

Background conditions of high-energy spectrometer NATALYA-2M on board CORONAS-PHOTON satellite. Observational capability of the instrument.

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Abstract. In submitted paper the concise description of structure and observational capabilities of a high-energy radiation spectrometer NATALYA-2M is described. NATALYA-2M is a part of scientific instrumentation complex PHOTON of CORONAS-PHOTON satellite¹. Gamma-ray spectrometer have wide energy range of 0,3 - 2000 MeV and based on CsI(Tl) single crystals with total area of 32x38 cm² and 18 cm thickness.

The space vehicle CORONAS-PHOTON with the scientific equipment, intended mainly for complex observation of the Sun, was launched from cosmodrome Plesetsk on 30 January 2009 into a low-Earth low-eccentricity, high-inclination orbit (altitude about 550km, inclination 82.5 deg).

Keywords: CORONAS-PHOTON NATALYA-2M spectrometer

I. DESCRIPTION OF THE INSTRUMENT

NATALYA-2M is a scintillation spectrometer of γ -radiation designed for carrying out the following measurements:

- studying of temporal behaviour of intensity and energy spectra of hard electromagnetic radiation of a solar and space origin in a wide energy range from 0,3 to 2000 MeV;
- registration of solar neutrons in the energy range of 20 - 300 MeV.

The registration block of the instrument NATALYA-2M consists of a set of scintillation modules (Fig. 1). For gamma registration the spectrometer on the basis of monocrystals CsI(Tl) by a total area 32x38 cm² and thickness of 18 cm, consisting of two sections (SE-1M and SE-2M), located one over another is used. The events associated with charged particles background, are excluded by means of plastic scintillation detectors (anticoincidence dome and plane detector AC).

The spectrometer is constructed by a modular principle and consists of 16 identical modules with the sizes of a monocrystal 380x80x45 mm, each one is viewed by two photomultiplier tubes FEU-183 from opposite sides.

¹The overview of the mission will be presented at the Conference by Yu.D.Kotov *et al.* (Abstract ID: 1523)

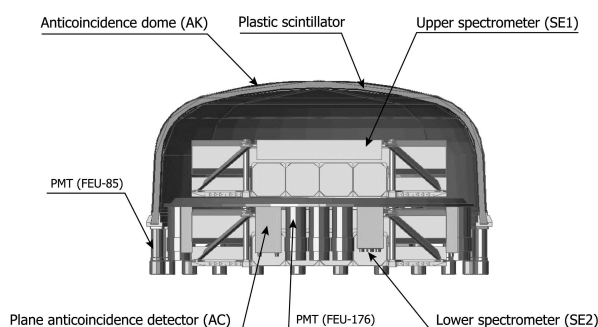


Fig. 1: NATALYA-2M registration block (RB)

Modules are laid in four layers, the nearby layers (A, B, C, D - four modules each) are rotated relative to each other by 90°.

The energy range of a spectrometer is 0,3 MeV - 2 GeV which is divided into four subbands for γ -radiations and the neutron channel for reduction of detector loading, improvement of the effect/background ratio and increases of reliability of the device. Ranges of registration of gamma radiation are as follows: 0,2-2 MeV, 1-18 MeV, 7-250 MeV, 50-1600 MeV. The spectral information for each range is processed by independent channels of processing (ADC), for a R-range there are 4 channels (one from each module of the top layer of spectrometer S-1 (R1-R4)).

Modules of information processing and output system SOVI-3M and SOVI-5M make final processing of signals:

- Formation of energy ranges;
- Logic selection by the set of criteria;
- Measurement and compression of energy spectra;
- Reception of two-dimensional spectra for neutron fluxes selection;
- Transfer of the received information to telemetering system SSRNI.

Besides, information, which is used for data acquisition for radiation fluxes in various ranges (ratemeters) is derived from BOSM module, which is carrying out selection of data by programmed criteria.

