Chapter 5

DEPARTMENT OF SPACE PHYSICS

5.1 STAFF

5.1.1 Scientific staff

Anna Antalová (until 1/2002), Ján Baláž, Pavol Bobik (from 11/2001), Ladislav Just, Karel Kudela (Head of Department), Marián Slivka

5.1.2 PhD students

Radoslav Bučík (TU Zvolen), Radovan Brenkus (PF UPJŠ)

5.1.3 Technical staff

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5.2 SCIENTIFIC ACTIVITIES

5.2.1 Introduction

The department of Space Physics is one of the oldest departments of the Institute. The current research of the department is oriented to the experimental study of energetic particles in space. Along with the cosmic ray (CR) studies related mainly to the ground based measurements, the experimental studies of medium energy particles on the satellites are continuing. The two types of studies are devoted mainly to obtain the relevant information on the physical processes within the Earth's magnetosphere and in the heliosphere: those in which the energetic particles are either directly involved or those on which the particles provide a remote characteristic. In addition, the passive dosimetric studies on the orbital station and the heavy nuclei interactions are also continuing.

5.2.2 Projects

Projects of the Agency for Support of Science and Technology APVT:

APVT 0259 Monitoring of energetic particles in near surrounding of Earth: relations to space weather - influence on flight personnel (started from October 2002, joint with the Air Force Military Hospital, Košice).
Principal Investigator: K. Kudela

Projects of the Slovak Scientific Grant Agency VEGA:

2/1147/21 Transport of energetic particles in the magnetosphere and heliosphere.
Principal Investigator: K. Kudela
Deputy Principal Investigator: M. Slivka

1/9036/02 Production of secondary particles in nuclear interactions of relativistic nuclei in emulsion detector.
Deputy Principal Investigator: L. Just

International collaboration

In the period 2001-2002 the collaboration with scientists and technicians of many institutions in abroad was productive and influenced the activity, scientific orientation and results obtained in the Department. Among them the collaborations with colleagues from laboratories in the following countries are listed below:

- Czech republic (Faculty of Mathematics and Physics of the Charles University Prague; Institute of Nuclear Physics of the Czech Academy

of Sciences, Prague; Institute of Atmospheric Physics of the Czech Academy of Sciences, Prague)

- Finland (University of Oulu)
- Greece (Demokritos University of Thrace, Xanthi)
- Hungary (RMKI KFKI Physical Institute, Hungarian Academy of Sciences, Budapest).
- China (Center for Space Science and Applied Research, Beijing)
- Ireland(Space Technology Ireland of National University of Ireland, Maynooth).
- Italy (IFSI CNR, Institute of Physics of Interplanetary Space, Rome; INFN Milan)
- Poland (CBK, Center for Space Research, Polish Academy of Sciences, Warsaw)
- Russia (Nuclear Physics Institute of the Moscow State University; Space Research Institute, Russian Acad. Sci., Moscow; Institute of Cosmophysics and Aeronomy, Yakutsk; IZMIRAN)
- Sweden (Institute of Space Physics, Kiruna)
- Ukraine (University of Kiev; Main Astronomical Observatory, Kiev)
- USA (Applied Physics Laboratory; Johns Hopkins University, Laurel, MD; NASA GSFC, Greenbelt, MD; University of Alabama, Huntsville; MSFC, Huntsville, Alabama; Aerospace Corporation, Los Angeles)

The collaboration with several institutions in Slovakia was productive, e.g. with Astronomical Institute of Slovak Academy of Sciences, Tatranská Lomnica; Faculty of Electrotechnical Engineering and Informatics, Technical University Košice; Faculty of Science; P.J. Šafárik University Košice).

The list is not complete and several new collaborations started recently.

