AURORAL PHENOMENA AS SEEN BY UVSIPS, IMAP-3, SKA-3 EXPERIMENTS ON BOARD THE INTERBALL-2 SATELLITE

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Abstract

The International Interball project investigates the system solar wind- magnetosphere by two satellites - Auroral and Tail probes. A set of experiments investigates the interactions energetic particles, magnetosphere, ionosphere. We present correlated results received by the optical instruments UV spectrometer UVSIPS, magnetometer IMAP-3 and SKA-3 (set of energetic particles detectors) on board the Auroral satellite, thus allowing to contribute substantially to the realization of the tasks and scientific aims of the Interball Project.

As a result of this combination of remote sensing and conjugate in-situ measurements, a new phenomenon was detected at the polar edge of the auroral oval - field-aligned upward electron beams at altitude $3R_E$, accompanied by bi-directional electron field aligned beams.

1. INTRODUCTION

The aim of the Interball Project is to study the interaction solar wind -magnetosphere –ionosphere system by two satellites - Auroral and Tail probes. Each satellite includes about 20 experiments. This provides a possibility for combined investigations to realise contemporary research of the solar-terrestrial influences and particularly the phenomena in the polar region. The simultaneous measurements of the magnetospheric substorms, the dissipated energetic particles in the polar atmosphere from the solar wind and the auroral phenomena contribute essentially to the understanding of the system Solar wind – Magnetosphere - Ionosphere [1]. The purpose of the paper is to present applied optical-magnetic and energetic particles measurement methods for joint investigations of the circum-terrestrial space and some results. The UV Spectrometer UVSIPS [4] maps ionospheric auroral characteristics in the magnetic field line footprint. The principle advantage of the optical remote sensing is the possibility to measure simultaneously parameters at large areas, determined by the field of view and the satellite altitude. The measurements of the emission intensity distribution in the vacuum UV-region have an

advantage in comparison with the measurements in the visible range, as the UV-radiation is absorbed by the underlying layer of the molecular oxygen in the region of the Schuman-Runge continuum (1300-1600 A° with the maximum around 1400-1425 A°) [2]. This atmospheric effect creates beneficial natural conditions to observe aurora from a satellite on the ***dayside*** of the Earth. The contrast of the emission auroral intensity at the background of the daily radiation of the upper atmosphere varies for different lines and, as a rule, exceeds the double value [2,3]. The experiment is realised with the co-operation of IKI-RAN (Moscow-Russia), ITMO (Institute Tochnoy Mekhaniki I Optiki- Saint Petersburg-Russia) and IKI (STIL)-BAS-Bulgaria.

The magnetometer IMAP-3 [5] was designed with the co-operation of IZMIRAN (Russia), NPL SDS (Bulgaria) and PIC GPI of RAS (Russia) organisations. The IMAP-3 magnetic field instrument is designed to study the following processes in the Earth's plasma environment: structure of the inner magnetosphere magnetic field; structure of the small scale field-aligned currents; dynamics of the field-aligned currents during sub-storms; relation of the processes in the auroral zone and in the tail. The SKA-3 (set of particle detectors) installed on the Auroral probe measures the distribution functions of the dissipated electrons and ions [6].

By means of appropriate cyclograms, determining the operation of the instruments in orbit, it is possible to make joint measurements.

2. EXPERIMENTS (METHODS AND INSTRUMENTATION)

The equipment of the three experiments is mounted on board the Auroral satellite of the International multi-satellite space project Interball (Russia, France, Canada, Bulgaria, Poland et al.). The three experiments described below, by their joint investigation contribute substantially to the experimental proof of the theoretical tasks aimed by the projects for studying the Earth‘s magnetosphere and solar wind-magnetosphere interactions [1].

The UV Spectrometer UVSIPS maps ionospheric auroral characteristics in the magnetic field line print in 3 spectral intervals, centred to wavelengths 1304 A°, 1356 A° and 1493 A°. The halfwidth of the spectrometer apparatus function is 32 A°.

The first channel measures the most intensive emission of the atomic oxygen (triplet 1302-04-06 A°).

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 reactions are described in detail in Ref. [4].

By remote sensing the spectrometer UVSIPS provides optical monitoring of the interaction solar wind-magnetosphere-ionosphere.

The triaxial flux-gate magnetometer IMAP-3 is designed to measure three components of the DC magnetic field towards the satellite construction axes continuously along the whole orbit in two ranges: ± 6800 nT with resolution 1 nT and ± 68000 nT with resolution 10 nT. IMAP-3 is described in Ref. [5]. The magnetometer transmits to the scientific telemetry system (SSNI) one vector every 3 sec as a 24-th bit number.

