Monitoring of space weather effects with the use of Moscow University Sozvezdie-270 Nano-satellite Constellation

SINP MSU

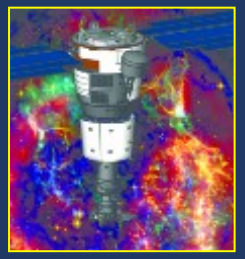
MSU space program: basic missions

Tatyana
2005

Tatyana-2
2009

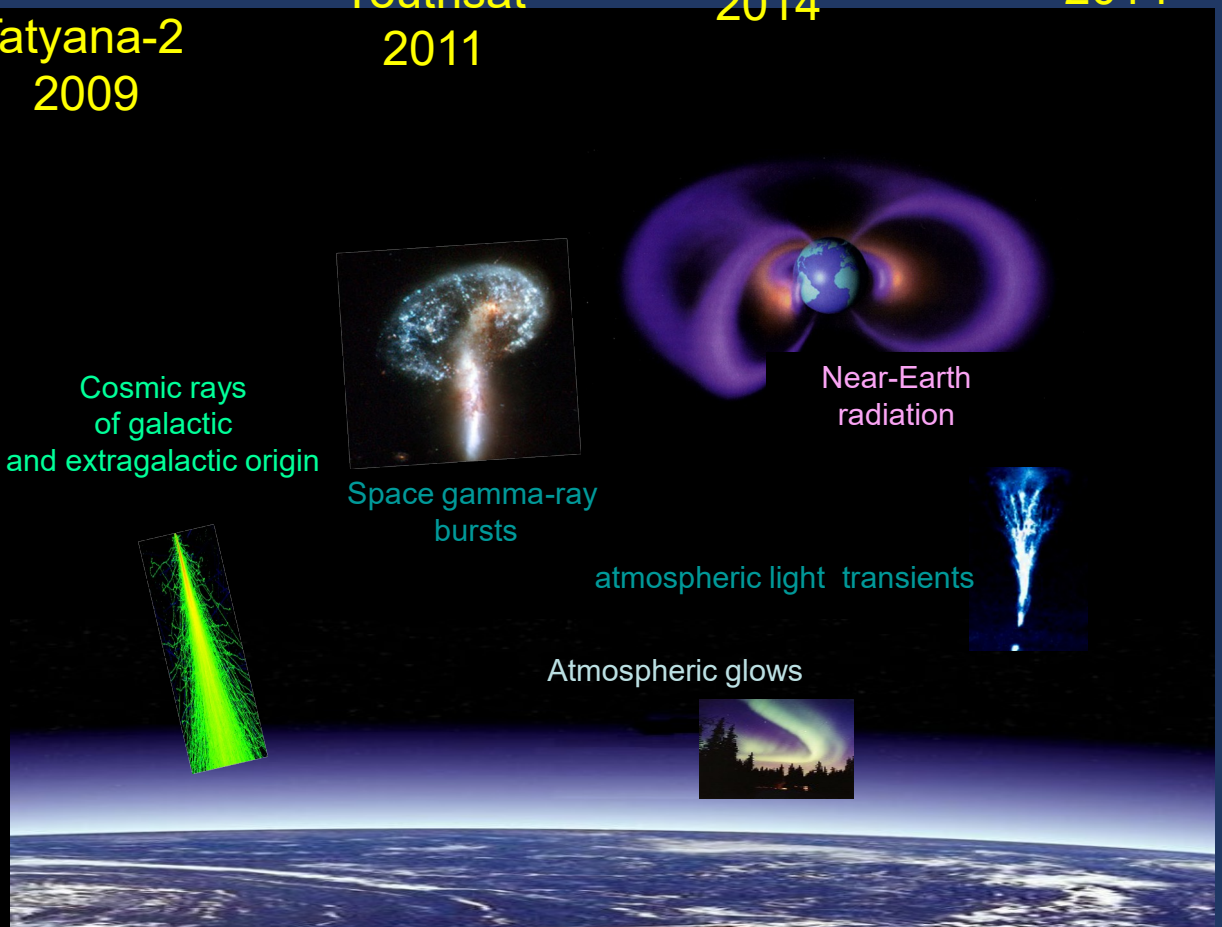
Youthsat
2011

Vernov
2014

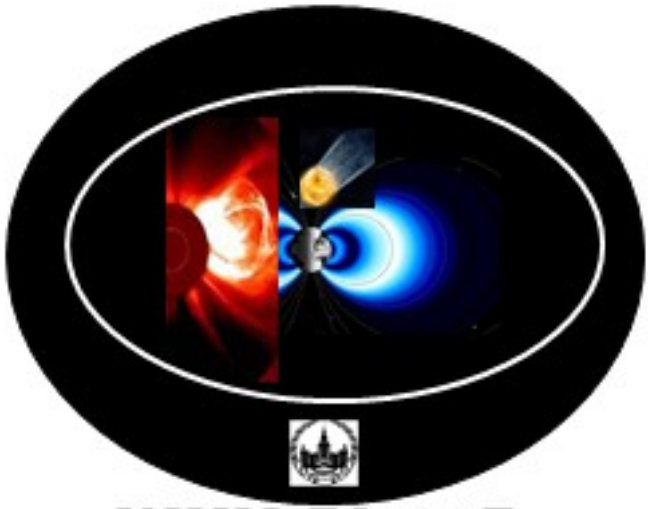


Nucleon
2014

Lomonosov
2016



University space project SOZVEZDIE-270

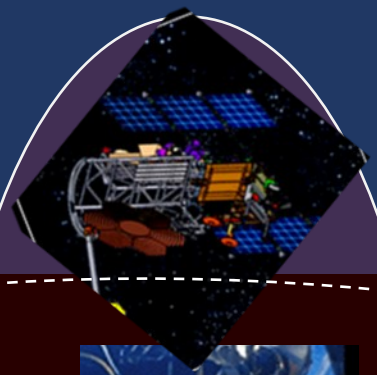


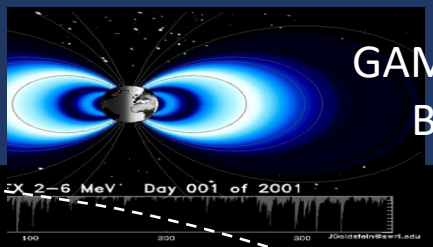
Small space satellites constellation for monitoring of space radiation and electromagnetic transients

Lomonosov Moscow State University

Space threats

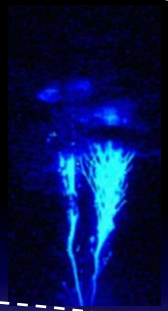
SOLAR
HIGH-ENERGY
PARTICLES



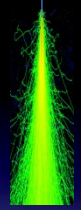


GAMMA-RAY
BURSTS

RADIATION



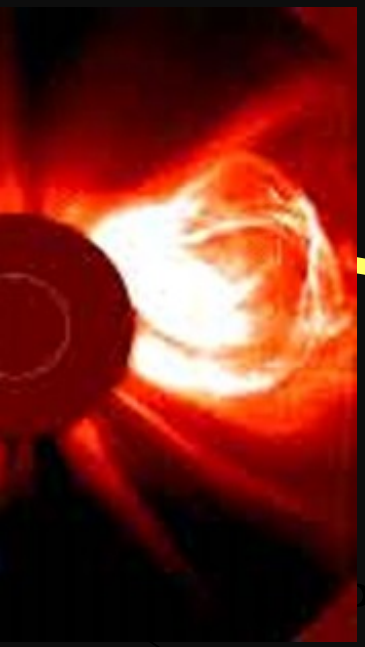
ASTEROIDS,
SPACE DEBRIS



ELECTROMAGNETIC
TRANSIENTS

УНИВЕРСАТ

Space radiation on the outskirts of the Earth



Galactic Cosmic ray

Earth's magnetic field

Solar energy particles

Radiation belts

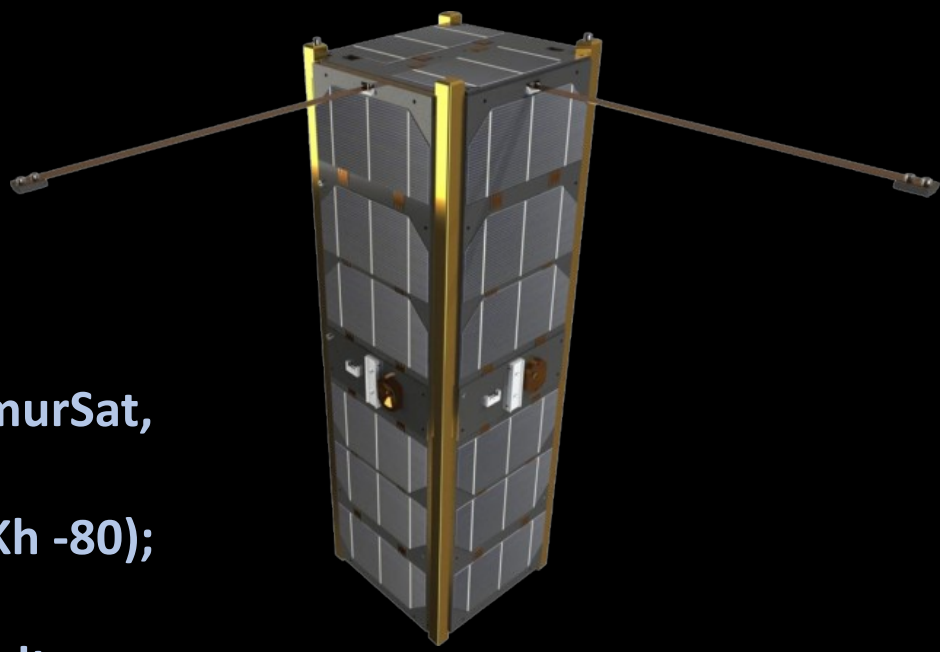
Goals of multi-satellite constellation in view of space weather monitoring

- - 1) sequential passage of the same area by closely spaced satellites, which will most reliably separate spatial and temporal effects;
- - 2) simultaneous measurements on different L-shells, which is necessary to restore the dynamic pattern of the trapped particle flux distribution in a wide range of orbits, which, in particular, will make it possible to observe the shift of the radiation belt maxima during geomagnetic disturbances;
- - 3) simultaneous measurements at the same altitude by the same type of instruments located on several satellites, shifted in longitude relative to each other, which will allow us to estimate the influence of the local time factor on the particle flux dynamics.

