Stratospheric X-rays detected at mid-latitudes with a miniaturized balloon-borne microscintillator-PiN diode system

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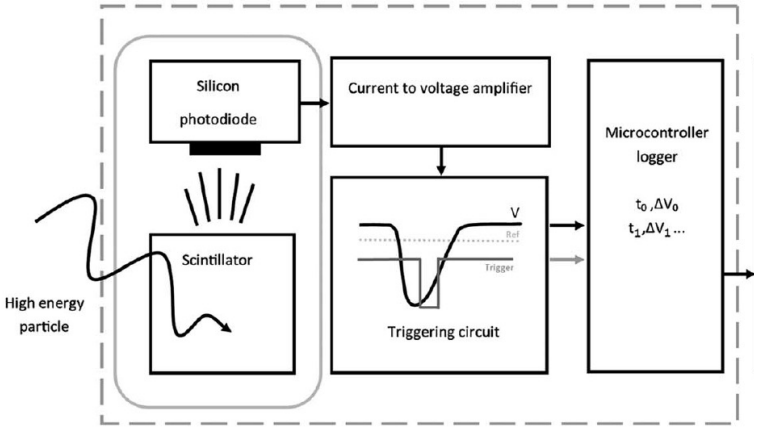
Microscintillator radiation detector - brief intro

Scientific motivation: to understand the effects of ionisation and energetic particles on weather and climate

A miniaturised detector – the **microscintillator** - measures **count rates and energies** of gamma and cosmic rays

Operating principle



Serial output for airborne applications (5 x 11 x 1 cm; mass approx 40g)

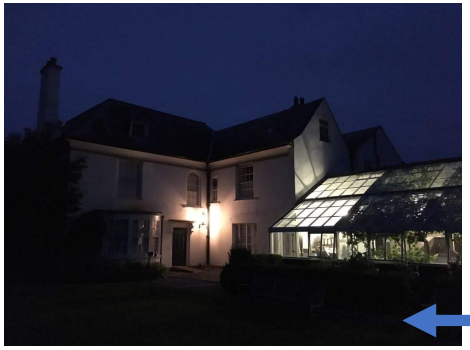
Bluetooth or USB link for portable or tabletop use (6 x 12 x 4 cm; mass 150 g with battery)

Aplin K.L., Briggs A.A., Harrison R.G. and Marlton G.J. (2017), Measuring ionizing radiation in the atmosphere with a new balloon-borne detector, *Space Weather*, **15**, doi: 10.1002/2017SW001610

Balloon flight over southern UK

- **27th August 2018**
- Launched from Berkeley, 20km north of Bristol, western UK (51.69°N, geomag lat 53.90°N)
- Evening launch to avoid wind
- Geiger counters plus scintillator
- Payload retrieved near Henley on Thames (90km east of Berkeley)

