Ioffe Physical-Technical Institute of the Russian Academy of Sciences

5. Research and Supervision Results Obtained by Russian Scientists and Specialists during (in the course of) Implementation of Flight Scientific Programmes in cooperation and with assistance of Foreign Scientists and Specialists

Studies of Cosmic Gamma-ray Bursts from the Joint Russian-American Konus-Wind Experiment on the U.S. Wind Spacecraft

The studies of the cosmic gamma-ray bursts and soft gamma repeaters that have been performed in the Russian-American Konus-Wind experiment during 2014-2015 years have been summarized. The experiment has been continuously performed using the Konus Russian scientific instrument on the Wind American spacecraft since 1994 under optimal interplanetary space condition in the absence of interferences caused by the Earth's radiations belts and the shadowing of detectors. Two high-sensitivity detectors have constantly observed the entire celestial sphere and recorded detailed time and spectral characteristics of bursts in a wide range of energies from 20 keV up to 15 MeV. The Konus-Wind data have been widely used in the present-day multi-wave studies of gamma-ray bursts. The results of the KONUS-WIND experiment on the research of short and ultra-long gamma-ray bursts are given.

1. Experimental approach

The Russian-American experiment aimed at studying cosmic gamma-ray bursts (GRBs) has been continuously performed on NASA's spacecraft since November 1994 using the Konus instrument designed and manufactured at the Ioffe Institute. The orbit and conditions for GRBs observing have been exceptionally favorable during the experiment. The instrument's detectors have constantly observed the entire celestial sphere in the situation where the radiation background is stable and interferences caused by the Earth's radiation belts and occultation by the Earth are absent.

The Konus-Wind instrument is a scintillation gamma-ray spectrometer including two identical spectrometric detectors of gamma-ray photons and an electronic unit used to record and preliminary process detector signals. Each detectors includes a NaI(Tl) crystal with a diameter of 130 mm and a height of 75 mm in a thin-walled aluminum container with a beryllium entrance window and a high-transmission lead-glass exit window in order to protect the detectors from the spacecraft background in the soft spectral region. Such a detector provides a low energy threshold for recording radiation from 10-12 keV, the photon registration range up to 15 MeV with an energy resolution of 8.5 – 9.0 % in the 660 keV Cs 137 line, and the burst detection sensitivity at the ~ 10^{-7} erg cm^{-2} level. These detectors have no analogs in the GRB observations with respect to the energy range and degree of protection from the spacecraft background. The detectors are located on the spacecraft stabilized by rotation in such way that they constantly observe the northern and southern ecliptic hemisphere.

The instrument constantly anticipated bursts. It begins to automatically record data on a gamma-ray with a high time resolution when a statistically significant increase in gamma-quantum count rate is recorded with a burst detection cell. At present, burst time profiles are recorded in the 20-80, 80-300, and 300-1200 keV energy channels with time resolution varying from 2 to 256 ms and a total registration duration of 230 s. The standard program for recording event time profile makes it possible to maintain a time resolution of 2 ms during first 0.5 s of burst and for 0.5 s before burst. The instrument also has two special time analyzers (so-called time verniers), which allow one to record any event profile section, including clearly defined increases in gamma-quantum count rates, with a high time resolution (2 ms).

Two multichannel amplitude analyzers with quasi-logarithmic scales in two energy intervals (20 – 1100 keV and 350 kev -15 Mev) are used to measure the event energy spectra. The special adaptive system automatically controls the spectrum accumulation time depending of burst intensity. This makes it possible to obtain data on fast spectral variability even for weak events under the condition of limited statistics.

The long-term gamma-ray burst observations in the Konus-Wind experiment and their comparison with data of other experiments confirmed that the selected algorithm for recoding the main characteristics of cosmic gamma-ray burst is optimal.

