

**The Results of TGFs and  
TLEs Observations in  
RELEC Experiment on board  
Vernov Space Mission**



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**“S.A.Lavochkin” Scientific and Production Association.,  
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**Space Research Institute, Russia**

**NILAKT, Russia**

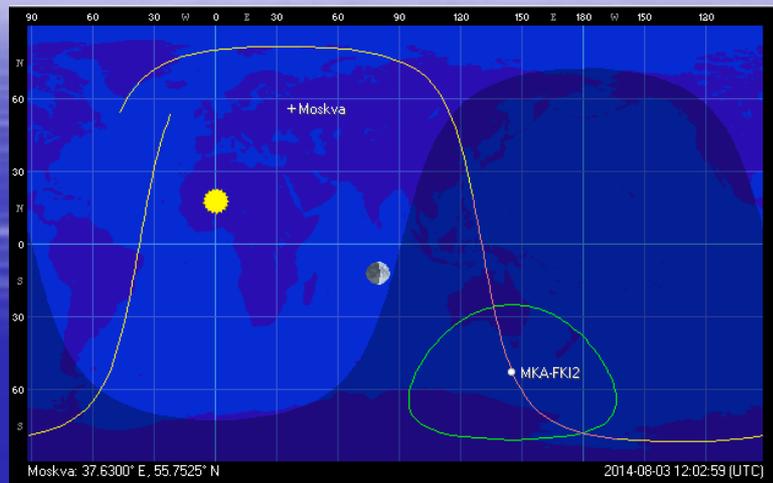
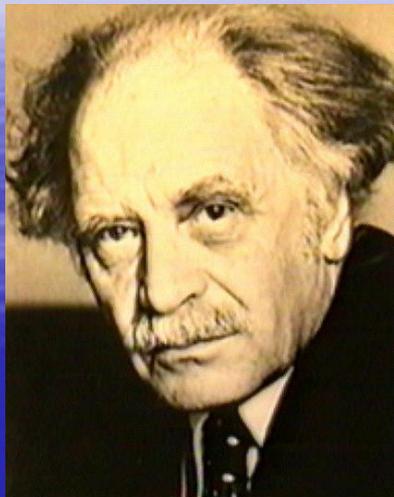
**Etvosh University, Hungary**

**Sungkyunkwan University (SKKU)., Seoul, Korea**

**Space Research Centrum, Poland Academy of Sciences,  
Poland**

**Lvov Center of Space Research Institute, Ukraine**

# RELEC set of instruments on-board spacecraft named Vernov elaborated and manufactured by Lavochkin Space Association was successfully launched on July, 8 2014



**MKA- 2 (RELEC)**

**Norad: 40070U**

**Inter. ID: 14037B**

**Launch.: 2014**

**.07.08**

**Period: 99.2 min.**

**Revs/day: 14.5**

**Incl.: 98.4 degrees**

**Apogee: 819 km**

**Perigee: 621 km**



# The Aims of RELEC Experiment

- *Transient energetic events in the Atmosphere such as Terrestrial Gamma Flashes (TGF) and Transient Luminous Events (TLE)*
- *Magnetosphere Relativistic Electron dynamics: acceleration, precipitation and acting on the upper Atmosphere*

# Instruments and Collaboration

- **DRGE-1 & DRGE-2** - two identical detectors of X-, gamma-rays and high-energy electrons of high temporal resolution and sensitivity (SINP MSU)
- **DRGE-3** - three axe directed detectors of energetic electrons and protons (SINP MSU)
- **Telescope-T (MTEL-2)** - optical imager (SINP MSU, Korea)
- **DUF** - UV detector (SINP MSU)
- **NChA (LFA)** - low-frequency analyser (Space Res. Inst. RAS, Etvos Univ., Hungary, Lviv Space Center, Ukraine)
- **RChA (RFA)** - radio-frequency analyser (Space Res. Inst. RAS, Space Center, Poland)
- **BE** - module of commands and data collection (NILAKT)

# DRGE design

**Instrument DRGE is a complex of scintillator detectors for study of x-rays, gamma-rays and electrons.**

**Two parts of the instrument**

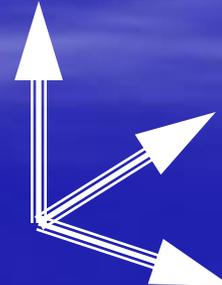
**DRGE-1, DRGE-2**

X-rays and gammas in 0.01-3 MeV energy range from atmospheric discharges with high time resolution (up to 15us)



**DRGE-3**

Electrons in 3 orthogonal directions, secondary x-rays and gammas produced by electrons.



# DRGE-1 and DRGE-2



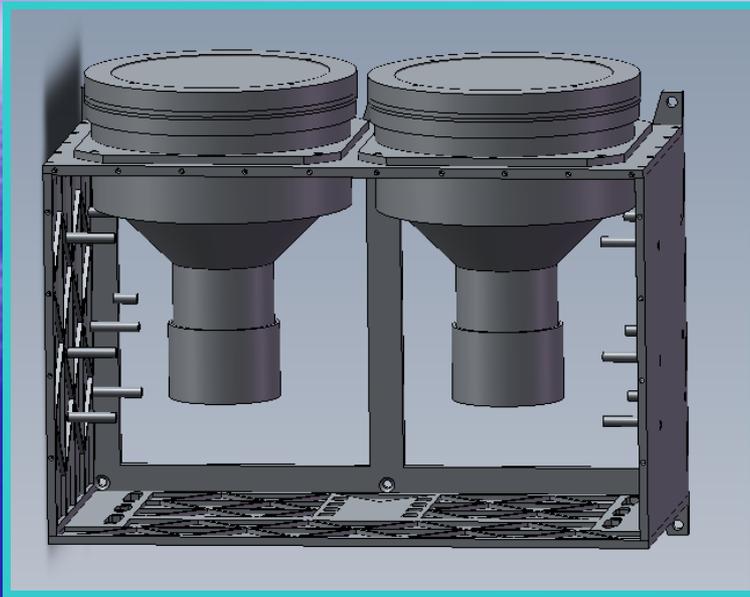
## Physical parameters:

Energy range	0.01-3.0 MeV,
Effective area	~120 cm <sup>2</sup> each (total ~500 cm <sup>2</sup> )
Time resolution in event mode	~15 mcs
Time resolution in monitoring mode	1 s

## Technical parameters (for DRGE-1 or DRGE-2) :

Mass	10.4 kg
Size	360x300x180 mm;
Power consumption at 27 V	< 9 W.

# Arrangement of DRGE-1(2) detector box



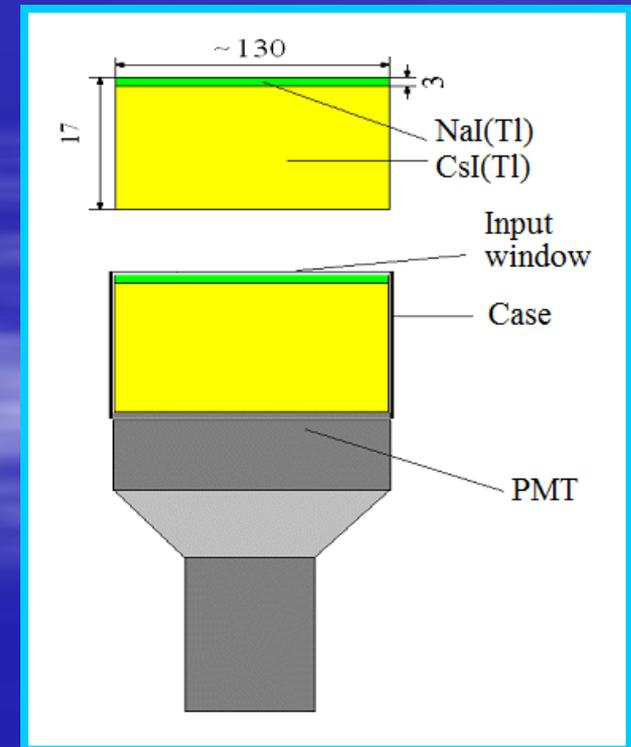
There are two identical detector boxes named DRGE-1 and DRGE-2.

Each of them consists of two identical detector units. These units made in one case work independently.

Detector consists of optically coupled thin (3mm) NaI(Tl) and considerably thick (17mm) CsI(Tl) crystals.

Thickness of NaI(Tl) is optimized for soft part of energy range. CsI(Tl) plays a role of active shield for soft radiation being the main detector for hard one.

Working ranges are 0.01-0.5 MeV for NaI(Tl) and 0.05-3 MeV for CsI(Tl) one.