First stage of Universat-SOCRAT flight tests

Launched 2019, July 5.
3 satellites of cubesat 3U format :

- SOCRAT
- AmurSat
- VDNKh-80



Payload:

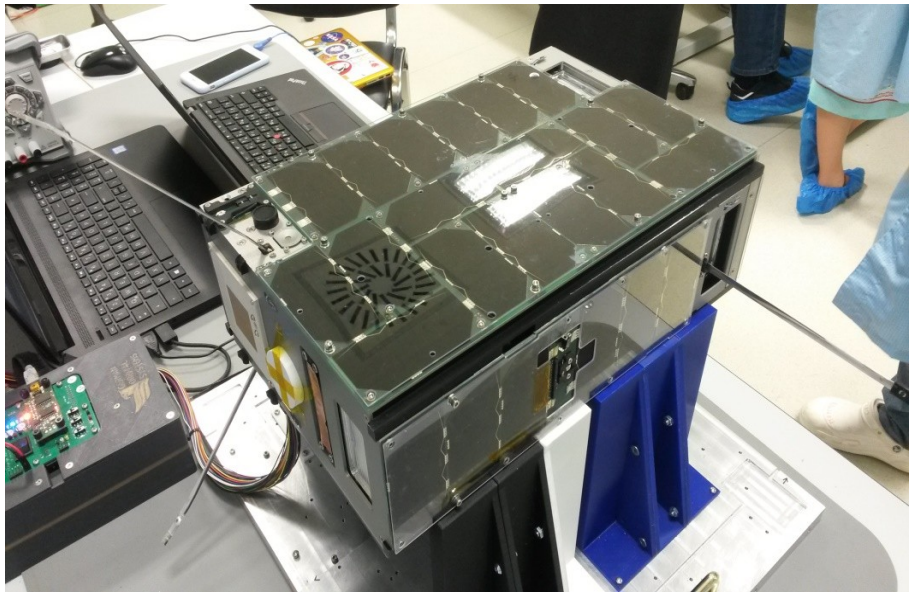
- Detector od space radiation DeCoR (AmurSat, VDNKh-80);
- Detector of UV radiation AURA (, VDNKh -80);
- Dosemeter SOCRAT-P (SOCRAT);
- Technological experiments with high voltage supply (SOCRAT) and photoelectron converter (AmurSat)

Second stage:

July 28, 2020 were launched 3 satellites of cubesat format:

- DECART (6U)
- Norbi (6U)
- Yarilo-2 (1.5U)

Orbit: H~550 km, 98°



DECART satellite

Payload:

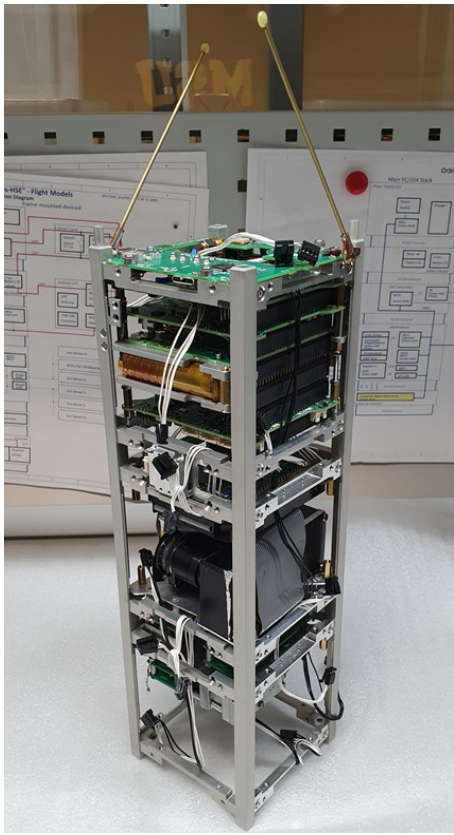
- DECART: 3 DeCoR instruments with normally directed axes, UV detector AURA-2;
- Norbi (joint with Novosibirsk State University): DeCoR instrument
- Yarilo-2 (joint with N.E. Bauman Moscow Technical University): DeCoR instrument

НИИЯФ МГУ

THIRD STAGE

2022, 9 AUGUST SUCESSFULLY LAUNCHED 3 SATELLITES OF CUBSATE 3U FORMAT WITH SINP MSU INSTRUMENTS :

- **MONITOR-1 (KODIZ INSTRUMENT)**
- **SKOLTECH-1B (DECOR-2 INSTRUMENT)**
- **SKOLTECH-2B (DECOR-2 INSTRUMENT)**



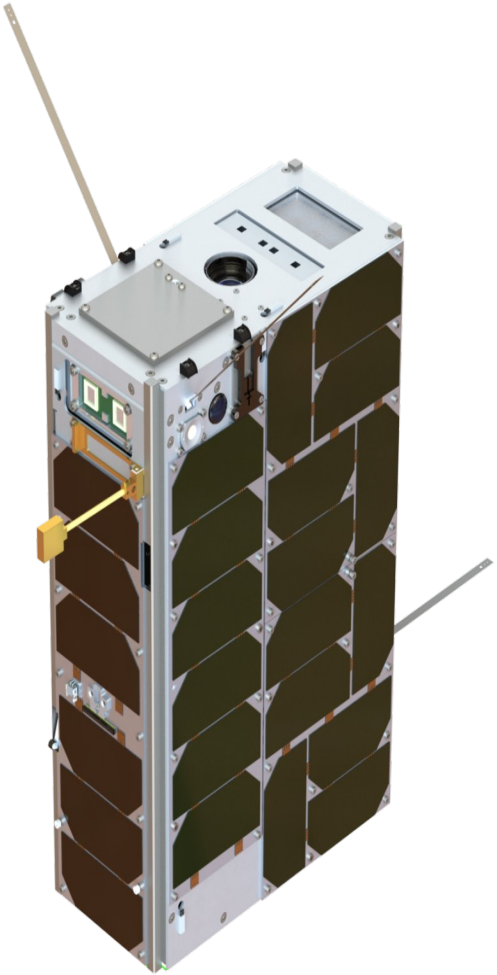
CURRENT AND FUTURE MISSIONS

Were launched 2023, June 27:

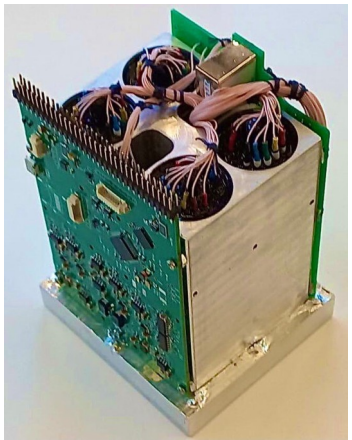
«Avion»: 6U cubesat with DeCoR complex of instruments (monitoring of space radiation, astrophysical and atmosphere gamma ray bursts and solar flares).

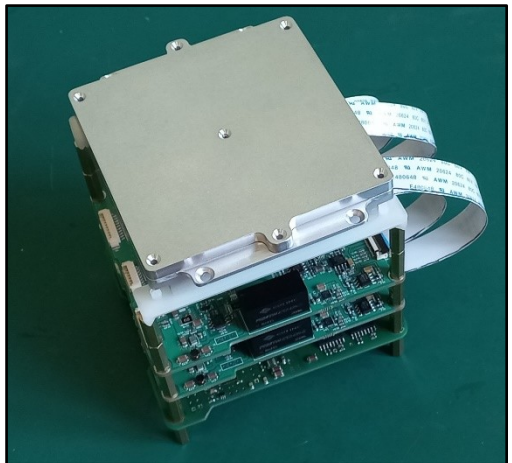
«Monitor – 2, 3, 4», UTMN-2, Sirius-SINP-3U, Saturn - 3U cubesats with DeCoR-2, AURA and KODIZ instruments (monitoring of space radiation, study of astrophysical and atmosphere gamma ray bursts, educational programme)

To the end of 2023 launching of steel 2 cubesats (3U & 6U) is planned. They will be equipped by advanced detectors of gammas and charged particles.



