Agenzia Spaziale Italiana

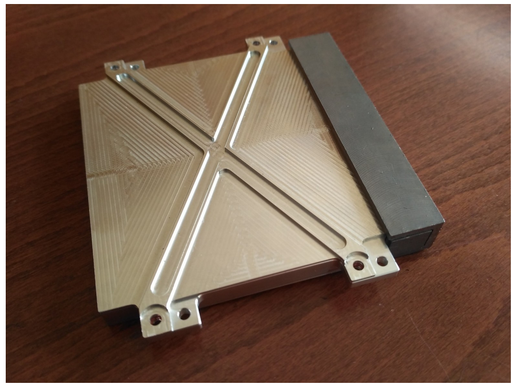
HERMES SP

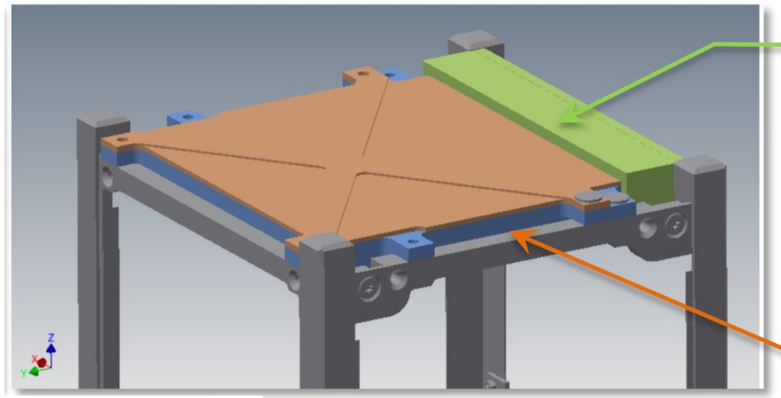
GRBAlpha: a 1U CubeSat for GRB Observation in Flight

Jakub Řípa, Norbert Werner

Masaryk University

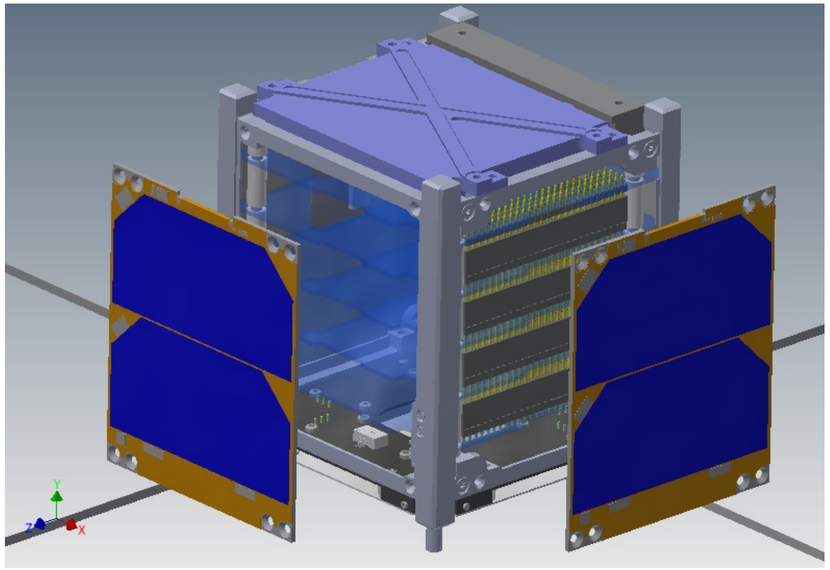
GRBAlpha: 1st Demo Flight of Future Constellation of CubeSats Monitoring and Localizing GRBs





2.5mmt Pb shield only around the MPPC to reduce the radiation dose

75x75x5mm^3 CsI scintillator Enclosed by 1mmt Al casing

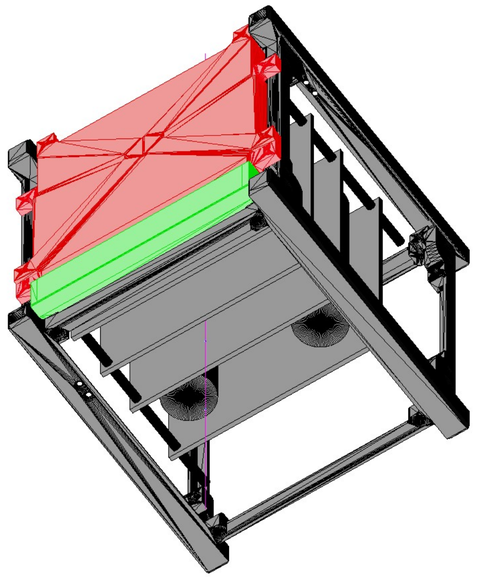


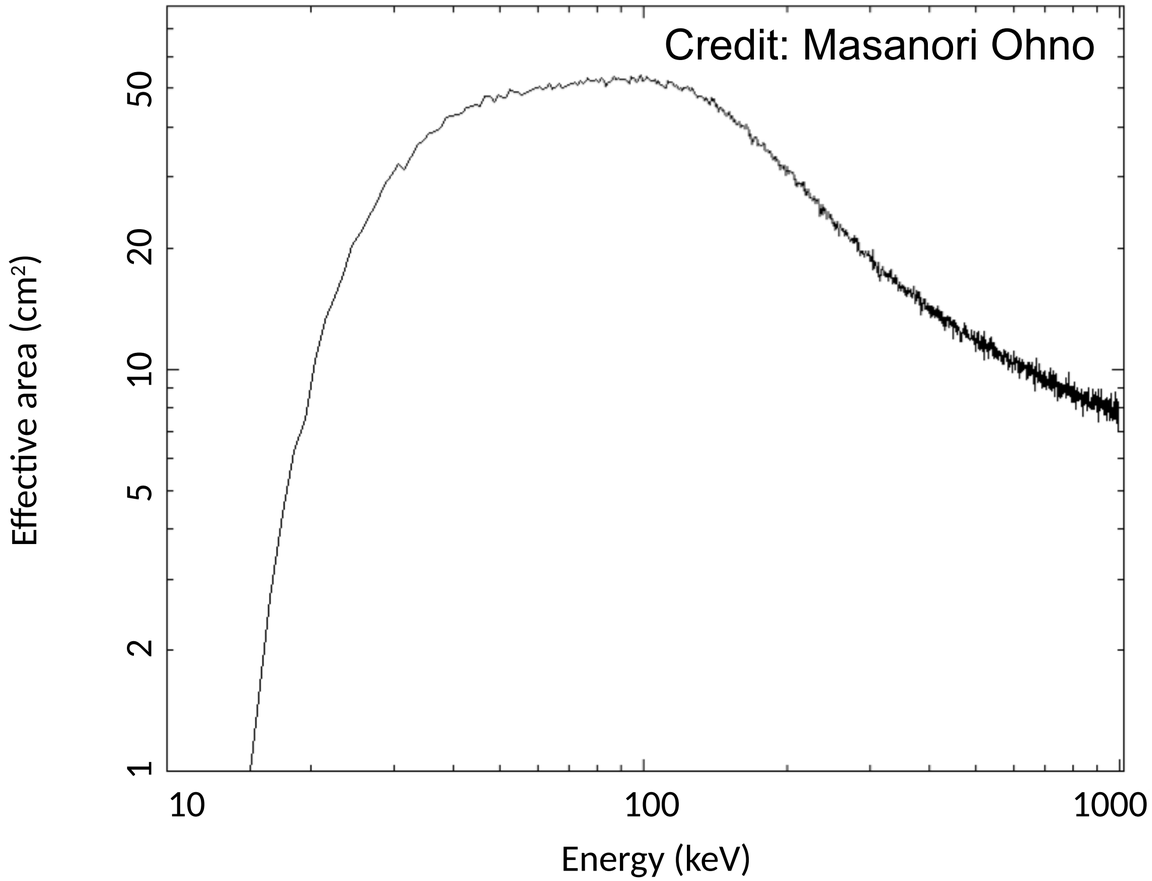
- Small size of scintillator (75x75x5mm^3) readout by 8 MPPCs

