

KONUS–W GAMMA-RAY BURST EXPERIMENT FOR THE GGS WIND SPACECRAFT

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Abstract. The Konus–W experiment to be flown on board the GGS–Wind spacecraft is designed to observe gamma-ray bursts and solar flares with moderate spectral and high time resolution. Two large scintillators are used to provide omnidirectional sensitivity. The primary scientific objectives are the study of the continuum energy spectra and spectral features of these events in the energy range of 10 keV to 10 MeV, as well as their time histories in soft, medium, and hard energy bands, with a time resolution to 2 ms.

1. Introduction

Too many questions implicit in the physics of cosmic gamma-ray bursts still remain unanswered despite the intensive study of related problems during the last two decades (Liang and Petrosian, 1984; Mazets and Golenetskii, 1988; Paciesas and Fishman, 1991). New, thorough observations and advanced models are necessary to approach a more clear understanding of this enigmatic phenomenon. This decade, opening with the launch of the Compton Gamma Ray Observatory (Fishman, 1988), promises to be a fruitful, new period of sustained gamma-ray exploration. One of the next steps will be occasioned by the GGS–Wind mission, with two gamma-burst experiments aboard, TGRS (Owens *et al.*, 1991), and Konus–W. The Wind mission provides an excellent opportunity for gamma-ray burst study, with its advantages of several years of a double lunar swingby orbit, to be followed by a halo orbit around the Lagrangian point L_1 .

The opportunity on GGS–Wind for an extended study of gamma ray bursts is also of timely importance, with the present uncertainties regarding their phenomenology, e.g., the existence and possible frequency of occurrence of cyclotron resonance features, the existence and possible rate of repetition of single-source, recurring bursts, the question of whether there are more than one kind of events, and of the possible relationships between these issues. Several particular advantages of the Konus instrumentation series in these connections are its history of successful application on a variety of Earth-orbiting and deep-space planetary missions, and

the similarity of the GGS–Wind detector to some of those employed on the Compton Gamma Ray Observatory (Fishman, 1988). Also, the monitoring of bursts on the GGS–Wind mission helps ensuring the continuity of interplanetary networks for the purpose of precise burst source determination.

2. The Instrument

The Konus–W instrument is a gamma-ray spectrometer designed primarily for the detection and study of cosmic gamma-ray bursts, with capabilities as well for the study of solar flares in the hard X-ray region. The instrument consists of two identical gamma-ray detectors and an electronic unit (KEB). Each detector is nearly omnidirectional in sensitivity; locating the two on opposite faces of the spacecraft will provide for the observation of the whole sky.

The principal goals of the experiment are as follows:

- the study of cosmic gamma ray burst intensity profiles with both good temporal and spectral resolution,
- the detection of spectral features, i.e., emission and absorption lines,
- the studies of the spectral composition of burst radiation and of the spectral variability in both the continuum and line emission,
- the study of the gamma-ray burst occurrence frequency and of the possibility of burst recurrence, and
- burst source localization by comparison with timing measurements from other spacecraft.

A schematic view of each gamma-ray detector is shown in Figure 1. The gamma-ray sensor is a NaI(Tl) crystal 5 inches in diameter and 3 inches in height, placed into an aluminum container faced with a beryllium entrance window. The crystal scintillator is viewed by a photomultiplier tube (PMT) through a 20 mm thick lead glass. The sensors are mounted on the two faces of the spacecraft pointed parallel to the spin axis; in space, these directions will face approximately towards the north and south ecliptic poles. Some knowledge of the ecliptic latitude of a burst source will thus be possible by the comparison of rates. Solar flares will be viewed always at the same, zero-latitude, angle.

The electronics associated with the detector (Figure 2) include a high voltage supply, amplifiers, threshold discriminators, differential analyzers, a gamma-burst trigger unit, and commandable control circuits.

