The Modern Physics of Compact Stars and Relativistic Gravity 2025

Report of Contributions

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Contribution ID: **39** Type: **not specified**

Equation of state of superdense matter from future high-precision neutron star radius measurements

To more precisely constrain the Equation of State (EOS) of supradense neutron-rich nuclear matter, future high-precision X-ray and gravitational wave observatories are proposed to measure the radii of neutron stars (NSs) with an accuracy better than about 0.1 km. However, it remains unclear what particular aspects (other than the stiffness generally spoken of in the literature) of the EOS and to what precision they will be better constrained. In this talk, within a Bayesian framework using a meta-model EOS for NSs, we discuss what aspects of nuclear EOS can (and what can not) be better constrained by future high-precision NS radius measurements. In particular, we infer the posterior probability distribution functions (PDFs) of incompressibility K_0 and skewness J_0 of symmetric nuclear matter (SNM) as well as the slope L, curvature $K_{\rm sym}$, and skewness $J_{\rm sym}$ characterizing the density dependence of nuclear symmetry energy $E_{\rm sym}(\rho)$, respectively, from mean values of NS radii consistent with existing observations and an expected accuracy ΔR ranging from about 1.0 km to 0.1 km. Effects of high-precision NS radius measurements on determining properties of first-order hadron-quark phase transition will also be discussed.

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Contribution ID: **40** Type: **not specified**

Antikaon Condensed Dense Matter In Neutron Star with SU(3) Flavour Symmetry

Observations of massive pulsars indicate that the core densities of compact stars can greatly exceed nuclear saturation density, possibly giving rise to exotic forms of matter such as hyperons, meson condensates, and quark matter. Among meson condensates, anti-kaon (K^-) condensation stands out as a promising candidate, though the nature of kaon-meson interactions remains incompletely understood. Employing SU(3) flavor symmetry, we compute hadronic couplings in the mesonic sector, building upon and refining previous quark model approaches. Important parameters—including the mixing angle (θ_v), the octet-to-singlet coupling ratio (z), and the symmetric-to-antisymmetric weight factor (α_v)—are determined, with α_v treated as a free parameter. Our findings demonstrate that increasing α_v leads to a stiffer equation of state, postpones the onset of K^- condensation, and results in higher neutron star masses. The K^- condensation emerges through a second-order phase transition, with its onset being highly sensitive to the value of α_v.

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Contribution ID: **41** Type: **not specified**

Spherical orbits and shadows of Kerr black holes surrounded by quintessence

Spherical orbits around rotating black holes have a major astrophysical importance. In the presence of quintessential matter [1, 2], the geodesic equations can be investigated using a combined numerical-analytical approach [3]. One may notice significant differences compared to the results previously derived for Kerr black holes [4]. Also, as it is known, the rotating black holes produce shadows that differ significantly from those of nonrotating black hokes which are perfectly circular. By comparing the theoretically derived shadow's observables with data on $M87 and\ Sgr\ A$ from the Event Horizon Telescope, one may impose constraints on the black hole's parameters and highlight the impact of quintessence [5].
References
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[5] S. Haroon et. al. Shadow and deflection angle of rotating black holes in perfect fluid dark matter with a cosmological constant. Physical Review D 99(4), 044015 (2019)

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Contribution ID: **42** Type: **not specified**

Inferring the Equation of State from Neutron Star Observables via Machine Learning

We have conducted an extensive study using a diverse set of equations of state (EoSs) to uncover strong relationships between neutron star (NS) observables and the underlying EoS parameters using symbolic regression method. These EoS models, derived from a mix of agnostic and physics-based approaches, considered neutron stars composed of nucleons, hyperons, and other exotic degrees of freedom in beta equilibrium. The maximum mass of a NS is found to be strongly correlated with the pressure and baryon density at an energy density of approximately 800 MeV.fm^{-3}. We have also demonstrated that the EoS can be expressed as a function of radius and tidal deformability within the NS mass range 1-2$M_{\odot}$. These insights offer a promising and efficient framework to decode the dense matter EoS directly from the accurate knowledge of NS observables.

