabling CEMeNt network independent operation. Also we would like to thank to all institutions involved for still growing support of network activities.

Projects KOSOAP (Cooperating Network of Astronomic Observational Projects, in Czech: Kooperující síť v oblasti astronomických odborně-pozorovatelských programů) and RPKS (Evolvement of the Cross Border Network for Scientific Work and Education, in Czech: Rozvoj přeshraniční kooperující sítě pro odbornou práci a vzdělávání) realized by Valašské Meziříčí Observatory (CZ) and Kysuce Observatory (SK) in cooperation with Society for Interplanetary Matter (SMPH) were co-funded by European Union (Cross-border Cooperation programme Slovak Republic – Czech Republic 2007-2013).

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Handling Editor: Javor Kac

Taurid swarm exists only in southern branch (STA)

Yasuo Shiba[1]

I present some features of the Taurid meteor shower in data obtained by the Japanese automatic TV meteor observation 'SonotaCo Network' from 2007 to 2015. (i) The Taurid shower is enhanced when the Earth encounters the Taurid swarm center at less than 30° in mean anomaly as described by Asher & Izumi (1998). A little enhancement was detected in 2011 when it was 71° from the center in mean anomaly. (ii) The Taurid meteor swarm exists only in the southern branch (STA) but not in the northern branch (NTA). (iii) The Taurid meteor swarm includes bright meteors more than the annual year components as also described in Asher & Izumi (1998). (iv) The STA swarm orbital period is equal to the 2:7 resonance with Jupiter. This orbital period agrees with the suggestion in Asher & Izumi (1998). However, the NTA orbital period also matches the 2:7 resonance with Jupiter, though no swarm exists. (v) The Taurid swarm longitude of perihelion is constant at 158° over its whole period. (vi) NTA orbit features vary smoothly over the season. No complex structure could be recognized in NTA in this study of observations by small video camera. (vii) The Taurid swarm orbit differs from the annual STA orbit at its peak, but is close to the annual component at the end of swarm activity. (viii) The annual STA component consists of some similar orbital streams.

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1 Introduction

The Taurid meteor shower is an annual meteor shower display from September to December. The Taurid shower does not display not so many meteors, but includes brilliant slow fireballs, arousing the interest of observers. Two separate radiants, north and south, drift to the east over the shower's long duration (Table 1). Many researchers have been interested in this long active duration with radiant drift and combined parent body complex (e.g., Porubčan & Očenáš, 1992). The antihelion source meteor stream produces sporadic meteors over all the season. Its radiant is close to the area of the Taurid radiant. In the Taurid radiant area it is not easy to decide which meteors belong to the meteor shower. Visual observation data lack the precision to analyze details of Taurid radiant area structure. TV observations have higher potential to make clear the complexity of the radiant area. Some TV observation analyses concluded that the Taurid meteor shower consists of some sub-meteor showers (e.g., Triglav-Čekada & Arlt, 2005).

The Taurid parent body was thought to be 2P/Encke (Whipple, 1940). Recently, some asteroids on similar orbits were found and their evolution discussed. Some asteroids having similar orbits with Taurid meteors were understood collectively as the 'Taurid complex' (Porubčan & Kornoš, 2002; Porubčan et al., 2006).

New knowledge on Taurids was published by Asher & Izumi (1998). They found a theoretical explanation for Taurids' irregular appearance over many years. Complicated irregular enhanced Taurid activity was explained by a resonance with Jupiter with orbital periods in the ratio 2:7. Especially enhanced meteoroid activity was named as the 'swarm'. Enhanced Taurid meteor showers were observed at the Earth when the Taurid swarm orbit was encountered. These phenomena were confirmed by Beech et al. (2004) and Dubietis & Arlt (2007) in additional visual observation records. P. Jenniskens described enhanced activity in the Taurids' southern branch in 2008 (Green, 2008) when the Earth encountered the swarm orbit.

Table 1 – Taurid radiants (J2000) from IAU Meteor Data Center (Kanuchova & Jopek, 2016). References: [1] Porubčan & Kornoš (2002); [2] Kresák & Porubčan (1970); [3] Jopek et al. (2003); [4] Brown et al. (2008); [5] SonotaCo (2009); [6] Brown et al. (2010).

00002 STA Southern Taurids							
Activity	$\lambda_\odot$ [deg]	RA [deg]	Dec [deg]	dRA [deg]	dDec [deg]	V_g [km/s]	Ref
annual	224	49.4	13	0.73	0.18	28	[1]
annual	207.6	40.6	10.3			27.8	[3]
2002–06	196.5	31	8	0.82	0.29	27.92	[4]
2007–08	219.7	50.1	13.4	0.73	0.16	27.2	[5]
2002–08	196	30.9	8.1	0.82	0.29	28.2	[6]

00017 NTA Northern Taurids							
Activity	$\lambda_\odot$ [deg]	RA [deg]	Dec [deg]	dRA [deg]	dDec [deg]	V_g [km/s]	Ref
annual	224	58.6	21.6	0.8	0.16	28.3	[1]
annual	224	44	18.9	0.82	0.22	30.69	[2]
annual	214.1	44.7	19.8			29.6	[3]
2002–06	224.5	53.3	21	0.88	0.19	28.1	[4]
2007–08	234.4	62	24	0.65	0.12	29.7	[5]
2002–08	219	48.9	17.7	0.84	0.25	28.1	[6]

The 'SonotaCo network', an amateurs' automatic TV meteor observation network, has operated in Japan from 2007 (SonotaCo, 2009). A high sensitivity small TV camera with mounted 3.8–12 mm lens can record brighter than +2 magnitude meteors. Observers analyze meteors and upload their analyzed data on to the SonotaCo network site. At 2015, about 20 regular observers upload meteor data. These data have enough potential to study the complexity of the Taurid meteor shower. Visual observation cannot accurately determine the Taurid radiant branches but TV observations' resolution realises the opportunity to study easily the Taurid complex. On the other hand, photo-

[1]SonotaCo Network, Japan. Email: kqc43540@biglobe.ne.jp

IMO bibcode WGN-443-shiba-taurids
NASA-ADS bibcode 2016JIMO...44...78S

Table 2 – Meteor shower list.

Code	No.	Meteor shower
AND	18	Andromedids
COM	20	Comae Berenicids
DAD	334	December α Draconids
DSX	221	Daytime Sextantids
GEM	4	Geminids
HYD	16	σ Hydrids
DKD	336	December κ Draconids
LEO	13	Leonids
LMI	22	Leonis Minorids
MOM	19	December Monocerotids
NOO	250	November Orionids
OCT	281	October Camelopardalids
OCU	333	October Ursae Majorids
OER	338	o Eridanids
ORI	8	Orionids
PSU	339	ψ Ursae Majorids
TPY	340	θ Pyxidids
URS	15	Ursids
AMO	246	α Monocerotids
CTA	388	χ Taurids
DPC	446	December ϕ Cassiopeiids
DSV	428	December σ Virginids
EGE	23	ε Geminids
EHY	529	η Hydrids
KUM	445	κ Ursae Majorids
LUM	524	λ Ursae Majorids
ORS	257	Southern χ Orionids
RPU	512	ρ Puppids
SLD	526	Southern λ Draconids
THA	390	November θ Aurigids
XDR	242	ξ Draconids
XVI	335	December χ Virginids

graphic observations could offer more accurate meteor orbit data. However, automatic TV observation can record so many more meteor data than photographic observation. I have carried out a Taurid meteor shower statistical study using these TV observation records from 2007–2015.

2 Observation data

All basic observation data were got from the SonotaCo network data site. Duration is the nine years from 2007 to 2015 and date from October 1 to December 10 in local time. Individual observers analyze captured meteor data by using the analyzing software UFOAnalyzer and upload to the SonotaCo Network site. I applied the orbital calculation software UFOOrbit for downloaded data to calculate individual meteors' orbital elements. The duration (October 1 to December 10) for which statistics were studied was divided into seven bins consisting of about ten day periods. Every meteor was classified into one of the following four categories: northern Taurids; southern Taurids; all other showers; and sporadic meteors. The 'other showers' class (Table 2) consists of all established meteor showers in this season as published at the IAU Meteor Data Center (MDC) with the addition of two non-established meteor showers LMI[1] and TPY. To classify meteors as northern and southern Taurids, input values to UFOOrbit are shower active duration, radiant position with its drift, and meteor velocity (Table 3). 'NTA' is Taurids northern branch, 'STA' Taurids southern branch, $\lambda_\odot$ solar longitude, 'RA' radiant right ascension, 'Dec' declination, R the radiant position's error circle radius, and V_g geocentric velocity. Classified meteor numbers are shown in Table 4. 'Showers' is belonging to all meteor showers excluding NTA and STA. Total meteor numbers for individual categories are 'showers':17162, 'NTA':2765, 'STA':3888 and 'sporadic':30272. Meteor brightness was calculated as the absolute magnitude which is standardized as if observed from a distance of 100 km.

3 Results

3.1 Taurids' appearance for individual years

Generally, meteor shower activity level is indicated as a 'Zenithal Hourly Rate' (ZHR) that is the observed meteor number under ideal sky conditions per hour by one person with the meteor shower radiant at the zenith. Automatic TV meteor observation is not equipped to record observing conditions, so that TV observation does not allow us to calculate absolute meteor influx or ZHR. Therefore I calculated number ratio of the NTA and STA to sporadic meteor number. Figure 1 is the results for every year, where $|\Delta M|$ is a quantity indicating whether the Taurid swarm is encountered (Asher & Izumi, 1998). $|\Delta M|$ is described as a function of year and is close to 0° in the 1971 Taurid season when the Earth encountered the estimated Taurid resonance center. We can expect to encounter the Taurid resonant swarm when $|\Delta M| < 30°$, which occurred the years 2008, 2012 and 2015. Of these three years, the smallest $\Delta M = 6°$ in 2015 was the year when the most spectacular Taurid shower, due to the swarm, was expected. Results agree with Asher & Izumi (1998), the years 2008, 2012 and 2015 clearly showing an increased

[1]The MDC moved LMI to the list of established showers before the final publication of this paper.

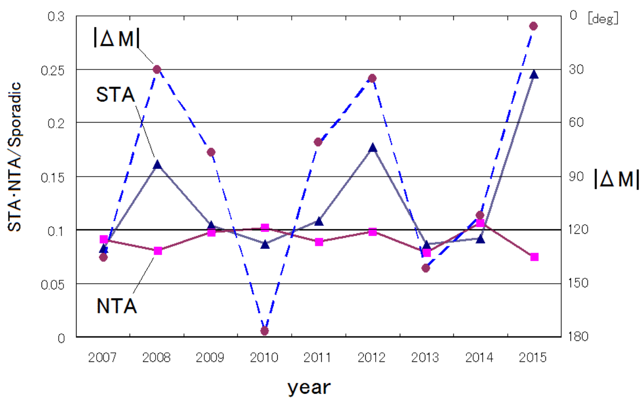

Figure 1 – Activity of NTA and STA with swarm phase $|\Delta M|$.

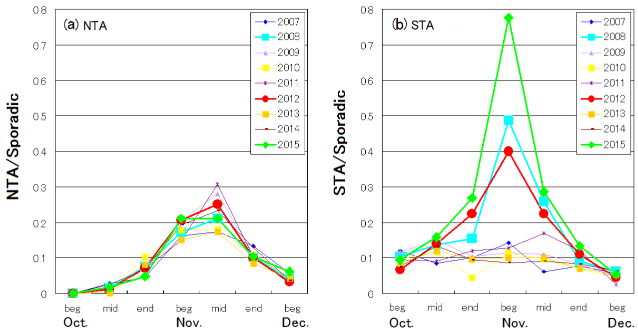

Figure 2 – (a) NTA and (b) STA activity during season.

STA meteor rate. However, NTA activity is not related with the ΔM value.

3.2 Maximum season

The number ratio of NTA and STA meteors to sporadic meteors for seven bins in every year is shown in Figure 2. NTA activity maximum is estimated at November 10–15 from Figure 2(a). The different years' NTA curves are similar to each other, and moreover, similar to IMO's TV observation results from 1999 to 2008 (Molau & Rendtel, 2009). Only the 2011 meteor ratio increased somewhat in the middle of November. The Taurid swarm is not found in Figure 2(a).

Figure 2(b) is the STA activity curve. In 2008, 2012 and 2015 the maximum was at the beginning of November which is the estimated swarm peak. Other years' STA peaks are not clear. The swarm appeared from the end of October to middle of November. The peak rate value of the swarm center, at the beginning of November in 2015, was seven times the STA rate in years with no swarm encounter. Hereafter in this paper, I describe the uniformly appearing STA meteoroids in years with no swarm encounter as 'annual components', and the meteoroids showing the clear peak components as 'swarm components'.