The two analog outputs, A1 and A2, are designed for spectral measurements in two energy ranges, 10–750 KeV and 0.2–10 MeV. Outputs SG1, SG2, SG3, and SZ of each sensor provide signals of standard amplitude used for measuring the gamma-ray burst time profiles and background in the energy windows 10–50 KeV (G1), 50–200 KeV (G2), 200–750 KeV (G3), and >10 MeV (Z). To control the operation of the pulse height analyzers, enable signals ES1 (10–750 KeV) and ES2 (0.2–10 MeV) are generated.

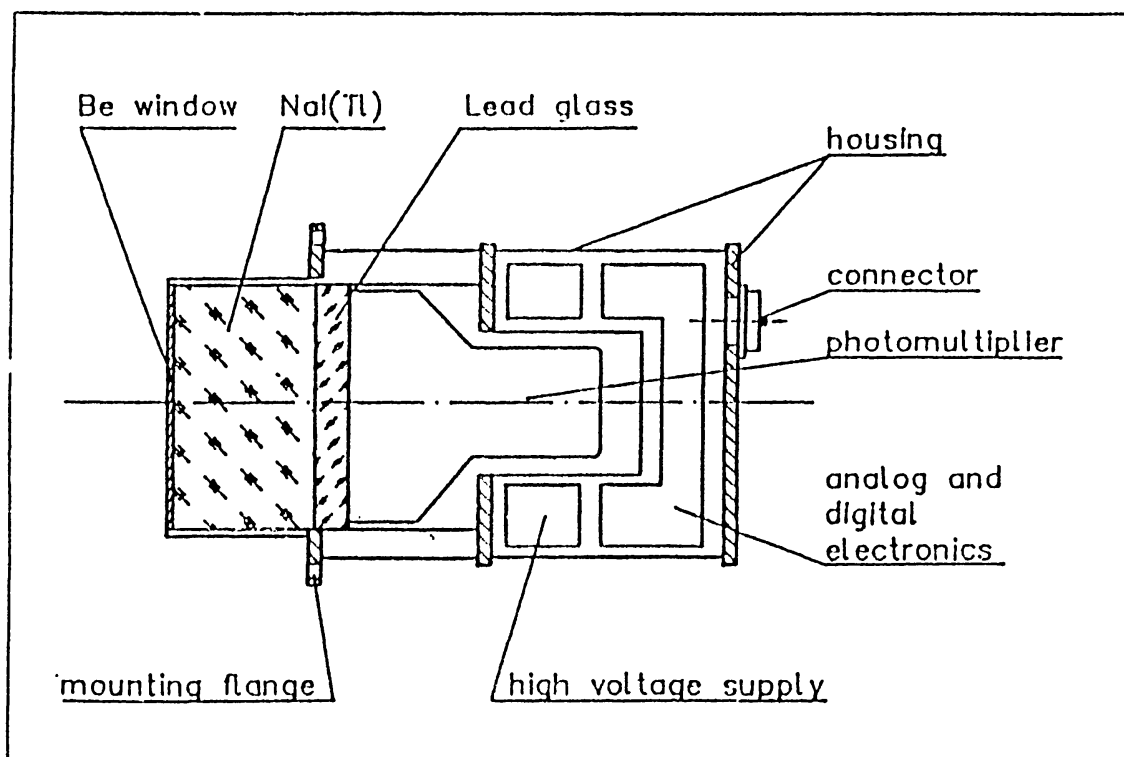


Fig. 1. Schematic view of the Konus-W gamma-ray sensor.