2. The results of the ultra-long gamma-ray burst research.

Multiwave studies have been made on ultra-long gamma-ray burst October 24, 2009. Its total duration was about 1300 seconds and full brightness curve in gamma rays was obtained only in the KONUS-WIND experiment (Fig. 1). The optical component of the burst was investigated by several ground-based telescopes, and it was determined that its cosmological redshift z is 1,09. No correlation was found between the peaks in the gamma radiation of the burst source and its optical radiation, what has been interpreted as the radiation of shock waves in a strongly magnetized plasma. The study of this burst in the broad range of wavelengths led to the conclusion that the ultra-long gamma-ray bursts are at the tail of the distribution of long bursts (F.R. Virgili, ... D.S. Svinkin et al, 2013, Astr.J., 778, 54)

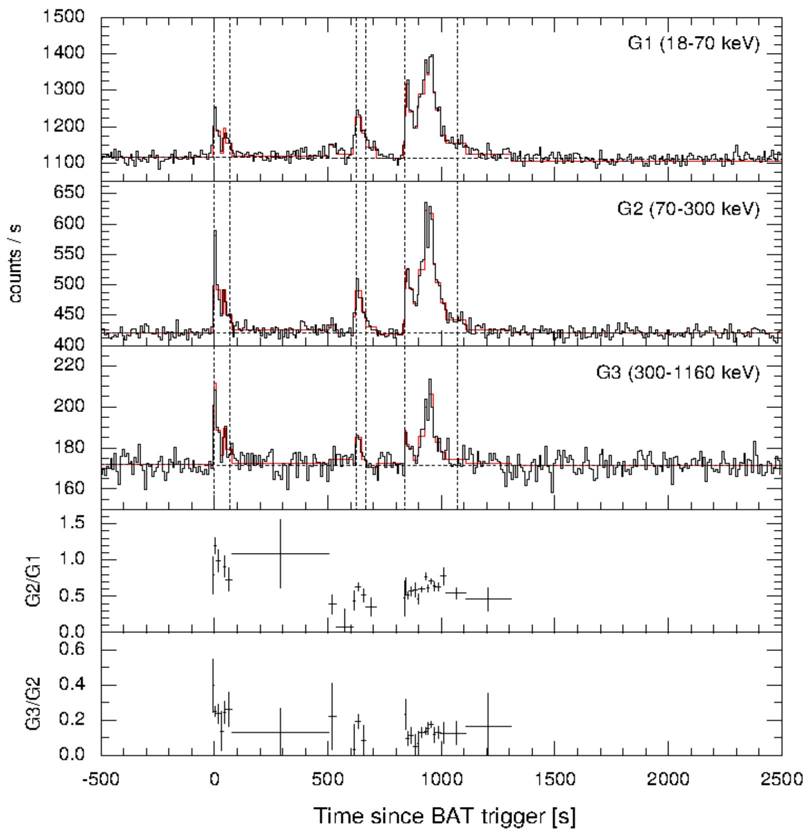

Fig. 1. Time history of GRB October 24, 2009 according to the KONUS-WIND experiment data. Three upper panels indicate the counts rate in the three energy ranges. The two lower panels indicate the cont rate relations in the energy intervals demonstrated the hardness of radiation.

Another ultra-long gamma-ray burst GRB130925A was registered with many spacecraft, but because of its unique length, which exceeded 20 thousand seconds, a complete picture of the burst source activity was obtained only in the KONUS-WIND experiment (Fig. 2).

The main episode of this burst, lasting more than 5000 seconds, was only studied in the KONUS-WIND experiment (Evans, ... Frederiks et al, 2014, MNRAS, 444, 2505). The X-ray afterglow of the burst source lasted more than 20000 seconds with uncharacteristic spectrum, testifying to the environment as a highly rarefied plasma with a density of particles n ~ 10^{-3} cm^{-3}. In yet another multiwave study of this burst involving the KONUS-WIND experiment and the GROND telescope the optical emission correlated with gamma irradiation was registered, delayed relativeto the gamma radiation for ~ 300 seconds (Fig. 3). Another burst of optical radiation from the source accompanied gamma radiation with energies of a few GeV registered by the Fermi / LAT telescope.

