International Conference

PHYSICS OF NEUTRON STARS

commemorating the 100th birthday of
Yakov Borisovich Zel'dovich

Saint-Petersburg, Russia
July 28 – August 1, 2014

Book of Abstracts

Editors: D.A. Baiko, Y.A. Uvarov

Saint-Petersburg
2014

The conference was supported by:

- Russian Foundation for Basic Research,
- Dmitry Zimin *Dynasty Foundation*.

Official conference operator: *CTO Congress* (www.ctocongress.ru).

Conference website: www.ioffe.ru/astro/NS2014/

Preface

The international conference "Physics of Neutron Stars – 2014" in Saint-Petersburg is the 10th event in the series after those in 1988, 1992, 1995, 1997, 1999, 2001, 2005, 2008, 2011. Its aim is to bring together physicists and astrophysicists working on neutron stars and related problems all over the world. In 2014 the conference will commemorate the 100th birthday of Yakov Borisovich Zel'dovich (1914–1987), the famous Soviet physicist and astrophysicist.

The conference covers all major topics of observations and theory of neutron stars, including rotation powered pulsars, pulsar emission mechanisms, pulsar wind nebulae, magnetars, isolated cooling neutron stars, central compact objects, accreting X-ray pulsars (particularly millisecond pulsars), neutron stars in low-mass X-ray binaries, X-ray bursts, equation of state, structure and evolution of neutron stars, mechanisms of supernova explosions and neutron star mergers. It is organized by Ioffe Institute (St. Petersburg, Russia) and Sternberg Astronomical Institute (Moscow, Russia). The official language of the Conference is English.

Scientific Organizing Committee:

V.S. Beskin (Lebedev Physical Institute, Moscow, Russia)
A. Harding (NASA/Goddard Space Flight Center, USA)
C. Heinke (University of Alberta, Edmonton, Canada)
W. Hermsen (SRON, the Netherlands)
M.R. Gilfanov (MPI, Germany; IKI, Moscow, Russia)
V. Kaspi (McGill University, Montreal, Canada)
C. Kouveliotou (NASA/MSFC, Huntsville, USA)
M. Kramer (MPI for Radioastronomy, Germany)
S. Mereghetti (INAF IASF, Milan, Italy)
D.K. Nadyozhin (Institute for Theor. Exper. Phys., Moscow, Russia)
G.G. Pavlov (Pennsylvania State University, USA), co-chair
S.B. Popov (Sternberg Astronomical Institute, Moscow, Russia)
J. Poutanen (Oulu University, Finland)
M. van der Klis (University of Amsterdam, the Netherlands)
D.G. Yakovlev (Ioffe Physical Technical Inst., St Petersburg, Russia), co-chair
S. Zane (Mullard Space Science Laboratory, London, UK)

Local Organizing Committee:

R.L. Aptekar (Ioffe Institute)
D.A. Baiko (Ioffe Institute), co-chair
S.A. Balashev (Ioffe Institute)
D.P. Barsukov (Ioffe Institute)
A.I. Chugunov (Ioffe Institute)
A.A. Danilenko (Ioffe Institute)
M.A. Del (CTO Congress)
M.E. Gusakov (Ioffe Institute)
A.D. Kaminker (Ioffe Institute)
E.M. Kantor (Ioffe Institute)
A.A. Kozhberov (Ioffe Institute)
K.P. Levenfish (Ioffe Institute)
S.B. Popov (Sternberg Astronomical Inst.)
K.A. Postnov (Sternberg Astronomical Inst.)
A.Y. Potekhin (Ioffe Institute)
Yu.A. Shibanov (Ioffe Institute)
P.S. Shternin (Ioffe Institute)
Yu.A. Uvarov (Ioffe Institute)
D.A. Varshalovich (Ioffe Institute), co-chair
D.A. Zyuzin (Ioffe Institute)

Contents

List of participants and their contributions

Name	Institution	Presentation	email
D. E. Alvarez-Castillo	JINR, Russia	The nuclear symmetry energy and the neutron star radius	alvarez@theor.jinr.ru
D. Antonopoulou	Astronomical Institute Anton Pannekoek, The Netherlands	Neutron star glitches: is there a minimum size?	D.Antonopoulou@uva.nl
P. Arumugasamy	The Pennsylvania State University, USA	X-ray timing and spectral analysis of the old γ-ray pulsar J1836+5925	prakash@astro.psu.edu
L. Arzamasskiy	Moscow Institute of Physics and Technology, Russia	Towards radio pulsar evolution theory	lev.arzamasskiy@ phystech.edu
A. Bahramian	University of Alberta, Canada	Discovery of the third transient X-ray binary in the Galactic globular cluster Terzan 5	bahramia@ualberta.ca
D. A. Baiko	Ioffe Institute, Russia	Screening corrections to the elastic moduli of neutron star crust	baiko@astro.ioffe.ru
D. P Barsukov	Ioffe Institute, Russia	The influence of small scale magnetic field on the polar cap X-ray luminosity of old radio pulsars	bars@astro.ioffe.ru
O. Benli	Sabancı University, Turkey	Long-Term Evolution and X-ray Enhancement Of Swift J1822.3-1606	onurbenli@sabanci.edu
V. S. Beskin	Lebedev Physical Institute, Russia	Radio Pulsars – Thirty Years After	beskin@lpi.ru
M. V. Beznogov	St. Petersburg Academic University, Russia	Diffusion currents and diffusion coefficients in dense stellar matter	mikavb89@gmail.com
A. V. Bilous	Radboud Universiteit Nijmegen, The Netherlands	LOFAR's view on PSR B0943+10	hanna.bilous@gmail.com
S. I. Blinnikov	ITEP, Russia	Stars from the very early universe	Sergei.Blinnikov@itep.ru
E. F. Brown	Michigan State University, USA	Soft X-ray Transients	ebrown@pa.msu.edu
N. Bucciantini	INAF - Osservatorio Astrofisico di Arcetri, Italy	Modeling Magnetized Neutron Stars in General Relativity	niccolo@arcetri.astro.it
A. I. Chugunov	Ioffe Institute, Russia	'Hot widows'/HOFNARS: new possible class of rapidly rotating neutron stars	andr.astro@mail.ioffe.ru
A. Danilenko	Ioffe Institute, Russia	The first Fermi pulsar with an X-ray spectral feature	danila@astro.ioffe.ru
A. T. Deibel	Michigan State University, USA	How unique is the crust of an accreting neutron star? A multicomponent study	deibelal@msu.edu
E. V. Derishev	Institute of Applied Physics RAS, Russia	Pair production feedback in pulsar - massive star binaries	derishev@ appl.sci-nnov.ru
V. A. Dommes	Ioffe Institute, Russia	An approximate method to study oscillations of superfluid hyperon stars	vasdommes@gmail.com
Ya. A. Doronina	Saint Petersburg State University, Russia	On the mass distribution of black holes and neutron stars	doronina.yana@gmail.com
E. Egron	INAF - Osservatorio Astronomico di Cagliari, Italy	Spectral analysis of the Double Pulsar PSR J0737-3039 with XMM-Newton	egron@ oa-cagliari.inaf.it
Ü. Ertan	Sabancı University, Turkey	Low-B Magnetars, High-B Radio Pulsars and Dim Isolated Neutron Stars: Long-term Evolution and Radio Emission Properties	unal@sabanciuniv.edu

Name	**Institution**	**Presentation**	**email**
C. M. Espinoza	Insituto de Astrofísica, Pontificia Universidad Católica de Chile, Chile	Glitches and timing noise	cespinoz@astro.puc.cl
A. F. Fantina	Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, Belgium	Properties of nuclear matter and neutron stars with unified equations of state	afantina@ulb.ac.be
C. Ferrigno	ISDC, Switzerland	IGR J18245-2452: the first pulsar swinging between rotation and accretion powered emission	carlo.ferrigno@unige.ch
M. Fortin	Copernicus Astronomical Center, Poland	Thermal evolution of neutron stars with an hyperonic equation of state	fortin@camk.edu.pl
D. K. Galloway	Monash Centre for Astrophysics, Australia	Observations of X-ray Bursters	duncan.galloway@monash.edu
M. A. Garasyov	Institute of Applied Physics of the Russian Academy of Sciences, Russia	Modeling of cyclotron lines in the spectra of isolated neutron stars	garasyov@mail.ru
M. R. Gilfanov	Space Research Institute, Russia	Accretion disk boundary layers around neutron stars	gilfanov@iki.rssi.ru
V. I. Globina	Central Astronomical Observatory of RAS, Russia	On the origin of pulsar-like White Dwarfs	gvi1109@gmail.com
O. A. Goglichidze	Ioffe Institute, Russia	The spin evolution of the pulsars with non-rigid core	goglichidze@gmail.com
S. A. Grebenev	Space Research Institute, Russia	New populations of high mass X-ray binaries with neutron stars	sergei@hea.iki.rssi.ru
M. Grudzinska	Astronomical Observatory, University of Warsaw, Poland	Modeling of spectra from TeV binaries with pulsars	mgrudzinska@astrouw.edu.pl
A. A. Gruzdev	Saint Petersburg Polytechnical University, Russia	Features of steady states of collisionless plasma layer with counterstreaming electron-positron beams	vedzurg@bk.ru
M. E. Gusakov	Ioffe Institute, Russia	Superfluid neutron stars	gusakov@astro.ioffe.ru
P. Haensel	Copernicus Astronomical Center, Poland	Maximum pulsar mass and equation of state of neutron-star core	haensel@camk.edu.pl
H. L. Hakobyan	Moscow Institute of Physics and Technology, Russia	Determination of the Pulsar Image in the Picture Plane	hayk.hakopyan@gmail.com
R. Hascoët	Columbia University, USA	X-ray emission mechanisms in magnetars	hascoet@astro.columbia.edu
A. W. Hermsen	SRON, The Netherlands	Simultaneous XMM-Newton Radio observations of the mode-switching radio pulsar PSR B1822-09	w.hermsen@sron.nl
A. P. Igoshev	Radboud University Nijmegen, The Netherlands	Comprehensive analysis of pulsars velocity distribution	a.igoshev@science.ru.nl
N. R. Ikhsanov	Central Astronomical Observatory of RAS, Russia	A new look at the Anomalous X-ray Pulsars	nazar.r.ikhsanov@gmail.com
A. D. Kaminker	Ioffe Institute, Russia	Thermal emission of neutron stars with internal heaters	kam@astro.ioffe.ru
E. M. Kantor	Ioffe Institute, Russia	Anti-glitches within the glitch model of Anderson and Itoh	kantor@mail.ioffe.ru
D. L. Kaplan	University of Wisconsin, USA	Nearby, Thermally Emitting Neutron Stars	kaplan@uwm.edu

Name	Institution	Presentation	email
O. Kargaltsev	George Washington University, USA	Multiwavelength observations of pulsar wind nebulae	kargaltsev@gwu.edu
A. Karpova	Ioffe Institute, Russia	Thermal properties of the middle-aged pulsar J1741-2054	annakarpova1989@ gmail.com
A. F. Kholtygin	Astronomical Institute, Saint-Petersburg University, Russia	Magnetic field of neutron star precursors: Wolf-Rayet stars	afkholtygin@gmail.com
S. O. Kiikov	South Ural State University, Russia	Investigation of the interaction between the two-flow magnetar jet and the interstellar medium	kiikov@susu.ac.ru
S. O. Kiikov	South Ural State University, Russia	Magnetocavitation mechanism of jet generation from accreting magnetar	kiikov@susu.ac.ru
V. Yu. Kim	Central Astronomical Observatory of RAS, Russia	Evidence for Magneto-Levitation Accretion in the 6.7 h isolated X-ray pulsar 1E 161348-5055	ursa-majoris@ yandex.ru
S. Konar	National Centre for Radio Astrophysics (TIFR), India	AMXP to MSRP : Transition (mis-) understood?	sushan@ncra.tifr.res.in
S. Konar	National Centre for Radio Astrophysics (TIFR), India	Radio Pulsar Recycling : The HMXB Question	sushan@ncra.tifr.res.in
V. I. Kondratiev	Netherlands Institute for Radio Astronomy, The Netherlands	Millisecond pulsars at low frequencies with LOFAR	vlad.kondratiev@gmail.com
V. N. Kondratyev	Taras Shevchenko National University, Ukraine	Soft γ-ray bursts as magnetoemission of junior magnetar crusts	vkondrat@mail.univ.kiev.ua
V.M. Kontorovich	Institute of Radio Astronomy NASU, Ukraine	Electromagnetic tornado semiclassical quantization and origin of the bands in the giant pulses frequency spectrum of the Crab pulsar	vkont1001@yahoo.com
A. A. Kozhberov	Ioffe Institute, Russia	Coulomb crystal mixtures in white dwarf cores and neutron star crusts	kozhberov@gmail.com
L. Kuiper	SRON-National Institute for Space Research, The Netherlands	The soft γ-ray pulsar population and its link to the Fermi-LAT pulsar population: a full high-energy picture	L.M.Kuiper@sron.nl
A. G. Kuranov	Sternberg Astronomical Institute, Russia	Modeling the Luminosity Function of Galactic Low-Mass X-Ray Binaries	alexandre.kuranov@ gmail.com
A. V. Kuznetsov	P. G. Demidov Yaroslavl State University, Russia	Creation of electron-positron pairs at excited Landau levels by a neutrino in a strong magnetic field	avkuzn@uniyar.ac.ru
B. Leibundgut	European Southern Observatory, Germany	Supernova explosions and neutron stars	bleibundgut@eso.org
B. Link	Montana State University, USA	Constraining the Origin of Magnetar Flares	link@physics.montana.edu
A. Majczyna	National Centre for Nuclear Research, Poland	Accuracy of surface gravity and gravitational redshift determination for neutron stars in X-ray bursters from simulated LOFT spectra	agnieszka.majczyna@ fuw.edu.pl
V. M. Malofeev	Pushchino Radio Astronomy Observatory, Russia	Detection of radio emission of 59 ms pulsar J141256.0+792204 (Calvera)	malofeev@prao.ru
I. F. Malov	Pushchino Radio Astronomy Observatory, Russia	On radio emission of anomalous pulsars	malov@prao.ru
S. Mereghetti	INAF, IASF-Milano, Italy	X-rays emission from isolated pulsars	sandro@ iasf-milano.inaf.it
R. Mignani	INAF, IASF-Milano, Italy	Pulsar Polarimetry	mignani@lambrate.inaf.it

Name	Institution	Presentation	email
J. P. Mitchell	Argelander Institut, University of Bonn, Germany	Search for Stable Magnetic Equilibria in Barotropic Stars	jmitchell@ astro.uni-bonn.de
A. A. Mushtukov	Tuorla observatory, University of Turku, Finland	X-ray pulsars: on the verge of a final understanding	al.mushtukov@gmail.com
D. I. Nagirner	Saint-Petersburg State University, Russia	Synchrotron Radiation by Ultra- and Moderate Relativistic Electrons	dinagirner@gmail.com
J. Nättilä	Tuorla observatory, University of Turku, Finland	Heavy metal neutron star atmosphers	nattila.joonas@gmail.com
C.-Y. Ng	The University of Hong Kong, China	High-Energy Emission of PSR B1937+21	ncy@bohr.physics.hku.hk
D. J. Nice	Lafayette College, USA	Measurements of Neutron Star Masses	niced@lafayette.edu
E. B. Nikitina	Pushchino Radio Astronomy Observatory, Russia	The structure of the magnetosphere of radio pulsars with interpulses	maggika@mail.ru
D. D. Ofengeim	St.Petersburg State Polytechnical University, Russia	Analytic approximations for electron-nucleus bremsstrahlung neutrino emissivity in a neutron star crust of any composition	ddofengeim@gmail.com
I. V. Panov	Institute for Theoretical and Experimental Physics, Russia	Spontaneous Fission and Production of Cosmochronometer Nuclei in the r-process	extra@terra.edu
A. Patruno	Leiden Observatory, Leiden University, The Netherlands	Observations of Accretion Powered X-ray Pulsars	patruno@strw.leidenuniv.nl
K. Pavlovskii	University of Alberta, Canada	Mass loss rates in X-ray binaries simulated by MESA	pavlovsk@ualberta.ca
Q. Peng	The Nanjing university, China	The Physics of Magnetars and Their Astrophysical Significance	qhpeng@nju.edu.cn
J. Pétri	Observatoire Astronomique de Strasbourg, Université de Strasbourg, France	Towards general-relativistic pulsars magnetospheres	jerome.petri@ astro.unistra.fr
J. Pétri	Observatoire Astronomique de Strasbourg, Université de Strasbourg, France	Phase-resolved polarization properties of the pulsar striped wind synchrotron emission	jerome.petri@ astro.unistra.fr
A. Philippov	Princeton University, USA	Recent advances in modeling pulsar magnetosphere	sashaph@princeton.edu
M. Pienkos	University of Silesia, Poland	The maximum neutron star mass and the role of the enhanced vector meson interactions	mpienkos@us.edu.pl
M. Pierbattista	NCAC-PAS, Poland	Radio and γ-ray light-curve morphology of young pulsars: comparing *Fermi* observations and simulated populations	mpierba@gmail.com
M. Pilia	ASTRON, the Netherlands Institute for Radio Astronomy, The Netherland	Low-Frequency Evolution of Pulsar Profiles with LOFAR	pilia@astron.nl
J. A. Pons	Universitat d'Alacant, Spain	Evolution of strongly magnetised neutron stars: The path from magnetars to normal pulsars	jose.pons@ua.es
S. B. Popov	Moscow State University, Sternberg Astronomical Institute, Russia	Radiotransients and neutron stars	polar@sai.msu.ru

Name	Institution	Presentation	email
B. Posselt	Pennsylvania State University, USA	Geminga and PSR B1055-52: similar pulsars, different PWNe	posselt@psu.edu
K. A. Postnov	Moscow State University, Sternberg Astronomical Institute, Russia	Nature of Bright Flares in Supergiant Fast X-ray Transients	kpostnov@gmail.com
V. V. Prokofev	Moscow Institute of Physics and Technology, Russia	On the Asymptotic Structure of the Pulsar Wind	
A. V. Prosvetov	Space Research Institute, Russia	LFN, QPO and fractal dimension of light curves from X-ray binaries	prosvetov@gmail.com
L. A. Pustil'nik	University ITMO, Russia	Spin evolution of pulsars challenges conventional accretion scenarios	levpust@post.tau.ac.il
B. Rangelov	George Washington University, USA	The far-UV bow shock of the nearest millisecond pulsar J0437–4715	rangelov13@gwu.edu
N. Rea	CSIC-IEEC, University of Amsterdam, The Netherlands	The extreme activity of high and low magnetic field magnetars	nanda.rea@gmail.com
A. Reisenegger	Instituto de Astrofísica, Pontificia Universidad Católica de Chile, Chile	Magnetic field evolution in neutron stars	areisene@astro.puc.cl
G. A. Rodriguez Castillo	INAF – Osservatorio Astronomico di Roma, Italy	Taking The Pulse of Transient Magnetars: Connecting Their Long-term Spectral and Timing X-ray Properties	grodriguezcas@gmail.com
D.A. Rumyantsev	P. G. Demidov Yaroslavl State University, Russia	Resonant mechanism of e^+e^- pair production in a strong magnetic field	rda@uniyar.ac.ru
D. M. Russell	New York University Abu Dhabi, UAE	Jets launched from accreting neutron stars: their power and their magnetic fields	dave.russell@nyu.edu
A. N. Semena	Space Research Institute, Russia	On the thickness of accretion curtains on magnetized compact objects from analysis of their fast aperiodic time variability	san@iki.rssi.ru
Yu. A. Shibanov	Ioffe Institute, Russia	Gamma-ray pulsars in the optical and infrared	shib@astro.ioffe.ru
P. S. Shternin	Ioffe Institute, Russia	Transport coefficients of nuclear matter in neutron star cores in BHF framework	pshternin@gmail.com
T. V. Smirnova	Pushchino Radio Astronomy Observatory, Russia	Study of scattering material with RadioAstron-VLBI observations	tania@prao.ru
V. Suleimanov	Kazan Federal University, Russia	Spectra of rapidly rotating X-ray bursting neutron stars	suleimanov@ astro.uni-tuebingen.de
S. J. Tanaka	Institute for Cosmic Ray Research, University of Tokyo, Japan	Constraint of Pulsar Wind Properties from Induced Compton Scattering off Radio Pulses	sjtanaka@ icrr.u-tokyo.ac.jp
D. A. Teplykh	Pushchino Radio Astronomy Observatory, Russia	The flare activity of PSR J0653+8051	teplykh@prao.ru
A. Timokhin	NASA Goddard Space Flight Center, USA	Plasma generation in pulsar polar caps: a modern view	andrey.timokhin@nasa.gov
H. Tong	Xinjiang Astronomical Observatory, China	Anti-glitch of magnetars in the wind braking scenario	tonghao@xao.ac.cn
S. Tsygankov	Finnish Centre for Astronomy with ESO (FINCA), University of Turku, Finland	Power spectra of transient X-ray pulsars: observational manifestation of the disk-magnetosphere interaction	stsygankov@gmail.com

Name	**Institution**	**Presentation**	**email**
A. I. Tsygan	Ioffe Institute, Russia	Differential rotation of neutron star polar caps	tsygan.astro@mail.ioffe.ru
R. Turolla	INAF–IASF, Italy	The variable X-ray emission of PSR B0943+10	turolla@pd.infn.it
Y. A. Uvarov	Ioffe Institute, Russia	A model of gamma ray flare generation in PWN	uv@astro.ioffe.ru
D. A. Uzdensky	University of Colorado Boulder, USA	Reconnection in Neutron Star Magnetospheres	uzdensky@colorado.edu
C. A. van Eysden	NORDITA, Sweden	Short-period pulsar oscillations following a glitch	ave@nordita.org
R. Wijnands	University of Amsterdam, The Netherlands	Cooling of accretion heated neutron stars	r.a.d.wijnands@uva.nl
G. Younes	USRA, USA	Spectral Evolution of Magnetar Bright Bursts	george.a.younes@nasa.gov
G. Younes	USRA, USA	XMM-Newton View of the best candidate Magnetar Wind Nebula	george.a.younes@nasa.gov
A. V. Yudin	SSC RF ITEP of NRC 'Kurchatov Institute', Russia	On some properties of hybrid stars	yudin@itep.ru
C. Yu	Yunnan Observatories, China	Magnetar giant flares and their precursors – flux rope eruptions with current sheets	cyu@ynao.ac.cn
G. Zhang	New York University Abu Dhabi, USA	Strong evidence for a link between coherent oscillations and the apparent emission area during the thermonuclear bursts	guobao.zhang@nyu.edu
S. V. Zharikov	Instituto de Astronomia, UNAM, Mexico	Radiation efficiencies of the pulsars (current update)	zhar@astrosen.unam.mx
X. Zhou	Xinjiang Astronomical Observatory, China	The role of magnetic damping in the r-mode evolution of accreting neutron stars	zhouxia@xao.ac.cn

The nuclear symmetry energy and the neutron star radius

D. E. Alvarez-Castillo[1]*, D. Blaschke[1,2]†, S. Kubis[3]‡

[1]Bogoliubov Laboratory of Theoretical Physics, JINR, Joliot-Curie 6 141980 Moscow region, Dubna, Russia

[2]Institute of Theoretical Physics, University of Wroclaw, pl. M. Borna 9, 50-204, Wroclaw, Poland

[3]Faculty of Physics, Cracow University of Technology, ul. Cadet 1, 30-084 Krakow, Poland

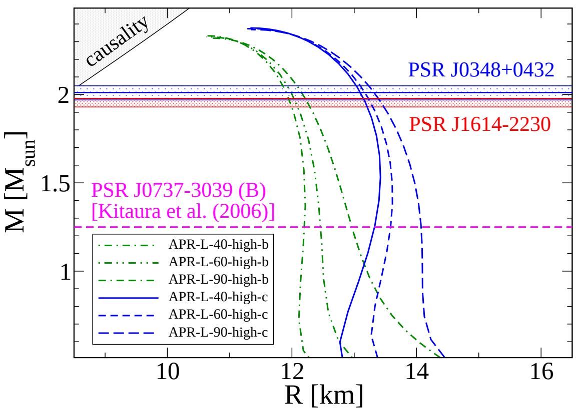

Figure 1: Mass-radius relations for some of the models studied here. The maximum mass is approximately the same for all of them since they bear identical E_0. The horizontal line marks the 1.25 $M_\odot$ critical value derived in [2].

For neutron star modelling we introduce two sets of models with symmetry energy functionals which at high baryon densities differ in stiffness [1]. The symmetric part of the energy per baryon is the same for all such models and is based on the APR EoS. We test the behavior of the symmetry energy by using a constraint on the total baryon mass for a gravitational mass of a 1.25 $M_\odot$ neutron star. This constraint is the result of a study performed by Kitaura et al. [2] on stellar explosions of stars with an O-Ne-Mg core.

Extending this study by replacing the energy for symmetric matter of the aforementioned models we find the same qualitative results. As a result we derive a linear relation between the neutron star radius and its baryonic mass which turns out to be a potential constraint for neutron star radius of the neutron star considered by Kitaura. Finally we discuss the role of the DUrca cooling because it can be activated above a threshold on the proton content which strongly depends on the symmetry energy [3, 4]. We present the favored models and their corresponding effects on the radii of neutron stars, see Fig. 1.

References

[1] D. E. Alvarez-Castillo and S. Kubis, ASP Conf. Ser. , 466, **199-202** (2012) [arXiv:1207.1078 [astro-ph.SR]].

[2] F. S. Kitaura, H. -T. Janka and W. Hillebrandt, Astron. Astrophys. **450**, 345 (2006) [astro-ph/0512065].

[3] J. M. Lattimer, M. Prakash, C. J. Pethick and P. Haensel, Phys. Rev. Lett. **66**, 2701 (1991).

[4] T. Klahn *et al.*, Phys. Rev. C **74**, 035802 (2006).

*E-mail: alvarez@theor.jinr.ru

†E-mail: david@theor.jinr.ru

‡E-mail: skubis@riad.pk.edu.pl

Neutron star glitches: is there a minimum size?

C. M. Espinoza[1,2], D. Antonopoulou[3*], B. W. Stappers[1], A. Watts[3], A. G. Lyne[1]

[1]Jodrell Bank Centre for Astrophysics, School of Physics and Astronomy, The University of Manchester, Manchester M13 9PL, UK.

[2]Instituto de Astrofísica, Facultad de Física, Pontificia Universidad Católica de Chile, Casilla 306, Santiago 22, Chile.

[3]Astronomical Institute Anton Pannekoek, University of Amsterdam, Postbus 94249, 1090GE Amsterdam, The Netherlands.

Glitches are abrupt spin-up events, observed in the rotation of different classes of neutron stars, from young rotationally powered pulsars, to RRATs and magnetars. Most glitches are followed by a slow relaxation towards the pre-glitch spin frequency, which provides a strong evidence for the existence of a neutron superfluid within neutron stars. Such a component might not follow the spin down of the rest of the star thus acting as an angular momentum reservoir. Glitches are thought to be sporadic, rapid exchanges of angular momentum between this component and the crust, however their trigger and the exact mechanism remain unexplained.

Knowledge of the glitch size distribution is critical to development and testing of theoretical models, but it can be difficult to probe due to observational biases. We present general glitch detectability limits, which can be used to adjust the monitoring strategy for individual pulsars in order to reveal their underlying glitch size distribution. Moreover, applying those limits on 29 years of daily observations of the Crab pulsar and using an automated method developed to identify small rotational irregularities, we uncover the full glitch size distribution for this source, with no biases.

The glitch size distribution in the Crab pulsar is consistent with a power-law, as it is also the case for other glitching pulsars [1], but contrary to theoretical expectations we observe a rapid decrease of the number of glitches below $\sim 0.05\,\mu$Hz which cannot be ascribed to incompleteness of the sample. Such a substantial minimum size can strongly constrain the trigger mechanism, since it implies that in a Crab pulsar glitch at least several billions of superfluid vortices need to be involved.

References

[1] A. Melatos, C. Peralta & J. S. B. Wyithe, *ApJ* 672, 1103 (2008)

*E-mail: D.Antonopoulou@uva.nl

X-ray timing and spectral analysis of the old γ-ray pulsar J1836+5925

P. Arumugasamy[1*], G. G. Pavlov[1†], J. D. Blake[1]

[1]The Pennsylvania State University, University Park, PA, USA.

PSR J1836+5925 is a bright γ-ray source with a long observational history in various energy bands. Its radio-quietness, and non-detection of X-ray pulsations in previous observations have hindered a detailed analysis of this source. At the characteristic age of 1.83 Myr, it is one of the oldest non-recycled γ-ray pulsars known, making it a useful object for understanding evolution of high-energy emission from rotation powered pulsars. In our 80 ks XMM-Newton observation of this pulsar, we detected unambiguous 5.77 Hz pulsations, consistent with its known γ-ray ephemeris and assessed a low X-ray pulsed fraction of ~ 0.34. In the $0.15 - 10$ keV phase-integrated spectrum, non-thermal emission with the photon index $\Gamma \approx 1.8 \pm 0.2$ dominates above 0.7 keV, whereas at lower energies, the spectrum requires a dominant $kT = 63 \pm 5$ eV blackbody or, alternatively, a 24 ± 3 eV neutron star atmosphere model. We will also present the phase-resolved analysis of the pulsar spectrum and phase-matched X-ray and γ-ray pulse profiles. Finally, we will discuss the implications of our results for thermal and magnetospheric emission of rotation powered pulsars.