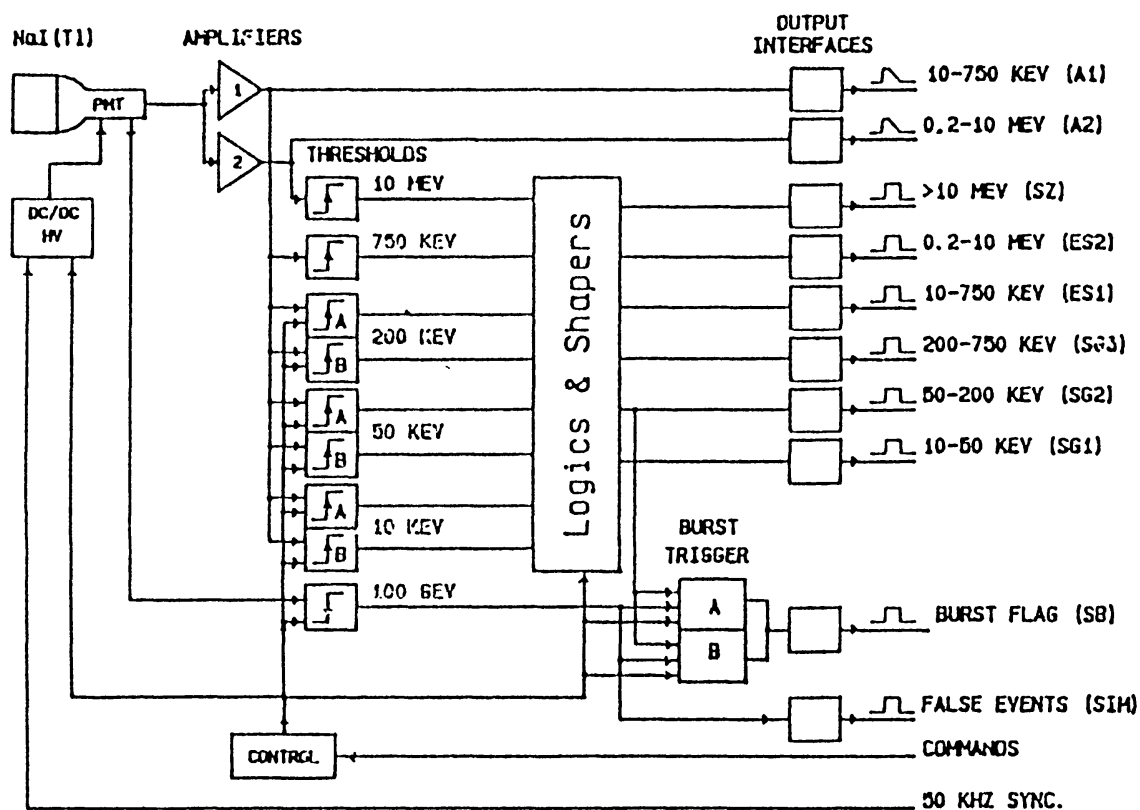


Fig. 2. A simplified functional block diagram of the Konus-W sensor.

The burst flag SB is generated by an analog burst trigger system. It operates with the G2 window (50–200 keV). This circuit continuously compares two current values of count rate, measured with time resolution 0.15 and 1.0 s, with the 30 s-averaged count rate. If any current value exceeds the reference level by a certain amount, a trigger signal is generated and sent to the data processing system. Nominally, the burst trigger threshold is set at the 6σ level and can be changed on command. It corresponds to a sensitivity of $(1-5) \times 10^{-7}$ erg cm⁻². The real sensitivity of burst detection depends on the structure of the event time profile and energy spectra.

Each sensor is controlled by 11 commands. Their purposes include:

- the adjustment and switching of the PMT high voltage,
- the configuration of redundant circuits,
- the control and switching of the burst trigger threshold
- the control and switching of the false-event protection threshold.

The Konus–W electronics box (KEB) processes analog and digital signals from the sensors (Figure 3). It contains:

- four pulse height analyzers (PHA) for spectral measurements in two energy ranges;
- four time history analyzers (THA) to measure the time profiles in three energy intervals;
- two high resolution time history analyzers (HRTHA);
- memory for storing PHA, THA and HRTHA data during the accumulation time;
- background measurement system (BMS);
- sensor selection and start of measurement system (BRTU);
- adaptation system controlling spectral measurements;
- control system for receiving commands and controlling instrument operation;
- TM system;
- housekeeping system;
- power supply system.

