Cosmic Gamma Ray Burst Observations in Lomonosov and Vernov Missions

“LOMONOSOV” SPACE MISSION

Launch date – 28/04/2016

Scientific objectives:

- Study of ultra-high energy cosmic rays
- phenomena in hard x-rays and soft gamma-rays (0.01-3.0 MeV)
- Search and detection of optical transients accompanying gamma-ray bursts
- study of transient luminosity events in the Earth atmosphere
- magnetosphere physics research

Parameters of "Lomonosov" mission:

Orbit: ~500 km, polar

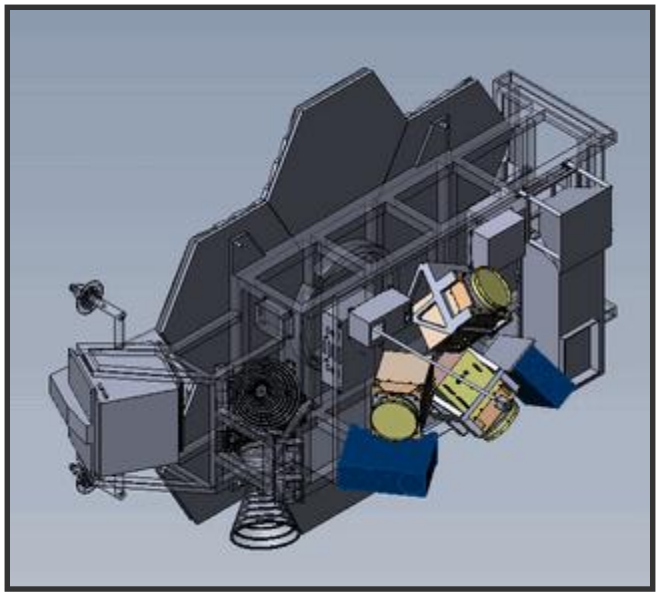
Mass: spacecraft ~600kg,

payload ~150kg

Total power ~ 300W

Data amount ~3Gb/day

Launch date – 28/04/2016



Complex of instruments for GRB studying:

- **BDRG – gamma spectrometer**
- **SHOK – wide field optical camera**
- **UFFO – coding mask x-ray telescope + UV telescope**

Multiwavelength study of GRB prompt emission:

- **Continuous recording of readings of wide field optical cameras (SHOK)**
- **Fast pointing of optical and UV telescope using its moving mirror (UFFO).**

BDRG + SHOK

X-ray, Gamma measurements, Trigger formation for GRB.

Optical cameras for GRB's, measurements

- **Composition of scientific equipment:**
  - **Three identic gamma-detectors with 90^0 between axes;**
  - **48 mm diameter camera lenses (2 pcs.)**
  - **Large-format CCD camera 12 megapixel (2 pcs.), 24x36 mm size; located on the focal plate of the objective**
  - **Electronics units for collection and storage of data from gamma-detectors and optic cameras, and for communication of these devices and onboard satellite systems.**

Instrument BDRG onboard "Lomonosov"

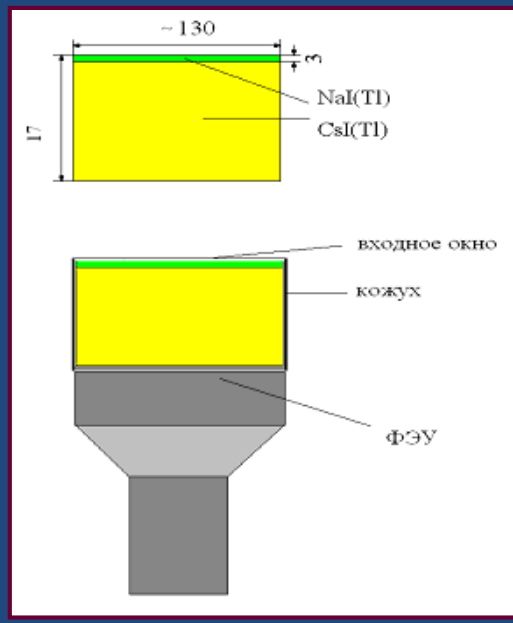
BDRG instrument consists of 3 similar detector boxes, connected to data analysis box.

Parameters of each BDRG box:

Detector: 3mm NaI(Tl) /17 mm CsI(Tl)
Sensitive area: ∅130mm
Energy range: 0.01 – 3 MeV
Mass: 5.5 kg
Power consumption of detector box: <3W

Power consumption of data analysis box ~15W

Sensitivity - ~10^{-7} erg/sm^2
GRB localization- ~2° for bright GRBs



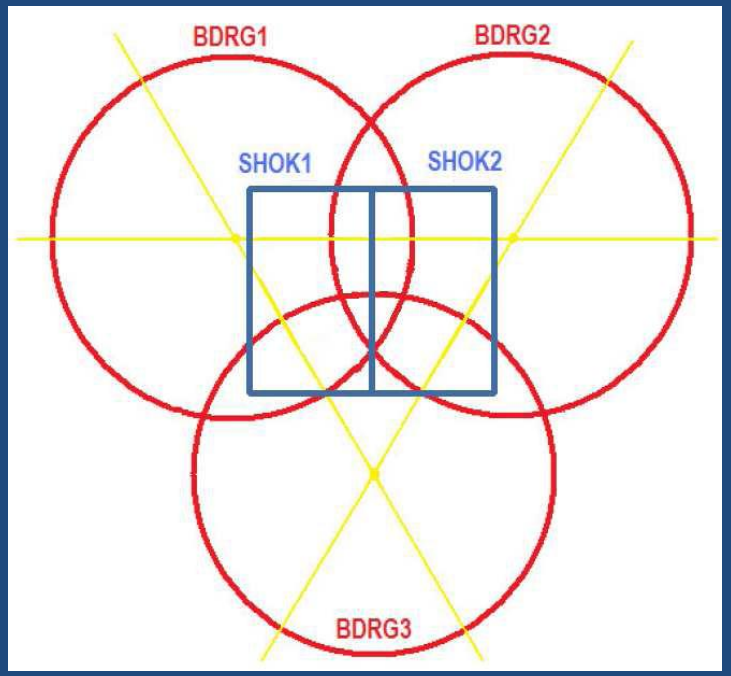
Goals of BDRG:

1. Production of GRB trigger
2. Spectral measurements and timing of GRB in hard x-ray and gamma range
3. Estimation of GRB coordinates
4. X-ray and gamma-ray monitoring

Production of GRB trigger

Axes of 3 BDRG detectors will be shifted for 90° from each other.

Cosine angular diagram of detectors (FWHM ~60°) allows to determine the coordinates of GRB with accuracy about several degrees for bright GRBs.