# Data frames of DRGE-1(2) detectors

## **1. Monitoring frame**

Contains number of events detected in wide energy channels separately for NaI(Tl) and for CsI(Tl)

## **2. Event frame**

Contains detailed data: (timer value at the moment of detection, fast and slow ADC codes) for each of gammas detected during the frame time but not more than some fixed value (default is 800 for equator, 200 for regions of trapped particles)

## **3. Telemetric frames**

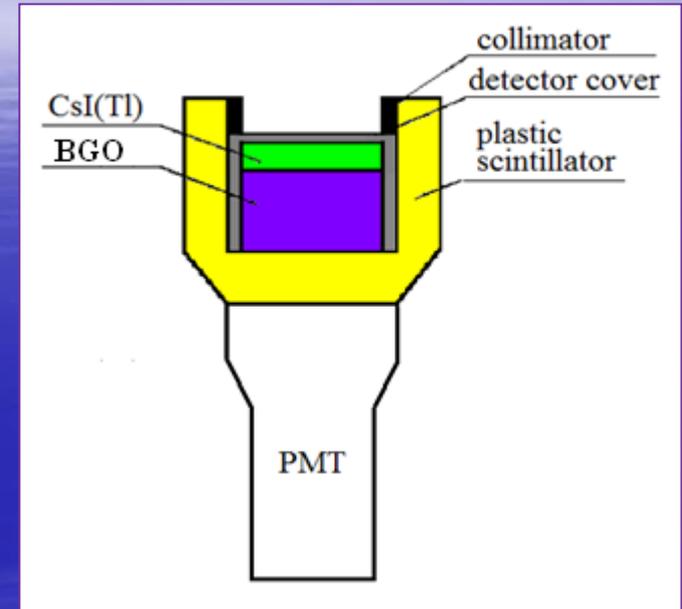
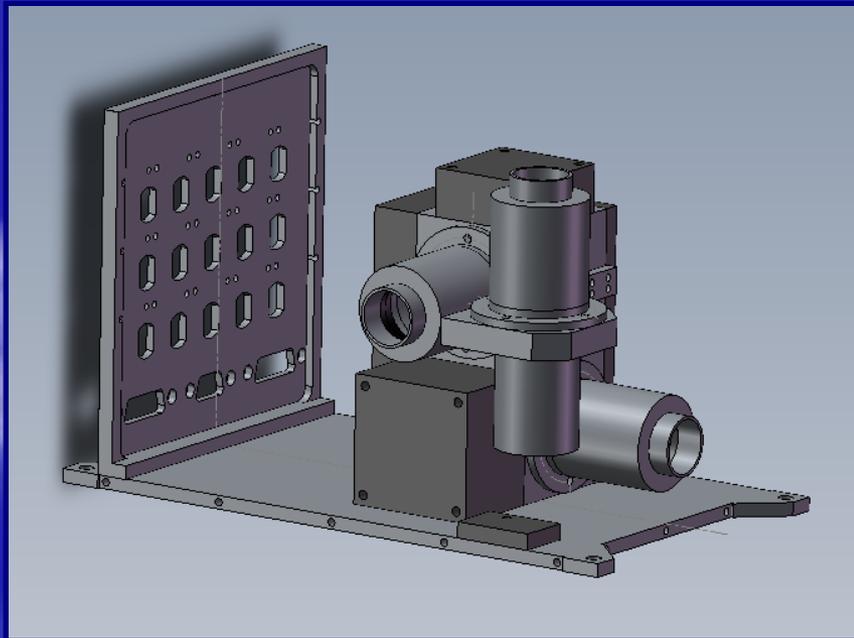
contain a number of health parameters including total rate, number of timer counts, energy thresholds etc

# Scintillation detectors of DRGE-3

Three identical BGO/CsI(Tl)/plastic scintillator phoswich detectors are directed along three axes mutually normal (as Cartesian coordinate system)



To the sky



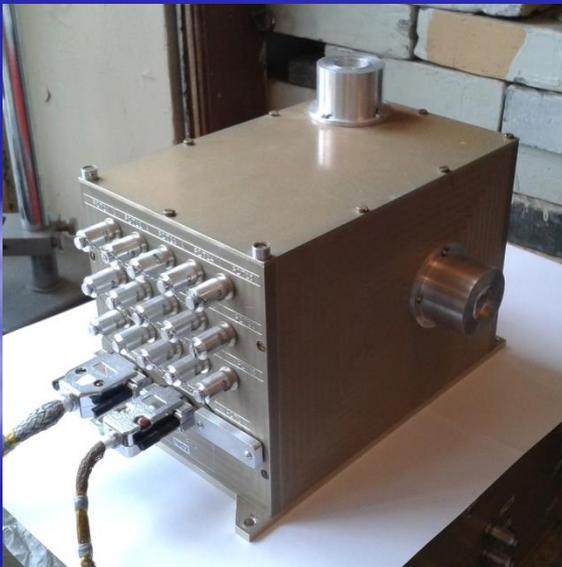
Detector consists of optically coupled thin (3mm) CsI(Tl) and considerably thick (17mm) BGO crystals with  $\varnothing 20\text{mm}$ . Surrounding plastic scintillator is 5mm thick. FOV is formed by cylindrical collimator made of 1mm Cu.



Along the geomagnetic field line

# DRGE-3 Physical parameters:

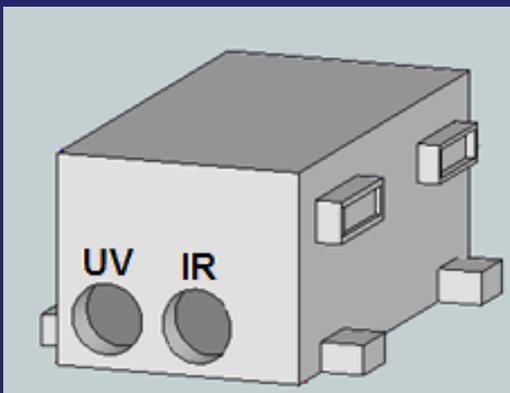
	electrons	protons
energy range	0.1-15.0 MeV,	1.0-100.0 MeV
geom. factor	~2 cm <sup>2</sup> sr	~2 cm <sup>2</sup> sr
temporal resolution	15.5 mcs	15.5 mcs
sensitivity	~10 part./cm <sup>2</sup> s	~10 part./cm <sup>2</sup> s



## Technical parameters

Mass	2.8 kg;
sizes	245x160x180 mm;
power consumption at 27 V	7 W.

# DUV instrument



1. Signal revealing algorithm, which selects the brightest flashes in every 5 s time interval.
2. Gain control algorithm for fixing PMT anode current across whole airglow range.
3. Interface algorithm for communication with the satellite board.
4. Waveform saving algorithm for storage waveforms of the flashes in digital form.

## DUV - detector

UV – 240-400nm

IR – 610-800nm

Sensitive - area 0.4cm<sup>2</sup>

Field of view ~ 20°

4x10<sup>3</sup>

Full dynamic range- 4x 10<sup>9</sup>

Maximum sensitivity -one photoelectron

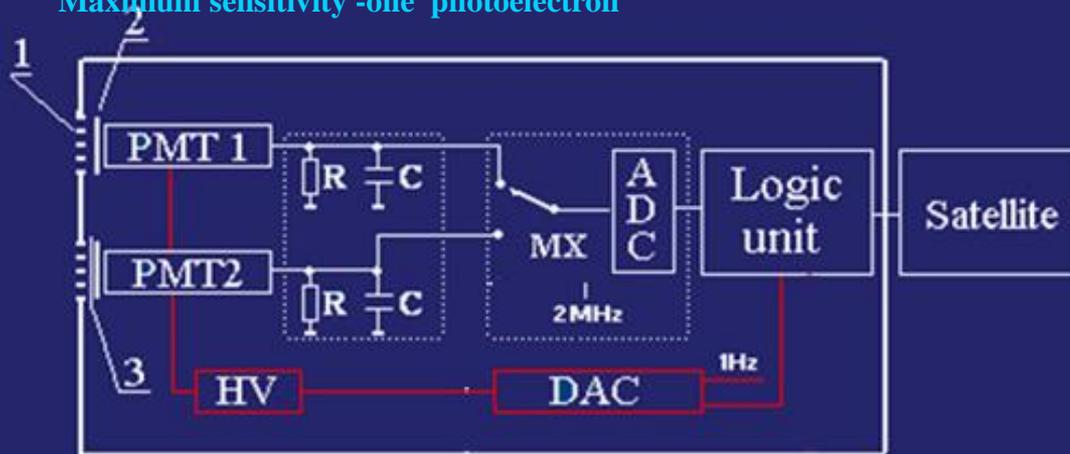
weigh– 0.5 kg

power consumption – 2.5W

gain control range – 10<sup>6</sup>

waveform window amplitude range

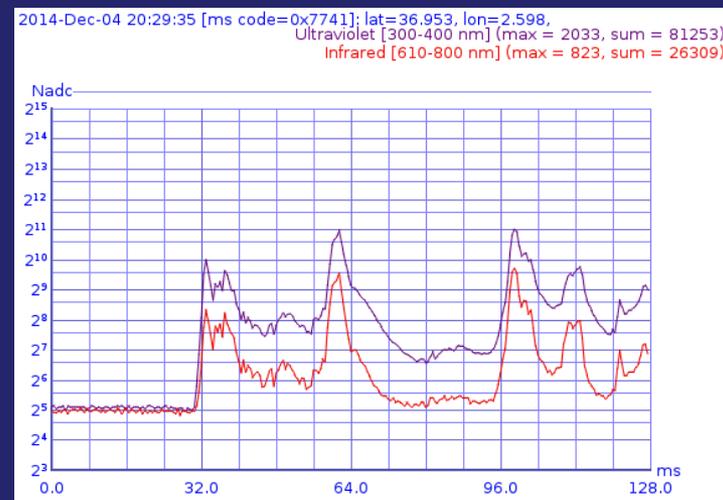
nadir observation



## Block diagram of the detector

(1) collimator, (2) UV-1 filter, (3) IR filter, MX-multiplexor, HV- PMT high voltage source, ADC and DAC— analog to digital and digital to analog converters, Logic Unit-FPGA.

## Waveform window



# Telescope –T (Mtel-2) instrument

Optical imager based on multi-grain mirror

Physical parameters:

Spectral band: 300-400 nm

Angle resolution:  $0.4^\circ$ .

Angle of view:  $\pm 7.5^\circ$ .

Cells number: 4000.

Photomultiplier channels  
number: 64.

Time resolution: 100  $\mu\text{s}$ .

Amplitude range:  $10^5$ .

**Technical parameters**

**Mass - < 5 kg;**

**sizes 200×200×400 mm;**

**power expenditure at 28 V**

**no more 6 W.**

# NChA instrument

Low-frequency analyzer: two magnetic field component meters, two electric field component meters and analyzer unit

Physical parameters:

Frequency band: 20 Hz - 20 kHz  
number of spectral components:  
1024  
frequency step: 20 Hz .  
Time resolution: 2 s.  
Number of spectral component  
categories: 16.