*E-mail: prakash@astro.psu.edu
†E-mail: pavlov@astro.psu.edu

Towards radio pulsar evolution theory

L. Arzamasskiy[1*], A. Philippov[2], A. Tchekhovskoy[3,4]

[1]Moscow Institute of Physics and Technology, Dolgoprudny, Institutsky per., 9, Moscow region, 141700, Russia

[2]Department of Astrophysical Sciences, Peyton Hall, Princeton University, Princeton, NJ 08544, USA

[3]University of California Berkeley, Berkeley, CA 94720-3411

[4]Lawrence Berkeley National Laboratory, 1 Cyclotron Rd, Berkeley, CA 94720, USA

Pulsars are famous for their rotational stability. Most of them steadily slow down having highly repetitive pulse shape. But some pulsars experience various timing irregularities such as nulling, intermittency, mode changing and timing noise. As changes in pulse shape are often correlated with timing irregularities, precession is a possible cause of these phenomena. Current numerical simulations [1] of pulsar magnetosphere provide us with a good physically motivated model of pulsar evolution. Here we present a study of pulsar precession according to this model.

Using the approach described in [2] we obtain geometrical parameters required to reproduce the observed irregularities of the Crab pulsar [3] and of the pulsar B1828-11 [4]. Our results are fully consistent with independent studies of these parameters.

References

[1] Philippov A., Tchekhovskoy A., Li J. *MNRAS* , (2013)

[2] Melatos A. *MNRAS* 313, 217 (2000)

[3] A. Lyne, F. Graham-Smith, P. Weltevrede, Ch. Jordan, B. Stappers, C. Bassa, M. Kramer *Science* 342, 598 (2013)

[4] I. Stairs, A. Lyne, M. Kramer *Nature* 406, 484 (2000)

*E-mail: lev.arzamasskiy@phystech.edu

Discovery of the third transient X-ray binary in the Galactic globular cluster Terzan 5

A. Bahramian[1*], C. O. Heinke[1], G. R. Sivakoff[1], D. Altamirano[2], R. Wijnands[3], J. Homan[4], M. Linares[5,6], D. Pooley[7,8], N. Degenaar[9], J. C. Gladstone[1]

[1]University of Alberta

[2]University of Southampton

[3]Astronomical Institute 'Anton Pannekoek'

[4]Kavli Institute for Astrophysics & Space Research

[5]Instituto de Astrofísica de Canarias

[6]Universidad de La Laguna

[7]Sam Houston State University

[8]Eureka Scientific, Inc.

[9]University of Michigan

We report and study the outburst of a new transient X-ray binary in Terzan 5, the third detected in this globular cluster, Terzan 5 X-3. We use multiple X-ray instruments (*Swift/BAT*, *MAXI/GSC*, *Chandra/ACIS*, and *Swift/XRT*) to study this outburst, particularly the spectral changes. We identify a Type I X-ray burst with a long (16 s) decay time, indicative of hydrogen burning on the surface of a neutron star (NS). We find clear spectral hardening during the rise of the outburst, from 10^{34} to 10^{36} ergs/s, using *Swift/XRT* observations. This hardening appears to be due to the decline in relative strength of a soft thermal component from the surface of the neutron star, matching models of hot Comptonizing NS atmospheres. The inferred long-term time-averaged mass accretion rate, from the quiescent thermal luminosity, suggests that if this outburst is typical and only slow cooling processes are active in the NS core, such outbursts should recur every $\sim$10 years.

*E-mail: bahramia@ualberta.ca

Screening corrections to the elastic moduli of neutron star crust

D. A. Baiko[1*]

[1]Ioffe Institute, St. Petersburg, Russia

Neutron star crust in a wide range of mass densities and temperatures is in a crystal state. At a given density, the crystal is made of completely pressure ionized atomic nuclei immersed into a charge compensating background of electrons. The electrons are strongly degenerate and very energetic, and it is considered a good approximation to treat them simply as a constant and uniform charge background (one-component plasma model). However, in reality, electrons respond to the ion charge density, which results in a screening effect. The screening strength can be characterized by the screening parameter $\kappa_{\rm TF} a$, where $\kappa_{\rm TF}$ is the Thomas-Fermi wavenumber and a is the Wigner-Seitz radius. The screening is not very weak even in the inner neutron star crust, where electrons are ultrarelativistic, and at the ion charge number $Z = 40$, $\kappa_{\rm TF} a \approx 0.63$. In the outer neutron star crust the screening parameter decreases with a decrease of Z but increases with the decrease of the mass density (and the electron relativity degree). Eventually (at sufficiently low density), it exceeds 1, and perturbative calculations based on the one-component plasma model fail.

In this work we calculate screening contribution to all second order elastic moduli of such a crystal with a body-centered cubic lattice. We treat electron screening perturbatively and compare the simple Thomas-Fermi model and the more realistic RPA model of the relativistic electron gas response developed by Jancovici. In the latter case we take into account the temperature dependence of the dielectric function. The results are important for a quantitative description of global oscillation modes of the neutron star crust.

This work was partially supported by RFBR (grant 14-02-00868) and by Rosnauka (grant NSh 294.2014.2).

*E-mail: baiko@astro.ioffe.ru

The influence of small scale magnetic field on the polar cap X-ray luminosity of old radio pulsars

A. I. Tsygan[1*], O. A. Goglichidze[1], D. P Barsukov[1,2]

[1]Ioffe Institute, St.Petersburg, Russia

[2]SPbSPU, St.Petersburg, Russia

The influence of small-scale magnetic field on the polar cap heating by reverse positrons is considered. The reverse positron current is calculated in the framework of rapid [1] and gradual [2] screening models. In the first model only a small area above the inner gap contributes to the reverse positron current, so the reverse current is about $10^{-3} - 10^{-2}$ of the primary electron current. In the case of the gradual screening model all areas above the inner gap contribute to the reverse positron current [3], so the reverse current achieves about $10^{-2} - 10^{-1}$ of the primary electron current (and in extreme case the two currents may become comparable). To calculate the electron-positron pair production rate we take into account only the curvature radiation of primary electrons and its absorption in the magnetic field. We use the polar cap model with steady space charge limited electron flow.

It is shown that in the case of some old pulsars the model of gradual screening predicts too strong polar cap heating and too large polar cap X-ray luminosity values which exceed the total observed X-ray luminosity. But in the case of some other pulsars the model of gradual screening seems more appropriate than the rapid screening model.

The work has been partly supported by the RFBR (project 13-02-00112) and by the State Program "Leading Scientific Schools of the Russian Federation" (grant NSh-294.2014.2).

References

[1] Arons J., Fawley W.M. and Scharlemann E.T., *ApJ* **231** (1979) 854.

[2] Harding A.K. and Muslimov A.G., *ApJ* **556** (2001) 987.

[3] Lyubarskii Yu.E., A&A **261** (1992) 544.

*E-mail: tsygan.astro@mail.ioffe.ru

Long-Term Evolution and X-ray Enhancement Of Swift J1822.3-1606

O. Benli[1*], Ş. Çalışkan[1†], Ü. Ertan[1‡], M. A. Alpar[1§], J. E. Trümper[2¶], N. D. Kylafis[3‖]

[1]Sabancı University, Orhanlı- Tuzla, Istanbul, 34956, Turkey

[2]Max-Planck-Institut fuer extraterrestrische Physik, Giessenbachstrase, 85740 Garching bei Muenchen, Germany

[3]Physics Department and Institute of Theoretical and Computational Physics, University of Crete, 71003 Heraklion, Crete, Greece

We simulate the long-term evolution of the recently discovered, second low-B magnetar, Swift J1822.3-1606 by using the fallback disk model. We show that the long period (8.4 s) of the neutron star can be produced by the effect of the disk torques in the long-term accretion phase (1 - 3 $\times 10^5$ years). The model curves that could represent the rotational properties (P, $\dot{P}$) and the X-ray luminosity of Swift J1822.3-1606 constrain the strength of the magnetic dipole field to the range of 1 - 2 $\times 10^{12}$ G on the surface of the NS. We also investigate the recently observed X-ray enhancement light curve of Swift J1822.3-1606. In a soft gamma burst epoch, the inner disk matter could be pushed back to a larger radius forming a density gradient. We show that the subsequent relaxation of this pile-up matter could account for the X-ray enhancement light curve of the source, with basic disk parameters similar to those employed to explain the X-ray enhancement light curves of other AXPs and SGRs.

We show that the long-term evolution and the short-term X-ray enhancement of Swift J1822.3–1606 could be explained by the fallback disk model.

*E-mail: onurbenli@sabanci.edu

†E-mail: sirincaliskan@sabanciuniv.edu

‡E-mail: unal@sabanciuniv.edu

§E-mail: alialpar@science.uva.nl

¶E-mail: jtrumper@mpe.mpg.de

‖E-mail: kylafis@physics.uoc.gr

Radio Pulsars – Thirty Years After

V. S. Beskin[1,2*], Ya. N. Istomin[1,2†], A. A. Philippov[2,3]

[1]Lebedev Physical Institute, Moscow, Russia

[2]Moscow Institute of Physics and Technology, Dolgoprudny, Russia

[3]Princeton University, Princeton, USA

Thirty years have passed since our group led by A.V. Gurevich at the Theoretical Physics Department of the Lebedev Physical Institute published our first article on the theory of the magnetosphere of radio pulsars. 25 years have passed since the publication of the article dealing with the development of the theory of radio emission of pulsars. And, finally, 20 years have passed since the publication of the monograph [1], in which a consistent theory was formulated of the principal processes responsible for the observed activity of radio pulsars. We would like to show that many analytical results obtained in 70-80th by many researchers (in spite of the fact that they were rather simple and actually very preliminary) help us now to understand main features of modern numerical simulations.

First of all, key results obtained by our group (the full screening of the magnetodipole radiation, the general expression for the current losses) are remembered. We show that now one can find additional observational confirmations of our predictions. In particular, this model can easily explain the inclination angle dependence of the total energy losses found in numerical simulations [2]. We discuss in detail the simple asymptotic analytical behavior of the pulsar wind. It is shown that the simplest force-free asymptotic solutions are really reproduced.

We have confirmed also the pulsar radio emission theory developed early. The more effective mechanism of radio wave generation is the collective curvature radiation by relativistic electron-positron flux in the pulsar magenosphere [3, 4].

Finally, it is shown that for the correct determination of the anomalous torque acting on the rotating sphere it is necessary to include into consideration the angular momentum of the electromagnetic field inside the sphere. As a result, the anomalous torque is to depend on the strucure of the magnetic field inside the body [5].

This work was supported by Russian Scientific Foundation, 14-12-01198.

References

[1] V. S. Beskin, A. V. Gurevich, Ya. N. Istomin, *Physics of the pulsar magnetosphere*, Cambridge University Press (1993)

[2] A. Philippov, A. Tchekhovskoy, & G. Li, *MNRAS* (2014) (in press) http://arxiv.org/abs/1311.1513

[3] Ya. N. Istomin & A. Philippov, V. S. Beskin, *MNRAS* 422, 2321 (2012)

[4] V. S. Beskin, Ya. N. Istomin & A. Philippov, *Phys. Uspekhi* 56, 164 (2014)

[5] V. S. Beskin & A. A.Zheltoukhov, *Phys. Uspekhi* (2014) (in press)

*E-mail: beskin@lpi.ru

†E-mail: istomin@lpi.ru

Diffusion currents and diffusion coefficients in dense stellar matter

M. V. Beznogov[1,2*], D. G. Yakovlev[2]

[1]St. Petersburg Academic University, Russia

[2]Ioffe Institute, St. Petersburg, Russia

Diffusion processes in weakly coupled Coulomb plasmas in ordinary stars are well studied. However strongly coupled plasmas in the outer envelopes of neutron stars and the cores of white dwarfs require special consideration.

We consider Coulomb contributions to diffusion currents and diffusion coefficients in multicomponent Coulomb liquid, where classical (suitable for weakly coupled plasma) expressions for the diffusive flux are inaccurate. We discuss a specific Coulomb contribution [1] to the diffusive flux. It produces additional Coulomb separation of ions and can separate even the ions with the same A/Z (mass to charge number) ratios. The Coulomb separation of ions affects chemical composition of white dwarf cores and neutron star envelopes and, consequently, changes heat capacity, thermal conductivity, neutrino emission, nuclear reaction rates as well as chemical, thermal, and nuclear evolution; it can affect also vibration properties of stars (as detailed in Ref. [1]). We show that Coulomb diffusion currents are available also at intermediate and weak couplings.

In addition, one needs diffusion coefficients themselves to deal with the diffusion problem. A promising effective potential approach has been recently proposed in Ref. [2]. It allows one to calculate the self-diffusion coefficient in a one component ion plasma using some extension of the standard Chapman-Enskog method from weak coupling to intermediate and strong couplings. We generalize this method to the case of binary ionic mixtures and calculate inter-diffusion coefficients for several such mixtures important for neutron stars and white dwarfs. We present convenient fits to the calculated diffusion coefficients in terms of generalized Coulomb logarithm.

The authors are grateful for the partial support by the State Program Leading Scientific Schools of RF (grant NSh 294.2014.2). The work of MB has also been partly supported by the Dynasty Foundation, and the work of DY by RFBR (grants Nos. 14-02-00868-a and 13-02-12017-ofi-M).

References

[1] M. V. Beznogov & D. G. Yakovlev, *Phys. Rev. Lett.* 111, 161101 (2013)

[2] S. D. Baalrud & J. Daligault, *Phys. Rev. Lett.* 110, 235001 (2013)

*E-mail: mikavb89@gmail.com

LOFAR's view on PSR B0943+10

A. V. Bilous[1]*, and LOFAR Pulsar Working Group

[1]Radboud Universiteit Nijmegen

PSR B0943+10 is an old normal pulsar mostly known for its two radio emission modes. In the so-called "bright" (B) mode the pulsar exhibits regularly drifting subpulses, whereas in the "quiet" (Q) mode the single pulses are sparse and chaotic. Recently, it has been revealed that X-ray emission properties of the B0943+10 change synchronously with the switching between the radio modes [1]. Unexpectedly, the pulsar is brighter in X-rays during the radio Q-mode, showing pulsed thermal component together with the weak unpulsed non-thermal one. In the radio B-mode only the latter unpulsed component is present. Such global change in conditions in the magnetosphere still awaits explanation. One of the ways to approach this problem is to investigate the differences between the radio modes in the low radio frequency regime, where the frequency-dependent changes in the pulse-profile morphology are the largest and the effects too subtle to be easily seen at higher frequencies are more straightforward to detect. In this work we investigate even lower frequencies than the previous 150-MHz results in [1]; we present the first-ever study at 20−80 MHz, spanning the lowest two octaves of the ionospheric radio window. We describe the frequency evolution of the average profile and constrain the emission regions in both modes within the framework of the radius-to-frequency mapping theory. We also investigate the gradual changes in the shape of the average profile within a single mode instance. Finally, we explore drifting subpulses in the B-mode and give a geometrical explanation for the discovered frequency-dependent delay in the drift phase.

References

[1] W. Hermsen et al., *Science* 339, 436-9 (2013).

*E-mail: hanna.bilous@gmail.com

Stars from the very early universe

S. I. Blinnikov[1,3,4*], A. D. Dolgov[1,2,3†], K. A. Postnov[4‡]

[1]ITEP, Moscow 117218, Russia
[2]Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Ferrara Polo Scientifico e Tecnologico–Edificio C, 44122 Ferrara, Italy
[3]Novosibirsk State University, Novosibirsk 630090, Russia
[4]Moscow State University, Moscow 119991, Russia

A mechanism of the creation of stellar-like objects in the very early universe, from the QCD phase transition until the big bang nucleosynthesis and somewhat later, is studied. This scenario leads to interesting consequences, such as the formation of primordial black holes (PBHs) with masses above a few solar masses up to superheavy ones. This may explain an early quasar creation with evolved chemistry in surrounding medium and the low mass cutoff of the observed stellar-mass black holes. It is also shown that dense primordial stars can be created at the considered epoch. Such stars could later become very early supernovae and, in particular, high redshift gamma-ray bursters. This helps resolve the problems of the early formation of black holes, quasars, GRBs, the first stars, and the enrichment of the interstellar space by metals at high redshifts. At the tail of the considered distribution, supermassive PBHs could be created, which might serve as galaxy formation seeds. In a version of the model, some of the created objects can consist of antimatter. A testable prediction of this version is the existence of compact stellar-type (or brown dwarf type) antimatter objects, which might populate the galactic halo and do not contradict the observed gamma-ray background.

*E-mail: Sergei.Blinnikov@itep.ru
†E-mail: dolgov@fe.infn.it
‡E-mail: pk@sai.msu.ru

Soft X-ray Transients

E. F. Brown[1*]

[1]Department of Physics and Astronomy, National Superconducting Cyclotron Laboratory, and the Joint Institute for Nuclear Astrophysics, Michigan State University, East Lansing, MI 48824 USA

Soft X-ray transients, in which a neutron star accretes intermittently from a low-mass companion, are wonderful tools for studying the dense matter equation of state and for exploring the properties of the neutron star's crust. In this talk, I shall first review the overall structure of the neutron star's crust. Accretion pushes the matter in the crust deeper; the rising pressure induces electron captures that drive the composition toward neutron drip. The temperature of the crust is then set by balancing the heat released from these reactions with conduction to the core and surface and with neutrino emission from the crust and core. Observations of neutron star cooling during quiescence probe the crust temperature. Finally, I shall discuss how electron capture/β^- decay cycles at densities $\approx 10^{10}\,\mathrm{g\,cm^{-3}}$ efficiently cool the outer neutron star crust [1]. This cooling thermally decouples the lower density regions of the neutron star; I will argue that this cooling, along with observations of transients and the ignition of superbursts, requires additional heating at lower densities.

This work was supported by the US National Science Foundation grants PHY 08-22648 (the Joint Institute for Nuclear Astrophysics) and AST 11-09176.

References

[1] H. Schatz, et al. Strong neutrino cooling by cycles of electron capture and β^- decay in neutron star crusts. *Nature*, 505:62, 2014.

*E-mail: ebrown@pa.msu.edu

Modeling Magnetized Neutron Stars in General Relativity

N. Bucciantini[1,2*], A. G. Pili[1,2,3†], L. Del Zanna[1,2,3]

[1]INAF - Osservatorio Astrofisico di Arcetri, Firenze, Italy

[2]INFN - Sezione di Firenze, Italy

[3]Dipartimento di Fisica e Astronomia, Università di Firenze, Italy

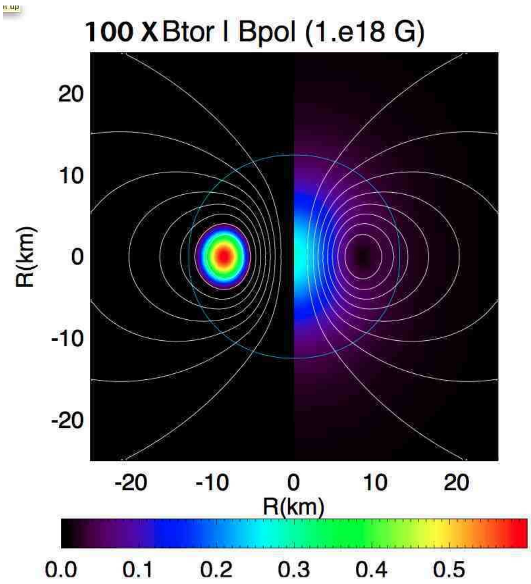

Figure 1: Toroidal (left) and poloidal (right) magnetic field distribution for a highly deformed mixed Twisted-Torus configuration.

Magnetic fields play a crucial role in many astrophysical scenarios and, in particular, are of paramount importance in the emission mechanism and evolution of many sources. Among them, Neutron Stars (NSs), which are the most compact objects of the Universe, endowed with an internal structure. They can rotate very fast and harbor very strong magnetic fields, up to 10^{16} G for magnetars. Magnetic fields of such magnitude are responsible for the phenomenology of many NSs like Anomalous X-Ray Pulsars and Soft Gamma Repeater and they are invoked in the *millisecond magnetar model* for Long and Short Gamma Ray Bursts. Finally, a strong magnetic field could deform the NS structure leading, together with rotation, to gravitational wave emission.

To understand the role of the magnetic field in compact objects it is important to obtain, as a first step, accurate equilibrium models for magnetized NSs. Using the conformally flat approximation we solve the Einstein's equations together with the GRMHD equations in the case of a static axisymmetric NS taking into account different magnetic configurations. This allows us to investigate the effect of the magnetic field on global properties of NSs such as their deformation.

Until now only simple configurations, of purely poloidal or purely toroidal magnetic fields, have been investigated in full GR. However a more realistic magnetic configuration, the so-called Twisted-Torus, expected to be stable, requires the presence of both poloidal and toroidal magnetic field. Here we present the first study done in full GR and for strong deformations. We will show that the simpler CFC assumption leads to configurations that are in excellent agreement with more sophisticated treatments (see Fig. 1). We will discuss the role of various current distributions, and how their location within the star, either in the core region or in the outer peripheral layers, affects the deformations of the NS, and possibly the efficiency of gravitational wave emission. We will show how magnetospheric currents can be modeled in a full GR regime, and what highly non linear configurations look like.

*E-mail: niccolo@arcetri.astro.it
†E-mail: pili@arcetri.astro.it

'Hot widows'/HOFNARS: new possible class of rapidly rotating neutron stars

A. I. Chugunov[1*], M. E. Gusakov[1†], E. M. Kantor[1‡]

[1]Ioffe Institute, St. Petersburg, Russia

We discuss a new hypothetical class of neutron stars dubbed 'HOFNARs' (HOt and Fast Non-Accreting Rotators) or 'hot widows' (similar to 'black widow' pulsars) which are hot and fast-rotating, but do not accrete matter. These sources are unstable with respect to r-modes and are formed in low-mass X-ray binaries (LMXBs), after exhausting the low-mass companion. Their high temperatures are maintained by r-mode dissipation; as we show they can stay hot during a very long period of time $\sim 10^9$ yrs. 'Hot widows'/HOFNARs can be observed as X-ray sources with purely thermal neutron star atmosphere spectrum, which perfectly matches spectral identification criteria for quiescent LMXBs (qLMXBs) candidates in globular clusters. This means that some of X-ray sources known as qLMXB candidates can in fact be 'hot widows'/HOFNARs. Observational evidences in favor of the 'hot widow'/HOFNAR hypothesis are presented. We discuss identification criteria for 'hot widows'/HOFNARs and analyze a variety of possibilities, which they provide to constrain dense matter properties.

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

*E-mail: andr.astro@mail.ioffe.ru
†E-mail: gusakov.astro@mail.ioffe.ru
‡E-mail: kantor.astro@mail.ioffe.ru

The first Fermi pulsar with an X-ray spectral feature

A. Danilenko[1]*, P. Shternin[1,2], A. Karpova[1,2], Yu. Shibanov[1,2], D. Zyuzin[1]

[1]Ioffe Institute, St. Petersburg, Russia

[2]St. Petersburg State Polytechnical University, Russia

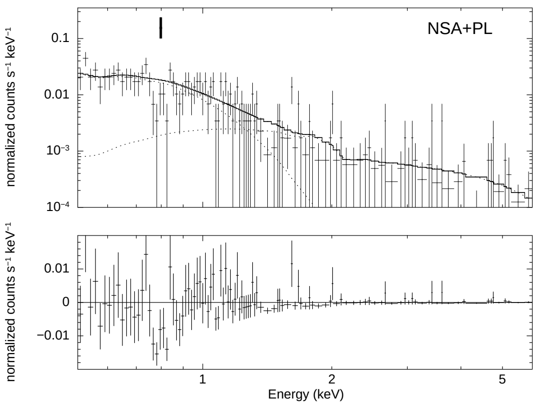

Figure 1: Chandra/ACIS-S spectrum of PSR J0633+0632 fitted by an absorbed NSA+PL model. The absorption line position is marked by the bold vertical bar.

The Fermi γ-ray observatory has recently discovered more than a hundred of new nearby pulsars [1]. Among them, PSR J0633+0632 (J0633) is one of the brightest in X-rays [5]. The first 20-ks *Chandra* observation showed that its spectrum contains the thermal component, equally well fitted by the blackbody and the hydrogen atmosphere model (NSA; [8]), and the non-thermal power-law (PL) component [5]. We performed a detailed analysis of these data.

In the spectral fit residuals (see Fig. 1), we found a hint of an absorption spectral feature at $\sim$ 0.8 keV. The Bayesian model checking [4] gives strong evidence for the line presence. Therefore J0633 is the first γ-ray pulsar with an absorption feature in X-ray spectrum.

Besides that, if J0633 is indeed covered by a hydrogen atmosphere, it is the coldest middle-aged ($\lesssim 10^5$ yr) neutron star with measured surface temperature. The middle-aged stars cool down via the neutrino emission from their interiors [6]. Following the method from [7] we found that the neutrino cooling rate of J0633 should be 10^2–10^4 times stronger than the standard neutron star cooling rate. Such a high cooling rate cannot be explained by the minimal cooling theory [2, 3].

We present details of our analysis and discuss how further thoughtful studies of this remarkable pulsar can contribute to our understanding of the neutron star physics.

References

[1] A. A. Abdo, et al., *ApJS* 208, 17 (2013)
[2] M. E. Gusakov, et al., *A&A* 423, 1063 (2004)
[3] D. Page, et al., *ApJS* 155, 623 (2004)
[4] R. Protassov, et al., *ApJ* 571, 545 (2002)
[5] P. S. Ray, et al., *ApJS* 194, 17 (2011)
[6] D. G. Yakovlev & C. J. Pethick, *ARAA* 42, 169 (2004)
[7] D. G. Yakovlev, et al., *MNRAS* 412, L108 (2011)
[8] V. E. Zavlin, G. G. Pavlov & Y. A. Shibanov, *A&A* 315, 141 (1996)

*E-mail: danila@astro.ioffe.ru

How unique is the crust of an accreting neutron star? A multicomponent study

Alex T. Deibel[1,2*], Edward F. Brown[1,2,3]

[1]Michigan State University, East Lansing, MI, USA

[2]The Joint Institute for Nuclear Astrophysics

[3]National Superconducting Cyclotron Laboratory, East Lansing, MI, USA

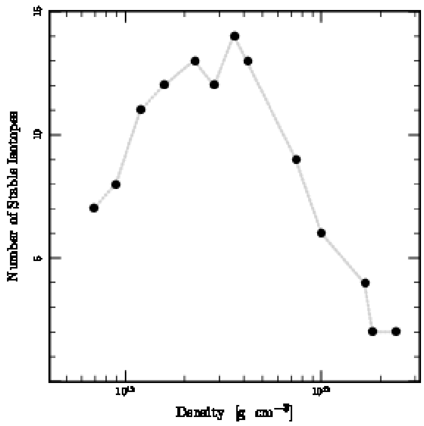

Figure 1: Number of stable isotopes as a function of density in the inner crust.

The crust of an accreting neutron star is expected to have a composition that is different from cold-catalyzed matter. The non-equilibrium reactions induced by the accretion of matter gradually transform the ashes of hydrogen and helium burning to neutron-rich matter in the inner crust [2–5]. These reactions heat and cool the crust, and if the composition is anisotropic, they may produce a mass quadrupole [1]. An important question, then, is how much the composition can vary in the inner crust. We examine this question by using nuclear mass models to investigate the stability of nuclei that must co-exist with degenerate electron and neutron gases. We show that there are few stable nuclei deep in the inner crust, see Fig. 1, and that the accreted inner crust does not contain equilibrium nuclei. We compare our multicomponent composition results with a full reaction network that includes finite electron and neutron capture reaction rates and pycnonuclear reactions from [6].

References

[1] L. Bildsten, *ApJ* 501, L89 (1998)

[2] Bisnovatyĭ-Kogan, G. S. & Chechetkin, V. M. 1979, *Soviet Physics Uspekhi*, 22, 89

[3] Sato, K. 1979, *Progress of Theoretical Physics*, 62, 957

[4] Haensel, P. and Zdunik, J. L. 1990, *A&A*, 227, 431

[5] Schatz, H. Bildsten, L., Cumming, A., & Wiescher, M. 1999, *ApJ*, 524, 1014

[6] Schatz, H., et al. 2014, *Nature*, 505, 62

*E-mail: deibelal@msu.edu

Pair production feedback in pulsar - massive star binaries

E. V. Derishev[1*], F. Aharonian[2,3]

[1]Institute of Applied Physics RAS, 46 Ulyanov st., 603950 Nizhny Novgorod, Russia

[2]Dublin Institute for Advanced Studies, 31 Fitzwilliam Place, Dublin 2, Ireland

[3]Max-Planck-Institut für Kernphysik, Postfach 103980, D-69029 Heidelberg, Germany

We propose a model for ultrarelativistic plasma wind from a pulsar, embedded into stellar wind from a massive companion star. The observed spectrum of such binaries spans a very broad spectral range, extending up to TeV energies. The proposed model takes into account the feedback, started by energetic photons, generated at the pulsar wind termination shock. These photons produce electron-positron pairs; some of the pairs are created within the unshocked wind and receive a huge energy gain when picked up by the ultrarelativistic plasma flow; these energetic secondary pairs radiate at the termination shock, producing new gamma-photons and thus closing the feedback loop. We consider dynamics and radiation of pulsar wind in the framework of the pair feedback model and discuss the resulting spectrum, which appears to be very broad and contains many components.

*E-mail: derishev@appl.sci-nnov.ru

An approximate method to study oscillations of superfluid hyperon stars

V. A. Dommes[1,2*], M. E. Gusakov[1†]

[1]Ioffe Institute, 26 Polytekhnicheskaya, St Petersburg 194021, Russia

[2]St. Petersburg Academic University, 8/3 Khlopina Str, St Petersburg, 194021, Russia

We analyze hydrodynamic equations governing oscillations of superfluid neutron stars with hyperon cores (hyperon stars). We extend the approximate method presented in [1] (for npe-matter) and propose a scheme that allows us to significantly simplify calculations of oscillation modes of such stars. The efficiency of this scheme is illustrated by calculation of sound waves as well as eigenfrequencies of superfluid and normal r-modes in hyperon stars at arbitrary temperature.

References

[1] M. E. Gusakov & E. M. Kantor, *Phys. Rev. D*, 83, 081304 (2011)

*E-mail: vasdommes@gmail.com

†E-mail: gusakov@astro.ioffe.ru

On the mass distribution of black holes and neutron stars

Ya. A. Doronina[1*], I. P. Igoshev[2†], A. F. Kholtygin[1‡]

[1]Saint Petersburg State University, Russia

[2]Radboud University Nijmegen, The Netherlands

We study the mass distribution of newborn neutron stars (NS) and black holes (BH) using a new population synthesis code for massive stars in the Milky Way. These distributions are in a good agreement with those obtained for galactic BH and NS in binary systems. Magnetic field generation in the disks around the BH is also considered.