Avion





The sensitive area of DeCoR-2 insttrument is increased to 64 cm^2

Cubesates with MSU instruments

SiriusSat 1,2 (15.08.2018 – 09.12.2020

SOCRAT (05.07.2019 – 2021)

AmurSat (05.07.2019 – 09.2022

VDNKh-80 (05.07.2019 – pr. time)

Norbi (28.07.2020 - pr. time)

DECART (28.07.2020 - pr. time)

MONITOR-1 (09.08.2022 - pr. time)

SKOLTECH-1B (09.08.2022 - pr. time)

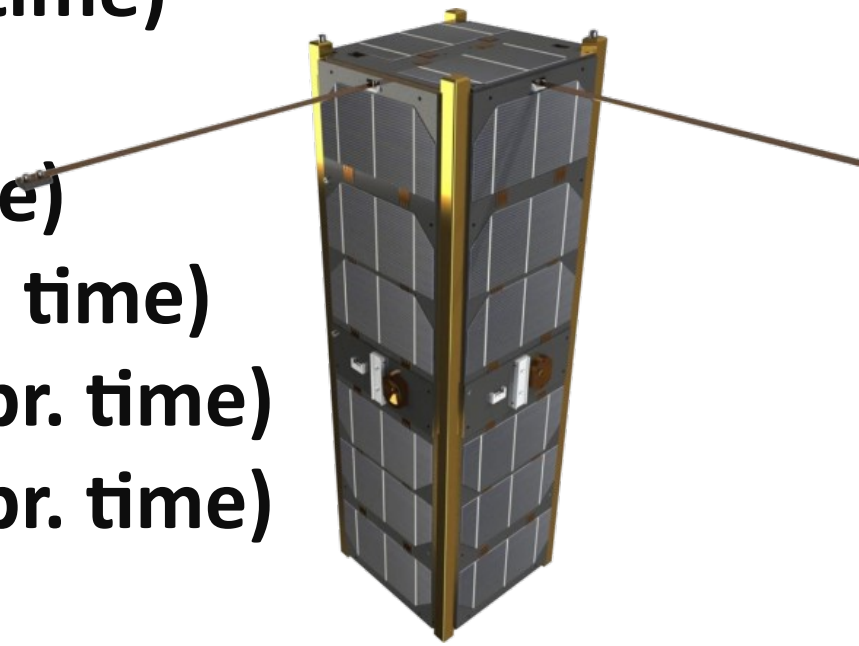
SKOLTECH-2B (09.08.2022 - pr. time)

Avion (27.06.2023 - pr. time)

Monitor – 1,2,3,4 (27.06.2023 - pr. time)

UTMN-2 (27.06.2023 - pr. time)

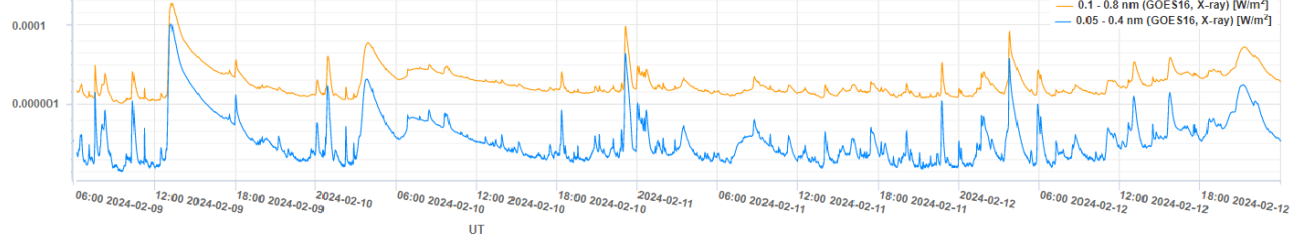
Saturn (27.06.2023 - pr. time)

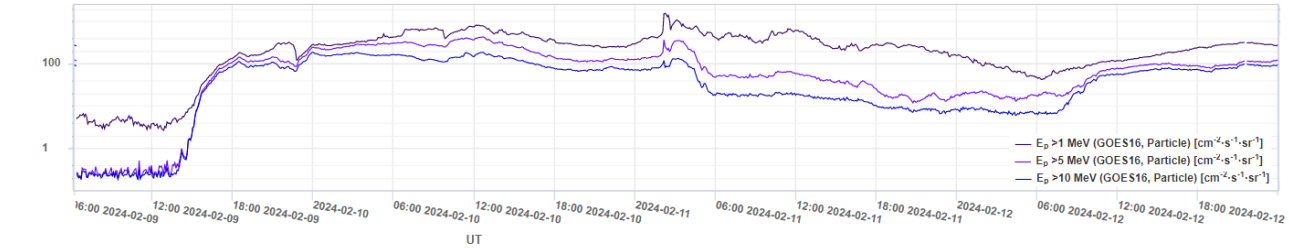


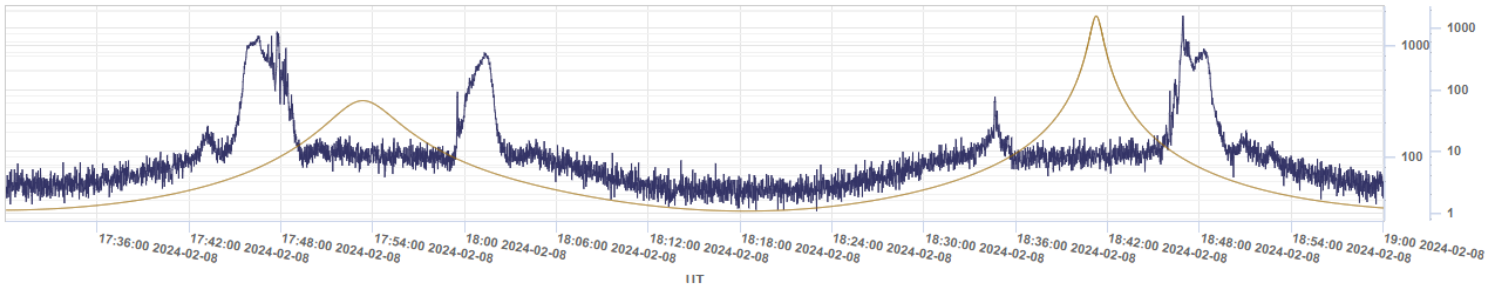
Main space weather effects observed by cubsate constellation

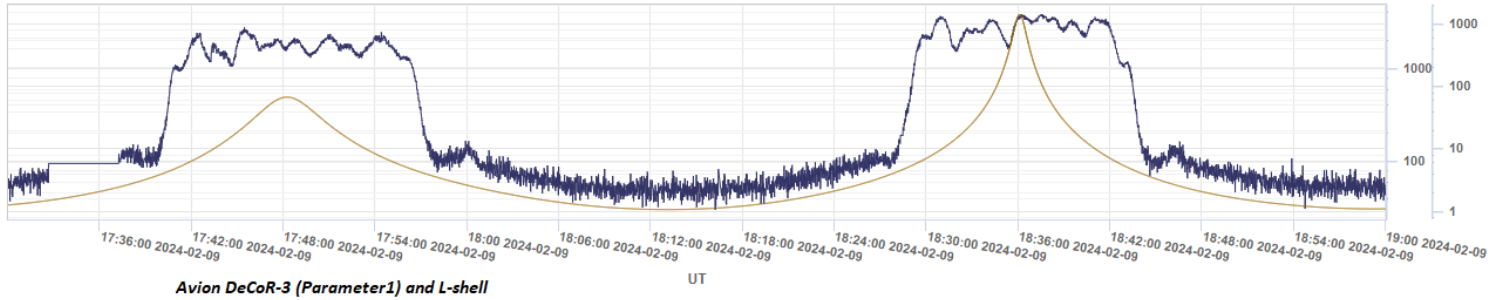
- solar cosmic ray filling of polar caps;
- dynamics of the Earth outer belt;
- electron precipitation in different regions of near-Eath space, i.e. isotropisation area (Arctic edge of the outer belt), slot, areas near the geomagnetic equator.

