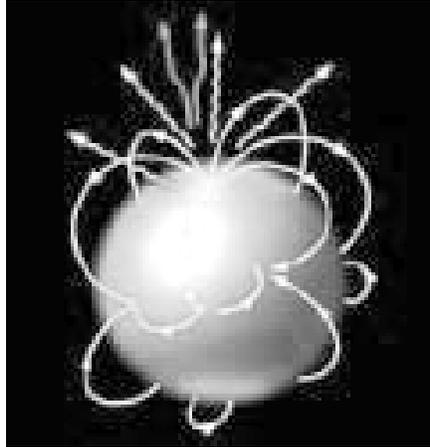


C O N F E R E N C E   O N

# Physics of Neutron Stars



# Programme and Abstracts

Ioffe Physico-Technical Institute

St. Petersburg, Russia, 6–8 June 2001



# Physics of Neutron Stars

## 2001

The Conference was held at the A.F. Ioffe Physical-Technical Institute (Ioffe Inst.) since June 6 to June 8, 2001. This was the sixth gathering on neutron star physics in St.-Petersburg (after those in 1988, 1992, 1995, 1997, and 1999). Its aim was to bring together scientists interested in physics and astrophysics of neutron stars. All subjects relevant to theory and observations of neutron stars were welcome.

The event gathered about 70 participants from 15 Russian institutions of St.-Petersburg (Ioffe Institute, Pulkovo Observatory, St.-Petersburg State University), Moscow (Sternberg Astronomical Institute, Moscow State University, Institute for Experimental and Theoretical Physics, Lebedev Physical Institute, Astro Space Center of the Russian Academy of Sciences, Astrophysics Institute at the Moscow State Engineering Physics Institute, Institute for Nuclear Research, Space Research Institute, Pushchino Radio Astronomical Observatory), Nizhny Novgorod (Institute of Applied Physics), Yaroslavl (Yaroslavl State University), and Nizhny Arkhyz (Special Astrophysical Observatory). There were also three foreign participants from Copernicus Astronomical Center (Poland) and George Mason University / Naval Research Laboratory (USA).

The three day meeting consisted of 12 sessions. Their main subjects were: radio pulsars; neutron stars as X-ray sources; internal structure and evolution of neutron stars; observations of isolated neutron stars; disks, QPOs, magnitospheres; neutron stars in the Galaxy and beyond; neutrino processes; gamma-ray bursts. The sessions included 9 review talks of 30–40 min. duration and 40 contributed talks (20 min.). In addition, there were 8 poster contributions.

The abstracts and programme were published in the form of a booklet "Programme and Abstracts" (Ioffe Physical Technical Institute, 49 pages, 2001) before the Conference. Two changes appeared in the programme during the Conference: the talk of V.M. Malofeev and O.I. Malov (see p. 31) was not presented and the contribution of A.G. Kuranov, K.A. Postnov and M.E. Prokhorov (see p. 27) was presented as a poster.

The booklet is presented here; it can also be accessed at the Ioffe Institute web pages: <http://www.ioffe.rssi.ru/astro/NS2001/index.html>.

A part of abstracts contain references to the web pages where the reader may find additional information on presentations. A part of abstracts contain references to published articles.

Conference was supported by the Russian Foundation for Basic Research, grant 01-02-26057, plus additional support for young scientists. A help of administration of the Ioffe Institute is also acknowledged. It was generally agreed by participants that Neutron Stars Conference was a useful and productive scientific event; it would be desirable to organize such meetings regularly, presumably once in two years.

The Conference is organized by  
**the Ioffe Physical Technical Institute**

*The Organizing Committee:*

- ◇ **D.A. Varshalovich** (*Chair*, Ioffe Physical Technical Institute, St. Petersburg)
- ◇ R.L. Aptekar (Ioffe Physical Technical Institute)
- ◇ G.S. Bisnovaty-Kogan (Space Research Institute, Moscow)
- ◇ Yu.N. Gnedin (Pulkovo Astronomical Observatory, St. Petersburg)
- ◇ A.V. Ivanchik (Ioffe Physical Technical Institute)
- ◇ A.D. Kaminker (Ioffe Physical Technical Institute)
- ◇ A.B. Koptsevich (Ioffe Physical Technical Institute)
- ◇ K.A. Postnov (Sternberg Astronomical Institute)
- ◇ A.Y. Potekhin (Ioffe Physical Technical Institute)
- ◇ M.E. Prokhorov (Sternberg Astronomical Institute)
- ◇ Yu.A. Shibano (Ioffe Physical Technical Institute)
- ◇ D.G. Yakovlev (Ioffe Physical Technical Institute)

The Conference is held at the Big Hall of the Main Building of the A.F. Ioffe Physical-Technical Institute for three days, from June 6 to June 8, 2001.

*Address:*

Politekhnikeskaya 26, St.-Petersburg 194021 (metro station Politekhnikeskaya)  
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<http://www.ioffe.rssi.ru/astro>

# **PROGRAMME**



**June 6, Wednesday***Session 1. WELCOME and GENERAL*

Chairman: D.A. Varshalovich

**10.00–10.10** D.A. Varshalovich (*Ioffe Institute*). Welcome**10.10–10.50** G.S. Bisnovaty-Kogan (*Space Research Institute*). Phase transitions in stars: stability, pulsations, convective Urca-shells and pre-supernovae**10.50–11.10** A.F. Zakharov (*Institute for Theoretical and Experimental Physics*). From white dwarfs to black holes (70th anniversary of the theory of compact objects)**11.10–11.30** I.V. Panov, F.-K. Thielemann (*Institute for Theoretical and Experimental Physics, University of Basel*). r-process in neutron star mergers and beta-delayed fission**11.30–12.00** *Coffee break**Session 2. RADIOPULSARS*

Chairman: M.E. Prokhorov

**12.00–12.20** A.D. Kuzmin (*Pushchino Radio Astronomy Observatory*). Comparative analysis of radio luminosity of millisecond and normal pulsars**12.20–12.40** I.F. Malov (*Pushchino Radio Astronomy Observatory*). On the pulsed optical emission from radio pulsars**12.40–13.00** V.M. Malofeev, O.I. Malov (*Pushchino Radio Astronomy Observatory*). First detection of pulsed radio emission from an AXP**13.00–13.20** M.V. Popov, V.I. Kondratiev (*Astro Space Centre FIAN*). Observed parameters of microstructure in pulsar radio emission**13.20–13.40** T.V. Smirnova (*Pushchino Radio Astronomy Observatory*). Diffractive scintillations of PSR 0809+74 and PSR 0950+08 at low frequencies**13.40–14.00** V.A. Soglasnov, M.V. Popov, V.I. Kondratiev, S.V. Kostyuk (*Astro Space Centre FIAN*). Giant pulses from radiopulsars**14.00–15.00** *Lunch**Session 3. NEUTRON STARS AS X-RAY SOURCES. Part 1*

Chairman: A.D. Kuzmin

**15.00–15.30** M.G. Revnivtsev, M.R. Gilfanov, E.M. Churazov, R.A. Sunyaev (*Space Research Institute*). Short-term X-ray variability of neutron stars: current status and perspectives**15.30–15.50** S.A. Grebenev, S.V. Molkov, A.A. Lutovinov, R.A. Sunyaev (*Space Research Institute*). X-ray bursts with signs of strong photospheric radius expansion of a neutron star**15.50–16.10** A.A. Lutovinov, S.A. Grebenev, S.V. Molkov (*Space Research Institute*). Review of X-ray bursters in the Galactic Center Region**16.10–16.30** S.V. Molkov, S.A. Grebenev, A.A. Lutovinov (*Space Research Institute*). X-ray spectral variability of the LMXB and Z-source GX340+0**16.30–17.00** *Coffee break**Session 4. NEUTRON STARS AS X-RAY SOURCES. Part 2*

Chairman: S.A. Grebenev

- 17.00–17.20** A.M. Bykov (*Ioffe Physical Technical Institute*). Hard-energy emission from supernova remnants
- 17.20–17.40** A.M. Krassilchtchikov, A.M. Bykov (*Ioffe Physical Technical Institute*). A model of sub-Eddington accretion onto a magnetized neutron star
- 17.40–18.00** A.N. Baushev, G.S. Bisnovatyi-Kogan (*Space Research Institute*). Theoretical interpretation of the X-ray pulsar spectra consisting of several cyclotron harmonics
- 18.00–18.20** A.V. Serber (*Institute of Applied Physics*). Cyclotron scattering with mode switching in accretion column of a magnetized neutron star
- 18.20–18.40** D.I. Kosenko, S.I. Blinnikov, E.I. Sorokina, K.A. Postnov (*Sternberg Astronomical Institute, Institute for Theoretical and Experimental Physics*). X-ray emission from young supernova remnants