The sensor selection and start of measurement system (BRTU) selects the sensor which detected the burst and generates a command to start the accumulation of THA and PHA data into the memory. If a burst is so intense that both sensors generate the burst flag, the system connects to KEB the sensor that was the first to detect the burst and, hence, is more favorably oriented with respect to its source.

The amplitude analyzers PHA 1, 2, 3, 4 have 63 channels each with a quasilog scale. They are identical and can be connected to one of the ranges, A1 or A2. The PHAs are controlled by the adaptation system which determines the accumulation time for each spectrum based on the current intensity of gamma-radiation. The total number of spectra measured during a burst is 64. The first four of them are obtained with a fixed accumulation time of 64 ms. For the subsequent 52 spectra, the adaptation system determines the accumulation time which can vary from

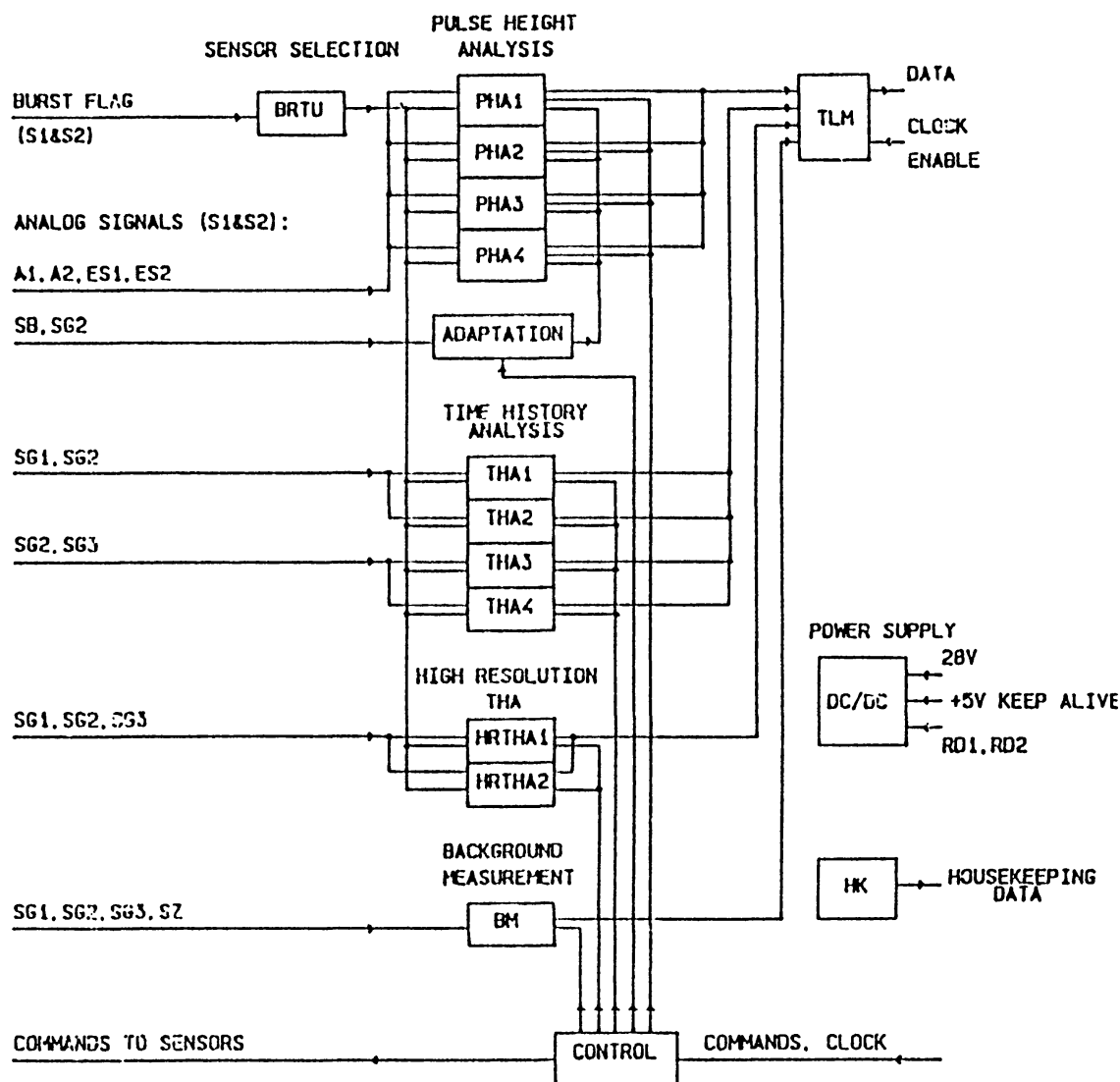


Fig. 3. A simplified functional block diagram of the Konus-W electronic unit.

0.256 to 8.192 s. The last 8 spectra are obtained in 8.192 s each. As a result, the minimum duration of spectral measurements is 79.104 s, and the maximum, 491.776 s. Figure 4 presents an example of energy spectra in the ranges A1 and A2 obtained during the test procedure at GSFC using a set of radioactive sources.

The time history analyzers THA 1, 2, 3, 4 have 4096 channels each and ensure measuring burst prehistories and histories in three energy windows consecutively with a resolution of 2 ms during the first 1.026 s, 16 ms during 32.768 s, 64 ms during 65.536 s, and 256 ms during 130.816 s. All THAs are identical and can be connected to any of the windows G1, G2, or G3.

The high resolution THAs (HRTHA) are intended for measuring high intensity sections of a time history with a 2 ms resolution in two energy windows. Each such section is 0.128 s long. The criterion for the recording to be made is that the number of counts at least in one 2 ms-interval be 16 or higher. Altogether, 64 sections of