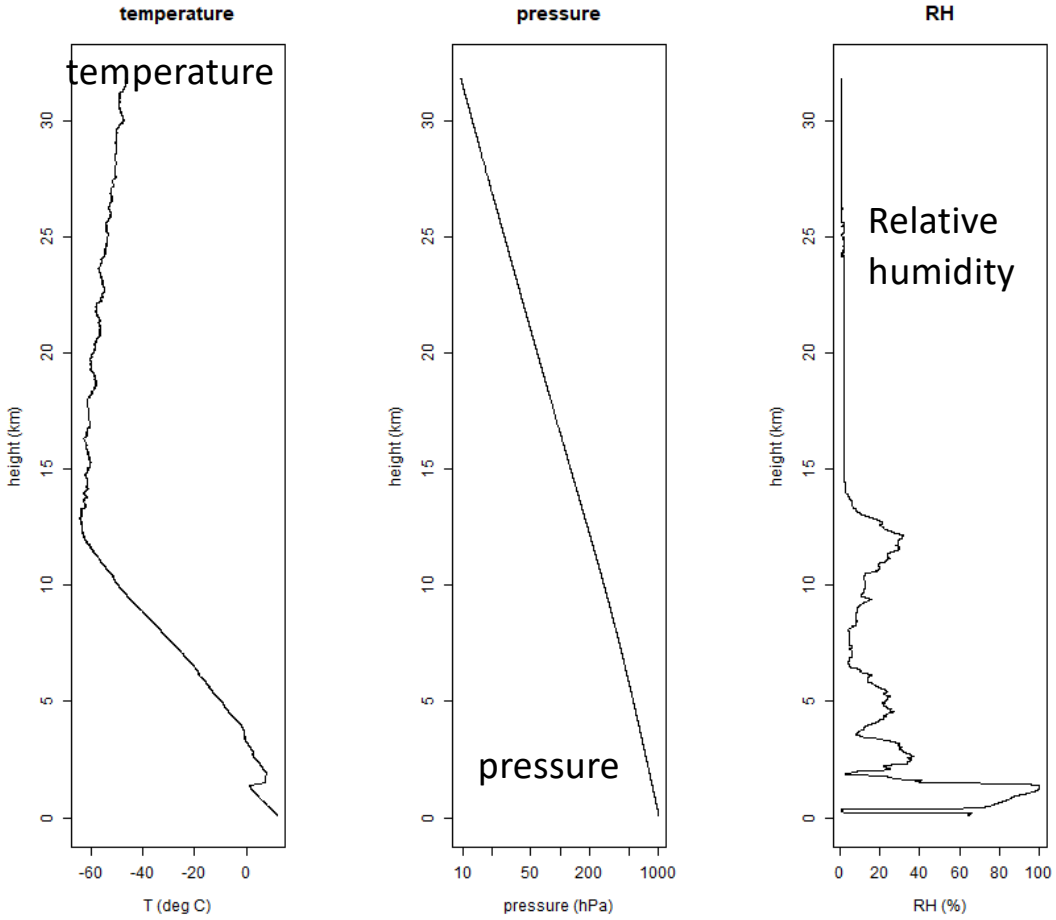
Add on to Vaisala meteorological radiosonde via University of Reading PANDORA technology (few hundred grams in total)



