GRBAlpha: 1U CubeSat

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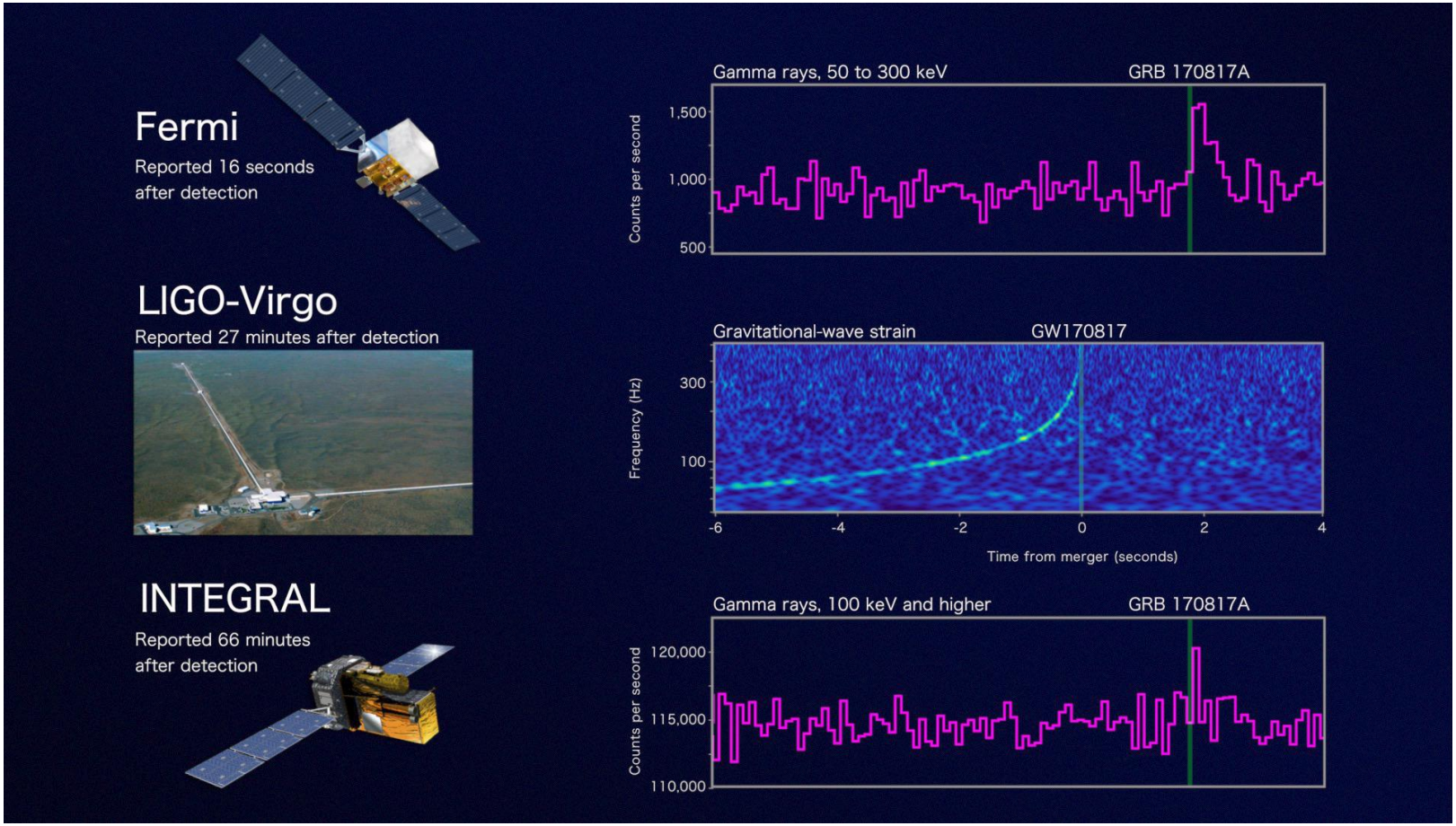
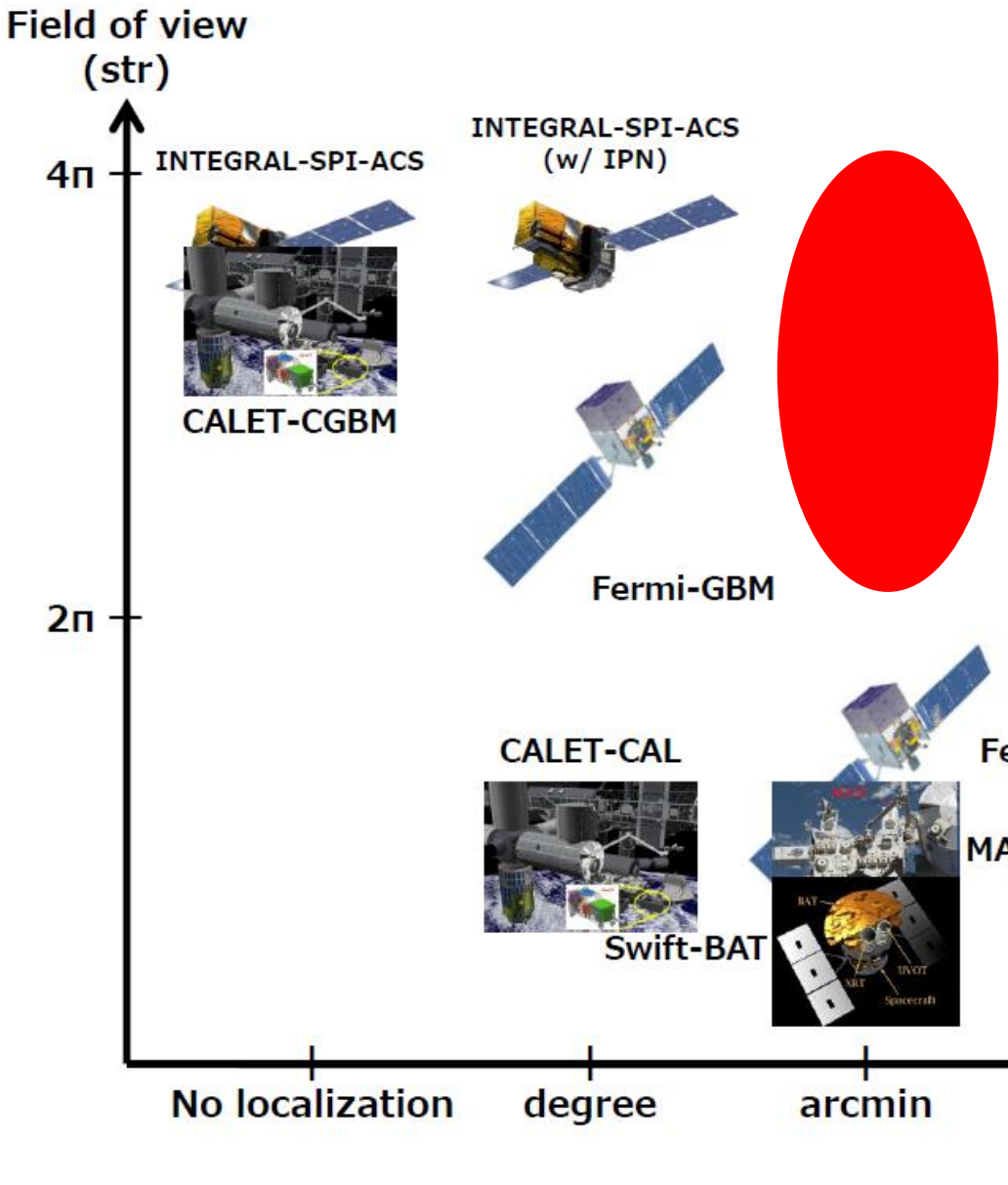
Multi-messenger astronomy with all-sky observations

