IMC 2018
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Balloon-borne video observations of Geminids 2016

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IMC 2018 – Pezinok-Modra (Slovakia)

Meteoroid flux determination

Spatial number density

Number of meteoroids larger than a given a mass in a volume unit

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

Flux density

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

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

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

$$vZHR = \frac{N+1}{T} \sin^{-\gamma} h_R \cdot r^{6.5-vlm}$$

Surface

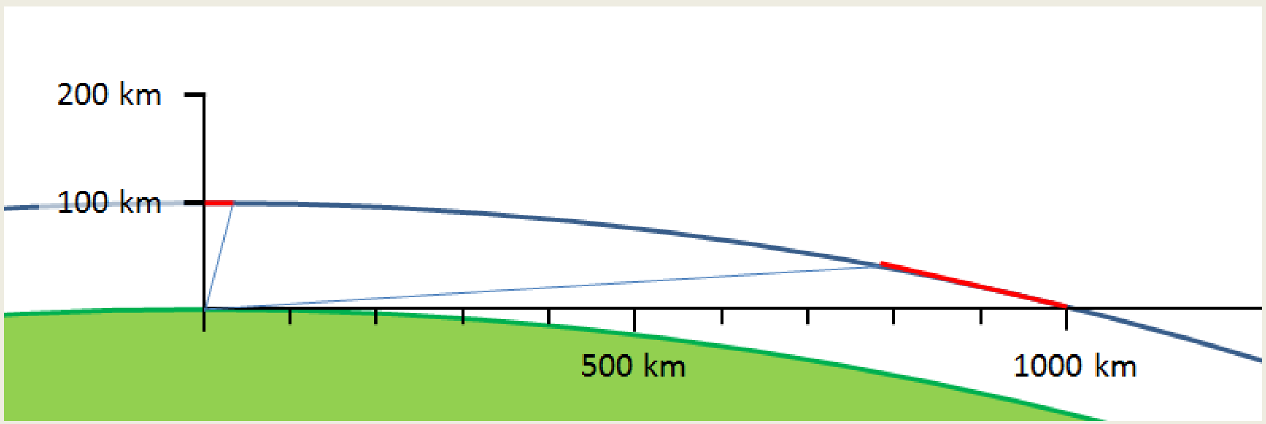
$$A_{red} = \sum_i A_i \cdot r^{5 \log \frac{H}{d_i} - \varepsilon_i}$$

