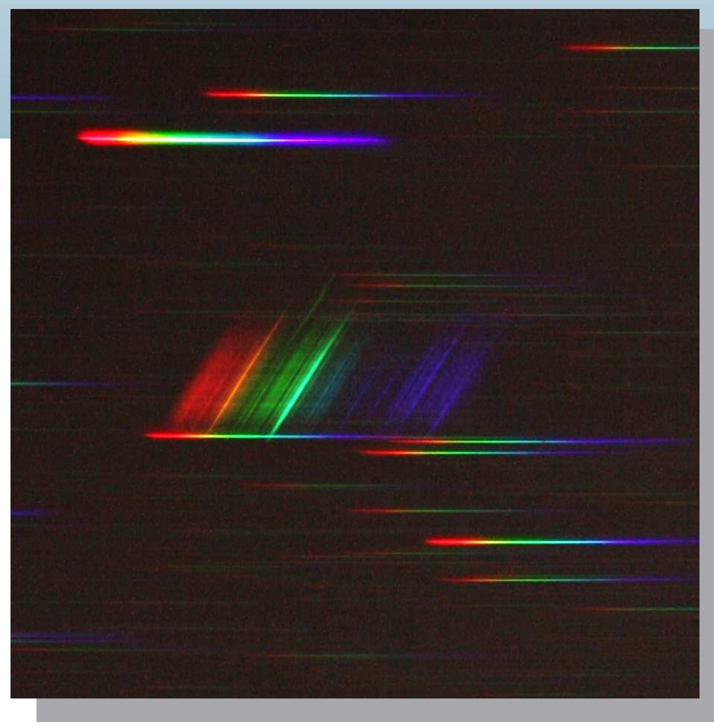
journal of the international meteor organization

WGN

39:2
april 2011



Meteor spectra
Geminid and Quadrantid orbits
Video meteors

ISSN 1016-3115

WGN Vol. 39, No. 2, April 2011, pp. 33 – 56

Administrative

Editorial — Meteor fluxes *Javor Kac* 33

Meteor science

Video observation of Geminids 2010 and Quadrantids 2011 by SVMN and CEMeNt *Juraj Tóth, Peter Vereš, Leonard Kornoš, Roman Piffl, Jakub Koukal, Štefan Gajdoš, Ivan Majchrovič, Pavol Zigo, Martin Zima, Jozef Világi and Dušan Kalmančok* 34

Meteor spectral observation with DSLR, normal lens and prism *Sihao Cheng and Simiao Cheng* 39

Preliminary results

Results of the IMO Video Meteor Network — December 2010 *Sirko Molau, Javor Kac, Erno Berko, Stefano Crivello, Enrico Stomeo and Antal Igaz* 47

Results of the IMO Video Meteor Network — January 2011 *Sirko Molau, Javor Kac, Erno Berko, Stefano Crivello, Enrico Stomeo and Antal Igaz* 53

Editorial note *Javor Kac* 54

Front cover photo

Spectrum of a very bright Geminid, captured on 2010 December 14 at 21^h21^m UT. Photo courtesy: Sihao Cheng. Author's reference: IMG8863.
See page 39 for details.

Future covers

Have you an interesting or spectacular meteor photograph that you think would look good on the cover of WGN? If so, please offer it to us. For the moment we can only accept machine-readable forms. More or less any image format will do, though ideally not JPEG as the JPEG compression algorithms lose information. A brief description will also be required: this should say what the photograph shows, when and where it was taken, plus (if possible) technical details such as the camera and exposure. We can be contacted at wgn@imo.net, but remember to put 'Meteor' in the subject line to get round the anti-spam filters.

Writing for WGN

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

Cover design

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Editorial — Meteor fluxes

Javor Kac

Fluxes of meteoroids causing visual meteors have traditionally been derived from visual observations, through the ZHR and population index calculations. The advent of video cameras has opened another way to tackle this important parameter of a meteor shower.

With the recently introduced new functionality of MetRec to record limiting magnitude in one-minute intervals, the effective collection area could be calculated. Based on these data, the software calculates flux densities, taking into account the population index, radiant altitude and meteor angular velocity for each shower active in a given night. Using all this data, the meteor flux profile can be created.

Now in the morning the camera operator processes the observation and uploads the flux data to Virtual Meteor Observatory server and it is immediately available for the world.

(Near)-live meteor flux viewer

Just in time for the Lyrids, Sirko Molau announced the availability of a web-based shower analysis tool MetRec FluxViewer (Molau, 2011). The tool was created by Geert Barentsen and is located at `http://vmo.imo.net/flx/`.

At the moment, Geert's magnificent tool enables the selection of the meteor shower, the time period for the calculation, and definition of variable bin size. The flux profile can be calculated based on data of a selected camera or from all cameras. The result is expressed as the number of meteoroids capable of producing meteors brighter than magnitude +6.5 per 1000 square kilometers per observing hour. The calculation is also done to convert the flux values into ZHR.

Depending on the observers' diligence, the flux profile can be displayed soon after the night's end. I am sure this will be a useful tool for the observers as well as for scientists.

As this is only the first test of using the video data, there are for sure many things that can be improved. For example, the population index is taken from the database so its value during the observation can be different. The major limitation for creating the continuous high-resolution flux profiles is the limited geographical spread of the cameras. At the moment, most cameras of the IMO Video Meteor Network are located in Europe and only a small fraction in the United States and Australia. The rest of the world is blank so far. Hopefully, more video observers from around the globe will join the effort.

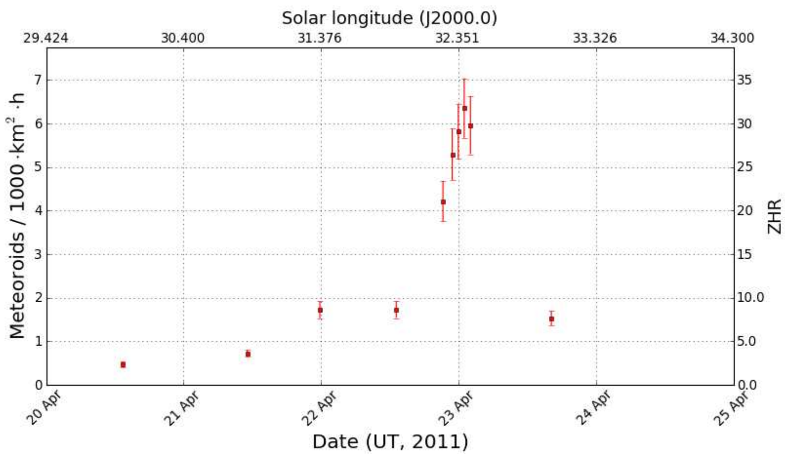

Figure 1 – The flux profile of the Lyrid meteoroids between 2011 April 20 and 25, based on observations submitted by the time of writing this editorial. Minimum bin duration of 60 minutes and preferred number of 80 meteors per bin were set for the calculation.

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IMO bibcode WGN-392-editorial NASA-ADS bibcode 2011JIMO...39...33K

Meteor science

Video observation of Geminids 2010 and Quadrantids 2011 by SVMN and CEMeNt

Juraj Tóth[1], *Peter Vereš*[1], *Leonard Kornoš*[1], *Roman Piffl*[2], *Jakub Koukal*[2], *Štefan Gajdoš*[1], *Ivan Majchrovič*[2], *Pavol Zigo*[1], *Martin Zima*[2], *Jozef Világi*[1] *and Dušan Kalmančok*[1]

Since 2009 the double station meteor observation by the all-sky video cameras of the Slovak Video Meteor Network (SVMN) brought hundreds of orbits. Thanks to several amateur wide field video stations of the Central European Meteor Network (CEMeNt) and despite not an ideal weather situation we were able to observe several Geminid and Quadrantid multi-station meteors during their 2010 and 2011 maxima, respectively. The presented meteor orbits derived by the UFOOrbit software account a high precision of the orbital elements and are very similar to those of the SonotaCo video meteor database.

Received 2011 March 11

1 Introduction

The Geminids and Quandrantids belong to the most active and spectacular annual meteor showers. Despite their high activity and relatively narrow orbital distribution, no active comets have been associated with Geminids and Quadrantids as the parent bodies yet. Geminids have very low perihelia (∼ 0.15 AU), moderate geocentric velocities (∼ 34 $\mathrm{km\,s^{-1}}$) and meteoroids seem to have high density and strong internal consistence (Borovička et al., 2010). Currently, asteroid (3200) Phaethon is strongly favored as the parent body (Whipple, 1983; Jenniskens, 2006). Quadrantids exhibit a high activity as well, with a sharp peak lasting only several hours. Their perihelia lie inside the Earth's orbit, inclinations are around 70 deg. Among parent body candidates, asteroid (196 256) 2003 $\mathrm{EH_1}$ has the most similar orbit to the Quadrantids and is considered to be a dormant comet (Jenniskens, 2004).

Both showers are well defined by many previous photographic, radar, telescopic and visual surveys (Jenniskens, 2006; Jacchia & Whipple, 1961; Brown et al., 2008). Yet, photography has remained the most precise technique for the orbit determination and atmospheric path definition. Recently, video observation with high resolution digital cameras become affordable and several meteor detection networks started operation all over the world. Among them are the Slovak Video Meteor Network (SVMN), operated by the Comenius University on the professional level, and Central European Meteor Network (CEMeNt) amateur network consisting of several stations in Czech Republic and Slovak Republic. Also we closely cooperate with the Polish Fireball Network and Hungarian Meteor Network. Video observations are able to detect fainter meteors than the classical photographic method, obtain better time resolution of individual meteors and thanks to available detection and analysis software, the data reduction is fast.

2 Slovak Video Meteor Network and CEMeNt

The Slovak Video Meteor Network currently consists of two semi-automated all-sky video cameras, developed and constructed at the Astronomical and Geophysical Observatory of the Comenius University (AGO) in Modra. The first station is located at AGO, the second one, remotely controlled, at the Arborétum Mlyňany (ARBO), at a distance of 80 km. AGO is equipped with the Canon fish-eye lens (15 mm, $f/2.8$), image intensifier Mullard XX1332 and digital video camera DMK41AU02.AS (1280 × 960 pixel, angular resolution 8.5 arcmin/pixel, stellar limiting magnitude +5.5, meteor limiting magnitude +3.5). The ARBO station contains the same optical components but the analogue camera Watec 902H2 (720 × 540 pixel, angular resolution 15 arcmin/pixel, stellar limiting magnitude +5, meteor limiting magnitude +3). The third station is portable, it has the same configuration as the station at AGO and was operating at the ARBO site during the Quadrantids. The network web site is located at: `http://www.daa.fmph.uniba.sk/meteor_network.html`.

The CEMeNt network arouse out of amateurs observers initiation and currently operates simultaneously with the SVMN. Observers among the CEMeNt work independently (`http://cement.fireball.sk`). The station at Dunajská Lužná is equipped with the Watec 902H2 Ultimate camera, XtendLan 2.8 mm lens. It uses the AD converter Canopus ADVC-55, the FOV is 114° × 85°. Also the Stochov station has the same Watec camera and AD converter as the Dunajská Lužná station but the Fujinon lens (3.6 mm). Its stellar limiting magnitude is +4.5, for meteors approximately +1.5 and the FOV is 80° × 60°. Kroměříž has the system consisting of the Watec 902 H2 camera (720 × 576 pixel), Goyo GADN varifocal 3–8 mm lens, with the FOV 75° × 60°, limiting stellar magnitude +4.6 and meteor limiting magnitude +2.5. Vyškov is in fact the same station as Kroměříž but in the mobile form. The Marianka station consists of the Watec 902H2 Ultimate camera,

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IMO bibcode WGN-392-toth-video
NASA-ADS bibcode 2011JIMO...39...34T

Figure 1 – Location of ground based video meteor stations of SVMN (AGO, ARBO) and CEMeNt (Stochov, Vyškov, Kroměříž, Marianka and Dunajská Lužná).

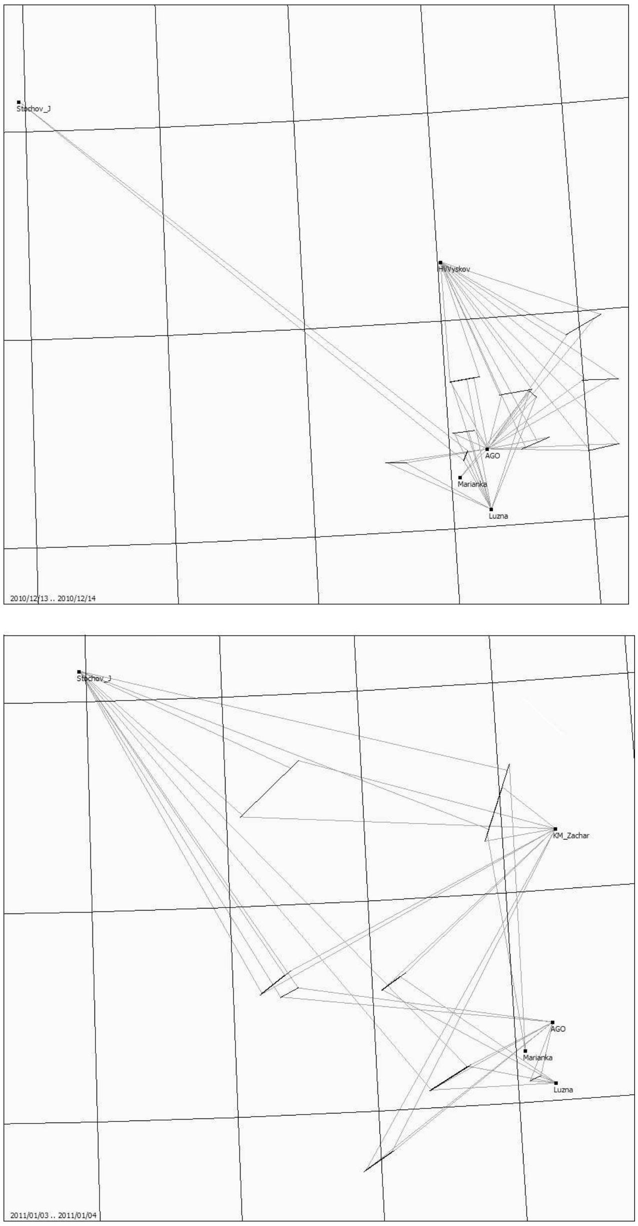

Figure 2 – Ground projection of the meteor trails detected by SVMN and CEMeNt. Upper image – Geminids 2010; lower image – Quadrantids 2011.