**Technical parameters**

**Mass - < 3 kg;**

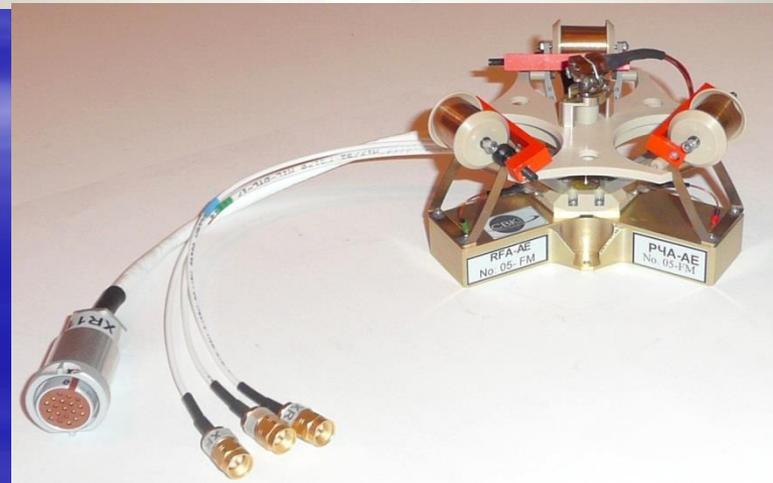
**sizes 160×130×80 mm;**

**power expenditure at 28 V  
no more 5 W.**

# RFA radio frequency analyzer

- The RFA instrument is an electronic device devoted to measure three electrical components of radio frequency emissions in the frequency range from 50.0 kHz upto 18.0 MHz.

- The instrument is composed of two main units:
  - Receiver and Control Block (RFA-E)
  - three dimensional electric antenna set (RFA-AE).



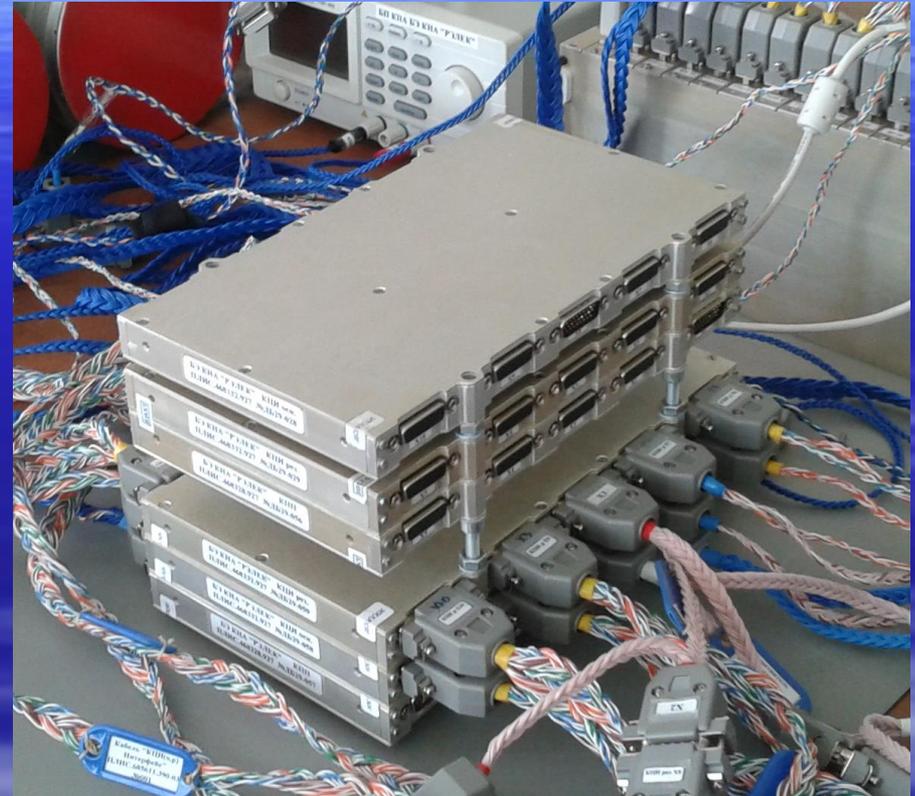
# BE instrument (data and command unit)

## Physical parameters:

Total data transfer: 500 Mbyte per day.  
Number of control commands : 24.  
Number of digital commands: 256 categories.  
Possibility of flexible trigger.

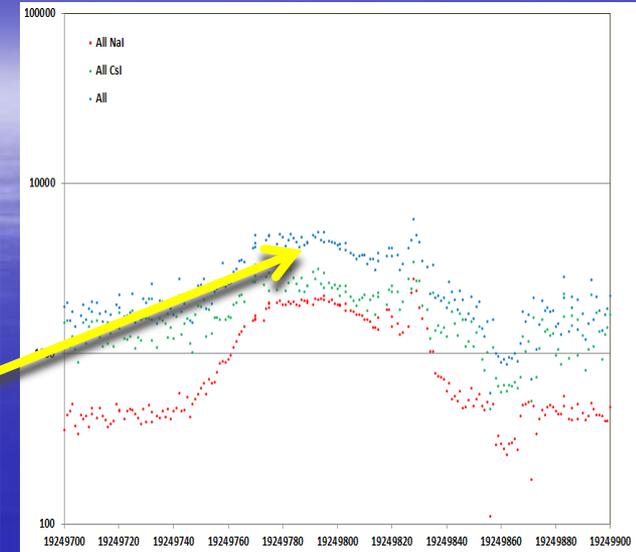
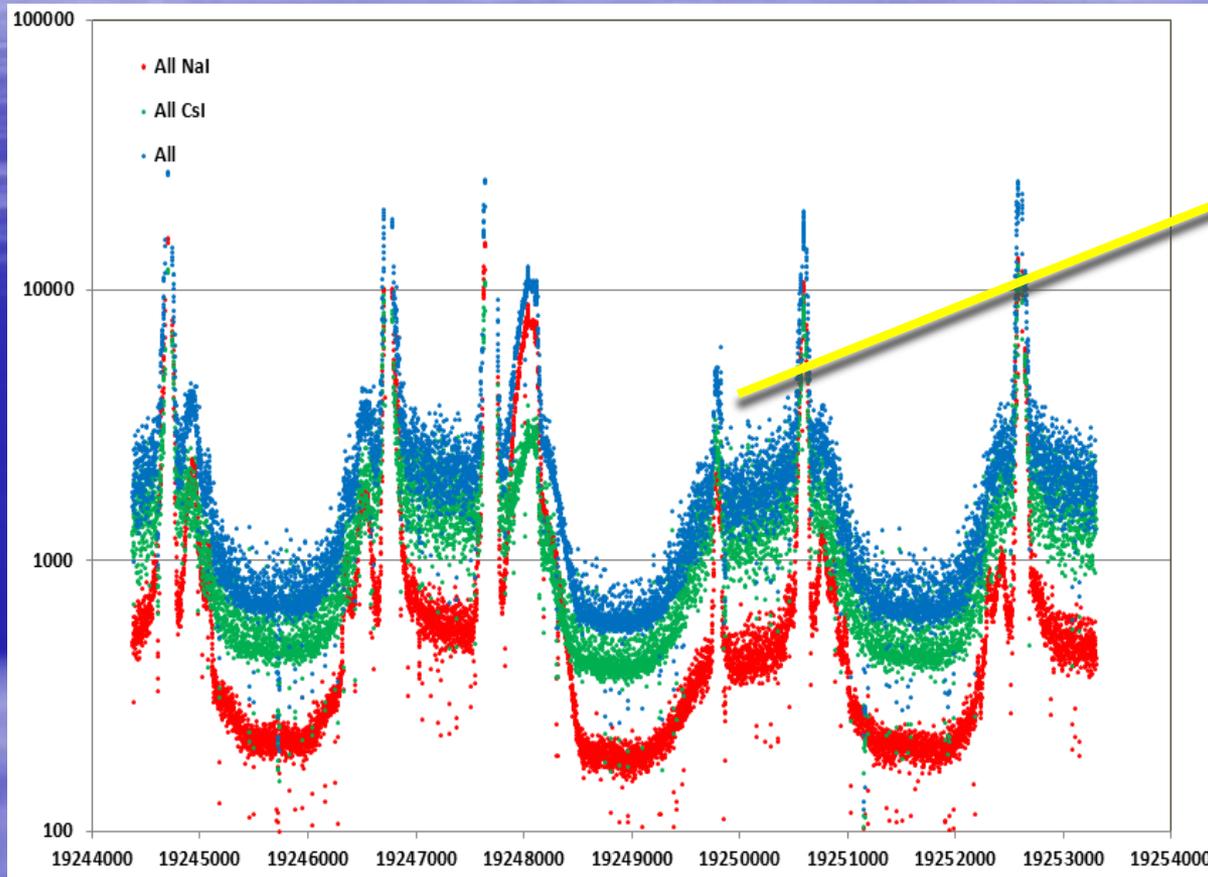
## Technical parameters

Mass - < 4 kg;  
sizes 270×250×200 mm;  
power expenditure at 28 V  
no more 4 W.