Method for flux determination

$$A_{red} = \sum_i A_i \cdot r^{5 \log \frac{H}{d_i} - \varepsilon_i}$$

Surface : **reduced or equivalent area**

- **A_i** – geometrical area subtended

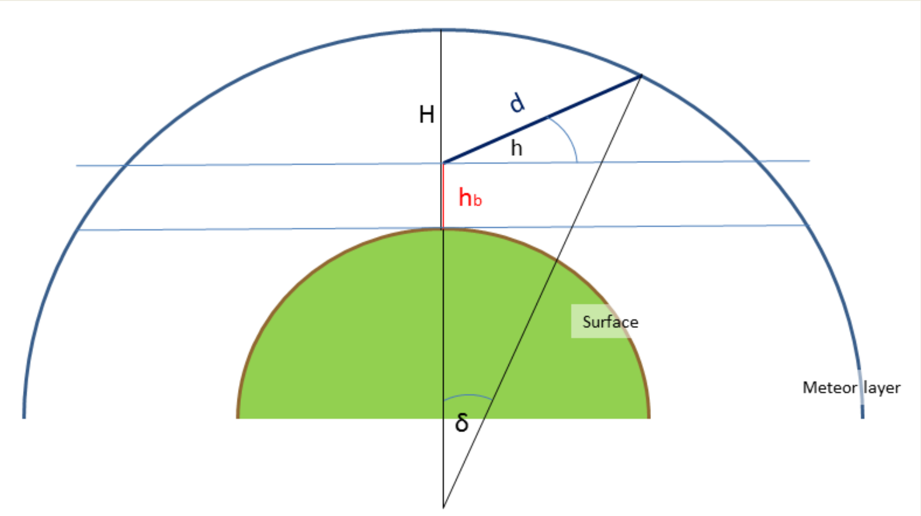


Adapted from *Richardson, 1999*

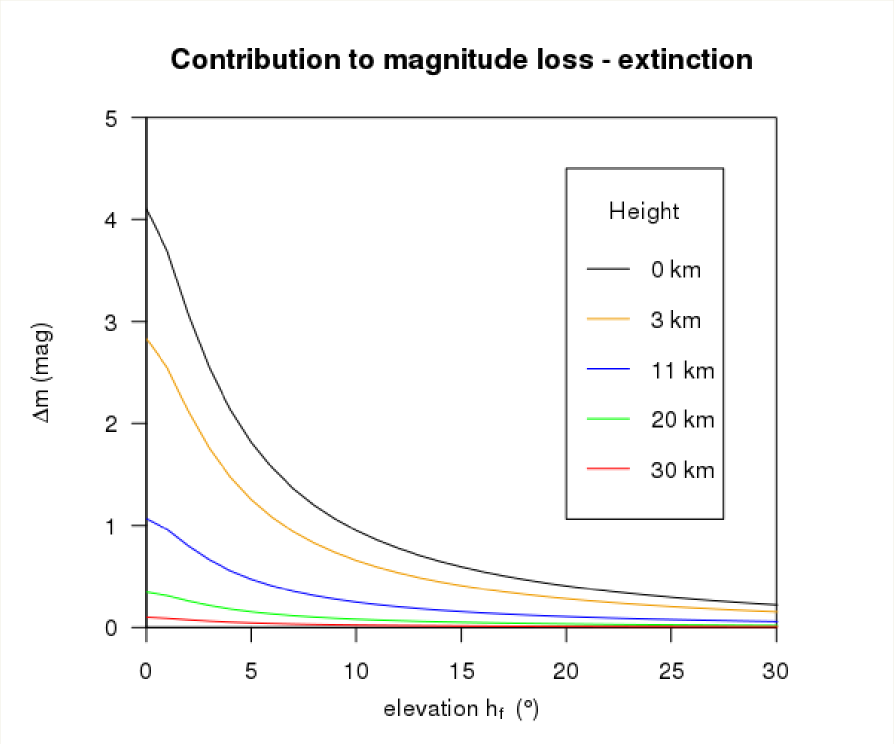
- Absolute magnitude correction $5 \log \frac{H}{d}$
- extinction $\boldsymbol{\varepsilon}_i$

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

Optimisation analysis

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

h_R – elevation of the radiant

A_i – geometrical area

ε_i – extinction

vlm – video limiting magnitude

$$\Delta m = 2.5\log\frac{\omega}{\omega_0}$$

$$\omega = V_\infty \frac{\sin D_{radiant}}{d_i}$$

$$\omega_0 = \frac{\text{resolution element (radians)}}{\text{integration time(s)}}$$