3.3 Meteor brightness

Meteor brightnesses are calculated as absolute magnitude by using UFOOrbit. Absolute magnitude means for a meteor observed at 100 km distance compared with stellar magnitude. Observed NTA, STA and sporadic meteors' mean absolute magnitude for every year are shown in Figure 3. The NTA mean absolute magnitude in 2011 was brighter than other years. The STA mean absolute magnitude shows fluctuation. The 2015 mean absolute magnitude was especially bright which includes the swarm component's nucleus. The other observed swarm component years, 2008 and 2012,

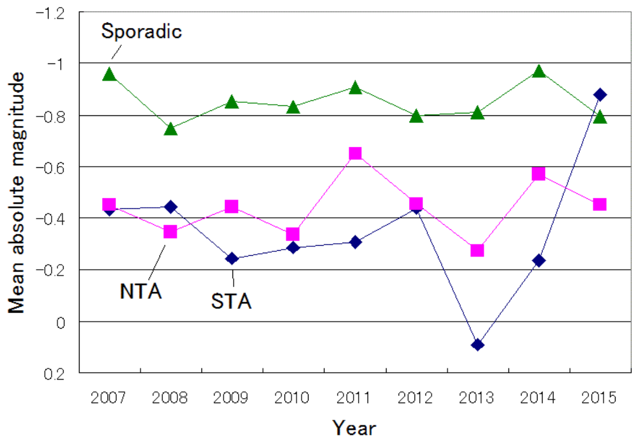

Figure 3 – Average absolute magnitude of NTA and STA.

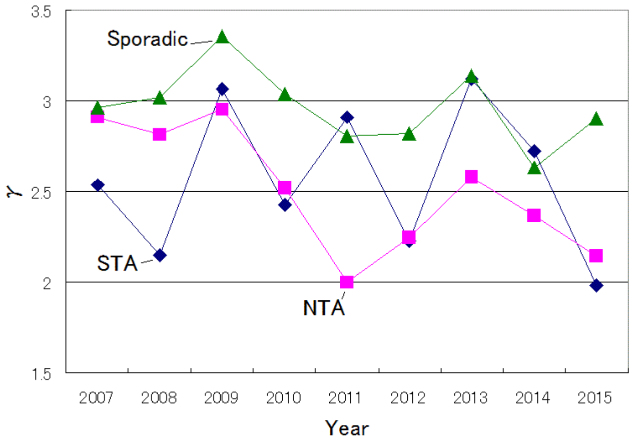

Figure 4 – Population index (r) of NTA and STA.

were somewhat bright. In contrast, 2013 was faint. Sporadic meteors show fewer fluctuations than NTA and STA (Figure 3): sporadic meteors comprise many samples and so are expected to have stable features.

The population index of NTA, STA and sporadic meteors is shown in Figure 4. Population index means by how many times the number of meteors increases for each one magnitude fainter. The population index for sporadic meteors is about 3.0 for the visual observation magnitude range (Rendtel, 2004). The SonotaCo network video observation result is the same at about 3.0 in Figure 4. For the NTA population index, 2011 was a minimum, agreeing with the increase in Figure 3 which indicated an encounter with many large meteoroids. The STA population index is small in 2008, 2012 and 2015 which agrees with the large values in Figure 3. This fact means that the Taurid swarm consists of large meteoroid particles.

Table 3 – Parameters of meteors judged to be Taurids in this study.

	NTA	STA
$\lambda_\odot$ [deg]	$202.9 \sim 258.0$	$178.0 \sim 275.3$
RA [deg]	$62.0 + 0.653(\lambda_\odot - 234.4)$	$50.1 + 0.727(\lambda_\odot - 219.7)$
Dec [deg]	$+24.0 + 0.121(\lambda_\odot - 234.4)$	$+13.4 + 0.161(\lambda_\odot - 219.7)$
R [deg]	6.6	7.2
V_g [km/s]	$15.9 \sim 39.9$	$15.6 \sim 41.9$

Table 4 – Numbers of meteors observed.

Year	2007							2008							2009						
	Oct			Nov			Dec	Oct			Nov			Dec	Oct			Nov			Dec
	beg	mid	end	beg	mid	end	beg	beg	mid	end	beg	mid	end	beg	beg	mid	end	beg	mid	end	beg
NTA	0	5	25	34	103	63	36	0	9	27	66	97	66	33	0	9	54	136	76	60	25
STA	32	15	55	30	36	37	36	50	78	55	186	119	59	49	20	111	77	75	30	46	25
Shower	12	89	1348	0	29	94	523	28	382	573	78	244	256	689	8	437	1246	110	165	193	452
Sporadic	268	178	552	210	591	473	635	475	571	357	382	460	648	803	169	736	740	661	272	549	551
Total	312	287	1980	274	759	667	1230	553	1040	1012	712	920	1029	1574	197	1293	2117	982	543	848	1053

Year	2010							2011							2012						
	Oct			Nov			Dec	Oct			Nov			Dec	Oct			Nov			Dec
	beg	mid	end	beg	mid	end	beg	beg	mid	end	beg	mid	end	beg	beg	mid	end	beg	mid	end	beg
NTA	0	5	7	157	116	60	34	0	4	42	47	72	67	9	0	8	52	100	151	38	26
STA	37	43	3	101	62	39	37	30	25	72	40	40	78	8	14	90	161	196	137	41	34
Shower	22	109	165	158	302	253	726	19	135	522	69	108	226	338	17	377	723	74	228	153	815
Sporadic	386	366	67	884	638	557	802	317	275	599	314	234	653	309	205	643	718	495	595	375	771
Total	445	523	242	1300	1118	909	1599	366	439	1235	470	454	1024	664	236	1118	1654	865	1111	607	1646

Year	2013							2014							2015						
	Oct			Nov			Dec	Oct			Nov			Dec	Oct			Nov			Dec
	beg	mid	end	beg	mid	end	beg	beg	mid	end	beg	mid	end	beg	beg	mid	end	beg	mid	end	beg
NTA	0	1	30	66	85	65	30	0	12	40	69	141	49	15	0	10	25	106	31	37	34
STA	17	66	36	44	49	55	38	17	62	57	31	55	31	26	58	88	140	391	42	46	30
Shower	12	88	184	55	242	330	722	14	178	382	63	218	210	373	42	195	526	97	52	191	493
Sporadic	202	555	370	440	487	762	703	227	463	597	356	605	377	411	608	555	522	503	147	347	551
Total	231	710	620	605	863	1212	1493	258	715	1076	519	1019	667	825	708	848	1213	1097	272	621	1108

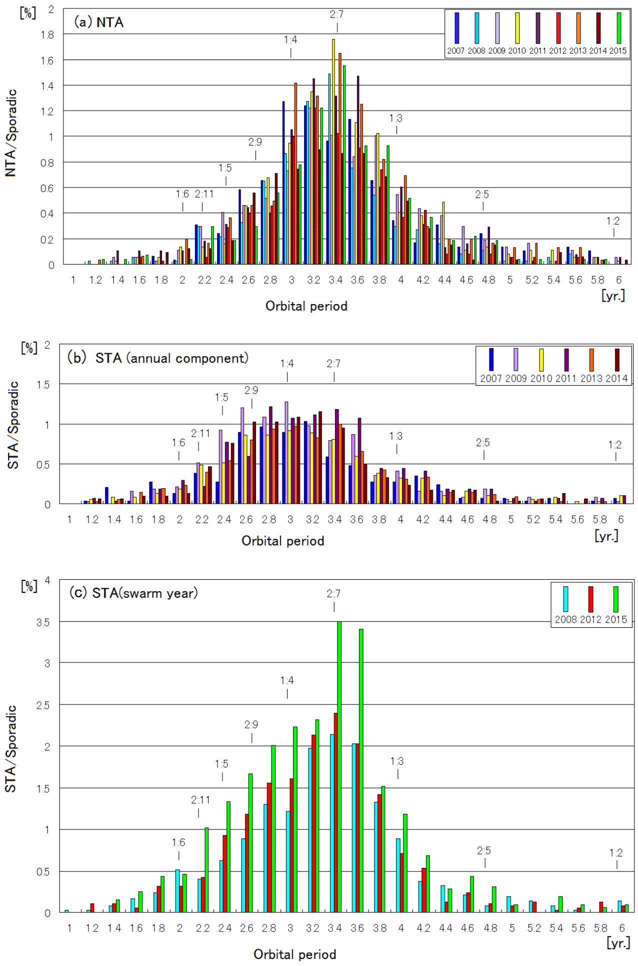

Figure 5 – Orbital period of NTA and STA.

3.4 Orbital periods

The distributions of the orbital periods were calculated by UFOOrbit for individual years (Figure 5). The vertical axis is the number ratio of Taurid meteors to sporadic meteors over the same duration. Some resonances for Jupiter's orbital period (11.86 yr) are labeled in Figure 5.

Figure 5(a) is the NTA orbital period distribution. The maximum is 3.4 yr, near the 2:7 resonance with Jupiter (3.39 yr). Figure 5(b) is the STA orbital period distribution for years with no swarm encountered, 2007, 2009, 2010, 2011, 2013 and 2014. This distribution indicates the annual Taurid components feature with a broad maximum centered around the 1:4 resonance (2.97 yr) with Jupiter. In 2011 a small peak is found at 3.2–3.6 yr in Figure 5(b). There can be considered to exist weak swarm components when the Taurid ΔM was $-71°$. Figure 5(c) is STA for swarm component years, 2008, 2012 and 2015. Again the maximum is about 3.4 yr, near the 2:7 resonance (3.39 yr) with Jupiter.

After this, statistical characteristics of some Taurid meteor orbital element features are explained, with the data divided into the 7 bins of 10 days activity.

Figures 6, 7 and 8 are orbital period statistics for the seven bins. The horizontal axis is period and vertical axis is the number ratio of Taurids to sporadic meteors over the same interval.

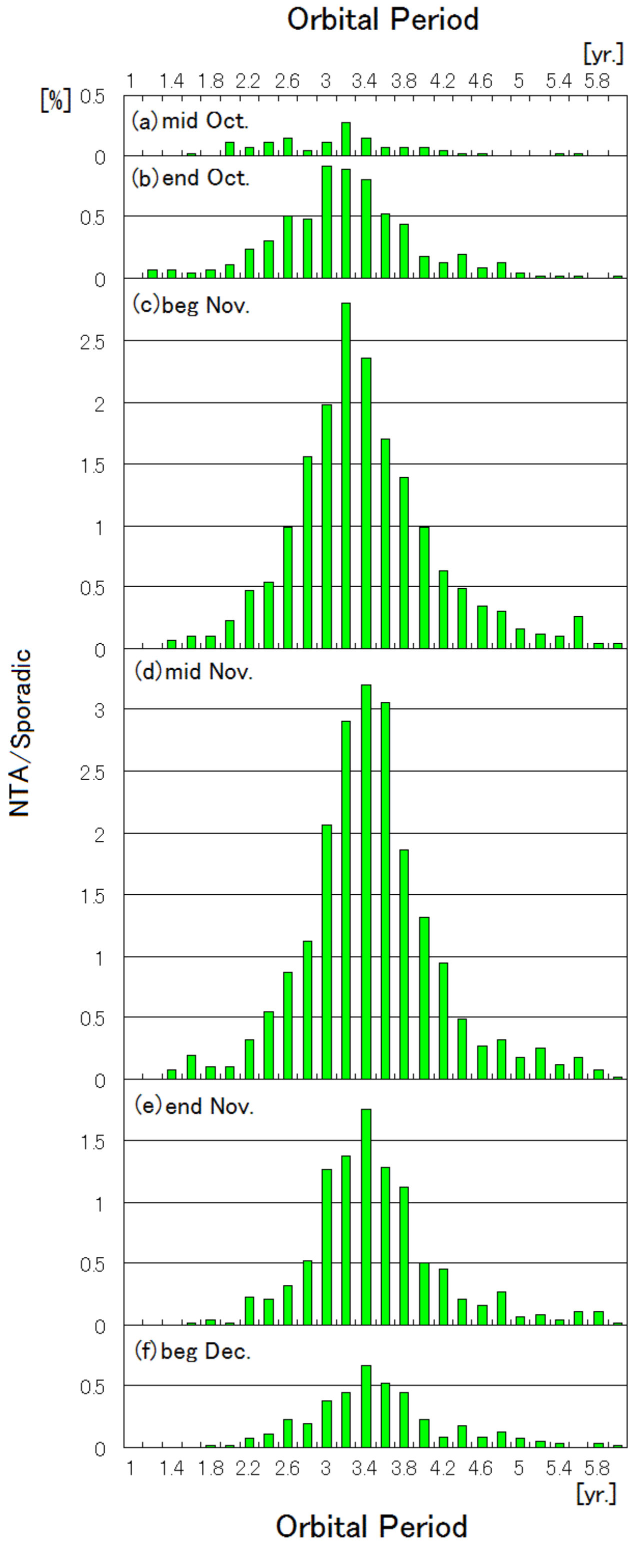

Figure 6 – Seasonal variation of orbital period (NTA).

