

PODSOLNUH-D X-RAY TELESCOPE FROM THE GRANAT PROJECT: RESEARCH PROGRAM AND SOME SPECIFICS IN ITS HARWARE IMPLEMENTATION

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Abstract.

The paper describes the tasks of the scientific program of the Podsolnuh instrument for the Granat Project. The main purpose of the Podsolnuh experiment is the study of X-ray bursts and X-ray pulsars, and the location of variable X-ray sources within the energy range of 2-25 KeV and the study of their temporal structure. The detector structure based on proportional gas-tilled counters installed on a rotating platform is examined. Via commands from the ground the Podsolnuh platform is directed so that the instrument may be also used to obtain spectra and to determine the time periodicity of stationary X-ray sources.

Keywords: X-ray burst, X-ray pulsar, X-ray telescope.

Introduction

The studies of γ -ray bursts were differentiated as an individual field of study after they were discovered. Usually, their energy spectra were measured in the energy range above 20-30 KeV. Measurements in the X-ray range were made quite rarely (Apollo-16, Vela-5) because of the high background level of wide-angle X-ray detectors.

A controlled orientated platform (Podsolnuh-P) which automatically directed the spectrophotometer (Podsolnuh-D) to the source of γ -bursts was constructed. This allowed to measure energy spectra within 31 channels in the energy range of 2-24 KeV as well as to perform intensity analysis in the same energy range.

The two basic modes of operation of the spectrophotometer significantly improved the observation potentials of the device.

1. The "burst" mode is switched on by a signal from the X-ray bursts registration system from a command line of the other devices watching for γ -ray bursts in energy spectra higher than 30 KeV. In this case, the prehistory of the γ -ray bursts is not recorded. The energy spectra are measured with accumulated times $t = 100$ ms, 500 ms, 5 s, and 10 s.

The intensity spectra are done within time $t = 10$ ms, 100 ms, 500 ms, and 1 s. The measurement times can be set constant by a ground-based control station or changed by the accumulation time adaptive estimation system.

2. The "observe" mode allows to measure energy spectra and to perform intensity analysis of stationary sources, X-ray pulsars, and other types of sources. The accumulation times for one spectrum in this mode are $t = 0.1, 0.5, 1.0, 5.0, 10,$ or 30 s. One point from the energy spectra can be recorded within some of the following times: 0.01, 0.1, 0.5, 1, 5, or 10 s. These times are set by a command from a ground-based control station.

Research tasks of the Podsolnuh-D device

The Podsolnuh-D spectrometer is designed for:

1. Study of the energy and temporary variations of the intensity of γ -ray bursts registered in the hemisphere opposite to the Sun in the energy range 2-24 KeV.
2. Study of the energy and temporary variations of the intensity of bursters, quasiperiodical sources, and X-ray pulsars.
3. Joint studies of low-energy X-ray sources using the Sigma, ART-P, and Art-S devices mounted on the Granat satellite.

In the first case, when the device Conus-S registering γ -bursts in the "X-ray burst" mode with amplitude of the flow ~ 10 erg, the data obtained from its detectors is fed to a platform control block where the γ -ray coordinates are calculated and the rotating platform orientates the Posolnuh device to this point. In bursts of the mentioned intensity the orientation accuracy is approximately 1° which provides for localization of the γ -bursts within a view angle of $2^\circ \times 2^\circ$ of the Podsolnuh device. The Podsolnuh-D spectrometer starts measuring energy spectra and radiation intensity variations by the command "End of orientation" from the platform. It records 30 spectra, the accumulation times of which can be set by a command from a ground-based control station or by the accumulation time adaptive estimation system, assuming values from 0.1 to 5.0 s.