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Contribution ID: **43** Type: **not specified**

Negative-energy and Tachyonic Solutions of Relativisti Equations

Abstract
We analyzed the recent controversies in the definitions of the Feynman-Dyson propagator for the field operator. In this work we present some insights with respect to this for spin 1/2. Both algebraic equation $Det(\hat{p} - m) = 0$ and $Det(\hat{p} + m) = 0$ for u− and v− 4-spinors have solutions with $p_0 = \pm E_p = \pm\sqrt{p^2 + m^2}$. The same is true for higher-spin equations (or they may even have more complicated dispersion relations, tachyons). The Fock space can be doubled on the quantum-field (QFT) level. In this talk we give additional bases for the development of the correct theory of spin particles in QFT. It seems, that it is imposible to consider the relativistic quantum mechanics appropriately without negative energies, tachyons and appropriate forms of the discrete symmetries, and their actions on the corresponding physical states.

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Contribution ID: **44** Type: **not specified**

$\tilde{\xi}$-attractors in metric-affine gravity

We propose a new class of inflationary attractors in metric-affine gravity. Such class features a non-minimal coupling $\tilde{\xi}\,\Omega(\phi)$ with the Holst invariant $\tilde{calR}$ and an inflaton potential proportional to $\Omega(\phi)^2$. The attractor behaviour of the class takes place with two combined strong coupling limits. The first limit is realized at large $\tilde{\xi}$, which makes the theory equivalent to a $\tilde{calR}^2$ model. Then, the second limit considers a very small Barbero-Immirzi parameter which leads the inflationary predictions of the $\tilde{calR}^2$ model towards the ones of Starobinsky inflation. Because of the analogy with the renown ξ-attractors, we label this new class as $\tilde{\xi}$-attractors.

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Contribution ID: **45** Type: **not specified**

Monistic modification of Einstein's geometrical physics

The pseudo-Riemann metric organization of spacetime can describe the quasi-elastic field hierarchy with the constant rest energy integral in the case of negligible inelastic losses or non-metric intrusions. Visible matter consists of very dense regions of massive fields associated with the material analogue of the Einstein tensor. The non-Schwarzschild metric solution of the non-dual analogue of the Einstein equation preserves the Euclidean 3 geometry for the inhomogeneous matterspace continuum and describes post-Newtonian gravity in line with known measurements. Locally dilated time in a nonlocal field hierarchy generates a primary reason for holistic mass densities and their auto-accelerations, rather than distant gravitational pulls in the dualistic alternative of pairwise interactions. Precise measurements can distinguish between the monistic and dualistic nature of observable astrophysical phenomena.

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Contribution ID: **46** Type: **not specified**

Tsallis holographic dark energy (Observational data)

We investigate Tsallis holographic dark energy (THDE) model in light of modern observations of supernovae, Hubble parameter measurements, data for baryon acoustic oscillations and fluctuations of matter density. The dark energy density for THDE model is written as ρd=3C2/L4−2γ where C and γ are some constants. Scale L is infrared cut-off length for which we use the event horizon. For analysis of type Ia supernovae (SNeIa) data Pantheon+ samples are involved. Dark Energy Spectroscopic Instrument (DESI) 2024 measurements serves as source of data about ratios between sound horizon rd and Hubble (dH) or volume averaged (dV) distances. The updated dataset of Hubble parameter for various redshift is also used in our analysis. Finally we consider the dependence of matter density fluctuations in past from redshift. The standard strategy of χ2 minimizing allows to estimate the optimal values of parameters (Ωde and H0) for some fixed values of C and γ. One note that best-fit values for parameters H0 from Hubble parameter and SNeIa data are more close than in standard ΛCDM model for some C and γ although problem of Hubble tension remains unsolved. The combined data analysis also gives slightly better results in comparison with standard cosmology. We include in our consideration the possible interaction between matter and holographic component and estimate the acceptable interval of model parameters in this case.