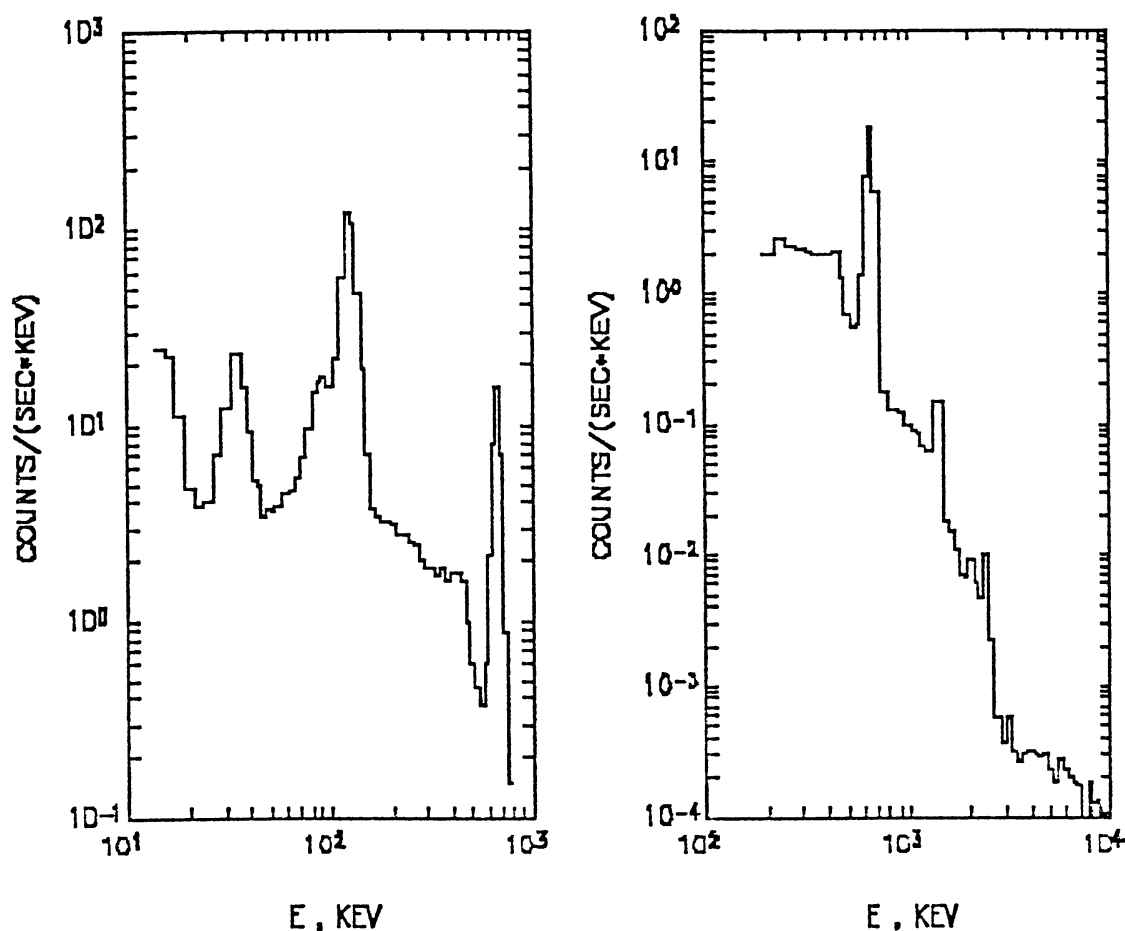


Fig. 4. Energy spectra with emission lines for burst simulated by radioactive sources.

total length 8.192 s can be measured with a high resolution in a burst. One section of time history in the energy bands G1 and G2 of a burst simulated by X-ray tube emission is shown in Figure 5. Spectral variability is revealed on a millisecond scale here, characteristic of the X-ray tube used in the test procedure at Ioffe.

The background measurement system (BMS) is designed for measurements of the gamma- and cosmic-ray background. The system operates continuously both in the absence of bursts (waiting mode of the instrument) and during burst measurements (burst detection mode). The instrument measures the count rates from both sensors in the ranges 10–50 keV (SG1), 50–200 keV (SG2), 200–750 keV (SG3), and >10 MeV (SZ) with accumulation time of 2.94 or 1.47 s depending on the telemetry rate. The background measurements are not transmitted during the time interval required to read out the data accumulated in the instrument memories during the burst. In this period only a limited part of the background data is transmitted through the housekeeping system, namely, the count rate SG2 from the sensor which detected the last burst.

The power supply system produces instrument secondary voltages. It consists of two independent DC/DC converters which can be switched by relay commands.

