JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 115, A00E24, doi:10.1029/2009JA014765, 2010

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Program of transient UV event research at Tatiana-2 satellite

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Received 18 August 2009; revised 18 November 2009; accepted 17 December 2009; published 8 May 2010.

[1] In a new Tatiana-2 mission the measurement of transient luminous events (TLE) in the Earth atmosphere in nadir direction are planned. Near UV temporal images of TLE in millisecond scale will be measured together with temporal profiles in 8 channels of wide spectrum of TLE emission. Simultaneously temporal variation of electron flux at the satellite orbit will be measured. Aims of these measurements are to continue research of bright UV flashes, started in the Tatiana-1 mission (Universitetsky–Tatiana satellite), their global distribution, their rate over oceans and continents, and their possible correlation with lunar phase. Special attention will be paid to search for correlation between UV flashes from the atmosphere and variations of electron flux in the atmosphere-magnetosphere system.

Citation: Garipov, G. K., et al. (2010), Program of transient UV event research at Tatiana-2 satellite, *J. Geophys. Res.*, *115*, A00E24, doi:10.1029/2009JA014765.

1. Results of the Universitetsky–Tatiana Mission

[2] The previous ultraviolet (UV) detector on board the Universitetsky–Tatiana satellite (polar orbit, height 950 km) has measured the atmosphere glow and transient events in near UV range (wavelengths 300–400 nm) [*Garipov et al.*, 2005a, 2005b, 2006; *Sadovnichy et al.*, 2007]. Measurements were done in period January 2005 to March 2007. It is an educational satellite, see Web site http://cosmos.msu.ru. The UV detector [*Garipov et al.*, 2006] was a photomultiplier tube (PMT) observing the atmosphere in nadir direction with field of view 14 degree (diameter of the observed area in the atmosphere 250 km). Important detector features are as follows: (1) Constant PMT's anode current (high voltage (HV) on the tube was controlled by UV intensity). Measurement of HV and analog-digital converter (ADC) signal codes provided measurement of UV intensity. (2) Temporal profiles of the selected UV flashes were measured in two time ranges as digital traces of 4 and 64 ms duration. The Universitetsky–Tatiana detector has measured ambient UV intensity from minimal nighttime values of 2×10^7 ph cm^{-2} s^{-1} sr^{-1} to maximal values of 10^{13} ph cm^{-2} s^{-1} sr^{-1} on the day side. At moonless nights the Universitetsky–Tatiana data indicate two regions of the UV intensity in the Earth atmosphere which differ by an order of magnitude: (1) auroral zones ($I_{UV} \sim 10^9$ ph cm^{-2} s^{-1} sr^{-1}) and (2) equatorial-middle latitude zones ($I_{UV} \leq 2 \times 10^8$ ph cm^{-2} s^{-1} sr^{-1}).

[3] In Figure 1 the measured UV intensity at two consequent orbits in the southern hemisphere winter time is presented. The latest in time large peaks are auroral radiation (latitudes of about 50–60°) while lower peaks are at middle latitudes. At the same nights far UV (130.4–135.6 nm) data from TIMED satellite (GUVI instrument) are available [*Christensen et al.*, 2003]. Good correlation of near UV radiation (Tatiana measurements) and far UV radiation (GUVI measurements) at auroral oval were observed.

[4] Tatiana data on the electron flux at the orbit allow comparison of the latitude profiles of electron flux and profiles of UV radiation. In auroral zone the position of UV intensity is correlated to electron intensity at the Tatiana orbit, if movement of electron to its track end in the atmosphere along the geomagnetic field is taken into account [*Dmitriev et al.*, 2009].

[5] At moonlit nights the Moon UV light back scattered from the atmosphere and from clouds is much brighter than other sources (UV intensity comes up to 3×10^9 ph cm^{-2} s^{-1} sr^{-1}). Full moon "albedo" effect from clouds is the key factor for UV intensity variations.