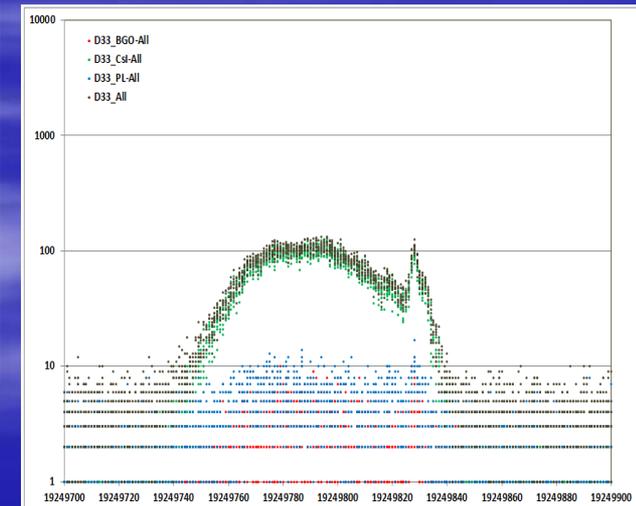


# DRGE monitoring data

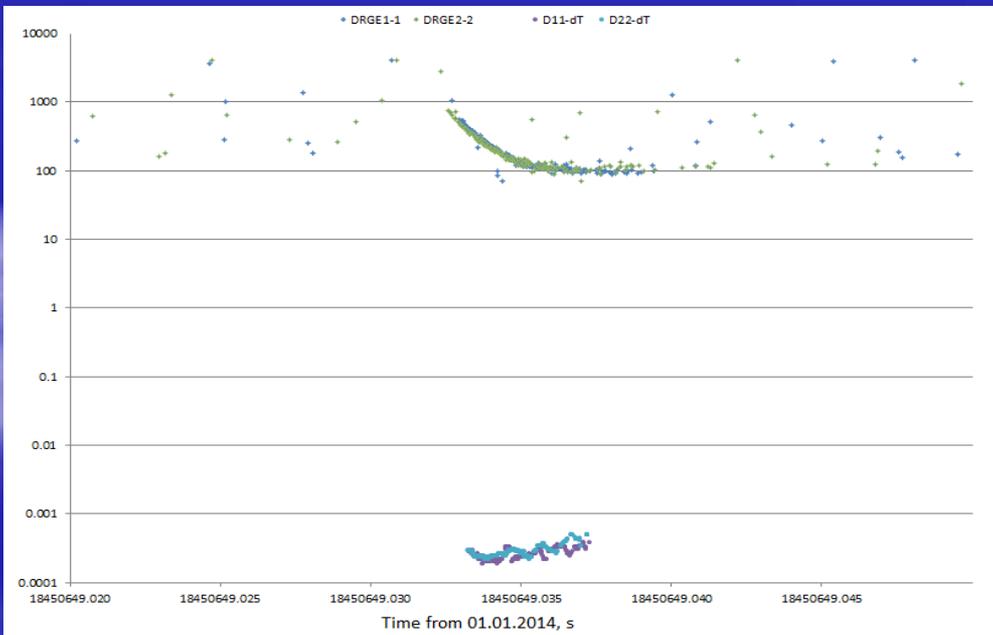
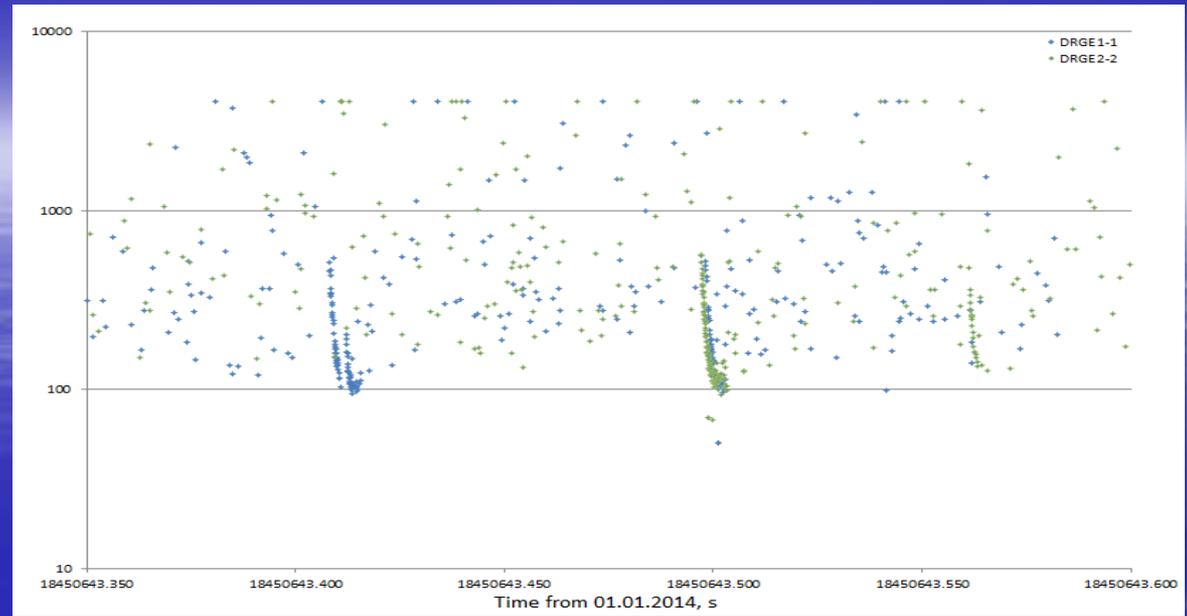
DRGE1-1



DRGE3-3



# Imitations of TGFs by protons of cosmic rays overloading the detector electronics



Upper: amplitude of each  
event trigger

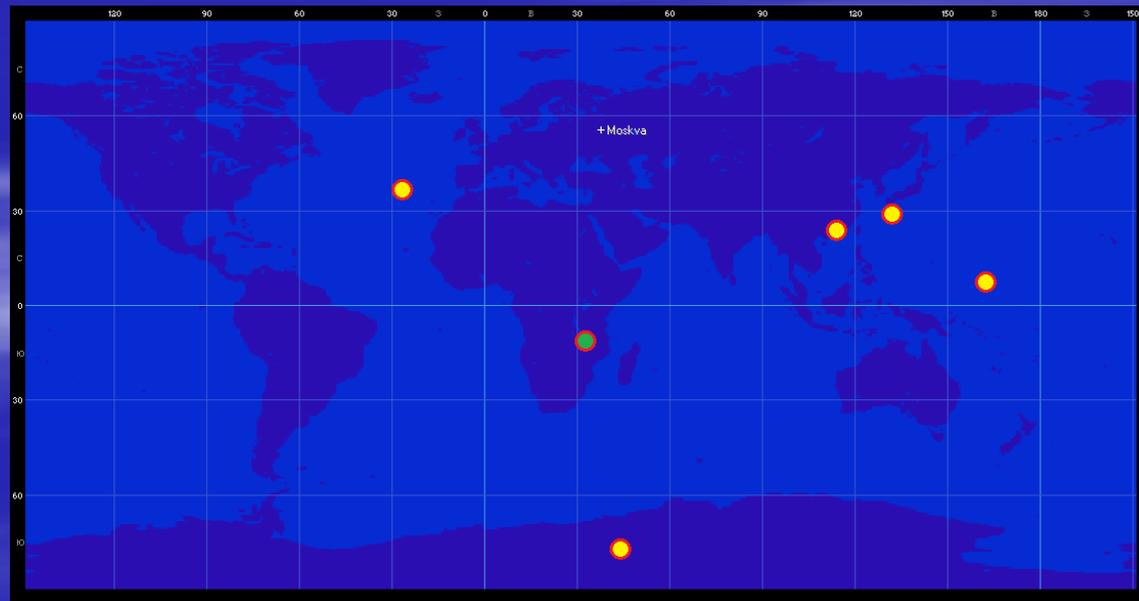
Lower: time interval between  
10 consequent events

# TGF triggers

Two types of TGF offline trigger were used

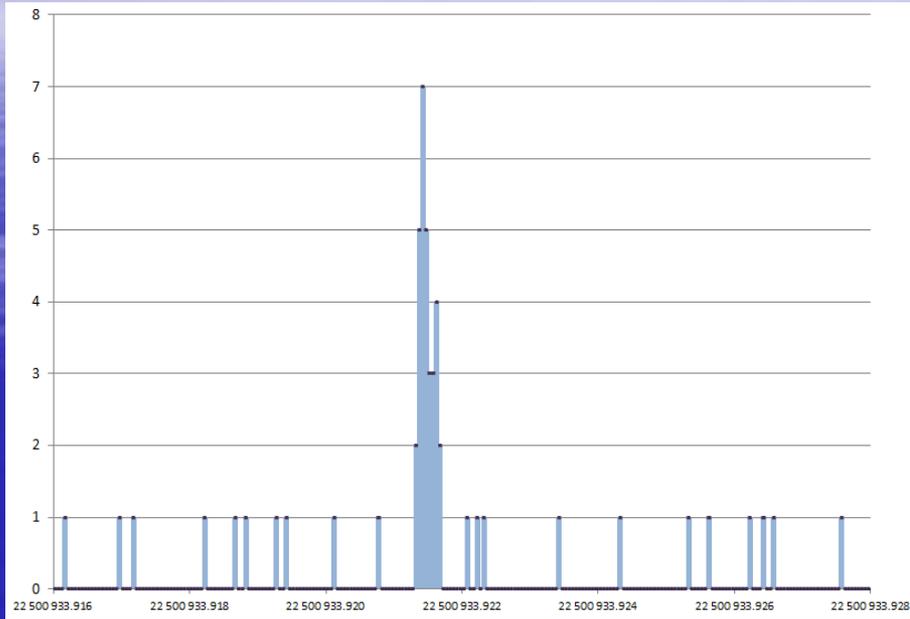
- 1)  $\geq 2$  detectors,  $\geq 5$  gammas with  $E > 300$  keV in 1ms
- 2)  $\geq 3$  detectors,  $\geq 3$  gammas with  $E > 300$  keV in 1ms