<u>Main goals of GRBAlpha:</u>

- Confirm the detector concept
- Characterize the detector degradation on orbit
- Characterize background at SSO for a gamma-ray detector

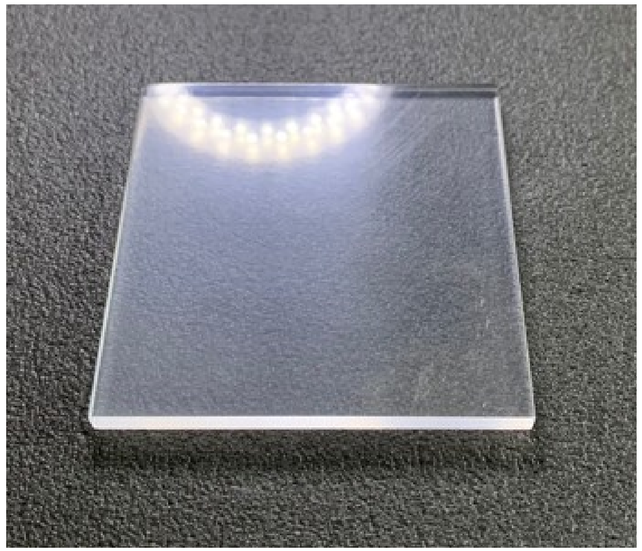
GRBAlpha: Effective Area



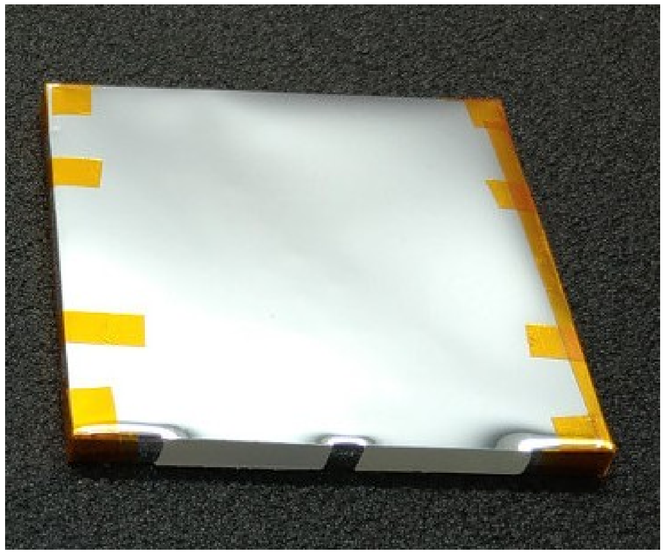


GRBAlpha: Detector Assembling

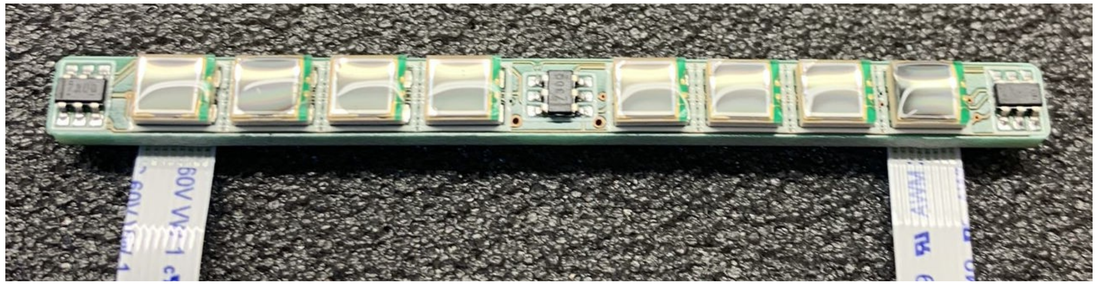
Pál+ 2020



CsI(Tl) scintillator



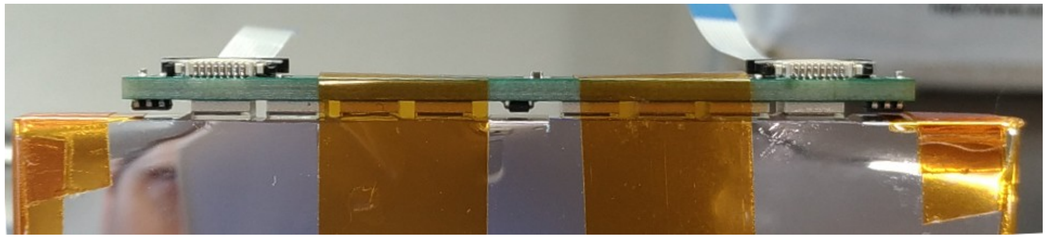
Wrapped in Enhanced Specular Reflector (ESR)

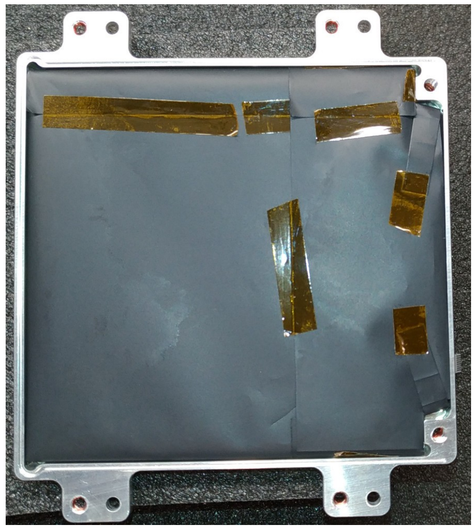


2 readout channels of 4 MPPCs (S13360-3050 PE) by Hamamatsu

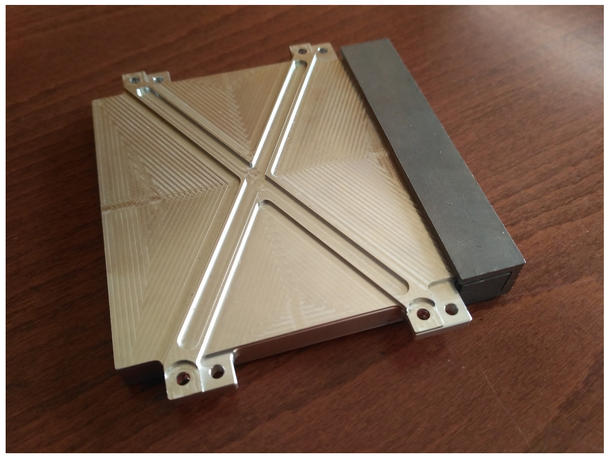
GRBAlpha: Detector Assembling

- MPPCs are coupled with crystal by optical glue DOWSIL93-500
- Detector is wrapped by optically thick DuPont TCC15BL3 polyvinyl fluoride (PVF) tedlar to prevent light leakage from outside