### June 7, Thursday

#### Session 5. INTERNAL STRUCTURE AND EVOLUTION

Chairman: I.F. Malov

- 10.00–10.40** P. Haensel (*N. Copernicus Astronomical Center*). Unified equations of state of dense matter and neutron star structure
- 10.40–11.10** D.G. Yakovlev, O.Y. Gnedin, A.Y. Potekhin (*Ioffe Physical Technical Institute Institute of Astronomy*). Thermal relaxation in young and old neutron stars
- 11.10–11.30** A.Y. Potekhin, D.G. Yakovlev (*Ioffe Physical Technical Institute*). Thermal structure and cooling of neutron stars
- 11.30–11.50** A.D. Kaminker, P. Haensel, D.G. Yakovlev (*Ioffe Physical Technical Institute, N. Copernicus Astronomical Center*). Masses of isolated neutron stars and superfluid gaps in their cores: constraints from observations and cooling theory
- 11.50–12.10** K.P. Levenfish, P. Haensel, D.G. Yakovlev (*Ioffe Physical Technical Institute, N. Copernicus Astronomical Center*). Viscous damping of neutron star pulsations
- 12.10–12.30** *Coffee break*
- 11.50–12.10** J.L. Zdunik (*N. Copernicus Astronomical Center, Polish Academy of Sciences*). Accreting strange stars

#### Session 6. POSTERS

Chairman: V.S. Beskin

1. E.V. Derishev, A.A. Belyanin (*Institute of Applied Physics*). Self-sustained neutron haloes in the inner parts of hot accretion disks
2. Yu.N. Gnedin, S.O. Kiikov (*Central (Pulkovo) Astronomical Observatory*). Magnetocavitation mechanism of gamma-ray burst phenomenon
3. D.V. Khangouljan, S.V. Bogovalov (*Astrophysics Institute at the Moscow state Engineering Physics Institute*). Interaction of anisotropic pulsar winds with interstellar medium
4. A.B. Koptsevich, P. Lundqvist, J. Sollerman, Yu.A. Shibano, S. Wagner (*Ioffe Physical Technical Institute, Stockholm Observatory, ESO, University of Heidelberg*). First detection of the Vela pulsar in IR with the VLT

5. E.N. Narynskaya, N.V. Mikheev (*Yaroslavl State University*). Familon emissivity of magnetized plasma
6. S.B. Popov, M.E. Prokhorov (*Sternberg Astronomical Institute*). Evolution of isolated neutron stars in globular clusters: number of accretors
7. M.Yu. Timofeev (*Astro Space Centre FIAN*). Some features of weak and strong pulses of pulsars

**13.40–14.40** *Lunch*

*Session 7. OBSERVATIONS OF ISOLATED NEUTRON STARS*

Chairman: B.V. Komberg

- 14.40–15.10** Yu.A. Shibarov (*Ioffe Physical Technical Institute*). Multiwavelength observations of isolated NSs: thermal emission vs nonthermal
- 15.10–15.30** A.B. Koptsevich, G.G. Pavlov, S.V. Zharikov, V.V. Sokolov, Yu.A. Shibarov, V.G. Kurt (*Ioffe Physical Technical Institute, The Pennsylvania State University, Obs. Astr. Nacional. de Inst. de Astronomia de UNAM, SAO RAS, Astro Space Centre FIAN*). Multiband photometry of the PSR B0656+14 and its neighborhood
- 15.30–15.50** V.N. Komarova, V.G. Kurt, T.A. Fatkhullin, V.V. Sokolov, Yu.A. Shibarov, A.B. Koptsevich (*SAO RAS, Astro Space Centre FIAN, Ioffe Physical Technical Institute*). Multiband photometry of Geminga
- 15.50–16.10** E.I. Chuikin (*Ioffe Physical Technical Institute*). Separation of millisecond and submillisecond pulsations in hard gamma radiation from the Geminga pulsar

**16.10–16.40** *Coffee break*

*Session 8. DISCS, QPOs, MAGNETOSPHERES*

Chairman: K.A. Postnov

- 16.40–17.10** L.G. Titarchuk (*George Mason University and Naval Research Laboratory*). Spectral and timing properties of neutron star and black hole systems. Theory and observations
- 17.10–17.30** Yu.N. Gnedin, S.O. Kiklov (*Central (Pulkovo) Astronomical Observatory*). The origin of QPOs of X-ray binaries
- 17.30–17.50** V.S. Beskin, R.Yu. Kompaneetz (*Lebedev Physical Institute, Moscow Institute of Physics and Technology*). On the 2D structure of a thin accretion disk
- 17.50–18.10** S.V. Bogovalov, F.A. Aharonian (*Astrophysics Institute at the Moscow state Engineering Physics Institute, Max-Planck-Institut für Kernphysik*). Gamma rays from pulsar winds
- 18.10–18.30** D.V. Khangouljan, S.V. Bogovalov (*Astrophysics Institute at the Moscow state Engineering Physics Institute*). Interaction of anisotropic pulsar winds with interstellar medium

## June 8, Friday

*Session 9. NEUTRON STARS IN THE GALAXY AND BEYOND*

Chairman: Yu.N. Gnedin

- 10.00–10.40** A.M. Cherepashchuk (*Sternberg Astronomical Institute*). Wolf-Rayet stars and relativistic objects

**10.40–11.00** M.E. Prokhorov, K.A. Postnov (*Sternberg Astronomical Institute*). Distribution of NS and BH masses and mechanism of SN explosion

**11.00–11.20** S.B. Popov, M.E. Prokhorov, M. Colpi, R. Turolla, A. Treves (*Sternberg Astronomical Institute, University Milano-Bicocca, University of Padova, University of Como*). Isolated neutron stars as X-ray sources: accretion vs. cooling

**11.20–11.40** A.I. Tsygan, V.D. Palshin (*Ioffe Physical Technical Institute*). The manifestations of different acceleration mechanisms of binaries containing neutron stars

**11.40–12.00** A.G. Kuranov, K.A. Postnov, M.E. Prokhorov (*Faculty of Physics, Moscow State University, Sternberg Astronomical Institute*). The evolution of binary stars in a globular cluster

**12.00–12.30** *Coffee break*

*Session 10. NEUTRINO PROCESSES*

Chairman: G.S. Bisnovatyi-Kogan

**12.30–13.00** A.A. Gvozdev, I.S. Ognev (*Yaroslavl State University*). Efficiency of  $e^+e^-$  pair production by neutrinos

**13.00–13.20** A.V. Kuznetsov, M.V. Chistyakov, N.V. Mikheev (*Division of Theoretical Physics, Yaroslavl State University*). Three-vertex loop processes in strong magnetic field

**13.20–13.40** M.V. Chistyakov, N.V. Mikheev (*Yaroslavl State University*). Photon-neutrino processes in a strongly magnetized plasma

**13.40–14.00** D.A. Rumyantsev, A.V. Kuznetsov, N.V. Mikheev (*Yaroslavl State University*). Lepton pair production by high-energy neutrino in an external electromagnetic field

**14.00–15.00** *Lunch*

*Session 11. GAMMA-RAY BURSTS. Part 1*

Chairman: A.M. Cherepashchuk

**15.00–15.30** K.A. Postnov (*Sternberg Astronomical Institute*). Relation of gamma-ray bursts to formation of compact stars

**15.30–15.50** B.V. Komberg, Ya.N. Istomin (*Astro Space Centre FIAN, Lebedev Physical Institute*). GRB as the result of interaction of supernova ejecta with NS companion of a closed binary

**15.50–16.10** D.D. Frederiks (*Ioffe Physical Technical Institute*). Short gamma ray bursts

**16.10–16.30** E.V. Derishev, V.V. Kocharovsky, V.I. Kocharovsky (*Institute of Applied Physics*). On the competition between synchrotron and Compton emission of electrons in relativistic shocks

**16.30–16.50** V.B. Ignatiev, A.G. Kuranov, K.A. Postnov, M.E. Prokhorov (*Faculty of Physics, Moscow State University, Sternberg Astronomical Institute*). Gravitational wave background from coalescing compact stars in eccentric orbits

**16.50–17.20** *Coffee break*

*Session 12. GAMMA-RAY BURSTS. Part 2*

Chairman: Yu.A. Shibano

**17.20–17.50** V.V. Sokolov (*SAO RAS*). On the gamma-ray burst progenitors

**17.50–18.10** T.A. Fatkhullin, V.V. Sokolov (*SAO RAS*). The modeling of spectra of GRB host galaxies

**18.10–18.30** Ya.Yu. Tikhomirova, B.E. Stern, R. Svensson (*Institute for Nuclear Research RAS, Astro Space Centre FIAN, Stockholm Observatory*). Evidence for a strong evolution of GRBs and constraints on the GRB intrinsic luminosity function with new GRB statistical data

**18.30–18.40** D.A. Varshalovich (*Ioffe Institute*). Closing



# **ABSTRACTS**



THEORETICAL INTERPRETATION OF THE X-RAY PULSAR SPECTRA  
CONSISTING OF SEVERAL CYCLOTRON HARMONICS**A.N. Baushev<sup>1</sup>, G.S. Bisnovatyi-Kogan<sup>1</sup>**

<sup>1</sup>*Space Research Institute, 84/32, Profsoyuznaja st., 117810, Moscow, Russia*  
E-mail: abaushev@mx.iki.rssi.ru, gkogan@mx.iki.rssi.ru

The spectrum of cyclotron radiation is calculated for anisotropically distributed relativistic electrons moving with nonrelativistic velocities across the magnetic field. It is shown that if such electrons are responsible for the formation of the “cyclotron” line in the spectrum of Her X-1 then the value of its magnetic field,  $(3-6) \cdot 10^{10}$  G, which results from this interpretation, is in a good agreement with some other observations and theoretical estimates. The case of multi-harmonical cyclotron line is also considered. Observations of temporal variations of the energy of this “cyclotron” line in the spectra of several X-ray pulsars is explained by variability of the average longitudinal energy of electrons, which decreases with increasing luminosity due to radiative deceleration of the accretion flow.

