New opportunities of TUS detector on-board Lomonosov satellite for TLE measurements

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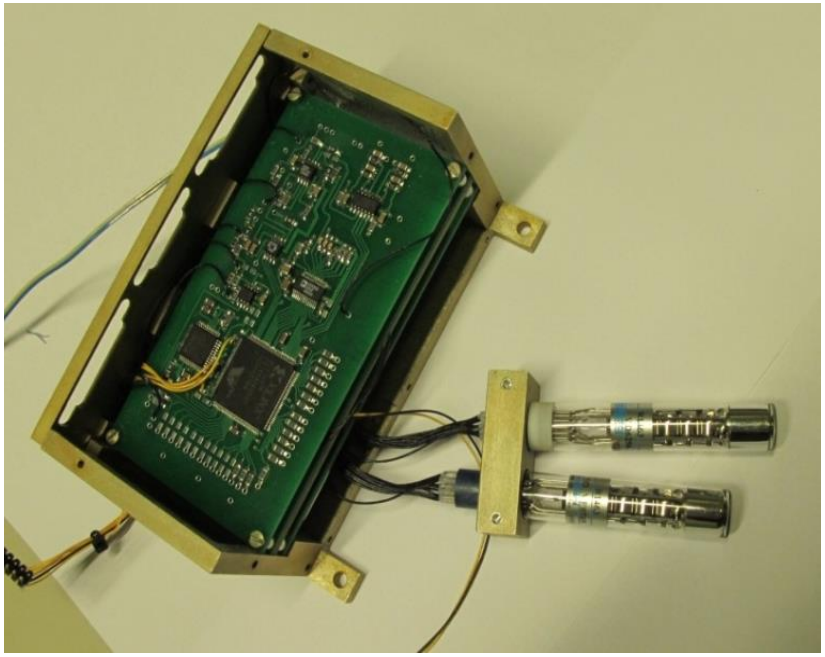
Outline

- Tatiana-1 → Tatiana-2 → TUS.
  Orbital UV detectors of TLE in the atmosphere development in SINP MSU
- TUS – Tracking UV Set-up on-board “Lomonosov” satellite (detector design)
- Tatiana-2 data. Estimation of TLE frequency for TUS detector
- Elves model and TUS signal simulation
- Conclusions

“Tatiana-1” → “Tatiana-2”



	«Tatiana-1»	«Tatiana-2»
Temporal resolution	16 us 64 us	1 ms
Oscillogram length	4 ms 64 ms	128 ms
Wavelength range	240 – 400 nm	240 – 400 nm 600 – 800 nm
TRIGGER	One event per orbit cycle	One event per minute

Detector TUS design

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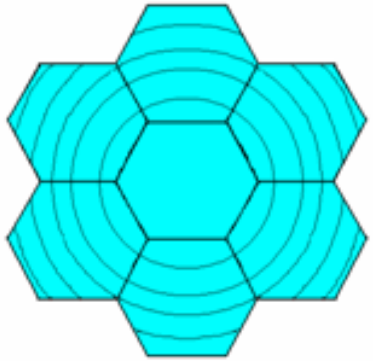
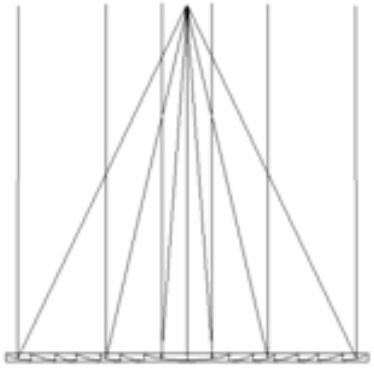