Fujinon 2.9–8 mm lens ($f/0.95$), the image is obtained by the internal TV grabber from Acer. The positions of SVMN and CEMENT stations are depicted in Figure 1.

3 Detection and data reduction

The video signal is analyzed and detected by the UFOCapture software (SonotaCo, 2009) which is able to recognize meteors and bolides. The meteor data had been processed by the UFOAnalyzer and UFOOrbit software (SonotaCo, 2009).

The meteor observations were performed during the maximum activity of the Geminids (2010 December 13–14) and Quadrantids (2011 January 3–4), where 44, respectively 100 meteors were observed simultaneously. In the data of the SVMN and CEMeNt we have identified 35 Geminids and 66 Quadrantids.

There are several UFOOrbit parameters that can evaluate the quality of the obtained meteor orbits. In order to separate hight quality orbits, we set multiple constraints on the data set. Due to the geometry of the incoming meteor trails we selected individual meteor pairs in order to get the maximum precision of the orbital elements. For the Geminids, we set the general quality criteria for the orbits to Q2 – internal condition of the UFOOrbit (Vereš & Tóth, 2010). Finally, we obtained 10 Geminid meteor orbits. Also, we selected Q3 quality criteria for Quadrantids and we present 8 Quadrantid orbits.

4 Results

Orbits of Geminids (2010) and Quadrantids (2011) obtained during the shower maxima are presented in Table 1 and Table 3, respectively. Also the mean orbit is calculated as the arithmetic mean of each orbital element with the corresponding standard deviation. In comparison we used the SonotaCo (2009) data set of meteor showers observed above the Japan during three years (2007–2009) and calculated the mean orbit of the Geminids (121 orbits) and Quadrantids (39 orbits) as well. Only SonotaCo orbits lying within the same range of the solar longitude as our observed meteors have been taken into account ($\lambda_{\odot,\mathrm{GEM}} \subset \langle 261\overset{\circ}{.}49; 261\overset{\circ}{.}79\rangle$ and $\lambda_{\odot,\mathrm{QUA}} \subset \langle 282\overset{\circ}{.}88; 283\overset{\circ}{.}32\rangle$). The comparison data were already filtered by the Q3 criterion in order to process only the high quality orbit. As seen on the bottom of the Tables 1 and 3, our mean orbits are very similar of those of the SonotaCo high quality subset according to its mean.

The ground projection of the individual meteor trails as seen by the multi-station observation is depicted in Figure 2. The heliocentric orbits in the view perpendicular to the ecliptic plane derived by the SonotaCo UFOOrbit software are shown in Figure 3.

To evaluate the quality of the derived meteor orbits, we employed widely used Southworth-Hawkins D-criterion (D_{SH}) (Southworth & Hawkins, 1963). The crucial role in the criterion usage is the selection of the reference nominal orbit. The obtained Geminid and

Table 1 – Multi-station Geminids detected on 2010 December 13–14, by SVMN and CEMeNt video networks. Orbital elements, geocentric velocity and observing stations are presented. Stations: Dunajská Lužná (Luz), Vyškov (Vys), Astronomical and Geophysical Observatory Modra (AGO). SonotaCo (2009) mean orbit from the solar longitude interval ($261\overset{\circ}{.}49 - 261\overset{\circ}{.}79$) is also presented.

No	a (AU)	q (AU)	e	i (°)	ω (°)	Ω (°)	α (°)	δ (°)	V_g (km/s)	Station
1	1.172	0.152	0.870	20.86	324.78	261.49	113.51	32.09	32.20	AGO-Vys
2	1.259	0.159	0.873	21.42	322.86	261.52	112.35	32.62	32.71	AGO-Vys
3	1.268	0.146	0.885	23.29	324.53	261.57	113.48	32.59	33.55	AGO-Vys
4	1.352	0.145	0.893	23.16	323.89	261.58	112.75	32.43	34.18	AGO-Vys-Luz
5	1.292	0.144	0.888	22.62	324.51	261.58	113.16	32.23	33.73	AGO-Vys
6	1.260	0.147	0.883	22.77	324.43	261.59	113.39	32.49	33.37	AGO-Luz
7	1.231	0.150	0.878	21.13	324.36	261.61	113.13	32.01	32.85	AGO-Vys
8	1.313	0.135	0.897	22.85	325.55	261.62	113.53	31.79	34.30	AGO-Luz
9	1.271	0.155	0.878	19.42	323.34	261.71	112.16	31.50	32.82	Luz-Mar
10	1.263	0.145	0.885	20.86	324.72	261.79	113.20	31.57	33.33	Sto-Luz
mean	1.268	0.148	0.883	21.84	324.30	261.61	113.07	32.13	33.30	
st. dev	0.048	0.007	0.008	1.28	0.76	0.09	0.49	0.41	0.67	
SonotaCo	1.279	0.149	0.884	22.69	324.03	261.69	113.24	32.45	33.47	121 orbits
st. dev	0.075	0.014	0.017	2.49	1.45	0.08	0.76	0.78	1.16	

Table 2 – Southworth-Hawkins D-criterion of Geminid orbits with respect to the SonotaCo (2009) mean orbit and putative parent body 3200 Phaethon.

No	$D_{\rm SH}$ (SonotaCo)	$D_{\rm SH}$ (3200 Phaethon)
1	0.036	0.043
2	0.034	0.057
3	0.012	0.037
4	0.013	0.041
5	0.008	0.031
6	0.005	0.034
7	0.028	0.039
8	0.029	0.029
9	0.059	0.065
10	0.034	0.035

Quadrantid orbits were compared with respect to the mean orbits of the showers derived from the SonotaCo video data (see Table 1 and Table 3). Likewise, the parent body orbits were used for the comparison. Individual ($D_{\rm SH}$) values with respect to the selected nominal orbits are shown in Table 2 and Table 4. Our orbits are very similar to the SonotaCo mean orbits of the Geminid and Quadrantid showers. Also the (3200) Phaethon orbit lies very close to those of our derived orbits. On the other hand, the orbit of the putative parent of the Quadrantids, (196 256) 2003 EH_1, lies apparently somehow beyond of the mean orbit of the SonotaCo and our data. The body undergone a series of close approaches to Jupiter in past centuries, the last one in October 1972 (~ 0.28 AU). The 2003 EH_1 was much closer to the presented Quadrantids about 170 years ago, when the orbits are integrated to the past.

The beginning and the terminal heights as a function of the absolute brightness of Geminids and Quadrantids are presented in Figure 4 and in the equations (1) and (2)

$$\begin{aligned} H_{\rm B} &= 96.4(\pm1.3) + 1.2(\pm1.8)\ M_{\rm A} \\ H_{\rm E} &= 84.2(\pm0.9) + 2.8(\pm1.3)\ M_{\rm A}, \end{aligned} \tag{1}$$

$$\begin{aligned} H_{\rm B} &= 95.6(\pm2.4) + 0.2(\pm0.9)\ M_{\rm A} \\ H_{\rm E} &= 81.1(\pm5.9) + 1.1(\pm2.4)\ M_{\rm A}, \end{aligned} \tag{2}$$

where $H_{\rm B}$ stands for the beginning height (km), $H_{\rm E}$ for the terminal height (km) and $M_{\rm A}$ for the absolute brightness. The brightest Geminid meteor (Figure 4) was not used in linear fit (1). It seems to be a special case of solid meteoroid. However, the beginning heights do not change too much, which is consistent with the results obtained by (Koten et al., 2004). Similarly, Quadrantids also show stable beginning heights vs. brightness, at least in the observed interval. Naturally, terminal heights decrease with the increasing brightness in both meteor showers.

5 Conclusion

We present 10 Geminid and 8 Quadrantid heliocentric orbits of meteors obtained by multi-station video observations done by the Slovak Video Meteor Network and Central European Meteor Network. The detection, data analysis and orbit derivation were made by using the SonotaCo UFO software package. The meteor shower orbits and their comparison with the SonotaCo database proposed parent bodies indicate that the video observation is able to provide relatively high quality data. Video observations offer a detection of fainter meteors and therefore higher numbers in comparison with classical photographic methods.

The coordinated video observation of meteors with amateur astronomers brings a significant number of high quality heliocentric orbits. This cooperation has proved to be useful due to uncertain weather in the Central Europe. In addition to current two professional stations, future observations with amateurs might bring more results, especially during active meteor showers or other observing campaigns.

Table 3 – Multi-station Quadrantids detected on 2011 January 3–4 by SVMN and CEMeNt video networks. Orbital elements, geocentric velocity and observing stations are presented. Stations: Marianka (Mar), Dunajská Lužná (Luz), Stochov (Sto), Kroměříž (Kro), Astronomical and Geophysical Observatory Modra (AGO). SonotaCo (2009) mean orbit from the solar longitude interval ($282\overset{\circ}{.}88 - 283\overset{\circ}{.}32$) is also presented.

No	a (AU)	q (AU)	e	i (°)	ω (°)	Ω (°)	α (°)	δ (°)	V_g (km/s)	Station
1	2.040	0.982	0.518	70.86	175.56	282.99	226.65	49.72	39.40	Mar-Sto-Kro
2	2.608	0.980	0.624	72.10	172.51	283.14	228.67	49.22	40.87	Kro-Sto
3	2.433	0.983	0.596	69.34	179.15	283.19	227.39	51.93	39.32	Kro-Sto
4	2.779	0.981	0.647	70.94	173.73	283.20	229.36	50.23	40.51	Kro-Sto
5	2.477	0.975	0.607	68.25	167.54	283.22	233.18	49.58	38.90	AGO-Kro
6	2.645	0.983	0.628	70.31	177.64	283.24	227.85	51.35	40.06	Ago-Sto-Luz
7	2.471	0.980	0.604	69.60	171.83	283.25	230.46	50.07	39.52	AGO-Sto
8	2.921	0.983	0.663	71.07	178.44	283.31	227.45	51.44	40.71	Ago-Luz
mean	2.547	0.981	0.611	70.31	174.55	283.19	228.88	50.44	39.91	
st. dev	0.264	0.003	0.044	1.20	3.93	0.10	2.12	1.00	0.73	
SonotaCo	2.467	0.978	0.606	70.162	169.89	283.30	230.39	49.20	39.82	39 orbits
st. dev	0.487	0.003	0.082	2.59	2.98	0.16	2.36	0.93	1.79	

Table 4 – Southworth-Hawkins D-criterion of Quadrantid orbits with respect to the SonotaCo (2009) mean orbit and putative parent body 2003 EH_1 in years 2011 and 1840.

No	SonotaCo	2003 EH_1 (2011)	2003 EH_1 (1840)
1	0.10	0.24	0.18
2	0.05	0.21	0.05
3	0.10	0.23	0.15
4	0.06	0.21	0.04
5	0.04	0.23	0.13
6	0.09	0.22	0.11
7	0.02	0.21	0.11
8	0.11	0.23	0.07

Acknowledgment

This work was supported by VEGA grant No. 1/0626/09. We greatly appreciate the video observations and data analysis done by the amateur astronomers of the CEMeNt network and their contribution to this work.

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Handling Editor: Javor Kac
This paper has been typeset from a LaTeX file prepared by the authors.

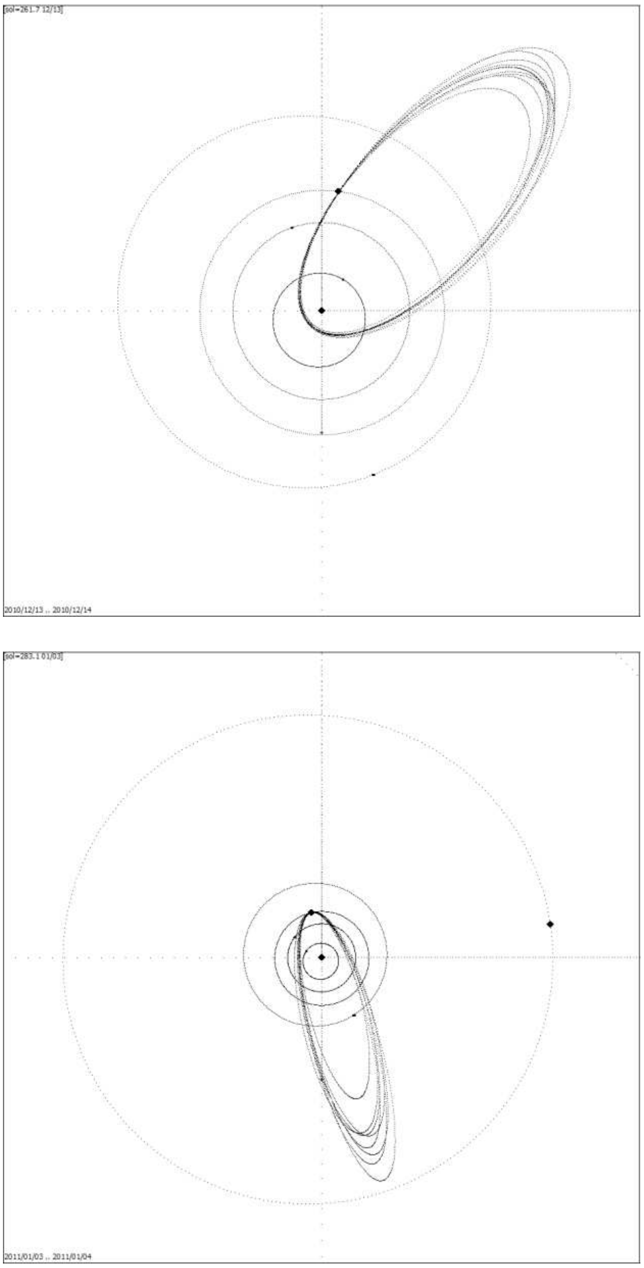

Figure 3 – Orbits of multi-station meteors detected by video stations, derived by UFOOrbit software. Upper image – Geminids 2010; lower image – Quadrantids 2011.