Results

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

Results of the analysis for the optimisation of meteoroid flux determination

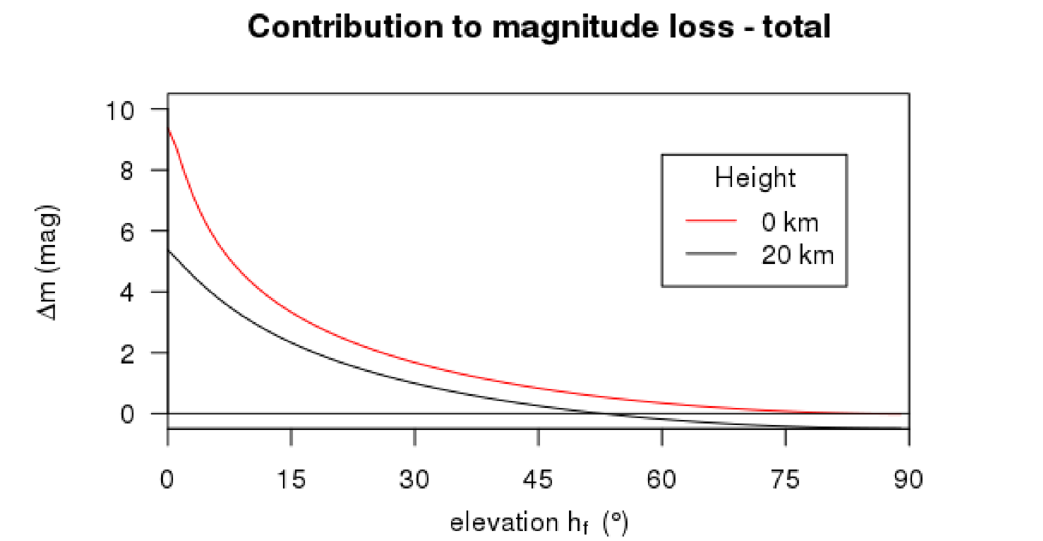
- Location close to the **subradiant point**
- **Trade-off** between meteor relative **speed and pixel size**
- Increase geometrical area pointing at **large zenithal angles**
- Increase geometrical area with **larger FoVs**
- **Decrease extinction**