Effects of solar cosmic rays

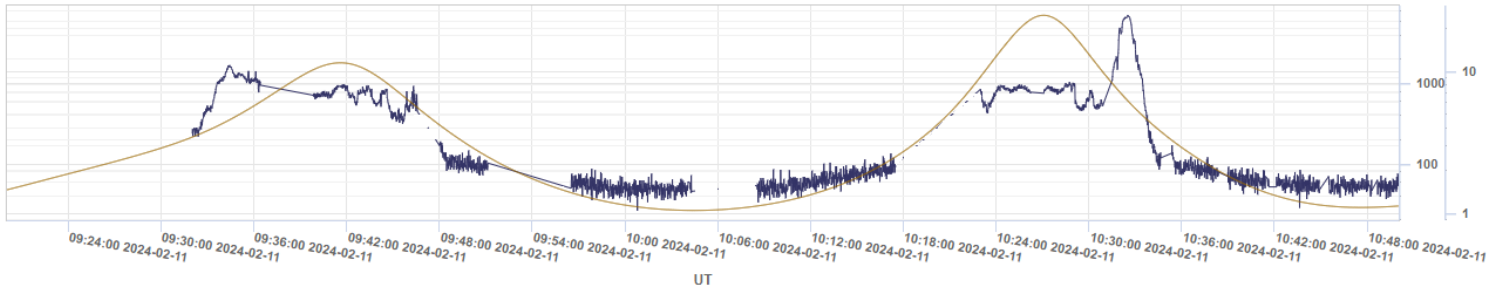




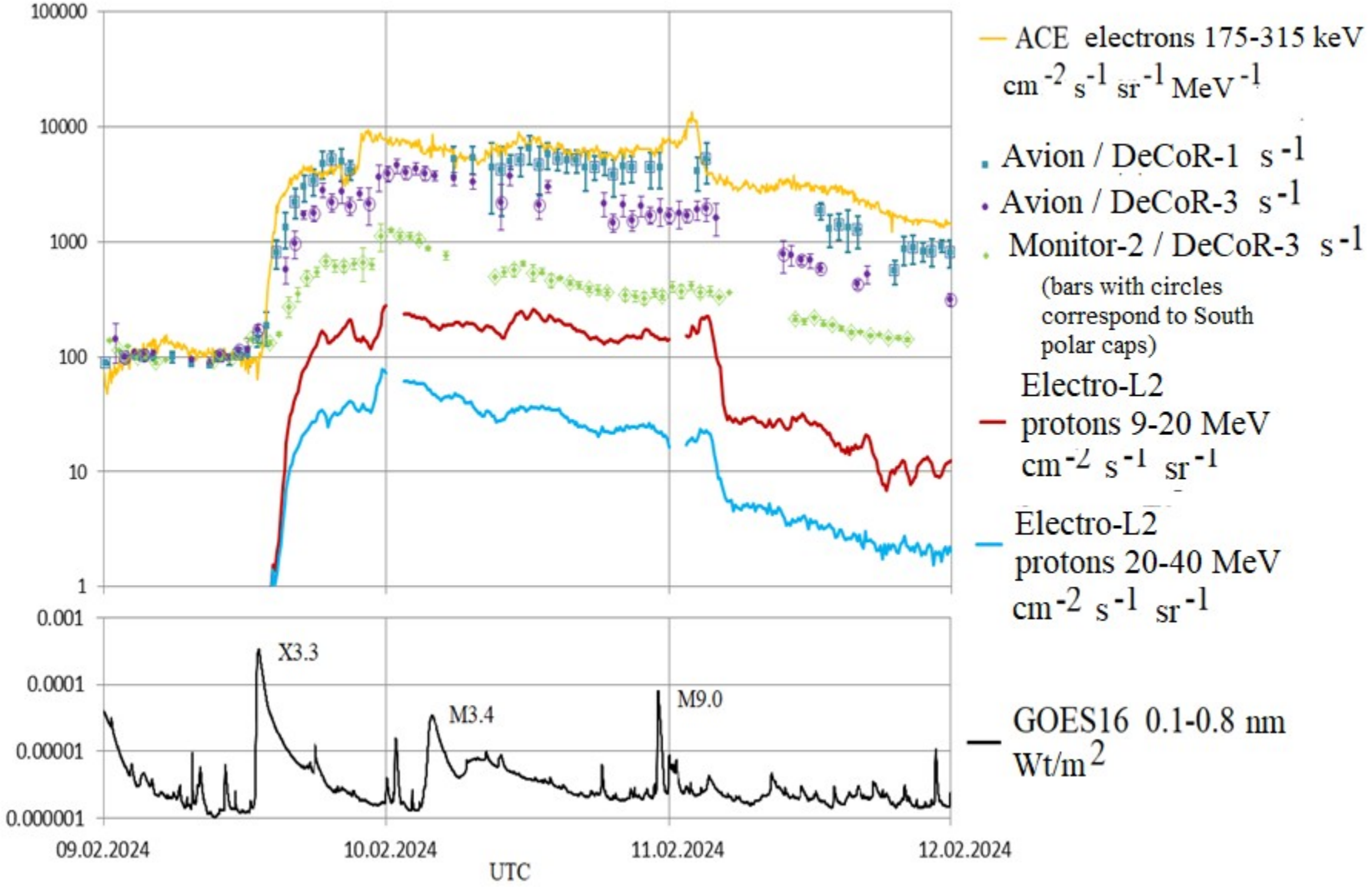




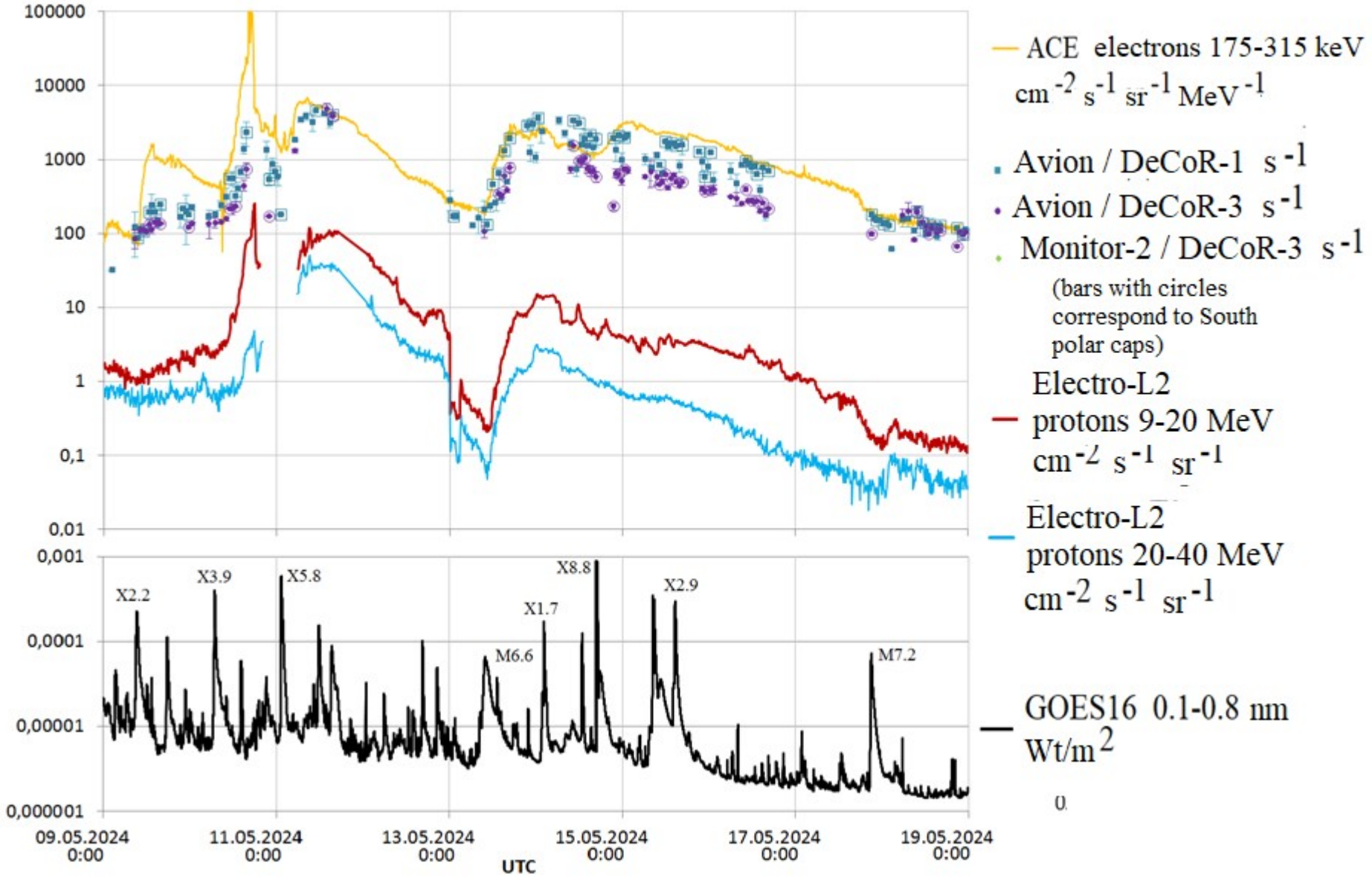
Avion DeCoR-3 (Parameter1) and L-shell



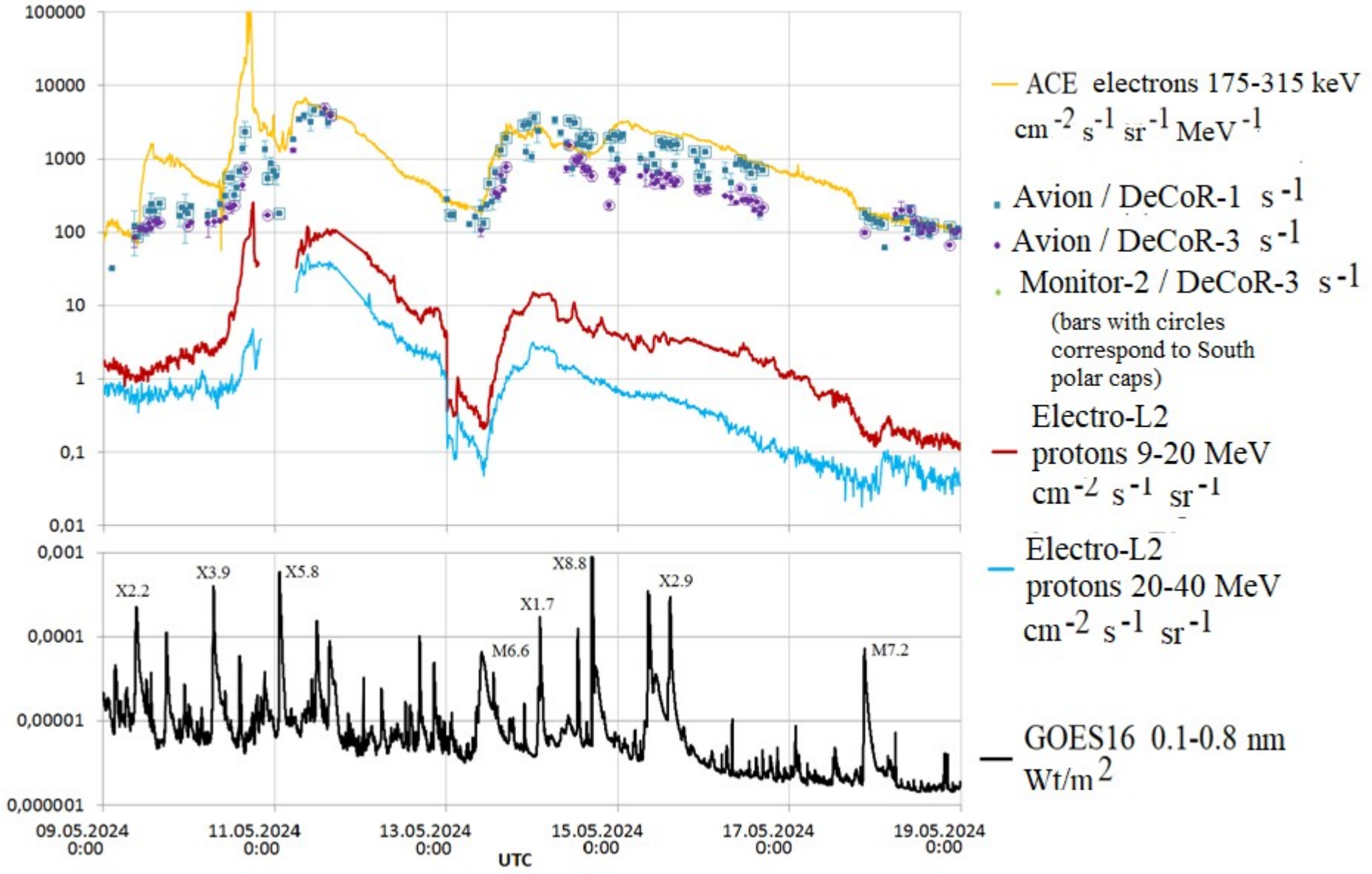
February, 9-12 2024

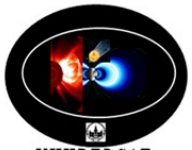


March, 22-27 2024



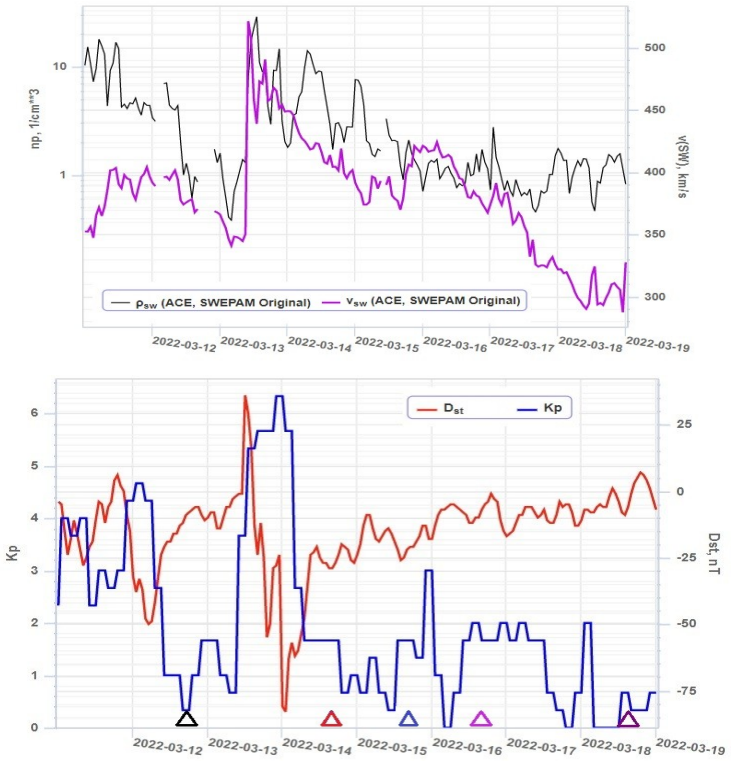
May, 9-19 2024

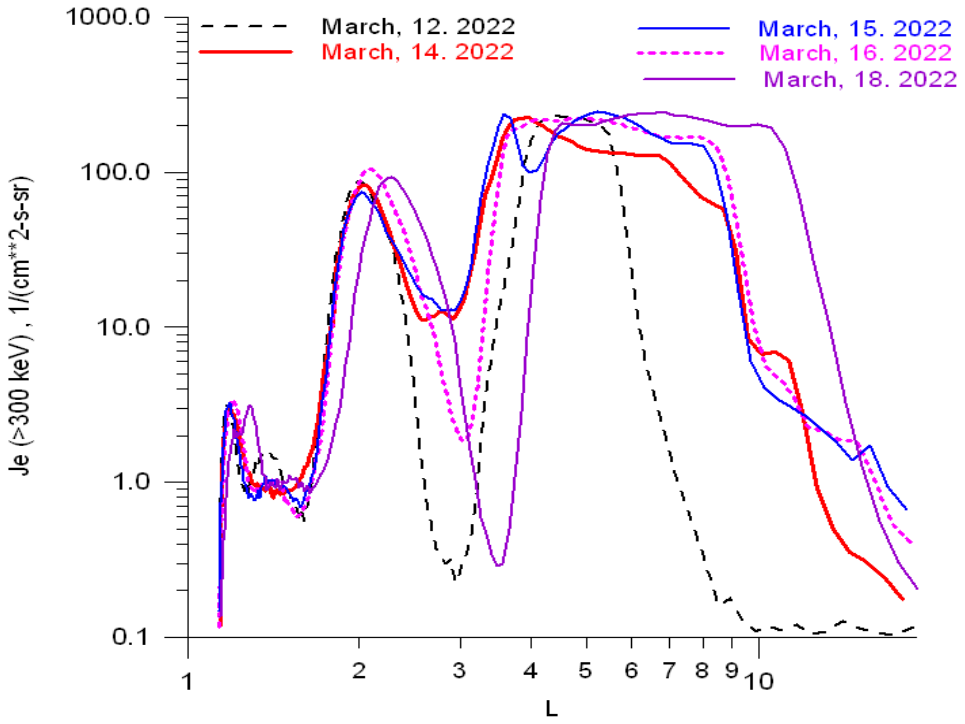

100000
10000
1000
100
10
1
0,1
0,01
0,001
0,0001
0,00001
0,000001
X2.2
X3.9
X5.8
M6.6
X1.7
X8.8
X2.9
M7.2
09.05.2024 0:00
11.05.2024 0:00
13.05.2024 0:00
15.05.2024 0:00
17.05.2024 0:00
19.05.2024 0:00
UTC
ACE electrons 175-315 keV cm -2 s -1 sr -1 MeV -1
