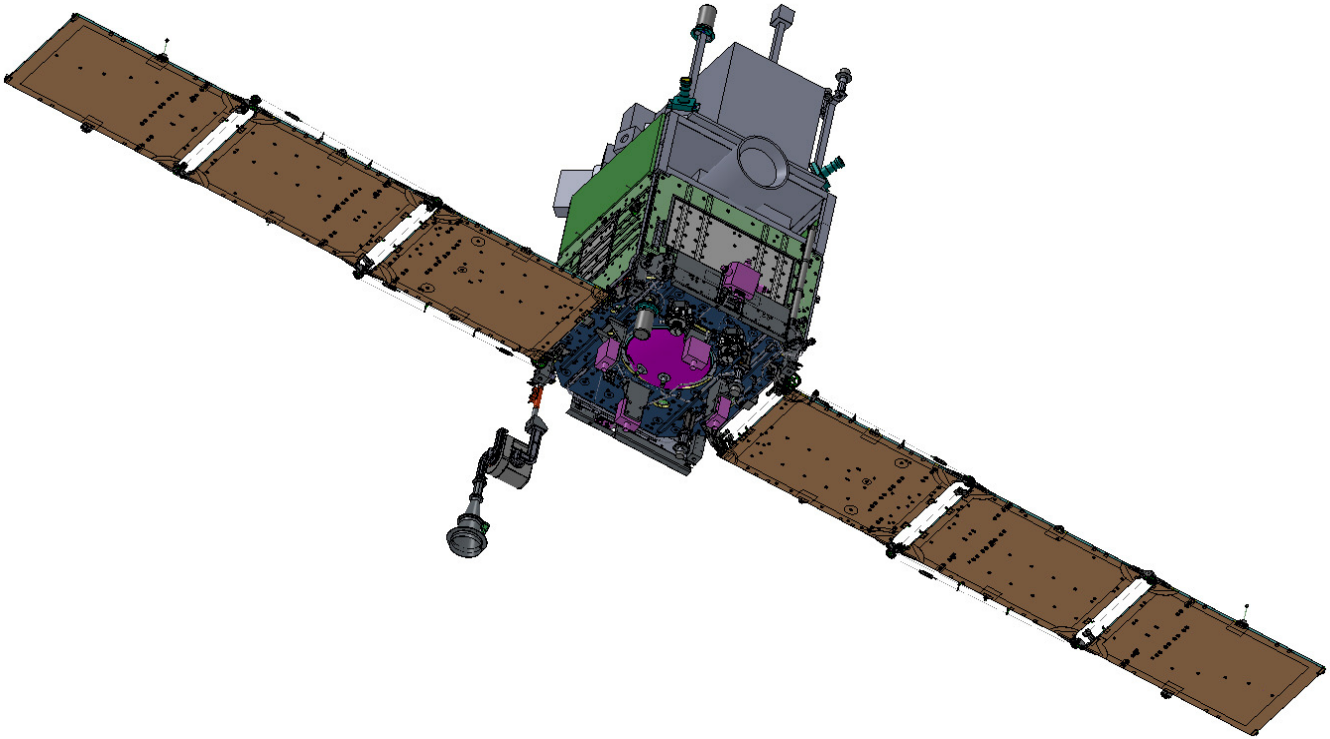
D. V. Skobeltsyn Institute of Nuclear Physics,
M. V. Lomonosov Moscow State University, Russia

Monitoring of space radiation and other hazards in multi-satellite project `Universat-SOCRAT`



General

D.V. Skobeltsyn Institute of Nuclear Physics of M.V. Lomonosov Moscow State University is developing a project `Universat-SOCRAT` of a system of small satellites for monitoring of the space threats:

ionizing radiation (flares, SEP, magnetosphere),

potentially dangerous objects of natural (asteroids, meteoroids) and artificial (space debris) origin,

electromagnetic transients of Earth`s (TGF, TLE) and space (GRB, SGR) origin.

Universat-SOCRAT collaboration

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1 - M. V. Lomonosov Moscow State University, Russia

2 - S. A. Lavochkin Space Corporation, Russia

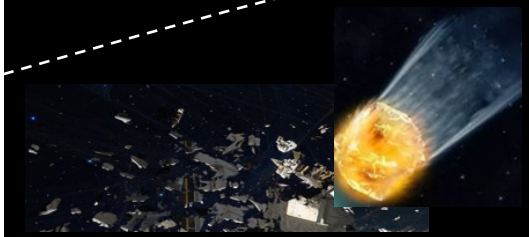
Cooperation:

- system concept, spectrometers of gamma-rays & charged particles – SINP MSU
- optical measurements & optical ground support – SAI MSU
- spacecraft bus – NPO Lavochkina (NPOL)

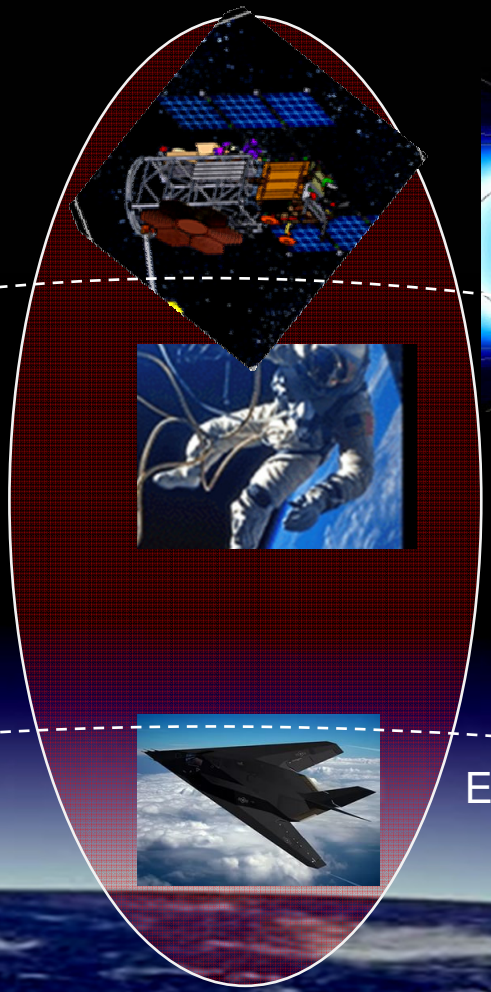
This work was provided by the Ministry of Education and Science of Russian Federation, Project № RFMEFI60717X0175.

