PHAROS Conference 2020: The multi-messenger physics and astrophysics of neutron stars

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Book of Abstracts


The multi-messenger physics and astrophysics of neutron stars
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Thematic Areas
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-Magnetic field formation, structure and evolution
-Neutron star observations: from radio to gamma-rays
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PHAROS
THE MULTI-MESSENGER PHYSICS AND ASTROPHYSICS OF NEUTRON STARS
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A FAST study of the slowest pulsar

Authors: Crispin Agar[1]; Patrick Weltevrede[1]

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I will discuss the results from a recent simultaneous observing campaign involving FAST and LOFAR to study PSR J0250+5854, the slowest known pulsar with a period of 23.54 seconds, across a wide range of frequencies. This will be one of the early science results from the currently-being-commissioned Five-hundred-metre Aperture Spherical Telescope (FAST) in Guizhou, China. FAST is the largest filled-aperture telescope in the world with an effective collecting diameter of 300 metres, offering an unprecedented means to study radio pulsars. The frequency evolution of the pulse profile of PSR J0250+5854, combined with the polarisation information provided by FAST allow us to infer geometrical information regarding the emission region of the pulsar, and highlights interesting unexpected frequency evolution of the pulse profile. It will be illustrated that FAST is ideal for the study of single pulses from radio pulsars which are otherwise too faint to be observed in this fashion.

Parallel 1A / 99

Braking indices of the glitching pulsars

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Measuring the braking indices gives the opportunity to search out the braking mechanism of pulsars and evolutionary links between the population. Such measurements should be though rigorous in some cases due to the short and intermediate term effects, most notably timing noise and glitches which superimpose the long-term behaviour of the spindown rate. In particular, various interglitch recoveries observed in the glitching young pulsars are the major obstacle to measuring the long-term braking indices. All pulsars with observed large glitches exhibited 'anomalous'interglitch braking indices, characterized by the larger second time derivative of the rotation rate, induced by glitches. We present the extensive study of the interglitch timing fits of various pulsars, supporting the universal occurrence of a non-linear dynamical coupling between the neutron star crust and interior superfluid components. Based on our understanding of the internal torques and clearing out the contributions coming from glitches, we finally determine the best fiducial epochs when the response of internal torques to the previous glitches have been completed to infer the underlying braking indices.

Parallel 2B / 5

A global model of the magnetorotational instability in proto-neutron stars

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The magnetorotational instability (MRI) is considered to be a promising mechanism to amplify the magnetic field in fast-rotating protoneutron stars. Many local studies have shown that the magnetic field could be amplified on small scales. However, the efficiency of the MRI at generating a large-scale field similar to the dipolar magnetic field of magnetars ($10^{14} - 10^{15}$ G) is still unknown.
To study this question, a three dimensional pseudo-spectral code has been used to develop an idealised global model of the MRI in a proto-neutron star. We show that a dipole field strength consistent with the values of magnetar field intensity can be generated by the MRI, even though it is lower than the small scale magnetic field. Overall, our results support the ability of the MRI to form magnetar-like large scale magnetic fields.

Invited Talks / 131

Superfluidity and Superconductivity in Neutron Stars (Invited)

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The observational evidence for superfluidity in neutron stars will be reviewed. Rotational and magnetic properties of superfluids and superconductors will be discussed, to lead to the current understanding of neutron star dynamics. In particular pulsar glitches and interglitch relaxation will be addressed in terms of superfluid vortex pinning, unpinning and creep. Extraction of information on neutron star structure, in particular of the moments of inertia fractions in various superfluid components of the star leading to possible constraints on the equation of state will be addressed, as well as entrainment effects and the resulting ambiguities in the implied moment of inertia fractions.

Parallel 2B / 192

Accretion-induced collapse to third family compact stars as trigger for eccentric orbits of millisecond pulsars in binaries

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A numerical rotating neutron star solver is used to study the temporal evolution of accreting neutron stars using a multi-polytrope model for the nuclear equation of state named ACB5. The solver is based on a quadrupole expansion of the metric, but confirms the results of previous works, revealing the possibility of an abrupt transition of a neutron star from a purely hadronic branch to a third-family branch of stable hybrid stars, passing through an unstable intermediate branch. The

accretion is described through a sequence of stationary rotating {stellar} configurations which lose angular momentum through magnetic dipole emission while, at the same time, gaining angular momentum through mas accretion. The model has several free parameters which are inferred from observations. The mass accretion scenario is studied in dependence on the effectiveness of angular momentum transfer which determines at which spin frequency the neutron star will become unstable against gravitational collapse to the corresponding hybrid star on the stable third-family branch. It is conceivable that the neutrino burst which accompanies the deconfinement transition may trigger a pulsar kick which results in the eccentric orbit. A consequence of the present model is the prediction of a correlation between the spin frequency of the millisecond pulsar in the eccentric orbit and its mass at birth.

Poster Session / 188

Timing noise induced by plasmoid formation at the light cylinder

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Pulsar-timing is plagued by several sources of noise whose physical origin is unclear. In recent years, pulsar magnetosphere models have shown that reconnection around the light cylinder plays a key role in particle acceleration and in the origin of the pulsed gamma-ray emission. The pulsar current sheet breaks up into a series of dynamical magnetic islands, which in turn lead to fast and time-dependent reconnection. In this work, we measure the impact of plasmoid formation on the fluctuating torque slowing down (spinning up) the star and we investigate whether this effect could contribute to the observed timing noise.

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Structure and features of formation of reversals in Galactic magnetic field

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It is reliably established that there are large-scale Galactic magnetic fields of several micro-gauss. There are numerous arguments in favor of the fact that in Galactic magnetic field is detected the so-called reversals associated with a change in its direction during transition from one area to another. Similar configurations are provided in framework of nonlinear equations of dynamo theory, which describes the evolution of large-scale magnetic field. Here we bring simulated versions using the so-called planar approximation which suggests that the galactic disk is quite thin. We show that it is possible a generation of magnetic field with both single and double inversion of field direction when you move away from the center of Galaxy. From an observational point of view, one of the methods for studying magnetic fields is the measurement of the Faraday rotation of radio waves coming to

us from pulsars. Its value can characterize the integral value of the magnetic field, and the sign - its direction. To study of large scale characteristics of Galactic magnetic field, observational data of pulsars with large faraday rotation values (|RM|> 200 rad / m2) were used. It was suggested that large |RM| values can be due to the contribution of the regions with increased electron concentration, projected on the pulsar. Most likely these are the HII regions, dark nebulae and molecular clouds. In these objects the magnetic field probably can be oriented in the direction of a large-scale field of the Galaxy, or simply is a deformed extension of the galactic field and consequently, data on pulsars with large |RM| contain information about the galactic magnetic field. It was shown that the Galactic distribution of rotation measures of pulsars with |RM|> 200 rad/m2Â partially corresponds to the circular model of Galactic magnetic field with the counter-clockwise direction of the magnetic field in the galactocentric circleÂ 4.8 kpc <R <7.3 kpc. At the boundaries of this ring the magnetic field changes its direction to the opposite. These results are in good consistent with both theoretical concepts and other works that are dedicated observations of the magnetic field structure of the Galaxy.

Parallel 2A / 35

Vortex dynamics in neutron stars

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In the superfluid interior of a neutron star the presence of quantized vortex lines defines an intermediate scale (in between the microscopic fermi-scale and the centimeter-scale) ranging from the radius of a vortex core to the typical separation between vortices. This complicates the hydrodynamic description of a neutron star interior. A classical treatment of a vortex moving through the lattice of nuclear impurities in the crust can be achieved by means of the vortex-filament model. Understanding the complex dynamics of vortices by means of vortex-filament simulations can deepen our understanding of superfluidity-related phenomena in neutron stars, like pulsar glitches.

Invited Talks / 71

The rotational dynamics of young, isolated pulsars (Invited)

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Timing of neutron stars leads to information about their energy losses, magnetic field and internal dynamics including superfluid phenomena. In young pulsars, the long-term evolution of the spin-down rate can often be probed, in addition to irregularities such as timing noise and spin-up glitches. We will review the main observational attributes of their rotation and discuss some of the most recent results and how they shape our understanding of neutron star dynamics.

Parallel 2B / 85

Probing binary neutron star merger components and remnant using isentropic equations of state

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Gross properties of merger components and remnant in GW170817 are investigated using equations of state (EoSs) within the finite temperature field theoretical models. Tidal deformabilities and radii of merger components are estimated in light of GW170817. An analytical expression for the radius of a merger component is derived in terms of the combined tidal deformability for binary neutron star masses in the range $1.1M_\odot \leq M \leq 1.6M_\odot$. The maximum mass, radius, Kepler frequency and moment of inertia of the rigidly rotating remnant for each EoS at fixed entropy per baryon. It is found that the Kepler frequency of the remnant is much lower at higher entropy per baryon than that of the case at zero temperature.

Parallel 3A / 63

Subpulse Drifting in Pulsar Radio emission

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The subpulse drifting, seen as periodic modulations in the single pulse radio emission, provides a direct observational window into the inner acceleration region (IAR) of pulsars. The drifting is associated with the sparking discharges responsible for the non-stationary plasma flow, where the sparks are expected to undergo ExB drift in the IAR. However, there is significant diversity observed in the drifting behaviour, and a self consistent physical mechanism that can explain this wide variety is still lacking. To understand the drifting behaviour in the pulsar population we have conducted sensitive observations of single pulse radio emission using the Giant Meterwave Radio Telescope (GMRT), and characterised the periodic behaviour using standard fluctuation spectrum analysis. A near complete sample of drifting pulsars, around 70 known cases, has been investigated in these studies which yielded significant constraints on the physical characteristics of subpulse drifting as well as the underlying mechanism, some of which are highlighted as follows.

a. We found the periodic modulations to be more generic in the pulsar population, and a systematic classification scheme allowed us to find a number of pulsars showing periodic modulations which are not associated with subpulse drifting. They constitute a newly emergent phenomenon in pulsars requiring different physical mechanism.

b. In the pulsars showing subpulse drifting behaviour, we found an anti-correlation between the modulation periodicity with pulsar spin-down energy loss. This suggests the presence of a Partially Screened Gap (PSG), where the potential drop in the IAR is partially screened by a steady outflow of ion from the heated surface, rather than a vacuum gap in the IAR.

In this talk we will present a detailed characterisation of the drifting behaviour that has emerged from our recent observations and contrast them with other periodic modulations seen in the pulsar radio emission. We will also postulate the physical processes likely to be responsible for the observed drifting behaviour.

Parallel 3B / 176

Perturbation to a magnetic neutron star with shear modulus

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The extent of the magnetic field at the interior of a neutron star is mostly unknown from the observed radiation features as it can probe up to the outer stellar surface. Theoretical models on the interior magnetic field geometry are generally oversimplified to avoid the complexity and mostly based on the axisymmetric barotropic fluid system. But these static magnetic equilibrium configurations are unstable with a short time scale against an infinitesimal perturbation to consider as a realistic model. The stellar material does not behave as a perfect fluid and the matter in the neutron star crust forms an ionic crystal. The electrostatic interactions between the crystallized charged particles can generate shear stress against any applied strain as a form of a perturbation. To incorporate the effect of crystallized crust on the dynamical evolution of the perturbed equilibrium structure, we study the effect of shear on the instability within the axisymmetric magnetic star. We find the limit of the critical shear modulus to prevent magnetic instability and the corresponding astrophysical consequences.

Parallel 2B / 161

Carbon burning in the envelopes of neo-neutron stars

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We investigate how deep carbon can survive in the envelope of very young (a few minutes after birth) and very hot neo-neutron stars. The question is motivated by the existence of at least two neutron stars which are best described with a carbon atmosphere model. Such models unfortunately do not answer the question of how deep a carbon layer can be (a few centimeters are sufficient to form a carbon atmosphere). They also do not answer the question of how that carbon might have appeared. If we assume that there is no accretion after the birth of the star then it could only have come from the initial fallback after the core collapse.

So, it is interesting to investigate whether this "initial" carbon could have survived the early stages of the neutron star evolution. To this aim, we have integrated the nuclear reaction network of the *MESA* stellar evolution package into our *NSCool* neutron star cooling code to investigate carbon burning in the neutron stars' envelopes. We have checked both simple run-away explosion criterion and performed carbon burning calculations fully coupled with the neutron star evolution. This provides us with restrictions on the possible thickness of a carbon layers in the envelope.

Parallel 1B / 69

The tireless magnetar

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In this talk, I will focus on the peculiar case of the magnetar 1E 1547.0-5408. This source underwent three outbursts, with the latest having onset in 2009. By analysing new and archival observations, we measured a steady flux over the last 9 years (about a factor 30 larger than its quiescent level and an order of magnitude fainter than the peak of the 2009 outburst). Moreover, we observed hard X-ray emission till ˜70 keV, after 10 years since the outburst onset. Our analysis suggests that the flux of 1E 1547 is not yet decaying to the pre-outburst level: this is a property that has not been seen in other magnetars. This result might suggest that magnetars can hop among different persistent states and that their persistent thermal emission can be almost entirely powered by the dissipation of currents in the corona.

Parallel 1B / 145

Numerical models for the amplification and growth of magnetic field in compact objects.

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The presence of strong magnetic fields in many compact objects, neutron stars in particular, as well as accretion disks, is key to understand their dynamical evolution and to explain the properties of their high-energy emission. The magnetic evolution inside the hosting relativistic plasma, is subject of complex behaviours: dynamo or chiral processes that can amplify any initial seed fields toward specific final configurations; quenching mechanisms; dissipation in thin current sheets and turbulent layers that are expected to take place in the magnetospheres of magnetars, pulsar and proto-neutron stars. Here we present a unified formalism for these non-ideal effects within the framework of 3+1 general relativistic magnetohydrodynamics (GRMHD) and the numerical algorithm adopted to stably solve those equations. We will also present numerical simulations obtained with the XECHO code, ranging from the kinematic to the full dynamical regime, including the role of quenching, and how the results relate to observed properties of compact systems.

Parallel 1B / 4

Complex magnetic field topologies in core-collapse supernovae

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The magnetic field is believed to play an important role in at least some core-collapse supernovae when its magnitude reaches 10^{15} G, which is typical of the most magnetic neutron stars called magnetars. In the presence of fast rotation, such a strong magnetic field can drive powerful jet-like explosions if it has the large-scale coherence of a dipole. The topology of the magnetic field is, however, probably much more complex with strong multipolar and small-scale components and the consequences for the explosion are so far unclear.

We investigate the effects of the magnetic field topology on the dynamics of core-collapse supernovae and the properties of the forming proto-neutron star (PNS) by comparing different multipolar orders and radial extents. Using axisymmetric relativistic MHD simulations, we find that higher multipolar

magnetic configurations lead to generally less energetic explosions, slower expanding shocks and less collimated outflows. Models with lower-order multipolar configuration tend to produce more oblate PNS, which in some cases are surrounded by a rotationally supported toroidal structure of neutron-rich material. Moreover, magnetic fields which are distributed on smaller angular scales produce more massive and faster rotating central PNS, suggesting that higher-order multipolar configurations tend to decrease the efficiency of the magnetorotational launching mechanism. Even if our dipolar models systematically display a far more efficient extraction of the rotational energy of the PNS, fields distributed on smaller angular scales are still capable of powering magnetorotational explosions and shape the evolution of the central compact object.

Parallel 1B / 107

GrailQuest & HERMES: Hunting for Gravitational Wave Electromagnetic Counterparts and Probing Space-Time Quantum Foam

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GrailQuest (Gamma-ray Astronomy International Laboratory for Quantum Exploration of Space-Time) is an ambitious astrophysical mission concept that uses a fleet of small satellites, whose scientific objectives are discussed below.
Within Quantum Gravity theories, different models for space-time quantisation predict an energy dependent speed for photons. Although the predicted discrepancies are minuscule, Gamma-Ray Bursts, occurring at cosmological distances, could be used to detect this signature of space-time granularity with a new concept of modular observatory of huge overall collecting area consisting in a fleet of small satellites in low orbits, with sub-microsecond time resolution and wide energy band (keV-MeV). The enormous number of collected photons will allow to effectively search these energy dependent delays. Moreover, GrailQuest will allow to perform temporal triangulation of high signal-to-noise impulsive events with arc-second positional accuracies: an extraordinary sensitive X-ray/Gamma all-sky monitor crucial for hunting the elusive electromagnetic counterparts of Gravitational Waves. A pathfinder of GrailQuest is already under development through the HERMES (High Energy Rapid Modular Ensemble of Satellites) project: a fleet of six 3U cube-sats to be launched by the end of 2021-beginning 2022.

Parallel 1A / 163

High-resolution phase coherent optical timing of the Vela pulsar and PSR J1023+0038 with Aqueye+ and Iqueye

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We present the results of an optical timing analysis of the Vela pulsar and the transitional millisecond pulsar PSR J1023+0038. The Vela pulsar was observed in 2009 with the fast photometer Iqueye

mounted at the ESO 3.5 m New Technology Telescope (Chile). We determined an independent optical timing solution and the most detailed optical pulse profile of this pulsar available to date. The quality of the Iqueye data allowed us to determine the relative time of arrival of the radio-optical-gamma-ray peaks with an accuracy of a fraction of a millisecond. PSR J1023+0038 was recently observed with the fast photometer Aqueye+ mounted at the Asiago 1.8 m Copernicus telescope (Italy). We derive a long-base phase coherent timing solution based entirely on optical data and determine the rotational period with an accuracy of ˜7x10ˆ-15 s. In addition, we constrain the value of the frequency derivative of the pulsar.

Invited Talks / 25

The Fast Radio Burst Phenomenon (Invited Review Talk)

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FRBs are currently one of the biggest unsolved and most tantalizing enigmas of astrophysics. They manifest themselves as millisecond duration pulses at cosmological distances. Over 100 FRBs have been discovered to date with a remarkable diversity of observed properties, but no consensus has emerged regarding the nature of their progenitor(s). Almost every radio telescope in the world is currently undertaking large-area surveys at radio frequencies ranging from 100 MHz up to tens of GHz to discover, study and understand these bursts. With the development of new instrumentation and software, we have now reached a point where radical changes in the field occur on timescales of a few months or so. As a result, the quest to answer the fundamental questions of their enigmatic nature, progenitors, environments, spatial distribution and their potential for use as cosmological probes is gaining enormous momentum. If FRBs are detectable in follow up multi-wavelength/multi-messenger observations, it will be the most straightforward way to answer the question of their origin. In my talk, I will present an overview of the field and various studies and experiments conducted till date to study FRBs, and also address the lessons learned.

Parallel 3B / 8

Rotating neutron stars with non-barotropic thermal profile

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Being able to determine the stationary structure of a neutron star allows to study its properties, like the parameter space of the equation of state, the mass-radius diagram, and the gravitational wave emission. Moreover, this stationary configuration can be used as initial condition for a much more resource demanding hydrodynamical simulation. A key approximation made for computing the stationary structure of hot and rotating neutron stars is that of barotropicity, namely that all thermodynamical quantities are in a one-to-one relationship, which in turn implies that the specific angular momentum of a fluid element is in a one-to-one relationship with its angular velocity. However, this is a poor approximation for the compact remnant of a core-collapse supernova or of a binary neutron star merger. In this talk I describe how, for the first time, we determine the structure of stationary, hot, rotating neutron stars without the barotropic approximation. To do so, we introduce a potential formulation for the Euler equation, which is a novel technique even in the context of Newtonian stars.

Parallel 3A / 118

Crystalline condensates in compact stars

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The phase structure of hadronic matter at high density could be extremely rich. In particular, several effective model calculations, as well as more refined studies based directly on QCD, suggest that spatially inhomogeneous phases might form in cold and dense quark matter, possibly leading to significant phenomenological consequences for the physics of compact stars.
In this contribution, I will discuss this scenario focusing on the formation of crystalline chiral condensates and discuss their influence on compact star observables as well as implications for the newly-born gravitational wave astronomy.

Parallel 3B / 109

Simulations of the magnetic field evolution in neutron star cores in the strong-coupling regime

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The evolution of the magnetic field in NSs is strongly related to their internal structure. In the NS core there is a fluid mixture of neutrons, protons, and electrons (joined by other species at increasing densities) that scatter off each other through strong and electromagnetic interactions, causing effective friction forces, and can also convert into each other by weak interactions ("Urca reactions"). In hot, young NSs, frictional forces keep the different components moving together. As charged particles and neutrons have different density profiles, their joint radial motions are constrained by stable stratification, which helps to stabilize the field. However, Urca reactions, hugely enhanced at high temperatures, can adjust the composition of a fluid element while it is pushed by the magnetic forces, letting the matter behave as a single fluid with time-varying composition, which moves together with the magnetic field on a time-scale set by the weak interactions, avoiding the buoyancy force that stabilizes the field.
Here, we present simulations of the long-term evolution of the magnetic field in this "strong-coupling" regime in the interior of an isolated, axially-symmetric neutron star. Special attention in given to the characterization of the different physical processes involved, as well as their corresponding timescales, which happen to be in agreement with our numerical estimates.

