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Radiants, orbits, spectra, and deceleration of selected 2011 Draconids

Jiří Borovička, Pavel Koten, Lukáš Shrbený, Rostislav Štork, and Kamil Hornoch

Astronomical Institute, Academy of Sciences, 251 65 Ondřejov Observatory,Czech Republic
`jiri.borovicka@asu.cas.cz`

We present radiants and orbits of eight Draconid meteors observed from Northern Italy on October 8, 2011. The radiants agree with theoretical predictions, with a hint that some meteors may belong to the pre-1900 meteoroid trails. The spectra confirm that Draconids have a normal chondritic composition of main elements (Mg, Fe, Na). There are, nevertheless, enormous differences in the temporal evolution of Na line emissions. The differences are correlated with the deceleration rate and can be ascribed to different meteoroid structures.

1 Introduction

The Department of Interplanetary Matter of the Astronomical Institute of the Academy of Sciences of the Czech Republic organized two expeditions to observe the predicted outburst (Maslov, 2011; Vaubaillon et al., 2011) of the Draconid meteor shower on October 8, 2011. Pavel Koten co-organized the airborne campaign (Vaubaillon et al, 2013), participated on it, and took three image intensified video cameras with him. The other staff planned ground-based observations. Since the weather development in the Czech Republic was not promising, the group decided, like several other groups from central Europe to go to Northern Italy (see Toth et al, 2012). Starting the trip in the morning of October 7, we finally set up two temporary observing sites in the wider vicinity of Milan before the sunset on October 8 and were able to observe the main outburst under clear skies.

In this contribution, we describe our observations and present preliminary results on eight Draconid meteors, which were observed by the spectral video camera. The final analysis will be published in a scientific journal.

2 Observations

Observing site A was located near Brenna in the province of Como, Lombardy, about 30 km north of Milan. Observing site B was located near Barengo in the province of Novara, Piemonte, about 55 km west of Milan. The exact GPS coordinates are given in Table 1. The mutual distance of the sites was 56.5 km, somewhat smaller than ideal, but still sufficient for good triangulation. Rostislav Štork, Lukáš Shrbený, and Vlastimil Vojáček operated site A; Jiří Borovička, Kamil Hornoch, and Jaroslav Boček operated site B. The program included image-intensified video, image-intensified spectral video, and non-intensified high-resolution video observation (not used in this work), wide-field digital still imaging, and visual meteor counting by K. Hornoch (reported to the IMO). The instruments were fed by portable power generators.

Table 1 – Coordinates of the observing sites.

Site	Name	λ (E)	φ (N)	h
A	Brenna	9°.18795 E	45°.73371 N	333 m
B	Barengo	8°.50505 E	45°.56606 N	238 m

All instruments at both sites were pointed to see a common volume of the atmosphere at a height of approximately 95 km. The aiming point for video cameras at site B was to the North (azimuth 0°) at an elevation of 35° above the horizon; at site A, the azimuth was 336° and the elevation 37°. The fields of view therefore avoided the bright Moon at the South and also the scattered light from the city of Milan. The geometric conditions for Draconid triangulation became, however, progressively worse in the course of night, with the convergence angle (computed for a Draconid meteor in the center of the field of view) decreasing. The aiming points were therefore changed at 21^{h} UT; no meteors observed after that time are reported here, however.

In this work, we studied the meteors detected by the spectral camera. The trajectories of the meteors were determined using the non-spectral video and DSLR cameras. The technical data of the used instruments are given in Table 2. The most advanced instruments are the MAIA video cameras (Koten et al., 2011) with 61 frames per second in progressive scan mode. The cameras are still in development. They were used at both sites but not all meteors were found in the record from site A. The cameras have intrinsically 10 bits per pixel but only 8 bits were used in our preliminary analysis. All velocities, decelerations, and light curves are based on the MAIA cameras.