Fresnel type mirror-concentrator

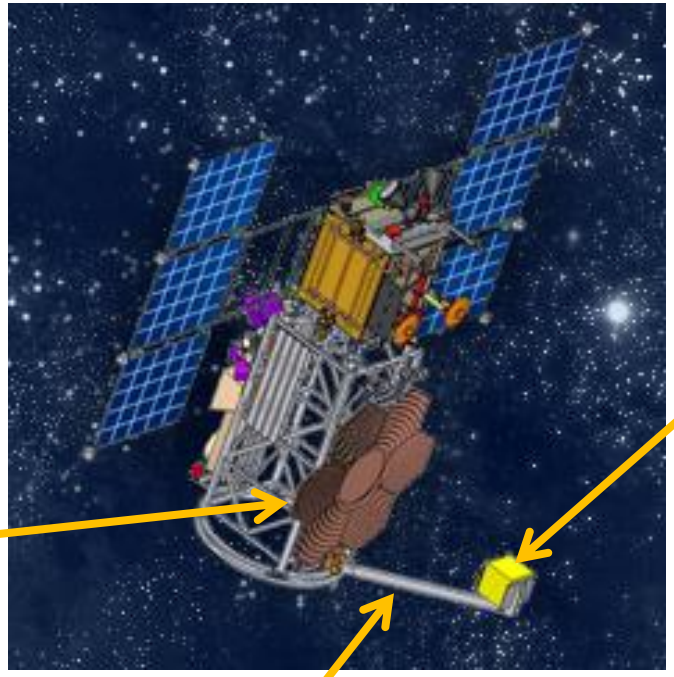
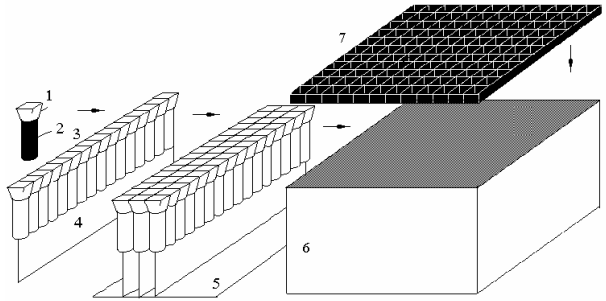
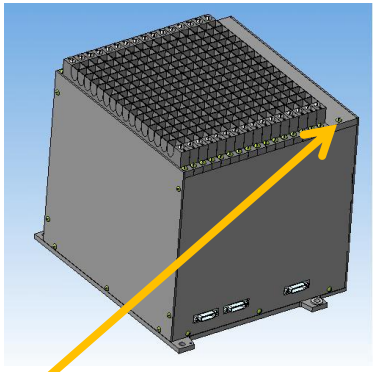
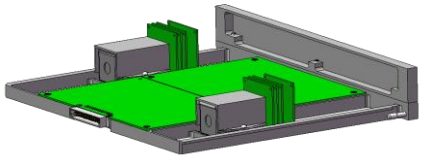


Photo receiver moving system

Photo receiver







Pin-hole camera

Detector TUS on-board Lomonosov satellite

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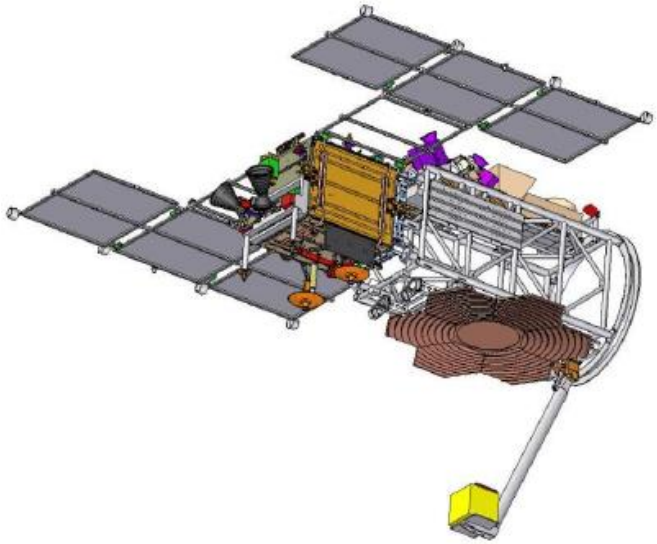
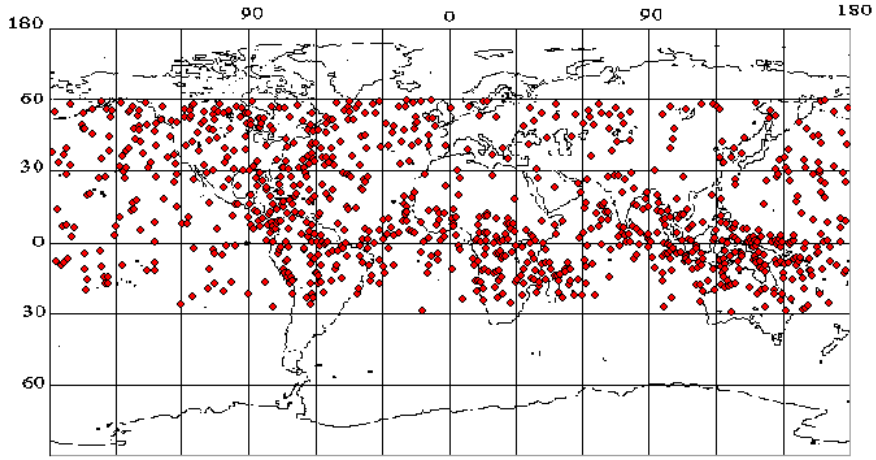