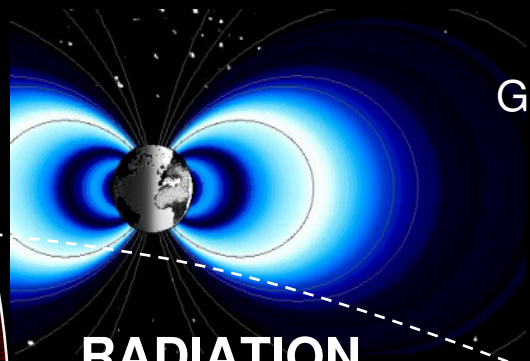
Space threats

Solar energetic particles

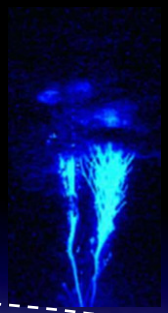


SPACE DEBRIS, ASTEROIDS

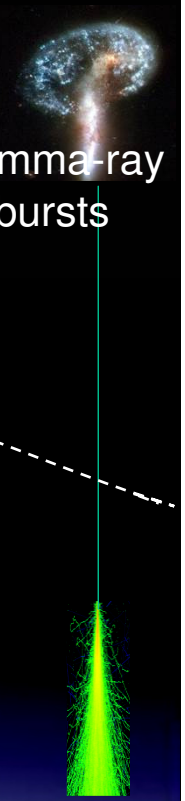




RADIATION



Electromagnetic transients in upper atmosphere



Gamma-ray bursts

General

From the operational (close to`real time) monitoring of the fluxes of energetic charged particles in the wide range of Earth`s radiation belts at least two satellites with a mass <50-100 kg will be launched to elliptical orbit with height of perigee and apogee ~700 and 8000 km and inclination 63.4 degrees, which crosses wide range of magnetic drift shells at different altitudes. Satellites will be equipped with multidirectional spectrometers of energetic protons and electrons.

Another satellite will be launched to Sun-synchronous low Earth orbit. It provides the payload mass about 100 kg. Tasks:

– operative monitoring of radiation for the region of all low altitudes, additional data for the satellites on elliptical orbit

– operative monitoring of space debris and asteroids using SHOK cameras together with the ground-based network of telescopes;;

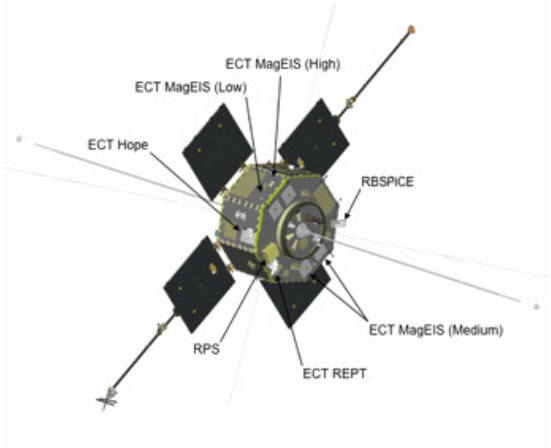
– secondary task: observations in UV/x-ray/gamma range of electromagnetic transients in the upper atmosphere and in the universe and/or solar flares.

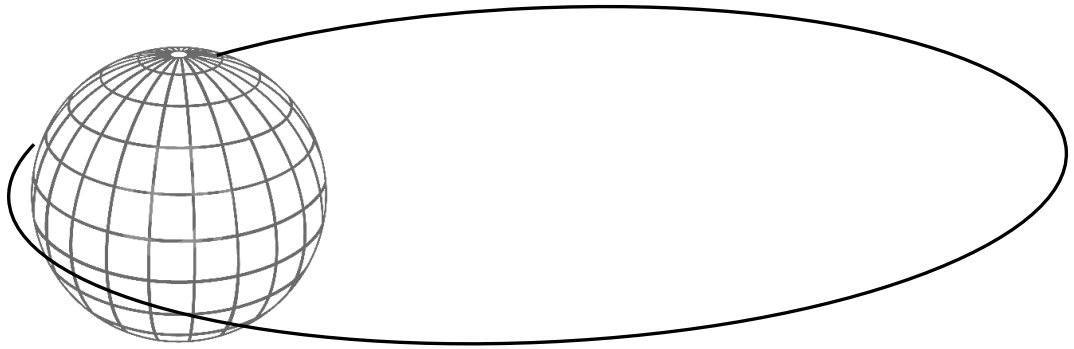
System of small spacecraft for radiation belt monitoring: concept

Concept #1 (NASA Explorer-45, RBSP/Van Allen Probes):
- highly-elliptical equatorial orbit (close to GTO), crossing the wide range of L-shells;
- satellite is rotating around the axis, directed to the Sun – measure pitch-angle distributions of fluxes;
- compute the fluxes for the other points of the L-shell ("altitude dependency" of fluxes) using Liouville theorem.

Disadvantages:
- high launch cost;
- necessity of very precise pitch-angle measurements.

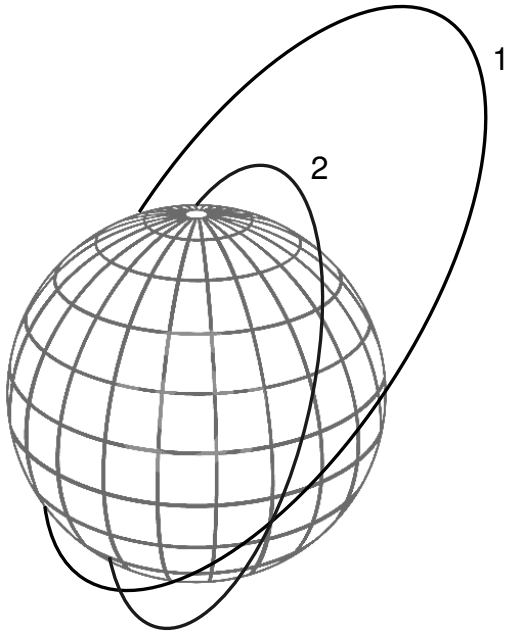
Concept #2: SINP MSU project:
- lower orbits with higher inclination, crossing wide range of L-shells at different altitudes
- measure omnidirectional fluxes at different points of each L-shell,
- compute the fluxes for other points of the L-shell by interpolation and extrapolation of the flux altitude dependency using known theoretical and empirical laws.