Parallel 1B / 132

Understanding GWs from core-collapse supernovae

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Core collapse supernovae is among the most exciting events that we expect to observe in the future by gravitational wave interferometers. They provide a unique multi messenger opportunity with the combined emission of gravitational waves, neutrinos and electromagnetic waves. In this talk I will focus in the current understanding of core-collapse GW signals and how they can be modelled in terms of normal oscillations modes of proto-neutron stars excited during the post-bounce phase before the onset of the SN explosion. The observation of such modes in the future by gravitational wave observatories (Virgo, LIGO) may allow to infer the properties of proto-neutron stars and learn about the engine powering supernova explosions.

Invited Talks / 24

A new look at the high-energy emission in pulsars from kinetic plasma simulations (Invited)

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The origin of the pulsed high-energy emission in pulsars is an outstanding open question since the early days of gamma-ray astronomy. Today, the combination of sensitive observations in the GeV domain and increasingly sophisticated numerical simulations have recently brought new insights into our understanding of the pulsed emission and particle acceleration processes in pulsars. I will review some of these new developments from the perspective of ab-initio global particle-in-cell simulations of pulsar magnetospheres and pulsar winds. Simulations show that the equatorial current sheet forming beyond the light cylinder is the main culprit for magnetic dissipation, particle acceleration and bright high-energy synchrotron radiation all together. The shinning current sheet naturally results in a pulse of light each time the sheet crosses our line of sight, which happens twice in most cases. Synthetic lightcurves present robust features reminiscent of observed gamma-ray pulsars by the Fermi-LAT and Agile, opening up new perspectives for direct comparison between simulations and observations.

Parallel 2A / 70

Investigation of emission and variability behavior of accreting neutron star LMXB 4U 1724-30

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Understanding the mechanism of outburst and modelling the corresponding detailed emission from compact objects in low mass X-ray binaries (LMXBs) is integral to probing the physics of strong gravity, ultra-dense degenerate matter and accretion dynamics. Broadband spectro-timing studies of these objects can put unique constraints on the evolution of the binary components in different spectral states. We report the analysis of broadband observation of the poorly studied accreting neutron star LMXB 4U 1724-30 jointly by SXT and LAXPC instruments on board AstroSat. The source was observed by Astrosat in 2017 which corresponded to the low-luminosity non-thermally dominated state of the source over 4 epochs. All the X-ray broadband spectra can be modeled by a combination of a thermal emission from the accretion disk and a non-thermal emission possibly originating from Inverse-comptonization of seed photons from disk. The timing variabilites were

also investigated to probe the origin of disk and coronal fluctuations and their dependence on mass accretion. Spectro-temporal analysis and time lag properties of the broadband emission was carried out to derive information about the complete radiative emission behavior and its evolution. The time-resolved spectroscopy of a thermonuclear burst detected during the last observation was performed and the correlation of the burst property on the spectral state was investigated. This broadband study will be instrumental to understand the nature of physical processes occurring in the accretion flow as well as corona along with the burst-corona interaction in the hard state.

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Unified equations of state of cold dense matter in nonaccreted neutron stars

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The interior of a neutron star is expected to contain at least three distinct regions: (i) an outer crust made of exotic nuclei coexisting with a degenerate electron gas, (ii) an inner crust where neutron-proton clusters are immersed in a sea of free neutrons in addition to electrons, and (iii) a liquid core made of neutrons, protons, and leptons. In this contribution, we will present our latest series of unified equations of state of cold dense matter in neutron stars, allowing for the existence of a liquid-crystal mantle of nuclear pastas. Based on the nuclear energy-density functional theory, these equations of state provide a thermodynamically consistent treatment of all regions of the star and were calculated using functionals that were precision fitted to experimental and theoretical nuclear data. These equations of state were specifically developed to assess the role of nuclear uncertainties on neutron-star properties. We will also present recent results for the neutron-proton entrainment parameters in neutron-star cores, which we have calculated consistently with our unified equations of state within the same microscopic framework and using the same functionals.

Parallel 1A / 75

Dense Matter Phases inside Neutron Stars: Constraints from Observations

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The measurement of tidal deformability from GW170817 and the existence of pulsars with $\sim 2M_{\odot}$ pose great challenges to the usual way of understanding the equation of state (EOS) of dense nuclear matter. We have studied a large set of relativistic mean field EOSs and found that only few can survive these constraints which predict a stiff overall equation of state but with a soft neutron-proton symmetry energy. Based on this analysis, we have also found an upper bound on the radius of a $1.4M_{\odot}$ star as $R_{1.4} \sim 12.9$ km. These evidences further indicate to the possibility of a hadron-quark phase transition inside the star. We have also studied the possible existence of nucleon superfluidity and its effect on the fluid nature of the neutron star. We have seen that entrainment between different fluids inside the star affects the tidal deformability.

Parallel 3A / 96

Unusually long thermonuclear bursts from neutron stars

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Thermonuclear bursts from neutron stars in low-mass X-ray binaries are the subject of advanced research on accretion and nuclear burning processes. Depending on the accretion rate and composition of the stellar material, bursts lasting tens of minutes can be explained by the ignition of an unusually thick pure helium layer, though the role of hydrogen remains uncertain in some systems. Besides, hour-long superbursts powered by the explosive burning of carbon, produced through H/He burning, are thought to originate from a thicker deeper layer, thus probing the thermal profile of the neutron star crust.
This talk will review fifty years of observations revealing that about 1% only of thermonuclear bursts last more than 10 minutes. A unique sequence of an intermediate long burst immediately leading a superburst will also be presented as the former possibly being the firestarter of the latter.

Parallel 3B / 134

Crust-Magnetosphere Feedback

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We investigate the magnetic field evolution in the crust and the magnetosphere of a neutron star considering the feedback between the two regions. The crustal magnetic field evolves due to the Hall effect and the subdominant Ohmic dissipation. We explore three main cases: (i) A magnetic field fully confined in the crust. (ii) A magnetic field evolving in the crust coupled to a current-free magnetosphere. (iii) A magnetic field that evolves in the crust and is coupled to a force-free magnetosphere. In case (iii) we assume that the magnetic reaches force-free equilibrium through a magnetofrictional process that is simulated separately. We quantify the differences in the overall evolution via a numerical calculation.

Parallel 2A / 78

Tidal Deformability, Phase Transitions and Stiffness of the Nuclear Equation of State

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We explore the connection between the stiffness of an hadronic equation of state with a sharp phase transition to quark matter to its tidal deformability. To this end we employ a hadronic relativistic mean field model with a parameterized effective nucleons mass to vary the stiffness in conjunction with a constant speed of sound EoS for quark matter. We compute multiple scenarios with phase transitions according to the four possible cases of a hybrid star EoS with a stable second branch. We demonstrate at the example of GW170817 how the effective nucleon mass can be constrained by using gravitational wave data. We find, that certain values of the effective nucleon mass are incompatible with GW170817 and a phase transition simultaneously.

Parallel 3B / **95**

The Variable Redback PSR J2039-5617

Author: Colin Clark[None]

Co-authors: Lars Nieder [1]; Alessandro Corongiu [2]; Roberto Mignani [3]; Guillaume Voisin [4]; on behalf of the Fermi-LAT collaboration

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The gamma-ray source 3FGL J2039.6-5618 contains a periodic optical and X-ray source that was predicted to be a ''redback" millisecond pulsar binary. However, without the detection of pulsations, this identification remained inconclusive. Using new optical observations to refine the orbital ephemeris, we searched for gamma-ray pulsations with 10 years of Fermi-LAT data using the Einstein@Home volunteer computing system. The successful discovery of gamma-ray pulsations confirms the redback prediction, and makes this source one of just a handful of millisecond pulsars that have been first identified through their gamma-ray pulsations, instead of their radio pulsations. I will describe how this discovery provides the missing puzzle piece required to interpret a wealth of multiwavelength data. Combined with optical spectroscopy and light curve modelling, timing the pulsar's orbit provides a new pulsar mass measurement. We detect long-term variability in both the optical light curve and the pulsar's orbital period, suggesting magnetic activity in the companion star may play an important role in the behaviour of this system. We also find a significant enhancement of the pulsed gamma-ray flux around the pulsar's superior conjunction, which we interpret as up-scattering of the companion's optical emission by leptons accelerated by the pulsar. Together, these phenomena make this system an important new specimen for understanding a wide range of neutron star astrophysics, from pulsar wind and emission mechanisms, to the evolution of pulsar binaries.

Parallel 1A / **37**

Hybrid modeling of high-energy emission in pulsars

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We will present an iterative hybrid approach that self-consistently combines ideal force-free electrodynamics in the bulk of the magnetosphere with particle acceleration along the equatorial current sheet. We derive analytic approximations for the orbits of the particles, and obtain the structure of the magnetosphere for various values of the pair-formation multiplicity parameter. We show that realistic magnetospheres are practically indistinguishable from the ideal force-free one, and therefore, the calculation of the spectrum of high-energy radiation must be based on analytic approximations for the accelerating electric field in the current sheet, and NOT on global PIC numerical simulations.

Parallel 3B / 174

Radio pulsations from the *Fermi*-LAT source 3FGL J2039.6-5618

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Clark et al. (in prep.) recently discovered a gamma-ray pulsar associated with the *Fermi*-LAT source 3FGL J2039.6-5618, now PSR J2039-5617, and they obtained an accurate pulsar ephemeris from the gamma-ray data. We processed observations with the Parkes Radio Telescope using the \gamma-ray ephemeris, and detected PSR J2039-5617 as a radio millisecond pulsar. The pulse shows a single broad peak profile, which is misaligned with the gamma-ray one. Full orbit observations at 1.4GHz show that the signal is eclipsed for about half of the orbit, thus confirming the foreseen RB classification for this system, and ascribing the eclipsing mechanism to the typical presence in RB system of intrabinary gas. The inferred value for the dispersion measure, $DM = 24.724 \pm 0.054$ pc cm^{-3}, indicates that the radio signal might be affected by interstellar scintillation, a phenomenon that can explain why pulses have not been detected in some observations taken around inferior conjunction. From the dispersion measure we derive a pulsar distance of 1.726 ± 0.690 kpc based on the YMW16 Galactic electrons distribution model, and compatible with the hydrogen column density obtained from the XMM-Newton spectrum. A comparison among radio and X-ray observations taken at different epochs shows no changes in the pulsar radio and X-ray emission.

Parallel 1A / 84

A successful quest for a transitional pulsar: the case of CXOU J110926.4-650224

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The recent discovery of three millisecond pulsars able to alternate a state powered by the rotation of the neutron star magnetic field and a state characterized by the presence of an accretion disk has revealed the existence of an extremely peculiar phase in the evolution of binary pulsars. These pulsars are known as transitional millisecond pulsars. I will present the results of systematic searches aimed at identifying new candidates, describing in particular the results of recent extensive multi-band campaigns that led to the discovery of a new transitional pulsar, CXOU J110926.4-650224

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Particle-in-cell simulations of pair discharges at pulsar polar caps

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When subject to the rotationally induced electric field of pulsar polar caps, electrons and positrons are accelerated along the magnetic field, producing gamma-ray curvature radiation. The emitted gamma-rays, in turn, are absorbed by the magnetic field, converting to new electron-positron pairs. The repetition of this process leads to a cascade of elementary particles that are the source of pulsar magnetospheric plasma. The final number of particles created in pair cascades and their connection with pulsar radio emission remains an open problem. Obtaining numerical models of pulsar pair discharges is a challenging endeavor and one that was only addressed in simplified one-dimensional simulations. In this work, we present two-dimensional particle-in-cell simulations of pair discharges near pulsar polar caps, including the Quantum Electrodynamics effects responsible for gamma-ray and pair production processes from first principles. These simulations allow studying the time dependence and distribution in altitudes and latitudes of pair cascades while resolving the relevant plasma electrodynamic scales. We analyze the particle spectra and discuss the constraints that our simulations put on pair production rates for use in global pulsar simulations, underlining the differences to previous models with simplified prescriptions. We also estimate the fraction of gamma-rays that escapes the polar cap and contributes to the flux of polar gamma-rays in Fermi data.

Parallel 3B / 190

The effects of localized heating in the crust of a neutron star

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In neutron stars, the magnetic field is believed to be mostly confined into the crust. Its topology strongly influences the surface temperature distribution, and hence the star observational properties. In this contribution, I will present some of the first simulations of the coupled crustal magneto-thermal evolution in three dimensions. In particular, I will discuss how the crust reacts to episodes of localised energy injection. This directly bears to the evolution of outbursts in magnetars, as well as to the surface temperature map of rotation powered pulsars. Simulations show that the surface temperature distribution exhibits a variety of patterns, as a consequence of non-trivial transport properties driven by the magnetic field. A remarkable result is that the hottest region on the star surface may drift while cooling.

Parallel 1A / 41

Transitional millisecond pulsar binaries during active radio pulsar state

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The multi-band variability of transitional millisecond pulsar binaries and redbacks during active radio pulsar state will be presented, comparing their properties over a wide energy range to understand whether all, if any, redback is prone to make transition to an accretion powered state.

Invited Talks / 115

Probing the interior of transiently accreting neutron stars (Invited)

Author: Nathalie Degenaar[1]

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When residing in an X-ray binary, a neutron star accretes gas from a companion star. As matter accumulates on the neutron star surface, the underlying crust is compressed and heated due to nuclear reactions induced by this compression. These heating processes play an important role in setting the observable properties of thermonuclear bursts and rapid variability (mHz QPOs) observed from accreting neutron stars, and in the long-term thermal evolution of the neutron star core.

Once accretion switches off, sensitive X-ray satellites can be employed to observe the thermal glow of the accretion-heated crust and how it cools in absence of accretion. Comparing these observations with theoretical simulations provides very valuable insight into the structure and composition of neutron star crusts and core. I will review recent observational and theoretical progress in this research field, which includes new constraints on the superfluid properties of the dense neutron star core.

Parallel 2A / 127

Hot-Neutron Rich Nuclear Matter Studied with the BCPM Nuclear Energy Density Functional

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We have studied the thermal properties of a recently formulated nuclear energy density functional. The functional is known as BCPM (Barcelona-Catania-Paris-Madrid) and it is based on Brueckner calculations using the realistic Argonne v_{18} potential plus three-body forces of Urbana type. This functional has been successfully used to describe finite nuclei and cold neutron stars. Investigating the properties of hot β-stable matter for neutrino-free and neutrino-trapped scenarios is essential to perform astrophysical applications of the BCPM functional. In this work, the predictions of this functional for the mass-radius relation and the tidal deformability of compact stars at finite temperature are studied.

Parallel 1B / 77

Constraining critical temperature profiles with r-mode instability in neutron stars

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We constrain the profiles of nucleon critical temperatures with a recently developed model of resonance stabilization of r-modes (Gusakov, Chugunov, Kantor PRL 112, 151101, 2014). To this end, we calculate the finite-temperature r-mode spectrum of a superfluid neutron star under realistic microphysics assumptions. Namely, we, for the first time, account for both muons and entrainment between neutrons and protons, adopting also realistic equation of state and superfluidity model.

Assuming that both rotation and entrainment effects are small, we find a non-analytic behavior of eigenfrequencies and eigenfunctions for superfluid r-modes. This prompts us to develop a specific perturbation scheme to calculate the spectrum. We find that the normal r-mode exhibits avoided-crossings with superfluid r-modes at certain values of temperature and rotation frequency. Near the avoided-crossings the r-mode dissipates strongly, which leads to substantial suppression of the r-mode instability at these resonance parameters. Extreme sensitivity of the positions of avoided-crossings to the superfluidity model allows us to constrain critical temperature profiles by confronting the calculated spectra with observations of neutron stars in low-mass X-ray binaries.

This study was supported by the Russian Science Foundation (grant number 14-12-00316).

Parallel 3B / 169

Scalarized neutron stars with a massive scalar field –astrophysical implications

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Scalarization is a very interesting nonlinear mechanism for developing of nontrivial scalar field that can have well pronounced observational signatures. If the scalar field is massive, the strong constraints on the theory coming from the binary pulsar observations, can be easily circumvented thus leading to large deviations from general relativity. In the talk we will discuss the astrophysical implications of such scalarized neutron stars, focusing on the electromagnetic and gravitational wave observations, as well as on certain universal relations.

Parallel 3A / 54

Spectral analysis of the quiescent low-mass X-ray binary in the globular cluster M30

Authors: Constanza Echiburú[None]; Sebastien Guillot[1]

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We present a recent Chandra observation of the quiescent low-mass X-ray binary containing a neutron star, located in the globular cluster M30. We fit the thermal emission from the neutron star to extract its mass and radius. We find no evidence of flux variability between the two observations taken in 2001 and 2017, so we analyze them together to increase the signal to noise. We perform simultaneous spectral fits using standard light-element composition atmosphere models (hydrogen or helium), including absorption by the interstellar medium, correction for pile-up of X-ray photons on the detector, and a power-law for count excesses at high photon energy. Using a Markov-chain Monte Carlo approach, we extract mass and radius credible intervals for both chemical compositions of the atmosphere: $R_{\rm NS} = 7.94^{+0.76}_{-1.21}$ km and $M_{\rm NS} = 0.79^{+0.40}_{-0.28}$ $\mathrm{M}_\odot$ assuming pure hydrogen, and $R_{\rm NS} = 10.50^{+2.88}_{-2.03}$ km and $M_{\rm NS} = 1.07^{+0.71}_{-0.51}$ $\mathrm{M}_\odot$ for helium, where the uncertainties represent the 90% credible regions. The small radii are difficult to reconcile with most current nuclear physics models (especially for nucleonic equations of state) and with other measurements of neutron star radii, with recent preferred values generally in the 11-14 km range. We discuss possible sources of systematic uncertainty that may result in an underestimation of the radius, identifying the presence of surface temperature inhomogeneities as the most relevant bias.

Parallel 1A / 82

On the torque reversals of accreting neutron stars

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In continuation of our earlier work on the accretion/propeller transition of accreting neutron stars, we have investigated torque and luminosity variations during the spin-up/spin-down transitions of these systems. Our analytical model includes the critical conditions for transitions from the strong propeller to the weak propeller and to the spin-up phase together with the accompanying X-ray luminosities and rotational properties. We have compared our results to the observations of accreting neutron stars with different rotation rates, magnetic field strengths and accretion rates. In particular, we have shown that how these sources undergo torque reversals without a significant change in both the torque magnitudes and the X-ray luminosities.

Parallel 1A / 105

The glitch size distribution of the Vela pulsar and small pulsar glitches

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The rotation of the Vela pulsar was regularly interrupted by large glitches 17 times during the last 50 years. In contrast, only 3 small glitches (sizes < 10 uHz) have been reported for the same time period. There is general agreement that all these glitches distribute normally around 20 uHz, with a standard deviation of close to 10 uHz. However, the completeness of this sample is unclear. We present

systematic searches for small glitches in nearly 17 years of observations of the Vela pulsar that were carried out at the Mount Pleasant Radio Observatory (Hobart, Australia). Given the high cadence of the dataset, we estimate that the searches are sensitive to sizes above ˜0.0005 uHz. Three new small glitches were found with sizes between 0.01 and 0.4 uHz. We also found a population of events with sizes < 0.01 uHz which could also be regarded as glitches. However, as it was reported for the Crab pulsar, there is a similar population of events with negative steps. One plausible interpretation is that these small events are the effect of timing noise like processes. The underlying glitch size distribution of the Vela pulsar and the possible existence of a minimum glitch size for most pulsars are discussed.

Parallel 2A / 15

Introducing a novel approach for modelling pulsar light curves together with their spectral energy distribution

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In this talk, I shall present recent works on the spectral characterization of the non-thermal X-ray emission and its subsequent modelling using synchro-curvature radiation. I shall introduce the use of the differential geometry Frenet-Serret equations to describe a magnetic line in a pulsar magnetosphere. These equations, which need to be solved numerically, fix the magnetic line in terms of their tangent, normal, and binormal vectors at each position, given assumptions on the radius of curvature and torsion. Once the representation of the magnetic line is defined, I shall comment on the relevant set of transformations between reference frames; the ultimate aim is to express the map of the emission directions in the star corotating frame. In this frame, an emission map can be directly read as a light curve seen by observers located at a certain fixed angle with respect to the rotational axis. I shall show that this approach offers a setting to achieve an effective description of the system's geometry together with the radiation spectrum. This allows to compute multifrequency light curves produced by a specific radiation process (and not just geometry) in the pulsar magnetosphere, and intimately relates with averaged observables such as the spectral energy distribution.

Parallel 1B / 39

Crystallization of the outer crust of non-accreting neutron stars

Authors: Anthea Francesca Fantina[1]; Sebastien De Ridder[2]; Nicolas Chamel[2]; Francesca Gulminelli[3]

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The interior of a neutron star is usually assumed to be made of cold catalysed matter. However, the outer layers are unlikely to remain in full thermodynamic equilibrium during the neutron-star formation and cooling, especially after crystallization occurs.
In this contribution, we present a study of the evolution of the nuclear distributions of the hot dense multicomponent Coulomb plasma and the equilibrium composition of the outer layers of a non-accreting neutron star down to crystallization.
The variation of the impurity parameter, generally taken as free parameter in cooling simulations and calculated in this work self-consistently using a microscopic nuclear model, will be discussed. Specifically, its non-monotonic behaviour, with values changing by several orders of magnitude reaching about 50, suggests that the crust may be composed of an alternation of pure (highly conductive) and impure (highly resistive) layers, which in turn may have sizeable impact on transport properties and the neutron-star evolution.