Channel	Energy range, MeV	Effective area, cm ²	Energy resolution, $\Delta E/E$	Time of accumulation
Roentgen and gamma-radiation				
R (Roentgen)	0,2-2	920	10 % (R3)-11 % (662 KeV), measured	Spectra: 1 s Counters: 0,1 s
L (Low gamma)	1-18	900	5,9 % (2,2 MeV), 4,6 % (4,4 MeV), measured	Spectra: 10 s Counters: 1 s
M (Medium gamma)	7-250	800	6 % (10 MeV), calculated 28 % (120 MeV), measured	Spectra: 10 s Counters: 1 s
H (High gamma)	50-1600	750	28 % (120 MeV) , measured	Spectra: 10 s Counters: 1 s
Neutrons				
N (Neutrons)	20-300	40-120	-	Spectra: 70 s Counters: 1 s

TABLE I: Instrument main parameters²

Implemented controlling scheme allows to carry out transfer of service files of program sequences from Earth, which are used for precise adjustment of spectrometer blocks of NATALYA-2M instrument.

II. FLIGHT ADJUSTMENT AND CALIBRATION

There are two systems that give possibility to adjust and calibrate instruments during the flight:

- System of gain stabilization;
- System of flight calibration.

The first one allows to regulate gain factor of everyone PMT, so that the peak from a known gamma line gets to the same ACP channel for all modules. The second one gives to each module R (L) - channels a line of isotope Co-60, provides background suppression in calibration mode, allows to carry out independent calibration of low-energy spectrometer channels. Fine adjustment provides alignment of energy scales for all modules of the instrument and allows to improve the energy resolution.

A. Stabilization system

Stability of spectrometer parameters is provided with the system of gain stabilization including a reference light source and gain adjustment cell for each PMT. The stabilization system allows to compensate influence on PMT gain factor of following factors:

- Influence of detector loading change
- Influence of external magnetic fields
- Effects of detector system degradation (PMT "ageing")

In each layer there is a reference source of light pulses based on current impulses generator and light-emitting diode (LED). Light from LED is branching by means of fiber optics and is injected into the central point of the large side of each module (Fig. 2). Stabilization boards for everyone PMT measure a signal corresponding to reference pulse and change voltage at the PMT dividers so that the signal amplitude remains constant and equal

²The values of the effective area resulted in the table for various ranges are received by simulation.
L-range calibration is received by means of a neutron PuBe-source. Calibration of M and H-ranges is received at atmospheric muons with use of a telescope mode.

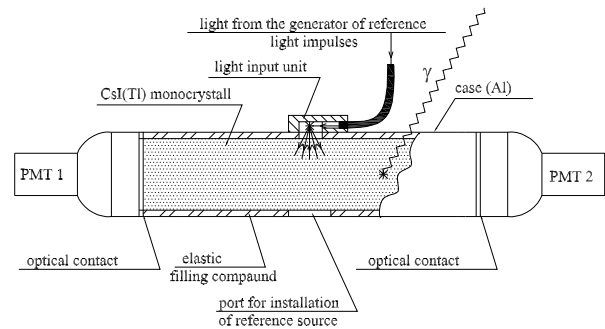


Fig. 2: Scintillation module scheme

to the basic voltage set by the digit-analogue converter (DAC). All DACs regulated by controllers of data processing system through the ISPI-interface. At device inclusion initial installations which can change, both in the course of instrument adjustment, and during flight experiment (according to the information transferred via radiochannel) are loaded into DACs. Measurements made with the help of stabilization system have shown, that it reduces instability of a spectrometer to size $\sim 0,1$ %.

B. Flight calibration system

System of in-flight calibration solves following problems:

- calibration of spectrometer low-energy channels during flight experiment
- process of device adjusting (the coordination of energy scales of scintillation modules)
- indication of long-term effects of ageing in the instrument (light-emitting diodes, monocrystals CsI(Tl))
- accounting of temperature instability influence

For energy scale calibration in flight the calibration γ -source (in form of plastic scintillator with dissolved Co60 isotope) is installed at spectrometer structure. The Co60 decay scheme is such, that 100 % γ -quanta are accompanied by β -particles with average energy $E_b \approx 96$ keV, thus permitting the creation of a tagged γ -quanta source. Plastic scintillator is viewed by individual

PMT, whose signal after passing discriminator-shaper (amplitude and duration forming) is used as the tagging signal. An additional ADC, which processes signals of the L-range and operates in coincidence mode with the tagging signal is included in the recording system for obtaining calibration spectra. If instrument works properly (after adjustment ends), it is planned to switch to calibration mode periodically and if necessary after processing of spectra on Earth to correct pulse amplitude of stabilisation system light-emitting diode.