Figure 6 shows the NTA orbital period from 2007–2015. NTA active duration was taken as being from the middle of October. Figure 6 indicates the maximum of the period distribution is 3.4 yr at the active peak season and also in the second half of the season, but a bit shorter (3.2 yr) in the first half.

Figure 7 is for the STA active season in years when the annual components were encountered (2007, 2009, 2010, 2011, 2013 and 2014). The orbital period peak

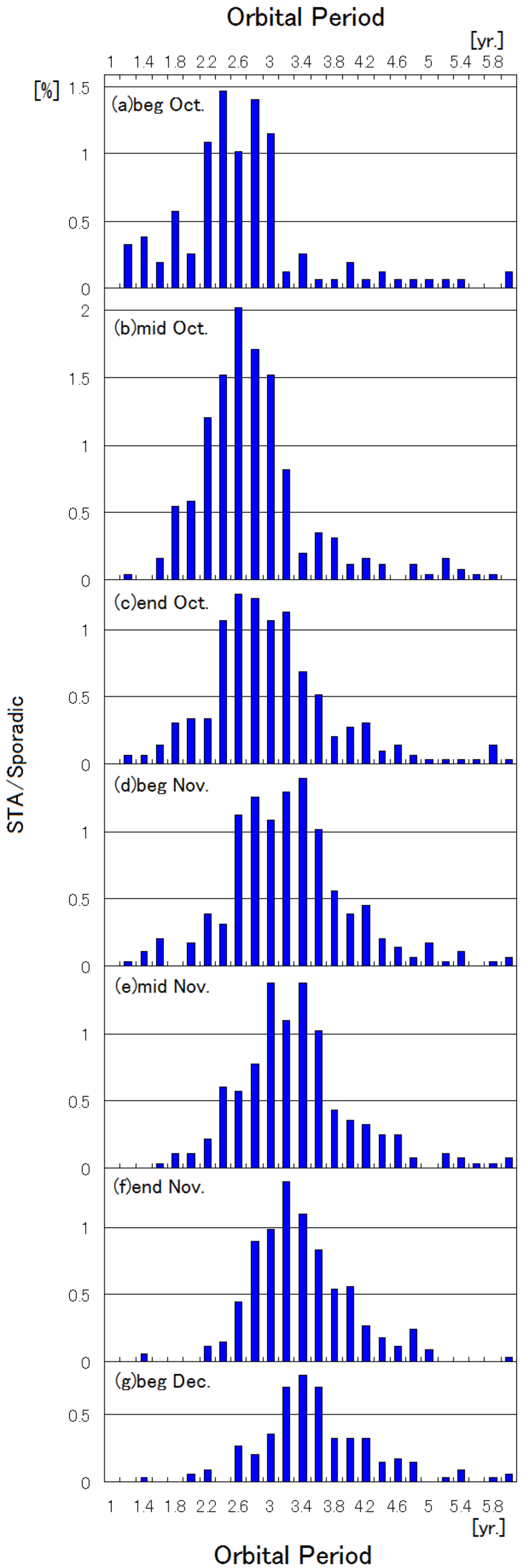

Figure 7 – Seasonal variation of orbital period (annual STA).

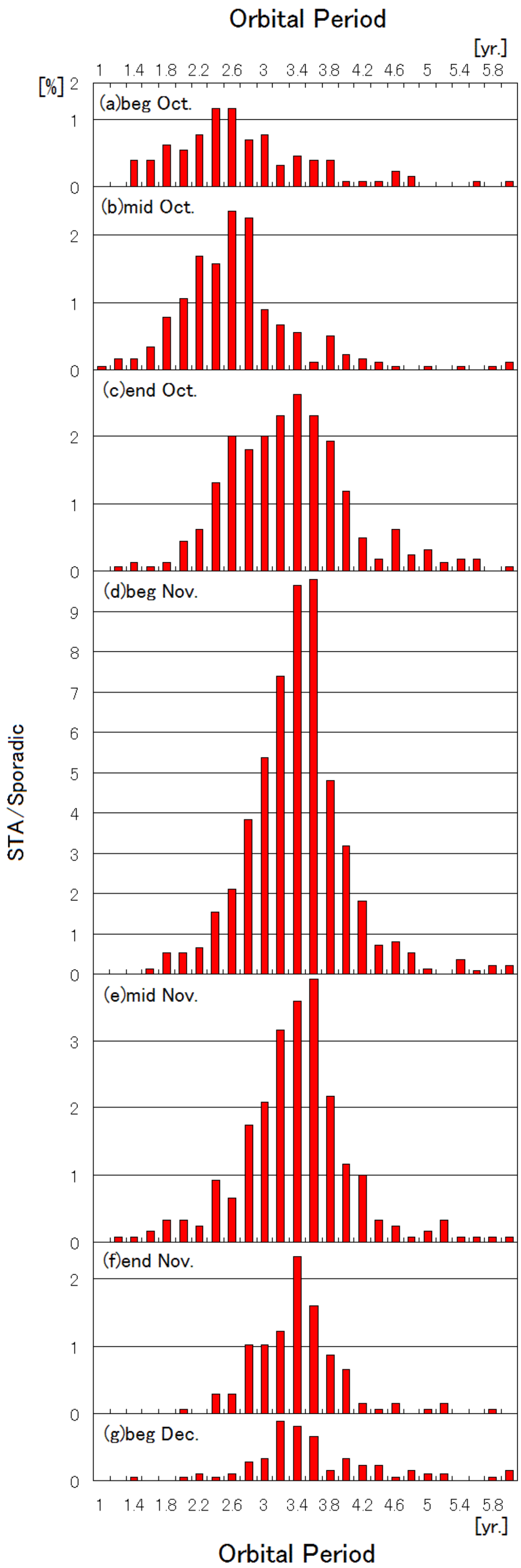

Figure 8 – Seasonal variation of orbital period (swarm year STA).

is 2.6 yr at the middle of October and increases about 0.5 yr per month. Another peak, 3.4 yr, appears from the beginning till middle of October. This peak may be swarm components included in 2011 and other years.

Figure 8 is years when the swarm components were encountered (2008, 2012 and 2015), in the STA active season. A clear peak at 3.4–3.6 yr exists. This suggests swarm components that are in 2:7 resonance with Jupiter or slightly longer.

3.5 Eccentricity

The Taurid orbit eccentricity distribution calculated by UFOOrbit from 2007 to 2015 is shown in Figures 9, 10 and 11. The horizontal axis is eccentricity and again the vertical axis is the Taurid to sporadic number ratio. The duration from October to beginning of December is divided into seven bins.

The NTA orbital eccentricity distribution is shown in Figure 9 from the middle of October to beginning of December divided into six intervals. The NTA eccentricity peak is 0.88 early in the active season (middle of October), 0.84 at maximum season (middle of November) and 0.80 at the end of the active season (beginning of December). The eccentricity peak decreased by 0.06 per month.

The eccentricity distribution peak for the STA annual components (years 2007, 2009, 2010, 2011, 2013 and 2014), shown in Figure 10, does not have a simple variation over its active season. The distribution has a complex peak which decreases to lower values of eccentricity as the season progresses.

Figure 11 is the STA swarm encounter years 2008, 2012 and 2015. The swarm component's eccentricity peak is 0.88 at the end of October, 0.85–0.86 at maximum season and 0.81 at the beginning of December: the peak goes back rapidly to lower values of eccentricity. At the end of the swarm activity season, the swarm peak is close to the annual component's peak.

3.6 Perihelion distances

The perihelion distance distribution calculated by UFOOrbit is shown in Figures 12, 13 and 14. The horizontal axis is perihelion distance [AU], vertical is Taurid to sporadic number ratio. The duration from beginning of October to beginning of December is divided into seven bins.

Figure 12 is the NTA perihelion distance distribution from 2007 to 2015 in six bins from the middle of October to beginning of December. NTA perihelion distances increase constantly at the rate of 0.05 AU per 10 days.

Figure 13 is STA in non-swarm years, 2007, 2009, 2010, 2011, 2013 and 2014. This histogram indicates that perihelion distances increase 0.04 AU per 10 days till the middle of November. However, the histogram indicates a twin peak in the ending part of the Taurid active season.

Figure 14 is the STA perihelion distance distribution when the Taurid swarm was encountered (2008, 2012 and 2015). The perihelion distance peak position increases from 0.30 AU at the end of October to 0.34 AU at the beginning of November and 0.43 AU at the middle of November. This peak shift is not constant and at the end of the swarm activity season the peak is close to one of the two annual component peaks.

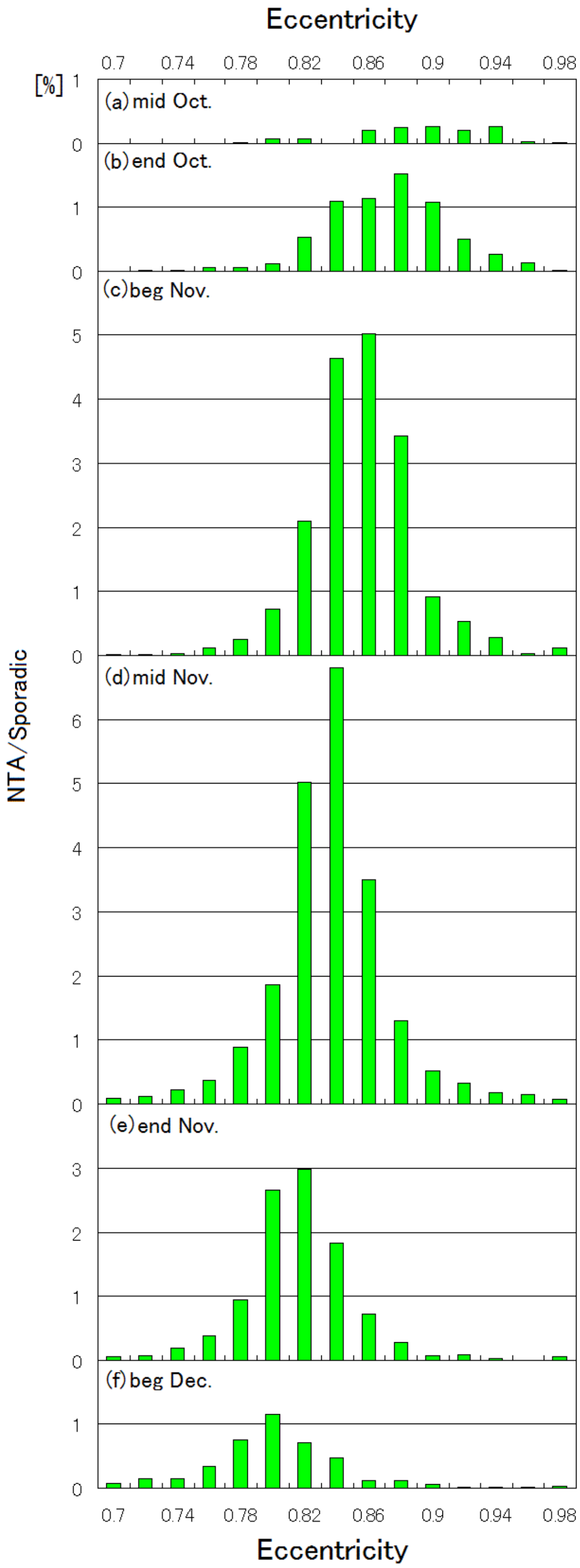

Figure 9 – Seasonal variation of eccentricity (NTA).

