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Gamma quanta and neutrinos from space: what we can see now and what we need to see more (Scientific session of the Division of Physical Sciences, Russian Academy of Sciences, April 21, 2023)

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April 21, 2023, in the Assembly Hall of the Ioffe Institute (PTI) of the Russian Academy of Sciences (RAS) (26 Polytechnicheskaya Street, St. Petersburg), the Division of Physical Sciences of the Russian Academy of Sciences held a scientific session, "Gamma quanta and neutrinos from space: what we can see now and what we need to see more."

The following agenda of the meeting was announced on the website of the Department of Physical Sciences of the Russian Academy of Sciences, www.gpad.ac.ru.

Review talks:

(1) **Sunyaev R A** (Space Research Institute (IKI), RAS, Moscow) "Main results of four complete surveys of the entire sky in X-rays with the eRosita telescope aboard the SPEKTR-RG satellite";

(2) **Troitsky S V** (Institute for Nuclear Research (INR), RAS, Moscow) "Origin of astrophysical high-energy neutrinos: results and prospects reviewed";

(3) **Bykov A M** (Ioffe Institute (PTI), RAS, St. Petersburg) "Sources of high-energy cosmic radiation: results and prospects";

(4) **Lutovinov A A** (IKI, RAS, Moscow) "Status and prospects of Russian orbital telescopes for high-energy astrophysics."

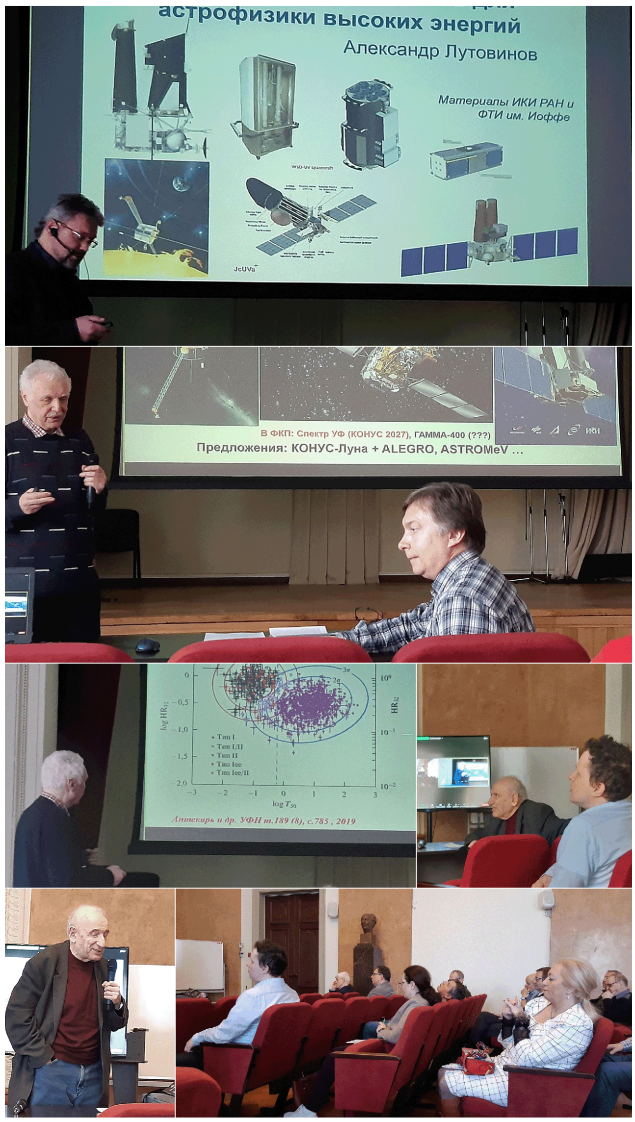
Discussion I: "Problems of high-energy astrophysics." Participants: M R Gilfanov (IKI, RAS), V A Dogel (Lebedev Physical Institute, RAS (FIAN), Moscow), L M Zeleny (IKI, RAS), Yu Yu Kovalev (Astro-Space Center, FIAN), V V Kocharovsky (Institute of Applied Physics, RAS, Nizhny Novgorod), L A Kuzmichev (Skobeltsyn Institute of Nuclear Physics of the Moscow State University), K A Postnov (Sternberg State Astronomical Institute, Moscow State University), E M Churazov (IKI, RAS), and others.

Discussion II: "Cosmic radiation detectors today and tomorrow" (moderators: R A Suris, A M Cherepashchuk, and K A Postnov).

(5) **Levin V V** (IKI, RAS, Moscow) "Detectors and integrated circuits of orbital telescopes";

(6) **Eremin V K** (Ioffe Institute, RAS, St. Petersburg). "Modern silicon detectors for high-energy astrophysics";

(7) **Vlasyuk V V** (Special Astronomical Observatory, RAS, Nizhny Arkhyz) "Modern solid-state receivers in astronomy: prospects for Russia";



At the Session

(8) **Afanasieva I V** (Special Astronomical Observatory, RAS, Nizhny Arkhyz) "Creation of photodetector systems based on large-format CMOS receivers at the Special Astronomical Observatory, RAS";

(9) **Lubsandorzhiev B K** (INR, RAS, Moscow) "Detectors for neutrino telescopes."