Mass	< 60 kg
Power (maximum)	65 W
Data (maximum)	200 Mbyte/day
FOV	±4,5 degree
Number of pixels	256 (16 clusters of 16 PMTs)
Temporal resolution	**0.8 μs**
Wavelength	240 – 400 nm
Pixel size (spatial resolution)	**10 mrad (5,5x5,5 km)**
Mirror area	**~2 m^2**
Focal distance	1,5 m
Duty cycle, %	30

Scientific goals and detector timing

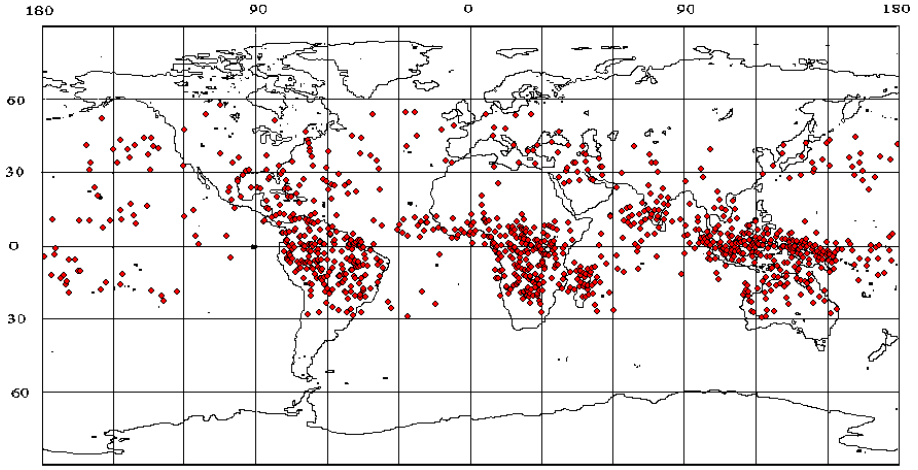
Phenomena	Time sample	Integration time	Oscillogram length
EAS	$\tau = \tau_0 =$ 0,8 μs	$t = 2^4\tau =$ 12,8 μs	$\Delta T = 256\tau =$ 205 μs
Sub-relativistic dust grain	$\tau = 2^5\tau_0 =$ 25,6 μs	$t = 2^3\tau =$ 0,2 ms	$\Delta T = 256\tau =$ 6,6 ms
Transient luminous event	$\tau = 2^9\tau_0 =$ 0,4 ms	$t = \tau =$ 0,4 ms	$\Delta T = 256\tau =$ 105 ms
Micro-meteor	$\tau = 2^{13}\tau_0 =$ 6,6 ms	$t = 2^4\tau =$ 105 ms	$\Delta T = 256\tau =$ 1,7 s