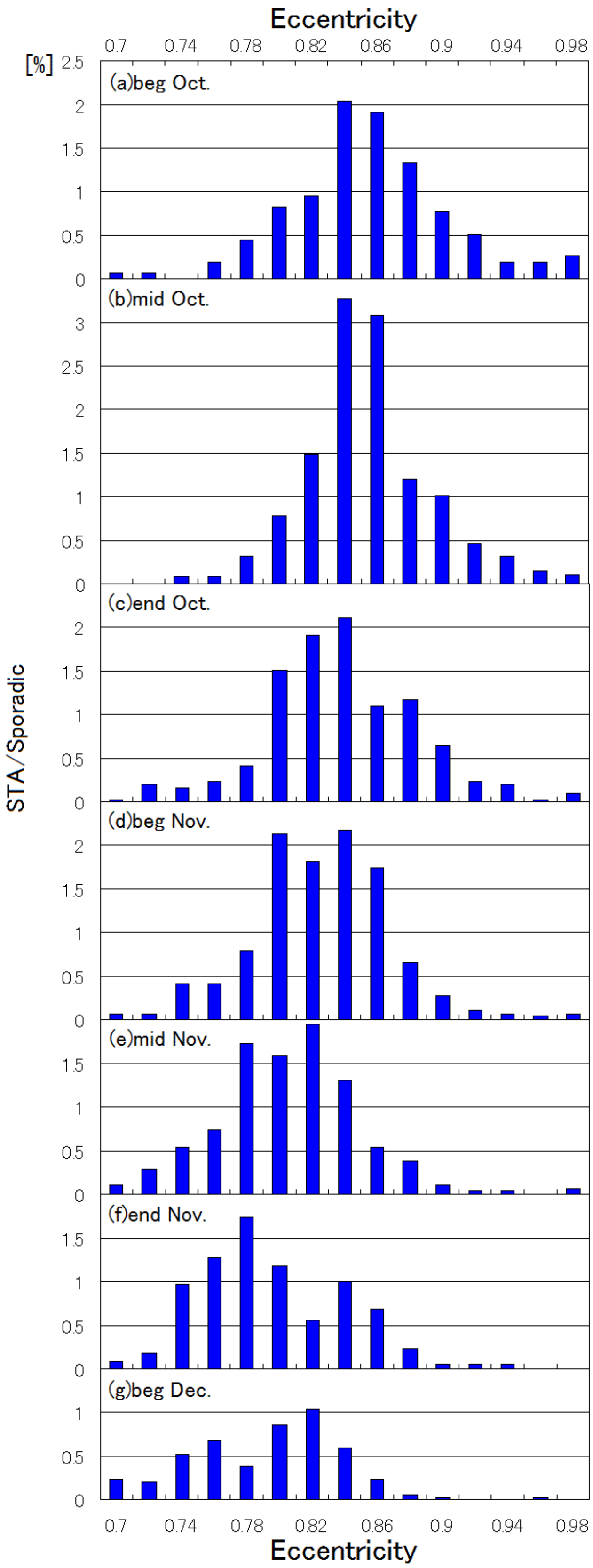

Figure 10 – Seasonal variation of eccentricity (annual STA).

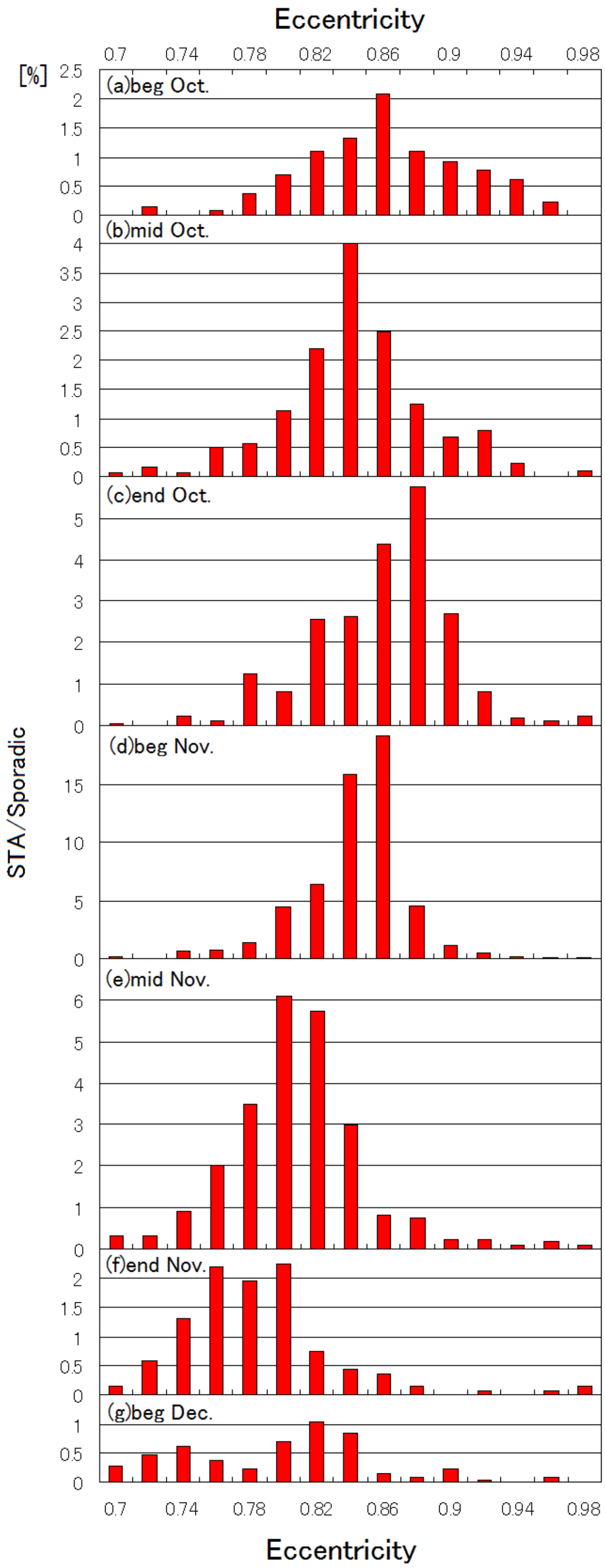

Figure 11 – Seasonal variation of eccentricity (swarm year STA).

3.7 Longitude of perihelion

Taurid meteors' orbital inclination is low. The calculated error level by small video camera observations is also considered. Thus I use the approximation that longitude of perihelion λ is obtained by adding longitude of the ascending node Ω and argument of perihelion ω:

$$\lambda = \Omega + \omega$$

The longitude of perihelion distribution calculated by UFOOrbit is shown in Figures 15, 16 and 17. The horizontal axis is λ and vertical axis is Taurid to sporadic meteor number ratio.

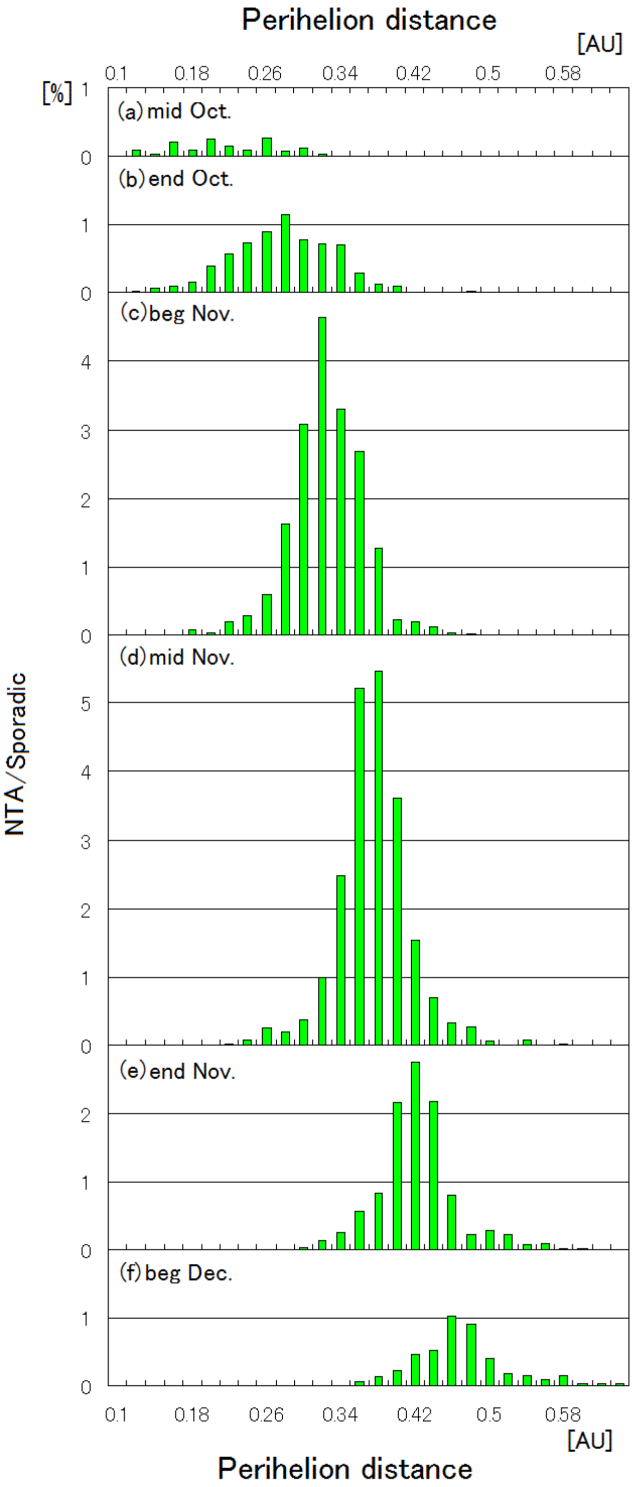

Figure 12 – Seasonal variation of perihelion distance (NTA).

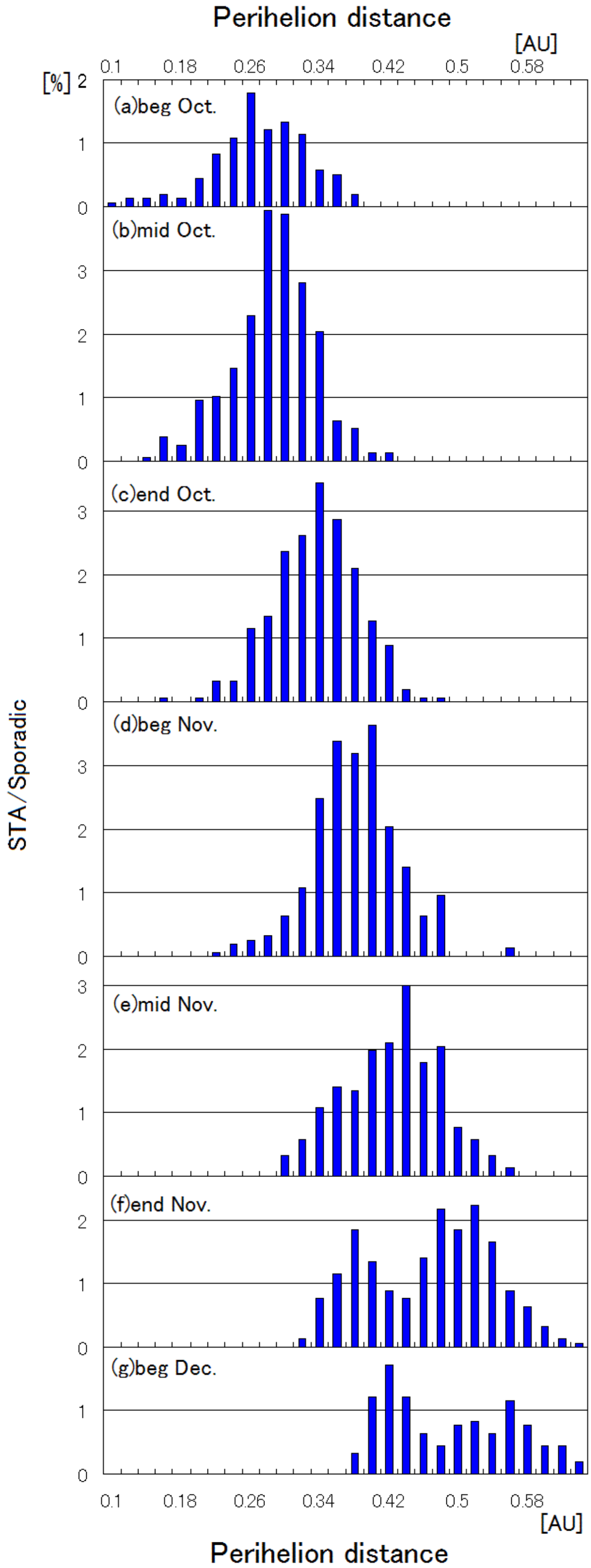

Figure 13 – Seasonal variation of perihelion distance (annual STA).

Figure 15 is the NTA longitude of perihelion distribution from the middle of October to beginning of December divided into six bins. The NTA longitude of perihelion goes forward 3° per 10 days.

Figure 16 is STA in non-swarm years, 2007, 2009, 2010, 2011, 2013 and 2014. The longitude of perihelion peak goes forward 5° per 10 days from the middle of October to beginning of November. But this forward shift stops at 158° from the middle till end of November. A twin peak appears from the end of November to beginning of December.