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Contribution ID: **47** Type: **not specified**

Hybrid Nuclear Matter EOS with Color Superconducting Quark Phase: Bayesian Constraints from Observations

We perform a Bayesian analysis of the equation of state (EOS) constraints using recent observational data, including pulsar masses, radii, and tidal deformabilities. Our focus is on a class of hybrid neutron star EOS that incorporates color superconducting quark matter, based on a recently developed nonlocal chiral quark model. The nuclear matter phase is described using a relativistic density functional approach within the DD2 class, while the phase transition between nuclear and quark matter is described using a Maxwell construction.
Our analysis identifies a region within the two-dimensional parameter space, defined by the vector meson coupling and scalar diquark coupling, where the observational constraints are met with the highest probability (90% of the maximum). We present the overlap of this region with those where other properties are fulfilled:
1. A strong phase transition that produces a third family of compact stars.
2. A maximum mass of the hybrid neutron star that exceeds that of the purely nucleonic star.
3. An onset mass for quark deconfinement below one solar mass.

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Contribution ID: **48** Type: **not specified**

Interaction of Cosmic Strings and Black Holes

The relationship between cosmic strings and black holes is examined in this work, with particular attention paid to how cosmic strings affect the spin and accretion processes of black holes. The study investigates the effects of a cosmic string on the mass, spin, and rotational energy of black holes and how changes in the innermost stable circular orbit (ISCO) of accretion disks can be used to identify these changes.

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Contribution ID: **49** Type: **not specified**

On peculiar Gaia neutron star binaries

Gaia detected a new population of neutron stars. They are the oldest neutron stars known, which are members of wide binaries with small orbital velocities. I argue that their current orbits are fossils of their turbulent youth and present considerable clues to the physics of their younger selves.

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Contribution ID: **50** Type: **not specified**

Motion of test particles around a magnetized black hole surrounded by quintessence

We investigate the dynamics of test particles near a magnetized black hole surrounded by quintessence which is modeled as an anisotropic fluid with a specific equation of state [1,2]. The motion of both massive and massless test particles is analyzed using the Lagrangian formalism, with particular focus on the effective potential governing their trajectories. Quintessence modifies the space-time curvature at large distances, while the magnetic field introduces Lorentz-like forces acting on charged particles[3,4]. We determine the conditions for the existence and stability of circular orbits and examine how the quintessence and magnetic field parameters influence the location of the innermost stable circular orbit (ISCO) and the presence of bounded trajectories. Our findings highlight the intricate interplay between dark energy effects and magnetic interactions, offering potential insights for astrophysical observations near active galactic nuclei and magnetized black holes.

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Contribution ID: **51** Type: **not specified**

Gapless superfluidity and neutron stars

Born from gravitational-core collapse supernovae, with initial temperatures as high as $\sim 10^{12}$K, neutron stars cool down to temperatures 10^9 K within a few days, providing a unique opportunity to explore matter under extreme conditions. In particular, neutron stars contain nuclear superfluids whose presence is supported by observations of pulsar frequency glitches, rapid decline in luminosity of the Cassiopeia A remnant, and crust cooling of neutron stars in low-mass X-ray binaries.

Despite the importance of the superfluid dynamics in interpreting these astrophysical phenomena, most microscopic calculations of the nuclear pairing properties have been carried out so far for static situations. We have recently studied the dynamics of hot neutron-proton superfluid mixtures within the time-dependent nuclear energy-density functional theory [1,2].

The disappearance of superfluidity has also been investigated and reveals the presence of a dynamical "gapless" state in which nuclear superfluidity is not destroyed even though the energy spectrum of quasiparticle excitations exhibits no gap. The absence of an energy gap affects considerably the neutron specific heat which becomes very different from that in the classical BCS state (in the absence of superflows) [3]. Implications for the crust cooling of neutron stars in low-mass X-ray binaries will be discussed, as well as the consequences of gapless superfluidity for neutron vortex dynamics [4].

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[4] V. Allard & N. Chamel, Phys. Rev. Lett. 132, 181001 (2024)

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Contribution ID: **52** Type: **not specified**

Uniform models of neutron and quark stars in General Relativity

Models of neutron and quark stars are considered in the case of a uniform density distribution. A universal
algebraic equation, valid for any equation of state, is obtained in General Relativity. This equation allows one to find
the approximate mass of a star for a given density without resorting to the integration of differential equations. The solutions neutron star models for various equations of state, are calculated. The maximum values of stable NS masses differ from the values in exact solutions obtained by the numerical integration of differential equations by at most 20%.