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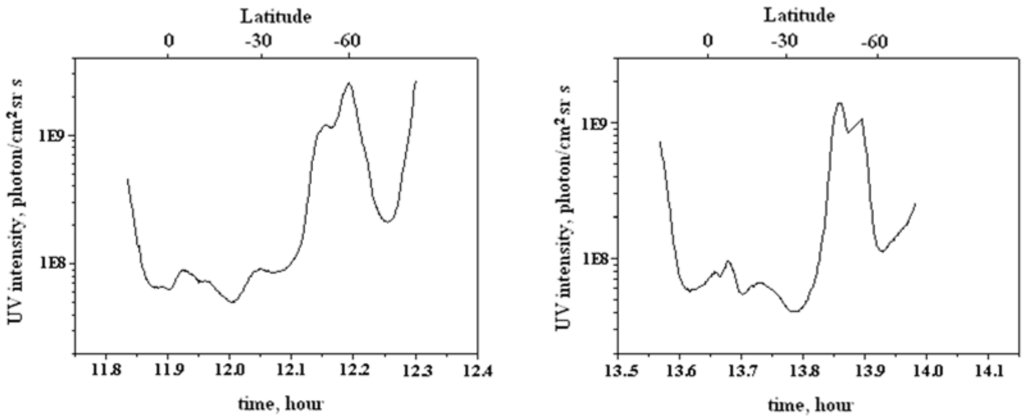

Figure 1. UV intensity on 10 July 2005, measured at two consequent orbits in the southern hemisphere when the satellite crosses the auroral oval (main peaks). At middle latitudes an order of magnitude less intensity is detected.

[6] One of the main aims of the Universitetsky–Tatiana mission was observation of UV flashes. Two oscilloscopes were used to measure temporal profiles of the flash: (1) with trace duration 4 ms, waveform sampling rate of 16 μs and (2) with the trace duration 64 ms, waveform samples 256 μs. Due to limited satellite data acquisition system only one, the brightest, UV flash in a given integral time (0.2 ms for the fast oscilloscope and 3.2 ms for the slower one) was selected per one orbit at night side of the Earth. This mode of selection gives bias for TLE against lightning: the UV radiation from TLE is much brighter than from the preceded lightning [*Kuo et al.*, 2005]. Most of the detected events were selected by the fast oscilloscope (80%) among them 78% of events were single pulses with average duration on half of the maximum 0.7 ms. Among 15 orbits per day only 3–5 orbits were available for measurements. In some orbits orientation of the satellite was not stable. In spite of those disadvantages ~300 UV flashes were detected. UV radiation energy release in the atmosphere for selected flashes is in the range of 1 KJ–1 MJ.

[7] The global map of the selected UV flashes shows an evident concentration in the near equatorial latitudes, Figure 2. More than half of UV flash events were detected above ocean, in contrast to distribution of lightning which is concentrated above continents (NASA overview available at http://www.ghcc.msfc.nasa.gov).

[8] The Tatiana data on UV flashes indicated a correlation with the lunar phase [*Garipov et al.*, 2008]. At full moon nights the rate of UV flashes with energy release in the atmosphere $E_{rel} \geq 50$ KJ is ≈4 times higher than at other