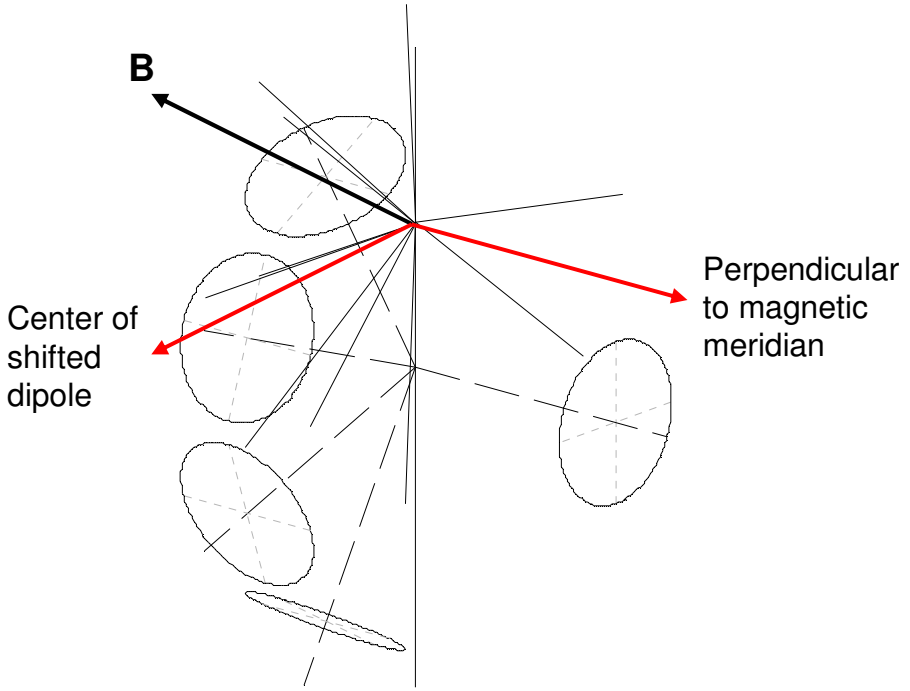


RBSP/Van Allen Probes satellite (particle detectors are marked) and its orbit

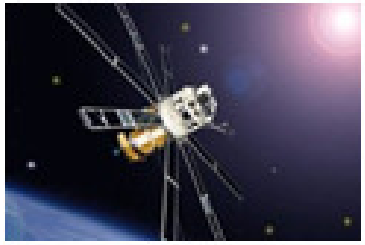
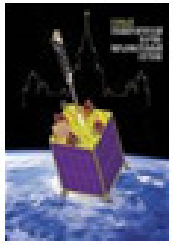
System of small satellites for monitoring the space threats: orbits

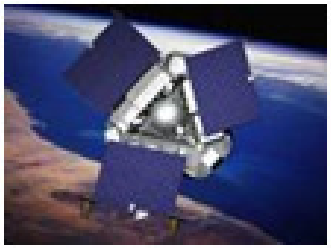
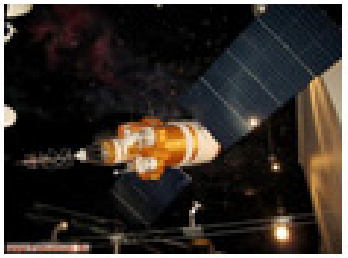
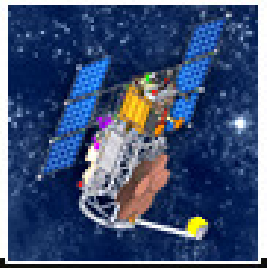


Orbits of multitask small satellite system



Possible orientation of particle detectors

CORONAS-F
2001

Tatiana1
2005

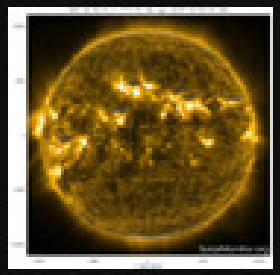
Tatiana2
CORONAS-Photon
Meteor-M N1
2009