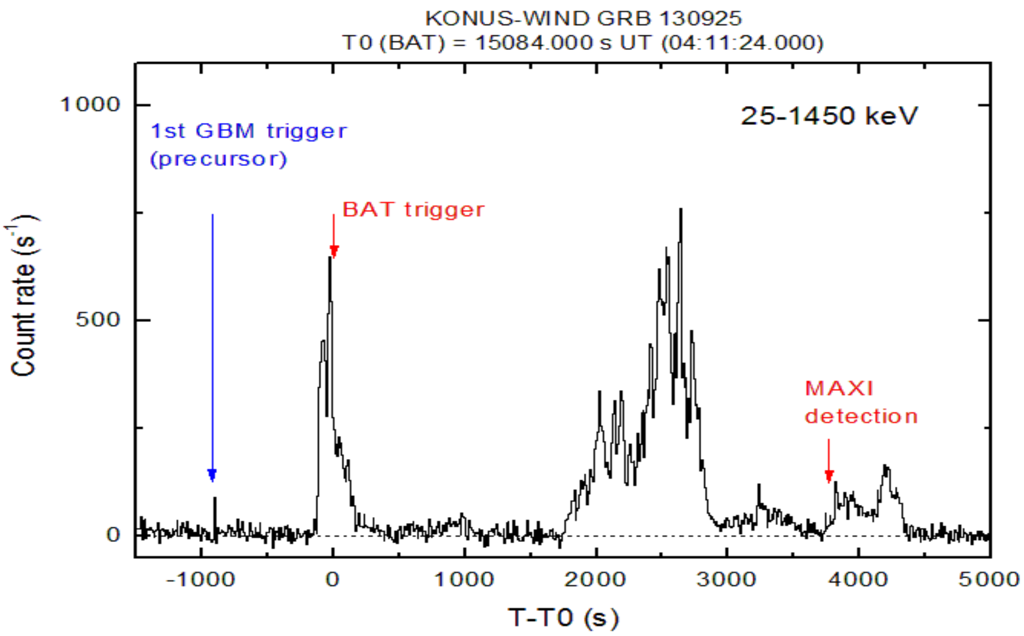

Fig. 2. GRB130925A brightness curve according to the KONUS-WIND experiment data together with the data from Swift / BAT, Fermi / GBM and MAXI instrument.

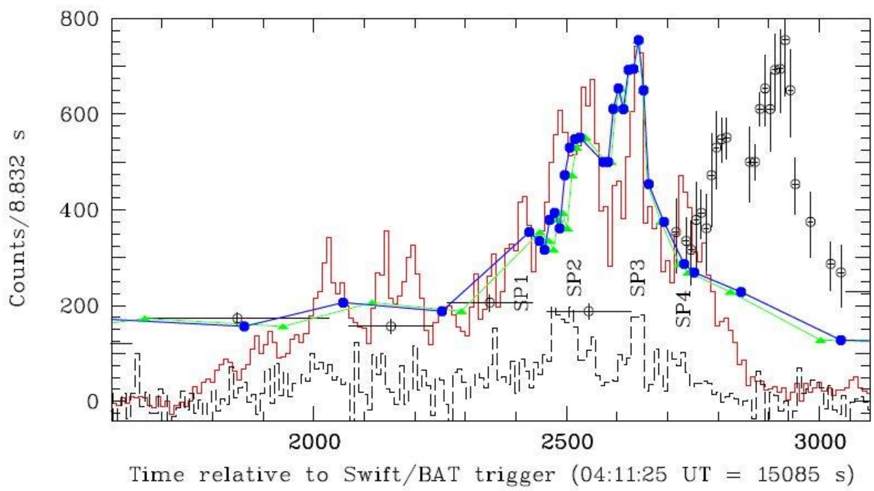

Fig. 3. Optical activity of the GRB130925 burst source according to the GROND Telescope data (blue dots). The red line is an Konus-Wind information. At the region of 3000 sec optical activity was observed, accompanying the formation of gamma radiation with energy of tens of GeV, according to the Fermi / LAT telescope data (green dots).

3. Studies of ultra-bright gamma-ray burst GRB140219A

Gamma-ray burst February 19, 2014 is one of the most intense events registered during the period of their studies. Fig. 4 shows the time history of the burst main phase, which lasted 2.5 seconds and was registered only by the KONUS-WIND experiment. Peak energy of the burst during this phase exceeds the amount of 2 MeV at energy flow 1,1 $x10^{-3}$ erg cm^{-2} (Golenetskii et al., GCN Circular № 15870, 2014). The burst source was localized by the IPN network and in the area of its localization the Fermi / LAT telescope registered gamma quants of ultrahigh energies from 1.6 GeV in the time interval from 500 to 2300 seconds after the KONUS-WIND trigger. The top panel of Fig. 5 shows the region of localization of the burst source by the IPN network together with the Fermi / LAT telescope data. At the bottom in the same figure the calculated characteristics of GRB140219A are shown in its own frame for different values of the cosmological redshift z varying from 0.1 to 1.0. For z = 1,0 full flow of energy from this source amounted to Eiso = $3x10^{54}$ erg s^{-1} and luminosity Liso = $8x10^{54}$ at peak energy ~ 6 MeV.