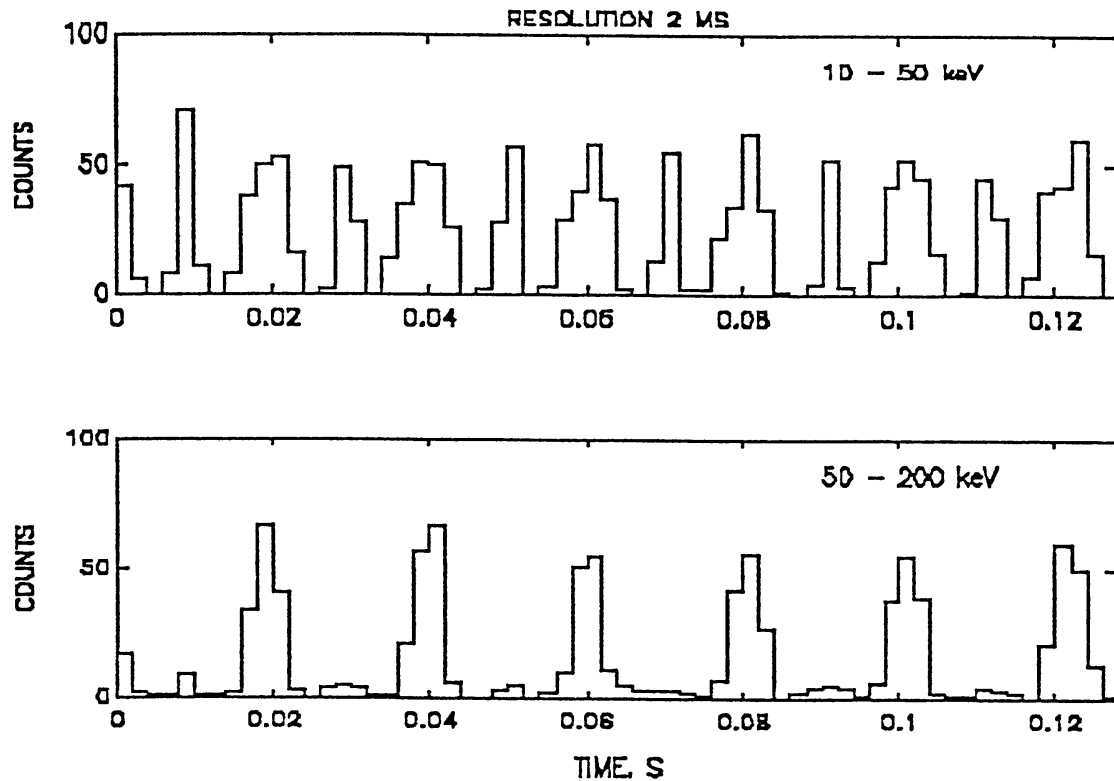


Fig. 5. Time profiles for burst simulated by pulsed X-ray tube.

In the absence of a gamma-ray burst or a solar flare, the instrument is in the waiting mode. The burst trigger signal from the sensor transfers the instrument into the data accumulation mode. Accumulation of burst data takes up 4 to 8 min. The desirable measuring program, e.g., a combination of energy spectra and time histories to be measured as well as the energy range to be covered, can be preselected by command.

On finishing the burst measurement mode, the instrument automatically switches to the data readout mode. The telemetry rate available for the Konus-W instrument is 55 bps. Hence, reading out the data stored in all instrument memories takes 100 minutes. This may result in a significant loss of burst detection, especially during periods of frequent solar flares. To reduce the dead time for gamma-ray burst detection, a nominal program of burst observations is envisaged. This program provides:

- measurement of 64 energy spectra in the 10–750 keV and 0.2–10 MeV bands with two pulse height analyzers (PHA),
- measurement of burst time histories in three energy windows with three time history analyzers (THA) and two high resolution time history analyzers (HRTA).

Such a volume of data requires only about 1 hour to be read out. This program permits observation and study of the spectral variability of the continuum and its features on a time scale of 0.25–8.0 s. Faster analysis on time scales up to 2 ms can

be performed by studying the variations of the hardness ratio, calculated using the event time histories recorded for different energy bands. This program is obviously valid for solar flares as well.

Instrument in-flight calibration will be checked using the 0.511 and 1.46 MeV lines; these are always present in the naturally occurring background, fortunately rendering unnecessary the flight of radioactive sources, such as must be used in ground- level testing and calibrations.

The burst data accumulated are time-tagged to the onboard clock within an accuracy of 1 ms. This permits combining the Konus-W measurements with observations from other, distant spacecraft to yield precise gamma-ray burst source localization by timing comparisons.

The Konus-W gamma-ray burst experiment was recommended for installation on board the GGS WIND Spacecraft by the U.S./U.S.S.R. Joint Working Group on Astronomy and Astrophysics (co-chairmen Dr C. Pellerin and Dr R. Sunyaev). This proposal was approved by NASA. The authors are thankful to their American colleagues from NASA Headquarters, the Goddard ISTP Project Office, GE Astrospace and EER Systems for their valuable contributions in the preparation and development of this experiment.

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