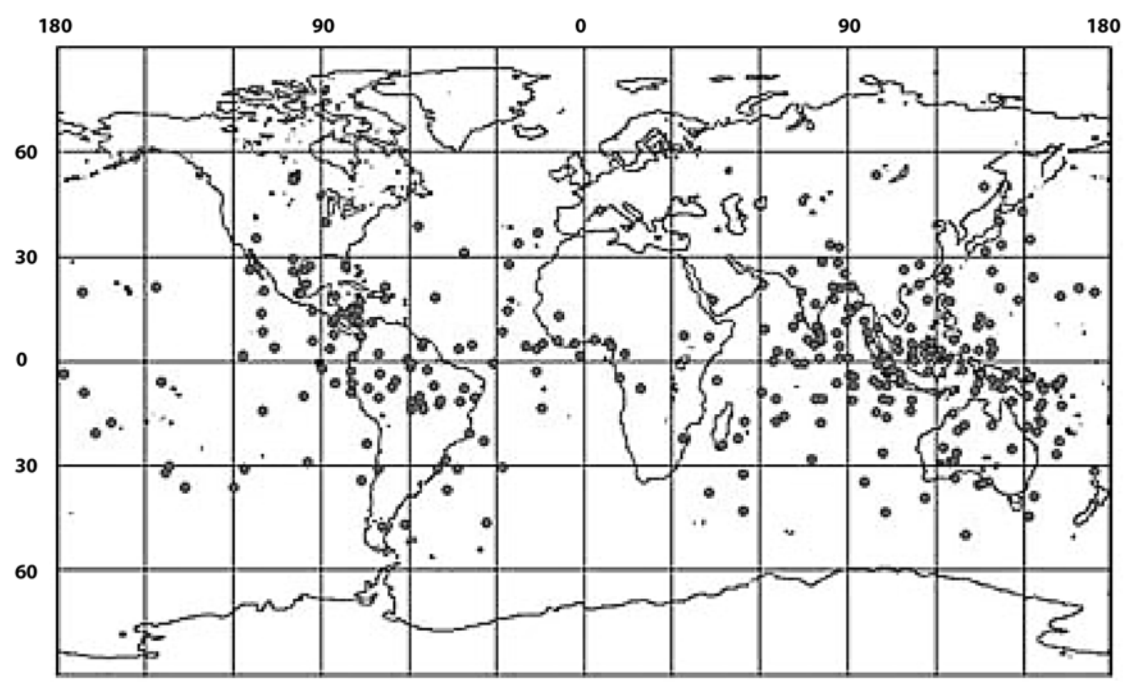

Figure 2. Map of Tatiana satellite positions when UV flashes were registered.

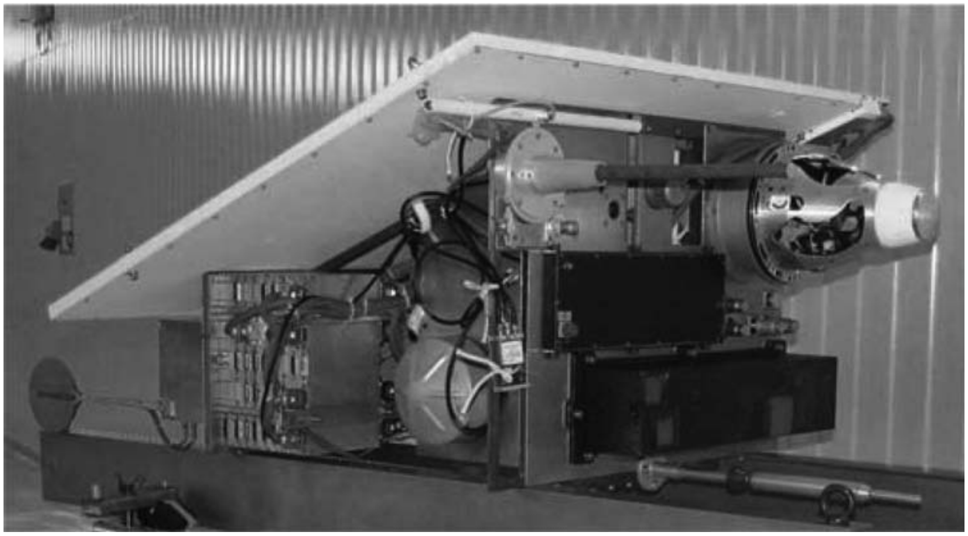

Figure 3. Tatiana-2 scientific payloads at the front side of the satellite looking to the Earth. The upper payload contains UV–Red detector and electron flux detector. The second payload contains MEMS telescope and spectrometer.

moon phases. Interesting to note that gigantic jets (5 events) detected by Taiwanese group [*Su et al.*, 2003] were also observed at full moon night. Experimental correlation of UV flashes brightness with moon phase will be checked in the next Tatiana-2 experiment.

2. Tatiana-2 Mission

[9] As was noted above the Universitetsky–Tatiana mission had the following disadvantages: (1) shortages of data transmittance system; only data for 3–5 orbits (among 15 per day) were recorded and transmitted, (2) there was no imager for transient events, and (3) only near UV range was available for transients.