- LIGO/Virgo detected several gravitational wave (GW) sources
- GW170817/GRB170817A :
  EM counterpart detection confirmed a open of the “GW astronomy era”
- More sample required by “All-sky/Always/Location” gamma-ray observations
- CubeSats constellation could be a solution



Current gamma-ray sky surveys



Wide FOV （>2π）

＋

Better angular resolution (<degree)

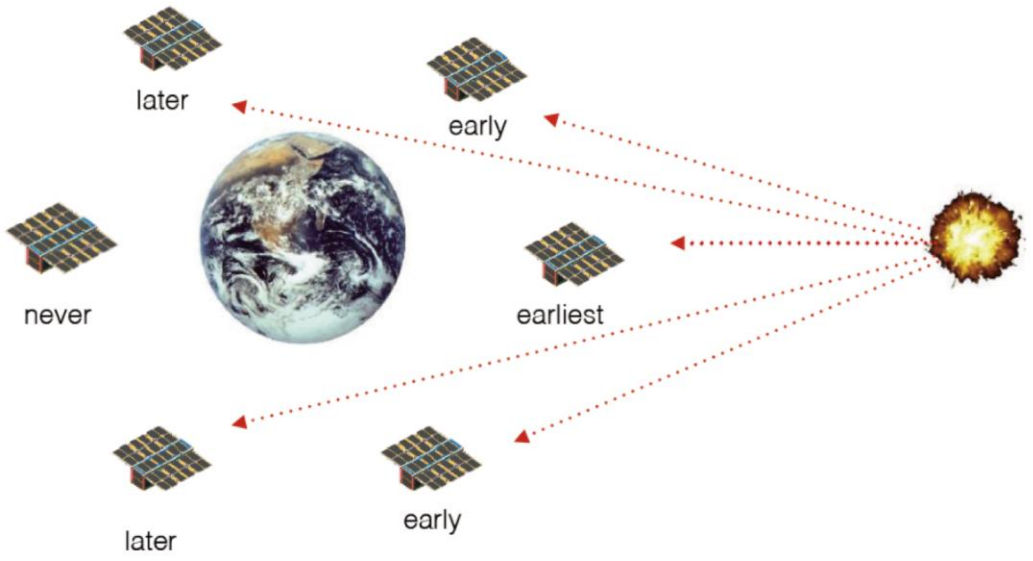
⇒ We are developing

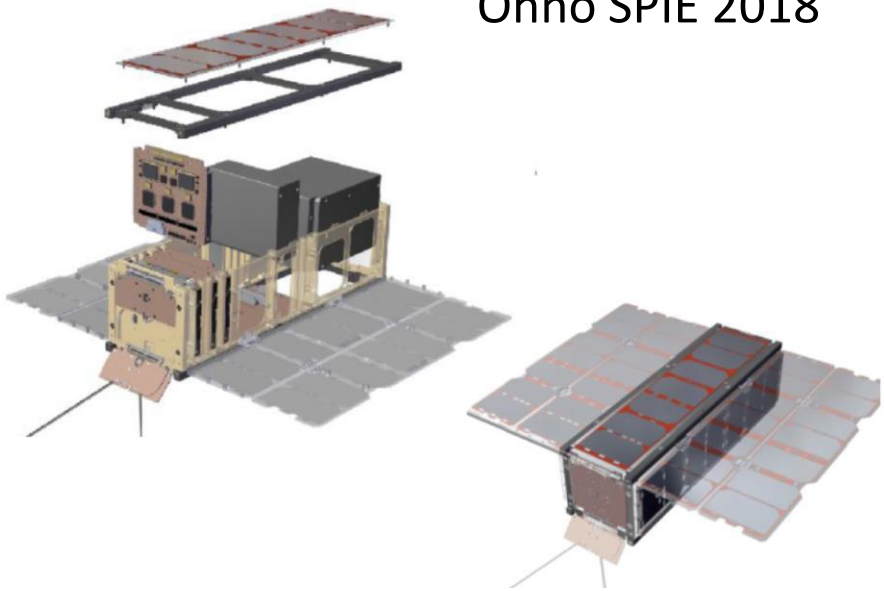
CAMELOT mission

CAMELOT: Cubesats Applied for MEasuring and LOcalising Transients

PI: Norbert Werner (Masaryk University, Czech)

Werner SPIE 2018
Ohno SPIE 2018



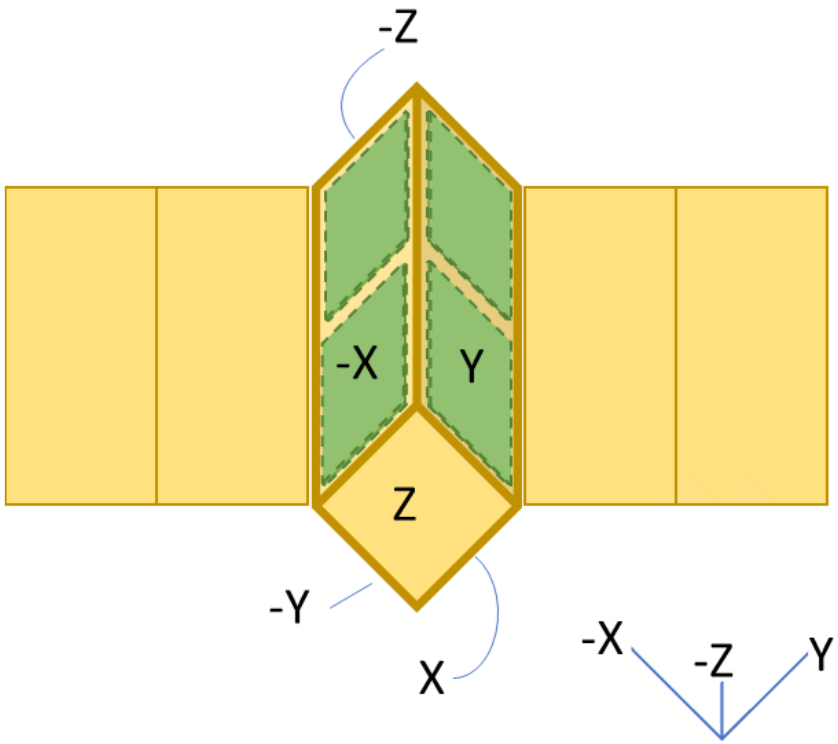


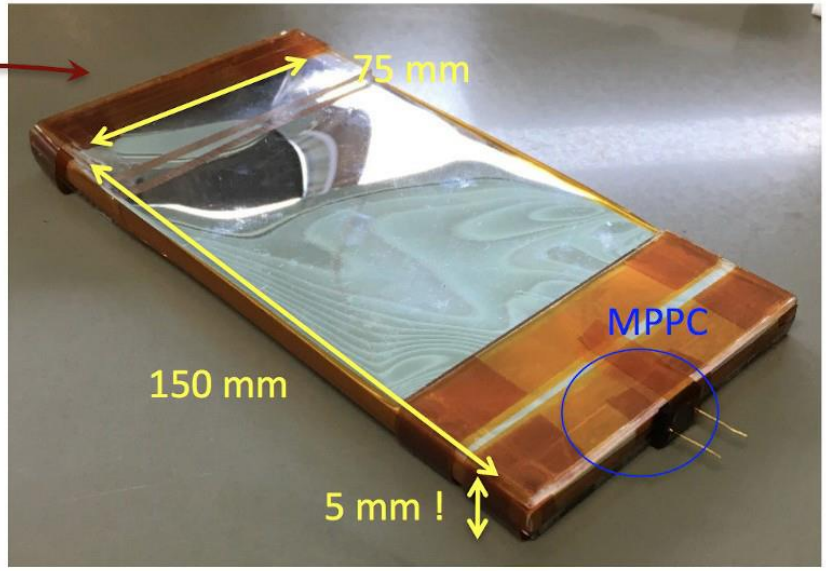
- Dozen CubeSat constellation ⇒ all-sky coverage
- Localization by photon arrival time