## ON THE 2D STRUCTURE OF A THIN ACCRETION DISK

**V.S. Beskin<sup>1</sup>, R.Yu. Kompaneetz<sup>2</sup>**

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<sup>2</sup>*Moscow Institute of Physics and Technology, Dolgoprudnyi 141700, Russia*  
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The internal structure of a thin accretion disk in the vicinity of a black hole inside the last stable orbit ( $R < 3R_g$ ) is considered within the hydrodynamical version of the Grad-Shafranov equation. It is shown that at any way up to the sonic surface the flow is not radial, the flow parameters in the equatorial region (e.g., the poloidal velocity) differing from those near the disk boundary.

PHASE TRANSITIONS IN STARS: STABILITY, PULSATIONS,  
CONVECTIVE URCA-SHELLS AND PRE-SUPERNOVAE

**G.S. Bisnovatyi-Kogan<sup>1</sup>**

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*E-print: astro-ph/0004281*

The problem of damping of stellar oscillations in the presence of Urca shell is solved analytically in a plane symmetrical approximation. Low amplitude oscillations are considered. Oscillatory pressure perturbations induce beta reactions of the electron capture and decay in a thin layer around the Urca shell, leading to damping of oscillations. Due to nonlinear dependence of beta reaction rates on the pulsation amplitude in a degenerate matter, even a low amplitude oscillation damping follows a power-law. It is shown that in the presence of the Urca shell the energy losses due to neutrino emission, and the entropy increase due to non-equilibrium beta reactions are much lower than the rate of decrease of the energy of pulsations by excitation of short-wavelength acoustic waves. Dissipation of the vibrational energy by the latter process is the main source of heating of matter. Convective motion in the presence of the Urca shell is considered, and equations generalizing the mean free path model of convection are derived. Convective motion is a source of both energy losses due to Urca reactions in the shell, and nonequilibrium beta heating of degenerate matter. This problem is closely related to thermal stability and boundary of SN type I explosions. Only self-consistent evolutionary calculations may clarify the effect of convective Urca-shell on the thermal stability of the pre-SN model.

## GAMMA RAYS FROM PULSAR WINDS

**S.V. Bogovalov<sup>1</sup>, F.A. Aharonian<sup>2</sup>**

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<sup>2</sup>*Max-Planck-Institut für Kernphysik, Postfach 103980, D-69029, Heidelberg, Germany*

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*E-print: astro-ph/0003157*

The relativistic winds of pulsars with average Lorentz-factor  $\gamma_W \sim 10^6$  could be directly observed through its inverse Compton (IC)  $\gamma$ -ray emission caused by illumination of the wind by low-frequency photons emitted by the surface of the pulsar and its magnetosphere. Calculations performed for the Crab and Vela pulsars show that even the interaction of the wind electrons with thermal emission of the neutron star gives detectable fluxes of the gamma-ray emission. Comparison of the observations of the Crab pulsar in gamma-rays above 0.5 TeV with calculations gives rather important constraints on the mechanism of the wind acceleration. To avoid overproduction of the pulsed TeV emission from Crab, the wind should be accelerated at a distance exceeding 30 light cylinders in conventional models of radio pulsars. The acceleration of the wind close to the light cylinder is possible only in the presence of rather strong constraints on the mechanisms of generation of soft nonthermal radiation by the pulsar.

## HARD-ENERGY EMISSION FROM SUPERNOVA REMNANTS

**A.M. Bykov<sup>1</sup>**

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*E-print: astro-ph/0010157*

Hard X-ray and gamma-ray emission has been detected from a number of galactic supernova remnants. We discuss relevant processes and models of hard emission production in supernova remnants simultaneously with the results of recent observations of SNRs obtained with CGRO, ASCA, BeppoSAX and XMM-Newton. Implications of the observed spectra of SNRs to test models of pulsar wind nebulae emission as well as the cosmic ray origin problem will be discussed.

## WOLF-RAYET STARS AND RELATIVISTIC OBJECTS

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The observed properties of Wolf-Rayet stars and relativistic objects in close binary systems are analyzed. The final masses  $M_{\text{CO}}^f$  for the carbon-oxygen cores of WR stars in WR+O binaries are calculated taking into account the radial loss of matter via stellar wind, which depends on the mass of the star. The analysis includes new data on the clumpy structure of WR winds, which appreciably decreases the required mass-loss rates  $M_{\text{WR}}$  for the WR stars. The masses  $M_{\text{CO}}^f$  lie in the range  $(1-2)M_{\odot} - (20-44)M_{\odot}$  and have a continuous distribution. The masses  $M_x$  of the relativistic objects are  $(1-20)M_{\odot}$  and have a bimodal distribution: the mean masses for neutron stars and black holes are  $(1.35 \pm 0.15)M_{\odot}$  and  $(8-10)M_{\odot}$ , respectively, with a gap from  $(2-4)M_{\odot}$  in which no neutron stars or black holes are observed in close binaries. The mean final CO-core mass is  $\overline{M}_{\text{CO}}^f = (7.4-10.3)M_{\odot}$ , close to the mean mass for the black holes. This suggests that it is not only the mass of the progenitor that determines the nature of the relativistic object, but other parameters as well — rotation, magnetic field, etc. One SB1R Wolf-Rayet binary and 11 suspected WR+C binaries that may have low-mass X-ray binaries with neutron stars and black holes.

PHOTON-NEUTRINO PROCESSES IN A STRONGLY  
MAGNETIZED PLASMA**M.V. Chistyakov<sup>1</sup>, N.V. Mikheev<sup>1</sup>**<sup>1</sup>*Yaroslavl State University, Sovietskaya 13, 150000, Yaroslavl, Russia**E-mail: mch@univ.uniyar.ac.ru**E-print: hep-ph/9907345*

The effect of strongly magnetized electron-positron plasma on photon-neutrino processes  $\nu \rightarrow \nu\gamma$  and  $\gamma\nu \rightarrow \nu$  is investigated. The amplitudes and probabilities of the processes are calculated taking into account the photon dispersion and large radiative corrections near the resonance. It is shown that the combined effect of plasma and strong magnetic field decreases the probability of the process  $\nu \rightarrow \nu\gamma$  in comparison with the value obtained neglecting the plasma effect. The probability of the process  $\gamma\nu \rightarrow \nu$  does not depend on the initial neutrino energy and is negligibly small in comparison with probability  $W_{\nu \rightarrow \nu\gamma}$  in the low temperature limit.

SEPARATION OF MILLISECOND AND SUBMILLISECOND PULSATIONS  
IN HARD GAMMA RADIATION FROM THE GEMINGA PULSAR**E.I. Chuikin**<sup>1</sup><sup>1</sup>*Ioffe Physical Technical Institute, Politekhnicheskaya 26, St. Petersburg 194021*  
*E-mail: evgeniy.chuikin@pop.ioffe.rssi.ru*

Separation of millisecond and submillisecond pulsations in radiation from the Geminga pulsar (PSR J0633+1746) with “Discrete temporal Fourier series analysis method” on the data base of GAMMA-1 observations (from 30 November 1990 to 2 February 1991) is discussed. The pulsations are analysed also with a “Superposition of epoch method”. Significant pulsations were found within the first peak of the Geminga light curve. Among the strongest ones there are the pulsations with period values 6.1313 ms, 1.7060 ms, 0.3966 ms. As in the previous studies of pulsations of the Vela pulsar, reliability of the results obtained for Geminga was confirmed by the phasogram pattern and phase of the peak being stable throughout the observational set.

ON THE COMPETITION BETWEEN SYNCHROTRON AND COMPTON  
EMISSION OF ELECTRONS IN RELATIVISTIC SHOCKS**E.V. Derishev**<sup>1</sup>, **V.V. Kocharovskiy**<sup>1</sup>, **VI.V. Kocharovskiy**<sup>1</sup><sup>1</sup>*Institute of Applied Physics, 46 Ulyanov st., 603600, Nizhny Novgorod, Russia*  
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We develop a self-consistent theory of the synchrotron-self-Compton emission for optically thin sources with a stationary injection of relativistic mono-energetic electrons. We investigate the electron distribution function, synchrotron and inverse Compton (IC) spectra and find their analytical asymptotes. It is shown that self-consistent steady-state electron distribution may produce a variety of low-energy spectral indices ranging from 1/2 to 1.

The spectrum of comptonized radiation is entangled with low-energy synchrotron emission via the electron distribution. We derive explicit expression allowing one to find IC spectrum by means of the integral transformation of synchrotron spectrum.

Applying this theory to Gamma-Ray Burst sources we find new arguments in favor of synchrotron origin of the observed sub-MeV radiation.

