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Overview of the 2011 Draconids airborne observation campaign

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On October 8, 2011, the Draconids (DRA, IAU#09) erupted in an outburst predicted by meteor shower forecasting models. The first European airborne meteor observation campaign was organized and conducted with two Falcon aircrafts, belonging to the French Scientific Research National Council (CNRS) and the German Aerospace Center (DLR), respectively. Objective was to provide data to test prediction models and obtain insight into past activity of the parent comet, 21P/Giacobini-Zinner. The Draconids peaked at around 20^{h} UT (predicted: $19^{h}57^{m}$ UT for the 1900-dust encounter), with a peak rate of 300 meteors per hour, about half the predicted level. Light curves are found to be surprisingly flat. Spectroscopy reveals an early release of sodium compared to magnesium, as observed during prior Draconids showers. The mission trajectory was designed so that the CNRS Falcon could cover the time period for the predicted 1873–1894 dust ejecta encounter as well, but no peak was seen with a rate estimate $\mathrm{ZHR}_{\max} < 50$ at 17^{h} UT.

1 Introduction

While studying the origin of the 1998 Draconid shower, Mikiya Sato of the Fuchu Astronomical Society of Japan found that the Earth would encounter the 1880–1900 dust trails of Comet 21P/Giacobini-Zinner on October 8, 2011, peaking at times between $16^{h}35^{m}$ and $20^{h}07^{m}$ UT. In a more complete modeling, Vaubaillon and Jenniskens confirmed the encounter with the 1900-dust trail at $20^{h}07^{m}$ UT, suggesting rates could reach storm level (Jenniskens, 2006). This prediction was most recently refined to put the peak of the 1900-dust encounter at around 600 per hour at $19^{h}57^{m}$ UT, while dust ejected in the period 1873–1894 would cause activity around $17^{h}09^{m}$ UT, provided the comet was active at that time (Vaubaillon, 2011).

In order to test these prediction models, and find out whether or not the shower's parent comet was active before 1900, an airborne observation campaign was conducted by IMCCE[1]-Paris Observatory, in collaboration with Ondřejov Observatory, the Comenius University in Bratislava, and the European Space Agency. The aircraft would put the observers above the clouds, and at a site where both peaks could be observed. Similar airborne campaigns were conducted in the past by NASA (Jenniskens and Butow, 1998; Jenniskens, 2002; Jenniskens and Vaubaillon, 2007). This would be the first time such campaign was organized and conducted by European researchers, albeit with support of some of the same teams participating in past missions. The patch is reproduced in Figure 1.

Here, we report on the mission planning and execution, and give an overview of the results to date.

Figure 1 – Patch of the 2011 Draconids airborne campaign.

2 Setting up the observations

Two research aircrafts were dedicated to the observation: one belonging to the French National Scientific Research Council (CNRS), SAFIRE lab, and the other belonging to the German DLR[2]. The later was made available by the European Facility for Research Aircraft (EUFAR). By deploying two aircraft, triangulation of the meteor trajectories became possible in order to reconstruct the 3-D trajectory in the atmosphere and measure the pre-atmospheric orbit and physical proper-

[1] *Institut de Mécanique Céleste et de Calcul des Éphémérides.*

[2] *Deutsches Zentrum für Luft- und Raumfahr.*

ties of the meteoroids. A second aircraft also provided insurance in case one plane was hampered by technical difficulties.

The approach to setting up the instruments inside the aircraft was different in the two planes. In the CNRS Falcon, all cameras had to be mounted on racks, and therefore much preparation work was needed. In the DLR aircraft, every camera was stored during takeoff and landing, and mounted once in the air. As a consequence, the team used tripods to setup the cameras in front of the windows.

The choice of cameras and research teams was dictated by the desire of covering as many scientific domains as possible. The total number of cameras was 11 in the French aircraft and 6 in the German one. Instruments ranged from simple DSLR and WATEC cameras to the more advanced SPOSH (Smart Panoramic Optical Sensor Head) camera. The camera field of view ranged from narrow to all-sky (Zigo et al., 2013). Their wavelength coverage ranged from visible to near-infrared. Spectroscopic measurements were performed by Ondřejov Observatory using a LCC1 camera mounted on a 50 mm lens equipped with a Spectral Zeiss 600 groves/mm grating, as well as a 902H2 Watec camera equipped with a 12 mm lens and a 300 groves/mm grating. The SETI Institute contributed an intensified XX1332 camera with 400 lines/mm grating. Other foreign contributions included a Utah State University InGaAs camera, and an NHK intensified HDTV camera. Due to the size of the aircraft, only three scientists could fly in each aircraft, meaning that everyone had several cameras to operate.

