The International Workshop on Quark Phase Transition in Compact Objects and Multimessenger Astronomy: Neutrino Signals, Supernovae and Gamma-Ray Bursts

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Content

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Cryostatting, modulation and measurement of neutron fluxes in the low background experiments

Streams of ultracold neutrons are used in experiments on measurement of the dipole moment of the neutron, and to test the hypothesis of the existence of neutron-antineutron oscillations with non-conservation of baryon quantum number ΔB = 2. We tested the possibility of cooling and formation of thermal neutron flux by a constructive neutron monitor NM - 64 [1] cooled by liquid nitrogen vapors. For neutron detection in the installation may be used the scintillation method [2] or proportional counters [3] . We also presented a helium cryostat for cooling and formation of neutron fluxes. Calculations have been done for cold neutron flux density by using a cascade generator and reaction t (d, n) 4He at a deuteron energy of 130 keV and for signal / background ratio for various lengths of neutron-antineutron oscillations in vacuumed vertically placed pipe with length L≈10 m.

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Energy bursts from deconfinement in high-mass twin stars

We estimate the energy reservoir available in the deconfinement phase transition induced collapse of a neutron star to its hybrid star mass twin on the ”third family” branch, using a recent equation of state of dense matter. The available energy corresponding to the mass-energy difference between configurations is comparable with energies of the most violent astrophysical burst processes. An observational outcome of such a dynamical transition might be fast radio bursts, specifically a recent example of a FRB with a double-peak structure in its light curve.

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The search for coincidences of rare events with LVD and BPST detectors

Results of the search for coincidences of rare events in LVD and Baksan Underground Scintillation Telescope (BUST) detectors are presented. We developed a procedure of the search for events in LVD and BUST detectors which could be induced by interaction between neutrinos and matter contained in them. It was shown that from 2011 to 2014 the coincidences are of random character and their sum quantity remains practically invariable.

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Baikal-GVD: status and plan

The future next-generation neutrino telescope Baikal-GVD will be a km^3-scale array aimed at detection of astrophysical neutrino fluxes. It will have a modular structure and consist of functionally independent sub-arrays – clusters of strings of optical modules. The prototyping phase of the project has been completed in 2015 with deployment of the first cluster of Baikal-GVD in the Lake Baikal. We discuss current status and prospects of the Baikal-GVD project.

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Sidereal time analysis as a tool for detection of gravitational waves and neutrino SN- bursts in the inhomogeneous Local Universe

Core-collapse of massive stars produces both neutrino signal and gravitational wave (tensor-transversal plus scalar-longitudinal) bursts. In the case of GW detectors having low angular resolution the method of sidereal time analysis of output signals was applied for extraction of GW-bursts from high level noise. This method was suggested by J.Weber, Phys. Rev. Letters 22, 1320, 1969 for signal analysis of his bar detector and developed for the case of existing GW detectors in papers byY. Baryshev and G. Paturel, A&A, 371, 378, 2001 (arXiv: astro-ph/0104115), P. Astone et al., CQG, 19,5449, 2002 (arXiv: gr-qc/0210053), G. Paturel and Y. Baryshev, A&A, 398, 377, 2003 (arXiv: astro-ph/0104115), G. Paturel and Y. Baryshev, ApJ Lett., 592, L99, 2003.

The same sidereal time approach can be also applied for low energy neutrino detectors having many years of observational time (e.g. Super-Kamiokande, LVD, Baksan). This method uses following basic things: 1) difference between sidereal and mean solar time (which help to delete noises related to day-night solar time), 2) directivity diagram (antenna pattern) of the detector (which chooses a particular sky region in particular sidereal time), and 3) known position on the sky the inhomogeneous distribution of the

possible sources of SN signals, such as Galactic plane, Galaxy center, closest galaxies, Virgo galaxy cluster, Super-galactic plane, Great Attractor. Main idea is calculation of the expected number of neutrino events as a function of sidereal time (scanning the sky by Earth rotation) produced by possible sources within fixed depth of the survey. The summation of all output signals within one Earth's revolution (~23h 56m 04s of mean solar day) during several years of observations will reveal certain structure at predicted sidereal hours (by using directivity pattern of a detector), so the detection has statistical sense.