5.3 RESULTS

5.3.1 Cosmic ray dynamics at neutron monitor energies and above [5-7, 13, 14, 19, 25, 26, 29, 30, 32, 33, 38-42, 54, 64-70, 75-77]

The extensive data sets of daily averages of cosmic ray intensity at several neutron monitors at different

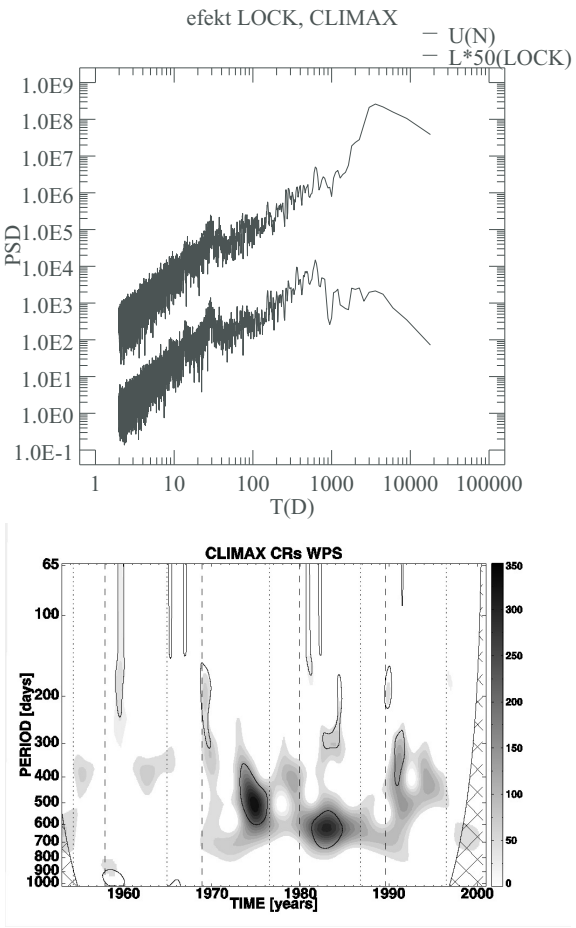

Figure 5.1: *Periodiogram of daily means of neutron monitor intensity plotted versus length of period for the period 1953-2000 (upper panel, days on x axis) and the wavelet power spectrum density indicating the temporal evolution of contribution of low frequency components to the signal.*

cutoff rigidities were analyzed by means of wavelet transform method in the period range 60 to 1000 days. The contributions of the time evolution of three selected quasi-periodic signals (150 days, 1.3 year, 1.7 year) to the global one were obtained While the 1.7 y quasi-periodicity, the most remarkable one in the studied interval, strongly contributes to the cosmic ray intensity profile of solar cycle 21, the 1.3 y one, which is better correlated with the same periodicity of interplanetary magnetic field strength, is present as a characteristic feature for the decreasing phases of cycles 20 and 22. Obtained results support the claimed difference in the solar activity evolution during odd and even solar cycles.

Relations of cosmic rays to various aspects of space weather effects were studied with using neutron monitor data. Magnetospheric transparency was shown to be strongly changed during a strong

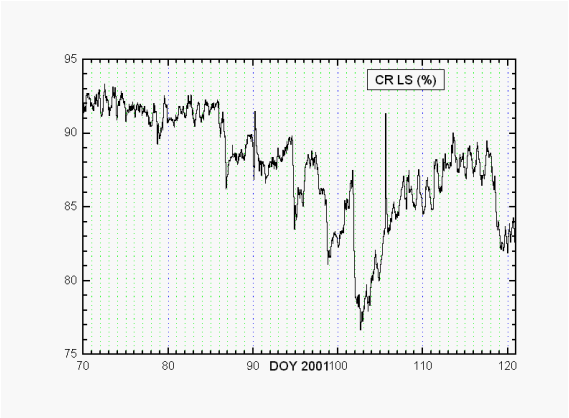

Figure 5.2: *The large variability of cosmic ray intensity observed at Lomnický Štít laboratory of the Department during days 70-120 of the year 2001. The variability is only by a factor of 1.6 smaller than that one from solar maximum to minimum. It can be used to estimate the deviations from the cosmic ray models like CREME96 for the period of solar maximum at middle latitudes. Along with the three strong Forbush decreases, there are observed two increases: (a) on day 90 (strong geomagnetic disturbance caused the decrease of geomagnetic cutoff and magnetospheric transparency for cosmic rays increased), (b) on day 105, when ground level event from a solar flare indicated acceleration on the Sun at least up to rigidities 4 GV. The event on day 105 was for the first time continuously, with the time step 1 min, observable on internet in real time from Lomnický Štít neutron monitor (http://neutronmonitor.ta3.sk).*

geomagnetic storm by the end of March 2001 and influencing count rate of neutron monitors up to highest cutoffs. Involving Dst addition to Tsyganenko'89 model is improving the estimates of the reduced cutoffs.