Figure 17 is STA in Taurid swarm encounter years, 2008, 2012 and 2015. A definite peak appeared at 158° in the whole swarm active season. This peak position is same as the annual components at the middle of November.

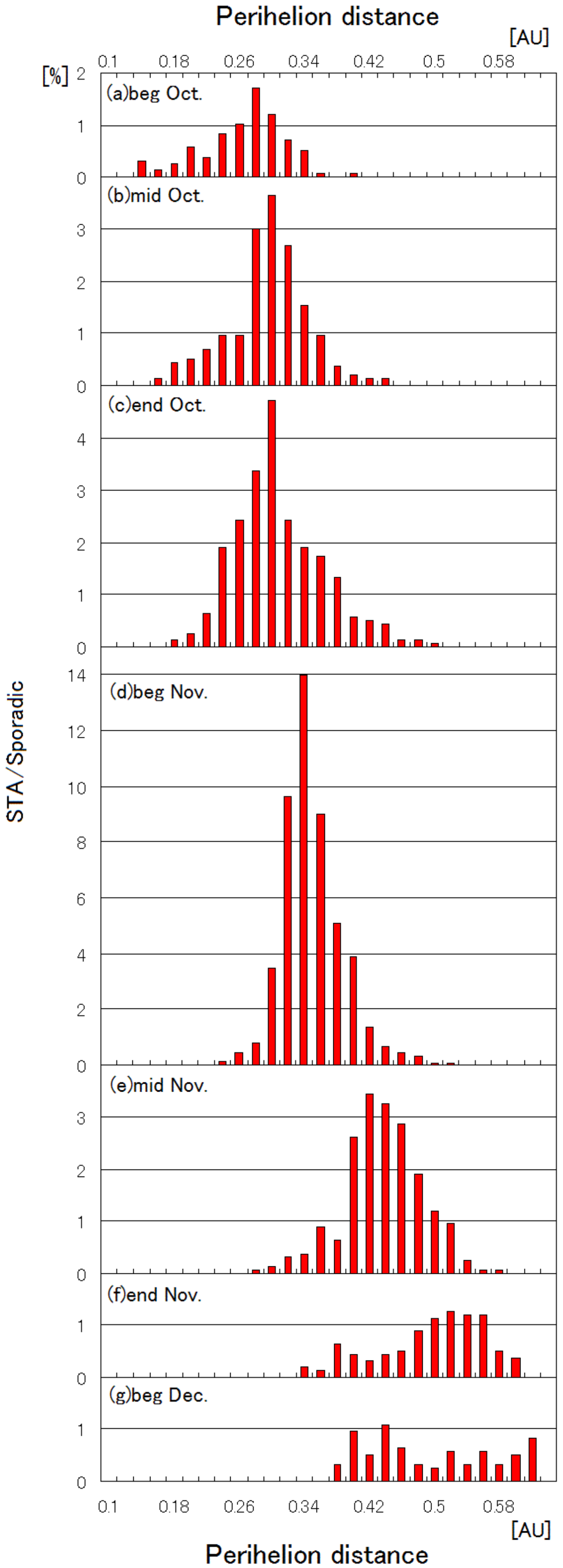

Figure 14 – Seasonal variation of perihelion distance (swarm year STA).

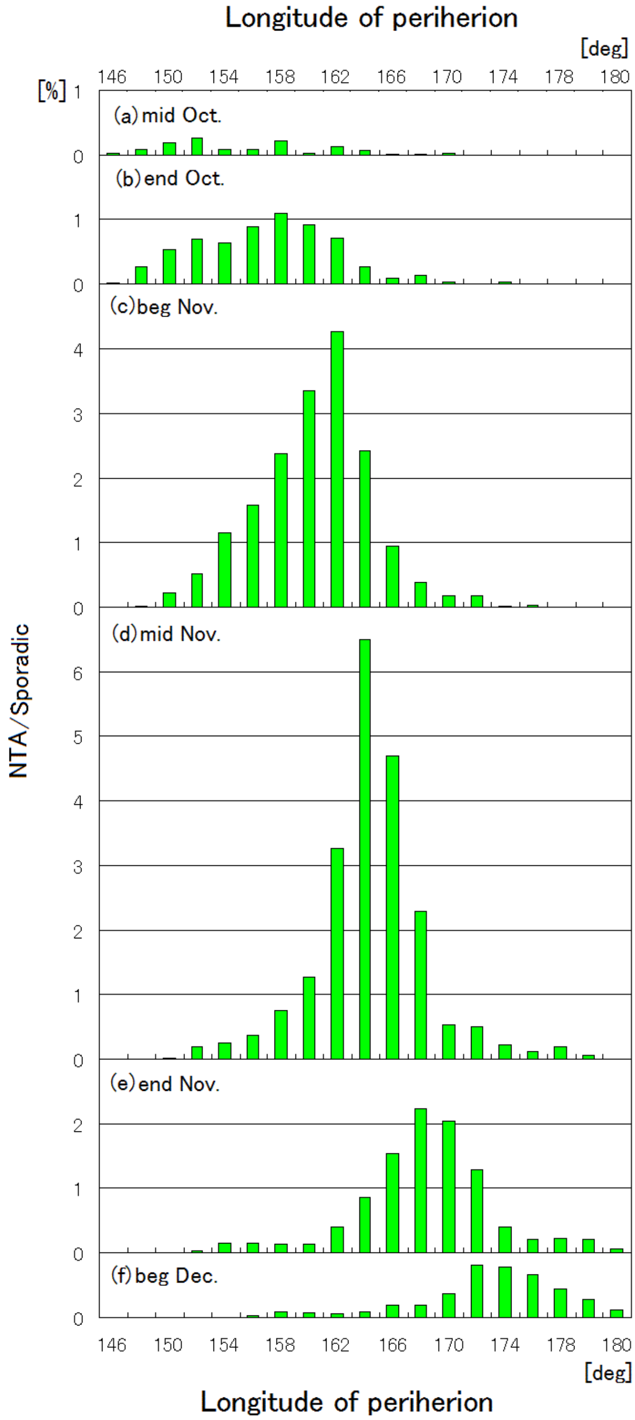

Figure 15 – Seasonal variation of longitude of perihelion (NTA).

4 Discussion

The Taurid swarm's existence was identified by visual meteor observation records in Asher & Izumi (1998), Beech et al. (2004) and Dubietis & Arlt (2007). I confirmed not only the Taurid swarm's existence in the southern branch but also detailed features of the swarm orbit by using small sensitive TV camera data that have higher potential to determine meteor orbit accuracy than visual observations. I note that the 'SonotaCo' automatic TV meteor camera network allows the inspection of error levels in the data.

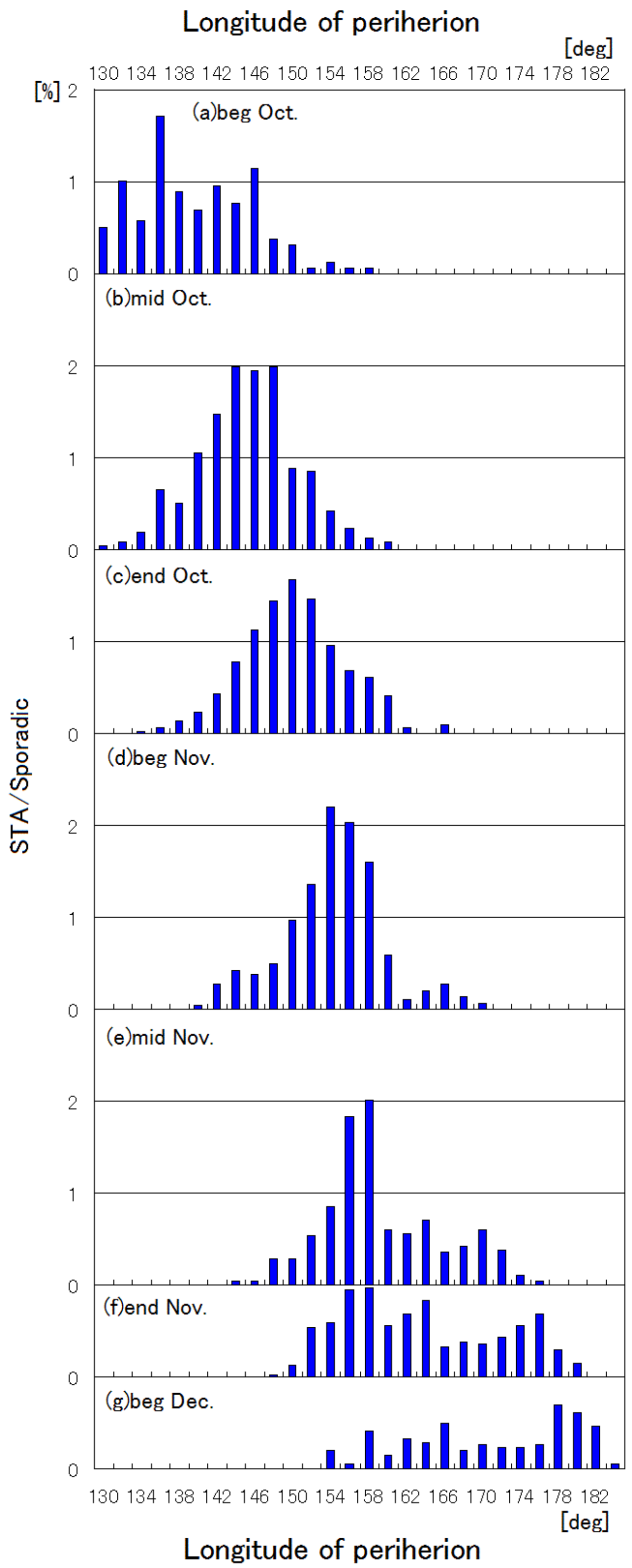

Figure 16 – Seasonal variation of longitude of perihelion (annual STA).

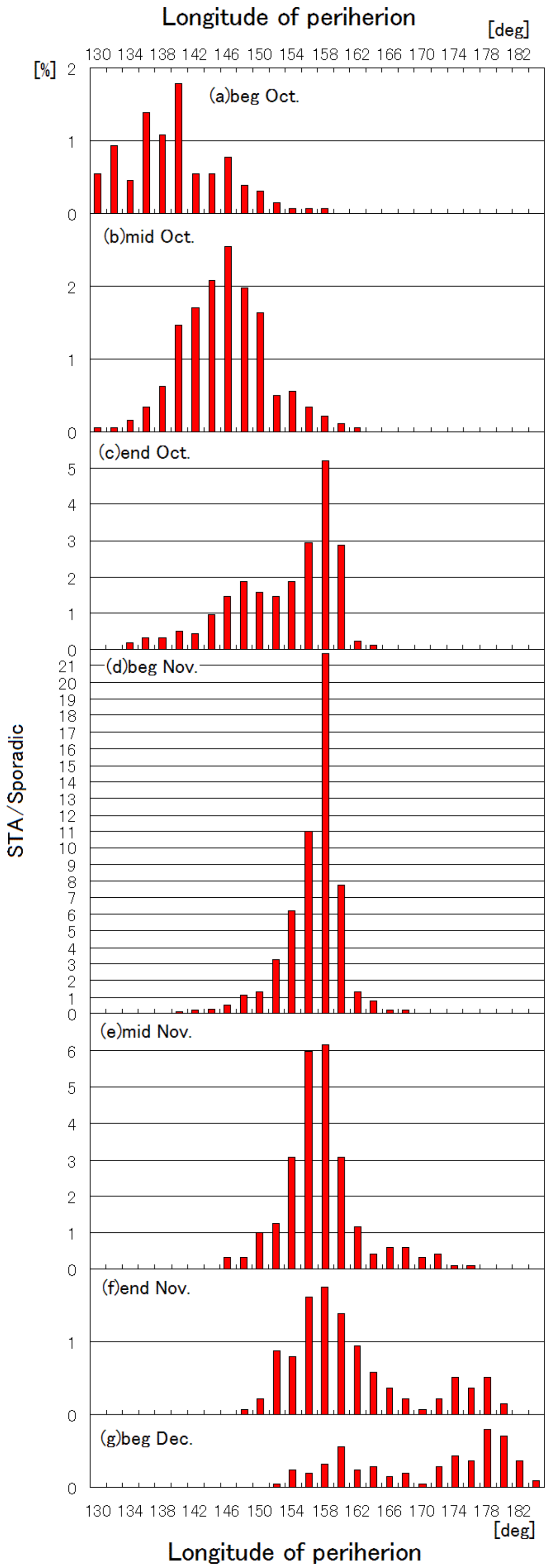

Figure 17 – Seasonal variation of longitude of perihelion (swarm year STA).

