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UNIQUE RESEARCH FACILITIES IN RUSSIA

For technical reasons, OCDE/GD(95)81 has been split into 9 parts. This is the Part 6.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Paris 1995

CHAPTER 5. ASTRONOMY AND SOLAR SYSTEM EXPLORATION

BIG ALT-AZIMUTH TELESCOPE

Special Astrophysical Observatory

Data of commissioning: trial operation -- from December 1975;
regular observations -- since January 1977.

Fields of science

Astronomy, space research (physics and evolution of stars and the interstellar medium, the Galaxy and the Metagalaxy, apparatus and techniques of astronomical observations).

Fields of research

Magnetic fields of stars at various stages of evolution; new polars; binary stars at critical stages of evolution; relativistic stellar objects; chemical composition of stellar atmospheres; stars on the asymptotic giants branch; galaxies with active nuclei and quasars; large-scale structures and anisotropic flows in the Universe; blue compact galaxies; improvement of the Big Alt-Azimuth Telescope (BTA); development of CCD-apparatus based on large matrices; high angular resolution imaging by the interferometric technique; development of observational methods for extended objects with high spectral and angular resolution; development of methods of high spectral resolution; and development of multi-channel methods for investigation of astronomical objects with super-high time resolution.

Main characteristics

Monolithic main mirror diameter, m	6
Prime focus	*f*/4
Two Nasmyth foci	*f*/30
Wavelength range, µm	0.3–100
Angular resolution	0.6 sec of arc
when using speckle-interferometer techniques	0.02 sec of arc
Main mirror mass, ton	42
Mass of a movable part of the telescope, ton	650
Height and diameter of the telescope dome, m	53 and 42
Limiting magnitude achieved in the standard photometric B band on CCD (1994), mag	26

Major advantages

BTA was the world's first and largest telescope on an alt-azimuth mounting. Owing to its success such large telescopes are now regularly constructed on azimuth mountings. BTA is the largest optical telescope in Europe. It is the first telescope of general use in Russia.

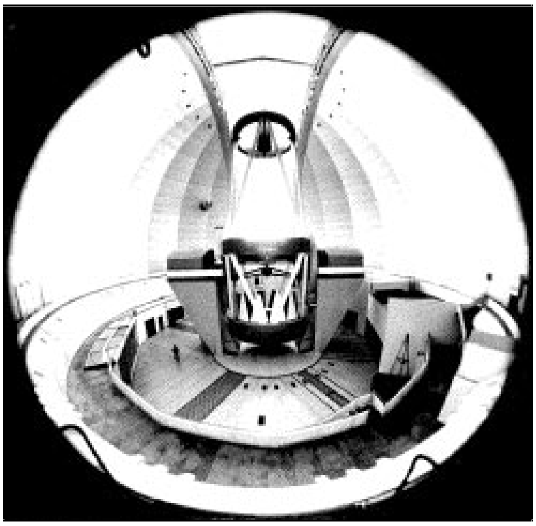
Observation time is allotted by a special Programme Committee. Requests are accepted from Russia, republics of the former USSR, and overseas.

BTA is equipped with modern instrumentation for observations of astronomical objects and with systems of signal recording, which are mainly designed and continuously modernised by staff members of the Observatory.

Current research

Spectral investigation of stellar and extra-galactic objects using:

- A main stellar spectrograph in the Nasmyth focus with three cameras.
- Echelle spectrometers of moderate and high resolution in the Nasmyth focus.
- A planetary spectrograph SP-124 with spectrum detection by a photon-counting system and CCD,. a multi-object spectrograph of the prime focus.
- A multi-pupil spectrograph of the prime focus.
- A long-slit spectrograph of the prime focus.
- A magnetometer of the prime focus for measurement of magnetic fields and emission polarisation.



Fabri-photometric investigation of stellar and extra-galactic objects using:

- A spectro-photometric complex in the Nasmyth focus (incorporates standard electro-photometry and electro-photometry with high time resolution, up to 10^{-7} s, in several colour bands simultaneously).
- Direct CCD images in the prime focus.

Interferometric investigation of stellar and extra-galactic objects using:

- A speckle interferometer in the prime focus.
- A scanning Perot interferometer in the pri-me focus.

Possible research

- Extension of observations to the infrared region will improve the efficiency of the telescope.
- Modernisation of BTA (improvement of the accuracy of telescope guiding and of the astro-climate in the dome, manufacturing of a new pyroceramic mirror, etc.) will bring it up to present-day requirements.
- Introduction of newer modern detectors will make it possible to apply the methods of high spectral resolution to fainter astronomical objects.
- Development of interference techniques for correction of wave fronts and reconstruction of images will increase the resolution of the telescope.
- Manufacturing of optics (an *f*/ratio reducer of the prime focus, cameras and collimators of the spectrographs with anti-reflection coating, etc.) at the up-to-date level will increase the penetrating power of the telescope.

Main scientific results

- Masses have been determined for 1 500 galaxies in double and triple systems. It has been shown that the contribution of dark intergalactic matter is not large and the principal mass is concentrated in the galaxies themselves.
- More than 500 new galaxies with active nuclei and quasars have been detected in the spectral survey of blue Markarian objects. One of the youngest objects in the Universe has been discovered, the blue dwarf galaxy SBS 0335-052 with an oxygen abundance 50 times less than that of our Galaxy.
- Vortex structures in the region of luminous ionised gas associated with nuclear activity are found using two-dimensional spectroscopy for a number of nearby Seyfert galaxies.
- A giant void of one billion light years in size has been found from the measurements of red shift in distant rich clusters of galaxies; its existence contradicts standard cosmological theories.
- On the basis of overall stellar spectroscopy it is shown that enrichment of the Milky Way with heavy elements (Ca, Ti, Fe, Ni, Ba, etc.) occurred most actively at the epoch of formation of spiral arms, and that no substantial enrichment of the galactic disk with heavy elements has taken place for the last five billion years.
- Measurements of magnetic fields in several hundreds of stars have shown that anomalous chemical composition and magnetic fields arise in them prior to the main cycle of thermonuclear reactions in the centre of a star.
- A new class of phenomena has been detected in binary stellar systems with x-ray emission—optical flares of a non-thermal nature with a duration of 1 ms to 1 s, arising at plasma interaction with a black hole or neutron star.
- The physical parameters of gas clumps ejected at a velocity of a quarter of the speed of light have been defined in the unique object SS433. Their density is 10^{13} cm^{-3}, electron temperature 15 000 K, kinetic energy carried away per unit of time of 10^{39} erg/s, which exceeds the Sun's luminosity by a five orders of magnitude.

Basic paper

I.I. Balega *et al.* (1994), Binary stars speckle measurements during 1989–1993 from the SAO 6-m and 1-m telescopes in Zelenchuk. *Astron. Astrophys. Suppl. Ser.,* Vol. 105, pp. 503–506).

V.G. Klochkova *et al.* (1994), Investigation of the II-90 giant in globular cluster M13. *Astron. Astrophys.*, Vol. 287, pp. 881–884.

I.D. Karachentsev *et al.* (1993), Photometric distance to the nearby galaxies visible through the Milky Way. *Astron. Astrophys. Suppl. Ser.*, Vol. 100, pp. 227–235.

S.N. Fabrika *et al.* (1994), Analysis of Balmer lines emission and radiation non-isotropy of SS433 jets. *Bull. SAO*, Vol. 37, pp. 136–142.

J.A. Stepanian *et al.* (1993), The slit spectra of galaxies of the Second Sky Survey. *Bull. SAO*, Vol. 35, pp. 197–237.

Yu.I. Izotov *et al.* (1993), Spectrophotometry of 83 possible blue compact dwarf galaxies from the Second Byurakan Survey. *Astron. Astrophys. Transactions*, Vol. 3, pp. 197–237.

V.L. Afanasiev *et al.* (1993), Vortex structure in the gaseous disk of the Galaxy r^{1040}. *Pis'ma Astron. Zh.*, Vol. 1994, p. 787.

G.M. Beskin *et al.* (1994), Investigation of relativistic and fast variable objects with a high time resolution. *Usp. Fiz. Nauk*, Vol. 164, pp. 660–662.

Yu.V. Glagolevskij (1994), Dependence of chemical anomalies on magnetic field in magnetic CP-stars. *Astron. Zh.*, Vol. 71, pp. 858–862.

Current financial support

Grants of the Russian Foundation for Basic Research:

95-02-03690, 95-02-03691, 95-02-04024, 95-02-04640, 95-02-05781, 93-02-03116, 94-02-03276, 94-02-03281, 94-02-04255, 94-02-06584, 93-02-17013, 93-02-17186, and 93-02-17189.

Grants of the European Southern Observatory (ESO):

Instrumentation of the 6 m telescope A-01-147/148/149/150/151
Photometric distances of galaxies in nearest groups A-02-016
Study of unique object SS433 and search for similar objects in nearby galaxies A-02-021
Surface magnetic field and rotational periods of white dwarfs A-02-022
Investigation of relativistic and fast variable objects A-02-023
The Second Byurakan Survey A-04-050
The search for magnetic white dwarfs and polars from Byurakan Sky Survey. Polarimetric study of the Survey A-05-008

Grants of the International Science Foundation:

Second Byurakan Survey NOJ-000;
A search and investigation of cosmical streams on the scales larger than 100 Mpc 50387-AST

International Association for the Promotion of Co-operation with Scientists from Independent States of the Former Soviet Union (INTAS): 2 grants.

Chrétien Grant, United States.

Collaborative Research Grant of the Northern Atlantic Treaty Organisation.

Joint projects fulfilled at the BTA:

Project “Hamburg–SAO”, Germany, Hamburg University Compilation of new samples of blue compact galaxies;
Project ISS, United States, National Optical Observatory, and Ukraine, Main Astronomical Observatory.

General information

Special Astrophysical Observatory
Nizhnii Arkhyz, v. Zelenchukskaya, Karachai-Circassia 357147 (located at an altitude of 2 100 m above sea level in the Caucasian mountains, 40 km to south-west of Zelenchukskaya village of Karachai-Circassia)
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ikost@sao.stavropol.su (scientific secretary)
Director of the Observatory: Yurii Yu. Balega
Responsible person: Tatiana N. Sokolova

RATAN-600
Special Astrophysical Observatory

Data of commissioning: 1974: first stage;
1977: full operation

Field of science

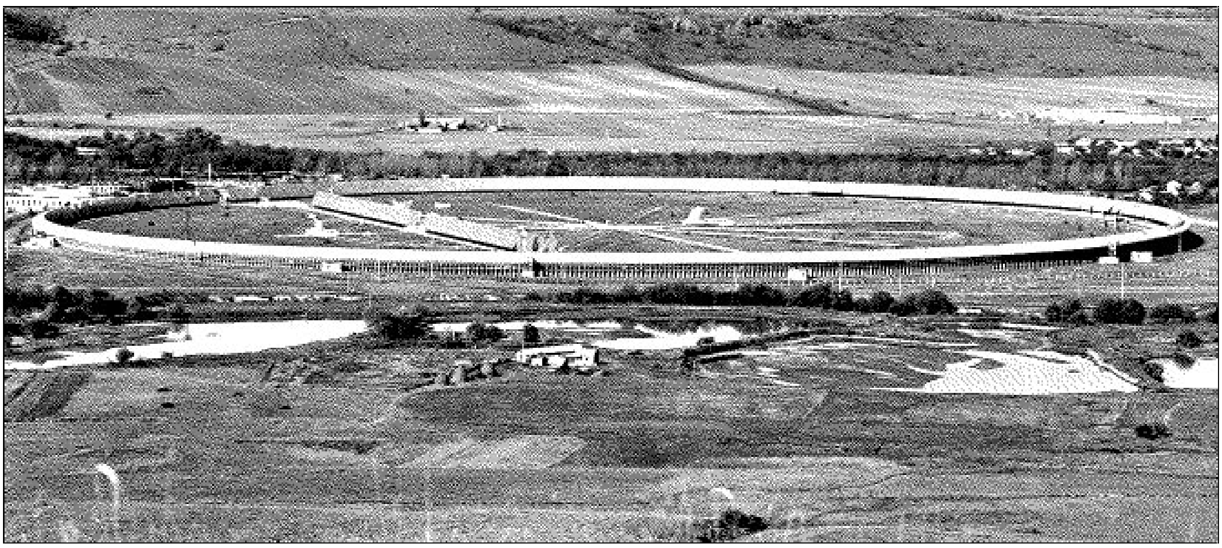
Radio astronomy (Sun and Solar system, physics and evolution of stars and interstellar space, the Galaxy and the Metagalaxy, equipment and methods of astronomical observations).

Fields of research

- Determination of the physical parameters of formations at the Moon's surface.
- Physics of the Sun (magnetic fields of solar spots, the active Sun, radio emissions).
- Investigation of the cloud structure of interstellar space in the Galaxy.
- Search for radio sources at a limited distance.
- Modernisation of the RATAN-600 radio telescope.
- Modernisation of receiving and measuring devices.
- Modernisation of the system of automated control and radio observations.