Avion / DeCoR-1 s -1
Avion / DeCoR-3 s -1
Monitor-2 / DeCoR-3 s -1
(bars with circles correspond to South polar caps)
Electro-L2 protons 9-20 MeV cm -2 s -1 sr -1
Electro-L2 protons 20-40 MeV cm -2 s -1 sr -1
GOES16 0.1-0.8 nm Wt/m 2



Outer radiation belt dynamics

Fluxes of electrons with energies >300 keV, measured with DeCoR instrument on-board DECART satellite at different L in March, 2022.



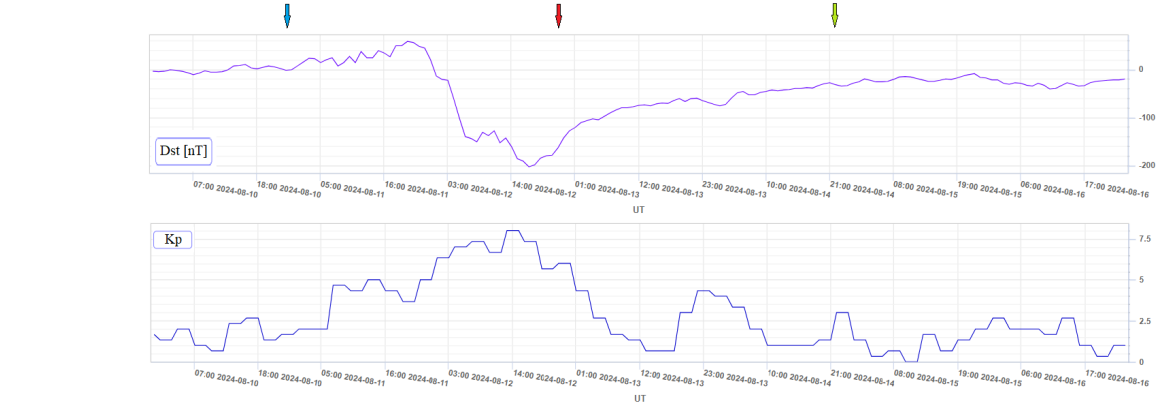


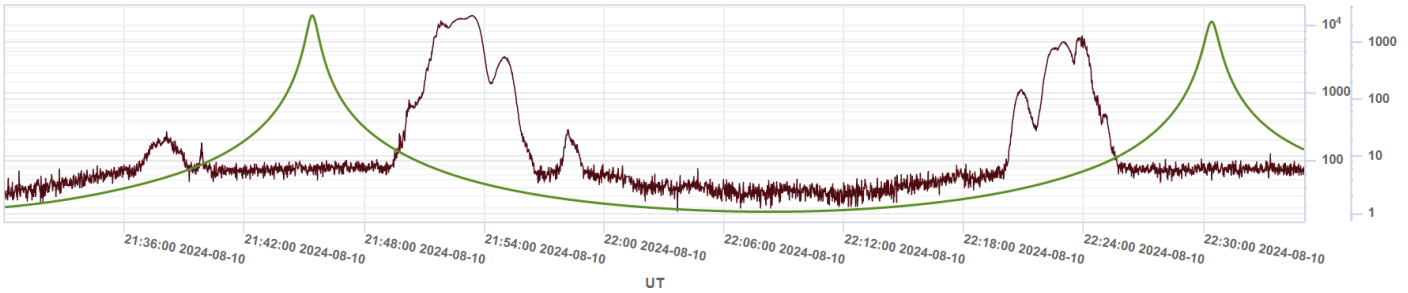
On March 2022, a high-speed solar wind stream came to Earth with a maximum velocity ~500 km/s and density ~10 particles/cm^3, which caused a magnetic storm with a maximum Kp=6 and Dst=-83 nT.