Trigger time	Triggered detectors	Latitude, Longitude	Comments
2014-08-07-22-20-54	1101	26.2W, 35.6N	TGF?
2014-08-08-00-31-06	1011	132.04E, 29.4N	
2014-08-16-13-06-54	-111	114.7E, 24.2N	Imitation?
2014-09-18-10-15-33	1001	160.4E, 8.3N	TGF
2014-10-11-06-46-19	11-1	32.4E, 12.4S	GRB
2014-11-02-03-34-13	1011	40,.7E, 77.6S	

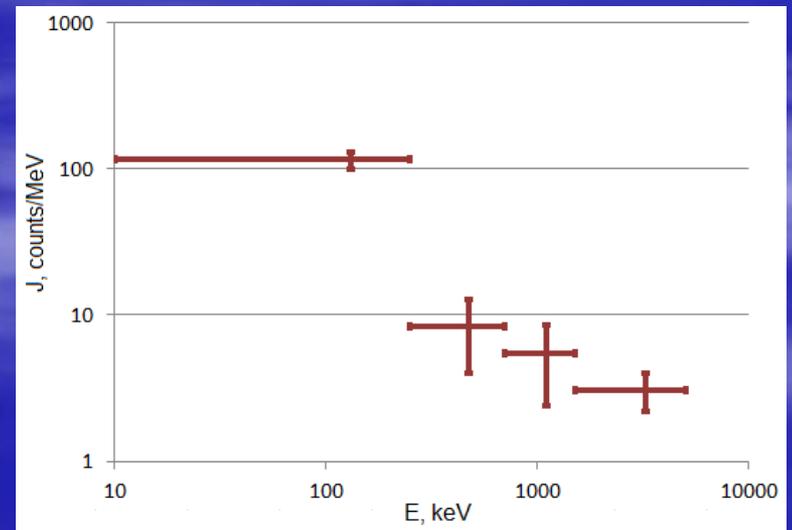
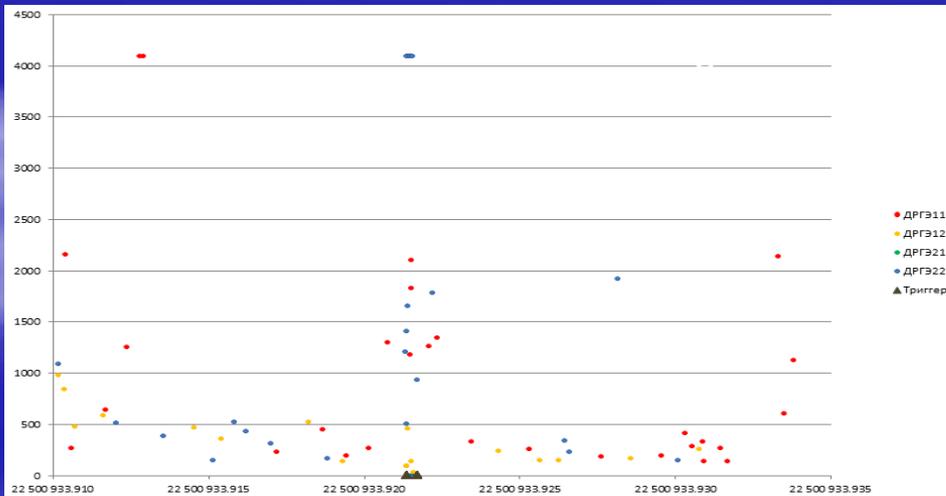
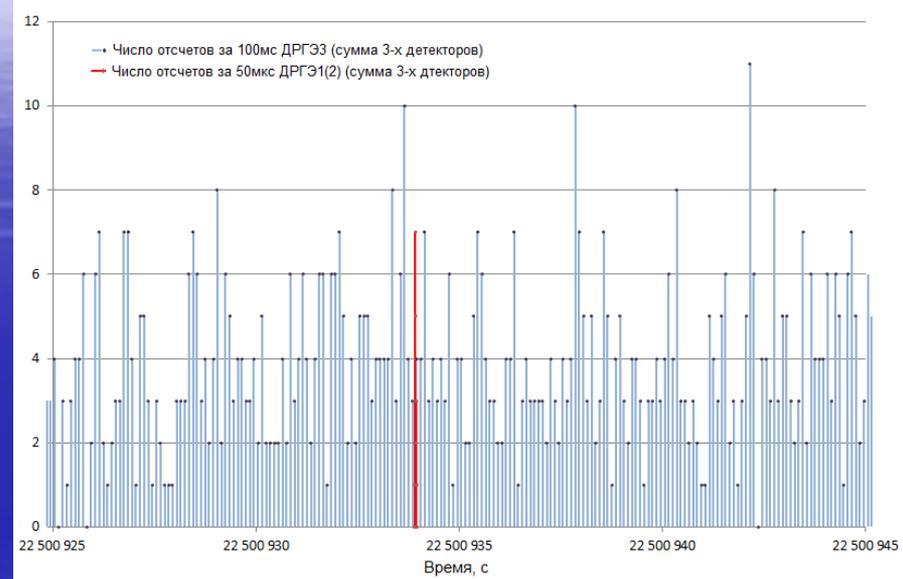


# TGF 2014-09-18-10-15-33

## DRGE-1(2)

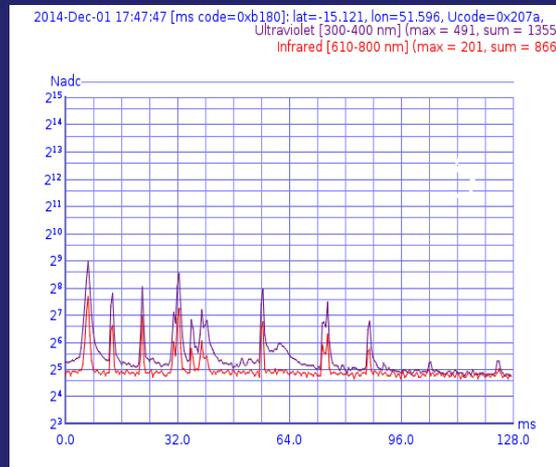
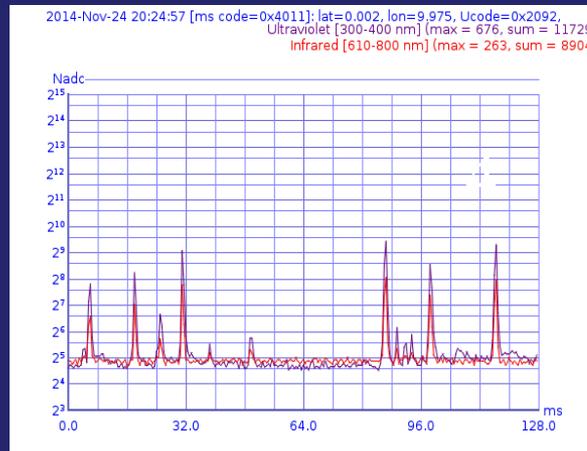
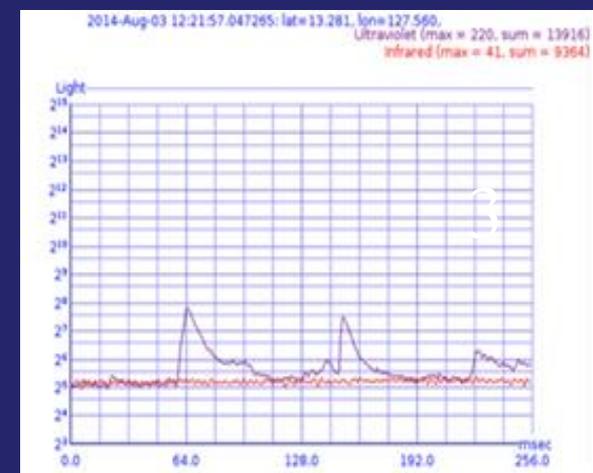
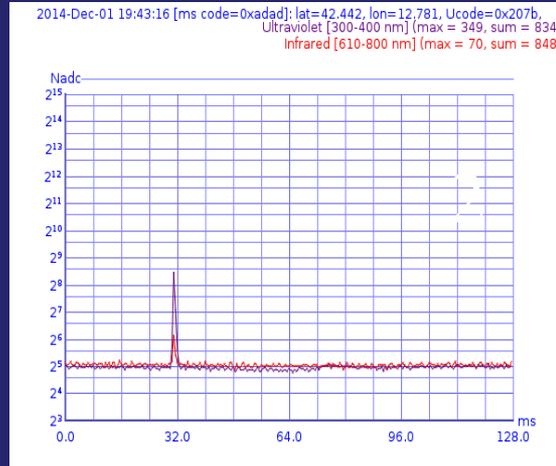
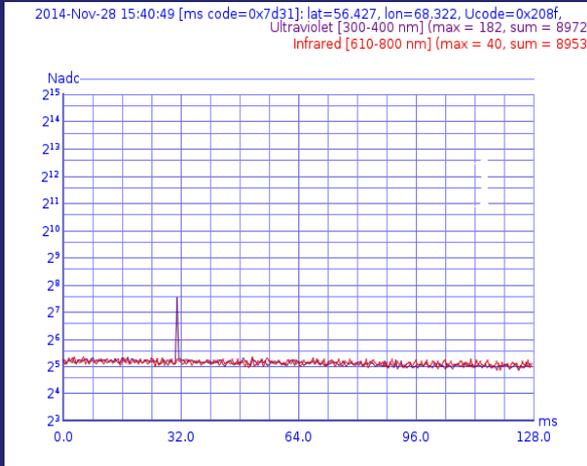