Main characteristics

Diameter, m	576
Number of antenna elements	895
Size of an element, m	11.4×2
Geometrical area, m^2	up to 20 000
Angular resolution, sec of arc	up to 1.7
Accuracy of co-ordinate determination, sec of arc	better than 1
Limiting sensitivity in flux density measurement (1994), mJy	1
Limiting sensitivity in brightness temperature measurement (1994), mK	50



Major advantages

RATAN-600 is the world's biggest reflector radio telescope. It possesses a unique reflector system using the method of aperture synthesis, as well as automated control of the surface allowing the reconstruction of the wave front.

About 75% of observational information in Russia in the field of radioastronomy is produced by RATAN-600.

Its reflector antennas have a record sensitivity with regard to the flux density and the antenna systems of aperture synthesis have record sensitivity with regard to brightness temperature.

Current research

- Study of the Universe as a whole, analysis of non-stationary energy release in galactic and extra-galactic objects of various types, investigation of evolution and chemical composition of the Galaxy and the nature of solar activity, ecology of the upper atmosphere and nearby space.
- Provision of methodical and technical facilities for observations on the largest telescopes under the programmes of Russian and foreign astronomical institutions.
- Elaboration of the newest means and methods of observations to realise the limiting characteristics of BTA and RATAN-600: sensitivity, spectral, spatial, and time resolutions.
- Development of the system for acquisition, storage and processing of astronomical data, and switch to the international astronomical data base network.

Possible research

In 1995 a new Automated Control System is introduced increasing up to an order the productivity of RATAN-600.

The system of super-fast processing of signals is being tested, and should open a new line in RATAN-600's investigation of pulsars.

A multi-frequency cryogenic complex with unique sensitivity broadens the opportunities of RATAN-600 to monitor nuclear activity of space objects at cosmological distances. A new generation of experiments can be started on primary non-uniformities in the Universe and on the search for a Sakharov's Cosmological Gene at this complex.

A new generation of panoramic spectrum analysers of solar radio emission will allow us to solve the three-dimensional problem of the Sun's atmosphere and magnetic structures and to study the dynamics of solar events in radio range with the use of the high resolution of RATAN-600.

The large (three-fold) broadening of the wavelength range will make it possible to use RATAN-600 as an all-wavelength instrument, including for the search for proto-structures at red-shifts greater than 5. In co-operation with the 6 m optical telescope, virtually the whole range of space radiation penetrating the terrestrial atmosphere will be accessible.

Main scientific results

- New limits have been set on anisotropy of the relic (3K) background, which drastically reduced the number of possible models of the Universe.

- About 20 000 new radio sources have been found, among which there are many radio galaxies with red shifts of greater than 1.
- Radio emission has been detected from the Galileo Jovian satellite.
- Radio emission of the Galaxy at centimeter wavelengths at high latitudes and compression of cold-gas clouds near the Galaxy Centre have been detected.
- Radio sounding of the Moon to a depth of 10 m has shown the presence of rock that may be a source of oxygen.
- Granulation in the Sun's chromosphere has been detected at centimeter wavelengths.
- Considerable change in the radio emission of Jovian radiation belts was detected when the Schoemaker-Levy comet fell onto Jupiter in 1994.

Absolute limits of the RATAN-600 parameters.

Parameter	Initial value (1974)	Improved to (1994)	Absolute limit	Future gain
Collecting area	300 m^2	3500 m^2	20 000 m^2	5.5
Resolution	20 sec of arc	2 sec of arc	(0.2 sec of arc)	(10)
Sensitivity	100 mJy	500 μJy	< 0.1 μJy	5000
Brightness limit	100 mK	50 μK	< 1 μK	> 50
Survey source number	100	20 000	> 100 000 000	> 5000
Dynamic range	1:100	1:10 000	> 1:200 000	> 20
Information flux	1 bit·s^{-1}	1 Kb·s^{-1}	100 Gb·s^{-1}	100 000 000
Min. wavelength	2 cm	3–10 mm	1 mm	3–10
Max. wavelength	6.5 cm	31 cm	1.35 m	4
Number of beams	1–2	1–2	> 10 000	> 5000
Tracking time	2 s	2 min	1 day	> 700
Background radiation	(70 K)	5.5 K	< 1 K	5.5

Basic papers

W. Goss, Y. Parijskij *et al*. (1991), The RATAN-600 7.6 cm catalog of radio sources from "Experiment Cold-80". *Astron. Astrophys. Suppl. Ser.*, Vol. 87, No. 1, pp. 1–32.

W. Goss, Y. Parijskij *et al*. (1992), The RATAN-600 7.6 cm catalog of radio sources within the interval 22–4 at declination of SS433. *Astron. Astrophys. Suppl. Ser.*, Vol. 96, pp. 583–592.

Y. Parijski (1993), RATAN-600 world's biggest reflector at the cross roads. *IEEE Antennas and Propagation J.*, Vol. 35, No. 4, pp. 7–12.

Y. Parijskij *et al*. (1993), CDM Model: COBE and RATAN-600 experiment. Int. School of Astrophysics "D. Chalonge", 2nd course, *Current Topics in Astrofundamental Physics.* Eds. N. Sanchez and A. Zichichi, World Sci., pp. 227–232.

M. Larionov *et al*. (1994), A 3.9-GHz survey for declination –1 to 0. *Astron. Astrophys. Suppl. Ser.*, Vol. 106, pp. 119–127.

I.V. Gosachinskij *et al*. (1994), Jovian emission at 18 cm during the comet C-L 9 impacts observed with RATAN-600 radio telescope. In: *Earth, Moon, and Planets*. Vol. 66, pp. 71–74.

Y. Parijskij *et al*. (1994), X-ray emission from the distant radio Galaxies from RC-Catalog and the Geometry of the Universe. *Astron. Zh.*, Vol. 71, No. 5, pp. 821-824.

R.C. Vermeulen *et al*. (1993), Daily spectra of radio flares from SS433 in May/June. *Astron. Astrophys*., Vol. 279, pp. 189–199.

C.T. Alissandrakis *et al*. (1993), Spectral observation of active regions sources with RATAN-600 and WSRT. *Astron. Astrophys*., Vol. 270, pp. 509–515.

Current financial support and co-operative projects

Russian Foundation for Basic Research Grants:

94-02-06510, 93-02-17208, 93-02-17220, 95-02-03779, 95-02-03783, 95-02-03990, 95-02-04972, 93-02-17086, and 93-02-17238.

International Scientific Foundation Grants:

Study of the release of energy in plasma structures of the solar active regions NVH000.
Spectroscopic investigation of extra-galactic proto-objects NS7000.
Study of the magnetosphere of solar active regions NS8000
Early Universe R96000

INTAS Grants (Co-operative investigation): 94-4625 and 94-4010.
Northern Atlantic Treaty Organisation Grant: 921394000.
US-FSU NSF programme: ATM9024506

Joint projects fulfilled at RATAN-600:

STEP (Solar–Terrestrial Energy Programme), United States
SMY (Solar Maximum Year), United States
MAX 91, United States
FLARES 22 Cycle, United States
United States, Tufts Univ. ATM 9024506
Holland, Joint Inst. of VLBI in Europe, Dwingellow.

General information

Special Astrophysical Observatory

RATAN-600 is located at an altitude of 973 m above sea level on the southern outskirts of Zelenchukskaya Village of Karachai–Circassia.

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E-mail: par@sao.stavropol.su, marat@sao.stavropol.su
Director of Observatory: Yurij Yu. Balega
Responsible person: Tatiana N. Sokolova

SPECIALISED COMPLEX OF SEVEN RADIO TELESCOPES "NIRFI, STARAYA PUSTYN RADIO ASTRONOMICAL OBSERVATORY”

Nizhny Novgorod Radiophysical Research Institute

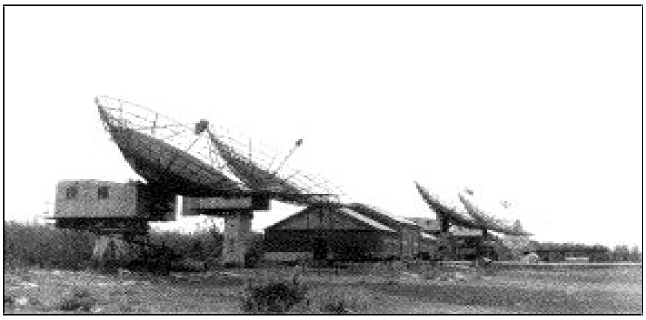
Date of commissioning: 1965.

Fields of science

Astronomy, radio physics (the Galaxy and Metagalaxy, the Sun and solar-terrestrial relations, astrometry, pulsar time-keeping, antenna technology).

Main characteristics

- An array of three 14 m parabolic steerable radio telescopes in the 10–200 cm wave band and feeds for two orthogonal (linear and circular) polarisation devices equipped at frequencies of 150, 290, and 610 MHz.
- Phase-stable interferometer of two 7 m parabolic steerable radio telescopes at 540 MHz.
- Two 10 m polarisation radio telescopes in the meter and decimeter bands.
- In-phase antenna array (under construction) of 38–90 MHz for polarisation studies of the interplanetary and local interstellar media.
- VLBI terminal in a MARK-2 standard with low-noise amplifier at 610 GHz;
- A movable radio holographic set-up at 4 and 11 MHz.
- An installation for antenna parameters measuring picosecond pulses.
- Two calibration towers 25 m high with remote control of uniformly heated 2 m "black" disks used as reference standards of noise signal.
- A time-keeping rubidium standard.



Major advantages

Possibility for carrying out polarisation investigations of Galaxy radio emissions, absolute precision measurements of radio emission flux densities from cosmic sources, large-aperture synthesis, a wide frequency band of investigations, low level of industrial noise, developed observatory infrastructure.

Current research

- Investigation of magnetic-field structure in the Galaxy and various radio sources, ionised interstellar gas, cosmic-ray propagation in the interstellar medium and intergalactic space. Study of the physics of the interplanetary medium, the magnetosphere and ionosphere, solar-terrestrial relations.

- Patrol observations of the variable radiation of young supernova remnants. Absolute intensity measurements of background radiation and cosmic radio source fluxes using artificial reference standards of noise radio emission.
- VLBI observations of quasars and pulsars in the decimeter wave band. Investigation of structure of radio sources by the aperture synthesis method.
- Millisecond-pulsar timing, setting up a pulsar time scale. Determination of the Earth's rotation parameters.
- Amplitude-phase (radio holography) measurements of antenna parameters. Improvement of efficiency of the largest Russian radio telescopes. Design of reference standards with a changeable temperature of emission in centimeter and decimeter radio wave bands.
- Solving problems of space navigation.

Possible research

- Measurement of the total electron content of the ionosphere (by a radio astronomical Faraday-polarisation method) for current correction, by the Faraday rotation of polarisation plane, of polarisation data and, by time delay, of interferometric data.
- Radio interferometric observation of short solar spikes with millisecond time resolution at a frequency of 540 MHz.
- Study of low-frequency interstellar scattering in pulsar observations.

Main scientific results

- A number of surveys of linearly polarised radio emission of the Galaxy has been carried out in the frequency range of 88–1680 MHz.
- By the method of multi-frequency radio astronomical polarisation observations of the galactic background radio emission in meter and decimeter wave bands, new data have been obtained on a three-dimensional structure of galactic magnetic field in the regions of the North Galactic Spur, the Loop III, and Polaris, testifying to a regular large-scale loop component of the interstellar magnetic field.
- Variability of linearly polarised radio emission from the Galaxy has been discovered at meter waves, as well as its relation to variations in galactic cosmic rays.
- A secular decrease has been discovered in the Crab Nebula radio emission flux. The flux density decrease at 927 MHz is non-monotonic with an average annual rate of 0.3% for last 30 years. Frequency and time dependencies of the flux density decrease rate for the young supernova remnant of Cassiopeia A have been investigated at decimeter and meter waves.

Basic papers

E.N. Vinyajkin, I.P. Kuznetsova, A.M. Paseka *et al*. (1994), On the spectrum of a polarised component of galactic radio emission in the direction of the north celestial pole at decimeter and meter waves. *NIRFI Preprint.* No. 404, Nizhny Novgorod, pp. 1–39.

E.N. Vinyajkin (1995), The investigation of a linearly polarised component of the galactic radio emission in the direction of the North Polar Spur at a wavelength of 31 cm. *Astron. Zh.*, Vol. 72.

A.M. Paseka (1993), Radio polarisation investigations of the Loop III in the long-wave part of decimeter wave band, *Astron.. Zh..*, Vol. 70, No. 2. pp. 257–264.

O.M. Kovalchuk, V.A. Razin, and A.I. Teplykh (1995), On polarisation parameters variability of observed galactic radio emission. *Odessa Astron. Publ.*, Vol. 7.