In the second case, the rotating platform orientates the Podsolnuh-D device to a given point from a chosen source to be studied as a priority mode. The mode of operation in which the platform periodically orientates to a point with diffuse background radiation can be used to separate the constant X-ray radiation. In case of observation of a burster and registration of an X-ray burst, the X-ray bursts registration system is switched on and 8 energy spectra preceding this moment are registered. Then, 30 subsequent energy spectra with accumulation time set adaptively or by a command from the ground are registered. The device measures intensity profiles with accumulation times estimated in a similar way. During the observation of semi-periodical sources and pulsars, the energy and temporal characteristics are measured with accumulation times accounting for the expected periodicity.

In the third case, the axis of the Podsolnuh-D spectrometer is orientated by the rotating platform in parallel to the axes of the Sigma, ART-P, and Art-S devices mounted on the Granat satellite. Energy spectra are measured and temporal analysis of the investigation source selected by the whole complex is made. The measurement times of the spectra are determined depending on the studied object and are set by a command from a ground-based station. In this mode, the X-ray bursts registration system can be switched on and thus the device is ready for registration of fast source intensity variations, for example, a transition from low to high condition of the Cyg X-1 source.

Description of the Podsolnuh-D device

The Podsolnuh-D device consists of two detector blocks mounted on a rotating platform, an analysis block, and a power supply and control block.

In the detector block, two proportional counters, CPIIO-304 M, with working surface of 120 cm are used. The input window of the sensor is covered by a $130 \mu\text{m}$ beryllium foil. The counters are filled up with composite gases: argon (63%) + helium

(27%) + methane (10%), with pressure of 0.8 atm. The sensors height is 6 cm. The detectors operate within the energy range of 2 to 24 KeV. The energy resolution is about 18% on the line of Fe⁵⁵.

To provide for calibration of the detectors during the flight, in their view field, an isotope Fe⁵⁵ (10 μCu) is introduced by the “Calibration” command from the ground. A passive square-shaped collimator of 2° by 2° limits the view field of each detector. The detectors axes are displaced from the platform axes along the X and Y coordinates by ± 1°, thus creating in the center of the common view field a square of 2° by 2° in which the common area of the detectors is constant (176 cm²). In this zone, the accuracy of localization of the X- and γ-bursts with respect to intensity is lower or equal to 10 angle minutes with intensity of approximately one Crab in the maximum and duration of a couple of seconds. In the 4°x4° square, outside the 2°x2° zone, localization may be more inaccurate. To control and verify the device axes and detectors efficiency, scanning of the Crab source in two orthogonal directions in autonomous operation mode is provided.

The signal from the proportional counters is amplified and formatted by preamplifiers mounted near the detectors. The signal thus processed is then fed to the input circuitry of the analyzers block mounted within the hermetic section of the satellite. The signal thus processed is fed to the input circuitry of the analyzers block, mounted within the hermetic section of the satellite. The charged particles are separated from X-ray photons and the front slope of the pulses and their amplitude is estimated. The pulses thus processed are fed to the integral intensimeters for X-ray photons and charged particles.

The amplitude analyzer has 32 channels. In order to fill in smoothly its channels, the amplitude-to-code converter operates after a pseudo-logarithmic law. The code generated at its output is fed to the microprocessor system and, upon processing, the signal is recorded in the respective channel. The maximal conversion time of the 32nd channel is about 16 μs. The intensity analyzer has 480 channels whereas, depending on the operation mode. The accumulation time for one spectrum may be either constant set up by a command from the ground, or variable defined by an adaptive block.

The device for registration and estimation of X-ray bursts consists of four identical channels, one for each detector, and operates with four accumulation times: 0.5, 1.0, 2.0, and 4.0 s. The algorithm identifying whether the phenomenon is an X-ray burst is the following: for 30 s, the mean intensity of the diffuse X-ray background is measured, and then for 1 s, it is standardized. The reliability of the sensor measurements is verified by comparison with some previously given values. From the sheet previously stored in the RAM, the threshold values of the number of pulses for the above mentioned four times is determined. Should the value of the pulses thus determined for any of the four times or for any of the four detectors be greater than the corresponding value from the sheet, a signal for an X-ray burst is generated. The number of pulses within a time interval of 50 ms for all detectors is accumulated. Once in 4 s, the information for the intensity of the X-ray background is updated.