Cosmic ray variations induced by solar activity are traditionally investigated using the ground-based neutron monitor network. However, the possibility to study the same variations by detectors on board near Earth high-inclination satellites has recently turned out, using the advantage of a single detector scanning particle variability at various latitudes during one orbit. The comparison is depending on the statistics of satellite measurements of particles. High geometrical factor of the device on board CORONAS I allowed comparison with ground based neutron monitors. The primary CRs out of the Earth's atmosphere are accompanied by additional flux generated by atmospheric and/or instrument albedo. We found that their contribution to the primary CRs depends on latitude. On the basis the high-energy proton observations from SONG instrument on CORONAS-I, maximum albedo deposit relatively to primary CRs was observed near the geomagnetic equator and minimum at high latitudes. The latitudinal profile of the intensity variations from these measurements has been investigated during magnetic storms in April 1994. At high latitudes (L>4) the Forbush decreases reached at least 6%, and at L 2-3 instead of Forbush effect the SONG instrument observed a significant particle enhancements probably caused by decreasing of the local geomagnetic cutoff. Similar results on rigidity cutoff variations were reported by other authors. The shadowing effect of charged energetic albedo, which masks Forbush decrease of primary CRs in the satellite experiments was also deduced. The actual new data from improved version of the SONG device on CORONAS-F, launched on July 31, 2001 are extremely needful for such type of studies.

5.3.2 Medium energy particles within the magnetosphere and near its boundaries

High apogee satellites. Interball [4, 9, 12, 31, 35, 36, 37, 47-51, 53, 55, 57-63, 71]

Both case and statistical type of studies was done with using the large amount of data by energetic particle instruments DOK-2 on Interball-tail and Interball-auoral, as well as by its simplified versions DOK-S on the corresponding subsatellites Magion-4 and Magion-5. Comparison with data of POLAR satellite (US) provided a possibility to study a unique case of particle acceleration at the bow shock to unusual high energy during a space weather event, when magnetosphere was strongly compressed. The comparison of upstream particle fluxes near the bow shock (Interball) and far from it (SOHO/LION) was done for 1996. In the diffusive upstream events observed near the bow shock much higher probability of observing high flux of protons for quasi-parallel connection to the bow shock than for the cases with quasiperpendicular geometry was demonstrated. This dependence is clear at low energies (20-30keV) and becomes less pronounced with increasing energy. On the other hand, the dependence on geomagnetic activity is increasing with increasing energy. Thus relative importance of the two possible sources of seed particles, namely those of solar wind ions and particles leaking from magnetosphere was estimated up to 300 keV.

The detailed energy spectra measured by DOK-2 at both satellites of Interball mission showed many cases of dispersive velocity events. They can be used for remote timing and place of injection of particles

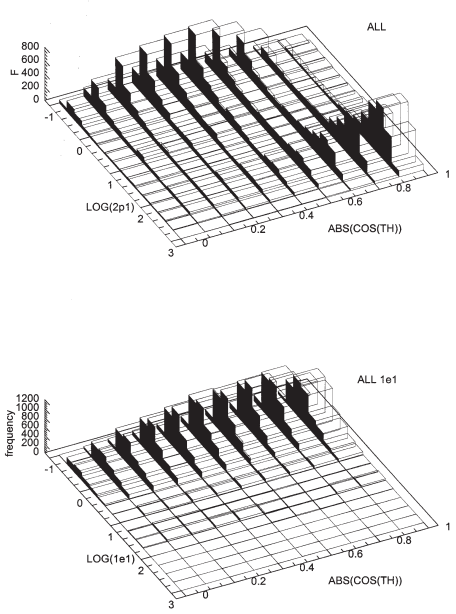

Figure 5.3: *Frequency distribution of count rate vs* $\cos\theta_{Bn}$ *based on total amount of 24662 2-minute averages in the upstream region by DOK-2. Energies of protons and electrons are 2p1 (20.6-26.7 keV) and 1e1 (21.2-25.7 keV), respectively. While the quasi-parallel connections to the model bow shock are important for proton fluxes (Fermi acceleration at the bow shock), it is not important for the electrons.* θ_{Bn} *is the angle between magnetic field vector* $\vec{B}$ *and normal to the bow shock at the connection point determined by the intersection of* $\vec{B}$ *at the satellite position and the model shape of bow shock.*