The number of signals determines the timing/localization accuracy.
⇒ Detectors with Large effective area (with lower threshold)

CAMELOT detector: Flat scintillator + SiPM (MPPC)

Werner SPIE 2018





・To maximize the effective area, the detectors based on CsI scintillators and Multi-Pixel Photon Counters (MPPC) will occupy two lateral extensions
(8.3 cm x 15 cm x 0.9 cm x 4)

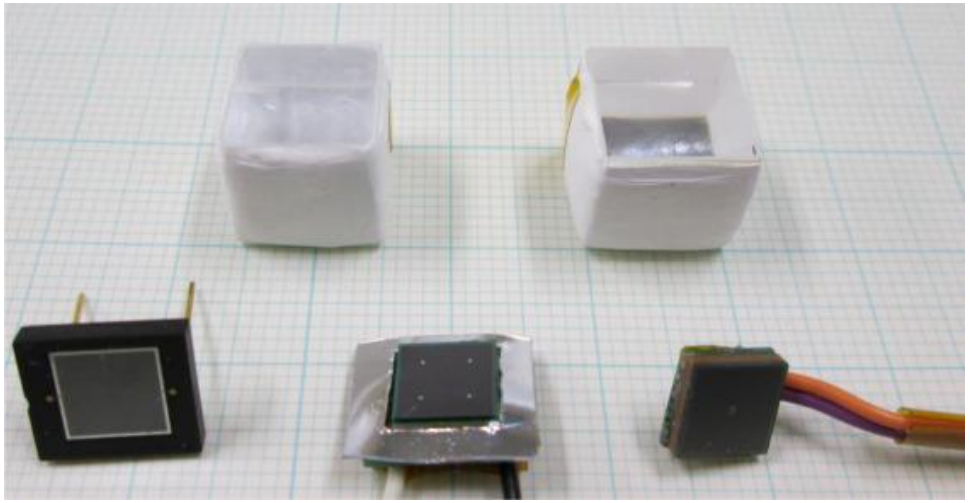
・The large and thin detectors with small readout area are challenging

・The read out of the CsI detectors with MPPC has been evaluated in the lab.

・The system provides a large light yield, compact readout area and relatively low operational voltage.

2 SiPM (MPPC) series from Hamamatsu (No damage)

	PDE (%)	Gain (10^6)	Dark current (uA)	Ope voltage (V)
S13360-6050VE	40	1.7	0.388	54.4
S14160-6050HS	50	2.5	1.63	41.0



We tested the low-energy performance of the scintillator readout.

- BGO / CsI(Tl)
- S13360 / S14160 differences (+ black-case effect)

https://doi.org/10.1016/j.nima.2020.164945
https://doi.org/10.1016/j.nima.2020.164673

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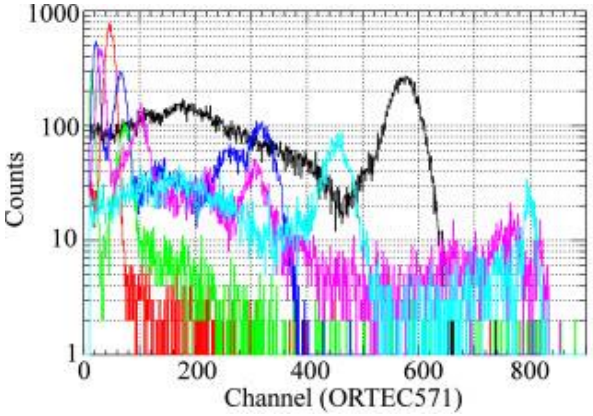
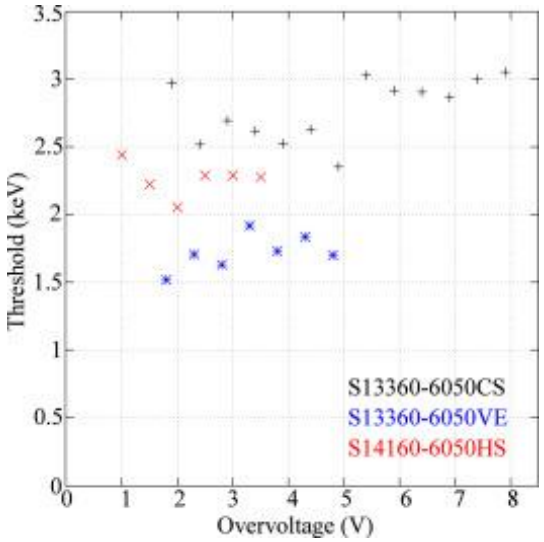
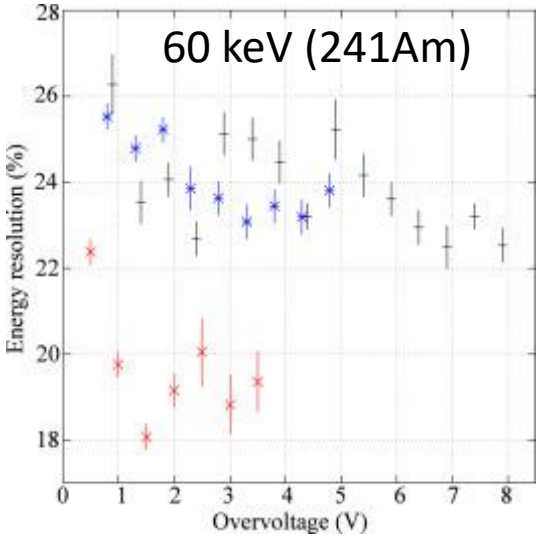
S13360-6050VE	40	1.7	0.388	54.4
S14160-6050HS	50	2.5	1.63	41.0

- S14160 has higher PDE/gain while noise (dark current) is worse.
- For the lower threshold of CAMELOT, S13360 is better.







https://doi.org/10.1016/j.nima.2020.164945
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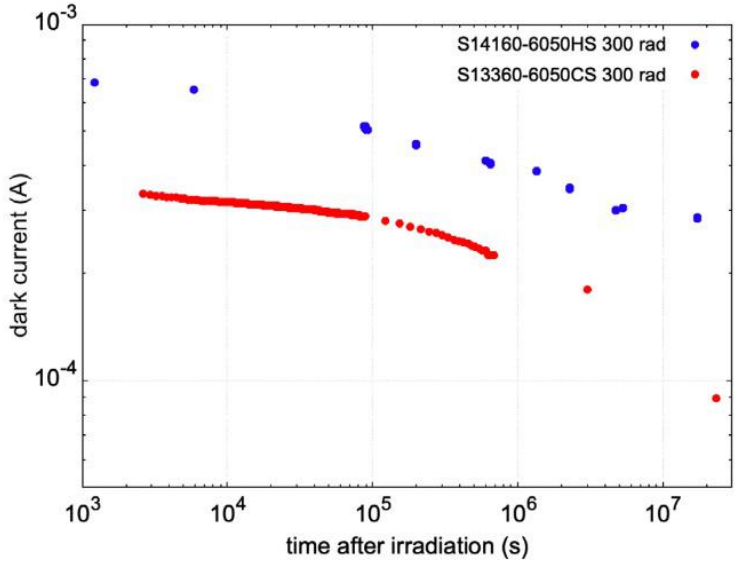
2 SiPM (MPPC) series from Hamamatsu (Proton damage)

See Matake's talk

	PDE (%)	Gain (10^6)	Dark current (uA)	Ope voltage (V)
S13360-6050VE	40	1.7	0.388	54.4
S14160-6050HS	50	2.5	1.63	41.0

・Both S13360 and S14160 showed the similar increase of dark current.
There is no significant differences about radiation tolerance between them.

