Starting grant report - Balloon-borne studies of the cosmic radiation for gymnasium students

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Introduction

The KTH Space Center provided a "start-up grant" for an outreach project which provides high-school (gymnasium) students the opportunity to make studies of the cosmic radiation using instrumentation flown on weather balloons high in the atmosphere. This is an extension of an outreach programme organised by MP and Vetenskapens Hus for over 10 years in the context of "gymnasieprojektarbete". In the original programme a constellation of cosmic-ray detectors was established at KTH and schools in the Stockholm region in order to observe showers of particles produced in the atmosphere by high-energy cosmic-rays. Students and teachers participated in the construction and operation of the detector stations. Eventually, it became too time-consuming to keep this project operational and a different approach is now adopted where-by smaller portable detectors were constructed which students could borrow to make measurements at school and other locations (in mines and aboard aircraft are among the more interesting places chosen by students...).

The start-up grant from KTH Space Centre allows the outreach programme to be extended to include measurements in the atmosphere by means of a hydrogen-filled weather balloon.

Balloon flight

The balloon flight took place on 10 October 2015 in order to synchronise with "Astronomins dag och natt"[1] - a nationwide event to promote astronomy to the public co-ordinated by Svenska Astronomiska Sällskapet.

The cosmic ray detector was a variant of that designed by MP to be used on-board the Interntional Space Station by Christer Fuglesang[2] (also here with an outreach focus). It comprises a plastic scintillator coincidence telescope which registers the passage of charged particles. In the balloon-version, data is stored in an on-board memory and can also be sent to the ground over a radio link. A GPS receiver is also flown which allows the position of the balloon to be followed in real-time. An atmospheric pressure and temperature sensor is also provided, as well as two cameras (one looking up and one looking down).

The balloon was launched NNW of Lima in Dalarna (figure 1) at approximately 11:25. The payload landed NW of Ludvika at approximately 15:15. A maximum altitude of 35 km was achieved before the balloon burst (as planned) and the payload returned to the ground by parachute. The balloon trajectory

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[1] www.astronominsdag.se

[2] http://www.nasa.gov/mission_pages/station/research/experiments/425.html

and cosmic-ray dependence on altitude can be seen in figures 2 and 3, respectively. A video of the flight is available on YouTube[3] - a frame from the video taken at maximum altitude is shown in figure 4.

Outreach programme

The balloon flight is an integral part of the student activity programme detailed in Appendix 1. A list of participating schools and students is also provided. Prior to the flight, students learnt about the science of cosmic-rays and the operation principles of the cosmic-ray detector. Particular emphasis is also placed on the analysis of data, including the use of statistics to draw scientifically rigorous conclusions from measurements. It proved logistically complicated to include high-school students in the balloon launch (arrangements will be reconsidered for a planned 2016 flight). Thanks to a real-time data and video link from the launch site, students were however able to follow developments from Vetenskapens Hus. During the flight, balloon data was available from a web-page and regular progress reports were posted on Twitter. After the flight, students were instructed how to analyse data using a web-based tool. Students will present their final results at a mini-conference held at Vetenskapens Hus on 15th March 2016.

Budget

	Cost (kr)
Expenses	
Personnel (Vetenskapens Hus)	2,000
Balloon launch (Open Aerospace)	8,580
Transportstyrelsen	4,200
Radio system (Sparv Embedded)	24,300
Travel	3,000
	42,080
Income	
Space Centre staring grant	**40,000**
Funded by MP	**2,080**

Comments on budget

Costs for staff from Vetenskapens Hus (undergraduate and postgraduate student assistants) were partially covered by the Space Centre grant. The balloon launch and consumables (balloon, parachute, gas, etc.) were provided by Mikael Ingemyr at Open Aerospace. In order to launch the balloon, an application must be submitted to Transportstyrelsen. The largest cost was a minaturised radio system obtained from Sprav Embedded. This allows the balloon data to be followed from the ground by students in real-time. The equipment will be reused for future flights. Travel costs concern the journey to/from the launch site (and ensuing balloon chase) by car.