## DRGE-3



# Examples of oscillogram of five different types of flashes detected in experiment

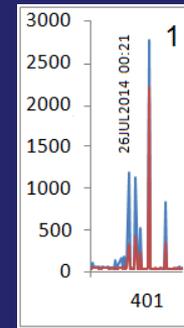
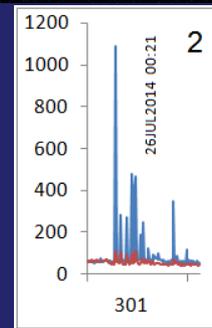
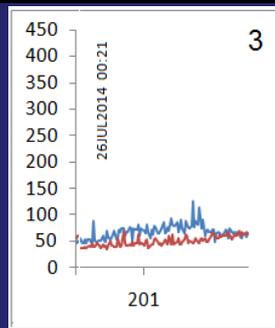
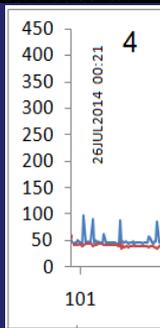
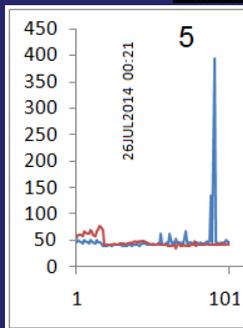
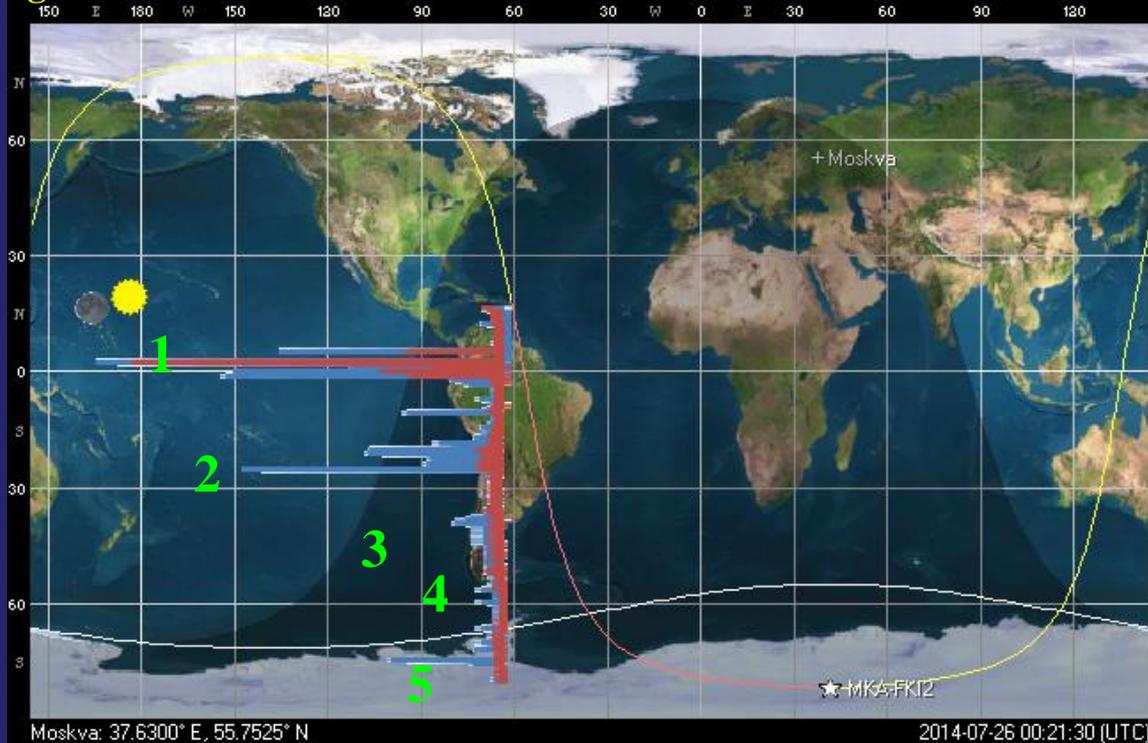
## variety of the flashes



1- low amplitude noise like signals.  
4 – UV & IR signals from lighting.

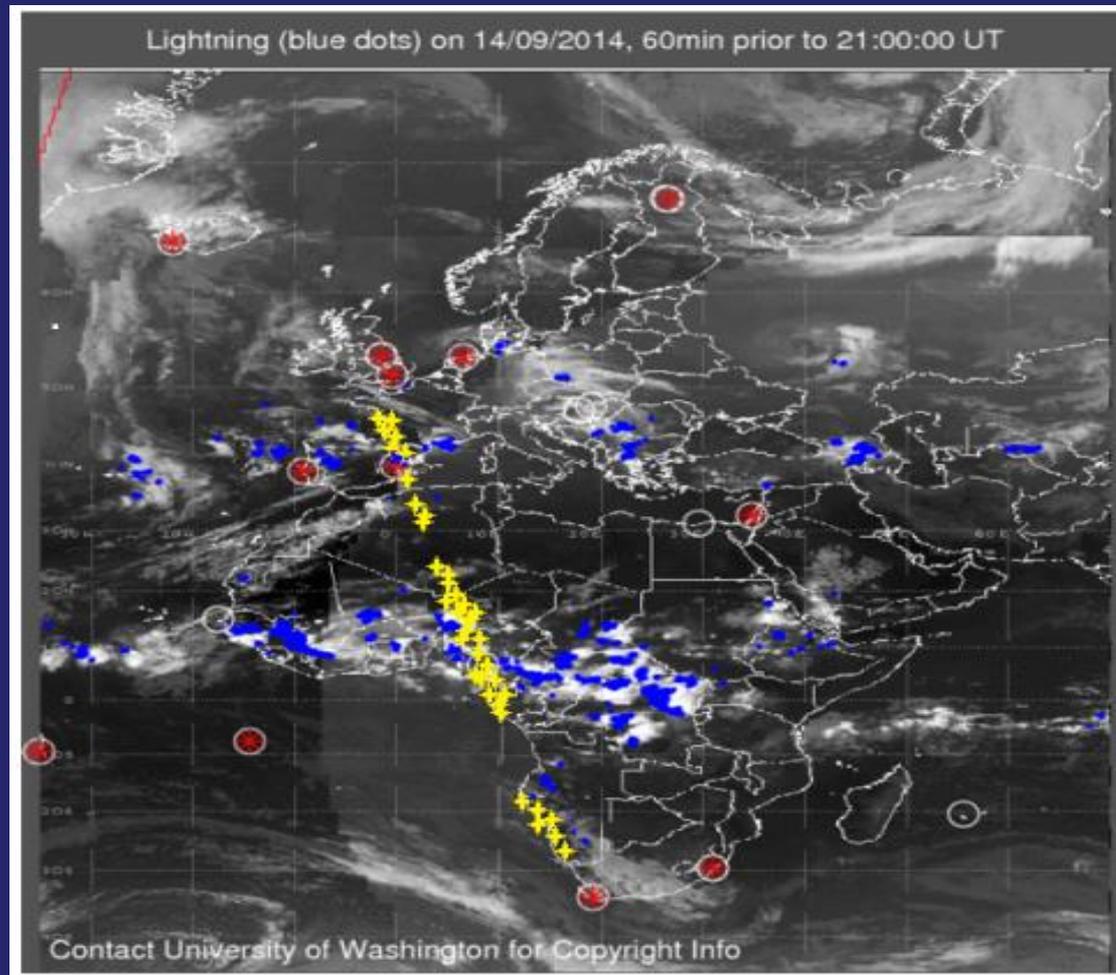
2- high latitudes flashes. 3- UV- blue flashes (UV/IR>10).  
5- mixed UV&IR signals from lightning and blue flash

Example of amplitude distribution of different flashes along satellite ground track on the map, which were observed on the night side of the orbit from 82 degrees south latitude to 16 degrees north latitude during 30 minutes. Part of flashes were observed in winter time in South hemisphere

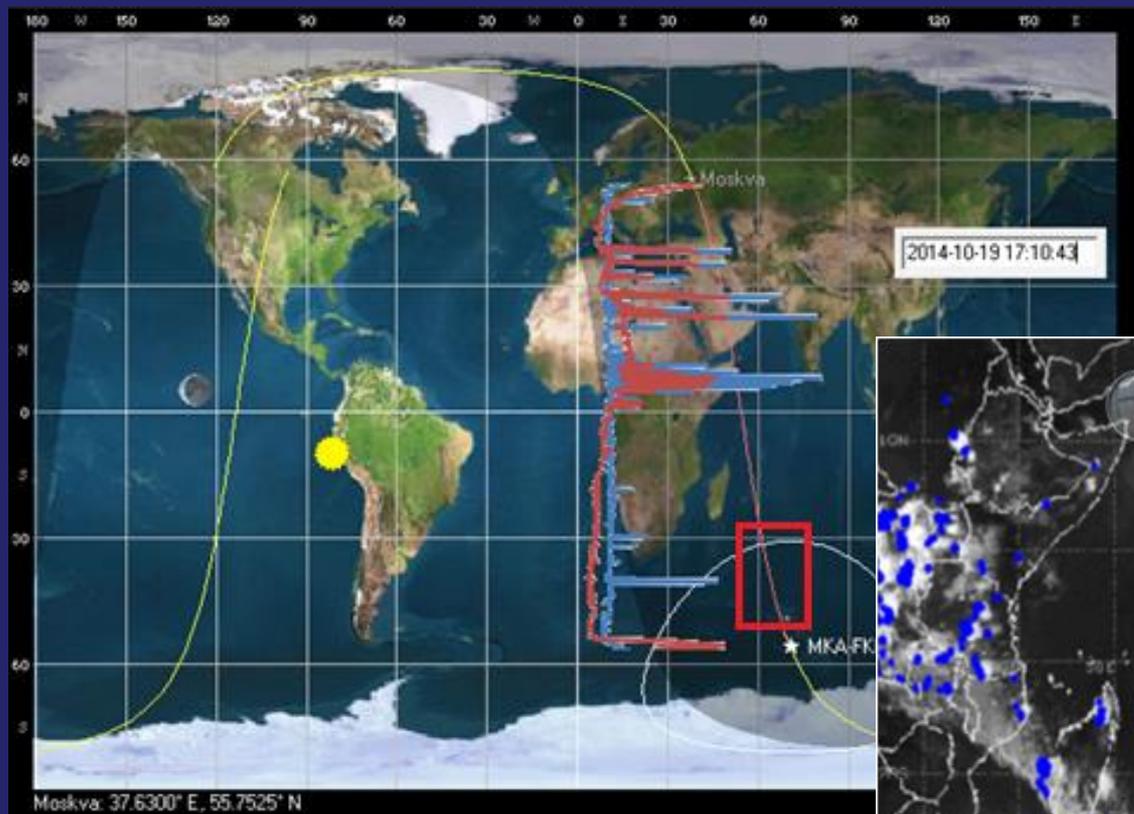


1 – UV - IR lightning flashes signals. 2- UV- blue flashes, UV/IR>10.  
 3- light glow produced by SAA particles in detector optical parts  
 4- low value noise like signals. 5- high latitudes flashes