Trigger logics

Main mode: BDRG1 → SHOK1 (any or if source in camera FOV)
BDRG2 → SHOK2 (any or if source in camera FOV)

Redundant mode: BDRG1 → SHOK1, SHOK2
BDRG2 → SHOK1, SHOK2
BDRG3 → SHOK1, SHOK2
Threshold levels will increase

For any trigger the burst mode information will be collected from all BDRG detectors

Alert levels of trigger

- **Internal trigger: BDRG DATA**
- **Trigger for SHOCK IMAGES FIXATION and UFFO FAST ORIENTATION**
- **Trigger for alerts via GlobalStar modem**

Structure and amount of information from BDRG

3 detector boxes, preliminary

Type of frame	Time interval between frames	Day (burst) amount, Mb
CONTINUOUS (180 MB PER DAY)		
Monitoring	100ms	87
Spectrum	15s	48
Event mode	15s	50
BURST MODE FOR FAST/SLOW BURST (5 MB PER BURST)		
Monitoring	1-10 ms	1.6
Spectrum	1-10 s	1.6
Event mode	Not regular, up to 10^6 events	1.6

ABILITY TO GRB DETECTION

SENSITIVITY - ~10^{-7} erg/sm^2

LOCALIZATION IN GAMMA-RAYS- ~$2^o \times 2^o$

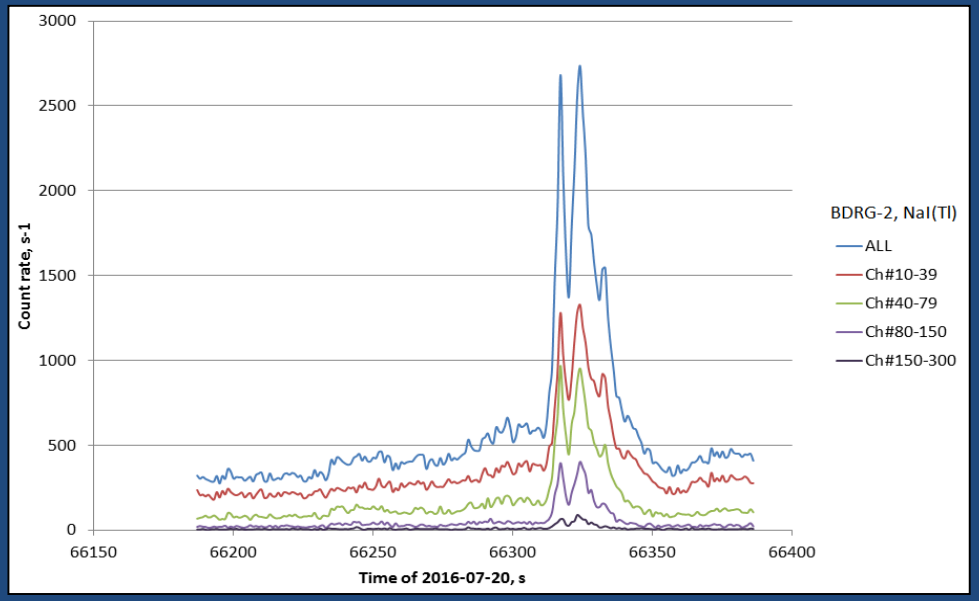
TEMPORAL RESOLUTION

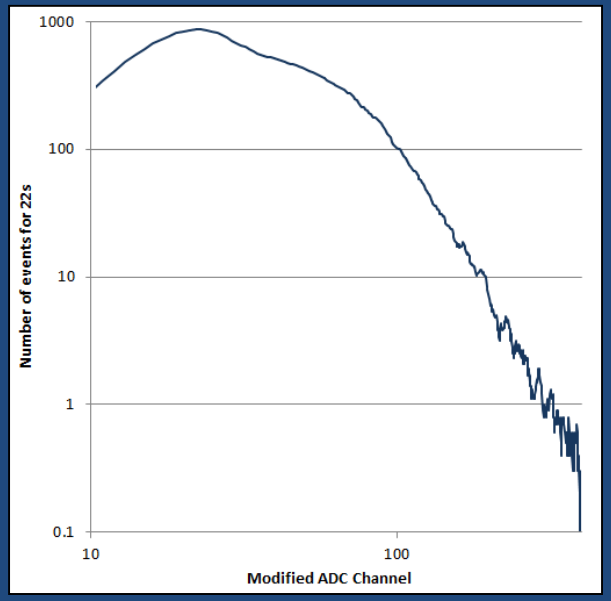
GAMMA-RAY ~1 ms

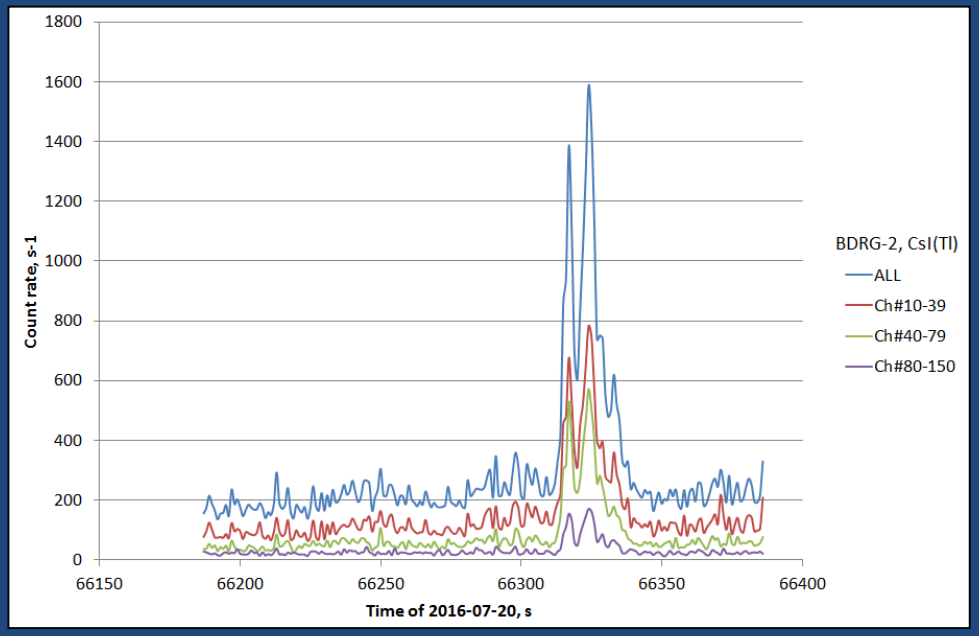
OPTICS ~0.2 s

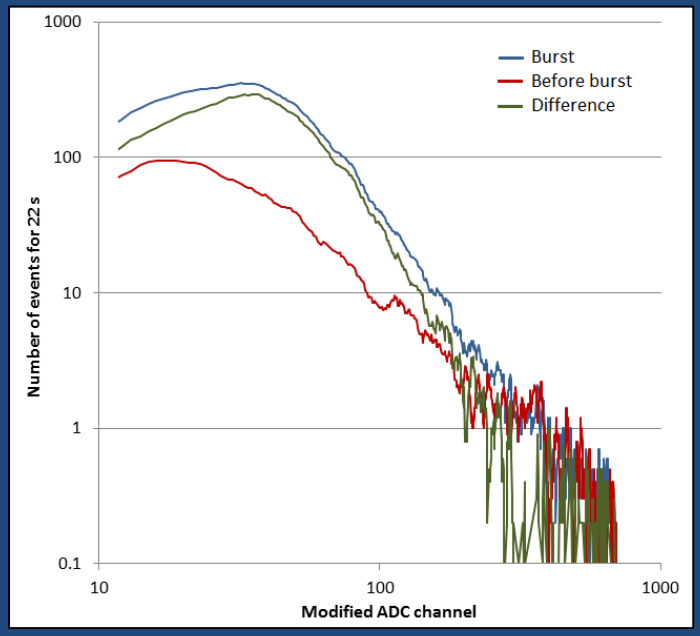
EXPECTED NUMBER OF GRBs WITH VISIBLE OPTICAL BRIGHTNESS LESS THAN 9 st.mag. – ~10 EVENTS PER YEAR.