=> We decided to keep using S13360 for CAMELOT mission.



https://doi.org/10.1016/j.nima.2020.164945
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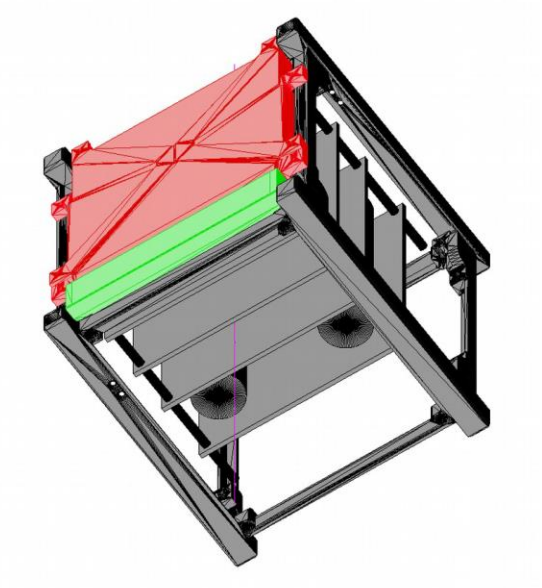
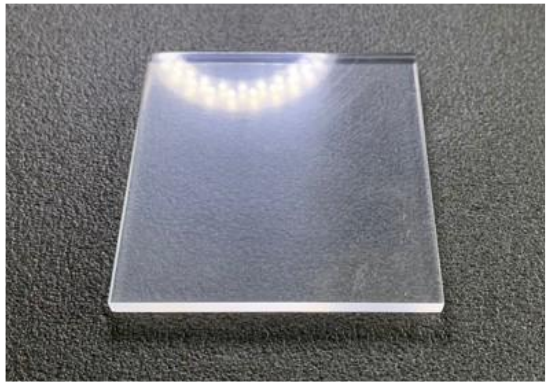
GRBAlpha: the first demo flight

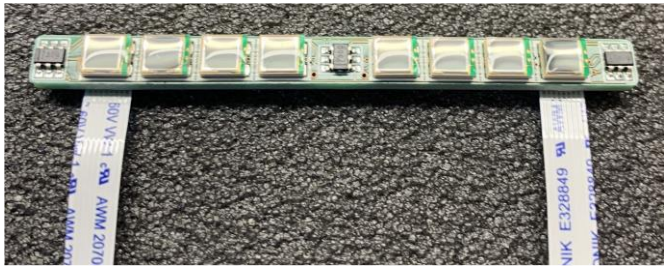
1U CubeSat (10x10x10 cm3)



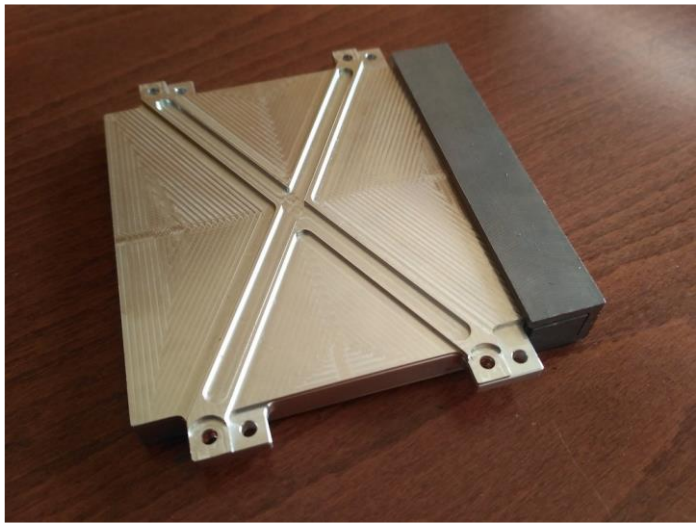


CsI(Tl) scintillator
7.5x7.5x0.5 cm3

Wrapped with ESR reflector



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

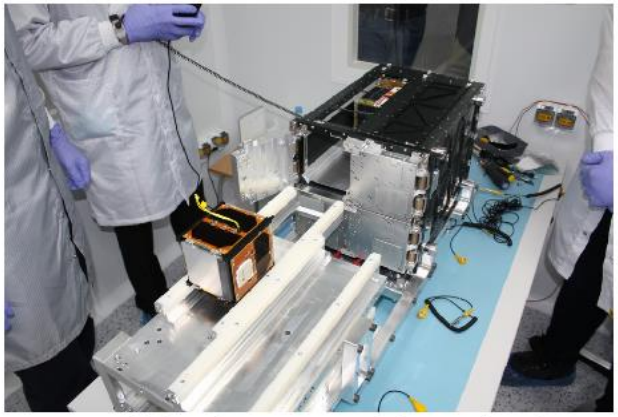


2.5mm Pb-Sb alloy shield
to reduce radiation damages for MPPCs

GRBAlpha launch on March 22, 2021

・After delivery to Moscow, GRBAlpha was integrated into the deployer in the facility of GK Launch Services

・Launched from Baikonur by Soyuz-2.1a rocket with the Frigate upper stage to 550 km SSO on March 22, 2021