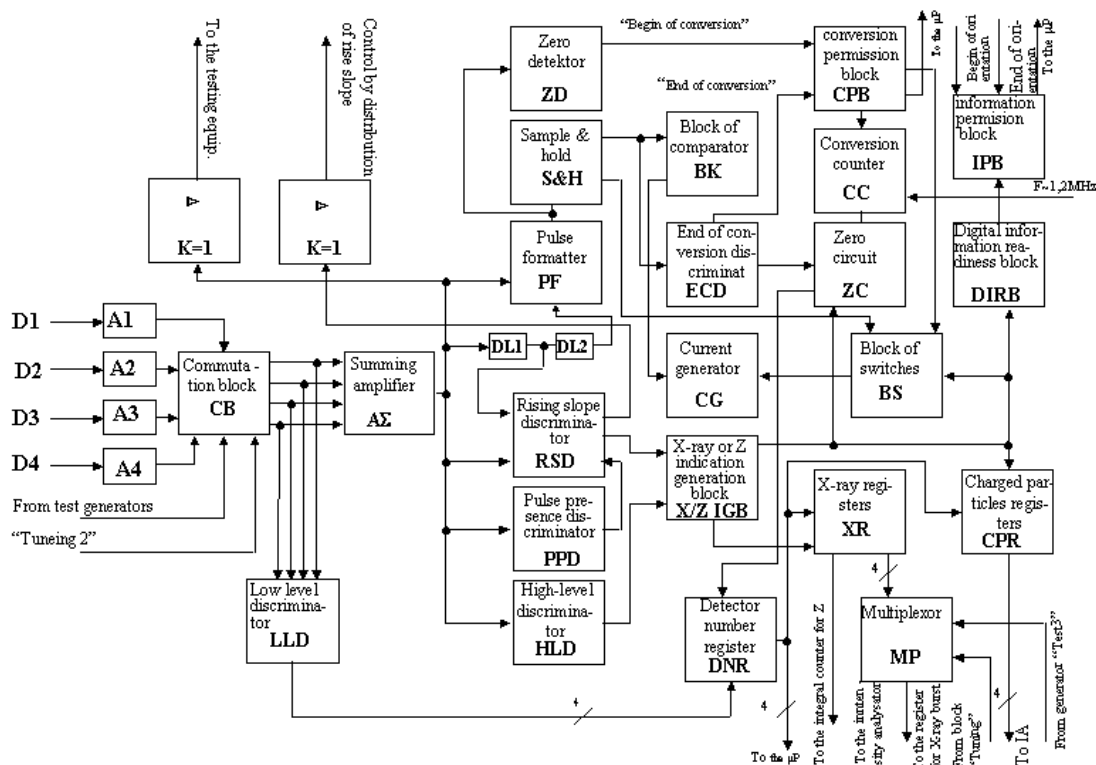
The device for adaptive estimation of the accumulation time accumulates periodically the number of the pulses for each detector within a time interval of 0.5 s. The maximal value is calculated and compared with three previously given threshold values. As a result of the comparison, the accumulation times of the two analyzers

mentioned in the introduction are estimated. The structure of the analyzers is described more precisely in [2,3].