The aircraft deployed from Toulouse and Munich to Northern Scandinavia, in particular to Kiruna in Sweden. Deployment from Kiruna would enable a flight path with dark skies over the full time period in which shower activity was expected (16^{h}–21^{h} UT). The two aircraft joined there one day prior to the scientific flight. Due to limited flight time allocation, the DLR Falcon would only cover the second, more important, peak. The expected first peak was observed under clear skies from Kiruna airport, with the DLR plane on the ground.

Leading up to the flight, the initial flight plan for the first peak was changed when authorization to fly over Russia was not granted. As a consequence, we followed an alternative flight plan developed by Jon Reijneveld of the Technical University of Delft (while working at the SETI Institute), to fly southeast over Finland during that time period.

During the second peak (Figure 2), the two planes flew towards the west, following one another for the inbound part, while flying 100 km side-by-side for the outbound part. The reason for this flight geometry was to save as much time as possible during the transition phase when the planes had to turn 180°. The east-to-west flight route would provide constant viewing towards the north, away from the Moon, during the period of the shower peak.

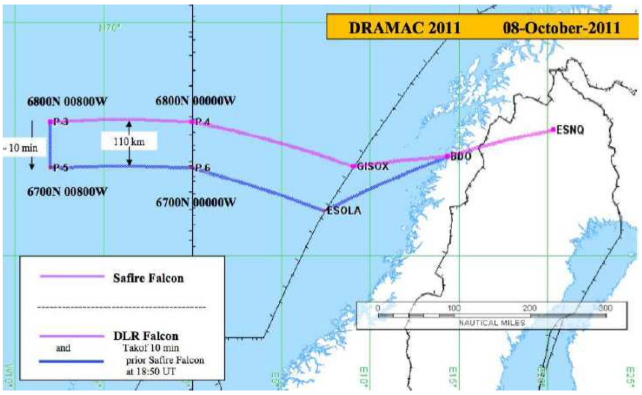

Figure 2 – Flight plan covering the second peak.

In parallel to the airborne observations, several ground-based observing campaigns were performed in France, Greece, Italy, and Germany (Leroy et al., 2013; Zigo et al., 2013, Tóth et al, 2012). At the IAP in Kühlungsborn, lidar observations were combined with optical observations of the meteors (Peter Jenniskens and Michael Gerding). These observations were conducted successfully. In Italy, too, weather permitted observations of meteor photography and triangulation (Juraj Tóth). Unfortunately, clouds prevented part of the IMCCE team from getting meteor data from Greece or the Pic du Midi Observatory.

3 The outburst: rates and magnitudes

Figure 3 compares the number of meteors observed from the aircraft and from the ground. The rate of detection by the same cameras on the plane was about 3 times that on the ground. Aurora during part of the shower may have lowered the detection rate on the aircraft at times.

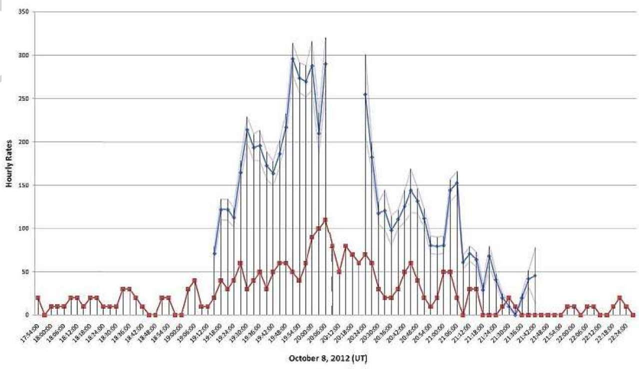

Figure 3 – Comparison of the HR from the DLR airplane above 11 000 m (thin curve) and from the same camera on the ground in Italy (thick curve). Computed by Juraj Tóth using the AMOS camera.

The 1900-dust Draconids were right on time! The good agreement between observed and calculated peak times for this encounter gives confidence in the prediction model. Figure 4 compares the activity profiles computed for the narrow FOV camera, the all-sky camera (both aboard DLR Falcon), and the IMO visual data. It is possible that the shower profile of the brighter meteors (bigger meteoroids) peaked about 15–20 minutes earlier than that of the fainter meteors (smaller meteoroids). The all-sky camera and narrow FOV cameras recorded different mass distribution indices. This was not modeled, and the reason is not understood.