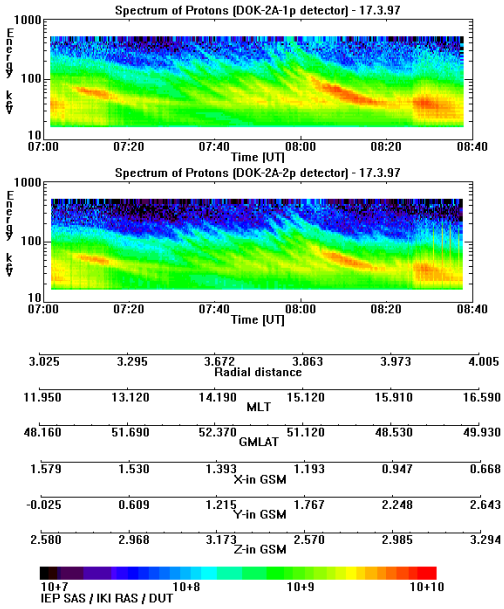

Figure 5.4: *Example of sequence of velocity dispersive events observed by DOK-2 in the sector of local afternoon on March 17, 1997.*

during geomagnetic disturbances. The particles are azimuthally drifting in the geomagnetic field and local maxima in their differential energy spectra are correspondingly evolving with time. Relations of the dispersive effects to brightening of UVI images by POLAR satellite and to the Pc 5 pulsations were analyzed.

Several results were observed also from the DOK-2 measurements within the magnetotail, in the lobes and in the magnetosheath on daily side. The magnetotail is the dynamic entity where energy imported from the solar wind is stored and than released to generate disturbance phenomena such as substorms. Its temporal variations occurs primarily in direct response to the variable conditions of the solar wind and the interplanetary magnetic field. The energetic particles accelerated in the magnetotail have extensive influence on processes in the inner magnetosphere. The behavior of these particles in the magnetotail is a subject of experimental and theoretical studies during last thirty years using the measurements of e.g. IMP-8, ISEE , Wind and Geotail and other satellites. Interball - 1 probe crossed the magnetotail during three months every year. A lot of information about proton and electron fluxes in plasma and neutral sheets according to the DOK-2 was obtained. The analysis from period October - December 1997, when the Interball-1 satellite measured in tail regions indicated, that within plasma sheet the proton fluxes are isotropic, while in the lobes the anisotropy is found (predominate proton fluxes in the tailward direction. The energy spectra of protons and electrons show their sudden changes during the satellite crossing of boundaries between the tail regions. The plasma sheet and its central part, the neutral sheet, is the most dynamic region of the magnetotail. It is a very important region for many magnetospheric processes, most of which are related with substorms. The magnetic reconnection process plays a crucial role in acceleration of particles in this region. The fluxes of energetic particles in plasma sheet region during a growth phase of a small substorm on December 3, 1996, when Interball-tail crossed the central plasma sheet region were analyzed in detail. A rather complicated and fast changes of ion anisotropy and energy spectra was observed: when plasma and B indicated po-

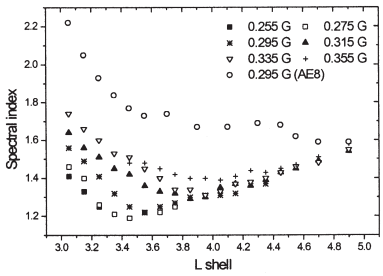

Figure 5.5: *The variation of the gamma ray spectral index of the power law (E-a) energy dependence in 0.12-8.3 MeV on L at various local B values. The data were averaged during the period from May, 1994 through June, 1994. The open circles represent the AE-8 power law spectral indices for energy range 0.1-6 MeV.*

sition of the satellite tailward from the reconnection point ($B_z < 0$, v_x is almost radial and negative - tailward plasma flow), the energetic ions are streaming tailwards (their anisotropy is observed up to 100 keV). When Interball-1 is earthward from reconnection point ($B_z > 0$, v_x is almost radial positive - earthward plasma flow), the energetic ions are streaming earthward. In the second situation the spectra is softer and its character is similar to the increase on WIND observed 8-10 min earlier. Observed fluxes of protons is very similar to bipolar fluxes reported earlier at lower energies.

Low altitude satellite measurements.