Parallel 2B / 123

Distinguishing double neutron star from neutron star-black hole binaries with gravitational wave observations

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The gravitational wave signal from the merger of two neutron stars cannot be easily distinguished from the signal produced by a comparable-mass mixed binary, in which one of the component is a black hole. Although the existence of low-mass black holes ($< 5M_{\odot}$) is astrophysically disfavoured, their formation may be of primordial origin or as the outcome of the interaction between neutron stars and dark matter or they could be formed in other evolutionary scenarios. Gravitational wave signals carry the imprint of the neutron star internal composition through the so called Love numbers, which depend on the stellar equation of state and vanish for vacuum black hole solutions.
In this talk I will present a new data analysis strategy able to identify mixed binaries using the values of the love numbers inferred by gravitational wave observations.
I will show the results for current and future generation of ground based interferometers, proving how the new approach is able to correctly identify the presence of a low-mass black hole for different binary configurations.

Parallel 2A / 23

Empirical constraints on the high-density equation of state from multi-messenger observables

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We search for possible correlations between neutron star observables and thermodynamic quantities that characterize high density nuclear matter. We generate a set of model-independent equations of state describing stellar matter from a Taylor expansion around saturation density. We found that the neutron star tidal deformability and radius are strongly correlated with the pressure, the energy density and the sound velocity at different densities. These correlations can be used to constrain the equation of state at different densities above saturation from measurements of NS properties with multi-messenger observations.

Parallel 2B / 38

BSN mergers with microscopic equations of state

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We investigate binary neutron star mergers employing state-of-the-art microscopic equations of state, considering both zero-temperature and finite temperature extensions of the same. I will discuss the results we have achieved in this context, with respect to the thermodynamic conditions and the gravitational wave emission.

Parallel 1B / 171

The Search for Gamma-ray Counterparts to Binary Neutron Star Mergers with Fermi

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The Fermi Space Telescope is an important tool in the growing area of multimessenger astronomy. The Fermi Gamma-ray Burst Monitor (GBM) has nearly full-sky continuous coverage allowing for simultaneous observations of gamma-ray bursts (GRBs) with gravitational-wave candidates from the Advanced LIGO and Advanced Virgo instruments. The power of these observations was shown with the detection of GRB 170817A in coincidence with the binary neutron star merger GW170817, confirming that the progenitor of short GRBs are binary neutron star mergers. This short GRB was likely a result of observing the relativistic jet off-axis, however, it is also the closest known short GRB and was detected onboard GBM. Because most mergers will be observed at farther distance than GW170817, we developed a search of the Fermi continuous data to look for GRBs coincident to gravitational-wave candidates below the onboard triggering threshold. The third observational run of Advanced LIGO/Virgo has been in full swing since April 2019 and produced over 30 public alerts for gravitational wave candidates with only a few being potential binary neutron star mergers. Utilizing an updated version of the Fermi-GBM substhreshold search, we automatically follow-up these public alerts. Here, we summarize our results for these public alerts so far, including the subthreshold GRB potentially associated with a subthreshold compact binary merger from LIGO/Virgo, Fermi GBM-190816 (reported in the GCN Circular 25406).

Poster Session / 166

A computational method for differentially rotating polytropic models in post-Newtonian approximation

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In this study, we develop an iterative method for computing both rigidly and differentially rotating polytropic models in critical rotation. We work in the framework of post-Newtonian theory

in order to simulate fully relativistic rotating neutron stars. Our method results as combination of three methods: the "Hybrid Approximative Scheme" (HAS), the "Complex-plane Iterative Technique" (CIT), and the "Seguin's Post-Newtonian Iterative Method". We implement this method to the computation of various physical characteristics of a neutron star (eg., gravitational, proper and baryonic mass, gravitational potential energy, rotational kinetic energy, equatorial and polar radius, etc.). We verify the validity of the method by comparing its numerical results with the corresponding results of other reliable numerical methods.

Parallel 2A / 28

Universality of the relativistic correction to glitch rise-times

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Despite its importance in determining the interior structure of neutron stars has been universally acknowledged, Einstein's theory of General Relativity has been up to now mostly neglected in the study of pulsar glitches. Its inclusion into the existing Newtonian models seems to be too expensive, compared to the moderate qualitative gain in accuracy and comprehension it gives. However, as the resolution of pulsar timing techniques increases, it will be soon important to be able to isolate the relativistic contributions to the glitch amplitude and rise-time, for a reliable quantitative comparison with observations. We will present, here, a simple universal formula for the relativistic correction to the glitch rise-time, given as a pure function of the compactness of the neutron star. It has been derived directly from Carter's multifluid hydrodynamics and can be easily employed to correct, a posteriori, any Newtonian estimation for the coupling time scale, without any computational expense.

Parallel 3A / 148

Intermittent Pulsars and their ON/OFF Transitions

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We have shown that the torques acting on the intermittent pulsars in the radio ON and OFF states can be reproduced by transitions between the strong and weak propeller phases of accreting neutron stars evolving with fallback discs. We have used the analytical model applied earlier to the transitional millisecond pulsars to explain their properties during transitions between the radio pulsar and X-ray pulsar states. In the model, the strong and weak propeller torques reproduce the spin down rates in the ON and OFF state respectively. The inner disc radius has a weak dependence on the mass-flow rate, and is close to the co-rotation radius in the ON and OFF states. The dominant torque is produced by the disc-field interaction while the magnetic dipole torque is negligible in both phases. The spin-up torque associated with accretion is weaker than the spin-down torque. When the accretion starts, the spin down rate decreases and the pulsed radio emission is quenched. Radio pulses are emitted only in the strong propeller phase with a stronger spin-down rate.

Parallel 2B / 2

General-relativistic corrections to pulsar radio and high-energy emission

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Due to the high compactness of neutron stars, signatures of relativistic effects are expected in their vicinity, effects that will affect, among other things, the trajectory of photons produced inside their magnetosphere. We have plotted light curves and sky maps for radio and high energy photons, taken into account light bending and Shapiro delay within the Scharwzschild metric, and compared it to flat space-time. Simulations of the emission maps from curvature radiation in the magnetosphere of a pulsar are realized following the polar cap and slot gap models. The objective of these researches is to determine a marker of general-relativistic effects in pulsars light curves, quantifying the significance of photon trajectory bending and Shapiro time-delay.

Parallel 1B / 90

Deformations of neutron stars with elastic crusts

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With the recent, first detection of a binary neutron-star merger by gravitational-wave detectors, it proves timely to consider how the internal structure of neutron stars affects the way in which they are deformed. Such deformations will leave measurable imprints on gravitational-wave signals and can be sourced through tidal interactions or the formation of mountains. In this talk, I will summarise the formalism that describes fully-relativistic neutron-star models with elastic crusts undergoing static perturbations. This formalism primes the problem for studies into a variety of different mechanisms that can deform a neutron star. I will present results from integrating the perturbation equations for barotropic equations of state, which enables us to compute interesting quantities such as the tidal Love number. I will show how to use the results from these integrations to show when and where the crust starts to fail during an inspiral. I will also present the latest estimates for the maximum deformations that neutron-star crusts can sustain.

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The Hellenic Radio telescope - Opportunities for pulsar monitoring

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We present the project of the 30m Hellenic Radio Telescope ThermopYlae.
The Radio telescope is the result of the conversion of a redundant 1982 NEC telecommunication antenna located in Thermopylae in the Center of telecommunications of OTE company.
The radio dish will be linked in EVN, VLBI and will be used for all radio astronomical single dish and interferometric continuum and spectral line observations.
We discuss the case of pulsar observations and monitoring

Poster Session / 66

Polarization Signatures of the Resonant Compton Upscattering Model for Magnetars

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Magnetars are young neutron stars with high surface magnetic fields, exceeding 10^{13} Gauss. Pulsed non-thermal quiescent X-ray emission extending between 10 keV to >150 keV has been observed in about 10 magnetars by RXTE, INTEGRAL, Suzaku, NuSTAR and Fermi-GBM. For inner magnetospheric models of such hard X-ray signals, inverse resonant Compton upscattering of soft thermal photons from the neutron star surface is the most efficient process for generating the continuum radiation in high magnetic fields. Such upscattering emission is anticipated to exhibit strong polarization above around 30 keV that is pulse phase-dependent. These signatures define science agendas for future hard X-ray polarimeters and Compton telescopes. In this paper we present detailed model predictions of emission spectra and polarization signals, addressing prospects for measuring the spectral cutoffs with a future Compton telescope such as AMEGO. Phase-resolved, spectropolarimetric observations will be critical in assessing the zones of activation, as well as constraining the viewing geometry and the angle between the magnetic and spin axes of magnetars. Polarization measurements may also probe fundamental strong-field QED processes operating in the magnetar magnetospheres, potentially distinguishing between spectral cutoffs due to magnetic pair production or photon splitting. Thus, polarization probes of magnetar X-ray emission can provide insights into nature that are currently beyond the reach of current terrestrial experiments.

Parallel 1B / 165

Population Synthesis of Young and Millisecond Pulsars from the Galactic Disk

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Recent advances in realistic descriptions of pulsar magnetosphere with regions of finite conductivity allow for the predictions of the gamma-ray intensity over the observer sky in the form of a sky map.

Such models incorporate trends of conductivity σ with spin-down power $\dot{E}$, cut-off energies $\epsilon_{\rm cut}$ with $\dot{E}$, and the gamma-ray luminosity L_γ with $\epsilon_{\rm cut}$, magnetic field B, and $\dot{E}$, thereby eliminating model free parameters. On the other hand, the radio luminosity L_ν requires three model free parameters the overall multiplicative factor f_ν and the exponents of the period P and period derivative $\dot{P}$ with α_ν and β_ν, respectively. We perform Markov Chain Monte Carlo simulations to search the parameter space in order to establish the most likely values of the model free parameters in the case of millisecond pulsars (MSP). We then perform a simulation of young pulsars (YP) assuming magnetic field decay. We present preliminary results of both MSPs and YPs from the Galactic Disk.

We express our gratitude for the generous support of the National Science Foundation under grant AST-1616632 and the Michigan Space Grant Consortium under grant NNX15AJ20H.

Parallel 3B / 74

Superconducting phases in a two-component microscale model of neutron star cores

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Macroscopic quantum behaviour is prominent in many physical systems, ranging from superfluid phases in ultra-cold atomic gases and heavy-ion collisions to superconducting transitions in metals and exotic quantum phases in dense nuclear matter as well as quark matter. With the interiors of neutron stars in mind, we consider the scenario of two coupled coexisting condensates, where one is charged and the other one neutral. We are specifically interested in the effects of entrainment (the non-dissipative coupling between two quantum states) on the equilibrium phases of the superconducting proton condensate. In this talk, I will discuss how we study its properties by means of a Galilean invariant, zero-temperature two-component Ginzburg-Landau model for realistic neutron star equations of state and energy gaps. The resulting superconducting phase diagram provides insights into the microphysical magnetic flux distribution throughout the neutron star core.

Parallel 3A / 181

Pasta phases within the QMC and QMC $\omega - \rho$ models

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Pasta phases are believe to exist in the inner core of neutron stars and in the low density regions of core-collapse supernovae. The search for the existence of nuclear pasta phases in this region is performed within the context of two versions of the quark-meson coupling (QMC) model. Fixed proton fractions are considered, as well as nuclear matter in Î² equilibrium at zero temperature. We analyse the influence of the two different versions of the QMC as well as the effect of the nuclear pasta on some neutron star properties. The equation of state containing the pasta phase will be part of a complete grid for future use in supernova and neutron star mergers simulations.

Parallel 1A / 68

Proton acceleration in pulsar magnetospheres

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Due to their huge rotational energy and large magnetic fields, pulsars have been proposed as candidate sources of high-energy cosmic rays. However, a precise description of the acceleration processes at play is still to be established.

Using particle-in-cell simulations, we study proton acceleration in axisymmetric pulsar magnetosphere. In these numerical experiments, electrons and protons are injected from the neutron star surface, and electrons and positrons are produced through pair production process. We focus on the influence of pair production, which has a crucial impact on the structure of the magnetosphere and the unscreened electric field, and thus on particle acceleration.

In all our simulations, protons are accelerated and escape. The acceleration sites are different for the protons and the pairs. Protons gain most of their kinetic energy below the light-cylinder radius within the separatrix current layers, and are not confined within the equatorial current sheet. As shown in previous studies, pairs are accelerated to their highest energies at the Y-point and in the equatorial current sheet.

Rescaling the simulation results to describe the proton maximum Lorentz factor and luminosities in realistic astrophysical objects is not straightforward. Therefore, in addition to the impact of pair production, we study the impact of the magnetic field and the stellar radius, which are downscaled in our simulations. Our estimates support that millisecond pulsars could accelerate cosmic rays up to PeV energies and that new born millisecond pulsars could accelerate cosmic rays up to ultra-high energies.

Parallel 2B / 160

The contribution of r-process heating on the dynamics of ejecta in binary neutron star mergers

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The modelling of ejected matter, its dynamics and thermodynamic properties, is of fundamental importance in the study of binary neutron star mergers (BNS); it serves as a starting point to investigate the gamma ray burst emission, r-process nucleosynthesis and kilonova signal. While processes such as neutrino transport, magnetic fields, viscous effects and relativistic gravity are usually taken into account in modelling BNS ejecta, the energy released into the system by the decay of r-process nuclei is generally ignored. In this work we discuss how this heating source can be modelled and how it is coupled to the hydrodynamics evolution in BNS relativistic numerical simulations; as well as its impact on the ejected mass, thermodynamic properties of the ejecta and kilnonova signal. Supported by European Research Council Grant No. 677912 EUROPIUM.

Parallel 2B / 79

Magnetorotational instability in protoneutron stars: the regime of high magnetic Prandtl numbers

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The birth of a neutron star with an extremely strong magnetic field, called a magnetar, has emerged as a promising scenario to power a variety of outstanding explosive events. This includes gamma-ray bursts, supernovae with extreme kinetic energies called hypernovae and super-luminous supernovae. The origin of these extreme magnetic fields (of the order of 10ˆ15 Gauss) is not fully understood and requires an amplification over several orders of magnitude during the formation of the neutron star. I will describe our current understanding of one of the physical processes that may lead to this magnetic field amplification: the magnetorotational instability. I will show results from the first numerical simulations exploring the regime of high magnetic Prandtl numbers relevant to protoneutron stars.

Parallel 2B / 94

Thermodynamically consistent equation of state for an accreted crust

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Neutron stars (NSs) in low-mass X-ray binaries have an accreted crust, whose equation of state and composition differs from that in isolated NSs. To determine it, one usually makes a number of simplifying assumptions regarding both thermodynamics and kinetics of crust matter. We critically revise some of these assumptions and propose new thermodynamically consistent derivation of the crust equation of state. As a by-product of this work, we also present a simple formula showing how much heat is released in the non-equilibrium crust per accreted baryon.

Parallel 1A / 42

The 2016 Vela Glitch and Implications for Neutron Star Structure and Dynamics

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High resolution, pulse to pulse observation of the 2016 Vela glitch and its relaxation provided us an opportunity to probe the neutron star internal structure and dynamics with unprecedented detail. Glitch spin up timescale is constrained below 12.6 seconds, which put stringent limits to the efficiency of angular momentum exchange between crustal superfluid and observed crust. Observed

overshoot in the rotation rate as compared to the postglitch equilibrium value implies a discrimination among crustal superfluid-crust lattice and core superfluid-crustal normal matter coupling timescales. An evident decrease in the crustal rotation rate immediately before the glitch was detected for the first time and consistent with the formation of a new vortex trap zone which initiates large scale vortex unpinning avalanche. All of these features are evaluated in terms of the vortex creep model and a scenario accounting for both the formation process and ensuing recovery is presented.

Poster Session / 187

Bulk viscosity of baryonic matter in neutron star mergers

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We study bulk viscosity arising from weak interaction processes in dense baryonic matter for temperature-density range relevant to neutron star mergers. We consider two compositions of baryonic matter: a) pure nucleonic matter, where the main source of bulk viscosity are weak current direct Urca processes –neutron decay and electron capture; b) hypernuclear matter, where the bulk viscosity arises from non-leptonic weak interaction processes involving Λ and Σ hyperons. We model the nuclear matter in relativistic density functional approach, taking into account the trapped neutrino component. We find that the resonant maximum of bulk viscosity would occur below the neutrino trapping temperature, therefore in the neutrino trapped regime the bulk viscosity decreases with temperature as T^{-2} , this decrease being interrupted by a drop to zero at a special temperature (for fixed density) where the neutron fraction becomes density-independent and the material scale-invariant. The bulk viscosity of nuclear matter drops sharply while moving from the neutrino-transparent regime to the neutrino-trapped regime. We conclude that the bulk viscosity will have its greatest impact on neutron star mergers in regions that are neutrino transparent rather than neutrino trapped. We further investigate the oscillation damping timescales of a post-merger object and identify regimes where these timescales are comparable to the merging timescales $\sim$10 ms.

Parallel 2A / 119

Observational signatures of superfluid neutron star turbulence

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The superfluid in the interior of a mature neutron star plays a key role in many observational phenomena, with the most striking example being pulsar glitches.
Very few models, to date, have however considered the observational signature of turbulence in the superfluid, a phenomenon that is well known to develop in laboratory superfluids. In this talk will discuss the theoretical framework to apply our understanding of laboratory superfluids to the neutron star crust when pinning is present (a regime not explored in the laboratory), and show the expected signature on pulsar glitches.

I will then compare the results to observations of glitches in the Vela pulsar and in PSR J0537-6910 and discuss the physical constraints that can be obtained.

Parallel 3A / 124

Simulations of stellar winds from X-ray bursts: Characterization of solutions and observable variables.

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- Context: Recent studies have suggested that a variety of heavy elements, whose origin is still debated, is synthesized as a result of nuclear reactions during X-ray bursts. The predicted luminosities indicate these heavy elements may escape neutron stars gravity through a radiative stellar wind, thus contributing to the observed galactic abundances. Stellar wind models, though studied in past decades, have thus regained interest and need to be revisited with updated data and methods.
- Aims: In this work we study the radiative wind model and its feasibility in the context of XRBs, with modern techniques and physics input. We focus on characterization of the solutions and study of observable magnitudes as a function of free model parameters.
- Methods: We implement a spherically-symmetric non-relativistic wind model in a stationary regime, with updated opacity tables and modern numerical techniques. Total mass and energy outflows $(\dot{M}, \dot{E})$ are treated as free parameters.
- Results: Solutions were found to transition from pressure-driven in the inner layers to radiatively-driven as the wind becomes supersonic. A high resolution parameter space exploration was performed to allow better characterization of observable magnitudes. High correlation was found between different photospheric magnitudes and free parameters. For instance, the photospheric ratio of gravitational energy outflow to radiative luminosity is in direct proportion to the photospheric wind velocity.
- Conclusions: We believe that the correlations found are of great importance and they can help determine the physical conditions of the inner layers, where nuclear reactions take place, by means of observable photospheric values.

Parallel 2B / 46

Thermal spots and light curves of magnetars: 3D MHD simulations

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Using 3D MHD code, we explore magnetic field configurations with different contributions of the toroidal component. We solve coupled magneto-thermal equations in the NS crust on Myr timescale

for magnetic fields of 1e14 G. In this research, we confirm previous findings that a large fraction of the toroidal magnetic field leads to the formation of small magnetic spots.
In general, we see a formation of a complicated pattern as an overlap of hot spots (belts and filaments) formed due to the Ohmic heating of the crust and one caused by crustal thermal transparency along the magnetic field lines. A presence of the toroidal magnetic field component strongly modifies the size of hot magnetic poles, making one of them smaller than another. The models with a small contribution of the initial toroidal magnetic field show weak variations in lightcurves at the maximum level of a few percents depending on the orientation of NS and its compactness. The model with 90 percent contribution of the toroidal magnetic field misaligned with the poloidal magnetic field forms a single hot spot which could cause up to 80 percent variation of soft thermal flux.

Parallel 2B / 155

Using a realistic equation of state in neutron star post-merger simulations.

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Neutron-star mergers provide unique environments for mass accretion, ejection, and r-process nucleosynthesis. Theoretically, however, simulating such systems are challenging, especially within the assumed equation of state (EOS) of the post-merger material. Although the ideal gas EOS, commonly used in simulations of post-merger systems, is a good approximation, a realistic EOS can account for electron-positron plasma degeneracy effects, thus, affecting the neutron abundances. This can change the composition of the disk, therefore, affecting the observed radiative signatures (e.g. kilonova). Here, I will present results of long-duration 3D general relativistic magnetohydrodynamic (GRMHD) simulations of post-merger systems with the use of a realistic Helmholtz EOS, evolved up to several seconds after the merger. In this, we treat ions as an ideal gas and electrons and positrons as a non-interacting Fermi gas, while including blackbody radiation with an assumption of the local thermodynamic equilibrium. The Helmholtz EOS, together with alpha-particle recombination, may contribute the to the unbinding of the disk material, thereby increasing the amount, and velocity, of ejected material. Moreover, I will compare these results to simulations where an ideal gas EOS was implemented, highlighting the differences within our results (e.g. mass accretion and ejection rate, jet power).