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Data from the NEMO neutrino telescope

In this work the questions connected with data processing on the NEMO test line will be discussed. In 2014 some preparations for functioning of the system were made, and it was necessary to analyze properties of water at the location (Capo Passero, near Sicily). It is essential for normal data processing in the Cherenkov neutrino telescope. In this work some problems related to the specific character of available data had to be solved. After that, the light signal was extracted and the plot of light attenuation was obtained. In addition, the calibration of photomultipliers was done. After that, using the computer simulation of light propagation, the parameters of environment were determined by fitting the actual attenuation plots to models with different parameters. This data may be suitable for correction of the obtained values. The algorithm can be also useful for other telescopes, and parameters themselves can help to the analysis in the neutrino experiment itself.

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Neutron star recycling scenario and constraints on the r-mode instability

Recycling scenario imposes important constraints on r-mode instability in neutron stars and thus on neutron star microphysics. Recent Ref. [1] concluded that ungapped interacting quark matter model is consistent with recycling scenario, including radio and x-ray data. However, this model leads to very high neutrino luminosity, thus high temperatures observed for neutron stars in low mass X-ray binaries can hardly be explained. On the contrary, our recent model [2] agrees with these observations, furthermore it is also consistent with neutron star cooling data, because it appeals to the same microphysical parameters as the minimal cooling model does [3]. Within our model, r-mode instability is suppressed because of the resonant interaction of oscillation modes at some internal temperatures ("resonant temperatures"). Here we demonstrate that this model agrees as well with observations of millisecond pulsars and provides observational evidences that the coupling parameter for resonant mode interaction at low temperatures should be rather large, in agreement with theoretical expectations [2].

This study was partially supported by RFBR (grants 14-02-00868-a and 14-02- 31616-mol-a), and by RF president programme (grants MK-506.2014.2 and NSh-294.2014.2).

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Restriction on parameters of the pulsar nebula DA 495 and its pulsar by data of the space observatories Chandra and XMM-Newton

We present spectral and timing analyses of the X-ray emission from the pulsar wind nebula DA 495 and its central object, J1952.2+2925, suggested to be the pulsar, using archival Chandra and XMM–Newton data. J1952.2+2925 has a pure thermal spectrum which is equally well fitted either by the blackbody model with a temperature of 215 eV and an emitting area radius of 0.6 km or by magnetized neutron star atmosphere models with temperatures of 80–90 eV. In the latter case, the thermal emission can come from the entire neutron star surface which temperature is consistent with standard neutron star cooling scenarios. We place also an upper limit on the J1952.2+2925 non-thermal flux. The derived spectral parameters are generally compatible with published ones based only on the Chandra data, but they are much more accurate due to the inclusion of XMM–Newton data. No pulsations were found and we placed an upper limit for the J1952.2+2925 pulsed emission fraction of 40 per cent. Utilizing the interstellar absorption–distance relation, we estimated the distance to DA 495, which can be as large as 5 kpc if J1952.2+2925 emission is described by the atmosphere models. We compiled possible multiwavelength spectra of the nebula including radio data; they depend on the spectral model of the central object. Comparing the results with other pulsar plus wind nebula systems, we set reasonable constraints on the J1952.2+2925 spin-down luminosity and age. We suggest that the Fermi source 3FGL J1951.6+2926 is the likely gamma-ray counterpart of J1952.2+2925.

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Baikal searches for neutrino signal from the Galactic Center and Dwarf Galaxies

We perform the analysis of a data set of Baikal neutrino telescope NT200 to search for neutrino signals from dark matter annihilation in the Galactic Center and in Dwarf Galaxies. From this analysis we set upper limits on dark matter annihilation cross sections for different annihilation channels. Also we discuss sensitivity of the gigaton volume telescope Baikal-GVD to this signal.

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Long and short GRBs in the two-families scenario

I will review the two-families scenario in which hadronic stars having rather small radii and masses not exceeding about 1.5 Ms coexist with quark stars, which can reach masses well above 2 Ms. I will discuss the implications of this scenario in particular for long and short GRBs, using the results of our recent work in which the process of quark deconfinement in compact stars has been revisited.

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A search for cosmic gamma-rays at the Carpet-2 EAS array: prospects and preliminary results

We analyze Carpet-2 EAS array data in order to search for events with anomalously low content of muons with energies Eμ > 1 GeV in extensive air showers with energy above 100 TeV. Monte-Carlo simulations of showers induced by primary protons and gammas have been performed using the CORSIKA code. The estimation of the upper limit on the flux primary gamma rays is presented.