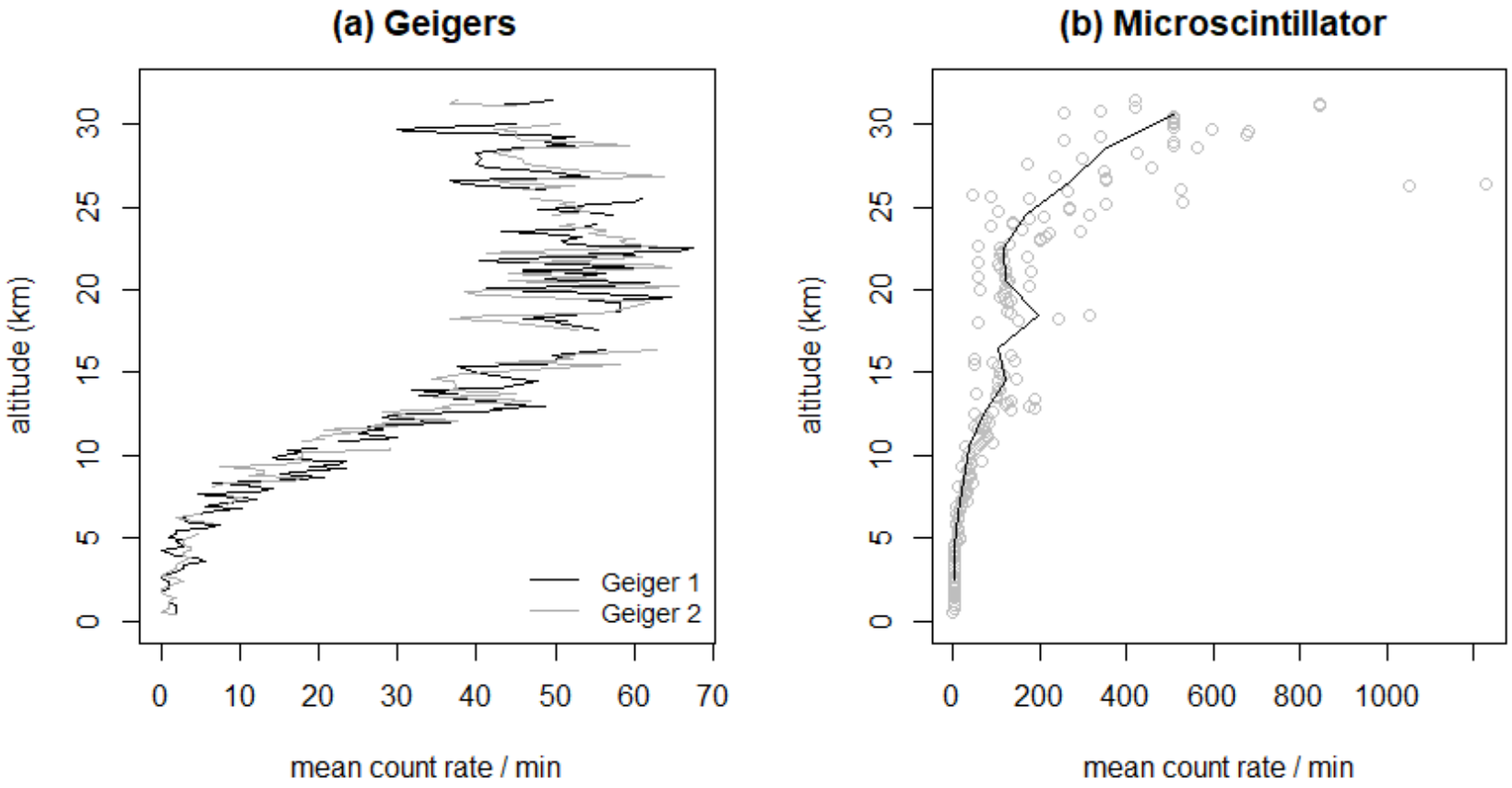
Home of Dr Edward Jenner “birthplace of vaccination” – now a small scientific museum