IMAP-3 was designed and manufactured with the co-operation of IZMIRAN (Russia), NPL SDS (Bulgaria) and PIC GPI of RAS [6]. The instrument was initially tested on 9 September and started regular operation on 14 September 1996.

The SKA-3 (set of particle detectors) installed on the Auroral probe measures the distribution functions of the electrons and ions. Electrostatic analysers in parallel for 8 angles around the satellite rotation axis and sequentially for 7 energies are used to measure the energy range from 0,03 to 15 keV. For higher energies (20-400 keV for electrons and from 30, 35 and 55 up to 400, 420 and 510 keV for protons, α-particles, and O^+ ions respectively), the measurements are performed by two oppositely directed identical time-of-flight energy/mass spectrometers, so that the angular scanning is due to the satellite rotation (about 120 sec.). The scientific aims are:

- How the solar plasma enters the magnetosphere, what determines the low–latitude boundary layer and polar mantle; the relative time delays for bursts of particles, pitch angles and masses above and within the auroral ionosphere during sub-storm; what is the role of the two plasma sources of the magnetosphere (solar wind and the Earth's ionosphere (polar wind)).

The experiment SKA-3 is described in detail in REF. [6].

By means of appropriate cyclograms, determining the operation of the instruments in orbit, it is possible to make joint measurements. Later, the data processing and the correlation provide new scientific information for explanation of the phenomena concerning the interaction solar wind/magnetosphere in the circle terrestrial environment and particularly in the polar region. The coordination of the Interball project with ground-based measurements provides information for the time/space development of the auroral phenomena necessary for the understanding of the local magnetospheric features, observed by the Interball experiments.

3. RESULTS

To illustrate the combined measurements and common analysis of the instruments data, let's examine the plot(Figure 1), shown below. The upper part demonstrates the spectrogram (time-space-energy-intensity) obtained with by measurement of electron and ion fluxes by the help of EM-1-1 semi-conducting analyzer of the SKA-3 complex as well as the intensity profile of the electron fluxes with energy 30 keV, obtained by the same instrument. The sine of the pitch angle for the EM-1-1 instrument is shown above the panels. In this figure with the same scale and time intervals the results of the measurements (profiles) of the electron and ion fluxes in the range 15 keV are presented, obtained by the optical analyzers EU-2, EU-3, respectively. Both the electron and ion profile intensities have been selected for directions, corresponding to the direction of the measurements performed by the EM-1-1 instrument. That's why the pitch angle, presented in the upper part of the figure, refers also to these results of the measurements. The instruments EA-2 and EA-3 in orbit 216 operated in a mode of fixed energetic interval centered to 15 keV (a mode of fixed sweep level).

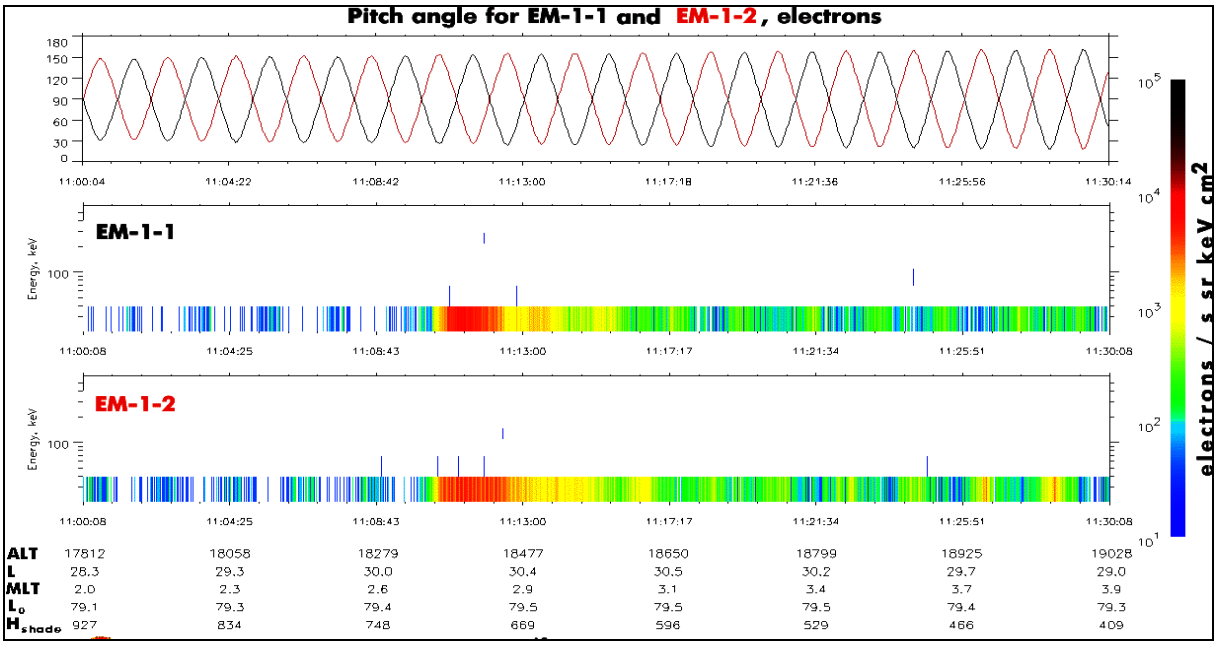
An example of joint investigations of the auroral phenomena and the magnetic fields by the UV spectrometer UVSIPS and the magnetometer IMAP-3 on board the Auroral satellite is shown in the middle right (intensity of lines 1304 A° and 1356 A°, measured by UVSIPS) and in the bottom right (magnetic field sub-storms, measured by IMAP-3).