SonotaCo Network camera lenses' focal lengths are mainly 3.8–12 mm. $^1/_2$" size CCD image sensor resolution is 640 × 480 pixel. Typical recorded meteor precision is about 4 arcmin (for 3.8 mm) to 1 arcmin (12 mm) angular distance error. This celestial sphere position error is several times larger than photographic observations (Svoreň et al., 2011). When we discuss individual meteor orbit errors, we must pay attention

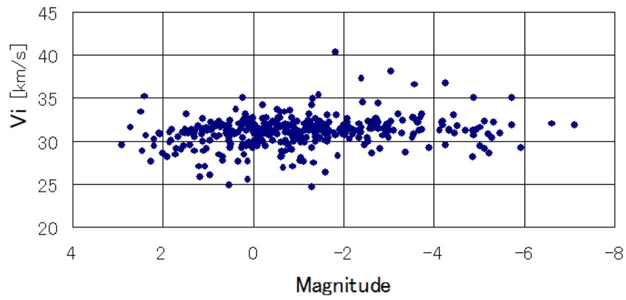

Figure 18 – Absolute magnitude – initial velocity of STA at beginning of November 2015.

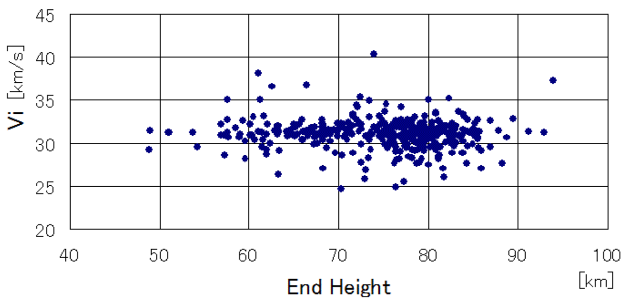

Figure 19 – End height – initial velocity of STA at beginning of November 2015.

to the influences on small video camera errors. On the other hand, automatic video camera observations have the advantage that we can get a great many meteor orbits. I could present over 6500 Taurid meteor orbits from 9 years observations in this study. It enabled us to study easily the statistics of meteor orbits.

Meteor velocity errors have the biggest influence – more than celestial sphere error – on calculated meteor orbit errors. The meteor velocity calculated as mean velocity in 'SonotaCo Network' used reduction software UFOAnalyzer and orbit calculation software UFOOrbit. If meteor velocity can be regarded as constant in the whole of the trajectory, this calculation method will conclude an accurate velocity. But, if the meteor velocity varies within its trajectory, the calculated initial velocity is not reliable. A meteor velocity generally suffers a drag force by Earth's atmosphere and is decelerated. Meteor deceleration is generally difficult to recognize by luminous observations because it has such a small value. However, we can detect a few cases of deceleration when particularly large meteoroids penetrate Earth's atmosphere. We must pay attention to the software's underestimate of these large meteoroids' initial velocity – meteors whose features are low velocity, bright luminous magnitude and extra low ending altitude. Thus, inspection was carried out by using a homogeneous sample of many bright STA swarm meteors that appeared at the beginning of November 2015. The relation between absolute magnitude and initial velocity is shown in Figure 18. The relation between ending heights and initial velocity is shown in Figure 19. If extra bright meteors or especially low end height meteors indicate small initial velocity value, the deceleration effect must have an influence. However, the deceleration effect cannot be recognized in Figures 18 and 19. As a conclusion, orbit error caused by Earth's atmospheric deceleration is negligible in this study.

Two other cases of TV meteor velocity error occurrence are considered. First is a whiteout image by an extra bright fireball. In this case, if only beginning and ending points record good conditions individually, the initial velocity can be determined accurately. Second is the case where a bright and long duration persistent train is recorded. If a false end point is adopted because of a bright persistent train, the initial velocity will be an underestimate. This effect indicates the same trend as atmospheric deceleration. This mistake did not appear in the Figure 18 and Figure 19 results. Incidentally, low velocity meteors existed for faint meteors and high end height meteors in Figures 18 and 19. The reason is considered that really relatively low velocity Taurid meteors as annual components are included. Very short luminous duration meteors recorded on a few frames of TV images tend to increase velocity random error. This trend leads to the inclusion of faint meteors or high end height meteors. However, you can see that random error does not increase in Figure 18 in the faint meteor region. As results on velocity error, although individual meteor velocity errors exist, I could not find evidence of systematic error or bias.

Next I discuss luminous magnitude error. Meteor magnitude had been defined traditionally based on visual observation records of the fixed stellar magnitude. Our TV mounted CCD observation spectral sensitivity differs from visual observations. CCD observations have the aptitude to record brighter on fast meteors, because CCD has higher sensitivity to long wavelength light than the human eye. Sporadic meteors include a high percentage of fast meteors compared with Taurid meteors. Sporadic meteors' mean magnitudes were recorded brighter than Taurids (Figure 3), for which the reason may be this sensitivity difference. Strangely however, sporadic meteors also have larger population index r in Figure 4. Large r generally indicates the inclusion of many faint magnitude meteors. One possible explanation is a low capture rate for faint and fast meteors by the TV observation software UFOCapture as moving object detection software. Mean velocities of sporadic meteors are faster than Taurid meteors, because faint sporadic meteors might have a reduced capture rate. However, we can study yearly changes in meteor magnitude neglecting these biases. Thus the meteor brightness conclusion, which is that STA bright meteors are enhanced in 2008, 2012 and 2015, is not influenced by assumed bias.

Next to discuss the method of evaluating observed meteor numbers. The standardized number of observed shower meteors was generally calculated for a long time as 'ZHR' based on visual observations. 'ZHR' is the meteor number that one observer can see in one hour under ideal good sky conditions when the shower radiant position is at the zenith. However, SonotaCo Network observation data is not able to calculate ZHR because UFOCapture observations lack a cloud cover parameter and limiting stellar magnitude record. So that, correction factors are not determined for calculat-

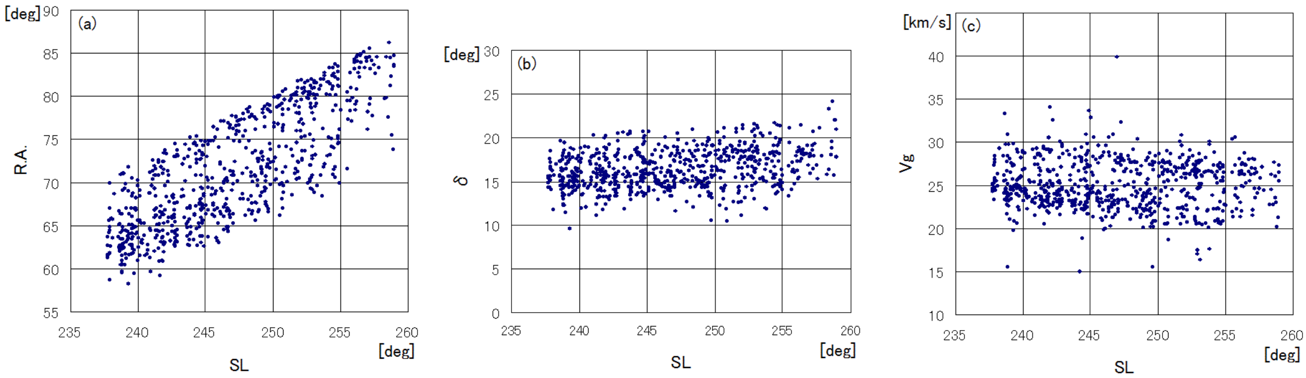

Figure 20 – STA radiant and geocentric velocity from end of November to beginning of December (2007–2015).

ing ZHR. Instead of ZHR, I evaluated the percentage of shower meteor numbers to sporadic meteors observed during the same time interval. This evaluation method is reliable at constant sporadic meteor flux for evaluated whole periods. But sporadic meteor flux varies by season (Rendtel, 2007). As a result, seasonal variations shown for Taurids (Figure 2) will be distorted somewhat from a precise reliable variation. Differences from precise seasonal variation will not be so large because the adopted period was only 70 days of a year. If you can take a trusted sporadic meteor ZHR value, you can calculate reliable NTA and STA seasonal ZHR values from Figure 2.

Finally to discuss the threshold for deciding meteor shower membership. The decision of whether meteors belong to NTA and STA is shown in Table 3. Radiant points' drift values were approximated as linear functions for right ascension and declination. However, the Taurid active period is quite long to describe as linear functions. So that, Taurid meteor shower radiants were not expressed well in beginning and ending periods. The shower meteor rate will fluctuate when circles of different radius around the (moving) mean radiant position are selected. A constant value of meteor velocity is adopted. But meteor shower velocities generally vary over long active periods. A good method for avoiding these error causes was indicated in the IMO Meteor Shower Calendar (McBeath, 2014) where radiant points and velocities are specified for some divided periods. This desirable method is still difficult to use for STA as a complex meteor shower. The STA radiant position consists of multi-radiants and have independent drifts. Radiant position and velocity in the ending part of the STA active period are shown in Figure 20. The data sources were from November 20 to December 10 in all of 2007–2015. Figure 20 (a), (b), (c) are respectively radiant right ascension, declination and geocentric velocity vs solar longitude. These figures suggest two meteor streams exist that correspond with separated peak distributions of some orbital elements as described in Section 3 earlier. So that, I could not provide satisfying results of beginning and ending parts of the Taurid activity periods. Taurids' complex structure, especially the meteor shower border in the activity season and the orbit, are problems for the future. However, the research on the central part of Taurid activity structure will not be disturbed by low confidence on the boundary region.

I discussed many kinds of error cause. Error cause can be classified as two kinds. First is systematic error that must be considered carefully to avoid misunderstanding results. I described up to now, systematic error influences on some results, but the main part of Taurid swarm features was not influenced. Second is random error. Random error can change resulting distribution features from sharp and narrow peaks to low and broad peaks. Small TV camera observation results in this article are affected by this random error. So that, many characteristics in the above figures are blurred from true characteristics. Nevertheless, peak positions do not need correction.

Acknowledgments

All data were taken from the 'SonotaCo Network' upload site. Observation data providing the statistics for this study cover 9 years and include data from 40 TV observation sites where amateur observers operated their cameras and analyzed at home or other stations. I'm very thankful for their effort. Mr. SonotaCo is managing the SonotaCo network (SonotaCo, 2009) and offered his software series (UFOCapture, UFOAnalyzer and UFOOrbit). I'm grateful for his software development and his managing an open data site. Mr. SonotaCo informed me of a part of the error evaluation. Dr. I. Hasegawa presented the ΔM quantity used in this paper at a local meteor conference 'Jusojuku'. Dr. Hasegawa taught many of us meteor astronomy but he died on 2016 May 1st. His contribution will be long remembered and appreciated.

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Preliminary results

Results of the IMO Video Meteor Network — January 2016

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The January 2016 report of IMO Video Meteor Network observations is presented, based on more than 9 000 hours of observations with almost 28 000 meteors recorded. The flux density profile is presented for the 2016 Quadrantids and compared to the profiles from the years 2011–2015. The flux density profile is also presented for the 2016 γ-Ursae Minorids. Development of a new algorithm for the calculation of the limiting magnitude is presented.

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1 Introduction

We rarely enjoy favorable observing conditions in January – only 2012 stands out somewhat from the previous years. Hence, the new observing year did not start worse than others. 76 cameras provided data to the IMO Network. The number was lower than previously, since a few cameras had to take breaks due to technical problems. A quick look at the observing statistics shows large gaps, particularly in the first half of January. Unfortunately, the Quadrantids became a victim of cloudy skies at many sites. The second half of January was not optimal either, but at least a little better.

Overall, only 30 cameras managed to observe on twenty or more nights, most of them being located in eastern and southern Europe. Salsa3 of Carl Hergenrother continued the positive series with 30 nights, and Detlef Koschny did not miss a single night thanks to the geographic spread of his cameras. In total we collected over 9 000 hours of effective observing time (Table 1 and Figure 1), which is a few percent less than in 2012 and 2015, but clearly more than in 2013 and 2014. With 28 000 meteors we surpassed January 2015 by 10%, but did not reach the yield of 2012.