[10] In the Tatiana-2 mission (launched on 17 September 2009 to solar-synchronized orbit of 820 km height and 98.8° inclination) the instrumentation for monitoring the atmosphere glow and observing the transient events is improved in the following ways: (1) data transmitter allows to send 5 Mbit of data per orbit, (2) monitoring of the atmosphere glow is done in two spectral ranges, UV (300–400 nm) and Red (600–700 nm), (3) every minute the largest UV flash is selected, its temporal profile is measured in the mentioned above UV and Red spectral ranges, in 1–128 millisecond range, (4) electron flux temporal profiles at the orbit is measured synchronously with UV–Red TLE profiles in the same millisecond range, (5) UV flash images were prepared to be measured in nadir direction in the range of wavelengths 300–400 nm by the new MEMS telescope, and (6) radiaton spectrum of the selected flashes was prepared to be measured in wide range of wavelengths (300–800 nm) by the spectrometer operating synchronously with MEMS telescope.

[11] In Figure 3 the TLE detectors on board of Tatiana-2 are presented. TLE detectors are combined in two payloads: the UV–Red detector and the electron flux detector in the first one, and the MEMS telescope and the spectrometer in the second one. Both of them are placed at the satellite side directed to the Earth.

[12] In Figure 4 the UV–Red detector of UV (300–400 nm) and red radiation (600–700 nm) is presented. Its operating wavelength range is selected by choice of the filters. Both PMTs has field of view (FOV) of 16°. For orbit height 820 km it means that the atmosphere is observed in the circle of ≈230 km diameter. Electronics of UV–Red detector selects TLE with the threshold in number of UV photons in the atmosphere -10^{21} (UV energy 0.5 KJ). Waveform digital profiles are sampled in 1 ms in trace of 128 samples. Every minute the triggering system selects the largest UV signal in the integration time of 1 ms. This

Figure 4. UV and Red detector: 1, entrance collimator; 2, PMT for UV; 3, PMT for Red; 4, electronics.

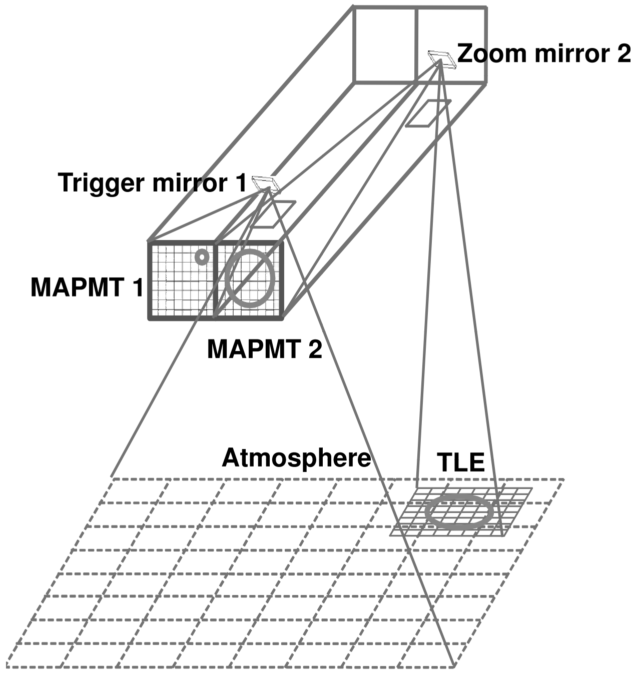

Figure 5. Schematics of MEMS telescope operation.

detector measures also the atmosphere ambient UV and red radiation intensity every 1 minute.