E.N. Vinyajkin (1993), Evolution of the Crab Nebula radio emission. European Astron. Society 2nd Meeting. Torun, Poland, p. 77.

N.A. Dugin (1993), Application of two-temperature black standard for absolute measurement of microwave radio emission intensity. *Abstracts 2nd Int. Symp. Electromagnetic Metrology* (ISEM' 93), Beijing, China.

Yu.I. Belov, V. Altunin, K. van't Kloster *et al*. (1992), Comparison of RF methods for testing of space radio telescope antenna on the ground. *OVLBI Earth Station Memo.* No. 29, May 1992, NRAD, United States.

Yu.I. Belov, Yu.P. Ilyasov, B.A. Poperechenko *et al*. (1994), Precise millisecond timing at 64-m disk radio telescope in Russia. *Proc. Int. Workshop on Pulsar Timing Observation*, Japan.

V.A. Alexeev, B.N. Levin, B.N. Lipatov *et al*. (1994), Use of NIRFI VLBI system for solar flare observations. CESRA –Workshop on Coronal Magnetic Energy Releases. Potsdam, Germany.

S. Skulkin (1994), An analysis of aperture antenna near field. *Proc. JINA'94 Symp*. Nice, France, p.340–343.

Current financial support

Grants of the American Astronomical Society:

The investigation of a small-scale structure of the magnetic field and ionised gas in the North Polar Spur (1992).

Plasma influence on the synchrotron radiation of relativistic electrons with small pitch angles in cosmic radio sources (1994).

164-channel pulsar receiver at a frequency of 610 MHz (1994).

Grant of the European Space Agency (ESA):

Radio holographic investigations of the largest Russian radio telescopes.

Grant of the Russian Foundation for Basic Research:

Investigation of the intensity and spectrum angle variations of the Galaxy and Metagalaxy background radio emission in the range from decameter to millimeter radio waves (from 1994).

Grants of the State Science and Technology Programme "Astronomy":

Development of new methods of recording the cosmic sources of radio emission (from 1992).

Radio polarisation investigations of magnetic fields, distributed ionised gas and relativistic electrons in the Galaxy and Metagalaxy (from 1993).

Investigation of variability of radio emission of galactic and extragalactic sources (from 1993).

The Observatory is carrying out investigations in the framework of the State Science and Technology Project "Astrocomplex" and the State Science and Technology Programme "Fundamental Metrology".

Scientific and technical personnel

18 researchers and 16 technicians.

Possibilities for international exchange

Opportunities for receiving of foreign scientists to work at the Observatory: 2 man-year.

Vacancies for accommodation of foreign specialists: 2 man-year.

General information

NIRFI, Staraya Pustyn Radio Astronomical Observatory
(located about 100 km south of Nizhy Novgorod)
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Director of the Institute: Sergei V. Polyakov
Responsible person: Vladimir A. Razin

RT-22 FIAN RADIO TELESCOPE

Lebedev Physical Institute
Pushchino Radio Astronomy Station

Stages of construction

1959: Construction of the RT-22 and first observations.
1964–68: Reconstruction of the RT-22 control and feed systems.
1975–80: Construction of data-acquisition systems.
1990–95: New generation of low-noise amplifiers using a micro-cryogenic closed loop; to a new control and data acquisition PC/AT system; the participation in European and Global VLBI networks.

Field of science

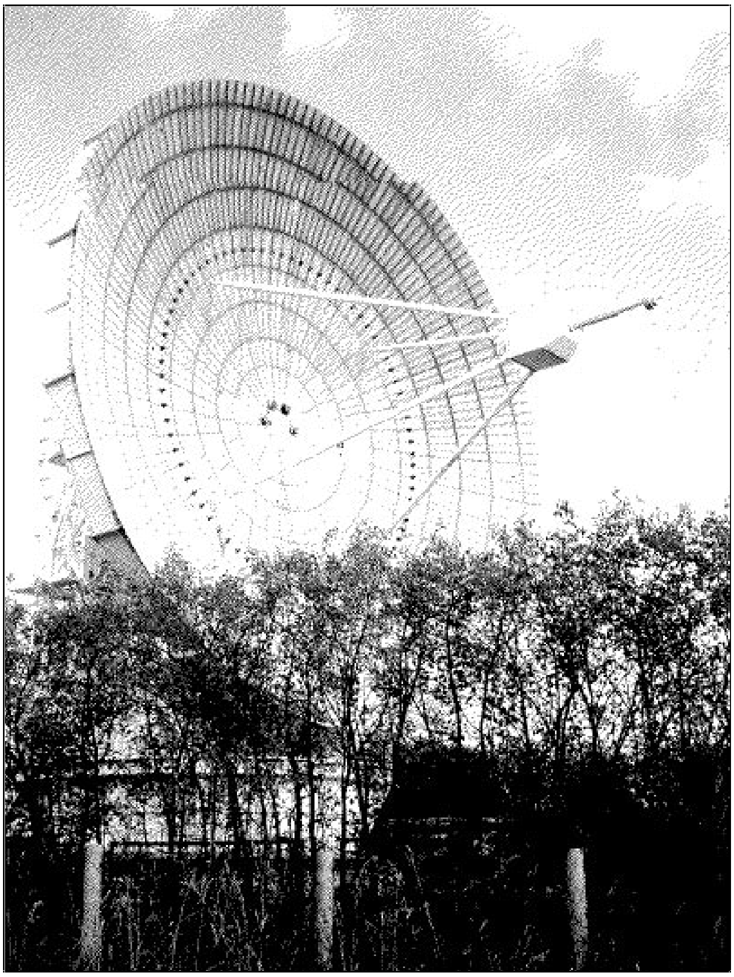
Astronomy (astrophysics, radio astronomy, study of galactic and extra-galactic radio emission).

Fields of research

Star formation; physical conditions in the diffuse interstellar medium; molecular cloud physics; space masers; giant atoms in space; active galactic nuclei.

Main characteristics

RT-22 is a fully steerable radio telescope with a main dish of 22 m in diameter. Accuracy of the dish surface provides effective operation up to millimeter wavelengths.



Major advantages

RT-22 is the only fully steerable antenna in Russia for radio astronomical observations. There are multi-channel spectrum analysers at the radio telescope, a micro-cryogenic loop is being used to cool low-noise amplifiers, and a beam-switching system reduces atmospheric fluctuations at 8 and 13 mm even on cloudy days. IBM-PC computers control the steering of the radio telescope and the data-acquisition system. During 1995, the sensitivity of RT-22 will be considerably improved. The radiotelescope RT-22 will be used as an element of the international VLBI network of interferometers to realise about 0.1 ms of arc angular resolution.

Current research

- Star-forming regions are studied by observing the spectral radio lines of highly excited atoms and the water-vapour line at 1.3 cm,
- New methanol masers are searched for in space and known sources of this type are investigated.
- The spectrum and intensity changes of about 50 space water-vapour masers are monitored regularly.
- Helium abundances are analysed in several galactic gas nebulae.
- Physical conditions in the interplanetary plasma near the Sun are studied by observations of compacted maser radio sources at small elongations.
- Objects for future space VLBI experiments are chosen in the framework of international co-operative programmes.

Possible research

In 1995-96 the RT-22 FIAN radio telescope has to be prepared as an element of the European and Global VLBI networks at 1.3, 6 and 18 cm wavelengths to join the broad international co-operation to study super-power engines in active galactic nuclei and star-forming regions with the angular resolution of 100 μs.

Main scientific results

First observations with this radio telescope were made at 8 mm in 1959. The angular resolution was the best for that time and many local radio sources on the Sun were identified with protuberances and flocculates. Many pioneer observations were carried out during the following years: the first catalogue of discrete radio sources at centimeter wavelengths was prepared, Crab Nebulae polarisation was detected, physical properties of lunar surface layers were studied and the conditions in atmospheres and on the surfaces of Venus and other planets were determined. Some of these results were very useful for elaboration of the Soviet near-space projects.

In 1964 the first radio recombination line corresponding to the transition from 91st to 90th level in the atom of hydrogen was detected. This result was registered by the Soviet Invention and Discovery Committee (Diploma No.47) and it made a good start for new studies of the interstellar medium and the physics of highly excited atoms. The study of hydrogen, helium and carbon radio recombination lines during the following two decades was awarded the USSR State Prize.

Regular observations of more than 50 sources of maser radio emission in the water-vapour line, which were carried out for 15 years, showed quasi-sinusoidal intensity variations for some of the sources (S140, ON1, etc.). These variations are interpreted as evidence of Keplerian (proto-planetary?) disks around a number of young stars. Over 20 new sources of radio emission of the methanol line were detected at 8.3 mm. For a few galactic nebulae a relative abundance of helium was determined, which can be used as a criterium to test the theories of the evolution of the Universe during the first minutes after the Big Bang.

Basic papers

R.L. Sorochenko (1990), Postulation, detection and observations of radio recombination lines (review). *Radio Recombination Lines: 25 Years of Investigation* Eds. M.A. Gordon and R.L. Sorochenko. Kluwer Acad. Publ., pp. 1–17.

A.P. Tsivilev (1990), The helium abundance in the HII region DR21, *Radio Recombination Lines: 25 Years of Investigation*, pp. 131–139.

R.L. Sorochenko (1994), Radiorecombination lines. *Astrophysics at the Boundary of 21st Century*. (Ed. N.S. Kardashev). Gordon & Breach.

I.I Berulis, S.V. Kalenskii, A.M. Sobolev, and V.S. Strel'nitski (1992), Observations of the methanol line in molecular clouds. *Astron. Astrophys. Trans.*, Vol. 1, pp. 231–245.

R.L. Sorochenko and C.M. Walmsley (1991), Radiorecombination lines of carbon C165(α) and C166(α) towards Cas A. *Astron. Astrophys. Trans,* Vol. 1, pp. 31–40.

E.E. Lekht, E. Mendosa-Torres, and R.L. Sorochenko (1994), Study of water maser in a radio source ON1. *Astronom. Zh.*, Vol. 71, p. 1.

V.O. Ponomarev, H.A. Smith, and V.S. Strelnitski (1994), Modeling of the hydrogen maser disk in MWC 349. *Astrophys. J.*, Vol. 424, p. 976

V.S. Strelnitski, V.O. Ponomarev, and H.A. Smith (1995), Hydrogen Masers. I. Theory and prospects. *Astrophys. J*. (in press).

V.S. Strelnitski, V.O. Ponomarev, and H.A. Smith. (1995), Hydrogen Masers. II. MWC 349. *Astrophys. J*. (in press).

Current financial support and co-operative projects

ISF Grants: MNW000, MNW300, NLG000, NLG300, RN5000, and RN5300.
ESO C&EE Programme Grants: A-01-042 and A-05-095.
Russian Foundation for Basic Research Grants: 93-02-02971, 94-02-04214, and 95-02-05078.
Grant of the State Scientific and Technical Programme "Astronomy" No. 4-151.
Grant of the NUZ "Kosmion"-- Project "Vselennaja".

Scientific and technical personnel

9 researchers and 16 technicians.

Possibilities for international exchange

Observations with individual participation of foreign scientists (Max Plank Radio astronomy Institute, Germany and University of Mexico, Mexico) are carried out 1–2 times per year.
Additional possibilities for receiving foreign scientists to work: 1–2 man-year.
Vacancies for accommodation of foreign scientists: 1 man-year.

General information

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Responsible person: Anatoly V. Kovalenko

DKR-1000 RADIO TELESCOPE

Lebedev Physical Institute

Pushchino Radio Astronomy Station

Stages of construction

1964: End of construction and first observations with the E–W arm.
1970: End of construction of the N–S arm.
1977–80: Construction of antenna pre-amplifiers and a beam-switching system for the E–W arm.
1985–88: Construction of the modern control and data-acquisition systems.
1994–96: 5-fold increased tracking duration and doubled sensitivity of the E–W arm.

Field of science

Astronomy (astrophysics, radio astronomy, study of galactic and meta-galactic radio emission).

Fields of research

- Physics of neutron stars and pulsars.
- Study of supernovae remnants and the interstellar medium.
- Investigation of low-frequency radio emission of radio galaxies and quasars.
- Study of interplanetary plasma and the solar wind.

Main characteristics

The wide-band cross-type radio telescope DKR-1000 FIAN is a meridional instrument consisting of two arms: E–W and N–S. Each arm is a parabolic cylinder with a width of 40 m and a length of 1 km. Wide-band feeds allowing observation over a range from 2.5 to 10 m are situated along the focal lines of both arms.

Major advantages

DKR-1000 is one of the biggest and most sensitive meter-wavelength radio telescope in the world. Its huge collecting area (80 m^2) and the possibility of observing any radio sources at several frequencies between 30 and 120 MHz simultaneously make it indispensable for the study of interplanetary and interstellar media, as well as of as pulsars, i.e. fast-rotating neutron stars. The radio telescope reconstruction programme for the next two years is to improve the telescope's sensitivity by several times and to increase the tracking time of observed objects.