A longer focal length was used for the spectral camera in order to increase spectral resolution. The camera had therefore a smaller field of view. The meteor limiting magnitude to obtain a spectrum was about +2. We had some problems of reading the tape record from the spectral camera; nevertheless, all important spectra were recovered. In total, eight meteors were analyzed. Spectrum no. 2 was only partly in the field of view. Spectra nos. 4 and 6 are very nice.

Table 2 – Instruments used in this work.

High frame rate video MAIA (M)
Camera: GigE Vision, 776 × 582 pixels, 61.15 fps
Image intensifier: Mullard XX1332, 2nd gen.
Lens: $f/1.4$, 50 mm
Field of view: 50°
Recording: continuous on PC
Sites: A (R. Štork) & B (K. Hornoch)

Supplementary video (V)
Camera: DFK31, 1024 × 768 pix, 15 fps
Image intensifier: Dedal 41, 2nd gen.
Lens: $f/1.4$, 50 mm
Field of view: 30°
Recording: continuous on laptop
Site: A (L. Shrbený)

Spectral video (S)
Camera: Panasonic NVS88, 768 × 576 pix, 25 fps
Image intensifier: Mullard XX1332, 2nd gen.
Lens: $f/2$, 85 mm
Grating: 600 grooves/mm
Field of view: 30°
Recording: continuous on S-VHS tape
Site: B (J. Borovička)

All-sky photo (A)
Camera: Canon EOS 5D Mark II, 5616 × 3744 pix
Lens: $f/2.8$, 15 mm
Field of view: 180° diagonal
Exposures: 30 s, ISO 1600
Site: B (J. Borovička)

Wide-field photo (W)
Camera: Canon EOS 450D, 4272 × 2848 pix
Lens: $f/3.5$, 10–22 mm @ 10 mm
Field of view: 95° × 70°
Exposures: 20 s, ISO 1600
Site: A (L. Shrbený)

3 Radiants and orbits

Table 3 lists the meteors detected by the spectral camera. Time of appearance, maximal stellar magnitude, and photometric mass are given. The cameras that detected the meteor and could be used for trajectory determination are also indicated.

In Table 4, the apparent radiant, (α_R, δ_R), the initial velocity at the entry into the atmosphere (v_∞), the geocentric radiant (α_G, δ_G), the geocentric velocity (v_G), and the usual orbital elements are given. The initial velocity was determined from the modeling of deceleration by the erosion model (Borovička et al., 2007). The error of the velocity was estimated from the spread of measurements. The convergence angle was quite small for meteors nos. 5 and 8, and their trajectories were therefore determined with much larger errors. We may be able to improve the trajectories in the future by using a more advanced method.

Table 3 – List of meteors with spectra.

No.	Time (UT)	m	Mass (g)	Site A M	Site A V	Site A W	Site B M	Site B A
1	$18^h03^m20^s$	+1	0.15	–	–	+	+	–
2	$18^h20^m00^s$	−2	2.4	–	+	+	+	+
3	$19^h58^m22^s$	−0.5	0.4	–	+	–	+	+
4	$20^h05^m35^s$	−2.5	3.2	+	+	+	+	+
5	$20^h19^m34^s$	0	0.4	+	+	+	+	–
6	$20^h28^m21^s$	−3	2.9	–	+	+	+	+
7	$20^h43^m51^s$	+0.5	0.3	–	+	+	+	–
8	$20^h55^m34^s$	+1.5	0.1	+	+	+	+	–

The geocentric radiants are plotted and compared with theoretical predictions (Maslov, 2011; Vaubaillon, 2011) in Figure 1.

The meteors from the 1873–1894 trails were predicted to encounter the Earth earlier (about 17^h UT) and have radiants 0.°4 to the south in comparison with the 1900 trail, which was responsible for the main activity peak around 20^h UT. The average radiants of the radar meteors observed by Kero et al. (2012) and of the optical meteors observed by Tóth et al. (2012) corresponded to the 1900 trail. We are able to provide more precise individual radiants.