CORONAS I. γ rays and their connection to radiation belt electrons [11,15-18, 43,44].

The interpretation of gamma ray measurements obtained by SONG on CORONAS-I in different regions of (L,B) space was done as a possible tool for indirect investigation of trapped electron population.When the satellite crosses the Earth's radiation belts, the main source of gamma rays with energies up to several MeV comes from the strong charged particle flux. These gamma rays override other components of gamma radiation (e.g. atmospheric or instrument albedo due to primary CRs) measured at low Earth's orbit. One of the largest components of the local gamma radiation arises from bremsstrahlung produced by trapped electrons stopped in the satellite near the detector as indicated by other papers earlier. The dependence of the differential gamma ray energy spectra in the 0.12-8.3 MeV on L shell for various values of the local magnetic field B is shown in Fig.5.5.

Also shown is the NASA AE-8 electron model

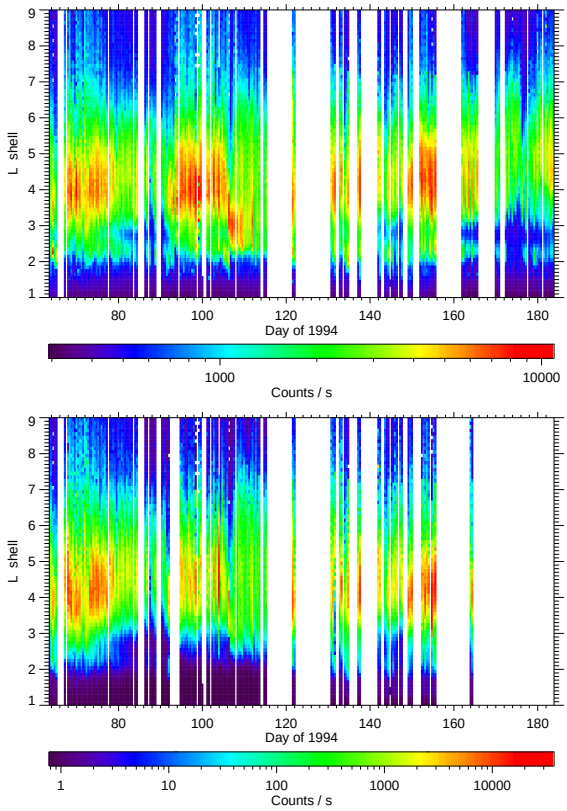

Figure 5.6: *The time history of gamma rays in the energy range 0.12-0.32 MeV (top) and 0.5-1.5 MeV MKL electrons (bottom) during the four months between 1994/64 and 1994/183 is shown in spectrogram format. These measurements were taken only when CORONAS-I was in the drift loss cone.*

spectral index. The softening gamma ray energy spectra with B indicate possible albedo origin of parent electrons at L=3-4. The softening energy spectra with L, for L>4, can be explained by acceleration of electrons during radial diffusion on lower L shells. The lack of B dependence at these L's gives also support for non-albedo electron production mechanism. The simplified estimate of bremsstrahlung production by AE-8 electrons has been obtained. For this purpose the Monte Carlo simulation of the mean amount of the matter (around SONG CsI scintillator) in complex geometry setting on CORONAS-I has been performed. During the magnetic storms the outer radiation zone is obeyed by strong temporal fluctuations. To study the dynamics of the relativistic electron population it is more convenient to concentrate on electrons in drift loss cone. These electrons are temporarily trapped during their longitudinal drift around the world until they precipitated into the upper atmosphere in the region of the South Atlantic magnetic anomaly where the result-

ing bremsstrahlung can be observed.

Figure 5.6 shows CORONAS-I observations of 0.12-0.32 MeV gamma rays and 0.5-1.5 MeV electrons over the four months in 1994 when the satellite was in operation. Several relativistic electron injection events occurred in the L range from 3.8 to 4.6, differing in magnitude and location of peak intensity. The time profile of Dst index indicates that these peaks appeared during the recovery phase of the magnetic storms in spring 1994. A correlation between the parent electrons (CORONAS-I and also Sampex observations) and daughter photons indicates the possibility to monitor remotely the relativistic electron population in the radiation belts for Space Weather purposes.