Parallel 3A / 122

Second look to the Polyakov loop Nambu–Jona-Lasinio model of quark matter in hybrid stars

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We revisit the Polyakov Loop coupled Nambu-Jona-Lasinio model that maintains the Polyakov loop dynamics in the limit of zero temperature. For this purpose we re-examine the form of the potential for the deconfinement order parameter at finite baryonic densities. Secondly, and the most important, we explicitly demonstrate that a modification of this potential at any temperature is formally equivalent to assigning a baryonic charge to gluons. In order to avoid this spurious effect we develop

a more general formulation of the present model that cures this defect and is normalized to match the asymptotic behaviour of the QCD equation of state given by $\mathcal{O}(\alpha_s^2)$ and partial $\mathcal{O}(\alpha_s^3 \ln^2 \alpha_s)$ perturbative results. Incorporation of the Polyakov loop dynamics to the model leads to significant stiffening of the quark matter equation of state, which is important for reaching the limit of two solar masses of compact stars.

Parallel 1A / 126

Distortions of polarization angle curve in radio pulsars

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Complex distortions of polarization angle curve in radio pulsars are mainly caused by superposition of radiation in two orthogonal polarization modes. The resulting polarization depends on several factors, such as the relative amount of the modes, their ellipticity, the statistical spread of their polarization state and on how precisely the modes are orthogonal. Moreover, the observed polarization depends on whether the modes are superposed coherently or incoherently. I have modelled selected complex polarization effects to determine the type of observed mode superposition (coherent vs incoherent). In particular, I will explain how it is possible to have orthogonal polarization mode transitions without large change in the magnitude of circular polarization, as observed for several pulsars, including B0031-07.

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The Thousand Pulsar Array programme on MeerKAT

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I will present initial results from the Thousand Pulsar Array (TPA) program on the MeerKAT interferometer. The TPA is a 5 year project which observationally aims to (a) observe more than 1000 pulsars to obtain high-fidelity pulse profiles, (b) observe some 500 pulsars over multiple epochs, (c) observe long sequences of single-pulse trains from several hundred pulsars. The scientific outcomes from the program will include determination of pulsar geometries, the location of the radio emission within the pulsar magnetosphere, the connection between the magnetosphere and the crust/core of the star, tighter constraints on the nature of the radio emission itself as well as interstellar medium (ISM) studies. Early results look extremely promising!

Parallel 1B / 120

Building mountains on accreting neutron stars

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The spin frequencies of the neutron stars in low-mass X-ray binaries may be limited by the emission of gravitational waves, potentially making them an interesting target for continuous gravitational wave searches. The gravitational waves may be produced by an asymmetry in the star's mass distribution. Such "mountains"could be created by temperature asymmetries within the stellar crust.

Little is currently known about the likely level of temperature asymmetry. We present our investigation of how internal magnetic fields might create such asymmetries, by making the thermal conductivity anisotropic.

Parallel 3A / 104

Estimation of Absolute Emission Altitude of Multi-component Pulsars

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Single pulses from pulsar are highly variable in shape, width etc, but the average profile is stable. Average profile of a pulsar is a unique property of any given pulsar, making it a best way to characterize the emission geometry. The evolution of pulse profile morphology with period and frequency is a study till date, and the pulse profiles are often classified based on number of visible components.

The absolute radio emission height of pulse components is one of the crucial parameters needed in developing the radio emission mechanism. There are mainly two types of methods proposed for estimating the radio emission altitudes: (1) a purely geometric method, which assumes that the pulse edge is emitted from the last open field lines; (2) a relativistic phase shift method, which assumes that the asymmetry in the conal components phase location relative to the core is due to the aberration-retardation (A/R) phase shift. The component peak locations are determined by fitting gaussians to individual components, and A/R phase shift of each component is estimated relative to the meridional plane. Core emission is expected to be emitted close to the surface of the neutron star, but from a finite distance from the NS surface. To estimate the absolute emission height of components including core, we have to estimate the phase shift of core and polarization position angle inflection point (PPAIP) with respect to the meridional plane. Meridional plane is a fiducial plane containing magnetic axis, rotation axis and the line of sight and is located halfway between core peak and PPAIP. Using the measured phase shift we can estimate the emission height of components in the pulsar magnetosphere.

To estimate the emission height of pulse components, we chose a few multi-component pulsars and recorded single pulses using the uGMRT (upgraded GMRT). We have performed simultaneous dual frequency (Band 3: 300-500 MHz and Band 4: 550-750 MHz) polarimetric observations. We plan to present the results obtained from the analysis of the data. Insights from the results, for example: (1) whether core emission follows RFM (Radius to Frequency mapping) or not, (2) whether the inner components follow a core-conal emission geometry, (3) the possibility of estimation of physical parameters such as plasma density, magnetic field strength (considering a di-polar magnetic field) etc at the obtained heights will be discussed. We strongly feel that the estimation of radio emission heights will give an insight into understanding the pulsar radio emission mechanism.

Parallel 2A / 172

From Fermi and NICER data to Pulsar Magnetosphere Models

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The Fermi data imply that the gamma-ray observables, i.e., the gamma-ray luminosity, spectral cut-off energy, stellar surface magnetic field, and spin-down power obey a relation that represents a 3D plane in the 4D log-space. This observed fundamental plane (FP) is remarkably close to the theoretical relation that is obtained, assuming that the pulsar gamma-ray emission is due to curvature radiation. Moreover, I will present advanced kinetic PIC models that reproduce both the shapes of the gamma-ray light curves and the FP. Recent NICER results suggest substantial deviations from the dipolar magnetic field structures. I will present vacuum and FF models corresponding to the sum of off-center dipole and quadrupole magnetic moments that reproduce the hot-spots observed by NICER. Finally, I will show how the Fermi and NICER data, together with the theoretical modeling unite to provide a comprehensive understanding of the high-energy emissions in pulsars.

Parallel 3B / 18

Current closure through the neutron star crust

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We study the current closure problem for a neutron star with a force-free pulsar magnetosphere that develops a large-scale poloidal electric current circuit. The electric current closes through the interior of the neutron star where it provides the torque that spins-down the star. We study the internal electric current in an axisymmetric rotator and evaluate the path of the electric current by requiring the minimization of internal Ohmic losses. In millisecond pulsars, the current reaches the base of the crust, while in pulsars with periods of a few seconds, the bulk of the electric current does not penetrate deeper than about 100 m. The region of maximum spin-down torque in millisecond pulsars is the base of the crust, while in slowly spinning ones it is the outer crust. We evaluate the corresponding Maxwell stresses and find that, in typical rotation-powered radio pulsars, they are well below the critical stress that can be sustained by the crust. For magnetar-level fields, the Maxwell stresses near the surface are comparable to the critical stress. We then employ a realistic conductivity profile, accounting for the Landau quantum levels applicable to strong magnetic fields (B > 10ˆ13 G). This profile has a non-monotonic dependence on radius. We find that while the current flow does not change drastically, the Ohmic heating power does, with regions of higher power being located underneath ones with lower Ohmic power.

Parallel 1A / 83

The observed evolution of pulsar rotation on human timescales

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I will present a summary of interesting phenomena related to the observed spin-down history of pulsars, with emphasis on those that depart from the canonical behaviour. In doing so, I will pose questions regarding how well we are estimating ages and magnetic fields, and point to observations and simulations that provide answers.

Parallel 1B / **58**

Long-duration gravitational wave transients - recent results and future prospects

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Gravitational waves can provide unique insight into the interiors of neutron stars. The signal types and timescales accessible to ground-based detectors range from the final orbits of binary mergers to continuous waves from mature spinning objects, with various long-duration transients in between. In this presentation I will focus on pulsar glitches as possible sources of long-duration quasi-monochromatic gravitational waves. I will present the first upper limits on signals from the Crab and Vela using Advanced LIGO data and prospects for improved searches during the most recent LIGO-Virgo observing run. I will also briefly cover efforts to detect post-merger gravitational waves from remnants of binary mergers.

Poster Session / **44**

Hydrodynamical instabilities in the superfluid interior of neutron stars with background flows between the components

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The interiors of mature neutron stars are expected to host superfluid neutrons that can flow relative to the normal component tracked by electromagnetic emission. Hence, analogously to the hydrodynamic description of terrestrial superfluids like He4, the system is best described by means of a two-fluid model, that is used in out calculations.
Wave propagation in the crust and core of a neutron star is studied by conducting a local plane-wave analysis of the two-fluid hydrodynamic equations for an homogeneous macroscopic element of nuclear matter. A background flow between the two components (as would be expected in the presence of pinning of superfluid vortex lines) is explicitly account. Entrainment coupling and both standard (Hall-Vinen) and isotropic (Gorter-Mellink) forms of the mutual friction are considered.
For standard mutual friction families of unstable inertial and sound waves both in the case of a counter-flow along the superfluid vortex axis and for counterflow perpendicular to the vortex axis are found. Inclusion of entrainment leads to a quantitative difference between instabilities in the crust and core of the star. For isotropic mutual friction no unstable branches of the dispersion law were found, so that instabilities in a straight vortex array may be linked to glitching behaviour, which then ceases until the turbulence has decayed.

Poster Session / 162

Particle diffusion in pulsar magnetospheres

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We explore the diffusion of charged in a pulsar magnetosphere by considering the adiabatic invariants describing the motion of particles due to an electric and magnetic field. Charged particles will perform a helical motion round a magnetic field line, they will be bounce between the northern and Southern Hemisphere and drift in the azimuthal direction forming a ring current. While these effects are most likely dynamically subdominant to affect the structure of the magnetosphere, they may impact the regions where particles are concentrated.

Parallel 2A / 60

Effect of particle diffusion on damping of neutron star oscillations

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It is believed that the main dissipative agents in oscillating neutron stars are bulk and shear viscosities (the effect of thermal conductivity is known to be weak and can be disregarded). But the internal layers of neutron stars are composed of a mixture of various particle species (neutrons, protons, electrons,…). Then additional, usually ignored, dissipation mechanism can arise, related to particle diffusion in oscillating matter. We study this mechanism in detail and demonstrate that it can compete with the ordinary bulk and shear viscous dissipation under certain circumstances.

Parallel 3B / 180

Fast Rotating Relativistic Stars: Spectra and Stability without Approximation

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The oscillations and instabilities of relativistic stars are studied by taking into account, for the first time, the contribution of a dynamic space-time. The study is based on the linearised version of Einstein's equations and via this approach the oscillation frequencies, the damping and growth times as well as the critical values for the onset of the secular (CFS) instability are presented. The ultimate universal relations for asteroseismology are derived which can lead to relations involving the moment of inertia and Love numbers in an effort to uniquely constrain the equation of state via all possible observables. The results are important for all stages of neutron star's life but especially to nascent or post-merger cases.

Parallel 2B / 159

Post-Merger Magnetic Field Geometries and their Effect on Long-Term Afterglows

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The detection of the binary neutron star merger (GW170817) marked the first multi-wavelength light and gravitational waves detection of a neutron star merger. While gravitational waves can provide us information about the mass and spin of the pre-merger system, the resulting merger and accretion disk, created by a combination of tidally disrupted material and the dynamical ejecta are responsible for the formation of jets and radioactive outflows, i.e. the kilonova. Theoretically, however, our current understanding of post-mergers systems is limited, especially the role of magnetic effects. It is known that the initial magnetic field configuration within post-merger accretion disks can substantially affect the amount of material accreted onto the black hole, occurring within a few hundred ms after the merger. However, it is unknown how this deeply rooted parameter can affect the long timescale evolution, specifically, in the afterglow, in which outflows can shock the circumburst medium, accelerating particles. These relativistic particles can radiate up to or exceeding thousands of days. To probe the importance of the initial magnetic field configuration, we utilize 3D general relativistic magneto-hydrodynamic (GR-MHD) simulations to investigate the resulting power within all outflows and jets as well as its spatial and velocity distribution. Here, I will present the long-duration afterglow lightcurves produced from structured outflows, containing relativistic jets and mildly relativistic disk winds. The outflows power distribution is coming from 3 different simulation runs for 3 different magnetic field configurations; 2 poloidal and 1 toroidal. In this, I will describe the key differences between each model, discussing how the initial magnetic configuration imprints itself on the long-term afterglow emission while comparing with current multi-wavelength observations.

Poster Session / 10

The Role of Magnetic Field Geometry in the Evolution of Neutron Star Merger Accretion Disks

Authors: Ian Christie[1]; Aris Lalakos[1]; Alexander Tchekhovskoy[1]; Rodrigo Fernández [2]; Francois Foucart[3]; Eliot Quataert[4]; Daniel Kasen[4]

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Neutron star mergers are unique multi-messenger laboratories of accretion, ejection, and r-process nucleosynthesis. Theoretically, however, our current understanding of such events is limited, especially of magnetic effects, such as the role the post-merger magnetic field geometry has on the evolution of merger remnant accretion disks. Through the use of 3D general relativistic magneto-hydrodynamic simulations, we investigate such effects while fully capturing mass accretion, ejection, and the production of relativistic jets, over time intervals exceeding several seconds. I will show that not only does an initially poloidal post-merger magnetic field geometry generate relativistic jets, but the more natural, purely toroidal post-merger geometry generates striped jets of

alternating magnetic polarity, a result seen for the first time. Our simulated jet energies, durations, and opening angles for all magnetic configurations span the range of sGRB observations. Concurrent with jet formation, sub-relativistic winds, launched from the radially expanding accretion disk, provide efficient collimation of the relativistic jets and an observational window into the observed kilonova. In comparison to GW 170817/GRB 170817A, I will demonstrate that the blue kilonova component, although initially obscured by the red component, expands faster, outrunning the red component and becoming visible to off-axis observers.

Invited Talks / **19**

Magnetic-field evolution in the presence of superconductivity

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This talk will review the effect that superconductivity has on a neutron star's magnetic field and its evolution. We will discuss some of the many open issues and uncertainties, and possible ways future observations may help reduce our collective ignorance.

Invited Talks / **73**

Populations of Neutron Stars (Invited)

Author: Lina Levin Preston[1]

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A good knowledge of the neutron star population of the Universe has important implications for our understanding of the sources that may be detected as gravitational wave emitters, gamma ray bursts, and FRBs, to name a few. It has been highlighted in the past that the current rate of core-collapsed supernovae is not large enough to explain the combined birth rates of various types of neutron stars, such as ordinary pulsars, magnetars, RRATs, and XDINS. A better knowledge of the different populations of neutron stars will aid in resolving this birth rate problem. In this talk, I will present a review of past and current neutron star population studies, and look forward to what new facilities, such as the SKA, will bring to this field in the future.

Invited Talks / **179**

What happened during 2016 Vela glitch? (Invited)

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In 2016, Parfreyman et al obtained exquisitely detailed observations of Vela during the epoch of one of its large glitches. One remarkable feature was a clear observation of a short-lived magnetospheric

disturbance. I will advance a theory for the disturbance and discuss its implications for the physics of glitches.

Parallel 3A / 130

Mullti-frequency observations of single pulse properties of two bright pulsars.

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We present the results of multi frequency single pulse observations of PSR B0329+54 and PSR B1133+16. The observations were conducted over a very wide range of frequencies, from 100 MHz to 8 GHz, using instruments such as LOFAR single stations, GMRT and Effelsberg. Large parts of these observations were conducted simultaneously at three or more frequencies. Our main golas were to study the single pulse behaviour and its frequency-dependent aspects to investigate the radiation beam structure of neutron stars. The effects we observed include subpulse drifting, nulling, mode changing and subpulse structure frequency variations.

Parallel 2B / 189

Super-Massive Neutron Stars and Compact Binary Millisecond Pulsars

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The maximum mass of a neutron star has important implications across multiple research fields, including astrophysics, nuclear physics and gravitational wave astronomy. Compact binary millisecond pulsars are key to constraining such maximum mass observationally. Applying a new method to measure the velocity of both sides of the companion star, we previously found that the compact binary millisecond pulsar PSR J2215+5135 hosts one of the most massive neutron stars known to date,
with a mass of 2.27+/-0.16 Msun. Here I will review the neutron star mass distribution in light of this and more recent discoveries, focusing on super-massive neutron stars with masses above 2 Msun.

Poster Session / 80

Polarized radiation from rapidly rotating oblate neutron stars

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We compute the polarization of radiation from two hot spots at surface of an oblate neutron star. We account for rotation of the polarization plane due to relativistic effects along the path from the star surface to the observer. We show that the obtained polarization angle (PA) may differ substantially from the corresponding values derived for a spherical star. We also study, with a toy model, how accurately the geometrical parameters of an accreting neutron star could be determined using the X-ray polarization measurements of upcoming polarimeters. The results imply that the observer and spot inclination angles can be constrained within a few degrees, if the PA is measured with accuracy of 2 degrees that is achievable with the upcoming Imaging X-ray Polarimeter Explorer or enhanced X-ray Timing and Polarimetry mission.

Poster Session / 135

Anisotropic Quark Stars with an Interacting Quark Equation of State

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A deep exploration of the parameter space that relates the interacting equation of state with the bag constant B, and the interaction parameter a, is fundamental for the construction of diverse models of quark stars. In particular, the anisotropy of quark stars with a well motivated quantum chromodynamics (QCD) equation of state is presented here. The contribution of the fourth order corrections parameter (a4) of the QCD perturbation on the radial and tangential pressure generate significant effects on the mass-radius relation and the stability of the quark star. An adequate set of solutions for several values of the bag factor and the interaction parameter are used in order to calculate the relation between the mass, radius, density, compactness, and consequently the maximum masses and the stability. Therefore, while the more interactive quark solution lead to higher masses, the weak interaction among quarks give solutions similar to the widely known MIT bag model.

Parallel 3B / 173

Radiation Transport in First-Principles Simulations of Merger Remnant Accretion Disks

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Neutron star (NS) mergers are thought to be one of the primary sites of heavy element production in the Universe. In order to inform and predict future observations and meaningfully interpret the existing ones, we need first-principle models that describe the physics of the merger and its aftermath (e.g. kilonova, afterglow). Such models would allow us to predict the amount, composition, and velocity distribution of all ejecta, as well as subsequent emission, and how it depends on the astrophysical unknowns such as the spin of the BH and the nuclear equation of state. Presently, one of the major limitations in simulating NS merger systems is the lack of accurate neutrino transport, which restricts our knowledge of the resulting outflow composition. Including neutrino transport into simulations of sufficient duration is crucial, because neutrino absorption changes the nuclear makeup of the ejected material and thus determines the amount of heavy nuclei produced by the merger event and the resulting color and duration of kilonova emission. Previous studies with neutrino transport were limited in duration to a few tens of milliseconds, whereas it takes 10 to 100 times longer for an outflow from a merger remnant disk to fully form. I will present results of 3D general relativistic magnetohydrodynamics (GRMHD) simulations of post-merger systems including the "two-moment"closure radiation transport scheme for photons, evolved up to seconds after the merger. This scheme approximates radiation as a separate fluid, reusing the infrastructure currently in place for the treatment of the gas. I will discuss how variations in parameters such as density, temperature, and geometry of the system will affect the long-term evolution under this new transport scheme. In addition, I will discuss the implications of applying the same scheme and a more accurate Monte-Carlo scheme to neutrino transport, to determine the outflow composition.

Parallel 2A / 36

The impact of glitches on the rotational evolution of young pulsars

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The spin down of many young pulsars are strongly affected by two distinct kinds of rotational irregularities: glitches and spin noise. In addition to allowing us to probe the interior dynamics of neutron stars, glitches introduce difficulties when attempting to model the long-term rotational evolution of pulsars. For instance, there is a long-standing question as to whether the anomalously high braking indices measured for some pulsars are the result of unaccounted glitch recovery. Using modern Bayesian methods, we analyse a sample of 76 pulsars that have been regularly observed by the Parkes 64-m radio telescope over ˜10 years. 55 of these pulsars have experienced glitches during this monitoring campaign. In addition to providing robust measurements of glitch properties, we study the inter-glitch changes in the spin down of these pulsars. This includes modelling any inter-glitch changes in a pulsar's braking index and variations in timing noise after or between subsequent glitches. We also examine relationships between glitch parameters and waiting times, and their potential implications for modelling the internal microphysics of neutron stars.

Parallel 3B / 81

Instability of twisted magnetar magnetospheres

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We present three-dimensional force-free electrodynamics simulations of magnetar magnetospheres with the Einstein Toolkit. Our recent work demonstrates the instability of certain degenerate, high energy equilibrium solutions of the Grad-Shafranov equation. This result indicates the existence of an unstable branch of twisted magnetospheric solutions and allows to formulate an instability criterion. The rearrangement of magnetic field lines as a consequence of this instability triggers the dissipation of up to 30% of the magnetospheric energy on a thin layer above the magnetar surface. We find that the estimated energy release and the emission properties are compatible with the observed

giant flare events. The newly identified instability is a candidate for recurrent energy dissipation, which could explain part of the phenomenology observed in magnetars.