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Radiochemical neutrino experiments today

Radiochemical neutrino detectors have played an important role in the study of neutrinos from the Sun. Features of radiochemical detectors - no external backgrounds and sensitivity only to electron neutrinos - make them a powerful tool for precision measurements of neutrino properties.

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The data analysis from GBM and LAT monitors from FERMI telescope

Gamma-ray bursts (GRBs) are thought to originate from collapsing massive stars or merging compact objects (such as neutron stars or black holes), and are associated with the formation of black holes in distant galaxies.

Fermi Gamma-ray Space Telescope has two monitors aboard — the Large Area Telescope (LAT) and the Gamma-ray Burst Monitor (GBM). The LAT is a pair-conversion telescope that observes photons from 20 MeV to >300 GeV with a 2.4-steradian field of view. The GBM consists of 12 sodium iodide (NaI, 8 keV to 1 MeV) detectors and two bismuth germinate (BGO, 200 keV to 40 MeV) detectors, positioned around the spacecraft to view the entire unocculted sky.

Gamma-ray burst spectral analysis takes advantage of the unique properties of this phenomenon: a relatively short transient from a point source. For the LAT there will usually not be competing emission from other sources in the field-of-view, while the GBM cannot distinguish spatially between burst photons and those originating from other sources. Therefore, the analysis is one dimensional: we determine the input burst flux from the apparent energies of the events (called 'counts').

For the LAT we select all the counts from a region 1-2 PSF-radii around the burst position from the time range which includes the burst. For the GBM the origin of the counts is unknown, and therefore all the counts from the burst's time range are selected.

Consider matrix equation $\mathbf{c_i = D_{ij}f_j+b_i}$, where $\mathbf{c_i}$ is count spectrum (the index **i** runs over energy channels), $\mathbf{b_i}$ is background, $\mathbf{f_j}$ is photon flux striking the detector in different energy channels and matrix $\mathbf{D_{ij}}$ is the 'Detector Response Matrix' (DRM) in the burst community. Note that for the LAT $\mathbf{b_i}$~0 but for the GBM $\mathbf{b_i}$ is substantial, and in many channels will dominate the burst counts.

In forward folding a model flux vector $\mathbf{f'_j}$ is folded through the response, resulting in a model count spectrum $\mathbf{c'_i}$. The underlying model flux is usually an analytic function (e.g., a power law) with a small number of spectral parameters. The model $\mathbf{c'_i}$ is compared to the observed $\mathbf{c_i}$, and then a new model flux vector $\mathbf{f'_j}$ is calculated until the model $\mathbf{c'_i}$ is sufficiently close to the observed $\mathbf{c_i}$, resulting in best-fit spectral parameters. 'Sufficiently close' is usually determined by minimizing χ^2 or if the number of counts per bin is not large enough, then the Cash statistic should be used instead of χ^2.

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Entropic and enthalpic phase transitions in high energy density nuclear matter

Features of Gas-Liquid (GL) and Quark-Hadron (QH) phase transitions (PT) in dense nuclear matter are under discussion in comparison with their terrestrial counterparts, e.g. so-called "plasma" PT in shock-compressed hydrogen, nitrogen, xenon etc. Both, GLPT and QHPT, when being represented in widely accepted temperature–baryonic chemical potential plane, are often considered as similar, i.e. amenable to one-to-one mapping by