Meteors nos. 1 and 2, observed before 18^h30^m UT, really had their radiants closer to the 1873–1894 radiant; nevertheless, the error bars are too large to draw any conclusions. Meteor no. 7 was also closer to that radiant, but it is not supposed to belong to the old trail, since it appeared late. The most precise meteors, nos. 3, 4, and 6, belonged almost certainly to the 1900 trail, as expected from their time of appearance.

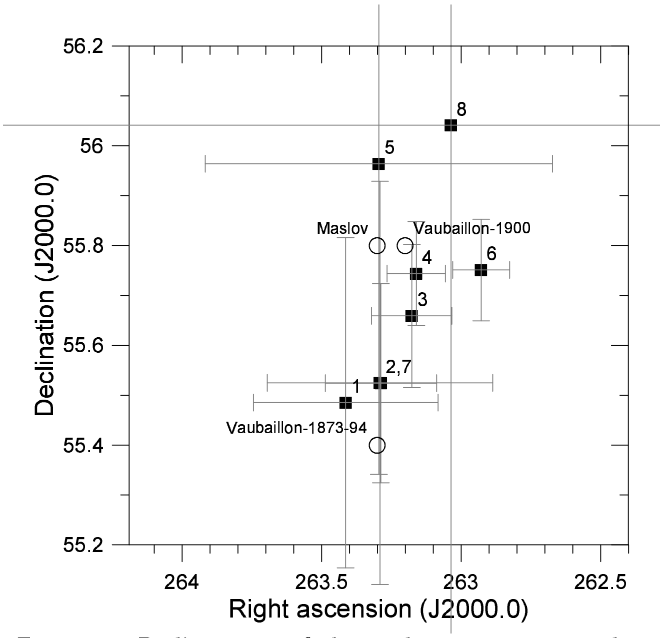

Figure 1 – Radiant map of observed meteors compared to the theoretical predictions of radiants for different trails. Some error bars go out of range.

Table 4 – Radiants and orbits of observed meteors. “Q” is the plane convergence angle. Apparent radiants are given in apparent coordinates. Geocentric radiants and orbital elements are given for the standard equinox J2000.0.

No.	Q	α_R	δ_R	v_∞ (km/s)	α_G	δ_G	v_G (km/s)	a (AU)	e	q (AU)	ω	i	Ω
1	34°	267°.03	+55°.56	23.44	263°.41	+55°.49	20.74	3.48	0.714	0.9966	173°.62	31°.46	194°.949
		±0°.22	±0°.31	±0.25	±0°.29	±0°.33	±0.28	±0.22	±0.018	±0.0002	±0°.23	±0°.33	
2	25°	267°.12	+55°.72	23.55	263°.29	+55°.52	20.88	3.56	0.720	0.9965	173°.54	31°.63	194°.960
		±0°.27	±0°.38	±0.25	±0°.33	±0°.40	±0.28	±0.24	±0.019	±0.0002	±0°.26	±0°.34	
3	46°	268°.24	+56°.70	23.20	263°.18	+55°.66	20.54	3.28	0.697	0.9965	173°.48	31°.30	195°.027
		±0°.11	±0°.11	±0.50	±0°.25	±0°.14	±0.57	±0.36	±0.033	±0.0001	±0°.21	±0°.63	
4	30°	268°.15	+56°.84	23.57	263°.16	+55°.74	20.96	3.54	0.719	0.9964	173°.50	31°.80	195°.032
		±0°.09	±0°.06	±0.15	±0°.14	±0°.10	±0.17	±0.13	±0.010	±0.0001	±0°.12	±0°.19	
5	2°	268°.45	+57°.19	23.48	263°.29	+55°.96	20.86	3.42	0.709	0.9966	173°.65	31°.76	195°.042
		±0°.23	±0°.59	±0.25	±0°.28	±0°.62	±0.28	±0.26	±0.022	±0.0002	±0°.24	±0°.38	
6	27°	268°.10	+57°.09	23.55	262°.93	+55°.75	20.95	3.51	0.716	0.9963	173°.33	31°.80	195°.048
		±0°.03	±0°.05	±0.15	±0°.10	±0°.10	±0.17	±0.12	±0.010	±0.0001	±0°.10	±0°.19	
7	15°	268°.59	+57°.03	23.38	263°.29	+55°.52	20.76	3.47	0.712	0.9964	173°.51	31°.49	195°.058
		±0°.13	±0°.17	±0.25	±0°.19	±0°.20	±0.28	±0.20	±0.017	±0.0001	±0°.15	±0°.32	
8	4°	268°.36	+57°.65	23.63	263°.04	+56°.04	21.04	3.51	0.716	0.9964	173°.49	32°.00	195°.066
		±0°.13	±3°.7	±0.40	±0°.53	±3°.8	±0.45	±1.2	±0.094	±0.0008	±0°.80	±1°.4	