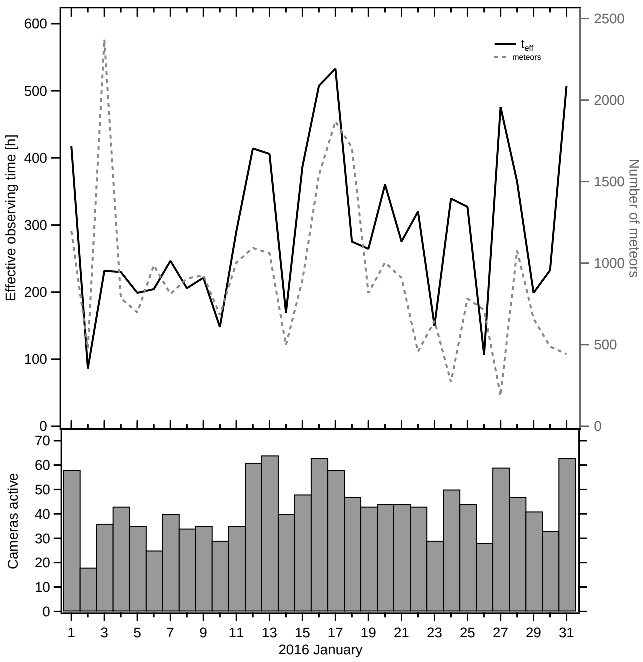

Figure 1 – Monthly summary for the effective observing time (solid black line), number of meteors (dashed gray line) and number of cameras active (bars) in 2016 January.

2 Quadrantids

In contrast with all other major showers of 2016 which suffer from poor lunar conditions, the Quadrantids were still quite favourable with a waning moon just past last quarter at the time of maximum. The peak was predicted for the mid-morning hours of January 4 (08^h UT), i.e. too late to be observed by European video cameras, but close enough to their observing window to track the ascending activity branch in the morning with the radiant altitude increasing. In addition, J. Vaubaillon had predicted a possible earlier peak time between 22^h UT on January 3 and 02^h UT on January 4 (Rendtel, 2015). That interval would have been perfectly located for central European observers. The weather was particularly cooperative for observers in Hungary and Poland, which is why most of the peak time data relies on their cameras.

Figure 2 shows the overview of the activity profile in 2016, compared to the previous years. The solar longitude interval covered is identical to the 2012 data set, but the flux density is almost twice as high. After we found the absolute low point of activity in 2015, the activity is significantly rising again. However, it is still quite a distance from the activity level observed in 2014.

Figure 3 shows a high-resolution activity profile for the night of January 3/4. It is clear that the activity was continuously rising until dawn. The supposed early peak cannot be confirmed, a result that was also

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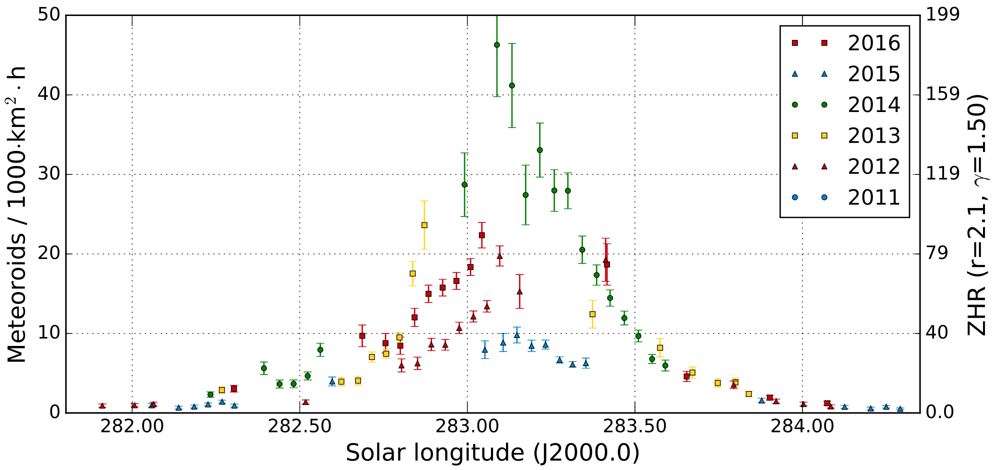


Figure 2 – Flux density profile of the Quadrantids in 2011–2016, derived from observations of the IMO Video Network.

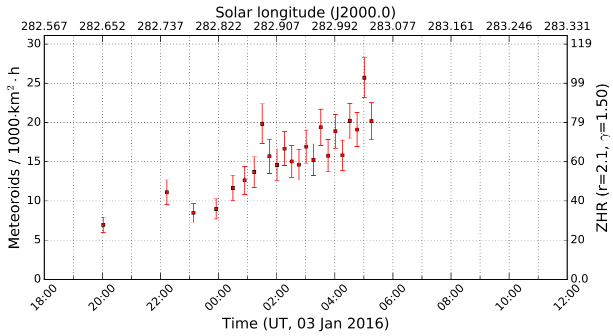


Figure 3 – High resolution flux density profile of the Quadrantids in the night of 2016 January 3/4.

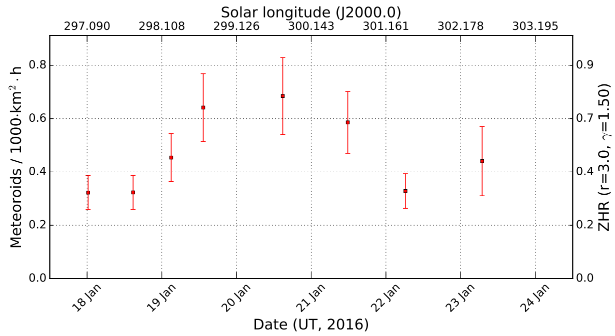


Figure 4 – Flux density profile of the γ-Ursae Minorids in January 2016, derived from observations of the IMO Video Network.

indicated by the IMO Quick look analysis of visual observations (International Meteor Organization, 2016).

3 Gamma Ursae Minorids

Jürgen Rendtel reported to have spotted three meteors during his visual observation on January 19, 03^{h}–05^{h} UT, which fitted well with the γ-Ursae Minorid radiant. Three meteors are not really fireworks, but given the rapidly decreasing meteor activity in January they are at least remarkable. The minor shower of the γ-Ursae Minorids (404 GUM) was discovered in 2010 by Peter Brown in the Canadian CMOR radar data (Brown et al., 2010) and confirmed in 2013 by our analysis of IMO Network video data (Molau, 2014). Based on 250 shower meteors, we detected the shower between January 18 and 24.

To confirm the activity in 2016, we re-calculated the meteor shower assignment for observations in mid-January and created a flux density profile (Figure 4). The shower could indeed be identified, even though at the detection limit. On the morning of January 19, the activity was rising, reaching highest values one day later.

4 MetRec development

There have also been improvements in recent weeks regarding the meteor detection software. In particular we addressed the problem that the limiting magnitude calculated by MetRec depends on the start value of the NoiseLevel parameter. This problem was described in the April report of 2015 (Molau et al., 2015). Here we want to reiterate it briefly and present a solution.

To determine the limiting magnitude, a number of video frames are averaged and high-pass filtered to highlight point-like objects. Thereafter a threshold is applied: all objects brighter than the threshold are segmented and identified according to their position in the field of view. They are either stars or false detections (noise), whereby "hot pixels" are removed first. The number of detected stars is translated into a limiting magnitude by the star field counting method. Thus, the limiting magnitude depends significantly on the segmentation threshold (the NoiseLevel): the lower the threshold, the more objects are segmented, among these more (fainter) stars which increases the calculated limiting magnitude. If the threshold is increasing, fewer objects are segmented, fewer stars are identified and the limiting magnitude decreases.

Since the observing conditions vary from camera to camera, from night to night and even from hour to

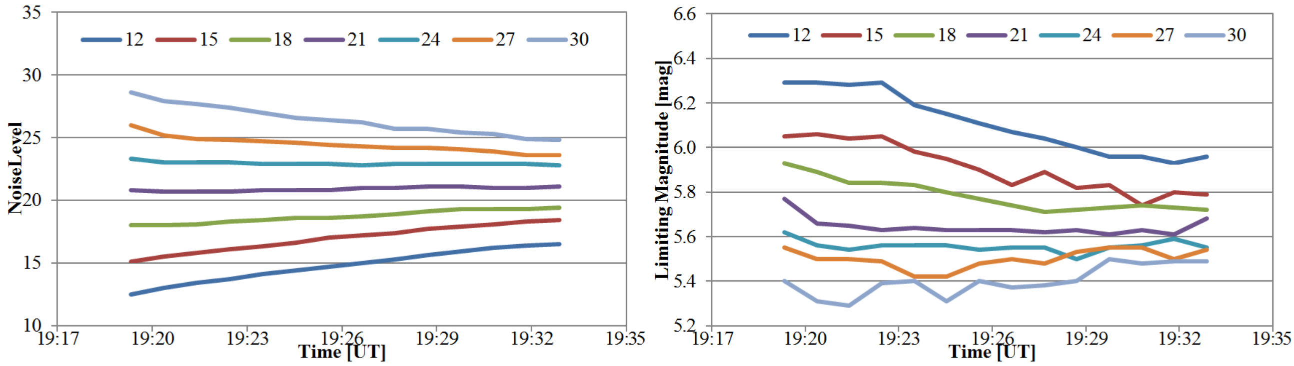


Figure 5 – Development of the NoiseLevel threshold (left) and the determined limiting magnitude (right) using the original procedure with variable target number of false detections.

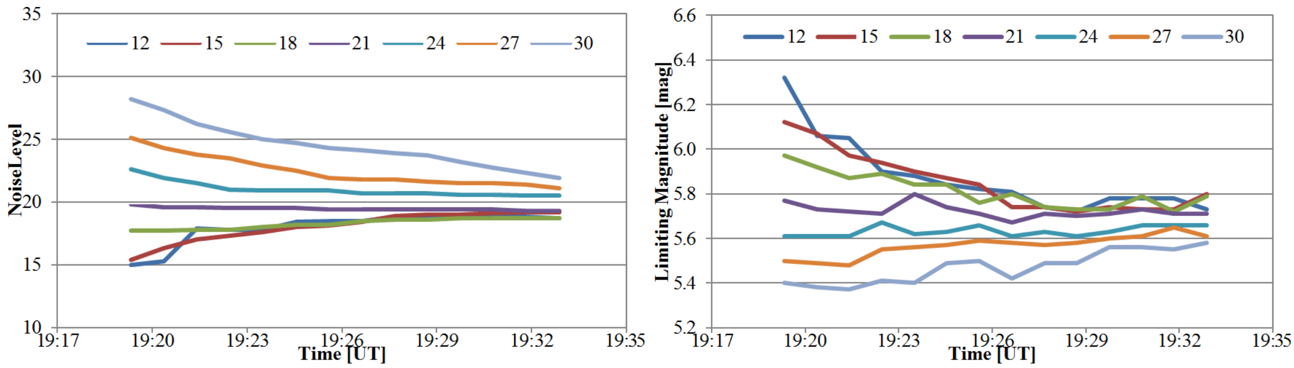


Figure 6 – Development of the NoiseLevel threshold (left) and the determined limiting magnitude (right) using the improved procedure with fixed target number of false detections.

hour, the threshold has to be adjusted dynamically to the noise level of the camera. This is done by looking at the number of false detections. Every minute the threshold is adjusted by a small amount such that the observed number of false detections converges to a given target number. Previously the target number has been variable: if only a few stars were identified, at least as many false detection should be detected. If the number of identified stars was increasing, a larger number of false detections were allowed, but their percentage relative to the total number of segmented objects was to decrease.

The analysis of April 2015 had shown that the NoiseLevel threshold would not converge to a stable value with this variable target number of false detections. If the procedure starts from a large NoiseLevel, the threshold reaches the target number of false detections with only just a few stars identified. However, if the procedure starts with a smaller NoiseLevel, the threshold converges to a larger number of false detections which also fits with the optimization criterion. That was confirmed by a series of tests (Figure 5). The same 15-minute chunk of video footage from the 2011 Draconids was processed several times with a different NoiseLevel start values. The left graph shows how the threshold evolves within a quarter of an hour, the right graph the corresponding limiting magnitude. Even after 15 minutes, the calculated limiting magnitude showed a scatter of almost half a magnitude!

Instead of using a variable target number of false detections it was investigated whether a camera-specific, but fixed target would improve the results. The target number was set equal to a predefined percentage of the overall number of active pixels in the field of view to account for smaller fields of view (e.g. of image-intensified cameras). The Noiselevel does indeed now converge faster from different start values (Figure 6). The dispersion halved after 15 minutes, but the algorithm still did not converge to a stable solution and the limiting magnitude still differed by over 0.2 mag depending on the start value.

The reason was that the update function for the NoiseLevel threshold yields only small corrections close to the target number. This restriction is necessary in order to avoid oscillations of the threshold, which have been observed for some cameras in the past.