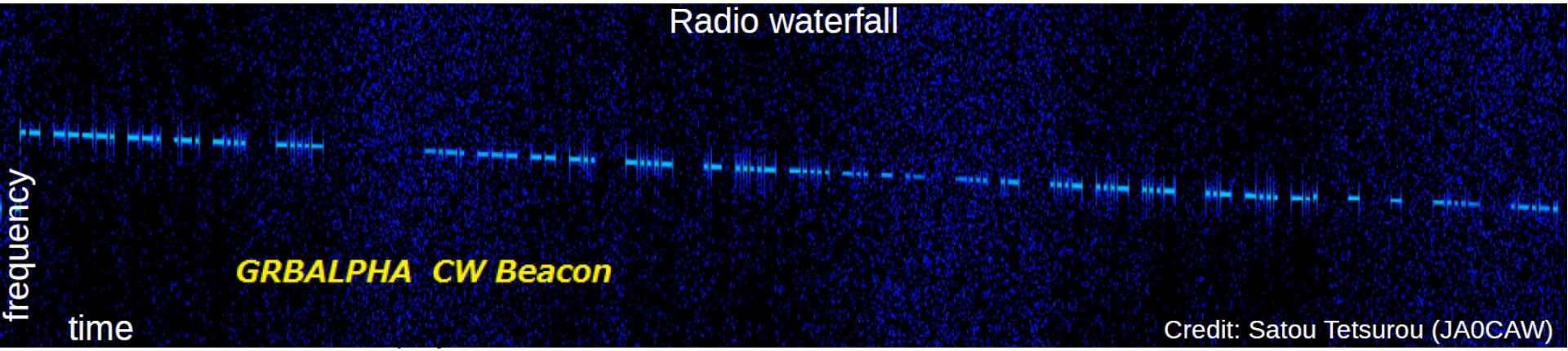
GRBAlpha integrated into deployer

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 signal

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



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

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

GS in Košice Technical University (Slovakia) - under construction

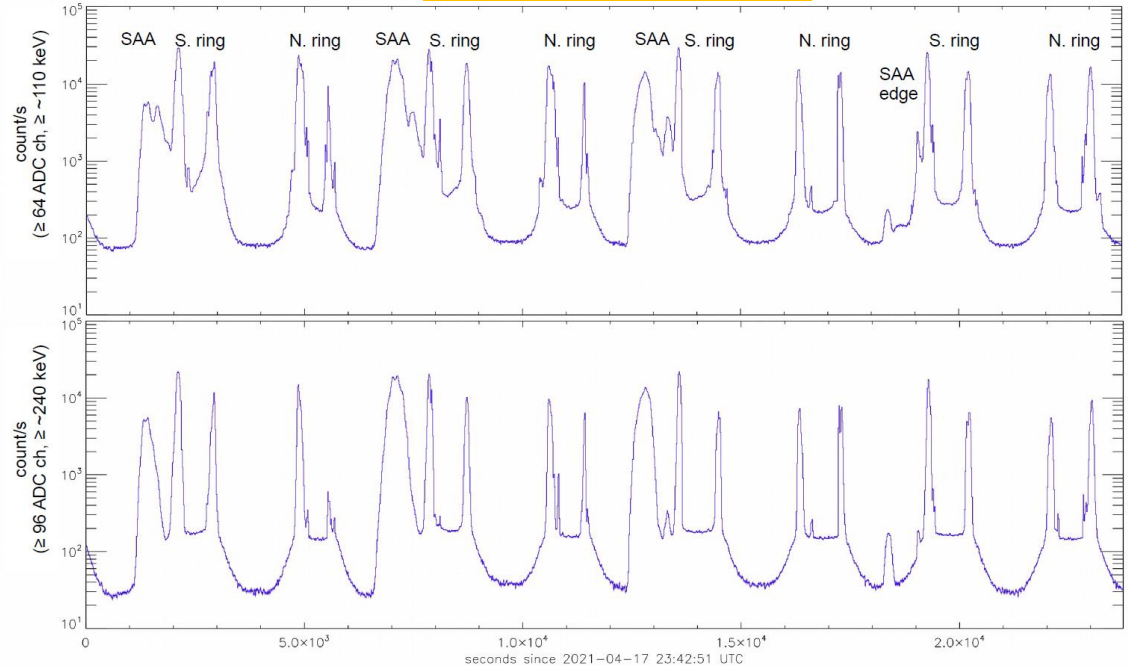
GS in Jablonec Jakub Kapuš Spacemanic (Czech) - under construction

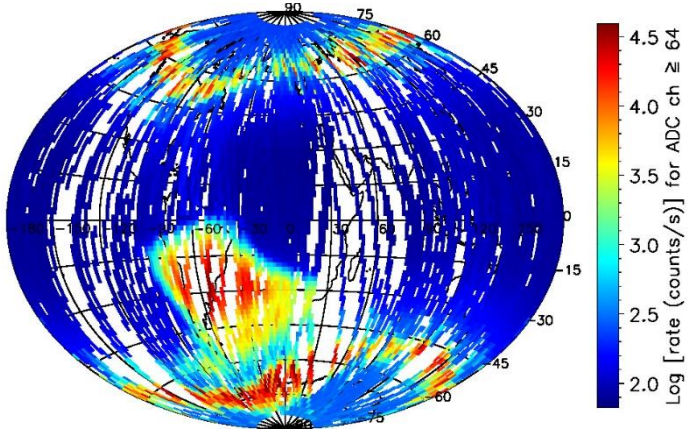
Japanese radioamateurs are downlinking HK/detector data.

GRBAlpha: Initial results

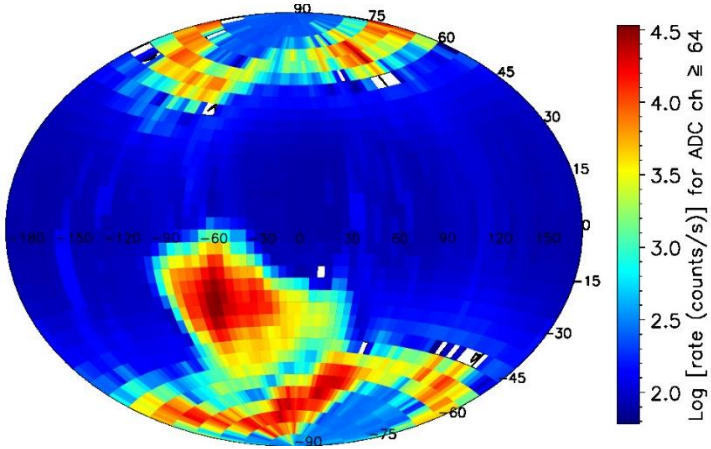
Focused on the background mapping in SSO during the first commissioning phase (during April)

4-orbit Lightcurve





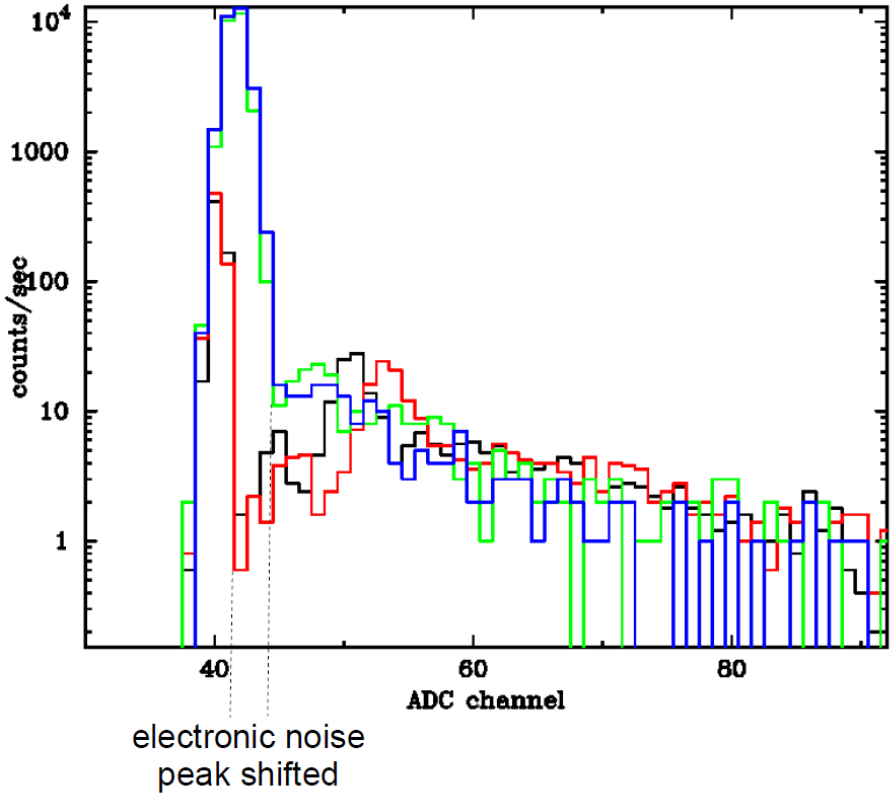
interpolated



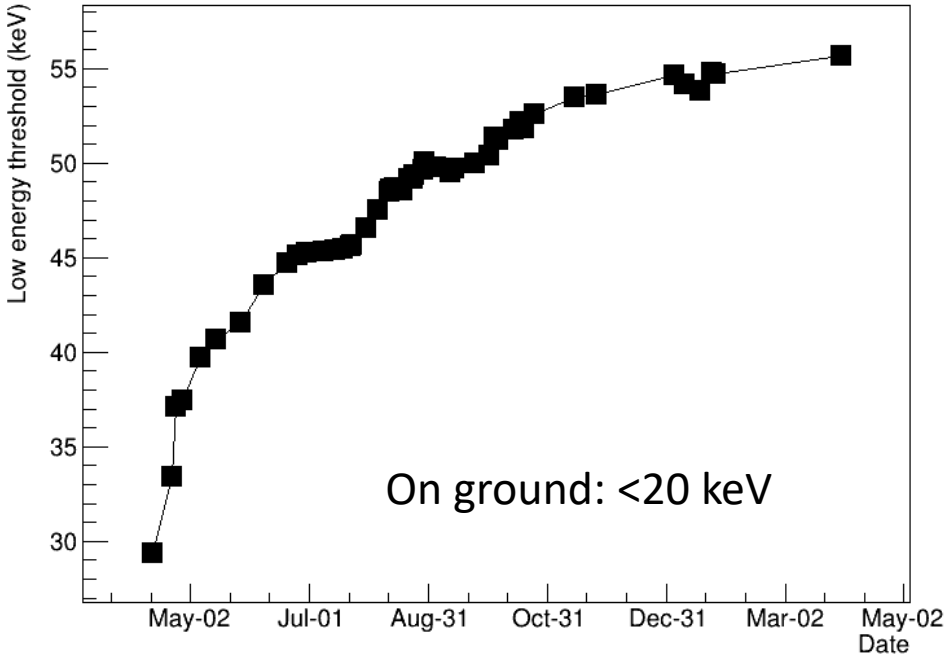
Outsides of polar/SAA regions,
the background rate is 200-250 counts/s.