SELF-SUSTAINED NEUTRON HALOES IN THE INNER PARTS  
OF HOT ACCRETION DISKS

**E.V. Derishev<sup>1</sup>, A.A. Belyanin<sup>1</sup>**

<sup>1</sup>*Institute of Applied Physics, 46 Ulyanov st., 603600, Nizhny Novgorod, Russia*  
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We suggest and analyze in detail the possibility of self-sustained neutron halo formation in the vicinity of disk-accreting black hole or neutron star. Initial seed neutrons originate from collisional dissociation of helium in a hot infalling plasma. Once the neutron halo is formed, it becomes “self-sustained”, i.e., supported by collisions of energetic neutrons from the halo with helium nuclei even if the ion temperature in the disk drops below the threshold for He dissociation by protons.

Our analysis shows that the halo formation is possible when the mass accretion rate is below the critical value  $\dot{M}_{max} \sim 5 \cdot 10^{16} M/M_{\odot} \text{ g/s}$ , where  $M$  is the black-hole mass. In this case neutrons accrete slower than ions which leads to the neutron pile-up: the density of neutrons can be much higher than the proton density. Under certain conditions neutrons may diffuse outwards into the cooler part of an accretion disk, leading to enhanced deuterium production accompanied by emission in a relatively narrow 2.2 MeV line.

Neutron halo exists in a broad range of disk parameters and mass accretion rates. We discuss the observability of various dynamical and radiative phenomena related to the existence of neutron halo.

## THE MODELING OF SPECTRA OF GRB HOST GALAXIES

**T.A. Fatkhullin<sup>1</sup>, V.V. Sokolov<sup>1</sup>**

<sup>1</sup>SAO RAS, Nizhny Arkhyz, 357147, Karachai-Cherkessia, Russia  
E-mail: timur@sao.ru

The modeling of some galaxies, where GRBs were detected, is performed. The main parameters of these galaxies (with characteristic color and spectral features of star formation burst): luminosity, mass, mean star formation rate and probable star formation scenario are determined taking into account extinction by dust and gas. It is shown that these galaxies are usual, with higher star formation rate; they are mainly observed in optics at redshifts about 1 and higher.

## SHORT GAMMA RAY BURSTS

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A review of “short GRB” observations with Konus instruments is given. An observational base of this intriguing class of bursts contains now more than 100 events. General properties of short GRBs are considered in comparison with long events. Some interesting bursts are discussed in detail.

## THE ORIGIN OF QPOs OF X-RAY BINARIES

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We present three mechanisms of generation of X-ray quasi-periodic oscillations (QPOs) in binaries. Two of them are based on the analogy to nonlinear oscillations of gaseous caverns in liquid. The first mechanism is called magnetocavitation; it implies that X-ray QPOs of a neutron star are produced by radial oscillations of the neutron star magnetosphere interacting with accreting plasma. To study X-ray QPOs of neutron stars with critical (Eddington) luminosity, the photon-cavitation mechanism has been considered. In this case X-ray QPOs of the neutron star are generated by radial oscillations of photon caverns in a fully ionized hydrogen plasma settling in the accreting column of the compact object. To explain X-ray QPOs of binaries with a black hole and cataclysmic variables we suggest the mechanism according to which X-ray QPOs are caused by nonlinear oscillations of current sheets originating in accreting disks. The calculated values of basic physical parameters of QPOs such as basic frequencies, frequency and amplitude dependence on the X-ray flux level and the energy of photons and also on QPOs lag time of photons of different energies are consistent with the observational data.

## MAGNETOCAVITATION MECHANISM OF GAMMA-RAY BURST PHENOMENON

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We consider the phenomenon of a gamma-ray burst as a nonlinear collapse of a magnetic cavity surrounding a neutron star with huge magnetic field due to the bubble shape instability in a resonant MHD field of an accreting plasma or a plasma on the neutron star surface. The QED effect of vacuum polarizability by a strong magnetic field is taken into consideration. We develop the analogy with the phenomenon of sonoluminescence in which the gas bubble is located in surrounding liquid with a driven sound intensity.

X-RAY BURSTS WITH SIGNS OF STRONG PHOTOSPHERIC RADIUS  
EXPANSION OF A NEUTRON STAR**S.A. Grebenev<sup>1</sup>, S.V. Molkov<sup>1</sup>, A.A. Lutovinov<sup>1</sup>, R.A. Sunyaev<sup>1</sup>**<sup>1</sup>*Space Research Institute, 84/32, Profsoyuznaja st., 117810, Moscow, Russia**E-mail: sergei@hea.iki.rssi.ru**E-print: astro-ph/0005082*

We present results of the GRANAT/ART-P and RXTE/PCA observations of several X-ray bursts with obvious signs of strong photospheric radius expansion (precursors and dips in profiles, delayed rise phase, etc). In particular, the photospheric radius exceeded 70 km during an intense X-ray burst detected from the source 1E1724-307 in the globular cluster Terzan 2. After the precursor which was comparable in strength with the main event the flux from the source fell below the persistent level. The very narrow precursor was detected in the profile of a long ( $\sim 10$  min) X-ray burst observed from GX17+2. We analyze correlations in the effective temperature and radius of the photosphere in these and other X-ray bursters and note that Comptonization may be responsible for the detected features. To describe in detail spectral evolution of the source during the burst a number of model spectra were computed taking into account both Comptonization and free-free absorption in the outer layers of the photosphere.

EFFICIENCY OF  $e^+e^-$  PAIR PRODUCTION BY NEUTRINOS**A.A. Gvozdev<sup>1</sup>, I.S. Ognev<sup>1</sup>**<sup>1</sup>*Yaroslavl State University, Sovetskaya 13, 150000, Yaroslavl, Russia**E-mail: gvozdev@univ.uniyar.ac.ru*

The dominating processes of the neutrino production and  $e^+e^-$ -pair creation by such neutrinos are investigated in the model of hyper-accreting disk around a Kerr black hole. These processes are studied both in vacuum and in the presence of strong magnetic field. It is shown that the efficiency of  $e^+e^-$ -plasma production is too small to explain the origin of cosmological GRBs.

UNIFIED EQUATIONS OF STATE OF DENSE MATTER AND  
NEUTRON STAR STRUCTURE

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Unified equation of state (EOS) describes in a physically consistent way neutron star matter within the crust and the liquid core, and is based on a single nuclear hamiltonian,  $\hat{H}_N$ . To make a solution of the nuclear many-body problem feasible, one uses an effective nuclear hamiltonian,  $\hat{H}_N^{\text{eff}}$ . It has to reproduce the ground state properties of laboratory nuclei, in particular of those with a large neutron excess, and to give correct saturation parameters of nuclear matter. Additional conditions, relevant for correct description of very neutron-rich matter in neutron stars have to be also imposed on  $\hat{H}_N^{\text{eff}}$ . Two examples of  $\hat{H}_N^{\text{eff}}$  are: an older FPS (Friedman-Pandharipande-Skyrme) model (Pandharipande & Ravenhall 1989), and a recent SLy (Skyrme-Lyon) one (Chabanat et al. 1997, 1998). Corresponding unified EOSs were calculated, assuming ground state,  $T=0$ , for the crust matter, and simplest (minimal)  $npe\mu$  composition of the liquid core: FPS EOS (Lorenz et al. 1993), SLy EOS (Douchin & Haensel 2000, 2001). Properties of the bottom layers of the neutron star crust will be discussed, with particular emphasis on the crust core interface (Douchin et al., Douchin & Haensel 2000). Neutron star models, calculated using these EOSs (Douchin & Haensel 2001), will be reviewed. In particular, properties of equilibrium configurations near minimum mass (Haensel, Zdunik, Douchin 2001), will be studied, and related to the specific features of the EOS near crust-core interface. Effects of rotation on both  $M_{\text{max}}$  and  $M_{\text{min}}$ , and on the mass-radius curves (Haensel, Zdunik, Douchin 2001) will be briefly reviewed. Finally, parameters of neutron star models will be confronted with available observational data (Douchin & Haensel 2001, Haensel 2001).

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## GRAVITATIONAL WAVE BACKGROUND FROM COALESCING COMPACT STARS IN ECCENTRIC ORBITS

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Stochastic gravitational wave background produced by a stationary coalescing population of binary neutron stars in the Galaxy is calculated. This background is found to constitute a confusion limit within the LISA frequency band up to a limiting frequency  $\nu_{lim} \sim 10^{-3}$  Hz, leaving the frequency window  $\sim 10^{-3}$ – $10^{-2}$  Hz open for potential detection of cosmological stochastic gravitational waves.