[*]E-mail: doronina.yana@gmail.com
[†]E-mail: ignotur@gmail.com
[‡]E-mail: afkholtygin@gmail.com

Spectral analysis of the Double Pulsar PSR J0737-3039 with XMM-Newton

E. Egron[1*], A. Pellizzoni[1†], M. N. Iacolina[1‡]

[1]INAF - Osservatorio Astronomico di Cagliari

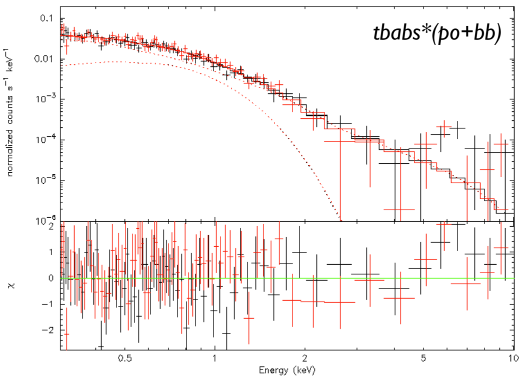

Figure 1: EPIC-pn data obtained in Oct 2006. The nature of the instumental or astrophysical emission feature observed at ∼ 6 keV is under investigation [6].

Since its discovery by [1] and [2] in 2003 and 2004, the first and unique Double Pulsar system PSR J0737-3039 retains all the attention (see [3] for a nice review). This exciting system is composed of two neutron stars: a mildly recycled 23 ms pulsar (heareafter referred to as pulsar A) and a younger pulsar with a period of 2.8 s (heareafter pulsar B), revolving in a tight orbit (∼ 1.25 solar radii) in 2.4 hr. Mean orbital velocities of ∼ 1 million km/h are much higher than those observed in other binary systems. This makes of the Double Pulsar the most relativistic system, and the best test so far to probe theories of gravity in the strong-field regime [2, 4].

The high-energy study of this system is extremely interesting to understand the physics of the magnetospheric emissions and interactions of both pulsars, in particular between the pulsar B's magnetosphere and the wind from pulsar A.

We present the spectral analysis of data from the two XMM-Newton "Large Programs" performed in October 2006 [5] and October 2011, resulting in a total exposure time of ∼ 600 ks. Different models can fit the data, which gives us possible physical interpretations that can explain the origin and nature of the X-ray emission in PSR J0737-3039. In particular, we present a plausible intriguing emission feature at about 6 keV (see Fig. 1) and variation of the spectra with the orbital phase. Moreover, we infer whether any changes are visible between 2006 and 2011 by comparing the results from the two large programs.

References

[1] M. Burgay, N. D'Amico, A. Possenti et al. *Nature* 426, 531 (2003)

[2] A. G. Lyne, M. Burgay, M. Kramer et al. *Science* 303, 1153 (2004)

[3] M. Kramer & I. H. Stairs, *Annual Review of Astronomy & Astrophysics* 46, 541 (2008)

[4] M. Kramer, I. H. Stairs, R. N. Manchester *Science* 314, 97 (2006)

[5] A. Pellizzoni, A. Tiengo, De Luca et al. *ApJ* 679, 664 (2008)

[6] Egron et al. in prep

*E-mail: egron@oa-cagliari.inaf.it

†E-mail: apellizz@oa-cagliari.inaf.it

‡E-mail: iacolina@oa-cagliari.inaf.it

"Low-B Magnetars", "High-B Radio Pulsars" and Dim Isolated Neutron Stars: Long-term Evolution and Radio Emission Properties

Ü. Ertan[1*], Ş. Çalışkan[1], O. Benli[1], M. A. Alpar[1]

[1]Sabancı University, Faculty of Engineering and Natural Sciences, Tuzla, Istanbul

We have investigated the long-term evolution of the so-called "low-B magnetars" and "high-B radio pulsars" with the fallback disk model employed earlier to explain the general properties of the anomalous X-ray pulsars (AXPs) and the soft gamma repeaters (SGRs). Our results indicate that the X-ray luminosity and the rotational properties of these sources can be acquired simultaneously by the neutron stars evolving with fallback disks and with conventional magnetic dipole fields ($10^{12} - 10^{13}$ G). We have also applied the same model with the same basic disk parameters to six dim isolated neutron stars (XDINs) with known period and period derivatives. We have shown that the present properties of XDINs can also be produced by the fallback disk in evolutionary scenarios with surface dipole field strengths $\sim 10^{12}$ G. Our results are consistent with the presence or lack of pulsed radio emission from these different neutron star systems. Most importantly, a large population of XDINs is expected to be observed as pulsed radio sources, if they are evolving in vacuum with the strong dipole fields inferred from the dipole torque formula ($10^{13} - 10^{14}$ G), which is in sharp contrast to observations. Our results indicate that the six XDINs have completed their accretion phase. At present, they do not accrete matter from the disk, while they are still being slowed down by the disk torques. In the fallback disk model dipole fields of XDINs are much weaker than those inferred from the dipole torque model. These fields together with long periods are not sufficient to produce radio emission. On the other hand, relatively young XDINs with shorter periods are evolving in the accretion phase to longer periods, and their radio emission is hindered by the mass flow onto the poles of the neutron stars.

*E-mail: unal@sabanciuniv.edu

Glitches and timing noise

C. M. Espinoza[1*]

[1]Insituto de Astrofísica, Pontificia Universidad Católica de Chile,
Vicuña Mackenna 4860, 7820436 Macul, Santiago, Chile

Glitches and timing noise are rotation irregularities that affect the otherwise smooth rotation of pulsars. While glitches are rapid and sporadic positive step changes in rotation rate, timing noise appears like a slow process, continuously decelerating or accelerating the rotation with respect to a simple slow down model. The exact physical mechanisms giving rise to these effects are unknown and it is unclear whether there is any connection between the two phenomena. In this talk I will summarise recent observational results on timing noise and glitches and I will review their main properties. As a case study, I will present ongoing analyses aiming to quantitatively characterise the timing noise of the Crab pulsar.

*E-mail: cespinoz@astro.puc.cl

Properties of nuclear matter and neutron stars with unified equations of state

A. F. Fantina[1*], N. Chamel[1], J. M. Pearson[2], S. Goriely[1]

[1]Institut d'Astronomie et d'Astrophysique, CP226, Université Libre de Bruxelles, 1050 Brussels, Belgium

[2]Dépt. de Physique, Université de Montréal, Montréal (Québec), H3C 3J7 Canada

The equation of state (EoS) of cold dense matter is studied using a family of generalised Skyrme functionals that have been recently developed by the Brussels-Montreal collaboration [1–3]. The unified EoSs employed here provide a consistent description of both the crust and the core of neutron stars using the nuclear energy-density functional theory with the same Brussels-Montreal functionals. The underlying functionals will be discussed in connection with the present data coming from nuclear physics experiments such as atomic masses, the analysis of experimental data from heavy-ion collisions, neutron skins in nuclei, giant dipole resonances, dipole polarizability measurements, as well as microscopic calculations of homogeneous neutron matter and symmetric nuclear matter (see e.g. Refs. [4–6] and references therein). The structure of neutron stars constructed with these unified EoSs will be discussed, in connection with both astrophysical observations (such as the mass-radius relation and the maximum mass [7]) and nuclear-matter parameters (such as the symmetry energy [8]).

References

[1] J. M. Pearson, S. Goriely, & N. Chamel, *Phys. Rev. C* 83, 065810 (2011)

[2] J. M. Pearson, N. Chamel, S. Goriely, & C. Ducoin, *Phys. Rev. C* 85, 065803 (2012)

[3] S. Goriely, N. Chamel, & J. M. Pearson, *Phys. Rev. C* 88, 024308 (2013)

[4] B.-A. Li, L.-W. Chen, & C. M. Ko, *Phys. Rep.* 464, 113 (2008)

[5] J. M. Lattimer, *Annu. Rev. Nucl. Part. Sci.* 62, 485 (2012)

[6] J. M. Lattimer & Y. Lim, *ApJ* 771, 51 (2013)

[7] A. F. Fantina, N. Chamel, J. M. Pearson, & S. Goriely, *Astron. Astrophys.* 559, A128 (2013)

[8] J. M. Pearson, N. Chamel, A. F. Fantina, & S. Goriely, *Eur. Phys. J. A* 50, 43 (2014)

*E-mail: afantina@ulb.ac.be

IGR J18245-2452: the first pulsar swinging between rotation and accretion powered emission

C. Ferrigno[1]*, E. Bozzo[1], A. Papitto[2], N. Rea[2,3], L. Pavan[1]

[1]ISDC, Department of Astronomy, Université de Genève, chemin d'Écogia, 16, CH-1290 Versoix, Switzerland

[2]Institute of Space Sciences (ICE; IEEC-CSIC), Campus UAB, Faculty of Science, Torre C5, Parell, 2a Planta, E- 08193 Barcelona, Spain

[3]Astronomical Institute "Anton Pannekoek", University of Amsterdam, Postbus 94249, NL-1090 GE Amsterdam, the Netherlands

After the INTEGRAL discovery of a new transient source in the Globular cluster M28 on March 20, 2013, a massive follow-up campaign has been triggered. We observed the new transient with Swift/XRT, XMM-Newton, ATCA, Chandra, and subsequently with various radio telescopes equipped for high timing resolution. IGR J18245-2452 revealed itself to be an accreting millisecond pulsar spinning with a period of 3.9 ms and orbiting with a companion star in 11 hours. In the previous years, a rotationally powered millisecond radio pulsar was observed at the same location with the same timing properties and named PSR J1824-2452I. The X-ray and radio source are thus the same object: the first one ever observed swinging from rotation to accretion powered pulsar emission and vice-versa proving the evolutionary link between these two classes of objects [1].

In this contribution, we review the observations performed so far and discuss the relevance of our findings in the evolutionary model of millisecond pulsars. We also study the intriguing variability of the X-ray emission concentrating on peculiar hard states lasting a few hundreds of seconds and appearing irregularly during the XMM-Newton campaign. We argue that the source swings from normal accretion to a propeller state due to the proximity of the magnetospheric and corotation radii [2].

References

[1] Papitto, A., Ferrigno, C., Bozzo, E., et al. 2013, Nature, 501, 517

[2] Ferrigno, C., Papitto, A., Bozzo, E., et al. 2013, ArXiv e-prints/1310.7784

*E-mail: carlo.ferrigno@unige.ch

Thermal evolution of neutron stars with an hyperonic equation of state

M. Fortin[1,2*], P. Haensel[1†], J. L. Zdunik[1‡]

[1]N. Copernicus Astronomical Center, Bartycka 18, 00-716 Warszawa, Poland

[2]LUTh, UMR 8102 du CNRS, Observatoire de Paris, 92195 Meudon Cedex, France

The recent observations of two 2 $M_\odot$ neutron stars (NSs) [1, 2] have put constraints on the nuclear equation of state (EoS) of dense matter. Among the recent EoSs consistent with these observations are the ones based on non-linear relativistic mean field models allowing for NSs with an hyperon core, e.g., [3, 4].

Models for the thermal evolution of NSs built with one of these [3] are confronted with recent observations [5, 6] of the thermal emission from isolated NSs and from NSs in soft X-ray transients in quiescent states. The former ones gradually cool down after their birth in supernova explosions, and the latter ones undergo short heating phases due to the accretion of matter from the binary companion and subsequent thermal relaxation during quiescence. In both cases, the thermal evolution is sensitive to the properties of the core [7, 8]. Recent developments for the microphysical ingredients (baryon and hyperon superfluidity, neutrino emission processes,. . .) are employed [4, 9].

References

[1] Antoniadis, J., Freire, P. C. C., Wex, N., et al. 2013, *Science*, 340, 448

[2] Demorest, P. B., Pennucci, T., Ransom, S. M., Roberts, M. S. E., & Hessels, J. W. T. 2010, *Nature*, 467, 1081

[3] Bednarek, I., Haensel, P., Zdunik, J. L., Bejger, M., & Mańka, R. 2012, *A&A*, 543, A157

[4] Gusakov, M. E., Haensel, P., & Kantor, E. M. 2014, *MNRAS* , 439, 318

[5] Heinke, C. O., Altamirano, D., Cohn, H. N., et al. 2010, *ApJ*, 714, 894

[6] Keane, E. F., McLaughlin, M. A., Kramer, M., et al. 2013, *ApJ*, 764, 180

[7] Yakovlev, D. G., Levenfish, K. P., & Haensel, P. 2003, *A&A*, 407, 265

[8] Levenfish, K. P., & Haensel, P. 2007, *ApSS*, 308, 457

[9] Tsuruta, S., Sadino, J., Kobelski, A., et al. 2009, *ApJ*, 691, 621

*E-mail: fortin@camk.edu.pl

†E-mail: haensel@camk.edu.pl

‡E-mail: jlz@camk.edu.pl

Observations of X-ray Bursters

D. K. Galloway[1,2*], J. J. M. in 't Zand[3]

[1]Monash Centre for Astrophysics (MoCA)

[2]School of Physics, Monash University, Clayton VIC 3800, Australia

[3]Space Research Organisation Netherlands, Utrecht, NL

Thirty years of studying thermonuclear (type-I) bursts from accreting neutron stars has revealed a surprisingly rich spectrum of behavior. A few sources which have been studied intensively offer confirmed examples of two of the three classes of ignition predicted theoretically, and these systems serve as crucial test-cases for numerical models. However, the behavior of the majority of systems cannot be fully reconciled with theoretical predictions, suggesting there is additional physics at work. Additionally, some new classes of bursts have emerged in recent years, including so-called "super" bursts, likely powered by unstable ignition of carbon, and intermediate-duration bursts which likely require a large accreted reservoir of pure helium.

In this talk I will attempt to summarise the observational status of thermonuclear bursts, including recent progress on the response of the accretion disk to bursts; searches for spectral features during bursts; observations of intermediate-duration and super-bursts; and quantifying the systematic uncertainties that affect measurements of mass and radius from bursts. Finally, I will describe recent observational studies of two remarkable bursters, the first a new transient, Terzan 5 X-2, and the second the well-known Rapid Burster. These sources have shown the most-frequent regular thermonuclear bursts of any source; the influence of their rotation speed (measured as 11 Hz in Terzan 5 X-2) and the comparison with theory will be discussed.

*E-mail: duncan.galloway@monash.edu

Modeling of cyclotron lines in the spectra of isolated neutron stars

M. A. Garasyov[1,2*], E. V. Derishev[1,2†], Vl. V. Kocharovsky[1]

[1]Institute of Applied Physics of the Russian Academy of Sciences, 46 Ulyanova Street , Nizhny Novgorod 603950, Russia

[2]University of Nizhny Novgorod, 23 Gagarin Avenue, Nizhny Novgorod 603950, Russia

We present the results of numerical modeling of radiative transfer in the hot and magnetized atmospheres of neutron stars, including effects of partial frequency redistribution of resonant photons in the cyclotron line. We assume that the atmosphere consists of fully ionized hydrogen or helium. We demonstrate that it is essential to take into account both frequency redistribution of photons during scattering and mode-exchange between the two polarizations in order to obtain the detailed cyclotron line profile and atmospheric structure. Using obtained solutions of radiative transfer equations we specify the range of parameters for which an outflow of plasma is possible under radiation pressure in the cyclotron line. The application of our results for observed neutron stars are discussed.

*E-mail: garasyov@mail.ru

†E-mail: derishev@appl.sci-nnov.ru

Accretion disk boundary layers around neutron stars

M. R. Gilfanov[1]*

[1]IKI, Moscow, Russia

In the accretion disk boundary layer around a neutron star the accreting material decelerates from the Keplerian velocity (of the order of half of speed of light) to the rotation velocity of the neutron star surface, releasing about a half of its gravitational energy. Correspondingly, in the emission spectra of accreting neutron stars a hot and luminous component appears which is absent in the case of black hole accretion. I will review various approaches to the problem of the radiation-dominated boundary layer and confront their predictions with X-ray observations of Galactic low-mass X-ray binaries.

*E-mail: gilfanov@iki.rssi.ru

On the origin of pulsar-like White Dwarfs

V. I. Globina[1,2*], N. R. Ikhsanov[1,3†]

[1]Central Astronomical Observatory of RAS at Pulkovo, Pulkovskoe Shosse 65-1, St. Petersburg 196140, Russia

[2]Ioffe Institute, Polytekhnicheskaya 26, St. Petersburg 194021, Russia

[3]Saint Petersburg State University, Universitetsky pr., 28, Stary Peterhof, St. Petersburg 198504, Russia

We analyze peculiar properties of the nova-like star AE Aquarii identified with a close binary system containing a red dwarf and a very fast rotating magnetized white dwarf. Our study has shown that the white dwarf in AE Aqr is in the ejector state and its dipole magnetic moment is $\mu \simeq 1.5 \times 10^{34}\,\mathrm{G\,cm^3}$. It switched into this state due to intensive mass exchange between the system components during a previous epoch. A high rate of disk accretion onto the white dwarf surface resulted in temporary screening of its magnetic field and spin-up of the white dwarf to its present spin period. Transition of the white dwarf to the ejector state had occurred at a final stage of the spin-up epoch as its magnetic field emerged from the accreted plasma due to diffusion. In the framework of this scenario the white dwarf in AE Aqr resembles a recycled pulsar.

*E-mail: gvi1109@gmail.com

†E-mail: nazar.r.ikhsanov@gmail.com

The spin evolution of the pulsars with non-rigid core

D. P. Barsukov[1,2*], O. A. Goglichidze[1†], A. I. Tsygan[1‡]

[1]Ioffe Institute, St.Petersburg, Russia

[2]Saint Petersburg State Polytechnical University, Russia

We formulate a model of pulsar spin evolution (braking, inclination angle evolution and radiative precession) that takes into account the differential rotation of neutron star core. We consider a neutron star whose shape is symmetrical with respect to the magnetic axis. The star core is described by Newtonian linearised quasistationary hydrodynamical equations in the one-fluid and two-fluids (neutron superfluidity) approximations. Two simple limiting cases have been considered. In the framework of the weak crust-core coupling limiting case it is supposed that the neutron star magnetic field does not penetrate the core and the crust-core interaction occurs only via the viscosity. The opposite limiting case of the strong crust-core coupling corresponds to the assumption that the core protons, electrons and normal neutrons rotate rigidly with the crust and the effect is produced only by the superfluid neutrons which interact with the rest of the neutron star core matter by a weak mutual friction force.

It is shown that the non-rigidity of the core rotation accelerates the inclination angle evolution and makes all pulsars evolve to the orthogonal or coaxial state. This effect depends on the amount of the non-rigidly rotating matter and the mechanism of its interaction with the rest of the star. Since rapid inclination angle evolution seems to contradict the observational data, the results probably may be used as an additional test for the neutron star core matter theories.

This work was partly supported by the Russian Foundation for the Basic Research (project 13-02-00112) and the Programme of the State Support for Leading Scientific Schools of the Russian Federation (grant NSh-294.2014.2).

*E-mail: bars.astro@mail.ioffe.ru
†E-mail: goglichidze@gmail.com
‡E-mail: tsygan@astro.ioffe.ru

New populations of high mass X-ray binaries with neutron stars

S. A. Grebenev[1*]

[1]Space Research Institute, Russian Academy of Sciences

INTEGRAL has discovered many previously unknown high mass X-ray binaries (HMXB) including their new populations: so-called “supergiant fast X-ray transients” and “strongly absorbed sources”. Most of the new binaries contain neutron stars with a strong magnetic field accreting matter from the stellar wind of their masive companions. I review observational properties of these new populations of binaries, general properties of the whole sample of known HMXB, and discuss how our understanding of physical processes accompanying the accretion in these sources coincides with the observations.

*E-mail: sergei@hea.iki.rssi.ru

Modeling of spectra from TeV binaries with pulsars

M. Grudzinska[1*], M. Kapala[2], T. Bulik[1], B. Rudak[3]

[1]Astronomical Observatory, University of Warsaw, Al.Ujazdowskie 4, 00-478 Warsaw, Poland
[2]Max-Planck-Institut für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany
[3]Nicolaus Copernicus Astronomical Center, Rabianska 8, 87-100 Torun, Poland

The development of ground and space based high energy observatories allowed for the identification of a new class of objects – high energy γ–ray binaries. They consist of a compact object and a massive star and emit high energy photons (100 MeV – 10 TeV). There are seven such systems known and only three of them have a well established nature of the compact object: one with a pulsar and two with black holes.

In this contribution we present the results of a numerical model of the γ–ray emission with the assumption that the compact object is a pulsar. We show the modeled spectra and light curves for a range of likely stellar parameters and describe detailed modelling of the LS 5039 binary.

*E-mail: mgrudzinska@astrouw.edu.pl

Features of steady states of collisionless plasma layer with counterstreaming electron-positron beams

A. Ya. Ender[1], A. A. Gruzdev[2*], V. I. Kuznetsov[1]

[1]Ioffe Physical-Technical Institute of the RAS, St. Petersburg, Russia
[2]Saint Petersburg Polytechnical University, St. Petersburg, Russia

In accordance with the Goldreich-Julian model, there are vast regions containing a plasma, formed by counterstreaming flows of relativistic electrons and positrons, in the vicinity of a pulsar. It is thought that powerful radiation in various spectral ranges is generated precisely in these regions. Previously, a steady-state problem for the external gap of the pulsar was studied under the assumption that the potential distribution (PD) was monotonic. We study a planar diode in which electron and positron flows having the same energy and the monoenergetic velocity distribution functions are supplied from opposite electrodes and move in the interelectrode gap with no collisions under a self-consistent electric field. The potential difference between the electrodes equals zero.

We have obtained the full classification of the PDs. As a rule, PD has a wavy form. There is a class of solutions with particle reflection, which occur if the potential barrier of the PD equals the particle energy at the electrode emitting electrons or positrons. These are solutions with a virtual electron emitter (VEE) or a virtual positron emitter (VPE). If the VEE exists, a portion of the electron beam is reflected at the point of the potential minimum and returns to the emitter. If the VPE exists, a positron reflection occurs at the point of the potential maximum. For the quantitative description of partial particle reflection, we introduce the reflection coefficients: r_e for electrons and r_p for positrons, respectively, which represent the density ratio of reflected and injected particles. Then, the particle density is multiplied by $1+r$ in the region occupied by the reflected particles, and by $1-r$ in all the other regions. We introduce dimensionless quantities and use the Debye length and the kinetic energy of electrons at the emitter, $\lambda_D = [2\epsilon W_{be}/(e^2 n_{be})]^{1/2}$ and $W_{be} = m_e v_{be}^2/2$, respectively, as length and energy units. Then, the coordinate is $\zeta = z/\lambda_D$ and the potential is $\eta = e\varphi/(2W_{be})$.

Our study has shown that such a potential distribution belongs to one of the following four types: (i) PD with no electron and no positron reflection ($r_e = 0, r_p = 0$), here $-1/2 < \eta(\zeta) < 1/2$; (ii) PD with partial electron reflection ($0 < r_e < 1$ and the potential minimum $\eta_m = -1/2$) and with no positron reflection ($r_p = 0$); (iii) PD with no electron reflection ($r_e = 0$) and with partial positron reflection ($0 < r_p < 1$ and the potential maximum $\eta_M = 1/2$); (iv) PD with both partial electron ($0 < r_e < 1$) and positron ($0 < r_p < 1$) reflection, with $\eta_m = -1/2$, $\eta_M = 1/2$, and $r_e = r_p$.

At a small electrode distance $\delta = d/\lambda_D$, the steady state is unique. When δ increases, three solutions appear, then two more solutions appear, and so on. A new branch of solutions appears at the bifurcation points. Thus, under the same parameters of the beams as a rule several steady-state solutions exist. Undoubtedly, some of the solutions are stable under small perturbations, and other ones are not.

*E-mail: vedzurg@bk.ru

Superfluid neutron stars

M. E. Gusakov[1*]

[1]Ioffe Institute, St. Petersburg, Russia

Baryons in the internal layers of not too hot neutron stars are likely to be in the superfluid state. Superfluidity has a dramatic effect on the microscopic and macroscopic properties of superdense matter and thus affects the neutron-star evolution in many ways. In my talk I will discuss various aspects related to theoretical modeling of superfluid neutron stars and analyze possible observational signatures of baryon superfluidity (such as glitches, neutron-star cooling and oscillations).

This work 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).

*E-mail: gusakov@astro.ioffe.ru

Maximum pulsar mass and equation of state of neutron-star core

P. Haensel[1*], J.L. Zdunik[1†], M. Bejger[1‡], M. Fortin[1§]

[1]N. Copernicus Astronomical Center, Bartycka 18, 00-716 Warszawa, Poland

Existence of 2 $M_\odot$ pulsars puts very strong constraints on the equation of state (EOS) of neutron-stars (NS) with hyperon cores, which can only be satisfied by some Relativistic Mean Field (RMF) models of hadronic matter. We study the impact of the presence of hyperon cores on the radius-mass relation for NS. We aim at finding how, and for which particular stellar mass range, a specific relation $R(M)$ is associated with the presence of a hyperon core [4]. We consider two sets of theoretical EOS of dense matter, {EOS.N} involving nucleons only, and {EOS.H} allowing for the presence of hyperons. For NS masses $1.0 < M/M_\odot < 1.6$, we get $R^{(H)} > 13.5$ km, while $R^{(N)} < 12.5$ km. The radius gap that we find is due to a high stiffness of the pre-hyperon segment of EOS.H. At nuclear density ($n_0 = 0.16\ \mathrm{fm}^{-3}$) $P^{(H)}$ is two-three times larger than $P^{(N)}$ [4]. These large values of $P^{(H)}(n_0)$ are strongly inconsistent with a robust upper bound obtained recently [2]. If massive NS do have a sizable hyperon core, their radii for $M = 1.4\ M_\odot$ are > 13.5 km, violating (90% CL) upper bound obtained in [3] from the analysis of X-ray spectra of X-ray bursters and transients. A future X-ray space observatory with < 5% precision of a simultaneous M and R measurement will have potential to solve the problem by observations of NS.

It has been proposed that replacing hyperon core by a sufficiently stiff quark-matter EOS.Q could yield $M_{\max} > 2\ M_\odot$. However, this would require a stiff EOS.Q with $v_{\mathrm{sound}}/c > 0.7$ [1], which could lead to an instability of massive NS with quark cores due to a reconfinement phase transition. However, in contrast to point-like quarks, baryons have finite size. Including baryon size effect via a relativistic excluded volume approximation increases $M_{\max}$ and solves the problem of a high-density reconfinement of quarks in NS cores [5].

References

[1] J.L. Zdunik & P. Haensel, A & A 551, A61 (2013)

[2] K. Hebeler, J.M. Lattimer, C.J. Pethick, A. Schwenk, *ApJ* 773, 11 (2013)

[3] A.W. Steiner, A.W., J.M. Lattimer, J.M., E.F. Brown, *ApJL*, 765, L5 (2013)

[4] J.L. Zdunik, P. Haensel, M. Bejger, M. Fortin, to be submitted for publication (2014a)

[5] J.L. Zdunik, P. Haensel, M. Bejger, M. Fortin, to be submitted for publication (2014b)

*E-mail: haensel@camk.edu.pl

†E-mail: jlz@camk.edu.pl

‡E-mail: bejger@camk.edu.pl

§E-mail: fortin@camk.edu.pl

Determination of the Pulsar Image in the Picture Plane

V. S. Beskin[1,2*], H. L. Hakobyan[2†]

[1]Lebedev Physical Institute, Moscow, Russia

[2]Moscow Institute of Physics and Technology, Dolgoprudny, Russia

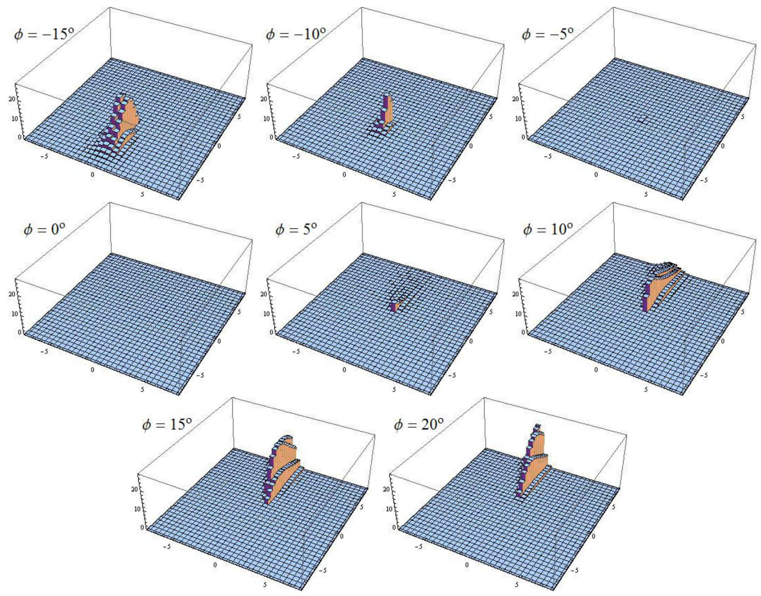

Figure 1: Image of the pulsar in the picture plane for different phases ϕ, the scale is in star radii.

The determination of the size of the radio pulsar in the picture plane is an important problem not only because of the possibility of direct angular resolution, but also for constraining and verification of the existing radio emission theories.

Assuming that the intensity of the emission is proportional to the number density of secondary plasma, we have directly calculated the form and the size of the radio pulse in the picture plane for the simple case of dipole magnetic field both for the extraordinary (X) and the ordinary (O) modes. We have also obtained the images for different model parameters, namely, for different heights and inclination angles. We find that in all cases the width of the image is several times larger on the edges of the pulse than in the middle. For radiation height $r_{\rm rad} = 10R$ the image width is approx. 10^7 cm, its velocity in the picture plane being approx. 1000 km/h, in full agreement with recent observations [1].