4 Spectra

The images of the two brightest spectra are given in Figure 2, and the plots of the spectra integrated along the meteor path in Figure 3. The spectra are similar to Draconid spectra observed in the past in the visible region (Millman, 1972; Borovička et al., 2007). The two brightest lines are the Mg and Na lines. Our data extend more to the infrared. The infrared O line, which is of atmospheric origin, is relatively faint, due to the low velocity of the Draconids. Other observed features include lines of Fe and Ca, bands of N_2, and a broad continuum. Comparing the total intensities of the Mg, Na, and Fe lines, all eight meteors were classified as normal in the scheme of Borovička et al. (2005).

A more interesting aspect is the temporal evolution of the spectra. Previous studies noted a shift of the Na line toward higher altitudes in some Draconids (Millman, 1972; Borovička, 2007). Interestingly, our two best spectra are quite different in this respect (see Figures 3 and 4). Meteor no. 4 is a pronounced example of an early start and early end of the sodium line. The maximum of Na is shifted up by about 5 km in comparison with Mg. In meteor no. 6, Na is present along the whole trajectory in nearly constant proportion to Mg. Though both meteoroids had almost the same initial mass (Table 3), meteor no. 6 also penetrated much deeper (76.6 km) than meteor no. 4 (82.5 km) and the shape of the light curve was different, with a flare in the second half of the trajectory. We suspect that both meteoroids had different structures.