III. FLIGHT CAPABILITIES ON CALIBRATION OF ENERGY RANGES

During carrying out of flight experiment for adjustment and calibration of the instrument following means are used:

- 1) For adjustment and calibration in R- and L-ranges (low energy)
 - an energy releases spectrum of spacecraft natural local background. Interpretation of data is complicated in a kind of ambiguity of background lines identification,
 - spectrum from the installed source of tagged photons Co60 (Fig. 3);
- 2) For calibration of M- and - ranges (high energy) the spectrum of relativistic protons of primary space radiation (a telescope mode) is used (Fig. 4). In this mode spectra of channels M and H are accumulated in coincidence with simultaneous signals of 4 crossing modules, on one in each layer (A2, B2, C2, D2) and anticoincidence protection detectors AK and AC, thus charged particles which are passing through the detector at angle 10 degrees through area, close to an axis of a spectrometer and having area approximately 44 cm, are registered. By corresponding choice of a threshold it is possible to select the events associated only with relativistic and ultra-relativistic particles for which the correct calculated energy-release spectrum can be received. The spectrum from detector AK will be simultaneously received. This mode also will allow to obtain data for fluxes of high-energy particles.

IV. BACKGROUND MEASUREMENTS

The instrument NATALYA-2M is designed mainly for registration of the events associated with large-scale energy releases. Rather quiet condition of the Sun now (till 12.05.2009) when according to GOES and other devices there are no present flares of a class C and above, gives the chance to carry out adjustment and flight calibration of the instrument, simultaneously with studying of background conditions.

At the moment of this abstract being written, fine adjustment of the instrument and event selection modes optimization are carried, operating modes are checked, working energy thresholds of detectors are specified. Temporal profiles of loading of NATALYA-2M detectors

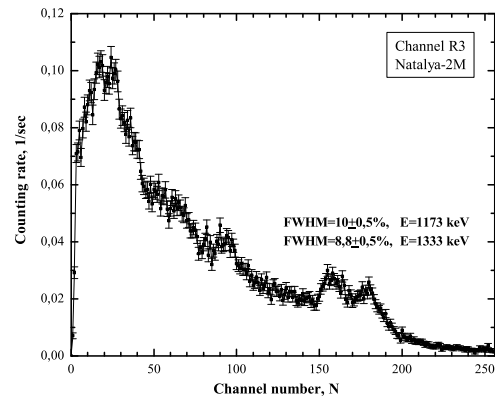


Fig. 3: R3-channel (0,2-2MeV) spectrum in coincidence with BSD (source Co-60) accumulated in equatorial area 26.03.2009 for 25 minutes

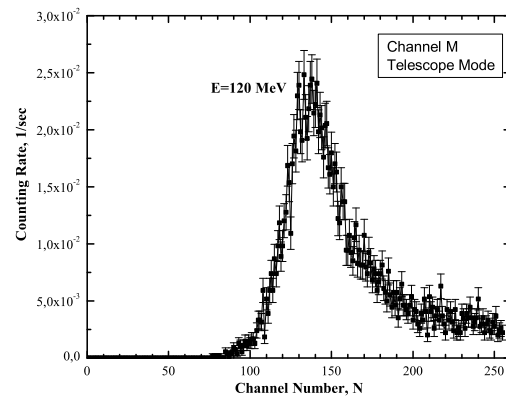


Fig. 4: M-channel (7-250MeV) spectrum of charged particles (protons) energy releases, accumulated in telescope mode 20:45 - 22:15 10.03.2009

on tracks of orbital rotation and spectra in gamma channels are received. Some received results are presented below.

The instrument registers also sufficiently strong gamma ray bursts, in particular GRB090408. The ob-

N2M 2nd Digital Source (BOSM) 8 ratemeters	1	AK	anticoincidence signals from AK and AC blocks
	2	AC	
	3	LC	signals from L-adders of separate layers of SE-2M
	4	LD	
	5	J1	signal which is given out at "big" energy release in the top layer of block SE-1M
	6	BSD	service signal of coincidence from β -synchronizer
	7	LA	signals from L-adders of separate layers of SE-1M
	8	LB	