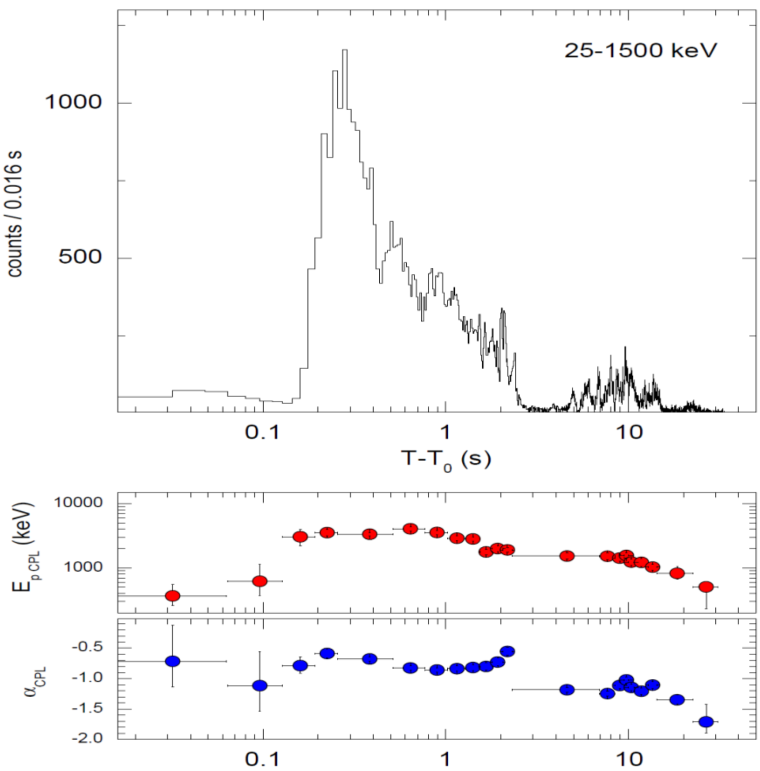

Fig. 4. The time history of the initial phase of GRB 140219A according to KONUS-WIND experiment data together with data on the peak energy and the model parameter α.