Current research

- Investigation of spectra and linear polarisation of pulsars.
- Study of physical conditions inside the interstellar cold plasma clouds through observation of spectral radio recombination lines of highly excited hydrogen and carbon atoms.
- Regular measurements of flux-density of about 100 extra-galactic radio sources to search for low-frequency variables.
- Study of processes of solar-wind acceleration through observation of radio emission scattered by the near Sun plasma.

Possible research

The radio telescope DKR-1000 is ready for observations in the aperture synthesis mode to obtain two-dimensional images of the most extended supernovae remnants and some near extra-galactic radio sources. A special complex has been constructed for observations of short-period (millisecond) pulsars.

Main scientific results

In 1965-70, just after construction of the E–W arm, the radio telescope was used for study of the near-Sun and interplanetary plasma, which led to the discovery of the radial magnetic field in the solar super-corona, registered by the USSR Invention and Discovery Committee (Diploma No.86). This study was the main part of a cycle of works, which was awarded the USSR State Prize in 1969. During the following years the "spectral index–flux density" dependence for extra-galactic radio sources was found and the similarity of the quasar and radio galaxy extended components was established. Observation of pulsars started immediately after the discovery of the first four pulsars (1968), and the first "Pushchino" pulsar, PP 0943, was found in May 1968. Study of the pulsar spectra at meter wavelengths revealed a typical maximum of radio emission at frequencies around 100 MHz and the cut-off at lower frequencies. Simultaneous multi-frequency observations have shown the pulsar's magnetic field twisting near the light cylinder owing to the fast rotation of the star and the corresponding radiation loss.

One of the most complete catalogues of supernovae remnants was compiled; absorptive properties of the interstellar medium were also studied, particularly in the vicinity of the Galaxy Centre.

Basic papers

R.L. Sorochenko and G.T. Smirnov (1990), Low frequency radio recombination lines towards Cas A. Radio Recombination Lines: 25 Years of Investigation. Eds. M.A. Gordon and R.L. Sorochenko. Kluwer Acad. Publ., pp. 189–202.

G.T. Smirnov, R.L. Sorochenko, and C.M. Walmsley (1994), Radio recombination lines toward the S140/L1204. *Bull. Amer. Astron. Soc.*, Vol. 26, No. 4, p. 1453

V.A. Izvekova, A.D. Kuzmin, A.G. Lyne, Yu.P. Shitov, and F.G. Smith (1993), Frequency dependence of characteristics of pulsars PSR 0031-07, 0320+39, 1133+16 & 2016+28. *Mon. Not. RAS*, Vol. 261, pp. 865–872.

T.H. Hankins, V.A. Izvekova, V.M. Malofeev, J.M. Rankin, Yu.P. Shitov, and D. Stinebring (1991), Microstructure-determined pulsar dispersion measures and the problem of profile alignment. *Astrophys. J.*, Vol. 373, pp. L17–L21.

V.A. Izvekova, A.D. Kuzmin, V.M. Malofeev, and Yu.P. Shitov (1989), Frequency variations in the form and time alignment of averaged pulse profile of pulsar radio emission. *Trudy FIAN.* Vol. 199, p. 13.

Yu.V. Volodin, A.G. Gubanov, and R.D. Dagkesamanskii (1990), A study of structure of extragalactic radio sources at 3.5 m wavelength. In: *Clusters of Galaxies and Extragalactic Radio Sources*. Ed. A.D. Kuzmin. Nova Science Publishers, pp. 229–280.

R.D. Dagkesamanskii, A.V. Kovalenko, and V.A. Udal'tsov (1994), The non-thermal radiosources and the interstellar gas in the vicinity of the Galaxy Centre. *Astronom. Zh.*, Vol. 71, pp. 30–36.

Current financial support

Grant No.850 of the American Astronomical Society.
ESO C&EE Programme Grant A-01-042.
ISF Grants: MNW000, MNW300, RN6000, and RN6300.
Grants of the State Scientific and Technical Programme “Astronomy”, Nos. 4-151, 3-179, and 3-180.
Russian Foundation for Basic Research Grants: 93-02-02971, 94-02-06490, and 95-02-05630.

Scientific and technical personnel

13 researchers and 16 technicians.

Possibilities for international exchange

Observations with individual participation of foreign scientists (Max Plank Radio astronomy Institute, Germany and University of Mexico, Mexico) are carried out episodically once or twice a year year.

Additional possibilities for receiving of foreign scientists to work: 1 to 2 man-year.

Vacancies for accommodation of foreign scientists: one man-year.

General information

Lebedev Physical Institute, Russian Academy of Sciences

Pushchino Radio Astronomy Station (located 110 km south of Moscow)
Pushchino, Moscow Region 142292
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Responsible person: Anatoly V. Kovalenko

SIBERIAN SOLAR RADIO TELESCOPE
Institute of Solar-Terrestrial Physics

Date of commissioning: 1984.

Fields of science

Astrophysics and physics of solar-terrestrial relationships (space research; solar physics, active regions, flares, flare prediction techniques, instrumentation and methods of radio astronomical observations of solar activity, all-weather monitoring of solar activity; plasma physics; automation of scientific research and distributed multi-system facilities; scientific instrument making).

Fields of research

Corona heating, energy storage and release, transient processes in the solar atmosphere, space-time features of the origination and development of active regions, build-up signatures, flare mechanisms and prediction, coronal mass ejections (transients), and coronal holes.

Main characteristics

SSRT, a 256-antenna radio interferometer, consists of two mutually orthogonal equidistant antenna arrays 623 m long. The parabolic antennas are 2.5 m in diameter each. The neighbouring maxima of the interference beam are spaced by 35′. The operating wavelength is 5.23 cm and fits the emission range with an effective manifestation of active regions and flares. The angular resolution at culmination is as high as 16″. The sensitivity is 0.05–0.1 SFU in the usual patrol mode and can be increased to 14 J in special modes. The dynamic range is 80 dB with the use of attenuators. Solar mapping employs multi-frequency reception and two-dimensional synthesis of one-dimensional scans. The one-dimensional mode (principal observing mode) records one-dimensional radio brightness and circular polarisation distributions in undisturbed and active regions of the solar atmosphere with specified time resolutions from 5 min to 14 ms.

Major advantages

SSRT is intended for research in the field of solar physics. It features an unmatched combination of high angular and temporal resolution when observing in daytime. Its characteristics make it possible to record simultaneously all spatial scales (from the radio diameter to structural details of active regions), all time scales (from daily changes of active regions to fast processes of flares) and all energy scales (from undisturbed regions to the flare flash). SSRT is used to carry out all-weather monitoring of the state and development of solar activity.

Current research

Under investigation are: space-time properties of the origination and development of active regions in the solar atmosphere, flare build-up signatures and prediction, energy storage and release mechanisms, fast processes at the time of flares or primary energy release events, and coronal mass ejections.

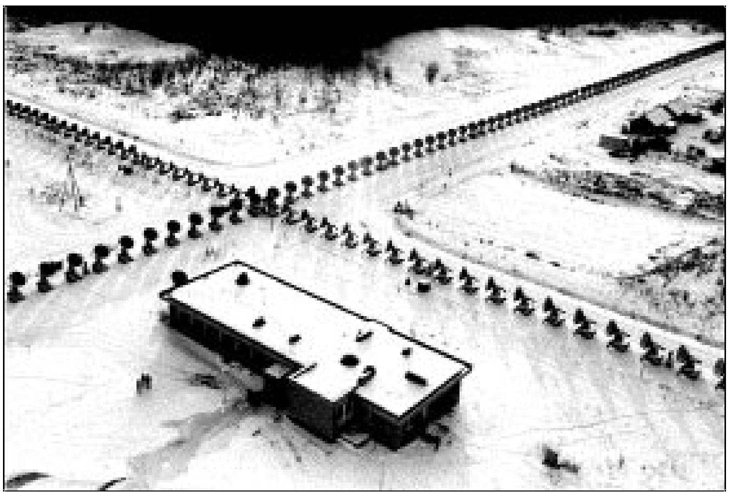
Possible research

Quasi-periodic oscillatory phenomena, coronal holes, filaments, relationship of active regions and flares manifested in the microwave and other ranges, and solar-terrestrial relationships can also be studied.

Main scientific results

A non-monotonic step-wise corona heating originating in active regions, where the magnetic flux emerges into the solar atmosphere; development of active regions, as a result of the interaction of magnetic fluxes. Abrupt changes in microwave emission are a fundamental property of the active region atmosphere.

Flare build-up signatures have been identified: an increase in the number of microflares versus the number of radio microbursts in the active region, the appearance of a compact microwave emission source with elevated brightness and quasi-zero circular polarisation over the polarity inversion line of the active region's magnetic field, and the difference in the distribution of circular polarisation of the active region's microwave emission compared to normal regions.



A technique has been developed for operative prediction of large flares related to the active region's characteristics and location.

Observational conditions for fast processes during flares have been achieved, permitting us to study primary energy-release events. By analysing several tens of hitherto recorded events, we determined the size of the emitting region of about several tens of second of arc, which increases from the solar disk centre to the limb due to the emission scattering.

Basic papers

G.Ya. Smolkov, A.A. Pistolkors, B.B. Krissinel, N.N. Potapov, V.A. Putilov, and T.A. Treskov (1986), The Siberian solar radio telescope: parameters and principle of operation, objectives and results of first observations of spatio-temporal properties of development of active regions and flares. *Astrophys. and Space Sci*., Vol. 119, No. 1, pp. 1–4.

L.B. Korobova, V.P. Nefedyev, G.Ya. Smolkov, and S. Urpo (1988), The connection of motion at the level of the photosphere with corona and chromosphere heating. *Proc. 3rd Finnish–Soviet Sympos. on Radio Astronomy* (Turku, May 24–26, 1988), Ed. Esco Vaitajoa, University Turku, Finland, p. 38.

V.P. Maksimov, V.P. Nefedyev, G.Ya. Smolkov, and I.A. Bakunina (1990), Flare activity prediction from polarisation distribution of microwave emission of sunspot groups, *Solar-Terrestrial Predictions* (Eds. R.Thomson *et al*.), Boulder, NOAA, Vol. 1, p. 526

C.E. Alissandrakis, B.I. Lubyshev, G.Ya. Smolkov, V.G. Krissinel, T.A. Treskov, and N.N. Kardapolova (1992), Two-dimensional solar mapping at 5.2 cm with the Siberian solar radio telescope. *Solar Phys*., Vol. 142, pp. 341–358.

R.A. Sych., A.M. Uralov, and A.N. Korzhavin (1993), Radio observations of compact solar sources located between sunspots . *Solar Phys*., Vol. 144, p. 59.

A.T. Altyntsev, V.V. Grechnev, L.E. Kachev, S.V. Lesovoi, M.I. Mansyrev, S.A. Molodyakov, A.V. Platonov, I.I. Saenko, G.Ya. Smolkov, R.A. Sych, T.A. Treskov, V.G. Zandanov, and N.A. Esepkina (1994), The observations of solar microwave bursts at the Siberian solar radio telescope with 50-millisecond resolution. *Astron. Astrophys*., Vol. 287, pp. 256–260.

G.Ya. Smolkov, N.N. Kardapolova, V.P. Nefedyev, and A.M. Uralov (1994), Step-wise emergence and development of active region microwave emission—a fundamental property of active solar corona. *Proc. of IAU Coll. No. 144 "Solar Coronal Structures*", Kluwer Publ. Co., p. 509.

Current financial support and co-operative projects

Russian Foundation for Basic Research Grant	1
Grants of State Scientific Programme "Astronomy"	3
Siberian Division of the Russian Academy of Sciences Grant	1
Grants of International Science Foundation	2
Programmes supported by the European Southern Observatory	2
International Association for Promotion of Co-operation with Scientists (INTAS) Grant	2

a) University of Athens (Greece), and Arcetri Observatory (Italy),

b) Observatoire de Meudon (France), and European Space Agency (The Netherlands).

The Radio astrophysical Observatory of ISTP has agreements on scientific co-operation with leading Chinese astronomical observatories (Beijing, Nanjing, Yunnan), the University of Athens (Greece), the Institute of Applied Physics of the University of Bern (Switzerland), the Astro-physical University in Potsdam (Germany), and the Astronomical Observatory of Trieste It also maintains contacts with observatories of Japan, Finland, Germany, the Netherlands, the United States, and Hungary.

Scientific and technical personnel

28 researchers, 44 engineers and technicians, and 28 auxiliary personnel.

Possibilities for international exchange

The number of foreign scientists to work at SSRT: 1 or 2 man-year.

Possibilities for additional reception of foreign scientists to work at SSRT: 10 man-year.

Estimated accommodation available for foreign specialists: 10 man-year.

General information

Siberian solar radio telescope is located 240 km south-east of Irkutsk.

