

The Helicon-I and Konus-UF gamma-ray burst experiments

M. V. Ulanov*, R. L. Aptekar, S. V. Golenetskii, D. D. Frederiks,
D. S. Svinkin, A. E. Tsvetkova

Ioffe Institute, St.-Petersburg, Russia; ulanov@mail.ioffe.ru

Abstract We present Konus-UF and Helicon-I, the future space-based experiments designed to study temporal and spectral characteristics of gamma-ray bursts, solar flares, soft gamma-repeater bursts, and other transient phenomena over a wide energy range from 10 keV to 15 MeV. The instruments will be mounted onboard the World Space Observatory–Ultraviolet (WSO-UV) and the InterhelioProbe spacecraft, respectively. The spacecraft orbits are going to be far from the Earth's magnetosphere, which enables nearly uninterrupted observations of the entire sky under stable background conditions.

Keywords: Gamma-Spectrometer, Gamma-Ray Bursts, Soft Gamma-Repeater

1. Introduction

Study of cosmic gamma-ray bursts (GRBs) and soft gamma-repeaters (SGRs) remains one of the most important tasks in modern astrophysics, despite several decades of observations and theoretical studies. The progenitors, formation and evolution of such sources remain the subject of modern experimental and theoretical researches around the world [1].

The Konus-UF and Helicon-I experiments are planned to study hard X-ray and gamma radiation from gamma-ray bursts, soft gamma-repeaters and solar flares in a wide energy range from 10 keV to 15 MeV with a high temporal resolution.

2. The Instruments

The Konus-UF instrument (Fig. 1) consists of two identical gamma-ray detector units and an electronics unit that provides data buffering, power supply and interface with on-board spacecraft systems. Each detector will be mounted on the opposite sides of the World Space Observatory–Ultraviolet (WSO-UV) [2] so the instrument will observe the whole sky (Fig. 2).

The Helicon-I instrument is a single gamma-ray detector similar to the Konus-UF one, containing all power and interfaces circuits within the unit. The instrument will be mounted onboard InterhelioProbe [3] spacecraft.

The Konus-UF and Helicon-I detectors consist of NaI(Tl) scintillation crystals with a diameter of 130 mm and a height of 75 mm, placed in a thin-walled aluminum container with a beryllium entrance window. The scintillation crystal is viewed with a photomultiplier tube through a 16 mm thick high transparency lead glass, which is used to screen gamma radiation scattered by the structures of the spacecraft. The detector effective area is about 80–160 cm² depending on the photon energy and the incidence angle of the radiation. The spectral resolution is ~ 8% on the ¹³⁷Cs line (662 keV), and the burst sensitivity is about of 10⁻⁷ erg/cm².

The entrance beryllium window allows to effectively observe soft gamma rays, the transparency of the entrance window for photons with an energy of 20 keV is about 95%.

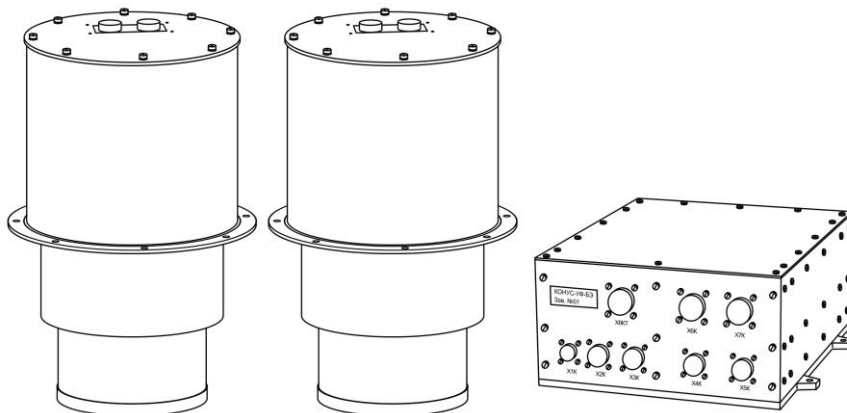


Fig1. The Konus-UF instrument consists of two identical detector units (Konus-UF-DS1, Konus-UF-DS2) and an electronics unit (Konus-UF-BE).

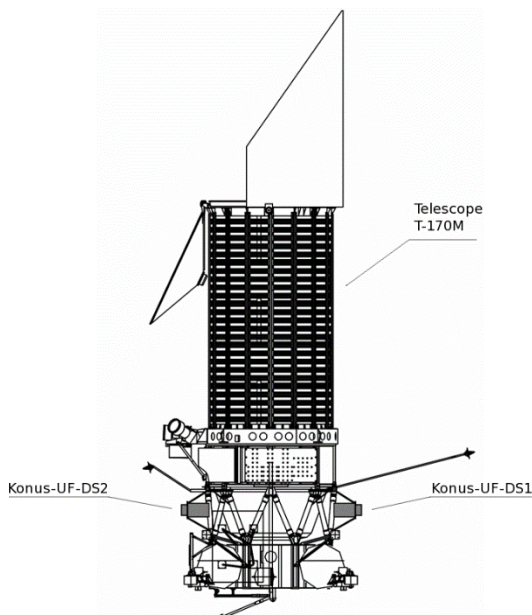


Fig2. Arrangement of the Konus-UF detectors onboard the WSO-UV spacecraft.