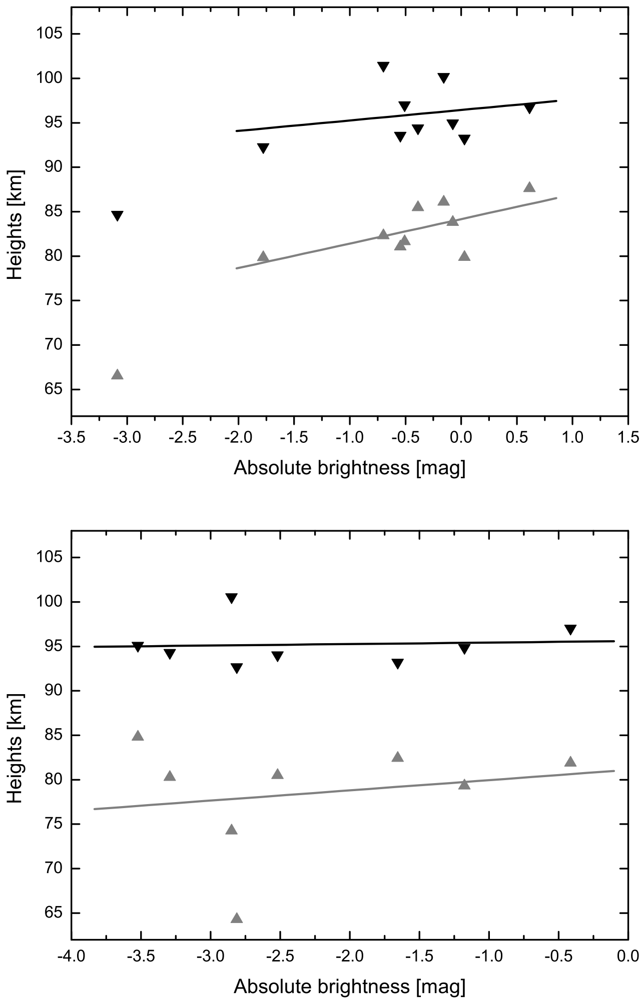

Figure 4 – The beginning (black triangles) and terminal heights (gray triangles) of Geminids (upper image) and Quadrantids (lower image) as a function of the absolute brightness.

Meteor spectral observation with DSLR, normal lens and prism

Sihao Cheng [1] *and Simiao Cheng* [2]

A method for recording meteor spectra using a digital single-lens reflex (DSLR) camera, a normal large aperture lens and custom designed prism is described. The complete setup is guided and directed to meteor shower's radiant. A detailed calculation of the performance of this setup and observations during Geminid's maximum in 2010 are presented: 13 spectra were obtained and more than 35 spectral features were found. This method is quite efficient and at acceptable price for amateur astronomers. Using the "Live View" function of DSLR camera helps with accurate focusing. The spectra are sharper and the resolution is higher compared to a classical film camera. Also, fainter spectra are recorded compared to a 35 mm film camera.

Received 2011 February 28

1 Introduction

Meteor spectroscopy is a tool for studying meteor phenomena, the composition of meteoroids and the Earth's upper atmosphere. High resolution meteor spectra were obtained and analyzed by different methods earlier (Airey, 1999; Borovička et al., 1996; Borovička & Majden, 1998; Borovička et al., 2006; Evans & Ridley, 1993; Cook & Millman, 1955; Russell, 1948; Harvey, 1978) but it is always valuable to record more spectra. The dispersion element of a meteor spectrograph is either an objective prism or objective grating, put in front of the camera lens. A prism is more favorable due to its high efficiency, i.e. all light from the meteor is dispersed into the spectrum whereas ordinary transmission grating leaves considerable energy in zero-order with no dispersion. More favorable is a blazed grating which concentrates the energy into one particular spectral order and leaves the other orders quite dark, but a blazed grating is expensive and still not 100% efficient. The disadvantage of prism is that, when used with a short focus lens the dispersion, and thus the resolution, of the spectrum is low. Also, the prism's size as well as the weight is considerably larger than a grating that produces the same spectral dispersion.

Many people believe that photographic observations of meteors need a wide field of view. Two choices of either shortening the focal length of the lens or enlarging the film format camera do exist. One of them is chosen by most meteor spectra observers. Larger format film and camera is usually employed by professional astronomers for its high resolution, but the price of large format camera, lens, film, and an appropriate prism is much higher than that of a standard 35 mm camera. An alternative solution, matching a short-focal-length lens and 35 mm camera, is much cheaper and is used by most amateur astronomers. However, only a few observers employ the latter solution because of low resolution that can be achieved with a prism. To some extent, this explains the relatively small number of meteor spectra recorded to date by amateurs.

As the digital technology progresses, most amateurs switch to using a wide field lens and digital single lens reflex (DSLR) camera coupled with a transmission grating. This combination sacrifices some of the available light and can only capture spectra of relatively bright meteors. Generally some 2 or 3 spectra can be obtained during the maximum of a major shower such as Perseids. As a comparison, 17 meteor spectra were photographed with a large format spectrograph during two consecutive Perseid showers (Russell, 1980).

This paper presents another method that is accessible to most amateurs: a combination of a DSLR camera and a large-aperture normal lens with a custom designed prism (historically some authors did employ such type of lens with 35 mm film camera, e.g. (Rajchl et al., 1995). This setup provides a nice balance of efficiency, resolution and price. It also allows observations of fainter meteor spectra. If this method is widely used by amateurs the database of meteor spectra can be enlarged and enriched considerably.

2 The efficiency of normal lenses in meteor photography

Many meteor observers think that a wide field is necessary for meteor photography. However this is not correct at the present time. The efficiency of a photographic device for meteor photography (including meteor spectra) can be understood as the number of meteors recorded which is not equal to the number of all meteors that occur in the field of view of the camera. While the technical details of the equipment influence the efficiency, equally important is the direction of field of view relative to the radiant if a normal lens is used to photograph meteors.

To improve the efficiency of the equipment, two possibilities exist: to enlarge the field of view, or to increase the light gathering efficiency. Being restricted to a common 35 mm camera or APS-C format digital camera, differences between these two approaches depend mostly on lens selection. The relationship between lens characteristics and recorded brightness of a meteor is different than that for stars or nebulae. Let us simply consider the brightness of meteor trail on a unit length of film or on each pixel of a CCD/CMOS detector (abbreviated as "pixel" below). This brightness is proportional to the focal length of the lens and inversely proportional to the square of its focal ratio, as discussed by Russell (Russell, 1964). That can be

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IMO bibcode WGN-392-cheng-spectra
NASA-ADS bibcode 2011JIMO...39...39C

understood assuming that the meteor is a moving light point. For example, the limiting meteor magnitude of a 50 mm $f/1.8$ lens, compared to a 17 mm $f/4$ lens, is about 3 magnitudes fainter than that of the later.

The position of the field of view relative to the radiant influences not only the length of the meteor trail, but also the efficiency of recording. Let us assume that meteoroids crash into the Earth's atmosphere isotropically. Their trails, when observed from the ground, do not look evenly distributed: more meteors occur near the horizon, and less near zenith. However, meteors near zenith are closer to the observer and look brighter than those near the horizon. In visual observations and wide field photography, fewer differences are seen by changing the direction of observing than in normal field of view photography. Thus, according to the "standard procedure", visual data do not need to record information of a meteor's direction. Telescopic observation requires the field of view to be close to the radiant for the sake of proper meteor length. A normal field of view photographic observation needs the field of view to be close to the radiant not only for this reason, but also because of a higher light gathering efficiency. If we suppose that the height and velocity of meteor are constant, it can be deduced from Figure 1 that:

$$L \propto \frac{t}{D^2} \tag{1}$$

$$t \propto \frac{D}{|\sin\theta|} \tag{2}$$

$$D \propto \frac{1}{\sin h} \tag{3}$$

$$N \propto \frac{D^2 \sin\theta}{\sin h} \propto \frac{\sin\delta}{\sin h^3} \tag{4}$$

Where f is the focal length of lens, A is the focal ratio of the lens, t is the time of meteor image staying at one pixel, δ is the elevation of the radiant, h is the elevation of meteor above the horizon, D is the distance from meteor to observer, θ is the elongation between the meteor and the radiant, L is the photographic brightness of the meteor and N is the number of all meteors that occur in the field of view (recorded or not).

Further, it can be seen that:

$$L \propto \frac{f \sin h}{|\sin\theta|\, A^2} \tag{5}$$

$$N \propto \frac{\sin\delta}{\sin h^3} \tag{6}$$

(not applicable when h is lower than 15° due to the curved atmosphere).

The length of meteor $l \propto f\ |\sin\theta|\ \sin h$, make it constant:

$$L \propto \frac{f^2 \sin h}{A^2} \tag{7}$$

The larger L and N are, the higher is the efficiency of the setup. Since the discussions above do not take atmospheric extinction into account, care should be taken when the field of view is near the horizon. Slow meteors are obviously easier to record than fast ones. For example, we should record more Geminids' spectra than Perseids' spectra, which is not quite in accord with spectral observational data. One possible explanation is that the Perseids shower produces more fireballs and most of former spectral observations had low limiting magnitude. The other factor may be the bad weather for the Geminids in some parts of the world.

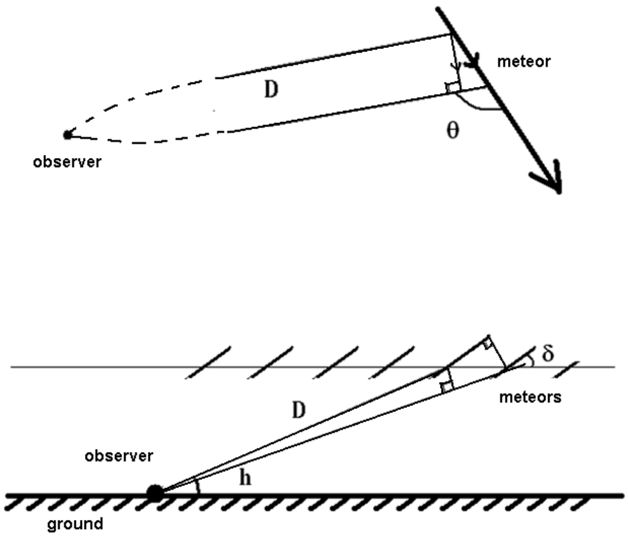


Figure 1 – A sketch of observer, meteor and relevant geometrical parameters. Upper panel shows the elongation between the line of sight and the radiant direction. The radiant direction is the direction opposite to the meteor flight. In the lower panel, parallel short lines represent meteors, assumed to be at the same height.

Several observations were carried out to test the efficiency of a normal lens, the most convincing one on 2009 December 13, from $14^{h}30^{m}$ to $21^{h}40^{m}$ UT. This observation of the Geminids was carried out at Miyun County, Beijing, China (117°08′32.0″ E, 40°41′18.9″ N) with nearly no artificial lights arround the site. A Canon 450D DSLR, Canon EF 50 mm $f/1.8$ II lens at f/2.2 and ISO 1600 was used. Images were taken in raw format, which was later converted into JPEG format with a size of 4272 × 2848 pixels. The weather was clear. During the total 370 minutes of recording (573 shots) 25 Geminids and 5 sporadic meteors were recorded. The average ZHR at this time was 105 according to the International Meteor Organization (2009). The finest ones are shown in Figure 2. Note that their trains are visible. This observation was also a test of lens quality. It turned out that at $f/2.2$, the off-axial quality of image is acceptable.