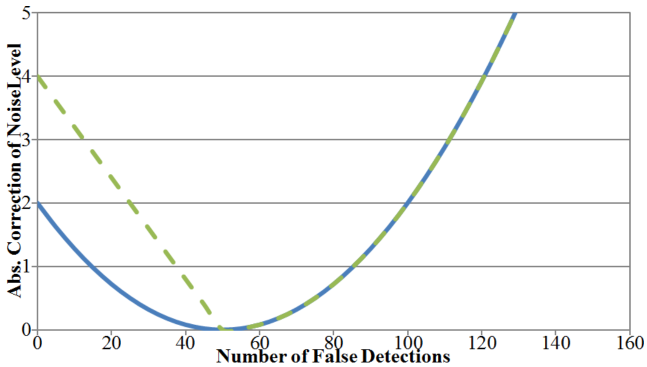
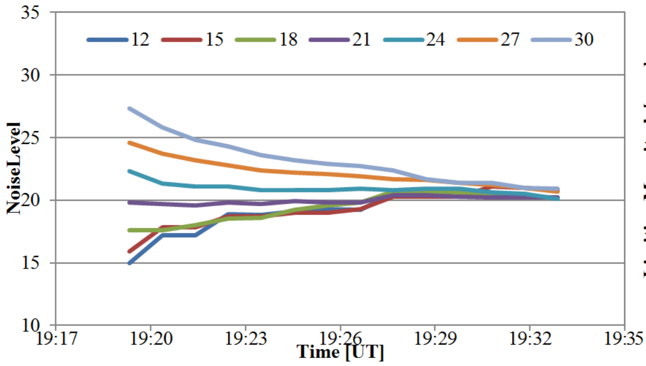


Figure 7 – Symmetric and asymmetric update function for the NoiseLevel threshold depending on the number of false detections (target value: 50).



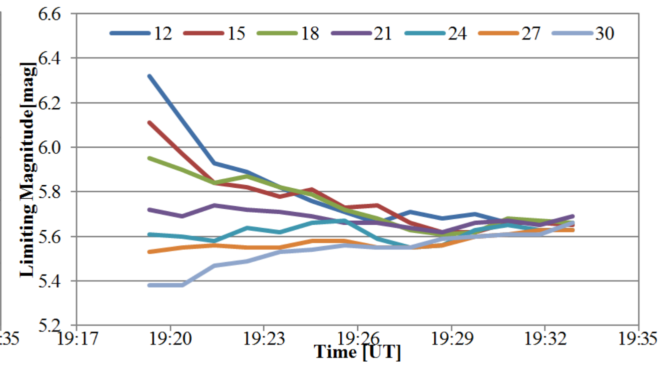


Figure 8 – Development of the NoiseLevel threshold (left) and the determined limiting magnitude (right) using the best procedure with fixed target number of false detections and asymmetric update function.

Thus we used a trick with an asymmetric update function (Figure 7): if there are more false detections than targeted, the update function remains flat as before. If there are fewer false detections, however, there will be larger, linear corrections. Even if the threshold is now overshooting, there will be no oscillations, since the backward correction is done in small steps only. Hence, the threshold is always approaching the target from one side and converging to the same value after a short amount of time.

Figure 8 confirms that independent of the start value indeed the same NoiseLevel threshold and limiting magnitude are reached after ten minutes. The dispersion is only 0.05 mag in the end.

The new software version is still being tested and will be provided shortly to all observers. After the software has been used for a few months, we will be able to analyze new observations, re-calculate the perception coefficients of the cameras and check if the newly determined limiting magnitudes and flux densities do indeed become more consistent and less dispersed.

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Table 1 – Observers contributing to 2016 January data of the IMO Video Meteor Network. Eff.CA designates the effective collection area; the overall number of nights is the number of nights with at least one camera operating, the overall observing time and number of meteors are sums over all cameras.

Code	Name	Location	Camera	FOV [°²]	Stellar LM [mag]	Eff.CA [km²]	Nights	Time [h]	Meteors
ARLRA	Arlt	Ludwigsfelde/DE	Ludwig2 (0.8/8)	1475	6.2	3779	21	96.9	468
BANPE	Bánfalvi	Zalaegerszeg/HU	Huvcse01 (0.95/5)	2423	3.4	361	13	18.1	118
BERER	Berkó	Ludányhalászi/HU	Hulud1 (0.8/3.8)	5542	4.8	3847	6	65.6	502
BOMMA	Bombardini	Faenza/IT	Mario (1.2/4.0)	5794	3.3	739	22	176.9	563
BREMA	Breukers	Hengelo/NL	Mbb3 (0.75/6)	2399	4.2	699	16	91.1	132
BRIBE	Klemt	Herne/DE	Hermine (0.8/6)	2374	4.2	678	20	118.5	265
		Bergisch Gladbach/DE	Klemoi (0.8/6)	2286	4.6	1080	20	91.3	192
CASFL	Castellani	Monte Baldo/IT	Bmh1 (0.8/6)	2350	5.0	1611	27	254.1	714
			Bmh2 (1.5/4.5)*	4243	3.0	371	26	258.3	545
CRIST	Crivello	Valbrevenna/IT	Bilbo (0.8/3.8)	5458	4.2	1772	20	154.4	517
			C3P8 (0.8/3.8)	5455	4.2	1586	16	131.1	261
			Stg38 (0.8/3.8)	5614	4.4	2007	23	167.0	775
DONJE	Donani	Faenza/IT	Jenni (1.2/4)	5886	3.9	1222	24	152.6	706
ELTMA	Eltri	Venezia/IT	Met38 (0.8/3.8)	5631	4.3	2151	15	122.3	279
FORKE	Förster	Carlsfeld/DE	Akm3 (0.75/6)	2375	5.1	2154	11	59.0	156
GONRU	Goncalves	Tomar/PT	Templar1 (0.8/6)	2179	5.3	1842	17	132.1	332
			Templar2 (0.8/6)	2080	5.0	1508	17	129.1	255
			Templar3 (0.8/8)	1438	4.3	571	20	128.0	138
			Templar4 (0.8/3.8)	4475	3.0	442	17	107.3	208
			Templar5 (0.75/6)	2312	5.0	2259	22	117.1	297
GOVMI	Govedič	Središče ob Dravi/SI	Orion2 (0.8/8)	1447	5.5	1841	18	127.8	212
			Orion3 (0.95/5)	2665	4.9	2069	20	123.9	173
			Orion4 (0.95/5)	2662	4.3	1043	20	142.9	159
HERCA	Hergenrother	Tucson/US	Salsa3 (0.8/3.8)	2336	4.1	544	30	253.1	537
HINWO	Hinz	Schwarzenberg/DE	Hinwo1 (0.75/6)	2291	5.1	1819	15	90.0	224
IGAAN	Igaz	Hódmezővásárhely/HU	Huhod (0.8/3.8)	5502	3.4	764	17	61.1	93
		Budapest/HU	Hupol (1.2/4)	3790	3.3	475	8	79.0	45
JONKA	Jonas	Budapest/HU	Husor (0.95/4)	2286	3.9	445	10	90.5	134
			Husor2 (0.95/3.5)	2465	3.9	715	13	89.2	154
KACJA	Kac	Ljubljana/SI	Orion1 (0.8/8)	1399	3.8	268	8	49.0	25
		Kamnik/SI	Cvetka (0.8/3.8)*	4914	4.3	1842	15	138.2	487
			Rezika (0.8/6)	2270	4.4	840	15	133.8	798
			Stefka (0.8/3.8)	5471	2.8	379	15	139.1	409
KOSDE	Koschny	Izana Obs./ES	Icc7 (0.85/25)*	714	5.9	1464	29	210.0	1251
		La Palma/ES	Icc9 (0.85/25)*	683	6.7	2951	21	163.3	1838
			Lic2 (3.2/50)*	2199	6.5	7512	24	177.9	2116
		Noordwijkerhout/NL	Lic4 (1.4/50)*	2027	6.0	4509	12	42.0	63
LOJTO	Łojek	Grabniak/PL	Pav57 (1.0/5)	1631	3.5	269	8	69.5	436
LOPAL	Lopes	Lisbon/PT	Naso1 (0.75/6)	2377	3.8	506	18	114.1	91

Table 1 – Observers contributing to 2016 January data of the IMO Video Meteor Network – continued from previous page.

Code	Name	Location	Camera	FOV [°²]	Stellar LM [mag]	Eff.CA [km²]	Nights	Time [h]	Meteors
MACMA	Maciejewski	Chełm/PL	Pav35 (0.8/3.8)	5495	4.0	1584	22	119.8	571
			Pav36 (0.8/3.8)*	5668	4.0	1573	18	104.7	423
			Pav43 (0.75/4.5)*	3132	3.1	319	12	105.3	260
			Pav60 (0.75/4.5)	2250	3.1	281	19	131.9	503
MARGR	Maravelias	Lofoupoli-Crete/GR	Loomecon (0.8/12)	738	6.3	2698	22	91.8	393
MARRU	Marques	Lisbon/PT	Ran1 (1.4/4.5)	4405	4.0	1241	16	108.3	176
MOLSI	Molau	Seysdorf/DE	Avis2 (1.4/50)*	1230	6.9	6152	11	61.0	288
			Escimo2 (0.85/25)	155	8.1	3415	14	108.1	87
			Mincam1 (0.8/8)	1477	4.9	1084	15	76.2	164
		Ketzür/DE	Remo1 (0.8/8)	1467	6.5	5491	22	109.7	515
			Remo2 (0.8/8)	1478	6.4	4778	19	110.7	514
			Remo4 (0.8/8)	1478	6.5	5358	23	116.1	461
MORJO	Morvai	Fülöpszállás/HU	Huful (1.4/5)	2522	3.5	532	19	138.1	171
MOSFA	Moschini	Rovereto/IT	Rover (1.4/4.5)	3896	4.2	1292	25	32.6	213
OTTMI	Otte	Pearl City/US	Orie1 (1.4/5.7)	3837	3.8	460	22	186.6	250
PERZS	Perkó	Becsehely/HU	Hubec (0.8/3.8)*	5498	2.9	460	23	165.2	548
ROTEC	Rothenberg	Berlin/DE	Armefa (0.8/6)	2366	4.5	911	2	13.7	60
SARAN	Saraiva	Carnaxide/PT	Ro1 (0.75/6)	2362	3.7	381	15	95.4	158
			Ro2 (0.75/6)	2381	3.8	459	15	100.8	162
			Ro3 (0.8/12)	710	5.2	619	16	110.2	208
			Sofia (0.8/12)	738	5.3	907	17	121.5	167
SCALE	Scarpa	Alberoni/IT	Leo (1.2/4.5)*	4152	4.5	2052	21	157.8	158
SCHHA	Schremmer	Niederkrüchten/DE	Doraemon (0.8/3.8)	4900	3.0	409	18	112.9	247
SLAST	Slavec	Ljubljana/SI	Kayak1 (1.8/28)	563	6.2	1294	15	135.3	217
			Kayak2 (0.8/12)	741	5.5	920	12	136.5	113
STOEN	Stomeo	Scorze/IT	Min38 (0.8/3.8)	5566	4.8	3270	25	179.3	703
			Noa38 (0.8/3.8)	5609	4.2	1911	25	194.2	606
			Sco38 (0.8/3.8)	5598	4.8	3306	25	209.4	802
STRJO	Strunk	Herford/DE	Mincam2 (0.8/6)	2354	5.4	2751	17	91.8	356
			Mincam3 (0.8/6)	2338	5.5	3590	16	95.4	234
			Mincam4 (1.0/2.6)	9791	2.7	552	12	23.3	72
			Mincam5 (0.8/6)	2349	5.0	1896	13	94.8	200
			Mincam6 (0.8/6)	2395	5.1	2178	13	89.9	174
TEPIS	Tepliczky	Agostyán/HU	Huago (0.75/4.5)	2427	4.4	1036	17	138.6	226
			Humob (0.8/6)	2388	4.8	1607	16	108.8	285
TRIMI	Triglav	Velenje/SI	Sraka (0.8/6)*	2222	4.0	546	18	76.7	221
YRJIL	Yrjölä	Kuusankoski/FI	Finexcam (0.8/6)	2337	5.5	3574	20	170.1	395
* active field of view smaller than video frame						Overall	31	9 087.7	27 969

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2015 Geminids from Munich

Composite image of 20 Geminids recorded on 2015 December 14, between 18^h50^m and 20^h20^m UT from Munich, Germany. The author used Sony Alpha 7S camera with a Canon FD 2.8/24 mm at $f/4.5$ wide angle lens in video mode with 25 frames per second at ISO 80000. Photo courtesy: Peter C. Slansky.