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Meteor science

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

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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 its 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.

1 Introduction

The Geminids and Quadrantids 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 km s⁻¹) and meteoroids seem to have high density and strong internal consistence [1]. Currently, asteroid (3200) Phaethon is strongly favored as the parent body [2, 3]. Quadrantids exhibit a high activity as well, with a sharp peak lasting only several hours. Their perihelia lie at the Earth's orbit, inclinations are around 70 deg. Among other parent body candidates, asteroid (196256) 2003 EH1 is having a most similar orbit to the Quadrantids and is considered to be a dormant comet [4].

Both showers are well defined by many previous photographic, radar, telescopic and visual surveys [3, 5, 6]. Yet, the photography has remained the most precise technique for the orbit determination and atmospheric path definition. Recently, the video observation with the high resolution digital cameras become affordable and several meteor detection networks started operation all over the world. Among them, 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 in Modra of the Comenius University (AGO). The first station is located at AGO, the second one, remotely controlled, at the Arborétum Mlyňany (ARBO), in the distance of 80 km. AGO is equipped with the Cannon Fish-Eye lens (15 mm, f/2.8), image intensifier Mullard XX1332 and digital video camera DMK41AU02.AS (1280 × 960 px, angular resolution 8.5 arcmin/pix, 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 px, angular resolution 15 arcmin/pix, 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: http://www.daa.fmph.uniba.sk/meteor_network.html.

The CEMeNt network arose 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 approx. +1.5 and the FOV is 80° × 60°. Kroměříž has the system consisting of the Watec 902 H2 camera (720 × 576 pix), Goyo GADN varifocal 3-8mm 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



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

of the Watec 902H2 Ultimate camera, Fujinon 2.9-8mm lens (F 0.95), the image is obtained by the internal TV grabber of the 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 UFO-Capture software [7] which is able to recognize meteors and bolides. The meteor data had been processed by the UFOAnalyzer and UFOOrbit software [7].

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

There are several UFOOrbit parameters that can evaluate the quality of the obtained meteor orbits. In order to separate high 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 [9]. 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 2. 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 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

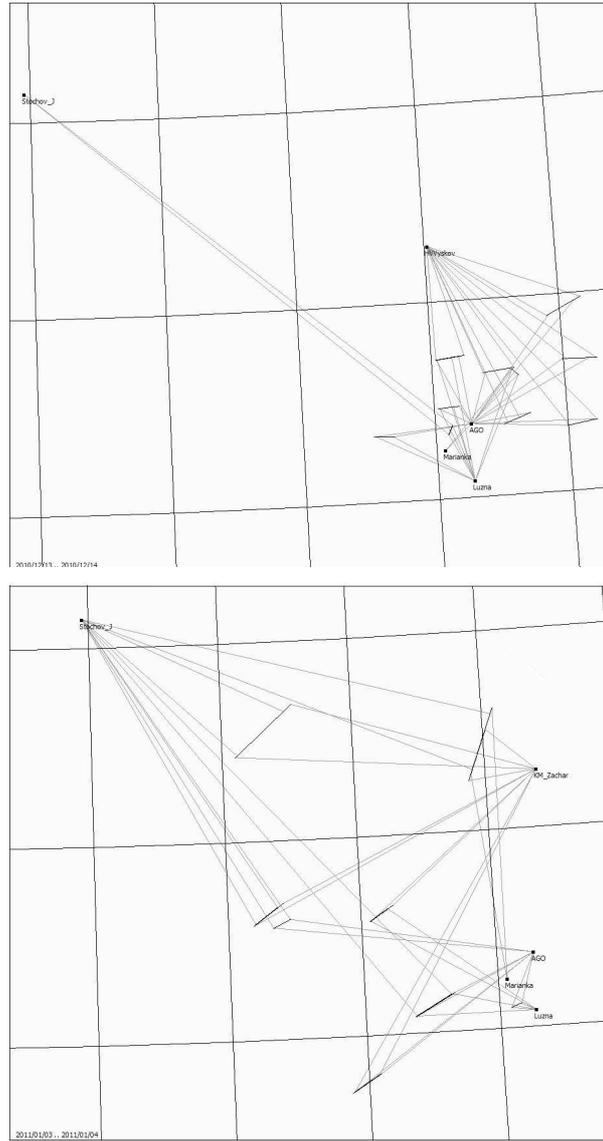


Figure 2: Ground projection of the meteor trails detected by SVMN and CEMeNt. Upper image - Geminids 2010, lower image - Quadrantids 2011.

account ($\lambda_{GEM\odot} \subset \langle 261.49; 261.79 \rangle$ and $\lambda_{QUA\odot} \subset \langle 282.88; 283.32 \rangle$) 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 Table 1 and 2, 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}) [8]. The crucial role in the criterion usage is the selection of the reference nominal orbit. The obtained Geminid and Quadrantid orbits were compared with respect to the mean orbits of the showers derived from the SonotaCo video data (see Table 1 and Table 2). Likewise, the parent body orbits were used for

Table 1: Multi-station Geminids detected on December 13–14, 2010 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 mean orbit from the solar longitude interval ($261.49^\circ - 261.79^\circ$) is also presented.

No	a (AU)	q (AU)	e	i ($^\circ$)	ω ($^\circ$)	Ω ($^\circ$)	α ($^\circ$)	δ ($^\circ$)	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: Multi-station Quadrantids detected on January 3–4, 2011 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 mean orbit from the solar longitude interval ($282.88^\circ - 283.32^\circ$) is also presented.