3 The spectroscopic setup

Our conclusions about a good spectroscopic setup using a prism and a DSLR are as follows:

Lens: large aperture and moderate focal length lenses (standard or portrait lenses) are ideal choice. They are highly efficient and well designed, so they can provide good image quality at economical price for am-

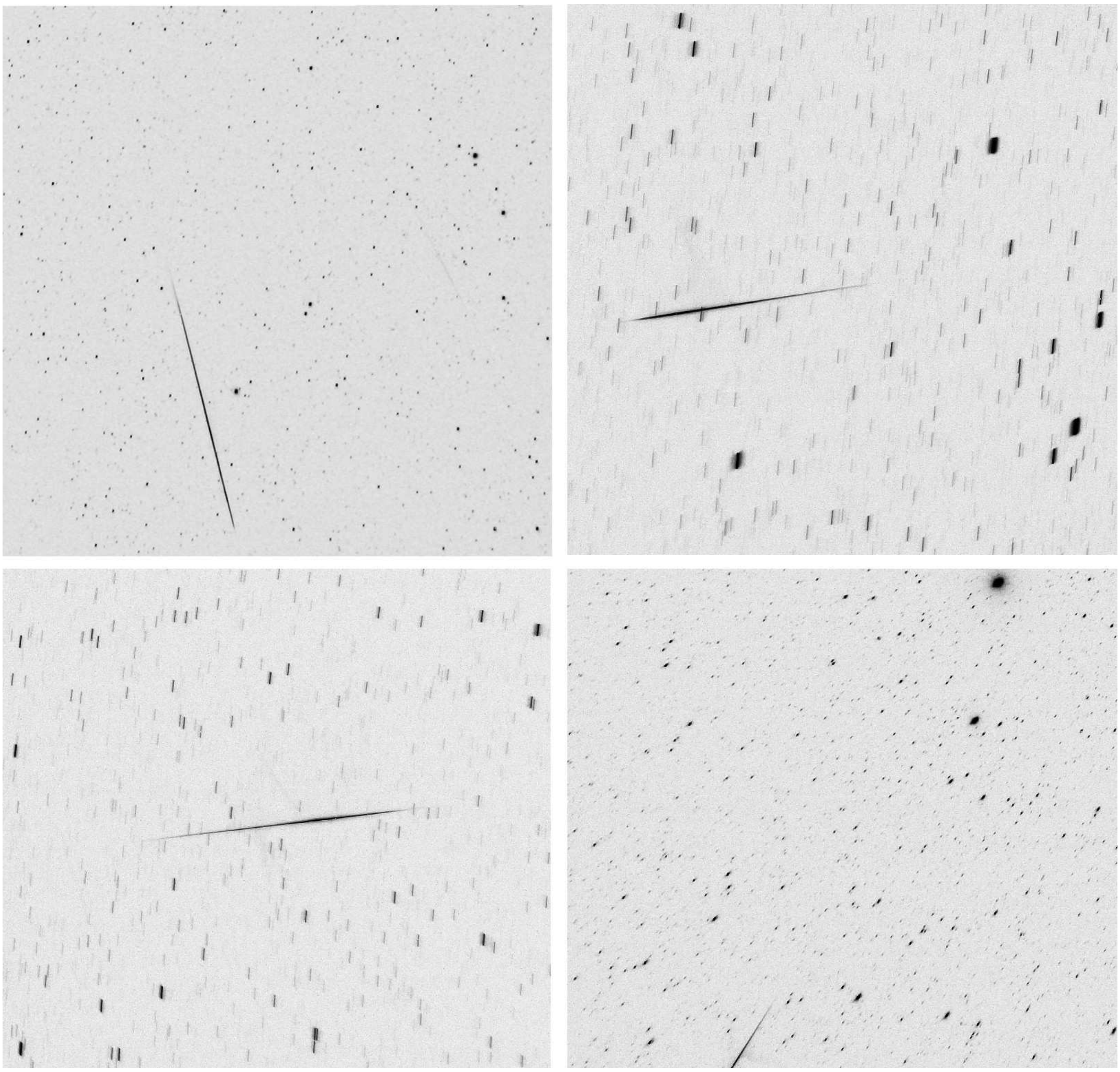


Figure 2 – 800×800 crops of 2009 Geminid photos (shown as negatives), with 5 Geminid meteors recorded on December 13. Taken with Canon 450D DSLR, 50 mm $f/1.8$ lens at $f/2.2$, exposed for 30 seconds (guided). Images were taken by Gao Bo in Miyun County, Beijing, China. Upper left: 16^h51^m UT, two Geminid meteors were captured in one image. Upper right: at 19^h41^m UT, persistent train is visible. Bottom left: at 19^h56^m UT, persistent train is visible. Bottom right: at 20^h58^m UT, persistent train is visible.

ateurs. Longer focal length provides higher efficiency and spectral resolution (since the limit of resolution for 50 mm lens is set up by the thickness and weight of prism), but at more cost and more demanding equatorial mount. So, 50 mm $f/1.8$, 85 mm $f/1.8$, 50 mm $f/1.4$, 100 mm $f/2$, etc. are best choice.

Camera: a Digital Single-Lens Reflex camera has many advantages. It is comparable in price to a large format camera, but is more useful in daily life. It is also more sensitive than film. Polychromatic results are a weakness for traditional astronomical work, but here they provide a convenient help in identification of lines by color, especially when only one or two lines are visible in meteor spectrum. All camera brands are acceptable; however, a camera with the "Live View" function is more practical and larger format is, of course, better. The "Live View" function makes focusing process easier and more accurate, which will considerably improve the resolution of the spectra.

Orientation: as calculated above, the regions near meteor shower's radiant are the best targets for a normal lens during a meteor shower. However, too close is not optimal, since it is better to have all meteor trails approximately in the same direction. A good compromise is to place the radiant at the center of photo's short border, or farther. Figure 3 presents one example. Pointing the camera higher than the radiant is better, due to smaller atmospheric extinction, especially when the radiant has set low, but to some extent, frequent changes of orientation will make processing and analysis of images difficult.

Figure 3 – A picture composed from 3 photos taken on 2010 December 14, the Geminid night, shows an example of setting the orientation. The radiant of Geminids is slightly beyond the right edge of the image.

Dispersion equipment: for most amateurs a prism is a better choice than a grating for this method. To cut down the cost of a prism, the authors have produced a few tens of them, with standardized dimensions. So far, many amateur astronomers in China possess DSLR camera and are interested in this project. For detailed information about this prism device refer to Part 4.

Exposure: follow the rule of background – do not make the signal of background too large. The Digital camera's sensor is sensitive enough to record signals of a few photons, which means the noise may be the dominant signal in recorded trails. Large noise will ruin details in spectra of faint meteors, and reduce the limiting meteor magnitude. Thanks to the reciprocity failure of film, the background on film grows very slowly and smoothly. On the contrary, a digital camera is linear, and the background brightens quickly, which requires frequent short exposures. The specific exposure time depends on the ISO setting of the DSLR, focal ratio and sky conditions. Focal ratio controls not only exposure, but also the image quality. The use of a rotating shutter will reduce the background glow.

Meteor: slow meteors are easier to capture than fast ones. Sporadic meteors can typically be captured with frequency of one per night.

Other:

1.) Particularly for Canon EF 50 mm $f/1.8$ lens, the focusing ring is quite loose and needs adhesive tape to fix it. Moisture may reduce the tape's adhesiveness so defocusing can occur. Cold does not show this effect. Thus, periodic check during observation is necessary.

2.) RAW digital format of the camera should be used for storing images. If the focal length of lens is not too long, for example 50 mm, the highest resolution is recommended. Digital camera provides a linear sensitivity and convenient format when linked to computer. Highest quality JPEG format is usable, but has less dynamical range than the RAW format.

4 The objective prism

Prism may be difficult to acquire because there are few models of prisms usable for meteor spectral work in stock and custom-made single piece is not economical. Hence, the authors designed and manufactured a batch of 9 pieces, with an acceptable cost of about 80 $US per piece, for 50 mm $f/1.8$ lens that can be ordered from an optical factory (Changchun Jixiang Optoelectronic Co., Ltd.). However, other similar lenses, such as 85 mm $f/1.8$, 55 mm $f/2$, 58 mm $f/2$ and 50 mm $f/1.4$ are also usable.

The prism mount consists of 4 parts: a 58 mm lens lid, a ring pressing on the prism, a prism with 35° wedge angle and a tube with a 52 mm screw thread. The prism is coated by MgF_2 layer to reduce reflection and protect the glass. This set can be used for other astronomical spectral work too. In order to use it with lenses of other sizes of screw thread, different filter adapters can be put between the tube and lens. Drawings of the complete setup are shown on Figure 4. The glass used is ZF6 from Chengdu Guangming Glass Company, n_d=1.75520 and v_d=27.53, similar to SF14 glass in Schott catalogue. Tube and ring are made of aluminium. The total weight of the setup is about 250 g. As the dispersion of prism is non-linear, the spectral dispersion, for a 50 mm focal length lens, is given in Table 1. Since different cameras have different size of pixels, the authors express the dispersion as "6 Å resolution", i.e. the length of 6 Å difference in wavelength on the image sensor, when the camera is equipped with a 50 mm lens.

5 Observations

The described method was successfully tried on a Geminid night of 2010 December 14, from 13^h06^m to 22^h24^m UT. In about 460 minutes of total exposure (1217 shots), 12 Geminids and 1 very faint sporadic meteor spectra were recorded with a Canon 450D DSLR, Canon EF 50 mm $f/1.8$ II lens and the prism described

Table 1 – The resolution of the prism device.

Wavelength (Å)	4000	4400	4800	5200	6000	6500	7000
6 Å resolution (μm)	12.5	8.5	6.1	4.6	3.0	2.2	1.7

above. The camera was pointed near the Geminids' radiant and guided, beneath a clear sky in Miyun county (116°49′47.4″ E, 40°33′03.3″ N, about 80 km from Beijing's downtown), Beijing, China. The brightest of the 13 meteors, IMG8863 was seen visually also, so that its visual brightness is known: magnitude −2. Figure 5 shows recorded spectra. As that was a single-station observation and no rotating shutter was used, the meteor trajectories are not known. Camera settings were as follows: M Mode, ISO 1600, Large and high quality JPEG format (resolution 4272×2848), $f/2.2$, 20 s or 30 s per shot. Table 2 shows data for all recorded meteors. It seems that Geminids tend to appear in groups.

6 Data processing and analysis

Except for IMG8498 whose lines overlapped each other due to unlucky direction of the meteor, many features were outstanding among Geminid spectra, see Figure 5. Every meteor produced Mg I triplet at 517.5 nm which is so strong that is over-exposed and O I at 557.7 nm. These two lines are the strongest lines in meteor spectra, as illustrated by IMG8456 and IMG8067 that show only these two lines. O I at 557.7 nm showed a tail-like structure at the very beginning of the meteor, which might be related to its persistent train. Na I at 589.3 nm was also strong with only those two exceptions, especially in bright ones, consistent with (Russell, 1964) result. A blend of lines with its core at 618 nm spans from about 610 nm to about 625 nm, similar to (Russell, 1964) description. There is also a wide glow in the red. It seems that bright meteors produce the red region at the end, while fainter meteors produce it at the beginning. Most other lines seen are neutral iron.

The spectrum of the sporadic meteor shows only one line, due to its color and a bit tail-like trail identified as the O I line at 557.7 nm.

The spectra of two brightest meteors, IMG8863 and IMG8400, were further analyzed and converted into a profile form. The profiles have not been corrected for the sensitivity of instrument. Using image processing software "ImageJ" , pixels along line parallel to dispersive direction were sampled to plot a brightness-position profile. To reduce the noise, 10 groups of data sampled along meteors' direction were obtained and then averaged for each curve (Figure 6). O I at 557.7 nm was not visible in profiles.

Clear and outstanding features are marked on Figure 7 and listed in Table 3. Different times of meteor IMG8863 evolution were selected to make a comparison, shown on Figure 8.

7 Conclusions

1.) Taking meteor photos with DSLR camera and large aperture normal lens pointed to meteor shower's radiant is efficient and economical. Compared to a large format camera it is cheaper and easier to use. We thus hope that this method will attract more amateur astronomers to meteor and spectral photography. Compared to a wide field lens combined with a DSLR it is also cheaper and more efficient, especially when pointed near the radiant.

2.) A prism with a normal lens is more efficient than a grating with a wide field lens. Even when used with the inexpensive 50 mm $f/1.8$ lens, it still has adequate spectral resolution.

