Balloon-borne video observations of Geminids 2016

Francisco Ocaña, Alejandro Sánchez de Miguel, Orison team and Daedalus Project
focana@sciops.esa.int

IMC 2018 – Pezinok-Modra (Slovakia)
Meteoroid flux determination

Spatial number density
Number of meteoroids larger than a given mass in a volume unit

\[ [\rho] = \frac{\text{meteoroids}}{\text{km}^3} \]

Flux density
Number of meteoroids larger than a given mass passing through an unit of area during a unit of time

\[ [Q] = \frac{\text{meteoroids}}{\text{km}^2 \cdot \text{hour}} \]

Absolute magnitude
Standard reference distance 100 km

\[ M = m - 5 \log \frac{d}{100} \]
Method for flux determination

- **Method** for meteoroid flux determination
  - **meteors crossing a surface** (meteor layer) at a height $H$
    - Visual observation  
      *(Koschack & Rendtel, 1990)*
    - Photography 
      *(Trigo-Rodríguez, 1993; Bellot-Rubio, 1994)*
    - Video 
      *(Several authors)*

This work updates the Bellot-Rubio’s method for fast-rate CCD camera and extends it for observations from the stratosphere.

Number of meteors

\[ vZH R = \frac{N + 1}{T} \sin^{-\gamma} h_R \cdot r^{6.5 - \nu m} \]

Surface

\[ A_{red} = \sum_i A_i \cdot r^{5 \log \frac{H}{d_i} - \varepsilon_i} \]
Method for flux determination

Surface: reduced or equivalent area

- $A_i$ – geometrical area subtended

- Absolute magnitude correction $5 \log \frac{H}{d}$
- Extinction $\varepsilon_i$

Adapted from Richardson, 1999
Method for flux determination

Observation from a point at a **height** $h_b$ **over the surface**

Implemented the calculation of distance and airmass for large zenithal angles

Extinction is significant up to 15km height

31/08/2018
Optimisation analysis

\[ Q(N, T, \gamma, h_R, vlm, A_i, d_i, \varepsilon_i) = \frac{N+1}{T} \sin^{-\gamma}(h_R) \cdot r^{6.5-vlm} \cdot Cr \cdot \sum_i A_i \cdot r^5 \log \frac{H}{d_i} \cdot \varepsilon_i \]

- \( h_R \) – elevation of the radiant
- \( A_i \) – geometrical area
- \( \varepsilon_i \) – extinction

\[ \Delta m = 2.5 \log \frac{\omega}{\omega_0} \]

\[ \omega = V_\infty \sin \frac{D_{\text{radiant}}}{d_i} \]

\[ \omega_0 = \frac{\text{resolution element (radians)}}{\text{integration time (s)}} \]
Results of the analysis for the optimisation of meteoroid flux determination

- Location close to the **subradiant point**
- **Trade-off** between meteor relative speed and pixel size
- Increase geometrical area pointing at **large zenithal angles**
- Increase geometrical area with **larger FoVs**
- **Decrease extinction**
Stratospheric observations

Observation from the stratosphere: **trade-off extinction vs geometrical area.**

At 20 km:

- the **area** surveyed by the instrument is **smaller**

- the **extinction** is several **times less** than at ground level

- the apparent magnitude of meteors is **brighter**
**Result:** largest effective area $A_{\text{red}}$ is achieved in **extinction-free environment at larger zenithal angles**.

- **Airborne campaigns** (Millman, 1973; Murray et al., 1999; Vaubaillon et al., 2015)
- **Stratospheric balloonborne observations**
Balloonborne platform

- Balloonborne missions from Daedalus Project (outreach, technology development)
- Including meteor detection payload for 8 nighttime missions
- Instrumental design for optimising the meteor detection. The design of the payload has been driven by science and technology development, and based on COTS components