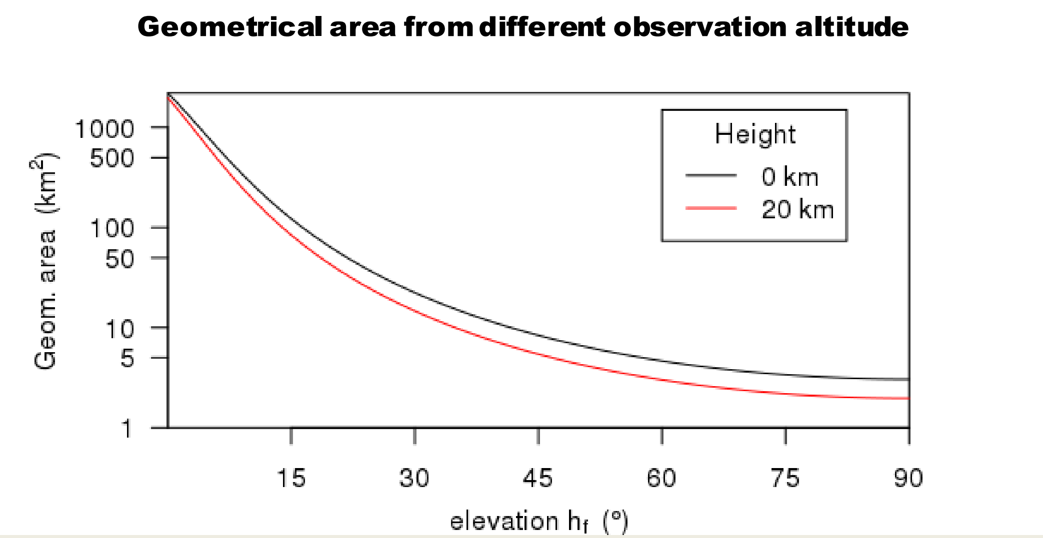
Stratospheric observations

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**

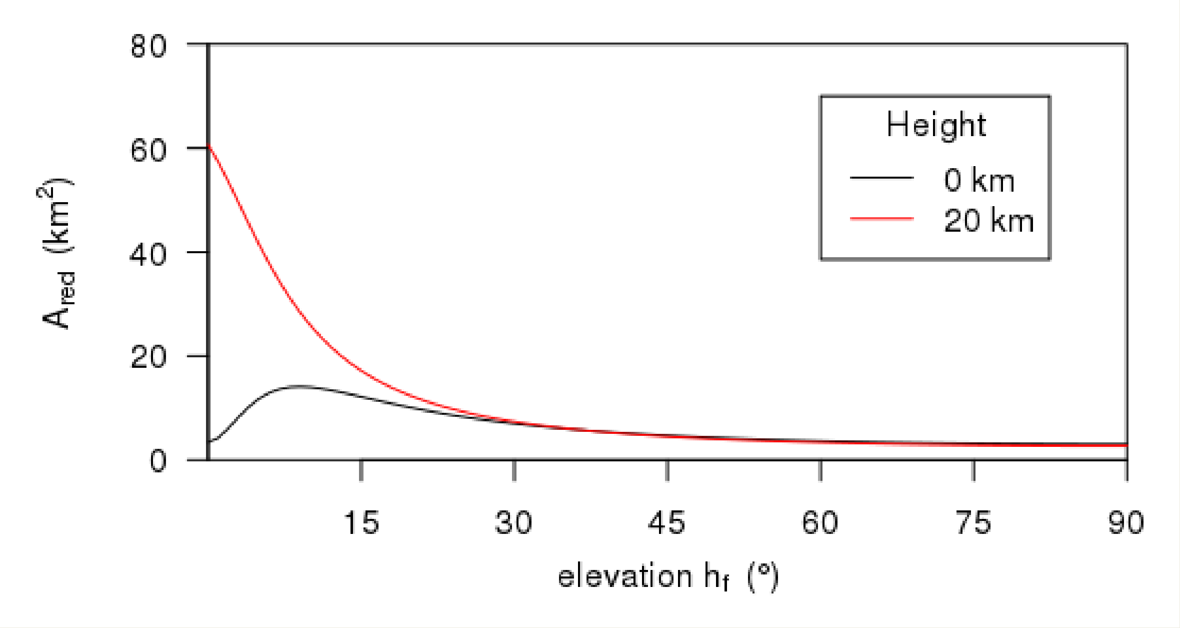




Stratospheric observations

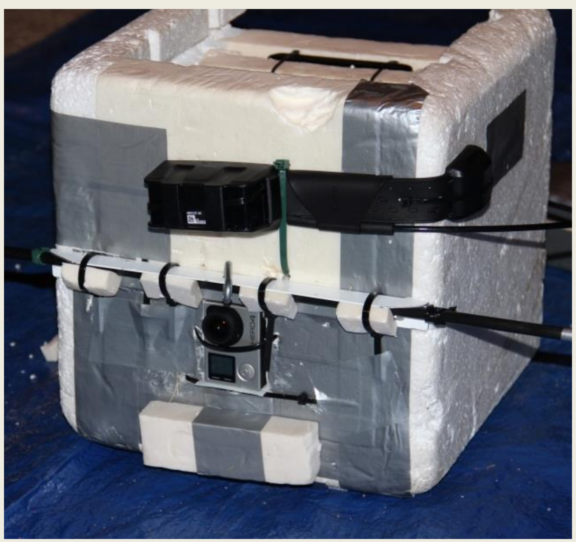
Result: largest effective area A_{red} is achieved in **extinction-free environment at larger zenithal angles.**

