Moscow State University Satellite “Mikhail Lomonosov” – the Multi-Purpose Observatory in Space. Technological Developments in Russia for JEM-EUSO Collaboration

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Abstract: The new mission “Mikhail Lomonosov” is dedicated to founder of Moscow State University M.V. Lomonosov. Its scientific program is devoted to extreme phenomena in the Universe (extreme energy cosmic rays EECR and gamma ray bursts GRB) and to study of phenomenon in near Earth space and upper atmosphere. The scientific payload consists of the fluorescence detector TUS for study EECR, GRB detectors measuring optical, X-ray and gamma ray radiation and other detectors described in the presentation. Mikhail Lomonosov instruments contain the parts (many-anode PM tubes, specific chips) developed for the JEM-EUSO mission which will be tested in space before use in large scale (thousands copies) in JEM-EUSO mission. TUS detector will provide first data on EECR events measured from space and is considered as “pathfinder” for JEM EUSO detector.

Keywords: Mikhail Lomonosov, Space Observatory, TUS, EECR

1 “Mikhail Lomonosov” general description

It is a medium scale satellite with full mass less than 400 Kg, platform mass 200 Kg and scientific payload 120 Kg. The payload consists of several detectors (figure 1) and information block. The detectors are:

- TUS (a box in focus of the mirror concentrator in figure 1) – UV telescope for measuring extreme energy cosmic ray particles.
- BDRG (shown in figure 2) – 3 identical detectors for measuring X-ray and gamma-ray fluxes and selection of GRB. Detector parameters: energy range – from 10 KeV to 3 MeV, time resolution – 100 µs, source sensitivity – up to \(10^{-7}\) Erg·sm\(^{-2}\), source angular resolution – 1–3°, field of view – 2π sr.
- SHOK (shown in figure 3) – 2 fast wide-angle cameras for measuring GBR in optical wavelengths. Field of view of each camera – 1000 sq.deg, maximum frame rate – 5–7 frame per second.
- UFFO + UBAT – 20-cm UV-optic telescope and X-ray camera for selection and measuring GRB in UV, X-ray and G-ray bands and forming “alerts” for ground-based optical observatories.
- DEPRON – detector for measuring charge particle flux on orbit and determining radiation environment on the satellite. Device includes: 1) charged particles dosimeter based on semiconductor detector;
- 2) thermal neutrons detector based on gas-discharge counter SI13N.
- ELFIN – instrument for measuring variations of the Earth magnetic field and charge particle flux on orbit. It consist of a Flux Gate Magnetometer, an Energetic Particle Detector for Electrons, and an Energetic Proton Detector for Ions.
2 The TUS detector

The TUS detector is the largest part of scientific instruments on board “Mikhail Lomonosov” satellite, figure 1. It is the first space detector of extreme energy cosmic rays in line of the “Airwatch” concept, suggested by John Linsley [1]. Today the most advanced Airwatch projects are JEM-EUSO [2] and KLYPVE [3] with its prototype: the TUS detector. TUS is abbreviation of “Track Ultraviolet Set-up”. TUS mass is 60 Kg, electric power 60 Wt, orientation to nadir $\pm 3^\circ$. Two main parts of TUS are: mirror-concentrator and photo receiver. The mirror area is $\sim 2 \text{ m}^2$, focal spot RMS is $< 7 \text{ mrad}$ in FOV of $4.5^\circ$ (for details see [4]). Photo receiver comprising 256 pixels everyone of 10 mrad covers the atmosphere area $(H \times 0.16)^2 \text{ km}^2$ ($H$ will change from 550 to 350 km during of 3 years operation). In this period expected exposure factor for EECR of energy more than 200 EeV is 12,000 $\text{km}^2 \text{ sr}$. EAS energy threshold of the TUS detector is $\sim 70 \text{ EeV}$, expected EAS event statistics in 3 years: 60 events.

The main goal of the TUS experiment is a search for the EECR energy spectrum in region beyond the GZK “cut-off” and a search for EECR sources in all sky measurements. In previous experiments there were indications on existence of events beyond the GZK limit – among them the event with energy 300 EeV detected by Fly-Eye detector [5] was widely discussed. The TUS experiment will search for events in this energy range, figure 4.

The TUS photo receiver contains 256 pixels. They are grouped in 16 clusters every of which contains 16 PMTs with common HV and electronics. The electronics is designed for a multi-purpose scientific program. The time sampling starts from 0.8 $\mu \text{s}$ as needed for EAS measurements. Slower developing objects (atmospheric electric discharges, sub-relativistic dust grains, micrometeors) will be observed with larger sampling 64 $\mu \text{s}$, 0.4 ms given by digital integration.

In two “Universitetsky-Tatiana” satellite missions [6] the TUS pixel and electronics were tested in measurements of the atmosphere glow and atmospheric flashes in near UV range (wavelengths 300-400 nm). They operated in polar orbits, heights 830-950 km.

The measured map of the UV glow intensity showed that at moonless nights the atmosphere UV intensity in different Earth regions varies from $3 \cdot 10^7$ to $2 \cdot 10^8 \text{ ph cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$. At full moon nights the intensity rises to 2-3$\times 10^9 \text{ ph cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$.

The short (1 ms) flashes with small photons numbers ($< 10^{22}$) were found to be uniformly distributed over the Earth, figure 5. Their rate in the TUS FOV is estimated as 0.01 per minute. Flashes with larger photons numbers ($> 10^{22}$) are concentrated in the equatorial region (latitudes $\pm 30^\circ$) above the continents, figure 6. Their rate in the TUS FOV is estimated as 0.1 per minute.

Rather high intensity of the atmosphere glow and the rate of atmosphere flashes put a difficult problem for selection of EAS events and suppression of the “not useful” triggering. One should remember that EAS fluorescent photon number at $E = 100 \text{ EeV}$ is four order of magnitude less than photon number $\sim 10^{20-10^{22}}$ in “small” flashes. At the early stage of a flash it may accidently give imitation of EAS event. For reliable distinction of flash events a pin-
The pinhole camera will select and measure the atmospheric UV flashes in time scale of 1 msec started from photon number in the atmosphere of $10^{22}$. The same events will be selected by the main TUS detector at much earlier stage – in time scale of about 0.1 msec. Comparison of the early flash rate and developed flash rate will give information on possible genetic connection between atmospheric flashes and EECR events.

3 Conclusions

- In near future (2011-2012) Space Observatory “Mikhail Lomonosov” will start to operate.
- Experience of the TUS detector operation will be important for final design of the next space detectors: JEM-EUSO and KLYPVE.

References

Figure 7: View of 2 pinhole cameras in a special section of the TUS photo receiver.

[4] Tkatchev L.G. et. al, The TUS Fresnel mirror production and optical parameter measurement. This conference, ID=0297