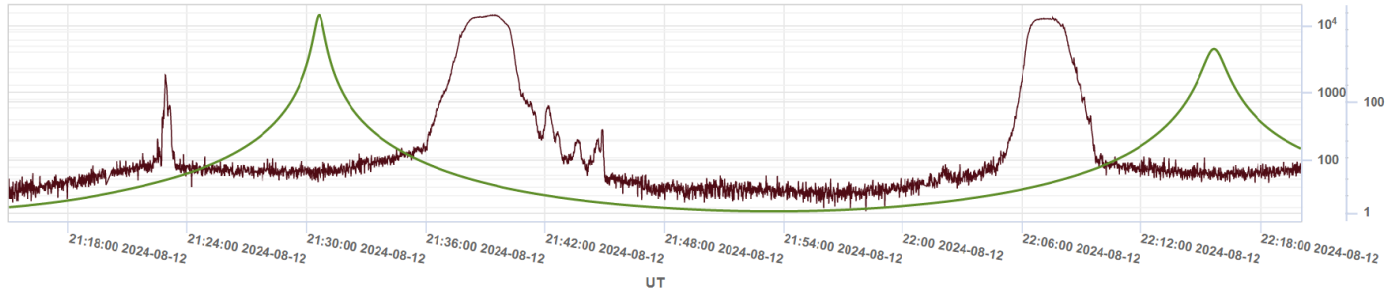
The triangles show the times of measurements on the satellite DECART on March 12, 14, 15, 16 and 18.

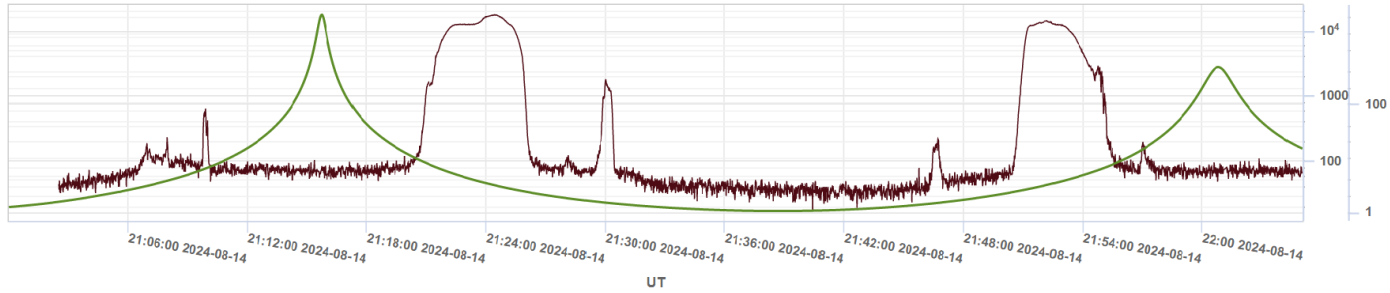
Electron fluxes >300 keV measured on the DECART satellite on March 12, 14, 15, 16 and 18 depending on L. The figures show that during the recovery phase of the magnetic storm (March 14 and 15), the outer belt noticeably expanded - its polar boundary shifted from L=9 to L>15, and its maximum shifted closer to the Earth, to smaller L - from L= 4.5 to 3.5. The equatorial boundary of the belt began to return to its original position, while the polar one remained in its original place. On March 18, the outer belt, remaining wide (L from 4 to 10), shifted further from the Earth, the maximum was observed at L=6.5-7.