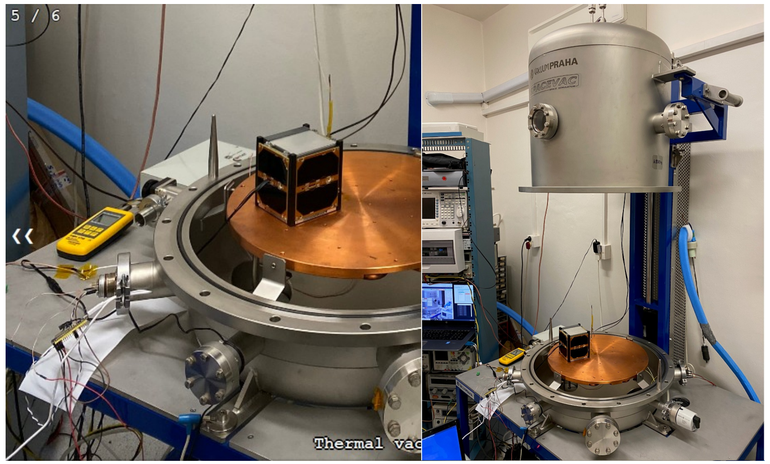


DuPont Tedlar TCC15BL3 wrapping

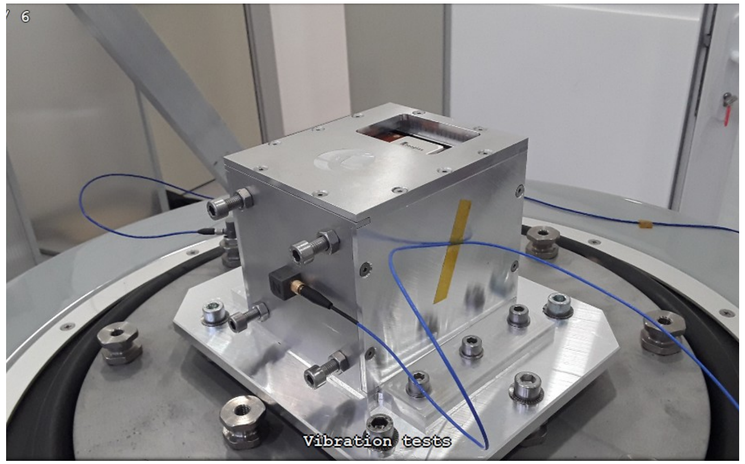


Assembled detector with Pb-Sb alloy to reduce MPPC degradation by protons

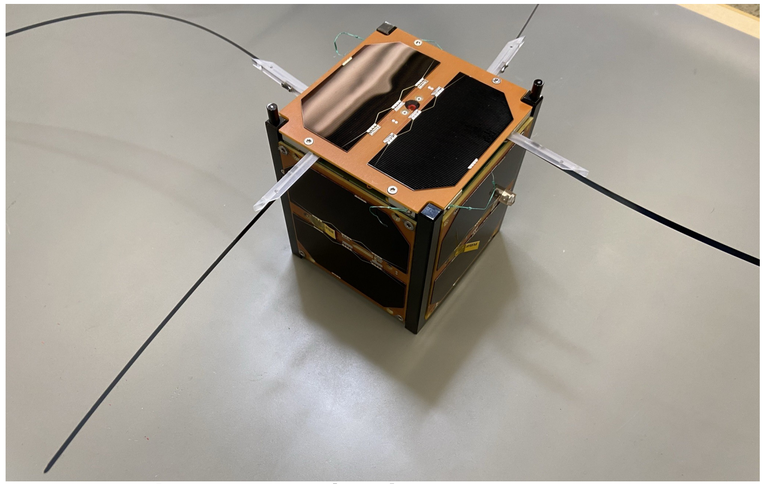
GRBAlpha: Detector Environmental Tests



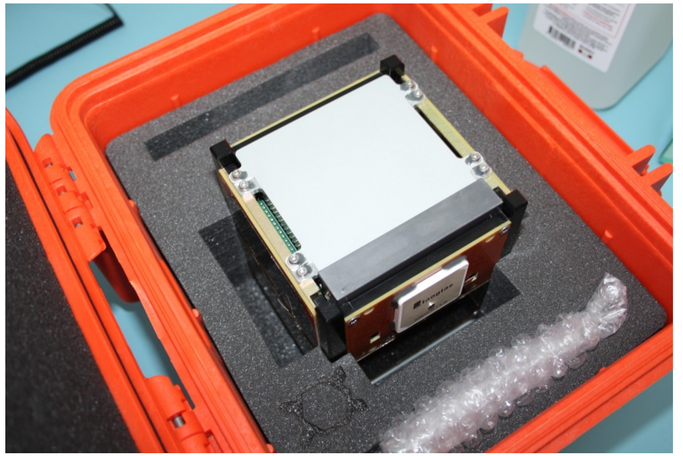
Thermal vacuum test



Vibration tests by Remred ltd. in Budapest



Antenna deployment test

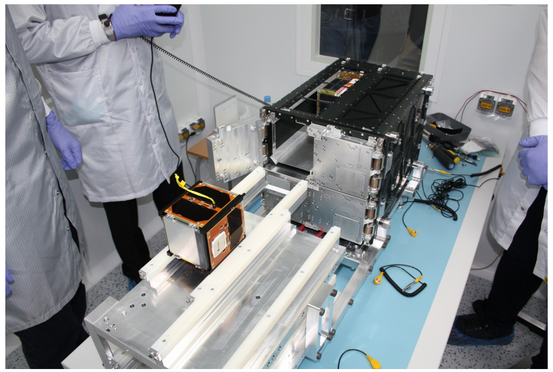


Ready for shipment to Moscow

GRBAlpha: Launch

https://grbalpha.konkoly.hu/
https://www.spacemanic.com/news/grbalpha-satellite-to-launch-from-baikonur/

- After delivery to Moscow it was integrated into the deployer in the facility of GK Launch Services
- Launched from Baikonur by Soyuz-2.1a rocket with the Fregat upper stage to 550 km SSO on **March 22, 2021**



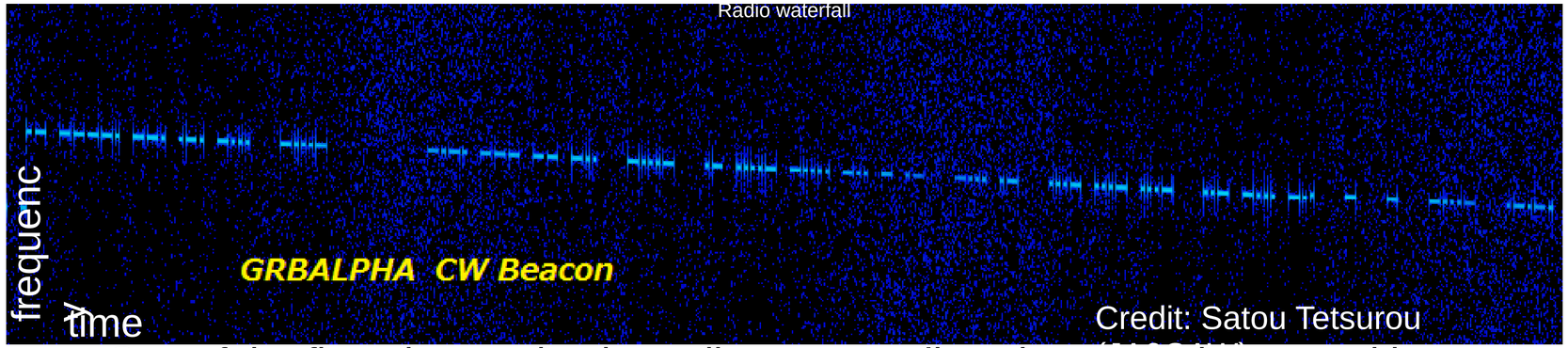
GRBAlpha integrated into deployer

Soyuz painted in unusual white/blue colors like Yuri Gagarin's Vostok 1

- 38 satellites from 18 countries launched at one time
- Main satellite was Korean CAS-500