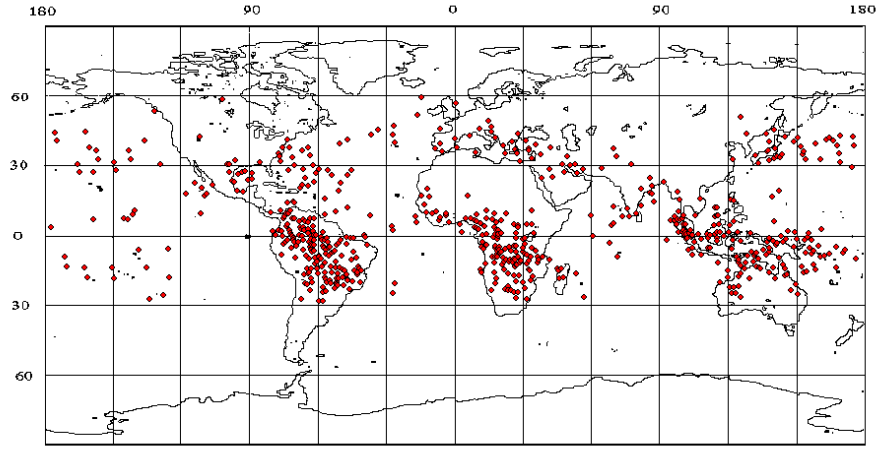
Geographical distribution (“Tatiana-2”)