References

[1] Ue-Li Pen, et al., *MNRAS* (2014) in press, http://arxiv.org/abs/1301.7505

*E-mail: beskin@lpi.ru
†E-mail: hayk.hakopyan@gmail.com

X-ray emission mechanisms in magnetars

R. Hascoët[1]*, A. M. Beloborodov[1]†

[1]Physics Department and Columbia Astrophysics Laboratory, Columbia University, 538 West 120th Street, New York, NY 10027, USA

In the magnetar model, the observed persistent luminosity and outbursts are both powered by dissipation of magnetic energy. The emission mechanisms of persistent and burst emission will be discussed and compared. Observations suggest the presence of hot spots on magnetars. They may result from internal (subsurface) or external (magnetospheric) heating. Both mechanisms appear to be needed to explain the data.

*E-mail: hascoet@astro.columbia.edu
†E-mail: amb@phys.columbia.edu

Simultaneous XMM-Newton Radio observations of the mode-switching radio pulsar PSR B1822-09

A. W. Hermsen[1,2]*, B. J.W.T. Hessels[2,3], L. Kuiper[1], J. van Leeuwen[2,3], D. Mitra[4], J.M. Rankin[5], B.W. Stappers[6], G.A.E. Wright[7], R. Basu[4]

[1]SRON, Netherlands Institute for Space Research, Sorbonnelaan 2, 3584 CA, Utrecht, The Netherlands

[2]Astronomical Institute Anton Pannekoek, Amsterdam, The Netherlands

[3]ASTRON, the Netherlands Institute for Radio Astronomy, Postbus 2, 7990 AA Dwingeloo, The Netherlands

[4]National Centre for Radio Astrophysics (NCFRA-TIFR), Post Bag 3, Ganeshkhind, Pune University Campus, Pune 411007, India

[5]Physics Department, University of Vermont, Burlington, VT 05405, USA

[6]Jodrell Bank Center for Astrophysics, School of Physics and Astronomy, The University of Manchester, Manchester M13 9PL, UK

[7]Astronomy Centre, University of Sussex, Falmer, Brighton BN1 9QJ, UK

With XMM-Newton, GMRT and LOFAR observations of the mode-changing near-aligned pulsar PSR B0943+10 we discovered synchronous switching in the radio and X-ray emission properties [1]. These extraordinary findings supported radio indications for rapid, global changes of the conditions in the magnetosphere, and challenged all proposed emission models. PSR B1822-09 is a fascinating orthogonal pulsar exhibiting similar mode switching in the radio band. Mode switching in the radio emission of PSR B1822-09 is not only seen in the main-pulse and precursor emissions (like for PSR B0943+10), but also in that of the interpulse. The latter switches in anti-correlation with the main pulse. We organized for this pulsar a similar campaign of simultaneous XMM-Newton, GMRT, WSRT and Lovell observations, the last observations being performed in March 2014. In this presentation we will report the results from the latter campaign and discuss these in comparison with those for PSR B0943+10 in the context of competing theoretical emission models.

References

[1] W. Hermsen et al., *Science* 339, 436 (2013)

Comprehensive analysis of pulsars velocity distribution

A. P. Igoshev[1]*, F. W. M. Verbunt[1]

[1]Department of Astrophysics/IMAPP, Radboud University Nijmegen

The velocity distribution of newly born neutron stars is an important ingredient in understanding the fractions of neutron stars retained in binaries and in globular clusters, and in understanding the galactic distribution of neutron stars. Notwithstanding the number of detailed studies over the last two decades, there is still no agreement on the velocity distribution, in particular in the low-velocity ($v < 50$ km/s, say) range. We present a simple test which indicates that the fraction of low-velocity neutron stars must be appreciable. We critically investigate the various methods used previously, in light of the newer and better measurements, and develop a novel non-parametric method which properly takes account of measurement errors in the proper motion and in the distance. This leads us to conclude that about 12% of all pulsars are born with velocities less than 50 km/s.

*E-mail: a.igoshev@science.ru.nl

A new look at the Anomalous X-ray Pulsars

G. S. Bisnovatyi-Kogan[1,2*], N. R. Ikhsanov[3,4†]

[1]Space Research Institute of RAS, 84/32 Profsoyuznaya Str, Moscow 117997, Russia
[2]National Research Nuclear University "MEPhI", Kashirskoye shosse 31, Moscow 115409, Russia
[3]Central Astronomical Observatory of RAS at Pulkovo, Pulkovskoe Shosse 65-1, St. Petersburg 196140, Russia
[4]Saint Petersburg State University, Universitetsky pr., 28, Stary Peterhof, Saint Petersburg 198504, Russia

We explore a possibility to model spin evolution of the Anomalous X-ray Pulsars (AXPs) in terms of accretion by an isolated neutron star from a fossil non-Keplerian magnetic disk. We show that the observed spin-down rates of the neutron stars can be explained within this scenario provided the surface magnetic field of the star is ranged within the interval $10^{10} - 10^{13}$ G [1]. The X-ray spectra of the pulsars under these conditions are soft and fit well the observed spectra. The period clustering and gamma-ray activity of these sources are briefly discussed.

References

[1] G.S. Bisnovatyi-Kogan & N.R. Ikhsanov, *Astronomy Reports* 58, No. 4, in press (2014) [arXiv:1401.2634]

*E-mail: gkogan@iki.rssi.ru
†E-mail: nazar.r.ikhsanov@gmail.com

Thermal emission of neutron stars with internal heaters

A. D. Kaminker[1*], A. A. Kaurov[2], A. Y. Potekhin[1,3], D. G. Yakovlev[1]

[1]Ioffe Institute, St. Petersburg, Russia

[2]University of Chicago, USA

[3]Central Astronomical Observatory at Pulkovo, St. Petersburg, Russia

We model thermal structure and thermal surface radiation of neutron stars with steady internal heaters. Using 2D and 1D cooling codes we analyze the propagation of heat from these heaters varying their locations, geometries and intensities. We take two equations of state (EOSs) of neutron star matter, SC+HHJ and BSk21, from Refs. [1] and [2], respectively. The former is based on a simple energy-density function. The latter is more elaborated; it is employed to test the sensitivity of the results to variations of EOSs. For both EOSs we investigate two neutron star models, with the standard neutrino emission from the core and with the fast neutrino emission provided by the direct Urca process. We demonstrate that the generated heat mainly propagates radially to the interior of the star (and is carried away by neutrinos from there), although a small part of the heat diffuses outwards to be emitted as the thermal surface radiation. In local regions near the heater the results can be well described with the 1D code. The heater creates a hot spot, which looks like heater's projection on the stellar surface. We discuss the existence of two heat propagation regimes. In the first *conduction outflow* regime, the heat rates $H_0 \lesssim 10^{20}$ erg cm^{-3} s^{-1} and the heater's temperature $T_{\rm h} \lesssim 10^9$ K are not too high, and the thermal surface emission of the star is controlled by the heater's power and the neutrino emission in the stellar core. In the second *neutrino outflow* regime, the heater is more powerful ($H_0 \gtrsim 10^{20}$ erg cm^{-3} s^{-1}, $T_{\rm h} \gtrsim 10^9$ K) and the thermal energy is mainly carried away by neutrinos. Then the surface and the outer layers of the crust become thermally decoupled from the interior and even strong variations of the heater's power cannot significantly affect the surface emission. The most economical heater should be placed in the outer crust and be moderately strong ($H_0 \sim 10^{20}$ erg cm^{-3} s^{-1}). We outline possible applications of the results to young and hot neutron stars, to neutron stars in soft X-ray transients, to magnetars and high-B pulsars.

The authors are grateful for the partial support by the State Program Leading Scientific Schools of RF (grant NSh 294.2014.2). The work of AK, AP, and DY was also partially supported by the RFBR grant 14-02-00868-a, and the work of DY by the RFBR grant 13-02-12017-ofi-M.

References

[1] M. E. Gusakov, A. D. Kaminker, D. G. Yakovlev, O. Y. Gnedin, *MNRAS*, 363, 555 (2005)

[2] A. Y. Potekhin, A. F. Fantina, N. Chamel, J. M. Pearson, S. Goriely, *Astron. Astrophys.*, 560, A48 (2013)

*E-mail: kam@astro.ioffe.ru

Anti-glitches within the glitch model of Anderson and Itoh

E. M. Kantor[1], M. E. Gusakov[1]

[1]Ioffe Institute, St. Petersburg, Russia

The generally accepted model of neutron star (NS) glitches, proposed in [1], assumes that sudden unpinning of a group of vortices from their pinning centers results in a spin up of the NS normal component – a glitch. Here we present a toy model which demonstrates that, under certain conditions, an opposite effect – anti-glitch – can take place due to avalanche-like unpinning of vortices. Our model takes into account the so-called ΔV-effect [2] – the dependence of the superfluid energy gap on the relative velocities of the normal and superfluid NS components. When a group of vortices leaves the superfluid region, the velocity lag between the normal and pinned superfluid components decreases and, due to ΔV-effect, the mass of the superfluid fraction increases. Such a redistribution of mass between the normal and superfluid liquid components, which has been ignored so far, can naturally lead to an anti-glitch for certain model parameters. The effect follows from the angular momentum conservation in the event,

$$I_{c0}\Omega_{\rm c0} + I_{s0}\Omega_{\rm s0} =$$
$$[I_{c0} + I_c'(\Delta\Omega_{\rm s} - \Delta\Omega_{\rm c})](\Omega_{\rm c0} + \Delta\Omega_{\rm c}) + [I_{s0} - I_c'(\Delta\Omega_{\rm s} - \Delta\Omega_{\rm c})](\Omega_{\rm s0} + \Delta\Omega_{\rm s}), \quad (1)$$

where we take into account that the moments of inertia of the pinned superfluid component I_s and the remaining 'normal' liquid component I_c depend on the rotation lag $\Omega_s - \Omega_c$ ($\Omega_{\rm s}$ and $\Omega_{\rm c}$ are the rotation frequencies for the pinned superfluid and normal liquid components, respectively). In Eq. (1) the subscript 0 refers to the quantities *before* the vortex unpinning; $I_c' = dI_c/d(\Omega_s - \Omega_c)$; Δ denotes the variation of the corresponding quantity in the event. It follows from this equation that we shall observe an abrupt pulsar spin down if

$$(\Omega_{\rm s0} - \Omega_{\rm c0})I_c' > I_{s0}. \quad (2)$$

A numerical estimate shows that the proposed effect can explain the recently observed anti-glitch [3] in a magnetar 1E2259+586, if one assumes that vortices are pinned to the flux tubes in the NS core.

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

References

[1] P. W. Anderson & N. Itoh, *Nature* 256, 25 (1975)

[2] M. E. Gusakov & E. M. Kantor, *MNRAS* 428, L26 (2013)

[3] R. F. Archibald, V. M. Kaspi, C.-Y. Ng et al., *Nature* 497, 591 (2013)

Nearby, Thermally Emitting Neutron Stars

D. L. Kaplan[1*], M. DeCesar[1], M. van Kerkwijk[2], J. Speagle[3], P. Demorest[4], S. Chatterjee[5]

[1]University of Wisconsin, Milwaukee
[2]University of Toronto
[3]Harvard University
[4]NRAO
[5]Cornell University

I will discuss observational constraints on the properties and evolution of nearby, thermally emitting neutron stars. Combining X-ray spectroscopy and timing with optical photometry and astrometry, we are working to understand their origin and structure, but new observations continue to puzzle. I will review what we have learned and include results from recent optical and X-ray observations.

*E-mail: kaplan@uwm.edu

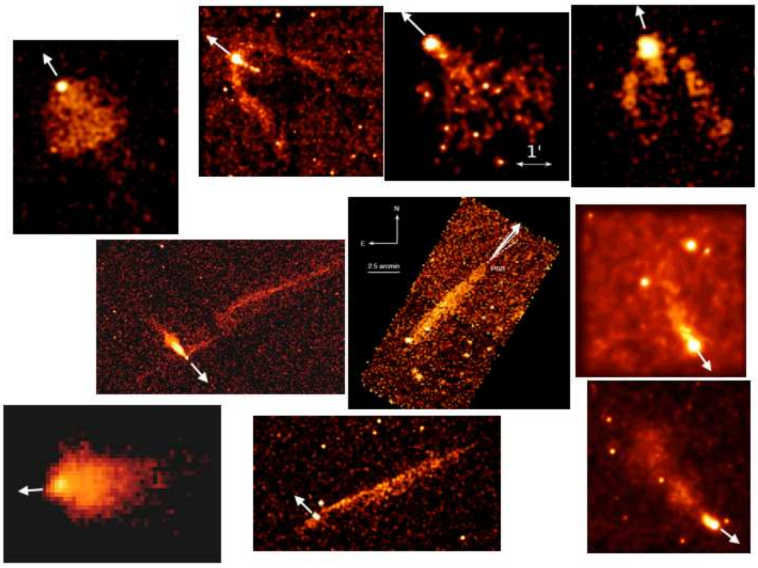

Figure 1: Chandra images of tails and other structures associated with fast moving pulsars. For each pulsar the arrows show the direction of proper motion.

Multiwavelength observations of pulsar wind nebulae

O. Kargaltsev[1*], G. G. Pavlov[2†], B. Rangelov[1‡]

[1]Department of Physics, George Washington University, Washington, DC, 20052

[2]Department of Astronomy & Astrophysics, Pennsylvania State University, University Park, PA, 16802

Multiwavelength observations have significantly advanced our understanding of pulsar winds and pulsar wind nebulae (PWNe). In particular, deep, high-resolution imaging in X-rays reveals the fine structure of pulsar winds, such as termination shocks in the equatorial wind, polar jets with moving knots, cometary-shaped bow shocks (see Figure 1), and more complex structures on different scales. The spatially-resolved X-ray spectroscopy allows measurements of the particle injection spectrum in the vicinity of the termination shock and enables investigations of the spectral evolution as a function of distance from the pulsar. Finally, multiple observations of the same PWNe have demonstrated that the PWNe can be highly variable on various timescales. I will review most recent interesting results, including deep Chandra observations of the Vela PWN and several long pulsar tails (see Figure 1), HST/Chandra/eVLA observations of the Crab PWN, HST far-UV imaging of the J0437–4715 bow shock, and dynamic nebula of B1259–63 binary. I will also discuss the multiwavelength properties of PWNe detected in high-energy γ-rays.

*E-mail: kargaltsev@gwu.edu
†E-mail: pavlov@astro.psu.edu
‡E-mail: blagoy.rangelov@gmail.com

Thermal properties of the middle-aged pulsar J1741−2054

A. Karpova[1,2*], A. Danilenko[1], Yu. Shibanov[1,2], P. Shternin[1,2], and D. Zyuzin[1]

[1]Ioffe Institute, St. Petersburg, Russia

[2]St. Petersburg State Polytechnical University, Russia

We present results of the spectral analysis of the X-ray emission from the middle-aged *Fermi* pulsar J1741−2054 using all *Chandra* archival data collected in 2010 and 2013. We confirm early findings by Romani et al. 2010 that the pulsar spectrum contains a thermal emission component. The component is best described by the blackbody model with the temperature ≈ 60 eV and the emitting area radius $\approx 17\ D_{\rm kpc}$ km. The thermal emission likely originates from the entire surface of the cooling neutron star if the distance to the pulsar is ≈ 0.8 kpc. The latter is supported by a large absorbing column density inferred from the X-ray fit and empirical optical extinction–distance relations along the pulsar line of sight. The neutron star surface temperature and characteristic age make it similar to the well studied middle-aged pulsar B1055−52. Like the latter PSR J1741−2054 is hotter than the standard cooling scenario predicts.

*E-mail: annakarpova1989@gmail.com

Magnetic field of neutron star precursors: Wolf-Rayet stars

A. F. Kholtygin[1]*

[1]Astronomical Institute, Saint-Petersburg University, Russia

Detections of magnetic fields in O stars, combined with known strong fields in their descendant neutron stars (NS) tell us that there is also a chance to observe magnetic fields of the Wolf-Rayet (WR) stars. We review the newest results of the magnetic field search in these objects [2]. The problems of the field detection associated with the presence of winds exceeding by an order of magnitude those of O stars are also discussed. We estimate the initial distribution of the magnetic fields for NS using our measurements of the magnetic field values for O and WR stars [1, 3].

References

[1] A.F. Kholtygin, S.N. Fabrika, N. Rusomarov et al. , *AN* 332, 108 (2011)

[2] A. de la Chevrotiére, N. St-Louis, A. F. J. Moffat & the MiMeS Collaboration, *ApJ* 781, id. 73 (2014)

[3] S. Hubrig, M. Scholler, I.Ilyin et al., A & A, 551, id. A33 (2014)

*E-mail: afkholtygin@gmail.com

Investigation of the interaction between the two-flow magnetar jet and the interstellar medium

S. O. Kiikov[1*]

[1] South Ural State University (National Research University), Prospect Lenina 76, Chelyabinsk, 454080, Russia

The interaction of the jet from a magnetar with the surrounding interstellar medium is studied. The magnetar jet consists of the inner fast and outer slow flows. The inner flow is launched from the central object or the innermost part of the accretion disk via the open magnetic field lines threading the magnetar or the inner edge of the accretion disk. The outer flow is launched from all parts of the accretion disk via the open magnetic field lines anchored in the disk. The plasma parameters of the interaction region between the two-flow magnetar jet and the interstellar medium are evaluated.

*E-mail: kiikov@susu.ac.ru

Magnetocavitation mechanism of jet generation from accreting magnetar

S. O. Kiikov[1]*

[1] South Ural State University (National Research University), Prospect Lenina 76, Chelyabinsk, 454080, Russia

The phenomenon of the jet generation from an accreting magnetar is studied. The magnetocavitation mechanism as a possible mechanism of the jet generation is suggested. According to this mechanism, the jet is produced because of the magnetospheric collapse associated with the processes of the magnetar quake, resonant interaction of the magnetosphere with the accreted plasma and actions of the shock waves from the accretion disk of the magnetar. Although the proposed mechanism puts some constraints on the jet parameters, the estimates of the jet parameters agree with the observational data within these constraints. A comparison of the jet parameters with those of the classical stellar wind, carried out in this work, reveals some laws governing the flows of the space plasma.

*E-mail: kiikov@susu.ac.ru

Evidence for Magneto-Levitation Accretion in the 6.7 h isolated X-ray pulsar 1E 161348-5055

N. R. Ikhsanov[1,2*], V. Yu. Kim[1†], N. G. Beskrovnaya[1‡], L. A. Pustil'nik[3,4§]

[1]Central Astronomical Observatory of RAS at Pulkovo, Pulkovskoe Shosse 65-1, St. Petersburg 196140, Russia

[2]Saint Petersburg State University, Universitetsky pr., 28, Stary Peterhof, Saint Petersburg 198504, Russia

[3]Israel Cosmic Ray and Space weather Center of Tel Aviv University, Israel Space Agency, and Golan Research Institute, Israel

[4]University ITMO, Saint Petersburg, Russia

The point X-ray source 1E 161348-5055 is observed to produce pulsations with the period of 6.67 hr. The source is associated with the 2000 yr old supernova remnant RCW 103 and is widely believed to be a neutron star. Observations give no evidence for the star to be a member of a binary system. Nevertheless, it resembles an accretion-powered pulsar with the magnetospheric radius ~ 3000 km and the mass-accretion rate $\sim 10^{14}\,\mathrm{g\,s^{-1}}$. We show that the origin and the current state of the pulsar can be explained in terms of an accretion from a fossil non-Keplerian magnetic disk (magnetic slab) provided the surface magnetic field of the star is about 10^{12} G [1]. The origin and basic parameters of the magnetic slab are briefly discussed.

References

[1] N.R. Ikhsanov, V. Yu. Kim, N.G. Beskrovnaya, & L.A. Pustil'nik, *ApSS* 346, 105 (2013) [arXiv:1212.0375]

*E-mail: nazar.r.ikhsanov@gmail.com

†E-mail: ursa-majoris@yandex.ru

‡E-mail: beskrovnaya@yahoo.com

§E-mail: levpust@post.tau.ac.il

AMXP to MSRP : Transition (mis-)understood?

S. Konar[1]*, D. Bhattacharya[2]†, D. Mukherjee[2]‡

[1]National Centre for Radio Astrophysics (TIFR), Pune, India

[2]Inter-University Centre for Astronomy and Astrophysics, Pune, India

A neutron star in a low-mass X-ray binary (LMXB) have its magnetic field significantly weakened ($B \leq 10^{10}$ G) through an extended phase of accretion. The variety of physical process taking place in such LMXBs are manifested as thermonuclear X-ray bursts; accretion-powered millisecond-period pulsations; kilohertz quasi-periodic oscillations; broad relativistic iron lines; and quiescent emissions [1]. These have given rise to two exciting observational classes in recent times - the accreting millisecond X-ray pulsars (AMXP) and the X-ray transients (XRT). An AMXP is an accretion powered X-ray pulsar with $\nu \geq 100$ Hz pulsations being seen in their persistent X-ray emissions [2]. Because the accretion rates are extremely small ($\dot{M} \leq 10^{-11}$ $M_\odot$/yr) in these LMXBs having very small donor stars ($M \leq 1$ $M_\odot$), even the weak magnetic fields of the neutron star manage to channel the flow of material. A fraction of the LMXBs emit X-ray bursts in addition to the persistent X-ray flux, produced by thermonuclear flashes of the freshly accreted matter. Underlying millisecond oscillations have now been detected in 17 such objects. These are the XRTs. With many of the AMXPs also showing bursts, it is now felt that these two groups are most likely identical.

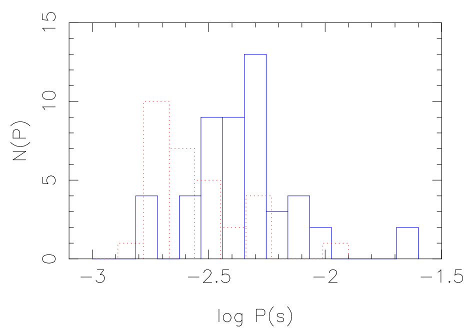

Figure 1: Period histogram of AMXPs (red dotted) and isolated MSRPs (blue solid).

In this work we investigate two aspects of the AMXP/XRT generation. First, we examine whether the presently accepted theories of field evolution [3] in accreting neutron stars can generate both the observed millisecond radio pulsar (MSRP) and the AMXP population and whether they come from similar progenitors. Next, we find that the spin-period distribution of the AMXPs appear to be different from that of the isolated MSRPs (which the AMXPs are expected to evolve into) as seen in Fig. 1. We compare the isolated MSRP population with that evolved from the AMXP population using a Monte-Carlo simulation and find that they remain different.

References

[1] Bhattacharyya, S., 2010, AdSpR, 45, 949

[2] Patruno, A., Watts, A. L., 2012, arXiv:1206.2727

[3] Konar S., Bhattacharya D., 1997, MNRAS, 284, 311

*E-mail: sushan@ncra.tifr.res.in

†E-mail: dipankar@iucaa.ernet.in

‡E-mail: dipanjan@iucaa.ernet.in

Radio Pulsar Recycling : The HMXB Question

S. Konar[1*]

[1]National Centre for Radio Astrophysics (TIFR), Pune, India

The magnetic field of neutron stars, ranging from 10^8 G in millisecond radio pulsars to 10^{15} G in magnetars, either evolves spontaneously or as a consequence of material accretion in binaries. This evolution effectively define the evolutionary links between different types of neutron stars. Some of the evolutionary pathways, for example, the connection between the ordinary radio pulsars and their millisecond cousins via processing in low-mass X-ray binaries (LMXB) or intermediate-mass X-ray binaries (IMXB), are now well established.

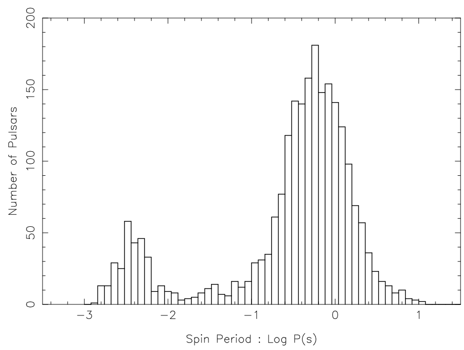

Figure 1: Period histogram of all radio pulsars.

However, the evolution in high-mass X-ray binaries (HMXB) has not yet been investigated in detail. Neutron stars in HMXBs typically have $B_p \sim 10^{12}$ G and O or B type companions. Since the timescales in such massive binaries are much smaller than those in LMXBs or IMXBs, the change of the magnetic field and the spin may not be significantly large. Interestingly, the spin-period histogram of all radio pulsars in Fig. 1 does indicate the existence of a separate population between the normal and the millisecond radio pulsars. In this work, we look at the end products of evolution in HMXBs and examine whether any particular sub-population of observed radio pulsars identify with them.

*E-mail: sushan@ncra.tifr.res.in

Millisecond pulsars at low frequencies with LOFAR

V. I. Kondratiev[1,2*] and LOFAR Pulsar Working Group

[1]ASTRON, Netherlands Institute for Radio Astronomy
[2]Astro Space Center of the Lebedev Physical Institute

We report on detection of 38 millisecond pulsars (MSPs) out of 55 observed so far with LOFAR at the frequencies of 110–188 MHz. This is the largest sample of MSPs ever observed and detected with a single radio telescope at these low frequencies. We have also detected 3 MSPs out of 9 observed with LOFAR LBAs in the frequency range of 38–77 MHz. We present the profiles of the detected MSPs, provide their flux measurements at 150 MHz and compare them with the expected values. We also present the measurements of the average values of dispersion measures (DMs) and discuss DM and profile variations. This unique data set allows us to study with unmatched precision pulse profile evolution with frequency, dispersion, rotation measure, and scattering from the interstellar medium. Characterizing and correcting these systematic effects will potentially improve pulsar timing precision at higher observing frequencies.

*E-mail: vlad.kondratiev@gmail.com

Soft γ-ray bursts as magnetoemission of junior magnetar crusts

Yu. V. Korovina [1], V. N. Kondratyev [2,3*]

[1] Department of Technology, Moscow Institute of Open Education, Moscow, Russia

[2] Physics Department, Taras Shevchenko National University of Kiev, 03022-UA Kiev, Ukraine

[3] Bogolubov Laboratory of Theoretical Physics, JINR, 141980, Dubna, Russia

The ultra-magnetized astrophysical objects, i.e., magnetars, were invoked to interpret the activity of soft gamma repeaters (SGRs) and anomalous X-ray pulsars (AXPs). Various observational data for these pulsars strongly support the magnetar concept implying, thereby, enormous stellar magnetization with field strengths up to hundred of tera-tesla.

In this contribution the SGR burst emission is considered as a release of magnetic energy stored in the baryonic degrees of freedom of the neutron star. Particular attention is paid to magnetodynamics of the star outer crusts being plausibly composed of well-separated magic nuclei, cf. [1]. The nuclear magnetization is demonstrated to display the sharp abrupt field dependence due to quantization of spatial motion. As shown for neutron star crusts such jump anomalies of magnetic moments in conjunction with the ferromagnetic inter-nuclide coupling give rise to jerky magnetodynamics with erratic sharp step-wise discontinuities in the crust (de)magnetization process due to avalanche propagation. As a consequence, sudden energy release to the magnetosphere leads to SGR-burst, cf. [1].

For a description of such noisy collective magnetoemission of neutron star crusts we develop the Randomly Jumping Interacting Moments (RJIM) model accounting for quantum fluctuations due to the discrete level structure, inter-nuclide coupling, disorder and demagnetization energy. The comparison of model predictions with observational data allows, therefore, to quantify crust properties. It is shown that the predicted by RJIM model scaling behavior, e.g., for the burst intensity and waiting time distributions are in a good agreement with SGR observations supporting thereby the credibility of the RJIM model. Further implications of the proposed magnetic emission mechanism in the analysis of the SGR activity can provide better understanding of the neutron star crust, in particular, strengths and evolution of the magnetic fields.

References

[1] V.N. Kondratyev, *Phys.Rev.Lett.* 88, 221101 (2002); *J.Phys.CS* 248, 012027 (2010); *PhANE* 4, 1102 (2013)

*E-mail: vkondrat@mail.univ.kiev.ua

Electromagnetic tornado semiclassical quantization and origin of the bands in the giant pulses frequency spectrum of the Crab pulsar

V. M. Kontorovich[1,2*],

[1]Institute of Radio Astronomy NASU

[2]Kharkiv National V.N. Karazin University

Giant radio pulses of pulsars have a circular polarization and characteristic bands in the inter pulse frequency spectrum (T.H. Hankins and J.A. Eilek, Ap.J., 670, 693, 2007), for which an adequate explanation is still absent. Assumptions made presently about the nature of the bands use an analogy with the solar plasma effects, but in this case the magnetic field must be sufficiently weak. Specifically, the formation of bands has to be associated with a specially introduced dense region far away from the star (near the light cylinder at the periphery of the magnetosphere). The model, which we discuss below, uses the quantization of the electromagnetic whirlwinds (tornadoes) introduced to explain the circular polarization of the giant pulses from pulsars. The tornadoes can occur at breakdown in the inner gap of pulsars, the particle acceleration region, located near the pulsar magnetic poles. They are cylindrical flows of electrons (or positrons) rotating around their axes in crossed beam space charge field and super strong magnetic field of the pulsar and they can be responsible for the generation of giant pulses (V.M. Kontorovich, JETP, 110, 966, 2010). There are two branches in the spectrum: the high energy modified Landau branch and the low energy drift one. The colossal value of the magnetic field $B \simeq 10^{12}G$ leads to quantization of the electron motion in the tornado. The result is the quantization of current in the gap, with the quantum of current determined only by the magnetic field. In the context of pulsars in such strong electric and magnetic fields and for the relativistic motion of particles it is necessary to consider the possible influence of the electron spin on the quantization of the electron motion as done in this report. In the quantization rule the electron spin enters through the topological Berry phase. Just as in the absence of an electric field by virtue of compensation of the orbital and spin terms there is no gap of zero-point vibrations in the spectrum. Due to this fact the semiclassical quantization is possible. The quantization allows one to offer a natural explanation for the observed bands in the frequency spectrum of the inter pulse radiation of pulsar PSR J0534 +22 in the Crab Nebula and to determine the tornado physical parameters. The relativistic aberration allows us to understand the difference between the spectra of the main pulse and the inter pulse at frequencies of emission mechanism change near the high-frequency spectrum break of the Crab pulsar, where the bands are observed (V.M. Kontorovich and A.B. Flanchik: Radio emission with acceleration of electrons in a polar gap of a pulsar. Physics of Neutron Stars – 2011, Saint-Petersburg, Russia, Abstract book, p.75; http://www.ioffe.ru/astro/NS2011/index.html). Some details of the observed spectral bands (two maxima in the band, frequency trend etc.) are discussed and also provided with a natural explanation in the framework of this model.