UVSIPS performed a scanning in 22:49 UT. The emission profile displays a high intensity zone in 1304 A° line with width of 3 sec., reaching more than 10 KR. This part of the profile is like a chord through the oval, approximately 2000 km long. By geometric considerations it can be said that this arc is at least 150 km wide. The profile analysis yields 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 with the polar aurora. The magnetogram of IMAP-3 begins with a calm interval which continues until 22:45 UT. The magnetic disturbances, observed after that may be connected 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. The minimum width of such a structure may be of the order of dozen km. In the near-pole half from 22:50 UT until 22:56 UT the field change is two times larger 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. A comparison is made of the optical emissions measurements to these of the magnetic field. At the moment of optical emissions scanning, the satellite has passed through the main zone of the field-aligned current layers. Their physical carriers are mainly low-energy electrons (E>>1 KeV). These particles degrade by energy at altitudes, higher than the atmospheric altitude, generating the observed optical effects. Here we note that a little before the meeting with this region, i.e. at 22:45-22:46 UT, a magnetic field increase is observed of the order of several Nt, corresponding to a restricted current structure. This interval namely corresponds to the intensive emissions zone, taking into consideration the direction of the magnetic-conjugated region.

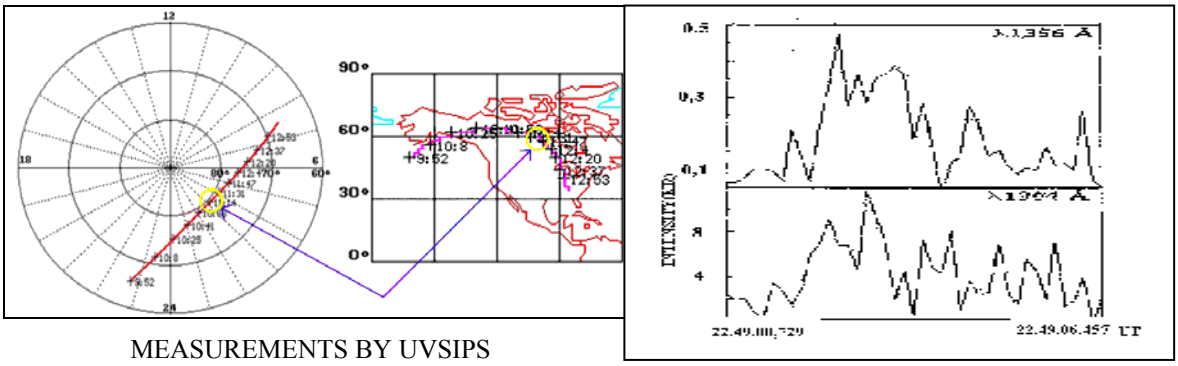
In the center left, the satellite orbit projection with co-ordinates invariant latitude (Λ_0) – geomagnetic local time (MLT) is shown. The orbit time, close to the moment of spectrophotometric measurements (22.49.00UT) is shown by the bolded point. At 22.49.03 the satellite has been in a point with coordinates: invariant latitude 71.0° and MLT=2,31^H. Here the projection of the axis of spectrometer UVSIPS field of view is shown at the altitude of the UV emissions maximum λ1304 and 1356 A° at 150 km. In