Vernov
2014

Meteor-M N2
2014

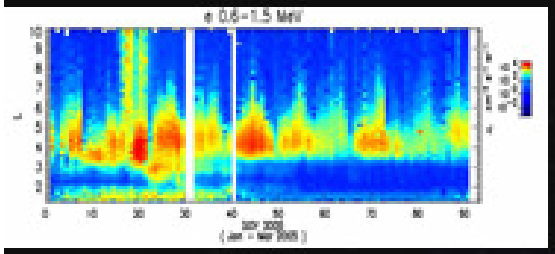
Lomonosov
2016

Near-Earth
radiation



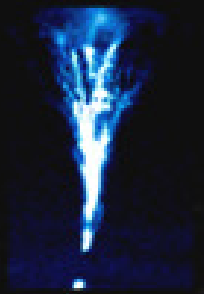
Solar X- and
gamma flares

Outer Earth's
Radiation belt
and SEP



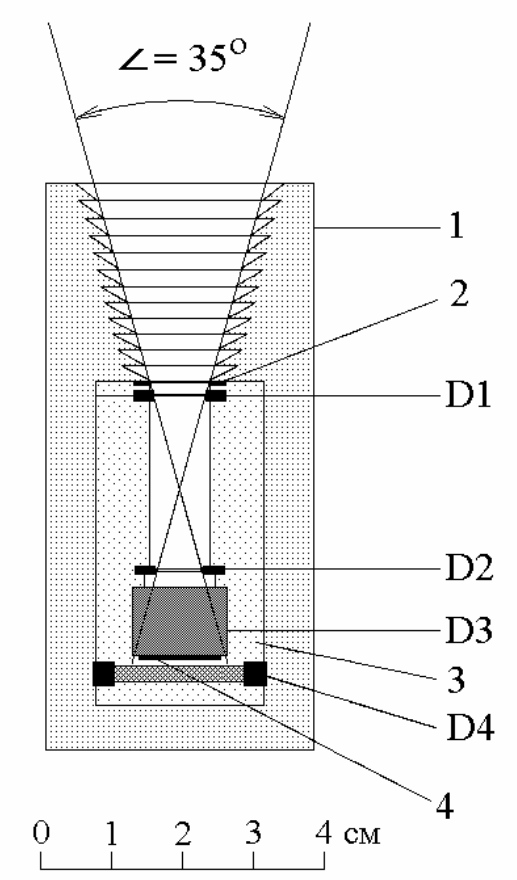
Gamma-ray

Atmospheric transients



Atmospheric emissions

System of small spacecraft for radiation belt monitoring: detectors



1 – telescope body

2 – foil, width ~ 0.01 mm Si

3 – isolator material

D1 – semiconductor detector (SCD), width 0.04 mm

D2 – SCD, width 0.5 mm

D3 – scintillation detector, width 10 mm

4 – photodiode

D4 – SCD, width 1 mm

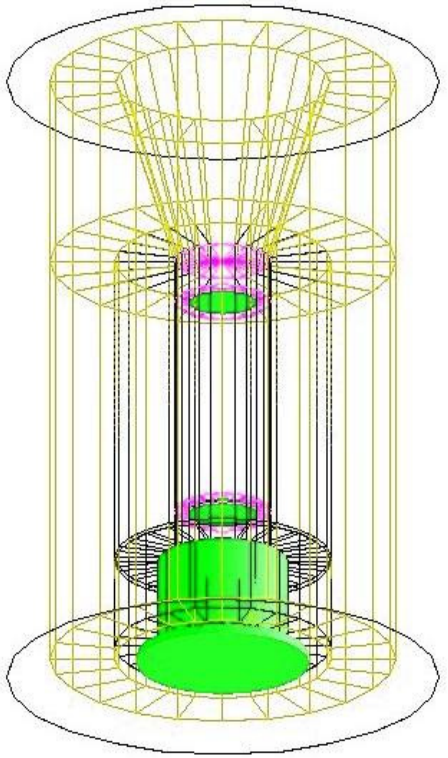
Registered particle energies:

electrons: 0.15–0.35, 0.35–0.6, 0.6–1, 1–2, 2–4, 4–10 MeV;

protons: 2–4, 4–9, 9–15, 15–30, 30–53, 53–100, 100–160, >160 MeV

Mass of telescope: ≤0.8 kg.

Right – 3d-model for GEANT4.



A scheme of the “telescope” detector assembly of spectrometer of energetic electrons and protons, containing 3 semiconductor detectors (D1, D2 and D4) and one scintillation detector (D3).

The aperture angle must be ≤60°, otherwise it is impossible to separate the measurements of electrons and protons.

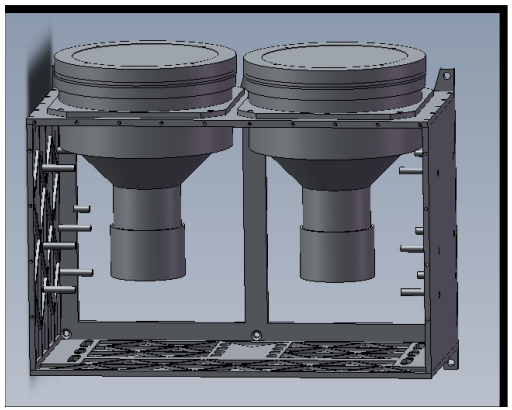
Problem: how to measure omnidirectional fluxes?

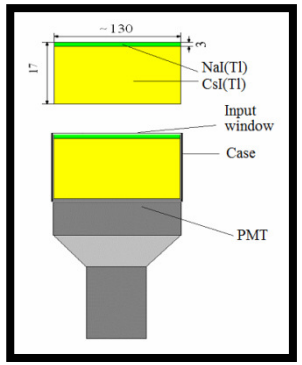
Gamma ray detector design
(DRGE/Vernov)

Two parts of the instrument

DRGE-1, DRGE-2

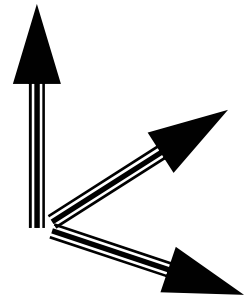
X-rays and gammas in 0.01-3 MeV energy range from atmospheric discharges with high time resolution (up to 15us)