Parallel 3A / 102

Investigating the multi-component emission of RRAT J1819-1458

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We discuss a detailed study of single-pulse detections from RRAT J1819-1458, with observations taken across a long period of time. Additionally to the usual sporadic nature of RRATs, this source exhibits a strong variation in the flux, shape and the number of components of the individual pulse detections. The arrival times of separate components have been examined in the past, which resulted in the discovery of distinct bands in timing residuals. However, the changes in the number of components and their shapes with time have not yet been studied in the same detail. We focus our investigation on the temporal separation of multi-compoment emission from other detections and their possible groupings. Combined with the overall change in the burst rate across longer observing periods, we find signs of the existence of quiet periods, with little to no emission detected, followed by bursts of multiple detections of pulses with more than once component in rapid succession. In the talk we will discuss the overall trends in this behaviour of the multi-component emission from J1819-1458 and the implications for the possible emission mechanisms. If confirmed across multiple observing campaigns, such behaviour could be an indication of J1819-1458 going through a period of more violent energy release, followed by a period of relative calmness, when the RRAT 'winds up' and accumulates the energy through still unknown process.

Poster Session / 64

Modelling the jet of the Neutron Star LMXB 4U 0614+091 with internal shocks

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Jets have been extensively observed in X-ray Binaries with Black Holes (BHs) or Neutron Stars (NSs), but jet properties in the two classes have several peculiar differences. In the last few years, the flat radio-to-mid-IR spectra of BH X-ray binaries was described using the internal shocks model, which assumes fluctuations in the velocity of the ejected shells along the jet driven by the fluctuations in the accretion flow. The success of this model confirms the strong interconnection between accretion and ejection in BH systems. I will present the first attempt to apply the internal shocks model to a NS Low Mass X-ray Binary, i.e. 4U 0614+091, a system persistently in hard state and with a known radio emission ascribed to the jet. We used the multi-wavelength study carried out by Migliari+2010, with a data coverage ranging from Radio to X-rays, and the quasi-simultaneous RXTE Power Spectral

Density. The method used takes advantage of the code ISHEM which simulates a "synthetic"Spectral Energy Distribution (SED). The code uses as an input a set of physical parameters related to the global properties of the source. In addition the PSD of the jet Lorentz fluctuations was assumed to be identical to that of the observed X-ray light curve that we use as a tracer of the accretion flow variability. The synthetic SED and the data are then compared by means of Xspec. Our results point out that a standard conical compact jet model is not compatible with the data. In order to improve the fit we changed some of the input parameters. A good fit is finally obtained when we allow for a different jet geometry, more "parabolic"than "conical", which means the jet is allowed to be more collimated. In the other BH systems for which ISHEM was applied, such switch in the jet geometry was not necessary. These results shed light over the possibility that jets in BHs and NSs may work somewhat differently, pointing out that more investigations about jets in NSs are necessary in the near future for a real understanding of the accretion/ejection coupling in X-ray binaries.

Parallel 2A / 48

The puzzling NS LMXB 1RXS J180408.9-342058 in intermediate state

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1RXS J180408.9–342058 is a low mass X-ray binary (LMXB) hosting a neutron star, which shows X-ray activity at very different mass-accretion regimes, from "very faint"outbursts to almost the Eddington luminosity.
In this work, we present a comprehensive X-ray study of this source using data from Swift, NuSTAR and INTEGRAL/JEM-X. In order to follow the spectral evolution, we analyzed the 2015 outburst using Swift data and three Nustar observations. Besides the canonical hard and soft spectral states, we identified the intermediate state, which is rarely observed in LMXBs hosting NSs. This was witnessed by the appearance of the accretion disk emission in the spectrum (at a disk temperature of ~0.7 keV) and the simultaneous cooling of the hot corona. In addition, we also unveiled a hard tail above 30 keV in this state. The fast changes in the spectra taken only days apart in this state points out that intermediate states in Neutron Stars LMXBs might last for short times, of the order of a few days, which might explain why catching these sources in intermediate state is quite challenging. In the hard state, a thermal Comptonization model with two seed photons populations (kT~1.5 keV and kT ~0.4 keV, respectively) and a hot Comptonising plasma, represents the physically best motivated scenario to describe the data. Finally, we studied a number of type-I X-ray bursts displayed from the source, one of them at the Eddington limit (observed with JEM-X). Their characteristics, combined with the clocked behavior observed during the intermediate state, point out H/He composition for the accreted material, which makes unlikely the helium dwarf nature for the companion.

Parallel 1B / 50

First results of reprocessing LOTAAS data with a Fast Folding Algorithm

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We are using the central “Superterp” core of the LOw Frequency ARray (LOFAR) to perform the LOFAR Tied-Array All-sky Survey (LOTAAS) for pulsars and fast radio transients. Each pointing of the survey covers 67 square degrees of sky in the range of 119 to 151 MHz and is observed for one hour. We then employ both periodicity and single pulse searching codes to look for astrophysical signals. LOTAAS has already resulted in the discovery of 73 radio pulsars, including the pulsar with the longest known spin period (P = 23.5 s). We are now reprocessing the LOTAAS dataset using a Fast Folding Algorithm (FFA) to search for periodic signals, which, for periods longer than around 200 ms, should be more sensitive than the Fast Fourier Transform (FFT) technique employed previously. This presentation lays out the first results to come from this reprocessing.

Parallel 1A / 52

A Single spark model for PSR J2144–3933

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The partially screened vacuum gap (PSG) in the inner acceleration region, a variant of the pure vacuum gap model, has been developed to account for the observed thermal X-ray emission from the polar cap as well as subpulse drifting timescales in normal radio pulsars. We have used this model to explain the presence of death lines in pulsar population and in particular understand the location of PSR J2144–3933 at extreme edge of the $P - \dot{P}$ diagram. The basic features of the PSG model entail that the polar cap is maintained close to a critical temperature and non-dipolar surface magnetic field is present to form the inner acceleration region. The vacuum gap models produce sparks and in the PSG model the thermostatic regulation near the critical temperature is maintained by these constant sparking discharges.We demonstrate that the non-dipolar surface magnetic field reduces the polar cap area in PSR J2144–3933, such that only one spark can be produced and sustain the critical temperature of the PSG. The pulsar has a single component profile over a wide frequency range. Single pulse polarimetric observations and the rotating vector model confirm the observer’s line of sight to traverse the emission beam centrally. These observations are consistent with a single spark operating within the framework of the PSG model, where the spark associated plasma results in single component emission. Additionally, the single pulse modulations of this pulsar, including lack of subpulse drifting, presence of single period nulls and microstructure property are compatible with a single spark either in PSG or in general vacuum gap model.

Parallel 1B / 116

The formation of “massive”proto-magnetars

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We model numerically the process of formation of proto-magnetars resulting from the collapse of the very compact, low-metallicity cores of high-mass stars. We explore the dependence of the proto-magnetar properties on the stellar progenitor rotational and magnetic properties as well as small variations thereof. These variations aim to parametrize the uncertainties with which 1D stellar evolution calculations can predict the progenitor properties. Also, they serve the purpose of assessing the key ingredients in stellar evolution that determine the post-collapse remnant, i.e. whether the end product after stellar death is a neutron star or a black hole. Our models track the post-bounce evolution of the core for nearly 10 seconds, combining special relativistic MHD, an approximately generally relativistic gravitational potential, and two-moment neutrino transport. After this long time, the fiducial conditions for a proto-magnetar engine, able to drive extreme events (e.g. superluminous supernovae, hypernovae and even gamma-ray burst), should be set according to the current theoretical models. We find that the poloidal magnetic field strength in the pre-collapse core is of utmost importance in determining whether the proto-neutron star resulting from core bounce will be sufficiently long-lived to contribute significantly in the stellar explosion and the associated high-energy transients.

Invited Talks / 1

A NICER view of neutron stars (Invited)

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The cores of neutron stars contain matter at densities and neutron-proton asymmetries that are inaccessible in laboratories. Thus astronomical observations of neutron stars are the only source of information we have about this state of matter, which is a key part of the QCD phase diagram. One of the most important such measurements is of the mass and radius of these stars. Recently, NASA's Neutron star Interior Composition Explorer (NICER) released information about its mass and radius determinations, using a method that is believed to be less susceptible to systematic errors than previous approaches. I will discuss those results and their implications for the equation of state of the cold, catalyzed, dense matter in the interiors of neutron stars.

Parallel 3A / 14

Ultraviolet pulsed emission from an accreting millisecond pulsar during its outburst

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Pulsars with millisecond spin periods and weak magnetic fields (˜10ˆ8 G) are thought to be spun up through a 0.1–1 Gyr-long phase by the transfer of matter and angular momentum from a low mass companion star. When the mass transfer is active, these neutron stars can be observed as accretion-powered millisecond X-ray pulsar, provided that their magnetic field is strong enough to channel the accreting matter towards the magnetic poles.
Observations performed with the Rossi X-ray Timing Explorer back in 1998 allowed to discovered the first coherent 2.5 ms X-ray pulsations in the X-ray (transient) binary system SAX J1808.4-3658 during outburst. Here I present the first detection of UV pulsations with HST/STIS from SAX J1808.4-3658 again, during the August 2019 outburst, at a significance level greater than 3.5σ. The pulsations were observed during the latest stages of the outburst, when the pulsar was surrounded by an accretion disc. X-ray pulsations were detected during a simultaneous NICER observation, as well. The detection of UV pulsations in transient accreting X-ray binaries opens a new observational window to discover new systems and opens the possibility to investigate and track their evolution.

Parallel 3A / 178

Equation of state of inner crust of neutron stars with finite range Gogny forces

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Nuclear systems exist in nature in a wide range of sizes and densities. Nuclear equation of state (EoS) is thus immensely important to know the basic nature of nucleon-nucleon interaction. As the exact nature of this interaction is still not known, there exist a huge number of EoSs in the literature based on different relativistic and non-relativistic interactions. Based on recent observations these interactions pretty much agree on the structure of the core of a neutron star. With reasonable certainty one can say that the core of neutron star is comprised of nuclear matter in beta equilibrium. However, the structure of the crust of a neutron star is not that well determined. It plays a significant role in determining the radius of the neutron star. We have used for the first time the non-relativistic finite range Gogny forces to construct the equation of state for the crust of the neutron star. There is a strong reason to believe that the shell correction and pairing interations of the nuclear force play crucial roles in determining the structure of the crust of the neutron star. The advantage of using Gogny forces over the conventional zero range forces (e.g Skyrme forces) is that the pairing can be handled in the same interaction. For consistency we used the same interaction to construct the EoS of the core of the neutron star. Results obtained with this unified EoS is compared with the existing works in the literature.

Parallel 1A / 59

Core and crust contributions in overshooting glitches: the Vela pulsar 2016 glitch

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During the spin-up phase of a large pulsar glitch - a sudden decrease of the rotational period of a neutron star - the angular velocity of the star may overshoot, namely reach values greater than that observed for the new post-glitch equilibrium. These transient phenomena are expected on the

basis of theoretical models for pulsar internal dynamics and their observation has the potential to provide an important diagnostic for glitch modelling. In this talk I present a simple criterion to assess the presence of an overshoot, based on the minimal analytical model that is able to reproduce an overshooting spin-up. We employ it to fit the data of the 2016 glitch of the Vela pulsar, obtaining estimates of the moments of inertia of the internal superfluid components involved in the glitch and of the spin-up and relaxation timescales. The results suggest the presence of a reservoir of angular momentum extending beyond the crust and an inner core, possibly made of non-superfluid matter, that is strongly coupled to the magnetosphere.

Poster Session / 111

Coupled Thermal and Magnetic Evolution of Neutron Star Cores

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In Castillo et al. (2017}, the first simulations of ambipolar diffusion in a spherical neutron star cores were reported, contributing to the understanding of the long-term evolution of their magnetic fields. In that work the NS interior is modeled as a charged-particle fluid of npe-matter, with a uniform and motionless background of neutrons that exerts a collisional drag force on the former. A more realistic approach is being extensively studied by Castillo et al. (in preparation), where a two-fluid simulation is performed including a dynamical neutron background. In this work we present preliminary results considering the evolution of the interior temperature, also taking into account the effect of β-decays. We are studying separately two different temperature regimes. One of these is the strong-coupling regime, at the early epoch of the star's life, with interior temperature $T >\sim 10^9\,K$, where charged particles and neutrons are strongly coupled to each other by collisions, but they can convert into each other by weak interactions (Urca reactions). Particularly, we are focusing on small departures from chemical equilibrium quantified by $\Delta\mu := \mu_n - \mu_e - \mu_p$, the so called "sub-thermal" regime ($\Delta\mu/k_BT <\sim 3$) characterized by a net neutrino cooling. The other is the \textit{weak-coupling regime}, relevant for late times of the star's life with temperatures $T <\sim 5 \times 10^8\,K$, where the weak interactions are essentially frozen and the cooling and heating mechanisms are due to photons emitted from the stellar surface and energy released by the friction between the two species (i.e. due to ambipolar diffusion), respectively.

Parallel 1B / 62

The Fast Folding Algorithm for large-scale pulsar surveys

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The Fast Folding Algorithm (FFA) is a fully phase-coherent search technique for periodic pulsar signals dating back to 1969, which consists of folding the input data at all distinguishable signal periods. It has historically seen limited use, having been dismissed in favour of the less computationally expensive Fast Fourier Transform (FFT) on which the standard search method is based. Interest in the FFA has been growing in the past few years and has been presented as a method more apt to find pulsars with periods of a few seconds or longer. However, we have demonstrated a much stronger result

from first principles: a properly implemented FFA search is *the* most sensitive search method for all periodic signals. The sensitivity improvement offered by the FFA over the standard method grows larger for narrower pulses, with the FFA being 5 times more sensitive to pulsars with short (0.1%) duty cycles. Part of the pulsar parameter space has therefore been systematically under-explored until now, which has significant consequences for pulsar population synthesis studies. We have developed and published an end-to-end FFA search pipeline fast enough to be run on modern all-sky pulsar surveys. The pipeline is currently running on survey data from Parkes and LOFAR, and will soon be running on GMRT and MeerKAT data. More than a dozen new pulsars that were missed by standard FFT search codes have already been discovered.

Parallel 2A / 154

Dramatic spectral changes at very low luminosity state of X-ray pulsars

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I will talk about dramatic spectral changes at very low luminosity state in accreting strongly magnetised neutron stars. These spectral changes were recently discovered in two X-ray pulsars - A 0535+262 and GX 304-1, - thanks to deep NuSTAR observations of these objects. This discovery can shed light on the process of spectra formation in accreting neutron stars under conditions of an extremely strong magnetic field. I will discuss the recent results of radiative transfer calculations accounting for X-ray polarization and test the theoretical results against the observational data.

Parallel 1B / 92

Unified description of magnetar crusts

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With their ultra-strong magnetic fields and densities exceeding that found inside heavy atomic nuclei, magnetars offer unique possibilities to study matter under extreme conditions that cannot be reproduced in the laboratory. We have determined the equilibrium properties of magnetar crusts taking into account the Landau-Rabi quantization of electron motion. Both the outer and inner crusts were treated consistently within the framework of the nuclear-energy density functional theory using functionals that were precision-fitted to theoretical and experimental data. Calculations were carried out for a wide range of magnetic-field strengths required for modelling astrophysical phenomena.

Parallel 3B / 175

The Magnetic Field Structure of Pulsating Ultra-Luminous X-ray Sources

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Pulsating Ultra Luminous X-ray sources (PULXs) are thought to be X-ray bright, accreting, magnetized neutron stars. Their apparent X-ray luminosity, in the range 0.1keV to 10keV, can exceed the Eddington luminosity for a neutron star by a few orders of magnitude. In a magnetized neutron star the accretion flow is channeled onto the polar caps and this gives rise to the observed sinusoidal modulation. However, the exact mechanism which powers the observed luminosity remains debated to this day. Opacity reduction due to the strong magnetic field may be a possible explanation for the high, super-Eddington luminosity. Assuming a purely dipolar field, this scenario can successfully account for the lumonosity of the source M82 X-2, but it fails to explain the even brighter source NGC 5907 ULX1. Instead, in the latter source a more complex magnetic field structure may be present, which allows for sufficient opacity reduction while avoiding the onset of the propeller effect. Here I will present a new simplified model of accretion onto a neutron star with a multipolar magnetic field, and I will discuss the implications and its application to the PULXs emission.

Parallel 3B / 157

Does the black widow PSR J1555-2908 have an additional planetary companion?

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The fast-spinning black-widow pulsar J1555-2908, recently discovered in radio, shows long-term variations in its spin frequency via gamma-ray timing analysis of *Fermi*-LAT data. If interpreted as a red timing noise process, these variations are much larger in amplitude than is observed from other millisecond pulsars. The frequency variations can also be explained by adding a second, lightweight companion to the system, with a wide orbit encompassing the black-widow system. With the current data, this hierarchical triple system model describes the pulsar's rotation as well as the timing noise model, and without increasing the number of free parameters. In this talk, we will describe the analysis and give details about the possible companion.

Parallel 2A / 167

An HD numerical model of the G21.5-0.9 Pulsar Wind Nebula

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Pulsar Wind Nebulae (PWNe) are powered by the rotational energy lost by the central compact star. Thus they are the perfect place to look at to obtain information on the pulsar in case of a non-direct identification. Multidimensional MHD numerical models of Pulsar Wind Nebulae (PWNe) have been shown to be extremely successful at accounting for a large variety of properties of those sources, down to very fine details. Unfortunately a complete description of the entire structure of a PWN, from the inner nebula to the outer part, is only possible with 3D models, which are very demanding in terms of time and numerical resources. Thus, in practice, they cannot be invoked as a possible tool for investigating large sets of different objects nor old systems. In addition, the connection between HD/MHD models and radiative models has not been explored in detail, and there is not a versatile prescription for this model linkage.
In this talk I will present our efforts in this sense and, in particular, show a prescription for combining HD simulations with radiative properties, and its application to the G21.5-0.9 nebula.

Parallel 2A / 61

Understanding the radio beam of PSR J1136+1551 through its single pulses

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The frequency widening of pulsar profiles is commonly attributed to lower frequencies being produced at greater heights above the surface of the pulsar; so-called radius-to-frequency mapping. Our understanding of the structures of pulsar radio beams is limited by the fact that we can only observe that emission which points along our line of sight. However, single pulses give us a population of instances where we can trace this frequency evolution along field lines in the magnetosphere, allowing us to build up a description of the shape of the active emission region. Assuming that emission is produced tangential to the magnetic field lines and that each emission frequency corresponds to a single height, we simulate the single pulse profile evolution resulting from the canonical conal beam model and a fan beam model, and compare the results of these simulations with single pulses of PSR J1136+1551, observed with the Giant Metrewave Radio Telescope.

Parallel 1A / 156

Studying the Neutron Star Interior in Transient Low-Mass X-Ray Binaries

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I will present recent progress on our long-term study of the thermal response of neutron stars to long phase of accretion in low-mass X-ray binaries. During the accretion phase, the crust of the neutron star is strongly heated and most of this heat flows into the core. During the quiescence phase, the star relaxes back to thermal equilibrium and observation of this phase allows us to map the physical properties of the stellar crust. Long term evolution also gives information about the core properties

as its neutrino emission efficiency and its specific heat. Evidence for very fast neutrino emission from a Direct Urca process has emerged in a few cases and recent constraints on the total stellar specific heat become comparable to theoretical expectations and may soon, with more data, provide relevant constraints on the nature of dense matter.

Parallel 1A / 53

A new low-density equation of state from an experimental data analysis including in-medium effects

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In the near future, the large amount of new data that will be made available by SKA will allow us to determine neutron star properties with much smaller uncertainties and set strong constraints on the equation of state of stellar matter. Neutron stars will, as a consequence, become a real laboratory to test the nuclear force under extreme conditions of density, proton-neutron asymmetry and temperature. Light (^{2}H, ^{3}H, ^{3}He, ^{4}He particles), and heavy (pasta phases) nuclei exist in nature not only in the inner crust of neutron stars (cold beta-equilibrium matter), but also in core-collapse supernova matter and neutron star mergers (warm stellar matter with fixed proton fraction). The appearance of these clusters can modify the neutrino transport, and, therefore, consequences on the dynamical evolution of supernovae and binary mergers, and on the cooling of proto-neutron stars, are expected. In this talk, the modification of the ground state properties of light clusters in the stellar medium is addressed, using chemical equilibrium constants evaluated from a new analysis of the (Xe+Sn) heavy-ion data measured by the INDRA collaboration. Three different reactions are considered, mainly differing on the isotopic content of the emission source. The thermodynamic conditions of the data samples are extracted from the measured multiplicities allowing for an in-medium correction. We show that this new correction, which was not considered in previous analyses of chemical constants from heavy ion collisions, is necessary, since the observables of the analysed systems show strong deviations from the expected results for an ideal gas of clusters. This experimental data set is further compared to a relativistic mean field model, and seen to be reasonably compatible with a universal correction of the attractive scalar σ meson coupling.

Parallel 1A / 133

Do transitional millisecond pulsars power dwarf pulsar wind nebulae?