the same part of the figure a thick line represents the part of the orbit projection where the measurements of the particles flux distribution have been conducted in time close to that of the spectrometric investigations. In the middle (right side), the northern hemisphere is shown as seen by the satellite at the measurement moment. The auroral oval is shown for forced geomagnetic conditions with index Kp=5+. The field of view of UFSIPS crosses the auroral oval through the chord in such a way that the intersection goes from the morning to the night section over Scandinavia. The co-ordinates of the footpoint are (at 22.49.03 UT for H =150 km) 74.3° latitude, 32.7° longitude, MLT=3.04^h, H shade = 647 km.In the bottom (left side) the magnetogram, obtained in Kiruna (lat=67,8º, log=20,4º) is shown which presents the geomagnetic conditions at the moment of measurements. Arrows on the magnetogram mark the measurement moment (of IMAP-3, UVSIPS, SKA-3) on board the Auroral satellite. It is evident that the measurements have been performed at the end of the sub-storm maximum phase – the initial phase of the recovery.

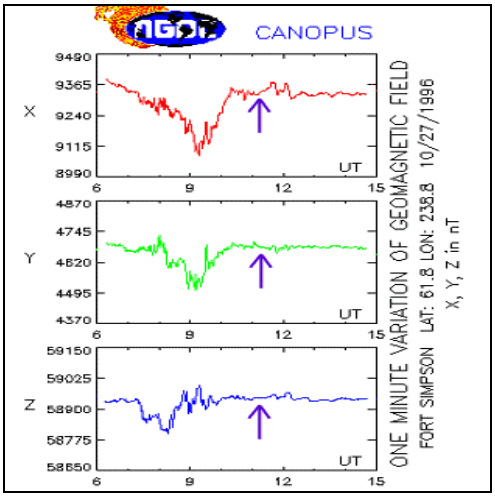
As a result of this combination of remote sensing and conjugate in-situ measurements, a new phenomenon was detected at the polar edge of the auroral oval (post-midnight-morning sectors) – field-aligned upward electron beams (20-45 keV at altitude $3R_E$ with intensity 10^4e/s.sr.keV.cm^2, a relatively long time (300-1000 sec.), accompanied by bi-directional electron field aligned beams with keV energy. We suppose that the satellite is between the bi-directional acceleration regions where the stochastic field-aligned acceleration is accomplished by plasma waves with fluctuating field-aligned components in both directions. The lower-hybrid, ion-sound waves, Langmuir and/or lower-hybrid cavitons, or ion holes seem to be possible candidates for such waves.



MEASUREMENTS BY SKA-3



MEASUREMENTS BY UVSIPS



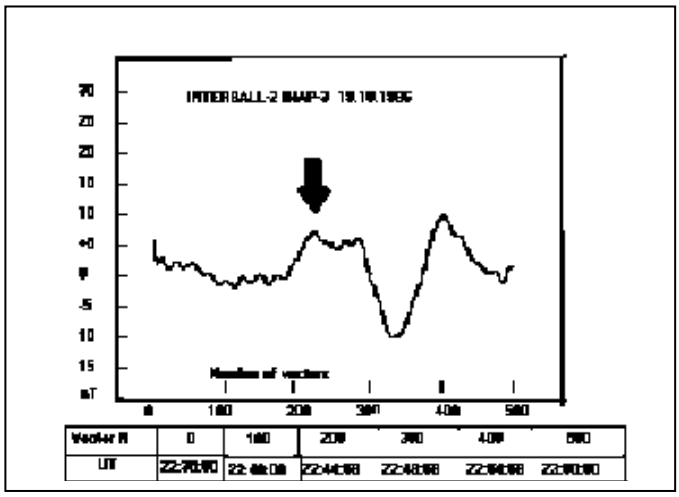


Figure1. PROJECT INTERBALL-AURORAL SATELLITE-COMBINED MEASUREMENTS BY EXPERIMENTS UVSIPS, IMAP-3, SKA-3

4. CONCLUSION

The presented results demonstrate the advantages of the joint investigations (glow + particles + magnetic field), allowing to detect and localize in the auroral oval the places of the active ionospheric ionizing-recombination processes, connected with the intensive dissipation of electrons and ions, and with upward directed field-aligned circuits. The correlation between the data of UVSIPS, IMAP-3, SKA-3 and the ground-based instruments (magnetometer in Kiruna) allows the connection of the magnetic sub-storms and their monitoring (auroral discrete forms). The combined measurements and the results, obtained after processing, allow to contribute substantially to the realization of the tasks and scientific aims of the Interball Project in order to study the interaction solar wind-magnetosphere –ionosphere.

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