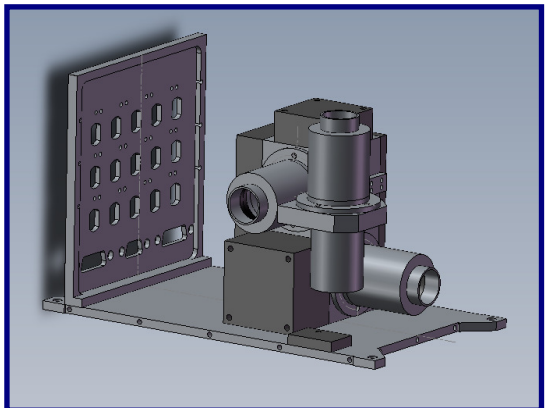


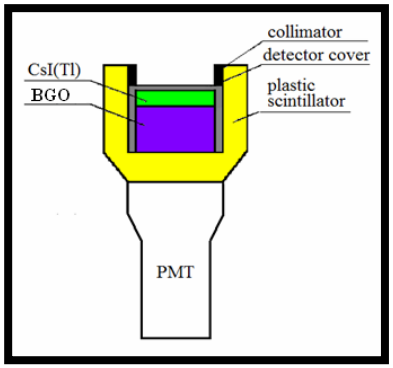


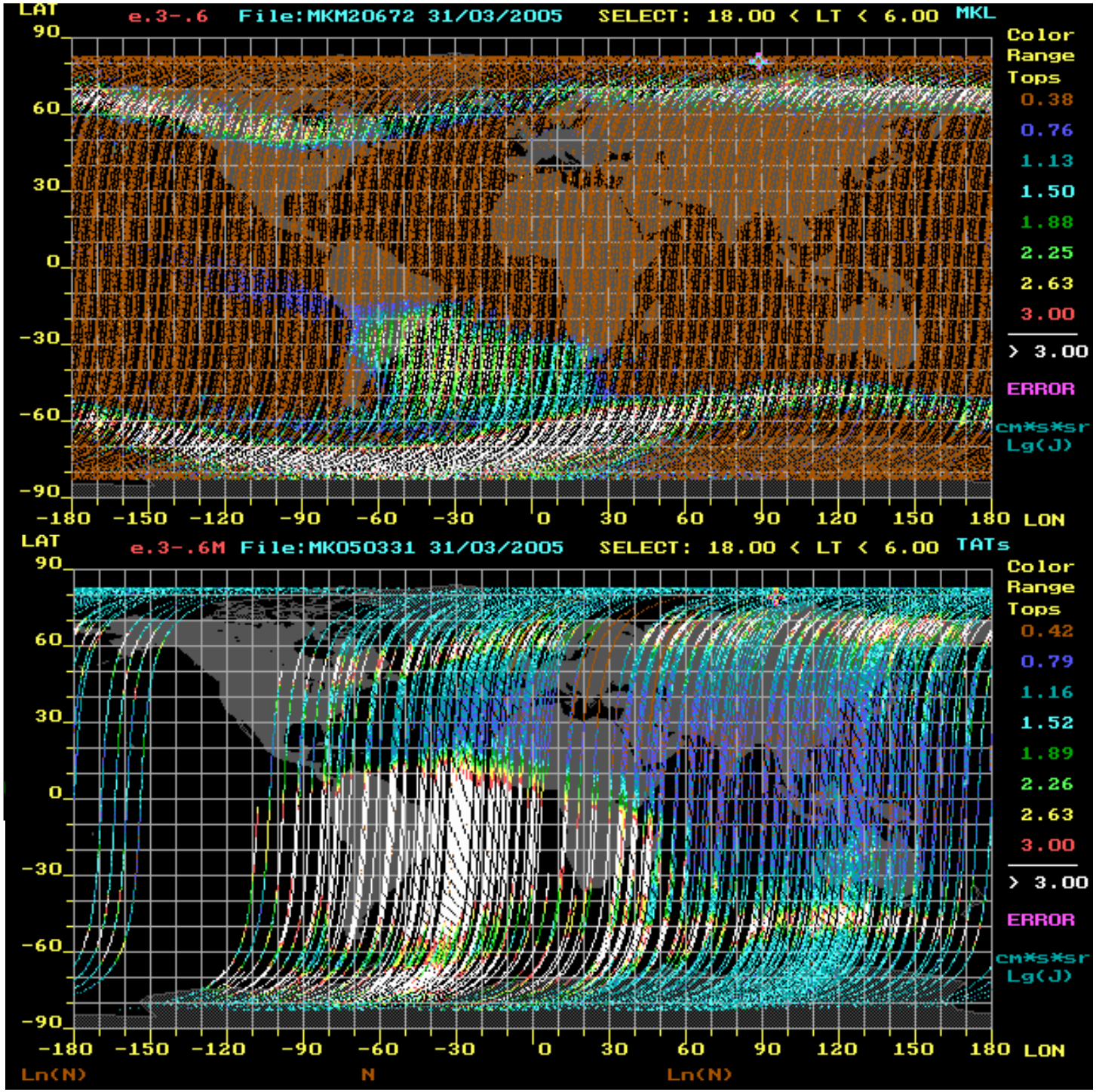
DRGE-3

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









March, 2005

CORONAS- F
350 km
Altitude

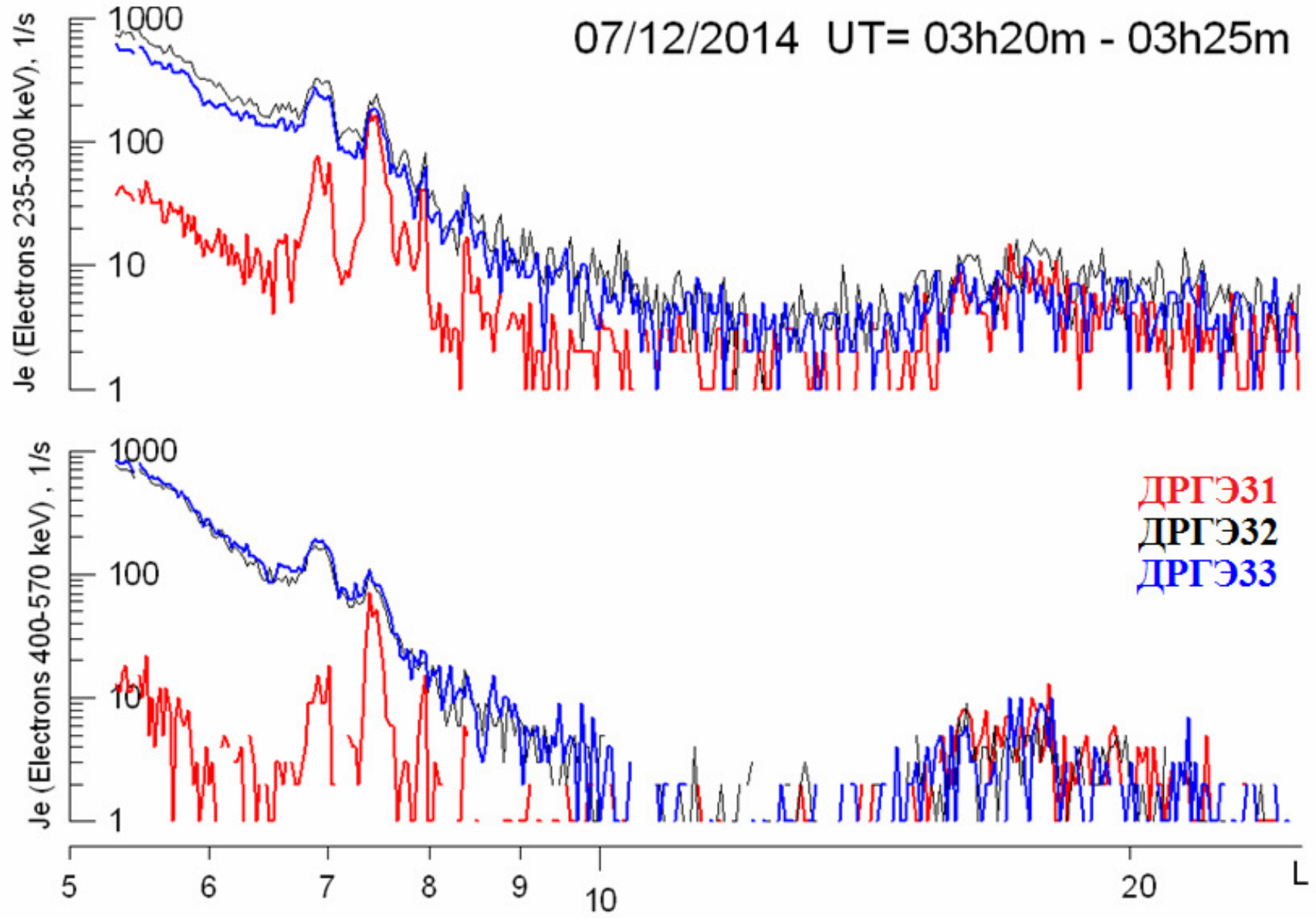
Electrons
300-500 keV

TATYANA-I

1000 km
altitude
Electrons
300-600 keV

Lomonosov/BDRG, 16 June, 2016

Vernov/DRGE3, 7 December, 2014



6)	EName	Start	Stop	Peak	GOES Class	Derived Position
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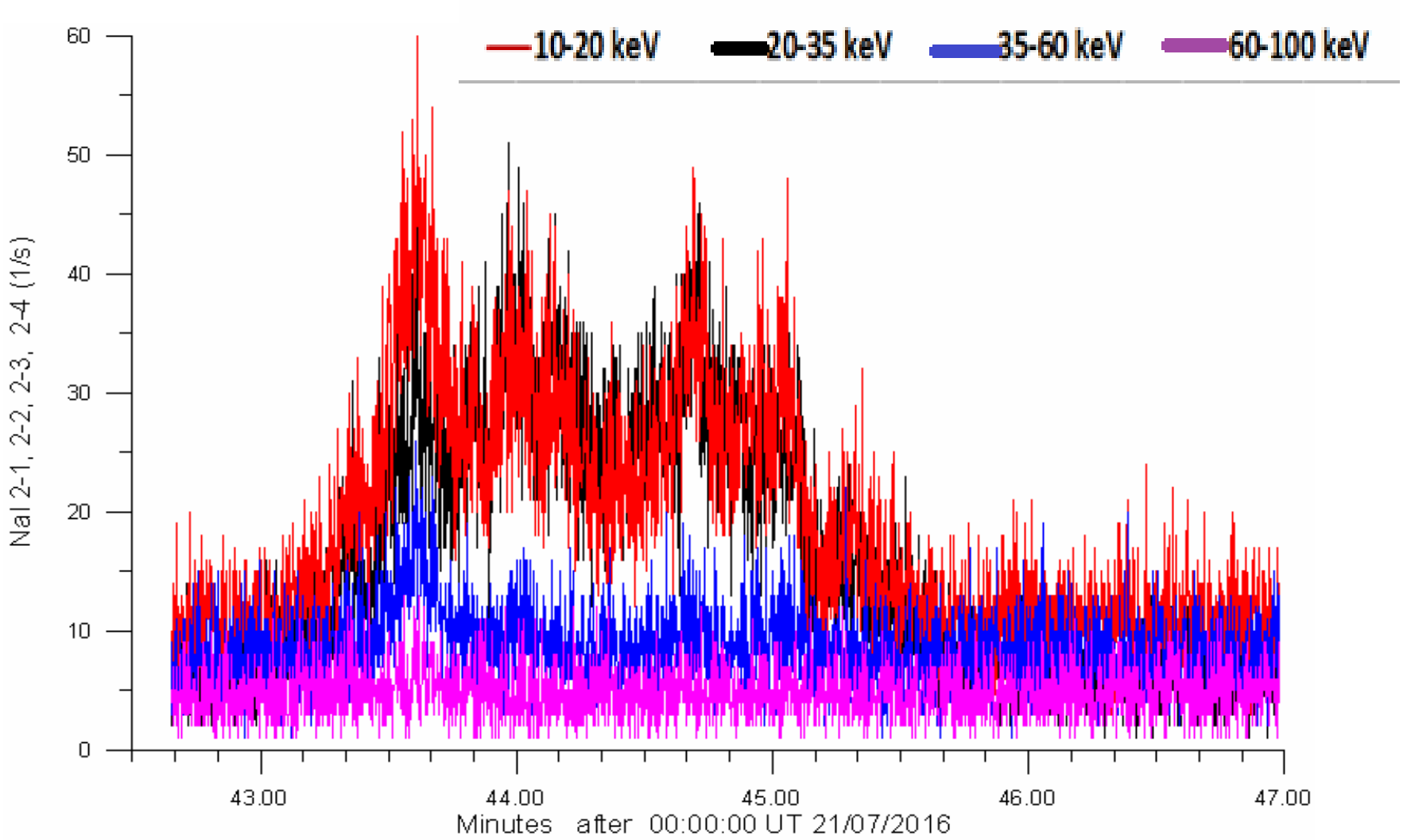


SHOK instrument – wide-angle cameras

11^{th} star's value for single shot or
13^{th} star's value for 100 serial shots (5–7 shots/sec)

- **Field of view of each camera ≈1000 square degrees;**
- **maximum framing rate 5-7 frames/second;**
- **In case of detecting the object fly-by the onboard hardware and software automatically process the image, and the key parameters are rapidly transmitted to the ground using the satellite communication systems**
- **In the ground data center the object parameters are compared with the database on existing known objects**
- **If it is found, that it is a new object, it's orbit is determined precisely using the "MASTER" MSU global ground network of analogous mini-telescopes**