MPPC degradation in orbit

Black, red: ^{241}Am on ground
Green, blue: in-orbit 2.5 weeks after the launch



Threshold is increasing.
<= Dark current increases as tested with proton beams on ground.



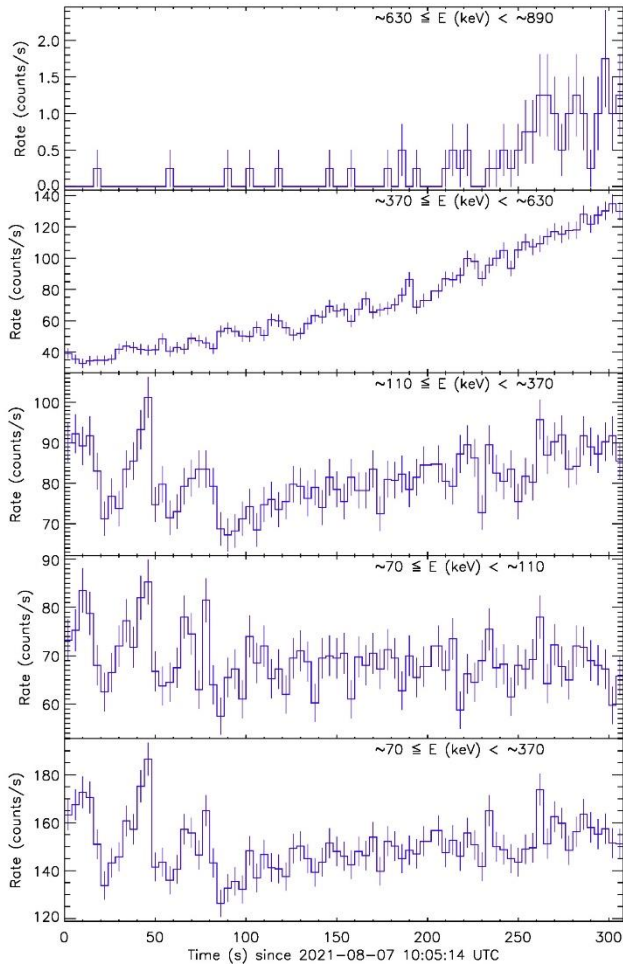
In-orbit, MPPC board temperature is -2℃—20℃.

GRB detections!!! First by 1U CubeSat

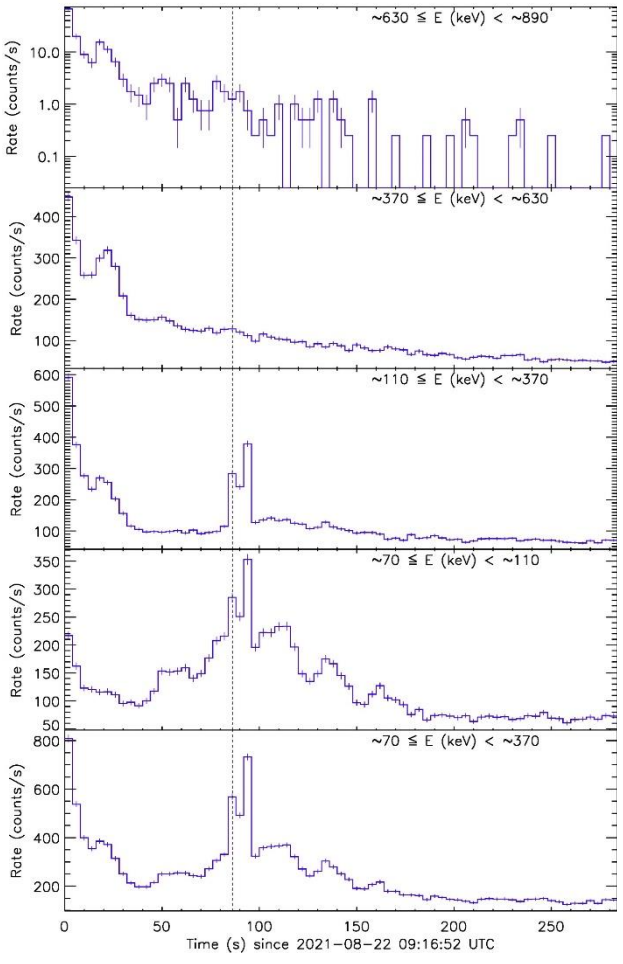
GRB 210806A, 210822A, 210909A
GRB 211018A, 211019A.

We are doing the same operation, and the detections depend on Poisson statistics (I think).

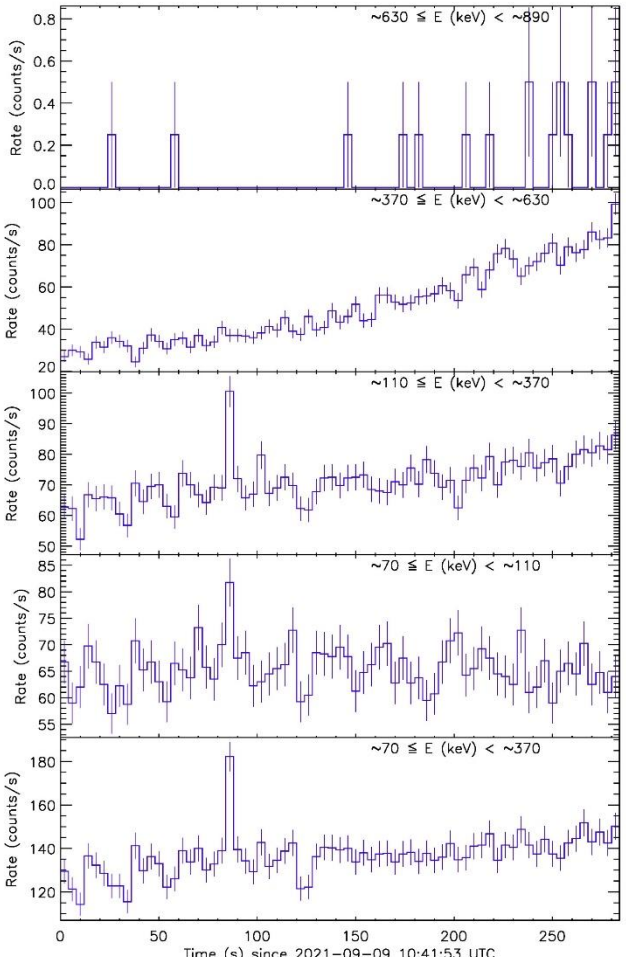
GRB 210806A



210822A (z=1.736)