Detailed study of GRB 2016-07-20



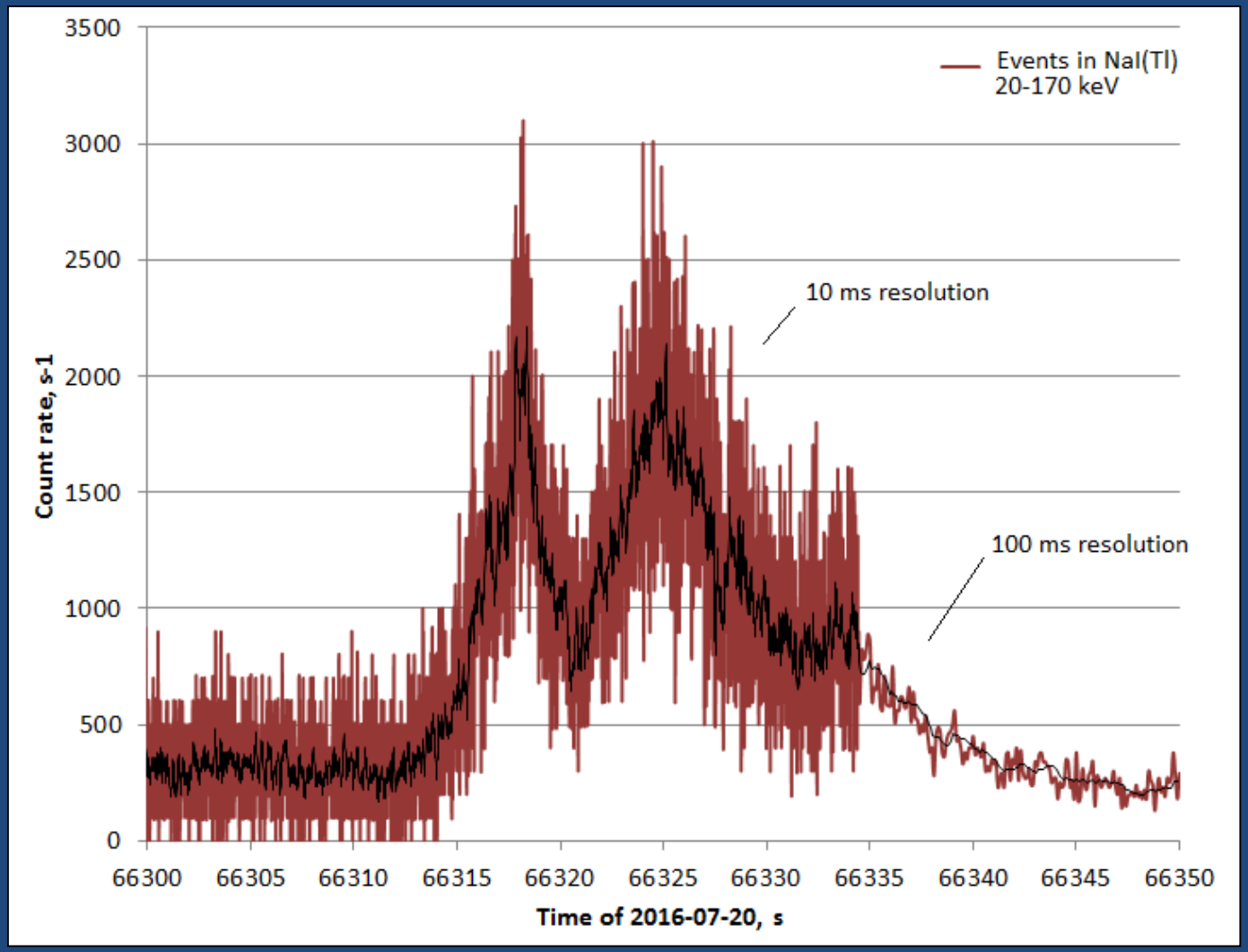




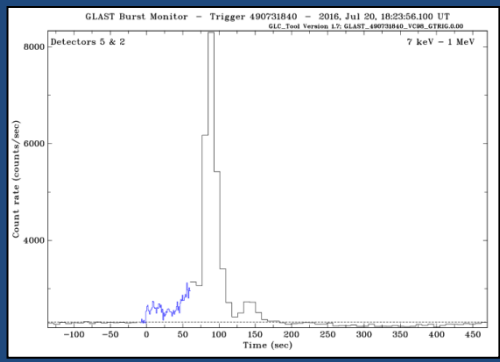


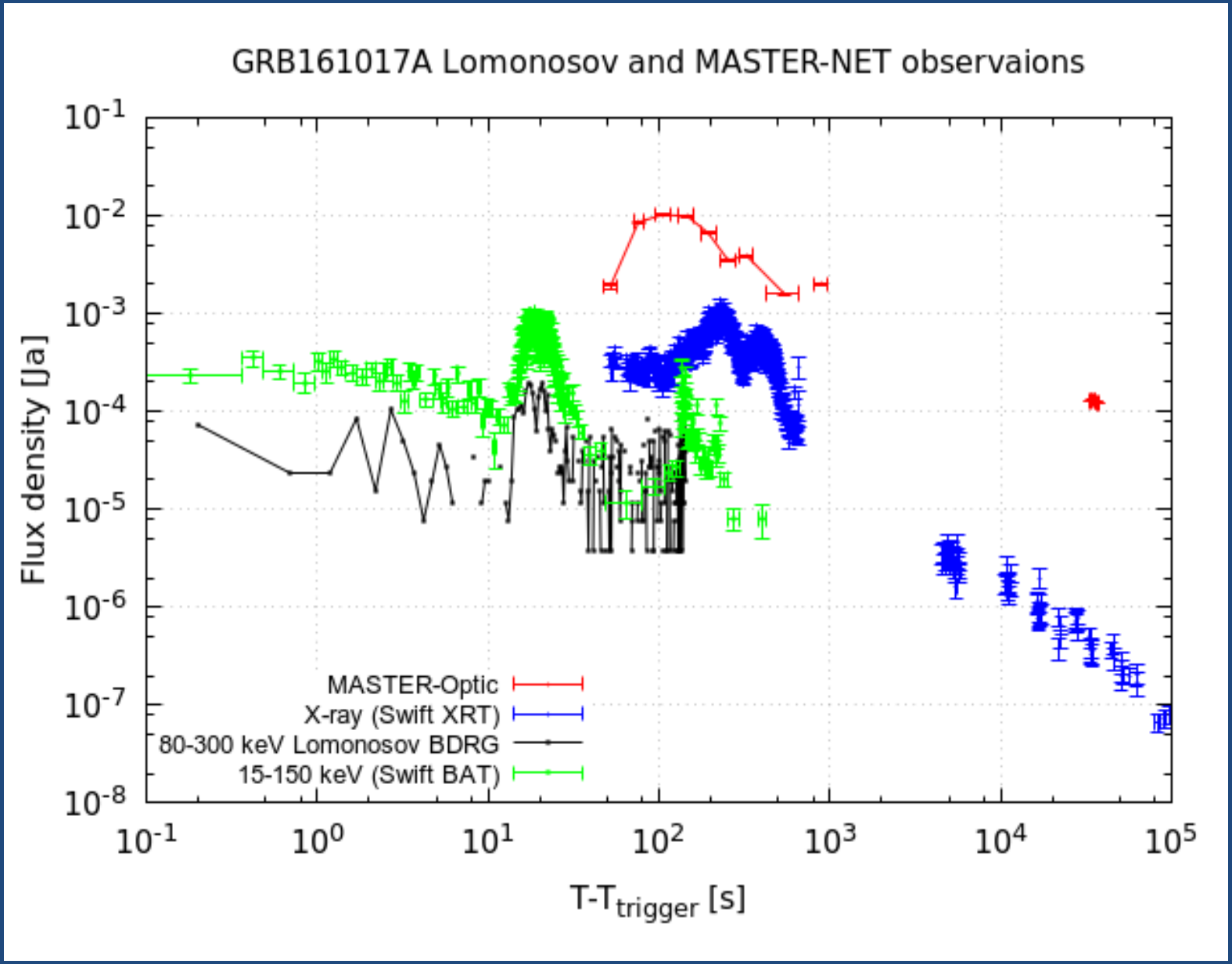
Detailed study of GRB 2016-07-20

BDRG-2/Lomonosov