[13] The MEMS space telescope, called MTEL (MEMS Telescope for Extreme Lightning), is a new type of telescope designed for obtaining fast TLE images [*Park et al.*, 2008]. The instrument operates in near UV wavelength range: 300–400 nm. In Figure 5 the MTEL operation is illustrated. There are two subtelescopes and their image measurements are provided by the 64 multianode PM tubes (MAPMT) of pixel size 2 mm × 2 mm. In the first telescope, a plane trigger mirror of size 3 mm × 3 mm is at the distance of 9.05 cm from the MAPMT and the atmosphere image is observed with resolution 1.4° (20 km in the atmosphere for orbit height 820 km). The FOV of this telescope is 11.2° or 160 km in the atmosphere. Electronics of this telescope measures signal every 10 μs by ADC. It selects the useful transient event as the largest signal during 40 μs (signal is added digitally in 4 ADC time samples) in period of 1 minute. By trigger command the event image starts to be recorded in all MAPMT pixels. Signals are recorded after the trigger 100 times every 40 μs, then 50 times every 1.28 ms, then 25 times every 2.56 ms, then 20 times every 10.2 ms and 8 times every 20.5 ms. Before the trigger, data in 15 previous samples (each equal to 10 μs) are also available.

[14] The zoom mirror of size 3 mm × 3 mm in the second telescope is an array of 64 MEMS micromirror cells. It is placed at the distance of 36.2 cm from MAPMT and the atmosphere image is observed with resolution 0.35° (5 km in the atmosphere). The address of the pixel triggered in the first telescope gives the direction for tilting the MEMS micromirror cells of the zoom mirror in the second telescope. Electronics for controlling the micromirror cell direction has a prepared table of commands for 64 tilting angles determined by the first telescope pixel address. The mirror cells are tilted with velocity of 1 degree per 50 μs. Time needed for turning the mirror to the FOV edge is 0.125 ms. Readout electronics of the second telescope is similar to the first one. Images in the second telescope are collected upon the trigger from the first telescope. In the worst case of the event at edge of FOV the "magnified" image in the second telescope will start to be recorded after the first three or four waveform samples of the first telescope have been recorded. Images in the first and second telescopes are recorded synchronously and will give complimentary information on TLE. Threshold energy (5 KJ) for selection of TLE in the telescopes is higher than in UV–Red detector because of smaller aperture of MAPMT pixels and mirrors.

[15] There is also a spectrometer inside of the box enclosing the MTEL. The spectrometer FOV covers the same area in the atmosphere as the first MTEL telescope. The FOV of every channel is organized by a simple "blend" collimator. Eight filters are used for dividing the measured range of spectrum into eight regions. The ninth window is open for all wavelengths. Central wavelengths and FWHM values (nm) of the filters are presented in Table 1.

[16] Spectrometer is triggered by the UV trigger from the first telescope. Electronics recording the temporal profiles in every wavelength range is similar to the telescope electronics and the spectral information is synchronized to the telescope information. In the spectrometer there is no option for monitoring the atmosphere night glow.

[17] Electron flux detector is presented in Figure 6. Electrons produce fluorescence light in the scintillation plate of 350 cm^2 area. The front view of the detector is covered by 1 mm thick aluminum plate. At the back side there is more matter of the satellite body so the electron energy threshold for penetrating to the scintillation plate is minimal for nadir direction (to the Earth) and is ≈1 MeV. Particles penetrated to scintillation plate generate fluorescence light which is gathered, converted and guided to PM tube by standard way of scintillation detector techniques. Electronics of the detector produce the digital temporal profiles in number of relativistic particles (r.p.) starting from several r.p. in waveform samples 1 ms with duration of 128 samples. The instrument is triggered by events selected by the UV–Red detector so that every minute the temporal profile of the electron detector event is available.

[18] One of the most interesting question is: could electrical discharge responsible for TLE be a source of near equatorial electrons detected in previous measurements? In the "run away electrons" TLE model electrons may be accelerated to energies of tens MeV so that some percentage of them (≈10%) [*Lehtinen*, 2000], are capable to escape the atmosphere. They will be trapped at L shells ~1–2. Life time

Table 1. Average Wavelengths and FWHMs of Spectrometer Windows

Central Wavelength (nm)	FWHM (nm)
355	60
410	55
485	80
560	50
610	40
655	40
715	60
790	70

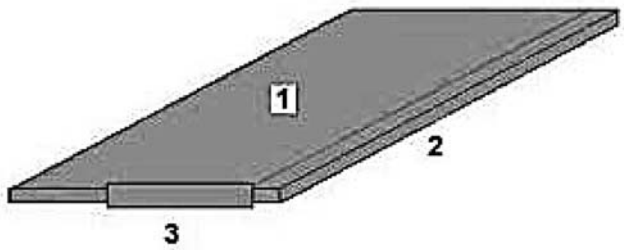

Figure 6. Electron flux detector: 1, scintillation plate; 2, light guide-convertor; 3, PM tube.

of such a "belt" is expected to be short (several bounces). At the conjugate point electrons are coming back to the atmosphere and produce an UV glow. Intensity of UV at the conjugate point will be much less than in the point of TLE origin.