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Contribution ID: **53** Type: **not specified**

Cosmological effect of coherent oscillation of ultralight scalar fields in a multicomponent universe

The idea that coherent oscillations of a scalar field, oscillating over a time period that is much shorter than the cosmological timescale, can exhibit cold dark matter (CDM) like behavior was previously established. In our work we first show that this equivalence between the oscillating scalar field model and the CDM sector is exact only in a flat Friedmann-Lemaitre-Robertson-Walker (FLRW) spacetime in the absence of cosmological constant and any other possible matter components in the universe when the mass of the scalar field is very large compared to the Hubble parameter. Then we show how to generalize the equivalence between the coherently oscillating scalar field model and the CDM sector in a spatially curved universe with multiple matter components. Using our general method, we will show how a coherently oscillating scalar field model can represent the CDM sector in the presence of non-minimal coupling of the CDM sector with radiation. Our method is powerful enough to work out the dynamics of gravitational collapse in a closed FLRW spacetime where the coherently oscillating scalar field model represents the CDM sector. We have, for the first time, presented a consistent method which specifies how a coherently oscillating scalar field model, where the scalar field is ultralight, acts like the CDM sector in a multicomponent universe.

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Contribution ID: **54** Type: **not specified**

Fastest spinning millisecond pulsars: indicators for quark matter in neutron stars?

We study rotating hybrid stars, with a particular emphasis on the effect of a deconfinement phase transition on their properties at high spin. Our analysis is based on a hybrid equation of state with a phase transition from hypernuclear matter to color-superconducting quark matter, where both phases are described within a relativistic density functional approach. By varying the vector meson
and diquark couplings in the quark matter phase, we obtain different hybrid star sequences with varying extensions of the quark matter core, ensuring consistency with astrophysical constraints from mass, radius, and tidal deformability measurements. We test whether the early deconfinement
phase transition is consistent with the present observational data. We show how the fastest spinning
pulsars and the appearance of the quasi-radial oscillations and non-axisymmetric instabilities constrain the strongly interacting matter equation of state at zero temperature. Our findings reveal that
incorporating the hybrid equation of state into the analysis of pulsars has significant implications for the constraints on the properties of strongly interacting matter and neutron stars which is of the
high interest for the future SKA observations.

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Contribution ID: **55** Type: **not specified**

Urca cooling of the neutron star in the Cassiopeia A supernova remnant

Observed cooling rate of the young neutron star (NS) in the Cassiopeia A supernova remnant (Cas A NS) exceeds theoretical expectations based on conventional scenarios of NS cooling, controlled mainly by modified Urca (mUrca) neutrino emission. Several hypotheses have been suggested to explain these observations. The most popular one assumes the cooling enhancement by neutrino emission due to the Cooper pair breaking and formation (PBF) just after the onset of neutron superfluidity in the NS core. This explanation requires strict constraints on critical temperatures of proton and neutron superfluidities in the NS core and on the efficiency of the PBF cooling mechanism. These constraints are in tension with the modern theory. To relax them, Lev Leinson (2022) suggested a hybrid cooling scenario, where the direct Urca (dUrca) process of neutrino emission from a small NS central kernel contributes to the cooling enhancement in addition to the PBF process. We show that Cas A NS cooling needs not to be hybrid, as the joint effect of Urca (dUrca+mUrca) processes can explain the observations equally well with or without superfluidity and the PBF mechanism. We explore the Urca scenario with different assumptions about NS equation of state, baryon superfluidity, and composition of the outer heat-blanketing envelope. We show that the observed cooling rate can be reproduced with many combinations of these assumptions by tuning the NS mass, which should slightly exceed the threshold mass for opening the dUrca process in the kernel. Then the core stays non-isothermal for centuries, delaying the onset of enhanced dUrca cooling to satisfy the Cas A NS observations. In addition, we present an analytic toy model which elucidates many features of the Urca scenario. The work was supported by the Russian Science Foundation Grant No.24-12-00320.