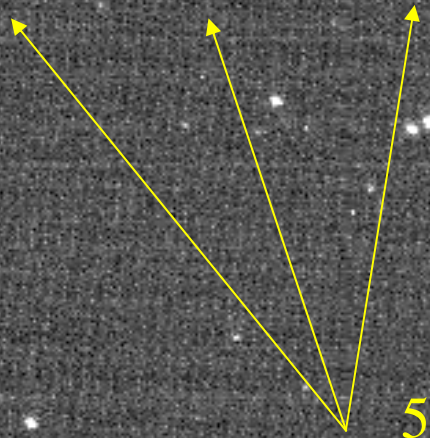
Other parameters:

– Optical system: mirror-lens (catadioptric);
– Aperture: 200 mm;
– Length of focus: 330 mm;
– Pipe weight: 10 kg

On ground test of SHOK instrument in MSU
(exposure – 5 sec, distance limit – the 12th star's value)

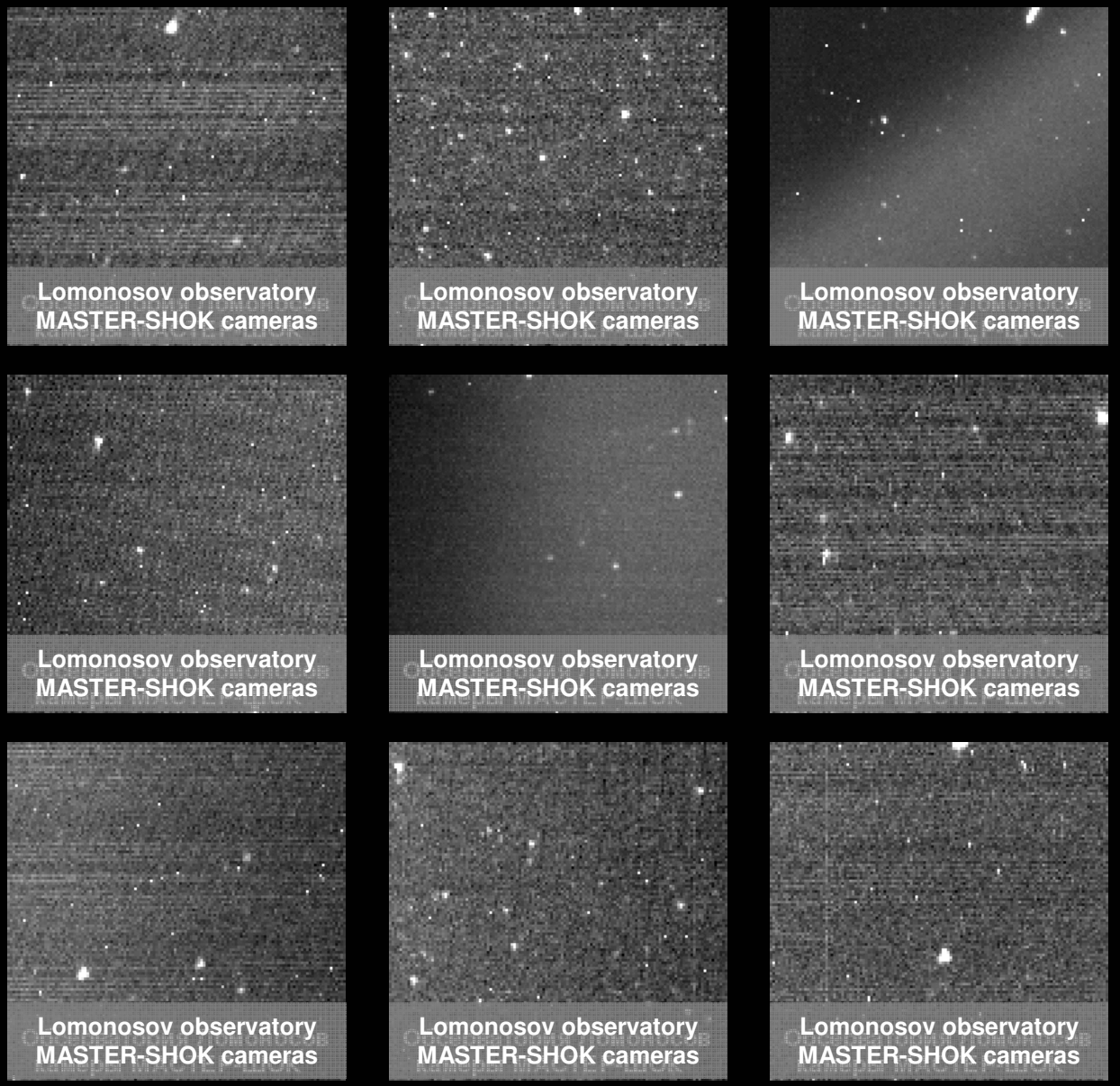
SHOK is able to detect objects on distance ≈50 kkm (“arrival” time ≈1 hour)

SHOK is able to detect near-Earth asteroids
– at a distance of ≈50 thousand kilometers,
– Flight time ≈1 hour.

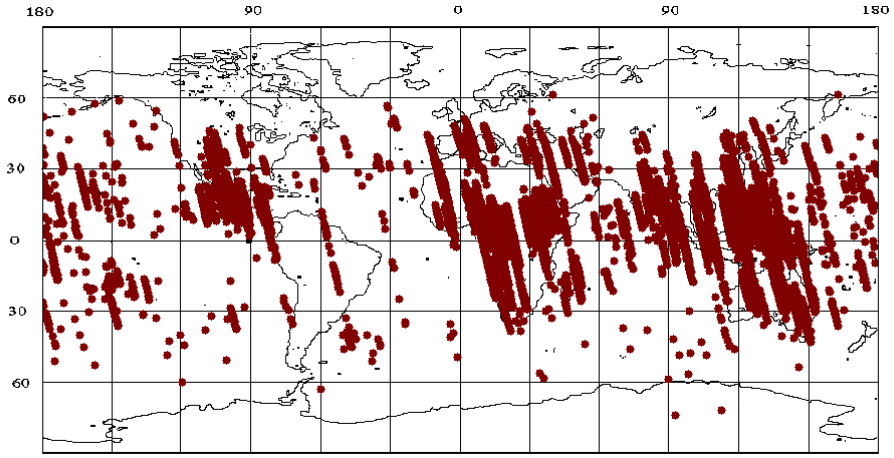


A span of a near-Earth asteroid 2012DA14 the size of 50 m. Near the Earth on the ground analog of the SHOK, the MASTER-VWF camera

