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Double station observation of Draconid meteor outburst from two moving aircraft

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ABSTRACT

A Draconid meteor shower outburst was observed from the boards of two scientific aircraft on 8 October 2011. In this paper we report the results of this double station experiment. The beginning and terminal heights are similar to other Draconid observations and confirm the fragile nature of the meteoroids. From the distribution function of terminal heights, a critical mass was found to be about 3.5 g. A behaviour of the terminal heights changes at this point. Light curves of Draconid meteors show great variability with a maximum of the *F*-number distribution around 0.35, which also confirms fragility of the material. Observed radiants of the meteors are in agreement with the theoretical model. Although encounters with two different filaments were predicted, it is impossible to distinguish between them from the radiants as well as the orbital data. Despite the complications with the data processing the airborne mission shows that such double station experiment is possible and provides valuable insight into meteor structure and dynamics.

1. Introduction

A Draconid meteor shower outburst was predicted and observed on the 8 October 2011 (Vaubaillon et al., 2011, 2015). As activity of the Draconids, one of the most interesting meteor showers, is typically low, little is known about this shower. Therefore the observational campaign was carefully planned to cover this exceptional event. Two aircraft were deployed above Northern Europe and Atlantic Ocean. Each was carrying instruments of different types to maximize data volume and science output. The flights of both planes were coordinated in order to establish a stable platform for double station observation of the meteors. More details about the DRAMAC (DRAconid Multi-instrument Aircraft Campaign) airborne mission can be found in an overview paper (Vaubaillon et al., 2015).

A previous first airborne campaign dedicated to meteor observations was performed by Czech astronomer Guth and co-workers, performing visual observations (Jenniskens and Butow, 1999). A photography of a meteor train from an airplane was performed by Monnig (1940). A series of such airplane observation campaigns were organized by Jenniskens and his team during the return of the Leonid meteor shower from 1998 to 2002 (Jenniskens and Butow, 1999; Jenniskens et al., 2000a; Jenniskens, 2002).

Double station aircraft measurements of the Leonid meteors were performed in 2000 and 2002, when two scientific aircraft were deployed. Double station data obtained by HDTV direct imaging and spectral (zero and 1st order spectra) cameras were analysed by Abe (2000). Simultaneous observations contributed to a number of other papers, mainly dedicated to the spectra of Leonid fireballs and persistent trains (Jenniskens et al., 2000b; Borovička and Jenniskens, 2000; Rossano et al., 2000). Double station aircraft based trajectories were also reported by Jenniskens (2007) during the 2007 Aurigid meteor shower.

The advantage of double station observation is the possibility to measure the 3-D trajectory and the orbit of each individual meteor. In this paper, we present the full analysis of double station Draconids meteor observed during the DRAMAC campaign.

The paper is organized in the following way: Section 2 briefly describes the method (observations, instrument setup and data

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processing techniques). Section 3 shows the results of the observations and the comparison to theoretical works. Section 5 is a discussion and conclusion regarding our understanding of the 2011 Draconids.

2. Method and data processing

The airborne observation campaign was carried out by the DLR Falcon (registration D-CMET) and French SAFIRE Falcon (registration F-GBTM) aircraft. Both aircraft were flying in formation to allow the double station experiment. The planes took-off from the Kiruna airport in Sweden ($\lambda = 20°19.6'$E; $\delta = 67°49.3'$N) and flew to the west for about two hours. D-CMET was flying ahead of F-GBTM by about 100 km. At the end of this leg D-CMET reached the position P3 ($\lambda = 8°$W; $\delta = 68°$N). During the return, the planes were flying side-by-side with D-CMET flying more to the south. The separation of both aircraft was 110 km. More details about the flights can be found in Vaubaillon et al. (2015).

Five instruments were used to perform the observations, for which technical specifications are provided in Table 1. The double station configuration was dictated by the location of the airplane. The two different legs (way in and out) of the flight are described in Vaubaillon et al. (2015). All the cameras were continuously recording during the flight, at nearly fixed pointing direction (owing to the constant roll of the aircraft) described in Table 2. Information about the Draconid radiant position and distance from the Moon are also provided. Two pairs of instruments were dedicated to the double station records. Firstly both all-sky cameras (SPOSH and AMOS) were intended to cover the whole sky and simultaneously record the brightest meteors. Secondly there was narrow FOV double station experiment aimed on fainter meteors using the video image intensifier cameras. Unfortunately the improper settings of the SAFIRE camera resulted in very low number of recorded meteors. Additional details regarding the instrument are available in Vaubaillon et al. (2015).