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Director of the Institute: Geliy A. Zherebtsov
Responsible person: Vladimir A. Kovalenko

LARGE SOLAR VACUUM TELESCOPE
Institute of Solar-Terrestrial Physics

Date of commissioning: 1985.

Fields of science

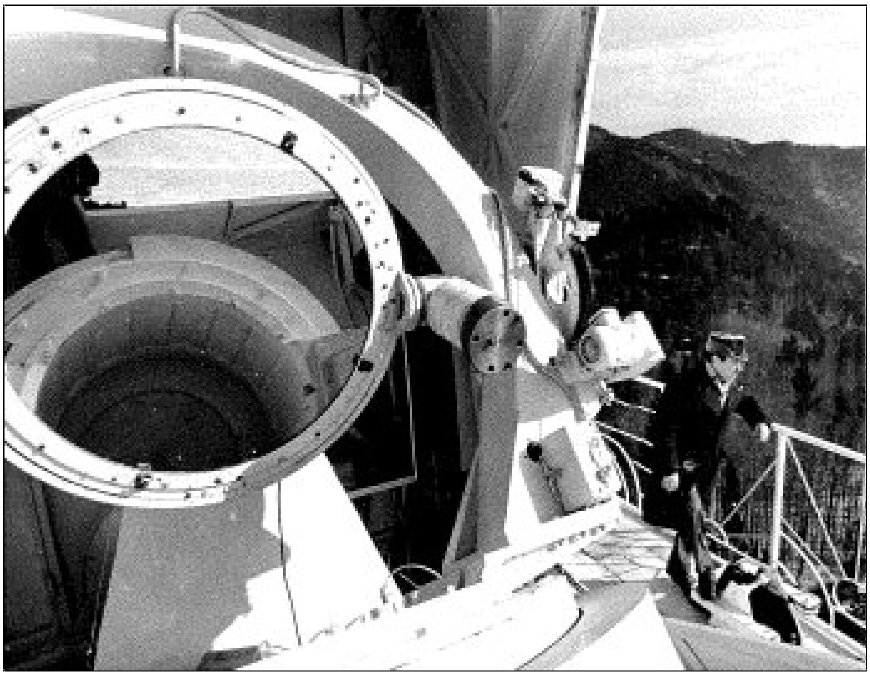
Physics, astronomy (the Sun and the solar system).

Fields of research

Investigation of the processes of energy accumulation and fast release in flares and other non-stationary phenomena on the Sun in order to develop their physical models and modernise, helio-geophysical prediction techniques.

Main characteristics

The large solar vacuum telescope (LSVT) is a mirror-lens telescope. Its solar tracking system, a single-mirror polar siderostat 1 m in diameter, is installed on a 25 m high column and makes the solar light pass along the polar axis (latitude 52°) toward a two-lens objective 760 mm diameter and 40 m focal lens. The telescope's metal tube is evacuated and sealed with two optical windows. The entrance window is placed within the inclined column at a height of 25 m between the primary mirror and the objective. The exit window 1 m diameter is located near the solar image 380 mm diameter. The telescope resolving power is about 0.3″. The telescope tube includes two side illuminators for directing a portion of the solar image to a birefringent filter and a spectrograph. The spectrograph collimator has a focal length of 9 m, while two camera mirrors are 600 mm diameter and have a focal length of 15 m. The diffraction grating is 200×300 mm by size with the number of rules 600 mm^{-1}. The resolving power is about 600 000, and the dispersion is 0.02 nm/mm.



Major advantages

The telescope is one of the world's largest ground-based solar vacuum telescopes and the only one in the FSU. The combination of optical/technical characteristics -- high quality and resolving power of the large-size optics and the vacuum optical path which eliminates atmospheric interferences within the telescope, real-time control system for the optical system, original pneumatic support that safeguards the primary mirror against deformations caused by its weight at any orientation, appropriate design, and aberration-free quality -- meet modern demands and render the telescope a unique optical instrument.

Current research

- Diagnosing chromospheric heating in solar flares from spectral line linear polarisation observations.
- Investigation of fine structure of the solar atmosphere and photosphere.

Possible research

Observations of velocity field and fine structure of various solar features using birefringent filters and a CCD-matrix-based recording system.

Main scientific results

According to current concepts, solar flares can be triggered by a beam of accelerated particles, protons and electrons through energy transfer from the corona to the chromosphere. This effect manifests itself in a collision linear polarisation of spectral lines in solar flares. Observations at the LSVT have been carried on for this programme since 1992. The polarisation parameters obtained made it possible to determine the energy (~200 keV) of the proton beam that excites the flare.

Basic papers

S.A. Kazantsev, N.M. Firstova, N.A. Lankevich, and A.V. Gubin (1991), On a possible spectro-polarimetric investigation of eruptive features on the Sun. *Optika Spektrosk.*, Vol. 70, No. 5, pp. 990–995.

S.A. Kazantsev, N.M. Firstova, A.G. Petrashen, and J.-C. Henoux (1993), Spectro-polarimetric determination of energy contribution to an optically active region of the chromosphere. *Optika Spektrosk*, Vol. 75, No. 3, pp. 664–657.

S.A. Kazantsev, N.M. Firstova., A.G. Petrashen., and J.-C. Henoux (1995), Energy determination of a proton beam produced during a solar flare using spectro-polarimetric data. *Optika Spektrosk*, Vol. 78, No. 5, pp. 1–9.

V.I. Skomorovsky and N.M. Firstova. (1995), *Solar Phys.* [in press].

S.A. Kazantsev, N.M. Firstova, A.G. Petrashen, and J.-C. Henoux (1993), *EGAS-25, Europhys. Conf. Abst.*, Vol. 17D, pp. P2–098.

E.A. Vitrichenko, V.E. Zuev, V.P. Lukin, and L.A. Pushnoi (1988), Analysis of errors of large telescopes. *Dokl. Akad. Nauk SSSR*, Vol. 300, No. 2, pp. 312–315.

Co-operative projects

Since 1993 a programme of co-operation with the Observatory of Paris (Meudon, France) has been implemented.

Scientific and technical personnel

2 researchers and 7 technicians.

Possibilities for international exchange

Vacancies for accommodation of foreign scientists: 4 man/year.

General information

The large solar vacuum telescope is located at 70 km south-east of Irkutsk on the shore of Lake Baikal.

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Responsible person: Vladimir A. Kovalenko

BAIKAL DEEP-UNDERWATER NEUTRINO TELESCOPE

Institute for Nuclear Research

Date of commissioning (first-stage array): April 1993.

Fields of science

Physics, astronomy, Earth sciences (physics of elementary particles, cosmic rays, neutrino astrophysics, and physical limnology).

Fields of research

- Investigation of natural neutrino flux at energies above 10 GeV.
- Search for isotropic flux of extra-terrestrial neutrinos produced inside active objects in the Universe.
- Search for directional high-energy neutrino fluxes from supernova bursts, neutrino stars, the centre of the Galaxy, and active nuclei of neighbouring galaxies.
- Search for new particles such as heavy magnetic monopoles, neutralinos, quark nuggets, etc., at super-high sensitivity.
- Experimental research in the field of high-energy cosmic-ray physics.
- Investigation of physical processes in Lake Baikal water, modelling of natural and anthropogenic impacts on the Baikal ecology.

Main characteristics

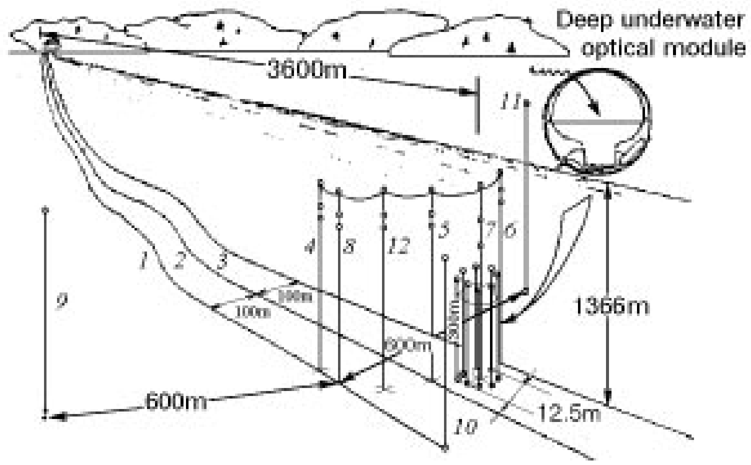
Depth of detecting modules, m	1100–1200
Distance to shore, km	3.6
Geometrical volume, m^3	about 90 000
Number of detecting modules	192
Effective area for muons, m^2	2 300 (muon energy 1 TeV)
	4 100 (muon energy 10 TeV)
Atmospheric muon counting rate, Hz	20
Counting rates for muons from lower hemisphere	600 per year

Major advantages

The set-up is the world's only operating full-scale deep-underwater Cherenkov detector for elementary particles. The next competing detector is planned to start operation not earlier than the end of 1995 (US-Japanese DUMAND Project, Hawaii). A deep-ice Cherenkov array in Antarctica will start not earlier than winter 1996.

The Baikal detector, even in its present state, is one of the largest arrays for investigation of cosmic-ray muons. It has the best possibilities for searching for superheavy magnetic monopoles and other dark-matter candidates.

The telescope, together with auxiliary acoustic and hydrologic systems, gives for the first time the opportunity to monitor simultaneously characteristics of the Baikal water in a volume of several cubic kilometers.



Layout of the Baikal neutrino telescope: *1, 2, 3* wire and optical cables to shore; *4, 5, 6* string stations for shore cables; *7* string station supporting the mechanical frame of the telescope; *8* test string for the optical cable; *9, 10, 11* autonomous string stations with acoustical equipment used for precise positioning; *12* hydrology string station.

Current research

- Intensity and its angle deep-underwater distribution flux are investigated for muons.
- Monopole search experiment is conducted.
- Data obtained are analysed to search for neutrino events and events produced by hypothetical dark-matter particles.
- Baikal water luminescence, optical parameters and temperature, as well as water currents at various horizons are measured continuously.

Possible research

- A bulky mass of data have been collected with the first-stage array. The data processing can be enlarged toward all the above directions.
- The devices measuring water temperature, concentration of oxygen, currents, seismic activity, etc., can be attached to the telescope.

Main scientific results

- Intensity and angle distributions of cosmic-ray muons were measured. That allows us to determine muon absorption up to a depth of 6 000 m, which agrees quite satisfactorily with theoretical predictions.
- The first limits were obtained for superheavy monopole flux, and are below a theoretical limit for small velocities (v/c = 0.0001).
- Baikal water luminescence was discovered and investigated.

Basic papers

I.A. Belolaptikov *et al*. (1990), The BAIKAL-experiment. *Nucl. Phys. B* (*Proc. Suppl.*) Vol. 14, p. 51.

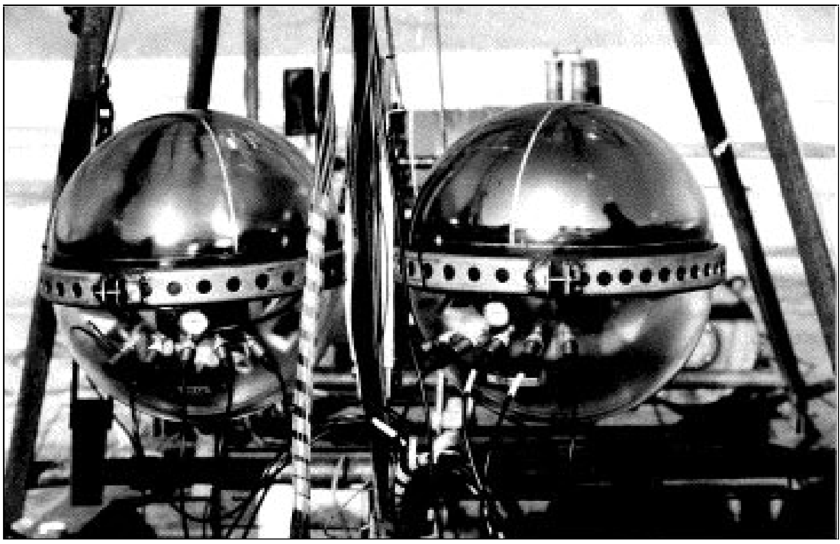
I.A. Belolaptikov *et al*. (1991), The lake Baikal deep underwater detector. *Nucl. Phys. B* (*Proc. Suppl.*) Vol. 19. p. 388.

S.D. Alatin *et al* (1992), Physics capabilities of the second-stage Baikal detector NT-200. *Nucl. Phys. B* (*Proc. Suppl.*) Vol. 28, p. 491.

L.B. Bezrukov *et al*. (1993), QUASAR-370. The Optical Sensor of the Lake Baikal Telescope. *Proc. 3rd Int. NESTOR Workshop*. Pylos, Greece, p. 645.