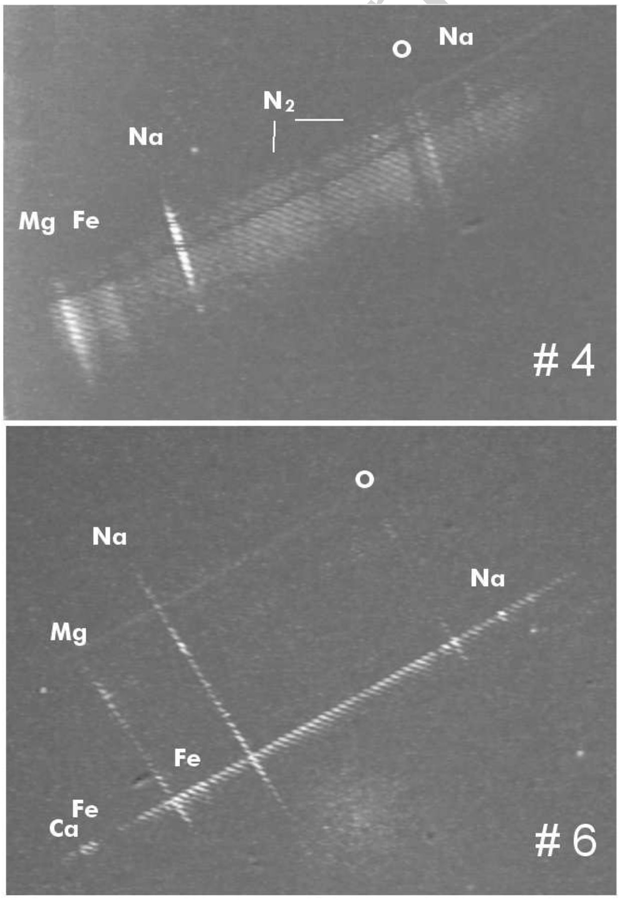

Figure 2 – Co-added video frames showing the spectra of meteors nos. 4 and 6. In both cases, the meteor flew from the upper left to the bottom right, and the wavelengths increase from the bottom left to the upper right. The main emissions are identified. There is a small gap in the data of meteor no. 4 due to tape failure.

5 Deceleration

In order to get more insight into the structure of the meteoroids, we measured decelerations and light curves and analyzed them with the erosion model of Borovička et al. (2007). The deceleration rates were very different from case to case (Figure 5). We found a clear correlation between the early release of Na and the deceleration rate. Meteors nos. 3, 4, 7, and 8 showed early

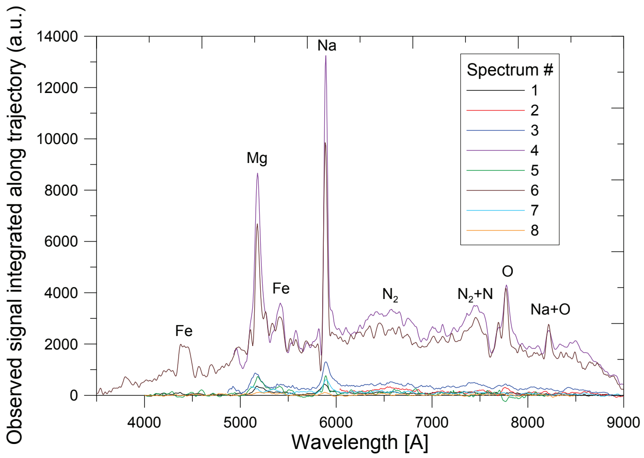

Figure 3 – Spectra of all eight meteors plotted together. Observed intensity (not corrected for the spectral response of the instrument) integrated over the whole trajectory is given as a function of wavelength.

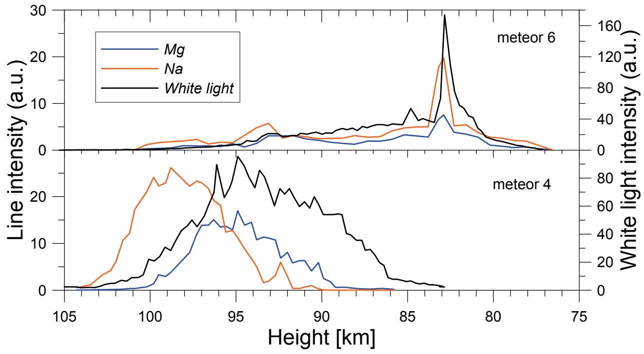

Figure 4 – Monochromatic light curves in the Mg and Na lines for meteors nos. 4 and 6, compared to the total light curve. The intensities are in relative linear scale. The scale in white light is different because the total intensity was measured on non-spectral cameras. The heights derived from the spectral camera are somewhat uncertain but no more than by 1 km.

Na release and high deceleration. Meteors nos. 1, 5, and 6 did not show early Na release and their deceleration was low (nos. 1 and 6) or medium (no. 5). The erosion modeling confirmed that all observed Draconids were porous aggregates of grains. The meteoroid bulk densities were found in the range 100–400 kg/m^3, the typical grain sizes were 20–200 μm. In the meteors with high deceleration, the grains were released very quickly, at heights above 94 km. The difference was that in the meteors with low deceleration, the disintegration into grains took much longer.