simple scaling. It is argued that this impression is illusive and that GLPT and QHPT belong to different classes: GLPT is typical *enthalpic* (e.g. Van-der-Waals-like) PT while QHPT (i.e. "deconfinement-driven" PT) is typical *entropic* PT. Subdivision of 1st-order fluid-fluid phase transitions into two subclasses: enthalpic and entropic PTs (i.e. *H*-PT and *S*-PT), was proposed in [arXiv:1403.8053/1504.05850]. The term "entropic PT" is not equivalent to the term "entropy-driven" PT, which was introduced previously by D. Frenkel. We clarify the difference of two types of PTs. Properties of *H*-PT and *S*-PT differ significantly. Entropic PT is always internal part of more general and more extended thermodynamic anomaly – domains with abnormal (negative) sign for the set of (usually positive) second cross derivatives of thermodynamic potential. Three of them are of primary importance: so-called Gruneizen coefficient, thermal expansion coefficient and thermal pressure coefficient. Negative sign of all that derivatives lead to violation of relative order and standard behavior in *P–V* plane for many iso-lines, e.g. isotherms, isentropes, shock adiabats etc. Entropic PTs have more complicated topology of stable and metastable domains within the two-phase region in comparison with conventional enthalpic (VdW-like) PTs. In particular, new additional (third) metastable region, bounded by new additional spinodal, appears in the case of entropic PT. All the features of entropic PTs and accompanying abnormal thermodynamics region have transparent geometrical interpretation -- multi-layered structure of thermodynamic surfaces for temperature, entropy and internal energy as a pressure-volume functions, e.g. for *T(P,V), S(P,V)* and *U(P,V)*.

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Observations of transient events with the Mini-MegaTORTORA wide-field monitoring system

Here we briefly summarize our long period experience of constructing and operating wide-field monitoring cameras with sub-second temporal resolution to look for optical components of GRBs, other rapid astrophysical phenomena, fast-moving satellites and meteors. General requirements for hardware for such systems are discussed along with algorithms of real-time detection and classification of various kinds of short optical transients. We also give a status report on the next generation, multi-objective and transforming monitoring system, the MegaTORTORA, whose 9-channel prototype (MiniMegaTORTORA) is now in operation at Russian Special Astrophysical Observatory. This system combines a wide field of view with subsecond temporal resolution in monitoring regime, and is able to reconfigure itself, in a fractions of second, to follow-up mode which has better sensitivity and provides us with multi-color and polarimetric information on detected transients simultaneously. We discuss first results of its work, as well as its prospects.

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The viscosity and surface tension of the hadron matter and quark-gluon plasma

In present the interest to nuclear matter hydrodynamics increases [1]. The Liquid Drop Model (LDM) is successfully used for semi-empirical formulation of surface and Coulomb terms in Bethe-Weizsacker mass formula. LDM is the foundation for the 5D harmonic oscillator collective nuclear model [2], which allows us interpreting vibration excitations of near-spherical nuclei. In the frame of nuclear liquid drop model an analytical solution for the frequency of capillary oscillations is obtained with taking into account the damping due to viscosity and surrounding medium polarizability. The model has been applied for estimation of even-even spherical nuclei surface tension and viscosity. It has been shown [3] that energy shift of capillary oscillations of even-even spherical nuclei due to viscous dissipation gives viscosities in the interval 4.2-7.6 MeV fm^{-2} c^{-1} for nuclei from Pd-106 to Hg-198. For non-zero temperatures the ratio of shear viscosity η to entropy density s is estimated and compared with the limit $\eta/s > 1/4\pi$ motivated by AdS/CFT for quark–gluon plasma [4].

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Fast optical transient detection by MASTER Global Robotic Net on the example of FERMI alerts

Early discovery of an optical afterglow of the gamma-ray burst GRB140801A in the 137° (3-σ error-box) of the Fermi Gamma-ray Burst Monitor (GBM). GRB140801A is one of the few GRBs whose optical counterpart was discovered solely from its GBM localization. The optical afterglow of GRB140801A was found by the MASTER Global Robotic Net 53 sec after receiving the alert, making it the fastest optical detection of a GRB from a GBM error-box. Spectroscopy obtained with the 10.4-m Gran Telescopio Canarias and the 6-m BTA of SAO RAS reveals a redshift of z=1.32. We performed optical and near-infrared photometry of GRB140801A using different telescopes with apertures ranging from 0.4-m to 10.4-m. GRB 140801A is a typical burst in many ways. The rest-frame bolometric isotropic energy release and peak energy of the burst is $E_{iso} = 5.54_{-0.24}^{+0.26} \times 10^{52}$ erg and $E_{p,\,rest} \cong 280$ keV, respectively, which is consistent with the Amati relation. The absence of a jet break in the optical light curve provides a lower limit on the half-opening angle of the jet $\theta = 6.1°$. The observed E_{peak} is consistent with the limit derived from the Ghirlanda relation. The joint Fermi GBM and Konus-Wind analysis shows that GRB140801A could belong to the class of intermediate duration. The rapid detection of the optical counterpart of GRB140801A is especially important regarding the upcoming experiments with large coordinate error-box areas.