[3] https://www.youtube.com/watch?v=SveD0H95q74

Acknowledgements

At Vetenskapens Hus, important contributions were made by Henrik Åkerstedt (project responsible), Klas Wallden and Jonas Nylund. SSC (Christian Lockowandt) are thanked for the use of their vacuum test facility which was used to flight certify the payload before launch.

Figures

Figure 1: The moment of launch - Henrik Åkerstedt from Vetenskapens Hus prepares to release the balloon. The lower white polystyrene box contains the cosmic-ray detector and cameras. The upper box contains the radio equipment and weather sensors. The parachute can be seen in the line connecting the balloon to the payload boxes.

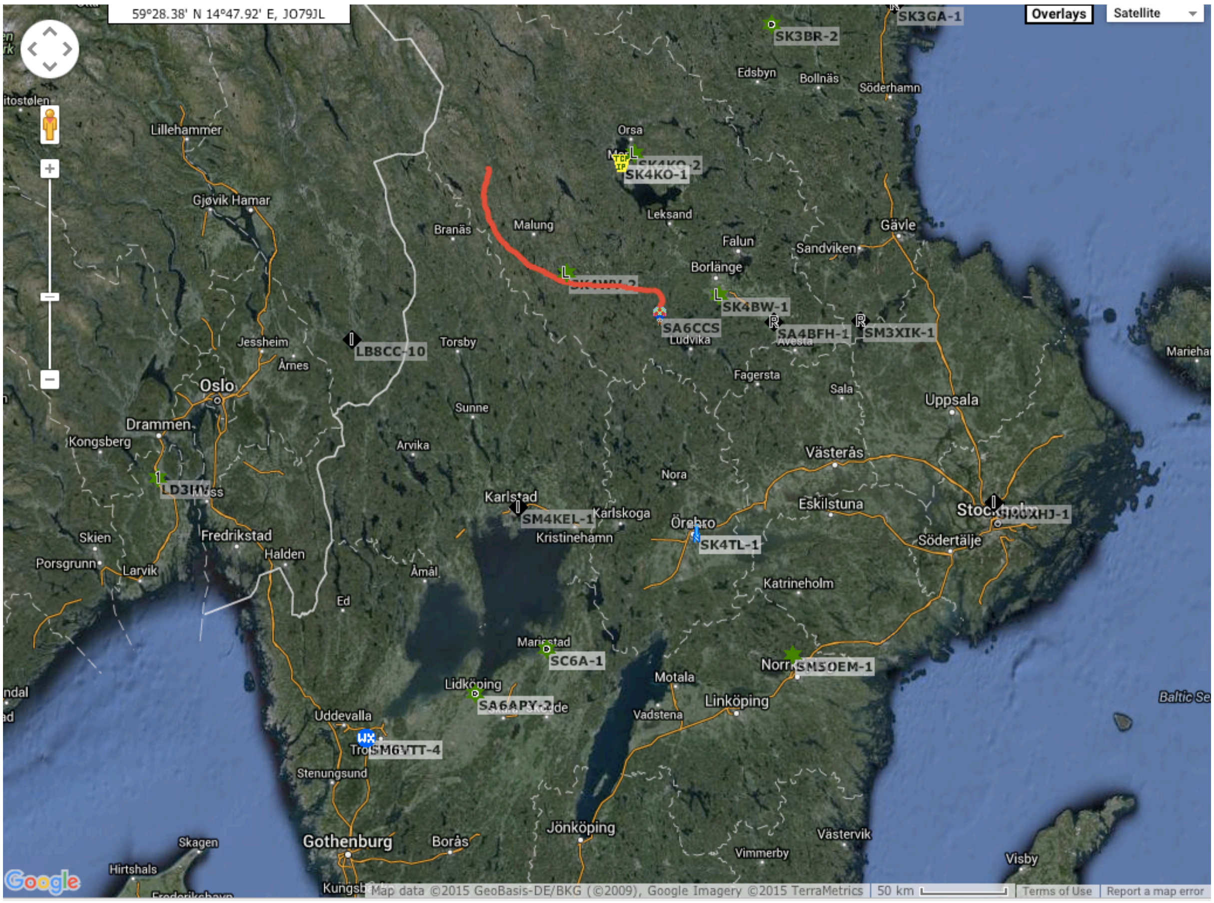

Figure 2: The trajectory of the balloon (red line). The location of shortwave amateur radio stations are shown in the grey boxes. Data from these stations allows a back-up triangulation of the balloon's position in case the on-board systems fail.

