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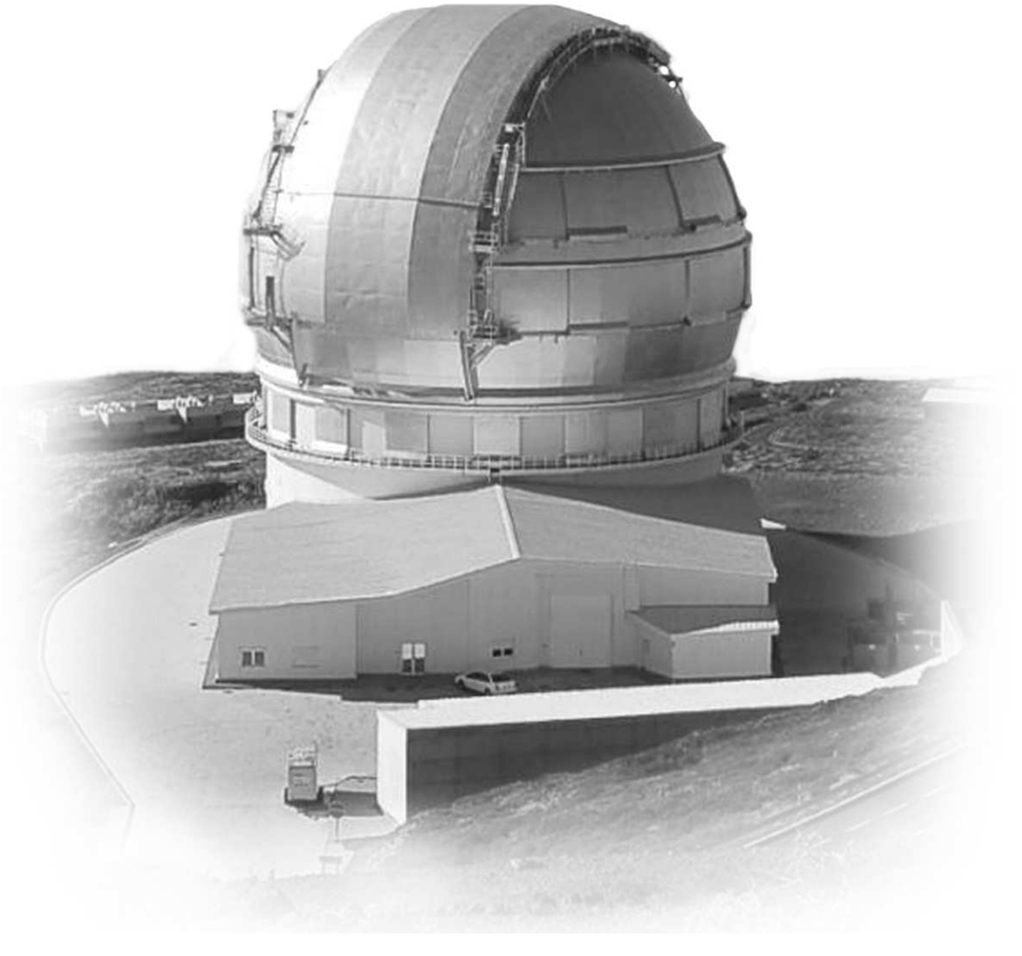

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The 2011 Draconid outburst: UCM group preliminary results from Spain

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The Draconid outburst of October 8, 2011, originating from the 1900 and 1907 trails, took place as predicted (Vaubaillon et al., 2011, and references therein) at approximately 20^{h} UT. The UCM group observed the event from the Observatorio de Sierra Nevada, a well-placed location at an elevation of 2900 m, with the radiant above 40° of altitude during the entire outburst. Continuous monitoring was also done from the Observatorio UCM at Madrid. Both stations used video techniques for flux measurements and DSLR imaging for orbit determination purposes. We obtained preliminary values of $(221 \pm 49) \times 10^{-3}$ meteoroids per square kilometer and per hour on October 8, 2012, at $20^{\mathrm{h}}06^{\mathrm{m}}$ UT, for meteoroids causing meteors brighter than magnitude +6.5 (meteoroid mass over 5 mg), assuming a population index $r = 2.8$. For meteoroids over 0.2 g, the maximum flux was $(4.9 \pm 1.1) \times 10^{-3}$ $\mathrm{km}^{-2}\mathrm{h}^{-1}$. These results are in good agreement with other preliminary results recently published. Despite the abundance of faint meteors, we recorded seven brights fireballs simultaneously from two or more stations, including a Draconid of magnitude −11 (Madiedo et al., 2012). They are currently being analyzed for trajectory and orbit determination.