ACTIVE and MIR [20,21,24,27,28]
The low-energy (< 1MeV) proton observations at low orbit satellites near geomagnetic equator (L<1.15) on different altitudes were analyzed. The observations in positions where no stable trapping is expected are discussed too. The data from Active satellite (1989-1991, altitude 500-2500 km, inclination 82°, energy 50 - 500 keV) and from the MIR station (year 1999, E=0.1 - 10 MeV, almost circular orbit, inclination 51.1°, altitude 400 km) were used. For different altitudes the energy spectra of protons obtained during the geomagnetically quiet periods (-20nT < Dst < 0) and during disturbed periods (Dst < -20nT) for two magnetic local time intervals (23-4 hours and 4-23 hours of MLT) were obtained. The comparison with ring current proton spectra was done.

In addition the data of electron fluxes with energies of 20 - 400 keV obtained on satellite Active and ones with energies 0.3 - 1.0 MeV obtained onboard MIR station (SPRUT-VI experiment in 1999) were analyzed. The distribution of electron fluxes at middle latitudes at 350 - 1500 km was obtained. The comparison with results of another satellites reveals, that in spite of those electrons in these zones were registered per different years, the borders of electrons precipitation practically coincide, situation of these areas as a whole is stable in time and space, that speaks about the existence of unknown mechanism of particles precipitation. It is possible, that electron precipitation in the region of L = 1.6-1.8 is related with the work of short-wave transmitters. The main experimental results at L=1.2-1.9: (a) electrons occupy latitude area of 1.2 < L <1.8, despite of electron distribution is non-uniform in this area, the maximal value of precipitation located near L = 1.3-1.4 and L = 1.6-1.7 regions; (b) the areas of electron fluxes distribution have precisely expressed longitude dependence; (c) the longitudinal dependence became less remarkable with the increasing altitude and practically disappears at 1300 km.

5.3.3 New experiments in space. Development of new instruments.

Participation at ISS.

The experimental participation of the Department on ISS, which is the first one in Slovakia, started by the passive measurements of the tracks of products induced by cosmic rays and other energetic particles inside the Russian module of the station. The stack of detectors is a small part of the complex experiment SCORPION (coordinated by Skobeltsyn Inst. of Nucl. Physics, Moscow, Russia, with the participation of several other laboratories). The stack was delivered to the ISS by the end of November 2001 and recovered in February 2002. The evaluation of the tracks from earlier similar experiment in the frame of Štefánik mission on MIR is in progress and evaluation of the foils exposed on ISS begins in December 2002.

Experiment SONG on CORONAS-F[45,46]

The "CORONAS-F" satellite, the second one of CORONAS satellite series, was launched on July 31, 2001 in Russia into a circular orbit with the altitude 507±21 km and 82.5^{circ} inclination. The satellite is oriented towards the Sun. A complex of instruments measuring predominantly corpuscular energetic emissions from the Sun (SKL, coordinated by Skobeltsyn Inst. of Nucl. Physics, Moscow, Russia) is a part of experimental devices. Institute of Experimental Physics, SAS, Košice, Slovakia participated at a device measuring energetic neutrons, gammas and protons by SONG-M instrument (see Fig. 5.7).

The first results from that experiment were obtained recently. One of the basic tasks of the project CORONAS-F satellite, is the study of the effects related to the transfer of energy in the solar atmosphere, and in particular to acceleration of solar particles. In the frame of the project there are several measurements of the hard X ray emissions in the range 0.01-10 MeV. Along with that, one of the experiments, namely SONG-M is providing measurements of gamma rays with energies up to 100 MeV and neutrons >20 MeV. The first results from that experiment were obtained recently. Several solar gamma ray emissions were observed until end of May 2002. The measurement is continuing.

Project Double Star / NUADU [52]

The geospace scientific project Double Star is a joint effort of Chinese Academy of Sciences and European