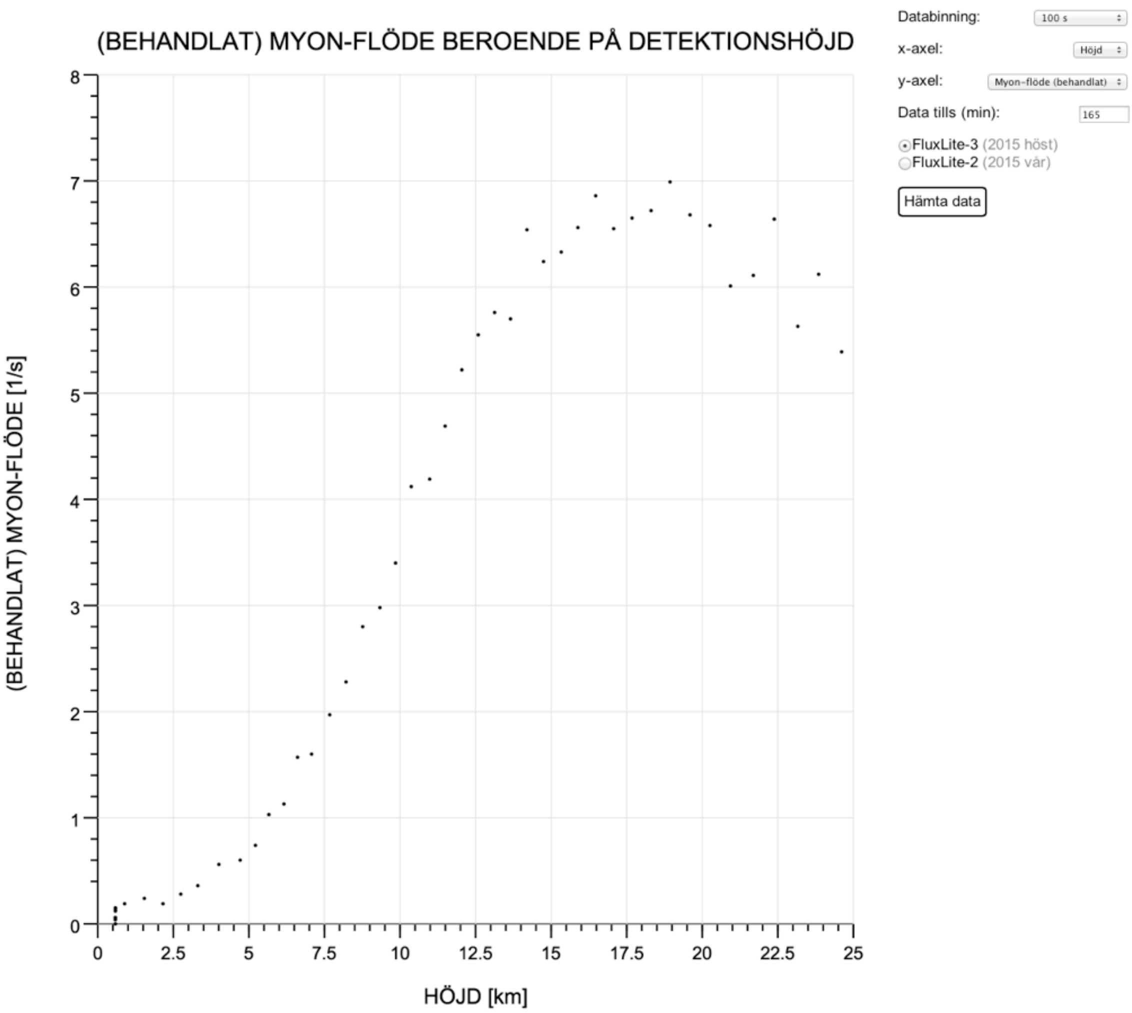

Figure 3: The counting rate for charged particle coincidences (Hz) as a function of altitude (km). The particles registered are mostly relativistic muons and pions (only at higher altitudes). The counting rate reaches a maximum around 17.5 km corresponding to the region in the atmosphere with maximum secondary particle production (the so-called Pfotzer maximum).

Figure 4: Photograph taken by on-board camera at an altitude of approximately 35 km. Although the wide angle camera lens distorts the image, the earth's atmosphere can be clearly seen.

Appendix A

The student activity programme for 2015/2016

VETENSKAPENS HUS

KTH VETENSKAP OCH KONST

KTH Fysik

Kosmisk strålning 2015/16

Ons 16/9	kl 17:30 – 19:30	Introduktion Föreläsning: *Kosmisk strålning intro* Genomgång detektorer, demonstrationer
Ons 30/9	kl 17:30 – 19:30	Föreläsning: *Vetenskaplig metodik* Lab: Kosmisk strålning, felanalys Diskutera möjliga frågeställningar
Tis 6/10	kl 17:30 – 19:30	Föreläsning: *Vetenskaplig metodik fortsättning* Genomgång av dataanalys Formulera frågeställning, förbereda ballongflygning Diskussion och frågor
Lör 10/10	Hela dagen	Ballongflygning
Tis 20/10	kl 17.30 – 19.30	Genomgång av data från ballongflygningen. Dataanalys Diskussion och frågor