GRBAlpha: First Signals from Orbit

- For downlink we are using amateur radio bands in UHF at 437.025 Mhz
- 1st confirmation that GRBAlpha is alive came ~5 hours after launch from radioamateur in Brisbane
- 1st pass over ground station in Brno was ~15 hours after launch
- Anyone can catch our data packets, see SatNOGS network



One of the first observation by radioamateurs listening to our beacon with

GS in Brno University of Technology (Czech) - **currently mainly used**

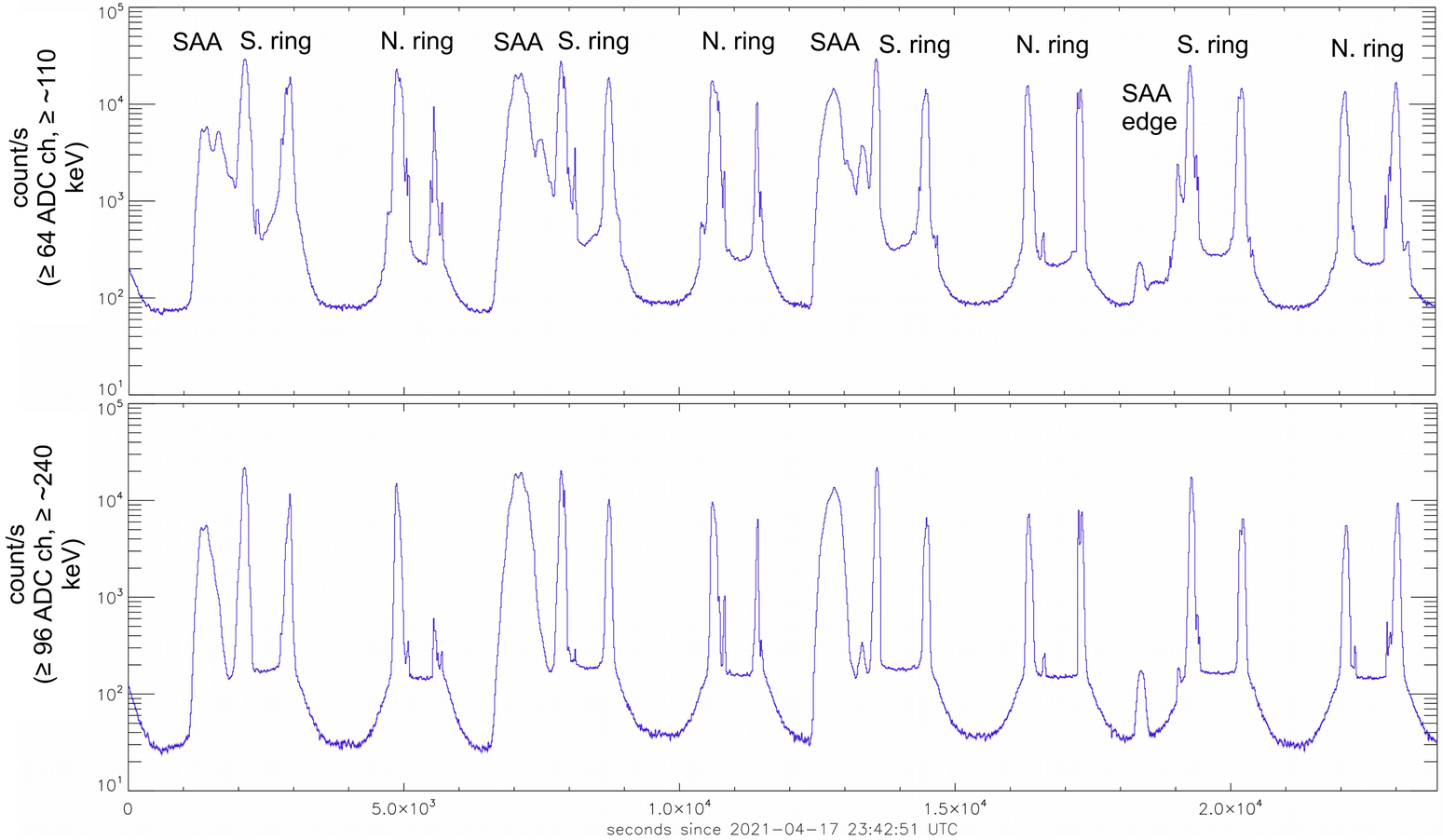
GS in Košice Technical University (Slovakia) - under construction