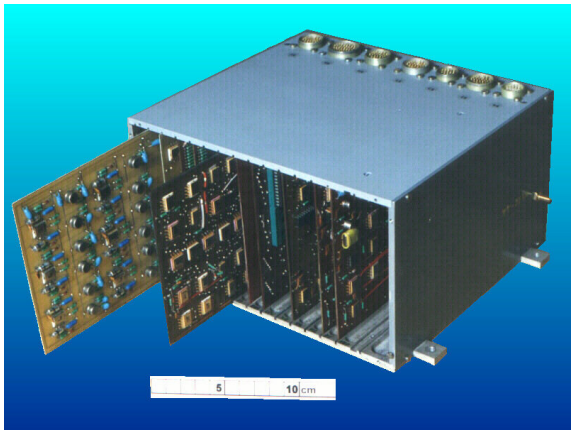

Figure 5.7: *One of the experiments within the complex of energetic particle devices SKL onboard CORONAS-F satellite is SONG (the acronym for Solar Neutrons and Gammas). It is a joint experiment of Skobeltsyn Inst. Nuclear Physics, Moscow State University, Russia and the Institute of Experimental Physics, SAS, Košice, Slovakia, where the block of electronics displayed in the figure was developed, constructed and tested.*

Space Agency (ESA). The project is based on exploration of the Earth's magnetosphere by two satellites on a near-equatorial and on a polar orbit respectively. The scientific payloads is based mostly on Cluster II (ESA) instrumentation, some Chinese scientific instruments and a new-developed energetic neutral atom imager (NUADU) for the polar satellite[52]. The launch of the polar satellite is scheduled to January 2004 from Xichang Satellite Launch Center (China) by the LM-2C/SD launcher. The orbit parameters are 39000 km × 700km × 90°. The experiment NUADU is a joint effort of Space Technology Ireland of National University of Ireland, Maynooth (prof. S. McKenna-Lawlor, Principal Investigator), Institute of Experimental Physics, Košice, Slovakia (dr. J. Baláž is the Experiment manager of the instrument, in charge of designing, testing and constructing the device, dr. K. Kudela, Co-Investigator), Institute of Space Physics, Kiruna, Sweden (dr. S. Barabash, Co-I) and Center for Space Science and Applied Research, Beijing, China (prof. LIU Zheng-Xing, Co-PI and dr. LU Li, Co-I).

Scientific background

Energetic neutral atoms (ENA) in the Earth's magnetosphere are produced by charge exchange between singly charged magnetospheric energetic ions and residual neutral atoms of the exosphere. Since they propagate unaffected by the electric and magnetic fields, ENAs can be used for remote imaging of plasma populations immersed in the neutral gas. The main source of ENAs in the inner magnetosphere in the high energy range (10 - 500 keV) is the ring current. The magnetospheric ring current is built-up by the charged particles trapped in the Earth's magnetic field and is the main plasma population defining dynamics of the inner magnetosphere. The dynamics of the ring current defines in the large extent the space weather conditions which affects technological systems and human activities on the Earth or in space. Therefore, ring current studies are the key element in space weather research. The ENA images of the ring current provide unique morphological information, which include such features as global asymmetry, energy-dependent particle drifts, location of the plasma injection. Since ENA emissions are directional and determined by the ion pitch-angle at the point of origin, ENA images are pitch-angle sensitive and thus can be used to reconstruct the ion distribution function for the entire inner magnetosphere.

Scientific objectives

- to define the morphology of the ring current under different magnetospheric conditions and characterize the inner magnetosphere for better understanding of local measurements performed on the Double Star and Cluster II spacecraft - to study particle energization processes in the inner magnetosphere and image plasma convection and substorm injections - to monitor the ring current / radiation belt to define space weather conditions and obtain the global ENA index (total ENA flux from the magnetosphere).

Measuring principle

The ENAs are detected by the sensor head consisting of 16 solid state detectors regularly spaced over elevation angle 180. While the charged particles are deflected out of the detector sensing field of view by the high voltage (10kV) deflection system, the ENAs move unaffected on their straight trajectory from the input aperture to the detector active area. Signals from detectors are discriminated to four discrimination levels and digitally processed. The sampling is space synchronized and provides 128 samples per each spacecraft spin. Thus full 4p solid angle is covered by 16 x 128 = 2048 pixels. The interface to the spacecraft systems consists of powering (28V), synchronization input (Sun reference pulse) and the MIL-STD-1553B dual-redundant bus for data communication.