No	a (AU)	q (AU)	e	i ($^\circ$)	ω ($^\circ$)	Ω ($^\circ$)	α ($^\circ$)	δ ($^\circ$)	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	

the comparison. Individual (D_{SH}) values with respect to the selected nominal orbits are shown in Table 3 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 EH1, 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 EH1 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)

$$\begin{aligned} H_B &= 96.4(\pm 1.3) + 1.2(\pm 1.8) M_A \\ H_E &= 84.2(\pm 0.9) + 2.8(\pm 1.3) M_A, \end{aligned} \quad (1)$$

Table 3: Southworth-Hawkins D-criterion of Geminid orbits with respect to the SonotaCo mean orbit and putative parent body 3200 Phaethon.

No	D_{SH} (SonotaCo)	D_{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

$$\begin{aligned} H_B &= 95.6(\pm 2.4) + 0.2(\pm 0.9) M_A \\ H_E &= 81.1(\pm 5.9) + 1.1(\pm 2.4) M_A, \end{aligned} \quad (2)$$

where H_B stands for the beginning height, H_E for the terminal height and M_A for the absolute brightness. The brightest Geminid meteor (Figure 4) was not used

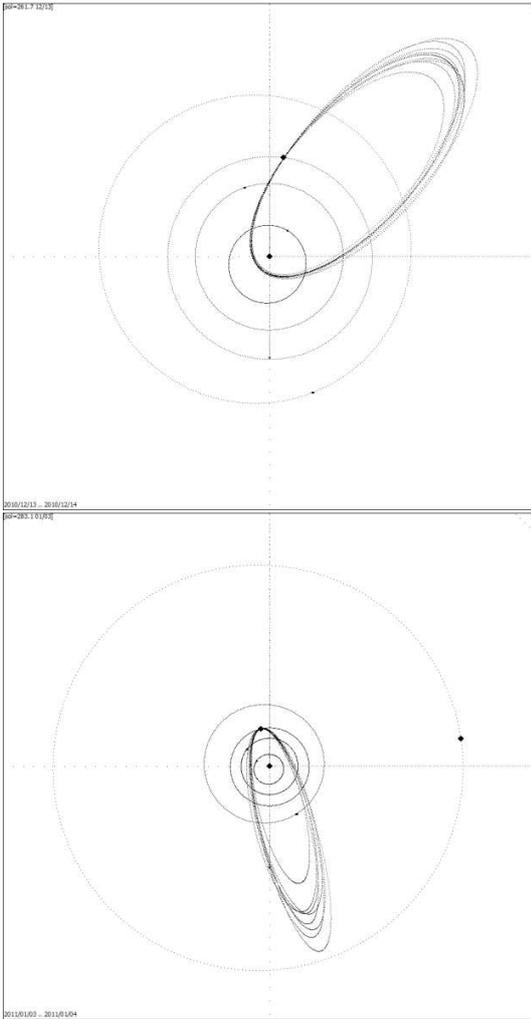


Figure 3: Orbits of multi-station meteors detected by video stations, derived by UFOOrbit software. Upper image - Geminids 2010, lower image - Quadrantids 2011.

Table 4: Southworth-Hawkins D-criterion of Quadrantid orbits with respect to the SonotaCo mean orbit and putative parent body 2003 EH1 in years 2011 and 1840.

No	SonotaCo	2003 EH1 (2011)	2003 EH1 (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

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 [10]. 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.

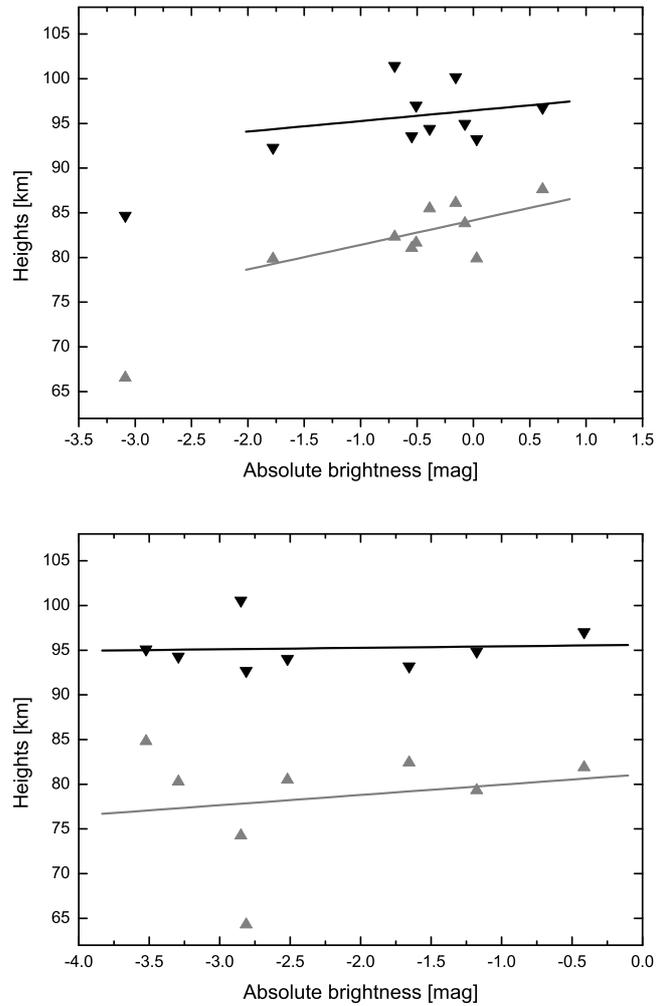


Figure 4: The beginning (black triangles) and terminal heights (gray triangles) of Geminids (upper image) and Quadrantids (lower image) as a function of the absolute brightness.

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 their 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.

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