*E-mail: vkont1001@yahoo.com

Coulomb crystal mixtures in white dwarf cores and neutron star crusts

A. A. Kozhberov[1*], D. A. Baiko[1]

[1]Ioffe Institute, St. Petersburg, Russia

In a wide range of densities and temperatures of physical interest matter in white dwarf cores and neutron star crusts can be modeled as a mixture of fully ionized atomic nuclei with different charges and masses arranged in a body-centered cubic crystal lattice and immersed into the uniform charge-neutralizing background of degenerate electrons. In this work we study electrostatic and thermodynamic properties of such substitutionally disordered Coulomb crystal mixtures composed of ions of two different types. The applicability of results is discussed.

*E-mail: kozhberov@gmail.com

The soft γ-ray pulsar population and its link to the Fermi-LAT pulsar population: a full high-energy picture

L. Kuiper[1*], W. Hermsen[1,2†]

[1]SRON-National Institute for Space Research, Sorbonnelaan 2, 3584 CA, Utrecht, The Netherlands
[2]Astronomical Institute "Anton Pannekoek", University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands

While at high-energy gamma-rays (> 100 MeV) the Fermi-LAT has already detected more than 145 pulsars since its launch in June 2008, the number of pulsars seen at soft gamma-rays (20 keV - 30 MeV) is still very limited, though steadily growing.

Namely, in recent years targeted deep radio and/or X-ray observations of Supernova remnants, GeV and TeV sources and newly discovered INTEGRAL sources revealed the presence of young and energetic pulsars, surrounded by bright pulsar wind nebulae.

Currently, the total number of detected soft gamma-ray pulsars counts 16 secure members. The average characteristics of these soft gamma-ray pulsars differ from those of the LAT detected pulsars. For instance, the Fermi LAT pulsar population typically reaches its peak luminosity at GeV energies, while the soft gamma-ray pulsar population does so at MeV energies. In this presentation I will discuss the characteristics of this soft gamma-ray pulsar population in comparison with the Fermi LAT findings in order to obtain a full high-energy picture of the pulsar population.

*E-mail: L.M.Kuiper@sron.nl
†E-mail: W.Hermsen@sron.nl

Modeling the Luminosity Function of Galactic Low-Mass X-Ray Binaries

A. G. Kuranov[1*], K. A. Postnov[1], M. G. Revnivtsev[2]

[1]Sternberg Astronomical Institute, Universitetskii pr. 13, Moscow, 119992 Russia
[2]Space Research Institute, ul. Profsoyuznaya 84/32, Moscow, 117997 Russia

The evolution of the family of binaries with a low-mass star and a compact neutron star companion (low-mass X-ray binaries (LMXBs) with neutron stars) is modeled by the method of population synthesis. Continuous Roche-lobe filling by the optical star in LMXBs is assumed to be maintained by the removal of the orbital angular momentum from the binary by a magnetic stellar wind from the optical star and the radiation of gravitational waves by the binary. The developed model of LMXB evolution has the following significant distinctions: (1) allowance for the effect of the rotational evolution of the magnetized compact remnant on the mass transfer scenario in the binary, (2) a more accurate allowance for the response of the donor star to mass loss at the Roche-lobe filling stage. The results of theoretical calculations are shown to be in a good agreement with the observed orbital period – X-ray luminosity diagrams for persistent Galactic LMXBs and their X-ray luminosity function. This suggests that the main elements of binary evolution, on the whole, are correctly reflected in the developed code. It is shown that most of the Galactic bulge LMXBs at luminosities $L_x > 10^{37}$ erg/s should have a post-main-sequence Roche-lobe-filling secondary component (low-mass giants). Almost all of the models considered predict a deficit of LMXBs at X-ray luminosities near $\sim 10^{36.5}$ erg/s due to the transition of the binary from the regime of angular momentum removal by the magnetic stellar wind to the regime of gravitational waves (analogous to the widely known period gap in cataclysmic variables, accreting white dwarfs). At low luminosities, the shape of the model luminosity function for LMXBs is affected significantly by their transient behavior – the accretion rate onto the compact companion is not always equal to the mass transfer rate due to instabilities in the accretion disk around the compact object. The best agreement with observed binaries is achieved in the models suggesting that heavy neutron stars with masses $1.4 - 1.9 M_\odot$ can be born.

*E-mail: alexandre.kuranov@gmail.com

Creation of electron-positron pairs at excited Landau levels by a neutrino in a strong magnetic field

A. V. Kuznetsov[1]*, D. A. Rumyantsev[1], V. N. Savin[2]

[1]P. G. Demidov Yaroslavl State University

[2]A. F. Mozhaiskiy Space Military Academy, Yaroslavl Branch

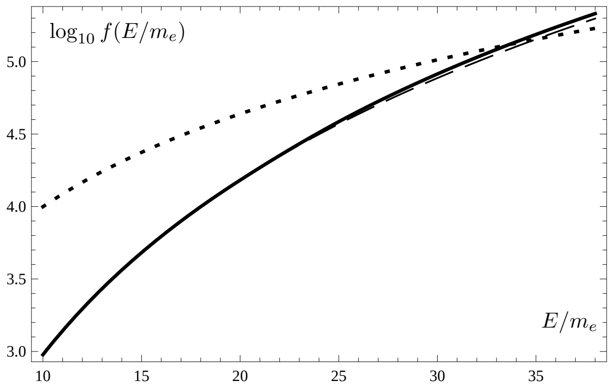

Figure 1: The function $f(E/m_e)$ obtained in the crossed field limit (dotted), with e^-e^+ created at the ground (0,0) Landau level (dashed), and for the sum of lower (0,0), (1,0), (0,1), (2,0), (0,2), (3,0), (0,3) Landau levels (solid).

The rate of the energy deposition into the $e^{\mp}$ plasma through the process $\nu \to \nu e^-_{(n)} e^+_{(\ell)}$ in a magnetic field of arbitrary strength, where electrons and positrons can be created in the states corresponding to the ground and lower excited Landau levels (n, ℓ), is calculated. The calculation techniques can be found e.g. in Ref. [1], and the details will be published elsewhere [2]. In Ref. [3], the formula (10) for the energy deposition rate was taken, which was calculated in the crossed field limit [4]. However, in the region of the physical parameters used in [3], the crossed field limit could be inapplicable. We parameterize the energy deposition rate as: $q_0 = (c_v^2 + c_a^2)\, \sigma_0 \, m_e^4 \, f(E/m_e)$, where c_v, c_a are the constants of the effective $\nu\nu ee$ Lagrangian, $\sigma_0 = 4\, G_{\rm F}^2 \, m_e^2/\pi$, and natural units ($c = \hbar = 1$) are used. In Fig. 1, the function $f(E/m_e)$ is shown at $B = 180 B_e$. At $E = 10 m_e$, the crossed field limit gives the result which is 10 times greater than the sum over the lower Landau levels. On the other hand, the partial rate corresponding to e^-e^+ created only on the ground Landau level is almost equal to the total energy deposition rate.

The study was performed with the support by the Project No. 92 within the base part of the State Assignment for the Yaroslavl University Scientific Research, and was supported in part by the Russian Foundation for Basic Research (Project No. 14-02-00233-a).

References

[1] A. V. Kuznetsov & N. V. Mikheev, *Electroweak processes in external active media* (Berlin, Heidelberg: Springer-Verlag, 2013)

[2] A. V. Kuznetsov, D. A. Rumyantsev & V. N. Savin, paper in preparation

[3] I. Zalamea & A. M. Beloborodov, *MNRAS* 410, 2302 (2011)

[4] A. V. Kuznetsov & N. V. Mikheev, *Phys. Lett. B* 394, 123 (1997); *Phys. At. Nucl.* 60, 1865 (1997)

*E-mail: avkuzn@uniyar.ac.ru

Supernova explosions and neutron stars

Bruno Leibundgut[1*]

[1]European Southern Observatory, Karl-Schwarzschild-Strasse 2, 85748 Garching, Germany

Observations of core collapse supernovae have revealed a very rich ensemble of displays. The different observational features of supernovae will be linked to the underlying physics as it is understood today. The identification of some of the progenitor stars has filled an important piece of the puzzle. Another approach has been the association of neutron stars with supernova remnants and the search for neutron stars in recent nearby supernovae.

Constraining the Origin of Magnetar Flares

Bennett Link[1]*

[1]Montana State University

Sudden relaxation of the magnetic field in the core of a magnetar produces mechanical energy primarily in the form of shear waves which propagate to the surface and enter the magnetosphere as relativistic Alfvén waves. Due to a strong impedance mismatch, shear waves excited in the star suffer many reflections before exiting the star, giving a minimum rise time for the flare that is much longer than oberved rise times of $\lesssim 10$ ms for both small bursts and for giant flares. Mechanisms for flares that rely on the sudden relaxation of the magnetic field of the core are rendered unviable by the impedance mismatch, requiring the energy that drives these events to be stored in the magnetosphere just before the flare.

*E-mail: link@physics.montana.edu

Accuracy of surface gravity and gravitational redshift determination for neutron stars in X-ray bursters from simulated LOFT spectra

A. Majczyna[1*], A. Różańska[2†], J. Madej[3], M. Należyty[3,4]

[1]National Centre for Nuclear Research; ul. Andrzeja Sołtana 7, 05-400 Otwock

[2]N. Copernicus Astronomical Center; ul. Bartycka 18, 00-716 Warsaw

[3]Astronomical Observatory University of Warsaw; Al. Ujazdowskie 4, 00-478 Warsaw

[4]Narcyza Żmichowska XV High School; ul. Klonowa 16, 00-591 Warsaw

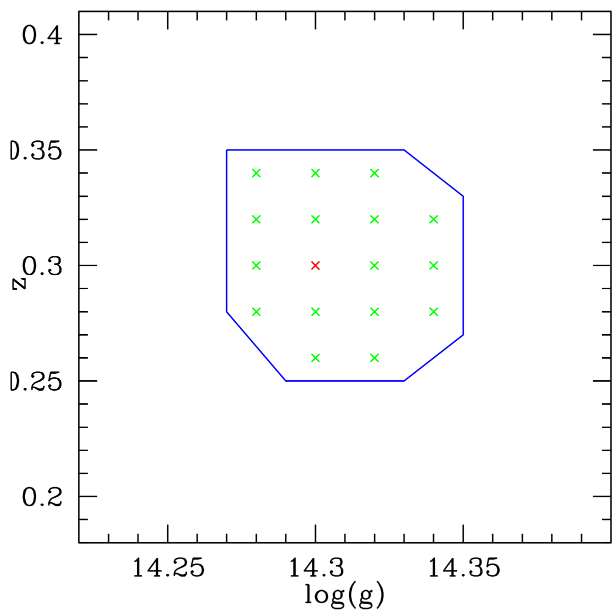

Figure 1: 3σ confidence contour of our fitting procedure calculated on log(g)-z plane. Central red cross denotes position of the simulated model and green crosses denote fitted models for which $\chi^2_{\rm red}$ is close to the minimum and fulfil the inequality $\chi^2_{\rm red,min} < \chi^2_{\rm min} < \chi^2_{\rm red,min} + 11.8$.

We present sample simulated spectrum of a hot neutron star as seen by the LAD detector on board of the LOFT satelite. The spectrum was computed for parameters: the effective temperature $T_{\rm eff}$=22 mln K, the surface gravity log(g)=14.3 (cgs) and the surface gravitational redshift z=0.3. We assumed hydrogen, helium and iron composition of solar proportion. These parameters correspond to the compact star in a Type I X-ray burster. Fitting the simulated spectrum to our extensive grid of 4200 model spectra with XSPEC 12.0.8 software resulted in previously assumed values of all three parameters ($T_{\rm eff} = 2.2 \times 10^7$ K, log(g)=14.30 and z=0.30) with 3σ confidence ranges of z=0.25-0.35 and log(g)=14.27-14.35.

*E-mail: agnieszka.majczyna@fuw.edu.pl

†E-mail: agata@camk.edu.pl

Detection of radio emission of 59 ms pulsar J141256.0+792204 (Calvera)

V. M. Malofeev[1]*, O. I. Malov[1], S. V. Logvinenko[1]

[1]Pushchino Radio Astronomy Observatory ASC LPI, Pushchino, Russia

We report on the first time detection of weak radio emission from X-ray and gamma-ray pulsar in Calvera [1]. This isolated neutron star can be a member of the CCO group or an old millisecond pulsars. We have measured the pulse profile, the dispersion measure and have made a flux density estimate. The observation has been made at 111 MHz using the Large Phased Array (Pushchino) and a digital receiver. This work was supported by the Russian Foundation for Basic Research (project no. 12-02-00661).

References

[1] S. Zane et al., Mon. Not. R. Astron. Soc. 410, 2428 (2011)

On radio emission of anomalous pulsars

I. F. Malov[1*]

[1]Pushchino Radio Astronomy Observatory, Astro Space Center, Lebedev Physical Institute, Moscow region, 142290, Russia

Earlier we have estimated angles between rotation axes and magnetic moments of neutron stars in a number of anomalous X-ray pulsars. It was shown that these angles were small and we could use the drift model to describe such objects. The peculiar feature of their magnetospheres is a larger size in comparison with the magnetospheres of the orthogonal rotators. In this case the conditions are fulfilled for generation of transverse waves due to the cyclotron instability. Spectra of generated emission are expected to be very steep (their spectral indices must be $\alpha > 3$). This prediction is in a good agreement with the observed values of spectral indices for radio emission of AXPs ($\alpha > 2$). Large magnetospheres permit the formation of sufficient pitch-angles of relativistic electrons and generation of the synchrotron radiation. Maximum of this radiation is in the microwave range. Such a mechanism gives rather high flux densities at frequencies of the order of tenths of GHz which can explain the observed growth of radiation intensities of AXPs in this range.

This work was financially supported by the Russian Foundation for Basic Research (project code 12-02-00661) and the Basic Research Program of the Presidium of the Russian Academy of Sciences "The Origin, Structure, and Evolution of Objects in the Universe".

*E-mail: malov@prao.ru

X-rays emission from isolated pulsars

Sandro Mereghetti[1*]

[1]INAF, IASF-Milano

I will review the properties of the X-ray emission from different classes of isolated neutron stars, concentrating on the main observational results obtained in the three years since the last conference in this series.

Pulsar Polarimetry

R. Mignani[1,2*], A. Shearer[3], P. Moran[3], A. Slowikowska[2]

[1]INAF - Istituto di Astrofisica Spaziale e Fisica Cosmica Milano, via E. Bassini 15, 20133, Milano, Italy

[2]Kepler Institute of Astronomy, University of Zielona Góra, Lubuska 2, 65-265, Zielona Góra, Poland

[3]Centre for Astronomy, National University of Ireland, Newcastle Road, Galway, Ireland

Polarisation measurements of pulsars offer unique insights into their highly-magnetised relativistic environments and a prime test for neutron star magnetosphere and emission models. Besides the radio band, optical observations are best suited to these goals, with X-ray polarimetry still moving its first steps. Unfortunately, optical polarisation measurements exist for a handful of pulsars only. Nonetheless, in the case of the Crab and Vela pulsars, they showed an intriguing alignment between the polarisation direction, the pulsar proper motion, the neutron star rotation axis, and the axis of symmetry of the X-ray nebula detected by Chandra. This alignment indicates a possible connection between the pulsar magnetospheric activity and the dynamical interactions occurring between the pulsar and its synchrotron nebula. In recent years, our group both constantly monitored the phase-resolved polarisation of the Crab pulsar and obtained phase-average polarisation measurements of all the brightest pulsars down to the magnitude of 25. In this contribution, we present the latest results of our pulsar optical polarisations measurements and outline future perspective of observations with both high-time resolution instruments and the E-ELT.

*E-mail: mignani@lambrate.inaf.it

Search for Stable Magnetic Equilibria in Barotropic Stars

J. P. Mitchell[1,2*], J. Braithwaite[1], N. Langer[1], A. Reisenegger[2], H. Spruit[3]

[1]Argelander Institut, University of Bonn, Auf dem Huegel 71, 53121 Bonn - Germany

[2]Instituto de Astrofísica, Facultad de Física, Pontificia Universidad Católica de Chile, Av. Vicuña Mackenna 4860 7820436 Macul, Santiago - Chile

[3]Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Str. 1, D-85748 Garching, Germany

It is now believed that magnetohydrodynamic equilibria can exist in stably stratified stars due to the seminal works of [1, 2]. What is still not known is whether magnetohydrodynamic equilibria can exist in a barotropic star, in which stable stratification is not present. It has been conjectured by [5] that there will likely not exist any magnetohydrodynamic equilibria in barotropic stars, which may be of importance in neutron stars. Although neutron stars are compositionally stratified in their cores, the processes of ambipolar diffusion and weak decays [3, 5] can erase composition differences and erode the stable stratification. This will result in the neutron star behaving as a stably stratified star on short timescales, and a barotropic star on longer timescales. We aim to test the claim of [5] by presenting preliminary MHD simulations of barotropic stars using the three dimensional stagger code of [4].

References

[1] Braithwaite, J. & Spruit, H. C. 2004, *Nature*, 431, 819

[2] Braithwaite, J. & Nordlund, A. 2006, *A&A*, 450, 1077

[3] Hoyos, J. , Reisenegger, A. & Valdivia, J. A. 2008, *A&A*, 487, 789

[4] Nordlund, Å. & Galsgaard, K. 1995, *http://www.astro.ku.dk/ aake/papers/95.ps.gz*

[5] Reisenegger, A. 2009, A & A, 499, 557

*E-mail: jmitchell@astro.uni-bonn.de

X-ray pulsars: on the verge of a final understanding

A. A. Mushtukov[1,2,3*], V. F. Suleimanov[4,5], S. S. Tsygankov[6,1], J. Poutanen[1]

[1]Tuorla observatory, Department of Physics and Astronomy, University of Turku, Finland

[2]Pulkovo Observatory of Russian Academy of Sciences, Saint-Petersburg, Russia

[3]Sobolev Astronomical Institute, Saint Petersburg State University, Saint-Petersburg, Russia

[4]Institut für Astronomie und Astrophysik, Kepler Center for Astro and Particle Physics, Universität Tübingen, Germany

[5]Kazan (Volga region) Federal University, Kazan, Russia

[6]Finnish Centre for Astronomy with ESO (FINCA), University of Turku, Finland

Cyclotron resonance scattering features are observed in the spectra of some X-ray pulsars and show significant changes in the line energy with the pulsar luminosity. In the case of low luminosity sources the line centroid energy is correlated with the luminosity while the bright ones show an anti-correlation. Such a change in the behavior is often associated with the onset and growth of the accretion column, which is believed to be the origin of the observed emission and the cyclotron lines for bright objects. In our work we find the critical value of the luminosity above which the accretion column appears over the neutron star surface [1]. For the first time the resonant scattering is taken into account. We also review the paradigm of the line formation in the case of the bright sources [2]. We argue that a more physically realistic situation is that the cyclotron line forms when the radiation emitted by the accretion column is reflected by the neutron star surface. The idea is based on the fact that a substantial part of the column luminosity is intercepted by the neutron star surface and the reflected radiation should contain absorption features. The reflection model is developed and applied to explain the observed variations of the cyclotron line energy in a bright X-ray pulsar V 0332+53 over a wide range of luminosities. The model gives clear and easily verified predictions. The obtained results are waiting for their check, which could happen any day now with the currently operating and planned missions.

References

[1] A. A. Mushtukov, V. S. Suleimanov, S. S. Tsygankov, J. Poutanen, in preparation (2014)

[2] J. Poutanen, A. A. Mushtukov, V. S. Suleimanov, S. S. Tsygankov, D. I. Nagirner, V. Doroshenko, A. A. Lutovinov *ApJ* 777, 115 (2013)

*E-mail: al.mushtukov@gmail.com

Synchrotron Radiation by Ultra- and Moderate Relativistic Electrons

D. I. Nagirner[1*]

[1]Saint-Petersburg State University, Russia

A generalization of the Schott formula, which defines radiation of a single electron rotating in the plane perpendicular to the magnetic field, to the case of electron moving along a spiral is derived using simple relativistic considerations. No restrictions are set on the electron energy. For a given radiation frequency we calculate the emissivity of electrons in a given direction in this line and in all the lines which contribute to the emission at this frequency. Then we obtain the emissivity for the ensemble of electrons of fixed energy and for electrons with an axisymmetric distribution function. Particular cases of the total radiation (in all directions) and of an isotropic electron distribution have been also considered. A comparison of our results with the canonical theory of the synchrotron radiation has shown that in the case of ultra-high energies our equations transform into the conventional form. Similar expressions have been derived for the Stokes parameters of the polarized radiation, and the matrix of absorption coefficients has been obtained. This allows us to formulate the kinetic equation, describing multiple actions of the mechanism with account of the polarization and the induced radiation. Numerical codes for computing the values of these parameters have been created. The results can be applied to the interpretation of spectra of jets in AGN and binary systems containing black holes or neutron stars.

*E-mail: dinagirner@gmail.com

Heavy metal neutron star atmosphers

J. Nättilä[1*], V. F. Suleimanov[2,3], J. Poutanen[1]

[1]Tuorla Observatory, University of Turku, Väisäläntie 20, 21500, Piikkiö, Finland
[2]Institut für Astronomie und Astrophysik, Kepler Center for Astro and Particle Physics, Universität Tübingen, Sand 1, D-72076 Tübingen, Germany
[3]Kazan (Volga region) Federal University, Kremlevskaja str., 18, Kazan 420008, Russia

Cooling of the neutron star (NS) type-I X-ray bursts from low-mass X-ray binaries can be used to study properties of matter at supranuclear densities. By comparing the observed time-resolved spectra with theoretical atmosphere models we can set constraints on the mass and radius of the NSs. The accuracy of these basic parameters is, however, limited by uncertainties in the chemical composition of the atmosphere.

The outer envelope of the NS is usually assumed to consist of pure hydrogen, helium or a (solar) mixture of the two, originating from the accreted matter from the companion star or from the interstellar matter. Recent simulations, however, indicate that the top layers are well mixed with the ashes of nuclear burning. The presence of these heavy element ashes can then change the pure H-He spectra significantly.

To investigate the effects arising from these heavy metals, we compute a detailed grid of atmosphere models with different exotic chemical compositions. We especially focus on iron compositions because iron is thought to be the most stable element on the surface of the NS. Our calculations are done in the local thermodynamical equilibrium using the plane-parallel approximation. Compton scattering is taken into account using the exact relativistic angle-dependent redistribution function. From the emerging model spectra we compute the color correction factors f_c that can be then compared to observations to get information of the chemical composition and to constrain the mass and radius of the NS.

*E-mail: nattila.joonas@gmail.com

High-Energy Emission of PSR B1937+21

C.-Y. Ng[1]*, J. Takata[1], G. C. K. Leung[1], K. S. Cheng[1], P. Philippopoulos[2]

[1]Department of Physics, The University of Hong Kong

[2]Department of Physics, McGill University

PSR B1937+21 is the first millisecond pulsar (MSP) detected and it is representative of an emerging class of MSPs that shows aligned pulse profiles in different energy bands [1]. We report on a study of the high-energy emission of the pulsar using archival *Chandra*, *XMM-Newton*, and *Fermi* LAT observations. Our results indicate that the pulsar X-ray emission is ∼100% pulsed and has a purely non-thermal spectrum with a hard photon index of 0.9 ± 0.1. Using 5.5 yr of *Fermi* survey data, we have obtained significantly improved constraints on the pulsar's gamma-ray timing and spectral properties. The pulsed spectrum is adequately fitted by a simple power-law with a photon index of 2.38 ± 0.07, and an exponential cutoff power-law model is not much better. Both the gamma-ray and X-ray pulse profiles exhibit similar two-peak structure and generally align with the radio peaks.

A comparison with other MSPs suggest that the aligned profiles and the hard spectrum in X-rays could be common properties among MSPs with high magnetic fields at the light cylinder. We discuss a simple model in which the non-thermal X-rays are contributed by IC scattering between radio waves and primary particles in the outer magnetosphere and by synchrotron radiation from secondary particles. As shown in Figure 1, this toy model is capable to qualitatively reproduce the observed spectral energy distribution in X-rays and gamma-rays.

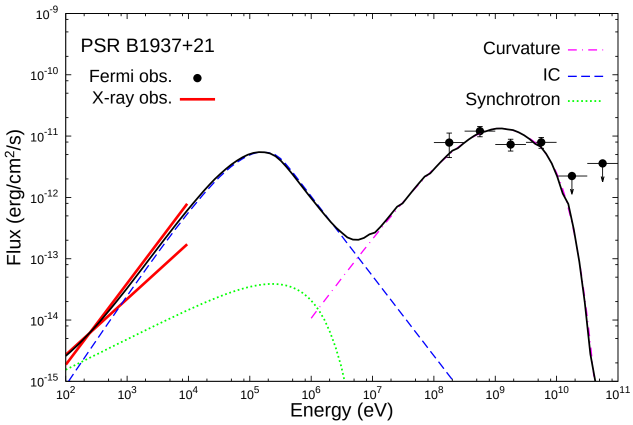

Figure 1: Broadband spectral energy distribution of PSR B1937+21 from X-rays to gamma-rays.

JT, GCKL, and KSC are supported by a GRF grant of Hong Kong Government under HKU7009/11P.

References

[1] Guillemot, L., Johnson, T. J., Venter, C., et al. 2012, ApJ, 744, 33

*E-mail: ncy@bohr.physics.hku.hk

Measurements of Neutron Star Masses

David J. Nice[1*]

[1]Lafayette College, Easton, Pennsylvania, USA

The observed distribution of masses can be used to constrain the equation of state for nuclear matter and to study astrophysical processes such as supernovae and binary star evolution. A question of particular interest is: "how heavy can a neutron star be?"

Neutron star masses can be inferred from observations of binary radio pulsar systems, particularly by the measurement of relativistic phenomena within these orbits. I will describe techniques used to make these mass measurements, and I will summarize the presently observed distribution of neutron star masses.

*E-mail: niced@lafayette.edu

The structure of the magnetosphere of radio pulsars with interpulses

I. F. Malov[1*], E. B. Nikitina[1†]

[1]Pushchino Radio Astronomy Observatory, Astro Space Center of P.N. Lebedev Physical Institute, Russian Academy of Sciences

Pulsars with interpulses - pulse components located between the main pulses - are investigated. About 50 such objects are known at this moment. The previously developed methods to estimate the angle between the rotation axis and the magnetic moment of a neutron star have been used to determine the magnetosphere geometry of these objects. For some pulsars $\beta < 20°$ and we can expect not only interpulses but also interpulse radiation and a correlation of the behaviour of the interpulses and the main pulses for those pulsars as well. This angle is more than 60° for other pulsars, and the appearance of the interpulses is possible if the radiation cone is sufficiently wide and there is a favorable orientation of the line of sight to the observer. We confirm the suggestion made earlier about two types of pulsars with interpulses - aligned and orthogonal ones. Estimates of the pulsar ages for these two groups indicate that the aligned rotators are several times older than the orthogonal ones.

This work was supported by the Russian Foundation for Basic Research (project 12-02-00661) and the Basic Research Program of the Presidium of the Russian Academy of Sciences "Non-stationary Phenomena in Objects of the Universe".

References

[1] I. F. Malov, *Radiopulsars* (Moscow: Nauka, 2004))

[2] I. F. Malov, E. B. Nikitina, *Angles Between the Rotation Axis and Magnetic Moment in 80 Pulsars from Observations near 1 GHz* (Astronomy Reports, V.55, No.1, p.19-30, 2011)

[3] I. F.Malov, E. B.Nikitina, *On the structure of pulsar magnetospheres*, (Advances in Astron.Sp.Phys., V.2, P.28-30, 2012)

[4] I. F.Malov, E. B.Nikitina, *The structure of the magnetosphere of radio pulsars with interpulse*, (Astronomicheskiy jurnal, v.90, p.907-918, 2013)

*E-mail: malov@prao.ru

†E-mail: maggika@mail.ru

Analytic approximations for electron-nucleus bremsstrahlung neutrino emissivity in a neutron star crust of any composition

D. D. Ofengeim[1*], A. D. Kaminker[1,2], D. G. Yakovlev[2]

[1]St. Petersburg State Polytechnical University, Russia

[2]Ioffe Institute, St. Petersburg, Russia

Neutrino bremsstrahlung emission due to collisions of electrons with atomic nuclei, $e + (Z, A) \to e + (Z, A) + \nu + \tilde{\nu}$, is an important mechanism for cooling of warm neutron star crust [1]. So far the neutrino emissivity of this process has been thoroughly analyzed for the ground state composition of the crust. However, the composition of the real crust can differ from the ground state especially if a star underwent a period of long accretion. Thus, one needs to have the bremsstrahlung neutrino emissivity for a wide range of nuclear compositions of the matter.