I.A. Belolaptikov *et al*. (1994), The Lake Baikal Underwater Telescope NT-36: First Months of Operation. *Nucl. Phys. B* (*Proc. Suppl.*) Vol. 35. p. 290

I.A. Belolaptikov *et al*. (1994), Track reconstruction and background rejection in the Baikal neutrino telescope. *Nucl. Phys. B* (*Proc. Suppl.*) p. 301



Deployment of the detecting modules

Current financial support and co-operative projects

The Baikal neutrino telescope was created and investigations with it are performed in co-operation with the DESY Institute for High-Energy Physics (Zeuthen, Germany). Some stages are supported by grants:

Russian Foundation for Basic Research Grant 95-02-06446,
International Science Foundation Grants M5M000 and NN6000.

Scientific and technical personnel

40 researchers and 30 technicians.

Possibilities for international exchange

Number of foreign scientists working at the installation: 9 man-year (DESY-IfH, Gemany).
Additional possibilities for receiving foreign specialists: 10 man-year.
Vacancies for accommodation of foreign scientists: 5 man-year.

General information

The telescope is located in the Irkutsk region, Sljudjanka district, 106 km Baikal railway.

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Responsible person: Leonid B. Bezrukov

SET OF FACILITIES FOR γ-RAY AND NEUTRINO ASTRONOMY AND FOR THE STUDY OF THE NUCLEAR COMPOSITION OF PRIMARY COSMIC RAYS

Institute for Nuclear Research

Stages of construction

First stage	1974: Carpet air-shower array.
Second stage	1978: Underground scintillation telescope.
Third stage	1993: Andyrchi air-shower array.
Fourth stage	Under construction: muon detector, Cherenkov detector, and neutron supermonitor.

Fields of science

Physics, astronomy (nuclear physics, cosmic-ray physics and neutrino astrophysics), and γ-ray astronomy.

Fields of research

High-energy neutrino and γ-ray astronomy, anisotropy of primary cosmic rays with energies above 10 TeV, chemical composition of primary cosmic radiation in the energy range 10-1000 TeV, structure of extensive air showers (EAS), and monitoring of cosmic-ray intensity.

Main characteristics

The Carpet air-shower array is unique as far as a continuous sensitive area (200 m^2) is concerned. It contains 400 scintillation detectors in the central part and six outdoor huts, each having scintillation detectors 9 m^2. Large area and high counting rate and detailed information about the core of a shower allow research to be carried out that could not be done with any other array.

The Baksan underground scintillation telescope (BUST) is a four-storey building in an underground man-made cave measuring 16.7 × 16.7 × 11 m, located under a mountain slope 550 m from the entrance to a horizontal mine. Four horizontal and four vertical planes are covered by scintillation detectors. The total number of detectors is 3 180, and they contain 330 tons of liquid scintillator. Their relatively shallow depth makes it possible to record rare processes as is usual in the so-called underground physics with simultaneous observation of muons with high statistical accurary.

The Andyrchi array is located on the mountain slope just above the BUST (the minimum distance between them is 358 m of rock) and is composed of plastic scintillators covering 45 000 m^2. The array is made like a standard one to be used with the BUST for energy calibration of underground events, but it will be used together with the Carpet array as well for mutual verification of counting rates and coincidences produced by giant EAS or fully independent (horizontal air showers can be studied owing to the inclined position of the array on the mountain slope).

The construction of the Cherenkov detector of air showers and the neutron monitor is planned for 1995. They will provide additional information which will improve considerably the performance of existing arrays.

A large muon detector of 700 m^2 is under construction and will be completed soon. The detector operates on an original principle: one large horizontal layer of liquid scintillator will be viewed by a regular lattice of PM tubes. A small pilot muon detector (the prototype scale is 1:21) was put into operation in 1993 and is now used to check all the detector and recording system units.

Major advantages

The BUST and Carpet operation has shown the high reliability and long-term stability of large-area detectors using liquid scintillators for many years. It is very important for cosmic-ray investigations, which often require several years of continuous operation. Development of research resulted in constructing a set of facilities, which included existing arrays (after some modernisation) and new installations. The construction, which began in 1990, will involve several stages. This gradual build-up has certain advantages:

- Each stage significantly improves information, and new experiments are started at the new installations to continue investigations done with the old instruments.
- The use of the complex does not require putting all installations into operation at once.
- There is a ready team of highly qualified physicists with great experience in exploiting experimental devices, processing techniques and data interpretation.

Current research

- Search for local sources of high-energy neutrinos.
- Search for neutrino bursts during gravitational collapse of stars in the Galaxy.
- Measurements of anisotropy and nuclear composition of primary cosmic rays.
- Studies of EAS structure.
- Search for local sources of ultra-high-energy γ-rays.
- Monitoring of cosmic-ray intensity and studies of its variations.

Possible research

When the Andyrchi air shower array is operational, the connection with the underground telescope and the Carpet array will widen research topics and make it possible to work in the higher-energy region. Once all the research complex is complete, the Baksan Neutrino Observatory of the Institute for Nuclear Research will be unique in terms of the diversity of its research activities.

Main scientific results

- Flux of high-energy atmospheric neutrinos from the lower hemisphere was measured for the first time.

- The world's best upper limit on heavy magnetic monopole flux was achieved.
- Amplitude and phase of anisotropy of primary cosmic rays were measured at energies $2{\cdot}10^{12}$ eV (using muon flux underground) and 10^{13} eV (using small air showers).
- A new effect, strong variations in cosmic rays connected with meteorological phenomena, was discovered, its correlation with the atmospheric electric field was demonstrated, and a quantitative description of the effect was proposed.
- As a result of the investigation of muon bundles underground, conclusions were drawn about the constant chemical composition of primary cosmic rays in the energy range 10^{13}–10^{15} eV;
- Strong bursts of cosmic-ray intensity were recorded during powerful solar flares, which were observed in the hard component of cosmic rays. This evidence of the production of very high energy particles during solar flares.
- By analysing multi-core events in EAS, the cross-section of high transverse-momentum jets in hadron–hadron collisions at centre-of-mass energy about 500 GeV was estimated (prior to the CERN SPS collider experiments).
- The excess of shower counting rate from the region of Crab Nebula was first observed on 23 February 1989, a phenomenon later confirmed by other experimental groups.
- The upper limit for the life-time of a proton, the best at the time, was obtained (the only experiment in Russia).

Basic papers

Yu.M. Andreev, V.I. Gurentsov, I.M. Kogai *et al*. (1989), Intensity and angular distribution of cosmic-ray muons according to Baksan scintillation telescope data. *Izvestiya AN SSSR*, *Ser. Fiz.*, Vol. 53, pp. 332–336.

V.V. Alexeenko, Yu.M. Andreev, A.E. Chudakov *et al*. (1990), Baksan EAS experiment on UHE gamma-ray astronomy. In: *High Energy Gamma Ray Astronomy*, Ed. J. Matthews, Amer. Inst. of Physics, N.Y., pp. 132–136.

Yu.M. Andreev, V.A. Kozyarivsky, V.Ya. Poddubny *et al.* (1991), Seasonal behaviour of diurnal intensity of muons with E_μ > 220 eV. *Izvestiya AN SSSR, Ser. Fiz.*, Vol. 55, pp. 1920–1922.

M.M. Boliev, A.V. Butkevich, V.N. Zakidyshev *et al*. (1991), Measurement of the flux and angular distribution of muons produced by cosmic-ray neutrinos. *Izvestiya AN SSSR, Ser. Fiz.*, Vol. 55, pp. 748–751.

V.N. Bakatanov, S.N. Boziev. Yu.F. Novoselþtsev *et al*. (1992), Recording of the giant muon families at the underground scintillation telescope of the Baksan neutrino observatory. *Pis'ma JETP*, Vol. 56, pp. 237–241.

V.V. Alexeenko, Yu.M. Andreyev, A.E. Chudakov *et al*. (1992), The ultra-high energy gamma-ray burst from the Crab Nebula observed by the Baksan EAS array. *J. Phys. G: Nucl. Phys.* Vol. 18, L83–L88.

A.V. Voevodsky, A.L. Tsyabuk, and A.E. Chudakov (1993), Muon bundles in an underground experiment and chemical composition of primary cosmic rays, *Yadern. Fiz.*, Vol. 56, pp. 143–154.

A.V. Voevodsky, V.B. Petkov, A.M. Semenov *et al.* (1994), Primary cosmic-ray composition: muon groups of high multiplicity with energy more than 0.25 TeV. *Bull. Russ. Acad. Sci. Phys.*, Vol. 58, No. 12, p. 2057.

Current financial support and co-operative projects

Grants of the Russian Foundation for Basic Research: 93-02-15484, 94-02-03388, 94-02-03470, 94-02-04573, 95-02-03934, 95-02-04660, and 95-02-07437.

Grant of the INTAS 93-303 (jointly with the Institute of General Physics University of Turin.

Grant of the International Science Foundation: Ph1-2078.

Collaboration with the Institute of Nuclear Study (Lodz, Poland) and the Physics Department of Durham University (United Kingdom).

Possibilities for international exchange

For work at this set-up, the Institute can receive 5–7 man-years.

General information

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Director of the Institute: Victor A. Matveev
Responsible person: Levon G. Gevorkov

YAKUTSK EXTENSIVE AIR-SHOWER ARRAY

Institute of Cosmophysical Research and Aeronomy

A full programme for detection of Extensive Air Showers (EAS) has been carried out since 1973.

Field of science

Physics (nuclear physics and high-energy astrophysics, experimental physics of elementary particles).

Field of research

Fundamental principles of the structure of matter in the microcosm and macrocosm.

Main characteristics

The array consists of 58 ground-based and six underground detectors of charged particles (electrons and muons), 50 detectors of the atmospheric Cherenkov light; 11 antennas to detect EAS radio emission at 32 MHz. Detectors are located over an area of 12 km^2 so that showers of primary energy above 10^{17} eV are detected.

Major advantages

Acceptance area of the Yakutsk Array is the greatest in the Former Soviet Union, and the complexity of the measurements is unique in the world. In contrast to analogous arrays in the United States (Fly's Eye) and Japan (AGASA), atmospheric Cherenkov light is used to estimate the energy of primary particles in the range $E > 10^{17}$ eV.

Current research

The nature of primary cosmic radiation (energy spectrum, angular distribution, and nuclear composition) and of nuclear-electromagnetic cascades in the atmosphere is studied by measuring charged particles, muons in EAS, and the Cherenkov light produced in the atmosphere by the shower.

Possible research

Measuring radio emission of EAS.

Main scientific results

- It was first revealed that the energy spectrum is irregular (with dip and bump) in the range $3 \cdot 10^{18}$–$5 \cdot 10^{19}$ eV.
- High isotropy has been established in the arrival-angle distribution of primary cosmic rays in the energy range 10^{17}–10^{18} eV, while at energies greater than $7 \cdot 10^{18}$ eV some excess is observed in

the particle flux from the equatorial/southern region of the Galaxy, which may be evidence for the galactic-component contribution to a primary flux at these energies.

- An anomalously high muon content in the showers has been found at primary energies above $5 \cdot 10^{18}$ eV, indicating possibly unknown nuclear interactions or unknown particles in the primary cosmic radiation in this range.

Basic papers

A.V. Glushkov, M.N. Diakonov, T.A. Egorov *et al.* (1993), Extensive air shower characteristics according to Yakutsk station data. *Bull. Russ. Acad. Sci. Phys.*, Vol. 57, No. 4, p. 660.

A.D. Krasilnikov, A.A. Ivanov, and S.I. Nikolsky (1993), Analysis of the arrival direction distribution of cosmic rays above $5 \cdot 10^{18}$ eV. *Proc. 23rd ICRC, Calgary*, Vol. 2, pp. 60–63.

X. Chi, A. Dudarevich, A.A. Ivanov *et al* (1993), Cosmic rays above $4 \cdot 10^{19}$ eV. *J. Phys. G*, Vol. 19, pp. 1393–1397.

A. Dudarevich, A.A. Ivanov, M.I. Pravdin *et al.* (1994), The trajectories of c.r. at the highest energies: III. Sensitivity of the anisotropy predictions to model parameters. *J. Phys. G*, Vol. 20, p. 665.

X. Chi, A. Dudarevich, A.A. Ivanov *et al.* (1994), The trajectories of c.r. at the highest energies: III. Applications of predictions to the data from EAS arrays. *J. Phys. G*, Vol. 20, p. 673.

V.P. Artamonov, B.N. Afanasiev, A.V. Glushkov *et al.* (1994), Modern state and outlooks of the Yakutsk EAS array. *Bull. Russ. Acad. Sci. Phys.*, Vol. 58, No. 12, p. 2026.

A.V. Glushkov, N.N. Efremov, I.T. Makarov *et al.* (1994), Irregularity of the EAS muon component at $E_0 > 5 \cdot 10^{18}$ eV. *Bull. Russ. Acad. Sci. Phys.*, Vol. 58, No. 12, p. 2022.