<table>
<thead>
<tr>
<th>Date</th>
<th>Code</th>
<th>Objective</th>
<th>Success</th>
<th>Instruments</th>
<th>Stab.</th>
<th># Balloons</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010/09/18</td>
<td>D2</td>
<td>LP</td>
<td>Yes</td>
<td>Cam+Rec</td>
<td>No</td>
<td>2</td>
</tr>
<tr>
<td>2011/10/08</td>
<td>D4</td>
<td>DRA</td>
<td>No</td>
<td>W+PC</td>
<td>No</td>
<td>2</td>
</tr>
<tr>
<td>2011/10/14</td>
<td>D5</td>
<td>LP</td>
<td>Partial</td>
<td>LX7</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>2012/08/24</td>
<td>D11</td>
<td>LP</td>
<td>Partial</td>
<td>Gopro</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>2012/12/12</td>
<td>D12</td>
<td>GEM</td>
<td>Yes</td>
<td>W+Rec+PC</td>
<td>No</td>
<td>2</td>
</tr>
<tr>
<td>2014/05/24</td>
<td>DX1</td>
<td>CAM &amp; LP</td>
<td>Yes</td>
<td>W+Rec &amp; LX7</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>2015/12/13</td>
<td>D17</td>
<td>GEM</td>
<td>No</td>
<td>SA7S</td>
<td>Pas</td>
<td>3</td>
</tr>
<tr>
<td>2016/01/04</td>
<td>D18</td>
<td>QUA</td>
<td>Yes</td>
<td>SA7S</td>
<td>Pas</td>
<td>1</td>
</tr>
<tr>
<td>2016/04/23</td>
<td>D19</td>
<td>LYR</td>
<td>Yes</td>
<td>SA7S &amp; Go4</td>
<td>Pas</td>
<td>2</td>
</tr>
<tr>
<td>2016/08/13</td>
<td>D20</td>
<td>PER</td>
<td>Yes</td>
<td>SA7S &amp; Go4</td>
<td>Pas</td>
<td>3</td>
</tr>
<tr>
<td>2016/12/13</td>
<td>D21</td>
<td>GEM</td>
<td>Yes</td>
<td>SA7S</td>
<td>Pas</td>
<td>3</td>
</tr>
</tbody>
</table>

(Ocaña+, 2016)
Platform constraints

- Several constraints (e.g., rotation speed). Data from the probe sensors.

- Limited weight budget. Instruments not extremely focus-sensitive.
- Loss risk. Design based on COTS (commercial off-the-shelf)
- Recording system included in the instrument
Balloonborne instrumentation

**Instrument design**
- Large FoV to ensure pointing
- Plate scale <10 arcmin/pixel

First prototype – **Watec 902 H2U**
- B&W, 30 fps
- Lens Tamron 12VG412ASIR
- FoV 92° x 69°
- Plate scale 9 arcmin/pixel
- vlm magnitude 3
- Missions D4, D12, DX1

**Instrument - Sony α7S**
- Colour, full-HD, 30 fps
- Lens Samyang 24 mm f/1.5
- FoV 82° x 46°, Plate scale 153 arcsec/pixel
- vlm magnitude 6
- Missions D17, D18, D19, D20, D21
Density flux determination: Geminids 2016

Showcase for the analysis of data from a balloon-borne campaign: Geminids 2016

- Launch 13\textsuperscript{th} December 2016 at 23h17m UT
- Burst at 01h50m UT
- Landed at 03h55m UT (276 minutes later)

- Full moon. Limiting magnitude 6.0
- Real-time videos
- Up to 8 meteors per minute

- +556 meteors in 4 hours
- ( https://www.youtube.com/watch?v=IDG1Y9yQtsE )
Density flux determination: Geminids 2016

Showcase for the analysis of data from a balloon-borne campaign.

All videos (raw data) are at the EU-funded repository: Zenodo.

https://zenodo.org/record/579708

https://zenodo.org/record/801598

https://zenodo.org/record/842269

Be patient, it is +50GB!
Density flux determination: Geminids 2016

Showcase for the analysis of data from a balloon-borne campaign. **Density flux** determined for the most stable part of the flight in the stratosphere

\[(15 \pm 3) \cdot 10^3 \text{ meteoroids (mass >0.6 mg) km}^{-2}\text{h}^{-1} \text{ at 01h44m UT (14}^{th}\text{ Dec)}\]

**Periodogram for the probe movement (3rd hour of mission)**

**Probe rotation**

\[P \text{ 400-600 s } \omega < 1 \text{ °/s}\]
Conclusions & Future work

– Balloon-borne observations have proven to be an excellent solution for meteoroid flux determination, overcoming troposphere handicaps like weather or extinction.

– We have designed and tested instrumentation for balloon-borne missions, and analysed the most stable part of the video of the Geminids 2016 campaign. We need a more stable platform to maximise the scientific output. The balloon-borne campaign for flux determination is break-through in the meteor research.
Conclusions & Future work

Future work:

- New algorithm including airmass calculation for elevations $h<0^\circ$ when observing from the stratosphere
- Analysis of another two balloon-borne missions for major showers performed in 2016. More campaigns are foreseen. Software to be developed.
Balloon-borne video observations of Geminids 2016

Francisco Ocaña, Alejandro Sánchez de Miguel, Orison team and Daedalus Project
focana@sciops.esa.int

IMC 2018 – Pezinok-Modra (Slovakia)