Pictures from launch

Meteorological conditions during flight (1800-2130BST)



Results: count rate

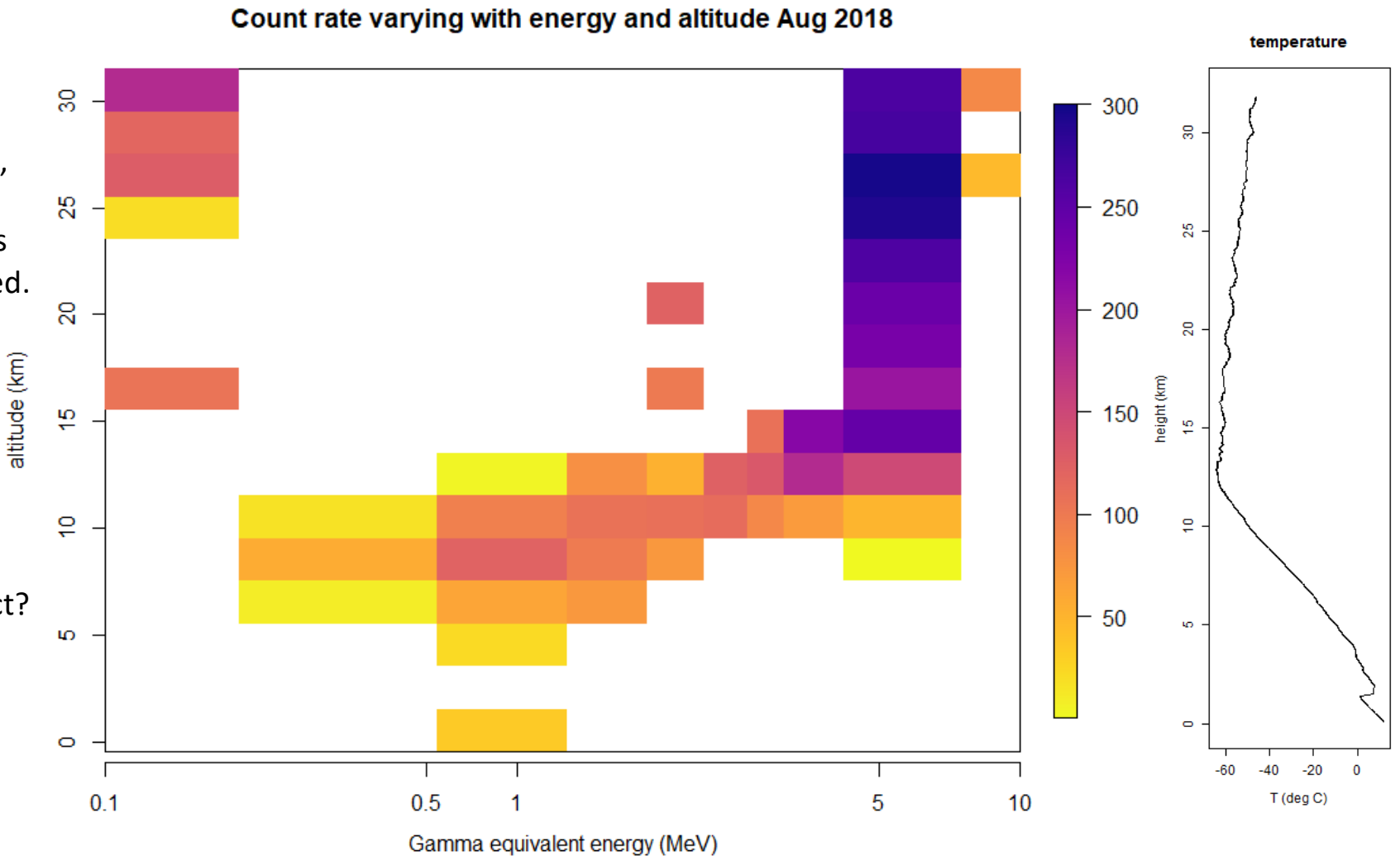


Results: particle energy distribution

Energetic particles with energy and altitude for 27th August 2018 launch, in 2km altitude bins. Particle energy increases with altitude, as expected.

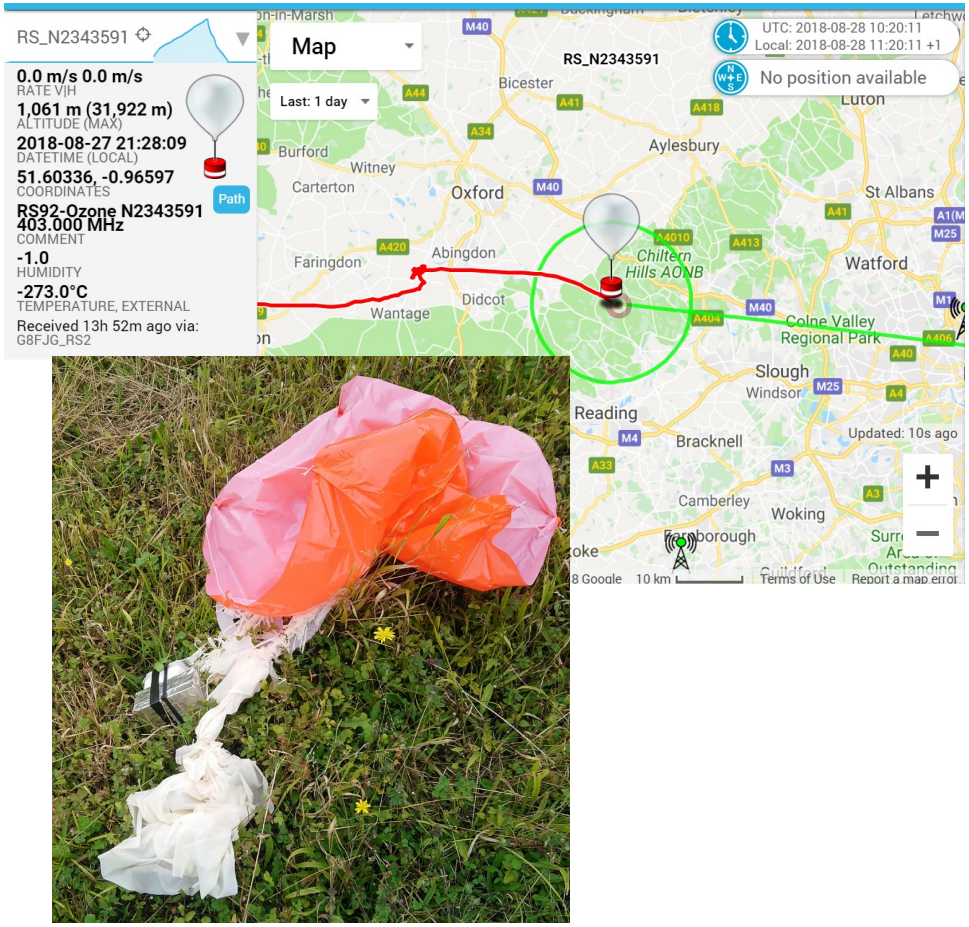
The lower-energy (100-200keV) particles above the ionisation maximum in the atmosphere are **unexpected**.