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Contribution ID: **56** Type: **not specified**

simulation of a neutron star with MDG model

We study the structure of neutron stars within the framework of Minimal Dilatonic Gravity (MDG), a scalar–tensor theory related to Brans–Dicke gravity with ω = 0. Using two realistic unified equations of state (EOS), LOCV1811 and LOCV1815, we analyze stellar configurations for different values of the dilaton field mass mΦ. Our results show that a dilaton halo forms around the neutron star, contributing significantly to the total mass. The halo mass fraction reaches 20–30% in neutron stars with masses greater than $2M_{\odot}$, leading to total masses that exceed those predicted by General Relativity. These results are consistent with mass measurements from recent gravitational wave and NICER observations. We also find that smaller dilaton field masses yield more massive neutron star–halo systems. For high-density stars, the dilaton pressure becomes negative at the center and behaves like dark energy, modifying the radial profile of the dilaton field.
Keywords: Minimal Dilatonic Gravity, neutron stars, LOCV1811, LOCV1815, dilaton field, scalar-tensor theory, dilaton halo

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Contribution ID: **57** Type: **not specified**

The Waveform Derivation of Inspiralling Compact Binary Mergers

The ground based gravitational wave detectors such as LIGO, measures metric perturbation in to a preferred polarization basis. The initial Ligo configuration runs were based on second post Newtonian approximation of quadrupolar moments. A post Minkowskian and a post Newtonian approach is adopted for the wave form generation of slow moving and non-spinning binaries. The non linearity of Einstein field equation is considered at higher masses (>12 M⊠). The gravitational damping is derived by taking account of a quasi-circular orbit. The angular velocity and phase angle are determined in time domain. The gravitational radiation causes shrink of orbital radius and increase in orbital frequency and amplitude. The gravitational chirp feature on wave form is derived. The gravitational wave strain effect on the detector antenna response is discussed in present scenario and future advancement of observatories.
Key words LIGO, Post Newtonian, Gravitational radiation, Gravitational chirp
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Contribution ID: **58** Type: **not specified**

Potential of probing the neutron star composition in accreting x-ray binaries

Transiently accreting low-mass x-ray binaries have the potential to probe the core composition of their neutron stars via deep crustal heating caused by nuclear reactions. We statistically assess this deep crustal heating scenario, taking into account the various microphysical and astrophysical uncertainties. We find that despite the sizable uncertainties, there is a chance to discriminate different compositional scenarios. Several observed sources statistically challenge a minimal hadronic matter composition, where cooling proceeds exclusively via slow modified Urca reactions. Considering here two exemplary extended uniform compositions, namely ultradense hadronic matter with direct Urca emission and ungapped quark matter, we find that they are even within uncertainties distinguishable. We show that although exotic forms of matter are generally only expected in an inner core, which could in principle have any size, sufficiently large astrophysical datasets nonetheless have the potential to statistically discriminate compositional scenarios, in particular when further mass measurements become available.

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Contribution ID: **59** Type: **not specified**

Advances in Numerical Relativity for Modeling Compact Binaries and Gravitational Wave Emission

Abstract:
Numerical relativity (NR) has revolutionized our understanding of strong-field gravity, enabling high-fidelity simulations of compact binary systems. This paper reviews recent breakthroughs in NR methodologies, with emphasis on binary neutron star (BNS) and black hole–neutron star (BHNS) mergers. We discuss advancements in adaptive mesh refinement, constraint-damping formulations, and microphysical treatments of neutron star matter. These developments have refined predictions of gravitational waveforms, kilonova signatures, and remnant behavior, directly impacting multimessenger astronomy. We also present new results from simulations of high-spin BHNS systems and high-mass-ratio BNS mergers, highlighting implications for upcoming gravitational wave detectors (e.g., Einstein Telescope, Cosmic Explorer) and nuclear astrophysics.

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Contribution ID: **60** Type: **not specified**