Photon number <5 10^{21}

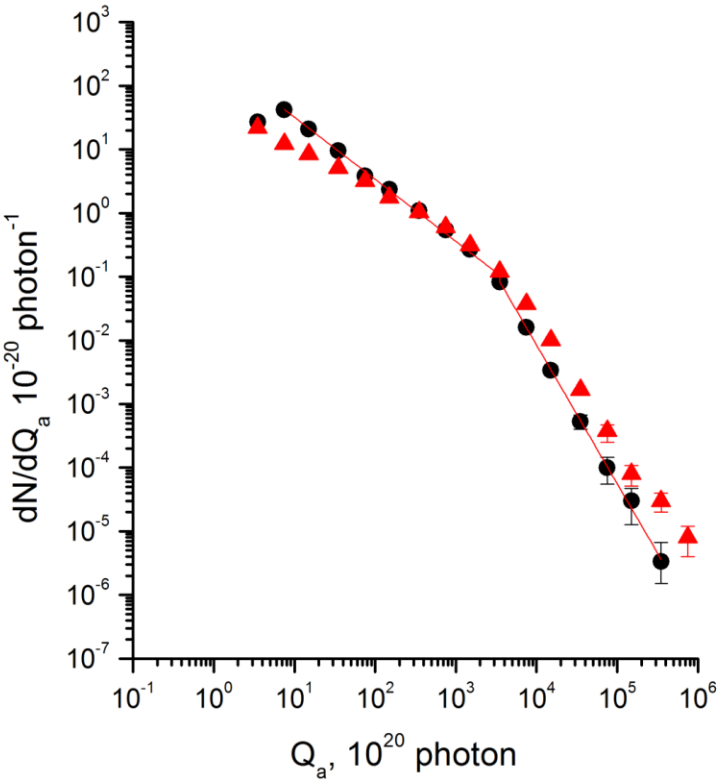
Photon number 5 10^{21} – 10^{23}

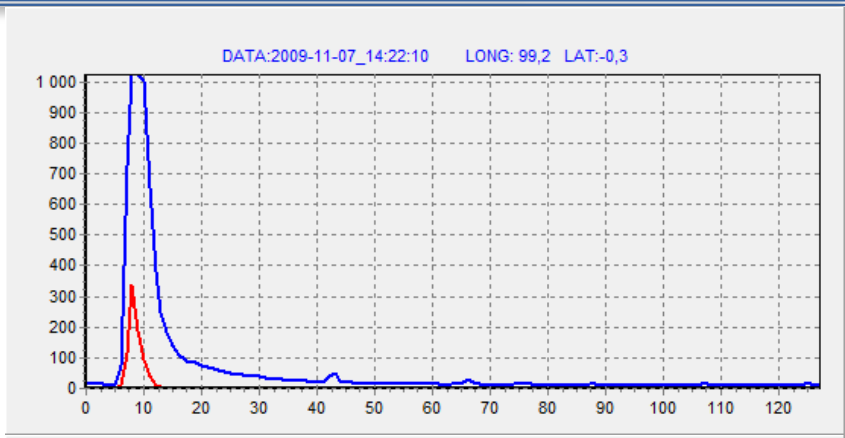


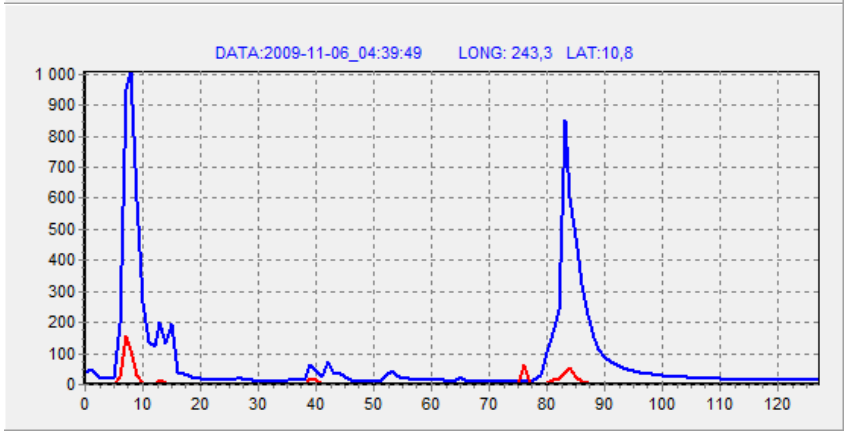


Photon number > 10^{23}

“Energy distribution” (“Tatiana-2”)







Selected transients distributed in wide range photons number $Q_a = 10^{20} - 10^{26}$.

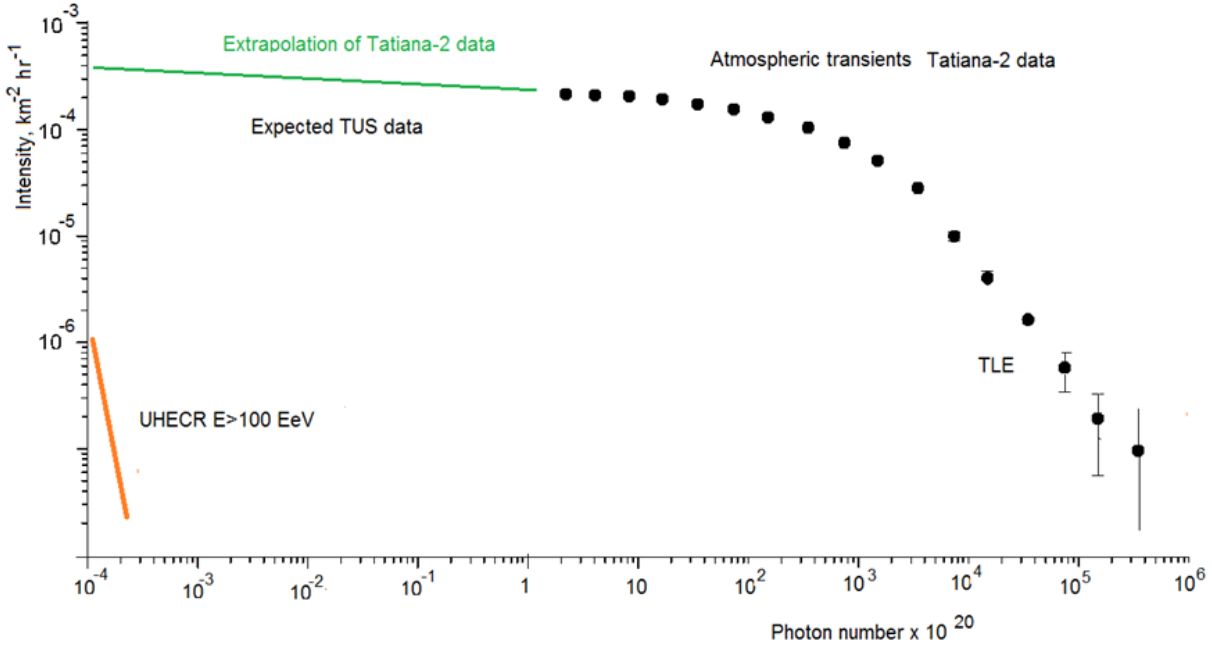
In range of $10^{21} < Q_a < 10^{23}$ the differential distribution could be approximated by power law with (absolute value) exponent 0.97 ±0.04.

From $Q_a = 10^{23}$ the power law exponent changed to 2.20 ± 0.13.