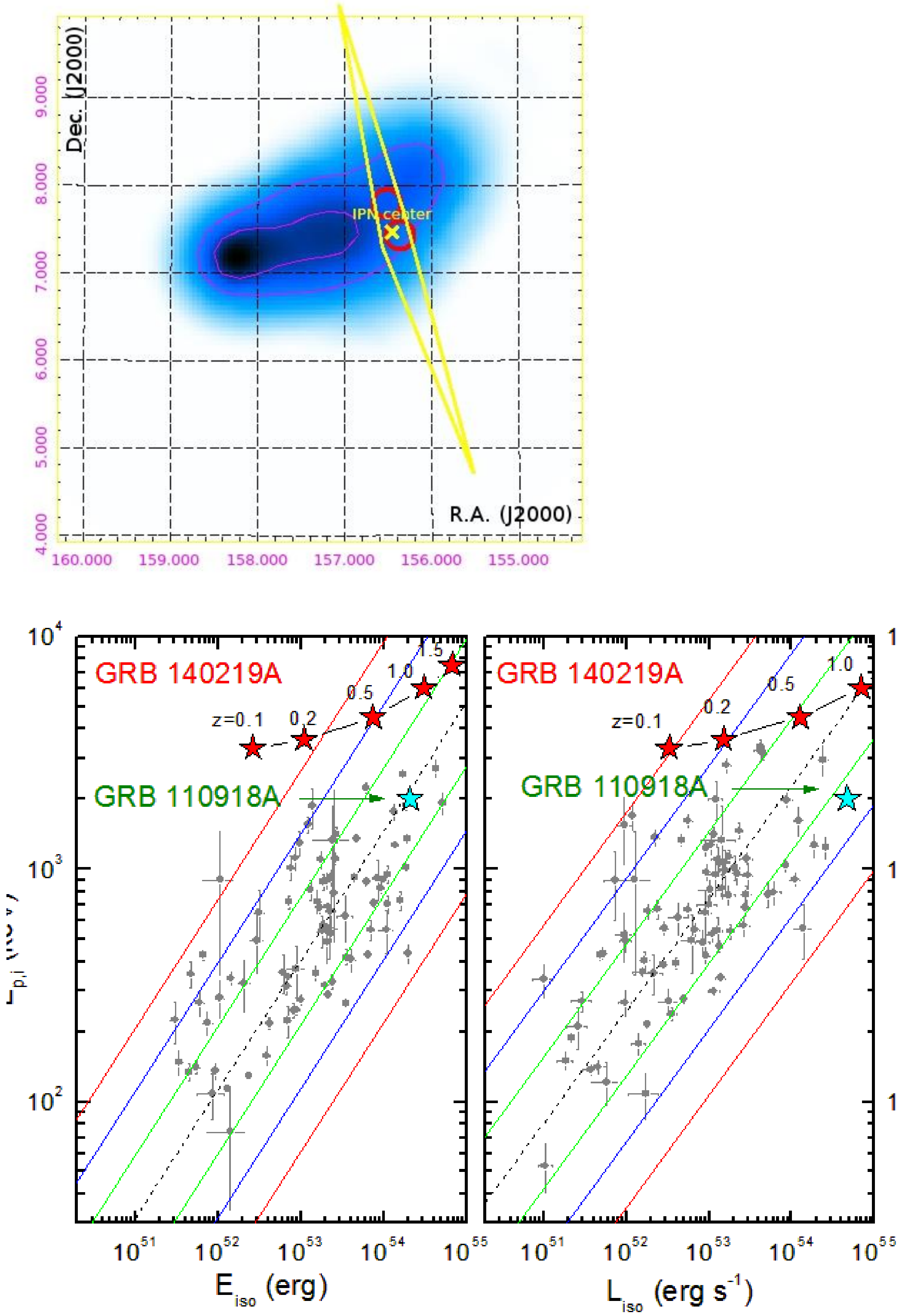

Fig. 5. At the top of the figure the data of the Fermi / LAT telescope are shown together with data on the source localization by the IPN network. The bottom part of the figure shows the calculated characteristics of GRB 140219A for different values of the cosmological redshift z and their comparison with the parameters of GRB110918A

4. Catalogue of short gamma-ray bursts of the KONUS-WIND experiment.

The second catalog of short gamma-ray bursts of the KONUS-WIND experiment was created and published (Svinkin D.S., et al, 2016, Astr.J.S., eccepted, arXiv: 1603.06832). The catalog contains information about the temporal and spectral characteristics of 293 short gamma-ray bursts registered in the period from 1994 to 2010. Among 214 gamma-ray bursts with multichannel spectra three events were revealed in order to describe which an additional power low component is required with photon index ~ 2. These gamma-ray bursts are among 10% most intense events. In the catalog the short gamma-ray bursts with extended emission, which had been analyzed for the first time in the KONUS-WIND experiment, are considered in detail.