Could they be an artefact?



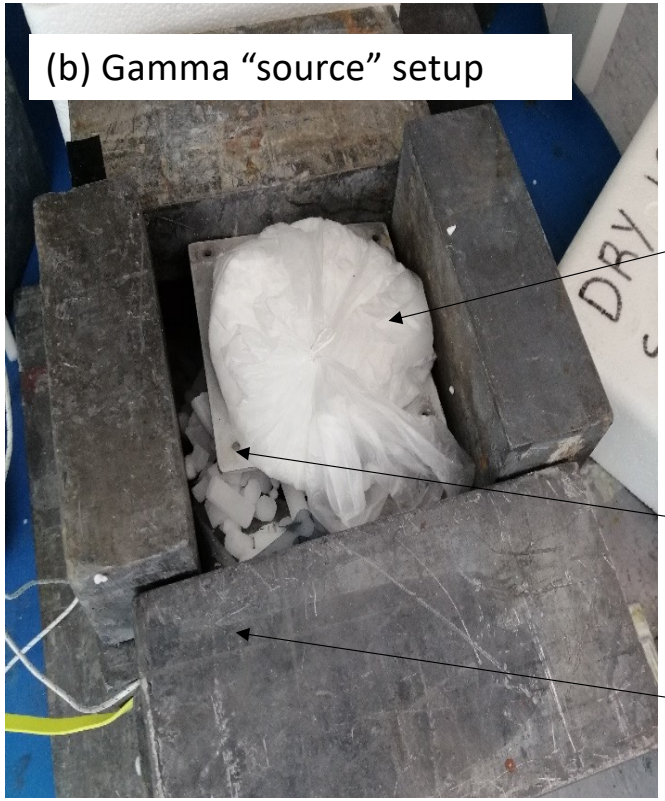
Instrument artefact possibilities

- Calibration error / changes during flight
  - Payload was retrieved and instruments recalibrated
  - So not this
- Temporary thermal effects?
  - Previously, extensive testing in a freezer -20°C
  - Stratosphere is about -60°C
  - More rigorous thermal testing needed