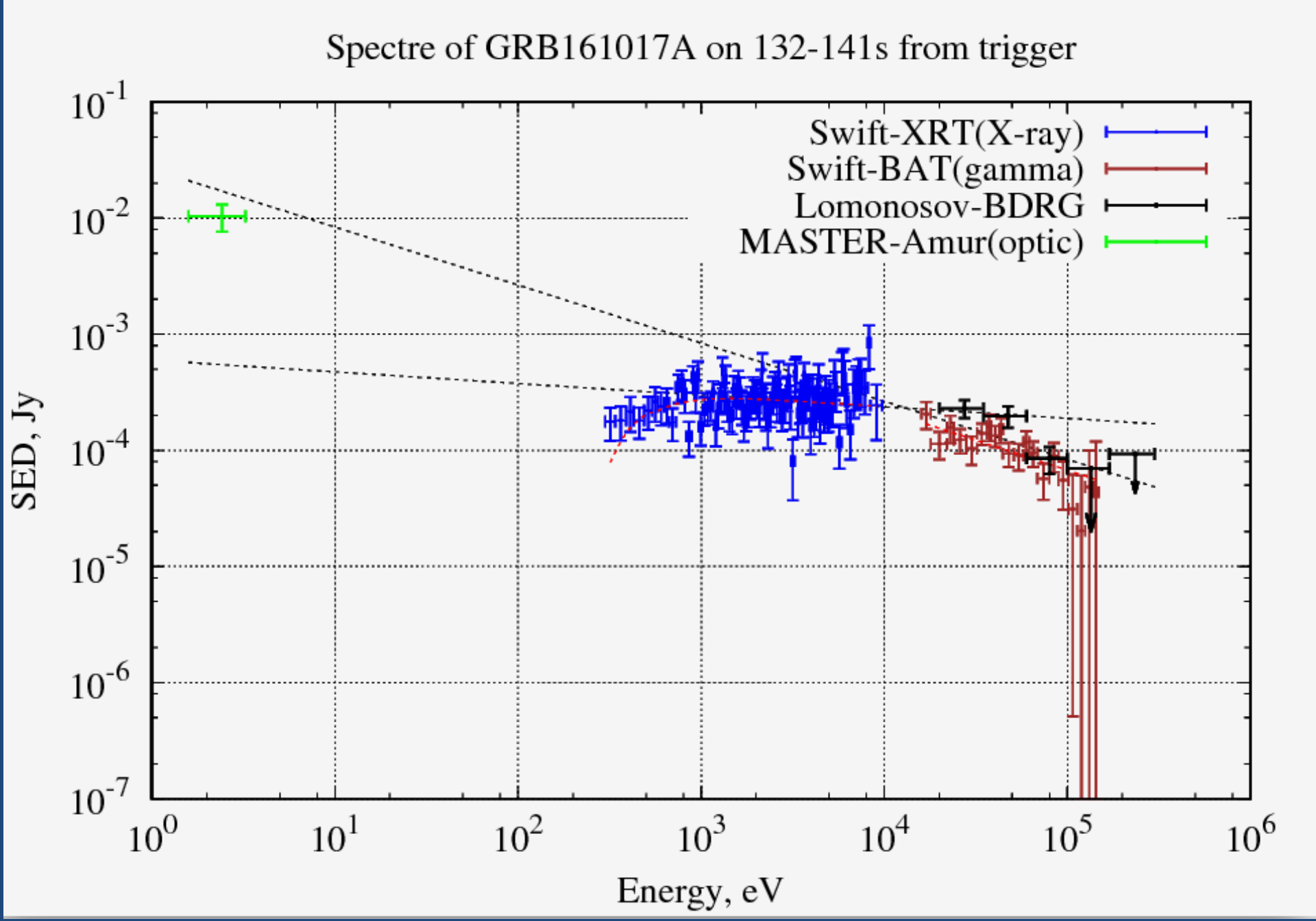


GBM/Fermi



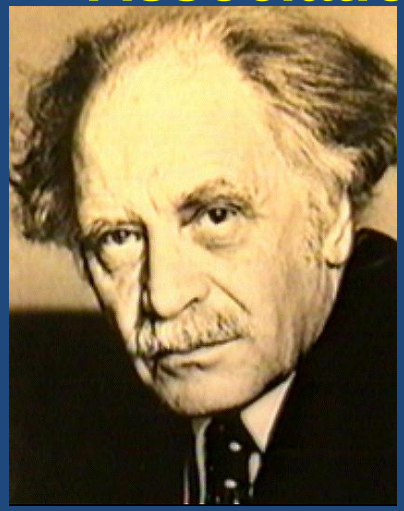


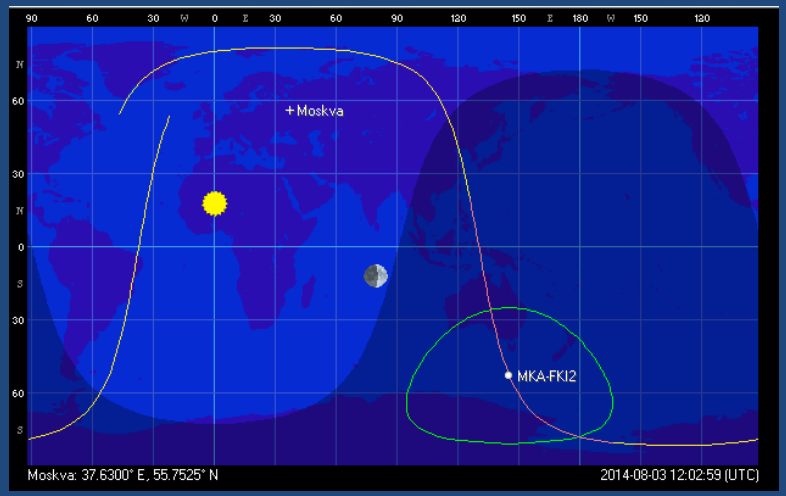
Common Lomonosov, MASTER-net and Swift observations of GRB 161017A in broad bands from optics to gamma.