3.) Prism devices designed for a 50 mm $f/1.8$ lens

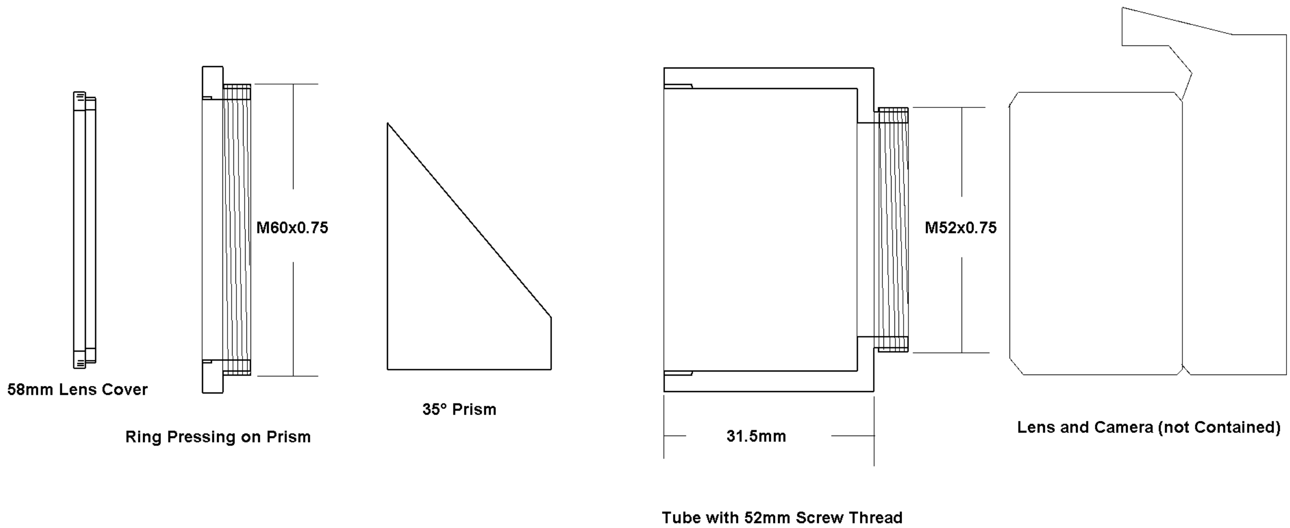
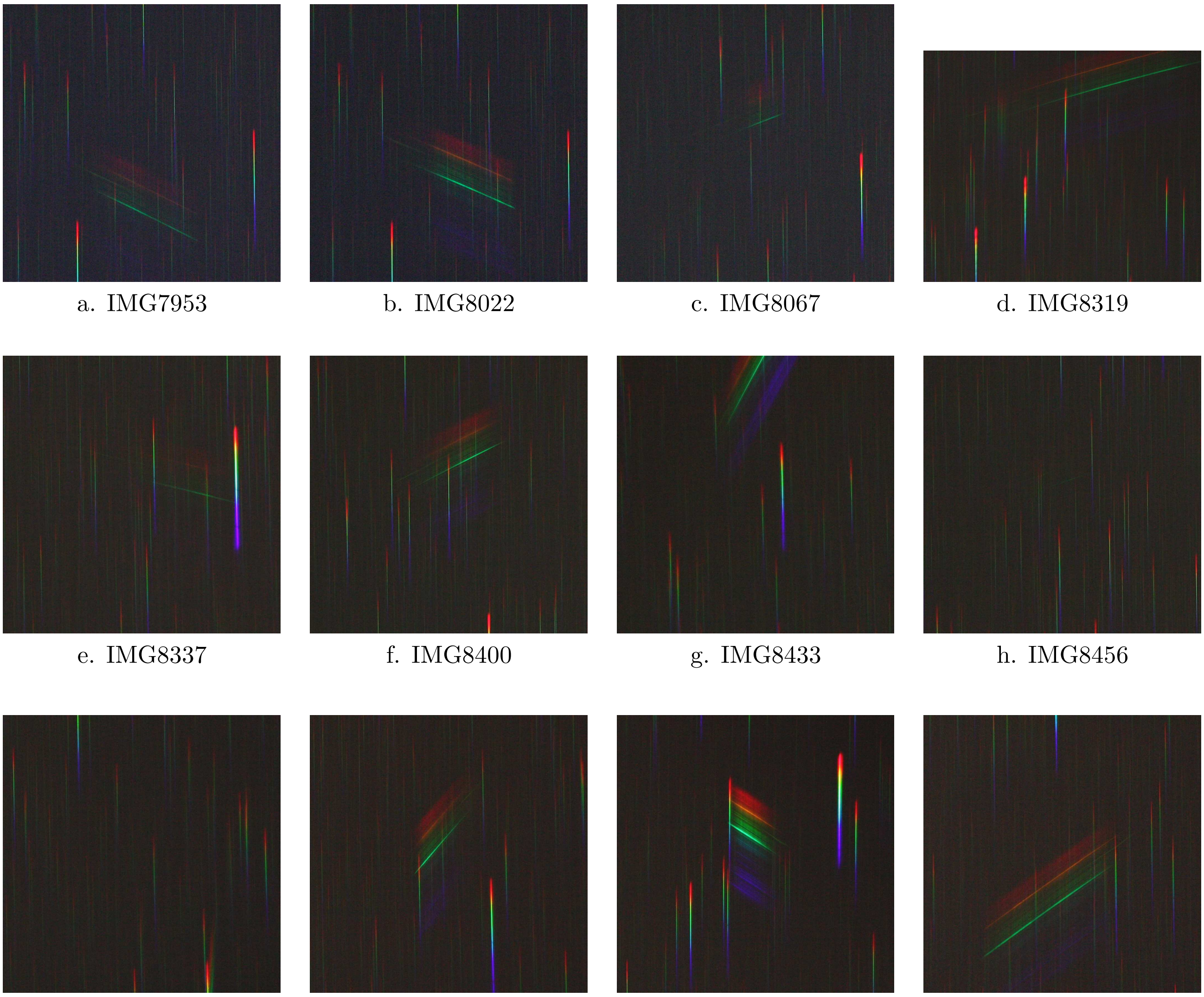


Figure 4 – The drawing of the prism device. Except camera and lens, the lens cover, ring, prism and tube that make up the device, cost about 80 $US.



a. IMG7953 b. IMG8022 c. IMG8067 d. IMG8319

e. IMG8337 f. IMG8400 g. IMG8433 h. IMG8456

i. IMG8498 j. IMG8724 k. IMG8863 l. IMG8961

Figure 5 – 1000×1000 or 1200×1000 parts of the 12 Geminid spectra recorded during the observation of 2010 December 14. For more detailed information refer to Table 2.

Table 2 – The list of meteor spectra captured on 2010 December 14.

No.	Time (UT)	Shower	Remarks
IMG7953	14^h56^m	GEM	Two peaks
IMG8022	15^h22^m	GEM	Two peaks
IMG8067	15^h39^m	GEM	
IMG8319	17^h28^m	GEM	Two peaks, head out of view
IMG8337	17^h36^m	GEM	
IMG8400	18^h00^m	GEM	
IMG8433	18^h13^m	GEM	Head out of view
IMG8456	18^h21^m	GEM	Only two lines visible
IMG8498	18^h51^m	GEM	Lines overlapped
IMG8705	20^h19^m	SPO	Only one line visible
IMG8724	20^h26^m	GEM	
IMG8863	21^h21^m	GEM	Very bright
IMG8961	21^h58^m	GEM	Two peaks

Table 3 – The list of meteor spectra captured on 2010 December 14.

No.	Measured wavelength (nm)	Species	Laboratory wavelength (nm)	Remarks
1	422.5	Ca I	422.67	absent at beginning, weak in faint meteors
2	425.5	Cr I	425.44	absent at beginning
3	427.0	Fe I, Cr I	427.18, 427.48	
4	430.5	Fe I?, Fe I	429.92?, 430.79	
5	432.5	Fe I	432.58	
6	437.5	Fe I, Fe I/Cr I	437.59, 437.68	
7	440.0	Fe I	440.48	
8	441.5	Fe I	441.51	weak at the end
9	446.0	Cr I	445.94, 445.98	
10	447.5	Fe I	447.30	
11	456.5	Cr I, Mg I	456.96, 457.17, 456.80	absent at beginning
12	461.0	Cr I, Cr I	461.34, 461.42	
13	464.0	Cr I	463.97	
14	469.5	? ?	absent at beginning	
15	487.0	? ?		
16	492.0	Fe I	492.05	
17	495.5	Fe I	495.76	
18	511.5	Fe I	511.04	weak at the end
19	517.0	Mg I(, Cr I)	516.73, 517.27, 518.36(, 520.84)	very bright
20	522.5	Fe I	522.72	
21	527.0	Fe I	526.95	
22	533	Fe I	532.80	
23	537	Fe I	537.15	
24	542	Fe I	539.71, 540.58, 542.97, 543.45	
25	553	Mg I	552.84	absent at beginning
26	559	? ?		
27	569	? ?		
28	589	Na I	589.00, 589.59	very bright
29	602	? ?		
30	618	Ca I?	616.8?	
31	633	? ?		
32	640	N_2?	637.16?	
33	648	N_2	? ?	weak at beginning, weak in faint meteors
34	668	N_2	? ?	
35	680	? ?		

have been made with a relatively reasonable price, about 80 US dollars a piece. It can be screwed onto the front of lens. The prism can also be used with longer focal length lenses as long as the lens aperture is not too large. Test observations were made with satisfactory results: 13 spectra were captured. The brightest spectra were analyzed and many typical features were identified.

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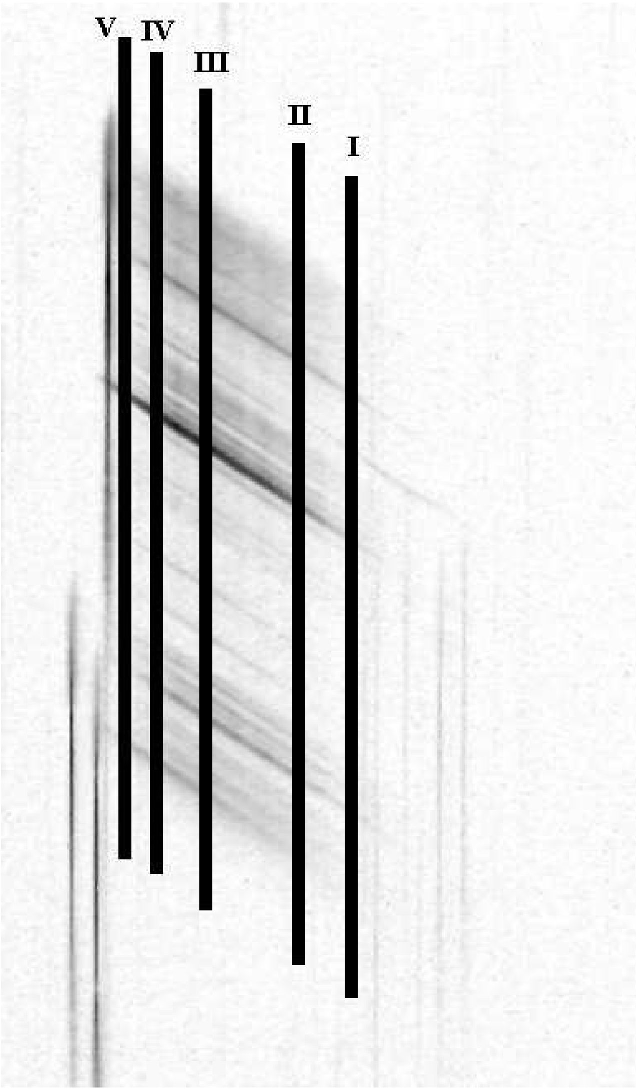

Figure 6 – The pixel selection example of IMG8863. Five times during the meteor's path were selected to make spectral curves.

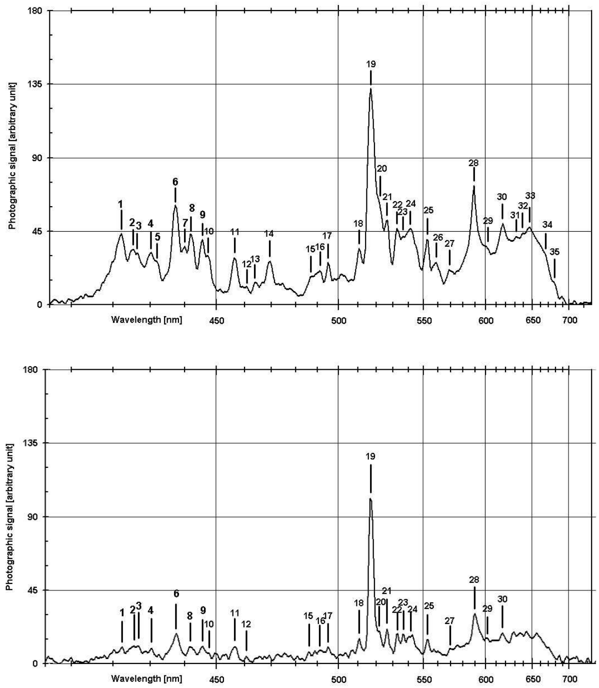

Figure 7 – Brightness versus wavelength profiles made with 10 lines which are parallel to dispersive direction. Top: the middle part of IMG8863, clear features was marked. Bottom: the middle part of IMG8400, same features to IMG8863 were marked.

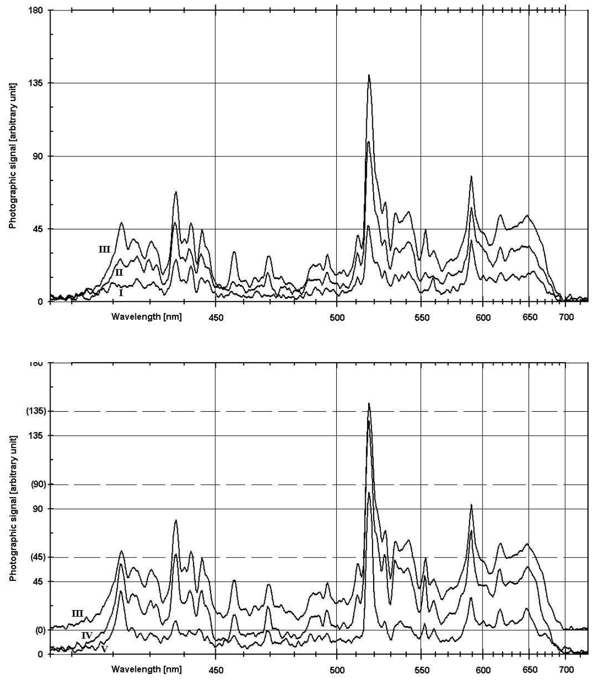

Figure 8 – Comparison of different time of IMG8863. The sampled position was marked on Figure 6, with I, II, III, IV and V. Since both tail and head of meteor are faint, it was separated into tail-to-middle and middle-to-head profiles. Top: the profiles of meteors tail-to-middle part. Bottom: the profiles of meteors middle-to-head part.

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Handling Editor: Željko Andreić

Preliminary results

Results of the IMO Video Meteor Network — December 2010

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Preliminary results for December 2010 are presented of the IMO Video Meteor Network data, obtained by 47 cameras of the Network. More than 30 000 meteors were recorded in more than 3 400 hours of effective observing time. The maximum of the Geminids is examined, and the activity profile is presented for December 13/14. The overall statistics of the Network in 2010 are presented. The Network expanded again, growing to 57 cameras that collected more than 35 000 hours of observing time and recorded more than 190 000 meteors.