## MASSES OF ISOLATED NEUTRON STARS AND SUPERFLUID GAPS IN THEIR CORES: CONSTRAINTS FROM OBSERVATIONS AND COOLING THEORY

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We present the results of new cooling simulations of neutron stars under the assumption that stellar cores consist of neutrons, protons and electrons. We assume further that nucleons may be in a superfluid state and use realistic density profiles of superfluid critical temperatures  $T_{cn}(\rho)$  and  $T_{cp}(\rho)$  of neutrons and protons. Taking a suitable profile of  $T_{cp}(\rho)$  with maximum  $\sim 5 \times 10^9$  K we obtain smooth transition from slow to rapid cooling with increasing stellar mass. Adopting the same profile we can explain the majority of observations of thermal emission from isolated middle-aged neutron stars by cooling of neutron stars with different masses either with no neutron superfluidity in the cores or with a weak superfluidity,  $T_{cn} < 10^8$  K. The required masses depend sensitively on the decreasing slope of the  $T_{cp}(\rho)$  profile at  $\rho \sim 10^{15}$  g cm<sup>-3</sup>. For one particular model  $T_{cp}(\rho)$  profile the masses range from  $\sim 1.2 M_{\odot}$  for (young and hot) RX J0822–43 and (old and warm) PSR 1055–52 and RX J1856–3754 to  $\approx 1.45 M_{\odot}$  for the (rather cold) Geminga and Vela pulsars. Shifting the decreasing slope of  $T_{cp}(\rho)$  profile to higher densities we may obtain higher masses of the same sources. This gives a new method to constrain neutron star masses and superfluid critical temperatures in the stellar cores.

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INTERACTION OF ANISOTROPIC PULSAR WINDS  
WITH INTERSTELLAR MEDIUM

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The objective of the work is to explain the morphology of X-ray plerions around the Crab and the Vela pulsars observed with the Chandra telescope. The X-ray plerions consist of toroidal structure and jet-like features directed along the axis of rotation. We assume that the observed structures are produced due to interaction of the anisotropic relativistic winds ejected by radio pulsars with interstellar medium. MHD models of the wind formation predict that the energy flux in the wind is concentrated at the equatorial region. For one of the simplest distributions of the energy flux in the wind we have calculated the shape of the terminating shock wave and compare it with observations.

MULTIBAND PHOTOMETRY OF GEMINGA

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The results of Geminga's investigation with the aid of BVRI-photometry based on observations with the 6 m telescope are presented. The obtained Geminga's magnitudes B ( $26.1 \pm 0.5$ ), V ( $25.3 \pm 0.3$ ) and  $R_c$  ( $25.4 \pm 0.3$ ) are consistent with the results of other studies of its optical emission in this spectral range. We derive for the first time the magnitude in  $I_c$ -band to be  $25^m.1 \pm 0.4$ , which is more than a magnitude higher if compared with the upper limit given in the paper by Bignami et al. (1996). The comparison of the broadband spectra of this middle-aged isolated neutron star with the results of observations in X-rays and hard ultraviolet allows us to assume the presence of the features probably of nonthermal character in Geminga's emission at least in some regions of the visible spectrum.

GRB AS THE RESULT OF INTERACTION OF SUPERNOVA EJECTA  
WITH NS COMPANION OF A CLOSED BINARY**B.V. Komberg<sup>1</sup>, Ya.N. Istomin<sup>2</sup>**<sup>1</sup>*Astro Space Centre FIAN, 117810, Moscow, Russia*<sup>2</sup>*Lebedev Physical Institute, 142292, Moscow, Russia**E-mail: bkomberg@ASC.rssi.ru*

The supernova explosion (I b/c or I bw type) in a closed binary (with separation of  $10^{13}$  cm) can produce magnetospheric flare possessing the properties of a GRB. According to our estimates, the NS magnetosphere intercepts  $10^{-11}$  of the full kinetic energy of the blast wave ( $10^{47}$  ergs). Extended magnetospheric tail ( $10^{10}$  cm) with the mean magnetic field  $10^6$  Gauss is the source of gamma-rays ejected into a small solid angle (0.1 rad). This radiation has the synchrotron nature being produced by accelerated particles ( $E \sim 1$  Gev). Fast electrons appear as a result of the magnetic field reconnection in the current layer, directed along the shock velocity. Such a model explains naturally high anisotropy of gamma-ray emission and connection of GRBs with phenomena of compact SNe.

## FIRST DETECTION OF THE VELA PULSAR IN IR WITH THE VLT

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We report detection of the Vela pulsar in near-infrared during observation performed with VLT/ISAAC on December 2000 – January 2001. The pulsar is clearly identified at the images in J and H bands. Preliminary estimations show that the emission is of nonthermal origin. By this detection Vela starts to be a forth member of a small family of radio pulsars (Crab, Geminga, and PSR B0656+14) detected in infrared.

MULTIBAND PHOTOMETRY OF THE PSR B0656+14  
AND ITS NEIGHBORHOOD

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We present the results of broad-band photometry of the nearby middle-aged radio pulsar PSR B0656+14 and its neighborhood obtained with the 6-meter telescope of the SAO RAS and with the *Hubble Space Telescope*. The broad-band spectral flux  $F_\nu$  of the pulsar decreases with increasing frequency in the near-IR range and increases with frequency in the near-UV range. The increase towards UV can be naturally interpreted as the Rayleigh-Jeans tail of the soft thermal component of the X-ray spectrum emitted from the surface of the cooling neutron star. Continuation of the power-law component, which dominates in the high-energy tail of the X-ray spectrum, to the IR-optical-UV frequencies is consistent with the observed fluxes. This suggests that the non-thermal pulsar radiation may be of the same origin in a broad frequency range from IR to hard X-rays. We also studied 4 objects detected within 5'' from the pulsar.

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X-RAY EMISSION FROM YOUNG SUPERNOVA REMNANTS

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We present the results of hydrodynamical simulations of the Tycho SN remnant. Our model is one-dimensional and spherically symmetrical but it takes into account kinetics and various types of radiative transfer. We can obtain detailed theoretical X-ray luminosity profiles of the remnant in different lines (silicon and iron) and compare it with the observational results. There are several models of type Ia SNe with different abundances and density profiles, so we could make an assumption about progenitor of the Tycho SN and choose the most viable model.

## A MODEL OF SUB-EDDINGTON ACCRETION ONTO A MAGNETIZED NEUTRON STAR

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A non-stationary one-dimensional collisionless two-fluid model of sub-Eddington accretion onto a magnetized neutron star is developed to be used for modeling of hard emission from X-ray binaries. Temporal evolution of accreting flows is studied for a range of accretion rates and magnetic fields within a first-order Godunov scheme with source terms splitting. Strong shocks accompanied by hot plasma regions are found to develop on timescales of about  $10^{-5}$  s; they are stable up to  $10^{-2}$  s or even longer. Hard emission from the hot regions may be detected by modern X-ray and gamma-ray missions. In this way parameters of the model may be constrained and typical physical conditions in the flow revealed.

## THE EVOLUTION OF BINARY STARS IN A GLOBULAR CLUSTER

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We present a model for the evolution of binary populations in a globular cluster. The evolution of a population of close binaries is traced in a collisional environment of evolving single stars. We consider primordial binaries, formed simultaneously with the single stars, as well as tidally captured binaries formed from encounters between stars. Any binary evolves due to internal processes (e.g. evolution of its components, stellar winds, mass transfer, etc.) and due to encounters with single stars of the clusters. We trace individual histories of all binaries under the action of different physical processes, such as mass segregation, scattering recoil, escape from the cluster. The results of our calculations can be applied to study formation and evolution of LMXBs and millisecond pulsars in globulars.

COMPARATIVE ANALYSIS OF RADIO LUMINOSITY  
OF MILLISECOND AND NORMAL PULSARS

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We present the results of comparative analysis of the integral radio luminosity of the millisecond and normal pulsars.

Analysis is based on our measurements of the flux densities, spectra and integral luminosities of 30 millisecond pulsars and on the data, borrowed from the literature, which allows us to construct the integral radio luminosities of 485 “normal” pulsars.

We find that contrary to the great difference of millisecond and “normal” pulsars in spin periods  $P$ , period derivatives  $\dot{P}$ , magnetic field strengths  $B$ , and characteristic ages  $\tau$ , the integral radio luminosities of these two pulsar populations are nearly equal. The same is true for their dependences on  $P, \dot{P}, B, \tau$  and on losses of the kinetic energy  $\dot{E}$ .

We find that the integral luminosities of both millisecond and “normal” populations of pulsars are nearly proportional to the parameter  $B/P^2$ , which characterizes potential difference between the base and the top of the gap of a polar cap.

We suggest that millisecond and “normal” pulsars have similar mechanism of radio emission, in which energetic properties are controlled by the potential difference between the base and the top of the gap of the polar cap.

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## THREE-VERTEX LOOP PROCESSES IN STRONG MAGNETIC FIELD

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A general analysis of the three-vertex loop amplitude in very strong magnetic field, based on the asymptotic form of the electron propagator in the strong field, is performed. In order to investigate the photon-neutrino process  $\gamma\gamma \rightarrow \nu\bar{\nu}$  and the photon splitting  $\gamma \rightarrow \gamma\gamma$ , the vertex combinations of the scalar–vector–vector (*SVV*), pseudoscalar–vector–vector (*PVV*), 3–vector (*VVV*), and axial-vector–vector–vector (*AVV*) types are considered. It is shown that only the *SVV* amplitude grows linearly with the magnetic field strength, while in the other amplitudes, *PVV*, *VVV*, and *AVV*, the linearly growing terms are exactly canceled. The process  $\gamma\gamma \rightarrow \nu\bar{\nu}$  is investigated in the left-right-symmetric extension of the standard model of electroweak interaction, where the effective scalar  $\nu\bar{\nu}ee$  coupling is possible. Using the *VVV* amplitude, the process of the photon splitting  $\gamma \rightarrow \gamma\gamma$  is investigated both below and above the pair creation threshold. The splitting probability is calculated taking account of the photon dispersion and large radiative corrections near the resonance. Possible astrophysical manifestations of the considered processes are discussed. Some previous results were published in the references below.