GS in Jablonec Jakub Kapuš Spacemanic (Slovakia) - under construction

- And Piszkéstető GS in Hungary recently built

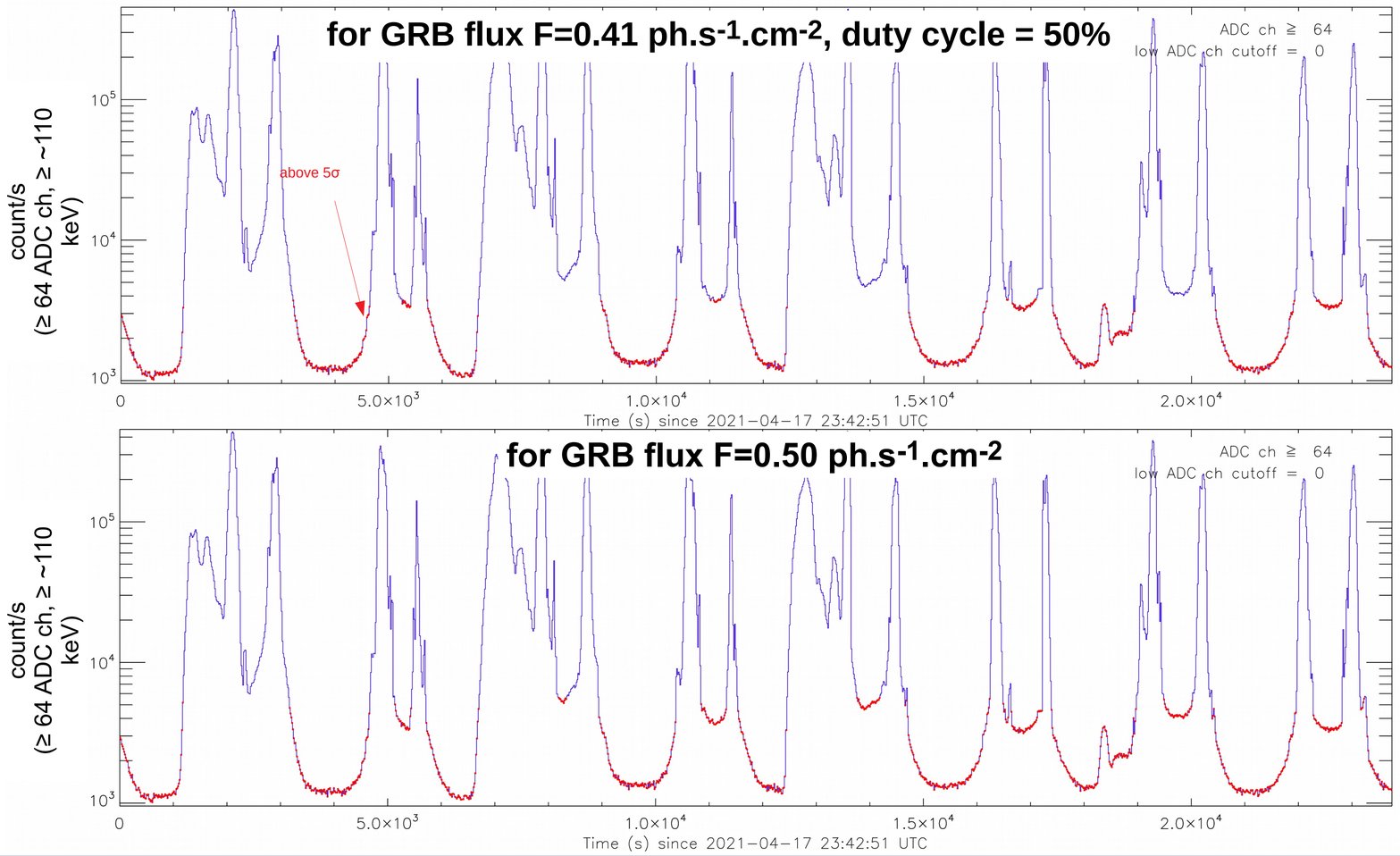
GRBAlpha Background Monitoring

- Count rate for E>~34 keV = ~200-250 cnt/s at latitude ~37°
- Geant4 simulations (Galgóczi+ 2021) for CAMELOT after scaling to GRBAlpha's detector size predicts background rate outside SAA and polar regions 180 cnt/s (for E>20 keV), but activation was not included
- Measured background and simulation result agrees within a factor of 2



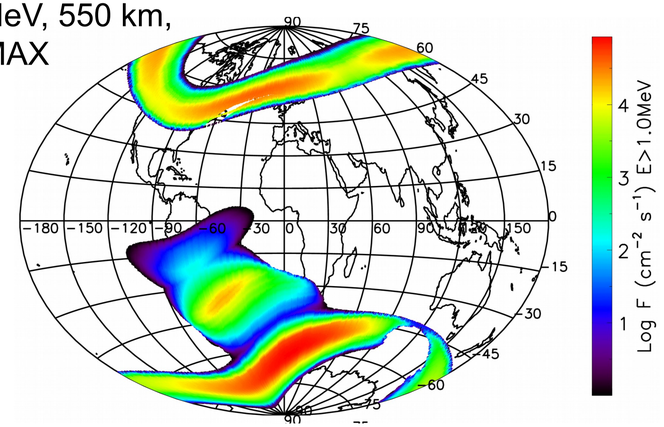
4-Orbits Background: Duty Cycle

- The duty cycle **based on background level** from 4-orbits
- For median flux of long GRBs, F=0.41 ph.s^{-1}.cm^{-2} E>107 keV (64 ADC), GBM fluence CPL spectrum, threshold 5σ: duty cycle ≈ 50%

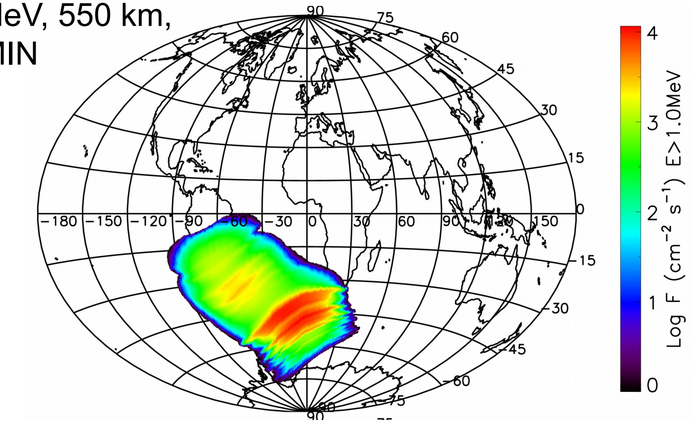


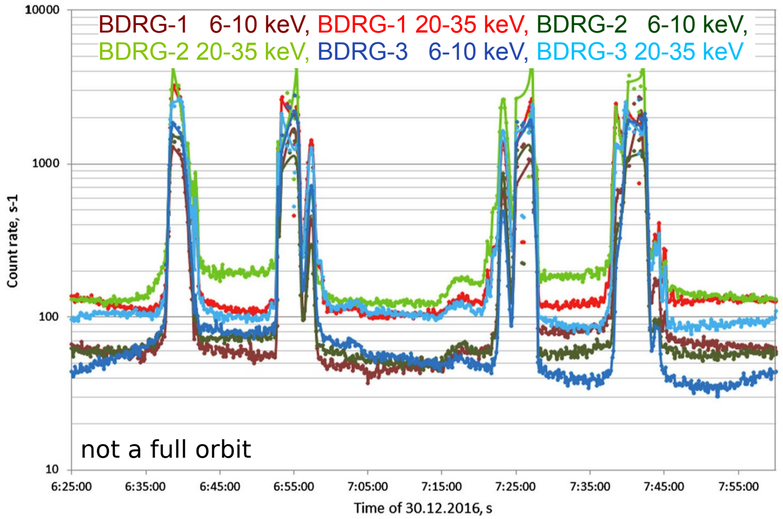
Duty Cycle for a GRB Instrument Largely Affected by Trapped Charged Particles

Trapped electrons model,
E>1 MeV, 550 km,
AE8 MAX



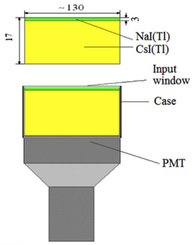
Trapped protons model,
E>1 MeV, 550 km,
AP8 MIN