In this paper, the operation principle of the system for estimation of the input signals and their digital conversion is considered in greater details (Fig.1). By the input amplifiers **A1**, **A2**, **A3**, and **A4** with amplifying coefficient of $2 \pm 25\%$, the signals from the preamplifiers are matched, and their amplitude for the given energy range is equalized. Then, through the commutation block **CB** which passes the signals from the detectors or from the test generators in the "Tuning-2" mode, the signals are fed to the summing amplifier **A Σ** . There, the signal from the detectors is amplified and then fed first to the low-level amplitude discrimination circuitry **LLD** where the signal indicating the presence of a pulse in the detectors is generated. From the output of LLD the signal goes to the detector number register **DNR**. From its output, along four channels, the information goes to the microprocessor and to the X-ray registers **XR** or to the charged particles registers **CPR** which are controlled by the X-ray or Z-ray indication generation block **X/Z IGB**. From the output of CPR, along four channels, the information goes to the intensity analyzer **IA**. From the output of XR, along four channels, the information is fed to multiplexor **MP** from whose output it is fed to the intensity analyzer, the device for registration of X-ray bursts, and to the platform if the signal locking "Tuning-3" is not available. In the "Tuning-2" mode, CB locks the signals from the detectors and passes the signal from the test generator **TG** located in the input circuitry and generates a signal with frequency of 512 Hz. In this mode, for each detector, 10 spectra are recorded in the energy analyzer **EA**. From the output of **A Σ** , via the buffering amplifier, the information is fed to the testing equipment. Simultaneously, the signal is fed to the slope discrimination circuitry in which the delay line **DL1**, the rising slope discriminator **RSD**, and the pulse presence discriminator **PPD** pass the signals with amplitude greater than 0.38 V and generate the signal "Prohibition by Slope". The **A Σ** output signal is fed also to the high-level discriminator **HLD** whose threshold voltage is 4 V. It generates the signal "Prohibition by amplitude". The signals "Prohibition by Slope" and "Prohibition by amplitude" go to the X/Z IGB and to the control blocks of the analogue-to digital converter **ADC**.

ADC operates by the following principle. The signal from **A Σ** formed in the pulse formatter **PF** is fed to the zero detector **ZD** and to the sample & hold device **S&H** which memorizes the amplitude of the input signal in the capacitor **C**. **ZD** generates the signal "Start of conversion" upon strobbing it with a signal with frequency $f = 1$ MHz. From the output of S&H the signal is fed to the end-of-conversion discriminator **ECD** where the signal "End of conversion" is generated. If a charged particle is registered, the current generator **CG** is switched on by the block of switches **BS** controlled by the "Z decision" and the capacitor in S&H, quickly allowing input circuitry to register the next signal. If an X-ray phenomenon is registered, the BS controlled by the "X-ray decision" permits operation of CG which discharges capacitor **C** by the pseudologarithmic law. The maximum conversion time is 32 ms. The operation frequency of the conversion counter **CC** is $f = 1$ MHz. It is controlled by the conversion permission block **CPB**. CPB is reset by the zero circuit **ZC**. CC is switched on by the signal "X-ray decision" and off by the signal "End of conversion". The ZC block generates a signal by the signals: "End of conversion", "End of rewriting in microprocessor", and "Z decision". The reset signal turns CC and the detector number register **DNR** in start position. Five-bit information for the amplitude of the signal goes to the input buffer of the microprocessor from the output

of the CPB. The microprocessor starts rewriting the information provided by the signal "Information is ready" in the digital information readiness block **DIRB**. The "Information is ready" signal is blocked by the signals "Start of orientation" and "End of orientation" coming from the command decoder to the information permission block **IPB**. As exact coordination of the observed phenomena with onboard time is necessary, a device for time registration with accuracy of 1 ms is made.



The whole information coming from the above described analyzers and intensimeters is memorized in the RAM device in a given sequence, depending on the character of the observed X-ray phenomena. By a command transmitted from the satellite's service system, the information is reformatted and translated to the onboard type recorder. After transmitting the whole information, the device automatically starts working in the mode transmitted by the ground-based station and written in the command memory.

The described complex of a controlled orientated platform "Podsolnuh-P" and a spectrometer "Podsolnuh-D" gives the possibility to observe and analyze all known X-ray phenomena in the energy range 2-24 Kev, accounting for their specific features.

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