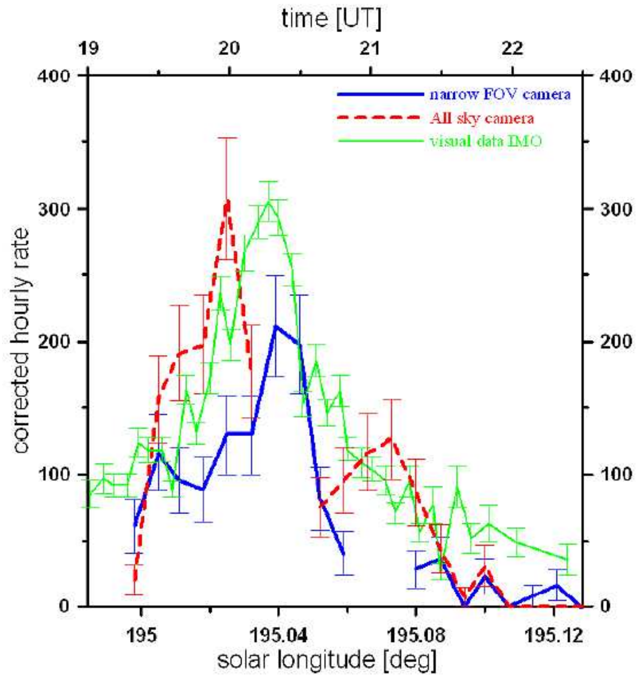

Figure 4 – ZHR from the DLR airplane, computed by Pavel Koten (Ondřejov Observatory).

The earlier peak from pre-1900 dust was not detected from the aircraft. It is possible that the airborne observations were hampered by the bright glare of twilight during this time period. Joe Zender, Pavel Koten, and Juraj Toth detected Draconids visually with a ZHR of several tens. The AMOS camera recorded 16 Draconids between $17^{h}00^{m}$ and $18^{h}30^{m}$ UT. Watanabe and Sato (private communication) observed during that interval from Japan and also recorded a rate of a few tens of meteors per hour. It is unclear at present whether this is a confirmation of the first peak activity or part of the second peak and/or a background activity.

The rates as measured from the aircraft are compared to those of the global campaign coordinated by the International Meteor Organization (IMO) in Figure 4. Both are in good agreement. Small, but perhaps insignificant, differences may be attributed to the higher background in airborne cameras caused by aurora. The Draconid outburst happened slightly after $20^{h}00^{m}$ UT, within minutes of what was expected by Vaubaillon (2011).

The level of activity, however, was only half of the predicted one. This discrepancy is not yet understood. Comet 21P/Giacobini-Zinner is fairly well-known since its apparition in 1900, and the same dust trail was encountered before. The level of the 2011 outburst was calibrated using the 1933 and 1946 storms. In those years, observers reported rates of a few thousand meteors per hour. It is possible that these past rates are overestimated, or the model dust trail may fall off in density faster behind the comet than expected.

4 Double-station observations

Double-station observations were performed from the air and from the ground. Only preliminary data are available from the airborne observations. However, we can already confirm that 32 orbits and trajectories, some with noticeable deceleration, were derived from CAMS data taken in Germany by Peter Jenniskens. Also, orbits were measured in southern France by Arnaud Leroy and Jean Lecacheux (Leroy et al., 2013). Gritsevich (2012) will use these data to estimate the physical properties of the 2011 Draconids meteoroids. This analysis is ongoing.

5 Light curves

A preliminary analysis of the light curves measured from the aircraft was performed by Detlef Koschny. The F-number does not look especially low, which is contrary to what was expected from fragile Draconid meteoroids. Flat light curves dominate the data, which is totally unexpected. Similar results were found by Pavol Koten, who analyzed light curves recorded by one of the narrow FOV cameras. The light curves of 130 Draconid meteors show significant variability of shape, with a broad distribution of F-values. More work will be needed in order to fully understand this feature of the 2011 Draconids.

6 Spectroscopy

A few dozen spectra were recorded during the flights. The analysis was performed by Regina Rudawska, Joe Zender, as well as Jiří Borovička. The spectra show emission lines from iron (Fe), magnesium (Mg), sodium (Na), calcium (Ca), and oxygen (O). Borovička concluded that Na is stronger at higher altitudes and fainter at lower altitudes in comparison with Mg, an effect detected earlier in some Leonids and Draconids as well. The continuum and traces of N_2 and possibly FeO (persistent trains) were detected in the brightest spectrum. Absolute calibration still needs to be performed in order to derive the relative abundances of the chemical elements (Berezhnoy and Borovička, 2010).