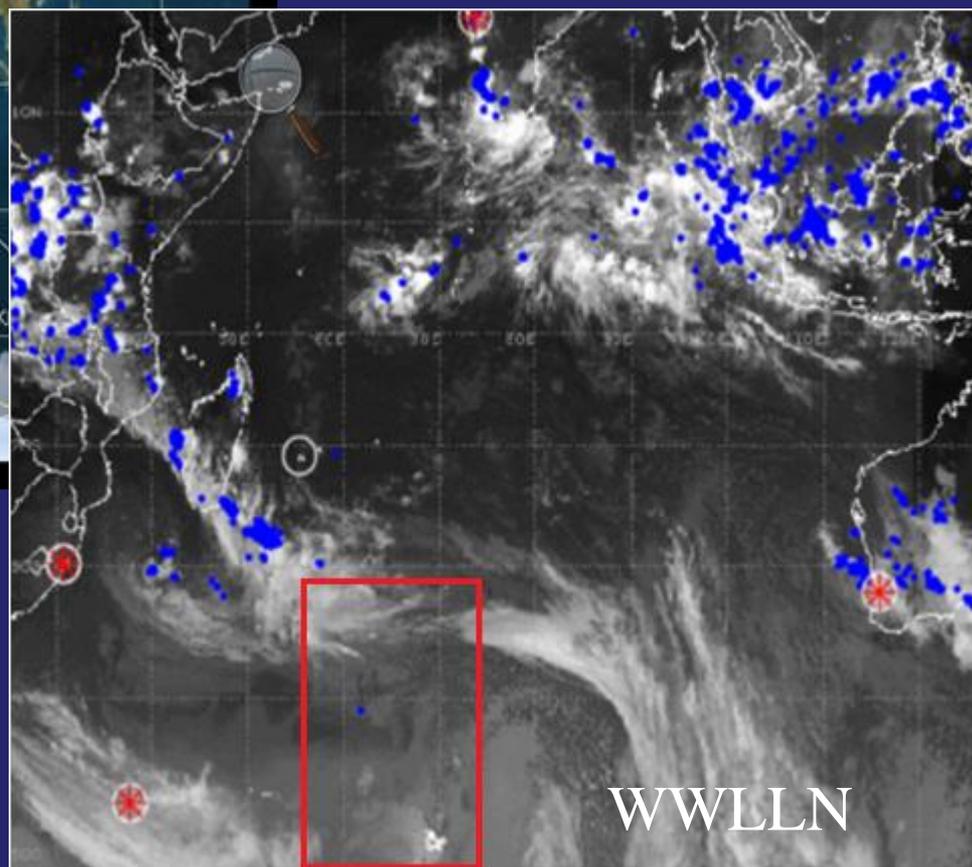
# 'Series' of flashes detected above Africa during one orbit



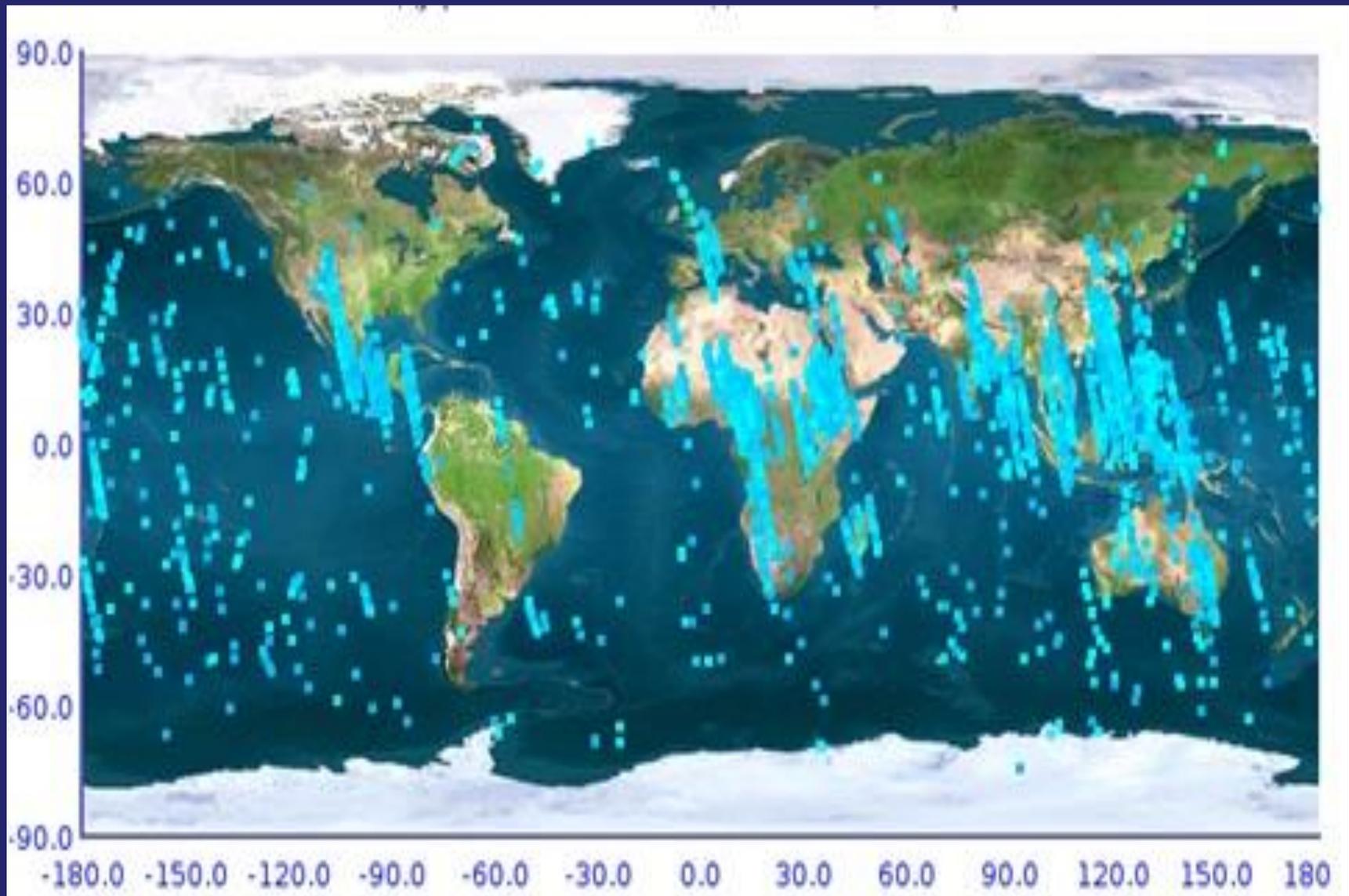
# Example of events detected in cloudless region in winter time



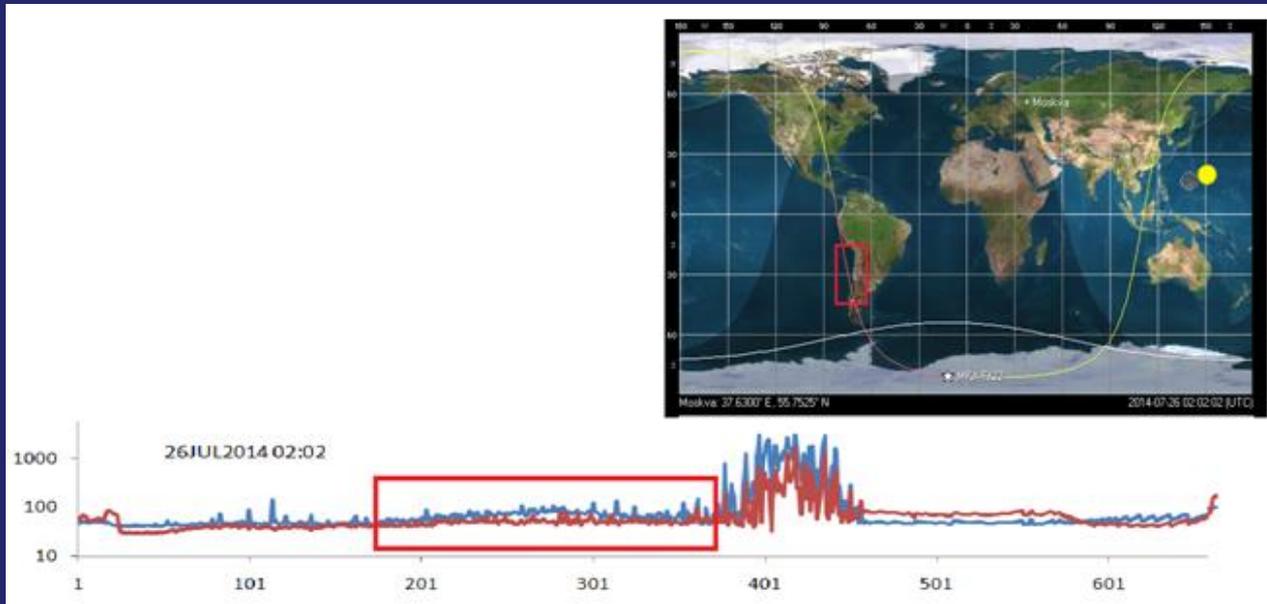
at the same time in the same region there were not detected thunderstorms