Common Lomonosov, MASTER and Swift spectrum during second re-brightening.

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

DRGE design

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

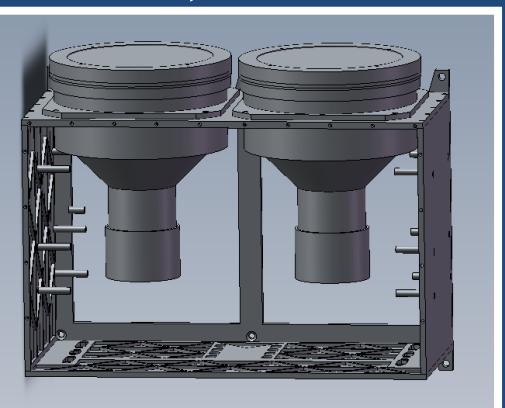
Two parts of the instrument

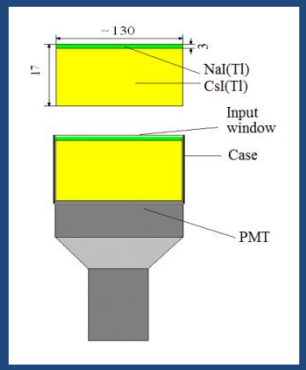
DRGE-1, DRGE-2

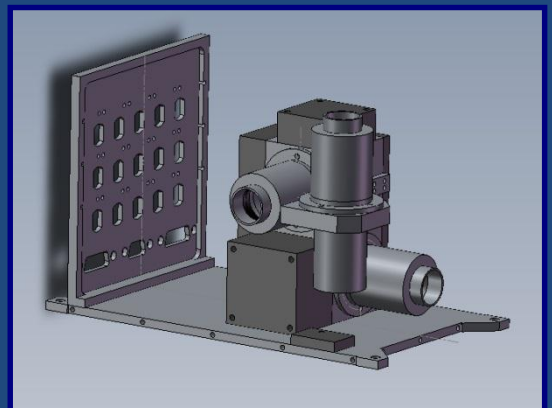
X-rays and gammas in 0.01-3 MeV energy range from atmospheric discharges with high time resolution (up to 15us)

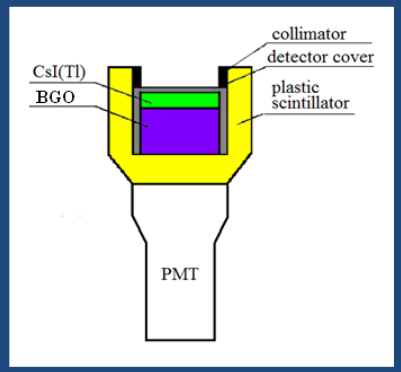
DRGE-3

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









DRGE-1 and DRGE-2

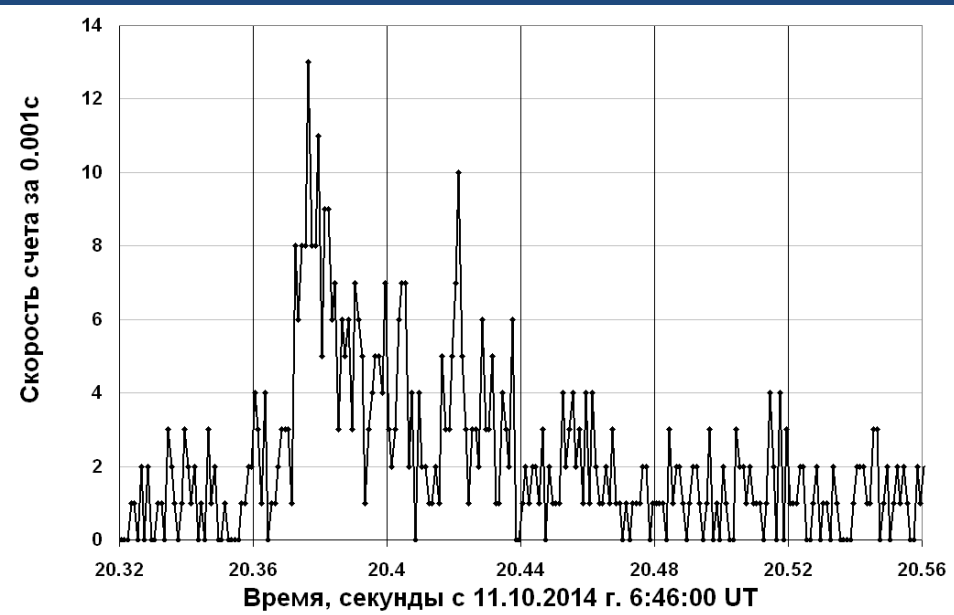
Physical parameters:

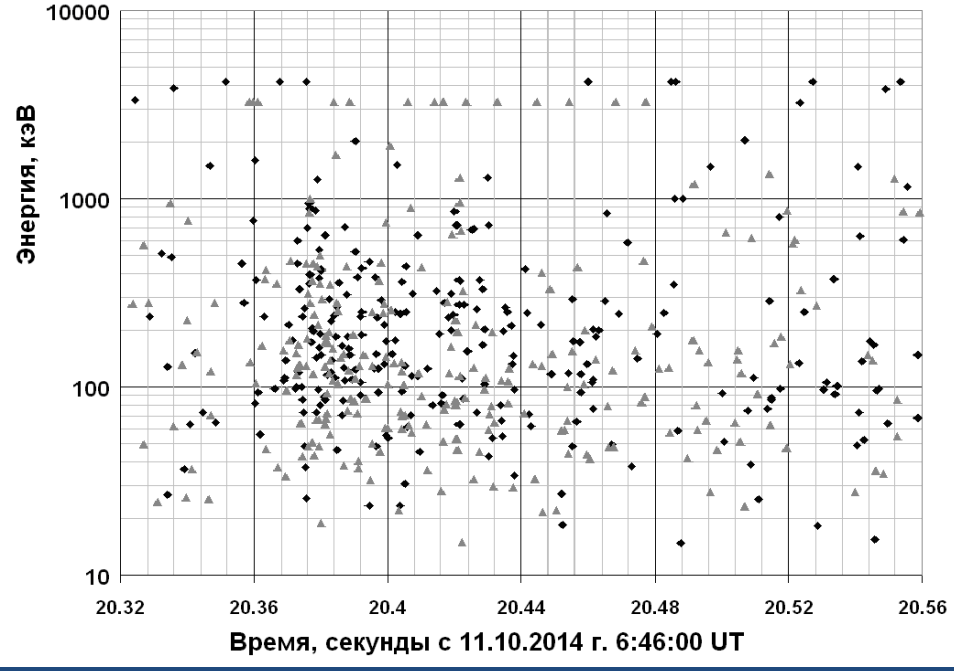
Energy range	0.01-3.0 MeV,
Effective area	~120 cm^2 each (total ~500 cm^2)
Time resolution in event mode	~15 mcs
Time resolution in monitoring mode	1 s