We have calculated the required neutrino emissivity using the formalism of Ref. [2]. The results are valid for the inner and outer neutron star crust provided the electrons are strongly degenerate and relativistic. The atomic nuclei are assumed to constitute either a strongly coupled Coulomb liquid or a crystal. Both, static lattice and phonon contributions to the neutrino emission in the crystal phase are included taking into account the electron band structure effects and the Debye-Waller factor. The nuclei are thought to be spherical, their size and mass are treated as free parameters. The emissivity is expressed through a generalized Coulomb logarithm, whose calculated values are fitted by analytic formulas as functions of free parameters of the problem. The results are expected to be valid in the density range from $\sim 10^8$ to $\sim 10^{14}$ g cm^{-3}, at temperatures from $\sim 10^7$ to $\sim 10^9$ K, as well as for representative ranges of nucleus charge and mass numbers $[Z = 6 - 50,\ A = (2 - 3)\,Z]$ and proton core radius r_p (up to 1/3 of the radius of the Wigner-Seitz cell). A total number of baryons in the Wigner-Seitz cell (bound in nuclei and free) ranges from A to ~ 1000.

The results can be useful for simulating a number of processes in neutron star crusts (like thermal evolution and relaxation) and in the cores of massive white dwarfs.

The authors are grateful for the partial support by the State Program Leading Scientific Schools of RF (grant NSh 294.2014.2). The work of AK and DY by was also partially supported by RFBR (grants Nos. 14-02-00868-a), and the work of DG by the RFBR grant 13-02-12017-ofi-M.

References

[1] D. G. Yakovlev, A. D. Kaminker, O. Y. Gnedin, P. Haensel, *Physics Reports*, 354, 1 (2001)

[2] A. D. Kaminker, C. J. Pethick, A. Y. Potekhin, V. Thorsson, D. G. Yakovlev, *Astron. Astrophys.*, 343, 1009 (1999)

*E-mail: ddofengeim@gmail.com

Spontaneous Fission and Production of Cosmochronometer Nuclei in the r-process†

I. V. Panov[1]*

[1]SSC RF Institute for Theoretical and Experimental Physics, Moscow, Russia

One of the most important subjects of the r-process investigation is the character of the nucleosynthesis in the region of transuranium nuclei, where fission impedes both the passage of the nucleosynthesis wave in the region of actinides and the production of superheavy elements. The inclusion of fission results in a change in the yields of actinides, in particular, the cosmochronometer nuclei and, thereby, in the age of the Galaxy determined by the isotopic ratio method. The set of main cosmochronometer nuclei includes eight isotopes with the half-lives from 10^7 to 10^{11} yr. Uranium (A = 235, 238) and thorium (A = 232) isotopes are usually used to determine the age of the Galaxy. Plutonium-244 is also sometimes considered, but data on its abundance have large errors.

In this work, we have applied the Swiatecki formula [1] for $logT_{sf}$ to the calculations of heavy element abundances [2] in the scenario of neutron star mergers [3]. It includes the dependence both on the fission barrier and on the fission-ability parameter fitted [4] to the calculations of the spontaneous fission within the macroscopic-microscopic model [5].

We have considered the variation of the calculated abundances of these elements for the duration of the nucleosynthesis from 3 x 10^8 to 4 x 10^9 yr. We conclude that the predictions for the spontaneous fission rates within the phenomenological model based on the calculations of the spontaneous fission rates of superheavy nuclei in the macroscopic-microscopic model are in a good agreement with observations and should be used in the calculations of nucleosynthesis.

References

[1] W. J. Swiatecki, *Phys. Rev.* 100, 937 (1955).

[2] I. V. Panov, I. Yu. Korneev, G. Martinez-Pinedo & F.-K. Thielemann, *Astronomy Letters* 39, 173 (2013).

[3] S. Rosswog, M. Liebendörfer & F.-K. Thielemann, *Astron. Astrophys.* 341, 499 (1999).

[4] V. I. Zagrebaev, A. V. Karpov, I. N. Mishustin, et al., *Phys. Rev. C* 84, 044617 (2011).

[5] Z. Patyk, R. Smolanczuk & A. Sobiczewski, *Nucl. Phys. A* 626, 337 (1997).

†the work was supported by RFBR grants 12-02-00955-a and 13-02-12106-ofi-m

*E-mail: extra@terra.edu

Observations of Accretion Powered X-ray Pulsars

A. Patruno[1,2*]

[1]Leiden Observatory, Leiden University, The Netherlands

[2]ASTRON, the Netherlands Institute for Radio Astronomy, The Netherlands

Accretion Powered X-Ray Pulsars in low and high mass X-ray binaries are excellent laboratories that can be used to test several aspects of accretion and neutron star physics in the most diverse environments. In this review I discuss the peculiarities and similarities of accreting X-ray pulsars that have emerged in the last few years.

I start by reviewing the main families of accreting pulsars: those in high mass X-ray binaries, slowly spinning accreting pulsars in low mass X-ray binaries and accretion powered millisecond pulsars. I will then focus on some surprising similarities that very different classes of objects share, highlighting in particular the recently discovered transitioning pulsar systems, i.e., accreting neutron stars that cyclically switch off accretion and turn on their pulsations at radio wavelengths. I will finally conclude by discussing the most urgent open problems that remain to be solved in the future.

References

[1] Patruno, A., & Watts, A. L. 2012, Accreting X-Ray Millisecond Pulsars, *Timing neutron stars: pulsations, oscillations and explosions", T. Belloni, M. Mendez, C.M. Zhang Eds., ASSL, Springer*

[2] Postnov, K., Shakura, N., González-Galán, A., et al. 2010, Wind accretion in symbiotic X-ray binaries, *Eighth Integral Workshop. The Restless Gamma-ray Universe (INTEGRAL 2010)*

[3] Sidoli, L. 2013, Supergiant Fast X-ray Transients: a review, *Solicited talk at the 9th INTEGRAL Workshop "An INTEGRAL view of the high-energy sky (the first 10 years)", held in Paris, France, on 15-19 October 2012; accepted for publication in Proceedings of Science*

*E-mail: patruno@strw.leidenuniv.nl

Mass loss rates in X-ray binaries simulated by MESA

K. Pavlovskii[1*], N. Ivanova[1]

[1]University of Alberta, 116 St. and 85 Ave., Edmonton, AB, Canada

X-ray binaries consisting of a neutron star and a mass transferring companion present an opportunity to test the parameters of neutron stars observationally. The mass transfer rate in an X-ray binary depends in part on the response of the donor to mass loss and in part on the adopted model of the mass transfer. In the recent years, modern and advanced stellar codes, such as MESA/star and MESA/binary have been used to simulate such systems. We explore some reasons due to which these simulations may produce misleading results. We provide prescriptions that help eliminate some issues of physical and numerical nature that affect the results. We show that certain X-ray binaries might have lower mass transfer rates than previously thought.

*E-mail: pavlovsk@ualberta.ca

The Physics of Magnetars and Their Astrophysical Significance

Qiu-he Peng[1*]

[1]The Nanjing university

1. We present the microscopic origin of the super strong magnetic fields in magnetars. The ultra-strong magnetic fields of the magnetars originate really from the induced paramagnetic moment of the $^3P_2$ superfluid if the mass of the superfluid significantly exceeds 0.1 $M_\odot$ and the interior temperature $T_7 \ll \eta$ is below the Curie temperature, $\eta = \frac{m(^3P_2)}{0.1M_\odot} R_{NS,6}^{-3} [\frac{(^3P_2)\triangle_n}{0.05MeV}]^{1/2}$, where $\triangle_n(^3P_2)$ is the energy gap of the neutron $^3P_2$ Cooper pair. In this case, a phase transition occurs from paramagnetism to ferromagnetism due to the induced paramagnetic moment of $^3P_2$ Cooper pairs in the presence of the background magnetic field. The upper limit of the magnetic field of the magnetars is $B_{max}^{in}(^3P_2) \approx 2.02 \times 10^{14}\eta$ G.

2. We find that the electron Fermi energy, $E_F(e)$, increases with the magnetic field strength and is proportional to $B^{1/4}$. We note that this result is exactly the opposite of the popular idea that the electron Fermi energy decreases with the magnetic field. The key reason for the dilemma is that an incorrect formula for the microscopic number of states of electrons in an intense magnetic field from some internationally well known popular textbooks on statistical physics has been repeatedly quoted by many authors.

3. We propose a new mechanism for the production of the high soft X-ray luminosities of magnetars. In particular, the Fermi energy of the electrons is higher than 60 MeV in ultra-strong magnetic fields, $B \gg B_{cr}$ ($B_{cr} = 4.414 \times 10^{13}$ G), which is much higher than the Fermi energy of the neutrons. In this case, the process of electron capture (EC) by protons around the proton Fermi surface would dominate in magnetars. The outgoing high-energy neutrons due to the EC process can easily destroy the $^3P_2$ Cooper pairs through the nuclear strong interaction. When one Cooper pair is destroyed, the orderly magnetic energy $2\mu_n B$ would be released and transformed into the disorderly thermal energy, which may then be radiated as soft X-rays. The energy is in the X-ray $-$ soft γ-ray range. The total magnetic energy of $^3P_2$ Cooper pairs can be estimated as $1 \times 10^{47} B_{15} \frac{m(^3P_2)}{0.1M_\odot}$ ergs. This energy release can be maintained over 10^{4-6} yrs for $L_X \sim 10^{34} - 10^{36}$ erg/s per magnetar. We have also calculated the theoretical luminosities of magnetars, and our results compare very well with observations of magnetars.

*E-mail: qhpeng@nju.edu.cn

Towards general-relativistic pulsars magnetospheres

Jérôme Pétri[1]*

[1]Observatoire Astronomique de Strasbourg, Université de Strasbourg, CNRS, UMR 7550, 11 rue de l'Université, 67000 Strasbourg, France

Pulsars are believed to lose their rotational kinetic energy primarily by a large amplitude low frequency electromagnetic wave which is eventually converted into particle creation, acceleration and is followed by a broad band radiation spectrum [1]. To date, there exist no detailed calculation of the exact spin-down luminosity with respect to the neutron star magnetic moment and spin frequency, including general-relativistic effects. Estimates are usually given according to the flat spacetime magnetodipole formula [2]. In this talk I will present accurate solutions of the general-relativistic electromagnetic field around a slowly rotating magnetized neutron star. I solve the full set of time-dependent Maxwell equations in a curved space-time following the 3+1 formalism [3]. The numerical code is based on the pseudo-spectral method [4]. I have adapted it to an arbitrary fixed background metric. Stationary solutions are readily obtained and compared to semi-analytical calculations [5]. I will also present some new results on its extension to force-free monopole solutions in general relativity [6] and discuss possible extension of this work.

References

[1] J. G. Kirk, Y. Lyubarsky & J. Pétri *Astrophysics and Space Science Library*, 357, 421 (2009)

[2] A. J. Deutsch *Annales d'Astrophysique* 18, 1 (1955)

[3] J. Pétri, *MNRAS* 439, 1071 (2014)

[4] J. Pétri, *MNRAS* 424, 605 (2012)

[5] J. Pétri, *MNRAS* 433, 986 (2013)

[6] J. Pétri, in preparation.

*E-mail: jerome.petri@astro.unistra.fr

Phase-resolved polarization properties of the pulsar striped wind synchrotron emission

Jérôme Pétri[1]*

[1]Observatoire Astronomique de Strasbourg, Université de Strasbourg, CNRS, UMR 7550, 11 rue de l'Université, 67000 Strasbourg, France

Since the launch of the Fermi telescope six years ago, many new gamma-ray pulsars have been discovered with intriguing properties challenging our current understanding of pulsar physics [1]. Observations of the Crab pulsar furnish today a broad band analysis of the pulsed spectrum with phase-resolved variability allowing to refine existing models to explain the pulse shape, the spectra and the polarization properties. The latter gives insight into the geometry of the emitting region as well as on the structure of the magnetic field. Based on an exact analytical solution of the striped wind with a finite current sheet thickness, we analyze in detail the phase-resolved polarization variability emanating from the synchrotron radiation [2]. We assume that the main contribution to the wind emissivity comes from a thin transition layer where the dominant toroidal magnetic field reverses its polarity, the so-called current sheet. The resulting radiation is mostly linearly polarized. In the off-pulse region, the electric vector lies in the direction of the projection onto the plane of the sky of the pulsar rotation axis. This property is unique to the wind model and is in a good agreement with the Crab data. Other properties such as a reduced degree of polarization and a characteristic sweep of the polarization angle within the pulses are also reproduced. These properties are qualitatively unaffected by variations of the wind Lorentz factor, the lepton injection power law index, the contrast in hot and cold particles, the obliquity of the pulsar and the inclination of the line of sight. The influence of the particle distribution function on the light-curves has been investigated in a previous paper [3]. Synchrotron cooling leptons reheated by magnetic reconnection can also account for the gamma-ray pulsar luminosity as explained in [4].

References

[1] A. A. Abdo et al.*ApJS*, 208, 17 (2013)
[2] J. Pétri, *MNRAS* 434, 2636 (2013)
[3] J. Pétri, *MNRAS* 412, 1870 (2011)
[4] J. Pétri, *MNRAS* 424, 2023 (2012)

*E-mail: jerome.petri@astro.unistra.fr

Recent advances in modeling pulsar magnetosphere

A. Philippov[1]*, A. Spitkovsky[1], A. Tchekhovskoy[2,3]

[1]Department of Astrophysical Sciences, Peyton Hall, Princeton University, Princeton, NJ 08544, USA

[2]University of California Berkeley, Berkeley, CA 94720-3411

[3]Lawrence Berkeley National Laboratory, 1 Cyclotron Rd, Berkeley, CA 94720, USA

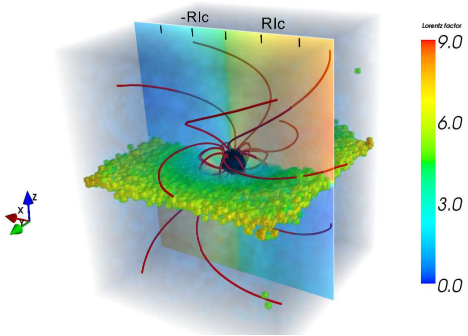

Figure 1: 3D structure of aligned pulsar magnetosphere obtained from PIC simulations. Thick lines represent the magnetic field lines. Mean Lorentz factor of particles averaged on a coarse grid is shown as 3D volume rendering. Color in the plane shows B_y component of the magnetic field.

We present new results on MHD modeling of a pulsar magnetosphere: the theory of the pulsar obliquity angle evolution [1] and the structure of the pulsar wind [2].

We demonstrate that the structure of the pulsar wind is laterally and azimuthally non-uniform. We demonstrate that this non-uniformity leads to the dependence of the pulsar spindown luminosity, $L \propto (1 + sin^2\alpha)$, on the pulsar inclination angle, α. We devise an analytical fitting model for the structure of the pulsar wind and present a direct comparison to 3D simulation results.

We also present the quantitative theory of the pulsar obliquity angle evolution. On general symmetry grounds we show that if a neutron star is spherically symmetric and is endowed with a dipolar magnetic moment, the pulsar evolves such as to minimize its spindown luminosity. We find that plasma-filled pulsars align in a power-law manner $\propto t^{-1/2}$.

Despite the fact that MHD modeling is extremely useful for understanding the global structure of the pulsar magnetosphere, plasma instabilities and particle acceleration in the magnetosphere that are required for ultimate emission modeling cannot be fully addressed within MHD or force-free approach, necessitating a kinetic treatment. For this reason we perform “first-principles” relativistic particle-in-cell (PIC) simulations of an aligned pulsar magnetosphere [3]. We calculate the magnetospheric structure, current distribution and spin-down power of the neutron star. We also discuss particle acceleration in the equatorial current sheet (PIC solution does not have any strong accelerating regions except for the current sheet).

References

[1] Philippov A., Tchekhovskoy A., Li J., arXiv:1311.1513, *MNRAS* in press (2013)

[2] Tchekhovskoy A., Philippov A., Spitkovsky A., in preparation

[3] Philippov A., Spitkovsky A., arXiv:1312.4970, *ApJLetters* in press (2013)

The maximum neutron star mass and the role of the enhanced vector meson interactions

M. Pienkos[1*]

[1]University of Silesia, Uniwersytecka 4, 40-007 Katowice, Poland

The existence of massive neutron stars calls into question the possibility of the emergence of hyperons in neutron star interiors. This motivates the study of models of hyperon-rich matter of neutron stars. In an attempt to analyze neutron star properties related to the strange, isospin asymmetric nuclear matter it is indispensable to select a suitable equation of state.

The equation of state of dense nuclear matter is the most important factor that determines not only the bulk of parameters but the internal structure of a neutron star as well. The systematic study of the neutron star matter is done within the relativistic mean field approach for different parameterizations. The characteristic feature of the considered models is the extended isovector sector which comprises a broad spectrum of mixed vector meson interactions.

The mixed vector meson interactions are very effective in describing the asymmetric nuclear matter as they provide a modification of the density dependence of the symmetry energy. The obtained parameterization in the isovector sector, which is related to the strength of the particular vector meson couplings, allows one to study the influence of the remodeled symmetry energy on neutron star properties. For sufficiently high density these models describe an additional repulsion in nucleon-hyperon and hyperon-hyperon interactions. This has remarkable consequences for the stiffening of the equation of state.

Analysis of non-linear models allows one to determine to what extent the change of the vector meson coupling constants influences this additional repulsion in the system. The vector meson coupling constants will be determine on the basis of SU(3) symmetry. The influence of different hyperon-nucleon and hyperon-hyperon potentials also will be included. Additionally, the presence of the scalar-isovector meson will be taken into account. The extension of the isovecor meson sector links the asymmetry of the model with the strangeness content and modifies the density dependence of the symmetry energy.

*E-mail: mpienkos@us.edu.pl

Radio and γ-ray light-curve morphology of young pulsars: comparing *Fermi* observations and simulated populations

Marco Pierbattista[1*], Isabelle Grenier[2†], Alice Harding[3], Peter Gonthier[4]

[1]NCAC-PAS, Rabiańska 8, PL-87-100 Toruń, Poland
[2]Lab. AIM, Univ. Paris 7/CEA-IRFU/CNRS, SAp, 91191 Gif/Yvette, France
[3]Astrophysics Science Division, NASA GSFC, Greenbelt, MD 20771, U.S.A.
[4]Hope College, Department of Physics, Holland MI, U.S.A.

In more than 5 years of sky surveying, the Large Area Telescope (LAT, [1]) on board the *Fermi* satellite provided the highest statistics of γ-ray-pulsar light curves ever. Studying their morphological characteristics can help identifying the location of the γ-ray emission region in the pulsar magnetosphere, and discriminating radiation and geometrical models that best explain the observations.

We have performed a morphological analysis of a number of γ-ray and radio light curves simulated according to several γ-ray radiation models, namely Polar Cap (PC), Slot Gap (SG), Outer Gap (OG), and One Pole Caustic (OPC), as well as to the radio core plus cone radiation model, and assuming the emission geometry from [2]. References to radiation models and simulation details can be found in [3]. For each model, a set of light-curve parameters like the peak number, the light-curve symmetry and sharpness, the height of the bridge between two peaks, among others, have been defined. Using these parameters we have built a shape classification and studied how it changes with pulsar characteristics and the emission model. We have applied the very same morphological analysis to the young pulsars that appeared in the second LAT γ-ray pulsar catalog [4], and we have compared the morphological properties of observed and simulated light curves.

We have found that all LAT-pulsar morphological characteristics such as γ-ray peak multiplicity, peak separation as a function of the radio lag, and their respective distributions, among others, are explained as a whole just by the outer magnetosphere OPC model. The SG model gives a better explanation of the γ-ray peak separation distribution since the OPC apparently fails to explain the observed fraction of widely separated γ-ray peaks. The classic OG emission model fails to explain almost all observed morphological characteristics while the PC model is completely ruled out as a possible emission geometry for the young γ-ray LAT pulsars.

References

[1] Atwood, W. B., et al., *ApJ*, 697, 1071 (2009)
[2] Dyks, J., et al., *ApJ*, 606, 1125, (2004)
[3] Pierbattista, M., et al., A & A, 545, A42, (2012)
[4] Abdo, A. A., et al., *ApJS*, 208, 17, (2013)

*E-mail: mpierba@gmail.com
†E-mail: isabelle.grenier@cea.fr

Low-Frequency Evolution of Pulsar Profiles with LOFAR

M. Pilia[1*] and LOFAR Pulsar Working Group

[1]ASTRON, the Netherlands Institute for Radio Astronomy, Postbus 2, 7990 AA, Dwingeloo, The Netherlands

We will present observations of the first 100 pulsars by the LOFAR telescope. LOFAR offers the unique capability of observing pulsars in a mostly unexplored range of frequencies: the 10-240 MHz range with a large fractional bandwidth. We have produced the cumulative pulse profiles of 100 pulsars in the 120-167 MHz range as well as the 15-63 MHz profiles for 25 of these pulsars. We present the results of the multi-frequency study of these profiles: we have followed the profile evolution from 1500 MHz to, where possible, 15 MHz. We have determined the relationship between this evolution and the geometry and astrometric parameters of the pulsars, or the external effects that alter the signal traveling towards us, prominent at lower frequencies.

In particular, we focused on the evolution of the profile with frequency: we will present the evolution of the full profile width and that of its single components, in the case of multiple peaks; also in the case of multiple peaks we have traced the evolution of the ratio of the amplitudes of the two most prominent peaks. In this work we show that the evolution of the profile width with frequency follows the so-called radius-to-frequency mapping. We have found a good agreement of our data with the empirical core + cones model from [2] and subsequent papers of the series, and with the phenomenological model from [1].

References

[1] A. Karastergiou & S. Johnston, *MNRAS* 380, 1678 (2007)

[2] J. Rankin, *ApJ* 274, 333 (1983)

*E-mail: pilia@astron.nl

Evolution of strongly magnetised neutron stars: The path from magnetars to normal pulsars

J. A. Pons[1]*

[1]Departament de Física Aplicada, Universitat d'Alacant, Ap. Correus 99, E-03080 Alacant, Spain

Observations of magnetars and some of the high magnetic field pulsars have shown that their thermal luminosity is systematically higher than that of classical radio-pulsars, thus confirming the idea that magnetic fields are involved in their X-ray emission. In this talk I discuss the results of two-dimensional simulations of the fully coupled evolution of temperature and magnetic field in neutron stars, including the state-of-the-art kinetic coefficients and, for the first time, the important effect of the Hall term. After gathering and thoroughly re-analysing in a consistent way all the best available data on isolated, thermally emitting neutron stars, we compare our theoretical models to a data sample of 40 sources (see http://www.neutronstarcooling.info/). We find that evolutionary models can explain the phenomenological diversity of magnetars, high-B radio-pulsars, and isolated nearby neutron stars by only varying their initial magnetic field, mass and envelope composition. I will also discuss the expected outburst rates and the evolutionary links between different classes.

This work was partially supported by grants AYA 2010-21097-C03-02, the *Prometeo* program for research groups of excellence of the Generalitat Valenciana (Prometeo/2009/103), and the MPNS COST action "NewCompstar" (MP1304).

*E-mail: jose.pons@ua.es

Radiotransients and neutron stars

S. B. Popov[1*], K. A. Postnov[1,2†]

[1]Moscow State University, Sternberg Astronomical Institute, Russia

[2]Moscow State University, Department of Physics, Russia

Recently several types of radiotransients have been discovered. Such sources are of special interest now as we are entering the era of sky monitoring in radio waves. In this contribution we focus on two classes of transients.

In 2007 Lorimer et al. [1] discovered the first millisecond extragalactic radio burst. In 2013 Thornton et al. [2] presented observations of four bursts of this type, thus confirming the existence of such class of transient phenomena. Several explanations have been suggested. We focus on our idea [3, 4] that the bursts are related to hyper flares of magnetars. Recently this proposal got support in the detailed study by Kulkarni et al. [5]. The work by Lyubarsky [6] contains a theoretical description of a mechanism of radio emission of such bursts. We demonstrate that from the point of view of statistics, energetics etc. magnetar bursts at the moment are the best candidates to explain millisecond extragalactic radio bursts.

In 2005 Hyman et al. [7] discovered a radio transient in the direction of the Galactic center GCRT J1745-3009. This source demonstrated several flares in few years. We discuss several mechanisms related to different types of isolated and binary neutron stars to explain these observations (see some early results in [8]). Namely, a highly magnetized neutron star on a propeller or a georotator stage, a transient propeller, and an ejector in a binary system are discussed. Simple populational estimates favor the transient propeller model.

References

[1] D. Lorimer et al., *Science* 318, 777 (2007)
[2] D. Thornton et al., *Science* 341, 53 (2013)
[3] S.B. Popov, K.A. Postnov, *arXiv:* 0710.2006 (2007)
[4] S.B. Popov, K.A. Postnov, *arXiv:* 1307.4924 (2013)
[5] S.R. Kulkarni et al., *arXiv:* 1402.4766 (2014)
[6] Yu. Lyubarsky, *arXiv:* 1401.6674 (2014)
[7] S.D. Hyman et al., *Nature* 434, 5 (2005)
[8] S.B. Popov, *arXiv:* 0812.4587 (2008)

*E-mail: polar@sai.msu.ru
†E-mail: pk@sai.msu.ru

Geminga and PSR B1055-52: similar pulsars, different PWNe

B. Posselt[1*], G.G. Pavlov[1†], G. Spence [1], and the XVP PWN Consortium

[1]Pennsylvania State University, University Park, PA, USA

The γ-ray pulsars PSR B1055-52 and Geminga have similar spin-down energies ($\dot{E} \sim 10^{34}\,\mathrm{erg\,s^{-1}}$), similar ages (a few 100 kyrs), and similar magnetic fields ($\sim 10^{12}$ G). Both pulsars are nearby and have very similar X-ray spectra consisting of non-thermal and strong thermal components. Sharing so many important pulsar characteristics, one difference is striking: Geminga has an impressive variable pulsar wind nebula (PWN), consisting of three tails, two of them reaching sizes of about 3 arcmin. In contrast to that, the PWN of B1055-52 is barely noticeable. We will present new X-ray observations of both neutron stars targeting their PWNe. In addition to reporting on our new findings, e.g., the changes seen in the Geminga PWN over time, or the significance of extended emission around B1055-52, we will compare the properties of these two pulsars and speculate about the reason why one produces an ostentatious PWN and the other one does not.

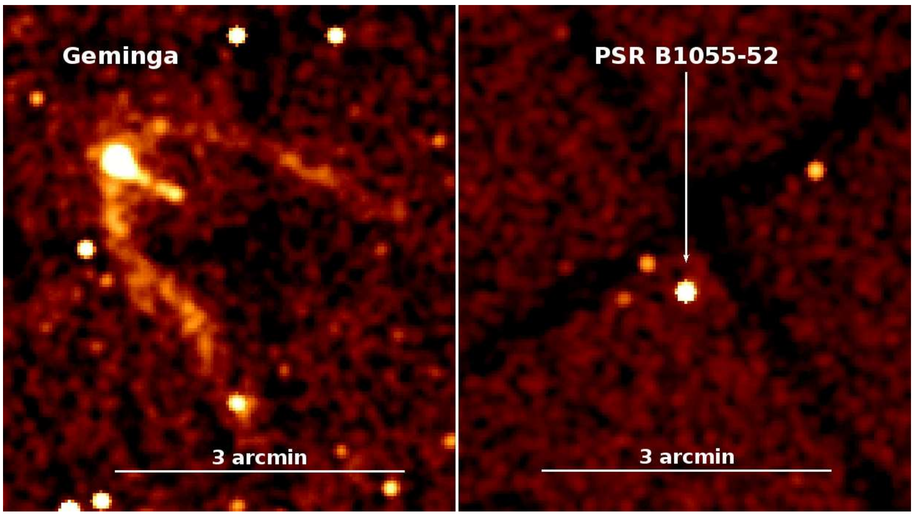

Figure 1: *Chandra* X-ray images of Geminga and PSR B1055-52 and their surroundings

*E-mail: posselt@psu.edu
†E-mail: pavlov@astro.psu.edu

Nature of Bright Flares in Supergiant Fast X-ray Transients

K. A. Postnov[1*], N. I. Shakura[1], L. Sidoli[2], A. Paizis[2]

[1]Sternberg Astronomical Institute, Moscow M.V. Lomonosov State University, Universitetskij pr., 13, 119992, Moscow, Russia

[2]INAF, Istituto di Astrofisica Spaziale e Fisica Cosmica, Via E. Bassini 15, I-20133 Milano, Italy

In steady low-luminosity states ($\sim 10^{33} - 10^{35}$ erg s^{-1}), Supergiant Fast X-ray Transients (SFXTs) can be at the stage of quasi-spherical settling accretion onto slowly rotating magnetized neutron stars from the O-B companion winds. At this stage, a hot quasi-static shell is formed above the magnetosphere, the plasma entry rate into the magnetopshere is controlled by (inefficient) radiative plasma cooling, and the accretion rate onto the neutron star is suppressed by a factor of ~ 30 relative to the Bondi-Hoyle-Littleton value. About $\sim 10\%$ of hot O-B stars are observed to have magnetic fields up to a few kG. We propose that the transition of SFXTs to the flaring stage can be triggered by the transient capture of the magnetized stellar wind plasma, when the magnetic reconnection facilitates the magnetospheric plasma entry. A bright flare develops on the free-fall time scale in the envelope, and the typical energy released in an SFXT bright flare correponds to the mass of the shell. This picture is consistent with the energy released in SFXT bright flares ($\sim 10^{38} - 10^{40}$ ergs) their typical dynamic range ($\sim 100 - 10000$), and with the observed dependence of these characteristics on the average unflaring X-ray luminosity of SFXTs.

*E-mail: kpostnov@gmail.com

On the Asymptotic Structure of the Pulsar Wind

L. I. Arzamasskiy[1]*, V. S. Beskin[1,2]†, V. V. Prokofev[1]

[1]Moscow Institute of Physics and Technology, Dolgoprudny, Institutsky per., 9, Moscow region, 141700, Russia
[2]P.N.Lebedev Physical Institute, Leninsky prosp., 53, Moscow, 119991, Russia

We investigate the asymptotic structure of the pulsar wind under force-free and two-fluid MHD assumptions. Within the force-free approximation we obtain simple asymptotic solutions of the Grad-Shafranov equation for quasi-spherical pulsar wind. In the case of an oblique rotator we have a good agreement with results of recent numerical simulations [1]. In particular, we show that the shape of the current sheet found in [2] does not depend on the radial structure of the magnetic field.