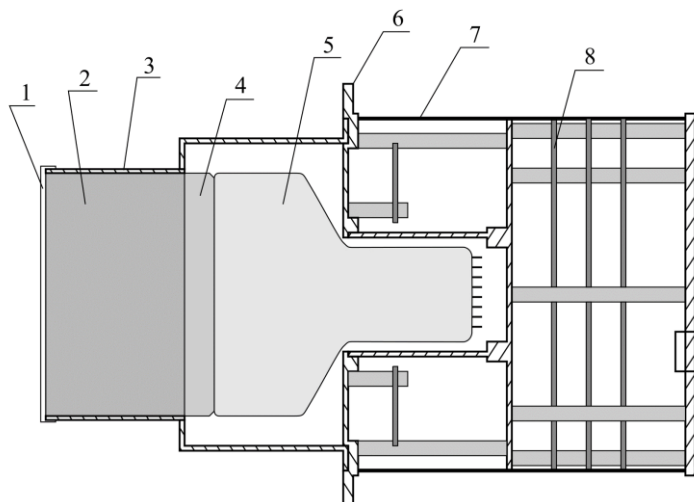


Fig3. Cross-section of the detector: 1 – beryllium entrance window, 2 – NaI(Tl) scintillator, 3 – aluminum housing, 4 – lead glass, 5 – photomultiplier tube, 6 – mounting flange, 7 – outer rim, 8 – electronics PCBs.

The WSO-UV observatory will be placed into geosynchronous orbit ($R = 42000$ km) with an inclination of 51.6° , while InterhelioProbe mission will consist of two identical spacecraft operating in the interplanetary space. Both orbits will allow continuous long-term observations uninterrupted by Earth occultation, and under conditions of a steady background undistorted by Van Allen radiation belts.

A high orbit will also allow to localize the GRB source using triangulation method with a high accuracy.

3. Observation program

The main objective of the Konus-UF and Helicon-I experiments is to observe cosmic gamma-ray bursts (GRBs), soft gamma-repeaters (SGRs), and solar flares. Such transients have a wide range of time scales from a few milliseconds (short GRBs and SGRs) to 1000 seconds (solar flares and long GRBs) and intensity range from $1 \text{ ph/cm}^2 \text{ s}$ (short GRBs and SGRs) to $10^7 \text{ ph/cm}^2 \text{ s}$ (SGR giant flares). The proposed instrument parameters and observation program will allow detailed analysis of time profiles and energy spectra of such transients.

The instruments operate in two main modes: waiting mode and triggered mode. In the waiting mode, time histories (light curves) are continuously recorded in 22 energy channels with a resolution of 1 s and multichannel spectra in 256 quasilogarithmic energy channels with an accumulation time of 60 s.

When the count rate in a certain energy channel exceeds a threshold above the background on one of two fixed timescales, 1 s or 100 ms, the instrument switches into the triggered mode. Two different conditions are used, since there are two different types of GRBs, which differ in duration and hardness of gamma-radiation [4].

In the triggered mode, time histories are recorded with a varying resolution of 2–64 ms in 22

energy channels, along with multichannel spectra with an accumulation time of 64–2048 ms. The total time history duration in triggered mode is 115 s, including the prehistory with duration of 2 s and a time resolution of 2 ms.

To study fine temporal structure of transients and accurate localization via triangulation, it is preferable to use the time-tagged event (TTE) photon registration mode. In the proposed experiments, operating in the triggered mode using TTE registration of individual photons, the amount of output data will be comparable to the amount of data using the traditional high-resolution time history and spectral data structures. The number of photons recorded by the detector with the most powerful GRBs is about 10^6 , which requires about 3 MB of data in the case of double-byte time code with a time resolution of 1 μ s and 256 energy steps.

During the waiting mode TTE in high-energy channels can also reduce the required data volumes, since the intensity of high-energy photons is low because the instruments will not be exposed to charged particles from the Van Allen radiation belts.

4. Conclusion

The proposed instruments will be a continuation of a series of Konus experiments, held at the Ioffe Institute for more than 40 years [5]. The instrument will contribute to the field of multi-messenger astrophysics, in particular in observation of short GRBs – the main targets of LIGO/Virgo gravitational wave observatories.

According to the results of more than 24 years of continuous observations in the Konus-Wind experiment [6] in interplanetary space, under similar conditions, the expected number of recorded GRBs is about 200 per year, which leads to the average daily amount of data about 100 MB per day.

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