6 Conclusions

Simultaneous spectral, dynamic, and photometric observations of the 2011 Draconids provided deeper insight into their structure. We confirmed that Draconids have normal cosmic ratios of Mg, Na, and Fe. Nevertheless, there are enormous differences in the behavior of the Na line and in the deceleration rate. These differences are related to meteoroid structure. In some cases, the disintegration into grains was much quicker than in other cases. We plan to model the ablation of Na in more detail in the future.

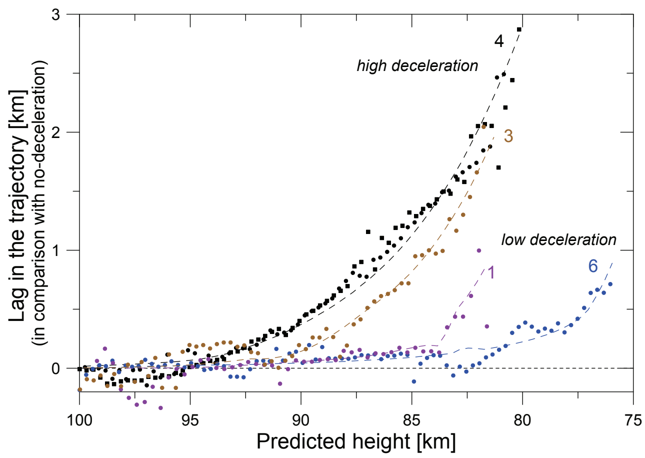

Figure 5 – Deceleration of four meteors. The lag in trajectory (distance between predicted and actual position) is plotted against predicted height. The predicted height is computed for constant velocity. Meteors without deceleration would therefore follow the zero line. The dashed lines are (imperfect) fits by the erosion model.

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References

Borovička J., Koten P., Spurný P., Boček J., and Štork R. (2005). "A survey of meteor spectra and orbits: evidence for three populations of Na-free meteoroids". *Icarus*, **174**, 15–30.

Borovička J., Spurný P., and Koten P. (2007). "Atmospheric deceleration and light curves of Draconid meteors and implications for the structure of cometary dust". *Astron. & Astrophys.*, **473**, 661–672.

Kero J., Fujiwara Y., Abo M., Szasz C., and Nakamura T. (2012). "MU radar head echo observations of the 2011 October Draconids". *Mon. Not. R. Astron. Soc.*, **424**, 1799–1806.

Koten P., Fliegel K., Vítek S., and Páta P. (2011). "Automatic video system for continues monitoring of the meteor activity". *Earth, Moon, and Planets*, **108**, 69–76.

Maslov M. (2011). "Future Draconid outbursts (2011–2100)". *WGN, Journal of the IMO*, **39**, 64–67.

Millman P. M. (1972). "Giacobinid Meteor Spectra". *J. R. Astron. Soc. Canada*, **66**, 201–211.

Tóth J., Piffl R., Koukal J., Żołądek P., Wiśniewski M., Gajdoš Š., Zanotti F., Valeri D., De Maria P., Popek M., Gorková S., Világi J., Kornoš L., Kalmančok D., and Zigo P. (2012). "Video observation of Draconids 2011 from Italy". *WGN, Journal of the IMO*, **40**, 117–121.

Vaubaillon J. (2011). 2011 Draconid predictions as given on `http://draconids.seti.org/`.

Vaubaillon J., Watanabe J., Sato M., Horii S., and Koten P. (2011). "The coming 2011 Draconids meteor shower". *WGN, Journal of the IMO*, **39**, 59–63.

Vaubaillon J., Koten P., Rudawska R., Bouley S., Maquet L., Colas F., Tóth J., Zender J., McAuliffe J., Pautet D., Jenniskens P., Borovička J., Koschny D., Leroy A., and Lecacheux J. (2013). "Overview of the 2011 Draconids airborne observation campaign". In Gyssens M. and Roggemans P., editors, *Proceedings of the International Meteor Conference*, La Palma, 20–23 September 2012, IMO, pages ??–??.