For the internal region of the current sheet in the pulsar wind where the force-free approximation is not valid we use the two-fluid approximation. Passing to the comoving reference frame we determine the electric and magnetic field structure as well as the velocity component perpendicular to the sheet. It allows us to estimate the efficiency of particle acceleration. Finally, investigating the motion of individual particles in the time-dependent current sheet we find self-consistently the width of the sheet and its time evolution.

References

[1] A.Tchekhovskoy, A. Spitkovsky & J. Li, arXiv:1211.2803 (2011)
[2] S. V. Bogovalov *Astron. Astrophys.* 349, 1017 (1999)

*E-mail: lev.arzamasskiy@phystech.edu
†E-mail: beskin@lpi.ru

LFN, QPO and fractal dimension of light curves from X-ray binaries

A.V. Prosvetov[1]*, S. A. Grebenev[1]

[1]Space Research Institute (IKI), Moscow, Russia

The origin of the low frequency noise (LFN) and quasi-periodic oscillations (QPO) observed in X-ray flux of Galactic black hole and neutron star binaries is still not recognized in spite of multiple studies and attempts to model this phenomenon. There are known correlations between the QPO frequency, X-ray power density, X-ray flux and spectral state of the system, but there is no model that can make these dependences understandable. For the low frequency (1 Hz) QPO we still haven't got even an idea capable of explaining their appearance and don't know even what part of the accretion disc is responsible for them. Here we have attempted to measure the fractal dimension of light curves of several X-ray binaries and to study its correlation with the frequency of quasi periodic oscillations observed in their X-ray light curves. The fractal dimension is a measure of the space-filling capacity of the light curves' profile. To measure the fractal dimension we used the R/S method, which is fast enough and has good reputation in financial analytics and in material science. We have found a clear correlation between the QPO frequency and the fractal dimension of the sources' emission. The relationship between these two parameters is solid but nonlinear. We believe that the analysis of light curves of X-ray binaries using the fractal dimension has a good scientific potential and may provide an additional information on the geometry of the accretion flow and on the fundamental physical parameters of the system.

*E-mail: prosvetov@gmail.com

Spin evolution of pulsars challenges conventional accretion scenarios

N. R. Ikhsanov[1,2*], N. G. Beskrovnaya[1†], Yu. S. Likh[1‡], L. A. Pustil'nik[3,4§]

[1]Central Astronomical Observatory of RAS at Pulkovo, Pulkovskoe Shosse 65-1, St. Petersburg 196140, Russia
[2]Saint Petersburg State University, Universitetsky pr., 28, Stary Peterhof, Saint Petersburg 198504, Russia
[3]Israel Cosmic Ray and Space weather Center of Tel Aviv University, Israel Space Agency, and Golan Research Institute, Israel
[4]University ITMO, Saint Petersburg, Russia

Quasi-spherical and Keplerian disk accretion scenarios encounter major difficulties explaining the origin and observed spin evolution of long-period X-ray pulsars. We show that these difficulties reflect an oversimplification of the scenarios in which the magnetic field of the accretion flow is neglected. We find that the accretion picture onto a neutron star which captures material from a magnetized wind differs from those previously suggested. It can be explained in terms of a dense non-Keplerian magnetic slab in which the material is confined by its intrinsic magnetic field. This scenario (the so-called Magneto-Levitation Accretion, MLA) has initially been developed by G.S. Bisnovatyi-Kogan and A.A. Ruzmaikin for the case of a black hole. We find that a neutron star accreting material from the magnetic slab brakes harder and its magnetospheric radius is significantly smaller than that evaluated in the traditional non-magnetic accretion flow scenarios. We show that the mass-transfer towards the neutron star in MLA scenario is governed by anomalous diffusion and the expected appearance of the MLA pulsar is in a good agreement with observations.

*E-mail: nazar.r.ikhsanov@gmail.com
†E-mail: beskrovnaya@yahoo.com
‡E-mail: yury.likh@gmail.com
§E-mail: levpust@post.tau.ac.il

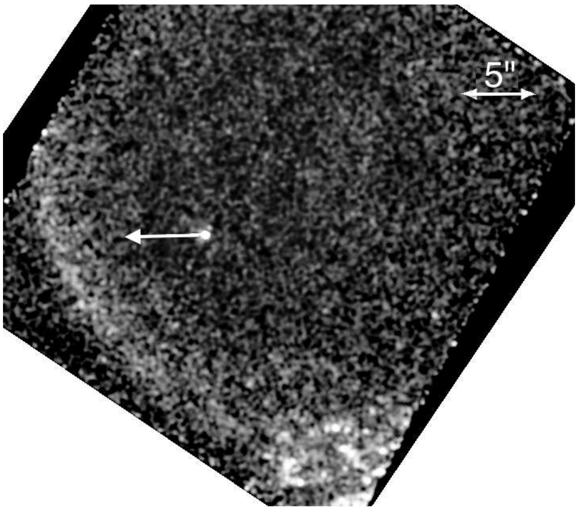

Figure 1: Smoothed *HST* UV (F140LP) image of J0437–4715 and its bow shock. The arrow shows the direction of the proper motion. North is up.

The far-UV bow shock of the nearest millisecond pulsar J0437–4715

B. Rangelov[1*], O. Kargaltsev[1], G. G. Pavlov[2], M. Durant[3], A. M. Bykov[4]

[1]George Washington University, Washington, District of Columbia, United States

[2]Pennsylvania State University, University Park, Pennsylvania, United States

[3]University of Toronto, Canada

[4]Ioffe Institute, St. Petersburg, Russia

Most pulsars are moving supersonically through the interstellar medium. The interaction between the pulsar wind and the ambient medium gives rise to a bow shock. Most of the bow shock pulsar wind nebulae have been found in X-rays while some are seen in H_α emission. In *HST* observations of the nearest millisecond pulsar J0437–4715, for which an H_α bow shock had been previously detected, we have discovered a bow shock of a similar shape at far-UV wavelengths (1250–2200 Å). Bow shocks at these wavelengths have neither been seen nor predicted by bow-shock models. We will discuss the properties of the far-UV bow shock emission and implications of our discovery.

*E-mail: rangelov13@gwu.edu

The extreme activity of high and low magnetic field magnetars

Nanda Rea[1*]

[1]CSIC-IEEC, University of Amsterdam, The Netherlands

I will review recent theoretical and observational results on strongly magnetized neutron stars, then focus on the discovery of a few peculiar magnetars that have recently changed, and deepened our understanding of these strong and bursting magnets. I will briefly report on the connection between magnetars and normal pulsars, and on an updated view of the Galactic neutron star census. These news results might have important consequences also on other research fields such as gamma-ray bursts, massive stars, and gravitational waves.

[*]E-mail: nanda.rea@gmail.com

Magnetic field evolution in neutron stars

A. Reisenegger[1*]

[1]Instituto de Astrofísica, Pontificia Universidad Católica de Chile, Santiago, Chile

I will discuss our current theoretical understanding of the physical effects and processes governing the evolution of magnetic fields, likely starting from stable MHD-equilibrium configurations in newborn neutron stars, which then slowly evolve through non-ideal MHD processes such as resistive dissipation and Hall drift in the crust, non-equilibrium beta decays and ambipolar diffusion in the core. The energy dissipated by these processes and their temperature-dependence lead to an interplay between the thermal and magnetic evolution. I will give our current best guesses for their effects in magnetars, classical pulsars, long-lived accreting low-mass X-ray binaries, and their final state as millisecond pulsars.

*E-mail: areisene@astro.puc.cl

Taking The Pulse of Transient Magnetars: Connecting Their Long-term Spectral and Timing X-ray Properties

G. A. Rodriguez Castillo[1,2*], G. Israel[1†]

[1]INAF – Osservatorio Astronomico di Roma, via Frascati 33, 00040, Monte Porzio Catone, Italy

[2]Dipartimento di Fisica, Sapienza Università di Roma, Piazzale Aldo Moro 5, 00185, Rome, Italy

State-of-the-art coherent timing analysis and spectral analysis resolved in phase and in time have been carried out for the first time on a magnetar and on a long baseline. The results were used to investigate the spatial and temporal evolution of the emission regions/components. Two transient magnetars, with different physical properties, have been studied with unprecedented details, namely the anomalous X-ray pulsar CXOU J164710.2–455216 and the soft γ-repeater SWIFT J1822.3-1606. In particular, they went on outburst in 2006 and 2011, respectively, and showed a very different outburst peak and decay behaviour. Moreover, they are characterized by different, by about an order of magnitude, magnetic field strength, making their comparison a first attempt to understand the possible dependence (if any) of the overall outburst properties on the magnetic field. We were able to identify different emission components on different zones of the neutron star surface/magnitosphere, and to follow their evolution through the outburst decay, covering an unprecedented time interval of ~ 3 and ~ 1.5 years, respectively. We have inferred the longest ever coherent timing solution, through the whole outburst, allowing us to infer a new value of the magnetic field for CXOU J164710.2–455216, well within the typical magnetar range (contrary to the latest reports). Thanks to the high accuracy of the timing analysis we were also able to significantly detect the second period derivative acting in the direction of slowing the spin-down rate, suggesting that the neutron star is slowly recovering to its pre-outburst value of the first period derivative (similarly to what is often observed in the post-glitch trend of standard radio pulsars). For SWIFT J1822.3-1606, thanks to the long baseline (1.5 yr) over which the timing analysis was carried out, we were able to better constrain the timing parameters, strongly affected by timing noise during the first months since its discovery. We have confirmed that this magnetar has the second lowest value of the magnetic field strength, close to those inferred in several "high field" standard radio pulsars.

*E-mail: grodriguezcas@gmail.com

†E-mail: gianluca@oa-roma.inaf.it

Resonant mechanism of e^+e^- pair production in a strong magnetic field

D. A. Rumyantsev[1*]

[1]P. G. Demidov Yaroslavl State University, Russia

The scattering of the surface thermal X-ray photons off ultrarelativistic electrons with electron-positron pair production, $\gamma e^\pm \to e^\pm e^+ e^-$, in the vicinity of a magnetar polar cap was considered. It has been shown that the cyclotron resonances are responsible for the main contribution to the amplitude. The simple analytical expression for the electron absorption coefficient is obtained in the following form (the calculation techniques can be found in Ref. [1]):

$$W \simeq \frac{\alpha}{2} T \frac{B}{B_e} \left(\frac{m}{E}\right)^2 \ln\left(1 - e^{-\frac{eB}{2ET}}\right)^{-1}. \qquad (3)$$

Here B is the external magnetic field, $B_e = m^2/e \simeq 4.41 \times 10^{13}$ G is the critical magnetic field, E is the initial electron energy, m is the electron mass, $e > 0$ is the elementary charge, T is the temperature of the equilibrium photon gas and natural units ($c = \hbar = k = 1$) are used.

We have obtained the electron free path as $\ell \simeq 57$ cm. This value is very small in comparison with the electric gap width ($h \sim 100$ m). On the other hand, the change of the electron number in the stream can be expressed as $N \simeq 0.99 N_0$, where N_0 is the initial electron number in the stream. Thus, the process $\gamma e^\pm \to e^\pm e^+ e^-$ being considered makes it possible to increase the number of particles of the electron-positron plasma in the region of the polar cap.

The study was performed with the support by the Project No. 92 within the base part of the State Assignment for the Yaroslavl University Scientific Research, and was supported in part by the Russian Foundation for Basic Research (Project No. 14-02-00233-a).

References

[1] D. A. Rumyantsev, *Phys. At. Nucl.* 76, 1520 (2013)

*E-mail: rda@uniyar.ac.ru

Jets launched from accreting neutron stars: their power and their magnetic fields

D. M. Russell[1]*

[1]New York University Abu Dhabi, PO Box 129188, Abu Dhabi, UAE

The fastest known flow of matter in our galaxy is reported to be launched from a neutron star X-ray binary (NSXB), Cir X-1 (Lorentz factor ~ 10). Relativistic jets have now been observed from several NSXBs at radio frequencies, and could be responsible for removing a significant amount of angular momentum and energy from the accretion flow, therefore affecting the long term neutron star spin evolution. Recently, evidence for synchrotron emission from jets in NSXBs has been mounting, from optical/infrared spectral, polarimetric, and (possibly) fast timing signatures. Synchrotron emission from jets can be highly linearly polarised, depending on the configuration of the magnetic field. Here, I present our latest results on this topic, including time-resolved polarisation measurements which constrain the structure of the tangled magnetic field near the jet base, and the location of the elusive jet spectral break in the broadband spectrum (a break in the power laws from optically thick to optically thin synchrotron emission, near the jet base). Apparent variability of the polarisation is suggestive of a tangled and turbulent magnetic field at the location of the compact jet base. The jet spectra and jet breaks (which are generally located at infrared wavelengths) provide us with the most accurate estimates of the total jet power as a fraction of the mass accretion energy, which may vary substantially from source to source. The radio/X-ray and infrared/X-ray correlations for neutron stars are discussed, and these and the jet powers and magnetic field properties are briefly compared to the black hole systems, allowing us to assess whether there could be a common jet launching mechanism for all compact objects.

*E-mail: dave.russell@nyu.edu

On the thickness of accretion curtains on magnetized compact objects from analysis of their fast aperiodic time variability

A. N. Semena[1*], M. G. Revnivtsev[1]

[1]Space Research Institute RAS, Moscow, Russia

It is widely accepted that accretion onto magnetized compact objects is channeled to some areas close to magnetic poles of the star. Thickness of this channeled accretion flow intimately depends on details of penetration of highly conducting plasma of the flow into the compact object magnetosphere, i.e., on magnetic diffusivity etc. Until now our knowledge of these plasma properties is scarce. In our work we present our attempts to estimate the thickness of the plasma flow on top of the magnetosphere from observations of accreting intermediate polars (magnetized white dwarfs). We show that properties of an aperiodic noise of accreting intermediate polars can be used to put constraints on cooling time of hot plasma, heated in the standing shockwave above the WD surface. Estimates of the cooling time and the mass accretion rate provide us with a tool to measure the density of the post-shock plasma and the cross-sectional area of the accretion funnel at the WD surface. We have studied the aperiodic noise of the emission of one of the brightest intermediate polars EX Hya with the help of data in the optical and X-ray energy bands. We put an upper limit on the plasma cooling time scale $\tau < 1$ sec, on the fractional area of the accretion curtain footprint $f < 6 \times 10^{-4}$. We show that measurements of accretion column footprints, combined with results of the eclipse mapping, can be used to obtain an upper limit on the penetration depth of the accretion disc plasma at the boundary of the magnetosphere, $\Delta r/r \approx 5 \times 10^{-3}$. If the magnetospheres of accreting neutron stars have similar plasma penetration depths at their boundaries, we predict that footprints of their accretion columns should be very small, with fractional areas $< 5 \times 10^{-6}$.

*E-mail: san@iki.rssi.ru

Gamma-ray pulsars in the optical and infrared

Yu. A. Shibanov[1,2*]

[1]Ioffe Institute, St.Petersburg, Russia

[2]St. Petersburg State Politechnical University, Russia

Deep optical and near-infrared observations of several Fermi pulsars obtained recently with large ground-based telescopes will be reported, combined with X-ray and γ-ray data, and discussed. We will analyze what is new that these data tell us on the pulsar physics in comparison with known multi-wavelength spectra of ordinary pulsars.

*E-mail: shib@astro.ioffe.ru

Transport coefficients of nuclear matter in neutron star cores in BHF framework

P. S. Shternin[1,2*], M. Baldo[3], P. Haensel[4]

[1]Ioffe Institute, 26, Politechnicheskaya st., 194021 St.-Petersburg, Russia

[2]Saint-Petersburg State Polytechnical University, 29 Politekhnicheskaya st., 195251 St.-Petersburg, Russia

[3]INFN Sez. di Catania, 64 Via S. Sofia, 95123 Catania, Italy

[4]CAMK, 18 Bartycka st., PL-00-716 Warszawa, Poland

We calculate thermal conductivity and shear viscosity of dense nuclear matter in the cores of neutron stars. We consider the simplest case of the $npe\mu$ matter and treat the in-medium effects in the non-relativistic Brueckner-Hartree-Fock framework. The nucleon-nucleon interaction is described by the Argone v18 potential with addition of the effective Urbana IX three-body forces. We find that the in-medium effects at two-body level increase the kinetic coefficients, while the inclusion of three-body force compensates this effect. The results of calculations are compared with results of other authors.

*E-mail: pshternin@gmail.com

Study of scattering material with RadioAstron-VLBI observations

T. V. Smirnova[1*], V. I. Shishov[1†], C. R. Gwinn[2‡], M. V. Popov[3§], A. S. Andrianov[3¶]

[1]Pushchino Radio Astronomy Observatory, Astro Space Center, Lebedev Physical Institute, Moscow region, 142290, Russia

[2]Department of Physics, University of California, Santa Barbara, California 93106, USA

[3]Astro Space Center, Lebedev Physical Institute, Profsoyuznaya str. 84/32, Moscow 117997, Russia

The RadioAstron spacecraft presents a unique opportunity to measure properties of interstellar scattering. The fluctuations responsible for scattering of radio waves from astronomical sources are small-scale (0.1 AU) fluctuations of the electron density in the interstellar medium. Pulsars offer a variety of observables for interstellar scattering. Observations of scattering of nearby pulsars and intra-day variable quasars point to the existence of a component of the interstellar medium (ISM) which has properties quite different from those of the more distant, diffuse ISM. We have observed several nearby pulsars as part of the RadioAstron's Early Science Program. These included pulsars B0950+08 and B1919+21. We present here results concerning the distribution and properties of the scattering material in the direction to these pulsars obtained with the cosmic interferometer.

This work was financially supported by the Russian Foundation for Basic Research (project code 12-02-00661) and the Basic Research Program of the Presidium of the Russian Academy of Sciences "The Origin, Structure, and Evolution of Objects in the Universe".

*E-mail: tania@prao.ru
†E-mail: shishov@prao.ru
‡E-mail: cgwinn.physics@gmail.com
§E-mail: popov069@asc.rssi.ru
¶E-mail: andrian@asc.rssi.ru

Spectra of rapidly rotating X-ray bursting neutron stars

V. Suleimanov[1,2*], J. Poutanen[3], M. Revnivtsev[4], K. Werner[1]

[1]Institut für Astronomie und Astrophysik, Kepler Center for Astro and Particle Physics, Universität Tübingen, Sand 1, 72076 Tübingen, Germany
[2]Kazan (Volga region) Federal University, Kremlevskaya str., 18, Kazan 420008, Russia
[3]Tuorla Observatory, University of Turku, Väisäläntie 20, FI-21500 PIIKKIÖ, Finland
[4]Space Research Institute (IKI), Russian Academy of Sciences, Profsoyuznaya 84/32, 117997 Moscow, Russia

It is well known that neutron stars (NSs) in low-mass X-ray binaries (LMXBs) rotate rapidly with typical frequencies 200-700 Hz. As a result, the NS shape is distorted, the visible surface is increased, and the effective temperature and the effective surface gravity become non-uniform. These effects can have a strong influence on NS mass and radius determination from the thermal emission during X-ray bursts. Here we present an approximate method for the computation of the shape of a rapidly rotating NS and local parameters together with a method of accounting for the rotation in the integral NS spectrum. We have computed a set of integral spectra from rapidly rotating NSs for different total luminosities. Using these computations, we introduce an improved cooling tail method for determination of the NS masses and radii in X-ray bursting LMXBs. The application of this improved method to the long photospheric radius expansion X-ray burst from 4U 1724-307 demonstrates that accounting for the rapid rotation leads to a decrease of the "effective non-rotating" NS radius by approximately 10-20%.

*E-mail: suleimanov@astro.uni-tuebingen.de

Constraint of Pulsar Wind Properties from Induced Compton Scattering off Radio Pulses

S. J. Tanaka[1]*, F. Takahara[2]

[1]Institute for Cosmic Ray Research, University of Tokyo, 5-1-5 Kashiwa-no-ha, Kashiwa City, Chiba, 277-8582, Japan

[2]Department of Earth and Space Science, Graduate School of Science, Osaka University, 1-1 Machikaneyama-cho, Toyonaka, Osaka 560-0043, Japan

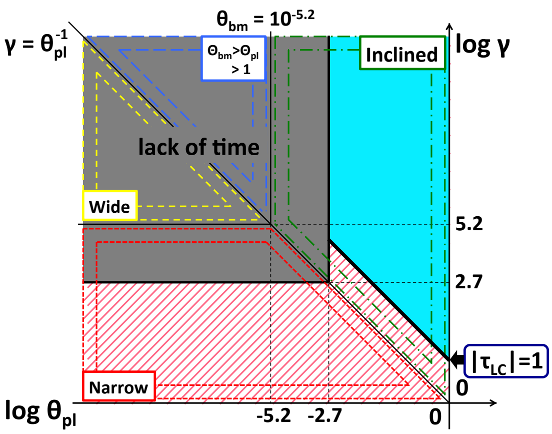

Figure 1: The $\gamma - \theta_{\rm pl}$ diagram of the Crab pulsar wind at $r_{\rm LC}$ taken from Tanaka & Takahara (2013) [2]. We take $r_{\rm e} = 10^3$ cm. Choosing one point on the diagram specifies the four velocity of the wind at $r_{\rm LC}$. The optical depth for induced Compton scattering at the light cylinder $\tau_{\rm LC}$ is less than unity at the light-blue area on the diagram. $\tau_{\rm LC} = 1$ line is expressed as $\gamma = 10^{1.7}\theta_{\rm pl}^{-1}(1+\sigma)^{-1/4}$.

Pulsar winds have problems in energy conversion and pair-cascade processes which determine the magnetization σ, the pair multiplicity κ and the bulk Lorentz factor of the wind γ. We study induced Compton scattering by a relativistically moving cold plasma to constrain wind properties by imposing that radio pulses from the pulsar itself are not scattered by the wind as was first studied by Wilson & Rees [1]. We find that relativistic effects cause a significant increase or decrease of the scattering coefficient depending on scattering geometry including the inclination angle of the wind plasma with respect to the radio pulses $\theta_{\rm pl}$ and the size of the radio emission region $r_{\rm e}$. Applying to the Crab pulsar wind (Figure 1), we obtain the lower limit of the bulk Lorentz factor of $\gamma > 10^{1.7}\theta_{\rm pl}^{-1}(1+\sigma)^{-1/4}$ at the light cylinder $r_{\rm LC}$ for a large inclination angle $\theta_{\rm pl} > 10^{-2.7}$. We also obtain the lower limit of the pair multiplicity using a relation $\kappa\gamma(1+\sigma) = 10^{10.5}$ for the Crab pulsar. Considering the lower limit of the pair multiplicity $\kappa > 10^{6.6}$ suggested by recent studies of the Crab Nebula [3], the large inclination angle of the wind velocity ($\theta_{\rm pl} \sim 1$), the small size of the radio pulse emission region ($r_{\rm e} \sim 10^3$ cm) and the small magnetization parameter ($\sigma \sim 1$) are required for the pair multiplicity to be $\kappa > 10^{6.6}$.

References

[1] D. B. Wilson, & M. J. Rees, *Mon. Not. R. Astron. Soc.* **185**, 297 (1978).
[2] S. J. Tanaka, & F. Takahara, *Prog. Theor. Exp. Phys.* **123E01** (2013).
[3] S. J. Tanaka, & F. Takahara, *Astrophys. J.* **715**, 1248 (2010)

*E-mail: sjtanaka@icrr.u-tokyo.ac.jp

The flare activity of PSR J0653+8051

V. M. Malofeev[1*], D. A. Teplykh[1†]

[1]Pushchino Radio Astronomy Observatory ASC LPI, Pushchino, Russia

We present the investigation of PSR J0653+8051 at frequency 111 MHz using the Large Phase Array. The observations were carried out during the period from October 2012 to December 2013. This pulsar shows three components in the range 102-4850 MHz. We have detected a few dozen of very strong pulses exceeding the amplitude of the mean profile a great deal. Usually this pulsar demonstrates very weak signal on the 3 sigma level in mean profile. The detailed analysis has shown that all strong pulses with the signal to noise ratio of 4-20 arrived at the longitude of the central component only. This effect is very seldom, because we detected such giant components only on one day out of more than three hundred days of observations.

[*]E-mail: malofeev@prao.ru
[†]E-mail: teplykh@prao.ru

Plasma generation in pulsar polar caps: a modern view

Andrey Timokhin[1,2*]

[1]NASA Goddard Space Flight Center, Greenbelt, Maryland, USA

[2]University of Maryland (UMD/CRESST), College Park, Maryland, USA

[3]Moscow State University, Sternberg Astronomical Institute, Moscow, Russia

Electron-positron pair generation in polar caps of pulsars is probably the most crucial part of (almost) all pulsar models - it is widely agreed upon that a neutron star is active as a radio pulsar when the polar cap pair cascades are active and ceases when the cascades die. In the last decade an important progress has been achieved in theoretical modeling of pulsar magnetospheres: now we have self-consistent models for the global structure of the pulsar magnetosphere as well as self-consistent models of particle acceleration in pulsar polar caps. Previous models of pulsar polar cap cascades have been shown to be incorrect and the subject of the pair plasma generation in pulsars needed a major revision. In this talk I will report on recent studies of physical processes in pulsar polar caps based on modern self-consistent models of particle acceleration. It turned out that particles are accelerated more efficiently, can produce more pairs and the escaping gamma-radiation is in lower energy bands than it was expected in previous models. I will discuss implications of these results for pulsar physics in general.

*E-mail: andrey.timokhin@nasa.gov

Anti-glitch of magnetars in the wind braking scenario

H. Tong[1]*,

[1]Xinjiang Astronomical Observatory, Chinese Academy of Sciences

The anti-glitch of magnetar 1E 2259+586 is analyzed theoretically. An enhanced particle wind during the observational interval will take away some additional rotational energy of the neutron star. This will result in a net spin-down of the magnetar, i.e., an anti-glitch. In the wind braking scenario of an anti-glitch, there are several predictions: (1) A radiative event will always accompany the anti-glitch, (2) Decrease/variation of the braking index after the anti-glitch, (3) The anti-glitch is just a period of enhanced spin-down. If there are enough timing observations, a period of enhanced spin-down is expected instead of the anti-glitch. Applications to previous timing events of SGR 1900+14, and PSR J1846−0258 are also included. It is shown that current timing events of 1E 2259+586, SGR 1900+14, and PSR J1846−0258 can be readily understood in the wind braking model. The enhanced spin-down and the absence of an anti-glitch before the giant flare of SGR 1806−20 is consistent with the wind braking scenario.

In the wind braking model, an enhanced particle wind can explain the observed anti-glitch event. At the same time, the opposite case is also possible. During a time interval, the particle wind may also be weaker. This may explain the spin-down behavior of intermittent pulsars.

This contribution is based on our previous works ([1] and [2]).

References

[1] Tong, H., 2014, Anti-gitch of magnetar 1E 2259+586 in the wind braking scenario, arXiv:1306.2445, ApJ in press

[2] Li, L., Tong, H., Yan, W. M., Yuan, J. P., Xu, R. X., Wang, N., 2013, Pulsar wind model for the spindown behavior of intermittent pulsars, arXiv:1312.1016, submitted

*E-mail: tonghao@xao.ac.cn

Power spectra of transient X-ray pulsars: observational manifestation of the disk-magnetosphere interaction

Sergey Tsygankov[1,2*]

[1]Finnish Centre for Astronomy with ESO (FINCA), University of Turku, Väisäläntie 20, FI-21500 Piikkiö, Finland

[2]Tuorla observatory, Department of Physics and Astronomy, University of Turku, Väisäläntie 20, 21500 Piikkiö, Finland

We report the results of studies of power density spectra (PDS) of the X-ray flux variability in accreting X-ray pulsars. PDS of X-ray pulsars fed from an accretion disk have a distinct break/cutoff at the neutron star spin frequency in the case of corotation [1]. This break is a manifestation of the transition from the disk to the magnetospheric flow at the frequency which is characteristic for the truncation radius of the accretion disk (magnetospheric radius). Suggesting that the PDS break frequency is directly related to the magnetospheric radius for a given value of the mass accretion rate, the method to estimate the magnetic moments of accreting neutron stars is proposed. The method is also applied for the verification of the accretion disk and magnetosphere interaction models.

References

[1] Revnivtsev M., Churazov E., Postnov K., Tsygankov S., A&A, 507, 1211 (2009)

*E-mail: stsygankov@gmail.com

Differential rotation of neutron star polar caps

A. I. Tsygan[1*], D. A. Shalybkov[1], D. P. Barsukov[1,2], O. A. Goglichidze[1],

[1]Ioffe Institute, St. Petersburg, Russia
[2]SPbSPU, St. Petersburg, Russia

Rotating neutron stars with electric current flowing from the magnetosphere into the liquid polar magnetic caps is considered. In the case of a simple axisymmetric configuration the current has one direction in the central part of the polar cap and the opposite direction in the outer ring. It is shown that the closure of the electric current under the surface leads to the differential rotation of the polar caps. The velocity structure is determined by the current distribution on the star surface. There are two rings rotating in opposite directions. The inner ring rotates always slower than the main rotation of the star. The velocity value is proportional to the radial gradient of the electric current. The velocity is $10^{-2} - 10^{-4}$ cm/sec (i.e. the period of rotation is 0.1 - 10 years) for typical current variation scale 1 - 10^2 cm, the main rotation period $P = 1$ sec and the magnetic field $B = 10^{12}$ Gauss.

The work has been partly supported by the RFBR (project 13-02-00112) and by the State Program "Leading Scientific Schools of the Russian Federation" (grant NSh-294.2014.2).