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Primary photons in cosmic rays with energy ~10^{17}eV from EAS MSU experiment data

We analyze EAS-MSU archival data in order to search for primary photons in cosmic rays at energies ~10^{17} eV. The method is based on the fact that for hadronic showers of such energies it is highly improbable to have zero muons in a central area of EAS (Extensive Air Shower) while it is possible for primary gamma rays.

We performed Monte-Carlo simulations of proton-induced showers using the CORSIKA simulation code with EGS4, QGSJET-02 and FLUKA packages to make a new constrains on a fraction of primary photons.

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Baksan Neutrino Observatory of the INR RAS: current state and prospects

An overall view of the Baksan Neutrino Observatory of the INR RAS infrastructure is presented. Ground-based and underground facilities used to study cosmic rays, rare nuclear reactions and decays, register solar neutrino, observe various geophysical phenomena are described. Some main results obtained with these facilities and prospects are given.

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On Burst Activity of the Crab Nebula and Pulsar at High and Ultra-High Energies

Recently, the Crab Nebula, once a “standard candle” of X-ray and gamma-ray astronomies, was shown by satellite gamma-ray telescopes Fermi-LAT and AGILE to produce flares of gamma-rays in the energy range around 100 MeV. However, as long ago as more than 20 years from now the data on a possible burst in the Crab Nebula at much higher energies, about 100 TeV, were published. Characteristics of transient and stationary fluxes of gamma rays from the Crab Nebula in various energy ranges are compared to discuss whether the old data obtained at ultra-high energy could be reasonably consistent with the modern pattern of burst activity of the source.

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The MASTER Global Robotic Net and main physical experiments

The MASTER Global Robotic Net is the unique modern Russian experiment in astrophysics.

MASTER is a both alert and survey telescope with its own developed software, which allows us discovering new optical transients in MASTER images within several minutes after readout from CCD. This information includes the full classification of all sources from an image, the data from previous MASTER-Net archive images for every source, full information from VIZIER database and all open sources, derivation of orbital elements for moving objects, etc. This software permitted us discovering more than 900 optical transients of more than 10 types within recent years.

The MASTER Global Robotic Net includes observatories at 3 continents and in the Atlantic ocean. All MASTER observatories are equipped by identical instruments with identical photometers with BVRI filters and polarizers. Each MASTER observatory provides a survey speed of 128 deg^2 per hour with a limiting magnitude of 20 mag at dark moonless nights (a wide field optical channel) and 800 square degrees per 1 second up to 12m (a very wide field optical channel).

These features allow us observing fields of view of FERMI (error-boxes of up to tens of square degrees), Swift, ANTARES, IceCube, LIGO/VIRGO in the alert mode and discovering optical transients in real-time.

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Mechanisms of supernova explosion: modern status.

The mechanisms of explosion of different type supernovae (SNe) are discussed. At least three mechanisms are under detailed inspection of scientific community for core collapse SNe. They are the instability of standing accreting shock front that results in the large scale 3-dimensional hydrodynamic flows, the magnetic-rotational expulsion of supernova envelope, and rotational fission of collapsing stellar core into a pair of proto neutron stas. The mechanism of explosion of cosmological SNe (of Type Ia) is physically understood as thermonuclear explosion of carbon-oxygen-helium matter. However there exists serious problem with modelling of the structure and propagation of unstable thermonuclear flame that is crusial for numerical agreement with observations.

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Search for neutrino burst signals from Supernovae at the Baksan Underground Scintillation Telescope

The current status of the experiment on recording neutrino bursts from core collapse stars is presented. The actual observational time is 29.76 years. The upper bound of the mean frequency of core collapse supernovae in our Galaxy is $f_{col} < 0.077$ year^{-1} (90% CL).

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Joint analysis of experimental data on the search for neutrino bursts using the BUST and LVD detectors

The first results of joint analysis of experimental data on the search for neutrino bursts using the BUST and LVD detectors are presented. We carried out a search for the coincidence of events in both facilities (BUST and LVD) using data for 2011- 2014 years. The obtained results can be explained by random coincidence of background events in LVD and BUST. The presented analysis of data of two and more facilities can be particularly useful in cases when optical SN is invisible for various reasons.