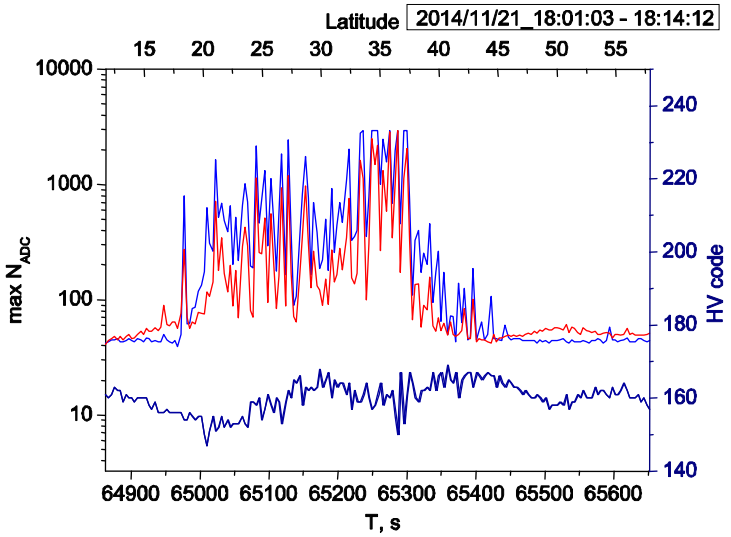
SHOK: wide field mini-telescopes – the shots and movies made onboard “Lomonosov” satellite

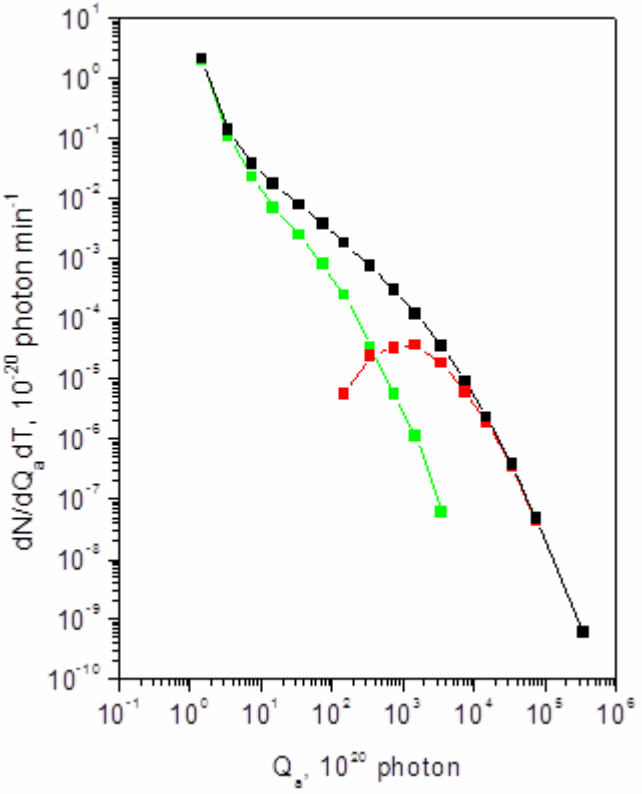


The Moscow University satellite results on transient light phenomena in the atmosphere of Earth



Geographical distribution demonstrates the global nature of the phenomena, both at the storm area and far beyond





UV flashes have very wide energy distribution (in numbers of photons), from tens of joules to 100 MJ.

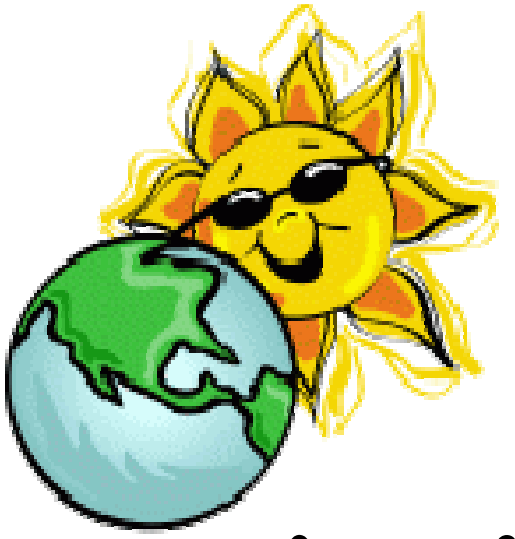
There are a long series of flashes over thousands of kilometers. Example: series of flashes for 8 minutes (4000 km along the Vernov satellite trajectory).

SUMMARY

D.V. Skobeltsyn Institute of Nuclear Physics of M.V. Lomonosov Moscow State University is developing a project `Universat-SOCRAT` of **a system of small satellites for monitoring of the space threats: ionizing radiation, potentially dangerous objects of natural (asteroids, meteoroids) and artificial (space debris) origin, and electromagnetic transients of Earth`s and space origin.**

One of the primary tasks for this satellite system is operational (close to `real time`) monitoring of the fluxes of energetic charged particles in the wide range of Earth`s radiation belts. For this purpose at least **two satellites with a mass <50-100 kg will be launched to elliptical orbit with height of perigee and apogee ~700 and 8000 km and inclination 63.4 degrees**, which crosses wide range of magnetic drift shells at different altitudes. Satellites will be equipped with multidirectional spectrometers of energetic protons and electrons.

Another satellite will be launched to Sun-synchronous low Earth orbit. It provides the payload mass about 100 kg and its aims besides the radiation monitoring also should be observation of other space hazards, such as space debris and asteroids and electromagnetic transients. Space debris and asteroids should be observed by several wide-field cameras and robotic telescopes of MASTER type. Satellite may also carry number of detectors for study of electromagnetic transients in different wavelength ranges - from infrared to gamma. This means observation of such phenomena, as transient luminous events (TLE) in the Atmosphere, terrestrial gamma ray flashes (TGF), cosmic gamma ray bursts



Thank you for your attention!

НИИЯФ МГУ