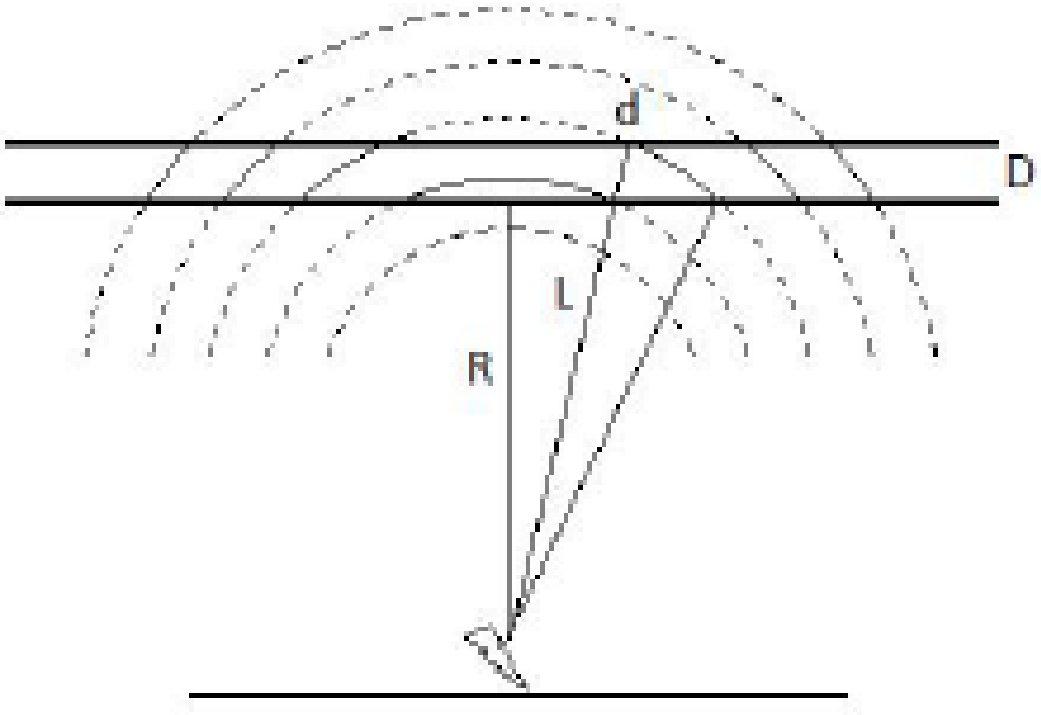
TLE frequency estimation

In period October 2009 – January 2010 Tatiana-2 detectors orbited the Earth 797 times with 320 hours of operation time in shadowed "night" part. During these three months more than 2000 events with $N_{ADC} > 80$ were measured. The average rate of TLE events from this data is **0.13 min^{-1}** or **10^{-4} hr^{-1} km^{-2}**. The instantaneous frequency in local thunderstorm area could be significantly more (~10^{-3} hr^{-1} km^{-2}).It is order of magnitude higher than TLE frequency, measured by ISUAL

Number of TLE events for TUS detector in case of the same trigger as in Tatiana-2 is ~1 event per hour (average).