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Prospects of detecting the QCD phase transition in the Galactic supernova neutrino burst with 20-kton scale liquid scintillation detectors

The QCD phase transition during the postbounce evolution of core-collapse supernovae can be observable as the second peak in the neutrino signal that is accompanied by significant changes in the energy of the emitted neutrinos. In contrast to the first neutronization burst, this second neutrino burst is dominated by the emission of antineutrinos. This circumstance is useful for detection of this peak due to the high cross section of inverse beta decay reaction.

Because the supernova explosion in the Galaxy is a rare event; the comprehensive study of the next one has absolute priority for the low-energy neutrino astronomy. Therefore the new-generation large liquid scintillation detectors must be ready to detect all flavors of neutrinos in order to understand the physics and astrophysics of core-collapse supernovae. For this purpose the new detector must have the capability to distinguish the various detection channels. Large statistics must be collected to study spectra and time profiles of all neutrino flavors, thereto the new detector should have large enough target mass. The

prospects for detecting the peculiarities in the neutrino signal from the core-collapse supernova in large liquid scintillation detectors will be discussed.

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Current status of the GW-experiment and multi-messenger astronomy

A brief review of present situation in development of GW detector technique is described. Current upper limits of GW radiation from main classes of relativistic astrophysical objects are given. Strategy of multichannel search for so called "multi messenger astronomy" is discussed. It is associated with the properties of three types of transient astrophysical sources that are well known in the EM spectrum. These sources are expected to produce transient GW signals in the laser interferometric detector frequency range, and possibly neutrino fluxes as well. In that number there are 1) coalescence of NS and BH binary systems, 2) core collapsing stars, 3) flaring/bursting NSs. Joint GW+EM and neutrino observations are expected to provide a wealth of information among which: a) improvement in the confidence in first GW detection, b) useful priors in GW data analysis parameter space, c) complement our knowledge of the physics of sources. Algorithms of joint multichannel data processing are under development. Past results from MM searches show no significant coincident events, and obtained upper limits on the energetics in GW and source rate density did not provide strong constraints on astrophysical models. However for the advanced detectors, starting from 2018 year probed distances are expected to contain significant number of GW sources localized in few degrees areas in the sky and the more than ten MoU partners will ensure EM and neutrino monitoring.

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Interaction of electron neutrino with LSD detector

The interaction of electron neutrino flux, originating in the rotational collapse mechanism on the first stage of Supernova burst, with the LSD detector components, such as ^{56}Fe - a large amount of this metal is included in as shielding material, and liquid scintillator C_nH_{2n}. is being investigated. Both charged and neutral channels of neutrino reaction with ^{12}C and ^{56}Fe are considered. The number of signals, produced in LSD by the neutrino pulse of Supernova 1987A is determined. The obtained results are in good agreement with experimental data.

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Terskol Observatory: new technologies of observing fast phenomena on celestial objects with ground-based optical telescopes

The project is based on a cluster of telescopes for the wide monitoring of the celestial sphere.
The project is aimed at the following goals:

- detection and monitoring of events in sub second range of time;
- using low-cost business models of telescopes;
- using well-known software for parallel processing in real time;
- high reliability and management of the project.

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A cluster of galaxies around the GRB 021004 sight-line at z ~ 0.57

The clustering of galaxies around GRB sight-lines is detected and studied in the same manner employed with quasar spectroscopy in many papers already. Galaxies that give rise to absorption line systems in gamma-ray bursts afterglow spectra have been directly imaged and investigated. So, it is possible to try to find the overdensity excess of GRB field galaxies around GRB positions by different methods – spectroscopic, photometric ones (deep images – multiband photometry) plus the search for correlation with Cosmic Microwave Background (CMB) and others. In this report we test for reliability any signatures of field galaxies clustering in GRB 021004 line of sight. (1) The first signature is the BTA and Hubble GRB 021004 field photometric redshift distribution with the peak at z ~ 0.57 estimated from multicolor photometry. (2) The second signature is the MgII 2796,2803 absorption doublet at z ~ 0.57 in GRB 021004 afterglow spectrum. (3) The third signature is some inhomogeneity in Plank + GRB 021004 fields. (4) And the fourth signature may be the galaxy clustering with an effective redshift of z = 0.57 from the Baryon Oscillation Spectroscopic Survey (BOSS), which is part of the Sloan Digital Sky Survey III (SDSS-III).