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As part of this scientific session of the Division of Physical Sciences of the Russian Academy of Sciences, an active discussion took place on the status and prospects of domestic and global projects in the field of observational astronomy and astrophysics, including neutrino astronomy and cosmic-ray astrophysics. The main focus was on the problem of radiation and particle detectors. The discussion was attended by 8 full members, 8 corresponding members, and 4 professors of the Russian Academy of Sciences, and more than 25 doctors of science and young researchers from the INR, Ioffe Physical–Technical Institute, IKI, Special Astronomical Observatory, Institute of Applied Physics, FIAN, Sternberg State Astronomical Institute, Skobeltsyn Institute for Nuclear Physics, PNPI, and others.

Studies of physical processes occurring in extreme conditions associated with space objects releasing a tremendous amount of energy in the vicinity of black holes of various masses and magnetars with magnetic fields exceeding the Schwinger field allow fundamental physical laws to be tested.

Important new results were recently obtained by the Spektr-RG, X-ray observatory including an all-sky X-ray survey of more than a million compact and tens of thousands of extended sources. New active galactic nuclei with cosmological redshifts greater than 6 and tidal destruction of stars by black holes have been detected. Large-scale extended structures of hot gas (''eROSITA bubbles'') were discovered, being remnants of the activity of the Galactic Center millions of years ago; new remnants of supernovae were found in the galactic halo, and important features of the formation of massive galaxy clusters were studied.

Gamma quanta detected by the KONUS-WIND orbital detector in the MeV range from the record-breaking gamma-ray burst GRB 221009A allowed estimating the isotropic equivalent of the radiation energy, of the order of 10^{55} erg. Radiation from this source with energies much greater than TeV was observed by the LHAASO and Kover-2 (Carpet 2) ground-based gamma-ray telescopes. In the data obtained by the Enrico Fermi telescope, an interesting spectral feature was discovered, which may be the annihilation line of the spectrum of electron–positron pairs strongly blueshifted by the relativistic flow. Such results are essential for understanding the processes of the formation of gamma-ray bursts, which are sources that have extreme properties.

Detection of neutrinos with energies in the TeV to PeV range from astrophysical sources has opened up new opportunities for studying the acceleration and emission of particles in the active nuclei of galaxies with supermassive black holes and for studying the sources of cosmic rays in the Milky Way and distant galaxies with active star formation.

Reviews presented at the session included new results obtained in this area with Russian X-ray telescopes (R A Sunyaev and A A Lutovinov, IKI) and gamma telescopes (A M Bykov, Ioffe PTI), as well as the first results of the Baikal GVD neutrino observatory (S V Troitsky, INR). The development of high-energy astrophysics in Russia and worldwide was discussed, including the prospects for building new orbital and ground-based telescopes. The materials of review talks 2 [1], 3 [2], 5 [3], 6 [4], 7 [5], and 9 [6], covering modern problems of high-energy astrophysics and the development of technologies for cosmic radiation detection, are published in this issue of *Physics–Uspekhi*.

A very useful exchange of views took place on the current status of modern hardware for large domestic world-class projects in the field of multi-messenger astronomy. In his talk, Eremin went into the details of the options for using the silicon position-sensitive detectors developed at the Ioffe PTI and intended for Compton detectors for space gamma-ray telescopes with the energy range of 0.3–10 MeV. Sketches of the possible design of a new-generation gamma-ray space telescope in the range of several MeV were discussed; the creation of a new world-class domestic project, Spektr-RGM, may become possible. Levin presented a range of modern systems developed at the IKI for fast processing of signals from detectors of the successfully operating Pavlinsky orbital X-ray telescope ART-XC aboard the Spektr-RG observatory. A review of the characteristics of photomultiplier tubes used in the modern neutrino telescopes Ice Cube, Baikal GVD, and KM3NeT, as well as prospects for the development of photon detectors for next-generation neutrino telescopes, such as TRIDENT in the South China Sea, were presented by Lubsandorzhiev (INR). The possibility of replacing photomultipliers with microchannel boards was also discussed.

The urgent need for modern developments of large-format optical radiation detectors based on low-noise CCD detectors was noted in the talks by Vlasyuk and Afanasyeva, astronomers at the Special Astrophysical Observatory of the Russian Academy of Sciences, and during the discussions.

Global experience shows that the implementation of new major projects in the field of optical, neutrino, X-ray, and gamma-ray astronomy also contributes to the development of breakthrough detector technologies that are in demand in various fields of science and the economy. Participants in the scientific session of the Department of Physical Sciences, Russian Academy of Sciences noted that developing and implementing large domestic world-class projects would require coordinating the efforts of Russian institutes and forming a consortium with the participation of microelectronics industrial enterprises and institutions, with the coordinating role of the Russian Academy of Sciences.

A M Bykov, *R A Suris*.
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