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OBSERVATIONS OF OPTICAL EMISSIONS AND MAGNETIC FIELDS ABOARD OF INTERBALL-2 SATELLITE

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Abstract

In the work, the Bulgarian experiments aboard of the INTERBALL-Auroral probe satellites, namely the investigation of optical emissions in the ultra violet (UV) range (UVSIPS spectrometer) and the magnetic field experiment (IMAP-3 magnetometer), are described. To ilustrate the common analysis of data from both units, the observations during the October 19, 1996 geomagnetic storm are analised.

The Bulgarian experiments aboard of the INTERBALL-Auroral probe satellite (briefly INTERBALL-2) include investigations of optical emissions in the UV range (UVSIPS spectrometer) and the magnetic field (IMAP-3 magnetometer). Optical emissions are closely related to precipitated electrons and ions, which ionize high atmosphere. Magnetic field disturbances are indicative of field-aligned currents which are generated in the magnetosphere boundary region; their closure currents flow in the ionosphere.

The physical bases of optical and UV-diagnostics of auroral ionosphere is as follows: auroral electrons and ions of various energies, which precipitate from the magnetosphere, as well as the secondary electrons produced by them, excite atoms, molecules and ions in the ambient media which begin to emit light quanta. By measuring the intensity of auroral emission distribution in the visible (VIS), UV and X-ray spectrum regions, or at least in only one of them, and using the relation between emission intensity and differential energy distribution of precipitating charge particles, we may obtain the distributions of precipitating electrons' characteristic energy Eo and energy flux Oe (Frank et al., 1981).

The major advantage of space experiments is the possibility to measure these parameters on large area, determined by the unit's view field and the satellite's height. Measurements of emission intensity distribution in the vacuum UV region have advantages compared to measurements in the VIS range, as UV –radiation is absorbed by the underlying layer of molecular oxygen in the region of Schumann-Runge continuum. This atmospheric effect creates beneficial natural conditions to observe aurora from satellite in the dayside of the Earth. The contrast of the emission auroral intensity at the background of the dayglow of the upper atmosphere varies with the different spectral lines and, as a rule, exceeds their double value (Kuzmin et al., 1985). This is an advantage of the UV method, which became a decisive factor for implementation of the UVSIPS spectrometer aboard of INTERBALL-2.

The INTERBALL project is an inherent part of a large cooperation between several space missions in the framework of the International Solar-Terrestrial Physics Program. The INTERBALL-2 was launched in 1996 to an orbit with apogee (perigee) 20,000 (800) km respectively, inclination 65 deg and period 6 hours. The spectrometer UVSIPS aboard of the INTERBALL-2 was designed to measure in three spectral intervals centred to wavelengths 1304 A°, 1356 A° and 1493 A°. The spectrometer apparatus function is 32 A°, which is an important advantage of the experiment. The first channel measures the most intensive emission of atomic oxygen (triplet 1302-04-06 A°). The second spectral interval of the spectrometer (channel 2) is centred to wavelength 1356 A° (line of atomic oxygen spin-forbidden doublet with wavelength 1356-9 A°), excited in the polar oval. The doublet of the atomic nitrogen 1492,6-1495 A°, radiated from level N1(2p) gets into the third spectral interval (channel 3), centred to wavelength 1493 A°.

The spectrometer was mounted on the outside surface of the satellite. Due to the rotation of the spacecraft, period 120 sec, the spectrometer scans in the rotational plane, perpendicular to the direction of the Sun. Based on the location and attitude of the satellite, a construction was designed in order to direct the device towards the footprint of the local magnetic field line 120 km above the Earth's surface. The control of the operation mode followed a cyclogram, fixed by radio commands. The UVSIPS performs 36 measurements (36 pixels) for a given exposition which takes 0.15-0.6 sec and sends 20 bytes per pixel, i.e. 36 x 20 = 720 bytes stored in 6 blocks of digital arrays.

The flux-gate magnetometer IMAP-3 measures the three components of the magnetic field along the satellite's construction axes continuously throughout the whole orbit. The device was designed and manufactured by a proprietary technology in the Scientific Industrial Laboratory for Special Sensors and Systems ("SDS" Lab's), Bulgarian Academy of Sciences (BAS), Sofia, Bulgaria, and the Solar-Terrestrial Influences Laboratory (STIL) - BAS, Sofia, Bulgaria (Arshinkov et al., 1985). The magnetometer data is transmitted by the satellite telemetry system with a sampling rate of 1 vector per 3 sec or 8 vectors/sec depending on the operation mode, which can be controlled by ground commands. Upon its receiving at the ground stations, telemetry data is distributed via Internet by the IKI- Moscow to the respective P.I.s.