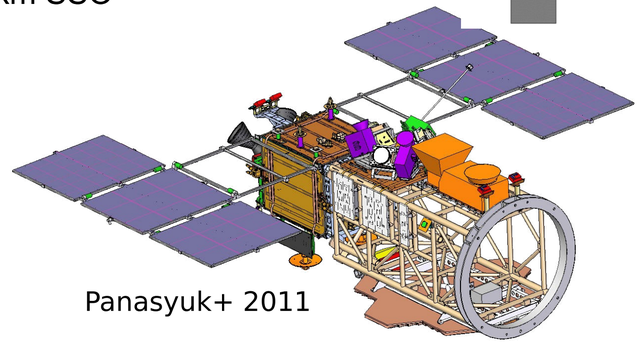




- Background from Lomonosov/BDRG gamma-ray burst instrument at 500 km SSO

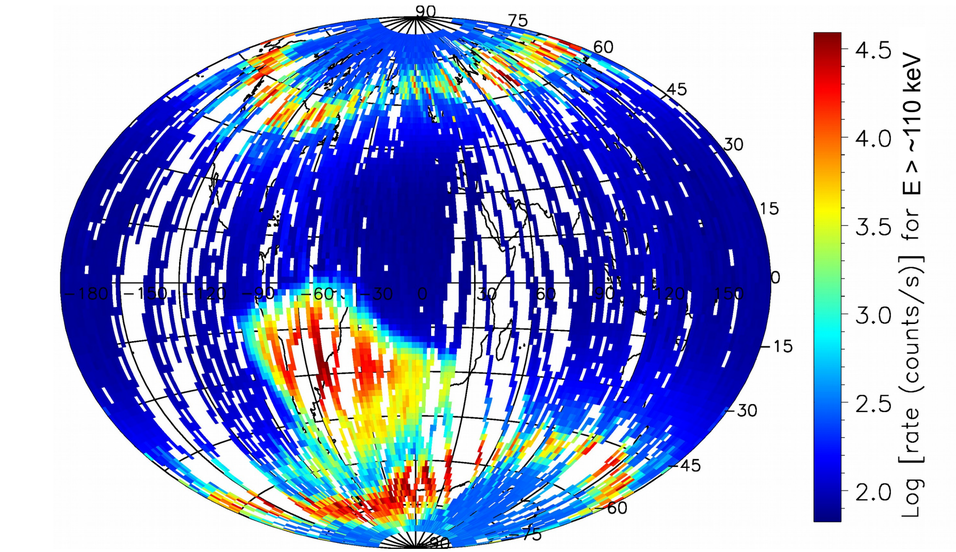
Svertilov+ 2018

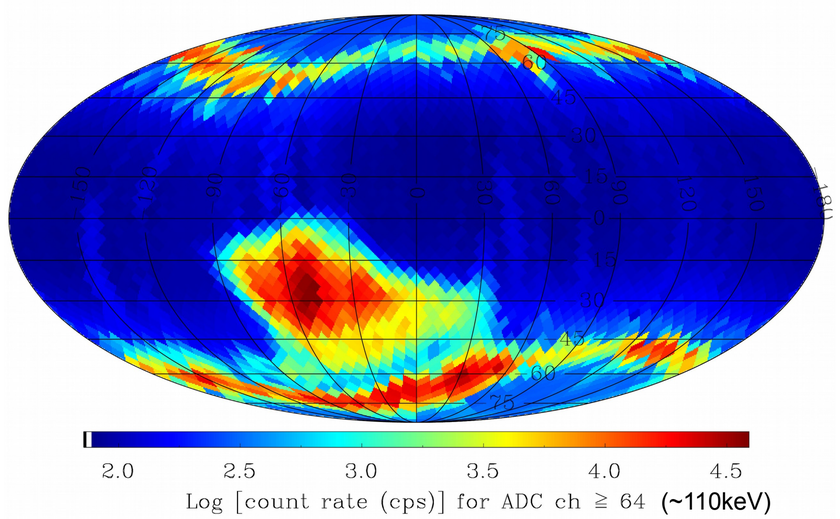




Panasyuk+ 2011

GRBAlpha Background Monitoring: Map





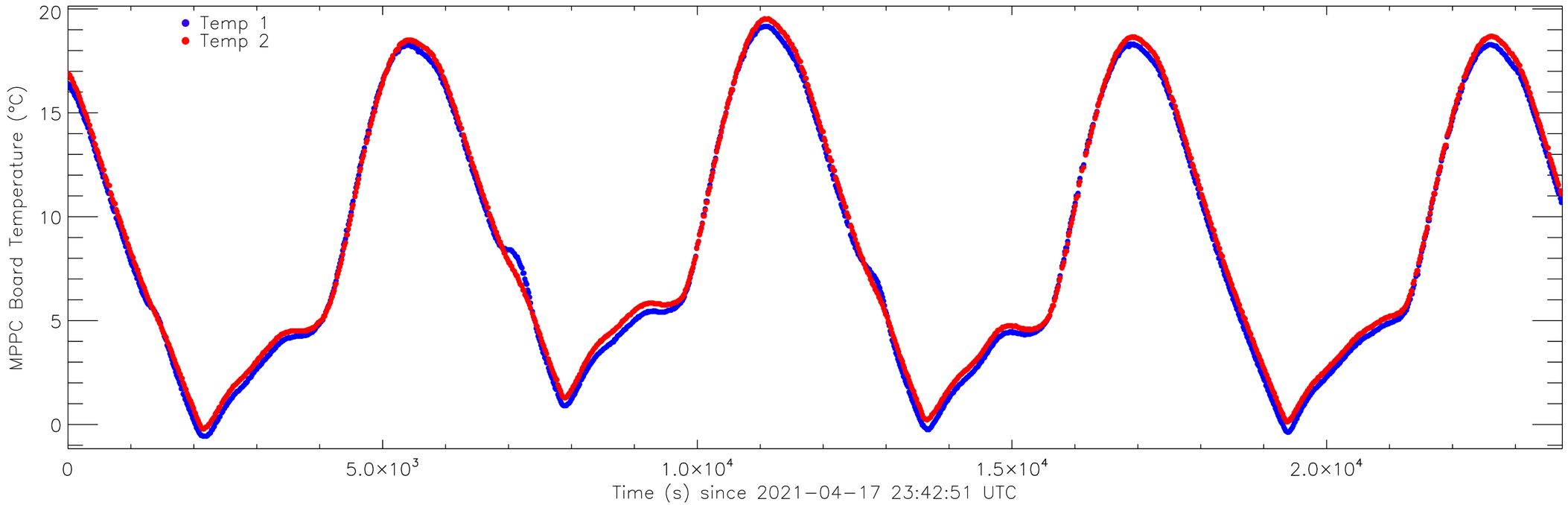
- satellite tracks (averaged flux when overlap) with 1s, 4s and 15s time resolution background measurements

- interpolation of measurements plotted with HEALPix tesselation

- plan is to use such a map on board to control data taking and in future possibly to control the rate trigger