ELVE modeling



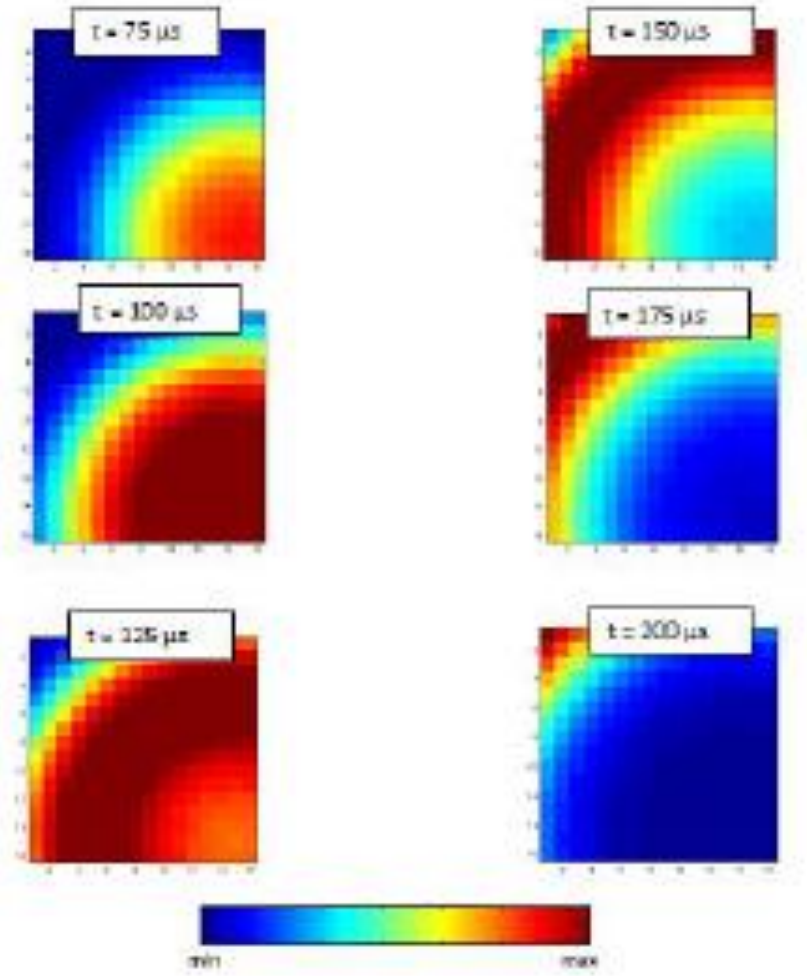
Elve model of heating the lower ionosphere by lightning electric pulse EMP propagation through the ionosphere layer. **R** is EMP radius at the lower border of chosen layer of the ionosphere, **D** is ionosphere layer thickness, **d** is radius of visible glow ring, **L** is EMP radius at the higher border.

The TUS detector signal

The temporal profile of the transient glow in the detector is determined by velocity of EMP sphere expansion, position of the ionosphere layer, ready to produce glow, and position of the center of the flash in the detector's FoV.

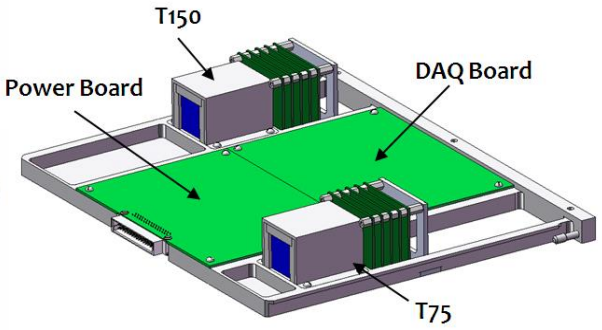
Model parameters were adjusted to experimental data of Tatiana-1 on temporal characteristics of small short flashes (signal rise time ~200 ms, signal fall time ~750 ms).

The figure shows spatial distribution of photons number in TUS pixels with temporal resolution 25 ms. In this example the center of the discharge is located at the corner of the detector's FOV.



Evolution of flash image in the TUS detector (results of simulation)

Pin-hole camera in TUS



MAPMT – R11265-00-64
64-channel PMT, which will be used in JEM-EUSO experiment

Two camera for TLE study:
✓T150 – FL:**150mm**, FOV: **84.48 x 84.48** km^2 **(~ 80 x 80** km^2**)**

✓T75 – FL: **75mm**, FOV: **168.96 x 168.96** km^2 **(~160 x 160** km^2**)**

The event information –**50 kbyte/event**
Number of pixel : 64 ch x 2 PMTs
Dynamic range : 10bit
Duration time : 512ms
Sampling time : 10us ~ 0.512ms
Number of sample : **312**
64ch x 2 x 10bit x 625 = 100 kbyte/event
The two pinhole cameras information – **30 Mbyte/day**
TLE trigger will operate 1 event/min.

Pin-hole camera has independent trigger system.
Search of events coincidences with TUS modules is supposed to make off-line.

Conclusions

- The TUS detector will provide measurements of faint TLE with high (0.8 μs 26 μs and 0.4 ms) temporal resolutions in UV wavelength band.