Received 2011 February 25

1 Introduction

December was fair to middling just as the whole year of 2010. Poor conditions persisted for most of the time – only during the Geminid maximum did the weather improve at most sites. More southern located observers were privileged again, as they enjoyed clear skies in the most interesting nights, whereas observers in Germany, for example, could catch only a few cloud gaps. For this reason, it became the hour of our observers in Hungary, Slovenia and Italy: The bright Moon could not really harm their wide-angle Mintron cameras, and so they obtained incredible results on December 13/14: C3P8 – 421 meteors, Noa38 – 470 meteors, Hubec – 500 meteors, Min38 – 524 meteors, Stg38 – 535 meteors, Stefka – 543 meteors, Rezika – 560 meteors and Sco38 even 620 meteors! The Moon was more harmful to the two image-intensified cameras of Klaas Jobse, which normally outperform the other cameras. In this case, however, "only" 419 and 421 meteors respectively were recorded. Those 36 cameras active in the Geminid maximum night captured over 8 300 meteors – the best result ever obtained in a single night. If we add the nights before, we end up with more than 22 000 meteors observed between December 9 and 14 alone, which ramp up the totals for this otherwise lame month (more than 30 000 meteors in 3 400 hours effective observing time, see Table 4 and Figure 1).

The observing series of Carl Hergenrother that we addressed already in our last report (Molau et al., 2011) ended on December 29. Thus, he managed to observe 125 nights in a row with his camera Salsa3 – another unparalleled result in the IMO network.

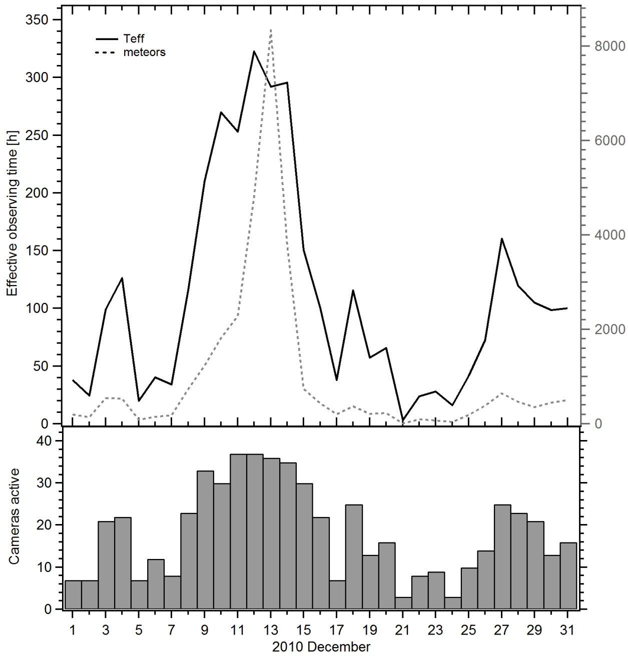

Figure 1 – Monthly summary for the effective observing time (solid black line), number of meteors (dashed gray line) and number of cameras active (bars) in 2010 December.

2 Geminids

Let us now have a closer look at the Geminid activity on December 13/14. The analysis was based on 11 cameras with the best observing conditions and covers half a day from 17^h30^m to 05^h30^m UT. Single intervals with partial cloud cover were omitted. For each camera, we calculated the number of Geminids in half hour intervals, corrected it by the radiant altitude, and averaged the number over all camera systems. The result, which is based on exactly 3 333 meteors, is given in Figure 2. The ZHR profile of the IMO quick look analysis based on 4 700 visual Geminids (International Meteor Organization, 2010) is given for comparison as a line. Both profiles show an increase in activity in the evening hours, with the slope in the visual data being slightly steeper. Between about 22^h30^m and 03^h30^m UT, the visual ZHR was beyond 100, but there is no clear maximum. Highest rates in the video data occurred between 22^h30^m and 03^h00^m UT, and the peak activity occurred in the interval 00^h30^m to 01^h00^m UT.

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IMO bibcode WGN-392-molau-viddec
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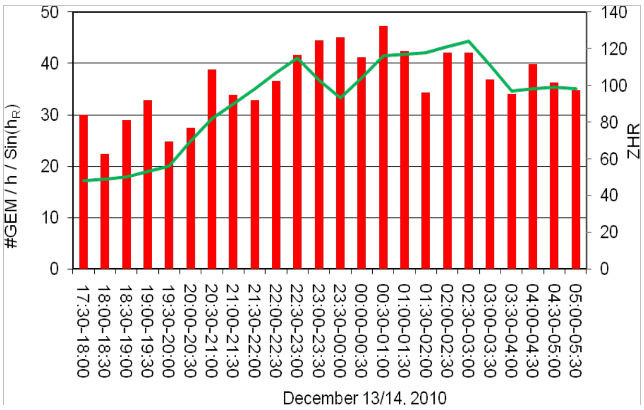

Figure 2 – Activity profile of the Geminids on 2010 December 13/14. The ZHR profile obtained by IMO from visual data (International Meteor Organization, 2010) is given for comparison as a line.

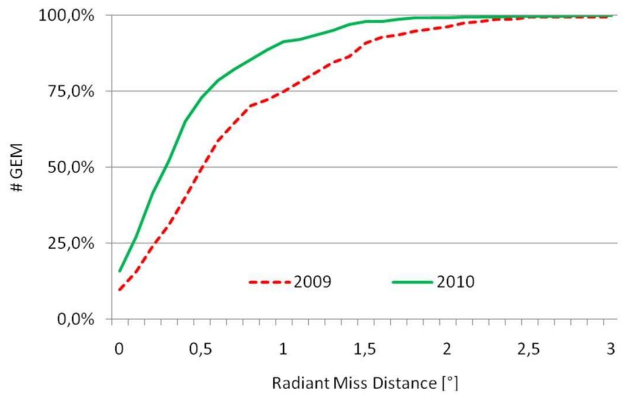

Figure 3 – Radiant miss distance of the Geminids recorded by C3P8 camera in 2009 and 2010.

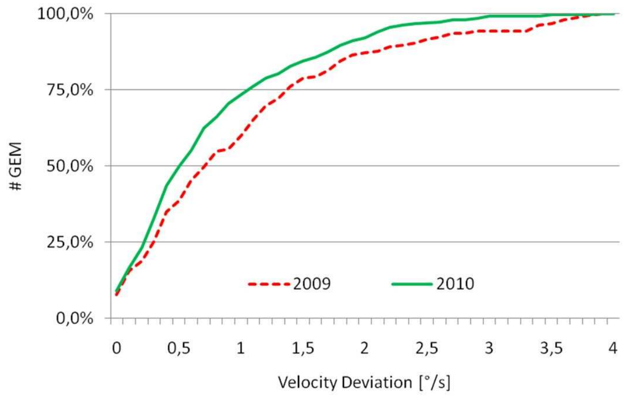

Figure 4 – Deviation of the observed from the expected angular velocity of the Geminids recorded by C3P8 camera in 2009 and 2010.

The quick look analysis included a second higher resolution profile, which shows a short-lived peak with almost doubled ZHR near $22^{h}50^{m}$ UT. That peak, however, cannot be confirmed with our video data.

3 MetRec development

One of the most important extensions of the MetRec software in 2010 was the identification of stars in the video data stream, and based on that the determination of the limiting magnitude. A "by-product" is a large number of star positions, which can be re-used to improve the estimation of the plate constants. That should improve the astrometric accuracy particularly for wide-angle cameras, because the strongly distorted edges of the field of view are better covered. But is it possible to verify this improvement quantitatively?

To answer this question we took the data set of C3P8 from the Geminid maximum (December 13/14) in 2009 and 2010. Thanks to the 3.8 mm lens, this camera has a large field of view. The orientation of C3P8 was left unchanged, and the camera recorded more than a hundred Geminids in both years (2009: 136; 2010: 325).

At first, the precise radiant position was obtained for both data sets. Then we calculated the distance of the backward prolongated meteors from the radiant, and the deviation from the expected angular velocity (in other words: the dispersion of observations). Higher astrometric accuracy should result in smaller deviations and a more compact radiant.

The result is presented in Figures 3 and 4. The x-axis represents the deviation in position and velocity respectively, and the y-axis gives the (cumulative) number of meteors. The deviation of the 2010 data set with about 4 400 (automatically) measured reference stars is clearly smaller than in the year before with about 100 (manually) measured stars. Hence, the new method yields the expected quality improvements for wide-angle cameras.

4 2010 statistics

Now we come to the overall statistics for the meteor year 2010. Given the monthly reports with all the records we registered in 2010 it is clear that the year was more successful for the IMO Video Meteor Network than any other year before. The real question is, by how much the previously best year 2009 was surpassed. 33 observers (2009: 24) from 12 countries (2009: 10) contributed with 57 camera systems (2009: 43) to the IMO network. The network is still focused on Central Europe and it grew fastest in Hungary. By the end of 2010, nine video cameras were operated there. So Hungary follows Germany (11 cameras) and Italy (10 cameras) closely. However, we should also not forget our observer from Down Under, as Steve Kerr covers the whole southern sky with his camera, where the data set is still insufficient.

A growing number of cameras naturally results in more effective observing time. Last year we collected a total of 35 300 hours, which is an increase of 10% (2009: 32 300). In that time we recorded more than 191 500 meteors, a 40% increase compared to 2009 (138 800). Including the 2010 data, the IMO Network Database has grown to a total of three quarters of a million meteors now.

The apparently higher hourly average of 5.4 meteors (2009: 4.3) is not due to higher activity. We were rather more consistent in also omitting smaller cloud intervals from the effective observing time.

Even though the weather was fine in a number of months, October and August have to be highlighted in particular, when the effective observing time and the meteor count reached undreamed of heights. February on the other hand was the clear loser. Table 1 gives the distribution of observations in 2010.

In the observer centric statistics, there has been a change on top for the first time in many years: Thanks to the perfect Arizona observing conditions, Carl Hergenrother clearly took the lead with 327 observing nights (with only one camera). Sirko Molau "only" ranked second with 291 nights (based on four cameras at two sites), chased closely by Stefano Crivello with 289 nights. There are nine more observers with over 200 observing nights, and another sixteen observers with over 100 nights. These figures underline the high degree of automation of our systems.

Looking at the effective observing time and number of meteors, the picture is slightly different. In this respect, Enrico Stomeo clearly outperformed all other observers in 2010 with his three Mintron cameras. Enrico alone recorded more than 27 000 meteors, almost as many as the second and third best (once more Sirko Molau and Stefano Crivello) together! With this fantastic result, Enrico passed Jörg Strunk and Javor Kac in the long-term statistics of the IMO network, and now ranks second. If we were in sports, we would probably suppose "illegal camera doping", but in this case it is a combination of an observing site with fine weather and three cameras with wide field of view, but still good limiting magnitude. It also seems that Enrico's cameras do not yet suffer from aging, which lets other cameras lose significant power after a few years.

Details for the individual observers are given in Table 2, whereby the number of cameras and sites refer to the main part of the year.

In the ranking of the ten most successful cameras, Carl Hergenrother is not present, because he switched from Salsa via Salsa2 to Salsa3 in the course of 2010. Also the cameras of Steve Kerr and Enrico Stomeo which recorded most meteors (Gocam1: 11 018; Sco38: 10 230; Min38: 9 043; Noa38: 8 003) just missed the TOP-10. The top of the list is occupied by Italian observers. South of the Alps, they simply enjoyed fine weather in 2010, whereas the conditions farther north were clearly inferior to the years before (Table 3).

All observations will be checked once more for consistency, and then the full data set will be provided in the Internet.

As every year, we would like to thank all observers for their passion and enthusiasm which led to this excellent result. We all wish that the success story of the IMO Video Meteor Network continues in this year.

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Handling Editor: Javor Kac

Table 1 – Monthly distribution of observations in 2010.

Month	Observing Nights	Eff. Observing Time	Meteors	Meteors / Hour
January	31	1 575.2	6 350	4.0
February	28	1 321.1	4 536	3.4
March	31	2 048.8	5 580	2.7
April	30	2 855.8	9 233	3.2
May	31	1 654.1	6 085	3.7
June	30	2 142.1	7 336	3.4
July	31	3 023.1	14 986	5.0
August	31	4 622.2	32 916	7.1
September	30	3 722.8	18 801	5.1
October	31	5 603.0	39 482	7.0
November	30	3 334.7	15 991	4.8
December	31	3 438.9	30 237	8.8
Overall	365	35 341.8	191 533	5.4

Table 2 – Details for the individual observers of the IMO Video Meteor Network in 2010.

Observer	Country	Observing Nights	Eff. Observing Time [h]	Meteors	Meteors / h	Cameras (Sites)
Carl Hergenrother	USA	327	1 580.2	5 567	3.5	1 (1)
Sirko Molau	Germany	291	2 839.9	15 080	5.3	4 (2)
Stefano Crivello	Italy	289	2 427.3	14 304	5.9	2 (1)
Flavio Castellani	Italy	271	2 096.3	8 947	4.3	2 (1)
Antal Igaz	Hungary	238	1 603.3	6 809	4.2	3 (1)
Rui Goncalves	Portugal	237	2 450.5	11 977	4.9	2 (1)
Bernd Brinkmann	Germany	223	826.5	3 089	3.7	1 (1)
Javor Kac	Slovenia	222	2 080.1	12 154	5.8	4 (3)
Enrico Stomeo	Italy	217	3 722.3	27 276	7.3	3 (1)
Hans Schremmer	Germany	217	620.2	2 202	3.6	1 (1)
Mitja Govedič	Slovenia	215	992.4	4 611	4.6	1 (1)
Mike Otte	USA	204	964.6	3 883	4.0	1 (1)
Jörg Strunk	Germany	190	1 302.4	5 731	4.4	3 (1)
Steve Kerr	Australia	179	1 292.7	11 018	8.5	1 (1)
Detlef Koschny	Netherlands	173	869.0	5 122	5.9	3 (1)
Mihaela Triglav	Slovenia	162	535.0	2 271	4.2	1 (1)
Eckehard Rothenberg	Germany	161	553.4	2 333	4.2	1 (1)
József Morvai	Hungary	160	637.7	2 073	3.3	1 (1)
Maurizio Eltri	Italy	158	884.6	4 019	4.5	1 (1)
Stane Slavec	Slovenia	142	589.4	1 969	3.3	1 (1)
Paolo Ochner	Italy	142	567.7	1 343	2.4	1 (1)
Istvan Tepliczky	Hungary	141	784.6	4 341	5.5	1 (1)
Orlando Benítez-Sánchez	Spain	130	451.8	1 579	3.5	2 (1)
Robert Lunsford	USA	126	764.8	4 526	5.9	1 (1)
Ilkka Yrjölä	Finland	123	537.9	2 343	4.4	1 (1)
Klaas Jobse	Netherlands	115	930.4	12 558	13.5	2 (1)
Wolfgang Hinz	Germany	113	524.9	2 113	4.0	1 (1)
Zsolt Perkó	Hungary	109	640.9	4 169	6.5	1 (1)
Biondani Roberto	Italy	65	321.8	1 238	3.8	1 (1)
Erno Berkó	Hungary	62	553.2	2 374	4.3	2 (1)
Szilárd Csizmadia	Hungary	32	152.3	670	4.4	1 (1)
Malcolm Currie	UK	26	117.3	996	8.5	1 (1)
Rosta Štork	Czech Rep.	15	126.4	2 848	22.5	2 (2)

Table 3 – The top ten cameras of the IMO Video Meteor Network with respect to the number of nights covered in 2010.