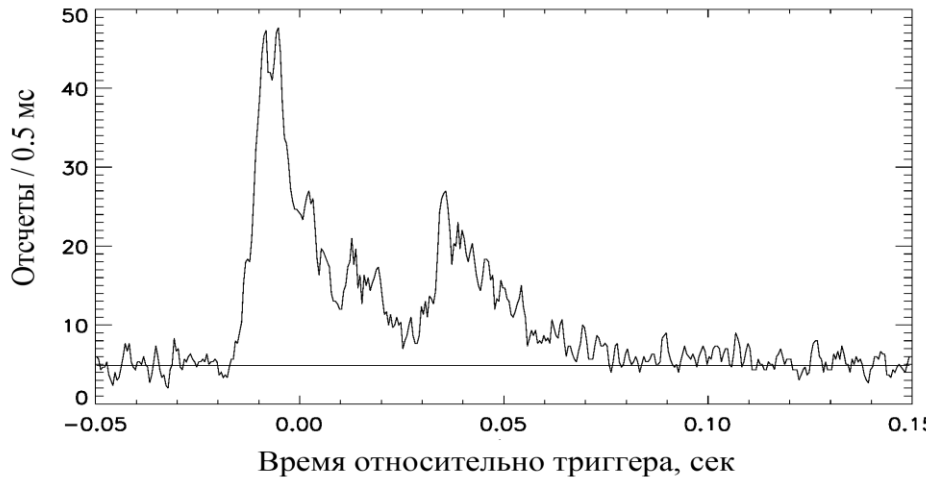
Technical parameters (for DRGE-1 or DRGE-2) :

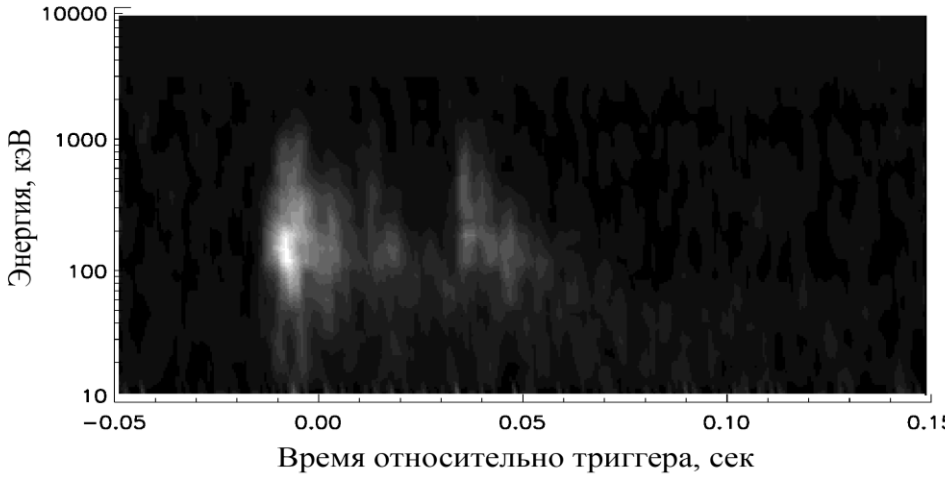
Mass	**10.4 kg**
Size	**360x300x180 mm;**

Power consumption at 27 V < 9 W.


Скорость счета за 0.001с
14
12
10
8
6
4
2
0
20.32
20.36
20.4
20.44
20.48
20.52
20.56
Время, секунды с 11.10.2014 г. 6:46:00 UT


Энергия, кэВ
10000
1000
100
10
20.32
20.36
20.4
20.44
20.48
20.52
20.56
Время, секунды с 11.10.2014 г. 6:46:00 UT

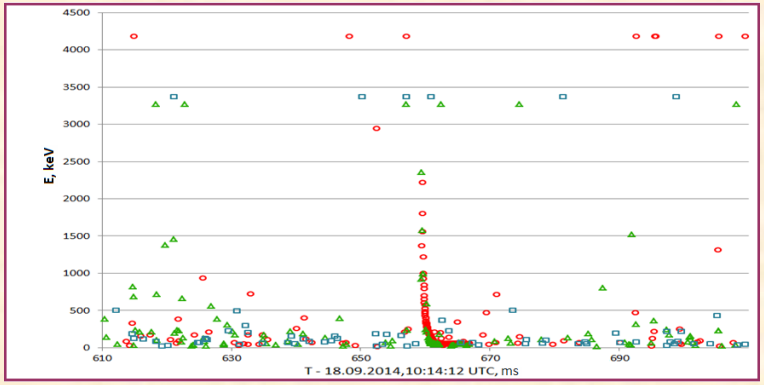

Отсчеты / 0.5 мс
50
40
30
20
10
0
−0.05
0.00
0.05
0.10
0.15
Время относительно триггера, сек


Энергия, кэВ
10000
1000
100
10
−0.05
0.00
0.05
0.10
0.15
Время относительно триггера, сек