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On the observed mass distribution of compact stellar remnants in close binary systems and possible interpretations proposed for the time being

There are two new observational facts: (1) the mass spectrum of neutron stars and black hole candidates (or collapsars) shows an evident absence of compact objects with masses within the interval from 2 MΘ (with a peak for neutron stars at about 1.4 MΘ) to approximately 6 MΘ, (2) and in close binary stellar systems with a low-massive (about 0.6 MΘ) optical companion the most probable mass value (the peak in the masses distribution of black hole candidates) is close to 6.7 MΘ. This puzzle of discrete mass spectra of compact objects demands some solution in the context of the supernovae and gamma-ray bursts relation, and in connection with the core-collapse supernovae explosion mechanism or, eventually, with QCD phase transition. Particularly, the long gamma-ray burst can be one of the first signals of core collapse of a massive star.

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The MSU neutrino group activity in the projects of deep-sea neutrino detectors

Astrophysical sources of information about distant objects in the Universe may be: primary protons, gamma rays and neutrinos. But at energies greater than a few TeV photons interact with infrared and microwave background. Protons and electrons due to their electric charge are affected by magnetic fields in space and cannot allow us determining their trajectory from a source to the Earth.

Neutrinos have a very low cross section and provide us information about distant sources with negligible distortions - their direction remains almost unchanged. It distinguishes neutrinos from other elementary particles as the unique messengers. This fact is one of the most significant differences between neutrino detection and registration of photons and high-energy protons. Cherenkov radiation began to be in common use for detection of ultrahigh-energy neutrinos in the early 90-ies of the last century. The result was creation of a new class of systems — large volume deep-see neutrino telescopes.

Since 2005 an MSU scientific group consisting of employees, graduate students and students of the Faculty of Physics and SINP participates in the work for designing, creation and data processing on the large volume neutrino telescopes in such projects as NEMO, ANTARES and KM3Net.

Now main efforts of the scientific work conducted by the group are aimed at the following questions:

- development and creation of new types of optical modules for photomultipliers on neutrino telescopes;
- a new algorithm for finding supernovae and other astrophysical objects of this type using neutrino detection was developed;
- the work for searching neutrinos from the recently discovered gamma-ray phenomena so-called "Fermi bubbles" which cause the luminescence in the galactic plane;

- the work in modeling various configurations of optical modules for KM3Net(It) neutrino telescope;
- the work on a possible acoustic detection of astrophysical neutrinos.

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Ultraluminous X-ray Sources as Super-Eddington Accretion Disks

The origin of Ultraluminous X-ray sources (ULXs) in external galaxies whose X-ray luminosities exceed those of the brightest black holes in our Galaxy by hundreds and thousands of times is mysterious. The most popular models for the ULXs involve either intermediate mass black holes (IMBHs) with standard accretion disks or stellar-mass black holes (~10 solar masses) accreting at super-Eddington rates. Here we review the ULX properties, their X-ray spectra indicate presence of hot winds in their accretion disks supposing the supercritical accretion. However, the strongest evidences come from optical spectroscopy. The spectra of the ULX counterparts are very similar to that of SS 433, the only known supercritical accretor in our Galaxy.

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High-energy neutrino astronomy - where are we now, where do we go?

The discovery of astrophysical neutrinos has lifted a new observational window to the Universe. A new generation of detectors aims to fully opening this window. The talk will describe the corresponding IceCube results which herald a new era in neutrino astronomy. It will also give an outlook to the future detectors on the multi-cubic kilometer scale: KM3NeT in the Mediterranean Sea, GVD in Lake Baikal and IceCube-Gen2 at the South Pole.

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Correlation between sphere distributions of gamma-ray bursts and CMB fluctuations

We have studied the distribution of gamma-ray bursts (GRBs) locations from the BATSE and BeppoSAX space observatories relative to the cosmic microwave background (CMB) data by Planck space mission.

Three methods were applied for data analysis:

(1) a histogram of CMB signal values in GRB directions,

(2) mosaic correlation maps calculated for GRB locations and CMB distribution,
(3) calculation of an average response (stacking procedure) in the area of "average GRB population" on the CMB map.
A correlation between GRB locations and CMB fluctuations was detected which can be interpreted as the systematic effects in the process of observations.