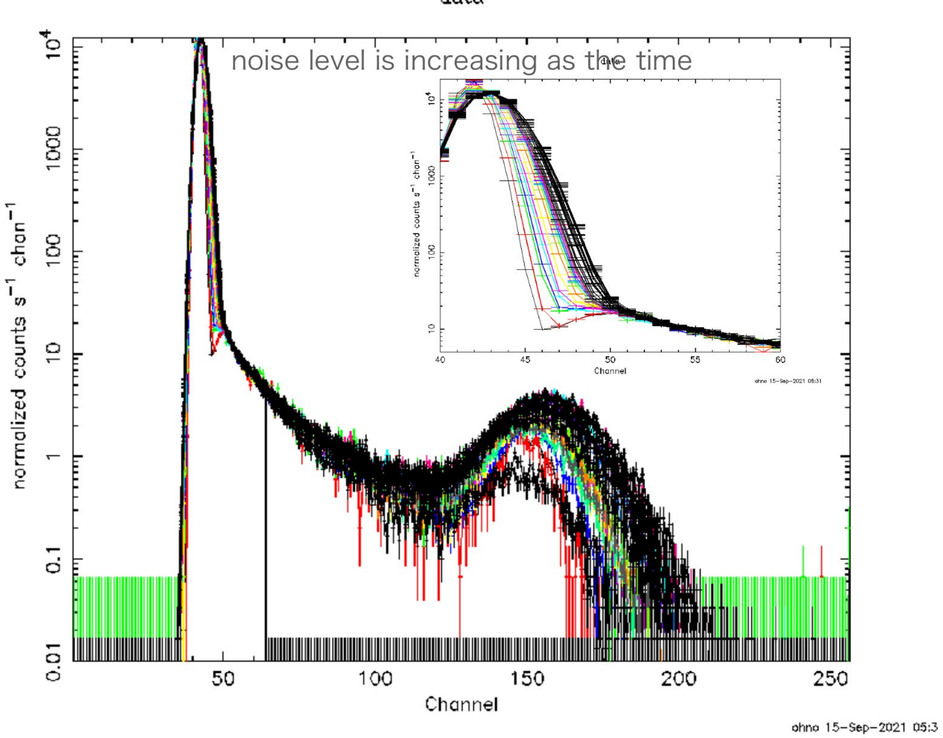
MPPC Board Temperature

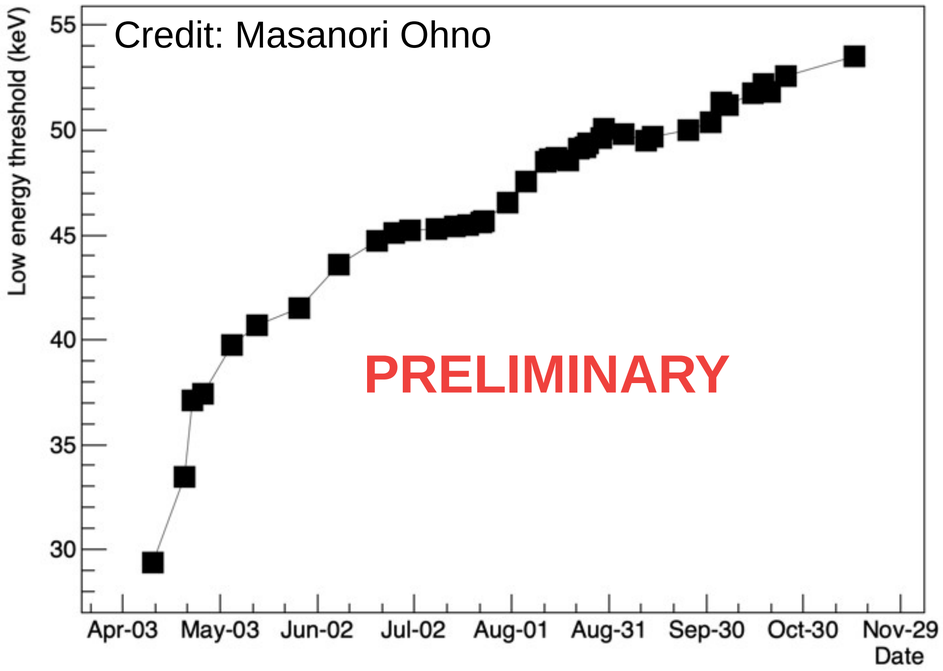
- MPPC board temperature fluctuates between -2°C and 20°C



MPPC Degradation in Orbit

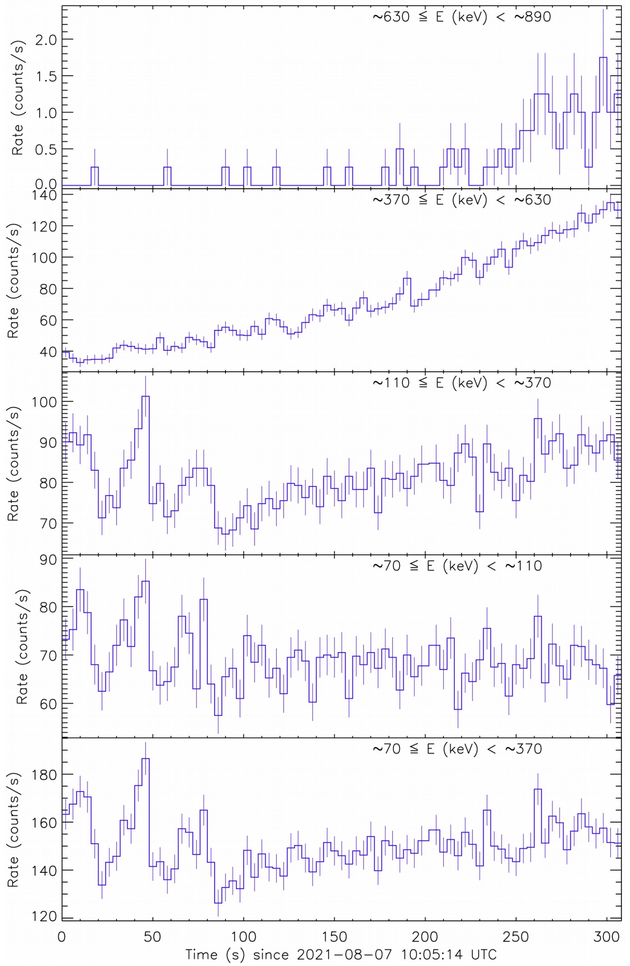
- Full channel spectra is measured at the first timing of each observation to monitor the detector gain and noise performance



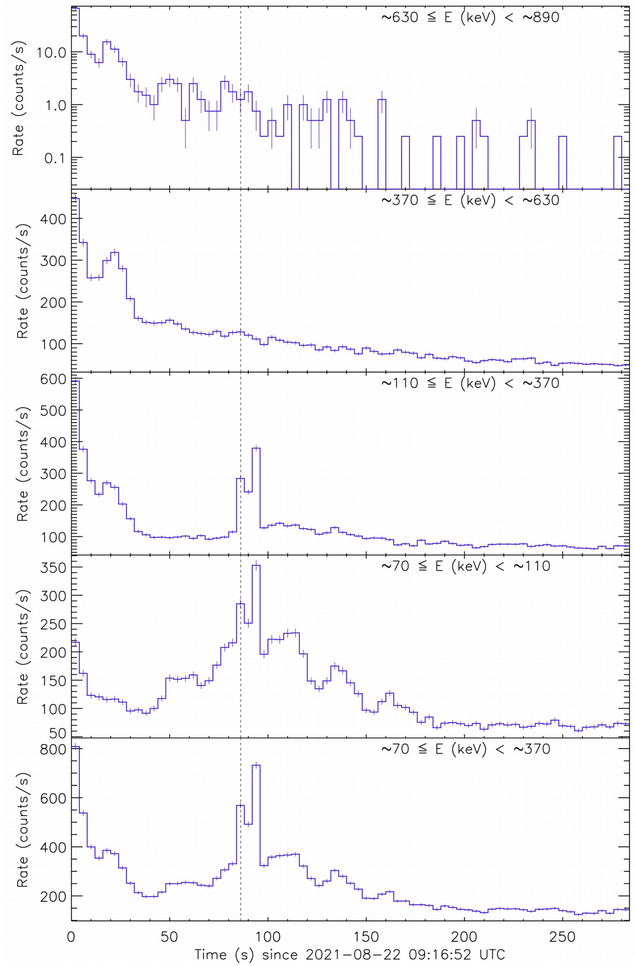


- The noise performance of the MPPC is still degrading due to the radiation damage by the trapped protons
- Expected by the ground beam experiment but the trend is not so simple with the exposure time
- Continuous monitoring would be interesting