A.A. Mikhailov (1994), Estimation of galactic neutron flux in ultrahigh energy cosmic rays. *J. Phys. G*, Vol. 20, p. 841.

N.N. Efimov and A.A. Mikhailov (1994), Search for point sources of highest energy cosmic rays. *Astropart. Phys.*, Vol. 2, pp. 329–333.

Current financial support

Grants of the Russian Foundation for Basic Research:

Autonomous array for detection of the Cherenkov light from EAS at energies 10^{17}-10^{18} eV, (1994–1996) (94-02-04700)

Galactic cosmic rays of extremely high energies (1994–1995) (94-02-05874)

Allocated system of data collection and processing of the Yakutsk complex array for investigation of cosmic rays of extremely high energies (1995–1997) (95-02-04844)

Grant of the International Science Foundation:

The primary cosmic radiation at energy above 10^{17} e (1994–1995) (Grant NZE000)

Scientific and technical personnel

22 researchers and 38 technicians.

Possibilities for international exchange

Vacancies for accommodation of foreign scientists: 2–3 persons per year.

General information

The array is located of about 50 km south-west of Yakutsk.

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LOW-BACKGROUND DEEP-UNDERGROUND LABORATORY OF THE GALLIUM–GERMANIUM NEUTRINO TELESCOPE

Institute for Nuclear Research

Date of commissioning: December 1987.

Fields of science

Physics, astronomy (nuclear physics, experimental particle physics, and neutrino astrophysics).

Fields of research

Measurement of the soft part of the solar-neutrino flux; investigation into the thermonuclear mechanism of solar-energy production and into the fundamental properties of particles.

Main characteristics

Excavated volume of the underground GGNT facility, m^3	18 800
Volume of an experimental hall, m^3	7200 ($60 \times 10 \times 12$)
Area of the hall floor, m^2	720
Thickness of low-background concrete, cm	70
Attenuation of γ-background, times	15–16 (0.2–3.2 MeV)
Global intensity of muons, $cm^{-2} \cdot s^{-1}$	$(3.03 \pm 0.10) \cdot 10^{-9}$
Average energy of muons, GeV	381
Equivalent flat-surface depth, m.w.e.	4 700

The gallium–germanium neutrino telescope (GGNT) includes:

- ten chemical reactors containing about 60 ton of metallic Ga;
- installation for concentrating microquantities of Ge approximately $5 \cdot 10^5$ times;
- installation for the synthesis of high-purity GeH_4 with 98% efficiency;
- a low-background system for detection of single ^{71}Ge decays with background in the *K*-peak window of 0.01 day^{-1} and in the *L*-peak window of 0.1 day^{-1}.

Major advantages

- The GGNT deep-underground laboratory is a unique facility with extremely low background radiation from cosmic rays and surrounding matter.
- The telescope is a large-scale radio chemical complex with a unique technology which makes it possible to carry out extraction of single atoms of ^{71}Ge from about 60 tons of metallic gallium and to count their decays.

Current research

At the present time the SAGE experiment on solar-neutrino detection is carried out in the GGNT Laboratory.

Possible research

It is possible to carry out further solar-neutrino search, including measurement of the spectrum of low-energy neutrino flux and investigations which demand extremely low-radiation background, such as the search for dark matter, etc.

Main scientific results

The most significant results in the GGNT Lab were received in the SAGE experiment. The solar-neutrino flux was measured in the radio chemical ^{71}Ga–^{71}Ge experiment initially employing 30 tons and later 57 tons of liquid metallic gallium. This provides integral measurement of the flux of solar neutrinos, with particular sensitivity to the dominant low-energy p-p solar neutrinos. Their capture rate is found to be 69 ± 11(stat) + 5/-7(syst) SNU, which is only 52–56% of the rate predicted by various standard solar models.

Basic papers

A.I. Abazov *et al*. (1991), (SAGE Collaboration) *Phys. Rev. Lett.* Vol. 67, p. 3332.

T.J. Bowles and V.N. Gavrin (1993), *Ann. Rev. Nucl. Part. Sci.* Vol. 43, p. 117.

J.N. Abdurashitov *et al*. (1994), (SAGE Collaboration) *Proc. 6th Int.Workshop on Neutrino Telescopes*. p. 119.

J.N. Abdurashitov *et al*. (1994), (SAGE Collaboration) *Proc. 16th Int. Conf. on Neutrino Physics and Astrophysics*, p. 60.

J.N. Abdurashitov *et al*. (1994), (SAGE Collaboration) *Phys. Rev. Lett. B.* Vol. 328, p. 234.

Current financial support and c-ooperative projects

Russian Foundation for Basic Research Grant 93-02-14438.

ISF Grant M7F000.

Joint Project "The Russian-American Gallium Experiment SAGE" Russian Research Centre “Institute for Nuclear Research”; Los Alamos National Laboratory, Los Alamos; University of Pennsylvania, Philadelphia; and University of Washington, Seattle).

Scientific and technical personnel

12 researchers and 45 technicians.

Possibilities for international exchange

Foreign scientists from Los Alamos National Laboratory, University of Pennsylvania, and University of Washington (United States) working at the facility: 12 man-year.

Possibilities for foreign scientists to work at the facility: 10 man-year.

Vacancies for accomodation of foreign specialists: 10 man-year.

General information

Russian Research Centre “Institute for Nuclear Research”, Russian Academy of Sciences.

Baksan Neutrino Observatory is located 30 km south of Tyrnyauz, in the Elbrus mountain area.
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Director of the Institute: Victor A. Matveev
Responsible person: Vladimir N. Gavrin

NEUTRINO WATER DETECTOR NEVOD

Moscow Engineering Physics Institute

Date of commissioning: 1994.

Field of science

Physics (nuclear physics, experimental elementary-particle physics).

Fields of research

- Development of techniques for detection and spectrometry of high-energy muons and neutrinos (measurement, calibration and reconstruction of events in the Cherenkov water detectors; studies of the conditions of cosmic-ray neutrino detection at the Earth's surface; improvement of pair meter technique for muon energy measurements).
- Investigation of cosmic-ray flux characteristics at the Earth's surface (energy spectrum and angular distribution of muons; muon bundles at large zenith angles; cores of EAS generated by hadrons, photons, and muons).
- Cosmic-ray physics and astrophysics studies (time variations; sidereal and narrow-angle anisotropy of high-energy cosmic-ray flux; high-energy particle component of solar radiation).

Main characteristics

The experimental complex includes the following physical detectors:

- The Cherenkov water detector of 2 100 m^3, the measuring system of which is represented by a spatial lattice including up to 250 special modules. To provide the same detection efficiency for Cherenkov radiation arriving from any direction, an original quasi-spherical module has been developed consisting of six PMT oriented along rectangular co-ordinate axes.
- A calibration telescope system for direct calibration of quasi-spherical modules by Cherenkov radiation of cosmic-ray muons. The system consists of 150 scintillation counters which are placed on the top and bottom of a water tank, thus forming 75 vertical and 5 550 inclined telescopes.
- A unique co-ordinate detector for horizontal cosmic-ray flux investigations. This detector is formed by a multi-layer system of 2 048 streamer-tube chambers and is arranged on outer walls of the water tank. The detector, with an area of 200 m^2, provides good spatial (1 cm) and angular (0.1°) resolution and high reliability of parallel particle identification.
- A hydroacoustic antenna for detecting acoustic radiation of cascade showers and EAS cores in water. Simultaneous detection of Cherenkov and acoustic signals make it possible to increase the sensitivity of the acoustic technique considerably and to perform its direct calibration.
- A wide-angle high-resolution muon telescope for investigations of high-energy radiation of the Sun. The telescope consists of five layers of plastic scintillation counters with $1 \times 2.5 \times 300$ cm dimensions, and allows detection of particles of energies above 1 GeV within a wide solid angle with a measurement accuracy of 1°.

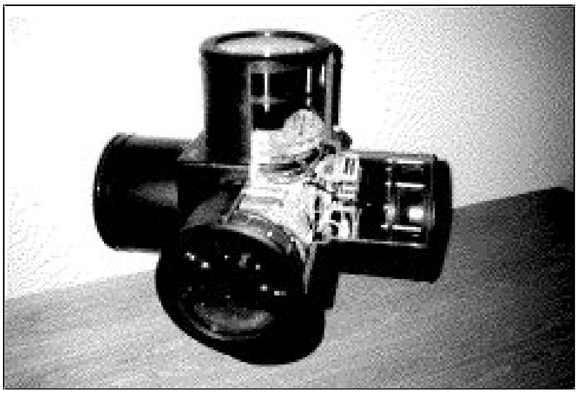
Major advantages

The detectors for investigations of neutrino fluxes of cosmic-ray origin are usually deployed deep underground or underwater, in order to decrease the background of other particles.

NEVOD is the world's only neutrino water detector at the Earth's surface. Therefore, one of the main tasks is experimental proof of possible detection of the events generated by neutrino flux from the lower hemisphere, and a study of their optimum selection under conditions of very high background. At the same time, the location of NEVOD allows one to investigate simultaneously other components of cosmic rays from the upper hemisphere (muons, EAS cores) in the energy range 1–10^5 GeV.

In particular, the first systematic investigation of muon bundles in horizontal cosmic-rays flux will be performed to study their production processes and to search for new particles decaying into muons.

The technological base of NEVOD will allow performance of necessary tests of design developments for future large-scale water detectors.



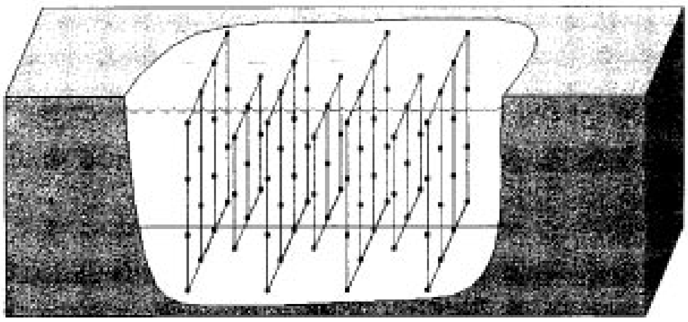
Current research

At present, the first stage of the installation is to detect single muons and cascade showers in order to elaborate techniques to reconstruct events of various types and to estimate a possible rejection factor for downward-going muon events, which is necessary to select muons produced by neutrinos from the lower hemisphere.

Possible research

The installation may be used for investigations of:

- High-energy muon interaction.
- Angular distribution of muons coming from the lower hemisphere, in order to evaluate a critical zenith angle for separation of neutrino-induced muons.
- Separation of the cores of EAS induced by hadrons and photons, on the basis of muon number measurements along the detector bottom.



Main scientific results

The first estimates of the downward-going muon flux rejection factor have been obtained. It is shown that the necessary rejection factor of $2{\cdot}10^{10}$ may be reached when detecting Cherenkov radiation of single muons by more than 8 quasi-spherical modules. Since at least 14 modules are involved in the effective zone of Cherenkov radiation detection for a single particle crossing the water tank, this gives evidence for possible selection of muons from the lower hemisphere.

Basic papers

A.V. Abin *et al*. (1990), 21 ICRC, Adelaide, Australia, Vol. 10, p. 234.

A.V. Abin *et al*. (1991), 22 ICRC, Dublin, Ireland, Vol. 4, p. 674.

C. Castagnoli *et al*. (1993), 23 ICRC, Calgary, Canada , Vol. 4, p.171 and p. 415.

V.V. Borog *et al*. Preprint of Moscow Eng. Phys. Inst. No. 028-93.

V.M. Aynutdinov (1994), 6th Int. Workshop “Neutrino Telescopes”, Venice, p. 565.

Light Background in the Ocean (1990), Moscow, Nauka.

A.G. Bogdanov *et al*. (1993), *Bull. Russ. Acad. Sci., Phys*., Vol. 57, No. 4, p. 673.

C. Castagnoli *et al*. (1994), *Bull. Russ. Acad. Sci., Phys*., Vol. 58, No. 2, p. 2067.

V.M. Aynutdinov *et al*. (1994), *Bull. Russ. Acad. Sci., Phys*., Vol. 58, No.12, p. 2071

A.G. Bogdanov *et al*. (1995), *Bull. Russ. Acad. Sci., Phys*., Vol. 59, No. 4

Current financial support and co-operative projects

Grants of the Russian Foundation for Basic Research:

Hydroacoustic detection of EAS cores with energies above 1 GeV (93-02-3952).
Muon hodoscope for investigations in solar-terrestrial physics (93-02-3061).
Surface Cherenkov water detector for γ-EAS detection (94-02-04513).

International project DECOR: Co-ordinate detector for horizontal cosmic ray flux investigations (Istituto di Cosmogeofisica del CNR, Torino, Italy).

Possibilities for international exchange

Number of foreign scientists working of the facility:

2 persons per year (Italy, Torino, Istituto di Cosmogeofisica del CNR);
2 persons per year (Switzerland, CERN).

Total number of scientists who could work at the facility: up to 6 persons per year.