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Transitional millisecond pulsars can swing between a radio
pulsar behaviour and a regime characterized by the presence of an accretion disk. The observed multi-wavelength properties of the disk state are enigmatic. Most of the models proposed involve some sort of ejection of plasma, but the driving physical mechanism has not yet been firmly singled out. The recent discovery that in one of these systems optical pulsations are emitted, closely tied to X-ray pulsations, strongly suggested that a radio pulsar is active although
with peculiar properties. We proposed that optical and X-ray pulses are produced from the intrabinary shock that forms where a striped pulsar wind meets the accretion disk, within a few light cylinder radii away, ~100 km, from the pulsar. I will discuss the assumptions and implications of this model, as well as its possible application to other astrophysical systems.

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The Arecibo PALFA survey and the observed population of Galactic millisecond pulsars

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The Arecibo PALFA survey searches for radio pulsars, Rotating RAdio Transients (RRATs) and Fast Radio Bursts (FRBs) in the Galactic plane at 1.4 GHz. The survey has been notably prolific in finding double neutron star (DNS) systems and millisecond pulsars (MSPs), both being valuable in the context of neutron star mass measurements and testing theories of gravity and binary evolution. Many MSPs are also high-energy emitters, making them important for understanding emission mechanisms. We recently obtained timing solutions for eight MSPs in binary systems that were discovered by PALFA. In this talk, I will present three of these systems that have particularly interesting properties: a non-eclipsing "black-widow" pulsar, a pulsar with pulsed gamma-ray emission and the longest-orbital-period intermediate-mass binary pulsar known to date. I will also discuss a study of the observed population of recycled radio pulsars PALFA has helped discover. Finally, I will show evidence of biases in pulsar surveys and discuss how those biases ultimately impact our understanding of the Galactic neutron star population.

Parallel 3A / 56

Understanding the long-term spin evolution of young radio pulsars.

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Young neutron stars provide unique insights into astrophysics that are not available from the bulk of the pulsar population. The smooth spin-down of young radio pulsars is perturbed by two non-deterministic phenomenon, timing noise and glitches. Timing noise is a type of rotational irregularity which causes the pulse arrival times to stochastically wander about a steady spin-down state while glitches are sudden jumps in the pulsars' spin-frequency. Both these phenomena allow us to probe nuclear and plasma physics at extreme densities. Long-term timing of young radio pulsars also provides the most promising avenues for studying their spin-evolution through measurements of the braking index (n). I will present results on the long-term evolution and timing noise properties of 85 high $\dot{E}$, young radio pulsars observed over ~ 10 years with the 64-m Parkes radio telescope using Bayesian inference. I will discuss significant measurements of n in a subset of 19 pulsars and show that they are consistent over time and in the presence of glitches. Finally, I will show that over decadal timescales, the value of n can be significantly larger than the expected value of 3 and discuss the implications for the long-term evolution of pulsars.

Parallel 1B / 125

Modeling the cooling phase of proto neutron stars

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The formation of neutron stars is an extremely complex problem involving many field of physics : general relativity, relativistic fluid mechanics, nuclear matter equation of state, neutrino-matter interactions…

This diversity makes neutron stars the ideal target for the era of multimessenger astronomy, but progress has to be made also on the theoretical aspects of the problem.

In this talk I will present recent work regarding the early evolution of the proto-neutron star when it is still very fast cooling due to neutrino emission. A newly developed simulation code will be shown and the influence on the simulations of accurate cross sections for neutrino-matter interactions that have been computed using RPA (random phase approximation) will be discussed.

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Finding extragalactic neutron stars through transient searches with EXOD

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Type I X-ray bursts are thermonuclear explosions that can last from seconds to minutes. These bursts occur in low mass X-ray binaries (LMXB) in which the accretor is a neutron star. Thus, the detection of such transients allows the identification of the accretor in an LMXB.
Currently, 112 galactic type I X-ray bursters are known. However, only two X-ray bursters have been observed in M31, our closest neighbour. A 1.2 s and a 3 s X-ray pulsars have been identified in M31. Although radio pulsar searches have been carried out in this same region, no candidates have been confirmed. These sources add up to a total of four known neutron stars in M31. Since this galaxy is more massive than our own, more than these four must clearly exist.
XMM-Newton has produced one of the largest X-ray catalogs to date, in which the variability of sufficiently bright sources is automatically studied through their fractional variability and χ^2 tests. However, these methods require a minimum number of counts to be reliable and thus short transients cannot be detected by the same means. Examples of such transients are extragalactic type-I X-ray bursts.
In order to automatically search XMM-Newton data for these short and faint transients, we have developed EXOD, the EPIC-pn XMM-Newton Outburst Detector. It computes the variability of the whole field of view and then applies an imaging technique to detect variable sources.
I will present how, by applying EXOD to every archival observation of M31 in XMM-Newton's catalogue, we have detected three new extragalactic type I X-ray bursters, and thus significantly increased the population of known neutron stars in M31.

Parallel 1B / 89

Recent Results from the North American Nanohertz Observatory for Gravitational Waves

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A small fraction of neutron stars that can be timed to high precision lend themselves to the scientific endeavors of pulsar timing array (PTA) experiments, which have the primary goal of directly detecting low-frequency gravitational waves. The North American Nanohertz Observatory for Gravitational Waves (NANOGrav) is one such PTA experiment and has been in operation for more than fifteen years. NANOGrav currently times more than six dozen millisecond pulsars using a combination of the Arecibo Observatory, the Green Bank Telescope and, more recently, the Very Large Array. In this talk I will introduce the latest NANOGrav dataset, the analyses of which has produced a variety of results that inform a wide range of astrophysics. Besides the flagship analyses attempting to measure the amplitude of the stochastic background of gravitational waves, there are findings relevant to our understanding of the interstellar medium, the interiors of neutron stars, and beyond. The gravitational wave signals are thought to arise from the slow coalescence of supermassive black hole binaries (SMBHBs), and NANOGrav's projected sensitivity is such that even a non-detection after several more years of observations would have important consequences for our understanding of SMBHBs and their environments.

Invited Talks / 55

Modelling multimessenger signals from compact binary mergers (Invited)

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Compact binary mergers are multi-dimensional, multi-physics, multi-scale phenomena that possibly produce a large variety of signals, including gravitational, electromagnetic and neutrino radiations. Moreover, they are major sites for the synthesis of heavy elements through the so called r-process nucleosynthesis. The outcome and the observables associated to these events have a non-trivial dependence on detailed microphysics, including for example the nuclear equation of state and the role of weak interactions. In this talk, I will present some recent results concerning the status of compact binary merger modelling with a special emphasis on the microphysics input. In particular, I will stress the potential impact of detailed microphysics and of the intrinsic astrophysical variability on the observables (like the kilonova signal), on the properties of the remnant, as well as on the nucleosynthesis outcome. Differences between neutron star-black hole and double neutron star mergers will also be considered.

Parallel 2A / 43

Tidal deformations of hybrid stars with sharp phase transitions and elastic crusts

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With the advent of gravitational wave (GW) astronomy, neutron star (NS) properties, such as its equation of state, could be better constrained. This is possible thanks to measurements of their tidal deformations, which modify gravitational waveforms of the early inspiral phase of binary NSs. Our main goal here is to show that, differently from usually believed, tidal deformations of hybrid stars with sharp phase transitions and elastic hadronic crusts may differ significantly from their perfect-fluid counterparts in several cases. The analysis is carried out in the usual context of nonradial perturbations with frequencies much smaller than the stellar modes and crusts presenting elastic aspects just when they are perturbed. We show that ordinary continuity conditions for perturbations actually lead to some unconstrained crustal degrees of freedom, which could greatly influence tidal deformations for some physically reasonable range of parameters. Besides, for large enough energy jumps, tidal deformations could also be significantly affected. Therefore, tidal deformations are actually very sensitive to crust-core and perfect fluid-elastic phase properties and GW observations could also be used to constrain aspects of phase transitions, elasticity and even perturbations of hybrid stars.

Poster Session / 51

Hybrid stars: a two model description with the Nambu-Jona-Lasinio quark model

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We explore hybrid equations of state with a hadron and a quark phase. The quark degrees of freedom are described by the 3-flavor Nambu-Jona-Lasinio model while the hadron degrees of freedom are modeled by a Taylor expansion around the saturation density, with coefficients connected to properties of nuclear matter at saturation.

Poster Session / 45

Role of the symmetry energy and the neutron-matter stiffness on the tidal deformability of a neutron star with unified equations of state

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The role of the symmetry energy and the neutron-matter stiffness on the tidal deformability of a cold nonaccreted neutron star was studied using a set of unified equations of state. Based on the nuclear energy-density functional theory, these equations of state provide a thermodynamically consistent treatment of all regions of the star and were calculated using functionals that were precision fitted to experimental and theoretical nuclear data. Predictions will be compared to constraints inferred from the recent detection of the gravitational-wave signal GW170817 from a binary neutron-star merger and from observations of the electromagnetic counterparts.

Parallel 3B / 142

Gravitational-wave-driven tidal secular instability in neutron star binaries

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We report the existence of a gravitational-wave-driven secular instability in neutron star binaries, acting on the equilibrium tide. The instability is similar to the classic Chandrasekhar-Friedman-Schutz instability of normal modes and is active when the spin of the primary star exceeds the orbital frequency of the companion. Modeling the neutron star as a Newtonian n=1 polytrope, we calculate the instability timescale, which can be as low as a few seconds at small orbital separations but still larger than the inspiral timescale. The implications for orbital and spin evolution are also briefly explored, where it is found that the instability slows down the inspiral and decreases the stellar spin.

Parallel 2A / 110

Is there a pulsar wind nebula or a disk around RX J0806.4-4123?

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Extended near-infrared emission was recently discovered with the Hubble Space Telescope at the position of RX J0806.4-4123, an X-ray thermal isolated neutron star and member of the so-called Magnificent Seven. The nature of this infrared source is still a matter of debate. Both a pulsar wind nebula or a circumpulsar disk could be explanations. We will present a summary of the multiwavelength phenomenology of this neutron star including updates from recent X-ray observations. We will discuss the different models for the extended infrared emission with respect to the observational evidence.

Invited Talks / 138

Crust structure and thermal evolution of neutron stars in soft X-ray transients (Invited)

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Thermal evolution of neutron stars in soft X-ray transients (SXTs) is sensitive to neutron-star equation of state (EoS), neutrino emission rates, and structure of the neutron-star crust. Therefore, comparison of observations of quiescent thermal emission of SXTs with numerical simulations of their heating and cooling is useful for verification of theoretical models of the dense matter in neutron-star interiors. We study thermal evolution of neutron stars in SXTs using modern models of the EoS, baryon superfluidity, formation and structure of the accreted and nonaccreted crust. We test currently competing models of composition and formation of the accreted crust and deep crustal heating during accretion episodes. We also study the effects brought about by impurities embedded in the nonaccreted part of the crust, considering a finite temperature of crust annealing in a newly born neutron star. Thermal relaxation of such an impure crust after an accretion episode is compared with the relaxation of the canonical nonaccreted crust composed of the ground-state cold catalyzed matter. We check the simulations of
thermal evolution of transiently accreting neutron stars against observations of SXTs in quiescence.

Parallel 2A / 40

Joint radio and X-ray modelling of PSR˜J1136+1551

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Multi-wavelength observations of pulsar emission properties are powerful means to constrain their magnetospheric activity and magnetic topology. Usually a star centred magnetic dipole model is invoked to explain the main characteristics of this radiation. However in some particular pulsars where observational constraints exist, such simplified models are unable to predict salient features of their multi-wavelength emission. This paper aims to carefully model the radio and X-ray emission of PSR˜J1136+1551 with an off-centred magnetic dipole to reconcile both wavelength measurements. We simultaneously fit the radio pulse profile with its polarization and the thermal X-ray emission from the polar cap hot spots of PSR˜J1136+1551. We are able to pin down the parameters of the non-dipolar geometry (which we have assumed to be an offset dipole) and the viewing angle, meanwhile accounting for the time lag between X-ray and radio emission. Our model fits the data if the off-centred magnetic dipole lies about 20\% below the neutron star surface. We also expect very asymmetric polar cap shapes and sizes, implying non antipodal and non identical thermal emission from the hot spots. We conclude that a non-dipolar surface magnetic field is an essential feature to explain the multi-wavelength aspects of PSR˜J1136+1551 and other similar pulsars.

Parallel 2A / 121

Modeling superfluidity in neutron stars with Brussels-Montreal functionals

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Despite 40 years of intensive study, the detailed mechanism for sudden increases in the spinning of neutron stars (known as glitches) remains a puzzle. It is believed that glitches are a direct manifestation of superfluidity in the stellar interior. One of the sources of the difficulty of modeling neutron stars is that the scales vary within many orders of magnitude. At the microscale one can construct models where neutrons and protons are the degrees of freedom. On the mesoscopic scale, glitches can be modeled by a semi-classical vortex filament model (VFM) in which impurities and vortices are the degrees of freedom. On the scale of the whole star, the hydrodynamical methods are utilized. It is not fully clear how the effective description emerges from the more fundamental one.

We use microscopic description to provide a solid underpinning of the so-called vortex filament model, the mesoscopic approach used to model vortex dynamics in neutron star crust. From fully microscopic simulations, employing Time-Dependent Density Functional Theory (TDDFT), it is possible to extract various parameters of the filament model, including vortex-impurity interactions and dissipation coefficients. For microscopic TDDFT calculations, we use BSk type energy density functional, which is a very accurate nuclear functional designed to agree with existing astrophysical constraints. Using this state-of-the-art functional we try to narrow down the range of values of parameters of VFM which may also affect, in principle, the parameter space of hydrodynamical models. Here, I will present the properties of a vortex in superfluid neutron matter.

Parallel 1A / 11

Finite temperature equation of state with exotic degrees of freedom

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The properties of slowly rotating proto-neutron stars and merger remnants are studied using finite-temperature equation of state models derived from the covariant density functional theory. In addition to the whole baryonic octet we account for Delta-isobars, as particle degrees of freedom. Wide ranges of entropy per baryon, lepton fraction and baryonic mass are considered. We investigate the I-Love-Q universality at finite temperature by confronting the predictions of hyperonic equation of states with those of their counterparts which additionally allow for Deltas.

Parallel 3A / 17

On the estimation of realistic growth rates for Langmuir instability in Pulsar plasma

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There is strong observational evidence that coherent radio emission from pulsars are excited by curvature radiation from charge bunches in relativistically streaming plasma along the open dipolar magnetic field lines, and detaches the pulsar magnetosphere below 10% of the light cylinder radius. The formation of charge bunches requires growth of instabilities in the plasma, however the exact mechanism of formation of stable charge bunch has remained an unresolved problem in pulsar physics. One popular choice for the plasma instability is the Growth of Langmuir mode driven by

two stream instability, where the system can be driven from linear to non-linear regimes, where eventually stable charge bunches can form. However so far growth rates for realistic pulsar parameters and how the system is driven from linear to nonlinear regime from first principles is not available in the literature. In this talk I will present the growth rates for Langmuir instability for realistic pulsar plasma parameters for the very first time. Three different physical scenarios will be explored- that due to high energy positron/ion beam, longitudinal drift in secondary plasma and cloud-cloud overlap of secondary plasma due to non-stationary discharges at the polar gap. I will demonstrate that only the cloud-cloud scenario can facilitate the entry of the Langmuir mode from linear to non-linear regime.

Parallel 2B / 3

Magnetar formation through convective dynamo in protoneutron stars

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Magnetars are isolated neutron stars characterized by a variable X-ray activity powered by the dissipation of strong magnetic fields. Their spin-inferred dipole field strengths range from 100 to 1000 times those of radio pulsars. For many decades now, understanding the origin of these objects has been a theoretical challenge. Thanks to the first 3D MHD direct numerical simulations of thermal convection that develops inside a nascent neutron star, we show that the in situ magnetic field amplification by dynamo action can explain magnetar formation. For sufficiently fast rotation rates, the instability saturates in the magnetostrophic regime with the magnetic energy exceeding the turbulent kinetic energy by a factor up to 10. Our results are compatible with the observational constraints derived from galactic magnetars and also provide strong theoretical support for millisecond protomagnetar models of gamma-ray bursts and superluminous supernovae central engines.

Parallel 1B / 139

New results on magnetar outbursts: the Galactic center magnetar and other outliers

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We will present new constraints on the physics of magnetar outbursts from recent observations of peculiar events, among which the long-term evolution of the Galactic center magnetar.

Parallel 2B / 100

X-ray emission from magnetized rotation-powered pulsars

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We present recent X-ray timing and spectral results on isolated pulsars, including the X-ray and radio mode switching PSR B0943+10, and PSR J0726-2612, which is an old radio pulsar sharing several of the properties of the XDINSs. Our analysis properly accounts for the effects of the (relatively) high magnetic field on the surface emission properties.

Previous studies of PSR B0943+10 showed that its X-ray flux consists of an unpulsed nonthermal plus a pulsed thermal component arising from a hot spot. We reanalyzed all the available X-ray observations, fitting the thermal component with appropriate models of magnetized hydrogen atmospheres as well as with models of condensed surfaces. We could successfully reproduce its spectral and timing properties, in particular the large pulsed fraction, with a geometry consistent with the radio observations. The derived emitting area and magnetic field are in agreement with the values inferred in the dipole approximation and we discussed these results in the broader context of the polar cap accelerator models in old pulsars.

PSR J0726-2612 is a highly magnetized (B=3x10ˆ13 G) slowly rotating pulsar (P=3.4 s), with a thermal X-ray spectrum and a double-peaked asymmetric pulse profile. The results of our spectral and timing analysis based on magnetized atmosphere models strengthen the similarity between PSR J0726-2612 and the XDINSs and support the possibility that the lack of radio emission from the latter might simply be due to an unfavourable viewing geometry.

Parallel 2B / 152

High Performance Computing in High-energy Astrophysics: the case of the Pulsating Ultra Luminous X-ray sources (PULXs)

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Making use of Big Data techniques and High Performance Computing (HPC) we explored high-energy data archives in new ways, extracting new information buried in the vast volume of high-energy astrophysical data. These efforts of mixed Data Mining and HPC approaches allowed us to uncover a new population of Extragalactic Neutron Stars (NS), and in particular showed that probably most of the Ultra Luminous X-Ray sources (ULXs) are powered by Neutron Stars (NS), instead of (stellar-mass or intermediate-mass) black holes, as was believed for over 25 years. The discovery of these Pulsating ULXs (PULXs), NS at strongly Super-Eddington luminosities, has change radically our views in the ULX population and widen our knowledge of the accretion processes. Now, we are focusing in a new approach mixing HPC with new, accurately selected, X-ray observations with the aim to wide the PULX population with the "UNSEeN" project. I will describe our past discoveries, their main implications and our new approach and what we expect in the fast changing ULXs field.

Parallel 1B / 98

The luminosity-volume test for cosmological fast radio bursts

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One way to probe the still unknown nature of fast radio bursts (FRBs) progenitors is to investigate how their sources are distributed in space. With this aim we have applied the luminosity–volume test, also known as $\langle V/V_{\max}\rangle$ test, to two samples of FRBs detected by ASKAP and Parkes, respectively. These samples have different flux limits and correspond to different explored volumes. We put constraints on FRB sources redshifts with probability distributions and applied the appropriate cosmological corrections to the spectrum and rate in order to compute the $\langle V/V_{\max}\rangle$ for the ASKAP and Parkes samples. Our findings suggest that the population of FRB progenitors is not consistent with the star formation rate (SFR) or any delayed SFR. If FRBs do not evolve in luminosity, the $\langle V/V_{\max}\rangle$ values of ASKAP and Parkes samples are consistent with a population of progenitors whose density strongly evolves with redshift up to $z \sim 0.7$.

Parallel 2A / 16

Some Glimpses of Plasma Process Involved on Modelling of Radio Pulsar's Power spectra

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Although there are copious amount of theory and observation dedicated to pulsar radio emission, very few have investigated the exact nature of emission mechanism and power spectra of radio pulsars. Some recent literature have tried to make out consensus with observed brightness temperature of radio pulsars by incorporating bunch, plasma physics along with suitably chosen emission beam geometry. But still there are some ambiguity regarding bunch formation mechanism scenario and their stability. In this abstract, I mostly try to confine on modelling of power spectra of radio pulsars by implementing non-linear plasma physics as a potential tool.
There are basically three prominent processes in which electromagnetic waves can undergo scattering in an ambient plasma medium. First, one is very well known Compton scattering, it is the process when the scattering of radiation occurs by a single electron. Second and third ones are Stimulated Raman Scattering (SRS) and Stimulated Compton Scattering (SCS), which are the relatively less known plasma process. By definition, SRS is a process, where the scattering of radiation occurs by longitudinal electron plasma mode, whereas SCS occurs by highly damped electron plasma mode. In this article, we have explored the possibility of explaining the radio power spectra of pulsar under different circumstances. We have computed growth rate due to SRS instability by using analytical formula (Drake et al. 1974; Liu and Kaw 1976) and growth rate due to SCS instability, numerically. Thereafter we have reproduced the full radio power spectrum of the following pulsar, PSR 2111+46 theoretically by assuming dispersion relation of un-magnetized plasma and the spatial variation associated with different plasma parameters like plasma density, Lorentz factor of electron jet, frequency and input flux of the pump wave. So it is possible to generate an empirical formula for each and individual radio pulsars by tuning them with different plasma index. Pump wave from background radiation in the pulsar magnetosphere interacts with relativistically moving electron jets, coming out from the pulsar surface. There exist some phase matching and other prevailing conditions on plasma parameter. If those particular conditions are satisfied for three wave interaction scenario, then input radiation gets enhanced and back-scattered, by interacting with electron

jets. Let's assume that electron jets do follow Maxwellian distribution. Now If the phase velocity of background radiation or pump wave falls in the negative slope region of the velocity distribution curve of electrons, electrons will get back energy from the pump wave and in the positive slope region electrons will imparts energy to pump waves. As a consequence electrons will suffer Landau damping and the scattered wave amplitude will grow with time and attain some non-linear unstable stage in positive slope regime and finally dissipate energy in terms of radio emission. This might be the most viable scenario in the context of enhanced growth rate, associated with radio emission of pulsars. We have tried to model two-segmented broken power law and single power spectra of radio pulsars, by incorporating different constraints associated with the plasma parameters with a valid theoretical basis.