- 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

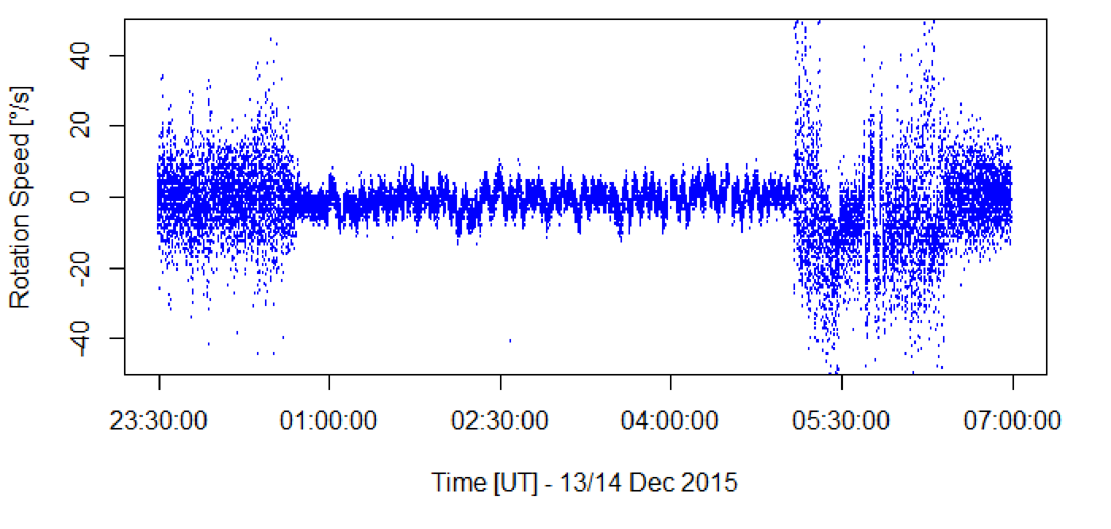


Date	Code	Objective	Success	Instruments	Stab.	# Balloons
2010/09/18	D2	LP	Yes	Cam+Rec	No	2
2011/10/08	D4	DRA	No	W+PC	No	2
2011/10/14	D5	LP	Partial	LX7	No	1
2012/08/24	D11	LP	Partial	Gopro	No	1
2012/12/12	D12	GEM	Yes	W+Rec+PC	No	2
2014/05/24	DX1	CAM & LP	Yes	W+Rec & LX7	No	1
2015/12/13	D17	GEM	No	SA7S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

(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 13th 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)


Geminids 2015

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

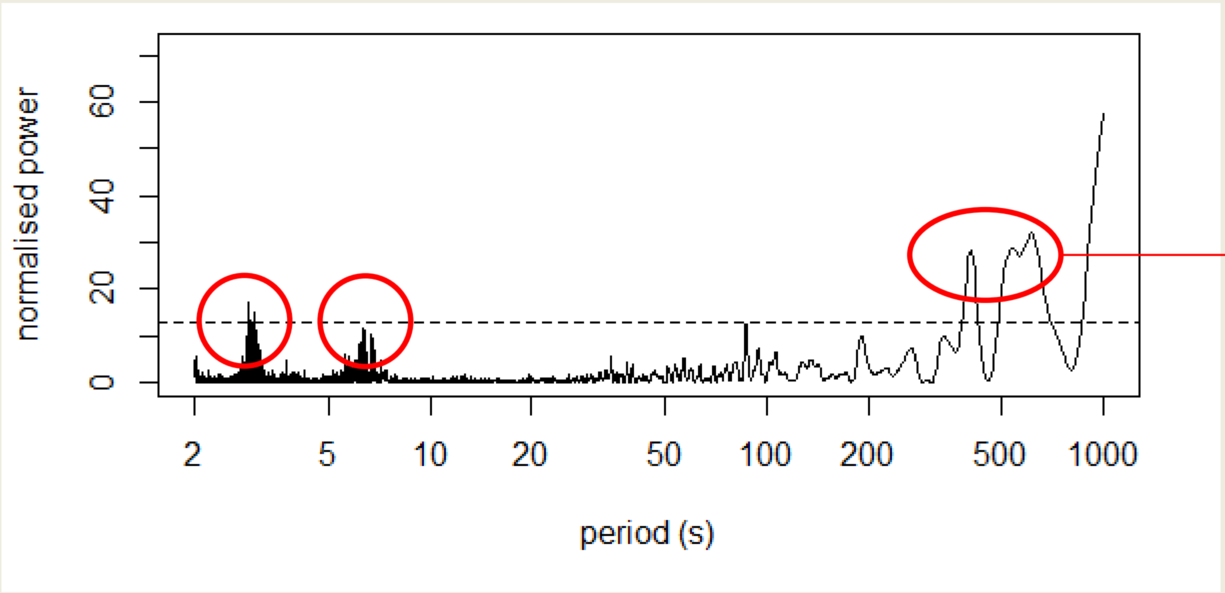
Be patient, it is +50GB!

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

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



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

Probe rotation

P 400-600 s
ω < 1 °/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° 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.

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