Accommodation: up to 6 persons per year in the prophylactorium of Moscow Engineering Physics Institute.

General information

Moscow Engineering Physics Institute

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OPTICAL CLOCK

Institute of Laser Physics

Date of commissioning: 1981.

Fields of science

Physics (quantum electronics, laser physics) and astronomy.

Fields of research

Absolute frequency measurements into IR, optical and UV ranges, precision laser spectroscopy, improvement of basic physical constants, verification of basic principles of quantum electrodynamics, and improvement of the State Time and Frequency Standard (ULC).

Main characteristics

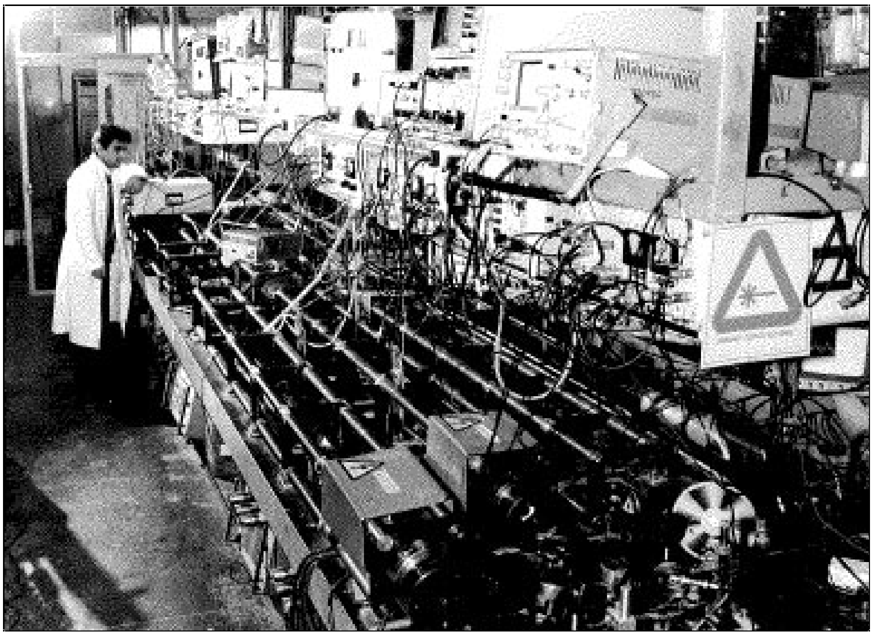
Short-term frequency stability, s^{-1}	$\sim 5 \cdot 10^{-15}$
Long-term stability	$\sim 10^{-15}$
Frequency reproducibility	$\sim 10^{-14}$
Accuracy of time-frequency measurement	$\sim 10^{-14}$

Major advantages

The clock is the only set-up which permits absolute-frequency measurement in the optical range with accuracy of 10^{-14} and better.

Current research

Absolute frequency spectroscopy of unperturbed $F_2^{(2)}P(7)\nu_3$-transition in methane, precision spectroscopy of hydrogen and muonium for refinement of the fine-structure constant and Rydberg constant, absolute-frequency measurements in visible, infrared and sub-millimeter ranges. Improvement of the set-up and creation of a new generation of optical clocks.



Possible research

Certification of quantum frequency and length standards operating in the radio to optical region with the accuracy of 10^{-14} and better, creation of optical time scale.

Main scientific results

Several methods have been proposed and realised for obtaining ultra-narrow optical resonances with a relative width of 10^{-11}–10^{-12}.

- The most monochromatic coherent radiation sources -- optical frequency standards with radiation line width of 0.07 Hz and relative long-term frequency stability of 10^{-15}–10^{-16} -- have been created on the basis of ultra-narrow optical resonances of 50 Hz wide.
- Direct comparison of frequency stability of the standards operating in optical and microwave ranges has been carried out. The advantages of the laser frequency standard have been shown.
- The methods of obtaining second-order Doppler-free resonances have been developed using optical selection of cold particles with effective temperature of 10^{-2} K and below.
- Precise laser apparatus for laser-frequency stabilisation and phase synchronisation of laser radiation has been developed, as well as methods of synthesis and absolute frequency measurement from optical to radio ranges.
- As a result, mobile laser frequency standards operating at the wavelength of 3.39 μm with relative radiation line width and long-term stability of 10^{-14}–10^{-15} have been created and provide a basis for a transportable optical clock.

Basic papers

V.G. Gol'dort, V.F. Zakhariash, V.M. Klementyev *et al*. (1982), Creation of an optical time scale. *Pisma v ZhTF (JETP Lett.)*, Vol. 8, No. 3, p. 157.

V.P. Chebotayev *et al*. (1982), Development of an optical time scale. *Appl. Phys. B,* Vol. 29, p. 63.

S.N. Bagayev and V.P. Chebotayev (1986), Laser frequency standards *Usp. Fiz. Nauk*, Vol. 148, p. 143.

S.N. Bagayev *et al*. (1986), Super-high resolution spectroscopy in methane with cold molecules, *Appl. Phys. B*, Vol. 48, p. 31.

S.N. Bagayev, V.P. Chebotayev, A.S. Dychkov *et al*. (1990), Absolute measurements of the 7-6 frequency transition of hyperfine structure of $F_2^{(2)}P(7)\nu_3$-absorption line in methane with the use of cold particles. *Opt. Spektrosk.*, Vol. 68, p. 1281.

S.N. Bagayev, V.P. Chebotayev *et al.* (1991), Second-order Doppler-free spectroscopy. *Appl. Phys. B*, Vol. 52, p. 63.

S.N. Bagayev, A.K. Dmitriyev *et al*. (1991), Portable He–Ne/CH_4 frequency standard on cold particles*. CPEM '94 Conf.* Digest, June 27–July 1, Boulder, CO, USA, p. 319.

S.N. Bagayev *et al.* (1994), Frequency shifts of non-linear resonances in the transit region due to the second-order Doppler effect. *Laser Physics,* Vol. 4, No. 2, p. 373.

S.N. Bagayev, A.K. Dmitriyev, M.V. Okhapkin *et al*. (1995), Measurements of g-factors of levels of 7–6 transition of $F_2^{(2)}$-line in methane. *Opt. Spektrosk.*, Vol. 78, p. 712.

Current financial support and co-operative projects

International project: Development of an absolute frequency standard for high-precision laser spectroscopy of muonium (in co-operation with the Ruprecht-Karls-Universität Heidelberg, Physikalisches Institut, Germany; University of Oxford, Department of Physics, Clarendon

Laboratory; and Rutherford Appleton Laboratory, Central Laser Facility, United Kingdom): INTAS grant 93-0263

International project: Super-high resolution laser spectroscopy and quantum metrology (in co-operation with Max-Planck-Institut für Quantenoptik, Garching, Germany).

International project: Development of ultra-stable laser sources of various types and absolute frequency measurements for scientific metrology (in co-operation with Laboratoire de Physique des Lasers, Université Paris-Nord XIII, France).

Agreement on scientific co-operation: Development of principles and technology of new generation of quantum time and frequency standards in microwave and optical ranges and creation of these devices with frequency reproducibility and accuracy up to 10^{-16}–10^{-17} (Chinese Academy of Sciences, Uhan Institute of Physics, P.R.China).

Grant of the International Science Foundation: Absolute frequency measurement of transitions of atomic hydrogen and muonium (RP 4000).

Grants of the Russian Foundation for Basic Research:

- Creation of a new generation of laser time and frequency standards (optical clock) (93-02-3438).
- Submillimeter super-high resolution laser spectrometer with the optical scale (93-02-14905).
- Second-order Doppler-free laser spectroscopy (94-02-04920)
- Ultra-stable compact tuneable laser systems of the basis of crystal- and semiconductor lasers (95-02-05857).

Scientific and technical personnel

10 researchers and 10 technicians.

Possibilities for international exchange

Number of foreign scientists working at the installation: 1.4 man-years.

- Max-Planck-Institut für Quantenoptik, Germany
- Université Paris-Nord XIII, France
- National Institute of Metrology, P.R.China.

Total number of scientists who could work at the installation: up to 10 man-years.
Vacancies for accommodation of foreign scientists: 10 man-years.

General information

The Institute is located in Akademgorodok, 30 km south-west of Novosibirsk.

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PULSAR-TIME CENTRE

Lebedev Physical Institute

Pushchino Radio Astronomy Station

Date of commissioning: 1979.

Field of science

Astronomy (astrophysics, radio astronomy, investigation of galactic and extragalactic radio emission, physics of neutron stars, fundamental metrology of time and space).

Fields of research

- Forming the Pulsar Time Scale by using precise timing of high-stability pulsars.
- Transfer of a local time scale to the radio telescopes DKR-1000, BSA, RT-22, and pulsar complex AS-102 FIAN with reference to the State Time–Frequency Standard (UTC).
- Very long base interferometry (VLBI).

Main characteristics

The pulsar complex AS-102 is used for precise timing of pulsars for investigations into the physical properties of pulsars and the interstellar medium.

Receiving frequency, MHz	102
Intermediate frequency, MHz	38
Number of channels	64
Band-width per channel, kHz	20

The complex is controlled by an IBM PC/AT computer in synchronised integration mode of radio signals received from pulsars.

The local time scale complex is used for permanent transmission of signals related to the UTC scale and of current-time codes to the DKR-1000, BSA, RT-22, and AS-102 at 5 MHz, 100 kHz and 1 pps reference frequency with an error not exceeding 0.1 μs. Referring the local time scale to the UTC (SU) scale is done using sample-frequency signals transmitted by TV channels with instrumental error of less than 20 ns. The RMS error of local-frequency signals with respect to UTC (SU) is less then $5 \cdot 10^{-14}$ per hour and $5 \cdot 10^{-13}$ per day. A rubidium standard of the type Ch1-74 is used as the reference time standard. A hydrogen maser Ch1-80 is used as the frequency standard.

Major advantages

The Pulsar-Time Centre was built in co-operation with the Main Metrological Centre of the State Time Service of Russia and has unique characteristics. All pulsar investigations and VLBI observations at the unique radio telescopes DKR-1000, LPhA, RT-22 FIAN, are made with metrological support of the Pulsar-Time Centre. The Centre thus provides these radio telescopes with the necessary time accuracy for experiments in astrophysics, astrometry, and radio astronomy. The Pulsar-Time Centre carries out the following functions:

- Forming the Pulsar Time Scale as the difference between time of arrivals of pulsar pulses and the UTC (SU) scale.
- Forming and storing a local time scale.
- Referring the local time scale to the UTC (SU).
- Automated processing of scale-comparing results.
- Transfer of reference signals of time and frequency to the experimental complexes of radio telescopes.

Current research

The Pulsar-Time Centre is now working with the radio telescopes DKR-1000, BSA, and RT-22 FIAN in various experiments. The pulsar complex AS-102 is regularly timing the pulsars to obtain long-term databases of time of arrival of pulses to create the Pulsar Time Scale. The complex is also used for investigations in the fields of physics of neutron stars and interstellar medium. The time of arrival for pulses of reference pulsars to the Solar system baricentre has been measured and collected since 1979.

Possible research

The Pulsar-Time Centre will develop possibilities fir transmission of the reference time and frequency signals to the experimental complexes of radio telescopes as they become equipped with new research facilities. The possibilities of AS-102 will be extended after further development of data-acquisition systems and software for data processing.

Main scientific results

The main scientific results, including publications list and common projects, can be found in the sections concerning the radio telescopes DKR-1000, BSA, RT-22 FIAN, which work together with the Pulsar-Time Centre in their experimental research.

Basic papers

Yu.P. Ilyasov, A.D. Kuzmin, T.V. Shabanova, and Yu.P. Shitov (1989), Pulsar time scale. In: *Pulsars*, Moscow: Nauka, pp. 149–159 (Trudy FIAN, Vol. 199).

V.G. Iliin, Yu.P. Ilyasov, A.D. Kuzmin *et al*. (1985), Pulsar time scale. *Doklady AN SSSR*, Vol. 275, No. 4, pp. 835–838.

O.V. Doroshenko and S.M. Kopeikin (1990), Algorithm of the high-precision phase analysis of single-pulsar observations. *Sov. Astron. Journal*, Vol. 67, pp. 986–997.

Yu.A. Fedorov, Yu.P. Ilyasov, A.S. Vdovin, and V.V. Oreshko (1989), Synchronisation of time standards of FIAN RAS with the State Standard of Time and Frequency. *Izmeritelnaya Technika*, pp. 27–30.

Yu.P. Ilyasov (1991), Problems and results of pulsar timing. In: *Galakticheskaya i Vnegalakticheskaya Radioastronomiya.* Ashhabad: FTI, pp. 7–8.

Current financial support and co-operative project

ISF Grants: M99000 and M99300,

Russian-Japanese project: Pulsar Time Scale. Precise timing of millisecond pulsars.

Scientific and technical personnel

8 researchers and 4 technicians.

General information

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