Geomagnetic Storm, August, 11-12, 2024

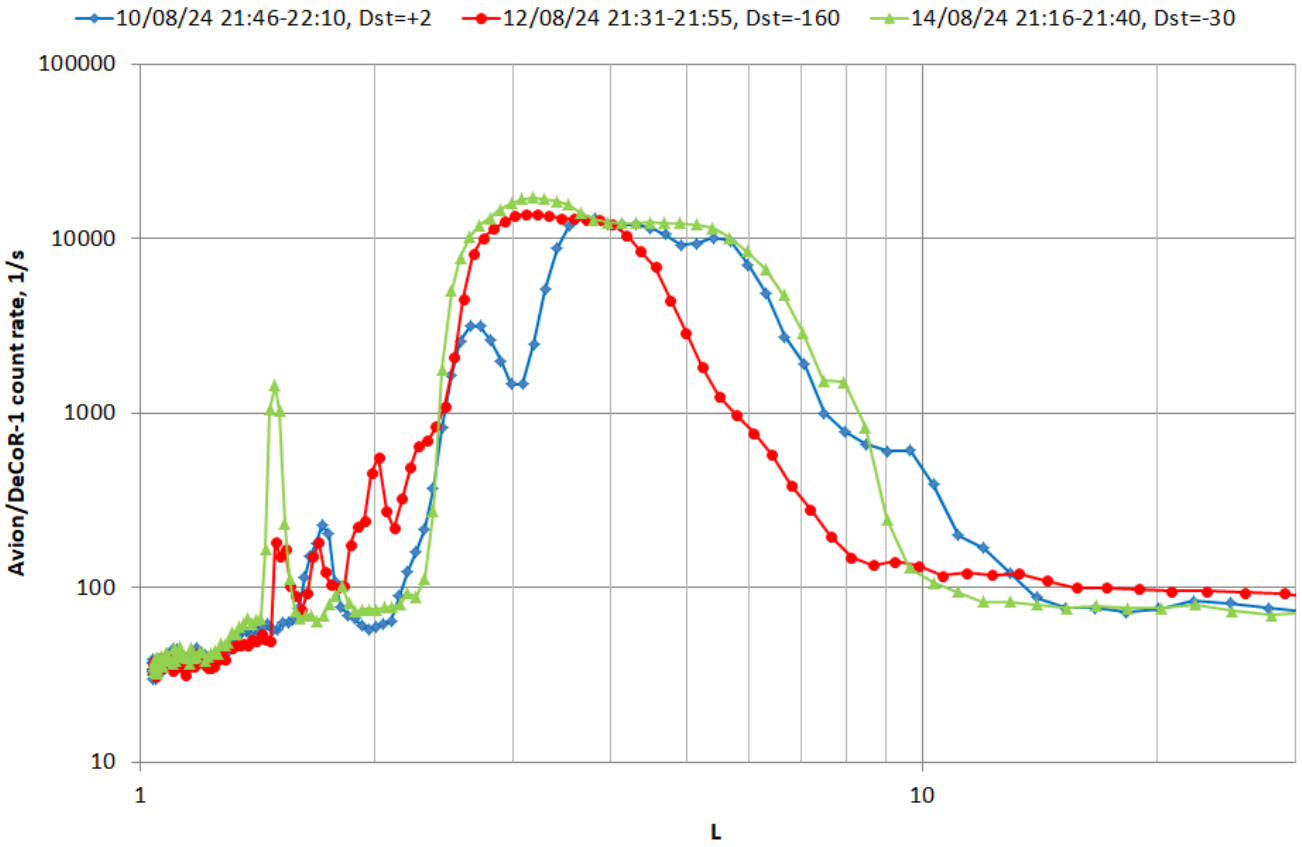


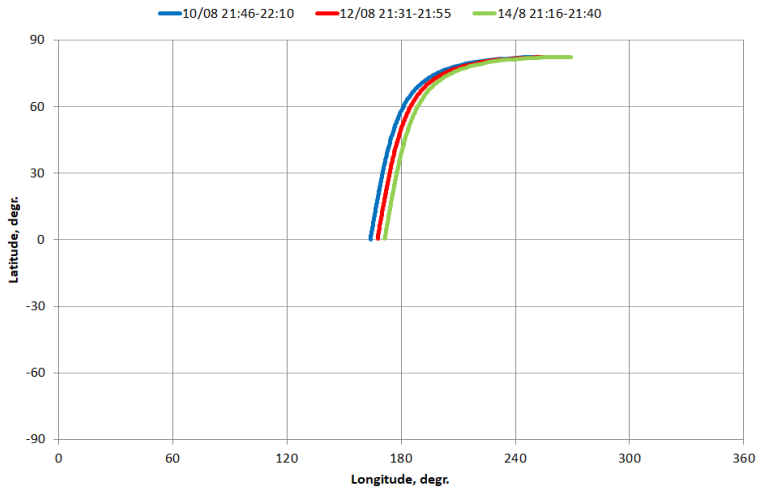




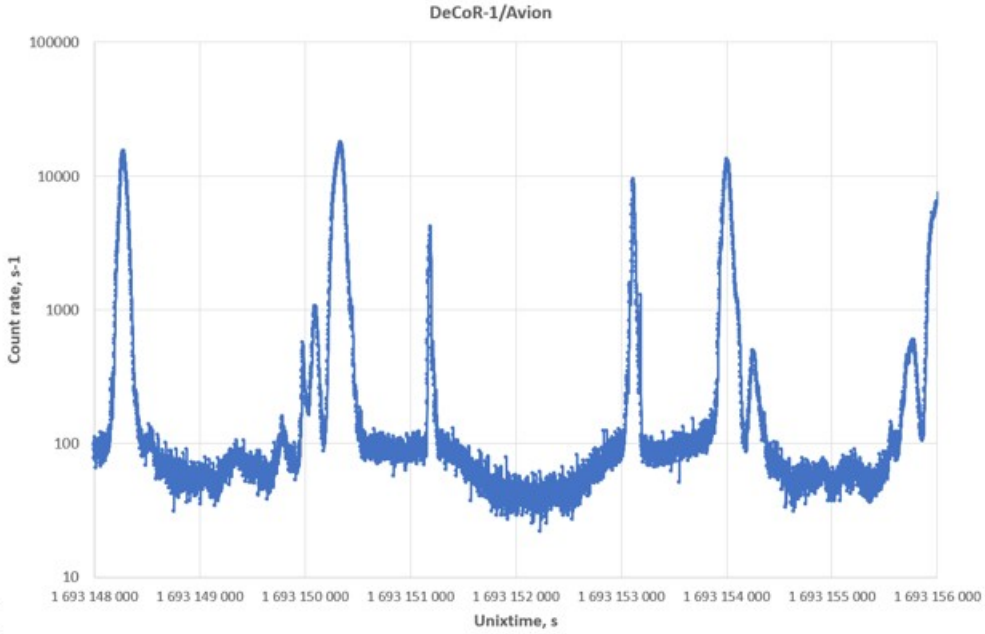


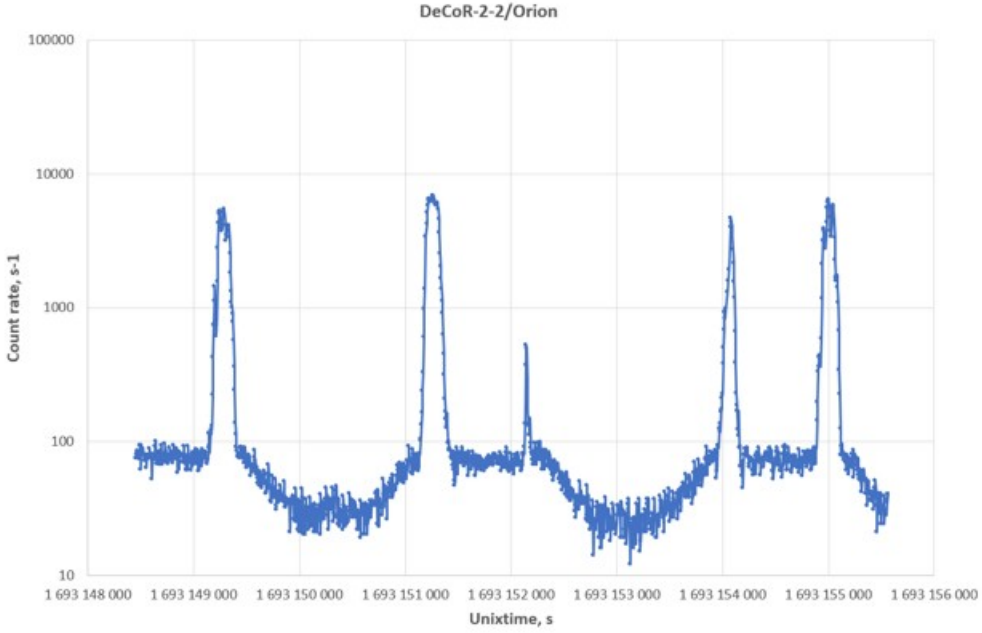
Geomagnetic Storm, August, 11-12, 2024



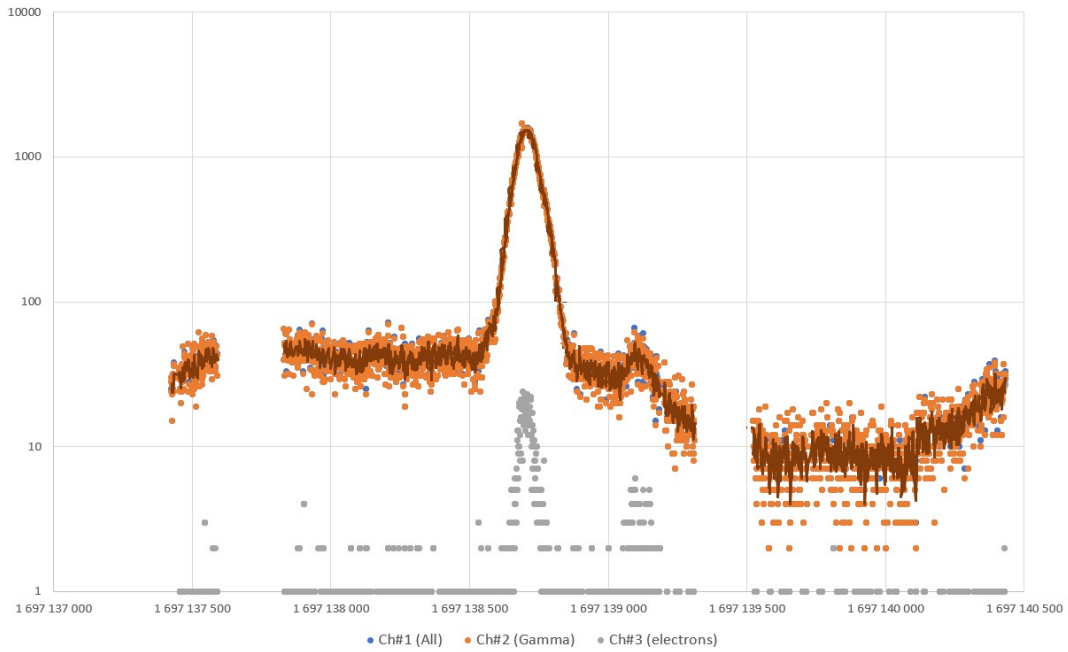


Electron precipitation

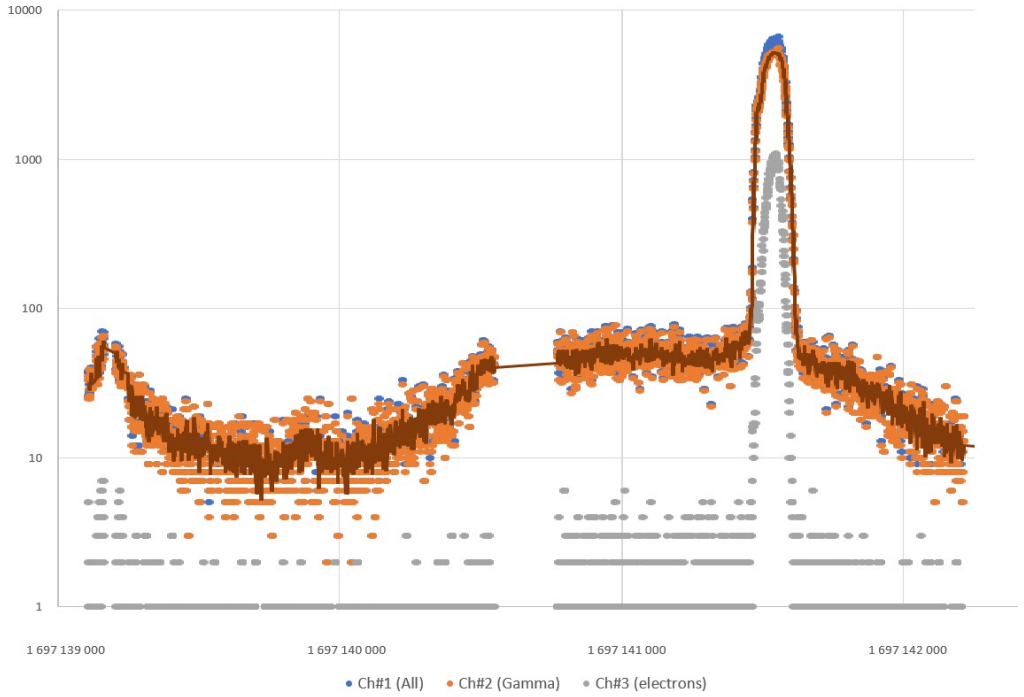

DeCoR-1/Avion
100000
10000
1000
100
10
Count rate, s-1
1 693 148 000
1 693 149 000
1 693 150 000
1 693 151 000
1 693 152 000
1 693 153 000
1 693 154 000
1 693 155 000
1 693 156 000
Unixtime, s

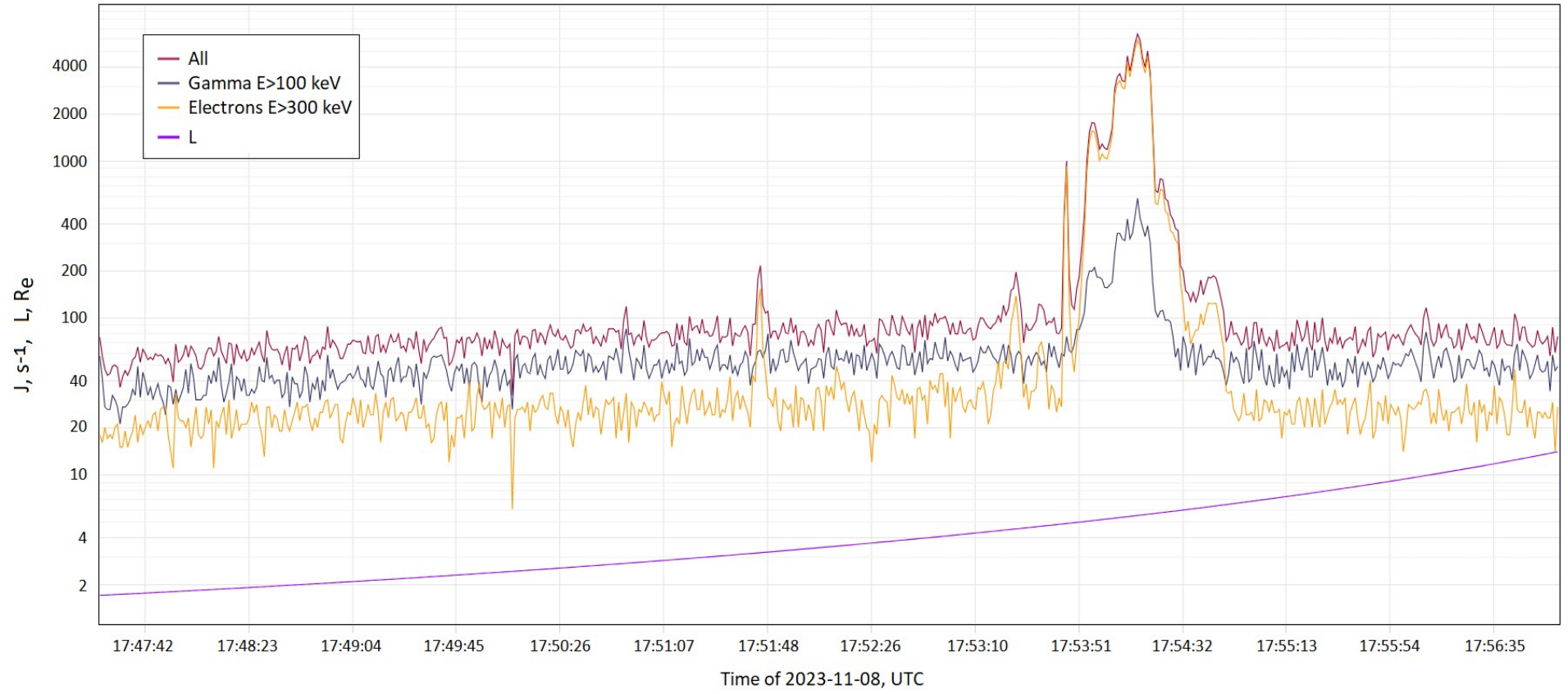

DeCoR-2-2/Orion
100000
10000
1000
100
10
Count rate, s-1
1 693 148 000
1 693 149 000
1 693 150 000
1 693 151 000
1 693 152 000
1 693 153 000
1 693 154 000
1 693 155 000
1 693 156 000
Unixtime, s