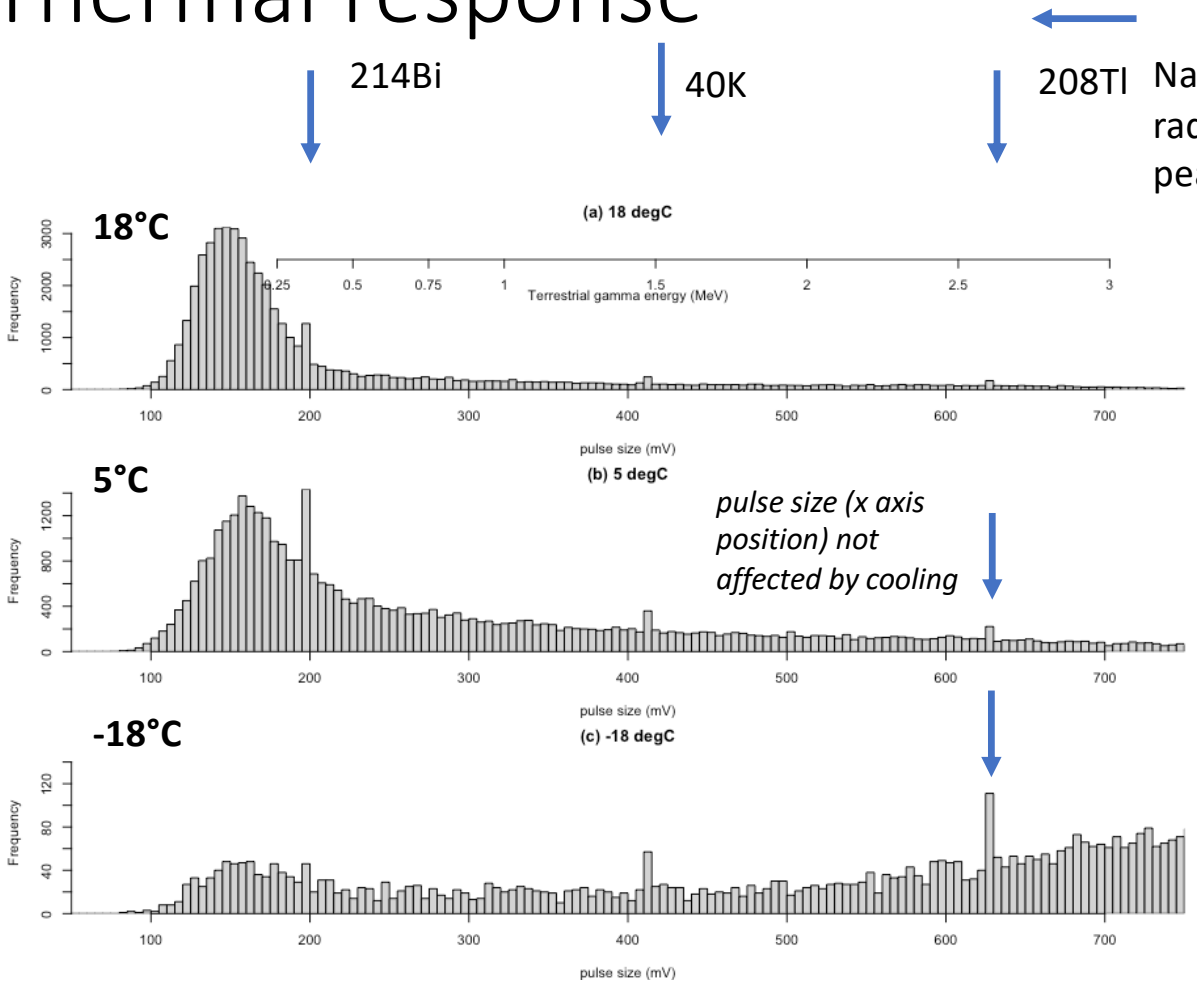


Thermal testing of detector

Down to -60degC with dry ice
Potassium chloride as a well-defined 1.4MeV gamma ”source”, plus natural radioactive background



Thermal response



The large peak on the LHS is due to the detector's quantum efficiency varying with energy (i.e. fraction of pulses detected)

Cooling shifts the shape of the background distribution but NOT the location of the individual pulses on the x-axis

Detector's efficiency varies with temperature, but NOT its energy sensitivity. (Possibly caused by a change in the contributions of different wavelengths to the scintillator signal)