1 Introduction

An outburst of Draconids took place on October 8, 2011, with the maximum around 20^{h} UT as forecast. The GUAIX (UCM group of Extragalactic Astrophysics and Astronomical Instrumentation) prepared a dedicated observing campaign to complement the continuous monitoring at the Observatorio UCM (Madrid). The scientific objective of the campaign was to obtain flux density and astrometric recordings of the Draconids in a well-placed location with good weather and optimal radiant elevation conditions. Part of the group went to the Observatorio de Sierra Nevada (OSN) of the Instituto de Astrofísica de Andalucía (IAA), at an altitude of 2900 m in the Sierra Nevada (Granada). Over 100 Draconids were recorded. Some fireballs were observed in multiple station by several nodes of the SPMN (SPanish Meteor Network). The highlight was the launch of a high-altitude helium balloon with a scientific payload for recording the Draconids. This was done in collaboration with Proyecto Daedalus that had successfully launched other balloons. The payload consisted of a netbook recording with the signal coming from a high-sensitivity Watec video camera.

This preliminary analysis is part of the undergraduate research project *Dungeons & Draconids (& Fellows!)*. M. F. Palos, B. Muñoz-Ibáñez, and A. Santamaría were participating undergraduate physics students.

2 Equipment and method

The 2011 Draconids were recorded using Watec 902H2 Ultimate cameras and wide-field lenses covering down to magnitude +3 and all-sky lenses down to +1. There were 7 cameras at Observatorio UCM (Madrid) and 5 cameras at OSN (Granada). High-resolution images were taken with DSLR cameras from OSN in double-station mode with other SPMN nodes in order to be able to calculate precise orbits.

The Draconid flux was calculated using video data from the UCM cameras at the OSN and UCM observatories. We use a standard method for flux density estimation (Bellot Rubio, 1994) and the software developed by the ESA/RSSD Meteor Research Group (Ocaña et al., 2011). The flux (Q) is basically the meteor rate divided by the area being monitored:

$$Q = \frac{\mathrm{vZHR} \times C_r}{A_{\mathrm{red}}} = 3600 V_\infty \rho. \qquad (1)$$

The area is corrected for geometric effects and extinction. The sum of the corrected areas is the reduced or standard area:

$$A_{\mathrm{red}} = \sum_i A_i r^{5 \log \frac{H}{d_i} - \varepsilon_i}, \qquad (2)$$

where A_i is the area of each individual tile projected into the meteor layer, H is the height of the meteor layer (beginning point), d_i is the distance from the observer to the point projected onto the meteor layer, and ε_i is the extinction in each individual direction. The video zenithal hourly rate is given by

$$\mathrm{vZHR} = \frac{N}{T} r^{6.5 - \mathrm{vlm}} \sin^{-\gamma} h_R, \qquad (3)$$

where vlm is the video limiting magnitude, γ the zenith exponent, and r the population index.

Table 1 – Observational parameters and values for each camera. The correction factor includes the relation between the effective and true area, and the $r^{\mathrm{vlm}-6.5}$ standardization. Both are strongly dependent on the population index r and, consequently, a large source of systematic errors in the flux determination.

Name	Field of view	vlm	True area	Effective area	Factor	Meteors
Bol02	69° × 52°	+2.3	10 584 km^2	95 058 km^2	680	20
Bol05	59° × 45°	+2.8	6 941 km^2	509 444 km^2	3294	18
Bol06	60° × 45°	+2.6	7 786 km^2	31 730 km^2	222	41
OSN01	39° × 29°	+2.7	3 131 km^2	240 125 km^2	3837	8
OSN05	71° × 54°	+2.7	10 843 km^2	230 201 km^2	1051	54

Table 2 – UCM group observing stations for the Draconids 2011 outburst.