# Global distribution of detected flashes

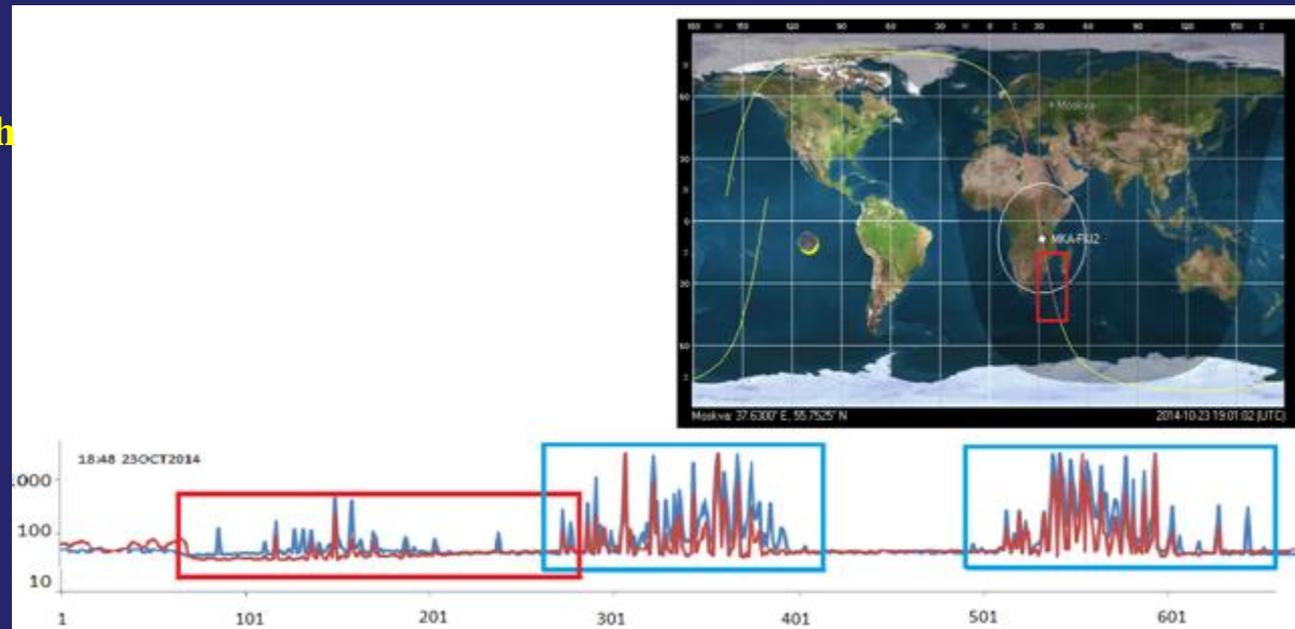


# Example of some differences of the signals recorded in SAA and to the south from the East coast of Africa

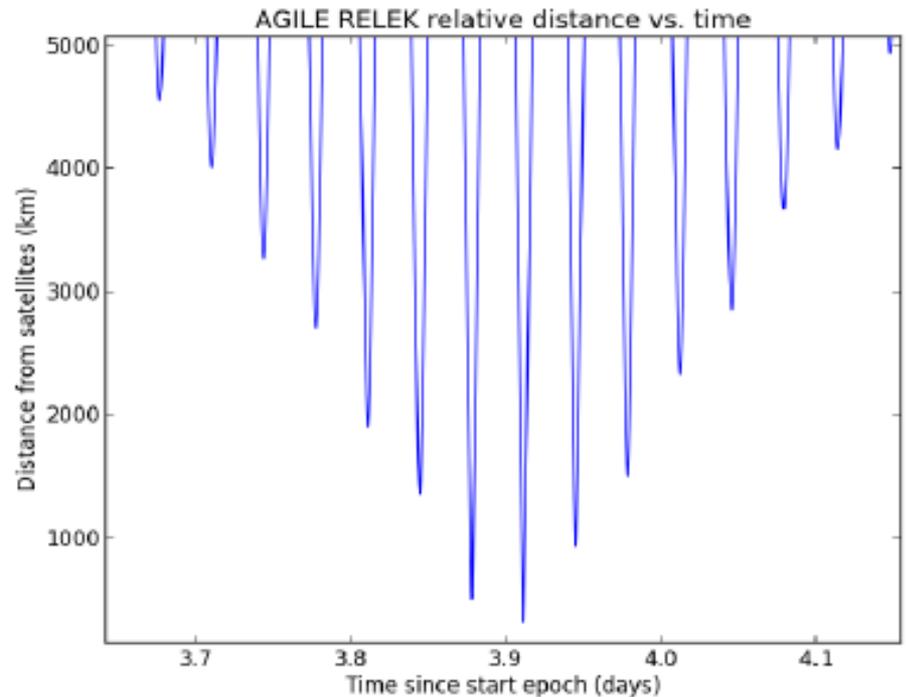
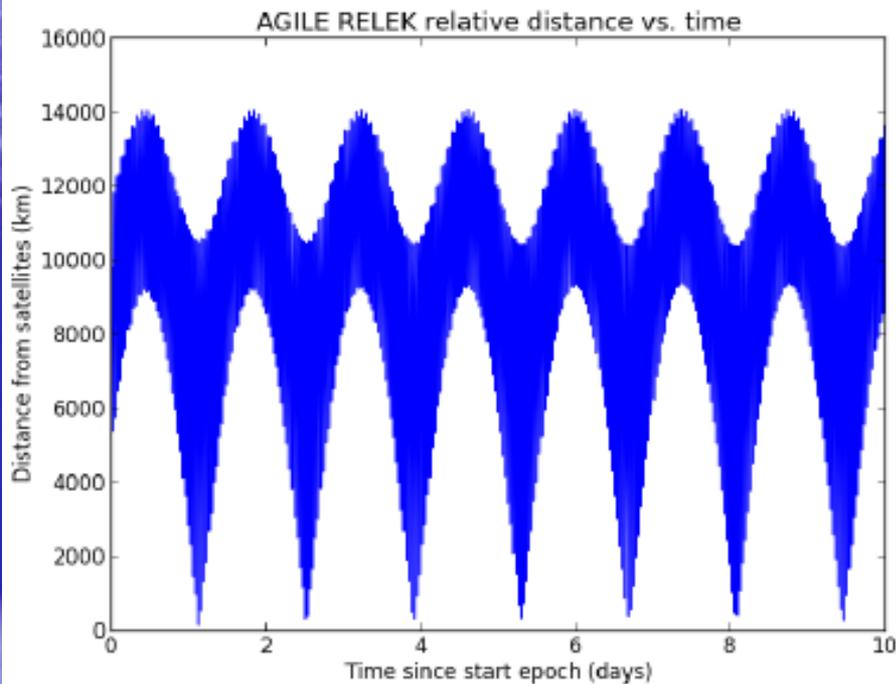


Signals in SAA have not clearly distinguishable peaks

Signals to the East from South Coast of Africa have clearly distinguishable peaks in the presence of charged particles and gamma rays.



# AGILE – RELEK minimum distance



- AGILE and RELEK get to closest distance about once every 1.3 days

# Close passes between 10 – 20 Sept. 2014

Посмотреть вложенных файлов

Date	Start time	Stop time	Longitude (°)	Latitude (°)	Minimum distance (km)	Good / bad
11/09/14	02:03:30	02:03:50	99.4	2.4	988	✘
11/09/14	02:50:50	02:53:30	-87.8	-2.3	154	✔
11/09/14	03:39:20	03:41:30	83.1	2.3	551	✘
12/09/14	11:56:50	11:59:20	134.7	-2.1	322	✔
12/09/14	12:45:10	12:47:40	-54.4	2.1	405	✔
13/09/14	21:02:50	21:05:10	-3.4	-1.9	513	✘
13/09/14	21:51:00	21:53:40	168.2	1.8	323	✘
13/09/14	22:40:30	22:41:20	-19.0	-1.6	938	✘
15/09/14	06:09:00	06:10:50	-141.3	-1.5	701	✘
15/09/14	06:57:00	06:59:40	30.9	1.4	330	✔
15/09/14	07:45:50	07:47:40	-156.3	-1.2	755	✘
16/09/14	15:15:10	15:16:30	81.5	-1.1	874	✘
16/09/14	16:02:50	16:05:30	-106.9	1.0	393	✘
16/09/14	16:51:30	16:53:50	65.9	-0.8	584	✘
18/09/14	01:08:50	01:11:20	116.0	0.5	491	✔
18/09/14	01:57:20	01:59:50	-71.8	-0.3	427	✔
19/09/14	10:14:50	10:17:10	-21.6	0.1	597	✘
19/09/14	11:03:10	11:05:50	151.1	0.2	281	✘
19/09/14	11:52:30	11:53:10	-37.2	-0.3	960	✘

Time window when  
AGILE and RELEK  
distance is less than  
1000 km (typically 2-3

• Select passages over  
continental areas  
with enhanced TGF  
production

• Select passes with  
minimum distance less  
than 600 km

Thank You!