The processing of the data was quite complicated because different teams provided different kinds of data format, and because the observation platform (aircraft) was constantly rolling, resulting in a shift of the FOV. In any cases usual automated routines for meteor detection failed due to the moving platform and the records were inspected visually.

The tapes recorded by the narrow FOV camera were searched visually several times. Times of the occurrence of the meteors recorded by other cameras onboard both planes were used for the detection of additional meteors. Altogether 200 meteors were found. All of them were digitalized and measured using semi-automatic software MetPho (Koten, 2002).

The pointing axis of the SPOSH camera was parallel to the yaw axis of the aircraft. The geometric calibration and pointing determination of the camera was performed using a custom-made software (Elgner et al., 2006) which uses the positions of stars as reference points. Owing to the moving camera platform, the calibration procedure had to be re-performed for each event of interest. The position of the meteor trails in the SPOSH images was computed by a semi-automated procedure. First, the orientation of the meteor trail with respect to the image coordinate system (sample, line) was defined manually. Then, the position of the meteor points was determined using the properties of the PSF of the imaging system. The position of each meteor in the local coordinate system (azimuth, elevation) was given with a standard deviation of $\pm 0.1°$.

The AMOS data were saved into 2 min long AVI files. Later short video sequences (2–3 s) with the meteors were produced. The frames of meteor appearance were stacked together producing star masks for reference astrometry (J2000.0). If the wobbling from the plane was large and star images were blurred or shifted, or if the background from aurora was high, the star reference image from only one frame at the middle of meteor appearance was selected. Finally, the UFO Analyser software (SonotaCo, 2009) was used for the astrometric reduction of the data, which resulted in position estimates of the meteor trajectory with a standard deviation of 0.05°. But taking into account the plane movement and 1 s time precision, the overall astrometric precision is of about 0.1°.

Each team converted their measured data into common format (azimuth, elevation) to be used for the trajectory and orbit computations. The meteor pairs were found by comparing the time of acquisition. GPS position of the plane was provided every 1 s and the time synchronisation accuracy of the recorded meteors was also of 1 s. The position of the aircraft was given by the GPS receiver onboard every second, yielding a position uncertainty of 100 m.

Finally, input data – azimuths and zenith distances of individual measured points along the meteor trajectory – were used to derive the meteor atmospheric trajectory and heliocentric orbit, which were calculated using the Milig software (Borovicka, 1990). This software is based on the standard procedures for calculation of meteor trajectories and orbits developed by Ceplecha (1987), which takes into account the propagation of the errors. Because of hard conditions of the airborne observation each meteor was handled very carefully, the measurement and calculation was performed manually and without any automatic software. All the cases which did not provide reliable trajectories and orbits were excluded from further analyses.

In addition, the meteor velocity vector was corrected for the aircraft cruise speed, although it was lower than 0.25 km s^{-1}. Such correction may not seem to be significant since the average

Table 1
Summary of the camera features used during the double-station observation of the 2011 Draconids. II: Image intensifier; AMOS: Automatic Meteor Orbit System; SPOSH: Smart Panoramic Optical Sensor Head. Provider: name of the institution owing the camera, fps: frame per second, FOV: camera field of view, MLM: meteor limiting magnitude. See also Vaubaillon et al. (2015).

#	Name	Provider	Type	Aircraft	fps	FOV (deg)	MLM
1.	Video II	Ondřejov obs.	Analogue	DLR	25	45	+5.5
2.	AMOS	Comenius U.	Digital	DLR	15	180	+3.5
3.	Video II	Ondřejov obs.	Analogue	SAFIRE	25	45	+5.5
4.	Watec	IMCCE	Digital	SAFIRE	30	50	+3.0
5.	SPOSH	ESA/ESTEC	Digital	SAFIRE	1	120	+4.5

Table 2
Azimuth ($az_{1/2}$) and elevation ($el_{1/2}$) of the narrow field-of-view (FOV) camera for flight leg 1 or 2, zenith distance of the Draconid radiant ($ZD_{1/2}$), distance of the centre of FOV from the radiant ($\tau_{1/2}$) and distance between centre of FOV and the Moon ($dMoon_{1/2}$). Sign ~means that the value did not change too much during the flight. See also Vaubaillon et al. (2015).

Aircraft	DLR		SAFIRE
az_1 (deg)	210		160
el_1 (deg)	36		40
ZD_1 (deg)		~28	
τ_1 (deg)	67–65		45–30
$dMoon_1$ (deg)	~110		~120
az_2 (deg)	220		330
el_2 (deg)	55		50
ZD_2 (deg)		30–45	
τ_2 (deg)	~55		~55
$dMoon_2$ (deg)	~110		~50