*E-mail: tsygan.astro@mail.ioffe.ru

The variable X-ray emission of PSR B0943+10

S. Mereghetti[1*], A. Tiengo[2,1†], P. Esposito[1‡], R. Turolla[3,4§]

[1]INAF–IASF, Milano, via E. Bassini 15, I-20133 Milano, Italy

[2]IUSS–Istituto Universitario di Studi Superiori, piazza della Vittoria 15, I-27100 Pavia, Italy

[3]Dipartimento di Fisica e Astronomia, Università di Padova, Via Marzolo 8, I-35131 Padova, Italy

[4]Mullard Space Science Laboratory, University College London, Holmbury St. Mary, Dorking, Surrey RH5 6NT, UK

PSR B0943+10 is one of the best studied radio pulsars showing changes between two modes of radio emission and the only rotation powered pulsar with regular X-ray variability. In the "B-mode" its radio pulses show a regular pattern of drifting subpulses and the X-ray flux is fainter, while in the "Q-mode" the radio pulses are irregular and the X-ray flux higher. X-ray pulsations at the radio period (1.1 s) have to date been detected only during the Q-mode. We present a reanalysis of all the XMM-Newton observations of PSR B0943+10, which indicates the presence of two emission components with different spectral and variability properties. During the B-mode the X-ray emission is consistent with a blackbody of temperature $kT = 0.26$ keV coming from a small hot spot with luminosity of 7×10^{28} erg/s. This is in good agreement with the prediction of the partially screened gap model, which also explains the properties of the radio emission in this mode. The upper limit on the pulsed fraction in this mode ($< 46\%$) is consistent with the geometry and viewing angle of PSR B0943+10 inferred from the radio data. The higher X-ray flux emitted in the Q-mode results from an additional power-law component which is pulsed and likely originating from non-thermal processes in the pulsar magnetosphere. A change in the beaming pattern or in the efficiency of acceleration of the particles responsible for the non-thermal emission is required to explain the reduced flux of this component during the radio B-mode. However, an alternative interpretation of the X-ray data, which attributes the pulsations and variability to the thermal component, cannot be ruled out. If this is confirmed, it would imply a large scale reorganization of the star magnetosphere related to the two radio modes.

*E-mail: sandro@iasf-milano.inaf.it

†E-mail: tiengo@iasf-milano.inaf.it

‡E-mail: paoloesp@iasf-milano.inaf.it

§E-mail: turolla@pd.infn.it

A model of gamma ray flare generation in PWN

A. M. Bykov[1*], Y. A. Uvarov[1†]

[1]Ioffe Institute, St.Petersburg, Russia

We present a model of generation a flaring synchrotron gamma-ray radiation from a pulsar wind nebula (PWN). Recent observations show that Crab Nebula is a highly variable source of gamma ray emission. The maximum energy and time variation of such gamma ray flares can't be explained in the standard one zone model of a diffuse shock acceleration at the termination shock. We consider a process of particle acceleration at the shock in an average magnetic field and a subsequent interaction of this nonthermal particle population with clumps of high magnetic field formed in a stripped pulsar wind zone and moving outward. In this interaction a pulse of a gamma-ray radiation is being formed by the synchrotron mechanism. Fast synchrotron cooling leads to a fast evolution of the particle distribution function and subsequently to the time variation and the spectral form evolution of a flare. We discuss an interpretation of Crab observations in the framework of this model.

Our work was partially supported by RAS scientific school grant 294.2014.2, by RAS Presidium Program P21 and by RAS OFN Program 17.

*E-mail: byk@astro.ioffe.ru

†E-mail: uv@astro.ioffe.ru

Reconnection in Neutron Star Magnetospheres

D. A. Uzdensky[1*], A. Spitkovsky[2†]

[1]University of Colorado Boulder

[2]Princeton University

The magnetosphere of a rotating pulsar naturally develops a current sheet beyond the light cylinder (LC). Magnetic reconnection in this current sheet inevitably dissipates a nontrivial fraction of the pulsar spin-down power within a few LC radii. We develop a basic physical picture of reconnection in this environment and discuss its implications for the observed pulsed gamma-ray emission [1]. We argue that reconnection proceeds in the plasmoid-dominated regime, via an hierarchical chain of multiple secondary islands/flux ropes. The inter-plasmoid reconnection layers are subject to strong synchrotron cooling, leading to a significant plasma compression. Using the conditions of pressure balance across these current layers, the balance between the heating by the magnetic energy dissipation and synchrotron cooling, and the Ampere's law, we obtain simple estimates for key parameters of the layers — temperature, density, and layer thickness. In the comoving frame of the relativistic pulsar wind just outside of the equatorial current sheet, these basic parameters are uniquely determined by the strength of the reconnecting upstream magnetic field. For the case of the Crab pulsar, we find them to be of order 10 GeV, $10^{13}\,\mathrm{cm}^{-3}$, and 10 cm, respectively. After accounting for the bulk Doppler boosting due to the pulsar wind, the synchrotron and inverse Compton emission from the reconnecting current sheet can explain the observed pulsed high-energy (GeV) and VHE (~ 100 GeV) radiation, respectively. Also, we suggest that the rapid relative motions of the secondary plasmoids in the hierarchical chain may contribute to the production of the pulsar radio emission.

References

[1] D. A. Uzdensky & A. Spitkovsky *ApJ* 780, 3 (2014)

*E-mail: uzdensky@colorado.edu

†E-mail: anatoly@astro.princeton.edu

Short-period pulsar oscillations following a glitch

C. A. van Eysden[1]*

[1]NORDITA, Sweden

The spin-up of magnetized plasma and its role in the post-glitch response of neutron stars was first studied over thirty years ago, when it was demonstrated that co-rotation between the crust and the plasma is established rapidly (within a few seconds) by a process analogous to the Ekman pumping in a viscous fluid [1]. However, in ideal magnetohydrodynamics, a final state of co-rotation is inconsistent with the energy conservation of the system. Using an exact analytical solution, we demonstrate that after the Ekman-like spin up is completed, magneto-inertial waves continue to propagate throughout the star, exciting torsional oscillations in the crust and the plasma. We investigate the nature of the oscillations and explore the consequences for neutron star observations [2]. The connection with magnetar oscillations is also discussed, as well as the effect of superconductivity.

References

[1] Easson, I., *ApJ* 228, 257 (1979)

[2] van Eysden, C.A., *ArXiv* 1403.1046

*E-mail: ave@nordita.org

Cooling of accretion heated neutron stars

R. Wijnands[1*]
[1]University of Amsterdam, The Netherlands

In X-ray binaries, neutron stars can be heated due to the accretion of matter onto their surfaces. Among the X-ray binaries, the X-ray transients form a special subgroup: the neutron stars in those systems are not persistently accreting matter at a high rate but they are accreting only occasionally during the so-called X-ray outbursts. The neutron stars in such systems are heated significantly during those outbursts, but when in quiescence they cool down again. In quiescence, the neutron stars can become directly observable when using sensitive X-ray instruments and those neutron stars appear as thermally emitting cooling objects. During the last decade, we have experienced a huge leap forward in our observational and theoretical understanding of the heating and cooling of accreting neutron stars. However, many significant open problems still remain. I will present an overview of our current understanding (both observationally as well as theoretically) on the heating and cooling behaviour of accreting neutron stars and how such systems can help us to get a better insight into the properties of ultra-dense matter in neutron stars.

*E-mail: r.a.d.wijnands@uva.nl

Spectral Evolution of Magnetar Bright Bursts

G. Younes[1*], C. Kouveliotou[2], A. van der Horst[3], The *Fermi*/GBM Magnetar Team

[1]USRA, 320 Sparkman Drive, Huntsville, AL., USA
[2]NASA-MSFC, 320 Sparkman Drive, Huntsville AL., USA
[3]University of Amsterdam, Netherlands

Magnetars are isolated neutron stars characterized by long spin periods (2-12 s) and large spin down rates, implying a very strong magnetic field, B>10E14 G. Magnetars exhibit short bursts of hard X-/soft gamma-rays with luminosities ranging from 10E37 to 10E41 erg/s. The magnetar SGR J1550-5418 entered an extremely active bursting episode, starting on 2008 October 03 until 2009 April 17, during which Fermi Gamma-ray Burst Monitor (GBM) observed several hundred bursts from this source. Such wealth of bursts resulted in the largest catalog of detailed temporal and spectral results for SGR J1550-5418 [1]. Here, we discuss new results from a time-resolved spectral analysis of the 63 brightest bursts from this source, down to 4 ms time-resolution.

We have followed the evolution of the spectral parameters of the two models that best fit the time-integrated spectra of SGR J1550-5418, a power-law with a high energy cut-off, and a two black-body model, with unprecedented detail. We discuss our results in the context of the fireball model, putting strong constraints on the underlying magnetar burst emission processes. Assuming that crust cracking is the triggering mechanism for SGR J1550-5418 short bursts [2], we were also able to derive, for the first time through observations, an upper limit on the internal magnetic field of magnetar SGR J1550-5418. Results are published in [3].

References

[1] van der Horst, A. J., Kouveliotou, C., Gorgone, N. M., et al. 2012, ApJ, 749, 122
[2] Thompson, C., & Duncan, R. C. 1995, MNRAS, 275, 255
[3] Younes, G., Kouveliotou, C., van der Horst, A. J., et al. 2014, arXiv:1402.6015

*E-mail: george.a.younes@nasa.gov

XMM-Newton View of the best candidate Magnetar Wind Nebula

G. Younes[1]*, C. Kouveliotou[2], O. Kargaltsev[3], G. Pavlov[4], E. Gogus[5], S. Wachter[6]

[1]USRA, 320 Sparkman Drive, Huntsville, AL., USA

[2]NASA-MSFC, 320 Sparkman Drive, Huntsville AL., USA

[3]George Washington University, USA

[4]Pennsylvania State University, USA

[5]Sabanci University, Turkey

[6]Max Planck Institute for Astronomy, Germany

Pulsar Wind Nebulae are produced by synchrotron and inverse Compton radiation originating at the shocked ambient medium from pulsar particle-outflows. While relatively common around rotation powered pulsars, such structures seem absent around slowly-rotating highly-magnetized neutron stars, e.g., magnetars. These latter sources are also expected to produce particle outflows, either steady or released during outbursts, hence the idea of a Magnetar Wind Nebula seems plausible. We will discuss the best candidate MWN to-date around the soft gamma repeater Swift J1834.9-0846, which we discovered in 2012 with a short XMM-Newton observation [1]. We will also present here our preliminary results of a 92 ks new XMM-Newton observation of this putative MWN.

References

[1] Younes, G., Kouveliotou, C., Kargaltsev, O., et al. 2012, ApJ, 757, 39

*E-mail: george.a.younes@nasa.gov

On some properties of hybrid stars

A. V. Yudin[1,2*], T. L. Razinkova[1], D. K. Nadyozhin[1,3], A. D. Dolgov[1,2,4]

[1]SSC RF ITEP of NRC "Kurchatov Institute", B. Cheremushkinskaya 25, Moscow, Russia

[2]Novosibirsk State University, Pirogova 2, Novosibirsk, Russia

[3]NRC "Kurchatov Institute" PNPI, Kurchatova 1, Russia

[4]University of Ferrara and INFN, Ferrara, Italy

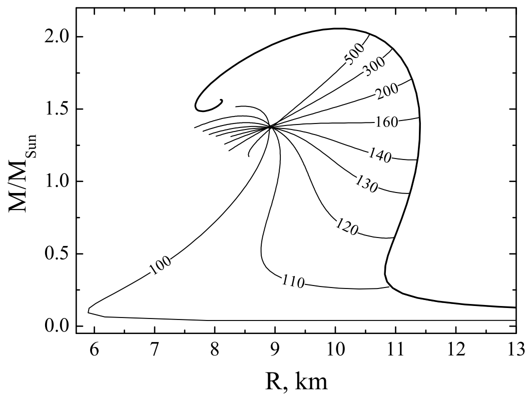

Figure 1: Mass-Radius diagram for hybrid stars.

We explore various properties of hybrid stars, i.e. neutron stars which contain the core made of quark matter. First, in the framework of the simple bag model of the quark matter equation of state we have found one interesting feature of the mass–radius diagram for hybrid stars (see Fig.1). As one can see, all the curves for hybrid stars with different values of the bag constant B (in MeV/fm^3, shown by numbers on lines) intersect inside a small region of $(M - R)$ diagram which we call "magic point". We find that this property is mostly caused by the linearity of the quark matter EOS and is independent of the parameters of the envelope. This also means that such a feature will be present not only for quark matter but for any exotic phase inside a neutron star whose EOS is well approximated by a linear relation between the pressure P and the energy density ϵ: $P = \alpha(\epsilon - \epsilon_0)$.

Besides this, we explore the interface between the ordinary matter and the quark matter phases using the Maxwell and Gibbs prescription for the phase transitions. Some interesting consequences for the properties of the mixed phase inside the hybrid stars are also discussed.

*E-mail: yudin@itep.ru

Magnetar giant flares and their precursors – flux rope eruptions with current sheets

Cong Yu[1,3*], Lei Huang[2,3†]

[1]Yunnan Observatories, Chinese Academy of Sciences, Kunming, China

[2]Key Laboratory for Research in Galaxies and Cosmology, Shanghai Astronomical Observatory, Chinese Academy of Sciences, Shanghai, China

[3]Key Laboratory for the Structure and Evolution of Celestial Object, Chinese Academy of Sciences, Kunming, China

We propose a catastrophic magnetospheric model for magnetar precursors and their successive giant flares. Axisymmetric models of the magnetosphere, which contain both a helically twisted flux rope and a current sheet, are established based on force-free field configurations. In this model, the helically twisted flux rope would lose its equilibrium and erupt abruptly in response to the slow and quasi-static variations at the ultra-strongly magnetized neutron star surface. In a previous model without current sheets, only one critical point exists in the flux rope equilibrium curve. New features show up in the equilibrium curves for the flux rope when current sheets appear in the magnetosphere. The causal connection between the precursor and the giant flare, as well as the temporary re-entry into the quiescent state between the precursor and the giant flare, can be naturally explained. Magnetic energy would be released during the catastrophic state transitions. The detailed energetics of the model are also discussed. The current sheet created by the catastrophic loss of equilibrium of the flux rope provides an ideal place for a magnetic reconnection. We point out the importance of the magnetic reconnection for further enhancement of the energy release during eruptions[1].

The further information of the presentation can be found at the link shown below.[‡]

References

[1] C. Yu & L. Huang, *ApJ* 771, L46 (2013)

*E-mail: cyu@ynao.ac.cn

†E-mail: muduri@shao.ac.cn

‡http://adsabs.harvard.edu/abs/2013ApJ...771L..46Y

Strong evidence for a link between coherent oscillations and the apparent emission area during the thermonuclear bursts

Guobao Zhang[1,2]*, Mariano Méndez[2], Tmoaso M. Belloni[3], Jeroen Homan[4]

[1]NYU Abu Dhabi, P.O. Box 903, New York, NY 10276, USA

[2]Kapteyn Astronomical Institute, University of Groningen, Groningen, the Netherlands

[3]INAF - Osservatorio Astronomico di Brera, Merate (LC), Italy

[4]MIT Kavli Institute for Astrophysics and Space Research, Cambridge, MA 02139, USA

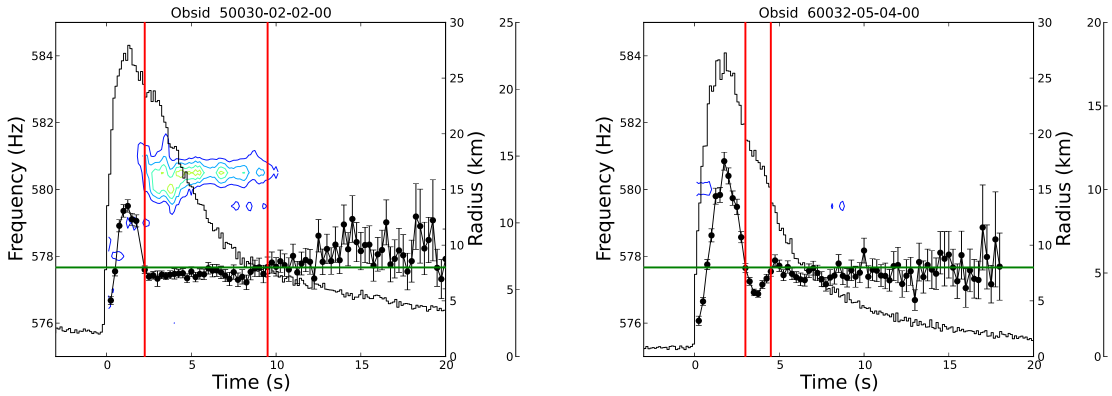

Figure 1: Left panel: PRE burst with tail oscillations. Right panels: PRE burst without tail oscillations. In each panel the black histogram shows the light curve of the burst at a resolution of 0.125 s. The intensity, in units of 1000 counts s^{-1}, is shown by the scale plotted to the right, outside of each panel. The contour lines show constant power values, increasing from 10 to 80 in steps of 10 (values are in Leahy units), as a function of time (x axis) and frequency (left y axis). Black filled circles connected by a line show the best-fitting blackbody radius as a function of time at a resolution of 0.25 s (see the right y axis).

Coherent oscillations and the evolution of the X-ray spectrum during the thermonuclear X-ray bursts have been studied intensively but separately. Recently we have analysed all archival data of the two burst-rich sources 4U 1636–53 and 4U 1728–34 with the Rossi X-ray Timing Explorer. We have found that during the bursting time, especially the cooling phase, the bursts, in which the blackbody radius remains more or less constant for > 2 s, show coherent oscillations (e.g. left panel of Figure 1), whereas those bursts, in which the blackbody radius changes rapidly, show no coherent oscillations (e.g. right panel of Figure 1). This is the first time that the presence of burst oscillations in the tail of X-ray bursts is associated with a systematic behaviour of the spectral parameters in that phase of the bursts. This result is consistent with predictions of models that associate the oscillations in the tail of X-ray bursts with the propagation of a cooling wave in the material on the neutron-star surface during the decay of the bursts.

Radiation efficiencies of the pulsars (current update)

S. V. Zharikov[1]*

[1]Instituto de Astronomia, UNAM, Mexico

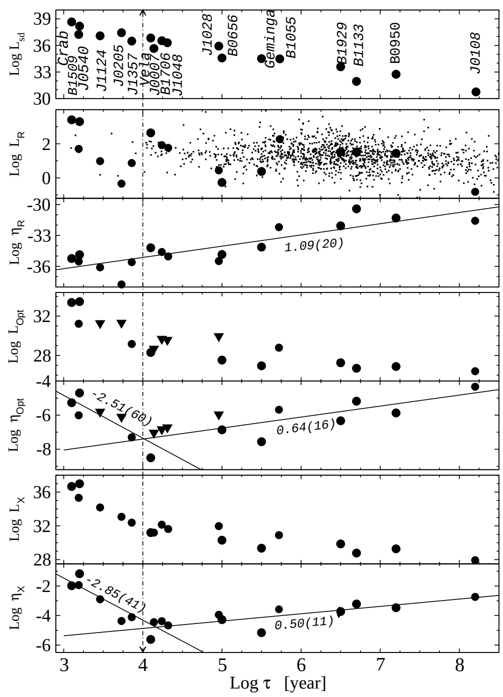

Figure 1: Evolution of the pulsar spin-down, radio, optical and X-ray luminosity, and respective efficiencies, as a function of the dynamical age.

Eighteen pulsars with optical counterparts or with significantly deep upper limits on the optical luminosity are known currently. Using available multiwavelenght data for these pulsars we reanalyze the efficiencies of the conversion of the pulsar spin-down power $\dot{E}$ into the observed non-thermal luminosity L in different spectral domains. This sample of pulsars confirms the non-monotonic evolution of the pulsar radiation efficiency $\eta = L/\dot{E}$ in the optical and X-ray domains (Zharikov et al. 2006). There is a clear evidence of a change in the behavior of the optical and X-ray efficiencies around $\tau \sim 10^4$ years. Efficiencies η_{opt} and η_X initially decrease before starting to flatten or increase at larger ages. The timescale $\tau \sim 10^4$ years is comparable to the transition between neutrino and photon cooling stages (Yakovlev et al. 2004, and references therein) in neutron stars. The change of the cooling stage probably affects the distribution of relativistic particles in the pulsar magnetosphere, which is reflected in the dependence of the optical/X-ray efficiency on the pulsar age. The slopes of the time evolution of $\eta_{opt}(\tau)$ and $\eta_X(\tau)$ after 10^4 years are practically similar and compatible with that of $\eta_R(\tau)$ (Fig. 1).

References

[1] Zharikov, S., Shibanov, Y., & Komarova, V. 2006, Advances in Space Research, 37, 1979

[2] Yakovlev, D. G., Gnedin, O. Y., Kaminker, A. D., Levenfish, K. P., & Potekhin, A. Y. 2004, Advances in Space Research, 33, 523

*E-mail: zhar@astrosen.unam.mx

The role of magnetic damping in the r-mode evolution of accreting neutron stars

G. J. Cao[1,2] X. Zhou[1,3*], N. Wang[1,3]

[1]Xinjiang Astronomical Observatory, CAS, Urumqi, 830011, China
[2]University of Chinese Academy of Sciences, Beijing, 100049, China
[3]Key Laboratory of Radio Astronomy, CAS, Urumqi, 830011, China

The magnetic damping rate was introduced in the evolution equations of r-modes, which shows that r-modes can generate very strong toroidal magnetic fields in the core of accreting millisecond pulsars induced by differential rotation. With consideration of the coupled evolution of r-modes, spin and thermal structure, we carefully investigate the influence of the magnetic damping on the differential rotation and nonlinear r-modes of accreting neutron stars. In the framework of the second-order r-mode theory, we have derived the equations of the coupled evolution of the star involving the magnetic damping rate. The numerical results show that the magnetic damping suppresses the nonlinear evolution of the r-modes since the saturation amplitude is reduced to a great extent. In particular, due to the presence of the generated toroidal magnetic field, the spin-down of the star is stopped and the viscous heating effects are also weakened. Moreover, we could get a stronger generated toroidal magnetic field using the second-order r-mode theory. We conclude that the gravitational radiation may be detected by the advanced laser interferometer detector LIGO if the amount of differential rotation is small when the r-mode instability becomes active and the accretion rate is not very high.

*E-mail: zhouxia@xao.ac.cn

Summary of the Program.

July 28, Monday	**July 29, Tuesday**	**July 30, Wednesday**	**July 31, Thursday**	**August 1, Friday**
09:10 Opening **Pulsars 1** 09:15 Mereghetti 09:50 Pierbattista 10:20 Shibanov	**Magnetars** 09:00 Rea 09:35 Younes 10:05 Hascoet	**Bursters, transients** 09:00 Galloway 09:35 Popov 10:00 Postnov	**Structure, thermal evolution** 09:00 Nice 09:35 Haensel 10:10 Page	**Superfluidity, glitches** 09:20 Gusakov 09:55 Espinoza 10:30 Antonopoulou
10:45 break	10:30 break	10:20 break	10:45 break	10:50 break
11:15 Kuiper 11:50 Hermsen 12:15 Turolla 12:40 Danilenko	11:05 Pons 11:40 Link 12:10 Ikhsanov 12:35 Pustil'nik	10:50 Brown 11:25 Wijnands 12:00 Suleimanov 12:20 Zhang 12:40 Bahramian	11:15 Kaplan 11:50 Fortin 12:15 Kaminker 12:40 Beznogov	**Accretion 1** 11:20 Patruno 11:55 Grebenev 12:20 Russel 12:40 Mushtukov
13:00 Lunch	13:00 Lunch	13:00 Lunch	13:00 Lunch	13:00 Lunch
Pulsars 2 15:00 Mignani 15:25 Kondratiev 15:50 Pilia 16:10 Bilous	**Magnetospheres** 15:00 Philippov 15:25 Beskin 15:45 Timokhin 16:10 Petri	Excursion	**SNe and PWNe** 15:00 Leibundgut 15:35 Kargaltsev	**Accretion 2** 15:00 Cumming 15:35 Gilfanov 16:00 Kuranov
16:30 break	16:30 break		16:10 break	16:20 break
17:00 Egron 17:20 Arumugasamy 17:40 Derishev 18:00 Igoshev	**Magnetic fields** 17:00 Reisenegger 17:30 Bucciantini 17:50 Mitchell		16:40 Posselt 17:00 Rangelov 17:20 Grudzinska 17:40 Uvarov	16:50 Ferrigno 17:15 Konar 17:35 Chugunov
18:20 end	18:10-21:00 informal poster session		Dinner. Blinnikov	18:00 Closing

Poster presentations. †

1.	David Alvarez-Castillo	The nuclear symmetry energy and the neutron star radius
2.	Lev Arzamasskiy	Towards radio pulsar evolution theory
3.	Denis Baiko	Screening corrections to the elastic moduli of neutron star crust
4.	Dmitry Barsukov	The influence of small scale magnetic field on the polar cap X-ray luminosity of old radio pulsars
5.	Onur Benli	Long-Term Evolution and X-ray Enhancement Of Swift J1822.3-1606
6.	Sergey Blinnikov	Stars from the very early universe
7.	Alex Deibel	How unique is the crust of an accreting neutron star? A multicomponent study
8.	Vasiliy Dommes	An approximate method to study oscillations of superfluid hyperon stars
9.	Yana Doronina	On the mass distribution of black holes and neutron stars
10.	Unal Ertan	Low-B Magnetars, High-B Radio Pulsars and Dim Isolated Neutron Stars: Long-term Evolution and Radio Emission Properties
11.	Anthea Fantina	Properties of nuclear matter and neutron stars with unified equations of state
12.	Mikhail Garasyov	Modeling of cyclotron lines in the spectra of isolated neutron stars
13.	Veronika Globina	On the origin of pulsar-like White Dwarfs
14.	Aleksandr Gruzdev	Features of steady states of collisionless plasma layer with counterstreaming electron- positron beams
15.	Hayk Hakobyan	Determination of the pulsar image in the picture plane
16.	Elena Kantor	Anti-glitches within the glitch model of Anderson and Itoh
17.	Anna Karpova	Thermal properties of the middle-aged pulsar J1741-2054
18.	Alexander Kholtygin	Magnetic field of neutron star precursors: Wolf-Rayet stars
19.	Sergei Kiikov	Magnetocavitation mechanism of jet generation from accreting magnetar
20.	Sergei Kiikov	Investigation of the interaction between the two-flow magnetar jet and the interstellar medium
21.	Vitaliy Kim	Evidence for Magneto-Levitation Accretion in the 6.7h isolated X-ray pulsar 1E 161348-5055

† The number of a poster is the number of the board to place it.

22.	Sushan Konar	Radio Pulsar Recycling : The HMXB Question
23.	Vladimir Kondratyev	Soft Gamma-Ray Bursts as magnetoemission of junior magnetar crusts
24.	Victor Kontorovich	Electromagnetic tornado semiclassical quantization and origin of the bands in the giant pulses frequency spectrum of the Crab pulsar
25.	Andrew Kozhberov	Coulomb crystal mixtures in white dwarf cores and neutron star crusts
26.	Alexander Kuznetsov	Creation of electron-positron pairs at excited Landau levels by a neutrino in a strong magnetic field
27.	Agnieszka Majczyna	Accuracy of surface gravity and gravitational redshift determination for neutron stars in X-ray bursters from simulated LOFT spectra
28.	Valery Malofeev	Detection of radio emission of 59 ms pulsar J141256.0+792204 (Calvera)
29.	Igor Malov	On radio emission of anomalous pulsars
30.	Dmitrij Nagirner	Synchrotron radiation by ultra- and moderate relativistic electrons
31.	Joonas Nattila	Heavy metal neutron star atmospheres
32.	Stephen Ng	High-Energy Emission of PSR B1937+21
33.	Elena Nikitina	The structure of the magnetosphere of radio pulsars with interpulses
34.	Dmitrii Ofengeim	Analytic approximations for electron-nucleus bremsstrahlung neutrino emissivity in a neutron star crust of any composition
35.	Igor Panov	Spontaneous Fission and Production of Cosmochronometer Nuclei in the r-process
36.	Konstantin Pavlovskii	Mass loss rates in X-ray binaries simulated by MESA
37.	Qiuhe Peng	The Physics of Magnetars and Their Astrophysical Significance
38.	Jerome Petri	Phase-resolved polarization properties of the pulsar striped wind synchrotron emission
39.	Monika Pienkos	The maximum neutron star mass and the role of the enhanced vector meson interactions
40.	Vadim Prokofev	On the Asymptotic Structure of the Pulsar Wind
41.	Artem Prosvetov	LFN, QPO and fractal dimension of light curves from X-ray binaries
42.	Guillermo Rodriguez Castillo	Taking The Pulse of Transient Magnetars: Connecting Their Long-term Spectral and Timing X-ray Properties

43.	Dmitry Rumyantsev	Resonant mechanism of e^+e^- pair production in a strong magnetic field
44.	Andrey Semena	On the thickness of accretion curtains on magnetized compact objects from analysis of their fast aperiodic time variability
45.	Petr Shternin	Transport coefficients of nuclear matter in neutron star cores in BHF framework
46.	Tatiana Smirnova	Study of scattering material with RadioAstron-VLBI observations
47.	Sergey Zharikov	Radiation efficiencies of the pulsars (current update)
48.	Shuta Tanaka	Constraint of Pulsar Wind Properties from Induced Compton Scattering off Radio Pulses
49.	Daria Teplykh	The flare activity of PSR J0653+8051
50.	Hao Tong	Anti-glitch of magnetars in the wind braking scenario
51.	Anatoly Tsygan	Differential rotation of neutron star polar caps
52.	Sergey Tsygankov	Power spectra of transient X-ray pulsars: observational manifestation of the disk- magnetosphere interaction
53.	Dmitri Uzdensky	Reconnection in Neutron Star Magnetospheres
54.	Cornelis van Eysden	Short-period pulsar oscillations following a glitch
55.	George Younes	XMM-Newton View of the best candidate Magnetar Wind Nebula
56.	Cong Yu	Magnetar Giant Flares and Their Precursors – Flux Rope Eruptions with Current Sheets
57.	Andrey Yudin	On some properties of hybrid stars
58.	Xia Zhou	The role of magnetic damping in the r-mode evolution of accreting neutron stars
59.	Oleg Goglichidze	The spin evolution of the pulsars with non-rigid core

Author index.