Scalar vacuum densities on Beltrami pseudosphere

The combined effects of spatial curvature and topology are investigated on the properties of the vacuum state for a charged scalar field localized on the (2+1)-dimensional Beltrami pseudosphere. It is assumed that the field obeys the quasiperiodicity condition along azimuthal angle with a constant phase. As important local characteristics of the vacuum state the vacuum expectation values (VEVs) of the field squared and energy-momentum tensor are evaluated. The VEVs are decomposed into compactified and uncompactified parts. The contributions in the VEVs coming from geometry with an uncompactified azimuthal coordinate are divergent, whereas the compact counterparts are finite. The renormalization of the VEVs is reduced to that for the uncompactified parts only. As an important special case we have discussed the conformally coupled massless scalar field. The geometry for the Beltrami pseudosphere is conformally related to the (2+1)-dimensional Rindler spacetime and the corresponding VEVs of the energy-momentum tensor in these two spacetimes are conformally related as well. The topological contributions are analysed asymptotically for the limiting values of the ratio of radial coordinate and compactification length. This ratio corresponds to the inverse of the proper radius of the compactified dimension measured in units of the curvature radius. For small values of the ratio, the decay of the compact counterpart in the energy density follows a power-law. The effect of nontrivial topology is strong for the radial and azimuthal stresses at small values of the radial coordinate in the conformally coupled massless case. The nontrivial topology is essential also in the opposite asymptotic limit, where the magnitudes of VEVs are increasing by a power-law.

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Contribution ID: **62** Type: **not specified**

General Relativistic Magnetohydrodynamic Simulations of Black Hole Accretion Disks

Understanding the dynamics of magnetically arrested accretion disks (MAD) is crucial for deciphering relativistic jet launching mechanisms in black hole systems. General relativistic magnetohydrodynamics (GRMHD) simulations provide the most comprehensive framework for probing these extreme environments, where angular momentum transport efficiency fundamentally governs accretion-ejection coupling. This study addresses critical gaps in modeling how radiative cooling and enhanced angular momentum transport (q = 1.0) regulate jet launching thresholds during MAD state transitions.
Our advanced GRMHD simulations reveal a significant phase transition at t = 5M (gravitational timescales), where magnetic flux saturation triggers relativistic jets through the Blandford-Znajek mechanism. The q = 1.0 parameterization delays MAD onset by 25% while boosting jet efficiency —resolving persistent timing discrepancies in jet activation observed in prior studies. Quantitative validation against Event Horizon Telescope (EHT) data shows good agreement, with peak jet Lorentz factors exceeding $\Gamma > 15$ and energy conversion to kinetic outflows reaching 68%.
These results establish q = 1.0 cooling models as essential tools for interpreting state transitions in low-luminosity active galactic nuclei (AGN), providing a self-consistent framework linking angular momentum transport physics to observable jet kinematics.
Keywords: GRMHD simulations, MAD accretion, Blandford-Znajek mechanism, jet launching, black hole astrophysics, EHT observables

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Contribution ID: **63** Type: **not specified**

Exotic Matter and the Neutron Star EOS: Observational Signatures of Hyperons, Bosonic Dark Matter, and Quark Matter

The presence of dark matter in neutron stars is of growing interest due to its possible impact on their structure and observables. Among proposed candidates, the hypothetical sexaquark has emerged as a promising bosonic dark matter particle, potentially forming under extreme conditions in neutron star cores.
We investigate this scenario using a relativistic density functional approach, including hyperons (DD2Y-T model) for the hadronic phase, coupled to a deconfined quark phase described by a non-local Nambu-Jona-Lasinio model.
The phase transition is modeled through a smooth crossover, and sexaquark-baryon interactions are introduced via an effective mass shift representing repulsion.
We assess whether this hybrid scenario, incorporating hyperons, bosonic dark matter, and deconfined quark matter,
is consistent with multi-messenger constraints from neutron stars. By scanning the parameter space,
we identify sexaquark masses that are consistent with mass-radius measurements and tidal deformability.
Our results show that the presence of the sexaquark softens the equation of state, enabling the model to satisfy both the radius and tidal deformability constraints around the canonical $1.4M_{\odot}$ neutron stars.
We incorporate all available NICER data, including PSR J0437-4715 and newly published PSR J0614-3329.
We find out that hybrid stars with sexaquark mass near 1900 MeV agree with all current observational limits,
including HESS J1731-347 and PSR J0952-0607, representing the lightest and most massive known neutron stars.
Furthermore, we perform a Bayesian analysis, which yields a favored sexaquark mass range of 1885-1935 MeV, supporting the potential role of this exotic particle in the interiors of neutron stars.