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## VISCIOUS DAMPING OF NEUTRON STAR PULSATIONS

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Bulk and shear viscosities of matter in neutron star cores composed of nucleons, hyperons and/or quarks are discussed taking into account the effects of superfluidity of various particle species. The bulk viscosity of nonsuperfluid matter is enhanced by 4–5 orders of magnitude if direct Urca process of neutrino emission is open, and it is further enhanced by several orders of magnitude in the presence of hyperons and quarks. Strong superfluidity of matter may greatly dump the bulk viscosity. Viscous damping times of neutron star pulsations (particularly, r-modes) are shown to be very sensitive to composition and superfluid properties of dense matter. In particular, this is crucial for gravitational radiation driven instabilities.

## REVIEW OF X-RAY BURSTERS IN THE GALACTIC CENTER REGION

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Results of observations of X-ray bursters in the Galactic Center region carried out with the RXTE observatory and the ART-P telescope on board GRANAT are presented. Eight X-ray bursters (A1742-294, SLX1744-299/300, GX3+1, GX354-0, SLX1732-304, 4U1724-307, KS1731-260) were studied in this region during five series of observations which were performed with the ART-P telescope in 1990-1992 and more than 100 type I X-ray bursts from these sources were observed. For each of the sources we investigated in detail the recurrence times between bursts, the bursts time profiles and their dependence on the bursts flux, the spectral evolution of source emission in the persistent state and during bursts. Two bursters (SLX1732-304, 4U1724-307) located in the globular clusters Terzan 1 and 2 were investigated also using the RXTE data.

## ON THE PULSED OPTICAL EMISSION FROM RADIO PULSARS

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The formula for a radio pulsar luminosity associated with synchrotron emission of the primary beam is obtained. The formula is based on the model of an emitting torus at the light cylinder and on the solution of the kinetic equation for pitch-angle distribution of relativistic particles. The high correlation between the observed optical luminosity of radio pulsars and the parameter  $\dot{P}/P^4$  is found:  $\log\left(\frac{L_{opt}}{L_{Crab}}\right) = (1.30 \pm 0.19) \log \dot{P}_{-14}/P^4 - 4.21 \pm 1.02$  (the correlation coefficient  $\rho = 0.97 \pm 0.14$ ). Here  $P$  is the pulsar period,  $\dot{P}$  is its derivative. This correlation allows one to predict possible optical emission from several dozens of pulsars (in particular, from all pulsars with  $P < 0.1$  sec). Comparison of this prediction with multiwavelength observations of radio pulsars shows that the predicted list contains all 27 known emitters of hard radiation. The shift of maximum frequency in the synchrotron spectrum to higher frequencies with decreasing period  $P$  is predicted. This prediction is in agreement with data for the same 27 pulsars. The obtained results show that the synchrotron model describes the main properties of non-thermal optical and harder emission of radio pulsars.

## FIRST DETECTION OF PULSED RADIO EMISSION FROM AN AXP

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We report on the discovery and some investigations of pulsed radio emission with period 6.98 s from the anomalous X-ray pulsar (AXP) 1E 2259+586. The observations were made from March 1999 to April 2001 at 111.5 MHz with the Large Phased Array in Pushchino. The mean flux density is about 70 mJy, the integrated profile is narrow and its width at 50 percent of maximum intensity is approximately 120 ms. The dispersion measure is  $80 \pm 5$  pc  $\text{cm}^{-3}$  that gives the distance to the pulsar of about 3.6 kpc. This value is confirmed with the estimation of the distance to SNR G109.1–1.0 (3.6 – 4.7 kpc) with the X-ray - bright central pulsar 1E 2259+586.

## X-RAY SPECTRAL VARIABILITY OF THE LMXB AND Z-SOURCE GX340+0

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We present the results of analysis of the PCA/RXTE data obtained during long ( $\sim 390$  ks) pointing towards the Z-source GX 340+0. The complete Z track has been traced out for this source in the color-color diagram. For the analysis we separated the whole set of data (24 separate observations) in 16-s time segments and accumulated X-ray spectra for each of the segments. We studied spectral behaviour of the source as a function of its position in the color-color diagram. In general the spectra could not be fitted with any simple model. We used two-component model: bremsstrahlung plus black-body with fixed photoelectric absorption. Our analysis reveals that the role of black-body emission increases during transition from the horizontal branch of Z track to the flared branch.

## FAMILON EMISSIVITY OF MAGNETIZED PLASMA

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Emission of familons in the processes  $e^- \rightarrow e^- + f$ ,  $e^- \rightarrow \mu + f$  in a magnetized plasma is investigated in the model in which familons either have or have not direct coupling to leptons via plasmon. Contributions of the lowest and excited Landau levels are analyzed. The differential probabilities and integral familon effect on the plasma are calculated. It is shown that in the process  $e^- \rightarrow \mu + f$  P – odd interference phenomenon leads to familon force acting on plasma along the magnetic field.

## DYNAMIC EFFECTS IN A COLLAPSTAR ENVELOPE DUE TO NEUTRINO PROPAGATION THROUGH A STRONGLY MAGNETIZED PLASMA

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Dominated neutrino-nucleon processes in a supernova remnant around a collapsing star with a strong magnetic field are investigated. The asymmetry of the envelope along the field direction produced by neutrino momentum transfer is calculated. It is shown that in the toroidal magnetic field these processes can develop a torque which quickly spins up the envelope. The influence of neutrino “spin-up” effect on dynamics of the collapsar envelope is discussed and numerically estimated.

## R-PROCESS IN NEUTRON STAR MERGERS AND BETA-DELAYED FISSION

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The studies of beta-delayed fission in r-process have a long history, but they have mainly been focused on cosmochronometers. It has been thought that its effect has small influence on the majority of r-process products, taken into account realistic fission barriers. For that reason the majority of investigations of the r-process employed beta-delayed fission of transuranium nuclei in a very simplified manner:  $P_{\beta df} \equiv P_{sf} = 1$  for all  $A > A_{fiss}$  (see [1] and references therein).

That is why reliability of both, beta-delayed fission rates (first of all, for cosmochronology) and mass distribution of fission products (important mainly for formation of nuclei with mass numbers  $A < 130$  [2]), has not been studied. In this work we make an attempt to solve these problems numerically. The kinetic network [3] calculations of r-process for conditions in neutron star mergers [4] have been performed. Different theoretical beta-delayed fission probabilities have been used, and different mass distributions of fission products have been considered.

Calculations with different fission rates show strong dependence on theoretical physics input. Our calculations give better agreement with observations, first of all in relative yields for peaks  $A \approx 130, 196$  and for nuclei with  $Z \approx 44-48$ . The problem of realistic mass distribution of nuclear fission products is still open because of poor knowledge of fission of very neutron rich transuranium nuclei. However there are some indications from both, nuclear physics and astrophysical observations [5], that asymmetric fission should be the main fission mechanism. The masses of fission products have to be determined taking into account shell effects. Preliminary results show significant dependence of the yields of nuclei-cosmochronometers from different fission data involved in calculations. Comparison of the results with observations of r-elements in very metal poor stars may help to find limits on probable mass distribution of fission products.

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OBSERVED PARAMETERS OF MICROSTRUCTURE  
IN PULSAR RADIO EMISSION

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The microstructure of several bright pulsars was investigated with a time resolution of 62.5 ns. The pulsars were observed with the 70-m NASA/DSN radio telescope at Tidbinbilla, Australia, at a frequency of 1650 MHz. Histograms of microstructure time scales show steep increase toward shorter time scales followed by a sharp cutoff at about 5 – 10  $\mu$ s. The shortest micropulse detected has a width of 2  $\mu$ s. No unresolved nanopulses or pulse structure with submicrosecond time scale were found. The statistics of the micropulses and their quasi-periodicities differ significantly for two components of PSR B1133+16. Microstructure quasi-periodicities are most likely unrelated to any modes of vibrations of neutron stars.

ISOLATED NEUTRON STARS AS X-RAY SOURCES:  
ACCRETION VS. COOLING

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We briefly review observational appearance of isolated neutron stars which are not observed as normal radio pulsars.

In some details we discuss dim X-ray sources in globular clusters. We present a simple population synthesis model of old isolated neutron stars in globular clusters to test suggestion made by Pfahl and Rappaport (2000), that these objects are powered by accretion of interstellar medium onto isolated neutron stars.

We discuss different interpretations (cooling vs. accretion) of 7 dim ROSAT sources ("The Magnificent Seven"). Log N- Log S distribution of accreting and cooling neutron stars is obtained. We suggest, that most of these sources are young cooling neutron stars. Otherwise magnetic field decay is necessary.

Influence of investigation of neutron stars in dim X-ray sources on nearby fields of astrophysics is briefly mentioned.