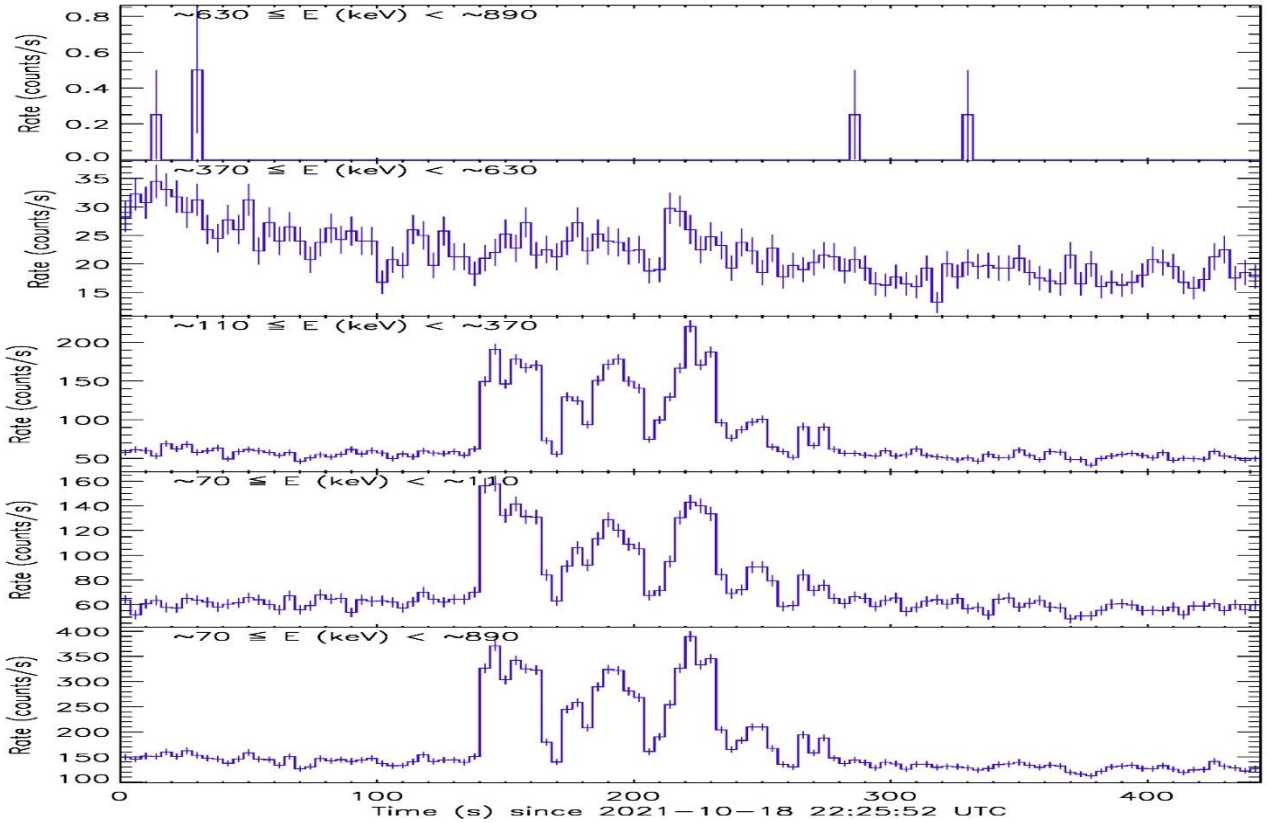


210909A (short GRB)

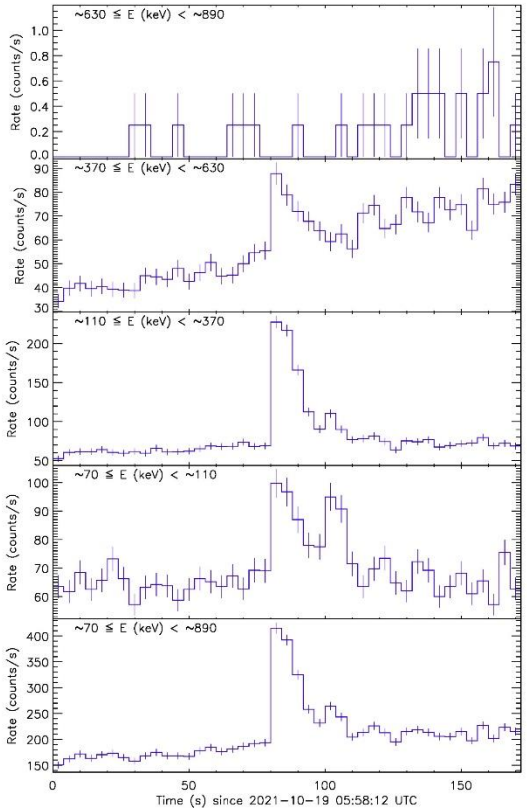


GRB detections!!! First by 1U CubeSat

211018A (very long)