Methods of TGF search in “RELEC” data

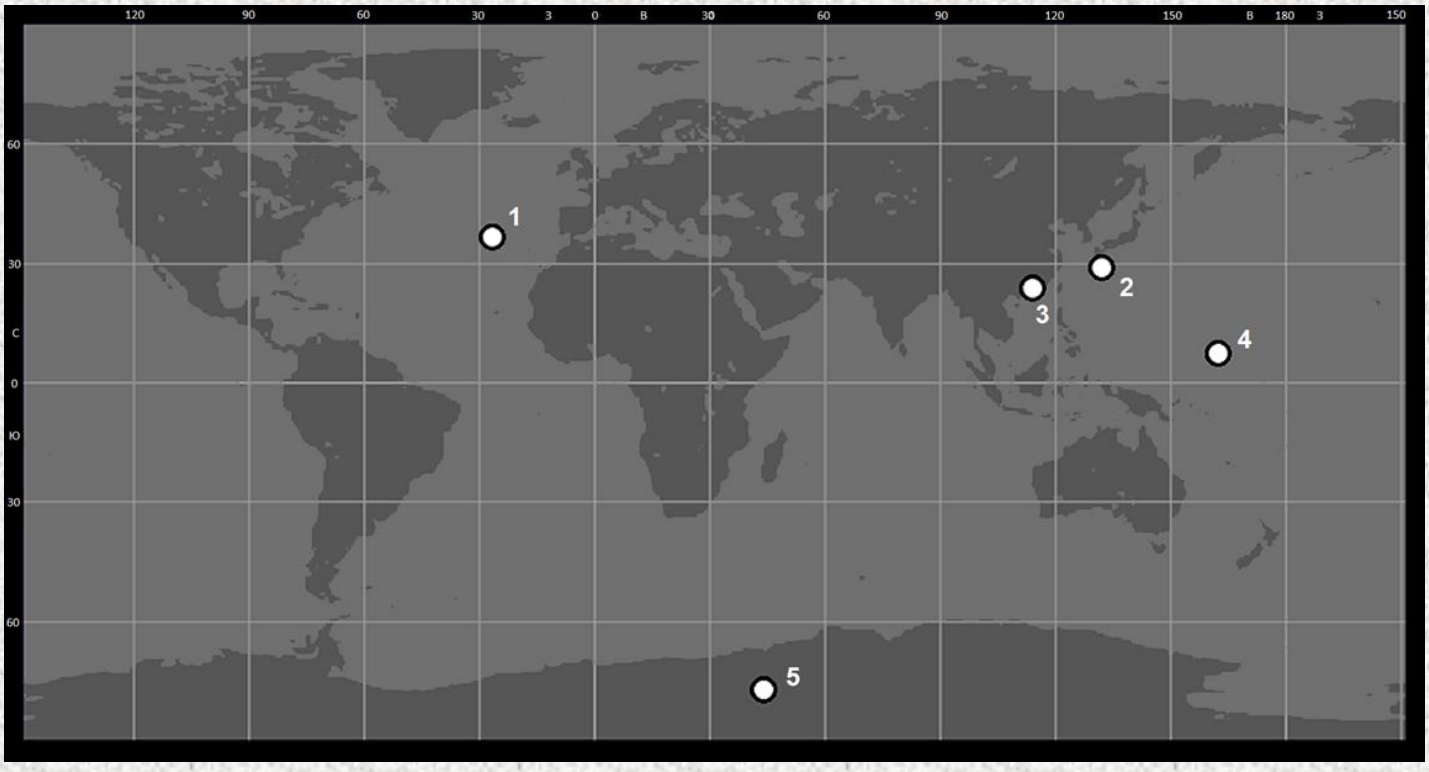
- Since atmospheric gamma-ray flashes are characterized by small durations (<1 ms) “event” frame data were used for their search. In Equatorial regions the record of all the events in the detector was made, while at high latitudes only about ~20% of events was fixed in event mode.
- Since the spectra of TGFs are hard only the events with energy over 400 keV were considered in the search algorithm.
- The requirement of coincident flash in two or more detectors was used. The candidate must satisfy one of two conditions:
  1. registration at least 5 gamma-quanta by at least two detectors in a time interval of 1 ms (12σ level for the equator)
  2. registration at least 3 gamma-quanta by at least three in a time interval of 1 ms (7σ level for the equator)
- To suppress imitations of bursts by cosmic rays an additional requirement excluding sequences when points on the graph of "energy – duration" shows a monotonous decline of the amplitude were excluded.

Example of TGF imitation by cosmic-ray proton with energy ~15 GeV



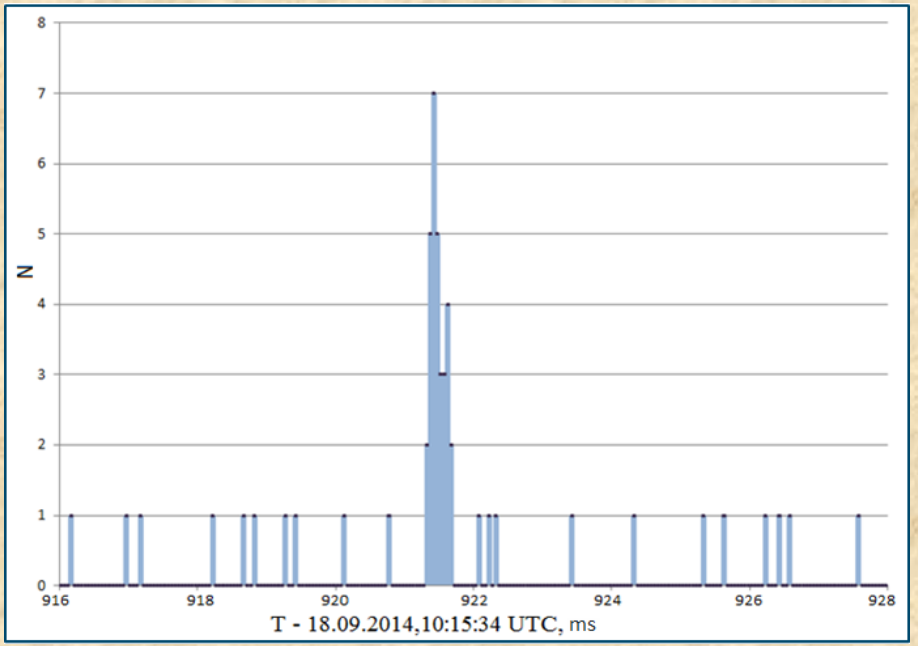
The results of TGF search

N	Time, UTC	Detectors 1234	Latitude, longitude	Duration (mcs)	Number of quanta	Notes
1	07.08.2014, 22:20:55	++-+	26.2W, 35.6N	800	10	TGF
2	08.08.2014, 00:31:07	+-++	132.04E, 29.4N	1000	12	candidate
3	16.08.2014, 13:06:55	0+++	114.7E, 24.2N	800	10	candidate
4	18.09.2014, 10:15:34	+-0+	160.4E, 8.3N	400	31	TGF
5	02.11.2014, 03:34:14	+0++	40.7E, 77.6S	2300	18	candidate