Camera	Observing Site	Observer	Observing Nights	Eff. Observing Time [h]	Meteors	Meteors / h
Stg38	Valbrevenna (IT)	Stefano Crivello	254	1245.8	7954	6.4
Bmh2	Monte Baldo (IT)	Flavio Castellani	241	1124.5	5236	4.7
Bmh1	Monte Baldo (IT)	Flavio Castellani	238	971.8	3711	3.8
C3P8	Valbrevenna (IT)	Stefano Crivello	236	1181.5	6350	5.4
Mincam1	Seysdorf (DE)	Sirko Molau	227	890.9	4100	4.6
Templar2	Tomar (PT)	Rui Goncalves	226	1138.9	4979	4.4
Hermine	Herne (DE)	Bernd Brinkmann	223	826.5	3089	3.7
Doraemon	Niederkrüchten (DE)	Hans Schremmer	217	620.2	2202	3.6
Orion2	Središče ob Dravi (SL)	Mitja Govedič	215	992.4	4611	4.6
Remo1	Ketzür (DE)	Sirko Molau	212	658.2	2210	3.4

Table 4 – Observers contributing to 2010 December data of the IMO Video Meteor Network. Eff.CA designates the effective collection area and Tot.CA the total collection area.

Code	Name	Place	Camera	FOV [°²]	Stellar LM [mag]	Eff.CA [km²]	Nights	Time [h]	Tot.CA [10³km²h]	Meteors
BENOR	Benitez-S.	Las Palmas	TIMES4 (1.4/50)	2359	3.2	492	17	75.8	55.3	396
			TIMES5 (0.95/50)	33	7.0	261	7	13.1	—	36
BERER	Berko	Ludányhalászi	HULUD1 (0.95/3)	6500	3.8	2209	10	53.1	—	311
			HULUD2 (0.95/2.8)	5977	4.2	2978	14	59.9	—	290
BRIBE	Brinkmann	Herne	HERMINE (0.8/6)	2374	4.2	1084	13	39.7	—	143
CASFL	Castellani	Monte Baldo	BMH1 (0.8/6)	2350	—	—	17	145.1	—	1143
			BMH2 (1.2/4.5)*	4243	—	—	18	169.4	—	1287
CRIST	Crivello	Valbrevenna	C3P8 (0.8/3.8)	5575	4.2	2525	17	150.1	349.5	1554
			STG38 (0.8/3.8)	5593	4.3	2810	17	141.3	—	1766
CSISZ	Csizmadia	Zalaegerszeg	HUVCSE01 (0.95/5)	2439	—	—	13	61.1	—	367
CURMA	Currie	Grove	MIC4 (0.8/6)	1471	5.2	3008	8	40.2	—	170
ELTMA	Eltri	Venezia	MET38 (0.8/3.8)	5620	—	—	14	129.7	—	823
GONRU	Goncalves	Tomar	TEMPLAR1 (0.8/6)*	2188	5.3	2331	10	86.3	151.2	659
			TEMPLAR2 (0.8/6)*	2303	5.0	2397	12	81.6	167.5	527
GOVMI	Govedič	Središče ob Dravi	ORION2 (0.8/8)	1471	6.0	3916	23	131.1	102.5	857
HERCA	Hergenrother	Tucson	SALSA3 (1.2/4)*	4332	4.0	1471	30	194.2	137.8	866
HINWO	Hinz	Brannenburg	AKM2 (0.85/25)*	754	5.7	1306	6	20.8	33.4	75
IGAAN	Igaz	Baja	HUBAJ (0.8/3.8)	5600	4.3	3338	15	72.0	—	477
		Hódmezővásárhely	HUHOD (0.8/3.8)	5609	4.2	3031	8	38.0	—	198
		Budapest	HUPOL (1.2/4)	3929	3.5	1144	11	46.7	—	265
JOBKL	Jobse	Oostkapelle	BETSY2 (1.2/85)*	1725	—	—	6	54.3	—	1382
			KLARA2 (1.2/85)*	1564	—	—	6	55.2	—	1211
KACJA	Kac	Kostanjevec	METKA (0.8/8)*	1381	4.0	2246	7	58.7	—	466
		Ljubljana	ORION1 (0.8/8)	1420	5.3	2336	16	77.7	—	649
		Kamnik	REZIKA (0.8/6)	2307	5.0	2293	12	97.4	—	1252
			STEFKA (0.8/3.8)	5540	4.2	2882	13	79.8	—	977
KERST	Kerr	Glenlee	GOCAM1 (0.8/3.8)	5238	4.2	2637	9	55.4	121.8	747

Table 4 – Observers contributing to 2010 December data of the IMO Video Meteor Network – continued from previous page.

Code	Name	Place	Camera	FOV [°²]	Stellar LM [mag]	Eff.CA [km²]	Nights	Time [h]	Tot.CA [10³km²h]	Meteors
KOSDE	Koschny	Noordwijkerhout	Lic4 (1.4/50)*	2027	5.3	2782	2	16.4	11.5	126
LUNRO	Lunsford	Chula Vista	Bocam (1.4/50)*	1860	5.1	1719	11	92.3	—	922
MOLSI	Molau	Seysdorf	Avis2 (1.4/50)*	1771	6.1	4182	6	14.9	24.8	82
			Mincam1 (0.8/8)	1477	4.9	1716	16	42.9	31.2	180
		Ketzür	Remo1 (0.8/3.8)	5592	3.0	974	5	25.4	20.2	191
MORJO	Morvai	Fülöpszállás	Huful (1.4/5)	2522	3.5	532	13	57.2	—	231
OTTMI	Otte	Pearl City	Orie1 (1.4/5.7)	3837	—	—	6	27.6	—	118
PERZS	Perko	Becsehely	Hubec (0.8/3.8)*	5448	3.4	1500	18	127.6	—	1229
ROTEC	Rothenberg	Berlin	Armefa (0.8/6)	2369	4.8	1801	5	14.9	28.8	167
SCHHA	Schremmer	Niederkrüchten	Doraemon (0.8/3.8)	5537	3.0	846	15	46.9	—	296
SLAST	Slavec	Ljubljana	Kayak1 (1.8/28)	604	6.5	1849	13	71.9	—	355
STOEN	Stomeo	Scorze	Min38 (0.8/3.8)	5631	4.1	2407	16	119.0	—	1775
			Noa38 (0.8/3.8)	5609	4.9	5800	12	98.7	—	1454
			Sco38 (0.8/3.8)	5598	—	—	12	112.0	—	1835
STRJO	Strunk	Herford	Mincam2 (0.8/6)	2357	—	—	10	22.6	—	129
			Mincam3 (0.8/12)	728	—	—	13	49.8	—	316
			Mincam5 (0.8/6)	2344	—	—	11	48.6	—	497
TEPIS	Tepliczky	Budapest	Humob (0.8/6)	2375	4.9	2258	11	57.7	—	317
TRIMI	Triglav	Velenje	Sraka (0.8/6)*	2222	—	—	20	101.0	—	777
YRJIL	Yrjölä	Kuusankoski	Finexcam (0.8/6)	2337	5.5	3574	9	63.8	—	346
						Overall	31	3 438.9	—	30 237

* active field of view smaller than video frame

Results of the IMO Video Meteor Network — January 2011

Sirko Molau[1], Javor Kac[2], Erno Berko[3], Stefano Crivello[4], Enrico Stomeo[5] and Antal Igaz[6]

Preliminary results for 2011 January are presented of the IMO Video Meteor Network data, obtained by 47 cameras of the Network. More than 12 500 meteors were recorded in over 2 800 hours of effective observing time. Highlight of the month were the Quadrantids. Their activity profile was calculated for January 3/4. The December Leonis Minorids presented activity similar to the Antihelion source. The January Leonids, α-Hydrids and ξ-Coronae Borealids were detected as well and their activity profiles are presented. The Southern δ-Cancrids did not stand out from the sporadic background.

Received 2011 March 17

1 Introduction

January is not really renowned for pleasant weather, and this year did not really start delightfully for meteor observers. As often, the weather conditions in southern Europe were better than in the north, but only four cameras of three observers yielded more than 20 observing nights. Still, we recorded more than 12 500 meteors in over 2 800 hours of effective observing time in total (Table 1 and Figure 1) – a plus of 1/3 in meteor counts compared to the previously best January result of 2009 (Molau & Kac, 2009).

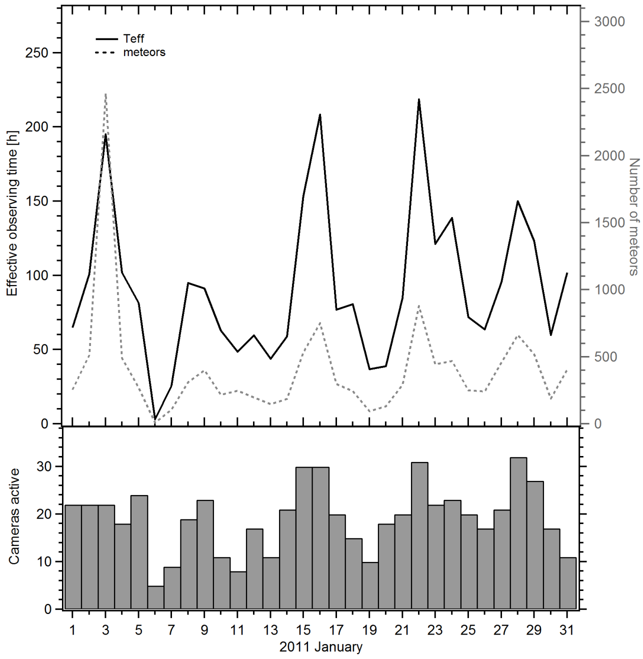

Figure 1 – Monthly summary for the effective observing time (solid black line), number of meteors (dashed gray line) and number of cameras active (bars) in 2011 January.

2 Quadrantids

The Quadrantids on January 3/4 were once more the highlight of the month. This time, the observing conditions were nearly perfect (new Moon, peak time in the European night time hours) so that poor weather was almost mandatory. Indeed, there were just three Italian observers (Enrico Stomeo, Maurizio Eltri, Flavio Castellani) as well as Mihaela Triglav in Slovenia who enjoyed prevailing clear skies. We could use the data sets of their seven cameras with 810 Quadrantids between 21^h30^m and 05^h00^m UT for our analysis. The shower meteor counts were derived in half-hour intervals, and corrected for the radiant altitude. It is well-known that the Quadrantid radiant is low in the sky before local midnight, which is why the corresponding rates have to be taken with care. It seems, however, that the activity was already rising by that time. It reached a plateau of high activity between 00^h30^m and 04^h00^m UT, and thereafter the rates declined again (Figure 2).

For comparison, we marked the visual activity profile from the IMO quick look analysis based on 1768 Quadrantids (International Meteor Organization, 2011)

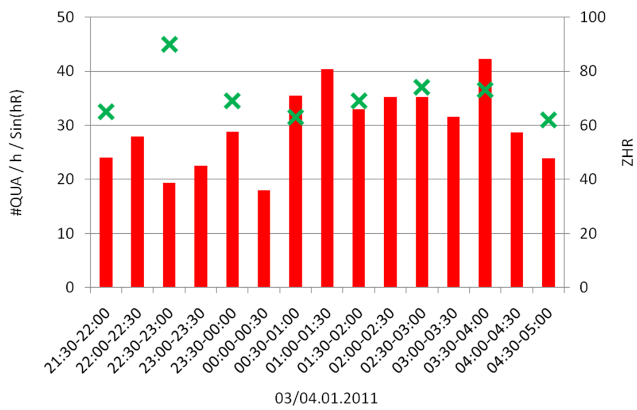

Figure 2 – Activity profile of the Quadrantids (normalized per camera) on 2011 January 3/4. Visual ZHR values from the IMO quick look analysis (International Meteor Organization, 2011) are marked with crosses.

with crosses. In principle, the overall profile is confirmed – only the visual peak at 22^h30^m UT is not present in the video data. However, more details can not be derived from the small data set.