ДеКоР-2/Монитор-3



ДеКоР-2/Монитор-4





Example of electron precipitation at L ~3.2 near the outer belt detected by DeCoR-1 instrument on board Avion satellite 08.11.2023

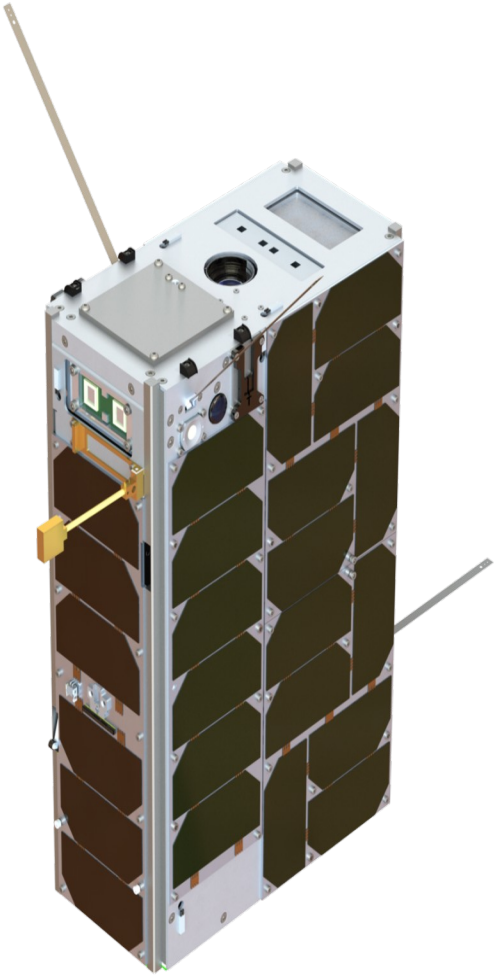
FUTURE MISSOONS

At leas three cubesats to be launched in 2024:

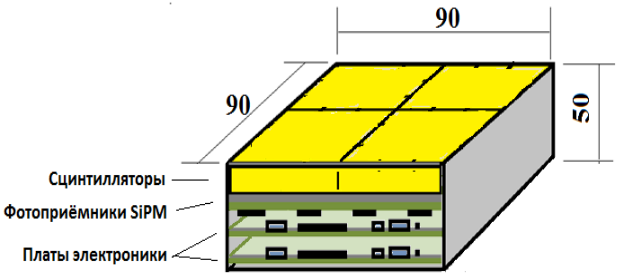
3U – with DeCoR 2 instrument

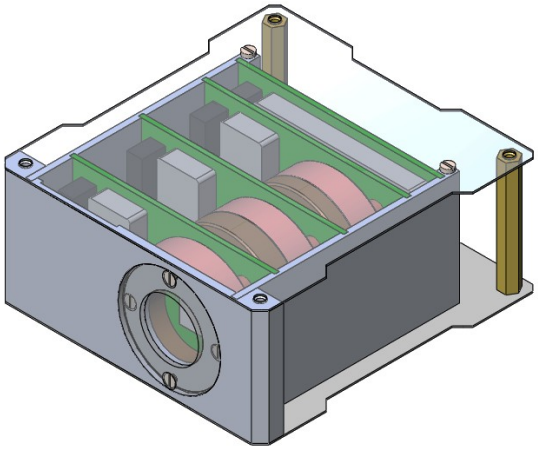
6U - Altair sayellite with advanced detectors of gamma quanta and charged particles

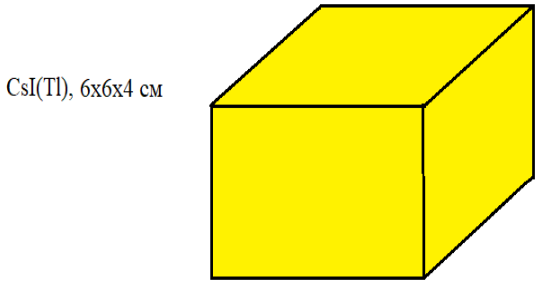
16U – Astrophysics and Astrobiology (Scorpion satellite)



Altair





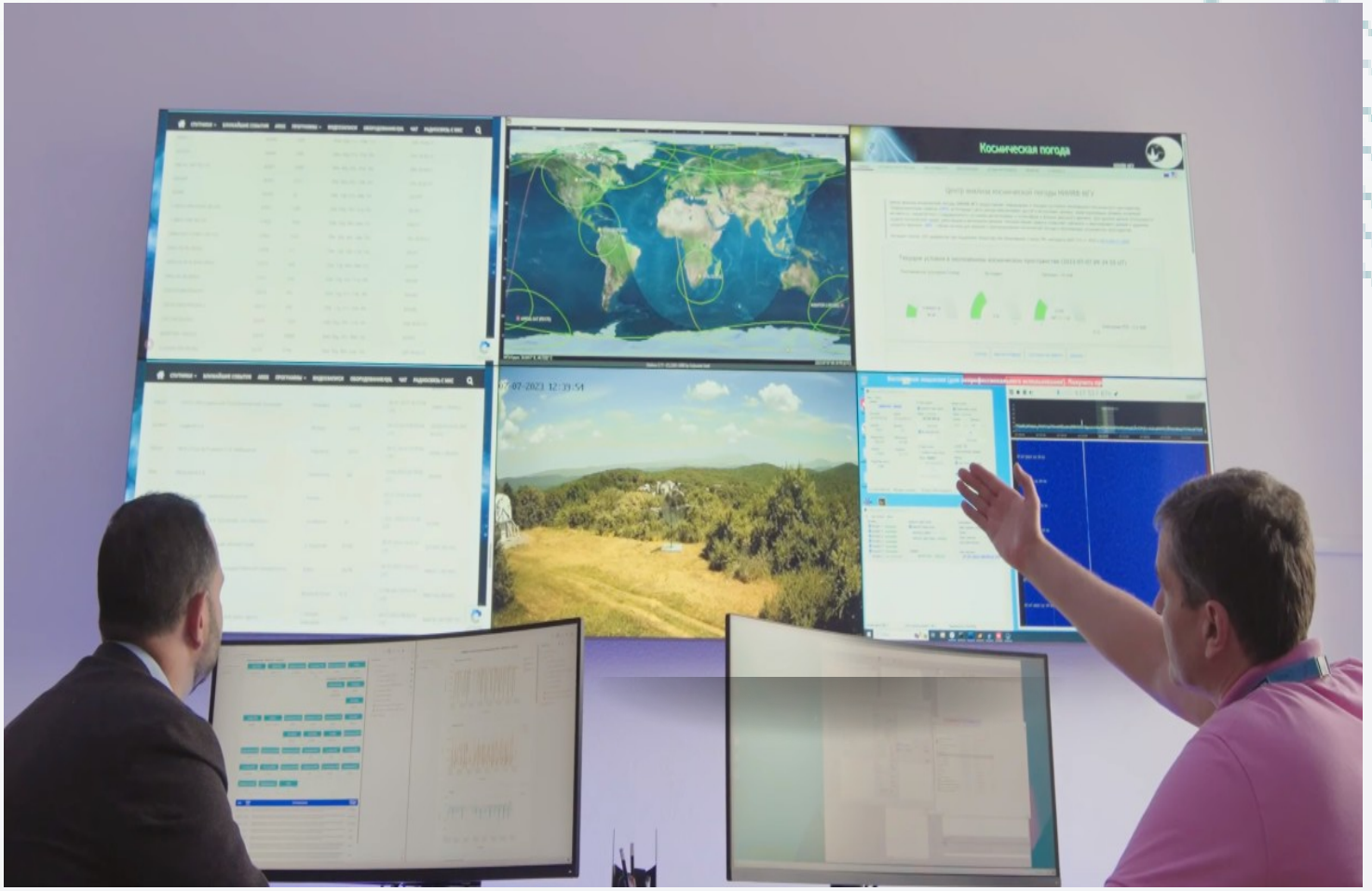


Universal semiconductor spectrometer

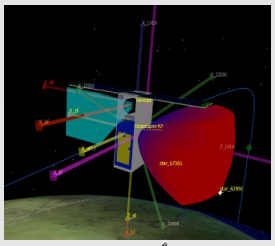
STATIONS MAP

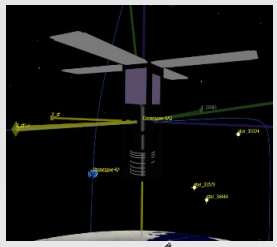
Deployment of a distributed network of receiving stations with centralized storage of received data. FM+X band.

mission control center



SPACE-EARTH SYSTEM





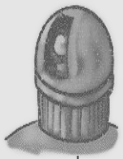
– small satellites of various form factors with profile payloads

Space

Earth

Ground receiving stations

Ground control stations



Control complex

Receiving, processing, distribution complex

The results of scientific data processing.
Data provision web services

Thank You

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