7 What did we learn?

From the operational point of view, we are glad that Europe was able to support both missions financially, and support our ongoing collaboration with researchers in the US and Japan that have prior mission experience. The crews of the two aircrafts coordinated both flights perfectly, putting the planes at the right time at the right place. We were fortunate to see that the flight plan could change two days prior to the flight, which was not a given, since we had to fly over many European countries. We all exchanged cameras between the two aircrafts in order to benefit from the other flights as much as possible. Thanks to the International Meteor Organization, results were available right after landing.

In hindsight, the flight plan was not ideal to cover the second outburst. The Moon was on the left-hand side of the plane during the first part, and on the right-hand side during the second. This was clearly a handicap for many cameras.

The operation of multiple cameras by a single operator proved difficult in the stressful environment during deployment. Significantly more practice in operating the cameras could avoid some mistakes made. Written procedures would also help not to forget to do things during the flight when time is precious. The spectral and orbit cameras should be coordinated, so that time-resolved spectra can be obtained as a function of altitude.

Last but not least, because the plane is always moving, and unless the camera is stabilized, the use of long exposure cameras, such as the CAmera for BEtter Resolution NETwork (CABERNET, Atreya et al., 2012), is not recommended. Recording at 25 Hz appears to be a minimum requirement.

8 Conclusions

The 2011 Draconids airborne observation campaign was executed as planned and collected much data. This was the first European multi-instrument airborne meteor observation campaign ever organized, to our knowledge. The shower occurred at the expected time. The observations show that models of the 1900-dust ejecta need to be further developed to understand the activity level, the distribution of meteoroid sizes in the profile, and the lightcurve shape. Light curves are found to be surprisingly flat. The early peak was not detected in observations from the aircraft. Implications for the Comet's past activity are being investigated. There is still a lot of work to be performed, but these first results are very encouraging.

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References

Atreya P., Vaubaillon J., Colas F., Bouley S., and Gaillard B. (2012). "CCD modification to obtain high-precision orbits of meteoroids". *Mon. Not. R. Astron. Soc.*, **423**, 2840–2844.

Berezhnoy A. A. and Borovička J. (2010). "Formation of molecules in bright meteors". *Icarus*, **210**, 150–157.

Gritsevich M., Zubko E., Kohout T., Muinonen K., Vaubaillon J., and Koschny D. (2012). "Density of interplanetary particles entering the Earth's atmosphere". In *Asteroids, Comets, Meteors 2012*, May 16–20, Niigata, Japan, *LPI Contribution Series*, LPI-001667, abstract id. 6323 *LPI Contributions*, **1667**, 6323.

Jenniskens P. (2002). "The 2002 Leonid MAC airborne mission: first results". *WGN, Journal of the IMO*, **30**, 218–224.

Jenniskens P. (2006). *Meteor Showers and Their Parent Comets.* Cambridge University Press.

Jenniskens P. and Butow S. (1998). "Successful Leonid airborne mission". *WGN, Journal of the IMO*, **26**, 249–252.

Jenniskens P. and Vaubaillon J. (2007). "The 2007 September 1 Aurigid meteor shower: predictions and first results from airborne and ground based observations". *AGU Fall Meeting Abstracts*, page C3.

Leroy A., Lecacheux J., Colas F., Maquet L., Bouley S., and Rudawska R. (2013). "Large 2011 Draconids outburst observing campaign: ground-based observations of the Paris Observatory team". In Gyssens M. and Roggemans P., editors, *Proceedings of the International Meteor Conference*, La Palma, 20–23 September 2012, IMO, pages ??–??.

Tóth J., Piffl R., Koukal J., Zołądek P., Wiśniewski M., Gajdoš S., Zanotti F., Valeri D., De Maria P., Popek M., Gorkova 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., Watanabe J., Sato M., Horii S., and Koten P. (2011). "The coming 2011 Draconids meteor shower". *WGN, Journal of the IMO*, **39**, 59–63.

Zigo P., Tóth J., Kalmančok D., and Kornoš L. (2013). "All-Sky Meteor Orbit System AMOS". In Gyssens M. and Roggemans P., editors, *Proceedings of the International Meteor Conference*, La Palma, 20–23 September 2012, IMO, pages ??–??.