EVOLUTION OF ISOLATED NEUTRON STARS IN GLOBULAR CLUSTERS:  
NUMBER OF ACCRETORS**S.B. Popov<sup>1</sup>, M.E. Prokhorov<sup>1</sup>**<sup>1</sup>*Sternberg Astronomical Institute, Universitetskij pr. 13, 119899, Moscow, Russia**E-mail: polar@sai.msu.ru**Web: <http://xray.sai.msu.ru/~polar/>**E-print: astro-ph/0102201*

With a simple model from the point of view of population synthesis we try to verify an interesting suggestion made by Pfahl & Rappaport (2000) that dim sources in globular clusters (GCs) can be isolated accreting neutron stars (NSs). Simple estimates show, that we can expect about 0.5 – 1 accreting isolated NS per typical GC with  $M = 10^5 M_{\odot}$  which agrees with observations. Properties of old accreting isolated NSs in GCs are briefly discussed. We suggest that accreting NSs in GCs experienced significant magnetic field decay.

## RELATION OF GAMMA-RAY BURSTS TO FORMATION OF COMPACT STARS

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We review current observational evidence and theoretical considerations on formation of relativistic compact stars during cosmic gamma-ray bursts.

## THERMAL STRUCTURE AND COOLING OF NEUTRON STARS

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Thermal structure of neutron stars with magnetized envelopes is studied using modern physics input – in particular, updated thermal conductivity of a dense magnetized plasma typical for neutron-star envelopes [1]. The relation between the internal ( $T_{\text{int}}$ ) and local surface temperatures is calculated and fitted by analytic expressions for magnetic field strengths  $B$  from 0 to  $10^{16}$  G and arbitrary inclination of the field lines to the surface. The luminosity of a neutron star with dipole magnetic field is calculated and fitted as a function of  $B$ ,  $T_{\text{int}}$ , stellar mass and radius.

In addition, we simulate cooling of neutron stars with magnetized envelopes, using the modern cooling code [2]. In particular, we analyse magnetic field effects in the ultramagnetized envelopes of magnetars on the cooling curves. Finally, we demonstrate that the magnetic field of the Vela pulsar strongly affects observational constraints on the values of critical temperatures of neutron and proton superfluids in its core.

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DISTRIBUTION OF NS AND BH MASSES  
AND MECHANISM OF SN EXPLOSION**M.E. Prokhorov<sup>1</sup>, K.A. Postnov<sup>1</sup>**<sup>1</sup>*Sternberg Astronomical Institute, Universitetskij pr. 13, 119899, Moscow, Russia**E-mail: mike@sai.msu.ru*

The observed distribution of masses of compact remnants of massive star evolution (neutron stars and black holes) is analysed and its relation with plausible core collapse supernova mechanisms is discussed. It is argued that the observed absence of compact stars with masses  $1.5\text{--}3.0 M_{\odot}$  is in favor of the magnetorotational mechanism of supernova explosion and soft equation of state of neutron star matter with a limiting mass near  $1.5 M_{\odot}$ . Observational consequences of this hypothesis are discussed.

SHORT-TERM X-RAY VARIABILITY OF NEUTRON STARS:  
CURRENT STATUS AND PERSPECTIVES

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The black holes and neutron stars are the fastest objects in the Universe. From the very beginning of X-ray astronomy there was a search for the shortest timescales in the X-ray variability of these compact objects. The great recent improvement in this topic was made with the help of Rossi X-ray Timing Explorer observatory. In this talk I would like to describe our latest results on the high frequency continuum variability of black holes and neutron stars. A special attention will be paid to the different patterns of X-ray variability of black holes and neutron stars at hundreds of Hz and to the continuum noise of compact objects at the highest available frequencies – up to  $\sim 30$  kHz.

LEPTON PAIR PRODUCTION BY HIGH-ENERGY NEUTRINO  
IN AN EXTERNAL ELECTROMAGNETIC FIELD

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The process of the lepton pair production ( $e^-e^+$ ,  $e^-\mu^+$ , ...) by a neutrino propagating in an external electromagnetic field is investigated in the framework of the standard model. Relatively simple exact expression for the probability of the process as the one-dimensional integral is obtained; it is suitable for a quantitative analysis.

CYCLOTRON SCATTERING WITH MODE SWITCHING IN ACCRETION  
COLUMN OF A MAGNETIZED NEUTRON STAR

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We consider scattering of cyclotron radiation at the first harmonic in a rarefied plasma near a neutron star with a dipole magnetic field. It is assumed that the case of strongly inhomogeneous magnetic field is realized, i.e., the size of the plasma region is large compared to the size of gyroresonance layer in the neutron-star magnetic field. This case is analyzed under the conditions that normal-wave polarization at the first harmonic is determined by vacuum birefringence and the efficient switching of the linearly-polarized ordinary and extraordinary modes takes place due to the cyclotron scattering at the first harmonic. The obtained solution of the corresponding equation of cyclotron-radiation transfer reveals that the cyclotron scattering with mode switching leads to an efficient depolarization of radiation outgoing from an optically thick gyroresonance layer.

MULTIWAVELENGTH OBSERVATIONS OF ISOLATED NSs:  
THERMAL EMISSION VS NONTHERMAL

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Multiwavelength observations are important tool to study the properties of thermal emission from cooling surfaces of isolated neutron stars (NSs), to distinguish thermal emission from nonthermal emission of their magnetospheres, to understand the mechanisms of the magnetospheric radiation in different wave bands, and to investigate structure and properties of pulsar nebulae forming due to interaction of NSs with ambient matter. A wealth of new information on the multiwavelength radiation from radio pulsars as well as from radio quiet isolated NSs has been obtained in recent years year with the Chandra and XMM-Newton X-ray observatories, HST, and new generation of large ground based optical telescopes VLT and Subaru. We review recent results obtained in a wide frequency range, from IR, through optical, X-ray, to gamma-ray bands, discuss their implications, and prospects of further studies of isolated NSs.

DIFFRACTIVE SCINTILLATIONS OF PSR 0809+74 AND  
PSR 0950+08 AT LOW FREQUENCIES**T.V. Smirnova**<sup>1</sup>

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Low frequency individual pulse observations were carried out for the pulsars PSR 0809+74 and PSR 0950+08 in the range from 64 to 111 MHz. Frequency - time structure of emission was studied to separate internal (due to pulsar) and external intensity variations due to electron density irregularities in the interstellar plasma. We report characteristic time and frequency scales of these variations at low frequencies.

## GIANT PULSES FROM RADIOPULSARS

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There are two pulsars, where remarkable phenomenon of "giant pulses" is observed: the Crab pulsar and the millisecond pulsar B1937+21. We present new results of our high time resolution observations of giant pulses from these pulsars. The events with extremely high flux, 300 000 Jy (Crab) and 65 000 Jy (1937+21), were detected. Many properties of giant pulses become rather unexpected (for instance, a very short - nanosecond - duration of GP from 1937+21), they are important for understanding physics of neutron star magnetosphere.

## ON THE GAMMA-RAY BURST PROGENITORS

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The recent observational data show that collapse of massive stars is a more preferable scenario to produce so-called long-duration GRBs, than naive expectations on merging of binary compact objects, which (the NS+NS scenario) appeared before the first determination of redshifts, measurements of spectra and images. Observed location distribution of variable optical sources, or optical transients (OT GRB), relative to their host galaxies allows us to suppose that GRB sources are associated with vigorous massive star-forming in distant galaxies: spiral, irregular, blue compact and others with transient burst of star formation in them. At least some OT GRBs can be located directly in star-forming regions (or in their vicinities) of these galaxies in which (massive) star formation rate is tens times higher than in the same galaxies in the local Universe. In addition to the characteristic “knee” on the light curve of OT GRB 970508 revealed by *I*-band photometric observations with the 6-m telescope, more evidences (GRB 970228, GRB 980326, 990712, 991208) of link between GRBs and Type Ib/c SNe (or core-collapse SNe) were found, which can be an additional argument in favor of the idea of massive stars as progenitors of cosmic gamma-ray bursts. The observations of  $K_{\alpha}$  lines of iron in afterglow X-ray spectra of GRBs (970508, 970828, 991216, 000214) and the observation of redshifted absorption feature of neutral iron (7.1 keV) simultaneously with the GRB 990705 give additional evidence in favor of massive stars as progenitors of GRBs.

EVIDENCE FOR A STRONG EVOLUTION OF GRBs AND  
CONSTRAINTS ON THE GRB INTRINSIC LUMINOSITY FUNCTION  
WITH NEW GRB STATISTICAL DATA

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We present new constraints on the evolution of GRBs sources and on their intrinsic luminosity function obtained with the recent data: the uniform sample of 3300 long GRBs found in the BATSE continuous records and the sample of 17 GRBs with measured redshifts. The latter sample has three GRBs with a very high intrinsic peak photon flux. If we fix the bright end of intrinsic luminosity distribution to these events and allow the rest of the distribution to vary as a broken power law we find: (i) nonevolving population models predict too large number of apparently strong GRBs, they are rejected at the  $10^{-5}$  level; (ii) the decline of the GRBs population from  $z = 1.5$  towards the present epoch is approximately as sharp as the decline of the star production; (iii) the intrinsic luminosity function behaves as  $dN/dP \sim P^{-1.5}$  through at least two orders of magnitude. The evolution of gamma bursters at large redshifts cannot be constrained. The data fit is not sensitive to the cosmological parameters.