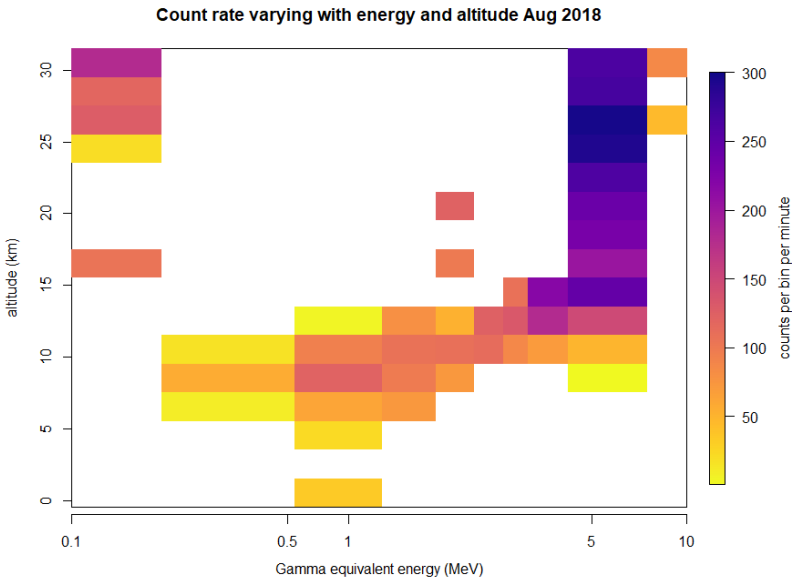
Thermal correction to balloon data

Laboratory test results used to generate a thermal “background” to subtract.

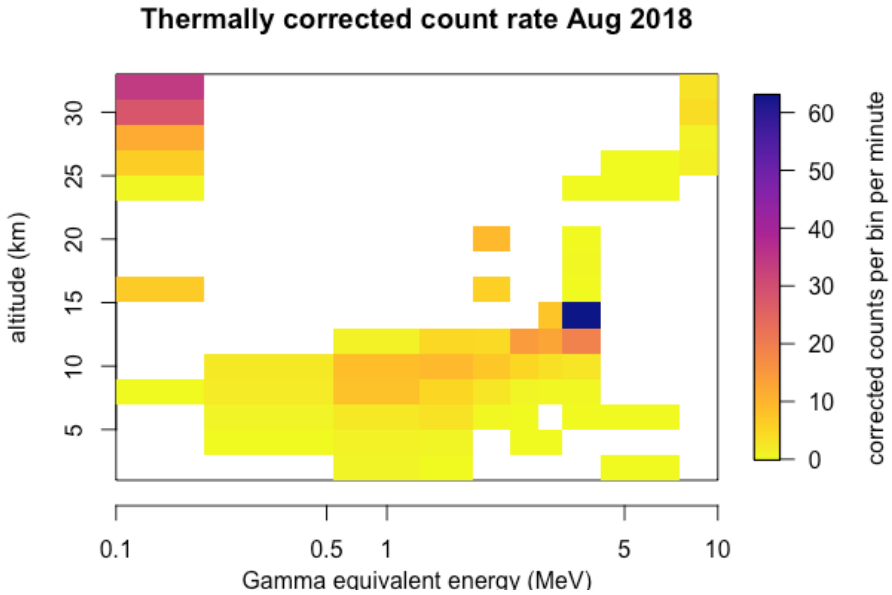
i.e. counts at ground level in lead box in dry ice as a function of temperature (in 10degC bins)

Low energy particles detected in the stratosphere are not an artefact

Uncorrected data



Corrected data



Space weather during balloon flight

Date and time of launch ->	27th August 2018 (17-2030 UT)
Parameter ↓	
L shell at maximum z	2.288
Kp index	5o during flight Second most disturbed day of month
Ap index	25
AE index (nT) (median ± se)	375±255
Dst index (nT)	**-59 (storm level disturbance)**
Oulu neutrons (min^{-1})	6649
Daily total sunspot number	13

Active geomagnetic conditions

- Active geomagnetic conditions trap electrons in the Van Allen Belts
- These electrons precipitate into the top of the atmosphere (relativistic or energetic electron precipitation, REP or EEP)
- X rays are released from the electrons by bremsstrahlung
- Relatively well known phenomenon in auroral oval
- Can affect atmospheric chemistry
- POES satellites detected precipitating electrons over the North Atlantic synchronously with balloon

Conclusions

- Balloon flight with microscintillator instrument measured ionisation rate
- Count rates consistent with Geiger counters
- Detected 100-200keV particles in the stratosphere during a geomagnetic storm
- Instrument artefacts (changes in calibration, thermal effects) ruled out
- These particles are **X rays from precipitating electrons**. **First measurements outside auroral regions? Consistent with POES satellite data**
- More flights planned to investigate how common this is and atmospheric effects (lightning triggering?)
- Published in *Space Weather* https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2021SW002809