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IMO bibcode WGN-392-molau-vidjan
NASA-ADS bibcode 2011JIMO...39...53M

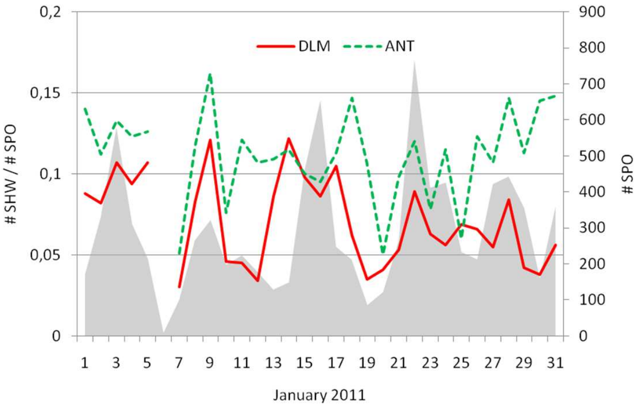

Figure 3 – Activity of the December Leonis Minorids (DLM) and the Antihelion (ANT) source in January 2011. Given is the number of shower meteors divided by the number of sporadics.

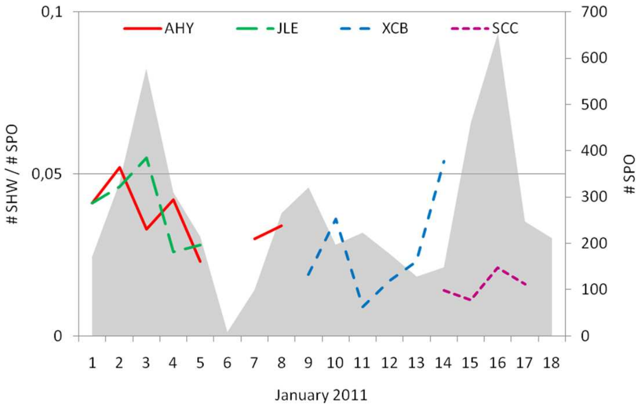

Figure 4 – Activity of the α-Hydrids (AHY), January Leonids (JLE), ξ-Coronae Borealids (XCB) and Southern δ-Cancrids (SCC) in January 2011. Given is the number of shower meteors divided by the number of sporadics.

3 Minor showers of January

Our extended meteor shower analysis of 2009 had revealed five other minor sources in January, mainly in the first half of the month (Molau & Rendtel, 2009). In the course of the present analysis, we recomputed the meteor shower assignment of all January meteors to check whether these showers were noticeably active in 2011 as well. We divided the number of shower meteors by the number of sporadics in the same night. The result is given in Figures 3 and 4. The absolute number of sporadic meteors is plotted in the background as an indicator for the size of the data set.

With 10% of the sporadic meteors, the December Leonis Minorids (32 DLM, in former years identified as Comae Berenicids) reached about the same activity as the Antihelion source. Only towards the end of the month, their rate slowly declined.

The other meteor showers were hardly noticeable in their respective activity intervals. At least there is agreement with the 2009 analysis in that the January Leonids (319 JLE) and α-Hydrids (331 AHY) reached their peak activity right at the beginning of January, and the ξ-Coronae Borealids (323 XCB) at the end of their activity interval. All three showers could be detected reasonably well at their peak with 5% of the sporadic activity. Only the Southern δ-Cancrids (97 SCC) did not stand out from the background at all.

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Handling Editor: Javor Kac

Editorial note

Javor Kac

We would like to draw your attention to the online issue of WGN. Those who receive the print version (with articles in B&W) should take the time to look at the electronic version of the journal. The journal in PDF form often contains figures in colour that we can only reproduce in grayscale in the printed from. For example, the colour plate of Figure 5 in Cheng & Cheng's Meteor spectra article (p. 44 in this issue) is well worth look at in colour!
You can access the electronic version of WGN by downloading the PDF from `http://www.imo.net/imo/wgn` (use the username and password that were sent to you for the 2011 volume earlier this year).

IMO bibcode WGN-392-kac-note
NASA-ADS bibcode 2011JIMO...39...54K

Table 1 – Observers contributing to 2011 January data of the IMO Video Meteor Network. Eff.CA designates the effective collection area and Tot.CA the total collection area.

Code	Name	Place	Camera	FOV [°²]	Stellar LM [mag]	Eff.CA [km²]	Nights	Time [h]	Tot.CA [10^3km²h]	Meteors
BENOR	Benitez-S.	Las Palmas	Times4 (1.4/50)	2359	3.2	492	5	9.6	7.1	32
BERER	Berko	Ludányhalászi	Hulud1 (0.95/3)	6500	3.8	2209	10	36.5	—	104
			Hulud2 (0.95/2.8)	5977	4.2	2978	12	41.7	—	94
BRIBE	Brinkmann	Herne	Hermine (0.8/6)	2374	4.2	1084	14	66.2	—	205
		Bergisch Gladbach	Klemoi (0.8/6)	2386	5.4	2781	9	62.1	199.3	189
CASFL	Castellani	Monte Baldo	Bmh1 (0.8/6)	2350	—	—	28	163.2	—	615
			Bmh2 (1.2/4.5)*	4243	—	—	26	160.7	—	558
CRIST	Crivello	Valbrevenna	C3P8 (0.8/3.8)	5575	4.2	2525	16	97.2	230.9	416
			Stg38 (0.8/3.8)	5593	4.3	2810	22	122.7	379.2	650
CSISZ	Csizmadia	Zalaegerszeg	Huvcse01 (0.95/5)	2439	—	—	16	49.6	26.5	183
CURMA	Currie	Grove	Mic4 (0.8/6)	1471	5.2	3008	10	55.7	44.0	159
ELTMA	Eltri	Venezia	Met38 (0.8/3.8)	5620	—	—	11	57.6	—	292
GONRU	Goncalves	Tomar	Templar1 (0.8/6)*	2188	5.3	2331	15	78.0	134.8	273
			Templar2 (0.8/6)*	2303	5.0	2397	17	65.5	181.8	192
GOVMI	Govedič	Središče ob Dravi	Orion2 (0.8/8)	1471	6.0	3916	19	72.9	—	300
HERCA	Hergenrother	Tucson	Salsa3 (1.2/4)*	4332	4.0	1471	30	154.3	171.0	479
HINWO	Hinz	Brannenburg	Akm2 (0.85/25)*	754	5.7	1306	5	44.0	44.6	245
IGAAN	Igaz	Baja	Hubaj (0.8/3.8)	5600	4.3	3338	15	78.6	61.8	285
		Hódmezővásárhely	Huhod (0.8/3.8)	5609	4.2	3031	12	42.9	43.4	131
		Budapest	Hupol (1.2/4)	3929	3.5	1144	11	48.2	64.7	137
JOBKL	Jobse	Oostkapelle	Klara2 (1.2/85)*	1564	—	—	4	45.4	—	378
KACJA	Kac	Kostanjevec	Metka (0.8/8)*	1381	4.0	2246	7	37.2	29.5	132
		Ljubljana	Orion1 (0.8/8)	1420	5.3	2336	19	31.0	—	110
		Kamnik	Rezika (0.8/6)	2307	5.0	2293	8	57.9	56.9	343
			Stefka (0.8/3.8)	5540	4.2	2882	9	53.3	—	175
KERST	Kerr	Glenlee	Gocam1 (0.8/3.8)	5238	4.2	2637	19	112.7	—	700

Table 1 – Observers contributing to 2011 January data of the IMO Video Meteor Network – continued from previous page.

Code	Name	Place	Camera	FOV [°²]	Stellar LM [mag]	Eff.CA [km²]	Nights	Time [h]	Tot.CA [10³km²h]	Meteors
LUNRO	Lunsford	Chula Vista	Bocam (1.4/50)*	1860	5.1	1719	6	53.6	73.5	239
MOLSI	Molau	Seysdorf	Avis2 (1.4/50)*	1771	6.1	4182	6	38.5	102.0	357
			Mincam1 (0.8/8)	1477	4.9	1716	16	74.9	79.1	311
		Ketzür	Remo1 (0.8/3.8)	5592	3.0	974	13	51.3	60.0	96
			Remo2 (0.8/3.8)	????	?.?	???	2	6.0	11.6	8
MORJO	Morvai	Fülöpszállás	Huful (1.4/5)	2522	3.5	532	16	62.5	39.5	167
OTTMI	Otte	Pearl City	Orie1 (1.4/5.7)	3837	—	—	14	66.2	111.3	247
PERZS	Perko	Becsehely	Hubec (0.8/3.8)*	5448	3.4	1500	17	81.7	180.7	356
ROTEC	Rothenberg	Berlin	Armefa (0.8/6)	2369	4.8	1801	9	31.8	64.5	97
SCHHA	Schremmer	Niederkrüchten	Doraemon (0.8/3.8)	5537	3.0	846	15	30.2	83.2	98
SLAST	Slavec	Ljubljana	Kayak1 (1.8/28)	604	6.5	1849	6	7.8	—	29
STOEN	Stomeo	Scorze	Min38 (0.8/3.8)	5631	4.1	2407	16	92.1	—	647
			Noa38 (0.8/3.8)	5609	4.9	5800	15	73.9	—	495
			Sco38 (0.8/3.8)	5598	—	—	16	106.0	—	751
STORO	Stork	Ondřejov	Ond1 (1.4/50)*	2195	5.8	4595	1	10.3	30.8	436
STRJO	Strunk	Herford	Mincam2 (0.8/6)	2357	—	—	8	21.2	—	89
			Mincam3 (0.8/12)	728	—	—	10	21.6	—	75
			Mincam5 (0.8/6)	2344	—	—	9	41.9	—	220
TEPIS	Tepliczky	Budapest	Humob (0.8/6)	2375	4.9	2258	7	53.0	93.2	180
TRIMI	Triglav	Velenje	Sraka (0.8/6)*	2222	—	—	18	62.1	—	324
YRJIL	Yrjölä	Kuusankoski	Finexcam (0.8/6)	2337	5.5	3574	7	26.1	99.7	63
						Overall	31	2 857.4	—	12 662

* active field of view smaller than video frame

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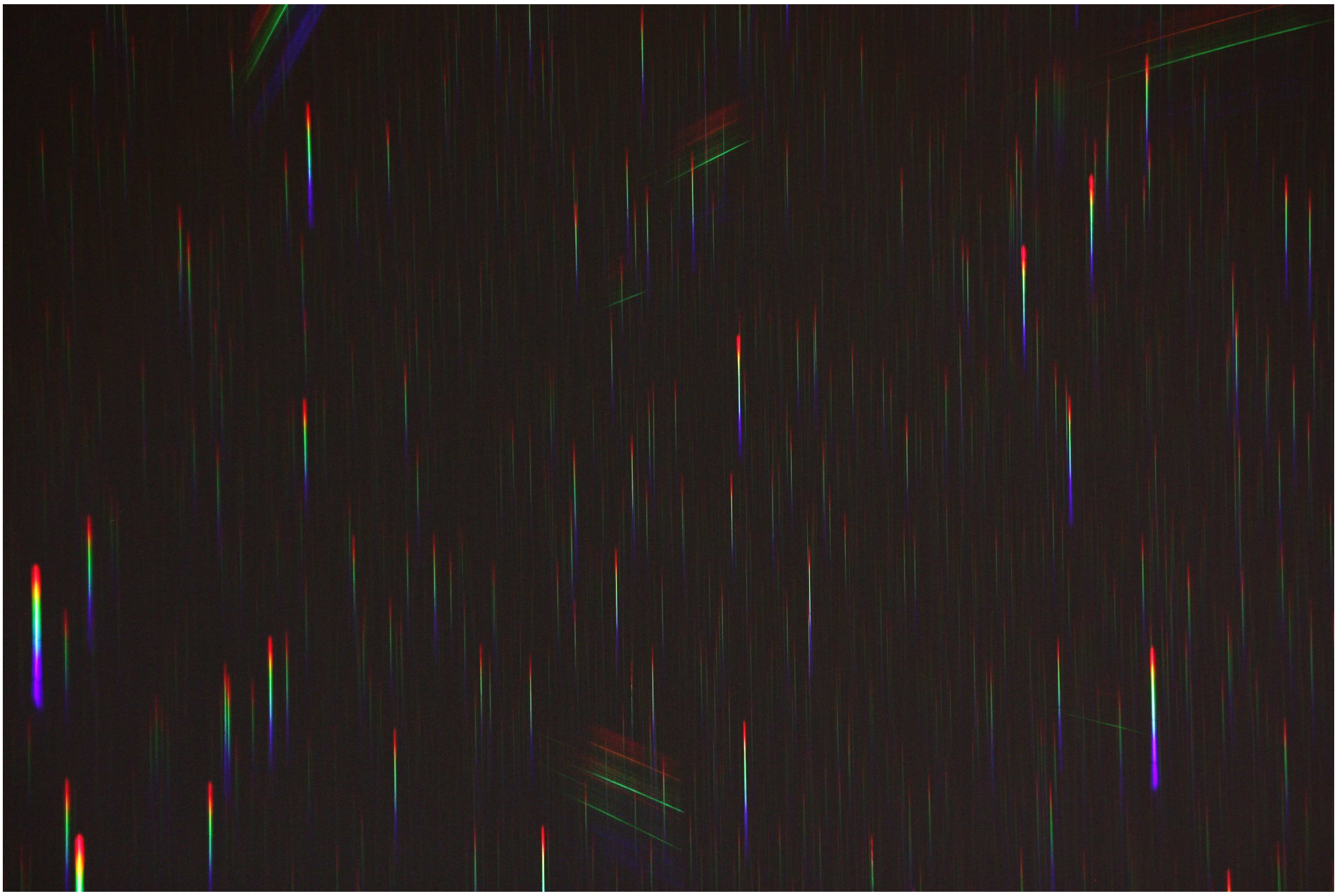
Geminid spectra



A composite picture from photos of the Geminid spectra taken on 2010 December 14 (top). Image below is a B&W reproduction of the same picture. See article by Cheng & Cheng on page 39 for details.