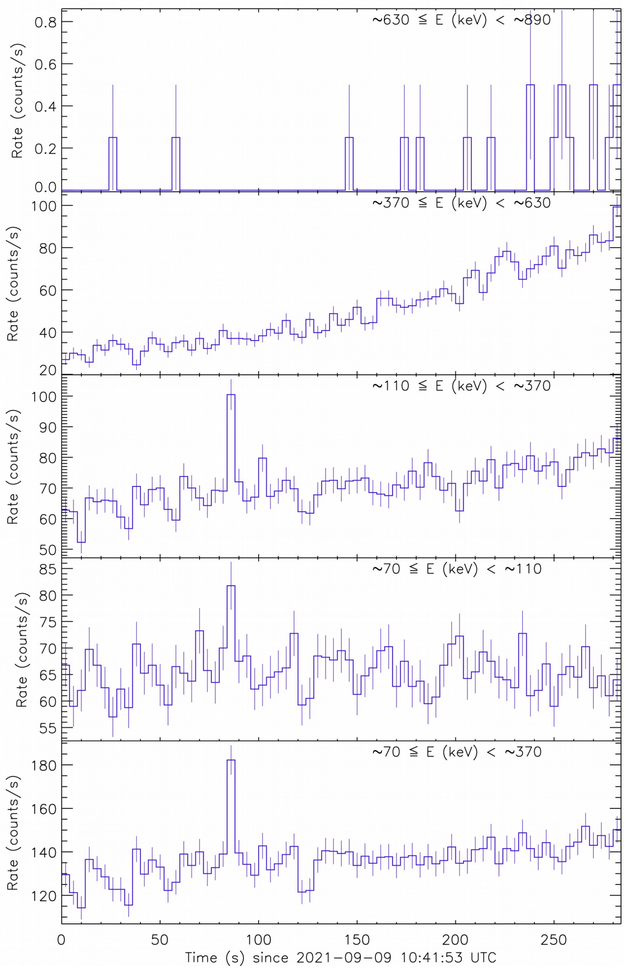
GRBAlpha: GRB Detections



GRB 210807A, GCN 30624
SNR ≈ 8, long GRB, likely collapse of massive fast rotating star

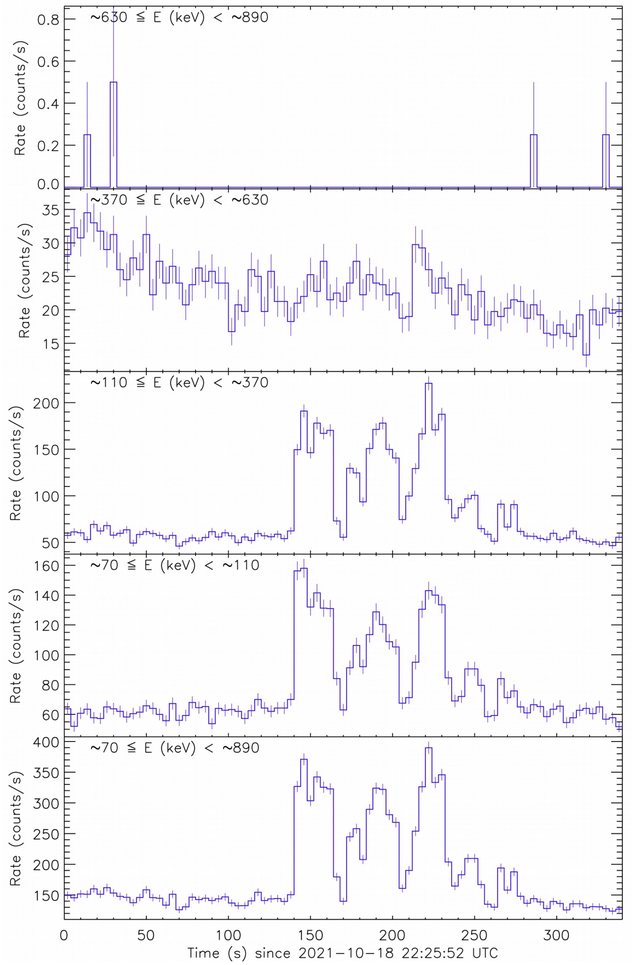


GRB 210822A, GCN 30697
SNR ≈ 45, z=1.736
light travel time is 10 Gyr!

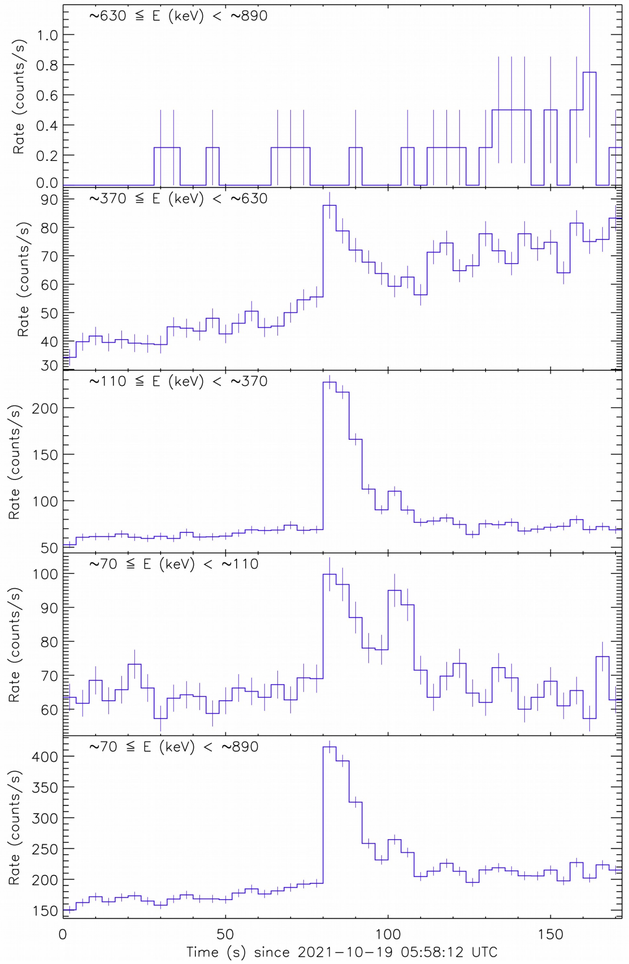


GRB 210909A, GCN 30840
SNR ≈ 9, short GRB
likely merger of NS/NS or NS/BH

GRBAlpha: GRB Detections



GRB 211018A
GCN 30945
SNR ≈ 46



GRB 211019A
GCN 30946
SNR ≈ 39

- Demonstration that nano-satellites can host payloads sensitive enough to detect GRBs!

Summary

- **Success in:**
  - detector functionality
  - study MPPC's degradation in LEO
  - monitoring background
  - GRBAlpha demonstrated the feasibility to routinely detect GRBs with a CubeSat. Given the higher duty cycle and lower energy threshold, we can expect beautiful results from HERMES.

- **Lessons learned for HERMES:**
  - capability to do in-orbit software updates
  - background radiation map and duty cycle for high inclination orbits