## SOME FEATURES OF WEAK AND STRONG PULSES OF PULSARS

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This presentation is based on the observations, which have been made in Effelsberg with the 100-meter radio telescope in April 1994. Recording was produced in the mode of the single pulses registration of five pulsars: PSR 0823+26, PSR 0950+08, PSR 1706–16, PSR 1929+10, PSR 2021+51 at 1.7 GHz with different time resolutions.

The goal of the programme is the investigation of some features of individual pulses. Parameter  $q$  was calculated for any single pulse. To do this, the maximum of intensity inside of pulse ( $I_m$ ) was found for any pulse and it was normalized by r.m.s. calculated outside the pulse. Single radio pulses were divided into groups according to the values of  $q$ , and thus average profiles of total intensity in the chosen region were calculated.

It is discovered that the width of an average profile of total intensity emission decreases while  $q$  increases. Also we have obtained some time shifts between average profiles with different  $q$ . Then Gaussian fits were made for any pulsar profile and the time shift and width parameters were refined.

The explanation of these effects can be the following. Pulsar radiation is generated in a magnetospheric layer. Strong pulses are generated at the inner side of the layer, close to the pulsar surface, where generation of the plasma oscillations may be expected. As the height increases, the synchronization condition is violated which leads to the emission of weaker pulses.

SPECTRAL AND TIMING PROPERTIES OF NEUTRON STAR AND  
BLACK HOLE SYSTEMS. THEORY AND OBSERVATIONS**L.G. Titarchuk**<sup>1</sup>

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I present continued development of a new theoretical paradigm, the Transition Layer Model (TLM), for explaining features of power density spectra (PDS) in accreting neutron stars and black holes. The prevailing model for all accreting neutron stars has been that an ionized disk extends inward in the equatorial plane until it encounters the magnetosphere at the Alfvén radius, inside which MHD effects govern the structure and flow. This paradigm was developed originally for binary pulsars. An attempt was made to extend it to low-mass binary systems (LMXBs) started after discovery of QPOs by EXOSAT. The attempted extension has encountered many difficulties. In the TLM paradigm the disk is only partially conducting and its structure inside a critical radius,  $R_{outer}$ , is governed by fluid physics. In TLM a pair of fluid oscillatory modes that become key features related to the observed PDS. The TLM has been developed through scrutiny of the full range of observational knowledge available concerning both the energy spectra and the PDS of neutron star and black hole sources. Successes include detailed fits to the variation of 6 PDS features in four LMXB sources with at most one free parameter, and even that one constrained. It is important to understand the limits of success of such a radical paradigm shift. This talk covers continued development of frontier areas of the theory as well as continuation of the crucial detailed confrontation with observational data, done within the TLM paradigm. Under this study both LMXB and black hole sources are studied. (It is possible that the paradigm will eventually extend even to the binary pulsars that were the starting point of the older paradigm).

THE MANIFESTATIONS OF DIFFERENT ACCELERATION MECHANISMS  
OF BINARIES CONTAINING NEUTRON STARS

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We present the results of calculations of the distribution function of low-mass binary systems containing a neutron star over the orbital angular momentum orientation for different heights  $z$  above the Galactic plane. We consider two acceleration mechanisms of the binaries: 1) acceleration by their own X-ray radiation at the stage of intense accretion of matter onto a neutron star with asymmetric magnetic field [1], 2) acceleration due to a supernova explosion.

In the first case the binaries are accelerated by asymmetric X-ray radiation. The radiative reaction force  $F = \xi L_X/c$  depends on X-ray luminosity of the neutron star,  $L_X$ , and on the X-ray asymmetry parameter  $\xi$ . The force points along the spin axis. For the disk accretion onto the star, its rotational axis aligns quickly perpendicular to the accretion disk (and the orbital plane), and the radiative reaction force will accelerate the binary along its orbital angular momentum. Thus, the systems with orbital angular momentum parallel to the Galactic axis will tend to be at large Galactic heights while the systems with orbital angular momentum perpendicular the Galactic axis will be accumulated in the Galactic plane. This is in contrast to the case of symmetric supernova explosion. For asymmetric one, the orbital angular momentum orientation depends mainly on the ratio of kick velocity to orbital velocity of neutron star.

We use the following system parameters:  $m_1 = 3M_\odot$ , the pre-supernova mass;  $m_2 = 1M_\odot$ , the companion mass;  $m_3 = 1.4M_\odot$ , the neutron star mass;  $P = 1$  day, the orbital period (the relative orbital velocity  $v = 290 \text{ km s}^{-1}$ ). The distribution of the kick velocities  $\mathbf{v}_k$  is assumed to be Maxwellian:  $(2\pi\kappa^2)^{-3/2} \exp[-u_k^2/2\kappa^2]$ , where  $\mathbf{u}_k \equiv \mathbf{v}_k/v$  is the dimensionless kick velocity, and  $\kappa$  is the dispersion of  $u_k$ .

To obtain the distribution functions for different  $z$  we have numerically solved the equations of motion of binaries in the Galactic potential. At the initial moment of time the systems are assumed to be in the Galactic plane, on the orbit of the Sun.

The computations show that in case of radiative acceleration (for  $\xi = 0.1, 0.2$ ) there is a linear increase of cosine of angle between the orbital angular momentum and the Galactic axis with increasing  $z$ . In case of asymmetric supernova explosion (for  $\kappa = 0.2$ ) the distributions of the survived binary systems over directions of orbital angular momentum (for different  $z$ ) is nearly isotropic.

The results may be valid for binary millisecond radiopulsars if they passed the stage of intense accretion. The possibility of pulsars recycling (to produce the millisecond pulsars) due to disk accretion in binary systems was first considered in [2].

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## THERMAL RELAXATION IN YOUNG AND OLD NEUTRON STARS

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Thermal relaxation in young isolated neutron stars and in soft X-ray transients is analyzed.

The relaxation process in young neutron stars lasts from 10 to 100 years (Lattimer et al. 1994, Gnedin et al. 2001). During the relaxation stage the effective surface temperature of the star is fairly insensitive to physical conditions in the stellar core, being mainly determined by poorly known physics of matter of subnuclear density in the neutron star crust. The end of the relaxation stage is manifested by a drop of the surface temperature, while subsequent thermal evolution of the star is mainly controlled by properties of matter in the stellar core. The temporal evolution of the surface temperature during the relaxation epoch carries important information on neutrino processes, thermal conductivity, heat capacity and superfluidity of neutrons in the stellar crust.

Another example of the thermal relaxation is provided by soft X-ray transients. These sources undergo periods of intense accretion separated by long phases of quiescence. Their thermal state is thought to be determined (Brown et al. 1998) by energy release (mainly due to pycnonuclear reactions) in accreted matter (Haensel and Zdunik 1990) sinking in deep layers of the stellar crust under the weight of newly accreted material. The quasisteady thermal state is reached (Colpi et al. 2001) in about  $5 \times 10^4$  yrs after the transient activity onset. The star becomes warm, some fraction of thermal energy flows into the core and is radiated away by neutrinos. The effective surface temperature in the quiescence periods becomes sensitive to neutrino emission mechanisms and superfluidity of matter in the stellar core, and therefore, to the stellar mass. This gives a new method (Colpi et al. 2001) to measure masses of neutron stars and superfluid transition temperatures in stellar cores.

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FROM WHITE DWARFS TO BLACK HOLES  
(70TH ANNIVERSARY OF THE THEORY OF COMPACT OBJECTS)

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We discuss basic ideas which laid foundation of the black hole concept. The major goal of the historical part is to explain the very long way of the birth of the black hole concept. The black hole solution was derived by K. Schwarzschild in 1916, but black hole concept was introduced by J.A. Wheeler only in 1967. We emphasize the great contribution of S. Chandrasekhar into development of this concept. We discuss the basic notations of the black hole theory and observational (astronomical) manifestations of black holes, for example, we analyse a possibility to interpret the very peculiar distortion of the iron  $K_{\alpha}$ -line in such a way.

ACCRETING STRANGE STARS

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The models of the rotating strange stars (SS) with crust are presented in the context of the spin up by accretion. Calculations are performed within the framework of general relativity. Equation of state of strange quark matter is based on the MIT Bag Model with massive strange quarks and lowest order QCD interactions. The crust is described by the BPS equation of state.

The properties of the rotating strange stars and main differences with respect to neutron stars are discussed (the large oblateness of rotating SS, the gravitational field in the outer spacetime, the properties of the innermost stable circular orbit [1,2,3]).

The evolutionary tracks for the strange stars accreting the matter from the marginally stable orbit are presented. If all the particle angular momentum is transferred to the star the evolutionary tracks terminate at mass-shed limit for almost all initial values of the stellar mass. Only stars with the mass very close to the maximum one can terminate by encountering the radial instability. However the collapse is the most probable fate of the accreting SS provided that only 50% of the particle angular momentum is deposited onto the star. The maximum amount of the accreted mass is about  $0.6 M_{\odot}$ , the required mass to spin up star to millisecond periods is  $\sim 0.2 M_{\odot}$ .

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