TABLE II: DS2 NATALYA-2M Ratemeters

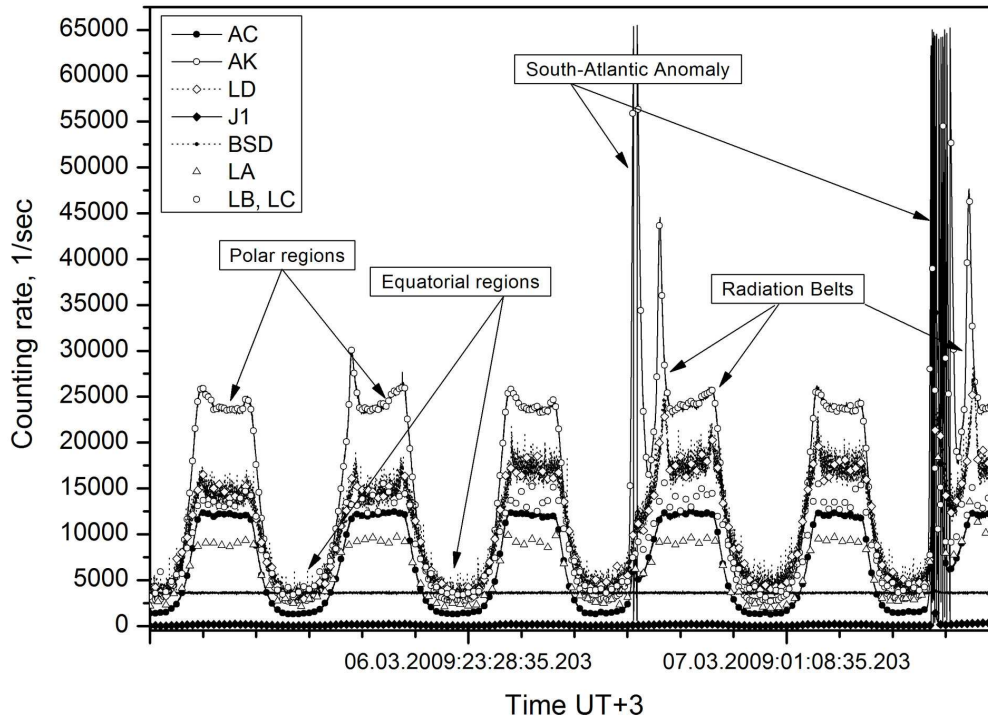


Fig. 5: DS2 of NATALYA-2M, ratemeters

Typical shape of temporal behaviour of ratemeters count rates on an example of three orbit loops 06.03.2009

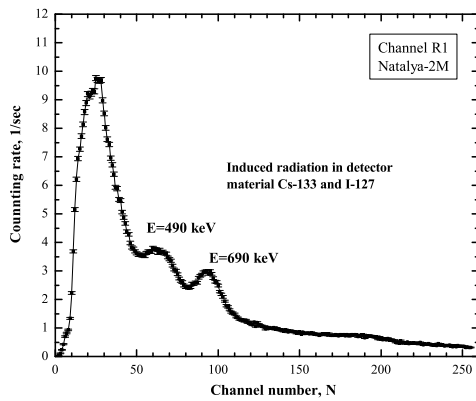


Fig. 6: R1-channel (0,2-2MeV) spectrum accumulated in area longitude 124-131 West and latitude 26-49 South 10.03.2009 for 20 minutes

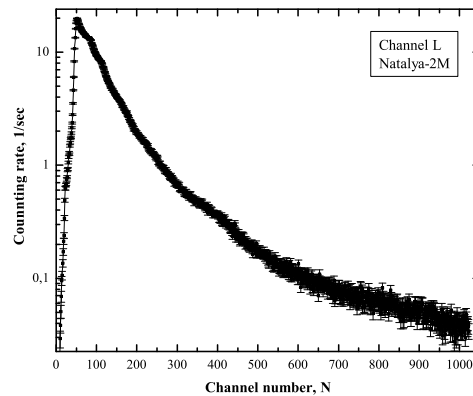


Fig. 7: L-channel (1-18MeV) spectrum accumulated in area longitude 124-131 West and latitude 26-49 South 10.03.2009 for 20 minutes

REFERENCES

tained data testify that the spectrometer is in workable conditions and is ready to perform the program of experiment.

- [1] Yu.D.Kotov *et al.*, *Stabilized 0.3-2000 MeV gamma-ray spectrometer for satellite mission CORONAS-PHOTON*, ICRC2001