Basic specification:

Weight: 6 kg

Figure 5.8: The view at the NUADU experiment

Max. dimensions (LWH): 290 mm 239 mm 239 mm
Power consumption: 5W (from 28V dc)
Number of detectors: 16
Detector type: PIPS (Canberra), light-tight, custom design
Single detector active area: 142 mm2 (14.2 mm 10 mm)
Discrimination levels: 20 keV, 50 keV, 100 keV, 300 keV
Field of view (each detector): 11,5°× 2,5° (fwhm, elev. × azimuth)
Geometrical factor (each detector): 0.0126 cm^2 sr
Resolution over 4p solid angle: 2048 pixels
Image synchronization: by Sun reference pulse
Continuous data rate: 0.5 kbps - 16 kbps
Charged particle cutoff energy: 300 keV
Deflection high voltage: 10 kV

The project description and its goals can be found in (Dennis Normile, Ding Yimin: China teams with Europe on Exploration of Magnetosphere, Science, Vol 296, p.1790, 7-JUN-2002)

ESA-ROSETTA

In the frame of cooperation with STIL, Maynooth, Ireland (responsible scientist Prof. S. McKenna-Lawlor) dr. J. Baláž contributed to the construction and testing of the Electrical Supporting System (ESS) for the ESA-ROSETTA mission to Wirtanen comet. The launch is scheduled for January 2003 and duration is expected 10 years. The sonde at the approaching to the comet will be divided into Lander and Orbiter. While the first one will land on the surface of the comet, the latter one will be orbiting around it. ESS is an important element of the technical system since it fulfills the communication between Lander and Orbiter (the communication with the Earth is done only from Orbiter).

5.3.4 Fragmentation of nuclei in emulsions [1-3,22,23,72-74]

In program of registration and detection of nuclei by nuclear emulsions method we started to research the process of fragmentation of light stabile and radioactive nuclei in emulsion and also we started with obtaining the survey information about charge stage of secondary nuclei which were irradiated by nuclei with medium and heavy mass. We start to illustrate the actual questions about cluster structure of light and radioactive nuclei. On the material from ^{6}Li, ^{8}Be and ^{10}B we observed:

1 - sharp decrease of average interaction free path in comparison with expected value - for example ^{10}B is λ=(14.7±1.2) cm. This indicate the extraordinary big radius of nuclear distribution in nucleus of ^{6}Li = (2.7±0.1) fermi.

2 - it was obtained very large number of relativistic deuterons. This indicate, that the nucleus ^{6}Li fragmentation in cluster of ^{3}He and ^{3}H form is about one order lower than the structure creation of clusters of ^{4}He and ^{2}H.

3 - coherent dissociations of not accompanies the target nucleus excitation. This is the best demonstration of cluster structure of ^{6}Li, ^{8}Be and ^{10}B.

Information about the nuclear fragmentation can offer us very valuable data about characteristic of unfixed nuclei with mass number 5 and 8, which are very important moderators in stars nuclear synthesis. They are the foundation of process named capture of fast protons [1-3,22,23].

5.4 PAPERS AND PRESENTATIONS

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5. A. Antalová: Daily soft X-ray flare indices (1985 and 1986), Contrib. Astron. Obs. Skalnaté Pleso, 31, p. 51-60, 2001

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5.5 Invited papers. Other activities.

- K. Kudela: Kosmické počasí a kosmické záření (Space weather and cosmic rays, in Czech), 14. conference of Czech and Slovak Physicists, Plzeň, Zpadočeská univerzita v Plzni, 9. - 12.9. 2002, pp.14, (invited paper)

- K. Kudela: Variabilita kozmického žiarenia a kozmické počasie (Variability of cosmic rays and space weather, in Slovak), 16th Solar Semina,

Turčianske Teplice, June 2002, pp. 9, (invited paper).

- K. Kudela: Vzťahy kozmického žiarenia (pozemné pozorovania) ku kozmickému počasiu (Relations of cosmic rays to space weather), Konferencia MTA-SAV, Cultural Institute of Hungary, Bratislava, November 20, 2001.

- K. Kudela, Feranec, J., Macho, L. (editors), Space Research in Slovakia 2000-2001, Slovak Academy of Sciences, COSPAR, Slovak National Committee, pp. 49, ISBN 80-968757-1-X, Košice, 2002 79.

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In the frame of Space Weather subject of the European Science and Technology Week (November 4-10, 2002), organized by EU (coordinator F. Jansen, U. of Greifswald, Germany) a talk K. Kudela: "Space Weather and energetic charged particles" with subsequent medialization of Space Weather and its impact for wider public was presented at Faculty of Electrical Engineering, Technical University, Košice.