It is known that under small perturbations, the spacecraft spin axis is misaligned from the nominal rotation axis. That is why data processing, in particular UVSIPS and IMAP-3, needs adequate attitude information provided by the satellite systems. Apart from the data from the scientific equipment, the following attitude parameters are also distributed:

(1) Coefficients A1, A2, A3, A4 and B1, B2, B3, B4 which define the ellipse along which the kinematics moment rotates with respect to the nominal axis of rotation (towards the Sun); $w1$ – angular velocity of the satellite rotation around the nominal axis, period ~ 120 sec; $w2$ – the angular velocity of rotation of the angular momentum relative to the satellite (this angular momentum relative to the satellite is moving along the surface close to the elliptic cone), period ~ 68 sec.

(2) "Top of spin" the time instance when the direction to the North Pole of the ecliptic passes through the XY plane of the satellite.

Based on both the geographic position of the satellite and attitude data, foot point of local magnetic field lines, and view field of UVSIPS with respect to the local magnetic field line, the components of the measured magnetic field in field-aligned coordinates and other geophysical coordinate systems are determined.

To illustrate the common analysis of the data from both units, let us examine a geomagnetic storm registered on 19.10.1996 (orbit 216 - Fig.3). UFSIPS has performed a scanning at 22:49 UT (Fig.1,2,3) with registered intensive emissions. The emission profile displays a high intensity zone in 1304 A° line with width of 3 sec, reaching more than 10 KR. (Fig.1). This part of the profile is like a chord through the oval, approximately 2,000 km long (Fig.3). By geometric considerations it can be said that this arc is at least 150 km wide. The profile analysis leads to the conclusion that at equatorial direction from the arc there is a weak glow halo whose width is of the same order. According to the expectations, such intensities are possible with precipitating particle energy fluxes with energy of about 50-100 erg/cm^2, observed during polar aurora.

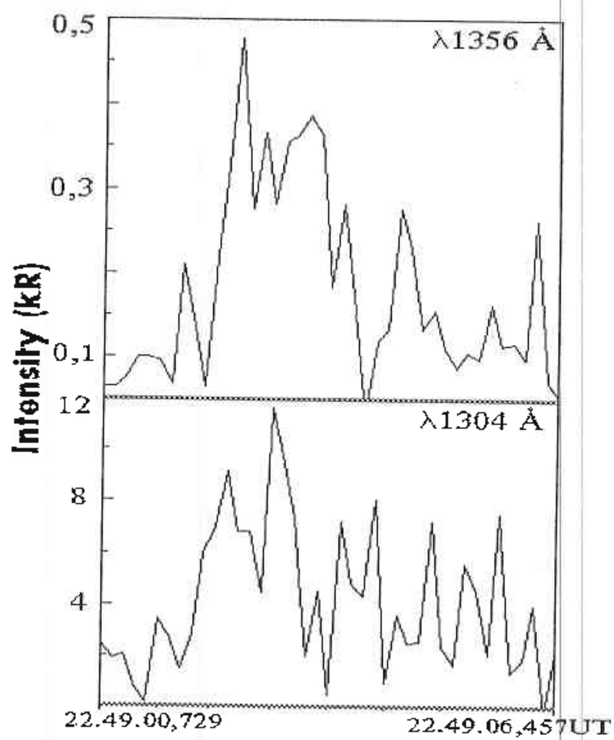


Fig.1. Intensity of lines 1304 A° and 1356 A°

The magnetogram begins with a calm interval (Fig. 4) which continues until 22:45 UT. The magnetic disturbances observed after that may be connected with current layers crossing. At the near-equator portion, from 22:45 UT until 22:50 UT, changes in the field up to 10 nT can be seen which might be treated as small-scale layers. The minimum width of such a structure may be of the order of 10 km. In the near-pole half from 22:50 UT until 22:56 UT, the field change is two times greater which is connected with a large-scale current structure crossing. The width of such a current layer is about 130 km reduced to atmospheric altitudes (at the footpoint). A comparison is made of the optical emissions measurements and the magnetic field. At the moment of optical emissions scanning, the satellite passed through the main zone of the field-aligned current layers. Their physical carriers are mainly low-energy (E~1 KeV) electrons. These particles degrade by energy at altitudes, higher than the atmospheric altitude, generating the observed optical effects. Here, we pay attention that a little before the encounter with this region, i.e. at 22:45-22:46 UT an increase of the magnetic field is observed of the order of several nT, corresponding to a re-stricted current structure. It is namely this interval that corresponds to the intensive emissions zone. We conclude that a localized discrete auroral arc was observed at the poleward edge of the auroral oval and that the main current region occurred polward of it. Our observations support the view that field-aligned current region in some cases can be displaced poleward from the auroral oval discrete arcs in the night-morning sector of the auroral oval.