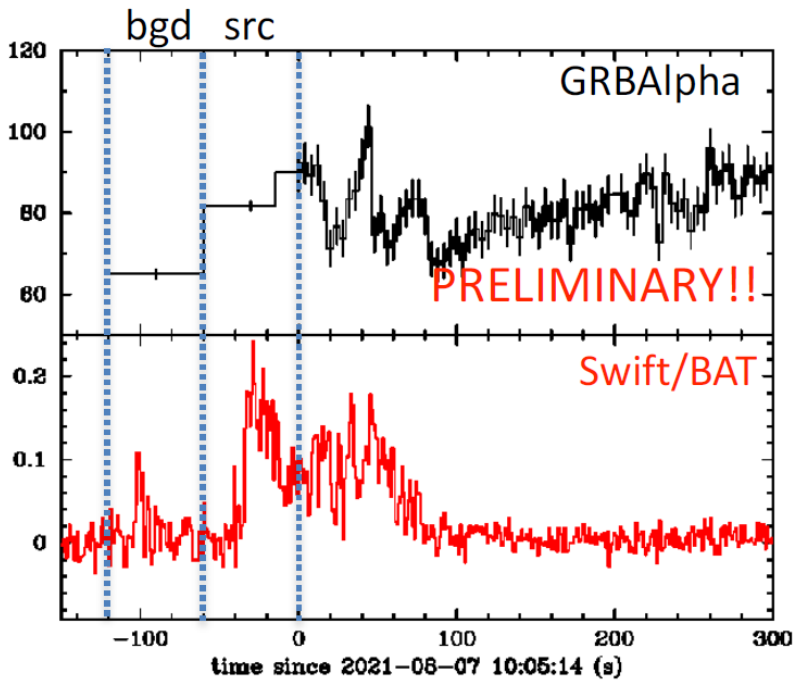


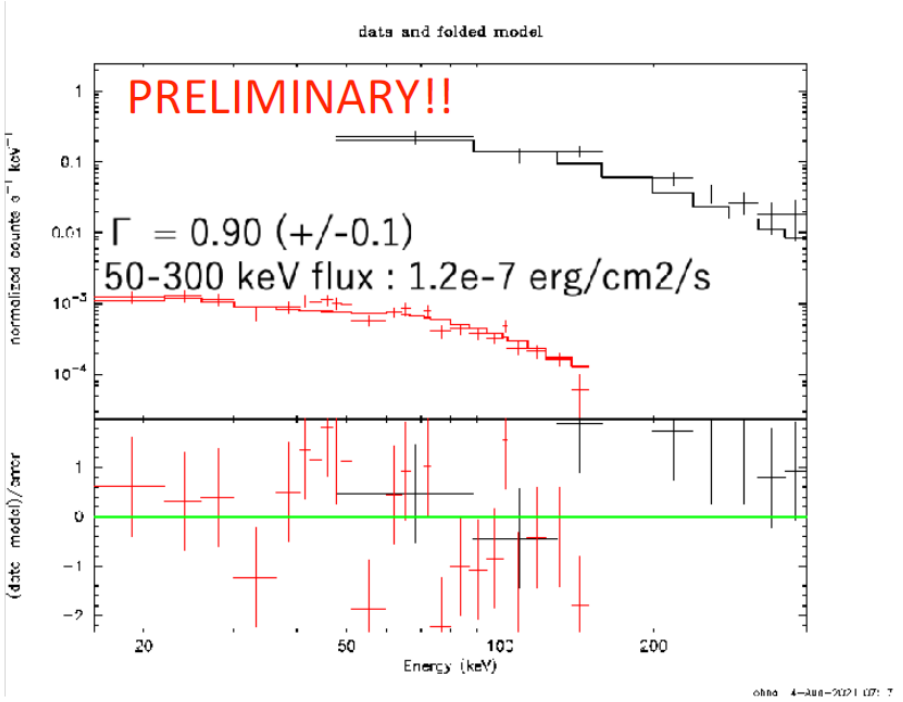
211019A



GRB spectrum!!! First by 1U CubeSat

1st GRB (GRB 210806A) was luckily observed when GRBAlpha was taking HK spectra (2x 60 s).



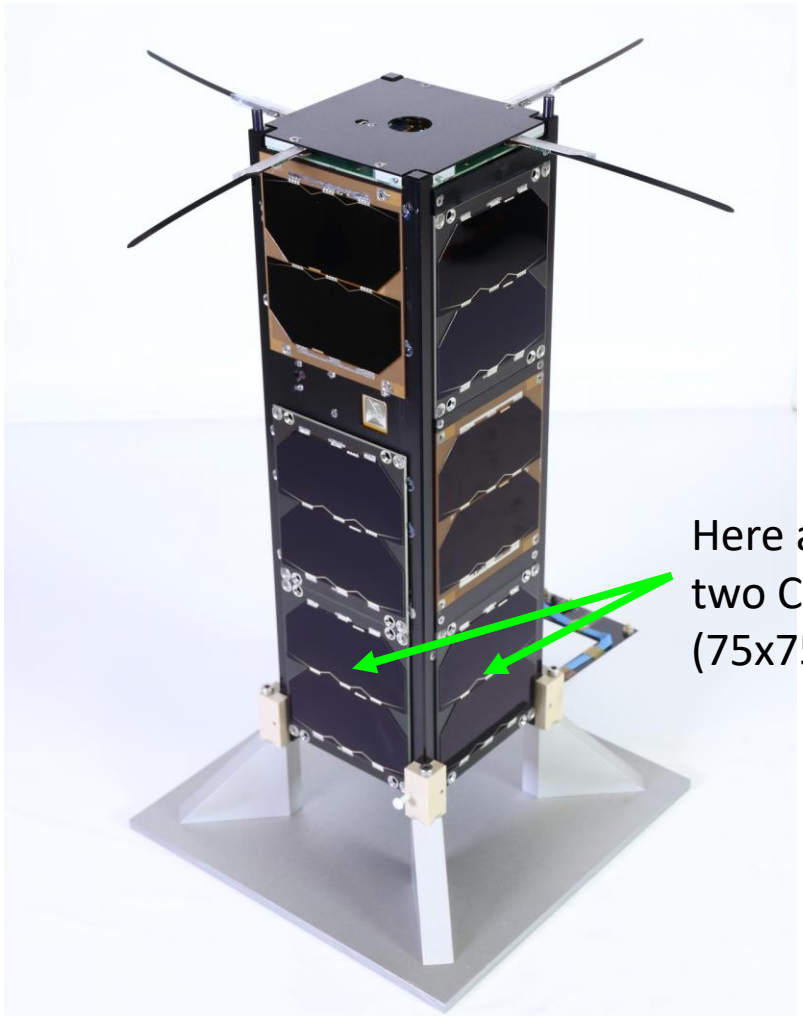


GRBAlpha spectrum shows a good agreement with Swift-BAT.

VZLUSAT-2

- VZLUSAT-2 is a technology mission (3U size) with an Earth observing camera as a primary payload developed by Czech Aerospace Research Centre.
- Two detectors (75x75x5mm3) as a secondary payload.
- The detector concept, the MPPCs and electronics are the same as on GRBAlpha.
- launched on January 13th, 2022. SSO 550 km by Falcon 9
- 1 GRB and 1 Solar flare were detected so far.

VZLUSAT-2

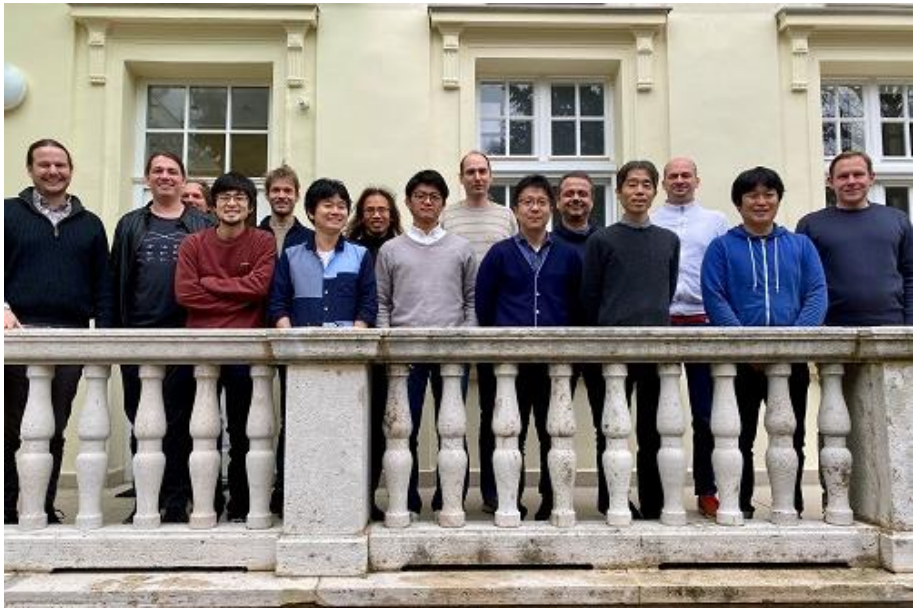


Summary & Future

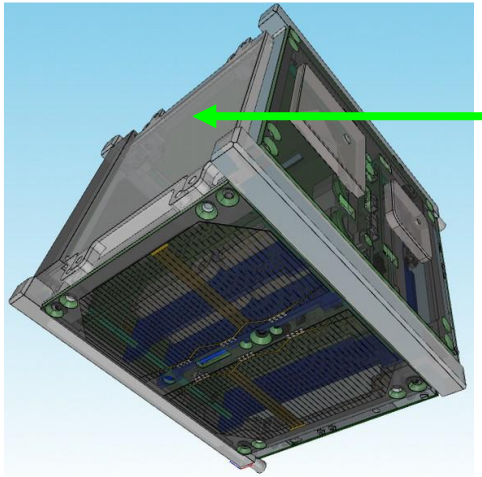
- GRBAlpha is the first demonstration 1U CubeSat prior to CAMELOT mission.
- S13360 series is used after the comparison with S14160.
- Since the launch on March 22nd, 2021 to 550 km, GRBAlpha is operating nominally.
- Lower threshold is increasing due to radiation damage as expected.
- There are 5 GRB detected so far. One is with the spectrum.

- VZLUSAT-2 (3U) was launched on January 13th, 2022 to 550 km.
- After finishing the commissioning, it started GRB/Solar flare detections.

Future:
We are planning to launch GRBBeta (1U) with improved component (hopefully this year).



GRBBeta



1 CsI detector
(75x75x5 mm^3).