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Contribution ID: **64** Type: **not specified**

QCD Dynamics of the Nuclear Core and Stability of Nuclear Matter

One of the important properties of nuclear forces is
the nuclear repulsive core which provides a stability for atomic nuclei, making
possible the emergence of a structure for the visible matter.
However the origin of the nuclear core is poorly understood. We discuss how
the strong repulsive nuclear core at short distances can emerge from QCD,
even though one should expect a diminishing interaction due to asymptotic freedom.
It is demonstrated that such a repulsion is associated with the non-nucleonic component in
the NN system and we demonstrate how to incorporate non-nucleonic components in the calculation of
nuclear structure at extremely short distances. We also elaborate the approach that the presented calculations can be extended to infinite nuclear matter at high densities.

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Accretion channels of subcritical X-ray pulsars: a study of hydrodynamics and radiation

We present the results of self-consistent radiation-hydrodynamic modeling of accretion channels of subcritical X-ray pulsars. The process of resonant Compton scattering and vacuum polarization is taken into account. It is shown that the radiation in the cyclotron line is determined by the hydrodynamic characteristics of the flow in the accretion channel and the position of the cyclotron line centroid has a positive correlation with the plasma deceleration degree, which corresponds to the observational data. In addition, we investigate the polarization of the X-ray radiation outgoing from the accretion channel.
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Instability windows of relativistic r-modes in neutron stars with hyperonic cores

R-modes are quasitoroidal oscillations of rotating stars, primarily restored by the Coriolis force. The fact that, among the variety of stellar oscillations, r-modes are the most susceptible to the Chandrasekhar-Friedman-Schutz (CFS) instability (i.e., instability with respect to gravitational wave emission) makes them promising targets for current and future gravitational wave searches. An r-mode becomes unstable if the energy supply to the mode by the CFS mechanism surpasses the energy losses caused by various dissipative mechanisms operating in the stellar matter. The corresponding stellar parameters - typically, rotation rate Ω and (redshifted) temperature T^{∞} - determine the so-called r-mode instability window on the (Ω, T^{∞}) plane. At high temperatures, bulk viscosity ζ, arising from out-of-equilibrium chemical reactions, is the dominant dissipative mechanism that opposes the CFS instability. Dissipation through ζ can be substantially enhanced by two independent mechanisms: (1) the presence of hyperons, which significantly increases the bulk viscosity coefficient, and (2) peculiar properties of relativistic r-modes in nonbarotropic matter, which strongly amplify their dissipation through bulk viscosity compared to that in Newtonian theory. In this study, we present the first investigation of the combined impact of these two mechanisms on the r-mode instability windows. Our calculations also estimate the effect of nucleon pairing on the instability windows and investigate the importance of accounting for chemical reactions in the adiabatic index of the matter. We find that hyperonic bulk viscosity is a much more efficient dissipative mechanism than previously thought and that it may provide the dissipation required to stabilize r-modes in the fastest-spinning and moderately hot neutron stars in low-mass X-ray binaries, even when nucleon pairing effects are taken into account. These results have important implications for the interpretation of observations and for the broader understanding of relativistic r-mode physics.

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Beyond Current Limitations: A New Approach to the Neutron Star Equation of State

The neutron star equation of state (EOS) remains one of the fundamental challenges in nuclear astrophysics, with current modeling approaches facing distinct limitations. Phenomenological models, while successful in reproducing nuclear and astrophysical constraints, suffer from inherent model dependencies in their parametrizations. These dependencies can introduce biases in posterior distributions when constraining neutron star properties from observational data, potentially affecting our interpretation of multi-messenger observations.
Model-independent and agnostic frameworks attempt to overcome these limitations through increased flexibility, but this comes at the cost of reduced physical interpretability and increased systematic uncertainties. The tension between flexibility and physical consistency presents a fundamental challenge: how can we develop EOS models that are both sufficiently flexible to capture diverse astrophysical constraints and physically motivated enough to provide meaningful insights into dense matter?
We present a new framework that addresses these challenges by combining the strengths of both approaches. Our method maintains theoretical consistency while achieving the flexibility necessary for modern astrophysical applications. By carefully constructing a framework that respects fundamental nuclear physics principles without being overly restrictive, we demonstrate improved performance in capturing current observational constraints across the full neutron star mass range. This work suggests that next-generation EOS modeling can move beyond the traditional dichotomy between phenomenological and agnostic approaches, offering new pathways for leveraging multi-messenger observations to constrain the properties of matter at extreme densities.

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