Observing station	Latitude	Longitude	Cameras	Notes
Observatorio UCM	40°27′04″ N	3°43′34″ W	5	
Villaverde del Ducado	41°00′08″ N	2°29′25″ W	4	Equipped with gratings
Observatorio Sierra Nevada	37°03′51″ N	3°23′05″ W	3	Also DSLR

Finally, C_r is the the perception correction factor. In the modern software era, it refers to the detection efficiency of the code. We use $C_r = 1$, implying the software is 100% efficient up to the limiting magnitude, althought this is still an open issue for the meteor community.

The video limiting magnitude for meteors is determined using the dimmest meteor detected by each camera, as we have checked that the number of meteors recorded by each camera is not enough to calculate it using the cumulative count method used by Brown et al. (2002). We used $r = 2.8$ as a constant value for the population index (Jenniskens, 2011) and the $\gamma = 1$ for the zenith exponent. For the beginning height, finally, we used $H = 105$ km (Suzuki et al., 1999; Koten et al., 2007).

3 Observation and data

The data used is divided in 12-minute bins in order to have at least 10 meteors per bin during the FWHM of the outburst. We have calculated the effective collecting area for each camera and counted the number of meteors. We use the sum of all the cameras to calculate a single value of flux density.

All cameras were working from civil twilight until 0^{h} UT. We analyze here the data of 5 cameras (see Table 1) at the OSN and UCM observatories from $18^{\mathrm{h}}48^{\mathrm{m}}$ UT to $23^{\mathrm{h}}00^{\mathrm{m}}$ UT. We discarded the other 3 cameras that were aimed for double-station observations. Weather was fine during the observation apart from some thin high clouds by the end of the observing period.

4 Error analysis

We also made a preliminary analysis of the flux uncertainties. The main source of uncertainties is the small number of meteors per bin (from statistics, the error is $\sqrt{N}$). The uncertainties on the zenith exponent γ and the population index r are considered to be systematic, and negligible in comparison to the main source.

Our main concern here is the error associated with the computation of the video limiting magnitude for meteors (vlm). A systematic error of -0.4 in magnitude means an increase of the flux (using $r = 2.8$) by more than 50%. Therefore, we use the Poisson statistical error ($\sqrt{N}$ for the N meteors detected by the 5 cameras) for the calculated fluxes, although we are aware that the systematic errors could be larger.

On the other hand, we realize that using a standard video limiting reference of value of +6.5 introduces a large source of uncertainty (the correction factor being in the order of 40 for our values of vlm $\approx +3$). In Section 7, we give flux values for meteors brighter than magnitude +6.5 (mass over 5 mg), and for meteors brighter than magnitude +2.8 (mass over 0.2 g) (Hughes, 1987). The latter calculations suffer from almost no uncertainty caused by the population index or the video limiting magnitude.

5 Double-station observations

The UCM group was running 12 video cameras from 3 different stations (see Table 2). At least 6 fireballs were detected simultaneously by the Observatorio UCM and Villaverde del Ducado (Guadalajara) cameras.

We recorded also several events by our cameras and other SPMN stations (Trigo-Rodríguez et al., 2012).

6 Balloon

The balloon was launched in Daimiel (Ciudad Real) and landed 200 km further, after a 4-hour flight. It reached a level of 29 km and descended slowly to a place close to Jaén. The probe was recovered just before astronomical twilight set in.