Parallel 3A / 31

Dark-matter admixed neutron stars

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We study an impact of asymmetric dark matter on properties of the neutron stars and their ability to reach the two solar masses limit, which allows us to present a new upper constraint on the mass of dark matter particle. Our analysis is based on the observational fact of existence of three pulsars reaching this limit and on the theoretically predicted reduction of the neutron star maximal mass caused by accumulation of dark matter in its interior. Using modern data on spatial distribution of baryon and dark matter in the Milky Way we found out an upper constraint on the mass of dark matter particles. We also demonstrate that light dark matter particles with masses below 0.2 GeV can create an extended halo around the neutron star leading not to decrease, but to increase of its visible gravitational mass. Furthermore, we predict that high precision measurements of the neutron stars maximal mass near the Galactic center, will put a stringent constraint on the mass of the dark matter particle. This last result is particularly important to prepare ongoing, and future radio and X-ray surveys.

Poster Session / 65

Modelling of the hybrid stars within the Polyakov Loop coupled Nambu-Jona-Lasinio model

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We present a thorough analysis of the properties of the hybrid stars based on a recently developed version the Polyakov Loop coupled Nambu-Jona-Lasinio model of quark phase that maintains the Polyakov loop dynamics in the limit of zero temperature. First, we demonstrate that incorporation of the Polyakov loop to the model significantly stiffens the quark matter equation of state, which is important for phenomenology of hybrid stars. For the hadron phase we consider a couple of realistic nucleonic equation of state. Furthermore, to construct the quark-hadron transition we utilize the Maxwell and Glendenning scenarios. We also show how the strength and the type of the transition

between hadron and quark phases affect observational properties of the star and as well as tidal deformability parameters.

Parallel 1A / 106

Observational updates on accreting millisecond pulsars

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After almost two decades from the discovery of the first accreting millisecond X-ray pulsar (AMXP) SAX J1808.4-3658, the sample of accreting rapidly-rotating neutron stars harboured in low mass X-ray binary systems has increased in number up to 22. The extremely short spin periods shown by the accreting millisecond X-ray pulsars are the result of long-lasting mass transfer from low mass companion stars through an accretion disc onto a slow-rotating NS as predicted by the so-called "recycling scenario". At the end of the mass transfer phase, a millisecond pulsar shining from the radio to the gamma-ray band, and powered by the rotation of its magnetic field, is expected to turn on. The close link shared by radio millisecond pulsars and AMXPs has been observationally confirmed by the transitional binary systems IGR J18245 2452 as well as by other transitional millisecond pulsars. Here I will discuss the temporal and spectral properties of the recently discovered AXMP IGR J17591-2342. Moreover, I will present the latest updates on the long-term orbital evolution of SAX J1808.4-3658 obtained combining the updated set of ephemeris from its 2019 outburst with those of the previous outbursts. The orbital period derivative will be then discussed in terms of the possible evolutionary scenarios of the binary system.

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Twin star categories considering exotic matter in compact stars

Authors: Zahra Sharifi[1]; Esmat Nasiri[1]; Mohsen Bigdeli[1]; David Edwin Alvarez Castillo[2]

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The discovery of gravitational waves from a binary neutron star merger event GW170817 has allowed for the study of the neutron stars'interior, particularly the matter at nuclear densities [1]. This detection has also resulted in the improvement of our insight into the maximum mass of neutron stars and their tidal deformability. Moreover, the new knowledge of matter at extreme densities and temperatures has been provided by the product of the merger, which necessitates applying a microscopic model of strongly interacting matter [2]. Indeed, the equation of state (EOS) of dense matter, which is dependent on the gravitational wave signal relevant to the mergers of binary neutron stars, has a key role in modeling the formation of compact stars. On the other hand, the possible existence of the third family of compact stars due to the strong phase transitions in dense matter has long been debated by many authors. There may be two phase transitions for hadronic matter at large densities: the phase in which hadrons are deconfined to quarks and gluons and the one with restoration of chiral symmetry [3]. One can perceive that the existence of two stars with the same mass but of different size is a signature of a phase transition in dense matter.
In this research, we aim to study the categories of twin star solutions and also the tidal effects of binary neutron star merger involved in GW170817. Considering the first-order phase transition from

hadronic matter to exotic matter, we apply the EOS with the lowest order constrained variational (LOCV) approach and various potentials like Argonne family potentials with and without three-nucleon interaction (TNI) contribution for the hadronic phase [4]. It is also noted that we consider the excluded nucleon volume, which makes the EOSs stiff enough and thus this can be regarded as a signal of phase transition to the high-density matter.

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Parallel 3A / 20

Towards an accurate description of an accretion induced collapse and the associated ejected mass

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We revisit the accretion induced collapse (AIC) process, in which a white dwarf collapses into a neutron star. We are motivated by the persistent radio source associated with the fast radio burst 121102, which was explained by Waxman (2017) as a weak stellar explosion with a small (~ $10^{-5}\,M_\odot$) mass ejection. Since a typical supernova ejects much larger amount of mass, we study the possibility that an AIC caused the weak explosion. Additionally, the interaction of the
relatively low ejected mass with a pre-collapse wind might be related to fast optical transients.
The AIC is simulated with a one-dimensional, Lagrangian, Newtonian hydrodynamic code, and we put an emphasis on accurately treating the equation of state and the nuclear reaction network, which is necessary for any study that attempts to accurately simulate this process.
We leave subjects such as neutrino physics and general relativity corrections for future work.
Using an existing initial profile and our own initial profiles, we find that the ejected mass is ~ $10^{-2}\,M_\odot$ – $10^{-1}\,M_\odot$ over a wide range of parameters, and construct a simple model to explain our results. Our results probably provide an upper limit to the ejected mass from AIC events.

Parallel 2B / 136

The crust of accreting neutron stars within simplified reaction network

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Transiently accreting neutron stars in low mass X-ray binaries are generally believed to be heated up by nuclear reactions in accreted matter during hydrostatic compression. Detailed modeling of these reactions is required for the correct interpretation of observations. We construct a simplified reaction network, which can be easily implemented and depends mainly on atomic mass tables as nuclear physics input. We show that it reproduces the results of the detailed network by Lau et al. (2018, ApJ, 859, 62) very well if one applies the same mass model. However, the composition and

the heating power are shown to be sensitive to the mass table used and treatment of mass tables boundary, if one applies several of them in one simulation. In particular, the impurity parameter $Q_{\rm imp}$ at density $\rho = 2 \times 10^{12}$ g cm^{-3} can differ for a factor of few, and even increase with density increase. The profile of integrated heat release shown to be well confined between results by Fantina et al. (2018, A&A, 620, 19) and Lau et al. (2018, ApJ, 859, 62). Detailed analysis of results allows us to reveal a hint of inconsistency in implicit assumptions, which are traditionally applied in models of accreted crust. Work is supported by Russian Science Foundation (grant no. 19-12-00133).

Parallel 1B / 153

Model-independent constraints on the superfluidity of superdense nuclear matter from the analysis of the cooling neutron star in Cassiopeia A supernova remnant.

Authors: Petr Shternin[None]; Dmitry Ofengeim[1]; Wynn Ho[2]; Craig Heinke[3]; Dmitry Yakovlev[4]; Daniel Patnaude[None]

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Neutron star in the center of young (330 yr) supernova remnant Cassiopeia A is thought to demonstrate enhanced cooling inconsistent with the standard neutron star cooling via the modified Urca processes. One of the possible explanations of this phenomenon is a recent (approx. 80 yr ago) transition of the neutron liquid in the neutron star interior to the superfluid state [1]. Recently [2] the new Chandra data of this object were presented, extending the cooling observations range to 18 years (2000-2018). These data demonstrate continuing cooling of the star with temperature decline rate about 2.7 per cent at 10 yr base, although the considerable skepticism exists [3].

In the talk we present new model-independent (applicable for a broad range of the equations of state) analysis of the neutrino emissivity due to triplet Cooper paring of neutrons. The developed technique is applied to the Cas A cooling data. We find that the (redshifted) maximal critical temperature of the superfluid transition is constrained in a range ($T^{\infty}_{Cn \ \rm max} = (5^{+1.5}_{-0.5} \times 10^8$ K). This restriction weakly depends on the equation of state or the specific density profile of the critical temperature, however it depends on the overall strength of the Cooper paring neutrino emission. The obtained constraints also hold if the actual cooling of the Cas A NS is slower, as suggested in [3]. We also set the robust minimal limit on the Cooper pairing cooling rate consistent with observations.

The work is supported by Russian Science Foundation, grant # 19-12-00133.

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[3] Posselt, Pavlov 2018, ApJ, 864, 135.

Invited Talks / 49

Magnetars and other classes of Isolated neutron stars in X-rays (Invited)

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Multi-wavelength observations over the last decades proved the existence of observationally very diverse manifestations of isolated NSs (INSs): radio-pulsars, Magnetars, X-ray Dim INSs (XDINSs), high-B rotation powered pulsars, Rotating radio transients (RraTs) , and Central Compact Objects (CCOs). Among them magnetars and XDINSs are the most highly magnetized NSs and they also represent key targets for future polarimetric observations. In this talk I will briefly summarize the main characteristics of the various classes and I will review some perspectives for X-ray polarimetric magnetar observations.

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The Third Fermi LAT Pulsar Catalog, 3PC

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The Third Fermi Pulsar Catalog (3PC) is nearing completion and will provide timing solutions, pulse profiles, spectra, and ancillary data for over 250 gamma-ray detected pulsars. This grand undertaking pursues the steady growth established by 1PC (46 pulsars) and 2PC (117 pulsars). Ever-more-sophisticated search techniques turn up very gamma-faint radio pulsars and a surprising number of radio-eclipsing binary millisecond gamma-ray pulsars. The edges of the parameter space occupied by gamma-ray pulsars continue to expand – for example, with the discovery of PSR J2208+4056, the lowest spindown power known for a non-recycled gamma-ray pulsar is now Edot=8e32 erg/s. This pulsar also stands out for being more linearly polarized than most radio pulsars in that Edot range, allowing speculation that gamma and polarized radio emission may come from related electron populations. Because radio emission in young pulsars is thought to identify the polar cap, the radio-loud population is particularly useful in constraining gamma-ray pulsar emission models. Indeed, the capability of finite-resistivity MHD models to produce the observed trends in 2PC data provided the first strong evidence for emission from the current sheet, beyond the light cylinder. We will present analogous results from 3PC for a much larger sample, as well as general properties of the population and further highlights from the analysis.

Parallel 3B / 144

Axisymmetric equilibrium models for magnetised neutron stars in Scalar-Tensor Theories

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Among the most promising "Alternative Theories of Gravity", one of the most studied class is that of "Scalar-Tensor Theories of Gravity", because they are the most simple extensions of GR, they don' t lead to pathologies in the spacetime properties, and show behaviours that look promising in the context of cosmological constraints.

Some of these theories predict a phenomenon known as "spontaneous scalarisation", which produces strong deviations from GR in compact objects (like neutron stars) while fulfilling the strong observational constraints in the weak gravity regime. Such phenomenon is potentially observable in this new year of GW astronomy.

We present here, for the first time, the results of numerical multi-dimensional modelling of NSs in STTs, with the inclusion of magnetic fields, accomplished by the simultaneous solution of the coupled Scalar-Einstein-Maxwell equations.
Our aim is to understand how global quantities (like mass, inertia moments, magnetic and tidal deformabilities), that are potentially observable, deviate from GR, in the hope of providing new tools to test these theories through future observations. We will present the formalism of our algorithm, showing how it can be extended to include: realistic EoSs, different coupling and screening mechanisms and different rotation profiles.

Parallel 2A / 147

Vortex pinning in the superfluid core of neutron stars and the rise of pulsar glitches

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Pulsar glitches are commonly interpreted as sudden transfers of angular momentum from a more rapidly rotating superfluid component to the rest of the neutron star, triggered by large-scale vortex unpinning events. However, large uncertainties remain concerning, e.g., the microscopic interactions between the neutron vortices and the proton flux tubes that are expected to be present in the outer core of neutron stars. In particular, the possible pinning of vortex lines onto flux tubes may affect significantly the dynamical evolution of both the rotation and magnetic field of the star. Within this context, the neutron star core may thus provide a sufficient reservoir of angular momentum to explain giant glitches as observed in the Vela pulsar. In this talk, I will present our recent results about the role of the core neutron superfluid on the dynamics of the glitch rise.

Invited Talks / 177

Kinetic simulations of pulsar magnetospheres (Invited)

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Parallel 1B / 26

FRBs and other transients with MeerTRAP

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MeerTRAP is a commensal program running on the MeerKAT telescope to look for Fast Radio Bursts and other radio transients. It simultaneously searches the sky in more than 400 beams using the sensitivity of MeerKAT to probe the furthest FRBs. It also has the capability to record the raw data from the telescopes to be able to form offline images to precisely localise any FRBs or other transients that it detects. I'll present the project, as well as our latest results on FRBs and RRATs detected as part of the program.

Invited Talks / 185

Neutron star EOS constraints through gravitational-wave observations (Invited)

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Observing binary neutron star mergers with gravitational-wave observatories allows for new constraints to be set on the properties of high-density matter in the core of neutron stars. I will discuss an absolute constraint on the minimum radius of neutron stars, based on source characteristics derived by the GW170817 event and on a minimal set of assumptions. Upgraded or third-generation gravitational-wave observatories will have sufficient sensitivity at high frequencies to also allow for the detection of gravitational waves from the post-merger phase of binary neutron star mergers. I will discuss a set of empirical relations for gravitational-wave asteroseismology in the post-merger phase, which can lead to accurate radius constraints, with maximum uncertainties of just a few hundred meters for typical neutron star masses.

Poster Session / 103

Systematic calculations of nuclear abundances in magnetar crusts

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The electromagnetic observations following the detection of gravitational waves from GW170817 by the LIGO-Virgo collaboration, have confirmed the occurrence of an r-process nucleosynthesis triggered by the decompression of ejected crustal materials from binary neutron star mergers. Magnetars - strongly magnetised isolated neutron stars - might be another astrophysical site for the r-process, matter being ejected during giant flares induced by magnetic-field reconfigurations. The outer crust is expected to be the main contributor to the ejected material and the final abundance distribution depends on its composition. We present a systematic study of the influence of the magnetic field on the composition of the outer crust of a magnetar for a wide range of magnetic-field strengths.

Parallel 1A / 86

Are tMSP Companions Roche-Lobe Filling In Their Pulsar State?

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Transitional millisecond pulsars (tMSPs) are a class of neutron star binary where the system is observed to transition between a rotation-powered pulsar state and an accretion-powered low-mass X-ray binary (LMXB) state, each lasting for several years. As such, tMSPs present a unique opportunity to unveil the mechanics of binary evolution, linking the two distinct populations of binary MSPs and LMXBs, as well as being an excellent astrophysical laboratory to study accretion on human timescales. We present new high time-resolution, multiband optical photometry of two tMSPs, PSR J1227-4853 and PSR J1023+0038 in their rotation-powered pulsar states, and discus our numerical modelling of their light curves using the Icarus code. Both sources show significant, colour-dependent asymmetries in their light curve, the cause of which is not fully understood. We have extended the Icarus model to account for this asymmetry and better constrain the orbital parameters of the systems. In particular, we focus on the measurement of their companion's Roche lobe filling factor, as changes in the size of the star are likely connected to the mechanism triggering the onset of the Roche lobe overflow seen in the accreting state.

Parallel 2B / 140

Partially accreted crusts of neutron stars

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Neutron stars in binary systems may accrete matter from their companion star ; so far, only the case of a crust fully replaced by accreted matter has been considered in detailed calculations. However if the star has only accreted a small amount of matter, the crust is not fully but only partially accreted. This could be for example the case of IGR J17480−2446. The observed decrease of its temperature after the accretion phase is the slowest of all ˜10 objects for which such a relaxation has been monitored in X-ray and its slow rotation indicates that the accretion of matter from the companion started relatively recently. These could indicate that IGR J17480−2446 has a partially accreted crust which nuclear and thermal properties could be different from the ones of a fully accreted crust.

We propose a model of partially accreted crusts for which we follow the originally catalyzed crust as it undergoes an increase in pressure due to the above accreted material falling at the surface. We study different properties of partially accreted crust, additional energy sources and discuss differences with respect to calalyzed and fully accreted crust.

Parallel 1A / 143

How model atmospheres help us to investigate neutron star interiors

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Thermal X-ray radiation of neutron stars gives a chance to study their fundamental characteristics such as radii, masses, effective temperatures, and chemical composition of the surfaces. The X-ray emergent spectra form in the gaseous envelopes of the neutron stars and can be computed together with the structures of the upper envelope layers which can be named atmospheres. Comparison of the computed spectra with the observed X-ray spectra allows to determine the neutron star properties. This approach was applied to the X-ray bursting neutron stars in low-mass X-ray binaries and the thermally emitting neutron stars in Supernova remnants, so called Central Compact Objects (CCOs). As a result we concluded, based on studying both types of objects, that neutron star radii are in the range 11-13 km, which is important for limitation of the possible supra-dense matter properties in the inner neutron star cores. The ages of the CCOs are also known. Thus, measurements of their effective temperatures and the chemical compositions of the envelopes allow to find limitations on their cooling history and evaluate the superfluidity importance in their inner cores. A short review of the obtained results will be presented together with the recent theoretical modeling allowing to estimate the effects of model uncertainties on the obtained results.

Parallel 2B / **32**

Magnetic field instabilities in neutron stars

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Neutron stars are incredibly dense compact objects having the strongest magnetic field in the universe known to date. The exact configuration of the field is not known and the simplest model that is often considered is that of a dipole. Such a dipolar poloidal field is however known to be unstable and the equilibrium configuration is an open problem of great astrophysical relevance. In order to study the field evolution in real-time, we perform magnetohydrodynamic simulations
using the publicly available code PLUTO. The field undergoes a cataclysmic rearrangement in few Alfven timescales. This develops a toroidal component with a comparable field strength as that of the poloidal component. We explore different initial conditions and discuss the different modes of instabilities visible in our simulations.

Parallel 3B / **183**

Cracking and convective stability of self-gravitating anisotropic polytropic spheres in general relativity

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Typically, self-gravitating objects are modeled through structure equations and assuming a polytropic equation of state that allows numerical determination of radial density profiles. This equation of state (EoS) is particularly interesting since it allows different astrophysical scenarios to be modeled by varying the polytropic index. In this work we determine the convective stability and the concept of cracking in anisotropic hydrostatic material configurations, with spherical symmetry, modeled by three different kind of polytropic EoS. The first one is a relationship as a power law between radial pressure and energy density. In the second one the relationship is between the pressure and the density of the baryonic mass. And in the third one, it is considered a master equation of state that consists of the sum of a polytropic plus a linear term and a constant.

The cracking approach consists in determining the appearance of total radial forces that change sign in the self-gravitating object, just after the hydrostatic equilibrium configuration has been disturbed. On the other hand, the concept of convective stability is based on the Archimedes principle: if the density of a fluid element displaced towards the center of the configuration increases faster than the density of the surrounding fluid, then the fluid element will fall towards the center of the sphere and the object will be unstable under this type of disturbance.

The results obtained conclude that all modeled objects are stable under the concept of cracking when considering local density disturbances; and are stable under convective motions in regions near the nucleus where the second derivative of the density profile is less than zero, however, they are unstable in the outer region of the material configuration.

Parallel 3A / 7

Assessing orbital parameters of binary pulsars produced by kick velocity

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This paper studies the formation of Millisecond Pulsars (MSPs) and the dynamical characterisation of their parameters with a distribution of long (Porb > 2d) circular (e ≤ 0.1) orbits. For this task, a distinct approach to the analysis of the orbital parameters of binary MSPs (in Galactic disk and globular cluster) produced by the asymmetric kick imparted during the Accretion Induced Collapse (AIC) of white dwarfs process. It turns out that the distribution of binary pulsar orbits peaks up to Por_b;f ≤ 90 d with strong circularisation of the orbits. Considering the different assumptions about the distribution of companion stars 3M⊠ ≤ M_com ≤ 7M⊠, the binary will affect toward setups of the balance condition of minimum energy. As a result, this would lead to contribute significantly to their distributions of orbital parameters. In addition, the binary evolution leading to AIC kicks is critically dependent on the inclusion of ratio of the \neta = v_kick v_esc. We demonstrate that when \neta ≥ 0.35, the kick velocity has very significant constraints and govern the dynamical effect on the orbital parameters. We indicate specific pulsar systems with orbital parameters where the results of this work are relevant to AIC-candidates.