Tor 26/11	kl 17:30-19:30	Gästföreläsning, Josefin Larsson Diskussion och frågor
	Jullov	
Ons 10/2	kl 17:30-19:30	Frågetillfälle – frivilligt (anmäl innan)
Tis 15/3	kl 17:30-19:30	Mini-konferens – Presentation av resultat

Lokal: Vetenskapens Hus

Participating schools and students

Förnamn	Efternamn	Skola
Jakob	Miller	Åva gymnasium
Simon	Wahlberg	Åva gymnasium
Mikaela	Lindberg	Thoren Business School
Annie	Farrel	Viktor Rydbergs gymnasium, Odenplan
Sebastian	Östlind	Norra real
Isabelle	Bonnier	Norra real
Emil	Johansson	Jensen gymnasium, Örebro
Jonna	Hidell	NTI-gymnasiet Stockholm
Anton	Åkesson	NTI-gymnasiet Stockholm
Jonas	Kallhauge	Fredrika Bremergymnasiet, Haninge
Sara	Lindholm	Danderyds gymnasium
Julia	Hallström	Danderyds gymnasium
Arvand	Jourabian	Mikael Elias Teoretiska
Albin	Öberg	Mikael Elias Teoretiska
Josefine	Ståhl	Viktor Rydbergs gymnasium, Djursholm
Anna	Mattsson	Viktor Rydbergs gymnasium, Djursholm
Malin	Rudal	Viktor Rydbergs gymnasium, Djursholm
Kaltum	Mohamud	Thorildsplans gymnasium
Samira	Hassan	Thorildsplans gymnasium
Hafsa	Hashi	Thorildsplans gymnasium
Senhit	Berhane	Thorildsplans gymnasium
Victor	Kojic	Thorildsplans gymnasium
Bamse	Lilja	Thorildsplans gymnasium
Samuel	Ndungu	Thorildsplans gymnasium