Besides, in the averaged areas of CMB maps, a difference between the distributions of average fluctuations for short and long GRBs was detected which can be caused by different natures of these events.

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The complex of SAO RAS optical telescopes as an instrument for studying transient phenomena in the Universe

We present a review of instrument facilities of SAO RAS optical telescopes – the 6-meter telescope BTA and the 1-meter telescope Zeiss-1000 aimed at the study of transient phenomena in the Universe including those whose localization in the celestial sphere is unknown in advance.

As a rule, the instruments for photometric and spectral investigation of such phenomena are parts of standard equipment of the telescopes and they can be used during most of their operational time.

Results of the spectral and photometric study of optical afterglow of gamma-ray bursts fulfilled with the SAO RAS telescopes from 1998 are presented. One of the important tasks carried out in the framework of programs of collaboration with other national instruments is the synchronous monitoring of samples of active galactic nuclei in optical and radio.

We adduce suggestions formulated in SAO RAS within the context of a program of scientific infrastructure development in the nearest 15-20 years and aimed at creation of survey instruments of medium size with the field of view of few degrees.

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X-ray binaries and Ultra-luminous X-ray sources

All known to date stellar mass black holes reside in X-ray binaries (XRB). They are connected with a number of uncommon phenomena like mass transfer, state transitions, and relativistic jets. Analysis of XRB gives us insights in their formation mechanism and particularly the origin of compact objects.

Probably, their most interesting feature is the "the mass gap" (i.e., the lack of compact objects with masses ~2-5 M_{Sun}). This observation is a stringent test for compact object formation mechanism.

Ultraluminous X-ray sources (ULX) are the strongest point-like X-ray sources known to date. The high energetic emission seems to be a hallmark of violent interactions between a strong gravitational field and matter. Recent works showed a strong

resemblance between ULXs and XRBs suggesting that they may constitute the extreme part of their population. We know several hundred ULXs which could prove to be the marvelous laboratories of extreme processes.

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3-flavour symmetry restoration in compressed baryonic matter

Our Universe contains baryonic matter (negligible but important for us) in the form of nuclei, which are 2-flavour symmetric (i.e., u and d flavours of quarks, known as the symmetry energy in nuclear physics). Nevertheless, we argue that 3-flavour symmetry (i.e., u, d and s flavours of quarks) would be restored when huge number of nuclei are compressed by gravity during a supernova, forming a gigantic macro-nuclei at last. Different manifestations of compact stars may hint that pulsars are macro-nuclei with 3-flavour symmetry.

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Energy injection in Gamma Ray Bursts

With the development of new observational techniques and the launch of Swift satellite, unexpected features, such as multiple X-ray flares and significant optical rebrightenings, which unveil the late-time activities of the central engines, have appeared in GRB afterglows. A lot of different interpretations have been proposed to explain these complex behaviors. The energy injection model, the two-component jet model, and the microphysics variation mechanism are very popular in view of the fact they can explain the exceptional optical rebrightenings well. In this report, we will introduce some special events, such as GRBs 081029, 100814A and 111209A, which were successfully explained by the energy injection model. Especially, we will focus on GRB 100814A, with an early-time shallow decay phase and a late-time significant rebrightening in its optical afterglow light curve. To explain the complex multi-band afterglow emission of GRB 100814A, we invoke a magnetar with spin evolution. We argue that the optical shallow decay phase and the X-ray plateau are due to energy injection from the magnetar in its early spin-down stage, while the significant optical rebrightening observed at late time naturally comes from the spin-up process of the magnetar, which is caused by subsequent fall-back accretion.

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On some exotic properties of hybrid stars

We consider two "wonders" of hybrid stars, i.e. stars that contain a core made of quark matter.

First, we explain the existence of a very small region on the mass–radius (M-R) diagram of hybrid stars where all of the lines representing the sequences of models with different values of the bag constant B intersect. This circumstance is shown to be a consequence of the linear dependence of pressure on energy density in the quark cores of hybrid stars.

Second, we show that the unusual thermodynamic properties of matter within the region of two-phase coexistence in hybrid stars result in a change of the standard condition for beginning of convection. In particular, the thermal flux transported by convection may be directed towards the stellar center. We discuss favorable circumstances leading to such an effect of "inverse" convection and its possible influence on the thermal evolution of hybrid stars.