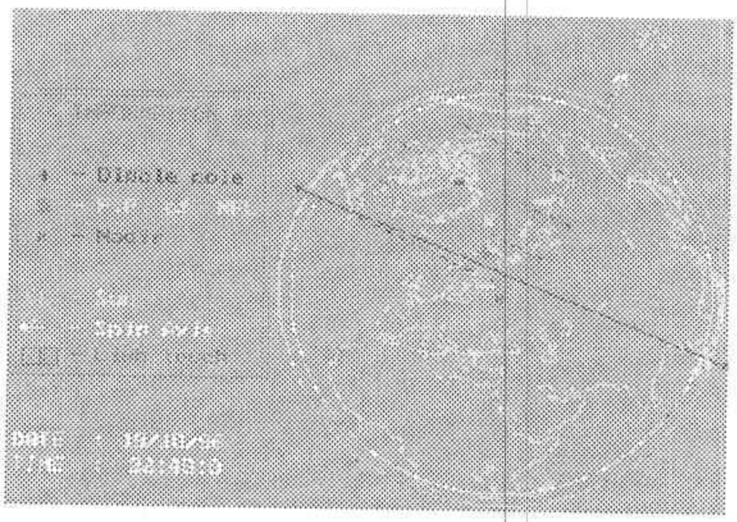


Fig.2. The northern hemisphere seen by the satellite at the moment of measurement. The symbols +, • , and Ò correspond to the dipole pole, the northern geographical pole, the point of intersection of the vector to the Earth centre, and the footpoint of the magnetic force line where the satellite is at that moment. The auroral oval is shown for forced geomagnetic conditions with index Kp=5+. The position of the terminator shows that the larger part of the auroral oval is situated in the shade. The position of the scan projection is marked by two arrow vectors. The view field of UFSIPS crosses the auroral oval through the chord in such a way that the intersection goes from the morning to the night section. Because of the deviation of the axis X-satellite-Sun, the footpoint occurred in the morning section out of the field of view. The coordinates of the footpoint are (at 22.49.03 UT for H = 150 km) 74.3° latitude, 32.7° longitude, MLT=3.04 h (Fig.3), H shade = 647 km.

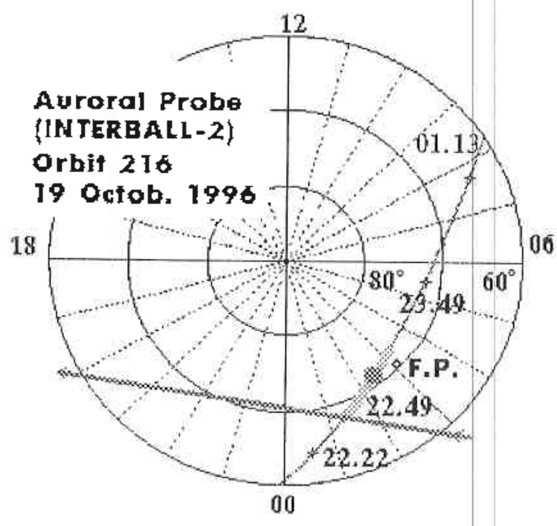
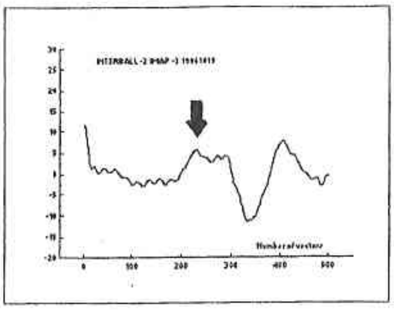


Fig.3. IMAP-3 magnetogram. It begins with a calm interval until 22:45 UT. The disturbances observed after that may be related with current layers crossing. At the near-equator half from 22:45 UT until 22:50 UT, changes in the field up to 10 nT can be seen which might be treated as small-scale layers. At 22:45-22:46 UT, an increase of the magnetic field is observed of the order of several nT. It is namely this interval that corresponds to the intense emissions zone. The main field-aligned current region is poleward (22:50 –22:56 UT).

INTERBALL-2 IMAP-3 19.10.1996



Vector No	0	100	200	300	400	500
UT	22:35:00	22:40:00	22:44:59	22:49:59	22:54:59	23:00:00

Fig.4.

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НАБЛЮДЕНИЯ НА ОПТИЧНИ ЕМИСИИ И МАГНИТНИ ПОЛЕТА НА БОРДА НА СПЪТНИКА ИНТЕРБОЛ-2

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Резюме

В работата е дадено кратко описание на двата български експеримента на борда на спътника ИНТЕРБОЛ-Авророрална сонда, а именно: изследване на оптичните емисии в ултравиолетовия диапазон на светлината (спектрометър УВСИПС) и изследване на магнитното поле (магнитометър ИМАП-3). За илюстрация на съвместния анализ е направен анализ на данни от двата уреда по време на геомагнитната буря от 19 октомври 1996 год.