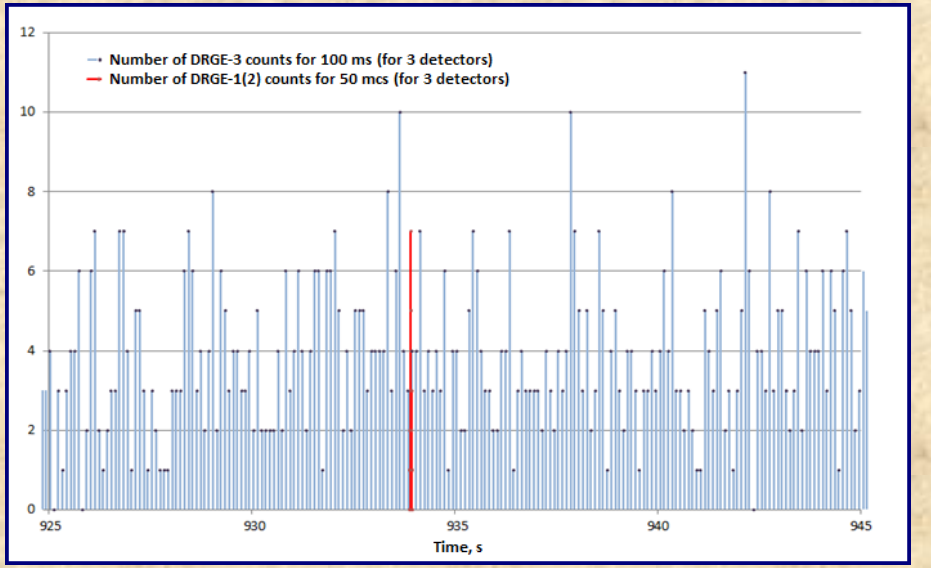


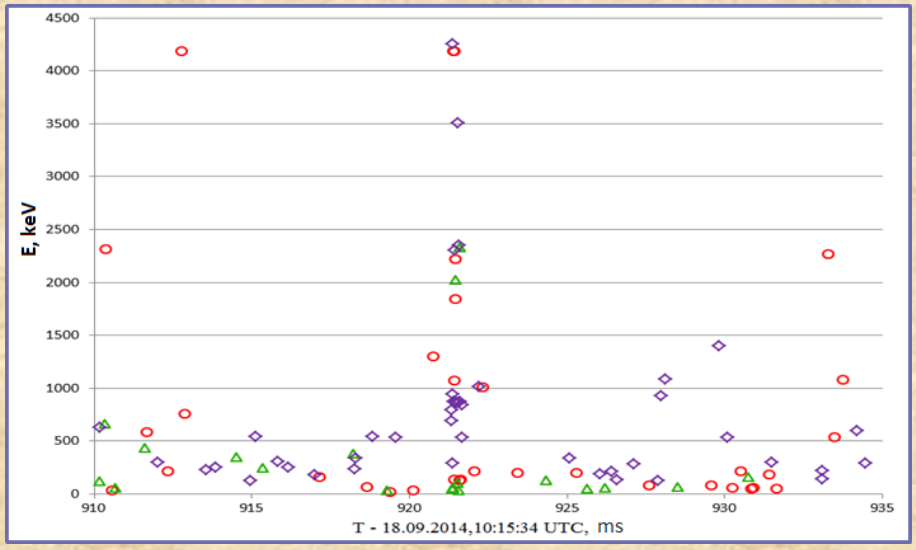
TGF 2014-09-18-10-15-34

Gamma-radiation in DRGE-1(2)

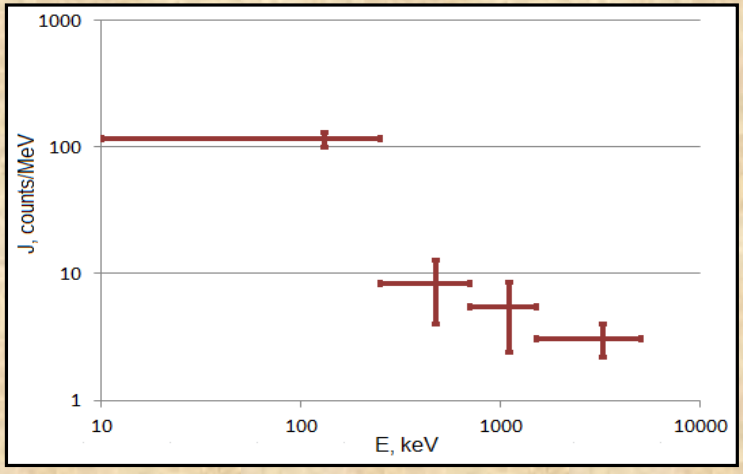


Electrons in DRGE-3





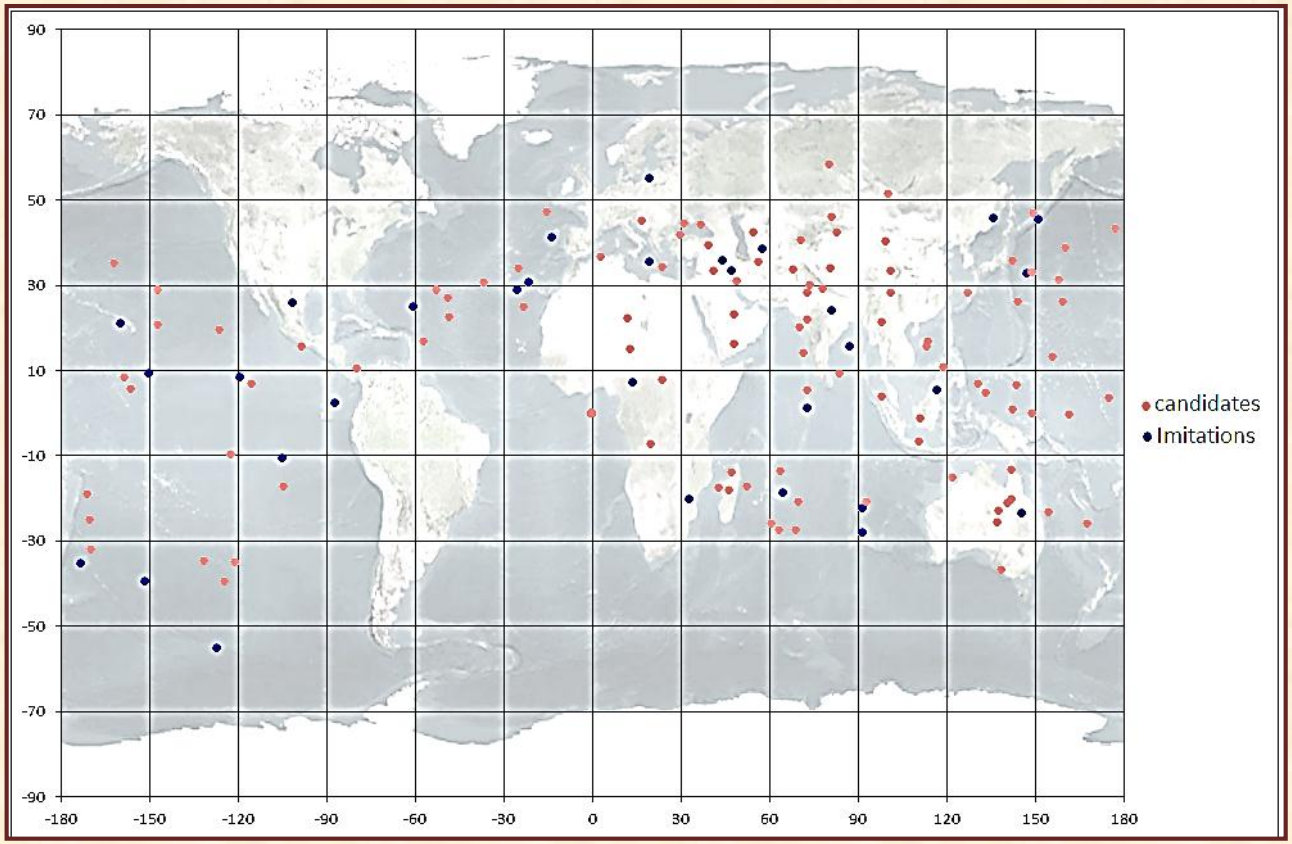
Energy loss spectrum in DRGE-1(2)



Next step of TGF search

New method of cleaning data from TGF imitations by particles, based on more accurate analysis of the time profile of candidate was realized. It allows to conduct a search of TGF according to the individual detectors (without coincidence), increasing the analyzed observation period of almost 2 times

Map of 111 new TGF candidates from detector DRGE1-1 for 294.5 h out of ERBs and polar caps



Search of TGFs in BDRG/Lomonosov data

1) Triggering for TGFs – 10 ms trigger, coincidence of at least 2 detectors, energy range E>300 keV at the level >5 events, 10 sigma. Detailed event-moda data and 1 ms monitoring are formed

2) Off-line search in recorded event-mode data – will be realized soon. The instrument must be reconfigured for data amount optimization. Now some amount of event-mode data from triggers is collected to start the search

Thank You!