Unfortunately, the computer stopped working after 30 minutes, when it was at around 11 000 m height. Previous launches by Daedalus had shown that the bal-

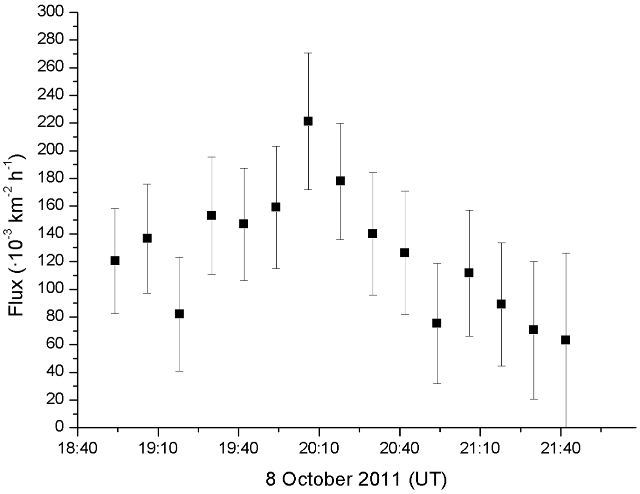

Figure 1 – Draconid flux profile for meteoroids with mass over 5 mg (meteors brighter than magnitude +6.5).

loon remains stable only after crossing the tropopause (about 15 km high). Therefore, the video is wobbly and shows stars up to only magnitude +2, and no Draconid was recorded during this period. The scientific payload consists of a notebook (Samsung NF 210), a Watec 902H2 Ultimate camera, as well as a 18 000 mAh battery (XPAL Power) with a total weight of about 3.5 kg.

The malfunctioning was due to the very high temperature reached by the CPU (over 85° C). This failure was completely unexpected, as CPUs had already been launched and reached 30 km without any problem. Actually, we were more worried about the possible low temperatures inside the probe. Maybe the thin air at high altitudes was not able to dissipate the heat produced by the CPU efficiently enough, or maybe the obstruction of the ventilation duct with the isolation foam caused the problem.

We plan to launch more balloons with similar setups during major showers. For the next launch we will use, a notebook with radiators and a lower-power dissipation processor. For the Geminids 2012, we already succeeded, and recorded several meteors from a helium statospheric balloon (Sánchez de Miguel et al., 2013).

7 Discussion and results

The flux density is calculated using 141 meteors observed from $18^{\mathrm{h}}48^{\mathrm{m}}$ to $23^{\mathrm{h}}00^{\mathrm{m}}$ UT (see Figure 1). The total collecting area of the cameras was 39 000 km^2 (equivalent to an effective area of approximately 1.1 million km^2), with an average limiting magnitude of +2.6. The population index value used is $r = 2.8$ and assumed to be constant along the outburst as a first approximation. Also, we used $\gamma = 1$ as hypothesis for the zenith exponent. The video limiting magnitude is taken from the faintest meteor detected by each camera.

Even using a 12-minute bin results in a noisy profile. We obtain a maximum flux density of $(221 \pm 49) \times 10^{-3}$ km^{-2}h^{-1} for meteoroids producing meteors which are brighter than magnitude +6.5 (corresponding to masses over 5 mg). The maximum took place around $20^{\mathrm{h}}06^{\mathrm{m}}$ UT. It had an FWHM of around 80 minutes, and shows a clear asymmetry, with a strong decay after the maximum. This is the result of the addition of peaks from the 1907 and 1900 trails (forecast at, respectively, $19^{\mathrm{h}}36^{\mathrm{m}}$ and $20^{\mathrm{h}}01^{\mathrm{m}}$ by Vaubaillon et al., 2011).

Our results are in good agreement with other results published. The numerical differences can be explained through different values for the population index. For instance, SPMN calculations use $r = 2.3$ and get a flux of $(102 \pm 13) \times 10^{-3}$ km^{-2}h^{-1} at $20^{\mathrm{h}}08^{\mathrm{m}}$ UT (Trigo-Rodríguez et al., 2013). Using that same value for the population index, we obtain $(105 \pm 23) \times 10^{-3}$ km^{-2}h^{-1}, in good accordance with their results. To compare with IMONET results (Molau et al., 2012), we use $r = 2.6$ and get $(163 \pm 36) \times 10^{-3}$ km^{-2}h^{-1}, similar to their result of $(126 \pm 13) \times 10^{-3}$ km^{-2}h^{-1}.

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