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The CIRADA slow pulsar survey using CHIME

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CHIME/FRB monitors the visible sky down to a declination of -11 degrees to search for Fast Radio Bursts. Consequently, daily, high time resolution data (˜1ms), wideband (400-800 MHz) observations of the whole visible sky is available. The Canadian Initiative for Radio Astronomy Data Analysis (CIRADA) slow pulsar survey aims to take advantage of this unique instrument by implementing a novel data-stacking search algorithm to improve the sensitivity towards low luminosity and/or distant isolated pulsars. The daily cadence will also allow for searching of nulling and intermittent pulsars. In this talk, I will describe the setup and the challenges faced by the survey, including handling the large data rate (estimated to be 1.5 PB/day), and the requirement of robust RFI excision to ensure the stacked data is not contaminated. Over time, this survey will probe deep into the CHIME visible sky, allowing us to better quantify the radio pulsar population at 400-800 MHz across a large part of the Galaxy, and to study the radio intermittency properties of pulsars. The survey will also potentially discover pulsars that are close to or even beyond the pulsar death line, which could help us constrain models of radio pulsar emission. The properties of all the pulsars detected by the survey will ultimately be made available as a public catalogue.

Parallel 1A / 29

How pair pair formation in polar caps fills magnetosphere with plasma, heats NS surface, and generates radio emission.

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I report on the recent progress in understanding the physics of pair formation in pulsar polar caps. I discuss how much pair plasma can be produced in polar cap cascades and what it means for the physics of pulsar magnetospheres and PWNs. Relativistic particles accelerated in pair formation zones heat the NS surface, I demonstrate that the temperatures of pulsar polar caps predicted in the frame of modern non-stationary cascade models agree with observations quite well. I also present a novel robust mechanism for direct generation of coherent radio emission in pair discharges and discuss its properties.

Invited Talks / 13

The Hadronic Equation of State for Neutron Stars (Invited Review Talk)

Author: Laura Tolos[None]

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The equation of state (EoS) of dense hadronic matter is of crucial importance for the description of the static and dynamical properties of neutron stars. In this talk I will review the current status of the hadronic EoS for neutron stars, from the point of both ab-initio many-body approaches and phenomenological models, paying a special attention to recent mean-field phenomenological schemes. The theoretical predictions for the hadronic EoS will be then compared to the data coming from both nuclear physics experiments and astrophysical observations, providing insights for future investigations.

Poster Session / 150

Implementation of a general relativity module in the OSIRIS PIC code

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The magnetospheres of compact objects are complex systems, that comprise kinetic-scale pair plasma physics, quantum electrodynamics (QED) processes, and general relativity (GR). To study such rich systems, advanced simulation techniques are required. Combining traditional particle-in-cell (PIC) codes with dedicated modules that capture these exotic processes allows for a global description of compact objects' magnetospheres. Furthermore, detailed simulations capable of coupling all these processes may be important to identify the key particle acceleration mechanisms and corresponding radiation signatures.

In this work, we will show the first results from the implementation of a GR module in the PIC code OSIRIS, with a focus on benchmarks of generalized Maxwell's equations solver and particle pushers. The GR generalized vacuum solution obtained numerically to the electromagnetic fields surrounding a neutron star will be presented and compared with an analytical solution. A new boundary condition for the fields that perfectly absorbs radial modes will be presented. Finally, we will also show trajectories of test particles obtained with GR generalized particle pushers in regions of combined strong spacetime curvature and electromagnetic fields. These particle pushers will be compared in their accuracy and numerical performances, in order to be used in future global simulations of compact objects' magnetospheres.

Parallel 2A / 76

Bayesian Inference of the Neutron Star Equation of State from Astrophysical Observations

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Astrophysical observations of neutron stars (NS) allow us to study the physics of matter at extreme conditions which are beyond the scope of any terrestrial experiments. In this work, we perform a Bayesian analysis putting together the available knowledge from the nuclear physics experiments, observations of different x-ray sources and the gravitational wave event GW170817 to constrain the equation of state of supranuclear matter.
In particular, we employ a relativistic mean field model to calculate the saturation properties of nuclear matter i.e. the symmetry energy and its slope parameter, the incompressibilty, the effective mass of nucleon, the binding energy per nucleon and the saturation density. Then, we investigate if it is possible to reconcile the inferred values of those quantities from observational data with the values obtained from nuclear experiments and compute a joint posterior of these quantities incorporating all the available knowledge. We also study the possibility of the existence of strange matter inside the NS in the form of hyperons or a phase transition into a strange quark star.

Invited Talks / 186

Neutron star mergers across the electromagnetic spectrum

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The discovery of the gravitational wave transient GW170817 and its electromagnetic counterparts ushered in a new era of multi-messenger. astrophysics, in which both gravitational waves and light provide complementary views of the same source. These observations gave astronomers an unprecedented opportunity to probe the merger of two neutron stars, solving decade-long mysteries about the origin of short duration gamma-ray bursts (GRBs) and the production of elements heavier than iron. In this talk, I will present the long-term evolution of GW170817 across the electromagnetic spectrum, and discuss its similarities with the sample of short GRBs at cosmological distances.

Invited Talks / 128

Resonant Shattering Flares as Multimessenger Probes of Neutron Star Physics (Invited)

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Resonant Shattering Flares (RSFs) are expected to occur during the inspiral phase for some NS-NS and NS-BH mergers. They result from the resonant tidal excitation of the NS crust-coreinterface mode fracturing the crust and sparking a relativistic pair-photon fireball, emitted seconds before the merger.

RSFs are prompt, bright, and isotropic, allowing potential detection and triggering from well beyond the LIGO-horizon and may be an important source for detectable electromagnetic counterparts to GW mergers. When a GRB is present, they appear as pre-cursors to the main flare, while for off-axis systems they should appear as isolated under-luminous GRBs with extremely short duration. RSFs will depend on the age and magnetic evolution of neutron stars, as they require sufficient surface magnetic field to mediate the energy release.

I will discuss the physics and detectable emissions for RSFs compared to other counterparts, in NS/NS and NS/BH mergers, as well as estimates of the number of expected RSFs compared to possible orphan events.

Poster Session / 164

Epicyclic oscillations in the Hartle-Thorne external geometry

Authors: Gabriela Urbancová[1]; Martin Urbanec[1]; Gabriel Török[None]; Zdenek Stuchlik[1]; Martin Blaschke[1]; John C. Miller[2]

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The external Hartle-Thorne geometry, which describes the spacetime outside a slowly rotating compact star, is characterised by the gravitational mass M, angular momentum J, and quadrupole moment Q of the star and gives a convenient description, which, for the rotation frequencies of more than 95% of known pulsars, is sufficiently accurate for most purposes. Our investigation is motivated by X-ray observations of binary systems containing a rotating neutron star that is accreting matter from its binary companion. We use realistic equations of state for the stellar matter and proceed in a self-consistent way, following the Hartle-Thorne approach in calculating both the corresponding values of Q, M, and J for the stellar model and the properties of the surrounding spacetime. Our results are then applied to a range of geodetical models for QPOs.

Parallel 3A / 158

Measuring mass of neutron star in LMXBs using QPO observations

Author: Martin Urbanec[None]

Co-authors: Gabriel Török ; Katerina Klimovicova ; Gabriela Urbancova ; Eva Sramkova

Detection of twin peak quasi-periodic oscillations in power-density spectra of low-mass X-ray binaries can be used to constrain mass of the compact object. In this presentations we will apply the so-called cusp torus model to neutron star in 4U 1646-53 to determine the mass of the neutron star. We will also discuss the possibility to constrain the radius of the neutron star as well.

Poster Session / 30

A Chandra proper motion for magnetar CXO J164710.2-455216

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We report on a Chandra exposure of CXO J164710.2-455216 using the ACIS-S detector on the board totaling ~ 120 ks for three observations. By registration of field X-ray sources in archival exposure, we have measured a notable proper motion for the magnetar over a ≈ 12.5 yr baseline. We discuss the magnetic field evolution of the source as well as spin-down age.

Parallel 2B / 12

Gravitational dynamics of relativistic binary pulsar systems

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Pulsars in relativistic binary systems are excellent probes of fundamental physics and binary evolution. Long term measurements of pulse arrival times from such pulsars enable theory-independent measurements of relativistic parameters that can then be used for testing different theories of gravity such as General Relativity and scalar-tensor theories of gravity. Assuming a theory of gravity, such experiments also provide highly precise measurements of neutron star masses and insights on their\nequation of state. In this talk, I will provide an introduction to pulsar timing, and present

recent results from long term timing campaigns of different relativistic binary pulsars including the first observations of Lense-Thirring precession in a binary pulsar system. I will also discuss a possible supra-massive pulsar in an eccentric binary system.

Invited Talks / 21

How giant magnets shine and slowly fade away (Invited)

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The coupled evolution of magnetism and temperature inside neutron stars has a direct imprint on the rotational and spectral properties observed in their population. These different manifestations of isolated neutron stars can be unified under an evolutionary scenario where the magnetic field and its long-term evolution plays a key role in shaping the X-ray detectability. In addition, the magnetosphere enriches the observable properties, by means of photon upscattering, instabilities triggered by internal stresses, and long-living, Sun-like coronal loops which heat the surface. I will review the evolutionary models for magnetised isolated neutron stars, and the connections to the magnetospheric outburst activity.

Parallel 3B / 57

Common–Envelope Episodes that lead to Double Neutron Star formation

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Double Neutron Stars (DNSs) have been observed as Galactic radio pulsars, gamma-ray bursts and gravitational-wave sources. They are believed to have experienced at least one common-envelope episode (CEE) during their prior evolution to DNS formation. In the last decades, there have been numerous efforts to understand the details of the common-envelope phase, but there is still no consensus. I present work on binary population synthesis of field-born double neutron stars in order to constrain the parameter space at the onset of the mass transfer episode leading to these CEEs. We present and discuss the properties of the donor and the binary at the onset of the Roche-lobe overflow leading to that CEE. These properties can be used as initial conditions for detailed simulations of the common-envelope phase. We find that there are three distinctive populations, which depend on the evolutionary stage of the donor at the moment of the onset of the Roche-lobe overflow (RLOF): giant donors with fully convective envelopes, cool donors with partially convective envelopes, and hot donors with radiative envelopes. We also estimate that, for standard assumptions, tides would not circularise a large fraction of these systems between the onset of RLOF and the start of the CEE. This makes the study and understanding of eccentric mass transferring systems relevant for DNS populations.

Parallel 2B / 72

Spritz: a new fully general relativistic magnetohydrodynamics code

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At the dawn of multi-messenger astrophysics with gravitational wave sources, numerical relativity simulations of compact binary mergers involving black holes and neutron stars play, more than ever, a central role. An accurate representation of these systems requires solving Einstein's equations on dynamical spacetimes, coupled with the general relativistic magnetohydrodynamic (GRMHD) equations. To face this challenge, we developed a new GRMHD code, named Spritz, capable of accurately evolving the magnetic field preserving its divergence-free condition, dealing with temperature and composition dependent equations of state, and taking into account neutrino radiation. In this talk, I will present the key features of this code and a range of possible applications, including in particular binary neutron star merger simulations.

Parallel 2A / 9

Discovery of subsecond jet variability in an accreting neutron star

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We present the discovery of sub-second X-ray/IR correlated variability in the accreting neutron star (NS) 4U 1728-34. The source was observed with simultaneous high time resolution XMM and HAWKI@VLT in February 2019. Data show a strongly correlated signal with a lag shorter than 0.125 s. Such behaviour is well known in black-hole transients, where fluctuations travel from the accretion inflow to an IR emitting jet with a lag of 0.1s. Given that observations were taken during the hard state (i.e. when the jet is active), this result points towards a common jet mechanism for BH and NS. We discuss the physical implications of this discovery and the future perspectives of multiwavelength variability in accreting NS.

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Spider binaries seen as two interacting magnetospheres

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Black widows and redbacks harbour a millisecond pulsar and a low-mass non-degenerate secondary in tight orbits, with an orbital period of just a few hours. In these systems, the interaction between the pulsar wind and a spider companion leads to observable features such as X-ray shocks, irradiation of the companion surface and radio eclipses due to evaporated material. Spiders thus provide us with an exceptional set of observables and a opportunity to peer into the properties of the pulsar wind. However, taking advantage of these observables implies a modelling effort if one hopes to extract long-sought quantities such as the magnetisation, Lorentz factor or even geometry of the pulsar wind. In this talk, after briefly reviewing the aforementioned observables, we will discuss a simple model describing the interaction between a cold current sheet and the companion's magnetosphere and explore the coupled geometry of the two interacting magnetospheres, considering them no longer as two separate colliding entities but as a whole.

Parallel 3B / 112

Predicting Broadband Emission from Millisecond Pulsar Binaries

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Black widow (BW) and redback (RB) systems are compact binaries in which the pulsar heats or ablates its low-mass companion by its intense wind of relativistic particles and emission. Radio, optical and X-ray follow-up of unidentified Fermi Large Area Telescope (LAT) sources has expanded the number of these systems from four to nearly 30. Orbital modulation in X-rays suggests that in many systems, an intrabinary pulsar termination shock exists as a site for particle acceleration, which in many instances wraps around the pulsar. We model the X-ray and γ-ray spectral components from nearby "spider binaries", including diffusion, convection and radiative energy losses in an axially-symmetric, steady-state approach. The code simultaneously yields energy-dependent light curves and orbital phase-resolved spectra. We constrain certain model parameters and estimate the broadband flux for various systems via data fitting, enabling us to identify the effect that different system conditions (e.g. shock orientation or stand-off distance) have on the expected emission from the two subclasses. Two sources, J1723-2837 (RB) and J1311-3430 (BW), have potentially been observed by Fermi-LAT, leading to constraints on the maximum particle energy and particle acceleration in this mini-PWNe. We find that nearby binaries in a 'flaring state'are promising targets for H.E.S.S. and the future Cherenkov Telescope Array (CTA), and that GeV photons (in the off-peak phases of the pulsar light curve) may be detectable by Fermi-LAT for optimistic parameter choices. Moreover, some of these systems will be excellent targets for future MeV missions such as AMEGO.

Poster Session / 113

Repeating FRBs from Low-twist Magnetars

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I will discuss our recently-published magnetospheric model for repeating FRBs generated during short bursts in magnetars with low-twist magnetospheres. I will detail current observational evidence supporting the model. Some theoretical and heuristic expectations of phenomenology will be discussed. Finally, I will detail how the model may be tested in the future, as well as implications of what could be learned from FRBs if the model is correct.

Parallel 3A / 47

Cooling of Hybrid stars

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The appearance of quark matter may show a different property with traditional NS in the cooling process. With this purpose, we investigate the cooling of hybrid star. For the hadronic sector, we use a microscopic EOS derived within the Brueckner-Hartree-Fock many-body theory with realistic two-body and three-body forces. For the description of quark matter, we employ the Dyson-Schwinger quark model. We also consider the MIT bag model and field correlator method for the comparison. We find that once the quark matter appears, the hybrid star initiates a fast cooling again even the hadronic sector is suppressed by the pairing gaps.

Invited Talks / 91

Radio emission as a probe for pulsar magnetospheres (Invited)

Author: Patrick Weltevrede[1]

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Over 50 years of pulsar observations has proven that understanding the structure of pulsars magnetospheres and the exotic processes taking in it is difficult. This includes the lack of understanding of how they generate radio emission. Nevertheless, radio observations provides a wealth of information related to variability, polarization and their spectral dependence. Important lessons can be learned about pulsar magnetospheres by studying their radio emission, even without a detailed understanding of the physical mechanism responsible for the production of radio emission. This should help steering theoretical efforts in providing a self-consistent description about how pulsars operate, which is relevant for much more than explaining the observed radio emission of pulsars.

Parallel 2A / 149

Quantum vortices in ultracold atomic gases and in neutron stars: similarities and differences

Author: Gabriel Wlazłowski[1]

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Superfluidity is a generic feature of various quantum systems at low temperatures. It has been experimentally confirmed in many condensed matter systems, in 3He and 4He liquids, in nuclear systems including nuclei and neutron stars, in both fermionic and bosonic cold atoms in traps, and it is also predicted to show up in dense quark matter. Quantized vortices are regarded as hallmark of superfluidity. Nowadays, these excitations are routinely created and imaged in ultracold atomic gases. This platform allows also to tune the system towards regime of strong interactions. In this limit cold atoms become a good approximation for the dilute neutron matter in the inner crust of neutron stars where neutron-rich nuclei form a Coulomb lattice immersed in a neutron superfluid.

In my talk I will overview recent progress related to studies of quantum vortices in strongly interacting ultracold fermionic gases. Impact of spin imbalance on the internal vortex structure will be presented. In context of neutron matter, the spin imbalance is generated as results of very strong magnetic field and thus the results are relevant to vortices in magnetars. Next, I will focus on dynamical properties of the vortices with special emphasis on vortex-vortex and vortex-impurity interaction. Finally, I will discuss how the neutron stars community can benefit from ongoing effort of vortex studies in ultracold atomic clouds, especially in context of constructing accurate hydrodynamic model of glitching neutron star starting from microscopic (nuclear) level.

Parallel 2B / 117

A resistive extension for GRMHD

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Neutron star (NS) matter is typically modelled as a superconductor, and as a result numerical simulations, by and large, evolve the ideal MHD equations. There is reason to believe that during events such as NS mergers or accretion on to black holes, however, resistive effects may become important and significantly change the structure of the magnetic fields and the dynamics of ejecta. In this talk, I will discuss how we have extended a resistive source term (REGIME) valid in SR to curved and dynamic spacetimes, the benefits gained over evolving a fully resistive GRMHD model, and the potential applications of such an extension.

Parallel 3B / 170

New neutron star solutions in tensor-multi-scalar theories

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In this talk we will present some very interesting solutions describing neutron stars in tensor-multi-scalar theories of gravity. It turns out that in certain subclasses of these theories, the spectrum of solutions can be very rich leading to interesting observational consequences. Taking into account that the scalar-tensor theories are ones of the few examples of mathematically well posed alternative theories of gravity, the presented solutions offer the perfect opportunity to study the dynamics and impose further constraints on the strong field regime of gravity via future astrophysical observations.

Parallel 3A / 93

Transient gravitational waves from pulsar post-glitch relaxations

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This talk explores whether gravitational waves (GWs) from neutron star (NS) mountains can be detected with current 2nd-generation and future 3rd-generation GW detectors. In particular, we focus on a scenario where transient mountains are formed immediately after a glitch. In a glitch, the NS's spin frequency abruptly increases and then often exponentially relaxes back to, but never quite reaches, the spin frequency prior to the glitch. If the relaxation is ascribed to an additional torque due to a transient mountain, we find that GWs from that mountain are not detectable with 2nd-generation detectors, but will be for 3rd-generation detectors such as the Einstein Telescope.

Parallel 2A / 151

Very cool gamma-ray pulsar J1957+5033

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The gamma pulsar J1957 + 5033 has a period of 375 ms, a characteristic age of 840 thousand years, and a rotation energy loss rate of 5e33 erg / s. According to the age, this pulsar can be at the beginning of the photon stage of the neutron star cooling process when according to standard cooling scenarios the surface temperature and thermal luminosity of a star, begin to drop exponentially with time. We present the results of X-ray observations of the pulsar with XMM-Newton. The data show that the thermal spectral component dominates in the low-energy part of its X-ray emission. Its spectral analysis results in a very low surface temperature of the neutron star, less than 30 eV (for a distant observer). This makes this neutron star one of the coldest among known neutron stars, where the thermal component from the entire star surface was found. The estimated bolometric luminosity of the thermal component is rather week and lies in the range 1.4e30 - 1.3e31 erg/s. If we take the characteristic age as an upper limit of the true age, then the low luminosity value can be explained either by direct Urca processes (which requires the star to be massive) or by nucleon superfluidity (which can be used to test modern superfluidity models).

Parallel 1B / 168

The First Day in the Life of a Magnetar

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The plateau phases in the X-ray light curves of gamma-ray burst afterglows are explained by the presence of newly-born millisecond magnetars that are slowing down under the action of the spin-down component of the magnetic dipole radiation torque. The alignment component of this torque affects the angle between the magnetic dipole moment and rotation axis of the star, i.e., the inclination angle. We present, for the first time, the effect of the alignment torque coupled with the spin-down torque on the evolution of a nascent millisecond magnetar in the presence of a corotating plasma by modeling the X-ray afterglow emission of gamma-ray bursts. We find that the rotation and magnetic axis of the magnetar align rapidly during the afterglow emission. We discuss that the magnetic dipole moment may also be decreasing rapidly during the first day of a nascent magnetar which suggests afterglows without an apparent plateau phase may be powered by magnetars. Finally, we show that the braking index of a nascent magnetar varies rapidly due to the alignment torque as well as rapid evolution of the magnetic dipole moment.