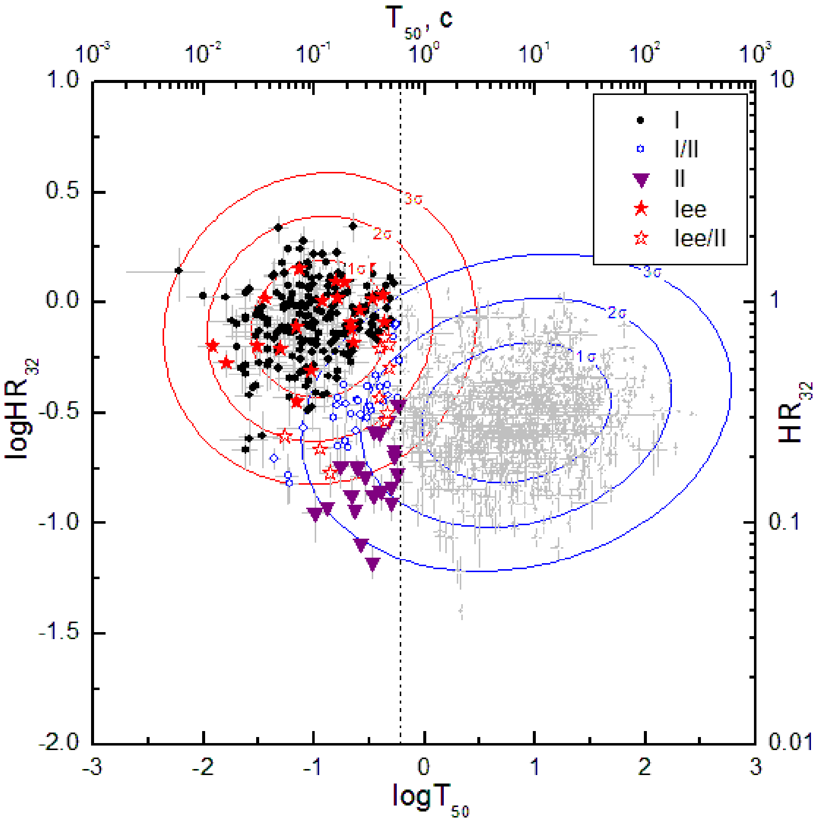

Fig. 6 illustrates the classification of 1143 brightest gamma-ray bursts of the KONUS-WIND experiment. The dashed vertical line indicates the border between long and short gamma-ray bursts.

5. **The KONUS-WIND hard X-ray Solar Flares Database (KWSFD)**

The Wind spacecraft is located in the interplanetary space (since July of 2004 – near Lagrange point L1), so the instrument sees the Sun 24 hours a day. KONUS-WIND instrument operates in two modes: waiting mode and triggered mode. In the waiting mode, the light curves in three wide energy bands G1 (now ~ 20 – 80 keV), G2 (now ~ 80 – 300 keV), and G3 (now ~ 300 – 1200 keV) are measured with time resolution of 2.944 s. In the triggered mode, the light curves in the same three energy bands are available with high (from 2 ms to 256 ms) time resolution. In addition, multichannel energy spectra are measured in two partially overlapping energy ranges (now ~20 – 1200 keV and ~250 keV – 15 MeV). During more than twenty years of continuous observations, KONUS-WIND detected more than 1000 solar flares in the triggered mode, which constituent the presented database. KWSFD provides spectral data in FITS format as well as light curves in IDL SAV and ASCII formats. The IDL routine for reading and processing KW FITS spectral files has been added to the OSPEX package and now available from SSW. We describe the KW solar data, their advantages and limitations. We illustrate the beauty of the data by presenting some interesting solar events, detected by KONUS-WIND (G.D. Fleishman,… A.L. Lysenko, A.T. Altyntsev et al, 2016, Astr.J., 822, 71). It is planned that this KWSFD database will available at the Ioffe Institute web-site not late than June 15, 2016.

6. **Participation of the KONUS-WIND experiment in search for gamma radiation from gravitational wave sources.**

In February 2016 the first data about the detection of gravitational waves due to the merger of two black holes were published by the LIGO / Virgo collaboration. (Abbot, P.B. at al., 2016, a PRL, 116, 061,102), Following this event, which was given a notation GW150914, data of the Fermi / GBM experiment were published on registration of a weak gravitational short gamma-ray burst in 0.4 seconds after the signal (V. Counnaughton et al, ApJ, 2016, submitted, arXiv:. 1602.03920). These findings have not been confirmed in the observation of the INTEGRAL / SPI-ACS instrument (V.Savchenko et al, ApJ, 2016, submitted, arXiv:. 1602.04180) and the KONUS-WIND experiment data and the IPN network (K. Hurley, ..., D. Svinkin, R. Aptekar, D. Frederiks, et al., in prep.). The KONUS-WIND experiment through the IPN network is involved in a broad collaboration to search for signals correlated with the signals of gravitational waves (B. P. Abbot, et al., ApJL, 2016, arXiv: 1602.08492). Further observations of such events in the KONUS-WIND experiment are extremely important, because its detectors, being in optimal conditions in interplanetary space, are constantly surveying the entire celestial sphere, and the interaction with the IPN network enables localizing of radiation sources by the triangulation method.

7. **Conclusions**

According to the significance, quality, and completeness of the data, the Russian-American Konus-Wind experiment is among the worldwide leaders in studying extreme explosive phenomena in the Universe. The program for the time and spectral measurements of the GRBs parameters is optimal and the orbit in the interplanetary space is almost ideal so that the high-sensitivity detectors of the instrument permanently observe the entire celestial sphere. For this reason, the experimental data have widely used in the present-day multi-wave studies of GRBs.

R.L. Aptekar, D.D. Frederiks, S.V. Golenetskii, F.P. Oleinik, D.S. Svinkin, M.V. Ulanov (Ioffe Physical-Technical Institute, Russian Academy of Sciences, St. Petersburg)
T.L. Cline (NASA, Goddard Space Flight Center, Greenbelt).