3. Summary

[19] Tatiana-2 instruments will help to get answers to the following questions put by Tatiana-1 mission:

[20] 1. How are different kind of UV flashes (UV TLE) distributed in the global map? Flashes will be classified by their lateral distribution(in the horizontal plane) and temporal profiles.

[21] 2. In which TLE electrons are accelerated to high energies so that they penetrate the upper atmosphere to the Tatiana-2 orbit?

[22] 3. Are there millisecond electron flux "flashes" independent of TLE? Do they occur at conjugate to TLE points (statistical analysis)?

[23] 4. Are UV flashes affected by the Moon?

[24] **Acknowledgments.** This work was supported by Creative Research Initiatives (RCMST) of MEST/KOSEF, by RFFI foundation grant 09-02-12162-ofi-m, and by Russia-Taiwan NSC-RF for Basic Research (RFBR) 2007–2008 Joint Research Project 96WFA0700011.

[25] Zuyin Pu thanks the reviewers for their assistance in evaluating this paper.

References

Christensen, A. B., et al. (2003), Initial observations with the Global Ultraviolet Imager (GUVI) in the NASA TIMED satellite mission, *J. Geophys. Res. 108*(A12), 1451, doi:10.1029/2003JA009918.

Dmitriev, A. V., et al. (2009), UV radiation from the night-time atmosphere seen from the "Universitetsky-Tatiana" satellite, *AIP Conf. Proc.*, *1118*, 116–121.

Garipov, G. K., B. A. Khrenov, M. I. Panasyuk, V. I. Tulupov, H. Salazar, A. V. Shirokov, and I. V. Yashin (2005a), UV flashes in the equatorial region of the Earth, *JETP Lett.*, *82*, 185–189.

Garipov, G. K., B. A. Khrenov, M. I. Panasyuk, V. I. Tulupov, A. V. Shirokov, I. V. Yashin, and H. Salazar (2005b), UV radiation from the atmosphere: Results of the MSU "Tatiana" satellite measurements, *Astroparticle Phys.*, *24*, 400–408.

Garipov, G. K., B. A. Khrenov, M. I. Panasyuk, I. A. Rubinshtein, V. I. Tulupov, H. Salazar, A. V. Shirokov, and I. V. Yashin (2006), UV radiation detector of the MSU research educational micro satellite "Universitetsky-Tatyana," *Instrum. Exp. Tech.*, *49*, 126–130.

Garipov, G. K., B. A. Khrenov, and M. I. Panasyuk (2008), Correlation of atmospheric UV transient events with lunar phase, *Geophys. Res. Lett. 35*, L10807, doi:10.1029/2007GL032679.

Kuo, G. L., et al. (2005), Electric field and electron energies inferred from the ISUAL recorded sprites, *Geophys. Res. Lett.*, *32*, L19103, doi:10.1029/2005GL023389.

Lehtinen, N. G. (2000), Relativistic runaway electrons above the thunderstorms, Ph.D. dissertation, Stanford Univ., Stanford, Calif.

Park, J. H., et al. (2008), Obscura telescope with a MEMS micromirror array for space observation of transient luminous phenomena or fast-moving objects, *Optics Express 16*, 20,249–20,257, doi:10.1364/OE.16.020249.

Sadovnichy, V. A., et al. (2007), First results of investigating the space environment onboard the "Universitetsky-Tatiana" satellite, *Cosmic Res.*, Engl. Transl., *45*, 273–282.

Su, H. T., et al. (2003), Gigantic jets between a thundercloud and the ionosphere, *Nature 423*, 974–976.

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